UNIT I WIRELESS CHANNELS

Large scale path loss–Path loss models: Free Space and Two-Ray models-Link Budget design– Small scale fading-Parameters of mobile multipath channels– Time dispersion parameters- Coherence bandwidth–Doppler spread & Coherence time, Fading due to Multipath time delay spread–flat fading–frequency selective fading–Fading due to Doppler spread– fast fading–slow fading.

UNIT-I / PART-A

1 What is meant by link budget Equation/Friss Equation / Free space equation? (or) Give the equation for average large-scale path loss between transmitter and receiver as a function of distance? (Dec 2016)

A link budget is the clearest and the most intuitive way of computing the received power of the signal with respect to distance. (In other words) It is simply a link budget equation used to predict received signal strength, when unobstructed line of sight (LoS) path exists between transmitter and receiver over a larger distance.

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

P_r= Total Received Signal Power
P_t = Transmitted Signal Power
G_t, G_r= Gain of the Transmitter and Receiver respectively.
λ = Wavelength of the Antenna
d= distance between Transmitter and Receiver

2 What is the need of path loss models in link budget design?

The path loss models are used to estimate the received signal level as the function of distance. It is also used to predict the SNR value of a mobile communication system. Some of the path loss models are listed follows**.** 1. Log distance path loss models
2. Log Normal Shadowing

3 Write the effects of fading.

- Rapid changes in signal strength over a small travel distance or time interval.
- Random frequency modulation due to varying Doppler shifts on different multipath signals
- Time dispersion caused by multipath propagation delays.

4 What is mean by fading? Bring out the significance and differences (Apr 2019) on its types (May 2013).

The time variation of received signal power due to changes in transmission medium or paths or obstacles is known as fading. Based on channel model parameters and position or movement of transmitter/receiver, there are two different fading types as mentioned below.

small scale fading	large scale fading
• Small scale fading is concerned with rapid fluctuations of received signal strength over very short distance and short time period. • These multipath fading types depend on propagation environment. • It is divided into two main categories viz. multipath delay spread and doppler spread.	• Large scale fading occurs when an obstacle comes in between transmitter and receiver. This interference type causes significant amount of signal strength reduction. This is because EM wave is shadowed or blocked by the obstacle. It is related to large fluctuations of the signal over distance. • It includes path loss and shadowing effects.

5 What is log normal shadowing?

The log normal shadowing describes the random shadowing effects which occur over a large number of measurement locations which have the same T-R separation distance but has different propagation path.

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_o) + 10n\log\left(\frac{d}{d_o}\right) + X_\sigma$$

Where,

X_σ *is Zero mean gaussian distributed random variable in dB and* σ *is the Std. Deviation*

6 **What is path Loss?**

Path Loss is the difference between the transmitted power and the effective received power.

$$\text{PL [dB](Path Loss in dB)} = 10\log\left(\frac{P_t}{P_r}\right)$$

7 **What are Fresnel zones?**

The concentric circles on the transparent plane located between a transmitter and receiver represent the loci of the origins of secondary wavelets which propagate to the receiver such that the total path length increases by λ/2 for successive circles. These circles are called Fresnel zones.

8 **Express the power 50 Watts in (i) dBw (ii) dBm**

To convert it into dBw:	**To convert it into dBm:**
dBw= 10 log(power $_{watts}$)	dBw= 10 log(power $_{watts}$ / 10^{-3})
=10 log(50)	=10 log(50 / 10^{-3})
50w = 17 dBw	50 w= 47 dBm

9 **What is far field distance/ Franhoufer distance? Find the far field distance for an antenna with maximum dimension of 2m and operating frequency 1 GHz?(Dec 2015)**

Franhoufer region of a transmitting antenna is defined as the region beyond the far field distance. If D is the largest linear dimension of the antenna, Far field distance D_f is given by,

$D_f = 2D^2 / \lambda$

$D_f = 2D^2/\lambda = 2 * 2 * 2/0.3$

$D_f = 26.7$ m

10 **Define Snell's law.**

Snell's law states that the ratio of the sine of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

11 **Calculate the Brewster Angle for a wave impinging on ground having a permittivity of ε_r =5. (May 2016)**

$$Sin\,\theta_B = \frac{\sqrt{\varepsilon_r - 1}}{\sqrt{\quad}} = 0.409$$ Brewster Angle = $\sin^{-1}(0.409) = 24.14$

12 **What are the effects of multipath propagation? (Nov 2017)**

The presence of reflecting objects and scatterers in the channel creates a constantly changing environment which can cause the following effects.

