SRM INSTITUTE OF SCIENCE & TECHNOLOGY (Deemed to be University u/s 3 of UGC Act, 1956)

SRM Institute of Science and Technology
College of Engineering and Technology
DEPARTMENT OF ECE
SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

SET-A
Batch 1
Placement Students

Academic Year: 2023-24 (ODD)

Test: CLAT–II | **Date: 17/10/2023**
Course Code & Title: 18ECC301T Wireless Communications | **Duration: 12.30 PM to 2.15 PM**
Year & Sem: IV / VII | **Max. Marks: 50**

Course Articulation Matrix:

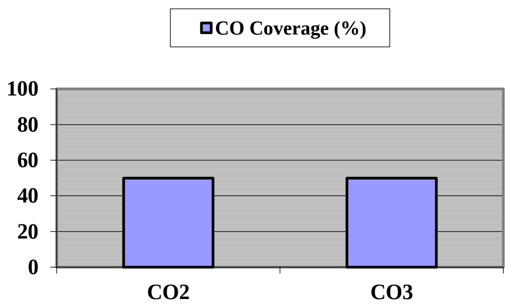
	18ECC301T - Wireless Communication	Program Outcomes (POs)														
		Graduate Attributes												PSO		
COs	Course Outcomes (COs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO-1	Interpret the concepts of Wireless communication and basic cellular networks	3	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO-2	Analyze different 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	-	-

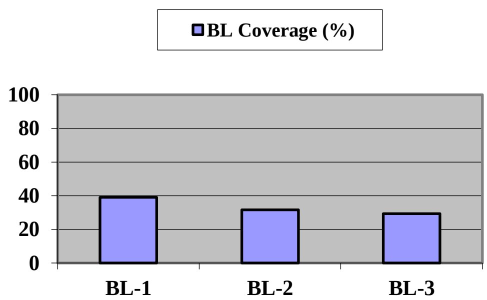
Part – A (10 × 1 = 10 Marks)[Instructions: Answer ALL Questions]

Q. No.	Question	Marks	BL	CO	PO
1	Calculate the Brewster angle for a wave impinging on ground having a permittivity of $\varepsilon_r = 6$. (a)25.09 (b) 22.21 (c) 27.09 (d) 23.09	1	2	2	4
2	____ occurs when a propagating electromagnetic wave impinges upon a rain drop (a) Refraction (b) Diffraction (c) Reflection (d) Scattering	1	1	2	2
3	If a transmitter produces 100 W of power, express the transmit power in units of dBm and dBw. (a) 17 and 47 (b) 19 and 49 (c) 50 and 20 (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 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	If coherence bandwidth is smaller than the bandwidth of the signal, _____ fading occurs. (a)Flat (b) Frequency selective (c) Fast fading (d) Time selective	1	1	3	3
9	The distribution present in small scale fading envelope of a non-fading signal component is ____________. (a) Rayleigh (b) Ricean (c) Gaussian (d) Normal	1	1	3	2

10	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	3
	Part – B1 (2 × 4 = 8 Marks) [Instructions: Answer any TWO Questions]				
11	For a wireless system, using Friis transmission formula and free space path loss model, deduce the path loss for the receiver to be placed at a distance ‘d’.	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.	4	3	2	2
13	Brief about the amoeba cells.	4	2	2	4
	Part – B2 (2 × 4 = 8 Marks) [Instructions: Answer any TWO Questions]				
14	Compare flat and frequency selective fading of multipath fading 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.	4	2	3	3
	Part – C (2 × 12 = 24 Marks)				
17	(a) Using necessary equations, derive the path loss for a wireless system using two ray model.	6+6	3	2	2
	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).	12	3	2	4
18	(a) For the scenario of small scale fading, derive the baseband impulse response model with relevant expressions.	12	3	3	2
	OR				
	(b) 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 deg) to be 1000 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?	8+4	3	3	3

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





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

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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	-	-

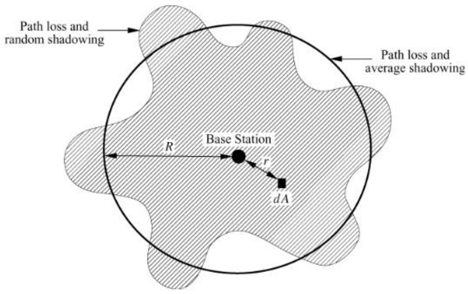
Part – A
(10 × 1 = 10 Marks)
Instructions: Answer ALL Questions.

