RTU Course "Theory of Signal Transmission"

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General data

Code	RDE602
Course title	Theory of Signal Transmission
Course status in the programme	Compulsory/Courses of Limited Choice
Responsible instructor	Vjačeslavs Bobrovs
Academic staff	Andris Ozols Rolands Parts
Volume of the course: parts and credits points	2 parts, 15.0 Credit Points, 22.5 ECTS credits
Language of instruction	LV, EN
Annotation	Signal transmission theory (STT) is the branch of science dealing with the transmission of signals in time and space by means of technical systems. STT is also a branch of cybernetics. STT originated in 1928 after the publication by American scientist R.V.Hartley of his seminal paper „Transmission of information" in Bell System Technical Journal. The main contribution to the development of STT foundations has been made by American scientists C.Shannon, N.Wiener, B.Oliver, J.R. Pierce, D.Midltone, H.Nyquist and by Russian scientists V. Kotelnikov, V.Siforov, A.Kolmogorov, A.Khinchine. Mathematically STT is based on Fourier analysis, probability theory, theory of random processes and mathematical set theory. STT consists of three parts: signal theory, noise-resistance theory and information theory. The latter includes also quantum information. Within the framework of this course on STT for Ph.D. students the following main topics are considered: Signals, their types and characteristics including spectra and correlation functions. Signal sampling. Classification of communication channels, the matching of their parameters with signal parameters. The foundations of linear vector space theory. Transmission of signals over the filters. Information capacity of different communication channels. Foundations of coding theory. Noise-resistant reception of signals. Signal mutiplexing in multichannel systems. The negentropy principle of information and its implications for telecommunications. The input signal reconstruction of a linear system. The influence of quantum effects on signal transmission. Quantum communications. Quantum cryptography. Quantum computers. Stochastic resonance. Efficiency of communication systems, its evaluation.
Goals and objectives of the course in terms of competences and skills	The goal of the course "Theory of Signal Transmission" is to enable students to become competent in this field at Ph.D. level. After mastering this course students will get profound understanding in the theoretical questions of signal transmission, and they will acquire the skill to use the obtained knowledge in their further scientific and practical work.
Structure and tasks of independent studies	Independent survey of technical and scientific literature in order to compile reports. Besides, serious independent work will be necessary to pass the examination.
Recommended literature	1.P.A.Lynn. An Introduction to the Analysis and Processing of Signals. Hemisphere Publishing Corporation, New York, 1989, 263 p. 2.B.Carlson. Communication Systems. Mc Graw Hill Book Company, New York, 1986, 662 p. 3.A.Grabinskis, L.Pētersons. Signālu pārvade un elektrosakari. Rīga, Zvaigzne, 1984, 172 lpp. 4.Теория электрической связи. Под ред. Д.Д.Кловского. Москва, «Радио и связь», 1999, 433 с. 5.B.Sklar. Digital Communications. Fundamentals and Applications. Prentice Hall, Upper Saddle River, New Jersey, 2001, 1100 p. 6.S.Haykin. Communication Systems. John Wiley&Sons, New York, 2001, 816 p. 7.J.Adamec. Foundations of Coding. John Wiley &Sons, Chichester, New York, 1991, 336 p 8.D.C.Mackay. Information Theory, Inference, and Learning Algoritms. Cambridge University Press, Cambridge, 2006, 628 p. 9.Ch.L.Nikias, A.P.Petropulu. Higher-order spectral analysis. PTR Prentice Hall, Englewood Cliffs, New Jersey 07632, 1993, 537 p. 10.Я.И.Хургин В.ПЯковлев. Методы теории целых функций в радиофизике, теории связи и оптике . Физматгиз, М.,1962, 220 с. 11.Я.И.Хургин В.ПЯковлев. Финитные функции в физике и технике. Наука, Москва, 1971, 408. 12. Ch. H. Bennett. Quantum Information and Computation. Physics Today, October 1995, pp. 24-30. 13.G.Jaeger. Quantum Information. An Overview. Springer, 2007, 284 p. 14.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 including Maxwell equations, physical optics (interference and diffraction in particular), quantum optics and the elements of quantum mechanics within the framework of the course in physics at RTU bachelor studies level.(MFA101). Ability to freely apply differential and integral calculus is necessary (DIM109).

