Engineering Tripos Part IB, 2P5: Electromagnetic Fields and Waves, 2018-19

Lecturer

Prof A Flewitt [1]

Timing and Structure

Weeks 6-8 Lent term. 6 lectures, 2 lectures/week

Aims

The aims of the course are to:

- To understand what a transmission line is, and how by analysing an equivalent circuit for a short length of the line allows us to understand wave propagaion along the line.
- To understand the Maxwell Equations of Electric and Magnetic Fields which allow us to understand the propagation of electromagnetic waves through free space and how such waves interact with other conducting and insulating materials.
- To appreciate how we can engineer the propagation of waves in free space and along transmission lines with a focus on communications applications.

Objectives

As specific objectives, by the end of the course students should be able to:

- To be able to create and solve a wave equation for an ideal transmission line from an equivalent circuit and appreciate how this differs in a lossy transmission line.
- To understand the characteristic impedance of a transmission line, and be able to use this to solve problems involving reflection and transmission of waves along transmission lines.
- To understand the physical significance of the Maxwell Equations and how the differential (vector calculus) form can be produced from the integral form.
- To use the Maxwell Equations to produce a wave equation for the free-space propagation of electromagnetic waves and deduce their behaviour (e.g. direction of propagation relative to the E and H field, the Poynting vector).
- To understand the basic operation of antennas and their figures of merit.
- To use the intrinsic impedance to understand how electromagnetic waves are reflected and transmitted at interfaces with dielectrics
- To understand how electromagnetic waves interact with conductors.

Content

Transmission Lines

- What is a transmission line?
- Ideal transmission line equivalent circuit
- The Telegrapher's Equations
- The wave equation solution to the Telegrapher's Equations
- Expressions for current and voltage waves
- Description of how waves propagate along transmission lines.
- Importance of the wavelength in considering whether wave effects on a line need to be considered

- The 'lossy' transmission line equivalent circuit and how this affects wave propagation
- Characteristic impedance
- Reflections from a load impedance
- Input impedance of a terminated line
- Ringing

The Maxwell Equations in Integral and Differential (Vector Calculus) Form

- The Gauss Law of Electric Fields
- The Gauss Law of Magnetic Fields
- The Faraday Law of Magnetic Fields
- The Ampère-Maxwell Law

Electromagnetic Waves in Dielectrics

- Derivation of wave equation for electric and magnetic fields from the Maxwell Equations
- Expressions for the electric and magnetic fields in plane electromagnetic waves
- Intrinsic impedance
- The power in an electromagnetic wave and the Poynting Vector

Antennas

- What is an antenna and a description of how they work
- Figures of merit for antennas including the Antenna Gain, Radiation Resistance and Effective Area

Electromagnetic Waves at Interfaces

- Boundary conditions: the conservation of E, D, H and B at interfaces
- Polarised plane electromagnetic waves
- Reflection and refraction of plane waves
- Polarisation by reflection and the Brewster Angle
- Anti-reflection coatings

Electromagnetic Waves in Conducting Media

- Derivation of wave equation for electric and magnetic fields from the Maxwell Equations
- Expressions for the electric and magnetic fields in plane electromagnetic waves
- The Skin Effect
- Intrinsic impedance of a conducting medium
- Waves at conducting interfaces

Booklists

Please see the Booklist for Part IB Courses [2] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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