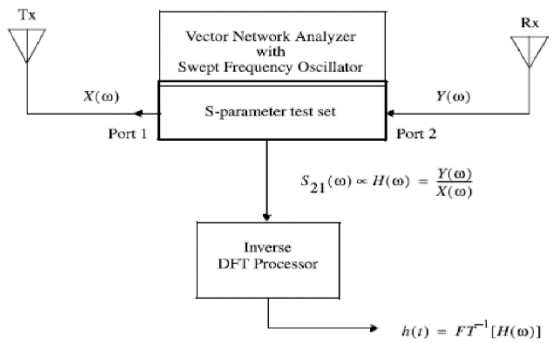
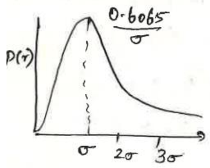
Q. No.	Question	Marks	BL	CO	PO
1	(b) 22.21	1	2	2	4
2	(d) Scattering	1	1	2	2
3	(c) 50 and 20	1	2	2	4
4	(d) df =(2 D^2)/ λ	1	1	2	4
5	(b) Walfish and Bertoni	1	1	2	2
6	(c) Direct RF pulse	1	1	3	2
7	(a) Bandwidth	1	1	3	2
8	(b) Frequency selective	1	1	3	3
9	(b) Ricean	1	1	3	2
10	(a)Relative received power	1	1	3	3

Part – B1
(2 × 4 = 8 Marks)
Instructions: Answer any TWO Questions.

<table>
<tr>
<td>11</td>
<td>
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: $P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$
$G = \frac{4\pi A_e}{\lambda^2}$ $\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$ $EIRP = P_t G_t$
$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right)$
• 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 $df >> \lambda$
• $P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$
• Use close-in distance and a known received power at that point
• $P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2 \quad d \geq d_0 \geq d_f$

Friis Equation – (1)
Briefing + Derivation – (2)
Final Expression – (1)
</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>
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)
$d_f = \frac{8}{0.3} = 26.667\ m$
$l = \lambda/4 = \frac{0.3}{4} = 0.075m$
(1) (1)
</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</table>

13	Combined path loss and shadowing leads to outage and amoeba-like cell shapes. The coverage area of a given cell in a cellular system is defined as the area of locations within the cell where the received power is above a given minimum. Consider a base station inside a circular cell of a given radius R. All mobiles within the cell require some minimum received SNR for acceptable performance. Assuming a given model for noise, the SNR requirement translates to a minimum received power Pmin throughout the cell. The transmit power at the base station is designed for an average received power at the cell boundary of P_R, averaged over the shadowing variations. In the absence of shadowing, the coverage area of this system is πR^2 since all locations have received power above the required minimum. However, shadowing will cause some locations within the cell to have received power below P_R, and others will have received power exceeding P_R. This is illustrated in Figure  where we show contours of constant received power based on a fixed transmit power at the base station for path loss and average shadowing and for path loss and random shadowing. For path loss and average shadowing, constant power contours form a circle around the base station because combined path loss and average shadowing is the same at a uniform distance from the base station. For path loss and random shadowing, the contours form an amoeba-like shape due to the random shadowing variations about the average.	4	2	2	4
Part – B2 **(2 × 4 = 8 Marks)** **Instructions: Answer any TWO Questions.**					
14	**Flat fading:** • In this bandwidth of the signal is smaller than the bandwidth of the channel. • In the flat fading all the components of the frequency of the signal will have the same magnitude of fading with respect to each other. • Flat fading, is that type of fading in which all frequency components of the received signal fluctuate in the same proportions simultaneously. • Signal undergoes flat fading if following conditions are met: **Bs << Bc** **Ts >>στ** **Frequency Selective Fading:** • In selective fading, the bandwidth of the signal is larger than the bandwidth of the channel. • Hence ,different components of the frequency signal will not experience the same fading.	4	1	3	2

<table>
<tr><td></td><td>Selective fading affects unequally the different spectral components of a radio signal.
Signal undergoes selective fading if following conditions are met:
Bs >Bc
Ts <στ</td><td></td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>Draw the block diagram of Frequency domain channel sounding system.

