COURSE OUTLINE

(1) GENERAL

SCHOOL	ENGINEERING		
ACADEMIC UNIT	ELECTRICAL AND COMPUTER ENGINEERING DEPT.		
LEVEL OF STUDIES	Undergraduate		
COURSE CODE	**ECE_K510**	**SEMESTER**	**5**
COURSE TITLE	ΨΗΦΙΑΚΕΣ ΕΠΙΚΟΙΝΩΝΙΕΣ		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures	2	
Seminars / Practice exercises	1	
Laboratory	1	
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (4).	4	5

COURSE TYPE ***general background, special background, specialised, general knowledge, skills development***	Special Background
PREREQUISITE COURSES:	No. Student is advised to have attended courses “Signals and Systems” and “Principles of Telecommunication Systems”
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	https://www.ece.uop.gr/

(2) LEARNING OUTCOMES

Learning outcomes
The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.
Consult Appendix A
- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning*

and Appendix B
- *Guidelines for writing Learning Outcomes*

The course aims to introduce students to fundamental and advanced topics of digital communications and train them in digital techniques used in modern communication systems. The course is structured in modules that include analog to digital transformation, basic concepts and design principles of a digital communication system, baseband transmission, usage of line coding, appearance and handling of intersymbol interference, usage of digital modulation techniques (ASK/FSK/PSK), resolving the synchronization problem in digital communications, techniques of high spectral performance(QAM/OFDM), multiplexing (TDMA/FDMA/CDMA) and channel coding (block and convolutional codes).

Key-words: digital communications, channel capacity, noise in digital communications, line signaling, intersymbol interference, channel equalization, digital modulation ASK, FSK, PSK, DPSK, QPSK, π/4 PSK, QAM, TDMA, FDMA, CDMA, OFDM.

Learning outcomes

On course completion students are able to:

At the knowledge level:

1. Describe clearly individual subsystems of a digital communication system, their characteristics and operation.
2. Describe the factors that affect the design of a digital communication system.
3. Describe the concept of baseband transmission, coding protocols, intersymbol interference effect and ways to resolve it.
4. Describe types of distortion and degradation in signal transmission through a communication channel.
5. Categorize modulation techniques according to information content and signal carrier, compare analog and digital modulation techniques and describe their performance criteria.
6. For each modulation technique (ASK, PSK, FSK, QAM, QPSK, π/4 PSK, etc) describe the principle of operation, bandwidth required, spectral performance, constellation diagrams and its resistance to a noisy channel environment.
7. Describe the characteristics and operations of the structures used to produce and detect digitally modulated signals (ASK, PSK, FSK and their subcategories).
8. Describe the differences between coherent and incoherent detection and explain the problem of synchronization in digital communications.
9. To explain the concept of orthogonality, the benefits it offers and its utilization in digital modulation.
10. Describe channel coding techniques(block coding and convolutional coding).
11. Describe principle of operation and advantages – disadvantages of each of the following techniques, FDMA, TDMA, CDMA and OFDM.

At the skill level:

1. Calculate channel capacity (without noise and with noise) using the Shannon theorem.
2. Study the spectral characteristics of signaling protocols and compare advantages – disadvantages of each.
3. Apply solutions to handle intersymbol interference and multipath propagation.
4. Calculate spectral performance and error rate for each digital modulation technique (ASK, PSK, FSK, QAM, QPSK, π/4 PSK, etc) and compare them.
5. Calculate the bandwidth required for operating any of the following digital modulations (ASK, PSK, FSK, QAM, QPSK, π/4 PSK, etc) for a given signal and channel.
6. Compare carrier demodulation techniques with respect to effectiveness and complexity.
7. Compare the performance of M-adic modulation techniques especially with respect to the theoretical Nyquist limit.
8. Compare channel coding techniques, i.e. block coding, advanced block coding, convolutional coding and TCM (Trellis Coded Modulation).

