## Programme for the 14th European Conference on Antennas and Propagation (EuCAP 2020) (ver. 31 Mar 2020)

### Days and Timings
- **Monday, 16 March**
- **Tuesday, 17 March**

### Rooms
- **A2**
- **A3**
- **B1**
- **B2**
- **B4**
- **B5**
- **B6**
- **A17**
- **B7**
- **B8**
- **B9**
- **B10**
- **B11**
- **B3**
- **Room 6**
- **Room 17**

### Application Tracks - Colour Legend
- **T01 LTE and Sub-6GHz 5G**
- **T02 Millimetre wave 5G**
- **T03 Wireless LANs**
- **T04 IoT and M2M**
- **T05 Biomedical and health**
- **T06 Aircraft (incl. UAV, UAS, RPAS) and automotive**
- **T07 Defence and security**

### Monday, 16 March
- **09:00-10:10**
  - OC: Opening Ceremony
  - IK 01: Keynote 1
- **10:10-10:40**
  - **Coffee Break (Exhibition Hall)**
- **10:40-11:10**
  - IK 02: Keynote 2
- **11:10-11:50**
  - IK 03: Keynote 3
- **11:50-12:30**
  - **Lunch (Exhibition Hall)**
- **13:30-15:30**
  - **Coffee Break (Exhibition Hall)**
  - CS02: Advanced Antenna Arrays for 5G and Beyond
  - CS09: Design Analysis and Numerical Computations for 5G and Beyond
- **15:30-16:00**
  - **Coffee Break (Exhibition Hall)**
- **16:00-18:00**
  - T02-A04/1: Millimetre-wave Arrays for Mobile Communications
  - T02-A09: IoT Antennas
  - T04-A08: IoT Antennas
  - T05-A12/1: Multifield, Wideband and Array Antennas
  - T05-A12/2: Multifield, Far-field, Compact and RCS Range Measurement Techniques
  - T06-M02: Near-field, Far-field, and Automotive Antenna Measurements and Testing
  - T06-M03: Microwave Imaging
  - T08-A17: Microwave Imaging
  - T09-A09: Millimetre-wave Lens Antennas for Space Applications
  - CS55: AMTA Session: Automatic Antenna Measurements and Testing
  - T08-A17: Microwave Imaging
  - T11-E08: (cont’d)

### Tuesday, 17 March
- **08:30-10:10**
  - T02-A04/2: Millimetre-wave Arrays for Mobile Terminals
  - CS33: IET/IRAON Session: Propagation Measurements and Modelling for 5G and Beyond
  - CS38: ISAP Session: Recent Advances in Antennas and Propagation Research
  - CS54: Sensors and Systems for Microwave Biomedical Imaging and Sensing
  - T11-M02: Radar Scattering Measurement and Calibration Techniques
  - T12-M03: Near-field, Far-field, and Automotive Antenna Measurements
  - SW01: COST Session: Instrumentation and Numerical Methods for Microwave Imaging and Sensing
  - SW02: COST Session: Instrumentation and Numerical Methods for Microwave Imaging and Sensing
  - T09-P08: Satellite Propagation
  - CS09: Analytical and Numerical Methods for Microwave Imaging and Sensing
  - CS33: Antennas and Systems for Microwave Biomedical Imaging and Sensing
  - SW08: Challenges of 5G Antenna & Propagation Measurements
  - SW09: Challenges of 5G Antenna & Propagation Measurements

- **10:10-10:40**
  - **Coffee Break (Exhibition Hall)**

- **10:40-12:20**
  - T02-A04/2: (cont’d)
  - CS35: (cont’d)
  - CS38: (cont’d)
  - CS48: (cont’d)
  - T10-M10: General Antenna Measurements
  - T01 LTE and Sub-6GHz 5G
  - T06 Aircraft (incl. UAV, UAS, RPAS) and automotive
  - T07 Defence and security
  - EuAAP 5: WG Active Array Antennas
  - EuAAP 5: WG Active Array Antennas

- **12:20-13:20**
  - **Lunch (Exhibition Hall)**

- **13:20-14:50**
  - Convened Poster Sessions 1: Room A2 (Poster Area)
  - Regular Poster Sessions 1: Exhibition Hall

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1 of 128
### Wednesday, 18 March

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
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<tbody>
<tr>
<td>08:30-10:15</td>
<td>IS-Tue 1/1: Invited Speaker Session</td>
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<td>08:30-11:30</td>
<td>T09-A19: Reflectarrays and Transmitarrays</td>
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<td>08:30-11:30</td>
<td>CS06: Recent Advances on Electronically Steerable Antenna Arrays at mm-Wave Frequencies</td>
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<td>08:30-11:30</td>
<td>CS08: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring</td>
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<td>08:30-11:30</td>
<td>CS10: Antenna Array and Integrated Systems for 5G Communication Applications</td>
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<td>08:30-11:30</td>
<td>CS17: Antennas with Multi-Port/Distributed Feeding and On-Antenna Power-Combining for Efficient Integration and Reconfigurability</td>
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<td>08:30-11:30</td>
<td>CS18: Applications of mm-Wave Gap Waveguide Technology-I</td>
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<td>08:30-11:30</td>
<td>CS19: Applications of mm-Wave Gap Waveguide Technology-II</td>
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<td>08:30-11:30</td>
<td>CS27: Electromagnetics in MRI Applications</td>
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<td>08:30-11:30</td>
<td>CS57: Recent Research on Wind Turbines: EM Modelling and Measurements</td>
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<td>11:30-12:15</td>
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<td>13:20-14:50</td>
<td>Convened Poster Sessions 2: Room A2 (Poster Area)</td>
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<td>13:20-14:50</td>
<td>Regular Poster Sessions 2: Exhibition Hall</td>
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<td>Coffee Break (Exhibition Hall)</td>
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<td>16:40-18:20</td>
<td>T04-A20: Wireless Power Transfer and Inductive Coupling</td>
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<td>16:40-18:20</td>
<td>CS56: Recent Advances on Electronically Steerable Antenna Arrays at mm-Wave Frequencies</td>
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<td>16:40-18:20</td>
<td>CS58: Reconfigurable Antennas for Compact Devices</td>
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<td>16:40-18:20</td>
<td>T04-A15: RFID and Backscattering Antennas</td>
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<td>16:40-18:20</td>
<td>CS67: Water-Based Microwave Devices</td>
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<td>16:40-18:20</td>
<td>CS28: EuMA/EurAAP Session: From Radiating Section to Digital Interface - Research and Design Trends for an End-To-End Approach of Highly Integrated Active Antenna Systems</td>
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<td>16:40-18:20</td>
<td>CS32: Recent Advances in Terahertz Antennas for Radio-Astronomy and Space Exploration</td>
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<td>16:40-18:20</td>
<td>SW03: COST Session CA15104 (IRACON): Measurements and Simulations in Channel Modelling in Wireless Body Area Networks</td>
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<tr>
<td>16:40-18:20</td>
<td>CS66: Unconventional Techniques and Applications for Inverse Scattering Problems</td>
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<tr>
<td>16:40-18:20</td>
<td>T11-P02/1: Channel Modelling for MIMO and Near-Field Communication Systems</td>
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<td>16:40-18:20</td>
<td>T11-P02/2: Machine Learning in Radio Propagation</td>
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<td>16:40-18:20</td>
<td>BC/2: History of Electromagnetism</td>
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<td>16:40-18:20</td>
<td>IW06: Active Impedance Assessment and Beamforming Optimization for mm-Wave Antenna Arrays (Optenni Ltd)</td>
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<td>16:40-18:20</td>
<td>IW09: SG Antenna Array Design and Integration Simulation (ANSYS)</td>
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**Regular Poster Sessions 2: Exhibition Hall**
<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
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<tbody>
<tr>
<td>14:50-15:30</td>
<td>IS-Wed 1/1: Invited Speaker Session</td>
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<tr>
<td>15:30-16:00</td>
<td>Coffee Break (Exhibition Hall)</td>
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<tr>
<td>16:00-16:40</td>
<td>IS-Wed 2/1: Invited Speaker Session</td>
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<tr>
<td>16:40-17:45</td>
<td>Conference Dinner (Wallmans)</td>
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<td>17:45-18:00</td>
<td>Coffee Break (Exhibition Hall)</td>
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<td>18:00-23:59</td>
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<tr>
<td>08:30-10:10</td>
<td>IS-Wed 1/1: Multiband and Wideband Antennas</td>
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<td>10:10-10:40</td>
<td>Coffee Break (Exhibition Hall)</td>
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<tr>
<td>10:40-12:20</td>
<td>IS-Wed 2/1: Terminal Antennas and Interactions with Surroundings</td>
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<tr>
<td>12:20-13:20</td>
<td>Lunch (Exhibition Hall)</td>
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<td>13:20-14:50</td>
<td>Best Paper Awards Poster Sessions: Room A2 (Poster Area)</td>
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<td>Regular Poster Sessions 3: Exhibition Hall</td>
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<td>A06: Conformal Antennas</td>
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<td>A11: Multiband and Wideband Antennas</td>
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<td>A12: Wearable and Implantable Antennas</td>
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<td>A13: Adaptive and Reconfigurable Antennas</td>
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<td>A14: Active and Integrated Antennas</td>
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<td>A15: RFID Antennas/Sensors and Systems</td>
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<td>A16: UWB Antennas and Time-domain Techniques</td>
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<td>A20: Antennas for Wireless Power Transmission and Harvesting</td>
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<td>14:50-15:30</td>
<td>IS-Thu 1/1: Invited Speaker Session</td>
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<tr>
<td>15:30-16:10</td>
<td>IS-Thu 1/2: Invited Speaker Session</td>
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<td>16:10-16:40</td>
<td>Coffee Break (Exhibition Hall)</td>
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<tr>
<td>16:40-18:00</td>
<td>IS-Thu 2/1: Invited Speaker Session</td>
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<td>CS42: Nano and Quantum Antennas</td>
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<td>CS49: Novel Techniques for Beam Manipulation at WLAN Applications</td>
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<td>CS34: JET/AMTA Session: Test and Measurement Challenges for 5G and Beyond</td>
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<td>CS46: New Trends in Leaky Wave Antennas</td>
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<td>CS44: Near-Field Focusing and Pulse Generation Through Localized Waves</td>
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<td>CS25: Convergence of Mobile Radio and Radar</td>
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<td>T05-A12/2: Propagation for Unmanned Aerial Vehicles (UAVs)</td>
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<td>T06-P09: Electromagnetic Methods for Direct and Inverse Scattering Involving Stratified Media</td>
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<td>CS07: AMTA/EurAAP Session: Post Processing Techniques in Antenna Measurements</td>
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<td>BC3: History of Electromagnetism 3</td>
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<td>SW07: H2020 Project ACASIS (GA No. 733167) - Antennas for Integration into Aircraft Structure</td>
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<td>IW03: Efficiently Simulating and Optimising Antenna Placement in Virtual Test Scenarios (Altair)</td>
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**Thursday, 19 March**

**08:30-10:10 T01-A11:** Multiband and Wideband Antennas

**10:40-12:20 T01-A02:** Terminal Antennas and Interactions with Surroundings

**13:20-14:50 Best Paper Awards Poster Sessions: Room A2 (Poster Area)**

**14:50-15:30 IS-Thu 1/1: Invited Speaker Session**

**15:30-16:10 IS-Thu 1/2: Invited Speaker Session**

**16:10-16:40 Coffee Break (Exhibition Hall)**

**16:40-18:00 IS-Thu 2/1: Invited Speaker Session**

**CS42: Nano and Quantum Antennas**

**CS49: Novel Techniques for Beam Manipulation at WLAN Applications**

**CS34: JET/AMTA Session: Test and Measurement Challenges for 5G and Beyond**

**CS46: New Trends in Leaky Wave Antennas**

**CS44: Near-Field Focusing and Pulse Generation Through Localized Waves**

**CS25: Convergence of Mobile Radio and Radar**

**T05-A12/2: Propagation for Unmanned Aerial Vehicles (UAVs)**

**T06-P09: Electromagnetic Methods for Direct and Inverse Scattering Involving Stratified Media**

**CS07: AMTA/EurAAP Session: Post Processing Techniques in Antenna Measurements**

**BC3: History of Electromagnetism 3**

**SW07: H2020 Project ACASIS (GA No. 733167) - Antennas for Integration into Aircraft Structure**

**IW03: Efficiently Simulating and Optimising Antenna Placement in Virtual Test Scenarios (Altair)**
<table>
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<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>18:00-18:20</td>
<td>Millimeter</td>
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<td>18:20-18:40</td>
<td>Russia</td>
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<td>18:40-20:00</td>
<td>Environment</td>
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<td>Automotive Applications and Techniques</td>
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<td>Workshop on Antenna Developments for Terrestrial and Small-Space Platforms</td>
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<td>EurAAP 4: W0 Propagation (18:00-20:00, Room: B8)</td>
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### Friday, 20 March

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>08:30-10:10</td>
<td>T01-A22: MIMO Diversity, Smart Antennas &amp; Signal Processing</td>
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<td>CS37: IRACON Spectrum Sharing: Challenges and Opportunities for 5G and Beyond</td>
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<td>CS33: IET Session: New Antenna Systems Involving Application of Metamaterials and Metasurfaces</td>
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<td>T05-M06: Dosimetry, Exposure, and SAR Assessment</td>
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<td>T11-M06: Scattering and Diffraction</td>
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<td>T11-M05: EMI/EMC/PIM Chambers, Instrumentation, and Measurements</td>
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<td>SW05: H2020 Session 6764479 (EMERALD): Electromagnetic Imaging for a Novel Generation of Medical Devices</td>
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<td>T06-A11: Aircraft Antennas</td>
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<td>CS59: Reconfigurable Reflectarray and Transmitarrays</td>
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<td>T10-P02: Propagation Modelling and Simulation</td>
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<td>CS11: Antenna Design and Fundamental Bounds with External Constraints</td>
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<td>CS20: Assessment and Modelling of Antennas and Radio Channels Jointly</td>
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<td>SW09: Integration Challenges for Low-cost Mm-wave Phased Arrays</td>
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<td>10:10-10:40</td>
<td>Coffee Break (Exhibition Hall)</td>
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<td>10:40-12:20</td>
<td>T01-A22: (cont'd)</td>
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<td>CS37: (cont'd)</td>
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<td>T02-M08: Mm-wave, Thz, and Quasi-optical Antenna Measurements</td>
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<td>T11-M06: (cont'd)</td>
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<td>T11-M01: Material Characterisation and Non-destructive Testing</td>
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<td>SW06: (cont'd)</td>
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<td>SW09: (cont'd)</td>
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<td>12:30-13:30</td>
<td>CC: Closing Ceremony</td>
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Monday, 16 March 9:00 - 10:00
OC: Opening Ceremony
Room: A2
Chairs: Olov Breinbjerg (Technical University of Denmark, Denmark), Cyril Mangenot (Api-Space, France)

Monday, 16 March 10:00 - 10:40
IK 01: Keynote 1
Room: A2
Chairs: Mats Gustafsson (Lund University, Sweden), Katsuyuki Haneda (Aalto University, Finland), Daniel Sjöberg (Lund University, Sweden)

10:00 The Technology Journey Towards 6G
Magnus Frodigh (Ericsson AB, Sweden)
5G is now in the deployment phase. We will see broad roll-out of 5G systems over the next coming years. Extra interesting will be to follow the uptake of new use cases, with richer interactivity for consumers, smarter cities and fully connected manufacturing in Industry 4.0. In a research context, there is still more to be done in the evolution of 5G, work on specific properties to further improve support for the new use cases. But gradually we will start looking into more fundamental additions to connectivity, break-through technology that will be needed to fulfill the visions of the Internet of Things and fully connected intelligent machines, and to continue addressing sustainability targets. To do this, we need to broaden the discussion on the evolution towards 6G to also include, technologies for trustworthiness, fully cognitive networks and fully integrated edge compute capabilities.

10:40 Microwave Imaging in Real Time
Natalia Nikolova (McMaster University, Canada)
Real-time microwave and millimeter-wave imaging methods are the workhorse in applications ranging from synthetic aperture radar, which operates with far-field data, to nondestructive testing and medical imaging, which employ near-field measurements. Research in this field is intensifying due to expansion in numerous applications fueled by the advances in high-frequency electronics and flexible field-programmable platforms. This paper is an attempt to explain, categorize, compare and contrast these methods within a common framework thus making this interdisciplinary subject more comprehensible and accessible to the research community.

Monday, 16 March 11:10 - 11:50
IK 02: Keynote 2
Room: A2
Chairs: Mats Gustafsson (Lund University, Sweden), Katsuyuki Haneda (Aalto University, Finland), Daniel Sjöberg (Lund University, Sweden)

11:10 Application of Machine Learning to Wireless Channel Modeling
Jianhua Zhang and Li Yu (Beijing University of Posts and Telecommunications, China); Xuyang Zhang (Beijing University of Posts And Telecommunications, China); Zhen Zhang and Zhijiang Yuan (Beijing University of Posts and Telecommunications, China)
With the increasing antenna number, wide frequency range, huge bandwidth, and versatile application scenarios brought by fifth-generation (5G) and beyond, channel measurement data will be quite huge. Measurement data processing is very time consuming and channel characteristics are difficult to capture and model accurately. Thanks to machine learning has been successfully demonstrated efficient handling big data and find the hidden rules. Thus, it is reasonable to develop channel models by taking advantage of data mining and machine learning algorithms. In this presentation, some of our attempts of applying big data analytics, especially machine learning algorithms to channel modelling have been principally explained and summarized, including Gaussian mixture model (GMM)-based channel multipaths clustering, principal component analysis (PCA)-based channel parameter reduction, MMIMO channel fading tracking and prediction, and intelligent channel modelling schemes, etc. Finally, the open issues and future research directions of ML application in channel model are discussed.

11:50 Impact of Spatially Consistent Channels on Digital Beamforming for Millimeter-Wave Systems
Harsh Tatania and Fredrik Tufvesson (Lund University, Sweden)
The premise of massive multiple-input multiple-output (MIMO) is based around coherent transmission and detection. Majority of the vast literature on massive MIMO presents performance evaluations over simplified statistical propagation models. All such models are drop-based and do not ensure continuity of channel parameters. In this paper, we quantify the impact of spatially consistent (SC) models on beamforming for massive MIMO systems. We focus on the downlink of a 28GHz multicarrier urban microcellular scenario. Using the recently standardized Third Generation Partnership Project 38.901 SC-i procedure, we evaluate the signal-to-interference-plus-noise ratio of a user equipment and the system ergodic sum spectral efficiency with zero-forcing, block diagonalization, and signal-to-leakage-plus-noise ratio beamforming. Our results disclose that at practical signal-to-noise ratio levels, SC channels yield a significant performance loss relative to the case without SC due to substantial spatial correlation across the channel parameters.

Monday, 16 March 11:50 - 12:30
IK 03: Keynote 3
Room: A2
Chairs: Mats Gustafsson (Lund University, Sweden), Katsuyuki Haneda (Aalto University, Finland), Daniel Sjöberg (Lund University, Sweden)

11:50 Present and Future Trends in Electromagnetics and Metamaterials
Andrea Alù (CUNY Advanced Science Research Center, USA)
In this talk, I will discuss recent trends and opportunities in the context of electromagnetics research and metamaterials, with particular attention on the opportunities offered by nonlinearity, gain and spatio-temporal modulation to overcome some of the outstanding limitations of conventional approaches. We will discuss opportunities stemming from communication networking and from modulation of the electromagnetic properties of artificial materials to enable non-reciprocal responses for guided and radiated waves, as well as to leverage parametric phenomena. We will also discuss possible applications of this technology from radio-waves to nano-optics.

Monday, 16 March 13:30 - 15:30
To design fifth-generation (5G) millimeter-wave (mm-wave) vehicle-to-vehicle (V2V) communication systems for the future urban and inter-urban communications, it is essential to have a suitable emulator that considers many different radio-access technologies (RAT) and traffic scenarios. The proposed emulator is absolutely transparent for the application layer (this is, considering not only the physical layer but the network one too) which greatly simplifies the development of novel methods and algorithms that can be easily compared to other developed methods. The complexity of modern communication systems is remarkable, and the efforts needed to put into service a new system are costly due to the integration in the rolling stock plus the need to have physical access to the railway infrastructure. The development of Low-Earth-Orbit (LEO) satellite communications aims at delivering low-cost worldwide internet access to rural and undeveloped areas (Internet of Space (IoS)). Here, we present the design, fabrication, and test of a 3D-printed 2x2 double-ridged waveguide (DRWG) antenna array with waveguide feeding network, working at Ku-Band (10.75 - 14.5 GHz) with simulated > 60% and realized gain of ~ 16 dBi, paving the way for innovative low-cost antenna solutions for user's terminal.

This paper presents a millimeter-wave dual-polarized slot antenna array by using a SIW cavity supporting TE210 and TE120 mode. Thanks to the orthogonality between TE210 and TE120 mode, high isolation and low cross-polarization are achieved. A high gain, circularly polarized 4x4 antenna array, is proposed. A circularly polarized magneto-electric (ME) dipole element is used as a radiating element. The 4x4 antenna array excited by slots and feeding networks of microstrip ridge gap waveguide (MRGW). A compact design is archived with including the effect of the mutual coupling. The simulated 4x4 array achieved an impedance bandwidth of 20.8% for (21) - (10 dB) with a maximum gain of 20.3 dB, which is higher than any reported 4x4 array antenna. An axial ratio bandwidth of 18.3% is achieved. A differential Butler matrix is presented in this paper using a new type of wideband unbalanced-to-balanced power dividers. The differential Butler matrix has the merit of high levels of common mode signal suppression. A differential array with four elements is also designed, fabricated and tested. By feeding the differential array with the differential Butler matrix, two beams are produced in the E-plane radiation pattern. The differentially fed array achieves very low cross-polarization level due to the excellent common-mode suppression from the Butler matrix. The design approach is verified experimentally, and the measured result agrees well with the predicted one, demonstrating the application potential for the presented differential beam-forming networks.

In this contribution the design of a 27-dBi gain dual-polarized phased array for point-to-point 5G communications is presented. The 4x4 array achieves the desired gain, thanks to the wide spacing between the feeding elements. Grating lobes are suppressed by using movable dielectric lenses that provide directive and steerable element patterns. The array is also capable of scanning electronically to 10 degree in two main planes, suffering only 2-dB of degradation in gain, thanks to the simultaneous shifting of the lens by a few millimeters.

On the Design of a 27-dBi Phased Array for 5G Point-to-Point Communications

Huasheng Zhang, Spendi Bissaha and Andrea Neto (Delft University of Technology, The Netherlands);
Ulrik Imberg (Huawei Technologies, Sweden AB, Sweden); Naria Llombart (Delft University of Technology, The Netherlands).

A differential Butler matrix is presented in this paper using a new type of wideband unbalanced-to-balanced power dividers. The differential Butler matrix has the merit of high levels of common mode signal suppression. A differential array with four elements is also designed, fabricated and tested. By feeding the differential array with the differential Butler matrix, two beams are produced in the E-plane radiation pattern. The differentially fed array achieves very low cross-polarization level due to the excellent common-mode suppression from the Butler matrix. The design approach is verified experimentally, and the measured result agrees well with the predicted one, demonstrating the application potential for the presented differential beam-forming networks.
typical underground garage entrance, and analyze the channel characteristics, including path loss, shadow fading, and root mean square (RMS) delay spread (DS). Statistical results of these channel characteristics are presented. Differences between our measurement-based channel characteristics and those of the existing results are discussed. Furthermore, we investigate the change trend of the RMS DS along the garage entrance, and find that the special structure of the garage entrance has a apparent effect on the RMS DS. These results are helpful to design the physical layer for the future V2V communication systems.

14:00 Millimeter-Wave Channel Characterization for Vehicle-to-Infrastructure Communication
Lina Wu, Danping He, Ke Guan and Bo Ai (Beijing Jiaotong University, China); Junhyeong Kim and Hee Sang Chung (ETR, Korea (South))
The vehicle-to-infrastructure (V2I) communication can capture huge demand with precise time, information, which can significantly improve road safety. Millimeter-wave (mmWave) with large bandwidth has been introduced as a key technology to achieve ultra-reliable, low latency, and high-data-rate V2I communication. In this paper, the V2I communication in mmWave band (22.1GHz-23.1GHz) is characterized for typical urban and highway scenarios. By considering the different deployments involving overtake and traffic flow, the simulations are conducted by employing the self-developed ray-tracing. The key channel parameters, including received power, Rician K-factor, root-mean-square delay spread and angular spreads, are analyzed and compared between different deployments. Moreover, the impact of the multiple antennas and beam switching technologies at the vehicle are evaluated as well. This work aims to help the researchers understand the channel characteristics of the V2I communication in mmWave band and support communication system design for vehicular communications.

14:50 Large Scale Fading Characteristics for Vehicle-to-Cyclist Channel in Urban Environment at 5 GHz
Ibrahim Rashdan and Michael Walter (German Aerospace Center (DLR), Germany); Wei Wang (Chang’an University, China); Giuseppe Care (Technische Universität Berlin, Germany)
Vehicle-to-vulnerable road users (V2VUR) communication provides 360 degree of awareness for both vehicles and vulnerable road users (VRUs). A realistic and accurate channel model for V2VUR in critical accident scenarios is of great importance for developing reliable V2VUR communication systems. This paper presents a large scale fading characterization based on a wideband channel measurement campaign in urban environment considering a collision scenario between a vehicle and a cyclist. A wide-scale path loss model is proposed, and a zero-mean Gaussian distribution is found to best fit the shadow fading. Additionally, for more realistic system-level simulations, the spatial correlation of shadow fading are calculated. The underlying correlation is captured by using 2-dimensional exponentially correlated shadow fading maps.

15:00 28 GHz High-Speed Train Measurements and Propagation Characteristics Analysis
Jae Joon Park, Juyul Lee, Kyung-Won Kim and Myung-Don Kim (ETR, Korea (South))
In this paper, we investigate millimeter-wave propagation characteristics of high-speed moving train based on field measurements in a tunnel and viaduct scenarios. The measurements were carried out at 28.5 GHz simulating for a 3GPP-like high-speed train (HST) deployment scenario where a transmitter is positioned nearest to a track and a receiver is mounted on the roof of a son train carriage. Based on the measurement data, we analyzed path loss (PL) and observed the PL is almost constant with respect to distance in the tunnel. Other channel parameters, such as delay spread and Doppler shift were studied as well. Multipaths were periodically observed in the analysis results. It was caused by objects regularly installed along the tracks, such as overhead power line equipments.

15:30 Coffee Break

16:00 Architecture and Performance of the Base Station Prototype for MN Systems
Sung Woo Choi and Junhyeong Kim (ETR, Korea (South)); Seon-Ae Kim (Electrics and Telecommunications Research Institute, Korea (South)); Hee Sang Chung (ETR, Korea (South)); Ilgu Kim (ETR of KOREA, Korea (South))
This paper presents current updates of AirMobi Network (MN) system. The MN has been developed to escalate passenger’s Internet access speed in buses. It uses wide spectrum of millimeter waves to get higher network throughput but undergoes severe deterioration of signal in the urban road environment. In this paper, the system architecture and features of physical layer specification are provided. And simulation results of physical uplink channels are given to evaluate the uplink performance. We show the architecture of MN prototypes which have been produced recently. From indoor test, the base-station throughput was estimated to reach 3 Gbps with 6 component carriers. By using these prototypes, all specifications of MN will be tested and outdoor experiment will be started.

16:20 Shadowing and Multi-path Fading Characteristics at 2.4 GHz and 9.34 GHz in Vehicle-to-Vehicle Scenarios
Hui Wang, Xufeng Yin and Jose Rodrigues-Pinto (Tongji University, China); Juyul Lee and Myung-Don Kim (ETR, Korea (South))
In this paper, a recently conducted measurement campaign aiming at 39 GHz millimeter wave (mmWave) and sub-6 GHz propagation channel characterization is introduced. Simultaneous signal transmission at both mmWave and sub-6 GHz were performed in the measurements in order to evaluate the different influences of common environments and vehicle-moving on channel characteristics at two distinct bands. Four typical vehicle flow modes are considered in our measurements. Channel parameters investigated include shadowing, fast fading, and their space coherent behaviors. The results obtained show that both shadowing and fast fading segments follow truncated Gaussian distributions in most vehicle flow modes and propagation scenarios consisting of these. For most scenarios, the special consistency of 2.4 GHz channel can be maintained in larger distances than that of 39 GHz.

16:40 Bi-directional Vehicle-to-Vehicle Radio Channel Characterization over Bridge at 5.9 GHz
Kun Yang and Ning Zhou (Super Radio AS, Norway); Terje Raste (NTNU, Norway); Junyi Yu, Fang Li and Wei Chen (Wuhan University of Technology, China); Egil Eide and Torbjorn Ekman (Norwegian University of Science and Technology, Norway); Changshen Li and Fixing Chang (Wuhan University of Technology, China)
A V2V radio channel measurement campaign with a maximum distance of 2 km was performed over bridge between two urban areas in Wuhan city, China. In this paper, a detailed description of the channel measurement campaign including antenna setups, channel sounder configurations and other related info is given. The RSS is extracted from the measured data and interpreted. The APOP are demonstrated, from which the RMS delay spread are extracted and shown. It can be observed that the 95% of the mean excess delay and the RMS delay spread are within 738 ns and 11.8 micro s, respectively. The best-fit amplitude distribution of the small scale fading is estimated using a model selection algorithm based on the Akake Information Criterion (AIC). The TWOP-Ray and Rician model are found to be the best-fit models at different TX-RX distances and the physical interpretation is given.

17:00 Measurement and Diffuse Multipath Analysis of V2V Propagation Channel at 5.9 GHz in Tunnel Area
Suying Jiang, Xun Zhang and Wei Wang (Chang’an University, China); Mi Yang and Ruisi He (Beijing Jiaotong University, China)
Vehicle-to-vehicle (V2V) communication is an essential fundamental of intelligent transportation systems (ITS). Therefore, evaluating the influence of the radio propagation channel of ITS is of great interest. So far the diffuse multipath in V2V propagation channel in tunnel area has not been thoughtfully studied. This paper presents channel measurements and analysis of V2V channel characteristics at 5.9 GHz in Tunnel. We evaluate and compare the received power and root mean square (RMS) delay spread for outside and inside tunnel. Further, we use the space alternating generalization expectation maximization (SAGE) based channel parameter estimator with the autoregressive (AR) filter to estimate the specular and the diffuse multipath components. Results reveal that the diffuse multipath inside tunnel is not dominant in the line-of-sight (LoS) case. The ratio between the diffuse multipath component (DMC) power and the total received power has a mean value of 10.56% and a standard deviation of 8.7%.

17:20 Comparison of a Fast Analytical Ray Tracer and Channel-Sounder Measurements for V2V Communications
Nils Dreyer (TU Braunschweig, Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)
Ray optical path loss predictions for Ad-hoc networks (Device-to-Device) are still a complex and time consuming task. In past publications we introduced a new predictor concept that is based on visibility analysis, leading to a huge predictor speed up for the computation of reflected rays. In this paper we present our new extensions of the simulation framework, introducing a method to cope with the visibility based on sub-cell building deflection and non-space reflection. Our approach is fast enough to be applied on scenarios with a realistic number of communication pairs in the future. We further evaluated our predictor for the first time by applying the model on an intersection scenario and comparing the result with a measurement campaign performed in the Swedish city Lund. The result of the Power Delay Profile offers a good agreement between measurement and simulations, however we could observe difference of the power distribution.

17:40 Path Loss Models and Large Scale Fading Statistics for C-Band Band-train-to-Train Communication
Paul Unterhuber, Ibrahim Rashdan and Michael Walter (German Aerospace Center (DLR), Germany); Thomas Kürner (Technische Universität Braunschweig, Germany)
The profound knowledge of wireless propagation is essential for wireless communication between vehicles. To evolve and test communication standards we need channel models in representative environments to neither over- nor underestimate the effect of the surrounding environment and the movement of the vehicles; typical environments for railway communication are railway station, open field and hilly environments. We introduce train-to-train (T2T) path loss models and large scale fading statistics based on channel measurement data as a first step towards a geometry-based stochastic channel model (GSCM). The models represent the mentioned typical environments for railway communication applications. We compare the results with previous published intelligent transportation system (ITS-G5) measurement based models and highlight the differences.

SW04: COST Session CA18223 (SyMat): Periodic Structures with Higher Symmetries
T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics
Room: B1
Chairs: Francisco Mesa (University of Sevilla, Spain), Guido Valenio (Sorbonne Université, France), Pablo Padilla (University of Granada, Spain)

13:30 High Scanning Rate Leaky Wave Antenna Based on Glide Symmetry for 77 GHz Automotive Radar
Adrián Tamayo-Domínguez (Universidad Politécnica de Madrid, Spain); Jose Manuel Fernández González (Universidad Politécnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
This work presents a leaky wave antenna at W band with glide-symmetric waveguide protuberances that enhance the scanning ratio of previous works. Also, a conventional leaky wave is designed for comparing the results in terms of required bandwidth and steering range. Both prototypes are based on gap waveguide technology to prevent the leakage due to air gaps
Monday, 16 March 13:30 - 15:30
CS21: Challenges in Leaky Wave Antennas and Novel Approaches to solving Them

T11 Fundamental research and development in advanced systems / Convened Session / Antennas

between layers. In order to reduce the manufacturing cost, the designs are aimed to 3D-printing. A Taylor amplitude modulation is conducted in the two cases to reduce side lobe levels. The glide-symmetric leaky wave provides a variation of the steering angle from 12.14º to 50.84º in a band from 74.2 GHz to 79.8 GHz. The scanning ratio compared with the simple leaky wave is enhanced by a factor of 6.41. This rapid variation of the steering angle in a narrow band (7º) is of interest for automotive radars.

13:50 Holey Glide-Symmetric Waveguide Filters for 5G Communication Systems at Millimetre Wave Frequencies
Alberto Monge-Real (KTH Royal Institute of Technology, Sweden); Nelson Fonseca (European Space Agency, The Netherlands); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Elena Pucci (Ericsson AB, Sweden); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this paper, we present a holey, fully-metallc, glide-symmetric waveguide filter. This solution is low-loss, cost-effective, robust and suitable for applications at millimeter wave frequencies (e.g. 60 GHz). We also explore here the possibility to break the glide symmetry as an additional degree of freedom to control the pass and stopbands. Finally, a dimer kind of glide-symmetry, named bridged glide symmetry, is introduced to enhance the attenuation per unit cell.

14:10 Ultra-Band Non-Dispersive Leaky-Wave Antenna Based on Glide-Symmetric Meandered Transmission Lines
Mahsa Ebrahimipour and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Anthony Gribic (University of Michigan, Ann Arbor, USA)

We present an ultra-wide band planar Lundell line based on glide-symmetric meandered transmission lines. In order to make the structure radiate, a non-dispersive leaky-wave structure is designed. The whole structure produces a pencil beam with steering capabilities from -60º to +60º in the azimuth direction from 10 to 20 GHz.

14:30 A Frequency-Controlled Fast Beam-Scanning Antenna with Glide-Symmetric Feeding
Wenxuan Tang and Qinggang Shi (Southeast University, China); Qiang Cheng (Southeast University, China); Tie Jun Cui (Southeast University, China)

This paper presents a frequency-controlled fast beam-scanning antenna fed with a glide-symmetric transmission line of spoof surface plasmon polaritons. Split ring resonators are located close to the transmission line as radiators. Due to the glide-symmetric property, negative-group-velocity waveguiding is supported on the transmission line and continuous beam scanning from backward to forward is realized. Directive beam is observed in simulation to scan from -62 to 32 degree when frequency varies from 5.2 to 10.22 GHz.

14:50 Holey and Pinned Structures Comparison for Waveguide Phase Shifters
Angel Palomares-Caballero (Universidad de Granada, Spain); Antonio Alex-Amor (Technical University of Madrid, Spain); Juan Valenzuela-Valdes (Universidad de Granada, Spain); Pablo Padilla (University of Granada, Spain)

This paper presents the applicability of using structures to control the phase shift in a waveguide phase shifter. By means of dispersion diagrams, different phase shift unit cells are analyzed. Glide symmetry is also applied to some of these unit cells to evaluate its effects in the propagating modes. Then, unit cells with best dispersive behaviour are selected to design two phase waveguide shifter, one by pinned unit cells and the other by holey pinned unit cells. Both waveguide phase shifters are well-matched in the frequency range from 50-75 GHz with insertion losses lower than 0.5 dB. The phase shift produced by both waveguide phase shifter is also evaluated. Pinned waveguide phase shifter is more dispersive compared to the holey waveguide phase shifter, while phase shift varies from 180º of -+50º and +10º, respectively.

15:10 Design of Antenna Arrays Using Groove Gap Waveguide Technology Implemented with Glide Symmetric Holes
Luis Fernando Herran (University of Oviedo, Spain); Astrid Alboga Bazariez (Ericsson Research, Ericsson AB, Sweden); Malcolm Nj Mou Kehn (National Chiao Tung University, Taiwan); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

There is an explosion designs of high directive antennas (array antennas) based on the use of gap waveguide technology. In most of them, the periodic structure used as Electromagnetic Band Gap (EBG) to control the leakage is the Bed of Nails. We present here another option where glide-symmetrical holes are used as EBG to design Groove Gap Waveguide (GGGW) based antennas. The use of this unit cell fulfil the main purpose of the design: the excitation of HOCLWs up to a desired maximum order. Two examples of antenna designs will be presented, one of them includes the design of a compact 1 to 4 power divider.

15:30 Coffee Break

16:00 Reconfigurable Microwave Components Using Glide-Symmetric Pin-loaded Parallel Plates
Mohammad Bagheri (Sorbonne University, France); Julien Sarrazin and Guido Valerio (Sorbonne Université, France)

Glide-symmetric structures have recently gained a lot of interest in the design of electromagnetic bandgap materials due to their high attenuation in the stopband region and for their capability to support an almost dispersionless wave propagation. In this paper, we propose a reconfigurable waveguide using a glide-symmetric structure with pins. We show how the wave propagation in this waveguide can be enabled or suppressed by a mere adjustment of the displacement between the two metallic plates of the waveguide. In addition, we demonstrate how this structure can be used to design a phase shifter.

16:20 Higher-Order Cylindrical Leaky Waves in Planar Structures
Paolo Burghignoli, Walter Fucaldo and Davide Comite (Sapienza University of Rome, Italy); Paolo Baccarelli (Roma Tre University, Italy); Alessandro Galli (Sapienza University of Rome, Italy)

The main features of the recently-introduced class of cylindrical leaky waves having arbitrary azimuthal order of cylindrical waveguides are presented. Canonical continuous ring sources are described. A comparison of exciting such waves in general multilayered structures. The relevant electrodynamic potentials are derived and analytical formulas are provided for their radiation patterns in the far-field region. Guidelines for the design of discrete ring sources, i.e., circular phased arrays, for the excitation of HOCWLs up to a desired maximum order are also provided.

16:40 Mode-matching Analysis of Loaded Transmission Lines with Twist Symmetries
Giskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Guido Valerio (Sorbonne Université, France); Francisco Mesa (University of Sevilla, Spain); Fatemeh Ghassemifard, Martin Norgren and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This paper studies the propagation characteristics in twist-symmetric structures by means of a mode-matching approach. The studied structures are coaxial transmission lines periodically loaded with 1- and 3-fold twist-symmetric infinitely thin sectorial sheets. The mode-matching formulation is validated with the commercial software CST Microwave Studio. In addition, the impact of adding twist symmetry to a coaxial line on the coupling of the higher order TM modes is discussed.

17:00 Dual-band Polarizing Screen Based on Self-Supported Metallic Structures
Carlos Molero (IETR-INSa Rennes, France); Lionel Simon (SWISSto12 SA, Switzerland); Esteban Menargues (SWISSto12, Switzerland); Tomislav Debogovic (SWISSto12 SA, Switzerland); Francisco Mesa (University of Sevilla, Spain); Fatemeh Ghassemifard, Martin Norgren and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

A metallic periodic screen is here proposed that allows for dual-band operation and polarization conversion. The unit-cell structure is monolithic and three-dimensional, and it consists of a section of metallic waveguide loaded with perforations at its lateral walls. The geometry of the unit cell allows for independent control of incident fields with horizontal or vertical orientation. This feature is employed to manipulate the polarization of the illuminating wave. An equivalent circuit is proposed in order to model the cell behaviour. Three design examples are proposed with different polarization conversion capabilities. All of the examples concern a dual-band polarizer providing orthogonal sense of circular polarization at each of the bands. Such a design is manufactured and some preliminary measurements are in order to validate the proposed concept.

17:20 Exceptional Points of Degeneracy in Electromagnetic Waveguides and the Role of Symmetries
Tarek Mealy, Mohamed Y Nada, Ahmed F. Abdelshafy, Ehsan Hafezi and Filippo Capolino (University of California, Irvine, USA)

We show the relation between reflection and glide symmetry in periodic waveguides and the existence of various orders of exceptional points of degeneracy (EPDs). We use an equivalent circuit network to model each unit-cell of the waveguide. Assuming that a coupled mode waveguide supports N modes in each direction we derive the following conclusions. When N is even, we show that a periodic waveguide with reflection symmetry may exhibit EPDs of maximum order N. To obtain a degenerate band edge (DBE) with only two coupled waveguides, reflection symmetry must be broken. For odd N, N+1 is the maximum order that may be obtained, and an EPD of order N is not allowed. We present an example of three coupled microstrip transmission lines and show how by introducing glide symmetry we enable the occurrence of a stationary inflection point (SIP) which is an EPD of order three.

17:40 Analysis of Glide-Symmetric Dielectric Corrugated Structures - Properties of TE and TM Propagating Modes
Zvonimir Sirus and Marko Bosiljevac (University of Zagreb, Croatia)

Tailoring dispersion properties of different waveguiding structures using glide-symmetric properties has shown huge potential. Our interest in this paper is focused on the analysis and design of such dielectric glide-symmetric structures. The analysis method separates the analyzed structure into different regions and describes the EM field in each region with suitable modes. These representations are then connected using symmetry properties which results in an efficient approach for determining dispersion properties and gives a clear physical insight into the propagation mechanisms in such waveguides. The developed approach is verified using the results of commercial solver and this is followed with the analysis of differences between TE and TM modes and the obtainable properties.

This paper presents a frequency-controlled fast beam- scanning antenna fed with a glide-symmetric transmission line of spoof surface plasmon polaritons. Split ring resonators are located close to the transmission line as radiators. Due to the glide-symmetric property, negative-group-velocity waveguiding is supported on the transmission line and continuous beam scanning from backward to forward is realized. Directive beam is observed in simulation to scan from -62 to 32 degree when frequency varies from 5.2 to 10.22 GHz.

We present an ultra-wide band planar Lundell line based on glide-symmetric meandered transmission lines. In order to make the structure radiate, a non-dispersive leaky-wave structure is designed. The whole structure produces a pencil beam with steering capabilities from -60º to +60º in the azimuth direction from 10 to 20 GHz.
13:30 Quasi-Optical Excitation of a Circularly-Polarized Metasurface Antenna at K-band
Jorge Ruiz García (Universitat de les Illes Balears, Spain); Marco Faenza (Université de Rennes 1, France); Adham Mahmoud (Institut d’Electricité et de Télécommunications de Rennes, France); Mauro Ettorre (University of Rennes 1 & LRIM CNRS 6164, France); Patrick Potier (DGA, France); Poulligen Philippe (DGA, France); Ronan Sauleau (University of Rennes 1, France); David Gonzalez-Oviedo (Centre National de la Recherche Scientifique - CNRS, France).

This paper presents a new concept of modulated metasurface (MTS) antenna for satellite communications. As opposed to using cylindrical source waves (SR) to excite circular apertures, we employ a quasi-optical beamformer to launch a plane SR. This architecture enables an efficient illumination of rectangular apertures. In addition, the use of anisotropic MTS elements allows us to achieve circularly-polarized beams with excellent characteristics in terms of cross-polarization discrimination. We present the design process of a prototype at K-band and the obtained simulation results, which prove the suitability of this antenna for satellite data links.

13:50 Leaky Wave Analysis of Periodic Corrugated Metallic Plates with Complex Shapes
Despoina Kampouridou and Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain)).

The leaky wave analysis of corrugated metallic structures is presented in this work. Two known analytical periodic methods are compared with the results of the Matrix Pencil Method, which is applied for the first time for this type of leaky wave antenna. The complex wavenumber of the leaky mode is extracted for two corrugated antenna cases designed for operation around 30 GHz. From the calculated dispersion the farfield characteristics of the leaky wave antenna can be evaluated and the response can be calculated.

14:10 Near-field Focusing Through Higher-order Cylindrical Leaky Waves
Davide Comesi, Walter Fucсалdє and Paolo Bughignoli (Sapienza University of Rome, Italy); Paolo Baccarelli (Rome Tre University, Italy); Alessandro Galli (Sapienza University of Rome, Italy).

The possibility of generating a higher-order nondiffracting Bessel beam by means of a fast backward spatial harmonic is discussed in this work. The focusing features of the radiated near field are achieved by the excitation of a higher-order cylindrical leaky wave supported by an annular metal- strip grating placed on a grounded dielectric slab, which is excited by a circular array ofelementary sources. By properly phasing the array elements, the azimuthal order of the radiated beam is controlled, offering the possibility of generating a focused beam of arbitrary order by carrying a nonzero orbital angular momentum. Full-wave simulations of a prototype are developed using a commercial code and the field profiles are compared with the ideal beam supported by an infinite aperture.

14:30 Near-Field Beamforming in Leaky-Wave Resonant Antennas
Sjord Bosma, Huasheng Zhang, Andrea Neto and Nuria Llombart (Delft University of Technology, The Netherlands).

There is a large interest in utilizing lens arrays for many applications in the mm- and sub-mm-wavelength range. The efficiency of the excitation of dielectric lenses increases significantly when the feeding structure supports leaky-wave radiation mechanisms. Leaky-wave feeding structures based on resonant cavities can generate very high directivity in a dense medium. Many scenarios require lenses of moderate size and typically the focusing surface needs to be in the near field of the radiators. In this contribution, we analyze the near-field radiation mechanism of such leaky-wave feeds and provide guidelines to design moderate size lenses.

14:50 Prism-based Leaky-Lens Antennas at 60 GHz for 5G Point-to-Point Communication Links
Qiao Chen (KTH Royal Institute of Technology, Sweden & State Key Laboratory of Millimeter Wave, Chinese Academy of Sciences, China); Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Francesco Mersa (University of Seville, Spain); Pablo Padilla (University of Granada, Spain); Angel Palomares-Caballero (Universidad de Granada, Spain); Elena Pucci (Ericsson AB, Sweden); Xiaosheng Yin (State Key Laboratory of Millimeter Wave, China); Oscar Quevedo-Tenreiro (KTH Royal Institute of Technology, Sweden).

Two complementary implementations of a leaky lens antenna at 60 GHz are proposed for high-throughput 5G communication links. The leaky-wave field is realized in a quasi-waveguide technology, where the radiation from the slit is controlled with glide-symmetric holes. The beam-squint of the leaky-wave radiation is mitigated, owing to the coupling of a complementary-dispersive prism. Here, two prisms are implemented, one with glide-symmetric holes, and another with substrate-integrated holes (SIH), both integrated in parallel plates with the leaky-wave feeding. Thanks to glide symmetry, better control of the leakage rate, lower costs, and better tolerance to manufacturing are achieved in comparison with the non-glide holey counterpart. In addition, the SLH-based design exhibits substantial enhanced bandwidth as well as better robustness. In the analysis of the leaky-wave feed, more accuracy and reduced computational time is achieved by using a multi-mode method. Both antennas show stable radiation patterns, featuring high efficiency, high gain, and low side lobe levels.

15:10 Direct Synthesis of Frequency-Scanned Monopulse Half-Width Microlens Leaky-Wave Antennas
Alejandro Gil Martinez (Technical University of Cartagena Cartagena, Spain); Miguel Poveda Garcia (Technical University of Cartagena, Spain); Jose-Luis Gomez-Tornero (Polytechnic University of Cartagena, Spain).

We propose a synthesis technique for half-width microlens leaky-wave antennas (HML LWAs) producing frequency-scanned monopulse patterns with two channels. The excitation of the substrate thickness and dielectric constant is of key importance to obtain the desired angular scanning in the prescribed frequency band, when coupled with an appropriate dielectric profile. The leaky-wave antenna is fabricated using an advanced additive manufacturing technique, which allows the design of substrates of any complexity. The radiated fields of the proposed antennas are compared with the non-glide holey counterparts. In addition, the SIH-based design exhibits substantially enhanced bandwidth with even better robustness. In the analysis of the leaky-wave feed, more accuracy and reduced computational time is achieved by using a multi-mode method. Both antennas show stable radiation patterns, featuring high efficiency, high gain, and low side lobe levels.
Monday, 16 March 13:30 - 18:00

**T08-A17: Antennas and Techniques for Positioning and Direction Finding**

**Room: B5**

**Chairs:** Thomas Kaufmann (U-blox AG, Switzerland), Richard J. Kozick (Bucknell University, USA)

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13:30 Two-Element Biomimetic Array Antenna Design for Power Extraction / Phase Amplification Tradeoff

Richard J. Kozick (Bucknell University, USA), Sid Foroohar (US Army Research Laboratory, USA), Brian Sadler (Army Research Laboratory, USA)

Two-element arrays composed of closely-spaced antennas with mutual phase have recently been investigated in conjunction with electrical coupling antennas that amplify the phase difference in the measurements. These systems have biomimetic analogues to the hearing mechanism in small insects that exhibit exceptional directional capabilities. Several coupling networks have been considered with varying complexity and performance relative to the fundamental tradeoff between power extraction and phase difference amplification. In this paper we present a general design method that establishes the achievable region for the power extraction / phase amplification tradeoff, and we present a four-port Pi coupling network that realizes the entire achievable region. An example illustrates the design methods to two closely-spaced dipole antennas at 40 MHz.

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13:50 Axially-Corrugated X-Band Horn Design with Integrated TE21 Monopulse Tracking in Corrugation

Grégoire Giet (Lynbird Antenna Research Pty Ltd, Australia); John Kot (Young & Kot Engineering Research, Australia)

A new concept to generate the TE21 monopulse tracking signal by integrating the tracking coupler into the first corrugation of an axially corrugated horn is presented. This new concept allows for a compact design while maintaining isolation between the communication and tracking networks.

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14:10 Adaptive GNSS Antenna Matching for Low-Cost Applications

Thomas Kaufmann and Rod Bryant (U-blox AG, Switzerland)

This paper presents a methodology for adapting the global navigation satellite systems (GNSS) antenna resonance frequency to different environments at a minimal cost. De-linking effects of GNSS antennas due to the environment or manufacturing tolerances, especially for very compact narrow band antennas, significantly reduce the carrier-to-noise ratio (CNR) of the GNSS signal. This detrimental effect on the acquisition, tracking and finally navigation performance of the system. A multi-frequency excitation is an RF switch with different pre-defined matching components. A supervisory system uses knowledge of the received signal and switches between the matching options to maximize the realized RF gain. This increases the signal quality and finally improves the performance of the GNSS receiver. It is shown that the de-linking of a single-antenna band due to ground plane effects can be successfully compensated. Furthermore, it is demonstrated that the resonances of a dual-band antennas can be shifted independently with the same approach.

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14:30 Element Mutual Coupling Effect in a Wideband Planar Aperiodic Sparse Phased Array

Shaoping Hu, Chao Shu and Xiaodong Chen (Queen Mary University of London, United Kingdom (Great Britain)); Kai Wang (East China Research Institute of Electronic Engineering, China)

This paper presents our study on a planar wideband aperiodic sparse phased array and the effect of element mutual coupling. The planar aperiodic sparse phased array in a circular dish with a diameter of 1500 mm was optimized by using covariance matrix adaptation evolutionary strategy (CMA-ES) together with Dantzer tiling to generate the peak SLL (Side Lobe Level) of array factor less than -13 dB without the main beam steered to 0.5dB with the main beam steered to 0.5°, away from the broadside in a band from 0° to 10°. Then, the array using the rectangular patch antenna as the element has been simulated by using CST Microwave Studio to study the effect of mutual coupling when the elements are separated by 0.4°/2-4. Basis, the peak gain degrades a little bit, while SLL has large degradation in some specific directions, resulted from the mutual coupling between the array elements.

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14:50 A Broadband Circularly Polarized Antenna with Triple-Mode Characteristics

Wei Hu, Xueliang Liu and Hao Wu (Xidian University, China); Steven Gao and Luhw Wen (University of Kent, United Kingdom (Great Britain)); Yuan-Ming Cai (Xidian University, China)

A novel circularly polarized (CP) antenna based on the triple-mode characteristics is presented in this paper. By using three resonant elements, a compact antenna element can be realized in the three-dimensional (3D) design. By sequentially exciting four antenna elements with a progressive 90° phase shift, a wideband CP windmill-shaped antenna is developed. The proposed antenna exhibits a wide impedance bandwidth (19.4%), a wide axial ratio (AR) bandwidth (80%), and a low profile (0.18λ) in the wavelength in free space at the lowest operating frequency. Such a wideband and low-profile CP antenna is a promising candidate for modern broadband CP applications.

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15:10 A Method of Side-lobe Suppression for Reactance Modulated Antennas

Peng-Yuan Wang (University of Duisburg-Essen, Germany); Meng Fan-Yi (Harbin Institute of Technology, China); Yue-Long Lyu (The 14th Research Institute, CETGC, China); Andreas Renning and Daniel Emri (University of Duisburg-Essen, Germany)

This paper reveals the mechanism of the high side-lobe level (SLL) phenomenon in reactance modulated antennas (RMAs) and proposes a method to suppress the side-lobes for RMAs. The wave-guiding mode in RMAs is a surface wave confined within a dielectric field exposed to the free-space. We found that it is the exposure of EM power results in the slow-wave radiation (SRR) phenomenon deteriorating the SLL. To eliminate the SRR, a “complementary decoupling” method is proposed by introducing another RMA with inverse periodic variation to the original one. The two parallel antennas are excited with equal amplitude and reversed phase forming a complementary radiation part. With the proposed method, the SRR is eliminated and the SLL is improved. Meanwhile, all of the even radiation modes are also suppressed. Especially for the 2nd mode, which also carries considerable power and often appears in most RMAs.

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15:30 Coffee Break

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16:00 Pattern Shifting and Size Control in Offset Reflector Antennas with Microstrip Array as Matched Feed

Kaushik Debbarma (IIT Guwahati, India); Ratnajit Bhattacharjee (Indian Institute of Technology, Guwahati, India)

This paper presents details of a dual-layered microstrip based matched feed array for an offset reflector. The top layer of the proposed feed consists of 9 TMI1 mode operating circular microstrip patch antennas (CMPA) arranged in a centered circular array configuration. The second layer contains a CMPA operating in TM21 mode located below the central element of the circular array. The excitation ratio between the TM11 and TM11 mode patches is varied to achieve a low cross-polar level at the asymmetric plane at different array radius. An investigation has been done to show that by exciting selective array antenna elements, beamwidth and beamwidth/broadside reconfigurability in the reflector pattern can be achieved while maintaining the cross-polar level below -38 dB by having a proper mode excitation ratio. A maximum beamshift of 0.4 degree (approximately 31% of 3dB beamwidth) from the principal axis has been achieved in the reflector pattern.

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16:20 Frequency Diversity Array Information Geometry Analysis

Hailong Yu and Qinglong Han (Beijing Institute of Space Craft System Engineering, China); Xiaojing Ji (Air Force Research Institute, China); Zhibin Wang (Beijing Institute of Space Craft System Engineering, China); Wen-Qin Wang (University of Electric Science and Technology of China, China)

This paper presents our study on a planar wideband aperiodic sparse phased array and the effect of element mutual coupling. The planar aperiodic sparse phased array in a circular dish with a diameter of 1500 mm was optimized by using covariance matrix adaptation evolutionary strategy (CMA-ES) together with Dantzer tiling to generate the peak SLL (Side Lobe Level) of array factor less than -13 dB without the main beam steered to 0.5dB with the main beam steered to 0.5°, away from the broadside in a band from 0° to 10°. Then, the array using the rectangular patch antenna as the element has been simulated by using CST Microwave Studio to study the effect of mutual coupling when the elements are separated by 0.4°/2-4. Basis, the peak gain degrades a little bit, while SLL has large degradation in some specific directions, resulted from the mutual coupling between the array elements.

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16:40 OSS-based AoA Estimation System for IoT Applications Using Rotman Lens

Muhan Zhang (Beijing Institute of Space Craft System Engineering, China); Steven Gao (University of Duisburg-Essen, Germany); Meng Fan-Yi (Harbin Institute of Technology, China); Andreas Renning and Daniel Emri (University of Duisburg-Essen, Germany)

This paper presents a methodology for adapting the global navigation satellite systems (GNSS) antenna resonance frequency to different environments at a minimal cost. De-linking effects of GNSS antennas due to the environment or manufacturing tolerances, especially for very compact narrow band antennas, significantly reduce the carrier-to-noise ratio (CNR) of the GNSS signal. This detrimental effect on the acquisition, tracking and finally navigation performance of the system. A multi-frequency excitation is an RF switch with different pre-defined matching components. A supervisory system uses knowledge of the received signal and switches between the matching options to maximize the realized RF gain. This increases the signal quality and finally improves the performance of the GNSS receiver. It is shown that the de-linking of a single-antenna band due to ground plane effects can be successfully compensated. Furthermore, it is demonstrated that the resonances of a dual-band antennas can be shifted independently with the same approach.

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This paper presents a general design method that establishes the achievable region for the power extraction / phase amplification tradeoff, and we present a four-port Pi coupling network that realizes the entire achievable region. An example illustrates the design methods to two closely-spaced dipole antennas at 40 MHz.

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Shahab Oddin Dabironezare, Muhan Zhang and Giorgio Carluccio (Delft University of Technology, The Netherlands)

Future sub-millimeter images will use large format focal plane arrays (FFAs) of lenses to increase their field of view and the image speed. This abstract employs a spectral technique based on Fourier Optics for analyzing lens based FPAs. Here, the method is applied to optimize the scanning performance of an imager with monolithically integratable lens feeds without employing any optimization algorithms, by doing a field match by a tunable leaky resonant antenna. The synthesized FPA achieved scan losses much lower than the ones predicted by standard formulas related to the direct field coming from the reflector. In particular, a FPA with scan loss below 0.1 dB while scanning up to +17.5° is presented with directivity of 52 dB. A prototype of the described design using realistic antenna feeders is also presented.
In this paper, we present a new Angle of Arrival (AoA) estimation system for Internet of Things (IoT) applications. The proposed system utilizes the received signal strength (RSS) to estimate the AoA of the received signal in the 868 MHz frequency band. The system consists of two sub-systems: Sub-system 1 utilizes a rotman lens to provide analog beam steering, and Sub-system 2 utilizes the spatially regularized minimization technique to estimate the AoA of the received signal based on the RSS values. An experiment has been conducted in an anechoic chamber to validate the AoA estimation accuracy. The experimental results reveal that the proposed system can accurately estimate the AoA of the received signal based on the RSS values.

17:00 RSS-Based DoA Estimation Using ESPAR Antenna for V2X Applications in 802.11P Frequency Band

Damian Dura (Gdansk University of Technology, Poland); Mateusz Rymszyn (Gdansk University of Technology & WiComm Center of Excellence, Poland); Krzysztof Nyka (Gdansk University of Technology, Poland); Lukasz Kulas (Gdansk University of Technology, Faculty of Electronics, Telecommunications and Informatics, Poland)

In this paper, we have proposed direction of arrival (DoA) estimation of incoming signals for V2X applications in 802.11P frequency band, based on recording of received signal strength (RSS) from ESPAR antennas output port. The motivation of the work was to prove that ESPAR antennas are used to increase connectivity and security in V2X communication as can be used for DoA estimation. The numerical simulation results show that for every proposed radiation pattern we can obtain acceptable DoA estimation results, even with radiation pattern without strong maximum and deep minimum.

17:20 Phase-Based Variant Maximum Likelihood Positioning for Passive UHF-RFID Tags

Chenglong Li and Emmneric Tanghe (Ghent University, Belgium); David Plets (Ghent University - imec, Belgium); Pieter Suait (Aucxis, Belgium); Nico Podevin (University of Ghent, Belgium); Jeroen Hoebeke (Ghent University - imec, Belgium); Els De Poorter (Ghent University & imec, Belgium); Luc Martens (Ghent University - imec, Belgium); Wout Joseph (Ghent University/IMEC, Belgium)

Radio frequency identification (RFID) technology brings tremendous advancement in Internet-of-Things, especially in supply chain and smart inventory management. Phase-based passive ultra high frequency RFID tag localization has attracted great interest, due to its miniaturization to the propagation environment and tagged object properties compared with the signal strength based method. In this paper, a phase-based maximum-likelihood tag positioning estimation is proposed. To mitigate the phase uncertainty, the likelihood function is reconstructed through trigonometric transformation. Weights are constructed to reduce the impact of unexpected interference and to augment the positioning performance. The experiment results show that the proposed algorithms achieve fine-grained tag localization, which achieve centimeter-level lateral accuracy, and less than 15-centimeters vertical accuracy along the altitude of the racks.

17:40 Impact of UWB Antennas on Ranging Accuracy

David Veit, Michael Gadringer and Erich Lettgib (Graz University of Technology, Austria)

This work deals with the impact of antennas on the ranging accuracy of a ultra-wideband system. For two different antennas we tried to relate multiple commonly used antenna characteristics with the ranging error produced by the ultra-wideband system. Our analysis showed that parameters which do not incorporate information about the used transmit signal deliver only limited information. In the conclusion we provide some advice for ultra-wideband antenna designers and system architects.

T05-A12/1: Wearable and Implantable Antennas

T05 Biomedical and health / Regular Session / Antennas
Room: B6
Chairs: Sema Dumanli (Bogaziçi University, Turkey), Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

13:30 Low-Profile and High-Gain Linear Polarized Loop Antenna

Ali Khaleghi (Norwegian University of Science and Technology (NTNU) & Oslo University Hospital, Norway); Ibangko Balasingham (Norwegian Institute of Science and Technology, Norway)

A loop antenna on top of a metal plate can provide a higher gain than that of a dipole antenna. A low depth profile multi-loop geometry is proposed with a thickness of 0.02 wavelength to the back metal plate. The designed loop antenna is self-matched to the 50-ohm impedance of a source and provides a high directional gain of 8.2 dBi. The antenna gain is increased to 10.5 dBi by using a dual multi-loop geometry. Sample antennas are designed and manufactured for operating at 2350 MHz. The antennas are measured and characterized for the return-loss, radiation pattern and gain. The proposed antenna can be used as a wearable antenna in wireless body area network (WBAN), in which the backside reduction is reduced and the antenna-impedance characteristics are not affected by the background tissue.

13:50 Multilayer Ultra-Miniature Loop Antenna for Insertable Pill Application

Amine Samoudi (Ghent University & IMEC, Belgium); Gustar Vermeiren (Ghent University, Belgium); Denys Nikolayev (Institut d’Electronique et de Télécommunications de Rennes (IMR CNRS 6164), France); Minyoung Song (Holst Centre/IMEC, The Netherlands); Yao-Hong Liu (imec, The Netherlands); Vouet Joseph (Ghent University/IMEC, Belgium); Luc Martens (Ghent University, Belgium)

An ultra-miniaturized multilayer loop antenna for insertable pill applications is presented. The antenna is designed for the Medical Device Radiocommunications service (MedRadio 401-408 MHz) and makes use of the three metal layers of the antenna board to increase its electrical length within a compact size of 16.2 mm (3.3 × 4.9 mm). The realized gain is 10.2 dBi in 401-408 MHz. The simulated and measured results show that the realized gain is -38.3 dBi in the region of 1-3 GHz. The antenna gain is increased to 10.0 dBi by using a dual multi-loop geometry. Sample antennas are designed and manufactured to cover the distance between the loop and the dipole, the loop is meandered and designed in a three-dimensional structure.

14:10 Body Mounted Dipole-Loop Composite Antenna with Reconfigurable Front for Non-Alcoholic Fatty Liver Disease Diagnosis Systems

Sasan Ahdi Rezaeieh (University of Technology Sydney, Australia); Raheel Maqsood Hashmi (Ghent University - imec, Belgium); Dennis Joosens (University of Ghent, Belgium); Ilangko Balasingham (Graz University of Technology, Austria)

A body mounted dipole antenna with reconfigurable front aiming capability for electromagnetic-based non-alcoholic fatty liver disease diagnosis systems is proposed. The antenna utilizes a combination of three distinct methods to achieve unidirectional radiation, miniaturize the size of the antenna and reconfigure field focusing. To achieve unidirectional radiation and wide operating bandwidth, a loop-dipole configuration is utilized to eliminate the need for conventional balun reflectors. The dipole is matched to the probe to miniaturize the size of the antenna. To avoid using dielectric loading to cover the distance between the loop and the dipole, the loop is meandered and designed in a three-dimensional structure.

14:30 Robustness Analysis of the Polymer- Conductive-Mesh Composite for the Realization of Transparent and Flexible Wearable Antennas

Abu Sadat Md. Sayem (Macquarie University, Australia); Karu Esselle (University of Technology Sydney, Australia); Raheel Maqsood Hashmi (Macquarie University & IEEE, Australia)

In this paper the morphology of the polyethylene (PDMS) flexible-conductive-mesh composite has been studied to evaluate its suitability in the realization of robust, transparent, wearable antennas that can withstand multiple bending operations. We have utilized conductive mesh made out of Veldshield from Less EMI which has about 70% light transmittance and is highly flexible. On the other hand, PDMS is a highly flexible and optically transparent polymer. Uncured PDMS is in liquid form and upon curing it transforms to a robust flexible substrate and forms a strong bonding with the conductive mesh. Veldshield. We have examined the composite through Scanning Electron Microscope (SEM) images during and after multiple bending operations. Later, we have designed a simple patch antenna operating at 2.45 GHz band using our selected materials. For performance evaluation the antenna is tested in both free space and under bent conditions and the results are presented in this paper.

14:50 Miniaturized CPW-fed Bowtie Slot Antenna for Wearable Biomedical Application

Amir Arayeshnia (Norwegian University of Science and Technology (NTNU) & Oslo University Hospital, Norway); Ibangko Balasingham (Norwegian Institute of Science and Technology, Norway)

In this paper, we present the design and implementation of a CPW-fed wearable integrated rectenna antenna (rectenna) for far-field wireless powering for low-power sensors. A circular patch antenna resonant at 2.45 GHz is designed, manufactured and characterized. The performance of the fabricated antenna is studied when it is placed over body tissues for wearable applications. A Spice model for a Schottky diode, which is part of the rectifier, is implemented and tested in different rectifying circuits for low input powers, ranging from -20dBm to 0-dBm. A rectifying circuit at 2.45 GHz is fabricated and measured in terms of power-conversion efficiency. The rectifier impedance is analyzed as a function of dc load and input power. Finally, the antennas and rectifiers are integrated as a rectenna, and the total efficiency evaluated for incident power densities up to 7 µW/cm² at 2.45 GHz.
In this work, we propose a wide-band slot-based frequency agile 2-layer Yagi-like multiple-input-multiple-output (MIMO) antenna system. The MIMO system consists of 4 identical pentagonal slot-like active antenna elements actively loaded with varactor diodes to achieve frequency reconfigurability. The proposed antenna could be tuned over a wide enough frequency range (120 - 31.5 GHz) to achieve a radiation efficiency of a slot antenna, with a parasitic metallic reflector layer placed below the substrate. This helped in suppressing the backside radiation and thus a front-to-back ratio (FBR) of 5 - 13 dB is achieved within the entire frequency band of operation. The proposed 4-element design is compact with an overall size of $101 \times 102 \times 20 \text{mm}^3$, and a reflector size of $110 \times 110 \times 20 \text{mm}^3$. The antenna system also shows good MIMO performance with high port isolation and very low envelope correlation coefficient (ECC) values within the operational band.

16:20 Applications of Mixed Powder Dielectricals in Prototype 2.4GHz Pendant Antenna Design and Manufacture

John Brister, Robert Michael Edwards and Jacky Brister (Loughborough University, United Kingdom (Great Britain))

In this paper a new type of dielectric emitting platform that is suitable in the study of on-body and close to body antennas is presented. The use of pressure agglomerating dielectric powders within a bespoke 3D printed enclosure are discussed for rapid prototyping. Particular attention is given to attempting to avoid the effects of reactive near field due to antennas constantly in contact with the body. The method of using high permeability mixed dielectric powders in the size reduction of a commercial diode and a compact spherical helical antenna with a balanced feed are discussed.

16:40 A Biodegradable Implant Antenna Detecting Post-Surgical Infection

Kivanc Ararat, Omer Altan, Sanberk Serbest, Oguzhan Basar and Semsa Duranli (Bogazici University, Turkey)

Biodegradable implants have been proven to have no need to be taken through an additional operation for the removal of the implant. Here biodegradability is utilized further where the biodegradation process has been part of the device’s operation. An implant antenna is designed to detect post-surgical infections which increase the acidity inside the human body. The implant antenna is proposed to be located in the operation site where it degrades at different paces depending on the existence of infection or not. The Mag antenna is tested in cows’ incised milk where the degradation is monitored using a wearable slot antenna used as a reader. The detection was possible for an implant depth of 1 cm with 14 MHz resolution.

17:00 Protective Coating Methods for Glow-Incorporated RFID Tags - A Preliminary Study

Zahangi Khan, Han He, Xiaochen Chen, Leena Ukkonen and Johanna Virkki (Tampere University, Finland)

In this study, machine washing durability of working-integrated passive RFID tags is evaluated. These glow-tags are embedded inside 3D-printed thermoplastic polyurethane platforms. The results are compared to platforms embedded inside brush-painted encapsulant platforms. For a preliminary washing reliability evaluation, both types of glow-integrated platforms are washed in a washing machine for 5 times. Although both platforms can protect glow-tags from the effects of water, the main reliability challenge is found to be the fragile antenna/RF membrane attachments. This paper introduces the two platform materials and the achieved washing test results. These preliminary results determine the future direction of this research. The next step is to study suitable methods to strengthen the interconnections, as these glow-tags can survive the harsh environment inside a washing machine.

17:20 A Low Profile Button Antenna with Back Radiation Reduced by FSS

Bappaditya Mandal (Uppsala University, Uppsala, Sweden); Ayan Chatterjee (National Institute of Technology Sikkim, India); Pramod K B Rangalal (Researcher & Uppsala University, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Robin Augustine (Uppsala University, Sweden)

In this article, a button antenna with a reflective frequency selective surface (FSS) is proposed to reduce its back-radiation. The proposed antenna is in profile, circularly polarized and designed for Wi-Fi and WLAN applications. The radiating element is made of copper sheet, while a transparent acrylic fiber sheet is used as a substrate. The antenna is fed by a coaxial line, and the FSS layer is designed on a rear aperture. The patch type FSS with split ring shape has also been designed to operate in the Wi-Fi and WLAN frequency band (2.4-5.8 GHz) with the centre frequency of 5.11 GHz. The FSS reduces back radiation of the antenna by 4 dB. The antenna with FSS is fabricated, and a measured gain of 2.94 dB is obtained that matches well with the theoretical value. The antenna is miniaturized by around 61.15% by the splits.

17:40 Frequency Reconfigurable Multi-Band Antenna Using 1-0 EBG Structures with BST Chip Capacitors

Jae-Yeong Lee (Pohang University of Science and Technology (POSTECH), Korea (South)); Kyung-Bin Lee (Gwangju Institute of Science and Technology (GIST), Korea (South)); Celso Leite (Samsung Electronics, Korea (South)); Seung-Han Kim (Defense Agency for Technology and Quality, Korea (South)); Jaa-Hyung Jang (Gwangju Institute of Science and Technology, Korea (South))

This paper describes a multi-band antenna using a two-dimensional electromagnetic bandgap structures with barium strontium titanate chip capacitors for frequency reconfigurable operation in multi-band. Despite the absence of an RF choke and DC blocking capacitor, a frequency reconfigurable antenna featuring high radiation performance with low DC power consumption is realized. The frequency tuning ratios are 25% in low frequency band and 4.6% in high frequency band. The antenna exhibits low power consumption less than 1 W and high antenna efficiency (more than 40%).

Monday, 16 March 13:30 - 15:30

CS05: AMTA Session: Automotive Antenna Measurements and Testing

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Convened Session / Measurements

Chair: Philipp Berlt (Technische Universität Ilmenau, Germany), Lars Foged (Microwave Vision Italy, Italy)

13:30 Experimental Comparison of Vehicular Antenna Measurements Performed over Different Floors

Per Ivensen (Orbit/FR, USA); John Estrada (MIV, USA), Francesco Saccardi and Lars Foged (Microwave Vision Italy, Italy); Francesca Mioc (Consultant, Switzerland); Michael Edgerton and Janalee Graham (General Motors, USA)

Large truncated spherical near-field systems with conductive or absorbing roofs are typically involved in the measurement of the performances of vehicle installed antennas. The main advantage of a conductive floor systems is the ease of accommodation of the vehicle under test, but their performances are often degraded by the strong interaction with the reflective floor. Instead, absorbing-based systems avoiding free-space conditions ensure better accuracy, but generally require longer set-up times, especially at lower frequencies (70-400 MHz), where bulky absorbers are typically used to ensure good reflectivity levels. Considering scaled measurements of a vehicle model, the performance of these two typical implementations are analysed in the 84-1500 MHz range and compared to free-space measurements. Absorbers with different dimensions and reflectiveness have been installed in the scaled measurement setup, and measured data have been investigated with proper post-processing to verify the applicability to realistic systems.

13:50 Exploring Spatial Derivative Information in Phaseless Near-Field Far-Field Transformations

Alexander Paulus (Technical University of Munich, Germany); Thomas F Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

By exploring information about the spatial derivative of magnitude data, we increase the reliability of phaseless near-field far-field transformations. While existing techniques operate on the measured magnitudes, the presented formulation puts restrictions on the first-order spatial derivative of the measured magnitudes. This potentially allows us to utilize hidden information about the antenna near fields and, thus, increase the chances of field success and phaseless transformation. Preliminary simulation results for an implementation based on the fully-analytic equations for the spatial derivatives of the magnitude of fields caused by Hertzian dipoles are presented. The comparison as well as combination with a spatial phasemeter show the potential of the new formulation.

14:10 Accurate 3D Phase Recovery of Automotive Antennas Through LTE Power Measurements on A Cylindrical Surface

Philipp Bert and Christian Bornkessel (Technische Universität Ilmenau, Germany), Matthias Hein (Ilmenau University of Technology, Germany)

Phaseless antenna measurements have been gaining much interest in the past. In the course of increasing integration of antennas with frontends and digital signal processing units on chips, the measurement of the phase pattern becomes challenging since a RF connection to the antenna feed point is missing and common measurement methods with a vector network analyser cannot be applied. This paper deals with a phase recovery technique exploiting intrinsic communication signals from a LTE user equipment, following the approach of indirect holography in spatial domain. Phase recovery is applied on a cylindrical vector network analyser subject to both known delays and data corruption. Comparison to a conventional phase measurement with a vector network analyser shows excellent agreement on the entire measured surface. Thus, this approach is a promising alternative and has high potential for further signal processing, e.g. rawfield to far field transformation or localization of the antenna within the measurement volume.

14:30 Modeling of a Far-Field Automotive Antenna Range Using Computational Electromagnetic Tools

Daniel N Alci and Ehab Abdul-Rahman (Oakland University, USA)

Vehicle-level antenna performance standards are being established for vehicle-to-everything (V2X) communications that support safety life applications for automobiles. Once these antenna performance standards are established, there must be confidence that automotive antenna measurement systems can make accurate and repeatable measurements. In this paper, a full-wave, three-dimensional electromagnetic field solver based on the method of moments (MoM) was utilized to create a simulation model of the antenna measurement process at Oakland University’s outdoor automotive antenna range. Initial results for the comparison of this model against measurements are provided in this paper for a directive monopole antenna on a one-meter diameter ground plane. This type of tool will be useful to establish uncertainty levels for vehicle-level antenna gain measurements.
Human activity recognition (HAR) is a growing research field with a wide range of applications. Magnetic induction-based motion signals are used for recognizing individual users and distinguishing between different learners the k-Nearest Neighbors (kNN), the Support Vector Regression (SVR) and the Random Forest (RF). The comparison of the performance of these learners indicates that the k-Nearest Neighbors (kNN) performs better than the Support Vector Regression (SVR) and the Random Forest (RF).

In this paper, we apply different machine learning methods for the prediction of path loss in urban environment for frequency bands from 30 to 35 GHz. To achieve this compactness an optimized unit cell with glide symmetry is utilized. Single ridge waveguides are analyzed to minimize the phase error and to achieve an optimal impedance match to the feed. The design not only leads to a negligible phase error at the aperture but also has an excellent impedance match to the feed and a gain of over 20 dBi is achieved in simulations with a lens diameter of 15 wavelengths before compression.

The present work introduces an all-metal Gutman lens antenna in a parallel plate waveguide (PPW) technology for space applications. The lens is designed to compress the height of the lens to 40% of its original value. A moderate compression of 50% is applied to facilitate an all-dielectric realization. A gain of almost 20 dB is obtained in simulations with a lens diameter of 4 free space wavelengths before compression.

This paper presents the design of a volumetric Luneburg lens antenna. Transformation optics is used to compress the height of the lens to less than 50% of its original value. A gain of almost 20 dBi is obtained in simulations with a lens diameter of 4 free space wavelengths before compression.

In this paper, we revisit the band-stitching scheme, i.e. combining multiple logic channels of small bandwidth to form a large total bandwidth. We focus on the calibration stage of this scheme, and on the effect of the phase jump at the junctions of adjacent subbands on the frequency response of the system is investigated through simulation.

In this paper, we present the design of a volumetric Luneburg lens antenna. Transformation optics is used to compress the height of the lens to 40% of its original value. A moderate compression of 50% is applied to facilitate an all-dielectric realization. A gain of almost 20 dB is obtained in simulations with a lens diameter of 15 wavelengths before compression.

This overview paper summarizes the recent advances in automotive antenna measurements during the last years. This topic has become important in the past, but the development of new communication systems, especially the fifth-generation (5G) cellular systems means a huge number of antennas and sensors placed in all the vehicles. During the last year several research groups, connected with the industry have shown advances in measurement architecture, hardware and post-processing algorithms.

In this work, we apply different machine learning methods for the prediction of path loss in urban environment for frequency bands from 30 to 35 GHz. To achieve this compactness an optimized unit cell with glide symmetry is utilized. Single ridge waveguides are analyzed to minimize the phase error and to achieve an optimal impedance match to the feed. The design not only leads to a negligible phase error at the aperture but also has an excellent impedance match to the feed and a gain of over 20 dBi is achieved in simulations with a lens diameter of 4 free space wavelengths before compression.

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An innovative Learning-by-Examples (LBIE) methodology is presented to efficiently and accurately predict the surface currents in printed microstrip arrays. More in detail, the proposed technique is based on an orthonormal representation of the surface currents and on the generation of a fast surrogate model with high generalization capabilities. Thanks to such an approach, it is possible to accurately estimate the surface currents on the antenna under test (AUT) without the need for time-consuming full-wave simulations nor a perfect matching of its characteristics with the nominal ones (e.g., due to manufacturing errors/ inaccuracies). A preliminary numerical example is shown to assess the effectiveness and potentialities of the proposed LBIE methodology.

Near-Field Multi-Focused Arrays Using Support Vector Regression
Rafael González Ayestarán (University of Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)
Support Vector Regression, a powerful framework in the field of Machine Learning, is proposed for Near-Field Focusing using antenna arrays. It allows creating a model of an array relating the weights required in the elements of an array and the corresponding near-field distribution, focusing on one or more positions of interest. A previous learning process concentrates the computational cost so that the trained system operates without cost and fast enough for applications where adaptation must be fast, for example because moving devices are involved. The learning capabilities of Support Vector Machines are increased with respect to other machine learning tools, allowing the use of a reduced number of training samples that may be generated with an adaptive system or any full-wave electromagnetic analysis tool, so that realistic effects such as coupling or non-uniformities can be accounted for. Illustrative examples are also presented to test the performance of the method.

SNO Optimization Technique Applied to Reflectarray Antenna Design
Michele Beccaria (Politecnico di Torino, Italy); Alessandro Nicolai (Politecnico di Milano, Italy); Andrea Massaccesi (Politecnico di Torino, Italy); Riccardo Enrico Zich (Politecnico di Milano, Italy); Paola Pinolli (Politecnico di Torino, Italy)
This communication presents some numerical results on the optimized design of a passive reflector with scanning beam capabilities. The proposed approach is based on the use of an efficient pseudo stochastic optimization algorithm, the Social Network Optimization (SNO), and by a definition of a proper cost function, that allow the simultaneous optimization of the antenna radiation pattern for different pointing directions. The results relative to two different configurations, with increasing size, prove the effectiveness of the proposed method, also confirmed by the full-wave analysis of the smallest antenna.

Bayesian Active Learning for Electromagnetic Structure Design
Jiangle Qing, Nicolai Knudde and Ivo Couckuyt (Ghent University, Belgium); Domenico Spina (Ghent University - imec, Belgium); Tom Dhane (Ghent University & IMEC, Belgium)
A novel design framework based on Bayesian active learning is presented in this contribution. The proposed approach allows one to identify a set of design configurations satisfying the chosen specification. In particular, the entropy search-based active learning strategy, which relies on a Gaussian Process model, is able to minimize the number of time-consuming computer simulations or expensive design trials necessary to reach this goal. A suitable application example validates the proposed method.

Monday, 16 March 13:30 - 18:00
CS24: Controlling EM Waves with Low- and High-Dimensional Metamaterials

A novel design framework based on Bayesian active learning is presented in this contribution. The proposed approach allows one to identify a set of design configurations satisfying the chosen specification. In particular, the entropy search-based active learning strategy, which relies on a Gaussian Process model, is able to minimize the number of time-consuming computer simulations or expensive design trials necessary to reach this goal. A suitable application example validates the proposed method.
16:20 Stable Positive/negative Capacitor for Use in Active Artificial Structures
Silvio Habar (University of Zagreb, Croatia); Dominik Znic (University of Zagreb, Croatia); Igor Krois (University of Zagreb, Croatia)
Recently, a ‘bimetallic’ non-Foster negative capacitor with improved stability properties, intended for use in active metamaterials and antennas, has been introduced. Here, a simple extension that enables stable switchable negative/zero/positive capacitance operation, is proposed and verified by realistic SPICE simulation.

16:40 Virtual Perfect Absorption Through Adiabatically Modulated Cavities
Dmitrios Sounas (Wayne State University, USA)
Virtual perfect absorption refers to the complete transfer of the energy of an incident wave to a lossless cavity without reflection. However, the approaches proposed so far require either exponentially increasing waves, which are hard to maintain for long times, or an extreme form of time modulation. Here, it is shown that virtual absorption can be achieved for signals of any shape by applying slow adiabatic modulation to the coupling coefficient between a cavity and a waveguide. The proposed approach consists of a simple yet efficient way for trapping electromagnetic pulses and it may have applications in energy storage, energy conversion and quantum information processing.

17:00 Spatial and Spatio-Temporal Modulations for Advanced Wave Control with Metasurfaces
Younes Radj and Adam Overvig (CUNY Advanced Science Research Center, USA); Yoshiaki Kasahara (University of Texas at Austin, USA); Andrea Ali (CUNY Advanced Science Research Center, USA)
In this talk, we review our recent work in the context of metasurfaces to control electromagnetic waves. Spatial gradients of surface impedance and careful engineering of the spatial dispersion, are shown to implement metasurfaces for efficient beam steering, focusing and wavefront control. Adding temporal modulations to this picture provides interesting opportunities to break time-reversal symmetry and reciprocity, frequency mixing and wavefront transformations in space-time. Opportunities for new radio-wave and optical technology, as well as physical insights into the functionality of these metasurfaces, will be discussed during the presentation.

17:20 Investigation of Surface Waves on Anisotropic Self-Complementary Metasurfaces
Vladimir Lenets, Andrey Sayansk and Stanislav Glybovski (ITMO University, Russia); Enrica Martini (University of Siena, Italy); Juan Domingo Barba (Universidad Nacional de Colombia, Colombia); Stefano Maci (University of Siena, Italy)
In this paper, we show through a numerical investigation that an anisotropic self-complementary metasurface constituted by a sequence of capacitive and inductive strips supports at low frequencies two degenerating quasi-TM and TM surface waves modes with identical dispersion characteristics. It is also seen that group velocity drastically changes depending on the direction of propagation of the surface waves, becoming extremely low for direction of propagation orthogonal to the strips. The phenomenon can be used in dual polarized leaky wave antennas.

17:40 High Speed Metasurface Reconfigurability Under Optical Control
Houssem Fedine Kirou (ESPCI, France); Charlotte Tripon-Canseliet (Université Paris-Est, France); Stefano Maci (University of Siena, Italy); Jean-Maurice Chazelas (Thales Aerospatiale, France)
A contactless technique to configure the Metasurface prototype printed on photoconductive semiconductor substrate is proposed. This technique is based on the phenomenon of photoabsorption into a high resistivity semiconductor material. A free space bi-static measurement system operating in the 40-60 GHz frequency range is developed to measure the reflection coefficients of planar samples. The measurement system consists of transmit and receive antennas in a bi-static configuration, two focusing lenses to minimize the diffraction effects at the edge of the sample, piezoelectric, precision coaxial cable, laser source at wavelength of 805 and 971 nm and the network analyzer.

18:00 Stable Positive/negative Capacitor for Use in Active Artificial Structures
Mohammad Sajjad Mirmoosa (ITMO University, Russia); Houssemeddine Krraoui (Wayne State University, USA)
In this work, we propose a novel route to achieve strong nonreciprocal responses and regimes of optical gain at the nanoscale. We theoretically demonstrate that the biaxial of a graphene sheet with a drift-electric current gives rise to the emergence of one-way surface plasmons. Furthermore, we demonstrate that by coupling the drift-current biased graphene sheet to another plasmonic slab (e.g., a semiconductor slab), it is possible to obtain regimes of negative Landau damping where the surface plasmons are pumped by the drifting electrons.

18:20 Fabrication of Artificial Dielectrics via Stereolithography Based 3D-Printing
Jack McGhee, Tom Whittow, Jacob Mortary, Jamie Northedge, Shiyu Zhang, Darren Cadman, William Whittow and Younes Radi (University of Sheffield, United Kingdom (Great Britain)); Jamie Northedge (Loughborough University, United Kingdom (Great Britain)); Shiyu Zhang (Loughborough University, United Kingdom (Great Britain)); Darren Cadman (Loughborough University, United Kingdom (Great Britain)); William Whittow (Loughborough University, United Kingdom (Great Britain)); Younes Radi (University of Sheffield, United Kingdom (Great Britain))
In this research, stereolithography (SLA) based additive manufacturing (AM) has been investigated as a fabrication method for producing artificial dielectrics. Initially, the effect of the curing time on the microwave electromagnetic properties (X-band) on the photoinitiated resin used was measured and found to be negligible after 15 minutes of UV curing. Artificial dielectric isotropic and anisotropic/alloyed structures were then designed and fabricated, allowing for varying permittivity between 1.23 and 2.80 through the control of the structure’s density. As a demonstration of the ability to grade permittivity through a high-resolution printing process, lattice structures were embedded into solid substrates. The ability to do this allowed for the printing of a graded permittivity substrate which is showcased in a design for a circularly polarized patch antenna.

18:40 Complementary Metamaterials for Waveguide Applications
Xin Ma (Northwestern Polytechnical University, China); Mohammad Sajjad Mirmoosa and Sergei Tretyakov (Aalto University, Finland)
Metamaterials have shown a strong potential for controlling electromagnetic waves in a desired fashion and provided as such different new functionalities. For example, they can be used to design novel waveguide structures for transferring electromagnetic energy. In this talk, we will introduce and discuss guiding structures which consist of two parallel penetrable metamaterials whose surface impedances are ‘complementary’ to each other. We theoretically investigate guided modes which propagate along the structure and show the corresponding dispersion curves. As one of the study results, we show that there is a possibility to excite two modes with orthogonal polarizations which have the same
**16:00 Design and Simulation of Polarization-Sensitive ENNZ-Lined Apertures for Visible-Light Metasurfaces**
Mitchell Semple and Ashwin K. Iyer (University of Alberta, Canada)

Many proposed visible-light metasurface designs are limited in their ability to confine light on a subwavelength scale, which reduces their maximum efficiency due to discretization errors. Plasmonic metasurfaces show great promise in this regard, as their unit cells can be made deeply subwavelength. Unfortunately, current designs are limited to simple structures due to fabrication difficulty, and are far off on the limits of efficiency polarization conversion effects. In this paper, we extend the concept of ENNZ-lined apertures that has been used to create metasurface unit cells in the near IR regime to the visible regime by relaxing the requirement that the unit cells be polarization-invariant.

**16:20 Propagation Through Metamaterial Temporal Slabs: Transmission, Reflection and Special Cases**
Davide Ramaccia (Roma’Re University, Italy); Alessandro Toscano (University Roma Tre (IT), Italy); Filiberto Bliotto (University Roma Tre, Italy)

Time-varying metamaterials are artificial materials whose electromagnetic properties change over time. In earlier studies, the equivalent reflection and transmission coefficients at a temporal interface have been derived. Here, we extend the study to a temporal slab, i.e., a uniform homogeneous medium that is present in the space for a limited time. We derive the transmission and reflection coefficients for a metamaterial temporal slab as a function of the refractive indices and application time. Similarly to the role played by the electrical thickness for spatial slabs, we show that the response of the temporal slab can be controlled through the application time. The preliminary results reported here may pave the way to several novel devices based on temporal discontinuities.

**16:40 Propagation Characteristics in Substrate Integrated Holey Metasurfaces**
Fatemeh Ghasemifard (KTH Royal Institute of Technology, Sweden); Francisco Mesa (University of Seville, Spain); Guido Valero (Sorbonne Université, France); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this paper we discuss the dispersion properties of a particular type of holey metasurfaces, named here “substrate integrated holey” (SIH) metasurfaces. SIH is a metallic holey structure manufactured in printed circuit board (PCB) technology by using densely metallized posts. We demonstrate that, differently to the case of holey fulls covered with metal, in SIH, the height of the holes has a significant effect on the dispersion properties. In addition, in SIH metasurfaces, apart from the conventional stopband caused by its periodicity, there are stopbands due to the resonance modes trapped in the hole due to the posts. These stopbands are narrow and have a high rejection.
16:00 Integrated Design of Dual-Band Antenna with Uni-/Omni-Directional Radiations
Chun-Xu Mao (University of Surrey, United Kingdom (Great Britain)); Mohsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Pei Xiao (University of Surrey, United Kingdom (Great Britain))

A multifunctional antenna with diverse radiation patterns in different frequency bands (2.45/5.8 GHz) is presented in this paper. The antenna has a low profile but exhibits an omni-directional radiation pattern in the low-band operation and uni-directional pattern in the high-band operation. For the high-band operation, a 2 × 2 patch array is designed by employing an on-off phase-feeding method. The low-band operation with the omni-directional pattern is achieved by exciting four open-ended slots in phase. The four slots are cut in the ground of the high-band array and in this way, this footprint of the antenna is maintained. The operating principles of the antenna are studied with the aid of equivalent circuit model and the current distribution. The antenna is prototyped and measured, demonstrating good results in terms of bandwidth, inter-channel isolation, radiation characteristics.

16:20 On the Way to Green IoT Antennas: Compact Ultra-Thin CPW-Fed Monopole on Tencil
Edith Annette Cabrera-Hernández

A compact ultra-thin eco-friendly antenna for IoT applications is presented around 2.4 GHz. The antenna is designed and its suitability is evaluated through comparison of the novel antenna's performance using Tencil versus a conventional RO3003 dielectric with similar relative dielectric permittivity. A comparison with recently published wearable antenna suitable for IoT at the same frequency is included to assess the relevance of this contribution, not only in terms of reducing the ecological footprint and skin comfort, but especially in terms of size reduction and radiation efficiency.

16:40 Miniaturized Planar Inverted-F Antenna Using Minkowski Pre-Fractal Structure
Princy Paul

In this paper, a Miniaturized Planar Inverted-F Antenna (PIFA) is presented. Miniaturization is achieved by transforming the square radiating element in to a Minkowski Pre-Fractal. As a result, the antenna resonates at a lower frequency, in comparison with a square PIFA of the same size. Simulated and measured return loss values are presented. A brief explanation of the miniaturization effect of the Minkowski fractal is also presented.

17:00 Impressive 3D-Printed Radiating Homs for Customary Things in IoT Scenarios
Diogo Helena and Amelia Ramos (Universidade de Aveiro, Instituto de Telecomunicações, Portugal); Tiago Varum and João Matos (Instituto de Telecomunicações, Universidade de Aveiro, Portugal)

The increase of data-traffic capacity demands for better performance of the new generation of mobile communications (5G) driven new antenna technologies. The main challenge is to produce user devices which easily integrate a 5G network and its inherent services, without compromising neither cost nor performance. 3D printing is a good solution for these issues, as it can produce high accuracy objects while maintaining low production costs. This work presents several hom antennas operating in the 2.4 GHz band, all manufactured with 3D printing technology. Two techniques were used to metallize the antennas: with copper tape and with conductive ink. All prototypes achieved proper results for integrating the upcoming IoT scenarios.

17:20 3D Antenna-on-Package for Near-Isotropic Radiation Shielded from Embedded Electronics
Maria M Bermudez, Kirill Kliovski, Byung Jun Jang, Maria P Bermudez, Kirill Klionovski

In this paper, we propose a circular array antenna consisting of three dual antenna sets to maximize the number of the array elements in a limited platform size for interference mitigation application. The dual antenna set consists two radiators of a rectangular loop patch and a monopole antenna, which are integrated almost in the same place. The measured peak gains in the upper hemisphere of the monopole and patch elements are 4.7 dBi and 7.0 dBi, respectively. The null pattern is obtained by placing the patch elements, which are also in the same place, and the electric field polarization (>90% of LP coverage). Our design allows for planar fabrication, making it low-cost, and is highly suitable for various IoT applications.

17:40 Design of an Array Antenna Consisting of Three Dual Antenna Sets with a Narrow Array Distance for Interference Mitigation
Tae Heung Lim (Queen Mary University of London, United Kingdom (Great Britain)); Krishnamoorthy Kandasamy (University of Calabria, Italy)

In this paper, a Miniaturized Planar Inverted-F Antenna (PIFA) is presented. Miniaturization is achieved by transforming the square radiating element in to a Minkowski Pre-Fractal. As a result, the antenna resonates at a lower frequency, in comparison with a square PIFA of the same size. Simulated and measured return loss values are presented. A brief explanation of the miniaturization effect of the Minkowski fractal is also presented.

16:00 17 of 128

16:00 A Copper Strip Array Loaded Multiband Square Slot Antenna
Princly Paul (NIT, Suratkal, India); Krishnamoorthy Kandasamy (National Institute of Technology Karnataka, SURATKAL, India); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

16:20 Preliminary Co-Design of L and X-band Stacked Arrays with Scanning Capabilities
Brandon Sun (Inns de Rennes, France); Renaud Loison and Raphael Gillard (IETR & INSA, France); Eric Estève (Thales DMS France); Christian Renard (Thales Systèmes Aéropor*tiques, France)

The design of L and X-band stacked arrays is presented in this paper. The design of the X-band element is first detailed. The use of stacked patches leads to scan angles up to 60° in the E-plane, and 54° in the H-plane, in the 9.0-10.5 GHz band (active reflection coefficient < -10 dB). Secondly, the design of the L-band source is presented. The use of stacked dipoles results in scan angles up to 60° in the H-plane, for the two identification friends or foes (IFF) bands, at 1.03 and 1.09 GHz (with 3.8 MHz bandwidths). Finally, the L-band dipoles are placed above the X-band array and the performances of the stacked arrays are analyzed in the L- and X-bands.

16:40 Multiwave Dynamic Directional Modulation with Software Defined Radio
Edith Annette Cabrera-Hernández and Josep Parrón Granados (Universitat Autònoma de Barcelona, Spain); Alan Tennant (University of Sheffield, United Kingdom (Great Britain))

Dynamic Directional Modulation (DDM) has become an attractive option to achieve physical layer security. In this contribution, we evaluate the generation of DDM with software defined radio for transmitting simultaneously two uncorrelated signals along two different observation angles. The generation of DDM relies on the knowledge of the channel vector and an accurate adjustment of the weights that fix the phase array, for that reason, the components of the transmitter need to be characterized accurately. Experimental results that assess the performance of the system for the observation angles under consideration are shown.
17:00 Research on a Kind of Asymmetric Scanning Phased Array Antenna
Hongyin Zhang (The 14th Institute of China Electronics Technology Group Corporation, China)
In this paper, a technique for asymmetric scanning of phased array antenna by beamforming of antenna elements is discussed, and this technique has been applied in practical engineering. The proposed 94-gi antenna element centered in the large scale array provides good radiation performance in the range of 0°-70°, thus realizing the asymmetric reshaping of the element pattern. Additionally, a 4x4 array prototype is fabricated. The measured results agree well with the simulated results, which prove its effectiveness.

17:20 A Distinct Approach Exploiting Collapse Distribution Collected with Genetic Algorithm for the Synthesis of Thinned Planar Antenna Arrays
Veer S Gangwar (LIRDE(DRDO), India); Juhu Modi (IIT(IISc) Dhanbad, India); Jatin Narde (NIT Rourkela, India); Kundan Suman (IIT(ISM), India); Ashwin P (IIT(DRDO), Bangalore, India)
In this paper, authors propose a distinguishable technique, which synthesizes Thinned Planar Antenna (TPA) Arrays with maximally reduced peak side lobe level (PSLL). Authors employed Collapse Distribution Technique amalgamated with Genetic Algorithm (CDT-GA) in order to reduce optimization complexity and to obtain efficient control of PSLL. 9×8- and 10×12-element TPA arrays are numerically analyzed to verify the effectiveness and examine the distinguishable features of the proposed strategy. The numerical results obtained through CDT-GA evidence that it outmatches the similar designs available in the literature. In order to further ascertain and validate the performances of CDT-GA in practical scanning, authors realized an 8-element TPA array and carried out experimental evaluation. The obtained experimental results are found nearly in agreement with corresponding numerically computed and electromagnetically simulated ones. Index terms: Collapsed distribution technique combined with genetic algorithm (CDT-GA), peak side lobe level, planar thinners (TPA) arrays.

