

**AMRUTVAHINI COLLEGE OF ENGINEERING,
SANGAMNER
DEPARTMENT OF E&TC ENGINEERING**

**Honors in Intelligent and Emerging Communication
Technologies
(18 Credits)**

Year	Semester	Course Code	Course Name	Credits
Second Year	III	R25-ET-HOC-201	Probability & Random Processes for Engineers	3
	IV	R25-ET-HOC-202	MIMO Technology in Modern Wireless Communication Systems	3
Third Year	V	R25-ET-HOC-301	Next Generation Networks for 5G & 6G,	3
	VI	R25-ET-HOC-302	Satellite, Optical and mmWave Communication	3
Final Year	VII	R25-ET-HOC-401	Cognitive Radio and Software Defined Radio (SDR)	3
	VIII	R25-ET-HOC-402	Information Theory and Quantum Communication	3


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**Honors Courses: Intelligent and Emerging Communication Technologies
(18 Credits)**

Year	Semester	Course Name	Credits	Suggested Reference Syllabus
Second Year	Sem III	Probability & Random Processes for Engineers	3	Probability and Random Processes NPTEL Course Code: 117103067 Probability and Random Processes, IIT Guwahati https://nptel.ac.in/courses/117103067 .
	Sem IV	MIMO Technology in Modern Wireless Communication Systems	3	Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ee115 Fundamentals Of Wireless Communication https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ee112
Third Year	Sem V	Next Generation Networks for 5G & 6G,	3	Advanced Computer Networks, IIT Indore and IIT Gandhinagar. https://nptel.ac.in/courses/106106243?utm_source=chatgpt.com
	Sem VI	Satellite, Optical and mmWave Communication	3	Satellite communication, IIT Kharagpur Prof. Kalyan Kumar Bandyopadhyay https://nptel.ac.in/courses/117105131
Final Year	Sem VII	Cognitive Radio and Software Defined Radio (SDR)	3	Basics of Software Defined Radios and Practical Applications, IIT Roorkee Prof. Meenakshi Rawat https://nptel.ac.in/courses/108107107
	Sem VIII	Information Theory and Quantum Communication	3	An Introduction to Information Theory https://nptel.ac.in/courses/117104129 Quantum Information and Computing https://nptel.ac.in/courses/115101092

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Program:		S.Y. B. Tech		Semester:		III	
Course:		Probability and Random Process for Engineers		Course Code:			
Teaching Scheme (Hrs/Week)				Examination Scheme			
Lecture	Practical	Tutorial	Credit	CCE	ESE	TW	PR
-	-	-	03			-	-
Course Description: This course introduces the fundamental concepts of probability, random variables, statistical methods and random processes required for modelling and analyzing uncertainty in engineering systems. It covers probability distributions, multiple random variables, correlation and covariance, random processes, stationary and ergodic processes, spectral analysis and noise. Emphasis is placed on engineering applications in communication systems, signal processing, electronics, control systems, IoT and artificial intelligence.							
Prerequisite: Engineering Mathematics and Basic Calculus							
Bridge Content:							
Course Objectives: 1. Understand the fundamental concepts and principles of probability applicable to engineering problems. 2. Analyse random variables using probability distributions and statistical measures. 3. Characterize multiple random variables using joint, marginal and conditional distributions. 4. Analyse random processes using correlation, covariance, stationarity and ergodicity. 5. Apply spectral analysis and random-process concepts to engineering systems and communication applications.							
Course Content							
Unit I	Fundamentals of Probability						
Introduction to probability: Concept of probability, Random experiments, Sample space and events, Types of events, Addition and multiplication theorems of probability							
Conditional Probability and Independence: Conditional probability, Independent events, Total probability theorem, Baye's theorem							
Random Experiment and Inequalities: Reliability and failure probability, Probability of error, Detection and decision-making, Markov inequality, Chebyshev inequality, Applications of probability inequalities							
Practical Applications and Usage: Communication errors and Fault detection							
Unit II	Random Variables and Probability Distributions						
Random Variables: Concept of random variable, Discrete and continuous random variables, Probability Density Function (PDF), Cumulative Distribution Function (CDF), Properties of PDF and CDF							
Mathematical Expectations: Mean or expected value, Moments, Variance, Standard deviation. Mean square value							
Probability Distributions: Uniform distribution, Gaussian/Normal distribution, Exponential distribution Rayleigh distribution							
Practical Applications and Usage: Noise modelling, Error analysis and Reliability analysis							

