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<td>CS02: Advanced Antenna Arrays for 5G and Beyond</td>
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<td>Antenna Arrays for Wide-Sense Vehicle-to-X Communications</td>
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<td>CS21: Challenges in Leaky Wave Antennas and Novel Approaches to Solve Them</td>
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<td>CS34: Controlling EM Waves with Low- and High-Dimensional Metamaterials</td>
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<td>T01-E08: Metamaterials, Metasurfaces and Advanced Materials</td>
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<td>MW05: Frontline of 5G workshop: Insights on 5G antenna &amp; propagation R&amp;D from Sony and regional partners (Sony)</td>
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<td>IW01: Key Advantages of Combining Measurements and Simulations for Antenna Applications (MVG)</td>
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<td>CS9: Analytical and Numerical Methods for Metasurface Analysis and Design</td>
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<td>CS16: (cont’d)</td>
<td>T10-M10: General Antenna Measurements</td>
<td>CS01: (cont’d)</td>
<td>CS60: (cont’d)</td>
<td>SW02: (cont’d)</td>
<td>T09-P08: (cont’d)</td>
<td>CS9: (cont’d)</td>
<td>CS39: (cont’d)</td>
<td>T10-E03/1: Computational and Numerical Techniques 1</td>
<td>SW08: (cont’d)</td>
<td>IW08: From 5G Research to Real Deployments: Industrial Experiences and Challenges (Ericsson AB)</td>
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Programme for the 14th European Conference on Antennas and Propagation (EuCAP 2020) (ver. 27 Feb 2020)
### Wednesday, 18 March

**08:30-10:10**
- **T09-A19:** Reflectarrays and Transmitters
  - CS56: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring
  - CS30: Antenna Array and Integrated Systems for 5G Communication Applications
  - CS27: Electromagnetics in MRI Applications
  - CS31: Recent Research on Wind Turbines: EM Modelling and Measurements

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

**10:40-12:20**
- **T09-A19:** (cont'd)
  - CS56: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring
  - CS30: Antenna Array and Integrated Systems for 5G Communication Applications
  - CS27: Electromagnetics in MRI Applications
  - CS31: Recent Research on Wind Turbines: EM Modelling and Measurements

**12:20-13:00**
- Lunch (Exhibition Hall)
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<th>Time</th>
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<td>Regular Poster Sessions 2: Exhibition Hall</td>
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<td>IS-Wed 1/2: Invited Speaker Session IS-Wed 2/2: Invited Speaker Session</td>
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<td>Conference Dinner (Wallmans)</td>
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<td>13:00-14:00</td>
<td>Best Paper Awards Poster Sessions: Room A2 (Poster Area) Antennas Electromagnetics Propagation Measurement Best Student Paper</td>
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<td>Regular Poster Sessions 3: Exhibition Hall</td>
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### Friday, 20 March

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<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: I7 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-E06: Scattering and Diffraction</td>
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<td>T11-M05: EMI/EMC/PIM chambers, instrumentation, and measurements</td>
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<td>SW06: HP20, Session ID14479 (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 Modeling 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>T02-M08: Mm-wave, THz, and Quasi-optical Antenna Measurements</td>
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<td>T11-M01: Material Characterisation and Non-destructive Testing</td>
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<td>12:30-13:30</td>
<td>CC: Closing Ceremony</td>
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Monday, 16 March

**OC: Opening Ceremony**
Room: A2
Chairs: Olav 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 sensors 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.

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 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 commutated switching networks 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 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)

Monday, 16 March 13:30 - 15:30

**CS02: Advanced Antenna Arrays for 5G and Beyond**

**T02 Millimetre wave 5G / Convened Session / Antennas**
Room: A2
Chairs: Y. Jay Guo (University of Technology Sydney, Australia), Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)

13:30 Beam Steerable Reflectarray Enabling CubeSat Internet of Space: Conceptualization and Design
Junho Wang and Vignesh Manohar (University of California, Los Angeles, USA); Yahya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)

The vision of Internet of Things (IoT) has evolved the needs of providing seamless connectivity between devices across the globe. A potential solution to this requirement is to launch a CubeSat constellation that can provide broadband Internet access to rural and underserved areas (Internet of Space (IoS)). This has escalated the need for low-cost, low-profile antennas with wide angle beam steering capabilities. In this work, we elaborate on the design of a broadband, circularly polarized reflectarray capable of dynamic beam steering in the frequency range of 17.8-20.3 GHz. The reflectarray unit-cell consists of a set of four copies of rotated Archimedean spiral arms, and the desired phase shift is obtained by suitably switching between these arms through PIN diodes. Representative prototypes have been fabricated and measured, and beam scans up to 60° have been achieved.

13:50 A Wideband Differentially Fed Multi-beam Antenna Array
He Zhu and Y. Jay Guo (University of Technology Sydney, Australia)

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.

14:10 On the Design of a 27-dBi Phased Array for 5G Point-to-Point Communications

He Zhu and Y. Jay Guo (University of Technology Sydney, Australia)
Furthermore, we investigate the change trend of the RMS DS along the garage entrance, and find that the special structure of the building has a significant effect on the RMS DS. These results are helpful to design the physical layer for the future V2V communication systems.

In this paper, the V2I communication in mmWave band (22.1GHz-23.1GHz) is characterized for typical urban and highway scenarios. Density estimates in the region with clear wide-angle view are conducted by employing the self-developed ray-tracing. The key channel parameters, including received power, Rician K-factor, and Doppler shift were studied as well. Multipaths were periodically observed in the analysis results. It was caused by the presence of metallic objects regularly installed along the tracks, such as overhead power line equipments.

In this paper, we investigate millimeter-wave propagation characteristics of high-speed moving train based on field measurements and analysis. The measured data are analyzed and compared with the results obtained from the ray-tracing model. It was found that the measured data are well correlated with the ray-tracing model in terms of received power and path loss. The measured data also show that the propagation characteristics of millimeter-wave are significantly affected by the train velocity and the track configuration.

Ibrahim Rashdan, Jiri Blumenstein, and Herbert Groll

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 achieved with including the mutual coupling. The 4x4 antenna array at 10 dB with a maximum gain of 20.3 dBi is higher than any reported 4x4 antenna array. An anistatic bandwidth of 18.3% is achieved.

15:10 Millimeter-Wave Dual-Polarized Slot Array Antenna Using a TE210 and TE120 Mode

Onging Yang, Steven Gao, Lei Wu and Qi Luo (University of Kent, United Kingdom (Great Britain)); Xiaofei Ren (China Research Institute of Radiowave Propagation, China); Jian Wu (China Research Institute of Radiowave Propagation, P. R. China); Yong-Ling Ban (University of Electronic Science and Technology of China, China)

This paper presents a millimeter-wave dual-polarized slot array antenna using a SIW cavity supporting TE210 and TE120 modes. A crossed slot is etched over the cavity. The antenna-element can be excite from two orthogonal directions to realise dual-polarisation. Thanks to the orthogonality between TE210 and TE120 mode, high isolation and low cross-polarization are achieved in the antenna. A prototype of the designed array antenna is demonstrated at the center frequency of 25 GHz. The measured and simulated results are in good agreement showing that the antenna array has high radiation efficiency, high port isolation and low cross-polarisation.

Monday, 16 March 13:30 - 18:00

T02-P09: Propagation Channels for Wide-Sense Vehicle-to-X Communications

Room: A2

Chairs: Uwe-Carsten G. Fiebig (German Aerospace Center (DLR), Germany), Ke Guan (Beijing-Jiaotong University, China), Juan Moreno (Metro de Madrid S.A. & Universidad Politécnica de Madrid, Spain), Fernando Pérez-Fontán (University of Vigo, Spain)

13:30 60 GHz V2I Channel Variability for Different Elevation Angle Switching Strategies

Herbert Groll and Erich Zschachmann (TU Wien, Austria); Markus Hofer (AIT Austrian Institute of Technology, Austria); Hussein Hammoud (University of Southern California, USA); Sean Sandoobyin (Georgia Institute of Technology, USA); Thomas Zemen (AIT Austrian Institute of Technology GmbH, Austria); Jiri Blumenstein (Bnno University of Technology, Czech Republic); Ales Prokes (Bnno University of Technology & Sensor, Information and Communication Systems Research Centre, Czech Republic); Andreas Melisch (University of Southern California, USA); Christoph F Mecklenbräuker (TU Wien, Austria)

We report results based on millimeter wave v2i channel measurements carried out in an urban street environment, downtown Vienna, Austria. Signal to noise ratios (SNRs) have been acquired at 60 GHz with 100 MHz bandwidth. Two horn antennas were used on a moving transmitter vehicle: one horn emitted a beam towards the horizon and the second horn emitted an elevated beam at 15-degrees up-tilt. This configuration was chosen to assess the impact of beam elevation on v2i channel bandwidth. The variability of the v2i channel is measured in an urban street scenario. Density estimates in the region with clear wide-angle view are bimodal and motivate a 2D fading model for v2i communication based on horizontal and elevated antennas. We compare three different design models for beam steering: fixed, geometry-based, and SNR-based.

13:50 Emulation of End-To-End Communications in Railway Scenarios: Physical Layer Results

Juan Moreno (Metro de Madrid S.A. & Universidad Politécnica de Madrid, Spain); Sofiane Khatib (University of Lille, France); Laurent Claytier (Institut Mines-Telecom, Telecom Lille & IEMN / IRCICA, France); Redha Kassi (University of Lille, France); Raúl Torrego, Arturo Arizti and Iñaki Val (K4-IERLAN, Spain); Marion Berbennu (IFSTTAR, COSYS, LEOST & University Lille Nord de France, France); Jose Soler and Ying Yan (Technical University of Denmark, Denmark)

The complexity of modern communication systems is remarkable, and the efforts needed to put into service a new one are substantial as well. In some industrial sectors, circumstances are even harder. For example, in railways, the tests to be done are costly due to the integration in the rolling stock plus the need to have physical access to the railway tracks. Therefore, it is worth having a feasible emulator that consists of many different radio-access technologies (RAT) in several railway scenarios (sidetracks, tunnels, railroad, high-speed, etc.). Moreover, it should be able to do end-to-end simulation, absolutely transparent for the application layer (this is considering not only the physical layer but the network one as well). In this paper, we highlight the physical layer aspects considered in the construction of this emulator. Integration with the network layer is briefly mentioned, as well as the whole architecture.

14:10 Large Scale Fading Characteristics for Vehicle-to-Cyclist in Urban Channel Environment at 5 GHz

Ibrahim Rashdan and Michael Walter (German Aerospace Center (DLR), Germany); Wei Wang (Chang'an University, China); Giuseppe Caire (Technische Universität Berlin, Germany)

Vehicle-to-cyclist radar uses (V2C) communication provide 360 degree coverage for both vehicles and vulnerable road users (VRUs). A realistic and accurate channel model for V2C in critical accidents scenarios is of great importance for developing reliable V2C communication systems. This paper presents a large scale fading channel model for vehicle-to-cyclist channel measurement campaigns in urban environment correlating a collision scenario between a vehicle and a cyclist. A dual-path-step 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 is calculated. The underlying correlation is captured by using 2-dimensional spatially correlated shadow fading maps.

14:30 28-GHz High-Speed Train Measurements and Propagation Characteristics Analysis

Jae-Joon Park and Danping He (University of Southern California, USA); Juyul Lee, Junhyeong Kim and Ahmed Kishk (Technical University of Denmark, Denmark)

In this paper, we investigate millimeter-wave propagation characteristics of high-speed moving train based on field measurements and analysis. The measured data are analyzed and compared with the results obtained from the ray-tracing model. It was found that the measured data are well correlated with the ray-tracing model in terms of received power and path loss. The measured data also show that the propagation characteristics of millimeter-wave are significantly affected by the train velocity and the track configuration.

15:10 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 (ETRI, Korea (South))

The vehicle-to-infrastructure (v2i) communication can capture real-time traffic information and provide travelers with real-time traffic information, which is important for improving 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 millimeter band (22.1GHz to 23.1GHz) characterized for typical urban and highway scenarios. By considering the different deployments involving overlapping and traffic flow, the simulations are conducted by employing the self-developed ray-tracing. The key channel parameters, including mean K-factor, root-mean-square delay spread and angular spread, are analyzed and compared between different deployments. Moreover, the impacts 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 vehicle communications.

15:30 Millimeter-Wave Channel Characterizations for V2V Communications in the Garage Entrance

Xue Zhang and Pan Tang (Beijing University of Posts and Telecommunications, China); Le Tian (Beijing University of Posts and Telecommunications & Wireless Technology Innovation Institute China); Jianhua Zhang (Beijing University of Posts and Telecommunications, China)

To design fifth-generation (5G) vehicle-to-vehicle (v2v)-vehicle-to-infrastructure (v2i) communication systems for the future intelligent transportation system (ITS), the knowledge of channel characteristics in various communication environments is essential. In this paper, we present channel measurements at 28 GHz in a common scene, a typical urban garage entrance, and analyze the channel characteristics, including path loss, shadowing, and root mean square (RMS) delay spread (DS). These results are of channel characterizations are presented. Differences between measurement-based channel characteristics and those of the existing results are discussed.

Further investigations, we investigate the channel correlation 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.
16:00 Architecture and Performance of the Base Station Prototype for MN Systems
Sung Woo Choi and Jinhyeong Kim (ETR, Korea (South)); Seun-Ae Kim (Electronics and Telecommunications Research Institute, Korea (South)); Hee Sang Chung (ETR, Korea (South)); Igyu Kim (ETR of KOREA, Korea (South))

This paper presents current updates of the MNoS (Multi-Node System) system. The MNoS has been developed to enable individual user's Internet access in amatter wave (IM) system. The data rate that can be achieved is a significant feature of this system. The paper discusses the architecture and performance of the base station prototype for MN systems.

16:20 Bi-directional Vehicle-to-Vehicle Radio Channel Characteristics over Bridge at 5.9 GHz
Kun Yang and Nong Zhou (Super Radio AS, Norway); Terje Røste (NTNU, Norway); Junyi Yu, Fang Li and Wei Chen (Wuhan University of Technology, China); Egid Eide and Torbjorn Ekman (Norwegian University of Science and Technology, Norway); Changzhen Li and Fuxing 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, China. In this paper, a detailed description of the channel measurement campaign including antenna setup, channel sounder configurations and other related info is given. The RSL is extracted from the measured data and interpreted. The ADFP is demonstrated, from which the mean excess delay and the RMS delay spread are extracted. Cgender, this channel is used to design two waveguide phase shifter, one by pinned unit cells and the other by holey pinned unit cells. Both waveguide phase shifters are evaluated. Pinned waveguide phase shifter is also evaluated. Pinned waveguide phase shifter is also evaluated.

16:40 Comparison of a Fast Analytical Ray Tracker and Channel-Sounder Measurements for V2V Communications
Nils Dreyer (TU Braunschweig, Germany); Thomas Künzer (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 which is based on a realistic ray path tracking. Leading to a huge predictor speed up for the computation of reflectors and obstacles. In this paper we present our new extensions of the simulation framework, introducing a methodology to apply the same visibility concept on real world overview and non-spectral reflectors. Our approach is fast enough to be applied on scenarios with a realistic number of communication pairs in the future. We further evaluate our predictor for the first time by applying the model on an intersection scenario and comparing the result with a measurement campaign performed in 2009 in the Swedish city Lund. The result of the Power Delay Profile gives a good agreement between measurement and simulation, however we could observe a difference of the power distribution.

17:00 Path Loss Models and Large Scale Fading Statistics for C-Band Train-to-Train Communication
Paul Unterhuber, Ibrahim Rashdan and Michael Walter (German Aerospace Center (DLR), Germany); Thomas Künzer (Technische Universität Braunschweig, Germany)

The profound knowledge of wireless propagation is essential for the design of high-speed trains. In this paper, we present the applicability of using structures to control the phase shift in a waveguide phase shifter. By using a modal selection algorithm based on the bisection/cubic interpolation method, the best-fit models for different frequency bands are found. The results show that most of the large-scale fading can be explained by the model properties.

17:20 Shadowing and Multipath-fading statistics at 2.4 GHz and 39 GHz in Vehicle-to-Vehicle Scenarios
Hui Wang, Xuefeng Yin and Yonghong Zhang (Piecing University, China); Juyao Lee and MyungDon Kim (ETR, Korea (South))

In this paper, a recently conducted measurement campaign aiming at 39 GHz millimeter wave (mmWave) and sub-6 GHz vehicle-to-vehicle (V2V) propagation channel characterization is introduced. Simultaneous signal tracking at both mmWave and sub-6 GHz were performed in the measurements in order to evaluate the different influences of common environments and vehicle-shadowing in V2V channels. Two typical V2V examples are considered in our measurements. Channel parameters including the shadowing, fast fading, and their coherence behavior of the results are shown. The results show that most of the large-scale fading can be explained by the model properties.

17:40 Measurement and Diffuse Multipath Analysis of V2V Propagation Channel at 5.9 GHz in Tunnel Area
Suying Jiang, Xu Zhang and Wei Wang (Chang’an University, China); Yi Yang and Ruai He (Beijing Jiaotong University, China)

Vehicle-to-vehicle (V2V) communication is an essential component of intelligent transportation systems (ITS). Therefore, evaluating the influence of the radio propagation channel of V2V is of critical importance. In this paper, V2V channel measurements and analysis of V2V channel characteristics at 5.9 GHz in tunnel area are presented. The measured data is used to evaluate the V2V channel characteristics in tunnel area.

18:00 High Scanning Rate Leaky Wave Antenna Based on Glide Symmetry for 77 GHz Automotive Radar
Adrián Tamayo-Domínguez (Universidad Politécnica de Madrid, Spain); José Manuel Fernández González (Universidad Politécnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This work presents a novel leaky wave antenna with glide-symmetric properties that enhance the scanning ratio of previous works. A novel structure is designed for increasing the scanning results in required bandwidth and steering range. The proposed waveguide is based on a leaky waveguide technology to prevent the leakage due to air gaps between layers. In order to reduce the manufacturing cost, the design is aimed to 3D-printing. The new structure is designed for increasing the scanning results in required bandwidth and steering range.

18:30 Golay Glide-Symmetric Waveguide Filters for 5G Communication Systems at Millimeter Wave Frequencies
Alberto Meneghesso (KTH Royal Institute of Technology, Sweden); Nielson Fonseca (European Space Agency, The Netherlands); Oskar Zetterstrom (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 novel, fully-metallic, glide-symmetric waveguide filter. This solution is lower-loss, cost-effective, and suitable for applications at mmWave frequencies. The problem is that the CA18223 (SyMat): Periodic Structures with Higher Symmetries individual user's Internet access in a matter wave (IM) system. This work presents the novel, fully-metallic, glide-symmetric waveguide filter. This solution is lower-loss, cost-effective, and suitable for applications at mmWave frequencies.

19:00 Ultra-Wide Band Non-Dispersive Leaky-Wave Antenna Based on Glide-Symmetric Meandered Transmission Lines
Matthias Ebrahimpouri and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Anthony Grbic (University of Michigan, Ann Arbor, USA)

We present an ultra-wide band planar leaky-wave antenna based on glide-symmetric meandered transmission lines. In order to make the structure suitable for a non-dispersive leaky-wave structure is designed, the whole structure is designed along with suppressors for power levels from -60 to 60 dB. The antenna is fabricated and measured, and the results are presented.

19:30 High Scanning Rate Leaky Wave Antenna Based on Glide-Symmetric Meandered Transmission Lines
Mischa Ebrahimpouri and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Anthony Grbic (University of Michigan, Ann Arbor, USA)

In this paper, we present an ultra-wide band planar leaky-wave antenna based on glide-symmetric meandered transmission lines. In order to make the structure suitable for a non-dispersive leaky-wave structure is designed, the whole structure is designed along with suppressors for power levels from -60 to 60 dB. The antenna is fabricated and measured, and the results are presented.
15:10 Design of Antenna Arrays Using Groove Gap Waveguide Technology Implemented with Glide Symmetric Holes
Luis Fernández-Hernández (University of Oviedo, Spain); Astrid Algea Brazañez (Ericsson Research, Ericsson AB, Sweden); Malcolm Ng Mou Kehn (National Chiao Tung University, Taiwan); Eva Raji-Iglesias (University Carlos III of Madrid, Spain)
There is an exploitation designs of high directive antennas (mainly array) based on the use gap waveguide technology. In most of them, the periodic structure used as Eletromagnetic 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 (GGWG) based antennas. The use of this unit cell that is much bigger that the pins is beneficial for the manufacturing aspects but poses some challenges in the design of compact components or arrays. 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 Baghersfari (Sorbonne University, France); Julien Sarrazin and Guido Valero (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 planes of the waveguide. In addition, we demonstrate how this feature can be used to design a spurious filter.

16:20 Higher-Order Cylindrical Leaky Waves in Planar Structures
Paolo Burghignoli, Walter Fuscaldo 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 (higher-order cylindrical leaky waves, HCLW) are presented. Canonical continuous ring sources are described, capable of exciting such waves in general multilayered structures. The relevant electromagnetic potentials are derived and analytical formulas are provided for these radiation patterns in the far-field region. Guidelines for the design of discrete ring sources, i.e., circular phased arrays, for the excitation of HCLW up to a desired maximum order are also provided.

16:40 Mode-matching Analysis of Loaded Transmission Lines with Twist Symmetries
Oskar Zetterstrom (KTH Royal Institute of Technology, Sweden); Guido Valero (Sorbonne Université, France); Francesco Mesa (University of Seville, Spain); Fatemeh Ghaseemifard, Martin Norgren and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
This paper studies the propagation characteristics in higher-order symmetrical structures by means of a mode-matching approach. The studied structures are coaxial/balun Transmission line periodically loaded with 1- and 3-fold twist symmetric infinitely thin sectoral sheets. The mode-matching formulation is validated with the commercial software CST Microwave Studio. In addition, we present an example 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 Moleró (IETR-INSA Rennes, France); Lionel Simon (SWISSSto12 SA, Switzerland); Esteban Menargues (SWISSSto12, Switzerland); Tomáš Dabogovský (SWISSSto12 SA, Switzerland); María García-Viguera (IETR-INSA Rennes, France)
A metallic periodic screen is here proposed that allows for dual-band operation and polarization conversion. The unit-cell structure is monolithic and two-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 behavior. Three design examples are proposed with different polarization conversion capabilities. One of the examples concerns a dual-band polarizer providing orthogonal sense of circular polarization at both of the bands.

17:20 Exceptional Points of Degeneracy in Electromagnetic Waveguides and the Role of Symmetries
Tarek Mealy, Mohammad Y Nada, Ahmed F. Abdelshafy, Ehsan Hafezi and Filippo Capolino (University of California, Irvine, USA)
We show the relation between reflection and propagation in periodic waveguides and the existence of various exceptions of points of degeneracy (EPs). 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 define the following considerations. When N is even, we show that a periodic waveguide with reflection symmetry may exhibit EPs 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 observed, and an EP of order N is not allowed. We present an example of three coupled microstrip transmission lines and show that by introducing glide symmetry we enable the occurrence of a stationary injection point (SIP) that is an EP of order three.

17:40 Glide Symmetry of Dielectric Corrugated Structures - Properties of TE and TM Propagating Modes
Zvonimir Sipus and Marko Bosiljevac (University of Zagreb, Croatia)
Tableting dispersion properties of different 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 methods separate the analysed structure into different regions and describes the EM field in each region with suitable modes. Those 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 structures. 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.

Monday, 16 March 13:30 - 15:30

CS21: Challenges in Leaky Wave Antennas and Novel Approaches to Solve Them

13:30 Quasi-Optical Excitation of a Cylindrically-Polarized Metasurface Antenna at K-band
Jorge Ruiz García (Université de Rennes, France); Marco Faenzi (Università degli Studi di Roma “La Sapienza”, Italy); Adham Mahmoud (Institut d'Électronique et de Télécommunications de Rennes, France); Mauro Ettorre (University of Rennes 1 & IMEP CNRS 6164, France); Patrick Potier (DGA, France); Pouliquen 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 novel concept of modulated metasurface (MTS) antenna for satellite communications. As opposed to using cylindrical surface waves (SW) to excite circular apertures, we propose a quasi optical beamformer to launch a plane SW. This architecture enables an efficient illumination of rectangular apertures. In addition, the use of anisotropic MTS elements allows us to create 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 conicalmet diagonal structures is presented in this paper. Two known analytical pertotic methods are compared with the results of the Mie-Parr-Clopet 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 far-field characteristics of the leaky wave antenna and its design procedure can be indicated.

14:10 Near-field Focusing Through Higher-Order Cylindrical Leaky Waves
Davide Comite, Walter Fuscaldo and Paolo Burghignoli (Sapienza University of Rome, Italy); Paolo Baccarelli (Roma 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 the work. The focusing characteristics 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 arrangement of elementary sources. By properly phasing the array elements, the azimuth order of the radiated field is controlled, offering the possibility of generating a focused beam of arbitrary order in carrying a nonzero-azimuth 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 Llobròrt (Delft University of Technology, The Netherlands)
There is a large interest in using lens arrays for many applications in the mm- and submm- wavelength ranges. The efficiency of the excitation of dielectric lenses increases significantly when the feeding structures support leaky-wave radiation mechanisms. Leaky-wave feeding structures based on resonant cavities can generate very high directivity in...
Two-element arrays composed of closely-spaced antennas with mutual coupling have recently been investigated in ... systems have biomimetic analogies to the hearing mechanism in small insects that exhibit exceptional direction finding... 

Richard J. Kozicki... 

Future sub-millimeter imagers will use large format focal plane arrays (FPAs) to increase their field of view... 

Shahab Oddin Dabironnezare... 

A broadband double-ridged waveguide to coax transition, specifically designed for 3D printing manufacturing is... 

Karina Hoel... 

An Artificial Magnetic Conductor (AMC) is a type of metamaterial that can be used to enhance the performance in several... 

John Sambles... 

Pavel Petrov... 

In this paper, a compact dual-mode substrate integrated hexagonal cavity (SIW) based filtering antenna is proposed. The... 

Prasun Chongder... 

In this paper, a compact dual-mode substrate integrated hexagonal cavity (SIW) based integrated filtering antenna is proposed. The design utilizes perturbation in a higher order mode to introduce radiation nulls in the antenna response thereby improving selectivity. The measured resonant frequency of the proposed filter is at 8.9 GHz with higher Q factors and... 

Alejandro Gil Martinez... 

Two cost-effective implementations of a leaky-lens antenna at 60 GHz are proposed for high-throughput 5G communication... 

Angel Palomares-Caballero... 

In this paper, a novel use of higher order mode of SIW cavity to realize compact filtering antenna that makes it suitable for low profile wireless communication applications is discussed. The measured axial ratio at 8.9 GHz with Q factors and a good return loss of 20 dB is achieved. The proposed design is fabricated and measured to be in good agreement with the simulation results. 

Prasun Chongder... 

Experimental Demonstration of Artificial Magnetic Conductors Constructed of Magnetically Coupled Helices

Pavel Petrov and Alastair Hibbins (University of Exeter, United Kingdom (Great Britain)); Ian Youngs (Platform Systems Division, Dstl, Salisbury, United Kingdom (Great Britain)); Mario Lima (Antenna Applied Research, Electronics Division, Leonardo, United Kingdom (Great Britain)); John Sambles (University of Exeter, United Kingdom (Great Britain))

An Artificial Magnetic Conductor (AMC) is a type of metamaterial that can be used to enhance the performance in several... 

Karina Hoel (FFI & University of Oslo, Norway); Stein Kristoffersen (FFI Norway)

A broadband double-ridged waveguide to coax transition, specifically designed for 3D printing manufacturing is presented. The transition employs a short-probe excitation topology. VSWR < 1.81 over the entire bandwidth of 6-18GHz is achieved. A sensitivity analysis to the dimensional parameters of the transition is carried out and the effect of the geometrical parameters on the performance is studied. Excellent repeatability is obtained with measured results closely resembling the theoretical response. 

15:10 Direct Synthesis of Frequency-Scanned Monopulse Half-Wavelength 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, Cartagena, Spain)

We propose a synthesis technique for half-wavelength microstrip leaky-wave antennas (HFM LWA) producing frequency-scanned monopulse patterns with two channels. The selection of the substrate thickness and dielectric constant is of key importance to obtain the desired angular scanning in the prescribed frequency band, and with high radiation efficiency. The two far advertising channels of Bluetooth Low Energy (BLE) protocol in the 2.45GHz band, we demonstrate that wide and narrow scanning designs can be directly obtained with the proposed approach, while dispensing from any numerical optimization. It is examined how different dielectric laminates and antenna sizes are convenient for each design.

Monday, 16 March 13:30 - 18:00

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

Shahab Oddin Dabironnezare (Delft University of Technology, The Netherlands); Angela Friso (University of Florence, Italy); Andrea Neto and Núria Llombart (Delft University of Technology, The Netherlands)

Future sub-millimeter imaging systems will use large format focal plane arrays (FPA) to increase their field of view and the imaging speed. This abstract employs a special technique based on Fourier Optics for analyzing lens based FPAs. Here, the method is applied to optimize the scanning performance of an imaging system with monomodally integrable lens feeds without employing any optimization algorithms, by using a field method with 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 1% dB while scanning up to +17.5° is presented with a directivity of 65 dB. A prototype of the described design using realistic antenna feeds is also presented.

T08 Positioning, localization & tracking / Regular Session / Antennas

Room: 825

Chairs: Thomas Kaufmann (U-blox AG, Switzerland), Richard J. Kozick (Bucknell University, USA)
13:50 Axially-Corrugated X-Band Horn Design with Integrated TE21 Monopulse Tracking in Corrugation
Chenglong Li and Emmerich Tanghe (Ghent University, Belgium); David Piets (Ghent University - imec, Belgium); Pieter Suait (Aixcix, Belgium); Nico Podewijn (University of Ghent, Belgium); Jeroen Hoebeke (Ghent University - imec, Belgium); Eli De Poorter (Ghent University & Imec, Belgium); Luc Martens (Ghent University - imec, Belgium); Wout Joss (Ghent University/IMEC, Belgium)

This paper presents a methodology for adapting the axially corrugated antenna feed design concept to the dual-polarization requirements of the new generation of X-band antennas. A novel design approach is proposed for the TE21 mode, which is characterized by its low cross-polar levels and its suitability for monopulse tracking. The developed design method includes a theoretical analysis of the corrugated horn's behavior and a practical implementation of the proposed design principles. The experimental results confirm the validity of the theoretical predictions, demonstrating the feasibility of the proposed design approach.

14:10 Adaptable GNSS Antenna Matching for Low-Cost Applications
Thomas Kaufmann and Rod Bryant (U-Blox AG, Switzerland)

This paper presents a methodology for designing adaptable antennas for low-cost GNSS applications. The proposed design approach allows for automated tuning of the antenna impedance to match the receiver's input impedance, thereby improving the signal-to-noise ratio and reducing the effect of multipath interference. The methodology is demonstrated through experimental results obtained from a prototype antenna, which shows significant improvement in the received signal quality compared to a conventional design without the automatic tuning capability.

14:30 Phase-based Variant Maximum Likelihood Positioning for Passive UHF-RFID Tags
Qinglong Han, Xuekang Liu (University of Duisburg-Essen, Germany); Steven Gao and Lehu Wen (University of Duisburg, United Kingdom (Great Britain)); Kai Wang (East China Institute of Electronic Engineering, China)

This paper presents a phase-based maximum likelihood positioning method for passive UHF RFID tags. The proposed method exploits the phase difference in the received signal to estimate the position of the tag. Theoretical analysis and experimental results show that the method achieves high positioning accuracy even in challenging environments, demonstrating its potential for applications in logistics and asset tracking.

15:10 A Broadband Circularly Polarized Antenna with Triple-Mode Characteristics
Wei Hu, Xuekang Liu and Hao Wu (Xidian University, China); Steven Gao and Lehu Wen (University of Duisburg, United Kingdom (Great Britain)); Yuan-Ming Cai (Xidian University, China)

This paper presents a novel broadband circularly polarized antenna with triple-mode characteristics. The antenna design utilizes a combination of different radiating elements to achieve a wide bandwidth and high efficiency. The proposed antenna is suitable for various applications requiring broadside radiation and high gain, such as satellite communications and radar systems.

15:30 Coffee Break

16:00 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); YueLong Liu (The 14th Research Institute, CETIC, China); Andreas Rennings and Daniel Emi (University of Duisburg-Essen, Germany)

This paper presents a new method for side-lobe suppression in reactance modulated antennas (RMAs). The proposed method uses a combination of reactance and inductive load modulation to control the radiation pattern of the antenna. The method is demonstrated through experimental results, which show significant suppression of side-lobe levels without compromising the main beam performance.

16:20 Pattern Shifting and Size Control in Offset Reflector Antennas with Microstrip Array as Matched Feed
Naushik Debbarma (RT Gueahati, India); Ramjanj Bhatiasan (Indian Institute of Technology, Guwahati, India)

This paper presents a novel approach for pattern shifting and size control in offset reflector antennas using a microstrip array as the matched feed. The proposed method allows for the modification of the radiation pattern and the reduction of the antenna size by controlling the excitation of the microstrip elements. The experimental results demonstrate the feasibility of the proposed method for applications requiring compact and versatile antenna designs.

16:40 Impact of UWB Antennas on Ranging Accuracy
David Veit, Michael Gadringer and Erich Leitgeb (Graz University of Technology, Austria)

This paper investigates the impact of UWB antennas on ranging accuracy in the presence of multipath effects. The study employs a comprehensive simulation framework to analyze the performance of UWB antennas in various propagation environments. The results highlight the importance of antenna design and selection in achieving accurate ranging performance.

17:00 RSS-based AoA Estimation System for IoT Applications Using Rotman Lens
Noori Bhilam, Arne Aerts and Dennis Joosens (University of Antwerp - imec, IDLab Research Group, Belgium); Jan Steckel (University of Antwerp - Cosys-lab Research Group, Belgium); Maarten Weyn (University of Antwerp - imec, Belgium)

This paper presents a novel RSS-based AoA estimation system for Internet of Things (IoT) applications. The system uses a Rotman lens antenna array to estimate the direction of arrival of signals in the presence of multipath. The performance of the system is evaluated through extensive simulations and experiments, demonstrating its potential for use in IoT device localization applications.

17:20 RSS-based DoA Estimation Using ESPAR Antenna for V2X Applications in 802.11p Frequency Band
Darian Duraj (Gdansk University of Technology, Poland); Mateusz Rzymowski (Gdansk University of Technology & Wicom Center of Excellence, Poland); Krzysztof Nyka (Gdansk University of Technology, Poland); Lukasz Kulas (Gdansk University of Technology, Faculty of Electronics, Telecommunications and Informatics, Poland)

This paper presents a novel RSS-based AoA estimation system for V2X applications in the 802.11p frequency band. The system uses an ESPAR antenna array to estimate the direction of arrival of vehicle-to-vehicle (V2V) signals. The experimental results demonstrate the feasibility and accuracy of the proposed system for V2X applications.

17:40 Frequency Diversity Array Information Geometry Analysis
Haifeng Yu, Qionglong Han (Beijing Institute of Space Craft System Engineering, China); Xiaoning Ji (Air Force Research Institute, China); Zhihui Wang (Beijing Institute of Space Craft System Engineering, China); Wen-Qin Wang (University of Electronic Science and Technology of China, China)

This paper introduces a novel frequency diversity array information geometry analysis method for improving the accuracy and robustness of antenna performance measurement. The proposed method utilizes the geometry information of the antenna array to estimate the direction of arrival of signals with high precision, even in challenging propagation environments.
14:10 Body Mounted Dipole-Loop Composite Antenna with Reconfigurable Focused Field for Non-Alcoholic Fatty Liver Disease Diagnosis Systems

Sasan Ahdi Rezaeeah and Amin Abbossh (The University of Queensland, Australia)

A body mounted antenna with reconfigurable focused field capability for electromagnetic-based non-alcoholic fatty liver diagnosis systems is presented. The antenna utilizes a combination of three distinct methods to achieve unidirectional radiation, miniaturize the size of the antenna and reconfigure field focusing. 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. Finally, to alter electric field intensity to scan different regions inside the body, the dipole is designed as six sub-elements that are electronically switched.

14:30 Robustness Analysis of the Polymeric-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 Masood Hashmi (Macquarie University & IEEE, Australia)

In this paper the morphology of the poly(methylmethacrylate) (PMMA)-flexible-conductive-mesh composite has been studied to evaluate its suitability in the realization of robust, flexible, transparent, wearable antennas that can withstand multiple bending operations. We have utilized conductive mesh made out of VeShiel from Les EMF which has about 70% light transmissivity and is highly flexible. On the other hand, PMMA is a highly flexible and optically transparent polymer. Uncured PMMA is in liquid form and upon curing it transforms to a robust flexible substrate and forms a strong bonding with the conductive mesh, VeShiel. 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

Sharawi (Polytechnique Montreal, Canada); Oguzhan Baser (KFUPM, Saudi Arabia); and Amin Abbossh (The University of Queensland, Australia)

In this paper a new type of tissue emulating phantom that is useful in the study of on-body and close to body antennas is presented. Particular attention is given to attempting to avoid the effects of reactive near field de-tuning in antennas constantly in contact with the body. The method of using high permittivity mixed dielectric powders in the size reduction of a common dipole and a compact spherical helical antenna with a balanced feed are discussed.

15:30 Coffee Break

16:00 Roundtable at 2.45 GHz for Wearable Applications

Mónica Borgoños-García, Ana Lopez-Yela and Daniel Segovia-Vargas (Universidad Carlos III de Madrid, Spain)

This paper presents the design and implementation of a 2.45 GHz wearable integrated rectifier 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 input and power. Finally, the antenna and rectifier are integrated as a rectenna, and the total efficiency evaluated for incident power densities up to 7 mW/cm2 at 2.45 GHz.

16:20 A Wide-band Slot-based Frequency Agile Yagi-Like MIMO Antenna System

Rifqat Hussain (KFUPM, Saudi Arabia); Syed Jahangir (United Arab Emirates University, United Arab Emirates); Umair Muneer Khan (Institute for Microwave and Millimeter-Wave Studies, Pakistan); Mohammad S. Shahvari (Polytechnique Montreal, Canada)

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-line based active antenna elements reactively loaded with reactor diodes to achieve frequency reconfigurability. The proposed antenna could be tuned over a wide frequency band from 1.5 - 2.1 GHz. To achieve Yagi-like directional characteristics of a slot antenna, a parabolic metal reflector layer was used below the substrate. This helped in suppressing the back-lobe radiation and thus a front-to-back ratio (F:BR) of 5 - 13 dB was achieved within the entire frequency band of operation. The proposed 4-element design is compact with an overall size of 100L x 100D x 203 mm, and a reflector size of 110T x 110D x 110L mm. The antenna system also shows good MIMO performance with high port isolation and very low envelope correlation coefficient (ECC) values within the operational band.

16:40 Applications of Mixed Powder Dielectrics in Prototype 2.45GHz 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 tissue emulating phantom that is useful 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 de-tuning in antennas constantly in contact with the body. The method of using high permittivity mixed dielectric powders in the size reduction of a common dipole and a compact spherical helical antenna with a balanced feed is discussed.

17:00 A Biodegradable Implanted Antenna Detecting Post-Surgical Infection

Kivanc Ararat, Omer Altan, Sabir Serbest, Oguzhan Basar and Sema Dumant (Bogazici University, Turkey)

Biodegradable implants have proven to be attractive where the patient will not need to go through an additional operation for the removal of the implant. Here biodegradability is utilized further where the biodegradation process has an idea of the incision’s operation. An implant antenna was designed to detect post-surgical infections which increase the acidity inside the human body. The implant antenna is supposed to be located in the operation site where it degrades at different pace depending on the existence of infection or not. The big antenna is tested in cow’s minced fat where the degradation is monitored using a wearable slot antenna used as a wiper. The detection was possible for an implant depth of 1 cm with 14 MHz resonance.

17:20 Protective Coating Methods for Glove-Integrated RFID Tags - A Preliminary Study

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

In this study, machine washing durability of working glove-integrated passive RFID tags is evaluated. These glove-tags are embedded inside 3D printed thermoplastic polymer platforms. The results are compared to platforms embedded inside brush-painted encapsulant platforms. For a preliminary washing reliability evaluation, both types of glove-integrated platforms are washed in a washing machine for 5 times. Although both platforms can protect glove-tags from the effects of water, the main reliability challenge is found to be the fragile antenna IC attachments. This paper introduces the two platform materials and the achieved washing test results. These preliminary results determine
In this article, a button antenna with a reflective frequency selective surface (FSS) is proposed to reduce its back radiation. The proposed antenna is low profile, circularly polarized and designed for WiFi and WLAN applications. The radiating element is made of copper sheet, while a transparent acrylic fibre sheet is used as a substrate. The antenna is fed by a coaxial line, and the FSS layer is designed on paper material. The patch type FSS with split ring shape has also been designed to operate in the WiFi and WLAN frequency band (5.250-5.350 GHz) with the centre frequency of 5.31 GHz. The FSS reduces back radiation of the antenna by 4 dB. The antenna with FSS is fabricated, and a measured gain of 12.96 dB is obtained that matches well with the theoretical value. The antenna is miniaturized by around 61.15% by the FSS.

In the fifth-generation (5G) new radio specifications, large signal bandwidth e.g. 400 MHz for frequency range 2 (FR2), is required in the down-link for the pre-5G services. In this paper, we revisit the band-stitching scheme, i.e. combining multiple logic channels of small bandwidth to form larger bandwidth. The method is demonstrated on a realistic 5G down-link channel model generated by the OAI platform.

A low profile button antenna with a reflective FSS is proposed to reduce its back radiation. The proposed antenna is low profile, circularly polarized, and designed for WiFi and WLAN applications. The radiating element is made of copper sheet, while a transparent acrylic fibre sheet is used as a substrate. The antenna is fed by a coaxial line, and the FSS layer is designed on paper material. The patch type FSS with split ring shape has also been designed to operate in the WiFi and WLAN frequency band (5.250-5.350 GHz) with the centre frequency of 5.31 GHz. The FSS reduces back radiation of the antenna by 4 dB. The antenna with FSS is fabricated, and a measured gain of 12.96 dB is obtained that matches well with the theoretical value. The antenna is miniaturized by around 61.15% by the FSS.
14:10 Analysis of Wide Band Wide-Scanning Quasi-Optical Systems Based on Fourier Optics
Shahab Oddin Odabianezare, Giorgio Carluccio, Andrea Neto and Nuita Lombard (Delft University of Technology, The Netherlands)
Sub-millimeter imaging systems with wide frequency bandwidth of operation as well as large steering capabilities are required for future security and space imaging applications. In this paper, a Quasi-Optical (QO) system with multiple reflective components is proposed to achieve these requirements. The system consists of hyper-hemispherical antenna feeders at its focal plane. Double-sided hyperbolic free-standing lenses are then used to link to the rest of the QO chain. A fast and accurate method based on Fourier Optics combined with Geometrical Optics is proposed to analyze these type of surfaces. The tool is validated against time consuming multi surface Physical Optics with excellent agreement. As the result, the proposed method can be used to design and optimize the performance of such QO systems.

14:30 Rotman Lenses with Rridged Waveguides In Q-Band
Sophie-Agathe Gomanne, Nelson Fonsaré, Petar Jankovic and Jaione Galdeano (European Space Agency, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Pietro Jankovic (European Space Agency, The Netherlands)
This paper provides a discussion on ridge waveguides Rotman lenses for satellite applications in Q-band. Two transition designs from the ridge waveguide feeding ports to the parallel plate waveguide lens cavity are compared. Whereas the longer transition provides slightly better return loss, the shorter transition reduces phase errors in the lens, translating into more accurate beam pointing and lower scan losses. Parameters and normalized array factors are computed over the frequency range from 37.5 GHz to 42.5 GHz for both lenses, confirming the benefits of shorter transitions.

14:50 Design of an Impedance-Matched Horn Antenna with Enhanced Directivity Using Conformal Transformation Optics
Hossein Ekanadi ( Ferdowsi University of Mashhad, Iran); Tomáš Tyc ( Masaryk University, Czech Republic); Juan Luis Albaldalejo-Lijarcio, Oskar Zetterstrom and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)
In this work, conformal transformation optics is employed to enhance the directivity of a horn antenna. The phase error at the horn's aperture is mitigated using a defected graded-index lens designed by the conformal transformation. The design not only leads to a negligible phase error at the aperture but also has an excellent impedance match to the vacuum. Simulation results show that a flat horn antenna with length and aperture width equal to 10 wavelengths, our method can enhance the directivity more than 5 dB.

15:10 All-Metal Graded Index Gunmetal Lens Antenna - A More Compact Lunarcope Lens
Petros Bantavis ( Université de Rennes 1, France); Cebrian Gonzalez (Idonial, Spain); Ronan Sauveau (University of Rennes 1, France); George Goustitis (University, France); Sépomé Tubau (Thales Alenia Space, France); Hervé Legay (Thalès Alenia Space, France)
The present work introduces an all-metal gunmetal lens antenna in a parallel waveguide (PW) technology for space applications at Ku band. Compared to the Lunarcope lens, the Gunmetal lens provides more compact size up to 35%. To achieve this compactness an optimized unit cell with glide symmetry is utilized. Single ridge waveguides are proposed to excite the lens along its focal axis to obtain a field of view with high beam overlap level between adjacent beams. Finally, the antenna presents broadband performance up to 45% with low losses and high directivity which is evaluated as an excellent candidate for satellite missions.

CS64: Trends and Advances in Machine Learning for Applied Electromagnetics

T10 EM-modelling and simulation tools / Convened Session / Electromagnetics
Room: B10

13:30 Modelling Ray Tracing Propagation Data Using Different Machine Learning Algorithms
Sotiris Goudos ( Aristotle University of Thessaloniki, Greece); Georgios E. Althanasiadou and George Tsoulos (University of Peloponnese, Greece); Vasileios Hekas ( Aristotle University of Thessaloniki, Greece)
In this paper, we apply different machine learning methods for the prediction of path loss in urban environment. A machine learning method is used to generate the training set using ray tracing technique assuming a flying base station at different heights within the city of Trikala, Greece. We produce prediction models for the path loss using three different learners the k-Nearest Neighbors (kNN), the Support Vector Regression (SVR) and the Random Forest (RF). The obtained numerical results are compared with the original data from the test dataset using representative performance indicators and overall they exhibit good precision.

13:50 A Comparison of Machine Learning Classifiers for Human Activity Recognition Using Magnetic Induction-based Motion Signals
Negar Goldestani and Mahta Moghaddam (University of Southern California, USA)
Human activity recognition (HAR) is a growing research field with a wide range of applications. Magnetic induction-based human activity recognition system (MI-HAR) is a wearable-based HAR system proposed for monitoring human motions and detecting activities based on the collected data. In this work, we focused on the performance analysis of different machine learning classifiers using magnetic induction-based motion signals. The main aim of this analysis is to compare the performances of six commonly used classifiers for HAR applications. Furthermore, we compared the classification performance using MI-motion data with the result reported in other studies using accelerometer data correspond to the same actions. Our results showed that Random Forest obtained the best performance of 91.5% on MI-motion data. Also, k-SVM and KNN models have respectively achieved accuracy of 91.4% and 85.4% on MI-motion data, which are both higher than the reported accuracy of 85.4% and 81.75 on accelerometer data.

14:10 A Learning-by-Examples Method for Rapid Estimation of Surface Currents in Microstrip Antenna Arrays
Marco Salucci (ELEDIA Research Center, Italy); Giulia Marsurro (Università degli Studi di Padova, Italy); Alessandra Polo (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento, Italy)
This work presents some numerical results on the optimal design of a passive reflecting surface with scanning antenna 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 model, also confirmed by the full wave analysis of the smallest antenna.

14:30 Near-Field Multi-Focused Arrays Using Support Vector Regression
Rafael Gonzalez Ayestaran (Universidad de Oviedo, Spain); Fernando Las-Heras (Universidad de Oviedo, Spain)
Support Vector Regression (SVR) is a powerful framework in the field of Machine Learning, is proposed for Near Field focusing using antenna array. It allows creating a model of an array relating the weights required in the elements of an array and the corresponding near-field distribution, focused on one or more points of interest. A previous learning process concentrates the computational cost so that the trained system operates without relevant 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.

14:50 SNO Optimization Technique Applied to Reflectarray Antennas Design
Michele Becerril (Politecnico di Torino, Italy); Alessandro Nicolai (Politecnico di Milano, Italy); Andrea Massaccesi (Politecnico di Milano, Italy); Riccardo Entrvo Zich (Politecnico di Milano, Italy); Paola Pittolii (Politecnico di Torino, Italy)
This communication presents some numerical results on the optimal design of a passive reflectarray using scanning antenna elements. The proposed method is based on a hierarchical 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 exemplary case is shown to assess the effectiveness and potentialities of the proposed LBE methodology.

15:10 Bayesian Active Learning for Electromagnetic Structure Design
Jixiang Qing, Nicolas Knudde, Ivo Coudsky and Domenico Spina (Ghent University, 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
T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics
Room: B10
13:30 A Subwavelength Microwave Bandpass Filter Based on a Chiral Waveguide
Malikh Hkhati Moghaddam (Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland); Romain Fleury (EPFL, Switzerland)
Wave manipulation at subwavelength scale has recently attracted significant interest, especially for low-frequencies. Recently, a few methods using locally resonant metamaterials have been proposed, foreseeing new technologies for ultra-compact passive components, e.g. in satellite communications. In this paper, we aim at exploiting a technique for designing a microwave waveguide filter, which guides modes at the interface between two locally resonant metamaterials with opposite chirality, so-called chiral waveguide. It has been recently demonstrated that a chiral waveguide has inherent robustness against imperfections in both the position and resonance frequencies of the local resonators, which can be used for realizing robust subwavelength systems. We use this property to realize a bandpass filter with improved RF purity, by purposefully integrating subwavelength resonators directly into the active region of the filter and also dispersion-engineering methods. Therefore we enhance the order of the filter and suppresses spurious bands, functionalities conventionally obtained by cascading bulky stages.

13:50 Broadband Offset-Reflector Beamformer on BCB in the 300-GHz Band
Ahmad Mahmoud (Institut d’Electronique et de Telecommunications de Rennes, France); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Ronan Sauleau (University of Rennes 1, France), Frédéric Aney, Nicolas Zouren and Anne-sophie Grimault (Université Paris Sud, France)
This paper presents the design of a broadband offset-reflector beamformer on a polymer substrate operating at submillimeter frequency bands. The offset reflector is used to excite a leaky-wave antenna array (LWA). The full system is fabricated in substrate integrated waveguide technology (SIW). Benzoxychlorophene (BCB) is used as a substrate due to its excellent electrical properties in this frequency range. A simulated field of view of 50° and a realized gain of more than 14 dB has achieved over a 25% fractional bandwidth, from 260 GHz to 340 GHz. The antenna efficiency is estimated to be 17%.

14:10 Matched Waves at Metaboundaries
Ali Sivola (Aalto University, Finland); Tino V Lindell (Aalto University, School of Electrical Engineering, Finland)
Electromagnetic boundary conditions regulate connections between the components of the electric and magnetic at this boundary. In the following, generalized boundary conditions are analyzed which define the connection between combinatorics of the tangential and normal components of the electric and magnetic fields. In particular, the focus is on matched waves: single waves which by themselves satisfy the given boundary condition.

14:30 Mini- And Multi-Dimensional Metamaterials
Serge Treytakoy (Aalto University, Finland)
Recently, metamaterial science and technology has been developing fast, with the emphasis on metasurfaces as two-dimensional metamaterials. Also, extreme-time modulations have been actively studied, and this technique can be viewed as expanding the space of design parameters into the fourth dimension, that is, time. In this conceptual review talk, I will discuss the notion of dimensionality of meta-atoms, metasurfaces, and metamaterials, emphasizing possible different understandings of this term in electromagnetics of complex space-time varying media.

14:50 A Method for Extending the Bandwidth of 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)
Modulated metasurface (MTS) antennas can provide a broadband pencil beam at the frequency where the cylindrical surface wave (CSW) travels. The mismatch between the SW wavelength and the period of the modulated impendence modulation limits the product bandwidth-gain. Here, we overcome this limitation by acting on the function that provides the local period for a given radial distance. Using this, we generate annular active regions on the antenna aperture. Such regions typically move from the antenna center to the circle at the frequency decreases. This paper shows that one can optimize the profile of the local periodic function to obtain broadband beams over large bandwidths, while preserving the flatness of the gain versus frequency response. The presented results prove that these antennas can provide high broadband gain over bandwidths difficult to reach by other flat antennas based on printed technology.

15:10 Analytic Design of Dual-Band, Dual-Polarized LP- to CP-Polarization Converters
Michele Del Mastro (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & UMR CNRS 6164, France); Anthony Gubic (University of Michigan, Ann Arbor, USA)
A systematic procedure for the design of dual-band, dual-polarized linear-to-circular polarization converters is presented. This class of polarizers can convert linear polarization to orthogonal circular polarizations in two separate frequency bands. The polarization converter is composed of three electric admittance sheets. The frequency response of each sheet is determined using an analytic approach, without relying on any optimization. A representative example is proposed in the Ka-band for future applications. The polarizer converts a 45° linearly-polarized plane wave to left-handed and right-handed circularly-polarized waves within the donut and uplink of the Ka-band. Specifically, relative bandwidths of 11% and 7% are achieved within the downlink and uplink, respectively, for normal incidence. Stable responses are demonstrated in simulation under oblique incidence up to 65° in elevation.

15:30 Coffee Break

16:00 Graphene Plasmonics with a Drift-Current Bias
Tiago Morgado (Instituto de Telecomunicacoes and University of Coimbra, Portugal); Malika M. Silbermina (Universidade de Lisboa - Instituto de Telecomunicacoes, Portugal)
We present a new route to achieve strong nonreciprocal responses and regimes of optical gain at the nanoscale. We demonstrate the bi-stability of 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 wherein the surface plasmons are pumped by the drifting electrons.

16:20 Stable Positive/negative Capacitor for Use in Active Artificial Structures
Silvio Habrat (University of Zagreb, Croatia); Dominik Zanic (University of Zagreb, Croatia); Igor Knezić (University of Zagreb, Croatia)
Recently, a ‘bandpass’ 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 simulations.

16:40 Virtual Perfect Absorption Through Aadiabatically Modulated Cavities
Dimitrios Sourais (Wayne State University, USA)
Virtual perfect absorption refers to the complete transfer of the energy 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 extreme forms 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 very effective way for trapping electromagnetic pulses and 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 radi and Adam Overvig (CUNY Advanced Science Research Center, USA); Yoshiaki Kasahara (University of Texas at Austin, USA); Andrea Aliu (CUNY Advanced Science Research Center, USA)
In this talk, we review our recent work in the context of metamaterials for control of electromagnetic waves. Spatial gradients of surface impedance, and careful engineering of the spatial distribution, are shown to implement metasurfaces for efficient beam steering, focusing and waveform control. Advanced 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 radar wave and optical technology, as well as physical insights into the functionality of these metamaterials, will be discussed during the presentation.

17:20 Investigation of Surface Waves on Anisotropic Self-Complementary Metasurfaces
Vladimir Lenets, Andrey Sayanskiy and Stanislav Glybovski (TOM University, Russia); Enrica Martini (University of Siena, Italy); Juan Domingo Baena (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 two TM surface-waves modes with identical dispersion characteristics. It is also seen that group velocity drastically changes on the direction of propagation of the waves, becoming extremely low for the direction orthogonal to the strips. The phenomenon can be used in dual polarized leaky wave antennas.

17:40 High Speed Metasurface Reconfigurability Under Optical Control
Houssemmedine Kraouli (ESPCI, France); Charlotte Trippon-Canseliet (Université Pierre et Marie Curie, France); Stefano Maci (University of Siena, Italy); Jean-Maurice Chazelas (Thales Aerospace Division, France)
A complete theoretical study to configure the Metasurface structure related on photonic semiconductor substrate material is proposed. This technique is based on the phenomenon of photon absorption into a high resistivity semiconductor material. A free space-to-static measurement system operating in the 40- -50 GHz frequency range is developed to measure the reflectivity coefficients of planar samples. The measurement system consists of a transmitt and receive antennas in the bistatic configuration, two focussing lenses to minimize the diffraction effects at the edges of the sample, pectro-pectro, precision coaxial cable, laser source at wavelength of 810 and 971 nm and the network analyzer...
In this paper we discuss the dispersion properties of a particular type of holey metasurfaces, named here “substrate-integrated anisotropic lattice structures”. The operating principle of the metasurface does not rely on established phase gradient along its surface because it allows one to overcome common limitations of the phase-gradient-based devices. Instead, we have developed a rigorous microscopic approach which allows the control of the interaction between the neighboring elements and engineer the radiative contribution of each scatterer to meet a required functionality. By varying the applied bias voltage, we experimentally demonstrate beam steering as well as generation and steering of two- (and more) beams with a single feeding antenna.

14:40 Degenerate Band Edge Resonances in Air-filled Substrate Integrated Waveguide
Tianyu Zhang (Sorbonne University, France); Massimiliano Casaletti (Sorbonne Universités UPMC, France); Ahmed F. Abdelshafy and Filippo Capolino (University of California, Irvine, USA); Zhuxiang Ren and Guido Valerio (Sorbonne Université, France)

We present a design of a reconfigurable sparse metasurface operating at microwave frequencies (X-band). The operating principle of the metasurface does not rely on established phase gradient along its surface but is designed to overcome common limitations of the phase-gradient-based devices. Alternatively, we have developed a rigorous microscopic approach which allows the control of the interaction between the neighboring elements and engineer the radiative contribution of each scatterer to meet a required functionality. By varying the applied bias voltage, we experimentally demonstrate beam steering as well as generation and steering of two- (and more) beams with a single feeding antenna.

14:50 Cold Sintered CaTiO3-K2MoO4 Microwave Dielectric Cylindrical Metamaterials for Low-Cost Metasurface Antennas
Dawe Wang (University of Sheffield, United Kingdom (Great Britain)); Shuy Zhang (Loughborough University, United Kingdom (Great Britain)); Kai Song (University of Sheffield, United Kingdom (Great Britain)); Janney Vardaxoglou, William Whittow and Darren Cadman (Loughborough University, United Kingdom (Great Britain); Di Zhou (Xian Jiaotong University, United Kingdom (Great Britain)); Kaiming Sun (Hanzhou Dianzi University, United Kingdom (Great Britain))

In this paper, we investigate guided modes which propagate along the structure and show the dependence of the dispersion curves. As a result of the study, we show that there is a possibility to excite two modes with orthogonal polarizations which have the same phase velocity within a broad frequency range.

15:00 Fabrication of Artificial Dielectrics via Stereolithography Based 3D-Printing
Jack McChee, Tom Whittaker, Jacob Moriarty, Jamie Northedge, Shuy Zhang, Darren Cadman, William Whittow and J (Yiannis) Vardaxoglou (Loughborough University, 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) of the photoinitiated resin used was measured and found to be negligible after 15 minutes of UV curing. Artificial dielectric isolating and anisotropic lattice structures were then fabricated, allowing for varying permittivity between 1.23 and 2.80 through the control of the structure density. 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.

15:30 Coffee Break

16:00 Complementary Metasurfaces for Waveguide Applications
Xin Ma (Northwestern Polytechnical University, China); Mohammad Sajjad Mirmoosa and Sergei Tretyakov (Aalto University, Finland)

Metasurfaces have shown a strong potential for controlling electromagnetic waves in a desired manner and provided us with 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 metasurfaces whose surface impedances are ‘complementary’ to each other. We experimentally investigate guided modes which propagate along the structure and show the dependence of the dispersion curves. As a result of the study, we show that there is a possibility to excite two modes with orthogonal polarizations which have the same phase velocity within a broad frequency range.

16:20 Design and Simulation of Polarization-Sensitive ENNZ-Lined Apertures for Visible-Light Metasurfaces
Mitchell Sample and Ashwin K. Iyer (University of Alberta, Canada)

A method based on electromagnetic inversion is extended to facilitate the design of passive, breakout, and reciprocal metasurfaces. More specifically, the inversion step is modified to ensure that the field transformation satisfies local power conservation, using available knowledge of the incident field. This paper formulates a novel cost functional to achieve this additional constraint, and describes the optimization procedure used to find a solution that satisfies both the user-defined field specifications and local power conservation. Lastly, the method is demonstrated with a two-dimensional (2D) example.

16:40 Enforcing Local Power Conservation for Metasurface Design Using Electromagnetic Inversion
Trevor Brown (University of Manitoba, Canada); Youssef Valahzadeh and Christophe Caloz (Ecole Polytechnique de Montreal, Canada); Puyan Mojabi (University of Manitoba, Canada)

A method based on electromagnetic inversion is extended to facilitate the design of passive, breakout, and reciprocal metasurfaces. More specifically, the inversion step is modified to ensure that the field transformation satisfies local power conservation, using available knowledge of the incident field. This paper formulates a novel cost functional to achieve this additional constraint, and describes the optimization procedure used to find a solution that satisfies both the user-defined field specifications and local power conservation. Lastly, the method is demonstrated with a two-dimensional (2D) example.

17:00 Impedance Matching Network Based on Blaschke Metamaterials for Metasurfaces Operating at High Microwave, Millimeter-Wave or Terahertz Frequencies
Mohammad Alkhaythmikani (Università degli Studi di Roma "Tor Vergata", Roma - Italy); Bal Virdie (London Metropolitan University, United Kingdom (Great Britain)); Chan H. Hwang See (Edinburgh Napier University, United Kingdom (Great Britain)); Raed Abd-Alhammed (University of Bradford, United Kingdom (Great Britain)); Francesco Mesà (University of Seville, Spain) and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this paper, a bi-static Blaschke-Metasurface unit-cell is theoretically modelled and boundary conditions determined that allow it to be used to utilise bi-static metasurfaces for wideband impedance matching as well as metasurfaces operating at high microwave, millimeter-wave or terahertz frequencies. Analytical equations are derived for the impedance parameters and the corresponding insertion loss of the effective electric and magnetic responses and the magnetoelectric coupling for achieving wideband impedance transformation when realized with transmission-line stubs.

17:20 Propagation Through Metamaterial Temporal Slabs: Transmission, Reflection and Special Cases
Davide Ramanzi (Roma Tre University, Italy); Alessandro Toscano (University Roma Tre (IT), Italy); Filiberto Biotti (University Roma Tre, Italy)

The 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 new applications based on temporal control.

17:40 Propagation Characteristics in Substrate Integrated Holay Metasurfaces
Fatemeh Ghasemifard (KTH Royal Institute of Technology, Sweden); Francesco Mesà (University of Seville, Spain); Guido Valerio (Sorbonne Université, France) and Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

In this paper we discuss the dispersion properties of a particular type of holay metasurfaces, named here "substrate-integrated holay" (SH) metasurfaces. SH is a metallic holay structure manufactured in printed circuit board (PCB) technology by using densely metallized posts. We demonstrate that, differently to the case of holes fully covered with metal,
Monday, 16 March 13:30 - 15:30

**IW05: Frontline of 5G workshop: Insights on 5G antenna & propagation R&D from Sony and regional partners (Sony)**

**T02 Millimetre wave 5G / Regular Session / Antennas**

**Room: B3**

Zhinong Ying, Sony

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16:00 Dual-Polarized Dielectric Resonator Antenna Array for mm-Wave Mobile Base Stations

Jerzy Kowalewski (Karlsruhe Institute of Technology, Germany); Aissa Jauch (Karlsruhe Institute of Technology (KIT), Germany); Joerg Eisenbeis (Karlsruhe Institute of Technology, Germany); Sören Marahrens (Karlsruhe Institute of Technology (KIT), Germany); Karina Schneider (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology, Germany)

Large-scale antenna arrays operating in the millimeter-wave (mmW) regime are required for mobile/radio base stations of the next generation. These arrays should support dual-polarization and cover the large available bandwidths. Two dual-polarized antenna concepts are presented addressing these challenges. The presented dielectric resonator antenna (DRA) is characterized by 3D printed resonator elements, whereas the stacked patch antenna array features a classical multilayer printed circuit board (PCB) structure. To verify the proper functioning a 2×2 DRA antenna array prototype around 28 GHz is built. The investigations show that both antenna designs can meet the requirements of 5G mmW large-scale antenna arrays, whereby the DRA antenna approach reduces the number of PCB layers and thereby lowers manufacturing costs.

16:20 Dual-band Dual-polarized Antenna for mm-Wave 5G Base Station Antenna Array

Zeeshan Siddiqui (University of Oulu & Centre for Wireless Communications, Finland); Marko Sonki and Jiangcheng Chen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellent Ltd., Finland); Marko E Leinonen and Aarno Pärsäinen (University of Oulu, Finland)

A dual-band dual-polarized antenna suitable for 5G millimeter-wave base station antenna array is presented in this paper. It operates at both the commercial millimeter-wave frequency allocated in 5G NR from 24.25 GHz to 40 GHz. The antenna is based on a novel stacked square ring patch configuration to achieve wide dual-band and stable radiation pattern. The antenna offers a sharp roll-off and a filter like response between the operating bands due to the strongly coupled resonators. Antenna design principle and simulated performance are discussed in detail. The -10 dB impedance bandwidth of the lower band starts from 24.25 GHz to 29.5 GHz while the higher band covers the 37 GHz to 40 GHz. The realized gain remains stable between 5 to 6 dBi at all the operating frequencies. The isolation between the ports and cross-polar discrimination remain better than 20 dB in all the covered frequency range.

16:40 Subarray Antenna Fed by Analog Beamforming Network for 5G Picocell Applications

Daneelys Rodriguez-Avila (Microwave and Antenna Group (MAG), École Polytechnique Fédérale de Lausanne, Switzerland); Anja K. Skrivervik (EPFL, Switzerland)

In this paper a subarray fed by an analog beamforming network for 5G picocell applications is proposed. Design requirements are presented taking into account frequency band operation, bandwidth, radiation pattern shape and both, antenna element and transmission line technologies. The synthesis and implementation of the analog beamforming network are described, and the final subarray architecture is provided. The proposed antenna, verified by simulation, operates at 26 GHz with a bandwidth larger than 35%. The realized gain is higher than 16 dB with cross-polarization better than -29 dB. Its radiation pattern in elevation fulfills the desired csc2 θ shape with side lobe level below -15 dB.

17:00 A Photonic Beam-Steerable Mm-wave Antenna Array for Radio over Fiber Applications

Alvaro J Pascual (University of Rennes 1 & IETR, France); Muhsin Ali, Luis Enrique Garcia Muñoz and Guillermo Carpineto (Universidad Carlos III de Madrid, Spain); David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France); Roman Sauleau (University of Rennes 1, France)

We present a photonic fed transmitter at E-band for radio over fiber (RoF) applications. The transmitter includes four photonic transmitters and four photonic receivers connected by a photonic phased array antenna (PAA). Simulation results on a simplified 2×1 prototype, which is under assembly, show a reflection coefficient below -10 dB and 15 dB for both sub-arrays at 76.5 GHz and 77 GHz, respectively. A prototype transmitter is under assembly at the University of Rennes 1.

17:20 Low-profile Millimeter-Wave Wideband Circularly Polarized Spiral Antenna Array

Huaqiang Chen, Yu Shao, Keyao Li, Changhong Zhang and Zhi-Zhong Zhang (Chongqing University of Posts and Telecommunications, China)

A single-fed low-profile millimeter-wave (mmW) wideband circularly polarized (CP) spiral antenna 2×2 array is presented. By employing the regular parallel feeding network technique to excite each CP spiral element with equal amplitude and phase, the proposed array achieves the impedance bandwidth (IBW) of 6.47 GHz around 23.1% of 28 GHz. A cross slot is introduced at the bottom layer for decoupling. The bandwidth of axial ratio (AR) lower than 3 dB is 9.5 GHz (24.8% referring to 28 GHz) from 24.87 GHz to 32.82 GHz. The polarisation sense at the top side and bottom side are left-hand circular polarisation (LHCP) and right-hand circular polarisation (RHCP), respectively. The gains of the whole desired frequency band (from 25 GHz to 31 GHz) are higher than 10 dB with peak gain of 11.3 dB at 28.5 GHz.

17:40 28 GHz Millimeter Wave Multibeam Antenna Array with Compact Reconfigurable Feeding Network

Yihua Zhou (Queen Mary University of London, United Kingdom (Great Britain)); Vedaprabhu Basavarajappa (University of Surrey, United Kingdom (Great Britain)); Pei Xiao (University of Surrey, United Kingdom (Great Britain))

A switchable multibeam antenna array with a compact planar feeding network is presented. Operating within 1 GHz bandwidth at 28 GHz, this 4×4 antenna can generate one-beam, two-beam and four-beam patterns based on two phase states, which are controlled by the reconfigurable feeding network. The whole structure is validated by simulating in CST Studio. The antenna is a promising candidate in millimeter-wave Massive MIMO for applications where multiple beams are required simultaneously.

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Monday, 16 March 16:00 - 18:00

**T02 Millimetre wave 5G / Regular Session / Antennas**

**Room: A2**

Chairs: Vedaprabhu Basavarajappa (University of Surrey, United Kingdom (Great Britain)), David González-Ovejero (Centre National de la Recherche Scientifique - CNRS, France)

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16:00 Integrated Design of Dual-Band Antenna with Uni-/Omni-Directional Radiations

Chun-Ku 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 slosh 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 out-of-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, the 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 Tencel

María Elena de Cos Gómez and Alicia Florez Berdasco (Universidad de Oviedo, Spain); Humberto Fernandez Alvarez and Fernando Las-Heras (University of Oviedo, Spain)

A compact ultra-thin eco-friendly antenna for IoT applications around 2.4 GHz is presented based on both simulations and measurements. The use of a botanical textile named Tencel is explored and its suitability is evaluated through comparison of the novel antenna's performance using Tencel versus a conventional RO3003 dielectric with similar relative dielectric permittivity. A comparison with recently published wearable antenna suitable for IoT at the same band 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 Fractal Structure

Sandra Costanzi and Adil Masoud Qureshi (University of Calabria, Italy)

In this paper, a Miniaturized Planar Inverted-F Antenna (PIFA) is presented. Miniaturization is achieved by transforming the square radiator element into 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 pre-fractal is also presented.

17:00 Inexpensive 3D-Printed Radiating Homs for Customary Things in IoT Scenarios

Diogo Helena and Amélia 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) drives 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 28 GHz band, all manufactured with 3D printing technology. Two techniques were used to metalize the antennas: with copper tape and with conductive ink. All prototypes achieved proper results for integrating the upcoming IoT scenarios.

17:20 INEXPENSIVE 3D ANTENNAS FOR IoT APPLICATIONS

Sandra Costanzi, Adil Masoud Qureshi & Humberto Fernandez Alvarez

In this paper, we present a compact, lightweight, and low-cost antenna for IoT applications. The antenna is designed using 3D printing technology, which allows for precise control of the shape and size of the antenna. The antenna operates at 2.45 GHz and is suitable for a variety of IoT applications, including wearables and mobile devices. We demonstrate the feasibility of 3D-printed antennas for IoT by showing measured performance metrics, including return loss, efficiency, and radiation pattern, which are comparable to conventional printed circuit board antennas. Our results indicate that 3D-printed antennas can be a viable solution for IoT applications, offering cost savings and ease of integration into existing designs.

17:40 Design of an Array Antenna Consisting of Three Dual Antenna Sets with a Narrow Array Distance for Interference Mitigation

Tae Heung Lim (Hongik University, Korea (South)); Byung Jun Jang (Kookmin Univ, Korea (South)); Hosung Choo (Hongik University, Korea (South))

In this paper, we propose and experiment with an array antenna consisting of three dual antenna sets to minimize the number of the array elements in a limited platform size for interference mitigation application. The dual antenna set consists of 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 nulling performance is observed to mitigate the five interference signals with optimum weights of each element. In this null pattern, the minimum null depth of -64.6 dB and the maximum null width of 15 deg are achieved among the five nulling points.
A simple copper strip array loaded multiband square slot antenna with microstrip-line feed is proposed in this paper. The slot antenna is designed to radiate at 2.28 GHz. The slot is loaded with a uniform array of rectangular copper strips to produce other resonances at 2.2 GHz, 3.4 GHz, 4 GHz, 6 GHz, 4.5 GHz, and 6.6 GHz. The proposed antenna is modeled and simulated using HFSS. The antenna prototypes are manufactured and tested. Good agreement is obtained between the measured and simulated results. The surface current distributions at the various resonant frequencies are simulated. The principle of operation is explained based on the distributions obtained and using analytic equations. An equivalent circuit model is also studied. Impedance bandwidths of 500 MHz, 300 MHz, 600 MHz, 400 MHz, 600 MHz and a gain of above 3 dB is obtained at the five resonant frequencies.

20.1 Preliminary Co-Design of L and X-band Stacked Arrays with Scanning Capabilities
Brandon Sun (Insa de Rennes, France); Renaud Loison and Raphael Gillard (IETR & INSA, France); Eric Estebe (Thales DAMS France, France); Christian Renard (Thales Systemes Aéroporptes, France)

The design of L- and X-band stacked arrays is presented in this paper. The design of the L-band element is first detailed. The use of stacked patch elements in the broadside angle of 60° in E-plane, and 45° in H-plane, in the 9.5–12.5 GHz band gives the reflectivity 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 Friend or Foe (IFF) bands, at 1.0 and 1.29 GHz with a 3.6 MHz bandwidth. Finally, the ground plane is placed above the X-band array and the performances of the stacked arrays are analyzed in the L- and X-bands.

20.16 Multichannel 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 multiphysic Laayered in this contribution. We evaluate the gain of DDM with software defined radio for transmitting simultaneously two uncorrelated signals along two different observation angles. A new version of DDM relies on the knowledge of the channel vector and an accurate adjustment of the weights that feed the phased array, for this reason, the components of the transmitter to match the desired frequency. Experimental results that assess the performance of the system for the observation angles under consideration are shown.

17.00 High-Performance Wideband Horn Antenna for Direction Finding Arrays
Saeed Manohari (Engineering Optimization and Modeling Center, Reykjavik University, Iceland); Sławomir Koziel (Gdańsk University of Technology, Poland); Lefur Lefidson (Iowa State University, USA); Andrés Alayón Glazounov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)

In this paper, a structure and design procedure of a novel double ridge 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 applied to adjust the antenna geometry parameter values. The achieved impedance bandwidth (VSWR < 2) is 1.5 to 12 GHz (81%). The antenna exhibits 7 dB to 20 dB gain, better than 95% 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.

20.17 A Distinct Approach Exploiting Collapse Distribution Colligated with Genetic Algorithm for the Synthesis of Thinned Planar Antenna Arrays
Veer S Gangwar (LRDE/DRDO, India); Johi Modit (IIT/ISM) Dhanbad, India; Jatin Narde (NIT, Rourkella, India); Kundan Suman (IT ISM, India); Ashwin P (DRDGO, Bangalore, India)

In this paper, authors propose a distinctive approach to collapsing the phasor antenna pattern, which synthesizes Thinplaned Angular Pattern (TPA) Arrays with maximally reduced peak side lobe level (PSLL). Authors employed Collapse Distribution Technique amalgamated with Genetic Algorithm (COGA) in order to reduce optimization complexity and to obtain efficient control of PSLL. B- and T-10×20 element TPA arrays are numerically analyzed to verify the effectiveness and examine the distinguishable features of the proposed strategy. The numerical results obtained through COGA evidence that it outmatches the similar designs available in the literature. In order to further ascertain and validate the performance of COGA in practical scenarios, authors carried out experimental validation. The obtained experimental results are found nearly in agreement with corresponding numerically computed and electromagnetically simulated ones. Index terms Collapse distribution technique combined with genetic algorithm (COGA), peak side lobe (PSLL), thinplạne antenna arrays (TPA).

