Short Courses

14:00-17:30

Room		Short course
S4-A – Poznan	SC01	Multibeam Antennas and Beamforming Networks
	~~SC02~~	~~THz Technology and Instrumentation~~ cancelled
Sopot	SC03	Wearable Small Antennas for Wireless Communication Systems
S3-B – Wroclaw	SC04	Microwave Imaging for Medical Diagnostic Applications: an Introduction from Theory to Practical Aspects
S4-B – Lublin	SC05	User Antennas for Internet Everywhere via Satellites
S4-C – Kielce	SC06	Wireless Communications with Unmanned Aerial Vehicles: from Wi-Fi and LTE to 5G
S3-A – Gdansk	SC07	Electromagnetic Machine Learning: Theory, Methods, and Applications
S4-D – Bytom	SC08	Channel Measurements and Channel Modelling in Vehicular Scenarios
A2 – Ustka	SC09	A New Look at the Problem of Antenna Design on Complex Platforms by Using Characteristic Modes, Eigenmodes and Characteristic Basis Functions
G1 – Gniezno	SC10	Antenna Boosters: Antenna Design for Mobile/IoT Devices
G2 – Opole	SC11	Antennas for Automotive Applications

Short Courses

Giovanni Toso

Piero Angeletti

SC01 Multibeam Antennas and Beam forming Networks

Room: **S4-A – Poznan**

Date: **5 April 2019**

Time: **14.00-17.30**

Giovanni Toso

(IEEE S'1993, M'00, SM '07) received the Laurea Degree (cum laude), the Ph.D. and the Post Doctoral Fellowship from the University of Florence, Italy, in 1992, 1995 and 1999. In 1996 he was visiting scientist at the Laboratoire d'Optique Electromagnétique, Marseille (France). In 1999 he was a visiting scientist at the University of California (UCLA) in Los Angeles, he received a scholarship from Alenia Spazio (Rome, Italy) and he has been appointed researcher in a Radioastronomy Observatory of the Italian National Council of Researches (CNR). Since 2000 he is with the Antenna and Submillimeter Section of the European Space Agency, ESA ESTEC, Noordwijk, The Netherlands. He has been initiating several R&D activities on Active and Passive Antennas for Telecom applications based on arrays, reflectarrays, lenses and reflectors. G. Toso has been coauthoring the best paper at the 30th ESA Antenna Workshop and the most innovative paper at the 30th and 36th ESA Antenna Workshops. In 2009 he has been coeditor of the Special Issue on Active Antennas for Satellite Applications in the International Journal of Antennas and Propagation. In 2014 he has been guest editor, together with Dr. R. Mailloux, of the Special Issue on "Innovative Phased array antennas based on non-regular lattices and overlapped subarrays" published in the IEEE Transactions on Antennas and Propagation and, for the same society, has been an Associate Editor (2013-2016). Since the first edition (2006) he has been significantly contributing to the ESoA course on Satellite Antennas organised at the European Space Agency teaching lectures on Terminal Antennas and on board Multibeam Antennas. Since 2010, together with Dr. Piero Angeletti, he has been instructing short courses on Multibeam Antennas and Beamforming Networks during international conferences (IEEE APS, IEEE IMS, IEEE IWCS, EUCAP, EuMW) that have been attended by more than 550 participants.

Piero Angeletti

received the Laurea degree in Electronics Engineering from the University of Ancona (Italy) in 1996, and the PhD in Electromagnetism from the University of Rome "La Sapienza" (Italy) in 2010. His 15 years experience in RF Systems engineering and technical management encompasses conceptual/architectural design, trade-offs, detailed design, production, integration and testing of satellite payloads and active antenna systems for commercial/military telecommunications and navigation (spanning all the operating bands and set of applications) as well as for multifunction RADARs and electronic counter measure systems. Dr. Angeletti is currently member of the technical staff of the European Space Research and Technology Center (ESTEC) of the European Space Agency, in Noordwijk (The Netherlands). He is with the RF Payload Systems Division of the ESA Technical and Quality Management Directorate which is responsible for RF space communication systems, instrumentation, subsystems, equipment and technologies. In particular he oversees ESA R&D activities related to flexible satellite payloads, RF front-ends and on-board digital processors. Dr. Angeletti authored/co-authored over 150 technical reports, book chapters and papers published in peer reviewed professional journals and international conferences' proceedings.

Abstract

The objective of this course consists in presenting the state of the art and the on-going developments in Multi-Beam Antennas (MBAs) and Beam-Forming Networks (BFNs). MBAs find application in several fields including communications, remote sensing (e.g. radars, radiometers, etc.), electronic surveillance and defense systems, science (e.g. multibeam radio telescopes), RF navigation systems, etc. Multibeam antennas are assuming as well an important role in emerging 5G communications. The BFN plays an essential role in any antenna system relaying on a set of radiating elements to generate a beam.

Course Outline

Multibeam Antennas are becoming more and more important in different areas for their performances, flexibility and reconfigurability. In particular, the topic is of interest for Space Applications but also for Radar Systems and Mobile Communications. In addition, multibeam antennas are assuming an important role in emerging 5G communications.

