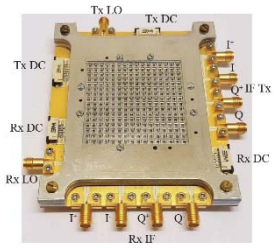
Program of ESoA course:

Challenges, Solutions and Developments of

Antenna Systems for 5G Communication

Type:

Gothenburg, Sweden, 20-24 May 2019



Coordinators:

J. YANG	A. ZAMAN	R. SAULEAU

Supported by

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SUMMARY

5G era is approaching and we now see some version of commercial 5G networks starting to go live at different parts of the world. The 5G communication technology will bring new experiences including higher bandwidth, higher data rate or greater capacity, security, and lower latency and will create new opportunities for society, businesses. 5G is going to make a significant change of how we live in this world. The key enabling 5G technologies under development include novel multiple access strategies, ultra-dense networking, all-spectrum access, massive MIMO, full digital beamforming or hybrid beam forming etc. The realization of these high level technologies brings about new challenges for the physical infrastructure designers which undoubtedly include the antenna and microwave engineers. After many years of collective effort on 5G antenna systems research, in both academia and industry, some challenges have been solved up to a certain extent. But many challenges are still need to be solved or waiting for better solutions. The implementation and completion of 5G systems will be carried out in several stages: first sub-6GHz, then step into millimeter wave regime, from 20 GHz to even 100 GHz.

This course presents the some updated research results on 5G antenna systems. It is not possible to include all the relevant results on the 5G topic, however some significant and promising results relevant from industrial perspective are covered. The teaching team includes well-recognized researchers in academia, and experts in industry covering the area of 5G antenna systems research and developments, mainly in Europe and also worldwide.

The contents of the course include: 1) **Antenna-Channel Interaction** such as OTA characterization of 5G antennas, RIMP and Random LOS environments and 3D massive MIMO models and Antenna optimization; 2) **5G Array Antenna Technologies** such as self-grounded Bowtie antenna array for sub-6GHz, capped Bowtie and magnetic-electric dipole antenna arrays; 3) **Gap waveguide Antennas for 5G mmW backhauling links** with principles, modeling and numerical tools for Gap waveguide technology and slot array antennas; 4) **SIW technology for 5G Antenna Systems** - hardware and Integration; 5) **Millimeter wave antennas for 5G applications**.

As an important part of the course we plan to organize 6 lectures with a focus on Industrial **Perspectives for 5G Wireless Systems**, given by experts from industry. The series lectures of industrial perspectives cover **5G communication systems**, antenna challenges in **users and handheld terminals for 5G**, Challenges and requirements for **radio access and backhauling links**, challenges in **automotive and V2X connectivity**, Challenges in **high speed railways** and 5G System **OTA Measurements**.

The course is organized as lectures, self-study time slots, discussion forum and study visits. Lunches for 5 days, two dinners with social activities and two coffees per day are offered by the course. You are welcome!

Course Information	
Date	20-24 May, 2019
Place	Dept. of Electrical Engineering, Chalmers University of Technology
Address	Hörsalsvägen 11, ED-building, 412 96 Gothenburg, Sweden
Lecture room	EDIT room, 3rd floor
Course registration fee	
Non-profit institution	€450 per participant
Profit institution	€1100 per participant
Registration	Webside (to be determined)

Travel Grants

We offer 4 travel grants for students to participate the course. The grants offer the grant recipient flight ticket and 7 days accommodation. The grants are available only for Master students and PhD students worldwide who have paid the course registration fee. The deadline of application for the grants is 30 April, 2019. The application includes a short motivation letter (maximum one page) and CV (maximum two pages), and you apply on website (to be determined).

Examination and Credit

There is an open examination for the participants in order to have a certificate and ECTS credits after the course week. The exam questions will be sent to all participants at the end of the course and the participants should solve the exam questions independently. The course give 2 ECTS credits for those who pass the examination.

Note

All course participants should bring own laptop since we will send course materials, updated information, exam questions and course evaluation form via email.

