SRM Institute of Science and Technology
College of Engineering and Technology

AK - SET-A

DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

Academic Year: 2023-24 (ODD)

Test: CLAT–II | **Date: 06/10/2023**
Course Code & Title: 18ECC301T Wireless Communications | **Duration: 08.00 AM to 09.40 AM**
Year & Sem: IV / VII | **Max. Marks: 50**

Course Articulation Matrix:

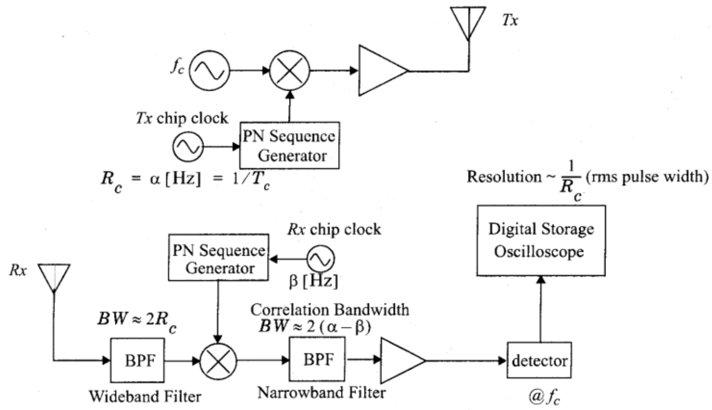
	18ECC301T - Wireless Communication	Program Outcomes (POs)														
		Graduate Attributes												PSO		
COs	Course Outcomes (COs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO-1	Interpret the concepts of Wireless communication and basic cellular networks	3	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO-2	Analyze different Radio wave propagation models for cellular communication	-	3	-	3	-	-	-	-	-	-	-	-	-	-	3
CO-3	Apply different multipath propagation channel models in wireless systems	-	3	3	-	-	-	-	-	-	-	-	-	-	-	2
CO-4	Illustrate the Link performance improvement techniques	-	3	-	-	-	-	2	-	-	-	-	-	-	-	3
CO-5	Summarize different wireless communication standards and systems	-	-	2	-	-	2	-	-	-	-	-	-	2	-	-

Part – A
(10 × 1 = 10 Marks)
Instructions: Answer ALL Questions.

Q. No.	Question	Marks	BL	CO	PO
1	Calculate the Brewster angle for a wave impinging on ground having a permittivity of $\varepsilon r = 5$. (a)21.09 **(b) 24.09** (c) 23.09 (d) 22.09	1	2	2	4
2	____ occurs when a propagating electromagnetic wave impinges upon an object which has very sharp featured dimensions and edges (a) Refraction **(b) Diffraction** (c) Reflection (d) Scattering	1	1	2	2
3	If a transmitter produces 50 W of power, express the transmit power in units of dBm and dBw. (a) 17 and 47 (b) 19 and 49 (c) 49 and 19 **(d) 47 and 17**	1	2	2	4
4	The fraunhofer distance is given by (a) $d_f = (2D^2)/\lambda^2$ (b) $d_f = (4D)^2/2\lambda$ (c) $d_f = (4D^2)/\lambda$ **(d) $d_f = (2D^2)/\lambda$**	1	1	2	4
5	______ Model is a special case of the piecewise model. (a) Okumara **(b) Dual slope** (c) Hata (d) Durkins	1	1	2	2
6	Flat fading or Frequency non-selective fading is a type of (a) **Multipath delay spread small scale fading** (b) Doppler spread small scale fading (c) Multipath doppler spread large scale fading (d) Delay spread large scale fading	1	1	3	2
7	When the dominant component fades away, the Ricean distribution degenerates to ________ distribution. (a)Gaussian **(b)Ricean** (c) Log normal (d) Gamma	1	1	3	2
8	If coherence bandwidth is smaller than the bandwidth of the signal, _____ fading occurs. (a)Flat **(b) Frequency selective**	1	1	3	3

	(c) Fast fading (d) Time selective				
9	The maximum excess delay of the channel is given by **(a)N$\Delta\tau$** (b) $\Delta\tau$/N (c) 2 N$\Delta\tau$ (d) (N-1)$\Delta\tau$	1	1	3	2
10	The power delay profile helps in determining (a)Small scale delay **(b) RMS delay spread** (c)Minimum delay spread (d) Excess doppler spread	1	1	3	3
	Part – B1 **(2 × 4 = 8 Marks)** **Instructions: Answer any TWO Questions.**				
11	For a wireless system with two paths between transmitter and receiver, express an expression for path loss if the receiver is placed at a distance 'd'. Two-ray path loss model: PL (dB)= 40 log d – [10 log G_t + 10 log G_r + 20 log h_t + 20 log h_r]	4	2	2	2
12	Calculate the far field distance for an antenna with maximum dimension of 2m and operating frequency of 1 GHz, also calculate the length of the monopole antenna if the antenna used is a monopole. $d_f = \frac{2D^2}{\lambda}$ — (1) $\boxed{\lambda = \frac{c}{f} = 0.3}$ $d_f = \frac{2\times 4}{0.3}$ (1) $d_f = \frac{8}{0.3} = 26.667$ m $l = \lambda/4 = \frac{0.3}{4} = 0.075$m (1) (1)	4	3	2	2