17.40 Research on a Kind of Asymmetric Scanning Phased Array Antenna
Hong-yin 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 Yu-qì antenna element centered in the large scale array provides good radiation performance in the range of 0-70 degree, thus realizing the asymmetric reshaping of the element pattern. Additionally, a 7×7 array prototýpe is fabricated. The measured results agree well with the simulated results, prove its effectiveness.

20.20 Near-field, Far-field, Compact and RCS Measurement Techniques
T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Regular Session / Measurements
Room: 07

Chair: Manuel Sierra-Castaher (Universitat Politècnica de Madrid, Spain); Christopher G Hynes (Simon Fraser University, Canada)

16:00 Experimental Validation of the Translated-SWE Technique Applied to Automotive Measurements over PEC-Floor and Standing Wave at Arbitrary Height
Francesco Saccardi (Microwave Vision Italy, Italy); Francesca Misci (Consultant, Switzerland); Per Iversen (Orbit/FR, USA); John Estrada (MVG, USA); Lars Foged (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 sphere is often terminated to a conductive 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 accommodation and measurement setup. Moreover, if the conductive floor lies on the horizon plane, truncation errors on the far-zone measurement can be solved by means of the so-called far-field transformation by simply mirroring the measured field image (through the floor). Due to mechanical constraints, or extension of the operational mode of some systems (e.g. absorber-based systems), sometimes the horizon plane doesn’t correspond to the horizon plane, and advanced techniques are needed to extrapolate the truncated area. The Translated-SWE technique, already presented in the past, is proposed for this 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 (Chiba Institute of Technology, Japan); Cybelle Belem (Universite de Lille, France); Cyril Luxey (University Nice Sophia-Antipolis, France); Fredic Gianesello (STMicroelectronics, France); Guillaume Ducoulau (IETR & INSA, France); Cyril Luxey (University Nice Sophia-Antipolis, France); Guillaume Ducoulau (IETR & INSA, France)

In this paper, we present a near-field measurement based on an electro-optic sensing at 300 GHz band. 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 an Log-Periodic Antenna at a Reduced Distance Without Considering the Phase Center Offset in a Non-cut Near-Far Field Transformation
Masanobu Hirose and Satoru Kurokawa (National Institute of Advanced Industrial Science and Technology, Japan)

We propose a new method to measure accurately the absolute gain patterns of log-periodic antenna over the operating frequency band at a reduced distance and a fixed setup position in a single-cut near-Far-field transformation (called the Kim method). By combining the Kim method and a source reconstruction method, our method does not require the information of the phase center position of the antenna. Therefore, we can measure the absolute gain patterns accurately over the frequency band without re-setting the antenna position to each frequency. At 1.3 GHz, our method makes it possible to determine the maximum absolute gain with 0.1 dB and the patterns errors below 0.2 dB over all angles at a measurement circle radius of 1.5 m.

17:00 Relative Phase Reconstruction Based on Multiprobe Solutions and Post-Processing Techniques
Ruben Tena Sanchez (Universidad Tecnica de Madrid, Spain); Manuel Sierra-Castaher (Universitat Politècnica de Madrid, Spain); Lars Foged (Microwave Vision Italy, Italy)

In a previous paper a referenceless measurement setup is presented on a referenceless array antenna used for characterizing the near-field radiation of antennas in the plane and spherical multiprobe systems. This paper proposes an alternative technique based on exploiting the intrinsic characteristics of multiprobe systems. One of the antennas from the multiprobe is used to retrieve the relative phase between measurement points. Post-processing is used since the relative phase between elements could not be 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 Alvarez, Kyriakos Kaslis, Jeppe Nielsen and Olav Brenberg (Technical University of Denmark, Denmark)

This work presents the 2019 campaign of Investigating measurements, which goal is to assess the robustness of the measurements setup when mounting large masses on the AUT position, such as for the case of the 300 kg MetOp-SG satellite, as well as the long-term reproducibility of the measurements. To this end a full measurement was performed, including complete uncertainty measurements, of the 971 Golden Standard array antenna (GSA) in two configurations, unloaded and loaded with 303 kg of dummy weight. The measurements of the unloaded and loaded configurations were compared and it is demonstrated that the AUT position is capable of absorbing an antenna with a mass comparable to the MetOp-SG 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 On the Accuracy of Standard Gain Horn Measurement

Maryam Razmhosseini, Christopher G Hynes and Rodney Vaughan (Simon Fraser University, Canada)

New measurement accuracy results are presented for a Standard Gain Horn in a profession-level system, the MVG Stargate 64. This system offers calibration options, and draws on the user’s knowledge to choose the most appropriate one. An ideal measurement in an ideally calibrated system should be 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 multicoil of ferrite beads (to suppress any currents on the cable outer), 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 (error product). The worst-case pattern variations appear to be related to the temperature variation of the system.

**T05-E05: Microwave Imaging**

Room: B8

**Chairs:** Marco Salucci (ELEDIA Research Center, Italy), Alessandro Fanti (University of Cagliari, Italy)

**16:00 Robust Multi-Resolution Microwave Imaging Through an Over-Constrained Approach**

Marco Salucci (ELEDIA Research Center, Italy); Paolo Rocca and Andrea Massa (University of Trento, Italy)

This paper 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 guessers with a remarkable robustness to noise. A preliminary numerical benchmark is presented to assess the potentialities 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**

MohammadQRanoudi (University of Limoges/CNRS, France); Stéphane Billa (XLM IMR 7252 Université de Limoges/CNRS, France)

This paper presents a new concept of multi-target tracking using hierarchial trackers based on kernel localization for envisioned functional microwave brain imaging application. For this purpose, the performance of brain-activated region tracking using BART video is improved. In the first stage, all of the moving regions in the BMRI video frames are detected. Then, by using the group tracking, histogram and distance corresponding to the moving-targets in the previous frame, the directions of moving-regions are determined. After determining the exact number of moving objects and tracking them, one by one, the direction of each vector is extracted. In addition, due to the kernel labelling, the proposed method has capability of separation and merging by group tracking in conditions of motion paths 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 Stroke Monitoring on Synthetic Numerical Data**

Jan Tesarik and Jan Vrba (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 hit tissue MI systems can help to differentiate the type of stroke. The main purpose of this contribution is to validate the newly designed multilevel 24-port MI system on numerical data. Inside the 3D human head phantom, the different stroke phantom types (HEM - haemorrhagic or ISCH - ishaemic) with different diameters were placed. With the reconstruction algorithm based on Born Approximation and TSDV the stroke phantoms can be followed and distinguished. The numerical analysis of MI system proved promising results where positions, diameters and types of stroke phantoms were successfully reconstructed. The paper showed some limitations as inability to detect objects with size lower than half of used wavelength which can be avoided in the future.

**17:00 Microwave Imaging of Cervical Myelopathy: A Preliminary Feasibility Assessment**

Chiara Dachena, Davide Merlantoni, Alessandro Polo (ELEDIA Research Center, Italy); Alessandro Fanti (University of Cagliari, Italy); Alessandro Fedeli (University of Genoa, Italy); Giuseppe Mazzarella (University of Cagliari, Italy); Matteo Pastoreno 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, a preliminary feasibility assessment concerning the application of such a technique to the monitoring of cervical myelopathy is reported. In particular, suitable working conditions are defined on the basis of a simplified multilayer 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**

Yoshikazu Kuhara and Akira Nozaki (Shizuoka University, Japan)

We examined the applicability of Folded Quasi Self-Complementary Antenna (FOSCA) to a microwave imaging system aimed at breast cancer detection. It is presented that FOSCA 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**

Jan Tesarik and Jan Vrba (Faculty of Biomedical Engineering, Czech Technical University in Prague, Czech Republic)

An approach for the diagnosis of the human chest in real time based on electro-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-examples (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 (DSF). Some preliminary results are shown to assess how the 3D-EIT problem can be efficiently, accurately, and robustly solved thanks to the proposed methodology.

**CS43: Near- and Far-Field Wireless Power Transfer**

Room: B9

**Chairs:** Yi Huang (University of Liverpool, United Kingdom (Great Britain)), Naoki Shinohara (Kyoto University, Japan), Hubrecht J. Visser (imec The Netherlands, The Netherlands)

**16:00 Wireless Power Transfer in Japan: Regulations and Activities**

Naoki Shinohara (Kyoto University, Japan)

Japan has a long history of research and development (R&D) in wireless power transfer (WPT) technologies. Recently, based on a WPT R&D agreement, there are interesting new WPT R&D and WPT research projects in Japan, and are discussed in the course of this paper. WPT technologies and its applications can make significant advancements not only through R&D and commercialization, but also in discussion of new radio regulations. Japan not only contributes in discussions of new radio regulations, but also in the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R). The status of the discussions in the new regulation of the WPT is further discussed in the course of this paper.

**16:20 Applied: A Computationally Efficient Modeling Tool for Multi-Layer Printed Inductors, for near Field Wireless Power Transfer Applications**

Brody Mahoney and Joshua R. Smith (University of Washington, USA)

This paper presents Applied, a computationally efficient open source environment for wireless power transfer coil design. The system allows designers to rapidly design and simulate coils. Applied extracts coil parameters and back-annotates the extracted values into a SPICE netlist model of the wireless power transfer coil. Applied 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/optimized circuit model. Final designs may then be exported to common PCB CAD software.

**16:40 3D Antenna Array for SWPT Sensing with WPT Capabilities**

Diego Rafael Pinto Pires and Daniel Belo (Instituto de Aeronáutica & Instituto de Telecomunicações, Portugal); Marina Jordão (Instituto Telecomunicações - Universidade Aveiro, Portugal); Pedro Pinho (IT - Instituto de Telecomunicações & ISEL - Instituto Superior de Engenharia de Lisboa, Portugal); Nuno Borges Carvalho (University of Aveiro/IT Aveiro, Portugal)

In this work, the design and development of an alternative three-dimensional array is presented. This arrangement aims to improve some Wireless Power Transmission (WPT) systems and to provide advantages when integrated into a Wireless Sensor Network (WSN) architecture. The conceived 3D antenna array consists of eight antenna elements operating at 5.65 GHz that are attached in a 3D printed hexagonal prism. With this structure, it is intended to achieve as close as possible to an omnidirectional radiation pattern with considerable gain, avoiding power losses. The experimental measurements carried out are in line with the performed electromagnetic simulations and validate the array operation. A full azimuth coverage was ensured with an average gain of 6.7 dBi. For some azimuth directions, the array proves to be a reliable solution to feed multiple low-power sensors that are placed over the 360 azimuth angles.
In this work, a novel dual-polarized mm-wave antenna for feedback wireless power transfer (WPT) applications is proposed. The antenna has the capability to receive RF power at fundamental frequency of 9.015 GHz and transmit the second harmonic at 18.3 GHz as a feedback signal simultaneously. Fundamental and harmonic resonances of a dipole antenna are utilized to design the dual-band antenna. A 0.5λ microstrip line resonator is coupled to the feed of the antenna to realize the duplexer action. The proposed antenna is for 9.015 GHz frequency band and has a measured bandwidth of 60 MHz (from 9.895 to 9.555 GHz). Port 2 is for 18.3 GHz frequency band (from 18.015 to 18.905 GHz). The worst-case isolation between the two ports is better than 13 dB at both bands. The proposed dual-polarized antenna exhibits similar gains and radiation patterns with good isolation, making it suitable for feedback WPT applications.

Dual-Band Dual-Polarized mm-Wave Slot Antenna Array for Mobile Handsets

This paper describes a novel dual-polarized mm-wave antenna for mobile phone devices. The mm-wave antenna 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 29.5 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.

A Novel Lens Antenna Design Based on a Bed of Nails Metasurface for Next Generation Mobile Devices

This paper presents a novel dual-polarized mm-wave array antenna that operates at 28 GHz (27.5-29.5 GHz) and 36 GHz (37.39 GHz) frequency bands and is usable in mobile handsets. The array is based on slot antennas as 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 dBi and it is capable of beam-steering for up to ±35° or ±50° at 28 GHz and 36 GHz bands, respectively. The performance of the array in the presence of a smartphone chassis is also studied.

100 W 6.78 MHz Inductive Power Transfer System for Drones

This article describes a novel dual-polarized mm-wave antenna for mobile phone devices. The mm-wave antenna module consists of a 0.5λ microstrip line resonator and a reflector to achieve higher directivity. This paper presents a structure-based dual-polarized antenna that operates at 28 GHz (27.5-29.5 GHz) and 36 GHz (37.39 GHz) frequency bands and is usable in mobile handsets. The array is based on slot antennas as 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 dBi and it is capable of beam-steering for up to ±35° or ±50° at 28 GHz and 36 GHz bands, respectively. The performance of the antenna in the presence of a smartphone chassis is also studied.
10:10 Coffee Break

10:40 Frequency Reconfigurable Endfire Vertical Polarized Array for 5G Handset Applications

Jin Zhang, Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

This paper proposes a frequency reconfigurable phased array antenna for 5G mobile terminals. The design consists of discrete fed slot radiators placed at the top edge of the mobile phone PCB. The configuration of the antenna element is composed of an L-shaped slot radiator with a single directivity. The detection and biasing RF switches (D1&D2) across the L-shaped slot radiators of the main design, the radiation beams of the phased array can be switched from end-fire to broadside radiation modes. The proposed design can provide a 2 GHz impedance-bandwidth with S11 ≤ -10 dB at 28 GHz (5G candidate band) and generates high-gain radiation beams in both end-fire and broadside modes. Fundamental characteristics of the design in terms of patterns, radiation efficiency, and antenna gain are investigated. The obtained results show promising performance of the array under different states of the switches.

11:00 A Beam-Steerable Antenna Array with Radiation Beam Reconfigurability for 5G Smartphones

Naser Oporudj Pakchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Rabed Al-Allameed (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Ming Shen (Aalborg University, Denmark)

A radiation-beam switchable phased array antenna is proposed for 5G mobile terminals. The design consists of discrete-fed slot radiators placed at the top edge of the mobile phone PCB. The configuration of the antenna element is composed of an L-shaped slot radiator with a single directivity. By implementing and biasing RF switches (D1&D2) across the L-shaped slot radiators of the main design, the radiation beams of the phased array can be switched from end-fire to broadside radiation modes. The proposed design can provide a 2 GHz impedance-bandwidth with S11 ≤ -10 dB at 28 GHz (5G candidate band) and generates high-gain radiation beams in both end-fire and broadside modes. Fundamental characteristics of the design in terms of patterns, radiation efficiency, and antenna gain are investigated. The obtained results show promising performance of the array under different states of the switches.

11:20 A Millimeter-Wave Dual Band Antenna with Circular Polarization

Sahmania Sadeghi-Maerati (University of Dublin, Ireland); Mohammad S. Sharawi (Polytechnique Montreal, Canada); Anding Zhu (University College Dublin, Ireland)

This paper presents a high efficiency dual band single layer antenna structure for MIMO array applications. The shape of patch that is surrounded by two conductive walls is designed on an RO3003 substrate with a thickness of 0.08 mm. The operating frequencies of this antenna are 28 GHz and 38 GHz. Circular polarization is achieved by designing the specific shape of the inner patch and cutting the edge of the outer ring. The reflection coefficient is less than -10 dB at 28 GHz and 38 GHz and maximum gain and efficiency 0.63 dB and 92% at 28 GHz and 5.2 dB and 71% at 38 GHz. This low-profile and lightweight antenna can be used in many 5G communication systems.

11:40 Substrate Integrated Dual Linearly Polarized End-Fire Antenna Array Operating at 28GHz

Halmi Boutayeb (Huawei Technologies, Canada); Wen Tong (Huawei Technologies Co., Ltd., Canada); Fayer Hajiye (Huawei Technologies Co., Ltd., Canada); Wenyao Zhao (Huawei Technologies Canada Research Center, Canada); Xin Peng (Huawei Technologies Co., Ltd., Canada)

We present a new cost-effective method for designing mm wave dual linearly polarized end-fire antennas and antenna arrays using multi-layer printed circuit boards. For vertical polarization (V polarization), we propose a modulated inverted F antenna with plated throughs. Horizontal polarization (H polarization) is obtained with quasi-Yagi-Uda printed dipole. VP and HP elements cross each other to ensure low coupling and size reduction. A conformal dual polarized array is fed by using a parallel plate feeding circuit. Transition from exciting ports to parallel plate horn and from horn to radiating elements are designed by using metallic via. For cross feed, no buried vias are used in the design. Based on this design methodology, an optimized dual-polarized beam steering antenna operating at 28 GHz is presented. Applications of this work include the design of beam-steering antennas with wide scanning angle.

12:00 Wideband Dual-Polarized Patch Antenna with Capacitive Coupling for mm-Wave Bands

Marko Sonkki (University of Oulu, Finland); Danping He (Beijing, Jiangtuong University, China); Zeehan Siddiqui (University of Oulu & Centre for Wireless Communications, Finland); Marko E. Leinonen (University of Oulu, Finland); Ke Guan (Beijing, Jiangtong University, China)

This paper presents a planar wideband dual-polarized antenna structure integrated on PCB. The patch itself is fed by capacitive coupling with simpler patches. Whereas in the simulations presented 24-40 GHz 10 dB impedance bandwidth, the measured ones shows 24-75 GHz 75 GHz bandwidth. The results are corresponding to 50% relative -10 dB impedance bandwidth. The patch antenna is designed for a ground plane of size 4.7 mm x 4.7 mm and the corner of the ground plane are cut to gain better XP. The manufactured prototype antenna is measured and simulated with a 50 ohm coaxial feed. Simulated and measured efficiency and XP are presented as a function of frequency. The total efficiency shows better than 0.8% (83%) efficiency, whereas the simulated XP is better than 14 dB. The simulated 3D radiation patterns are presented at 24 GHz, 32 GHz, 40 GHz with gains of 2.8 dB, 5.4 dB, and 4.3 dB, respectively.

CS35: IET/IRACON Session: Propagation Measurements and Modelling for 5G and Beyond

T02 Millimeter wave / Convened Session / Propagation

Room: A3

Chairs: Mark Beach (University of Bristol, United Kingdom (Great Britain)), Sana Salous (Durham University, United Kingdom (Great Britain))

8:30 Investigation of Resonance Based Propagation Loss Modeling for THz Chip-to-Chip Wireless Communications

Jinbing Fu, Fratikle Juyul, Baki Yilmaz and Alenka Zajic (George Institute of Technology, USA)

This paper proposes a path loss model for THz chip-to-chip wireless communication in desktop-size metal enclosures with respect to transceivers positions. This path loss model accounts for the attenuation due to the signal spreading, resonant modes inside the cavity, and the radiation pattern of the antenna. Measurements were performed in LOS and 2-D and 3-D misalignment propagation scenarios. The model prediction shows a good agreement with measured results, which proves the validity of the model.

8:50 A Hardware-in-the-Loop Evaluation of the Impact of the V2X Channel on the Traffic-Safety Versus Efficiency Trade-offs

Alessandro Bazzi (University of Bologna, Italy); Thomas Blazek (TU Wien, Austria); Michele Menarini (CNR-IEEEI, Italy); Barbara M. Masi (CNR - IIEIT & University of Bologna, Italy); Alberto Zanella (Istituto di Elettronica e di Ingegneria dell’Inform., delle Telecomunicazioni, Italy); Christoph F. Mecklenbräuker (TU Wien, Austria); Gisela Ghaeisi (Norwegian University of Science and Technology, Norway)

Vehicles are increasingly becoming connected and short-range wireless communications promise to introduce a radical change in the drivers’ behaviors. Among the main use cases, the interaction management is surely one of those that could mostly impact on both traffic safety and efficiency. In this work, we consider an intersection collision warning application and exploit a hardware-in-the-loop (HIL) platform to verify the impact on the risk of accidents as well as the average time to travel a given distance. Besides including real 5G mobile channel emulators, the platform also includes a channel emulator with real signals. Results show that the risk of collisions can be drastically reduced, with an overall trade-off between safety and traffic efficiency. At the same time, it is shown that the presence of channel conditions and signal processing.

9:10 Multipath Characteristics of Outdoor-to-Indoor Propagation Based on 32-GHz Measurements

Juyul Lee, Kyung-Won Kim, Myung-Gon Kim and Jae-Joon Park (ETR, Korea (South))

This paper investigates measurement-based multipath characteristics of millimeter-wave (mmWave) outdoor-to-indoor (O2I) propagation. The measurement campaigns were conducted in a typical office building with a 500 MHz bandwidth channel sounder operating at frequencies 32 GHz. The multipath propagation characteristics are analyzed in spectrum-based approaches in temporal (delay) and spatial (angular) domains. In our measurement, we considered the effect of the transmit incident angles on the multipath characteristics. In the perpendicular incidence, we observed regularly recurring multipath components reflecting from the back side and the front-side windows. However, in non-perpendicular incidence, it was hard to identify the sources of multipath reflections from the background reflection. From the measurement data analysis, we also observed that the delay spread and the angular spread do not have any meaningful dependency on the incidence angles; these are more relevant to the surrounding indoor environments near the IX.

9:30 Penetration Loss at 60 GHz for Indoor-to-Indoor and Outdoor-to-Indoor Mobile Scenarios

Kang Yun Jun (National Institute of Standards and Technology, USA); Derek Caudill and Jack Chuang (NIST, USA); Peter Papazian (NIST Division 673, USA); Anuraag Bodla (National Institute of Standards and Technology, USA); Camillo Gentile, Jelena Senic and Nada Golmie (NIST, USA)

This paper investigates the penetration loss of an office building in indoor-to-indoor and outdoor-to-indoor mobile scenarios. The measurements were collected using our 60-GHz double-directional switched antenna channel sounder. 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 was predicted versus incident angle by electromagnetic propagation theory using the ITU-R Recommendation P.1240 model parameters and compared with the measurement results. The wooden door, plastic material, and interior glass were observed to have penetration losses ranging from 26 dB to 41 dB, 12 dB to 32 dB, and 8 dB to 18 dB, respectively, while the exterior building materials exhibited even larger penetration losses, ranging from 30 dB to 67 dB.

9:50 Hybrid Channel Modeling for Intra-Wagon Communication in Millimeter-Wave Band

Xiping Wang, Danping He, Ke Guan and Bo Ai (Beijing Jiaotong University, China); Juan Moreno (Universidade Politecnica de Madrid, Spain); Cesar Briso (Universidade Politecnica de Madrid & ETIS Universitecomunicacion, Spain)

Millimeter-wave (mmWave) wideband communication is considered to be an efficient way to increase the 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. It is complicated and time-consuming to work in harsh environments, where dense multipath 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.
In this paper, we present a broadband full-wave 3D SAW measurements of the radio channel plus some early results taken on a very singular 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 intrusion of antennas in order to know the condition of these mechanical elements. The channel sounder is based on a commercial module (Decawave DWM1001) intended for indoor location but with some tinkering could be used to obtain channel measurements.

8:30 Reconfigurable Tarahara Reflectarray Based on Graphene Radiating Patches

Tao Li, Qiang Zeng, Ling Chen, Pengfei Cai; Ruou Cui and Zhonglie Mei (Lanzhou University, China)

A reflectarray antenna based on graphene radiating patches is proposed for reconfigurable radiation patterns at 1 THz. The all radiating 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 polarisation, the simulated phase curve shows that a cycle phase range of 360° 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 wave with excellent performance.

8:50 Achieving Wider Impedance Bandwidth Using Full-Wavelength Dipoles

Can Ding (University of Technology Sydney, UTS, Australia); Haiyan 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 FW D for base station applications as examples. The first antenna is an isolated cross-dipole employing two FW D with simple configuration. It is able to cover the lower band for cellular communication from 698 to 960 MHz. The second antenna has four FW D arranged in a square-array loop form and tightly coupled with each other. The employed full-wavelength dipoles are bent 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 1.5 to 7.7 GHz and the gain ranges from 1.6 to 3.3 and 5.4 to 7.7 GHz for the 800-900 MHz and the 2.4-5.5 GHz band, respectively.

9:10 Single and Dual Beam Waveguide Slotted Antenna Using 3D Printing Technique for 5G Application

Muazzez Wathiq, Almeshees (Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Malaysia); Noor Aznia Murad (Universiti Technology Malaysia, Malaysia); Mohamad Kamal A Rahim (Universiti Teknologi Malaysia, Malaysia); Band Zubir (Universiti Teknologi Malaysia & Faculty of Electrical Engineering, Malaysia); Osman Bin Ayop and Mohd Farus Mohd Yusoff (Universiti Teknologi Malaysia, Malaysia); Huda A. Majid (Universiti Tun Hussein Onn Malaysia, Malaysia); Mohamed Nourin Osman (Universiti Perdana Malaysia, Malaysia); Mohamad Zonlin Abidin Bin Abd Aziz (Universiti Teknikal Malaysia Melaka & Hang Tuaq Jaya, Malaysia)

This paper presents comparison between three 3D metal printed antennas at Ka-band by using different process. The antennas are designed and fabricated using a 3D metal printing technique. The performance 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 less than -10 dB for all antennas. The measured gain of ranging from 7-14 dB for all the prototypes are obtained with more than 90 % of antennas efficiency. These 3D metal antennas are suitable for Ka-band applications such as 5G cellular network.

9:30 Modified Binomial Power Distribution Beamformer for Switched-Beam Circular Array

Sheng-Wei Wu; Kun-You Lin and Shih-Yuan Chen (National Taiwan University, Taiwan)

In this paper, we proposed a modified binomial power distribution circular beamforming network (BFN) with a single input port at the center and 12 antenna ports uniformly located along the outer rim of the BFN for full 360° azimuth coverage switched-beam circular array. By combining and interleaving two modified binomial power distribution (BPD) circuits, a compact full horizontal plane coverage beam-switching beamformer is formed. While six switches are needed in the proposed BFN, a simplified prototype BFN without the switches is fabricated and tested for preliminary verification. Measured results agree well with those simulated. The proposed 1+12 modified binomial power distribution circular beamforming network possesses several advantages over conventional circular BF designs, including compact size, single-layered structure, and a wide bandwidth up to 11.4% centered at 5.6 GHz.

9:50 Microwave Metasurface-based Lens Antennas for 5G and Beyond

Zhi Ning Chen (National University of Singapore, Singapore); Teng Li (Southeast University, China); Wei E. L. Liu (National University of Singapore, Singapore)

Lens antennas have long been used at millimeter-wave bands and above because of their excellent power focusing performance, aperture sharing, and simple feeding structure. However, the conventional high-gain dielectric lens at microwave bands usually are too bulky. With the development of metasurfaces, the lens design has been replaced by single or multiple layered planar structures such as patterned PCB boards. This paper first briefs 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 multibeam antenna design. The progress of microwave metasurface lens antennas shows us the huge potential of metamaterial-based antennas (metamaterials in short) in advanced wireless systems.
The exponential growth of IoT imposes increased needs for understanding and exploitation of EM phenomena. Consequently, many engineers, many of them lacking deep knowledge of applied electromagnetics. To meet such needs it is necessary to provide accessible solutions for solving EM problems. This paper presents a few of such solutions.

8.50 A Realistic and Accurate Model for Inductive Elements
Symon K. Podilchak, Changhyeong Lee, Wei-Yu Li, (University of Rochester, United States); Shenheng Xu, and Kin-Lu Wong, (Tsinghua University, China)

Inductive elements are a necessary part of an antenna's matching circuit. The complexity of modeling such elements is due to their non-linear behavior and sensitivity to environmental factors. In this paper, we present a novel model for inductive elements that is accurate, robust, and easy to use.

9.00 An Overview of Physical Bounds on Antennas
Jaakko Juntunen, (Czech Technical University in Prague, Czech Republic)

Physical bounds are limits that are imposed by the laws of physics. They are essential for antenna designers to understand the limitations of their designs. This talk will provide an overview of the most important physical bounds on antennas.

9.10 From Optimal to Industrial Antenna: The Designer Dilemma for Compact MB-ITT Terminal
Fabien Ferrero, (University Nice Sophia Antipolis, CNRS, LEAT & CREMANT, France); Lars Jonsson, (KTH Royal Institute of Technology, Sweden); Leonardo Lizzio, (University Côte d'Azur, CNRS, LEAT, France)

Antenna design is a challenging task that requires a balance between performance and size. In this talk, we will explore the trade-offs involved in designing antennas for compact MB-ITT terminals.

9.30 Implementation and Use of Physical Bounds for Antenna Optimization
Mats Gustafsson, (Lund University, Sweden); Miodrav Capek, (Czech Technical University in Prague, Czech Republic)

Physical bounds are used to guide the design process and ensure that the final product meets the desired performance criteria. This talk will present a method for using physical bounds in the optimization of antenna designs.

9.50 Design Cosntrains for In-body Antennas Based on Frequency Analysis of Fundamental Radiation Limitations
Zvonimir Spus and Marko Bosiljevac, (Pohang University of Science & Technology, Korea (South)); Bashar Bahaa Qas Elias, (University of Belgrade, Serbia); Milos Pavlovic, (WIPL-D DOO, Serbia)

In-body antennas are subject to a number of constraints due to their location within the human body. This talk will present a method for analyzing the fundamental radiation limitations of in-body antennas.

10.00 Coffee Break

10.40 Metal Stamped Antenna-in-Package for Millimeter-wave Large-scale Phased-array Applications Utilizing Multiphysics Analysis
Junho Park, (Pohang University of Science & Technology, Korea (South)); Wonbi Hong, (Pohang University of Science and Technology (POSTECH), Korea (South))

This paper presents a metal stamped antenna-in-package concept for mm-wave large-scale phased-array applications. A multiphysics analysis is presented, including detailed results of the antenna structure.

11.00 Antennas and Propagation Technologies of V2V Communications for Platoonizing
Kazuma Tomimote and Kokiishi Seriotsu, (SoftBank Corp., Japan); Masayuki Matushita, (SoftBank Corp., Japan); Ryo Yamaguchi, (SOFTBANK Corp., Japan); Takeshi Fukusako, (Kumamoto University, Japan)

V2V communications are becoming increasingly important for platoonizing high-speed vehicles. This talk will present recent advances in antenna and propagation technologies for V2V communications.

11.20 Novel Millimeter-Wave Phased Array Antenna for 5G Wireless Communications
Fan Yang, Shenhe Xu, Yezen Li and Yongli Ren, (Tsinghua University, China)

This talk will present a novel millimeter-wave phased array antenna concept for 5G wireless communications.

11.40 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)

This talk will present a highly integrated dual-band mmWave antenna array concept for 5G mobile phones.
T11 Fundamental research and emerging technologies / Regular Session / Measurements
Room: B4

8:30 Radar Section Measurement Within Reverberation Chamber: Stirrer Position Issues
Ariston Reis (Université Paris Est-Marne-la-Vallée, France); Francois Sarrazin (University of Paris Est-Marne-la-Vallée & ESYCOM, France); Poulqueen Philippe (DGA, France); Jerome Sol (NSA Rennes, France); Philippe Benoist (ETR, France); Elodie Richalot (Université Paris-Est (Marne-la-Vallée), France)

The paper presents the evaluation of the Radar Section Cross (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 RCS. A good agreement is obtained when compared with classical RCS measurement inside an anechoic chamber. This communication also highlights the photic potential of stirrer positioning issues and their impact on the retrieved RCS accuracy.

8:50 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 giraffe). The rotation was maintained either in a horizontal (H)-plane or in a vertical (V)-plane containing the center of the quiet zone (OZ). 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 OZ in the H- or V-direction. Preliminary results at several S-band frequencies are presented and discussed.

9:10 Effects of the Antenna Measurement Uncertainties on the Estimation of the Differential Reflectivity
Brais Sánchez-Rama, Veronica Santalla del Río, Rubén Nocelo López and María Vera-Izasa (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 knowing 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.

9:30 Analysis of the Cross-polar Radiation Effects on Differential Reflectivity Calibration
Veronica Santalla del Río, Rubén Nocelo López and Bras 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. Additionally, it is shown how the polarization phase is propagated through a transmitting medium considerably affects the results.

9:50 On Models and Approaches for Human Vital Signs Extraction from Short Range Radar Signals
Mikołaj Wojciech Czerekowski, Christer V. Illoids, Carmine Clemente, Craig Michie, Ivan Andonovic and Christos Tachtatzis (University of Strathclyde, United Kingdom (Great Britain))

This paper presents an assessment of the modelling approaches for the processing of signals in CW and FMCW radar-based systems for the detection of vital signs. It is shown that use of the widely adopted phase extraction method, which relies on the approximation of the target as a single point scatterer, has limitations in respect of the simultaneous estimation of both respiratory and heart rates. A method based on a velocity spectrum is proposed as an alternative with the ability to treat a wider range of application scenarios.

Tuesday, 17 March 8:30 - 10:10

T11 Fundamental research and emerging technologies / Regular Session / Measurements
Room: B4

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8:50 Front End Radiating Module for Advanced Active Antenna
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); Yes Sermers (MDA Corporation, Canada); Nicholas Boudreau, Jean-Daniel Dea and Eric Amyotte (MDA, Canada)
This paper describes the analysis of radiated spurious of active antennas. It outlines an analysis methodology and presents radiated spurious performance of selected beam layouts for Direct Radiating Array (DIRA) and Array Fed Reflector (AFR) active antennas.

9:30 Additive Manufacturing: Enabling Technology for Active Antennas in LEO and Geosatellites
Esteban Menagues and Santiago Capdevila (SWIStoS12, Switzerland); Tomislav Debovic (SWIStoS12 SA, Switzerland); Maria García-Vigurres (IEETR-INSIA Rennes, France); Emil de Rijk (SWIStoS12 SA, 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 SWIStoS12 in the development of direct radiating arrays. Such advantages are highlighted through the design of two examples. The paper reviews SWIStoS12 manufacturing process, including measured RF performance of relevant active antenna hardware and presents innovative components to enable DIRA for GEO constellations.

9:50 Potential Applications of Active Antenna Technologies for Emerging NASA Space Communications Scenarios
Felix Miranda (NASA, JPL Research Center, USA)
NASA is implementing far-reaching changes within the framework of both space and aeronautics communications architectures. Near-earth re-y is looking to transition from few large geostationary satellites to constellations of thousands of small GEO satellites while lunar space communications will require the need to relay data from many assets on the lunar surface back to earth. In aeronautics, satellite communications for BLOS links are being investigated in tandem with the proliferation of US systems within the IUM environment. Thus, future communications architectures will need to connect and quickly transition between many nodes for large data volume transport. NASA GRC is exploring 5G-based beamformer technologies to leverage commercial timescale and volume production cycles, hereafter not existent within frequencies used by NASA. An overview of future applications of phased arrays being envisaged by NASA are 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 Earth Observation Missions in Thales Alenia Space Italia
Pasquale Capece (Thales Alenia Space Italia, Italy); Giovanni Gasparro (THALES ALENIA SPACE ITALIA, Italy); Roberto Giordani and Roberto Mizzoni (Thales Alenia Space Italia, Italy); Alberto Meschini (ThalesAleniaSpace Italia, Italy); Giovanni Mannocchi (THALES ALENIA SPACE ITALIA, Italy); Andrea Suriani (THALES ALENIA SPACE, Italy); Salvatore Contu (Thales Alenia Space, Italy)
The paper presents an overview of the most significant active phased array products for Earth Observation developed by Thales Alenia Space Italia over the 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 Earth Observation, Telecom, 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 IRAAD, Telecom and Observation and Science.

11:20 Rigid-Flexible Antenna Array (RFAA) for Lightweight Deployable Apertures
William F. Moulder, Rabindra N. Das, Andrew C. Maccabe, Landon A. Brown, Erik M Thompson and Patrick J Bell (MIT Lincoln Laboratory, USA)
This paper presents the Rigid Flexible Antenna Array (RFAA), a concept for realizing ultra-light thin flexible antenna arrays that can readily integrate active components. The enabling realization of phased arrays that can be compactly stored in small satellite, where mass and volume for antenna payloads are extremely limited. The RFAA is constructed with a very thin, physically flexible material and minimal rigid material, allowing it to be realized with an area density as low as 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
Pietro Focardi (Jet Propulsion Laboratory & California Institute of Technology, USA); Jefferson Harrell (Jet Propulsion Laboratory, USA)
NISAR (NASA/ISRO SAR, National Aeronautics and Space Administration, Indian Space Research Organization, Synthetic Aperture Radar) 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 movement and activity of various natural systems. The enabling instrument for this mission is a dual-band radar (L-band and S-band) that feeds a 12m deployable mesh reflector. This paper presents the experimental campaign of the L-band flight feed in its passive configuration. Further measurements will be performed 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 Baquer-Escudero, Pablo Soto and Vicente Borja (Universidad Politécnica de Valencia, Spain); Giovanni Tosio (European Space Agency, ESA ESTEC, The Netherlands); Piero Angelotti (European Space Agency, The Netherlands); Marco Guglielmi (University of Valencia, Spain)
Possible applications of completely metallic radiating elements based on below-cut-off 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

TOS Biomedical and health / Convened Session / Antennas

8:30 Microwave Radar Breast Screening: System Interaction with the Post-Biopsy Clip
Lena Kranold and Milica Popović (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 stable 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 feasibility of the clipped microstrip, typically left in the tissue as a marker after biopsy, on the overall ability of our system to screen the patient frequently post-biopsy. This line of investigation is essential for the population of women with dense breast tissue, where the mammogram struggles to give reliable results and hence the biopsy is used as a follow-up procedure.

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 Mull (Goethe University Frankfurt am Main, Germany); Christian Kessel and Duy Hai Nguyen (Goethe University Frankfurt, Germany); Avik Santra (Infineon Technologies AG, Germany); Andrea Aliverti (Politecnico di Milano, Italy); Viktor Krozer (Goethe University of Frankfurt am Main, Germany); Vadim Iasakow (Infineon Technologies AG, Germany)
Microwave breast cancer detection has been widely studied as an alternative 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 dwindling of components together with an integrated transceiver would lead to a compact and cost-effective imaging system. This paper investigates the possibility of using an integrated ultra-wideband frequency-modulated continuous-wave (FMCW) radar system operating at a center frequency of 24 GHz and bandwidth of 8 GHz for breast cancer imaging. System considerations are developed and first imaging results based on numerical data are presented.

9:10 Qualitative Techniques for Generating Spatial Prior Information for Biomedical Microwave Imaging
Martina Teresa Bevacqua (Università Meditarranea di Reggio Calabria, Italy); Nasim Abdullahian and Ian Jeffrey (University of Manitoba, Canada); Tommaso Ismea (University of Reggio Calabria, Italy); Joe LoVetri (University of Manitoba, Canada)
MR compatible hyperthermia devices exploit MR thermometry capabilities for non-invasive treatment monitoring. These devices are designed to be used in conjunction with MRI imaging to monitor the temperature distribution during hyperthermia treatments.

Hyperthermia, i.e. heating tumour tissue to 40-43°C, is applied clinically to enhance the effectiveness of various cancer therapies. Locoregional hyperthermia (heating of deep-seated tumours to 40-43°C) increases effectivity of chemotherapy by enhancing the uptake of chemotherapeutic agents into the cancer cells and increasing the sensitivity of the tumour tissue to radiation.

To optimize the treatment planning and delivery, a detailed understanding of the temperature distribution within the tumour is required. A preliminary study on the implementation of a microwave imaging system for biomedical applications is outlined in this paper. The analysis is repeated for a lossy medium and highlights that losses increase the coverage estimation, and that the optimal choice of the magnetic field strength can increase the detectability of the magnetic nanoparticles. This applies both to synthetic and real nanoparticles.

In this paper, preliminary results of the first-in-human clinical investigation with the Wavelia Microwave Breast Imaging System for Breast Cancer Detection: Clinical Feasibility and Identified Technical Challenges are described. The feasibility of the system, in terms of potential to detect both malignant and benign palpable breast lesions, is illustrated with the MBI results of two patient scans. Some identified technical challenges, related to the patient positioning and breast deformation, are also discussed.

In this paper, we present a methodology to build a numerical phantom for the head and neck regions, which can be used to test the performance of microwave imaging systems. Such models will be the starting point to develop microwave imaging devices suitable to detect metastatized cervical lymph nodes and as a result contribute to the correct staging of head and neck cancer.

The use of quantitative microwave imaging for biomedical applications represents one of its 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 the reconstruction accuracy and resolution. In the following we propose the use of two quantitative imaging methods, the linear sampling and the orthogonally sampling methods, to generate spatial profiles that are used as a numerical homogenization 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 reconstructions 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.
The Required Patient Modeling Realism in Radiofrequency Heating Simulation Studies

Gennaro G. Bellizzi (Erasmus University Medical Center, The Netherlands); Kernal Sueris (Erasmus MC Cancer Institute, The Netherlands); Margaretha M. Paulides (Eindhoven University of Technology, The Netherlands)

Clinical effectiveness of hyperthermia would benefit from a more controlled and target conformal heating of the tumor. Over the years, dosimetry using electromagnetic simulations 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 database of real and patient-based models for those with an approximated shape, a reduced tissue number and/or 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.

5:00 Monitoring Microwave Thermal Ablation Using Electrical Impedance Tomography: An Experimental Feasibility Study

Anna Bottigliani (Transnational Medical Device Lab & National University of Ireland, Galway, Ireland); Eoghan Dunne (National University of Ireland & Transnational Medical Device Lab, Ireland); Barry McDermott (Transnational 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 Fafina (National University of Ireland Galway & CURAM Ireland)

Low-cost microwave ablation allows to monitor the size of the ablation zone in real-time using microwave techniques. 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 liver 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 MATS applicator operating at 30W for 10 hours at 2.45GHz. The results report 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

10:40 Effects of Choke in Minimally-Invasive Small-Profile Microwave Ablation Applicators

Giuseppe Ruivo (National University of Ireland, Galway, Ireland); Marta Cavagnaro (Sapienza University of Rome, Italy)

Microwave ablation is a fast-growing hyperthermic treatment option for unresectable malignancies. From pioneering percutaneous microwave procedures to treat liver lesions, nowadays several new clinical indications are emerging. The spread of microwave ablation in clinical practice is growing alongside with the requirements for minimally-invasive procedures and, consequently, minimally invasive microwave applicators. Tissue-structural changes and choke have been proposed in the literature as techniques to improve the ablation performance of needle-shaped antennae. In this paper, these techniques are compared in terms of electric field distribution, return currents on the feed cable and specific absorption rate when integrated into an 8-gauge applicator.

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

Jan Sebek (Kansas State University & Czech Technical University, USA); Faraz Chamani (Kansas State University, USA); Jie Cheng (Texas Heart Institute, USA); Dhanunjaya Lakshminaryan (Kansas City Heart Rythym 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 serious complication associated with ablation is perforation of the esophagus, which is prone to severe bleeding. Several strategies for managing esophageal luminal temperature by limiting the temperature rise 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 esophageal surface. Here, we report on measured temperature profiles in a custom ex vivo layered tissue preparation during radiofrequency ablation. Over 45 measurements, temperatures on the mucosal surface of the esophagus ranged between 37-38.1 °C versus surface thermal doses ranged between 0-80 CESQ43. These findings may contribute to the identification of safety thresholds for esophageal temperature, which may preclude the incidence of esophageal perforation during cardiac ablation.

11:20 Portable 3-D Microwave Imaging System for Cardiovacular Diseases Monitoring

Jorge Alberto Tovar Vasquez (Politecnico di Torino, Italy); Ryszard Szczęsny (CNR-National Research Council of Italy, Italy); Giovanna Turvani (Politecnico di Torino, Italy); Gennaro Bellizzi (University of Naples Federico II, Italy); David O. Rodríguez Duarte (Politecnico di Torino, Italy); Nadine Joachimowicz (Group of Electrical Engineering - Paris / CentraleSupelec, France); Bernard Duchâtre (Laboratoire des Signaux et Systèmes/Supélec/CNRS, France); Mario Roberto Casu (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)

This paper describes the first prototype of a portable 3-D microwave imaging system for cardiovacular diseases monitoring and its initial experimental validation on an anthropomorphic head phantom. The proposed device is meant to address the current lack of a technology capable of performing continuous bedside monitoring of the patient after the stroke onset. A proper management of the post-stroke stage of the disease is needed to verify the effectiveness of the therapies and timely adjust them according to the evolving clinical situation. To this end, the device is designed to match portability and imaging capabilities, by exploiting the optimal tradeoff between frequency antenna elements to achieve the goal of estimating the position and size of the stroke using measurements taken at different times. The initial experiment described here confirms such a capability and sets the ground for extensive testing aimed at full assessment of the device.

11:40 Potentials of Inverse Scattering Techniques for Breast Cancer Imaging at Millimeter-Waves Frequencies

Martina Teresa Bevacqua (Università degli Studi di Reggio Calabria, Italy); Simona Di Meo (University of Pavia, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Tommaso Isemissa (University of Reggio Calabria, Italy); Giulia Matrone and Marco Pasian (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 electromagnetic field and radar imaging, being tested in some cases even on real patients. However, the low working frequency of these systems, which allows to reach minimum superfluous targets, has been in some cases the main cause of a non-optimal resolution. Based both on the results of recent dielectric characterisation 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 array scenario at the frequency of 30 GHz is proposed. In particular, we investigate reconstruction techniques, the Linear Sampling Method and the Born Approximation, are proposed and compared.

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

Benedek Adje-Frimpong and László Csurgai-Horváth (Budapest University of Technology and Economics, Hungary)

In the experimental campaign using the Alphasat Aldo Paraboni satellite payload at Budapest University of Technology and Economics, we contribute to characterizing the Ka/Ku propagation model. 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 cumulative distributions. Relevant recommendations from the ITU-R rain attenuation prediction models are compared with the measurements to classify the measured data sets, which will be used to assess performance of the Ka/Ku band satellite propagation channel in Budapest. We also demonstrate different data processing techniques showing how they influence the goodness of fit with the ITU-R model.

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

Sebastien Rougerie (ONERA - The French Aerospace Lab, France)

This paper presents an optimized Land Mobile Satellite (LMS) propagation channel model for Ku/Ka band. Here, a statistical approach [1] is combined with an electromagnetic model, while keeping a good representation of the satellite propagation channel. This approach is complementary of full statistical approaches. The aim of this work is to test the performance of electromagnetic and statistical propagation channel models on available LMS data sets. The results show that the proposed model is able to accurately predict the channel behavior in realistic LMS scenarios.

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

Domingo Pimentela-del Valle (Universidad Politécnica de Madrid, Spain); Pedro García-del-Pino (Universidad Politécnica de Madrid, Spain); 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 statistic, long data periods are needed. The Universidad Politécnica de Madrid (UPM) is receiving the 40-GHz signal coming from the Q-band Alphasat beacon, with 6 years of measurements processed up to now. With the available excess attenuation data, fade slope distributions can be derived. Annual and period excess attenuation distributions and fade slope probabilities are presented, together with the comparison of fade slope results with the Rec. ITU-R P.622-3 model. The predictions of the ITU-R model follow adequately the experimental results, with most of the differences being obtained for the higher analyzed time intervals (from 60 to 180 s) and attenuations (higher than 15 dB and of up to 25 dB).
### CS09: Analytical and Numerical Methods for Metasurface Analysis and Design

#### 9:30 Heights of the 0°C Isotherm and the Bright Band in Madrid: Comparison and Variability

Anna Benachó (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 0°C isotherm height as proposed in ITU-R Recommendations and also from radiosonde measurements. Statistical results on the variability of the 0°C 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 (VRM-2) have allowed comparing the height of the 0°C 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.

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

Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Susana Meta (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 obtain 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

Arjan Krémkó and Áles Švitjig (Jozef Stefan Institute, Slovenia); Andrej Hrovat (Jozef Stefan Institute, Slovenia)

In order to achieve larger capacities needed for modern multimedia services, satellite communications are using high frequencies, such as the Ka/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 and orbit 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 analysis of rain attenuation from Alphastat satellite at 19.7ºC and 29.4 G in Ljubljana. Moreover, the performance of time diversity in two-site diversity system is investigated based on two-years experimental signal data from Astra 3B satellite at 12.09ºC 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. Efrem and Nikolaos Lytras (National Technical University of Athens, Greece); Charilaos Koungorgos and Technology Facilities Council/RAIL Space, United Kingdom (Great Britain); Athanasios D. Papagopoulos (National Technical University of Athens, Greece); Pantelis Daniel Arapoglou (European Space Agency, The Netherlands)

Optical satellite networks have recently been proposed as an alternative solution for such satellite networks. This paper studies the Medium Earth Orbit (MEO) optical satellite communication systems More specifically, simple models for the optical selection of the locations 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 coverage, 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 CDF/STC statistics for MEO satellite communication systems based on the Integrated Liquid Water Content (ILWC) 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 Angle Slope Paths: Measurements and Modelling

Erik W Alksner (University of Bergen, Norway); Martin Rydt (Norwegian Defence Research Establishment (FFI), Norway)

Gaseous attenuation variability for a 3.2º elevation angle satellite link operating at 20 GHz in the Norwegian Arctic is analyzed with different models. At a very low elevation link 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 ground 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 model the agreement is very good with the measured data, with a clear difference in accuracy between them.

#### 11:40 Potentials of the Numerical Weather Prediction Model MM5 to Produce Attenuation Statistics in Tropical Regions

Valentin Le Moine (ONERA, France); Xavier Boulanger (CNES, France); Laurent Castanet (ONERA, France); Bouchra Benammar (Centre National d'Etudes Spatiales (CNES), France); Laurent Féral (Laboratoire LAPLACE, France)

This paper presents the use of a Numerical Weather Prediction model (MM5) coupled with an electromagnetic model to create 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 data led to the conclusion that the MM5 model is able to predict the attenuation levels with good accuracy.

#### 12:00 Performance Trends at 26.5 GHz for a Receiving Ground Station at Polartropic Latitudes: The SNOWBEAR Project

Matteo Marchetti and Donato Lospalluto (University of Pavia, Italy); Filippo Concorso (European Space Agency, Germany); Filomena Romano and Domenico Cimini (CNR-IMAA, Italy); Marco Pasian (University of Pavia, Italy)

Radio links at around 26.5 GHz for space communications between Earth observation satellites and ground stations at Polartropic latitudes are being considered in recent years to increase the downlink performance. However, the precise link budget modelling and the experimental validation of such links is still open, partially 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 structure (e.g., the antenna volute). This paper presents the link budget model implemented in the framework of a dedicated project (SNOWBEAR) under European Space Agency coordination and examples of validation of such a model against experimental data, including cases either in clear sky condition or during a snowstorm. In addition, possible upgrades for the model, based on the use of the ERAS database, are outlined.

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**T10 EM modelling and simulation tools / Convened Session / Electromagnetics**

**Room: 89**

**Chair:** Christophe Craeye (Université Catholique de Louvain, Belgium), Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

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#### 8:30 Metasurface for Dense Dipole Array Decoupling in Ultra-High Frequency MIMO

Marc Dubois (Institut Fresnel, France); Anna Hurskainen (ITMUM University, Russia); Masoud S. M. Mollaei (Aalto University, Finland); Sergei Kudrjumov (ITMUM University, Russia); Rehana Abdulrahim (Aix Marseille University, France); Stefan Enoch (CNRS & Institut Fresnel, France); Stanislav Glybovsky (ITMUM University, Russia); Constantin Simovski (Aalto University, Finland)

This paper presents a meta-material structure with two resonant modes that allow for a decoupling of arrays of dipoles. The corresponding eigenvalues are related to the resonance frequencies and the eigenvectors are the corresponding surface currents. The study is performed using the finite-difference time-domain method. The results show that the proposed structure is able to achieve a high level of decoupling for a wide range of frequencies.

#### 8:50 Elliptical Glide-Symmetric Hole Metasurfaces for Wideband Anisotropy

Antonio Alex-Amor (Technical University of Madrid, Spain); Fatemeh Ghassemifard (KTH Royal Institute of Technology, Sweden); Guido Valero (Politecnico University, Italy); Pablo Padilla (University of Granada, Spain); Jose Manuel Fernandez Gonzalez (Universidad Politecnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This paper presents a new kind of glide-symmetric elliptical metasurfaces that are capable of achieving wideband anisotropy. The elliptical holes are designed to have a high degree of anisotropy, which allows for the control of the electromagnetic wave propagation. The proposed structure is shown to be capable of achieving high levels of anisotropy over a wide range of frequencies.

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

Raúl Rodríguez-Berral (University de Sevilla, Spain); Francisco Mesa (University of Seville, Spain); Francisco Medina (University of Sevilla, Spain)

This paper presents a new method for the derivation of circuit models for periodic surfaces with multiple resonances. The method is based on the eigenvalue problem for the periodic structure, which allows for the derivation of the circuit parameters in a systematic way. The proposed method is shown to be capable of accurately predicting the circuit parameters for complex periodic structures.

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#### 9:30 IE-GSTC Analysis of Metasurface Cavities and Application to Redirection Cloaking

Mohajiba Dehhammadia and Christophe Caloz (Ecole Polytechnique de Montreal, Canada)

This paper presents a new type of metasurface cavity that is capable of achieving high levels of anisotropy. The proposed structure is shown to be capable of achieving high levels of anisotropy over a wide range of frequencies. The results show that the proposed structure is capable of achieving high levels of anisotropy over a wide range of frequencies.
CS39: Machine Learning in Antennas

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

Moaybde Akinsele (Gynder University, United Kingdom (Great Britain)); Keyur Motry (University of Huddersfield, United Kingdom (Great Britain)); Bo Liu (University of Glasgow, United Kingdom (Great Britain)); Peter S Eccle (Gynder University, United Kingdom (Great Britain))

Antenna design optimization continues to attract much interest. This is mainly because traditional antenna design methodologies are exhaustively hard- and have no guarantee of yielding successful outcomes due to the complexity of contemporary antennas in terms of topology and performance requirements. Though design automation via optimization continues to be an important area of research, antenna design optimization still presents a number of challenges. The main challenges in antenna design optimization include the efficiency and optimization capability of available methods to address a broad scope of antenna design problems considering the growing stringent specifications of modern antennas. This paper presents a review of the most recent progress in antenna design optimization and a focus on methods which address the challenges of efficiency and optimization capability via machine learning techniques. The methods highlighted in this paper will likely have an impact on the future development of antennas for a multiplicity of applications.

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

Duygu Kan (Ghent University & IMEC, Belgium); Simon De Ridder, Domenico Spina and Ivo Ciocek (Ghent University, Belgium); Flavia Grassi (Politecnico di Milano, Italy); Tom Dhaene (Ghent University & IMEC, Belgium); Hendrik Rogier and Dries Vande Ginste (Ghent University, Belgium)

A machine learning-based framework is proposed to evaluate the effect of design parameters, affected by both aleatory and epistemic uncertainty, on the performance of antennas. In particular, possibility theory is leveraged to define aleatory and epistemic uncertainty in a common framework. Then, a method combining Bayesian optimization and Polynomial Chaos expansion is applied to accurately and efficiently propagate both uncertainties throughout the system under study. A suitable application example validates the proposed method.
Achilles D. Bourisakis (Aristotle University of Thessaloniki, Greece); Stavros Koulouridis (Aristotle University of Thessaloniki, Greece).
In this paper, we design an reconﬁgurable antenna for wearable applications. The proposed antenna is a planar inverted-F antenna (PIFA) for operation at SGH. The antenna design procedure is accomplished using a new nature inspired algorithm, the Whale Optimization Algorithm. Numerical results exhibit the applicability and validity of the proposed design framework.

A Compact Frequency Reconfigurable DPA for GSM, LTE, and 5G Applications Services
Chechmedine Zehri (Ferhat Abbas University of Setif, Algeria); Djamel Saidy (University of 20 Aout, United Kingdom (Great Britain)); Jamal Kousa and Widad Mshwat (University of Bradford, United Kingdom (Great Britain)); Issa Ellergani and Jonathan Rodriguez (Instituto de Telecomunicacões, Portugal); Reza A Abd-Allahmed (University of Bradford, United Kingdom (Great Britain)).
A compact PIFA diode frequency reconfigurable dielectric resonator antenna (DRA) for GSM, LTE and 5G applications is studied and presented. The proposed antenna provides operating frequencies between 1.8 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 permittivity 12.85 for R01 and R03 and 1.96 for R02, of different dimensions. Two PIN diode switches are adequately placed on the microstrip line between the two dielectric resonators to assure the reconﬁguration function. The proposed antenna size is 20×36×8.8 mm3. Simulation results are presented and discussed. For the antenna structure validation and to highlight its performances, 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%.

A 4th New Broadband MIMO Antenna System for Sub 6 GHz 5G Cellular Communications
Naser Qajoudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Yasir Ismael Abdulrahim Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Ahmed Maan Abdullahkale (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Halieh Jahangibkh Basherlou (Bradford College, United Kingdom (Great Britain)); Atha Ullah and Reza A Abd-Alhameed (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 FR-4 substrate (εr=4.4, δ=0.02) with a dimension of 75×150 mm2 is employed as the motherboard substrate. The proposed design offers good isolation, dual-polarized full radiation coverage, and sufﬁcient efﬁciencies. In addition, a wide impedance bandwidth (551 to 10 dB) of 3.3 to 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 Abdullahkale (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Maan Yahya (Northern Technical University, Iraq); Naser Qajoudi Parchin (University of Bradford, United Kingdom, United Kingdom (Great Britain)); Yasir Ismael Abdulrahim Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Maryam Sajedin (University of 20 Aout, United Kingdom (Great Britain))
In this paper, the design of a three-way Doherty amplifier based on the harmonic generating mechanism is presented. The saturated power in the output stage is achieved by using the third harmonic. The power-added efﬁciency (PAE) is improved to 33% by minimizing the third harmonic distortion. The proposed antenna offers average power gains 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 Voltage Standing Wave Ratio (VSWRs). Mutual coupling effect on three-way Doherty power ampliﬁer is stud- ied, where the ampliﬁer is targeting 3.4-3.8 GHz for 5G applications using three GaN HEMT devices (W1:25W and 45W) to achieve a 70% 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 in the back-off region. In addition, the performance variation of the designed amplifier was tested for different Voltage Standing Wave Ratio (VSWR) considering the antenna impedance changing due to mutual coupling. In addition, a new mode of operation is presented and discussed. For the antenna structure validation and to highlight its performances, 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%.

8:30 The Road to Electromagnetism
Andrew D. Jackson (University of Copenhagen, Denmark)
The electromagnetic revolution began with Hans Christian Ørsted’s observation of the effect of an electric current on a compass needle. The events that led to this discovery will be reviewed.

8:50 The Discovery of Electromagnetism by Hans Christian Ørsted 200 Years Ago
Oliv Breindberg (Technical University of Denmark, Denmark)
In 1820 Hans Christian Ørsted (1777-1851), then a professor of natural philosophy at the University of Copenhagen and later a founder and the first president of the Technical University of Denmark, observed systematic dependence between electricity and magnetism are related. He thus discovered an entirely new natural science that he termed electromagnetism, a science that became a paramount importance for understanding the nature of matter and technologies developing the modern society. This paper reviews Ørsted’s epoch making discovery through his own writings published between 1820 and 1830.

9:10 Electromagnetism Before Maxwell: From Ørsted to Weber
Ovidio Mario Bucci (University of Naples, Italy)
This paper summarises the main stages of the development of Electromagnetism before Maxwell, from Ørsted’s discovery of the magnetic effect of currents, through the Ampere’s development of electrodynamics and Faraday’s discovery of electromagnetic induction, until the development of Weber’s electrodynamics. The emphasis is on the conceptual evolution that led from one stage, to the unification under electromagnetic theory, sound theory of all known electromagnetic phenomena within the Newtonian paradigm of instantaneous action at distance, from the other side to lay the foundation for the Maxwell’s revolution, which definitively changed such paradigm.

9:30 After Ørsted’s Discovery: Johann Jacob Nervander and the Quantification of Electric Current
Ali Sihlwa (Aalto University, Finland)
This paper focuses on the developments in electromagnetism after Ørsted’s discovery in 1820. In particular, the principles to measure and quantify the electric current are given attention. Scherzer, Poggendorff, Noilai, and Poullet contributed to the development of the galvanometer. The article also specifies emphasis on the researches of Johann Jacob Nervander, whose “tangent bussol”, presented to the University of Paris in 1834, and later published in Annales de Chimie et de Physique, was an important development in the instrumentation of electrical engineering.

5:00 Oliver Heaviside, Maxwell’s Apostle of Eccentric Elegance
This paper presents an energy efﬁcient asymmetrical Doherty ampliﬁer based on the harmonic tuned Class-F and inverse Class-F mode of operations. In addition, the design procedure of multi-resonant circuits tuned for second and third harmonics at the device input/output are explored. The saturated Doherty architecture is designed by 10W GaN HEMT devices from Cree at 3.6 GHz and power added efﬁciency of 50% at 80% back-off of 55% at maximum output power of 4dBm have been achieved. This superposition performance has been conﬁrmed by comparing the simulated results with that of conventional one.
Tuesday, 17 March 10:40 - 12:20

**T10-M10: General Antenna Measurements**

**Room: B4**

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

10:40 Fast Antenna Array Characterization with Numerical Basis Functions

Marco Righero and Andrea Scabasbrio (LINKS Foundation, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

A technique to exploit a priori information about an array antenna to reduce the number of near-field samples needed for its characterization in far field is shown. Custom basis functions are built, considering the pattern of the isolated element, the element 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.

11:00 Near-to-Near- And Near-to-Far-Field Transformation for Millimeter-Wave Frequencies

Serge Pfaff (Foundation for Research on Information Technologies in Society (ITIS Foundation), Switzerland); Tjhang Xi (The Foundation for Research on Information Technologies in Society (ITIS), ETH Zurich, Switzerland); Sven Kuhn (ITIS Foundation, Switzerland); Beyhan Kocalti (Schmid&Pfaffner Engineering AG, Switzerland); Niels Kuster (ITIS Foundation, Switzerland)

With the advent of 5G mobile communications at millimeter-wave frequencies, exposure assessment by means of power density evaluation will become important; this, in turn, requires knowledge about the electric and magnetic field. To avoid measuring these quantities in the full volume of interest, 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 SIRA95 E5mmW 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.

11:20 Fast Antenna Measurement via Model Order Reduction

Benjamin Fuchs (University of Rennes 1 - IETR, France); Athanasios Polimantis (Q bio, USA)

A general procedure to characterize antennas from a reduced number of field samples is proposed. It relies on the construction and the fast evaluation of the reduced order model (ROM) of the antenna measurement problem. The ROM is built by computing the singular value decomposition (SVD) of the radiation operator that maps the equivalent currents surrounding the antenna under test (AUT) to the radiated near- or far-field. The SVD yields orthonormal basis for both sets and enables to compress the matrix of the discretized integral equation. The evaluation of the so-constructed reduced order model is expedited by using the discrete interpolation method (DIM) that selects a small number of field sampling points. 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.

11:40 Singularity Extraction of Electric-Field Integral Equations in Spherical Near-Field Antenna Measurement

Rezvan Rafiee Alavi, Rashid Mirzazadeh and Pedram Mousavi (University of Alberta, Canada)

In the solution of electric field integral equation (EFIE) by the method of moment (MOM) on discretized planar triangles, singularities emerge in the inner integrals on the basis functions. In this paper, formulas for the singularity extraction of EFIE in the application of near-field measurement of antennas are systematically developed and presented. The simulations and measurements are performed to compare the results with and without singularity extraction. The results confirm the validity and accuracy of the proposed method.

12:00 Revisiting the Poincaré Sphere as a Representation of Polarization State

Brett Walkenhorst and Steven R. Nichols (NSI-MI Technologies, USA)

Graphical representations of the polarization state of an antenna or an electromagnetic wave propagating through space are useful tools to supplement rigorous mathematical analyses. One such example, the polarization ellipse, is frequently used in combination with the mathematical development of polarization theory. The Poincaré sphere is another graphical representation but is much less widely used. Since each possible polarization state appears as a point on the surface of the sphere, it has limited value in representing a single polarization state. However, it can be quite useful for visualizing the relationships between multiple polarization states. In this paper, we show a different way of presenting the Poincaré sphere using a Meratoni projection and elliptical parameters. We also describe a tool that implements this technique and provides on-screen display of polarization state as a function of frequency.

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Tuesday, 17 March 10:30 - 12:20

**T10-E03/1: Computational and Numerical Techniques**

**Room: B11**

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

10:40 An Iterative Method for the Analysis of Large Disjoint Antenna Arrays

Matthews Chose (Stellenbosch University & University of Stellenbosch, South Africa); Matthias M. Botha (Stellenbosch University, South Africa)

A new iterative method is presented, for the efficient method of moments (MoM) analysis of large antenna arrays with identical, disjoint elements. The method is an extension of the domain Green’s function method (DGFM). At each iteration, a local domain radius is used to identify sub-problems of closely-coupled elements 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.

11:00 Directional Method to Compute Reduced Matrix System in MBF Solvers

Keshav Sewraj and Matthias M. Botha (Stellenbosch University, South Africa)

Computation of reaction terms in macro basis function (MBF) solvers is computationally very expensive. A directional cross approximation technique is used in this paper to compute the reaction terms, which is a multilevel low-rank compression technique. The motivation to use a directional method is to keep the compression rank bounded irrespective of subdomain size, so as a fast algorithm can be ensured. 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.

11:20 An Efficient Parallelization Strategy for the Adaptive Integral Method Based on Graph Partitioning

Damián Marek, Shashwat Sharma and Piero Triverio (University of Toronto, Canada)

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Tuesday, 17 March 8:30 - 12:20

**SW08: Challenges of Modern Material Measurements**

**Room: B3**

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

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Tuesday, 17 March 8:30 - 12:20

**SW08: Challenges of Modern Material Measurements**

**Room: B3**

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

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Tuesday, 17 March 8:30 - 12:20

**SW08: Challenges of Modern Material Measurements**

**Room: B3**

**Chairs: Benjamin Fuchs (University of Rennes 1 - IETR, France), Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy)**
11:40 A False-Resonance-Free Integral Equation Formulation for the Electromagnetic Transmission Problem

Anders Karlsson and Johan Helings (Lund University, Sweden)

We present a boundary integral formulation of the transmission problem where an incident electromagnetic wave is scattered from a bounded dielectric object. The formulation provides unique solutions for all combinations of wave numbers with non-negative imaginary parts for which the Maxwell equations have unique solutions.

12:00 An Explicit Time Domain Finite Element Boundary Integral Method with Element Level Domain Decomposition for Electromagnetic Scattering Analysis

Ming Dong (King Abdullah University of Science and Technology (KAUST), Saudi Arabia); Peng Li (The University of Hong Kong, Hong Kong); Hakan Bagci (King Abdullah University of Science and Technology (KAUST), Saudi Arabia)

A numerical scheme, which hybridizes the element level dual-field time domain finite element domain decomposition method (ELDFD/TDFEM) and time domain boundary integral (TDBI) method to accurately and efficiently analyze open-region transient electromagnetic scattering problems, is proposed. The element level decomposition permits an efficient leap-frog-like explicit marching scheme to be used to integrate Maxwell’s equations in time. The hybridization with TDBI method ensures that an accurate solution can be obtained in the smallest computational domain possible. The accuracy and applicability of the proposed hybrid method is demonstrated by numerical experiments.

IW08: From 5G Research to Real Deployments: Industrial Experiences and Challenges (Ericsson AB)

Room 6

Tuesday, 17 March 13:20 - 14:50

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

EurAAP

12:50 - 14:50 Room: TBD

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

EurAAP

12:40 - 14:00 Room: TBD


EurAAP

13:20 - 14:50 Room: TBD

Convened Poster 1-CS08: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring

Convened Poster 1-CS08: Analysis, Design and Use of Microwave Techniques, Models, Systems, and Antennas for Snowpack Avalanches Monitoring

T08 Positioning, localization & tracking / Convened Session / Propagation

Room: A2 (Poster Area)

Chairs: Guido Luzi (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain), Marco Pasian (University of Pavia, Italy)

CP1.01 Monitoring of Snow Cover Properties Using Active and Passive Microwave Sensors in Boreal Forests: Implications of Variable Canopy Transmissivity

Juha Lemmetinen and Anna Kontturi (Finnish Meteorological Institute, Finland); Mike Schwank (German Research Centre for Geosciences (GFZ), Germany); Qinghuan Li (University of Waterloo, Canada); Kimmo Rautiainen (Finnish Meteorological Institute & Arctic Research, Finland); Juho Vehviläinen (Finnish Meteorological Institute, Finland); Jouni Pulliainen (Finnish Meteorological Inst., Finland)

Localized, continuous measurements of microwave signatures are instrumental in the development of geophysical retrieval algorithms for satellite sensors. Ground-based instruments allow to relate these signatures to quantified natural processes with increased accuracy and temporal resolution compared to direct use of satellite observations; in particular for coarse resolution passive microwave sensors, understanding the different contributions from heterogeneous terrain components is a prerequisite for interpreting satellite observations, necessitating focused observations over several terrain types. Changes in e.g. snow microstructure, wetness and impurities have different effects at different bands across the microwave and optical spectrum, highlighting the importance of multi-wavelength observations.

CP1.02 Complex Dielectric Constant of Wet Snow Using Bi-Static Synthetic Aperture Radar

Jon Håvard H Eriksrød, Kristian G Kjeldgaard and Tor Sverre Lande (University of Oslo, Norway)

This paper presents a feasible method for measurements of the complex dielectric constant for snow assessment using a coherent bistatic synthetic aperture radar. The complex dielectric constant may be measured directly for both wet and dry snow. Since signal delay as well as signal loss is measured, the complex permittivity can be constructed as a closed form expression. The radar system performance is validated on a characterized snow phantom with good results even for high water content indicating adequate measurements for wet snowpacks.

CP1.03 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); Fernando Mira Perez (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Michele Crosetto (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Ping Li (The University of Hong Kong, Hong Kong); Kristian G Kjeldgaard and Tor Sverre Lande (University of Oslo, Norway)

The use of Sentinel-1 SAR images for snow behavior monitoring is one of the most studied applications, but due to the high temporal and spatial heterogeneity of this media, is quite challenging. The presence of reference targets in the observed areas is of main concern both for amplitude and interferometric based techniques, but in a typical scenario as snow covered slopes or glaciers there is a lack of stable natural targets; this can demand the installation of Corner Reflectors. In this study, the design and the first test of an active corner reflector (ACR) operating at 5.405 GHz ± 50 MHz band, designed to be used in support to ESA Sentinel-1 spaceborne SAR images analysis and processing, is reported. The system here described was designed aiming at a tradeoff between low-cost, simple functioning, easy and rugged hardware to be deployed also in sites, as snow covered areas and glaciers.
Convened Poster 1-CS10: Antenna Array and Integrated Systems for 5G Communication Applications

Room: A2 (Poster Area)

CP1.07 Antenna-Amplifier Co-design: On a Method to Shape the Antenna Impedance
Lars Jonsson and Ahmad Emaraddini (KTH Royal Institute of Technology, Sweden)

In this paper we examine a particular type of shape optimization to improve the antenna input impedance. In a co-integration approach, the impedance goal is to approach an optimal load for the power amplifier, while maintaining low losses and good radiation properties. This is increasing importance of above 20GHz, since commercially available, high efficient amplifiers tend to have a strong frequency variation in their optimal load-pull impedance. A classical approach to matching is a matching network, however at these higher frequencies such networks are associated with losses from conduction, conduction and dielectrics. Here we instead study how antenna shaping can be perturbed to exhibit the desired frequency response. This is a natural topic focusing on the antenna impedance at a given frequency and for a few generic antenna types.

CP1.08 5G Multibeam Magneto-Electric Dipole Antenna Fed by a Single-Layer Corporate-Feed Network Based on Ridge Waveguide
Wai Yan Yong (University of Twente, The Netherlands), Thomas Emauelsson (Gaspawaves AB, Sweden), Aydon Blu Aliyev (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 waveguide (RWG) 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 RWG. Our design allows for a smaller antenna volume as it excited the antenna directly by the RWG 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 produces S11 -10dB over 24 - 30 GHz resulting in a 22% fractional bandwidth. The maximum directivity over the operating bandwidth of the simulated 2x2 ME-dipole antenna element is approximately 15.4 dBi.

CP1.09 Design of Millimeter Wave True-Time-Delay Beam-formers for 5G Wireless Systems
Dimitrios I. Lialis, Konstantinos D. Paschaloudis, Anastasios G. Koutinos, Emplouk Tzihat and Nikolaios Ntetsikas (Democritus University of Thrace, Greece); Vasilis Kassouras (Center for Security Studies (KEMEA), Greece); Konstantinos Kardaras and Dimitrios S. Kritharidis (Intracom Telecom, Greece); Christos Kolitsidas (Ericsson, Sweden); George A. Kyariuc (Kimmerna Campus, Greece); Marinos Karkas (University of Twente, The Netherlands), Thanos Oikonomou (University of Thrace, Thessaloniki, Greece)

The exploitation of the millimeter wave (mmW) spectrum is determinant in the upcoming fifth generation (5G) wireless communications, as it meets the requirements for high capacity links, large data rates and low 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 "low diagram topology", while the other architecture employs a Blas matrix, which is a known beamforming network at the microwave regime.

CP1.10 Circularly and Linearly Polarized Planar Reconfigurable Active Array Antennas in Ka Band
Alfonso T. Muru Barrado, Jorge Catalayud Maeso, Antonio Rodriguez Gallego, Jose Manuel Fernandez Gonzalez and Manuel Sierra-Perez (Universidad Politecnica de Madrid, Spain); Pablo Sanchez-Oliva (Autonoma de Madrid, Spain)

This paper presents an evaluation procedure of a commercial integrated circuit (IC) phased antenna array beam steering within mobile satellite communication applications at Ka Band (28-38 GHz). It avoids to control amplitude and phase delays for only few active elements. Therefore, only the transmission system is evaluated. Two different passive arrays are proposed to evaluate IC-performance in 2x2 planar array with switchable circular polarisation (CP) capabilities and a full planar array for feeding in columns for azimuth beam steering with linear polarisation (L). Thus, since the first array is not as big enough for evaluation beam steering performances, it is only used for CP-performance evaluation. A second bigger array, which is bigger but not circularly polarized, allow beam steering evaluation. Measurements of the proposed full integrated system will be presented in the conference.

CP1.11 Broadband CTS Array in PCR Technology
Michel Del Mastro (University of Rennes 1, France), Adham Mahmoud (Institut d’Electronique et de Télécommunications de Rennes, France); Thomas Potelon (ETR - University of Rennes 1, France); Ronan Saulieu (University of Rennes 1, France); Mauro Ettorre (University of Rennes 1 & UMR 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 plate waveguide technology. An embedded pillars 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., 4,7% 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.

CP1.12 A Simplified Extended SWI Supporting TE_011 Integrated with a Feeding Structure
Christos Kolitsidas and Darwin Blanco (Ericsson, Sweden)

A TE_011 substrate integrated waveguide is presented in this work. To avoid the propagation of this typically unperturbed mode the SWI is integrated with an electromagnetic band gap (EBG) structure that confines the field with the waveguide structure. The EBG is simply stacked top and bottom of the proposed structure allowing manufacturing ease. The overall proposed structure is simulated and the results indicate very low insertion loss in the pass-band of the waveguide.

Convened Poster 1-CS11: Antennas with Multi-Port/Distributed Feeding and On-Antenna Power Combining for Efficient Integration and Reconfigurability

Room: A2 (Poster Area)

CP1.13 Efficient Waveguide Power Combines at mm-Wave Frequencies
Ralph van Schelven, Marco Spinolo and Daniele Cavalli (Delft University of Technology, The Netherlands)

In this work, an efficient power combiner for mm-wave frequency transmitters is investigated. The concept 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 amplitude 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.

CP1.14 Reducing User Effect on Mobile Antenna Systems with Antenna Cluster Technique
Rasmus Luomaniemi, Albert Salmi and Anu Lehtovuori (Aalto University, 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 user. Furthermore, the cluster technique can also be used to reduce the user effect by adapting the cluster operation for different environments.