The course will cover both theoretical and practical aspects for the following topics:

- Overview of system requirements
- Multibeam Antennas
- Linear and Planar Direct Radiating Arrays (based on Periodic or Aperiodic lattices)
- Reflector-based architectures (Single-Feed-per-Beam, Multiple-Feed-per-Beam)
- Lens-based architectures (free space and constrained)
- Beamforming Networks
- Analogue BFNs (Corporate, Blass, Nolen, Butler matrices)
- Digital BFNs
- RF Technology for Active Components
- Low Noise Amplifiers (LNAs, High Power Amplifiers (HPAs), T/R Modules, etc.
- Overview of some Operational Multibeam Antennas/BFNs
- MBAs for spaceborne Narrowband and Broadband Satellite Communication Systems
- MBAs for Wireless Communications
- On-going European Developments

Current Design and Technological Challenges

The course content is updated regularly by the two co-authors who are deeply involved since more than twenty years in this field.

Albert Sabban

SC03 Wearable Small Antennas for Wireless Communication Systems

Room: Sopot

Date: 5 April 2019

Time: 14.00-17.30

A. Sabban

(IEEE M'87-SM'94) received the B.Sc degree and M.Sc degree Magna Cum Laude in electrical engineering from Tel Aviv University, Israel in 1976 and 1986 respectively. He received the Ph.D. degree in electrical engineering from Colorado University at Boulder, USA, in 1991. Dr. A. Sabban reasearch interests are microwave and antenna engineering. In 1976 he joined the armament development authority RAFAEL in Israel. In RAFAEL he worked as a senior researcher, group leader and project leader in the electromagnetic department till 2007. In 2007 he retired from RAFAEL. From 2008 to 2010 he worked as an RF Specialist and project leader in Hitech companies. From 2010 to date he is a senior lecturer and researcher in Ort Braude and Kinneret Colleges in Israel in the electrical engineering department. He published over 65 research papers and hold USA patents in the antenna area. He wrote four books and two chapters in books on microwave and antennas engineering.

Abstract

Communication, medical and cellular industry is in continuous growth in the last few years. Several wearable and small antennas will be presented in the course. The effect on human body tissues on the antenna and medical system will be presented in the course. Design considerations, computational results and measured results of several compact wideband printed antennas with high efficiency will be presented in the course. Novel wideband passive and active efficient wearable antennas for BAN applications are presented in this paper. Active wearable antennas may be used in receiving or transmitting communication and medical systems.

Course Outline

Wearable Systems For medical applications

- Microstrip wearable antennas
- Loop wearable antennas
- Helix wearable antennas
- Antennas S11 Variation as Function of Distance from Body
- Tunable antennas
- Applications of wearable antennas
- New Fractal small antennas

Lorenzo Crocco

Panagiotis Kosmas

SC04 Microwave Imaging for Medical Diagnostic Applications: an Introduction from Theory to Practical Aspects

Room: S3-B – Wroclaw

Date: 5 April 2019

Time: 14.00-17.30

Lorenzo Crocco

SMIEEE'10, is a Senior Researcher with the Institute for the Electromagnetic Sensing of the Environment, National Research Council of Italy (IREA-CNR). His scientific activities mainly concern theoretical aspects and applications of electromagnetic scattering, with a focus on diagnostic and therapeutic uses of EM fields, through-the-wall radar and GPR. On these topics, he has published more than 100 papers, given keynote talks and led or participated to research projects. He has served as Guest Editor for international journals and is currently associate editor for the IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology (IEEE J-ERM). He has co-edited the book "Emerging Electromagnetic Technologi currently es for Brain Diseases Diagnostics, Monitoring and Therapy". From 2009 to 2012, he has adjunct professor at the Mediterranea University of Reggio Calabria, Italy, teaching Electromagnetic Waves and Non-invasive EM Diagnostics. In 2018, he was habilitated as full professor of Electromagnetic Fields by the Italian Ministry of Research and University. Since 2013, he has been an instructor for the European School of Antennas (ESOA), giving lectures on inverse scattering and biomedical applications of MWI. Dr. Crocco is a Fellow of The Electromagnetics Academy (TEA), and a recipient of the "Barzilai" Award for Young Scientists from the Italian Electromagnetic Society (2004). In 2009, he was awarded among the best under 40 scientists of CNR. From 2013-2017, Dr Crocco served as an elected Working Group Leader for the MiMed COST action (TD1301) on microwave imaging, and he is currently a member of the MyWAVE COST action (CA17115) on electromagnetic hyperthermia.

Panagiotis Kosmas

SMIEEE'13, joined King's College London (KCL) as a Lecturer in 2008, and is currently a Reader at KCL's Department of Informatics. Prior to his appointment, he held research positions at the Center for Subsurface Sensing and Imaging Systems (CenSSIS), Boston, USA, the University of Loughborough, UK, and the Computational Electromagnetics Group, University of Wisconsin-Madison, USA. His expertise in microwave imaging includes radar and tomographic methods, and he has pioneered the use of time reversal for microwave breast cancer detection. He has over 90 journal and conference publications on microwave imaging and related areas. He is also the co-founder of Mediwise Ltd, an award-winning UK-based SME focusing on the use of EM waves for medical applications. Beyond microwave medical imaging, Dr Kosmas' research interests include computational electromagnetics with application to other areas of subsurface sensing, antenna design, and inverse problems theory and techniques. He has taught undergraduate and graduate courses on EM theory, antennas and propagation, electronics, and stochastic processes. He has co-authored a chapter for a Springer monograph on microwave medical imaging titled "An Introduction to Microwave Imaging for Breast Cancer Detection". From 2013-2017, Dr Kosmas served as an elected Working Group Leader for the MiMed COST action (TD1301) on microwave imaging, and he is currently a member of the MyWAVE COST action (CA17115) on electromagnetic hyperthermia.