1. CVs of Lecturers

Ronan Sauleau (M'04–SM'06-F'18) graduated in electrical engineering and radio communications from the Institut National des Sciences Appliquées, Rennes, France, in 1995. He received the Agrégation degree from the Ecole Normale Supérieure de Cachan, France, in 1996, and the Doctoral degree in signal processing and telecommunications and the "Habilitation à Diriger des Recherches" degree from the University of Rennes 1, France, in 1999 and 2005, respectively. He was an Assistant Professor and Associate Professor at the University of Rennes 1, between September 2000 and November 2005, and between December 2005 and October 2009, respectively. He has been appointed as a full Professor in the same University since November 2009. His current research fields are numerical modeling (mainly FDTD), millimeter-wave printed and reconfigurable antennas, substrate integrated waveguide antennas, lens-based focusing devices, periodic and non-periodic structures (electromagnetic bandgap materials, metamaterials, reflectarrays, and transmitarrays) and biological effects of millimeter waves. He has been involved in more than 60 research projects at the national and European levels and has co-supervised 23 post-doctoral fellows, 44 PhD students and 50 master students. He has received 20 patents and is the author or coauthor of more than 215 journal papers and 470 publications in international conferences and workshops. He has shared the responsibility of the research activities on antennas at IETR in 2010 and 2011. He was co-director of the research Department 'Antenna and Microwave Devices' at IETR and deputy director of IETR between 2012 and 2016. He is now director of IETR. Prof. Sauleau received the 2004 ISAP Conference Young Researcher Scientist Fellowship (Japan) and the first Young Researcher Prize in Brittany, France, in 2001 for his research work on gain-enhanced Fabry-Perot antennas. In September 2007, he was elevated to Junior member of the "Institut Universitaire de France". He was awarded the Bronze medal by CNRS in 2008. He was the co-recipient of several international conference awards with some of his students (Int. Sch. of BioEM 2005, BEMS'2006, MRRS'2008, E-MRS'2011, BEMS'2011, IMS'2012, Antem'2012, BioEM'2015). He served as a guest editor for the IEEE Antennas Propogat. Special Issue on "Antennas and Propagation at mm and sub mm waves". He served as a national delegate for COST VISTA and for EurAAP. He is a member of the board of directors of EurAAP.

Jian Yang (M'02-SM'10) received B.S. degree from the Nanjing University of Science and Technology, Nanjing, China, in 1982, and the M.S. degree from the Nanjing Research Center of Electronic Engineering, Nanjing, China, in 1985, both in electrical engineering, and the Swedish Licentiate and Ph.D. degrees from the Chalmers University of Technology, Gothenburg, Sweden, in 1998 and 2001, respectively. From 1985 to 1996, he was with the Nanjing Research Institute of Electronics Technology, Nanjing, China, as a Senior Engineer. From 1999 to 2005, he was with the Department of Electromagnetics, Chalmers University of Technology as a Research Researcher. During 2005 and 2006, he was with COMHAT AB as a Senior Engineer. From 2006 to 2010, he was an Assistant Professor at the Department of Signals and Systems, Chalmers University of Technology. From 2010 to 2016, he was an Associate Professor. From 2016, he has been a professor at the Department of Signals and Systems, Chalmers University of Technology. He has published more than 60 journal articles and about 150 peer reviewed conference papers. H-index: 26. His research interests include ultra-wideband antennas and UWB feeds for reflector antennas, mmWave antennas, mmWave multilayer phased array antennas, mmWave SWE (sheet waveguide element) antennas, Gap waveguide antennas, UWB radar systems, UWB antennas in near-field sensing applications, hat-fed antennas, reflector antennas, radome design, and computational electromagnetics.