</td><td>4</td><td>2</td><td>3</td><td>2</td></tr>
<tr><td>16</td><td>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
σ² - 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</td><td>4</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td></td><td colspan="5" align="center">Part – C
(2 × 12 = 24 Marks)</td></tr>
<tr><td>17</td><td>(a)Two ray model 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 towers (heights which exceed 50 m), as well as for line-of-sight microcell channels in urban environments.</td><td>12</td><td>3</td><td>2</td><td>2</td></tr>
</table>

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

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

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

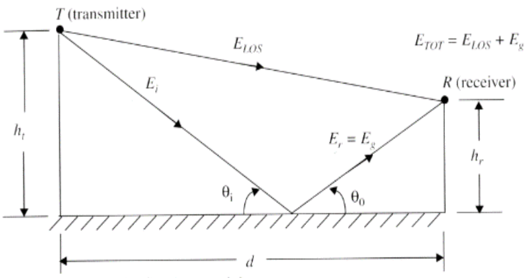


Figure 4.7 Two-ray ground reflection model.

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

let E_0 be $|\ \bar{E}\ |$ at reference point d_o then

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

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

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

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

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

	$$E_{TOT}\left(d, t=\frac{d''}{c}\right) = \frac{E_0 d_0}{d'}\cos\left(\omega_c\left(\frac{d''-d'}{c}\right)\right) - \frac{E_0 d_0}{d''}\cos 0^\circ = \frac{E_0 d_0}{d'}\cos\theta_\Delta - \frac{E_0 d_0}{d''} \approx \frac{E_0 d_0}{d}[\cos\theta_\Delta - 1]$$ • $$\lvert E_{TOT}(d)\rvert = \sqrt{\left(\frac{E_0 d_0}{d}\right)^2(\cos\theta_\Delta - 1)^2 + \left(\frac{E_0 d_0}{d}\right)^2 \sin^2\theta_\Delta}$$ $$\lvert E_{TOT}(d)\rvert = \frac{E_0 d_0}{d}\sqrt{2-2\cos\theta_\Delta}$$ $$\lvert E_{TOT}(t)\rvert = 2\frac{E_0 d_0}{d}\sin\left(\frac{\theta_\Delta}{2}\right)$$ $$\frac{\theta_\Delta}{2} \approx \frac{2\pi h_r h_t}{\lambda d} < 0.3 \text{ rad}$$ • $$E_{TOT}(t) \approx 2\frac{E_0 d_0}{d}\frac{2\pi h_r h_t}{\lambda d} \approx \frac{k}{d^2} \text{ V/m}$$ $$d >> \sqrt{h_t h_r}$$ $$\vec{E}_{TOT}(d)\rvert \approx \frac{4\pi E_0 d_0 h_t h_r}{\lambda d^2}$$ $$P_r \approx \frac{P_t G_t G_r h_t^2 h_r^2}{d^4}$$ 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)** **Numerical – (6)**	6+6	3	2	4

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 (h_{re}) 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 $A_{mu}(f, d)$ (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, A_{mu} is the median attenuation relative to free space, $G(h_{te})$ is the base station antenna height gain factor, $G(h_{re})$ is the mobile antenna height gain factor, and G_{AREA} 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.

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

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

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

Numericals(6)

free Space Path loss.

$$L_F = 10\log \frac{\lambda^2}{(4\pi)^2 d^2}$$

$$= 10\log\left[\frac{(3\times10^8/900\times10^6)^2}{(4\pi)^2\times(50\times10^3)^2}\right] \quad \text{— (2 marks)}$$

$= 125.5\text{dB}$

Amu (f.d) = Amu (900 MHz, 50km) = 43 dB.