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

Room: A2 (Poster Area)

CP1.04 Analysis of Snow Water Equivalent (SWE) of Snowpack by an Ultra Wide Band Frequency Continuous Wave Radar (FWCR)
Rafael Alonso, José María García del Pozo and Ismael Peruga (University of Zaragoza, Spain); Samuel Buissin (Territorial Delegation of AEMET (Spanish State Meteorological Agency) in Arazpín, José Adolfo Álvarez (Ebro River Basin Authority (CHE))

A ground-based step frequency continuous wave radar (SFCW) based on a software defined radio (SDR), in the range from 150MHz to 6GHz has been designed, fabricated and tested under real conditions. The radar has been applied to measure the snow water equivalent (SWE) of snowpack in the Spanish Pyrenees. A matrix method is applied to solve the electromagnetic reflection of multilayer cover snow including frequency and wave length dependence of complex relative dielectric permittivity of snow layers. An approximated method to obtain SWE is presented. The model is based on the comparison of measured reflected signal vs distance plot with the calculated with an "equivalent" snow layer. Preliminary results are presented and compared with those provided by a cosmic-ray neutron SWE gauge over the 2019 winter. These results suggest the viability of the proposed method.

CP1.05 Identification of Multi-Temporal Snow Melting Patterns with Microwave Radars
Marco Pasian and Pietro Fidel Espin Lopez (University of Pavia, Italy); Valentina Premier (Eurac Research, Italy); Claudia Notarnicola (Eurac, Italy); Carlo Marin (Eurac Research, Italy)

Not available
Convened Poster 1-CS18: Applications of mm-Wave Gap Waveguide Technology

This work presents a high-frequency packaging solution which paves the way towards system integration above 100 GHz.

Ahmed Hassona
Qingbi Liao

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

This work presents a high-frequency packaging solution which paves the way towards system integration above 100 GHz.

Ahmed Hassona, Vessen Vassilev, Ashraf Uz Zaman and Herbert Zirath (Chalmers University of Technology, Sweden)

This work presents a high-frequency packaging solution which paves the way towards system integration above 100 GHz.

Ahmed Hassona, Vessen Vassilev, Ashraf Uz Zaman and Herbert Zirath (Chalmers University of Technology, Sweden)
CP1.25 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); Tianning 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 and 2-to-4 power dividers to achieve a compact size. The 1-to-8 power divider adopts a double-layer structure. The top layer in the feeding structure of the power divider, and the bottom layer contains the loads. The simulated results show that the proposed power divider exhibits the impedance matching bandwidth for the reflection coefficient below -15 dB is from 23.7 GHz to 30 GHz, and isolations between the output ports is more than 18 dB.

CP1.26 Mechanical Phase Shifter in Gap-Waveguide Technology
Daniel Sánchez-Escudero (Universitat Politècnica de València, Spain); José Ignacio Herranz-Herruzo (Universidad Politécnica de València, Spain); Miguel Ferrando-Rocher (Universitat Politècnica de València, Spain); Alejandro Valero-Noaga (Universidad Politécnica 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-moves applications. The use of the gap-waveguide technology allows to divide the device into two main blocks distributed in two levels: a low-loss movable block, in charge of the power distribution and the phase shifting, and an upper fixed block with the output waveguide. In this paper, the lower and upper blocks are designed using Groove-gap waveguides (GGW), 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 in the input port, within the operating frequency band.

CP1.27 Considerations in Designing Inverted Microstrip Gap Waveguide Components
Francisco Pizarro (Pontificia Universidad Católica de Valparaíso, Chile); Carlos Sánchez-Cabello (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-CS27: Electromagnetics in MRI Applications

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

Chairs: Theodore Andonian, Vitaly Zhurbenko
(Technical University of Denmark, Denmark)

CP1.28 Design of Distributed Spiral Resonators for the Decoupling of MRI Array Coils
Danilo Brizi, Nunzia Fontana, Filippo Costa and Rocco Matera (University of Pisa, Italy); Gianluigi Tiberi (London South Bank University, London, UK); Angelo Galante (University of L'Aquila, Italy); Marcello Alecchi (University of L'Aquila and INFM-LNLS, L'Aquila, Italy); Agostino Monorchio (University of Pisa & CNIT, Italy)

This paper describes a distributed filter layout for the design of a 7T Radio Frequency (RF) Magnetic Resonance Imaging (MRI) 1H planar array coils based on miniaturized spiral resonators on an FR substrate. The spirals, opportunely designed in terms of resonant frequency and with an optimised 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 filters obtaining 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.

CP1.29 Hybridized Electric Dipoles Applications in Ultra-High Field MRI
Marc Dubois (Institut Fresnel, France); Tania Vergara Gomez and Frank Kober (Aix Marseille Univ, CRIBM, France); Luisa Ciobanu (DRF/IZIB/Neurospin/INRIS, France); Alexandre Vignaud (Commissariat à l'Energie Atomique & NeuroSpin, France); Redha Abdeldaim (Aix Marseille University, France); Stefan Enoch (CNRS & Institut Fresnel, France)

In this work, we demonstrate how a set of hybridized resonators can be used to achieve efficient and tunable electromagnetic field control in the radiofrequency range. We show that near field coupling between multiple electric dipoles 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 inserted in a human head coil at 7T and i) coupled to a surface coil for small animal MRI at 17.3 Tesla.

CP1.30 A Nesting Approach for the Numerical Analysis of MRI Birdcage Antennas in the Presence of the Human Head
Farzad Jabbari gargari (Université Catholique de Louvain, Belgium); Chan-Sun Park (Yonsei University, Korea (South)); Donia Oueslati (ICTEAM Institute, Université Catholique de Louvain, Belgium); Denis Tihon (University of Cambridge, Belgium); Clément Durochat (Multiscale Imaging SAS, Marseille, Belgium); Thibaut Letertre (Aix Marseille University, CNRS, Centrale Marseille, Institut Fresnel, France); Pierre Sabourou Pierre Sabourou (Institut Fresnel, France); Christophe Crayé (Université Catholique de Louvain, Belgium)

Integrated equation approaches are among the most widely used techniques to efficiently solve RF fields in MRI scanners, in particular when the human body is divided into a collection of homogeneous objects. This solver can be relatively insensitive in terms of computation time and memory if the full solution is executed every time minor changes are considered in the MRI antennas. In this work, an efficient solving tool based on a nesting approach is proposed. The idea consists of recursively avoiding re-computation of the equivalent cells inside the body. A validation is provided for a simple structure with a commercial solver (CST) then 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.

CP1.31 Experimental Validation of the Concept of an Openedge Head Coil for Ultra-High Field MRI
Anton Nikulin (PSL Research University, France); Marc Dubois (Institut Fresnel, France); Tania Vergara Gomez (Aix Marseille Univ, CRIBM, France); Djamel Berrahou (Multiscale Innovation SAS, France); Alexandre Vignaud (Commissariat à l'Energie Atomique & NeuroSpin, France); Redha Abdeldaim (Aix Marseille University, France); Stefan Enoch (CNRS & Institut Fresnel, France); Pierre Sabourou Pierre Sabourou (Institut Fresnel, France); Christophe Crayé (Université Catholique de Louvain, Belgium)

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CP1.32 Matching and Decoupling Networks for Receive-only MRI Arrays
Wenjun Wang, Vitaly Zhurbenko, Juan Diego Sánchez-Herrera and Jan Henrik Ardenkjær-Larsen (Technical University of Denmark, Denmark)

Matching/decoupling between elements on an MRI detector array greatly complicates the process of impedance-matching of the array. This problem is even more severe in flexible arrays, where coupling matrix will change with the shape of the array. To overcome this problem a low noise amplifier can be integrated in each element with a network providing simultaneous noise matching and power matching/decoupling. This work describes the design of such an impedance transforming networks that allow minimizing the influence of the inductive coupling and, at the same time, to ensure minimum noise figure of the connected low noise preamplifier. Different circuit topologies are analysed. Their performance with regard to bandwidth and noise figure are compared. The networks ensure minimum noise figure and decoupling level up to about 28 dB. The presented analysis would be useful for MRI and antenna array designs where element coupling presents a practical problem.

CP1.33 Enhanced Low Frequency MRI Using Flexible Shape Arrays Made of Standard Wire
Juan Diego Sánchez-Herrera, Wenjun Wang, Rie Beck Olin, Vitaly Zhurbenko and Jan Henrik Ardenkjær-Larsen (Technical University of Denmark, Denmark)

Flexible coil arrays are increasingly popular in magnetic resonance imaging (MRI), due to their superior anatomical fitting and patient comfort. Several coil shapes have been proposed, using self-resonant structures for the implementation of the detecting coils. In this work, we show that flexible coil arrays can be implemented in a simpler way, using standard flexible copper wire, as long as the decoupling between elements is kept high. The design approach proposed here can be extended to any frequency, and an example of 7-channel array for 1.5T (3T) (for SNRI increase of about 60% for a human head phantom, compared to state-of-the-art traditional coil arrays). The results show that the flexibility of the coil array does not affect the quality of the MRI image.

CP1.34 Design and Implementation of Solenoid and Alderman-Grant Coils for Magnetic Resonance Microscopy at 7T
Marios Masouridis, Tim Dyrbj and Vitaly Zhurbenko (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 scheme. The coils are designed to provide over 50 field homogeneity in a 125 mm^2 imaging area using electromagnetic simulations, and experimentally in a 7 Tesla preclinical MRI scanner.
In this paper, two designs of micromachined dielectric resonator antennas operating at 60 GHz are presented. The antennas ... to be mounted on the other side. The feeding lines are terminated by magnetic dipole which excite the dielectric resonator and causes its radiation. In order to enhance the bandwidth of the antenna, the dielectric resonator is loaded with a circular or crescent patch antenna. These designs are characterized by their fabrication simplicity, and high radiation performance. Additionally, the proposed antennas have wide impedance bandwidth reaching more than 10% (21%) of the central frequency for the circular/crescent patch loaded dielectric resonator antennas.

Convened Poster 1-CS57: Recent Research on Wind Turbines: EM Modelling and Measurements

**Room:** Exhibition Hall

**Antennas**

P1.001 On-Chip Micromachined Dielectric Resonator Antennas Loaded with Parasitic Circular/Crescent Patch for mm-Wave Applications
Mai Sallam (The American University in Cairo & Katholieke Universiteit Leuven, Egypt); Mohamed Serry (The American University in Cairo, Egypt); Sheetf Sedky (AUC, Egypt); Atif Shamim (King Abdullah University of Science and Technology, Saudi Arabia); Guy Vandebosch (Katholieke Universiteit Leuven (KU Leuven), Belgium); Ezzeldin Soliman (The American University in Cairo, Egypt)

In this paper, two designs of micromachined dielectric resonator antennas operating at 60 GHz are presented. The antennas 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 dipoles which excite the dielectric resonator and cause its radiation. In order to enhance the bandwidth of the antenna, the dielectric resonator is loaded with a circular or crescent patch antenna. These designs are characterized by their fabrication simplicity, and high radiation performance. Additionally, the proposed antennas have wide impedance bandwidth reaching more than 10% (21%) of the central frequency for the circular/crescent patch loaded dielectric resonator antennas.

P1.002 Filtering Dielectric Resonator Antenna Using Terminal-Loaded Resonators
Yan-Ting Liu and Kwok Wo Leung (City University of Hong Kong, Hong Kong)

A new filtering dielectric resonator (DR) antenna (GRA) is presented in this paper. The GRA and its feeding line provide a bandpass response. The antenna feeding line consists of two terminal-loaded microstrip resonators (MRRs), which gives two independently tuned nulls with an improved selectivity. For the DRA, it is excited in the HEM113 mode, serving not only as a radiator but also as the last-stage resonator of bandpass filter (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); Assaf Badawi (Zewail City of Science and Technology, Egypt)

Plasmonic single nanoantennas and meta-surfaces can both enhance and manipulate emission from potential quantum emitters while their interlayer thick structure enables them to integrate into quantum and nano-devices. Here we propose an isotropic Star Nanoantenna design, which coupled to a single quantum dot emitter, offered 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 are 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
Jianjia Yi and Menglan 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)

Despite the novel design for vortex beam generation is proposed by utilizing phase-gradient all-dielectric metamaterials. The pluggable element of proposed design is able to provide a full transittance-phase covering the range of 2π together with a high transmittance efficiency. The elements corresponding to each value of phase are encoded to 360 modules. Thus, designated phase modules can be judiciously adjusted 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 lenses paving the way for the applications of vortex beam.

P1.005 Impedance Bandwidth Performance of TM105 Mode in Equilateral Triangular DRA
Anoop P (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.
Radiated by an antenna.

Innovative concepts and ideas are presented for addressing paramount challenges in the design of future wireless systems. In classical antenna designs, rising in complex propagation scenarios must not be regarded as an obstacle, but rather as a key-asset for realizing innovative and unconventional systems in order to meet the ever-growing demand of high-data-rate connectivity.

This work proposes a novel design of a two-layered antenna array targeting the D-Band region of the spectrum, likely to be used in future wireless communications. The 8×8 cavity backed antenna array exhibits a thin planar footprint with a volume of (30.1×26.4×1.235 mm3) and is capable of achieving a 3-dB gain bandwidth greater than 19% and a cross-polarization level lower than 23 dB.

We present for the first time a 3-bit linearly-polarized substrate-integrated planar lens with focal source antenna designed by using a cost-effective PCS technology in D-band. The effective volume occupied by this compact antenna is 10.5x10.5x4.52 mm3. An experimental gain of 21.1 dBi at 153 GHz, an aperture efficiency of 22.3%, and a Q-factor of 175 are measured.

This paper presents the design of a two-dimensional (2-D) wide-scanning flat Luneburg lens antenna operating at Ka-band. The proposed method for calculating the impedance bandwidth is also validated by comparing with the practical bandwidth of the proposed antenna. The 2-D flat Luneburg lens can be used in a Frequency-Modulated Continuous Wave (FMCW) radar system.
P1.016 Tiled Arrays: Low Cost Solutions for Next Generation Communication and Sensing Systems
Nicola Anselmi (ELEDIA 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 ELEDIA Research Center, assuring exact tiled array designs by exploiting analytic filling theorems and optimization-based techniques. Single shape tiling methods, as well as recent multi-shape multi-array tiling approaches are reviewed and discussed. An illustrative example is reported showing the effectiveness of the proposed approaches when considering square shaped tiles of different sizes.

P1.017 A Novel Probabilistic Interval Arithmetic Method for Tolerance Analysis of Phased Arrays Beamforming Networks
Nicola Anselmi (ELEDIA Research Center, Italy); Alessandro Polo (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca and Andrea Massa (University of Trento, Italy)

This work presents a novel Interval Arithmetic (IA) methodology for the probabilistic tolerance analysis of linear phased array beamforming networks. Efficient IA-based array antenna 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 yielding a more informative tolerance analysis with respect to IA-based state-of-art methods.

P1.018 Optimization of Modular Multi-Function Radar Architectures for Two-Way Pattern Sidelobe Minimization
Nicola Anselmi (ELEDIA Research Center, Italy); Alessandro Polo (ELEDIA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento, Italy);

This contribution proposes a modular phased array architecture suitable for the implementation of Radar/Communication system. The rectangular antenna aperture is divided into a set of identical tile-shaped domains, and according to the number of tiles, the dynamic range of each tile is extended. The proposed approach is validated by means of full-wave electromagnetic simulations for several radar communication system scenarios.

P1.019 Modeling of a Realistic Hybrid Metal-Plasma Transmit-array with Beam-scanning Capabilities
Giulia Marcotti (Università degli Studi di Padova, Italy); Mohammad Hannan (ELEDIA Research Center, University of Trento, Italy); Federico Boulos (ELEDIA/UniTN - DISI, University of Trento, Italy); Paolo Rocca (University of Trento, Italy); Paola De Carlo and Antonio-D. Capobianco (University of Padova, Italy; Alberto Tusizi (ASI - Italian Space Agency, Italy)

This paper presents the design of a realistic hybrid metal-plasma transmit-array antenna with beam-scanning capabilities. The antenna operates at 1.07 GHz and consists of an active metallic dipole, a metallic ground plane, and a set of cylindrical plasma devices arranged in a 2D lattice. The main beam of the antenna can be tilted towards different directions simply by tuning on/off specific subsets of plasma devices. Towards this aim, a two-steps optimization strategy based on the combination of a particle swarm optimization and of a genetic algorithm is adopted. The antenna has been modeled in CST Microwave Studio using realistic design parameters for the plasma devices. In 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.

P1.020 An Irregular Tightly Coupled Dipole Array with Wide Scanning Angles
Yen-Kai Ma (University of Electronic Science and Technology of China, China); Shi Wen Yang (University of Electronic Science and Technology of China, China); Yikai 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 dome-shaped tiles. A 1x2-port finite array operating at 8.12GHz has been implemented, where the port spacing is 0.576 wavelength at the highest frequency. In order to achieve a 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.

P1.021 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); Yikai Chen, Shi-Wei Qu and Jun Hu (University of Electronic Science and Technology of China, China)

For improving the security of wireless communication systems, physical layer security techniques are increasingly introduced by introducing time as the forth controlling factor of physical layer secure transmission. However, traditional direction modulation technique of 4-D antenna arrays always inevitably leads to highest 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. The technique is able to reduce the radiation power at side-lobe region by optimizing the time sequences. Meanwhile, 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 CubeSats
Eduardo Yoshimoto and Marcos V. T. Hecker (Universidade Federal do Pampa, Brazil)

This work describes the application of symmetry schemes and the Fast Fourier 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 signal distortion were synthesized, as to assess the affecting the environment with uniform power density. Good agreement with the desired beams had been achieved.

P1.023 Design of TDCA Avoiding Half-wavelength Limitation Using PC
SeoungKim Kim (Seoul National University, Korea (South))

Low-profile arrays are important in many defense and commercial communication systems. Although tightly coupled dipole arrays (TCDAs) have several advantages, their bandwidth is limited by their ground plane. The use of resistive frequency-selective surfaces to overcome this limitation generates ohmic losses which then deteriorate the radiation efficiency of the array. In this paper, a new algorithm is proposed for optimizing the TCDAs, which eliminates the half-wavelength limitation and enhances the radiation efficiency. The proposed method is validated by a case study of a 2x3 TDCA using resistive frequency-selective surfaces.

P1.024 Global Optimization of Pencil Beams with Constrained Dynamic Range Ratio
Maja Jurisic Bellotti and Mladen Vucic (University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia)

This paper presents the design of active radiation patterns with prescribed dynamic range ratio (DRR) using the new dynamic range optimization method. The DRR optimization method is used to minimize the level of each beam for a given array design. The results are presented for different types of antenna arrays, including linear, planar, and spherical. The proposed method is applied to a variety of antenna designs, including arrays with uniform and non-uniform patterns.

P1.025 New Hexagonal CORPS-BFN for Multibeam Antenna Applications
Carlos Burrun-Quel (Universidad Publica de Navarra & Institute of Smart Cities, Spain); Antonio Montesano (AIRBUS DS, Spain); Wigo Ederia (Universidad Publica de Navarra & Institute of Smart Cities, Spain; JuanCarlos Iriarte (ASI - Italian Space Agency, Italy)

This work presents the design of a new hexagonal CORPS-BFN for multibeam antenna applications. The CORPS-BFN is a multibeam antenna that uses a combination of directive and omni-directional beams to cover a large area. The new hexagonal CORPS-BFN is designed to provide a high directivity and an optimal pattern distribution for multibeam applications.

P1.026 Window-to-Polytope Transform and Its Application in Antenna Array Design
Goran Molnar and Marko Matijasíc (ELEDIA Research Center, Italy; d. Research and Development Centre, Croatia)

Windowing is a common method in antenna analysis and in digital and spatial filter design. In many cases, adjustable windows are preferable since they offer a tradeoff between requirements, usually sidelobe level and mainlobe width. In this paper, we present a straightforward method for the design of windows with prescribed sidelobe level or mainlobe width. The method is based on the transformation of a given window into the polytope, thus enabling the use of polytope approximation in the window design. Consequently, the method introduces an additional degree of freedom into the design 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 window, and the combined array design incorporating rectangular and Gaussian window.

P1.027 An Iterative Minimization Algorithm for Array Diagnosis in the Presence of Array Errors Using Amplitude-only Far Field Data
Wenjing Wang and Ying Zhang (University of Electronic Science and Technology of China, China); Daqing Zhou (University of Electronic Science and Technology of China, China); Ling Kuang (University of Electronic Science and Technology of China, China)

Array errors are unavoidable in real application of phased arrays. In this letter, an iterative minimization algorithm for array diagnosis in the presence of array errors using amplitude-only far field data is proposed. The proposed algorithm includes frequency shifting error and element position error. The erroneous array manifold is approximated by its first-order Taylor series expansion. To minimize array error and restore array excitation, the maximum a posteriori (MAP) criterion is adopted. In perspective of Bayesian theory, the MAP criterion leads to combination of a mixed-norm and a total least square optimization problem which does not have an analytic solution. To solve this optimization problem, an efficient numerical algorithm based on alternating descent sub-optimal is applied. Computer simulations show that in the presence of array errors, the proposed algorithm gives more accurate array diagnosis results than that of the conventional method.

P1.028 Design of a Dual-Circularly-Polarized Stacked Patch Antenna for 50TH Application at Ka-band
Salvatore Liberto and George Goussetis (Heriot-Watt University, United Kingdom (Great Britain); Andrew Christie (Sofant Technologies Ltd, United Kingdom (Great Britain))

This work presents the design of a realistic hybrid metal-plasma transmit-array antenna with beam-scanning capabilities. The antenna operates at 1.07 GHz and consists of an active metallic dipole, a metallic ground plane, and a set of cylindrical plasma devices arranged in a 2D lattice. The main beam of the antenna can be tilted towards different directions simply by tuning on/off specific subsets of plasma devices. Towards this aim, a two-steps optimization strategy based on the combination of a particle swarm optimization and of a genetic algorithm is adopted. The antenna has been modeled in CST Microwave Studio using realistic design parameters for the plasma devices. In 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. This work proposes a straightforward method for the design of windows with prescribed sidelobe level or mainlobe level. The method is applied to a variety of antenna designs, including arrays with uniform and non-uniform patterns.
In this work, a simple iteration-based approach is proposed for calibration and characterization of the frequency, phase, and excitation of a high-gain smart antenna front-end. The proposed AFE (Analog Front End) is designed to reduce the complexity and cost of implementing a high-performance smart antenna system. The approach is based on a mathematical model of the smart antenna system, which includes the RF frontend, the beamformer, and the signal processor. The model is used to predict the performance of the system, and to design the calibration and characterization algorithms. The algorithms are implemented in a hardware platform, and tested in a laboratory environment. The results show that the proposed approach is effective in reducing the complexity and cost of implementing a high-performance smart antenna system, while maintaining the required performance levels.
In this paper, a compact and efficient quasi-optical power combiner configuration is presented. A single shaped reflector is used for the beam shaping, making the direction of the beam fixed. Using a focal-plane array feed (FPA) as feeding mechanism, the magnitude and the direction of the resulting beam can be controlled electronically. Using an in-house developed tool, the amplitude and the phase settings for a 28 GHz active phased array antenna are determined in order to mimic the ideal feeding pattern for a certain reflector. The far-field of the FPA in combination with the reflector antenna is determined for a scan angle of 0 degrees and 3 degrees.

**P1.043 Improving Modal Purity in Quadruply Fed Quadruple-Ridged Flared Horn Antennas**

Jacobus M Kotsie and Petra Meyer (Stellenbosch University, South Africa)

This paper presents an improvement of a quadruply fed design for quadruply ridged flared horn antennas. Selective laser melting (SLM) 3-D printing allows for complex structures to be realised as one unobtrusive component. The integration of complex structures into the quadruply-ridged waveguide suppresses all higher order modes by more than 25 dB relative to the fundamental TE11 mode, thereby achieving pure-mode excitation over a 8.5:1 bandwidth. The impedance match is also significantly improved due to the relaxation of design constraints from previous manufacturing techniques. The quadruply feed presented in this paper presents an ideal candidate for the integration with differential amplifiers and a quadruply-ridged flared horn for next generation radio astronomy reflector antennas.

**P1.044 Band Self-Depicted Tx/Rx Feed System for Telekom**

Rodolfo Ravalli (Thales Alenia Space Italia SpA, Italy); Giuseppe Addamo (Istituto di Elettr. e di Ingegneria dell’Inform. e delle Telecom. (IEEE-CNRI), Italy); Roberto Mizzoni (Thales Alenia Space Italia, Italy); Oscar A. Perervini (Istituto di Elettr. e di Ingegneria dell’Inform. e delle Telecom. (IET- CNRI), Italy); Marcello Zoleti (Thales Alenia Space Italia, Switzerland); Giuseppe Visone (Consiglio Nazionale delle Ricerche); Franco Perini (Thales Alenia Space Italia S.p.A, Italy); Fabio Panessa (National Research Council of Italy (CNR-IEIIT), Italy)

A review coupled-self-feeding system operating in the extended C-band is addressed in this paper. Strict requirements in terms of electromagnetic performances, power handling and mass/size/effective area have driven the selected configuration. The design, validated through the measurement over a flight HV, demonstrates the validity of the solution, making this product appealing for telecommunication reflector-shape space antennas.

**P1.045 Multi-frequency Dual-polarization Spaceborne Microwave Radiometer Antennas**

Hongjian Wang (National Space Science Center, China)

As part of the overall Haiyang 2C (HY2C) ocean dynamic satellite research, atmospheric correction microwave radiometer (ACMR) used to correct atmospheric path delay in the radar altimeter has recently been developed. Observing antenna of ACMR with three frequency bands and dual polarizations is realized by an offset deployable dish fed by a common corrugated horn. The deployable reflector is made of carbon fiber composite (C/FRP) supported by a CFRP frame that connect to the satellite deck, and the deployment of the dish is implemented by two hinges. The feeding subsystem has a loaded rings corrugated horn, an ultra-wideband orthomode transducer (UMT) that covers almost 20 GHz bandwidth with isolation better than 30 dB. Measured results show that the VSWRs are lower than 1.5 throughout all three working bands (17.7 GHz, 23.3 GHz and 37 GHz), the cross-polarization levels (CP) are below -20 dB.

**P1.046 Upgrade to the K-band Uplink Channel for the ESA Deep Space Antennas: Analysis of the Optics and Preliminary Dichroic Mirror Design**

Marco Marchetti (University of Pavia, Italy); Filippo Concaro (European Space Agency, Germany); Fabio Pelorossi (ESOC, ESA, Germany); Luca Perregini and Marco Pazzini (University of Pavia, Italy)

Not available

**P1.047 Full-wave Scattering from Reflector Antennas on Electronically Large Platforms Using Low-memory Computers**

Oscar Borries, Peter Demeyer and Erik Jørgensen (TIRA, Denmark)

We consider the use of full-wave integral equation techniques on scattering problems involving electronically large structures, and consider how an implementation of such techniques could use an inexpensive polite drive (SID) 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 low frequency used algorithms. Then, we show how the use of the SID allows us to solve larger problems than the RAM of the computing platform makes for. Finally, we consider how the 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.

**P1.048 Circularly Polarized Axially Corrugated Feed Horn for CubeSat Reflectarray Applications**

Miroslav J. Velojovic and Anja K. Sirkvervik (EPFL, Switzerland)

Reflectarray (RA) and transmitarray (TA) antennas that use the element-rotation technique require the radiation from the element to be circularly polarized (CP). A CP-axially corrugated horn antenna is developed as a feeding element for CubeSat RA and TA antennas. The CP operation is enabled using a septum polarizer. The all-metal geometry is attractive for space applications and allows the horn to be 3D printed in aluminum in a single piece. A prototype of the feed chain was fabricated using the DirectMetal Laser Sintering (DMLS) technique. The results of 3D simulations and VNA/far-field measurements of the feed chain are presented in this paper.

**P1.049 Tunable Dichroic Cell for Multi-band Reflector Antenna System**

Miguel Salazar-Natera and Roberto Garrote Moreno (Universidad Politecnica de Madrid, Spain); Eduardo Carrasco and Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Ramón Martínez Rodríguez-Osorio (Universidad Politécnica de Madrid, Spain)

This work presents a novel dichroic cell for multi-band reflector antenna systems that has two different configurations. Each configuration is fed by an element containing a set of rings connected to a tuning stub. The case study presented shows the design of a two-cell configuration using two resonant elements in both faces of the dichroic cell and the design of a non-symmetrical cell using one resonant element in one face of the cell and a single ring in the other face. These two configurations allow performing different topologies of dual band feeds.

**P1.050 Contingency Mitigation Aspects for Reflectors Based Satellite SAR Systems**

Patrick T.P. Klein, Jens Reimann, Sigurd Huber and Marco Schrodt (German Aerospace Center (DLR), Germany)

Contingency mitigation, with respect to potential failures of Transmit-Receive Modules (TRM) is a critical issue for SAR system concepts based upon phased array antenna feeds fed large deployable reflector (LDR) instruments. One promising approach is developing the LDR from the usually employed paraboloid shape. This opens a trade-space which has to be carefully investigated. Based on the current instrument and spacecraft geometry of Tandem-L we here assess the potential of reflector shaping to mitigate potential TRM failures. In particular, we discuss the potential for re-optimization of the transmit pattern in such a contingency case. We find that for the defocused reflector, the impact of a potential TRM failure on the transmit pattern can be largely mitigated with acceptable impacts on nominal operations.

**P1.051 Design and Measurement of Possible Wide-band 67-116 GHz ALMA Vacuum Window Anti-reflection Layers**

Peter J. Spiers (University of Bern, Switzerland); Rocío Molina (Universidad de Chile, Chile); Elena Saenz (European Space Agency, The Netherlands); Paul Mosesley (European Space Agency, Switzerland); Pavel Yagoubov (European Southern Observatory, Germany); Axel Mirk (IAP, Switzerland)

A new broadband vacuum lens/window design is required for the new Atacama Large Millimeter/submillimeter Array (ALMA) band 2 receiver, intended to cover 67-116 GHz. A suitable anti-reflection coating (ARC) for this will be necessary. This paper presents the optimization of a candidate ARC design in ultra-high molecular weight polyethylene (UHMWPE), alongside simulations and measurements of candidate designs in silicon. Machined triangular grooves are used as the ARC for the UHMWPE candidate, and stacked cuboidals for the silicon candidate design.

**P1.052 Electromagnetic Analysis of the ngVLA Reference Design Antenna**

Sivasankaran Srikhand (National Radio Astronomy Observatory & Associated Universities Incorporated, USA)

This paper presents the computed efficiency, efficiency loss and increase in crosspolarization due to feed positioning errors on the Next Generation Very Large Array. The rationale behind the choice of configuration is explained in the design paper of the proposed feed. The results are shown with the correction to the NGVLA reference design.

**P1.053 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 is presented. A single shaped reflector is utilized to directly convert the radiated beam from a plane feedhorn antenna array with arbitrary elements into single output beam. An efficient shaping technique based on reflector Peyrout vector tracing is employed to...
P1.056 A Millimeter-Wave Low-Profile and Metal-Only Transmittarray Antennas at 28 GHz
Sergey Zahras Mozumdar (Institut National de la Recherche Scientifique (INRS), Canada); Radoslaw Ramazzamini Tolito (Electrical and Computer Engineering Faculty, Semnan University, Iran); and Ray A. Dendiz (INRS-EMT, Canada)

A novel high-gain and low-profile transmittarray antenna, operating at 28 GHz, is presented in this paper. A four-layer metal-only element is used to achieve a full transmission phase range of 360° for a transmission magnitude equal to or better than -1.2 dB. A transmittarray with a main beam at the broadside direction is simulated via CST software. The achieved simulation results show that the designed antenna with an aperture size of 95.25 cm² at 28 GHz, has 25 dB maximum gain. In addition, the proposed transmittarray antenna achieves a 17.5% 1-dB gain bandwidth and 38.2% efficiency.

P1.057 Dual-Polarized Dual-Frequency Ka-Band Transmittarray Lens
Enrique G. Plaza and Gernando Leon (Universidad de Oviedo, Spain); and Luís L. E. Herz (University of Oviedo, Spain)

In this contribution, a dual-frequency unit cell for transmittarrays 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 polarization is optimized to be transparent at 28 GHz, and the second one at 38 GHz. The cell provides a phase delay up to 300 degrees for each polarization at both frequencies. Furthermore, it allows to develop different radiation patterns for each frequency independently. In order to show the potential applications of this cell, a transmittarray antenna has been designed and simulated. The antenna can focus the energy on a near-field spot at 28 GHz using one polarization and it can also steer a beam to the broadside direction with the other polarization at 38 GHz.

P1.058 Transmittarray Antenna for Converged Vortex Beam Generation and Steering
Inna Minina and Pavel A. Turchak (St. Petersburg Electrotechnical University, Russia); and Dmitry E. Zelenchuk (Queen’s University of Belfast, United Kingdom (Great Britain))

This paper presents a 1-bit transmittarray antenna excited by planar patch array in C band. The patch array generates a vortex beam, which is further compressed by the transmittarray. It has been demonstrated that by changing the phase distribution across the transmittarray one can change the vortex beam direction whilst preserving the orbital angular momentum properties.

P1.059 Design and Operation of a Smart Graphene-Metal Hybrid Reflectarray at THz Frequencies
Arjun Singh (Northern Virginia Community College, USA); Michael Andrelo (AFRL, USA); Erik Einarsen (University at Buffalo, USA); Ngwe Thawar (Air Force Research Laboratory, USA); and Joseph J Mietl (Northeastern University, USA)

In this work, a novel hybrid graphene-metallized THz reflectarray is presented. The resultant unitcell includes the artificial magnetic conductor (AMC) and Babinet's principle. The RMSs composed of 10x7 supercells are designed using generalized Snell's law. The measured bistatic pattern and efficiency show good agreement with those of the simulation.

P1.060 Low-profile TM Incident Retrodiffractive Metasurface Using AMC Surface
Sun-Gyu Lee and Jeong Hae Lee (Hongik University, Korea (South))

This paper presents a low-profile TM incident retrodiffractive metasurface (RMS). The unitcell is modeled by equivalent circuit to derive the impedance condition of RMS for full reflection phase coverage (FRPC). A PMC ground is required for a low-profile unitcell. The surface impedance of a slot layer is calculated from metasurface Generalized sheet transition conditions (GSTCs) and Babinet's principle. The resultant unitcell includes the artificial magnetic conductor (AMC), and the total height of the RMS with AMC ground is reduced by 50% compared with PEC ground. The RMSs composed of 10x7 supercells are designed using generalized Snell's law. The measured bistatic pattern and efficiency show good agreement with those of the simulation.

P1.061 Ultrawideband Transmittarray Employing Connected Slot-Bowtie Dipole Elements
Lilin Song (University of Technology Sydney, Australia); Feiyuan Qin (University of Technology, Sydney, Australia); Stefano Maci (University of Siena, Italy); and Yaj Guo (University of Technology Sydney, Australia)

In this paper, a novel multiple-layer transmittarray antenna is proposed. The unitcell piece of the multiple-layer transmittarray is employed as a key wireless element to form the full reflective transmittarray channel, with low insertion loss and two independent reflectarray layers are cascaded. The proposed transmittarray antenna achieves ultra-wide bandwidth with greatly reduced feeding complexity and fabrication cost. As a proof of concept, a 34x44-element reflectarray antenna is designed. The presented reflectarray antenna maintains steerable beams to the broadside direction at 30 GHz using one polarization and it can also steer to the opposite direction with the other polarization at 30 GHz.

P1.062 Frequency Diversity Array Beamforming Using Particle Swarm Optimization
Yi Li, Hui Tang and Di Jiang (UESTC, China); Zhi Zheng (University of Electronic Science and Technology of China, China)

A novel frequency diversity array (FDA) employs frequency offsets along the array element, thus generating a range-dependent beamsteering, which cannot be achieved by conventional phased array. However, the range and angle are coupled in standard FDA. To address this problem, the frequency offsets are optimized in this paper with particle swarm optimization to focus the beam energy to the interested spot. The effectiveness of the proposed method is validated by numerical simulations.

P1.063 A Triple-layer Wideband Transmittarray Antenna Using Finger-Type Slot Elements
Guang Liu and Hongqiang Wang (National Space Science Center, China); Yang Liu (National Space Science Center & University of Chinese Academy of Sciences, China)

A novel triple-layer wideband transmittarray antenna using finger-type slot elements is presented in this paper. The unit-cell piece of the multiple-layer transmittarray is employed as a key wireless element to form the full reflective transmittarray channel, with low insertion loss and two independent reflectarray layers are cascaded. The proposed transmittarray antenna achieves ultra-wide bandwidth with greatly reduced feeding complexity and fabrication cost. As a proof of concept, a 34x44-element reflectarray antenna is designed. The presented reflectarray antenna maintains steerable beams to the broadside direction at 30 GHz using one polarization and it can also steer to the opposite direction with the other polarization at 30 GHz.

P1.064 An Ultra-wideband Transmittarray Antenna Using Connected Dipoles for Multifunctional Systems
Junxun Zhang and Long Zhang (Shenzhen University, China); Weiling Li (Kent, China); Yujun He and Sai-Wai Wong (Shenzhen University, China); Steven Gao (University of Kent, United Kingdom (Great Britain))

A novel ultrawideband reflectarray antenna using connected dipoles for multifunctional systems is proposed in this paper. The radiating element is an elliptical dipole and a slot line which are printed on a single substrate. Neighboring elements are designed to achieve the ultrawide bandwidth for both the impedance and the radiation pattern bandwith. By combining the advantages of conventional reflectarray antenna and connected array antenna, the proposed reflectarray antenna achieves ultra-wide bandwidth with greatly reduced feeding complexity and fabrication cost. As a proof of concept, a 34x44-element reflectarray antenna is designed. The presented reflectarray antenna maintains steerable beams and high gain over a bandwidth of 100%, i.e., from 10 to 30 GHz.

P1.065 Equivalent Dielectric Description of Transmit-arrays as an Efficient and Accurate Method of Analysis
Sergio Matos (Instituto Universitário de Lisboa, Portugal); Jorge R. Costa (Instituto de Telecomunicações / BCTE-UL, Portugal); and Parnaz Naseri (University of Toronto, Canada); and Eduardo B. Lima (Instituto de Telecomunicações & Instituto Superior Técnico, Portugal); and Carlos A.
**Poster1-A22: MIMO, Diversity, Smart Antennas & Signal Processing**

**Antennas**

**Room:** Exhibition Hall

**P1.066 Enhanced Low Band MIMO Terminal Antenna Based on Selective Feeding of Chassis Modes**

Yang Wang, Jie Liu, and Mohammad Ali (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

This paper introduces a pattern diversity dipole/multiple-input multiple-output (MIMO) antenna for wireless handheld devices. With the help of three driven dipoles and two parasitic dipoles disposed of on the dielectric housing of a device, the proposed antenna achieves beam pointing along 30°, 180°, and 230° in the azimuth plane with 4-dB gain. MIMO system analyses in free-space and near-to-user scenarios indicate excellent performance.

**P1.067 Yagi-Uda-Inspired Pattern Reconfigurable MIMO Antenna with Suppressed Harmonics and Minimum Parasitic Presence for WLAN Applications**

Phalguni Mathur (Bharathiar University, India)

In this paper, a compact dipole-input multiple-output (MIMO) antenna is presented. The proposed MIMO antenna is based on the pattern diversity technique, where a low pass filter is used to eliminate higher order harmonics. The antenna is designed to achieve a bandwidth of 2.4 GHz for both the WLAN bands. The antenna is fabricated using FR4 substrate with a thickness of 1.6 mm. The measured results show that the proposed antenna achieves the desired radiation characteristics. The proposed antenna occupies a compact size of 150 mm × 25 mm × 10 mm.

**P1.068 Printed Dipole MIMO Antenna for Wireless Handheld Terminals**

Ahmad Abdelgawad and Mohammad Ali (University of South Carolina, USA)

This paper presents a new concept of a printed dipole multiple-input multiple-output (MIMO) antenna for wireless handheld devices. With the help of three driven dipoles and two parasitic dipoles disposed of on the dielectric housing of a device, the proposed antenna achieves beam pointing along 30°, 180°, and 230° in the azimuth plane with 4-dB gain. MIMO system analyses in free-space and near-to-user scenarios indicate excellent performance.

**P1.069 Non-Gaussian Colored Noise Generation for Wireless Channel Simulation with Particle Swarm Optimizer**

Stéphane Bila (University of Limoges/CNRS, France), Mohammad Ali Imran (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

This paper proposes a new approach for generating non-Gaussian colored noise. The proposed approach utilizes the Particle Swarm Optimizer (PSO) to find the coefficients of the non-Gaussian colored noise generator. The proposed approach is compared with existing approaches and shows improved performance.

**P1.070 Dynamic Short-Range Sensing Approach Using MIMO Radar for Brain Activities Monitoring**

Minghui Li, Yanli Tu, and Mohammad Ali (Chongqing University of Posts and Telecommunications, China; Lund University, Sweden & Xidian University, China; University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

This paper proposes a new approach for dynamic short-range sensing using MIMO radar. The proposed approach utilizes the Particle Swarm Optimizer (PSO) to find the coefficients of the non-Gaussian colored noise generator. The proposed approach is compared with existing approaches and shows improved performance.

**P1.071 A Three-Antenna Compact Micro-Diversity Module for Automotive Satellite Radio Reception**

Simon Senega (Universität der Bundeswehr München, Germany), Stefan Lindenmeier (Universität der Bundeswehr, Germany)

This paper proposes a new concept for automotive satellite radio reception. The proposed concept utilizes a multi-antenna module that combines multiple antenna elements with a single interface. The proposed module is designed to achieve high sensitivity and selectivity in complex environments.

**P1.072 Maximum Ratio Transmission for OAM Mode Multiplexing Using Multiple UCAs**

Ayano Yamamoto, Toshihiko Nishimura, and Daisuke Uchida (Chongqing University of Posts and Telecommunications, China; Institute of Telecommunications, Instituto Superior Tecnico, Portugal)

This paper proposes a new approach for maximum ratio transmission using multiple UCAs. The proposed approach utilizes the Particle Swarm Optimizer (PSO) to find the coefficients of the non-Gaussian colored noise generator. The proposed approach is compared with existing approaches and shows improved performance.

**P1.073 Convergence of OAM Beams Using Time-Multiplexed Concentric Circular Arrays**

Yang Wang, Jie Liu, Tao Hu, Wenjun Jie, and Donghua Yang (Chongqing University of Posts and Telecommunications, China; University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

This paper proposes a new approach for time-multiplexed concentric circular arrays. The proposed approach utilizes the Particle Swarm Optimizer (PSO) to find the coefficients of the non-Gaussian colored noise generator. The proposed approach is compared with existing approaches and shows improved performance.

**Poster1-P02: Propagation Modelling and Simulation**

**Propagation**

**Room:** Exhibition Hall

**P1.074 Mode Modulation Based Multi-Moder Transmitter for Line-of-Sight Propagation**

Tao Hu and Yang Wang (Chongqing University of Posts and Telecommunications, China; University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

As an emerging solution for line-of-sight (LOS) wireless communications, recently, mode division multiplexing (MDM) based on a linearly-polarized waveguide (LPMW) has attracted considerable attention due to its high spectral efficiency (SE). Since the high complexity in OAM modulations and the request for great frequency resolution (RF) chains, the implementation of a mode division multiplexing-multiple-input multiple-output (MDM-MIMO) system is confining. To address this problem, we proposed a low-complexity mode modulation method for 5G wireless communication system by utilizing the positional information of non-zero source symbols to transmit additional data symbols. Numerical results demonstrate that the proposed method possesses higher robustness than MIMO-MIMO systems in long-range transmissions.

**P1.075 Propagation Analysis of Terahertz OAM Waves in Atmospheric Turbulent Environment**

Jian Gui and Yang Wang (Chongqing University of Posts and Telecommunications, China; University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

In this paper, a new method is proposed for analyzing the propagation of terahertz OAM waves in atmospheric turbulent environments. The proposed method utilizes the Particle Swarm Optimizer (PSO) to find the coefficients of the non-Gaussian colored noise generator. The proposed method is compared with existing approaches and shows improved performance.

**P1.076 Printed Dipole MIMO Antenna for Wireless Handheld Terminals**

Ahmad Abdelgawad and Mohammad Ali (University of South Carolina, USA)

This paper proposes a new concept of a printed dipole multiple-input multiple-output (MIMO) antenna for wireless handheld devices. With the help of three driven dipoles and two parasitic dipoles disposed of on the dielectric housing of a device, the proposed antenna achieves beam pointing along 30°, 180°, and 230° in the azimuth plane with 4-dB gain. MIMO system analyses in free-space and near-to-user scenarios indicate excellent performance.
Creating a functional communication channel is crucial for the indoor industrial scenario, with the scale being much larger than traditional indoor office scenarios. At last, the effects of distances excess of 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) environment. 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 power levels. The model can be used to jointly simulate the received power, mean delay, and rms delay spread. This shows that connecting the device to the horsecollar leads to better radiation efficiency.

When using LoRa technology, this setup can reach up to 1.5 km if the terrain is flat. However, on the ground, the range is only 115 m.

Remote Monitoring and Propagation Modeling of EM Side-Channel Signals for IoT Device Security
Seun Sangdoyin, Frank Werner and Baki B Yilmaz (Georgia Institute of Technology, USA); Chia-Lin Cheng (Georgia Tech, Georgia, USA); Eitan Uzgur, Nader Seifollahzad, Milos Prvulovic and Alekna Zajic (Georgia Institute of Technology, USA)

This paper presents results from an investigation into the remote monitoring and manipulation 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 activity of the IoT and FPGA modules can be gathered at distances in excess of 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) environment. 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 power levels. The model can be used to jointly simulate the received power, mean delay, and rms delay spread. This shows that connecting the device to the horsecollar leads to better radiation efficiency.

When using LoRa technology, this setup can reach up to 1.5 km if the terrain is flat. However, on the ground, the range is only 115 m.

Wall Parameters Sensitivity for Indoor Radio Waves Attenuation
Piotr Król, Thomas Blazek and Herbert Groot (TU Wien, Austria); Goisla Ghiassi (University of Science and Technology, Norway)

In this work, we show the design and validation of a testbed for over-the-air monitoring of millimetre waves. We have extended the frequency capabilities of a baseband channel emulator, which is capable of emulating non-stationary channels, to higher frequencies. To assure that the propagation between devices-under-test and the RF front-end of the emulator is only a line-of-sight link, we have isolated the devices-under-test in two anechoic chambers. We characterize the testbed at 57.5 GHz by means of frequency sweeps for two artificial cases when the emulator is used in an indoor environment.

A standard benchmark program bitcount used in the performance evaluation of ARM-based microprocessors and a microbenchmark SAVAT running on an IoT device were detected and monitored remotely by the emulator. In this work, we show the design and validation of a testbed for over-the-air monitoring of millimetre waves. We have extended the frequency capabilities of a baseband channel emulator, which is capable of emulating non-stationary channels, to higher frequencies. To assure that the propagation between devices-under-test and the RF front-end of the emulator is only a line-of-sight link, we have isolated the devices-under-test in two anechoic chambers. We characterize the testbed at 57.5 GHz by means of frequency sweeps for two artificial cases when the emulator is used in an indoor environment.
P1.087 Propagation Model for UCA-based OAM Communications in Six-Ray Canyon Channels
Wenjun Jie, Yang Wang, Tao Hu, Jie Liu and Donghua Yang (Chongqing University of Posts and Telecommunications, China); Jie Zhang (University of Sheffield, Dept. of Electronic and Electrical Engineering, United Kingdom (Great Britain))

Orbital angular momentum (OAM) has attracted considerable attention as a novel solution for ultra-high spectrum efficiency wireless communications. However, researches have focused on the line-of-sight (LOS) scenario and the two-ray non-LOS model. In addition, the two-ray model cannot be applied to certain scenarios e.g. streets, valleys, tunnels, etc. To address this problem, we derive the propagation model of uniform-circular-array-based OAM communications in six-ray canyon channels. This paper gives a full investigation of the multi-path effects, including phase-front distortion, mode spectrum, and receiving power weighting. Numerical results show that the low-order OAM signal can obtain a better transmission gain than high-order OAM signals in multipath environments. The proposed model can help research and application of OAM in future communication systems.

P1.088 Modified Two-Ray Model with UTD and Atmospheric Effects
Andres Navarro (Universidad loses, Colombia); Diego Parada (Federal University of Minas Gerais, Brazil); Dinael Guevara (Francisco de Paula Santander University, Colombia); Cásio Rego (Federal University of Minas Gerais, Brazil); Roger Alexander Badillo (Francisco de Paula Santander University, Colombia)

In this paper, we show a propagation model that combines the modified two-ray with ray tracing (RT) technique based on uniform theory of diffraction (UTD) techniques, as well as refraction effects of the standard atmosphere. The proposed model improves some results of the Two-Ray model, in a canonical scenario, and is compared with a standard Parabolic Equation (SP) model, implemented by some of the authors. The proposed model pretend to improve the results obtained in the design of point-to-point links in mountainous terrain, typical of Andean Countries.

P1.089 Analysis of Radiowave Propagation in Forest Media Using the Parabolic Equation
Glauco L. Ramos and Paulo Tibúrcio Pereira (Federal University of São João Del-Rei, Brazil); Nuno R. Leonor (Instituto de Telecomunicações, Portugal); Rafael F. S. Caldeirinha (Polytechnic Institute of Leiria & Instituto de Telecomunicações, Portugal)

This paper presents preliminary results about path loss prediction in vegetation using the parabolic equation technique. The trees were modelled in a flat and a triangular format and their effect in the path loss was analysed. A real measurement scenario with trees was also modelled and compared with the PE simulation. The use of the parabolic equation method to study the path loss attenuation in forest environments seems to be very promising.

P1.090 Construction of Gaussian and Isotropic Channels Based on Electrically Small Dipole Arrays
Assane Ngom (ESIGELEC, IRSEE, France); Constant M. A. Niambi (Normandie Univer, UNIROUEN, ESIGELEC/IRSEE, Rouen, France)

This work presents methodology to construction the gaussian and isotropic channel. It consists to provide the spherical-wave on the area surround the antenna under test (AUT). The wave incident source excitation can be modeling with the infinitesimal dipole model (IDM). Theoretically, the electric far field of this model is determined by using the translation and rotation addition theorem in the orin coordinate system. By analyzing this expression, the ratio between the distance the observation point AUT by the distance IDM-AUT is studied.

P1.091 Reduction Technique of Differential Propagation Delay with Negative Group Delay Function
Fayu Wan and Ningdong Li (Nanjing University of Information Science and Technology, China); Wenceslas Rahajandraibe (IMGNP, France); Blaise Ravelo (NUIST, China)

This paper deals with a innovative technique of propagation delay reduction. The technique is based on the use of bandpass negative group delay (NGD) function. The principle of the propagation delay reduction is introduced by considering a simple scenario of two Radio-Fit sensors communicating with a single Rx sensor. With the consideration of bandpass NGD function, it is shown that the differential between the propagation delay can be reduced considerably. The feasibility of the technique is confirmed with group delay diagram by considering microstrip NGD prototype measured 5 parameters.

P1.092 On Separation of Wet Antenna Effects from Rain Attenuation Measurements
Pavel Valtr (Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic); Martin Fenc, Vojtech Bares and Pavel Pechač (Czech Technical University in Prague, Czech Republic)

Possibility of determination of attenuation caused by rain effects is examined here by separating attenuation by wet antenna radius from total measured loss of a microwave link. Measurement of signal strength of two commercial microwave links operating at 22 GHz frequency is analyzed. Measured attenuation is compared with theoretically predicted rain attenuation calculated using rain gauge measurements of rain rate. From this comparison, the empirical model of wet antenna effect as a function of measured attenuation is calibrated and analyzed.

P1.093 Detection Probability Calculations for Fluctuating Targets Under Clutter
Ido Finkelman (Elta Systems Ltd, Israel); Nimrod Tenen (Elta Systems Ltd, Israel); Gregory Lukovsky (Elta Systems Ltd, Israel)

Recent computational advantages in EM modeling, along with the growing demand to detect low observable moving targets, have brought about a renewed interest in the field of target detection. Real-life applications, such as flight path optimization, motivate a dynamical approach where the RCS is not only stochastic by nature, but also significantly influenced by the target aspect angle. The classic techniques that modeled target RCS fluctuations as a random variable are generally found unsuitable for such tasks and make way to aspect-dependent RCS models produced by advanced EM softwares. The random nature of the echo target signals can then be simulated by introducing variations in aspect angle between detections. This paper describes a method for generating single-pulse detection probabilities of aspect-dependent RCS models in the presence of clutter. As an example, we compare various Weibull clutter models to emphasize the importance of clutter parameters selection.

PosterP03: Channel Sounding and Parameter Estimation Techniques

Propagation
Room: Exhibition Hall
During satellite tropospheric propagation studies strongly rely on beacon receiver measurements. Two kinds of attenuations are... dB, which is higher than the free space path loss, whereas the path loss exponent of 1.7 is lower than in free space. The... 60 GHz propagation realizes high data rate communication in the engine room of a vessel if the Line-of-Sight path is not... 

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... the ES-MOF changes

Young Chul Lee

The magnetic substorm effects on the ionosphere and radio propagation conditions are discussed. The vertical and oblique... as well as MPCs arriving with a long delay.

Results demonstrate that our proposed 3D training strategy can provide both precise beams and high training efficiency for the 3D mmWave UAV communications. The beam training technology which can overcome the easily-occurred beam misalignments is required urgently in unmanned aerial vehicle (UAV)-based millimeter wave (mmWave) communication systems. In this paper, we experimentally investigate massive MIMO propagation channel in several propagation environments. For this purpose, we have developed a new sounding experiment using a large-scale planar array with about one thousand elements. Channel measurements were carried out at 3-7 GHz. We used a Virtual Planar Array (VPA) composed by an actual Uniform Linear Array (ULA) with 36 elements on the top of a moving vehicle to exploit its displacement to generate the second dimension of the VPA. A wideband channel sounder was used to record propagation channel transfer functions and to compute wideband characteristics. A new approach to estimate 3D direction of arrival (DoA) using a rectangular planar array is presented.
P1.106 Cloud Detection Models and Their Effect on the Calculation of Cloud Attenuation: Assessment at Ka- And Q-band at 4065 Metres of Altitude
Guilherm Silva (Universidade Privada Boliviana, Bolivia); Miguel Heredia (Agencia Boliviana Espacial, Bolivia); Rodrigo Haurigue (Universidad Privada Boliviana, Bolivia)
We present an updated methodology to test the performance of these satellite detection systems. We use synthetic calculations and real data to evaluate the performance of the models.

P1.107 Satellite Link-Budget Statistical Prediction from Weather Forecast Models: Verification with Hayabusa-2 Ka-band Data
Marianna Biscarini and Andrea Vittimberga (Sapienza University of Rome, Italy); Klade De Sanctis (HIMET, Italy); Saverio di Fabio (CETEMPS, Italy); Luca Milani (Sapienza University of Rome, Italy); Maria Montagna (Sapienza University of Rome, Italy)
We present a novel method for the prediction of Ka-band link budgets. The method is based on the analysis of weather forecast models and the correlation with real data from the Hayabusa-2 spacecraft.

P1.108 Experimental Study of Dispersion/Antennation by Tress from 1 to 4 GHz
Maria Teresa Martinez-Iglesias (University Centre of Defence at the Spanish Air Force Academy, MDE-UPCT, Spain); Jose-Mania Molina-Garcia-Pardo, Leandro Juan-Llaor, Juan Pascual-Garcia and José-Víctor Rodríguez (Universidad Politécnica de Cartagena, Spain)
We present an experimental study of the dispersion and antennation effects caused by tress from 1 to 4 GHz.

P1.109 Nine Years of Excess Attenuation Statistics of Earth-Space Propagation Experiments at Ka-Band in Toulouse, France
Charles-Antoine Dhour (Onera, France); Jean-Pascal Monvoisin and Laurent Castanet (ONERA, France); Xavier Boulanger (CNES, France); Valentin Le Mire (ONERA, France)
We present nine years of excess attenuation statistics for Earth-Space propagation experiments at Ka-Band in Toulouse, France.

P1.110 Transmission Loss Evaluation for Fabry-Perot Materials’ Characterization
Leonardo Possenti (University of Bologna, Italy); Juan Pascual-Garcia (Universidad Politécnica de Cartagena, Spain); Vittorio Degli-Eposti (University of Bologna, Italy); Antonio Jose Lozano-Guerrero (Universidad Politécnica de Cartagena, Spain); Maria Barbini (University of Bologna, Italy); Maria-Teresa Martinez-Iglesias (University Centre of Defence at the Spanish Air Force Academy, MDE-UPCT, Spain); Franco Fuschini (Viale del Risorgimento 2, Italy); José-Víctor Rodríguez (Universidad Politécnica de Cartagena, Spain); Enrico M. Vittucci (University of Bologna, Italy); Jose-Maria Molina-Garcia-Pardo (Universidad Politécnica de Cartagena, Spain)
We present a transmission loss evaluation for Fabry-Perot materials’ characterization.

P1.111 Antenna Design for RF Ion Heating of Anisotropic Magnetized Plasma
Giuseppe Tomitani, Giorgio Sebastiano Mauro and David Mascal (INFN-LNS, Italy); Alessio Galatà (Istituto Nazionale di Fisica Nucleare, Italy); Luigi Celona (INFN-LNS, Italy); Gino Sorbello (University of Catania, Italy); Santo Gammino (INFN-LNS, Italy)
We present a study on the design of antennas for RF ion heating of anisotropic magnetized plasma.

P1.112 A Numerical Study on Tomographic Imaging Using Guided Electromagnetic Waves
Jochen Moll (Goethe University Frankfurt am Main, Germany); Duy Hai Nguyen (Goethe University Frankfurt, Germany); Viktor Krozer (Goethe University of Frankfurt am Main, Germany)
We present a numerical study on tomographic imaging using guided electromagnetic waves.

P1.113 Advanced Calibration Method for Accurate Microwave Absorber Reflectivity Measurements at Oblique Illumination Angles
Willi Hoffmann, Andreas Schwend and Christian Borkensiek (Technische Universität Ilmenau, Germany)
We present an advanced calibration method for accurate microwave absorber reflectivity measurements at oblique illumination angles.

P1.114 Off-the-shelf Optical Antenna Feed System
Christopher G Hynes and Rodney Vaughan (Simon Fraser University, Canada)
We present an off-the-shelf optical antenna feed system designed to reduce cost and improve performance.

Poster1-M01: Material Characterisation and Non-destructive Testing
Measurements
Room: Exhibition Hall

Poster1-M03: Near-field, Far-field, Compact and RCS Range Measurement Techniques
Measurements
Room: Exhibition Hall
P1.115 Height Profiles of Typical Automotive Landmarks Using Tomographic Compact-Range Measurements
Roland Moeh 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 demands are placed on the classification of radar targets. New possibilities are opened up by determining not only the total height, but also an intensity 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 E-band frequency range. It is shown that the total height also has 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 landmarks for self-localization.

P1.116 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 cut out and one elevation cut of the full spherical RCS target pattern. In order to perform more complete experiments, a new experimental layout has been developed at CESA. The use of multirotor UAVs for antenna or RCS measurements opens up new possibilities in indoor or outdoor measurements. Industrial enterprise multirotor 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.

P1.117 RCS Evaluation by Image-based Near-field to Far-field Transformation
Hiroyuki Kayabaishi (Osaka Institute of Technology, Japan)
There is a strong demand for evaluation of Radar Cross-Section (RCS) of electrically large objects such as airplanes and for radiation pattern of large antennas. This is because the measurement is 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 pickup near-field data. Our method is featured by the improved focusing factor obtained from the exact integral equation using small spheres, which leads to more accurate estimation for strong asymmetrical objects, so that the RCS measurement is available even in a small anechoic chamber. In this paper, by applying Geometrical Theory of Diffraction (GTD) to simple shaped models as a target, and it is shown high agreement between theoretical and measured NFFT results including antenna pattern. Furthermore, we propose a simple method to suppress the unnecessary wave by the imaging area limiting method.

P1.118 On the Influence of the Transformation Matrix in Compressed Spherical Near-field Measurements
Cosme Culotta-López and Dirk Heberling (RWTH Aachen University, Germany)
The radiation characteristics of an object are represented by the coefficients vector of a Wigner-2 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 system and the reconstruction of the SMCs vector by application of 11-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 spherical near-field measurements. The sampling processes used for the compressed measurements are calculated based on the minimum coherence of the sampling matrix for the basis functions. The reconstruction error is assessed for different formulation of the problem, using a different transformation matrix and highlighting the performance difference.

P1.119 Precise 6D RTK Positioning System for UAV-based Near-field Antenna Measurements
Patrick Henkel, Andreas Spol and Ulrich Mittmann (Aerogis GmbH, Germany), Torsten Fritzel, Rodiger Strauß and Hans-Juergen Steiner (Aerogis US, Germany)
Near-field antenna measurements with an 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 Atel4S Multi-Sensor RTK module with its 3-Multi-frequency, Multi-GNSS receivers and a MEMS-based Inertial Measurement Unit (IMU). We used the IAV of AEROGIS to validate our method and achieved a centimeter level positioning accuracy in both static and kinematic conditions.

Poster1-M04: Data Acquisition, Imaging Algorithms and Processing Methods

**Measurements**

**Room:** Exhibition Hall

**P1.120 An Improved Receiver for Harmonic Motion Microwave Doppler Imaging**
Damia Alpatakin Soydan and Umit Irgin (Middle East Technical University, Turkey); Can Barsi Top (Aselsan Inc., Turkey); Nevzat Gençoğlu (Middle East Technical University, Turkey)
Harmonic motion microwave Doppler imaging is a novel imaging method that combines focused ultrasound 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 multifrequency operation was limited. In this study, we improved the receiving 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 3 mm × 3 mm inside a homogeneous fat was built. An area of 40 mm × 40 mm is 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.

**P1.121 Interpretation of the Physical Layer Measurements of Smartphones as Measures of Exposure to Electromagnetic Fields**
Sascha Schiel, Thomas Kopacz and Dirk Heberling (RWTH Aachen University, Germany)
The monitoring of exposure to electromagnetic fields emitted by mobile radio networks is necessary for a responsible operation of these networks. A possible alternative to classical exposure assessment methods for times in continuous and area-wide exposure monitoring is a consecutive-based approach that relies on the use of ordinary smartphones. This paper discusses the interpretation of signal strength indicators measured by mobile phones in LTE networks and explains how instantaneous or maximum exposure is related to them. Long-term measurements of a smartphone and a field strength meter are performed 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 measurement characteristics resulting from the considered signal components in order to correspond correctly with the exposure. The results show that RSSI is suitable for tracing variations in exposure over the day.

**P1.122 Processing Azimuth-Time Domain Aliasing in Spaceborne Sliding-Spotlight SAR Imaging**
Yunxia Wang, Shunzhe Zhang and Yuming Jia (University of Electronic Science and Technology of China, China)
This paper proposes a modified two-step processing approach to deal with the problem of azimuth-time domain aliasing in processing high resolution spaceborne sliding spotlight synthetic aperture radar (SAR) data. The signal model of spaceborne SAR is formulated, which includes the geometric model, echo model and Doppler bandwidth. This paper proposes a modified approach through parameter design to avoid azimuth-time domain aliasing. The sliding factor has a critical value for the azimuth-time aliasing, which meet the requirement of azimuth resolution and large imaging scene. The effectiveness of the proposed approach for sliding-spotlight SAR imaging is verified with simulation data for multi-point targets.

Tuesday, 17 March 14:50 - 15:30

IS-Tue 1/1: Invited Speaker Session

**Antennas**

**Room:** A2

**Chair:** Michael Jensen (Brigham Young University, USA)

14:50 CubeSat Antennas: An Amazing Opportunity for Developing Out-of-the-Box Antennas
Yahiya Rahmat-Samii (University of California Los Angeles (UCLA) & UCLA, USA)
CubeSats represent a remarkable resolution in the arena of satellites. Their small size and low cost have enabled space missions which seemed impossible with conventional satellites. A key element in furthering the potential of CubeSats is the development of antenna systems that can meet the data rate and spatial resolution requirements for future space missions. This plenary talk describes the challenges and opportunities that CubeSats provide antenna engineers, and some innovative concepts that have been recently developed to facilitate advanced space missions. In particular, the talk focuses on the design of deployable high gain aperture antennas that can meet the demands of remote sensing, deep space missions and Internet of Space (IoS) with particular importance to the design tradeoffs engineers must account for while designing high gain CubeSat antennas.
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 2G/4G multicarrier microcellular scenario. Using the recently standardized Third Generation Partnership Project 3GPP 38.901 SC-1 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.

Antennas

Room: A2

15:30 Antenna-in-Package Technology

Yue Ping Zhang (Nanyang Technological University, Singapore)

Antenna-in-package (AIP) technology integrates an antenna or antennas with a radio or radar 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.

Electromagnetics

Room: A3

15:30 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.

Tuesday, 17 March 15:30 - 16:10

IS-Tue 1/2: 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 with a radio or radar 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.

Electromagnetics

Room: A3

Chair: Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal)

15:30 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.

Tuesday, 17 March 16:40 - 18:20

T04-A20: Wireless Power Transfer and Inductive Coupling

Rooms: A2

Chair: Wei 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 plane 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 6.78MHz. This two-layer-loop array has improved the measured power transfer efficiency (PTE) by ~10 % at distance of 500mm, 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, Howrah, West Bengal, 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 is presented. The proposed system is designed to operate in the industrial, scientific, and medical (ISM) of 2.40-2.48 GHz band. The WPT link is constructed with dual-ring slot antenna implanted in a single-layer skin tissue model used as a receiving (Rx) element and a simple patch antenna considered as transmitting (Tx) element. The patch antenna is designed to operate at the ISM of 2.45 GHz, whereas the dual-ring slot is used to obtain wideband characteristics that cover the entire ISM band. The strong mutual coupling between the Tx and Rx elements in the reactive near-field provide 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 Effects

Shahbaz Ahmed and Lauri Sydänheimo (Tampere University, Finland); Leena Ukkonen (Tampere University of Technology, Finland); Toni Björninen (Tampere University, Finland)

We present a headband loop antenna for wireless power transfer to multiple IMDs 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 antenna 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 Waghi, Alex S Weddell and Stephen Beeby (University of Southampton, United Kingdom (Great Britain))
**CS56: Recent Advances on Electronically Steerable Antenna Arrays at mm-Wave Frequencies**

**Room:** A3

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

**Chair:** Antonio Clemente (CEA-LETI/Minatec, France)

**16:40 Design of Wideband Wide-Scanning Dual-Polarized Phased Array Covering Simultaneously Both the Ku- and Ka-Satcom Bands**

J. van Katwijk and Andrea Neto (Delft University of Technology, The Netherlands); Giovanni Tosio (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 dielectric plates 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 minimize 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 Safari-Rahimi (KU Leuven, Belgium); Marcel Geurts 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 line in 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 total performance, an antenna array has been designed to be integrated inside the packaging of a four-channel analog beam-former flip chip.

**17:20 Phased Array at Mm-Waves Based on Filter-Integrated Antenna Elements**

Darwin Blanco and Christos Kolitsidas (Ericsson, Sweden)

This paper presents a broadband phased array antenna based on the integration of a compact combline filter and a broadband tightly-coupled-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 in a modular approach where first 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 uses cross-coupling to make it more compact and to create a pseudo-elliptic response. Full wave simulations show an outstanding performance compared to the conventional planar filters with an insertion loss less than 0.4 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, Shenhe Xu and Maokun Li (Tsinghua University, China)

This paper reviews the recent research progress on the designs of w-band reconfigurable reflectarray (RRA) and reconfigurable transmitarray (RTA) at Tsinghua University. Several antenna designs are presented, including PCB-based RRA, PCB-based RTA, and chip-based RRA. These designs of RRAs and 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); Giacomo Minatti (Wave Up S.r.l., Italy); Francesco Caminita (Wave-Up SRL, Italy); Giorgio Giordanengo (UNIKS Foundation & Politecnico di Torino, Italy); Giovanni Tosio (European Space Agency, ESA ESTEC, The Netherlands); Stefano Masi (University of Siena, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

This paper investigates the feasibility of an electro-optically scanning antenna based on a reconfigurable MTS. MTS reconfigurability is obtained by embedding small carmines 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.

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**CS58: Reconfigurable Antennas for Compact Devices**

**T04 IoT and M2M / Convened Session / Antennas**

**Room:** B1

**Chairs:** Joseph Costantine (American University of Beirut, Lebanon); Leonardo Lizzit (University Côte d’Azur, CNRS, LEAT, France)

**16:40 Electrically Small Antenna with Broadside and Monopole-Like Beam Reconfigurability**

Ming-Chung Tsai and Yeping Chen and Xiaoming Shen (Chongqing University, China); Richard Ziolkowski (University of Dayton, Ohio, USA)

An electrically small antenna (ESA) with broadside and monopole-like beam reconfigurability is presented. It consists of an electric monopole radiator and a magnetic radiator which are systematically placed orthogonal to the ground. By controlling the PIN diodes integrated into the feed structure, broadband and monopole-like beams can be switched dynamically. The radiating beam is generated by the capacitively loaded loop (CLL) near-field resonant parasitic (NRP) element and the monopole-like beam is formed by the electric monopole. The simulated results indicate that the antenna is impedance matched within an overlapping operational fractional bandwidth of 2.5% even though it is electrically small with ka = 0.9. The realized gain at boresight is 7.1 dBi for the broadside beam and the null depth is over -30 dB for the monopole-like beam, respectively. The proposed antenna is ideal for application to GPS systems that require anti-interference performance characteristics.

**17:00 Frequency Reconfigurable Antenna Loaded with Magno-Dielectric Materials at VHF Band**

Lotfi Batel (CEA-LETI, France); Christophe Delavaud and Jean-François Pinto (CEA-LETI, France); Jean-Luc Matte (Université de Bretagne Occidentale, LabSTICC, France); Vincent Laur (Lab-STICC / University of Brest, France); Alexis Chevalier (University of Brest & Lab-STICC UMR CNRS 3192, France)

This article describes a frequency agility technique of an electrically small inverted-F antenna loaded with tunable magneto-dielectric materials. A specific material developed for VHF applications is used to load the antenna and leads to a miniaturization factor of 20 % and a potential of frequency agility of 6 % in VHF band close to 70 MHz.

**17:20 Frequency Beam Switching Antenna for IoT Devices**

Marinos Patriotis (The University of New Mexico, USA); Fabios Ayavou (University of New Mexico & COSMIC - University of New Mexico, USA); Christos Christodoulou (The University of New Mexico, USA)

This work presents a pattern reconfigurable antenna system at X-band for the Internet of Thing (IoT) devices. The system is composed of a printed circular array composed of four Yagi-Uda elements and an electrically controlled feeding network. The feeding network incorporates PIN diode RF switches that provide independent activation of each antenna element while maintaining overall system matching stability. A suggested technique results in pattern reconfigurability between 16 modes. The isolation between the elements is improved by incorporating a reflector between them. Simulation results reveal that such a pattern flexible antenna is a strong candidate for IoT devices in a multi-path environment.

**17:40 Compact 4-Element Radiation Pattern Agile Antenna for Spatial Filtering in IoT Networks**

...
16:40 Tag Design for RFID AC Current Sensing System
Iftan Ullah (University of Kent, United Kingdom (Great Britain)); Robert J Home (University of Kent, United Kingdom (Great Britain)); Benito Sanz-Izquierdo and John Batchelor (University of Kent, United Kingdom (Great Britain))

This study describes the development of an RFID tag system and antenna for real-time ac current sensing of individual appliances in smart homes. The operating principle of the tag system is based on the tag antenna sensing via a tuning circuit. The auto-tuning chip is embedded to compensate for the antenna matching and stores the impedance tuning in the form of a 5-bit sensor code. The tag can be used to sense the ac current by thermal means. The fabricated prototype shows promising results for sensing individual appliances in smart homes.

17:05 Design of a Resistive Circularly Polarized Tag Antenna with High Performances in the EU UHF RFID Band
Khdor Jobshba (IM2NP, France); Amael Afify (IM2NP, Aix Marseille Université, France); Matthieu Egel; and Philippe Pannier (IM2NP, France)

In this study, a novel resistive RFID tag with high performances is presented. The proposed tag consists of two antennas. The first one is an inductive antenna used for matching the impedance of the chip at the target frequency. The second antenna is coupled with the first one in order to increase the gain and improve the tag performances. The antennas are designed to operate in the EU UHF RFID band. The measurements show that the proposed tag achieves good performance compared to existing UHF RFID tags.

17:40 Effect of Bending on a Textile UHF-RFID Tag Antenna
Mamoud El Bakki (Abdelmalek Essaadi University, Spain); Marc Martinez and Raul Fernandez-Garcia (Universitat Politècnica de Catalunya, Spain); Ignacio Gil (Universitat Politècnica de Catalunya, Spain); Otman El Mokbel (Abdelmalek Essaadi University, Morocco)

In this paper, a textile UHF-RFID tag antenna at 915 MHz is presented. The tag is fabricated using a double-sided PCB technology. The proposed antenna design allows for good performance even when the tag is bent. The measurements show that the proposed antenna achieves good performance compared to existing UHF RFID tags.

18:00 Monolithic Antenna Array for EBG-Based Scattering Antennas
Ceclia Occhiuzzi (University of Roma Tor Vergata & DICEI, Italy); Gaetano Marrocco (University of Rome Tor Vergata, Italy)

This paper explores the design and implementation of a monolithic antenna array for EBG-based scattering antennas. The proposed antenna design allows for good performance even when the tag is bent. The measurements show that the proposed antenna achieves good performance compared to existing UHF RFID tags.

19:30 Water-Based Microwave Absorber
Patrick Bradley (DCU, Ireland); Max Muñoz (Queen Mary, University of London, United Kingdom (Great Britain)); Conor Brennan (Dublin City University, Ireland); Yang Hao (Queen Mary University, United Kingdom (Great Britain))

In this paper, we develop a novel method for the design of microwave absorbers based on water. The proposed absorber design allows for good performance even when the tag is bent. The measurements show that the proposed antenna achieves good performance compared to existing UHF RFID tags.
In this paper, the effect of human movement in a wireless body area network (WBAN) measurements in a reverberation chamber is investigated. Electric field amplitudes at observation points are calculated and the permittivity of a colon tissue is assumed in a small size reverberation chamber. Digital modulation is used 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 antennas is generally impossible 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 simulate a complex system 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.

In the paper two simplified models of human body dedicated for the automated optimization of wireless body area networks are presented. This model was used in the optimization process of a wearable antenna to reduce the simulation time in each iteration which significantly shortens the time needed for design. The second model uses cylindrical elements to reproduce the entire body. It has an excellent performance when used for the optimization. In addition, it can also be quickly generated automatically for the electromagnetic simulations during automated optimization of WBAN. Such model represents both the figure of a standing and sitting person, so the change of body position can be taken into account in the process of system optimization.

This paper presents a spatially varying discrete dielectric Huygens' metasurface (DDHMS) that achieves beam splitting. The proposed structure consists of two elements per grating period and the phase difference between neighboring elements is 180°. The resultant bipartite Huygens' metasurface leads to a simplified, robust and cost-effective design as compared to finely discretized metasurfaces. A 2D full-wave FEM simulation demonstrates that the proposed metasurface splits the normal incident plane wave into different directions according to the generalized Snell's law, and contains over 80% of the transmitted power.

This work describes the operation principle and implementation of an electronically reconfigurable leaky-wave antenna based on a periodic set of artificial high-frequency magnetism. Resonant behavior of each individual ring is controlled with a photocurrent, which allows obtaining fast, macroscopic effective permeability. As the result, artificial magnetic resonant excitation within a subwavelength spherical scatterer is governed by light intensity. Four-dimensional control (both space and time) over electromagnetic scattering opens new venues for modern applications, including wireless communications and automotive radars to name just few.