Ashraf Uz Zaman received the M.Sc. and Ph.D. degrees from the Chalmers University of Technology, Gothenburg, Sweden, in 2007 and 2013, respectively. He is currently a Docent (Associate Professor) with the Communication and Antenna Systems Division, Chalmers University of Technology. His research interests include millimeter-wave planar beam scanning antennas, high gain planar antenna arrays, gap waveguide technology, frequency-selective surfaces, microwave passive filters, and packaging techniques and integration of RF MMICs and circuits with the antennas. He has authored or co-authored over 100 referred journal and conference papers and a number of book chapters. He has also filed 6 patents. He is also serving as an Associate Editor for the IEEE transactions on Antennas and Propagation

Ke Wu is a Professor of electrical engineering, and Future Wireless Technology Research Chair with the Polytechnique Montréal (University of Montreal), QC, Canada. He has been the Director of the Poly-Grames Research Center. He was the founding Director of the Center for Radiofrequency Electronics Research of Quebec (Regroupement stratégique of FRQNT) and Tier-I Canada Research Chair in RF and millimeter-wave engineering. Currently, he is also with the School of Information Science and Engineering, Ningbo University, on leave from his home institution, leading a 5G and future wireless research program. He has held guest, visiting, and honorary professorships with many universities around the world. He has authored or co-authored over 1200 referred papers and a number of books/book chapters. He has filed more than 50 patents. His current research interests involve substrate integrated circuits and systems, antenna arrays, field theory and joint field/circuit modeling, ultra-fast interconnects, wireless power transmission and harvesting, and MHz-through-THz technologies and transceivers for wireless sensors and systems as well as biomedical applications. He is also interested in the modeling and design of microwave and terahertz photonic circuits and systems. Dr. Wu is a Fellow of the IEEE, of the Canadian Academy of Engineering (CAE) and of the Royal Society of Canada (The Canadian Academy of the Sciences and Humanities). He is a Member of Electromagnetics Academy, Sigma Xi, URSI, and IEEE-Eta Kappa Nu (IEEE-HKN). He has held key positions in and has served on various panels and international committees including the chair of Technical Program Committees, International Steering Committees, and international conferences/symposia. In particular, he was the General Chair of the 2012 IEEE Microwave Theory and Techniques (IEEE MTT-S) International Microwave Symposium (IMS). He has served on the Editorial/Review Boards of many technical journals, transactions, proceedings and letters as well as scientific encyclopedia including Editor and Guest Editor. He was the Chair of the joint IEEE Montreal chapters of MTT-S/AP-S/LEOS and then the restructured IEEE MTT-S Montreal Chapter, Canada. He has served IEEE MTT-S and Administrative Committee (AdCom) as Chair of the IEEE MTT-S Transnational Committee, Member and Geographic Activities (MGA) Committee, Technical Coordinating Committee (TCC) and 2016 IEEE MTT-S President among many other AdCom functions. Currently, he is the Chair of the IEEE MTT-S Inter-Society Committee. He was an IEEE MTT-S Distinguished Microwave Lecturer (2009-2011). Dr. Wu is the inaugural representative of North America as a Member of the European Microwave Association (EuMA) General Assembly. He was the recipient of many awards and prizes including the first IEEE MTT-S Outstanding Young Engineer Award, the 2004 Fessenden Medal of the IEEE Canada, the 2009 Thomas W. Eadie Medal of the Royal Society of Canada, the Queen Elizabeth II Diamond Jubilee Medal in 2013, the 2013 FCCP Education Foundation Award of Merit, the 2014 IEEE MTT-S Microwave Application Award, the 2014 Marie-Victorin Prize (Prix du Quebec - the highest distinction of Québec in the natural sciences and engineering), the 2015 Prix d'Excellence en Recherche et Innovation of Polytechnique Montréal, and the 2015 IEEE Montreal Section Gold Medal of Achievement.

