Electromagnetics in Magnetic Resonance Imaging

Course held within the PhD School of Politecnico di Torino

Period: end of January, beginning of February

Language: English

Duration: 24 hours

Teachers: O. Bottauscio, A. Arduino, L. Zilberti, U. Zanovello

Course description

Magnetic Resonance Imaging (MRI) is a largely used clinical imaging modality. Compared to other medical imaging techniques, MRI provides better contrast in images of soft tissues and, being based on non-ionizing radiation, it is intrinsically safer. Imaging generation is done by a proper combination of different electromagnetic fields (static, radiofrequency, pulsed) able to excite the nuclear magnetic spin of hydrogen nuclei and spatially locating them in the human body.

The course introduces the main physical principles of MRI and describes how the electromagnetic fields are designed to allow imaging generation. The course then focuses on two relevant topics of nowadays research in MRI. One is the transition from qualitative to quantitative MRI, providing general concepts and detailing the tomography of electrical properties with MRI. The other is related to the interaction between electromagnetic fields and the human body, governed by the fundamental laws of electromagnetics, and have a strong impact on image quality and safety aspects for patients and medical staff. In this context, the analysis of the extension of MRI diagnostics to patient's carrying implantable medical devices will be deepened.

The course will provide methodological hints, both related to advanced modeling techniques (simulation tools and digital human models) and measuring techniques for electromagnetic field characterisation.

Course topics

- Basic principles of Magnetic Resonance Imaging (MRI)
- Electromagnetic field sources in MRI (concepts, characteristics, design principles and experimental characterization)
- General concepts of quantitative MRI. Theory and development of magnetic resonance-based Electric Properties Tomography (EPT).
- Interaction between electromagnetic fields and human tissues (static, radio-frequency and pulsed fields). General concept of biological/physical effects. Relevant phenomena (tissue heating, nerve stimulation) and methodology for modeling predictions.
- MRI and implanted medical devices: physical effects (thermal and mechanical effects), methods of analysis, safety aspects.

TENTATIVE LESSON SCHEDULE

(*The final schedule will be defined during the Introduction in the first day*)

Day	Date	From	To	Lesson	Teacher
				MODULE 1	
1	28/1/2025	9:30	13:00	**Introduction to the course (1/2 hour)**	Oriano BOTTAUSCIO
				Lesson 1.1: Basic principles of Magnetic Resonance Imaging (3 hours)	Umberto ZANOVELLO
2	29/1/2025	10:00	12:00	**Lesson 1.2: Overview of electromagnetic field sources in MRI (static, RF, GC). Instrumentation and measurement methods (2 hours)**	Umberto ZANOVELLO
				MODULE 2	
3	30/1/2025	10:00	13:00	**Lesson 2.1: Basic principles of quantitative magnetic resonance imaging (1 hour)**	Alessandro ARDUINO
				Lesson 2.2: Methods for the magnetic resonance-based electric properties tomography (2 hours)	Alessandro ARDUINO
4	31/1/2025	10:00	13:00	**Lesson 2.2 (cont'd): Methods for the magnetic resonance-based electric properties tomography (1 hour)**	Alessandro ARDUINO
				Lesson 2.3: Applications of the magnetic resonance-based electric properties tomography (2 hours)	Alessandro ARDUINO
				MODULE 3	
5	4/2/2025	10:00	13:00	**Lesson 3.1: Biological Effects of Electromagnetic Fields & Modeling of the Human Body (3 hours)**	Luca ZILBERTI
6	5/2/2025	10:00	13:00	**Lesson 3.2: Computational dosimetry: methodologies, simulation accuracy and numerical artifacts (3 hours)**	Oriano BOTTAUSCIO
7	6/2/2025	09:00	11:00	**Lesson 3.3: Patient exposure to MRI radiofrequency (RF) fields (2 hours)**	Oriano BOTTAUSCIO
		11:30	13:00	**Lesson 3.4: Gradient fields and peripheral nerve stimulation (1 hour)**	Luca ZILBERTI
				Lesson 3.5: Motion-Induced Fields (1 hour)	Luca ZILBERTI
				MODULE 4	
8	7/2/2025	09:00	10:00	**Lesson 4.1: Forces on implanted metallic objects (vibrations and motion induced) (1 hour)**	Luca ZILBERTI
		10:00	13:00	**Lesson 4.2: Exposure of patients carrying implants: heating related issues (3 hours)**	Oriano BOTTAUSCIO