Unit III	Multiple Random Variables		
Joint Random Variables: Two-dimensional random variables, Joint PDF, Joint CDF, Marginal probability distributions. Conditional probability distributions Independence: Statistical independence, Independent random variables, Conditional independence Statistical Parameters: Conditional mean, Conditional variance, Covariance, Correlation coefficient Operations of Multiple Random Variables: Sum and difference of random variables, Transformation of two random variables, Distribution of sum of random variables, Central Limit Theorem			
Practical Applications and Usage: Signal estimation, Measurement uncertainty and Statistical data analysis			
Unit IV	Random Process		
Introduction to Random Processes: Definition of random process, Classification of random processes, Continuous-time and discrete-time random processes, Sample functions and ensemble, Deterministic and random signals Statistical Characterization: Mean function, Autocorrelation function, Cross-correlation function, Autocovariance function, Cross-covariance function Stationary Processes: Strict-Sense Stationarity (SSS), Wide-Sense Stationarity (WSS), Time averages and ensemble averages Ergodic Processes: Concept of ergodicity, Mean ergodicity, Correlation ergodicity, Relationship between stationarity and ergodicity			
Practical Applications and Usage: Network traffic modelling and Packet arrival processes			
Unit V	Spectral Analysis and Noise		
Power Spectral Density: Concept of power spectrum, Power Spectral Density (PSD), Properties of PSD, Relationship between autocorrelation and PSD Cross-Spectral Density: Cross-power spectral density, Relationship between cross-correlation and cross-spectrum Noise Process: Concept of noise, White noise, Gaussian noise, White Gaussian Noise, Thermal noise			
Practical Applications and Usage: Noise in communication receivers and Noise filtering			
Probability and Random Processes — IIT Guwahati Instructor: Prof. Prabin K. Bora NPTEL Course Code: 117103067 NPTEL – Probability and Random Processes, IIT Guwahati https://nptel.ac.in/courses/117103067.			

Program:		S. Y. B. Tech		Semester:		II	
Course:		MIMO Technology in Modern Wireless Communication Systems		Course Code:		R25-ET-	
Teaching Scheme				Examination Scheme			
Lecture	Practical	Tutorial	Credit	CCE	ESE	TW	PR
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Course Description: This course provides an understanding of modern wireless communication and MIMO systems, including wireless channels, MIMO architectures, diversity, multiplexing, beamforming, and advanced MIMO techniques. It covers the application of MIMO in 5G, IoT, and V2X systems and introduces emerging technologies such as RIS, Massive MIMO, THz communication, and 6G wireless systems. Course Relevance: This course is relevant to the design, analysis, and application of modern MIMO-based wireless communication systems, with emphasis on 4G/5G, IoT, V2X, and emerging 6G technologies. It develops skills in advanced antenna techniques, beamforming, Massive MIMO, and next-generation wireless technologies required for research and industry applications.							
Prerequisite: -							
Bridge Content: - Basics of wireless communication							
To understand the fundamentals, architecture, and characteristics of modern wireless communication systems and wireless channels. To study the principles, architectures, and performance parameters of MIMO communication systems and antenna techniques. To understand advanced MIMO techniques such as STBC, beamforming, precoding, and Massive MIMO. To understand the application of MIMO techniques in 5G wireless communication systems and emerging applications. To introduce emerging MIMO technologies for next-generation 6G wireless communication systems.							
Course Outcomes: After learning the course, students will be able to							
CO	Course Outcome						Bloom's Level
CO1	Explain the fundamentals, characteristics, and performance of modern wireless communication channels.						2
CO2	Describe MIMO architectures, channel capacity, diversity techniques, and antenna performance parameters.						2
CO3	Explain advanced MIMO techniques such as STBC, beamforming, precoding, and Massive MIMO.						2
CO4	Describe the application of MIMO techniques in 5G wireless communication systems.						2
Course Contents							
Unit 1	Fundamentals of Modern Wireless Communication				09Hrs.	CO1	
Wireless communication system architecture , Wireless channel characteristics ,Path loss, shadowing and multipath propagation ,Small-scale fading: Rayleigh and Rician fading ,Doppler effect and coherence time ,Diversity and multiplexing concepts							