Zvonimir Šipuš received the Ph.D. degree in electrical engineering from Chalmers University of Technology, Gothenburg, Sweden, in 1997. From 1988 to 1993, he worked at Rudjer Boskovic Institute, Zagreb, Croatia, as a research assistant. In 1994, he joined the Antenna Group at Chalmers University of Technology as a Ph.D. student. In 1997, he joined the Faculty of Electrical Engineering and Computing, University of Zagreb, where he is now a Full Professor (since 2008). From 1999 to 2005, he was also an Adjunct Researcher at Chalmers University of Technology. Since 2006 he is participating as a lecturer in the European School of Antennas. Prof. Šipuš research interests are in the area of analysis and design of electromagnetic structures and in the area of optical communication and sensor systems. Related to the analysis of microwave antennas and antenna arrays prof. Šipuš worked on modeling antenna arrays, especially conformal microstrip and waveguide arrays. He also worked on the modeling periodic electromagnetic structures (frequency selective surfaces, EBG structures, metamaterials, metasurfaces), as well as on the analysis of electromagnetic soft and hard surfaces. His main two contributions are modeling of periodic structures (metasurfaces, soft and hard surfaces, etc.) using approximate boundary conditions and development of a method for deriving Green's functions of general multilayer planar and curved structures. The algorithm was extensively used in last 20 years and it was given to various research groups (without any cost) to be used in scientific research. Prof. Šipuš is the author or co-author of more than 60 scientific papers published in scientific journals, and of more than 200 conference papers. He is also the co-author of several EM softwares for analyzing planar and conformal antennas and scatterers. He was supervisor of 10 Ph.D. students who successfully defended their thesis. Prof. Šipuš received the annual national science award in 2006 for research of conformal antennas and periodic structures.

Andres Alayon Glazunov (SM'11) was born in Havana, Cuba, in 1969. He received the M.Sc. degree in physical engineering from Peter the Great St. Petersburg Polytechnic University (Polytech), Saint Petersburg, Russia, in 1994, the Ph.D. degree in electrical engineering from Lund University, Lund, Sweden, in 2009, and the Docent (Habilitation) degree in antenna systems from the Chalmers University of Technology, Gothenburg, Sweden, in 2017. From 1996 to 2005, he held various research and specialist positions at telecom industry, e.g., Ericsson Research, Telia Research, and TeliaSonera, all in Stockholm, Sweden. From 2001 to 2005, he was the Swedish delegate to the European Cost Action 273 and was active in the Handset Antenna Work Group. From 2009 to 2010, he was a Marie Curie Senior Research Fellow with the Centre for Wireless Network Design, University of Bedfordshire, Luton, U.K. From 2010 to 2014, he held a postdoctoral position with the Electromagnetic Engineering Laboratory, KTH-Royal Institute of Technology, Stockholm. From 2014 to 2018, he was an Assistant Professor with the Chalmers University of Technology. Dr. Glazunov has contributed to and initiated various European Research Projects, e.g., currently, the is3DMIMO, the WAVECOMBE, and the Build-Wise Projects under the auspices of the H2020 European Research and Innovation Program. He has also contributed to the international 3GPP and the ITU standardization bodies. He has been one of the pioneers in establishing over-the-air measurement techniques. Currently, Dr. Glazunov is an Associate Professor with the Department of Electrical Engineering, University of Twente, Enschede, The Netherlands, and also affiliated with the Chalmers University of Technology. He is leading the Radio, Propagation and Antenna Systems Research Group, University of Twente, while at Chalmers, he is leading the over-the-air (OTA) characterization of antenna systems research area. He is currently the Dutch delegate to the IRACON Cost Action. He has authored more than 100 scientific and technical publications. He has co-authored and co-edited the text book LTE-Advanced and Next Generation Wireless Networks Channel Modeling and Propagation (Wiley, 2012). His current research interests include MIMO antenna systems, electromagnetic theory, fundamental limitations on antenna–channel interactions, radio propagation channel measurements, modeling and simulations, and the OTA characterization of antenna systems and wireless devices.

2. CVs of Industrial Speakers

Astrid Algaba-Brazález received her Ph.D from Chalmers University of Technology, Gothenburg, Sweden, in 2015. She has been working as a senior researcher at Ericsson Research, Ericsson AB, Gothenburg, Sweden, since November 2014. Her main research interests include millimeter wave antenna systems, including antenna array design, filters, transitions, and metamaterials. She has been involved in the development of gap waveguide and glide symmetry technology for millimeter and sub-millimeter wave applications.

