ECT402	WIRELESS COMMUNICATION	CATEGORY	L	T	P	CREDIT
		PCC	2	1	0	3

Preamble: This course aims to introduce students to basic theory and principles of wireless communication systems in general, and cellular systems in particular. It also introduces basics of radio wave propagation.

Prerequisite: ECT 305 Analog and Digital Communication

Course Outcomes: After the completion of the course the student will be able to

CO1 K2	Summarize the basics of cellular system and cellular design fundamentals.
CO2 K2	Describe the wireless channel models and discuss capacity of wireless channels.
CO3 K4	Analyze the performance of the modulation techniques for flat-fading channels and multicarrier modulation.
CO4 K3	Illustrate how receiver performance can be enhanced by various diversity techniques.
CO5 K3	Identify advantages of various equalization techniques and multiple-access techniques in wireless communication.
CO6 K3	Calculate system parameters such antenna height, range, maximum usable frequency in different modes of radio wave propagation.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO1	3	3	2		1			2				2
CO2	3	3	3		3							2
CO3	3	3	3		3							
CO4	3	3	3		3							
CO5	3	3	3		3							
CO6	3	3	3									2

Assessment Pattern

Bloom's Category		Continuous Assessment Tests		End Semester Examination
		1	2	
Remember				
Understand	K2	15	15	30
Apply	K3	20	20	40
Analyse	K4	15	15	30
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1) : Summarize the basics of cellular system and cellular design fundamentals. (K2).

1. List certain challenges in the design of a cellular wireless communication system.
2. A total of 33MHz of bandwidth is allocated to an FDD cellular system which uses two 25kHz simplex channels to provide full-duplex voice & control channels. Compute the number of channels available per cell if the system uses 7-cell reuse.
3. Describe methods to improve coverage and capacity of a cellular system.

Course Outcome 2 (CO2): Describe the wireless channel models and discuss capacity of wireless channels. (K2)

1. Compare and contrast flat-fading and frequency-selective fading channels.
2. How are Doppler spread and coherence time related? What is their significance?
3. Consider a Rayleigh fading channel with average received power of 25dBm. Compute the probability that the received power is below 10dBm.
4. Differentiate between ergodic capacity and capacity with outage.

Course Outcome 3 (CO3): Analyze the performance of the modulation techniques for flat-fading channels and multicarrier modulation. (K4)

1. Under Rayleigh flat-fading, derive an expression for the required average SNR to ensure that outage probability does not below P_{out} .
2. How can subcarrier fading be mitigated?
3. Why is cyclic prefix required in OFDM?

Course Outcome 4 (CO4): Illustrate how receiver performance can be enhanced by various diversity techniques. (K3)

1. Explain receiver diversity technique of maximal ratio combining technique.
2. Describe Almouti scheme for 2x2 MIMO.
3. Find the outage probability of BPSK modulation at $P_b = 10^{-3}$ for a Rayleigh fading channel with SC diversity for M = 1 (no diversity) M = 2. Assume equal branch SNRs of 15 dB.

Course Outcome 5 (CO5): Identify advantages of various equalization techniques and multiple-access techniques in wireless communication. (K3)

1. Describe the steps for LMS algorithm.
2. Compare multiple-access schemes TDMA, FDMA and CDMA.
3. Consider a channel with impulse response h(t) = exp(-t/T) u(t). Find two-tap Zero-forcing equalizer for this channel?

Course Outcome 6 (CO6): Calculate system parameters such antenna height, range, maximum usable frequency in different modes of radio wave propagation. (K3)

1. Derive expression for critical frequency, maximum usable frequency and skip distance (assuming flat earth's surface) for sky wave propagation.
2. A communication system is to be established at a frequency of 50MHz with a transmitter power 1.2kW. The field strength of the directive antenna is 3 times that of a half wave antenna, ht = 50m , hr = 5m. A field strength of 80μV/m is required to give satisfactory reception. Find the range of the system.

SYLLABUS

Module 1: Introduction to Wireless Communication Systems (8 Hours)

1.1 Introduction to Wireless Communication Systems (4): Generations: 2G, 3G, 4G, 5G. Wireless LAN, Bluetooth and Personal Area networks, Broadband Wireless Access -- WiMAX Technology. Wireless Spectrum allocation, Standards.

1.2 Cellular System Design Fundamentals (4): Frequency Reuse, channel assignment strategies, Handoff strategies, Interference and system capacity, trunking and grade off service, improving coverage and capacity – cell splitting, sectoring, microcells.

Module 2: Wireless Channels (7 Hours)

2.1 Path loss and shadowing (1): Free space path loss, Two-Ray model, Shadowing,

2.2 Statistical Multipath Channel Models (4): Time-varying channel impulse response, Narrowband fading, Wideband fading models, Delay spread and Coherence bandwidth, Doppler spread and Coherence time, Flat fading versus frequency selective fading, Slow fading versus fast fading, Discrete-time model.

