



UNIVERSITÀ DI PISA  
**DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE**  
**Dottorato di Ricerca in Ingegneria dell'Informazione**

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Doctoral Course

**“Battery-free intelligent systems: RFID, wireless power, and smart sensing”**

Prof. Daniele Inserra

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**Short Abstract:** The rapid growth of the Internet of Things (IoT), artificial intelligence, and data-driven technologies is transforming research across a wide range of disciplines, including engineering, healthcare, environmental sciences, transportation, and smart infrastructure. A key challenge for future intelligent systems is how to collect, process, and communicate information in a sustainable and scalable manner, particularly when billions of interconnected devices are expected to operate in diverse and resource-constrained environments.

This course introduces the fundamental concepts and emerging trends of battery-free intelligent systems, with a particular focus on RFID technology, wireless power transfer, energy harvesting, and smart sensing. Starting from the foundations of passive wireless systems, the course explores how sensing, communication, and energy management can be integrated to enable autonomous and sustainable intelligent devices. Real-world applications from different domains, including healthcare, industrial monitoring, smart cities, environmental sensing, and digital twins, will be discussed to highlight the interdisciplinary impact of these technologies.

The course also examines current research challenges and future directions at the intersection of sensing, wireless communications, artificial intelligence, and sustainable system design. Through case studies and interactive discussions, participants will be encouraged to reflect on how the concepts presented can be applied within their own research fields and to identify opportunities for interdisciplinary innovation.

The course is intended for PhD students from different scientific and engineering backgrounds and does not require prior expertise in RFID or wireless communications.

**Course Contents in brief:**

- *RFID and the foundations of intelligent sensing* (the evolution of intelligent systems, RFID fundamentals and passive wireless systems, RFID applications across disciplines, intelligent sensing and future trends)

- *Wireless power transfer and energy harvesting* (the energy problem in modern electronics, energy harvesting fundamentals, battery-free intelligent systems, applications and future perspectives)
- *Smart sensing, AI, and future interdisciplinary systems* (from sensors to intelligent decision systems, intelligent wireless environments, interdisciplinary innovation and research challenges, final interactive session)

**Total # of hours of lecture: 12**

#### **References:**

- [1] K. Finkenzeller, RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication, 3rd Edition, Wiley, 2010
- [2] B. Clerckx, R. Zhang, R. Schober, D. W. K. Ng, D. I. Kim, H. V. Poor, Fundamentals of Wireless Information and Power Transfer: From RF Energy Harvester Models to Signal and System Designs, IEEE Journal on Selected Areas in Communications, 2019
- [3] B. Clerckx, J. Kim, K. W. Choi, D. I. Kim, Foundations of Wireless Information and Power Transfer: Theory, Prototypes, and Experiments, IEEE Communications Surveys & Tutorials, 2022
- [4] A. Al-Fuqaha et al., Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications, IEEE Communications Surveys & Tutorials, 2015
- [5] T. Jiang, Y. Zhang, W. Ma, M. Peng, Y. Peng, M. Feng, and G. Liu, "Backscatter Communication Meets Practical Battery-Free Internet of Things: A Survey and Outlook," IEEE Communications Surveys & Tutorials, 2023

#### **CV of the Teacher**

Daniele Insera received the BSc Degree (2007) and the MSc Degree (2009, *summa cum laude*) in electrical engineering, and the Ph.D. degree in industrial and information engineering (2013), all from the University of Udine, Udine, Italy. He was a member of the Wireless and Power Line Communications Lab at the University of Udine until 2013. From 2013 to 2014 he was with Calzavara S.p.a., Italy, as both responsible of the Non Ionizing Radiation Laboratory measurement activities and a member of the technical staff (antennas and electromagnetic compatibility designer). From 2015 to 2021 he was a postdoctoral research fellow with the University of Electronic Science and Technology of China, Chengdu, China, where now he is an associate professor. His research interests include battery-free intelligent systems, RFID, wireless power transfer and energy harvesting, antenna and antenna array design, wireless communication systems, radio localization and positioning techniques, hardware/software co-design, rapid prototyping methodologies, hardware and RF devices characterization and measurement systems.

He received the Young Scientist Award at Photonics and Electromagnetism Research Symposium (PIERS), 21-25 November 2021, Hangzhou, China. He was selected as IEEE Antennas and Propagation Society Young Professional Ambassador for the year 2022, and he is IEEE Council of RFID Ambassador (for the period 2026-2027). He is associate editor of IEEE Journal of RFID. He has authored more than 80 journal and/or conference papers, one book chapter, and holds 10 patents. He serves as reviewer of many IEEE journals such as IEEE Transactions on Antennas and Propagations and IEEE Antennas and Wireless Propagation Letters, and it has been acknowledged as one of the top 200 best-performing reviewers (out of more than 2200) for the period May 2021-April 2022,

May 2022-April 2023, May 2024-April 2025 by the IEE Transactions on Antennas and Propagation journal.

**Final Exam:** multiple choice questions and a short open question (scheduled for late morning on July 29)

### **Room and Schedule**

Room: *Meeting room Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor(July 27); Meeting room Dipartimento di Ingegneria dell'Informazione, Largo Lazzarino 1, Pisa – 6th Floor(July 28, 29);*

Schedule:

July 27th – 14.00-18.00

July 28th – 9.00-13.00 corso di dottorato (14:30-16:00 seminario)

July 29th – 9.00-15:30