## AI Techniques for Microwave Antenna Design

Abstract:

This short course provides attendees with hands-on experience with cutting-edge artificial intelligence (AI)-driven antenna design approaches. The course covers the theory and application of AI-driven antenna design methodologies. Additionally, the course demonstrates, through case studies, how contemporary and challenging antenna design problems for modern applications can be addressed. Tutorials are provided on how antenna designers can use AI-driven microwave design tools.

Graphical abstract:
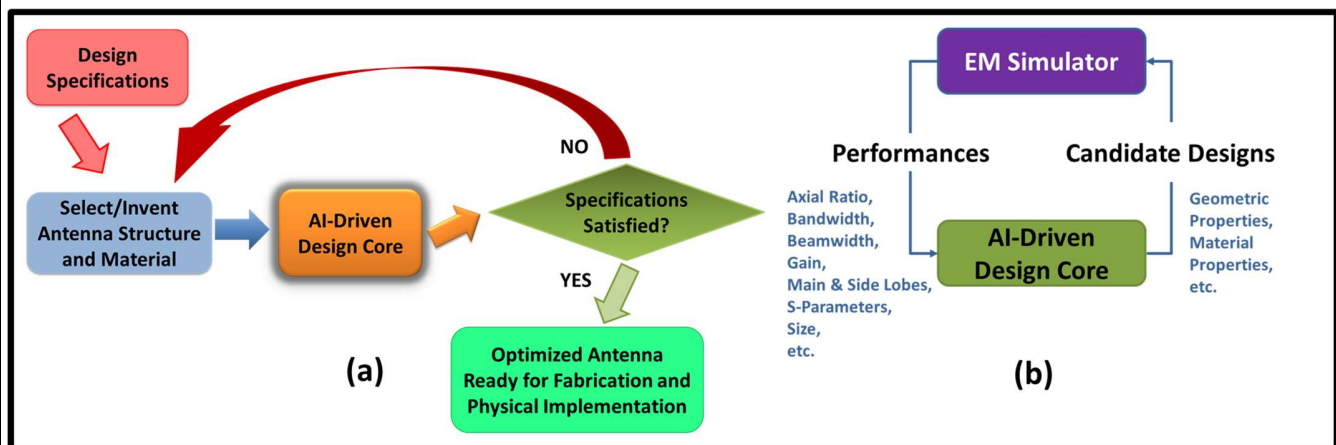
Recommended prerequisites for attendees:

The course requires a basic knowledge of antenna design, characterization and optimization. Attendees are also expected to have some background in the use of computer-aided design (CAD) software tools and environments for antenna modelling and characterization. Some of such tools and environments may include (but are not limited to) CST Microwave Studio, Anys HFSS, and MATLAB Antenna Toolbox. Attendees who have no background or knowledge in the aforesaid areas but are keen on exploring the field of AI-driven antenna design for modern applications are also welcome to attend and participate in the course.

Learning objectives:

After the course, the participant will be able to:

1) Demonstrate a general knowledge of the state-of-the-art approaches available for AI-driven antenna designs.

2) Identify some of the present-day challenges in the design of antennas for contemporary applications such as 5G mmW, 5G sub-6 GHz, radars and others.

3) Understand the steps involved in the practical design of antennas using AI techniques.

4) Use MATLAB for the AI-driven design of antennas.

Course outline:

The short course will comprise four interactive lecture sessions on interrelated topics on AI-driven antenna design to be delivered by the instructors. The course outline is as follows:

1) AI-driven antenna design concepts and methods. (B. Liu)
   a. In this lecture, the attendees are introduced to the concept and methods of AI-driven antenna design using real-world examples. Particularly, state-of-the-art methodologies for the AI-driven design of antennas are presented and discussed.
   b. This lecture will be delivered via a PowerPoint presentation.

2) Challenging antenna cases solved by AI-driven design methods. (L. Wang)
   a. In this lecture, practical antenna cases that are challenging in terms of applying conventional design methodologies are discussed. Then emphasis is laid on how AI techniques have assisted in the design process of these antennas.
   b. This lecture will be delivered via a PowerPoint presentation.

3) Implementing AI-Driven Antenna Design: Step by Step Tutorial. (M. O. Akinsolu)
   a. In this lecture, the formulation of antenna design problems into optimization problems will be discussed using practical examples to demonstrate how objectives and constraints can be defined and set meticulously. Then, an AI-driven antenna design tool will be employed to further demonstrate how a real-world antenna can be designed expeditiously using AI.
   b. This lecture will be delivered via a PowerPoint presentation and a demo of the AI-driven antenna design tool.