Abstract

As medical imaging applications of electromagnetic fields are gaining interest in the EURAAP community, there is a strong need to introduce microwave engineers to the theory and challenges in the practical implementation of microwave imaging (MWI). This course aims to achieve this goal by introducing MWI theory in a simple manner, and then focusing on emerging applications, (e.g. breast cancer and stroke

diagnosis). The instructors will use the experience gained from delivering the course in three previous EuCAP meetings, to offer a tutorial that can be useful not only to newcomers, but also to more experienced researchers looking for insight into the challenges of MWI in life sciences. The course will also serve as a training course for a new H2020 Marie Curie Initial Training Network (MC-ITN) project in microwave imaging, EMERALD. The material will be mostly covered with PowerPoint slides, but answers to questions and general discussion will be a key part of the course. The instructors will pay specific attention to answering questions and explaining how the (sometimes complex) mathematical concepts can be implemented in practice via numerical codes. A whiteboard may be used to cover complex mathematical concepts and explanations if necessary.

Course Outline

Part I: Introduction & Theoretical Background

- Overview of emerging microwave medical imaging applications, which are based on the methods presented in the course. This will emphasize the need for microwave imaging and will motivate the material covered in the course.
- Background theory on microwave imaging including a review of fundamental theory of inverse scattering problems, delivered in a simple manner that does not require strong mathematical background.
- Q&As and Break

Part II: From theory to implementation - the microwave imaging practitioner toolbox with examples

- Linear model-based inversion and its application to differential imaging for clinical follow-up, and contrast enhanced microwave imaging
- Non-linear microwave tomography methods (Gauss-Newton methods, contrast-source inversion) for quantitative imaging of human tissues' dielectric properties
- Emerging topics in MWI: sparsity-based imaging techniques, projection-basis regularization

Part III: Examples of reconstructing experimental data with different approaches

Gerard Caille

Nelson Fonseca

SC05 User Antennas for Internet Everywhere via Satellites

Room: **S4-B – Lublin**

Date: **5 April 2019**

Time: **14.00-17.30**

Gerard Caille

is graduated from Ecole Polytechnique (Paris) and ENSEEIHT (Electronics & Telecom in Toulouse, Microwave option

- His industrial career occurred within Alcatel, then Thales group, Space Divisions.

- He was first design engineer for satellite active antennas (space SAR and telecom), then manager of the Active Antennas group

- At the end of his career, he was responsible for the Advanced Antennas Research in Thales Alenia Space, and company Expert for Active Antennas.

- Retired in January 2015; he is now board member of SEE* Midi-Pyrenees, and teaches in several engineers schools & learning courses for engineers.

- His contributions to the design of first European active antennas in Space, STENTOR & ASAR, was decisive; and he was expert for SKYBRIDGE project (worldwide internet via LEO satellites), both for satellite antennas, and User terminal ones

- He managed the Array Antennas activity within ACE (Antenna Centre of Excellence, 2002-2008), led several consortia for ESA or European Commission (FP5, FP7, H2020).

- He is the main author of a dozen of approved patents concerning antennas for Space systems, on-ground & onboard, two of them implemented in presently flying space antennas.

- Gerard CAILLE performed numerous tutorial talks at JINAs (Journées Internationales de Nice sur les Antennes) from 1990 to 2004, organised Array Antenna sessions at EuCAP 2006-2007; and delivered oral presentations at most EuCAP conferences until 2014.

*SEE: Société de l'Electricité, l'Electronique, des Techniques de l'Information et la Communication.

Nelson J. G. Fonseca

(IEEE Senior Member since 2009) received the M.Eng. degree from Ecole Nationale Supérieure d'Electrotechnique, Electronique, Informatique, Hydraulique et Télécommunications (ENSEEIHT), Toulouse, France, in 2003, the M.Sc. degree from the Ecole Polytechnique de Montreal, Quebec, Canada, also in 2003, and the PhD degree from Institut National Polytechnique de Toulouse – Université de Toulouse, France, in 2010, all in electrical engineering. Since 2009, he is with the Antenna and Sub-Millimetre Wave Section of the European Space and Technology Centre of the European Space Agency (ESA), Noordwijk, Netherlands.

His current research interests include multiple beam antennas for space missions, beam-formers theory and design, user terminal antennas and novel manufacturing techniques. He has authored or co-authored more than 170 papers in peer-reviewed journals and conferences. He contributed to 20 technical innovations, protected by over 40 patents issued or pending. Dr. Fonseca chaired the 38th ESA Antenna workshop on Innovative Antenna Systems and Technologies for Future Space Missions, October 2017 and co-chaired the 2018 IET Loughborough Antennas & Propagation conference (LAPC 2018). He received several prizes and awards, including ESA Technical Improvement Awards in 2015 and 2017. He was the recipient of the IEEE Antennas and Propagation Society Commendation Certificate recognizing the exceptional performance of a reviewer for the IEEE Transactions on Antennas and Propagation in 2016.

Dr. Fonseca is in charge of courses on user terminal antennas in the frame of an ESA internal training on "Satcom Ground Segment" since 2017 and in the frame of the European School of Antennas since 2018

Short Courses

Abstract

Internet access everywhere is a fundamental need nowadays, and satellite systems play a specific role in all cases where terrestrial networks cannot offer a reliable connectivity. Efficient while low-cost terminals for users connected to satellites are compulsory, and this is finally one of the main condition for the viability of such systems. In the user terminal, its antenna front-end is the most critical sub-system, as in most cases it requires that a directive beam tracks one (or 2) satellite(s) over a very wide field-of-view, because either the user or the satellite is moving or even both simultaneously.