13	Brief about the combined path loss model and shadowing. **Explanation - (3)** **Equation – (1)** • The complexity of signal propagation makes it difficult to obtain a single model that characterizes path loss accurately across a range of different environments. • Accurate path-loss models can be obtained from complex analytical models or empirical measurements when tight system specifications must be met or the best locations for base stations or access-point layouts must be determined. • However, for general trade-off analysis of various system designs it is sometimes best to use a simple model that captures the essence of signal propagation without resorting to complicated path-loss models, which are only approximations to the real channel anyway. Thus, the following simplified model for path loss as a function of distance is commonly used for system design Models for path loss and shadowing can be superimposed to capture power falloff versus distance along with the random attenuation about this path loss from shadowing. In this combined model, average dB path loss ($\mu_{\psi_{dB}}$) is characterized by the path-loss model while shadow fading, with a mean of 0 dB, creates variations about this path loss, as illustrated by the path-loss and shadowing curve in Figure 2.1. Specifically, this curve plots the combination of the simplified path-loss model (2.39) and the log-normal shadowing random process defined by (2.46) and (2.50). For this combined model, the ratio of received to transmitted power in dB is given by $$\frac{P_r}{P_t}\text{ dB} = 10\log_{10} K - 10\gamma\log_{10}\frac{d}{d_0} - \psi_{dB}, \quad (2.51)$$ where ψ_{dB} is a Gauss-distributed random variable with mean zero and variance $\sigma^2_{\psi_{dB}}$. In (2.51) and as shown in Figure 2.1, the path loss decreases linearly relative to $\log_{10} d$ with a slope of 10γ dB/decade, where γ is the path-loss exponent. The variations due to shadowing $$\frac{P_r}{P_t} = K\left(\frac{d_0}{d}\right)^{\gamma}\psi$$ $$\frac{P_r}{P_t}(dB) = 10\log_{10} K - 10\gamma\log_{10}\left(\frac{d}{d_0}\right) + \psi_{dB},$$ $$\psi_{dB} \sim N(0,\sigma^2_{\psi})$$	4	2	2	4
	Part – B2 **(2 × 4 = 8 Marks)** **Instructions: Answer any TWO Questions.**				
14	Compare slow and fast fading of multipath fading channel. **Point wise comparison each 1 mark – (4)** **Fast Fading:** The channel impulse response changes rapidly within the symbol duration. • The coherent time of the channel is smaller than the symbol period of the transmitted signal. • Cause frequency dispersion due to Doppler spreading. • A signal undergoes fast fading if $T_S > T_C$ and $B_S < B_D$ • Depending on how rapidly the transmitted baseband signal changes as compared to the rate of change of the channel, a channel may be classified either as a *fast fading* or *slow fading* channel.	4	1	3	2

	Slow Fading: The channel impulse response changes at a rate much slower than the transmitted baseband signal s(t). • The Doppler spread of the channel is much less then the bandwidth of the baseband signal. • A signal undergoes slow fading if $T_S << T_C$ and $B_S >> B_D$				
15	Draw the block diagram of Spread spectrum sliding correlator channel sounding.  	4	2	3	2
16	Brief about the significance of Ricean fading. Explanation – (2) Equation – (2) Ricean: there is a dominant stationary (non fading) signal component present (LOS), Small scale fading envelope is Ricean. - Random multipath components arriving at diff angles are superimposed on stationary dominant signal. - At the output of envelope detector – effect of adding a dc component to multipath. - Effect of dominant signal with many weaker multipath signals. – dominant signal weakens – Rayleigh. $P(r) = \begin{cases} \frac{r}{\sigma^2} e^{-\frac{(r^2+A^2)}{2\sigma^2}} I_0\left(\frac{Ar}{\sigma^2}\right) & (A \geq 0, r \geq 0) \\ 0 & r < 0 \end{cases}$ A – peak amplitude of dominant signal I_0 – Bessel fn of first kind.	4	2	3	3
	Part – C **(2 × 12 = 24 Marks)**				
17	(a) Using Friis transmission formula, derive the path loss for a wireless system using free space path loss model. If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, What is Pr (10 km)? Assume unity gain for the receiver antenna. **Friis Equation – (2)** **Briefing + Derivation – (2)** **Final Expression – (2)**	6+6	3	2	2

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear line-of-sight path between them.
As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the T -R separation distance raised to some power (i.e. a power law function).

Friis free space equation: $P_r(d) = \dfrac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$

$G = \dfrac{4\pi A_e}{\lambda^2}$ $\quad \lambda = \dfrac{c}{f} = \dfrac{2\pi c}{\omega_c}$ $\quad EIRP = P_t G_t$

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right)$$

- When antenna gains are excluded

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left(\frac{\lambda^2}{(4\pi)^2 d^2}\right)$$

- The far-field region of a transmitting antenna is defined as the region beyond the far-field distance

$$d_f = \frac{2D^2}{\lambda}$$

- To be in the far-filed region the following equations must be satisfied $d_f >> D$ and $d_f >> \lambda$
- $P_r(d) = \dfrac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$
- Use close-in distance and a known received power at that point
- $P_r(d) = P_r(d_0)\left(\dfrac{d_0}{d}\right)^2 \quad d \geq d_0 \geq d_f$

Transmitter power

$P_t(dBm) = 10\log \dfrac{P_t\ mW}{1\ mW}$

$= 10\log[50\times10^3]$

$= 47\,dBm$

$P_t(dBW) = 10\log \dfrac{P_t\ W}{1\ W}$

$= 10\log 50$

$= 17\,dBW$ ——— 2 marks

Received power

$P_r = \dfrac{P_t \cdot G_t \cdot G_r \lambda^2}{(4\pi)^2 d^2 L}$

$= \dfrac{50\times1\times1\times(1/3)^2}{(4\pi)^2\times(100)^2\times(1)}$

$= 3.5\times10^{-6}\,W = 3.5\times10^{-3}\,mW$

$P_r(dBm) = 10\log P_r(mW)$

$= 10\log(3.5\times10^{-3})$

$= -24.5\,dBm$ $\longrightarrow$ 2 marks

for 10 km, $d_0 = 100m$ $\quad d = 10\,km$

$P_r(10\,km) = P_r(100) + 20\log\dfrac{100}{10000}$

$= -24.5\,dBm - 40\,dB$

$= -64.5\,dBm$ $\longrightarrow$ 2 marks.

OR

(b) Explain in detail Okumara empirical model to calculate the mean path loss.