Martin Johansson (M'93-SM'06) received the M.S. degree in Engineering Physics and the Ph.D. degree in Electromagnetics from Chalmers University of Technology, in 1986 and 1997, respectively. He joined Ericsson Research at Ericsson AB, Gothenburg, Sweden, in 1997 where he now serves as Expert in Antenna Technology. His current research interests include antenna technology for mobile communications, antenna system modeling, and deterministic propagation modeling.

Thomas Emanuelsson born in Sweden, 1958. He received his Master of Science in Electronic Engineering from Chalmers University of Technology in 1984 and is currently holding a position as CTO at Gapwaves AB and is an Adjunct Professor at the Microwave Electronics Laboratory, Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology. Extensive background in mmWave radio communication, Radar phased array systems and MMIC technology.

Zhinong YING is currently a principle engineer of antenna technology in the Access Technology Lab within the Research and Technology, Sony Mobile Communication AB, Lund, Sweden, also as a distinguish engineer within the whole Sony group. He has been in Ericsson, Sony Ericsson as antenna expert in his engineer career since 1995. He also has been a guest professor in the Joint research centre of Royal institute of Technology, Sweden and Zhejiang University, China since 2001. He is a senior member of IEEE. He has many hundreds of publications and patents and also has published 5 book chapters in mobile antenna area.

Nima Jamaly received a PhD degree in Advanced Wireless Communication Systems from Chalmers University of Technology, Sweden, in early 2013. Dr. Jamaly is most known for inventing the first ultra-wideband in-ground MIMO antennas for small-cell applications worldwide. His research area is broad and includes compact multiport antenna design, wideband base station antenna design, radiating cable design, characterisation of multipath environments etc. Dr. Jamaly has several patents which have been licensed to different European companies and has won a number of international awards and grants.

Amir Majidzadeh is recognized as automotive antenna expert and go-to-person regarding questions related to antenna systems and reception performance within broadcasting as well as wireless communications. He received his second M.S. degree in Digital Communication Systems from Chalmers University of Technology in 1999 and has several years of industrial and research experience in developing electronic/telecommunications and automotive products especially

within antenna and RF design. Currently he is holding the position of Technical Expert within Antenna & Reception Performance at Volvo Cars Corporation in Sweden.

Robert Rehammar received a Ph.D. in applied physics from the Applied Physics department at Chalmers University of Technology 2012. Between 2012 and 2015 he was with Bluetest as a research engineer and between 2015 and 2018 with Qamcom Research and Technology as a microwave and antenna specialist. 2018 he re-joined Bluetest, now as CTO. His research interest involve complex electromagnetic structures, measuring antenna performance and testing of wireless terminals. Robert has published more than 10 papers in international journals and conferences. He also has several pending patents in the area of microwave technology.

3. Sponsors

ERICSSON Xxxxx

GAPWAVES Gapwaves originates from research conducted at Chalmers University of Technology and was founded in 2011. Gapwaves vision is to be the leading supplier of active antenna solutions. Gapwaves develops waveguide and antenna products based on the patented waveguide technology. The company's markets are e.g. telecom radio links, automotive radars, surveillance systems, and space observatories

BLUETEST.se Bluetest is the market leader in OTA testing of wireless terminals, with virtually all major vendors using our equipment in design, verification and production. Bluetest has delivered more than 300 chambers and is continuously increasing our product offering, adding new measurements to our capabilities.

ANSYS xxxxx

SIMULIA The electromagnetic simulation software CST Studio Suite is part of the portfolio of SIMULIA, a Dassault Systèmes brand. Powered by the 3DEXPERIENCE® Platform, SIMULIA delivers realistic simulation applications that enable users to reveal the world we live in. SIMULIA partners with the European School of Antennas by supporting the course "*Challenges, Solutions and Developments of Antenna Systems for 5G Communication*" with one student grant.

is3DMIMO Indoor Small-Cell Networks with 3D MIMO Array Antennas (is3DMIMO) is a RISE project providing in total 291 person-months of researcher secondments and high-quality interdisciplinary, intersectoral and international research training and knowledge sharing activities for a new generation of scientific researchers, who will benefit directly from the entrepreneurial and creative environment created by the is3DMIMO consortium, and deliver impact at both European and international levels.