1. Multiple versions of the transmitted signal can arrive at the receiver.
2. Random phases and fluctuations lead to fading.
3. It can also lead to Inter Symbol Interference. (ISI)

13	**What are the factors influencing small scale fading and its causes?** The factors influencing small scale fading are Speed of surrounding objects, Multipath propagation, Speed of the mobile, Transmission bandwidth of the signal. And its causes were Random frequency modulation due to varying Doppler shifts on multipath signals and Time dispersion caused by multipath propagation delays.
14	**Define coherence bandwidth. (May 2016) (Dec 2015) (April 2021)** **Definition 1:** The coherence bandwidth is related to the specific multipath structure of the channel. The range of frequencies over which the similar fading occurs is called coherence bandwidth. **Definition 2:** The range of frequencies over which the two frequencies are having strong potential for amplitude correlation. It is inversely proportional to the rms delay spread of the channel. $$B_c = \frac{1}{50\sigma_t}$$
15	**What is coherence time? (Dec 2015) (Nov/Dec 2018)? In what way does this parameter decide the behaviour of wireless channel? (May 2017) (April 2021)** **Definition 1:** The range of time over which the similar fading occurs is called coherence time. **Definition 2:** The time over which signals are having strong potential for amplitude correlation. It is inversely proportional to the Doppler frequency of the channel. $$T_c = \frac{1}{fm}$$ Coherence time definition implies that the two signals arriving with a time separation greater than T_c are affected differently by the channel.
16	**Define Doppler shift/ Doppler frequency.** The relative moment between Mobile and Base station each multipath wave experiences an apparent shift in frequency. This shift is called the Doppler shift/ Doppler frequency. It is directly proportional to the velocity and spatial angle between the directions of the mobile with respect to the arrival of wave. It is denoted by $$f_m = \frac{v}{\lambda}\cos\theta$$
17	**Write the fading effects due to multipath spread, Doppler Spread?** **Fading effects due to multipath spread** ➢ Frequency Selective Fading ➢ Frequency non selective fading (Flat Fading) **Fading effects due to Doppler Spread:** ➢ Time selective fading (Fast Fading) ➢ Time Non selective fading (Slow Fading)
18	**What is Doppler spread?** It is a measure of spectral widening caused by the time rate of change of mobile radio channel and is defined as the range of frequencies over which the received Doppler spectrum is essentially non-zero.
19	**What is flat fading? (Nov 2017) (April 2018)** If the mobile radio channel has a constant gain and linear phase response over a bandwidth which is greater than the bandwidth of the transmitted signal, then the received signal will undergo flat fading. If channel bandwidth is greater than coherence bandwidth then flat fading will occur.
20	**What is frequency selective fading? (Dec 2016) (April 2018)**

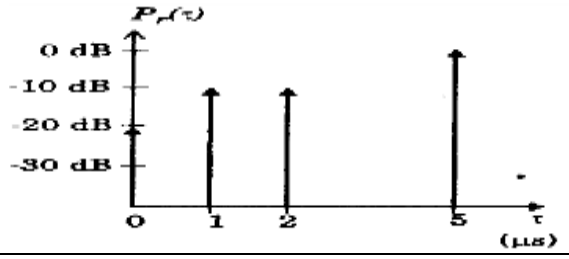
	If the channel possesses a constant gain and linear phase response over a bandwidth that is, smaller than the bandwidth of transmitted signal, then the channel creates frequency selective fading on the received signal. $B_{signal}>B_{coherence}$
21	**Write the difference in conditions for flat fading and frequency selective fading.**

flat fading	**frequency selective fading**
BW of signal<<BW of channel Bs<<Bc Symbol period>>Delay spread Ts>>στ	Bandwidth of Signal> Coherence B Bs>Bc Symbol period< Delay spread Ts< στ

22	**Define fast fading channel. (April 2018) (Nov/Dec 2018)** The channel impulse response changes rapidly within the symbol duration. If the time duration of signal is greater than coherence time then fading will occur very fastly. This type of channel is called fast fading channel.
23	**Define slow fading channel. (April 2018)** The channel impulse response changes at a rate much slower than the transmitted baseband signal. If the time duration of signal is less than coherence time then fading will occur very fastly. This type of channel is called slow fading channel.
24	**Write the conditions for fast and slow fading.** **Fast fading:** Time duration of Signal> Time duration of Channel ($T_{signal}>T_{coherence}$) **Slow fading:** Time duration of Signal< Time duration of Channel ($T_{signal}<T_{coherence}$)
25	**What is the major advantage of wireless communication? (May 2017)** Wireless communication has several advantages with the following being some of the most important: Cost effectiveness, Flexibility, Convenience, Constant connectivity.
26	**State the condition for the occurance of Flat and Frequency selective fading. (April 2021)**

flat fading:	**frequency selective fading:**
BW of signal<<BW of channel Bs<<Bc	Bandwidth of Signal> Coherence Bandwidth Bs>Bc
Symbol period>>Delay spread Ts>>στ	Symbol period< Delay spread Ts< στ