Explanation – (4)

Equation – (3)

Sub Equations – (3)

Main Equation Legends explanation – (2)

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Okumura Model:

Okumura`s model is one of the most widely used models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHz to 1920 MHz (although it is typically extrapolated up to 3000 MHz) and distances of 1 km to 100 km. It can be used for base station antenna heights ranging from 30 m to 1000 m. Okumura developed a set of curves giving the median attenuation relative to free space (Amu), in an urban area over a quasi-smooth terrain with a base station effective antenna height (hte) of 200 m and a mobile antenna height (hre) of 3 m. These curves were developed from extensive measurements using vertical omni-directional antennas at both the base and mobile, and are plotted as a function of frequency in the range 100 MHz to 1920 MHz and as a function of distance from the base station in the range 1 km to 100 km. To determine path loss using Okumura`s model, the free space path loss between the points of interest is first determined, and then the value of Amu(f, d) (as read from the curves) is added to it along with correction factors to account for the type of terrain. The model can be expressed as

$L50(dB) = LF + Amu(f, d) - G(te) - G(re) - G_{AREA}$

where L50 is the 50th percentile (i.e., median) value of propagation path loss, LF is the free space propagation loss, Amu is the median attenuation relative to free space, G(hte) is the base station antenna height gain factor, G(hre) is the mobile antenna height gain factor, and G A R E A is the gain due to the type of environment. Note that the antenna height gains are strictly a function of height and have nothing to do with antenna patterns.

$$G(h_{te}) = 20\log\left(\frac{h_{te}}{200}\right) \qquad 1000\ \text{m} > h_{te} > 30\ \text{m}$$

$$G(h_{re}) = 10\log\left(\frac{h_{re}}{3}\right) \qquad h_{re} \le 3\ \text{m}$$

$$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) \qquad 10\ \text{m} > h_{re} > 3\ \text{m}$$

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(a) For the scenario of small scale fading, derive the baseband impulse response model with relevant expressions.

Briefing – (2)
Equations – (4)
Impulse Block Diagram – (4)
Final response equation – (2)

A mobile radio channel may be modelled as a linear filter with a time varying impulse response

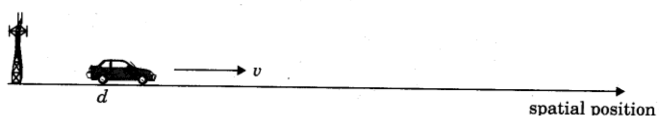
- time variation is due to receiver motion in space
- filtering is due to multipath

The channel impulse response can be expressed as *h(d,t).* Let *x(t)* represent the transmitted signal, then the received signal *y(d,t)* at position *d* can be expressed as

$$y(d,t) = x(t) \otimes h(d,t) = \int_{-\infty}^{\infty} x(\tau)h(d,t-\tau)d\tau$$

- For a causal system

$$y(d,t) = \int_{-\infty}^{t} x(\tau)h(d,t-\tau)d\tau$$



$$y(vt,t) = \int_{-\infty}^{t} x(\tau)h(vt,t-\tau)d\tau$$

$$y(t) = \int_{-\infty}^{t} x(\tau)h(t,\tau)d\tau = x(t) \otimes h(t,\tau)$$

$$\frac{1}{2}r(t) = \frac{1}{2}c(t) \otimes \frac{1}{2}h_b(t,\tau) \qquad \text{or} \qquad r(t) = \frac{1}{2}c(t) \otimes h_b(t,\tau)$$

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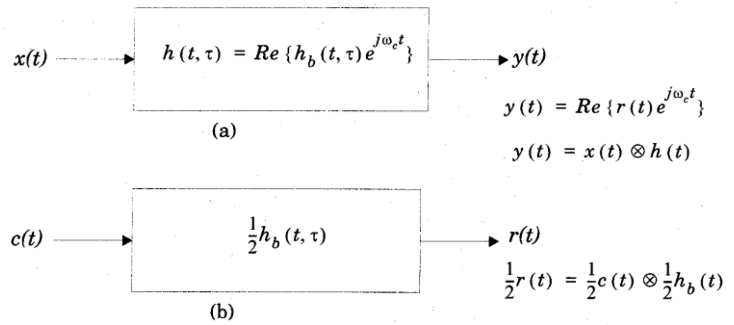
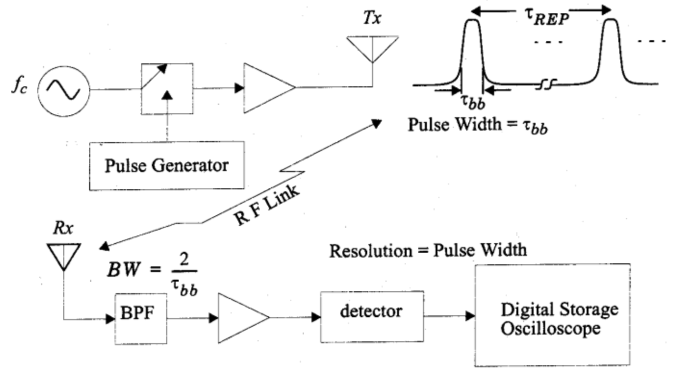
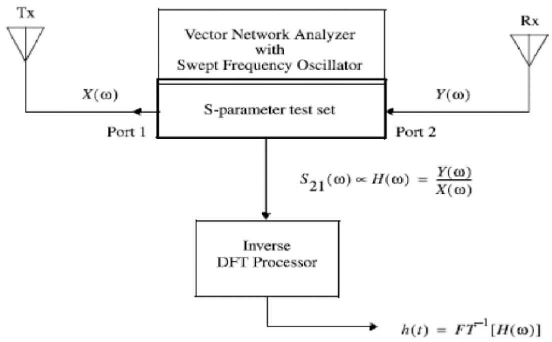
	