Garea = 9dB.

$G(h_{te}) = 20\log\left(\frac{h_{te}}{200}\right) = -12.04\text{dB}$ (2 marks)

$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) = 20\log 5/3 = 4.44\text{dB}$

Mean Path Loss

$L_{50}(dB) = L_F + A_{mu} - G\,h_{te} - G\,h_{re} - G_{area}$

$= 125.5 + 43 - (-12.04) - 4.44 - 9$

$= 167.1\text{ dB}$ — (2 marks)

Received Power

$P_r(d) = EIRP(dBm) - L_{50}(dB) + G_r(dB)$

EIRP = 1 kW

$P_r(d) = 60\text{dBm} - 167.1\text{dB} + 0\text{dB}.$

$= -107.1\text{dBm}$

— 2 marks.

18	(a) For the scenario of small scale fading, derive the baseband impulse response model with relevant expressions.	12	3	3	2

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

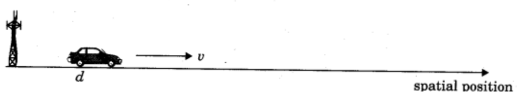
- time variation is due to receiver motion in space
- filtering is due to multipath

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

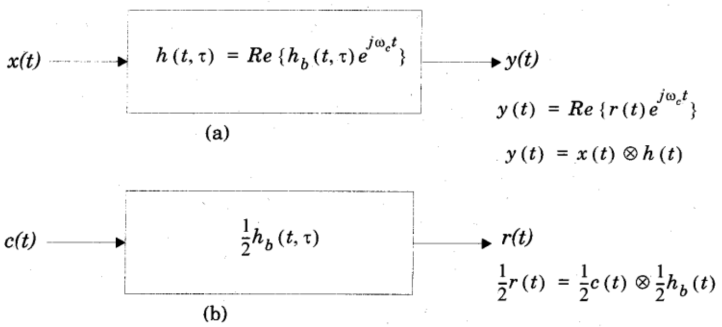
$$y(d,t) = \int_{-\infty}^{t} x(\tau) h(d, t-\tau) d\tau$$



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

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

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



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

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

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

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

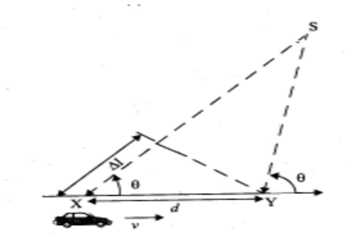
- The baseband response of a multipath channel can be expressed as

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

OR

(b) 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 1000 km/hr. What is the expected doppler shift of the received signal if the communication between the aircraft and control tower operations are at 200MHz? **Derivation each step 2 marks – (6)** **Diagram – (2)** **Numerical – (4)**	8+4	3	3	3



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:

$$f_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cos\theta$$

Speed of aircraft → 1000 km/hr

f_c → 200 MHz

v_m = 1000 km/hr

$= \frac{1000\times10^3}{3600} = 277.77$ m/s. —(2m)

$\theta = 25^\circ$

$\cos 25 = 0.906$

∴ doppler freq $f_d = \frac{v_m}{\lambda}\cos\theta$

$= \frac{f_c}{c} v_m \cos\theta$

$= \frac{200\times10^6}{3\times10^8}\times 277.77\times 0.906$

$= 167.77$ Hz. —(2m)

$\Delta f = f_c + f_d$

$= 200$ MHz $+ 167.77$ Hz.