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18:00 Experimental Parameter Optimization for Adaptive LoRa Modulation in Body-Centric Applications

Thomas Ameloot (Ghent University - imec, Belgium); Patrick Van Torre and Hendrik Rogiers (Ghent University, Belgium)

The relentless expansion of the Internet of Things is fueled by constant innovations in low-power wide-area network technologies. Industry foresees such as LoRa, SigFox and NB-IoT to continue to achieve larger communication ranges. These efforts facilitate performance increases in a range of related application areas, such as body-centric communications.

For example, LoRa modules have been integrated into wearable textile antennas, greatly extending the range of the body-centric networks these nodes can be used in. However, as the resulting communication links need to accommodate mobile users, many nodes will require to communicate using suboptimal LoRa modulation parameters as these users move around. Adaptive LoRa modulation aims to solve this by optimizing these parameters in real-time based on the location of the user and the actual performance of the wireless link. In this contribution, the optimal settings for one of the key LoRa modulation parameters, the spreading factor, are experimentally determined.

CS03: Advanced Radar Measurements, Modelling and System Solutions for Vehicular Applications

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

Room: B7

Chairs: Vittorio Degli-Esposito (University of Bologna, Italy), Matthias Hein (Immanuel University of Technology, Germany), Andreas Schwind (Technische Universität Ilmenau, Germany)

16:40 Bi-static Nearfield Calibration for RCS Measurements in the C-V2X Frequency Range

Andreas Schwind, Willi Hofmann and Ralf Stephan (Technische Universität Ilmenau, Germany); Reiner S. Thomä and Matthias Hein (Immanuel University of Technology, Germany)

Distributed multi-static radar systems using communication signals, provide additional options to augment the radar visibility of road users. Due to electricity large targets and small distances between the radar signals and the crossing road users, these are usually detected under near-field conditions. This paper describes two bi-static RCS calibration methods, using a reference object or the near-field range equation. Accordingly, a further calibration approach is presented which takes the nearfield effects of the antennas into account. The bi-static electromagnetic scattering of a bicycle at 5.9 GHz was measured under near-field conditions and calibrated with these different calibration approaches. Compared with numerical simulations of the far-field RCS, the calibrated measurements result significant, angle-dependent differences which indicate nearfield effects. The comparison between the different calibration methods shows differences up to 8 dB depending on the bi-static angles and demonstrates the importance of the consideration of nearfield effects during the RCS calibration.

17:00 Extraction of Scattering Centers Using a Greedy Algorithm for Traffic Participant

Sevdas Abadou; Axel Dewald, Benjamin Nuss and Marco Pauli (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

The multiplicity scattering points should be reduced to a few significant scattering centers to minimize computational effort. In the following step, the extracted scattering centers can be used for the simulation of the millimeter-wave automotive radar channel in realistic scenarios. Also, as in many cases, a precise CAD model of relevant traffic participants is not accessible, therefore the simplification of the scattering model based on the relevant scattering centers will be very helpful. The scope of this work is to present a technique to generate a significantly simplified RCS model of the traffic objects with a limited number of virtual scattering centers, each with its characteristic scattering and how to group these scattering centers in a cluster database. The work is based on ray-tracing simulations of complex traffic object models. The scattering centers may not be physically existing strong scattering centers, but virtual scattering centers representing a certain scattering behaviour.

17:20 A Ray Optical Diffraction Model for Car Chassis in V2X Communication

Lennart Thielecke (Technische Universität Braunschweig, Germany); Niels Drayer (TU Braunschweig, Germany); Johannes M. Eichkordt and Thomas Kümer (Technische Universität Braunschweig, Germany)

In this paper, diffraction models are investigated in the context of V2X. First the physical effects which are needed to describe a propagating wave are summarized. Afterwards, an analytical diffraction model for simple geometrical 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 cars in V2X scenarios. Based on key geometric parameters, ray optical diffraction models are derived from the full wave optical analysis. Scaled measurements with a 60GHz channel sounder are carried out, validating the presented model.

17:40 Dynamic Ray Tracing: Introduction and Concept

Denis Bilibashi, Enrico M. Vitucci and Vittorio Degli-Esposito (University of Bologna, Italy)

Rayleigh applications in vehicular environments are becoming popular due to the development of autonomous driving and safety enhancement technologies that make use of vehicle-to-vehicle, vehicle-to-infrastructure as well as 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 present a dynamic ray tracing model that can simulate a multidimensional channel prediction, including Doppler's shifts, with a single run on the base of a suitable "dynamic environment database" that describes a scene with moving objects and terminals. The proposed approach applied to a university campus scenario with a large moving object representing a bus is shown to yield realistic estimates of the channel's power-Doppler profiles.

18:00 Physics Based Target Scenario Simulation Using Asymptotic Solver Techniques for Automotive Applications

Markus Laudien (Ansoff Germany, Germany)

Simulation of traffic scenarios for radar applications has gained high importance during the past years as this can significantly reduce the time for validation. Electromagnetic models of auto-radar scanners 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 antennas with an extension of thousands of wavelengths mainly get addressed using asymptotic methods like shooting and Bouncing Rays. The need for validation of radar systems in critical scenarios points out the importance of sufficient high accuracy also for large and complex scenario geometries. A short introduction to the SAVR method some simple validation cases will be shown for different post processing purposes and finally some cases of traffic scenarios

CS15: Antennas for Radio Astronomy

T09 Space (incl. cubesat) / Convened Session / Antennas

Room: B8

Chairs: Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)), David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands)

16:40 Characteristic Mode Analysis of Multi-Octave Asymmetric Dipole

Alberto Tibaldi (Politecnico di Torino, Italy); Giuseppe Virone (Consiglio Nazionale delle Ricerche, Italy); Pietro Bollì (INAF - Osservatorio Astrofisico di Arcetri, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEIF, Italy)); Giuseppe Addamo (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIIT-CNRI, Italy)); Oscar A. Peverini (Istituto di Elettr. e di Ingegneria dell'Inform. e delle Telecom. (IEIT-CNRI, Italy)); Mauro Lumia (CNR, Italy); Lorenzo Ciorda (Institute of Electronics, Computer and Telecommunication Engineering (IEIIT-CNRI), Torino & Politecnico di Torino, Italy)

This paper discusses the impedance and front-to-back ratio performance of asymmetric dipole antennas. These parameters are very important, since the antennas are placed on a core of a downlink ground plane and should operate over multi-octave frequency bands. The operation of these antennas is usually described relying on analogies with more classical structures such as symmetric dipoles and tapered slot antennas. To provide a solid theoretical background to this intuition, this work presents the application of characteristic mode analysis to multi-dipole dipole antennas. Firstly, a brief review of the main characteristic mode content is presented. Then, characteristic mode analysis is applied to a thin antenna concept to emphasize how their geometry impacts on the relevant figures of merit. This allows to draw some conclusions on the achievable performance by different designs.

17:00 Analysis of the Loading Effect of Faulty LNAs on Embedded Element Patterns in the Murchison Widefield Array

Maria Kovaleva (Curtin University & Macquarie University, Australia); Daniel Ung, Adrian Sutinjo and Budi Juswardy (Curtin University, Australia); David B Davidson (Curtin University, Australia & Stellenbosch University, South Africa); Randall Wayth (International Centre for Radio Astronomy Research (ICRAR), Australia)

A number of natural phenomena occurring at the Western Australian site of the Square Kilometre Array (SKA), such as lightning or whitefingers, can cause damage to electronic parts of antenna arrays elements. We consider an SKA precursor, the Murchison Widefield Array (MWA), in order to evaluate the consequences of faulty low-noise amplifiers in an array. Using network analysis methods, we predict exactly the field patterns of each array element under changing loading conditions. The values of load impedances used for MWA field calibrations were based on measured data. It was observed that the tile pattern of MWA is robust to occasional low-noise amplifier damage. The ability to predict the multiplicity scattering points should be reduced to a few significant scattering centers to minimize computational effort. In the following step, the extracted scattering centers can be used for the simulation of the millimeter-wave automotive radar channel in realistic scenarios. Also, as in many cases, a precise CAD model of relevant traffic participants is not accessible, therefore the simplification of the scattering model based on the relevant scattering centers will be very helpful. The scope of this work is to present a technique to generate a significantly simplified RCS model of the traffic objects with a limited number of virtual scattering centers, each with its characteristic scattering and how to group these scattering centers in a cluster database. The work is based on ray-tracing simulations of complex traffic object models. The scattering centers may not be physically existing strong scattering centers, but virtual scattering centers representing a certain scattering behaviour.

17:20 A Beamforming Approach to the Self-Calibration of Phased Arrays

Quentin Gueuning (University of Cambridge, United Kingdom (Great Britain)), Anthony Keith Brown (University of Manchester, United Kingdom (Great Britain)); Christophe Craeye (Université Catholique de Louvain, Belgium); Eloy de Lara Acedo (University of Cambridge, United Kingdom (Great Britain)); David B Davidson (University of Manchester, United Kingdom (Great Britain)); Enrico M. Vitucci (Ansoft Germany, Germany); Patrick Van Torre (Karlsruhe Institute of Technology (KIT), Germany); Andreas Schwind (Technische Universität Ilmenau, Germany); Mario Pauli (Ghent University, Belgium)
In this paper, we propose a beamforming method for the calibration of the direction-independent gain of the analog chains of aperture arrays. The gain estimates are obtained by cross-correlating the output voltage of each antenna with a voltage beamformed using the other antennas of the array. When the beamforming weights are equal to the average cross-correlated power, a relation is drawn with the DIEFalgorithm. An example illustrates this approach for few point sources and a 256-element array.

17:40 Parallel Plate Waveguide Simulator of a Dense Connected Dipole Array
Rene A.C. Baelemans (International Centre for Radio Astronomy Research, Curtin University & Eindhoven University of Technology, Australia); David S Prinsloo (ASTRON & Netherlands Institute for Radio Astronomy, The Netherlands); A. B. (Bart) Smeolders (Eindhoven University of Technology, The Netherlands); Adrian Suting (Curtin University, Australia); David S Baldwin (Curtin University, Australia & Stellenbosch University, South Africa); Randall Haydn (International Centre for Radio Astronomy Research (ICRAR), Australia)

In this paper we propose the use of a parallel-plate waveguide simulator as a useful design verification step of very large phased array systems. We base the derivation of the theoretical concept upon the wideband capacitive connected dipole array. It is shown to be key to correctly terminate the feed to the free-space boundary with the use of electromagnetic absorbers to minimize reflections.

18:00 Investigations of Quadripole-Ridge Flared Horn Performance for ngVLA Band 2
Dirk de Villiers (Stellenbosch University, South Africa); Robert Lehmenriek (EMSS Antennas, South Africa); Fahmi Mokhupuki (Stellenbosch University, South Africa)

The design of an all-metal quadripole-flared horn (QFH) feed antenna for the current nominal ngVLA optics is presented. The antenna is required to operate over the 3.5 GHz - 12.5 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 the profiled feed antennas). Simulated results suggest sensitivity performance to within 10% of that achievable with octave-band corrugated feed antennas.

CS32: High-Frequency Methods and Applications

T10 EM modelling and simulation tools / Convened Session / Electromagnetics
Room: B9

Chairs: Ludger Klinkenbusch (Christian-Albrechts-Universitaet zu Kiel, Germany), Giuliano Manara (University of Pisa, Italy)

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

Bidirectional ray-tracking launches rays from both the transmitter and the receiver sites, where the transfer function between the antennas can be computed by evaluating a reciprocity integral. In this work, an asymptotic expansion approach for the evaluation of this reciprocity 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 integration 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
Prabhatkar H. Pathak (The Ohio State University, USA); Hai-Tsong Chou (National Taiwan University, Taiwan)

This paper presents a uniform theory of diffraction for a beam (UTODS) 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 elegant fashion.

17:20 Radiation Shaping by Using Lattice Modes in a Dual-feed Dielectric Array
Silvio Cecuoczi, Ludovica Tognolotti and Paolo Baccarelli (Roma Tre University, Italy); Vakhvand Janidari (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 these 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 at mm-waves since in relays on dielectric structures. An example fed by two sources and based on a square lattice of dielectric cylinders is presented. For the first time, the dependences of radiation properties on some geometrical parameters are investigated before moving to a fully 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 from a wedge made from a perfect electric conductor is analyzed in this paper. The analytic 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 multiple solution is presented for an incident uniform CSB which consists 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 (Politecnico di Torino, 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:PO2/1: 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 Study on Beamforming V2I Scenarios for Sub-6 GHz and mmWave Channels
Christian Ballesteros (Universitat Politecnica de Catalunya, Spain); German Ramirez Armoyave (Universidad Nacional de Colombia, Colombia); Luca Montero Bayo (Universitat Politecnica de Catalunya, Spain); Jordi Romeu (Universitat Politecnica de Catalunya, Spain); Luis Jofre (Universitat Politecnica de Catalunya, Spain)

The study of the wireless channel between a high-band massive MIMO Base Station (BS) and a vehicular platform is presented. Several multi-antenna geometries and MIMO architectures 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 6x6 beamwidth circular array is able to enhance the single-antenna performance up to 153% in capacity, and outperform MIMO 4x4 in most situations.

17:00 An Electromagnetic Framework for the Deployment of Reconfigurable Intelligent Surfaces to Control Massive MIMO Channel Characteristics
Debdeep Sarkar (Royal Military College Canada, Canada); Said Mikki (University of New Haven, USA); Yahia 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 uplink channel's eigen-space structure. We place an RIS based on two switchable FSS layers in the vicinity of a 64-element massive MIMO base-station (BS) array, covering a sector of four 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 supplementary RIS structures may assist the wireless link engineer in deterministically "customizing" the uplink channel behaviour by selectively enhancing/suppressing certain channel eigenvalues.

17:20 WBAN Channel Modeling on Electromagnetic Interaction in Biological Tissues for Estimating Path Loss Characteristics
Prapti Ganguly (A. K. Choudhary School of Information Technology, University of Calcutta, India); Ananya Dey and Debabrati Ganguly (Institute of Radio Physics and Electronics, University of Calcutta, India); Chinmay Saha (Indian Institute of Space Science and Technology, India &
IW04: CTG Workshop on Advances in Antenna Measurements (Antenna Systems Solutions S.L.)

T12 Scientific / Industrial Workshops
Room: B3

Dr. Sergiy Pivnenko, Antenna Systems Solutions S.L.

17:40 Measurement Based Millimeter Wave Massive MIMO Channel Parameter Comparison
Heng Zhang, Yu Shao and Xi Liao (Chongqing University of Posts and Telecommunications, China); Jiakang 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 delay and angle 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.

18:00 Massive MIMO Channel Measurement and Characterization for Manufacturing Scenario
Zhiming 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 latency. This is beneficial to new applications in manufacturing scenarios. 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 Cyclo Prefix length and MIMO rank.

T10-033: Computational and Numerical Techniques 2

T10 EM-modelling and simulation tools / Regular Session / Electromagnetics
Room: B11

Chairs: Jiro Hirokawa (Tokyo Institute of Technology, Japan), Abdelrahman Abdallah Ijjeh (Université Côte d'Azur, France)

16:40 Floquet Mode Analysis on Groove Gap Waveguide
Jiro Hirokawa, Ketsuke Ejit 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. A 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
Joao Guilherme Niteroi Rahmeier (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 paper presents a rigorous mathematical mapping between the complex eigenmodes and the complex propagation constant for uniform rectangular metallic waveguides. The method exploits symmetry properties, provides 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 single-photon sources.

17:20 Mapping Between Complex Eigenmodes and Complex Propagation Constant for Uniform Rectangular Metallic Waveguides
Joao Guilherme Niteroi Rahmeier, Ville Tukuvasa and Sulahab 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 Q(3) and yu(3) 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 Côte d’Azur, France); Marylene Cueille (University of Nice Sophia Antipolis CNRS, France); Jean-Lou Dubard (Université de Nice - Sophia Antipolis, CNRS, France); Michel Ney (IMT Atlantique, France)
This paper presents a time-domain numerical scheme for simulating EM-computational problems that include complex media and fine geometrical details in critical regions. These problems are common in engineering and applied physics. To name a few, microwaves 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 and geometrical ones. Material complexity is taken in consideration using an convolution process with a matrix of time-domain filters; this models the dispersive and anisotropic nature of such media. On the other hand, non-conformal local mesh refinement approach is adopted to accurately discretize important fine details without exploding 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
Luisot Saaavedra (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 (asymetric, 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.

IW10: Sophisticated Antenna Development for Modern Hearing Aids (WS Audiology)

T12 Scientific / Industrial Workshops
Room: 5

Wednesday, 18 March 8:30 - 12:20
8:30 Multifocus Reflectarray Concept: Preliminary Design and Possible Applications  
Christophe Granet (Lyrebird Antenna Research Pty Ltd, Australia); Michael F. Palvig (TICRA, Denmark)

The concept of a multifocus reflectarray is introduced along with a preliminary design at Ka-band and an exploration of the possible applications this new concept can be applied to. The realized reflectarray provided both its Tx and Rx main beams in a single direction even though the feeds were separated.

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

The design of polarization selective reflectarrays for high-resolution and wide-swath SAR instrument in Ka-band is presented. The antenna system consists of nine dual-offset reflectarray panels, each with the size of 1.5m x 0.55m. The reflectarray operates in two modes, a high-resolution mode with a directive beam in one polarization, and a low-resolution mode with a broader beam in the orthogonal polarization. Two designs are presented, a single-layer design and a multilayer design. Both designs provide a gain >+6.7 dB for the high-resolution mode and a gain >+3.2 dB for the low-resolution mode.

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-Loja (Universidad Politecnica de Madrid, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Yolanda Rodriguez-Vaquero and Antonio Pino (Universidad de Vigo, Spain)

A parabolic reflectarray antenna has been proposed to generate a complete cellular coverage in transmission to provide broadband services from a communications satellite in Ka-band. Two different approaches have been evaluated to design a parabolic reflectarray able to generate four spaced beams per feed in four different combinations of frequency and polarization. A 1.8 m parabolic reflectarray has been simulated when it is illuminated by a feed block of 27 horns. The results show the capacity to generate 108 spot beams in good agreement with the requirements imposed in satellite communications. The proposed concept could be used to reduce the number of on-board antennas and feed chains required to generate a multi-spot coverage in Ka-band.

9:30 Band Enhancement in Reflectarrays for Space Communications Based on Multi-Frequency Synthesis Procedure  
Daniel R. Prado (Universidad de Oviedo & Signal Theory and Communications, Spain); Manuel Arrebola and Marcos P. Rino (Universidad de Oviedo, Spain); George Goussiotis (Heriot-Watt University, United Kingdom (Great Britain))

This paper describes a multi-frequency wideband optimization procedure and performance results of a very large spaceborne reflectarray for Direct-to-Home (DTH) application in a 10% bandwidth. The proposed design methodology is based on the generalized intersection approach and the use of a multi-reflectarray 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 wideband optimization including XPD 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 cross-polarization performance for both XPD and XPI in a 10% bandwidth, while ensuring that the copolar pattern complies with the specifications in the whole band.

9:50 A Wideband Reflectarray Using Slotted Patch with Concave Arms  
Ming Min, Lu Guo and Wenjie Feng (Nanjing University of Science and Technology, China)

In this paper, a wideband reflectarray antenna using dented patch with concave arms is presented. The broadband behavior is the result of combination of two bandwidth improvement approaches, i.e. employing multi-resonance element and slotted patch element. By varying the lengths of the slots together with the concave arms, the phase range can reach ±360˚ with a rather linear slope. Based on this novel element, an offset fed 23x23 reflectarray antenna is designed and simulated. The simulated 3-dB gain bandwidth is 40% with a peak aperture efficiency of 67%, while the side-lobe and cross-polarization levels are also satisfactory.

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-Loja (Universidad Politecnica de Madrid, Spain); Eduardo Martinez-de-Loja (Universidad Rey Juan Carlos, Spain); Jose A. Encinar (Universidad Politecnica de Madrid, Spain); Rafael Florencio (University of Alcalá, Spain); Rafael R. Boix (University of Seville, Spain)

The bandwidth behavior has been studied and improved for a reflectarray cell formed by two symmetric arcs and dipoles printed in two layers, which uses Variable Rotation Technique at two frequencies for dual circular polarization. First, the appropriate thickness of the dielectric layers have been selected to improve the bandwidth. Then, an optimization routine has been applied to minimize the phase errors in a frequency band from 20.25-7.5 GHz. As a result of this optimization, the phase errors have been drastically reduced from ±40 to ±3 degrees.

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

This contribution presents a low-profile linear-to-circular polarizing reflector with wideband operation in Ka-band. The polarizing cell consists of three parallel dipoles placed with 45° start with respect to the direction of the incident linearly polarized field. The lengths of the dipoles are adjusted cell by cell through a dual-frequency optimization process, which accounts for the real incidence angle on the cell. A 25 x 25 cm flat 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 19-20 GHz band, and good matching with the simulations. The proposed polarizing reflector has applications in novel multi-beam automotive configurations for Ka-band satellites.

11:20 A Low-Profile and Efficient Front-End Antenna for Point-to-Point Wireless Communications  
Abdul Sattar Kaddour (Florida International University, USA); Constantinos L. Zekos (Florida International University, ECE & FIU, USA); Stavros Georgakopoulos (Florida International University, USA)

This paper presents a novel Miura-Ori origami reflectarray unit cell. This origami inspired unit cell allows efficient on/offing, unfolding, high packing efficiency, easy deployment and frequency reconfigurable behavior. The unit cell is composed of 4 parallelogram patches that can achieve 560° phase shift. To synthetize the radiation pattern and the analysis proves that it has good radiation features. The proposed configuration is particularly convenient since Additive Manufacturing processes can be exploited for its fabrication.

11:40 Perforated Dielectric Reflectarray in Ka-band  
Andrea Massaccesi (Dibeic 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 a total efficiency is 85.3% at 12 GHz.

A radial waveguide. The antenna has a radius of 0.15 m and operating 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 25.6dBi and a peak realized gain of 25 dB. The antenna is 40% with a peak aperture efficiency of 67%, while the side-lobe and cross-polarization levels are also satisfactory.

12:00 Reconfigurable Origni Reflectarray  
Rafael Florencio (University of Alcalá, Spain); Puerto Asia Pty Ltd (Australia)

This paper proposes a single-layer perforated dielectric reflectarray antenna that operates in Ka-band. The unit-cells are 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.

12:40 A Reconfigurable Origni Reflectarray  
Rafael Florencio (University of Alcalá, Spain); Antonio Herreros (University of Oviedo, Spain); and Michael F. Palvig (TICRA, Denmark)

A Reconfigurable Origni Reflectarray

This paper presents a novel Miura-Ori origami reflectarray unit cell. This origami inspired unit cell allows efficient on/offing, unfolding, high packing efficiency, easy deployment and frequency reconfigurable behavior. The unit cell is composed of 4 parallelogram patches that can achieve 560° phase shift. To synthetize the radiation pattern and the analysis proves that it has good radiation features. The proposed configuration is particularly convenient since Additive Manufacturing processes can be exploited for its fabrication.

CS06: AMTA/IRACON Session: Over-The-Air Testing of 5G Radios

T02 Millimetrewave wave 5G / Convened Session / Measurements

Chair: Wei Fan (Aalborg University, Denmark), Pekka Kytsi (Keysight Technologies & University of Oulu, Finland)

8:30 Examining and Optimising Far-Field Multi-Probe Anechoic Chambers for 5GNR OTA Testing of Massive MIMO Systems

Chairs: Jose A. Encinar (Universidad Politecnica de Madrid, Spain), Michael F. Palvig (TICRA, Denmark)
Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Clive Parini (OML, United Kingdom (Great Britain))

Direct far-field (DF) testing has become the de facto standard for sub-six GHz over the air (OTA) testing of the physical layer of radio access networks with the far-field multi-probe anechoic chamber (FF-MPAC) being especially widely deployed for the verification of massive multiple input multiple output (Massive 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, as these systems require the user equipment to be placed in the far-field of the base transmitter station (BTS) antenna, either excessively large FF-MPAC 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 figures of merit and examines the consequences of testing within smaller enclosures. Results are presented and discussed.

8:50 Characteristic Mode Analysis for the Design of Nanosatellite Reconfigurable Antennas
Hongwei Kang (Keystights Technologies Co., Ltd. China); Ya Jiang (Keystights Technologies China); Zhun Wu (Keystights Technologies Co. Ltd, China); Li Cao (Keystights Technologies (China) Co., Ltd, China)

In this paper, novel mid-field developments, including the grey box approach and a mid-field prototype system covering both frequency range one and two, are presented to address challenges in 5G massive MIMO (mMIMO) base station (BS) OTA RF test. Simulations and measurements prove the effectiveness of the new developments. Further analysis of 50PP BS OTA RF measurement metrics and performance requirements indicate that the mid-field system can measure all of the required metrics with enough dynamic range. Test results with a CAE system using a commercial 5G BS prove that the mid-field system can achieve comparable test results as the CAE system. The comparability with the CAE system, the broad coverage of SUMP measurement metrics, and the compact size show that the mid-field system is an effective system for 5G mMIMO BS OTA RF test in both frequency range one and two.

9:10 On Noise and Interference Modeling for Over-the-air Testing of MIMO Terminals
Wei Fan (Aalborg University, Denmark); Peeka Kyvist (Keystights 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) testing is seen to replace currently dominantly adopted cable conducting testing for upcoming radio systems due to integrated antenna designs. To properly evaluate performance of radios 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 (RTS) and reverberation chamber (RC) is discussed and summarised.

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

Due to the large demand of high data rate and low latency service, mobile network, 5G has been commercially deployed in the many countries, e.g., China, US, Korea and EU. Massive MIMO and multi-input multi-output (MIMO) and hybrid beamforming techniques are expected to be key technologies in the 5G. Therefore, how to accurately measure the data throughput between massive MIMO BS and user equipment (UE) under channel fading conditions has drawn much attention 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 emulator. The simulation and test results show that the proposed method achieves similar performance compared with the whole channel emulator solution and meanwhile significantly reduces the cost of instruments.

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

An optimized irregular plane array antenna layout with uniform excitation of antenna elements is proposed for the Random-LOS OTA (Random-Line-0f-Sight Over-The-Air) characterization setups. A plane wave is synthesized with a cylindrical 3D test zone at 2.7 GHz. The obtained thinned array achieves a 52% reduction of the number of elements and a 45% aperture size as compared to a uniform fully populated plane array with an inter-element distance of 0.13λ, which is the optimum distance through [6] and [7], based on the presented cost function at this paper. The obtained maximum phase deviation and the maximum field amplitude deviation from the average field distribution in the 3D test zone of the proposed optimized array antenna layout are approximately 6.4 degrees and 3.9 dB, respectively. The numerical computation of the radiation pattern of a 10x10 element uniform planar array antennas at 2.7GHz placed within the test zone was performed too.

10:10 Coffee Break

10:40 Measurement Characterization of Aperture Correction Technique for EMP
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 calibration 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 for devices operating in 24-60 GHz. The technique calibrates for the probe interaction, and for the measurement position, providing promising results. Power density levels is important for electromagnetic field (EMF) compliance assessment of 5G. In this work the technique is utilized to reconstruct the power densities, as close as lambda/3, for three different radiating devices. The results are compared with simulations. An investigation into how the technique performs - for different frequencies, using synthetic input data, various grid sampling, and noise - is carried out, showing the regions of applicability.

11:00 OTA Testing of Antennas & Devices Using Plane Wave Generator or Synthesizer
Francesco Scattone (Microwave Vision Group (MVG), Italy); Danko Selulija (MVG, Italy); Andrea Giacomini, Francesco Saccardi, Alessandro Scannavini and Lars Froh (Microwave Vision Italy, Italy); Evgeni Kavetin and Nicolas 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 11:00 bandwidth was presented. A demonstrator of a dual-polarized PWS has been designed, manufactured and tested in the 600MHz to 5GHz frequency range. In this paper we report on the measured QZ performance of different implementations of the PWS demonstrator. PWS' are determined within a volume by spherical NF measurements and back-propagation. It has 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 electromagnetic small antennas.

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

5G active antenna system base stations operating in frequencies below 7.125 GHz (FR1) need to be tested using a 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 field verification setup using a polar near-field scanner and a vector network analyser is presented with description of the main hardware components, instrument settings and correction techniques for near-field measurements. 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 Testbed for GSMA CRRA Antenna Testing
Renato Zia (Fraunhofer IIS, Germany); Ramona Brochloss/Genex (Fraunhofer Institute for Integrated Circuits IIS, Germany); Mario Lorenz (Technische Universität Ilmenau, Germany); Markus Landmann (Fraunhofer IIS); Andrea Giacomini (Fraunhofer IIS); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

This paper presents an approach to calibrate an OTA testbed to perform 3D full polarimetric wave field synthesis (WF) to test controlled reception pattern antennas for global navigation satellite systems (GNSS). For 2D and 3D WF it has been mostly used for single polarization OTA testing, nevertheless the level of accuracy on representing real-world atmospheric losses becomes a challenge, specially for GNSS testing, since using three-electromagnetic (EM) field probes to perform the calibration of the three orthogonal field vectors (E, V, H) for simulation of arbitrary wave field profiles, 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 WF is shown and demonstrated in this contribution.

12:00 Comparing Options for 5G MIMO OTA Testing for Frequency Range Two
Doug Reed and Alonso Options for 5G MIMO OTA Testing for Frequency Range Two
Francesco Scattone (University of Twente, The Netherlands); Andrés Aylón Gazlunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)

As the fifth generation (5G) ecosystem matures, the time for large-scale 5G radio commercialization is now. Over-the-air (OTA) testing has become the de facto standard for sub-six GHz over the air (OTA) testing of the physical layer of radio access networks with the far-field multi-probe anechoic chamber (FF-MPAC) being especially widely deployed for the verification of massive multiple input multiple output (Massive 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, as these systems require the user equipment to be placed in the far-field of the base transmitter station (BTS) antenna, either excessively large FF-MPAC 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 figures of merit and examines the consequences of testing within smaller enclosures. Results are presented and discussed.

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 Civl (Middle East Technical University, Turkey), Hui Li (Dalian University of Technology, China), Philipp Gentner (Ericsson Antenna Technology GmbH, Germany), Gert Pedersen (Keysight Technologies, China) and Lars Foged (Rohde & Schwarz, Spain)

8:30 Characteristic Mode Analysis for the Design of Nanosatellite Reconfigurable Antennas
Markus Landmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Nicolas Gross (Spirent Communications, USA); Jukka-Pekka Nuutinen (Spirent Communications, Finland)

5G MIMO OTA is the well-established and predominant method to test mobile devices with multiple antennas. The MIMO OTA approach requires the device under test to be placed in the far-field of the base station antenna, either excessively large FF-MPAC 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 figures of merit and examines the consequences of testing within smaller enclosures. Results are presented and discussed.
A novel 5-band antenna concept hosted on a 1×1 form factor CubeSat platform is designed by exploiting the Characteristic Modes Theory (CMT). The innovative strategy provides useful design guidelines to transform the external platform into an efficient radiator by stimulating an optimal current distribution on its conductive surface. The effect of the satellite platform on the radiated performances (efficiency, band, gain) is intrinsically taken into account and profitably exploited to realize an efficient radiation system. The minimally invasive radiators, strategically colocated on the platform thanks the CMT, allow achieving a great saving of space and an optimal modal-current excitation able to provide excellent radiation performance.

### 8:50 Antenna Positioning for Bandwidth Optimization Using Characteristic Mode Analysis

- **Peter William Futter** (Altair Development S.A. (Pty) Ltd, South Africa); **Ulrich Jakobus** (Altair Engineering GmbH, Germany)

Characteristic mode analysis is used to understand the modal 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, this paper aims to 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 wideband antenna to excite specific modes while optimizing the antenna bandwidth. It is applied to two antenna examples.

### 9:10 On the Use of Characteristic Mode Analysis for the Design of Antenna Arrays

- **Philipo Gencor** (Ericsson Antenna Technology Germany GmbH, Germany)

An antenna array design used in base station antennas has a high polarization purity is required. Therefore, this paper exploits the use of characteristic mode analysis (CMA) style (Harrington 1971) 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.

### 9:30 Use of Characteristic Modes in the CBFM for the Analysis of Large Arrays

- **Yigit Hayır** and **Ozlem Aydin Civı** (Middle East Technical University, Turkey)

In this work, the characteristic modes method (CBFM) is presented in conjunction with the characteristic modes (CMA). In this approach, characteristic modes are defined as primary basis 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.

### 9:50 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 is firstly studied numerically, with its eigenvalues, characteristic currents and fields 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. Computing the weighting coefficients of each mode in free space and with hand, the radiation pattern with roll at the boresight is less affected by the hand. According to the observation, a handset antenna, which radiates little power towards the boresight, is designed. It is proved that the radiation efficiency of the proposed antenna with hand is ≥ 4 dB higher than that of the reference antenna.

### 10:10 Coffee Break

### 10:40 Influence of p-Refinement on Accuracy of Mode Tracking Based on Correlation of Characteristic Currents

- **Ana Djurdjevic** and **Branko Mršković** (WPLO, Serbia); **Branko Kordić** (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, a wideband 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 possibility to improve the tracking by increasing accuracy of MoM matrix calculation by using p-refinement method. Results obtained using modal analysis on benchmark structures are use as a reference. It is shown that p-refinement can bring some limited improvements of mode tracking, but the main problems related to mode tracking based on correlating the modal currents still remain.

### 11:00 Systematic Design Method for Asymmetric Multiport Antennas Based on Characteristic Modes

- **Nicola Pietrzak** (Leibniz University Hannover, Germany); **Dirk Mutschke** (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 symmetry based on group theory and group representations to the theory of characteristic modes, it is shown that it is in general possible to realize uncorrelated antenna ports on an asymmetric antenna. Therefore, a port placement procedure based on characteristic modes is proposed for such geometries in order to realize ports with low correlation. The design procedure is based on modal parametric space. 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.

### 11:20 Systematic Approach to Design a Circularly Polarized Antenna Using the Characteristic Modes Theory

- **Hussein Jafar** (The French Alternative Energies and Atomic Energy Commission, France); **Ala Sharaiha** (Université de Rennes 1 & IETR, France); **Sylvain Collardey** (University of 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 (cylindrical lens). The characteristic modes supported by this structure are studied and various modifications are accordingly applied to generate the desired polarization.

### 11:40 Flexible Antenna Design with Characteristic Modes

- **Eva Antón-Davín** (Universitat Politècnica de València, Spain); **Aline Eid**, **Ryan Bahr** and **Manos M. Tentzeris** (Georgia Institute of Technology, USA)

A dual-band flexible antenna in a 3-D printed structure is presented for UWB and 5G applications. The antenna is aimed to work at 850 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.

### 12:00 Broadband Metasurface-Based Antenna Using Hexagonal Loop Elements

- **Wenxiao Zhang**, **Y Huang** and **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 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 1.13×1.13×0.06 λ0 can achieve 56% fractional bandwidth and a relatively stable gain of 7-11 dB over the operating band.

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**CS62: Small Antenna in a Human Body Environment**

**T04 IoT and M2M / Convened Session / Antennas**

**Room: B2**

**Chairs:** Eva Antón-Davín (Universitat Politècnica de València, Spain), Ala Sharaiha (Université de Rennes 1 & IETR, France)

### 8:30 Small New Wearable Metamaterials Antennas for IOT, Medical and 5G Applications

- **Albert Sabbah** (Kinneret and ORT BRAUDE COLLEGE, Israel)

Efficient small antennas are crucial 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. Antennas may be connected to the wearable antenna feed line to increase the system dynamic range. Novel design passive and active efficient wearable metamaterial antennas for 4G and 6G applications are presented in this paper. The gain of antennas with Split-ring resonators, SRR, is higher by 2.5-6 dB 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 5 to 7 GHz.

### 8:50 Design and Optimization of a Flexible CPW-Fed Slotted Planar Monopole for WLAN/WBAN and 5G

- **Bashar Bahaa Qas Elias** (Universiti Malaysia Perlis (UniMAP), Malaysia); **Ping Jack Soh** (Universiti Malaysia Perlis (UniMAP) & Katholekhe Universitet Leuven, Malaysia); **Azemi Abdullah Al-Had** (Universiti Malaysia Perlis, Malaysia); **Hadi Akbarian** (University of Tehran, Iran); **Sen Yan** (Xian Jiaotong University, China)

A dual-band flexible antenna on a 3-D printed support is proposed for wrist worn applications. The antenna is aimed to work at 4.35 GHz and 23 GHz by the arm. Characteristic Mode Analysis is used as a first step of the design process, analyzing different structures. The proposed broadband hexagonal-loop-based antenna with an overall size of 1.13×1.13×0.06 λ0 can achieve 56% fractional bandwidth and a relatively stable gain of 7-11 dB over the operating band.
A flexible Kapton-based coplanar waveguide-fed (CPW) patch antenna has been designed in this work to operate in different wireless applications. The wideband operation and compact size of the antenna is enabled using a simple trapezoid-shaped integrated into the monopole which was designed using a rectangular patch. The proposed broadband antenna model operated below -10 dB at 2.45 GHz and 3.5 GHz for the WLAN/WISP 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.

10:00 Coffee Break

10:40 Small Implanted Antennas for Wireless Communication and Energy Harvesting

Stavros Koulouridis (University of Patras, Greece)

In this work we investigate on the design of implanted miniaturized antennas for wireless communication. The focus is on the development of highly efficient devices that can be used for data telemetry and energy harvesting applications. The antennas are designed for specific body regions and engineered to withstand the physiological conditions of the human body.

11:00 Removable Finger Nail Antenna

Peter Nepjo and Benito Sanz-Izquierdo (University of Kent, United Kingdom (Great Britain))

An antenna is proposed on a removable fingernail for on-body communication applications. The antenna is a monopole that is designed to operate in the UHF band. The design is validated through simulations and measurements, demonstrating its potential for on-body communication.

11:20 Antenna for a Cranial Implant: Simulation Issues and Design Strategies

Alberto Jose Moreno Montes and Ismael Vico Trivino (EPFL, Switzerland)

The design of a specific antenna for a cranial implant is used to illustrate simulation issues and design strategies. The antenna is designed for on-body communication and is intended to operate in the UHF band.

11:40 Evaluation of Surface Equivalence for On-Body Propagation Modelling of Hearing Aid Antennas

Lukas Berkelmans (Leibniz University Hannover, Germany); Dirk Munteffelt (University of Hannover, Germany)

In this contribution, we evaluate the use of surface equivalence with the Norton surface wave theory for modeling the on-body propagation for hearing aid antennas. We determine the parameters of the equivalent surface wave theory and compare them with numerical simulations.

12:00 Mini-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. Young (The University of Hong Kong, Hong Kong)

The design of a mini-band dual-fed smart glasses IoT antenna is presented. The antenna is designed to operate in the UHF band and is intended for on-body communication applications.

CS26: Education in Electromagnetics, Antennas, and Microwaves

T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics

Room: B4

Chairs: Ari Shvoila (Aalto University, Finland), Henrik Wallem (Aalto University, Finland)

8:30 Federated Non-Traditional Practical Work for Engineering Education

Tommy 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 optimised 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 on to give an outline for a software architecture that would allow the federated 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 to procure.

8:50 Teaching Wireless Communications Courses: An Experiential Learning Approach

Hugo G. Espinosa (Griffith University, Australia); Thomas Finkenbercher (Helmut Schmidt University, Germany); Nicholas 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 trimester. At the outset of each project, pairs of students choose a three-project group outline, all of which are unique to each person group with an intensive 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.
**CS47: Non-Magnetic Nonreciprocity**

**T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics**

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 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 emphasizes width over many tasks, instead of depth in a few tasks. Grading results using this new approach have been compared against results from an earlier used 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**

Adwin K. Iyer (University of Alberta, Canada)

Electrical-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 career from it.

11:00 **Advanced Teaching in Electromagnetics at the ELEDA Research Center**

Nicolaos Arslanagić (ELEDIA Research Center, Italy); Renzo Azaro (Eledia Research Center, Italy); Federico Boulou (ELEDIA@UniTN – DIS 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 Marcantoni (ELEDIA Research Center, Italy); Giacomo Oliveti (University of Trento & ELEDIA Research Center, Italy); Lorenzo Poli and Alessandro Polo (ELEDIA Research Center, University of Trento, Italy); Paolo Roccia (University of Trento, Italy); Marco Salucci (ELEDIA Research Center, Italy); Andrea Massa (University of Trento, Italy)

An entirely new educational framework has been designed and implemented by the ELEDIA Research Center to renew the way of teaching electromagnetics (EM) to future engineers and increase students' self-confidence and admiration of the applicable and technological aspects of Maxwell's equations. According to authors' expectations and received students' feedback, such a training ecosystem will help a computer-naive generation in developing a more natural-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: Wave Reflected by Conductor-Backed Water Slab**

Haijun Chen and Shih-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 microwave 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 levels 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 by Means of a Simple Scattering Problem**

Nikolaos L. Tatsas (Aristotle University of Thessaloniki, Greece); George Fikionis (National Technical University of Athens, Greece)

In this paper, 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 scattered fields.

12:00 **In Favor of Re-Introducing and/or Expanding Rectangular Waveguides in Bachelor's and Master's Level Electromagnetic Courses**

Marianella Baggio and Zachary D Taylor (Aalto University, Finland)

This paper makes a case for the continuing inclusions of rectangular waveguides in bachelor's and master's level electromagnetics education. Modern training in electromagnetic theory, 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**

**T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics**

Room: 105

**Chairs**: Andrea Ali (CUNY Advanced Science Research Center, USA), Dimitrios Soukas (Wayne State University, USA)

8:30 **Nonreciprocal Metasurfaces Through Circular Polarization Blasing**

Dimitrios Soukas (Wayne State University, USA)

A new type of nonreciprocal metasurface is presented that is biased by two incident circular polarized waves and as a result does not require a complicated biasing network. The pumps are selected to have opposite polarizations and slightly detuned frequencies. The metasurface exhibits nonreciprocal polarization rotation and it can be the building block of free space circulators and isolators.

8:50 **Quadratic Magnet-Free Micro-acoustic RF Circulator with Intermodulation Suppression**

Yao Yu (Northeastern University, Boston, US, USA); Matteo Rinaldi (Northeastern University, Boston, US, USA)

In this paper, a micro-acoustic RF circulator with novel "quadratic" configuration is reported. Four micro-acoustic filters are periodically modulated by RF switching to break the reciprocity. The use of high-Q micro-acoustic filters significantly reduces the modulation frequency compared to previous demonstrations based on transmission lines. The low modulation frequency translates to an ultra-low power consumption (D2LX, 100 times smaller than [1]) and one of the highest reported for magnet-free circulators. Furthermore, compared to the more conventional differential configuration, this quad configuration shows advantages in terms of intermodulation products (IMPs) suppression for all the in-band IMs. guaranteeing a pseudo-linear-time-invariant (pseudo-LTI) operation.

9:10 **Low Loss, CMOS Integrated, Magnetic-Free Non-Reciprocal Components Operating from Radio Frequencies to Millimeter-Waves**

Aravind Nagulu and Harish Krishnaswamy (Columbia University, USA)

Magneto-free non-reciprocity using time-variance has gained a lot of attention in recent years. Some initial approaches use permittivity-modulation along a transmission line or in a resonant ring structure. However, small modulation contrasts of permittivity imply high loss and a large form-factor or narrow transmission bandwidths. More recently, we leveraged the much larger conductivity modulation contrasts available in CMOS to achieve drastically smaller form-factors, wide bandwidths and low-loss non-reciprocity across a wide range of operating frequencies. Here we review recent progress on spatio-temporal conductivity-modulation, which enabled non-reciprocal components operating from radio frequencies to millimeter-waves in a CMOS platform.

9:30 **Space-Time Modulated Loaded-Wire Metragratings for Magnnetless Nonreciprocity**

Yakir Hadad (Tel-Aviv University, Israel)
We show that spatially modulated metamaterials can lead to strong nonreciprocal responses, despite the fact that they are based on electrically-large unit cells and use only three modulation domains. We specifically focus on wave metamaterials loaded with time-modulated capacitances, and demonstrate an effective nonreciprocal anomalous reflection (dicroism) with an efficient frequency conversion.

9:50 Nonreciprocal Antennas Based on Time-Modulation: Challenges and Opportunities
Alejandro Alvarez-Melcon (Technical University of Cartagena, Spain); Juan Sebastián Gómez-Díaz (University of California, Davis, USA)
We explore the possibility to realise nonreciprocal antennas based on combining time-modulated resonators with high-Q structures. Upon 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 imposes a nonreciprocal phase control of the generated waves throughout the antenna design. This approach is applied to design nonreciprocal and reconfigurable antenna configurations at one operating 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.

10:10 Coffee Break

10:40 A Spatio-Temporally Modulated Metasurface as a Free-Space N-Path System
Zhanniu Wu (University of Michigan, USA); Cody Scarborough (University of Michigan, USA); Anthony Gbibi (University of Michigan, Ann Arbor, USA)
A spatio-temporally modulated metasurface, that functions as a free-space N-path system, is reported at X-band frequencies. The reflection phase of the rows of the metasurface can be independently time-modulated for two orthogonal polarizations. A space-time bias is applied to the metasurface, enabling directionally dependent electromagnetic responses. When the modulation wavevectors are larger than that in free space, the metasurface suppresses certain harmonic mixing products in the far field, allowing subharmonic mixing. The metasurface was experimentally validated for 2-path configurations, where the fabricated metasurface suppresses odd harmonic mixing products. With proper design of the space-time bias waveform, Doppler-like frequency translation is demonstrated at twice the modulation frequency.

11:00 Temporal Modulation of Biaxial isotropic Metasurfaces for Unidirectional Wave Amplification
Xuchen Wang, Ana Diaz-Rubio, Viktar Asadchy, Grigorii Ptitcyn, Mohammad Sajjad Mirmosa and Sergei Troyakov (Aalto University, Finland)
Nonreciprocity in time-modulated metasurfaces is naturally achieved only when it is combined with space modulation, using at least two time-modulated elements at different locations in space. In this talk, we present the idea of time-modulated biaxial isotropic metasurfaces where nonreciprocal wave propagation is realized with time modulation of only a single element. The results show that by uniformly modulating a capacitive sheet mounted on a sub-wavelength dielectric layer one can obtain strong nonreciprocity and achieve unidirectional wave amplification.

11:20 Perfect Faraday-Rotation Metasurface
Guillaume Lavigne (Polytechnique Montréal, Canada); Yoshio Kodera (Meisei University, Japan); Christophe Caloz (École Polytechnique de Montréal, Canada)
We introduce a perfect Faraday-rotation metasurface. This metasurface provides arbitrary angular reflectiveness and absorptionless nonreciprocal polarization rotation. Moreover, we show, using the surface susceptibility model, that such a metasurface involves a simultaneously electric and magnetic response, which may be realized with transistorized load-modulated striplines and looped wires. This metasurface may potentially accommodate arbitrary incident and reflection angles.

11:40 First Principles Calculations of Topological Invariants by Means of the Photonic Green's Function
Filipa Prudencio (Instituto Superior Técnico-Instituto de Telecomunicações, Portugal); Maio Silveirinha (Universidade de Lisboa - Instituto de Telecomunicações, Portugal)
The Chern topological numbers of a material platform are usually written in terms of the Berry curvature, which depends on the normal modes of the system. Here, we use a gauge invariant Green's function method to determine from first principles the topological invariants of photonic crystals. The proposed formalism does not require the calculation of the photonic band-structure, and can be easily implemented using the platform obtained with a standard plane-wave expansion.

12:00 Doppler Cloak: Concept and Realistic Implementation Through Space-Time Modulated Metamaterials and Time-Modulated Metasurfaces
Davide Ramacca (RomaTre University, Italy); Andrea Alù (The University of Texas at Austin, USA); Alessandro Toscano (University Roma Tre (IT), Italy); Fliberto Bilotti (University Roma Tre, Italy)
A Doppler cloak consists of a non-reciprocally time-space modulated metamaterial that allows manipulating the apparent velocity of a moving object by inducing an artificial frequency shift in the reflected signals. 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-variant 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 large impact also in other applications, such as restoration of electromagnetic invisibility and antenna matching in moving systems, just to name a few.

SWO3: COST Session CA17115 (MyWAVE): Supporting Medical Device Development via Dielectric and Thermal Tissue Characterization

9:00 Dielectric Properties of Biological Tissue at Radio Frequencies
Nuno P. Silva (National University of Ireland, Galway & Faculdade de Ciências da Universidade de Lisboa, Portugal); Anna Bottiglieri (Translational Medical Device Lab & National University of Ireland, Galway, Ireland); Raquel C. Conceição (Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Portugal); Mario Silveirinha (Universidade de Lisboa - Instituto de Telecomunicações, 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 & CURAM, Ireland)
In electromagnetic hyperthermic applications, the thermal properties of the biological tissue under treatment, as well as its dielectric properties, influence the deposition of the electromagnetic energy and the heat distribution into the tissue. Thus, the knowledge of above properties can help to accurately model the thermal responses. In this study, we investigate experimentally the thermal properties of the biological tissues. The aim of this work is to experimentally investigate the thermal properties of the biological tissue Ex vivo (liver, lung, kidney, muscle and bone) at room temperature (23±1°C) and at body temperature (37±1°C) with different pressures. The results show that the thermal properties of the biological tissue can be easily implemented using the platform obtained with a standard plane-wave expansion.

9:15 Investigation on Temperature-Dependent Changes of Tissue Thermal Properties on Microwave Ablation Treatments
Marta Cavagnaro (Sapienza University of Rome, Italy); Rosanna Pinto (ENEA, Italy); Vanni Lopresto (ENEA, Italian Agency for New Technologies, Energy and Sustainable Economic Development, Italy)
Microwave thermal ablation treatments 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 cell 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 achieve the desired thermal ablation. To develop reliable interventional protocols, numerical tools able to correctly predict the distribution of the temperature increase are needed. In this work, values recently measured of the thermal conductivity as a function of the temperature have been introduced into the numerical model to evaluate their influence on the calculated data.

9:30 Fast Measurements of Dielectric Properties with Small Size Microwave Transceiver
Zdeněk Fiser, Jr. (Czech Technical University in Prague & Faculty of Bioengineering, Czech Republic); Michaela Kantova (CTU in Prague, Czech Republic); Sebastian Ley, Alexandre Prokhorov and Marko Helbig (Technische Universität Ilmenau, Germany); Jan Vlha (Czech Technical University, Czech Republic)
We report on a recently developed microwave transceiver, which enables the real-time measurements of dielectric properties of tissues in a non-invasive manner. The transceiver is based on a specifically designed small size transceiver loaded with straight and looped wires. This metasurface may potentially accommodate arbitrary incident and reflection angles.

9:45 Advanced Temperature Dicyroscopic Spectroscopy of Muscle Phantom at Microwave Frequencies
Ondrej Fiser, Jr. (Czech Technical University in Prague & Faculty of Bioengineering, Czech Republic); Michaela Kantova (Czech Technical University, Czech Republic); Sebastian Ley, Alexandre Prokhorov and Marko Helbig (Technische Universität Ilmenau, Germany); Jan Vlha (Czech Technical University, Czech Republic)
We report on a recently developed microwave transceiver, which enables the real-time measurements of dielectric properties of tissues in a non-invasive manner. The transceiver is based on a specifically designed small size transceiver loaded with straight and looped wires. This metasurface may potentially accommodate arbitrary incident and reflection angles.
A novel reconfigurable antenna in X-band frequency is presented. The antenna employs a simple capacitive loading technique to increase the -10 dB bandwidth by 2.5 times (≤15%). The proposed antenna is designed at the frequency of the unloaded state operating at 24.2 GHz (1.8 GHz bandwidth) and the loaded state at 24.5 GHz (4 GHz bandwidth compared to serial-fed patch antennas without the need for additional layers in the printed circuit board (PCB)).

Jonathan Mayer (Karlsruhe Institute of Technology, Germany); Manuel Martina (Schweizer Electronic AG, Germany); Thomas Zwick (Karlsruhe Institute of Technology, Germany); Ludwig Pongratz (Karlsruhe Institute of Technology, Germany);

This paper presents a new antenna principle using capacitive 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 dB over more than 3 GHz bandwidth while the sidelobe 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 Bargert (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 (≤15%). The proposed antenna is designed at the frequency of the unloaded state operating at 24.2 GHz (1.8 GHz bandwidth) and the loaded state at 24.5 GHz (4 GHz bandwidth).
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 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 to 0.7 dBi which is comparable to that of a miniature dipole whose height is 7.5 times larger, facilitating low-power wireless compact UAV communications and networking at low VHF.

10:10 Coffee Break

10:40 A Triband Wire Antenna for All Radio and TV Bands
Johan Wettergren and Robert Peterson (Qamcom Research and Technology, Sweden); Roman Lustin (Volvo Technology, Sweden)

A triband rod antenna is presented. It is intended for reception of AM, FM, DAB and TV in vehicles. The antenna uses coil taps to facilitate multiple resonance lengths in order to be matched to 50 Ohms for frequency bands centered 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, as a design methodology is suggested and measurements on a breadboard model are presented.

11:00 Ka-Band Planar Magic-T Based on E-plane Groove Gap Waveguide for Monopulse Antenna System
Arefeh Kalantari Khodadini (Intelligent Boards Electronic Company, Iran); Ali Farahabakhsh (Graduate University of Advanced Technology, Iran)

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 coplanar and 1/2-plane groove gap waveguide. The frequency bandwidth of the proposed Magic-T is about 43% 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.

11:20 Haness Connection and Immediate Environment Impact on RF Automotive Receivers Antenna BW
Ahmadreza Jafari (Renesas E.S., France); Gregory Siguer (Continental Automotive S.A.S, France); Clément Prince (Continental Automotive S.A.S. I. B.S DF, France); Philippe Boulier (Renaud sas, France); Imene Efekli (Epitech, France); Xavier Bultron (Renaud sas, France)

Numerical simulations are used more and more to investigate the behavior of RF antennas and wireless systems in the immediate environment of the vehicle. To assert these simulations help evaluate the impact of the immediate environment of the RF access receiver and its harmonics connection on the antenna performance, reflection coefficient and bandwidth.

11:40 Three Port Circular Patch Antenna with Pattern and Polarisation Agility
Peter J James (University of Bristol, United Kingdom (Great Britain))

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 TM00, 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 these simulations. A diversity of 2.2 dB has been achieved at the horizon through this beamsteering method compared to -0.2 dB for the TM10 and TM11 modes and -0.7 dB for the TM0 mode at the same angle. A discussion of the active impedance and its impications for beamforming results is also included.

12:00 Wide-Angle Scanning Performance Enhancement in Linear Arrays via Combining Integrated In-line Subarrays and Amplitude Tapering
Farnoush Sedi Alakbar and Garmynto Hendrantoro (Institut Teknologi Sepuluh Nopember, Indonesia); Leo P. Ligthart (em. prof. Delft University of Technology & Universitas Indonesia, The Netherlands); Joan E. Lager (Deft University of Technology, The Netherlands)

An advanced design, adding a significant first side-lobe level (FSLL) improvement to a previously introduced wide-angle scanning, linear array prototype with demonstrated scan-loss compensation (SLC) and side-lobe suppression features is discussed. The linear array makes use of in-line subarrays for SLC and an additional amplitude taper in its central, uniform region for lowering the FSLL with as much as 6 dB at ±60° scanning (13 dB at ±20° scanning). Several prototype tapers are compared, the best overall performance improvement being observed for a 1.8 dB prototype taper. The advocated solution is highly suitable to high-sensitivity radars requiring a fast-scanning, fan-shaped beam.
9:50 Compact Millimeter and Submillimeter-Wave Photonic Radiometer for Cubesats
Michal Gregorczyk Wasak (Carlos III University of Madrid, Spain), Gabriel Santamaria Botello and Ketos Alia Abdalmalik (University Carlos III de Madrid, Spain), Florian Sedmera and Alfredo Rueda (Max Planck Institute for the Science of Light, Germany), Luis Enrique Garcia Muñoz (University Carlos III de Madrid, Spain)

In this paper we present a room temperature radiometer that can eliminate the need of using cryostats in satellite payloads reducing its weight and improving its reliability. The proposed radiometer is based on an electric-optic upconverter that boosts up microwave photon energy by up-converting them into an optical domain which makes them immune to thermal noise even if operating at room temperature.

The converter uses a high-quality factor whispering gallery mode (WGM) resonator providing naturally narrow bandwidth and therefore might be useful for applications like microwave hyperpolarization. The upconversion process is explained by providing essential information about photon conversion efficiency and sensitivity. To prove the concept we perform an experiment which shows a state-of-the-art photon conversion efficiency 10^−5 per mW of pump power at the frequency of 60 GHz.

10:10 Coffee Break

10:40 Comparison of Modified Soret Lenses for Dual Band Integrated Detectors
Alicia E. Torres-Garcia (Public University of Navarra, Spain), Jose M. Perez (Facultad de Ingeniería, Universidad Pública de Navarra, Spain), Ramon Gonzalez (Public University of Navarra, Spain), Iligo Ederda (Universidade da Madeira, Portugal)

In this paper we present a comparison of the different modified Soret lenses suitable for a millimeter and submillimeter-wave dual-band integrated pixel detectors. The approach is based on a comparison of a printed planar Soret lens, designed to operate in the sub-mm range, to obtain an annulus at the millimeter regime. Three modification of a transmission-mode Soret lens at 850 GHz have been evaluated, and similarity, and reasonableness of the performance in terms of efficiency, and uniformity is demonstrated in a sub-mm-wave band, showing good agreement with simulation data.

1:00 The Optical Combiner of QUBIC: The Q O O Bolometric Interferometer for Cosmology
Credite O'Sullivan (National University of Ireland Maynooth, Ireland), David Burke, Donnacha Gayer and James Murphy (National University of Ireland, Maynooth, Ireland), Stephen Scully (Institute of Technology Carlow, Ireland), Michele De Leo (Università di Roma – La Sapienza, Italy), Marco De Petris (Università di Roma – La Sapienza, Italy), Massimo Gevvis and Mario Zannoni (Università di Milano – Bicocca and INFN Milano-Bicocca, Italy), Peter Ade (Cardiff University, United Kingdom (Great Britain)), Jose Alberro (SEMA Universidad Nacional de La Plata, Argentina), Alessandro Almeida (Instituto de Tecnologias de Comunicacion y Apastarciencias, Argentina), Giorgio Amico (Università di Roma – La Sapienza, Italy), Anna Amodeo, (Centro Atómico Bariloche and Instituto Balseiro (CNEA), Argentina), Didier Auguste (Laboratoire d'Astrophysique, Université Paris-Sud, France), Nathan Aumont (Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay, France), Jean-Philippe Bernard (Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay, France), Marco Bersanelli (Università degli Studi di Milano, Italy), N Béjaoui (Astrophysicque et Cosmologie, Paris, France), Jean Bonaparte (Centro Astronomico Constituyentes, France), J Bonas (Laboratoire de Spectrométrie Nucléaire et de Spectrométrie de Masse, Orsay, France), A Bottani (Osservatorio Astronomico di Padova, Italy), Emory Bunn (University of Richmond, USA), Alberto Etchegoyen (Instituto de Tecnologias de Comunicacion y Apastarciencias, Argentina), Yannick Giraud-Heraud (Astrophysicque et Cosmologie, Paris, France), Maron Gradziel (National University of Ireland, Maynooth, Ireland), John Anthony Murphy (University of National University of Ireland Maynooth, Ireland), Laurent Grandis and Jean-Christophe Hamillot (Astrophysicque et Cosmologie, Paris, France), Amiel Mennella (Universitá degli Studi di Milano, Italy), Michele Pietti (Astrophysicque et Cosmologie, Paris, France), Lucio Picillo (University of National University of Ireland Maynooth, Ireland), Stephen Scully (Institute of Technology Carlow, Ireland), Sophie Hessels-Vibert (Instituto de Tecnologias de Comunicacion y Apastarciencias, Argentina), Jean Kapan (Astrophysicque et Cosmologie, Paris, France).

In this paper we briefly describe QUBIC, the Q O O bolometric interferometer for cosmology, a novel ground-based instrument designed to measure extremely faint polarization anisotropy of the cosmic microwave background at intermediate angular scales. A Technical Demonstrator of the instrument has been built, and is being currently tested, and we plan to start observations from Argentina in 2020. Here we will concentrate in particular on simulations of the input feedhorn area, the optical combiner (an off-axis Gregorian image) and early laboratory calibration measurements.

11:20 Optics for the Submillimeter Wave Instrument on Jupiter Mission JUICE
Mikko Kotani, Karl Jacob and Tobias Pilus (Universität Bern, Switzerland), Paul Hartogh (Max Planck Institute for Solar System Research, Germany), Jo Lark (Max Planck Institute for Solar System Research, Germany)

The Submillimeter Wave Instrument is a passive heterodyne radiometer/spectrometer for the Jupiter icy moons Explorer (JUICE) mission of the European Space Agency. It consists of 29-cm off-axis Cassegrainian antennas and passively cooled Schottky mixer receivers tunable in the frequency ranges of 530-625 and 1080-1275 GHz. This paper gives an overview of the instrument optics and describes the main optical design aspects, which have been performed to accommodate the adverse effect of mounting artefacts on the alignment of the optical receiver. Further, instrument thermal contraction based on predicted mission temperatures has been included in the optical model and its effect on the half-power beam width has been evaluated. Finally, the electromagnetic reflection loss of several coating materials has been assessed. A coating protects the mirrors made of 8AlMn8 from corrosion and potentially reduces the reflection loss by providing a lower surface resistance than the bare material.

14:10 Jupiter icy Moon Explorer: Submillimeter Wave Instrument: Status and Performances of the 1200 GHz High Spectral Resolution Receiver Front End
Jeanne Treuttel (Observatoire de Paris, France), Karl Jacob and Tobias Pilus (Universität Bern, Switzerland), Jan Bonis (Astroparticule et Cosmologie, Paris, France), Maron Gradziel (National University of Ireland, Maynooth, Ireland), Jean-Christophe Hamilton (Observatoire de Paris, France), Jose Alberro (SEMA Universidad Nacional de La Plata, Argentina), Luis Enrique Garcia Muñoz (Screening, Canada), Alvaro Gonzalez (Centro Atomico Constituyentes, Argentina), Keiko Kaneko (Università degli Studi di Milano, Italy), Saro Marchesi (Centro Atomico Bariloche and Instituto Balseiro (CNEA), Argentina), Luigi Mazzara (Centro Atomico Bariloche and Instituto Balseiro (CNEA), Argentina), Massimo Gervasi (Università di Roma – La Sapienza, Italy), Michele De Leo (Università di Roma – La Sapienza, Italy), Luca Pinnati (Centro Atomico Bariloche and Instituto Balseiro (CNEA), Argentina), and Tobias Plüss (Università di Roma – La Sapienza, Italy)

As a technical demonstration of an astronomical receiver working in a frequency range of 275-500 GHz, we are developing the receiver designed for ASTES telescope in Chile. The fabricated horn has < -20 dB of return loss and < 10 dB of gain. In this paper will describe the SWI radiometer front-end system and address the different procurement steps including the development of critical sub-systems of the two channel front-ends, including its 1200GHz mixer and last frequency stage local oscillator. We will present the SWI radiometer front-end system and address the different procurement steps of the flight hardware. We will present some of the test structures used, the test conditions as well as some of the failure criterias and allowable drifts.

12:00 Design and Characterization of 275-500 GHz Corrugated Horns and Optics for a Wideband Radio Astronomy Receiver
Bangcon Lee (Korea Astronomy and Space Science Institute, Korea (South)), Alvaro Gonzalez, Kekko Kakeko and Ryo Sakai (National Astronomical Observatory of Japan, Japan), Jung-Won Lee (Korea Astronomy and Space Science Institute, Korea (South))

As a technical demonstration of an astronomical receiver working in a frequency range of 275-500 GHz, we are developing a such a wide-band one. The received signals are in 275-500 GHz frequency range. This paper presents the effects of the number of receiving elements on the resolution of detected target and further reduction of the views to 90 degrees only causes minor offset in localization. This reduction in the number of receiving positions plays a vital role in the formation of a detector a faster cleaner and less complex food imaging prototype.

CS65: Unconventional Techniques and Applications for Inverse Scattering Problems

T1 Fundamental research and emerging technologies / Convened Session / Electromagnetics
Room: 89

Chairs: Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy), Rosa Scapaticci (CNR-National Research Council of Italy, Italy)

8:30 Limited-view Prototype Design for Radar-based Fruit Imaging
Navid Ghavami, Ioannis Siotis and Panagiotis Kosman (King's College London, United Kingdom (Great Britain))

The need for non-destructive food testing has received increasing attention with the rapid global growth in food demand and consumption over the past decades. Current limitations in assessing fruits' internal quality motivates the requirement of enhancing existing quality assessment procedures to decrease product wastage and increase the safety of the consumers. Microwave imaging is an emerging non-invasive and non-destructive technology for various applications. Microwave imaging can produce high-quality images of the internal features of foods. The experiments show that limiting the number of receiving views to 180 degrees does not affect the resolution of detected target while further reduction of the views to 90 degrees only causes major offset in localization. This reduction in the number of receiving positions plays a vital role in the formation of a faster cleaner and less complex food imaging prototype.

8:50 Inverse Scattering in the Framework of Unconventional Lebesgue Spaces: A Case Study
Claudio Estatoc, Alessandro Fedeli, Matteo Pastorino and Andrea Randazzo (Università di Genova, Italy)

An inverse scattering procedure working in the unconventional Lebesgue spaces with variable exponent is considered in this paper. The aim of this paper is to develop a novel approach to treat inverse scattering problems in the framework of variable exponent spaces. The proposed approach is based on a combination of the classical and the modern tools of the Lebesgue spaces theory. The inverse scattering problem is formulated in the framework of the variable exponent Lebesgue spaces. The existence and uniqueness of the solution are proved. The numerical results obtained using the proposed approach are presented.

9:10 A Phaseless Gauss-Newton Inversion Algorithm for Imaging and Design
Chaitanya Naikendra and Piyun Mubaj (University of Manitoba, Canada)

A novel phaseless Gauss-Newton inversion algorithm is presented and extended with three forms of multiplicative regularization schemes: weighted L2 norm total, partial derivative and spatial prior regularization. It is shown that the presented algorithm, along with regularization, can invert experimental data and can be used to design dielectric objects that produce a desired magnitude pattern when illuminated by a known source.
9:30 Recent Advances and Current Trends in Compressive Processing as Applied to Inverse Scattering
Lorenzo Poli and Alessandro Cappellini (ELEDA Research Center, University of Trento, Italy); Marco Salucci and Nicola Anselmi (ELEDA Research Center, Italy); Giacomo Oliveri (University of Trento & ELEDA Research Center, Italy)
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 compact source framework. Representative numerical results are presented in a comparative fashion with those obtained with a conventional compressive sensing (CSE) approaches.

9:50 Comparison Between MR, CT, and Quantitative Microwave Holography Images of a Compressed Breast Phantom
Daniel Tayj, Natalia Nikolova and Michael Roseworthy (McMaster University, Canada)
Microwave imaging has been explored for use in medical diagnostics over the past 40 years. While advantages related to the use of non-ionising 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 scanning microwave prototype. The images are compared with those obtained with two conventional diagnostic methods, X-ray Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). The results highlight the differences between microwave imaging, CT, and MRI. They demonstrate that, although the QMH resolution is inferior to CT and MRI, it is more than sufficient to detect tumors of sub-centimeter size. The ability of QMH to generate 2 quantitative images per object, one for the permittivity and one for the conductivity, adds diagnostic value.

10:10 Coffee Break

10:40 Machine Learning for Microwave Imaging
Michelle Ambrosiano (Università di Napoli Parthenope, Italy); Stefano Franceschini (University of Naples Parthenope, Italy); Fabio Basile (Università degli Studi di Napoli Parthenope, Italy); Vito Pascazzo (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 as output an estimate of the unknown complex permittivity in a non-linear scheme. The proposed approach requires a pre-training step, which is also addressed as an automated 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 results 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 Warping Method for Probe Location in near/field Transformation
Mania Antonia Maisto and Raffaele Solimene (Università degli studi della Campania Luigi Vanvitelli, Italy); Rocco Pieri (Università della Campania Luigi Vanvitelli, Italy)
In this paper, a planar near field measurement techniques are addressed. In particular, a strategy to collect the near field data which allow the decrease of the number of measurements and to foresee the plane wave spectrum within the valid angular region recently introduced in [10] is illustrated.

12:00 Microwave Imaging Device for In-Line Food Inspection
Marco Rocci (Politecnico di Torino, Italy); Lorenzo Crocco (CNR - National Research Council of Italy, Italy); Francesca Vipiana (Politecnico di Torino, Italy)
In this paper, we introduce a novel microwave imaging method using spherical harmonics and sparse processing. As the source of the spherical harmonics, we use multiples of different orders. Based on theorectical considerations and as shown by numerical examples this approach is capable of retrieving concave shapes, which is particularly interesting when imaging complex shaped targets. In this paper, we limit ourselves to the utilization of the multipole parallel to the axis. We implement rigorous analytical expressions describing the first three multipole orders to improve the method's accuracy. As a test bed we analyze a centered and an offset star shaped object in the presence of noise. For such a meaningful case, satisfactory results have been obtained.

12:00 Microwave Imaging Profilitym for Plasma Diagnostics
Karunakaran Shudhi (ISI Institutions, India); Giuseppe Torrisi and David Mascali (INFN-LNS, Italy); Nagarajapn Prabagaran (ISI, India); Gino Sorbello and Loreto Di Donato (University of Catania, Italy)
Microwave imaging can provide effective means for non-invasive diagnostic of plasma diagnostics in plasma to visualize several features with respect to traditional techniques. Although microwave imaging entails solution of a full-wave inverse electromagnetic problem, it can be addressed in a less complex but not simpler way considering the one-dimensional inverse scattering problem for microwave imaging profiling (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

Chair: Mohammad Ojaroudi (University of Limoges/CNRS, France)

8:30 Vogelfelt: Multiple Knife-Edge Diffraction Imaging Using Deep Neural Network
Viet-Dung Nguyen (ENSTA Bretagne, France); Huy Phan (University of Kent, United Kingdom (Great Britain)); All Mansour and Arnaud Coatanhay (ENSTA Bretagne, France)
Multiple knife-edge diffraction estimation is a fundamental problem in wireless communication. One of the most well-known algorithms for predicting diffraction is Vogelfelt algorithm which has been shown to reach the state-of-the-art results in both simulation and measurement experiments. However, it can not be easily used in practice due to its high computational complexity. In this paper, we propose Vogelfelt, a data-driven diffraction estimator, by converting the Vogelfelt algorithm into a deep neural network-based system. To train Vogelfelt, we propose to minimise a regularised loss function using Levenberg Marquardt backpropagation in conjunction with a Bayesian regularisation. Our numerical experiments show that Vogelfelt provides fast solution in order of milliseconds while its performance is very close to that of the classical Vogelfelt algorithm.

8:50 Study on Radio Propagation Prediction by Machine Learning Using Urban Structure Maps
Tatsuya Naoa and Takahiko 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 complex radio propagation characteristics in an urban environment. In this paper, we present 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); Stéphane Billa (XUMI UMR 7215 Université de Limoges/CNRS, France); Mahdi Salimtorokam Roki (Bio-Electromagnetic Group, Microwave Technology Company (MWT), Tehran, Turkey)
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 test the proposed system in full-head based from 5.5-22GHz an appropriate matching medium is designed. In addition, a hierarchical preprocessing method is employed to calibrate the reflected signals. In the processing section, a cortical image-reconstructing algorithm based is used. Finally, a new method of combining the algorithms including discrete wavelet transform (DWT) and principle component analysis (PCA) for feature extraction and reduction, respectively. The reconstructed image 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
Takahiko Hayashi, Tatsuya Naoa and Satoshi Ito (KDDI Research, Inc., Japan)
Not only has the volume of mobile traffic been increasing exponentially, making various services available, such as in-cell and connected cars, has 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 in other words in radio propagation prediction it is able 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 with DNN using 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 (Vottswch Industrietechnik GmbH, Reisicrhen, Germany); Timo Lähivaara (University of Eastern Finland, Finland)

Selective heating 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 dielectric 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.

BC/2: History of Electromagnetism 2

T13 Bicentennial Session / Electromagnetics
Room: B11

Chairs: Ari Sihvola (Aalto University, Finland), Arthur D Yaghjian (Electromagnetics Research Consultant, USA)

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), the international union of radio science (URSI), and in particular its program to involve young researchers into the community, during the times of the the Cold War up to the breakup of Soviet Union.

8:50 EM Modeling of Stratified Media: From Radio Propagation over Ground to The Graphene Antennas
Juan R Mosig (École 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); Hai-Tsong 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
Elshd 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: 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.

IW06: Active Impedance Assessment and Beamforming Optimization for mm-Wave Antenna Arrays (Optenni Ltd)

T12 Scientific / Industrial Workshops
Room: B3

Jaakko Juntunen,Optenni Ltd

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: 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.

IW09: 5G antenna array design and integration simulation (ANSYS)

T12 Scientific / Industrial Workshops
Room 6

David Preistaux, ANSYS

Wednesday, 18 March 10:40 - 12:20

T11-P04: Experimental Methods and Campaigns

T11 Fundamental research and emerging technologies / Regular Session / Propagation
Room: B10

Chairs: Maria A Sergeeva (CONACYT, SCIEESMEX, LANCHE, UNAM, Mexico), Elizabeth Verdugo (PUC RIO, Brazil)

10:40 Possibility of Signal Reflection from the Northern Crest of Ela: Case Study
Maria A Sergeeva (CONACYT, SCIEESMEX, LANCHE, UNAM, Mexico); Alexey S Kaltshin (Arctic and Antarctic Research Institute, Russia); Olga Mal'tseva (Institute for Physics & Southern Federal University, Russia); Donat Iglavoshevskiy (Saint-Petersburg State University of Aerospace Instrumentation, Russia); Juan Americo Gonzalez-Esparrza (Universidad Nacional Autonoma de Mexico, Mexico); Pedro Corona-Romero (Instituto de Geofisica, Universidad Nacional Autonoma de Mexico, Mexico); Victor Jose Gatica-Acevedo (Instituto Politecnico Nacional, Mexico)
The case of the anomalous signal propagation in the low-latitude American sector was studied. The possibility of the signal reflection from the electron density gradient caused by the northern crest of the equatorial ionization anomaly at the background of geomagnetic activity increase was considered. In the absence of other probable causes, it seems that the short-time anomalous signal reflection from the density gradient is possible when the geomagnetic index Kp is more or equal to 5 during the evening hours.

11:00 Measured Activity in 860 MHz Channels
Jesper Ø Nielsen (Aalborg University, Denmark); Maria Fresia (Intel Deutschland, Germany); Gert Pedersen (Aalborg University, Denmark)

This work presents the measured activity in the European license free 863-870 MHz band via measurements in 7 widely different urban and suburban areas. The data is analyzed in 8 different sub-bands. The measured 1 ms sweeps are used to characterize the random activity, where the estimated complementary cumulative distribution functions (CCDF) is found to be highly dependent on both location and sub-band. In addition, the probability of observing an unused channel for varying lengths of time is estimated.

11:20 Signal Reception Measurements Using Mobile HD Radio and DRM Systems in Two Urban Regions in Brazil
Elizabeth Verdugo (PUC-Rio, Brazil); Luiz da SIlva Melo (CETUC-PUC-Rio & Imetno, Brazil); Marta Pudwedil Chaves de Almeida (Imetno, 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 Radios. Comparison of electrical field strengths with predictions from ITU recommendations are presented. Large- and small-scale fading probability distribution functions of the received signals were estimated for each measurement route.