	UNIT I / PART B
1	(i) Explain in detail about free space propagation model. And also calculate the pathloss. **(April 2018) (April 2019)** (ii) Given that the coherence bandwidth is approximated by the equation $B_c = \frac{1}{5\sigma_\tau}$, show that a flat fading channel occurs when $T_s = 10\sigma_\tau$
2	Explain in detail about two ray ground reflection model. **(May 2017) (April 2018)**
3	If 50 w power is applied with unity gain antenna with the carrier frequency of 900 MHZ (i) Find the Received power in dbm at the free space distance of 100 m? (ii)Find the Received power in dbm at the free space distance of 10 km? (iii) Comment on the results based on the two power values. **(May 2017) (April 2019)**
4	In free space propagation describe how the signals are affected by reflection, diffraction and scattering. **(May 2016)**
5	Explain in detail about the link budget design equation using path loss models/ Explain on path

	loss Estimation techniques using path loss models. **(Nov 2017)**
6	(i) Explain the advantages and disadvantages of two ray ground reflection model. **(Dec 2015)** (ii) In the following cases, tell whether the two ray model could be applied, and justify why or not? h_1=35m h_2= 3m d=250 m h_1=30m h_2= 1.5m d=450 m (iii) Prove that in the two ray ground reflected model $\Delta = \frac{2h_t h_r}{d}$
7	Explain i) Fading and ii) Multipath propagation.
8	Describe small-scale fading and derive expression for parameters of mobile multipath channels. **(Nov/Dec 2018)**
9	Explain the time variant two path model of a wireless propagation channel / Write the impulse response of a wireless multipath channel. **(Dec 2015), (Dec 2016)**
10	Consider transmitter which radiates the sinusoidal carrier frequency of 1850 MHZ for a vehicle Moving at 60 km/hr. Compute the Received carrier frequency if (i) the vehicle is moving towards the transmitter (ii) the vehicle is moving away from transmitter (iii) the vehicle is moving the direction of transmitter. **(April 2018)**
11	Calculate the mean excess delay, rms delay spread, maximum excess delay (10 dB) for the multipath Profile given below. Estimate 50% coherence bandwidth of the channel. 
12	Explain fading effects due to multipath time delay spread and fading effects due to Doppler spread **(April 2019)**. **(Dec 2016)**
13	What is i) Frequency -selective fading? Explain **(Nov/Dec 2018)** (ii) frequency-non-selective (Flat) fading **(April 2019)**/ Fading effects due to multipath time delay spread
14	(i) Write short notes on i) Time-selective fading (Fast Fading) ii) Time-Non-Selective channels (Slow Fading) **(ii)** Compare and contrast fast and slow fading. "In practice fast fading occurs for very low data rate Communications: Why? **(May 2017) (Nov 2017)**
15	Explain the various path loss models for small-scale fading. **(Nov/Dec 2018)**
16	(i) Derive the received power in dBm for a free space propogation model **(ii)** Determine the Fraunhofer distance for an antenna with maximum dimension of 1m and operating frequency of 900MHz. If the antennas have unity gain calculate the path loss. **(April 2021)**
17	Discuss the impact of time dispersion parameter, coherence bandwidth , Doppler spread and coherence time on small scale fading. **(April 2021)**
18	With a neat sketch explain and derive the received power for a two ray ground reflection model. **(April 2021)**
	UNIT II CELLULAR ARCHITECTURE

Multiple Access techniques - FDMA, TDMA, CDMA– Capacity calculations– Cellular concept- Frequency reuse-channel assignment-handoff-interference & system capacity-trunking &grade of service–Coverage and capacity improvement.

UNIT-II / PART-A

1 **What is the difference between multiplexing and multiple access schemes?**

Multiple Access schemes: When a resource is accessed by multiple users, it is called multiple access.

Multiplexing: It is a process of simultaneously transmitting two or more individual signals over a single communication channel.

2 **What is Multiple access schemes. What are the different types of multiple access schemes? (Dec 2013), (May 2016), (April 2018)**

Multiple Access: When a resource is accessed by multiple users, it is called multiple access.

Frequency division multiple access (FDMA)-each user is assigned with different frequencies within the allocated spectrum.

Time division multiple access (TDMA) - each user is assigned with different time slots within the allocated spectrum

Code division multiple access (CDMA)-each user is assigned a different code within the allocated spectrum.

Space division multiple access (SDMA)- is a channel access method used in mobile communication systems which reuses the same set of cell phone frequencies in a given service area using sectorized antennas.

3 **What are the disadvantages of FDMA?**

- It requires tight RF filtering to minimize the adjacent channel interference.
- If the FDMA channel is not in use, it cannot be used by another user.
- It is prone to fading and Inter modulation

4 **Compare FDD and TDD.**

FDD (Frequency Division Duplexing)	**TDD (**Time Division Duplexing)
Allows two distinct bands of frequencies to every user	Allows multiple users to share a single radio channel in different time slots.
The frequency separation of forward and reverse channel is constant throughout the system.	The time separation of forward and reverse channel is small throughout the system.
Duplexer is used inside the subscriber unit.	TDD uses Single channel and does not require duplexer.

5 **What are the advantages of FDMA?**

- FDMA channel carries only one phone circuit at a time.
- Since FDMA is a continuous transmission scheme fewer bits are only needed for synchronization.
- ISI (Inter Symbol Interference) is low.
- Complexity of FDMA is very low.