	
	$r(t) = c(t) \otimes \frac{1}{2}h_b(t,\tau)$
	where $c(t)$ and $r(t)$ are the complex envelopes of $x(t)$ and $y(t)$, defined as
	$x(t) = Re\{c(t)\exp(j2\pi f_c t)\}$
	$y(t) = Re\{r(t)\exp(j2\pi f_c t)\}$
	• The baseband response of a multipath channel can be expressed as
	$h_b(t,\tau) = \sum_{i=0}^{N-1} a_i(t,\tau)\exp(j2\pi f_c \tau_i(t) + j\phi(t,\tau))\delta(\tau - \tau_i(t))$
	OR
	(b) Describe direct RF Pulse and frequency domain measurement technique of small scale multipath channels.
	Assume the speed of an aircraft (which is moving towards the airport control tower with an elevation angle of 60 deg) to be 200 km/hr. What is the expected doppler shift of the received signal if the communication between the aircraft and control tower operations are at 200 MHz?
	Direct RF Pulse – Diagram – (2) + Explanation – (2)
	Frequency domain - Diagram – (2) + Explanation – (2)
	Numerical – (4)
	Direct RF Pulse:
	• This method help us to determine the power delay profile directly
	• Objective is to find impulse response
	• A narrow pulse is used for channel sounding.
	• At the receiver the signal is amplified and detected using an envelope detector.
	• It is then stored on a high speed digital oscilloscope.
	• If the receiver is set on averaging mode, the local average power delay profile is obtained
	• Direct RF pulse system
	    • This system transmits a repetitive pulse of width , and uses a receiver with a wideband filter with bandwidth
	    • Envelope detector to detect the amplitude response.
	• Minimum resolvable delay
	• No phase information can be measured.
		8+4	3	3	3



Frequency domain :

Frequency Domain channel Sounding:
dual relationship betwn time & frequency – channel IR in freq. domain
– measuring channel IR
– A vector network analyzer controls a Synthesized freq Sweeper.
– S parameter test set is used to monitor the freq response of the channel.
– freq Sweeper Scans a particular freq band by stepping through discrete freqs. / Start & Stop freq
– need to have Synchronization betwn Tx & Rx. (losses)
– Not real time – IR.
– Lot of measurements needed. for every step.
– For every freq point, channel changes averaging needed.
– Number and spacing of freq steps impact time resolution of IR
– Network analyzer determines the complex response $S_{21}(\omega)$ of the channel over the measured freq range.
– Transmissivity – freq domain representation of channel IR
– Response is converted to time domain by IDFT



18 (b) 200 km/hr → speed of aircraft

200 MHz → f_c

$V_m = 200\ km/hr$

$= \frac{200 \times 10^3}{3600} = 55.55\ m/s$ → 2 marks

$\theta = 60^\circ$

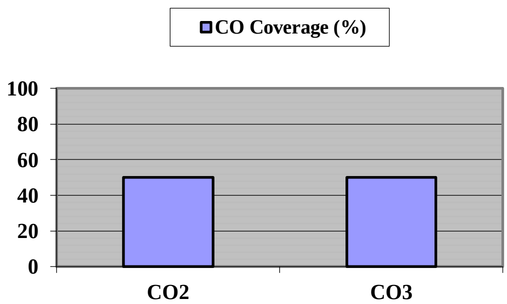
$\cos 60 = 0.5$

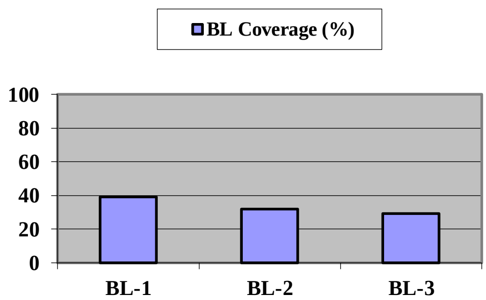
∴ doppler freq $f_d = \frac{f_c}{c} V_m \cos 60^\circ$

$= \left(\frac{200 \times 10^6}{3 \times 10^8}\right) \times 55.55 \times 0.5$

$= 18.51\ Hz$ → 2 marks.

Course Outcome (CO) and Bloom's level (BL) Coverage in Questions





Approved by the Course Coordinator **Signature of the Question paper setter**

Evaluation Sheet

Name of the Student: **Register No.: ………………….………**

Part-A (10 × 1 = 10 Marks)					
Q. No	CO	PO	Maximum Marks	Marks Obtained	Total
1	CO2	4	1		
2	CO2	2	1		
3	CO2	4	1		
4	CO2	4	1		
5	CO2	2	1		
6	CO3	2	1		
7	CO3	2	1		
8	CO3	3	1		
9	CO3	2	1		
10	CO3	3	1		
Part-B1 (2 × 4 = 8 Marks)					
11	CO2	2	4		
12	CO2	2	4		
13	CO2	4	4		
Part-B2 (2 × 4 = 8 Marks)					
14	CO3	2	4		
15	CO3	2	4		
16	CO3	3	4		
Part-C (2 × 12 = 24 Marks)					
17(a)	CO2	2	12		
17(b)	CO2	4	12		
18(a)	CO3	2	12		
18(b)	CO3	3	12		

Consolidated Marks:

CO	Maximum Marks	Marks Obtained
2	25	
3	25	
Total	50	

PO	Maximum Marks	Marks Obtained
2	45	
3	18	
4	19	
Total	72	

Signature of Course Teacher

Signature of the Course Coordinator

Signature of the Academic Advisor

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College of Engineering and Technology

AK-SET-B

DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

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Year & Sem: IV / VII	**Max. Marks: 50**

Course Articulation Matrix:

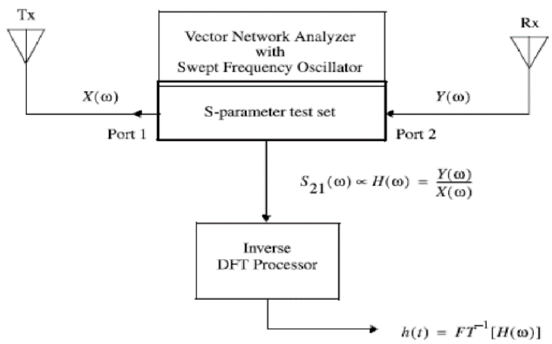
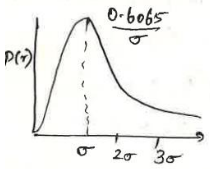
	18ECC301T - Wireless Communication	**Program Outcomes (POs)**														
		Graduate Attributes												**PSO**		
COs	**Course Outcomes (COs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
CO-1	Interpret the concepts of Wireless communication and basic cellular networks	3	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO-2	Analyze different Radio wave propagation models for cellular communication	-	3	-	3	-	-	-	-	-	-	-	-	-	-	3
CO-3	Apply different multipath propagation channel models in wireless systems	-	3	3	-	-	-	-	-	-	-	-	-	-	-	2
CO-4	Illustrate the Link performance improvement techniques	-	3	-	-	-	-	2	-	-	-	-	-	-	-	3
CO-5	Summarize different wireless communication standards and systems	-	-	2	-	-	2	-	-	-	-	-	-	2	-	-

Part – A
(10 × 1 = 10 Marks)
Instructions: Answer ALL Questions.