2.3 Capacity of Wireless Channels (2): Review of Capacity in AWGN, Capacity of flat fading channel – Ergodic capacity, Capacity with Outage, Capacity with CSI-R. (Derivations of capacity formulae are not required; Only expressions, computations and significance required.)

Module 3: Modulation techniques (7 Hours)

2.1 **Digital Signaling for Flat fading Channels (4):** Analysis of Average Error Probability and Outage probability of BPSK in flat-fading channels.

2.2 **Multi-carrier Modulation (3**): Data transmission using multicarrier modulation for frequency-selective fading channels. Overlapping subchannels, Mitigation of Subcarrier Fading, Discrete Implementation of multicarrier – OFDM. Cyclic prefix, Peak-to-average-power-ratio.

Module 4: Diversity, Equalization, and Multiple Access (8 Hours)

4.1 Diversity (3 hours): Receiver diversity – selection combining, maximal ratio combining. Transmitter diversity – Alamouti scheme for 2x2 MIMO.

4.2 Equalization (3): Equalization – Linear and non-linear equalization, Zero forcing, MMSE equalizers. LMS algorithm. Adaptive Equalization.

4.3 Multiuser Systems (2): Uplink and Downlink, Multiple Access, Frequency-Division Multiple Access (FDMA), Time-Division Multiple Access (TDMA), Code-Division Multiple Access (CDMA), Orthogonal Frequency-Division Multiple Access (OFDMA).

Module 5 Radio Wave Propagation (7 Hours)

Ground wave propagation, Plane earth reflection, Space wave and surface wave, Spherical earth propagation, Tropospheric waves, Ionospheric propagation, Effects of earth's magnetic field, Critical frequency, Maximum usable Frequency, Virtual height.

Text Books

1. Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2005
2. Theodore S. Rappaport, Wireless communication: Principles and Practice, 2/e, Pearson Education, 1990
3. Aditya Jagannatham, Principles of Modern Wireless Communication Systems, Mc Graw Hill, 2017.
4. Robert Collin, Antennas and Radiowave Propagation, McGraw Hill, 2016.

Reference Books

1. David Tse and Pramod Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005
2. Jochen Schiller, Mobile Communications, Pearson, 2008
3. Andreas F Molish , Wireless Communications, 2nd Edition , Wiley India Publications, 2013
4. W. C. Y. Lee, Mobile Cellular Telecommunication, McGraw Hill,
5. Gordon L. Stuber, Principles of Mobile Communication , Springer,2017
6. Rahim Thafazoli, Technologies for The Wireless Future , Volume 2 , Wiley and Sons , 2004
7. Edward C Jordan and Keith G Balmain, Electromagnetic Wave and Radiating System, Pearson.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Introduction to wireless communication systems (8 Hours)**	
1.1	Generations: 2G, 3G, 4G, 5G.	2
1.2	Wireless LAN, Bluetooth and Personal Area networks, Broadband Wireless Access -- WiMAX Technology.	1
1.3	Wireless Spectrum allocation, Standards	1
1.4	Cellular concept, Frequency Reuse, channel assignment strategies,	2

	Handoff strategies	
1.5	Interference and system capacity, trunking and grade off service.	1
1.6	improving coverage and capacity – cell splitting, sectoring, microcells.	1
2	**Wireless Channels (7 Hours)**	
2.1	Free space path loss, Two-Ray model, Shadowing	1
2.3	Time-varying channel impulse response, Narrowband fading	2
2.4	Wideband fading models – Delay spread and Coherence bandwidth, Doppler spread and Coherence time	1
2.5	Flat fading versus frequency selective fading, Slow fading versus fast fading, Discrete-time model.	1
2.6	Review of Capacity in AWGN, Capacity of flat fading channel – Ergodic capacity, Capacity with Outage, Capacity with CSI-R.	2
3	**Modulation Techniques (7 Hours)**	
3.1	Average Probability of error and outage probability	1
3.2	Performance evaluation of BPSK in flat fading channels	2
3.4	Multi carrier modulation in frequency-selective channel	1
3.5	OFDM – DFT/IDFT, Cyclic Prefix	2
3.6	PAPR	1
4	**Diversity, Equalization and Multiple Access (8 Hours)**	
4.1	Receiver Diversity – Selection combining, Maximal ratio combining	2
4.2	Transmit Divesity – Alamouti for 2x2 MIMO	1
4.3	Equalization – linear and nonlinear, ZF and MMSE, LMS, Adaptive	3
4.4	Multiple access – FDMA, TDMA, CDMA, OFDMA	2
5	**Radio Wave Propagation (7 Hours)**	
5.1	Ground wave propagation, Plane earth reflection, Space wave and surface wave	2
5.2	Spherical earth propagation, Tropospheric waves, Ionospheric propagation	2
5.3	Effects of earth's magnetic field, Critical frequency, Maximum usable Frequency, Virtual height.	3
	Total Hours	**37**

