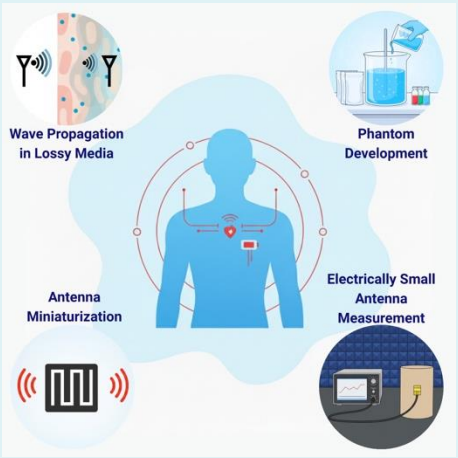
SC08 - Antennas for In-Body Sensing: Design Principles, Measurement Techniques, and Open Challenges



Abstract:

Wireless communication or powering of implanted sensors is difficult due to high signal losses. The implanted antenna is a key component that strongly affects the overall link efficiency. Moreover, implanted antennas can also be directly used as sensors or part of a sensor system in some applications. Designing such antennas involves two major challenges: miniaturization, since the implant's size is much smaller than the wavelength, and operation in a lossy medium, unlike traditional antennas in free space. These factors greatly influence link performance, design strategies, and measurement techniques. This course reviews these challenges, explores efficient design and testing methods, and discusses remaining open issues in implantable antenna technology. Strategies to obtain benchmarks for specific scenarios will be explained. Examples of antennas used for telemetry, sensing and remote powering will illustrate all points made.

Recommended pre-requisites:

The course requires a basic knowledge of antennas as acquired in an undergraduate antenna course. The student should be familiar with basic concepts like antenna gain, polarization, radiation pattern, far field, near field, efficiency and the scattering parameter (S matrix).

Learning Objectives:

After the course, the students will have a basic knowledge of the challenges paused by the design of implantable antennas. They will be able to analyze these challenges for their specific scenarios, and, accordingly, develop proper antenna design strategies to solve their problem.

The students will be able to obtain benchmarks for the achievable radiation characteristics depending on the implantable scenario, which will enable them to assess the quality of different solutions of their specific design problems.

The students will be aware of the specific challenges linked to the measurement of antennas in lossy media, especially for electrically small antennas and will have the tools to meet these challenges.

Finally, through several real-life examples, the students will be exposed to the way of thinking and strategies used in successful implantable antennas design.

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Course Outline:

1. Challenges, physical limitations and benchmarks: The main challenges linked to implantable antennas are discussed: antenna miniaturization, antennas embedded in lossy media, main difference with the free space case. We will then introduce some physical limitations linked to antennas in lossy media, which will lead us to a simple way to obtain link budgets and performance benchmarks prior to the antenna design.

2. Design principles: Design techniques for miniaturization and optimization of the radiation efficiency of the antenna will be presented. We will continue with highlighting how sensing capabilities can be added to the antennas.

3. Measurement techniques. The common pitfalls of small antenna measurements will be highlighted: first, the challenges linked to the measurement of electrically small antennas in general will be discussed, then, the added difficulty caused by the lossy media around the antenna will be presented. Measurement techniques to circumvent those challenges will be shown. Finally, the phantoms requested to perform those measurements will be discussed.

4. Examples and open challenges: The course will end with a short presentation of open challenges and real examples of implantable antennas.

Instructors

Sema Dumanli received the B.Sc. degree in electrical and electronic engineering from METU Ankara, Turkey, in 2006, and the Ph.D. degree from the University of Bristol, Bristol, U.K., in 2010. She conducted research at Toshiba Research Europe, Bristol from 2010 to 2017. She is currently an Associate Professor at Bogazici University, Istanbul. She is the founder and the director of Antennas and Propagation Research Laboratory (BOUNtenna) and Bioelectromagnetics Laboratory (AntennAlive).

Her current research interests include antenna design for implantable and wearable devices, in-body sensor design, biohybrid implants, biodegradable sensors, chipless RF-ID sensors and multi-scale communications.

She is the recipient of Science Academy's Young Scientist Award (BAGEP) 2025, the IEEE APS Donald G. Dudley Jr. Undergraduate Teaching Award 2022, and three times recipient of Bogazici University Faculty of Engineering's Excellence in Teaching Award. She currently serves as the vice chair of IEEE APS YP Committee, Associate Editor of IEEE APS Digital Communications, the chair of IEEE APS/MTT/EMC/ED Turkey Joint Chapter. She also is a board member and the secretary of URSI Turkey and the chair of URSI Turkey Commission K.

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Anja Skrivervik obtained her master's degree in electrical engineering from Ecole Polytechnique Fédérale de Lausanne in 1986, and her PhD from the same institution in 1992, for which she received the Latsis award. After a stay at the University of Rennes as an invited Research Fellow and two years in the industry, she returned to EPFL as an Assistant Professor in 1996, and is now a Professeur Titulaire at this institution. In addition, she was a visiting professor at the University of Lund from 2021 to 2024. Her teaching activities include courses on microwaves and antennas. Her research activities include electrically small antennas, implantable and wearable antennas, multifrequency and ultra wideband antennas, and numerical techniques for electromagnetics. She is author or co-author of more than 250 peer reviewed scientific publications.

She is very active in European collaboration and European projects. She was the chairperson of the Swiss URSI from 2006 to 2012, is the Swiss URSI commission B representative since 2012, is a Board member of the European School on Antennas and is frequently requested to review research programs and centers in Europe. She was member of the board of directors of the European Association on Antennas and Propagation (EurAAP) from 2017 to 2022.

Key Bibliography

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