UNICUSANO
ROME

Code: ING-INF/02 **Credits: 9**
Course: Electromagnetic Field
Main language of instruction: Italian
Other language of instruction: English

Teaching Staff

Head instructor
Prof. Stefano VELLUCCI - stefano.vellucci@unicusano.it

Objectives

The course has as its main objective to provide the basic knowledge of electromagnetism. The fundamental concepts of electrostatics and magnetostatics, typically presented in physics courses, will be revisited and developed to present Maxwell's equations in both integral and differential forms. The theory of electromagnetic waves will then be used to describe the fundamental principles of free-space propagation, guided propagation, and electromagnetic radiation.

Course structure

The course is organized into six subjects. The first subject reviews some fundamental concepts of mathematical analysis and geometry. The second and third subject illustrate the fundamentals of Maxwell's electromagnetic theory and the fundamental principles of free-space propagation. The fourth subject illustrates the fundamental principles of guided propagation. The fifth subject illustrates the fundamental principles of electromagnetic radiation. Finally, the sixth subject is devoted to the introduction to the use of commercial full-wave electromagnetic simulators.

Competencies:

A. Knowledge and understanding:

At the end of the course, the student will have knowledge of electromagnetic wave theory and the fundamental physical principles for the generation, propagation, and reception of electromagnetic waves. In particular, the student will be able to

understand the implications of Maxwell's equations, in both integral and differential forms, in the study of transmission lines, plane wave propagation, guided propagation, and radiation phenomena. Furthermore, through the Etivity activities, students will acquire the ability to formulate electromagnetic problems within the CST Microwave Studio software.

B. Applying knowledge and understanding:

The student will be able to use electromagnetic theory and the related analytical tools to construct simplified models of electromagnetic problems, with particular reference to the context of transmission lines, waveguide propagation, and electromagnetic radiation. They will also be able to use these models to evaluate and quantify the required parameters.

C. Making judgements:

The student will be able to identify the most appropriate models to describe the individual functional blocks of a complex electromagnetic system (e.g., generator, transmission line, radiating element) and apply methods to critically verify the results obtained.

D. Communication skills:

The student will be able to describe and engage in discussions on the physical/mathematical models for analyzing applications based on the propagation of electromagnetic waves, correctly identifying the relevant physical quantities and using appropriate terminology.

E. Learning skills:

At the end of the course, the student will have learned electromagnetic theory and its related analysis techniques, and will be able to distinguish between the lumped-parameter approach (typical of electrical engineering) and the distributed-parameter approach or the one based on the use of electromagnetic fields. This will allow them to continue their engineering studies with greater maturity and provide a foundation for learning the content presented in specialized electromagnetism courses (e.g., antennas and microwaves).

Syllabus

Subject 1 – Review of fundamental mathematic principles

Complex numbers; matrix algebra; vectors; scalar and vector fields; coordinate systems.

Subject 2 – Fundamentals of Maxwell's electromagnetic theory
Fundamental equations of the electromagnetic field; boundary conditions; complex notation and complex vectors; polarization of a vector field: linear, circular, elliptical; fundamental theorems; constitutive relations and electromagnetic properties of materials.

Subject 3 – Plane waves
Homogeneous Helmholtz equation; wave functions; plane waves; general properties of plane waves; uniform non-attenuated plane wave; non-uniform attenuated plane wave perpendicular to the propagation direction; uniform attenuated plane wave; plane wave spectrum; non-monochromatic plane waves; group velocity of a wave packet.

Subject 4 – Transmission-line theory
Introduction to transmission lines; transmission line equations; progressive and stationary waves; line impedance and admittance; characteristic impedance and propagation constant; input impedance; reflection coefficient and standing wave ratio; transmission line matching, quarter-wave transformer, matching problems; Smith chart.

Subject 5 – Electromagnetic radiation
Green's function for free space; electrodynamic potentials; Hertz dipole; introduction to antennas; electrical and radiative characteristics.

Subject 6 – Electromagnetic simulators
Introduction to CST Studio Suite electromagnetic simulation software; basic interface; using the program's help feature; defining a simulation setup; available solvers; material definitions; frequency range, boundary conditions, and symmetry planes definitions; types of electromagnetic excitation; defining field monitors; simulation of a $\lambda/2$ dipole and visualizing its characteristics; simulation of a waveguide and visualizing its characteristics; simulation of a magic-T and its characteristics.

Evaluation system and criteria

The assessments of course is based on the following criteria:
I) Final exam (84 %)
II) Homework (16 %)
The final exam consists of two open theoretical questions. The homework consists of the writing of a technical report containing the results of numerical simulations of relevant structures.

Bibliography and resources

1. *Materials to consult*

- Lecture notes
- Recorded and live lectures

2. *Recommended bibliography*

- L.D. Landau and E. M. Lifshitz, "Electrodynamics of Continuous Media", 2nd Edition, Butterworth and Heinemann.
- J. D. Jackson, “Classical Electrodynamics”, John Wiley & Sons, Inc., 3rd edition.