11:40 Aircraft Measurements of the Marine Surface Layer Refractive Index During the TAPS Campaign
Andrew Kulesa (Airborne Research Australia, Australia); Jörg Hacker (Airborne Research Australia & Flinders University, Australia); Hedley J Hansen (Defence Science Technology, Australia); Marion Kermann (Airborne Research South Australia, Australia); Alex Vanderkugt ( DST, Australia); Jacques Claverie (CINEC It-Cyr & ITR, France)

This paper describes some of the airborne atmospheric measurements, within the atmospheric surface layer, undertaken during the TAPS field campaign. A hybrid (flux – Bulk) model for refractivity 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 refractivity.

12:00 Observations and Modelling of Propagation Loss in the Turbulent Sea Surface Environment
Hedley J Hansen (Defence Science Technology, Australia); Alex Vanderkugt ( DST, Australia); Andrew Kulesa (Airborne Research Australia, Australia); Jörg Hacker (Airborne Research Australia & Flinders University, Australia); Stephen Salamon (University of Adelaide & Telstra Corporation, Australia); Martin Vasse (MET Office, United Kingdom (Great Britain))

This 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 Atmosphere Ocean (TAPS) in the Coral Sea November–December 2013 have been modelled with reflectivity profiles derived from a bulk parameterization based on Monin-Obukhov similarity theory using near-surface data that was co-located 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 (PEM) appropriate to the sea surface environment at the time of the RF reception measurements, improves the predictive modelling of the path loss measurements.

T06-M10: UAV-Based Antenna Measurements (AMTA)  
T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Regular Session / Measurements
Room: B11
Chair: Giuseppe Vicino (Consiglio Nazionale delle Ricerche, Italy)

10:40 Versatile Low-Cost and Light-Weight RF Equipment for Field Measurements
Jonas Kromprobst (Technical University of Munich, Germany); Raimund A. M. Maenmeyer (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 (RFoF) connection. The main purpose of the hardware is near-field antenna measurements, but possible use-cases also include imaging and other inverse-source scenarios. The SDR hardware features "low-cost" and "light-weight" are important for the use on an unmanned aerial vehicle (UAV). Crashes should not financially ruin the UAV itself and the RFoF 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 transmit 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 Gese and Björn Neubauer (Technische Universität Braunschweig, Germany); Fabian T. Faul (Technical University of Munich, Germany); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany); Torsten Fritzel, Hans-Juergen Steiner and Rüdiger Strauß (Aerospace UX, Germany)

This contribution presents measurements with a self-built high frequency receiver architecture for nearfield measurements without synchronisation 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 transformation. One application for that is the navigation of an inspection navigation system. 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 unsynchronized phase accuracy of better than 8° at 2 GHz.

11:20 Comparison Between Measured and Simulated Antenna Patterns for a LOFAR LBA Array
Paola Di Ninni (National Research Council of Italy (CNR - IEIIT), Italy); Pietro Bolli (INAF - Osservatorio Astrofisico di Arcetri, Italy); Fabio Paonessa (National Research Council of Italy (CNR - IEST), Italy); Giuseppe Pupillo (IRA - INAF, Italy); Giuseppe Vicino (Consiglio Nazionale delle Ricerche, Italy); Stefano Jacob Wijnholds (ASTRON, The Netherlands)

A UAV-based system has been employed for a measurement campaign on a station of the radio telescope LOFAR to characterize the individual Low Band Antenna patterns. The experimental setup 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 Q-Band Test-Source for the Validation of the Large Scale Polarization Explorer
Fabio Paonessa (National Research Council of Italy (CNR - IEST), Italy); Giuseppe Vicino (Consiglio Nazionale delle Ricerche, Italy); Lorenzo Ciorba (Institute of Electronics, Computer and Telecommunication Engineering (IIEF-CNIR), Torino & Politecnico di Torino, Torino, Italy); Oscar A. Peveoli (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-CNIR, Italy); Mauro Lumia (CNR, Italy); Marco Bersanelli and Arielle Menella (University degli Studi di Milano, Italy)

The Unmanned Aerial Vehicles (UAVs) technology represented a significant innovation for antenna measurements in the last years. So far, UAVs have been 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 Q-band is planned to be used for the validation of the future Survey Terahertz Imager (STIRP) of the Large-Scale Polarization Explorer (LSPE), an Italian project. This contribution presents a proofed solution and a preliminary test performed.

12:00 Advanced Remote-Controlled Airborne Sensor Systems
Thorsten Schrader (Physikalisch-Technische Bundesanstalt, Germany); Jochen Bredmeyer (FCS Flight Calibration Services GmbH, Germany); Thomas Kleine-Ostmann and Marius Mihalachi (Physikalisch-Technische Bundesanstalt, Germany)

Based on commercially available optics, PTB has developed flight measurement platforms with RF front ends for various frequency bands. The remote-controlled measurement systems are designed for calibrated on-site measurements of the signals emitted by terrestrial navigation systems and radar. They are used to measure signal strengths quantitatively and to investigate the disturbance potential of wind turbines.

IW02: Analysis and Design of Advanced Antenna Systems using TICRA Tools (TICRA)  
T12 Scientific / Industrial Workshops
Room: B3
A Concept of Flexible Non-Metallic Dielectric Resonator Antenna for Conformal Applications

Using Superdirectivity to Enhance the Performance of Different Scattering Processes

Metamaterial-inspired Near-Field Resonant Parasitic Dipole Antennas on High Permittivity Dielectrics

Telemetry Antennas Withstanding Very High Accelerations and Centrifugal Forces

Mechanical and Environmental Aspects of Antennas for a Novel Maritime Search and Rescue System

3D Printed Ceramic Antennas for Space Applications

Optimal Frequency of Operation and Radiation Efficiency Limitations of Implantable Antennas

Fundamental limits on radiation performance of implantable antennas serve as the design quality gauge, facilitate the choice of the antenna type, and provide simple design rules to maximize the radiation performance. This study obtains the limits using two formulations: 1) theoretical spherical-wave expansion using elementary magnetic and electric dipoles and 2) realistic full-wave 2D-axisymmetric models of TM10 and TE10 mode capsule antennas. Using both formulations, the optimal radiation conditions are investigated, the effects of antenna dimensions and their implantation depth are quantified. The results also demonstrate that an electric antenna operating close to the optimal frequency could achieve higher efficiency than a magnetic one. The latter, however, is more efficient below the optimal frequency range.

This paper presents the mechanical and environmental aspects of a novel dual-band harmonic radar antenna for maritime search and rescue system. These aspects are considered in the mechanical design of the proposed antenna. The dual-band radar antenna operates in the frequency range from 2.90 GHz to 2.95 GHz (S-band) and from 5.80 GHz to 5.90 GHz (C-band). The antenna configuration is based on two slotted waveguide antennas sharing the same housing and provides dual polarisations. One waveguide array employs edge slots with horizontal polarisation, the other waveguide uses broadwall slots with vertical polarisation. The mechanical design of the antenna is presented providing a low profile and lightweight structure that is compatible with the marine environmental conditions. A radome made of glass fibre reinforced plastic is used to protect the antenna against environmental influences. The radome structure is flexible enough to be easily integrated with the antenna.

This paper is an application and an evolution of the new technology that has been already used for a GNSS L1 patch antenna. Based on a patented technology, the dielectric material is structured with a 3D lattice design to obtain the desired effective permittivity. Two different lattices have been studied in this paper which are applied to a miniature circularly polarized dielectric resonator antenna (DRA). Simulated results are given and discussed.

This paper demonstrates a promising antenna solution for operation in harsh environment: it consists of a metal-only antenna configuration. The latter is based on a C-shaped slot unit-cell exhibiting a phase variation of 360 degrees with insertion loss below 1 dB at 29 GHz. Several antenna prototypes have been fabricated and their performance has been characterized in anechoic chamber. Here, two different antenna prototypes are presented demonstrating, respectively, beam pointing at 30 degrees and 50 degrees with good agreement between simulated and measured results. For beam pointing at boresight, the aperture efficiency is greater than 50% and the half power bandwidth is around 7.5%.

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Cellular mobile communication systems are subject to power losses, especially in the downlink. The future 5G outlook includes an enhanced system performance to increase coverage by reducing power losses. This paper presents a novel dual-band harmonic radar antenna for maritime search and rescue system. The dual-band radar antenna operates in the frequency range from 2.90 GHz to 2.95 GHz (S-band) and from 5.80 GHz to 5.90 GHz (C-band). The antenna configuration is based on two slotted waveguide antennas sharing the same housing and provides dual polarisations. One waveguide array employs edge slots with horizontal polarisation, the other waveguide uses broadwall slots with vertical polarisation. The mechanical design of the antenna is presented providing a low profile and lightweight structure that is compatible with the marine environmental conditions. A radome made of glass fibre reinforced plastic is used to protect the antenna against environmental influences. The radome structure is flexible enough to be easily integrated with the antenna.

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Convened Poster 2-CS36: Innovative Lens Antennas for Future Communication Systems

Convened Poster 2-CS31: Metasurfaces for Mobile (5G and Beyond) and Satellite Communication Systems
**CP2.21 An Ultra-thin Wide-Angle Scanned Planar Array Antenna for Satellite Communication**

**Yuejia Liu** (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 Munoz** (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 steerability of nearly 60 degree without utilizing any costly phase shifter. This is achieved by rotating the relative position of the upper radiator 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.

**CP2.22 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.

**CP2.23 Metasurface-Based Circularly-Polarized Multibeam Reflect-/Transmit-Arrays**

**Zhi Hao Jiang**, **Fan Wu** and **Xiaowei Zhu** (University of Science and Technology of China, China); **Qiang Ren** (Beihang University, China); **Pingguan 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 Babinet and/or dynamic phase, highly-directive circularly-polarized multibeam can be generated with a single feed or a cluster of feeds. Two proof-of-concept arrays are showcased, which are all validated by experimental measurements.

**CP2.24 Recent Advances on Modulated Metasurfaces Antennas for SatCom**

**Marco Faenzi** (Université de Rennes 1, France); **Gabriele Minati** (Wave Up S.r.l., Italy); **David González-Ojeda** (Centre National de la Recherche Scientifique - CNRS, France); **Francesco Caminita** (Wave-Up SRL, Italy); **Enrica Martin** (University of Siena, Italy); **Cristian Della Giovampaola** (Wave Up srl, 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 MTS antennas 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.

**CP2.25 Electro-Mechanically Tunable Meta-Surfaces for Beam-Steered Antennas from mm-Wave to THz**

**Muhammad S Rabban**, **James Churm** and **Alexandros Feresidis** (University of Birmingham, United Kingdom (Great Britain))

Electro-mechanically tunable meta-surfaces are presented for high gain, beam steerable Leaky-Wave Antennas (LWAs) 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 an independent antenna. The phase shift is achieved by varying the mechanical position separation between the HIS/PRS periodic antenna 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 antenna at the selected frequency bands may find applications in broadband mobile communications in 5G and beyond. The presented antenna yields a wide $\pm$11.5$\pm$1 bandwidth (BW), high gain and wide beam scanning range as required for broadband mobile applications.

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**Convened Poster 2-CS50: Novel Wave Phenomena in Metamaterials and Metasurfaces Applied to Antennas and Propagation**

**Chair:** Davide Ramaccia (RomaTre University, Italy)

**CP2.28 Analytical Study of Dielectric-wall 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-wall conical horn antenna is developed in order to characterize its radiation characteristics. An approximate model analysis is formulated in a semi infinite conical geometry in order to calculate the modes supported by the antenna. It is proven that the designed hybrid HET11 mode is excited and allows the hollow dielectric cone to perform as an antenna with high directivity, low sidelobe levels, good polarization purity and very stable phase center in a wide frequency range. This study will allow us to define the design criteria for conical dielectric-wall horn antennas which can effectively replace metallic corrugated horns as reflector feeds in the millimeter wave band.

**CP2.29 Ray-tracing in Dielectric Inhomogeneous Metamaterials**

**Francesca Maggiorelli** and **Matteo Albani** (University of Siena, Italy); **Stefano Maci** (University of Siena, Italy)

We present a very fast and efficient analysis of inhomogeneous dielectric lenses 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 transport equations, respectively. Once the field distribution at the lens-antenna aperture has been achieved, the radiation pattern, derived by aperture type radiation integral. The developed algorithm has been validated by full-wave analysis, after predetermining the feed source, the lens dimensions and the reflective index profile. Thus, the source incident field is obtained by lens is supposed to be known by simulation or measurements. Results achieved by the homogeneous algorithm and the full-wave analysis have shown to be in good agreement.

**CP2.30 Dielectric Rectangular Lens for Antenna Array Scansilless Mitigation**

**Giorgio Gottardi** and **Alessandro Polo** (ELEIDA Research Center, University of Trento, Italy); **Giacomo Oliveri** (University of Trento & ELEIDA 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 suitably weighted array structures to minimize the scan-loss of resulting radiation systems 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.

**CP2.31 Study of Printed Scattering Reflectors Based on Discretised Metamaterials**

**Michal Cerveny**, **Kenneth Lee Ford** and **Alain Tennant** (University of Sheffield, United Kingdom (Great Britain))

In this paper, we present a new approach for the design of 2D and 3D scattering structures in which the permittivity is determined from the scattering of a single source. This approach is based on the construction of a set of scattering matrices for different source positions, which are then interpolated to obtain the permittivity distribution. The method is demonstrated on several examples, including a simple square scatterer and a more complex geometrical shape.

**CP2.32 Latest Developments on Non-linear and Time-varying Metasurfaces and Topological Antennas**

**David Ramacchia** (RomaTre University, Italy); **Mirko Barbuto** and **Alessio Monti** (Niccolò Cusano University, Italy); **Stefano Vellucci** (Roma Tre University, Italy); **Angelika Viola Marini** (Università degli Studi Roma Tre, Italy); **Alessandro Toscano** (University Roma Tre (IT), Italy); **Filiberto Blotti** (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 multiband cloaks for antennas, allowing them to become invisible/visible to an electromagnetic wave depending on the power level or waveform of the incident wave, respectively; the second one allows to realize 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 antennas with reconfigurable radiation characteristics exploiting the position of the phase singularities of vortex fields.

T10 EM modelling and simulation tools / Convened Session / Antennas

Room: A2 (Poster Area)

Chairs: Nicola Anselmi (University of Trento, Italy), Marco Donald Migliore (University of Cassino, Italy)

CP2.34 Multiband Patch Antenna Design for RF Energy Harvesting Applications Using Coyote Optimization Algorithm
Achilles D. Bourouisaris, Dimitrios Georgoulas, Maria Papadopoulos and Apostolia Karampata (Aristotle University of Thessaloniki, Greece); Juliano Pierzean (Universidade Federal do Paraná - UFPR, Brazil); Leandro dos Santos Coelho (Pontifical Catholic University of Paraná & Federal University of Paraná, Brazil); Viviana Mariani (Pontificia Universidade Católica do Paraná & Universidade Federal do Paraná, Brazil); Katherine Siakavara and Sotiris Goudos (Aristotle University of Thessaloniki, Greece)

Radio frequency energy harvesting is a relatively recent and quite interesting technique for delivering adequate amounts of energy in low power consumption wireless networks. This technique faces several challenges; most of them are related to the antenna design of the harvesting system. In this paper, we address to these challenges by designing a multiband microstrip patch antenna with three slots. The proposed antenna operates in the LuftdN (Long Range Wide Area Network) and the cellular (ISM-1800 and UMTS) communication frequency bands. Numerical results demonstrate a satisfactory performance of the proposed patch antenna as an energy harvester in radio frequency environments.

CP2.35 Synthesis of Sparse Linear Arrays Including Directivity via a Hybrid L1 Minimization Algorithm
Feng Yang (University of Electronic Science and Technology of China & University of Electronic Science and Technology of China (UESTC), China); Shiwen Yang (University of Electronic Science and Technology of China (UESTC), China); Yikai Chen (University of Electronic Science and Technology of China, China); Paolo Rocca (University of Trento, Italy)

A hybrid L1 minimization algorithm with enhanced sparsity is proposed for the synthesis of sparse linear arrays. Moreover, the desired directivity as a constant condition is fixed in the hybrid algorithm in order to obtain a better pattern. In particular, the proposed hybrid algorithm can be divided into two steps. The first step is to iteratively solve a smooth-weighted L1 minimization problem. The obtained weight vector is then considered as the initial weight vector in the second step, where a weighted L1 minimization problem is solved. In comparison to other methods, simulation results show that the proposed method has an improved synthesis efficiency for sparse arrays.

CP2.36 Efficient and Effective Synthesis of Large Arrays for 5G and Beyond
Daniele Pinchera (University of Cassino, Italy); Fulvio Schettino (Università degli Studi di Cassino, Italy); Mario Lucido (University of Cassino and Southern Lazio, Italy); Marco Donald Migliore (University of Cassino, Italy)

In this contribution we will discuss the synthesis of very large arrays, that are going to become a key technology of 5G and beyond communication systems. By means of a slightly improved version of IDOA (Infinitesimal Defating Exploration Algorithm), we demonstrate the ability to synthesize very sparse arrays, with a strong reduction of the number of control points with respect to a classical equipped array radiating a beam with the same specifications.

CP2.37 Shannon and Kolmogorov in Space Communication Channels
Marco Donald Migliore (University of Cassino, Italy)

The aim of this paper is to discuss an asymmetry between the space-channel and the time-channel in wireless space-time communication systems and its consequence when we use Shannon and Kolmogorov to evaluate the amount of information transmissible along a space channel. It is also shown that the use of unbounded “Maximal Antenna” radiation systems restore, at least theoretically, the symmetry between space and time.

CP2.38 The Sparsity and Incoherence in Compressive Sensing as Applied to Field Reconstruction
Baozhi Li (Nanjing Normal University, China); Marco Salucci (ELEDA Research Center, Italy); Paolo Rocca (University of Trento, Italy); James Ben and Wanchun Tang (Nanjing Normal University, China)

Compressive Sensing (CS) opens up new perspectives for field reconstruction. Electromagnetic far field can be reconstructed by CS from a reduced number of samples when no prior knowledge of the radiating source is available with large probability as long as two constraints are satisfied, that is sparsity and incoherence. A set of representative numerical examples considering different sampling strategy and different recovery algorithms is reported and discussed to demonstrate that when CS condition holds true, a perfect reconstruction with large probability is guaranteed.

CP2.39 Tools for the Efficient Implementation of the DBM Algorithm in Microwave Imaging Experiments
Pan Li (King's College London, United Kingdom (Great Britain)); Juan Córcoles (Universidad Autónoma de Madrid, Spain); Panagiotis Kosmas (King's College London, United Kingdom (Great Britain))

We present two efficient tools to improve both the experimental data and the reconstruction results in microwave imaging. The time gating technique can remove part of the unexpected reflections of the cables and tags, thus improving the quality of the received signals obtained from the experiment system. We also apply the fast L1 shrinkage thresholding algorithm (FISTA) to the distorted Born iterative method (DBIM) as a linear inverse solver at each iteration of the DBIM, which shows better capabilities than the conventional conjugate gradient least squares (CGLS) method with experimental data. Results confirm that the two tools used in the DBIM can be efficient and accurate when employed in the microwave imaging system.

CP2.40 Direction of Clutter Estimation by Total-Variation Compressive Sensing
Mohammad Hannan and Alessandro Polo (ELEDA Research Center, University of Trento, Italy); Paolo Rocca (University of Trento, Italy); Antonio Clemente (CEA-LETI Minatec, France);

The problem of estimating the direction of clutter (DoC) is reformulated as a problem of estimating the directions of many closely spaced targets. Therefore, the sparseness is exploited in the gradient domain and exploited as sparse in the total-variation sense. Therefore, the sparseness is exploited in the gradient domain and exploited as sparse in the total-variation sense. Therefore, the sparseness is exploited in the gradient domain and exploited as sparse in the total-variation sense.

P2.01 Three-Element Directivity and Gain Optimization
Alexandre Debard (University of Grenoble Alpes & CEA-LETI, France); Antonio Clemente (CEA-LETI Minatex, France); Christophe Delaveaud (CEA-LETI, France)

This paper presents the results of the optimization of two three-element end-fire linear arrays based on straight- and bent-electrical dipoles, respectively. To achieve a compact architecture, the inter-element distance is fixed to 0.12λ, while λ is the wavelength calculated at the operation frequency (850 MHz). The antenna complex excitation coefficients have been optimized to achieve maximum directivity. The synthesis procedure is based on the optimization of the directivity and gain of the antenna array factor and the array factor 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 9.35 dB (gain 6.76 dB) in the case of the straight- and bent-electrical-dipole-based arrays, respectively. Instead, the maximum gain is equal to 6.1 (directivity 8.44 dB) and 7.65 dB (directivity 9.19 dB), respectively.

P2.02 A Miniaturized Circularly Polarized Antenna Using a Meandered Folded-Shorted Patch Array for CubeSats
Yuepei Li (Hestor Watt University, United Kingdom (Great Britain)); Symon K. Podilchak (Hestor Watt University, United Kingdom (Great Britain)); Dimitris E. Anagnostou (Hestor 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 consisting of a network of meandered-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 by 9 cm. Good CP performances are observed for the developed UHF-band antenna and with an antenna size of 0.135λ x 0.135λ considering the 450 MHz design frequency.

P2.03 A Broadband Transition from Microstrip to Groove Gap Waveguide for Ka-Band Applications
Davood Zarifi and Atefe Ahadrfan (University of Kashan, Iran)

This paper describes a wideband and low-loss microstrip to groove gap waveguide transition for millimeter wave applications. The microstrip mode 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 46 GHz.

P2.04 Closed Form Characterization of Mutual Coupling in Uniform Linear Arrays
Achilles D. Boursianis (Heriot Watt University, United Kingdom (Great Britain)); Panagiotis Kosmas (King's College London, United Kingdom (Great Britain)); Mohammad Hannan (Aristotle University of Thessaloniki, Greece);

In this contribution we will discuss the synthesis of very large arrays, that are going to become a key technology of 5G and beyond communication systems. By means of a slightly improved version of IDOA (Infinitesimal Defating Exploration Algorithm), we demonstrate the ability to synthesize very sparse arrays, with a strong reduction of the number of control points with respect to a classical equipped array radiating a beam with the same specifications.

P2.05 Broadband Compressive Sensing Algorithm, we demonstrate the ability to synthesize very sparse arrays, with a strong reduction of the number of control points with respect to a classical equipped array radiating a beam with the same specifications.
This paper proposes a pragmatic methodology to characterize mutual coupling in uniform linear array (ULA). The classical coupling method is used in the literature of multiple input multiple output (MIMO) antenna arrays 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 ULAs with different antenna types and number of elements. We provide closed form expressions for the mutual coupling characterization of the studied ULA's, which are then used to evaluate the spectral efficiency performance of a MIMO cellular system. Our results show that the proposed method can provide more accurate characterization of the studied mutually coupled ULAs and hence better estimate of the spectral efficiency in comparison to the classical method.

P2.056 Approximating the Directivities of Antenna Elements and Arrays

Maor Mordehai (HHI-Holon Institute of Technology, Israel); Maor Kadosh (HIT, Israel); Ely Levine (AEFEK, 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 array. Two kinds of arrays are treated: a dipole array and an antenna array. It is shown that the proposed method, based on the definition of the directivity, is the simple formula of the sum of (1/D) of the directivity of the element and the directivity of the array factor (AF). Moreover, we show that the deviation of the directly calculated by the proposed method from the simulated directivity is less than 0.5 dB.

P2.06 Double-Layer Machine Learning Assisted Optimization for Antenna Sensitivity Analysis

Qi Wu, Haoming 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 superiority in both robustness and accuracy.


Mai Khaleghi (University of New Haven, USA)

We solve the problem of antennas radiating into generic nonlocal metamaterials by using a momentum-space formalism to rigorously derive the general radiation formula. The energy per metre 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 anharmonic part of the dyad will contribute to the radiation field. We avoid any spectral integration or using the Pytong 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.

P2.08 A New Feed Network for the Communication Signal and Excitation of Surface-Wave-Driven Plasma Antennas

Fatemeh Sadeghikia, Ali K. Horestani, Mohammad reza Dorbin and Mahmoud Talefi Noghani (Aerospace Research Institute, Iran); Hajar Jafari (University Teknologi MARA, Malaysia)

The 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 plasma column. As a result, the plasma conductivity at the communication signal point is maximized. On that basis, 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.

P2.09 Beamwidth Control of a Helical Antenna Using Truncated Conical Plasma Reflectors

Mahsa Valipour, Fatemeh Sadeghikia and Ali K. Horestani (Aerospace Research Institute, Iran); Mohamed Himdi (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 structure 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 antenna up to around 17%.

**Antennas**

**Room: Exhibition Hall**

**P2.01 A Novel Wearable RF Head Coil for High Resolution 7T Magnetic Resonance Imaging**

Pouya Goodarzi and Fatemeh Geran Gharakhili (Shahid Rajaee Teacher Training University, Iran); Hamidreza Salighad and Mohammad Reza Nazem Zadeh (Tebran University of Medical Sciences, Iran)

In this work, a new structure of 7T magnetic resonance imaging RF coil has been designed and presented. The flexibility of this coil distinguishes it from others traditional coils. The mentioned coil consists of 8 channels, each made of two antenna elements. The results show that using compressed elements in designing this coil provides a desired return 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, resources, 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 far input power, and the B_1^- homogeneity distribution are 1.1%, 0.0769 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.

**P2.02 A Method of Reducing Mutual Coupling for a Finite Array**

Lei Chen and Tianling 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 widespread and beam steering is presented in this paper. By adding an extra decoupling network, the mutual coupling can be efficiently controlled for the finite array. To verify the validity of the proposed method, a 1 x 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 decreased from -6.98 dB to -8.24 dB, and the mutual coupling between adjacent elements is reduced to below -16.73 dB covering 20-33 GHz with the beam steering angle range of ±70º.

**P2.03 Antenna Adaptation Circuits for High Data Rate Magnetic Inductive Underwater Communications**

Thierry Desbonnes de Paillette, Alain Gargou (La Roche University, France); Alain Gargou (La Roche University, France)

Environmental and waterfront monitoring is rapidly experiencing an increase in demand. The need of submarine images transmission in real time require higher data rate. In this paper we introduce an innovative prototype of reliable magnetic-induction based wireless submarine communication system adapted to a medium-range underwater telemetry application matching those requirements.

**P2.04 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 nonlinear compressive buckling to tune their operating frequency through 0 to 30% uniaxial or biaxial strains of their elastic 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 the conventional metallic materials, we have demonstrated two designs of 3D stretchable antennas: "Poppy convoluted loop antenna" and "Poppy 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.

**P2.05 Statistical Comparison of Coupling Effects Between Thin and Thick Dipoles in Random Sets**

Imad Adjali (University Paris-Est, ESYCOM, UPEM, France); Benoit Pouscot (University Paris-Est, France); Shermila Mostashrdi (Université Paris-Est Mame-la Ville, France); Jean-Marc Lahaure (Université Paris-Est Mame-la Ville, France)

A statistical analysis of the matching properties of a dipole surrounded by thin and thick randomly distributed dipoles is presented. The input impedance and input reflection coefficient of the dipole antenna is obtained by using the IEMF method and validated by NEC and measurements. The cumulative distributed functions are presented for different dipole densities and the mismatch of a surrounded thin and thick dipoles studied for different surrounding loads.

**P2.06 Wireless Link for Micro-scale Biomedical Implants Using Magnetoelectric Antennas**

Fazel Rangriz (NTNU, Norway); Ali Khalighi (Norwegian University of Science and Technology (NTNU) & Dølo University Hospital, Norway); Ilango Balasingham (NTNU, Norway)

This paper proposes 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 structure 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 antenna up to around 17%.
Thus, the field from the feeding is divided in different wavefronts that are composed at the antenna aperture to get an omnidirectional radiation pattern. Antennas with periodic parallel strips are printed after antenna aperture to improve the impedance matching with the air. The proposed antenna consists of two coupled rectangular waveguide modes feeding a SIW aperture antenna. The SIW acts as partially detached walls in order to form 4 adjacent subapertures at the end of the aperture antenna. The feeding system is designed to support the fundamental and first higher order modes of the SIW, which are characterized by eigenvalue solutions. 

This paper presents the compact design of a substrate-integrated waveguide (SIW) antenna based on H-plane aperture configuration. The proposed antenna system consists of a SIW aperture antenna and a SIW feeding system. The SIW antenna is excited by a SIW feeding system, which consists of a pair of striplines and a pair of square slots. The SIW antenna is designed to operate in the frequency range of 60 GHz to 80 GHz. The design is validated through full-wave electromagnetic simulations. The results show that the proposed antenna has a high gain of 19.8 dBi, a 3-dB beamwidth of 50°, and a realized gain of 15.6 dBi. The antenna is fabricated and measured, and the measured results are in good agreement with the simulated results. The antenna exhibits a good performance in terms of gain, bandwidth, and radiation pattern. 

Cleofás Segura-Gómez
Dayan Pérez

Cleofás Segura-Gómez (University of Navarra, Spain); Dayan Pérez (Aalto University, Finland)

In this work, we present the simulation and measurement results of patch antenna segments for fully digital transceiver. Different types of transmission lines are designed and fabricated. Results for both patch antennas and transmission lines are presented. The measured results show high agreement with simulated results. 

Each station of the SKA1-Low radio telescope is composed by 256 dual-polarized log-periodic antennas deployed over a 400 by 400 meter area, with an infinite ground plane, which drastically reduces the computational time. This contribution shows that a finite ground plane can bring about significant differences in some-embodied 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% due to the ohmic loss considered in the material.

Poster2-A04: Mm-, Sub-mm-wave, and Nano-optical Antennas

Antennas
Room: Exhibition Hall

Poster2-02 Wideband 8-Antenna Array with High Isolation for Sub-6 GHz MIMO Applications
Xiao-Ting Yuan and Xuan-Ji Wu (Shenzhen University, China); Zhe Chen (City University of Hong Kong, Hong Kong); Chong Zhi Han (Shenzhen University, China); Xiao Zhang and Tao Yuan (Shenzhen University, China)

In this paper, an 8-element patch antenna array is presented for sub-6 GHz MIMO applications. The array is designed to have high isolation and low mutual coupling between elements. The proposed antenna array consists of 8 identical patches, arranged in a 2x4 configuration. The antenna is designed to operate in the frequency range of 4.5 GHz to 6.5 GHz. The antenna array is fabricated and measured, and the measured results show high agreement with simulated results. The antenna array exhibits a good performance in terms of isolation, coupling, and radiation pattern. 

Poster2-03 UpLink Design of Millimeter Wave Moving Network System
Dae-Soon Cho (Korea, South Korea)

In this paper, we present the simulation and measurement results of a millimeter wave moving network system. The system is designed to operate in the frequency range of 60 GHz to 110 GHz. The proposed antenna array consists of 16 identical patches, arranged in a 4x4 configuration. The antenna is designed to operate in the frequency range of 60 GHz to 110 GHz. The antenna array is fabricated and measured, and the measured results show high agreement with simulated results. The antenna array exhibits a good performance in terms of isolation, coupling, and radiation pattern. 

Poster2-04 Characterizing 60 GHz Patch Antenna Segments for Fully Digital Transceiver
Jaakko Haarlo (Aalto University School of Electrical Engineering, Finland); Vassili Semkin (YYT Technical Research Centre of Finland, Finland); Ken Zhang and Aditya Dhananjay (NYU, USA); Marco Messavilla (NYU Tandon School of Engineering, USA); Juha Ala-Laurinaho (Aalto University, Finland); Ville Viikari (Aalto University & School of Electrical Engineering, Finland)

In this work, we present the simulation and measurement results of patch antenna segments for 60 GHz fully digital transceiver. The antenna is designed to operate in the frequency range of 60 GHz to 65 GHz. The proposed antenna array consists of 16 identical patches, arranged in a 4x4 configuration. The antenna is designed to operate in the frequency range of 60 GHz to 65 GHz. The antenna array is fabricated and measured, and the measured results show high agreement with simulated results. The antenna array exhibits a good performance in terms of isolation, coupling, and radiation pattern. 

Poster2-05 High-gain Resonant Continuous Transverse Stub Array Using Ridge Gap-Waveguide Technology
Javier Benavides/Vazquez, Jose-Luis Vazquez-Roy and Eva Rajo-Iglesias (University Carlos III of Madrid, Spain)

This work presents an 8 x 8 continuous transverse stub (CTS) array operating at 60 GHz with a high gain of 26.9 dBi. The antenna is designed to operate in the frequency range of 58 GHz to 65 GHz. The proposed antenna array consists of 16 identical patches, arranged in a 4x4 configuration. The antenna is designed to operate in the frequency range of 58 GHz to 65 GHz. The antenna array is fabricated and measured, and the measured results show high agreement with simulated results. The antenna array exhibits a good performance in terms of gain, isolation, and radiation pattern. 

Poster2-06 A Gap Waveguide Fed Circular Polarization Antennas in the Millimeter Wave Range
Dayan Pérez (Public University of Navarra (UPNA) & Institute of Smart Cities (ISC), Spain); Alicia E. Torres-Garcia (Public University of Navarra, Spain); Wiggo Ederna (Universidad Pública de Navarra & Institute of Smart Cities, Universidad Pública de Navarra, Spain); Miguel Beruete (Universidad Pública de Navarra, Spain)

In this paper, a novel method to generate circular polarization using a gap waveguide (GW) technology is described. The antenna is fed from the bottom of a WR-15 waveguide (V-band), which couples the wave to the GW system, working in the millimeter-wave band (60 GHz). The antenna is designed to have a high-gain and low-profile design, which is suitable for small-scale and portable applications. The proposed antenna is fabricated and measured, and the measured results show high agreement with simulated results. The antenna exhibits a good performance in terms of gain, isolation, and radiation pattern. 

Poster2-07 Design of Compact H-plane SIW Antenna at Ka Band
Clafenys Segura-Gómez and 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 compact design of a substrate-integrated waveguide (SIW) antenna based on H-plane aperture structure. The antenna is composed of a coiled feeding and an aperture. In this aperture, a waveguide is fabricated to provide a continuous feeding of the antenna. The SIW antenna is designed to operate in the frequency range of 30 GHz to 40 GHz. The antenna is fabricated and measured, and the measured results show high agreement with simulated results. The antenna exhibits a good performance in terms of gain, isolation, and radiation pattern. 

These are 10 randomly selected examples out of the entire text.
used for AR/VR services that require high data rate and ultra-low latency. Qian Zhu

This paper introduces concept, simulation and measurement results for a broadband dual-polarized stacked microstrip antenna designed for high data rate and low profile. The antenna is composed of a dual-polarized microstrip ridge-gap waveguide and a microstrip patch. The antenna is designed for operation in the 30-300 GHz band. The simulated and measured results show good agreement. The antenna has a gain of more than 14 dBi and a directivity of more than 40 degrees. The antenna is suitable for high-speed wireless communication systems.

A single-layer corporate-fed substrate integrated waveguide slot array is newly proposed. Since every radiating slot is excited by a corporate-fed waveguide, the proposed array antenna achieves a simple structure, low profile and high gain. The array performance has been verified. A 16×16-element slot array is designed by HFSS and is fabricated. The measured results show that the array achieves good radiation characteristics over the frequency ranging from 57 to 66 GHz.

A series-fed high-gain gap waveguide planar array antenna is presented in this paper. The element is a corporate-fed long slot antenna. Since every radiating slot is excited by the quasi-TEM wave and series-fed concept, the proposed array antenna achieves a simple structure, low profile and high gain. The measured results show that the array achieves good radiation characteristics over the frequency ranging from 57 to 66 GHz.

Trapped Microstrip-Ridge Gap Waveguide for Standalone Millimeter Wave Structures

This paper presents a novel design of trapped microstrip-ridge gap waveguide by using partially filled air gaps in a conventional microstrip-ridge gap waveguide. The proposed method offers an alternative solution for obviating frustrating assembly processes for standalone high-frequency circuits employing the low temperature co-fired ceramics (LTCC) technology which supports buried cavities. The proposed concept is introduced, followed by designing a power divider. The proposed concept is verified by using a Feedi ng structure which is used to feed a four element array antenna. The bandwidth of the proposed array is 13 GHz from 64-76 GHz and provides the realized gain of over 10 dB that is 95% of the total efficiency of about 80% throughout the operational band. The antenna is an appropriate candidate for upper bands of WiGig (60-72 Ghz) and FCC approved 70 GHz band (71-76 GHz) applications.

A Multifeed Connected Leaky Slot Antenna for In-Antenna Power Combining in 0.13um SiGe BiCMOS Technology

Jiangcheng Chen and Shiha He (University of Ulm, Germany); Markus Berg (University of Ulm and Excellent Ltd., Germany); Aapo Pirkola (University of Ulm, Finland)

In this paper, a dikearrly driven wideband multi-feed on chip antenna for mm-Wave and millimeter wave applications is presented. The in-antenna power combining concept is based on combining parallel amplifiers in the multi-port radiator where each port corresponds to a differential power amplifier (PA) stage. Specifically, the differential PA has a combined output power of 12 db and its output is directly connected with the balun. Consequently, the proposed multi-feed antenna has four differential microstrip low loss lines connected with four Marchand baluns driven by four parallel differential PA stages respectively. Also, to compensate for the loss, pre-amplifier PA stage is necessary. An extended hemispherical silicon lens is used to suppress the substrate modes. Simulations results show that the antenna has over 50% fractional bandwidth and calculated DCRP is 16dBm.

A Millimeter-Wave Wide Beam Steering 5G MIMO Antenna Array in Mobile Terminals

Mohammad Mehdi Samadi Taheri and Abdolali Abdipour (Amirkabir University of Technology, Iran); Shuai Zhang and Gert Pedersen (Aalborg University, Denmark)

In this paper, multiple-input multiple-output (MIMO) millimeter-wave wide beam scan 5G antenna array for 28 GHz applications in the mobile terminals is presented. The antenna array composed of eight element tapered dipole antennas. The proposed antenna array can scan the beam in a wide coverage region of 70 degrees in wide-operating bandwidth with scan loss better than 3 db. The antenna coverage efficiency is better than 94 %, 79 % and 52 % for minimum realized gain of 5, 6 and 8 dB respectively. The antenna has a good impedance matching (S11 < -10 dB) and mutual coupling better than -20 db in wide operating frequency bands from 25-30 GHz.

A Practical Low-Loss Substrate-Integrated Feed for mm-Wave PCB Antenna Designs

James R Henderson and Marcus C Walden (Pielect, United Kingdom (Great Britain))

This paper discusses a novel SiW feed network which demonstrates a substantial reduction in the insertion loss of SiW at V-band (50-75 GHz). More than 30 dB improvement was obtained in the loss-per-unit-length compared with that for same-width SiW on a thin substrate. This design technique targets multi-layer PCBs that carry both mm-wave electronic devices and planar antennas and is particularly beneficial for designs that feature electrostatically large, high gain-mm-wave antennas, including those with a corporate-feed network synthesized in SiW.

A V-Band Low-Sidelobe Cavity-Backed Slot Array Based on Gap Waveguide

Davood Zarifi (University of Kashan, Iran); Ali Farahbaksh (Graduate University of Advanced Technology, Iran); Ashraf Uz Zaman (Chalmers University of Technology, Sweden)

A cavity-backed slot antenna array element is designed to operate in V-band with low sidelobe level (SLL). The element is fed by a groove gap waveguide (GGW) cavity in the bottom layer. Simulated results indicate that the array element can achieve a 7.4% bandwidth (97.7-94.3 GHz) with a gain of more than 16.5 dBi. Besides, the low SLL performance has been verified and the simulated first SLLs are below -20 dB across the desired working band.

A Polarization-Recognizable Patch Antenna-on-Package for Millimeter-Wave Operations with DC Bias Circuit Design

Hsinju Chen and Shih-Yuan Chen (National Taiwan University, Taiwan)

The proposed polarization-recognizable antenna design is implemented into a waveguide IC packaging. For verification, we used Rogers RO4003C boards which closely resembles the material of PCB with packaging. Our prototype switches the switchable PIN diode with copper strip and is measured using a network analyzer. With DC block and RF choke design, the measured results show that the design achieves 3-dB axial ratio with sub-6-dB reflection coefficient at 30 GHz.

A Magneto-Electric Dipole Antenna for S-5 Applications

Giuseppe Scalise and Luigi Boccia (University of Calabria, Italy); G. Amendola (Universita della Calabria, Italy); Mohadjir Rousta and Alireza Shamsafar (Amplion Netherlands BV, The Netherlands)

Magneto Electric (ME) dipoles have been widely studied over the last few years. They are becoming increasingly popular as components for high gain mm-wave antennas. The proposed method is verified by using a PIN diode. The simulated and measured results show that the ME dipole can achieve a 40% bandwidth (4.5-6.5 GHz) with a gain of more than 7 dB. Besides, the low SLL performance has been verified and the simulated first SLLs are below -20 dB across the desired working band.

A High-gain and Low-profile Dielectric Cuboid Antenna at λ-band

Yuto Suzuki and Kazuyuki Yamada (Ritsu, Japan); Oleg Vladilenovich Minin (National Research Tomsk State University, Russia); Atsushi Kanno (National Institute of Information and Communications Technology, Japan); Norihiko Sekine (National Institute for Information and Communications Technology, Japan); Junichi Nakajima (Softbank Japan); Igor Vladilenovich Minin (Siberian Academy of Geodesy, Russia); Shintaro Hisatake (Gifu University, Japan)

We demonstrate a high-gain and low-profile dielectric cuboid antenna at λ-band. The antenna is composed of a co-planar waveguide (CPW) slot dipole. The proposed design is verified by using a PIN diode. The simulated and measured results show that the antenna achieves a 10-dB gain and high efficiency at λ-band.

A Series-fed High-Gain Gap Waveguide Planar Array Antenna Fed by Quasi-TEM Wave

Tianling Zhang and Lei Chen (Xidian University, China); Ashraf Uz Zaman and Jian Yang (Chalmers University of Technology, Sweden)

A series-fed high-gain gap waveguide planar array antenna is presented in this paper. The element is a corporate-fed dipole slot which is excited by the quasi-TEM wave in the wideband prototype gap waveguide. The developed DCA is made of polyethyleneethylene terephthalate (PET) and can be connected to a standard waveguide (WG3-4). The structure is very simple, and the size is in mesoscopic scale. It is expected that this structure can be used in many applications, such as high-speed communication systems. The measured results show that the antenna achieves a good performance of high gain and high efficiency at λ-band.
A dipole-fed photomixer based 7Th dielectric resonator antenna (DRA) has been truncated from an electrically Gallium Arsenide (GaAs) substrate. The photomixer is supported by a low temperature GaAs substrate with two dimensional photonic crystal (2D-PhC) and optical superstrate that maximize the optical power absorption. As a result, the optical-to-THz power conversion has been improved by a factor of 25. Additionally, a 7th dielectric superstrate has been employed above the DRA, which results in an overall antenna gain of 10dB and an input resistance of 43Ω. Consequently, the radiated THz power from the proposed DRA has improved substantially due to the improved optical-to-THz power conversion and enhanced matching and radiation efficiencies.

P2.04 Axion-hypotongs Lens for Reflectivity Measurements of Curved Surfaces
Aleksi Tamminen, Samu-Ville Pälli and Juha Ala-Laurinaho (Aalto University, Finland); Mika Sakkola (Tampere University, Finland); Antti V. Räsänen and Zachary D Taylor (Aalto University, Finland)

We present a quadrupole 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 quasioptical designs, such as the Gaussian-beam telescope, diffraction from an axicon surface allows for significant relaxation in alignment requirements. This research is motivated by in vivo corema measurements where achieving optimal optical alignment is difficult. Combined axion-hypotong lenses were designed for 220-330 GHz and fabricated of TOPAS, a low-loss material at millimeter waves. The lens performance is evaluated with near-field measurements. Compared to the Gaussian beam, the in-range alignment requirement can be relaxed by an order of magnitude with the Bessel beam.

P2.05 Circularly Polarized Conical Beam Antenna with Stable 3dB Azimuth Beamwidth
Junxing Yang and Shih-Shan Qian (Nanjing University of Science and Technology, China); Wen Wu (Nanjing University of Science and Technology, China)

A new geometry is proposed for an antenna producing circularly polarized (CP) conical beam with wide 3 dB aximuthal beamwidth. A co-axisal linearly polarized 6-way power divider has been employed to feed eight helices. The symmetrically placed helices around the sphere control the circular polarization purity. The locations, dimensions, and spin angles of the helices are tuned to achieve wide 3-dB AR beamwidth. The simulated results show that the proposed antenna achieves an impedance-bandwidth of 16.5% from 21.1 GHz to 37.9 GHz with the gain no less than 6.36 dBic at 30°, and 3dB AR beamwidth steadily covers from 1° to 58° over the bandwidth. The proposed antenna has a compact size of 1.1 mm×1.1 mm×0.2 mm, which will be useful in satellite communication applications.

P2.06 Improved Equivalent Norton Circuit for Pulsed Photocurrent Antennas
Andrea Degasperi, Arturo Fiorellini Bernardis, Andrea Neto and Nuria Llobart (Delft University of Technology, The Netherlands)

A revised version of the Norton equivalent circuit proposed in [1] is presented in order to describe more accurately the saturation at high optical powers. The revised model relies on an improved characterization of the generator impedance, now approximate one order of magnitude lower than the previous one and comparable to the impedance of the bow-tie antenna. The model is validated with a full wave simulation of the photocurrent antenna (PCA) in CST Microwave Studio. The proposed models are discussed in details and are presented as a new tool in literature to model PCAs.

P2.07 Circular-Polarization Mushroom EBG Antenna Module for 122 GHz Monostatic Radar Sensor in L-TCC Technology
Aruna Bhatari, Karlsruhe Institute of Technology (KIT), Germany; Benjimin Göttel (Wellellradar-und Sensortechnik GmbH & Co KG, Germany); Thomas Zeick (Karlsruhe Institute of Technology (KIT), Germany)

This paper presents a circular-polarization Mushroom electromagnetic bandgap (EBG) antenna module for realizing a 122 GHz monostatic radar sensor in L-TCC technology. The mushroom shaped antenna is designed by rotating half of the crossed dipole by 90° and folding its arms to form a small E-shaped antenna. The mushroom antenna is fabricated on 0.508 mm (0.28λo × 0.32λo × 0.0055λo at 3.22 GHz), a measured |S11| < -10 dB impedance bandwidth of 2.75-3.6 GHz (26.77%), and a simulated 3-dB axial ratio bandwidth of 3.0-3.45 GHz (13.95%).

P2.08 Advanced Circularly Polarized EBG Antenna Module for 60-GHz Customer Station Applications
Ikmo Park (Ajou University, Korea (South)); Javier Herranz-Alpanseque (Universitat Politècnica de València, Spain); Jose Luis Masa-Campos (Universidad de Jaén, Spain); Andrea Degasperi (Universita degli Studi di Padova, Italy); and Antonio Boccia (Università di Roma, Italy)

A new geometry is proposed for an antenna producing circularly polarized (CP) conical beam with wide 3 dB azimuthal beamwidth. The antenna comprises two orthogonal stripline feeds to the Mushroom EBG antenna, thus generating circular polarization. The locations, dimensions, and spin angles of the EBG are tuned to achieve wide 3-dB AR beamwidth. The simulated results show that the proposed antenna achieves an impedance-bandwidth of 16.5% from 21.1 GHz to 37.9 GHz with the gain no less than 6.36 dBic at 30°, and 3dB AR beamwidth steadily covers from 1° to 58° over the bandwidth. The proposed antenna has a compact size of 1.1 mm×1.1 mm×0.2 mm, which will be useful in satellite communication applications.

P2.09 Circularly Polarized Conical Beam Antenna with Stable 3dB Azimuth Beamwidth
Junxing Yang and Shih-Shan Qian (Nanjing University of Science and Technology, China); Wen Wu (Nanjing University of Science and Technology, China)

A new geometry is proposed for an antenna producing circularly polarized (CP) conical beam with wide 3 dB azimuthal beamwidth. The antenna is designed by rotating half of the crossed dipole by 90° and folding its arms to form a small E-shaped antenna. The mushroom antenna is fabricated on 0.508 mm (0.28λo × 0.32λo × 0.0055λo at 3.22 GHz), a measured |S11| < -10 dB impedance bandwidth of 2.75-3.6 GHz (26.77%), and a simulated 3-dB axial ratio bandwidth of 3.0-3.45 GHz (13.95%).

P2.10 Compact Circularly Polarized E-Shape Crossed-Dipole Antenna
Kam Kedze (Apu University, Korea (South)); Youngwook Kim (Apu University, Korea (South))

The study proposes a circularly polarized (CP) hybrid E-shaped crossed-dipole antenna comprising two crossed dipole-dipole arms and their of-coated quarter-pinned rings. The design goals are attained through the rotation and folding of the arms of the conventional crossed-dipole antenna to achieve a miniaturized CP antenna. A compact antenna is designed by rotating half of the crossed dipole by 90° and folding its arms to form a small E-shaped antenna that generates CP radiation with satisfactory performance. The performance of the proposed antenna is designed and confirmed both numerically and experimentally. This antenna has overall dimensions of 26.8 mm × 30.6 mm × 0.508 mm (0.28ca × 0.32ca × 0.0055ca at 3.22 GHz), a measured |S11| < -10 dB impedance bandwidth of 2.75-3.6 GHz (26.77%), and a simulated 3-dB AR bandwidth of 3.0-3.45 GHz (13.95%).
P2.052 Compact Circular Polarized Antenna for Multi-band Operation
Sarra Jemmeli (University of Limoges, France); Laure Huitema (Xlim Laboratory, France); Thierry Monediere (XLIM University of Limoges, France)

In the present communication, we present a multi-band and circular polarized patch antenna based on ferrite material. The main properties of ferrites are presented with an highlight on their anisotropic behavior and their non-reciprocal character allowing the generation of circular polarized antenna operating over several frequency bands. A further challenge of downsizing the antenna dimensions is also proposed. Good performances in terms of impedance matching, axial ratio and radiation efficiency are demonstrated.

P2.053 Compact UHF Printed Antennas for Nano-Satellites
Juner M. Vieira (Aeronautics Institute of Technology, Brazil); Rodrigo Facco (Federal University of Pampa, Brazil); Maross V. T. Heckler (Universidade Federal do Pampa, Brazil)

This paper presents the application of miniaturization techniques to UHF printed antennas designed for installation onto 8-U nano-satellites. The first structure studied is a rectangular dielectric resonator antenna and the second one is a compact active-loaded slot antenna. Both radiators are used to compose four-element planar arrays. The analyzed topologies are compared, whereby the array composed of slot antenna yielded the lighter solution with good electromagnetic performance.

P2.054 Circularly Polarized Electrically Small Antenna Using Chiral Metamaterials and Based on Characteristic Modes Theory
Nadja Kar (University Paris Est, ESYCOM & FITSTAR, COVIS, LEOST, France); Divitha Seetharam (IFSTTAR, LEOST & Univ Lille Nord de France, France); Jean-Marc Laheurte (Université Paris Est-Marne-la-Vallée, France); Francois Sarrazin (University of Paris Est-Marne-la-Vallée & ESYCOM, France)

This paper presents a novel circularly polarized electrically small antenna that has been designed thanks to the Characteristic Mode Analysis. It is based on the energy conservation between two elements: a non-resonant dipole antenna 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 intermediate coupling between the dipole and the metamaterial is studied between the modes to propose a better understanding of the net stored energy conservation. The coupling between the two structures is through the magnetic and electric modes and it thus increases the overall efficiency. Circular polarization of the antenna occurs through the chiral properties of the helix. The proposed antenna resonates at 2.35 GHz. The radiation pattern of the antenna is omnidirectional with a far axial ratio for a circularly polarized antenna.

P2.055 A Novel Design Methodology for Non-Foster Antennas in Broadband Self-oscillating Antennas
Bair Busanue (St. Petersburg Electrotechnical University LETI, Russia); Leo Vincze (University of Zagreb, Croatia); Dmitry Khodolynk (Saint Petersburg Electrotechnical University LETI, Russia); Silvio Hrabar (University of Zagreb, Croatia)

Non-Foster elements are electronic circuits with inverse dispersion properties compared to ordinary reactive elements. The evolution of their design is mostly related to self-oscillating matching applications. Moreover, recent introduction of self-oscillating non-Foster antenna has motivated the negation of a complex impedance via negative impedance converter (NIC). This negation is affected by NIC conversion error, which is dependent on both load Q-factor and NIC properties. Here, we propose a novel method for design of LinVif’s NIC, based on its decomposition into passive and active building blocks. Proposed approach is verified by analysis of LinVif’s NIC for recently investigated self-oscillating non-Foster antenna.

Poster-A2:10: Slotted-waveguide and Leaky-Wave Antennas

Antennas
Room: Exhibition Hall

P2.056 The Slotted Waveguide Array Antenna with Reflection Canceling Stairs in Millimeter Waveband
Wenbo Liu (Graduate School of Engineering, Takushoku University, Japan); Yasuhiro Tsunemitsu (Takushoku University, Japan)

We propose and design 36 GHz slotted waveguide antenna with reflection canceling stairs to improve aperture efficiency. The waveguide includes 10 linearly arranged slits 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 stair position and height are designed to suppress the reflection. The simulation of the full model confirms that aperture efficiency is improved to 64.9%.

P2.057 Electronic Beam Scanning Leaky-Wave Antenna Based on Delta Shape Half-Mode Substrate Integrated Waveguide
Nima Javanbakht, Barry Syrett and Ronny E. Amaya (Carleton University, Canada); Jafar Shaker (Communications Research Centre Canada, Canada)

A novel reflectible leaky-wave antenna is presented in this paper. The proposed antenna is based on a full mode substrate integrated waveguide. The beam-scanning is achieved using novel cells. The effective surface impedance is changed by adjusting the cells. Sweeping the bias voltage causes variation of the phase constant which leads to electronic beam scanning. The operating frequency is chosen as 28.5 GHz in the support of operating 5G communications systems. The length, width, and height of the antenna are 67 mm, 4.5 mm, and 0.3 mm, respectively. To achieve an optimal response, cells are located in the delta configuration. Electronic beam-scanning capability, compactness, and high gain of the proposed antenna make it a suitable candidate for future 5G wireless networks.

P2.058 Quasi-Periodic Leaky-Wave Antenna Based on Substrate Integrated Waveguide and Liquid Crystal Technologies
Anastasios C Polycarpou (University of Nicosia, Cyprus)

A quasi-periodic leaky-wave antenna (D/A) based on substrate integrated waveguide (SIW) and liquid crystal (LC) technologies is presented in this paper, which is very suitable for dynamic beam steering. The antenna works based on the fundamental space harmonic (n=1) in the frequency band from 10.2 GHz to 12.5 GHz. A 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 electrical anisotropy of the LC compound and the substrate-to-LC thickness ratio. Simulation results based on the ANSYS HFSS commercial software are used in order to numerically verify the design concept.

P2.059 Design of an Array of Stacked Groove Gap Waveguide Leaky-Wave Antennas in the Ka Band
Nafsika Memeletzoglou (Graduate School of Engineering, Takushoku University, Japan); Javier Elorriaga (University Carlos III of Madrid, Spain)

In this paper, the design of an array of leaky-wave antennas in groove gap waveguide technology is developed. The array is formed by stacking leaky-wave antennas on top of another. The design of the array 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 all the elements radiate in phase, aiming to achieve maximum directivity. The central frequency of the design is 28 GHz, and the array of four elements, achieves an enhancement of +5 dB, reaching 24.5 dB of directivity, in comparison to 19.6 dB of directivity of the single leaky-wave antenna made in this technology. The proposed design was validated experimentally with a prototype.

P2.060 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 (Universitat Politècnica de València, Spain); Alejandro Valero-Nogueira (Universitat Politècnica de València, Spain)

A T-shaped slot array antenna fed by a Quadrature Groove Gap Waveguide (QGGW) is presented in this paper. The array operates at 30 GHz. The array is excited, along with the T-shape on its left side, a compact single-layer architecture. A uniform linear array of 12 elements is designed to demonstrate the viability of this concept for high-efficiency single-layer slot array antennas. Practical results show a frequency bandwidth of 1–8 GHz with an input reflection coefficient below −5 dB. In addition, being a full metallic array, the expected efficiency is high. It is worth stressing the good polarization purity achieved, being below 1.5 dB within the band of interest.

P2.061 A Low-Profile Millimeter-Wave Circularly-Polarized Multilayered Waveguide Antenna Array for Satellite Communication Application
Hong-Tao Zhang (No. 38 Research Institute of CETC, China); Wei Wang (No. 38 Research Institute of CETC, China); Lu-Li Huang (Shenzhen University, China); Yongqing Zou (East China Research Institute of Electronic Engineering (ECRIE), China)

A low-profile circularly-polarized multilayer waveguide antenna array operating in Ka-band is proposed. The antenna array is characterized for low axial ratio (AR), high efficiency and wide operating bandwidth. To achieve a wide operating bandwidth from 29.4 GHz to 31.0 GHz and improve the AR, sequential rotation technique is utilized. The complete array is composed of five aluminium layers firmly bonded 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 1.6 and 2 dB respectively, have been realized with high radiation gain. The proposed antenna array is an excellent candidate for advanced satellite communication (Satcom).

P2.062 Practical Design of Radiating Part of Post-Wall Waveguide-Fed Parallel Plate Slot Array Antenna by Method of Moments
Koh Hashimoto and Makoto Higaki (Toshiba Corporation, Japan)

A practical design of a radiating part of a post-wall waveguide-fed parallel plate slot array antenna is presented. The slot pairs are designed by the method of moments (MoM). In the MoM analysis, unknown equivalent magnetic currents on slot apertures are expanded with entire-domain 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.
In this paper, we present a simple technique to achieve electronically-controlled beam scanning, by properly acting on the inbuilt surface susceptance of the waveguide. Such an approach allows to avoid the surface susceptibility spatial modulation, thus it inherently simplifies the antenna design problem. The proposed method is then demonstrated using a numerical example.

**Poster P2-E02: EM Theory and Analytical Techniques**

**Room: Exhibition Hall**

**P2.064 Proposal on Hybrid Propagation Analysis of Aperture Field Integration and Ray Tracing Method Suitable for Airplane in VHF Band**

Satoshi Kuoda and Ryosuke Suga (Aoyama Gakuin University, Japan); Atsushi Kezuka (Electronic Navigation Research Institute, MPAT, National R&D Agency, Japan); Osamu Hashimoto (Aoyama Gakuin University, Japan)

A hybrid propagation analysis method of ray-tracing method and aperture-field-integration method for air interface is proposed. Its effectiveness is evaluated by measurements using a 1/50 scale model. As a result, the simulated power distribution by the proposed method agreed with the measured one.

**P2.065 Volume Integral Equation Formulation for Electromagnetic Scattering by Highly Inhomogeneous Anisotropic Cylinders**

Konstantinos Katsanos, Georgios Zouros and John Routneloitis (National Technical University of Athens, Greece)

In this work, we report a volume integral equation formulation for the electromagnetic scattering by highly inhomogeneous anisotropic circular cylinders under normal incidence. The development of the method is based on a vectorial 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 are defined on the basis of vector functions which are constructed so as to guarantee orthogonality relations in the circular domain of anisotropy. The method is validated with the exact solution for single and double layered isotropic cylinders, for both TE and TM incidence, as well as with the commercial FEM software for anisotropic permittivity profiles. Numerical results are given for various values of the parameters.

**P2.066 Evaluating the RCS Contributions of Geometrical (Tensile and Thin) Anisotropies**

Alexandre Corazza and Pascal Pagani (CEA - CEN Saclay, France); Sylvain Morvan (CEA DAM & Centre des Etudes Scientifiques et Techniques Aquitaine, France)

In the context of radar detection, the assessment of Radar Cross Section (RCS) requires computing the scattered electromagnetic field using numerical simulations. In order to efficiently compute the RCS, we propose to investigate the contribution of the geometric anisotropies. The method based on physical optics is valid for small profile variations in the object illuminated region. The proposed model is validated for a circular cylinder. Moreover, the proposed approach can be extended to a statistical description of the geometry variability. As an illustration, the RCS contribution of a random surface roughness is evaluated.

**P2.067 Depolarization Due to Wedge Diffraction In Satellite Radiowave Communication**

Ankit Regmi, Md. Rafique Islam and Aarno Pärssinen (University of Oulu, Finland); Markus Berg (University of Oulu & Excellent Ltd., Finland)

In this paper, the depolarization effect due to the electromagnetic wave diffraction from the wedge rooftop of a building at 1.575 GHz frequency is presented. Diffraction measurement was performed using a device circularly polarized (CP) antenna system. The Right Hand Circularly Polarized (RHCP) Global Positioning System (GPS) satellite transmission was utilized for measurement. The orbital motion of a single satellite enabled diffraction measurement as a function of receiver depth in the shadow region, while the receiver was static. The experimental result of RHCP signal was compared with a theoretical knife-edge diffraction model and they were in agreement. In case of the deep shadow region, we found the levels of left-hand and right-hand circular polarized signals to be equal, which indicates a strong depolarization of the incident RHCP wave. The observed depolarization for conduction wedges is explained by the geometrical theory of diffraction.

**Poster P2-E03: Computational and Numerical Techniques**

**Room: Exhibition Hall**

**P2.068 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 for 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 (GSTC). These curvilinear surfaces are next described by parametric equations allowing for an elegant formulation for geometricaly complex systems. The proposed method is then demonstrated using a numerical example.

**P2.069 Gradient-Induced Heating of a Metallic Hip Implant in Magnetic Resonance Imaging**

Alessandro Arduini, Oriano Bottaccio, Mario Chiampi and Luca Zilberti (INRIM, Italy)

Localization of heat is an important issue in MRI, where a correlation between the temperature and the resulting tissue damage is often observed. In this work, the temperature-time evolution of a metallic implant was studied in an MRI environment. The extraction of information from the images was performed using a novel algorithm that exploits the gradient field information. The results of this study show the potential of MRI to monitor the temperature increase of metallic implants during an MRI examination.

**P2.070 Model Simplification and Validation of Virtual Prototypes for Vehicular Antenna Design**

Irfan Youst (Lunds University & Volvo Cars Corporation, Sweden); Kranti Kumar Katare (IIT Kanpur, India); Buon Kiong Lau (University of Oulu & Excellant L Td., Finland)

Wireless connectivity is becoming an important feature in cars, which is based on the development of new devices for car design point to precision. In this work, we address the problem of predicting the performance of an antenna in simulation, to speed up the design cycle. We are working on an algorithm that can accurately represent structurally complex real cars in simulation. This paper proposes a car model simplification approach for designing vehicular antennas, exemplified using three progressively simplified models of a chassis-based car. For validation, we use a monopole and a PIFA operating at 800 MHz and 2.4 GHz, respectively, and performed measurements in two locations on these prototypes. The proposed scheme reduced the computational time to less than a third, while maintaining similar simulated antenna performance. Specifically, the antenna patterns of the simplified prototypes are the same as the original prototypes when the mock antenna is scaled by 4% and 5% at 800 MHz and 2.4 GHz, respectively. Therefore, the proposed scheme promises to be a promising for realistic applications.

**P2.071 Integral Equation Formulation for Planar Plasmonic Nano Structures in Layered Media**

Eeeraa Mahdy (Cario University, Faculty of Engineering, Egypt); Alaa Abdelmageed (Cairo University, Egypt); Erzedin Soliman (The American University in Cairo, Egypt)

The paper presents a novel integral equation formulation for planar plasmonic structures in layered media. First, closed-form spatial domain Green's functions are obtained from 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 general metasurface boundaries are represented in terms of surface susceptibilities which are then integrated within the MoM using the Generalized Sheet Transition Conditions (GSTC). The proposed method is then demonstrated using a numerical example.

**P2.072 Impact of Parameters Variability on the Performances of an Implanted Antenna for Biomedical Applications**

Shuiling Ding (GePis & CentraleSupelec, France); Yao Pei (University Paris-sud, France); Lionel Pichon (Group of Electrical Engineering Paris, Universite Paris-Saclay & GeePs Laboratory, France); Stavros Koukouris (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 are presented and discussed. The results show that the proposed method is promising for realistic applications.

**P2.073 Application of non-PEC Walled Mode-Matching Techniques to a Prototype SAFARI M-band Multi-Mode Receiver**

Joseph Brennan (Maynooth University, Ireland); Marco Gradziel (National University of Ireland, Maynooth, Ireland); Neil Trappe (Aoyama Gakuin University, Japan); Peter Ade (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 which are not generally included in the analysis of guide structures. In particular, these losses manifest themselves more significantly in multi-layered structures, as field distributions for increasing azimuthal order modes are biased to a greater extent at the boundary walls. This lossy mode-matching method is applied to a prototype M-band horn for the proposed SAFARI system. We here attempt reconcile the measured data with simulation results by considering the surface impedance of the guide walls due to the finite
**P2.074 Neural Network Approach for the Characterization of Tissues in Microwave Frequencies Using Coplanar Waveguide Transmission**
Viktor Mattsson (Uppsala University, Sweden); Mauro D Perez (Uppsala University, Sweden & National Technological University, Argentina); 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 provide 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 consistency of accuracy. A complete system with a trained network is proposed to be used in a lab or in vivo.

**P2.075 Feeding Positions Providing the Lowest TARC of Uncorrelated Channels**
Michael Maric (Czech Technical University in Prague & AMEC ESI s.r.o., Pilsen, Czech Republic); Mislav Capko and Lukas Jelinek (Czech Technical University in Prague, Czech Republic)

In this paper, group theory is utilized for the simultaneous block-diagonalization of all linear operators representing the underlying symmetrical structure. This procedure 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.

**P2.076 PML Effectiveness in the Transmission Line Modelling Method for Radiation and Scattering Applications**
Jomliju Odeyemi, Chris Smartt, Ana Vukovic, Trevor Benson 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 superset of the new PML over the TLM matched boundary is demonstrated by application to electromagnetic scattering and radiation simulations.

**P2.077 Effects of Common Approximations in the Modeling of a Liquid-Crystal-Based Patch Antenna: A Numerical Investigation**
Nectarios Papamichalopoulos, Anastasia C Polygerinos and Marinos Christou (University of Nicosia, 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 Oseen-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 adopt 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.

**P2.078 Hybrid MoM-T/M Method for Analysis of Interaction Between Objects**
Vit Lunescu, Craig Ckap and Lukas Jelinek (Czech Technical University in Prague, Czech Republic); Mats Gustafsson (Lund University, Sweden)

A hybrid method for analysis of interaction between electromagnetic scatterers is introduced. The method connects the method of moments and T/M method and represents a promising candidate capable of solving problems associated with 5G or antennas 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.

**P2.079 A Parallelized Fast Array Analysis Approach**
Danie Ludick and Tameez Ebrahim (Stellenbosch University, South Africa)

In this work, a hybrid distributed/shared memory parallelization scheme is presented for the domain green's function method (DGFM). The DGFM is a domain decomposition-based computational electromagnetic (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 MPI/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.

**P2.080 Accuracy and Modeling Improvements for an Integral Equation Framework Applied to Thin Layer Microstrip and Substrate Integrated Waveguide (SIW) Structures**
Thomas Vaupel (Fraunhofer FHR, Germany)

For the analysis and design of PCBs or antennas embedded in a layered dielectric medium, commercial tools based on integral equation methods (IE) or finite elements (FE) show sometimes a low efficiency leading to long meshing and solution runtimes or doubtful solutions. Furthermore, the direct integration of lumped elements within (microstrip) circuit or antenna structures is not possible. Then an improved layer-extraction quadrature is introduced well suited for the computation of coupling integrals of our IE approach leading to a higher accuracy especially for circuits on thin layers which often lead to unreliable results with commercial solvers. Then we show the additional integration of lumped elements not possible with HFSS together with an interface for a co-simulation. Another application comprises the improved modeling of substrate integrated wavegourde (SIW) and antennas based on a very accurate size dimensioning of equivalent quadratic via for the improved design process of e.g. leaks wave antennas.

**P2.081 Electromagnetic Design of Beam Positioner on Diffraction Radiation from Twin Dielectric Nanowires**
Daria O. Herasymova (Institute of Radio-Physics and Electronics NASUI, Ukraine)

The diffraction radiation of modulated beam of charged particles, which flow between twin 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 show 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.

**P2.082 Simulations and Measurements of Brick-Like Axial-Mode Helix Antenna Using CAD Tools**
Dragan I. Ocan (University of Belgrade, Serbia); Umut Bulus (Antocom Antenna Technologies, Turkey)

We present an axial-mode uniform helix antenna made of brick-like elements. The antenna is modeled using a CAD tool and numerically analysed using method of moments with higher order basis functions for the approximation of surface currents. The prototype of the antenna is built and measured. The simulated and measured radiation patterns match very well.

**P2.083 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 alternative way of modelling the experiment. 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.

**P2.084 Antenna Design Exploration and Optimization Using Machine Learning**
Christoph Mauser (Germany, Germany); Peter William Futter (Altair Development S.A. (Pty) Ltd, South Africa); Gopinath Gampala (Altair Engineering Inc., USA)

Design exploration using numerical field simulation is a valuable approach to analyse 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.

**P2.085 Optimal Beamforming Using Clustered Evolutionary Teaching and Learning**
Aminshah Daneshvar and Ahmad Khihi (Concordia University, Canada); Ataollah Ebrahimzadeh (Babol Noshirvani University of Thecnology, Iran); Samineh Sarbarz Gulsaz (Concordia University, Canada)

An improved Teaching and Learning Based Optimization algorithm, (C-TELBO), is employed to obtain user-defined shaped radiation patterns. An example of 70-element linear array with a specific asymmetric mask is considered. A novel redistribution mechanism is adopted in order to increase the convergence rate of the original optimizer. The mechanism uses the concept of multiple teachers to cluster the learner groups. It triggers an extra exploration with the same objective 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 large dimensional beam-shaping problem.

**Poster2-E04: Optimisation Methods in EM**

Electromagnetics
Room: Exhibition Hall
The transmission and absorption responses are achieved by using lumped inductor/capacitor (LC) and resistor elements, which can be tuned to achieve desired performance. The proposed structure is simple and can be fabricated with standard printed circuit board (PCB) techniques. Full-wave simulations and experimental results demonstrate the effectiveness of the proposed design.

Zhefei Wang (THALES AIRBORNE SYSTEMS, France); and

Joseph Botros (University of Reggio Calabria, Italy)

In this paper, a novel Frequency Selective Surface (FSS) with polarization staggered bands is proposed. The beams in orthogonal polarization of different frequency bands are divided into a group and transmitted by the FSS. The rest are divided into another group and are reflected by the FSS. The proposed FSS with polarization staggered bands, which separate two bands near 90GHz and 108GHz, is fabricated and tested. The reflection coefficient of TM polarization is about 1dB, and the transmission and reflection coefficients in the other band or polarization are less than 0.6dB.

The FSS with polarization staggered bands is good at separation the bands with narrow transition zone, which realizes transmission and reflection of the incident waves in different frequency bands. Zhefei Wang (THALES AIRBORNE SYSTEMS, France); and Joseph Botros (University of Reggio Calabria, Italy)

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Zhefei Wang (THALES AIRBORNE SYSTEMS, France); and Joseph Botros (University of Reggio Calabria, Italy)
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 24º effective bandwidth for an incidence angle of 45º in both x and y-planes. The proposed converter provides an unique combination of wide-bandwidth, thin profile, and stable response with respect to the angle of incidence. It can be integrated to any linearly polarized antenna to generate circular polarization without affecting the antenna performance.

P.097 Dual-Band Band-Pass Frequency Selective Surface Based on the Matryoshka Geometry with Angular Stability and Polarization Independence

Alfredo Neto (Federal Institute of Paraíba & Grupo de Telecomunicações e Eletromagnetismo Aplicado - GETEMA, Brazil); Jefferson Costa Silva (Instituto Federal do Paraíba & IFPB, Brazil); Alexandre Sanches (UFCSG, Brazil); Marina Alencar (IFPB, Brazil); Ianes Coutinho (Instituto Federal do Paraíba, Brazil); Thamyris da Silva Evangelista (Instituto Federal de Educação Ciência e Tecnologia da Paraíba, Brazil)

This paper describes by the first time, at least of the authors' knowledge, a frequency selective surface, FSS, based on the Matryoshka geometry, with dual-band pass-band frequency response, keeping the interesting features previously outlined: angular stability and polarization independence. Moreover, it is a single layer FSS and the reduction of the resonant frequencies, a characteristics of the Matryoshka geometry, was maintained. Initial design equations are proposed, providing good guidelines, making easy the design of the FSS for other resonant frequencies and specific applications. Two FSS were designed, fabricated and characterized, verifying a good agreement between numerical and experimental results. The resonant frequencies remain almost constant for different incident angles, for θ = 0º to 45º, confirming the angular stability.

P.098 Microwave Polarization Converter with Multi-Layer Metasurfaces

Fuheng Zhang, Guoming Yang and Ya-Qu Jin (Fudan University, China)

This paper introduces low profile linear-to-circular polarization and left hand circular polarization converters based on third-order metasurface structure that operates at the X-band. The metasurface unit cell is composed of three metal layers and is separated by two dielectric substrates. The transmission coefficients at two orthogonal directions are equal, while a 90º or 180º transmission phase difference is introduced between them over a wide bandwidth. A form antenna is employed as a linear source to verify the performance of the linear-to-circular polarization converter, while a helical antenna is designed as the left hand circular polarization to right hand circular polarization converter. The results show that the designed metasurface can effectively convert linear polarization (LP) wave to a left hand circular polarized (LHCP) wave or a right hand circular polarized wave to right hand circular polarized wave.

P.099 Novel Dichroic Subreflector Design for Cassegrain Antennas

Seymour Shukurov (Yeditepe University & Profen Communication Technologies, Turkey)

Novel subreflector design for Dual Band Cassegrain Antenna systems was proposed in this paper. Proposed Frequency Selective subreflector reflecting frequencies in X-Band and transmitting in S-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 GPS satellite beacon signals. It was shown that total antenna efficiencies at both frequency bands using Frequency Surface Sub-reflector dichroic designs were more than 65%.

P.100 Retrieval of Effective-Permittivity and Permeability of Periodic Structures on Dielectric and Magnetic Substrates

Peng Mei and Shuai Zhang (Aalborg University, Denmark); XiaoLin 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 structure 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 served as an example to elaborate the retrieval process. Firstly, the equivalent circuit of the feeding structure is modeled with inductor and capacitor, where the values of these components are determined by the simulated S-matrix of the feeding structure. After that, the responses 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 form of equivalent circuit on purpose. The compensating values are also determined from the simulated S-parameter of the structure with supporting substrates. The formulas of effective permittivity and permeability are ready to deduce and obtained from the original and compensating values of components in the equivalent circuits.

Poster2-P05: Mm-wave and UWB Propagation

Generation of millimeter-wave and UWB propagation

P.101 Channel Measurement and Analysis for Polarisatibe Wideband Outdoor Scenarios at 26 GHz: Directional Vs Omni-Directional

Sohail Payami (University of Surrey, United Kingdom (Great Britain)); Michsen Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Sohail Taheri (VIAV Solutions, United Kingdom (Great Britain)); Konstantinos Nikopolous and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

This paper presents the measurement results and analysis for outdoor wireless propagation channels at 26 GHz over 2 GHz bandwidth for two receiver antenna polarization modes. The angular and wideband properties of directional and virtually omni-directional channels, such as angular spread, root-mean-square delay spread and coherence bandwidth, are analyzed. The results indicate that the reflections can have a significant contribution in some realistic scenarios and increase the angular and delay spreads, and reduce the coherence bandwidth of the channel. In addition, the analysis shows that when using a directional transmission can result in an almost uniform frequency flat channel over the measured 2 GHz bandwidth, which consequently has an impact on the choice of system design choices such as beamforming and transmission numerology.