SRM Institute of Science and Technology
College of Engineering and Technology
DEPARTMENT OF ECE

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

Academic Year: 2023-24 (ODD)

SET-B
Batch 2
Placement Students

Test: CLAT–II	**Date: 17/10/2023**
Course Code & Title: 18ECC301T Wireless Communications	**Duration: 12.30 PM to 2.15 PM**
Year & Sem: IV / VII	**Max. Marks: 50**

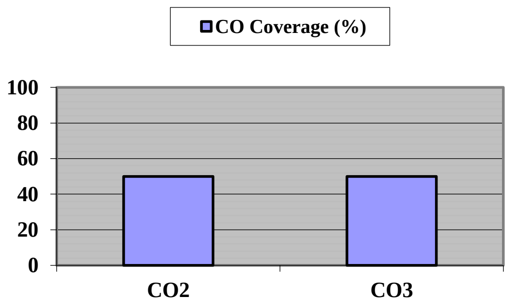
Course Articulation Matrix:

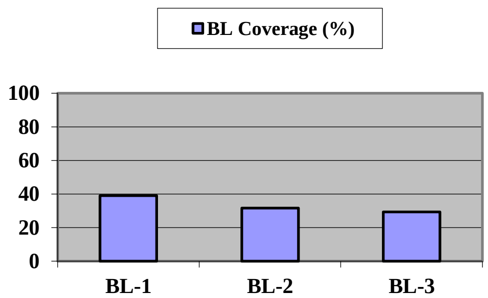
	18ECC301T - Wireless Communication	**Program Outcomes (POs)**														
		Graduate Attributes												**PSO**		
COs	**Course Outcomes (COs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
CO-1	Interpret the concepts of Wireless communication and basic 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 1 m and operating frequency of 3000 MHz (a) 20 (b) 40 (c) 60 (d) 80	1	2	2	4
2	____ occurs when a propagating electromagnetic wave impinges upon an object which has very sharp edges (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 $\lambda/4$ 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 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 Delay spread large scale fading	1	1	3	2
7	When the dominant component fades away, the Rayleigh distribution degenerates to ________ distribution. (a)Gaussian (b)Ricean (c) Log normal (d) Gamma	1	1	3	2
8	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	3
9	Power delay profile is represented as plots of __________ with respect to fixed time delay reference.	1	1	3	2

	(a)Relative received power (b) Frequency (c)Transmitted power (d)Relative phase				
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 two paths between transmitter and receiver, express an expression for path loss if the receiver is placed at a distance ‘d’.	4	2	2	2
12	Calculate the ratio of the Brewster angle with respect to two dielectrics with dielectric constants of 5 and 6.	4	3	2	2
13	Elaborate on the piece wise linear model.	4	2	2	4
Part – B2 (2 × 4 = 8 Marks) [Instructions: Answer any TWO Questions]					
14	List the factors influencing the small scale fading.	4	1	3	2
15	Draw the block diagram of Spread spectrum sliding correlator channel sounding.	4	2	3	2
16	Compare fast and slow fading of multipath fading channel.	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 100 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 100 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 300 m from the antenna, What is Pr (30 km)? Assume unity gain for the receiver antenna. OR (b) Explain in detail Okumara empirical model to calculate the mean path loss.	6+6 12	3 3	2 2	2 4
18	(a) Describe frequency domain measurement technique of small scale multipath channels. Assuming the speed of an aircraft (which is moving towards the airport control tower with an elevation angle of 60^0) to be 300 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? OR (b) Explain the impulse response model with relevant expression and graphical representation.	8+4 12	3 3	3 3	2 3

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





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

SRM Institute of Science and Technology
College of Engineering and Technology

DEPARTMENT OF ECE

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

Academic Year: 2023-24 (ODD)

AK - SET-B – Placement Students

Test: CLAT–II | **Date: 1710/2023**
Course Code & Title: 18ECC301T Wireless Communications | **Duration: 12.30 PM to 02.15 PM**
Year & Sem: IV / VII | **Max. Marks: 50**

Course Articulation Matrix:

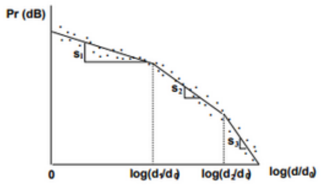
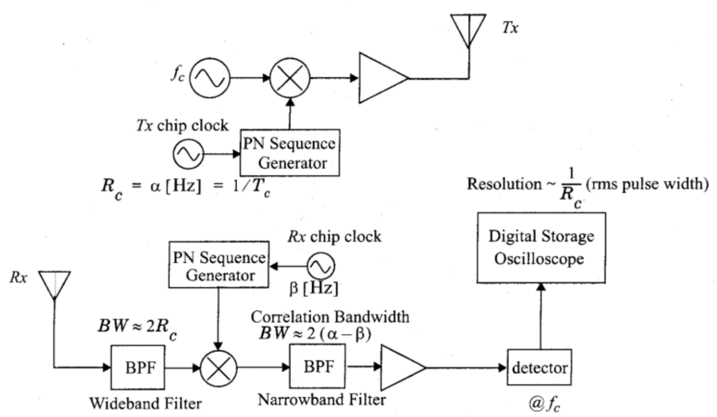
	18ECC301T - Wireless Communication	Program Outcomes (POs)														
		Graduate Attributes												PSO		
COs	Course Outcomes (COs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO-1	Interpret the concepts of Wireless communication and basic cellular networks	3	-	-	3	-	-	-	-	-	-	-	2	-	-	-
CO-2	Analyze different 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	(a) 20	1	2	2	4
2	(c) Diffraction	1	1	2	2
3	(d) 0.083	1	2	2	4
4	(d) 1.5	1	1	2	4
5	(b) Dual slope	1	1	2	2
6	(a) Multipath delay spread small scale fading	1	1	3	2
7	(b)Ricean	1	1	3	2
8	(a)$N\Delta\tau$	1	1	3	3
9	(a)Relative Received Power	1	1	3	2
10	(a) Multipath Propagation	1	1	3	3

Part – B1
(2 × 4 = 8 Marks)
Instructions: Answer any TWO Questions.

Q. No.	Question	Marks	BL	CO	PO
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: $PL\text{ (dB)} = 40 \log d - [10 \log G_t + 10 \log G_r + 20 \log h_t + 20 \log h_r]$	4	2	2	2
12	Equation - $\sin(\theta_B) = \sqrt{(\varepsilon_r - 1)} / \sqrt{(\varepsilon_r^2 - 1)}$ - **(1)** Brewster angle – 24.09^0 for dielectric const 5– **(1)**	4	3	2	2

	Brewster angle – 22.14^0 for dielectric const 6– **(1)** **Ratio –1.088 - (1)**				
13	Piece wise linear model  Piecewise Linear Model for Path Loss. A piecewise linear model with N segments must specify N − 1 breakpoints d1,...,dN−1 and the slopes corresponding to each segment s1,...,sN . Dual-slope model $P_r(dB) = \begin{cases} P_t + K - 10\gamma_1 \log_{10}(d/d_0) & d_0 \le d \le d_c \\ P_t + K - 10\gamma_1 \log_{10}(d_c/d_0) - 10\gamma_2 \log_{10}(d/d_c) & d > d_c \end{cases}.$	4	2	2	4
	Part – B2 **(2 × 4 = 8 Marks)** **Instructions: Answer any TWO Questions.**				
14	**Fact Factors influencing small-scale fading** • 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 Spread spectrum sliding correlator channel sounding.  	4	2	3	2
16	**Fast Fading**	4	2	3	3

	It varies quickly with the frequency. Fast fading originates due to effects of constructive and destructive interference patterns which is caused due to multipath. Doppler spread leads to frequency dispersion and time selective fading. **Fast Fading** results due to following: ➡High Doppler Spread ➡Coherence Time < Symbol Period ➡Channel impulse response changes rapidly within the symbol duration. ➡Occurs if Ts > Tc, Bs < B_D ➡It occurs for very low data rates. **Slow Fading** It does not vary quickly with the frequency. It originates due to effect of mobility. It is result of signal path change due to shadowing and obstructions such as tree or buildings etc. **Slow Fading** results due to following: ➡Low Doppler Spread ➡Coherence Time >> Symbol Period ➡Impulse response changes much slower than the transmitted signal. ➡It occurs if Ts << Tc, Bs >>B_D				
	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 100 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 100 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 300 m from the antenna, What is Pr (30 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: $P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$

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

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

- 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 $d_f >> \lambda$
- $P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$
- Use close-in distance and a known received power at that point
- $P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2 \qquad d \geq d_0 \geq d_f$

Transmitter Power

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

$= 10\log[100\times10^3]$

$= 50\,dBm$ —— (1)

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

$= 10\log[100]$ —— (1)

$= 20\,dBW$.