Trading the best solutions, building innovative efficient designs is a stringent challenge for antenna engineers. We will review designs based on electronic or mechanical steering, hybrid solutions (combining mechanical and electronic steering), and new concepts applied to these missions.

Course Outline

1. Need for satellite systems enabling internet access anywhere in the world:
   - where there is no efficient terrestrial network: small isolated, rural areas in most developed countries, and large ones in the 3rd world;
   - during long-travels in airplanes, high-speed trains, trucks, camping-cars…
2. Overview of various satellite systems enabling such ubiquitous internet access:
   - with few GEO satellites, tens in MEO, hundreds to thousands in LEO; present systems and those under-development ; in L, X, Ku, Ka bands ; comparing available overall throughput and constraints for the users.
3. Technical challenges for User antenna front-end's connecting to such systems; they should combine high performances and low cost as consumer products:
   - Requiring to steer/scan their beam over a wide field-of-view for mobile users (on vehicles, aircrafts…) even if connected with GEO satellites; with added difficulty for most Ku-band systems, requiring linear polarisation alignment.
   - Adding for users connected to MEO or LEO satellites, the need to switch instantaneously from one satellite of the constellation to another (handover).
4. For each application (aeronautical, maritime, land-mobile), we will detail the various options for the antenna front-end:
   - mechanical steering or full-electronic scanning;
   - hybrid antennas, combining mechanical steering over large angles, especially in azimuth, and electronic scanning within smaller angular domains, as in elevation and for fine tracking in both dimensions);
   - innovative concepts: metamaterial-based, VICTS, variably-biased liquid crystals, retro-directive antennas.
5. We will present the best state-of-the-art worldwide:
   - developments funded by ESA, and on-going in US (Thinkom, Kymeta…) and Japan,
   - addressing also briefly the technologies for amplifiers and control devices, part of the antenna front-end.

Evgenii Vinogradov

Sofie Pollin

SC06 Wireless Communications with Unmanned Aerial Vehicles: from Wi-Fi and LTE to 5G

Room: S4-C – Kielce

Date: 5 April 2019

Time: 14.00-17.30

Evgenii Vinogradov

received the Dipl. Engineer degree in Radio Engineering and Telecommunications from Saint-Petersburg Electrotechnical University (Russia), in 2009. After several years of working in the field of mobile communications, he joined UCL (Belgium) in 2013, where he obtained his Ph.D. degree in 2017. His doctoral research interests focused on multidimensional radio propagation channel modeling. In 2017, Evgenii joined the electrical engineering department at KU Leuven (Belgium) where he is working on wireless communications with UAVs. He has given various invited talks and a tutorial related to UAV communication to the industry and academic audiences.

Sofie Pollin

obtained her PhD at KU Leuven in 2006. She continued her research on wireless communication at UC Berkeley. In November 2008 she returned to imec to become a principal scientist in the green radio team. Since 2012, she is professor at the electrical engineering department at KU Leuven. Her research centers around Networked Systems that require networks that are ever more dense, heterogeneous, battery powered and spectrum constrained. She has been working on drone communication since 2012, and given various invited talks on the topic, and authored invited book chapters, journals and tutorials related to UAV communication. She is also co-founder of the ACM workshop DroNET, focusing on drone communication and networks. Prof. Pollin has experience with tutorials at academic conferences such as ICC or Crowncom, or mixed industry/academic fora such as Embedded Silicon West or the SDR forum.

Abstract

The growing use of Unmanned Aerial Vehicles~(UAVs) for various applications requires ubiquitous and reliable connectivity for safe control and data exchange between these devices and ground terminals. Depending on the application, UAV-mounted wireless equipment can either be an aerial user equipment (AUE) that co-exists with the terrestrial users, or it can be a part of wireless infrastructure providing a range of services to the ground users. For instance, AUE can be used for real-time search and rescue and Aerial Base Station (ABS) can enhance coverage, capacity, and energy efficiency of wireless networks. We will start with discussing the open challenges of communication with UAVs. To give answers to the posed questions, we will focus on the UAV communication basics, providing the channel modeling background and giving guidelines on how various channel models should be used. Next, theoretical, simulation- and measurement-based approaches to address the key challenges for AUE usage will be presented (for several frequency bands). Moreover, we will provide a comprehensive overview on how UAV-mounted equipment (e.g. ABS) can be used as a part of the communication network. Based on the theoretical analysis, we will show how various network parameters (for example coverage area of ABSs, power efficiency, or user localization error) can be optimized. Finally, we will discuss how to ensure the safe use of UAVs via various RF-based techniques for detecting the presence of UAVs in the airspace (including Machine Learning and Passive Coherent Location techniques).

