Tutorials	Session Number	Organisers	Topic	Abstract
10:00–12:35	T-1	Jaim Nulman /Yang Yang	Microwave Circuits and Antennas Using Cutting-Edge Additively Manufactured Electronics (AME) Technology: From Design to Test	Additively manufactured electronics (AME) technology enjoys the advantages of fast-prototyping, low-entry-cost, and in-house short-run manufacturing, which empowers millions of start-ups and companies with demanding confidentiality and accelerated innovation. The advancement of AME technology will circumvent the limitations of traditional 3D printed microwave circuits and antennas. This tutorial aims to present the fundamental knowledge about AME technology and its capability in microwave circuits and antenna designs. Step by step guidelines on designing microwave circuits and antennas will be delivered in two parts: (1) Part A covers the fabrication process, printing mechanism, and novel ink materials. The cutting-edge conductive and dielectric multi-material printing technique will be discussed as well as general aspects of design and tests. Examples of applications include AME Capacitors, Low Pass Filters, embedded components, monolithic devices, and other electronic devices will also be overviewed; (2) In Part B, the AME techniques in microwave circuits and antennas will be investigated from the sub-6 GHz microwave bands to the mm-wave and terahertz regime. The design examples include bandpass filters, metasurfaces, metalens antennas, and multilayer patch antennas and arrays. The tutorial will immediately benefit the defence, space, and telecommunication industries by advancing the knowledge of customizable high-performance microwave systems.
	T-2	Graham Brodie / Mohan Jacob	Microwaves for Materials, Wastes and Agriculture	Microwave processing of materials requires a different approach to electromagnetics than antenna design, although some times antennas, operating in the reactive near field, are used. We propose a discussion about applying microwave energy to materials, which requires an 'applicator' to apply the microwave energy to the material in a way that maximises absorption efficiency. We will use several examples (pyrolysis, graphene production, microwave heating of food, medical applications, and weed killing) to illustrate how microwave processing systems and applicators are designed and developed. Applicators for material processing are often cavity resonators, which could be single mode or multi-mode systems. When a material is introduced into these cavities, the microwave field distribution is perturbed, resulting in complex design problems. Another important consideration is that the dielectric properties of most materials are temperature dependent, so the field distribution and energy absorption changes during the processing. There are also open structures, such as slow-wave structures, which are used to apply microwave energy to materials. Our proposed tutorial will address some of these considerations.
	T-3	Maria Kovaleva/ Karu Esselle	Optimization of antennas with constraints using model-based optimization algorithms	This course is for both beginners and advanced users of optimization techniques in engineering. It is well-suited for those who have always been fascinated by nature-inspired, evolutionary and probability-based optimization methods, but never had a chance to start implementing these algorithms to their work effectively. We are going to begin with the basics of global optimization and compare metaheuristics with model-based optimization. Advanced users will benefit from the detailed review of model-based optimization algorithms and multiple examples. A simple explanation of how the cross-entropy method iteratively updates the distributional parameters and converges will be presented. Every participant will receive a script that is ready to be executed to optimize a group of test functions. Then, we will discuss the examples of antennas with constraints that were optimized using the cross-entropy method. You can bring your designs to discuss how to set them up for optimization or ask your questions during the Q&A session at the end of the Tutorial.
14:05–16:40	T-4	Jerzy Krupka, Bartlomiej Salski, and Pawel Kopyt	Resonant measurement methods of dielectric and ferromagnetic materials in microwave and mm-wave spectra	The course will address state-of-the-art and recent advances in electromagnetic characterization of dielectric and ferromagnetic materials at frequencies spanning from 1 GHz up to 110 GHz with the aid of resonant methods. The most common and standardized method of measuring of the in-plane permittivity of dielectric sheets in the 1-15 GHz frequency range is based on split-post dielectric resonators (SPDR). The theory of operation of SPDRs and their practical use will be addressed with the emphasis on advantages and limitations of the method. At frequencies spanning from 20-110 GHz, where SPDRs are hardly applicable due to technological and fundamental limitations, a Fabry-Perot open resonator (FPOR) can be applied. Automation of the measurement associated with an accurate electromagnetic model of the FPOR allow characterizing dielectric sheets with the loss tangent as low as 10^{-5} in a reasonable time. It will be also shown that the FPOR can be exploited in the measurements of the electric conductivity of metallic samples, including metallization layers on microwave laminates. In case of the out-of-plane permittivity of dielectric sheets, which is essential in a design of microwave circuits, the use of a cylindrical cavity resonator will be presented. Another broad field in microwave characterization that will be discussed is the measurement of liquids and aqueous mixtures with the aid of a cylindrical dielectric resonator. Particular application of the permittivity measurements in the extraction of the soil moisture will be discussed. Eventually, recent advances in the measurement of a ferromagnetic linewidth of ferromagnetic materials in the microwave range will be addressed, including a new accurate approach based on the mode splitting phenomenon.
	T-5	Florinel Balteanu /Venkata Vanukuru	5G RF Front End Design Techniques for Cellular Applications	The research area of improving the performance, cost, and size of RF solutions for 5G LTE is very active with many developments which shapes the semiconductor industry evolution. Mobile cellular subscribers are expected to reach more than 6.5 billion by 2021 and 5G LTE will bring high data capacity as well as low latency using sub-6GHz and mm-Wave spectrum. The short course presents the status of 5G LTE RF Front End (RFFE) techniques to deliver an over gigabit-per-second data rate such as Carrier Aggregation, MIMO as well Wider Modulation Bandwidth for LTE and mm-Wave spectrum. The RFFEs will integrate power amplifiers, switches, couplers, tuners, and active acoustic filters. The short course will cover practical design aspects for 5G FEMS with emphasis for FEM architectures, power amplifiers, switches, and active filters as well the technologies involved into these designs. The course will also cover aspects of new 5G LTE integration for envelope tracking and LNA design. 5G LTE New Radio (NR) will increase the complexity for RFFEs and will be covered in this short course.
	T-6	Vikass Monebhurrun, Lars Jacob Foged and Vince Rodriguez	Antennas & Propagation Standards	The terminology standards on antennas (IEEE Std. 145) and radio wave propagation (IEEE Std. 211) are important documents that guarantee the right use of accepted terms in technical papers and reports. IEEE Std. 149 (antenna measurement), IEEE Std. 1720 (near field antenna measurement) & IEEE Std. 1502 (radar cross-section measurement) prove useful when performing antenna measurements. The workshop will provide an overview of these standards that have been developed by the IEEE Antennas & Propagation Standards Committee. The tutorial will cover the following standards: 1. Introduction to Standards. 2. IEEE Std. 145 on Antenna Terminology. 3. IEEE Std. 211 on Radio Wave Propagation Terminology. 4. IEEE Std. 149 on Antenna Measurement. 5. IEEE Std.1720 on Near Field Antenna Measurement. 6. IEEE Std.1502 on Radar Cross-Section Measurement.