4) MATLAB Antenna Toolbox: an interactive AI-driven antenna design environment. (G. Zucchelli)
   a. In this lecture, the MATLAB antenna toolbox and how its in-built state-of-the-art AI technique for antenna design and optimization, SADEA, works will be presented and discussed.
   b. This lecture will be delivered via a PowerPoint presentation and a demo of the MATLAB antenna toolbox.

Bo Liu received the B.Eng. degree from Tsinghua University, China, in 2008 and the Ph.D. degree from University of Leuven (KU Leuven), Belgium, in 2012. Currently, he is a Professor of Electronic Design Automation at University of Glasgow. He is a Fellow of IET and a Senior Member of IEEE. His research focuses on novel data-driven optimization and machine learning algorithms for electronic (analog ICs and systems, microwave devices, and micro-electromechanical systems) design and their real-world applications.

In terms of AI-driven antenna design, he is the inventor of the SADEA series. The SADEA series is the first to address the bottleneck of computationally expensive electromagnetic simulations together with poor or no initial design in antenna design exploration – this makes the AI-driven antenna design approach suitable for industrial requirements.

More information can be found at https://www.gla.ac.uk/schools/engineering/staff/boliu/

Lei Wang received the Ph.D. degree in electromagnetic field and microwave technology from Southeast University, Nanjing, China, in 2015. From September 2014 to September 2016, he was a Research Fellow and held a post-doctoral position at the Laboratory of Electromagnetics and Antennas, Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland. From October 2016 to November 2017, he was a Post-Doctoral Research Fellow with the Electromagnetic Engineering Laboratory, KTH Royal Institute of Technology, Stockholm, Sweden. From November 2017 to February 2020, he was an Alexander von Humboldt Scholar with the Institute of Electromagnetic Theory, Hamburg University of Technology (TUHH), Hamburg, Germany. Since March 2020, he has been an Assistant Professor with the Institute of Signals, Sensors and Systems, Heriot-Watt University, Edinburgh, U.K. His research includes antenna theory and applications, active electronically scanning arrays, integrated antennas and arrays, substrate-integrated waveguide antennas, leaky-wave antennas, and wireless propagations. Dr. Wang was awarded the Chinese National Scholarship for Ph.D. Candidates in 2014 and was granted the Swiss Government Excellence Scholarship to conduct research at EPFL in 2014 too. He was also granted by the Alexander von Humboldt Research Foundation to take research at TUHH in 2016. Moreover, he received the Best Poster Award at the 2018 IEEE International Workshop on Antenna Technology (iWAT 2018), the Best Paper Award at the 5th International Conference on the U.K.–China Emerging Technologies (UCET 2020) and the Best Antenna Paper Award in 2023 European Conference on Antennas and Propagation (EuCAP 2023). He is a Senior Member of the IEEE.

Mobayode O. Akinsolu received the M.Sc. degree with distinction in electrical and electronic engineering from the University of Bradford, Bradford, U.K., in 2014, after his undergraduate studies and compulsory national service in Nigeria, and the Ph.D. degree from the University of Chester, Chester, U.K., and Wrexham Glyndwr University, Wrexham, U.K., in 2019. He has worked as a Research Fellow (Industrial Attaché) and a Visiting Researcher with the National Space Research and Development Agency, Nigeria, and the RFID Research Centre, African University of Science and Technology, Nigeria, respectively, until 2016. From 2016 to 2019, he was a Ph.D. Scholarship Awardee in recognition of a joint project between Wrexham Glyndwr University and the University of Birmingham, Birmingham, U.K. He received a commendation from the University of Chester for the publications record relating to his PhD work. His contributions to applying artificial intelligence techniques to automate

and expedite engineering design processes have led to the co-authorship of several articles in reputable peer-reviewed journals and presentations at international conferences. He is currently a Senior Lecturer in electronic and communication engineering at Wrexham Glyndwr University. He is a Chartered Engineer with the Engineering Council, a fellow of the Higher Education Academy, a senior member of the IEEE, a member of the IET, and a registered Electrical Engineer with the COREN.

Giorgia Zucchelli is the product manager for RF and mixed-signal at MathWorks. Before moving to this role in 2013, she was an application engineer focusing on signal processing and communications systems and specializing in analog simulation. Before joining MathWorks in 2009, Giorgia worked at NXP Semiconductors on mixed-signal verification methodologies and at Philips Research developing system-level models for innovative communications systems. Giorgia has a master's degree in electrical engineering and a doctorate in electronics for telecommunications from the University of Bologna.