Course Outline

- Introduction: i) Applications of UAVs ii) wireless communication links for UAV communication
- Channel modelling fundamentals: i) Channel components, ii) Popular models for large and small-scale fading mechanisms iii) future works
- Performance of LTE and Wi-Fi for aerial users estimated via: i) theory, ii) simulations and iii) measurements
- Adapting millimeter waves for cellular-connected UAVs: i) comparison with LTE, ii) Interference cancellation, beamforming, iii) Future works
- Aerial Base stations for future cellular networks: i) Motivation and challenges, ii) Network design (power, optimal positioning, coverage, capacity, achievable rates), iii) Future works
- UAV detection: i) Passive RF sensing, ii) Radar, iii) Future works
- Localisation: i) of an intruder drone, ii) of ground nodes, iii) Future works
- Conclusions, questions, and discussions

Said Mikki

SC07 Electromagnetic Machine Learning: Theory, Methods, and Applications

Room: **S3-A – Gdansk**

Date: **5 April 2019**

Time: **14.00-17.30**

Said M. Mikki

graduated from University of Mississippi in 2008 with a Ph.D degree in Electrical Engineering. From 2009 to 2015 he worked as a Research Fellow with the Electrical and Computer Engineering Department, Royal Military College of Canada, Ontario. In September, 2015, he joined the Electrical and Computer & Computer Science (ECECS) department in University of New Haven, West Haven, Connecticut, United States. He has published about 100 papers, book chapters, and books in the areas of fundamental electromagnetic theory, computational methods and optimization techniques in electromagnetics, nano-electrodynamics, metamaterials, antenna near fields, and novel methods for characterizing antenna systems, including antenna synthesis algorithms and designs. In 2016, he published New Foundations for Applied Electromagnetics: Spatial Structures of Fields, Artech House (London and Boston.) His current research interests include wireless communications, electromagnetic theory, antennas and circuits, machine learning and artificial intelligence, quantum information processing, and nanotechnology.

Abstract

Aims

The short course aims to introduce (to our best knowledge) the first focused coverage of the emerging research field electromagnetic machine learning (EM ML), outlining a new theory of the topic and developing novel applications falling into a broad technological spectrum including antenna design,

digital communications, radar and inverse modeling, and nanotechnology. The unique approach adopted in this course underscores the need for formulating an integrated formalism combining electromagnetics, communications/signal processing, and artificial intelligence/machine learning within a unified framework suitable for real-life data-driven applications to electromagnetic and communication engineering. We highlight the extremely important role played by electromagnetic data in maintaining the correct operational performance of in the techniques proposed. Use of data in the process of solving electromagnetic problems has not received sufficient attention in the applied electromagnetic and communication communities. This course aims - among other things - to place data at the center of the design and development of a new generation of electromagnetic and communication devices.

A key feature in this course is differentiating electromagnetic machine learning from the now poplar statistical machine learning found in mainstream academic and industrial research. The latter is now used in business and industrial applications and is heavily deployed by companies like Google, Amazon, Microsoft, Nvidia. The latter, the approach advocated here, introduces a specialized form of machine learning closer to the spirit of scientific computing and engineering and communication applications. As proposed by EM ML, electromagnetic machine learning differs from existing mainstream approaches to machine learning in not being based on statistical learning theory. More specifically,

1) In contrast to statistical machine learning, electromagnetic machine learning can either reduce the need or even completely eliminate the process of regularization essential in the mainstream approach (examples: the infinitesimal dipole method).

2) Electromagnetic machine learning can predict new features hidden in the data difficult or impossible to discover by classical learning algorithm (example applications radar inverse modelling and remote sensing).

3) Electromagnetic machine learning is "smarter" than their purely statistical counterparts, and hence can often learn with considerably smaller datasets.

Course Outline

The course will outline a unified EM-signal processing including statistics to be used in order to build a series of applications, including the following topics to be covered:

Part I: General Introduction

1. What is machine learning?
2. Statistical Machine Learning Vs. Electromagnetic Machine Learning
3. Outline of EM ML Theory and Applications

Part II: Theoretical Foundations

1. The Electromagnetic Infinitesimal Dipole Model (EM IDM) Machine Learning Approach
2. The Need for Rigorous and Accurate Electromagnetic DSP (EM DSP) Models in Real-life ML Applications
3. How to Construct an EM DSP Model for Practical Problems
4. Case Study: An EM DSP Model of Antenna

Part III: Applications

1. Applications of the EM IDM approach to problems in wireless communications and antenna design.
2. Machine learning approach to electromagnetic mutual coupling and interactions in large-and-complex antenna arrays (e.g., massive MIMO).
3. Spectral efficiency enhancements in wireless communication systems (5G and MIMO).
4. Inverse modeling and radar target identification.
5. Introduction to Massively-parallel processing algorithms for wireless communication and electromagnetics.

Juan Moreno García-Loygorri

César Briso Rodríguez

SC08 Channel Measurements and Channel Modelling in Vehicular Scenarios

Room: **S4-D – Bytom**

Date: **5 April 2019**

Time: **14.00-17.30**

Juan Moreno García-Loygorri

Dr. Moreno is a rolling stock engineer in the Engineering and Research department of Madrid Metro, where he has led some of the most important projects on railway communications. He also works as a part-time lecturer at the Technical University of Madrid since 2015. He has been working in railways since 2007, first on high speed trains and then on subways. He has participated in many railway-related research projects like the EU-funded Roll2Rail, EmulRadio4Rail and Tecrail, and is the author or co-author of more than 30 research & conference papers on the physical layer (channel measurement and modelling) of railway communications. In 2017 in Paris he co-chaired the first Eucap convened session on railways which was followed by the second one in 2018 in London. His research interests are channel modelling, wireless systems in complex environments and software-defined radio. His PhD Thesis was also focused on railway communications.