6 **What are the features of TDMA?**

- In TDMA a single carrier frequency is shared among multiple users.
- Each user is assigned a non-overlapping time slot. Number of time slots per

	frame depends on (1) available bandwidth, (2) modulation techniques etc. • Transmission for TDMA users is not continuous, but occurs in bursts, resulting in low battery consumption. • The subscriber transmitter may be turned off during non-transmission periods. • Hand off process is simpler for a subscriber, since it can listen to other base stations during non-transmit times.
7	**Define CDMA and mention its significance.** Code Division Multiple Access (**CDMA**) is a sort of multiplexing that facilitates various signals to occupy a single transmission channel. It optimizes the use of available bandwidth. The technology is commonly used in ultra-high-frequency (UHF) cellular telephone systems, bands ranging between the 800-MHz and 1.9-GHz. Better system capacity (supporting high no. of users) is one of the **advantages** of **CDMA** mobile system. The main **advantage** of WCDMA is the much higher data rate than GSM. Therefore, one gets more data services including high speed internet communications. It also provides communication privacy between users.
8	**What is SDMA? What are the advantages of SDMA?** *Space Division Multiple Access* (SDMA): this is an alternative way of increasing the capacity of TDMA/FDMA systems. In this method, cluster size (frequency reuse) remains unchanged, while the number of users within a given cell is increased. Multiple users can be served on the *same* time/frequency slot, using sectorized antennas. The same frequency can be reused multiple times and signals on the same frequency do not interfere with one another.
9	**What is near and far effect? How it influence CDMA? What are counter measurements?** The near–far problem or hearability problem is the effect of a strong signal from a near signal source in making it hard for a receiver to hear a weaker signal from a farther source due to adjacent-channel interference, co-channel interference, distortion, capture effect, dynamic range limitation, or the like. Such a situation is common in wireless communication systems, in particular CDMA.
10	**Define Fixed channel Allocation (FCA).** **Fixed channel Allocation (FCA):** Each cell is assigned with a predetermined set of voice channels. If all the channels in the cell are occupied, then the call is blocked and the user does not get service. In variation of a fixed channel assignment, a cell can borrow a channel from its neighbouring cells, if its own channels are full.
11	**Define Dynamic Channel Allocation (DCA).** In **Dynamic Channel Allocation (DCA)**: In this scheme, Voice channels are not allocated to different cells permanently. Each time a call request is made, the base station requests a channel from Mobile switching centre (MSC). To ensure the minimum QoS (Quality of Service), MSC allocates a given frequency, if that frequency is not currently used in the cell, which falls into the limiting frequency reuse distance. Thus DCA reduces the likelihood of call blocking which can improve the capacity of a cellular system.
12	**When does handoff occur?** Hand-off occurs when a received signal from its serving cell becomes weak and another cell site can provide a stronger signal to the mobile subscriber. If the new cell-site has some free voice channels then it assigns one of them to the handed-off call.

13 Differentiate soft and hard handoff. (May 2016).

Hard handoff	Soft handoff
It is characterized by a mobile having a radio link with only AP at any time.	The mobile can simultaneously communicate with more than one AP during the handoff.
Thus, the old connection is terminated before a new connection is activated. This mode of operation is referred to as **break before make.**	Thus, new connection is made before breaking the old connection, and is referred to as **make before break.**

14 Difference between adjacent channel interference and Co-channel interference?

adjacent channel interference	Co-channel interference
It is caused due to signals that are adjacent in frequency.	It is caused due to the cells that reuse the same frequency set.
Problem can be severe if the interferer is very near to the subscriber's receiver.	CCI cannot be overcome by the increasing the carrier power of the transmitter.

15 Define frequency reuse. (April 2021)

The design procedure of allocating channel groups for all of the cellular base station within a system is known as frequency reuse or frequency planning.

Frequency Reuse factor = **1/ N where N= $i^2 + j^2 + ij$** and **N-number of cells in a cluster.**

Possible values of N are 1, 3, 4,7,12…

- To increase the number of users
- To increase the capacity and coverage area.

To reduce the co channel and adjacent interference.

16 Why the cell shapes are hexagons?

Hexagons are geometric shapes that approximate a circle.(for Omni directional radiation) Moreover a circle or triangle will create lot of empty geographical area which is not feasible for wireless communication.

Using Hexagon geometry, fewest numbers of cells can cover the entire geographical region.

17 What is meant by cell capacity?

Consider a cellular system with S duplex channels. Suppose each cell is allocated to K channels. Let these S channels be divided among N cells. (Cluster)

S=KN

If a cluster of N cell is replicated M times in the system, the total number of duplex channels C is the cell capacity

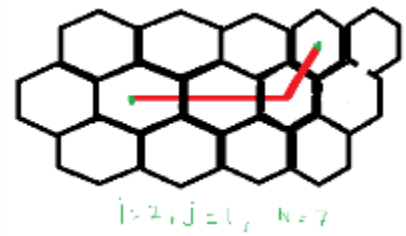
C= MS= MKN

18 Write down the procedure involved in the determination of co-channel cell. (April 2021)

- Move i cells along any chain of hexagon.
- Turn 60^o counter clock wise and move j cells

$N= i^2 + j^2 + ij$

N-Number of cells in a cluster.