At the level of abilities:

1. To correlate power performance, bandwidth and data throughput in a digital link.
2. To design raised cosine filters to handle intersymbol interference.
3. To design and evaluate channel equalizers.
4. To recognize problems in digital communications using the eye diagram.
5. To select the appropriate digital modulation (among ASK, PSK, FSK, QAM, QPSK, π/4 PSK, etc) for given communication specifications (spectral performance, error rate, etc).
6. To evaluate circuit operation of transmission and detection for each of the known modulations (ASK, PSK, FSK, QAM, QPSK, π/4 PSK, etc).
7. To design the modulation subsystem of a communication system based on one of the multiple access techniques (FDMA, TDMA, CDMA).
8. To design the modulation subsystem of a communication system based on OFDM.
9. To design interleaving block codes and Reed-Solomon codes.
10. To design Trellis diagrams.
11. To design systems combining source coding, channel coding and modulation.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
	Respect for difference and multiculturalism
Adapting to new situations	*Respect for the natural environment*
Decision-making	*Showing social, professional and ethical responsibility and*

Working independently	*sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

- Search for, analysis and synthesis of data and information, with the use of the necessary technology.
- Working independently
- Team work
- Working in an international environment
- Project planning and management
- Criticism and self-criticism
- Production of free, creative and inductive thinking

(3) SYLLABUS

Short Course Description

Design principles of a digital communication system. Basic concepts of digital communications. Communication channels. Electromagnetic spectrum. Binary signaling. Multi level signaling. Channel capacity. Shannon-Hartley theorem. Baseband transmission of digital data. Pulse modulation (line coding, Manchester etc). Intersymbol interference Noise and interference in digital communication systems. The need for modulation. BPSK, DPSK, DEPSK, QPSK, 16QAM, FSK, MSK, π/4DQPSK digital modulation techniques. Constellation diagrams. Study of spectral performance and error rate. Frequency synthesis with PLL, DDS and their combination. Orthogonal modulation (QPSK, MQAM), noise effect. Multitone transmission techniques (FDM/OFDM, DMT). Multiple access techniques (FDMA/TDMA/CDMA).

Theory lectures:

1. **Overview of a Digital Communication System and Basic Principles and Concepts of Digital Communications**
   Information source. Source coding and decoding. Communication channel. Modulator, demodulator. Channel coder and decoder. Communication Networks. Transmission standards. OSI model. Factors that affect system design. Communication channels. Electromagnetic spectrum. Communication channel effects on signals. Binary signaling. Representation of digital signals. Data pulse spectrum. Spectrum of baseband data sequence. Modulation process. Vector modulation. Basic principles of data transmission.
2. **Channel capacity – Shannon-Hartley theorem – Introduction to concept of modulation**
   Binary signaling. Kinds of binary signaling. Multi-level signaling. Multi-level symbols. Channel capacity calculation. Shannon-Hartley theorem. Need for modulation. Kinds of modulation. Modulation with sinusoidal carrier (analog modulation of continuous signal, digital modulation of continuous signal). Pulse carrier modulation (pulse analog modulation, pulse digital modulation). Comparison of analog - digital modulations. Comparison of demodulators. Performance criteria.
3. **Digital Amplitude Modulation - Amplitude Shift Keying (ASK)**
   Amplitude Shift Keying (ASK). Mathematical description of binary ASK (BASK). Spectrum of BASK modulated signal. Mathematical description of MASK. Power spectral density and spectral performance of MASK modulated signal. Probability of error. Error rate in MASK modulation. Transmission and detection of BASK signal. Comparison of coherent and non-coherent detection. Constellation diagrams.
4. **Digital Phase Modulation - Phase Shift Keying (PSK)**
   Mathematical description of binary PSK (BPSK). Spectrum of BPSK modulated signal. Mathematical description of MPSK. Power spectral density and spectral performance of MPSK signal. Error rate (BER) in MPSK. Transmission and detection of BPSK signal. Differential encoding of data – DEPSK. Differential phase modulation – DPSK. Constellation diagrams. Comparison of coherent and non-coherent PSK.
5. **Orthogonal amplitude shift modulation - Quadrature Amplitude Modulation (QAM)**
   Orthogonal signaling. Quadrature phase shift keying (QPSK). Differential QPSK (DQPSK). π/4 QPSK modulation. Combined amplitude and phase modulation – QAM. Characteristics of M-QAM. Comparison between PSK and QAM.
6. **Digital Frequency Modulation - Frequency Shift Keying (FSK)**
   Digital frequency modulation (FSK). Mathematical description of BFSK. Spectrum of BFSK modulated signal. Power spectral density of BFSK signal. Transmission of continuous phase FSK (CPFSK). Coherent

and non-coherent FSK detection. Advantages and disadvantages of FSK. Minimum Shift Keying (MSK) modulation. Transmission and detection of MFSK. Mathematical description of MFSK. Comparison of binary digital modulation methods. Comparison of m-nary digital modulation methods. Comparison of digital methods with respect to the Shannon limit.