César Briso Rodríguez

Prof. Briso is a full professor in the Technical University of Madrid, Spain. He has a long experience as a reviewer and organizer of special sessions in different congresses. Particularly in EuCAP 2016 he successfully organized and chaired the 1st phase and 2nd phase of convened session “Propagation Channels for Wide-Sense Vehicle-to-X Communications”, in 2017 he co-chaired the first convened session on railways and in 2018 the second one. His research interests are in the field of measurement and modelling of wireless propagation in complex environments, especially in railway environment where he has been working the last 15 years. He has participated and led more than 20 national and international projects on railway communications. He has authored/co-authored over 100 research papers in international journals and conferences on the relative topics of high capacity communications on railways environment.

Abstract

It is not necessary to highlight the importance of channel modelling to have high-capacity and reliable communications, but the challenges are greater when you are in vehicular scenarios, which is one of the most extreme environments for channel propagation. For example, high-speed trains can run at 350 km/h and if a reliable communications channel between train and ground is needed, many aspects need to be taken into account like Doppler shifts, coherence time, etc. in order to achieve this target. In this sense,

vehicular scenarios include not only trains, but also UAVs and cars, each one of them with their own challenges. The idea behind this course is to explain how to take channel measurements in these extreme environments and how to obtain models from them, with a special mention of the current models available in the literature. Therefore, the authors will provide some examples of measurements taken by them in order to explain the most important concepts of the course with straightforward examples.

Course Outline

This short course will present an overview on channel modelling through all the steps to be followed: instrumentation, measurements, processing and modeling.

- Channel Modelling:
  - Introduction. Types of models. Channel functions.
  - Multipath. Short-term fading.
  - Narrowband channels: path-loss, angle of arrival, angle of departure
  - Wideband channels: power-delay-profile, Doppler spectrum, WSSUS and non-WSSUS channels, etc.
- Propagation measurements in extreme environments.
  - Narrowband measurements.
  - Wideband measurements: Channel sounding
  - Auxiliary instrumentation: positioning, etc.
  - Representation and processing of results
- Channel models in vehicular scenarios
  - V2X models: Winner II, 3GPP, HST, …
  - Propagation models for tunnels
  - Air-to-ground models, UAVs
- Practical examples.
  - Railways
  - V2V
  - Air-to-ground.

Attendees will get some source code examples that demonstrate many of the techniques covered in the short course. The final part of the course will consist on running these examples on the instructor's laptop but attendees may bring their own laptop if they want to run the examples by themselves.

Short Courses

Raj Mittra

SC09 A New Look at the Problem of Antenna Design on Complex Platforms by Using Characteristic Modes, Eigenmodes and Characteristic Basis Functions

Room: **A2 – Ustka**

Date: **5 April 2019**

Time: **14.00-17.30**

Raj Mittra

is a Professor in the Department of Electrical Engineering & Computer Science department of the University of Central Florida in Orlando, FL., where he is the Director of the Electromagnetic Communication Laboratory. Prior to joining the University of Central Florida, he worked at Penn State as a Professor in the Electrical and Computer Engineering from 1996 through June, 2015. He was a Professor in the Electrical and Computer Engineering at the University of Illinois in Urbana Champaign from 1957 through 1996, when he moved to the Penn State University. Currently, he also holds the position of Hi-Ci Professor at King Abdulaziz University in Saudi Arabia.

He is a Life Fellow of the IEEE, a Past-President of AP-S, and he has served as the Editor of the Transactions of the Antennas and Propagation Society. He won the Guggenheim Fellowship Award in 1965, the IEEE Centennial Medal in 1984, and the IEEE Millennium medal in 2000. Other honors include the IEEE/AP-S Distinguished Achievement Award in 2002, the Chen-To Tai Education Award in 2004 and the IEEE Electromagnetics Award in 2006, and the IEEE James H. Mulligan Award in 2011.

Recently he founded the e-Journal FERMAT (www.e-fermat.org) and has been serving as the co-editor-in-chief of the same. Dr. Mittra is a Principal Scientist and President of RM Associates, a consulting company founded in 1980, which provides services to industrial and governmental organizations, both in the U.S. and abroad.

Abstract

The course will begin with a brief review of the theory upon which the Characteristic Mode analysis (CMA) is based. It would provide a historical perspective on the CMs that were introduced back in the ‘70s by Harrington and Garbacz, when the computing power was rather limited, which prompted them to utilize an eigenvalue equation for defining the Characteristic Modes whose eigenvectors and eigenvalues are both real, enabling them to generate the CMs with a limited computing power, less than what would be needed if they were to deal with the eigenvalue equation corresponding to the MoM matrix whose eigenvalues and eigenvectors are necessarily complex. A few years later Baum introduced the Singularity Expansion Method (SEM) for solving EM scattering (as opposed to antenna analysis and design) problems that was based on the Eigenmode equation corresponding to the MoM matrix, whose eigenvalues and eigenvectors are all complex, as they theoretically should be for open region problems. The SEM was used by Baum as well as by many others to solve a whole host of scattering problems in a numerically efficient way. The Eigenmode approach, upon which the SEM is based, was recently investigated by Oueslati for the problem of an antenna located above a rectangular ground plane. She showed that the current induced on the plane is accurately represented by far fewer eigenmodes than CMs.

Turning next to complex platforms, recent studies have pointed out the difficulties in using the CMAs when materials other than PEC, e.g., lossy or lossless dielectrics, or artificial dielectrics (aka metamaterials) are involved. We note that the Eigenmode analysis does not suffer from this difficulty and can be used for any arbitrary type of material.