P.102 Ray-tracing Based Channel Clustering and Analysis at 28 GHz in Conference Environment

He Ding (Beijing University of Posts and Telecommunications, China); Lei Tian (Beijing University of Posts and Telecommunications, China); Mohammad R. Khan (King's College London, United Kingdom (Great Britain)); Zhongqian Cai (King's College London, United Kingdom (Great Britain)); and Guomin Yang (University of Surrey, United Kingdom (Great Britain))

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P.103 A Comparative Study for Indoor Factory Environments at 4.9 and 28 GHz

Yichong 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 industrial Internet of Things (IIoT) has benefited from the fifth-generation (5G) wireless network and is providing new possibilities for the Internet of Things (IoT) applications. Microwave and millimeter wavebands will constitute hybrid wireless communication systems, thus it is essential to have accurate channel models for indoor factory environments. In this paper, we compare a few state-of-the-art channel models and evaluate the performance of these models in factory environments. The results indicate that the models' accuracy is significantly affected by the factory environment.

P.104 5G Millimeter-Wave NLOS Coverage Using Specular Reflections Buildup

Robbert Schulpen, A. B. (Bart) Smolders and Mohsen Khalily (University of Electronic Science and Technology of China, China); and Francesco Greco (Ericsson Research & Ericsson AB, Sweden);

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P.105 Availability of 7 Km-Long Parallel 18 GHz Band and E-band Links for Multi Band Solutions

Sohail Payami (University of Surrey, United Kingdom (Great Britain)); Michael Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Sohail Taheri (VIAV Solutions, United Kingdom (Great Britain)); Konstantinos Nikopolous and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

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P.106 Multi-band Characterization of Propagation in Industry Scenarios

Sohail Payami (University of Surrey, United Kingdom (Great Britain)); Michael Khalily (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Sohail Taheri (VIAV Solutions, United Kingdom (Great Britain))

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For wireless capsule endoscopes, high data rate communication is needed between a transmitter in the esophagus and the receiver in the small intestine. To the best of our knowledge no comprehensible channel models exist for the scenario of in-body transmission. 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 3×3 spatial grid, moving in the environment, was considered. The on-the-moving side we consider a full multi-antenna at the receiver side. The multi-path components have been extracted by means of high resolution algorithms. The results obtained with the full multi-antenna are compared with those obtained with a single sub-array, in order to investigate the effect of antenna size in channel modeling.

Finally, experimental measurement is done on ex-vivo tissue made of porcine skin, fat and muscle at the frequency range from 20 to 30 GHz. The fat layer using the Poynting Vector theory and the multi-layer dielectric Green’s function (MGF). To calculate the multi-layer dielectric properties the empirical Poynting vector method or commercial software CST Microwave Studio 2019 should be applied and used in the environment, and this is compliant with the theoretical Poynting vector path loss estimation.

The beyond-5G vehicular communications are expected not only to utilize the already explored millimeter-wave band but also to explore the already explored higher bands. The reported measurement data may be used as a reference for the vehicle-specific channel and interference models for future wireless communications in the low terahertz band.
This paper presents a novel low-cost and stable dielectric composite from non-toxic particulate, Marmite and Clover mixture. 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, 4.5 GHz and optical frequency are 48.13, 10.13 and 7.61 respectively. The reflection time for this phantom is 19.23 ps. 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.

This paper proposes a planar microstrip sensor that consists of four distinct hexagonal-shaped complementary split ring resonators (CSRRs) configured in the honeycomb pattern. The sensor element operating at 1.5-3 GHz is fabricated on an FR4 dielectric substrate and excited via a microstrip technology in the cm-wave band. The proposed sensor is used as a near-field probe to detect the glucose level in the blood mimicking aqueous 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 excels others in the literature. The sensor sensitivity, reliability and repeatability are demonstrated by the in-vitro measurements via a Vector Network Analyzer (VNA).

This paper presents a numerical and experimental study and channel characterization of 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, 402-408 MHz). 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 difficulties between the two devices. To address this problem, the signal propagation pattern of a system that consists of two devices, over a sampled trajectory is carried out. We then extended our study using virtual human models. Simulation results are mapped and experimentally confirmed.

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This paper presents an automated measurement setup for the on-body link of wireless body area networks. The setup contains a test channel and experimental equipment to measure the channel characteristics for different body-worn antennas. Near-field sources are used to simplify the simulations and reduce the number of mesh cells. The procedure is validated with conventional full 2-port CST T-solver simulations. Next, the direct path loss between each of five different hearing solutions and a connectivity device placed on the chest are presented and discussed. Finally, it is reported that the simulation time for some of the hearing solutions is improved with up to a factor of 5.

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P.128 Experimental Results on Rain Detection at Ka-Band Based on Range-Doppler Signal Processing

Aishan Taremi Zadeh, Mortiz Malzer and Jonas Simon (Goethe University Frankfurt am Main, Germany); Sebastian Beck (Goethe University Frankfurt am Main, Germany); Jochen Möll (Goethe University Frankfurt am Main, Germany); Viktor Krozer (Goethe University Frankfurt am Main, Germany)

Rain radar in the mm-wave frequency window 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 1.2 and 2.0 mm operation in the Ka-band from 33.4 GHz to 35.0 GHz. This radar is a low-cost, portable system that requires minimum supervision in the field. As such, we use this system for structural health monitoring of rotor blades on wind turbines, detection of flying animals e.g. birds and bats and rain detection. When analyzing rain data with Range-Doppler (RD) algorithm, we notice characteristic patterns of rain, which we investigated more closely. To better understand these patterns, we designed an experiment and implemented a novel modeling framework. Experimental and numerical results for rain detection and classification are presented and discussed here.

P.129 Estimation of the Number of Persons in a Reverberant Environment Using Bistatic Radar

Marianne Zuffa Mussi, Giuliano Fabiano and Ilaria De Acunto (Goethe University & IMEC, Belgium); Emmeric Tanghe (Ghent University, Belgium); Eli De Poorter (Ghent University & Imec, Belgium); Luc Martens (Ghent University - imec, Belgium); Pierre Lalé, Davy P Gaillot and Martine Liebrand (University of Lille, France); Wout Joseph (Ghent University/IMEC, Belgium)

The theory of room electromagnetics provides a simple characterization of an environment as a box cavity, 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 decay time constant, also known as reverberation time. First, we verify the reverberation nature of the room. 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 88%, the estimation error is only 1 person when 16 spatially averaged antennas are used.

P.130 Simulation Validation of High Resolution Indoor Terahertz Synthetic Aperture Radar Imaging

Amar Barsa (University of Duisburg-Essen, Germany); Michael Wiemeler (Universität Duisburg-Essen, Germany); Diana Goehringer (Technische Universität Dresden, Germany); Thomas Kaiser (Universität Duisburg-Essen, Germany)

Indoor Terahertz Synthetic Aperture Radar (STAR) is an emerging technology for material characterization, high resolution imaging and localization. In combination with other technologies, it provides benefits in hazardous environments 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 geometry and system parameters have to be evaluated. For this purpose, we model the propagation channel and the target as a 4x4cm 3D scene with a black and white object. To evaluate 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 350 GHz are presented. Additionally, the proof of theoretical resolution across the range and azimuth is shown with the resulting simulations.

P.131 Temporal-Range-Doppler Features Interpretation and Recognition of Hand Gestures Using mmW FMCW Radar Sensors

Guoyuan Zhang, Shenchang Lan, Kang Zhang and Lintong Ye (Harbin Institute of Technology, China)

This paper introduces a comparative study of using deep neural networks in non-contact hand gesture recognition based on mmW 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-LSM, are respectively constructed to reveal the temporal gesture motion signatures encoded in multiple adjacent radar maps. With the proposed networks, the recognition accuracy of six popular hand gestures reach to 95%. Meanwhile, this latter further explores the performance of the proposed networks in the impact of training data size on the recognition accuracy. The proposed methods can be applied in the recognition of human finger motions, providing some preliminary experimental results compared with other baseline methods.

P.132 Human Motion Detection Using Planar Array FMCW Radar Through 3D Point Clouds

Ibrahim Alhujaimi (California State University, Fresno, USA); Iomo Park (Ajou University, Korea (South)); Youngwook Kim (California State University, Fresno, USA)

We propose to detect different human motions using a planar phased array FMCW radar through investigating 3D point clouds. We have yet to perform our analysis on other types of FMCW radars. Range-Doppler maps have been monitored using a microphone signature, studies investigating an approach that employs point clouds are lacking. We measured 7 human motions including bending, kicking, punching, walking, running, sitting down, and standing using a phased-array FMCW radar system operating at 770MHz. Next, 3D point clouds were extracted by calculating direction of arrival from point scatterers on the human body. As the point clouds contained human joint positions, we classified the motions using convolutional neural networks. The classification accuracy was 86%.

P.133 Data Transfer and Communication in Radar Networks

Peter Müller, Matthias Weiß, Stephan Sandenbergh, Daniel O Hagan and Peter Knott (Fraunhofer FHR, Germany)

A robust architecture for the transfer and centralised storage of time stamped multi-sensor data of arbitrary types and sizes is aimed strictly at networks using physical infrastructure. The idea is to observe the environment with the aid of multiple sensors of different types has existed for many decades. However, advances in synchronisation, localisation and network standards have enabled the integration of different types of sensors in networks. Multitude distributed sensors offer many advantages over single sensors. More target information can be extracted and it has increased survivability, detection, and classification abilities. Hence, there is a strong drive to further develop and enhance the underlying technologies of sensor networks. One such technology is robust transfer of data between the network nodes and at a central storage network. 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.

Poster2-P13: Radio Science and Remote Sensing

Propagation
Room: Exhibition Hall

P.134 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)

We propose a new design of THz filters for a high-speed, spectrally continuous THz receiver system. The filters are based on high-purity, AlGaAs/GaAs superlattices and single crystal InP substrates. We design and fabricate wideband, superconducting, InP-based, integrated filter-banks for astronomy. The dispersion mechanism is an array of shorted microstrip bandpass filters realizing 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-limit sensitivity, Microwave Kinetic Inductance Detectors (MKIDs) are employed to sense the filtered THz radiation. In this paper, we present a full transmission line model for a bandpass filter that can be cascaded resembling to ABCD matrices to enable the study of larger filter banks. Fast and accurate predictions are thereby obtained for the frequency response of a filter bank. With the insights obtained from the model, several prototype chips have been designed and are under fabrication.

P.135 On the Use of Adjunct Methods for Refractivity Estimation in the Troposphere

Uygar Karabaş (ENAC & ISAE-SUPAERO, France); Youssef Douane (ISAE-SUPAERO, France); Rémi Douvenot (ENAC, France)

This paper presents a preliminary study of a new inversion strategy combining the method of adjoint applied to the wide-angle parallax and the method of split-step waveform for tropospheric refractivity estimation. Our main motivation is to use a gradient-based optimisation method to infer atmosphere from radio-frequency data, in order to efficiently perform such an inversion. This method has been successfully used in the field. As such, we use this system for structural health monitoring of rotor blades on wind turbines, detection of flying animals e.g. birds and bats and rain detection.
14:50 A Holy Grail Quest: The Concept of Stored Electromagnetic Energy
Guy Vandenbosch (Katholieke Universiteit Leuven (KU Leuven), Belgium)

The quest for the “final” expressions for the energy stored in a radiator is overviewed. First, the 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
Electromagnetics
Room: A3
Chair: Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands)

14:50 Computational Electromagnetics in Space
Erik Jørgensen, Oscar Borries, Min Zhou, Peter Meinske, Stig Sørensen, Niels Vesterdal 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, hybridization 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.
IEEE 802.11n and LTE made the term MIMO common place in technical literature. The 5G New Radio (NR) is doing the same ... imprecisely at best. At a minimum, this can cause confusion between readers with different specializations, but can also

When placed on the market, mobile handsets are required to comply with relevant electromagnetic field (EMF) exposure ... of incident power density (IPD). In this work, the equivalent currents (EQC) method is applied to assess the IPD of a

A three-band LTE Cat-M1 PCB antenna is simulated and measured. The 900MHz-1800MHz band is covered by a conventional dipole-like element. The array synthesis has been carried out by time-domain full-wave simulators where excitation is applied to a unit cell embedded in an array. Then, array theory is applied to estimate the far-field of the entire structure. This is computationally efficient, which allows us to optimize the performance of the array with both analytical and numerical approaches.

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 in different frequency bands. The new design is suitable for base station LTE mobile platforms. A good agreement is achieved between the measurement and simulation results.

A novel broadband dual-polarized planar dipole antenna is proposed for LTE/5G base stations. The proposed antenna is fed by a microstrip feedline that is directly fed by a coaxial cable, making the dual-polarized antenna a completely planar structure. Due to the strong coupling between feedline and dipole antenna, a broad impedance bandwidth can be achieved. It is shown by simulation and experiment that bandwidth enhanced dual-polarized antenna achieves a wideband of 49.9% (64.7-233GHz) for reflection coefficients < -15 dB with an isolation of 28 dB. The enhanced IPD is greater than 20dB in the axial direction and greater than 10 dB within ±60º at the horizontal plane. A stable gain of 8.34 ± 0.71 dBi over the operating bands and half-power beamwidth of 68.15º ± 2.75º, suitable for base station applications.

A wideband dual-polarized antenna for base station application is proposed. By embedding a pentagonairing in the square loop dipole and adopting Branch-shaped feeding structure, a wideband impedance bandwidth was achieved. We can also enhance the cross-polarized discrimination (CPD) by adding four vertical parasitic elements. It is shown by simulation and experiment that bandwidth enhanced dual-polarized antenna achieves a wideband of 49.9% (64.7-233GHz) for reflection coefficients < -15 dB with an isolation of 28 dB. The enhanced IPD is greater than 20dB in the axial direction and greater than 10 dB within ±60º at the horizontal plane. A stable gain of 8.34 ± 0.71 dBi over the operating bands and half-power beamwidth of 68.15º ± 2.75º, suitable for base station applications.
Analysis of 60-GHz In-street Backhaul Channel Measurements and LiDAR Ray-based Simulations

A Dynamic Visibility Algorithm for Ray Tracing in Outdoor Environments with Moving Transmitters and Scattering

Performance Comparison of Single- And Multi-Lobe Antenna Arrays in 5G Urban Outdoor Environments at mm-Waves via Intelligent Ray Tracing

3D Antenna simulation and performance analysis of massive MIMO base stations in urban environments. The simulation setup includes 3D models of buildings, streets, and pedestrians. The impact of different antenna array designs on the system performance is evaluated, including channel capacity, beamforming gain, and interference mitigation.

Wednesday, March 14th 9:30-10:10

Title: \textit{Analysis of 60-GHz In-street Backhaul Channel Measurements and LiDAR Ray-based Simulations}

Authors: Abdelhakim Ait Taha, Konstantinos Anagnostopoulos, and Thierry Belan

Institute: University of Waterloo, Canada

Abstract: The authors present an analysis of 60-GHz in-street backhaul channel measurements and LiDAR ray-based simulations. The study investigates the propagation characteristics in urban environments, focusing on the impact of LiDAR point cloud data on channel modeling. The results highlight the importance of LiDAR data for accurate propagation prediction and underline the benefits of ray-based simulations in reducing computational complexity.

Title: \textit{A Dynamic Visibility Algorithm for Ray Tracing in Outdoor Environments with Moving Transmitters and Scattering}

Authors: Aurelien Bria, Alexander Yarovoy, and Monika Jäger

Institute: Ericsson AB, Sweden

Abstract: The authors propose a dynamic visibility algorithm for ray tracing in outdoor environments, considering moving transmitters and scattering effects. The algorithm aims to improve the efficiency of ray tracing by dynamically updating the visibility information, allowing for accurate prediction of signal strength and interference in time-varying scenarios.

Title: \textit{Performance Comparison of Single- And Multi-Lobe Antenna Arrays in 5G Urban Outdoor Environments at mm-Waves via Intelligent Ray Tracing}

Authors: Yanki Aslan and Jan Pusksely

Institute: Delft University of Technology, The Netherlands

Abstract: The authors compare single- and multi-lobe antenna arrays in 5G urban outdoor environments at mm-waves. They use intelligent ray tracing to analyze the performance of different antenna array designs in terms of coverage, capacity, and interference mitigation. The study highlights the benefits of multi-lobe arrays in enhancing system performance under urban conditions.

Thursday, March 15th 9:30-10:10

Title: \textit{Throughput and Spherical Coverage Performance of mmWave Dual Polarized Antenna Arrays}

Authors: Ali Hazmi and Antoine Roederer

Institute: Huawei Technologies, Finland

Abstract: The authors analyze the performance of mmWave dual polarized antenna arrays in terms of throughput and spherical coverage. They evaluate the impact of antenna positioning and polarization on system capacity and coverage. The study demonstrates the potential of dual-polarization for improving spectral efficiency in mmWave systems.

Title: \textit{ESM Exposure Assessment of Massive MIMO Radio Base Stations Based on Traffic Beam Pattern Envelopes}

Authors: Tian Hong Loth, Davide Comolli, and Christer Törnevik

Institute: University of Skövde, Sweden

Abstract: The authors present a method for assessing the electromagnetic field (EMF) exposure of massive MIMO radio base stations based on traffic beam pattern envelopes. They develop a technique to evaluate the EMF exposure at different traffic scenarios, taking into account the beamforming patterns.

Title: \textit{Fading Channel Emulation for Massive MIMO Testing Using a Conductive Phase Matrix Setup}

Authors: Jonas Flidén and Sam Agaenssens

Institute: Ericsson AB, Sweden

Abstract: The authors describe a fading channel emulation technique for massive MIMO testing, using a conductive phase matrix setup. This method enables realistic channel emulation in the lab, which is crucial for validating novel MIMO technologies.

Title: \textit{EMF Exposure Assessment of Massive MIMO Radio Base Stations Based on Traffic Beam Pattern Envelopes}

Authors: Ali Hazmi, Antoine Roederer, and Fabien Héliot

Institute: Keysight Technologies & University of Oulu, Finland; Delft University of Technology, The Netherlands

Abstract: The authors explore the impact of traffic beam pattern envelopes on the electromagnetic field exposure of massive MIMO radio base stations. They propose a method to assess the EMF exposure for different traffic conditions and discuss the implications for the design of safe and efficient wireless systems.

Title: \textit{Performance Comparison of Single- And Multi-Lobe Antenna Arrays in 5G Urban Outdoor Environments at mm-Waves via Intelligent Ray Tracing}

Authors: Yanki Aslan and Jan Pusksely

Institute: Delft University of Technology, The Netherlands

Abstract: The authors evaluate the performance of single- and multi-lobe antenna arrays in 5G urban outdoor environments at mm-waves. They use intelligent ray tracing to analyze the coverage and capacity of different antenna designs and present findings on the optimal array configuration for specific scenarios.

Tuesday, March 13th 9:30-10:10

Title: \textit{ESM Exposure Assessment of Massive MIMO Radio Base Stations Based on Traffic Beam Pattern Envelopes}

Authors: Tian Hong Loth, Davide Comolli, and Christer Törnevik

Institute: University of Skövde, Sweden

Abstract: The authors provide an assessment of the electromagnetic field (EMF) exposure of massive MIMO radio base stations based on traffic beam pattern envelopes. They develop a method to evaluate the EMF exposure at different traffic scenarios, taking into account the beamforming patterns.
Recent Advances in Magnet-less Non-reciprocal Leaky Wave Antennas

Anirban Sarkar (School of Electrical and Electronics Eng., Chung-Ang University, Korea (South)); Sungjoon Lim (Chung-Ang University, Korea (South))

In this paper, we explore the use of nonreciprocal leaky wave antennas in millimeter wave communication systems. Nonreciprocal leaky wave antennas have been proposed in the past but they require complex and bulky magnetized materials. The recent developments in material science and microwaves have enabled the design of magnet-free leaky wave antennas.

We present a nonreciprocal leaky wave antenna design that does not require any magnetic material. The antenna is designed using a specific geometry that ensures nonreciprocal behavior. The proposed antenna is validated through simulation and experiment. The results show that the antenna has the desired nonreciprocal behavior and can be used in millimeter wave communication systems.

10:50 Coffee Break

11:00 Controlling Dual Polarization with Metasurface Leakage

Alice Benni and Enrica Martin (University of Siena, Italy); Charlotte Tripon-Canseliet (Université Pierre et Marie Curie, France); Jean-Maurice Chazelas (Thales Aerospace Division, France); Stefano Maci (University of Siena, Italy)

This paper presents a new approach for controlling dual polarization using metasurfaces. The proposed metasurface is designed to manipulate the polarization state of a wavefront in a desired manner. The metasurface is based on a specific arrangement of subwavelength elements that can be individually tuned to control the polarization state.

The metasurface is experimentally validated using a set of polarization measurement techniques. The results show that the metasurface is capable of controlling the polarization state with high accuracy. The proposed technique has potential applications in satellite communication systems for improving the performance of dual polarization systems.

11:20 Leaky-Wave Analysis of an Ultrathin Planar High Impedance Surface Antenna

Ahmad T. Almutawa (PAAET, Kuwait); Filippo Capolino (University of California, Irvine, USA)

High impedance surfaces (HIS) have been used in the past to act as artificial magnetic conductors to improve the efficiency of a dipole antenna. In this paper, we present a new type of antenna that combines the benefits of HIS and leaky wave technology. The proposed antenna is designed to have high gain and wide bandwidth.

The antenna is experimentally validated using a set of measurement techniques. The results show that the proposed antenna has high gain and wide bandwidth, making it a potential candidate for use in wireless communication systems.
11:40 Cylindrical Aperture Synthesis with Metasurfaces
Fareis Alsalamy (University of Michigan Ann Arbor, USA); Anthony Gbic (University of 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 realized using 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 Deyze Hankel Transform (DHT). As an example, a radially polarized Gaussian beam launcher is designed.

12:00 Holographic-Based mmW-Band Bidirectional Frequency Scanning Leaky Wave Antenna
Ali Arghari (University of Surrey, United Kingdom (Great Britain)); Mohsen Khayati (University of Surrey & 5G Innovation Centre, Institute for Communication Systems (ICS), United Kingdom (Great Britain)); Pei Xiao and Rahim Tafazoli (University of Surrey, United Kingdom (Great Britain))
Utilizing the holography theory, a bidirectional wideband leaky wave antenna in the millimeter wave band is presented. The antenna includes a printed pattern of continuous metallic strips on an Alumina 99.5% sheet, and a surface wave launcher (SWL) to produce the initial reference waves on the substrate. To achieve a bidirectional radiation pattern, the fundamental TE mode is excited by applying a Vivaldi antenna (the SIW). The proposed holographic-based leaky wave antenna (HULA) is fabricated and tested and the measured results are aligned with the simulated ones. The antenna has 22.6 % fractional bandwidth with respect to the central frequency of 30 GHz. The interference pattern is determined to generate a 15-degree back tilted bidirectional radiation pattern with respect to the normal of the hologram sheet. The frequency scanning property of the designed HULA is also investigated.

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

T11 Fundamental research and emerging technologies / Convened Session / Antennas
Room: 84

8:30 Engineering the Realizations of Localized Waves with Independently Addressable Pulse Driven Arrays
Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)
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 is emphasized. It is further described that many of the exotic properties associated with launched localized waves can be realized with these arrays.

8:50 Terahertz X-wave Launchers by Metallic Spindle-Profiled Homs
Srdan Pakovic (Université de Rennes 1, France); Nicola Bartolomei (Université de Rennes 1, France); Mauro Etter (University of Rennes 1 & UMR CNRS 6164, France); Ronan Saulieux (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 spindle-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 is compared to other solutions presented in the literature.

9:10 An Overview of the Techniques to Generate Limited-diffractive Bessel Beams and Localized Pulses by Using RLSA and Leaky-Wave Antennas
Santi Concetto Pavone (Università degli Studi di Catania, Italy); Walter Fuscaldo (Sapienza University of Rome, Italy); Alessandro Gali (Sapienza University of Rome 1, Italy); Matteo Albani (University of Siena, Italy)
In this paper, two different but complementary techniques developed to generate limited-diffractive electromagnetic (EM) beams and pulses by using radial line slot arrays (RLSA) and leaky-wave (LW) planar devices at microwave/millimeter wave frequencies are discussed. In the first part of the paper, the two kinds of RLSA beam launcher designs are presented, obtained by implementing an inward cylindrical wave-tapering aperture distribution in the longitudinal and transverse electromagnetic fields. Moreover, in the second part, two different LW launcher designs are presented, namely based on forward and backward leaky waves.

9:30 Multi-spot Adaptive Near-Field Focusing Through Transmitting Time-Modulated Arrays
Rafael González Ayestarán (Technical University of Cartagena, Spain); Marcos R. Pino (Universidad de Oviedo, Spain); Paolo Neja (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 propagation of digital signals and phase shifting of the time to create a spatial distribution of the radiation 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 a strong reduction in 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.

9:50 Space-Fractional Bessel Beams with Self-Healing and Diffraction-Free Propagation Characteristics
Aqsa Khan and Muhammad Qasim Mehmood (Information Technology University of the Punjab, Pakistan); Yee Sin Ang (Singapore University of Technology and Design, unknown); Lay Kee Ang (SUTD, Malaysia); Muhammad Zubair (Information Technology University of the Punjab, Pakistan & Singapore University of Technology and Design, Singapore)
In the recent years, fractional-dimensional approach has gained the attention of researchers due to its applications in modeling complex structures. In this paper, we introduce a new class of non-diffracting space-fractional Bessel beam using a new type of solution of the cylindrical wave equation in a fractional-dimensional space. It encompasses the limiting cases of both the ordinary integer order Bessel beam and the fractional-order Bessel beam. In contrast to the ordinary Bessel beam, the fractional-order Bessel beam can have an arbitrary non-integer dimension that is less than or equal to three. This beam preserves the non-diffracting property of Bessel beam and is also self-healing in nature. The propagation features of this new class of solutions are discussed in comparison with ordinary Bessel beams. beams of these types have evident advantages in the near-field applications such as optical trapping and manipulation.

10:10 Coffee Break

10:40 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); Roberto Palmeri (Università Mediterranea di Reggio Calabria, Italy); Tommaso Isiami (University of Reggio Calabria, Italy)
We propose a new approach to deal with second harmonic generation (SHG) in dielectric bore antennas by focusing the field inside the antenna gap. This is conveniently done via convex optimization techniques which ensure global optimal solution for both scalar and vector fields. For the sake of simplicity we consider such a problem in 2D geometry dealing with parallel TE and orthogonal polarization (TM) of the electric field.

11:00 Field Focusing for Nanophotonic Engineering and Applications
Loreto Di Donato (Università di Catania, Italy); Davide Rocco (Università degli Studi di Brescia, Italy); Gino Sorbello (Università degli Studi di Brescia, Italy); Costantino De Angelis (Università degli Studi di Brescia, Italy)
We propose a new strategy to deal with second harmonic generation (SHG) in dielectric bore antennas by focusing the field inside the antenna gap. This is conveniently done via convex optimization techniques which ensure global optimal solution for both scalar and vector fields. For the sake of simplicity we consider such a problem in 2D geometry dealing with parallel TE and orthogonal polarization (TM) of the electric field.

11:20 Frequency-Scanned Focused Leaky-Wave Antennas for Direction-of-Arrival Detection in Proximity BLE Sensing Applications
Miguel Poveda-Garcia (Technical University of Cartagena, Spain); Alejandro Gil Martinez (Technical University of Cartagena, Spain); Jose Luis Gomez-Tornero (Polytechnical University of Cartagena, Spain)
The synthesis of monopulse functions in the Fresnel region for Direction-of-Arrival (DoA) detection in proximity sensing applications, based on the use of near field focused leaky wave antenna (LWA), is presented in this work. It is demonstrated that, using the three advertising channels provided by the Bluetooth Low Energy (BLE) protocol: channel 247, 470 and 483 at the frequencies 2.402, 2.426 and 2.44 GHz, respectively, the focusing technique allows for obtaining well-defined radiation patterns in the vicinity of the antenna, which properly overlap to obtain monopole functions. This is not possible with conventional far-field focused antennas, in which the radiation pattern is very distorted in the near-field region, as it is shown in the work. Also, the limits of this near-field focused antenna is discussed.

11:40 Cascaded-Metasurface Non-Integer Cylindrical Bessel Beam (NIC-BB) Generator
Rafael González Ayestarán (Technical University of Cartagena Cartagena, Spain); Costantino De Angelis (Technical University of Cartagena Cartagena, Spain); Giada Battaglia (Technical University of Cartagena, Spain)
We present a generator of Non-Integer Cylindrical Bessel Beams (NIC-BB), which may find applications in com- munication systems, polarmatic instrumentation and particle routing. This device consists of a pair of cascaded phase- plate metasurfaces illuminated by a uniform circularly polarized wave, where the first metasurface provides the required phase distribution while the second provides the required polarization distribution. It is accompanied by a powerful design procedure, which involves a unique metaparticle shape with fast axis rotated according to the geometric phase principle and Stokes parameter synthesis.
CS25: Convergence of Mobile Radio and Radar

T08 Positioning, localization & tracking / Convened Session / Propagation
Room: B5

Chairs: Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany); Reiner S. Thomä (Ilmenau University of Technology, Germany)

8:30 Towards Joint Sensing and Communication for 5G and Beyond Systems
Andrea Masca and Paolo Rocca (University of Trento, Italy); Marco Salucci and Nicola Anselmi (ELEDA Research Center, Italy)

The acquisition of an accurate channel model through high-resolution environmental sensing is of crucial importance to future multi-Hop multiple-input multiple-output (MIMO) systems. Nevertheless, noalways MIMO beam-forming networks perform the channel sensing through pilot signal transmission, using sets of orthogonal beams, therefore not optimal sensing of the channel is acquired. For this reason, a novel mobile communication paradigm is presented in this work as the joint point of the sensing and communication beams, in order to enable high channel capacity through capacity-driven synthesis of the communication beams, and (high) resolution modeling of the channel through dedicated beam patterns synthesized for optimal sensing performances.

8:50 An OCDM Radar-Communication System
Lucas Giroti de Oliveira, Mohamad Basim Alabd and Benjamin Nuss (Karlsruhe Institute of Technology, Germany); Thomas Zwick (Karlsruhe Institute of Technology (KIT), Germany)

This study investigates a Radar-Communication (RadCom) system based on the orthogonal chip division multiplexing (OCDM) scheme, which is introduced as an alternative to the conventional orthogonal frequency-division multiplexing (OFDM). In this context, a description of the system model addressing both communication data and radar signal generation is presented. Next, the communication and radar aspects of the introduced OCDM RadCom system are compared with the ones of a OFDM counterpart. It is concluded that the introduced system yields lower bit error rate values, while demanding higher computational complexity and presenting higher sideband level than OFDM RadCom.

9:10 IQ-Imbalance Compensation for Wideband OFDM-Radar
Benedikt Schweizer and Christina Knill (Ulm University, Germany); Daniel Schindler (Robert Bosch GmbH, Germany); Christian Waldschmidt (University of Ulm, Germany)

Stepped-carrier orthogonal frequency division multiplexing (OFDM) radar is a promising low-cost alternative to conventional frequency-modulated continuous-wave (FMCW) radars. In this paper, we investigate centralized time-frequency resource allocation strategies in OFDM radars. We present a novel approach to perform Boolean relaxation to obtain an efficiently solvable convex program. Simulation results demonstrate radar-optimal and communication-optimal operation regimes, providing insights on time-frequency weightings along the trade-off curve.

9:30 A MIMO Joint Communication-Radar Measurement Platform at the Millimeter-Wave Band
Preeti Kumari (UT Austin, USA); Amine 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 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 using mmWave channel measurements. We develop this platform by extending a mmWave communication setup 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 our testbed at 73 GHz with 2 GHz bandwidth can capture the JCR channel with high range/doppler estimation accuracy. The comparison between the communication and radar channel shows the potential for improving JCR performance by exploiting the antenna diversity due to widely-separated communication and radar receivers.

9:50 Mutual Over-The-Air Synchronization of Radar Sensors
Thomas Dallmann (Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, Germany)

Orthogonal frequency-division multiplexing is a promising modulation format for future automotive radar sensors. Although it benefits from a simple homodyne interference-free design, it requires quadratic signal generation and evaluation, which suffers from IQ imbalance in transmitter and receiver. This paper describes the effects of IQ imbalance on OFDM radars in general and demonstrates how digital signal processing techniques can be adopted to mitigate this impairment based on adaptive filtering. The effectiveness of the approach is demonstrated with simulations.

10:10 Coffee Break

10:40 System Level Synchronization of Phase-Coded FMCW Automotive Radars for RadCom
Franz Lampel (Eindhoven University of Technology, The Netherlands); Fanuk Ulusoy (Delft University of Technology, The Netherlands); Recep Fait Tügíner (Eindhoven University of Technology, the Netherlands); Simone Ortu (Delft University of Technology, The Netherlands); Alvarado (Eindhoven University of Technology (Tu/e), The Netherlands); Frans MJ Willems (Technical University Eindhoven, The Netherlands); Alexander Varoy (TU Delft, The Netherlands)

This paper describes an FMCW based radar and communication (RadCom) system and addresses the challenges in the synchronization of multiple units for communication functionality. We propose a novel technique to detect the FMCW 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, an approach based on FMCW RadCom signal time of arrival estimation is proposed. The potential capabilities of a RadCom system is experimentally demonstrated for the first time by a set of automotive-grade mmWave radars with GPS-based synchronization.

11:00 Performance of OFDMA Resource Scheduling in Joint Mobile Radio and Radar Networks
Steffen Schier (Ilmenau University of Technology, Germany); Michael Dobrerer (Technische Universität Ilmenau & Fraunhofer IIS, Germany); Reiner S. Thomä and Christian Schneider (Ilmenau University of Technology, Germany); Giovanni Del Galdo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universität Ilmenau, Germany)

Joint mobile radio and radar systems using real 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 our testbed at 73 GHz with 2 GHz bandwidth can capture the JCR channel with high range/doppler estimation accuracy. The comparison between the communication and radar channel shows the potential for improving JCR performance by exploiting the antenna diversity due to widely-separated communication and radar receivers.

11:20 Stepped-Carrier OFDM V2V Resource Allocation for Sensing and Communication Convergence
Musa Furkan Keskin, Canan Aydogdu and Henk Wybomsch (Chalmers University of Technology, Sweden)

Stepped-carrier orthogonal frequency-division multiplexing (OFDM) radar is a promising low-cost alternative to conventional OFDM radar for automotive applications due to its capability to provide high resolution with low-rate analog-to-digital converters (ADCs). In this paper, we investigate centralized time-frequency resource allocation strategies in vehicular networks for vehicle-to-vehicle (V2V) safety applications employing stepped-carrier OFDM for joint radar and communications. To quantify resolution and communication performance trade-offs, we formulate a non-linear integer programming problem for weighted optimization of radar accuracy and communication spectral efficiency, and perform both relaxation to obtain an efficiently solvable convex program. Simulation results demonstrate radar-optimal and communication-optimal operation regimes, providing insights into time-frequency weightings along the trade-off curve.

11:40 Accuracy Requirements for Cooperative Radar with Sensor Fusion
Mohd Ashshy (TU Wien, Austria); Christian Elaisch (Vienna University of Technology, Austria); Thomas Blazek and Christoph F Mecklenbräuker (TU Wien, Austria)

Reliability and robustness are the essential requirements for automotive radar systems. However an automotive radar system suffers from environmental conditions and interference. Applying a proper radar data fusion algorithm can significantly increase the detection probability and robustness. This paper investigates the accuracy requirements based on the geometric parameters for cooperative radar systems with central sensor fusion. The results show that a radar sensor fusion approach for cooperative radars can increase the detection probability and therefore the system robustness by using at least two radar sensors. Furthermore, results show that three to four sensors at a minimum distance of ten meters are sufficient for high quality estimation. At the same time the system requirements regarding the accuracy for each 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 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 can be calculated for each component individually. Thereby, the model relates the amplitudes 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 a specular reflector. A comparison of modeled
We have developed a portable, side-by-side transmission 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 design, transmission mode utilizing adjacent open-circuit coaxes, and narrowing of the aperture in the co-located planes. These features are in stark contrast to the more ubiquitous and commercially available reflection-based dielectric probes. We have exploited 3D printing technology to develop geometries that can provide both performance and user convenience.

8:50 An NRW Extension for Dielectric Characterization of Arbitrary Length Low-Loss Materials
Hassan Shwaykani; Joseph Costantine and Ali EHeri (American University of Beirut, Lebanon); Mohamdd Al-Husseini (Beirut Research and Innovation Center, Lebanon)

In this paper, we propose an extension for the Nicolson-Ross-Weir (NRW) method that enables the retrieval of the electrical parameters of low-loss materials that are thicker than one-half wavelength (L/2). The proposed extension overcomes the NRW intrinsic limitation that causes a divergence of results at frequencies where the material thickness is an integer multiple of L/2. The proposed method may be used for characterizing a wide class of materials found in biological and medical settings.

9:10 Clustering of Dielectric and Colour Profiles of an Ex-vivo Burnt Human Skin Sample
Pramod K B Rangash (Researcher & Uppsala University, Sweden); Javad Ebrahimi Zadeh (University of Uppsala, Sweden); Abhishek Honganally Nagaranj (Uppsala University & Uppsala, Sweden); Irina Ali-El and Mokhitar Kouki (Datametrix AG, Switzerland); Bappadiyappa Mandal (Uppsala University, Uppsala, Sweden); Fredrik RM Huss (Uppsala University Hospital & Uppsala University, Sweden); Mauricio D Perez (Uppsala University, Sweden); Robin Augustine (Uppsala University, Sweden)

In this work, we introduce two techniques to characterize human skin tissue using dielectric and colour profiling. The first method is the vectorial measurement of permittivity by using an open-ended coaxial 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 mean 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 intensity range, various centroid values, and silhouette evaluation.

9:30 Non-Invasive Transmission Based Tumor Detection Using Anthropomorphic Breast Phantom at 2.45 GHz
Laya Joseph (FTE, Angstrom Laboratory, Lägerhyddsvägen 1 & Uppsala University, Sweden); Noor Badarshah Asan (Uppsala University, Sweden & FPEKK, Universiti Teknologi Malaysia Melaka, Malaysia); Javad Ebrahimi Zadeh (University of Uppsala, Sweden); Arvind Selvan Chezhian (Uppsala University, Sweden); Mauricio D 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 stable breast phantom with skin, fat, muscle and spherical Human tissue model and a transmission-based sensing for tumor detection. The proposed breast phantom emulates the anatomical, physical and electrical properties of human breast tissue. The dielectric properties of the breast tissues are measured using open ended coaxial probe from Keysight Technologies in the frequency range of 500 MHz-2 GHz. The S21 sampling parameters are measured and studied for a normal breast phantom and breast phantom with tumor models representing its different growth stages using Topology Optimized Planar Antenna (TOPA) based probe. The study shows a detection S21 amplitude variation of 2 - 12 dB for tumor inclusion model of size from 4mm - 16mm diameter with respect to normal breast model. This study indicates that with further development transmission-based methods can be used for preliminary screening of breast tumor.

9:50 On the Optimal Matching Medium and Working Frequency in EM-based Medical Devices
Gennaro G. Bellizzi (Enamurs University Medical Center, Italy); Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy)

From an engineering perspective, propagation theory is underlying all electromagnetic-based medical devices development. Optionally selecting the matching medium and the operating frequency has a pivotal role in terms of technical as well as clinical efficiency of such devices. Hence, sub-optimal, yet easy to realize, working conditions are usually adopted without taking into account some important aspects of propagation theory. In this paper, 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
Bappadiyappa Mandal (Uppsala University, Uppsala, Sweden); Laya Joseph (FTE, Angstrom Laboratory, Lägerhyddsvägen 1 & Uppsala University, Sweden); Javad Ebrahimi Zadeh (University of Uppsala, Sweden); Mauricio D Perez (Uppsala University, Sweden & National Technological University, Argentina); Thiemo Voigt (Swedish Institute of Computer Science & Uppsala University, Sweden); Robin Augustine (Uppsala University, Sweden)

A flexible low profile bio compatible implantable antenna for fat intra-body communication is presented. This article gives an idea of fat channel communication at different distances. The antenna is designed on 0.23 mm thick low loss coaxial material. The antenna is cover by 0.1 mm thick PTFE (Polytetrafluoroethylene) to ensure bicoompatibility with human tissue. A coplanar wave (CPW) microstrip line is used to feed the antenna. This antenna has been optimized to operate at the 2.4 GHz ISM band frequency in the human three-layer tissue model. The simulation, as well as experimental measurement, was done at minimum distance of 10 mm, and the maximum distance of 70mm between two implantable antennas. The measured path loss of the fat channel by using the proposed implantable antenna is estimated to be almost 2.55 dB per centimeter. The measured bandwidth of the proposed antenna found to be 60 MHz.

11:00 Optimal Probe Geometry for Microwave Monitoring During In-Lab Ex-Vivo Measurements
Giselle González-González (Universitat Politècnica de Catalunya, Spain); Susana Amoros García 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 applications is presented. This geometry is meant to be of use for mimicking the shape and dielectric properties of certain parts of the human body, and to recreate 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 setup, and the results are presented.

11:20 MetaSurfaces Sensors for Healthcare Applications
Antoine Durant (Edinburgh Napier University, United Kingdom (Great Britain) & Université Grenoble Alpes, France); Celia Lacooste (INP-ENSEEHT University of Toulouse, United Kingdom (Great Britain)); Erin Donnelly and Luigi Spada (Edinburgh Napier University, United Kingdom (Great Britain))

Electromagnetic sensors have received huge attention in the last few years due to the increasing demand of devices able to improve quality, performance and safety in different industrial sectors: both sensing and medical industries are outstanding examples. Despite reliable diagnostic technologies have been developed, some drawbacks are still present: bandwidth, huge dimensions and limited control response. Metasurfaces, bi-dimensional engineered materials, represent an optimal solution to overcome such issues existing systems for an accurate diagnosis. Therefore, in this paper, meta-surface-based sensors are proposed and realized by using new additive manufaturing processes. The structures are finally experimentally tested and verified in different medical diagnostic applications, namely: cancer stage recognition, glucose/sugar levels measurements and blood oxygen saturation detection. The high performances shown by such meta-sensors, in terms of selectivity and sensitivity, pave an new way to realize advanced platforms for non-invasive, high quality and faster patient diagnosis.

11:40 An Accelerometer - Based Evaluation of Tintelli Scale
Andrea Tilocca (Politecnico di Torino, Italy); Guido Pagana (LINKS Foundation, Politecnico di Torino)

In this work we developed a system to identify in a more objective way subjects at risk of fall using the Tinetti Scale tool. The aim of the work is to show the efficiency of new smart wearable flexible sensors, in special accelerometer to help medical figure to evaluate the capability of recognizing frail subjects reinforcing the score of the scale.

12:00 Multiple-Pole CSRR-based Microwave Sensor for Glucose Levels Detection
Ala Eldin Omr (University of Waterloo, Canada); George Shaker (University of Waterloo & Spark Tech Labs, Canada); Safedinn Safavi-Naeini (University of Waterloo, Canada); Hamid Kokabi (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, Canada); Georges Alquier (UPMC, France); Frederique Frederique Deshouls (Laboratory of Electronics and Electromagnetism (L2E), Sorbonne University, France)

We propose a microwave biosensor that comprises a rectangular piezoelectric channel integrated on a multiple-hole complementary splitting resonator structure. The sensor operates in the center-band 1.5 - 6 GHz and is fabricated on top of a thin PFA 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 near-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
Reducing the Dimensionality of 6-D MoM Integrals Applying Twice the Divergence Theorem

Giacomo Fassano (Aalto University, Finland); Giuseppe Esposito (IREA-CNR, Italy); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

In order to separate the contributions of the different factors in the dimensionalities of MoM integrals, we present a new methodology to reduce the dimensionality of 6-D MoM integrals using the double divergence theorem. This technique is applicable to both the MoM and MOF methods, and it significantly reduces the computational cost. The effectiveness of the proposed methodology is demonstrated through numerical examples involving complex 3-D geometries.

Analytic Expressions for Matrix Elements of Integral Equation Operators and Aspects of Their Numerical Implementation

Pasi Ylä-Ojala and Henrik Wallén (Aalto University, Finland)

The matrix field integral operator (MFIO) based characteristic mode formulation is widely used in the analysis of electromagnetic scattering problems. In this paper, we present analytic expressions for the matrix elements of the MFIO, which are derived using the method of moments. These expressions are useful for reducing the computational complexity of the method and for improving the accuracy of the numerical implementation.

Characteristic Mode Equations for Non-Symmetric Surface Integral Operators

José Rodríguez-Piñeiro, Tomás Dominguez-Bolaño (University of A Coruña, Spain); Xuefeng Yin (Tongji University, China); Yooj Lee (ETRI, Korea (South)); David W Matolak (University of South Carolina, USA)

The characteristic mode equations for non-symmetric surface integral operators are derived in this paper. These equations are used to solve electromagnetic scattering problems involving non-symmetric surfaces. The proposed methodology is validated through numerical examples, and the results show excellent agreement with previous studies.

Synthetic Translation Operators for Multiple-Resolution Fast Multipole Method

Zheyu Huang and José Rodríguez-Piñeiro (Tongji University, China); Tomás Dominguez-Bolaño (University of A Coruña, Spain); Xuefeng Yin (Tongji University, China); Yooj Lee (ETRI, Korea (South)); David W Matolak (University of South Carolina, USA)

The multiple-resolution fast multipole method (MRFMM) is a powerful technique for solving electromagnetic scattering problems. In this paper, we present synthetic translation operators for the MRFMM, which significantly improve the accuracy and efficiency of the method. The effectiveness of the proposed operators is demonstrated through numerical examples involving complex 3-D geometries.

Characterization of Discrete-Time Waveguide Filters

Marek Bleszynski, Dr (Monopole Research, USA); Yosef Pinhasi (Ariel University, Israel); Wei Fan (Ariel University, Israel)

Discrete-time waveguide filters are used in various applications, such as signal processing and communication systems. In this paper, we present a detailed characterization of discrete-time waveguide filters, including their frequency response and group delay. The results are validated through experimental measurements.

Matrix-based Characteristic Mode Formulation for Non-Symmetric Scattered Radar Cross Section

Yair Richter (Ariel University, Israel); Wei Fan (Ariel University, Israel)

The matrix-based characteristic mode formulation is a powerful technique for solving electromagnetic scattering problems involving non-symmetric surfaces. In this paper, we present a new matrix-based characteristic mode formulation for non-symmetric scattered radar cross section (RCS). The effectiveness of the proposed formulation is demonstrated through numerical examples involving complex 3-D geometries.

Reducing the Dimensionality of 6-D MoM Integrals Applying Twice the Divergence Theorem

Giacomo Fassano (Aalto University, Finland); Giuseppe Esposito (IREA-CNR, Italy); Thomas F. Eibert (Technical University of Munich (TUM) & Chair of High-Frequency Engineering (HFT), Germany)

In order to separate the contributions of the different factors in the dimensionalities of MoM integrals, we present a new methodology to reduce the dimensionality of 6-D MoM integrals using the double divergence theorem. This technique is applicable to both the MoM and MOF methods, and it significantly reduces the computational cost. The effectiveness of the proposed methodology is demonstrated through numerical examples involving complex 3-D geometries.
This paper proposes a scheme for evaluating the 6-D interaction integrals appearing in volume integral equation solved with the Method of Moments and tetrahedral elements. We treat as a whole the double integral applying, the divergence theorem first on the source domain and then on the test domain. With the proper variable transformation and reordering, the 6-D integrals are expressed as two radial integrals plus four linear integrals over the source and observation domain planes.

9:50 Toward Extremely Scalable IE-DDM for Distributed Computing
Víctor Martín (Universidad de Extremadura, Spain); Diego M Solis (University of Pennsylvania, USA); David Larios (Universidad de Extremadura, Spain); Luis Landesa (Universidad de Extremadura, Spain); Fernando Obelleiro (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 (SIE-DDM) in distributed memory computers for the simulation of extremely large scale and complex problems. The proposed approach greatly reduces the global communication and memory burden, providing an extremely scalable implementation both in time and, especially, in memory.

10:10 Coffee Break

10:40 Overview of Surface-Surface Electric Field Integral Equation Formulations for 3-D Composite Metal-Dielectric Objects
Reza Ghofrani (University of Toronto & University of Manitoba, Canada); Shuochen Zheng and Vladimir Okhmatovski (University of Manitoba, Canada)
The Surface-Surface Electric Field Integral Equation (SSEFIE) 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 SSEFIE formulation utilizes only the electric field dyadic Green's functions, it can be extended to the case of composite objects situated in non-magnetic planar multilayered media by casting its operators into the mixed-potential form using classical Michalowski-Zheng's approach. Examples of the above SSEFIE formulations are summarized in the paper.

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/statistical model to analyze the information transmission 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 into the mathematical information theory. The work qualitatively characterizes the correlated Rayleigh diffusive multipath, coherent specular direct paths, and mutual coupling between antennas. The theoretical research is evaluated and validated through representative experiments.

11:20 Modal Characterization of Thermally Emitting Using the Method of Moments
Denis Yiron (University of Cambridge, Belgium); Stafford Withington (Cavendish Laboratory, University of Cambridge, Great Britain); Christophe Craeye (Université Catholique de Louvain, Belgium)
Emissive sources relying on spontaneous emission are difficult to characterize without a proper framework due to the partial spatial coherence 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 eigenmode corresponds to one independent degree of freedom through which the emitter radiates power. The proposed formalism is implemented using the Method of Moments (MoM) and applied to axi-symmetric and a cavity. It is shown that electrically small structures can be characterized with 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
Abdelhakine 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 only useful for designing new antennas, but for improving the performance of legacy designs as well. However, these antennas are usually multistatic in nature and they typically require an inordinately long time when simulated by using commercial solvers. In this work, we present a new approach for analyzing antennas that utilize Metasurfaces (MTFs) and Metamaterial (MTMs). The proposed method exploits 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 EM solvers. Several illustrative examples are presented in the paper to demonstrate the efficiency of the present approach when simulating MTMs and MTs based antennas.

12:00 Fast and Accurate Analysis of Multiperiodic Structures Using the Design of Reflectarray and Metasurfaces
Miguel Camacho (University of Pennsylvania, USA); Rafael R. box (University of Seville, Spain); Francisco Medina (University of Seville, Spain)
The spectral domain 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 reflectory and metasurfaces antennas. 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 (D 2 FT) of the basis functions can not 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 commercial solvers. Moreover, the SD-MoM turns out to be faster than the conventional SD-MoM customarily used when the 2-D FT of the basis functions can not be obtained in closed-form.

T10-E05/1: Electromagnetic Methods for Direct and Inverse Scattering Involving Stratified Media

8:30 Electromagnetic Excitation of a Layered Medium by N Magnetic Dipoles
Andrews Kalogeropoulos and Nikolaos L. Tsitsas (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
Sida Barooti, Mehrosh Niaz, Fabio Mangini and Fabrizio Frezza (Sapienza University of Rome, Italy)
This paper analyses the electrostatic responses of polarly 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 yield cloaking 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 the presence of the NID space and ordinary space. However, SRA spherical shell is independent of the presence of NID space for NID space and ordinary space.

9:10 Reflected Wave Fields from a Fluctuating Earth Surface - a Phase-Space Approach
Valon Blakaj (Research Associate, United Kingdom (Great Britain)); Gabrielle Gradoni, Stephen Creggh 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 modeling complex and noisy sources. We focus on the application of this approach to modeling of wave fields reflected from rough Earth, with potential applications in microwave remote sensing.

9:30 Towards Asteroid Tomography: Modellings and Measurements Using an Analog Model
Christelle Eyraud (Institut Fresnel, Aix Marseille Université, CNRS, Centrale Marseille, France); Lisa-Ida Sorsa (Tampere University, France); Alain Hériqué (Université Grenoble Alpes, CNRS, IPAG, France); Jean-Michel Geoffrin (Institut Fresnel & Aix Marseille Univ, CNRS, Centrale Marseille, France); Sampsa Pursiainen (Tampere University, France); Wlodko Kofman (Université Grenoble Alpes, CNRS, IPAG/Space Research Centre, PAS, France)
The interior structures of the comets and asteroids, still poorly known, might hold a 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, and might hold a unique signature of the object itself. To reach the ultimate goal of reconstructing their interior structure via multiple measurements, constitutes a challenging inverse problem. To reach this objective and to 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 objects 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 Modeling Cylindrical Slot Antenna for Beetle GPR

T10 EM modelling and simulation tools / Regular Session / Electromagnetics

Room: 20

Chairs: Alessandro Fedeli (University of Genoa, Italy), Cristina Ponti (Rome Tre University, Italy)
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: 3D Analytical Model

Alexei Popov (Puchkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russia); Pavel Morozov (IZMIRAN, Russia); Fedor Morozov (JSC VNISM, Russia); Igor Prokoppovich (IZMIRAN, Russia)

A numerical approach to GPR probing of homogenous medium is developed, based on the coupled wave NWB approximation. The numerical model is validated using a 

11:00 Qualitative Imaging of Experimental Multistatic Ground Penetrating Radar Data

Michele Ambrosano (Università di Napoli Parthenope, Italy); Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy): Vito Pascazzo (Università di Napoli Parthenope, Italy); Tommaso Ieseia (University of Reggio Calabria, Italy)

Subsurface imaging of unknown buried objects is of fundamental importance in several fields, spanning from civil engineering applications to safety and biomedical issues. The detection of objects located in an investigation domain in a nondestructive fashion can be faced via addressing an electromagnetic inverse scattering problem. In this paper, an experimental assessment of a simple, linear approach, known as a linear sampling method (LSM) is proposed. The results show good recovery performance and robustness against moderate errors while keeping low computational burden, which is very important for practical, almost real-time applications.

11:20 Multi-Resolution Through-the-Wall Microwave Imaging of Strong Scatterers

Federico Bouda (ELEDA@UnInT - DISI, University of Trento, Italy); Marco Salucci (ELEDA Research Center, Italy); Kuiwen Xu (Hangzhou Dianzi University, China); Yu Zhong (A*STAR IHP, Singapore); Andrea Massa (University of Trento, Italy)

The use of highly non-linear through-the-wall microwave imaging (TWMI) problems is addressed. An inverse scattering inversion (LS) methodology is proposed to retrieve strong scatterers embedded within a known homogeneous background. Towards this goal, the LS problem at hand is formulated in a differential imaging framework allowing the exploitation of a priori information on the probed domain. Then, the localization and regularization capabilities of the difference contractive integral equation (D–CIE) method are compared with those of a multi-resolution (MT) inversion scheme for yielding accurate and reliable quantitative reconstructions. Some preliminary numerical results are shown to verify the effectiveness of the D–CIE approach, as well as to demonstrate its superior performance over standard single-resolution (SR) solution strategy.

11:40 Forward and Inverse Scattering Models Applied to Through-Wall Imaging

Alessio Fedeli and Matteo Pastorino (University of Genoa, Italy); Cristina Ponti (Roma Tre University, Italy); Andrea Randazzio (University of Genoa, Italy); Giuseppe Schettini (Roma Tre University, Italy)

Through-wall imaging is an application field in which microwaves play an important role, thanks to their ability of penetrating foreign materials. In this framework, the aim of this paper is to extend it. On the one hand, it presents an analytic forward model able to effectively describe the scattering phenomena by fully taking into account all the reflection and transmission effects due to the wall. On the other hand, a new inversion procedure, able to address the full underlying non-linear inverse scattering problem, is introduced. Some numerical results aimed at validating the two approaches are shown.

12:00 Image Radar Determining the Nominal Body Contour for Characterization of Concealed Person-Worn Explosives

Mohammad M. Tagdini, Kurt Jaisle and Carey Rappaport (Northeastern University, USA)

Accurate characterization of suspicious body-worn objects may speed up the passenger screening process by reducing the number of manual screenings while maintaining the ability to detect more complex threats. This improves passenger experience in the screening process while preserving strong security. This paper presents an innovative real-time method for millimeter wave near-field radar reconstructing the nominal contours of human bodies without affording foreign objects. This important step is required for characterizing unique aspects of concealed objects when they are affixed to the body. The method is verified experimentally when applied to the images of a recently developed laboratory prototype millimeter-wave scanning system. The method works well both when there is a weak dielectric object affixed to human body and when a portion of the body cross-section is not captured by the imaging system. The reconstructed contour can be used to estimate the dielectric constant of the suspicious body-worn objects.

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

Room: B10
Chair: Francesco Saccardi (Microwave Vision Italy, Italy)

8:30 Near-field to Far-field Transformation for Fast Linear Slide Measurements

Santosh Rodriguez Varela (Universidade Politécnica de Madrid, Spain); Ruben Tena Sanchez (Technical University of Madrid, Spain); Manuel Jose Ramirez-Lopez (Universidad Carlos III de Madrid, Spain); Manuel Sierra-Castañer (Universidad Politécnica de Madrid, Spain)

This paper presents an algorithm for the far-field transformation of fields measured over linear cuts (slides) in planar measurement scenarios. Instead of scanning the complete plane, only two perpendicular slide measurements are performed, which reduces drastically measurement times. From these two measurements, the radiation pattern in the main cut can be obtained, and then, the full 3D pattern is derived. The algorithm is based on particularizing the plane near-field to far-field transformation theory to one-dimensional space. The proposed technique is presented and tested using simulated and measured data, showing low transformation errors and promising capabilities for the fast testing of antennas.

8:50 Fast Single-Cut Antenna Characterization by near Field Measurements

Amedeo Capozzoli, Claudio Curcio and Angelo Liserio (Università di Napoli Federico II, Italy)

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

Yasuhiro Omi (Université de Genève, Switzerland); Lucio Scialacqua (Università di Napoli Parthenope, Italy); Frédéric Masson (ELEDA Research Center, Italy); Kuiwen Xu (Hangzhou Dianzi University, China); Yu Zhong (A*STAR IHP, Singapore); Andrea Massa (University of Trento, Italy)

A single-cut near-field (NF) radar cross-section (RCS) measurement method is proposed which is based on the full-wave formulation. The method enables the exact prediction of RCS by 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 (NFFFT) for antenna measurements and consists of NFFFT and implicit plane-wave synthesis (IPWS) steps. The proposed method is formulated based on the scanning theory discussed and validated numerically and experimentally.

9:30 Experimental Determination of the Total Radiated Power of Automotive Antennas in the Installed State

Mehmet Emre Yalagah and Christian Bommel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

The non-redundant sampling representations of electromagnetic fields and the image principle are properly applied in this work to develop an effective probe-compensated near-field to far-field (NF/FF) 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 is first tested and the image is assumed as an enclosed in a surface consisting of a cylinder ended in two half spheres. Then, an efficient 2-D optimal sampling interpolation scheme is used to reconstruct the NF data required by the standard spherical NF/FF transformation from the NF samples collected over the upper hemisphere and from those properly synthesized from the other half. Numerical examples are shown to assess the effectiveness of the developed non-redundant spherical NF/FF transformation.

9:50 AUT Far-field Pattern Reconstruction from a Reduced Set of Near-field Data Collected in Presence of an Infinite Perfectly Conducting Ground Plane

Fernando Rodríguez Varela (Universidad Politécnica de Madrid, Spain); Michaela Amaya (NHU/AIST, Japan); Masanobu Hirose (NMIJ/AIST, Japan); Masanobu Hirose (National Institute of Advanced Industrial Science and Technology, Japan)

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.

10:10 Coffee Break

10:40 Diagnostics on Electrically Large Structures by a Nested Skeletonization Scheme Enhancement of the Equivalent Current Technique

Lucia Scalaqua (Microwave Vision Italy, Italy); Francesca Moic (Consultant, Switzerland); Lars Foged (Microwave Vision Italy, Italy); Giorgio Giordanengo (LINKS Foundation & Politecnico di Torino, Italy); Marco Righero (LINKS Foundation, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)
11:00 Supressing Undesired Echoes by Sparsity Based Time Gating of Reconstructed Sources

Joseph Knapp, Jonas Krompobret and Thomas F. Eibert (Technical University of Munich, Germany)

The free-space radiation characteristic 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 presented 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 the 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 radiation can be determined accurately even at the borders of the measured bandwidth.

11:20 Portable, Freestand System for Antenna Diagnosis Using Amplitude-Only Data

Guillermo Alvarez Narosandi (University of Oviedo, Spain), Jaime Laviada (University of Oviedo, Spain); Yuri Alvarez-Lopez (University of Oviedo, Spain); Guillaume Ducournau (EEMN, University of Lille, France); Cyril Luxey (University Nice Sophia-Antipolis, France); Frédéric Gianello (STMicroelectronics, France); Fernando Las-Heras (University of Oviedo, Spain)

A freestanding 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 analyser 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 current distribution on the AUT aperture, enabling antenna diagnosis. For that, near-field samples are acquired in a scanning zone parallel to the antenna aperture. The far-field pattern radiated by the AUT is computed by means of NF-FF transformation. The system was tested measuring a Ka band horn from an 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.

11:40 Characterisation of a Fibre-Optic Active Probe for Compensation of the Test-Zone Field

Thomas M Gmemer (RWTH Aachen University, Germany), Wieland Mann (enprobe GmbH, Germany); Dirk Heberling (RWTH Aachen University, Germany)

Compensation of the non-ideal Test Zone Field (TZF) in which an antenna under test is characterised 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 polarization 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 determine the suitability of this fibre-optic probe for measuring the incident field and the importance of test-zone probe correction.

12:00 Locating Sources of Reflection Errors in an Anechoic Chamber by Creating an Error Surface Plot

Alé-Hélène Boster (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.

Thursday, 19 March 8:30 - 10:10

BC/3: History of Electromagnetism

Room: B11

Chairs: Ari Shihola (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 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 antennas in the radio wave domain by Hertz, and then march through the evolution of reflector antennas in three major regimes: radars, 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 Spacelab (1975) to the multiple beam array fed reflector antennas of today’s Telecommunication satellites. Some key developments of antennas for telemeetry, tracking & command, of reflector, lens and array antennas for communications, localization and remote sensing will be highlighted, as well as their associated modelling 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 Mallick (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.

Thursday, 19 March 8:30 - 12:20

SW07: H2020 Project ACASIAS (GA N° 723167) - Antennas for Integration into aircraft structure

T12 Scientific / Industrial Workshops

Room: B3
waves are blocked by buildings, trees, etc. In such an environment, it is necessary to clarify the characteristics of ... blockage. The vegetation loss has been standardized as ITU-R P.833-9, but the region and kinds of trees considered are ... and so are not multipath-rich environments. Therefore, it is considered that the received power is reduced when direct ... scenarios will allow for detailed system-level simulations for specific locations and their characteristics. However, planning ... are required appropriate input data. In this paper, we present a process for the generation of realistic railway-based mobility ... used to design the antenna response using a receiver antenna. 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 bulky human tissue in the antenna's near field has an adverse effect on the radiator's performance. The focus of this paper is on studying the change in the antenna performance due to 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/IFA 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 phantom in the numerical simulations and it is found that the variation of the complex relative permittivity within a large range of values does not change largely the S parameters and radiation efficiency of the antenna.

Effect of Dielectric Properties of Human Hand Tissue on Mobile Terminal Antenna Performance
Stanislav Stefanov Zhivkov and Gert Pedersen (Aalborg University, Denmark)
A broadband resonant antenna has been developed for handheld devices, and it is a two-port. It does not use any matching/tuning circuits or extended ground-planes. It can be bent/folded 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 terminal antenna has been developed. 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 from different directions with different polarization in any complicated environment.

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 handheld devices, and it is a two-port. It does not use any matching/tuning circuits or extended ground-planes. It can be bent/folded 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 terminal antenna has been developed. 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 from different directions with different polarization in any complicated environment.

Improvements of Multi-Antenna Specific Absorption Rate Using a Two-Stage Technique
Yuan-Hung Lin and Yin-Sheng Chen (National Taipei University of Technology, Taiwan)
In this paper, we propose a two-stage optimization technique that reduces the multiple-input multiple-output (MIMO) specific absorption rate (SAR) for mobile terminals. In multi-antenna devices, the SAR is affected by amplitude distributions and excitation phases of feed 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 estimation model, which assesses only a few pre-processed simulations yet leads to predictions of SAR resulting from any combination of feed currents. Next, the prediction of SAR is cast into an optimization framework, and an optimization algorithm is applied to determine the current distribution that minimizes the peak MIMO SAR. A four-element antenna is validated to minimize the maximum SAR value of several situations. The optimization results demonstrate that the method exhibits an average improvement of 13.8%.

12:00 Comparison of Different Antenna Cluster Weighting Methods
Jari-Matti Hannula (KTH Royal Institute of Technology, Sweden); Anu Lehtovuori (Aalto University, Finland); Ville Viikari (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 obtain the weights that realize certain impedances. In this work, we consider the case where the weighting is performed by measuring the antenna response using a receiver antenna.

12:20 A Study on Vegetation Loss Mode with Seasonal Characteristics
Daigo Ogata, Akishin Satot, Shota Kimura and Hideki Omote (Softbank Corp., Japan)
In mobile communications, it is necessary to accurately estimate and evaluate the influence of the environment between the BS and the MS, such as the terrain, clutter, vegetation, etc. Round law provide four 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 diffracted 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...
11:40 Channel Modeling for Wireless Sensor Networks Deployment in the Smart City
Eran Greenberg (RAFAEL, Israel); Amitay Bar and Edmund Kiozid (Israel), Lat Polet-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. Unattended 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 near ground/building 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 Analytic Propagation Approximation over Variable Terrain and Comparison to Data
Dmitry Chizhik (Nokia Bell Labs, USA), Jani Moilanen (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 parabola, 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 of Fuerteventura, Spain, resulting in 8.5 dB RMS error, an improvement over a linear fit to data, which has 12.5 dB RMS deviation. The model is intended for use in future lunar missions where rapid coverage calculations are important for selection of optimum landing sites.

T11-P10: Propagation in Biological Tissues

T11 Fundamental research and emerging technologies / Regular Session / Electromagnetics
Room: B7

Chairs: Gennaro G. Bellizzi (Erasmus University Medical Center, Italy), Charles Sammut (University of Malta, Malta)

10:40 EM-Thermal Co-Simulation of Microwave Ablation Applicator in Liver Tissue Phantom with Bowtie-Slot Surface Antenna
Muhamed A. Al-Khan (RheinMain University of Applied Sciences, Germany); Georg Rose (VGU, Germany), Bernd Schweizer (RheinMain University of Applied Sciences, Germany), Andreas Brening (Hochschule RheinMain, Germany)

In this paper, design and electromagnetic-thermal co-simulation of a microwave applicator and a bowtie-slot body matched antenna is discussed. The applicator 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 MRI-guided Hyperthermia
Gennaro G. Bellizzi (Erasmus University Medical Center, Italy), Kernal Simmer (Erasmus MC Cancer Institute, The Netherlands); Ria Forner (UMC Utrecht, The Netherlands), Tommaso Drizdal (Czech Technical University in Prague, Czech Republic), Margarethus 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 FMR thermometry, integrated into a phased array for heating purposes. An experimental setup was constructed consisting of a 4-element heating array working at 8.5 MHz and a 2-channel MRI receiver coil array working at 63.5 MHz. In our approach, these arrays are oriented to exploit polarization decoupling. Vortex vector analyzer measurements showed satisfactory reflection and transmission characteristics for the heating (8.5 MHz) and imaging (63.5 MHz) arrays and the inter-array coupling was as low as 56 dB. We conclude that this combined arrangement is highly suitable for a simultaneous operation.

11:20 An Open-Access Experimental Dataset for Breast Microwave Imaging
Tyson Renner, 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 promising results, but before adequate clinical studies can be conducted, clinical trials need to be performed with a larger dataset. This work addresses the challenges of small sample sizes and a lack of experimental data by providing an open-source experimental dataset, obtained using a pre-clinical BMI system. At time of submission, the University of Manitoba BMI Dataset (UM-BMI) contains data from 452 phantom scans and will be expanded to contain 1257 scans. UM-BMI is publically 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 studied to demonstrate one use of UM-BMI. The diagnostic accuracy of the classifier was (85 ± 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
Jeantide Said Camilleri, Lourdes Farrugia, Julian Bonello and Nikolai Paul Pace (University of Malta, Malta); Adam Santorelli (National University of Ireland, Galway & Translational Medical Device Lab, Ireland); Emily Porter (University of Texas at Austin, USA), Martin OHalloran (National University of Ireland, Ireland); Charles Sammut (University of Malta, Malta)

This paper investigates an innovative method to determine the red and white blood cell concentrations in blood using their dielectric properties at microwave frequencies. The dielectric properties characterise the interaction of a time-varying electric field with the biological tissue. The concentrations of red blood cells (RBCs) and white blood cells in a sample of whole blood can vary due to illness or disease. This study is a proof-of-concept, where the dielectric properties of samples containing RBCs and plasma are investigated. The dielectric properties of samples of different concentration of RBCs in plasma are measured and used to train artificial neural networks which measure the concentration of the known concentrations of RBCs. The results show that a trained neural network can predict the RBC concentrations in arbitrary samples not used to train the model with an average error of ±0.37% with respect to the actual concentration in the samples.

12:00 Temperature-Corrected SAR Focusing in Cancer Hyperthermia
Rosella Gaffoglio and Marco Righezi (LINKS Foundation, Italy); Giorgio Giordano (UNICS Foundation & Politecnico di Torino, Italy), Marcello Zucchi and Giuseppe Vecchi (Politecnico di Torino, Italy)

In hyperthermia cancer treatments, the tumour mass temperature is selectively increased to a supra-physiological level to generate cell death. The power density of a focused microwave is limited. In this paper, we measure and analyze the vegetation loss of deciduous trees in different seasons in Japan. From the results, we propose a new vegetation loss model that can take frequency and seasonal characteristics into consideration.

T12-E01: EM Theory

T11 Fundamental research and emerging technologies / Regular Session / Electromagnetics
Room: B11

Chairs: Daniel Sjöberg (Lund University, Sweden), Niklas Wellander (Swedish Defence Research Agency, Sweden)

10:40 Multiple Scattering by a Collection of Randomly Located Obstacles Distributed in a Dielectric Slab
Gerhard Kristensson (Lund University, Sweden); Niklas Wällander (Swedish Defence Research Agency, Sweden)

Scattering of electromagnetic waves by disordered, randomly distributed objects inside a slab is addressed. The non-interacting scattering objects can be of arbitrary form, material and shape with a number density of 10 (number of scatterers per volume). The main aim of this paper is to calculate the coherent reflection and transmission characteristics for this configuration. Typical applications of the results are found at a wide range of frequencies (radar up to optics), such attenuation of electromagnetic propagation in rain, fog, and clouds etc. The integral representation of the solution of the deterministic problem constitutes the underlying framework of the stochastic problem. Conditional averaging and the employment of the Quasi-Crystalline Approximation lead to a system of integral equations in the unknown expansion coefficients. Explicit solutions for tenueous media and low frequency approximations can be obtained for spherical obstacles.

11:00 Radiation of Planar Dielectric Waveguide Eigenwaves Scattered by Graphene Strip Grating in the THz Range
Mstyslav Kaliberda and Sergey Pogarsky (Karazin National University of Kharkiv, Ukraine), Lubov Kaliberda (Kharkiv Petro Vasylkovo National Technical University of Agriculture, Ukraine)

Scattering of planar dielectric waveguide H-polarized eigenwaves by graphene strip grating in the THz range is considered. The grating is placed inside the waveguide. Our analysis is based on the method of singular integral equations. The scattering and absorption cross section, as well as the radiation patterns, are presented. We concentrate our analysis on studying the characteristics near the plasmon resonances and the grating mode resonances.

11:20 Analytical Modeling and Multiphysics Simulation of Accousto-Electromagnetic Interaction
Niklas Wingen and Daniel Sjöberg (Lund University, Sweden)
11:40 Re: Moving the Scattered Energy from Dielectric Objects in Spatial and Frequency Domain for Cloaking Techniques
Giuseppe Labate (Wave Up S. R. L., Italy); Roberta Palmeri (Università Mediterranea of Reggio Calabria, Italy); Tommaso Iamaia (University of Reggio Calabria, Italy); Andrea Aliu (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 multipolar scattering cancellation, as generalized for dielectric objects, able to suppress the scattered wave on 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 coats able to shift the energy content outside the visible range.

12:00 On the Optical Theorem and Optimal Extinction, Scattering and Absorption in Lossy Media
Sven Nordebo (Linnaeus University, Sweden); Mats Gustafsson (Lund University, Sweden); Yevhen Ivanenko (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 both as well as dielectric background media. Explicit derivations, formulae, 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.

Thursday, 19 March 13:20 - 14:50
Poster Awards: Best Paper Awards Poster Sessions

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)

We explore the possibility to realize nonreciprocal antennas based on combining time-modulated resonators with high-Q structures. Upon an adequate low-frequency nonreciprocal 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 manipulation of the generated waves through the photonic Aharonov-Bohm effect. This approach is demonstrated to be nonreciprocal and reconfigurable antenna configurations, including phased arrays able to independently control transmission and reception radiation patterns at the same operation frequency, reflectarray antennas, and planar Yagi-Uda filter-antennas. We explore the exciting opportunities of 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.

A Method for Extending the Bandwidth of 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)

Modulated metasurface (MTS) antennas can provide a broadband pencil beam at the frequency where the cylindrical surface wave (SW) becomes a true leaky wave because of the impedance mismatch. SW excitation on the MTS is achieved via a multi-layer waveguide technology, where an air-filled waveguide transmission line is formed by stacking several unconnected thin metal plates. The MWS bandpass filter is designed by combining low-pass and high-pass filter linking structures, and consists of 19 separate metal layers. A SW with a fixed Q-factor and a specified frequency range is excited. A MTS antenna is used to couple a specific frequency band of the SW to the antenna. Numerical results confirm that the advantages of MWS technology for implementing ultra-compact bandpass filters showing low loss and potential for being mass-produced at millimeter-wave frequencies.

P3.034 A Compact Mass-producible E-band bandpass Filter Based on Multi-Layer Waveguide Technology
Abbas Vosoughi (Metasum AB, Sweden); Austen Allgaier Brazaier (Ericsson Research, Ericsson AB, Sweden); Yinggang Li (Ericsson AB, Sweden); Zhongxia Simon He (Chalmers University of Technology & Microwave Electronic Lab, Sweden)

This paper presents the design, implementation and experimental validation of a bandpass filter for high-data rate point-to-point links at E-band. The proposed design is developed in multilayer waveguide (MWW) technology, where an air-filled waveguide transmission line is formed by stacking several unconnected thin metal plates. Our MWS bandpass filter is designed by combining low-pass and high-pass filter linking structures, and consists of 19 separate metal layers. The fabricated filter provides a bandpass from 71 to 76 GHz with measured return loss better than 15 dB, and insertion loss less than 1.3 dB. These results confirm the advantages of MWS technology for implementing ultra-compact bandpass filters showing low loss and potential for being mass-produced at millimeter-wave frequencies.

P1.031 Compact and Modular Ka-Band Front-end Concept for SATCOM and 5G
Winfred Simon (IMST GmbH, Germany); David Schaefer (IMST & Antennas & EM Modelling, Germany); Simona Bruni (IMST GmbH, Germany); Marta Arias Campo (IMST GmbH, Germany & IMST GmbH, Germany); Simon Otto (IMST GmbH, Germany); Sybille Holzwarth (IMST GmbH, Germany)

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 RF feeding and antennas. Metallic waveguide and backplane act 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 chips this design concept can be used for SATCOM or 5G.

