Indian Institute of Technology Jodhpur

M.Tech. in Communication Systems
(previously M.Tech. in Intelligent Communication Systems)
Revised Curriculum Structure for AY 2025-26 Onwards

Introduction

During the past few years, there has been an exponential growth in the usage of internet. The fast development of economy and society requires modern and high-performance communications systems that can cater for massive deployment of Internet of Things, while still offering acceptable levels of energy consumption, equipment cost and network deployment and operation cost. It needs to support a wide variety of applications and services requiring increased spectral efficiency, higher data rates, low latency and high reliability. Communication technologies need to meet the growing connectivity requirements for new use cases (e.g. for ultra-low latency or high reliability cases) and new applications for industry, opening new revenue streams also for operators. The M. Tech. program in Communication Systems prepares students for an advanced engineering career by in-depth understanding of modern communication systems at all layers and their associated signal processing methods. The program provides students with an opportunity to learn the specialization in depth by updating and renewing their technical knowledge in a rapidly changing telecommunication industry.

Objective of the Program

Graduates from the program will have in-depth knowledge and critical awareness of theoretical and practical solutions to problems at the forefront of communications and the processing of signals. They would be ready for careers in fields such as development, research, operations and management of next-generation telecommunication networks and information processing systems.

Graduate Attributes

- The graduates of this program will have strong fundamentals in modern communications technology and signal processing methods.
- Understanding of cutting-edge research on future generations of wireless communication.
- Analytical and experimental skills required to design and implement next-generation communication systems for various applications like Internet-of-Things, smart health, Smart City, Intelligent Transportation Systems
- Ability to do critical and creative thinking, and to conduct independent and original research and scholarship
- Ability to apply existing skills and knowledge to identify and formulate new problems, produce new ideas, approaches or actions
- Ability to teach and express ideas in both written and oral formats

Learning outcome

- Ability to statistically characterize and evaluate the performance of communication systems.
- Ability to apply the different methods for signal detection and estimation to real world engineering problems and advanced research
- Develop understanding of cutting-edge research on future generations of wireless communication.
- Analyze multi-user networks and understanding of techniques like opportunistic communication, multiuser diversity, superposition coding and successive interference cancellation
- Implement end-to-end wireless communication systems with various MIMO technologies like maximal ratio combining, OFDM, interleaving/de-interleaving, and Alamouti codes
- Ability to master a specific set of methods appropriate to their dissertation, with the depth needed to produce methodologically rigorous research.
- Carry out research work demonstrating scientific problem solving and generate IPR

Program's Structure

Overall Structure (M. Tech. Degree Requirements for Communication Systems)

Cat.	*Course Number, Course Title*		*L-T-P*	*Credits*		*Cat.*	*Course Number, Course Title*		*L-T-P*	*Credits*
I Semester						**II Semester**				
C	EEL7XX0	**Applied Linear Algebra**	**3-0-0**	**3**		C	EEL7XX0	**Wireless Communications**	**3-0-0**	**3**
C	EEL7XX0	**Statistical Signal Analysis**	**3-0-0**	**3**		E	EEL7XX0	*Elective*	3-0-0	3
C	EEL7XX0	**Digital Communications**	**3-0-0**	**3**		E	EEL7XX0	*Elective*	3-0-0	3
E	EEL7XX0	Elective	3-0-0	3		E	EEL7XX0	*Elective*	3-0-0	3
NG1	HSN7XX0	Non-Graded I	1-0-0	S/X		NG2	HSN7XX0	*Non-Graded II*	1-0-0	S/X
			Total	**12**					*Total*	**12**
III Semester						**IV Semester**				
T	EET8XX0	Thesis		16		T	EET8XX0	Thesis		16
			Total	**16**					*Total*	**16**

