RTU Course "Telecommunications Theory (special course)"

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General data

Code	RDE701
Course title	Telecommunications Theory (special course)
Course status in the programme	Compulsory/Courses of Limited Choice
Responsible instructor	Inna Kurbatska
Academic staff	Vjačeslavs Bobrovs Andris Ozols Elans Grabs
Volume of the course: parts and credits points	1 part, 5.0 Credit Points, 7.5 ECTS credits
Language of instruction	LV, EN
Annotation	The study course is intended to deepen their knowledge of signal sampling and approximation, of linear system theory based on entire analytic function theory, as well as of other communication technology theoretical problems. The theory of entire analytic functions is a valuable tool in communication theory and practice because entire analytic functions in the complex plane corresponding to the functions with limited spectra on the real axis. The latter are just functions that describe signals transmitted over the bandlimited communication channels. In this way, it turns out that the well-known sampling (Kotelnikov) theorem is merely the special case of Lagrange’s interpolation formula of entire analytic functions enabling also other sampling possibilities including nonuniform sampling. Similarly, other new possibilities appear in signal approximation and in approximation error evaluation, as well as in signal restoration if only partial information about the signal is known. The following main topics are covered in this study course: entire analytic functions and their application in signal sampling, approximation, and restoration; properties of Fourier transform; signal multiplexing in multichannel systems, CDMA systems; the negentropy principle of information and its meaning for telecommunications; the influence of quantum effects on signal transmission; quantum communications; quantum cryptography; quantum computers; stochastic resonance.
Goals and objectives of the course in terms of competences and skills	The goal of the study course is to provide students with a deeper understanding of the main questions of communication theory. It is assumed that after mastering the study course students will freely orient themselves in the theoretical questions of communications and that they will acquire the skill to use the obtained knowledge in their further work and to follow the modern development trends of communication technology. The main tasks of the study course are: - to provide basic knowledge about analytic functions for the discretization of signals, and evaluation of the existing signal discretization methods from this point of view; - to explain the operation of linear systems including communication channels and how to perform the signal approximation and restoration in terms of the theory of entire analytic functions; - to provide basic knowledge about code division and statistical signal multiplexing methods; - to provide basic knowledge about quantum communications including characteristics of quantum communication channels, quantum cryptography, quantum teleportation, and comparison with classical channels; - to explain the operation and design principles of quantum computers, and the possibilities of their applications.
Structure and tasks of independent studies	The unaided work of students will be organized in the framework of practical works where students will prepare the presentations. Besides, a serious independent work will be necessary to pass the examination
Recommended literature	Obligātā/Obligatory: 1. M.Lueck. Analytic and Entire Functions. 2004. 7 p. http://pirate.shu.edu/~wachsmut/Teaching/MATH3912/Projects/papers/lueck_analyticity.pdf 2. B.Sklar. Digital Communications. Fundamentals and Applications. Upper Saddle River, New Jersey: Prentice Hall 2001. 1100 p. 3. D.C.Mackay. Information Theory, Inference, and Learning Algoritms. Cambridge: Cambridge University Press, 2006. 628 p. 4. A.J.Viterbi. CDMA. Principles of Spread Spectrum Communication. Addison-Wesley, Reading, Massachusetts etc.,1995. 245 p. 5. L.Brillouin. Science and Information Theory. New York, etc.: Academic press, Inc., 1956. 320 p. 6. G.Jaeger. Quantum Information. An Overview. Springer, 2007. 284 p. 7. Ch. H. Bennett. Quantum Information and Computation. Physics Today. October 1995. 24-30 p. Papildu/Additional: 1. K.Wiesenfeld, F.Moss. Stochastic resonance and the benefits of noise: from ice ages to crayfish and SQUIDs. Nature. January 1995, vol.373, No 6509. 33-36 p. 2. M.D.Donnel, N.G.Stocks, Ch.E.Pearce, D.Abbot. Stochastic Resonance. Cambridge, 2008. 425 p.
Course prerequisites	The necessary course prerequisites include the knowledge of electromagnetic wave theory, physical optics (especially, interference and diffraction), and the elements of quantum mechanics. The ability freely to apply differential and integral calculus is necessary. The foundations of Fourier analysis and complex variable theory should be known, as well as signal theory and electric communication theory at the bachelor.