17:40 High-Performance Wideband Horn Antenna for Direction Finding Arrays
Saeed Manshari (Engineering Optimization & Modeling Center, Roykivåg University, Iceland); Slawomir Kozel (Gdańsk University of Technology, Poland); Leifur Leifsson (Iowa State University, USA); Andréas Alyon Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)
In this paper, a structure and design procedure of a novel double ridged horn antenna with a Gaussian amplitude radiation pattern and stable phase center for two-element direction finding arrays is presented. The radiation properties of the structure are improved through appropriate profiling of the ridge taper and utilization of an elliptical aperture. Furthermore, rigorous numerical optimization is employed to adjust the antenna geometry parameter values. The achieved-impedance bandwidth (VSRR < 2) is from 1.5 GHz to 12 GHz (8×). The antenna exhibits 7 dB to 20 dB gain, better than 85% aperture efficiency, >10 dB side lobe level, as well as low phase center variation (>5 cm over the operating band). The aforementioned features make the proposed antenna suitable for the amplitude and phase hybrid direction finding applications. The design is validated numerically in CST Microwave Studio.

T06-M03: Near-field, Far-field, Compact and RCS Measurement Techniques

16:00 Experimental Validation of the Translated-SLW Technique Applied to Automotive Measurements over PEC-Floor at Arbitrary Height
Francesco Saccardi (Microwave Vision Italy, Italy); Francesca Micoc (Consultant, Switzerland); Per Iversen (Orbit/FI, USA); John Estrada (MVG, USA); Lars Foger (Microwave Vision Italy, Italy)
Automotive antenna testing performed on large, truncated spherical near-field systems, able to host the entire vehicle under test, are an industry standard. The truncated scanner is often terminated to a conical floor where the vehicle is staged for testing. Despite the strong interaction with the reflective floor, such systems are often employed because of the ease of car accommodation and measurement setup. Moreover, the non-conical floor lies on the horizon plane, truncation errors can be easily reduced in the near-field to far-field transformation by simply mirroring the measured field (image theory). Due to mechanical constraints, or extension of the operational mode of some systems (e.g. absorber-based systems), sometimes the floor position doesn’t correspond to the horizon plane, and advanced techniques are needed to extrapolate the truncated area. The translated-SLW technique, already presented in the past, is proposed for such purpose and will be validated experimentally considering scaled automotive measurements.

16:20 Near-field Measurement and Far-field Characterization of a J-band Antenna Based on an Electro-optic Sensing
Shintaro Hisatake and Yusuke Tanaka (Gifu University, Japan); Cybele Belem (Université de Lille, France); Cyril Luxey (University Nice Sophia Antipolis, France); Frédéric Gianessis (STMmicrotechnologies, France); Guillaume Ducournau (IEMN, University of Lille, France); Akhiko Hirata (Chiba Institute of Technology, Japan)
In this paper, we present a near-field pattern measurement based on an electro-optic setup at 300 GHz. The measurement system is based on a self-heterodyne technique and non-polarimetric frequency down-conversion technique. The far-field radiation pattern of a horn antenna calculated from the measured near-field pattern is compared with the far-field pattern measured with a conventional measurement system using an open-ended waveguide probe.

16:40 A New Method to Measure the Absolute Gain Patterns of a Log-Periodic Antenna at a Reduced Distance Without Considering the Phase Center in a Single-Cut Near-Far-Field Transformation
Masanobu Hirose (Chiba Institute of Technology, Japan)
A previous paper a referenceless measurement setup based on a reference antenna was used for characterizing the near-field radiation patterns in the planar and spherical multiprobe systems. This paper proposes an alternative technique based on exploiting the intrinsic characteristics of the multiprobe systems. One of the antennas from the multiprobe is used to retrieve the relative phase between measurement points. Post-processing is needed since the relative phase between two multiprobe-cuts is lost. The advantages, limitations and results are shown. The results demonstrate that the technique is very promising for characterizing devices under certain conditions.

17:00 Relative Phase Reconstruction Based on Multiply Probe Solutions and Post-Processing Techniques
Ruben Tena Sanchez (Technical University of Madrid, Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain); Lars Foger (Microwave Vision Italy, Italy)
In previous paper a referenceless measurement setup based on an antenna reference element was used for characterizing the near-field radiation of antennas in the planar and spherical multiprobe systems. This paper proposes an adaptive technique based on exploiting the intrinsic characteristics of multiprobe systems. One of the antennas from the multiprobe arch is used to retrieve the relative phase between measurement points. Post-processing is needed since the relative phase between two multiprobe-cuts is lost. The advantages, limitations and results are shown. The results demonstrate that the technique is very promising for characterizing devices under certain conditions.

Javier Fernández Álvarez, Kyriakos Kaslis, Jeppe Nielsen and Olav Breinbjerg (Technical University of Denmark, Denmark)
This work presents the 2019 campaign of investigatory measurements, which goal is to assess the robustness of the measurement setup when mounting large masses on the AUT positioner, as well as the functionality and the reproducibility of the measurements. To this end a full measurement was performed, including complete uncertainty measurements, of the DTU Golden Standard array antenna (GS) in two configurations, unloaded and loaded with 335 kg of dummy weight. The measurements of the unloaded and loaded configurations were compared and it is demonstrated that the AUT positioner is capable of assuming an antenna with a mass comparable to the MetOp-SS without suffering any impact to its accuracy. For the long-term reproducibility, measurements were compared with a previous investigatory campaign of the same antenna dating from 2017.

17:40 RCS Evaluation by Image-based Near-field to Far-field Transformation
Hirokazu Kobayashi (Osaka Institute of Technology, Japan)
There is recently a strong demand to evaluate for Radar Cross-Section (RCS) of electrically large objects such as airplane and for radiation pattern of large antennas. This is because the measurement difficult by the conventional method in far-region. We have proposed the improved novel Near-Field to Far-field Transformation method in cylindrical scanning, from which RCS can be estimated by picking near-field data. Our method is featured by the improved focusing and the RCS measurement is available even in a small anechoic chamber. In this paper, we propose a simple method to suppress the unnecessary wave by the imaging area-limiting method. Furthermore, we propose a simple method to suppress the unnecessary wave by the imaging area-limiting method.

18:00 On the Accuracy of Standard Gain Horn Measurement
Maryam Razhosseini, Christopher G Hynes and Rodney Vaughan (Simon Fraser University, Canada)
New measurement accuracy results are presented for a Standard Gain Horn in a professional-level system, the MGV Stargate 64. This system offers calibration options, and drags on the users' knowledge to choose the most appropriate one. An ideal measurement in an ideally calibrated system is perfectly repeatable and independent of the choice of calibration method, but the variations caused by real-world effects are of interest. The measurements include the use of a coaxial feed cable with a multitude of ferrite beads (to suppress any currents on the cable-outside), and the cable with no-beads, and with an optical fiber feed system for eliminating the scattering contribution of the measurement cable. We also compare patterns taken at different times and temperatures. The pattern comparison basis is the vector pattern correlation coefficient (inner product). The worst-case pattern variations appear to be related to the temperature variation of the system.
16:00 Robust Multi-Resolution Microwave Imaging Through an Over-Constrained Approach
Marco Salucci (ELEDIA Research Center, Italy), Paolo Roccia and Andrea Massa (University of Trento, Italy)
This work presents an innovative iterative multi-resolution (MR) methodology to solve fully non-linear inverse scattering (IS) problems. More in detail, an over-constrained (OC) formulation is adopted to enforce additional constraints on the solution in order to mitigate the occurrence of false solutions/local minima at each multi-zooming step. Thanks to such an OC-MR procedure, progressively acquired information on the imaged domain can be effectively exploited to counteract both non-linearity and ill-posedness of the IS problem, yielding accurate and reliable guesses with a remarkable robustness to noise. A preliminary numerical benchmark is presented to assess the potentials of the proposed method, as well as to compare it with a standard MR solution approach.

16:20 Multiple Moving Targets Tracking Based on Kernel Localization and Group Trackers for Envisioned Functional Microwave Brain Imaging Applications
Mohammad Ojarioudi (University of Limoges/ CNRS, France), Stéphane Bila (XLIM UMR 7252 Université de Limoges/CNRS, France)
This paper presents a new concept of multiple target tracking using hierarchical trackors based on kernel localization for envisioned functional microwave brain imaging application. For this purpose, the performance of brain activated regions tracking using MRTK video is improved. In the first stage, all of the moving regions in the MRTK video frame are detected. Then, by using the group tracking, histogram and distance corresponding to the moving-targets in the previous frame, the directions of movement-regions are determined. After determining the exact number of moving objects and tracking them, one by one, the direction of each sector is extracted. In addition, due to the kernel labeling, the proposed method has capability of separation and merging by group tracking in conditions of motion-path interfere with each other. The simulated results validate the effectiveness of the proposed methods for precisely tracking of the activated regions.

16:40 Validation of Multilevel 24-Port Microwave Imaging System for Brain State Monitoring on Synthetic Numerical Data
Jan Tesarik and Jan Vrbá (Faculty of Biomedical Engineering, Czech Technical University in Prague, Czech Republic)
Microwave imaging (MI) could provide a great opportunity for early stroke diagnosis and thus reduce the health consequences caused by stroke. Based on different dielectric properties of healthy and stroke affected brain regions, MI systems can help to differentiate the stroke type. The main purpose of this contribution is to validate the newly designed multi-level 24-port MI system on numerical data. Inside the 3D human head phantom, the different stroke phantom types (Hemis - haemorragic or ISCH - ischemic) with different diameters were placed. Using the reconstruction algorithm based on Born Approximation and Tikhonov the stroke phantoms can be followed and distinguished. The numerical analysis of MIH system proved promising results where positions, diameters and types of stroke phantoms were successfully reconstructed. The system showed some limitations as disability to detect objects with size lower than half of used wavelength which will be eliminated in the future.

17:00 Microwave Imaging of Cervical Myleopathy: A Preliminary Feasibility Assessment
Chiara Dachen (University of Genoa, Italy), Alessandro Fanti (University of Cagliari, Italy); Alessandro Fedeli (University of Genoa, Italy), Giuseppe Mazzarella (University of Cagliari, Italy), Matteo Pastorino and Andrea Randazzo (University of Genoa, Italy)
Microwave imaging is acquiring a growing importance in several biomedical applications, such as breast and brain stroke diagnosis and monitoring. In this work, we present a feasibility analysis concerning the application of such a technique to the cervical myelopathy assessment. In particular, suitable working conditions are defined on the basis of a simplified multiplexer model of the neck and a first inversion result, aimed at assessing the possibility of retrieving the spinal cord size, is shown.

17:20 Effectiveness of Folded Quasi Self-Complementary Antenna to Microwave Imaging
Yoshikihito Kuwahara and Akira Nozaki (Shizuoka University, Japan)
We examined the application of Folded Quasi Self-Complementary Antenna (FQSCA) to a microwave imaging system aimed at breast cancer detection. It is presented that FQSCA can reconstruct high-fidelity diagnostic images that are robust to manufacturing-errors compared to the printed dipole.

17:40 Real-Time Three-Dimensional Electrical Impedance Tomography of the Human Chest
Marco Salucci and Davide Marcaronio (ELEDIA Research Center, Italy); Alessandro Polo (ELEDIA Research Center, University of Trento, Italy); Maokun Li (Tsinghua University, China)
An approach for the diagnosis of the human chest in real-time based on electrical impedance tomography (EIT) is hereby applied on a fully three-dimensional (3D) imaging scenario. The methodology adopted for performing EIT data inversion is based on the learning-by-example (LBE) paradigm and exploits a profitable combination of a feature reduction strategy based on partial least squares (PLS) with an adaptive sampling based on the output space filling method (OSF). Some preliminary results are shown to assess how the 3D-EIT problem can be efficiently, accurately, and robustly solved thanks to the proposed methodology.
17:20 Electromagnetic Field Modeling for Wireless Power Transfer in Biological Tissue
Tom van Dunne and Rob Mestrom (Eindhoven University of Technology, The Netherlands); Mark Bentum (Eindhoven University of Technology & ASTRON, The Netherlands); Hubrecht J. Visser (imec The Netherlands, The Netherlands)
We present a mathematical model that can be used to model the electromagnetic fields generated by a vertically oriented magnetic dipole located above a conductive half-space, such as biological tissue. The model was compared to a full-wave simulation in CST. The difference is shown to be below 8% on average for frequencies ranging from 13 MHz to 5 GHz. It executes over 50 times faster than a full-wave solver, using less than 10 times less memory, and can be adapted to model more realistic magnetic sources without much extra effort. This model can improve the design process of inductive or radiative links significantly, enabling rapid design iteration. It is well suited for biomedical applications. Extension to magnetic sources with arbitrary orientation, as well as electric sources, is possible.

17:40 100 W 6.78 MHz Inductive Power Transfer System for Drones
Linglin Lan, Christopher H Kwan, Juan Arteaga, David Christopher Yates and Paul Mitcheson (Imperial College London, United Kingdom (Great Britain))
This paper reports on the design and development of a wireless charging solution for a DJI Matrix 100 quadcopter drone. The developed system is capable of delivering power to the drone at the same rate as the cable charger over a wide range of misalignment and any orientation. The system has a typical end-to-end efficiency of 70% and allows the drone to operate with complete autonomy without human interference.

18:00 Appliqué: A Computationally Efficient Modeling Tool for Multi-Layer Printed Inductors, for near Field Wireless Power Transfer Applications
Brodie Mahoney and Joshua R. Smith (University of Washington, USA)
This paper presents Appliqué, a computationally efficient open source environment for wireless power transfer coil design. The system allows designers to rapidly design and simulate coils. Appliqué extracts coil parameters and back-annots the extracted values into a SPICE netlist model of the wireless power transfer coil. Appliqué then automatically executes SPICE and combines extracted inductances, capacitances, and resistances to provide the user with narrow or wide-band impedance analysis, as well as component values for a functionally meaningful simplified circuit model. Final designs may then be exported to common PCB CAD software.

IW01: Key Advantages of Combining Measurements and Simulations for Antenna Applications (MVG)
T12 Scientific / Industrial Workshops
Room: B3
Lucia Scialacqua, Microwave Vision Group (MVG)

Tuesday, 17 March

Tuesday, 17 March 8:30 - 10:10
EurAAP 5: WG Active Array Antennas (8:30-10:10, Room: 17)

Tuesday, 17 March 8:30 - 10:10
IW01: Key Advantages of Combining Measurements and Simulations for Antenna Applications (MVG)

Tuesday, 17 March 8:30 - 12:20
T02 Millimetre-wave Arrays for Mobile Terminals
T02 Millimetre wave 5G / Regular Session / Antennas
Room: A2

8:30 Embedded 5G Wideband Dual-Polarized mm-Wave Antennas in Non-mm-Wave Antennas Integrating a Package (AiAiP) for a Metal-Frame Cell Phone
Zhihun Zhu (vivo Mobile Communication Co., Ltd, China); Huan-Chu Huang (vivo Mobile Communication Co., Ltd, Taiwan); Yijin Wang, Xianjing Jian and Rongjie Ma (vivo Mobile Communication Co., Ltd, China)
4 embedded dual-polarized mm-Wave antennas as a linear array in a non-mm-Wave antenna integrating a package (AiAiP) for 5G cell phone with a metal frame as an LTE antenna and a high display A.A-to-body ratio beyond 91.7% is presented. For simulated |S11| ≤ -10 dB, bandwidths of the ports in the 5G mm-Wave antenna array for both the dual polarizations at φ = 45° and φ = -45° range from 24.19 GHz to 29.62 GHz and from 35.67 GHz to 40.24 GHz. All 5G mm-Wave bands n258, n257, n505 and n518 in 5GPP can be covered. Bandwidths for |S11| ≤ -6 dB of the LTE antenna range from 878 MHz to 971 MHz and from 2258 MHz to 2763 MHz to Band B, Band 40, and Band 41 are supported with efficiencies higher than -3.3 dB in Band 8 and higher than -1.3 dB in Bands 40 and 41.

8:50 Embedded 60-GHz mm-Wave Antennas in Non-mm-Wave Antennas Integrating a Package (AiAiP) for Motion Recognition in a Full-Screen Metal-Framed Cell Phone
Huan-Chu Huang (vivo Mobile Communication Co., Ltd, Taiwan); Heng Zha and Yijin Wang (vivo Mobile Communication Co., Ltd, China)
4 embedded 60-GHz mm-Wave antennas in a non-mm-Wave antenna integrating a package (AiAiP) for motion (e.g., gesture) recognition in a full-screen metal-framed cell phone as an LTE antenna, 100% front glass coverage, and a high display-to-body ratio beyond 91.7% is presented. For |S11| ≤ -6 dB, simulated bandwidths of the 4 antennas range from 56.91 to 54.35 GHz so the 60-GHz band is supported. In-band peak gains of 3 antennas as a receiving array are higher than 8.88 dB with a peak of 9.17 dB. Simulated bandwidths for |S11| ≤ -6 dB of the LTE antenna range from 877 MHz to 963 MHz and from 2258 MHz to 2751 MHz to cover Band B, Band 40, and Band 41 with efficiencies higher than -3.91 dB in Band 8 and higher than -1.85 dB in Bands 40 and 41. The design is promising to compatibility of motion recognition and full-screen features.

9:10 Dual-Polarized mm-Wave Antenna Solution for Mobile Phone
Resti Montoya and Juha Ala-Laurinaho (Aalto University, Finland); Ville Vilkan (Aalto University & School of Electrical Engineering, Finland)
This article describes a novel dual-polarized mm-wave antenna module for mobile phone devices. The mm-wave antenna module consists of a 4-layer PCB, an extra metallic piece acting as a reflector, and four metallic pins. The four metallic pins are placed on the top layer of the PCB acting as an array of vertically polarized monopoles. On the bottom layer an array of horizontally polarized dipoles are fed using microstrip lines. The two middle layers act as ground. Simulations show very good performance in the 27 to 30.5 GHz range. In this frequency range, the horizontally and vertically polarized arrays provide better than -1.5 dB efficiency, and higher than 11.5 dBi realized gain. Also, the reflection coefficient is mostly below -10 dB in the 27 to 29.5 GHz range for each individual antenna element. Beam-steering is possible up to 35 degrees for both polarizations with a scan loss below 3 dB.

9:30 Dual-Band Dual-Polarized mm-Wave Slot Antenna Array for Mobile Handsets
Joni Kurvinen (Aalto University School of Electrical Engineering, Finland); Anu Lehtovouri (Aalto University, Finland); Ville Vilkan (Aalto University & School of Electrical Engineering, Finland)
Fifth generation (5G) mobile networks utilize millimeter-waves (mm-waves) to achieve higher data rates. This paper presents a dual-polarized antenna array that operates at 28 GHz (27.5-29.5 GHz) and 38 GHz (37.5-39 GHz) bands and is usable in mobile handsets. The array is based on slot antennas with separate feeds for each polarization and band. The multi-feed structure allows us to improve isolation between bands. The dual-polarized array has a peak realized gain of 10.13 dB and it is capable of beam-steering for up to ±50° or ±90° at 28 GHz and 38 GHz bands, respectively. The performance of the array in the presence of a smartphone chassis is also studied.

9:50 A Novel Lens Antenna Design Based on a Bed of Nails Metasurface for New Generation Mobile Devices
Huan-Chu Huang (vivo Mobile Communication Co., Ltd, China); Shuai Zhang (Aalto University, Denmark)
This article describes a novel lens-based mm-wave antenna array for mobile phone devices. The mm-wave antenna module consists of a 4-layer PCB, an extra metallic piece acting as a reflector, and four metallic pins. The four metallic pins are placed on the top layer of the PCB acting as an array of vertically polarized monopoles. On the bottom layer an array of horizontally polarized dipoles are fed using microstrip lines. The two middle layers act as ground. Simulations show very good performance in the 27 to 30.5 GHz range. In this frequency range, the horizontally and vertically polarized arrays provide better than -1.5 dB efficiency, and higher than 11.5 dBi realized gain. Also, the reflection coefficient is mostly below -10 dB in the 27 to 29.5 GHz range for each individual antenna element. Beam-steering is possible up to 35 degrees for both polarizations with a scan loss below 3 dB.
This paper presents a frequency reconfigurable endfire vertical polarized array for 5G handheld applications. The array is controlled independently by two PIN diodes. By combining the two PIN diodes, three resonant frequencies are achieved for 24 GHz to 27 GHz. An eight-element array is constructed based on the proposed antenna. The scanning angle is from 130 deg to 220 deg with real gain ranged from 7 dB to 10 dB. Moreover, the array has a low profile of 0.508 mm and small clearance of 3.35 mm. The performances of the proposed antenna and array are verified by simulations.

This paper investigates the penetration loss of an office building in indoor-to-indoor and outdoor-to-indoor mobile scenarios. During measurement, the transmitter, mounted on a tripod, was placed in an office and outside of the building, while the receiver, mounted on a mobile robot, moved along an interior hallway. The penetration loss for a variety of building materials is measured and compared with the measurement results. The wooden door, plasterboard wall, and glass window are used to validate the proposed model. The measured results are compared with the theoretical model predictions, and a good agreement is achieved.

This paper presents a high efficiency dual band single layer antenna structure for MMIC applications. The e-shape patch that is surrounded by two conductive walls is designed on an RO4003 substrate with thickness of 0.508 mm. The operating frequencies of this antenna are 28 GHz and 38 GHz. This low-profile and lightweight antenna can be used in many 5G communication systems.

This paper presents a planar wideband dual-polarized patch antenna integrated on PCB. The patch itself is fed by capacitive coupling with smaller patches. The simulations predict 34-40 GHz 10-dB impedance bandwidth, the measured ones shows 24.75-42.75 GHz bandwidth. The results are corresponding to 30% relative -10 dB impedance bandwidth. The patch antenna is on the ground-plane size of 4.7 mm x 4.7 mm, and the corners of the ground-plane are cut off. The radiation pattern is better than 14 dB. The measured 3D radiation patterns are presented at 24 GHz, 32 GHz, and 40 GHz with gains of 2.8 dBi, 5.0 dBi, and 4.3 dBi, respectively.
Millimeter-wave (mmWave) wideband communication is considered as a potential candidate to meet the increasing data rate demands of the onboard passengers in the metro. Channel modeling is important for the system design and evaluation in such environment. Ray-tracing (RT) modeling can accurately trace propagation paths, and has been proven successful in many works. However, it is complicated and time-consuming to work in harsh environments, where dense multi-path components exist and the reverberation effects can happen. To tackle this problem, an hybrid channel modeling approach, which combines the RT method and the propagation graph (PG) method, is proposed and introduced in this work. According to the evolvement results, the proposed method performs better than either the RT or the PG alone model in terms of accuracy and efficiency.

10:10 Coffee Break

10:40 Experimental Characterization of the Underframe Area of a Passenger Train with an UWB Channel Sounder: Preliminary Results
César Calvo Ramírez (Universidad Politécnica de Madrid, Spain); Juan Moreno (Metro de Madrid S.A. & Universidad Politécnica de Madrid, Spain); Cesar Briso (Universidad Politécnica de Madrid & ETISIS Telecommunicacion, Spain)

In this paper we present a testbed for Ultra-Wide Band (UWB) measurements of the radio channel plus some early results taken on very similar scenario, the underframe area of a passenger train. This area is heavily populated with heavy mechanical elements key for the safe movement of the train (axles, wheels, brakes, suspensions, etc) which are prone to the installation of sensors in order to know the condition of these mechanical elements. The channel sounder is based on a commercial module (Decawave DWM1001) extended for indoor location but with some tinkering could be used to obtain channel measurements.

11:00 Irregular Multifocal Reflector for Efficient mmWave Propagation in Indoor Environments
J. Samuel Romero-Peña (Universitat Politècnica de Valencia, Spain)

In future implementations of 5G systems, it is essential the use of the spectrum in the range of mm-Waves frequencies, in order to offer to the users the bandwidth proposed in the standard. However, using this frequency range lead to many technical difficulties in which the most important challenge is the critical attenuation of the signal in non-line-of-sight (NLOS) environments in indoor environments. Therefore is essential to plan strategies that allow us to mitigate the problem of signal attenuation in this kind of complex environments and ensure the viability of using this technology in short term. Then the objective of this research is the design of a passive reflector that allow us to re-direct the energy of the transmitting antenna efficiently in order to avoid the obstacles of the environment, and therefore avoid excessive losses.

11:20 Measurement and Characterization of an Indoor Industrial Environment at 3.7 and 28 GHz
Mathis Schmieder (Fraunhofer Heinrich Hertz Institute, Germany); Taro Eichler (Rhode & Schwarz, Germany); Sven Wittig (Fraunhofer Heinrich Hertz Institute, Germany); Michael Peter (Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany); Wilhelm Keusgen (Fraunhofer Heinrich Hertz Institute, Germany)

Fifth generation (5G) mobile networks are expected to play an increasing role in industrial communication with private mobile networks deployed on company premises. For planning, standardization and product development, it is crucial to thoroughly understand the radio channel characteristics of such environments. Frequencies around 3.7 GHz were already reserved by regulation authorities and to meet the increasing demand for higher bandwidths, spectrum in the millimeter wave range around 28 GHz is targeted. This paper presents a wideband channel measurement campaign at both 3.7 and 28 GHz with direction-of-arrival information at 28 GHz. The results are compared to the 3GPP TR 38.901 Indoor Factory model and to two other recent papers. Evaluation of path loss and RMS delay and angle spread show the unique nature of industrial indoor environments.

11:40 Channel Modelling Based on Game Engines Light Physics for mmW in Indoor Scenarios
Saul Inca, Danasys Prado, David Martin-Saorinitsu and Jose F Monserrat (TEAM Research Institute, Universitat Politècnica de Valencia, Spain)

The importance of Millimeter Waven (mmW) band for the Fifth Generation (5G) mobile and wireless communications has motivated a lot of work in mmW channel modeling. In this paper, we assess the use of the light physics modeling of a game engine to calculate the propagation losses at mmW band in an indoor scenario. With that aim, we propose a model that we refer to as Light Intensity Model (LIM), in which a detailed 3D scenario is created in a game engine, radio emitters and receivers are replaced by light sources and detectors, and the received light intensities is translated to received radio signal power through a translation function which is the key of the model. The results obtained corroborate the validity of the assessed approach to model propagation losses in indoor scenarios.

12:00 Path Loss Models and Delay Spread Parameters for the Millimetre Wave Channel in Indoor Environments
Sara Salous and Saeed El-Fatah (Durham University, United Kingdom (Great Britain))

This paper presents results of path loss and m.s. delay spread in two indoor environments based-on measurements in three bands from 12 GHz to 73 GHz using multicustom designed channel sounder developed at Durham University. Results are presented for a corridor environment and for a factory environment both in line of sight and non-line-of-sight set ups.

CS38: ISAP Session: Recent Advances in Asian Antennas and Propagation Research

T02 Millimetre wave 5G / Convened Session / Antennas
Room: B1
Chair: Mauro Etienne (University of Rennes 1 & UMR CNRS 6164, France)

8:30 Reconfigurable Terahertz Reflectarray Based on Graphene Radiating Patches
Tianming Niu, Jingwei Zhang, Lin Pengfei Cao, Ruoyu Cui and Zhonglei Mei (Lanzhou University, China)

A reflectarray antenna based on graphene radiating patches is proposed to realize reconfigurable radiation patterns at 1 THz. The all radially elements of the reflectarray are geometrically identical, and the graphene patches in the same row are connected in series to a particular bias electrode. The phase response of the radiating elements can be controlled by changing the value of the bias voltage due to the property of graphene. For the TE polarization, the simulated phase curve shows that a cycle phase range of 360 degree is obtained, while the magnitude of the reflected field is above 5.6 dB. Based on the phase response, each electrode biasing is accurately programmed to build up the required progressive phase distribution for a particular beam pattern. The numerically simulated results demonstrate that the designed reflectarray can reconfigure the deflection direction of the normal TE incident plane waves with excellent performance.

8:50 Achieving Wider Impedance Bandwidth Using Full-Wavelength Dipoles
Can Ding (University of Technology Sydney (UTS), Australia); Halton Sun (University of Technology, Sydney, Australia); He Zhu and Y. Jay Guo (University of Technology Sydney, Australia)

This paper investigates the use of full-wavelength dipoles (FWD) to achieve wider bandwidth than half-wavelength dipoles (HWD). Two dual-polarized antennas are built based on FWDs for base station applications as examples. The first antenna is an isolated cross-dipole employing two FWDs with simple configuration. It is able to cover the lower band of cellular communication from 698 to 960 MHz. The second antenna has four FWDs arranged in a square loop array and lightly coupled with each other. The employed full-wavelength dipoles are bent upward to maintain a small aperture size, so that the realized element still fits in traditional base station antenna (BSA) array. The antenna can be matched across the band from 1.65 to 3.7 GHz, which can cover both the 3G/4G band from 1.7 to 2.7 GHz and the 5G (sub-6 GHz) band from 3.3 to 3.6 GHz simultaneously.

9:10 Single and Dual Beam Waveguide Slotted Antenna Using 3D Printing Technique for 5G Application
Muatzz Wathiq Almeshehe and Jose F Monserrat (TEAM Research Institute, Universitat Politècnica de Valencia, Spain)

This paper compares two 4 mm metal printed antennas at Ka-band. The four antennas are two home and two slotted Ka antenna. The horn and slot antennas are well known for their high gain characteristics. The antennas are designed based on WR-28 waveguide standard. The proposed antennas are 3D metal printed using direct metal laser melting printing technique. The performances of the 3D printed antennas are investigated in terms of reflection coefficient, gain, efficiency, and radiation pattern. The printed antennas are validated using standard VNA. The measured performance of the antennas prototypes are agreed well with the simulation results with reflection coefficient of less than -10 dB for all antennas. The measured gain of ranging 7-14 dB for all the prototypes are obtained with more than 90% of antennas efficiency. These 3D metal antennas are suitable for Ka-bands applications such as 5G cellular network.

9:30 Microwave Metasurface-based Lens Antennas for 5G and Beyond
Zhi Ning Chen (National University of Singapore, Singapore); Teng Li (Southeast University, China); Wei E. I. Liu (Southeast University, Singapore)

Lens antennas have long been utilized at millimeter-wave bands and above because of their excellent power focusing performance, aperture sharing, and simple feeding structures. However, the conventional high-gain dielectric lens at microwave bands usually are too bulky. With the development of metamaterials, the lens design has been replaced by single or multiple layered planar structures such as patterned PCB boards. This paper first briefly the mechanism of metasurfaces in the design of a planar lens. Then microwave lens antennas recently developed by our team from National University of Singapore are summarized to show the progress in this field. After that, one design for 5G NR (the fifth-generation new radio) demonstrates the feasibility of metasurface-based lens in multi-beam antenna design. The progress of microwave metasurface lens antennas shows us the huge potential of metamaterial-based antennas (metamirrors in short) in advanced wireless systems.

9:50 Coffee Break
CS16: Antennas in IoT Wireless Devices: Modelling and Industrial Considerations
T04 to M2M / Convened Session / Antennas
Room: B2

Chairs: Jaime Anguera (FRACTUS Antennas & Universitat Ramon Llull, Spain); Miloslav Capek (Czech Technical University in Prague, Czech Republic)

9:30 A Small Metamaterial Dual-band Dipole Antenna Fed by Small Metamaterial Balanced-Feed

Changhyeong Lee, Heejun Park and Gang-Gyu Namgung (Incheon National University, Korea (South)); Yegue Seo (Incheon National University, Korea (South)); Sungteie Kahn (University of Incheon, Korea (South))

In this paper, a new design method is introduced to make a planar metamaterial dual-band dipole antenna fed by a small metamaterial balanced-feed. The PEMSA is integrated with a high efficiency feed and a wave control circuit can perform real-time beam-scanning by reconfiguring the phase of each electromagnetic surface unit. The prototype of the PEMS is fabricated and measured. The measurement results indicate that the PEMS achieves high gain and fast-beam-steering. Compared to the conventional phased array antenna, the proposed PEMS has the advantages of low power consumption, low cost, and conformal geometry. Due to these characteristics, the PEMS is promising for wide applications in 5G millimeter-wave communication systems.

9:40 Highly-Integrated Dual-Band mmWave Antenna Array for 5G Mobile Phone Application

Wei-Yu Li and Wei Chung (Industrial Technology Research Institute, Taiwan); Kin-Lu Wong (National Sun Yat-Sen University, Taiwan)

A highly-integrated 28 GHz and 39 GHz antenna array for 5G mobile phones is presented. The 28 GHz array consists of dual-openslot antennas as array elements and the 39 GHz array consists of folded loop antennas as array elements. This article demonstrates that 0.25 wavelength slot mode of the open-slot antennas and 1.5 wavelength loop mode of the folded loop antennas are promising candidates for generating directional radiation patterns fulfilling beam-scanning applications. And by properly designing the 0.25 wavelength slot mode to cover 28 GHz band and the 1.5 wavelength loop mode to cover the 39 GHz band, the proposed 28 GHz and 39 GHz antenna array can be compatible and coexist at a limited side space of a mobile phone with keeping independent beam scanning operations for a higher space utilization rate. This will be useful and attractive for future multiband and multimode millimeter wave mobile phones.

9:50 Implementation and Use of Physical Bounds for Antenna Optimization

Mark Gustafsson (Lund University, Sweden); Miloslav Capek (Czech Technical University in Prague, Czech Republic)

Here, we present an overview of physical bounds on antennas with a focus towards their use for antenna design and implementation. The developed bounds are based on optimization over the antenna currents and can be considered application oriented in the meaning that they are easily adapted to practical design constraints in shape, size, and performance. Electrodynamic simulation codes based on the method of moments (MoM) and characteristic mode analysis (CMA) are used to find solutions in terms of resonant frequencies. In addition, results of the radiation efficiency, gain, bandwidth and current distribution of the proposed model are discussed. From the systematic investigation of the bending effects for the proposed wearable antenna is also presented.

10:00 Design Concerns for In-body Antennas Based on Frequency Analysis of Fundamental Radiation Limitations

Zvonimir Sipus and Marko Bosiljevac (University of Zagreb, Croatia); Anja K. Skrivarh (EPEL, Switzerland)

Fundamental radiation limitations of in-body or implantable antennas should give us an estimate on the feasibility of some desired system. It was shown that near-field effects and distance to the body - free space boundary are critical aspects, while the shape does not play a major role in the achievable power. Through the frequency analysis of these limitations in this paper we provide another perspective and show how rigorous and approximate approach to near-field and reflection losses manifest in the results. This is demonstrated on a spherical body example which contains a small spherical implant which can be placed at different positions within the body in order to simulate different implant depths. The results reveal that reasonably accurate description of in-body loss mechanisms can be achieved using our previously defined fundamental radiation limitations for power density, however, depending on the frequency different loss aspects must be treated with special care.

10:10 Coffee Break
Active Antennas for Onboard Space Applications

Branko Kocunzija (University of Belgrade, Serbia); Tomislav Mileovic (WIPL-0, Serbia); Milos Pavlovic (WIPL-0 DOO, Serbia); Branko Mrdakovic (WIPL-0, Serbia)

The exponential growth of IoT imposes increased needs for understanding and exploitation of EM phenomena. Consequently, there are growing demands for more flexible, accurate, and efficient 3D EM simulation, easy accessible to many engineers, many of them lacking deep knowledge of applied electromagnetics. To meet such needs it is necessary to adjust existing tools to create friendly 3D simulation environment, not only for development and testing of IoT, but even for inclusion of these tools into functioning of IoT. In this paper we propose the concept/structure of such environment. For the base of such environment we propose WIPL-0 software. In addition we added libraries of EM models of electrical and environmental elements, and templates that combine them into IoT scenarios. Special tools are included to enable easy creation of new libraries/components and their composition into complex scenarios, as well as for effective processing of EM field data obtained by simulation.

Embedded Antennas in Cellular IoT Platforms

Jaume Anguera (Fractus Antennas & Universitat Ramon Llull, Spain); Aurora Andújar (Fractus, Spain); José Leiva (Fractus Antennas, Spain); Rosa Mateos (Fractus, Spain)

The continuous increase of wireless devices boosts RF/microwave and wireless engineers to design in a simple, quick and effective way. For this purpose, a method for designing multiband antenna systems from a very simple antenna element is proposed. This results in a procedure where the antenna is seen as an impedance box where the number of bands is fixed exclusively by the design of a multi-band matching network with lumped elements. The design of said multiband matching network is addressed by a computerized procedure giving as a result the matching network topology and the values of each lumped element. To validate the procedure, a multiband antenna system operating at 2/4/6/8GHz and 1710-2690MHz is built. The matching network has been obtained using a fully automated method with the ability to treat a wider range of application scenarios.

Radar Cross Section Measurement Within Reverberation Chamber: Stirrer Position Issues

Ariston Reis (Université Paris-Est Marne-la-Vallée, France); François Samarin (University of Paris-Est-Marne-la-Vallée & ESYCOM, France); Pouliguen Philippe (DGA, France); Jérôme Sol (INSA Rennes, France); Philippe Bernier (IETR, France); Elodie Richalot (Université Paris-Est Marne-la-Vallée, France)

This paper presents the evaluation of the Radar Cross Section (RCS) of a metallic object by measurements accomplished within the diffuse-field environment produced by a Reverberation Chamber (RC). The method is based on the extraction of the ballistic wave between the antenna and the target that is mixed with the backscattering response of the RC. A good agreement is obtained when compared with classical RCS measurement inside an anechoic chamber. This communication also highlights the potential stirrer positioning issues and their impact on the retrieved RCS accuracy.

5:00 Measurements on Extended Vertical Objects for Radar Field Probes

Pax S. P. Wei (The Boeing Company, (retired), USA)

As a novel field probe concept, RCS measurements are reported on long rigid objects rotated within a small angular range about the broadside condition (called a girth). The rotation was maintained either in a horizontal (H)-plane or in a vertical (V)-plane containing the center of the girth (G). Processing the RCS data by DFT yields a spectrum which is recognized as the field distribution along that object. Such spectrum compares extremely well to traditional field probes taken earlier by translating a sphere across the G in the H- or V-direction. Preliminary results at several 5-band frequencies are presented and discussed.

Effect of the Antenna Measurement Uncertainties on the Estimation of the Differential Reflectivity

Brais Sánchez-Rama, Veronica Santalla del Rio, Rubén Nocelo López and María Vera-Ibañez (University of Vigo, Spain)

The parameters of interest in polarimetric weather radars, defined in terms of the scattering coefficients of the target, are affected by non-ideal radiation systems. The effect of the cross-polar radiation has been studied and the requirements that radiation patterns must verify in order to maintain the error of the estimates below a predefined value have been established. Unfortunately, these requirements are strict and difficult to achieve with phased array antennas. Recently, it was shown that the effect caused by antenna systems can be separated from the scattering parameters and, consequently, corrected. Hence, this technique could be used to make the transition to phased-array polarimetric radar systems feasible. However, this correction requires knowledge of the antenna radiation patterns, so they must be measured. The aim of this work is to study the effect of the uncertainties introduced by the antenna measurement procedure in the correction of the differential reflectivity factor.

Analysis of the Cross-polar Radiation Effects on Differential Reflectivity Calibration

Veronica Santalla del Rio, Rubén Nocelo López and Brais Sánchez-Rama (University of Vigo, Spain)

This paper discusses the effects of cross-polar radiation on the calibration methods usually employed for the calibration of the differential reflectivity. It is shown that cross-polar radiation has significant effects when simultaneous transmission and reception of horizontal and vertical polarizations are used to obtain polarimetric measurements.

Embedded Antennas in Cellular IoT Platforms

Jaume Anguera (Fractus Antennas & Universitat Ramon Llull, Spain); Aurora Andújar (Fractus, Spain); José Leiva (Fractus Antennas, Spain); Rosa Mateos (Fractus, Spain)

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Breast Cancer Imaging Using a 24 GHz Ultra-Wideband MIMO FMCW Radar: System Considerations and First Imaging Results

Benoit Lejay (Thales Alenia Space, France)

This paper presents the current development of a front end radiating module in Ka band for advanced active antennas dedicated to Medium Earth Orbit mission at Thales Alenia Space France.

9:10 Active Antennas Radiated Spurious

Jonathan Hill (MDA Corporation, Canada); Michel Bellemare (MDA, Canada); Yves Demers (MDA Corporation, Canada); Nicholas Boudreau, Jean-Daniel Dea and Eric Amyotte (MDA, Canada)

This paper describes the analysis of radiated spurious performance of active antennas. It outlines an analysis methodology and presents selected spurious performance of selected beam layouts for Direct Radiating Array (DRA) and Array Feed Reflector (AFR) active antennas.

9:30 Additive Manufacturing: Enabling Technology for Active Antennas in LEO and GEO Satellites

Esteban Menargues and Santiago Capdevila (SWISSInet 12, Switzerland); Tomislav Debovic (SWISSInet 12, Switzerland); Maria Garcia-Vigueras (IETR-INSa Rennes, France); Emile de Rijck (SWISSInet 12, Switzerland)

Active antennas are one of the key elements in the upcoming flexible payloads for LEO constellations and GEO satellites. This paper describes the advantages in terms of mass, assembly, integration, test and RF performance of using the additive manufacturing process developed by SWISSInet in the development of direct radiating arrays. Such advantages are highlighted through the design of two examples. The paper reviews SWISSInet manufacturing process, includes measured RF performance of relevant active antenna hardware and presents innovative components to enable DRA and AFR for LEO constellations.

9:50 Potential Applications of Active Antenna Technologies for Emerging NASA Space Imaging Scenarios

Felix Miranda (NASA John H. Glenn Research Center, USA)

NASA is implementing far-reaching changes within the framework of both space and aeronaetics communications architectures. Near earth relays are looking to transition from a few large geostationary satellites to constellations of thousands of small LEO satellites while lunar space communications will require the need to relay data from many assets on the lunar surface back to earth. In aeronaetics, satellite communications for BLOS links are being investigated in tandem with the proliferation of UAS systems within the UAM environment. Thus, future communications architectures will need to connect and quickly transition between many nodes for large data volume transport. NASA JSC is exploring 5G-based beamformer technologies to leverage commercial timescales and volume production cycles, hereinafore not present within frequencies used by NASA. An overview of future applications of phased arrays being envisioned by NASA is discussed, along with technology feasibility demonstrations being conducted by GRC implementing low cost, 5G-based beamformer technologies.

10:10 Coffee Break

10:40 Active Antennas for Breast Earth Observation Missions in Thales Alenia Space Italy

Pasquale Capace (Thales Alenia Space Italy, Italy); Giovanni Gasparro (THALES ALENIA SPACE ITALIA, Italy); Roberto Giordani and Roberto Mizzoni (Thales Alenia Space Italy, Italy); Alberto Meschini (ThalesAleniaSpace, Italy), Giovanni Mannocchi (THALES ALENIA SPACE ITALIA, Italy), Andrea Surtani (THALES ALENIA SPACE, Italy), Salvatore Contu (Thales Alenia Space, Italy)

The paper provides an overview of the most significant active phased array products for Earth Observation developed by Thales Alenia Space Italy (TAS-I) over last two decades. In the first section the X band active antennas are presented while in the second part the electronics for phased array antennas working in L, C and X bands, developed also in the frame of international collaboration, are described. Finally on going studied for next generation SAR systems in C, X and Ka band are briefly reported.

11:00 AIRBUS DS SPAIN Active Antennas for Observations, Telecommunication, and Deep Space: Past and Future Challenges

Antonio Montesano (AIRBUS DS, Spain)

This paper presents some key heritage projects in AIRBUS DS in Madrid-Barajas, and current challenges facing the future in RADAR, Telecom, Earth Observation and Science.

11:20 Rigid-Flexible Antenna Array (RFA) for Lightweight Deployable Apertures

William F. Moulter, Rabindra N. Das, Andrew C. Maccabe, Landon A. Bowen, Erik M Thompson and Patrick B Bell (MIT Lincoln Laboratory, USA)

This paper presents the Rigid-Flexible Antenna Array (RFA), a concept for realizing ultra-light flexible antenna arrays that can readily integrate active components. This enables realization of phased arrays that can be compactly stowed in small satellites, where mass and volume for antenna payloads are extremely limited. The RFA is constructed with a very thin, physically flexible material and minimal rigid material, allowing it to be realized with an area density no less than 1.1 kg/m2. It employs a compact novel capacitive antenna feed, which simplifies its construction. The concept is validated through simulation of two RFAA element designs, and measurements of two prototype arrays.

11:40 NISAR Flight Feed Passive Antenna Measurements

Pablo Facordi (Jet Propulsion Laboratory & California Institute of Technology, USA); Jefferson Harrell (Jet Propulsion Laboratory, USA)

NISAR (NASA/USG, S4R, National Aeronautics and Space Administration, India) Space Research Organisation, Synthetic-Aperture Radar (SAR) is an Earth science project currently in its final development phase at NASA Jet Propulsion Laboratory (JPL) and at ISRO. Due for launch in 2022 it will assess how our planet changes over time by measuring differences in the Earth’s solid surface due to factors like climate change, movement and melting of glaciers, earthquakes, landslides, deforestation, agriculture and others. The enabling technology for this mission is a dual band (L-band and S-band) that feeds a 12m deployable mesh reflector. This paper describes the measurement campaign of the L-band flight feed in its passive configuration. Further measurements will be done using the antenna with the active radar components but they are not part of this paper.

12:00 Multibeam Array Antennas Based on Evanescent-Mode Ridge-Waveguide Radiating Filters

Daniel Sanchez (Universidad de Valencia, Spain); Mariano Baquero-Escudero, Pablo Soto and Vicente Boria (Universidad Politécnica de Valencia, Spain); Giovanni Toso (European Space Agency, Esa ESTEC, The Netherlands); Piero Angeletti (European Space Agency, The Netherlands); Marco Giglietti (University of Valencia, Spain)

Possible applications of completely metalic radiating elements based on below-cutoff apertures are presented. The four below-cut-off sub-apertures are associated to two different linear polarizations and two different frequencies. The four elements are physically interleaved but behave as completely overlapped elements permitting to reuse four times the entire physical aperture of the radiating element. Possible applications in passive and active array antennas for multibeam applications are discussed.

CS60: Sensors and Systems for Microwave Biomedical Imaging and Sensing

T05 Biomedical and health / Convened Session / Antennas

Room: B6

Chairs: Sandra Costanzo (University of Calabria, Italy), Natalia Nikolova (McMaster University, Canada)

8:30 Microwave Radar Breast Screening: System Interaction with the Post-Biopsy Clip

Lena Kranold and Milica Popovic (McGill University, Canada)

This work reports on recent progress in our feasibility assessment of the microwave radar prototype aimed at tumor detection through frequent breast screening. The previously reported time-domain system has 16 antenna-sensors in a multistatic arrangement. The phantoms used in our study are viable and carbon-based. With updated hardware, we now test the prototype to address an issue vital for our long-term clinical trials. Using phantoms in a controlled laboratory environment, we assess the influence of the miniature clip, typically left in the tissue as a marker after a biopsy, on the overall ability of our system to screen the patient frequently post-biopsy. This line of investigation is essential for our long-term clinical trials and will test the prototype to address an issue vital for our long-term clinical trials.

8:50 Breast Cancer Imaging Using a 24 GHz Ultra-Wideband MIMO FMCW Radar: System Considerations and First Imaging Results

Maria Virginia Prati (Politecnico di Milano, Italy); Jochen Moli (Goethe University Frankfurt am Main, Germany); Christian Kexel and Duy Hai Nguyen (Goethe University Frankfurt, Germany); Avik Santra (Infineon Technologies AG, Germany); Andrea Alvertti (Politecnico di Milano, Italy); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Vadim Issakov (Infineon Technologies AG, Germany)

Microwave imaging for breast cancer detection has been widely studied as an alternative technique to the conventional X-ray mammography. The systems developed until now operate at frequencies of a few gigahertz. This limits the achievable image quality. Higher operational frequencies are advantageous for achieving a better resolution, at the expense of a lower penetration depth. The downsampling of components together with an integrated radiating transceiver would lead to the development of an integrated ultra-wideband frequency-modulated continuous-wave (FMCW) radar system operating at a center frequency of 20 GHz and bandwidth of 8 GHz for breast cancer imaging. System considerations are developed and first imaging results based on numerical data are presented.
SW02: COST Session CA17115 (MyWAVE): Developments in Electromagnetic-Based Medical Technologies

9:10 Phaseless Approach to Microwave Biomedical Imaging: System Requirements Towards Clinical Applications
Sandra Costanzo and Giuseppe Lopez (University of Calabria, Italy)
A preliminary study on the implementation of a microwave imaging system for biomedical applications is outlined in this work. A low-cost, portable and easy implementable manufacturing setup for dielectric characterization of biomedical scenarios, specifically in the field of breast imaging, is discussed. It is combined with the use of a phaseless reconstruction strategy for the solution of the related non-linear inverse scattering problem.

9:30 Head and Neck Numerical Phantom Development for Cervical Lymph Node Microwave Imaging
Ana Catarina Pelicano (Faculdade de Ciências, Universidade de Lisboa, Portugal); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)
In this paper, we present a methodology to build a numerical phantom for the head and neck regions, which can be used to develop a cervical lymph node microwave imaging device. We have shown a pipeline of data processing steps which can be applied to Magneto-Resonance Imaging (MRI) of the head and neck.

9:50 Integrating Nodal Adjunct Jacobian Method in the Discrete Dipole Approximation-based Image Reconstruction Algorithm
Samar Hossenmehdadeh, Andreas Fagher and Mikael Persson (Chalmers University of Technology, Sweden); Paul M. Meaney (Dartmouth College, USA)
This paper focuses on the computational complexity of microwave image reconstruction algorithms. In microwave tomography, computing the forward solutions during the iterative reconstruction process directly impacts the accuracy and computational efficiency. Towards this end, we have applied the discrete dipole approximation for the forward solutions with significant time savings. However, we have discovered that the imaging problem configuration can dramatically impact the computation time required for the forward solve. It can be equally beneficial in constructing the Jacobian matrix required in the iterative image reconstruction algorithms. Key to this implementation, we propose to use the same simulation grid for both the forward and inverse domain discretizations. In this way, the nodal adjunct method for computing the Jacobian matrix reduces to an O(N) computation for each row of the matrix which is a dramatic improvement over previous implementations.

10:10 Coffee Break

10:40 A Tomographic Multistatic System for Biological Microwave Sensing
Igor Bisto, Claudio Estatito, Alessandro Fedeli, Fabio Lavagetto, Matteo Pastorino, Andrea Randazzo and Andrea Sciarrone (University of Genoa, Italy)
The use of microwave techniques for biomedical sensing and imaging is in continuous evolution, and the realization of accurate and high-speed systems is a key in enhancing the gap between the biological and medical device development and its practical application. In this paper, a prototype of multistatic imaging system, mainly designed for the quantitative reconstruction of the dielectric properties of the human head in brain stroke detection, is presented and some experimental results, obtained by processing the acquired data with a non-linear inverse scattering technique, are shown.

11:00 Pilot Patient Study with the Wavelia Microwave Breast Imaging System for Breast Cancer Detection: Clinical Feasibility and Identified Technical Challenges
Angé Fasoula and Luc Duchesne (Microwave Vision (MVG)); Brian M. Molyneux (Lambe Institute for Translational Research); Julio Daniel Gill Cano and Cecile Chenot (Microwave Vision (MVG), France); Barbara L. Oliveira (HRB Clinical Research Facility Galway, Ireland); Jean-Gaël Bernard (Microwave Vision (MVG)); Sani M. Abd Elwahab and Michael Kerin (Lambe Institute for Translational Research, Ireland)
In this paper, preliminary results of the first-in-human clinical investigation with the Wavelia Microwave Breast Imaging (MBI) system prototype are presented. The clinical feasibility of the system, in terms of potential to detect both malignant and benign palpable breast lesions, is illustrated with the MRI results of two patient scans. Some identified technical challenges, related to the patient positioning and breast deformation, are also discussed.

11:20 Coverage Estimation for Microwave Imaging Using Full Multistatic Radar Imaging Algorithms with Restricted Acquisition
Hamza Benchakroun (University of National Irland Galway, Ireland); Angé Fasoula (Microwave Vision Group, France); Luc Duchesne (MVG Industries, France); Martin O’Halloran (National University of Ireland, Galway, Ireland); Declan O’Loughlin (University of National Irland Galway, Ireland)
Many clinical investigations of microwave breast imaging systems are ongoing. However, few studies have investigated the optimal antenna design to maximise imaging performance. In this paper, the impact of the radial behaviour of the antenna on coverage area is investigated. A simplified antenna model in a homogeneous medium is used to estimate the power density and hence the coverage within the antenna array. Results from different antenna array configurations are compared, showing coverage can vary depending on the number of antennas used for multistatic imaging. The analysis is repeated for a lossy medium and highlights that losses increase the coverage estimation, although higher power and better signal-to-noise ratio would be required. In summary, this paper shows a preliminary design of an optimal antenna design parameters to maximise coverage.

11:40 Investigation of Influences on the Detectability of Magnetic Nanoparticles by Means of Waves for Biomedical Applications
Sebastian Ley (Technische Universität Ilmenau, Germany); Bernd Faenger (University Hospital Jena & Institute of Diagnostic and Interventional Radiology, Germany); Jürgen Sachs (Ilmenau University of Technology, Germany); Ingrid Hilger (University Hospital Jena, Germany); Marko Helbig (Technische Universität Ilmenau, Germany)
This paper deals with the detection of magnetic modulated nanoparticles by means of ultra-wideband sensing. Magnetic nanoparticles are modulated by an external magnetic field. The resulting scattering changes of the magnetic nanoparticles are analyzed depending on the mass, the magnetic field strength and the surrounding medium in which the particles are embedded. The experiments are carried out on phantom measurements and the results show a linear behaviour of the measured radar signal strength with respect to the magnetic field strength. Furthermore, the experiments show that the optimal choice of the magnetic field strength can increase the detectability of the magnetic nanoparticles. This applies both to particles that are diluted in distilled water and to particles that are embedded in a solid surrounding medium.

12:00 Qualitative Techniques for Generating Spatial Prior Information for Biomedical Microwave Imaging
Martina Teresa Bevacqua (Technische Universität Ilmenau, Germany); Nasim Abdollahi and Ian Jeffrey (University of Manitoba, Canada); Tommaso Ismaea (University of Reggio Calabria, Italy); Joe LoVetri (University of Manitoba, Canada)
The use of quantitative microwave imaging for biomedical applications represents one of the most relevant application areas due to the specificity of the complex-valued permittivity with regard to differentiating normal and diseased anatomical tissues. The success of such quantitative methods relies on improving their reconstruction accuracy and resolution. In the following paper, we propose the use of two different magnetic imaging methods, the linear sampling and the orthogonality sampling methods, to generate spatial priors that are used as a numerical inhomogeneous background medium within the quantitative contrast source inversion scheme. Both qualitative imaging methods are able to create morphological maps, in almost real-time, from the same microwave scattered-field data. The resulting quantitative show improvements in both accuracy and resolution, compared to blind reconstruction, and thus the combined technique represents a significant contribution towards the design of simpler and low-cost imaging systems.

SW02: COST Session CA17115 (MyWAVE): Developments in Electromagnetic-Based Medical Technologies

T05 Biomedical Health / Convened Session / Electromagnetics
Room 87

8:30 Loco-regional Hyperthermia Delivery: Patient-specific Set-Up Procedures for Treatment Optimisation
Johannes Crezee, Remko Zweije and Petra Koik (Academic Medical Center / University of Amsterdam, The Netherlands)
Loco-regional hyperthermia (heating of deep-seated tumours to 40-42°C) increases effectiveness of chemotherapy and radiotherapy. Phased arrays of antennas are positioned around the patient, using phase steering to focus energy deposition onto the tumour. This paper describes patient-specific set-up procedures for treatment optimisation of loco-regional hyperthermia devices using an E-Field probe at or near the tumour location. A phase-scan is performed for each individual antenna so that reference antennas are determined to optimise the phase-setback. An E-Field probe at the phase-shift when the probe cannot be positioned at the tumour location. Correctness of phase settings thus found is verified using temperature rise measurements after a 60 sec power pulse for three different phase settings. Effectiveness of the method is demonstrated by numerical simulations and clinically for patients with a cervical and bladder tumour. Results show this is a robust patient-specific method for clinical phase optimisation during loco-regional hyperthermia.

8:50 Hyperthermia Treatment Planning: Clinical Application and Ongoing Research
Petra Koik and Johannes Crezee (Academic Medical Center / University of Amsterdam, The Netherlands)
Hyperthermia, i.e. heating tumour tissue to 40-43°C, is applied clinically to enhance the effectiveness of chemotherapy and radiotherapy. Treatment planning can be a very valuable tool to improve clinical treatment quality. Initially, hyperthermia treatment planning started as a research tool, but developments over the past decade have resulted in more advanced simulation tools and integration of treatment planning in clinical workflow is emerging. This paper discusses the most important clinical applications of hyperthermia treatment planning and ongoing research.

Kernal Sumser (Erasmus MC Cancer Institute, The Netherlands); Margarethus M. Paulides (Eindhoven University of Technology, The Netherlands); Sennaro G. Bellizzi (Erasmus University Medical Center, Italy); Gerard C. van Rhoo (Erasmus MC Cancer Institute, The Netherlands); Juan
9:30 The Required Patient Modeling Realism in Radiofrequency Heating Simulation Studies

Gennaro G. Bellrìzi (Erasmus University Medical Center, Italy); Katalin Sümser (Erasmus MC Cancer Institute, The Netherlands); Margarethus M. Paulides (Eindhoven University of Technology, The Netherlands).

Clinical effectiveness of hyperthermia would benefit from a more controlled and targeted conformal heating of the tumor. Over the years, dosimetry using electromagnetic simulators has become a potent tool to study improvements in the application of hyperthermia. Literature suggests that simulation accuracy is dependent on the realism of the patient model. In this work, we compare the results for a detailed head and neck patient model to those for models with an approximated shape, a reduced tissue number and/or a spherical target volume. Our comparison shows a relative difference above 25% in the administered power absorption pattern. This large difference calls upon 1) follow-up research to establish the true impact using a larger set of patient models and 2) the development of a reference set of patient models to facilitate benchmarking of novel devices, methods and treatment approaches.

9:50 Monitoring Microwave Thermal Ablation Using Electrical Impedance Tomography: An Experimental Feasibility Study

Anna Bottiglieri (Translational Medical Device Lab & National University of Ireland, Galway, Ireland); Eoghan Dunne (National University of Ireland & Translational Medical Device Lab, Ireland); Barry McDermott (Translational Medical Device Lab, National University of Ireland, Galway, Ireland); Marta Cavagnaro (Sapienza University of Rome, Italy); Emily Porter (University of Texas at Austin, USA); Laura Farina (National University of Ireland Galway & CURAM, Ireland).

Low-cost and reliable methods for monitoring the state of the ablation zone during microwave thermal ablation (MTA) are crucial in the oncological clinical practice. The aim of this work is to test the performance of electrical impedance tomography (EIT) for the real-time monitoring of the ablation area where relevant temperature increases occur. In this work, two experimental studies were performed with a 16-electrode EIT system using a live mimicking agar phantom. First, an EIT system was tested to monitor the cooling of the phantom from an initial temperature of about 72°C. Secondly, the heating and the consequent cooling of the phantom were monitored. The heating was performed using a MTA operator operating at 30W for 10 minutes at 2.45GHz. The results reporting the voltage and temperature data acquired, as well as the reconstructed time series images, confirm the feasibility of EIT to monitor the changes of the electrical conductivity with temperature.

10:10 Coffee Break

11:00 Characterization of Esophageal Temperature Profiles During Cardiac Radiofrequency Ablation

Jan Sebek (Kansas State University & Czech Technical University, USA); Faraz Chamari (Kansas State University, USA); Jie Cheng (Texas Heart Institute, USA); Dhanunjaya Lakshminarayana (Kansas City Heart Research Institute and Research Foundation, USA); Punit Prakash (Kansas State University, USA).

Radiofrequency ablation is a widely used approach for treatment of symptomatic atrial fibrillation by achieving pulmonary vein isolation. A rare, but severe, complication associated with ablation is perforation of the esophageal wall due to unintended passive heating, leading to esophageal fistulas. Several strategies for managing esophageal lumen temperatures during ablation have been proposed, with the objective of limiting thermal damage and preventing perforation. However, there remains a limited understanding of the relationship between esophageal luminal temperatures and temperatures on the mucosal surface. Here, we report on measured temperature profiles in a custom ex vivo layered tissue preparation during radiofrequency ablation. Over n=62 ablations, temperatures on the mucosal surface of the esophageus ranged between 37-38.1 °C as mucosal surface thermal ranges between 60-65.4°C. These findings may contribute to the identification of safety thresholds for esophageal temperatures, which may preclude the incidence of esophageal perforation during cardiac ablation.

11:20 Potentialities of Inverse Scattering Techniques for Breast Cancer Imaging at Millimeter-Waves Frequencies

Martina Teresa Bevacqua (Università degli Studi di Pavia, Italy); Simona Di Meo (University of Pavia, Italy).

Breast cancer is one of the leading causes of cancer death among women in industrialized countries. Several microwave imaging systems have been proposed for the diagnosis of breast cancer, based on both the tomographic and radar approach, being tested in some cases even on real patients. However, the low working frequency of all these systems, which allows to reach non-superficial targets, has been in some cases the main cause of a non-optimal resolution. Based both on the results of recent dielectric characterization campaigns on ex-vivo tissues of the human-breast up to 50 GHz and on the promising achievements about the feasibility studies of mm-wave imaging systems, in this article, the tomographic approach to manipulate the simulated results of a linear radar scenario at the frequency of 30 GHz is proposed. In particular, two image reconstruction techniques, the Linear Sampling Method and the Born Approximation, are proposed and compared.

T90-P08: Satellite Propagation

T90 Space (incl. cubesat) / Regular Session / Propagation

Room: B8

Chairs: Mario Pescato (University of Pavia, Italy), Martin Rytr (Norwegian Defence Research Establishment (FIII), Norway)

8:30 First and Second Order Statistics of Two Years Alphasat Ka/Q Band Satellite Propagation Measurements in Budapest

Bernard Adjei-Frimpong and László Csurgai-Horváth (Budapest University of Technology and Economics, Hungary).

In the experimental campaign using the Alphasat Albo Parabol satellite payload at Budapest University of Technology and Economics, we contribute to characterizing the Ka/Q channel propagation. The satellite transmits unmodulated carrier signals on both frequencies in support of propagation experiments across Europe. Using data collected from Alphasat measurements, we investigate the atmospheric effects, mainly rain attenuation. In this paper we provide the analysis of our measured and pre-processed data relating to the first and second order statistics by presenting their long term cumulative distributions. Relevant recommendations from the ITU-R rain attenuation prediction models are compared with the measurements processed to classify the measured time series, which will be used to assess performance of the Ka/Q band satellite propagation channel in Budapest. We also demonstrate different data processing techniques showing how they influence the goodness of fits with the ITU-R model.

8:50 A Physical-Statistical Hybrid Model for Land Mobile Satellite Propagation Channel at Ku/Ka Band

Sebastien Rougerie (CNES, France); Jonathan Israel (ONERA - The French Aerospace Lab, France).

This paper presents an optimized Land Mobile Satellite (LMS) propagation channel model for Ku/Ka band. Here, a physical-statistical hybrid approach is proposed in order to simplify as much as possible the synthetic environment and the electromagnetic model, while keeping a good representation of the satellite propagation channel. This approach is complementary of full statistical approach [7] or a specific environment can be tackled instead of a mixture of different propagation conditions. An original validation of the model is presented here, with an innovative method based on 360° panoramic images analysis in order to rebuild a simple synthetic environment. [1] Recommendation ITU-R P.681-11, "Propagation data required for design systems in the land mobile-satellite service", 08/2019.

9:10 Fade Slope Analysis with Q-band Alphasat Satellite Measurements in Madrid

Domingo Pimienta-del-Valle (Universidad Politécnica de Madrid, Spain); Pedro García-del-Pino (Universidad Politécnica de Madrid, España); Jose M Riera (Universidad Politécnica de Madrid, Spain).

One of the second order statistics used to assess the adverse propagation effects of meteorological events in the signal propagation through the atmosphere is the distribution of fade slope. In order to characterize properly this statistical long data periods are needed. The Universidad Politécnica de Madrid (UPM) is receiving the 40-GHz signal coming from the Q-band Alphasat satellite beacon, with five years of measurements processed up to now. With the available excess data, fade slope distributions can be derived. Annual and period excess attenuation distributions and fade slope results are presented, together with the comparison of fade slope results with the Rec. ITU-R P.1623-1 model. The predictions of the ITU-R model follow adequately the experimental data, with most of the differences being observed for the higher analyzed time intervals (from 60 to 180 s) and attenuations (higher than 15 dB and up to 25 dB).

9:30 Heights of the 0ºC Isotherm and the Bright Band in Madrid: Comparison and Variability

Ana Benarroch (Universidad Politécnica de Madrid, Spain); Gustavo Siles (Universidad Privada Boliviana, Bolivia); Jose M Riera and Santiago Pérez-Peña (Universidad Politécnica de Madrid, Spain).

Rain attenuation prediction models may require rain height data that can be obtained from the 0ºC isotherm height as proposed in ITU-R Recommendations and also from radiosonde measurements. Statistical results on the variability of the 0ºC isotherm in all conditions and in rainy conditions are presented in this paper for ten years of radiosonde data. Concurrent with these data, nine years of rainfall measurements performed with a vertical Doppler radar (MRR-2) have allowed comparing the height of the 0ºC isotherm with the height of the bottom of the bright band considering simultaneous events. The variability of both heights and of their difference has been investigated as well.
Time diversity is a diversity scheme to mitigate rain attenuation in Earth-Satellite links operating above 10 GHz. Here we derive an empirical model to estimate time diversity statistics using two years of statistical data obtained at Ka and Q-bands.

10:10 Coffee Break

10:40 Statistical Analysis of Satellite Communication Experimental Time Diversity in Slovenia

Aarosl Kelmendi and Ales Sivic (Jožef Stefan Institute, Slovenia); andrej hrovat (Jožef Stefan Institute, Slovenia).

In order to achieve larger capacities needed for modern multimedia services, satellite communications are using high frequencies, such as the Ka/Q bands and above. However, due to several atmospheric factors, in particular rain along the propagation path, communication at these high frequencies are subject to attenuation, which limits the availability and reliability of links. To mitigate signal attenuation, several fade mitigation techniques exist. Diversity techniques, such as site diversity, orbital-diversity and time diversity, represent one such group. In this paper the performance of time diversity is investigated based on one-year measurement data statistical analyses of rain attenuation from Alpehabat satellite at 19.70° and 35.40° in Lithuania. Moreover, the performance of time diversity in two-site diversity system is investigated based on two years experimental signal data from Astrak 3B satellite at 120.70° measured at three locations in Slovenia.

11:00 Cloud Free LOS Probability Estimation for MEO Optical Satellite Systems and Optical Satellite Network Dimensioning

Christos N. Efferm and nikolaos lysas (National Technical University of Athens, Greece); charilaos kouropigoras (Science and Technology Facilities Council/RAL Space, United Kingdom (Great Britain)); thanassis d. Parapangopoulos (National Technical University of Athens, Greece); pantelis-daniel arapoglou (European Space Agency, the Netherlands).

Optical satellite networks have been recently proposed as an alternative solution of backhaul satellite networks. This paper studies the Medium Earth Orbit (MEO) optical satellite communication systems. More specifically, simple algorithms for the optimum selection of the location of the optical ground stations (OGSs) for a MEO optical satellite system are presented. The objective is to satisfy an availability threshold for each month for each orbital position of the MEO satellite. The algorithms take into account the monthly variability of cloud cover, take advantage of locations in different hemispheres and select OGSs which are within the visibility area of the satellite for longer time. Additionally, an engineering methodology for the estimation of single and joint C-FLOS statistics for MEO satellite communication systems based on integrated Liquid Water Content (LWC) monthly statistical parameters is presented. Finally, using the proposed methodologies useful numerical results are presented.

11:20 Variability of Gaseous Attenuation at Very Low Elevation Slant Paths; Measurements and Modelling

Erik W. Aalseth (University of Bergen, Norway); Martin rjistr (Norwegian Defence Research Establishment (FfI), Norway).

Gaseous attenuation variability for a 3° elevation angle ground link operating at 26 GHz in the Norwegian Arctic is analysed and compared with different models. At a very low elevation angle like this one, gaseous attenuation reaches high values and has significant temporal variation over short periods of time. 5 months of measured data are compared with a model based on measured-ground meteorological data and two different numerical weather prediction (NWP) models. The simplified model based on measured data gives lower values than the measured levels and is unable to model the observed fast variations. Both the NWP model based on predictions and the one based on re-analysis of past data are able to model most of the fast variations. When cloud attenuation is included in the NWP models both show excellent agreement with the measured data, without a clear difference in accuracy between them.

11:40 Potentials of the Numerical Weather Prediction Model WRF to Produce Attenuation Statistics in Tropical Regions

Valentin le mire (ONERA, France); Xavier Boulanger (CNES, France); Laurent Castanet (ONERA, France); bouchra benammar (Centre National d'Études Spatiales (CNES), France); laurent féral (Laboratoire LAPLACE, France).

This paper presents the application of a Numerical Weather Prediction model (WRF) coupled with an electromagnetic module to create rain attenuation time series and statistical results in a tropical region. Simulated results are compared with experimental data collected within a CNES/ONERA sponsored propagation experiment near Kourou, in French Guiana. Both simulated and experimental complementary distribution functions of rain attenuation (CDF) are presented in an annual and monthly basis. Finally, a brief ground-study model is developed to better understand the impact of the rain-drop size distribution (DSD) on the obtained results.

12:00 Performance Trends at 26 GHz for a Receiving Ground Station at Polar Latitudes: The SNOWBEAR Project

Matteo Marchetti and donato lospalluto (University of Pavia, Italy); filippo concaro (European Space Agency, Germany); filomena romano and domenico cimini (CNR-IMAA, Italy); marco passian (University of Pavia, Italy)

This link at around 26 GHz for space communications between Earth observation satellites and ground stations at Polar latitudes are being considered in recent year to increase the downlink performance. However, the precise link budget modeling and the experimental validation of such links is still open, particularly due to large propagation losses at these frequencies and partially because of the effect of the harsh Polar environment (e.g., snow) on the antenna performance. Moreover, the recent link budget modeling and the experimental validation of such a link is still open, particularly due to large propagation losses at these frequencies and partially because of the effect of the harsh Polar environment (e.g., snow) on the antenna performance. This work presents a modeling and simulation technique to study the dispersive features of periodic structures composed of glide-symmetric elliptical holes. As a difference from purely numerical methods, our formulation provides physical insight on the Floquet harmonics. At the same time, the computational cost is reduced compared to general purpose commercial software. The fields inside the holes are described by means of Mathieu functions and subsequently used to compute the full 2-D dispersion diagram. With the presented analysis, we demonstrate that glide-symmetric periodic structures with elliptical holes offer antistatic refractive inductive indexes over a wide range of frequencies.

20:30 Metasurface for Dense Dipole Array Decoupling in Ultra-High Field MRI

Marc Dubois (Institut Fresnel, France); Anna Hurshkainen (ITMO University, Russia); Massoud S. M. Mollaei (Aalborg University, Denmark); sergei kirdjulov (ITMO University, Russia); redha abdeddaaim (Aix Marseille University, France); stefan enoch (CNRS & Institut Fresnel, France); Stanislav Glybovsky (ITMO University, Russia); constantin simovski (Aalborg University, Finland).

Transmit phased array are developed in order to gain control over the radiofrequency magnetic field and reduce the interference to the patient. However, arranging dense array of such elements leads to increased costs and logistics for the medical system. This work presents an eigenproblem approach in characteristic the resonances of a 2-D periodic surface. The corresponding eigenfunctions are related to the resonance frequencies and the eigenfunctions are the corresponding surface current resonant profiles on the metalized portion of the unit cell. Further, the orthogonality properties of the resonant profiles lead to the derivation of simple circuit models with canonical topology (Foster's second form). The numerical results will show that, within the non-diffraction regime, the resonant profiles are a convenient set of macrobasis functions and also that the circuit model provides reasonably accurate results.

9:10 Derivation of Circuit Models Based on an Eigenvalue Problem for Periodic Surfaces with Multiple Resistors

Erik W Alsaaker (CNES, France); Donato Lospalluto (University of Pavia, Italy); Filippo Concaro (European Space Agency, Germany); Filomena Romano and Domenico Cimini (CNR-IMAA, Italy); Marco Passian (University of Pavia, Italy). This paper presents a modeling and simulation technique to study the dispersive features of periodic structures composed of glide-symmetric elliptical holes. As a difference from purely numerical methods, our formulation provides physical insight on the Floquet harmonics. At the same time, the computational cost is reduced compared to general purpose commercial software. The fields inside the holes are described by means of Mathieu functions and subsequently used to compute the full 2-D dispersion diagram. With the presented analysis, we demonstrate that glide-symmetric periodic structures with elliptical holes offer antistatic refractive inductive indexes over a wide range of frequencies.

9:30 Statistical Analysis of Satellite Communication Experimental Time Diversity in Slovenia

Aarosl Kelmendi and Ales Sivic (Jožef Stefan Institute, Slovenia); andrej hrovat (Jožef Stefan Institute, Slovenia).

In order to achieve larger capacities needed for modern multimedia services, satellite communications are using high frequencies, such as the Ka/Q bands and above. However, due to several atmospheric factors, in particular rain along the propagation path, communication at these high frequencies are subject to attenuation, which limits the availability and reliability of links. To mitigate signal attenuation, several fade mitigation techniques exist. Diversity techniques, such as site diversity, orbital-diversity and time diversity, represent one such group. In this paper the performance of time diversity is investigated based on one-year measurement data statistical analyses of rain attenuation from Alpehabat satellite at 19.70° and 35.40° in Lithuania. Moreover, the performance of time diversity in two-site diversity system is investigated based on two years experimental signal data from Astrak 3B satellite at 120.70° measured at three locations in Slovenia.

9:50 An Empirical Model for Time Diversity Statistics at Ka- And Q-band

Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); susana mota (University of Aveiro & Instituto de Telecomunicações, Portugal).

Time diversity is a diversity scheme to mitigate rain attenuation in Earth-Satellite links operating above 10 GHz. Here we derive an empirical model to estimate time diversity statistics using two years of statistical data obtained at Ka and Q-bands.
In this paper, the design of a five layer Fabry-Perot cavity leaky wave antenna is proposed via an optimization method. Each antenna layer is a partially reflective surface which consists of 7 x 7 patch elements, where the outer two layers placed around the birdcage coil can increase the efficiency at its resonance similarly to an ideal cylindrical magnetic wall of the same diameter.

11.00 Robust Homogenized Impedance Model for Periodically Modulated Metasurfaces

Enrica Martini (Uniwersytet w Sienie, Włochy); Francesco Campanta (Wave-Up SRL, Włochy); Stefano Maci (Uniwersytet w Sienie, Włochy)

This paper presents a review of the most recent progress in antenna design optimization with a focus on modern antennas. This paper highlights in this paper will likely have an impact on the future development of antennas for a multiplicity of applications.

8:30 Machine Learning-assisted Antenna Design Optimization: A Review and the State-of-the-art

Alexandros Feresidis, Naser Ojaroudi Parchin, Stanislav Glybovski (CNRS & Institut Fresnel, Francja); Andrea Alù (The University of Texas at Austin, USA)

This paper presents a review of various recent machine learning based optimization approaches for antenna design, focusing on methods and strategies for improving antenna performance. It highlights the potential of using machine learning techniques in antenna design optimization.

8:50 Machine Learning-Based Hybrid Random-Fuzzy Modeling Framework for Antenna Design

Huanan Li, Andrea Alù (The University of Texas at Austin, USA); Peter S Excell (University of Birmingham, United Kingdom)

The paper presents a hybrid Random-Fuzzy Modeling Framework for antenna design optimization. This framework combines the strengths of random and fuzzy models to improve the accuracy and efficiency of the design process.

9:10 Compact Millimeter-Wave MIMO Antenna for 5G Applications

Issa Elfergani, Jonathan Rodriguez (Instituto de Telecomunicaciones, Portugalia); Md. Aminul Islam (Multimedia University, Malaysia); Maryam Sajedian (University of Aveiro, Portugalia); Amjad Iqbal (University of Bradford, United Kingdom)

This paper presents a compact millimeter-wave MIMO antenna for 5G applications. The antenna design is based on a novel approach that combines multiple small elements to achieve high antenna efficiency and wideband performance.

9:30 A Dual-Polarized 5G Base Station Antenna Using Machine-Learning Based Optimization Method

Giang Hua, Yi Huang, Chaojun Song and Tianyuan Jia (University of Liverpool, United Kingdom); Xu Zhu (University of Liverpool, United Kingdom)

This paper presents a dual-polarized 5G base station antenna using machine-learning based optimization method. The antenna design is optimized using a machine learning algorithm to achieve high performance and efficiency.

9:50 A Doherty Power Amplifier Based on the Harmonic Generating Mechanism

Maryam Sajedian (University of Aveiro, Portugalia); Issa Elfergani and Jonathan Rodriguez (Instituto de Telecomunicaciones, Portugalia); Raed A Abd-Alhameed (University of Bradford, United Kingdom)

This paper presents a Doherty power amplifier based on the harmonic generating mechanism. The amplifier uses a novel approach to achieve high efficiency and linearity in 5G applications.

10:10 Coffee Break

10:40 Machine Learning-Driven Design Optimization for a Multi-Layer Metasurface Antenna

Despoina Kampoulidou, and Alexandros Feresidis (University of Birmingham, United Kingdom)

This paper presents a machine learning-driven design optimization approach for a multi-layer metasurface antenna. The approach uses a neural network to predict antenna performance and guide the design optimization process.

11:00 Wearable 5-Gigahertz Wi-Fi Antenna Design Using Whale Optimization Algorithm

Xuchen Wang and Ana Diaz-Rubio (Aalto University, Finland); Huanan Li (City University of New York, USA); Sergei Tretyakov (Aalto University, Finland); Andrea Alu (The University of Texas at Austin, USA)

This paper proposes a novel wearable 5-Gigahertz Wi-Fi antenna design using whale optimization algorithm.
11:20 A Compact Frequency Reconfigurable DRA for GSM, LTE, and 5G Applications Services
Chernomordik Zebin (Heriot Watt University of Salf, Algeria); Djamel Sayad (University of 20 Aout, United Kingdom (Great Britain)); Jamal Kosha and Widad Mshwat (University of Bradford, United Kingdom (Great Britain)); Issa Elfergani and Jonathan Rodriguez (Instituto de Telecomunicaciones, Portugal); Raad A Abd-Alahmeed (University of Bradford, United Kingdom (Great Britain))
A compact PIN diode frequency reconfigurable dielectric resonator antenna (DRA) for GSM, LTE and 5G applications is studied and presented. The proposed antenna provides operating frequencies between 1.80 GHz, 2.6 GHz, 3.6 GHz and the lower 5G bands (3.4-3.8 GHz and 3.4-3.7 GHz) which makes it suitable for mobile communication devices. The antenna structure consists of three rectangular Dielectric Resonators (DR1, DR2, and DR3) with permittivities 12.85 for DR1 and DR3 and 1.94 for DR2, of different dimensions. Two PIN diode switches are adequately placed on the microstrip line between the two dielectric resonators to assure the reconfigurable function. The proposed antenna size is 20×40×8.8 mm². Simulation results are presented and discussed. For the antenna structure validation and to highlight its performance, the results are compared with data published in the literature. The proposed antenna, offering suitable performance, provides three modes of operation with bandwidths of 19%, 11%, and 9%

11:40 A New Broadband MIMO Antenna System for Sub 6 GHz 5G Cellular Communications
Naser Ojaroudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Yaser Ismail Abdulrahem Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Ahmed Maan Abdulhalq (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Haleh Jahanbakhsh Bashiorou (Bradford College, United Kingdom (Great Britain)); Atta Ullah and Raad A Abd-Alahmeed (University of Bradford, United Kingdom (Great Britain))
A new MIMO antenna system with broadband antenna radiators is introduced for sub 6 GHz fifth-generation (5G) mobile communications. The proposed design contains four pairs of compact coplanar-waveguide (CPW)-fed antennas with polarization diversity that are symmetrically placed at four corners of the smartphone printed circuit board (PCB). Therefore, the proposed 5G antenna design contains four horizontally polarized and four vertically polarized antenna elements in total. A low-cost FR4 substrate (εr = 4.4, δ = 0.022) with a dimension of 79×150 mm² is employed as the mainboard substrate. The proposed design offers good isolation, dual-polarized full radiation coverage, and sufficient efficiencies. In addition, a wide impedance bandwidth (S11 ≤ -10 dB) of 3.3 to 5.6 GHz has been obtained for each antenna radiator. Moreover, the proposed design exhibits sufficient performance in the presence of the human-hand.

12:00 Mutual Coupling Effect on Three-Way Doherty Amplifier for Green Compact Mobile Communications
Ahmed Maan Abdulhalq (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Maan Yahya (Northern Technical University, Iraq); Naser Ojaroudi Parchin (University of Bradford, United Kingdom (Great Britain)); Yaser Ismail Abdulrahem Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Maryam Sajedin (University of Aveiro, Portugal); Issa Elfergani (Instituto de Telecomunicaciones, Portugal); Raad A Abd-Alahmeed (University of Bradford, United Kingdom (Great Britain)); Ashwan Rayi (SARAS Technology Ltd. (SARAS), United Kingdom (Great Britain)), Jonathan Rodriguez (Instituto de Telecomunicaciones, Portugal)
Mutual coupling effect on three-way Doherty power amplifier is studied, where the amplifier is targeting 2.4-3.8 GHz for 5G applications using three GaN HEMT transistors (GW 25W and 45W) to achieve a 7W peak power. A new impedance modulation configuration is used, where a gain of 12.5 dB was achieved over the design band. Changing the location of the peaking amplifier or changing the operation sequence of the peaking amplifier can achieve good efficiency at the back-off region. In addition, the performance variation of the designed amplifier was tested for different Voltage Standing Wave Ratio (VSWRs) considering the antenna impedance changing due to mutual coupling. There was an average of 3 dBm output power variation and ±11% efficiency variation at the peaking power and fewer variations in the performance for both factors at the back-off region for different VSWRs.
Anders Karlsson

The adaptive integral method (AIM) is frequently use to efficiently solve scattering problems involving conducting objects. Custom basis functions are built, considering the pattern of the isolated element, the elements position within the array, and additional auxiliary sources to account for coupling phenomena. Synthetic experiments show a four-fold reduction factor with respect to standard Near Field to Far Field techniques.

Damian Marek

Apart from the computational efficiency, a controlled and very good accuracy can be obtained with the directional method. The application focus of this work is large antenna arrays.

Computation of reaction terms in macro basis function (MBF) solvers is computationally very expensive. A directional method is used, which uses a compressed basis and ensures a fast algorithm. Apart from the computational efficiency, a controlled and very good accuracy can be obtained with the directional method. The application focus of this work is large antenna arrays.

Keshav Sewraj

Rigorous MoM analysis is used on these local domains to account for strong mutual coupling, with an iterative domain solver. The analysis is performed on each local domain, and the results are combined to obtain the overall solution. Numerical results demonstrate that the technique can converge rapidly for arrays with closely spaced elements.

Matthews Chose

A new iterative method is presented, for the efficient method of moments (MoM) analysis of large antenna arrays. The method is an extension of the domain Green's function method (DGFM). At each iteration, a local domain is used to identify sub-problems of closely-coupled elements centred around each antenna element. Rigorous MoM analysis is used on these local domains to account for strong mutual coupling, with an iteratively-refined current scaling assumption used to account for the influence of currents on the rest of the array elements. Numerical results demonstrate that the technique can converge rapidly for arrays with closely spaced elements.

Rezvan Rafiee Alavi

Experimental results of antenna prototypes for both near- and far-field radiation demonstrate the accuracy and the reduction of the measurement duration of the proposed approach.

Benjamin Fuchs

With the advent of 5G mobile communications at millimeter-wave frequencies, exposure assessment by means of power density evaluation has become important. This paper presents a method to reconstruct these quantities from measurements at very close distances, i.e., at a fraction of the wavelength, from the antenna. It is based on field integral equations and measurements with SPEAG's EuMetaVs probe. The method is evaluated in simulations with simulated measurement data. A successful reconstruction in the near and far-field is achieved both qualitatively and quantitatively. The deviation of reconstruction from simulation reference is less than 0.4 dB for the peak spatial average power density. Therefore, this method is very promising for compliance assessment, and may reduce test time tremendously.

Serge Pfeifer (Foundation for Research on Information Technologies in Society (ITiS Foundation), Switzerland); Jingtian Xi (The Foundation for Research on Information Technologies in Society (ITiS), ETH Zurich, Switzerland); Sven Kuhn (ITiS Foundation, Switzerland); Beyhan Kochali (Schmid+Partner Engineering AG, Switzerland); Niels Kuster (ITiS Foundation, Switzerland)

Chairs: Matthys M. Botha (Stellenbosch University, South Africa), Anders Karlsson (Lund University, Sweden)

A False-Resonance-Free Integral Equation Formulation for the Electromagnetic Transmission Problem

Chairs: Benjamin Fuchs (University of Rennes 1 - IETR, France), Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy)

T10-M10: General Antenna Measurements

T10 EM modelling and simulation tools / Regular Session / Measurements

Room: B4

Chairs: Benjamin Fuchs (University of Rennes 1 - IETR, France), Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy)
<table>
<thead>
<tr>
<th>Event</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>EurAAP 1: WG Measurements + AMTA Europe</td>
<td>12:50-14:00</td>
<td>Room 5</td>
</tr>
<tr>
<td>EurAAP 2: WG Small Antennas</td>
<td>12:40-14:00</td>
<td>Room 17</td>
</tr>
</tbody>
</table>

**EurAAP 1: WG Measurements + AMTA Europe (12:50-14:00, Room: 5)**

- Convened Poster 1-CS08: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring
  - Chair: Guido Luzi (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain), Marco Pasian (University of Pavia, Italy)

- CP1.01 Complex Dielectric Constant of Wet Snow Using Bi-Static Synthetic Aperture Radar
  - Jon Håvard H Erikstad, Kristian G Kjellård, and Tor Sverre Lande (University of Oslo, Norway)

- CP1.02 A Low Cost Active Corner Reflector to Assist Snow Monitoring Through Sentinel-1 Images
  - Guido Luzi and Enric Fernandez (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Ferrn Mira Perez (Centre Tecnològic de Telecomunicacions de Catalunya, Spain); Michele Crosetto (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain)

- CP1.03 Analysis of Snow Water Equivalent (SWE) of Snowpack by an Ultra Wide Band Step Frequency Continuous Wave Radar (SFCW)
  - Rafael Alonso, José Maria Garcia del Pozo, and Ismael Peruga (University of Zaragoza, Spain); Samuel Busián (Territorial Delegation of AEMET (Spanish State Meteorological Agency) in Aragón); José Adolfo Álvarez (Ebro River Basin Authority (CHE))

- CP1.04 Identification of Multi-Temporal Snow Melting Patterns with Microwave Radars
  - Marco Pasian and Pedro Fidel Espin Lopez (University of Pavia, Italy); Valentina Premier (Eurac Research, Italy); Claudia Notarnicola (EURAC, Italy); Carlo Marin (Eurac Research, Italy)

**EurAAP 2: WG Small Antennas (12:40-14:00, Room: 17)**

- Convened Poster 1-CS10: Antenna Array and Integrated Systems for 5G Communication Applications
  - Chair: Darwin Blanco (Ericsson, Sweden), Christos Kolitsidas (Ericsson, Sweden)

- CP1.05 Antenna-Amplifier Co-design: On a Method to Shape the Antenna Impedance
  - Lars Jonsson and Ahmad Emadeddin (KTH Royal Institute of Technology, Sweden)

- CP1.06 5G Wideband Magneto-Electric Dipole Antenna Fed by a Single-Layer Corporate-Feed Network Based on Ridge Gap Waveguide
  - Wai Yan Yong (University of Twente, The Netherlands); Thomas Emanuelsson (Gapwaves AB, Sweden); André Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)
This paper proposes a wideband magneto-electric (ME) dipole fed by a single-layer corporate-feed network based on the ridge gap waveguide (RGW) for 5G backhauling applications. The proposed antenna is composed of two layers. The top layer is the radiating layer that is composed of the 2x2 ME-dipole antenna element. The bottom layer is the corporate-feed network designed based on RGW. Our design allows for a smaller antenna volume since it excited the antenna directly by the RGW without the need of cavity layer. In addition, with the use of the ME-dipole, the bandwidth performance supported by the proposed design is larger as compared to the conventional designs. From the obtained simulation results, the proposed antenna presents S11 ≤ −30 dB over 24 – 30 GHz resulting in a 27% frequency bandwidth. The maximum directivity over the operating bandwidth of the simulated 2x2 ME-dipole antenna element is approximately 15.4 dBi.

**CP1.07 Design of Millimeter Wave True-Time-Delay Beam-formers for 5G Wireless Systems**

Dimitrios I. Lialis, Konstantinos D. Paschalidis, Anastasios G. Koulomos, Emiliouk Tihot and Nikolas Ntetsikas (Democritus University of Thrace, Greece); Vasilis Kassouros (Center for Security Studies (KINGEA), Greece); Konstantinos Kardaras and Dimitrios S. Kirtharidis (Intrascom Telecom, Greece); Christos Kolitsidas (Ericsson, Sweden); George A. Kyriacou (Kimmeria Campus, Greece & Democritus University of Thrace, unknown)

The exploitation of the millimeter wave (mmW) spectrum is the upcoming fifth generation (5G) wireless communications, as it meets the requirements for high-capacity links, large data rates and small latency. However, the growing complexity of the 5G mobile communication systems requires the existence of antenna arrays with multiple-beam capability. To this scope, the current work presents two novel designs of millimeter wave beamforming networks. The first one refers to a “true-time delay” topology, while the other architecture employs a Blass matrix, which is a known beamforming network at the microwave regime.

**CP1.08 Circularly and Linearly Polarized Planar Reconfigurable Active Array Antennas in Ka Band**

Alfonso T. Muriel Barredo, Jorge Calatayud Maeso, Antonio Rodríguez Galiano, José Manuel Fernández González and Santiago M. Sierra-Pérez (Universitat Politècnica de Catalunya, Spain); Pablo Sanchez-Olivares (Universidad Politécnica de Madrid, Spain);

This paper presents an evaluation procedure of a commercial integrated circuit (IC) for phased array antenna beam steering within mobile satellite communication applications at Ka Band (28–30 GHz). It allows to control amplitude and phase delivery from one common port to 8 independent channels. Therefore, only the transmission system is evaluated. Two different passive arrays are proposed to evaluate IC performance: a 2x2 planar array with switchable circular polarisation (CP) capabilities and a 8x8 planar array in feeding in columns for aothruham beam steering with linear polarisation (LP). Thus, since the first array is not as big enough for evaluate beam steering performance, it is only used for CP performance evaluation. A second legyer array, which is bigger but not circularly polarized, allows beam steering evaluation. Measurements of the proposed full integrated system will be presented at the conference.

**CP1.09 Broadband CTS Array in PCB Technology**

Michele Del Mastro (University of Rennes 1, France); Adham Mahmoud (Institut d’Électronique et de Télécommunications de Rennes, France); Thomas Potelton (ETR - University of Rennes 1, France); Ronan Sauleau (Université de Rennes 1, France); Mauro Ettorre (Université de Rennes 1 & I.UM CNRS 6164, France)

In this paper, a very low-profile wideband long-slot array is presented. The antenna system is realized using standard printed-circuit board (PCB) technology. Its architecture consists of radiating long slots, etched on the upper face of a PCB panel. The slots are parallel fed by a corporate feeding network made in parallel-plane waveguide technology. An embedded pldips coupler is employed to feed the structure. The antenna module is low-cost and presents a very low-form factor. The proposed solution covers the full Ka-band for Satcom applications (i.e., 47% of relative bandwidth). Very clear radiation patterns are shown in the H-plane. The maximum gain is about 18 dB at 25 GHz. Moreover, the antenna efficiency is about 85% in the Ka-band.

**CP1.10 A Simplified Extended SIW Supporting TE_{01} Integrateed with a Feeding Structure**

Christos Kolitsidas and Darwin Blanco (Ericsson, Sweden)

A TE_{01} substrate integrated waveguide is presented in this work. To avoid the propagation of this typically unsuppressed mode the SIW is integrated with an electromagnetic band gap (EBG) structure that confines the field with in the waveguide structure. The EBG is simply stacked top and bottom of the proposed structure allowing manufacturin g ease. The overall proposed structure is simulated and the results indicate very low-insertion loss in the pass band of the waveguide structure.

**Convened Poster 1-CS17: Antennas with Multi-Port/Distributed Feeding and On-Antenna Power-Combining for Efficient Integration and Reconfigurability**

**T02 Millimeter wave 5G / Convened Session / Antennas**

Room: A2 (Poster Area)

Chairs: Marriana Iwashina (Chalmers University of Technology, Sweden); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

**CP1.11 Efficient Waveguide Power Combines at mm-Wave Frequencies**

Ralph van Schelen, Marco Spirito and Daniele Cavallo (Delft University of Technology, The Netherlands)

In this work, an efficient power combiner for mm-wave frequency transmissions is investigated. The combiner is based on a parallel plate waveguide (PPW) excited with multiple parallel feeds and can be realized using standard PCB technology. The Doherty power combiner scheme can be also integrated in the proposed concept, to increase the efficiency of the amplifiers for implementing true-time delay modulation. The advantage of the proposed PPW combiner with respect to other concepts, e.g. the ones based on substrate integrated waveguide (SIW), is the wider bandwidth and the scalability to arbitrarily large number of inputs.

**CP1.12 Reducing User Effect on Mobile Antenna Systems with Antenna Cluster Technique**

Rasmus Luomanen, Albert Salmi and Anu Lehtovuori (Aalto University, Finland); Ville Viikari (Aalto University School of Electrical Engineering, Finland)

This paper studies the use of antenna cluster technique in mobile antenna systems and especially its use in reducing the user effect. The study is conducted with measurements of two different antenna designs using a hand phantom to represent the user holding the device. The results show that antenna designs based on the antenna cluster technique can retain good performance in the presence of a user. Furthermore, the cluster technique can also be used to reduce the user effect by adapting the cluster operation for different environments.

**CP1.13 Theory, Design and Validation of a Tunable, Injection-Matched, 2-Port Antenna**

Long Shen, Peter Mgya Kihogo, Peter Gardiner and Costas Constantinou (University of Birmingham, United Kingdom (Great Britain))

The wideband frequency tunability of a two-port microstrip-fed patch antenna is achieved using injection matching. It is demonstrated that controlling the relative amplitude and phase shift between the excitation at port one and port two microstrip-fed patch antenna can tune its operating band to a wider wideband frequency range compared to the fundamental intrinsic resonance frequency of the corresponding one-port antenna. The resulting two-port antenna has an overall efficiency in excess of 80% with fairly stable radiation pattern in the E-plane. The antenna is suitable for use in wireless communication applications in the C-band.

**CP1.14 Filter Design Considerations for an Integrated Doherty Power Amplifier - Antenna for Telecommunication Applications**

Petrie Meyer (Stellenbosch University, South Africa)

A system solution is proposed for incorporating filtering in integrated Doherty Power Amplifier - Antenna Element subcomponents. It is shown that such topologies do not allow for filters in front of the antenna element, as the impedance matrix terminating the amplifiers has to conform to very stringent requirements. In the proposed system, the filtering function is split into pre- and post-filtering functions, with the latter only used for harmonic suppressor, thus leaving the terminating impedance matrix unchanged at the design frequency. A case study is presented at 2.14GHz.

**CP1.15 High Power mm-Wave Spatial Power Combiner Employing On-Chip Isolation Resistors**

Artem Roë (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Marion Matters-Kammerer (Eindhoven University of Technology, The Netherlands); Marriana Iwashina (Chalmers University of Technology, Sweden)

A spatial power combiner interfacing four power amplifiers (PA) with isolation load resistors to a single substrate integrated waveguide (SWG) is presented. The isolation load resistors are envisioned on chip and have been optimized to provide both the optimal active load impedance for the interconnected PAs as well as to mitigate undesired power combiner coupling effects due to non-ideal excitations between PA channels. The proposed solution is compared to an ideal Wilkinson combiner in the presence of non-ideal PAs. The main performance targets are the combined output power, gain, and power efficiency at the 1-dB compression point. Simulation results demonstrate that introducing isolation load resistors allows to significantly reduce the impact of a non-uniform excitation on the combiner performance metrics.

**CP1.16 In-Antenna Power Combining for Highly-Integrated Millimeter-Wave Transmitters**

Benjamin Göttel (Wielenzahl Radar- und Sierontecrichtung GmbH & Co KG, Germany); Akanksha Bhutani (Karlsruhe Institute of Technology, Germany); Sören Marahrens and Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

In this paper an in-antenna power combining approach based on a circularly-polarized primary radiator is investigated. The radiator is based on the principle of an integrated lens antenna, where the primary radiator consists of a slot antenna with eight excitation elements. The output power of parallel amplifiers can be directly combined in the primary radiator itself without an additional power combiner network. The bandwidth and axial ratio of the proposed primary radiator is investigated through simulations and whenever possible verified by measurements. In this work, the passive antenna, the connected amplifiers and the active antenna are investigated in detail and are finally compared with each other.

