The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6239 RADIO TRANSCEIVER SYSTEM & CIRCUIT DESIGN

Credits: 15

Course Description including Aims

This 15 credit module aims to provide students with a range of theoretical skills and relevant associated lab-based practical skills appropriate for designing contemporary RF systems and circuits. Taught time will be split between theory delivered in lecture format and associated supporting practical lab exercises (working on hardware and CAD tools).

The overall aim of the course is to convey how hardware-based subsystem are used by Software Defined Radio (SDR) systems and how they are actually designed, created and tested. Therefore, the course will have a strong RF hardware design bias and will suit students interested in lab based research and development or product development. A course blank PCB will be used by the students during their lab design exercises, which will represent an elementary product development activity.

The module complements EEE6220 and re-enforces the importance of key RF design concepts such as S-parameters, linearity and noise figure.

By the end of the course, the students will have been introduced to:-

1) Key system and circuit blocks associated with transmission and reception of RF signals at microwave frequencies
2) RF system and circuit figures-of-merit, including: Noise Figure, 2nd and 3rd order Intercept Points, 1dB Compression Point and Error Vector Magnitude. The students will thus understand the impact of such parameters on real-world RF system operation
3) Considerations in partitioning between RF analogue / digital hardware / DSP algorithm domains when implementing radio functionality. This will lead to an appreciation of hybrid Software Defined Radio (SDR) transceiver philosophy.
4) Lab design, prototyping and characterisation of RF circuits
5) Usage of high performance contemporary RF circuit simulator (Keysight ADS) and elementary SDR system simulators (Matlab).

There is a well-known shortage of RF Design Engineers in industry and this course is intended to help prepare and excite interested students for such a career.

Outline Syllabus

INTRODUCTION: The diversity and importance of radio applications. Course overview. **RADIO SUBSYSTEMS:** Transmitter, Receiver and Transceiver architectures and subsystem blocks. Noise. RF System performance metrics and cascade analysis. Single-chip transceiver case-study.

RF CIRCUITS AND ANALOGUE SYSTEMS: Circuits for LNAs, Circuits for RF mixers, Filters for RF and IF, Circuits for frequency generation: VCOs & PLLs and DDS, multiplication. Circuits for modulation & demodulation, RF Power Amplifiers. MMIC design.

SOFTWARE DEFINED RADIO (SDR): Software Defined Radio architectures. A-to-D and D-to-A data converters in RF systems. Digital down conversion, Subsampling, FIR filters, modulation and demodulation. Example SDR using AD8348 receiver combined with Red Pitaya / RTLSDR and Matlab/Python.

Time Allocation

The course delivery consists of 36 formally taught hours, distributed as:-

- 18 lectures in weeks 1 to 18,
- 18 hours of RF design & CAD laboratories in weeks 1 to 18 (expected to be 3 hour sessions)

Additionally, there are 12 hours of guided independent study, based on 6 important background topics.

Recommended Previous Courses

Second year modules covering transistor level circuit design, signal processing and communications or a bachelors degree in a relevant discipline.

Assessment

Paper examination of 3 out of 5 questions (55%), 2 hours.

Written course work, relating to aspects of a receiver design (30%).

Participation in Lab Exercises for design, prototyping and measurement (15%).

Recommended Books

Earl McCune	Practical Digital Wireless Signals	Cambridge University Press
Steve Winder	Filter Design	Newnes
Y. Huang & K. Boyle	Antennas – From Theory to Practice	Wiley
Dean Banerjee	PLL Performance – Simulation and Design	Dog Ear Publishing
William F. Egan	Frequency Synthesis by Phase Lock	Wiley
Steve C. Cripps	RF Power Amplifiers for Wireless Communications	Artech House
Stephen A. Maas	The RF and Microwave Circuit Design Cookbook	Artech House
Stephen A. Maas	Practical Microwave Circuits	Artech House
Jack R. Smith	Modern Communication Circuits	Mc Graw Hill
Guillermo Gonzalez	Microwave Transistor Amplifiers – Analysis and Design	Prentice Hall
Fugin Xiong	Digital Modulation Techniques	Artech House
P.M. Grant, C.F.N. Cowan, B. Mulgrew, J.H. Dripps	Analogue and Digital Signal Processing and Coding	Chartwell-Bratt
C. Richard Johnson, William A. Sethares, Andrew G. Klein	Software Receiver Design	Cambridge University Press
William F. Egan	Practical RF System Design	Wiley Interscience
Steve Marsh	Practical MMIC Design	Artech House
Jeffrey H. Reed	Software Radio – A Modern Approach to Radio Engineering	Prentice Hall PTR
Guillermo Gonzalez	Foundations of Oscillator Circuit Design	Artech House
Randall W. Rhea	Oscillator Design and Computer Simulation	Noble Publishing

Objectives

By the end of this module, a successful candidate will be able to:

1. Calculate and use radio system performance metrics (NF, IIP2, IIP3, phase noise, P1dB, data rate, SNR, etc) required to meet use-case specifications, for arbitrary product design scenarios and architectures.
2. Design, prototype and analyse a range of simple RF circuits (amplifiers, mixers, filters, oscillators) and be able to characterise them in the lab.
3. Design and characterise an elementary SDR system
4. Describe and quantify the benefits and disadvantaged of SDR as a radio architecture for arbitrary applications.
5. Demonstrate combined theoretical and practical skills in solving RF Engineering design problems.
6. Apply standard concepts and techniques, such as S parameters and Smith Charts, in the design of RF circuits constituting a hybrid SDR.
7. Demonstrate a working knowledge of lab RF measurement practices.