Received Power

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

$= \frac{100\times1\times1\times(1/3)^2}{(4\pi)^2(300)^2(1)}$

$= 3.12\times10^{-6}\,W = 3.12\times10^{-3}\,mW$ —— (1)

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

$= 10\log(3.12\times10^{-3})$

$= -55.05\,dBm$ —— (1)

for 30 km, $d_0 = 300\,m$ $d = 30\,km$

$P_r(30km) = P_r(300) + 20\log\left(\frac{300}{30000}\right)$

$= -55\,dBm + (-40\,dB)$

$= -95\,dBm$. —— (2) marks

OR

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

Explanation – (4)

Equation – (3)

Sub Equations – (3)

12	3	2	4

	Main Equation Legends explanation – (2)				

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, A_{mu} is the median attenuation relative to free space, $G(h_{te})$ is the base station antenna height gain factor, $G(h_{re})$ is the mobile antenna height gain factor, and G_{AREA} 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.

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

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

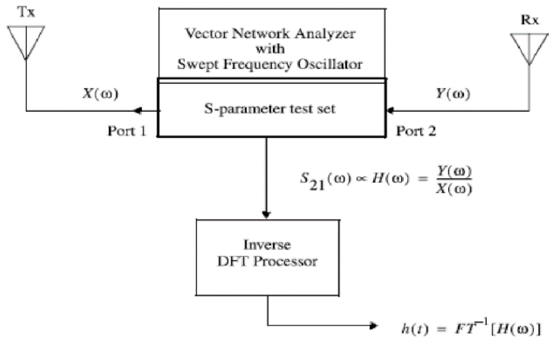
$$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) \qquad 10\text{ m} > h_{re} > 3\text{ m}$$

18	(a) 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 300 km/hr. What is the expected doppler shift of the received signal if the communication between the aircraft and control tower operations are at 128 MHz?	8+4	3	3	3

Frequency domain - Diagram – (2) + Explanation – (2)
Numerical – (4)

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



Speed of aircraft → 300 km/hr

$f_c = 128$ MHz

$V_m = 300$ km/hr — (2m)

$= \frac{300 \times 10^3}{3600} = 83.33$ m/s

$\theta = 60°$

$\cos 60 = 0.5$

$f_d = \frac{f_c}{c} V_m \cos 60°$

$= \frac{128 \times 10^6}{3 \times 10^8} \times \quad \times 0.5$

$= 17.77$ Hz — (2m)

doppler shift $= f_d + f_c$

$= 128$ MHz $+ 17.77$ Hz.

(b)Impulse response model.

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

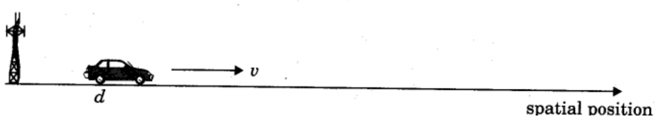
- time variation is due to receiver motion in space
- filtering is due to multipath

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

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

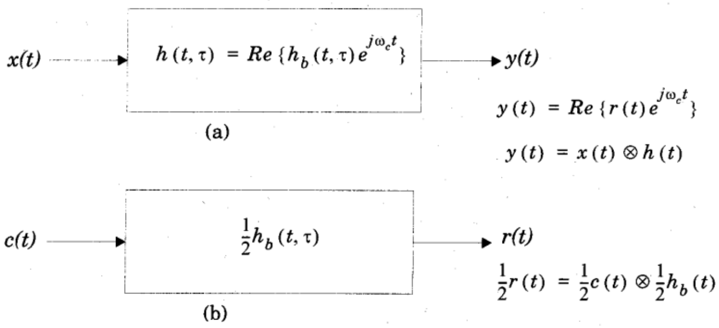


$$y(vt,t) = \int_{-\infty}^{t} x(\tau) h(vt, t-\tau) d\tau$$

12	3	3	2

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

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



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

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

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