Module Name: Communications Systems Modelling

Module Acronym: CSM

Module Manager: Prof Kai-Kit Wong

Course Summary:

The complexity of communication and signal processing systems has grown considerably during the past decades. At the same time the emergence of a variety of new technologies such as fast and inexpensive hardware for DSP, fibre optics, integrated optical devices and microwave ICs etc has had significant impact on the implementation of communication systems. Computer-aided techniques are therefore vital for engineers to evaluate performance and to optimise designs in a timely, cost-effective and effort-free manner. The purpose of this course is to gain in-depth understanding of the theories, techniques and tools to model, analyse and simulate today’s communications systems and networks. Consideration is given to both the Physical Layer (link-level) and the Network Layer (network-level) and the module looks at the theory of modelling and practical applications using standard simulation packages. This module equips the students to understand and apply analytic and simulation techniques appropriate for the representation, analysis and performance evaluation of communications systems and networks. Also, the course uses MATLAB simulation tools as an example to develop the analytical and simulation skills for performance evaluation.

Intended Learning Outcomes (ILOs)

On completion of this course, students should be able to:

- Become familiar with the various performance evaluation methods;
- Understand the hierarchical modeling approach for communications networks;
- Understand the use of conditional experiments for simulations;
- Understand the error sources in simulations;
- Understand signals and systems in the time and frequency domains;
- Use Fourier Series and Transforms and convolution to analyse signals and systems;
- Use Hilbert Transform to obtain the complex envelope of signals;
- Design systems with proper sampling rate;
- Use DFT and FFT for fast computation of signals in the frequency domain;
- Design analogue filters using Butterworth and Chebyshev low-pass filters;
- Use frequency transformations to obtain different kinds of filter responses;
- Use impulse invariance methods, matched-Z transform and bilinear transformation to design a digital filter from a continuous time analogue filter;
- Design a linear-phase digital FIR filter from an IIR filter;
Introduction and the Need of CSM via Simulation

The importance of CSM is described and the challenges of performance evaluation of communications systems are discussed. The focus is on the methods for performance evaluation and the simulation approaches. The hierarchical model for communications networks is also introduced and a set of computer software technologies is reviewed.

Basics of Simulation and Modelling Methodology

Problem solving techniques using simulation are introduced and the relevant modelling concepts are discussed. Error sources in simulation and some practical issues are also described.

Representation of Signals and Systems in Simulation

The analytical tools are reviewed to understand and characterise signals and systems that are important for simulation.
MSc Communications Programmes

- Continuous and Discrete-Time Signals
- Signals in the Time and Frequency Domains
- Fourier Series and Transforms
- Convolution
- Probability and Stochastic Processes
- Discrete and Fast Fourier Transform (DFT/FFT)
- Hilbert Transform and the Complex Envelope
- Sampling, Signal Design and Analysis

Modelling and Simulation of LTI Systems

Modelling and simulation of linear systems are discussed in detail.

- Analogue Filter Design using Butterworth and Chebyshev filters
- Conversion Method from Analogue to Digital Filters (Impulse Invariant method, Matched-Z transform and Bilinear Transformation)
- Frequency Transformations for Filter Design
- Approximate Continuous Time Structures in Discrete Time for Simulation
- Linear-Phase FIR Filter Design
- Windowing Effects and Optimisation
- Simulation of Filtering with IIR Filters
- Simulation of Filtering with FIR Filters
- Time-Varying Linear Systems in the Time and Frequency Domains

Modelling and Simulation of Nonlinear Systems

Concepts used to model and analyse nonlinear systems are introduced.

- Bandwidth Estimation for Nonlinear Systems
- Memoryless Baseband Nonlinearities
- Power Series Analysis
- Memoryless Bandpass Nonlinearities
- Nonlinearities with Memory
- Volterra Series Modelling

Simulation and Generation of Random Numbers

Here we describe the techniques to generate independent and correlated random sequences for simulation of noises and random communications sequences.

- Principle of Monte Carlo Simulation
- Random Number Generation
- Generation of Uniform Random Numbers
- Generating Random Numbers from a PDF
- Generating Gaussian Random Variables
- Generating Independent Random Sequences
- Generating Correlated Random Sequences

Case Study: OFDM Wireless Networks
MSc Communications Programmes

- Modelling for Wireless Channels
- Multi-ray Frequency Selective Fading Channels
- OFDM Systems
- SER and BER Simulations

**Network Modelling and Queueing Theory**

- Stochastic Processes (e.g., Poisson Process)
- Markov Chains
- Little’s Theorem
- Birth-Death Process
- M/M/1 Queue
- Demonstration of NS-2 Simulation

**Assessment:**

50% will be come from a two-hour unseen written examination held under UCL MSc examination regulations at UCL while the remaining 50% will be obtained from a lab report assignment.

**Tutorials/Workshops:**

- A 2-hour tutorial will be held following the teaching of the course.
- There will also be two full-day laboratory work (12 hours in total) for working on a few case studies of simulating communications networks.