Topic Clouds

Applied Linear Algebra	***Statistical Signal Analysis***	***Digital Communications***	***Wireless Communications***
• Fundamental Concepts of Linear Algebra • Eigenvalues, Eigenvectors, and Diagonalization • Matrix Theory & Factorization • Matrix Computations in Signal Processing & Communications	• Random Processes • Stationarity and Ergodicity • Random parameter estimation • Non-random parameter estimation • Multiple parameter estimation	• Signal Representation and Digital Modulation Schemes • Receiver Design, Sufficient Statistics and Performance Analysis • Carrier and Symbol Synchronization • Introduction to Coding and design tradeoffs	• Fading channel models • Error performance in AWGN and fading channels • Diversity Techniques • Capacity of fading channels • Multiuser systems-multiple and random access techniques • Multiuser diversity • Ad-Hoc Networks

List of Program Electives

S. No.	Course Number	Course Title	L-T-P	Credits
1	EEL7240	Cellular Communication Networks	3-0-0	3
2	EEL7200	Data Communication and Networking	2-0-2	3
3	EEL7110	MIMO Wireless Communications	3-0-0	3
4	EEL7990	RF system design for Communications	3-0-0	3
5	EEL7630	Coding Theory	3-0-0	3
6	EEL71320	Network Information Theory	3-0-0	3
7	EEL7760	Design and Analysis of Communication Networks	3-0-0	3
8	EEL7030	Advanced Digital Signal Processing	3-0-0	3
9	EEL7930	Optical Communication Systems	3-0-0	3
10	CSL7620	Machine Learning	3-0-0	3
11	CSL7590	Deep Learning	3-0-0	3
12	EEL7480	Machine Learning for Communications	3-0-0	3

Curriculum of Core Courses

Title:	**Applied Linear Algebra**	**Number:**	EEL7XX0
Department:	Electrical Engineering	**L-T-P [C]**	3-0-0 [3]
Offered for:	M. Tech. and Ph.D.		
Type:	Core Course for Communication and Signal Processing groups		

Objectives:

The instructor will:

1. introduce fundamental definitions and concepts of Linear Algebra
2. introduce matrix computations required for signal processing and communication

Learning Outcomes:

At the end of the course, the students will be able to:

1. Analyze vector spaces, orthogonality, and linear transformations to establish mathematical foundations for signal processing and communication
2. Apply matrix computations and factorizations to solve problems in signal processing and communication.

Contents:

Fundamental Concepts of Linear Algebra (12 Lectures)
Algebra of Matrices, Systems of Linear Equations, Vector Spaces & Subspaces, Linear Dependence and Independence, Inner Product Spaces, Norms, orthogonality, Gram-Schmidt process, Linear Transformations & Change of Basis

Eigenvalues, Eigenvectors, and Diagonalization (9 Lectures)
Eigenvalues & Eigenvectors, Diagonalization & Spectral Theorem, Jordan Canonical Form – Generalized eigenvectors and applications, Singular Value Decomposition (SVD), Pseudoinverse & Moore-Penrose Inverse

Matrix Theory & Factorization (12 Lectures)
Matrix Operations – Rank, inverse, determinant, trace, Special Matrices – Symmetric, skew-symmetric, Hermitian, Toeplitz, circulant matrices, LU Decomposition, QR Factorization, Cholesky Decomposition
Matrix Computations in Signal Processing & Communications (9 Lectures)
Fourier & Wavelet Transforms in Matrix Form, Fast Algorithms in Signal Processing, Compressive Sensing & Sparse Signal Recovery, Signal Subspace Estimation and Array Processing, Linear and Quadratic programming

Textbook:

1. Strang, Gilbert. Linear Algebra and Its Applications 4th ed. 2012.
2. Meyer, Carl D. Matrix analysis and applied linear algebra. Society for Industrial and Applied Mathematics, 2023.

