EEE6223 ANTENNAS, PROPAGATION & SATELLITE SYSTEMS

Credits: 15

Course Description including Aims

1. To bridge the gap between fundamental electromagnetic theory and its practical implementation in basic antenna analysis.
2. To analyse the performance of canonical wire, array, aperture and printed antennas with regard to input impedance, directivity and radiation pattern.
3. To provide an introduction to macroscopic HF and VHF propagation phenomena.
4. To understand the fundamental principles underlying the design of satellite communication systems.

Outline Syllabus

Review of electromagnetic theory for antenna analysis. Metrics used for quantifying antenna performance: radiation pattern, gain, input impedance. Half wave, full wave dipole antennas, monopole antennas. Image theory. Antenna arrays: isotropic source, two-element array, uniform linear array. Polarization: linear, elliptical, axial ratio. Aperture theory: Fourier transformation between aperture field and radiation pattern, rectangular and circular aperture, effective aperture. Microstrip antennas. Antenna radiation hazards: SAR and body interactions with antenna near fields. Propagation in a plasma: critical frequency, refractive index. Ionospheric propagation of HF radio waves: ionospheric layers, ionospheric refraction, multi-hop skip distances, MUF, ionosonde. Tropospheric propagation of VHF/UHF waves: refraction and ducting. Outline of numerical antenna analysis techniques: moment and finite difference methods.

Noise in communication systems. Basic satellite principles. Satellite orbits. Satellite communications systems. Earth stations – types and performance. Satellite transponders – amplifiers, redundancy, tramsmitters, frequency translation. Multiple access systems.

Time Allocation

36 lectures plus 12 hours of additional support material.

Recommended Previous Courses

Background knowledge equivalent to EEE345 and MAS381

Assessment

Written 3 hour examination, answer 4/6 questions.

Recommended Books

Balanis, C.A.	*Antenna Theory*	Harper and Row
Collin, R.E.	*Antennas and Radio Wave Propagation*	McGraw-Hill/ISE
Jull, E.V.	*Aperture Antennas and Diffraction Theory*	IEE Peter Perigrinus

Silver, S.	*Microwave Antenna Theory and Design*	McGraw-Hill
Ramo, S., Whinnery, J.R., Van Duzer, T.	*Fields and Waves in Communication Electronics*	John Wiley & Sons
Benoit, H.	*Satellite Television*	Arnold
Gomez, J.M.	*Satellite Broadcast Systems Engineering*	Artech House

Objectives

By the end of the unit a successful student will be able to

1. Demonstrate understanding of the basic principles behind the operation of the various types of antenna employed in practice.
2. Analyse the performance of antennas in well-defined situations.
3. Display awareness of propagation phenomena and their impact on communication systems.
4. Assess the suitability of antennas for specific deployment scenarios such as in terrestrial cellular networks or satellite communications.

Detailed Syllabus

1. A historical perspective on antennas and propagation, Hertz, Maxwell, Marconi, Appleton.
2. Review of Maxwell's equations and solution methods in terms of the electric field and mixed potential integral equations (EF/MPIE).
3. Vector and scalar potentials, Green's functions, source and field co-ordinates, propagation of currents and charges to fields.
4. The infinitesimal electric dipole element as a basic solution of the EFIE, near zone and far zone fields, spherical co-ordinate system, radiation pattern.
5. Radiation patterns of wire dipole antennas, current distributions and feed points.
6. Radiation resistance, input impedance, matching, and directivity of (wire) antennas.
7. Antenna efficiency. Gain, loss mechanisms, electrically small antennas, tuning and bandwidth.
8. Dipole / loop antenna duality, square loop antennas.
9. Images of horizontal and vertical current elements over a perfect groundplane. The counterpoised monopole antenna compared to its dipole counterpart.
10. Array theory. Array factor, directivity, main lobe / side lobe levels and position, phased arrays.
11. Polarization. Linear, elliptical, axial ratio. Circularly polarised antennas.
12. Antenna radiation safety issues. Specific absorption rate, ICNIRP maximum exposure levels. Human body resonances.
13. Aperture theory. Fourier transformation between aperture field and far field.
14. Rectangular and circular apertures, radiation pattern and directivity. Maximum effective aperture.
15. Microstrip and printed antennas and feed networks. Effect of dielectric substrates.
16. Wave propagation in plasmas. Critical frequency and refractive index.
17. Ionospheric propagation from ~1 -> 50MHz. Sunspot cycle. D, E, F, layers and progressive refraction.
18. Ionosonde, ionospheric layer critical frequency, incidence angle and skip distance, maximum usable frequency.
19. Tropospheric propagation from ~50 -> 1000MHz. Standard linear troposphere.
20. Tropospheric refraction of radio waves, spherical earth model.

21. Anomalous propagation mechanisms. Sporadic E, tropospheric ducting, solar storms.
22. Review of numerical methods in antenna analysis. Finite element, moment and finite difference methods, focussing on their spheres of application rather than detailed theory.
23. Future antenna technologies, such as gas and semiconductor plasma antennas.
24. The basic free-space communication system.
25. Antenna characteristics, free-space path loss, Friis formula.
26. History of satellite systems and applications.
27. Noise temperature, noise figure, overall noise figure of a receiving system. External and internal noise sources.
28. Satellite orbits, Earth coverage area.
29. Satellite environment.
30. Satellite transponder.
31. Earth stations – fixed and mobile performance.
32. Multiple access systems – FDMA, TDMA, CDMA.
33. Case study of ASTRA system.
34. Future technologies and deployments.
35. Allowed for over flow.
36. Q&A review session before exam.