The course will next go on to discuss why the modal analysis, whether eigenmode or CMA, is not best suited for the problem of designing and placing antennas on complex platforms such that they meet the design specifications for multiband frequency coverage, return loss and efficiency, all of which are tied to the excitation issue that are absent from the CM or Eigenmode analyses. There is no clue that tells us how to handle the situation when the number of significant modes is much fewer than the number of bands we wish to cover. For large platforms, the situation is totally different, since typically the number of significant modes is very large. In any case, it is difficult to decide, in this situation, how many CMs are to be retained, how to downselect them, and above all how to excite them to satisfy the desired specifications. Furthermore, for large problems, e.g., mobile phone platforms at millimetre waves, ships, drones, other aircrafts, etc., computing and tracking the modes is often prohibitive and impractical, since the associated MoM matrix size is very large.

Finally, the course will propose a slight modification of Eigenmode approach by introducing the excitation aspect in the picture right from the start, thus circumventing the issues that are encountered in the modal analyses. The solutions generated by using different excitations are called the Characteristic Basis Functions (CBFs) and it is shown how they, rather than the modes that are source-free solutions, are used to co-design the antenna and the platform, and to place the antenna(s) on the platform at allowable locations in a manner such that the design specifications specified by the user are met in terms of metrics such as return loss, bandwidth, frequency coverage bands, radiation efficiency, as well as radiation patterns of the antenna systems located on the complex platform. Two different class of problems, namely single and multiple type of antenna excitations, both of which arise in real-world applications, are considered, and a number of illustrative examples are provided. Rather than using a non-linear optimization procedure to realize the desired pattern, the pattern design process can be transformed into an eigenvalue problem of a matrix whose rank is only 4 or 5, and which is considerably more numerically efficient to solve to find the best-fit solution that maximizes the energy radiated in the desired angular range, while minimizing the undesired radiation outside of this range. The issue of introducing a notch in the pattern to supress the interference will also be addressed.

Short Courses

Dr. Jaume Anguera

Dr. Aurora Andújar

SC10 Antenna Boosters: Antenna Design for Mobile/IoT Devices

Room: G1– Gniezno

Date: 5 April 2019

Time: 14.00-17.30

Dr. Jaume Anguera

Jaume Anguera, SM-IEEE, was born in Vinaròs, Spain. Founder partner at Fractus Antennas (Chief Scientist, 2017-up to date) and Associate Professor at Universitat Ramon LLull (1999-up to date), Barcelona, Spain. Previously, he was R&D Manager at Fractus (1999-2017). Author of more than 220 scientific journal and conference papers and authored four academic books. Inventor of more than 130 granted antenna patents many of them licensed to wireless companies. He worked in South Korea (Fractus-Korea) designing small and multiband antennas for the mobile industry (e.g. Samsung and LG). In Korea, he headed up the research team. One of his main tasks was to provide training, education and development of the team's core competency, and to provide R&D vision to address the rapidly growing mobile device market.

He has supervised more than 100 bachelor/master thesis and several PhD thesis and served as a chairman at various antenna conferences.

With more than 19 years of experience in industrial design for small and multiband antennas for wireless devices, he has received awards such as New Faces of Engineering (IEEE), finalist with other inventors at the European Patent Award for the contribution of small antennas for the mobile industry as well as two awards for the best PhD thesis given by COIT (Colegio Oficial Ingenieros de Telecomunicación) and Telefónica. Dr. Anguera has been participating in more than 17 funded national and international research projects valued more than 6M€ (e.g. H2020), many of them as a principal researcher. He is an Associate Editor at Electronics Letters, member of the editorial board at several scientific journals and reviewer at prestigious journals (IEEE, IET, PIER).

Dr. Aurora Andújar

Aurora Andújar, M-IEEE was born in Barcelona, Spain. Founder partner at Fractus Antennas (Product Manager, 2017 – up to date). She received the Bachelor's degree in Telecommunication Engineering in 2005, the Master degree in 2007, and PhD degree in 2013 from the Universitat Politècnica de Catalunya (UPC). From 2007 to 2017 she worked with Fractus as R&D Engineer where she was in charge of the development of technological projects focused on the design of miniature and multiband antennas for wireless devices. She was also involved in the maintenance and growth of the patent portfolio of the company, including the development, writing, and prosecution of new inventions and patents (2007-2013). Since 2009 she is leading research projects in the antenna field for wireless devices in the collaborative university-industry framework. In 2013, she moved to the Products and Service Department where she was in charge of the development and release of new antenna products for wireless devices.

Dr. Andújar has more than 11 years of experience in the antenna industry. Author of more than 20 patents in the antenna field. She has published more than 85 papers in scientific journal, international, and national conferences. She has directed more than 34 bachelor and master thesis. She received two awards for the best PhD thesis given by COIT (Colegio Oficial Ingenieros de Telecomunicación) as well as special awards given by UPC.

She is editor of International Journal on Antennas and Propagation.

Abstract

The short-course will introduce the audience to a small and multiband antenna technology based on replacing a complex and usually customized antenna design with an off-the-shelf, standardized, miniature component called antenna booster. Being surface-mount and chip-like in nature, the antenna booster fits seamlessly in an electronic printed circuit board the same way any other electronic component such an amplifier, filter or switch, to name a few, does. It can be assembled with a conventional pick-and-place machine, making the manufacture and design of the new generation of IoT/Mobile or wireless device simpler, faster and more effective.

The audience (from PhD students to researchers in the field) will be introduced to the theory behind designing an antenna booster, will be given practical examples, and will participate in a hands-on, practical application using Microwave Office circuit design software.