**CP1.17 Circuit-antenna Interactions in Multi-Port Active Antennas**

Peter Gardiner, Yi Wang, Costas Constantinou, Long Shen and Peter Mgya Kihogo (University of Birmingham, United Kingdom (Great Britain))

This paper presents a review of research in which multiple port antennas have been used to absorb circuit or system functions into the antenna structure. Examples reviewed include image reject mixers, LINQ modulators and push-pull amplifiers. In the content of a convened conference session on multi-port antennas, the review provides discussion...
Convened Poster 1-CS18: Applications of mm-Wave Gap Waveguide Technology-I

T02 Millimetre wave 5G / Convened Session / Antennas
Room: A2 (Poster Area)

CP1.20 Microstrip to Ridge Gap Waveguide Transition for 28 GHz Steerable Slot Array Antennas
Alireza Bagheri (Gapwaves AB, Sweden & University of Twente, The Netherlands); Hanna Karlsson, Carlo Benvenuti, Abolfazl Haddadi and Thomas Emanuelsen (Gapwaves AB, Sweden); Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)

Gap waveguide technology enables a cost-effective and low-loss manufacturing of high frequency fully metallic components. With this technology, the microwave components can be made in two pieces that are assembled together after-wards. Between these two pieces, an undesired air gap due to surface roughness or manufacturing tolerances may cause energy leakage. To prevent this leakage, periodic structures that produce electromagnetic bandgaps (EBGs) are used. Here, we compare the performances of two today EBG surfaces, which are a conventional holy periodic metasurface and a metastructure with glide symmetry. The glide-symmetric structure has a wider EBG and a similar leakage prevention with less number of hole rows. Using glide-symmetric holes, a 4×4 slot array antenna is designed. This slot array is excited with the TE40 mode and has a rotationally symmetric radiation pattern.

CP1.21 Groove Gap Waveguide Slot Array Based on Glide-Symmetric Holes
Qingbi Liao (KTH Royal Institute of Technology, Sweden); Eva Rajo-Iglesias (University Carlos III of Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this paper three types of contactless vertical transitions from microstrip to double ridge waveguide are presented. The designs are compact in size and robust, with improved isolation by employing a pin structure, making them ideal for 5G millimeter phased arrays. All transitions cover the 26.5–29.5 GHz band, their dimensions are less than half a wavelength in pitch and have insertion losses less than 0.6 dB. The three designs apply different matching strategies and offer a trade-off between bandwidth and PCB areas. Finally, the behavior within an array configuration is analyzed.

Convened Poster 1-CS19: Applications of mm-Wave Gap Waveguide Technology-II

T02 Millimetre wave 5G / Convened Session / Antennas
Room: A2 (Poster Area)

CP1.23 A Compact Double-Layer Groove Gap Waveguide Power Divider with High Isolation
Enlin Wang (National Key Laboratory of Antennas and Microwave Technology, Xidian University, China); Tianlang Zhang and Lei Chen (Xidian University, China); Ashraf Uz Zaman and Jian Yang (Chalmers University of Technology, Sweden)

A compact double-layer power divider with high isolation between output ports based on the groove gap waveguide (GGW) is presented in this paper. A five-port 1-to-2 power divider is designed based on the gap waveguide technology. Then a 1-to-8 power divider is built up by connecting seven 1-to-2 five-port power dividers. To achieve a compact size, the 1-to-8 power divider adopts a double-layer structure. The top layer is the feeding structure of the power divider, and the bottom layer contains the loads. The simulated results show that the proposed power divider exhibits an impedance matching bandwidth for the reflection coefficient below -15 dB is from 23.7 GHz to 30 GHz, and isolation between the output ports is more than 18 dB.

CP1.24 Mechanical Phase Shifter in Gap-Waveguide Technology
Daniel Sánchez-Escudero (Universitat Politècnica de València, Spain); José Ignacio Herranz-Herrero (Universitat Politècnica de València, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València, Spain); Alejandro Valero-Nogueira (Universitat Politècnica de València, Spain)

This contribution presents a low-loss mechanical phase shifter in gap-waveguide technology. The phase shifter is aimed at ground terminals for Ka-band satellite-on-the-move applications. The use of the gap waveguide technology allows to divide the device into two main blocks distributed in two levels: a lower-movable block, in charge of the power distribution and the phase shifting, and an upper-fixed block with the output waveguides. In this paper, the lower and upper blocks are designed using Groove-gap waveguides (GGGW) and Ridge-gap waveguides, respectively. In order to couple the energy between the two levels, a slot on the metallic plane between the two layers is used. Results show a good performance in terms of phase shift between consecutive output ports, and return loss level at the input port, within the operating frequency band.

Convened Poster 1-CS27: Electromagnetics in MRI Applications

T05 Biomedical and health / Convened Session / Electromagnetics
Room: A2 (Poster Area)

CP1.25 Considerations in Designing Inverted Microstrip Gap Waveguide Components
Francisco Pizarro (Pontificia Universidad Catolica de Valparaiso, Chile); Carlos Sánchez-Caballero (Universidad Carlos III de Madrid, Spain); Jose-Luis Vazquez-Roy and Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This paper presents a parametric study of the properties of the inverted microstrip-gap waveguide with respect to the effects that the characteristics of the substrate and the bed of nails employed in its design have on the transmission line behavior. The work will focus on the line impedance sensitivity and the losses. To this aim, a methodology based on simulations is described and we include as well some experimental verification. The results are of great interest for designers of circuits in this technology.
Convened Poster 1-CS57: Recent Research on Wind Turbines: EM Modelling and Measurements

T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics

CP1.26 Design of Distributed Spiral Resonators for the Decoupling of MRI Array Coils
Dario Botti, Ruzica Fontana, Filippo Costa and Rocco Matesa (University of Pisa, Italy); Gianluigi Tiberi (London South Bank University, London, UK); Angelo Galante (University of L'Aquila, Italy); Marcello Alecci (University of L'Aquila and INFN-LNS L'Aquila, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)
This paper describes a distributed coil layout for the decoupling of 7T Radio Frequency (RF) Magnetic Resonance Imaging (MRI) 1H planar array coils based on miniaturized spiral resonators as cells. The spiral, opportunistically designed in terms of resonant frequency and with an optimized layout to minimize their number, are placed on the same dielectric substrate of the RF coils. We demonstrated through numerical simulations the decoupling effectiveness of the distributed filter, achieving a decoupling greater than -20 dB and satisfying matching levels (-30 dB) for the RF coils. The possibility to print on the same substrate both the coils and the filter results in practical advantages like excellent mechanical robustness and less sensitivity to potential fabrication tolerances.

CP1.27 Hybridized Electric Dipole Applications in Ultra-High Field MRI
Marc Dubois (Institut Fresnel, France); Tania Vergara Gomez and Frank Kober (Aix Marseille Univ, CRBM, France); Luisa Ciofani (DIP/FSBM/Neurosor/UNIRIS, France); Alexandre Vignaud (Commissariat à l'Énergie Atomique & NeuroSpin, France); Redha Abdeddaim (Aix Marseille University, France); Stefan Enoch (Institut Fresnel, France)
In this work, we demonstrate how a set of hybridized resonators can be used to achieve efficient and tunable electromagnetic field in the radiofrequency band. We show that near field coupling between multiple electric dipole lenses yields multiple eigenmodes whose response can be exploited to improve different canonical scenarios of magnetic resonance imaging (MRI) acquisitions. Two main examples will be covered: the metamaterial will be i) inserted in a human head coil at 7 Tesla and ii) coupled to a surface coil for small animal MRI at 17.2 Tesla.

CP1.28 A Vestigial Approach for the Numerical Analysis of MRI Birdcage Antennas in the Presence of the Human Head
Farzad Jadabari, Saba Jalil (Université Catholique de Louvain, Belgium); Chan Sun Park (Yonsei University, Korea (South)); Donia Oueslati (ICTEAM Institute, Université Catholique de Louvain, Belgium); Denis Thion (University of Cambridge, Britain); Clément Durochat (Multiwave Imaging SAS, Marseille, Belgium); Thibaut Letertre (Aix Marseille University, CRBM, Centrale Marseille, Institut Fresnel, France); Pierre Sabourou Pierre Sabourou (Institut Fresnel, France); Christiane Czabez (Université Catholique de Louvain, Belgium)
In this work, we show that integral-equation approaches are among the solvers that can be used to analyse RF fields in MRI scanners, in particular when the human body is divided into a collection of homogeneous objects. This solver can be relatively expensive in terms of computation time and memory if the full solution is run every time minor changes are considered in the MRI antenna design. We show that an efficient working tool based on a vestigial approach is proposed. The idea consists of avoiding re-computation of the equivalent currents inside the body. A validation is provided for a simple structure with a commercial solver (OST), and by using a developed in-house code, the magnetic field inside the brain is shown when a birdcage antenna is used around the human head.

CP1.29 Experimental Validation of the Concept of an Opencage Head Coil for Ultra-High Field MRI
Anton Nikulin (PSL Research University, France); Marc Dubois (Institut Fresnel, France); Tania Vergara Gomez (Aix Marseille Univ, CRBM, France); Djamel Berrahou (Multiwave Innovation SAS, France); Alexandre Vignaud (Commissariat à l’Énergie Atomique & NeuroSpin, France); Redha Abdeddaim (Aix Marseille University, France); Julien de Rosny (CNRS, ESPCI Paris, PSL Research University, France); Abdelwahab Darut (Université Langévin ESPCI Paris CNRS, France)
At 7T, birdcage coil is used as a transmit radiofrequency coil for head imaging. However for some applications sufficiently wide opening is required. Here, we propose to replace the shielded birdcage coil by an original volume coil that provides an access to the sample under examination while maintaining the desired homogeneous magnetic field distribution. The designed coil, called Opencage, is a non-periodic cylindrical cage. An approach based on transmission line modeling is developed to optimize it in order to provide homogeneous magnetic field. The result has been validated with a full wave numerical simulation. An experimental demonstration of such an opencage is shown. The magnetic field that is generated is close to the one of a conventional birdcage coil.

CP1.30 Matching and Decoupling Networks for Receive-only MRI Arrays
Wenjun Wang, Vitaly Zhubenko, Juan Diego Sánchez-Heredia and Jan Henrik Ardenkjær-Larsen (Technical University of Denmark, Denmark)
Magnetic resonance imaging (MRI) has rapidly evolved over the years, mainly due to the development of powerful gradient coils and wider bore systems. As a result, the application of MRI to small animals has also become more widespread. This has often led to the development of receive-only MRI (RO MRI) arrays. In this work, we design and implement a network to decouple and match a set of five receive-only coils that are not only electrically isolated but also connected to each other by mutual coupling. The designed network is shown to work well in simulations and experimental validation.

CP1.31 Enhanced Low Frequency MRI Using Flexible Shape Arrays Made of Standard Wire
Juan Diego Sánchez-Heredia, Wenjun Wang, Ricie Böklund and Vitaly Zhubenko (Technical University of Denmark, Denmark)
In this work, we present a new design for an MRI receive-only array that utilizes flexible copper wire. The design is based on the use of standard flexible copper wire and minimizes the number of connections required. The results show that the design is effective in reducing cross-talk and improving signal-to-noise ratio (SNR).

CP1.32 Design and Implementation of Solenoid and Alderman-Grant Coils for Magnetic Resonance Microscopy at 7T
Marcos Masoudinis, Tim Dybro and Vitaly Zhubenko (Technical University of Denmark, Denmark)
Magnetic resonance microscopy is an advanced type of magnetic resonance imaging (MRI) where the image resolution goes beyond of conventional clinical MRI to image very small tissue samples. The image resolution directly depends on the sensitivity of the detector coil, which is responsible for sensing weak magnetic fields from small samples in an MRI scanner. This paper describes the design and comparison of two magnetic field detection coils based on a solenoid and Alderman-Grant shapes. The coils are designed to provide over 90% field homogeneity in a 125 mm^3 volume.

CP1.33 Design of a Quadrature Coil for MRI of Carbon in Human Liver at 7T
Alapdin Rustemi (Technical University of Denmark, DTU, Copenhagen, Denmark); Vincent Boer (Danish Research Centre for Magnetic Resonance, Denmark); Vitaly Zhubenko (Technical University of Denmark, Denmark); Jan Henrik Ardenkjær-Larsen (Technical University of Denmark, Denmark)
Magnetic Resonance Imaging (MRI) is a method of generating images of soft tissues inside the human body by means of hydrogen nuclei. While typically hydrogen nuclei is used for imaging purposes, imaging other nuclei can vastly extend the potential of MRI. In this work, we demonstrate how a set of hybridized resonators can be used to achieve efficient and tunable electromagnetic field in the radiofrequency band. We show that near field coupling between multiple electric dipole lenses yields multiple eigenmodes whose response can be exploited to improve different canonical scenarios of magnetic resonance imaging (MRI) acquisitions. Two main examples will be covered: the metamaterial will be i) inserted in a human head coil at 7 Tesla and ii) coupled to a surface coil for small animal MRI at 17.2 Tesla.

CP1.34 Wind Turbine Blade Defection Sensing Using Blade-Mounted Ultrawideband Antennas
Onofre Freke (Aalborg University & APMS Section, Denmark); Shuai Zhang, Kim Olsen and Patrick Eggers (Aalborg University, Denmark); Claus Byskov (LMT Wind Power, Denmark); Gert Pederesen (Aalborg University, Denmark)
Wind turbine blade deflection sensing system using ultrawideband radio links propagating along the blade is presented. Special focus is given to the challenges related to the multipath propagation along the blade. Results of electromagnetic modeling of the wireless link budget for deflected blades are presented. Some aspects of the sensing system that are different from a typical wireless communication link are discussed.

CP1.35 An Improved Forecast Method for the Interaction of Wind Turbines with Doppler VOR
Thorsten Schrader (Physikalisch-Technische Bundesanstalt, Germany); Jochen Bredemeyer (FCS Flight Calibration Services GmbH, Germany); Thomas Kleine-Ostmann and Marius Mihalachi (Physikalisch-Technische Bundesanstalt, Germany)
The installation of wind turbines leads to bearing errors of Doppler Very High Frequency Omni-Directional Range used for terminal navigation. The German air navigation service provider uses an simple model to calculate bearing errors. Here, the results of an improved forecast tool are compared to the results from the original tool, full wave simulations and measurements for a distinct trajectory close to the DVOR Hehlingen.
**Poster1-A07: Dielectric Resonator Antennas**

**Antennas**

Room: Exhibition Hall

**P1.001 On-Chip Micromachined Dielectric Resonator Antennas Loaded with Parastatic Circular/Rectangular Patch for mm-Wave Applications**

Mai Sallam (The American University in Cairo & Katholieke Universiteit Leuven, Belgium); Mohamed Serry (The American University in Cairo, Egypt); Sherif Sedky (AUC, Egypt); Alif Shamim (King Abdullah University of Science and Technology, Saudi Arabia); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Ezzeddin Soliman (The American University in Cairo, Egypt)

In this paper, the design of on-chip micromachined dielectric resonator antennas (DRA) operating at 60 GHz are presented. The DRA are fabricated using a single silicon wafer in which the dielectric resonator is located at one side of the wafer while the feeding network is located on the other side. The feeding lines are terminated by magnetic dipole which excite the dielectric resonator and creates its radiation. In order to enhance the bandwidth of the antenna, the dielectric resonator is loaded with circular/rectangular patch antenna. Both designs are characterized by their fabrication simplicity, and high radiation performance. Additionally, the designed antennas have wide impedance bandwidth reaching more than 10% (20%) of the central frequency for the circular/rectangular patch loaded dielectric resonator antennas.

**P1.002 Filtering Dielectric Resonator Antenna Using Terminal-Loaded Resonators**

Yun-Ting Liu and Kewk-Wa Leung (City University of Hong Kong, Hong Kong)

A new filtering dielectric resonator (DR) antenna (DRA) is presented in this paper. The DRA and its feedline provide a bandpass response. The antenna feedline consists of two terminal-loaded microstrip resonators (MIR), which gives two independently tunable nulls with an improved selectivity. For the DRA, it is excited in the HE11 mode, serving not only as a radiator but also as the last-stage resonator of bandpass filters (BPF).

**P1.003 An Asymmetric Star Design for the Dynamic Control of Quantum-Emitter-Coupled Plasmonic Nanoantenna Emission**

Hisham Ashraf Amer and Tamer Ali (Zewail City of Science and Technology, Egypt)

Asymmetric single nanoantennas and meta-surfaces can both enhance and manipulate emission from potential quantum emitters while their layer-like nano-thick structure renders them integrable into quantum and nano-devices. Here, we propose an intrinsic Star Nanoantenna design, which when coupled to a single quantum dot emitter, offers unique resonant enhancements in both single and array arrangements. This enhancement was most established with the array, where 3 main polarization tunable behavioral states were identified, ones we described as double, single and steady mode patterns. This polarization-driven functionality could offer a much-needed means of control over quantum emitters.

**P1.004 Reconfigurable All-dielectric Transmission Lens for Vortex Beam Generation**

Jiangyi Yi and Menghuan Lin (Key Laboratory of Integrated Services Networks, Xidian University, China); Lina Zhu (Xidian University, China); Caijie Dong (Key Laboratory of Integrated Services Networks, Xidian University, China); HaiLin Zhang (Xidian University, China)

In this paper, a novel design of vortex beam generation is proposed by utilizing phase-gradient all-dielectric metamaterials. The pluggable element of proposed design is able to provide a full transmission-phase covering the range of $2\pi$ together with a high transmission efficiency. The elements corresponding to each value of phase are encoded into 560 modules. Thus, designed phase modules can be judiciously arranged to generate vortex beams carrying orbital angular momentum with different modes. Full-wave simulations validate the spiral-shaped phase fronts of the vortex beam. The proposed lens paves the way for the applications of vortex beam.

**P1.005 Impedance Bandwidth Performance of TM105 Mode in Equilateral Triangular DRA**

Amini P (Indian Institute of Technology Guwahati, India); Ranajit Bhattacharjee (Indian Institute of Technology Guwahati, India)

In this paper a method for calculating the impedance bandwidth around the resonance frequency of TM105 mode excited inside an Equilateral Triangular Dielectric Resonator Antenna (ETDRA) is reported. The method utilizes the expression of quality factor (Q-factor) of TM105 mode, which is obtained through curve fitting approximation technique. (Q-factor is a function of aspect ratio $a/b$ and the material dielectric constant $\epsilon_r$) The bandwidth performances of such modes around the resonance frequencies for different degrees of impedance matching are discussed. The proposed method for calculating the impedance bandwidth is also validated by comparing with the practical bandwidth of the ETDRA reported in the literature.

**Poster1-A09: Lens Antennas**

**Antennas**

Room: Exhibition Hall

**P1.006 2-D Wide-Scanning Flat Luneburg Lens Antenna for 5G Communication**

Luming Liu (University of Electronic Science and Technology of China, China); Shi Wen Yang (University of Electronic Science and Technology of China, China); Shi-Wei Qu, Yi-kai Chen and Jun Hu (University of Electronic Science and Technology of China, China)

This paper presents the design of a two-dimensional (2-D) wide-scanning flat Luneburg lens antenna operating at 5G-band. Based on the transformation optics (TO) theory, the conventional Luneburg lens is compressed to the flat form while keeping its beam focus characteristics unchanged. The 2-D flat Luneburg lens consists of six discretized lens layers made of all-dielectric materials. A 15-element linear patch antenna array is employed to feed the lens between the metallic parallel plates. Experimental results show that the 2-D beam-scanning lens antenna has a scanning coverage of $-50^\circ$ – $48^\circ$ in the azimuth plane, which can be obtained by switching the feed array elements. The 3-dB beamwidth in the elevation plane is $79^\circ$ at 28 GHz due to the low profile of proposed lens antenna. With the advantages of low profile, wide-scanning and low cost, the proposed 2-D flat Luneburg lens antenna is attractive for 5G communication.

**P1.007 Ka-band Multi-beam Planar Lens Antenna for 5G Applications**

Eduardo Garcia-Marín (Universidad Autonoma de Madrid, Spain); Dejan Filipovic (University of Colorado at Boulder, USA); Jose Luis Masa-Campos (Universidad Autonoma de Madrid, Spain); Pablo Sanchez-Olivares (Universidad Politecnica de Madrid, Spain)

A low-cost solution for multi-beam antenna systems is explored for 5G applications in the 26-GHz band. A 4-port stacked-patch microstrip antenna is used as both a feeder of a perforated flat lens. Each feeder is placed in a different position with respect to the lens, yielding four high-directivity independent beams. The beams cover an angular range from 0° to 30° degree scanning with a peak gain over 12 dB. The antenna has been implemented by low-cost processes, employing Printed Circuit Board fabrication for the feeder and 3D printing for the lens.

**P1.008 H-band Quartz-Cavity Leaky-Wave Lens Feeder with Novel Chip Interconnect**

Marta Arias Campo (IMST GmbH, Germany & Delft University of Technology, The Netherlands); Katarzyna Holc (Fraunhofer Institute for Applied Solid Physics IAF, Freiburg, Germany); Arnulf Leuther (Fraunhofer Institute for Applied Solid Physics, Germany); Rainer Weber (Katholieke Universiteit Leuven, Belgium); Jean Cavillot (ENAC, France)

This paper presents an overview of research activities at the Fraunhofer Institute for High-Frequency Physics and Radar Techniques IAF, Germany, with respect to possible interferences from wind turbines against radar systems. Starting from phenomenological effects observed in measurements behind a wind farm, various types of electromagnetic simulations have been performed in order to investigate the principal scattering mechanisms.

**P1.009 Acceleration of Physical Optics Interactions Using Inhomogeneous Plane Waves**

Oumaima Mhadhbi (Icteam, Universite Catholique de Louvain, Belgium); Jean Cavillot (ENAC, France); Katarzyna Holc (Fraunhofer Institute for Applied Solid Physics IAF, Freiburg, Germany); Jean Cavillot (ENAC, France)

In this paper a method for calculating the impedance bandwidth around the resonance frequency of TM10δ mode excited in an Equilateral Triangular Dielectric Resonator Antenna (ETDRA) is reported. The ETDRA and its feedline provide a bandpass response. The antenna feedline consists of two terminal-loaded microstrip resonators (MIR), which gives two independently tunable nulls with an improved selectivity. For the ETDRA, it is excited in the HE11 mode, serving not only as a radiator but also as the last-stage resonator of bandpass filters (BPF).

**P1.010 Filtering Dielectric Resonator Antenna Using Terminal-Loaded Resonators**

Yan-Ting Liu and Kewk-Wa Leung (City University of Hong Kong, Hong Kong)

A new filtering dielectric resonator (DR) antenna (DRA) is presented in this paper. The DRA and its feedline provide a bandpass response. The antenna feedline consists of two terminal-loaded microstrip resonators (MIR), which gives two independently tunable nulls with an improved selectivity. For the DRA, it is excited in the HE11 mode, serving not only as a radiator but also as the last-stage resonator of bandpass filters (BPF).

**P1.011 Impedance Bandwidth Performance of TM105 Mode in Equilateral Triangular DRA**

Amini P (Indian Institute of Technology Guwahati, India); Ranajit Bhattacharjee (Indian Institute of Technology Guwahati, India)

In this paper a method for calculating the impedance bandwidth around the resonance frequency of TM105 mode excited inside an Equilateral Triangular Dielectric Resonator Antenna (ETDRA) is reported. The method utilizes the expression of quality factor (Q-factor) of TM105 mode, which is obtained through curve fitting approximation technique. (Q-factor is a function of aspect ratio $a/b$ and the material dielectric constant $\epsilon_r$) The bandwidth performances of such modes around the resonance frequencies for different degrees of impedance matching are discussed. The proposed method for calculating the impedance bandwidth is also validated by comparing with the practical bandwidth of the ETDRA reported in the literature.
This work presents a novel Interval Arithmetic (IA) methodology for the probabilistic tolerance analysis of linear phased arrays. The method is applied to a 2x2 phased array antenna system, where the proposed IA method is compared to Monte Carlo simulations. The results show that the proposed IA method provides more accurate and reliable power pattern bounds, and extended to provide a probabilistic analysis of the possible random patterns.

Nicola Anselmi
(ELEDA Research Center, University of Trento, Italy)

To summarize, the proposed IA methodology offers a promising alternative for the probabilistic analysis of phased array antenna systems, providing more accurate and reliable results compared to traditional Monte Carlo simulations.

P1.010 Waveguide Switch Based on Ferrite Circulator for Antenna Beam Steering Applications

Stephanie Smith (CISRO & Astronomy and Space Science, Australia); Andrew Weily (Antenna Engineer, Australia); Ken Smart, Nick Carter and Santiago Castillo (CISRO Astronomy and Space Science, Australia)

A low loss waveguide switch based on the ferrite circulator concept has been designed, analyzed with coupled electromagnetic and magnetostatic solvers, manufactured and tested for operation at 220GHz. A prototype single-pole three-throw switch is presented here. This switch will form part of a larger switch network for antenna beam steering applications.

P1.011 Zero Index Metamaterial for High Gain Array

Jiang Tingyou (EPLF, Switzerland); Ning Hui and Zhou Heng (Northwest Institute of Nuclear Technology, China)

Traditional metamaterials involving metal wire grid were used to enhance the radiation performance of the antenna, especially for the gain, a critical parameter of antenna array. In this study, a novel zero index metamaterial (ZIM) is proposed, consisting of double metal layers with periodic circular perforations for horn antenna loading. Full-wave simulations are used to demonstrate the characteristics of horn array loaded with the proposed ZIM, and a significant enhanced performance is demonstrated due to zero refractive index. Experiments are performed to verify the effects of antenna array loaded with ZIM. The results show that the gain of the loaded array increases by nearly 2.5 dB, the maximum aperture efficiency of horn antenna increase from 0.5 to 0.88 at the resonant frequency while the tapering length is half of the optimum horn and the aperture dimension remains the same. Thus, the loaded horn array shows a promising application.

P1.012 Ray-Tracing Analysis of the near and Far Fields of Focusing Geodesic Lens Antennas

Germán León and Omar Ogrea (Universidad de Oviedo, Spain); Nelson Fonseca (European Space Agency, The Netherlands); Oscar Quevedo-Tened (KIT Royal Institute of Technology, Sweden)

Geodesic lenses are a class of rotational-symmetric lenses that recently regained interest for the design of large aperture antenna beams. Key features of these lenses include mechanical simplicity, wide scanning range and high efficiency. In this paper, a hybrid model to analyze focusing geodesic lenses is described. The method combines a ray tracing analysis and a point source array model. This model allows to calculate the near and far fields of a geodesic lens antenna in few seconds. Some results of a lens antenna in the Ka-band are compared with full wave simulations, validating the model despite small differences in the main beam. This paper also discusses the ability of geodesic lenses to focus the energy in the near field which could be of interest for some applications.

Poster A17: Array Antennas, Antenna Systems and Architectures (incl. Radomes)

Antennas Room: Exhibition Hall

P1.013 Effect of Element Number Reduction on Inter-User Interference and Chip Temperatures in Passively-Cooled Integrated Antenna Arrays for 5G

Yankai An and Jan Puskely (Delft University of Technology, The Netherlands); Antoine Roederer (Technical University of Delft, The Netherlands); Alexander Yarovsky (TU Delft, The Netherlands)

The impact of reducing the total number of elements in passively-cooled, chip-integrated and space-division multiple-access (SDMA) antenna arrays is investigated for multi-user space-division multiple-access applications. A convex element position optimization algorithm is used to synthesize the array layouts. The study highlights that reducing the number of elements does not help in reducing the inter-user interference and can even improve the interference on the target user.

P1.014 An Irregular Tightly Coupled Dipole Array with Wide Scanning Angles

Yankai Ma (University of Electronic Science and Technology of China, China); Shi Wen Yang (University of Electronic Science and Technology of China, China); Yaike Chen, Shi-Wei Qu and Jun Hu (University of Electronic Science and Technology of China, China)

An innovative architecture is proposed for tightly coupled dipole arrays partitioned irregularly by domino-shaped tiles. A 15×15 port finite array operating at 87GHz has been implemented, where the port spacing is 0.57λ wavelength at the highest frequency. In order to achieve large elevation angle scanning, differential evolution (DE) algorithm is used to synthesize active radiation patterns and suppress the port active reflection coefficients simultaneously. Simulation results show that the finite array is able to achieve almost no reduction in gain for scanning to broadside and only less than 2dB for scanning up to 60° as compared to fully populated arrays.

P1.015 Tiled Arrays: Low Cost Solutions for Next Generation Communication and Sensing Systems

Nicola Anselmi (ELEDA Research Center, Italy); Paolo Rocca and Andrea Massa (University of Trento, Italy)

Array tiling is a promising architectural solution for next generation communication and sensing antennas. This work reports a review of the array tiling synthesis methodologies developed at the ELEDA Research Center, assuring exact tiled array designs by exploiting analytic tiling theorems and optimization-based techniques. Single-tile tiling methods, as well as recent developed multi-shape tiling approaches are reviewed and discussed. An illustrative numerical example is reported, showing the effectiveness of the proposed approaches when considering square shaped tiles of different sizes.

P1.016 From 'Hostile' to 'Nice' Environment in Communication and Sensing

Marco Sausco (ELEDA Research Center, Italy); Giorgio Storti (ELEDA Research Center, University of Trento, Italy); Paolo Rocca and Andrea Massa (University of Trento, Italy)

Innovative concepts and ideas are presented for addressing persistent challenges in the design of future wireless systems. According to the "smart electromagnetic (EM) environment" paradigm, multi-path scattering phenomena arising in complex propagation scenarios must not be regarded as an obstacle (as done in classical antenna designs), but rather as a key asset for realizing innovative and unconventional systems in order to meet the ever-growing demand of link quality and mobile data traffic. Within this context, a proof-of-concept is shown to provide an illustrative example of how the surrounding complex environment can be opportunistically exploited to yield a desired field distribution tailored by an antenna.

P1.017 An 8×8 Cavity Backed Waveguide Antenna Array for D-Band Backhauling Communications

Sherif R. Zahr and Luigi Boccia (University of Calabria, Italy); Giandomenico Amendola (IEEE, USA); Stefano Moscato (SIAE Microelettronica, Italy); MatteoOLDINI (SIAE Microelettronica S.p.A., Italy); Dario Tresoldi (SIAE Microelettronica, Italy)

This work proposes a novel design of two-layered antenna array targeting the D-Band region of the spectrum, likely to be required for future highly-multipolarized phased arrays. The antenna consists of a 8×8 port cavity backed array antenna exhibiting a planar footprint with a gain of 30.3×26.4×1.235 mm³ and is capable of covering the 153-161GHz band with a 3-dB gain bandwidth greater than 19% and a cross-polarization level lower than 23 dB.

P1.018 Compact and Low Cost Linear Array Antenna for Millimeter Wave Automotive Radar Applications

Imran Arzt (Uppsala University & MIP University of Science and Technology, Mirpur Azad Jammu and Kashmir, Pakistan); Wan-Chun Liao (Chalmers University of Technology, Sweden); Haniel Alakbari (Lund University, Sweden); Winfried Simon (IMST GmbH, Germany)

A low-cost microstrip patch antenna array is proposed in this paper for automotive radar applications in 77GHz band. The elements of the center-fed array are connected in series to make a compact design with low complexity by exploiting Wilkinson power divider. This approach also helps to reduce the dielectric losses of the array. A full-wave electromagnetic (EM) software EMPIRE XPU is used in the design process. The measurement results show 25 percent fractional bandwidth in terms of antenna impedance (32.75-33GHz), 8.5-dB maximum gain, 6-degrees half power beam width (HPBW), -12 dB side lobe level (SLL), and more than 50 dB isolation between TX/RX in the desired frequency range.

P1.019 A Novel Probabilistic Interval Arithmetic Method for Tolerance Analysis of Phased Arrays Beamforming Networks

Nicola Anselmi (ELEDA Research Center, Italy); Alessandro Polo (ELEDA Research Center, University of Trento, Italy); Paolo Rocca and Andrea Massa (University of Trento, Italy)

This work presents the novel Interval Arithmetic (IA) methodology for the probabilistic analysis of linear phased array beamforming networks. Efficient IA-based antenna array tolerance techniques are used to compute accurate and reliable power pattern bounds, and extended to provide a probabilistic analysis of the possible random patterns within the computed intervals. The computation of the probabilities is performed analytically, without executing time-consuming random simulations. Eventually, a preliminary result is reported to assess the effectiveness of the proposed technique, showing its advantage in providing a more informative tolerance analysis with respect to IA-based statistical methods.
P1.020 Optimization of Modular Multi-Function Radar Architectures for Two-Way Pattern Sidelobe Minimization
Nicola Anselmi (ELEIDIA Research Center, Italy); Alessandro Polo (ELEIDIA Research Center, University of Trento, Italy)
This contribution proposes a modular antenna architecture for simultaneous transmit/receive functionalities. Rectangular antenna apertures are partitioned into domino shaped tiles, arranged according to irregular layouts fully covering the available physical aperture area. The multi-functionality is obtained assigning to each module a single function (i.e., transmission or reception) with the aim of synthesizing a two-way radiation pattern having the lowest possible side-lobe level. Towards this end, an innovative hybrid GA-based method is proposed for the joint optimization of the clustering scheme and the membership of each module to one of the two functions. A simple exemplary procedure is shown regarding the effectiveness of the proposed irregular tiled architecture for multi-function radar systems.

P1.021 Improving Physical Layer Security Technique Based on 4-D Antenna Arrays with Pre-Modulation
Kejin Chen (University of Electronic Science and Technology of China, China); Shi Wen Yang (University of Electronic Science and Technology of china, China); Yike Chen, Shi-Wei Qu and Jun Hu (University of Electronic Science and Technology of China, China)
Four-dimensional (4-D) antenna arrays formed by introducing time as the forth controlling variable are able to be used to regulate the radiation fields in space, time and frequency domains. Thus, 4-D antenna arrays are actually the excellent platform for achieving physical layer secure transmission. However, traditional direction modulation technique of 4-D antenna arrays always inevitably leads to higher side-lobe level of radiation pattern or less randomness. Regarding to the problem, this paper proposed a physical layer secure transmission technique based on 4-D antenna arrays, which combines the advantages of traditional phased arrays, and 4-D arrays for improving the physical layer security in wireless networks. This technique is able to reduce the radiated power at side-lobe region by optimizing the time sequences. Moreover, the signal distortion caused by time modulation can be compensated in the desired direction by pre-modulating transmitted signals.

P1.022 On the Use of Symmetry for Shaped-Beam Antennas Installed onto 8-U Cubesat
Eduardo Yoshimoto and Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil)
This work describes the application of symmetry schemes and the Firefly Algorithm (FA) for the optimization of planar antenna arrays. The method is applied to non-uniformly spaced arrays composed of isotropic antennas operating in S-Band (2.26 GHz) and installed onto an 8-U Cubesat. In order to demonstrate the potential of this technique, radiation patterns with surfix distribution were synthesized, so as to allow illuminating the Earth surface with uniform power density. Good agreement with the desired model has been obtained.

P1.023 Design of TDCA Avoiding Half-wave Length Limitation Using PC
Seoungkim Kim (Seoul National University, Korea (South))
Low-profile antenna arrays are important in many defense and commercial communication systems. Although tightly-coupled dipole arrays (TDCA) have several advantages, their bandwidth is limited by their ground plane. The use of resistive frequency-selective surfaces to overcome this limitation generates omic losses which then deteriorate the radiation efficiency of the array antenna. In this paper, we propose a new TDCA with no omic loss. The proposed array employs a polarizer converter to overcome bandwidth limitation when antenna height is half the wavelength (λ). The impedance bandwidth for VSWR < 3 covers 0.43-8.06 GHz to broadband radiation (18.7%), and antenna height is 0.07 λ at the lowest operating frequency.

P1.024 Optimization of Pencil Beams with Constrained Dynamic Range Maja Jurisic Bellotti and Maden Vucic (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)
The synthesis of array patterns with reduced dynamic range ratio (DRR) of excitation coefficients is important because it enables better control of mutual coupling between antennas and simplifies the design of the feeding networks. In this paper, a method for global optimization of linear pencil beams with constrained DRR is presented. The optimization problem is formulated such that the fabricated antenna is a given beamformer and DRR. The problem is solved by using branch and cut algorithm. The proposed method supports positive and negative coefficients including the values of 1 and 1. The design is fast, enabling interactive experimenting with various numbers of antenna elements and DRRs.

P1.025 New Hexagonal CORPS-BFN for Multibeam Antenna Applications
Carlos Bueno-Quil (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Antonio Montesano (AIRBUS DS, Spain); Hiego Edera (Universidad Publica de Navarra & Institute of Smart Cities, Universidad Publica de Navarra, Spain); JuanCarlos Intarte (Public University of Navarra & Antenna Group, Spain); Carlos del-Rio (Universidad Publica de Navarra & Institute of Smart Cities, Spain)
This work presents a new topology of a Coherently Radiating Periodic Structure - Beam Forming Network (CORPS-BFN) and its application for multibeam systems. A unit cell, consisting of a transition from a coaxial input to an intersection of three striplines with an angular span of 120 degrees, is proposed and analysed. A periodic replication of the cell gives rise to a uniform layer, allowing a proper matching of the ports of the network. Stacked layers allow in-phase propagation and distribution of the energy through the structure, increasing the number of output ports with each layer.

P1.026 Window-to-Polynomial Transform and its Application in Antenna Array Design
Goran Molnar and Marko Matijasevic (Ercisson Nikola Tesla d. i. Research and Development Centre, Croatia)
Windowing is a common method in signal analysis and in digital and spatial filter design. In many cases, adjustable windows are preferable since they offer a tradeoff between requirements, usually side-lobe level and mainlobe width. In this paper, we present a straightforward method for the design of windows with prescribed side-lobe level or mainlobe width. The method is based on the transform of a given window into the polynomial window, thus enabling the uniform adjustment of the polynomial approximation in the windows design. Consequently, the method introduces an additional degree of freedom in the optimization process. The features of the method are illustrated with the design of linear antenna arrays having low dynamic range ratio and high beam efficiency. In particular, the adjustment of Taylor-kaiser arrays, the design of arrays with minimum dynamic range ratio based on the transformed Gaussian windows, and the combined array design incorporating rectangular and Gaussian window.

P1.027 Design of a Dual-Circularly-Polarized Stacked Patch Antenna for SOTM Application at Ka-band
Salvatore Liberto and George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Andrew Christie (Soofant Technologies Limited, United Kingdom (Great Britain))
A dual-circularly-polarized stacked patch antenna subarray block for satellite on the move (SOTM) applications at Ka-band is presented. The proposed multilayer antenna is designed for the downlink band operating in the region of 18 to 20 GHz with compliant scan performance up to 45° in both E- and H-planes. The subarray includes a highly integrated miniaturized 90° hybrid such that the antenna can operate in switchable circular polarization. It also includes an integrated power splitting radiation pattern. The antenna element size is 0.8 mm x 0.8 mm x 2 mm and achieves an impedance bandwidth and circular polarization bandwidth (3-dB axial ratio) of 2 GHz (18 - 20 GHz). Index Terms: Dual-Circularly-polarized stacked patch, phased array, SOTM, surface wave, highly-integrated, HIP, Branch Line Coupler, Phased Array.

P1.028 Reflectarray Antenna Changing Beam Direction by Polarization
Mitsuo Fukuya and Shigeru Makino (Kanazawa Institute of Technology, Japan); Michio Takawaki and Hirotsuru Nakajima (Mitsubishi Electric Corporation, Japan)
In this report, the design of an element to realise a reflectarray, which emits beams in different directions, is discussed. The emission in different directions depends on the polarization, radiation pattern, and gain when the element is applied to a mirror surface. As for the elements, independent phase control is realised by separating the elements into two layers for each polarization, and a gradual phase change is obtained by varying the element length of the three line sections for each polarization. The difference from the desired angle was 0.1 ° for the H polarisation and 0.3 ° for the V polarisation.

P1.029 Compact and Modular Ka-Band Front-end Concept for SATCOM and 5G
Winfred Simon (ELEDIA Research Center, Italy); Johann W Odendaal (IMST & Antennas & EM Modelling, South Africa); Cecile Jung-Kubiak (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento, Italy); Maria Alonso-delPino (AIRBUS DS, Spain); Antonio Montesano (IMST GmbH, Germany);
Heyo Edera (Universidad Publica de Navarra & Institute of Smart Cities, Spain); JuanCarlos Intarte (Public University of Navarra & Antenna Group, Spain); Carlos del-Rio (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Johann W Odendaal (IMST & Antennas & EM Modelling, South Africa); Cecile Jung-Kubiak (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento, Italy); Maria Alonso-delPino (AIRBUS DS, Spain); Antonio Montesano (IMST GmbH, Germany);
Heyo Edera (Universidad Publica de Navarra & Institute of Smart Cities, Spain); JuanCarlos Intarte (Public University of Navarra & Antenna Group, Spain); Carlos del-Rio (Universidad Publica de Navarra & Institute of Smart Cities, Spain)
This work describes the application of symmetry schemes and the Firefly Algorithm (FA) for the optimization of planar antenna arrays. The method is applied to non-uniformly spaced arrays composed of isotropic antennas operating in S-Band (2.26 GHz) and installed onto an 8-U CubeSat. In order to demonstrate the potential of this technique, radiation patterns with surfix distribution were synthesized, so as to allow illuminating the Earth surface with uniform power density. Good agreement with the desired model has been obtained.

P1.030 Exploiting Real Field Patterns into the Multiplicity of Solutions for Linear Array Pattern Synthesis: Bandwidth Studies
Aaron A Salas-Sanchez (Heriot-Watt University, Italy & University of Santiago de Compostela, Spain); Paolo Rocca (University of Trento, Italy); Juan Carlos Intarte (Public University of Navarra & Institute of Smart Cities, Spain)
On the basis of equipped linear array synthesis, bandwidth studies of performance for different type of distributions were developed in this communication. Antenna array pattern quality parameters such as maximum Directivity, Half-Power Beamwidth, Side-Lobe Level and ripple level were evaluated. Also, active impedance terms were studied maximum absolute value, maximum real part, and maximum value of edge and central elements. To develop all these studies, some tested elements such as - which manage different lengths of the elements- were calculated by means of standard formalism. The key innovation of these studies is the inclusion of pure real pattern distributions into the discussion about bandwidth performance. Accordingly, the multiplicity of equivalent pure-real and complex pattern distributions in presence and absence of ground plane have been analysed.

P1.031 Optimized Polarization for Rotationally Tiled, Wideband, Dual-Polarized Vivaldi Arrays
Elizabeth Reike, Johann W Odendaal and Johan Joubert (University of Pretoria, South Africa)
Gating lobe mitigation was achieved for planar, wideband dual-polarized Vivaldi arrays through the rotation and translation of equilateral pentagonally shaped subarrays that form an approximately circular array. The subarray outlines can be adjusted in order to included fewer elements per subarray, but this will result in less grating lobes reduction. By using dual-polarized elements optimized polarization in the main beam can be achieved. The array patterns were determined with measured and simulated single element patterns of the dual-polarized Vivaldi element. The mutual coupling between the elements in the array was shown to be negligible.

P1.032 On the Development of a Scanning Lens Phased Array at 550GHz
Nuria Llombart and Sjepid Bosma (Deft University of Technology, The Netherlands); Maria Alonso-delPino (Jet Propulsion Laboratory, USA); Cecile Jung-Kubiak (NASA-JPL, Caltech, USA)
A reverse coupled self-diplexing feed-system operating in the extended C-band is addressed in this paper. Strictly speaking, a self-diplexing feed-system is one in which the input signal is simultaneously radiated in two spatially distinct beams, differing by a 180° phase shift. This requires the effective negative reflection of the feed in the external environment to be achieved by the reflector system. The presented antenna is the first one of its kind operating in the C-band. The design, validated through the measurement over a flight H/W, demonstrates the validity of the solution, 

Rodolfo Ravanelli

dB relative to the fundamental TE11 mode, thereby achieving pure-mode excitation over a 8.5:1 bandwidth. The impedance matching of these antennas is not an easy task, as the design of the feed is strongly related to the nature of the supported modes. The quadraxial feed presented in this paper presents an ideal candidate for the integration with differential techniques. The quadraxial feed is also preferable over the conventional diplexing solutions in terms of bandwidth and isolation, as it provides a better performance in terms of bandwidth and isolation. The quadraxial feed is also preferable over the conventional diplexing solutions in terms of bandwidth and isolation, as it provides a better performance in terms of bandwidth and isolation. The quadraxial feed is also preferable over the conventional diplexing solutions in terms of bandwidth and isolation, as it provides a better performance in terms of bandwidth and isolation.

This paper firstly describes the global architecture of a complete transceiver working from 22.5GHz to 27GHz devised to be adapted to a large variety of frequency bands. From the corrugated horn to the diplexer, the choosing of their architecture is justified and their main simulated figures of merit are shown.

A closed formula that well approximates the magnification factor of centered dual reflector ring focus imaging systems is proposed. Numerical verifications carried out on specific optics geometries provide a good correlation to the analytical formula.

Numerical verifications carried out on specific optics geometries provide a good correlation to the analytical formula. This paper presents a novel methodology for the optimization of antenna arrays. The proposed methodology is based on the use of an advanced optimization algorithm, which is able to efficiently search for the best possible configuration of the antenna array. The results obtained confirm the effectiveness of the proposed approach and highlight its potential for future applications.

When contaminated with an Additive White Gaussian Noise (AWGN). The work presented here has implications of future studies for optimization and real-world application where SNR environment is noisy while requiring accurate DOA estimation.

particular, each plasma bar includes not only the plasma material, but also the glass envelope and the metallic electrodes used to confine and generate the plasma respectively.

The modal approach was used to maximize the directivity of the line dipole array with a perfect electric conductor ground plane. The directivity was maximized for the direction perpendicular to the ground in which this array can produce maximal directivity from all directions by a proper excitation. The modal approach was also connected with the optimization of geometrical parameters of the array to obtain not only optimal excitation currents for the array with fixed geometry but also optimal geometry of the array. It was observed that, thanks to the presence of the ground, the currents are equivalent and can be set to be real.

A dual horn antenna with low sidelobes and high gain was designed and simulated. The antenna is matched to SWR = 1.8 in the frequency range 6 - 9 GHz. The height of the antenna is 85.5 mm, the directivity is between 15.8 to 18.6 dBi, and the side-lobe level ranges are between -26.9 to -18.5 dBi in the E-plane and between -36.4 to - 21.7 dB in the H-plane. It is shown that the directivity of the proposed antenna is higher by 4.7 dB than the directivity of a conventional horn having similar side-lobe level in the E-plane and main lobe, in the center frequency.

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Poster1-A19: Reflectarrays and Transmitarrays
Antennas
Room: Exhibition Hall

P1.046 Full-wave Scattering from Reflector Antennas on Electrically Large Platforms Using low-Memory Computers
Oscar Borries, Peter Demeyer and Erik Jergensen (TIFR, Denmark)

We consider the use of full-wave integral equation techniques on scattering problems involving electrically large structures, and consider how an implementation of such techniques could use an inexpensive solid-state drive (SSD) rather than costly random access memory (RAM). We begin by showing how a Multi-Level Fast Multipole Method (MLFMM) code based on Higher-Order (HO) basis functions has fundamental properties that make it feasible to use disk storage for the less frequently used algorithm data. Then, we show how the use of the SSD allows us to solve larger problems than the RAM of the computing platform makes room for. Finally we consider how this implementation has only a modest impact on the computational time, particularly when compared to the reduction in financial cost of SSD storage rather than RAM.

P1.047 Broadband Beam-Steering with Focused Connected Arrays in Quasioptical Systems
Marc Le Roy (SRON, The Netherlands), Daniele Cavallo (Delft University of Technology, The Netherlands)

This work presents an effective array for multi-band reflector antenna systems that has two different configurations using a resonant element formed by crossed rings with tuning stubs. The case study presented shows the design of a symmetrical cell using two resonant elements in both faces of the dichroic cell and the design of a nonsymmetrical cell using one resonant element in one face of the cell and a single ring in the other face. These two configuration allows performing different topologies of dual-band feeds.

P1.049 Contingency Mitigation Aspects for Reflector Based Satellite SAR Systems
Filippo Concaro (Beihang University, China); Markus Helfenstein, Moin Khayatt, Peter Demeyer, Peter Roelse, Petr Kellnhofer, Peter Karpowiz, Jens Reimann, Fabio Pelorossi, Raaffat Lababidi, Axel Murk, Luiz Perregrini, Luc Luik (European Space Agency, Germany, The Netherlands, Italy); Jose A. Encinar (Universidad Politécnica de Madrid, Spain); Paul T. Meister, Frank K. Kreimeyer (The Aerospace Corporation, USA); Jens Reimann (German Aerospace Center (DLR), Germany)

Our work focuses on the impact of a potential Transmit-Receive Module (TRM) failure on the transmit pattern. The TRM is a critical component of a SAR satellite system, and its failure could result in a significant degradation of the system's performance. To address this issue, we propose a contingency mitigation approach that allows the system to continue operating with acceptable performance degradation.

P1.050 Design and Measurement of Possible Wide-band 67-116 GHz ALMA Vacuum Window Anti-reflection Layers
Peter J. Speirs (University of Bern, Switzerland); Rocio Molina (Universidad de Chile, Chile); Elena Sanz (European Space Agency, The Netherlands); Paul Morsey (European Space Agency, Switzerland); Pavel Yagoubov (European Southern Observatory, Germany); Axel Murk (IAP, Switzerland)

A new broad-band vacuum lens/window design is required for the new Atacama Large Millimeter/submillimeter Array (ALMA) band 2 receivers. To cover 67-116 GHz a suitable antireflection coating (ARC) is needed. This paper presents the optimization of a candidate ARC design in ultrahigh molecular weight polyethylene (UHMWPE), alongside simulations and measurements of candidate designs in silicium. Machined triangular grooves are used as the ARC for the UHMWPE candidates, and stacked cuboids for the silicon/candidate design.

P1.051 Electromagnetic Analysis of the ngVLA Reference Design Antenna
Sivarsikan Srikhanth (National Radio Astronomy Observatory & Associated Universities Incorporated, USA)

This paper presents computed efficiency, efficiency loss and increase in crosspolarisation due to feed positioning errors on the Next-Generation Very Large Array antenna. The rationale behind the choice of configuration of the antenna is explained. The design of the proposed feed is shown.

P1.052 Compact Quasi-Optical Power Combiner with Single Shaped Reflector
Dong Xia and Liao Ma (Beihang University, China); Ming Jin (Beijing University of Chemical Technology, China); Ming Bai (Beihang University, China)

In this paper, a compact and efficient quasi-optical power combiner configuration is presented. A single shaped reflector is utilized to direct the radiated beam from the planar feedhorn antenna array with arbitrary elements into single output beam. An efficient shaping technique based on reflector Poynting vector tracing is employed to optimize the reflector, which shows obvious advantages over existing iterative wave-front shaping approaches. For validation, two shaped reflectors designed for a 3+2 and a 5+4 feedhorn array are designed. Satisfying power distribution results are obtained through full-wave electromagnetic simulation.

P1.053 4-40 GHz In-Phase/180° Out-of-Phase Power Dividers with Enhanced Isolation
Hadi Haji (Lab-STICC/ENSTA Bretagne, France); Marc Le Roy (Lab-STICC, France); Rasaf Lababidi (Ensta Brest, France); Denis Le Jeune (ENSTA Bretagne, France); Andre Perrenec (Lab-STICC, France)

This paper demonstrates a simple topology to implement ultra-wideband in-phase and 180° out-of-phase power dividers which will be dedicated for ultra-wideband frontends and balanced antennas systems that require a decent amount of isolation between ports. Both power dividers are formed of two couples of microstrip-to-elliptic transitions terminated with radial stubs and then cascaded with a multisection Wilkinson power divider. A parametric study of the microstrip-to-elliptic transition is performed to identify the main parameter’s influence on its frequency response, followed by a full-wave optimization. Both power dividers are designed on RO4003 substrate and both have the same size of 22×38 mm2. Simulation results show that the power dividers can operate between 4 and 40 GHz with less than 6 dB insertion loss and with small amplitude and phase imbalances between output ports. And most importantly, both devices have at least 40 dB of isolation between output ports over the entire bandwidth.

P1.054 Upgrade to the K-Band Uplink Channel for the ESA Deep Space Antennas: Analysis of the Optics and Preliminary Dichroic Mirror Design
Matteo Menchetti (University of Pavia, Italy); Filippo Concaro (European Space Agency, Germany); Fabio Pelorossi (ESOC, ESA, Germany); Luca Perregrini and Marco Pasian (University of Pavia, Italy)

Not available

P1.055 A Millimeter-Wave Low-Profile and Metal-Only Transmitarray Antennas at 28 GHz
Seyedeh Zahra Mousavi (Institut National de la Recherche Scientifique (INRS), Canada); Eyed Ramazanov, Tulu (Electrical and Computer Engineering Faculty, Senman University, Iran); Tayeb A. Denidni (INRS-EMT, Canada)

We present an ultra-efficient transmitarray antenna that utilizes novel in-phase and out-of-phase elements in a single design. The antenna is designed to operate at 28 GHz with a 3-dB beamwidth of 65 degrees and an efficiency of 15%. The antenna is fabricated on a thin metal substrate and achieves a low profile of 0.14λdd. The proposed transmitarray antenna is compared to traditional phased arrays and demonstrates superior performance in terms of efficiency and beamforming capability.

P1.056 Dual-Polarized Dual-Frequency Ka-band Transmitarray Lens
Enrique G. Plaza and Germán León (Universidad de Oviedo, Spain); Susana Loredes and Lucas Fernando Herranz (University of Oviedo, Spain)

In this contribution, a new dual-frequency unit cell for transmitarray is presented. This cell is based on a rectangular structure consisting of 4-stacked rectangular patches coupled 2 by 2 using a cross slot. One of the polarizations is optimized to be transparent at 28 GHz, and the perpendicular one at 38 GHz. The cell provides a phase delay up to 300 ns.
degrees for each polarization at both frequencies. Furthermore, it allows to develop different radiation patterns for each polarization at both frequencies. Moreover, a conventional terminal chassis only offers one resonant mode below 1 GHz, complicating multi-antenna design. Recently, it has been shown that the chassis can be modified to offer multiple resonant modes. In this work, we propose dual-feed antenna ports to improve selective feeding of the resonant modes of an existing two-port MIMO terminal antenna below 1 GHz. Simulation results reveal significantly enhanced bandwidths of 30% and 15% for the two ports, as well as high isolation of over 32 dB.

Multiple-input multiple-output (MIMO) is a mature technology in modern wireless communications. However, it is challenging to implement multi-antennas for MIMO operation in compact mobile terminals, due to high mutual coupling and correlation among closely spaced antenna elements. A novel ultra-wideband reflectarray antenna using connected dipoles for multifunctional systems is proposed in this paper. The reflectarray antenna is composed of an elliptical dipole and a slot line which are printed on a single substrate. Neighboring elements are connected to achieve the ultra-wide bandwidths for both the impedance and the radiation pattern bandwidths simultaneously. By combining the advantages of conventional reflectarray antennas and connected array antennas, the proposed reflectarray antenna achieves ultra-wide bandwidth with greatly reduced feeding complexity and fabrication cost. As a proof of concept, a 354-element reflectarray antenna is designed. The performance of the reflectarray antenna maintains undistorted beams and high antenna gain over a bandwidth of 100%, i.e., from 10 to 20 GHz.

Terahertz (THz)-band (0.1 - 10 THz) communication is envisioned as a key wireless technology to fulfill the demand for high data rates. In this light, the use of new 2D nanomaterials, such as graphene, to design reprogrammable reflectarrays is being explored. This paper presents a novel graphene-metal hybrid reflectarray for THz communications. The reconfigurable element of the reflectarray is designed to have strong reconfigurable properties and high tunability. The trade-offs in the design of the hybrid element are exhaustively studied. The ability to perform continuous dynamic beamforming is demonstrated. Extensive numerical results are provided to show the feasibility of the reflectarray to engineer NLOS paths for communication.

To conclude, this paper highlights the potential of connected dipole antennas for multifunctional wireless communications. The developed prototypes and simulations demonstrate the feasibility of using connected dipoles to achieve wideband and high isolation performance in small devices, enabling new applications in wireless communications and beyond.
**Poster 1-M01: Material Characterisation and Non-destructive Testing**

**Measurements**

Room: Exhibition Hall

1. **P1.068 Non-Gaussian Colored Noise Generation for Wireless Channel Simulation with Particle Swarm Optimizer**
   - **Shaowei Dai** (University of Glasgow, Singapore); **Minghui Li, Qammer H Abbas** and **Muhammad Ali Imran** (University of Glasgow, United Kingdom (Great Britain))

2. **Random Variable with Different Probability Density Function (PDF) and Power Spectral Density (PSD) is a critical component for simulation of different wireless channel fading profile. To get a specific PSD for simulation of different multi-path scenario, the usual method is to pass a white noise through a filter with the required shape. But the filtering process will change the random variable's PDF unless the input noise follows Gaussian Distribution. In this paper, we present a Particle Swarm Optimization (PSO) based method to generate Non-Gaussian noise by a pre-distortion filter and Inverse Transform Sampling (ITS) that meets both the requirement of PSD and PDF is described. As the solution is based on filtering, after the filter weight is found using PSO, the simulation can be carried out in a real-time manner compared to block-based methods. The numerical simulation confirms its effectiveness.**

3. **P1.069 Dynamic Short-Range Sensing Approach Using MIMO Radar for Brain Activities Monitoring**
   - **Mohammad Ojajobi** (University of Limoges/CNRS, France); **Stéphane Bille** (XLIM UMR 7252 Université de Limoges/CNRS, France)

   - **This paper presents a new concept of functional microwave imaging using m-sequence multiple-input multiple-output (MIMO) radar as a non-invasive application of functional brain imaging. The underlying hypothesis is that, if we can detect local changes in blood volume inside the brain precisely enough, we can infer which parts of the brain are activated when performing various tasks. In this context, we present a method to participate in such tasks and localise brain activity by using MIMO radar.**

4. **The radiation characteristics of an object are represented by the coefficients vector of a Wigner-D expansion. For most truncate processes, the SMCs of antennas calculated from measurement data are used to simulate compressed sensing. In this work, the SMCs of two antennas calculated from measurement data are used to simulate compressed sensing. In this work, the SMCs of two antennas calculated from measurement data are used to simulate compressed sensing. In this work, the SMCs of two antennas calculated from measurement data are used to simulate compressed sensing. In this work, the SMCs of two antennas calculated from measurement data are used to simulate compressed sensing.**

**Poster 1-M02: Optimalpropagation conditions can only be achieved by sufficient knowledge of the frequency- and angle-dependent scattering properties of technical systems. At oblique illumination angles based on a combination of the established RCS- and NRL-arch methods is proposed.**

**Poster 1-M03: Near-field, Far-field, Compact and RCS Range Measurement Techniques**

**Measurements**

Room: Exhibition Hall

1. **P1.070 A Three-Antenna Compact Micro-Diversity Module for Automotive Satellite Radio Reception**
   - **Simon Senega and Sebastian Matthie** (Universität der Bundeswehr München, Germany); **Stefan Lindenmeier** (Universität der Bundeswehr München, Germany)

   - A new compact micro-diversity module is presented which integrates three antennas elements with a single-phase diversity circuit for satellite radio services at 2.3 GHz. The module has a size of 55 mm x 55 mm x 26 mm, 17 g, and 79.6 x 26 mm with a small additional ground plane. A ring antenna structure working in different modes are combined with a monopole with roof capacitance in the center. The new module is tested in a strong fading environment near Detroit (USA) showing a significant reduction of audio noises compared to a single antenna. On the dashboard as well as on the roof edge with a strong tilting angle, the micro-diversity achieves acceptable mute ratios while a single antenna would fail. The diversity module offers new mounting positions as well as new regions of reception due to additional gain and 3rd antenna diversity in fading environments.

2. **P1.071 Maximum Ratio Transmission for OAM Mode Multiplexing Using Multiple UCAs**
   - **Ayano Yamamoto, Toshikio Nishimura and Takeo Ohgane** (Hokkaido University, Japan); **Tomoya Tandai and Daiuske Uchida** (Toshiba Corporation, Japan)

   - In recent years, a new spatial multiplexing transmission scheme using the orthogonality of OAM modes has attracted attention with growth of the millimeter wave and 5G technology. A UCA is one of the candidates for generating multiple OAM modes. However, each mode has different characteristics, and the maximum ratio transmission method using multiple UCAs at the transmitter side for improving the quality and stability of each OAM mode. In this paper, we propose a new spatial multiplexing transmission method using multiple UCAs at the transmitter side for improving the quality and stability of each OAM mode.

3. **P1.074 Off-the-shelf Optical Antenna Feed System**
   - **Christopher G Hynes** and **Rodney Vaughan** (Simon Fraser University, Canada)

   - An optical antenna feed system reduces or eliminates conducting feed cable effects and provides much more accurate antenna far-field pattern measurements. Optical feed systems can be expensive and require custom design. We present a simple optical feed system for antenna pattern measurement systems, using low-cost off-the-shelf components. We describe the performance-limiting factors of the optical system, and compare measurement results from an MVG Stargate 64 using a standard coaxial cable feed system with those from the optical feed system. The pattern accuracy improvement is significant, demonstrating that this type of system offers a simple and low-cost upgrade for antenna measurements.

4. **P1.075 Height Profiles of Typical Automotive Landmarks Using Tomographic Compact-Range Measurements**
   - **Roland Moch and Dirk Heberling** (RWTH Aachen University, Germany)

   - Height estimation of radar targets is of particular importance for self-localization and autonomous driving. It is an essential part of the risk assessment and makes it possible to assess whether certain obstacles can be traversed or an evasive maneuver must be initiated. In order to evaluate such situations as reliably as possible, high-precision profiles are placed on the classification of radar targets. New possibilities are opened up by determining not only the total height, but also a density distribution resolved by the height. To prove the advantages, typical landmarks, namely two signs and a guide post, were measured in a compact antenna test range in the 0.6-0.8 meter frequency range. It is shown that besides the total height also the most important features of the landmarks can be identified in the height profile. This improves the overall perception of the environment as well as the detection of additional indicators for self-localization.

5. **P1.076 A Novel Indoor and Outdoor Drone-Based Antenna and RCS Measurement Facility**
   - **Pierre Massaloux** (CESTA, France)

   - Indoor RCS measurement facilities are usually dedicated to the characterization of only one or two axes and cut one end of the full spherical RCS target. In order to perform more complete characterizations, a novel experimental layout has been developed at CEA. The use of multi-copter UAVs for antenna or RCS measurements opens up new possibilities in indoor and outdoor measurements. Industrial purpose multi-copter UAVs provide an excellent ground for research and development activities and for proof-of-concept measurements. This paper presents the new measurement system and the different results obtained on RCS measurements.

6. **P1.077 On the Influence of the Transformation Matrix in Compressed Spherical Near-Field Measurements**
   - **Cosme Cifuentes** and **Dirk Heberling** (RWTH Aachen University, Germany)

   - The radiation characteristics of an object are represented by the coefficients vector of a Wigner-D expansion. For most physical antennas and with appropriate choice of the expansion's center, the coefficients vector, also called the Spherical Mode Coefficients (SMCs) vector, is proven sparse. The sparsity of the vector allows the undersampling of the SMCs vector by application of l1-minimization methods. However, the reconstructed results, for equivalent analytical formulations of the problem, change depending on the used transformation matrix. In this work, the SMCs of two antennas calculated from measurement data are used to simulate compressed sensing using a modified version of the l1-minimization method.
**Poster 1-M04: Data Acquisition, Imaging Algorithms and Processing Methods**

**Measurements**

*Room: Exhibition Hall*

**P1.078 An Improved Receiver for Harmonic Motion Microwave Doppler Imaging**

*Damlı Aptekin Soydan and Umit Ingin* (Middle East Technical University, Turkey); *Can Baris Top (Aselsan Inc., Turkey); Nezvat Gençer* (Middle East Technical University, Turkey)

Harmonic motion microwave Doppler imaging is a novel imaging method that combines focused ultrasonic and radar techniques to obtain data based on mechanical and electrical properties of the tissue. In previous experimental studies, scanning time was high, the signal-to-noise ratio was low, and the multiplexing ratio was limited. In this study, we improved the receiver system with a low noise amplifier which led to an increase in signal-to-noise ratio. A breast phantom containing a cylindrical tumor of size 5 mm × 3 mm inside a homogenous fat was built. An area of 40 mm × 40 mm was scanned in 45 minutes which is 50 % of the previous scanning time. The vibration frequencies which are higher than 35 Hz are employed for the first time to create 2D images. The increase in the vibration frequency resulted in the improvement of resolution; however, the signal-to-noise ratio of the images deteriorated.

**P1.079 Interpretation of the Physical Layer Measurements of Smartphones as Measures of Exposure to Electromagnetic Fields**

*Sascha Schell, Thomas Kopacz and Dirk Heberling* (RWTH Aachen University, Germany)

The monitoring of exposure to electromagnetic fields emitted by mobile networks is necessary for a responsible operation of these networks. A possible alternative to classical exposure assessment methods is a time-continuous and area-wide exposure monitoring. This work demonstrates the feasibility of using smartphones as a cost-effective and non-invasive approach to measure exposure in urban areas. This paper presents the interpretation of signal strength indicators measured by mobile phones in LTE networks and explores how instantaneous or maximum exposure is related to them. Long-term measurements of a smartphone and a field strength meter are presented in comparison, which show the time-dependent variation of the utilization of the cell. In addition, it is demonstrated how the measurement data of the smartphone have to be adjusted to the measured characteristics of the measured area in order to correspond correctly with the exposure. The results show that RSI is suitable for tracking variations in exposure over the day.

**Poster 1-P02: Propagation Modelling and Simulation**

**Propagation**

*Room: Exhibition Hall*

**P1.081 Wall Parameters Sensitivity for Indoor Radio Waves Attenuation**

*Eran Greenberg (RAFAEL, Israel); Gil Segal (RAFAEL, Israel)*

In this contribution we investigate the propagation through walls and the loss sensitivity to a variety of parameters including permittivity, conductivity, wall width, incident field angle, frequency and polarization. The wall is modeled as a finite depth homogeneous slab and its influence is calculated using the effective Fresnel transmission coefficient. A statistical investigation reveals that as increasing the wall conductivity, the loss is increased, the general influence of the frequency and permittivity is almost negligible, and the loss for perpendicular polarization is higher than for parallel polarization. Sensitivity analysis shows that the incidence angle, conductivity and wall width are the most important medium parameters and the knowledge of only these input variables values is sufficient to estimate the loss variance.

**P1.082 Assessment of sub-TW Mesh Backhaul Capabilities from Realistic Modelling at the PHY Layer**

*Grégoire Gougeon, Yoann Corre and Mohamed Zahir Adam* (SIRADEL, France); *Simon Bicaís and Jean-Baptiste Doné* (CEA, France)

Spatially distributed 5G RAN is a key promising investigation domain to offer future wireless networks with performance beyond 5G: 20 GHz data rate or sub-ms latency. As the propagation is strongly constrained at those frequencies, the short-range connectivity is a relevant target application. However, the huge bandwidth available can also serve the backhaul network in the perspective of ultra-dense deployments, and massive data flows across streams. This paper investigates the feasibility and characteristics of using the Sub-TW mesh backhauling either in the streets or inside a large venue. The study relies on the highly realistic simulation of the physical layer performance, based on detailed geographical representation, ray-based propagation modelling, RF phase noise impairment, and a new robust pol濁 modulation. It is shown that each link of a dense mesh backhaul network can reliably deliver several Gbit/s per 1 GHz carrier bandwidth.

**P1.083 Joint Statistical Modeling of Received Power, Mean Delay, and Delay Spread for Indoor Wideband Radio Channels**

*Ayush Bharti* (Aalborg University, Denmark); *Laurent Clavier* (Institut Mines-Telecom, Telecom Lille & IEMN / IIRICA, France); *Troels Pedersen* (Aalborg University, Denmark)

We propose a joint statistical model for the received power, mean delay, and rms delay spread, which are derived from the temporal moments of the radio channel responses. We begin by analyzing indoor wideband measurements from two different data sets. It appears that the temporal moments are strongly correlated random variables with skewed marginals. Based on the observations, we propose a multivariate log-normal model for the temporal moments, and validate it using the experimental data sets. The proposed model is found to be flexible, as it fits different data sets well. The model can be used to jointly simulate the received power, mean delay, and rms delay spread. We conclude that independent fitting and simulation of these statistical properties is insufficient in capturing the dependencies we observe in the data.

**P1.084 A Bandwidth Scalable Millimetre Wave Over-The-Air Test System with Low Complexity**

*Erich Zöchmann (PIDSO - Propagation Ideas & Solutions GmbH); Terje Mathiesen (Norwegian University of Science and Technology, Norway); Thomas Blazek and Herbert Groll (TU Wien, Austria); Golisa Ghaasia (Norwegian University of Science and Technology, Norway)*

In this work, we have demonstrated a novel testbed for over-the-air measurements of mmWave waveforms. We have extended the frequency capabilities of a bandwidth channel simulator which is capable of simulating non-stationary channels, to higher frequencies. To assure that the propagation between devices-under-test and the RF-frontend of the emulator is only a line-of-sight link, we have isolated the devices-under-test in two anechoic chambers. We have measured channels which were acquired during a vehicular mmWave measurement campaign conducted in Vienna in 2018.

**P1.085 Achievable Synchronisation Gain in Uncalibrated Large Scale Antenna Systems**

*Jens Abraham and Torbjorn Ekman* (Norwegian University of Science and Technology, Norway)

Large scale antenna systems are used to exploit spatial-multiplexing gains in massive MIMO systems. To realise those gains, channel state information has to be acquired at a base station. However, an initial control channel has to be provided to synchronize time and frequency at the user. This control channel should be uncoupled to deeply cover the base stations operational area and can therefore not exploit the coherent array gain without additional strategies. Beam sweeping has been proposed to provide increased spatial coverage. Its performance for large scale antenna systems in Rayleigh and Ricean fading environments is evaluated. Even an orthogonal basis of antenna weights for full spatial coverage can not provide the full array gain. The results quantify the gap between achievable synchronisation and full array gain for uncorrelated antennas. Closed form solutions for the distribution of the gain gap under Rayleigh fading conditions are derived.

**P1.086 Elastic Microwave Propagation Channel Modelling for ITU Condition Monitoring of Subsea O&G Pipelines**

*Knut Grythe (SINTEF, Norway); Irene Jensen (SINTEF ICT, Norway); Ole Knudsen (SINTEF Industry, Norway)*

A real-time situation awareness of an O&G pipeline enhances the response time in case of an oil spill. With the help of a multi-stage research framework, we have established a two-way communication system which is used as a backup system for monitoring pipelines. We show that our system can be used to monitor pipelines in harsh environments such as water and cold regions. Our system is based on a fiber optic technology which is used to transmit data from the pipeline to a receiver located onshore. The data is then processed and transmitted to a control center where it is used to make decisions about the status of the pipeline. Our system has been successfully tested in the field and has shown to be reliable and robust. We conclude that our system can be used to monitor pipelines in harsh environments and that it is suitable for use in real-world applications.

**P1.087 Combined Antenna-Channel Characterization for Wireless Communication from Horse Hoof to Base Station**

*Jasper Goethals (Ghent University & IMEC, Belgium); Gunter Vermeerden (Ghent University, Belgium); Denys Nikolayev (Institut d’Électronique et de Télécommunications de Rennes (UMR CNRS 6164), France); Margot Denuyck (Ghent University - IMEC, Belgium); Luc Martens (Ghent University & IMEC, Belgium)*

This paper proposes a joint statistical model for the received power, mean delay, and rms delay spread, which are derived from the temporal moments of the radio channel responses. We begin by analyzing indoor wideband measurements from two different data sets. It appears that the temporal moments are strongly correlated random variables with skewed marginals. Based on the observations, we propose a multivariate log-normal model for the temporal moments, and validate it using the experimental data sets. The proposed model is found to be flexible, as it fits different data sets well. The model can be used to jointly simulate the received power, mean delay, and rms delay spread. We conclude that independent fitting and simulation of these statistical properties is insufficient in capturing the dependencies we observe in the data.

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Possibility of determination of attenuation caused by rain effects is examined here by separating attenuation by wet and dry rain components. Measured attenuation is compared with theoretically predicted values.

Orbital angular momentum (OAM) has attracted considerable attention as a novel solution for ultra-high spectrum efficiency transmission. The OAM multiplexing property offers the potential for increasing the capacity of communication systems. However, the two-ray model cannot be applied to certain scenarios, e.g., streets, valleys, tunnels, etc. In order to enable context-aware environments within the Internet of Things paradigm, distributed transceiver systems capable of providing low-cost, low-latency capabilities are required. Single Input Multiple Output systems provide an adequate solution by enabling non-coherent energy-based detection. Phase distributions play a key role in transceiver design and hence overall system operation. In this work, SIMO operation based on volumetric phase analysis is performed on indoor scenarios, employing deterministic 3D Ray Launching channel estimation. The proposed method enables the estimation of system performance as a function of distributed transceiver location, aiding in network planning and deployment tasks.

In this paper, we present measurements that were conducted at 4.9 GHz and 28 GHz. Based on the measured data, it can be found that the root-mean-square (RMS) delay spread (DS) is well fitted by a lognormal distribution. Besides, the mean RMS DS at 28 GHz is much smaller than that at 4.9 GHz. Compared with 3GPP standard, the mean RMS DS in the indoor industrial scenario is much larger than that in the traditional indoor office scenario. At last, the effects of the TX-RX distance and the TX-RX heights on RMS DS are investigated. By modeling DS as a function of the TX-RX distance, it is found that the in-line-of-sight (LOS) scenario, RMS DS increases linearly with the TX-RX distance. Finally, it is found that in non-line-of-sight (NLOS), the mean RMS DS in the clutter-elevated scenarios is 12% smaller than that in the clutter-embedded scenario.

In this paper, we present a systematic experimental analysis of the effects of roughness onto propagation is also analyzed. The guidelines for optimum antenna positions on humans and robots for safe air/space communications are proposed according to the simulations results.

In this paper, we present results into a long-range detection and monitoring of Electromagnetic (EM) side-channel signals leaked from Internet-of-Things (IoT) and Field Programmable Gate Array (FPGA) devices. Our work shows that operational information and program activities of the IoT and FPGA modules can be gained at distances of more than 25 m in an indoor Line-Of-Sight (LOS) environment, while at about 10 m in an indoor (through the wall) Non-Line-Of-Sight (NLOS) scenario. We provide a propagation model that can be used to predict the received power (and corresponding variation i.e., shadowing gain) of leaked EM side-channel signals at various distances and scenarios. A standard benchmark program built-on penetrates the performance evaluation of ARM-based microprocessors and a microbenchmark SATAV running on an IoT device were detected and monitored remotely in our work.

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Due to the highly metallic nature of the propagation environment, reflections make communication possible in an obstructed Line-of-Sight configuration, but there is no clear distance relationship, which is higher than the free space path loss, whereas the path loss exponent of 1.7 is lower than in free space. The ... realizes high data rate communication in the engine room of a vessel if the Line-of-Sight path is not obstructed.

This paper presents the results of a mmWave channel sounding campaign in a bulk carrier vessel. Using the Terragraph nodes in the engine room and steering control room of the vessel. The path loss at reference distance 1.5 m is 74.6 dB,

Finally we compare the evolution of the dynamic channel in the presence of people at 5.8 GHz and at 60 GHz in the same computer room. The channel propagation measurements provide a statistical characterization for the power loss into a realistic environment.

In this work, we study the dynamic 60 GHz radio propagation channel conducted by measurements in an open-space office. These measurements quantify the effect of natural people movements on the path loss before and during working hours. Thus, it's possible to compare the effect produced by these movements with the static case when the office is empty of people. Measurements were performed using a VNA operating on 2 GHz bandwidth, whereas the path loss exponent of 3.6 is lower than in free space. The obtained results allow to compute successfully the channel path loss, its probability-density function and its cumulative distribution function.

We propose that the proposed 4M system outperforms conventional MDM-MIMO systems. Furthermore, the 4M scheme possesses higher robustness than MDM-MIMO systems in long-range communications.

The beam training technology which can overcome the easily-occluded beam misalignments is required urgently in unmanned aerial vehicles (UAV) based millimeter wave (mmWave) communication systems. In this paper, a novel three-dimensional (3D) beam training strategy for UAV-assisted mmWave communications is proposed. The inverse discrete-space Fourier transform is introduced to construct the training beam with flat-topped characteristic. In addition, the hybrid beamforming (BF) system is taken into account and the greedy geometric (GG) algorithm is adopted to obtain the optimal beam. Numerical simulations are conducted to evaluate the performance and the simulation results demonstrate that our proposed 3D training strategy can provide both precise beams and high training efficiency for the 3D mmWave UAV communications.

In this paper, we present the extensive characterization of the local propagation effects in various environments such as urban, rural, highway or railway environments. The statistical analysis of measurements made in a busy urban environment with a high spatial-resolution of the large scale anemology enables the extraction of weak multipath components (WMPs) as well as MPCs arriving with a long delay.

The ionospheric effects on the ionosphere and radio propagation conditions are discussed. The vertical and oblique Es layers are revealed, their multilayer structure and diffuse F-formations as well as the EsMOF changes and the processes in the ionosphere were qualitatively similar within 400 km distance southward where the reflection point of the mid-latitude radio path lies was revealed.

As an emerging solution for line-of-sight (LOS) wireless communications, recently, mode division multiplexing (MDM) based on orbit angular momentum (OAM) has attracted considerable attention due to its high spectral efficiency (SE). Since the high complexity in OAM-modulations and the request for great radio frequency (RF) chains, the implementation of a modulator at the transmitter is a challenge. In this paper, we have developed a new channel model that models LOS fluctuations as a random variable generated by an ARMA process and make way to the parameter estimation of the LOS model. The random nature of the channel contains a Rician path and can be simulated by introducing variations in angle between reflections. This paper describes a method for generating single-pulse detection probabilities of angle-dependent Rician models in the presence of clutter. As an example, we compare various Weibull clutter models to emphasize the importance of clutter parameters selection.

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Antennas
Room: A2
Chair: Michael Jensen (Brigham Young University, USA)

14:50 CubeSat Antennas: An Amazing Opportunity for Developing Out-of-the-Box Antennas
Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)
CubeSat represents a revolutionary niche in the arena of satellites. Their size and low cost have enabled space missions which seemed impossible with conventional size and cost. A key element in furthering the potential of CubeSat is the development of antenna systems that can meet the data rate and spatial resolution requirements for future space missions. This paper describes and demonstrates that CubeSats provide a unique opportunity for developing state-of-the-art antennas for CubeSat missions.
14:30 Antennas and Over-The-Air Testing for Millimeter-Wave Systems
Gert Pedersen (Aalborg University, Denmark)
Over-the-air (OTA) testing, where radio waves (rather than coaxial cables) are used to connect the device under test (DUT) and testing instruments, has been used to evaluate the true radio performance of antenna systems. OTA testing of single-antenna mobile handsets was proposed at Aalborg University (AAU) around 20 years ago, and has later become international standards. OTA testing for sub-6 GHz LTE multiple-input multiple-output (MIMO) handsets has been developed in recent years, where AAU was deeply involved in research and development of two standardized methods, namely the multi-probe anechoic chamber method and wireless cable method, together with industrial partners. Recently, OTA testing solutions are seen inevitable for more complicated and advanced antenna systems applied in automotive applications and 5G antenna systems. This plenary talk will discuss the history and research activities on OTA testing in recent years in antenna, propagation and millimeter-wave systems (APMS) group at AAU. Furthermore, the group has recently invested heavily in antenna measurement facilities, which include a world-class and unique anechoic chamber for antenna testing. The design and functionality of this anechoic chamber will be detailed in the talk. The APMS group has also been heavily involved in antenna design for millimeter-wave terminals and nano-satellites. Research challenges and recent research highlights on this topic will be addressed as well in the talk.

Tuesday, 17 March 15:30 - 16:10
IS-Tue 1: Invited Speaker Session
Antennas
Room: A2
Chair: A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

15:30 Antenna-in-Package Technology
Yue Ping Zhang (Nanyang Technological University, Singapore)
Antenna-in-package (AiP) technology integrates an antenna or antennas on the same chip with a radio or radio transceiver die (or dies) into a standard surface mount package. AiP technology well balances performance, size, and cost. Hence, it has been widely adopted by chip makers for radios and radars. It is believed that AiP technology will also provide elegant antenna and packaging solutions to the fifth generation cellular networks and beyond operating in the lower millimeter-wave (mmWave) bands. This paper will provide an overview of the development of AiP technology.

Tuesday, 17 March 16:40 - 18:20
T04-A20: Wireless Power Transfer and Inductive Coupling
T04 IoT and M2M / Regular Session / Antennas
Room: A2
Chair: We Lin (University of Technology Sydney, Australia), Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India)

16-40 Efficient Two-layer Loop Array for Selective Magnetic Resonance Wireless Power Transfer
Yonghyun Nam and Jeong Hae Lee (Hongik University, Korea (South))
This paper presents an efficient two-layer planar loop array resonator for selective magnetic resonance wireless power transfer (MR WPT). This two-layer structure provides two important functions with improved efficiency by adjusting the lumped capacitance of each loop: selective MR WPT, the ability of position- and alignment-free with the receiver. The optimal capacitance of each loop can be found using a genetic algorithm (GA). The two-layer array of 2×2 and 4×4 is designed at an operating frequency of 6.78 MHz. This two-layer loop array has improved the measured power transfer efficiency (PTE) by ~10 % at distance of 300 mm, compared with that of the previous single-layer 4×4 loop array.

17:00 Wireless Power Transfer System Design in Reactive Near-Field for Implantable Devices
Tarakeswar Shaw (Indian Institute of Engineering Science and Technology, Shibpur, India); Bappaditya Mandal (Uppsala University, Uppsala, Sweden); Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India); Robin Augustine (Uppsala University, Sweden)
In this paper, a wireless power transfer (WPT) system design for charging the bio-implantable devices in the reactive near-field of the antenna is presented. The proposed system is designed to operate in the industrial, scientific, and medical (ISM) of 2.4-2.48 GHz band. The WPT link is constructed with dual-rotor slot antenna implanted in a single layer skin tissue model. The power receiver is a linear voltage regulator (LVR) with a linear charge pump (LCP). The system is designed to deliver a stable 5 V output at a distance of 10 mm from the transmitter. The proposed system is designed to operate in the reactive near-field and provides high power transfer efficiency for the proposed WPT system.

17:20 Headband Antenna for Wireless Power Transfer to Millimeter-Sized Neural Implants with Minimal Misalignment Effect
Shahbaz Ahmed and Lauri Sydänheimo (Tampere University, Finland); Leena Ukkonen (Tampere University of Technology, Finland)
We present a headband loop antenna for wireless power transfer to multiple-ICDs located in the cranial cavity at the depth of 10 mm from the skin. We characterize the wireless power transfer link in terms of the power gain and the power delivered to the IMD, when maximum SAR compliant transmission power is fed to the headband antenna at the frequency of 5 MHz. We also consider two types of misalignments i.e. lateral and angular, between the IMD antennas and the headband antenna and discuss their impact on the transducer gain, impedance matching and on the power delivered to the IMD.

17:40 Sub-1 GHz Flexible Concealed Rectenna Yarn for High-Efficiency Wireless-Powered Electronic Textiles
Mahmoud Wagih, Alex S Weddell and Stephen Beeby (University of Southampton, United Kingdom (Great Britain))
Electronic textiles and seamlessly integrated flexible wearable electronics are emerging platforms for wearable computing. Batteries and energy harvesters relying on specific materials and transducers are not fully compatible with a textile-based fabrication and mass production. This study proposes a radio frequency energy harvesting rectenna, operating in the sub-1 GHz license-free band, packaged in the form of a textile yarn which can be concealed in standard textile weaves. The textile rectenna is fabricated using thin-riveted copper laminates using photolithography. The rectenna is composed of a 500 millimeter-line coplanar waveguide monopole antenna and a voltage doubler rectifier, with a lumped matching network. The rectenna achieves 63.4% RF-DC efficiency and 8.8 V DC output at 6 and 11 dBm input power, respectively. This is the highest voltage output of a textile wearable rectenna, while maintaining high efficiency down to -30 dBm and a 7 dBm 1-V sensitively.

18:00 A Dual-Polarized Rectenna with High Efficiency at Low Input Power Density
Jun-Hui Ou and Junyu Pan (South China University of Technology, China); Shi-Wei Dong (National Key Laboratory of Space Microwave Technology, China); Xinjun Zhan (South China University of Technology, China)
This paper presents a new 2.45-GHz rectenna with 1×1 dual-polarization for low-power-input microwave power transmission. By utilizing a 45° dual-linearly-polarized antenna element, the rectenna is available for receiving incident power with arbitrary polarization angle, while avoiding 3-dB CP-to-LP polarization loss. In this way, the requirement of the receiving end to the placement angle is greatly liberated. Differential rectifier structure is utilized. The effect of cross-connected load of two branches, which create DC voltage with opposite polarities, are studied. An integrated rectenna design is formed, fabricated and measured. Peak-power conversion efficiency of 74.76% is found at input power density of 100.19 pW/cm² in the measurement. The power conversion efficiency of the rectenna stays higher than 58.4% regardless of the incident angle under the input power density of 63.91 pW/cm².

CS56: Recent Advances on Electronically Steerable Antenna Arrays at mm-Wave Frequencies
T02 Millimetre wave 5G / Convened Session / Antennas
Chair: Claude Oestges (Université Catholique de Louvain, Belgium)
Antennas
Room: A3
16:40 Design of Wideband Wide-Scanning Dual-Polarized Phased Array Covering Simultaneously Both the Ku- and the Ka-Band Frequencies
Alexander J van Katwijk and Andrea Neto (Delft University of Technology, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Daniele Cavallo (Delft University of Technology, The Netherlands)

We present the unit cell design of a wideband wide-scanning phased array operating in both Ku- and Ka-bands, for satellite communication applications. The radiating elements are dual-polarized connected slots loaded with an artificial dielectric superstrate, acting as a wide angle impedance matching (WAIM) structure. The design of the multi-layer artificial dielectric is based on analytical formulas describing the equivalent reactance of each layer, valid for geometries that are not periodic in the vertical direction. This allows to maximize the total number of metal layers composing the artificial dielectric. The predicted matching performance is investigated by means of simulations based on infinite array approximation.

17:00 Towards the Realization of the E-Wall Concept at Mm-Waves
Marzieh Salar Rahimi (KU Leuven, Belgium); Marcel Saurais and Tonny Kamphuis (NXP Semiconductors, The Netherlands); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

The so-called e-wall is a recently introduced concept with the implementation goal of making a flexible and cost-efficient infrastructure for next generation wireless communication systems in indoor environments. This paper is in line with our former paper, discussing the most recent steps toward the realization of the e-wall concept. An active beam-forming array based on the sub-array has been fabricated and successfully measured. In addition, to improve the technical performance an antenna array has been designed to be integrated into the packaging of a four-channel analog beam-former flip-chip.

17:20 Phased Array at Mm-Waves Based on Filter-Integrated Antenna Elements
Dawid Bianco and Christos Kolitsidou (Erissson, Sweden)

This paper presents a broadband phase array antenna based on the integration of a compact combline filter and a broadband wide-impedance-angle dipole antenna. The presented approach can be easily scaled to any other application in the millimeter-wave ranges keeping the low-cost and low-profile of a PCB structure. The methodology is based on a modular approach where the broadband and large-angle antenna is introduced. Then, a multi-layer combline filter is used as the input of the broadband antenna at the array element level. The designed combline filter use cross-coupling to make it more compact and to create a pseudo-elliptical response. Full wave simulations show an outstanding performance compared to the conventional planar filters with an insertion loss of less than 0.6 dB in the transmission band from 23.5 GHz to 25.5 GHz.

17:40 Review of W-band Reconfigurable Reflectarray and Transmitarray Antennas at Tsinghua University
Xiaotian Pan, Fan Yang, Shengheng Xu and Maikun Li (Tsinghua University, China)

This paper reviews the recent research progress on the designs of reconfigurable reflectarray/transmitarray antennas (RRA/RTA) at Tsinghua University. Several antenna designs are presented, including PCB-based RRA, PCB-based RTA, and chip-based RRA. These designs of RRAs/RTAs show promising potential in the W-band fast-beam-steering applications, especially for high-resolution imaging systems.

18:00 Liquid Crystal-based Reconfigurable Metasurface for Beam Scanning at Millimeter Wave Frequencies
Enrica Martini (University of Siena, Italy); Gabriele Minatti (Wave Up S. r. l., Italy); Francesco Caminita (Wave-Up SRL, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Stefano Maci (University of Siena, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

This paper investigates the feasibility of an electronically scanning antenna based on a reconfigurable MTS. MTS reconfigurability is obtained by embedding small capsules filled with liquid crystals in the constituent unit cells. This approach can provide a low-profile solution with the possibility of continuous beam scanning with low bias voltage and power consumption.

CS58: Reconfigurable Antennas for Compact Devices
Room: A3

T04 IoT and M2M / Convened Session / Antennas

48 of 128
16:40 Tag Design for RFID AC Current Sensing System
Inran Uhan (University of Kent, United Kingdom (Great Britain)); Robert J Home (University of Kent, United Kingdom (Great Britain)); Benito Sanchez-Izquierdo and John Batchelor (University of Kent, United Kingdom (Great Britain))
This study describes the development of an RFID system and antenna for real-time ac current sensing of individual appliances in smart homes. The operating principle of the presented tag is based on the tag antenna tuning via a tuning circuit. The auto-tuning chip is embedded to compensate the antenna matching and stores the impedance tuning in the form of a 5-bit sensor code. The tag wirelessly streams the 5-bit sensor code that represents the ac current drawn by the electrical load, to the dedicated RFID reader in the range of 3 m at 868 MHz. The tag device is an energy harvester and a cost-effective ac current sensing solution compared to commercial smart meters in smart power metering systems. The antenna is designed to fit around the housing of the current sensor.

17:00 Design of a Resistant Circularly Polarized Tag Antenna with High Performances in the EU EHF RFID Band
Khodor Jabbawi (IMSNP France); Amal Alfay (IMSNP Aix-Marseille University, France); Matthieu Egels and Philippe Pannier (IMSNP France)
In this study, a novel resistive tag antenna with high performances is proposed. The presented tag consists of two antennas. The first one is an inductive antenna used for matching the imaginary part of the chip impedance at the target frequency. This antenna is coupled with the first one in order to increase the gain and improve the tag performances. The tag antennas are designed to operate in the EU EHF RFID band. The crossed dipole antenna technique is used to achieve the CP in the operating band. Many prototypes have been manufactured, and good agreement between simulations and measurements has been achieved. The band covered for an AP + 3dB is from 669 to 869MHz. The Read Range (RR) of the tag has been measured in a standard anechoic chamber. From the measured results in EU EHF band, the tag has a maximum RR of about 16.25m at 868MHz.

17:20 Effect of Bending on a Textile RFID UHF Tag Antenna
Mohamed El-Bakkali (Abdelmalek Essaâdi University, Morocco); Marc Martinez and Rafael Fernandez-Garcia (Universitat Politècnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain); Otman El-Mabret (Abdelmalek Essaâdi University, Morocco)
In this paper, a textile UHF-RFID Tag antenna at 915 MHz based on a T-match dipole loaded with circular patch on a felt fabric substrate is presented and discussed. In addition, the bending impact on the read range is analyzed by means of full 3D electromagnetic simulations. The bending analysis results indicate that the proposed textile tag can be used under both, concave and convex bending with a reduction of read range lower than 10 % in all cases. These results confirm that the proposed UHF-RFID Tag is a useful design in application where the devices can be deformed, such as wearable applications.

17:40 Performances of a 3.6 GHz Epidermal Loop for Future 5G RFID Communications
Francesco Amato (University of Roma Tor Vergata, Italy); Cecilia Occhialini (University of Roma Tor Vergata & DICIL, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)
This paper explores, through simulations and preliminary experiments, the feasibility of a 5G-RFID loop for a backscattering epidermal sensing architecture integrated within the 5G network. It demonstrates how a 3.6 GHz loop tag could provide the same read distance (one meter) of three-times larger UHF counterparts. The proposed loop is compliant with regulations on electromagnetic exposure and can theoretically achieve data rates up to 0.9 Gbps.

18:00 Monolithic Antenna Array for Epidermal 5G Backscattering Communications
Cecilia Occhialini (University of Roma Tor Vergata & DICIL, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)
5G network is expected to sensibly boost the diffusion of personal area networks for health and wellness monitoring purposes, especially with regard to battery-less devices and backscattering based communications. To overcome the power path-loss, however, high efficiency radiating elements are mandatory, especially for the highest frequencies. Here, the feasibility of adopting monolithic grid antenna arrays directly adhering onto the human skin is investigated. Numerical parametric analysis are performed to evaluate the backscattering link budget of the proposed epidermal devices and to derive their upper-bound performances. Early results demonstrate the rationality of the approach and the possibility to reach communication distances ranging from 20cm to 1m in case of sub-grid structures are adopted.
16:40 Active Antenna Architectures for Enhanced 5G System Performance
Bruno Bisconti*, Juan Segador and Ignacio Gonzalez (Huawei Technologies, Germany)
In this paper, we present a Massive MIMO antenna architecture whose system performance is higher in comparison with the traditional aperture geometry. Its advantage is explained in terms of an improved exploitation of the antenna Degrees of Freedom.

17:00 Machine Learning-aided Design of Thinened Antenna Arrays for Optimized Network Level Performance
Mattia Leci and Paolo Testolinda (University of Padova, Italy); Mattia Rebato (Università degli Studi di Padova, Italy); Alberto Testolini (University of Padova, Italy); Michele Zorzi (Università degli Studi di Padova, Italy)
With the advent of millimeter wave (mmWave) communication, the combination of a detailed 5G network simulator with an accurate antenna radiation model is required to analyze the realistic performance of complex cellular scenarios. However, due to the complexity of both the electromagnetic and network models, the design and optimization of antenna arrays is generally infeasible due to the required computational resources and simulation time. In this paper, we propose a Machine Learning framework that enables a simulation-based optimization of the antenna design. We show how learning methods are able to emulate a complex simulator with a modest dataset obtained from it, enabling a global numerical optimization over a vast multi-dimensional parameter space in a reasonable amount of time. Overall, our results show that the proposed methodology can be successfully applied to the optimization of thinned antenna arrays.

17:20 Reconfigurable Metasurface Antenna for 5G Base Stations
Cristian Della Giovampaola (Wave Up srl, Italy); Francesco Caminita (Wave-Up SRL, Italy); Giuseppe Labate (Wave Up S.R.L., Italy); Enrica Martini and Stefano Maci (University of Siena, Italy)
This work describes the operation principle and implementation of an electronically reconfigurable leaky-wave antenna based on an array of periodically modulated metasurface channels for 5G applications. While the scan angle along the channels is dictated by the base voltage of PIN diodes distributed along the channels, the beam angle on the transverse plane is controlled by a digital network feeding the channels. Numerical results show good performance in terms of beam shape, beam direction control, and field of view coverage.

17:40 ML Based Fully Digital UWB Antenna for Direction Finding Systems
Antonio Manna (Elettronica S.p.A, Italy)
A new generation UWB Radio Frequency Direction Finding System is presented. The architecture of such system is based on phase interferometry and it exploits leading-edge technologies such as, Radio Frequency direct sampling and Artificial Intelligence for the processing of incoming RF signal. Thanks to these new solutions, a minimum number of antennas are needed to cover a multi octave-band capable to operate in the so-called “folded mode”, folding the RF band in the first Nyquist Zone, the instantaneous observation band is than identical to the entire operating band. The presented solution is based on four full band interferometer antenna array. The same signal collected from each antenna is digitized with different sampling frequencies to get the diversity needed to solve the frequency ambiguity problem. Machine Learning approach is adopted to face this issue and for the estimation of Direction of Arrival. Comparison between standard processing and ML is presented.

18:00 A 5G Active Antenna Tile and Its Characterization in a Reverberation Chamber
Eduardo Anjos and Marzieh Safarlahimi (KU Leuven, Belgium); Robert Rehammar (Bluestet AB & Chalmers University of Technology, Sweden); Dominique Schreurs (KU Leuven, Belgium); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Marcel Geurts (NXP Semiconductors, The Netherlands)
This paper presents a 5G active antenna tile, enabling the flexible construction of hybrid beamforming (HBF) arrays. The proposed tile was fabricated using a standard PCB manufacturing process and to validate its performance. Using a Reverberation Chamber (RC), the tile was measured in both Tx and Rx mode, achieving up to 1.6 GHz in bandwidth around a central frequency of 27.8 GHz.
In this paper we propose the use of a parallel-plate waveguide simulator as a useful design verification step of very large radio array antennas. It is shown to be key to correctly terminate the cavity to the free-space boundary with the use of cross-correlated power, a relation is drawn with the StEFCal algorithm. An example illustrates this approach for few point sources and a 256-element array.

A number of natural phenomena occurring at the Western Australian site of the Square Kilometre Array (SKA), such as atmospheric scattering and Earth's rotation, can be described by means of the propagation model that we present. It is shown to be able to reproduce the measured scattering patterns with high accuracy also for large and complex scenario geometries. After a short introduction to the SBR method some simple validation cases will be shown for different post-processing purposes and finally some cases of traffic scenarios will be presented.

A Ray Optical Diffraction Model for Car Chassis in V2X Communication
Lennart Thielecke (Technische Universität Braunschweig, Germany); Nils Dreyer (TU Braunschweig, Germany); Johannes M. Eichhardt and Thomas Kümer (Technische Universität Braunschweig, Germany)

In this paper, diffraction models are investigated in the context of V2X scenarios. First the physical effects which result from a propagating wave are summarized. Afterwards, an analytical diffraction model for simple geometric objects is derived from a full wave optical analysis. Using an equivalence principle, it is possible to apply this model to the calculation of diffraction effects from car chassis in V2X scenarios. Based on key geometric parameters, a ray optical diffraction model is derived from the full wave optical analysis. Scaled measurements with a 60GHz channel sounder are carried out, validating the presented model.

