UNICUSANO ROME

Code: ING-INF/02 **Credits:** 9
Course: Antenna Theory and Design
Main language of instruction: Italian
Other language of instruction: English

Teaching Staff

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

Objectives

The course is designed to provide students with the essential elements for understanding the transmission and reception of electromagnetic fields and for the characterization and design of the most common radiating systems for terrestrial and satellite applications. The course aims to provide both theoretical and practical information on the main types of antennas and antenna alignments, as well as their related design techniques. Particular emphasis is placed on the physical understanding of the phenomena that characterize the radiation and reception of electromagnetic fields.

Course structure

The course is organized into seven subjects. The first subject reviews the fundamental concepts of electromagnetic fields. The second subject describes the physical phenomena behind the transmission and reception of electromagnetic fields in free-space propagation. The third describes the analytical techniques necessary for antenna problem analysis. The fourth and fifth subjects illustrate the main electromagnetic quantities used to characterize radiating systems and the characteristics of the main antenna systems. The sixth subject describes the basic elements for antenna and antenna alignment design. Finally, the seventh subject sescribes the basics of radar theory.

Competencies:

A. Knowledge and understanding:

At the end of the course, the student will be familiar with and able to use the physical quantities used to characterize a generic antenna, both in transmitting and receiving modes. Furthermore, the student will be familiar with the analytical techniques used to analyze various types of antennas, as well as the methodologies for analyzing and designing the most common types of antennas and antenna alignments, their operating principles, characteristics, and their advantages and disadvantages. Finally, the student will understand the propagation modes of the electromagnetic field in free space in relation to the frequency band used, both for terrestrial and satellite applications, and the basics of radar theory.

B. Applying knowledge and understanding:

At the end of the course, the student will be able to design a radio link and a simple radar system, as well as design different types of radiating systems, such as linear antennas, loop antennas, antenna alignments, and aperture antennas based on specific design requirements. The student will also be able to verify the quality of the analytical design and improve it using numerical calculation software for electromagnetic simulation.

C. Making judgements:

At the end of the course, the student will have the ability to choose the most appropriate type of antenna based on the design specifications and environmental characteristics for both terrestrial and satellite communications. Additionally, the student will have developed the critical ability to interpret the results obtained during a numerical exercise and simulation, both in terms of physical consistency and engineering feasibility of the identified solution.

D. Communication skills:

At the end of the course, the student will have developed a correct and clear scientific language that will enable them to express, in an unambiguous and understandable way, the technical knowledge acquired in the field of antenna theory and free-space electromagnetic field propagation theory.

E. Learning skills:

At the end of the course, the student will have developed the ability to apply the knowledge acquired to solve unfamiliar problems related to the transmission and reception of information over an electromagnetic carrier.

Syllabus

Subject 1 – Introduction
Fundamentals of electromagnetic theory. Maxwell equations. Constitutive relationships of materials.

Subject 2 – Green's function and elementary radiators
Electrodynamic Potentials. Green's Function: Green's function for free space. Radiation from an infinitesimal electric dipole and radiation from an infinitesimal magnetic dipole.

Subject 3 - Antenna characteristics
Introduction. Antenna characteristics: electrical characteristics and radiative characteristics.

Subject 4 – Receiving antennas
Receiving antennas: reciprocity theorem, effective area and length, noise in communication systems, and noise temperature of an antenna.

Subject 5 –Field regions and Friis formula
Near field region, Fresnel field region, and Fraunhofer field region. Friis formula.

Subject 6 – Wire antennas
Dipole antennas: short non-infinitesimal dipole, half-wave dipole, balun. Wire antennas placed near infinitely extended ideal conductors: image theory and effects of a real ground plane. Other types of wire antennas.

Subject 7 – Loop antennas
Loop antennas: small current loop, circular loop with uniform current, circular loop with non-uniform current. Polygonal loop antennas. Loop antennas with ferrites.

Subject 8 – Antenna array
Alignment factor. Uniform one-dimensional and two-dimensional arrays: broadside and endfire alignments and Hansen-Woodyard condition. Non-uniform arrays: binomial and Schelkunoff polynomial array, Chebyshev array. Parasitic array: Yagi-Uda alignments and log-periodic alignments.

Subject 9 – Aperture antennas
Radiation from a planar aperture: Fourier transform method. Radiation from rectangular and circular apertures: uniform field with linear phase variation and

tapered field. Equivalence principles: Love's equivalent field principle. Radiation from rectangular and circular waveguides. Rectangular, circular, and pyramidal horn antennas. Corrugated horn antennas. Radiation from slits and slit alignments.

Subject 10 – Parabolic reflectors
Geometrical optics. Microwave lenses. Parabolic reflector antennas: power losses in parabolic reflector antennas, cross polarization, and low cross polarization feeds. Physical optics. Offset reflectors and dual-reflector systems.

Subject 11 – Microstrip antennas
Introduction. Characteristics of microstrip antennas: radiation mechanism and main characteristics, surface waves, excitation techniques. Rectangular patch antennas: LdT model and cavity model.

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 three parts: two numerical exercises and one open question. 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*

- C. Balanis, "Antenna theory, analysis and design", Wiley-Interscience.
- Robert E. Collin, "Antennas and Radiowave Propagation", Mcgraw-Hill College.