Self-learning Material:

Strang, Gilbert., Linear Algebra, Spring 2010, MIT OpenCourseWare, Massachusetts Institute of Technology: https://ocw.mit.edu/courses/18-06-linear-algebra-spring-2010/
Rao, Vittal., Advanced Matrix Theory and Linear Algebra for Engineers, NPTEL Course ID 111108066: https://nptel.ac.in/courses/111108066

Title:	Statistical Signal Analysis	Number:	EEL7XX0
Department:	Electrical Engineering	L-T-P [C]	3-0-0 [3]
Offered for:	M. Tech. and Ph.D.		
Type:	Core Course for Communication and Signal Processing groups		

Objectives:

The instructor will:

1. introduce fundamental definitions and concepts of Probability, Random Variables and Random Processes
2. provide background to understand the fundamental aspects of parameter estimation and hypothesis testing

Learning Outcomes:

The students will be able to:

1. perform filtering, parameter estimation, and hypothesis testing concepts of signal detection and estimation for deterministic and random signals
2. apply the theoretical knowledge to applications in communication, machine learning, optimization, and signal processing

Contents:

Review of Probability Theory (8 Lectures)

Introduction to Probability Theory, Conditional Probability & Bayes' Theorem, Independence, Conditional independence, Markov property, Discrete Random Variables, Continuous Random Variables, Expectation, Characteristic and Moment-Generating Functions, Joint Distributions of Multiple Random Variables, Functions of Random Variables, Conditional Expectation, Law of Large Numbers and Central Limit Theorems

Stochastic Processes and Linear Filtering (14 Lectures)

Stochastic Processes, Classification and characterization, Stationarity & Ergodicity, Gaussian and Poisson Processes, Markov Chains and Markov Processes, Spectral Representation of Stochastic Processes, Power Spectral Density (PSD), Linear Systems with Random Inputs, White Noise & Colored Noise Models, Wiener Filter, Least Squares Estimation and Linear Prediction, Kalman Filtering

Parameter Estimation (10 Lectures)

Parameter Estimation: Introduction to Statistical Estimation: Bias, Variance, MSE, Maximum Likelihood Estimation (MLE), Cramér-Rao Bound (CRB) and Efficiency of Estimators, Bayesian Estimation: MMSE, MAP, and Posterior Distributions

Hypothesis Testing and Detection (10 Lectures):

Likelihood Ratio Test (LRT), Neyman-Pearson Theorem, Bayesian Hypothesis Testing, Minimum Probability of Error Criterion, Matched Filter, Energy Detector (6 Lectures)

Textbook:

Papoulis, Athanasios, and S. Unnikrishna Pillai. 2002. Probability, Random Variables, and Stochastic Processes. 4th ed. New York: McGraw-Hill.

Kay,S.M., (1998), Fundamentals of Statistical Signal Processing: Vol. 1 Estimation Theory, 1st Edition, Prentice Hall

Kay,S.M., (1998), Fundamentals of Statistical Signal Processing: Vol. 2 Detection Theory, 1st Edition, Prentice Hall

Self-learning Material:

Chakraborty, Mrityunjay. *Probability and Random Processes,* NPTEL Course ID 117105085: https://nptel.ac.in/courses/117105085

Sinha, Rohit, *Signal Detection and Estimation Theory*, NPTEL Course ID 117103018: https://nptel.ac.in/courses/117103018

Title	**Digital Communication**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M. Tech. and PhD	Type	Compulsory
Prerequisite	Knowledge of Probability Theory and Fundaments of Communications		

Objectives

The instructor will:

1. Provide strong theoretical foundation of digital communication modulation schemes and performance evaluation.
2. Help students understand the fundamentals of communication through band limited channels and synchronization.

Learning Outcomes

The students will be able to:

1. Design receivers for optimum performance.
2. Analyze communication systems for their bit error performance.

Contents

Signal Representation and Digital Modulation Schemes (8 Lectures)

Complex baseband representation of signals, Gram-Schmidt orthogonalization procedure, M-ary orthogonal signals, bi-orthogonal signals, simplex signal waveforms, Memoryless modulation schemes, signaling schemes with memory, power spectral density of digitally modulated signals

Receiver Design, Sufficient Statistics and Performance Analysis (14 Lectures)

Coherent and non-coherent demodulation: Matched filter, Correlator demodulator, square-law, and envelope detection; Detector: Optimum rule for ML and MAP detection Performance: Bit-error-rate, symbol error rate for coherent and non-coherent schemes, Recurrent Neural Networks and their use for robust and adaptive receiver design

