EI2423 Principles of Wireless Propagation Channel Modeling 7.5 credits

Grundläggande kanalmodellering för trådlös kommunikation

This is a translation of the Swedish, legally binding, course syllabus.

If the course is discontinued, students may request to be examined during the following two academic years

Establishment

Course syllabus for EI2423 valid from Autumn 2011

Grading scale

A, B, C, D, E, FX, F

Education cycle

Second cycle

Main field of study

Electrical Engineering

Specific prerequisites

- Linear algebra
- Complex analysis
- Vector calculus

- Probability theory
- Basic electromagnetic field theory

Language of instruction

The language of instruction is specified in the course offering information in the course catalogue.

Intended learning outcomes

After the completion of the course the student shall

- become familiar with the fundamental physical laws as well as empirical relationships governing wireless propagation channels and be able of applying them to model a given practical wireless propagation scenario,
- acquire a physical and mathematical understanding of the basic properties of multipath wireless channels in terms of their temporal, spatial and spectral properties and be able of applying them to the analyzing and modeling of realistic propagation channels,
- understand the antenna-channel interaction principles and be able of applying them to the optimization of the performance of a wireless system over multipath channels according to given criteria, e.g., Multiple-Input Multiple-Output (MIMO) link capacity or diversity gain maximization,
- be able to find and use relevant technical literature to solve problems requiring wireless channel modeling.

Course contents

The course covers topics within multiple areas of knowledge such as electromagnetic wave propagation, antenna theory, digital radio communication, stochastic signal processing and probability theory.
The main topics of the course are given below in non-chronological order:

- **Fundamental Electromagnetic Wave Propagation Concepts** - The wave equation, plane, cylindrical and spherical wave solutions, wave polarization, free space propagation, reflection, transmission, refraction, diffraction, scattering, waveguiding and superposition principle
- **Fundamental Antenna Concepts** - Far-field, near-field, transmit antenna mode, receive antenna mode, antenna reciprocity, antenna radiation pattern, antenna gain, directivity, total radiated power, antenna array, antenna coupling, the dipole antenna
- **Fundamental Multipath Channel Concepts** - Small-scale fading, large-scale fading, pathloss, double-directional representation, angle-of-arrival, angle-of-departure, frequency selectivity, delay dispersion, spatial selectivity, angular dispersion, coherence bandwidth, coherence length, linear time-variant channel, linear time-invariant channel, cross-polarization ratio, channel reciprocity, uncertainty relationships
- **Multidimensional System and Correlation Functions** - Channel transfer function, channel impulse response, power delay profile, scattering functions, Doppler spectrum, power angle spectrum, polarimetric channel representation

- **Multipath Propagation Characterization** - The propagation channel as a stochastic process, wide-sense stationarity, uncorrelated scattering, homogeneous scattering, the WSSUS channel, 1st order statistics, signal envelope probability distribution function, 2nd order statistics, auto-correlation function, spatial correlation
- **Channel Models** - The two-path model, Saleh-Valenzuela channel model, line-of-sight propagation, non-line-of-site propagation, narrowband models, wideband models, ultra-wideband models, spatial models, deterministic models
- **Multiple-Input Multiple-Output (MIMO) Channel Concepts** - H-matrix, sampled signal model, channel normalization, full-correlation matrix, channel rank, diversity measure, multipath richness, degrees-of-freedom, channel capacity
- **MIMO Channel Models** - The i.i.d model, the Kronecker model, the Key-hole model, Weichselberger model, geometry based channel models
- **Antenna-Channel Interaction Characterization** - Mean effective gain, bounds on MEG, effective and apparent diversity gain, optimal antenna radiation patterns
- **Environment- and System-Specific Propagation Channels** - indoor, outdoor, indoor-to-outdoor, car-to-car, femto-, pico-, micro- and macro-cell propagation channels
- **Channel Measurement Techniques** - Time-domain methods, frequency-domain methods, spatially resolved methods
- **Channel Estimation, Statistical Inference and Model Selection** - Beamforming, ESPRIT, Capon's beamformer, Akaike information criterium, tests for gaussianity

Disposition

Lectures and problem solving seminars. In total there will be 25 sessions and each of them will be 2 hours long.

Course literature

As the course has a wide coverage, no single book can cover all topics. The course will be primarily based on lecture notes and slides. The following non-comprehensive list of suitable text books can be consulted.

- A.F. Molisch, "Wireless Communications"
- S.R. Saunders, "Antennas and propagation for wireless communication systems"
- T. S. Rappaport, "Wireless communications: Principles and practice"
- L. Ahlin, J. Zander, "Principles of wireless communications"
- R. Vaughan, J. B. Andersen, "Channels, propagation and antennas for mobile communications"
- J. D. Parsons, "The mobile radio propagation channel"
- H. L. Bertoni, "Radio propagation for modern wireless systems"
- N. Blaunstein, J. B. Andersen, "Multipath phenomena in cellular networks"

Examination

Based on recommendation from KTH's coordinator for disabilities, the examiner will decide how to adapt an examination for students with documented disability.

The examiner may apply another examination format when re-examining individual students.

A compulsory 5-hour exam (oral or written)

Other requirements for final grade

- Two compulsory assignments have to be handed in and approved within given deadlines to gain access to the final exam.
- Final mark is given based 100 % on written (or oral when deemed necessary) examination at the end of the period.

Ethical approach

- All members of a group are responsible for the group's work.
- In any assessment, every student shall honestly disclose any help received and sources used.
- In an oral assessment, every student shall be able to present and answer questions about the entire assignment and solution.