Design of a Wide-Scan Lens Based Focal Plane Array for Sub-millimeter Imaging Systems Using Coherent Fourier Optics
Shahab Oddin Dabironezare (Delft University of Technology, The Netherlands); Muhan Zhang (Delft University of Technology, The Netherlands); Gianluca Cailia (Delft University of Technology, The Netherlands); Angelo Freni (University of Florence, Italy); Andrea Alù (University of California, Davis, USA)

Future sub-millimeter imaging systems will use large format focal plane arrays (FPAs) of lenses to increase their field of view and the imaging 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 integrable 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 1 dB while scanning up to ±17.5° is presented with directly of 0.2 dB. A prototype of the described design using realistic antenna feeds is also presented.

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 Ivanenko (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 both as well as dielectric background media. Explicit derivations, formulae, 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 Tiukuvaara (Carleton University, Canada); Tom Smy (Carleton University, Canada); Shulabh Gupta (Carleton University, Canada)

Space modulation diffraction gratings are modelled and analyzed using a zero thickness metasurface grating approach, and demonstrated using numerical examples. The constitutive parameters of the grating are described using surface susceptibilities of the Lorentzian form, while their resonant frequencies are sinusoidally modulated. They are then solved self-consistently with the Generalized Sheet Transition Conditions (GSTCs) to determine the scattered fields from the metasurface for specified plane-wave incident fields, for various cases of modulation periodicities and depths.
Elliptical Glide-Symmetric Holyst Metasurfaces for Wideband Anisotropy

Antonio Alex-Amor (Technical University of Madrid, Spain); Paternè Ghassimfarid (KTH Royal Institute of Technology, Sweden); Guido Valero (Sorbonne Université, France); Pablo Padilla (University of Granada, Spain); José Manuel Fernández González (Universidad Politécnica de Madrid, Spain); Oscar Quevedo-Teruel (KTH Royal Institute of Technology, Sweden)

This paper presents a mode matching technique to study the dispersive properties of periodic metamaterials composed of glide-symmetric elliptical hole pairs. As a demonstration, an analytical model is derived and subsequently used to compute the full 2×2 dispersion diagrams. With the presented analysis, we demonstrate that glide-symmetric periodic structures exhibit a wide range of frequencies.

A Spatio-Temporally Modulated Metasurface as a Free-Space N-Path Antenna

Zhenni Wu (the University of Michigan, USA); Cody Scarborough (University of Michigan, USA); Anthony Giblin (University of Michigan, Ann Arbor, USA)

A spatio-temporally modulated metasurface, that functions as a free-space N-pulse path system, is reported at X-band frequencies. The reflection phase of the matrix can be independently time-modulated for two orthogonal polarizations. A space-time bias is applied to the metasurface, enabling directionally dependent electromagnetic responses. When the modulation parameters are adjusted, a large number of spatio-temporal parameterization results to be in the free field of the transmission. In this contribution, we analyse the wave-front field interaction mechanism of such a wave-front antenna and provide guidelines to design suitable size antennas.

EuCAP Best Paper Award - Propagation

The MEKap Project: Measuring Tropospheric Impairments at Ka Band with MEO Satellites

Josef Knapp
Reiner S. Thomä
Sergii Skoblikov
Andrea Martellucci
(Contemporary Network Engineering, Munich, Germany); Viktor Krozer (Microwave Research Institute, Germany); Yoann Corre (Infineon Technologies AG, Germany); Christian Keitel (University of Michigan, USA); Augusto Marziani (Sapienza University of Rome, Italy); Augusto Marziani (Sapienza University of Rome, Italy); Remo Riva (Di Telecomunicazioni, Italy); Carlo Riva (Di Telecomunicazioni, Italy); Clive Parini (University of Oxford, UK); Guido Valerio (University of Oxford, UK); Christian Keitel (University of Michigan, USA); Andrea Martellucci (Contemporary Network Engineering, Munich, Germany)

The design phase of an ESA-funded project (MEKap - ME Delay of MEO Ka-band Propagation) is described. The purpose is to create an empirical model of the average tropospheric propagation channel between Ka-band satellites and Earth Stations. The project's key findings are that the troposphere can be characterized by a statistical model, which can be used to predict the attenuation in a wide range of frequencies. The model is validated using a large dataset of real measurements and is shown to be capable of predicting the attenuation with high accuracy.

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); Joochen Moi (Goethe University Frankfurt am Main, Germany); Christian Keitel (Goethe University Frankfurt, Germany); Avik Santra (Infineon Technologies AG, Germany); Andrew Aliverti (Politecnico di Milano, Italy); Viktor Krozer (Goethe University Frankfurt, Germany); Vadim Issakov (Infineon Technologies AG, Germany)

Microwave imaging breast cancer detection is a technique that can detect tumours in a non-invasive manner. In this paper, a breast cancer imaging system operating at 24 GHz is demonstrated. The system uses a phased array antenna system, which can be steered to different parts of the breast. The imaging system is shown to be capable of imaging breast lesions with high resolution.

Physical Modeling for Device-Free Localization Exploiting Multipath Propagation of Mobile Radio Signals

Martin Schmidhammer (German Aerospace Center DLR, Germany); Michael Walter (German Aerospace Center DLR, Germany); Christian Genteur (German Aerospace Center DLR, Germany); Stephan Sand (German Aerospace Center DLR, Germany)

This work proposes a model to describe the impact of anisotropic multipath conditions on the received signal. The model is validated using experimental data obtained in an anechoic chamber. The results show that the proposed model is capable of predicting the received signal power with high accuracy.

Suppressing Undesired Echoes by Sparsity Based Time Gating of Reconstructed Sources

Josef Knapp (Technical University of Munich, Germany); Jonas Kornprobst (Technical University of Munich, Germany); Thomas F. Ebert (Technical University of Munich, Germany)

The present paper introduces a new technique to suppress undesired echoes in ultrasound imaging. The technique is based on the principle of sparse signal recovery. The results show that the proposed technique is capable of suppressing undesired echoes with high efficiency.

EuCAP Best Paper Award - Measurement

Examining and Optimising Far-Field Multi-Probe Anechoic Chambers for SIRG OTA Testing of Massive MIMO Systems

Stuart F Gregson (Queen Mary, University of London, United Kingdom (Great Britain)); Clive Parini (Queen Mary, University of London, United Kingdom (Great Britain))

Direct far-field (DF) 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 (FF-MPAC) being especially widely deployed for the verification of massive multiple input multiple output (Massive MIMO) antennas in the presence of several users. This paper presents a detailed analysis of the use of a multi-probe anechoic chamber for DF testing of radio access networks. The results show that the proposed technique is capable of providing accurate measurements.
Conformal Antennas

P1.13 Advanced Calibration Method for Accurate Microwave Absorber Reflectivity Measurements at Oblique Illumination Angles
Willi Hofmann (Technische Universität Ilmenau, Germany); Andreas Schwid (Technische Universität Ilmenau, Germany); Christian Bomkessel (Technische Universität Ilmenau, Germany); Matthias Hein (Ilmenau University of Technology, Germany)

The increasing miniaturization of new radio systems requires a change of measurement sites toward more sophisticated virtual electromagnetic environments. RF absorbers are essential for the realization of these environments to achieve the propagation conditions desired by obtaining well-defined measurement conditions and suppressing interfering signals. 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 RIS- and NRL-arch methods is proposed. Measurement results obtained by the new technique show good consistency with the NRL-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 accurately, but additionally knowledge of the off-normal reflectivity will also contribute to the optimization of measurement sites such as virtual electromagnetic environments.

P2.041 Axicon-Hypersonic Lens for Reflectivity Measurement of Curved Surfaces
Alessio Tamminen (Aalto University, Finland); Samu-Ville Palli (Aalto University, Finland); Juha Ala-Laurinaho (Aalto University, Finland); Mika Salkola (Icare Finland Oy, Finland); Antti V. Räisänen (Aalto University, Finland); Zachary D Taylor (Aalto University, Finland)

We present a geometric 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 axicon surface allows for significant reduction in alignment requirements. This research is motivated by in vivo cornea measurements where achieving optimal alignment is difficult. Combined axicon-hypersonic lenses were designed for 220-330 GHz and fabricated of TOPAS, a low-loss material at millimeter waves. The lens performance is evaluated with near-field measurements. Compared to the Gaussian beam, the in-line 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 stampled AIP concept for enhanced cooling in millimeter wave phased-array systems. To verify the proposed AIP concept, the POC design is performed and fabricated using standard PCB and metal stamping process. The fabricated POC model achieves impedance bandwidth of 0.7 GHz with a center frequency of 28.3 GHz. Good agreement is achieved between the measured and simulated radiation pattern with the measured gain of 14.01 dB. 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 antenna is demonstrated to verify the feasibility of a practical application of MRFMA Massive MIMO systems with main beam scanning range of 30° in both elevation and azimuth planes. Computational fluid dynamics 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
Chia-Lin Cheng (Georgia Tech, USA); Seun S. Spongpyon (Georgia Institute of Technology, USA); Alekza Zajic (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 x 4 Multi-Input Multi-Output (MIMO) channel are also investigated. Furthermore, Doppler shift in THz 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) geometric model of the interference degree that includes moving scattering (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 Kumari (UT Austin, USA); Amine Mezghani (Electrical and Computer Engineering & University of Manitoba, Canada); Robert Heath (The University of Texas at Austin, USA)

A fully digitalized wideband joint communication-radar (JC/R) 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 JC/R systems using novel measurement methods. We developed the platform by extending a millimeter-wave communication setup with an additional full-duplex radar receiver and by capturing the MIMO JC/R channel using a moving antenna on a sliding rail. To characterize the JC/R performances, we conduct indoor experiments and apply traditional/advanced processing algorithms on the measured data. The results demonstrate that the tested band at 73 GHz with 2 GHz bandwidth can capture the JC/R channel with high range/direction estimation accuracy. The comparison between the communication and radar channel shows the potential for improving JC/R performance by exploiting the antenna diversity due to vastly-separated communication and radar receivers.

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)); Jinfeng Zhou (University of Liverpool, United Kingdom (Great Britain))

A broadband metasurface-based antenna with hexagonal loop elements is presented. To achieve a broadband response, an array of hexagonal loop elements is taken as the main metasurface-based radiation. The antenna is fed by a microstrip line through a coupling slot. To reveal the underlying mode behaviors, the characteristic mode analysis was used for modeling, analyzing, and optimizing the antenna structure. The designed broadband hexagonal-loop-based antennas with an overall size of 1.10 x 1.10 x 0.06 A0 can achieve 55% fractional bandwidth and a nearly stable gain of 7.11 dB over the operating band.

3-D Printed Terahertz Lens for Generation of Non-diffactive 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-diffactive 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 at low cost. Measured results demonstrate that the designed 3-D printed lens can generate THz non-diffactive Bessel vortex beam carrying OAM.
Poster3-A11: Multiband and Wideband Antennas

**Antennas**

**Room: Exhibition Hall**

P.0309 A Single-feed Compact Wideband Circularly Polarized Antenna for IMR/AR/GNSS Applications

N Nasimuddin and Xiaoming Qiong (Institute for Infocomm Research, Singapore)

A single-feed low profile compact wideband circularly polarized (CP) stacked antenna is proposed for IMAR/AR/GNSS applications. The antenna consists of a ring-slotted radiating patch with a ground metallic ring, a slit-fed parasitic patch, and a coaxial feeding probe. The wideband CP radiation is attributed to the stacked slit-fed patches, coplanar ring-slot antenna, and coaxial feeding probes. The proposed antenna achieves satisfactory performances such as compact size, low profile, and wide bandwidth. The proposed antenna is suitable for mobile terminal applications, especially below 1 GHz. The prototype of the proposed antenna shows less than 12 dBVSWR, over 90% axial ratio bandwidth within the range of 2.5-10.2 GHz, and gain greater than 5.2 dB across the whole bandwidth.

P.0301 A Dual-Element Folded Strip Monopole with SRR Loading for Mobile Handset MIMO Applications

Nasir Qorqi Parchin (University of Bradford, United Kingdom, Great Britain); Xianming Qing (Institute for Infocomm Research, Singapore)

A multi-band antenna with SRR loading for mobile handset MIMO applications is proposed. The antenna design does not only exhibit multi-band operation but also generates the polarization diversity characteristics which make it suitable for multi-mode operation. The proposed antenna consists of eight modified planar inverted-F antenna (PIFA) elements located at different corners of the handset. The proposed design is validated through simulated and fabricated prototypes, and it is found that the antenna elements and ground plane are etched on the same layer. The fabricated antennas satisfy the VSWR less than 2 for all the frequency bands of interest. The results show that the proposed antenna offers good CP radiation performance and efficiency. In addition, the calculated TARC and ECC results of modified PFAs are low over the operation bands.

P.0312 Ultra-Wideband MIMO Diversity Antenna System for Future Handsets

Nasir Qorqi Parchin (University of Bradford, United Kingdom, Great Britain); Xianming Qing (Institute for Infocomm Research, Singapore)

A new design of ultra-WB-MIMO diversity antenna system is proposed for future smartphones. The design contains four pairs of compact microstrip-fed slot antennas with dual-polarized function that are placed symmetrically at different edges corners of the smartphone mainboard. Each antenna part consists of a circular ring-slot radiator fed by two independently fed folded monopole feeding lines which exhibit high gain and polarization diversity characteristics. The characteristics of the smartphone antenna are examined using both simulations and measurements and good results are achieved. An impedance bandwidth of 2.5-10.2 GHz with 12% fractional bandwidth (FBW) is achieved for S11 < -10 dB. However, for S11 > -4 dB, this value is more than 130 dB (2-11 GHz). In addition, the calculated diversity performance of the proposed antenna are very low over the operation bandwidth. Furthermore, sufficient values for the channel capacity and its loss are obtained.

P.0313 A Compact Multiband FCA Antenna with Coupled-Fed Mechanism for Mobile Phone Applications

Di Wu and Yu-Xiang Sun (Shenzhen University, China)

A novel coupled-fed folded inverted Conformal Antenna (FCA) with compact size for smart phone application is presented in this paper. The proposed antenna is mounted at the bottom side of the PCB, which consists of a closed slot, a folded driven branch for the coupled-fed, a shorting pin, and an impedance matching network. Three resonant modes have been generated to cover the lower band from 2.34 to 3.52 GHz and upper band from 3.71 to 2.72 GHz. In addition, both of the clearance and height of the proposed antenna are only 4 mm, which makes the antenna very compact, low-profile and suitable for the narrow frame smart phone applications.

P.0314 Multi-Band Wide Band Printed Quasi Helical Antenna

Fayez Hidaye (Huawei Technologies Co. Ltd., Canada); Hamel Boutayeb (Institute for Infocomm Research, Singapore)

A technique is proposed for designing multi-band and/or wide band printed quasiplanar helical antennas. This technique uses a narrow slot and a tuning section in the vicinity of the feeding ports. This section contains an elongated body and a tail member extending away from the body. A geometry of the tail member is selected for modifying an impedance of the feeding element and broadening the antenna resonance bandwidth. A four port antenna is designed for wide band operation (24, S11 < -10 dB) in three frequency bands, with one of the frequency bands being more than 24% (S11 < -10 dB): 1.88-2.12 GHz (E-UTRA 39), 2.32-2.4 GHz (E-UTRA 40) and 3.34-3.8 GHz (E-UTRA 42 and 43). Index quasi-planar helical antenna, multiband, wide band
This paper presents an ultra-wideband stacked spiral helical antenna. The proposed antenna consists of two stacked spirals on a potted helix. By connecting the two stacked spirals through two inductors, the effective electrical length is increased, and thus the low-end cutoff frequency of the proposed antenna can be greatly decreased. By reasonably designing the height and number of turns of the helix, the helical antenna can operate in the axial mode. Since the proposed antenna is mainly radiated by the spiral at high frequency and mainly radiated by the helix at low frequency, the proposed antenna can obtain bi-directional radiation at high frequency range and unidirectional radiation at low frequency range. Simulated results show that the proposed antenna can achieve a 3-dB accessible bandwidth from 1.5 GHz to 25 GHz.

The paper proposes the application of a resonant textile antenna as moisture sensor. Two setups are discussed, the first one is based on E-field distribution in ex-vivo porcine skin layer from a subsurface UHF transmitter, and the second one is based on the spiral at high frequency and mainly radiated by the helix at low frequency. The proposed antenna can obtain bi-directional radiation at high frequency range and unidirectional radiation at low frequency range. Simulated results show that the proposed antenna can achieve a 3-dB accessible bandwidth with 1.5 GHz to 25 GHz.
A beam steerable resonant antenna (BRA) 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 (CFS) which consists of square loop patch and slot arrays. The reflection phase of PRS unit cells can be tuned by adjusting the biasing status of varactors, while the reflection magnitude keeps a relative high value within a frequency band of interests, owing to the complementary configuration. 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 a 10° scannable directive beam. An implementation is demonstrated with simulated results, which exhibit maximum scanned angle of 13 degrees with a gain of 13.6 dB for 23×23 A antenna aperture size.

In this paper, an easy-to-manufacture and relatively low profile sectoral antenna for receiving radiosonde signals is designed. As the top antenna as well as six patch antennas with linear polarization as side antennas are designed. In the patch antenna gain. The AFSS screens are arranged around the dipole antenna in a hexagonal shape to steer the radiation pattern in six different directions. The transmission/reflection characteristics of the proposed antenna are investigated in various combinations for dipole ON/OFF states for both AFSS screens. The proposed antenna can switch its gain between 140° and 172°. The performance of the antenna is evaluated at 5.8 GHz.

In this paper, the miniaturized electronically steerable parasitic array radiator (ESPAR) antenna is presented. The size of the proposed antenna is 40*100*0.76 mm³, making it suitable for compact wireless handheld devices. The antenna system satisfies Yagi as well as MIMO performance metrics.

A Beam Steerable Resonant Array Antenna Based on Partially Reflective Surface

Shufeng Zheng, Fan Di, Na Zhou and Le Kang (Xidian University, China); Mohammad Wasif Niaz (Northwestern Polytechnical University, China)

A compact single layer frequency reconfigurable Yagi-like MIMO antenna system is first described. The antenna is designed to satisfy multiple standards for wireless communication and broadband applications. The antenna is comprised of one resonator feed with a half-wavelength mode, the radiated fields of the slot and dipole have the same amplitudes and 90° phase difference; in addition, the two radiating elements are arranged in an orthogonal configuration. Consequently a CP radiation is obtained. To make a polarization reconfigurable design, a pair of screws are used as the actuating elements of the dipole arm. By manually turning the two screws, the axial ratio and polarization state of the antenna can be changed. For the proposed reconfigurable antenna, the analysis for key components are performed, and a prototype is constructed. Both measured and simulated results show that the CP reconfigurable antennas have a 3 dB-axial-ratio bandwidth of more than 22.5%.

A Compact Pattern Reconfigurable Uniform Patter for UHF Internet of Things Applications

Saeed A. Haydah (King Fahad University of Petroleum and Minerals, Saudi Arabia); Fabien Ferrero (University Nice Sophia Antipolis, CNRS, LEAT & CREMANT, France); Leonardo Lizzii (University Côte d’Azur, CNRS, LEAT, France); Azzedine Zerguine (KFUPM, Saudi Arabia); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

A beam steerable resonant antenna (BRA) 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 (CFS) which consists of square loop patch and slot arrays. The reflection phase of PRS unit cells can be tuned by adjusting the biasing status of varactors, while the reflection magnitude keeps a relative high value within a frequency band of interests, owing to the complementary configuration. 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 a 10° scannable directive beam. An implementation is demonstrated with simulated results, which exhibit maximum scanned angle of 13 degrees with a gain of 13.6 dB for 23×23 A antenna aperture size.

Ultra Wideband Frequency Reconfigurable Antenna

Banu Didi Alaks and Ozgur Ozdemir (Istanbul Technical University, Turkey)

In this study, the frequency reconfigurable antenna structure which is switchable between LTE 1.8 GHz, 2.1 GHz, 2.6 G Hz, WLAN 2.4 GHz, 5 GHz frequencies is presented. The design of the proposed antenna is composed of a combination of a slot antenna and a bumpout excited by a coplanar waveguide. The characteristics of the antenna are analyzed using full wave simulations in CST Microwave Studio. The results show that the proposed antenna covers the spectrum of interest with good radiation performance and efficiency.

A Concept of Pattern Reconfigurable Single-Element Antenna Operating at 2.45 GHz

Farhad Ghorbani (IETR-INSA, Rennes, France); Ahmadreza Saffarzadeh (Amirkabir University of Technology, Iran); Mohammad S. Sharawi (Polytechnique Montreal, Canada)

Designed antenna is characterized by a half-wavelength mode, the radiated fields of the slot and dipole have the same amplitudes and 90° phase difference; in addition, the two radiating elements are arranged in an orthogonal configuration. Consequently a CP radiation is obtained. To make a polarization reconfigurable design, a pair of screws are used as the actuating elements of the dipole arm. By manually turning the two screws, the axial ratio and polarization state of the antenna can be changed. For the proposed reconfigurable antenna, the analysis for key components are performed, and a prototype is constructed. Both measured and simulated results show that the CP reconfigurable antennas have a 3 dB-axial-ratio bandwidth of more than 22.5%.

A Beam-Steering Antenna with Variable Gain

Ghada Elzawari (EMT-NRS, Canada); Rabee Alkhathithi (NRS, Canada); Tayeb A. Denidni (NRS-EMT, Canada)

In this paper, a beam-steering antenna with variable gain on frequency selective surfaces (AFSSs) is proposed. The proposed design comprises of a dipole antenna as a source of the electromagnetic waves (EM waves), two reconfigurable AFSS screens, and six metallic sheets placed around the source to increase the values of the proposed antenna gain. Two patterns follow magnetic-dipole patterns along the azimuthal plane with peak gains of -2.18 dB, and radiation efficiencies above 33.2%. Two patterns follow magnetic-dipole patterns along the elevation plane phi=120 degrees. Pattern reconfigurability is achieved using PIN diodes. The used substrate is FR-4 with a dielectric constant of 4.4, and a loss tangent of 0.02.
A DC voltage boosting technique in radio frequency (RF) wireless power transfer (WPT) systems is proposed. This technique, beam steering transponder based on load modulation, is presented as an alternative method to multi-stage rectifiers that can increase the DC output voltage without decreasing the efficiency of the system. The concept of beam steering transponder based on load modulation is proposed to enhance the received power of wireless power transfer systems. The transponder utilizes a reactive component to modulate the load, which results in an increase in the DC output voltage. The proposed technique is validated through simulations and experimental results, demonstrating a significant improvement in the DC output voltage for conventional single- and multi-stage rectifiers. First, the use of multi-stage rectifiers in wireless power transfer is reviewed, followed by an explanation of the concept of beam steering transponder based on load modulation. The technique is then applied to a practical wireless power transfer system, and the results show a significant increase in the DC output voltage compared to conventional rectifiers.

Kyriakos Neophytou

The concept of beam steering transponder based on load modulation is proposed to enhance the received power of wireless power transfer systems. The transponder consists of an antenna array element, a load modulator, and a power conditioner. The antenna array element is configured to receive the RF signal, while the load modulator is responsible for modulating the load to increase the DC output voltage. The power conditioner then converts the modulated DC output voltage into a usable form.

Tauseef Ahmad Siddiqui

The concept of beam steering transponder based on load modulation is proposed to enhance the received power of wireless power transfer systems. The transponder consists of an antenna array element, a load modulator, and a power conditioner. The antenna array element is configured to receive the RF signal, while the load modulator is responsible for modulating the load to increase the DC output voltage. The power conditioner then converts the modulated DC output voltage into a usable form.
3.049 A UHF RFID Reader Antenna with Tunable Axial Ratio and Fixed Beamwidth
Raj Chitt and Shuai Yang (University of Cambridge, United Kingdom (Great Britain)); Apek M Nidhin (University of Cambridge, 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 proposed. The antenna has a unique property as being able to change its axial ratio (AR) without affecting its gain, beamwidth or impedance matching performance, enabling the isolated study of the effect of different axial ratios in RFID tag reading.

3.049 On Complex Radar Cross Section and Backscatter Modulation Efficiency in RFID Systems
Christoph Degen (Hochschule Niederrhein University of Applied Sciences, Germany); Patrick Bosselmann (Bochum University of Applied Sciences, Germany)

The objective of this paper is to provide a thorough analysis of complex radar cross section treatment in different backscatter modulators. Such modulation is a key aspect in radio-frequency identification (RFID) communication. The main point in the contribution is the introduction of a complex radar cross section that describes amplitude and phase effects of any reflecting object but especially of RFID tag antennas. Then, 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 metal plate.

3.050 Modified Yagi-Uda Antenna for UHF RFID Smart-Glove
Rajesh K Singh, Andrea Michel and Paolo Nepa (University of Pisa, Italy); Alfredo Salvatore (Sensor ID, Italy)

This paper introduces a modified Yagi-Uda antenna with the capability of focusing field in an aperture-like direction. The antenna comprises of a rectangular shaped driven element with a parasitic element. Parasitic element is used as a director to focus the field in a particular direction and increases its strength compared to other antennas. The antenna is analyzed in terms of the electric and magnetic field distribution in the near-field to the structure. A prototype is developed by using copper tape on a stretchable fabric to validate the design. 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 15 cm in rear direction is achieved with a transmitted power of 45 mW. The presented antenna is compact in size and is able to be integrated into an UHF RFID Smart Glove.

3.051 Reduced Size RFID Reader Antenna Based on Reconfigurable Network Realized with Artificial Transmission Lines
Enrico Tolini (Politecnico di Torino, Italy) & IMST GmbH, Germany; Achim Bahr and Simona Bruni (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 proposed. This is the proposed reconfigurable concept based on a switchable network feeding, which uses only four state-of-the-art CMOS switches for both covering the EU and US frequency bands and for selecting among four linear polarizations. Moreover, the reconfigurable feeding network 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 95 mm. This compact design can be easily integrated in standard RFID systems. Circuit 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 turning and circular polarized antenna RFID reader antenna designs.

3.052 An Enhanced Road Vehicle Positioning Method Using Roadside Microwave Frequency Identity Tags and the EPC Gen2 Standard
Zhan Wang and Robert Michael Edwards (Loughborough University, United Kingdom (Great Britain))

In this paper, a method for augmenting current self-localization methods for autonomous navigation based on Global Navigation Systems (GNSS) and LIDAR is introduced as a backbone system for primary equipment. The method uses Radio Frequency Identity Tags (RFID) running under a modified EPC Gen2 Standard. Simulated results are presented for a representative 8.5m long track around Loughborough, UK town centre with a 911 items inventory of roadside furniture. The virtual test track is used as input for an RFID tag simulator that uses an interrogator/interrogating protocol. The technique is shown to be a good candidate for improving safety in Autonomous Vehicles and position finding for vehicles in general.

3.053 A Passive RFID Tag for Biomass Tracking
Ajam Ali, Rodenick Mackenzie, Edward Lester, Ola Williams and Steve Greedy (University of Nottingham, United Kingdom (Great Britain))

This paper presents the design for a low cost miniaturised chipped 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 design is capable of encoding 2n unique IDs in 4 to 9 GHz frequency band, whereas n is the number of etched dots. The angular stability makes this tag readable from any angle in biomass. Moreover, this chipped RFID tag has no hazard as compared to battery-based active tags during biomass combustion processes.

3.054 A Compact Printed Wideband Circularly Polarized Slot Antenna for Universal UHF RFID Reader
Nathapat Suprayatnitkul, Nonnaphat Tiansuksutthorn, Phanuphong Boontamchauy and Muneeck Rattanattukul (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 high frequency (HF) identification (RFID) reader antennas. This antenna fed by a coplanar waveguide (CPW) with an L-shaped feeding line for achieving impedance-matching wide bandwidth and wideband CP operation can be obtained by two rectangular shaped slits in the square slot of the ground plane. The measured 10-dB reflection coefficient (return loss) bandwidth is 790 MHz (920-1410 MHz, 8.7% centered at 900 MHz). The measured 3-dB axial ratio (AR) bandwidth is about 445 MHz (795-1240 MHz, 49.4% centered at 900 MHz). The maximum measured gain of the antenna is about 3.7 dBi. The dimension of the proposed antenna is 122.0 x 201.6 x 6 mm3.

Poster 3-A16: UWB Antennas and Time-domain Techniques
Room: Exhibition Hall

P3.055 Single-Chip Impulse-Radar Integrated Circuits for Microwave-Imaging
Takamaro Kikkawa (Hiroshima University, Japan); Akioh Toya (Kure National College of Technology, Japan); Yoshihiro Masui (Hiroshima Institute of Technology, Japan); Hiroki Yato (Tokyo Institute of Technology, Japan); Takuichi Hirano (Tokyo City University, Japan); Mutsuhiro Sugawara (Hiroshima University, Japan); Tomoaki Maeda, Masahiro Ono, Yoshitaka Murakasa, Toshifumi Inamura and Atsushi Iwata (A-RTec Corporation, Japan); Yuuichi Matsumura and Michumasu Yamaguchi (Syswave Corporation, Japan)

In order to develop a portable multi-static radar system for microwave imaging, a single chip impulse radar large scale integrated circuit (LSIC) 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) are generated by the impulse energy and its waveforms are measured. The transmitted pulse energy is measured to be 19 dBm and the peak pulse energy is 83 mJ. The waveforms of the transmitted pulse are measured to be Gaussian mono-cycle pulses and this chipless RFID tag has no hazard as compared to battery-based active tags during biomass combustion processes.

P3.056 A 2-18 GHz Semi-Omnidirectional Antenna
Gokhan Ucuncu and Mustafa Kuloglu (Akaslan 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 3dB beamwidths about 180 degrees or more. One sample antenna is designed, manufactured and measured. For more than 90 percent of the bandwidth, the antenna has over 10 dB gain suppression in the blind sector. Gain of the antenna is measured to be minimum -2.21 dBi higher than 0 dB for frequencies higher than 3.6 GHz. E-plane beamwidth of the antenna is greater than 15 degrees in the entire 2-18 GHz frequency range.

P3.057 Clown Shaped Super Wideband Antenna
Sarthak Singhali (Malayia National Institute of Technology, India); Rahul Kumar Garg (LNMI Institute of Information Technology, India); Raghuv Tomar (LNMIIT, Jaipur, India)

In this paper, a clown shaped monopole antenna for super wideband applications is proposed. The proposed clown shaped radiator is fed by coplanar waveguide feed. The RF (Circular) SSB0 substrate of 1.6 mm thickness is used for antenna design. The simulation results show an impedance bandwidth of more than 47.41 GHz (from 2.59 GHz to more than 50 GHz for 50Ω) and 1.13 times at a frequency of 29 GHz. Stabile semi-omnidirectional radiation patterns are achieved. The prototype is fabricated and simulated results are validated.

P3.058 Pulsed 20 ElectroMagnetic Field Propagation in a Rectangular Waveguide
Martin Štuim replenished (Bruno University of Technology, Czech Republic); Ioan E. Lager (Deft University of Technology, The Netherlands); Guy Vandenbosch (A-R-Tec Corporation, Japan); Yoshitaka Murasaka (Tokyo City University, Japan); Hiroshi Ito (Hiroshima University, Japan); and Patrick Bosselmann (Sensor ID, Italy)

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 excited by an electric line current applied against the rectangular cross section. This field is written as a supposition of time-domain (TD) constituents denoted as generalized-rays, progressing 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.

P3.059 Time-Domain Reflectometry for Measuring Scattering Parameters: Comparison of M-sequence Device and Step-generator TDR
Shokoufeh Abdollahi and Somayeh Chaamani (K. N. Toosi University of Technology, Iran); Jürgen Sachs (Imenau 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 systems and processing. In this study, we examined a comprehensive method for two
This paper describes the design procedures and manufacturing processes of a self-sustained vertically polarized biconical antenna proposed for use in self-powered Internet of Things (IoT) devices. The antenna design process involves the development of a compact, lightweight structure that minimizes the overall weight while maintaining high efficiency. The antenna is designed to operate in the frequency range of 2.6 GHz to 2.9 GHz, with a fractional bandwidth of 31%. The antenna design includes the use of advanced 3D printing techniques to fabricate the antenna components, allowing for rapid prototyping and customization. The antenna design and manufacturing processes are validated through simulations and experimental measurements, demonstrating the feasibility of the proposed design for IoT applications.

Rapid prototyping of antennas is crucial to validation of simulation models when designing conformal antennas on unusual surfaces. This paper presents a novel approach to rapid prototyping of antennas using direct-write dispenser printing on thin flexible substrates. The method involves printing conductive inks on ultra-thin (25 μm) substrates using specialized dispenser printers. This approach allows for the rapid fabrication of antennas with high resolution and flexibility, making it suitable for the development of low-cost unobtrusive IoT devices.

In this paper, the authors present a methodology for the design and electromagnetic performance of a low-profile and extremely wideband antenna. The antenna is designed to operate over a wide frequency range, from 1 to 40 GHz, and is suitable for use in various wireless communication applications. The antenna design includes the use of resistively loaded low-profile absorbers, which are used to shape the radiation pattern and enhance the absorption phenomenon in the near field. The antenna exhibits a fractional bandwidth of 124%, covering the frequency range from 3.0 GHz to 12.89 GHz. The overall volume of the antenna is compact, with a size of 14° x 18° x 5 mm. The antenna is fabricated using a resistive-loaded absorber, which is used to control the radiation pattern and enhance the absorption in the near field. The antenna is designed to be highly efficient, with measured and simulated co-pol. and cross-pol. gain and efficiency in good agreement with the selected operating frequencies.

This paper reports the optimization of pulse waveforms for efficiency improvement of rectifiers in MPT application. Two types of pulses are investigated: improve matching performance of the rectifier and recycle the power which is reflected from the antenna. 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 mismatching of power generation and power absorption. The rectifiers operate efficiently, and the sensors are successfully function due to the impedance mismatch, when input power varies. The mechanism of these approaches is introduced briefly, while the effectiveness of extending input power dynamic range, RF powered wireless sensors are integrated, and an MPT system is divided into two types: improve matching performance of the rectifier, or recycle the power which is reflected from the rectifier due to impedance mismatch, when input power varies.

This paper reports the waveform optimization for efficiency improvement of traditional RF-to-dc Rectifiers Without Input Matching Network. The authors present a novel approach to optimize the waveform of RF signals for maximum power conversion efficiency. The optimization process involves the use of a non-optimized rectifier and a modified optimization process. The results show that the optimization of the waveform can improve the efficiency of the non-optimized rectifier by up to 20%. The authors also present a comparison between optimized and non-optimized waveforms, demonstrating the effectiveness of the proposed approach. The waveform optimization process is validated through experimental measurements, showing a significant improvement in efficiency compared to the non-optimized waveform.

In this paper, the authors report on the design and electromagnetic performance of a low-profile and extremely wideband antenna which works from 10 to 40 GHz. The antenna is designed to have a bandwidth of 2.6% and 2.3% in the X-band and X (k-band) respectively, as well as matching the full-wave 3D simulation of the connectorized assembly. The antenna is fabricated using direct-write dispenser printing on ultra-thin (25 μm) substrates, allowing for rapid prototyping and customization. The antenna design includes the use of resistively loaded low-profile absorbers, which are used to control the radiation pattern and enhance the absorption in the near field. Measurement results show that even though the locations of sensors are changed significantly, the rectifiers operate efficiently, and the sensors are successfully function.
In this paper, an ultra-broadband microwave absorber covering the C-band and Ku-band has been proposed, and the proposed nature of this absorber is based on the combined use of multilayer structure and multimodal 3D printing technology. The designed unit cell is a stack of 22 pairs of layers made of metal and dielectric square patches with a total thickness of 13.5mm (0.5 centre wavelength). Two dielectric materials with different relative permittivity (2.6 and 8.0) are used to obtain ultra-wideband behaviour. The simulation results show more than 93% absorptivity over an ultra-wideband from 3.5 to 18.5 GHz (fractional bandwidth of 1.36). The structure offers a good robustness under oblique incidence with more than 80% absorptivity from 4.0 to 18.5 GHz up to 45° in both TE and TM polarizations. The paper demonstrates a new way to design and manufacture promising low profile and ultra-wideband absorbers for microwave applications.

**P3.070 Temperature Characterization of High-μ Resonators for mm-Wave Indoor Localization Tag Landmarks**  
Alexei Jimenez-Saez (Technische Universität Darmstadt, Germany); Martin Schülle (TU Darmstadt, Germany); Damian Pandol (University of Duisburg Essen, Germany); Christopher Krause (Fraunhofer IMS, Germany); Yeong Zhao (Fraunhofer- Institut für Mikroelektronische Schaltungen und Systeme IMS, Germany); Gerold Völbel (Fraunhofer IMS, Germany); Neas Benson (Institute for Nanomaterials and Structures (NTS), University of Duisburg Essen, Germany); Rolf Jakoby (Institute for Microwaves Engineering and Photonics, Technische Universität Darmstadt, Germany)

This paper discusses a temperature-dependent characterization of deep reactive ion etched high resistive silicon (DBR HR-Si) 3D printed aluminas and rolled Rogers RT/ Duroid 6010 LAM. The characterization is performed by measuring high-Q photonic crystal resonator samples in W-band and the measurements are taken from 30 to 115°C. HR-Si is the material with the lowest losses at room temperature. However, its losses increase with temperature and become higher than 3D printed aluminas at 75°C, reducing the radar cross section and maximising detectable range of chirpless wireless RFID tags integrating several of these resonators. These results demonstrate that, while HR-Si performance is high for the usual temperatures in an indoor localization scenarios, 3D printed aluminas is more suitable if a temperature-stable resonance is required or if the tags need to operate in higher temperatures, such as in open air.

**P3.071 A Conformal Spherical DRA for Mobile Applications in Ka-Band Realized with Additive Manufacturing**  
Valeiro Panaro (Airbus Italia S.p.A., Italy); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); Esteban Manargues (SWISSLAB12, Switzerland); Alfredo Catalani (European Space Agency – ESTEC, Noordwijk, The Netherlands)

Active phased arrays have been widely studied for mobile communication and space communication and has been mainly developed in Europe for geostationary orbit (GEO) defence applications, Low (LEO) and Medium Earth Orbit (MEO) constellations. This class of arrays allow generating multiple beams with a high degree of re-configurability and flexibility. Considering a MEO application, a conical spherical array operating in its Ka-band (27.5 to 30 GHz), due to conformal circular polarisation, has been designed and optimised with additive manufacturing and tested.

**P3.072 Simulation of Effective Medium Theory for Additive Manufacturing to Dielectric Media**
Gregory A Mitchell (Army Research Laboratory, USA); Quang Nguyen (United States CCDC Army Research Laboratory, USA); Theodore K Anthony (US Army Research Laboratory, USA)

We compared the Maxwell-Garnett effective medium theory to a full wave simulation using the NEC-3D-Rose-Well 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.

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**Poster3-A23: Other Antenna Topics**

**Antennas**

**Room: Exhibition Hall**

**P3.073 A Differential-Fed Dual-Polarized High-Gain Filtering Antenna Based on SiW Technology for 5G Applications**
Yasir Ismail Abdulaheem Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Naser Qaroudi Parchin (University of Bradford, United Kingdom (Great Britain)); Mohammad Fahes (University of Basra, Iraq); Ahmed Maan Abdulkhalique (University of Bradford & SARAS Technologies, United Kingdom (Great Britain)); Mustafà Bakr (University of Leeds, United Kingdom (Great Britain)); Mohammad Al-Sadoon (Richmond Road, Bradford, BD7 1DP, United Kingdom (Great Britain) & University of Bradford, Iraq); Jamal Kasha & 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. Good performance is obtained with wide bandwidth of 11%, realised gain of 8 dBi at the resonant frequency (3.5 GHz) and low cross-polarization level due to the differentially driven ports, and complete symmetry using SIW technology.

**P3.074 Antenna Phase Center and Angular Dispersion Estimation Using Planar Acquisition Setup Applied to Microwave Breast Imaging**
João M. Falcão (Instituto de Telecomunicações, Portugal); Jose Bouças (Instituto de Telecomunicacoes, Portugal); Jorge R. Costa (Instituto de Telecomunicações / ISCTE-IUL, Portugal); Carlos A. Fernandes (Instituto de Telecomunicações, Instituto Superior Técnico, 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. The data's useful in microwave imaging applications where the antenna operates 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 pseudo 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, acquiring it to microwave breast imaging. We believe this type of antenna-characterisation techniques will allow 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.

**P3.075 Holographic Antenna Using Slotted Hologram Patterns for High Efficiency**
Sang Hyuk Han, Seongjin Park and Young Joong Yeon (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 so-called wave-guide. The proposed antenna using the slotting pattern 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.

**P3.076 A Bird-Cage Coil for MRI Studies of Unsaturated Granular Materials**
Sina Mohrabe (Laboratoire Navier (UMR 8205 CNRS, IFSTTAR, Ecole des Ponts ParisTech, France)); Hakim Tahkmed (Paris-Est Marne-la-Vallée University, France); Patrick Pouillet (ESSEE, France); Marjorie Grzeskowiak (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 different objects. In this paper, using MRI an experiment magnetic resonance image is induced (according to Friedman's law of induction) in a device called 'probe'. MRI probes are simply near field antennas designed in a specific way to in order to produce a homogeneous magnetic field at a specific frequency in the region of interest. MRI is a strong technique to study unsaturated granular materials. However, it suffers from a significant drawback, that is inherent small signal-to-noise ratio. To overcome this problem the probe used for a specific MRI experiment must be optimised. In this work a bird-cage probe operating at 21.3 MHz, optimised to study unsaturated granular materials under shear stress as well as some experimental results will be presented.

**P3.077 Validation Tests for the Application of a Circular PMA with Slotted Ground Plane for Partial Discharges Detection in Power Transformers**
Arthur Souza (UFCG, Brazil); Luiz Nobrega (Universidade Federal de Campina Grande, Brazil); Alexandre Serres (UFCG, Brazil); Edson G da Costa (Federal University of Campina Grande, Brazil); George Xavier (Universidade Federal de Campina Grande, Brazil); Ana Cruz and Matheus Gomes (UFCG, Brazil)

In this article, the applicability of an UHF circular printed monopole antenna with slotted ground plane was evaluated in order to detect partial discharges in power transformers. To verify the applicability of the antenna for this purpose, validation tests were performed: reflection coefficient (bandwidth) and gain in an anechoic chamber to avoid external interferences; and PD sensitivity tests from the comparison with the conventional method of IEC 60270, using for this purpose an oil cell with immersed flat-tip electrodes. These analyses were performed for the design of an antenna with optimized performance. The obtained values for the antenna's bandwidth, size, gain and PD detection sensitivity make it possible to classify the antenna as efficient in detecting partial discharges in power transformers.

**P3.078 Eco-Friendly Metamaterial Antenna for 2.4 GHz WLAN Applications**
Georgina Serres (Federal University of Campina Grande, Brazil); Raimundo Freire (Federal University of Campina Grande, Brazil); Samuel Morais, Carolina Rodrigues de Albuquerque and Jéssica Araujo (Federal University of Campina Grande, Brazil); Alexandre Serres and Laura de Carvalho (UFCG, Brazil); Joaohan Nequera de Carvalho (Federal University of Education, Ciência e Tecnologia da Paraíba, IPB, Brazil)

In this paper, an eco-friendly metamaterial antenna for 2.4 GHz WLAN applications 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 (CSR). The substrate that separates these two layers is a mixture of polyethylene (or polyethylene) and polyvinylidene chloride (PVC) 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 2.44 GHz and bandwidth of 140 MHz, simulated gain of 4.03 dBi and half power beam width of 48.2°, which shows great potential for WLAN applications.
P3.079 Miniradiation of Base-station Antenna Element Using Non-uniform Meta-surface
Yuewei Oli and Haikang Zhu (Northwestern Polytechnical University, China); Jingkang 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 45° 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 119.5∗119.5∗27mm3 (0.332∗0.332∗0.19A), 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 stable radiation pattern and high port isolation are achieved over the operating frequency band.

P3.080 Mechanically Tunable MTM-EBG-based Bandstop Filter
Jacob A Brown and Ashwen 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 structure (MTM-EBG) is demonstrated here that relies on a single mechanically tunable element. This structure, without any tuning mechanism attached, has a simulated 10-dB transmission absolute bandwidth (ABW) of 225 MHz centered at 4.18 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, which changes the reactive loading and subsequently shifts the response. Using a plate of RO4035B, a tuning range from 3.43 to 4.05 GHz with a 12.6% variation in ABW is demonstrated in simulation.

P3.081 Wideband Vertically Pivoted Dual-Beam Antenna Using Modulated Metasurfaces
Ali Mohammad Hakimi, Homayoon Owati, Ali Kavehav and Ahamed Amos Ali (Iran University of Science and Technology, Iran)

In this paper a dual beam vertically pivoted metasurface antenna with broad bandwidth and high gain potential 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 13-19 GHz with suitable levels of cross polarization. Also, the gain of two different beams are approximately equal all over the operational bandwidth. The Fourier technique is used to explore the antenna to synthesize the dual-beam pattern. Moreover, there is a good agreement between this method and the full-wave simulations.

P3.082 Ultra Wideband Dual Polarization Metamaterial Absorber for 5G Frequency Range
Majid Amiri (University of Technology Sydney, Sydney, Australia); Farzad Tofighi (University of Technology, Sydney, Australia); Negin Shariati (University of Technology Sydney, Australia); Justin Lipman (University of Technology, Sydney (UTS), Australia); Mehran Abolhasan (University of Technology Sydney, Australia)

Implementing 5G technology contribute to improve the communication quality and facilitate several interesting applications in daily life such as Internet of Things. Despite outstanding features of 5G, the amount of ambient electromagnetic waves will be increased significantly in environment, which may be undesired. Ultra-wideband metamaterial perfect absorber is a promising solution to collect these undesired signals. Using lumped elements in absorber structure, to increase the absorption bandwidth to design and fabrication process complexity. In this paper, a low profile polarization angle selective metamaterial absorber has been designed to absorb signals in the frequency range of 21.79 GHz to 55.23 GHz with more than 90% efficiency. The relative absorption bandwidth of the final structure is 83.81%. Moreover, the final structure is reasonably insensitive facing different incident angle up to 40 degree.

P3.083 A Hybrid SSPs-EBG Filter with Glide Symmetry for 5G Applications
Maizan SalariRahimi (KU Leuven, BE); Guoyi Vandenbosch (Katholieke Universiteit Leuven, BE), Belgium

In this paper, we present a metamaterial-based low-pass band-pass hybrid filter combining the low-pass features of a spoof surface plasmon polaritons transmission line and band-reject features of an edge via mushroom-like glide-symmetric EBG structure. The idea of the proposed hybrid filter is to increase the degrees of freedom to tune the performance. The filter has been designed for 5G applications, covering both the sub 6 GHz and millimeter-wave frequency range. A stopband suppression of more than 25 dB has been achieved.

P3.084 A Compact Mass- producible E-band Low-pass Band-pass Filter Based on Multi-Layer Waveguide Technology
Abbas Vosoughi (Metsam As, Sweden); Astrid Alagba Braelaz (Ericsson Research, Ericsson AS, Sweden); Yingqiang Li (Ericsson AS, Sweden); Zhongping Simon He (Chalmers University of Technology & Microwave Electronic Lab, Sweden)

A novel low-pass band-pass filter for high-data rate applications is designed and experimental validation of a broadband filter for high-data rate applications is achieved. The proposed design is developed in multilayer waveguide (MTM) technology, where an air-filled waveguide transmission line is formed by stacking several unconnected thin metal plates. Our M/L waveguide band-pass filter is designed by combining low-pass and high-pass filtering structures, and consists of 19 separate metal layers. An array of glide-symmetric holes, which act as an electromagnetic band gap (EBG) structure, are used to prevent any possible field leakage due to the air gaps between the layers. The fabricated filter provides a bandpass from 71.5 to 76 GHz with measured return loss better than 15 dB, and insertion loss better than 1.3 dB. These results confirm the advantages of M/L technology for implementing ultra-compact band-pass filters showing low loss and potential for being mass-produced at millimeter-wave frequencies.

P3.085 All-Dielectric Hughes’ Metasurfaces Pair for mm-Wave Circularly-Polarized Beam-Forming
Mohamed K. Elma (Carleton University, Canada); Takashi Tomura and Jiro Hinokawa (Tokyo Institute of Technology, Japan); Shulang Gao (Carleton University, Canada)

A novel all-dielectric Hughes’ metasurfaces pair capable of circularly-polarized beam-forming is proposed. The proposed structure consists of two layers of dielectric resonators separated by approximately one quarter-wavelength at the design frequency. Each dielectric resonator is symmetrically to allow the transmission of circularly-polarized waves. In order to physically design the structure, each resonator is connected to neighboring resonators through four symmetrical bridging stripes. The second dielectric layer is added to cancel reflections caused by the bridges, allowing for the achievement of perfect matching. Full-wave simulations are used to demonstrate the full phase range achieved by varying unit cell dimensions. The operation of the proposed meta-surface is further demonstrated by obtaining reflected and difference-pattern beams from a circularly-polarized slot antenna.

P3.086 T/Hz Power Divider Based on Self-Complementary Metasurfaces
Andrey Sayanski and Vladimir Lenets (ITMO University, Russia); Sergei A. Kuznetsov (Rzhanov Institute of Semiconductor Physics SB RAS, Russia); Stanislav Glybovski (ITMO University, Russia); Juan Domingo Baena (Universidad Nacional de Colombia, Colombia)

In this work we present a study of self-complementary metasurfaces which is excited by circularly polarized wave providing spatial separation of the co- and cross-polarized THz beams. We show that the metasurface will create the cross-polarized beam focusing in the certain focal point, while keeping the co-polarized beam transmitted in the broadband. It could be obtained by gradually altering the geometry of the unit cell enabling the metasurface to get different phase jumps for the cross-polar transmission coefficient.

P3.087 Wideband Substrate Integrated Longsbus Lens Using Glide-Symmetric Technology
Lei Wang (Heriot-Watt University, United Kingdom (Great Britain))

With a glide-symmetric mushroom unit cell, a wideband Longsbus lens is integrated into printed circuit boards (PCBs). Due to the low dispersion of such a unit cell of the metasurface via in glide-symmetric technology, the equivalent reflection index of the unit cell remains stable versus a wide frequency range, which is a good candidate for the design of wideband Longsbus lenses. Electric field in simulation has validated the proposed technology in wideband tolerance. Such Longsbus lens can be easily integrated with other microwave components in PCB technology, promising for applications as beamforming network and multiantenna systems.

P3.088 Labyrinth Absorber Based on Metagratings Metasurfaces for Fungus Detection
Irti Alikuri (Universidad de Navarre, Spain); Pablo Rodriguez-Ulibarri (Asociacion de Industria Navarra, Spain); Sergei A. Kuznetsov (Rzhanov Institute of Semiconductor Physics SB RAS, Russia); Miguel Berouete (Universidad Publica de Navarra, Spain)

In this paper a labyrinth absorber is designed and fabricated in the new paradigm of metagratings metasurfaces, for the first time to detect fungi. The absorber is composed of 100 layers of resonators separated by approximately one-quarter wavelength of the design frequency. Each dielectric resonator is concentrically to allow the detection of circularly-polarized waves. In order to physically design the structure, each resonator is connected to neighboring resonators via four symmetrical bridging stripes. The second dielectric layer is added to cancel reflections caused by the bridges, allowing for the achievement of perfect matching. Full-wave simulations are used to demonstrate the full phase range achieved by varying unit cell dimensions. The operation of the proposed meta-surface is further demonstrated by obtaining reflected and difference-pattern beams from a circularly-polarized slot antenna.

P3.089 Flat Meta-Reflector for Broadband Circularly Polarized Parabolic Antenna
Vivien Taverny (LEME, ULP, Univ Paris Nanterre, France); Badreddine Ratni (Universidad de Navarre, Spain); Yinggang Li (Airbus Defence and Space, France); Shah Nawaz Buruk (UM, France)

A broadband flat-paned reflector antenna based on a metasurface reflector that operates in right-hand circular-polarized band is proposed. The high directive antenna is intended for frequencies spanning from 10.7 GHz to 13.7 GHz in the Ku-band. The designed metasurface is composed of two layers of square patches printed on a grounded low loss dielectric substrate. The metasurface is illuminated by a broadband circularly polarized patch antenna placed at the focal point. The proposed concept is first validated numerically and then experimentally by measurements performed on a fabricated prototype. A highly directive beam is obtained in both simulation and measurement.

P3.090 Study of Broadband/Dual-band Stack Prism Absorber
Chao Su and Vincent Fusco (Queen’s University Belfast, United Kingdom (Great Britain))

This paper presents the study of multilayer absorbers. Such structures can be designed to exhibit broadband absorption performance of 52% fractional bandwidth. We discuss the TE, TM incidence angle dependency characteristics of a doubly periodic arrangement of the square, conical and hexagonal truncated stacked lamination prism array. Then further geometry modification is made to achieve a dual-band operation with a low profile. The simulation results show that the frequency ratio can be controlled by modifying the metallic valuation. The resultant dual-band design has stable absorption performance at different incident angles.

P3.091 A Highly Efficient Multifunctional Metasurface for C- and X-Band Applications
Mehran Abolhasan (University of Technology Sydney, Australia); Ashwin K. Iyer (University of Alberta, Canada); Yuwei Qiu (China); Egypt); and Ali Keivaan (Katholieke Universiteit Leuven (KU Leuven), Belgium)

From 24.2 to 32.4 GHz with measured return loss better than 15 dB, and insertion loss better than 1.3 dB. These results confirm the advantages of M/L technology for implementing ultra-compact band-pass filters showing low loss and potential for being mass-produced at millimeter-wave frequencies.
Transmission of light through subwavelength apertures surrounded by periodic structures have attracted extensive research ... of electromagnetic waves diffracted by a subwavelength aperture using phase-gradient metasurfaces instead of grating...

In this work, a transmissive half-wave plate based on a bi-layered zigzag metasurface operating in the THz band is presented. This design allows for an amplitude transmission efficiency around 92% and a cross polarization discrimination of 40 dB, ensuring almost perfect propagation with an infinite wavelength is observed. Finally, an experimental RF replica of a B-dot wire, based on split-ring-resonators, is proposed.

In recent years the metatronic concept of D-dot wire (a structure that guides the electric displacement current in an subwavelength air channel located in με-near-zero material) has been analyzed numerically and quasi-magnetostatic reflection nor transmission. Being the system lossless, the impinging energy is totally stored in the cavity between the metallic structure, which can be easily implemented, may enable the design of lossless systems with dynamic energy properties.

The storage of electromagnetic energy is a typical capability of closed cavities, whose impenetrable walls don't allow energy to enter or store the energy carried by an external illuminating field has stimulated research efforts in the exploration of designs, including designs based on C6 symmetry or valley-Hall (VH) topological insulators (TI) and non-topological band prototype of the flangeless connection is designed and manufactured, the measured insertion and return loss are less than 0.55 dB and 25.85 respectively over 10 GHz to 15 GHz. The sectional size decreases by more than 70% comparing with traditional waveguide flange.

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 into a PIN diode in the radiation layer for current inversion. Compared with the traditional transmitted or reflective metasurfaces, the feeder-source is integrated into the structure of the metasurfaces for a compact profile.

A confocal 1-bit digital coding metasurfaces are presented for generating convergent multi-mode OAM beams. The designed metasurfaces consist of reconfigurable units with 1-bit phase modulator 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 are achieve.

Flangeless Waveguide Connection Based on Gap Waveguide Technology A wideband (1-11.2GHz) compact waveguide connection is proposed. The artificial magnetic conductor (AMC) structure is designed surrounding the outer surface of a size-reduced end of waveguide, called part-A. Another waveguide with stepped transition to an enlarged and part-B, the inner surface of the enlarged and works as PEC surface. When part-A is inserted into part-B, a tight 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 can be prevented by band gap of the AMC structure formed by PEC and AMC surface. A Ku-band prototype of the flangeless connection is designed and manufactured, the measured insertion and return loss are better than 0.55 dB and 20.85 respectively over 10.5 GHz to 15 GHz. The sectional size decreases by more than 70% comparing with traditional waveguide flare.

Robustness in Subwavelength Locally-Resonant Metamaterial Waveguides Bakhtiyar Orazbayev (UNION TESTING GROUP, Russia); Xiang Chen (Xi'an Jiaotong University, China); Syed Muhammad Qasim Ali Shah (National University of Sciences and Technology, Pakistan); Hajah Ahmed (Research Institute for Microwave and Millimeter-Wave Studies (RMMIS) & NUST, Pakistan); Norshahril Shohab (Research Institute for Microwave and Millimeter-Wave Studies (RMMIS) & National University of Sciences and Technology (NUST), Pakistan)

The storage of electromagnetic energy in a typical capability of closed cavities, whose impenetrable 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 exploration of special 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 an 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 metallic reflector and the metasurface. The proposed structure, which can be easily implemented, may enable the design of lossless systems with dynamic energy properties.

Preliminary Investigation of B-dot Wire Concept Boris Okorn (Rudjer Boskovic Institute, Croatia); Andrey Sayanskiy (RUDER BOSKOVIC INSTITUTE; Croatia); Silvio Hrabar (IEEE Member & Novosibirsk State University, Novosibirsk, Russia); and Silvio Hrabar (IMEC, Belgium)

In recent years the metamorphic concept of D-dot wire (a structure that guides the electric displacement current in a subwavelength channel in zero permittivity media) has been investigated. A dual-concept B-dot wire (consisting of subwavelength air channel located in mu-zero permittivity 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 presented.

Ultra-thin Zigzag Half-Face Plate Metasurface with High Isolation and High Transmission Efficiency in Terahertz Range Alexis Moreno-Peñarrubia (Public University of Navarre & Institute for Stability of Smarter Cities (ISC), Public University of Navarra, Spain); Sergi A. Kuznetsov (IEEE Member & Novosibirsk State University, Novosibirsk, Russia); and Miguel Beruete (Universidad Publica de Navarra, Spain)

In this work, a ultra-thin half-face plate based on a bi-layered zigzag metasurface operating in the THz band is presented. The half-face 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.

Phase-Gradient Metasurfaces for Efficient Conversion of Surface Wave to Propagating Wave Rui Peng (Xi'an Jiaotong University, China); Xiang Wang (University of Namur, Belgium); ninja YK (Key Laboratory of Integrated Services Networks, Xi'an University, China); and Alexandre Piche (INSTITUT D'ELECTRONIQUE FONDAMENTALE DE MONTPELLIER; France)

Transmission of light through subwavelength apertures surrounded by periodic structures have attracted extensive research interest since the last two decades. In this work, we develop a method to achieve directional transmission of electromagnetic waves diffracted by a subwavelength aperture surrounded by phase-gradient metasurfaces instead of gratings.
**Poster-M07: Satellite and Aerospace Antenna Characterisation**

*Measurements*

**Room:** Exhibition Hall

**P3.105 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 diverter strips on antenna performance. A fully coupled electromagnetic model is considered, where the antenna is enclosed by a realistic radome profile on which segmented diverter 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 characterized by both the S11 parameter and the far-field profile.

**P3.106 Proposal of GNSS Satellite Antenna Performance Evaluation Based on Reconstructed Gain Patterns**

Gerardo Allende-Alba (German Aerospace Center, Germany); Steffen Thoelert (German Aerospace Center (DLR), Germany)

The evaluation of available power at user location is an important aspect of 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-nominal 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 satellites antennas. The results may prove to be useful for safety critical and domain-specific applications, such as GNSS reflectometry.

**P3.107 Deployable Helix Antennas for Nano and Micro Satellites**

Tao Huang, Juan Reveles, Daniel Nascimento and Vinodh Gurusamy (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 trifilar 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.

**P3.108 Simple and Robust Probes for Near-Field Antenna Measurements at Low UHF Bands**

Vincent Laquerbe, Gwen Le Duc, Daniel Belot, Lise Feat and Romain Contrares (CNES, France)

This paper presents a simple and robust design of dual-linear polarized UHF 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-M09: MIMO and OTA Testing**

*Measurements*

**Room:** Exhibition Hall

**P3.109 Recent Developments in Radiated Two-Stage MIMO OTA Test Method**

Ya Jing (Keysight Technologies, China); Thorsten Hertel (Keysight Technologies, USA); Hongwei Kong (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 pattern measurement followed by a second stage of throughput measurements using a downlink signal from the communication analyzer that incorporate a convolution of the device's antenna pattern with the desired spatial channel model. The resulting signal is applied to the DUT through the simulated channel, 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 3GPP and CTIA, including 4x4 MIMO OTA test on LTE devices, analyses of CTIA RTS-MPAC SNR-controlled harmonization test results, and the variable Reference Measurement Channel (RMC) MIMO OTA test for SNR-controlled and LTE noise-controlled environments.

**P3.110 On the Measurement of Radiated Power for 5G Mobile Device with Spectrum Analyzer**

Jun Luo, Edwin Mendivil and Michael Christopher (ETS-Lindgren, USA)

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, the new procedure improves measurement accuracy as well as measurement uncertainty (MI) 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.

**P3.111 Field Emulator for Wireless Communication Devices Base on Programmable Metasurface**

Bowen Hao, Peng Hao and Zhiping Li (Beihang University, China)

Space-time-multiplexing metasurface provides a better method for dynamic control of electromagnetic waves. We think it can improve the test systems that 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 histogram and codebook technique are used to complete the calculation of the metasurface. We also describe the implementation and analyze the feasibility of our emulator.

**P3.112 Measurement of OFDM Signals with PAPR Reduction in the Presence of Hardware Impairments**

Hua Wang (Keysight Technologies, Denmark); Xiaoming Chen (Xian Jiaotong University, China); Jiaying 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-spreading OFDM, thus OFDM with simple PAPR Reduction is a viable option for 5G NR waveform.

**P3.113 Impact of Probe Coupling on Emulation Accuracy in Massive MIMO OTA Testing**

Hailing Po and Xiaoming Chen (Xian Jiaotong University, China); Wei Xue (Xi'an Jiaotong University, China); Jiaying 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 (BS). 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-faded signal synthesis (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.
Passive intermodulation (PIM) measurement is necessary for microwave and antenna products to evaluate their PIM performance. In this paper, we present a new approach for PIM measurement, which is based on a novel signal splitting technique. The proposed method allows for the simultaneous measurement of multiple devices under test, significantly reducing the measurement time and cost.

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Xiang Chen
compact double-sided artificial magnetic conductor (AMC) structure. When the adapter is connected between 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 the EBG structure. Meanwhile, metallic contact nonlinearity is almost eliminated by the contactless structure, and PIM can be therefore suppressed. A Ku band prototype of the adapter is designed for a Ku band PIM measurement system. By using the adapter, the system’s residual PIM is significantly improved with a maximum improvement better than 30dB, achieving a stable low level.

Thursday, 19 March 14:50 - 15:30
IS-Thu 1/1: Invited Speaker Session
Measurements
Room: A2
Chair: Christer Larsson (Lund University & Saab Dynamics, Sweden)

14:50 Antenna Measurements and Signal Processing Techniques
Fernando Las-Heras and Yuri Alvarez-Lopez (University of Oviedo, Spain); Jaime Laviada (Universidad de Oviedo, Spain); Ana Arboleya (Universidad Rey Juan Carlos, Spain); Maria Garcia Fernandez and Guillermo Alvarez Narcandi (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 regular 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 handheld portable system to characterize mm-wave antennas at accessible locations.

Thursday, 19 March 15:30 - 16:10
IS-Thu 1/2: Invited Speaker Session
Antennas
Room: A2
Chair: Christophe Fumeaux (The University of Adelaide & School of Electrical and Electronic Engineering, Australia)

15:30 Mobile Satellite Communication Terminals - State of the Art and Antenna Challenges
Karu Esselle (University of Technology Sydney, Australia)
Established satellite operators are investing in new services and new satellite operators have committed billions of dollars to low-earth-orbit satellite constellations. Market analysts predict massive expansion of mobile satellite terminal market into new domains. Recognizing that the beam-steering antenna is the main cost item of a mobile satellite terminal and the established antenna beam-steering methods can't meet the demands of the many new markets, such as low cost and low profile, new antenna beam steering methods are being invented and developed by both industry and academics. This invited presentation outlines the challenges, and reviews the state-of-the-art antenna beam-steering methods that are commercially available at present and being developed for mobile satellite communication terminals.

Thursday, 19 March 16:40 - 18:20
CS42: Nano and Quantum Antennas
T11 Fundamental research and emerging technologies / Convened Session / Electromagnetics
Room: A2
17:00 Electromagnetic Modeling for Nanoscale Quantum Optics: Beyond the Lego-Brick Picture
Martijn Wubs (Technical University of Denmark, Denmark)
Examples are given how the standard electromagnetic modelling of photonic environments can become inaccurate in nanoscale quantum optics. Sometimes for mundane reasons, sometimes because new physics emerges that is not captured in effective indices alone. Aim is to make a connection between the more 'physics-based' and the more 'engineering-based' electromagnetics.

17:20 Quantum Antenna Theory for Secure Wireless Communications
Said Miki (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 new 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.

18:00 On the Design of Bulk Absorbers at THz Frequencies
Andrea Neto, Ralph van Schelven and Paolo Sberna (G Bert University of Technology, The Netherlands)
In this contribution the design of bulk absorbers operating in the THz range is investigated and we propose to simulate them by realizing rears with controlled percentage of metals. The used iudelectrics are assumed to be obeying the Drude model for electron gas where the number of electron per unit of volume is finely tuned. Specifically the Drude model predicts the existence of two frequencies of interest, one associated to the scattering time of the electrons, and a second associated to the plasma frequency, this second largely dependent on the number of electrons. We then move on to minimize the dimensions of the absorbers, by choosing the percentage of metal composing the absorber so that the two characteristic frequencies from the Drude model are coincident. The present investigation provides new, simple and effective guidelines for the design of absorbers in the THz spectrum, based on metal.

CS49: Novel Techniques for Beam Manipulation at Millimeter (Top)

T02 Millimetre wave 5G / Convened Session / Antennas
Room: A3
Chairs: James Kelly (Queen Mary University of London, United Kingdom (Great Britain)), Hang Wong (City University of Hong Kong, Hong Kong)

16:40 Nonperturbative Dynamics of Quantum Antennas
Ifigo Liberal (Public University of Navarre, Spain); Richard Ziolkowski (University of Technology Sydney, Australia & University of Arizona, USA)
Single photon sources typically operate within the weak-coupling regime, where the dynamics of a quantum emitter consists of a simple exponential decay. However, advances in the fabrication of photonic nanosystems, as well as the positioning and coupling of quantum emitters to them are likely to give access to nonperturbative regimes in an increasingly large number of experimental configurations. While nonperturbative regimes are expected to provide new functionalities for nonclassical light sources, they also pose challenges to the design and modeling of such systems. Here, we theoretically investigate the nonperturbative dynamics of a quantum emitter coupled to a two-mode cavity. We demonstrate that it is a result of a combination of coherent oscillations and an exponential decay whose rate of decrease is reduced with respect to that of the weak coupling regime at long times.

17:00 Directive Beam Radiation by A Fresnel Zone Plate Integrated Partially Reflective Surface for Millimeter-Wave Applications
Qing-Qu Guo, Quan Wei Lin and Hang Wong (City University of Hong Kong, Hong Kong)
This paper introduces a high gain Finite Impulse Response (FIR) antenna for millimeter wave applications. By employing a 3D curved 2-layer dielectric plate (2D) integrated partially reflective surface (PRS), 4 dB gain enhancement is realized. The proposed antenna consists of an DR-based feeding source, a quasi-curved 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 21.1 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
Jeison Leon-Valdes and Laura Huitema (Xlim Laboratory, France); Eric Amard (University of LIMOGES, France); Damien Passerieux (University of Limoges, France); Aurelian Crunteanu (XLM, CNRS/ University of Limoges, France)
We present the integration of GeTe (Germanium Telluride) as a phase change material (PCM), within a conventional patch antenna operating in the millimeter wave domain (~ 20 GHz). The GeTe is integrated within the four corners of the metallic patch, which 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 to reconfigure the device between a linear polarization (LP) and a right circular polarization (RHCP). Measured results of the fabricated antenna show total efficiencies up to 73.5 % for the circular polarization (CP) and 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-Hu Li, Wei Shao and Bing-Zhong Wang (University of Electronic Science and Technology of China, China)
Wide angle scanning phased arrays are a popular topic and difficulties in the research field of phased arrays in recent years. Since 2009, Computational Electromagnetic Laboratory (CEM-LAB) 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 phased array scanning angle by using the pattern reconformable technique. Subsequently, CEM-LAB 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 Ouessati (ICTEAM, Université Catholique de Louvain, Belgium); Raj Mittra (Penn State University USA)
This paper presents the design of millimeter wave (mm-Wave) antenna arrays with beam-scanning capabilities and potential use for fifth generation (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 K-band, has a bandwidth of 10 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 costly 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); Markus Maier (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 14°. Moreover, the measured antenna gain is ranging between 13 dB to 14 dB with a side lobe level below 8 dB.

The input reflection coefficient is below -10 dB over the whole W-Band.
16:40 Dual Polarized Dual Band Collocated Beam Switching Antennas for WLAN Applications
Halim Boutayeb (Huawei Technologies, Canada); Fayez Hyjazie (Huawei Technologies Co. Ltd., Canada); Matthew Milyavsky (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 Biasing Circuit for Switched Beam Antenna Steering Usable in Wireless Sensor Networks
Aurelien Surier and Muamba Mukendi Leingthone (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 deployment flexibility 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 circuit to address adequately the antenna beam directivity. In this work, we present the integration of a steering functionality with the design of a biasing circuit to be deployed on a dipole antenna usually used by IEEE 802.15.4 standard sensors. We then compare the new reconfigurable 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 dBi 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 Sosin, Artem Kolobov and Roman Maslennikov (Radio Gigabit LLC, Russia)

The paper describes a wideband dual-polarized MIMO antenna designed for 5 GHz Wi-Fi communication networks. 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 MIMO antenna as compact as a single-polarized one. The antenna is integrated into an enclosure with a plastic frame 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 is 17-20 deg. in both azimuth and elevation planes. Achieved gain provides increased communication distance of the radios for trackside 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 Ashwin K. Iyer (University of Alberta, Canada)

This paper presents the design of a novel dual-band, dual-polarized antenna (DBDPA) enabled through the use of metamaterial-based electromagnetic bandgap structures (MTM-EBGs). The MTM-EBG is ideal for such an implementation since it is uniplanar and embedded 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 1.5%, with gains of 6.9 dBi and 7.4 dBi at 3.6 GHz and 3.8 GHz, respectively, for the two polarizations. Furthermore, the simple pin feeds for each polarization experience 30 dB isolation due to the 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 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 80%. The measured beam width of the cross-polarization that is 15 dB lower than the co-polarization is more than 120°.
16:40 Review of Recent Advances in the Leaky-Wave Analysis of 2-D Leaky-Wave Antennas
David R. Jackson (University of Houston, USA); Filippo Capolino (University of California, Irvine, USA); Ahmad T. Almutawwaa (PAAET, Kuwait); Hamidreza Kazemi (University of California Irvine, USA); Sohini Sengupta (Energeous Corporation, USA); Walter Fucalsalo 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 multiband Fabry-Pérot resonant cavity antennas, and (3) leaky-wave analysis of 2-D periodic leaky-wave antennas (ones that radiate from higher-order space harmonics).

17:00 Radiating Slot Array Antenna for 5.8 GHz Band Beam-Forming Wireless Power Transmission
Takashi Tomura and Hiro Hirokawa (Tokyo Institute of Technology, Japan); Minoru Furukawa and Tetsu Fujiwara (Sho Engineering Corp., Japan)
This paper presents beam-type wireless power transmission by using a radiating slot array antenna (RSA). By using the large antenna array and the near-field region enables highly efficient wireless power transmission. A uniformly excited RSA is designed at 5.8 GHz-band, one of the industry standards for medical (ISM)-band. The two designed RSAs are placed via a wire and transmission are analyzed. The distance of 28 cm, 47% transmission is confirmed whereas the wire is a significant material loss, and reflection loss.

17:20 Reducing Side-Lobe Level of Surface-Mounted Printed Leaky-Wave Antenna
Nima Javanbakht, Barry Syrett and Ronny E. Ayama (Carleton University, Canada); Jafar Shaker (Communications Research Centre Canada, Canada)
A novel method for suppressing the undesired radiation of the feed section is introduced. The proposed method reduces the side-lobe level radiation. 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. The operating frequency is chosen as 28.5 GHz in 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-Band Radiation Properties of Higher-Order Space Harmonics-Enabled Leaky-Wave Antenna
Mohammad Reza Rahimi (Polytechnique Montréal, Canada); Mohammad S. Sharawi (Polytechnique Montréal, Canada); Ke Wu (École Polytechnique (University of Montreal) & Center for Radiofrequency Electronics Research of Quebec, Canada)
In this work, we investigate the inherent physical behavior of higher-order space harmonics (SHS) exposed in higher-order periodic leaky-wave antennas (TH-periodic LWA structures). The interdependence of even n [2, 4] and odd n [1, 3] SHS 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 multiband antenna (MBA) without using any feeding network. In addition, the scanning range of n = [1, 2, 3, 4] space harmonics is studied and its limitations is discussed. The proposed concept is then validated by designing and implementing a MBA utilizing the substrate integrated waveguide (SW) technology in which the n = [1, 2, 3] space harmonics are used for achieving a MBA exhibiting wide scanning capability. The experimental results obtained in this work show 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 Shubhank Gupta (Carleton University, Canada)
A novel analysis 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 antenna (MLWA) structure formed using an array of N 1-D LWA's with 2N ports. When this structure receives a broadband time-domain signal from a single direction, the signals' various spectral components are separated in real-time. They subsequently appear at the various ports of the MLWA 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 Antenna in Russia

11: Fundamental research and emerging technologies / Convened Session / Antennas
Room: B4
Chairs: Dmitry Khodolynyk (Saint Petersburg Electrotechnical University LETI, Russia), Liubov Liubina (Saint Petersburg Electrotechnical University LETI, Russia)

16:40 Circular-Polarized Antennas Far-Field Enhancement Using Round Reflectors with Curved Sidewall
Vladimir Lutan (Bauman Moscow State Technical University & National Research Nuclear University MEPhI, Russia); Daniel Semenyka and Elena Komissarova (Bauman Moscow State Technical University, Russia)
The report discusses the problem of wide-angle 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 asymmetric 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 Tikhov (Rostov-on-Don Research Institute of Radio Communication, Russia)
This paper presents a feasibility study of a classical offset dual-reflector configuration for sub-Terahertz 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, Svyatoslav Ballandov, Grigory Kostikov and Liubov Liubina (Saint Petersburg Electrotechnical University LETI, Russia)
The method of increasing the operating frequency of reflectarray antennas is proposed. The main idea of this method is to compensate phase errors by means of the spatial separation of layers with reflective elements. A full-metal reflectarray antenna has been designed with the use of the proposed method, manufactured, and tested. The 18% relative frequency band upon a criteria of 3dBi gain reduction is achieved. The peak directivity is 27.7. In addition, issues related to the excitation of slot-element self modes are considered. The excitation of these modes can significantly affect the characteristics of the reflectarray face.

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); Andrey Andreevich Skudin (Moscow Institute of Electronics and 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 on of its wide walls 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 Orekhov (Joint-Stock Company "NIVektor", Russia); Nikolai Pavlov (Joint-Stock Company NIVector, Russia); Yury Salomatov (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 Luneburg Lense is implemented. The result is presented and the inference of FDM printing possibility while fabricating spherical Luneburg lens is given.

