

## ECTS Document

RF Signals And Systems	ECTS	STUDY TIME (HOURS)			Period (semester)
		Theory	Exercises Guided	Exercises Non-guided	
	2	18	8	4	1

**Area of study:** Advanced Electronic System Design and Integration Technologies

**Course topic:** RF Signals and Systems

**Study Program:** Post Graduated Course

**Number of Credits:** 2

**Study Time:** 30 hours

**Period (Semester):** Semester 1

**Course responsible:** Ivan Uzunov

**Course lecturer:** Ivan Uzunov

### **Objectives:**

The basic goal of the module is to learn the basic principles and ideas for transmitting information via radio-frequency channels. It includes:

1. Characterization of RF signals
2. Modulation technique
3. Noise and its influence on RF communication
4. RF transmitters and receivers
5. Basic RF circuits

### **Contents:**

#### **Theory**

##### **1. Introduction**

- Information, messages, signals
- Elements of a communication system
- Fundamental limitations in communications
- Modulation and coding technique
- Digital vs. analog communications

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##### **2. Signals in Time and Frequency Domain**

- Periodic continuous signals; Fourier series
  - Non-periodic continuous signals; Fourier Transform
  - Discrete signals, Sampling theorem; Discrete Fourier transform
  - Time and frequency relations (scaling, delay, modulations, frequency translation)
  - Convolution
  - Measurements in time and frequency domain
  - Laplace transform
  - z-transform
- 3. Signal Transmission**
- Response of linear time-invariant system (LTI) in time domain: impulse response and step response
  - Response of linear LTI in frequency domain: frequency response; channel bandwidth.
  - Transfer functions. First and second order transfer functions. Wideband and narrowband systems
  - Distortion in signal transmission – conditions for non-distorted transmission
  - Linear distortion and equalization. Intersymbol interference
  - Nonlinear distortion and companding. Characterization the non-linear distortion (THD; 1-dB compression point; IP3)
  - Power transmission loss
- 4. RF channels**
- RF propagation, electromagnetic waves and fields
  - Atmospheric absorption and refraction
  - Diffraction of radio-waves
  - Ionospheric and ground wave propagation
  - Line RF propagation (two-wire, coaxial, stripline)
- 5. Noise**
- Noises and noise sources in RF transmission: description and characterization
  - Noise generation in electronic circuits. Thermal noise, shot noise, flicker noise, popcorn noise, avalanche noise.
  - Equivalent input noise sources. Minimum detectable signal
  - SNR and noise figure. Noise figure of multistage systems (Friis formula)
  - Dynamic range
- 6. Modulation and detection**
- General considerations. Analog and digital modulation techniques
  - Amplitude modulation
  - Phase and frequency modulation
  - Digital modulation (shift keying): ASK, FSK, PSK.
  - Binary modulation
  - Quadrature modulation
  - Sampling and pulse modulation
  - Power efficiency of modulation schemes
- 7. Multiple access techniques**

- Frequency division multiplexing
  - Time division multiplexing
  - Code division multiple access
  - Mobile RF communications
  - Wireless standards
- 8. Radio transceiver architectures**
- Receivers: heterodyne, homodyne, image reject, digital IF, sub-sampling.
  - Transmitters: direct conversion, two-step.
  - Transceiver performance test
- 9. Antennas, low-noise amplifiers, mixers, RF filters, demodulators**
- Antennas: operation characteristics, antenna types, antenna noise
  - Low-noise amplifiers: basic principles, input matching, circuits
  - Down-conversion mixers: requirements, circuits, noise
  - RF filters: requirements and limitations, circuits, tuning, noise
  - Demodulators
- 10. Oscillators and frequency synthesizers**
- Basic oscillator circuits: Colpitts, Hartley, fully differential circuits, quartz-crystal oscillators
  - Voltage-controlled oscillators
  - Phase-locked loops (PLL)
  - Frequency synthesis: integer-N PLL, fractional PLL, direct digital synthesis
  - Producing two signals in quadrature (I and Q signals)
  - Frequency instability in oscillators: phase noise and jitter, destructive effect
- 11. Power amplifiers (PA)**
- Class A and class B PA
  - Class C PA
  - High efficiency PA
  - Linearization techniques
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- 12. DSP techniques in signal transmission (short review)**

### Guided exercises

#### **1. RF Signals and Noise**

- RF noise
- Modulations

#### **2. RF Building Blocks**

- Low-noise amplifiers
- Oscillators
- Frequency synthesizers
- Power amplifiers

#### **3. RF Systems**

- Radio receivers
- Cordless telephones

- Cellular telephone systems
- Wireless communication systems

### **Non-guided exercises**

#### **1. RF Signals and Noise**

Miniproject. Modulations. (5-6 pages on single line spacing)

The student should present a detailed explanation of one of the following modulations:

- Conventional amplitude modulation
- Conventional frequency modulation
- Quadrature modulation
- Frequency division multiplexing
- Phase shift keying
- Direct sequence spread spectrum

#### **2. RF Building Blocks**

Miniproject. RF integrated circuit (5-6 pages on single line spacing)

Structure, characteristics and application examples on IC. Students should choose one of the following topics:

- Low-noise amplifier
- Analog front end
- Crystal oscillators
- Mixers
- Power RF amplifiers

#### **3. RF systems**

Miniproject. Communication systems (5-6 pages on single line spacing)

Students should choose one of the following topics:

- Antennas
- FM transmitter
- 2.4 GHz cordless phones
- 5.8 GHz cordless phones
- 2.5G GSM
- 3G GSM
- Satellite relay communication systems
- Satellite relay earth stations

**Teaching and Learning Method:** e-learning and self study

### **Prerequisite Knowledge:**

- Mathematics: higher mathematics (basic university course); complex numbers; Fourier series and Fourier transform; Laplace Transform
- Basic circuit theory

- Basic physics of semiconductor devices

### **Teaching and Learning Material**

- E-learning tutorials for theory
- E-learning exercises
- Recommended references

### **Recommended References**

1. A. Bruce Carlson, P. B. Crilly, J. C. Rutledge, Communication Systems, 4<sup>th</sup> ed., McGraw-Hill, 2002, ISBN 0-07-011127-8.
2. B. Razavi, RF Microelectronics, Prentice Hall, 1998, ISBN 0-13-887571.

**Evaluation Method:** solutions of exercises should be send to lecturer for the guided exercises.

**Examination Method:** multiple choice exams for theoretical part (55%) and mini-projects evaluation (45%).