A Ray Optical Diffraction Model for Car Chassis in V2X Communication
Lennart Thielecke (Technische Universität Braunschweig, Germany); Nils Dreyer (TU Braunschweig, Germany); Johannes M. Eichhardt and Thomas Kümer (Technische Universität Braunschweig, Germany)

Radio applications in vehicular environment are becoming popular due to the development of autonomous driving and safety enforcement technologies that make use of vehicle-to-vehicle, vehicle-to-infrastructure as well as of radar solutions. Due to the large variety of possible environment configurations, and to the highly dynamic characteristics of the environment, specific deterministic radio propagation models must be developed to assist the design and simulation of such vehicular applications. In the present work we study a dynamic ray-tracing model that can provide a multidimensional channel prediction, including Doppler shifts, with a single run on the base of a "dynamic" environment description that features a scenario with moving objects and terminals.

Physics Based Target Scenario Simulation Using Asymptotic Solver Techniques for Automotive Applications
Markus Lauten (Aerospatial, Germany)

Simulation of traffic scenarios for radar applications has gained high attention during the past years as this can significantly reduce the time for validation. Electromagnetic models of auto-radar scenarios require models of the TX- and RX-antennas that radiate towards the reflecting targets embedded within a model of the whole environment. While small antenna modules can be simulated using full-wave methods like FEM, IE or FD-TD geometrical large geometries with an embedded car chassis cannot be simulated with high accuracy also for large and complex scenario geometries. After a short introduction to the SBR method some simple validation cases will be shown for different post-processing purposes and finally some cases of traffic scenarios will be presented.

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18:00 Investigations of Quadraple-Ridge Flared Horn Performance for ngVLA Band 2
Dirk de Villiers (Stellenbosch University, South Africa); Robert Lehmannsiek (EMISS Antennas, South Africa); Fahmi Mohuquzi (Stellenbosch University, South Africa)

The design of an all-metal quadraple-ridge flared horn (ORFH) fed antenna for the current nominal ngVLA optics is presented. The antenna is required to operate over the 3.5 GHz - 12.3 GHz band with a reflection coefficient of better than 15 dB, while maximizing the receiving sensitivity over the band. Analytical profiles for the horn and ridges are employed to reduce the design space dimensionality (over that of pristine profiled antennas). Simulated results suggest sensitivity performance to within 10% of that achievable with octave-band horned horn antennas.

CS32: High-Frequency Methods and Applications

16:40 Asymptotic Expansion of the Reciprocity Integral in a Bidirectional Ray-Tracing Approach
Mehmet Mert Tayyar (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

Bidirectional ray-tracing bunches rays from both the transmitter and the receiver sides, where the transfer function between the antennas can be computed by evaluating a reciprocity interaction integral. In this work, an asymptotic expansion approach for the evaluation of this interaction integral is introduced and discussed. By using an oscillatory integral representation and high-frequency assumptions, it is shown that the stationary phase approximation yields a simple algebraic expression for the result of the integral. Thus, the evaluation of the reciprocity integral becomes much more straightforward without any significant decline in terms of accuracy. The strong dependency between computation time and operating frequency is mostly avoided, in contrast to the traditional integral approaches. As a result, substantial speed-up factors can be achieved. Numerical results demonstrate the merits of this approach.

17:00 A Uniform Theory of Diffraction for a Curved PEC Wedge Excited by an Obliquely Incident Astigmatic Electromagnetic Gaussian Beam
Prabhakar H. Pathak (The Ohio State University, USA); Hsi-Tsung Chou (National Taiwan University, Taiwan)

This paper presents a uniform theory of diffraction for a beam (UTDB) when it illuminates a general curved edge in an otherwise smooth PEC surface. The solution obtained is utilized for analyzing large reflector antennas in a very rapid fashion.

17:20 Radiation Shaping by Using Lattice Modes in a Dual-feed Dielectric Structure
Silvio Ceccuzzi, Ludovica Tognolatti and Paolo Baccarelli (Roma Tre University, Italy); Vakhtrang Jandieri (General and Theoretical Electrical Engineering (ATE), Faculty of Engineering, Germany); Cristina Ponti and Giuseppe Schettini (Roma Tre University, Italy)

Electromagnetic Band-Gap (EBG) media, working right above the band-gap can shape the radiation of a simple emitter embedded in their periodic structures. In this region of the dispersion diagram, degenerate lattice modes can be selectively excited with a proper positioning of the primary sources. This paper presents the design of an antenna that exploits such physical mechanism, which is potentially attractive in mm-waves since it relies on dielectric structures. An antenna fed by two sources and based on a square lattice of dielectric cylinders is presented. For the first time, the dependencies of radiation properties on some geometrical parameters are investigated before moving to a final realistic design.

17:40 3D Diffraction of a Complex Source Beam by a PEC Wedge
Ludger Klinkenbusch (Christian-Albrechts-Universitaet zu Kiel, Germany); Giuliano Manara and Sergio Terranova (University of Pisa, Italy)

The scattering and diffraction of a 3D Complex-Source Beam by a wedge made from a perfect electric conductor is considered in this paper. Analytical solution is based on the corresponding scalar (acoustic) fields where both soft and hard boundary conditions have to be considered at the wedge faces. In particular, a new spherical-multipole solution is presented for an incident uniform CSB which consist of both diverging and converging parts. First numerical results include the scattering and diffraction of a scalar 3D uniform CSB by both acoustically soft and hard wedges.

18:00 Wiener-Hopf Analysis of the Scattering from an Abruptly Ended Dielectric Slab Waveguide
Vito Daniele (Polytechnic of Turin, Italy); Guido Lombardi (Politecnico di Torino, Italy); Rodolfo Zich (Politecnico di Torino & ISMB, Italy)

Abruptly ended dielectric slabs are important components in several areas of applied electromagnetics. For the study of these geometries, a variety of analytical methods have been proposed in the past. In this paper we formulate the problem in terms of Wiener-Hopf equations and we apply the novel and effective semi-analytical solution technique known as Fredholm factorization.

T11-P02/1: Channel Modelling for Massive MIMO and Near-Field Communication Systems

T11 Fundamental research and emerging technologies / Regular Session / Propagation
Room: B10
Chair: Said Mikki (University of New Haven, USA)

16:40 Measurement Based Millimeter Wave Massive MIMO Channel Parameter Comparison
Heng Zhang, Yu Shao and Xi Liao (Chongqing University of Posts and Telecommunications, China); Jiangle Zhang (The University of Sheffield, United Kingdom (Great Britain)); Jie Zhang (University of Sheffield, Dept. of Electrical and Electronic Engineering, United Kingdom (Great Britain))

Massive multiple-input-multiple-output (MIMO) plays a key role in millimeter wave (mmWave) communications. In this paper, a measurement campaign based on virtual antenna arrays is proposed to characterize indoor massive MIMO channel in mmWave band. Measurements are taken place in an empty hall environment and a rich scattering environment. Measurements are conducted using a virtual uniform rectangular array (VURA) whose total elements are set to be 5 by 5, 10 by 10 and 20 by 20 respectively at 28 GHz and 38 GHz with bandwidth of 4 GHz. The power angle delay profiles in each scenario are presented and channel characteristics are analyzed. MIMO performances, such as beam width, side lobe level and spatial resolution are compared with different array sizes and frequencies. Measurement results show that the beamwidth of the main lobe decreases with array size and central frequency, and therefore the resolution of multipath becomes higher.

17:00 Massive MIMO Channel Measurement and Characterization for Manufacturing Scenario
Zhizeng Zhong (Huawei Technologies Co., Ltd., China); Yuntian Pan (Huawei Technologies CO, Ltd, China); Jianyao Zhao (Huawei Technologies Co., Ltd., China)

One of the main differences between 5G and previous generations of cellular networks is that 5G supports not only mobile broadband enhancement, but also unprecedented reliability and very low latencies. This is beneficial to new applications in manufacturing scenario. In order to design a feasible wireless solution for manufacturing scenarios, the particular characteristics of manufacturing environments need to be considered. In this paper, the massive MIMO channel measurement in factory was conducted, and the channel propagation in the spatial and frequency domains were analyzed and compared with a general indoor scenarios. Due to more metal reflections and big machine deployment, it was found that there were dense multipath so that the delay and angular spreads are larger than the ones in office scenario. Moreover, the effect of particular channel characteristics on communication system in a manufacturing scenario, was investigated in terms of Cyclic-Prefix length and MIMO rank.

17:20 Study on Beamforming V2I Scenarios for Sub-6 GHz and mmWave Channels
Christian Ballesteros (Universitat Politècnica de Catalunya, Spain); German Ramirez Arroyave (Universidad Nacional de Colombia, Colombia); Luca Montero Bayo (Universitat Politècnica de Catalunya, Spain); Jordi Romeu (Universitat Politècnica de Catalunya, Spain); Luis Jofre (Universitat Politècnica de Catalunya, Spain)

The study of the wireless channel between a hybrid massive MIMO Base Station (BS) and a vehicular platform is presented. Several multi-beam antenna designs in both vehicle and BS are numerically modeled and compared. Different metrics are used for the assessment of the system performance, including channel capacity, in two frequency bands, sub-6 GHz (5.9 GHz) and millimeter-wave (mmWave) (26 GHz), under different propagation conditions. The use of beamforming techniques on the vehicle side is compared to conventional SISO and MIMO solutions. In the urban scenario used in the study, a 4x3 beamformed circular array is able to enhance the single monopole performance up to 157% in capacity, and outperform MIMO 4x4 in most situations.

17:40 An Electromagnetic Framework for the Deployment of Reconfigurable Intelligent Surfaces to Control Massive MIMO Channel Characteristics
Debdip Sarkar (Royal Military College Canada, Canada); Said Mikki (University of New Haven, USA); Yasha Antar (Royal Military College of Canada, Canada)
In this paper, we deploy a full-wave FDTD paradigm to investigate the effect of reconfigurable intelligent surface (RIS) - switchable frequency-selective surfaces (FSS) - on generic massive MIMO split-channel's eigenspace structure. We place an RIS based on two switchable FSS layers in the vicinity of a 64-element massive MIMO base-station (BS) array, serving a cluster of four fixed user equipment (UE) units. Utilizing an electromagnetic tool based on time-averaged Poynting flow developed recently by the authors, we demonstrate how the illumination of BS-array aperture can be controlled by the intentional deployment of various switching states in the RIS placed near the BS. We show that such complementary RIS structures may assist the wireless link engineer in deterministically "customizing" the uplink channel behaviour by selectively enhancing/suppressing certain channel eigenvalues.

18:00 IWBA Channel Modeling on Electromagnetic Interaction in Biological Tissues for Estimating Path Loss Characteristics
Prapti Ganguly (A. K. Choudhury School of Information Technology, University of Calcutta, India); Ananya Dey and Debarati Ganguly (Institute of Radio Physics and Electronics, University of Calcutta, India); Chinmoy Saha (Indian Institute of Space Science and Technology, India & Royal Military College of Canada, Canada); Jawad Y Siddiqui (University of Calcutta, India & Royal Military College of Canada, Canada)

The increasing use of miniaturized non-invasive health monitoring devices have facilitated the growth and development of WBANs (Wireless Body Area Networks). Antennas used for this kind of applications are designed taking into account the properties of the biological medium on which they are to be placed. This paper presents results for deploying a channel model for on-body-to on-body communication between two sensors placed on samples of animal tissue. The design and measurement results for the antenna, centered at 2.4GHz have been included.

T10-E03/2: Computational and Numerical Techniques 2

16:40 Floquet Mode Analysis on Groove Gap Waveguide
Jiro Hinokawa, Kasuke Ejiri and Takashi Tomura (Tokyo Institute of Technology, Japan)

This paper presents the Floquet mode analysis on a groove gap waveguide by considering the structural periodicity in the propagation direction. The Floquet modes are categorized into not only regular propagating and attenuating modes but also modes having the complex propagation constant reflecting the existence of the pin. The expansion of generalized scattering matrix using the Floquet modes gives difference from that using conventional cross-sectional modes in an example of a converter between a regular rectangular waveguide and the groove gap waveguide.

17:00 Modeling of Quantum-Dot Elliptical Nanowire Single-Photon Sources
Uğur Meriç Gür, Niels Gregersen, Samel Arslanagić and Michael Mathes (Technical University of Denmark, Denmark)

True monomode operation and polarization control capability of elliptical nanowires leads to the need of efficient solvers for open elliptical nanophotonic structures. In this contribution, a full-wave vectorial modal method for open boundary elliptical geometries is presented for designing quantum-dot elliptical nanooptics structures. The method exploits symmetry properties, providing insight into the physical behavior of the system giving direct access to propagation constants and mode profiles, which will be used in the efficiency calculations of the single-photon sources.

17:20 Mapping Between Complex Eigenmodes and Complex Propagation Constant for Uniform Rectangular Metallic Waveguides
Joao Guilherme Nizer Rahmeier, Ville Tiukuvaara and Shulabh Gupta (Carleton University, Canada)

This paper presents a rigorous mathematical mapping between the complex eigenmodes and the complex propagation constant for a homogeneous lossy waveguide structure. We validate the results for a rectangular waveguide, comparing the analytical mapping with the results from a FEM-EM solver. It has been found that a precise mapping between ω(β) and γ(ω) exists, which enables predicting the driven mode solution from the eigenmode analysis. While valid for a simple canonical case of a dispersive waveguide, such mapping establishes the underlying principles of how the complex eigenmodes are formulated inside typical commercial simulators.

17:40 Time-Domain Modeling and Simulation of EM-Fields Propagation in Anisotropic Dispersive Media with Non-Conformal Meshing
Abdelrahman Abdallah Ijjeh (Université Cote d'Azur, France); Jun Liu and Shulabh Gupta (University of Victoria, Canada)

This article presents a time-domain numerical scheme for simulating EM-computational problems that include complex materials. To name a few, microwave and optical devices that contain complex media, antennas characterization in presence of complex media, such as biological tissues, biomedical technology... etc. Modeling such scenarios requires the ability to handle two types of complexities, namely material's anisotropic and dispersive nature of such media. On the other hand, non-conformal local mesh refinement approach is adopted to accurately discretize important fine details without exploiting the computational resources. Numerical simulations are presented to show the efficiency, the accuracy and the stability of the proposed approach, with comparisons to FEM method and TLM method with regular fine-meshing.

18:00 Perturbational Method for Modeling Electromagnetic Propagation Through Non-axisymmetric Geophysical Formations
Lisseth Saavedra (Pontifical Catholic University of Rio de Janeiro & Center for Telecommunications Studies, CETUC, Brazil); Guilherme Simon da Rosa (Pontifical Catholic University of Rio de Janeiro, PUC-Rio, Brazil); Jose R Bergmann (PUC-Rio, Brazil)

This work presents a new technique for modeling electromagnetic sensors used in well prospecting. These sensors are usually immersed in complex (asymmetric, inhomogeneous, and dispersive) geophysical formations, resulting in a challenging problem for traditional computation electromagnetic techniques. We analyzed this propagation problem by using a perturbational method based on the Born approximation for solving a Fredholm integral equation. Numerical results are presented for evidencing the effects of non-symmetric geophysical formations in the response of electromagnetic well logging tools.
8:30 Multifocus Reflectarray Concept: Preliminary Design and Possible Applications
Christophe Granet (Lynbyrd Antenna Research Pty Ltd, Australia); Michael F. Palvig, Min Zhou and Stig Sørensen (TICRA, Denmark)

The concept of a multifocus reflectarray is introduced along with a preliminary design at 436 GHz and an explanation of how this new concept can be applied to the realized reflectarray. The preliminary design was conducted on a different system with a lower frequency than the proposed design. The proposed design uses a lower frequency and a smaller aperture size. The results show that the proposed design is feasible and can be used in practical applications.

8:50 Design of Ka-band Reflectarray Antennas for High Resolution SAR Instrument
Min Zhou, Michael F. Palvig, Stig Sørensen and Jakob Rosenkrantz de Lassen (TICRA, Denmark); David Manote Alvarez (Airbus/CSA, Spain); Michael Notter (Airbus DS Ltd, United Kingdom (Great Britain)); Dennis T. Schobert (European Space Agency, The Netherlands)

The design of the Ka-band reflectarray antennas for high-resolution SAR instruments is presented. The design involves the use of a new reflectarray design technique and the incorporation of advanced signal processing methods. The results show that the proposed design is feasible and can be used in practical applications.

9:10 Preliminary Simulations of a 1.8 M Parabolic Reflectarray in a Geostationary Satellite to Generate a Complete Multi-Spot Coverage for TX
Daniel Martinez-de-Roja (Universidad Politécnica de Madrid, Spain); Jose A. Encinar (Universidad Politécnica de Madrid, Spain); Yolanda Rodriguez-Vaquero and Antonio Pino (University of Vigo, Spain)

A parabolic reflectarray antenna has been proposed to generate a complete cellular coverage in high-resolution SAR instruments. This paper explores range length effects on several figures of merit and examines the consequences of testing within smaller enclosures. Results are presented and discussed.

9:30 A Wideband Reflectarray Using Slotted Patch with Concave Arms
Ming Min, Lu Guo and Wenyi Feng (Nanjing University of Science and Technology, China)

In this paper, a wideband reflectarray antenna using slotted patch with concave arms is presented. The broadband behavior of the antenna is achieved by the combination of two bandwidth improvement approaches: i) employing multi-resonance element and slotted patch element. By varying the length of the slots together with the concave arms, the phase can reach 360° with a rather linear slope. Based on this novel element, an offset-fed 2323° reflectarray antenna is designed and simulated. The simulated 1-2 dB gain bandwidth is 45%, with a peak aperture efficiency of 67%, while the side-lobe and cross-polarization levels are also satisfactory.

9:50 Band Enhancement in Reflectarrays for Space Communications Based on Multi-Frequency Synthesis
Daniel R. Prado (Universidad de Oviedo & Signal Theory and Communications, Spain); Manuel Arrebola and Marcus R. Pinto (Universidad de Oviedo, Spain); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain))

This paper describes a multi-frequency wideband optimization procedure and presents results of a very large spaceborne reflectarray for Direct-to-Home (DTT) application in a 10% bandwidth. The proposed design methodology is based on the generalized interaction approach and the use of a multi-resonant unit cell with multiple degrees of freedom (DoF). The procedure is divided into three stages to facilitate convergence towards a wideband performance. First, a initial narrowband design at central frequency is obtained. Then, a broad optimization including SRF requirements is carried out with a limited number of DoF. Finally, more DoF are included in the last stage optimization to obtain a wideband reflectarray with improved cross-polarization performance. A minimum improvement of 4.8 dB is achieved in the crosspolarization performance for both XRF and XPR in 10% bandwidth, while ensuring that the copolar pattern complies with the specifications in the whole band.

10:10 Coffee Break

10:40 Bandwidth Improvement of Reflectarray Cells Using Variable Rotation Technique at Two Frequencies for Dual Circular Polarization
Daniel Martinez-de-Roja (Universidad Politécnica de Madrid, Spain); Jose A. Encinar (Universidad Politécnica de Madrid, Spain); Rafaelicolio (University of Alcalá, Spain); Rafael R. Boix (University of Sevilla, Spain)

The bandwidth behavior has been studied and improved for a reflectarray cell formed by a symmetric arc and a dipole printed in two layers, which uses Variable Rotation Technique at two frequencies for dual circular polarization. First, the appropriate thickness of the dielectric layers has been selected to improve the bandwidth. Then, an optimization routine has been applied to minimize phase errors in a frequency band from 29.25-73.75 GHz. As a result, the phase behavior has been drastically reduced from 450 to 1 degree, which is an improvement of over 100 times.

11:00 Design of a Wideband Linear-to-Circular Polarizing Reflector for Ka-band Satellite Applications
Eduardo Martinez-de-Roja (Universidad Rey Juan Carlos, Spain); Jose A. Encinar (Universidad Politécnica de Madrid, Spain)

This paper presents a high-performance linear-to-circular polarizing reflector with wideband operation in Ka-band. The polarization cell consists of three parallel dipole plates placed with 45° with respect to the direction of the incident linearly polarized field. The lengths of the dipoles are adjusted by the cell through a dual-frequency optimization process, which accounts for the maximum radiation angles in the cell. A linear to circular polarizing reflector prototype has been manufactured and tested to validate the concept. The measurements show an axial ratio lower than 1.8 dB within the 19-30 GHz band, and good matching with the simulations. The proposed polarization reflector has applications in Ka-band multibeam antennas for Ka-band satellite systems.

11:20 A Low-Profile and Efficient Front-End Antenna for Point-to-Point Wireless Communication Links
Mot Nishat Yasmin Koli and Muhammad Usman Afzal (Macquarie University, Australia); Karu Esselle (University of Technology Sydney, Australia); Rahee Maqbool Hashmi (Macquarie University & IEEE, Australia); Md Zahidul Islam (Telesat: Serveno Australia Pty Ltd, Australia)

This paper presents a low-profile, high-performance, medium-gain, front-end antenna of the type of radial line slit array (RLSAs) for wireless communication systems. The antenna consists of two conducting metal plates forming a radial waveguide. A single coaxial connector is used to feed the electromagnetic energy from the bottom of the radial waveguide. The antenna has a radius of 0.15 m and operates at a frequency of 12 GHz. It was simulated using CST Microwave Studio 2019 and the results show that the antenna has an acceptable level of impedance matching in the frequency range from 11 GHz to 13 GHz, with a peak directivity of 25.6 dBi and a peak realized gain of 25 dBic at 12 GHz. The antenna has 3-dB gain bandwidth of 13.9% from 11.4 GHz to 13.1 GHz. Its radiation efficiency is 96% and total efficiency is 85.3% at 12 GHz.

11:40 Perforated Dielectric Reflectarray in Ka-band
Andrea Massaccesi, Michele Becarra and Paola Pirino (Politecnico di Torino, Italy)

This paper proposes a single-layer perforated dielectric reflectarray antenna that operates in Ka-band. The unit-cell is made up of a dielectric element perforated by a centered square hole, whose size is used to control the phase of the reflection coefficient. This cell has been used to design a 52x52 offset reflectarray working at 30 GHz, whose numerical analysis proves that it has good radiation features. The proposed configuration is particularly convenient since Additive Manufacturing processes can be exploited for its fabrication.

12:00 A Reconfigurable Origami Reflectarray
Abdul sattar Kaddour (Florida International University, USA); Constantinos L. Zekos (Florida International University, ECE & FILL USA); stavros Geogkopoulos (Florida International University, USA)

This paper presents a novel multifocus origami reflectarray cell unit. This origami-inspired unit-cell allows efficient folding/unfolding, high packing density, reconfigurable behavior. The unit-cell is composed of 4 parallel planar patches that can achieve 50° phase shift. To synthesize the radiation pattern and the directivity of a deployable 25 x 25 element reflectarray, for different folding states, a procedure based on the conventional approximative procedure is proposed. A maximum directivity of 32.8 dBi is obtained with a 25 dB bandwidth from 8.2 GHz to 4 GHz (13%). The proposed origami antenna can adjust its operational frequency band by changing its folding angle, therefore, it is physically reconfigurable. The main advantage of this antenna is that its size at its maximum folded state is approximately 6 times smaller than its volume when it is fully deployed thereby offering a significant advantage for small satellites applications.

CS06: AMTA/IRACON Session: Over-The-Air Testing of 5G Radios
T02 Millimetre wave 5G / Convened Session / Measurements
Room: A3
Chairs: Wei Fan (Aalborg University, Denmark), Pekka Kyosti (Keysight Technologies & University of Oulu, Finland)

8:30 Examining and Optimising Far-Field Multi-Probe Anechoic Chambers for 5G NR OTA Testing of Massive MIMO Systems
Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Clive Parini (QMUL, United Kingdom (Great Britain))

Direct far-field (DFF) testing has become the de facto standard for sub-6 GHz over-the-air (OTA) testing of the physical layer of radio access networks with the far-field multi-probe anechoic chamber (FMPAC) being especially widely deployed for the verification of massive multiple input multiple output (MIMO) antennas in the presence of several users. The adoption of mm-wave bands within the fifth generation new radio (5G NR) specification has meant that these systems require the use of equipment placed in the far-field of the base transceiver station (BTS) antennas, either exclusively new FMPAC test systems are required or the user equipment is placed at range-lengths very much shorter than that suggested by the classical Rayleigh criteria. This paper explores range-length effects on several communication system parameters and examines the consequences of testing within smaller enclosures. Results are presented and discussed.

8:50 Mid-Far Field OTA RF Test Method: New Developments and Performance Comparison with the Compact Antenna Test Range (CATR)

This paper presents the development of a new method for mid-far field (intermediate range, 5-25 meters) OTA testing of 5G NR MIMO antennas. The method involves the use of a compact antenna test range (CATR) to simulate the far-field conditions. The results show that the proposed method is accurate and can be used in practical applications.

54 of 128

| 54 of 128 |
9:10 On Noise and Interference Modeling for Over-the-air Testing of MIMO Terminals
Wei Fan (Aalborg University, Denmark); Pekka Kyosti (Keystones Technologies & University of Oulu, Finland); Yilin Ji and Gert Pedersen (Aalborg University, Denmark)

As the fifth generation (5G) ecosystem matures, the time for large-scale 5G radio commercialization is now. Over-the-air (OTA) radiated testing is seen to currently dominate cable conducted testing for upcoming radio systems due to integrated antenna designs. To properly evaluate performance of radio systems in fading channel conditions, it is typically needed to model the realistic signal, interference and noise conditions in the testing environment. However, interference and noise modeling is largely overlooked in the literature in OTA testing, since the discussion is typically focused on the signal alone. In this paper, interference and noise modeling in three OTA setups, including the multi-probe anechoic chamber (MPAC), radiated two stage (HTS) and reverberation chamber (RC) is discussed and summarized.

9:30 The Study of 5G Massive MIMO End-to-End MPA5 Test Solution
Xiang Zhang (University of Posts and Telecommunications, China); Xiaolong Liu (Beijing University of Post Telecommunications, China); Guoming Wei (China Academy of Information and Communications Technology, China); Yichen Zhao (China Mobile Group Device Co., Ltd., China); Yuhang Guo (Beijing University of Posts and Telecommunications, China);

Due to the large demand of high data rate and low latency in mobile service, 5G network has been commercially deployed in the many countries, e.g., China, US, Korea etc. Massive multiple input multiple output (MIMO) and hybrid beamforming techniques are observed as the key technique in the physical layer, and therefore, how to accurately measure the data throughput between massive MIMO gNB and user equipment (UE) under channel fading conditions has drawn much attentions in recent years. This paper introduces a novel simplified bidirectional 3D channel reproducing method for multi-probe anechoic chamber, in which the channel parameters are co-generated by the phase shift box and channel simulator. The simulation and test results achieved show performance similar compared with the whole channel simulator and meanwhile significantly reduce the cost of instruments.

9:50 Chamber Array Antenna Layout for Compact OTA Measurements
Mohammad Poorodehre (University of Twente, The Netherlands); Andrés Alayón Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden);

An antenna layout with uniform excitation of antenna elements is presented for Random-Los OTA (Random Line Of Sight - The Antenna Characterization Setup). A plane wave is synthesized within a cylindrical 3D test zone of 2.7 GHz. The obtained array achieves a 52% reduction of the number of elements and a 45% aperture size as compared to a uniform fully populated planar array with an inter-element distance of 0.93λ, which is the optimum distance through λ/2. Results are shown to demonstrate that the QZ field uniformity can be traded off with size. Results of the verification testing and comparison to spherical near-field measurements are reported using electrically small devices.

10:10 Coffee Break

10:40 Measurement Characterization of Aperture Correction Technique for EMF
Johann Lundgren, Jakob Helander and Mats Gustafsson (Lund University, Sweden)

Techniques for accurate, robust and efficient over-the-air testing for devices in the next generation communication system are important. This work aims at presenting the use of an aperture correction technique, through which field values and power density values are reconstructed at an arbitrary plane in the near-field from a measurement of a separate plane wave source. The technique is applied for the calibration of an 2D far-field measurement setup covering 38-56 GHz. The technique calibrates for the probe interferences, and for the measured sample, two different radiating devices. The results are compared with simulations. An investigation into the techniques performance is carried out. The experimental measurement data is used in an antenna verification test in order to test the performance of a new antenna verification system.

11:00 OTA Testing of Antennas & Devices Using Plane Wave Generator or Synthesizer
Francesco Scattone (Microwave Vision Group (MVG), Italy); Darko Sekuljica (MVG, Italy); Andrea Giacomini, Francesco Saccardi, Alessandro Scannavini and Lars Foged (Microwave Vision Italy, Italy); Evgenii Kaverine and Nicolaus Gross (MVG Industries, France); Per Iversen (Orbit/FR, USA)

The Plane Wave Synthesizer (PWS) approximates the plane-wave condition and, thus, the Far-Field condition over a finite volume at a reduced distance called the Quiet Zone (QZ). It consists of an array of elements with suitably optimized complex excitation coefficients. The concept of a high performance, dual polarized PWS supporting up to 1:10 bandwidth was presented. A demonstrator of a dual polarized PWS has been designed, manufactured and tested in the 600MHz to 60GHz frequency range. In this paper, we report on the measured QZ performance of different implementations of the PWS demonstrator. QZ fields are determined within a volume by spherical NF measurements and back-propagation. It is shown experimentally that the QZ field uniformity can be traded off with size. Results of the verification testing and comparison to spherical near-field measurements are reported using electrically small devices.

11:20 Quiet Zone Verification of Plane Wave Synthesizer Using Polar Near-Field Scanner
Adam Tankejuel, Anes Beikacem, Mustafa Akinci and Mert Celik (Rohde & Schwarz GmbH & Co. KG, Germany); Hendrik Bartko (Rohde & Schwarz, Germany); Benoit Derat (Rohde & Schwarz, Spain)

The Plane Wave Synthesizer (PWS) allows testing with far-field conditions at the near-field distance with the minimum system dimensions. Uniformity of the synthesized plane wave field in the quiet zone (QZ) is a key performance parameter of PWS. QZ verification setup using a polar near-field scanner and a vector network analyzer is presented with description of the main hardware components, instrument settings and correction techniques for new measurement data. Various field uniformity metrics are defined and calculated for one measurement example. Measurement repeatability is also verified to evaluate stochastic errors in the verification.

11:40 3D Calibration of an Over-the-Air Test Chamber for GNSS CRPA Antenna Testing
Renato Zea (Fraunhofer IIS, Germany); Ramona Brockholz-Germer (Fraunhofer Institute for Integrated Circuits IIS, Germany); Marco Lorenz (Technische Universität Ilmenau, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Alexander Rügamer (Rohde & Schwarz, Germany); Giovanni Del Galdo (MVG, Italy)

This paper presents an approach to calibrate an OTA test field to perform 3D full polarimetric wave field synthesis (WFS) to test controlled reception pattern antennas for global navigation satellite systems (GNSS). For 2D and 2.5D WFS is mostly used for single polarization OTA testing, nevertheless the level of accuracy on representing real-world scenarios becomes always a challenge, specially for GNSS testing, since the azimuth and elevation angles of the satellites with relation to the device under test can be approximately calibrated only in a 3D environment. Instead of using three electromagnetic (EM) field probes to perform the calibration of the three orthogonal field vectors (X,Y,Z), this approach uses only one EM field probe to perform the entire calibration process. The limitations and accuracy of the proposed calibration procedure for full polarimetric WFS is shown and demonstrated in this contribution.

12:00 Comparing Options for 5G MIMO OTA Testing for Frequency Range One
Doug Reed and Anselmo Rodriguez-Herrera (Spirent Communications, USA); Jukka-Pekka Nuu tinen (Spirent Communications, Finland)

MIMO OTA is the well-established and predominant method to test mobile devices with multiple antennas. The MIMO OTA chamber setup using a chamber test with a single anechoic chamber is recommended due to its simplicity and the capability to test large number of devices. However, there are several issues with this approach such as high cost, long testing time, and limitations of test setup. In this paper, we evaluate the performance of the MIMO OTA setup using a traditional anechoic chamber and a hybrid anechoic chamber. The results show that the hybrid anechoic chamber setup is more efficient and cost-effective than the traditional anechoic chamber setup.

CS45: New Perspectives and Applications of Characteristic Mode Analysis in Antenna Design
T11 Fundamental research and emerging technologies / Convened Session / Antennas
Room: B1
Chairs: Ozlem Aydin Civis (Middle East Technical University, Turkey); Hui Li (Dalain University of Technology, China); Philipp Genthner (Ericsson Antenna Technology Germany GmbH, Germany)

8:30 Characteristic Mode Analysis for the Design of Nanosatellite Reconfigurable Antennas
Simone Genovesi (University of Pisa, Italy); Francesco Alessio Dicidio (Greenwaves, Italy)

A new methodology is presented for the design of antennas on a 1U form factor CubeSat platform designed by exploiting the Characteristic Modes Theory (CMT). The innovative strategy provides useful design guidelines to transform the antenna platform into an efficient radiator by stimulating an optimal current distribution on its conductive surface. The effect of the satellite platform on the radiated performance (efficiency, band, gain) is intrinsically taken into account and efficiently exploited to realize an efficient radiation system. The minimally invasive radiator, strategically colocated on the platform, allows achieving a great saving of space and an optimal modal current excitation able to provide excellent radiation performance.

55 of 128
CS62: Small Antenna in a Human Body Environment

8:50 Antenna Positioning for Bandwidth Optimization Using Characteristic Mode Analysis
Peter William Futter (Altair Development S.A. (Phy) Ltd, South Africa); Ulrich Jakobus (Altair Engineering GmbH, Germany)
Charateristic mode analysis is used to understand the model behavior of antennas, and how they interact with the structure they are mounted on. While this insight can be applied in various ways to improve the design, one of the biggest challenges is often how to place the antenna on the structure to excite specific modes. Previous work describes a good approach but imposed certain limitations: multiple antennas were used, and a narrow frequency band was considered. For many applications an approach was needed to position a single antenna that operates in a wider frequency band. This paper will attempt to broaden the understanding of those limitations and proposes a design approach which surpasses the limitations, albeit at the cost of exciting additional modes. The approach covers positioning a single wider band antenna to excite specific modes while optimizing the antenna bandwidth. It is applied to two antenna examples.

9:10 Use of Characteristic Modes in the CBFM for the Analysis of Large Arrays
Yigit Haykir and Ozlem Aydin Civi (Middle East Technical University, Turkey)
In this work, the characteristic basis function method (CBFM) is presented in junction with the characteristic modes (CMs). In this approach, characteristic modes are defined as primary basiss functions on each array element. In order to take into account mutual couplings, secondary basis functions are introduced as in conventional CBFM. Since characteristic modes are excitation-free, the basis functions and consequently the reduced matrix obtained by the CBFM are also independent of the excitation.

9:30 Reducing User Effects on Mobile Handset Antennas Using Mode Mapping
Miao Wu, BaoYi Wang and Hui Li (Dalian University of Technology, China)
In this work, we investigate how different radiation patterns are influenced by the user's hand, based on which we design handset antennas that are robust to the hand effect. Handset antennas working at dual bands are firstly simulated numerically, with its eigenvalues, characteristic currents and farfields calculated. Afterwards, the total pattern of the antenna is mapped to its characteristic patterns using weighting coefficients. To study the influence of the hand on each modal pattern, the pattern for the antenna with hand is then obtained. Comparing the weighting coefficients of each mode in free space and with hand, the radiation pattern with null at the bionose is less affected by the hand. According to the observation, a handset antenna, which radiates little power towards the bionose, is designed. It is proved that the radiation efficiency of the proposed antenna with hand is 2-4 dB higher than that of the reference antenna.

9:50 Influence of p-Refinement on Accuracy of Mode Tracking Based on Correlation of Characteristic Currents
Ana Djurdjevic and Branko Mrđakovic (WPI4-L, Serbia); Branko Kolundzija (University of Belgrade, Serbia)
Characteristic mode analysis (CMA) is a useful tool that enables a deep insight into the physical behavior of the analyzed structure. In majority of cases of practical interest wide band CMA is required. Mode tracking is then very important, but also very challenging task. In this paper we are focused on mode tracking based on correlation of the modal currents over frequency, and possibly to improve the tracking by increasing accuracy of Modal matrix calculation by using p-refinement method. Results obtained from mode tracking based on correlation of characteristic fields are used as a reference. It is shown that p-refinement can bring some limited improvement of mode tracking, but the main problems related to mode tracking based on correlating the modal currents still remain.

10:10 Coffee Break

10:40 Systematic Design Method for Asymmetric Multiport Antennas Based on Characteristic Modes
Nikola Petzmeier (Leibniz University Hanover, Germany); Dirk Manschewitz (University of Hannover, Germany)
A systematic design procedure for placing ports with low correlation on an asymmetric antenna geometry is presented. By applying the mathematical description of group theory and group representations to the theory of characteristic modes, it is shown that it is in general not possible to realize uncorrelated antenna ports on an asymmetric antenna. Therefore, a port placement procedure based on correlation of characteristic modes is proposed for such geometries in order to realize ports with low correlation. The design procedure is based on modal parameters alone. Thus, only one full simulation run is needed in order to perform the modal analysis. The proposed procedure is illustrated by means of numerical examples.

11:00 Systematic Approach to Design a Circularly Polarized Antenna Using the Characteristic Modes Theory
Hussein Jaafar (The French Alternative Energies and Atomic Energy Commission, France); Aïa Sharaïha (Université de Rennes 1 & IETR, France); Sylvain Collard (Université de Rennes 1, France)
This paper presents a systematic approach to design a circularly polarized antenna by taking advantage of the physical insights provided by the characteristic modes theory (CMT). A non-conventional structure is considered (coiled triax). The characteristic modes supported by this structure are studied and various modifications are accordingly applied to generate the desired polarization.

11:20 Flexible Antenna Design with Characteristic Modes
Eva Antonino-Davìu (Universitat Politècnica de València, Spain); Aline Eid; Ryan Bahr and Manos M. Tentzeris (Georgia Institute of Technology, USA)
A dual-band flexible antenna on a 3D printed support is proposed for wrist worn applications. The antenna is aimed to work at 820 MHz and 2.4 GHz. A spatial diversity technique is used to overcome the blocking of the radiation by the arm. Characteristic Mode Analysis is used as a first step of the design process, analyzing different structures.

11:40 Broadband Metasurface-Based Antenna Using Hexagonal Loop Elements
Wenchang Zhang, Yi Huang and Jiezhong Zhu (University of Liverpool, United Kingdom (Great Britain))
A broadband metasurface-based antenna with hexagonal loop radiating elements is presented. To achieve a broadband response, an array of hexagonal loop elements is taken as the main-metasurface-based radiator. The antenna is fed by a microstrip line through a coupling slot. To reveal the underlying modal behaviors, the characteristic mode analysis was used for modeling, analyzing, and optimizing the antenna structure. The proposed broadband hexagonal loop-based antenna with an overall size of 1.13λ x 1.13λ x 0.06 λ can achieve 56% fractional bandwidth and a relatively stable gain of 7-11 dBi over the operating band.

12:00 On the Use of Characteristic Mode Analysis for the Design of Antenna Arrays
Philipp Genthner (Ericsson Antenna Technology Germany GmbH, Germany)
For antenna array design using in base station antenna a high polarization purity is required. Therefore this paper exploits the use of characteristic mode analysis (CMA) [1-2] for the design of antenna arrays. The classical antenna array description is extended with the results from a modal analysis. With this method in hand, the modes can be differentiated and selected for the application in mind; additionally the potential bandwidth and the current distribution on the elements can be explored.

CS62: Small Antenna in a Human Body Environment

T04 to I7 and M2M / Convened Session / Antennas
Room: B2
Chairs: Eva Antonino-Davìu (Universitat Politècnica de València, Spain), Aïa Sharaïha (Université de Rennes 1 & IETR, France)

8:30 Small New Wearable Metamaterials Antennas for IOT, Medical and 5G Applications
Albert Sabbah (Kinneret and ORT BRAUDIE COLLEGE, Israel)
Efficient small antennas are crucial in the development of wearable wireless communications systems. Low efficiency is the major disadvantage of small antennas. Meta materials technology and active components are used to improve the efficiency of small antennas. Moreover, the dynamic range and the efficiency of communication system may be improved by using active antennas. Amplifiers may be connected to the wearable antennas feed line to increase the system dynamic range. Novel wearable passive and active efficient wearable metamaterial antennas for 5G and 4G applications are presented in this paper. The gain of antennas with Split-ring resonators, SRR, is higher by 2.5dB than the antennas without SRR. The resonant frequency of the antennas with SRR is lower by 4% to 11% than the antennas without SRR. Active small wearable antennas may be used in communication systems. For example, the active metamaterial antenna gain is 13+3dB for frequencies from 1.25 GHz and 5.3 GHz for the WLAN/WBN and 5G band, respectively. The antenna optimization process is explained when varying the ground structure, patch dimensions, feed width, and substrate thickness using FEKO software. The performance of the antenna is studied in terms of radiation efficiency, gain, bandwidth and current distributions. Results indicate that the proposed antenna operates throughout the 2.45 and 3.5 GHz bands, with a bandwidth of 1710 MHz.
9:10 User Body Effects on Mobile Antennas and Wireless Systems of 5G Communication
Kun Zhao (Sony Research Center Lund, Sweden & Aalborg University, Denmark); Zhongbing Ying (Sony Corporation, Sweden); Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)
User body effects on mobile antennas and wireless systems for the fifth generation (5G) mobile network is analyzed in this paper. User body effects on different antenna technologies in mobile handsets include single antenna systems, multiple antenna systems, and the antenna arrays are discussed with simulation and measurement results. The corresponding impacts on the wireless networks are studied with ray-tracing simulations. Several technologies on mitigating user body effects have also been provided.

9:30 An Ultrasubband Conformal Antenna for Implantable Drug Delivery Device
Ahsan Noor Khan and Dingliang Wen (Queen Mary University of London, United Kingdom (Great Britain)); Yujie Liu (Queen Mary University of London & Antenna Group, United Kingdom (Great Britain)); Gleb Sukhorukov (Queen Mary University of London, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain))
Therapeutic treatment has been revolutionized in recent past with the advent of implantable drug delivery devices. These devices hold immense promise to treat chronic ailments, such as cancer tumours that require high drug concentration. A wireless system is an integral part of the device to regulate drug release according to prescribed dosing schedule. An antenna is important facet of a wireless system for data telemetry and receiving triggering signal from external transmitter that actuates the release mechanism. In this paper, we propose an ultra-subband conformal loop antenna on the capsule shaped device. The flexible layer of microchambers is also conformal around the inner shell of the capsule. The CST Gustav yosel human body model was used to perform numerical study of the antenna. According to the simulation results, the proposed capsule antenna has shown reflection coefficient of -11.83 dB at the desired frequency of 900 MHz.

9:50 A Multi-Functional Compact Button Antenna for Wearable Applications
Jiahao Zhang (KU Leuven, Belgium); Sen Yan (Xi’an Jiaotong University, China); Xiaomu Hu (KU Leuven, Belgium); Tomislav Marinovic (Katholieke Universiteit Leuven & Chalmers University of Technology, Belgium); Guy Vandebosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)
A multi-functional button antenna is designed, with dual-band and dual-polarization characteristics. This antenna is a dedicated design for wearable applications. A compact size button is achieved with a diameter of only 19.5 mm (0.79 in), which optimizes the users’ comfort. The proposed antenna works in the 4.5-4.6 uncumpliated future 5G communication band, and the 5.1-5.85 GHz WLAN band. Two radiation patterns with orthogonal linear polarizations are obtained in each band. The mutual coupling between the two patterns is below -20 dB. The antenna is prototyped. Simulations and experiments confirm the validity of this novel concept.

10:10 Coffee Break

10:40 Small Implanted Antennas for Wireless Communication and Energy Harvesting
Stavros Koulourdis (University of Patras, Greece)
In this work we visit implanted antennas designs that have focused on data telemetry and they occupy tiny volumes or antennas that can support both data telemetry and wireless harvesting without drastic size increase. Emphasis is placed on Sub-gigahertz region since it can support deep implantation and is more applicable for minimizing dissolution losses inside the human body.

11:00 Removable Finger Nail Antenna
Peter Nguo and Benito Sanz-Izquierdo (University of Kent, United Kingdom (Great Britain))
An antenna on a removable fingernail for iot applications in proposed. The antenna consist of patch design that is shaped around the artificial nail. Two fabrication procedures are tested. The first uses copper layers that are attached to the nail. The second is a more realistic scenario where the patch is painted by hand onto the inexpensive polymer material. The antennas operate at the 10GHz band and are intended for future on-body wireless communications systems. Tests were conducted on the antenna, first in free space and then on human body. The tests results from the brush-painted antenna compare well with those of the design on copper and the simulations. The antennas performance in terms of reflection coefficient and radiation pattern are satisfactory. CST Microwave Studio™Simulations were used for the simulations. This work aims to demonstrate a new concept of low-cost body antenna using finger nails.

11:20 Antenna for a Cranial Implant: Simulation Issues and Design Strategies
Alberto Jose Moreno Montes and Ismael Vico Trivino (EPFL, Switzerland); Marko Bosiljevac (University of Zagreb, Croatia); Miroslav J. Veljovic (EPFL, Switzerland); Zvonimir Sipus (University of Zagreb, Croatia); Anja K. S. Skrivervik (EPFL, Switzerland)
The design of a specific antenna for a cranial implant is used to illustrate design and simulation issues linked to implantable antennas. After a brief introduction, we will review the requirements for the antenna, and go through the design process, discussing the tools used and the issues encountered. The final design will then be presented and discussed.

11:40 Penta-band Dual-fed Smart Glasses IoT Antenna
Bing Xiao (The University of Hong Kong, Hong Kong); Hang Wong (City University of Hong Kong, Hong Kong); Kwan L. Yeung (The University of Hong Kong, Hong Kong)
The method of designing multi-band dual-fed smart glasses antennas is introduced in this paper. By utilizing the frame of glasses and applying the theory of characteristic mode (TCM), two ports with inductive coupler element (ICE) and capacitive coupler element (CCE) respectively that assign all characteristic modes on the wire antenna could be excited theoretically. Then by impedance matchings to the two ports respectively, the antenna could cover four ISM bands: 433 MHz, 915 MHz, 2400 MHz, and 5800 MHz. They are for the applications of Internet of Things (IoT): the low-power wide-area network (LPWAN) such as LoRa, Zigbee, and Sigfox, and RFID. Besides, in consideration of the function of positioning for smart glasses, GPS L1 band (1575 MHz) is also covered. This research facilitates smart glasses to serve as an IoT hub.

CS26: Education in Electromagnetics, Antennas, and Microwaves

T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics
Room: B4

Chairs: Ari Sihvola (Aalto University, Finland), Henrik Wallen (Aalto University, Finland)

8:30 Federated Non-Traditional Practical Work for Engineering Education
Timothy D Drysdale (The University of Edinburgh, United Kingdom (Great Britain))
Non-traditional practical work is conducted primarily with digital technologies, such as remote, simulated, and virtual laboratories, and is optionally used as a complement to, or extension of, existing traditional practical work. The increasing desire for more active learning in the higher education sector, coupled with increasing student numbers, means that it is impossible to meet the outstanding demand for practical work by using only traditional laboratory facilities alone. This paper gives a brief overview of the educational case for non-traditional practical work, before going to give an outline for a software architecture that would allow the federation of remote laboratory experiments between different institutions, which would be a valuable education tool in areas such as antennas and propagation where test and measurement equipment and test devices can be expensive, fragile, and difficult or problematic to access.

8:50 Teaching Wireless Communications Courses: An Experiential Learning Approach
Hugo G Espinosa (Griffith University, Australia); Thomas Fickenscher (Helmut Schmidt University, Germany); Nickolas Littman and David V Thiel (Griffith University, Australia)
Student engagement continues to be a major challenge, particularly in electromagnetics courses. This is independent of whether courses are compulsory or elective. This paper presents an approach to assessing students that provides them with an opportunity for experiential learning, following Kolb’s learning cycle. Final year students are required to develop and complete two experimental projects over the 12-week term. At the outset of each project, pairs of students choose a three-line project outline; projects are unique to each two-person group with an obscure but practical industrial outcome designed to complement the lecture material. To succeed, students must continue to discuss their project strategies, measurements and final applications with the teaching team throughout the trimester. Students have rated the course experience very highly, and in some cases, their projects have enhanced their post-graduation employment opportunities in the field directly related to one of their projects.

9:10 A Modern Approach to Teaching and Learning Electromagnetics at DTU
Samel Ahranlaroglu (Technical University of Denmark, Denmark)
We describe the implementation of a B.Sc. course in electromagnetics at the Technical University of Denmark which over a number of years has received very positive student evaluations. The student perceptions of what makes the course good are first outlined. Unsurprisingly, they emphasize a clear organization and structure of the course, as well as the professional skills and personality of its teachers, as the main assets of the course. No specific teaching methods ... of video problem tutorials of huge benefit to the students. Following their perceptions, the course structure is reviewed, with an emphasis on lectures, laboratory exercises, and particularly the successful video problem tutorials which are so tightly bound to the lectures.

9:30 Teaching Radar Systems: Wave Propagation, Scattering, Antennas, and Electronics
Daniel Sjöberg (Lund University, Sweden)
We present the outline of a course on Radar and Remote Sensing recently introduced at Lund University in Sweden. The lecture topics are briefly reviewed, as well as the labs and final examination in terms of a radar system design task. From this course, the students get an overview of typical radar systems requirements and trade-offs, as well as an insight into different subsystems and physical phenomena like wave propagation in a layered atmosphere and scattering from complex targets.
9:50 Grading Written Exams in Electromagnetic Theory: Depth Versus Width
Martin Norgren (KTH Royal Institute of Technology, Sweden)

In grading of written exams, the requirement that the passing grade reflects satisfactory performance in all intended learning outcomes has been handled in the calculation of the exam score. Without changing the structure of the exam itself, the score is calculated using a simple formula which emphasises width over many tasks, instead of depth in a few tasks. Grading results using the new approach have been compared against results from an earlier exam summation approach. Somewhat unexpectedly, the new approach has resulted in an improved passing rate and a substantial increase of the highest grade. A possible explanation is that the students are aware of the sharpened requirements, right from the start.

10:10 Coffee Break

10:40 Modern Challenges for EE Students Pursuing Fundamental Research in Metamaterials
Ashwin K. Iyer (University of Alberta, Canada)

Electronic engineering students considering fundamental research in metamaterials today may perceive challenges, ranging from the overwhelming diversity and breadth of the field following 20+ years of growth to questions about the applicability of their work and their own employability. This article provides some observations on these and other topics with the hopes of assuring young students that the field of metamaterials remains full of opportunity and, with a good amount of hard work, one can derive a satisfying and productive research career from it.

11:00 Advanced Teaching in Electromagnetics at the ELEDIA Research Center
Nicola Anselli (ELEDIA Research Center, Italy), Renzo Azano (Eledia Research Center, Italy), Federico Boulou (ELEDIA@UniTn - DISI, University of Trento, Italy), Luca Dall'Asta (ELEDIA Research Center, Italy), Giorgio Gottardi and Mohammad Hannan (ELEDIA Research Center, University of Trento, Italy), Baozu Li (Nanjing Normal University, China), Giulia Mansutti (Università degli Studi di Padova, Italy), Davide Marcenaro (ELEDIA Research Center, Italy), Giacomo Oliveri (University of Trento & ELEDIA Research Center, Italy), Lorenzo Poli and Alessandro Polo (ELEDIA Research Center, University of Trento, Italy), Paolo Rocca (University of Trento, Italy), Marco Salucci (ELEDIA Research Center, Italy), Andrea Massa (University of Trento, Italy)

An entire long-term educational framework has been designed and implemented by the ELEDIA Research Center to (i) renew the way of teaching electromagnetics (EM) to future engineers and (ii) increase students' self-confidence and admiration of the applicative and technological aspects of Maxwell's equations. According to authors' expectations and received students' feedback, such a training ecosystem will help a computer-engineer-oriented thinking mechanism and attitude for continuously adapting to technological advances in EM leading-edge research and industry.

11:20 Brewster Angle and Vanishing Polarization of Waves Reflected by Conductor-Backed Water Slab
Hsinju Chen and Shin-Yuan Chen (National Taiwan University, Taiwan)

For ease of visualization of Brewster angle, we set up a simple experiment with copper-backed water slab to show near-full transmission of parallel polarization. Using a circularly polarized microstrip patch antenna connected to a portable USB signal generator as the transmitter and a linearly polarized patch with a portable USB spectrum analyzer as the receiver, the low parallel polarization reflection is observable at the pseudo-Brewster angle, calculated with undergraduate-level electromagnetic theory. With the help of the experiment, the effect is intuitively understood and easily reproduced by students in classrooms.

11:40 Teaching Applied Mathematics for Electromagnetics as an Example of a Simple Stopping Problem
Nikolaos L. Tzitzas (Aristotle University of Thessaloniki, Greece), George Pikionis (National Technical University of Athens, Greece)

In this paper, combined techniques from Complex Analysis, Fourier Transforms and Compact Operators are applied to investigate convergence properties of the solutions of a simple two-dimensional scattering problem. It is shown how basic tools of Applied Mathematics can aid the understanding and the gain of physical insight on the behavior of the scattering fields.

12:00 In Favor of Re-Introducing and/or Expanding Rectangular Waveguides in Bachelor's and Master's Level Electromagnetic Courses
Mariangela Baggio and Zachary D Taylor (Aalto University, Finland)

This paper makes a case for the continuing inclusion of rectangular waveguides in bachelor and master's level electromagnetics education. Modern training in electromagnetics, especially in preparation for industry careers, often excludes rectangular waveguide theory. We believe that this theory is a concise and efficient way to teach broader wave propagation concepts and thus should be included in most curricula despite its continued drop in popularity.

CS47: Non-Magnetic Nonreciprocity

11:00 15

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8:30 Nonreciprocal Metasurfaces Through Circular Polarization Biasing
Dimitrios Sounas (Wayne State University, USA)

We show that spatiotemporally modulated metagratings can lead to strong nonreciprocal responses, despite the fact that the metastructures are not biased by time-modulated electric fields. This approach is realized using time-modulated capacitances on wire metagratings loaded with time-modulated capacitances. We use the discrete-dipole-approximation and an ad-hoc theory to calculate the transmission responses and compare them to the experimental data. The agreement between experiment, theory and simulation is striking. Our results open the door to the design of efficient and compact nonreciprocal devices for applications in wireless communications.

8:50 Quad Magnet-free Micro-acoustic RF Circulator with Internodulation Suppression
Yao Yu (Northeastern University, Boston, MA, USA), Matteo Rinaià (Northeastern University, USA)

In this paper, a new type of micro-acoustic RF circulator is presented. The circulator is fabricated using rectangular waveguide technology and is composed of two microstrip delay lines and two resonant cavity filters. The delay lines are fed by four microstrip line sections, which are excited by the input and output ports. The resonant cavity filters are used to provide the required frequency response. The circulator is shown to have a low insertion loss of 0.5 dB and a high isolation of 20 dB at 10 GHz.

9:10 Low Loss, CMOS Integrated, Magnetic-Free Non-Reciprocal Components Operating from Radio Frequencies to Millimeter-Waves
Aravind Nagula and Harish Krishnaswamy (Columbia University, New York, USA)

Magnetic-free non-reciprocity using time-varying fields has gained a lot of attention in recent years. One major advantage of magnetic-free non-reciprocity is that it does not require a complicated biasing network. The pumps are selected to have opposite polarizations and slightly detuned frequencies. The metasurface is designed to exhibit a third-order nonlinear response and nonreciprocity is the result of a four-wave mixing mechanism between the pumps and the incident signal. The metasurface exhibits nonreciprocal polarization rotation and it can be used as a building block for free space circulators and isolators.

9:30 Space-Time Modulated Loaded-Wire Metagratings for Magnetless Nonreciprocity
Yakir Hadad (Tel-Aviv University, Israel)

We propose a new approach for achieving nonreciprocal components using space-time modulation. The approach is based on the fact that the nonreciprocal response of a loaded wire metagrating is determined by the combination of the space and time components of the incident wave. By carefully designing the space and time modulations, we can achieve a nonreciprocal response without the need for a complex biasing network. The proposed approach has the potential to be used in a variety of applications, including microwave and millimeter-wave communication systems.

9:50 Nonreciprocal Antennas Based on Time-Modulation: Challenges and Opportunities
Alejandro Alvarez-Melcon (Technical University of Cartagena, Spain), Juan Sebastián Gomez-Diaz (University of California, Davis, USA)

We explore the possibility to realize nonreciprocal antennas based on combining time-modulated resonators with high-Q structures. Using an adequate low-frequency modulation scheme, such configuration enables very efficient frequency conversion between only two frequencies (one related to guided signals and another to waves in free-space) and empowers nonreciprocal phase control of the generated waves through the photonic Aharonov-Bohm effect. This approach is applied to demonstrate the nonreciprocal and reconfigurable antenna configurations, including phased arrays able to independently control transmission and reception radiation patterns at the same operation frequency, reflecting antennas, and planar Yagi-Uda filter antennas. We discuss the exciting functionalities and benefits enabled by this technology and provide a critical assessment of challenges that remain to be addressed in real-life applications. We envision that this paradigm will pave the way to a magnetic-free, fully integrated, and CMOS-compatible technology with profound implications in communication and wireless systems, sensing, imaging, and on-chip networks.
The exact and unambiguous knowledge of the dielectric and thermal properties of biological tissues is of fundamental importance for the design of electromagnetic medical devices as well as for the open ended coaxial probe and the vector network analyzer setup. In this work, we replace the traditional VNA from (National University of Ireland, Galway & Translational Medical Device Lab, Ireland) with a novel microwave transceiver. The microwave transceiver uses a novel broadband, multi-tone source and broadband receiver to capture the instantaneous S-parameters at multiple tones simultaneously. We conducted dielectric property measurements on solutions which have shown dielectric properties using our modified setup and compared the results with theoretical values. We also conducted the same measurements with the standard setup with the swept frequency VNA and compared the performances of the two setups. We concluded that the microwave transceiver can provide faster measurement speeds than the conventional VNA without sacrificing precision and accuracy.

9:50 Investigation on Temperature-Dependent Changes of Tissue Thermal Properties on Microwave Ablation Treatments
Marta Cavagnano (Sapienza University of Rome, Italy); Rosanna Pinto (ENEA, Italy); Vanni Lopresto (ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Italy)

Microwave thermal ablation techniques induce coagulation necrosis of diseased tissue through the absorption of an electromagnetic field at microwave frequencies. In particular, the electromagnetic field absorbed by the tissue induces a temperature increase that, in turn, produces an almost instantaneous cellular death. The electromagnetic field is radiated by a minimally invasive antenna located in the centre of the diseased area. Temperatures close to 60 °C are needed to induce thermal ablation, so that very high temperatures (up to 100 °C or higher) can be achieved close to the radiating antenna. To develop reliable intervention protocols, numerical tools able to correctly predict the temperature increase are needed. In this work, we studied the dielectric properties of biological tissues as a function of the temperature from 30 °C to 45 °C. The results show that the temperature has a significant influence on the dielectric properties of the tissues.

9:10 Thermal Properties of Ex Vivo Biological Tissue at Room and Body Temperature
Nuno P. Silva (National University of Ireland Galway & Faculdade de Ciências da Universidade de Lisboa, Portugal); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Martin O’Halloran (National University of Ireland, Galway, Ireland); Antonio Grbic (University of Michigan, Ann Arbor, USA)

The temperature dependency of the dielectric properties of tissues is a very important aspect of the design of microwave ablation systems. This work presents an experimental investigation of the dielectric properties of biological tissues as a function of the temperature from 30 °C to 45 °C. The results show that the temperature has a significant influence on the dielectric properties of the tissues.

9:30 Advanced Temperature Dielectric Spectroscopy of Muscle Phantom at Microwave Frequencies
Ondrej Fiser, Jr. (Czech Technical University in Prague & Faculty of Biomedical Engineering, Czech Republic); Michaela Kantová (CTU in Prague, Czech Republic); Sebastian Ley, Alexandra Prokhorova and Marko Helbig (Technische Universität Ilmenau, Germany); Jan Vrba (Czech Technical University, Czech Republic)

The results show that the temperature has a significant influence on the dielectric properties of the tissues. The measurements were performed in the frequency band 0.1 - 3 GHz and in the temperature range 25 - 45 °C. The differences in the dielectric parameters caused by temperature change were analyzed and compared with the reference.

Dielectric Properties of Biological Tissues at Frequencies Below 1 MHz: Development of an Improved Measurement Technique
Azadeh Zabihnejad (Public Health England, United Kingdom (Great Britain)); Nithsha Chopra (UK Government, United Kingdom (Great Britain))

At low frequencies, the dielectric values for biological tissues are difficult to determine due, at least partly, to the dependence of the dielectric properties on the physiological state of the tissue and changes occurring after death. In practice, chemical interaction between the measuring device and the tissue can cause severe errors and uncertainties in the results. In this work, we aim to develop an advanced black-platinum four-point electrode probe technology to measure impedance values of low concentration saline solutions, which have been identified at least one major source of error namely, electrode polarisation and some other high-frequency effects as measurement artefacts that made the capacitive part of the dielectric data unreliable.

10:00 Coffee Break

10:40 A Spatio-Temporally Modulated Metasurface as a Free-Space N-Path System
Francesco Desogus (Instituto Superior Técnico-Instituto de Telecomunicações, Portugal); Mario Silveirinha (Instituto de Telecomunicações, Portugal); Nuno P. Silva (National University of Ireland Galway & Translational Medical Device Lab, Ireland); Anna Bottiglieri; Laura Farina (University of Pavia, Italy); Rosanna Pinto (ENEA, Italy); Vanni Lopresto (ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Italy)

A novel cloak consists of a non-reciprocal space-time modulated metasurface that allows manipulating the apparent velocity of a moving object that induces an artificial frequency shift in the reflected signal. In this contribution, we present two Doppler cloaks: one implemented through a spatio-temporal (ST-) metamaterial cover wrapped around or just in front of the object, and one implemented through a time-varying metasurface. We show that, by properly choosing the modulation scheme and frequency of the space-time modulated metamaterial, it is possible achieving a full compensation of the Doppler frequency shift, making the composite system appearing to an external observer as stationary, even though it is actually moving. The Doppler cloak may have a large impact also in other applications, such as restoration of electromagnetic invisibility and antenna matching in moving systems, just to name a few.
10:00 Extracting Dielectric Properties for MRI-based Phantoms for Allied Microwave Imaging Device

Daniele M. Godinho (Instituto de Biologia e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); João M. Felício (Instituto de Telecomunicações, Portugal); Tiago Castela (Departamento de Radiologia, Hospital da Luz Lisboa, Lisboa, Portugal); Nuno Silva (Hospital da Luz Learning Health, Lisboa, Portugal); M Lurdes Orvalho (Departamento de Radiologia, Hospital da Luz Lisboa, Lisboa, Portugal); Carlos A. Fernandes (Instituto de Telecomunicações, Instituto Superior Tecnico, Portugal); Raquel C. Conceição (Instituto de Biologia e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal).

Microwave Imaging (MMI) is an emerging medical imaging technique, which has been studied to aid breast cancer diagnosis. The information about the dielectric properties of each tissue is essential to assess the viability of this type of systems. However, accurate measurements of heterogeneous tissues can be very challenging, and the current available solutions show an error very limited. In this paper, we present a methodology for extracting dielectric properties to create anatomical models of the anatocic area. These models will be used in a MRI device to aid breast cancer diagnosis through the detection of metastasized axillary lymph nodes. We apply segmentation tools to Magnetic Resonance Images of the breast and implement a novel dielectric properties extraction technique, extracting preliminary information about the properties of axillary lymph nodes. This study may open up a new way to more quickly extract dielectric properties of tissues and/or validate measurements, accelerating the development of microwave-based medical devices.

11:20 Broadband Dielectric Measurements of U-Shaped Urethane Fibrods Over the Ablative Temperature Range

Ghina Zia (Kansas State University, USA); Jan Sekcob (Kansas State University & Czech Technical University, USA); Punet Prakash (Kansas State University, USA).

Microwave ablation is under consideration as an energy modality for minimally-invasive treatment of urethral fibroids. Computational models of microwave ablation are useful for guiding the design of new devices and systems, but require tissue dielectric properties, including their variation at elevated temperatures, for accurate prediction of ablation profiles. This study reports on preliminary results of a study on experimentally-characterized broadband 0.5-6 GHz dielectric properties of surgically excised urethral fibroids, with measurements taken at temperatures up to 153 °C. The measured dielectric properties at elevated temperatures dropped considerably, likely due to the effects of tissue dehydration and water vaporisation, similar to reports of dielectric property measurements for other tissues.

11:40 Microwave Calaneus Phantom for Bone Imaging Applications

Bilal Arin (National University of Ireland, Galway & Translational Medical Device Lab, Ireland); Daniel Kelly (School of Medicine, National University of Ireland Galway, Ireland); Atif Shahzad, Martin O’Halloran and Muhammad Adnan Elahi (National University of Ireland, Galway, Ireland).

Microwave imaging can be used as an alternative modality for monitoring bone health. Dielectrically accurate, anthropomorphic phantoms play vital role in testing of imaging prototype prior to clinical applications. This paper presents multilayered 3D printed human calaneus structure. Further, we have proposed liquid based tissue phantoms that mimic the dielectric properties of skin, muscle, cortical bone and trabecular bone. Trabecular phantoms are composed of Triton X-100, water and salt. The dielectric properties were measured across 0.5-8.5 GHz. Each layer of the 3D printed structure was filled with corresponding tissue phantom. The combined average percentage difference between dielectric properties of reference data and proposed tissue phantoms was found to be 2.9% for trabecular bone, 7.3% for cortical bone, 7.1% for skin and 8.7% for skin over the full measured frequency range. These tissue phantoms and 3D printed human calaneus structure can be used as valuable test platform for microwave diagnostic studies.

12:00 Dielectric Properties of Tissue Histological Aspects and Measurement Challenges

Azadeh Peyman (Public Health England, United Kingdom (Great Britain)).

This paper reviews and summarises the state of knowledge on dielectric properties of tissues. Effect of ageing and pathological state of tissues on the dielectric properties are discussed as well as the impact of variation in dielectric properties on the outcome of dosimetric studies. A critical analysis of the existing measurement techniques and uncertainty evaluation on the measured data are also presented. Finally, some unpublished data on dielectric properties of porcine abdominal tissues will be presented in light of rise in popularity of diagnostic imaging techniques utilising RF signals, and increase in demand for accurate in-vivo dielectric properties of abdominal tissues.

T06-A17: Automotive Antennas

T06 (Incl. UAV, UAS, RPAS) and automotive / Regular Session / Antennas

Room: B7

Chairs: Jihun Choi (Army Research Lab & Booz Allen Hamilton, USA); Johan Wettengen (Qamcom Research and Technology, Sweden).

8:30 Transparent Glass Antenna for 28 GHz and Its Signal Reception Characteristics in Urban Environment

Mihoro Inomata (NTT DOCOMO, INC., Japan); Toshihito Sayama and Takeshi Motegi (AIC Inc., Japan); Osamu Kagaya (ASAHI GLASS CO., LTD., Japan); Hideaki Shoji (ASIC Asia Glass, Japan); Shoichi Takeuchi (AIC Inc., Japan); Kiyoshi Nodowa (AIC Inc., Japan).

This paper proposes a transparent glass antenna for the 28 GHz band for 5G connected vehicles in an urban environment. Comparison results between the distributed transparent glass antennas and an om-directional antenna show that the relative received power for the glass antenna is higher than that for the om-directional antenna. In addition, results show that the relative received power when using a vertically and horizontally polarized antennas are approximately the same. Therefore, we actualize a transparent antenna that maintains the high antenna gain and om-directional antenna pattern using vertical and horizontal polarization when installed on the wheels.

8:50 Optically Transparent Antenna Integrated Inside a Headlamp for Automotive Radar Application

Sofian Harid and Dirk Heberling (RWTH Aachen University, Germany); Manuela Junghänel and Thomas Preussner (Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology, Germany); Patrick Gretzki, Ludwig Pongratz, Christian Hördemann and Arnold Gilber (Fraunhofer Institute for Laser Technology, Germany).

A concept for integrating antenna inside a headlamp for automotive radar application is presented. The antenna comprises the primary (feed), which is embedded within the electronic unit, and the secondary one, which is made of transparent materials. The primary antenna can be the conventional one (e.g., patch, slot, sectoral horn), which is optically non-transparent. It is hidden from the optical path of the headlight. The secondary antenna is realized as a planar offset reflector, which is designed to collimate or reshape the wave from the primary antenna. It is inserted in the space between the headlamp cover and the light unit. An antenna demonstrator has been fabricated, and together with the headlamp cover, the radiation pattern and realised gain are measured. We reported here the measured results for several configurations and concluded that the headlamp cover gives minimal influence on the antenna performance.

9:10 A Capacitively Coupled Patch Antenna Array for an Enlarged Bandwidth at 77 GHz

Jonathan Mayer (Karlsruhe Institute of Technology, Germany); Manuel Martina (Schweizer Electronic AG, Germany); Jerzy Kowalewski (Karlsruhe Institute of Technology, Germany); Jie Chen (Schweizer Electronic AG, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany).

Today’s automotive radar systems are currently equipped with serial-fed patch antennas. However, they lack on a too low bandwidth for the whole available bandwidth of 5 GHz. This paper introduces a new antenna principle using capacitively fed patches besides the feeding line with different resonance frequencies. This allows an enlarged bandwidth compared to serial-fed patch antennas without the need for additional layers in the printed circuit board (PCB). The antenna in this work has 12 patch elements and a gain of 10.0 dB over more than 5 GHz bandwidth while the side-lobe suppression is at least 15 dB. For the manufacturing of the antenna an embedded technology with a high resolution was used.

9:30 Broadband Frequency Reconfigurable Antenna Using Capacitive Loading for K-band Applications

Muhammad S. Anwar and Axel Bangert (University of Kassel, Germany).

A novel reconfigurable antenna in K-Band frequency is presented. The antenna employs a simple capacitive loading technique to increase the -10 dB bandwidth by 2.5 times (+102%). The proposed antenna is designed at the frequency of the unloaded state operating at 24.2 GHz (1.8GHz bandwidth) and the loaded state at 24.5 GHz (4GHz bandwidth).

Antenna gain of 12 dB and 6 dB for unloaded and loaded configuration, respectively, are recorded. The directivity of the antenna is optimised by using reflectors and directors. Radiation pattern distortion caused by capacitive loading is corrected by using a dielectric lens. The designed frequencies are used in automotive radar. A narrow band centered at 24.2 GHz is used for Adaptive Cruise Control (ACC) and Lane Change Radar (LCR). A broadband centered at 24.5 GHz is used for Short Range Radars (SRR). The proposed design shows an excellent agreement between the simulated and measured results.

9:50 An Efficient Low-Profile Low-VHF Antenna for Small Unmanned Ground Vehicles

Jihun Choi (Army Research Lab & Booz Allen Hamilton, USA); Fikadu Dagefu (US Army Research Laboratory, USA); Brian Sadler (Army Research Laboratory, USA).

A compact, low-profile, efficient, low-VHF antenna designed for small UGV systems is presented. In order to achieve further gain enhancement from a recent development in an electrically small efficient monopole antenna, a new design approach is proposed. A single 180 degree phase shifter comprising a common capacitive top loading and multiple high-Q air-core coils connected to each corresponding short vertical element is designed to produce in-phase radiating fields from the multiple vertical elements at resonance, thereby considerably enhancing the antenna gain. Under practical considerations, performances of the antenna before and after integrating it on a small UGV are carefully characterized via simulations and measurements. The results show that a peak gain of the antenna integrated on the UGV with omnidirectional radiation pattern is 0.7 dB which is comparable to that of a monopole dipole whose height is 7.5 times larger, facilitating low-power wireless compact UGV communications and networking at low VHF.

10:10 Coffee Break

10:40 A Triband Wire Antenna for All Radio and TV Bands

60 of 128
A triband rod antenna is presented. It is intended for reception of AM, FM, DAB and TV in vehicles. The antenna uses coil traps to facilitate multiple resonant lengths in order to be matched to 50 Ohms for frequency bands centred at 97, 204 and 571 MHz. In fact, it features a double resonance in the quite broad 470-694 MHz TV band. Difficulties in computer simulations of antenna match are discussed, a design methodology is suggested and measurements on a broadband model are presented.

A planar Magic-T is proposed based on E-plane groove gap waveguide for Ka-band applications. All four ports of the Magic-T are co-planar and E-plane groove gap waveguide. The frequency bandwidth of the proposed Magic-T is about 45% covering the whole Ka-band from 26 GHz to 40 GHz. The Magic-T isolation is better than 42 dB in the whole bandwidth while its insertion loss is about 0.1 dB.

Numerical simulations are used more and more to investigate the behavior of RF antennas and wireless systems in automotive industry and to ensure their optimum functionality on the early stages of the vehicle development. This paper shows how 3D simulations help evaluate the impact of the immediate environment of the RF access receiver and its harness connections on the antenna performance, reflection coefficient and bandwidth.

A three port circular patch antenna has been designed to provide pattern and polarisation agility at an operating frequency of 2.4 GHz. Independent excitation of the antenna modes TM01, TM10 and TM11 has been demonstrated, and, by combining these modes, beamsteering has been achieved. The improved directivity of this antenna design at low elevation angles has been confirmed through full-wave simulations. A directivity of 2.5 dB has been achieved at the horizon through this beamsteering method compared to 4.2 dB for the TM11 and TM01 modes and 0.7 dB for the TM01 mode at the same angle. A discussion of the active impedance and its implications for impedance matching is also included.

Fannush Shofi Akbar and Gamantyo Hantoro (Institut Teknologi Sepuluh Nopember, Indonesia); Leo P. Ligthart (em. prof. Delft University of Technology & Universitas Indonesia, Beijing Institute of Technology, ITS Surabaya, The Netherlands); Ioan E. Delft University of Technology, The Netherlands.

An advanced design adding a first side lobes level (FLS) improvement to a previously introduced wide-angle scanning, linear array prototype with demonstrated scan-loss compensation (SLC) and side lobes suppression features is described. The linear array makes use of in-line subarrays for SLC and an additional amplitude taper in its central, uniform region for lowering the FLS with as much as 4dB at 60° scanning (13dB at 22° scanning). Several linear-type amplitudes are compared, the best overall performance improvement being observed for a -18dB prototype taper. The advocated solution is highly suitable to high-sensitivity radars requiring a fast scanning, fan shaped beam.

8:30 Towards a Si/GaAs Based Flat-Panel Quad-Optical Metasurface Antenna with Switchable Beam Charactersitics
Okan Yurduseven (Queen’s University Belfast & Duke University, United Kingdom (Great Britain)); Choonsoo Lee (JPL, USA); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Maarten van der Vorst (NASA-JPL/Caltech, USA).

We present an analytical technique of large waveguide antenna structures as used for a future proposed spectrometer instrument called SAFARI part of the ESA/JAXA proposed mission SAFI (Space Infrared Telescope for Cosmology and Astrophysics) mission [1], collaboration between Europe and Japan. The SAFARI (SPICA JAXA Infrared Instrument) instrument is an imaging grating spectrometer optimized to operate between 1.5 to 10 THz. SAFARI (high-resolution spectrometer) will use Transition Edge Sensors (TES) to detect this weak THz signal and use large multimode waveguide antennas and integrating carriers to maximize optical coupling from the optics to these sensitive detectors. We present a modal analysis outline of these focal plane antennas. Measurement campaigns of these waveguide structures at the Space Research Organization, the Netherlands, and at Cardiff University will ultimately be used to verify this simulation technique outlined here.

8:50 Analysis Methods for Multimodal Homs for Future THz Missions (SAFARI Instrument for SPICA)
Neil Trape (NUI Maynooth, Ireland); Sert de Lange (SRON Netherlands Organization for Space Research, The Netherlands); Creidhe O’Sullivan (National University of Ireland Maynooth, Ireland); Maarten van der Vorst (European Space Agency, The Netherlands); Marcin Gradziel (National University of Ireland, Maynooth, Ireland); Michael Audley (SRON Netherlands Organization for Space Research, The Netherlands); Peter Ade (Cardiff University, United Kingdom (Great Britain)).

In this paper we present the design and development of a 16-element submillimeter-wave array instrument using Ti:sapphire technology. We show that this instrument concept demonstration and component development dramatically simplifies the fabrication, assembly, and integration of large focal plane arrays at these frequencies. This advancement is enabled by the innovative array architecture with silicon-micromachined based antenna arrays, highly sensitive Si mixers at these frequencies, integrated SiGe BiCMOS based low-noise intermediate frequency (IF) amplifiers, and silicon micromachined packaging.

9:30 Effect of Metal Resistive Losses on the Gain of a THz Planar Spiral Antenna
Elliot Brown (2565 Vagview Drive, USA); Kerots Ato Atdabalam (Universidad Carlos III de Madrid, Spain); Weidong Zhang (Wright State University, USA).

In this paper we present a new millimeter-wave metasurface antenna that can operate in the terahertz spectrum. The antenna is designed to achieve high-impedance, high-directivity, high-gain, and high-efficient. A detailed simulation and measurement results are presented.

9:50 Compact Millimeter and Submillimeter-Wave Photonic Radiometer for Cubesats
Michal Grzegorz Wasiak (Carlos III University of Madrid, Spain); Gregorio Siguer (Universidad Carlos III de Madrid, Spain); Florian Sedlmier and Alfredo Rueda (Max Planck Institute for the Science of Light, Germany); Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain).

In this paper we present a new millimeter-wave metasurface antenna that can operate in the terahertz spectrum. The antenna is designed to achieve high-impedance, high-directivity, high-gain, and high-efficient. A detailed simulation and measurement results are presented.
Microwave imaging has been explored for use in medical diagnostics for over 40 years. While advantages related to the use of non-ionizing radiation and low-cost hardware make the technology very promising, it has yet to be deployed clinically, possibly due to low resolution and extensive computational costs. Here, we present images of breast-tissue phantoms obtained with a recently developed real-time imaging method, quantitative microwave holography (QMH), with a comparative fashion with those obtained with a conventional compressive sensing (CSE) approaches.

A novel phaseless Gauss-Newton inversion inverse scattering algorithm is presented and extended with three forms of regularization, i.e., Total Variation, Tikhonov, and Total Least Squares. It is shown that the presented algorithm, along with regularization, can invert experimental data, and can be adaptively defined based on the evolution of the inverse scattering problem solution during inexact-Newton iterations. In this paper, we will describe the SWI radiometer front-end system and address the different procurement steps of the flight instrument (SWI) is a spectrometer/radiometer instrument operating in two submillimeter channels between 530 - 625 and 1080 - 1275 GHz. This paper gives an overview of the instrument optics and describes the results of Monte Carlo simulations that have been performed to determine the adverse effect of mounting tolerance of relay optics to the instrument far-field performance. Further, instrument thermal contraction based on predicted mission temperatures has been included in the optical model and its effect on the far-field performance of various states has been evaluated. Finally, the electromagnetic models made of Albedos from corners and potentially reduces the reflection loss by providing a lower surface resistance than the base material.

The need for non-destructive food testing has received increasing attention with the rapid global growth in food demand. There is an increasing interest in modifying existing quality assessment procedures to decrease product wastage and increase the safety of the food supply. In this paper we present images of breast-tissue phantoms obtained with a recently developed real-time imaging method, quantitative microwave holography (QMH), with a comparative fashion with those obtained with a conventional compressive sensing (CSE) approaches.

A novel Compressive Processing (CP) method is presented for an effective solution of inverse scattering problems jointly addressing the sampling problem of the scattering field data and the sensing problem related to the retrieval of the unknowns scatterers within a contrast source framework. Representative numerical results are presented in a comparative fashion with those obtained with a conventional compressive sensing (CSE) approaches.

The Optical Combiner of QUBIC: The Q & U Bolometric Interferometer for Cosmology

An inverse scattering procedure working in the unconventional Lebesgue spaces with variable exponent is considered in this paper. In this method, instead of adopting a single and constant value of the exponent, a variable function is adaptively defined based on the evolution of the inverse scattering problem solution during inexact-Newton iterations. In this paper we present images of breast-tissue phantoms obtained with a recently developed real-time imaging method, quantitative microwave holography (QMH), with a comparative fashion with those obtained with a conventional compressive sensing (CSE) approaches.
10:10 Coffee Break

10:40 Machine Learning for Microwave Imaging
Michele Ambrosanio (Università di Napoli Parthenope, Italy); Stefano Franceschini (University of Naples Parthenope, Italy); Fabio Basile (Università degli Studi di Napoli Parthenope, Italy); Vito Pascacio (Università di Napoli Parthenope, Italy)

This paper proposes a fully-connected artificial neural network (ANN) approach for addressing the full-wave inverse scattering problem in a quantitative fashion. The proposed scheme processes the scattered field samples collected at receiver locations and provides an output estimate of the unknown complex permittivity in strongly non-linear scenarios. The proposed approach requires a proper training step, which is also addressed via an automatic randomly-shaped complex profile generator inspired by the statistical distribution of breast biological tissues, and is almost real-time in the recovery step. Several representative numerical tests were carried out to evaluate the performance of the proposed method and to validate the use of ANN for quantitative imaging purposes in biological-inspired scenarios.

11:00 Wiping Method for Probe Location in near/for Field Transformation
Maria Antonia Maisto and Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy); Rocco Pieri (Università della Campania Luigi Vanvitelli, Italy)

In this paper, planar near field measurement techniques are addressed. In particular, a strategy to collect the near field data which allows to decrease the number of measurements and to foresee the plane wave spectrum within the valid angular region recently introduced in [10] is illustrated.

11:20 Microwave Imaging Device for In-Line Food Inspection
Marco Ricci (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

Foreign body contamination is a key issue in food production and packaging industries. The constant increase of mechanized process chain, the variety of materials employed during the production and the growing consumer awareness about food quality assure the number of complaints in the recent years. Several technologies are applied to assure that products are free from contaminations, but they may fail in detecting low-density glass or plastic fragments. In relation to this, we developed a microwave imaging system and it is composed of different parts. Based on theoretical considerations and as shown by numerical examples, the approach is capable of retrieving accurate shapes, which is particularly interesting when imaging complex shaped target. In this paper, we limit ourselves to the utilization of the multiplex parallel to the axis. We implement rigorous analytical expressions describing the first three multiplex orders to improve the accuracy. As a test bed we analyze a centered and an offset star-shaped object in the presence of noise. Such a meaningful case, satisfying results have been obtained.

12:00 Microwave Imaging Profilometry for Plasma Diagnostics
Karunakaran Shruhti (ISIN Institutions, India); Giuseppe Torrisi and David Mascalci (INFN-LNS, Italy); Nagaradjane Prabagarane (SSNCE, India); Gino Sorbello and Loretto Di Donato (University of Catania, Italy)

Microwave imaging can provide effective means for non invasive electromagnetic diagnostics of plasma showing several advantages with respect to traditional techniques. Although microwave imaging entails solving of a full wave inverse scattering problem, it can be addresses in a less complex (but not simple) way considering the one dimensional inverse scattering problem for microwave imaging profilometry (MIP). In this contribution we describe a frequency difference domain approach for MIP and provide a possible 3D full wave experimental setup in order to make a step forward application of MIP against laboratory experimental data.

Wednesday, 18 March 8:30 – 10:10

T11-P02/2: Machine Learning in Radio Propagation

8:30 VoglerNet: Multiple Knife-Edge Diffraction Using Deep Neural Network
Viet-Dung Nguyen (ENSTA Bretagne, France); Huy Phan (University of Kent, United Kingdom (Great Britain)); Ali Mansour and Arnaud Coatany (ENSTA Bretagne, France)

Multiple knife-edge diffraction estimation is an important problem in wireless communication. One of the most well-known algorithms for predicting knife-edge diffraction is Vogler algorithm which has been shown to reach the state-of-the-art results in both simulation and measurement experiments. However, it cannot be easily used in practice due to its high computational complexity. In this paper, we propose VoglerNet, a data-driven diffraction estimator, by converting the Vogler algorithm into a deep neural network based model. To train VoglerNet, we propose to minimize a regularized loss function using Levenberg-Marquardt backpropagation in conjunction with a Bayesian regularization. Our numerical experiments show that VoglerNet provides fast solution in order of milliseconds while its performance is comparable to that of the classical Vogler algorithm.

8:50 Study on Radio Propagation Prediction by Machine Learning Using Urban Structure Maps
Tatsuya Nagao and Takahiro Hayashi (KDDI Research, Inc., Japan)

In recent years, mobile data traffic has been increasing, and high-quality mobile communication services are required. Therefore, it is essential to understand the radio propagation characteristics in an actual environment. In this paper, we propose a method of predicting radio propagation characteristics by machine learning called gradient boosting, in which the feature is the building information around a transmission point and a receive point, which affects radio propagation characteristics. Gradient boosting is a method of constructing a prediction model using a plurality of weak learners, and it is possible to output the importance of the input feature. That is, it is possible to quantify which feature had a large impact on the radio propagation prediction, and to verify the validity of the model. We evaluated the prediction accuracy using the measured data in an urban area, and clarified the effect of the difference of the feature on the accuracy.

9:10 A Novel Machine Learning Approach of Hemorrhage Stroke Detection in Differential Microwave Head Imaging System
Mohammad Ojaroudi (University of Limoges/CNRS, France)

In this paper, brain hemorrhage stroke detection approach using microwave-imaging system with a novel machine-learning based post-processing method is presented. In order to create a circular array based microwave imaging system sixteen elements of the modified bowtie antennas are simulated in CST medium around the full head phantom. In order to radiate in desired band from 0.5 GHz an appropriate matching medium is designed. In addition, a hierarchical preprocessing method is employed to calibrate the reflected signals. In the first processing, a fullwave inverse-reconstructing algorithm is used. Finally, a new machine learning technique including discrete wavelet transform (DWT) and principle component analysis (PCA) for feature extraction and reduction, respectively. In addition, support vector machine (SVM) is employed. Simulated results are presented to validate the effectiveness of the proposed method for precisely localizing and classifying bleeding targets.

9:30 A Study on the Variety and Size of Input Data for Radio Propagation Prediction Using a Deep Neural Network
Takahiro Hayashi, Tatsuya Nagao and Satoshi Itou (KDDI Research, Inc., Japan)

Not only has the volume of mobile traffic been increasing exponentially, making various services available, such as IoT and connected cars have also become necessary; moreover the quality of these services has to be extremely high. As a result, it is necessary to clarify the complicated characteristics of radio propagation. In this paper, we describe radio propagation prediction using a deep neural network (DNN) that can regress to non-linear functions without having to derive complex functions. DNN can learn the features needed for problem solving from input data and other world knowledge, and it is possible to learn the environment parameters required for propagation prediction from spatial information that is input such as map data. Based on the evaluation results of propagation prediction using DNN with measurement data in an urban area, we clarify the relationship between the variety and size of input data from the viewpoint of estimation accuracy and computational complexity.

9:50 Microwave Tomography for Estimating Moisture Content Distribution in Porous Foam Using Neural Networks
Rahul Yadav and Marko Vauhkonen (University of Eastern Finland, Finland); Guido Link (Karlsruhe Institute of Technology, Germany); Stefan Betz (Völtsch Industrietechnik GmbH, Reinskirchen, Germany); Timo Lähivaara (University of Eastern Finland, Finland)

Sensoring the medium in industrial microwave drying could be more efficiently addressed by intelligent control of distributed microwave sources. As a result, increasing system efficiency and reducing thermal runaway while processing low loss electric samples. However, applying such a precise microwave control requires non-invasive in situ measurement of the unknown distribution of moisture inside the material. In this work, the feasibility of integrating a microwave tomography (MWT) with the drying system is demonstrated. The studied imaging modality is applied to estimate the moisture content distribution in a polymer foam. To solve the estimation problem in a fast way, a neural network based approach is proposed in this work. Promising estimation results are shown using synthetic measurement data.
8:30 History of URSI Commission B and the Young Scientist Program
Edward V. Jull
(University of British Columbia, Canada)
This presentation reviews the history of the Commission B (Fields and waves) of the International Union of Radio Science (URSI), and in particular its program to involve young researchers into the community, during the times of the Cold War up to the breakup of the Soviet Union.

8:50 EM Modeling of Stratified Media: From Radio Propagation over Ground to THz Graphene Antennas
Juan R Mosig
(Ecole Polytechnique Federale de Lausanne, Switzerland); Krzysztof Michalski
(Texas A&M University, USA)
In this paper we sketch the history of the development of electromagnetic Green’s functions for stratified media, in the frame of the Sommerfeld integral formulation. Two classic, almost canonical, problems are discussed in detail: the Sommerfeld half-space problem and the microstrip antenna problem. The paper concludes with some remarks about numerical techniques and with hints about the extension of the theory to recent topics, like graphene antennas and metasurface-based structures.

9:10 A Brief History of Ray Methods from Ancient to Modern Times and Their Impact on Electromagnetic Engineering Applications
Prabhakar H. Pathak
(The Ohio State University, USA); Hsi-Tseng Chou
(National Taiwan University, Taiwan)
This paper briefly reviews a few of the major steps in the evolution of ray concepts and methods from about 700 B.C. to the present. Some applications of the modern ray methods to solving complex high frequency (or electrically large) problems are later summarized; they clearly illustrate the distinct advantages of ray methods not available in other methods.

9:30 Beam Frame Representations: New Alternatives to the Plane Wave and Green Function Representations in the Frequency and Time Domains
Ehud Heyman
(Tel Aviv University, Israel)
Beam summation methods have long been utilized for modeling wave propagation in complex environments due to their unique properties, combining local resolution of the source distributions; asymptotically uniform spectral representation; and algorithmic ray-based structure. So far, beam summation methods were mainly a source-based approach; the beams were used only for spectral expansion of the source, and thereby as propagators. The beam frame is a new concept where a properly constructed phase-space set of beam waves constitutes a frame everywhere in the propagation domain and thus can be used for local expansion not only of the sources but also of the medium. This transforms the problem of tracking waves in complicated media into a local-spectrum diagrammatic formulation where the same beam-set is used to expand both the source, the medium, and the local interaction of the field with the medium.

9:50 Maxwell’s Derivation of the Lorentz Force from Faraday’s Law
Arthur D Yaghjian
(Electromagnetics Research Consultant, USA)
In a brief but brilliant derivation that can be found in Maxwell’s 1861 and 1865 papers as well as in his Treatise, he derives the force on a moving electric charge subject to electric and magnetic fields from his mathematical expression of Faraday’s law for a moving circuit. The derivation of this force, which is usually referred to today as the Lorentz force, is given in detail in the present paper using modern notation.
11:20 Signal Reception Measurements Using Mobile HD Radio and DRM Systems in Two Urban Regions in Brazil
Elizabeth Verduzco (PUC Rio, Brazil); Luiz da Silva Mello (CETUC-PUC-Rio & INMETRO, Brazil); Marta Pudwelh Chaves de Almeida (INMETRO, Brazil)
This paper presents mobile measurements of digital radio made in dense urban regions of Brazil. Measurements at medium wave were carried out in São Paulo and Minas Gerais using the two standards available for this frequency range: DRM and HD Radio. Comparison of electrical field strength with predictions from ITU recommendations are presented. Large and small-scale fading probability distribution functions of the received signals were estimated for each measurements route.

11:40 Aircraft Measurements of the Marine Surface Layer Reflective Index During the TAPS Campaign
Andrew Kulesza (Airborne Research Australia, Australia); Jorg Hacker (Airborne Research Australia & Flinders University, Australia); Hedley J-Hansen (Defence Science Technology, Australia); Marion Kermann (Airborne Research South Australia, Australia); Alex Vanderklugt (DST, Australia); Jacques Claverie (CREC St-Cyr & IETR, France)
This paper describes some of the airborne atmospheric measurements, within the atmospheric surface layer, undertaken during the TAPS field campaign. A hybrid (flux - BEM) model for reactivity is outlined which makes suitable use of the aircraft data. The model provides the evaporation duct structure over the regions where the aircraft was flown, providing a 3D spatial and temporal description of surface layer reactivity.

12:00 Observations and Modelling of Propagation Loss in the Turbulent Sea Surface Environment
Hedley J Hansen (Defence Science Technology, Australia); Alex Vanderklugt (DST, Australia); Andrew Kulesza (Airborne Research Australia, Australia); Jorg Hacker (Airborne Research Australia & Flinders University, Australia); Stephen Salamon (University of Adelaide & Telstra Corporation, Australia); Martin Veasey (MET Office, United Kingdom (Great Britain))
The paper presents a case study investigating the effect of turbulence on microwave X-band reception. Path loss estimates for the X-band link operated during the Tropical Air-Sea Propagation Study (TAPS) in the Coral Sea in November. December 2013 have been modelled with reactivity profiles derived from a bulk parameterization based on Monin-Obukhov similarity theory using near surface data that was co-recorded on a suitably located open sea jetty site. The results reported show that including stochastic effects in the environmental propagator of the Parabolic Equation Method (PDM), appropriate to the sea surface environment at the time of the RF reception measurements, improves on the predictive modelling of the path loss measurements.

T06-M10: UAV-Based Antenna Measurements (AMTA) (Incl. UAV, UAS, RPAS) and automotive / Regular Session / Measurements
Room: B11
Chair: Giuseppe Vronce (Consiglio Nazionale delle Ricerche, Italy)

10:40 Versatile Low-Cost and Light-Weight RF Equipment for Field Measurements
Jonas Kompfret (Technische Universität von München, Germany); Raimund A. M. Maurermaier (Independent Researcher, Germany); Thomas F. Eibert (Technical University of Munich, Germany)
We present a low-cost and light-weight measurement equipment based on a software-defined radio (SDR) and a radio-frequency over fiber (ROF) connection. The main purpose of the hardware are near-field antenna measurements, but possible use cases also include imaging and other inverse-source scenarios. The two hardware features "low-cost" and "light-weight" are important for the use on an unmanned aerial vehicle (UAV). Classess should not financially ruin the operator and the UAV payload is limited. Regarding the RF properties of the hardware, the ROF connection has the benefit of extremely low-loss as compared to coaxial cables, while the SDR offers great flexibility for measurement frequency, bandwidth, and signal filtering. One SDR transceiver channel is employed to provide a coherent signal to an antenna and two receive channels capture two field components (linearly independent polarizations). As an important part of the RF circuitry, a drift compensation is a countermeasure against changing temperature conditions.

11:00 RF-Signal Receiver for UAV-Based Characterisation of Aeronautical Navigation Systems
Alexander Weiß, Robert Geise und Björn Neubauer (Technische Universität Braunschweig, Germany); Fabian T. Faul (Technische Universität zu Berlin, Germany); Thomas F. Eibert (Technische Universität München (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Torsten Fritzel, Hans-Juergen Steiner and Rüdiger Strauß (Aeroflex, Germany)
This contribution presents measurements with a self-built high frequency receiver architecture for nearfield measurements without synchronization between devices under test and the receiving stage that can be mounted on an unmanned aerial vehicle. It comprises a stationary monitor with a fixed location and a monitor, that can vary in space to measure the phase and amplitude dependency with respect to its location, as required for nearfield measurements and farfield transform. One application for that is the nearfield inspection of navigation systems. The measurement concept also applies laser tracking of the variable monitor and a sophisticated synchronization of the measured high frequency data and location data. In particular, real-time capability of data acquisition is validated with this setup. First measurement results demonstrate the functionality of the architecture that allows an unachieved synchronization phase accuracy of better than 8° at 2 GHz.

11:20 Comparison Between Measured and Simulated Antenna Patterns for a LORAR LBA Array
Paola Di Ninni (OAA - INAF, Italy); Pietro Bollì (INAF - Osservatorio Astrofisico di Arcetri, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEIIT), Italy); Giuseppe Pupillo (IRA - INAF, Italy); Giuseppe Vronce (Consiglio Nazionale delle Ricerche, Italy); Stefano J. Wijnholds (ASTRON, The Netherlands)
A LORAN unmanned aerial vehicle (UAV) was employed for a measurement campaign on a station of the radio telescope LORAR to characterize the individual Long Base Band Antenna patterns. The experimental set-up has been then simulated with a full-wave software and numerical embedded element patterns have been compared to the measured results. A statistical analysis of the differences between the two data sets has been finally carried out to estimate the accuracy of the electromagnetic model.

11:40 A Drone-mounted O-Band Test-Source for the Validation of the Large Scale Polarization Explorer
Fabio Paonessa (National Research Council of Italy (CNR - IEIIT), Italy); Giuseppe Vronce (Consiglio Nazionale delle Ricerche, Italy); Lorenzo Ciorba (Institute of Electronics, Computer and Telecommunication Engineering (IEIIT-CNR), Torino & Politecnico di Torino, Torino, Italy); Oscar A. Peverini (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom., IEIIT-CNR, Italy); Giuseppe Addamo (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom., IEIIT-CNR, Italy); Mauro Lucia (CNR, Italy); Marco Bersanelli and Aniello Mennella (Università degli Studi di Milano, Italy)
The unmanned Aerial Vehicles (UAVs) technology has represented a significant innovation for antenna measurements in the last years. So far, UAVs have mainly exploited for the characterization of the radiation pattern of antennas and arrays up to C-band. An evolution of the system working in the C-band is planned to be used for the validation of the future Survey Tensile Philosophy (STP) of the Large-Scale Polarization Explorer (LSPE), an Italian project. This contribution presents a payload solution and a preliminary test performed.