Course contents

Content	Full- and part-time intramural studies		Part time extramural studies	
	Contact Hours	Indep. work	Contact Hours	Indep. work

1. Definition and goal of signal transmission theory. The main formation principles of communication systems	4	0	0	0
2. The types of signals and their parameters.	4	0	0	0
3.The types of stochastic signals and their characteristics.	4	0	0	0
4.Gaussian and Markovian processes.	2	0	0	0
5. The main theorems of Fourier analysis. Expansion of the Fourier transform concept. Uncertainty relation.	6	0	0	0
6.Definitions of signal spectra. The connection of spectra with correlation functions. Bispectra and trispectra.	4	0	0	0
7. The criteria for spectral width and impulse duration determination. Their choice and relation between them.	4	0	0	0
8.Theory of analytic signals. The quasiharmonic form of a signal, its applications.	4	0	0	0
9. Sampling methods of continuous-wave signals. Applications of entire analytic functions theory.	4	0	0	0
10.Approximation of signals in communication theory based on entire analytic functions.	4	0	0	0
11. Foundations of the theory of linear vector spaces. Orthogonal and non-orthogonal signals.	4	0	0	0
12. Modulation of continuous-wave carrier signals.	4	0	0	0
13. Modulation of interrupted continuous-wave carrier signals.	4	0	0	0
14. Modulation of digital signals.	4	0	0	0
15. Pulse-code modulation.	2	0	0	0
16. Comparison of different modulation methods.	4	0	0	0
17. Correlation functions and power spectra of modulated signals.	4	0	0	0
18. Models of communication systems.	4	0	0	0
19. The transmission of deterministic signal over the deterministic linear filter. The main characteristics of filters.	4	0	0	0
20. The transmission of stochastic signal over the deterministic linear filter.	2	0	0	0
21. Value prediction of a stochastic signal. Goals and methods.	2	0	0	0
22. Quantitative definition of information in digital messages.	1	0	0	0
23. Entropy and redundancy of a digital message source. Mutual information.	1	0	0	0
24. The Shannon theorem for a discrete noiseless channel. Optimal coding. Shannon-Fano code.	4	0	0	0
25. Information capacity of discrete communication channels with and without noise.	4	0	0	0
26. Information measures of continuous message source.	4	0	0	0
27.Shannon’s theorem for a noisy continuous communication channel. Shannon’s formula .Beyond the Shannon limit?	6	0	0	0
28. Noise-resistant coding and decoding. Code classification, code tables and code trees. Hamming distance.	6	0	0	0
29. Hamming codes.	2	0	0	0
30.Cyclic codes. Reed – Solomon codes.	4	0	0	0
31. Convolutional codes.	2	0	0	0
32. Fink-Hagelbarger codes.	2	0	0	0
33. Methods of discrete signal processing in receivers.	4	0	0	0
34. Coherent and incoherent detection methods of signals	2	0	0	0
35. Matched filters, their realization.	4	0	0	0
36. Criteria for noise-resistant digital signal reception.	4	0	0	0
37. Optimal reception of binary signals on the white noise background. Error calculation.	4	0	0	0
38. Optimal linear filtering of continuous-wave signals.	2	0	0	0
39. Different mathematical forms of the maximum likelihood criterion and the corresponding optimal receivers.	4	0	0	0
40. Non-optimal receivers.	2	0	0	0
41. Optimal reception of continuous-wave signals and its characteristics.	2	0	0	0
42. Formation principles and methods (linear and nonlinear) of multichannel communication systems.	4	0	0	0
43. CDMA/DS and CDMA/FH multiplexing systems. Correlation receivers in CDMA systems.	4	0	0	0
44. Statistical multplexing in analogue and digital communication systems.	2	0	0	0
45. The negentropy principle of information. Its application in electronic and photonic channels.	4	0	0	0
46. The input signal reconstruction of a linear system from its output signal. The main integral equation .	2	0	0	0
47. The uniqueness and correctness of the main integral equation solution. Method of analytic continuation.	2	0	0	0
48. Effect of noise on the reconstruction accuracy of input signal.	2	0	0	0
49. Quantum limitations to the capacity of a communication channel. Quantum multiplexing.	4	0	0	0
50. Quantum communication channels, their peculiarities.	4	0	0	0
51. Shannon entropy and von Neumann entropy. Schumacher theorem for the quantum channel.	4	0	0	0
52. Quantum cryptography.	4	0	0	0
53. Quantum computers.	6	0	0	0
54. Stochastic resonance: the use of noise to increase the sensitivity of receivers.	4	0	0	0

55. Efficiency of information transmission systems. Efficiency criteria, the methods of its determination and increase.	4	0	0	0
Total:	192	0	0	0

Learning outcomes and assessment

Learning outcomes	Assessment methods
Ph.D. students will acquire knowledge of the main issues of the signal transmission theory; they will master the main principles and methods.	Two assessment methods will be used assessment of reports during the practical classes and in public final examination.
Students are able to apply the obtained knowledge in their scientific and practical work in the field of telecommunications.	Two assessment methods will be used: assessment of reports during the practical classes and in public final examination.
After the mastering of the course on Theory of Signal Transmission Ph.D. students are able to follow the developments in the field of telecommunications.	Two assessment methods will be used: assessment of reports during the practical classes and in public final examination.

Study subject structure

Part	CP	Hours per Week			Tests		
		Lectures	Practical	Lab.	Test	Exam	Work
1.	7.0	4.0	0.0	3.0	*		
2.	8.0	4.0	4.0	0.0		*	