The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6035 HIGH SPEED CIRCUIT DESIGN

Credits: 10

Course Description including Aims

The course deals with design, fabrication and measurement in the context of circuits that operate in the 10s of MHz to 10 GHz frequency range - a range that encompasses high speed digital systems, most communications and radar systems and some instrumentation systems. At these frequencies transmission line concepts are used extensively, passive components like resistors and capacitors deviate from ideal behaviour due to parasitic elements, "S" parameters are used as a black box modelling tool for many active and passive devices, fabrication and layout issues are crucial and specialised measuring instruments are used.

This unit aims to introduce students to the special methods and ideas used to design, fabricate and test high frequency analogue, mixed signal or digital circuits (where pulse edges may be very fast even if the clock frequency is modest). More specifically, the aims fall into five main categories:

- To introduce the concept of a distributed system and how to handle and model it using high frequency transmission line theory. This will involve vital concepts such as reflection coefficient, insertion loss, transferred impedances and impedance matching.
- To show how parasitic elements dominate the behaviour of devices at high frequency and to introduce the idea of "S" parameters, used by manufacturers to specify component behaviour, and how to use them in the design process.
- To introduce an awareness of the various RF devices available and their relative merits, and of the impact that circuit layout and substrate dielectric quality have on circuit performance including the idea of skin depth and its significance for conduction losses in interconnects.
- To discuss importance of linearity and the related issues of intermodulation in RF power devices and the way these parameters are specified and also to discuss noise and noise figure and ways of minimising both.

To introduce the specialist measurement equipment - network analysers, spectrum analysers, signal sources, power meters etc - commonly used in a high frequency design/test environment and outline the principles behind their operation.

Outline Syllabus

Introduction: Definition of 'high-speed' (>50MHz?), why traditional analysis and design techniques no longer apply. **High frequency transmission lines:** basic TL theory, Smith chart, impedance matching, (stubs, etc.) pulses on transmission lines, reflections, matching and power transfer, open, short and matched terminations, standing waves, types and characteristics of 'modern' lines, microstrip, coax, etc. basic RF design techniques, impedance matching techniques, e.g. quarter wave transformer, RF chokes, etc. design implications for high speed digital systems, cct board layout. **Device characteristics at high frequency:** types of devices used: op-amps, transistors, hybrids, passive lumped/distributed elements, high frequency device specifications, self-resonance, device parasitics, S-parameters, return loss, insertion loss Noise figure, small signal characteristics, op-amps. **High power amplifies:** linearity,

gain, efficiency, IMP issues, current high frequency technology and design techniques, preferred devices. **Circuit board lay-out:** techniques, types of circuit board, material characteristics, ground plane techniques, skin depth, Ag/Au plating techniques, EMC: shielding, interline coupling, suppression of unwanted modes. **Measurements:** S parameters, VNA, phase and amplitude, TDR, fault location, Spectrum analyser (bandwidth, IMP) Data rates, eye-diagrams.

Time Allocation

24 lectures plus 12 hours of additional support material

Recommended Previous Courses

Background knowledge equivalent to EEE220 “Electric and Magnetic Fields”.

Assessment

2 hour examination.

Recommended Books

Reinhold Ludwig, Pavel Bretchko	*RF Circuit Design; Theory and Applications*	Prentice-Hall
Vincent F. Fusco	*Microwave Circuits; Analysis and Design*	Prentice-Hall
Jeremy Everard	*Fundamentals of RF Circuit Design*	Wiley

Objectives

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

1. Display a working knowledge of basic high frequency transmission line behaviour by solving quantitative problems based on reflection coefficient and insertion loss.
2. Use a Smith chart to design impedance matching stubs.
3. Recognise the different forms in which a transmission line may appear.
4. Describe the various forms of active device and subsystems available for RF designs and their relative advantages and disadvantages.
5. Demonstrate knowledge of the high frequency equivalent circuit of both passive and active devices and the ability to use passive device equivalent circuits to predict performance.
6. Use "S" parameters to design simple RF circuits.
7. Use noise specifications to make quantitative estimates of the noise performance of simple RF systems.
8. Understand the terms used to specify linearity in power amplifiers.