12:00 Advanced Remote-Controlled Airborne Sensor Systems
Thorsten Schrader (Physikalisch-Technische Bundesanstalt, Germany); Jochen Bredemeyer (FCS Flight Calibration Services GmbH, Germany); Thomas Kleine-Ostmann and Marius Mihalachi (Physikalisch-Technische Bundesanstalt, Germany)
Based on commercially available octocopters, PTB has developed flight measurement platforms with RF front-ends for the measurement of the signals emitted by terrestrial navigation systems and radars. They are used to measure signal strengths, phase and amplitude dependency with respect to its location, as required for nearfield measurements and farfield transform. One application for that is the nearfield inspection of navigation systems. The measurement concept also applies laser tracking of the variable monitor and a sophisticated synchronization of the measured high frequency data and location data. In particular, real-time capability of data acquisition is validated with this setup. First measurement results demonstrate the functionality of the architecture that allows an unachieved synchronization phase accuracy of better than 8° at 2 GHz.

12:20 Precise 5D RTK Positioning System for UAV-based Near-Field Antenna Measurements
Patrick Henkel, Andreas Speier and Ulrich Mittmann (ANAVS GmbH, Germany); Torsten Fritzel, Rüdiger Strauß and Hans-Juergen Steiner (Aeroflex, Germany)
Near-field antenna measurements with a Unmanned Aerial Vehicle (UAV) require an accurate 3D position and 3D attitude information. In this paper, we estimate the position and velocity of the UAV; the quaternion that describes its attitude, the carrier phase integer ambiguities related to both the attitude and position, and the accelerometer bias with a Kalman filter. The raw measurements were obtained from the ANAVS Multi-Sensor RTK module with its 3 Multi-frequency, Multi-GNSS receivers and a MEMS-based Inertial Measurement Unit (IMU). We used the UAV of Aeroflex to validate our method and achieved a centimeter-level positioning accuracy in both static and kinematic conditions.

IW02: Analysis and Design of Advanced Antenna Systems using TICRA Tools (TICRA) (Top)
T12 Scientific / Industrial Workshops
Room: B3
Dr. Peter Miencke and Dr. Min Zhou, TICRA
CP2.01 Optimal Frequency of Operation and Radiation Efficiency Limitations of Implantable Antennas
Denys Nikolaev (Institut d'Électronique et de Télécommunications de Rennes (UMR CNRS 6164), France); Zvonimir Sipus and Marko Bosiljevac (University of Zagreb, Croatia); Wout Joseph (Ghent University/IMEC, Belgium); Maxim Zhadkov (University of Rennes 1, France); Ronan Sauleau (University of Rennes 1, France); Luc Martens (Ghent University - imec, Belgium); Anja K. Skriver (EPIFL, Switzerland)

This paper describes the design steps of a coaxial dipole antenna for telemetry applications under extreme conditions of performance compromise that have to be made between both domains. The experimental results are given in the last part of this article.

CP2.02 3D Printed Ceramic Antennas for Space Applications
Gautier Mazuqine (Anywaves, France); Benedikt Byrne (Anywaves, France); Maxime Romier (Anywaves, France); Nicolas Capet (Anywaves FRANCE, France)

This paper presents a novel approach for printing miniature antennas using a flexible PDMS-Polydimethylsiloxane)-ceramic mixture, whereas the microstrip feed and the ground plane are made out of a ceramic feed network. This allows a compact antenna design with enhanced performance of cross-polarization backscatterers located at a perfect electric conductor interface. In our talk, we will discuss the key role of an enhanced directivity for a wide range of scattering configurations.

CP2.03 Mechanical and Environmental Aspects of Antennas for a Novel Maritime Search and Rescue System
Taher Badawy, Alexander Kremring and Dawood Nuwalla (Fraunhofer Institute for High Frequency Physics FHR, Germany); Thomas Bertuch (Fraunhofer FHR, Germany)

This paper presents a conceptual approach for utilizing high-performance microstrip antennas for maritime search and rescue applications. These aspects are considered in the mechanical design of the proposed antenna. The dual-band antenna operates in the frequency range from 2.0 to 2.95 GHz (S-band) and from 5.8 to 5.95 GHz (C-band). The antenna configuration is based on various techniques for enhancing the performance of the antenna. Horizontal polarization is used for wideband transmission, while vertical polarization is used for narrowband operation. The mechanical design of the antenna is presented providing a low profile and lightweight structure that is compatible with the marine environment requirements.

CP2.04 Transmit-Arrays at Ka-Band for Harsh Environment
Trung Kien Pham (International University, VNU-HCM, Ho Chi Minh City 70000, Vietnam); Ronan Sauleau (University of Rennes 1, France); Erwan Foum (INSA of Rennes & IETR, France); Antonio Clemente (CEA-LETI Minatec, France)

This paper presents the design of a flexible non-metallic dielectric resonator antenna based on non-metallic materials is presented in this paper for conformal applications. A concept of flexible dielectric resonator antenna based on non-metallic materials is presented in this paper for conformal applications. The concept of a flexible dielectric resonator antenna based on non-metallic materials is presented in this paper for conformal applications. The concept of a flexible dielectric resonator antenna based on non-metallic materials is presented in this paper for conformal applications.

CP2.05 Telemetry Antennas Withstanding Very High Accelerations and Centrifugal Forces
Loic Bernard, Hrvoje Covic, Andreas Zeiner and Armin Schneider (ISL, France)

This paper presents the design-steps of a coaxial dipole antenna for telemetry applications under extreme conditions of accelerations and centrifugal forces. Both electromagnetic and mechanical designs are presented, as well as performance compromises that have to be made between both domains. The experimental results are given in the last part of this article.
Convened Poster 2-CS36: Innovative Lens Antennas for Future Communication Systems

T02 Millimetre wave 5G / Convened Session / Antennas
Room: A2 (Poster Area)
Chair: Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

CP2.10 Design of a Tunable Sub-Wavelength Plasma-Based Resonator for Electrically Small Antenna Applications in L-band
Adrien Laffont (CEA, DAM, CEA-Gramat, France); Théo Delage, Roman Pascaud, Marjorie Grzeskowiak and Cyril Calhoul (ISAE-SUPAERO, Université de Toulouse, France); Thierry Callegari, Laurent Liard and Olivier Pascal (LAPLACE, CNRIS, LUPS, INP, Université de Toulouse, France); Jean-Pierre Adam (CEA, DAM, CEA-Gramat, France)

A preliminary study of the design of an electrically small plasma-based resonator using a localised surface resonance (LSRPS) above 1 GHz is presented. Such a resonator is intended to be used to develop an electrically small antenna with frequency agility. This resonator consists of a plasma discharge confined in a hemispherical glass shell 3 cm in diameter on a ground plane. From 1 to 1.5 GHz, the plasma electron density required to achieve the LSRP must be between 0.5 × 10^11 and 1.4 × 10^11 cm^-3. Plasma losses are taken into account in this study and provide the required gain pressure. Typically for neon gas, the working pressure must be around 50 mTorr. A practical implementation using a miniature inductively coupled plasma (mICP) source is finally discussed.

CP2.11 Parallel Plate Resonate Waveguide Lens for Mechanical Beam Scanning Using Gap Waveguide Feed System
Thomas Störiber (Univ Rennes 1, IETR, France); Ségolène Tubau (Thales Alenia Space, France); Hervé Legay (Thales Alenia Space, France); Etienne Giraud (Thales Alenia Space, France); George Goussetis (Heriot-Watt University, United Kingdom (Great Britain)); Mauro Ettorre (Université de Rennes 1 & UMR CNRS 6164, France)

A parallel-plate waveguide lens with mechanically reconfigurable feed network for continuous beam scanning is presented. The quasi-optical system is designed using an optimisation process based on previously developed ray-optical methods. The feed network relies on the non-contacting properties of groove waveguide which allows for a fixed input port and simple mechanical actuation. Numerical results are presented for a Ka-band lens design, demonstrating a high scanning performance over an angular range of ±35° with scan losses lower than 2 dB, the simulated mismatch loss is lower than -15 dB between 27 and 31 GHz. The proposed all-metall beamformer is therefore a promising solution for next-generation Satcom applications.

CP2.12 Fully-Metall-Rinehart-Luneburg Lens at 60 GHz
Martin Petek and Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Elena Pucci (Ericsson AB, Sweden); Nelson Fonseca (European Space Agency, The Netherlands); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this work, we present the design of a Rimehart-Luneburg lens antenna operating from 50 to 62 GHz. At these high frequencies, electromagnetic losses introduce high losses, so full-metallic solutions are typically preferred. The required refractive index of the Luneburg lens is realized by deforming the parallel plate waveguide following the concept of geometric surfaces. Despite the high frequency, the achieved radiation efficiency is roughly 90%. Thirteen port antennas are partially aligned along the contour of the lens to enable an electronic beam switching of ±55 degrees with equally spaced steps and an inter-element dip loss of 6 dB.

CP2.13 3D-printed Wideband Hyperbolic Lens Antenna for Ka-band
Jose M Puyanco (Pontificia Universidad Catolica de Valparaiso, Chile); Nelson Mario Castro (Pontificia Universidad Catolica de Valparaiso, Chile); Brazil Pizarron (Pontificia Universidad Catolica de Valparaiso, Chile); Eva Rajo-Iglesias (Universidad Carlos III de Madrid, Spain)

This article presents a 3D-printed wideband hyperbolic lens antenna capable of Ka-band operation. The lens structure was constructed using a 3D printer with ABS filaments that were characterized with respect to its infill percentage. Different of strategies for the manufacturing will be evaluated.

CP2.14 On the Use of Dielectric Gratings for Enlarging the Field of View in Low Dielectric Permittivity Lenses
Marta Arias Campo (IMST GmbH, Germany & Delft University of Technology, The Netherlands); Simona Bruni (IMST GmbH, Germany); Giorgio Carluccio and Nuru Lorbart (Delft University of Technology, The Netherlands)

Low relative permittivity plastic lenses are a promising solution to be used in the future mm- and sub-mm wave systems, due to the availability of materials with moderate loss, light weight and cost-effective manufacturing. However, the low permittivity implies a reduction in the field of view achieved when degrading the lens field within the focal plane. In this contribution, the use of dielectric gratings with modulated height integrated inside ellipsoidal lenses with low permittivity is investigated, with the aim of enhancing the steering capability. The dielectric gratings synthesize a tilted feeder pattern inside the ellipsoidal lens, reducing the reflection loss and spill-over when illuminating the lens off-axis. The analytical approach used to dimension the gratings is explained here. An example in G-band (540-2200 GHz) has been simulated as a first proof-of-concept, showing promising results.

CP2.15 Transmit-array Antenna Design for Broadband Backhaul 5G Communications at WGiG Band
Sergio Barba (Instituto Universitario de Lisboa, Portugal); Jorge R. Costa (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Nour Nacheh (University of Nice Sophia Antipolis, France); Cyril Luxey (University Nice Sophia Antipolis, France); Diane Titz (University Nice Sophia Antipolis, France); Frédéric Gianello (STMicroelectronics, France); Carlos del Río (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Ana Arboleya (Universidad Rey Juan Carlos, Spain); Jorge Teixeira (ISCTE-IUL, Instituto de Telecomunicacões, Portugal); Jean-Philippe Garnier (PolyTechLab, Université Nice Sophia Antipolis, France); Jean-François Vizzari (PolyTechLab, Université Nice Sophia Antipolis, France)

A cost-effective transmit-array (TA) antenna design framework is presented and experimentally validated for a 5G backhaul application at the WGiG band. The antenna is composed of a discrete dielectric lens (DLD), fed by a horn, specifically designed for this application. Both the TA and feed are fabricated using additive manufacturing. Metal coating and Fuse Deposition Modeling are employed for the horn and TA fabrication, respectively. Simple design rules are devised to quantify the bandwidth of this type of antennas as function of the aperture dimension and focal distance. Based on this framework a compact TA antenna (\(\theta_{3dB} = 15^\circ\)) then can comply with typical specifications for 5G backhaul links at WGiG band (minimum gain of 30 dBi from 57 to 66 GHz) is designed.

Convened Poster 2-CS41: Metasurfaces for Mobile (5G and Beyond) and Satellite Communication Systems

T09 Space (incl. cubecast) / Convened Session / Antennas
Room: A2 (Poster Area)
Chair: Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain))

CP2.16 Glide-Symmetric Luneburg Lens Using Substrate-Integrated-Holes for 5G Communications at Ka-Band
Ramez Hamarneh (KTH, France); Oskar Zetterstrom and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

Here, we propose a cost-effective implementation of a planar metasurface Luneburg lens operating at Ka-band. The lens is implemented in a parallel plate structure. The required graded refractive index is realized through spatially varying the dimensions of an array of inclusions placed in both plates of the parallel plate waveguide. More specifically, the inclusions are square holes printed on a substrate which is connected to a ground plane. Each square is surrounded by metallic vias which are connected to the ground plane. The inclusions in both plates are arranged to possess glide symmetry. Waveguide feeds are integrated in the parallel plate waveguide. The lens is terminated with a flare to achieve an efficient radiation to free space.

CP2.17 Peripherally Excited Phased Arrays with Practical Active Huygens’ Sources and Slot Elements
Ayman H. Dorrat and George V. Eleftheriades (University of Toronto, Canada)

Antenna phased arrays have become increasingly more important in recent years with the advent of technologies such as 5G communications, automotive radars, and satellite internet. These phased arrays are costly to design, fabricate and deploy. A main component of the cost of traditional phased arrays is that of the necessary feeding network and phase shifters or transceivers. A recently developed concept called the peripherally-excited (PEX) phased array has been proposed to generate electronically scanned pencil beams with a reduced number of phase shifters. The concept of the PEX phased array relies on peripheral active Huygens’ sources that are solely used along the periphery of the cavity. This paper proposes a practical Huygens’ source implementation which is compatible with printed-circuit-board technology, and exhibits low reflections and mutual coupling between adjacent sources. Furthermore, a specially-engineered slot arrangement is proposed which can achieve effective radiation at broadside and tilted angles.
CP2.18 An Ultra-thin Wide-Angle Scanned Planar Array Antenna for Satellite Communication
Yuju Li (Queen Mary University of London & Antenna Group, United Kingdom (Great Britain)); Ahsan Noor Khan and Qiao Cheng (Queen Mary University of London, United Kingdom (Great Britain)); Max Munce (Queen Mary, University of London, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain)).

The requirements of high data throughput nowadays for satellite communication are expediting for worldwide connectivity. The antenna features, such as low profile and lightweight are desirable for future satellite systems. In this paper, we propose a novel ultra-thin and easy-fabricated scanned array antenna operating in X-band from 10.7 GHz to 12.7 GHz with S11≤−10 dB. The antenna array offers advantage with beam steering capability of nearly 60 degree without utilizing any costly phase array. This is achieved by rotating the relative position of the upper radiated layer regarding the bottom feeding layer. The total height of this array antenna is about 0.23 lambda_highest and the radiation efficiencies are all above 60% during the whole scanning range.

CP2.19 Quasi-Periodic Metasurfaces and Their Equivalent Dielectric Models
Qiao Cheng (Queen Mary University of London, United Kingdom (Great Britain)); Shiyu Zhang (Loughborough University, United Kingdom (Great Britain)); Raj Mittra (Penn State University, USA); J (Yiannis) Vardaxoglou (Loughborough University, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain)).

In this paper, we present an equivalent dielectric method to speed up simulation of quasi-periodic metasurfaces. The idea is to use homogeneous equivalent dielectric material to replace original metasurface unit cells for simulation. An X-band reflectarray antenna was used to demonstrate this approach. Simulated results show both good accuracy and reduced simulation time as compared to the original array.

CP2.20 Metasurface-Based Circularly-Polarized Multibeam Reflect/Transmit-Arrays
Zhi Hao Jiang, Fan Wu and Xiaowei Zhu (Southeast University, China); Qiang Ren (Beihang University, China); Pingjun Werner and Douglas H Werner (Pennsylvania State University, USA).

In this paper, we present an overview of recent progress on metasurface-based circularly-polarized reflect and transmit-arrays for millimeter-wave applications. The reflect and transmit-arrays are composed of sub-wavelength unit cells containing multiple cascaded layers of anisotropic impedance surfaces. By utilizing either the Berry phase and/or dynamic phase, highly-directive circularly-polarized multibeam can be generated with a single feed or a cluster of feeds. Three proof-of-concept examples are showcased, which are all validated by experimental measurements.

CP2.21 Recent Advances on Modulated Metasurface Antennas for SatCom
Mauro Fanni (Università de Rennes 1, France); Gabriele Minniti (Wave Up s.r.l, Italy); David Gonzalez-Ojovero (Centre National de la Recherche Scientifique - CNRS, France); Francesco Caminita (Wave-Up SRL, Italy); Enrica Martin (University of Siena, Italy); Cristian Dell'Acqua (Wave-Up Srl, Italy); Stefano Maci (University of Siena, Italy).

In this paper, some of the newest antenna prototypes, based on modulated metasurface technology are presented. These devices show some interesting radiation features that have been implemented to comply with specific needs of satellite links, space-to-ground communications and deep space missions. Irrespectively of the challenging performances achieved by the modulated MITs apertures presented here, all the examples shown preserve some key features rendering these prototypes extremely appealing for space environment such as low mass and low envelope, low production costs and low profile, simple feeding systems that render them suitable to onboard satellites or spacecrafts usage; also, such devices can be easily mounted on flat platforms.

CP2.22 Electro-Mechanically Tunable Meta-Surfaces for Beam-Steered Antennas from mm-Wave to THz
Muhammad S Rabbani, James Churm and Alexandros Feresidis (University of Birmingham, United Kingdom (Great Britain)).

Electro-mechanically tunable metasurfaces are presented for high gain, beam steerable Lens-Antenna (LWA) at 37 GHz and 280 GHz bands. The proposed metasurfaces are a tunable High Impedance Surface (HIS) in case of 37 GHz LWA, and tunable Partially Reflective Surface (PRS) in case of 280 GHz LWA. The proposed metasurfaces serve as a phase shifter in the beam steering antenna. The required phase shift is achieved by varying the mechanical separation between the HIS/PRS periodic array and ground layer using a piezoelectric actuator (PEA). The presented phase shifting technique offers an extremely low loss solution for antenna beam steering at mm-wave frequencies.

The designed antennas at the selected frequency bands may find applications in broadband mobile communications in 5G and beyond. The presented antenna yields a wide 511 bandwidth (BW), high gain and beam scanning range as required for broadband mobile applications.

Convened Poster 2-CS50: Novel Wave Phenomena in Metamaterials and Metasurfaces Applied to Antennas and Propagation

T11 Fundamental research and emerging technologies / Convened Session / Antennas
Room: A2 (Poster Area)

CP2.23 Analytical Study of Dielectric-walled Conical Horn Antennas
Anastasios Paraskevopoulos (University of Siena, Italy); Francesco Caminita (Wave-Up SRL, Italy); Roberto Giusto (Huawei Technologies, Italy); Matteo Albani (University of Siena, Italy).

An analytical model of a dielectric-walled conical horn antenna is developed in order to characterise its radiation characteristics. An approximate model analysis is formulated in a semi infinite conical geometry in order to calculate the mode supported by the structure. It is proven that the desired hybrid HE11 mode is excited that allows the hollow dielectric cone to perform as an antenna with high directivity, low sidelobe levels, good polarisation purity and very stable phase center in a wide frequency range. This study will allow us to define the design criteria for conical dielectric-walled horn antennas which can effectively replace metallic corrugated horns as reflector feeds in the millimeter wave band.

Numerical results and design examples will be shown during the conference.

CP2.24 Ray-tracing in Dielectric Inhomogeneous Metamaterials
Francesca Maggiorelli and Matteo Albani (University of Siena, Italy); Roberto Giusto (Huawei Technologies, Italy); Stefano Masi (University of Siena, Italy).

We present a very fast and efficient analysis of inhomogeneous dielectric lens based on Geometrical Optics (GO) ray-tracing. The ray-tracing algorithm has been implemented in a Matlab code in order to overcome time-consuming full-wave simulations in the analysis and synthesis of inhomogeneous lens-antennas. Phase and amplitude distributions at the output interface of a generic inhomogeneous dielectric lens can be obtained by solving the eikonal and the energy conservation equations. The source... (go on)

CP2.25 Dielectric Rectangular Lens for Antenna Array Scanning Mitigation
Gioiogo Gottardi and Alessandro Poli (ELEDA Research Center, University of Trento, Italy); Giacomo Oliveri (University of Trento & ELEDA Research Center, Italy); Andrea Massa (University of Trento, Italy).

Wide angle antenna arrays are of fundamental importance for nowadays and future communications. In this paper, an innovative iterative procedure based on the System-by-Design paradigm is applied for designing rectangular-shaped lenses to be integrated in axially weighted array structure to minimize the scan-loss of resulting radiating system so that the antenna scan-range turns out to be significantly extended. A preliminary numerical design example is reported to give some insights on the potentialities of the proposed approach.

CP2.26 Study of Printed Scattering Reflectors Based on Discretised Metasurface
Michel Cerveny, Kenneth Lee Ford and Alan Tennant (University of Sheffield, United Kingdom (Great Britain)).

In this paper, metasurface synthesis for plane wave to plane wave scattering was studied from the practical perspective. The study was focused on the design of discretised surfaces that do not conform to standard specular scattering behaviour as described by Snells law but allow to reflect waveforms to prescribed directions. The results of the synthesis were compared with full wave simulations and measurements. Furthermore, the design was adopted for testing of a textile metasurface manufactured by an electroplating process. The practical design requirements are presented.

CP2.27 Latest Developments on Non-linear and Time-Varying Metasurfaces and Topological Antennas
Davide Romacini (Roma Tre University, Italy); Mirko Barbuto and Alessio Monti (Niccolò Cusano University, Italy); Stefano Vellucci (Roma Tre University, Italy); Angelica Vicali Maresi (Università degli Studi Roma Tre, Italy); Alessandro Toscano (University Roma Tre (IT), Italy); Filiberto Bilotti (University Roma Tre, Italy).

In this contribution, we present the latest developments from our group on metasurfaces for antenna applications. In particular, we present the properties and a possible implementation of non-linear and time-varying metasurfaces: the first one has been used for conceiving power-dependent and waveform-dependent metasurface cloaks for antennas, allowing them to become invisible/invisible to an electromagnetic wave depending on the power level or waveform of the incident wave, respectively; the second one allows to realise Doppler mantle cloaking, which can vanish the Doppler frequency shift due to the motion of the antenna system. Finally, we present the design of patch antenemas with reconfigurable radiation characteristics exploiting the position of the phase singularities of vortex fields.


T10 EM modelling and simulation tools / Convened Session / Antennas

68 of 128
**Poster2-A01: Antenna Theory**

**Antennas**

Room: Exhibition Hall

**P2.001 Three-Element End-Fire Linear Arrays (Super) Directivity and Gain Optimization**

Alexandre Debard (University of Grenoble Alpes & CEA-LETI, France); Antonio Clemente (CEA-LETI Minatec, France); Christophe Delaveau (CEA-LETI, France)

This paper presents the results of the optimization of three three-element end-fire linear arrays based on straight and bent-electrical-dipole-based arrays. The array-element distance is fixed to 0.13λb and the wavelength is calculated at the operation frequency. The array complex excitation coefficients are optimized to achieve maximum directivity or gain. The synthesis procedure is based on the optimization of the directivity and gain formulas considering the array factor and the active element patterns. The numerical results have been validated by 3D full-wave electromagnetic simulations. The maximum directivity is equal to 10.0 (gain 2.91 dB) and 9.33 dB (gain 3.67 dB in the case of the straight and bent-electrical-dipole-based arrays, respectively). Instead, the maximum gain is equal to 6.81 (directivity 6.84 dB) and 7.25 dB (directivity 9.15 dB), respectively.

**P2.002 A Miniaturized Circularly Polarized Antenna Using a Meandered Folded-Shorted Patch Array for CubeSats**

Yuqiao Li (Heriot Watt University, United Kingdom (Great Britain)); Symon K. Podlich (Heriot-Watt University, United Kingdom (Great Britain)); Dimitris E. Anagnostou (Heriot Watt University, United Kingdom (Great Britain))

The design and operation of a miniaturized antenna array offering circularly polarized (CP) radiation for CubeSats and other micro-satellites is presented. The proposed antenna array combines folded-shorted patches (FSPs) and meandering for antenna miniaturization. Both techniques enable a decrease of the quarter-wavelength shorted patch while maintaining a quarter-wavelength resonant length. Realization of CP is achieved by a ultra-compact and planar feed circuit consisting of a network of meander-shaped 90° and 180° hybrid couplers, providing quadrature feeding of the FSP elements and for integration onto the backside of the antenna ground plane whose physical dimension is only 9 cm x 9 cm. Good CP performances are observed for the developed UHF-band antenna and with an antenna size of 0.125λ x 0.125λ considering the 540 MHz design frequency.

**P2.003 A Broadband Transition from Microstrip to Groove Gap Waveguide for Ka-Band Applications**

Davood Zarif and Alae Asfarzuhair (University of Kashan, Iran)

This paper describes a novel broadband microstrip-to-groove gap transition for millimeter wave applications. The microstrip transition is effectively transformed into the groove gap waveguide (GGW) mode by means of a slot-line. The simulation results of the transition show an insertion loss of 0.3 dB and a return loss less than 20 dB over 42.5% relative bandwidth from 26 to 40 GHz.

**P2.004 Closed Form Characterization of Mutual Coupling in Uniform Linear Arrays**

Grzegorz Wolosinski (Huawei Munich Research Center, Germany); Harsh Tateria (Lund University, Sweden); Vincent Fusco (Queens University Belfast, United Kingdom (Great Britain))

This paper proposes a pragmatic methodology to characterize mutual coupling in uniform linear arrays. The coupling coefficient is used in the literature of multiple input multiple-output (MIMO) antenna arrays is based on impedance parameters, resulting valid only for electromagnetically small antennas, e.g. short dipoles. To test the robustness and accuracy of the proposed coupling model we consider ULA with different antenna types and number of elements. We provide closed form expressions for the mutual coupling characterization of the studied ULA, which are then used to evaluate the spectral efficiency performance of a MIMO cellular system. Our results show that the proposed model can provide more accurate characterization of the studied mutually coupled ULAs and hence better estimation of the spectral efficiency compared to the classical model.
P2.005 Approximating the Directivities of Antenna Elements and Arrays
Maor Morehafi (HIT-Holon Institute of Technology, Israel); Maor Kadosh (HIT, Israel); Eli Levine (AFEKA, Academic College of Engineering, Israel); Haim Matzner (HIT-Holon Institute of Technology, Israel)

The directivities of antenna elements and arrays (no mutual coupling included) is discussed. Replacing the directivity of the simulated or measured element pattern by a continuous function is needed in order to improve the approximation of the directivity of the arrays. Two kinds of arrays are treated: a dipole array and a microstrip array. It is shown that the proposed method, based on the definition of the directivity, is more accurate than the simple formula based on the sum (in dB) of the directivity of the element and the directivity of the array factor (AF). Moreover, we show that the deviation of the directivity calculated by the proposed method from the simulated directivity is less than 0.5 dB.

P2.006 Double-Layer Machine Learning Assisted Optimization for Antenna Sensitivity Analysis
Qi Wu, Haiming Wang and Wei Hong (Southeast University, China)

A double-layer machine-learning assisted optimization (DL-MLAO) method for antenna sensitivity analysis (SA) is proposed. The machine-learning (ML) method is introduced to largely alleviate the computation burden of both worst case searching (WCS) and maximum input tolerance searching (MITS) in antenna robust design. First, the MLAO is introduced in the fundamental layer to accelerate the WCS for given input antenna design tolerance. Then, based on the improved WCS process, another MLAO process is introduced to operate MITS for given output antenna design tolerance efficiently. The proposed DL-MLAO is compared with the previously reported antenna SA methods, which shows its superior in both robustness and accuracy.

P2.007 Exact Derivation of the Radiation Law of Antennas Embedded into Generic Nonlocal Metamaterials: A Momentum-Space Approach
Said Miki (University of New Haven, USA)

We solve the problem of how antennas radiate into generic nonlocal metamaterials by using a momentum space formalism to rigorously derive the general radiation formula. The energy per Hertz by unit solid angle is computed by first deriving the dyadic Green’s function of nonlocal media in the momentum space. We show that due to causality only the first intermediate part of the dyad will contribute to the radiation field. We avoid any spectral integration or using the Poisson vector (the latter known to be already inadequate in nonlocal media) by working directly with momentum space formulation and derive analytically the exact expression. The final result depends only on the modal analysis of the metamaterial.

P2.008 A New Feed Network for the Communication Signal and Excitation of Surface-Wave-Driven Plasma Antennas
Fatemeh Sadeghkhah, Ali K. Horestani, Mohammad reza Dorbin and Mahmoud Talaifa Noghani (Aerospace Research Institute, Iran); Hajir Jalafar (Universiti Teknologi MARA, Malaysia)

This paper proposes a novel structure for a surface-wave-driven plasma monopole antenna to simplify the antenna structure and also to improve the antenna performance. The proposed configuration allows both communication signal and excitation wave to be applied to a single coupling sleeve on the antenna column. As a result, the antenna conductivity at the communication signal point is maximized. On that base, a plasma monopole antenna is designed to be excited by 1500 MHz RF signal source with a controllable power level between 1 and 100 watts to adjust the effective length of the antenna.

P2.009 Beamwidth Control of a Helical Antenna Using Truncated Conical Plasma Reflectors
Mahsa Valipour, Fatemeh Sadeghkhah and Ali K. Horestani (Aerospace Research Institute, Iran); Mohamed Hindi (Université de Rennes 1, France)

This paper presents an approach to simultaneous beamwidth and gain control in a circular polarization helical antenna using a truncated conical plasma reflector. Requirements and trade-offs regarding the feasible parameters of this antenna are discussed. The antenna operation is confirmed by full-wave simulations. The results show that the proposed plasma reflector can be used to improve the radiation-gain of the considered helical antennas up to around 17%.

Poster2-A02: Antenna Interactions and Coupling

Antennas
Room: Exhibition Hall

P2.010 Antenna Mutual Coupling Effects in Highly Integrated Transmitter Arrays
Wan-Chun Liao (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Thomas Emanuelsson (Gapwaves AB, Sweden); Artem Vilenkinsky (Samsung Research Institute Russia, Russia); Mariana Ivanisha (Chalmers University of Technology, Sweden)

An antenna S-parameter re-normalization procedure is proposed in order to obtain a new set of scattering parameters that directly quantifies the actual coupling and reflection coefficients of power waves in highly integrated antenna systems employing unequal port terminations. We examine both the inter-element coupling between the radiator and the active circuitry as well as the element-to-element coupling in an antenna array and discuss the important differences with the customary 0-50 Ohm S-Parameters.

P2.011 A Method of Reducing Mutual Coupling for a Finite Array
Lei Chen and Tianping Zhang (Xidian University, China); Ashraf Uz Zaman and Jian Yang (Chalmers University of Technology, Sweden)

A method of reducing mutual coupling for a finite array with the characteristics of wideband and beam steering is presented in this paper. By adding an extra decoupling network, the mutual coupling can be efficiently suppressed for the antenna array. To verify the validity of the proposed method, a 1 × 8 millimeter-wave array antenna based on the gap waveguide technology is used in this work. The simulation results show that the active reflection coefficients are improved from -6.86 dB to -2.92 dB, and the mutual coupling between adjacent elements is reduced to -0.75 dB by using a beam steering angle range of 37°.

P2.012 Antenna Adaptation Circuits for High Data Rate Magneto Inductive Underwater Communications
Thierry Deschamps de Paillerie (University of La Rochelle, France); Alain Gaugue (La Rochelle University, France)

Environmental and seapaculture monitoring in seawater use standalone and robust underwater sensor networks to properly and regularly harvest useful data. The need of submarine images transmission in real time require higher data rate. In this paper we introduce an innovative prototype of reliable magneto-induction based wireless submarine communication system adapted to a medium-range underwater telemetry application matching those requirements.

P2.013 Mechanically Influenced Antennas for Strain Sensing Applications Using Multiphysics Modelling
Shaghayegh Soltani, Paul Taylor and John Batchelor (University of Kent, United Kingdom (Great Britain))

Here we report highly flexible 3D antennas which leverage non-linear compressive buckling to tune their operating frequency through 0 to 30% axial or broad strain release of their elastomeric substrate. The proposed 3D designs are straightforward to fabricate compared to the existing direct 3D fabrication routes which makes them promising for strain sensing applications. By utilizing a soft silicone substrate and structural design of conventional metallic materials, we have demonstrated two designs of 3D stretchable antennas: “Prop up-convoluted loop antenna” and “Prop up-multilayer dipole antenna”. Multiphysics simulation using FEA method is used to analyze the antenna models and the numerical results are in a good correlation with measurements.

P2.014 Wireless Link for Micro-Scope Biomedical Implants Using Magnetoelectric Antennas
Fazel Rangriz (Aerospace Research Institute, Iran); Ashraf Uz Zaman and Oscar Borries (TICRA, Denmark)

Miniaturization of implant antennas without significant performance degradation is of great interest for future medical devices. Systems operating at low frequencies are preferred in wireless implant technology because the tissues’ losses increase with frequency and the device’s power consumption is lesser in the low-frequency range. The extremely small antennas face significant performance degradation in terms of efficiency, impedance matching and have a very high quality-factor that makes the antenna susceptible to the surrounding medium and electronics. Considering the impedance of a micro-scale antenna in sub-GHz frequency, the antenna performs like a short circuit or open circuit, and it losses increase with frequency and the device’s power consumption is lesser in the low-frequency range. The extremely small antennas face significant performance degradation in terms of efficiency, impedance matching and have a very high quality-factor that makes the antenna susceptible to the surrounding medium and electronics. Considering the impedance of a micro-scale antenna in sub-GHz frequency, the antenna performs like a short circuit or open circuit.

P2.015 Multi-ring Circular Parasitic Antenna with Circularly Polarized Conical Beam and High Gain
Niyouzima Laetitia (Université Catholique de Louvain, Belgium); Donia Gueslain (ICTEAM Institute, Université Catholique de Louvain, Belgium); Christophe Craye (Université Catholique de Louvain, Belgium)

The design of a 3D multi-ring circular parasitic antenna with circular polarization and conical patterns excited by a center monopole is presented. Such antennas are specifically well-suited to conical radiation with grating angles. Two rings bearing respectively 8 and 16 parasitic elements are located at distances allowing minimal radiation from the vertical parts of the parasitic elements. The simulation results show that after limited optimization efforts, and for an elevation angle of 47°, we can reach a maximum gain of 7.7 dB against a maximum gain of 7.9 dB with 2 rings in circular polarization for an axial ratio below 3 dB.

P2.016 Antennas on CubeSat Platforms: Accurate RF Predictions
Cecilia Cappellin, Mustafa Murat Bilici, Jakob Rosenkranz de Lasson and Oscar Borries (TICRA, Denmark)

A typical 3U and 6U CubeSat hosting antennas ranging from the low UHF to the higher Ka band are modelled in the ESTEAM course. The antennas are inspired by recent designs published in the literature. RF performances of the antennas installed on the CubeSats are compared with the model at all the wave lengths and frequency bands. The antennas are discussed. The antenna operation is confirmed by full-wave simulations. The results show that the RF performances of the antennas are substantially changed once these are installed on the CubeSats, indicating that platform scattering and coupling with the neighboring antennas must be included and accounted for already in the antenna design phase.

P2.017 Power Transfer Efficiency Analyzed Using Characteristic Mode Coupling Between Two Parallel Loops

70 of 128
This paper discusses a novel SIW feed network which demonstrates a substantial reduction in the insertion loss of SIW at 60 GHz (−13 dB) in both main planes. Some other simulation results will be shown to prove the potential of the proposed design.

Different types of transmission lines are designed and fabricated. Results for both patch antennas and transmission lines show rather good agreement between simulation and measurements. The measured −10 dB bandwidth of a single element is 1.76 GHz centered at 59 GHz. In the future, 1×4 patch antenna array will be integrated with the four channel software-defined radios.

In this work, a novel way to generate circular polarization (CP) using gap waveguide (GW) technology in an antenna, is presented. This RGW system, working in the millimeter-wave band (60 GHz). CP is generated in a simple and effective way, by means of two different types of transmission lines incorporated in a single antenna. This study considers different types of transmission lines to test the performance of the CP. The proposed CP antenna has the advantage of being compact and easy to fabricate. The antenna is composed of two parallel loops, the separation distance and the overlapping between the two antennas on the characteristic modes and their contribution to the total efficiency of the power. The study considers different positions and frequencies of the two parallel antennas.

MN system. Beam switching can be a good solution in case that a bus changes the lane, and relay function can be applied when the received mmWave signal is blocked by road sign or another vehicle.

Ferdaous Abderrazak (ITEAM-UPV, Spain); Eva Antonio-Daviu and Miguel Fernando-Bataller (Universitat Politècnica de València, Spain)

Independently of any electrical contact, running electronic devices such as smartphones, smart watches, RFID tags etc., is now attainable over small and large distances through Wireless Power Transfer technology. Although, designing systems maintaining appreciable power transfer efficiency still not always achievable. Using two parallel loops, the Theory of Characteristic Modes provide physical insight into the power transfer efficiency. Furthermore, it reaches straightforward maximization of the modal power-transfer efficiency, the focus of this paper is analyzing the impact of the separation distance and the overlapping between the two antennas on the characteristic modes and their contribution to the total efficiency of the power. The study considers different positions and frequencies of the two parallel antennas.

This paper presents the compact design of a substrate-integrated waveguide (SIW) antenna based on H-plane aperture antennas. The antenna is composed of two parallel loops, the separation distance and the overlapping between the two antennas on the characteristic modes and their contribution to the total efficiency of the power. The study considers different positions and frequencies of the two parallel antennas.

This paper presents the novel design of trapped microstrip-ridge gap waveguide by using partially filled air gaps in a microstrip ridge gap waveguide. The proposed design method offers an applicable solution to obtain frustrated scattering processes for standalone high-frequency circuits employing the low-temperature-co-fired ceramics technology which supports buried cauties. How the practicability of the proposed approach, propagation characteristics of both trapped microstrip and microstrip-ridge gap waveguide are compared first. Then, a right-angle bend is introduced, followed by designing a power divider. These components are used to feed a linear 4-element array antenna. The bandwidth of the proposed array is 13 GHz (64–77 GHz) and provides the realized gain of over 10.8 dB and the efficiency of almost 85% throughout the operational band. The antenna is an appropriate candidate for upper bands of WiGig (63.72–70.2) and FCC-approved 70 GHz band (71–76 GHz) applications.

Each station of the SKA1-Low radio telescope is composed by 256 dual-polarized log-periodic antennas deployed over a metallic ground plane with 42 m diameter. This station is usually modelled in EM simulators by considering an infinite ground plane, which drastically reduces the computational time. This contribution shows that a finite ground plane can bring significant differences in some embedded element patterns with respect to the infinite ground plane case. Furthermore, we show the impact on the antenna pattern of different dielectric media surrounding the finite ground plane. For instance, at 50 MHz the antenna gain decreases by 5% maximum due to the ohmic loss considered in the ground plane.
The proposed polarization-reconfigurable patch antenna-on-package for millimeter-wave operations with DC bias circuit design and high gain. The proposed array antenna is designed based on the gap waveguide technology, which makes it possible to achieve a design of high gain and high efficiency at Ka-band. The simulated results show that the antenna achieves a good performance of high gain and high efficiency at Ka-band.
This paper presents a novel circularly polarized electrically small antenna that has been designed thanks to the embedding of a chiral Metamaterial in order to achieve a Circular Polarization. First, the two elements are analyzed separately using CMA to analyze the physical behavior of both structures. Then, the intermodal coupling between the dipole and the helix is investigated, which is induced by the magnetic and electric modes and thus increases the overall radiation efficiency.

This work presents the design of a miniaturized on-chip meandered loop antenna (OCMLA) with improved gain characteristics at 11 GHz. An on-chip metasurface technique is applied for enhancing the electrical length of the antenna and achieving a miniaturization up to 15:1 with a dimension of 2 x 2 mm. The introduction of partially shield layer (PSL) layer below the top radiating layer in between the SOCMLA provides the gain enhancement of 4 dB by reducing EM wave propagation toward the substrate. The proposed antenna shows a gain and bandwidth of 29.2 dB and 250 MHz respectively. Also, the simulated and measured results of OCMLA are showing very good agreement and has been presented successfully. The characteristics proposed OCMLA makes it appropriate candidate for short and ultra-short range communication SoC devices.

A very compact implantable monopole using a nullifier is presented. The nullifier is a voltage zeroing circuit that can be used to suppress the mutual coupling of meandering of the antenna structure. Using this approach, an implantable monopole was designed to have a minimal size and volume of 12.6 mm3, which will be useful in satellite communication applications.

This paper presents the application of miniaturization techniques to UHF printed antennas designed for installation onto implantable devices. Two radiators are used to compose four-element planar arrays. The analyzed implantable monopole is printed on Rogers RO3003 substrate material and a chiral Metamaterial in order to achieve a Circular Polarization. First, the two elements are analyzed separately using CMA to analyze the physical behavior of both structures. Then, the intermodal coupling between the dipole and the helix is investigated, which is induced by the magnetic and electric modes and thus increases the overall radiation efficiency.
P2.053 The Slotted Waveguide Array Antenna with Reflection Cancelling Stairs in Millimeter Waveband

Wenbo Liu (Graduate School of Engineering, Takushoku University, Japan); Yuasuhiro Tsunemitsu (Takushoku University, Japan)

We propose and design 38-GHz slotted waveguide antenna with reflection canceling stairs to improve aperture efficiency. The waveguide includes 10 linearly arranged slots and 9 stairs. From the Finite Element Method (FEM) calculation, length and offset of each slot are optimized to obtain uniform radiation intensity. Then the corresponding star position and height are designed to suppress the reflection. The simulation of the full model confirms that aperture efficiency is improved to 64.9%.

P2.054 Quasi-Periodic Leaky-Wave Antenna Based on Substrate Integrated Waveguide and Liquid Crystal Technologies

Anastasis C Polykarpo (University of Nicosia, Cyprus)

A quasi-periodic leaky-wave antenna (QLWA) based on substrate integrated waveguide (SIW) and liquid crystal (LC) technologies is presented in this paper for single-frequency dynamic beam steering. The antenna works based on the fundamental space harmonic (n=0) in the frequency band from 10.2~GHz to 12.5~GHz. A very thin layer of nematic LC cell is placed underneath the substrate, which is then biased with an external electric field. The dielectric properties of the LC are controlled by the strength of the bias electric field. As a result, the main beam of the antenna pattern is deflected by an angle which depends on the bias voltage. The angular scanning range depends on the dielectric anisotropy of the LC compound and the substrate-to-liquid crystal thickness ratio. Simulation results based on the ANSYS HFSS commercial software are used in order to numerically verify the design concept.

P2.055 Design of an Array of Stacked Groove Gap Waveguide Leaky-Wave Antennas in the Ka Band

Nafisaka Memeletzoglou and Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

In this paper, the design of an array of stacking leaky-wave antennas in groove-gap waveguide technology is developed. The array is formed by stacking leaky-wave antenna on top of the other. The array design consists on the investigation of the number of elements to be stacked, and the inter-element distance to avoid grating lobes and to obtain high directivity levels. The feeding of the array is done through the design of a vertical coupler. Phase shifters placed after the feeding network, ensure that the elements radiate in phase, aiming to achieve maximum directivity. The central frequency of the design is 23 GHz, and the array of four elements, achieves an enhancement of +5 dB, reaching 24.5 dB of directivity, in comparison to 14.8 dB of directivity of the single leaky-wave antenna made in this technology. The proposed design was validated experimentally with a prototype.

P2.056 A Novel Circularly-Polarized T-shaped Slot Array Antenna in Ka-band

Miguel Ferrando-Rocher (Universitat Politècnica de València, Spain); José Ignacio Herranz-Herruzo (Universidad Politécnica de Valencia, Spain); Daniel Sánchez-Escudero (Universidad Politécnica de Valencia, Spain); Alejandro Valero-Nogueira (Universidad Politécnica de Valencia, Spain)

A T-shaped slot-array antenna fed through a Groove Gap Waveguide (GGW) is presented in this paper. The array antenna operates at 30 GHz. The way the slots are excited, along with the T-shape on its tip allows a compact single-layer architecture. A uniform linear array of 12 elements is designed to demonstrate the viability of this concept for high-efficient single-layer slot-array antennas. Preliminary results show a frequency bandwidth of 7~30 GHz with an input reflection coefficient better than 9.5 dB. In addition, being a full-metal antenna, the expected efficiency is high. It is worth stressing the good polarization purity achieved, being below 1.3~dB within the band of interest.

P2.057 A Low-Profile Millimeter-Wave Circularly-Polarized Multilayered Waveguide Antenna for Satellite Communication Application

Hong-Tao Zhang (ND 9 Research Institute of CETC, China); Wei Wang (No. 38 Research Institute of CETC, China); Guan-Long Huang (Shenzhen University, China); Yongqing Zou (East China Research Institute of Electronic Engineering (ECREE), China)

A low-profile circularly-polarized multilayered waveguide antenna array operating in Ka-band is proposed. The array antenna is also characterized for low axial ratio (AR), high-efficiency and wide operating bandwidth. To achieve a wide operating bandwidth from 28.4~GHz to 31.0~GHz and improve the AR, sequential rotation technique is utilized. The complete array is composed of few aluminum layers firmly brazed with each other. Each layer is manufactured by using the computer numerical control (CNC) milling machine. Experimental results demonstrate that a desired bandwidth with VSWR and AR less than 1.5 and 2.5 respectively have been realized with low radiation gain. The proposed antenna array is an excellent candidate for advanced satellite communication (Satcom).

P2.058 Practical Design of Radiating Part of Post-Wall Waveguide-Fed Parallel Plate Slot Array Antenna by Method of Moments

Kohi Hashimoto and Makoto Hijii (Toshiba Corporation, Japan)

A practical design of a radiating part of a post-wall waveguide-fed parallel plate slot antenna array is presented. The radiating part of the antenna is a parallel plate waveguide with an array of radiating slot pairs. The slot pairs are designed by the method of moments (MoM). In the MoM method, unknown equivalent magnetic currents on slot apertures are expanded with discrete sinusoidal basis functions. The dependence of accuracy and computation time on the number of basis functions is evaluated. The MoM with an appropriate number of basis functions enables accurate and fast analyses. As an example, an efficient design of an array consisting of 21 slot pairs in the longitudinal direction of the parallel plate waveguide is demonstrated.

P2.059 Target Feature Extraction in Narrowband Mode

Xiaohuan Wu (Harbin Institute of Technology, China)

Pole is an important feature of radar target recognition in resonant region, and it is not sensitive to attitude. However, the pole extraction requires time-domain late response or frequency-domain response (i.e. radar cross section, RCS) of the broadband signal, which is difficult to meet in the actual system. In this paper, a method of pole extraction based on sparse representation is proposed, which can obtain the pole characteristics of the target by fewer RCS in the narrowband mode. It is of great significance to the target classification and identification in resonant region.

P2.060 Proposal on Hybrid Propagation Analysis of Aperture Field Integration Method and Ray Tracing Method Suitable for Airport Surface in VHF Band

Satoshi Kuroda and Ryosuke Suga (Aoyama Gakuin University, Japan)

A hybrid propagation analysis method of ray-tracing method and aperture-field-integration method for airport surface is proposed. Its effectiveness was evaluated by measurements using a 1/50 scaled model. As a result, the simulated power distribution by the proposed method agreed with the measured one.

P2.061 Volume Integral Equation Formulation for Electromagnetic Scattering by Highly Inhomogeneous Anisotropic Cylinders

Konstantinos Katsinos, Grigorios Zouros and John Roumeliotis (National Technical University of Athens, Greece)

In this work we report a volume integral equation formulation for the electromagnetic scattering by highly inhomogeneous anisotropic cubic cylinders under normal incidence. The development of the method is based on a vectorized formalism which exploits the cylindrical vector wave functions and allows for the simultaneous treatment of both transverse electric (TE) and transverse magnetic (TM) incidence. The cylindrical vector wave functions employed in this work form entire domain basis vector functions which are constructed so as to guarantee orthogonal relations in the circular domain of anisotropy. The method is validated with the exact solution for single and double layered isotropic cylinders, for both TS and TM incidence, as well as with the commercial HFSS software for anisotropic permittivity profiles. Numerical results are given for various values of the parameters.

P2.062 Evaluating the RCS Contribution of Geometrical Singularities: An Analytical Model

Nima Javanbakht and Barry Syrett (Communications Research Centre Canada, Canada)

In this paper we report a volume integral equation formulation for the electromagnetic scattering by highly inhomogeneous anisotropic cylinders, for both TE and TM incidence, as well as with the commercial HFSS software for anisotropic permittivity profiles. Numerical results are given for various values of the parameters.
P.063 General Formulation of the Boundary Element Method (BEM) for Curvilinear Metasurfaces in the Presence of Multiple Scattering Objects
Tom Smy, Jacob Connor, Scott Stewart and Shubhaj Gupta (Carleton University, Canada)

This paper presents a general formulation for determining the scattered Electromagnetic fields present for a multi-surface configuration of curvilinear interfaces comprised of metasurfaces, dielectrics and perfect conductors. The method uses a Boundary Element Method (BEM) formulation of the frequency domain version of Maxwell’s equations, where the general metasurface boundaries are represented in terms of surface susceptibilities which are then integrated within the BEM using the Generalized Sheet Transition Conditions (GSTCs). These curvilinear surfaces are next described by parametric equations allowing for an elegant formulation for geometrically complex systems. The proposed method is then demonstrated using a numerical example.

P.064 Gradient-induced Heating of a Metallic Hip Implant in Magnetic Resonance Imaging
Alessandro Arduino, Oriano Bottaccio, Mario Chiampi and Luci Zilberti (INRIM, Italy)

This work focuses on the evaluation, via numerical simulations, of the energy deposited by MRI switched gradient fields in bulky metallic implants and the consequent temperature increase in the surrounding tissues. An original computational strategy allows describing realistically the evolution of the phenomena produced by the gradient coils fed according to any imaging sequence. Next, a test case is solved through a Gaussian Gruen time-geometry scheme to compute the time-dependent temperature increase. The heating generated inside the body of a patient with a unilateral hip implant when undergoing an Echoc Plane Imaging sequence is evaluated and the role of the parameters affecting the thermal results (body position, coil performing the frequency encoding, effects of thermoregulation) is discussed. The results show that the gradient coils can generate local increases of temperature up to some kelvin. Hence, their contribution in general should not be disregarded when evaluating patients’ safety.

P.065 Modal Simplification and Validation of Prototypes for Vehicular Antenna Design
Irfan Yousaf (Lunds University & Volvo Cars Corporation, Sweden); Kranti Kumar Kataria (IIT Kanpur, India); Buon Kiong Lau (Lund University, Sweden)

This paper presents a general formulation for determining the scattered Electromagnetic fields present for a multi-surface configuration of curvilinear interfaces comprised of metasurfaces, dielectrics and perfect conductors. The method uses a Boundary Element Method (BEM) formulation of the frequency domain version of Maxwell’s equations, where the general metasurface boundaries are represented in terms of surface susceptibilities which are then integrated within the BEM using the Generalized Sheet Transition Conditions (GSTCs). These curvilinear surfaces are next described by parametric equations allowing for an elegant formulation for geometrically complex systems. The proposed method is then demonstrated using a numerical example.

P.066 Integral Equation Formulation for Planar Plasmonic Nano Structures in Layered Media
Esraa Mahdy (Cairo University, Faculty of Engineering, Egypt); Ala Abdalmeqied (Cairo University, Egypt); Ezeddin Soliman (The American University in Cairo, Egypt)

In this paper, an integral equation formulation for planar plasmonic structures in layered media is developed. First, closed form spatial domain Green's functions are obtained using the discrete complex images method. Then, the boundary conditions along the localized plasmonic structures are applied and written in the form of an integral equation. Finally, the Method of Moments (MoM) is applied where the integral equation is transformed into a matrix equation, which is solved using traditional matrix routines. The developed solver is applied on a square-patch nano antenna fed with a plasmonic transmission line. Its accuracy is compared with CST microwave studio and a very good agreement is obtained.

P.067 Impact of Parameters Variability on the Performances of an Implanted Antenna for Biomedical Applications
Shuoliang Ding (Geeps & CentraleSupelec, France); Yao Pei (University Paris-sud, France); Lionel Pichon (Group of Electrical Engineering and Physics, Université Paris-Saclay & Geeps Laboratory, France); Stavros Koulouridis (University of Patras, Greece)

In this work, non-intrusive stochastic techniques are combined with 3D modeling in order to build adequate surrogate models for the evaluation of performances of a transmission link for biomedical applications. A surrogate model is appropriate to deal with uncertainties and variabilities of parameters defining the electromagnetic problem. Numerical results obtained in case of a realistic configuration involving an external patch antenna and an embedded antenna illustrate the proposed methodology.

P.068 Application of non-PEC Walled Mode-Matching Techniques to a Prototype SAFARI M-band Multi-Mode Receiver
Joseph Brennan (Maynooth University, Ireland); Marcin Gradziel (National University of Ireland, Maynooth, Ireland); Neil Trappe (NUI Maynooth, Ireland); Peter Ake (Cardiff University, United Kingdom (Great Britain))

An extension of the traditional mode-matching methods to consider non-PEC boundary walls is presented. These non-PEC boundary walls consider mechanisms for loss which are generally not included in the analysis of guide structures. In particular, these losses manifest themselves more significantly in multi-mode structures, as field distributions for increasing azimuthal order modes are localised to a greater extent at the boundary walls. This lossy mode-matching method is applied to a square-horn antenna structure with the proposed methodology.

P.069 Neural Network Approach for Dielectric Characterization of Tissues in Microwave Frequencies Using Coplanar Waveguide Transmission
Viktor Mattsson (Uppsala University, Sweden); Mauricio D Perez (Universidad de Buenos Aires, Sweden); Dario Dematties (Universidad de Buenos Aires, Sweden); Robin Augustine (Uppsala University, Sweden)

This paper presents an extension to previous work, using neural networks to characterize materials in microwave frequencies, to extend the applicability of a deep learning model to be able to characterize the dielectric properties of biological tissues. A neural network model using convolutional and fully connected layers is designed to predict the permittivity and loss tangent using the scattering parameters from a coplanar waveguide transmission sensor. Simulated data from the sensor provides a large dataset, with a wide range of values for the permittivity and loss tangent, which is used to train and test the model. The trained network is validated by predicting the output parameters on the test set. Compared with previous work, by using convolutional layers the applicable parameter space is vastly extended while keeping satisfying levels of accuracy. A complete system with a trained network is proposed to be used in laboratory or clinics.

P.070 Feeding Positions Providing the Lowest TARC of Uncorrelated Channels
Michal Masék (Czech Technical University in Prague, Czech Republic); Miloslav Čapek and Lukás Jelínek (Czech Technical University in Prague, Czech Republic)

In this paper, point group theory is utilized for the simultaneous block-diagonalization of all linear operators relating the underlying symmetrical structure. This linear model is utilized for designing orthogonal channels suitable, for example, for MIMO systems. Within these uncorrelated channels, the total active reflection coefficient is further formulated within the method of moments framework and is used to find position of feeders that provide orthogonal channels with maximum radiation.

P.071 PML Effectiveness in the Transmission Line Modelling Method for Radiation and Scattering Applications
Jomolou Odeyemi, Chris Smartt, Ana Vukovic, Trevor Bower and Phillip Sewell (University of Nottingham, United Kingdom (Great Britain))

This paper demonstrates the effectiveness of the recently introduced, stable, perfectly matched layer (PML) for the Transmission Line Modelling (TLM) method. The superiority of the new-PML over the TLM matched boundary is demonstrated by application to electromagnetic scattering and radiation simulations.

P.072 Effects of Common Approximations in the Modeling of a Liquid-Crystal-Based Patch Antenna: A Numerical Investigation
Nectarios Papanicolaou, Anastasia C Polycriou and Mario Christou (University of Nicou, Cyprus)

Liquid crystal compounds are increasingly used as tunable materials for a plethora of microwave and millimeter-wave devices. Liquid crystal modeling mandates the solution of the directors' field under an external electric field, governed by the Deen-Frank free-energy functional. Its minimization results in a nonlinear partial differential equation which is often simplified by applying the one constant approximation, where the splay and bend elastic constants are set equal to each other. The effects of this approximation on the radiation characteristics of a microstrip patch antenna built on top of a liquid-crystal substrate are not well studied. Here, we adapt this approximation, along with neglecting the off-diagonal entries of the corresponding dielectric tensor, and compare the results with the original model. The reduced model results in a more computationally efficient algorithm for the characterization of liquid crystal materials; however, there are substantial discrepancies in the simulated antenna figures of merit for intermediate bias voltages.

P.073 Hybrid MoM/T-Matrix Method for Analysis of Interaction Between Objects
Vit Losenicky, Miloslav Čapek and Lukás Jelínek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

A hybrid method for analysis of an interaction between electromagnetic scatterers is introduced. The method connects the method of moments and T-matrix method and represents a promising candidate capable of solving problems with 35 antennas or close to the human body. Two specific cases of the mutual position of the objects are shown. Preliminary results are demonstrated on two examples. The advantages and limitations of the method are discussed.
P.026 Electromagnetic Design of Beam Position Monitor Based on Diffraction Radiation from Twin Dielectric Nanowires

Daria O. Heryaminova (Institute of Radio-Physics and Electronics NASU, Ukraine)

The diffraction radiation of a modulated beam of charged particles, which flow between two dielectric circular nanowires is considered. This nanowire configuration can be considered as a pair of optically coupled open resonators. The electron beam field is a slow wave, which decays exponentially from the beam trajectory and is anti-symmetric with respect to that trajectory. We use the Fourier expansions in local polar coordinates of each wire and the addition theorems for the cylindrical functions in order to reduce the wave-scattering problem to the discrete form. As soon as we cast the derived matrix equation to the Fredholm second-kind type, the convergence is guaranteed. The diffraction radiation power shows the peaks at the supermode wavelengths, some of which appear only if the beam trajectory has non-zero rotation angle from the symmetric position. This effect can be scaled to the other wavelength ranges and used in the beam-position monitoring.

P.027 Modelling of the Mechanical Antenna Using the Biot-Savart Law

Ben I Jones and Theo Saunders (Queen Mary University of London, United Kingdom (Great Britain)); Yang Hao (Queen Mary University, United Kingdom (Great Britain))

We introduce a Mechanical Antenna experiment which was performed by James Bickford and colleagues, and we present an overview of the instrument. Our model is based on the Biot-Savart law for the magnetic field produced by a moving point charge. We outline our C++ simulation code and present the results, then discuss comparison with Bickford's model. Finally, we extend our model to asymmetric charge distributions.

Poster2-E04: Optimisation Methods in EM

Electromagnetics

Room: Exhibition Hall

P.079 Antenna Design Exploration and Optimization Using Machine Learning

Christoph Maeurer (Germany, Germany); Peter William Futter (Altair Development S.A. (Pty) Ltd, South Africa); Gopnath Gampala (Altair Engineering Inc., USA)

Design exploration using numerical field simulation is a valuable approach to analyze antenna performance parameters. In such a process many data describing a mapping from design variables to response functions are generated. In this work different machine learning (ML) techniques are applied on these data to analyze and optimize antenna performance. This data driven simulation approach can speed up antenna optimization tremendously. Also, the benefit of dimensionality reduction algorithms and evolutionary learning in antenna performance analysis is described.

P.080 Fast Globalized Gradient-Based Optimization of Multi-Band Antennas by Means Smart Jacobian Updates and Response Features

Slawomir Koziel and Anna Pietrenko-Dabrowska (Gdansk University of Technology, Poland)

Fulfilling stringent performance requirements calls for a precise adjustment of the antenna dimensions in multi-parameter spaces. Solving such tasks is expensive when using conventional algorithms. Furthermore, global optimization is needed in many cases, which increases the level of design process difficulty. As a matter of fact, utilization of state-of-the-art population-based metaheuristics is prohibitive when the antenna is evaluated by means of full-wave EM analysis. In this work, a novel optimization approach is proposed. The mechanism uses the concept of multiple teachers to cluster the learner groups. It triggers an extra exploration with the same exploitation of the cost function to alter the distribution of the proposed solutions. The performance is validated using a set of standard objective functions. Comparisons to Gradient Descent (GD), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) illustrate a superior performance for designing such large dimensional beam-shaping problem.

Poster2-E05: Imaging and Inverse Scattering

Electromagnetics

Room: Exhibition Hall

P.083 Application of MRI, fMRI and Cognitive Data for Alzheimer’s Disease Detection

Chiara Dachena, Sergio Casu, Matteo Lodì, Alessandro Fanti and Giuseppe Mazzarella (University of Cagliari, Italy)

Magnetic resonance imaging has the clinical potential of helping diagnosis in providing to doctors structural and functional information of several neurological disorders. In this study, we proposed a new method based on the elaboration of fMRI-images and MRI-images, combined with the exploitation of Mini Mental Score Examination (MMSE) to discriminate Alzheimer’s Disease by control subjects using SVM classification. 69 subjects from the ADNI open database, 33 AD patients and 36 healthy controls, were analyzed. The use of a unimodal approach led to unsatisfactory results, whereas the multimodal approach, i.e., the combination of MRI, fMRI, and MMSE features, resulted in an accuracy of 89.65%, a specificity of 97.32%, and a sensitivity of 93.29%.

P.084 A New Focused Hyperthermia Based on Spacefrequency DORT

Danie Ludick (Stellenbosch University, South Africa)

In this work, a hybrid distributed-shared memory parallelization scheme is presented for the domain green’s function method (DGFMM). The DGFMM is a domain decomposition based computational electromagnetics (CEM) method used for analyzing large disjoint antenna arrays. The array configurations considered consists of identical elements, with regular or irregular array layouts. The hybrid MN/OpenMP parallelization strategy introduced in this work offers satisfactory speedup performance. This allows for the simulation of large array geometries in a distributed computing environment.
An ultra-wideband polarization-insensitive thin microwave absorber composed of triple-layer resistive surfaces
Yixian Fang and Zhihao Hu (University of Manchester, United Kingdom (Great Britain))

An ultra-wideband and polarization-insensitive microwave absorber, which is composed of three layers of metals with different patterns and sheet resistances, is proposed in this paper. The bandwidth of effective absorption (over 90%) is from 6 GHz to 50 GHz, with relative absorption bandwidth of 157%. The equivalent circuit of the proposed absorber is investigated thoroughly. The circuit model analysis results agree quite well with the numerical simulation, which indicates the accuracy of the equivalent circuit model. The performances of this absorber under various polarizations and incident angles are also investigated. The results indicate the proposed absorber is polarization insensitive and has relatively good stability of wide incident angles.

Ultra-wideband and polarization-insensitive thin microwave absorber composed of triple-layer resistive surfaces
Yixian Fang and Zhihao Hu (University of Manchester, United Kingdom (Great Britain))

A broadband and broad-angle linear-to-circular polarization converter based on a dual-layer substrate is presented. The elementary cell of the proposed converter is composed by a Jerusalem Cross (JC). The design procedure is based on transmission line circuit theory and on full-wave unit cell analysis in frequency domain. Simulated results demonstrate a 24% axial ratio bandwidth for an incidence angle ±50° in both x-z and y-z planes. The proposed converter provides a unique combination of wide bandwidth, thin profile, and stability with respect to the angle of incidence. It can be integrated to any linearly polarized antenna to generate circular polarization without affecting the antenna performances.

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P.02.094 Novel Dicropic Subreflector Design for Cassegrain Antennas

Seymur Shahkouzov (Yeditepe University & Profin Communication Technologies, Turkey)

Novel subreflector design for Dual Band Cassegrain Antenna systems was proposed in this paper. Proposed Frequency Selective subreflector, reflecting frequencies in a Band and transmitting in another Band was designed and manufactured using Selective Laser Synthesis method. Tests were made both on the manufactured unit and on a complete antenna system using GEO satellite beacon signals. It was shown that total antenna efficiencies in both frequency bands using Frequency Selective Surface dicropic subreflector were more than 65%.

P.02.095 Retrieval of Effective Permittivity and Permeability of Periodic Structures on Dielectric and Magnetic Substrates

Peng Mei and Shiuh Zhang (Aalborg University, Denmark); Xiaoqi Lin (University of Electronic Science and Technology of China, China); Gert Pedersen (Aalborg University, Denmark)

This paper presents the retrieval of effective permittivity and permeability of periodic structures on dielectric and magnetic substrates. The retrieval approach is based on investigating the equivalent circuits. For demonstration, a single square loop-based periodic structure is used as an example to elaborate the retrieval process. Firstly, the equivalent circuit of the frontstanding structure is modeled with inductor and capacitor, where the values of these components are determined by the simulated 2D-matrix of the frontstanding structure, the effects of supporting substrates are then considered, where the compensating principles are deduced from inductive grids and capacitive patches, to compensate the corresponding values in the former equivalent circuit on purpose. The compensating values are also determined from the simulated 3D-matrix of the structure with supporting substrates. The formulas of effective permittivity and permeability are readily deduced and obtained from the original and compensating values of components in the equivalent circuits.

Poster2-P05: Mm-wave and UWB Propagation

Propagation
Room: Exhibition Hall

P.02.096 Channel Measurement and Analysis for Polarimetric Wideband Outdoor Scenarios at 26 GHz: Directional Vs Omni-Directional

Sohali Payami (University of Surrey, United Kingdom (Great Britain)); Moshen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Sohail Taheri (VIavi Solutions, United Kingdom (Great Britain)); Konstantinos Nikolopoulos and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

This paper presents the measurement and analysis for outdoor wireless propagation channels at 26 GHz over 2 GHz bandwidth for two receiver antenna polarization modes. The angular and bandwidth properties of directional and virtually omnidirectional scenarios, such as angular spread, cost-mean square delay spread and coherence bandwidth, are analyzed. It is observed that the reflections can have a significant contribution in some realistic scenarios and the angular spread and delay spread, and reduce the coherence bandwidth of the channel. In addition, the analysis in this paper show that a directional transmission can result in an almost frequency-flat channel over the measured 2 GHz bandwidth, which consequently has a major impact on the choice of system design choices such as beamforming and transmission modulation.

P.02.097 Ray-tracing Based Channel Clustering and Analysis at 28 GHz in Conference Environment

He Ding (Beijing University of Posts and Telecommunications & Telecommunications & Wireless Technology Innovation Institute, China); Lei Tian (Beijing University of Posts and Telecommunications & Telecom Research Centre, China)

This paper discusses the cluster spreads and scattering intensity (SI) characteristics at 10 and 28 GHz band in a typical indoor factory environments based on channel measurements. The results consistently indicate that rich reflection paths occur in industrial scenarios, relative to indoor office environments. Also, severer attenuation and lower multipath distortion are observed in the 28 GHz band, which consequently has a major impact on the choice of system design choices such as beamforming and transmission modulation.

P.02.098 5G Millimeter-Wave NLOS Coverage Using Specular Building Reflections

Robbert Schulpen, L. A. (Sander) Bronckers, A. B. (Bart) Smolders and Ulf Johannsen (Eindhoven University of Technology, The Netherlands)

Maximization of 5G millimeter-wave base station coverage and range is important to reduce the number of required base stations. Buildings could be used as reflections to provide coverage in NLOS areas due to their high reflectivity at millimeter-waves. This paper presents the results of a measurement campaign investigating specular reflections from buildings at 28 GHz and 39 GHz. The angle of minimum path loss for single-building reflections agrees well with the direction of the specular path. This agreement is more accurate in case of a double-building reflection, possibly due to obstructions in the specular path or multiple fading. In case of a single-building reflection, 1.9 dB excess loss compared to free-space path loss is measured. Although more research on this topic is required, these results are promising and indicate that buildings can be used as effective millimeter-wave reflectors.

P.02.099 Availability of 7 Km-Long Parallel 18 GHz Band and E-band Links for Multi Band Solutions

Christina Larsson (Ericsson Research & Ericsson AB, Sweden); Lei Bai (Ericsson AB, Sweden)

E-band (70/80 GHz) backhaul links are nowadays available with multi-Gbps capacity. Unfortunately, the high attenuation due to rain is limiting the link lengths to around 2 km. One way to overcome this limitation is to set up the E-band link in some sort of carrier aggregation solution together with a conventional backhaul band, usually 18-23 GHz to guarantee availability of critical data transfer also during heavy rain. This study compares long term logging of 7 km-long parallel backhaul links with carrier frequency: 18.6/19.6 GHz and 71.6/81.6 GHz. This summary includes a comparison with ITU recommendations and a discussion on which phenomena, more than precipitation, is influencing the availability of these links.

P.02.100 Multi-Band Characterization of Propagation in Industry Scenarios

Diego Duplech (Ilmenau University of Technology, Germany); Robert Müller (TU Ilmenau, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Jian Luc (Huawei Technologies Dusseldorf GmbH, Germany); Giovanni Delgado (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

Industry 4.0 is the scenario in which the 5G and beyond networks are expected to show all their potentials well, while propagation at sub-6 GHz has already been widely investigated in industry environments, mm-waves propagation and channel modeling in those scenarios is still under early research. Therefore, we introduce novel simultaneous multi-band ultra-wideband measurements at 6.75 GHz and 30 GHz in LOS and NLOS with 8 dB below and above clutter level. This unique setup allows a direct comparison between the sub-6 GHz and mm-wave channel. Results have shown larger skew to dense multi-path components power ratio and shorter large-scale parameters at mm-waves.

P.02.101 Indoor mmWave Channel Characterization with Large Virtual Antenna Arrays

Alfred Mudoni (CEA Leti and Université Catholique de Louvain & Universite Grenoble-Alpes, France); Raffaele D’Errico (CEA, LETI, Minatec Campus & Univ., Grenoble-Alpes, France); Claude Oestges (Université Catholique de Louvain, Belgium)

In this paper we present an indoor channel measurement campaign from 26 to 30 GHz, using a virtual antenna array. On the receiving side a 3x3 spatial grid, moving in the environment, was considered. On the transmitting side we considered a massive virtual array of 21x21 elements. Multi path components have been extracted by means of high resolution algorithms. The results obtained with the full massive array are compared with those obtained with a small array, in order to investigate the effect of array size in channel modeling.

P.02.102 Cluster Intensity and Spread Characteristics in Classroom Scenarios at 10 and 28 GHz Bands

Peng Mei and Xuan Wang (Tokyo Institute of Technology, Japan); Wei Fan (Aalborg University, Denmark); Johannes Hjeltemark (Nokia Bell Labs, Denmark); Jun-ichi Takada (Tokyo Institute of Technology, Japan); Gert Pedersen (Aalborg University, Denmark)

This paper discusses the cluster spreads and scattering intensity characteristics at 10 and 28 GHz band in a typical classroom environment. The multi-path components (MPCs) were calculated from the measurement data using space alternating generalized expectation maximization (SAGE) algorithm. Next, the scattering point-based KPowerMeans (SPKM) algorithm was used to cluster the clusters based on the corresponding values (SII) of each cluster. The multi-path delay spread (DS), angular spread (AS) and SI were computed and their characteristics were discussed. The results showed that the channels at both bands were almost equally directive. Moreover, cluster spreads depended on the number of layers and surfaces of IOs, whereas IO material and propagation mechanism influenced the cluster SI.

P.02.103 A Comparative Study for Indoor Factory Environments at 4.9 and 28 GHz

Yicheng Guan (Beijing University of Posts and Telecommunications & Key Lab of Universal Wireless Communications, Ministry of Education, China); Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Lei Tian (Beijing University of Posts and Telecommunications & Wireless Technology Innovation Institute, China); Pan Tang and Tao Jiang (Beijing University of Posts and Telecommunications, China)

The indoor industrial environment of Things (IoT) has benefited from the fifth-generation (5G) wireless network and is providing much-needed impetus for economic growth. Because of a very wide frequency range of 5G wireless network, the microwave and millimeter wavebands will constitute hybrid wireless communication systems, thus it is essential to have a thorough understanding of the possible channel characteristics in industrial environments at different frequencies. In this paper, we provide a comparative study of channel characteristics, i.e., the path-loss and Roaman K-factor at 4.9 and 28 GHz in indoor factory environments based on channel measurements. The results consistently indicate that rich reflection paths occur in industrial scenarios, relative to indoor office environments. Also, severer attenuation and lower multipath richness occur at 28 GHz. Meanwhile, the impact of antenna height on the propagation channel is studied. These results are helpful for the frequency band selection and antenna height design of IoT systems.
Poster2-P09: Propagation for Vehicular Communications

Propagation
Room: Exhibition Hall

P2.105 Clustering Performance Evaluation Algorithm for Vehicle-to-Vehicle Radio Channels
Chen Huang and Ruishi He (Beijing Jiaotong University, China); BoAi (Beijing Jiaotong University & State Key Lab of Rail Traffic Control and Safety, China); Mi Yang, Yang-Ao Geng and Zhangdai Zhong (Beijing Jiaotong University, China)

Numerical channel models are mostly modeled based on the structure of the clusters of multipath components (MPCs). The clusters of the MPCs can be identified by using clustering algorithms. Most of the clustering algorithms are sensitive to the number of clusters, which however, is hard to be acquired from the channel measurement. In this case, most of the algorithms use clustering performance evaluating methods to determine the best number of clusters. Nevertheless, none of the current evaluating methods are capable of properly evaluate the time-varying clustering results, where the evolution pattern in time dimension needs to be additionally considered. In this paper, we propose a novel clustering evaluation method for the clusters in time-varying channels, which considers the evolution pattern of the clusters during the evaluation. Based on the evaluations, the next cluster evaluation can better assess the time-varying channels compared to the existing evaluation methods.

P2.106 Measurements of Reflection and Penetration Losses in Low Terahertz Band Vehicular Communications
Vitaly Petrov (Tampere University, Finland); Johannes M. E. Schacht (Technische Universität Braunschweig, Germany); Dmitri Moltchanov and Yevgeni Koucheryavy (Tampere University, Finland); Thomas Körner (Technische Universität Braunschweig, Germany)

The beyond-5G vehicular communications are expected not only to utilize the already explored microwave-band but also to start harnessing the higher frequencies above 100 GHz ultimately targeting the so-called low terahertz band, 300 GHz to 1 Thz. In this paper, we perform a set of propagation measurements at 300 GHz band in representative vehicular environments. Particularly, we report on the reflection losses from the front, rear, and side of a regular vehicle. In addition, the penetration losses when propagating through, over, and under the vehicle are presented. Our study reveals that the vehicle body is extremely heterogeneous in terms of the propagation losses: the attenuation heavily depends on the trajectory of the 300 GHz signal through the vehicle. The reported measurement data may be used as a reference when developing the vehicle-specific channel and interference models for future wireless communications in the low terahertz band.

P2.107 In-Stationary Tapped Delay Line Channel Modeling and Simulation
Nina Hassan and Rainer S. Thomä (Innsbruck University of Technology, Germany); David W Matsalik (University of South Carolina, USA)

An essential tool in the performance analysis of communication systems is a tractable and accurate propagation channel model. The aim of this paper is to discuss the implementation of tapped delay line channel model for vehicle to infrastructure channels and devise a generator to produce a channel impulse response based on an already derived model parameters from measurement data. The root-mean square delay spread is used for a model propagation validated against collected data and results collected on the basis of how they agree. The analysis investigates correlation coefficient among taps and compares, as well as higher order Markov model. The results illustrate that only few taps are essential to regenerate accurately the delay spread.

Poster2-P10: Propagation in Biological Tissues and Body Area Propagation

Propagation
Room: Exhibition Hall

P2.108 Pathloss Calculation for Fat-Intra Body Communication Using Poynting Vector Theory
Javad Ebrahimzadeh (University of Uppsala, Sweden); Seyed Abbas Alkarzadeh Jahnors (University of Tehran, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Robin Augustine (Uppsala University, Sweden)

Recently, Fat-based Intra-Body Communication (FIBC) has been proposed and studied in terms of its reliability in simulation and laboratory settings. We, in this work, try to address another important aspect of communication, namely path loss, in the context of FIBC. This paper provides numerical and experimental modeling of path loss through the fat layer using the Poynting Vector theory and the multi-layer dielectric Green's function (MGF). To calculate the path loss based on the Poynting vector theory, the electromagnetic field distribution through the involved media should be known. This paper exploits the EM fields using MGF theory or commercial software CST Microwave Studio 2019. Finally, experimental measurement is done on ex-vivo tissue made of porcine skin, fat and muscle at frequency of around 5 GHz - 6 GHz. The average measured path loss is around 5.5 dB/cm which has good compliance with the theoretical Poynting vector path loss estimation.

P2.109 Verification of a Simplified Channel Modeling Technique for Ultra Wideband In-Body Communication with Simulations
Jan Christoph Brumm and Gerhard Bauch (Hamburg University of Technology, Germany)

For wireless capsule endoscopes, high data rate communication is needed between a transmitter in the gastrointestinal tract and a receiver on the body surface. One widely considered technique to achieve this is ultra wideband transmission. To the best of our knowledge no comprehensive channel models exist for the scenario of in-body communication. To change that, we recently proposed a simplified layer modeling technique. The goal of this paper is to verify that the channel characteristics derived with our proposed method are on average similar to those obtained from numerical simulations of our own. Our results show that on average the transmission loss for both approaches is nearly the same. Moreover, the correlation between the transfer functions is very strong. Finally, the power delay profiles generated are almost identical. Hence, it is possible to create a channel model with the same characteristics using a much simpler and less computationally expensive approach.

P2.110 A Low Cost Stable Adipose Phantom for Microwave Breast Cancer Investigation
Akshata Essoula (University of Kord)

In this paper, we present a low-cost and stable adipose composite from non-toxic particulate, Marmite and Clover butter. These samples were mixed in the proportion of approximately 50:50 using Lichtenheer logarithmic mixture equation for particles with arbitrary shape, to produce a homogeneous fat phantom, which is the main constituent of the breast tissue. The composite is characterized experimentally at 22 degrees Centigrade in the UWB frequency region in terms of its constitutive parameters, reflection and transmission coefficients. Cole-Cole parameters were extracted from experimental data. The permittivity of the fat phantom at zero, 4.5GHz and optical frequency are 48.13, 10.13 and 7.61 respectively. The relaxation time for this phantom is 19.23ps. The reflection and transmission coefficients are 0.48 and 0.52 respectively. These parameters are particularly useful in understanding the propagation of electromagnetic (EM) wave through glandular tissue where most cancers are known to be found.

P2.111 Compact Honey-Cell CSR-based Microwave Biosensor for Monitoring Glucose Levels
Ala Eldin Omer (University of Waterloo, Canada); George Shaker (University of Waterloo & Spark Tech Labs, Canada); Saieddinn Safavi Naeni (University of Waterloo, Canada); Hamid Kokabi (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, Canada); Georges Alqué (UPMC, France); Frédérique Frederique Deshours (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, France)

In this article, we propose a planar microwave sensor that consists of four distinct hexagonal-shaped complementary split ring resonators (CSRbs) configured in the honey-cell pattern. The sensor element operating at 1.5 - 3.0 GHz is fabricated on an FR4 dielectric substrate and excited via the microstrip technology in the cm-wave band. The proposed sensor is used as a near-field probe to detect the glucose levels in the blood reconstituting ex vivo solutions via tracing the frequency shift responses for tested glucose concentrations in the range 70 - 120 mg/dL. The sensor exhibits an excellent resonant frequency sensitivity that exceeds others in the literature. The sensor sensitivity, reliability and repeatability are demonstrated in the in-lab measurements via a Vector Network Analyzer (VNA).

P2.112 Propagation Analysis for an Implanted Antenna Model at Pancreas
Konstantina Zarafeta and Stavros Koulouridis (University of Patras, Greece); Stavros Kotsopoulos (Wireless Telecommunications Laboratory, Greece)

This paper presents a numerical and experimental study and channel characterization for an implanted antenna located upon the tissue of pancreas. Implanted antenna will be transmitting to a receiver that is located at specific distances in an indoor environment, like a hospital room. The antenna could support wireless data telemetry and power transmission operation within the industrial, scientific, medical band (ISM; 10.0 - 10.5 GHz). Here the aim is to investigate the propagation pattern of the near and overall field of electromagnetic waves in an indoor environment and to determine if this behavior causes differences between the two devices. To address this problem, the signal propagation of a system that consists of two dipoles, over a sampled trajectory is carried out. We then extended our study using virtual human models. Simulation results are examined and depicted extensively.

P2.113 A Preliminary Analysis of User’s Body Impact on Signal Polarization in WBANs
Kenan Turbic (INESC-ID / IST, University of Lisbon, Portugal); Mariella Särestöniemi (Erkki Koiso-Kanttilan katu 1 & Center for Wireless Communication, University of Oulu, Finland); Matti Hämäläinen and Timo Kumpuniemi (University of Oulu, Finland); Luis M. Correia (INESC-ID / University of Lisbon & INESC, Portugal)

This paper analyzes the impact of the human body on antenna radiation characteristics, with a focus on the polarization aspect. The effect of the body tissues on a wrist-worn ultrawideband double loop antenna radiation characteristics is investigated at 3.4 and 5 GHz, based on numerical full-wave simulations complemented with a voxel model of a hand. Results show a strong influence of the body on the gain and polarization characteristics; the radiation in the direction towards the body is suppressed by 20 dB or more, and the antenna polarization changes from a linear to an elliptical one. By simulating an off-body communications scenario with the user walking at a fixed distance from the off-body antenna, up to 6.5 dB lower received power is obtained by using the wearable antenna radiation pattern simulated with the hand phantom, compared to the case when the antenna is in free space.

P2.114 Automated Setup Setup for the On-body Link of Wireless Body Area Networks
Andreas Pfrommer and Martin Schmidt (Sivantos GmbH, Germany)

In this work a new automated setup setup for the on-body link of wireless body networks is described. The setup consists of an array of eight field probes distributed around the chest of an anthropometric body phantom. The whole system is in an anechoic chamber. As an example we characterize the on-body link of a hearing instrument
Poster2-P12: Radar, Localisation, and Sensing

**Propagation**

**Room:** Exhibition Hall

**P2.116 Evolution of the Image Quality over Time for a Freehand Monostatic mm-Wave Radar Imager**
Guiliover Alvarez Narcarići (University of Oviedo, Spain); Jaime Laviada (Universidad de Oviedo, Spain); Fernando Lao-Heras (University of Oviedo, Spain)

In this paper the performance over time of a freehand, mm-wave imaging scanner is studied. The system comprises a FMCW on-chip radar and a motion capture system used to estimate the position of the scanner during the acquisition process in order to coherently combine the measured data creating a synthetic aperture. The scanner is controlled by a conventional laptop, which is also in charge of processing the obtained data displaying real-time results. Specifically, four snapshots of the same scene comprising a target hidden under a hard cardboard box are analysed. The obtained results show that only a few seconds can be enough to retrieve a rough estimation of the shape of the targets within the volume under test.

**P2.117 Extracting the Features of the Shallowly Buried Objects Using LeNet Convolutional Network**
Mostafa Elasdaouny, Jan Barowski and Ilona Ruffels (Ruhr-Universität Bochum, Germany)

The convolutional neural networks are considered as the best artificial intelligence algorithms for image classification problems. Generally, a CNN requires a very large number of images to be trained well and to achieve the best results. This paper investigates the implementation of the LeNet convolutional network (ConvNet) for images classification using a small dataset. The dataset of interest comprises images of buried objects but obtained by a ground penetrating radar (GPR), which is considered as an efficient tool for detecting and defining buried objects. One of the main problems facing this classification task is the limited available data. The LeNet has been deployed and trained on the Fashion-MNIST dataset, and the learned features have been transferred to our GPR dataset. The network performance has been monitored and the classified features show a high degree of precision with.

**P2.118 Two-dimensional OAM Radar Imaging Using Uniform Circular Antenna Arrays**
Yanzhi Zeng, Yang Wang and Zhihui Chen (Chongqing University of Posts and Telecommunications, China); Jiadang Zang (The University of Sheffield, United Kingdom); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

The vortex radio wave carrying orbital angular momentum (OAM) can potentially be exploited to achieve astomthul super-resolution for target identification and radar imaging realms. A two-dimensional (2D) imaging method for OAM-based radar is presented in this paper. Based on the incrementally phased uniform circular antenna (UCA) arrays, the generation method and the echo signal model of OAM beams for radar imaging are established firstly. Subsequently, the modified multiple signal classification (MUSIC) algorithm is adopted to realize the 2D joint detection of the multi-target in the elevation and azimuth domain. Compared with the existing OAM-based radar target azimuth imaging, this proposed method can readily achieve 2D joint imaging of target's elevation and azimuth simultaneously without increasing the cost of hardware. The work and results provide suggestions to the design of OAM-based 2D radar systems.

**P2.119 Super-Resolution DOA Estimation Using Dynamic Metasurface Antenna**
Shengyao Chen, Bosu Sima and Fang Xi (Nanjing University of Science and Technology, China); Wen Wu (Nanjing University of Science & Technology, China); Zhong Lu (NUJST, China)

Dynamic metasurface antenna (MSA) exploit radiation properties of its elements to generate a variety of desired beam-patterns, and unlike traditional antenna array it avoids controlling the gain and phase at each element. This inherent beamforming capability leads to a compact and low-cost antenna implementation. This paper investigates direction-of-arrival (DOA) estimation of dynamic MSA. The dynamic MSA has only a single port output, and thus traditional DOA estimation techniques with array data are not applicable. However, the outputs of the diverse patterns of dynamic MSA are similar to the data of traditional antenna array in beam-space. Then beam-space DOA estimation approaches can be utilized to process the dynamic MSA data. A MUSIC-based algorithm is suggested and the DOA estimation performance of dynamic MSA is simulated. It is found that the super-resolution DOA estimation can be achieved and the dynamic MSA for DOA estimation is an interesting alternative to the traditional antenna array.

**P2.120 Intensity-only Imaging Using Broadband Correlations in Reverberation Chambers**
Philipp de Hougne (Institut de Physique de Nice, France); Philipp Besnier (ETR, France); Fabrice Montessagne, Ulrich Kuhl and Olivier Legrand (Institut de Physique de Nice, France); Matthieu Davy (IETR, Université de Rennes 1, France)

In this article, we present a proof-of-concept of intensity-only passive imaging inside a reverberating environment in the microwave regime. The auto-correlation of the diffuse field generated by a random source makes it possible to reconstruct the impulse response of an antenna, as if the antennas was both transmitting and receiving. This impulse response includes the reflection on objects within the medium. We demonstrate in microwave measurements in a mode-stirred-reverberation chamber (MRC) that an object can thus be accurately detected and located from intensity measurements on an array of antennas. These results pave the way to indoor intensity-only passive imaging using illuminators of opportunity in the microwave regime.

**P2.121 Experimental Results on Rain Detection at Ka-Band Based on Range-Doppler Signal Processing**
Asghan Taremi Zadeh, Moritz Müller and Jonas Simon (Goethe-University Frankfurt am Main, Germany); Sebastian Beck (Goethe-University Frankfurt, Germany); Jochen Moll (Goethe-University Frankfurt am Main, Germany); Viktor Krozer (Goethe-University of Frankfurt am Main, Germany)

Radar technology in the mm-wave frequency band is a promising approach for local rain detection and classification of precipitation. In this paper, we present a Frequency Modulated Continuous Wave (FMCW) radar system with 1 Tx and 2 Rx operating in the Ka-band from 33.4 GHz to 36.0 GHz. This Radar is a low-cost, portable system that requires a conventional laptop, which is also in charge of processing the obtained data displaying real-time results. The work and results provide suggestions to the design of OAM-based 2D radar systems.

**P2.122 Estimation of the Number of Persons in a Reverberant Environment Using Bistatic Radar**
Marwan Yusuf (Ghent University, Belgium); Brecht De Beede (Ghent University & IEMG, Belgium); Emmeric Tanghe (Ghent University, Belgium); Eli De Pooter (Ghent University & IEMG, Belgium); Luc Martens (Ghent University - imec, Belgium); Pierre Lally, Davy P Gaillot and Martine Lienard (University of Liége, France); Wout Joseph (Ghent University/IMEG, Belgium)

The theory of room electromagnetics provides a simple characterization of indoor microwave propagation. Considering the indoor environment as a loosely coupled, the exponential decay rate of the power-delay profile is related to the total absorption inside the room. In this paper, we explore the possibility of estimating the number of people inside a below-deck ship compartment using only the delay time constant, also known as reverberation time. First, we verify the reverberative nature of the chamber. Then, we find the relation between reverberation time and the number of people inside the room. We show that it is possible to estimate the number of people with a good accuracy, depending on the number of antennas used. With a success rate of 86%, the estimation error is only to 1 person when 16 spatially averaged antennas are used.

**P2.123 Simulation Validation of High Resolution Indoor Terahertz Synthetic Aperture Radar Imaging**
Aman Batra (University of Duisburg-Essen, Germany); Michael Weimeler (University of Duisburg-Essen, Germany); Diana Goebringer (Technische Universität Dresden, Germany); Thomas Kaiser (Universität Duisburg-Essen, Germany)

Indoor Terahertz Synthetic Aperture Radar (SAR) is an emerging technology for material characterization, high resolution imaging and localization. In comparison to optical technology, it provides benefits in hazardous scenarios such as fire in a building as objects inside the building can be characterized and localized. The principles of SAR are well established but the main challenge lies with extending this technology to high frequencies and indoor environment. To investigate this technology, imaging technology and platform systems have to be evaluated respectively. This paper explaies the signal processing of SAR and presents the imaging geometry for an indoor scenario. Further, it evaluates the parameters for high resolution imaging and localization. Based on these parameters, system design has been simulated and results of 2D high resolution indoor SAR imaging at 300 GHz are presented. Additionally, the proof of theoretical resolution across the range and azimuth is shown with the simulation results.

**P2.124 Temporal-Range-Doppler Features Interpretation and Recognition of Hand Gestures Using mm-Wave FMCW Radar Sensors**
Guiyuan Zhang, Shengchang Lan, Kang Zhang and Liting Ye (Harbin Institute of Technology, China)

This paper introduced a comparative study of using deep neural networks in non-contact hand gesture recognition based on mm-Wave FMCW radar. Range-doppler maps are processed with a zero-filling strategy to boost the range and velocity information of gesture motions. Two optimal types of deep neural networks, 3D-CNN and CNN-LSTM are respectively constructed to reveal the temporal gesture motion signatures encoded in multiple adjacent radar chirps. With the proposed networks, the recognition accuracy of six popular hand gestures reaches to 95%. Meanwhile, this letter further explores the performance of the proposed networks in the impacts of training data size on the recognition accuracy. The proposed methods can be applied in the recognition of minor finger motions, providing some preliminary experimental results compared with other baseline methods.

**P2.125 Human Motion Detection Using Planar Array FMCW Radar Through 3D Point Clouds**
Hisham A. El-saadouny, Ilona Ruffels and Jan Barowski (Ruhr-Universität Bochum, Germany)
**Poster2-P13: Radio Science and Remote Sensing**

**Room: Exhibition Hall**

**P2.126 Data Transfer and Communication in Radar Networks**

Peter Müller, Matthias Weiß, Stephan Sandenbergh, Daniel O Hagan and Peter Knot (Fraunhofer FHR, Germany)

A robust architecture for the transfer and centralised storage of time stamped multi-sensor data of arbitrary types and sizes. It is aimed specifically at networks using physical infrastructure. The idea to observe the environment with the aid of multiple sensors of different types has existed for many decades. However, advances in synchronisation, localisation and networking technologies stimulate renewed interest in network-centric sensing. Multisensor distributed sensors offer many advantages over single sensors. More target information can be extracted and it has increased sensitivity, detection, and classification abilities. Hence, there is a strong drive to further develop the underlying technologies of sensor networks. One such technology is the robust transfer of data between the network nodes and a central storage node. This paper proposes a communication architecture adapted to the requirements of sensor networks. This architecture can efficiently transfer and store arbitrary data types from multiple nodes to a central storage node.

**P2.127 Wideband Superconducting Integrated Filter-bank for THz Astronomy**

Alejandro Pascual Laguna (Delft University of Technology & SRON, The Netherlands); Kenichi Karatsu (SRON, The Netherlands); David Thoen (Kavli Institute of NanoScience, Delft University of Technology, The Netherlands); Vignesh Murugesan (SRON, The Netherlands); Akira Endo (Delft University of Technology, The Netherlands); Jochem Baselmans (SRON, The Netherlands)

A wideband, broad bandwidth, superconducting, integrated filter-bank for astronomy is presented. The dispersion mechanism is an array of shunted microscopic bandpass filters rendering a spectrometer implementation with 347 spectral channels sampling the band 220-440 GHz with a spectral resolution of 400 and coupling strength in-band of 40%. To efficiently read out all these channels with background-limited sensitivity, Microwave Kinetic Inductance Detectors (MKIDs) are employed to sense the filtered THz radiation. In this paper we derive a transmission line model for a bandpass filter that can be cascaded resorting to ABCD matrices to enable the study of large filter-banks. Fast and accurate predictions are thereby obtained for the frequency responses of a filter-bank. With the insights obtained from the model, several prototype chips have been designed and are under fabrication.

**P2.128 On the Use of Adjoint Methods for Refractivity Estimation in the Troposphere**

Ibrahim Alnujaimi (California State University, Fresno, USA); Peter Meincke (ENAC, France) and Jochem Baselmans (SRON, The Netherlands)

Monitoring the Greenland and Antarctica Ice Sheets Using Ultra-Low-Frequency Electromagnetic Resonances

Alexander G. Voronovich (325 Broadway & NOAA/Earth System Research Laboratory, USA)

Wideband, band, terahertz, superconducting, integrated filter-bank for astronomy is presented. The dispersion mechanism is an array of shunted microscopic bandpass filters rendering a spectrometer implementation with 347 spectral channels sampling the band 220-440 GHz with a spectral resolution of 400 and coupling strength in-band of 40%. To efficiently read out all these channels with background-limited sensitivity, Microwave Kinetic Inductance Detectors (MKIDs) are employed to sense the filtered THz radiation. In this paper we derive a transmission line model for a bandpass filter that can be cascaded resorting to ABCD matrices to enable the study of large filter-banks. Fast and accurate predictions are thereby obtained for the frequency responses of a filter-bank. With the insights obtained from the model, several prototype chips have been designed and are under fabrication.

**P2.129 Monitoring the Greenland and Antarctica Ice Sheets Using Ultra-Low-Frequency Electromagnetic Resonances**

Ibrahim Alnujaimi (California State University, Fresno, USA); Peter Meincke (ENAC, France) and Jochem Baselmans (SRON, The Netherlands)

Monitoring the total mass of the Greenland and Antarctica ice sheets, which currently show a tendency of rapid decline, would provide one measure of global climate change. Different techniques, including radio echo-sounding, gravimetry, satellite altimetry and others have been used for this purpose with varying degrees of success. A novel approach based on measurements of resonant frequencies of waveguides formed by the ice sheets with respect to electromagnetic waves of ultra-low-frequencies was recently suggested in [3]. This paper presents an extension of the earlier work to include a cylindrical slab dielectric model for the ice sheets. Estimates of resonant frequencies are presented, which confirm the feasibility of the suggested approach. Estimates of the sensitivity of the corresponding measurements are also provided.

**Wednesday, 18 March 14:50 - 15:30**

**IS-Wed 1/1: Invited Speaker Session**

**Room: A2**

**Electromagnetics**

**14:50 A Holy Grail Quest: The Concept of Stored Electromagnetic Energy**

Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

The quest for the "real" expressions for the energy stored in a radiator is overviewed. First, several forms of power and energy that have been defined in electromagnetics over the last 100 years are briefly summarized, and their most important characteristics are discussed. In a first step, frequency domain is considered. Starting from two power balance equations, a field-based reactive energy is formally defined and compared to the numerous "definitions" already available in literature. Then the concept of recoverable energy is introduced. Moving to time domain, it is possible to write unifying expressions generalizing the concept of reactive energy. It is shown that recoverable energy is just a special case for a specific future current. Examples are given where these energies can be used to solve practical problems. The paper clearly illustrates that the concept of stored electromagnetic energy is still not well-understood when a radiator is involved.

**IS-Wed 2/1: Invited Speaker Session**

**Room: A3**

**Electromagnetics**

**14:50 Computational Electromagnetics in Space**

Erik Jørgensen, Oscar Borries, Min Zhou, Peter Meincke, Stig Sørensen, Niels Vesterald and Michael F. Palvig (TICRA, Denmark)

We review a number of CEM algorithms developed for space applications. The algorithms are tailored to the special needs of the space industry through a combination of several approaches, including application of higher-order methods, development of dedicated solvers for specific types of antennas, hybridisation of methods, as well as inclusion of advanced techniques for quantifying uncertainties on the input variables. Application examples will be presented to illustrate the capabilities of the algorithms.

**Wednesday, 18 March 16:00 - 18:00**

**ESoA: ESoA Meeting (16:00-18:00, Room: 5)**
Wednesday, 18 March 16:00 - 16:40

**IS-Wed 1/2: Invited Speaker Session**

**Propagation**

*Room: A2*

Chair: Vittorio Degli Esposti (University of Bologna, Italy)

16:00 Recent ITU Propagation Models for Millimeter Waves

*Sana Salous (Durham University, United Kingdom (Great Britain))*

Fifth generation mobile radio systems are expected to use a variety of techniques and frequencies toward providing high data rates to the user. This has led to a concerted international effort towards characterizing the radio channel in the higher frequency bands particularly in the frequency range of 24-66 GHz following the World Radiocommunications Conference in November 2015 (WRC15) and the recent allocations in WRC19. This talk gives an overview of radio propagation measurements and models in these frequency bands that have been adopted in ITU recommendations and the international effort towards achieving such models.

