Course Description

Course name	**#082 - 5G and Beyond Wireless Communication System Design**
Duration	**3 days**
Format	**Public Classroom, Inhouse Event and Online**

Overview

Professor Djuradj Budimir, from the University of Westminster, London, UK, is teaching this 3-day course with insight into the **5G and Beyond wireless communication system design** from a system point of view. Designers will be familiarized with the latest development of 5G and Beyond wireless communication systems and different approaches that are used in their analysis. They will understand application in systems such as 5G and beyond mobile wireless systems, and wireless RF and micro-/mm-wave circuit and system design.

The aim of this course is to provide a thorough understanding of principles, techniques and the state-of-art of the RF and micro-/mm-wave circuit and 5G and Beyond wireless communication system design. Demonstration of some available CAD software packages (e.g. EPFIL, ADS, emSonnet, Matlab, and CST) will be used to illustrate the performance of design circuits.

Technical Focus

The steady growth in commercial interest in RF, micro-/mm-wave and Terahertz wireless communication networks and systems, especially in wireless communications such as 5G and Beyond/6G, Internet of Things (IoT), security and wireless sensor applications, and military and transportation electronics, has provided a significant challenge to conventional RF, micro-/mm-wave circuits and their design methodologies.

The fifth generation (5G) technology is one of the most hyped topics in technology with enthusiasts promising it will be the gateway to virtual reality (VR), augmented reality, the Internet of Things (IoT), 3D services, pervasive high-resolution video and self-driving cars. The development of wireless communication over the last three decades has revolutionized our lives. In the past decade there has been a proliferation of wireless services and devices, followed by increasing demands for higher data rates.

Many new technologies will rely extensively on enhancements to Multiple-Input-Multiple-Output (MIMO) systems including systems such as mm-Wave cellular systems and massive MIMO. Recent advances in RF, micro-/mm-wave computer-aided circuit design technology suggest the feasibility of interfacing electromagnetic simulations directly to sophisticated optimization systems. With the availability of powerful computers this optimization-based approach to the design of RF, micro-/mm-wave circuits become a desirable tool. CAD has become an essential tool in the design and manufacturing of RF, micro-/mm-wave circuits and 5G and Beyond/6G wireless systems.

Course Content

This 3-day course gives theoretical insight into the 5G and Beyond/6G wireless communication system design from a system point of view and provide a thorough understanding of principles, technologies and the state-of-the-art of the wireless communication systems – 5G and Beyond/6G. To familiarize designers with the latest development of 5G and Beyond/6G wireless communication systems and different approaches that are used in their analysis. To enable designers to understand application in systems such as 5G and Beyond/6G wireless systems, and wireless RF, micro-/mm-wave and Terahertz circuit and system design. The aim of this course is to provide a thorough understanding of principles, techniques and the state-of-art of the RF, micro-/mm-wave and Terahertz wireless circuit system design. Demonstration some of available CAD software packages (e.g. EPFIL, ADS, emSonnet, CST and Matlab) will be used to illustrate the performance of design circuits and systems.

The individual objectives to achieve this aim can be summarised as follows:

- To enable participants to understand 5G and Beyond/6G wireless communication from a network system view point to provide a thorough understanding of principles, technologies and the state-of-art of the wireless communication systems.
- To give theoretical insight into the wireless RF, micro-/mm-wave and Terahertz field;
- To enable you to use your knowledge to design an RF or micro-/mm-wave and Terahertz filters, amplifiers, linearisers, antennas, transceivers and subsystems;
- To give the adequate background to enable you to analyse subsystem components and circuits such as filters, amplifiers, linearisers and antennas;
- To enable participants to understand circuit design in technologies such as waveguides, and microstrip.
- To familiarise participants with the latest development of 5G and Beyond/6G wireless systems and technologies and different approaches that are used in their analysis.
- The development of an integrated perspective to the design of wireless systems looking at the trade-offs of system requirements and hardware capabilities.

Who Should Attend

The methods described here are useful for anyone designing hardware or software for 5G and B5G/6G wireless communication and Internet of Things (IoT) systems. Postgraduate and final year undergraduate students, engineers, managers and scientists who need an expanded, up to date understanding of advanced 5G and Beyond/6G and IoT wireless system design.

Course Daily Schedule

Day 1.

The first day begins with a theoretical insight into 5G and Beyond/6G wireless communication systems, a review of 5G and Beyond Technology and wireless communication system design. Application of 5G and Beyond will be briefly reviewed. The sub-6 GHz (e.g. n77: 3.3-4.2 GHz; n78: 3.3-3.8 GHz; n79: 4.4-5.0 GHz) and mmWave (e.g. n261: 27.5-28.35 GHz; n257: 26.5–29.5 GHz; n258: 24.25-27.5 GHz; n260: 37-40 GHz) 5G frequency bands will be reviewed briefly. Day 1 continues with a study of a basic theory of high frequency filters, filter technologies, and filter design for 5G and Beyond wireless communication applications. The rest of the day will be devoted to waveguide and microstrip filter, diplexer and multiplexer synthesis, analysis and design procedures. The EPFIL software package developed by instructor seeks to improve waveguide filter and diplexer design and decrease performance variations without creating overly stringent manufacturing tolerances. The accompanying manual helps the reader to cut design time and improve accuracy by quickly and easily predicting performance parameters before building costly prototypes. Using the mode-matching method as a foundation, the software supplies a full-wave solution for filter discontinuities, aiding you in the design of E-plane waveguide filters specifically intended for RF, micro-/mm-wave 5G and beyond applications. This means you can substantially reduce development and production costs, reduce time-to-market, and effectively increase circuit performance.