Exemplars / Practical Applications and usage: Wireless network planning			
Unit 2	MIMO Fundamentals and Antenna Techniques	09 Hrs.	CO2
MIMO system architecture and principles , SISO, SIMO, MISO and MIMO systems ,Spatial diversity and spatial multiplexing ,MIMO channel model ,Channel capacity of MIMO systems ,Transmit and receive diversity ,Antenna correlation and mutual coupling ,Isolation enhancement techniques ,Envelope Correlation Coefficient (ECC) ,Diversity Gain (DG) and Total Active Reflection Coefficient (TARC)			
Exemplars / Practical Applications and usage: Antenna array design			
Unit 3	Advanced MIMO Techniques	09 Hrs.	CO3
Space-Time Block Coding (STBC) ,Alamouti scheme ,Space-Time Trellis Codes ,Beamforming and precoding ,Maximum Ratio Transmission ,Zero-Forcing and MMSE techniques ,Multi-user MIMO Massive MIMO.			
Exemplars / Practical Applications and usage: 5G base stations: Beamforming and Massive MIMO			
Unit 4	MIMO in 5G Wireless Systems	09 Hrs.	CO4
5G NR architecture and MIMO ,Massive MIMO in 5G ,Beam management and beamforming ,Sub-6 GHz and millimetre-wave MIMO ,OFDM and MIMO-OFDM ,Carrier aggregation ,MIMO for enhanced mobile broadband ,MIMO applications in IoT and V2X communication			
Exemplars / Practical Applications and usage: Enhanced Mobile Broadband (eMBB): MIMO-OFDM and carrier aggregation			
Unit 5	Advanced and Emerging MIMO Systems	09 Hrs.	CO5
Reconfigurable Intelligent Surfaces (RIS) ,Cell-free massive MIMO ,Distributed MIMO ,Cooperative MIMO ,Full-duplex MIMO ,Terahertz communication and ultra-massive MIMO ,MIMO for 6G wireless communication			
Exemplars / Practical Applications and usage: Reconfigurable Intelligent Surfaces (RIS)			
Textbooks:			
1. T. S. Rappaport, <i>Wireless Communications: Principles and Practice</i>, 2nd ed. Upper Saddle River, NJ, USA: Prentice Hall, 2002. 2. A. Goldsmith, <i>Wireless Communications</i>. Cambridge, U.K.: Cambridge University Press, 2005. 3. E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, and H. V. Poor, <i>MIMO Wireless Communications</i>. Cambridge, U.K.: Cambridge University Press, 2007. 4. T. L. Marzetta, E. G. Larsson, H. Yang, and H. Q. Ngo, <i>Fundamentals of Massive MIMO</i>. Cambridge, U.K.: Cambridge University Press, 2016.			
Reference Books:			
1. D. Tse and P. Viswanath, <i>Fundamentals of Wireless Communication</i>. Cambridge, U.K.: Cambridge University Press, 2005. 2. A. Paulraj, R. Nabar, and D. Gore, <i>Introduction to Space-Time Wireless Communications</i>. Cambridge, U.K.: Cambridge University Press, 2003. 3. S. Sesia, I. Toufik, and M. Baker, <i>5G System Design: Architectural and Functional Considerations and Long Term Research</i>. Hoboken, NJ, USA: Wiley, 2015.			
MOOCs Links and additional reading material:			

1. Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications
https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ee115
2. Fundamentals Of Wireless Communication

https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ee112