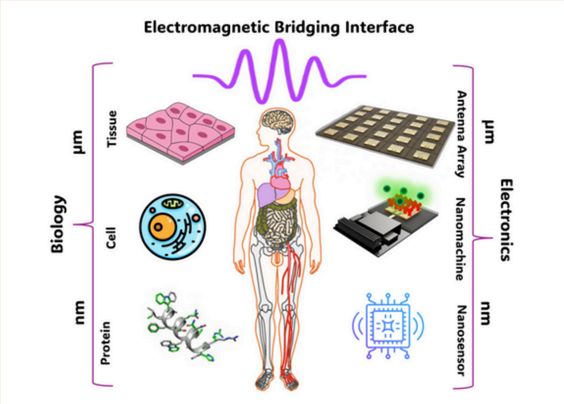
SC04- Electromagnetic Propagation and Antenna Design for Intra-body Nanoscale Sensing and Communication



Abstract

Nanotechnology is enabling the development of cutting-edge sensors and actuators capable of detecting events at the nanoscale with high sensitivity. These advancements are driving the creation of nano-sensing and nano-actuating systems designed for in-vivo applications, paving the way for real-time health monitoring and targeted therapies. To enable communication between these nanodevices, electromagnetic nano-communication has been proposed, leveraging the terahertz and optical frequency bands, including infrared and visible light. Through these frequencies, this course will equip participants with a comprehensive understanding of recent advances in antenna design and electromagnetic propagation theory at the nanoscale, while focusing on intra-body applications.

Recommended prerequisites

Participants should have basic knowledge of antenna design and electromagnetic theory.

Learning objectives

After completing this course, participants will be equipped with a solid understanding of the fundamental principles and recent advancements in nanoscale communication technologies, particularly within the context of intra-body communication.

They will be able to:

1. Explain the basics of nanotechnology and its role in developing nanosensors, nanoactuators, and communication systems for intra-body applications.
2. Understand electromagnetic nano-communication principles, specifically using terahertz and optical frequency bands for enabling communication between nanodevices within biological environments including tissues, cells and proteins.
3. Apply antenna design concepts tailored for the nanoscale, considering the challenges and opportunities posed by the unique properties of the human body as a communication medium.
4. Analyze electromagnetic propagation models within the body, and understand how different frequency bands behave and how to optimize their performance.
5. Evaluate emerging applications of nano-communication in fields such as neurological disorders, targeted drug delivery, cancer detection and health monitoring.
6. Critically assess current research and technological trends, enabling them to contribute to ongoing developments in nano-communication and related fields.
7. Analyze the photothermal effect of electromagnetic nano-communication as well as the safety limits, while making connection with the current standardization.

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Course outline

The course will be delivered through a series of well-structured slides, each focusing on key theoretical and practical aspects of nanoscale communication technologies. These slides will provide a visually engaging and systematic overview, incorporating diagrams, simulations, and case studies. A key feature of the course is the introduction of the TeraNova testbed—the world's first integrated testbed for true terahertz communication—which measures real-world conditions in which terahertz waves propagate. We will explore how the testbed can be tailored and integrated with other instruments to enable nanocale applications including intra-body communication. Our goal is to offer participants a comprehensive learning experience that effectively bridges theory and practice.

1. Introduction to Nanotechnology and Nano-Communication: Overview of nanosensors, nanoactuators, and their potential for in-vivo applications.
2. Terahertz and Optical Communication: In-depth exploration of terahertz and optical frequencies (infrared and visible) for nano-communication, examining their unique properties and challenges in biological environments as well as using the TeraNova platform.
3. Antenna Design for Nanodevices: Key principles for designing antennas at the nanoscale, addressing challenges such as size, efficiency, and material limitations.
4. Electromagnetic Propagation in Biological Media: Examination of how electromagnetic waves propagate through tissues, cells and proteins, with a focus on optimizing communication performance.
5. Applications in Healthcare: Investigation of cutting-edge applications, including health monitoring, targeted drug delivery, and biosensing.

All course materials, including the slides, will be available for download after the session.

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Hadeel Elayan is a postdoctoral fellow at the Ultrabroadband Nanonetworking Laboratory at Northeastern University, Boston, USA. She holds the prestigious NSERC Postdoctoral Fellowship from the Canadian government. Hadeel received her Ph.D. from the Electrical and Computer Engineering Department at the University of Toronto, Canada. Her research focuses on terahertz communication, particularly for nanoscale applications. In 2024, she was recognized as an N2Women Rising Star for her contributions to the communications field.

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