Simulation Assignments:

1. Simulate flat fading and frequency-selective fading wireless channel models using Python/MATLAB
2. Evaluate BPSK, QPSK, QAM in wirelss fading channels using Python/MATLab.
3. Evaluate zero-forcing and MMSE equalization techniques using Python/MATLAB.
4. Simulation of standard path loss models using Python/MATLab.
5. Simulation of Alamouti scheme using Python/MATLab
6. Students can undertake course projects based on following topics: (a) Channel Modelling of wireless channels (b) Comparison of modulation schemes for wireless system (c) Multi carrier modulation schemes (d) Comparison of equalization techniques (e) Implementation of MIMO schemes.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

EIGHTH SEMESTER B. TECH. DEGREE EXAMINATION

Course Code: ECT402

Course Name: WIRELESS COMMNICATION

Max. Marks: 100 Duration: 3 Hours

PART A

(Answer ALL Questions. Each Question Carries 3 Marks.)

1. Give important features of 5G system.
2. Discuss different handoff strategies.
3. Explain the notion of delay spread and coherence bandwidth.
4. Give the expression for capacity of flat fading AWGN channel with CSIR. Describe how it is obtained assuming AWGN capacity.
5. Define outage probability.
6. What is the purpose of using cyclic prefix in an OFDM system?
7. Consider a channel with impluse response h(t) = exp(-t/T) u(t). Find tap coefficients of a two-tap zero-forcing equalizer for this channel.
8. Why do we say that maximal ratio combining achieves full diversity?
9. Distinguish between critical frequency and maximum usable frequency.
10. Define virtual height in antennas. [10 X 3= 30]

PART – B

(Answer one question from each module; each question carries 14 marks)

Module I

11. (a) How are co-channel signal-to-interference ratio, cluster size and system capacity are related to one another in a cellular system ? Explain with necessary equations. [07 Marks]

(b) Explain the architecture of wireless LAN (WLAN). [07 Marks]

OR

12. (a) List three differences between 2G and 3G systems. [03 Marks]

(b) A total of 33MHz of bandwidth is allocated to an FDD cellular system which uses two 25kHz simplex channels to provide full-duplex voice & control channels. Compute the number of channels available per cell if the system uses 7-cell reuse. [03 Marks]

(c) What is cell splitting? How does it improve system performance? [08 Marks]

Module II

13. (a) Explain the effect of multipath propagation using 2-ray model. [07 Marks]

(b) Assuming narrow band fading model, derive statistical characterization of in-phase and quadrature components of a received signal when an unmodulated carrier is transmitted. [07 Marks]

OR

14. (a) Derive time-varying impulse response of multipath wireless channel. [07 Marks]

(b) Consider a flat-fading channel with iid channel gains g[i] which can take on values g1=0.05 with probablity p1=0.1, g2=0.5 with probability p2=0.5, and g3=1 with probability p3=0.4. The transmit power is 10mW, noise spectral density N0 = 10^{-9} W/Hz, and channel bandwidth is 30kHz. Assume instantaneous CSI-R, but transmitter does not have CSI. Compute the capacity of the channel. [07 Marks]

Module III

15. (a) Derive expression for average probability of error in BPSK under Rayleigh flat-fading when symbol duration is roughly equal to channel coherence time. [07 Marks]

(b) What is Peak-to-Average Power-Ratio (PAPR) in OFDM system? How can it be reduced ? [07 Marks]

OR

16. (a) Determine the average SNR per bit of BPSK modulation in Rayleigh slow-fading channel such that 95% of the times, average probability of bit error is less than 10^{-4} . [05 Marks]

(b) Explain multi-carrier modulation in OFDM. [09 Marks]

Module IV

17. (a) Explain Least-Mean-Square algorithm for equalization. [09 Marks]

(b) Compute the average probability of bit error of BPSK under maximal-ratio-combining two-branch diversity with iid Rayleigh fading. Average SNR on each branch is 10dB. [05 Marks]

OR

18. (a) Describe Alamouti scheme for 2x2 MIMO. [07 Marks]

(b) Describe how multiple-access works on uplink and downlink in CDMA. [07 Marks]

Module V

19. (a) Derive an expression for the LOS distance in km when the antenna heights above ground are ht and hr respectively for the transmitter and receiver antennas. [07 Marks]

(b) A receiving antenna is located at 80km from the transmitting antenna. The height of the transmitting antenna is 100m. What is the required height of the receiving antenna? [07 Marks]

OR

20. (a) An HF radio communication is to be established between two points on the earth's surface. The points are at a distance of 2600km. The height of the ionosphere layer is 200km and critical frequency is 4MHz. Find maximum usable frequency. [07 Marks]

(b) Derive expression for critical frequency, maximum usable frequency and skip distance (assuming flat earth's surface) for sky wave propagation. [07 Marks]