Q. No.	Question	Marks	BL	CO	PO
1	Find the far – field distance (in metres) for an antenna with maximum dimension of 2 m and operating frequency of 1000 MHz (a) 20.64 **(b) 26.64** (c) 24.64 (d) 25.64	1	2	2	4
2	____ occurs when a propagating electromagnetic wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave (a) Refraction **(b) Reflection** (c) Diffraction (d) Scattering	1	1	2	2
3	A mobile is located 10 km away from a base station and uses a vertical λ/4 monopole antenna with a gain of 2.55 dB to receive cellular radio signals. The E field at 1 km from the transmitter is measured to be 10-3 V/m. The carrier frequency used for this system is 900 MHz, calculate the length (in metres) of the receiving antenna. (a) 0.093 (b) 1.083 (c) 0.077 **(d) 0.083**	1	2	2	4
4	The path loss exponent 'n' value for free space is (a) 0 (b) 2 (c) 1 **(d) 1.5**	1	1	2	4
5	______ Model uses diffraction to predict average signal strength at street level. (a) Okumara **(b) Walfish and Bertoni** (c) Hata (d) Durkins	1	1	2	2
6	__________ small scale multipath measurement uses a wideband pulsed bistatic radar that transmits a repetitive pulse width. (a) Spread spectrum (b) Indirect RF pulse **(c) Direct RF pulse** (d) Envelope detector	1	1	3	2
7	In slow fading channels, Doppler spread of the channel is much less than the _____of baseband signal **(a) Bandwidth** (b) Time (c) Phase (d) Symbol period	1	1	3	2
8	The distribution present in small scale fading envelope of a non-fading signal component is ____________.	1	1	3	3

	(a) Rayleigh **(b) Ricean** (c) Gaussian (d) Normal				
9	Power delay profile is represented as plots of ___________ with respect to fixed time delay reference. **(a)Relative received power** (b) Frequency c)Transmitted power (d)Relative phase	1	1	3	2
10	The presence of reflecting objects and scatters in the channel create a constantly changing environment that dissipates the signal energy in amplitude, phase, and time is known as __________. **(a) Multipath propagation** (b) Doppler effect (c) Line of sight (d) Doppler shift	1	1	3	3
	Part – B1 **(2 × 4 = 8 Marks)** **Instructions: Answer any TWO Questions.**				
11	For a wireless system with only one line of sight path between transmitter and receiver, deduce an expression for path loss if the receiver is placed at a far field distance. **Friis Equation – (1)** **Briefing + Derivation – (2)** **Final Expression – (1)** The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear line-of-sight path between them. As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the T -R separation distance raised to some power (i.e. a power law function). **Friis free space equation:** $P_r(d)=\frac{P_tG_tG_r\lambda^2}{(4\pi)^2d^2L}$ $G=\frac{4\pi A_e}{\lambda^2}$ $\lambda=\frac{c}{f}=\frac{2\pi c}{\omega_c}$ $EIRP=P_tG_t$ $PL(dB)=10\log\frac{P_t}{P_r}=-10\log\left(\frac{G_tG_r\lambda^2}{(4\pi)^2d^2}\right)$ • When antenna gains are excluded $PL(dB)=10\log\frac{P_t}{P_r}=-10\log\left(\frac{\lambda^2}{(4\pi)^2d^2}\right)$ • The far-field region of a transmitting antenna is defined as the region beyond the far-field distance $d_f=\frac{2D^2}{\lambda}$ • To be in the far-filed region the following equations must be satisfied d_f >> D and df >> λ • $P_r(d)=\frac{P_tG_tG_r\lambda^2}{(4\pi)^2d^2L}$ • Use close-in distance and a known received power at that point • $P_r(d)=P_r(d_0)\left(\frac{d_0}{d}\right)^2$ $d\ge d_0\ge d_f$	4	2	2	2
12	Define Brewster angle and calculate the Brewster angle for a dielectric constant of 5. Angle at which no reflection occurs **– (2)** Equation - **$\sin(\theta_B) = \sqrt{(\varepsilon_r-1)}/\sqrt{(\varepsilon_r^2-1)}$** **- (1)** Brewster angle – 24.09^0 **– (1)**	4	3	2	2
13	Brief about the simplified path loss model. **Explanation – (2)** **Equation – (2)** **Simplified path loss model:** For general trade-off analysis of various system designs it is better to use a simple model that captures the essence of signal propagation Thus, the simplified model for path loss as a function of distance is commonly used for system design $P_r = P_t K [d_0/d]^\gamma$ The dB attenuation is thus P_r dBm = P_t dBm + K dB - $10\gamma\log_{10}[d/d_0]$ K is a unitless constant that depends on the antenna characteristics and the average channel attenuation, d0 is a reference distance for the antenna far field, and γ is the pathloss exponent.	4	2	2	4

Part – B2
(2 × 4 = 8 Marks)
Instructions: Answer any TWO Questions.