UK-SPEC/IET Learning Outcomes

Outcome Code	Supporting Statement
SM1p	General underpinning electromagnetic theory given within an historical context relevant to the evolution of understanding of antenna radiation and propagation mechanisms. The history and evolution of satellite and optical communications are discussed. The systems and components making up those systems are studied in detail to appreciate their context. Future technologies and developments are presented. Assessed in exam
SM2p / SM2m	Mathematical techniques such as vector identities and integration methods relevant to obtaining field patterns from source distributions explained. The mathematical principles of satellite antennas, signal propagation in free space and the relevance and sources of noise are given. System link equations are presented. These are backed up by tutorial sheets and many worked examples throughout the course. Assessed in exam. Mathematical techniques relevant to solving antenna problems explained, such as integration methods. Assessed in exam
SM3p	Appreciation of software engineering with regard to computational solutions for antenna problems encouraged. The principles of communication systems and networks are pulled into the course and relate to components and data communications aspects of satellite communications. Mechanical engineering problems particularly relating to large satellite systems are discussed. Assessed in exam
SM3m / SM3fl	These scientific principles are then focussed towards practical antenna analysis and design in an engineering context relevant to RF communications systems with reference to the related discipline of (plasma) physics. The principles of propagation and the principles of operation of the devices and components used in these systems is presented together with their shortcomings. The relationship of these long distance high capacity systems is put into the context of global and local communication networks. Assessed in exam

SM4m	Emergent antenna technologies such as plasma antennas described. The development of satellite is presented and their future progression in terms of capacity and new device technologies are all discussed. Assessed in exam
SM6m	These scientific principles are then focussed towards practical antenna analysis and design in an engineering context relevant to RF communications systems with reference to the related discipline of (plasma) physics. The principles of propagation and the principles of operation of the devices and components used in these systems is presented together with their shortcomings. The relationship of these long distance high capacity systems is put into the context of global and local communication networks. Assessed in exam
SM2fl	Emergent antenna technologies such as plasma antennas described. The development of satellite is presented and their future progression in terms of capacity and new device technologies are all discussed. Assessed in exam
EA1p	Engineering issues with regard to practical antenna design presented, for instance in the design of electrically small antennas with low efficiencies. Satellite communication systems are analysed and related to the devices and components and their limitations. Assessed in exam
EA2p / EA2m	Analytical analysis of canonical dipole antenna presented to obtain radiation pattern, directivity and input impedance, leading to systems of these dipoles to form arrays. System link equations are developed in the course and used to analyse performance. Analytical analysis of basic antenna components used to describe the performance of antenna systems such as arrays. Assessed in exam.
EA3p	Numerical evaluation of radiation pattern, gain and input impedance explained. Mathematical models are presented for system performance that are easily programmed. Assessed in exam
EA3m	Mathematical models relevant to computational antenna analysis explained. Mathematical models for systems performance are used in the lectures and tutorials. Noise is a particular issue. Limitations from noise and component performance are identifiable from this modelling. Assessed in exam
EA5m	Use of Maxwell's equations to analyse plasma antennas. The shortcomings of both components and their use in systems is discussed and analysed. This is then taken further by discussing how performance can be improved. For example how can we make and launch large antennas into space to increase system capacity. Assessed in exam
EA2fl	Use of Maxwells equations to analyse plasma antennas. The shortcomings of both components and their use in systems is discussed and analysed. This is then taken further by discussing how performance can be improved. For example how can we make and launch large antennas into space to increase system capacity. Assessed in exam
D2m	Risk assessment discussed in light of satellite launch and deployment in orbit. Energy usage emphasised. Assessed in exam
D5p / D5m	Cost is a defining design issue in communications systems and this is emphasised throughout. Assessed in exam
ET2m / ET2fl	Commercial and economic issues are discussed in the course and green aspects emphasised. Assessed in exam
ET5m / ET5fl	ICNIRP / HPA safety guidelines regarding exposure to antenna radiation covered. Assessed in exam
ET2fl	Commercial and economic issues are discussed in the course and green aspects emphasised. Assessed in exam

EP1p / EP1m	The engineering of current systems is applied to future technology development such as mobile systems and deployable antennas. Assessed in exam
EP2p / EP2m	Materials relevant to antenna interactions with the environment described, such as plasmas, dielectrics, biological tissue. Radiation pattern measurements also mentioned. Engineering materials used in satellite components presented throughout the course. Assessed in exam
EP9m	Possible future developments in antenna design discussed. Current engineering of components and systems forms large part of course. The limitations lead to discussions of future technologies and applications and how to move technology forward. Assessed in exam.
EP10m	Commercial constraints are discussed and their impact on the choice of long range communication system to be adopted. Industrial constraints are discussed with reference to the engineering solutions available and future technology developments. Assessed in exam
EP1fl	Materials relevant to antenna interactions with the environment described, such as plasmas, dielectrics, biological tissue. Radiation pattern measurements also mentioned. Materials used in satellite components presented. Assessed in exam
EP2fl	Possible future developments in antenna design discussed. Current engineering of components and systems forms large part of course. The limitations lead to discussions of future technologies and applications and how to move technology forward. Assessed in exam
EP3fl	Commercial constraints are discussed and their impact on the choice of long range communication system to be adopted. Industrial constraints are discussed with reference to the engineering solutions available and future technology developments. Assessed in exam