- 5G and Beyond wireless systems overview
- Evolution of wireless mobile technologies
- 5G Use cases
- 5G standardisation timeline
- 5G frequency spectrum
- Basic theory of high frequency filters
- Filters characteristics
- Filter design procedure
- Overview of filter technologies
- Waveguide and microstrip filters
- Exercise: waveguide bandpass filter design
- Demonstration some of available CAD software packages (e.g. EPFIL, ADS, emSonnet, and CST)

Day 2

begins with a study of a basic theory of antennas, antenna systems fundamentals, including basic antenna properties: impedance, directivity, radiation patterns, polarization, etc. Antennas systems such as mMIMO systems, beamforming and beamforming architectures will be briefly reviewed. Rest of the day continues with fundamental multi antenna array theory, types of antenna arrays, feed

network design considerations and rectennas for wireless energy harvesting for sub-6 GHz and mmWave 5G and Beyond wireless communication system applications and health effects from 5G exposure.

- Recap from Day 1
- Basic theory of antennas
- Antenna Systems Fundamentals
- MIMO Antenna Technology
- Massive MIMO Antenna Systems
- Examples of 5G Sub-6 GHz and mmWave Massive MIMO
- Beamforming and beamforming architectures
- SIngle RF chain multi-user beamforming
- Adaptive beam-steering technique
- Feed network design considerations
- Design of antennas arrays
- Exercise: microstrip antennas array design
- Rectennas for wireless energy harvesting applications
- EMF exposure: Common sources
- Health Effects from 5G Exposure
- Example: Assessment of the exposure of the general public to 5G em waves
- Example: Massive MIMO EMF exposure
- Demonstration some of available CAD software packages (e.g. ADS, emSonnet, and CST)

Day 3

focusses on a review of wireless subsystem and transceivers. Also, it involves a considerable amount of design of wireless circuits and transceivers and covers link budget calculations together with their parameters for current and next generation wireless communication systems. Day 3 continues with overview of wireless communication transceiver architectures and wireless system design, **t**ransmitter system parameters, signal distortion and spectral regrowth; receiver system parameters, direct and heterodyne conversion, analysis of noise characteristics; noise figure & link budgets; assessing performance of wireless communication systems. Finally, the practical implementation of linearised power amplifiers, filters, filtennas and antenna arrays will be reviewed and discussed.

- Recap from Day 2
- Introduction to wireless transceiver architectures

- Noise in wireless receivers
- Sensitivity, minimum detectable signal and dynamic range
- Wireless receiver design
- Spectral regrowth and linearity
- Simulation of spectral regrowth with different modulation formats
- Evaluation of nonlinear distortion in 5G Transmitters
- 5G wireless system specifications
- Free space path loss, link budgets and capacity of the link
- Exercise: wireless communication system design
- Evaluation of wireless system performance
- Demonstration some of available CAD software packages (e.g. EPFIL, ADS, emSonnet, CST and Matlab)

Course summary, conclusion and discussion

Instructor Biography

Professor Djuradj Budimir received the Ph.D. degree in electronic and electrical engineering from the University of Leeds, Leeds, U.K. In March l994, he joined the Department of Electronic and Electrical Engineering at Kings College London, University of London, UK.

Since January 1997, Prof. Budimir has been with the School of Computer Science and Engineering, University of Westminster, London, UK, where he is now a professor of wireless communications and leads the Wireless Communications Research Group. He is also a Visiting Professor at the School of Electrical Engineering, University of Belgrade.

He has published more than 300 papers in refereed journals and conference proceedings, four books/book chapters and software's (the book Generalized Filter Design by Computer Optimization, ISBN 0-89006-579-9, Artech House Books, March 1998, and the Software and User's Manual EPFIL-Waveguide E-plane Filter Design (Artech House, 2000) and a book chapter in Encyclopedia of RF and Microwave Engineering (Wiley, 2005) over over 20 Invited papers/lectures, over 20 Seminars/Workshops, one TV program (BBC World Service programme on Microwaves, 17 Nov. 2010) in the field of RF/microwave and millimetre-wave wireless systems and technologies.

Professor Budimir´s expertise includes design of circuits from RF through Microwave to Millimetre-wave frequencies for 4G, and 5G wireless communications, WLAN, wireless sensors, Internet of Things (IoT) and wireless power transfer applications. He serves as an Associate Editor for IET Electronic Letters, He was a local co-chair of European Microwave Conference (EuMW2016), will be a local co-chair of European Antennas and Propagation Conference (EuCAP2018) and member of the TPC of several conferences. He is a Member of the EPSRC Peer Review College, a senior Member of IEEE, a Member of IET and a Chartered Engineer. He has supervised 22 PhD/4 MRes and over 100 MSc theses through to completion and is currently supervising 2 PhD theses as the main supervisor (DoS).

Professor Budimir has been a member of the Continuing Education Institute-Europe faculty since 2019.

Publications:

1. D. Budimir, "Generalized Filter Design by Computer Optimization", Artech House, 1998
2. D. Budimir, EPFIL: Waveguide E-plane Filter Design Software (Microwave software library), Artech House, Nov. 1999.