14	List out the factors influencing the small scale fading. **Each Point – (1) – 4x1 – (4)** • Multipath propagation: reflection objects and scatters • Speed of the mobile: Doppler shifts • Speed of surrounding objects • Transmission bandwidth of the signal The received signal will be distorted if the transmission bandwidth is greater than the bandwidth of the multipath channel. Coherent bandwidth: bandwidth of the multipath channel.	4	1	3	2
15	Draw the block diagram of Frequency domain channel sounding system.  	4	2	3	2
16	Brief about the significance of Rayleigh fading. **Briefing – (2)** **Equation + Graph – (2)** Rayleigh – Used to describe the statistical time varying nature of received envelope of a flat fading signal. or envelope of individual multipath component. - Envelope of sum of two quadrature gaussian noise signal obeys a Rayleigh Pdf  $p(r) = \begin{cases} \frac{r}{\sigma^2} \exp\left(\frac{-r^2}{2\sigma^2}\right) & 0 \le r \le \infty \\ 0 & r < 0 \end{cases}$ σ – rms value of received voltage signal before envelope detection σ^2 – time avg power of recd signal before envelope detection Probability the envelope of received signal does not exceed a specified value R is given by CDF	4	2	3	3

Part – C
(2 × 12 = 24 Marks)

17	(a) Derive an expression to show that the path loss for the two ray model is PL(dB) = 40logd-(10logGt+10logGr+20loght+20loghr). **Diagram : (2) Explanation with equation: (10)** • In a mobile radio channel, a single direct path between the base station and a mobile is seldom the only physical means for propagation, and hence the free space propagation model of Equation Pl(dB) is in most cases inaccurate when used alone. • The two-ray ground reflection model shown in the below slide is a useful propagation model that is based on geometric optics, and considers both the direct path and a ground reflected propagation path between transmitter and receiver. • This model has been found to be reasonably accurate for predicting the large-scale signal strength over distances of several kilometers for mobile radio systems that use tall	12	3	2	2

towers (heights which exceed 50 m), as well as for line-of-sight microcell channels in urban environments.

- In most mobile communication systems, the maximum T-R separation distance is at most only a few tens of kilometers, and the earth may be assumed to be flat.
- The total received E-field, E_{TOT}, is then a result of the direct line-of-sight component, E_{Los}, and the ground reflected component, E_g.
- *ht* is the height of the transmitter and *h,* is the height of the receiver.
- If E_0 is the free space E-field (in units of V/m) at a reference distance d_0 from the transmitter, then ford> d_0, the free space propagating E-field is given by

$$E(d,t) = \frac{E_0 d_0}{d}\cos\left(\omega_c\left(t-\frac{d}{c}\right)\right) \qquad (d > d_0)$$

-

$$E_{LOS}(d',t) = \frac{E_0 d_0}{d'}\cos\left(\omega_c\left(t-\frac{d'}{c}\right)\right)$$

-

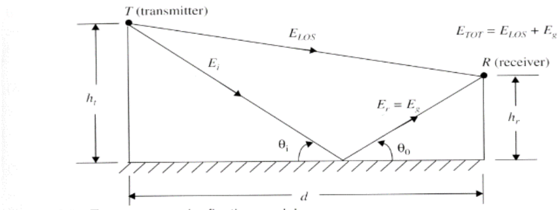


Figure 4.7 Two-ray ground reflection model.

$$\vec{E}_{TOT} = \vec{E}_{LOS} + \vec{E}_g$$

let E_o be $|\ \vec{E}\ |$ at reference point d_o then

$$\vec{E}(d,t) = \left(\frac{E_0 d_0}{d}\right)\cos\left(\omega_c\left(t-\frac{d}{c}\right)\right) \quad d > d_0$$

$$\vec{E}_{TOT}(d,t) = \left(\frac{E_0 d_0}{d'}\right)\cos\left(\omega_c\left(t-\frac{d'}{c}\right)\right) + \Gamma\left(\frac{E_0 d_0}{d''}\right)\cos\left(\omega_c\left(t-\frac{d''}{c}\right)\right)$$

Equation (4.40): $\Delta = d'' - d' = \sqrt{(h_t+h_r)^2 + d^2} - \sqrt{(h_t-h_r)^2 + d^2}$

$$\begin{aligned}
\Delta = d'' - d' &= \sqrt{(h_t+h_r)^2 + d^2} - \sqrt{(h_t-h_r)^2 + d^2} \\
&= d\sqrt{\left(\left(\frac{h_t+h_r}{d}\right)^2 + 1\right)} - d\sqrt{\left(\left(\frac{h_t-h_r}{d}\right)^2 + 1\right)} \\
&\approx d\left(1 + \frac{1}{2}\left(\frac{h_t+h_r}{d}\right)^2\right) - d\left(1 + \frac{1}{2}\left(\frac{h_t-h_r}{d}\right)^2\right) \\
&\approx \frac{1}{2d}\left((h_t+h_r)^2 - (h_t-h_r)^2\right) \\
&\approx \frac{1}{2d}\left((h_t^2 + 2h_th_r + h_r^2) - (h_t^2 - 2h_th_r + h_r^2\right. \\
&\approx \frac{2h_th_r}{d}
\end{aligned}$$

$$\theta_\Delta \text{ radians} = \left(\frac{\Delta}{\lambda}\text{wavelengths}\right)\left(\frac{2\pi \text{ radians}}{\text{wavelength}}\right) = \frac{2\pi\Delta}{\lambda} = \frac{2\pi\Delta}{\left(c/f_c\right)} = \frac{\omega_c\Delta}{c}$$

$$E_{TOT}\left(d, t = \frac{d''}{c}\right) = \frac{E_0 d_0}{d'}\cos\left(\omega_c\left(\frac{d''-d'}{c}\right)\right) - \frac{E_0 d_0}{d''}\cos 0^\circ$$
$$= \frac{E_0 d_0}{d'}\cos\theta_\Delta - \frac{E_0 d_0}{d''}$$
$$\approx \frac{E_0 d_0}{d}[\cos\theta_\Delta - 1]$$

$$|E_{TOT}(d)| = \sqrt{\left(\frac{E_0 d_0}{d}\right)^2(\cos\theta_\Delta - 1)^2 + \left(\frac{E_0 d_0}{d}\right)^2 \sin^2\theta_\Delta}$$

$$|E_{TOT}(d)| = \frac{E_0 d_0}{d}\sqrt{2 - 2\cos\theta_\Delta}$$

$$|E_{TOT}(t)| = 2\frac{E_0 d_0}{d}\sin\left(\frac{\theta_\Delta}{2}\right)$$

$$\frac{\theta_\Delta}{2} \approx \frac{2\pi h_r h_t}{\lambda d} < 0.3 \text{ rad}$$