	
19	**State advantages of CDMA over FDMA? (Dec2014) (Dec 2016)** CDMA technology has bandwidth thirteen times efficient than FDMA and forty times efficient than analog systems. CDMA also have better security and higher data and voice transmission quality because of the spread spectrum technology it uses, which has increased resistance to multipath distortion. CDMA has greater coverage area when compared to FDMA. The main advantage of the CDMA is that, in the single detection method it is more flexible than FDMA or joint detection. CDMA is said to have higher capacity than FDMA.
20	**Define Grade of Service? (Dec2015) (Dec 2016)** Grade of Service in Wireless communication can be defined as the measure of congestion which is specified as a probability. The probability of a call is being blocked (Erlang B) The probability of a call being delayed beyond a certain amount of time (Erlang C)
21	**List the features of cellular concept used for mobile telephony. (May 2017)(Nov/Dec 2018)** With limited frequency resource, cellular principle can serve thousands of subscribers at an affordable cost. In a cellular network, total area is subdivided into smaller areas called “cells”. Each cell can cover a limited number of mobile subscribers within its boundaries. By using the frequency reuse concept, more number of users can use the service with high coverage and maximum capacity.
22	**In a cellular network, among handoff call and a new call, which one is given as priority? Why? (May 2017)** Handoff calls are given higher priority over new calls. A new call occurs when a user requests a new connection, while a handoff occurs when an active user moves from one cell to other. Call dropping occurs when a call in progress is forcefully terminated due to lack of available sources in the new cell. On the other hand, Call blocking takes place when a new call may not be served. Call dropping is less desirable than call blocking. Hence, Handoff calls are given higher priority over new calls.
23	**What do you mean by forward and reverse channel? (Nov 2017)** **Forward Channel** The forward channel can be defined as the link between cell-to-mobile direction of communication or the downlink path. **Reverse Channel** The reverse channel can be defined as the link between mobile-to-cell direction of communication or the uplink path.
24	**What do you mean by mobile assisted handoff? (May 2019)** Every mobile station measures the received power from the surrounding base stations. Hand off is initiated when the power received from the base station of a neighbouring cell begins to exceed the power from the current base station by a certain

	level or for a certain period of time.
	UNIT II / PART B
1	Compare and Contrast TDMA, FDMA and CDMA techniques. **(May 2016) (Nov/Dec 2018).**
2	Explain in detail about the Channel Assignment and Handoff Strategies. **(May 2017) (April 2018)**
3	How can capacity of cellular communication system be improved? Explain any two-capacity expansion techniques. **(Nov/Dec 2018).**
4	Explain in detail about TDMA Techniques. **(Nov 2017)**
5	Explain in detail about CDMA Techniques**.(April 2019)**
6	Explain the various methods that increase the channel capacity and coverage area of a cellular system. **(May 2016).**
7	Explain how Hand off in cellular networks is implemented and various types of Handoff techniques. **(Dec 2013) (Dec 2014) (Nov/Dec 2018).**
8	Explain Hand off process in detail. **(April 2018)**
9	Explain the co channel interference and adjacent channel interference of a cellular system. Describe the techniques to avoid the interference. **(Dec 2016)**
10	**(i)** Explain in detail how frequency is efficiently allocated in an cellular systems? **(Dec 2016)** **(ii)** Explain in detail a handoff scenario at cell boundary. **(Dec 2016)(April 2019)**
11	A spectrum of 33 MHZ is allocated to a wireless FDD cellular system which uses two 25KHZ Simplex Channels to provide full duplex voice and control channels, compute the number of Channels available per cell if a system uses (a)four-cell reuse (b)seven-cell reuse ,and (c)12-cell reuse. If 1 MHZ of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control Channels and voice channels in each cell for each of systems? **(May 2017)(April 2019)**
12	A cellular service provider decides to use TDM Scheme which can tolerate the Signal to interference ratio as 15 dB in the worst case. Find the optimal value of N? **(Dec 2015)** 1. Omni directional Antennas 2.120^o Sectoring 3. 60^o Sectoring 4. Should sectoring be used? If so which case (60^o or 120^o) should be used? (Assume n=4)
13	A hexagonal cell within a four cell system has a radius of 1.387 km. A total of 60 channels are used within the entire system. If the load per user is 0.029 Erlang and λ = 1 call/ hour. Compute the following for an Erlang C system that has a 5% probability of a delayed call. (i) How many users per square kilometer will support this system? (ii) What is the probability that a delayed call will have to wait for more than 10