Carrier and Symbol Synchronization (4 Lectures)

carrier recovery and symbol synchronization in demodulation, carrier phase estimation, symbol timing estimation

Introduction to Coding (12 Lectures)

Linear block codes, properties and examples, soft decision decoding, hard decision decoding, convolutional codes, Viterbi decoding

Design Tradeoffs (4 Lectures)

Rate, bandwidth efficiency, power efficiency, modulation and coding tradeoffs

Textbook

1. Proakis, J. G. and Salehi, M., (2007), *Digital Communications*, 5th Edition, McGraw-Hill
2. Madhow, U., (2008), *Fundamentals of Digital Communication*, 1st Edition, Cambridge University Press
3. Barry, J. R., Lee, E. A., and Messerschmitt, D. G., (2004), *Digital Communications*, 3rd Edition, Springer

Preparatory Course Material

1. Jagannatham, A. K., *Principles of Communication II*, Department of Electrical Engineering, Indian Institute of Technology Kanpur, https://nptel.ac.in/courses/108104098/

Title	**Wireless Communications**	Number	EEL7XX0
Department	Electrical Engineering	L-T-P [C]	3–0–0 [3]
Offered for	M.Tech.-Ph.D. Dual Degree (Comm. Engg.)	Type	Compulsory
Prerequisite	Fundamentals of Communications		

Objectives

The instructor will:

1. Provide students with an understanding of the concepts related to communication over wireless fading channel.
2. Expose students to concepts and techniques for exploiting fading and application of these concepts in multiuser communication systems context.

Learning Outcomes

The students will be able to:

1. Interpret and apply core principles of deep fading, diversity strategies, and channel capacity in the context of point-to-point wireless communication systems.
2. Analyze multi-user networks and understanding techniques like opportunistic communication, multiuser diversity, superposition coding and successive interference cancellation.
3. Analyze and design wireless ad-hoc networks with special emphasis on energy constrained networks

Contents

Wireless Channels [10 Lectures]:
Review of signal detection over AWGN channels and M-ary Modulation (5L)
Modelling of wireless channels; space, time and frequency channel coherence; input/output channel models for single and multi-antenna systems - SIMO, MISO, and MIMO (5L)

Diversity Techniques [14 Lectures]:
Digital modulation and its performance in fading (4L)
Deep fade and diversity (3L)
Realizing diversity: time diversity (1L), frequency diversity (3L), antenna diversity – SIMO, MISO, and MIMO (3L)

Wireless Channel Capacity [11 Lectures]:
Capacity of the Gaussian channels –SISO, SIMO, MISO and MIMO (4L)
Outage limited and ergodic capacity of fading channels (4L)
Water filling algorithm and opportunistic communication (3L)

Multiuser system design [7 Lectures]:
Multiple access techniques (2L)
Multiuser channel capacity and multiuser diversity (5L)

Textbook

1. Tse, D. and Viswanath, P., (2005), *Fundamentals of wireless communication*, Cambridge University Press.
2. Goldsmith, A., (2005), *Wireless Communications*, Cambridge University Press.
3. Simon, M. K. and Alouini, M. S., (2004), *Digital communication over fading channels*, John Wiley and Sons.

Self-Learning Material

1. Zheng, L., Principles of Wireless Communications, MIT OpenCourseWare, Electrical Engineering & Computer Science, Massachusetts Institute of Technology, https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-452-principles-of-wireless-communications-spring-2006/index.htm

Preparatory Course Material

1. Jagannatham, A. K., *Principles of Communication II*, NPTEL Course Material, Department of Electrical Engineering, Indian Institute of Technology Kanpur, https://nptel.ac.in/courses/108104098/
2. Zheng, L. and Gallager, R., *Principles of Digital Communications I*, MIT OpenCourseWare, Electrical Engineering & Computer Science, Massachusetts Institute of Technology, https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-450-principles-of-digital-communications-i-fall-2006/