- $$E_{TOT}(t) \approx 2\frac{E_0 d_0}{d}\frac{2\pi h_r h_t}{\lambda d} \approx \frac{k}{d^2} \text{ V/m}$$
- $$d >> \sqrt{h_t h_r}$$

$$\bar{E}_{TOT}(d)| \approx \frac{4\pi E_0 d_0 h_t h_r}{\lambda d^2}$$

$$P_r \approx \frac{P_t G_t G_r h_t^2 h_r^2}{d^4}$$

$$\bar{E}_{TOT}(d)| \approx \frac{4\pi E_0 d_0 h_t h_r}{\lambda d^2}$$

$$P_r \approx \frac{P_t G_t G_r h_t^2 h_r^2}{d^4}$$

- Two-ray path loss model:
  PL (dB)= $40 \log d - [10 \log G_t + 10 \log G_r + 20 \log h_t + 20 \log h_r]$

Now d^4 instead of d^2 for free space

OR

(b) Elaborate on Okumara model and calculate the mean path loss using the aforementioned model for the distance d = 50 km, height of the transmitter and receiver to be 50m and 5m respectively in a suburban environment. If the base station transmitter radiates an EIRP of 1KW at a carrier frequency of 900 MHz, Find the EIRP (dBm) and the power received at the receiver where gain at the receiving antenna is 20 dB. Assume the following data for computations (from the Okumura curves Amu (f, d) = 43 dB and GArea = 9 dB).

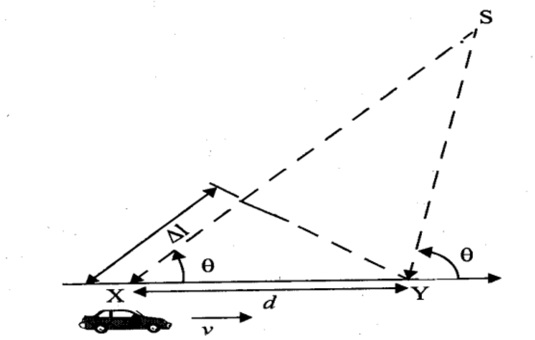
Elaboration of the model – (6)

Okumura Model:

Okumura`s model is one of the most widely used models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHz to 1920 MHz (although it is typically extrapolated up to 3000 MHz) and distances of 1 km to 100 km. It can be used for base station antenna heights ranging from 30 m to 1000 m. Okumura developed a set of curves giving the median attenuation relative to free space (Amu), in an urban area over a quasi-smooth terrain with a base station effective antenna height (hte) of 200 m and a mobile antenna height (hre) of 3 m. These curves were developed from extensive measurements using vertical omni-directional antennas at both the base and mobile, and are plotted as a function of frequency in the range 100 MHz to 1920 MHz and as a function of distance from the base station in the range 1 km to 100 km. To determine path loss using Okumura`s model, the free space path loss between the points of interest is first determined, and then the value of Amu(f, d) (as read from the curves) is added to it along with correction factors to account for the type of terrain. The model can be expressed as

$L50(dB) = LF + Amu(f, d) - G(te) - G(re) - G_{AREA}$

Numerical – (6)

<table>
<tr><td></td><td>
The free space path loss L_F can be calculated as
$$L_F = 10\log\left[\frac{\lambda^2}{(4\pi)^2 d^2}\right] \quad \text{— [illegible]}$$
$$= 10\log\left[\frac{(3\times10^8/900\times10^6)^2}{(4\pi)^2\times(50\times10^3)^2}\right]$$
$$= 125.5\text{ dB} \quad \text{— 2 Marks}$$
Given that, from the okumura curves,
$$A_{mu}(f,d) = A_{mu}(900\text{MHz}, 50\text{Km}) = 43\text{dB}$$
$$G_{AREA} = 9\text{ dB}$$
$$\left.\begin{aligned} G(h_{te}) &= 20\log\left(\frac{h_{te}}{200}\right) = 20\log\left(\frac{50}{200}\right) = -12.04\text{ dB} \\ G(h_{re}) &= 20\log\left(\frac{h_{re}}{3}\right) = 20\log\left(\frac{5}{3}\right) = 4.44\text{ dB} \end{aligned}\right\} \text{3 Marks}$$
The total mean path loss is
$$\text{1 Mark} \leftarrow L_{50}(\text{dB}) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$
$$= 125.5 + 43 - (-12.04) - 4.44 - 9$$
$$= 167.1\text{ dB} \longrightarrow \text{2 Marks}$$
The median Received power is
$$P_r(d) = EIRP(\text{dBm}) - L_{50}(\text{dB}) + G_r(\text{dB})$$
$$\text{2 Marks}\left\{\begin{aligned} EIRP &= 1\text{kW} \rightarrow \text{in terms of dBm} = 60\text{dBm} \\ P_r(d) &= 60\text{dBm} - 167.1\text{dB} + 0\text{ dB} \\ &= -107.1\text{ dBm} \end{aligned}\right.$$
</td><td></td><td></td><td></td><td></td></tr>
<tr><td>18</td><td>
(a) Consider an aircraft is moving at a constant velocity ‘v’, along a path segment having length ‘d’ between the points X and Y, while it receives signals from a remote source ‘P’. Derive the path length, phase change in the received signal and the apparent change in the doppler frequency. With the aid of the aforementioned derivation, assuming the speed of an aircraft (which is moving towards the airport control tower with an elevation angle of 25^0) to be 500 km/hr. What is the expected doppler shift of the received signal if the communication between the aircraft and control tower operations are at 128MHz?
Derivation each step 2 marks – (6)
Diagram – (2)
Numerical – (4)


Path length
$$\Delta l = d\cos\theta = v\Delta t\cos\theta$$
Phase change
$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t}{\lambda}\cos\theta$$
Apparent shift in frequency:
$$f_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cos\theta$$
</td><td>8+4</td><td>3</td><td>3</td><td>2</td></tr>
</table>

$v = 500\ km/hr = \frac{500 \times 1000}{3600} = 138.88\ m/s \rightarrow (1)$

$f_d = \frac{v}{\lambda} \cos\theta$

$= \frac{138.88}{c} \times f \cos\theta$

$= \frac{138.88}{3 \times 10^8} \times 128 \times 10^6 \times \cos 25° \longrightarrow (1)$

$= 59.26 \cos 25°$

$f_d = 53.68\ Hz \longrightarrow (1)$

$\Delta f = f_c + f_d = 128\ MHz + 53.68\ Hz \longrightarrow (1)$

OR

(b) Explain the impulse response model with relevant expression and graphical representation.