2. Lecture program

Monday 2019-05-20

08:30 – 08:50	Welcome and Course plan information	
08:50 – 10:10	**Industrial perspectives on 5G Antenna Systems I:** 5G system infrastructure and Properties	Dr. Martin N Johansson & Dr. Astrid Algaba Brazalez, Ericsson AB
10:00 – 10:30	Coffee	
10:30 – 12:00	**Industrial perspectives on 5G Antenna Systems II:** Challenges in users and handheld terminals	Zhinong Ying, Principal Engineer on antennas, Sony Mobile AB
12:00 – 13:15	Lunch	
13:15 – 15:00	**Antenna-Channel Interaction**	Assoc. Prof. Andrés Alayón Glazunov, University of Twente
15:00 – 15:30	Coffee	
15:30 – 17:00	Self-study with exercises and discussions	Andrés, UT

Tuesday 2019-05-21

08:30 – 10:00	**Industrial perspectives on 5G Antenna Systems III:** Challenges and requirements for Radio Access and Backhauling links	Thomas Emanuelsson, CTO of Gapwaves AB
10:00 – 10:30	Coffee	
10:30 – 12:00	**Industrial perspectives on 5G Antenna Systems IV:** Challenges in automotive and V2X connectivity	Amir Majidzadeh, Technical Expert , Volvo Cars AB
12:00 – 13:15	Lunch	
13:15 – 15:00	**5G Array Antenna Technologies**	Prof. Jian Yang, Chalmers University of Technology
15:00 – 15:30	Coffee	
15:30 – 17:00	Self-study with exercises and discussions	Jian, Chalmers
18:00 – 21:00	Social activity and dinner	

Wednesday 2019-05-22

08:30 – 10:00	**Industrial perspectives on 5G Antenna Systems V:** Challenges in high speed railways	Dr. Nima Jamaly, Swisscom, Switzerland
10:00 – 10:30	Coffee	
10:30 – 12:00	**Gap waveguide Antennas for 5G mmW I:** Origin of gap-waveguide technology, modeling, numerical tool	Prof. Zivonimir Sipus, University of Zagreb
12:00 – 13:15	Lunch	
13:15 – 15:00	**Gap waveguide Antennas for 5G mmW II:** design principles, losses, packaging and antennas	Assoc. Prof. Ashraf Zaman, Chalmers
15:00 – 15:30	***Coffee Break Lecture: Overview of ANSYS' antenna capabilities***	Ansys
15:30 – 17:00	Self-study with exercises and discussions	Zvonimir and Ashraf

Thursday 2019-05-23

08:30 – 10:00	**Industrial perspectives on 5G Antenna Systems VI:** 5G System OTA Measurements by Reverberation Chambers	Dr. Robert Rehammer, CTO, Bluetest AB
10:00 – 10:30	Coffee	
10:30 – 12:00	**SIW technology for 5G Antenna Systems: hardware and Integration I:** Fundamental of SIW technology	Prof. Ke Wu, Ecole Polytechnique, Montreal, Canada
12:00 – 13:15	Lunch	
13:15 – 15:00	**SIW technology for 5G Antenna Systems: hardware and Integration II:** Application and integration	Prof. Ke Wu, Ecole Polytechnique, Montreal, Canada
15:00 – 15:30	Coffee	
15:30 – 17:00	Self-study with exercises and discussions	Ke, polymtl
18:00 – 21:00	Social activity and dinner	

Friday 2019-05-24

08:30 – 10:00	**Millimeter wave antennas for 5G applications I:** Use cases and specifications	Prof. Ronan Sauleau, University of Rennes 1
10:00 – 10:30	Coffee	
10:30 – 12:00	**Millimeter wave antennas for 5G applications II:** antenna arrays with quasi-optical beam formers and broadband arrays	Prof. Ronan Sauleau, University of Rennes 1
12:00 – 13:15	Lunch	
13:15 – 17:00	**Study Visit and Forum**	
17:00	Course closed and photographing	