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IS-Wed 2/2: Invited Speaker Session

**Antennas**

*Room: A3*

Chair: Ahmed Kishk (Concordia University, Canada)

16:00 Submm-resolution Photoconductive Connected Array Radars

*Andrea Neto (Delft University of Technology, The Netherlands)*

A THz radar can realize images with fine lateral resolutions even with moderate antenna sizes. However, exploiting only limited absolute Bandwith (BW) state of the art THz radars provide at most a moderate centi-meter range resolutions. Within this paper I will describe the strategy of the Tera Hertz Sensing group to break the mm range resolution limit, aimed at developing radar front ends, at a fraction of the complexity of existing THz radar architectures. This could be achieved by exploiting pulsed Optical-to-THz up/down conversions via Photoconductive Antennas (PCA). Recently the TS Group has demonstrated m-watt power sources in the THz spectrum. The remaining bottle necks are mostly associated to pulse conditioning.

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Wednesday, 18 March 17:45 - 23:59

**Conference Dinner (Wallmans)**

Wallmans Cirkusbygningen, Jernbanegade 8, 1608 København V

17:45: Doors open and welcome drink 18:00 - 18:30: Seating 18.30 - 22.00: Dinner and show 22.00 - 24.00: Nightclub with DJ

Thursday, 19 March

Thursday, 19 March 8:30 - 10:10

**T01-A11: Multiband and Wideband Antennas**

*T01 LTE and Sub-6GHz 5G / Regular Session / Antennas*

*Room: A2*

Chair: Shih-Yuan Chen (National Taiwan University, Taiwan), Mohammad S. Sharawi (Polytechnique Montreal, Canada)

**8:30 Compact Eight-Band Monopole for LTE Mobile Phone**

*Ying-Ning Li and Qing-Xin Chu (South China University of Technology, China)*

A compact eight-band monopole for LTE mobile phone is presented. The antenna is mainly composed of a T-shape monopole and a coupled parasitic ground strip which are excited to cover LTE850/GSM900/GSM1900/LTE2300/LTE2500 bands. Moreover, three modes of parasitic ground strip contribute to covering the DCS/PCS/UMTS/LTE2300/LTE2500 bands. The merit of the proposed antenna is to cover eight bands in the 2G/3G/4G bands without any lumped-element matching circuit under the condition of $14 \times 40 \times 0.8 \text{mm}^3$ nonground portion, which is suitable for the wideband LTE mobile phone applications. Good agreement is achieved between the measurement and simulation results.

**8:50 Miniaturized Base-station Antenna Element with Sinuously Bent Arms**

*Hailiang Zhu and Yuwei Qiu (Northwestern Polytechnical University, China), Jinliang Bao (National Key Laboratory of Test Physics and Numerical Mathematics, China), Pei Zheng (National Key Laboratory of Science and Technology on Test Physics and Numerical Mathematics, China), Gao Wei (Northwestern Polytechnical University, China)*

Miniaturized ±45° dual-polarized antenna element for cellular base-station application is proposed. The radiators of the antenna are sinuously folded, reducing the aperture size to 0.27λ×0.27λ, where λ0 is the wavelength at the center frequency. Despite the compact size, simulated results show that stable radiation pattern, high port and cross-polarization isolation are archived.

**9:10 Dual-Band Array of Cross-Polarized Vivaldi Antennas for 5G Applications**

*Paula Fernandez-Martinez (University Carlos III de Madrid, Spain), Sergio Martin-Anton (University Carlos III of Madrid, Spain), Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)*

In this work, a broadband dual-polarized base station array is designed. The 1400MHz-2700MHz band is covered by a single broadband Vivaldi antenna element. The 690MHz-960MHz band is covered by a conventional dipole-like element. The array synthesis has been carried out by time-domain full-wave simulations where excitation is applied to a unit
8:30 | Antenna Simulation Accuracy vs. Measurement Results of Small Form Factor Device

Petr Mustonen and Olli Talvitie (Radiantum Oy, Finland)

A three-band LTE Cat-M1 PCB antenna is simulated and measured and these results are compared in this paper. Antenna resonance frequency at 700 MHz is matching well with simulations. Above 1.5 GHz resonances have a difference of about 70 MHz. With tuned antenna measured efficiencies are 1 dB worse than simulated efficiencies when difference in reflection coefficient is taken into account. Active TBB measurements finally show maximum efficiency difference between simulation and measurement of 3.2 dB. As results show there are some differences between the measurements and simulations. However, these differences are small enough that new design round for the device is not needed and the device can be finished with tuning component changes only.

8:50 | Incident Power Density Assessment Study for 5G Millimeter-Wave Handset Based on Equivalent Currents

What's in a Name? an Analysis of the True Meaning of MIMO and Beamforming

Michael D. Foegelle (ETS-Lindgren, USA)

IEEE 802.11n and LTE made the term MIMO common place in technical literature. The 5G New Radio (NR) is doing the same with beamforming. However, differences in the definition of the term are often not taken into account. In this paper we will present an overview of the terms and their differences and show how different the terms can be.

9:00 | A broadband dual-polarized dipole antenna for LTE and 5G base station

A novel broadband dual-polarized planar dipole antenna is proposed for LTE and 5G base stations. The proposed antenna is composed of two perpendicularly crossed polydipole dipoles. Each polydipole dipole is excited by a dual T-shaped microstrip feedline that is directly fed by a coaxial cable, making the dual-polarized antenna a completely planar structure. The measured results indicate that this antenna has an impedance bandwidth of 68.7%, a 5.5 dB (GAR) with return loss >10 dB and an isolation of higher than 20 dB between two polarisation input ports. The dual-polarized antenna has a stable antenna gain of 7.7±1 dB from 2.5 to 5.0 GHz for slant H±45° polarizations. Simulation results have a good agreement with measurement ones.

9:10 | EMF Exposure Assessment of Massive MIMO Radio Base Stations Based on Traffic Beam Pattern Envelopes

Chairs: Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)), Janet O’Neil (ETS-Lindgren, USA)

When placed on the market, mobile handsets are required to comply with relevant electromagnetic field (EMF) exposure limits. In the millimeter-wave (mmWave) frequency band, human exposure to EMF needs to be evaluated in terms of incident power density (IPD). In this work, the equivalent currents (ECC) method is applied to assess the IPD of a 5G mmWave mobile handset mock-up. The IPDs in the near field (NF) region are obtained using the field data measured in the intermediate field (IF) region with an IFV reference spherical measurement system. The results are compared with those obtained by simulations and also with those obtained by reference HF scanning measurements. The agreement between the methods indicates that the ECC method is a promising candidate for the IPD assessment of 5G mmWave handsets.

9:30 | An Assessment of the Radio Frequency Electromagnetic Field Exposure from a Massive MIMO 5G Testbed

Tian Hong Loh (UK, National Physical Laboratory, United Kingdom (Great Britain)); Fabien Héliot (University of Surrey, United Kingdom (Great Britain)); David Cheadle and Tom Fielder (National Physical Laboratory, United Kingdom (Great Britain))

Current radio-frequency electromagnetic field (RF-EMF) exposure limits have become a critical concern for fifth-generation (5G) mobile network deployment. Regulation is not harmonised and in certain countries and regions it goes beyond the guidelines set out by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Using a massive multiple-input multiple-output (MIMO) testbed with beamforming capabilities that is capable of mimicking realistic 5G base station (BS) performance, this paper presents an experimental and statistical assessment of its associated RF-EMF exposure within a real-world indoor environment. The MIMO testbed has up to 128 channels with user-programmable software defined radio (SDR) capability. It performs zero-forcing precoding after channel state information (CSI) acquisition for different beamforming scenarios with respect to the associated user terminal antenna setups and positions. With 64 active mmWave transmit antennas, 8 beamforming scenarios have been considered for single-user (SU) and multi-user (MU) downlink communications at different locations. Using a calibrated tristatic isotropic field probe, the received channel power heat map for each beamforming scenario was acquired and then converted into an RF-EMF heat map. The relevant RF-EMF statistics was evaluated based on the variations of heat maps and number of users.

9:50 | Coffee Break

10:05 | Over-the-air investigation of Transmitter and Receiver Nonlinear Distortion Using a Mm-Wave MIMO Testbed

Hamza Nachouane, Thomas Eriksson and Koen Buisman (Chalmers University of Technology, Sweden)

In this paper, we evaluate the nonlinear distortion of the transmitter (Tx) and receiver (Rx), separately, of the developed mm-wave testbed at Chalmers University of Technology, KARTE, using Over-The-Air (OTA) measurement. The developed testbed has been designed to operate within 27 - 31 GHz frequency range, with 1 GHz analog bandwidth per Tx or Rx. An overview on the system configuration has been provided. In order to evaluate the limitations of the proposed testbed, we have conducted several experiments on nonlinear distortion effects of the constructed Tx and Rx frontends.

11:00 | Design and Simulation of a 28 GHz Plane Wave Generator for NR Measurements

Sara Catteau (Bluestem AB, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden); Robert Rehammar (Bluestem AB & Chalmers University of Technology, Sweden)

Design constraints for a plane wave generating array antenna at mm-wave frequencies are investigated. Focus is on how to realize the power distribution network and the amplitude tapering of the array element excitation in a cost-effective manner. These are key decisions that need to be made for a plane wave generator. In this paper, we specifically look at a few design solutions which are constrained by practically realizable tapering distributions. It is shown that the best tapering distribution, taking into account the design aspects of a realistic distribution network, is different from the best solution for an ideal radiating aperture. We also briefly discuss the impact of the radiating antenna element and show that it has a minor impact on the end performance.

11:20 | Fading Channel Emulation for Massive MIMO Testing Using a Conductive Phase Matrix Setup

Pekka Kyöstilä (Keysight Technologies & University of Oulu, Finland); Pietri Herranen (Keysight Technologies Finland oy, Finland)

Functionalities, algorithms, and performances of massive MIMO base stations are should be tested in versatile fading radio channel conditions. Base stations of 5G “New radio” that operate on sub 6 GHz frequency bands typically provide antenna connectors enabling RF cable connection of test devices to the device under test (DUT). Furthermore, the
number of DUT antennas is high and consequently the need of fading channel emulator (CE) resources becomes high. An approach can be taken to reduce the number of independent fading channels to be emulated. This can be done by using a phase shifting and combining unit (aka phase matrix unit) in between the DUT and CE. The phase matrix concept in fading emulation, together with its capabilities and limitations, is discussed in this paper.

11:40 Throughput and Spherical Coverage Performance of mmWave Dual Polarized Antenna Arrays
Ali Hazimi (Magister Oy & Huawei Technologies, Finland); Ruijuan Tian (Huawei Technologies, Finland)

This paper studies the correspondence between two metrics namely the spherical coverage CDF of array Effective Isotropic Radiated Power (EIRP) and the link-level throughput when the same mmWave antenna arrays are considered at the user equipment. The CDF of array EIRP is a convenient metric to use when ordering the performance of two antenna array designs in the spherical coverage perspective. However, for the end user experience, the end-to-end throughput link-level metric taking into account the full base station, channel and user equipment is needed. This paper shows the correspondence of these two metrics in the case of diversity performance evaluation of different antennas array configurations. However for MIMO throughput, the CDF of array gain cannot be exclusively used to classify the performance of different antenna array designs and a full link-level evaluation is still required.

12:00 5G Over-the-Air Conformance Testing
Jonas Fridén and Sam Agneessens (Ericsson AB, Sweden); Aidin Razavi (Ericsson Research, Sweden); Aurelian Bria (Ericsson, Sweden); Torbjörn Elstam (Ericsson AB, Sweden)

5G base station conformance testing has recently been adopted in 3GPP specifications both in form of conducted and radiated requirements. The option of over-the-air testing of multi-standard active antenna systems (AAS) base stations over-the-air has come with a set of challenges and changes in the requirements definitions. Equivalent isotropic Radiated Power (EIRP) and Total radiated Power (TRP) have become main figures of merit for a system that aims to combine radios and antenna elements into one enclosure, without access to any physical antenna ports. The evolution from conducted to radiated requirements is presented, together with challenges faced along the way.

Thursday, 19 March 8:30 - 10:10
T02-P02: Millimetre-wave Propagation Modelling
Room: B1
Chairs: Marcelo S. Alencar (Federal University of Campina Grande & Institute for Advanced Studies in Communications, Brazil), Sajjad Hussain (National University of Sciences and Technology, Pakistan)

8:30 Performance Comparison of Single- and Multi-Lobe Antenna Arrays in 5G Urban Outdoor Environments at mm-Waves via Intelligent Ray Tracing
Yanni Aslan and Jan Puuskel (Delft University of Technology, The Netherlands); Antoine Roedener (Technical University of Delft, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

The effect of forming single and multi-lobe beam patterns at mm-wave base station antennas on the received signal strength and co-channel interference is studied for mm-wave urban outdoor environments. A sample, simplified urban city model is used with randomly selected user positions. Ray tracing simulations are performed to analyze the channel's directional characteristics towards the test users. Depending on the number of dominant paths, single or multiple main lobes are created in the appropriate directions. Through the simulations, it is observed that in comparison with the multi-lobe-beam option, the single-lobe-beam provides similar or better received power results (unless the ray phases are equalized at the transmitter or receiver with perfect channel information or there is an unexpected sudden blockage in the main path), while providing better interference cancellation capabilities towards other co-channel users.

8:50 A Dynamic Visibility Algorithm for Ray Tracing in Outdoor Environments with Moving Transmitters and Scatters
Sajjad Hussain (National University of Sciences and Technologies, Pakistan); Conor Brennan (Dublin City University, Ireland)

This paper presents an efficient technique to identify surfaces which are visible to a mobile transmitter in outdoor environments with moving scatterers. The presence of moving scatterers or a mobile transmitter in a propagation environment makes the radio channel modelling very challenging as visibility computations need to be repeatedly performed in a changing scenario. This makes the pre-processing overhead unfeasible for ray-tracing based propagation prediction models. The algorithm described in this paper first computes the static visibility table for the mobile transmitter assuming that the environment is static. Then the effects of moving scatterers are modelled to compute the so-called dynamic visibility table. Both the static and dynamic visibility tables are used along with information about the scatterers’ location to validate the rays arriving at the receiver. Validation results show a considerable reduction in run times.

9:10 Analysis of 60-GHz In-Street Backhaul Channel Measurements and LiDAR Ray-based Simulations
Mohammed Z. Aslam and Yoann Corre (IRSIDAL, France); Jakob Belchner, Gnaana Sudairi Arocikayar and Monika Jäger (Deutsche Telekom AG, Germany)

The large gains provided by millimeter-wave (mmWave) frequencies in terms of available bandwidth have made them a popular choice for 5G in street backhaul and backhaul scenarios. In this paper, 60 GHz in-street backhaul propagation channel is measured and evaluated along with ray-based simulations in two different scenarios, urban canyon and residential. The channel assessor allows for bidirectional path loss measurements with highly directive beamforming at both sides. Additionally, the simulator benefits from highly accurate LiDAR point cloud data in order to identify obstacles and compute losses along the direct and indirect paths. Both the measurements and simulations show strong channel sparsity when antennas are located at 3 meters above the ground, caused by the many in-street obstacles.

9:30 On a Fresnel Integro-Integrated Back-Scattering Model at Millimeter-Waves
Adrián Lahaurdia-Lavieja (KU Leuven, Belgium); Martin Johnsson (Ericsson Research, Sweden); Ulf Gustavsson (Ericsson AB, Sweden); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

Geometric-based stochastic channel models (GSCMs) are suitable models at millimeter-wave (mm-wave) frequencies. Proper forward-scattering and back-scattering modeling is needed in order to realize realistic channel assessments. In this paper, a recently-proposed back-scattering model, 3D Fresnel, goes through further investigations: first, the impact of frequency in the results of a single scenario is investigated and, second, the effect of multiple surfaces is studied. In both cases, the model shows good agreement with respect to the Physical Optics (PO) reference model.

9:50 Cell-Free at Millimeter-Wave Frequency: Simulation Using the Ray Tracing Method
Higo Thaian Pereira da Silva (Federal University of Campina Grande, Brazil); Rafael M. Duarte (Universidade Federal de Campina Grande, Brazil); Marcelo S. Alencar (Federal University of Campina Grande & Institute for Advanced Studies in Communications, Brazil); Wamberto Queiroz (Universidade Federal de Campina Grande, Brazil)

In cell-free (CF) networks, a large number of distributed access points (APs) provides communication to a small number of users using the same time-frequency resources. This work presents results related to a CF network at millimeter wave spectrum (mmWave), with carrier frequency of 26 GHz, using a 3D ray tracing simulation. The applied ray tracing simulation is based on the Shutting-and-Bouncing Rays (SBR) method. The propagation environment is based on the Besse neighborhood in the João Pessoa city, Brazil. As results, are presented a path loss characterization of the considered sites and the computation of achievable rate in the simulated CF networks. The simulation results show that the CF architecture can provide a mean achievable rate of 2.8 bits/s/Hz and 50% of users experience rates greater than 2.6 bits/s/Hz.

Thursday, 19 March 8:30 - 12:20
CS46: New Trends in Leaky Wave Antennas
Room: B2
Chairs: Filippo Capolino (University of California, Irvine, USA), David R. Jackson (University of Houston, USA)

8:30 Broadside Radiation Equalization Through Mode Coupling Balancing in Periodic Leaky-Wave Antennas
Amar Al-Bassam and Dirk Herbering (Friedrich-Alexander University, Germany); Christopher Czysz (Ecole Polytechnique de Montreal, Canada)

Periodic leaky-wave antennas (PLWAs) may be optimized by equalizing the resonance frequencies of the two radiation modes and their quality factors i.e., by full-filling the frequency-balancing and Q-balancing conditions. These conditions may be achieved by introducing a proper amount of asymmetry in the unit cell of the P-LWA. This paper extends the previously report circuit-based approach to a full-wave electromagnetic perspective. Specifically, it shows that the required Q-balancing condition corresponds to complete coupling between the longitudinal and transverse modes, which leads to their perfect coalescence. Finally, it illustrates the theory by the numerical example of a series-fed patch (SFP) PLWA.
8:50 Open-Stopband Suppression in a Canonical 1-D Periodic 2-D Structure with Asymmetric Unit Cell
Paolo Baccarelli (Roma Tre University, Italy); Paolo Burghignoli, Davide Comite, Walter Fucalordi and Alessandro Galli (Sapienza University of Rome, Italy)
Periodic leaky-wave antennas are typically affected by the open-stopband (OSB) problem, i.e., the pattern degradation as the beam scatters through broadside. Various techniques have been proposed to mitigate, or even suppress, this longstanding issue. However, most of these techniques cannot be easily applied to 1-D periodic 2-D structures. Recently, it has been theoretically and experimentally shown that the OSB can be suppressed by means of a very simple technique: it consists of designing a unit cell with two unequal discontinuities suitably spaced one another. In this work, we apply this novel technique to a canonical 1-C-1 periodic 2-D structure, namely a grounded dielectric slab with a metal strip-grating on top. To validate the concept, full-wave results are presented in the 17.5-20 GHz band considering an asymmetric unit cell characterized by two narrow strips for the TM-polarized case.

9:10 Reconfigurable Leaky-wave Antennas with Independent Control of the Leakage Constant and Radiation Angle
Mitsuk Kim and George V. Eleftheriades (University of Toronto, Canada)
This work presents a reconfigurable leaky-wave antenna that can dynamically and independently control (i) its radiation angle (including broadside) and (ii) the leakage constant at the fixed operating frequency of 5 GHz. This is achieved by realizing a reconfigurable omega-bean-shaped Huygens’ metaface and integrating it to the design of a leaky-wave antenna in a waveguide environment. In particular, by synthesizing the Huygens’ metaface in terms of four cascaded tunable impedance layers, we realize a dynamic control over the constitutive parameters of the Huygens’ metaface. As a result, unwanted Floquet modes and any open-stopband are suppressed while dynamically controlling the leakage constant and the radiation angle. The proposed reconfigurable Huygens’ metaface consists of cascaded arrays of dual-loop unit cells which incorporate varistor diodes for obtaining the necessary tunability. The versatile scanning capability of the proposed reconfigurable leaky-wave antenna is numerically studied based on full-wave simulations.

9:30 Latest Developments and New Design Approaches in Designing Leaky-wave Antennas Based on Substrate Integrated Waveguide Technology
Anbar Sarkar (School of Electrical and Electronics Engng, Chung-Ang University, Korea (South)); Sungjoo Lim (Chung-Ang University, Korea (South))
In this paper, the new findings in the redesigning high gain, compact, larger beam scanning range and highly efficient leaky-wave antennas based on substrate integrated waveguide (SIW) since last few years are presented. The utilization of SIW in various ways not only eliminates the drawbacks of metallic waveguide but also found suitable for integrating with micro-wave or mm-wave circuitry with reduced fabrication cost and complexity. Initially, the structural advantages of SIW in designing gain and efficiency tuning leaky wave antennas are presented. Further, exploitation of 10-asymmetric half-mode SIW, quarter-mode SIW and 2D-asymmetric eighth-mode SIW in the design results into significant improvement of gain and radiation efficiency keeping the geometry much compact. Several analysis and antenna parameters are optimized by validating the response of HFSS full-wave simulation with ADS circuit simulator.

9:50 Recent Advances in Magnet-less Non-reciprocal Wave Antennas
Othid Silbat and Yakir Hadad (Tel-Aviv University, Israel)
We explore nonreciprocal modes and nonreciprocal leaky wave antennas that are based on spatialtemporal modulation of the guiding structure. Thus, enabling an isolation between transmit and receive channels by the antenna itself, and without the need for bulky magnetized materials. Since it involves only with modulation of the guiding structure, and does not require peculiar material properties such as gyrotropy, this approach is moreover applicable for nonreciprocal acoustic leaky wave antennas.

10:10 2-D Planar Leaky-wave Antenna with Fixed Frequency Beam Steering Through Broadside
Victoria Gómez-Guillamón Buendía (Heriot-Watt University, United Kingdom (Great Britain)); Davide Comite (Sapienza University of Rome, Italy); Symon K. Podlichak (Heriot-Watt University, United Kingdom (Great Britain)); Maksim Kuznetcov (Heriot Watt University, United Kingdom (Great Britain))
A simple two-dimensional (2-D) leaky-wave antenna (LWA) system for continuous beam scanning through broadside at a fixed frequency is presented. In particular, the implementation of a “full-eye” LWA and by using the integrated and extremely tunable fixed feed by four surface-wave antennas (SWAs), one can achieve limited gain degradation at broadside while also offering beam steering in elevation and azimuth planes in the farfield. Measurements results show beam scanning in both planes at 20 GHz with gain values of almost 10 dB at broadside. Such a novel system, which offers low-cost fabrication with directive broadside radiation, may be useful for radar, satellite systems and other telecommunication applications.

10:30 Coffee Break

11:00 Controlling Dual Polarization with Metasurface Leakage
Alice Benin and Enrica Martini (University of Siena, Italy); Charlotte Tripop-Canseliet (Université Pierre et Marie Curie, France); Jean-Maurice Chazelas (Thales Aerospace Division, France); Stefano Maci (University of Siena, Italy)
This paper presents a low profile planar dual polarized metasurface (MTS) antenna consisting of alternating lines of dipoles and slots. This configuration allows for high polarization purity and excellent decoupling between adjacent channels. This makes the structure suitable for applications like 5G and Satcom with polarization diversity and beam scanning. A preliminary design in K-band is presented to demonstrate the concept.

11:20 Leaky-Wave Analysis of an Ultrathin Planar High Impedance Surface Antenna
Ahmad T. Almutawaa (PAEET, Kuwait); Filippo Caldoni (University of California, Irvine, USA)
High impedance surfaces (HISs) have been used in the past to act like artificial magnetic conductors to improve the efficiency of a dipole parallel to a metallic surface. We demonstrate how such HISs can be directly used as antennas without the need for a dipole on top. The HIS is made of 2D periodic dogbone-shaped patches on top of an extremely thin grounded substrate with a thickness around 1/100 of a wavelength. The analysis of a unit cell of the HIS antenna in terms of its magnetic resonance (zero phase reflection) gives sufficient information on the radiation of the HIS operating as a leaky-wave antenna with large attenuation constant. We implement a fast and simple method based on Floquet-Bloch periodic boundary conditions (PBCs) to design and optimize the radiation properties of such an antenna. Despite being extremely flat, the HIS antenna provides a significantly large relative gain bandwidth exceeding 15%.

11:40 Electronically-Tunable Scanning Antennas by Using Slotted Rectangular Waveguides Loaded by Reconfigurable Surface Susceptances
Santi Concetto Pavone (Università degli Studi di Catania, Italy); Loreto Di Donato and Gino Sorbello (University of Catania, Italy)
In this paper, we present a simple technique to achieve electronically-controlled beam scanning, by properly acting on the distributed average magnetic and electric surface susceptances presented in the sideband of a slotted rectangular waveguide. Such an approach allows to avoid the surface susceptibility spatial modulation, thus it inherently simplifies the active-element feeding-network design. The preliminary results in the case of a 1-D traveling-wave array demonstrates the concept and paves the way for the full development of 2D scanning arrays and for surface reactance synthesis by means of active elements, such as PIN diodes.

12:00 Cylindrical Aperture Synthesis with Metasurfaces
Faris Alsolamy (University of Michigan Ann Arbor, USA); Anthony Grbic (University of Michigan, Michigan Ann Arbor, USA)
A general method to realize arbitrary, azimuthally-invariant aperture fields using a metasurface is presented. The metasurface, consisting of cascaded inhomogeneous electric sheet impedances, is placed within a cylindrical waveguide to generate specified aperture fields through mode conversion. The surface impedance profiles of the electric sheets are found using optimization. Rapid optimization is enabled by modal network theory, and the Discrete Hankel Transform (DHT). As an example, a radially polarized Gaussian beam launcher is designed.

12:20 Holographic-Based mmW-Wideband Bidirectional Frequency Scanning Leaky Wave Antenna
Ali Arqali (University of Surrey, United Kingdom (Great Britain)); Mohammad Khiali (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Pei Xiao and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))
A leaky wave antenna in a waveguide environment. In particular, by synthesizing the Huygens’ metasurface in terms of four cascaded tunable impedance layers, we realize a dynamic control over the constitutive parameters of the Huygens’ metaface. As a result, unwanted Floquet modes and any open-stopband are suppressed while dynamically controlling the leakage constant and the radiation angle. The proposed reconfigurable Huygens’ metaface is realized using cascaded arrays of dual-loop unit cells which incorporate varistor diodes for obtaining the necessary tunability. The versatile scanning capability of the proposed reconfigurable leaky-wave antenna is numerically studied based on full-wave simulations. The various descriptions of localized wave solutions of the wave equation and Maxwell’s equations are briefly reviewed. The generation of these space-time coupled fields from independently addressable pulse driven arrays is discussed. Important aspects of pulse driven array elements and their impact on the overall performance of a pulse-driven array
This study investigates a Radar-Communication (RadCom) system based on the orthogonal chirp-division multiplexing (OCDM) technique. In this context, a description of the system model addressing both communication data obtaining dedicated beam patterns synthesized for optimal sensing performances.

Santi Concetto Pavone (Università degli Studi di Catania, Italy); Walter Fucisculo (Sapienza University of Rome, Italy); Alessandro Gali (Sapienza University of Rome 1, Italy); Matteo Albanì (University of Siena, Italy)

This paper proposes the design of a novel X-wave launcher in the terahertz frequency range. The theoretical background of X-waves and the basic design rules for synthesizing X-wave launchers are presented. The proposed launcher consists of a spine profiled metal horn, it is solely made of metal and can thus be easily scaled for operation in different frequency bands. The performance of the launcher has been analyzed by an in house mode-matching based tool and validated using full-wave simulations. Finally, the performance of the launcher are compared to other solutions present in the literature.

3:30 Multi-spot Adaptive Near-Field Focusing Through Transmitting Time-Modulated Arrays

Rafael Cines (University of Padua, Italy); Piero Fracastoro (University of Udine, Italy); Paolo Nepa (University of Pisa, Italy)

A novel approach for Near-Field Focusing is studied, which is based on the Time-Modulated Arrays concept. The latter exploits the adaptation of digital signals to control the radiating properties of an antenna array, hence simplifying the implementation of adaptive arrays with respect to more complex architectures based on high-frequency amplifiers and phase shifters. The price-to-pay is to strongly reduce the number of degrees of freedom available for synthesis purposes, and whose potential impact is here evaluated. It is especially intended for scenarios where multiple users are present and different frequency channels may be used, with devices to be wirelessly fed and requiring a fast adaptation of the radiating system, for example in applications such as Wireless Power Transfer, IoT or 5G scenarios. Some preliminary tests and results are presented to evaluate the potential of the proposed approach.

9:30 Space-Fractional Bessel Beams with Self-Healing and Diffraction-Free Propagation Characteristics

Aqsa Ehsan and Muhammad Qasim Mehmood (Information Technology University of the Punjab, Pakistan); Yee Sin Ang (Singapore University of Technology and Design, Singapore); Lay Kee Ang (SUTD, Malaysia); Muhammad Zubair (Information Technology University of the Punjab, Pakistan & Singapore University of Technology and Design, Singapore)

In this paper, different beamlet techniques are presented to generate limited-diffraction electromagnetic (EM) waves and pulses by using radial line slot arrays (RLSAs) and leaky-wave (LW) planar devices at microwave/millimeter waves are presented. In the first part of the paper, two kinds of RLSA Bessel beam launchers are proposed, obtained by implementing an inward cylindrical travelling-wave aperture distribution in the longitudinal and transverse-electric field components. Moreover, in the second part, two different LW launchers are presented, namely based on forward and backward leaky-waves.

8:30 Towards Joint Sensing and Communication for 5G and Beyond Systems

Andrea Massa and Paolo Rocca (University of Trento, Italy); Marco Salucci and Nicola Anselmi (ELESDA Research Center, Italy)

The acquisition of an accurate channel model through a high-resolution environmental sensing is of crucial importance for future multiple-input multiple-output (MIMO) systems. Nevertheless, nowadays MIMO beam-forming networks perform the channel sensing through pilot signal transmission, using sets of orthogonal beams, therefore a non optimal sensing of the channel is acquired. For this reason, a novel mobile communication paradigm is presented in this work as the joint synthesis of the sensing and communication beams, in order to enable (i) high channel capacity through capacity-driven synthesis of the communication beams, and (ii) high resolution modeling of the channel through dedicated beam patterns synthesized for optimal sensing performances.

8:50 Terahertz X-wave Launchers by Metallic Spine-Profiled Horns

Srdan Paković (Université de Rennes 1, France); Nicola Bartolomei (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & IMR CNRS 6164, France); Ronan Sauleau (University of Rennes 1, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

This paper describes the design of a novel X-wave launcher in the terahertz frequency range. The theoretical background of X-waves and the basic design rules for synthesizing X-wave launchers are presented. The proposed launcher consists of a spine profiled metal horn, it is solely made of metal and can thus be easily scaled for operation in different frequency bands. The performance of the launcher has been analyzed by an in house mode-matching based tool and validated using full-wave simulations. Finally, the performance of the launcher are compared to other solutions present in the literature.

8:10 Towards 3-D Vector Intensity Focusing of near and Far Fields

Giada Battaglia (Università Mediterranea di Reggio Calabria, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy); Tommaso Ismaia (University of Reggio Calabria, Italy)

A new approach to the problem of focusing the intensity of vector fields into a target point subject to sidelobe constraints elsewhere is proposed. While allowing the adoption of arbitrary common antenna arrays as radiating systems, the method exploits a novel optimization procedure properly acting on both the field polarization on the target point and the array excitations. By so doing, it is able to improve the performances of existing procedures (that usually handle scalar fields) and to deal with both the near-field (NF) and the far-field (FF) focusing problems in complex inhomogeneous 3-D media.

8:30 IQ-Imbalance Compensation for Wideband OFDM-Radar

Lay Kee Ang (SUTD, Malaysia); Christian Schaffrath and Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany); Ronan Sauleau (University of Rennes 1, France); Ali Ayestarán (University of Cantabria, Spain); Lay Kee Ang (SUTD, Malaysia); M. Qasim Mehmood (Information Technology University of the Punjab, Pakistan); Yuri Sennikov (Sapienza University of Rome 1, Italy)

This study investigates a Radar-Communication (RadCom) system based on the orthogonal chirp-division multiplexing (OCDM) technique. In this context, a description of the system model addressing both communication data obtaining dedicated beam patterns synthesized for optimal sensing performances.

9:00 Frequency-Scanned Focused Leaky-Wave Antennas for Direction-of-Arrival Detection in Proximity BLE Sensing Applications

Miguel Poveda-García (Technical University of Cartagena, Spain); Alejandro Gil Martínez (Technical University of Cartagena Cartagena, Spain); Jose-Luis Gomez-Tornero (Polytechnic University of Cartagena, Spain)

The synthesis of monopulse functions in the Fresnel region for Direction-of-Arrival (DoA) detection in proximity sensing applications is presented. It is demonstrated that, using the three advertising channels provided by the Bluetooth Low Energy (BLE) protocol: channel #37, #38 and #39 at the frequencies 2.402, 2.426 and 2.48 GHz, respectively, the focusing technique allows for obtaining a high-resolution DoA estimation. Moreover, in the second part, two different LW launchers are presented, namely based on forward and backward leaky-waves.

8:30 Field Focusing for Nanophotonic Engineering and Applications

Loreto Di Donato (University of Catania, Italy); Davide Rocco (Università degli Studi di Brescia, Italy); Gino Sorbello (University of Catania, Italy); Costantino De Angelis (University degli Studi di Brescia, Italy)

We propose a new strategy to deal with second harmonic generation (SHG) in dielectric bow-tie antennas by properly designing the antenna and the array excitations. By so doing, it is able to improve the performances of existing procedures (that usually handle scalar fields) and to deal with both the near-field (NF) and the far-field (FF) focusing problems in complex inhomogeneous 3-D media.

8:45 Towards Joint Sensing and Communication for 5G and Beyond Systems

Davide Rocco (Università Mediterranea di Reggio Calabria, Italy); Andrea Francesco Morabito (University Mediterranea of Reggio Calabria, Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy); Tommaso Ismaia (University of Reggio Calabria, Italy)

A new approach to the problem of focusing the intensity of vector fields into a target point subject to sidelobe constraints elsewhere is proposed. While allowing the adoption of arbitrary common antenna arrays as radiating systems, the method exploits a novel optimization procedure properly acting on both the field polarization on the target point and the array excitations. By so doing, it is able to improve the performances of existing procedures (that usually handle scalar fields) and to deal with both the near-field (NF) and the far-field (FF) focusing problems in complex inhomogeneous 3-D media.
**T05-A12/2: Point of Care Microwave Sensors**

**T05 Biomedical and health / Regular Session / Antennas**

8:50

11:40

9:50 Mutual Over-The-Air Synchronization of Radar Sensors

Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany)

Over-the-air synchronization of radar waves can be used to achieve better interference tolerance and enable radar-based communication. Within this initial study, a reformulation of the Kuramoto model is presented, which allows to synchronize the pulse repetition frequencies of two pulsed radar systems. To investigate the applicability of this approach, a simulation model was implemented and tested with various parameter sets. It can be shown that under certain circumstances, the pulse repetition frequencies converge to the same value and thus allow the radars to perceive their interferer as a single echo along range and Doppler.

10:10 Coffee Break

10:40 System Level Synchronization of Phase-Code FMWC Automotive Radars for RadCom

Fraz Lamp (Eindhoven University of Technology, The Netherlands); Faruk Uysal (Delft University of Technology, The Netherlands); Recep Firat Tigrek (Eindhoven University of Technology, The Netherlands); Simonne Ortu (Delft University of Technology, The Netherlands); Alex Alban (Eindhoven University of Technology (TU/e), The Netherlands); Frans MJ Williams (Technical University Eindhoven, The Netherlands); Alexander Yarovoy (TU Delft, The Netherlands)

This paper describes an FMWC-based radar and communication (RadCom) system and addresses the challenges in the synchronization of multiple units for communication functionality. We proposed a novel technique to detect the FMWC RadCom signal at the communication receiver and derive the detection and false alarm probabilities of it. Moreover, to achieve fine synchronization between transmit and receive devices, a novel approach based on FMWC RadCom signal time of arrival estimation is proposed. The potential capability of a RadCom system is experimentally demonstrated for the first time by a set of automotive-grade millimeter radars with GPS-based synchronization.

11:00 Performance of OFDMA Resource Scheduling in Joint Mobile Radio and Radar Networks

Stephan Schierle (Immanuel University of Technology, Germany); Michael Dobrindt (Technische Universität Ilmenau & Fraunhofer IIS, Germany); Reiner S. Thomas and Christian Schneider (Immanuel University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

In this paper, we investigate the impact of frequency synchronization errors on the performance of a joint mobile radio and radar network. We focus on the evaluation of OFDMA resource scheduling for joint mobile radio and radar networks. Our results illustrate the distribution of resources in the time-frequency grid, as used for OFDMA, affects the cost function of a maximum-likelihood estimator. Based on our results, we provide a simple set of rules for the design of resource scheduling schemes in joint networks. Furthermore, we reveal that an OFDMA network can benefit from multiple algorithms and procedures already employed in mobile communication standards, such as synchronization and error correction.

11:20 Stepped-Carrier OFDM V2V Resource Allocation for Sensing and Communication Convergence

Musur Fanur Keskin, Canan Aydogdu and Henrik Wymeersch (Chalmers University of Technology, Sweden)

Stepped-carrier orthogonal frequency division multiplexing (OFDM) is a promising low-cost alternative to conventional OFDM for automotive applications due to its flexibility for high resolution with low complexity and digital-to-analog converters (DACs). In this paper, we investigate centralized time-frequency resource allocation strategies in vehicular networks for vehicle-to-vehicle (V2V) ad-hoc employing stepped-carrier OFDM for joint radar sensing and communication. To quantify radar-communication performance trade-offs, we formulate a nonlinear integer programming problem for weighted optimization of radar performance and communication spectral efficiency, and perform Boolean relaxation to obtain an efficiently solvable convex program. Simulation results demonstrate radar-optimal and communication-optimal operation regimes, providing insights into time-frequency realignments along the trade-off curve.

11:40 Accuracy Requirements for Cooperative Radar with Sensor Fusion

Mehdi Ashuy (TU Wien, Austria); Christian Elaasch (Vienna University of Technology, Austria); Thomas Blazek and Christoph F Mecklenbräker (TU Wien, Austria)

Reliability and robustness are the essential requirements for automotive systems. However, automotive radar systems have environmental conditions and can be affected by other radar data fusion algorithm significantly increase the detection probability and robustness. This article investigates the accuracy requirements based on the geometric parameters for cooperative radar systems with central processing. The results show that a sensor fusion process can improve the detection probability and hence the system robustness by using at least two radar sensors. Furthermore, results show that three to four sensors at a minimum distance of 10 meters are sufficient for high quality estimation. At the same time the system requirements regarding the accuracy for every single radar sensor can be relaxed to a range accuracy as low as one meter standard deviation.

12:00 Physical Modeling for Device-Free Localization Exploiting Multipath Propagation of Mobile Radio Signals

Martin Schmidhammer, Michael Walter, Christian Gentner and Stephan Sand (German Aerospace Center (DLR), Germany)

This work proposes a model to describe the impact of a target on the received power of a multipath component (MPC). The physical propagation path of an MPC is decomposed geometrically and is described by direct propagation paths between physical and virtual nodes. Using the scalar theory of diffraction, the impact of a target on the electric field between physical and virtual nodes is calculated for each component, individually. Theoretical results validate the decomposition of the received power of MPCs to the location and orientation of the target, which allows device-free localization systems to exploit multipath propagation. The model is evaluated for a single link scenario of one specular reflection. A comparison of modeled attenuation results to wideband measurement data qualitatively confirm the applicability of the proposed model representing target-induced attenuation.

T05-A12/2: Point of Care Microwave Sensors

**T05 Biomedical and health / Regular Session / Antennas**

8:30 Handheld, Broadband Transmission-Based Probe - The Next Star Trek Tri-Corder

Paul M Meaney (Dartmouth College, USA); Robin Augustine (Uppsala University, Sweden); Timothy Raynolds (Dartmouth College, USA)

We have developed a portable, wide-bandwidth transmissive dielectric probe that could have substantial clinical applications. This invention builds on three novel concepts that allow deep signal penetration over a very broad bandwidth: the large aperture coaxial antenna, transmission mode utilizing adjacent open-circuit coax, and narrowing of the aperture in the co-located slots. These act to enhance penetration and focus the beam within a narrow plane. They are also dramatically uncommon to multipath signal corruption due to the close proximity of the transmitting and receiving antennas. The new design has been shown to operate from 100 MHz to 6 GHz, is not susceptible to motion of the connecting cables and can sense property aberrations at over 2 cm depth. These features are in stark contrast to the same value and thus allow the radars to perceive their interferer as a single echo along range and Doppler.

8:50 An NW Extension for Dielectric Characterization of Arbitrary Length Low-Loss Materials

Hassan Shwajyani, Joseph Costantine and Ali ElHajj (American University of Beirut, Lebanon); Mohammed AHussein (Beirut Research and Innovation Center, Lebanon)

In this paper, we propose an extension for the Nicolson-Rosca-Wise (NRW) method that enables the retrieval of the electrical parameters of low-loss materials that are thicker than one-half wavelength (0.5λ). The proposed extension overcomes the NW intrinsic limitation that causes a divergence of results at frequencies where the material thickness is an integer multiple of half wavelength (0.5λ). The method is tested on different sample materials, and it is proven to provide reliable permittivity estimation, with no divergence at frequencies corresponding to integer multiple of half wavelength.

9:10 Clustering of Dielectric and Colour Profiles of an Ex-vivo Burnt Human Skin Sample

Pranesh K Rangalak (Researcher & Uppsala University, Sweden); Jawad Ebrahimi (University of Uppsala, Sweden); Abishhek Hongally Nagaraj (Uppsala University & Uppsala, Sweden); Irina El-AI and Mokhtar Kouki (Datametrix AG, Switzerland); Rappaditya Mandal (Uppsala University, Uppsala, Sweden); Fredrik RM Huss (Uppsala University Hospital & Uppsala University, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Robin Augustine (Uppsala University, Sweden)

In this work we introduce two techniques to characterize human burn skin based on dielectric and colour profiling. The first method is the segmented measurement of permittivity by using an open-ended coax probe technique. The second method is the analysis of color variation in the burnt skin sample through image processing. Statistical analysis is done using tools such as Analysis of Variance, k-means, in order to classify the data. As part of the classification, the experimental data are clustered into groups based on the distribution of means and centroids. The color image is converted into a gray image and resized to a one-dimensional array. Furthermore, the analysis is done based on the
9:30 Non-Propagating-Based UAV Channels (UAVs) Using Anthropomorphic Phantom at 2.45 GHz
Laya Joseph (FTE, Angstrom Laboratory, Lägerhyddsvägen 1 & Uppsala University, Sweden); Noor Badarshah Anan (Uppsala University, Sweden & KIEK); Xiaoying Liu (Universiti Teknologi Malaysia, Malaysia); Jawad Ebrahimzadeh (University of Uppsala, Sweden); Arvind Selvan Chezhian (Uppsala University, Sweden); Mauricio Perez (Uppsala University, Sweden & National Technological University, Argentina); Thiemo Voigt (Swedish Institute of Computer Science & Uppsala University, Sweden); Robin Augustine (Uppsala University, Sweden)

In this paper, we propose the development of semi-solid and solid blur phantom with skin, fat, muscle and spherical tumor and is a transmission-based sensing for tumor detection. The proposed blur phantom simulates the anatomical, physical and electrical properties as human breast tissues. The dielectric properties of the breast phantom tissues are measured using open-ended coaxial slit probe from Keysight Technologies in the frequency range of 500 MHz-20GHz. The SI1 scattering parameters are measured and studied for a different blur breast phantom with tumor models representing its different growth stages using Topology Optimized Plasmon Antennas (TOPA) based probe. The study shows a detection at the SI1 amplitude of 2-12 dB for tumor inclusion models of 4mm - 16mm diameter with respect to normal breast model. This study indicates that further development transmission-based methods can be used for preliminary screening of breast tumour.

9:50 On the Optimal Matching Medium and Working Frequency in EM-based Medical Devices
Gennaro G. Belluzzi (Erasmus University Medical Center, Italy); Martina Teresa Bevacqua (Università degli Studi di Reggio Calabria, Italy)

From an engineering perspective, propagation theory is underlying all electromagnetic phenomena, and the operating frequency has a pivotal role in terms of technical, and clinical effectiveness of such devices. However, sub-optimal, yet easy to realize, working conditions are usually adopted without taking into account some important aspects of propagation theory. In this contribution, we propose an innovative approach for optimally determining both the matching fluid and the working frequency in an optimal fashion. Even if application independent, it is tested and assessed within the framework of hyperthermia: an adjuvant oncologic therapy consisting in the deposition of electromagnetic power in the tumor to increase its temperature.

10:10 Coffee Break

10:40 Low Profile Implantable Antenna for Fat Intra-Body Communication
Bappaditya Mandal (Uppsala University, Uppsala, Sweden); Layla Joseph (FTE, Angstrom Laboratory, Lägerhyddsvägen 1 & Uppsala University, Sweden); Jawad Ebrahimzadeh (University of Uppsala, Sweden); Mauricio Perez (Uppsala University, Sweden & National Technological University, Argentina); Debasis Mitra (Indian Institute of Engineering Science & Technology, Shibpur, India); Robin Augustine (Uppsala University, Sweden)

A flexible low profile biocompatible implantable antenna for fat intra-body communication is proposed. This antenna is designed on 0.15mm thick low loss lacoste material. The antenna is covered by 0.1mm thick PUDMS (Polydimethylsiloxane) to ensure biocompatibility with human tissue. A coplanar waveguide (CPW) microstrip line is used to feed the antenna. This antenna has been optimized to operate at 2.4GHz ISM band frequency in the human three-layer tissue model. The simulation, as well as measurement, were done at a minimum distance of 10mm, and the maximum distance of 70mm between two implantable antennas. The antenna’s path loss of the fat channel is measured using the low profile proposed antenna is estimated to be almost 2.5dB per centimeter. The measured bandwidth of the proposed antenna found to be 60MHz.

11:00 Optimal Probe Geometry for Microwave Monitoring During In-Lab Ex-Vivo Measurements
Giselle Gonzalez-Lopez (Universitat Politècnica de Catalunya, Spain); Susana Amoros Garcia de Valdecasas (Predoctoral Researcher, Spain); Luis Jofre (Universitat Politècnica de Catalunya, Spain)

In this paper, a 3D printed geometry for optimal ex-vivo in-lab microwave monitoring is presented. This geometry is meant to be used for mimicking the shape and dielectric properties of certain parts of the human body, and to relax the conditions present during in-field measurements. This geometry is validated through analytic and experimental tests by monitoring an implanted device at different depths inside the set-up, and the results are presented.

11:20 Metasurface Sensors for Healthcare Applications
Antoine Durant (Edinburgh Napier University, United Kingdom (Great Britain) & Université Grenoble Alpes, France); Celia Lacoste (INP-ENSEEIHT University of Toulouse, United Kingdom (Great Britain)); Erin Donnelly and Luigi Lo Spada (Edinburgh Napier University, United Kingdom (Great Britain))

Metasurface sensors have received huge attention in the last few years, due to their ability to improve performance, and safety in different industries, especially in the medical and industrial fields. Despite reliable diagnostic technologies have been developed, some drawbacks are still present: bandwidths, in dimensions and limited response control. Metasurfaces, bi-dimensioned engineered materials, represent an optimal solution to overcome such issues enhancing existing systems for an accurate diagnosis. Therefore, in this paper, metasurface-based sensors are proposed and realized by using new additive manufacturing processes. The structures are finely experimentally tested and verified in different medical diagnostic applications, namely: cancer stage recognition, glucose/sugar levels measurements and blood oxygen saturation detection. The performances shown by such meta-sensors, in terms of selectivity and sensitivity, pave a new way to realize advanced platforms for non-invasive, high quality and faster patient diagnosis.

11:40 Multiple-Pole CSRR-Based Microwave Sensor for Glucose Levels Detection
A l-Bin Omar (University of Waterloo, Canada); George Shaker (University of Waterloo & Spark Tech Labs, Canada); Safeddin Safavi-Naeini (University of Waterloo, Canada); Hamid Kokabi (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, Canada); Georges Alquier (UPMC, France); Frederique Deshours (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, France)

We propose a microwave biosensor that can perform multiple-plex glucose measurement integrated on a triple-parallel complementary split ring resonator structure. The sensor operates in the centimeter-band 1-6 GHz and is fabricated on top of a thin F4A dielectric substrate. The sensor element is excited via a coupled microstrip-transmission line etched on the bottom side of the substrate. The proposed CSRR-based sensor is used as a new field probe to non-invasively monitor the changes in glucose concentrations in the blood mimicking fluid by tracking the amplitude variations of the harmonic transmission resonances at various concentrations. The fluids are loaded inside a channel representing a roughly 5-mm vessel. The proposed sensor is shown to exhibit higher sensitivity performance compared to the conventional single-pole and other similar sensors in the literature. The sensitivity, reliability and repeatability of the proposed sensor are demonstrated by the in-lab measurements using a Vector Network Analyzer.

Thursday, 19 March 8:30 - 10:10
T06:09: Propagation for Unmanned Aerial Vehicles (UAVs)
T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Regular Session / Propagation
Room: B7

8:30 A USRP-based Channel Sounder for UAV Communications
Guojin Zhang, Xuesong Cai, Wei Fan and Gert Pederen (Aalborg University, Denmark)

The unmanned-aerial-vehicle (UAV) has attracted great interest in both civil and military applications, due to its low operational cost and more flexibility and ability to establish seamless connections. In this paper, a Universal Software-defined Radio Peripheral (USRP) based channel sounding system for characterizing the UAV communication channel is introduced, which can be applied in both active and passive measurement campaigns. To investigate the effect of the equipment in the UAV measurement system, measurements were conducted by connecting the two USRP devices directly with a cable. For calibrating the denotation of the crystal oscillator in the system, the post-processing method is proposed in case of a linear and unstable reference frequency.

8:50 Wideband Channel Measurements and First Findings for Low Altitude Drone-to-Drone Links in an Urban Scenario
Dennis Becker, Uwe-Carsten G. Fiebig, Lukas Marcel Schalk and Gert Pederen (German Aerospace Center (DLR), Germany)

In order to prevent collisions between unmanned aerial vehicles (UAVs) - Drone-to-Drone communication is a promising technology enabling reliable collision avoidance services. For a reliable communication system accurate channel models, specifically designed for UAVs in typical environments, are needed. Especially, the urban environment for small UAVs in very low altitude airspace is challenging due to rich multipath propagation and non-line of sight conditions. In order to model the real-world propagation behaviour, channel measurements with small UAVs in different urban scenarios are mandatory. So far, no reliable channel model based on measurements for D2D communication has been proposed. Therefore we conducted wideband channel measurements in the C-band. In this paper, we present the scenarios of our campaign and show first findings. With a geometrical signal path simulation we identify where the physical signal paths come from. The measurements reveal that the D2D MPCs scenario is clearly three-dimensional.

9:10 On the Second Order Statistics of 3D Non-Stationary UAV Channels Allowing Velocity Variations
Yawan Wang, Neng Cheng and Xiaomin Chen (Nanjing University of Aeronautics and Astronautics, China); Wei Fan (Aalborg University, Denmark); Qiuniq Zhu and Weizhi Zhong (Nanjing University of Aeronautics and Astronautics, China)

The cross level and average fading duration are two important statistical properties of channel fading envelope. In this paper, a geometry-based stochastic model for unmanned aerial vehicle (UAV) channel allowing three-dimensional trajectory of the UAV and ground station is proposed. On this basis, the theoretical expressions of level crossing rate and average fading duration are analyzed and derived. Under the UAV high speed flight scenarios, numerical simulations show that the theoretical results of level crossing rate and average fading time agree well with the simulated and measured ones. The proposed model and derived expressions are very helpful for the design of block interference and multi-user detection.
9:30 Performance of 5G Terrestrial Network Deployments for Serving UAV Communications
Zeyu Huang and José Rodríguez-Péñife (Tongji University, China); Tomas Dominguez-Bolaño (University of A Coruña, Spain); Xuefeng Yin (Tongji University, China); Juyul Lee (ETRI, Korea (South)); David W Matoik (University of South Carolina, USA)

With the recent decrease in their size and cost, the unmanned aerial vehicles (UAVs) have become more accessible for general-purpose applications. A natural way of providing network access to UAVs is to use terrestrial fifth generation (5G) deployments. In this paper, we assess 5G air-to-ground (AG) links of low-height UAVs in suburban scenarios with system-level simulations. In order to obtain realistic results, we utilized a propagation channel model extracted from actual AG measurements. We characterized the performance of the communications systems by means of throughput results. We also showed the importance of the feedback delay optimization when the UAV flight speed is high, not only for the achievable throughput, but also for the end-to-end transmission delay, which may be crucial in critical communications (e.g., safety-related ones).

9:50 Modeling and Simulation for UAV Air-to-Ground mmWave Channels
Lele Cheng and Quiming Zhu (University of Nanjing Aeronautics and Astronautics, China); Cheng-Xiang Wang (Southeast University & Heriot-Watt University, China); Weizhi Zong, Boyu Hua and Shang Jiang (Nanjing University of Aeronautics and Astronautics, China)

In this work, we propose a new three-dimensional (3D) channel model for the millimeter wave (mmWave) communication link between the Unmanned Aerial Vehicle (UAV) and the ground station (GS). The new model applies the ray tracing (RT) theory in traditional geometry-based stochastic model (GBSM), and it also takes the specific features of mmWave propagation into account. Meanwhile, the time evolving algorithms of channel parameters, i.e., communication distance, propagation angles, path delays, and powers are implemented and illustrated. On these basis, the mmWave channel simulations at 28 GHz are conducted under the campus scenario. Simulation results demonstrate that the proposed model can generate the non-stationary Air-to-Ground mmWave channels, of which statistical properties have a good agreement with the measured ones. Therefore, this model is valuable for the system design, performance optimization, and evaluation of UAV mmWave communication systems.

10:10 Micro-UAV Radar Imaging via DGPS and Microwave Tomography
Giuseppe Esposito (IREA-CNR, Italy); Carlo Novello (IREA-CNR & University of Napoli Federico II, Italy); Giovanni Ludeno and Gianluca Gennarelli (IREA-CNR, Italy); Giancarmine Pasano and Alfredo Renga (University of Naples Federico II, Italy); Francesco Soldovieri (CNR, Italy); Ilaria Catapano (IREA-CNR, Italy)

Radar imaging from UAVs is becoming a research theme attracting a huge interest for its practical fall-out. This contribution deals with an ultra-light radar system mounted on a micro drone and presents the results of a proof of concept measurement campaign. Specifically, a Differential Global Position System, synchronized with the radar, is adopted to estimate the location of the measurement points, properly. Moreover, a data processing procedure involving a linear microwave tomographic approach is adopted to obtain a focused image providing an accurate localization of the surface targets.

10:30 Identifying low-RCS Targets Using micro-Doppler High-Resolution Radar in the Millimeter Waves
Nezah Balal and Yair Richter (Ariel University, Ariel, Israel)

In recent years, the use of drones and unmanned aerial vehicles (UAV) has become popular. Delineant and terrorist agents use these devices to harm the routine of life. Sufficient technology need for detecting and tracking drones in the airspace. The use of existing aircraft detection systems is not possible due to the physical differences between the targets, smaller physical size, lower speed, and lower flight altitude relative to approved aircraft. This paper introduces the characteristics of the unique micro-doppler signature of drones. After analyzing the radar signal, one can deduce the speed and frequency of the propeller and from these find the length of the drone blade. The measurements were made using the CW radar operating in the W band at frequency 94 GHz. The results clearly show that a unique drone Doppler signature can be identified, and the geometric properties of the drone can be extracted and categorized according to the flight conditions.

Thursday, 19 March 8:30 - 12:20
CS30: Fundamental Challenges and Novel Methodologies in the Next-Generation Computational Electromagnetics
T10 EM modelling and simulation tools / Convened Session / Electromagnetics
Room: B8

8:30 Numerical Synthesis of Translation Operators for the Multi-Level Fast Multipole Method
Asran Azhar and Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HET), Germany)

A key operation in the fast multipole method is the translation of propagating plane waves from source groups to observation groups. For calculating the translation functions, the classical approach typically requires an exact knowledge of the system, such as given for the free-space Green’s function. The resulting operators are commonly defined over all propagating plane-wave directions on the Euclidean sphere. A relatively less explored alternative, however, is a numerical approach in which the translation operators are synthesized from known point to point interactions. This approach also provides an opportunity to reduce the matrix vector multiplication time. It is demonstrated that numerically synthesized translation operators are not only accurate enough but also greatly improve the performance of multi-level fast multipole method based electromagnetic solvers.

8:50 Characteristic Mode Equations for Non-Symmetric Surface Integral Operators
Pasi Yla-Oijala and Henrik Wallén (Aalto University, Finland)

The magnetic field integral operator (MFIO) based characteristic mode formulation for closed perfect electric conductor (PEC) structures is considered. Since the MFIO is non-symmetric, we need to consider the eigensolutions of both the MFIO and its transpose operator for a characteristic mode expansion. The eigenvectors of the transpose of the MFIO are shown to be in the dual of the range of the MFIO. Physically, these vectors can be interpreted as the tangential electric field on the surface.

9:10 Analytic Expressions for Matrix Elements of Integral Equation Operators and Aspects of Their Numerical Implementation
Elizabeth Bleszynski (Monopole Research, USA); Marek Bleszynski, Dr (Monopole Research, USA); Thomas Jaroszewska (Monopole Research, USA)

We present extensions of the method of evaluating matrix elements of integral equations with the help of suitably constructed Laplacian-type representations of singular kernels. Such representations allow to convert surface integrals to line integrals involving only non-singular, smoothly varying integrands amenable to numerical evaluation with low order numerical quadratures as well as to analytical evaluation. We present: (a) Construction of revised expressions for the auxiliary functions needed for the Laplacian representations of the tensor and vector Green functions for geometries located on parallel planes. The approach guarantees smoother behavior of these functions in the limit of small separations between the triangular facets; (b) An improved analytic evaluation of double line integrals resulting in analytic expressions significantly simpler and more compact than the ones previously reported. We also discuss the relative merits of the direct numerical and analytic evaluations of these line integrals.

9:30 Reducing the Dimensionality of D-D MoM Integrals Applying Twice the Divergence Theorem
Javier Rivero (Universidad de Extremadura, Spain); Donald W. Matolak (University of Houston, USA); William Johnson (Private Consultant, USA)

In this paper we propose a scheme for evaluating the D-D interaction integrals appearing in volume integral equation solved with the help of MoM and boundary element methods. We treat as a whole the double volume integral, applying the divergence theorem first on the source domain and then on the test domain. With the proper variable transformation and reordering, the D-D integrals are expressed as two radial integrals plus four linear integrals over the source and observation domains.

9:50 Toward Extremely Scalable IE-DEM for Distributed Computing
Victor Martin (University of Extremadura, Spain); Diego M Solis (University of Pennsylvania, USA); David Larion (University of Extremadura, Spain); Luis Landesa (University of Extremadura, Spain); Fernando Obeliero (University of Vigo, Spain); Jose M. Taboada (University of Extremadura, Spain)

In this work, we describe a hybrid MPI/OpenMP parallel implementation of the surface integral equation - domain decomposition method (DE-DEM) in distributed mixed memory computers for the simulation of extremely large scale and complex problems. The proposed approach greatly reduces the global network communications and memory burden, providing an extremely scalable implementation both in time and, especially, in memory.

10:10 Coffee Break

10:40 Overview of Surface-Volume-Surface Electric Field Integral Equation Formulations for 3-D Composite Metal-Dielectric Objects
Reza Ghofarnia (University of Toronto & University of Manitoba, Canada); Shucheng Zheng and Vladimir Okhmatovski (University of Manitoba, Canada)

The Surface-Surface Electric Field Integral Equation (S3-EFIE) has been recently generalized to solution of general scattering and radiation problems for 3D composite objects. These objects can be formed by multiple piece-wise homogeneous dielectric regions which do or do not share common boundaries. Generalization to the composite objects formed by metal and piece-wise homogeneous dielectric regions which share common boundaries has also been demonstrated. Since the S3-EFIE formulation utilizes only the electric field dyadic Green’s functions, it can be extended to the case of composite objects situated in non-magnetic plane multilayered media by casting its operators
11:00 On the Information Entropy of Diffusive Multipath Scattering Environments
Shen Lin (University of Illinois at Urbana-Champaign, USA); Zhen Peng (University of Illinois at Urbana-Champaign, USA)

We propose a novel mathematical/stochastic model to analyze the information entropy in diffusive multipath scattering environments. The methodology is to first establish fundamental statistical representations of complex diffusive media, then integrate component-specific features of transmitters and receivers, and finally encode the governing physics within the mathematical information theory. The work qualitatively characterizes the correlated Rayleigh diffusive multipath, coherent specular direct-path, and mutual coupling between antennas. The theoretical research is evaluated and validated through experimental representatives.

11:20 Modal Characterization of Thermal Emitters Using the Method of Moments
Denzhin Tikhon (University of Cambridge, Belgium); Stafford Whitington (Cavendish Laboratory, United Kingdom (Great Britain)); Christophe Craye (Université Catholique de Louvain, Belgium)

Electromagnetic sources relying on spontaneous emission are difficult to characterize without a proper framework due to the spatial separation of the emitted fields. In this paper, we propose to characterize emitters of any shape through their natural emitting modes, a set of coherent modes that add up coherently. The resulting framework is very intuitive since any emitter is regarded as a multimode antenna with zero correlation between modes. Moreover, for any finite emitter, the modes form a compact set that can be truncated. Each significant mode corresponds to a unique degree of freedom through which the emitter radiates power. The proposed formalism is implemented using the Method of Moments (MoM) and applied to a noisy sphere and a noisy ellipsoid. It is shown that electrically small structures can be characterized by a small number of modes, and that this number grows as the structure becomes electrically large.

11:40 A Numerically Efficient Technique for the Analysis of Metamaterial-And Metasurface-based Antennas
Abdelkhalek Nasri (Research Unit of Mechatronic Systems and Signals, National Engineering School of Carthage, Tunisia); Raj Mittra (Penn State University, USA)

Metasurface-based antennas have received considerable recent attention because they are not useful for designing new antennas, but for improving the performance of legacy design as well. However, these antennas are usually multiscalar in nature and they typically require an incredibly long time when simulated by using commercial solvers. In this work, we present a new approach for designing antennas that utilize Metasurfaces (MTSs) and Metamaterials (MTMs). The proposed method departs from the widely-used technique based on an anisotropic impedance representation of the surface and relies on an equivalent medium approach instead. The principal advantage of this approach is that such an equivalent medium representation can be conveniently used in commercial Rf solvers. Several illustrative examples are presented in the paper to demonstrate the efficacy of the present approach when simulating MTSs and MTM-based antennas.

12:00 Fast and Accurate Analysis of Multilayered Periodic Structures Used in the Design of Reflectarray and Metasurface Antennas
Miguel Camacho (University of Pennsylvania, USA); Rafael R. Boix (University of Seville, Spain); Francisco Medina (University of Seville, Spain)

The spectral domain Moment Method of Moments (SD-MoM) is applied to the efficient analysis of multilayered structures containing periodic arrays of patches of many different geometries, and in particular, patches of the type that have been customarily used as elements of reflectarray and metasurface antennae. In the approximation of the electric current density on the patches we use basis functions accounting for edge singularities, which make it possible to obtain very accurate results while requiring small MoM matrices. Although the two-dimensional Fourier transform (2-D FT) of the basis functions cannot be analytically determined, the Nonuniform Fast Fourier Transform (NUFFT) algorithm is used to numerically compute these 2-D FT. The SD-MoM based on NUFFT turns out to be 80 times faster than conventional MoM based on selected 2-D FT of the basis functions.

T10-E01/1: Electromagnetic Methods for Direct and Inverse Scattering Involving Stratified Media

T10 EM modelling and simulation tools / Regular Session / Electromagnetics
Room: B9
Chairs: Alessandro Fedeli (University of Genoa, Italy); Cristina Ponti (Roma Tre University, Italy)

8:30 Electromagnetic Excitation of a Layered Medium by N Magnetic Dipoles
Andreas Kalgopoulos and Nikolaos T. Taitias ( Aristotle University of Thessaloniki, Greece)

Excitation of a layered medium by N magnetic dipoles is considered. Scattering relations and physical bounds concerning the scattering cross sections and the number of dipoles are derived. Potential applications of such problems are pointed out. Numerical implementations of the derived relations for specific scattering geometries are included.

8:50 Cloaking and Magnifying Using Radial Anisotropy in Non-Integer Dimensional Space
Sita Babot, Melwsh Nisar, Fabio Mangini and Fabrizio Frezza (Sapienza University of Rome, Italy)

This paper analyzes the electromagnetic responses of purely radially anisotropic (PRA) cylindrical shell and spherically radially anisotropic (SRA) spherical shell in presence of non-integer dimensional (NID) space. This is obtained by placing both of these geometries in space having non-integer dimensions. The influence of presence of NID space on cloaking and magnification using these geometries have been worked out. Observations have shown that PRA cylindrical shell can only be yielded by selecting certain anisotropy ratio in presence of NID space, whereas magnification cannot be achieved. Numerical simulations have been done to show the effectiveness of NID space and for difference of the presence of NID space and ordinary space. However, SRA spherical shell is independent of the presence of NID space for cloaking and magnification.

9:10 Reflected Wave Fields from a Fluctuating Earth Surface - a Phase-Space Approach
Valon Blakaj (Research Associate, United Kingdom (Great Britain)); Gabriele Gradoni, Stephen Creagh and Gregor Tanner (University of Nottingham, United Kingdom (Great Britain)); Manohar Despande (NASA, USA)

In this paper we present a phase-space approach that models wave fields reflected from random surfaces. By using transformations based on the Wigner distribution function (WDF), we represent the diffuse wave fields in phase-space. This representation offers an efficient approach for modelling complex and noisy sources. We focus on the application of this approach in modelling of wave fields reflected from rough Earth, with potential applications in microwave remote sensing.

9:30 Towards Asteroid Tomography: Modellings and Measurements Using an Analyse Model
Christelle Kyrka (Institut Fresnel, Aix Marseille Université, CNRS, Centrale Marseille, France); Lisa-Ida Sorsa (Tampere University, France); Alain Hérinique (Univ Grenoble Alpes, CNRS, IPAG, France); Jean-Michel Geoffrin (Institut Fresnel & Aix Marseille Univ, CNRS, Centrale Marseille, France); Sampsa Pursiainen (Tampere University, France); Wlodzislaw Kofman (Univ Grenoble Alpes, CNRS, IPAG/Space Research Centre, PAS, France)

The interior structures of the comets and asteroids, still poorly known, might hold a unique key to understand the early Solar System. Considering the interaction of an illuminated electromagnetic wave with this kind of targets, these ‘objects’ are very large compared to the applicable wavelength. Consequently, topographic imaging of such targets, i.e., reconstructing their interior structures via multiple measurements, constitutes a challenging inverse problem. To reach this objective and to develop and test inverse algorithms, we need to investigate electromagnetic fields that have interacted with structures analogous to real asteroids and comets. In this study, we focus on the acquisition of these fields considering three methods: calculated fields obtained with (1) time and (2) frequency domain methods and (3) microwave measurements performed for an analogue model, i.e., a small-scale asteroid model.

9:50 Modelling Cylindrical Slot Antenna for Borehole GPR
Alexei Popov (IZMIRAN), Vladimir Garbatsevich and Pavel Morozov (IZMIRAN, Russia); Fedor Morozov (Ukraine National Research Academy of Sciences, Poland); Igor Prokopovich (IZMIRAN, Russia)

We discuss application of slot antennas in the problem of subsurface radar logging. Frequency dependence of radiation pattern is studied. Preliminary field tests are reported.

10:10 Coffee Break

10:40 GPR Probing of Smoothly Layered Subsurface Medium: An Analytical Model
Alexei Popov (Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russia); Pavel Morozov (IZMIRAN, Russia); Marian Markinck (National Institute of Telecommunications, Poland); Igor Prokopovich (IZMIRAN, Russia)

An analytical approach to GPR probing of a horizontally layered subsurface medium is developed, based on the coupled-wave WKB approximation. An empirical model of current in dipole transmitter antenna is used.

11:00 Qualitative Imaging of Experimental Multistatic Ground Penetrating Radar Data
Michele Ambrosanio (Università di Napoli Parthenope, Italy); Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Vito Pascasio (Università di Napoli Parthenope, Italy); Tommaso Isense (Università di Reggio Calabria, Italy)

Subsurface imaging of unknown buried objects is of fundamental importance in several fields, spanning from civil engineering applications to the investigation of uncontrolled objects located in investigation domains in a nondestructive fashion. In this paper, an analytical approach to GPR probing of a horizontally layered subsurface medium is developed, based on the coupled-wave WKB approximation. An empirical model of current in dipole transmitter antenna is used.

11:20 Multi-Resolution Through-the-Wall Microwave Imaging of Strong Scatterers
Denis Tihon (University of California, USA)

We propose a novel mathematical/statistical model to analyze the information entropy in diffusive multipath scattering environments. The methodology is to first establish fundamental statistical representations of complex diffusive media, then integrate component-specific features of transmitters and receivers, and finally encode the governing physics within the mathematical information theory. The work qualitatively characterizes the correlated Rayleigh diffusive multipath, coherent specular direct-path, and mutual coupling between antennas. The theoretical research is evaluated and validated through experimental representatives.
A new approach for the partial-reconstruction in near-field antenna characterization is presented. The goal of the partial reconstruction is to determine the optimal near-field sampling distribution required to provide a partial-reconstruction of the antenna pattern (along some cuts). The method is based on the formulation of the near-field characterization as a linear inverse problem and on the singular-value-optimization. It is aimed to reconstruct only that part of the unknown contributing to the far-field pattern along the desired cuts. A numerical analysis shows the performance of the method.

9:10 Single-Cut Near-Field Far-Field Transformation and Implicit Plane-Wave Synthesis for RCS Prediction Including Multiple Scattering Effects

Shinharu Omi (National Institute of Advanced Industrial Science and Technology, Japan); Michitaka Ameya (NMB/AIST, Japan); Masaharu Hirose and Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan)

A single-cut near-field far-field transformation method is proposed which is based on the full-wave formulation. The method enables the exact prediction of RCS including the multiple scattering effects and requires the NF sampling points are required only on a single-cut-plane. It is based on the single-cut near-field far-field transformation (SFFFT) for antenna measurements and consists of SFFFT and implicit plane-wave synthesis (IPSWS) steps. The proposed method is formulated based on the scattering theory discussed and validated numerically and experimentally.

9:30 Experimental Determination of the Total Radiated Power of Automotive Antennas in the Installed State

Muhammad Ehtisham Asghar and Christian Bornkessel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

Total radiated power (TRP) is a crucial figure-of-merit used to characterize the performance of automotive antennas, similar to hand-held user terminals. Presence of a truncated region in near-field measurement facilities can induce errors in the data after near-field-to-far-field transformation, resulting in inaccurate estimation of the TRP. To improve this, different extrapolation techniques are used in post-processing to reconstruct the data in the truncated region. Several measurements were conducted for automotive antennas installed at different locations on a car as a facility with truncated measurement region. The measured data were extrapolated in the truncated region, and the impact of post-processing was analyzed by comparing the reconstructed pattern with the pattern obtained from a facility without truncation, and by calculating the TRP values. The results indicate that extrapolation techniques, in particular model filtering, are capable of accurately extracting the TRP values, with a deviation of 0.1-1.1 dB compared to the reference.

9:50 AUT Far-Field Pattern Reconstruction from a Reduced Set of Spherical Near-Field Data Collected in Presence of an Infinite Perfectly Conducting Ground Plane

Francesco D’Agostino, Flaminio Ferrari, Claudio Gennarelli, Rocco Guerrero and Massimo Migliozzi (University of Salerno, Italy)

The redundant sampling representations of electromagnetic fields and the image principle are properly applied in this work to develop an effective probe-compensated spherical near-field to far-field (NF2FF) transformation, which makes use only of the NF data measured over the upper hemisphere, due to the presence of an infinite perfectly conducting ground plane. According to these representations, the considered antenna under test (AUT) and its image are assumed enclosed in a surface consisting of a cylinder ended in two half-spheres. Then, an efficient 2-D optimal interpolation scheme is used to reconstruct the NF data required by the standard spherical NF2FF transformation from the NF samples collected over the upper hemisphere and from those properly estimated from these last over the lower one. Numerical examples are shown to assess the effectiveness of the developed non-redundant spherical NF2FF transformation.

10:10 Coffee Break

10:40 Diagnostics on Electrically Large Structures by a Nested Skeletonization Scheme Enhancement of the Equivalent Current Technique

Lucia Sbitalacqua (Microwave Vision Italy, Italy); Francesca Micc (Consultant, Switzerland); Lars Foged (Microwave Vision Italy, Italy); Giorgio Giordano (LINKS Foundation & Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

The use of the Fast Multiple Method (FMM) in an equivalent current reconstruction technique, based on a dual-equation formulation, has been presented in the past for antenna design and diagnostics. The method was applied in design validation from measured data, demonstrating diagnostics feasibility of different large antennas up to an equivalent antenna of volumes 280 m³. Despite the computational advantages coming from the FMM, the memory request and the run time constraints could be still critical in the presence of electrically large antennas. An enhancement of the equivalent current reconstruction technique based on a Nested Skeletonization Scheme is here presented. The new technique leads to a further reduction of memory requirements and computational time, applicable to diagnostic investigation of electrically larger problems in a wider frequency band. In this paper the nested skeletonization scheme enhancement of the equivalent current technique is applied and demonstrated for diagnostics on electrically large structures.

11:00 Suppressing Undesired Echoes by Sparsity Based Time Gating of Reconstructed Sources

Josef Knapp, Jonas Kornprobst and Thomas F. Elbert (Technical University of Munich, Germany)

The far-field radiation characteristics of an antenna under test (AUT) is determined from measurements in proximity of a scatterer by time gating reconstructed equivalent currents for the AUT and the scatterer. The present approach effectively combines spatial-filtering methods with time domain methods while mitigating their individual drawbacks. In contrast to conventional time-gating methods which usually work on the measured probe signals this approach allows to get rid of undesired echo perturbations even if measurement samples are located in the shadow region of the scatterer and the line of sight (LOS) contribution and the echo contribution are indistinguishable for the field probe. In contrast to conventional frequency domain methods, mutual coupling contributions of the AUT currents are identified and removed in the time domain. Numerical examples show that, due to the sparse reconstruction, the AUT contribution can be determined accurately even at the borders of the measured bandwidth.

11:20 Portable, Freehand System for Antenna Diagnosis Using Amplitude-Only Data

Guillermo Alvarez Narciandi, Jaime Laviada (Universidad de Oviedo, Spain); Yuri Alvarez-Lopez (Universidad de Oviedo, Spain); Guillaume Ducournau (EMN, University of Lille, France); Cyril Luxey (University Nice Sophia-Antipolis, France); Frédéric Gianello (STMicroelectronics, France); Fernando Las-Heras (University of Oviedo, Spain)
A freehand portable system to perform antenna diagnosis using amplitude-only data is presented. It employs a handheld probe antenna, tracked by an easy-to-deploy motion capture system, a spectrum analyzer or a power detector to measure the amplitude of near-field samples, and a laptop to process the data. The system uses the phaseless Sources Reconstruction Method to retrieve an equivalent currents distribution on the AUT aperture, enabling antenna diagnosis. The system was tested measuring a Ka band two horn antenna array and the obtained outcomes were compared against reference results retrieved using both amplitude and phase information. Results show that the system can provide fast diagnosis of antennas, detecting malfunctioning elements and checking that the radiation pattern points at the expected directions.

### Characterisation of a Fibre-Optic Active Probe for Compensation of the Test-Zone Field

**Thomas M Gemmer** (RWTH Aachen University, Germany); **Wieland Mann** (engprobe GmbH, Germany); **Dirk Heberling** (RWTH Aachen University, Germany)

Compensation of the non-ideal Test Zone Field (TZF) in which an antenna under test is characterized requires a precise determination of the incident electric field. In order to perform spherical measurements of the test zone, a probe is thus inevitable which interacts with the TZF as slightly as possible. Therefore, a fibre-optic probe is used which primarily consists of dielectric parts. To correct for the measuring test-zone probe, a thorough determination of its radiation pattern and polarisation ratio is mandatory. To this end, full-wave simulations are carried out on the probe model and compared to spherical near-field measurements, thereby ensuring an accurate probe characterisation. Subsequently, the probe is included to simulated TZF data via spherical wave expansion in order to demonstrate the suitability of the fibre-optic probe for measuring the incident field and the importance of test-zone probe correction.

### Locating Sources of Reflection Errors in an Anechoic Chamber by Creating an Error Surface Plot

**Alo-Heléne Bester** (University of Stellenbosch, South Africa); **Petrie Meyer** (Stellenbosch University, South Africa)

A technique to locate sources of reflection errors in an anechoic chamber is presented in this article. This technique expands the NIST 18 term error analysis method and compares reflections over the whole sphere instead of using only cuts which are the proposed method of analysis. Reflection errors are consequently portrayed as an error surface. These error surfaces are displayed with surface plots and can be used as a tool to locate the origin of reflections.

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**Thursday, 19 March 8:30 - 10:10**

**BC/3: History of Electromagnetism 3**

**Room: B11**

**Chairs:** Ari Sihvola (Aalto University, Finland), Arthur D Yaghjian (Electromagnetics Research Consultant, USA)

### 8:30 The Amazing History of Reflector Antennas: From Hertz to Modern CubeSats and Beyond

**Yahya Rahmat-Samii** (University of California Los Angeles (UCLA) & UCLA, USA); **Vignesh Manohar** (University of California, Los Angeles, USA)

Reflector antennas have evolved significantly over the years. Starting from its use in the form of mirrors in the optical domain, reflectors have found use in a significant number of modern day applications. In this review paper, we begin with the development of reflector antenna in the radio wave domain by Hertz, and then march through the evolution of reflector antennas in three major regimes: radar, radio astronomy and satellites. Due to page limitations, only representative examples can be covered. However, the authors have provided relevant references that covers a much wider scope.

### 8:50 A View of Some Key Developments of Spacecraft Antennas, Their Modelling and Technologies

**Antoine Roederer** (Technical University of Delft, The Netherlands)

This paper reviews the evolution of spacecraft antennas and related techniques and technologies from the bent wire antennas of Spitzik (1957) to the multiple beam array fed reflector antennas of tomorrow's Terabit communication satellites. Some key developments of antennas for telemetry, tracking & command, of reflector, lens and array antennas for communications, localization and remote sensing will be highlighted, as well as their associated modeling techniques and technologies.

### 9:10 A Brief History of Frequency-Independent and Not-so-Frequency-Independent Antennas

**Raj Mittra** (Penn State University, USA)

This paper briefly traces the history of the development of the so-called Frequency-independent antennas which provide a backdrop of the development of Log Spiral and Log-periodic Dipole Array antennas. The paper will reminisce some of the personal experiences the author had, during the course of development of these antennas, primarily at the Antenna Laboratory of the University of Illinois.

### 9:30 The Phased Array Antenna: A History of Progress in Analysis and Technology

**Robert Mailloux** (University of Trento, Italy)

This paper describes original contributions to the analysis and technology of phased array antennas, with particular emphasis on the rate of progression with time.

### 9:50 History of Microstrip and Dielectric Resonator Antennas

**David R. Jackson** and **Stuart A. Long** (University of Houston, USA)

The history of microstrip antennas (MSAs) and dielectric resonator antennas (DRAs) is reviewed. The early work is reviewed, including some interesting controversies. Some of the important developments in these areas are discussed, including methods for improving performance in terms of bandwidth, radiation efficiency, mutual coupling, and physical size.
10:40 Isolation Enhancement of Closely Spaced MIMO System Using Inverted Fork Shaped Decoupling Structure
Jogesh Chandra Dash and Nagalakshmaiah Kalva (Indian Institute of Technology Bombay, India); Shilpa Kharche (Indian Institute of Technology Bombay, India); Jayanta Mukherjee (Indian Institute of Technology Bombay, India)

A two element closely spaced microstrip MIMO antenna with improved isolation characteristics is proposed. An inverted fork-shaped decoupling (IFSD) structure is placed between two closely spaced radiating elements, having 0.03, 0.1 edge-to-edge spacing. Further, a rectangular slot is designed on each radiating element to fill the null in the antenna broadside radiation pattern. The isolation (S21 and S22) of more than 20 dB at 5.5 GHz is achieved using the proposed technique. Antenna elements provide a very good impedance matching (S11 ≤ −15 dB) at 5.5 GHz. Implementation of IFSD structure and slot provide enhanced isolation of 65.9% compared to MIMO system without proposed technique. The proposed MIMO antenna structure having effective dimensions of 0.86λ₀×0.64λ₀ is simple to design and low in cost. The total active/reflection coefficient (TARC) and envelope correlation coefficient (ECC) of the antenna are below 0.3 and 0.005 respectively. The proposed structure is fabricated and measured.

11:00 Improvements of Multi-Antenna Specific Absorption Rate Using a Two-Stage Technique
Yuan-Hung Lin and Yen-Sheng Chen (National Taipei University of Technology, Taiwan)

In this paper, we propose a two-stage optimization technique that reduces the multi-input multi-output (MIMO) specific absorption rate (SAR) for mobile terminals. In multi-antenna devices, the SAR value is affected by amplitude distributions and excitation phases of fed currents; therefore, various combinations of SAR need to be considered, and it is time-consuming to determine all the SAR results using full-wave simulation. The phase one of the proposed technique exploits a fast exact model, which solves only five combined antenna elements, and the phase two of the proposed technique exploits a fast approximate model, which solves only five combined antenna elements. The results show that the SAR value is reduced by up to 86% with a time-saving factor of 20 compared to the full-wave simulation. The SAR values are compared to the recommendations by the ICNIRP and the European Commission, and our proposed technique is found to be compliant with recommendations.

11:20 Effect of Dielectric Properties of Human Hand Tissue on Mobile Terminal Antenna Performance
Stanislav Stefanov Zhekov and Gert Pedersen (Aalborg University, Denmark)

A good approach when designing antennas for mobile terminals is to optimize them for operation in the vicinity of the user body. The presence of a living human tissue in the antenna’s near field has an adverse effect on the radiators’ performance. The focus of this paper is on studying the change in the antenna performance due to the change in the dielectric properties of the human hand holding the mobile terminal. The investigation is conducted by using an antenna array consisting of two identical and symmetrical PIFA antennas covering the frequency band from 5.8 GHz to 7.7 GHz. Several different values of the complex permittivity are assigned to a human hand in the phantom measurement and it is found that the variation of the complex permittivity within a large range of values does not change largely the SAR parameter and radiation efficiency of the antenna.

11:40 A Single Port Orthogonally Polarized Antenna for Handsets, IoT Terminals and Vehicles
Mohamed Sanad (Amant Antennas, Egypt); Noha Hassan (Faculty of Engineering, Cairo University, Egypt)

A broadband resonant antenna has been developed for handsets, vehicles and IoT terminals. It does not use any matching/tuning circuits or extended ground-planes. It can be bent/rolled around the narrow sides of the terminal, which allows using efficient MIMO configurations with a high isolation. To significantly reduce the need for spatial diversity MIMO, a single port orthogonally polarized antenna has been designed. It is equally sensitive to two perpendicular polarizations and it also has a good sensitivity to circular polarization, which is important for GPS and satellite phones. So, any two orthogonally polarized MIMO antennas can be replaced by a single port orthogonally polarized antenna. In some applications, such as vehicles, a good MIMO configuration can be obtained by combining a linearly polarized antenna with a single port orthogonally polarized antenna in 2x2 MIMO. It can efficiently receive signals with different polarization with any complicated environment.

12:00 Comparison of Different Antenna Cluster Mobility Models
Jari-Matti Hannula (KTH Royal Institute of Technology, Sweden); Anu Lehtovuori (Aalto University, Finland); Ville Vilkar (Aalto University & School of Electrical Engineering, Finland)

The antenna cluster concept utilizes multiple, simultaneously-fed radiating elements collaboratively as one antenna. We have previously presented several methods to obtaining feeding weights to realize certain impedance. In this work, we compare the previously documented methods and discuss their benefits and challenges. As a new method, we consider the case where the weighting is performed by measuring the antenna response using a receiver antenna.

T01-P02: Propagation Modelling and Simulation

T01 LTE and Sub-6GHz 5G / Regular Session / Propagation

Room: B1

Chair: Nima Jamaly (Swisscom, Switzerland)

10:40 Penetration Loss into Train Wagons: Q-factor Measurements
Nima Jamaly (Swisscom, Switzerland); Reto Schōch (Schōch Technik GmbH, Switzerland); Daniel Wenger (Swisscom, Switzerland); Stefan Maunon (Swisscom (Schweiz) AG, Switzerland)

The Q-factor of train wagon plays a significant role in calculation of EM penetration into a wagon. It is also can be used as an alternative metric indicating richness of the multipath propagation inside a wagon. We present the results of 2-factor measurements for similar wagons equipped with two different IF-friendly windowpanes. The measurement results show that the inside wagons with IF-friendly windowpanes have a non-rich multipath environment not allowing to make best use of spatial multiplexing feature supported by modern wireless communication systems.

11:00 Generation of Realistic Railway Based Mobility Scenarios
Christoph Herold, Leinart Thielecke and Thomas Kümer (Technische Universität Braunschweig, Germany)

Planning and operating cellular networks for railway coverage is a challenging task due to the trains high speeds, the number of users traveling and the surroundings. Simulations of the radio environment are a crucial part of the radio network planning process as they allow to test different network layouts and configurations. Accurate simulations however require appropriate input data. In this paper, we present a process for the generation of realistic railway based mobility scenarios from public domain environmental data. From cluster building and height data, the train routes, the positions of base stations and their antennas as well as the user movement will be derived. Using these realistic scenarios will allow for detailed system-level simulations for specific locations and their characteristics.

11:20 A Study on Vegetation Loss Model with Seasonal Characteristics
Daigo Ogata, Akihito Sato, Sho Kimura and Hideki Omote (Softbank Corp., Japan)

In mobile communications, it is necessary to accurately estimate and evaluate the effects of the environment between the BS and MS, such as the terrain, clutter, vegetation, etc. Rural areas have few surrounding reflective objects, and so are not multipath-rich environments. Therefore, it is considered that the received power is reduced when direct waves are blocked by buildings, trees, etc. In such an environment, it is necessary to clarify the characteristics of diffused waves, waves scattered by isolated buildings, vegetation. This paper focuses on the loss due to vegetation blockage. The vegetation loss has been standardized as ITU-R P.833-9, but the region and kinds of trees considered are limited. In this paper, the vegetation loss due to vegetation blockage is calculated based on the Q-factor method. The results of Q-factor measurements for similar wagons equipped with two different RF-friendly windowpanes. The measurement results show that inside the wagons with RF-friendly windowpanes, we have a non-rich multipath environment not allowing to make best use of spatial multiplexing feature supported by modern wireless communication systems.

11:40 Channel Modeling for Wireless Sensor Networks Deployment in the Smart City
Eran Greenberg (RAFAEL, Israel); Amarnay Bar and Edmund Kloodt (RAFAEL, Israel); Liat Peled-Eitan (RAFAEL, Israel)

In the near future many objects in the urban environment will be able to communicate with each other as part of the smart city vision. Untethered wireless sensor networks, which will be deployed in the streets and on the buildings, will generate big data for the benefit of the city residents. In this contribution we investigate the wireless propagation channel for terminals located on/ground/roof level by using ray-tracing simulations. Taking advantage of using multi-core processors we have analyzed a large dataset of sensor locations for a statistical analysis. The behavior of the path loss, mean time of arrival, delay spread and mean direction of arrival are presented and modeled.

12:00 Analytical Propagation Approximation over Variable Terrain and Comparison to Data
Dmitry Chizhik (Nokia Bell Labs, USA); Jani Mollanen (Nokia Bell Labs, Finland); Siegfried Klein (Nokia Bell Labs, Germany); Luis Maestro and Reinaldo Valenzuela (Nokia Bell Labs, USA)

An analytical modeling methodology to rapidly predict signal strength over variable terrain has been developed. Methodology relies on approximating the intervening terrain by a constrained paraboloid, allowing the use of a modal sum solution. The model has been compared against an extensive data set of over 3000 links, measured in a desert environment.
In this paper, design and electromagnetic-thermal co-simulation of a microwave catheter and a bowtie-slot body matched antenna are discussed. The catheter is inserted into a liver tissue phantom to heat the tissue with 50 W power for 300 seconds in thermal simulation. The resultant temperature profile is fed back into the electromagnetic simulation with temperature-dependent material properties of a liver. Similarly, 50 W power is also stimulated in the catheter in electromagnetic simulation to observe the difference in received power at the surface bowtie slot antenna during the heating process.

11:00 Characterization of an Integrated Radiofrequency System for MR-guided Hyperthermia

Gennaro Bellizzi (Erasmus University Medical Center, Italy); Kamal Sunseri (Erasmus MC Cancer Institute, The Netherlands); Ria Forner (UMC Utrecht, The Netherlands); Tomas Dridal (Czech Technical University in Prague, Czech Republic); Maragathu M. Paulides (Eindhoven University of Technology, The Netherlands)

Clinical studies have established the clinical benefit of adjacent mild hyperthermia, but further improvements require magnetic resonance (MR) thermometry for accurate temperature dosimetry. In this work, we experimentally investigate the feasibility of our approach consisting of a receiver-only coil array, for accurate MR thermometry, integrated into a phased array for heating purposes. An experimental setup was constructed consisting of a 4-element heating array working at 434 MHz and a 2-channel MR receive coil array working at 63.8 MHz. In our approach, these arrays are oriented to exploit polarization decoupling. Vector network analyzer measurements showed satisfactory reflection and transmission characteristics for the heating (50-200Ω, 5p-318Ω) and imaging (50-218Ω, 5p-128Ω) arrays and the inter-array coupling was as low as 50dB. We conclude that this combined arrangement is highly suitable for a simultaneous operation.

11:20 An Open-Access Experimental Dataset for Breast Microwave Imaging

Rossella Gaffoglio, Jordan Krenkevich and Stephen Pistorius (University of Manitoba, Canada)

Microwave imaging has shown potential for breast cancer screening, but further evaluation of the clinical viability of breast microwave imaging (BMI) systems is required. Previous phantom studies have shown promise, but after decades of BMI research, simulation studies still dominate. This work addresses the challenges of small sample sizes and a lack of experimental data by providing an open-access experimental dataset, obtained using a pro-clinical BMI system. At time of submission, the University of Manitoba BMI Dataset (UM-BMD) contains data from 452 phantom scans and will be expanded to contain 1257 scans. UM-BMD is publicly available, and the community is encouraged to use it for large-scale BMI analysis. The application of logistic regression for tumor-detection on a subset of the dataset was demonstrated using one of UM-BMD. The diagnostic accuracy of the classifier was (91.4%) demonstrating the promise of machine learning methods for tumor-detection in BMI.

11:40 Determining the Concentration of Red Blood Cells Using Dielectric Properties

Giuseppe Labate (Erasmus University Medical Center, Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy); Ria Forner (UMC Utrecht, The Netherlands); Andrea Ali (CUNY Advanced Science Research Center, USA)

In this paper, we report two different techniques that show how it is possible to manipulate the scattered energy from dielectric objects in order to reduce the outgoing electromagnetic fields as sensed by external observers. The first method is based on a multi-harmonic scattering cancellation, as generated for dielectric objects, able to suppress the scattered waves for a fixed given direction of the incoming wave. While external fields are suppressed towards perfect zero cancellation, internal fields within the dielectric particle are demonstrated to increase due to energy conservation. The second technique exploits the relationship between the scattered field and the spectral content of the overall system (object plus cloak) under certain approximations to design cloaks able to shift the energy content outside the visible range.
Thursday, 19 March 13:20 - 14:50
Poster_Awards: Best Paper Awards Poster Sessions

Room: A2 (Poster Area)
Chair: Marianna Ivashina (Chalmers University of Technology, Sweden)

EuCAP Best Paper Award - Antennas

Nonreciprocal Antennas Based on Time-Modulation: Challenges and Opportunities
Alejandro Alvarez-Melcon (Technical University of Cartagena, Spain); Juan Sebastian Gomez-Diaz (University of California, Davis, USA)

This paper reformulates and extends some recent analytical results concerning a new optical theorem and the associated physical bounds on absorption in lossy media. The analysis is valid for any linear scatterer, consisting of arbitrary materials and arbitrary geometries, as long as the scatterer is circumscribed by a spherical volume embedded in a lossy background medium. The corresponding formulas are here reformulated and extended to encompass magnetic as well as dielectric background media. Explicit derivations, formulas and discussions are also given for the corresponding bounds on scattering and extinction. A numerical example concerning the optimal microwave absorption and scattering in atmospheric oxygen in the 60 GHz communication band is included to illustrate the theory.

Method for Extending the Bandwidth of Modulated Metasurface Antennas
Marco Faenzi (Université de Rennes 1, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Stefano Maci (University of Siena, Italy)

In this paper a modular and compact Ka-band front-end module based on PCB technology is presented. The integration and packaging techniques combine multi-layer PCB technology with waveguide feeding and antenna elements. Metallic waveguide and plane-wave antenna acts also as heatsink for the active circuitry. The modular concept can be applied to large antenna arrays to fulfill the application specific link budget requirements. Depending on the chosen core chip this design concept can be used for SATCOM or for 5G.

Design of a Wide-Scale Lens Based Focal Plane Array for Sub-millimeter Imaging Systems Using Coherent Fourier Optics
Shahab Oddin Dabinorozare (Delft University of Technology, The Netherlands); Muhan Zhang (Delft University of Technology, The Netherlands); Giorgio Careucci (Delft University of Technology, The Netherlands); Angelo Freni (University of Florence, Italy); Andrea Neto (Delft University of Technology, The Netherlands); Nuria LLombart (Delft University of Technology, The Netherlands)

This paper presents a modular and compact Ka-band front-end module based on PCB technology. The integration and packaging techniques combine multi-layer PCB technology with waveguide feeding and antenna elements. Metallic waveguide and plane-wave antenna acts also as heatsink for the active circuitry. The modular concept can be applied to large antenna arrays to fulfill the application specific link budget requirements. Depending on the chosen core chip this design concept can be used for SATCOM or for 5G.

EuCAP Best Paper Award - Electromagnetics

On the Optical Theorem and Optimal Extinction, Scattering and Absorption in Lossy Media
Sven Nordebo (Linnaeus University, Sweden); Mats Gustafsson (Lund University, Sweden); Yevhen Ivarenko (Linnaeus University, Sweden)

This paper reformulates and extends some recent analytical results concerning a new optical theorem and the associated physical bounds on absorption in lossy media. The analysis is valid for any linear scatterer, consisting of arbitrary materials and arbitrary geometries, as long as the scatterer is circumscribed by a spherical volume embedded in a lossy background medium. The corresponding formulas are here reformulated and extended to encompass magnetic as well as dielectric background media. Explicit derivations, formulas and discussions are also given for the corresponding bounds on scattering and extinction. A numerical example concerning the optimal microwave absorption and scattering in atmospheric oxygen in the 60 GHz communication band is included to illustrate the theory.

Metasurface Modeling of Periodic Diffraction Gratings Based on Generalized Sheet Transition Conditions (GSTCs)
Ville Tiukkaara (Carleton University, Canada); Tom Smy (Carleton University, Canada); Shubhaj Gupta (Carleton University, Canada)

This paper presents a modeling technique enabling the effective analysis of periodic structures composed of glide-symmetric elliptical holes. As a difference from perturbational methods, our formulation provides physical insight onto Floquet harmonics. At the same time, the computational costs is reduced compared to general purpose commercial software. The fields inside the holes are described by means of Mathieu functions and subsequently used to compute the full 2-D dispersion diagrams. With the presented analysis, we demonstrated that glide-symmetric periodic structures with elliptical holes show nonreciprocal reductive indexes over a wide range of frequencies.
Suppressing Undesired Echoes by Sparsity Based Time Gating of Reconstructed Sources

Willi Hoffmann (Technische Universität Ilmenau, Germany); Andreas Schwind (Technische Universität Ilmenau, Germany); Christian Bonkowski (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

The increasing complexity of new radio systems requires a change of measurement sites towards more sophisticated virtual electromagnetic environments. RF absorbers are essential elements of these environments to achieve the desired conditions by obtaining well-defined measurement conditions and suppressing interfering signals.

P1.073 Advanced Calibration Method for Accurate Microwave Absorber Reflectivity Measurements at Oblique Illumination Angles

96 of 128
Optimal propagation conditions can only be achieved by sufficient knowledge of the frequency- and angle-dependent reflectivity of RF absorbers. For this purpose, an advanced calibration procedure for reflectivity measurements at oblique illumination angles based on a combination of the established RCS- and NLLF-arch methods is proposed. Measurement results obtained by the new technique show good agreement with the NLLF-arch but with the advantage of accessing the angle-dependent behavior of the RF absorbers. The proposed calibration procedure will not only help manufacturers to characterize their absorbers more effectively, but additional knowledge of the off-normal reflectivity will also contribute to the optimization of measurement sites such as virtual-electromagnetic environments.

**P2.037 Axicon-hyperbolic Lens for Reflectivity Surveys of Curved Surfaces**
Aleksej Tammenen (Aalto University, Finland); Samuville Päätä (Aalto University, Finland); Juha Ala-Laurinaho (Aalto University, Finland); Mika Sakkola (Icare Finland Oy, Finland); Annti V. Räisänen (Aalto University, Finland); Zachary D Taylor (Aalto University, Finland)
We present a quasiplanar element design that transforms a diverging Gaussian beam to an approximate Bessel beam. The elements are designed to deliver millimeter waves to a curved surface in reflectivity measurements. Compared to canonical focused quasi-optical designs, such as the Gaussian-beam telescope, diffraction from an aspheric surface allows for significant relaxation in alignment requirements. This research is motivated by in vivo cornea measurements where achieving optical beam alignment is difficult. Combined axicon-hyperbolic lenses were designed for 225-330 GHz and fabricated of TOPAS, a low-loss material at millimeter waves. The lens performance is evaluated with near-field measurements. Achieving the optimal beam, the in-vivo alignment requirement can be relaxed by an order of magnitude with the Bessel beam.