	s? (iii) What is the probability that a call will be delayed for more than 10 s? (**Dec 2015)**
14	(a) Explain the impact of interference in a cellular system and system capacity **(Nov/Dec 2018).** (b) Consider Global System FDMA/TDD system that uses 25 MHz for the forward link, which is broken into radio channels of 200 MHz. If 8 speech signals are supported on a single radio channel and if no guard band is assumed. Find the number of simultaneous users that can be accommodated in GSM. **(c)** If GSM uses a frame structure where beach frame consists of eight time slots, and each time slot contains 156.25 bits, and data is transmitt5ed at 270.833 kbps in the channel. Find (i) the time duration of a bit (ii) the time duration of a slot (iii) the time duration of a frame and (iv) how long must a user occupying a single time slot wait between two successive transmissions? **(May 2017)**
15	Explain in detail (i) cell splitting (ii) Trunking and Grade of Service of Cellular System. **(Nov 2017)(April 2019)**
16	(i) Discuss your understanding on various multiple access techniques namely FDMA,TDMA and CDMA. **(ii)** Highlight their advantage, disadvantage and uses in cellular communication. **(April 2021)**
17	**(i)** Explain with neat sketch, handoff mechanism adopted in cellular communication detailing the condition for proper handoff. **(April 2021)** (ii) Highlight the significance of prioritizing handoffs and practical handoff consideration.
18	Analyse the impact of both co-channel and adjacent channel interference on system capacity in a cellular system. **(April 2021)**
UNIT III DIGITAL SIGNALING FOR FADING CHANNELS Structure of a wireless communication link, Principles of Offset-QPSK, p/4-DQPSK,MinimumShift Keying, Gaussian Minimum Shift Keying, Error performance in fading channels, OFDM principle– Cyclic prefix, Windowing ,PAPR.	
UNIT-III/ PART-A	
1	**Define Digital modulation.** Digital Modulation is nothing but mapping the digital data into the analog waveform for transmitting the signal via channel. E.g.: Binary Modulation (two bits), M-ary Modulation.
2	**What is demodulation?** It is the process of recovering the original modulating signal (Digital data) from a modulated signal.
3	**Write the advantages of digital over analog modulation.** •Spectral Efficiency is high. •Adjacent Channel Interference is low. •Greater noise immunity,

	•Robustness to channel impairments •Easier multiplexing of various forms of information and Greater security
4	**What is nonlinear modulation?** In nonlinear modulation, the amplitude of the carrier is constant regardless of the variation in the modulating signal.
5	**What is linear modulation? Mention the merits and demerits of nonlinear modulation.** In linear modulation technique, the amplitude of the transmitted (carrier) signal varies linearly with the modulating digital signal. In general, linear modulation does not have a constant envelope Merits: Lower efficient class c amplifiers can be used without introducing degradation in the Spectrum occupancy of the transmitted signal. Low out of band radiation of the order of -60dB to -70dB can be achieved. Limiter-discriminator detection can be used, which simplifies receiver design and provides high Immunity against random FM noise and signal fluctuations due to Rayleigh fading. Demerits: Constant envelope modulations occupy a larger bandwidth than linear modulation scheme In situations where bandwidth efficiency is more important than power efficiency, constant Envelope modulation is not well suited.
6	**What do you meant by signal constellation diagram?** A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying. It displays the signal as a two-dimensional xy-plane scatter diagram in the complex plane at symbol sampling instants. The angle of a point, measured counter clockwise from the horizontal axis, represents the phase shift of the carrier wave from a reference phase. The distance of a point from the origin represents a measure of the amplitude or power of the signal.
7	**Define the following terms: Absolute Bandwidth, Half Power Bandwidth, Null-Null Bandwidth.** Absolute Bandwidth: The range of frequencies over which the signal has non zero power spectral densities. Null to Null Bandwidth: Width of the main spectral lobe of power spectral densities. Half Power Bandwidth: It is defined as the interval between the frequencies at which the power spectral densities has dropped to 3 dB (or) half power below to the value.
8	**Explain the following terms a) Baud rate b) Bit rate** Baud rate: Speed at which symbols are transmitted in a digital communication system, i.e. no of symbols/second. Bit rate: Speed at which data bits is transmitted in a digital communication system, i.e. no of bits/sec.
9	**What is meant by Phase shift keying?** If phase of the carrier is varied depending on the input digital signal, then it is called phase shift keying.

10	**What is Quadrature modulation? What is meant by QPSK?** Sometimes two or more Quadrature carriers are used for modulation. It is called Quadrature Modulation. QPSK is a multi-level modulation in which four phase shifts are used for representing four symbols.
11	**What are the advantages of π/4 Quadrature Phase Shift Keying over QPSK?** •It is the compromise between QPSK and BPSK. •It uses the two constellation diagram of QPSK. •The maximum phase change is limited to 135o as compared to 180o for BPSK and 90o for QPSK.
12	**What are the features of π/4 Quadrature Phase Shift Keying? (Nov 2017)** •It uses non coherent detection which greatly simplifies the receiver design. •In the presence of multipath spread and fading, π/4 QPSK performs better than QPSK.
13	**What is offset QPSK? (Nov 2017)** It is the advanced version of QPSK modulation in which the signal doesn‟t get down to zero because only one bit of the symbol is changed at a time. By offsetting the timing of odd and even bits by one half period, then in phase and Quadrature Phase will never change at a time. Phase shift is limited to not more than 90^o at a time.
14	**What are the features of offset QPSK? (May 2019)** •It prevents the generation of side lobes and spectral widening •Less ISI. •The staggered alignment of nature of the spectrum will save the bandwidth effectively. •It performs better than QPSK in noisy environment.
15	**What is MSK? What is the advantage of MSK over QPSK?** MSK is a special type of continuous phase frequency shift keying wherein the peak frequency deviation ratio is ¼ th of bit rate. Modulation index of MSK is 0.5. In QPSK the phase changes by 90 or 180 degrees. This creates abrupt amplitude variations in the waveform. Therefore bandwidth requirement of QPSK is more. MSK overcomes this problem. In MSK, the output waveform is continuous in phase hence there are no abrupt changes in amplitude.
16	**Why MSK is called as fast FSK? (May 2016). Mention some merits of MSK. (May 2017)** MSK is called fast FSK, as the frequency spacing used is only half as much as that used in conventional non-coherent FSK. Merits: Constant envelope, Self-synchronizing capability, Spectral efficiency, Good BER performance.
17	**Why MSK cannot be directly used in multi user communications?** 1. The main lobe of MSK is wide. This makes MSK unsuitable for the applications where extremely narrow bandwidths and sharp cut-offs are required. 2. Slow decay of MSK power spectral density curve creates adjacent channel interference. Hence MSK cannot be used for multiuser communications.
18	**What is the need of Gaussian filter in GMSK? (Dec 13)(Dec 2016)** Gaussian filters are used to reduce the transmitted bandwidth of the signal. Gauss Filters smooth the phase trajectory of MSK signal and stabilises the instantaneous