Course contents

Content	Full- and part-time intramural studies		Part time extramural studies	
	Contact Hours	Indep. work	Contact Hours	Indep. work
Motivation, goal and content of study course. The main concepts.	1	0	0	0
Entire analytic functions, their significance in communication theory and mathematical properties.	3	4	0	0
The main theorems of Fourier analysis. Widening of the Fourier transform concept. Uncertainty relation.	2	3	0	0
Functions with limited spectra and entire analytic functions	2	3	0	0
Sampling (Kotelnikov) theorem as a special case of Lagrange’s interpolation formula.	2	3	0	0
Uniform and nonuniform sampling of signals.	2	3	0	0
Approximation of signals in communication theory and the approximation errors.	2	3	0	0
Classification of signal multiplexing methods.Linear and nonlinear multiplexing methods.	2	3	0	0
Code division multiplexing of signals (CDMA). CDMA/DS and CDMA/FH systems.	2	3	0	0
Correlation receivers in the case of white noise and signal multipaths propagation.	2	3	0	0
Orthogonal coding of channel signals. Walsh-Hadamard and Casami coding.	2	3	0	0
Statistical multiplexing in analogue and digital communication systems.	2	3	0	0
Linear systems in communication engineering. The inverse problem.	2	3	0	0
The main integral equation of linear systems and its solution.	2	3	0	0
Solution unitarity and correctness. The practical meaning of these mathematical properties.	2	3	0	0
Signal restoration by the analytic continuation method.	2	3	0	0
Effect of noise on the restoration precision of the input signal.	2	3	0	0
Quantum effects and their influence on the communications.	2	3	0	0
Stochastic communication channels with thermal noise.	2	3	0	0
The negentropy principle of information, its applications in electronic and photonic channels.	4	5	0	0
Quantum limits of electronic and photonic communication channels.	2	3	0	0
Peculiarities of quantum systems – their stochasticity and nonlocality.	1	2	0	0
Quantum bits – qubits. Quantum communication channels. Schumacher theorem.	2	3	0	0
Redundancy of quantum signals, their multiplexing and teleportation.	2	3	0	0
Quantum cryptography.BB84 and EPR protocols.	2	3	0	0
Operation principles and development trends of modern computer technology.	1	2	0	0
Fourier optics and holography.	2	3	0	0
Analogue quantum computers.	2	3	0	0
RSA code and Shor’s algorithm. The operation principles of digital quantum computers.	2	3	0	0
Potentialities of digital quantum computers and their practical realization.	2	3	0	0
Stochastic resonance and its mathematical description.	2	3	0	0
Stochastic resonance in nature and technology.	2	3	0	0
Course project (Research and evaluation of nonlinear transmission system).	16	26	0	0
Total:	80	120	0	0

Learning outcomes and assessment

Learning outcomes	Assessment methods
Is able to apply the theory of entire analytic functions for the discretization of signals, and to evaluate the existing signal discretization methods from this point of view.	Two assessment methods will be used: by self-made reports during the practical works and in the final examination.
Is able to analyse the operation of linear systems including communication channels and to perform the signal approximation and restoration in terms of the theory of entire analytic functions.	Two assessment methods will be used: by self-made reports during the practical works and in the final examination
Is able to orient themselves in code division and statistical signal multiplexing methods.	Two assessment methods will be used: by self-made reports during the practical works and in the final examination
Is able to orient themselves in the problems of quantum communications including characteristics of quantum communication channels, quantum cryptography, quantum teleportation, comparison with classical channels.	Two assessment methods will be used: by self-made reports during the practical works and in the final examination
Knows the operation and design principles of quantum computers, and the possibilities of their applications.	Two assessment methods will be used: by self-made reports during the practical works and in the final examination

Evaluation criteria of study results

Criterion	%
Practical works	50
Exam	50
Total:	100

Study subject structure

Part	CP	Hours per Week			Tests		
		Lectures	Practical	Lab.	Test	Exam	Work
1.	5.0	4.0	1.0	0.0		*	