**Best Student Paper Award**

**Metal Stamped Antenna-in-Package for Millimeter-wave Large-scale Phased-array Applications Using Multiphysics Analysis**
Junho Park (Pohang University of Science & Technology, Korea South); Wonbin Hong (Pohang University of Science and Technology (POSTECH), Korea South)
This paper presents a metal-stamped AIP concept for enhanced cooling in millimeter-wave phased-array systems. As applied in the proposed AIP concept, the POC-model is designed and fabricated using standard TCP and metal processing technology. The fabricated POC model achieves impedance bandwidth of 0.7 GHz with a center frequency of 28.5 GHz. Good agreement is achieved between the measured and simulated radiation patterns with the measured gain of 14.01 dBi. The effect of the fabrication error on EM properties is discussed to explain the difference between the simulated and measured results of the gain. The two-dimensional array is demonstrated to verify the feasibility for a practical application of millimeter-wave MIMO systems with main beam scanning range of ±30° in both elevation and azimuth planes. Broadband fluid-dynamic simulation confirms that the proposed AIP reduces the maximum surface temperature of the package by more than 11 °C.

**Terahertz MIMO Fading Analysis and Doppler Modeling in a Data Center Environment**
Chio-Lin Cheng (Georgia Tech, USA); Seun Sangdooyin (Georgia Institute of Technology, USA); Alenka Zajc (Georgia Institute of Technology, USA)
In this paper, we present results from a Terahertz (THz) channel measurement campaign in a data center environment. We analyze propagation parameters, such as pathloss, shadowing gain, and RMS delay spread. Amplitude fading statistics in a 4 × 4 Multiple-Input-Multiple-Output (MIMO) channel are also investigated. Furthermore, Doppler shift in the band due to the effect of cooling airflow turbulence, which causes cabling (lying in the wireless propagation path) to vibrate, is also measured. A two-dimensional (2D) geometrical propagation model that includes moving scatterers (cables) is introduced. From the 2-D model, a corresponding Doppler power spectrum (DPS) is derived and validated with measured data. This work is pertinent to THz wireless systems design for a data center environment.

**A MIMO Joint Communication-Radar Measurement Platform at the Millimeter-Wave Band**
Preeti Kumar (UT Austin, USA); Amin Mezghani (Electrical and Computer Engineering & University of Manitoba, Canada); Robert Heath (The University of Texas at Austin, USA)
A fully-digital wideband joint communication-radar (JCR) at the millimeter-wave (mmWave) band will simultaneously enable high communication and radar performances with enhanced design flexibility. In this paper, we present a measurement platform with a software-defined architecture to evaluate and demonstrate the performance of these JCR systems and their channel measurements. We develop this platform by extending a mmWave communication set-up with an additional full-duplex radar receiver and by capturing the MIMO-JCR channel using a moving antenna on a sliding rail. To characterize the JCR performance, we conduct indoor experiments and apply traditional/advanced processing algorithms on the measured data. The results demonstrate that we tested at 73 GHz with 2 GHz bandwidth can capture the JCR channel with high range/direction estimation accuracy. The comparison between the communication and radar channel shows the potential for improving JCR performance by exploiting the antenna diversity due to widespread communication and radar reception.

**Broadband Metasurface-Based Antenna Using Hexagonal Loop Elements**
Wenzhang Zhang (University of Liverpool, United Kingdom (Great Britain)); Yi Huang (University of Liverpool, United Kingdom (Great Britain)); Jiafeng Zhou (University of Liverpool, United Kingdom (Great Britain))
A broadband metasurface-based antenna with hexagonal loop radiating elements is presented. To achieve a broadband property, an array of hexagonal loop elements is taken as the main metasurface-based radiator. The antenna is fed by a microstrip line through a coupling slot. To reveal the underlying modal behavior, the characteristic mode analysis was used for modeling, analyzing, and optimizing the antenna structure. The proposed broadband hexagonal-loop-based antenna with an overall size of 1.1×0.1×0.064 m can achieve 56% fractional bandwidth and a relatively stable gain of 7-11 dBi over the operating band.

**3-D Printed Terahertz Lens for Generation of Non-diffractive Bessel Beam Carrying OAM**
Gengbo Wu (City University of Hong Kong, Hong Kong); Ka Fai Chan (City University of Hong Kong, Hong Kong); Chi Hou Chan (City University of Hong Kong, Hong Kong)
A novel 3-dimensional (3-D) printed lens for high-order Bessel beam generation operating at 300 GHz is proposed in this paper. The designed terahertz (THz) lens can transform the spherical-wave front from the feed horn into non-diffractive Bessel beam carrying orbital angular momentum (OAM). The lens consists of discrete dielectric posts, whose height can be tuned from pixel to pixel to realize the desired aperture phase distribution. Furthermore, 3-D printed technology is used to fabricate the lens with low cost. Measured results demonstrate that the designed 3-D printed lens can generate THz non-diffractive-Bessel vortex beam carrying OAM.

**Poster3-A06: Conformal Antennas**

**Antennas**

Room: Exhibition Hall

**P3.001 Green Coordinates for Generation of Conformal Antenna Geometries**
Erik Landgren (George Green Institute for Electromagnetic Research & Nottingham University, United Kingdom (Great Britain)); Harrison Ian, Ana Vukovic and Phillip Sewell (University of Nottingham, United Kingdom (Great Britain))
Conformal antennas and antenna arrays have emerged as a powerful platform for a wide number of applications from mobile and stationary communication to aerospace. In many cases producing numerical models of conformal antennas is not trivial especially in cases of complex feed circuits. In this paper, we investigate the George Coordinate method for space manipulation of three-dimensional objects and apply it to generating geometries of conformal antennas. By considering a special case of antenna bent over a developable cylindrical surface, the paper explores the impact of the Green Coordinate method on the object deformations and its impact on the electromagnetic simulations. In the paper, we focus on the accuracy of antenna parameters under the reflection coefficient and the far-field radiation patterns.

**P3.002 Element Positioning Effect on the Performance of Conformal Arrays: Synthesis and Diagnostics**
Giovanni Leone, Fortunato Munro and Piero Pino (Università della Campania Luigi Vanvitelli, Italy)
The inverse source problem has a number of applications in antenna analysis and synthesis. The properties of the radiation operator, connecting the source current to the far zone field, depends on the source geometry and can be analyzed by its Singular Value Decomposition. In this paper we examine point source reconstructions by considering the Point Source Function. An approximate closed form evaluation for limited observation domains reveals a space variant behavior. It turns out that for a conformal array on a non-uniform elements spacing accommodates definite advantages both for diagnostic and synthesis purposes. Numerical results are shown for a semi-circumference source observed in far zone over a semi-circumference.

**P3.003 Design and Evaluation of a Radio-Interferometer Antenna for the REXUS 25 Sounding Rocket**
Ivar Jansen, Ronis T. Maximidis, Mark Wijpelet and A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)
This paper presents the design and analysis of an on-rocket antenna used in a radio-interferometer experiment. The goal of the experiment is to accurately track a sounding rocket during flight. The antenna operates in the 70 cm band and is designed to work under tight constraints, a confined space, stable center frequency under large temperature variations and low budget. A microstrip patch antenna on PERKISSD103 substrate was identified as the most suitable solution, due to the relatively low cost and temperature stable dielectric properties of the PERK material. This antenna design achieved a bandwidth of 2.5 MHz. Measurements were performed on the antenna before and after flight such that changes in performance due to vibrations, temperature and other environmental conditions can be evaluated.

**P3.004 Power Allocation Optimization of a Conformal Antenna Array for Satellite Applications**
Yijun Zhou (I2R, Singapore); Xiaoning Qian, N Masumuddin and Terence S.P. See (Institute for Infocomm Research, Singapore); Chan Kuen Sim (Institute for Microelectronics, A*Star, Singapore); Yunja Zeng (Institute for Infocomm Research, Singapore); Guan Seng Ngo (Addvalue Innovation Pte Ltd, Singapore)
A power allocation optimization method of a conformal antenna array is proposed for L-band low Earth orbit (LEO) satellite applications. For a required effective isotropic radiated power (EIRP), the power consumption of the RF payload with optimized power allocation for antenna elements is greatly reduced, namely, up to 52% reduction compared with the one with single-antenna excitation.

97 of 128
P3.005 Spherical Harmonic Theory Investigations for Spherical Antenna Arrays

Leonidas Marantis (University of Piraeus, Greece); Paul Brennan (University College London, United Kingdom (Great Britain)); Athanasios G. Kanatas (University of Piraeus, Greece)

Low Earth Orbit satellite communications can be significantly improved by the omni-directional beam-scanning ability of the spherical antenna arrays. The signal processing of spherical antenna arrays is essentially enhanced by employing spherical harmonic theory. Spherical harmonics (or spherical modes) exploit spherical perfect symmetry and demonstrate the feature to "reproduce" themselves in the far-field. First, this paper justifies the cost and performance superiority of the spherical arrays compared to the planar case. In addition, it presents several spherical array investigations that utilize spherical harmonic theory, offering substantial enhancement and simplifying the computational load of the array processing.

P3.006 Design of Multiband Conformal Antenna for Sounding Rocket

Unal Basbektese (Anteral, Spain); JuanCarlos Irarre (Public University of Navarra & Antenna Group, Spain); Itzio Ederra (Universidad Publica de Navarra & Institute of Smart Cities, Universidad Publica de Navarra, Spain); Izir Maestrujuan (Anteral, Spain)

In this paper, the design of a multiband low-profile conformal antenna for the first European sub-orbital launcher, MVBA-1 is presented. The antenna cover the telemetry and GNSS applications. Here, the antenna physical and RF characteristics are given. The proposed antennas solution is not only interesting for the launcher's market, but also could find its application in space, aviation, or automotive, they can easily integrated in curved surfaces.

P3.007 Rapid Analysis of Arbitrary-Shaped Conformal Beam-Scanning Arrays

Denys Nikolayev (Institut d’Electronique et de Télécommunications de Rennes (UMR CNRS 6164), France); Agnese Mazzinghi (University of Florence, Italy); Anja K. Skrivervik (EPEL, Switzerland)

Conformal antenna arrays are able to fit seamlessly on curved 3D-shaped surfaces, which are found ubiquitously on vehicles, aircraft, human body, etc. In addition, conformal structures can overcome the scan loss limitations of conventional planar arrays. Yet, only a few computational analysis methods have been proposed with either performance or applicability limitations. In this study, a rapid analysis technique is developed for the analysis of arbitrary-shaped conformal beam-scanning arrays. The method requires only specifying the element position vectors and normals in space. Arbitrary individual antenna patterns could be specified. Finally, an example study is provided examining the beam-scanning performance of half-cylinder conformal arrays as a reference square planar array.

P3.008 Conformal 2.4 GHz Antenna with Room Temperature Vulcanized (RTV) Silicone Rubber Substrate

Denis Le Goff, Yuchau Song, Ghislain Riondet and Koen Mouthaan (National University of Singapore, Singapore)

A flexible and conformal antenna for 2.4 GHz applications, using a commercial off-the-shelf (COTS) room temperature vulcanized (RTV) silicone rubber substrate and flexible polyimide-printed circuit board (PCB) technology, is presented. Three different solutions for the ground plane are investigated. Antennas are tested on a flat surface and confirmed to a cylindrical well as well. The presented antennas greatly simplify the fabrication of high conformable and conformal antennas and the practical implementation of flexible antennas with minimal performance degradation and at a relatively low cost.
low frequency range. Simulated results show that the proposed antenna can achieve a 3-dB axial ratio bandwidth from 1.5 GHz to 20 GHz.

P3.016 Shared Aperture Dual-S- and X-band Antenna for Nano-Satellite Applications
Daniel E. Sper, Robin Williams, Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)
This paper presents the simulation performance of a dual-S- and X-band shared aperture antenna design. The antenna is 82 by 82 mm and it has a total height of less than 4 mm. This size allows the antenna to fit within the parameters of a nano-satellite unit structure. The antenna is right hand circularly polarized in both bands. The antenna is tuned to a S-band frequency range from 2.025 to 2.075 GHz and a X-band frequency range from 7.75 to 8.75 GHz. The design has a Realized right hand circularly polarized gain of more than 6 dB in the S-band and more than 12 dB in the X-band. The impedance bandwidth is very wide as it exceeds the selected frequency ranges. The cross-coupling is below -25 dB in the S-band and below -30 dB in the selected X-band frequency range.

P3.017 Low Attenuation Dichroic Sub-Reflector for Wide Incident Angles for Ka/Ku Band Satellite Antenna Systems: An ECA Analysis
Chung-Chin Jian, Yu-Lun Su, Thomas Lohey and Yu-Ling Lee (Atom Element Matter B. V., The Netherlands); Hsi-Sheng Goan (National Taiwan University, Taiwan)
In this paper, we conduct an equivalent circuit approach (ECA) analysis to investigate the incident angle tolerance for different frequency-selective-surface structures and arrangements in dichroic sub-reflectors (DSRs). We find a DSR with low-attenuation performance for a range of incident angles, capable of combining both Ku band TV and Ku band broadband interactive services with the LNB located beside the feedhorn of a one-arm satellite antenna dish.

P3.018 Roof/ Side Mount Combination Antenna for LTE and Satellite Communication Applications
Liu Guifeng (The 54th Research Institute of China Electronics Technology Group Corporation, China); Biao Du (JRA.T, China); Chuanfeng Xu (Joint Laboratory of Radio Astronomics Technology, China); Yingran He (The 54th Research Institute of CETC, China)
A roof/side mount combination antenna for Long Term Evolution (LTE) and satellite communication applications is presented. The proposed antenna includes 4G (The Fourth Generation Mobile Communication System) antenna and VHF (Very High Frequency) antenna. In order to realize a compact structure, some miniaturization and multiband techniques are employed, such as meandered structure, lumped element and multiple branch radiating elements. Finally, the paper in this author presents a compact volume of 360mm*95mm*34mm. The 4G antenna produces two wide bands which can cover GSM850, GSM900, DC1800, PCS1900, UMTS2100 and LTE2300/2300. The two bands yield by VHF antenna can cover 135-143MHz and 145-1498MHz. Besides, the two antennas in this paper are planar printed structures which can significantly reduce the cost.

P3.019 A Single-feed Compact Wideband Circularly Polarized Antenna for INMARSAT/GNSS Applications
Nasimuddin Aslam and Xuming Ong (Institute for Infocomm Research, Singapore)
A single-feed low profile compact wideband circularly polarized (CP) stacked antenna is proposed for INMARSAT/GNSS applications. The antenna consists of a ring-slot feeding patch with a grounded metallica, a slit-slotted parasitic patch, and a coaxial feeding probe. The wideband CP radiation is attributed to the stacked slotted/patched combination and ring-slot patched with grounded via. An antenna prototype at the C-band with an overall size of 0.388λ by 0.388λ by 0.006λ (λ is the free space wavelength at 1.518 GHz) shows a measured 3-dB axial ratio (AR) bandwidth of 9.8% (1.35 GHz to 1.67 GHz), impedance bandwidth (10-dB reflection coefficient) of 12.9% (1.479 GHz to 1.845 GHz), and gain greater than 5.3 dB across the whole bandwidth.

Posters-A12: Wearable and Implantable Antennas

P3.020 Graphene Printed Flexible and Conformal Array Antenna on Paper Substrate for 5.8GHz Wireless Communications
Xinyu Peng and Ting Lei (University of Manchester, United Kingdom (Great Britain)); Kewen Pan (University of Manchester, United Kingdom (Great Britain)); Mahmoud Abdellahman Abdalla (MTC, Cairo, Egypt); Zhuxu Hu (University of Manchester, United Kingdom (Great Britain))
In this paper, we present a compact circularly polarized (CP) antenna for wearable passive UHF RFID tags. The antenna is a square-shaped microstrip printed patch on paper substrate. The array achieves 73.7% total radiation efficiency and a peak gain value of 4.8 dBi at 5.8GHz, with a bandwidth range from 4.6GHz to 7.9GHz (58.8%). Over the operating frequency, the radiation of the antenna has been proved to be a typical radiation pattern of a patch antenna array.

P3.021 Circularly Polarized Corner-Truncated and Slotted Microstrip Patch Antenna on Textile Substrate for Wearable Passive UHF RFID Tags
Duc Viet Le (University of Tampere, Finland); Leena Ukkonen (Tampere University of Technology, Finland); Toni Bjorninen (Tampere University, Finland)
We present a compact circularly polarized CP antenna for wearable passive UHF RFID tags. The antenna is a square-shaped microstrip printed patch on paper substrate. The array achieves 73.7% total radiation efficiency and a peak gain value of 4.8 dBi at 5.8GHz, with a bandwidth range from 4.6GHz to 7.9GHz (58.8%). Over the operating frequency, the radiation of the antenna has been proved to be a typical radiation pattern of a patch antenna array.

P3.022 Antenna Packaging for In-body Applications
Jordi Romeu, Giselle Gonzalez Lopez and Sebastian Blanch Boris (Universitat Politècnica de Catalunya, Spain); Luis Joher (Universitat Politècnica de Catalunya, Spain)
A cylindrical-mode expansion of the fields produced by an embedded antenna is used to determine the dimensions of the antenna packaging in order to minimize antenna impedance changes when the antenna is immersed in a varying dielectric medium.

P3.023 A 915 MHz Wristwatch-Integrated Antenna for Wireless Health Monitoring
Sanjeev Kumar (Tyndall National Institute, University College Cork, Ireland); John Laurence Buckley (Tyndall National Institute & University College Cork, Ireland); John Barton (Tyndall National Institute, Ireland); Robert Newberry (Sanmina Corporation, USA); Gary Dunlop (Sanmina Corporation, Ireland); Matthew Rodencal (Sanmina Corporation, USA); Carlo Webster, Mélusine Pigeon and William G. Scanlon (Tyndall National Institute, Ireland); Brendan O’Flynn (Tyndall National Institute, Ireland)
A compact 915 MHz antenna integrated within an wristwatch wireless sensor device is presented. The antenna is a variant of a planar inverted F antenna (PIFA) and uses a diode-resistor configuration. The results of simulation and measurement are shown to be in good agreement with the antenna exhibiting desirable impedance and radiation characteristics together with low Specific Absorption Rate (SAR) performance. The antenna is fabricated using a low-cost flexible printed circuit and is fully integrated into the watch device. Measurements on the prototype antenna show a -10 dB impedance bandwidth of 30 MHz, a peak realized gain of 4.9 dBi and a peak radiation efficiency of 15.9 % at 915 MHz. The antenna also has a low specific absorption rate (SAR) value of 0.003 W/kg making it suitable for a wide range of wrist-worn wireless applications.

P3.024 E-Field Distribution in Ex-Vivo Porcine Skin Layer from a Subsurface UHF Transmitter
Noor Alabdin, Yana Salchak, David V Thiel and Hugo G Espinosa (Griffith University, Australia)
A tunable slotted antenna has been used for radio communications with internal transmitters/transmitters for in-vivo medical applications. The 2.45 GHz properties (permittivity and conductivity) shows that porcine skin tissue can be used as a substitute for human skin tissue in medical applications. In this study, a measure of the E-field distribution on the skin surface of human and porcine tissue is presented. Its in vivo measurements on boneless layered porcine belly fat (4cm thick 300cm2 x 150 mm sample of skin, fat and muscle) were compared with numerical modelling for a subcutaneous PIFA tuned antenna. The surface electric field distribution is quite well matched to an analytical formula over a -10 dB impedance bandwidth of 30 MHz, a peak realized gain of -4.9 dBi and a peak radiation efficiency of 15.9 % at 915 MHz. The antenna also has a low specific absorption rate (SAR) value of 0.003 W/kg making it suitable for a wide range of wrist-worn wireless applications.

P3.025 A Novel Wearable RF Head Coil for High Resolution 7T Magnetic Resonance Imaging
Pouya Goodarzi and Fatemeh Geran Gharkhali (Shahid Rajae Teacher Training University, Iran); Hamidreza Salehig Rad and Mohammad Reza Nazem Zadeh (Tehran University of Medical Sciences, Iran)
In this article, a new structure of 7T magnetic resonance imaging RF coil has been designed. The flexibility of this coil distinguishes it from others. The common array coil consists of 8 channels, each made of two antenna elements. The results show that compressed elements in designing this coil provides a desired recursive factor (isolation better than 35 dB), while coupling is kept less than 60 dB between non-adjacent elements. In this report, the structure coupling effects include mutual effects of coil elements, nusances, and phantom. The obtained results of the magnetic field homogeneity, bandwidth, and specific absorption rate are also evaluated. The results show that the bandwidth, the SAR for the 1w input power, and the S1^-1 homogeneity distribution are 1.1%, 0.07969 W/kg, and 84%, respectively. To present this coil for a brain imaging, elements miniaturization is done where the elements size has been decreased in design.

P3.026 Textile Antenna as Moisture Sensor
Davor Bonefačić (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)
The paper applies the realization of a resonant textile antenna as moisture sensor. Two setups are discussed, the first considering the textile antenna used in transmission and the second considering only the reflection at the antenna input. Laboratory tests have been performed on both setups, showing that the second, reflection-based approach, shows better sensitivity and accuracy for moisture measurement.
A beam steerable resonant cavity antenna (RCA) enabled by using tunable partially reflective surface (PRS) is proposed in this paper. Tunable PRS loaded with varactor diodes evolves from complementary frequency selective surface (CFSS) which consists of square loop patch and slot arrays. The reflection phase of PRS unit cell can be tuned by adjusting the biasing status of varactors, while the reflection magnitude keep a relative high value within a frequency band of interest, owing to the complementary behaviour of the CFSS. The reflection coefficients of PRS unit cells are independently controlled in rows so that a gradient phase distribution within the aperture can be achieved, leading to an 1D scannable directive beam. An implementation is demonstrated with simulated results, which exhibits maximum scan range of 13 degrees with a gain of 13.6 dB for a 24x24 antenna aperture size.

**Mechanically Circular Polarization Reconfigurable Antenna**

Jeon-Sheen Riew and Po-Kai Wang (National Changhua University of Education, Taiwan)

A concept of pattern-reconfigurable single-element antenna operating at 2.45 GHz is proposed in this paper. The antenna is designed for Internet of Things (IoT) applications. The resonant frequency of the antenna is 2.45 GHz, no matter what the feed is matched at frequency of operation. A simple yet effective method to compensate them has been proposed. Designed antenna is characterized by dielectric constant of 4.4, and a loss tangent of 0.02. A compact pattern reconfigurable antenna is proposed for IoT applications. The resonant frequency of the antenna is 2.45 GHz with a -10 dB impedance bandwidth of 9 MHz. The size of the antenna is 200x120 mm (Credit Card Size). Three pattern configurations are obtained from this design with peak gains above -1.98 dB, and radiation efficiency above 92.2%. Two patterns follow magnetic dipole patterns along the azimuthal plane with maximum peak gains directed to phi+120 degrees and phi+70 degrees, and one electrical dipole pattern along the elevation plane phi+120 degrees. Pattern reconfigurability is achieved using PIN diodes. The used substrate is FR4 with a dielectric constant of 4.4, and a loss tangent of 0.02.

**Miniaturization of ESPAR Antenna Using Low-Cost 3D Printing Process**

Mateusz Czelen (Gdansk University of Technology, Poland); Mateusz Rzymski (Gdansk University of Technology & WiCom Center of Excellence, Poland); Krzysztof Nika (Gdansk University of Technology, Poland); Lukasz Kulas (Gdansk University of Technology, Faculty of Electronics, Telecommunications and Informatics, Poland)

In this paper, the miniaturized electronically steerable parasitic array radiator (ESPAR) antenna is presented. The structure of the antenna consists of two back-to-back half-mode substrate-integrated cavities with switchable shortings at both radiation apertures. One of the cavities is fed by an SMA probe while the other cavity is excited by the coupling through an array. The reflection phase of PRS unit cell can be tuned by adjusting the biasing status of varactors, while the reflection magnitude keep a relative high value within a frequency band of interest, owing to the complementary behaviour of the CFSS. The reflection coefficients of PRS unit cells are independently controlled in rows so that a gradient phase distribution within the aperture can be achieved, leading to an 1D scannable directive beam. An implementation is demonstrated with simulated results, which exhibits maximum scan range of 13 degrees with a gain of 13.6 dB for a 24x24 antenna aperture size.

**A Novel Frequency Reconfigurable Yagi-Like MIMO Antenna System**

Syed Jahangir (United Arab Emirates University, United Arab Emirates); Nifagat Hussain (KFUPM, Saudi Arabia); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

A compact single-layer frequency reconfigurable Yagi-like multiple-input-multiple-output (MIMO) antenna system is presented based on slot excitation. The traditional omidirectional radiation pattern of a slit antenna is made directional by using a common complementary slot reflector (CSR) element. The total size of the CSR is 9.5x70 mm2. The proposed MIMO antenna system can cover the frequency bands from 2.3-4.5 GHz, with a minimum bandwidth of 200 MHz. The frequency reconfigurability is achieved using varactor diodes. The overall size of the proposed antenna system is 40100x75 mm2, making it suitable for compact wireless handheld devices. The antenna system satisfies Yagi as well as MIMO performance metrics.
This paper presents a tunable antenna with frequency reconfigurability caused by an external bias voltage. The antenna is composed of a patch with two stubs and commercial graphene nanoplatelets deposited in designated gaps between the antenna and the stubs. As the graphene nanoplatelets are biased with a dc voltage, their sheet resistance is varied causing a change in the reactance at the radiating edge of the patch antenna resulting in a variation of the resonant frequency. Even though commercial graphene nanoplatelets bearing higher sheet resistance are deployed yet the prototype is designed so as to provide comparable frequency shift to tunable antennas based on lab grown graphene flakes. Simulated values of return-lost are compared to measured values. The resulting shift in the frequency is 370 MHz at a frequency of 5GHz.

**Poster3-A14: Active and Integrated Antennas**

**Antennas**

**Room:** Exhibition Hall

**P3.038 Post-Manufacturing Calibration Procedure for Medium-Sized Silicon-Based Active Phased Arrays for mm-Wave Wireless Communications**

Antonius Johannes van den Biggelaar, Niels Vertegaal and Ulf Johannsen (Eindhoven University of Technology, The Netherlands); Marcel Geurts (NXP Semiconductors, The Netherlands); A. B. (Bart) Smolders (Eindhoven University of Technology, The Netherlands)

This paper presents a novel approach to post-manufacturing calibration that allows for an accurate tuning of the phase shifters in large phased arrays without the need for special test equipment. The method is validated through experiments on a 4x4 mm-wave phased array.

**P3.039 A Hybrid Beamforming-Based Transceiver with Antenna In Package for Millimeter-Wave Small Cell**

Ruiheng Zhang and Guangqi Yang (Shanghai University, China)

A millimeter-wave hybrid beamforming-based (HBF) transceiver design for small cell scenarios is presented. The design utilizes two-stage hybrid beamforming and a compact antenna in package (AiP) solution to achieve high isolation and low peak-to-average ratio (PAPR) for efficient power delivery. The prototype shows promising results in terms of radiation efficiency and PAPR reduction.

**P3.040 Frequency Reconfigurable Self-oscillating Active Integrated Antenna Using Metamaterial Resonators and Diode Switches**

Tzyh-kuang Ma, Huy Nam Chu and You-Juin Wang (National Taiwan University of Science and Technology, Taiwan)

A frequency reconfigurable self-oscillating active antenna (AOA) utilizing metamaterial resonators and diode switches is presented. The design enables dynamic control of the operating frequency, making it suitable for reconfigurable wireless communication systems.

**P3.041 A Compact and Broadband Four-Way Dual-Polarization Waveguide Power Divider for Antenna Arrays**

Charalampos Stoumpos (Thales Alenia Space & Heriot-Watt University, France); Jean Philippe Fraysse and Ségolène Tubau (Thales Alenia Space, France); George Gouyet (Heriot-Watt University, United Kingdom (Great Britain)); Ronan Sauleau (University of Rennes 1, France); Hervé Legay (Thales Alenia Space, France)

A compact and broadband four-way dual-polarization waveguide power divider is presented. The design is suitable for antenna arrays in wireless communication systems, providing high efficiency and wide bandwidth.

**P3.042 AMOLED In-Display Antennas**

Sengle Foo (Huawei Technologies Canada, Canada)

This paper presents a novel concept of in-display antennas, which is integrated with AMOLED displays and enables efficient radio frequency (RF) signal transmission. The design is validated through simulations and experiments.

**P3.043 Transmit and Receive Module with a Fully-Digital Interface**

Yasuyuki Wada, Koji Fujita, Yoshinori Koji, Masashi Ikawa and Tomohide Mizuno (Toshiba Infrastructure Systems & Solutions Corporation & Komukai Complex, Japan); Masahiro Tanabe (Toshiba Infrastructure Systems & Solutions Corporation, Japan)

A fully-digital transmit and receive module is presented, enabling efficient wireless communication with minimal distortion and interference.

**Poster3-A15: RFID Antennas/Sensors and Systems**

**Antennas**

**Room:** Exhibition Hall

**P3.044 Concept of Beam Steerable Transponder Based on Load Modulation**

Tauseef Ahmad Siddiqui (School of Electrical Engineering, Aalto University, Finland); Prabhat Khanal (Chalmers University of Technology, Sweden); Jani Holopainen (Aalto University School of Electrical Engineering, Finland); Ville Vikari (Aalto University School of Electrical Engineering, Finland)

The concept of beam steering transponder based on load modulation is proposed to enhance the received power of backscattered communication devices. The transponder consists of antenna array elements of equal length operating at the Wi-Fi frequency band of 2.4 GHz. By properly weighting the modulated signal in each port, the received power can be maximized in a particular direction depending on the direction of arrival (DoA) of the signal. This method improves the system's capacity and spectral efficiency.

**P3.045 High PAPR Multi-Tone Waveforms as a Method of Boosting DC Voltage in RF Wireless Power Transfer Systems**

Kynakos Neophytou and Marco A. Antoniades (University of Cyprus, Cyprus)

A DC voltage boosting technique in radio frequency (RF) wireless power transfer (WPT) systems is proposed. The technique utilizes high PAPR multi-tone waveforms. It is demonstrated that increased efficiencies and DC voltages can be achieved for conventional single- and multi-stage rectifiers. First, the use of multi-stage rectifiers in wireless power transfer is investigated and it is shown that at low input powers the implementation of a large number of stages can reduce the efficiency dramatically. Then, high PAPR waveforms are presented as an alternative method to multi-stage rectifiers that can increase the DC output voltage without decreasing the efficiency as low input powers. Finally, it is shown that by incorporating high PAPR waveforms with multi-stage rectifiers can increase the required number of rectifier stages, and hence increase the rectifier efficiency at extremely low input powers.

**P3.046 A UHF RFID Reader Antenna with Tunable Axial Ratio and Fixed Beamwidth**

Rui Chen and Shuang Yang (University of Cambridge, United Kingdom (Great Britain)); Akef M Nefedov (Cambridge University, United Kingdom (Great Britain)); Ian White (University of Cambridge, United Kingdom (Great Britain)); Richard Penty (Cambridge University, United Kingdom (Great Britain)); Michael J Crisp (University of Cambridge, United Kingdom (Great Britain))

A novel ultra-high-frequency (UHF) RFID reader antenna is presented. The antenna has a unique property as being able to change its axial ratio (AR) without affecting its gain, beamwidth or impedance matching performance, making it suitable for use in different environments.
P3.047 On Complex Radar Cross Section and Backscatter Modulation Efficiency in RFID Systems
Christoph Deegen (Hochschule Niederer Berliner der Ingenieurswissenschaften, Germany); Patrick Bosselmann (Bochum University of Applied Sciences, Germany)
The objective of this paper is to provide a thorough complex-valued treatment of different aspects in backscatter modulation. Such modulation is a key aspect in radio-frequency identification (RFID) communication. The main point in this paper is the introduction of a complex radar cross section which describes amplitude and phase effects of any reflecting object but especially of RFID tag antennas. Thus, the efficiency of backscatter modulation is derived based on switching between different complex radar cross section values. Finally, the modulation efficiency is illustrated in an example scenario with a tag antenna placed in front of a metallic plate.

P3.048 Modified Yagi-Uda Reader Antenna for UHF RFID Smart-Glove
Rajesh K Singh, Andrea Michel and Paolo Nipa (University of Pisa, Italy); Alfredo Salvatore (Sensor ID, Italy)
This paper introduces a modified Yagi-Uda antenna with the capability of focusing field in a particular direction. The antenna comprises of a rectangular shaped driven element with one parasitic element. Parasitic element is used as a director to focus the field in a particular direction. The antenna is analyzed using full-wave electromagnetic (EM) simulation. A prototype is developed by using copper cladding on the structure. Results show that the proposed antenna is capable of focusing the field in a particular direction. A good agreement between measured and simulated results in terms of input impedance matching and field distribution is obtained. The read range of 30 cm in front direction and 10 cm in rear direction is achieved with the transmitted power of 400 mW. The presented antenna is compact in size and it is suitable to be integrated into a UHF RFID Smart Glove.

P3.049 Reduced Size RFID Reader Antenna Based on Reconfigurable Feeding Network Realized with Artificial Transmission Lines
Enrico Tolin (Politecnico di Torino, Italy) & IMST GmbH, Germany); Achim Bahr and Simona Bruhn (IMST GmbH, Germany); Francesca Vipiana (Politecnico di Torino, Italy)
In this paper, a compact and low-cost solution for a frequency and polarization reconfigurable UHF RFID reader antenna is presented. The proposed reconfigurable concept is applied to a reduced size square patch antenna with 60 mm side length, mounted on an electrically small ground plane with dimensions 95 mm x 15 mm. This compact design can be easily integrated in standard RFID applications. Circuits and EM simulation have shown promising results. Being a compact and low-cost solution, the frequency and polarization reconfigurable feeding network is an alternative to standard aperture tuning and circular polarized antenna RFID reader antenna designs.

P3.050 An Enhanced Road Vehicle Positioning Method Using Roadside UHF Reader with Frequency Identity Tags and the EPC Gen2 Standard
Zhan Wang and Robert Michael Edwards (Loughborough University, United Kingdom (Great Britain))
In this paper, a new method for augmenting current self-localization methods for autonomous based on Global Navigation Systems (GNSS) and LiDAR is introduced as a backup system for primary purpose. The method uses Radio Frequency Identity Tags (RFID) running under a modified EPC Gen2 Standard. Simulated results are presented for a representative 5.5km circular track around Loughborough, UK town centre with a 9.11 items inventory of roadside furniture. The virtual test track as input for an RFID tag simulator that uses an interrogator/inventory protocol. The technique is shown to be a good candidate for improving safety in Autonomous Vehicles and position finding in general.

P3.051 A Passive RFID Tag for Biomass Tracking
Amjad Ali, Roderick Mackenzie, Edward Lester, Oliver Williams and Steve Greedy (University of Nottingham, United Kingdom (Great Britain))
This paper presents the design for a low cost miniaturized chipless RFID tag for short-range biomass tracking and monitoring purposes. The concentric hexagonal geometry and angular stability, leading to higher data capacity are the novel aspects of the proposed design, which can encode four data bits within a compact size of 1 cm radius. The designed tag is capable of encoding 2m unique IDs in a 4 x 4 R2 frequency band, whereas in the case of embedded tags. The angular stability makes this tag readable from any angle in biomass. Moreover, this chipless RFID tag has no hazard as compared to battery-based active tags during biomass combustion processes.

P3.052 A Compact Printed Wideband Circularly Polarized Slot Antenna for Universal UHF Reader
Nathapat Suppenysthikul, Nonapchat Tewaratthukon, Phanuphon Boonthamchaik and Manas Ratanasuttanakul (Civil Aviation Training Center of Thailand, Thailand)
A compact circularly polarized (CP) slot antenna is proposed in this research, which has a wideband operation bandwidth for universal ultrahigh frequency (UHF) identification (RFID) reader applications. This antenna is fed by a coplanar waveguide (CPW) with an L-shaped feeding line for achieving impedance matching over bandwidth and wideband CP feeding can be obtained by two rectangular-shaped stubs on the square slot of the ground plane. The measured 10-dB reflection coefficient (return loss) bandwidth is 760 MHz (625-1410 MHz, 87.7% centered at 900 MHz). The measured 3-dB axial ratio (AR) bandwidth is about 445 MHz (795-1240 MHz, 49.44% centered at 900 MHz). The maximum measured gain of the antenna about 3.7 dBi. The dimension of the proposed antenna is 120x120x1.6 mm3.

P3.053 Single-Chip Impulse-Radar Integrated Circuits for Microwave-Imaging
Takamori Kikkaawa (Hiroshima University, Japan); Akito Taya (Kure National College of Technology, Japan); Hiroshi Masui (Hiroshima Institute of Technology, Japan); Hiroyuki Ito (Tokyo Institute of Technology, Japan); Takeshi Hino (Tokyo City University, Japan); Mitsutoshi Sugawara (Hiroshima Institute of Technology, Japan); Tomoaki Maeda, Masahiro Ono, Yoshitaka Murasaka, Toshifumi Iimura and Atsushi Iwata (A-Tech Corporation, Japan); Toshiyuki Matsumura and Michimasa Yamaguchi (Siohecye Corporation, Japan)
In order to develop a portable multi-static radar system for microwave imaging, a single chip impulse radar large scale integrated circuit (IC) is developed by 65-nm complementary metal oxide semiconductor (CMOS) technology. Total area and power consumption are 1.7 mm x 0.74 mm and 90 mW, respectively. Gaussian mono-cycle pulses (GMP) having the pulse width of 250 ps and the repetition period of 10 ns are transmitted and received via ultrabroadband (UWB) bowtie patch antennas with the size of 5 mm x 20 mm. Received signals are sampled by the effective time sampling with 9.77 ps shifting clock and converted to digital data by 8-bit successive approximation register to analog converter (SAB-AOD).

P3.054 A 2.18 GHz Semi-Omnidirectional Antenna
Giskhan Ucuncu and Mustafa Kologlu (Aselsan Inc., Turkey)
A semi-omnidirectional antenna which operates in 2.18 GHz frequency band. A semi-omnidirectional antenna is a modified biconical antenna having a "blind" sector (i.e. a sector where gain is suppressed) and has H-plane beamswidths about 180 degrees or more. One sample antenna is designed, manufactured and measured. For more than 90 percent of the band, the antenna has about 10 dB gain suppression in the blind sector. Gain of the antenna is measured to be minimum -2.21 dB and higher than -0.5 dB for frequencies higher than 3.5 GHz. E-plane beamswidth of the antenna is greater than 15 degrees in the entire 2.18 GHz frequency range.

P3.055 Pulsed 2D Electromagnetic Field Propagation in a Rectangular Waveguide
Martin Stump (Ismo University of Technology, Czech Republic); Joan E. Lager (Delft University of Technology, The Netherlands); Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)
Closed-form space-time expressions are derived for the two-dimensional electromagnetic (EM) field propagating in a rectangular waveguide. The pulsed EM field inside the waveguide is achieved by an electric line current source applied across the rectangular cross section. This field is written as a superposition of time-domain (TD) constituents denoted as generalized rays, propagating along the waveguide via multiple reflections against its conducting walls. Illustrative numerical examples are presented. The thus constructed propagating field is compared against results available in literature, demonstrating the effectiveness and accuracy of the generalized rays approach.

P3.056 Time-Domain Reflectometry for Measuring Scattering Parameters: Comparison of M-sequence Device and Step-generator TDR
Shekoufeh Abdollahi and Somayeh Chamaani (K.N. Toosi University of Technology, Iran); Jürgen Sachs (Femeta University of Technology, Germany)
Scattering parameters of microwave networks and antennas could be measured in time domain to lower the measurement cost and time. Although time-domain data may include some errors and inaccuracies, they can be compensated by proper measurement procedures and processing. In this study, we examined a comparative method for two measurement methods for scattering parameters: time-domain reflectometry and maximum length sequence (M-sequence) sensor. The resulted scattering parameters are compared with frequency domain results measured by a vector network analyzer (VNA). Both measurements are in agreement with the frequency domain results, however, considering the effect of random errors in two devices, maximum length sequence should be a accurate measurement results according to its higher signal-to-noise ratio. Index Time-domain reflectometry, scattering parameters, antenna measurements, microwave network measurements, maximum length sequence.

P3.057 A Novel Approach for Compact Antenna with Parasitic Elements Aimed at Ultra-Wideband Applications
Sudeep Baudha (BITS PILANI K K BIRLA GOA Campus, India); Manish Varun Yadav (BITS PILANI K K BIRLA GOA Campus & BITS PILANI, India); Isha Srivastava (BITS PILANI K K BIRLA GOA CAMPUS, India)
A novel approach for compact antenna with parasitic elements is proposed and investigated for wideband electromagnetic applications. The proposed structure consists of multiple rectangular parasitic elements etched on flame retardant (FR-4) substrate with 50Ω feed line. Return loss (magnitude of S11 < -10 dB) and the simulated bandwidth of the structure is 3.0 GHz to 12.9 GHz with the fractional bandwidth of 124%. The overall volume of the structure has a compact size of 141*91*1.5 mm3 and has a maximum gain and maximum radiation efficiency of 2 dB and 75% respectively. Measured and simulated Co-pol and Cross-pol are in relatively good agreement with the selected operating frequencies. The proposed antenna’s properties make it suitable for UWB frequency range which includes 3.5-5.5 GHz (WMAXA), 5.2-5.8 GHz (WLANA), 8.12 GHz (X-band). The results of this work are validated with respect to various parameters in the wireless communication field.

P3.058 Low Profile Absorber Backed Extremely Wideband Antennas
Umar Naeem (Centre for Wireless Innovation, ECT Institute, Queen’s University Belfast, United Kingdom (Great Britain)); Vincent Fusco (Queen’s University Belfast, United Kingdom (Great Britain)); Dmitry E Zelenchuk (Queen’s University of Belfast, United Kingdom (Great Britain));
Poster A20: Antennas for Wireless Power Transmission and Harvesting

**Antennas**

**Room:** Exhibition Hall

**P3.059 Waveform Optimization for Efficiency Improvement of Traditional RF-to-dc Rectifiers Without Input Matching Network**

Alessandro Calcaterra (McGill University, Canada); Christian Canestri and Domenico Gaetano (Friedrich-Alexander University, Germany); Pietro Bia (Institute of Microwaves and Photonics, Germany); Gerald Gold (FAU Erlangen-Nürnberg, Germany); Yixiong Zhao (Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS, Germany); Konstantin Lomakin and Mark Sippel (Friedrich-Alexander University, Germany); Christian Canestri and Domenico Gaetano (Friedrich-Alexander University, Germany); and Esteban Menargues (SWISSto12, Switzerland)

This paper presents a waveform optimization, based on pulse-modulated signal, for efficiency improvement of three traditional rectifiers: series, shunt and voltage doubler rectifiers. The circuits do not contain input matching networks. The measurement results show that the optimization of the pulse waveforms, by varying the duty cycle, makes it possible to compensate for the decrease in efficiency due to the absence of a matching circuit and also to the load resistance that deviates from its optimum value. In this work, the effort of design and optimization is reported on the waveform. At 20 dBm input power level, the efficiency of RF pulse signal on un-optimized series- and voltage doublers is 58% higher than that of 1 time signal applied on optimized rectifier. Meanwhile, at different loads, the efficiency of RF pulse can be 3 times higher than 1 time signal. Similar results are obtained with shunt-mounted diode and voltage doubler rectifiers.

**P3.060 Impact of Multisine and RF Pulse Signals on the Efficiency of Different Rectifier Topologies for WPT**

Alessandro Calcaterra (McGill University, Canada); Christian Canestri and Domenico Gaetano (Friedrich-Alexander University, Germany); Pietro Bia (Institute of Microwaves and Photonics, Germany); Gerald Gold (FAU Erlangen-Nürnberg, Germany); Yixiong Zhao (Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS, Germany); Konstantin Lomakin and Mark Sippel (Friedrich-Alexander University, Germany); Christian Canestri and Domenico Gaetano (Friedrich-Alexander University, Germany); and Esteban Menargues (SWISSto12, Switzerland)

This paper presents the impact of Power Optimized Waveforms (POW) such as RF Pulse and Multisine Signals (MS) on the efficiency of several rectifiers with different topologies such as voltage doubler, shunt and series, with and without input matching networks. The aim consists to demonstrate that instead of optimizing accurately the rectifiers, one can compensate the performance by optimizing the waveform. In this study, a comparison is made between optimized and non-optimized rectifiers, supplied by CW (Continuous Waves) and POW, respectively. The optimized circuits contain input matching networks. Measurement results show that the efficiency of multisine signals increases with respect to the number of subcarriers. Also, the performances of non-optimized rectifiers supplied by multisine signals becomes comparable and close to those of optimized rectifiers supplied with CW. RF pulse signal gives the highest output dc voltage over the frequency band of interest for duty cycle values less than 15%.

**P3.061 A Dual-Port, Dual-Polarized and Wideband Slot Rectenna for Ambient RF Energy Harvesting**

Sæger S Alja'afreh (Nanjing University of Aeronautics and Astronautics, China); Lei Xing (Nanjing University of Aeronautics and Astronautics, United Kingdom (Great Britain)); Gerd vom Bögel (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany); and Robert Cahill (Queens University Belfast, United Kingdom (Great Britain))

This paper presents a new way to design and manufacture promising low profile and ultra-wideband absorbers for microwave applications. Square patches with a total thickness of 13.5mm (0.5 centre wavelength) are printed on substrate using double layers with different relative permittivity. Two dielectric materials with different relative permittivity are used to achieve 93% absorptivity over an ultra-wideband from 3.5 to 18.5 GHz (fractional bandwidth of 1.36). The structure offers a good tradeoff between size, absorptivity and bandwidth.

**P3.062 3D Printed Helix Antenna for 77 GHz**

Konstantin Lomakin and Mark Sippel (Friedrich-Alexander University, Germany); Ingrid Ullmann (Friedrich-Alexander University, Germany); and Christian Canestri and Domenico Gaetano (Friedrich-Alexander University, Germany)

This paper deals with the design and optimization of a 3D-printed helical antenna for the automotive 77 GHz band. A novel feed concept is proposed including a transition from the helix coil to an E-plane waveguide, which allows for tuning of antenna matching. Measurements suggest a 5.5dB bandwidth of 75% for S11 < -10 dB and 10 dB bandwidth of 51% for S11 < -10 dB respectively with a fractional bandwidth of 20%. An axial ratio below AR < 5 dB is achieved within the entire 75% bandwidth and even AR < 3 dB within 51% bandwidth in main lobe direction. The used technology is Digital Metal Laser Sintering (DMLS) technique. The radiating element is a stack of 22 pairs of layers made of metal and dielectric substrates. TwoCoplanar Waveguide (CPW) monopole antennas have been designed for the 2.4 GHz band and fabricated using dispensor metal laser sintering and printed photolithography. The impedance bandwidth and gain of both antennas have been compared and the printed prototype was found to match the performance of the etched antenna within a 2.6% and 2.3% margin respectively, as well as matching the full-wave 3D simulation of the connectorized antenna. The designed layout provides mechanical stability to the antenna through optimized printed microstrip line and matching network. The design has been validated through simulations (using different solvers) and measurements.

**P3.063 Direct-Write Dispenser Printing for Rapid Antenna Prototyping on Thin Flexible Substrates**

Mahmoud Waghi (University of Southampton, United Kingdom (Great Britain))

A rapid prototyping of antennas is crucial to validation of simulation models. A novel technique to design and fabricate conformal antennas on unusual substrates such as polymer and textiles is proposed. This paper presents direct-write dispenser printing, using a commercial Printed Circuit Board (PCB) printer, as a simple means of prototyping planar antennas on ultra-thin (25 μm) flexible Polyimide substrates. Two Coplanar Waveguide (CPW) monopole antennas have been designed for the 2.4 GHz band and fabricated using dispenser metal laser sintering and printed photolithography. The impedance bandwidth and gain of both antennas have been compared and the printed prototype was found to match the performance of the etched antenna within a 2.6% and 2.3% margin respectively, as well as matching the full-wave 3D simulation of the connectorized antennas. Based on the measured performance of the printed antennas, the potential of utilizing commercial dispenser printers to prototype and manufacture low-volume antennas for low-cost unobtrusive Internet of Things applications is demonstrated.

**P3.064 Self-Sustained Biconical Antenna Realized in Additive Manufacturing Technology**

Alessandro Calcaterra, Domenico Gaetano, Christian Canestri, Pietro Bia and Cosmo Mitranio (Elettronica Group)

This paper describes the design, process and manufacturing processes of a self-sustained vertically polarized biconical antenna for ultra-wideband (UWB) applications. The proposed antenna has been designed for Additive Manufacturing (AM) fabrication to reduce the total weight, simplify the assembly operations and facilitate the installation on the platform. In particular, it has been produced via Direct Metal Laser Sintering (DMLS) technique. The radiating element works from 1 GHz to 4 GHz with good impedance matching, high total efficiency and omnidirectional patterns on the azimuth plane (elevation = 0 deg.). The designed layout provides mechanical stability to the antenna through optimized printed microstrip line and matching network.

**P3.065 Ultra-broadband Multilayer Microwave Absorber by Multiplanar 3D Printing**

Thi Quyen Van Hoang and Brigitte Losseaux (Thales Research & Technology, France)

In this paper, an additively manufactured helix antenna for a center frequency of 10 ~ 77 GHz is presented. A novel feed concept is proposed including a transition from the helix coil to an E-plane waveguide which allows for tuning of antenna matching. Measurements suggest a 15.5 dB bandwidth of 90% at S11 < -8 dB and 10 dB bandwidth of 99.1% for S11 < -10 dB respectively with a fractional bandwidth of 20%. An axial ratio below AR < 5 dB is achieved within the entire 90% bandwidth and even AR < 3 dB within 51% bandwidth in main lobe direction. The direct signal at input power level, the efficiency of RF pulse signal on un-optimized series- and voltage doublers is 58% higher than that of 1 time signal applied on optimized rectifier. Meanwhile, at different loads, the efficiency of RF pulse can be 3 times higher than 1 time signal. Similar results are obtained with shunt-mounted diode and voltage doubler rectifiers.

**P3.066 Temperature Characterization of High-Q Resonators of Different Materials for mm-Wave Indoor Localization Tag Landmarks**

Esteban Menargues (SWISSto12, Switzerland); Bertrand Ramond (University of Liege, Belgium); and Thierry Leclercq (Technical University of Eindhoven, The Netherlands)

This paper deals with the design and optimization of a 3D-printed microwave absorber, covering the C-band, X-band and Ku-band, has been proposed and investigated. The innovative nature of this absorber is based on the combination of multi-layer structure and material 3D printing technology. The designed unit cell is a stack of 22 layers made of metal and dielectric materials with different relative permittivity. A novel feed concept is proposed including a transition from the helix coil to an E-plane waveguide, which allows for tuning of antenna matching. Measurements suggest a 15.5dB bandwidth of 90% at S11 < -8 dB and 10 dB bandwidth of 99.1% for S11 < -10 dB respectively with a fractional bandwidth of 20%. An axial ratio below AR < 5 dB is achieved within the entire 90% bandwidth and even AR < 3 dB within 51% bandwidth in main lobe direction. The designed layout provides mechanical stability to the antenna through optimized printed microstrip line and matching network.

**P3.067 A Conformal Spherical DRA for MEO Applications in Ka-band Realized with Additive Manufacturing**

Valero Panaro (Airbus Italia S.p.A., Italy); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Esteban Menargues (SWISSto12, Switzerland); Alfredo Catalani (European Space Agency – ESTEC, Noordwijk, The Netherlands)

This paper presents a new way to design and manufacture promising low profile and ultra-wideband absorbers for microwave applications. A conformal antenna is considered to validate the simulation models. A novel feed concept is proposed including a transition from the helix coil to an E-plane waveguide, which allows for tuning of antenna matching. Measurements suggest a 15.5 dB bandwidth of 90% at S11 < -8 dB and 10 dB bandwidth of 99.1% for S11 < -10 dB respectively with a fractional bandwidth of 20%. An axial ratio below AR < 5 dB is achieved within the entire 90% bandwidth and even AR < 3 dB within 51% bandwidth in main lobe direction. The designed layout provides mechanical stability to the antenna through optimized printed microstrip line and matching network.
P3.068 Simulation of Effective Medium Theory for Additive Manufacturing of Dielectric Media

Gregory A Mitchell (Army Research Laboratory, USA); Quang Nguyen (United States CDCC Army Research Laboratory, USA); Theodore K Anthony (US Army Research Laboratory, USA)

We compare the Maxwell-Garnett effective medium theory to a full wave simulation utilizing the Nicolson-Ross-Weir method to predict effective permittivity in a representative additively manufactured medium. Three-dimensional anisotropy in the medium highlights differences between the two methods, and we discuss potential causes and solutions to the observed discrepancies.

Post3-A23: Other Antenna Topics

Antennas

Room: Exhibition Hall

P3.069 A Differential-Fed Dual-Polarized High-Gain Filtering Antenna Based on SIW Technology for 5G Applications

Yasec Ismael Abdulkareem Al-Yase (University of Bradford, United Kingdom (Great Britain)); Naser Ghassemi Parchin (University of Bradford, United Kingdom (Great Britain)); Mohamad Fares (University of Basra, Iraq); Ahmed Maan Abdulkareem (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Mustafa Bakir (University of Leeds, United Kingdom (Great Britain)); Mohamed Al-Radooon (Richmond Road, Bradford, BD7 1DP, United Kingdom (Great Britain) & University of Bradford, Iraq); Majal Koshia and Raed A Abd-Alhameed (University of Bradford, United Kingdom (Great Britain))

A new differential-fed wideband dual-polarized microstrip filtering antenna exhibiting high gain, and high common-mode rejection is presented in this paper. The presented antenna is composed of a square patch radiator mounted on a substrate integrated waveguide (SIW) cavity. The structure is excited by two differential pairs of feeding probes providing differentially exciting signals. The filtering response is achieved by introducing symmetrical defected ground structures (DGS) in the ground layer surrounding the four excitation ports for dual-polarized antenna. The DGS is optimized to introduce nulls at the high and low edges of the passband transmission maintaining high gain and wide bandwidth. The scanning bandwidth of antenna is achieved for the frequency band of 16-19.5 GHz with 40° in both E and H-plane. The Fourier technique is used in the aperture of antenna to synthesize the dual-beam pattern. Moreover, good performance is obtained with wide bandwidth of 11%, realized gain of 8-8 dB at the resonant frequency (3.5 GHz) and low cross-polarization level due to the differentially driven ports, and complete symmetry using SIW technology.

P3.070 Eco-Friendly Metamaterial Antenna for 2.4 GHz WLAN Applications

Georgina Serres (Federal University of Campina Grande, Brazil); Raimundo Freire (Universidade Federal de Campina Grande - PB, Brazil); Samuel Morais, Camila Caroline Rodrigues de Albuquerque and Jéssica Araujo (Federal University of Campina Grande, Brazil); Alexandre Serres and Laura de Carvalho (UFCD, Brazil); Joaobson Noqueira de Carvalho (Instituto Federal de Educação, Ciência e Tecnologia da Paraíba, IPFB, Brazil)

In this paper, a dual beam vertically polarized metasurface antenna with broad bandwidth and high polarization purity is presented. The rectangular patch antenna is composed of two copper tape layers, one as the radiating element and the other as the modified ground plane with Complementary Split Ring Resonators (CSRR). The substrate that separates these two layers is a mixture of polystyrene adipate-co-terephthalate (PAT) and polyethylene terephthalate (PET) polymers, both biodegradable. The electrical characteristics of the mixture were performed using the probe method and the antenna simulations were performed using the commercial software ANSYS Electronics Desktop. Convergent results were obtained with simulated and measured prototypes, with a measured resonant frequency in 2.4 GHz and bandwidth of 360 MHz, simulated gain of 4.01 dB and half power beam width of 48.2°, which shows great potential for WLAN applications.

P3.071 Antenna Phase Center and Angular Dispersion Estimation Using Planar Acquisition Setup Applied to Microwave Breast Imaging

Joao M. Felicio (Instituto de Telecomunicações, Portugal); Jose Biocas (Instituto de Telecomunicações, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandez (Instituto de Telecomunicaciones, Instituto Superior Tecnico, Portugal)

We propose a "near field phase center" estimation technique based on planar acquisition setup. It requires a single antenna and an electrically small object to serve as target. The technique allows to estimate the phase center spatial coordinates, as well as its angular dispersion. This data is useful in microwave imaging applications where the antenna operate in near-field regime, such as medical applications (e.g. breast and head imaging). We demonstrate that for a commonly used Vivaldi antenna operating in the 2.5 GHz band, the angular dispersion of the phase center can be as high as 50 mm. Moreover, we show that incorporating this data in the signal processing algorithms improves the imaging results, by applying it to microwave breast imaging. We believe this type of antenna-characterization techniques will leverage the use of more informative imaging algorithms (e.g. truncated singular value decomposition), since they increase the accuracy of the distance calculations, thus improving the signal to noise ratio.

P3.072 Holographic Antenna Using Slotted Hologram Patterns for High Efficiency

Sang Hyuck Han, Seongin Park and Young Joong Yoon (Yonsei University, Korea (South))

This paper proposes the holographic antenna using slotted hologram patterns for high efficiency at 24 GHz. The 4 slotted quasi-Yagi antennas are arrayed as a surface-wave launcher. The proposed antenna using the slotted patterns provides the higher gain at the broadside direction and more compact size than conventional holographic antennas with metal line patterns. The proposed antenna has the maximum gain of 15.8 dBi at broadside direction and the aperture efficiency is 30.65%, which is higher than 9.25% compared to the conventional antenna.

P3.073 A Bird-Cage Coil for MRI Studies of Unsaturated Granular Materials

Sina Marhshe (Laboratoire Navier (UMR 8205 CNRS, IFSTTAR, Ecole des Ponts ParisTech, France); Hakim Tahkedem (Paris-Est Marne-la-Vallée University, France); Patrick Poulihet (ESIEE, France); Marjorie Grzeszkiew (ISAE Supaero, France); Abdoulaye Fall (Université Paris-Est, France)

Magnetic Resonance Imaging (MRI) is a powerful and non-invasive technique that can be used to reveal useful information about a material’s structural properties. In the present work, we propose a novel MRI coil, the so-called "bird-cage" coil, for the study of unsaturated granular materials. This coil geometry is chosen because it allows for the excitation of a homogeneous magnetic field at a specific frequency in the region of interest. The bird-cage coil design is optimized to achieve high signal-to-noise ratio. In this work, we demonstrate the potential of this new coil design for MRI studies of unsaturated granular materials.

Post3-E08: Metamaterials, Metasurfaces and EBG

Electromagnetics

Room: Exhibition Hall

P3.074 Miniaturization of Base-station Antenna Element Using Non-uniform Meta-surface

Yuwei Gao and Hailiang Zhu (Northwestern Polytechnical University, China); Jialiang Bai (National Key Laboratory of Test Physics and Numerical Mathematics, China); Pei Zheng (National Key Laboratory of Science and Technology on Test Physics and Numerical Mathematics, China); Gao Wei (Northwestern Polytechnical University, China)

This work reports a novel WRD® dual-polarized base-station antenna element with small aperture and low profile utilizing non-uniform meta-surface. The whole size of the antenna element is 119.9*119.9*27mm3 (0.328*0.328*0.109), making it competitive in terms of miniaturization. The antenna exhibits bandwidth from 0.69 to 0.96 GHz, which covers the lower operating band of base station. Simulated results show that the minimum reflection and high isolation are achieved over the operating frequency band.

P3.075 Mechanically Tunable MMT-EBG-based Bandstop Filter

Jacob A Brown and Ashwin K. Iyer (University of Alberta, Canada)

Tunable filters are increasingly popular components in telecommunication systems as they are flexible and adaptable to changing conditions. A tunable bandstop filter based on the recently proposed metamaterial-based electromagnetic bandgap (MTM-EBG) is demonstrated here that relies on a single mechanically tuned element. This structure, without any tuning mechanism attached, has a simulated 10 dB transmission absolute bandwidth (ARBW) of 225 MHz centered at 14.18 GHz. It is then made tunable by placing a dielectric plate on the surface of the MTM-EBG and varying the position of the plate, this changes the reactive loading and subsequently shifts the response. Using a plate of RO3003, a tuning range from 3.43 to 4.05 GHz with a 13.6% variation in ARBW is demonstrated in simulation.

P3.076 Wideband Vertically Polarized Dual-Beam Antenna Using Modulated Metasurfaces

Ali Mohammad Hakimi, Homayoon Oraizi, Ali Keivan and Arash Alamin (Iran University of Science and Technology, Iran)

In this paper, a dual beam vertically polarized metamaterial antenna with broad bandwidth and high polarization purity is designed. Its aim is to improve the antenna polarization all over the visible region. Furthermore, by implementing a surface-wave reflector and removing the destructive effects of backward modes, the operational bandwidth of antenna is significantly improved. The scanning bandwidth of antenna is achieved for the frequency band of 16-19.5 GHz with suitable levels of cross-polarization. Also, the gain of two distinct beams are approximately equal all over the operational bandwidth. The Fourier technique is used in the aperture of antenna to synthesize the dual-beam pattern. Moreover, there is a good agreement between this method and the full wave simulations.
Snoek’s law is a well-known theory used to describe the relationship between ferromagnetic resonant frequency, \( f_{res} \), and permittivity \( \varepsilon_r \) for ferromagnetic materials. It is given by the equation:

\[
\frac{1}{f_{res}^2} = \frac{1}{f_0^2} + \frac{1}{f_m^2}
\]

where \( f_0 \) is the bulk magnetic resonance frequency and \( f_m \) is the high-frequency magnetic resonance frequency. This relationship is particularly relevant in the design of microwave components like resonators and filters.

Recently, Rogers Corporation introduced magneto-dielectric material with permeability and permittivity that are responsible for dynamically controlling the reflection magnitude and phase. An equivalent circuit model for these materials uses lumped-element controls. It is shown that an arbitrary combination of reflection amplitude and phase can be achieved by an equivalent circuit model.

Studies (RIMMS) & National University of Sciences and Technology (NUST), Pakistan

A broadband flattened parabolic antenna based on a metasurface reflector that operates in right-handed circular polarization was designed by Chao Gu. The designed metasurface is composed of two layers of square patches printed on a grounded low loss substrate. The antenna is designed to operate in the Ku-band (15 GHz to 20 GHz) for 5G applications, covering both the sub 6 GHz and millimeter-wave frequency ranges. A stopband suppression of more than 25 dB has been achieved.

In order to physically design the structure, each resonator is connected to neighboring resonators using four symmetrical metallic vias. In this way, perfect matching is achieved over a wide frequency range, which is a good candidate for the design of broadband metasurfaces.

A highly efficient multifunctional metasurface for C- and X-band applications was designed by Ahmed F. Abdelshafy. The designed metasurface is composed of two layers of perfect magnetic conductors (PMC) that are used to achieve the perfect matching of the structure. The performance of the designed metasurface is further demonstrated by successfully guiding the energy from one layer to another. The design shows that the proposed metasurface is able to achieve a high-performance C- and X-band application.

A hybrid SSPPs-EBG filter with glide symmetry for 5G applications was designed by Marzieh SalarRahimi. The filter has been designed for 5G applications, covering both the sub 6 GHz and millimeter-wave frequency ranges. A stopband suppression of more than 25 dB has been achieved.

A degenerate band edge (DBE) is a special fourth order degenerate point in a dispersion diagram, where four eigenmodes coalesce to a single degenerate eigenmode. It leads to field enhancement of the Bloch mode and to high quality factors, which are useful for high-impedance and ultra-sensitive sensors. The air-filled substrate integrated waveguide (ASIW) is a novel form of SIW which is low-cost and low-loss. We propose a design of an ASIW supporting a degenerate band edge (DBE). We show the occurrence of the so-called “polariton resonance” associated to the DBE and we study how losses influence the DBE.

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P3.090: Fano Resonance Based Multiple Angle Retrodirective Metasurface
Mohammed Kalaagi, III (Univrsite Lille 1 & The French Institute of Science and Technology for Transport, Spatial Planning, Development and Networks, France); Divtha Seetharamadoo (IISTTAR, LEOST & Univ Lille Nord de France, France)

In this paper, a Fano resonance based multi-angle retrodirective metasurface is introduced. The aim is to investigate the potential of Fano-resonating structures, to suppress the losses and complexity of metasurface designs with high super-cell periodicities. A dolmen structure is given in this case which is shown known for its Fano-resonating characteristics. It consisted two sub-radiant modes and one super-radiant mode. The design is given followed by the generalized phase two of reflection and surface impedance modulation for higher efficiency. The super-cell design has been given with a periodicity of 5.7λ, and frequency of 24 GHz. This is to achieve numerous retroreflectors at different incident angles based on Floopet harmonic analysis. On the other hand, by exciting the super-radiant mode/retroreflectivity has been achieved at three incident angles during the coupling between the individual elements of the Fano-resonating structure. The monostatic RCS has been calculated to determine the performance of the retrodirective metasurface.

P3.091: Generation of Multi-Mode OAM Waves Through 1-Bit Direct-Radiating Programmable Metasurfaces
Xudong Bai (Shanghai Aerospace Electronics Co., Ltd, China)

A direct radiating programmable metasurfaces is presented for generating multi-mode OAM beams. The proposed direct-radiating metasurfaces is composed of 1-bit electronically reconfigurable units, which are integrated with PIN diodes in the radiation layer for current inversion. Compared with the traditional transmitted or reflective metasurfaces, the receiver feeder is therefore integrated into the functional structure of the metasurfaces for a lower profile.

P3.092: 1-Bit Digital Coding Metasurfaces for Efficient Generation of Convergent Multi-Mode OAM Beams
Fanwei Kong, Yuntao Sun and Xudong Bai (Shanghai Aerospace Electronics Co., Ltd, China)

A reconfigurable 1-bit digital coding metasurfaces are presented for generating convergent multi-mode OAM beams. The designed metasurfaces consist of 1-bit phase modulation by introducing a PIN diode to change the unit resonant property. By digitally controlling the coding distribution on the metasurfaces, the convergent multi-mode-OAM beams can be generated.

P3.093: Flangeless Waveguide Connection Based on Gap Waveguide Technology
Wanzhu Cui (China Academy of Space Technology Xi’an, China); Xiang Chen (Xi’an Jiaotong University & China Academy of Space Technology Xi’an, China); Dongquan Sun (Xidian University, China); Yongning He (Xi’an Jiaotong University, China)

To reduce the size of traditional waveguide flanges, a solution of plugable flangeless waveguide connection is proposed. Artificial magnetic conductor (AMC) structure is designed surrounding the outer surface of a size-reduced end of a waveguide, called part A. Another waveguide with stepped transition to an enlarged end part B, the inner surface of the enlarged and works as a PEC surface. When Part-A is inserted into part B, a flangeless waveguide connection is achieved under proper size conditions. Tiny air gap exists between the PEC and AMC surface, the electromagnetic leakage from the air gap is prevented by band gap of the AMC structure formed by PEC and AMC surface. A X-band prototype of the flangeless connection is designed and manufactured, the measured insertion loss and return loss are better than 0.08dB and 20dB respectively over 10.5GHz to 15GHz. The sectional size decreases by more than 75% compared with traditional waveguide flanges.

P3.094: Robustness in Subwavelength Locally-Resonant Metamaterial Waveguides
Bakhityar Orazbayev (IEEPL & The Laboratory of Wave Engineering, Switzerland); Nodige Kaina and Roman Fleury (IEEPL, Switzerland)

Guiding electromagnetic energy at a subwavelength scale is one of the most highly demanded functionalities in a variety of applications, including compact, lightweight satellite communications, signal and data processing, and power systems. The existing schemes for subwavelength waveguiding, including topological designs, are usually based on the use of locally resonant metamaterials and generally sensitive to the lattice imperfections and disorders induced backscattering. Theoretically, we have the robustness of subwavelength-edge modes in different angle configurations, including designs based on CS symmetry or valley Hall (1+1) topological insulators (TI) and non-topological designs based on chirality or a frequency dependent line. The statistical results demonstrate that all waveguiding schemes provide a similar level of robustness, the edge modes for different disorder and super robustness of V1 and chiral metamaterial waveguides to all three types of disorder.

P3.095: Scattering-free Energy Flow in Open Cavities Bounded by Metasurfaces
Angela Vio Spolenac (Université de Montréal; Rome, Italy); Davide Ramaccia (Romula, University Rome Italy); Alessandro Toscano (University Rome Tre (IT), Italy); Filiberto Blotto (University Roma Tre, Italy)

The storage of energetic transverse magnetic (TM) modes in a TM01 cavity, whose impervious walls don’t allow energy leakage in the form of electromagnetic radiation. Recently, the interest in open or partially-open cavities able to absorb and store the energy carried by an external illuminating field has stimulated research efforts in the exploitation of open cavities exhibiting anomalous scattering properties. In this contribution, we investigate the scattering properties of a partially-open cavity, bounded on one side by an infinite reflector and on the other by a infinite metasurface. We show that for a specific illumination signal, the cavity may operate in its virtual absorption state, exhibiting neither reflection nor transmission. Being the system lossless, the impinging energy is totally stored in the cavity between the metatic reflector and the metasurface. The proposed structure, which can be easily implemented, may enable the design of lossless systems with dynamic energy properties.

P3.096: Preliminary Investigation of B-dot Wire Concept
Boris Okorn (Rudjer Boskovic Institute, Croatia); Andrej Sayanski, Vladimir Lenets and Stanislaw Gibyskow (TU Vienna, Russia); Silvio Harub (University of Zagreb, Croatia)

In recent years the metasurface concept of B-dot wire (a structure that guides the electric displacement current in subwavelength channels in zero permittivity media) has been investigated. A dual concept of B-dot wire (consisting of an subwavelength air channel located in mu-near-zero material) has been analyzed numerically and quasi-magnetostatic propagation with an infinite wavelength is observed. Finally, an experimental RF replica of a B-dot wire, based on split-ring-resonators, is proposed.

P3.097: Ultra thin Zigzag Half-Wave Plate Metasurface with Near-Unity Axial Ratio and High Transmission Efficiency in Terahertz Range
Alexia Moreno-Peñafiel (Public University of Navarre & Institute of Smart Cities (ISC), Public University of Navarra, Spain); Sergei A. Kuznetsov (IEEE Member & Novosibirsk State University, Novosibirsk, Russia); Miguel Benueo (Universitat Publica de Navarre, Spain)

In this work, a transmission half-wave plate based on a bi-layered zigzag metasurface operating in the THz band is presented. The half-wave plate thickness is only 100 μm, less than 1/20 at the operation frequency and achieves an amplitude transmission efficiency around 92% and a cross polarization discrimination of 40 dB, ensuring almost perfect circular polarization conversion.

P3.098: Phase-Gradient Metasurfaces for Efficient Conversion of Surface Wave to Propagating Wave
Rui Feng (Xidian University, China); Badreddine Ratni (Univ Paris Nanterre, France); Jianjia Yi (Key Laboratory of Integrated Services Networks, Xidian University, China); Alexandre Pichere (Airbus Defence and Space, France); Andre de Lustrac (Institut d’Electronique Fondamentale - Université Paris Sud, France); Hai Lin Zhang (Xi’an Jiaotong University, China); Shah Nawaz Burokur (LEME, France)

Transmission of light through subwavelength apertures surrounded by periodic structures has attracted extensive research interests since the last two decades. In this work, we propose a method to achieve directional transmission of electromagnetic waves diffracted by a subwavelength aperture using phase-gradient metasurfaces instead of grating structures. Near-field distributions from both numerical simulations and experimental measurements are presented to validate the concept. The extraordinary transmission is further maintained over a non-negligible frequency band ranging from 9 GHz to 12 GHz by modulating the phase profile of the metasurface through electronically controlled varactor diodes inserted in the constituting unit cells of the metasurfaces.

P3.099: Tunable Terahertz Polarization Converter Based on Graphene Metasurfaces
Behzad Bakhtiar and Homayoun Oraizi (Iran University of Science and Technology, Iran)

In this paper, a tunable Polarization Converter is proposed based on Graphene Metasurfaces in the Terahertz band. It provides a wideband polarization conversion from 6.44 to 8.53 THz with fractional bandwidth of 38% and a polarization conversion ratio (PCR) of more than 0.97. In this designed structure not only can the maximum response be controlled by localizing the plasmon resonance through altering the geometrical dimensions of its shape but also it can be changed through the deposited characteristics in a tunable frequency response regardless of the geometric parameters.

Poster-M307: Satellite and Aerospace Antenna Characterisation

Measurements
Room: Exhibition Hall

P3.100: Impact of Lightning Diverter Strips on Antenna Radiation Patterns
Ana Vukovic, Phillip Sewell and Trevor Benson (University of Nottingham, United Kingdom (Great Britain)); Chris Jones and Simeon Earl (BAE SYSTEMS, United Kingdom (Great Britain))

This paper investigates the impact of lightning segmented diverts on antenna performance. A fully coupled electromagnetic model is considered, where the antenna is enclosed by a realistic realistic radome profile on which segmented diverters strips are placed. The geometric model of a radome with lightning diverter strips is generated by using a computer graphics method for seamlessly morphing two surfaces together. The antenna performance is characterised by both the S11 parameter and the far-field profile.

P3.101: Proposal of GNSS Satellite Antenna Performance Evaluation Based on Reconstructed Gain Patterns
Gerardo Allende-Alba (German Aerospace Center, Germany); Steffen Thoeriot (German Aerospace Center (DLR), Germany)

The evaluation of available power at user location is an important task as part of a navigation signal quality verification. This is particularly important for safety critical applications using signals from the Global Navigation Satellite Systems (GNSS). Due to a variety of factors, the performance of GNSS satellite antennas may exhibit a non-normal performance. Efforts to characterize gain patterns of such antennas have been conducted in the past using complex observation setups. In this contribution, GNSS antenna gain patterns are reconstructed using observations from a simple measurement setup. Reconstructed patterns have been used for a characterization of performance of GNSS satellite antennas. The results may prove to be useful for safety critical and domain-specific applications, such as GNSS reflectometry.

P3.102 Deployable Helix Antennas for Nano and Micro Satellites
Tao Huang, Juan Revese, Daniel Nascimento and Vinhoo Gusumany (Oxford Space Systems, United Kingdom (Great Britain)); Benedetta Fiorelli (European Space Agency, The Netherlands)

This paper presents three different deployable helix antennas developed in Oxford Space Systems for VHF/UHF telecommunications in Nano and Micro satellites. The helix antennas are of trihedral format, driven by a feed Balun and require no ground plane. Both directive high gain beam and isotropic wide beam can be achieved to meet specific mission requirements. The antenna structures are different in response to different storage and deployment requirements. The design goal however is the same – to yield high storage efficiency to fit into Nano and Micro satellite platforms and to provide high stiffness when the antenna is fully deployed.

P3.103 Simple and Robust Probes for Near-Field Antenna Measurements at Low SDR Bands
Vincent Laguerre, Gwenn Le Fu, Daniel Red’Iv, Lisa Feat and Romain Cornetres (CNES, France)

This paper presents a simple and robust design of ideal-linear polarized U/F antennas, based on the magnetoelectric dipole concept, for near-field measurements. Two specific probes have been designed and manufactured in order to cover the 350-750 MHz frequency bands. Measurements are currently in progress and only few preliminary results are discussed.

Poster-M309: MIMO and OTA Testing

Measurements
Room: Exhibition Hall

P3.104 Impact of Probe Coupling on Emulation Accuracy in Massive MIMO OTA Testing
Huling Pei and Xiaoming Chen (Xi’an Jiaotong University, China); Wei Xue (Xi’an Jiaotong University, China); Ming Zhang (Xi’an Jiaotong University, China); Tommy Svensson (Chalmers University of Technology, Sweden)

The sectored multi-probe anechoic chamber (MPAC) setup has been proposed in the literature for OTA testing of Massive MIMO base stations (BSs). However, the previous studies assume ideal isotropic probes, i.e., the radiation patterns and mutual coupling among the probe antennas have not been considered. In this paper, the impact of the mutual coupling of realistic probes on the simulation accuracy of two popular channel emulation methods, i.e., pre-failed signal simulation (PFS) method and plane wave synthesis (PWS) method in the sectored MPAC system is investigated. Our results show that the PWS method is more robust to mutual coupling than the PFS method.

P3.105 Recent Developments in Radiated Two-Stage MIMO OTA Test Method
Ya-Jing (Keysight Technologies, China); Thorsten Hertel (Keysight Technologies (China) Co., Ltd., China); Penghui Shen (General Test Systems, China); Yang Liu (GTS, China)

This paper discusses recent developments with RTS MIMO OTA test method. It first introduces the concept of the two-stage method which is based on a first stage of antenna parameter measurement followed by a second stage of throughput measurements using a downlink signals from the communication analyzer that incorporate a convolution of the device’s antenna patterns with the desired spatial channel model. The resulting signal is applied to the DUT through the radiated connection, which has the equivalent wireless cable effect. The RTS method was approved by 3GPP in Technical Report 37.977 and is considered harmonized with the Multi Probe Anechoic Chamber (MPAC) methodology. This paper will review recent RTS advancements in 5G NR and 5GSA, including 4x4 MIMO OTA test on LTE devices, analysis of CTA RTS MPAC SNR controlled harmonization test results, and the variable Reference Measurement Channel (VMC) MIMO OTA test for SNR controlled and UE noise limited environments.

P3.106 On the Use of Radiated Power for 5G Mobile Device with Spectrum Analyzer
Jun Luo, Edwin Mendivil and Michael Christopher (ETS Lindgren, Germany)

A novel procedure to measure the radiated power of 5G mobile devices in an anechoic chamber (AC) with the spectrum analyzer is presented. In contrast to the traditional method, it can provide a more accurate spectrum emission measurement as well as measurement uncertainty (MU) and presents the proper spectrum flatness information of the device. This paper also discusses the key test parameters, such as resolution bandwidth (RBW), video bandwidth (VBW), sweep-time, and detector type for 5G mobile devices radiated power measurements with spectrum analyzers.

P3.107 Measurement of OFDM Signals with PAPR Reduction in the Presence of Hardware Impairments
Hua Wang (Keysight Technologies, Denmark); Xiaoming Chen (Xi’an Jiaotong University, China); Jiaxing Zhang (EM-Testing, China)

Orthogonal frequency-division multiplexing (OFDM) has been selected as a 5G New Radio (NR) waveform for carrier frequency below 6 GHz. In order to satisfy the low peak-to-average power ratio (PAPR) requirement for high power amplifier (PA) efficiency, OFDM with PAPR reduction is highly desirable. In this paper, we evaluate the performance of OFDM with various receiver agnostic PAPR reduction techniques in the presence of hardware impairments. The evaluations are performed in hardware-in-the-loop trials. The measurement results showed that in case of nonlinear PA and high power transmission, OFDM with PAPR reduction schemes can effectively reduce the PAPR of OFDM signals and can achieve similar performance as compared to DFT spread OFDM. Thus OFDM with simple PAPR reduction is a viable option for 5G NR waveform.

P3.108 Field Emulator for Wireless Communication Devices Based on Programmable Metasurface
Bowen Hao, Peng Hao and Zhiping Li (Beihang University, China)

Space-time-coding metasurface provides a better method for dynamic control of electromagnetic waves. We think it can improve the test systems that are used to require multiple probes in different directions. In this paper, we propose an emulator based on programmable metasurface to solve the measurement problems in wireless communication system. It can dynamically emulate the field of receiving equipment at a specific location in complex communication environment. The hologram and corresponding quantization technique are used to complete the calculation of the metasurface. We also describe the implementation and analyze the feasibility of our emulator.

Poster-M310: General Antenna Measurements

Measurements
Room: Exhibition Hall

P3.109 Beam Optimization for 28 GHz Phased Array Utilizing Measurement Data
Mikk Leino, Jan Bergmann and Juha Ala-Laurinaho (Aalto University, Finland); Ville Vikari (Aalto University & School of Electrical Engineering, Finland)

This paper presents beam optimization methods for a phased array operating at 28 GHz. The phase of each antenna element is controlled by the desired spatial channel model. The resulting signal is applied to the DUT through the radiated connection, which has the equivalent wireless cable effect. The optimization increases the measured gain compared to the nominal case by 1.3 dB at broadside. Furthermore, the element amplitude variation allows optimization for the lower side lobes to be done by finding the correctly weighted amplitudes. Taylor distribution is used for this optimization and the side-lobe level decreases 2.4 dB for the broadside beam.

P3.110 Numerical Study of Chebyshev RF Absorber Arrangements Versus Tilted RF Absorber Pyramids
Vince Rodriguez (NIST-MI Technologies, LLC & University of Mississippi, USA)

Driven by economics, it is common to repurpose existing indoor antenna ranges for different applications such as hardware-in-loop (HIL) testing of systems. If the range was originally intended to have a centered line-of-sight, using it for a different use may create reflected paths with high angles of incidence onto the lateral walls. These reflected paths can have angles of incidence into the absorber that are very large and cause the absorber to perform poorly. Two different approaches are possible to improve the range performance. One of them is to use a Chebyshev approach. The second approach is to tilt the absorber blocks to change the angle of incidence to the incoming wave. In this paper numerical methods are used to study the difference between the two approaches to see their advantages and disadvantages.

P3.111 Robot-based Calibration of Multi-GNSS Receiver Antennas Using Real Satellite Signals
Johannes Kröger, Yannick Breva, Tobias Kersten and Steffen Schön (Leibniz Universität Hannover, Germany)

Precise positioning and navigation based on GNSS signals require knowledge about the exact location where the signal is measured at the receiving antenna. The reception point varies with the direction of the incoming waveform of the individual satellite. These variations can reach up to decimeter level for carrier-phase measurements. Correction files, so-called phase center corrections (PCC), are determined either by anechoic chamber measurements or calibrations in the field. Currently, for geostationary antennas only PCC for GPS and GLONASS L1 and L2 frequencies are publicly available from the IGS. In this contribution, we present calibration results for these missing GNSS and frequencies obtained from field calibration with a robot using real GNSS signals and a method newly developed at the Institut für Erdmessung. The estimated PCC show an overall good repeatability (RMS<2 mm) for different GNSS receiver antennas which are frequently used in the global IGS tracking network.

107 of 128
**P3.112 SSEEM - An Innovative Spread Spectrum System for SatCom Antenna Radiation Patterns Measurements**

Marco Andreacci (MBI, Italy); Riccardo Andreotti (MBI Srl, Italy); Claudia Casali, Michele Gammone and Leonardo Nanna (M.B.I., Italy); Alessandro Le Perla, Fritz Schurig and Daniele V. Finocchiaro (Eutelsat S.A., France)

This paper describes an innovative system, named SSEEM, for co-polar and cross-polar pattern measurements of earth station antennas. The SSEEM system is based on highly spread spectrum waveforms and, due to its high processing gain (PG), is able to overcome the limitations of the conventional approach used by satellite operators, based on transmitting a high-power continuous wave (CW). Indeed, the SSEEM system can operate in very low corner-to-noise-plus-interference ratio regions (around -35 dB for 72 MHz bandwidth). Consequently, it does not cause interference on adjacent satellites nor with a signal present within the satellite transponder used for the measurement. This means such tests can be carried out in any moment, without the need for a free satellite slot for transmission. In addition, the high PG allows for resolving even far side lobes of the antenna radiation patterns, without increasing transmission power, as in the CW case.

**P3.113 LS & C Band Medium Gain Ridge Horn Intercomparison Campaign Results**

Maria Alberica Saporetti and Lars Foged (Microwave Vision Italy, Italy); Antonis A. Alexandridis (NCSR Demokritos, Greece); Isabel Expósito (University of Vigo, Spain); Cosme Culotta-Lopez (RWTH Aachen University, Germany); Bengt Svensson (Saab AB, Sweden); Ana Arboreya (Universidad Rey Juan Carlos, Spain); Martin Böttcher (IMST GmbH, Germany); Manuel Sierra-Castaher (Universitat Politècnica de Madrid, Spain)

The measurements working group of the European Association on Antennas and Propagation (EuAAP), promotes cooperation to advance research and development of antenna measurements. An on-going task of this group is to support inter-comparisons of measurement facilities. The different campaigns also serve as input for a new task, recently approved in WOS, about self-evaluation from inter-comparison results. The LS & C bands medium gain ridge horn (MMRH) has been selected as reference antenna for an EuAAP ACE campaign. In order to enhance the correlation in different facilities, the MVR-D003 has been equipped with an absorber plate and employed in a new extensive comparison campaign. In this paper, we described the activities and showed preliminary results. Result of the comparison is reported in terms of gain, directivity, equivalent noise level, Barge ratio and Exocone considering the uncertainty declared by each facility.

**P3.114 Electric Field Analysis and Measurement for a Resistively Loaded Monocone**

Jiang Tingyong (EPFL, Switzerland); Wang Xiaojia (Northwest Institute of Nuclear Technology, China); Zhou Heng (Northwest Institute of Nuclear Technology, Switzerland)

A novel resistively loaded monocone was proposed to extend the application for electric field calibration. Electric field analysis and measurement was carried out to verify the design of a proposed monocone. As revealed by the results, the S11 of the monocone feed was reduced from near 0 dB to below -17 dB in the low frequency. The measured electric wavefront was also consistent with the excited wavefront after loading. The electric field uniformity was improved by resistive loading, and the maximum variation of electric field was reduced to 1.3 dB from DC to 500 MHz at the given line, which suggest an enhancement when compared to the unloaded monocone. The analysis and measurement results demonstrated a possible potential for electromagnetic field calibration both in time and frequency domain in the future.

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**Thursday, 19 March 14:50 - 15:30**

**IS-Thu 1/1: Invited Speaker Session**

**14:50 Antenna Measurements and Signal Processing Techniques**

Fernando Las-Heras and Yuri Alvarez-Lopez (University of Oviedo, Spain); Jaime Lavarda (Universidad de Oviedo, Spain); Ana Arboreya (Universidad Rey Juan Carlos, Spain); Maria Garcia Fernández and Guillermo Alvarez Narciandi (University of Oviedo, Spain)

Several recent advances for in situ antenna measurements are reviewed in this contribution. This kind of measurements are challenging as they usually require the use of phaseless techniques and non-rigid acquisition grids. Thus, the main techniques for phaseless measurements as well as their last advances are firstly reviewed. Next, two novel systems for in situ measurements are described. The first one is based on the use of Unmanned Aerial Vehicles to characterize outdoor antennas at remote places. The second one consists of a freehand portable system to characterize mm-wave antennas at accessible locations.

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**14:50 Channel Modeling at Sub-millimeter Wave and Terahertz Frequencies for Wireless Chip-to-Chip Communications**

Aleksa Zajo (Georgia Institute of Technology, USA)

To enable future THz wireless communication between chips in a system and between boards/blades in a rack-mounted system typical for base stations, and between boards in a data center environment (with raised floors, rows of racks, cooling ducts, etc.), Note that these propagation environments significantly differ from typical wireless channels because there might be significant propagation losses due to signal interaction with metal and plastic parts of the packaging as well as from air circulation inside the packaging/data center. This paper summarizes the latest findings from 300 GHz measurements for computer motherboard and data center environments and reviews proposed channel models for these environments.

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**15:00 Propagation**

Chair: George Tsonos (University of Peloponese, Greece)

**15:00 Channel Modeling at Sub-millimeter Wave and Terahertz Frequencies for Wireless Chip-to-Chip Communications**

Aleksa Zajo (Georgia Institute of Technology, USA)

To enable future THz wireless communication between chips in a system and between boards/blades in a rack-mounted system typical for base stations, and between boards in a data center environment (with raised floors, rows of racks, cooling ducts, etc.). Note that these propagation environments significantly differ from typical wireless channels because there might be significant propagation losses due to signal interaction with metal and plastic parts of the packaging as well as from air circulation inside the packaging/data center. This paper summarizes the latest findings from 300 GHz measurements for computer motherboard and data center environments and reviews proposed channel models for these environments.

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**Thursday, 19 March 15:30 - 16:10**

**IS-Thu 2/1: Invited Speaker Session**

**14:50 Channel Modeling at Sub-millimeter Wave and Terahertz Frequencies for Wireless Chip-to-Chip Communications**

Aleksa Zajo (Georgia Institute of Technology, USA)

To enable future THz wireless communication between chips in a system and between boards/blades in a rack-mounted system typical for base stations, and between boards in a data center environment (with raised floors, rows of racks, cooling ducts, etc.). Note that these propagation environments significantly differ from typical wireless channels because there might be significant propagation losses due to signal interaction with metal and plastic parts of the packaging as well as from air circulation inside the packaging/data center. This paper summarizes the latest findings from 300 GHz measurements for computer motherboard and data center environments and reviews proposed channel models for these environments.

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**Thursday, 19 March 15:30 - 16:10**

**IS-Thu 2/1: Invited Speaker Session**

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On the Design of Bulk Absorbers at THz Frequencies

Iñigo Liberal (Public University of Navarre, Spain); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)

In this paper and presentation, we will focus on different aspects of backscattering-based wireless communication and power transfer to small biomedical implants. We will present three different antenna topologies for data and power transfer through tissue, in vitro and in vivo studies on implantable intracranial pressure (ICP) sensors and give insight and analysis on wireless link reliability in tissue environment. We will also present radio frequency identification (RFID)-based implant platform and communication method. Moreover, we will focus on differences and challenges of in vivo environment compared to laboratory phantoms and tissue models. In our studies, different types of implantable antennas have been tested to investigate reliability, accuracy and sensitivity of the brain implants: a hybrid near-field far-field system with a piezoelectric sensor for ICP monitoring, a UHF band split-ring resonator system and LC tank based miniature implantable antenna.

Electromagnetic Modeling for Nanoscale Quantum Optics: Beyond the Lego-Brick Picture

Said Mikli (University of New Haven, USA)

We provide a very broad outline for a new research area within the domain for Future Antennas, namely quantum antenna (q-antenna) theory and their applications to building secure digital communication lines. The proposed quantum antenna theory purports to presenting a natural extension of RF antennas in classical wireless to the now established field of quantum communications. The paper provides a bird's eye view on the subject, highlighting the main themes and the expected results and benefits of such research domain.

Nonperturbative Dynamics of Quantum Antennas

Iñigo Liberal (Public University of Navarre, Spain); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)

Andrea Neto, Ralph van Schelven and Paolo Sbrana (Delft University of Technology, The Netherlands)

Since plasmonic structures at deep-nanometer scale cannot be fully handled by classical electromagnetics, a semiclassical hydrodynamic model has been introduced. The hydrodynamic model essentially describes the motion of the free electron gas in nonlocal metals by imposing additional boundary conditions (ABC). In this work, the hard wall hydrodynamic model with the Sauter ABC is employed, to characterize the optical features of a spherical nanoparticle. The studied hydrodynamic model provides multiple natural frequencies and wave response of the structure. It is shown that the studied hydrodynamic model provides multiple natural frequencies and natural modes. The natural frequencies are in excellent agreement with extinction resonances.
16:40 Directive Beam Radiation by a Fresnel Zone Plate Integrated Partially Reflective Surface for Millimeter-wave Applications
Qing-Yi Guo, Quan Wei Lin and Hang Wong (City University of Hong Kong, Hong Kong)

This paper introduces a high gain Fabry Perot cavity (FPC) antenna for millimeter-wave applications. By employing a Fresnel Zone Plate (FZP) integrated partially reflective surface (PRS), a 4 dB gain enhancement is realized. The proposed antenna consists of an SIW based feeding source, a quasi-circular reflector and the proposed FZP integrated PRS. All parts of the proposed antenna can be implemented by low-cost and mature printed-circuit-board (PCB) technology, which is convenient in circuit integration. For validation, a prototype of 60 GHz FPC antenna is designed and measured. It yields a measured impedance bandwidth of 17.8% and a 3-dB gain bandwidth of 13.3%. The measured peak gain is 31 dB at broadside direction. The proposed antenna finds potential applications in 5G communications.

17:00 Polarization Reconfiguration of a Millimeter-Waves Antenna Using the Optical Control of Phase Change Materials
Jehison Leon-Valdes and Laure Hutenma (Xlim Laboratory, France); Eric Amaud (University of Limoges, France); Damien Pasaarieux (University of Limoges, France); Aurelian Crunteanu (Xlim, CNRS/ University of Limoges, France)

We present the integration of Germanium Telluride (GeTe), a phase change material (PCM), within a conventional patch antenna. The patch is excited by a microstrip line. The phase changes between the insulating (OFF) and metallic (ON) states of GeTe are controlled using short ultraviolet (UV) laser pulses. That allows the reconfiguration of the device between a linear polarization (LP), a left hand circular polarization (LHCP) and a right hand circular polarization (RHCP). Measured results of the fabricated antenna show total efficiencies up to 75% for the circular polarization (CP) and a 3 dB bandwidth of axial ratio (AR) over 350 MHz around 29.5 GHz.

17:20 Implementation Methods for Planar Wide-Angle Scanning Phased Array
Xiao Ding and Ren Wang (University of Electronic Science and Technology of China, China); You-Feng Cheng (Southwest Jiaotong University, China); Yan-He Lu, Wei Shao and Bing-Zhong Wang (University of Electronic Science and Technology of China, China)

Wide-angle scanning phased arrays are hotspots and difficulties in the research field of phased arrays in recent years. Since 2015, Computational Electromagnetic Laboratory (CEMLAB) at University of Electronic Science and Technology of China (UESTC) has carried out related research work, and proposed a theoretical and experimental scheme to break the bottleneck of the limitation of phased array scanning angles by using the pattern reconﬁgurable technique. In this paper, the CEMLAB conducted in-depth research and gradually developed theoretical methods based on the electromagnetic mirror principle, surface wave assisted method, magnetic current source technique or time reversal (TR) adaptive optimization method to realize planar phased arrays with wide-angle scanning performance. At last, the development trend of wide-angle scanning phased arrays is predicted in the conclusions.

17:40 Wideband Fixed- And Scanned-Beam Millimeter Wave Antenna Arrays for 5G Applications
Donia Oueslati (ICTEAM Institute, Université Catholique de Louvain, Belgium); Raj Mittra (Penn State University, USA); You-Feng Cheng (Southwest Jiaotong University, China); Yan-He Lu, Wei Shao and Bing-Zhong Wang (University of Electronic Science and Technology of China, China)

This paper presents the design of millimeter wave (mm-Wave) antenna arrays with beam-scanning capabilities and potential-use for 5G applications. We begin with a fixed-beam low-profile antenna array, which has a wide bandwidth and high gain in the millimeter-wave (mm-wave) band, and then go on to add the beam-scanning feature to the array. The proposed antenna covers most of the Ka-band, has a bandwidth of 13 GHz and exhibits a maximum gain of approximately 25 dB for the array dimension investigated, which exhibits good aperture efﬁciency. Next, the array is modiﬁed by using a beam scanning technique, which enables it to carry out a 2D beam scan at a ﬁxed frequency, without using conventional phase shifters that are lossy as well as costly at mm waves. The issue of circular polarization (CP) is also investigated and CP is achieved by adding transverse radiating elements to the aperture array.

18:00 Fully Dielectric Phased Array for Beamsteering Using Liquid Crystal Technology at W-Band
Ersin Polat and Roland Reese (Technische Universität Darmstadt, Germany); Henning Tesmer (TU Darmstadt, Germany); Matthias Nickel (Technische Universität Darmstadt, Germany); Rolf Jakoby (Institute for Microwave Engineering and Photonics, Technische Universität Darmstadt, Germany); Holger Maune (Technische Universität Darmstadt, Germany)

In this work, we present a liquid crystal based fully dielectric phased array for beamsteering at W-Band. The array consists of 1 x 4 rod antennas including liquid crystal phase shifters and a single multimode interference power divider. With this approach, a fully dielectric approach is possible allowing a very lightweight, compact and low-loss design. Each rectangular phase shifter has a tapered dielectric rod antenna at its end. For beamsteering, dielectric subwavelength phase shifters are filled with a novel liquid crystal mixture. The realized demonstrator achieved a maximum steering range of ±15°. Moreover, the measured antenna gain is ranging between 13dB to 14dB with a side lobe level below -4dB. The input reﬂection coefﬁcient is below -10dB over the whole W-band.
16:40 Dual Polarized Dual Band Collocated Beam Switching Antennas for WLAN Applications
Haleh Bostanabad (Huawei Technologies, Canada); Faeys Hysaie (Huawei Technologies Co. Ltd., Canada); Matthew Milvyinsky (Huawei Technologies, Canada); Teyan Chen (Huawei Technologies CO. Ltd, China); Tao Wu (Huawei Technologies Co., Ltd, China)
Future Access Points (APs) for Wireless Local Area Network (WLAN) systems require more streams to enhance channel capacity by using Multiple Inputs Multiple Outputs (MIMO) techniques. Furthermore, antennas with reconfigurable patterns can increase significantly the communication throughput. It is a great challenge to integrate more reconfigurable antennas elements into a limited space. We propose a technique for designing four collocated antennas in order to achieve dual bands and dual polarizations with reconfigurable patterns by using a small area. Using the proposed concept, it is possible to increase the number of streams up to 16 within the same size for conventional antenna arrays in Wireless Fidelity (Wi-Fi) APs. Experimental results will be presented and discussed during the conference.

17:00 Adapted Low-Footprint Blasing Circuit for Switched Beam Antenna Steering Usable in Wireless Sensor Networks
Aurélien Surier and Muamila Mukananda Lengthong (Université du Québec en Abitibi-Témiscamingue, Canada); Nadir Hakem (Université du Québec en Abitibi-Témiscamingue & LRTCS Research Laboratory Télébec in Underground Communications, Canada); Michel Misson (Université de Clermont Auvergne, France)
Wireless Sensors Networks are of great interest for their flexible deployment and low cost in many applications. Switched Beam Antennas can help to achieve a usable transmission range in higher frequency bands like 2.4 GHz. The switching facility may need to add a control circuitry to address adequately the antenna beam direction. In this work, we present the integration of a steering functionality with the design of a blasing circuit to be deployed on a dipole antenna usually used by IEEE 802.15.4 standards sensors. We then compare the new configurable antenna with the former static Switched Beam Antenna design. The simulated antenna with the redesigned cells features results with a high directivity of 10.9 dB and a 32° beam aperture that can be steered to cover 360° in azimuth plane.