7. **OFDM modulation**
   Basic principles of OFDM. Design of OFDM systems. Multiple antenna usage of OFDM (MIMO, MISO, SIMO and SISO). OFDM combination with error correcting techniques (FEC) or code multiplexing (CDM). OFDM usage in broadband systems Digital Video Broadcasting Terrestrial (DVB-T).
8. **Digital modulation techniques for multiple users**
   Multiple access with frequency division (FDMA). Multiple access with time division (TDMA). Multiple access with code division (CDMA). Relation of CDMA with TDMA and FDMA. CDMA operation. CDMA spectral utilization. Algorithms of CDMA code generation.
9. **Synchronization in digital communications**
   Phase locked loop (analog PLL, digital PLL). Carrier synchronization. Temporal synchronization.
10. **Baseband data transmission**
    Baseband signals. Baseband transmission. Line coding. Line coding categories. Signaling. Intersymbol interference. Handling intersymbol interference with Nyquist filters. Raised cosine filters. Noise effect on baseband systems.
11. **Digital communications in channels with intersymbol interference**
    Intersymbol interference. Handling intersymbol interference with Nyquist filters. Raised cosine filters. Eye diagrams. Matched filters. Equalizers (linear, non-linear). Maximum likelihood sequence detection. Viterbi algorithm.
12. **Broadband network technologies**
    Wired broadband access technologies. xDSL technologies. Optical fiber networks. Cable TV networks. Electrical power networks. Wireless broadband access technologies. Wi-Fi wireless access. Stable wireless access. WiMAX wireless access. Wireless mobile access 3G/UMTS and 4G/LTE. Bidirectional satellite access.
13. **Telephone switching**
    Systems of circuit switching. Simple switchboard center. Strowger automatic selection system. Traffic load and quality of service. Hierarchy of switchboard centers. Multi-level switching. Time division multiplexing. Analog switching with time division. Time slot interchanging (TCI). Space Array. Combined space and time switching. Mobile telephony – cellular principle.

<u>Laboratory experiments</u>

The lab part of the course includes practical experiments that aim to provide theory application and understanding:

- Amplitude shift keying - ASK
- Frequency shift keying – FSK
- Quadrature phase shift keying QPSK (½)
- Quadrature amplitude modulation – QAM
- Orthogonal frequency division multiplexing OFDM
- Code division multiple access (CDMA)
- Wideband code division multiple access (WCDMA)

(4) TEACHING and LEARNING METHODS-EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face in classroom and lab

USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	• Course notes for theory lectures at e-Class. • Guides for lab experiments at e-Class. • Solution of lab exercises uploaded after due dates. • Support of the learning process with e-Class platform (for announcements, note distribution, additional material, resources, bibliography and midterm and final examination of the lab part, etc.) • Specialized simulation environment of communication systems (AWR) for the lab part installed in individual workstations for every student. • Availability of above software through site licensing for student home access. • Utilization of open software (octave) or commercial matlab. • Lecture videos.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	see table below

Activities	Semester course load
Theory lectures	26
Tutorials	13
Laboratory experiments	13
Laboratory preparation	25
Study of lectures and bibliography	48
Total *(25 hours course load per credit)*	***125 hours*** ***(5 ECTS)***

STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	A. Evaluation of Theory part: • Midterm exam (30%) that includes problem solving and scaled difficulty multiple questions. • Final written exam that includes problem solving, multiple questions and comparative assessment of scaled difficulty theory. B. Evaluation of Lab part: • Oral exam during the lab exercises (30%) • Midterm exam (30%) that includes problem solving. • Final written exam (40%) that includes problem solving, Remarks: • Final grade is derived from weighted average of theory grade and lab grade with coefficients 60% and 40% respectively. • Evaluation is done in the greek language. • Evaluation process and criteria are posted on the course webpage at e-Class.

(5) RECOMMENDED BIBLIOGRAPHY

- Suggested bibliography:
- Related academic journals:

1. Lathi P. B. - Ding Zhi, Σύγχρονες Αναλογικές και Ψηφιακές Επικοινωνίες, (4η έκδοση), Τζιόλα 2018
2. Sklar Bernard, Ψηφιακές Επικοινωνίες, (2η έκδοση), Παπασωτηρίου 2011
3. Haykin Simon, Moher Michael, Συστήματα Επικοινωνίας (5η έκδοση), Παπασωτηρίου 2010
4. Rice Michael, Ψηφιακές επικοινωνίες, Τζιόλα 2009
5. Proakis John, Salehi Masoud, Communication Systems Engineering (2nd ed) Prentice Hall 2002
6. Tranter W.,Shanmugan S.,Rappaport T.,Kosbar K., Principles of Communication Systems Simulation with Wireless Applications, Prentice Hall 2004