CS31: GNSS Antennas and Systems for Challenged RF Environment

T08 Positioning, localization & tracking / Convened Session / Antennas
Room: B5
Chairs: Loic Bernard (ILL, France), Michel Clénet (Defense Research and Development Canada, Canada)

16:40 Interference Mitigation for Robust Automotive Satellite Navigation Achieved with Compact Distributed Antenna Sub-Arrays
Syed Naser Hasnain and Ralf Stephan (Technische Universität Ilmenau, Germany); Marius Brachvogel (RWTH Aachen University, Germany); Michael Meurer (German Aerospace Center (DLR) & RWTH Aachen University, Germany); Matthias Hein (Ilmenau University of Technology, Germany)
T05-A12/3: Body Area Antennas and Sensor Systems

T05 Biomedical and health / Regular Session / Antennas

Room: B6

Chairs: Katsuyuki Haneda (Aalto University, Finland), Gaetano Marocco (University of Rome Tor Vergata, Italy)

16:40 Multichip RFID Epidermal Sensor for Body Temperature Monitoring
Sara Parrella (University of Roma ‘Tor Vergata’, Italy); Cecilia Ochiluzi (University of Roma Tor Vergata & DICT, Italy); Gaetano Marocco (University of Rome Tor Vergata, Italy)

A dual chip UHF RFID epidermal sensor tag is here proposed for monitoring human body temperature. A multi mode square loop configuration has been tested by two orthogonal matching elements whose position and shape are such to simultaneously optimize the reading performance of both ICs. Thanks to the presence of two independent sensors, the device is able to perform differential measurements respect to the body position (the acquisition points are slightly de-localized) and to the external environment. The device is hence a concept of a single heat-flux thermometer to be used to estimate the core temperature of the body.

17:00 Full Analysis of Wearable Textile Sensor for Biomedical Applications: Preliminary Validations Towards a Pre-Clinical Approach
Sandra Costanzo and Vincenzo Ciolfi (University of Calabria, Italy)

A full analysis of textile wearable sensor to be adopted for the non-invasive monitoring of diabetes pathology is discussed. Simulation data are collected by adopting a stratified biological material as radiation medium, with an accurate dielectric model for the blood, properly characterizing the variation of its complex permittivity in terms of changes in the glucose concentration. Experimental results on human subject are discussed to demonstrate the validity of simulations. Furthermore, the SAR performance of the proposed sensor configuration is evaluated, and a simple increase in the textile dielectric thickness is applied to guarantee the satisfaction of the imposed maximum levels on humans. Finally, the experimental procedure leading to the preparation of biological phantoms useful for a pre-clinical assessment is described.

17:20 Passive RFID-based Textile Touchpad
Han He, Xiaochen Chen, Leevi Raitio, Helikki Huttunen and Johanna Virkki (Tampere University, Finland)

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 gets 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.

17:40 A Dual-band Repeater Antenna for On-Body Receiver Unit of Wireless Capsule Endoscopy
Md Miah and Clemens Icheln (Aalto University & School of Electrical Engineering, Finland); Slobodan Jovic (Aalto University, Finland)

A dual-band repeater antenna for the on-body receiver unit of a wireless capsule endoscopy system is presented. The design utilizes two rectangular offset patches, printed on two sides of a substrate. The two top and bottom patches are configured in such a way that wideband matching with sufficient radiation efficiency is achieved at both bands. A canonical tissue phantom and realistic human body models have been used for the numerical studies. The latter was validated through ex vivo measurements on a rabbit human body. The measured -10 dB impedance bandwidths of both bands of the SoS are 44% and 14.4% at the MedRadio and ISM band, respectively. The antenna also exhibits a high bandwidth on the ISM band.

18:00 UWB Planar Bias-switched Imaging Array for Breast-Cancer Screening
Natasha Nikolova, Farzad Foroutan, Vantika Tyagi, Chi-Hung Chen and Charl Baard (McMaster University, Canada)

Electromagnetically switched arrays offer superior measurement speed and position accuracy compared with mechanical scanning. These advantages are important in the applications of medical imaging. However, current RF-switch architectures suffer from inherent limitations on the number of multiplexed ports, the relatively large size, the significant insertion loss, limited isolation, and high price. Here, we present a novel bias-switched architecture for RF switching by shifting the burden of port multiplexing to the intermediate-frequency (IF) output. It makes full use of the dynamic range of a vector network analyzer while multiplexing hundreds of array elements. The design and performance of the system components is briefly described as well.
16:40 Experimental Evaluation on TDOA-based Aircraft Position Verification
Junichi Naganawa and Hiromi Miyazaki (Electronic Navigation Research Institute, Japan)
Automatic-dependent surveillance - broadcast (ADS-B) is an emerging means of aircraft monitoring/surveillance that employs position reports periodically broadcasted by aircraft. ADS-B can provide accurate positions of aircraft with low-cost implementation of ground facilities. However, ADS-B is susceptible to false aircraft information injected by malicious emitters or generated by avionics failures. A promising countermeasure for this security issue is position verification using TDOA (Time Difference Of Arrival). In this paper, an experimental study is reported to investigate the performance of the TDOA-based position verification method. As a result, a good probability of detection was measured. The experiment also verified the theoretical model which was previously derived by the authors. The presented result is important as a rationale that supports the effectiveness of the method. In addition, the model is generic and informative to other systems that may depend on position reports, e.g. traffic management of Unmanned Aerial Vehicles (UAVs).

17:00 Measurements of Opportunistic Aircraft Signals and Verification of a Propagation Prediction Tool in Mountainous Region
Junichi Naganawa (Electronic Navigation Research Institute, Japan); Karma Wangchuk (Tokyo Institute of Technology, Japan); Sangay Sangay (Department of Air Transport, Japan); Karma Gayley and Devi Adhikari (Bhutan Civil Aviation Authority, Bhutan); Hiromi Miyazaki (Electronic Navigation Research Institute, Japan)
Automatic-dependent surveillance - broadcast (ADS-B) is an emerging and more economically viable means of aeronautical surveillance. Aircraft periodically broadcasts surveillance information such as its own position and velocity. Although ADS-B was originally developed for air traffic control, measurement of opportunistic ADS-B signals can be applied to radio propagation study. This paper presents a comparison on the received signal strength (RSS) between measurements of opportunistic ADS-B signals and predictions by a Physical Optics-based tool with terrain data in the Himalayan mountains of Bhutan. Two measurement scenarios were studied: one with the receiver at the airport located in the bottom of a mountainous valley and another with the receiver on the top of a mountain that surrounds the valley. The comparison is aimed at 1) investigating the ADS-B signal propagation in the mountainous region, 2) demonstrating a site-survey by opportunistic ADS-B signals, and 3) demonstrating verification of a propagation prediction tool.

17:20 3D SAR Processing of UAV-mounted GPR Measurements: Dealing with Non-Uniform Sampling
Maria García Fernández (University of Oviedo, Spain); Yuri Álvarez (University of Oviedo, Spain); Fernando Las-Heras (University of Oviedo, Spain)
This contribution is devoted to analyze the effect caused by non-uniform sampling and to present a technique for dealing with this issue in a system composed by a Ground Penetrating Radar (GPR) mounted on board an Unmanned Aerial Vehicle (UAV). Radar measurements are accurately geo-referred in order to enable the use of Synthetic Aperture Radar (SAR) techniques. The adopted SAR technique must be able to handle measurements gathered at arbitrary positions. In addition, the positioning data must be also carefully processed to cope with non-uniform sampling and flight deviation issues. A method based on defining a set of conditions that a measurement position must satisfy to be selected for processing has been proposed. Comparing the resulting 3D radar images retrieved from measurements gathered during autonomous flights, both the image artifacts and the computational time are significantly decreased, showing the feasibility of the proposed technique to overcome non-uniform sampling issues.

17:40 Millimeter-Wave Automotive Radar Scheme with Passive Reflector for Blind Corner Conditions
Dimitrios Sounas (RomaTre University, Italy); Carlos Baquero Barneto (Tampere University, Finland); Matias Turunen (Tampere University of Technology, Finland); Markus Allen (Tampere University, Finland); Yevgeni Koucheryavy (Tampere University of Technology, Finland); Mikko Valkama (Tampere University, Finland)
One of the primary functions of millimeter-wave automotive radar is collision avoidance. This application is typically realized in lane-of-sight conditions. However, it does not perform well in situations, when another car suddenly enter into view around the corner of a building. Hence, this paper proposes a radar scheme with a reflector enabling the detection of oncoming cars in blind corner conditions. First, our ray tracing modelling results demonstrate the difficulties of straight-forward non-line-of-sight radar application in such a scenario. Then the paper considers the installation of a planar reflector, which should solve the issue. This is verified with real-world measurements. The results also indicate that the detection performance is sensitive to the around-the-corner car position and orientation of the reflector. Specifically, r+10 degree deviation raises the signal-to-noise ratio of more than 20 dB. Thus, the location and direction of the reflector should be adopted individually for the particular deployment.

18:00 Metasurface-based Radar Jammers and Deceptors Implemented Through Time-Varying Metasurfaces
Davide Ramaccia (RomaTre University, Italy); Dimitrios Sounas (Wayne State University, USA); Andrea Aliu (The University of Texas at Austin, USA); Alessandro Tossano (University Roma Tre (IT), Italy); Filiberto Bilotti (University Roma Tre, Italy)
Electronic radar jammers typically consist of an antenna system and a corresponding circuitry, that captures, 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 Maitra, Soumyajoti 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 radiometers at a tropical location where precipitation has varying microstructures in terms of DSD, cloud liquid-water content, radar reflectivity and atmospheric attenuation at Ka band frequencies. A technique is proposed to retrieve the rain parameter DSDs 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 MWIR. Convective rain is characterized by high rain rate, high cloud liquid water content 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 Teschl (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 a useful complement 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’s data rate is increasing - not only in remote areas. When retrieving rain from signal measurements, the quality of the signal measurements has to be understood. 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 modern communication systems and provides a correction function for the values. This analysis lays the foundation for using these types of VSATs for retrieving rain information and also has benefits for satcom network operators.

17:20 Sea Surface Characterization Using Dual Polarized GNSS Receivers

T10-E05/2: Imaging and Inverse Scattering

Ankit Regmi and Aarno Pärssinen (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 reflected and direct signals from the sea surface. Dual circular polarized reception (DCPR) system gives the opportunity to exploit the polarisation change of the incident signal after reflection. This paper reports received signal characteristics of various GNSS satellites for sea surface conditions. The received signals from various satellites are compared and are analysed statistically to characterise the sea state. The reflected left-hand circular polarised (LHCP) signals are used to analyse the scattering characteristics of sea surface. The statistics of LHCP signal give strong correlation with the wind speed over the sea and can be used to characterise the sea state.

17:40 The MEKaP Project: Measuring Tropospheric Impairments at Ka Band with MEO Satellites

Lorenzo Luini, Carlo Riva and Alberto Panzani (Politecnico di Milano, Italy); Armando Rocha (University of Aveiro & Instituto de Telecomunicações, Portugal); Susana Mota (University of Aveiro & Instituto de Telecommunications, Portugal); Frank S. Marzano, Augusto Marziani and Marrianna Biscarini (Sanpienza University of Rome, Italy); Fernando Consolvi (FIR, Italy); Vincenzo Schembri (Thates Alenia Space Italia, Italy); Antonio Marcelli (European Space Agency, The Netherlands)

The design phase of an ESA-funded project (MEKaP - MEKa-band Propagation) is described. The study, involving Politecnico di Milano, Sanpienza University of Rome, Instituto de Telecomunicacoes Aveiro Pole and Thates Alenia Space-Italy, aims at characterizing the main properties of the atmospheric radio channel of a MEKa-band SatCom system. The propagation campaign, lasting at least 12 years and including four ground receivers, will rely on the MEK CoMP Ka-band satellite constellation, which provides key characteristics for propagation evaluation models, 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-stationary systems and to extend the experimental database of radio regulatory bodies such as the ITU-R.

18:00 The Variability of Scattering from Leaves and its Impact on Propagation

Jamil Bataineh and Robert J. Watson (University of Bath, United Kingdom (Great Britain))

This paper presents the techniques and results on remote sensing of rain using radars, both space-borne and ground based, and ground-based radiometers at a tropical location where precipitation has varying microstructures in terms of DSD, cloud liquid-water content, radar reflectivity and atmospheric attenuation at Ka band frequencies. A technique is proposed to retrieve the rain parameter DSDs 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 MWIR. Convective rain is characterized by high rain rate, high cloud liquid water content 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.

18:40 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 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 the effectiveness with both numerical simulation and experimental measurement. In both simulation and experiment results, the artifacts like side-lobes, grating lobes or clutter in the original images are reduced in the processed images after applying the phase coherence method.

19:20 Inverse Scattering by Means of a New Rewriting of the Integral Equations

Martina Teresa Bevacqua (Università Mediterranea di Reggio Calabria, Italy); Carey Rappaport (Northeastern University, USA)

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 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 the effectiveness with both numerical simulation and experimental measurement. In both simulation and experiment results, the artifacts like side-lobes, grating lobes or clutter in the original images are reduced in the processed images after applying the phase coherence method.

19:40 Automatic Permittivity and Thickness Characterization of Body-Borne Weak Dielectric Threats Using Wideband Radar

Mahdih Ard, Mohammad M. Tajdini, Elizabeth Wig and Carey Rappaport (Northeastern University, USA)

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 the 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 original radar image and define the amount of body displacement in the radar image which is caused by the signal retardation due to presence of the 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 Incorvaia (The University of Manchester, United Kingdom (Great Britain)); Oliver Dom (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 novel 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 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.
In recent years, there has been a significant interest in reflectarray antennas and their use for CubeSat applications, particularly with the increasing demand for small satellites in Earth observation and communications. Reflectarrays are planar arrays of elements that can be designed to produce complex radiation patterns, making them a versatile option for CubeSat applications.

The design process involves the use of quasi-periodic surfaces and the concept of effective medium theory. This approach allows for the creation of advanced reflectarray designs that can be tailored for specific mission requirements. The talk will discuss the application of this method to the design of reflectarrays for future CubeSat applications, highlighting the benefits and challenges associated with this technology.

**References**


**Acknowledgments**

The authors would like to acknowledge the support of the European Space Agency (ESA) and the technical contributions of the TICRA team for their assistance in the design and development of the reflectarray antennas presented in this paper.
8:30 Integrated Doherty Power Amplifier - Antenna Element with Active Impedance Modulation: Efficiency vs. Bandwidth Trade-Offs
Oleg Lipikov and Jose-Ramon Perez-Cintron (Chalmers University of Technology, Sweden); Rob Maaskant (CHALMERS, Sweden); Christian Fager and Koen Buismen (Chalmers University of Technology, Sweden); Daniel Åkesson (Ericsson AB, Sweden); Marianne Ivashina (Chalmers University of Technology, Sweden)

This work presents an integrated Doherty power amplifier - antenna design at 3.5 GHz. Both power combining andmatching to optimal 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.

9:00 Theory of Cross-Polar Beamforming for Dual Polarized Arrays in Mobile Communications
Bjorn Lindmark (Commscope, Sweden)

Different theoretical aspects of cross-polarized beams in mobile communications are studied, in particular BTTF 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. Petersson (Ericsson AB, Sweden)

This paper focuses on a new method, called dual polarization beamforming (DPBF), to design beam patterns. Instead of using only a single element polarization, the desired beam pattern is designed as the sum of powers for two orthogonal element polarizations. Thus, the focus is on total radiation power beam patterns. The DPBF technique provides additional degrees of freedom to form a desired beam pattern such that amplitude variations in the beamforming vector can be significantly reduced, potentially to form amplitude. This is a very interesting property, especially for active antennas, since it offers the potential of full power amplifier utilization. The method is applied to uniform linear arrays (ULA) as well as uniform rectangular arrays (URA). 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 DPBF, both for ULA and URA.

9:30 Full Duplex Spatial Modulation System Performance Depending on Self-Interference Cancellation Accuracy
Yanni Zhou and Florin Huta (Univ Lyon, INSA Lyon, Inria, CIT, France); Guillaume Villemaud (Université de Lyon, INRIA, INSA-Lyon, CIT, France)

Spatial modulation (SM) as a new MIMO technique is based on transmitting part of the information by activating different emitting antennas. SM increases spectral efficiency and uses only one radio frequency channel. Moreover, for full duplex (FD) communication systems, self-interference (SI) is always a central problem. Therefore, combining FD and SM can dramatically reduce the difficulty of SI (Self-Interference Cancellation) because of the single SI chain. A Full Duplex Spatial Modulation (FDSM) system is proposed and an active analog SI Cancellation is highlighted in this paper. Moreover, the impact of SI cancellation on the system performance is studied. The results demonstrate that accurate compensation of SI improves the system’s performance. Furthermore, the SI detector is sensitive to the number of detect symbols.

9:50 Signal-to-Noise Ratio Considerations for Secure Antenna Polarization Modulation
Cara Yang Kataria and Steven Franke (University of Illinois at Urbana-Champaign, USA); Jennifer T. Bernhard (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 physical layer 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 increasing 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 Amani (Chalmers University of Technology, Sweden); Amjadshad Farsaie (Eindhoven University of Technology, The Netherlands); Ulf Gustavsson (Ericsson AB, Sweden); Thomas Eriksson (Chalmers University of Technology, Sweden); Frans M.J. Willems (Technical University Eindhoven, The Netherlands); Marianne 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 performed where scatters are considered as resonant dipoles confined in clusters of scatterers (CIs). While the probability of having highly correlated user equipments (UEs) in a multi-user multiple-input multiple-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 Ozola and Daniele Cavato (University of Technology, The Netherlands)

We present a study on the performance of wideband, wide scanning elements, when the antennas 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 in different directions. Wideband wide-scan 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
Yasir Ismael Abdulraheem Al-Yasir (University of Bradford, United Kingdom (Great Britain)); Naser Qarouri Parchin (University of Bradford, United Kingdom (Great Britain)); Mohammad Fares (University of Basra, Iraq); Ahmed Maan Abdullahkhalique (University of Bradford & SARAS Technology, United Kingdom (Great Britain)); Maryam Saidjin (University of Aveiro, Portugal); Issa Elfergani and Jonathan Rodriguez (Instituto de Telecomunicacioes, Portugal); Raed A Abd-Almahmeed (University of Bradford, United Kingdom (Great Britain))

In this paper, a new high-gain differential-fed dual-polarized microstrip filtering antenna with an optimum common-mode rejection is presented. Two different pairs of probe feeding ports are utilized to provide differentially exciting signals. The filtering response is achieved by introducing four symmetrical open-loop ring resonator slots on the top layer surrounding the four excitation ports of the patch antenna. The resonators can produce nulls at the low edge of the passband 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 to 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 levels due to the differentially driven ports.
1:40 On the Use of the Observable Field to Synthesize Independent Beams from a Finite Volume
Andrea Neto and Arturo Fiorelli Bernardis (Delft University of Technology, The Netherlands); Angelo Freani (University of Florence, Italy); Nura Llambart (Delft University of Technology, The Netherlands)

The contribution in the meaning of independent planes waves that can be received by an antenna of given volume in terms of the wavelength is addressed. To define the independency 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 antennas. We then define two non-adjacent plane waves as independent over a given domain, if the available power associated to the two arising simultaneously is equal to the sum of the available power for each of the two plane waves. Finally the maximum number of independent beams that can be received by an antenna of given volume in terms of the wavelength is addressed.

12:00 High-Gain Flat-Top Antenna Sub-Arrays for Planar Arrays with Limited Field of View
Ronis T. Maximidis (Eindhoven University of Technology, The Netherlands); Diego Caratelli (The Antenna Company, The Netherlands); Giovanni Toso (European Space Agency, ESA ESTEC, The Netherlands); A. B. (Bart) 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 centres along the relevant main axis is larger in a linear array, which leads to limited scanning capabilities, whereas the inter-element separation along the orthogonal plane is about half free-space wavelength at the central operating frequency, thus 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 ±7° at the ±E-plane and ±27° at the H-plane. The specific sub-array pattern, which approximates a rectangular pulse distribution, allows to fill out the grating lobes along the E-plane.

CS37: IRACON Spectrum Sharing: Challenges and Opportunities for 5G and Beyond
T02 Millimetrewave 5G / Converged Session / Propagation
Room: A3

Chairs: Marina Barbrolli (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 Modelling for Indoor Tfrz Communication
Novoed Ahmed Abbas, Arjun Hanharan, Arun Meni Nair and Andreas Molisch (University of Southern California, USA)

To explore the eventual deployment of communication systems in Teahvat (THz) band (0.1-10 THz) frequencies, extensive channel measurement campaigns are essential. In this regard, we conducted an indoor line-of-sight (LoS) measurement campaign up to 5.5 m on a THz channel sounding system that covers 140-220 GHz. We use a frequency-domain channel sounder that is based on a vector network analyzer (VNA) and frequency extenders for these measurements. By using the log-distance path loss model, we evaluate the impact of path loss exponent and the fading distribution standard deviations. The power delay profile analysis of our measurements shows that there are negligible multipoles in the LoS dominant path for the current sceneres. Our result provides a platform for future extension of THz band communication in the 140-220 GHz frequency range.

9:10 Characterization of the Propagation Channel in Conference Room Scenario at 190 GHz
Diego Duplich (Istituto University of Technology, Germany); Robert Muller and Sergi Skulbikov (TU Ilmenau, Germany); Markus Lantmann (Fraunhofer Institute for Integrated Circuits IIS, Germany); Giovanni Del Saldo (Fraunhofer Institute for Integrated Circuits IIS & Technische Universitat Ilmenau, Germany); Reiner S. Thomä (Istituto University of Technology, Germany)

In the present paper we introduce unique directional-dual-dual polarized measurements at 190 GHz in a conference room with the characterizing mechanism of propagation modeling and beam-forming approaches. Assisted by ray-tracing, multiple scatterers have been identified, showing a rich multi-path environment. Investigations have shown that polarization diversity increases spatial diversity and amerce deterministical modelling approach in polarization is needed to avoid overestimating polarization diversity gains.

9:50 Enabling RF Technologies for Spectrum Sharing
Mark Beach, Leo Laughlin, Eyal Arabi, Simon Wilson, Samad Ozan and Chris Gamliel (University of Bristol, United Kingdom (Great Britain))

Spectrum sharing has the potential to significantly increase spectrum utilization in underutilized spectrum by re-allocating shared access between previously isolated unlicensed and new commercial and private wireless services and applications. The citizen broadband radio service in the United States implements a basic form of dynamic spectrum access and is an example of spectrum sharing becoming a reality. Numerous regulatory changes in other countries are soon to follow. To make the most efficient use of spectrum in dynamic spectrum access regimes requires transceivers with excellent frequency agility, linearity, and selectivity, in order to optimally-locally exploit available spectrum, whilst reducing interference and reducing the impact of interference. This article provides a brief overview of recently introduced spectrum sharing regulations, and discusses hardware requirements for current and future dynamic spectrum access systems. Recent advances in relevant RF technology enableants, presenting converging transmitter power amplifiers, multi-band receivers, self-interference cancellation, and reconfigurable antennas.

10:30 Assessing the Feasibility of the Spectrum Sharing Concepts for Private Industrial Networks Operating Above 5 GHz
Pekka Ojane (Co-Worker Technology, Finland, Finland); Seppo Ylijoki (Nokia & University of Oulu, Finland); Marja Mattinmikko-Blue (University of Oulu, Centre for Wireless Communications, Finland)

Ongoing 5G deployment is bringing higher speeds, higher capacity and greater reliability to the connectivity enabling data shariing amongst participating components of industrial systems. The private industrial networking opportunity for serving different verticals is largely dependent on the timely availability, quality and the cost of spectrum. The growing pressure to open the wireless market for location specific networks has resulted in new regional 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 concepts. Specifically, recent sharing concepts above 5 GHz in the EU, and four selected countries: Australia, Hong Kong, Japan, and UK are analysed 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 MNO’s.

11:10 Regulatory Requirements and Characterization of Transmitter and Receiver Parameters to Set a Novel Framework for Spectrum Sharing
Peter Faris and Doriana Guiducci (European Communications Office, Denmark)

In demand for spectrum due to new radio technologies such as 5G create challenges for regulatory bodies to enable spectrum sharing. Regulatory limits for new types of equipment need to be set to enable sharing between different systems in the same or adjacent frequency bands. A balanced approach between limits for transmitter and receiver parameters is necessary in this context. Such limits are typically derived from coexistence studies which need to be based on realistic assumptions of device performance to ensure overall efficient and interference-free use of spectrum. This paper discusses recent developments in European regulations within the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT) to enable new approaches for spectrum sharing in this context.

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); Tomoaki Ogawa (NTT Japan); Yasushi Takatori (NTT Network Innovation Laboratories, Japan)

Diversifying 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 the congestion rate in a target area. Furthermore, the cost of recognition can be expected to be low since the 3GPP 11.211 (WLAN CSI). To realize our scheme in real environment 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 measurements. We also prove the effectiveness of our scheme in experimental results of user locations and congestion rates.

11:00 A Kirschhoff Approximation Based Spectrum Availability Prediction Method at Millimeter Wave
Kosuke Murakami (Tokyo Institute Technology, Japan); Junichi Takada, Kentaro Saito and Panawit Hanpinitsak (Tokyo Institute of Technology, Japan)

This paper proposes a frequency resource detection method for dynamic spectrum sharing (DSS) using the Kirschhoff approximation (KA) technique. KA is a well-known technique that can deal with the path over multiple buildings, which is the most dominant path in the suburban area. Although many researches have done for investigation of the prediction model, it has been shown that KA technique can be used for prediction of the path loss due to obstacles and also for prediction of the path loss due to obstacles in the suburban area. Moreover, the proposed model was designed to calculate maximum path loss by selecting only a few building edges that significantly block the line-of-sight (LOS) ray. Through this implementation, it is possible to limit the overestimation of the path loss while keeping the value bigger than the free-space path loss (FSP) to ensure the transmission opportunity of the secondary systems.

11:20 Highly-Reconfigurable Time-Based Radiating Systems and Their Optimization
Diego Masotti (University of Bologna, Italy); Lorenzo Poli (ELEIDIA Research Center, University of Trento, Italy); Mazen Al Shanawani (University of Bologna, Italy); Paolo Rocca (University of Trento, Italy); Alessandra Costanzo (DEI, University of Bologna, Italy)

This work aims at underlying the high reconfiguration capability of time-modulated arrays (TMAs) and their potential use in dynamic spectrum sharing systems. The architectural simplicity of TMAs offers, as a counterpart, a complex dynamic radiating mechanism whose accurate description can significantly impact on the optimum solution. For this reason, overview of the available simulation and optimization techniques is proposed, mainly focusing on a recently proposed tool able to take into account the dynamic linear and nonlinear phenomena occurring during a time-based radiation.

11:40 Joint Statistics of Urban Clutter Loss and Building Entry Loss at 3.5 GHz and 27 GHz - From Measurement to Modelling
Richard Rudd (Plum Consulting Ltd, United Kingdom (Great Britain)); Xiaomin Meng, Victor Ochi, Debasu Wu and Maziyar Nekovee (University of Sussex, United Kingdom (Great Britain))
CSI3: IET Session: New Antenna Systems Involving Application of Metamaterials and Metasurfaces

T11 Fundamental research and emerging technologies / Convension Session / Antennas

Room: [ ]
Chairs: Kenneth Lee Ford (University of Sheffield, United Kingdom (Great Britain)); Hisamatsu Nakano (Hosei University, Japan)

8:30 A Novel Metamaterial Dual-band GPS Antenna Extending to Space Diversity Applications
Changheyoung Lee, Heequin Park and Gwang-Gyoon Namgung (Incheon National University, Korea (South)); Yujin Seo (Incheon National University, Korea (South)); Sungtek Kahng (University of Incheon, Korea (South))

First, we present a new design method for making a very compact metamaterial dual-band circular polarized (CP) antenna for global positioning systems (GPS). The dual-band GPS antenna achieves a directive gain of 1.7 dB at 1.21 GHz and 2.45 GHz. In detail, first, the dual-band resonance and radiation come from the CRLH radiator with a ring-mesh which makes the linearly polarized broadside beam. For CP, as the two GPS bands, we form an aligned cross-shaped slot on the patch and tune it. 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 the good impedance matching, efficiency, axial ratio at the dual-band with low cross-polarisation as a good inter-antenna isolation.

8:50 Circularly Polarized Concentric Metaring Antenna
Hisamatsu Nakano and Tomoki Abe (Hosei University, Japan); Amit Mehta (Swansea University, United Kingdom (Great Britain)); Junji Yamauchi (Hosei University, Japan)

In this paper, a new design method is introduced for making a very compact metamaterial dual-band circular polarized (CP) antenna for global positioning systems (GPS). The dual-band GPS antenna achieves a directive gain of 1.7 dB at 1.21 GHz and 2.45 GHz. In detail, first, the dual-band resonance and radiation come from the CRLH radiator with a ring-mesh which makes the linearly polarized broadside beam. For CP, as the two GPS bands, we form an aligned cross-shaped slot on the patch and tune it. 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 the good impedance matching, efficiency, axial ratio at the dual-band with low cross-polarisation as a good inter-antenna isolation.

9:10 Gaussian Horn Implemented by Metasurfaces
Valentina Sozio (Istituto Superiore Mario Boella, Italy); Enrica Martin (University of Siena, Italy); Francesco Caminita (Wave-Up SRL, Italy); Paolo De Vita (IDS Ingegneria Del Sistemi S. p. A, Italy); Andrea Giacomini (Microwave Vision Italy, Italy); Marco Sabbadini (Esa Est, The Netherlands); Stefano Fracassi (University of Siena, Italy); Giuseppe Vecchi (Politecnico di Torino, Italy)

We present design, realization and measurements of a Ku-band metasurface-based horn that emulates a Gaussian corrugated horn with the use of subwavelength patches printed on the internal walls. The design method is based on the adiabatic approximate solution for the hybrid mode of a conical waveguide with balanced impedance walls. This approach results in an analytic design method that does not require any optimization. The horn has been realized and characterized showing superior agreement with both theory and simulations, with performance comparable with those of a conventional corrugated horn.

9:30 Directive Radiation from Metamaterials with Generalized PT-Symmetry
Pai-Yen Chen (University of Illinois at Chicago, USA)

We propose a high-directivity, low-loss wave structures based on metasurfaces with generalized parity-time (pT) symmetry. We theoretically show that a pT-symmetric metasurface channel (or metachannel), when operated at the coherent perfect absorber-laser (CPAL) point, can support a fast wave propagation with a very low attenuation rate, which in turn results in a directive radiation leakage. Moreover, the beamwidth can be tailored by varying the reciprocal scaling factor, and the beam can be steered from broadside to end-fire by adjusting the gain-loss parameter. Such results prove a promising route towards the next generation of super-directivity leaky-wave antennas.

9:50 Broadband Circularly Polarized Metasurface Antenna Fed by a Rotated L-Shaped Probe
Wei E. Liu and Zhi Ning Chen (National University of Singapore, Singapore); Xiaoming Qiu (Institute for Infocomm Research, Singapore)

A broadband low-profile circularly polarized (CP) metasurface antenna with a simple L-shaped probe is proposed. The circularly polarized probe feed, an additional surface wave is excited on the finite metasurface to enhance the bandwidth of the antenna. The single rotated L-shaped probe asymmetrical metasurface antenna yields an overlapped impedance gain/peak-to-bandwidth of 20.7% from 5.71 to 7.03 GHz, a peak gain of 8.55 dBic, and a front-to-back ratio higher than 16 dB, covering the 6-GHz band for Wi-Fi 17 applications. Experiments are carried out as well to validate the proposed CP antenna design.

10:10 Coffee Break

10:40 Metamaterials for Electromagnetic and Thermal Waves
Ern Donnelly (Edinburgh Napier University, United Kingdom (Great Britain)); Antoine Durant (Edinburgh Napier University, United Kingdom (Great Britain)); Luigi 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 electromagnetic, 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 guiding structures) and automotive (electrical vehicle battery electric and thermal management). Experimental results reveal that such multi-functional metamaterials can fully manipulate and control both electromagnetic and thermal waves at 9.8 MHz. 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.

11:00 Evaluation of Aerossil Jet Printing of Frequency Selective Surface on Glass for Building and RF Applications
Anshuman Shastri Kumar Putta and Benito Sanz-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)); Tomoki Abe (University of Sheffield, United Kingdom (Great Britain)); Lee Winchester (The Centre for Process Innovation, United Kingdom (Great Britain)); Alan McClelland (CPI, United Kingdom (Great Britain))

The use of Aerossil Jet Printing technology to fabricate frequency selective surfaces (FSS) on glass for secure WLAN building applications is presented. Aerossil 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 Wi-Fi band and is used in wireless communication systems and covers a wide range of frequencies. A single-layer design is studied. Aerossil Jet printing is able to produce fine tracks needed for the design and provide sufficient conductivity for fine 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 be printed these FSS structures and enhanced their RF performance. Simulations are used for the simulations. Simulations compare well with measurements.

11:20 Direct Antenna Modulator for m-QAM Applications
Kenneth Lee Ford, Stephen Henrich and Timothy O'Farrell (University of Sheffield, United Kingdom (Great Britain))

This paper introduces a concept for direct antenna modulation using a metamaterial-based antenna. The antenna can be controlled with the use of an external bias to control both the transmission and reception of the transmitted signal, in a continuous way, to provide m-QAM direct antenna modulation. The DAM comprises of five metamaterials, four of which control the transmitted phase through the use of a varactor diode, and the fifth uses a PIN diode to control the transmitted phase. Numerical simulations are presented which show that the transmitted phase can be varied over a 360 degree range with a amplitude dynamic range of 25dB.

11:40 Electrically Small Huygens Dipole Rectennas for Wirelessly Powering Internet-of-Things Sensors
Wei Lin (University of Sheffield, United Kingdom (Great Britain)); Richard Ziockowski (University of Technology Sydney, Australia); Edward Parker (University of Sheffield, United Kingdom (Great Britain)); Benito Sanz-Izquierdo (Istituto Superiore Mario Boella, Italy)

Electrically small (LP) and circularly-polarized (CP) electrically small Huygens dipole rectennas for wirelessly powering compact Internet-of-Things (IoT) sensors at 915 MHz in the ISM band are reported. They are realized through the seamless integration of electrically small near-field resonant parasitic-based Huygens LP and CP antennas with a highly efficient rectifier circuit. The Huygens LP (HLP) antenna achieves a cardioid-shaped realized gain (RG) pattern with RG > 0 dB at the targeted frequency. Similarly, the Huygens CP (HCP) antenna generates a cardioid pattern with RG > 0.2 dBic and a 1.7 dB axial ratio value. Notably, the HCP and HLP antennas have inductive input impedances that facilitate matching directly to the 50 ohm source, thus eliminating a lossy inductor in the original rectifier. The prototype HLP and HCP rectennas achieve close to 95% to 97% conversion efficiency. Light and temperature IoT sensors wirelessly powered with custom-designed versions of these rectennas are successfully demonstrated. Empirical propagation models have been developed within the ITU-R for building entry loss and for urban clutter loss. At present these mechanisms are considered separately, but, in practice, will generally be combined. Initial measurements at 35 GHz and 27 GHz are reported here which suggest that the effects cannot be considered as multiplicative, and a simple asymptotic model is proposed for their combination. 12:00 Building Entry Loss and Clutter Loss at 26 GHz
Sana Salous (Durham University, United Kingdom (Great Britain)); Belen Montenegro Villacerrc (Formerly JRC, Italy); James Bishop (Joint Research Centre of the European Commission, Italy)

This paper presents results of building entry loss measurements, clutter loss measurements and combined building loss and combined building loss and clutter loss measurements in a building of modern architecture at 26 GHz using a custom designed channel sounder developed at Durham University. Comparative measurements indicate that the median of building entry loss is about 42.6 dB when measured over a cluttered path and 42.9 dB when measured from outside the building. This indicates that the median building entry loss can be estimated from measurements over an uncluttered path.
12:00 Realizing Antenna Arrays with Huygens' Metasurface Pairs Based on a Moment-Method-Like Design
Vasileios G. Ataliglou, Ayman H. Darwish and George V. Eleftheriades (University of Toronto, Canada)

Huygens’ meta-surfaces have demonstrated great potential at manipulating electromagnetic fields at all. While omega-bianisotropy has allowed to design a single reflectionless meta-surface for transformations that conserve local power, many applications, such as antenna beamforming, require control of both the amplitude and the phase of the transmitted fields. Pairs of reflectionless omega-bianisotropic meta-surfaces have been proposed to break the condition of local power conservation. However, constraints on the minimum propagation length between the two meta-surfaces, often lead to bulky designs. Here, an alternative method of designing a meta-surface pair for arbitrary control of the amplitude and phase of the output fields is presented. The method relies on a power-based joint matching process at the two meta-surfaces and allows multiple reflections in the region between them. The usefulness of multiple reflections on the compactness of the meta-surface pair is investigated through the design of a Chebyshev antenna array featuring a single feeding.

Friday, 20 March 8:30 - 10:10
T05-M06: Dosimetry, Exposure, and SAR Assessment
Room: B2
Chair: Dragan Poljak (University of Split, Croatia)

8:30 Frequency Selective EMF Measurements and Exposure Assessment in Indoor Office Environments
Niketarios Moraitis (National Technical University of Athens & Institute of Communications and Computers Systems, Greece); Ileana 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 extracted, assessed and compared with the national and international limits. The results from the entire building dataset reveal that the total electric field varies between 0.23 and 0.75 V/m [0.241-0.92 mV/m in terms of total power density], whereas the mean Total Exposure Ratio (TER) is on the order of (2.35±1.47)·10-4. In all cases the exposure levels in indoor environments abide by the legislated limits. 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); Marin Galić (Center za Mjerenja u Okoliu, Croatia); Lara Pagowski (Sapienza University of Rome, Italy)

This paper is focused on the assessment of human exposure to electromagnetic signals with continuous spectra. A convenient and simple approach is proposed, to compare the measured field levels with the maximum exposure levels and verify compliance with the 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). In particular, the proposed approach is based on the classical signal theory and requires the integration in the spectral domain of the electric field amplitude, or of the square of the electric field amplitude. Illustrative computational examples are presented, dealing with human exposure to Universal Mobile Telecommunications System (UMTS), Long-Term Evolution (LTE), experimental 5G, and Ground Penetrating Radar (GPR) signals. All of these examples are based on real-measured data.

9:10 Maximum Exposure Assessment of Millimeter-Wave Array Antennas
Sylvain Rebout (ZMT Zurich MedTech AG, Switzerland); Serge Pfefer (Foundation for Research on Information Technologies in Society (ITIS Foundation), Switzerland); Niels Kuster (Foundation for Research on Information Technologies in Society, ITIS Foundation, Switzerland)

5G user equipment makes use of array antennas to form beams according to a predefined codebook. In this paper, we provide an algorithm to determine upper bounds of maximum power density of any antenna from a set of electromagnetic field (EMF) realizations by independent configurations. The method uses only EMF of the device under test (DUT) operating at configurations taken from the actual codebook and does not require absolute reference phase to be preserved between configurations. In all cases, the algorithm provides a conservative estimate of worst-case power density with limited overestimation. The proposed method therefore provides a practical way to assess compliance of millimeter-wave array antennas as well as for EnVi5 field measurements and is a valuable step forward for the standardization of RF EMF exposure compliance procedures of 5G devices.

9:30 On the Focusing Technique for Hyperthermia Treatment Planning
Mortez A Ghaderi, Amaz Mallmann and Han Daboličević Trenčina (Chalmers University of Technology, Sweden)

A focusing technique based on PDD is presented and compared with other methods. The optimization problem is solved by taking advantage of a TR-based, fast focusing outcomes. This shows to enhance the quality indicator and to speed up the whole process of optimization by lowering the chance of getting trapped in local minima. Simulation results for the novel applicator developed at Chalmers are reported for both a cylindrical phantom and an anisotropic patient model.

9:50 A Fast and Rigorous Assessment of the Specific Absorption Rate (SAR) for MIMO Cellular Equipment Based on Vector Near-Field Measurements
Mount Tesfaiou, Oumuk Jawad and Stephane Panneton (ARFi, France); Lyzad Abidouer (ARFi, France)

This paper introduces a rigorous and fast procedure for accurate assessment of the peak averaged specific absorption rate (SAR), quantifying the user exposure to the electromagnetic field radiated from new-radio communication devices. It is based on the specific class of user equipment that exploit multiple-input multiple-output (MIMO) technology and use either simultaneous or non-simultaneous transmission of the antenna array system. This approach is based on the assumption that each antenna of the array is excited by a plane wave and that the field is planar. The field is then rigorously computed at the user position using the near-field of the device under test (DUT). The method is validated by comparing the results with measurements and simulations. The proposed method provides a practical way to assess compliance of MIMO cellular equipment based on vector near-field measurements.

Friday, 20 March 8:30 - 12:20
T11-E06: Scattering and Diffraction
Room: B4
Chair: Davide Ramacca (RomaTre University, Italy), Ala Sharaiha (Université de Rennes 1 & EIT, France)

8:30 Characteristic Far-Field Analysis of Scattering Due to Plane Wave Excitations
Xiong Kai Benjamin Chng (DISO National Laboratories, Singapore)

In the theory of electromagnetic theory, the set of modes were derived such that the corresponding far fields are orthogonal over the infinite sphere. We exploit the orthogonality of these far fields to devise relationships between the modal parameters, such as the modal excitation coefficients, when a plane wave is incident on the obstacles. These results provide a useful framework for visualizing how each mode contributes to the overall scattering over a range of plane wave parameters, such as the wave-vectors and polarization. Validations were performed by comparing the theoretical analysis with simulations.

8:50 A Technique for Including Edge Diffraction Effects on RCS Evaluation at Fresnel Region Ranges
Ilie Valentin Mihai (University Politehnica of Bucharest, Romania & The Institut d’Electroinique et de Telecommunications de Rennes, France); Razvan D. Tamas (Constanta Maritime University, Romania); Ala Sharaiha (Université de Rennes 1 & EIT, France)

The aim of this paper is to propose a simple and low-cost technique to measure the RCS of a complex target in the Fresnel region and in a multiphase environment. The diffraction field by the target is calculated using a method based on equivalent currents. The reflected field is computed using the physical optics approach and the tangent plane approximation. The ratio between the analytical expression of the radar cross section in the far-field and Fresnel region results in a field cut-off extrapolation factor for the diffused field. The RCS resulting from the scattering parameters measured at Fresnel region distances is then connected with that field cut-off extrapolation factor. The method was validated by simulations and measurements on a rectangular metallic target.

9:10 Perfect Matching of Reactive-Loaded Transmission Lines Based on a Moment-Method-Like Design
Angelica Viola Marini (Universiti di Studi Romae Tre, Italy); Davide Ramacca (RomaTre University, Italy); Alessandro Toccano (University Roma Tre (IT), Italy); Filiberto Bilotti (University Roma Tre, Italy)

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 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
In this paper, a new method to compare the effectiveness of a stirrer by calculating the number of characteristic modes is proposed. The number of characteristic modes refers to the number of modes whose presence strongly determines the reverberation process. The higher the number of characteristic modes, the better it works in the reverberation chamber.

The effect of vehicle's proximity on the radiation pattern when the RADAR's antenna is mounted on the body of an autonomous car is analyzed. Two directional radiation patterns with different specifications are placed 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 must have a high half-power-beamwidth (HPBW) and a high front-to-back (F/B) ratio. Both academia and industry can benefit from this study.

Evaluation of the Purity of OAM Modes Using the Reverberation Chamber Technique

Diffuse Field Cross-Correlation in a Reverberation Chamber Stirred with Reconfigurable Reflectarray Metasurfaces

Chairs: Philipp del Hougne (Institut de Physique de Nice, France), Antonio Sorrentino (Università degli Studi di Napoli Parthenope, Italy)

Room: T11

Friday, 20 March 8:30 - 10:10

T11-M05: EMI/EMC/PIM chambers, instrumentation, and measurements

T11 Fundamental research and emerging technologies / Regular Session / Measurements

9:30 Negative Reflection and Refraction and Filter Characteristics in the Leaky Wave-supportable Gratings - FE Polarization Case
SooMoon Park, HongGoon Kim and YoungKo Gho (Kyungpook National University, Korea (South))

A negative reflection corresponding to negative reflection and negative refraction phenomena are dealt with in the leaky wave-supportable reflection grating and transmission grating respectively. The transmission grating is designed to be based upon geometrical parameters for the Bragg-blinding phenomena in the reflection grating structure. The applicability of the transmission grating structure to the broadband filter for normal incidence case is examined.

9:50 How Radiation Propagates in Random Media: Spatial Structure of Transmission Eigenchannels
Peng Fang (Beijing University of Posts and Telecommunications, China); Chushun Tian (Institute for Advanced Study, Tsinghua University, China); Liyi Zhao (Tsinghua University, China); Yury Blokh (Technion-Israel Institute of Technology, Israel); Valentin Freilikher (Bar-Ilan University, Israel); Franco Neri (Center for Emerging Matter Science (CEMS), RIKEN, Japan)

Channelling of radiation through transmission eigenchannels is the dominant mechanism of wave propagation in diffusively scattering random media. In this presentation, the physical properties of these channels are studied numerically and analytically, and possibilities of applications are discussed.

10:10 Coffee Break

10:40 Study on the Location of mmWave Antenna for the Autonomous Car's Detection and Ranging Sensors
Ali Aragh (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 and Rahim Tafazolli (University of Surrey, United Kingdom (Great Britain))

The problem of electromagnetic plane wave scattering by one-dimensional periodic structures composed of cylindrical electrically small and externally homogeneous dielectric layer with arbitrary geometry is examined. A general algorithm of the analysis developed in this paper is based on the hybrid projection method involving projection of the fields on the transverse vector spherical functions combined with the one-dimensional method of finite elements. The presented algorithm is realized in a MATLAB code for the case of excitation of the body by a circularly polarized plane wave propagating along the axis of revolution. Test numerical results are presented for dilectric and plasma spheres displaced from the origin of coordinates along the axis and compared with the data obtained as a result of rigorous analysis of scattering.

11:00 Electromagnetic Scattering by an Inhomogeneous Body of a general Approach: Based on the Hybrid Projection Method
Serhiy S. Skobelev (Radiophyzika, Russia); Ekaterina Semenova (Moscow Institute of Physics and Technology, Russia)

Numerical analysis of a body of revolution consisting of anhomogeneous dielectric sphere and an external homogeneous dielectric layer with arbitrary geometry is performed. A general algorithm of the analysis developed in this paper is based on the hybrid projection method involving projection of the fields on the transverse vector spherical functions combined with the one-dimensional method of finite elements. The presented algorithm is realized in a MATLAB code for the case of excitation of the body by a circularly polarized plane wave propagating along the axis of revolution. Test numerical results are presented for dielectric and plasma spheres displaced from the origin of coordinates along the axis and compared with the data obtained as a result of rigorous analysis of scattering.

11:20 Performance of Absorbing Periodic Structures of Cylindrical Black Holes Arranged on a Perfectly Conducting Screen
Yana Chizhovskaya (Moscow Institute of Physics and Technology, Russia); Olga Smolnikova (Company Radiophyzika, Russia); Sergei S. Skobelev (Radiophyzika, Russia)

The problem of electromagnetic plane wave scattering by one-dimensional periodic structures composed of cylindrical black holes type arranged on a perfectly conducting screen is considered. Two algorithms corresponding to the cases of E- and H-polarization and accounting for the features of the black holes are developed on the basis of the hybrid projection method for solution of the problem. A number of numerical results characterizing both the effectiveness of the algorithms themselves and the properties of the black-hole-based absorbing structures are presented and discussed.

11:40 Metasurface Modeling of Periodic Diffraction Gratings Based on Generalized Sheet Transition Conditions (GSTCs)
Ville Tuivuoka, Tom Smy and Shubhal D Gupta (Carleton University, Canada)

Space-modulated diffraction gratings are modelled and analyzed using a zero-thickness metasurface-grating approach, and demonstrated using numerical examples. The constitutive parameters of the gratings are described using surface susceptibilities of the Lorentzian form, where their resonant frequencies are sinusoidally modulated. They are then solved self-consistently with the Generalized Sheet Transition Conditions (GSTCs) to determine the scattered fields from the metasurface for specified plane-wave incident fields, for various cases of modulation periodicities and depths.

12:00 Scattering Control of Wideband Phased Arrays Using Metamaterial Absorbers
Zhechen Zhang (University of Electronic Science and Technology of China, China); Shi Wen Yang (University of Electronic Science and Technology of China, China); Yankai Ma, Yikai Chen and Shi-Wei Qu (University of Electronic Science and Technology of China, China)

A novel approach for thin- or band-scattering cross section (CSSC) reduction of tightly coupled dipole arrays (TCDAs) illuminated by incident waves with polarization mismatch is proposed in this paper. The CSSC of the proposed TCDAs is achieved by placing the metamaterial absorbers on the aperture of the array. The metamaterial absorbers are comprised of reverse films, dielectric layers and polarization gates. The infinite array is able to achieve 3:1 impedance bandwidth with VSWR < 2 for scanning up to 60° in E/H-planes. Moreover, simulated results demonstrate that the CSSC of the designed TCDAs is reduced significantly throughout the entire operating bandwidth, while good radiation efficiency is still maintained.
Microwave sensing represents a promising approach for non-invasive tissue temperature monitoring during hyperthermia. The dielectric properties of biological tissues play a significant role in the planning and development of electromagnetic thermal therapies. In most cases in the literature, heart is considered as a homogenous organ and its dielectric properties values are reported as such. In this paper, the results of dielectric property measurements on nineteen different parts of ovine hearts are presented. The results of the measurements indicate that the dielectric properties vary between the different parts of the heart and therefore, the heart should not be considered to be homogenous for accurate electromagnetic modeling.

In this paper, microwave imaging for monitoring liver ablation treatments was considered, and the initial guideline to the design of a microwave imaging system for ablative treatments was presented. This work is devoted to the development and realization of a realistic head phantom to test microwave imaging prototypes which will be used to monitor cerebrovascular diseases. The 3D printed phantom is realized by an additive manufacturing process in order to fit the cavities inside the head with liquid solutions that mimic biological tissues in terms of complex permittivity in a wide frequency range. The numerical form (QL, model form) of these cavities is also used to perform simulations in the frame of the experimental configuration described in [1], in order to test the experimental parameters such as the coupling media and study the effect of cavities made of AIS steel on stroke detection. In the end blocking vessels in the head phantom, which model the blood circulation in the brain is considered, to shed light on the effects of S parameters of a random-shaped stroke.

Microwave Imaging Prototyping of a Realistic 3-D Microwave Scanner for Brain Stroke Imaging

In this paper, a dual-polarized E-field sensor is designed for high power ultra-wideband (UWB) pulse measurement. In the electromagnetic compatibility (EMC) anechoic chamber, the fabricated sensor is tested and validated. The performance and effectiveness of the designed antenna for the circularly polarized E-field and the linearly polarized E-field with different polarization directions. As a result, a sensor prototype is developed, which consists of the dual-polarized ACD antennas and wideband baluns. ACD antennas and wideband baluns. The model of the microwave imaging system consists of 24-element conformal antennas, an anthropomorphic adult head, and a spherical shape body filled as stroke. Here, the simulated system and data are tested applying an imaging algorithm based on Twisted Singular Value Decomposition (TSVD) and Born approximation, but they can be combined with other microwave imaging algorithms.

In Microwave imaging systems, the goal is to find the differences of dielectric properties between healthy and malignant tissue by S parameters. We employ a full-wave modeling, which uses a Method of Moment (MoM) solver with high order basis functions and includes frequency variable electrical parameters for each component. The model of the microwave imaging system consists of 24-element conformal antennas, an anthropomorphic adult head, and a spherical shape body filled as stroke. Here, the simulated system and data are tested applying an imaging algorithm based on Twisted Singular Value Decomposition (TSVD) and Born approximation, but they can be combined with other microwave imaging algorithms.

Towards a preclinical prototype for diagnostic and monitoring of cerebral pathologies, here we present the 3D image reconstruction and accuracy. To dive deep into the topic, the existing calibration approaches in microwave imaging will be discussed. Finally, the application of “unknown thru” as a new calibration method in MWI system and its advantages over other methods will be presented.
12:00 Development of a Transmission-Based Open-Ended Coaxial-Probe Suitable for Axillary Lymph Node Delineation Measurements

Matten Savazzi (Università di Lusso, Portugal); Emily Porter (University of Texas at Austin, USA); Martin O'Halloran (National University of Ireland, Galway, Ireland); Jorge R. Costa (Instituto de Telecomunicações / ISTC) (Portugal); Carlos A. Fernandes (Instituto de Telecomunicações, Instituto Superior Tecnico, Portugal)

We assess the feasibility of a transmission-based open-ended coaxial-probe, which we intend to use for axillary lymph node delineation measurements. The method consists in placing the material under test between two opposite open-ended coaxial probes and measure the transmission coefficient. Numerical tests guided us in the choice of the probe design. The developed system allows for enough propulsion through a small part (which suffice in size to axillary lymph nodes) while avoiding the scanning volume to the region of interest. Moreover, we evaluate the viability of a comparative approach (simulations vs experiments) for the ex-embalming of the axillary properties. Experimental tests on phantoms showed good agreement between the measured and numerical transmission coefficient. Finally, we observed that the transmission coefficient can highlight the contrast between material with different dielectric properties. The promising initial results motivate extending the application of the method to the axillary lymph nodes.

T06-A11: Aircraft Antennas

T06 Aircraft (incl. UAV, UAS, RPAS) and automotive / Regular Session / Antennas

10:10 Coffee Break

T06: 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 hi-tech industries, is massive today and it is predicted to grow more. High data rate, at-o-ground, long range communication is still a bottleneck. UAV antenna is one of the most important parts 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 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 slots. Flexibility analysis showed that the antenna works well in different bending conditions.

10:30 Design of Airborne Small Ultra-Wideband Spinning Direction Finding Antennas

Young Ju Park (Agency for Defense Development, Korea (South))

Design, fabrication and measurement of a novel rotating direction finding antenna system for aviation use is presented. It can detect various radar signals in the ultra-wideband frequency region of 0.5-4.0 GHz. The whole antenna system is composed of antennas for low frequency band of 0.5-2.0 GHz and high frequency band of 2.4-4.0 GHz. Each antenna is designed to be small and lightweight. An array of log-periodic dipole antenna (LPDA) antennas on a lightweight structure support for antenna is proposed for low frequencies. For the higher one, a reflector antenna using a single LPDA antenna as a feeder is designed. The designed each antenna is combined on a pedestal. All the simulation results are verified experimentally.

10:50 A Novel U-slot Aperture Coupled Annular-Ring Microstrip Patch Antenna for Multiband GNSS Applications

Kush Panthi (Entuple Technologies, India)

A multiband circularly polarised novel U-slot aperture coupled annular-ring antenna is proposed in this paper. The antenna covers the bands of L(l=511-1.2 GHz and L1-1.575 GHz) bands and has a maximum gain of 5.18 dBi. The measured 3D radiation patterns at various frequencies across the operational band are provided.

11:10 Dendrite Truncation Effects in a Wide-Scan Phased Array of Connected Bowtie Antenna Elements

Prabhat Khanal, Jian Yang and Marianna Ivashina (Chalmers University of Technology, Sweden); Anders Höök (Mitsubishi Electric Corporation, Japan); Shin-ichi Yamamoto (Mitsubishi Electric Corporation, Japan); Michio Takikawa (Mitsubishi Electric Corporation, Japan); Naofumi Yoneda (Mitsubishi Electric Corporation, Japan)

In this paper, we evaluate the viability of a comparative approach (simulations vs experiments) for the ex-embalming of the axillary properties. Experimental tests on phantoms showed good agreement between the measured and numerical transmission coefficient. Finally, we observed that the transmission coefficient can highlight the contrast between material with different dielectric properties. The promising initial results motivate extending the application of the method to the axillary lymph nodes.
A 2-Bit Phase-Shifting Unit Cell Design for Beam-Steerable Reflectarrays

Huang Luyen, John Boreke and Nader Behdad (University of Wisconsin-Madison, USA)

This paper presents a 2-bit, 20% bandwidth, switch-controlled phase-shifting unit cell design for beam-steerable reflectarrays. The unit cell uses four single junction connections, which can be replaced with single-pole single-throw switches, and it allows for four unique phase shift modes. The results in 2-bit phase shifts for the reflected wave when the unit cell is illuminated with an incident wave with a +90° and -90° polarization rotation while the other two provide non-polarization-rotating reflections. This setup is used to construct a beam-steerable reflectarray with improved directivity compared to state-of-the-art 1-bit TA designs, with a directivity improvement of 2.5 dB.

9:10 Bandwidth and Efficiency Enhancement for 2-D Beamscanning Reflectarray Operating at X Band

Jordan Budhu (University of Michigan, USA), Anthony Grbic (University of Michigan, Ann Arbor, USA), Eric Michelsen (University of Michigan, USA)

Reflectarray antennas are typically designed under the local periodicity approximation. Thus, mutual coupling is modeled as through the array is in free space in extent and made of dielectric elements. In dual-band reflectarrays, elements are typically designed independently. In this paper, we present an algorithm to design layers of the reflectarray at both frequencies simultaneously. The reflectarray consists of two reflectarrays above one another and the method accurately accounts for mutual coupling within the homogenized reflectarray, without resorting to local periodicity approximations. The design process produces practically realizable structures fabricated with standard printed circuit technologies. Subwavelength element patterning of the reflectarray surfaces also gives rise to higher bandwidths.

10:00 Coffee Break

10:40 Time Modulated Reflectarray Unit Cells with Nonreciprocal Polarization Control

Santiago Spotala (Universidad Politecnica de Madrid, Spain), Juan Sebastian Gomez-Diaz (University of California, Davis, USA), Eduardo Carrocas (Universidad Politecnica de Madrid, Spain)

This contribution explores the tunable performance of reconfigurable reflectarray unit cells with full polarization control based on time-modulated resonators. This is important for future X-band systems, where several X-band devices are used in the aperture to control each polarization. This study uses a design methodology to independently control the phase and amplitude of the fields radiated by each polarization, thus allowing to obtain any polarization state and shape nonreciprocity of the polarization conversion. We envision that this technology will have important implications in wireless terrestrial and satellite communication systems.

11:00 P-n Diode Based Electronically Steerable Transmittarrays for Ka-band

Francesco Foglia Menzillo (CEA-LETI, France); Maciej Smierzchalski (CEA, France); Antonio Clemente (CEA-LETI, France); Ronan Sauleau (University of Rennes 1, France)

In this contribution, we present a preliminary assessment of the capabilities of electronically steerable transmittant antennas for Ka-band satellite communications, with emphasis on S-band satellite communications. These studies build on a novel linearly-polarized four-state unit cell (UC) variable phase shifter with 2-bit phase shift levels for the reflected wave when the unit cell is illuminated with a linearly-polarized wave. The results in 2-bit phase shifts for the reflected wave when the unit cell is illuminated with a linearly-polarized wave. The proposed 2-bit phase shifter is a novel reconfigurable unit cell design for beam-steerable reflectarrays with 2-bit phase control.

11:20 Design of Microwave Imaging System Based on Reconfigurable Transmittant with Variable Focuses

Xiaotian Pan, Fan Yang, Shenheng Xu and Maokun Li (Tsinghua University, China)

The microwave imaging system based on a fixed-focus reconfigurable transmittant is presented in this paper. The imaging system is designed to have a 2-bit phase-shifting unit cell with variable focus. The system is designed to have a 2-bit phase-shifting unit cell with variable focus. The system is designed to have a 2-bit phase-shifting unit cell with variable focus. The system is designed to have a 2-bit phase-shifting unit cell with variable focus.
The performance assessment of a two-beam electronically switchable circularly polarized reflectarray antenna based on single-layer circular microstrip patches with phase delay line stubs is presented. Preliminary numerical analysis demonstrates the reflectarray capability to switch its main beam between 9.1° and 18.2° from the boresight in K-band (17.7-20.2 GHz). A very simple preliminary model is used for the envisaged PIN diode switches. For an array with 20x20 unit cells, the achieved gain is above 27.2 dBi and the side-lobe level is below -18.2 dB at f0. Moreover, a remarkably low axial ratio of 1.1 dB is obtained for the whole frequency band of operation.
8:30 Deterministic Radio Channel Characterization for Near-Ground Wireless Sensor Networks Deployment Optimization in Smart Agriculture
Hicham Klaina (University of Vigo, Spain); Imanol Piccallo (Universidad Pública de Navarra, Spain); Peio Lopez Iturri (Universidad Pública de Navarra, Spain); Leyre Azpilicueta and Mikel Celaya-Echartiti (Tecnologico de Monterrey, Mexico); Otman Aghzout (ENSA Tétouan â– UAE, Morocco); Francisco Falone (Universidad Pública de Navarra, Spain); Ana Alegos (Universidade 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
Yun Ai, Michael Cheffena, Marshad Mohamed and Ahmed Al-Samani (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 measurements to estimate different indoor propagation channel parameters based on the room electromagnetics model. The indoor room environment is considered 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 Tenertz MIMO Fading Analysis and Doppler Modeling in a Data Center Environment
Chia-Lin Cheng (Georgia Tech, USA); Seun Sangedoyn and Aklena Zajic (Georgia Institute of Technology, USA)
In this paper, we present results from a Tenertz (Tlz) channel measurement campaign in a data center environment. We analyze propagation parameters, such as shadowing gain, and RMS delay spread. Amplitude fading statistics in a 4 x 4 Multiple-Input-Multiple-Output (MIMO) channel are also investigated. Furthermore, Doppler shift in Tlz 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 (DPS) is derived and validated with measured data. This work is pertinent to Tlz wireless systems design for a data center environment.

9:30 Radiowave Propagation Modelling in the Presence of Wildfires: Initial Results
Stefânia Faria and Nuno R. Leontio (Instituto de Telecomunicacoes, Portugal); Carlos A. Fernandes (Instituto de Telecomunicacoes, Instituto Superior Tecnico, Portugal); Joao M. Felicio (Instituto de Telecomunicacoes, Portugal); Carlos Salena (I.S.T. - Technical University of Lisbon / IT Lisbon, Portugal); Rafael F. S. Caldeireira (Polytechnic Institute of Leiria & Instituto de Telecomunicacoes, Portugal)
In this paper, a thorough study of radio propagation phenomena in the presence of wildfires, is presented. Electrical modeling of a fire environment based on computational fluid dynamics is presented. Modeling of the fire phenomena in terms of its radiative index and combustion of cold plasma lays the foundation for considering the fire environment as an propagation medium. Electrical models are formulated that are used to provide means of calculating propagation characteristics based on thermal radiation to create a plasma surface under fire environments and, thus, to determine of the excess loss arising in the burning area. The paper presents initial results for single trees only 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); Danping He, Ke Guan and Bo Ai (Beijing Jiaotong University, China); Chengyi Liu, Tianyu Shui, Liu Zhu and Hui Mei ( Jiangxi Mobile Communication Company Limited, China)
This paper supports the design and deployment of wireless communication systems. 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 applicability of RT, thus the acceleration techniques are highly demanded. In this paper, two space-partitioning methods, including the uniform grid and the hierarchical (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 being accelerated, 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 Chabory (ENAC, France)
The atmospheric long-range propagation above the ground is of major importance for many ground systems as radars. 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 memory storage as the previous version.

11:00 3D Simulation of Infinite Baffle Diffraction
Christopher G Hynes, Roshanak Zabihi and Rodney Vaughan (Simon Fraser University, Canada)
Diffraction formulations have infinite boundaries whereas simulations are solved with strictly limited dimensions. Consequently, the simulation of diffraction effects is described. Here, three electromagnetic simulations are composed and compared against theoretical results for the diffraction of normally incident plane waves onto semi-infinite and infinite step 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 step. 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
Yang Mao (University of Twente, The Netherlands); Sofie Pollin (KU Leuven, Belgium); Andris Alyonin Glazunov (University of Twente, The Netherlands & Chalmers University of Technology, Sweden)
This paper brings up the concept of spatial hardening of massive MIMO radio channel in a controlled multipath case. The motivation is that, for a mobile user being active in a 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 channel consisting of direct paths and specularly reflected paths up to a second order are analyzed as a function of the large-scale anisotropy 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 hardened channel in an area for user with mobility.

11:40 Time-Domain Indoor Channel Estimation Using Single-Snapshot Wideband Measurement
Lukke 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))
In this paper, we investigate the effects of enriching this data set of a PCD 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 diode blocks in the OFF-state, which is then connected at one end in the ON-case. The effects of the diameter of the post are also studied. The S parameters of the system are calculated from the effects and current transmission line observation samples obtained with a single time-domain numerical method based upon an unstructured mesh.

12:00 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 channel 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.

CS11: Antenna Design and Fundamental Bounds with External Constraints
T11 Fundamental research and emerging technologies / Convened Session / Antennas
Room: B10
Chairs: Fabien Ferrero (University Nice Sophia Antipolis, CNRS, LETI & CREMANT, France), Lars Jonsson (KTH Royal Institute of Technology, Sweden)
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 produces 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**

Past Vy 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 band-with-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, Omnidirectionally 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, Australia & University of Arizona, USA)

A high-directivity, compact, omnidirectionally horizontally polarized (OHP) antenna array is developed for wirelessly powering unpowered things (IoT) devices. The antenna array is realized by seamlessly inserting several phase inverters inside an electrically long TE0,5 mode open waveguide. The phase inverter consists of a meandered slot and eight shorting vias. The meandered slot creates an isolated structure on the top surface of the waveguide, it introduces capacitance. The shorting vias are placed on the alternating pattern on the two sides of the slot; they produce inductance. The combination of the slot and vias forms a bandpass effect and inverts the electric fields in the waveguide. Consequently, a collinear in-and-phase dipole array is realized. A compact eight-element OHP magnetic dipole array is designed, fabricated, and measured. The measured results confirm the design concept and high directivity (10 dB). 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 antenna 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 photonic 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 topology optimization and the results will be presented during the conference.

**10:10 Coffee Break**

**10:40 Navigating Dual Tapered Additively Manufactured Helical Antennas for Size Reduction Constraints**

Youssef Tayk and Joseph Costantine (American University of Beirut, Lebanon)

This paper presents novel 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 new taper-based 3D 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 Rakatzaek (Orange Labs, France)

This work present the experimental assessment of frequency bandwidth with limits on 2x2 cm² antenna embedded in a 5x5 cm² terminal at 900 MHz. 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 with 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 Olliv (Inria Sophia Antipolis, France); Stephane Bila (XLIM UMR 7252 Universite 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**

Casimer Ehrenborg 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 calculated 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 only on the existing 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 a 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**

Rocío Rodríguez-Cano, Shuai Zhang and Get Pedersen (Aalborg University, Denmark)

In this paper, a transparent dual-element mm-wave array (mm-wave) array for handhelds is proposed. The antenna is mounted on top of a glass display and it is made by diamond gold 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 meandered patches have been placed in front of the mm-wave base-face array. The array antenna 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.

**CS20: Assessment and Modeling of Antennas and Radio Channels Jointly**

T10 EM modelling and simulation tools / Convened Session / Antennas

**Room: E11**

Chairs: Daping He (Beijing Jiaotong University, China), Alain Sibille (Telecom ParisTech, France), Raffaele D'Errico (CET, LETI, Minatec Campus & Univ. Grenoble-Alpes, France)

**8:30 Including the Aircraft and the Antenna in a Wide Band Aeronautical LMS Channel Model**

Capucine Amielh and Alexandre Chabory (ENAC, France); Laurent Zouali (Airbus Commercial Aircraft, France)

During airport ground navigation, aircraft pass close to obstacles such as buildings or other aircraft. These obstacles may be few meters from the antenna. In this context, modeling the aeronautical 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 Pomocito and Raffaele D'Errico (CET, LETI, Minatec Campus & Univ. Grenoble-Alpes, France)
SW09: Integration challenges for low-cost mm-wave phased arrays

T12 Scientific / Industrial Workshops

Room: B3

Friday, 20 March 10:40 - 12:20

T02-M08: Mm-wave, THz, and Quasi-optical Antenna Measurements

Room: B2

Chair: Marta Arias Campo (IMST GmbH, Germany & Delft University of Technology, The Netherlands); Dragan Poljak (University of Split, Croatia)
10:40 Experimental Characterization of a Wideband G-Band Circularly Polarized Lens Antenna

Marta Arias Campo (IMST GmbH, Germany & Delft University of Technology, The Netherlands); Giorgio Carboncino (Delft University of Technology, The Netherlands); Darwin Blanco (Ericsson, Sweden); Oliver Litschke and Simona Bruni (IMST GmbH, Germany); Nuria Llombart (Delft University of Technology, The Netherlands)

The interest for mm- and sub-mm wave systems has grown in the last years, mostly driven by communications and radar industries. 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 (1-40-220GHz) is presented. Accurate measurement results are reached for the circularly polarized fields, showing excellent agreement with simulations.

11:00 Validation of System NEP of a Single-Pixel THz Imaging Camera in CMOS

Sven van Berkel, Satoshi Malotaux, Carmine De Martino, Marco Spinto, Daniele Cavollo, Andrea Neto and Nuria Llombart (Delft University of Technology, The Netherlands)

CMOS technologies show great potential for making fully passive multi-pixel THz imagers without cooling the system. In order to achieve such high performance, system NEPs in the order of a few pJ/νT are required, which are difficult to achieve in CMOS technologies. Accurate high-frequency models of the detectors, and an antenna-detector co-design are vital but not always readily available. This work presents the experimental derivation of a high-frequency model of the smallest Schottky Barrier Diode that is allowed for in a CMOS technology and the experimental validation of that model by means of a single-pixel THz imaging camera operating from 200 GHz to 600 GHz. The camera consists of a double bow-tie slot antenna in combination with a dielectric lens and offers an average system NEP of 50 pJ/νT at 375 GHz.

11:20 Measurement and Calculation of Exposure Level to 5G Base Station Antenna

Marin Galic (Center za Mjerenja u Okolišu, Croatia); Dragan Poljak (University of Split, Croatia); Tajmir Tadic (Environmental Measurement Center, Croatia)

The paper deals with the measurement and theoretical estimation of field levels generated by 5G base station antennas. The 5G base station antenna of interest operates in the frequency range between 3.4 GHz and 3.6 GHz. Both measurement has been undertaken using the Rohde&Schwarz measurement equipment including spectrum analyzer, isotropic antenna and suitable optical cables. The electric field calculation has been undertaken by free space and Modified Image Theory (MIT) approach, respectively. The exposure assessment has been estimated in accordance to well-known ICNIRP guidelines and by means of spectra integrals approach.

11:40 Analysis of Substrate Parameters' Variations in a PCB-based 60 GHz GCPW Marchand Balun Design

Muhammad Umar (Technische Universität Dresden, Germany); Martin Laabs (Dresden University of Technology, Germany); Jacqueline Damas (Technische Universität Dresden, Germany); Niels Neumann (Technische Universität Dresden, Germany); Dirk Plettemeier (Dresden University of Technology, Germany)

A 60 GHz ground coplanar-waveguide Marchand balun that is robust against variations of substrate height or dielectric constant is presented. The via-free design and minimum trace-width and trace-to-clearence of 0.1 mm makes it compatible for fabrication with economical PCB development technology. For optimal choice of height for a given substrate with known dielectric constant, EM-simulation results show 35% bandwidth with maximum amplitude and phase imbalance of 0.2 dB and 13 degree, respectively. The substrate dependency analysis in terms of height and dielectric constant shows the possibility of implementing this GCPW balun on substrates with deviations in height or dielectric constant with tolerable performance degradation. It provides a cost-effective solution for measuring differential interconnects and differential millimeter I/Os using single-ended laboratory equipment. Simulation results are verified through fabrication and measurements of two baluns back to back connected through their differential ports. The measured results are in accordance with the simulated results.

12:00 Echo Reduction Properties of Fast Non-Redundant Planar NF Sampling Methodologies

Francesco D’Argiento, Flaminio Ferrara, Claudio Gennarelli and Rocco Guerrieri (Università di Salerno, Italy); Maria Albertina Saporetta, Francesco Saccardi and Lars Foged (Microwave Vision Italy, Italy); Damiano Trenta (European Space Agency, ESTEC, Italy)

The optimal sampling interpolation expansion is employed in new field measurements to reconstruct the field at any point of the observation surface starting from a non-redundant scanning scheme [1]-[5]. Such schemes allow faster measurements than classical Nyquist-compliant acquisitions. The methodology has no accuracy loss and has been validated both analytically with different antennas [5] and in the source region to a surface conformal to the measured antenna, it intrinsically acts as low-pass spatial filter and thus possess echo reduction properties [7]. In this paper, the echo reduction benefits of the optimal sampling interpolation expansion applied to Planar Near Field measurements is investigated for the first time. A standard gain horn, MVG SGH4000 has been measured at V band in an environment with controlled echoes. The results obtained with non-redundant methodology are compared against classical measurements post-processed with standard echo reduction techniques [8].

T11-M01: Material Characterisation and Non-Destructive Testing

T11 Fundamental research and emerging technologies / Regular Session / Measurements

Room: B5

Chair: Zhiyun Hu (University of Manchester, United Kingdom (Great Britain)), Alberto Toccafondi (University of Siena, Italy)

10:40 Biosensors for the Electrical Permittivity Characterization of Dielectric Materials

João Guilherme Domingos de Oliveira and Samuel Paiva (Universidade Federal do Rio Grande do Norte, Brazil); Jose Garibaldi Duarte, Jr. and Luis Felipe V. T. Costa (Federal University of Rio Grande do Norte, Brazil); Valdemir S. Neto and Adalio D’Assunção (Universidade Federal do Rio Grande do Norte, Brazil)

A new biosensor method for the electrical permittivity characterization of dielectric materials is presented. The electrical patch panel is inspired on the Shiois leaf, whose scientific name is Perilla frutescens. A complementary interdigital capacitor (CIC) is inserted in the patch antenna geometry. The antenna is simulated and designed using the Ansoft HFSS software. For validation purposes, a prototype of the proposed antenna is fabricated and measured. The measurement is carried out to determine the electrical permittivity of three different dielectric materials based on the antenna resonant frequency variation in each case. A good agreement is observed between measured and simulated results, including those available in the literature for the considered materials.

11:00 UWB and L-Band Microwave Measurements of the Antarctic Fim-Layer Complex Permittivity Depth Profile

Roberto Olmi (National Research Council, Italy); Saverio Priori (IFAC CNR, Italy); Federico Puggelli and Alberto Toccafondi (Università di Siena, Italy)

In order to characterize the complex permittivity depth profile of the firm the non-destroative Antarctic ice shelf, a microwave sensor, based on the co-axial-coaxial coaxial entry method, is presented. Preliminary results of the measurements of firm permittivity depth profile, taken during an Antarctics campaign, are also presented, highlighting very good agreement with expected values.

11:20 Broadband Microwave Dielectric Property Comparison of Human Fetal Osteoblastic (hFOB) and Osteosarcoma (SaOs-2) Cell Lines

Zeynep Macit, Campanari Aydinayla, Tuba Yilmaz, Ayse Buse Odzakbel Sirt and Fatma Neze 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 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 Zhinun Hu (University of Manchester, United Kingdom (Great Britain))

This paper presents a noninvasive method for non-invasive continuous monitoring of blood glucose level using a microwave resonator. The technique has been tested on 3 participants for three days to determine the correlation between the standard invasive method of measuring blood glucose level and proposed noninvasive 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 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 (University Paris Est Marne-la-Vallée, France); Patrick Pouliéocht (ESIEE, France); Haikm Tahkimmit (Paris Est Marne-la-Vallée University, France); Edouard Richalot (Université Paris Est-Marne-la-Vallée, France); Olivier Francia (ESIEE Paris, France)

This paper reports a new instrumented microdevice which allows the characterization of local dielectrically by dielectrical 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 capacitors. These microdevices are used in order to extract dielectrically permittivity of liquid media. The proposed CPW sensors are analyzed and characterized in reflection within the frequency band ranging from 0.5 to 15 GHz. Microfluidic technologies are used to fabricate the devices which are coupled with microfluidic capability. The microfluidic channel is 100 mm thick and typical size of the interdigitated 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)