17:20 Wideband Dual-polarized Antenna for Wi-Fi Communication Networks
Oleg Soykin, Alexey Artemenko, Vladimir Sasin, Artem Kolobov and Roman Maslenikov (Radio Gigabit LLC, Russia)
The paper describes a wideband dual-polarized MMIC antenna designed for 5 GHz Wi-Fi communication applications. The antenna consists of two orthogonally polarized 4x4 antenna arrays with dipole-like elements providing enhanced bandwidth. Apertures of the two arrays are overlapped by disposal of the corresponding PCBs one above another making the MMIC antenna as compact as a single-polarized one. The antenna is integrated into an enclosure with a plastic radome and has two output connectors. Measurement results confirm good matching and high cross-polarization isolation levels in the 4.9-6.0 GHz frequency range with 17.5-18.5 dB gain. Beamwidth of the antenna in 17.20 deg. in both azimuth and elevation planes. Achieved gain provides increased communication distance of the radio typically needed for any outdoor fixed wireless access application while the antenna is primarily developed for tradiocle networks in subways. Thus, it is already used in Moscow metro to provide high-throughput internet access to passengers.

17:40 Embedded MTM-EBGs in Patch Antenna for Simultaneously Dual-Band and Dual-Polarized Operation
Braden P. Smyth and Ashwink K. Iyer (University of Alberta, Canada)
This work presents the design of a novel dual band, dual polarized antenna (DBDPA) enabled through the use of metamaterial-based electromagnetic bandgap structures (MTM-EBG). The MTM-EBG is ideal for such an implementation since it is planar and embeddable directly into microwave devices such as patch antennas, and as such the DBDPA is compact and easily fabricated with conventional single-layer PCB fabrication methods. The antenna produces 10-dB return loss bandwidths of 1.6% and 1.0%, with gains of 6.9 dB and 7.4 dB at 5.6 GHz and 5.8 GHz, respectively, for the two polarizations. Furthermore, the simple pin feeds for each polarization experience 30 dB isolation due to symmetry of the structure, and the general design procedure ensures that the DBDPA is practical for applications at arbitrary frequencies.

18:00 A Compact Folded Air Patch Antenna with Low Cross-Polarization
Hao Chen and Ke-Li Wu (The Chinese University of Hong Kong, Hong Kong)
In this paper, a compact folded air patch antenna with low cross-polarization radiation is proposed. The air patch antenna is folded along the E-plane so that the size of the antenna is reduced by more than 50%. Additionally, the folded structure can introduce multiple vertical current components to cancel the parasitic cross-polarization radiation from the feeding port. The feeding probe, leading to a low cross-polarization level in the H-plane. A prototype antenna working in the 2.4 to 2.5 GHz ISM band is designed and measured. The simulated and measured results show good agreement. The measured maximum gain at 2.45 GHz is 8.2 dBi and the measured antenna efficiency is higher than 88%. The measured beamwidth of the cross-polarization that is 15 dB lower than the co-polarization is more than 1200.

T02-A10: Leaky-wave and Traveling-wave Antennas
T02 Millimetre wave 5G / Regular Session / Antennas
Room: B2
Chair: David R. Jackson (University of Houston, USA)

16:40 Review of the Recent Advances in the Leaky-Wave Antenna Analysis of 2-D Leaky-Wave Antennas
David R. Jackson (University of Houston, USA); Filippo Capolino (University of California, Irvine, USA); Ahmad T. Almutawa (PAAEET, Kuwait); Hamideza Kazemi (University of California Irvine, USA); Sohini Sengupta (Energous Corporation, USA); Walter Fuscaldos and Alessandro Galli (Sapienza University of Rome, Italy); Stuart A. Long (University of Houston, USA)
Recent developments are reviewed in the area of leaky-wave analysis of two-dimensional (2-D) leaky-wave antennas. Recent results are reviewed in three areas: (1) new beamwidth formulas for 2-D leaky-wave antennas, (2) leaky-wave analysis of wideband Fabry-Perot resonant cavity antennas, and (3) leaky-wave analysis of 2-D periodic leaky-wave antennas (area that radiate from higher-order space harmonics).

17:00 Radial Line Slot Array Antenna for 5.8-GHz-Band Beam-Type Wireless Power Transmission
Takashi Tomoda and Jiro Shimizu (Tokyo Institute of Technology, Japan); Minoru Furukawa and Tetsuo Fujishiro (Sho Engineering Corp., Japan)
This paper presents beam-type wireless power transmission by two radial line slot array antennas (RLSAs). Using electrically large antennas and their near-field region enables high-efficiency wireless power transmission. A uniformly excited RLSA is designed at 5.8-GHz-band, one of the industry science and medical (ISM) band. The two designed RLSAs are placed via-axis and transmission are analyzed. All of the distance of 28 cm, 67% transmission is confirmed whereas the rest is split-over, material loss, and reflection loss.

17:20 Reducing Side-Lobe Level of Surface Mounted Printed Leaky-Wave Antenna
Nina Javanabadi, Barry Syrett and Rory E. Amaya (Carleton University, Canada); Jafar Shaker (Communications Research Centre Canada, Canada)
A novel method for suppressing the undesired radiation of the feed section is introduced. Implementing the proposed method results in the side-lobe level reduction. To validate the proposed approach, we designed a leaky-wave antenna using the novel feed section. The antenna is realized based on the substrate integrated waveguide (SIW) technology. The operating bandwidth is reduced from 28.5 GHz in the support of modern 5G wireless networks. The length, width, and height of the antenna are 110 mm, 31 mm, and 1.3 mm, respectively. Ease of fabrication, efficiency, and adaptability of the proposed method make it a suitable candidate for suppressing the unwanted radiation from the feed section of the printed antennas.

17:40 Multi-Beam Radiation Properties of Higher-Order Space Harmonics-Enabled Leaky-Wave Antenna
Mohammad reza Rahimi (Polytechnique Montreal, Canada); Mohammad S. Sharawi (Polytechnique Montreal, Canada); Ke Wu (Ecole Polytechnique (University of Montreal) & Center for Radiofrequency Electronics Research of Quebec, Canada)
In this work, we investigate the undesired radiation of higher order space harmonics (HDH) along one-dimensional periodic leaky-wave antenna (1-D periodic LWAA) structures. The interdependence of even n = [-2, -4] and odd n = [-1, -3] HDHs on each other is examined in detail and a method is devised and demonstrated for analyzing their radiation properties which allow us to develop a multi-beam antenna (MBA) exhibiting wide scanning capability. The experimental results obtained in this work shows a good agreement with the simulation and analysis counterparts.

18:00 Multi-Port Leaky-Wave Antennas as Real-Time Analog Spectral Decomposers
Mohamed K. Emara and Shulabh Gupta (Carleton University, Canada)
A novel analog and real-time spectral decomposition system for signal processing at millimeter-wave (mm-wave) frequencies is proposed and demonstrated using full-wave simulations. The system is based on a multi-port leaky-wave antennas (LIWA) structure formed using an array of N 1-D LIWAs with 2N ports. When this structure receives a broadband time-domain signal from a single direction, the signal’s various spectral components are separated in real-time. They subsequently appear at the various ports of the LIWAs following their respective beam-scanning laws. The proposed concept is demonstrated using frequency- and time-domain full-wave simulations of two slot array antennas to decompose a transient pulse into four frequencies. The frequency outputs are then correlated back to the beam-scanning laws of the antennas.

CS63: State of the Art in Antenna Research in Russia
16:40 Circular-Polarized Antennas Far-Field Enhancement Using Round Reflectors with Curved Sidewall

Vladimir Litvin

This report discusses the problem of wide axial ratio beamwidth and high front-to-back ratio compact antenna design problem. As a prospective solution, a system design employing crossed dipole element and circular reflector with a curved sidewall, is proposed. In the first step of research, the reflector’s influence on radiation characteristics is examined using a simplified model. Numerical analysis shows the potential front-to-back ratio value around 36 dB while the far-field radiation pattern in the upper hemisphere is close to asymptotic and has a low cross-polarization component level for the same reflector’s geometry.

17.00 A 220-300 GHz Offset Dual-Reflector Antenna for Point-to-Point Radio

Alexey Kosogor and Yuri Tikhonov (Rostov-on-Don Research Institute of Radio Communication, Russia)

This paper presents a feasibility study of a classical offset dual-reflector configuration for sub-Thz high gain wideband antenna demanded for radio links with multi-Gbps throughput. To the best of the authors’ knowledge, this is the first demonstration of the designed, fabricated and tested offset Cassegrain antenna practical at 220-300 GHz. Antenna embodiment demonstrates notable size and weight.

17:20 Design of Wideband Reflectarray Antennas

Yury Antonov, Mikhail Sugak, Syvatolav Ballandovich, Grigory Kostikov and Liubov Liubina (Saint Petersburg Electrotechnical University LETI, Russia)

The method of increasing the operating frequency band of reflector antennas is proposed. The main idea of this method is to compensate frequency band by means of the spatial separation of layers with reflective elements. A full-metall reflectarray antenna has been designed with the use of the proposed method, manufactured and tested. The 18% relative frequency band upon a criteria of 38% gain reduction is achieved. The peak directivity is 27.7. In addition, issues related to the excitation of slot-element mode are discussed. The excitation of these modes can significantly affect the characteristics of the reflector antennas.

17:40 Computer Simulations of Multiband Waveguide Filter on Modulated Metasurface

Andrey Albertovich Yelizarov and Igor Vasilevich Nazarov (Moscow Institute of Electronics and Mathematics, NRU Higher School of Economics, Russia; Andrei Andreovich Skuridin (Moscow Institute of Electronics&Mathematics, NRU Higher School of Economics, Russia)

The paper presents the results of computer simulation of electromagnetic wave propagation in a segment of rectangular waveguide that has one of its sides made in the form of a mushroom-shaped-modulated metasurface. We used electromagnetic simulation program Ansoft HFSS to obtain the field distribution, characteristics of the complex transmission coefficient S21 and VSWR associated with fundamental mode H10. The results indicate that it is possible to create multiband waveguide rejection filters with improved characteristics and parameters using proposed structure.

18:00 A 3D Printed Luneburg Lens Fabricated by Fused Deposition Modelling

Roman Orlovich (Joint-Stock Company NilVector, Russia); Yury Salimakov (Siberian Federal University, Russia); Mikhail Sugak (Saint Petersburg Electrotechnical University LETI, Russia)

The possibility of spherical Luneburg lens fabrication by FDM 3D-printing is investigated. Phase-field distribution in a lens antenna aperture is experimentally defined. Comparison with simulating results is presented and the inference of FDM printing possibility while fabricating spherical Luneburg lens is given.
In radar countermeasures, the terms jamming and deception are used to indicate the intentional emission of radio signals designed to mislead a radar system. Electronic radar jammers typically consist of an antenna system and a corresponding circuitry, that captures, amplifies, and retransmits signals to deceive the radar. The jamming signal is designed to cover the entire frequency band and can be tailored to the specific radar system.

The detection performance is sensitive to the around-the-corner car position and orientation of the target. This is because the radar signal interacts with the target in a non-linear manner, leading to different signal strengths and directions. The location and direction of the reflector should be adopted individually for the particular deployment.

Ray tracing models have been developed to predict the behavior of radar signals in complex environments. These models can predict the reflection and diffraction of signals, which is crucial for understanding the detection performance in blind corner conditions. The ray tracing results demonstrate the potential of using a planar reflector, which should solve the issue. This is verified with real-world measurements. The results also show that the detection performance is sensitive to the around-the-corner car position and orientation of the target.

Experimental evaluation has been conducted to verify the theoretical models. The results show that the detection performance is sensitive to the around-the-corner car position and orientation of the target. The location and direction of the reflector should be adopted individually for the particular deployment.

This contribution is devoted to analyze the effect caused by non-uniform sampling and to present a technique for dealing with it. A dual-band repeater antenna for the on-body receiver unit of a wireless capsule endoscopy system was proposed. The authors have derived a theoretical model which was previously validated with experimental results. The presented result is significant as it validates the model under real-world conditions.

This paper presents the first prototype of a passive RFID-based textile touchpad. Our unique solution takes advantage of ICs from passive UHF RFID technology. These components are combined into a textile-integrated IC array, which can be used for handwritten character recognition. As the solution is fully passive and generates all the needed energy from the RFID reader, it enables a maintenance-free and cost-effective user interface that can be integrated into clothing and into textiles around us.

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elaborates, and re-radiates the proper interfering signals. In this contribution, we present a radar jammer implemented through a time-modulated metasurface. Such a metasurface is an electrically thin artificial structure, whose properties are dynamically changed over time to realize an elaboration of the illuminating signal. We demonstrate that such a metasurface is able to jam Doppler radars, implementing sweep-jamming and velocity pull-off techniques.

T09-P13: Propagation Aspects in Remote Sensing

T09 Space (incl. cubesat) / Regular Session / Propagation

Room: B8

Chairs: Michael Schönhuber (Joanneum Research, Austria), Franz Teschl (Graz University of Technology, Austria)

16:40 Remote Sensing of Tropical Precipitation with Radar and Radiometric Measurements

Animesh Malta, Souryajyoti Jana and Gargi Rakshit (University of Calcutta, India)

This paper presents the techniques and results on remote sensing of rain using radars, both space-borne and ground-based, and ground based radometers at a tropical location where precipitation has varying microstructures in terms of DOS, cloud liquid water content, radar reflectivity and atmospheric attenuation at Ka-band frequencies. A technique is proposed to derive three-parameter DOSs from dual frequency radar measurements onboard GPM satellites. Time evolution of precipitation features has been studied for different types of rain using a ground based multi-frequency microwave radiometer and an MRR. Convective rain is characterized by high rain rate, high cloud liquid water content and abundance of large rain drops whereas stratiform rain is characterized by radar bright band, low cloud liquid water and dominance of small rain drops. The atmospheric attenuation at 22.24 and 31.4 GHz is controlled by the relative contribution of rain and water vapour during two types of rain.

17:00 Calibrating Ka Band Satellite Down-Link Modem Measurements for Rainfall Monitoring

Franz Teschl and Reinhard Heidrich (Graz University of Technology, Austria), Valentin Eder (Space Analyses GmbH, Austria)

The observation of the signal level in microwave satellite links for remote sensing of rainfall can be useful complementation of existing sensors like rain gauges or weather radars. The number of very small-aperture terminals (VSATs) that provide internet connectivity is constantly rising. As such terminals are more and more used in corporate networks, the VSAT density is increasing - not only in remote areas. When retrieving rain rate from signal measurements, the quality of the signal level is important. This study compares signal measurements of two common types of co-located terminals with a reference demonstrator. It shows both over- and underestimation of various objects and provides a correction function for the values. This analysis lays the foundation for using these types of VSATs for retriving rain information and also has benefits for satellite network operators.

17:20 Sea Surface Characterization Using Dual Polarized GNSS Reception System

Aniket Regmi and Aamo Pärsänen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellent Ltd., Finland)

GNSS signal reception using Dual Circular Polarized method has been proposed to simultaneously record direct and reflected signals from the sea surface. Dual circular polarized reception (DCPR) system gives the opportunity to exploit the polarization change of the incident signal after reflection. This paper presents received signal characteristics of various GPS satellites for bare sea conditions. The received signals from various satellites are compared and are analyzed statistically to characterize the sea-state. The reflected left-hand circular polarized (LHC) signal is used to analyze the scattering characteristics of sea surface. The statistics of LHC signal give strong correlation with the wind speed over the sea and can be used to characterize the sea-state.

17:40 The MEKaP Project: Measuring Tropospheric Impairments at Ka Band with MEO Satellites

Lorenzo Lui, Carlo Riva and Alberto Panzeri (Politecnico di Milano, Italy); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Susana Mota (University of Aveiro & Institute of Telecommunications, Portugal); Frank S. Marzano, Augusto Marziani and Marianna Biscarini (Sapienza University of Rome, Italy); Fernando Consoli (FIB, Italy); Vincenzo Schena (Thales Alenia Space Italia, Italy); Antonio Martellucci (European Space Agency, The Netherlands)

The design phase of an ESA-funded project (MEKaP - MEO Ka-band Propagation) is described. The study, involving Politecnico di Milano, Sapienza Università di Roma, Instituto de Telecomunicações, Aveiro Politécnica and Thales Alenia Space Italia, aims at characterizing the main properties of the atmospheric radio channel of a MEO Ka-band SatCom system. The propagation campaign, lasting at least two years and including four ground receivers, will rely on the MEO COMS Ka-band satellite constellation, which provides key characteristics for propagation measurements, such as continuous observation time (always at least one satellite is visible) and global coverage up to mid-latitudes. The experimental data collected during the campaign will be used to test and improve the available propagation models for non-geostationary systems and to extend the experimental database of radio-attenuation bodies such as the ITU-R.

18:00 The Variability of Scattering from Leaves and Its Impact on Propagation

Jami Batenneh and Robert J Watson (University of Bath, United Kingdom (Great Britain))

Models for the scattering of leaves is a key input to the current ITU-R recommendation P.833-9 for attenuation in vegetation. This paper examines the variability of scattering from leaves due to uncertainties in various leaf-related parameters including size, shape, curvature, homogeneity and moisture content. The resulting scattering amplitudes have been determined using finite-element methods at frequencies of 1.9 and 26 GHz. The modelling assumptions made in current literature, backed up by measurements are reasonable up to around 10 GHz. However, at 26 GHz and beyond it is shown that some of these assumptions begin to break down.

T10-E05/2: Imaging and Inverse Scattering

T10 EM modelling and simulation tools / Regular Session / Electromagnetics

Room: B9

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Carey Rappaport (Northeastern University, USA)

16:40 Improving the Reconstruction Image Quality of Multiple Small Discrete Targets Using the Phase Coherence Method

Guanying Sun, Mohammad Hossein Nemati and Carey Rappaport (Northeastern University, USA)

In this work, we investigate the application of the phase coherence method for improving the quality of reconstructed images of small isolated objects with our Advanced Imaging Technique (AIT) nearfield millimeter-wave radar security scanning system. Based on the phase diversity of the reconstructed solutions for different transmitters, a phase coherence factor (PCF) is designed to weight the coherent sum. We verify its effectiveness with both numerical simulation and experimental measurement. In both simulation and experiment results, the artifacts like side-lobes, grating lobes or cluster in the original images are reduced in the processed images after applying the phase coherence method.

17:00 A Coarse-fine Mesh Approach for Improved Solution of 3-D Inverse Problems in Unbounded Media

Abhijit Aydogan (Izmir Bakircay University & Istanbul Technical University, Turkey); Emre Kilic (Technische Universität München, Germany); Mehrmet Mert Taygur (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM)) & Chair of High-Frequency Engineering (HFT), Germany)

A coarse-fine mesh approach is proposed to enhance the inverse scattering method for a three-dimensional problem. The problem is decomposed into exterior and interior problems to reduce the computational cost by invoking the equivalence principle. The exterior radiation problem is formulated by a boundary integral equation which enables to estimate the unknown surface current density. The estimated current density forms the boundary conditions of the interior problem to extract the dielectric profile. The interior problem is formulated by the finite-element technique and solved by the Gauss-Newton method. The associated surfaces and volumes are respectively discretized by triangular and tetrahedral meshes in the decomposed problems. The interior problem is solved with increasingly finer meshes. The exterior problem is solved for each mesh to form the boundary conditions with the associated discretization while the extracted profile in the previous step is used as the initial solution in the interior problem.

17:20 Inverse Scattering by Means of a New Rewriting of the Integral Equations

Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isernia (University of Reggio Calabria, Italy)

In this contribution, the integral equations underlying the two-dimensional electromagnetic inverse scattering are reformulated in a new form. The proposed inverse scattering model is based on an original decomposition of the adopted Green's function and the use of the 'reduced scattered field', which is underlying a recently introduced qualitative method. Its adoption could allow to simplify the solution of inverse scattering problems.

17:40 Automatic Permittivity and Thickness Characterization of Body-Borne Weak Dielectric Threats Using Wideband Radar

Ahmet Aydoğan (Izmir Bakircay University & Istanbul Technical University, Turkey); Mehrmet Mert Taygur (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM)) & Chair of High-Frequency Engineering (HFT), Germany)

This paper proposes a method for determining permittivity and thickness of body-borne objects automatically by processing wideband radar images. The algorithm can be used to find the explosive threats and rule out the benign objects. Having reconstructed millimeter wave radar image of the body with an anomaly attached to it, we extract the nominal body contour, which shows the body surface in the absence of the object, then we subtract the ideal body response from the image and define the amount of body displacement observed in the radar image which is caused by the signal retardation due to presence of weak dielectric object and look for the front surface reflection of the attached foreign object. Finally, we calculate the amount of permittivity based on body displacement and the anomaly's thickness.
18:00 Tracking Targets from Indirect Through-The-Wall Radar Observations
Gabriele Incorvia (The University of Manchester, United Kingdom (Great Britain)); Oliver Dorn (University of Manchester, United Kingdom (Great Britain))

In this paper we address the practically important task of identifying and tracking moving objects (e.g. people) inside a building from through-the-wall radar data obtained outside the building. In order to solve this task, we combine modern regularization techniques for solving non-linear inverse scattering problems with a Kalman filter approach for tracking targets from (indirectly) obtained observations. A level set based shape reconstruction technique is employed in order to obtain accurate initializations for the Kalman filter iterations, and a sparsity regularized inverse scattering approach is used in the Bayesian analysis steps. Numerical simulations in 2D show for a proof-of-concept setup that this combined approach of filtering and regularized inversion is very promising for efficiently and accurately tracking moving objects (potentially) in real time.

CS48: Novel Antenna Measurement Data Analysis and Techniques

T11 Fundamental research and emerging technologies / Convened Session / Measurements
Room: B10

Chair: Dennis Lewis (Boeing, USA); Janet O’Neil (ETS-Lindgren, USA)

16:40 Equivalent Source Technique Processing of Broadband Antenna Measurements
Lucia Scalciacqua (Microwave Vision Vision, Italy); Francesca Mirc (Consultant, Switzerland); Lars Foged (Microwave Vision Italy, Italy); Giorgio Giordano (LINKS Foundation & Politecnico di Torino, Italy); Marco Righeira (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

The equivalent source technique (ESC) has proved to be a useful aid in antenna processing, diagnostics and in the link with Computational Electromagnetic Tools (CETM). For broadband frequency antennas or in case of very large number of frequencies, reduction of the number of frequency points to be computed is a desirable feature, to significantly limit the global computational time. In recent applications this is a realistic need, since antennas are present in almost all commercial products, operating on a large set of frequency bands, and exhibiting a wide variety of pattern types. Therefore, they need to be analyzed on a relevant number of frequency points, to finally check compliance with standards. For this purpose, in case of multi-frequency processing, an interpolation technique based on radiation patterns and antenna S-parameters has been implemented in the ESC. In this paper the new implementation is applied and demonstrated on a large band antenna.

17:00 Improved-Reliability Phase-Retrieval with Broadband Antenna Measurements
Alexander Paulus, Josef Knapp, Jonas Komporgst and Thomas F. Eibert (Technical University of Munich, Germany)

Conventional phaseless near-field measurement data is not adequate for reliable transformation into the far-field. We tackle this challenge by a formulation working with multi-frequency phaseless measurements under the assumption of coherently measured spectra. Such data is, for instance, obtained with a transmitting antenna under test and standard receivers featuring a nonzero coherent bandwidth. The focus of this work is on an advanced algorithm to demonstrate that this ansatz is very promising for further research and real-world investigations. Empirical studies based on simulation data demonstrate that appropriately merging this multi-frequency data significantly increases the chance of successful phaseless near-field far-field transformation. As a by-product, this multi-frequency phase retrieval method supports also the retrieval of the phase of far-field antenna measurements.

17:20 Direct Wave Removal in Anechoic Chamber Range Imaging from Planar Scanned Data
Zhong Chen (ETS-Lindgren, USA); Zubiao Xiong (ETS-Lindgren, Inc., USA); Dennis Lewis (Boeing, USA)

Quiet Zone (QZ) reflectivity levels in an anechoic chamber are typically qualified using free-space VSWR method. The VSWR provides no information about the directions of the stray signals. Using a planar scanner and vector measurements, a chamber image can be developed from Fourier transform to show both signal levels and directions. It is desirable to remove the direct path signal in the image. We investigate two methods for the removal. First method is to subtract a plane wave normalized to the peak value of the spectrum. However, this approach may leave some residual effects. The second method is to apply time domain gating. Measured results are compared to show that the time domain gating method provides several advantages including a more thorough direct wave subtraction and the ability to isolate internal cable reflections or receiver leakages.

17:40 Site Validation Based on the Use of Broadband Calculable Antennas and Numerical Simulations
Carlo Carobbi (University of Florence, Italy); Alessio Bonci (ITT G. Ferrari San Giovanni Valdarno, Italy)

Semi-anechoic chambers and open area test sites validation in the frequency range between 30 MHz and 1000 MHz is typically carried out by comparing measurement results obtained by using a pair of biconical and log-periodic (broadband) dipole antennas with tabulated reference values of normalized site attenuation (NSA) provided by CISPR and ANSI standards. It is here shown, through simulations based on validated electromagnetic models of biconical and log-periodic dipole antennas, that the NSA reference values reported in the CISPR 16-1-4 and ANSI C63.4 standards may differ up to about 3 dB from those obtained by using pairs of calculable broadband antennas. Large deviations are observed both in the lower frequency range (30 MHz - 250 MHz), where the use of the biconical antenna pair is prescribed, and in the higher frequency (300 MHz - 1 GHz), where a pair of log-periodic dipole antennas is required.

18:00 An In-Depth Understanding of Salient Features of Antenna Near-Field Measurements Through Full Wave Simulations
Vignesh Manohar (University of California, Los Angeles, USA); Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)

Full wave solvers today are capable of solving very complex electromagnetic problems and enable the design of complex antennas. They also allow engineers to confidently assess the antenna performance in a real-time environment prior to its fabrication and physical integration with the desired system. In this work, we use the power of full-wave simulators to understand several salient aspects of near-field antenna measurements so as to facilitate the measurement of advanced antennas for emerging technologies. The modeling of the measurement process in a full-wave solver is elaborated in detail, followed by an investigation of two representative aspects of near-field measurements, which are assessing the impact of non-ideal probe and improving the efficiency of phase retrieval algorithms.

Thursday, 19 March 16:40 - 18:40

SW05: ESA Session: Selected Papers from the 40th ESA Workshop on Antenna Developments for Terrestrial and Small-Space Platforms

T09 Space (incl. cubesat) / Regular Session / Antennas
Room: B11

Chair: Nelson Fonseca (European Space Agency, The Netherlands), Maarten van der Vorst (European Space Agency, The Netherlands)

16:40 A Tribute to Niels Elskov Jensen
Antoine Roederer (Technical University of Delft, The Netherlands)
Not available

17:00 A 1X3 Circular Polarized Linear Array with High-Gain near Horizon Scanning and Full Azimuth Coverage for Land Vehicles to Satellite Communications
B. J. Falkner (Swansea University, United Kingdom (Great Britain))
Not available

17:20 Design of Advanced Reflectarrays for Future CubeSat Applications
Min Zhou, Erik Jørgensen, Stig Sørensen, Niels Vejstedal, Michael F. Palvig, Andreas Ericsson, Oscar Borries, Tonny Rubæk and Peter Meinecke (TICRA, Denmark)

In recent years, there have been a significant interest in reflectarray antennas and their use for CubeSat applications due to their planar nature. In this paper, we present a dedicated design tool, QUPES, that has been developed by TICRA for the design of quasi-periodic surfaces and show how it can be used to design advanced reflectarrays for future CubeSat missions. Two application examples are considered, a Ku-band reflectarray and a Ka-band reflectarray.

17:40 Experimental Validation of a Water Drop Geodesic Lens Design at Ka-Band
Nelson Fonseca (European Space Agency, The Netherlands)
18:00 Outdoor Unit for Satcom Next Generation Non-GEO Satellite
Passquale Nicolaiz (Space Engineering S.p.A., Italy)
Not available

18:20 Novel Design of Deployable Mesh Reflector Antenna for Mini Satellites
Oleksandr Sushko (EOS Ukraine, Ukraine)
Not available

Thursday, 19 March 18:00 - 20:00
EurAAP 4: WG Propagation (18:00-20:00, Room: B8)

18:00 - 20:00 Room B8

Friday, 20 March

Friday, 20 March 8:30 - 12:20
T01-A2: MIMO, Diversity, Smart Antennas & Signal Processing

T01 LTE and Sub-6GHz 5G / Regular Session / Antennas

Room: A2

Chairs: Björn Lindmark (Commscope, Sweden), Nuria LLombart (Delft University of Technology, The Netherlands)

8:30 Integrated Doherty Power Amplifier - Antenna Element with Active Impedance Modulation: Efficiency vs. Bandwidth Trade-Offs
Oleg Lapikov and Jose-Ramon Perez-Cifuentes (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Christian Fager and Koen Buismann (Chalmers University of Technology, Sweden); Daniel Akesson (Ericsson AB, Sweden); Marianna Ivashina (Chalmers University of Technology, Sweden)

This work presents an integrated Doherty power amplifier - antenna design at 3.5 GHz. Both power combining and matching to optimum transistor impedances at the fundamental frequency are realized on-antenna. A novel aperture-coupled cavity-backed patch antenna with a multi-port feeding is selected as the radiating element in order to provide a stable radiation pattern versus output power. The power-added efficiency (PAE) versus bandwidth trade-off of the designed integrated active antenna system is quantitatively analyzed. Simulated PAE values higher than 50% at 6 dB output power back-off within 5% bandwidth are obtained.

8:50 Theory of Cross-Polar Beamforming for Dual Polarded Arrays in Mobile Communications
Björn Lindmark (Commscope, Sweden)

Different theoretical aspects of cross-polarized beams in mobile communications are studied, in particular RTR beamforming systems. We show that closed form expressions exist for the weights of orthogonal pairs of cross-polarized beams and how the beamwidth can be changed for said beams.

9:10 Power-Efficient Beam Pattern Synthesis via Dual Polarization Beamforming
Sven O. Pettersson (Ericsson AB, Sweden)

This paper presents a new method, called dual polarization beamforming (DPIB), to design beam patterns. Instead of using only a single element-polarization, the traditional technique, a desired beam pattern is designed as the sum of powers for two orthogonal element-polarizations. Thus, the focus is on total radiated power beam patterns. The DPIB technique provides additional degrees of freedom to form a desired beam pattern such that amplitude variations in the beamforming vector can often be significantly reduced, potentially to uniform amplitude. This is a very interesting property, especially for active radiation, since it offers the potential of full power amplifier utilization. The method is applied to uniform linear arrays (ULAs) as well as uniform rectangular arrays (URAs). It is shown that a second beam, with identical beam pattern but orthogonal polarization in all directions compared to a first beam, can be designed with DPIB both for ULAs and URAs.

9:30 Full Duplex Spatial Modulation System Performance Depending on Self-interference Cancellation Accuracy
Yanni Zhou and Florin Huu (Univ Lyon, INSA Lyon, Inria, CITI, France); Guillaume Villemaud (Université de Lyon, INRIA, INSA-Lyon, CITI, France)

Spatial modulation (SM) is a new MIMO technique that transmits all the data bits by changing the spatial configuration of radiating elements in a MIMO antenna system. The accuracy of the self-interference rejection system is one of the main factors which limits the performance of SM. In this paper, we propose two practical SM transceivers and evaluate their performances under different self-interference cancellation systems. The effects of different antenna configurations and self-interference cancellation techniques on the performance of SM are analyzed.

9:50 Signal-to-Noise Ratio Considerations for Secure Antenna Polarization Modulation
Cara Yang Katara and Steven Franke (University of Illinois at Urbana-Champaign & Electromagnetics Laboratory, USA)

We investigate the impact of additive white Gaussian noise on the performance of secure antenna polarization modulation (SAPM), a technique for wireless frequency domain security. The secrecy rate, calculated from the mutual information of intended versus eavesdropper channels, serves as a metric for evaluation. With increasing signal-to-noise ratio (SNR), system designers can also choose to increase spectral efficiency by using a higher order of modulation. This significantly improves the level of security provided by SAPM by narrowing the range of spatial angles for which information may be received. We use simulation data to calculate the mutual information and symbol error probability over varying SNR levels to illustrate these effects.

10:10 Coffee Break

10:40 Array Configuration Effect on the Spatial Correlation of MU-MIMO Channels in NLoS Environments
Navid Amini (Chalmers University of Technology, Sweden); Amrashkan Farsaei (Eindhoven University of Technology, The Netherlands); Ulf Gustavsson (Ericsson AB, Sweden); Thomas Eriksson (Chalmers University of Technology, Sweden); Frans MJ Willems (Technical University Eindhoven, The Netherlands); Marianna Ivashina (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden)

In this paper, three different base-station antenna (BSA) configurations are compared in terms of inter-user spatial correlation in a two dimensional (2D) non-line-of-sight (NLoS) environment. The three configurations are (i) a regular uniform linear array (ULA); (ii) a periodic sparse array; and (iii) an aperiodic sparse array. Electromagnetic modeling of the NLoS channel is proposed where scatterers are considered as resonant dipole confined in clusters of scatterers (CLoD). While the probability of facing highly correlated sub-arrays decreases in a multi-user multi-input multi-output (MU-MIMO) system is decreasing as the richness of multipath increases, the sparsity (increased inter-element spacing) is seen to be capable of reducing this probability as well. This is due to the larger spatial variations experienced by the sparse array. Moreover, the results show that further improvement can be achieved by deploying an aperiodic distribution of antenna elements into the sparse antenna aperture.
11:00 Efficiency Analysis in Multibeam Wideband Phased Arrays

Riccardo Ozzola and Daniele Cavallo (Delft University of Technology, The Netherlands)

We present a study on the performance of wideband, wide-scanning arrays, when the elements are fed with a set of amplitudes and phases aiming at generating multiple independent beams. The formation of multiple beams is relevant in modern wireless communication applications, when diverse data streams can be sent from a single transmitter to users located at different directions. Wideband wide-scanning arrays are characterized by strong mutual coupling between antenna elements. The impact of such coupling on the capability to generate multiple beams is investigated. More specifically the active reflection coefficient of the elements and the total efficiency of the array are estimated for different beamforming configurations.

11:20 New High-Gain Differential-Fed Dual-Polarized Filtering Microstrip Antenna for 5G Applications

Yaser Ismael Abdulrahem Al-Yaziz (University of Bradford, United Kingdom (Great Britain)); Naser Ojjarudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Mohammad Fares (University of Basra, Iraq); Ahmed Maan Abdulkhaleq (University of Bradford & SARAS’s Technology (Great Britain)); Maryam Safdini (University of Aveiro, Portugal); Issa Eflerangi and Jonathan Rodriguez (Instituto de Telecomunicaciones, Portugal); Raed A. Al-Abameed (University of Bradford, United Kingdom (Great Britain))

In this paper, an elliptical differential-fed dual-polarized microstrip filtering antenna with high common-mode rejection is presented. Two differential pairs of probe feeding ports are utilized to provide differentially exciting ports. The filtering response is achieved by introducing four symmetrical open-loop resonator slots on the top layer surrounding the four excitation ports of the patch. The resonators can produce nulls at low the passband bandwidth with high gain and wide stopband characteristics. Because of the strictly symmetric configuration of the proposed antenna, the design is studied and analyzed only in one polarization configuration. Compared with other presented filtering antenna designs, the proposed design has not only high gain and dual-polarized characteristics but also introduces high efficiency and much lower cross-polarization level due to the differentially driven ports.

11:40 On the Use of the Observable Field to Synthesize Independent Beams from a Finite Volume

Andrea Neto and Arturo Fioretino Bernards (Delft University of Technology, The Netherlands)

This contribution describes the independent wideband antennas that can be obtained by an array of antennas of a certain volume in terms of the wavelength is addressed. To define the independence of the beams we resort to the concept of the observable field, which was developed to investigate the properties of antennas in reception, and specifically the available power for an array. We then define two incident plane waves as independent over a given area, if the available power associated to the two beams is equally distributed. The main result is that the field of the observable field generates an equal power splitting between the two beams.

12:00 High-Gain Flat-Top Antenna Sub-Arrays for Planar Arrays with Limited Field of View

Ronis T. Maximidis (The Antenna Company, The Netherlands); Giovanni Tosco (European Space Agency, ESA ESTEC, The Netherlands); A. B. (Bar) Smolders (Eindhoven University of Technology, The Netherlands)

This paper presents an antenna array which is based on a novel sub-array architecture. Each sub-array is a linear array of open-ended waveguides. The proposed sub-array structure exhibits high-gain characteristics with a flat-top distribution and is used as a unit cell in a two-dimensional array. The distance between the sub-array centers along the relevant main axis is large in terms of wavelengths, which limit the scanning capabilities, whereas the element-interference pattern along the orthogonal plane is about half-free-space wavelength at the central working frequency, leading to a wide scan range. Using the presented approach, an array operating at 28.5 GHz was designed in such a way as to feature a maximal scanning angle of ±14° along the E plane and ±7.4° along the H plane. The specific sub-array pattern, which approximates a rectangular pulse distribution, allows to filter out the grating lobes along the E plane.

CS37: IRACON Spectrum Sharing: Challenges and Opportunities for 5G and Beyond

T02 Millimetre wave 5G / Convened Session / Propagation

Room: A3

Chair: Marina Barbieri (University of Bologna, Italy); Doriana Guiducci (European Communications Office, Denmark), Sana Salous (Durham University, United Kingdom (Great Britain))

8:30 Channel Measurements and Path Loss Modeling for Indoor THz Communication

Naveed Ahmed Abbas, Arjun Harharan, Arun Moni Nair and Andreas Molisch (University of Southern California, USA)

In this paper, we present an overview of recent channel measurements and path loss modeling studies that have been conducted for indoor THz communication systems. We focus on the measurement campaigns performed in three different indoor environments: an office, an apartment, and a laboratory. We present the main results obtained from these campaigns, including channel impulse responses, frequency selectivity, and path loss models. We also discuss the challenges and opportunities for future research in this field.

8:50 Characterization of the Propagation Channel in Room Scenario at 190 GHz

Diego Dulmeche (Ilmenau University of Technology, Germany); Robert Müller and Sergej Skibiow (TU Ilmenau, Germany); Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technical University Ilmenau, Germany); Reiner S. Thom (Ilmenau University of Technology, Germany)

State-of-the-art channel sounders are a valuable tool to characterise the indoor multipath propagation channel at Terahertz frequencies. In this contribution, we present the first measurements of an indoor channel at 190 GHz, which was conducted in a conference room. The measurements were performed using a state-of-the-art channel sounder and a high-resolution signal processing algorithm. The measured channel impulse responses were then used to extract the channel parameters and to develop a channel model. The developed channel model can be used to predict the performance of future THz communication systems.

9:10 Enabling RF Technologies for Spectrum Sharing

Mark Beach, Leo Laughlin, Eyad Arabi, Simon Wilson, Sarmaid Ozan and Chris Garnath (University of Bristol, United Kingdom (Great Britain))

This paper presents an overview of the latest advances in enabling RF technologies for spectrum sharing. We discuss the key enablers, such as RF harvesting, spectrum sensing, and spectrum sharing protocols, and their potential impact on future wireless communications. We also highlight the challenges and opportunities for future research in this field.

9:30 Assessing the Feasibility of the Spectrum Sharing Concepts for Private Industrial Networks Operating Above 5 GHz

Peikai Qian (Co-Worker Technology Finland, Finland); Seppo Ypola (Nokia & University of Oulu, Finland); Marja Matinmikko-Blue (University of Oulu, Centre for Wireless Communications, Finland)

Ongoing 5G deployment is bringing higher speeds, higher capacity, lower latency and greater reliability to connectively enabling data sharing amongst participating components of industrial systems. The private industrial network opportunity for serving different verticals is largely dependent on the timely availability and cost of the spectrum. The growing pressure to open the wireless market for location specific networks has resulted in new local licensing and sharing-based models for spectrum management. This paper discusses private industrial network requirements for the spectrum management through a framework that can be used to assess the feasibility of the spectrum management approaches. Specifically, recent sharing concepts above 5 GHz in the US, Europe and four selected countries: Australia, Hong Kong, Japan, and UK are analyzed from the viewpoint of private industrial networks. Each of the selected sharing concepts is a unique approach to make wideband spectrum available for other network providers than traditional MNOs.

9:50 Regulatory Requirements and Characterisation of Transmitter and Receiver Parameters to Set a Novel Framework for Spectrum Sharing

Peter Faris and Doriana Guiducci (European Communications Office, Denmark)

In this paper, we present an overview of the regulatory requirements and characterisation of transmitter and receiver parameters to set a novel framework for spectrum sharing. We discuss the key factors that influence the development of the regulatory framework, including the technical limits and the economic aspects. We also highlight the challenges and opportunities for future research in this field.

10:10 Coffee Break

10:40 A Study of an Environment Recognition Scheme Using WLAN CSI for Dynamic Spectrum Sharing

Tomoki Murakami (NTT Corporation, Japan); Shinya Otsuki (NTT Service Integration Laboratories, Japan); Tomoki Ogawa (NTT, Japan); Yasushi Takatori (NTT Network Innovation Laboratories, Japan)

Diversified devices and use scenarios have been focused on spectrum sharing according to communication environments in a target area. This paper proposes an environment recognition scheme for dynamic spectrum sharing systems. Our scheme dynamically uses CSI to allocate spectrum resources by recognizing the user location and congestion rate in a target area. Furthermore, low-cost recognition can be expected with the IEEE 802.11ac WLAN CSI. To realize our scheme in realistic environments with actual devices, we developed a CSI monitoring system that uses the commodity WLAN devices, and we evaluated the environment recognition performance in our experimental

117 of 128
A broadband low-profile circularly polarized (CP) metasurface antenna fed by a single rotated L-probe is proposed. With this concept, matching, efficiency, axial ratio at the dual-band with low correlation-coefficient as a good inter-antenna isolation. Second, for CP at two GPS bands, we form a tilted cross-shaped slot on the patch and tune it. Third, the proposed metamaterial-dual-band antenna is applied to four multiple antennas as space diversity approach like anti-jamming. Both simulated and measured results show that the proposed antenna achieves good impedance matching, efficiency, axial ratio at the dual-band with low correlation-coefficient as a good inter-antenna isolation. A great broadband low-profile circularly polarized (CP) metasurface antenna fed by single rotated L-probe is proposed. The L-shaped probe feed, an additional surface wave resonance is excited on the finite metasurface to enhance the bandwidth of the antenna. The single rotated L-probe fed asymmetrical metasurface antenna yields an overlapped impedance/gain/sidelobe bandwidth of 20.7% from 5.71 GHz to 1.03 GHz, a peak gain of 8.85 dBi, and PIN higher than 19 dB, covering the 6- GPS band for coexisting Wi-Fi 7 applications. Experiments are carried out so well to validate the proposed CP antenna design.

9:50 Coffee Break

10:20 Metamaterials for Electromagnetic and Thermal Waves

Erm Donnelly (Edinburgh Napier University, United Kingdom (Great Britain)); Antoine Durant (Edinburgh Napier University, United Kingdom (Great Britain) & Université Grenoble Alpes, France); Celia Laccoste (INP-ENSEEIHT University of Toulouse, United Kingdom (Great Britain)); Luigi La Spada (Edinburgh Napier University, United Kingdom (Great Britain))

In the last decade, electromagnetic metamaterials, thanks to their exotic properties, become crucial building blocks to develop new technologies in several applications. Until now metamaterials have been mostly associated with electromagnetism, but the same concept can be also applied to other wave phenomena, such as thermodynamics. For this reason, the aim is to realize a metamaterial able to control simultaneously both electromagnetic and thermal waves. The structure is manufactured by using Additive Manufacturing techniques and tested for the following applications: sensing and medical diagnostics (optical and thermal imaging), military/safety (electromagnetic and thermal guarding structures) and automotive (electrical vehicles battery electric and thermal management). Experimental results revealed that such multi-functional metamaterial can fully manipulate and control both electromagnetic and thermal waves at will. The proposed structure appears to be highly versatile and scalable, with great potential to be used also for other wave phenomena such as mechanics, acoustics and hydrodynamics.

10:40 Evaluation of Aerosol Jet Printing of Frequency Selective Surface on Glass for Building and RF Applications

Anshuman Shastri, Kumar Putta and Benito Sánchez-Izquierdo (University of Kent, United Kingdom (Great Britain)); Edward Parker (The University of Kent, United Kingdom (Great Britain)); Steven Gao (University of Kent, United Kingdom (Great Britain)); Lee Winchester (The Centre for Process Innovation, United Kingdom (Great Britain)); Alan McClelland (CP, United Kingdom (Great Britain))

The use of Aerosol Jet Printing technology to fabricate frequency selective surfaces (FSS) on glass for secure WLAN building applications is presented. Aerosol Jet Printing is combined with nano-particle silver inks to produce the FSS array. A square loop design in a square lattice is employed in this demonstrator. The structure operates around the 2.5 GHz frequency band commonly used in wireless communication systems and covers a wide-range frequencies. A single layer array design is studied. Aerosol Jet printing is able to produce fine tracks needed for the design and provide sufficient conductivity for the filtering performance. The aim is to demonstrate a potential solution for the development of FSS for building and radio frequency (RF) shielding applications. In particular, windows can contain these printed RF structures and enhance their RF capabilities. CST Microwave Studio was used for the simulation of the FSS. Simulations compare well with measurements.
A Fast and Rigorous Assessment of the Specific Absorption Rate (SAR) for MIMO Cellular Equipment Based on Vector Near-Field Measurements

Mounir Teniou, Orousck Jawad and Stephane Panettier (ART-FI, France); Lyzad Acherb (Art-FI, France)

This paper introduces a new fast and rigorous test procedure for accurate assessment of the peak averaged specific absorption rate (SAR) for MIMO cellular equipment. The SAR of mobile devices is a critical parameter that affects the user safety. The proposed method allows for an accurate assessment of the SAR while taking into account the complex behavior of MIMO systems. The method is based on a combination of near-field and far-field measurements, providing a comprehensive evaluation of the device's electromagnetic exposure.

The method is validated through measurements on a range of MIMO devices, demonstrating its accuracy and reliability. The results show that the proposed method can effectively predict the SAR, allowing for the development of safer and more efficient wireless communication devices.

Friday, 20 March 8:30 - 10:10
T05-M06: Dosimetry, Exposure, and SAR Assessment

Room: B2

8:30 Frequency Selective EMF Measurements and Exposure Assessment in Indoor Office Environments

Nektarios Moraitis (National Technical University of Athens & Institute of Communications and Computer Systems, Greece); Ilieana Popescu and Konstantina Nikita (National Technical University of Athens, Greece)

The results of an extensive radio-frequency electromagnetic field (RF-EMF) measurement campaign in indoor office locations are presented. Frequency selective EMF recordings have been carried out in different corporate buildings between 75 and 3000 MHz. Exposure levels for the general public are estimated and compared with the national and international limits. The results from the entire building dataset reveal that the total RF field varies between 0.29 and 0.75 V/m (2-2.7 V/m) depending on the time of day. Furthermore, the exposure values are found to be strongly related with the floor level, increasing linearly. Finally, broadcast and cellular emissions account for more than 57% of the total radiated levels, especially at higher floors, where they reach up to 80%.

8:50 Human Exposure to Electromagnetic Signals with Continuous Spectra

Dragan Poljak (University of Split, Croatia)

This paper focuses on the assessment of human exposure to electromagnetic signals with continuous spectra. A convenient and simple method is proposed, to compare the measured field levels with the maximum exposure levels and verify compliance with the relevant regulations. In the presence of signals with continuous spectra, the proposed method yields more accurate results than the procedure outlined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Furthermore, the proposed method is straightforward and requires only the integration in the spectral domain of the electric field amplitude, or of the square of the electric field amplitude.

9:10 Maximum Exposure Assessment of millimeter-Wave Array Antennas

Sylvain Reboux (ZMT Zurich MedTech AG, Switzerland); Serge Pfeifer (Foundation for Research on Information Technologies in Society (ITIS Foundation, Switzerland); Niels Kuster (Foundation for Research on Information Technologies in Society, ITIS Foundation, Switzerland)

Antennas operating at frequencies above 10 GHz can be used to enable high-speed wireless communication. This paper presents a method for assessing the maximum exposure of a person when exposed to millimeter-wave antenna arrays. The proposed method is based on the calculation of the maximum exposure level and takes into account both the direct and reflected field components. The results show that the method is accurate and can be used to ensure compliance with the relevant regulations.
characteristic angles fall between 135 and 225 degrees. The effectiveness of a stirrer is measured in terms of the field ... power of the total electric fields at the eight vertices of the working volume. Three types of stirrers with the same

In this paper, a new method to compare the effectiveness of a stirrer by calculating the number of characteristic modes ... the better it works in the reverberation chamber. The number of characteristic modes refer to the number of modes whose

Huilin Huang (Xi'an Jiaotong University, China); Xiaoming Chen (Xi'an Jiaotong University, China); Ping Fang (Institute of Physics of China); Soonwoo Park (University of Surrey, United Kingdom (Great Britain)); Razvan D. Tamas (Universitatea Politehnica of Bucharest, Romania)

The effect of vehicle's proximity on the radiation pattern when the RADAR's antenna is mounted on the body of autonomous cars is analyzed. Two directional radiation patterns with different specifications are analyzed at different locations of a realistic car body model. The simulation is performed based on ray-tracing method at 77 GHz, the standard frequency for self-driving applications. It is shown that to obtain a robust RADAR sensor, the antenna radiation pattern is better to have relatively higher gain and lower side-lobe-level (SLL), than narrower half-power-beamwidth (HPBW) and higher front-to-back (F/B) ratio. Both academia and industry can benefit from this study.

Any lossless transmission line terminated on an arbitrary reactive load suffers from reflections, due to the high impedance mismatch between the real characteristic impedance of the transmission line and the imaginary impedance of the load. A resistive-lumped component must be added at the end of the line for ensuring power dissipation and achieving the required zero reflection. Here, we present a way to achieve perfect matching condition for purely reactive loads by exploiting the properties of complex frequency excitation. By exciting the circuit with a signal having a proper time profile, we demonstrate that the amplitude of the reflected wave can be brought to zero. Being the load purely reactive, energy isn't dissipated, but stored in the load, giving rise to an interesting singularity in the transient regime, referred to as virtual absorption. The stored energy can be released at will by changing or stopping the applied complex excitation.

The effect of vehicle's proximity on the radiation pattern when the RADAR's antenna is mounted on the body of autonomous cars is analyzed. Two directional radiation patterns with different specifications are analyzed at different locations of a realistic car body model. The simulation is performed based on ray-tracing method at 77 GHz, the standard frequency for self-driving applications. It is shown that to obtain a robust RADAR sensor, the antenna radiation pattern is better to have relatively higher gain and lower side-lobe-level (SLL), than narrower half-power-beamwidth (HPBW) and higher front-to-back (F/B) ratio. Both academia and industry can benefit from this study.

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**8:50 Diffuse Field Cross-Correlation in a Reverberation Chamber with Reconfigurable Reflectarray Metasurfaces**

**Philippe Hougne** (Institut de Physique de Nice, France); **Philippe Besnier** (IEET, France); **Fabrice Mortessagne**, **Elodie Richalot** (Group of Electrical Engineering - Paris / CentraleSupelec, France); **Emily Porter** (University of Warwick, United Kingdom)

The impulse response between two antennas operating in the same room can be retrieved via a cross-correlation technique leveraging thermal noise or stimulated chaotic wave fields in reverberation chambers (RC). We report an implementation of the latter using an unventional stirring mechanism: rather than rotating a mechanical mode stirper, we use reconfigurable reflectarray metasurfaces placed on the RC walls in different random configurations. We detail how the data processing must be adapted to this stirring mechanism and we demonstrate the convergence of the cross-correlation toward the impulse response.

**9:10 Evaluation of the Purity of OAM Modes Using the Reverberation Chamber Technique**

**Wei Xue** (Xi’an Jiaotong University, China); **Xiaohua Chen** and **Hongguo Shi** (Xi’an Jiaotong University, China); **Huihui Huang** (Xi’an Jiaotong University, China); **Jian Chen** and **Anzhu Zhang** (Xi’an Jiaotong University, China)

Orbital angular momentum (OAM) waveforms have been applied to various applications: the task is to determine the purity of different OAM modes. OAM waveforms can be generated using different techniques. However, the generated OAM-ways are not pure, which influences the OAM purity. Thus it is important to evaluate the purity of the OAM modes. The common method for purity assessment is less convenient in practical measurements. In this paper we develop a new method based on reverberation chamber (RC) to evaluate the purity of the OAM mode. In contrast to the conventional measurement in the anechoic chamber, the proposed method can conveniently evaluate the purity over the entire measurement bandwidth for one frequency point, which is helpful in determining the working bandwidth of the OAM generator.

**9:30 A Dual-Polarized Asymptotic Conical Dipole (ACD) Sensor for Ultra-Wideband E-field Measurement**

**Minxiang Gao** (Xi’an Jiaotong University, China); **Yanfeng Xie** (Xi’an Jiaotong University, China)

This paper presents a dual-polarized E-field sensor for high-power ultra-wideband (UWB) pulse measurement. Based on the technique of conventional asymptotic conical dipole (ACD) sensor, two pairs of planar ACD antennas are assembled perpendicularly to measure E-field in dual-polarization. Simulation results show the working effectiveness of the designed sensor. We expect that the proposed sensor can be applied to microwave hyperthermia therapy.

**10:10 Coffee Break**

**10:30 3D Electromagnetic Imaging of Human Brain with Metamaterials**

**Olympia Karadima** (King’s College London, United Kingdom (Great Britain)); **Anxue Zhang** (University of Warwick, United Kingdom (Great Britain)); **Philippe Besnier** (IEET, France); **Elodie Richalot** (Group of Electrical Engineering - Paris / CentraleSupelec, France); **Mykolas Ragulskis**

Towards a preclinical prototype for diagnostic and monitoring of cerebral pathologies, here we present the 3D electromagnetic imaging approach of human brain with metamaterials. The common method for imaging the brain requires the use of invasive medical devices which can cause considerable side effects. In this paper we propose to use reconfigurable reflectarray metasurfaces placed on the RC walls in different random configurations. We detail how the data processing must be adapted to this stirring mechanism and we demonstrate the convergence of the cross-correlation toward the impulse response.

**11:10 Comparison of Antenna Radiation Efficiency Measurement Techniques in Reverberation Chamber Using or Not a Reference Antenna**

**Wafa Krouka** (Université Paris-Est & ESYCOM, France); **Francois Sarrazin** (University of Paris-Est-Marne-la-Vallée & ESYCOM, France); **Jérôme Soîl** (INSA Rennes, France); **Philippe Besnier** (IEET, France); **Elodie Richalot** (Université Paris-Est (Marne-la-Vallée), France)

Antenna characterization using reverberation chamber (RC) has become the new trend in RC measurements. In this work, we compare three antenna characterization methods in reverberation chamber. These methods are applied in order to determine the radiation efficiency of a patch and a long-periodic antenna. Results are compared and show good coherence. The accuracy of the applied methods is discussed and a solution is proposed in order to enhance the accuracy of reference antenna-based methods.

**11:30 Simulation of Multi-Source Effects on the SAR of a Moving Target in an RCS Scattering Environment**

**Xiang Chen** (Xi’an Jiaotong University & China Academy of Space Technology (Xian), China); **Wei Wang** (China Academy of Space Technology Xian, China); **Yongjin He** (Xi’an Jiaotong University, China)

Passive intermodulation (IM) measurement is necessary for microwave and antenna products to evaluate their radiation pattern. To achieve stable low residual IM level of measurement system and make accurate IM test, a compact waveguide flange adapter is proposed based on waveguide, dielectric-based feed of relays is adopted to construct compact configuration. The waveguide is connected with standard waveguide flanges, double-sided contactless electromagnetic band gap (EBG) structure with air gap is formed inside the flange connection. Electromagnetic leakage is prevented by stop band of EBG structure. Meanwhile, metallic contact continuity is almost eliminated by the contactless structure, and EBG can be therefore suppressed. A Ku band prototype of the adapter is designed for a Ku band IM measurement system. By using the adapter, the system's residual IM is significantly improved with a maximum improvement better than 30 dB, achieving a stable low level.

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**Friday, 20 March 8:30 - 12:20**

**SW06: H2020 Session ID764479 (EMERALD): Electromagnetic Imaging for a Novel Generation of Medical Devices**

**T05 biomedical and health / Convened Session / Electromagnetics**

Room: B6

**Chairs:** Marija Nikolic (University of Belgrade, Serbia), Jorge A. Tobon Vasquez (Politecnico di Torino, Italy)

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**10:10 Coffee Break**

**11:10 Investigation of S-parameter Calibration Effects on Image Reconstruction in Microwave Imaging Systems**

**Chih-Chung Chen** (University of Alberta, Canada); **Mark Borkowski** (University of Alberta, Canada); **Tushar Singh** (University of Alberta, Canada)

S-parameter measurement is used as the first step for microwave imaging (MI) systems. However, the traditional S-parameter calibration methods, such as the network analyzer and bridge technique, show poor performance in terms of image accuracy and reconstruction. In this paper, we investigate the effects of S-parameter calibration on image reconstruction in MI systems. We propose a new calibration method, called the “unknown thru” calibration, which shows significant improvement in image reconstruction accuracy compared to other traditional methods. This method can be applied to both small and large scale MI systems, and it provides a practical solution for improving the performance of MI systems.

**11:30 Detailed Dielectric Characterisation of the Heart and Great Vessels**

**Niko Ithuk** (University of Limerick, Ireland); **Barry McDermott** (University of Limerick, Ireland); **Emily Porter** (University of Texas at Austin, USA); **Adam Santorelli** (University of Limerick, Ireland); **Philippe Besnier** (IEET, France); **Elodie Richalot** (Group of Electrical Engineering - Paris / CentraleSupelec, France); **Hélène Roussel** (Institut de Physique de Nice, France)

The dielectric properties of biological tissues play a significant role in the planning and development of electromagnetic thermal therapies. In most cases, the literature shows a three-dimensional, homogeneous model for the dielectric properties. However, this approach is not always accurate, and the results of this study indicate that the dielectric properties are more complex than previously thought. Our results suggest that the dielectric properties of biological tissues are highly dependent on the orientation and position of the measurement.

**11:50 Homogenization of Voxel Models Using Material Mixing Formulas**

**Tushar Singh** (University of Limerick, Ireland); **Mladen Stefanec** (University of Limerick, Ireland); **Mykolas Ragulskis** (University of Limerick, Ireland)

In this paper, we develop a procedure for simplifying highly inhomogeneous numerical phantoms based on dielectric mixing formulas. Numerical experiments are performed to investigate the accuracy of the proposed approach. The results show that the homogenization method is effective in simplifying the numerical phantoms without sacrificing the accuracy and computational efficiency of the simulation.

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**12:20 End of Session**
A Wideband 122 GHz Cavity-Backed Dipole Antenna for Millimeter-Wave Radar Altimetry
Cristina Yepes
(University of Electronic Science and Technology of China)
and
Bing-Zhong Wang
(University of Electronic Science and Technology of China)

In this paper, a wideband cavity-backed dipole antenna at 122 GHz for radar altimetry applications is presented. The antenna is designed to cover a bandwidth from 119 GHz to 126.6 GHz with a maximum gain of 6.9 dBi. The measured 3D radiation patterns at various frequencies across the operational band are provided. These patterns are investigated by full wave simulations and validated through the fabrication and measurement of the antenna prototype. The antenna design is optimized for low cross polarization and a wide incident angle. In addition, the validity of the proposed radome is also shown in measurements.

8:30 Bandwidth Enhanced Flexible UAV Antenna with 360 Azimuth Coverage for Air to Ground Communication
Azamat Bakytbekov and Atif Shamim
(King Abdullah University of Science and Technology, Saudi Arabia)

Utility of UAVs, particularly in microwave industries, is massive today and it is predicted to grow more. High data rate, air-to-ground, long range communication is still a bottleneck. UAV antenna is one of the most important part of the system and ideally it must be planar and conformal so that it does not create aerodynamics issues. Moreover, it must have omnidirectional radiation pattern to achieve 360 azimuth coverage while measuring with decent gain and bandwidth. It is also required that the antenna performance is not deteriorated due to placement on UAV body. In this paper, a wideband antenna has been designed which meets all the above-mentioned requirements. The antenna has omnidirectional radiation pattern with −5 dB gain. Bandwidth enhancement has been achieved from 0.9% to 3% at 2.4 GHz on a thin substrate through additional parasitic elements. Flexibility analysis shows that the presented antenna is well suited for different bending conditions.

9:10 Study of a Low-Loss Planar Radome for a Wide-Coverage Antenna
Hiromasa Nakajima
(Mitsubishi Electric Corporation, Japan)
and
Hiroyasu Yamamoto
(Mitsubishi Electric Corporation, Japan)

In this paper a multilayer radome with low-loss over a wide angle for active Electronically Scanned Arrays (ESA) is proposed. The proposed radome is divided into some regions and the layer configuration of each region is optimized, depending on the incident angle from the antenna to the radome. This design approach leads to low transmission loss over a wide incident angle. In addition, the validity of the presented radome is also shown in measurements.

9:50 Dual Band GNSS Antenna with High Back Lobe Suppression
Sachit Varma and Stefano Caizzone
(Instituto de Telecomunicacoes, Portugal)
and
Jorgo R. Costa
(Instituto de Telecomunicacoes, Portugal)

This paper presents the study of a novel dual band GNSS antenna for E5a and E5b bands (i.e., at the central operating frequencies of 1.176 GHz and 1.575 GHz) with high gain and very low back lobe for multipath reduction in high end static (e.g., geodesy) or dynamic (e.g. UAV) environments. The antenna itself is 56 mm in diameter and has a vertically stacked aperture of approximately 10 mm diameter that forces the cancellation of electromagnetic fields underneath the ground plane, thereby drastically improving the cross polarization discrimination and allowing for multipath suppression in both bands of operation.

10:10 Coffee Break

10:40 Temperature Dependent Dielectric Properties of Tissue Mimicking Phantom Material in the Microwave Frequency Range
Alexandra Prokhova and Sebastian Ley
(Technische Universität Ilmenau, Germany)
and
Jan Vrba
(Technische Universität Ilmenau)

This paper presents the study of a novel dual band GNSS antenna for E5a and E5b bands (i.e., at the central operating frequencies of 1.176 GHz and 1.575 GHz) with high gain and very low back lobe for multipath reduction in high end static (e.g., geodesy) or dynamic (e.g. UAV) environments. The antenna itself is 56 mm in diameter and has a vertically stacked aperture of approximately 10 mm diameter that forces the cancellation of electromagnetic fields underneath the ground plane, thereby drastically improving the cross polarization discrimination and allowing for multipath suppression in both bands of operation.
Design of Microwave Imaging System Based on Reconfigurable Transmitarray with Variable Focuses

Ahmed Abdelmottaleb Omar

This paper presents a 2-bit, 20% bandwidth, switch-controlled phase-shifting unit cell design for beam-steerable reflectarray antennas. The proposed unit cell is designed to support both linear and circular polarization using two different bias states. The design is verified experimentally.

Design of Dualband, Multilayer Metasurface Reflectarrays

Reza Shamsy

A dualband, multilayer metasurface reflectarray is presented in this paper. The reflectarray consists of two layers of subwavelength elements, with each layer operating at a different frequency band. The design approach involves optimizing the element sizes and spacings to achieve wideband performance across both frequency bands. The proposed reflectarray is suitable for applications requiring dualband operation.

CS59: Reconfigurable Reflectarray and Transmitarrays

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: BB

Chairs: Nader Behdad (University of Wisconsin-Madison, USA), Nima Ghalichechian (The Ohio State University, USA)

11:00 11:20

Design of Transmitarray with a Deformable Ground

Nader Behdad

This design represents a novel implementation of the connected-array concept that offers wide-scan capabilities while maintaining a compact size. The approach involves connecting multiple antenna elements in a way that allows for a wide range of radiation patterns.

Design of Airborne Small Ultra-Wideband Spinning Direction Finding Antennas

Youngju Park

A design methodology for reconfigurable reflectarrays with a deformable ground is presented in this paper. The approach involves using a deformable ground plate to control the radiation pattern of the reflectarray, allowing for variable directivity and beam steering.

11:40 Amended Design of Travelling-Wave Slot Arrays

Sourya Sheel and Jacques Coetzee

Travelling wave slot arrays provide wider bandwidth in comparison to slot arrays implemented in standing wave configurations. This design approach allows for increased flexibility in terms of radiation pattern design. The results demonstrate improved performance compared to traditional slot array designs.

Design of Reflectarray Antennas for High-Power Applications

Xiaotian Pan

The design of reflectarray antennas for high-power applications is presented in this paper. The approach involves optimizing the element sizes and spacings to handle high-power densities while maintaining good radiation characteristics.

12:00 12:20

Time Modulated Reflectarray Unit-Cells with Nonreciprocal Polarization Control

Santiago Sapatula

This paper presents a design methodology for time-modulated reflectarray unit cells with nonreciprocal polarization control. The proposed approach uses a combination of time-reversal and polarization reversal techniques to achieve wideband performance.

Design of Time-Dependent, Nonreciprocal Metasurface Reflectarrays

Anthony Grbic

A design methodology for time-dependent, nonreciprocal metasurface reflectarrays is presented in this paper. The approach involves using time-varying surface impedances to control the radiation characteristics of the reflectarray.

12:40 13:00

Design of Microwave Imaging System Based on Reconfigurable Transmitarray with Variable Focuses

Xiaotian Pan, Fan Yang, Shengwen Xu and Maokun Li

The microwave imaging system based on a reconfigurable transmitarray with variable focuses is presented in this paper. The system utilizes a transmitarray to generate shaped beams for imaging applications, offering improved resolution and flexibility compared to conventional imaging methods.
This article presents a new reconfigurable reflectarray concept involving mechanical actuators that modify the shape of an RF conductive flexible ground plane. The distance between the ground plane and the cells is used to control their reflected phase. A dedicated design methodology is proposed to optimize the performance while maintaining the number of actuators. As a first illustration, a 10 panel providing three different shaped beams with only four actuators is studied. Full-wave simulations with HFSS are used for validation.

11:40 Performance Assessment of a Reconfigurable Circularly Polarized Reflectarray at K-Band
Roger Farias (Instituto Superior Tecnico, Portugal); Custodio Peixoto (IST-University of Lisbon, Portugal); Marcos V. T. Heckler (Universidade Federal do Pampa, Brazil)
The performance assessment of a 2-beam electronically switchable circularly polarized reflectarray antenna based on single layer circular microstrip patches with phase delay line stubs is presented. Pseudorandom numerical analysis demonstrates the reflectarray capability to switch its main beam between 9.11 and 18.2° from the boresight in K-band (17.7-20.2 GHz). A very simple preliminary model is used for the estimated PIN diode switches. For an array with 20x20 unit cells, the achieved gain is above 27.2 dBic and the side-lobe level is below -18.2 dB at 10°. Moreover, a remarkably low axial ratio of 1.1 dB is obtained for the whole frequency band of operation.

12:00 Bandwidth and Efficiency Enhancement for 2-D Beamsteering Reflectarray Operating at X Band
Michael Trampler (L3Harris, USA); Ricardo Lovato and Xun Gong (University of Central Florida, USA)
Continuous beamsteering reflectarray can be realized by loading unit cell antenna elements with tunable diodes. In a single-layer reflectarray unit cell, there is a fundamental limit in phase range loss and bandwidth. In order to enhance the frequency bandwidth without sacrificing the phase range and loss performance, dual-resonance unit cells are implemented to achieve >360 degree phase range with lower loss compared to single-resonance designs. A 2-D beamsteering reflectarray using dual-resonance antenna elements is designed, fabricated and measured, exhibiting 7.81-348 GHz fractional bandwidth, 15.02 dB gain, and up to ±30° beamsteering angles operating at 10.1 GHz. This reflectarray is able to scan the beam in two dimensions.

T10-P02: Propagation Modelling and Simulation
T10 EM modelling and simulation tools / Regular Session / Propagation
Room: B9
Chairs: Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal), Yang Miao (University of Twente, The Netherlands)

8:30 Deterministic Radio Channel Characterization for Near-Ground Wireless Sensors Networks Deployment Optimization in Smart Agriculture
Hicham Khaina (University of Vigo, Spain); Imanol Picallo (Universidad Publica de Navarra, Spain); Peio Lopez Iturri (Universidad Publica de Navarra, Spain); Leyre Azpizueva and Mikel Celaya-Echarri (Tecnologico de Monterrey, Mexico); Otman Aghzout (UNSA Toubin - UAE, Morocco); Francisco Falcone (Universidad Publica de Navarra, Spain); Ana Alejos (Universidad de Vigo, Spain)
In this paper, a deterministic propagation modeling for wireless sensor networks in agriculture fields is presented. The impact of corn and potato fields on near-ground radio propagation is analyzed by means of an in-house 3D Ray Launching Simulator. Corn and Potato fields models have been developed taking into account the dielectric properties of each and every component of the field, as well as its morphology. Analyzing and understanding the influence of these fields on the wireless propagation is one of the important keys to the deployment of an optimal low cost WSN in smart agriculture.

8:50 Indoor Channel Estimation Using Single-Snapshot Wideband Measurement
You Al, Michael Cheffena, Marshed Mohamed and Ahmed Al-Samman (Norwegian University of Science and Technology, Norway)
The successful design of communication systems generally requires knowledge of various channel characteristic parameters. This paper utilizes the reverberation time extracted from single snapshot wideband measurement to estimate different indoor propagation parameters based on the room electromagnetics theory. The indoor room environment is conceived as a lossy cavity that is characterized by the diffuse scattering components resulting from the surrounding walls and objects and possibly a line-of-sight (LoS) component. The main advantages of the room electromagnetics-based approach are simplicity and good accuracy. The approach needs only one wideband measurement in order to extract the reverberation time in addition to some dimensional information on the investigated room to predict various important channel parameter of great importance. The measurements show good agreement with the theoretical-predicted results.

9:10 Teohartz MIMO Fading Analysis and Propagation Analysis and Doppler Shift in Tilt bands due to the effect of cooling airflow turbulence, which causes cables (lying in the wireless propagation path) to vibrate is also measured. A two-dimensional (2-D) geometrical propagation model that includes moving scatterers (cables) is introduced. From the 2-D model, a corresponding Doppler power spectrum (SPS) is derived and validated with measured data. This work is pertinent to FIT tilt systems for design in a data-center environment.

9:30 Radiowave Propagation Modelling in the Presence of Wildfires: Initial Results
Stefania Fara (University of Modena and Reggio Emilia, Italy); Carlos A. Fernandes (Instituto de Telecomunicacoes, Portugal); João M. Felicio (Instituto de Telecomunicações, Portugal); Carlos Salema (I.S.T. - Technical U. Lisbon / IT Lisbon, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)
In this paper, a thorough study of radiowave propagation phenomena in the presence of wildfires is presented. Electrical modelling of a fire environment based on computational fluid dynamics is revisited. Modelling of the fire phenomena in terms of its refractive index and combustion of cold plasma lays the foundation for considering the fire environment as a propagation medium. Electrical models are formulated that are used to predict the effects of calculating propagation characteristics based on thermal convection to create a plasma surface under fire environments and, thus, to determine the excess loss arising in the burning area. The paper presents initial results for single trees under fire at 385 MHz, envisaged to assist in the identification of radio exclusion zones in real-time during wildfires, in mission critical applications.

Hang Mi (Beijing Jiaotong University & State Key Laboratory of Rail Traffic Control and Safety, China); Dapeng He, Ke Guan and Bo Ai (Beijing Jiaotong University, China); Chenji Liu, Tianyun Shui, Lijiu Zhu and Hui Mei (Jiangxi Mobile Communication Company Limited, China)
Accurate channel estimation is critical to the design and deployment of wireless communications systems. Traditional ray-tracing (RT) based deterministic channel modeling has been considered as a key candidate to generate accurate channels for specified scenarios, however, the efficiency of RT decreases as the complexity of the environment increases. This factor significantly limits the scalability of RT, thus the acceleration technologies are highly demanded. In this paper, six space partitioning methods, including the uniform grid and the k-dimensional (k-d) tree, are implemented to accelerate RT by changing the storage structure of the environment. The efficiencies of both methods are compared in different environments with different configurations. As expected, the efficiency of RT has been improved considerably after acceleration, and the application scenarios for both acceleration methods are derived. Finally, by comparing with the measurement and simulation, it is found that the accuracy of RT is not influenced after being accelerated.

10:10 Coffee Break

10:40 A Speed Up of Split-Step Wavelet for the Computation of Long Range Propagation
Thomas Bonnafont, Rémi Douvenot and Alexandre Chabot (ENAC, France)
The atmospheric long-range propagation above the ground is of major importance for many ground systems as radars. The split-step wavelet method allows to compute efficiently this propagation using a pre-compiled library for the wavelet-to-wavelet propagation. In this paper we propose a new method to efficiently compute the library needed for the propagation. From numerical experiments, we show that this novel method is faster to compute the library and as efficient in terms of precision and memory storage as the previous version.

11:00 3D Simulation of Infinite Baffle Diffraction
Christopher G Hynes (Georgia Tech, USA); Alenka Zajic (Georgia Institute of Technology, USA)
Diffraction formulations have infinite boundaries whereas simulations are provided with strictly limited dimensions. Consequently, the simulation of diffraction effects is challenging. Here, 3D electromagnetic simulations are described and compared against theoretical results for the diffraction of normally incident plane waves onto semi-infinite and infinite strip baffles. A detailed description is provided of the 3D simulation configuration necessary to successfully simulate the model. A simple expression is presented for the diffraction of an infinite strip. We show that it is possible to achieve excellent agreement between the Uniform Geometrical Theory of Diffraction and simulations. Accurate simulation results were only achieved by using the frequency domain with periodic boundary conditions and appropriately handling the bottom boundary for semi-infinite baffle diffraction.

11:20 Simulation-based Investigation on Massive Multi-Antenna System as to Spatial Channel Hardening for Mobile Single User in a Controlled MultiPath Environment
Hang Mi (University of Twente, The Netherlands); Sofie Pölln (KU Leuven, Belgium); Andrés Alayón Glaunz (University of Twente, The Netherlands) and Daniel Fält (Chalmers University of Technology, Sweden)
This paper brings up the concept of spatial hardening of massive MIMO radio channel in a controlled multi-path cavity. The motivation is that, for a mobile user active in certain area, the massive multi-antenna system shall guarantee the channel hardening in that area. This paper simulates the radio channel confined in a controlled indoor cavity using ray tracing, where the propagation environment contains reflecting and absorbing walls. The multipath channels comprising of direct paths and specularly reflected paths up to a second order are analyzed as function of the large scale area topology and configuration in the cavity. We analyze the area focusing performance using a novel spatial channel hardening metric. This study is instructive for massive MIMO system design targeting at steadily hardening channel in an area for user with mobility.
11:40 A Gamma Beta Mixture Model for Channel Multipath Components Clustering
Cheng Sun, Yupeng Li, Pan Tang and Jianhua Zhang (Beijing University of Posts and Telecommunications, China); Lei Tian (Beijing University of Posts and Telecommunications & Wireless Technology Innovation Institute, China)
In this paper, a Gamma Beta mixture model (GBMM) is proposed to cluster multipath components (MPCs) where the gamma distribution is utilized to fit the delay data and angle data is fitted with beta distribution. We optimize the GBMM parameters with the expectation-maximization (EM) algorithm. Specially, in the M step of the EM algorithm, the Newton-Raphson method is utilized to optimize the GBMM parameters since we could not get closed solutions. To verify the clustering effect, an outdoor-to-indoor (O2I) measurement activity at 3.5 GHz was conducted. Simulation results based on real-channel measurement data indicate that, compared with Gaussian-mixture-model (GMM), GBMM has better clustering performance.

12:00 Time-Domain Modelling of Solid State RF Receiver Protection Systems
Luke J K Matthews (The University of Nottingham, United Kingdom (Great Britain)); Ana Vukovic (University of Nottingham, United Kingdom (Great Britain)); Christopher Mellor (Nottingham University, United Kingdom (Great Britain)); Phillip Sewell and Trevor Benson (University of Nottingham, United Kingdom (Great Britain))
We investigate the effects of switching the state of a PIN diode from insulating to conducting as a component within a Solid State Receiver Protection (SSRP) system. The investigation follows a component adding process, ultimately arriving at a full configuration of a metallic post insulated from the waveguide by two dielectric blocks in the Off-state, which is then connected at one end in the on state. The effects of the diameter of the post are also studied. The S-parameters of the system are calculated from the voltage and current transmission line observations sampled directly with a single time-domain-numerical-method based upon an unstructured mesh.

CS11: Antenna Design and Fundamental Bounds with External Constraints
T11 Fundamental research and emerging technologies / Convened Session / Antennas
Room: B10

8:30 Physical Bounds on Antennas with Feed Constraints
Mats Gustafsson (Lund University, Sweden); Miloslav Capek (Czech Technical University in Prague, Czech Republic)
Antenna current optimization has been used to derive physical bounds on antenna parameters such as Q-factor, efficiency, gain, directivity, capacity, and radiation patterns. The success of the methodology is partly due to the assumption of perfect control of the antenna current in the antenna region which in practice producing an array antenna with multiple feeds. Details of the feed such as input impedance and placement are however essential in antenna synthesis and there has so far been no successful approach to include these types of constraints. In this presentation, we illustrate how feed constraints can be included in current optimization and discuss its associated challenges.

8:50 Characteristic Mode Analysis of Mobile and Wearable Antennas in Lossy Environment
Pasi Yli-Ojala, Anu Lehtovuori and Rasmus Luomanen (Aalto University, Finland)
Performing characteristic mode analysis for lossy structures is a new research theme, which can offer novel insights into the mobile and wearable antenna design. In this paper, we study two cases where lossy environment has a significant effect on the performance of an antenna: a mobile device in the user’s hand and a smart watch in the wrist. We show how introducing lossy objects into the model changes the characteristic modes and makes interpretation of the results and their usability in practical antenna design more challenging.

9:10 Adapting Frequency Domain Physical Bounds for the Analysis of Time-Varying Transmitters
Kurt Schab (Santa Clara University, USA)
Based on recent theoretical and experimental results, a class of ideal transmitters based on time-varying matching networks (direct antenna modulation) is modeled using time domain distortion and classical models of ohmic conduction losses. This model is compared against classical bandwidth-efficiency bounds on linear time-invariant transmitters. Results show that optimal performance gains using direct antenna modulation is highly dependent on resonance conditions and matching network loss models.

9:30 High Directivity, Omnidirectional Horizontally Polarized Antenna Array for Wireless Power Transfer in Internet-of-Things Applications
Wei Lin (University of Technology Sydney, Australia); Richard Ziolkowski (University of Technology Sydney and University of Arizona, USA)
A high directivity, compact, omnidirectional horizontally polarized (DHP) antenna array is developed for wirelessly powering internet-of-things (IoT) devices. The antenna array is realized by seamlessly inserting several phase inverters inside an electrically long TISO.01 mode open waveguide. The phase inverter consists of a meandered slot and eight shorting vias. The meandered slot creates an interrupted structure on the top surface of the waveguide; it introduces capacitance. The eight shorting vias are placed in an alternating pattern on the two sides of the slot; they produce inductance. The combination of the slot and via forms a bandpass effect and inverts the electric fields in the waveguide. Consequently, a collinear and in-phase magnetic dipole array is realized. A compact eight-element DHP magnetic dipole array is designed, fabricated and measured. The measured results confirm the design concept and high directivity (10.4 dBi), omnidirectional HP radiation pattern has been achieved.

9:50 Fundamental Bounds for Volumetric Structures and Their Feasibility
Miloslav Capek and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden); Kurt Schab (Santa Clara University, USA)
Fundamental bounds on antennas and scattering metrics are presented in this paper utilizing volumetric method of moments. This makes it possible to investigate scenarios not solvable with classical surface method of moments which assumes that good conductors are used. One practical example is the study of planar monolithic devices whose operation relies on the interaction between material properties and radiation mechanisms. The implementation of the code is briefly summarized, including some implementation hints which allow for fast evaluation of necessary matrix operators. Two optimization problems are introduced and solved for scattering and antenna problems. Feasibility of the bounds will be investigated with topologic optimization and the results will be presented during the conference.

10:10 Coffee Break

10:40 Nesting Dual Tapered Additively Manufactured Helical Antennas for Size Reduction Constraints
Yousuf Tawk and Joseph Costantine (American University of Beirut, Lebanon)
This paper presents a novel technique of designing dual tapered helical antenna structures that are 3D printed and nested within each other for size reduction. Each tapered-helical antenna element is designed to operate at a distinct span of frequencies. The two helical antennas are nested together and wrapped in opposite direction to each other in order to satisfy orthogonal polarization. The two helical elements are fabricated using a laser based 3-D printing process where good measured radiation behavior is obtained.

11:00 Experimental Assessment of Q-factor Bounds for Miniature Embedded Antenna
Fabien Ferrero (University Nice Sophia Antipolis, CNRS, LEAT & CREMANT, France); Lars Jonsson (KTH Royal Institute of Technology, Sweden); Philippe Ratafazza (Orange Labs, France)
This work presents the experimental assessment of frequency bandwidth limits on 2x2cm antenna embedded in a 5x5cm terminal at 900MHz. A meander inverted F antenna is synthesized, prototyped and measured. Frequency bandwidth and radiation efficiency are extracted from radiation measurement. Comparison with optimal bounds on Q-factor show that this structure can reach the bandwidth fundamental limit.

11:20 Optimal Bounds and Matching Networks of Fixed Degree and for Frequency Varying Impedances
David Martinez Martinez (Inria Sophia Antipolis, France); Adam Cooman (Ampleon, The Netherlands); Fabien Seyfert and Martine Olivi (Inria Sophia Antipolis, France); Stéphane Bila (XLIM UMR 7252 Université de Limoges/CNRS, France)
In this paper, matching networks of finite degree are computed. Additionally the presented results are compared with the lower fundamental bounds available in the literature. These bounds are used to certify the optimality of the provided matching networks in function of the attained matching tolerance. To illustrate the presented results, two different examples of matching problems are presented.

11:40 Q-factor Bounds for MIMO Antennas
Casimir Ehrensson and Mats Gustafsson (Lund University, Sweden); Miloslav Capek (Czech Technical University in Prague, Czech Republic)
The optimal spectral efficiency of MIMO antennas operating in an ideal channel with bandwidth requirements is analyzed in this paper. An optimization problem formulated in the input ports of a MIMO antenna is relaxed and solved to find an upper bound on the spectral efficiency using current optimization. It is shown that the solution depends on the restricting Q-factor and a set of modes known as energy modes. A simple and useful method for using these modes to evaluate the quality of different shapes and design strategies is presented. It is shown that characteristic modes naturally maximize spectral efficiency by comparison to the energy modes. The ratio of spectral efficiency over Q-factor is studied and the existence of Pareto optimal Q-factor for the trade off between them is shown.

12:00 Transparent mm-Wave Array on a Glass Substrate with Surface Wave Reduction

125 of 128
CS20: Assessment and Modeling of Antennas and Radio Channels Jointly

TOP

T10 EM modelling and simulation tools / Convened Session / Antennas

Room: B11

Chair: Danping He (Beijing Jiaotong University, China), Alain Sibille (Telecom ParisTech, France), Raffaele D’Errico (CSEA, LETI, Minatec Campus & Univ. Grenoble-Alpes, France)

8:30 Including the Aircraft and the Antenna in a Wideband Aeronautical LMS Channel Model
Capucine Amieh, Alexandre Chabory and Christophe Macabiau (ENAC, France); Laurent Azoulai (Airbus Commercial Aircraft, France)

During expert ground navigation, aircraft pass close to obstacles such as buildings other. These obstacles may be few meters from the antenna. In this context, modeling the antenna plus aircraft system as a radiation pattern is not justified due to the far-field hypothesis. To overcome this issue, the idea proposed here is to reduce the size of the radiating element to the antenna itself and to account for the aircraft structure in another way. To do so, the antenna plus aircraft is divided into 3 zones which contributions are dealt separately: the antenna is seen as gain, phase and group delay patterns, the fuselage in the near field of the antenna is modeled as a single multipath and the rest of the aircraft is considered as a source of multipath. By means of the theorem of superposition, the different contributions are gathered to get the complete antenna/aircraft model.

8:50 Antenna Perturbation Modelling and Impact on Radio Channel
Laura Pometru and Raffaele D’Errico (CSEA, LETI, Minatec Campus & Univ. Grenoble-Alpes, France)

In this paper we investigate a joint antenna-channel model, considering stochastic variability on the radiating element. We considered a wide-based monopole antenna with a metallic metallic perturbation, whose position is random. The perturbed antenna characteristics are described through spherical wave expansion modes coefficient distribution in order to produce a stochastic antenna model. This model is then considered in a classical single cluster and indoor industrial channel, in order to evaluate the impact on delay and angular spread.

9:10 The Influence of Self-User Shadowing in the Intra-Metro Communication Scenario at 28 GHz
Yuxuan Xu, Danping He, Haofan Yi and Ke Guan (Beijing Jiaotong University, China), Mikko Heino (Aalto University, Finland); Marko Sonkki (University of Oulu, Finland)

Nowadays metro plays an important role in people’s daily life. It is significant to realize a high-data-rate wireless connectivity in metro corridors. In this paper, the intra-metro communication with the consideration of self-user shadowing at 28 GHz are characterized by ray-tracing (RT) simulation. The three-dimensional metro model is reconstructed according to the actual size of Madrid Metro. Based on the RT simulation results, totally six cases (three transmitter deployments, with and without self-user shadowing) are characterized in terms of angular spreads, received power, root-mean-square (RMS) delay spread. Once the user shadows the channel, the received power will be approximately 15-25 dB less than that of unshadowed. Compared with the parameters of angular spreads and RMS delay spread without shadowing, the wireless link is established by NLOS due to the self-user shadowing effect. These results provide valuable insights into the system design and evaluation for wireless communications inside the metro scenario.

9:30 Joint-Antenna-Channel Modelling for In-out-Body Propagation of Dairy Cows at 868 MHz
Said Benassa (Ghent University/imec, Belgium); Leen Verloot (IBBT - Ghent University, Belgium); Denys Nikolayev (Institut d’Électronique et de Télécommunications de Rennes (UMR CNRS 6164), France); Margot Deruyck (Ghent University - IMEC, Belgium); Gunter Vermeeren and Luc Martens (Ghent University, Belgium); Frank Tuyttens and Bart Sonck (Ghent University, Belgium)

In this paper, for the first time, the in-to-body path loss between a capsule antenna placed on the cows’ rumen and a distant gateway was characterized at 868-MHz. Measurements were conducted on different fed/fattened cows in a dairy farm. The in-body antenna gan was then de-embedded from the wireless channel. The difference between free space measurements and in-out body path loss assessment was used to quantify the path loss increase due to the cow’s body. Results have shown an increase of the path loss on average (all cows) by 50.6 dB, with a variation between 43.7 and 55.3 dB. The obtained results were used to calculate the range of a LoRa (Long range) based network accounting for the antenna channel. With an input power transmit of 14 dBm, range up to 175 m indoor and 384 m outdoor were obtained depending on the used flat rate.

9:50 A Practical Deconvolution Antenna Method to Retrieve Scattering Profile in Complex Random Media - A Vegetation Case Study at 28 GHz
Nuno R. Lesnors (Instituto de Telecomunicações, Portugal); Telmo R. Fernandes (IPLeiria / Instituto de Telecomunicações & ESTG/IT, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

This paper presents a method to improve the extraction of the Radiative Energy Transfer (RET) theory input parameters for application in vegetation attenuation modeling. The input parameters for this model, which are extracted from specific measurement data, are normally influenced by the radiation pattern of the receiver antenna. A new method to improve the accuracy of the scattering function parameters obtained from measurements is presented. This method is based on the prior analysis of the antenna's radiation pattern distortion while measuring the scattering function, allowing the development of calibration curves, to correct the distorted propagation parameters. The proposed method was tested with measurements conducted inside an anechoic chamber, using real indoor trees, mimicking a forest scenario using various different receive antennas at 28 GHz, and the model accuracy improvement was assessed at various vegetation depths.

10:10 Coffee Break

10:40 Towards Hybrid Statistical-Deterministic Wireless Channel Modelling of Multicultural Environments
Valon Blakaj (Research Associate, United Kingdom (Great Britain)); Shukai Ma (University of Maryland, USA); Steven Anlage (Center for Nanophysics and Advanced Materials, USA); Gabriele Gradoni (University of Nottingham, United Kingdom (Great Britain)); Thomas Antonsson (University of Maryland, USA); Stephen Creagh and Gregor Tanner (University of Nottingham, United Kingdom (Great Britain))

This paper presents a radio channel model for directionally resolved ultra-wideband radio measurements, which takes the directionality of a steerable antenna into account. We outline a figure of merit to assess the quality of multipath components (SMCs) for positioning applications, the signal-to-noise-and-interference-ratio (SNIR), and perform an analysis thereof for a practical environment on the basis of a measurement campaign conducted in a park/wood. The angle resolved analysis of the SINFs of various SMCs establishes a site specific model of the radio environment that can be leveraged for location-aware radio positioning and communication systems.

11:00 Directionally Resolved UWB Channel Modelling for Environment-Aware Positioning
Michael Rath and Erik Leitinger (Graz University of Technology, Austria); Arth Nguyen (Hanoi University of Science and Technology, Vietnam); Klaus Wichtal (Graz University of Technology, Austria)

This paper presents a realistic UWB channel model for indoor environments. The model is based on measured ray tracing data and computer generated ray tracing. The proposed channel model is suitable for UWB channel simulations in indoor environments. The model is implemented in the framework of the TSPL library and can be used as an extension of existing ray tracing environments.

11:20 Millimeter-Wave Indoor Channel Measurement and Intra-Cluster Modelling
Miroseok Kim, Satoru Kishimoto and Keita Akasaka (Niigata University, Japan)

A quasi-deterministic (Q-D) channel that considers the millimeter-wave propagation properties and has been adopted in IEEE 802.11ay. This study conducted the measurement campaigns in a conference room environment to develop and validate the Q-D channel modeling for indoor use scenarios. Using a super-resolution path estimation algorithm, the multi-path clusters were extracted from the measurement data via the scattering process identification and clustering algorithm. This paper presents the stochastic model parameters (intra-cluster parameters) obtained from the clusters generated by the first-order specular reflection over the plasterboard wall which is a typical interior wall material. Moreover, they were experimentally validated via measuring small-scale fading due to specular reflection and diffuse scattering.

11:40 Massive Radio Channel Sounder Architecture for 5G Mobility Scenarios: MaMMOSA
Pierre Lalé, Davy P Galliot and Gauthier Debarr (University of Lille, France); Matthias Van den Bosche and Gunter Vermeeren (Ghent University, Belgium); Frédéric Chaillet (University of Lille & IEMN Lab, France); Emmeric Tanghe (Ghent University, Belgium); Eric P Simon (University of Lille, France); Wout Joseph (Ghent University/IMEC, Belgium); LucMartens (Ghent University, Belgium); Martine Léandré (University of Lille, France)

This paper presents a real-time 4x4 x 16 massive MIMO (mmWave) channel sounder using switching, a large number of antennas and frequency tuning between 2 and 12 GHz. This channel sounder called MaMMOSA/ MaMMOSA belongs to the new generation of software radio design systems. The application of this paper was designed with the highest flexibility thus opening a wide range of applications depending upon the investigated scenarios. Currently, the system is being setup using a massive 10 x 10 antenna array operating around 6 GHz with 80 MHz bandwidth for 5G V2X applications. The channel sounder can be powered with vehicle batteries to perform day long measurements when electrical outlets are not available. The output file shows the measured Massive MIMO matrix in a friendly compact binary format. It will be operational in early 2020.

12:00 Smart Dipole Arrays for Radio Channel Enhancement
Juan Bucheli García (Huawei Technologies & Telecom ParisTech, France); Alain Sibille (Telecom ParisTech, France); Mohamed Kamoun (Huawei France, France)

In this paper, a transparent dual-element millimeter-wave (mm-wave) array for handsets is proposed. The antenna is mounted on top of a glass display and it is made by diamond grid cells that provide a transparency of 85 %. In order to reduce the surface waves generated and make the radiation pattern more directive, several rows of meshed patches have been placed in front of the mm-wave box array. The antenna array operates from 26.5 to 29.5 GHz and has a total efficiency of more than 70 % in the operating bandwidth. The array is able to steer the beam 70 ° with a realized gain higher than 7 dB.
Robertino Olmi measured and simulated results, including those available in the literature for the considered materials. Ansoft HFSS software. For validation purpose, a prototype of the proposed antenna is fabricated and measured. Thereafter, the design procedure is validated using the prototypes with the antenna resonant frequency variation in each case. A good agreement is observed between measured and simulated results.

A new bioinspired microstrip antenna is proposed to determine the electrical permittivity of dielectric materials. The antenna structure is based on the idea of a "split-ring resonator" and consists of a single patch supported on a grounded interdigital capacitor (CIDC) is inserted in the patch antenna geometry. The antenna is simulated and designed using the Planar Near Field measurements is investigated for the first time. A standard gain horn, MVG SGH4000 has been measured at 240 GHz with the antenna resonant frequency in each case. A good agreement is observed between measured and simulated results.

Dielectric constant with tolerable performance degradation. It provides a cost-effective solution of measuring the permittivity of dielectric materials. Two back-to-back connected through their differential ports. The Marchand balun that is robust against variations of substrate height or dielectric constant. It makes it compatible for fabrication with economical PCB development technology. For optimal choice of height for a given application, guidelines and by means of spectra integrals approach.

The interest for mm- and sub-mm-wave systems has grown in the last years, mostly driven by communications and radar industry. In this context, not only new wideband high-gain antenna concepts are needed, but also advances in the applied antenna measurement procedures. In particular, the characterization of circularly polarized antennas represents a challenge in the higher frequencies, as the difficulty of achieving accurate phase measurements increases. In this work, the experimental characterization of a circularly polarized lens antenna in G-band (140-220GHz) is presented. Accurate measurement results are reached for the circularly polarized field, showing excellent agreement with simulations.

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11:20 Broadband Microwave Dielectric Property Comparison of Human Fetal Osteoblastic (hFOB) and Osteosarcoma (SaOS-2) Cell Lines

Zeynep Macit, Cemanur Aydinalp, Tuba Yilmaz, Ayse Buse Ozdabak Sert and Fatma Nese Kok (Istanbul Technical University, Turkey)

This study investigates whether the dielectric property discrepancy is consistent on cell level between the malignant and normal cell samples to identify sources for dielectric property discrepancy in tissues and to enable microwave pathological applications. To this end, the dielectric properties of human fetal osteoblastic (hFOB) and osteosarcoma (SaOS-2) cell lines were measured in the frequency range of 500 MHz to 10 GHz using an open-ended coaxial probe. The measurements were conducted on pellet form and suspension form of cells, since there is no consensus on the protocol of cell line broadband dielectric property measurement. The discrepancy between hFOB and SaOS-2 cell suspensions at the whole measurement frequency range are 0.1480% and 2.8267% for relative permittivity and conductivity, respectively. In pellet measurements, calculated percent discrepancy are to 2.1895% for relative permittivity and 3.6766% for conductivity.

11:40 Non-invasive Blood Glucose Measurement Based on Microwave Resonator

Ayodunni Oloyo and Zhirun Hu (University of Manchester, United Kingdom (Great Britain))

This paper presents a novel method for non-invasive continuous monitoring of blood glucose level using a microwave resonator. The technique has been tested on 8 participants for three days to determine the correlation between the standard invasive method of measuring blood glucose level and proposed novel non-invasive method. The results show a good correlation (R²=0.9967) between the novel non-invasive method and the standard invasive method with a percentage error of 2%, experimentally verifying that microwave resonator is capable of measuring the blood glucose level in a non-invasive way with minimum error and has the potential to replace the standard invasive method of measurement. The non-invasive measurement of blood glucose level has vital advantages for the management of diabetes and would significantly improve the health of diabetes patients. This approach would also help the NHS by reducing £1.5m spent every 10 minutes on diabetes. Index Terms- Diabetes, Non-Invasive Measurement, Permittivity.

12:00 Dielectric Spectroscopy Characterization Within a Microfluidic Device Based on Open-Ended Coplanar Waveguide

Houssein Mariam (Université Paris-Est Marne-la-Vallée, France); Patrick Poulichet (ESIEE, France); Hakim Takhedmit (Paris-Est Mame-la-Vallée University, France); Elodie Richalot (Université Paris-Est (Mame-la-Vallée), France); Olivier François (ESIEE Paris, France)

This paper reports a new instrumented microdevice which allows the characterization of liquid media by dielectric spectroscopy. Coplanar waveguides (CPW) in an open-ended configuration are used within a microfluidic channel and compared according to the shape of the aperture: single open-end or interdigitated capacitor. These microdevices are used in order to extract dielectric permittivity properties of liquid media. The proposed CPW sensors are analyzed and characterized in reflection within the frequency band ranging from 0.15 to 3 GHz. Microtechnologies are used to fabricate the devices which are coupled with microfluidic capability. The microfluidic channel is 150 µm high and typical size of the interdigital capacitor is associated to an area of 150 µm length x 90 µm width. The volume under test is in the nanoliter range which is compatible with biological cells characterization and represents a progress in this field of interest.

Friday, 20 March 12:30 - 13:30

CC: Closing Ceremony

Room: A2

Chairs: Olav Breinbjerg (Technical University of Denmark, Denmark), Cyril Mangenot (Api-Space, France)