	frequency variation over time. Thus reduces the side lobe levels.
19	**What is GMSK? What are the advantages and disadvantages of GMSK? (Nov/Dec 2018)** GMSK is a derivative of MSK. The side lobe levels of the spectrum are further reduced by passing a modulating NRZ data to the Gaussian Pulse Shaping Filter. Advantages: GMSK has high power efficiency. GMSK has high spectral efficiency. Disadvantages: Gaussian filter introduces the ISI in the transmitted signal. But the degradation is not severe when Bandwidth-time product (BT) is greater than 0.5.
20	**What is OFDM?** OFDM (Orthogonal Frequency Division Multiplexing) is a digital multicarrier communication method used in 4G, Digital Subscriber Links (DSL) Internet Access OFDM is a fundamental concept of LTE (Long Term Evolution), Wi-Max (Wireless worldwide Inter-operability for microwave access), IEEE 802.11 a, IEEE 802.11 g, IEEE 802.11 n.
21	**Define cyclic prefix. (Dec 2016) (April 2018)** When the two consecutive blocks of OFDM symbols are transmitted, it will create the Inter Block Interference (IBI). To remove this, samples are taken from the tail of the OFDM block 1, cycling them in cyclic pattern and add it to the prefix of the transmitted OFDM Symbol 1. It will remove the Inter Block Interference (IBI) (or) Inter Carrier Interference. (ICI)
22	**Define PAPR. (Nov 2017) (Nov/Dec 2018).** The ratio between maximum instantaneous Powers to the average signal power is called peak to average power ratio (PAPR) $PAPR = \frac{\max(x(t).\, x^{*}(t))}{E(x(t).\, x^{*}(t))}$ A low PAPR allows the transmit power amplifier to operate efficiently, whereas a high PAPR forces the transmit power amplifier to have a large back off in order to ensure linear amplification of the signal. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system.
23	**Define Windowing. (May 2016).** Windowing is multiplying the large signal peak with Gaussian shaped windows. It is used to reduce sensitivity to frequency offsets in an OFDM system. This process involves cyclically extending the time domain signal with each symbol by „v‟ samples. The resulting signal is then shaped with a window
24	**What is the advantage of using multicarrier communications such as OFDM? (May 2017)** OFDM has been used in many high data rate wireless systems because of the many advantages it provides, (a) Immunity to selective fading (b) Resilience to interference (c) Spectrum efficiency.
25	**Why GMSK is used in cellular communication? (April 2021)** GMSK has high power efficiency. GMSK has high spectral efficiency.

26	**How OFDM differ from FDM? (April 2021)** OFDM is a multicarrier modulation technique whereas FDM is a single carrier modulation technique. ODFM is less affected by ISI but in FDM technique the ISI is more.
	UNIT-III / PART-B
1	Explain in detail about the structure of wireless communication link.
2	Explain QPSK transmitter and receiver with signal space diagram and give an expression for spectral Efficiency. **(Nov 2017)** (or) Explain OQPSK? Why it is preferred, justify. **(Nov/Dec 2018)**
3	Explain π/4 Differential QPSK and compared with traditional QPSK **(Nov/ Dec 2018)**
4	Explain π/4 Differential QPSK & OQPSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(June 2013)(May 2016)(April 2018)**
5	Explain MSK transmitter and receiver with signal space diagram and give an expression for spectral Efficiency. **(June 2013), (Dec 2015) (Dec 2016) (Nov 2017)**
6	Explain GMSK transmitter and receiver with signal space diagram and give an expression for spectral Efficiency **(Dec 2015), (May 2016).**
7	Discuss about the performance of digital modulation with and without fading channels. **(Dec 2013), (May 2017)**
8	Discuss any four reasons for the physical error floors in delay and frequency dispersive fading channels. **(May 2019)**
9	Draw the basic arrangement of OFDM transceivers and discuss its overall operation. **(Dec 2016) (May 2017) (Nov/Dec 2018)** and compare it with FDMA with a sketch. **(May 2019)**
10	Write short notes on PAPR reduction techniques. **(May 2017)**
11	**(i)** State the principle of operation of π/4QPSK transmitter with a neat diagram **(May 2019)** **(ii)** Explain MSK and its importance in wireless communication. **(Nov/Dec 2018)** Explain its power spectral density. **(Dec 2014)**
12	Why are constant envelope modulation schemes such as MSK and GMSK used in wireless communication system? Compare and contrast these two modulation techniques. **(May 2017)**
13	List the advantages and applications of BFSK.
14	Prove that the OFDM system converts the delay spread channel into a set of parallel fading channels, using the concept of cyclic prefix. **(April 2018)**
15	Derive the BER for BPSK modulation for frequency flat fading channels. **(April 2018)**
16	(i) "OFDM is more popularly used in wireless communication"- Justify with proper explanation detailing the working principle, cyclic prefix, implementation structure. **(ii)** State the significance of windowing and PAPR. **(April 2021)**
17	(i) Explain the working mechanism of transmitter and receiver block of MSK modulation technique. **(ii)** State the salient features observed in the power spectral density of MSK when compared with QPSK and OQPSK. **(April 2021)**