Briefing – (2)
Equations – (4)
Impulse Block Diagram – (4)
Final response equation – (2)

A mobile radio channel may be modelled as a linear filter with a time varying impulse response

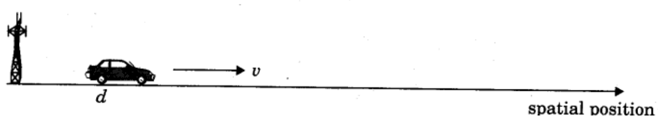
- time variation is due to receiver motion in space
- filtering is due to multipath

The channel impulse response can be expressed as *h(d,t).* Let *x(t)* represent the transmitted signal, then the received signal *y(d,t)* at position *d* can be expressed as

$$y(d,t) = x(t) \otimes h(d,t) = \int_{-\infty}^{\infty} x(\tau) h(d, t-\tau) d\tau$$

- For a causal system

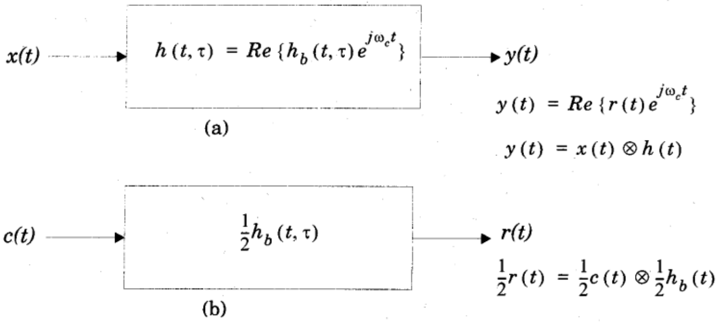
$$y(d,t) = \int_{-\infty}^{t} x(\tau) h(d, t-\tau) d\tau$$



$$y(vt,t) = \int_{-\infty}^{t} x(\tau) h(vt, t-\tau) d\tau$$

$$y(t) = \int_{-\infty}^{t} x(\tau) h(t,\tau) d\tau = x(t) \otimes h(t,\tau)$$

$$\frac{1}{2} r(t) = \frac{1}{2} c(t) \otimes \frac{1}{2} h_b(t,\tau) \qquad \text{or} \qquad r(t) = \frac{1}{2} c(t) \otimes h_b(t,\tau)$$



(a)

(b)

$$r(t) = c(t) \otimes \frac{1}{2} h_b(t, \tau)$$

where $c(t)$ and $r(t)$ are the complex envelopes of $x(t)$ and $y(t)$, defined as

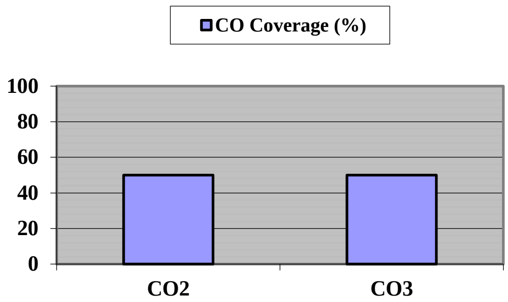
$$x(t) = Re\{c(t)\exp(j2\pi f_c t)\}$$

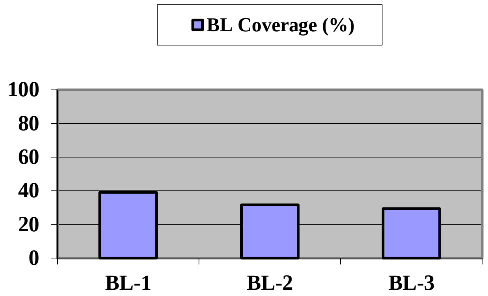
$$y(t) = Re\{r(t)\exp(j2\pi f_c t)\}$$

- The baseband response of a multipath channel can be expressed as

$$h_b(t,\tau) = \sum_{i=0}^{N-1} a_i(t,\tau)\exp\big(j2\pi f_c \tau_i(t) + j\phi(t,\tau)\big)\delta(\tau - \tau_i(t))$$

Course Outcome (CO) and Bloom's level (BL) Coverage in Questions





Approved by the Course Coordinator **Signature of the Question paper setter**

Evaluation Sheet

Name of the Student: **Register No.: ……………….………**

Part-A (10 × 1 = 10 Marks)					
Q. No	**CO**	**PO**	**Maximum Marks**	**Marks Obtained**	**Total**
1	CO2	4	1		
2	CO2	2	1		
3	CO2	4	1		
4	CO2	4	1		
5	CO2	2	1		
6	CO3	2	1		
7	CO3	2	1		
8	CO3	3	1		
9	CO3	2	1		
10	CO3	3	1		
Part-B1 (2 × 4 = 8 Marks)					
11	CO2	2	4		
12	CO2	2	4		
13	CO2	4	4		
Part-B2 (2 × 4 = 8 Marks)					
14	CO3	2	4		
15	CO3	2	4		
16	CO3	3	4		
Part-C (2 × 12 = 24 Marks)					
17(a)	CO2	2	12		
17(b)	CO2	4	12		
18(a)	CO3	2	12		
18(b)	CO3	3	12		

Consolidated Marks:

CO	Maximum Marks	Marks Obtained
2	25	
3	25	
Total	50	

PO	Maximum Marks	Marks Obtained
2	45	
3	18	
4	19	
Total	72	

Signature of Course Teacher

Signature of the Course Coordinator **Signature of the Academic Advisor**