Course Outline

The short course will be divided in two parts.

The first part will include a detailed presentation on the theory, regarding how to design small/multiband antenna systems with antenna boosters and matching networks. The importance of physics in understanding how the technology works will be emphasized and the related applications of the technology will be fully discussed.

The second part will provide a hand-on experience and each attendee will have the opportunity to put the theory into practice. Using Microwave Office, two examples starting from scratch will be fully detailed. The examples will include the design of an ISM antenna system on a wireless platform and a multiband design for 4G operation (824MHz-960MHz and 1710MHz-2690MHz). Both examples will use an antenna booster of only 86.4mm3.

Attendees should bring a laptop and will be given a temporary license of Microwave Office to practice multiband matching networks during the course.

PROGRAM

Part I: Theory (1h)

- Introduction
- Fundamentals
- Antenna boosters
- Matching network architectures
- Single band applications
- Multiband band applications
- Other architectures
- Reconfigurability
- MIMO
- Questions and answers

Part II: Design with Electromagnetic (EM) Software –Microwave Office and AXIEM EM Simulator (2h)

- Design of a small antenna system at ISM (Industrial-Scientific-Medical)
- Design of a multiband antenna system at 4G (824MHz-960MHz and 1710MHz-2690MHz)

- Both designs will start from scratch: from the initial S-parameter of an antenna booster without a matching network, to the final design including the optimized matching network with an antenna booster

Final questions and answers

Conclusion

Note 1: To make the course more productive, it is recommended attendees bring a personal laptop, since access to Microwave Office will be provided for designing some the examples given in the course.

Note 2: Each attendee will receive antenna booster samples as the ones used in the short-course to test in their facilities. Also, PCBs with the full antenna system as the ones designed in the tutorial will be given under request.

Montaha Bouezzeddine

SC11 Antennas for Automotive Applications

Room: **G2 – Opole**

Date: **5 April 2019**

Time: **14.00-17.30**

Montaha Bouezzeddine

was born in Brih El Chouf, Lebanon. She received the Dipl.Eng. degree in networks and communication systems from the National Institute of Applied Sciences (INSA),Rennes, France, in 2012. She is currently pursuing a Ph.D. degree in electrical engineering at the University of Duisburg-Essen, Duisburg, Germany.

She has been a Research Engineer with the RheinMain University of Applied Sciences, Ruesselsheim, Germany, in the field of multi-port antenna systems for cognitive radio. She worked at Telit, Hamburg, Germany, where she was an RF hardware engineer, then she joined, in 2017, Kathrein Automotive, Rosenheim, Germany, as an antenna and RF engineer. She is currently working at Ford Motor company in Cologne, Germany, as a core engineer. She is a regular reviewer on IEEE transactions and EUCAP conferences. Her research interests include MIMO antennas, tunable and reconfigurable antennas, characteristic modes theory, radio navigation systems, adaptive tuning and digital control.

Ms. Bouezzeddine published many papers and was the recipient of the ESoA Best Student Paper Award at EUCAP2016 and other awards.

Abstract

The course will focus mainly on one industrial and practical application of antenna designs which is the automotive industry. Nowadays, the vehicles are much more than mechanics, especially with the emergence of Internet of Things IoT and the concept of connected cars. A primordial interest is allocated to the ever-increasing number of antennas, which need to be implemented in future cars. The aim of this course is to present the different wireless services, requirements and expected performances of antennas for vehicular applications. Basic and advanced concepts will be developed. Nowadays, expertise in antenna engineering and development is gaining more importance in the automotive industry. Many topics are of interest such as small omnidirectional and reconfigurable antennas, MIMO antennas, DSRC for V2V, GNSS antennas, antennas for IoT applications, and chassis modes... Getting familiar with the different challenges and requirements may allow engineers to develop their ideas and bring some practical solutions the industry.

Course Outline

I. Introduction and Outline

- Signals and their frequencies in vehicles
- Standards of different wireless services

II. Antenna Development for Vehicular Applications: Concepts, Challenges and Performance Evaluation

- Example designs of antennas for different applications in the automotive industry will be presented. Considerations regarding performances (radiation patterns, coupling and diversity...), weight, materials, and aesthetics (imposing the size, visibility, and location on car) are highlighted. The antenna design must take into account EMC issues to avoid any degradation of the performance.
- A special attention is given for antennas in the context of connected cars and V2X communications (DSRC, Bluetooth, WiFi, navigation and satellite antennas, Telephone)
- Antenna diversity with MIMO and beam-forming functions to overcome obstructions, increase data rate and cover different polarizations for 5G
- Antenna pattern measurements APM and OTA testing and the associated challenges over different frequency ranges are illustrated

III. Antennas for self-driving cars with illustration of many scenarios

Levels of cars autonomy and what they mean in terms of antenna requirements and performances (High autonomy levels having more stringent requirement compared to low autonomy levels)

- 5G as a must for autonomous cars
- From passive antennas to active adaptive antennas
- Extension to frequencies above 6 GHz and communications for fast-moving vehicles
- Possible cases which need to be thought of (NLOS, big trucks obstructing signals...) (videos)
- Overview of industrial design process, safety issues, autonomous vehicles market

Other required technologies for self-driving cars

- RADARS (and LIDARS) used with the adaptive control cruise and for collision avoidance, phased antenna arrays

IV. Future trends and conclusions:

- IoT and artificial intelligence AI
- Frequency bands and standardization