UNIT IV MULTIPATH MITIGATION TECHNIQUES	
Equalisation–Adaptive equalization, Linear and Non-Linear equalization, Zero forcing and LMS Algorithm .Diversity–Micro and Macro diversity, Diversity combining techniques, Error probability in fading channels with diversity reception, Rake receiver	
UNIT-IV / PART-A	
1	**What are the techniques used to improve the received signal quality? (April 2019)** Equalization, Diversity and Channel coding
2	**What are the factors used in adaptive algorithms? (Dec 2014)** ❖ Rate of convergence, ❖ Misadjustment, ❖ Computational complexity ❖ Numerical properties.
3	**What is the need of equalization?** ❖ Equalization is used to compensate the inter-symbol interference created by multipath environment. ❖ An equaliser within a receiver compensates the average range of expected channel impulse response amplitude and delay characteristics. ❖ Equaliser should be adaptive since the channel is unknown and time varying.
4	**What is diversity and mention the types of diversity. (May 2017)** Transmitting the same information across independent fading channels is called diversity. 1. Spatial diversity 2.Antenna diversity 3.Frequency diversity 4.Time diversity 5.Polarization diversity
5	**Write the functions of diversity. (Dec 2013)** ❖ Diversity is used to compensate for fading channel impairments, and is usually implemented by using two or more receiving antennas. ❖ Diversity improves transmission performance by making use of more than one independently faded version of the transmitted signal.
6	**What is equalizer? (Dec 2013)** The device which equalizes the dispersive effect of a channel is referred to as an equalizer.
7	**Define adaptive equalizer. (May 2016)** As the channels are random and time varying, Equaliser must track the time varying nature of the mobile channel to combat ISI, thus are called adaptive equalizer
8	**What is training mode in an adaptive equalizer?** First, a known fixed length training sequence is sent by the transmitter, then the receiver's equalizer may adapt to a proper setting of minimum bit error rate detection. Those training sequence is pseudorandom binary signal or a fixed and prescribed bit pattern. Training sequence permits the equaliser to acquire filter coefficients under worst channel conditions.
9	**What is tracking mode in an adaptive equalizer?**

	When the data of users are received, the adaptive algorithm of the equaliser tracks the changing nature of channel. As a result, filter characteristics of adaptive equaliser continuously changes over time.
10	**Write a short note on i) linear equalizers ii) non-linear equalizers (Dec 2016) (Nov/Dec 2018)** **Linear equalizer:** If the output is not used in the feedback path to adapt, then this type of equalizer is called linear equalizer. **Non-linear equalizer:** If the output is fed back to change the subsequent outputs of the equalizer, this type of equalizer is called nonlinear equalizers.
11	**Why nonlinear equalizers are preferred?** The linear equalizers are very effective in equalizing channels where ISI is not severe. The severity of ISI is directly related to the spectral characteristics. In this case there are spectral nulls in the transfer function of the effective channel; the additive noise at the receiver input will be dramatically enhanced by the linear equalizer. To overcome this problem, nonlinear equalizers can be used.
12	**Write the advantages of LMS algorithm.** ❖ It maximizes the signal to distortion at its output within the constraints of the equalizer filter length. ❖ Low computational complexity and Simple program
13	**List out the factors that affect the performance of adaptive equalizer algorithms (May 2021)** 1. Mean Square Error (MSE) 2. Elapsed Time
14	**What is the need for diversity schemes? (May 2017)** ❖ To increase signal to noise ratio ❖ To degrade the bit error Probability ❖ For High Immunity of fading
15	**Explain Diversity concept.** If one radio path undergoes a deep fade, another independent path may have a strong signal. By having more than one path to select from, both the instantaneous and average SNRs at the receiver may be improved.
16	**Define spatial diversity. (Nov 2017)** The most common diversity technique is called spatial diversity, whereby multiple antennas are strategically spaced and connected to a common receiving system. While one antenna sees a signal null, one of the other antennas may see a signal peak, and the receiver is able to select the antenna with the best signals at any time.
17	**Differentiate between Macro diversity and Micro diversity. (Dec 2014) (Dec 2016)**

Macro diversity	**Micro diversity**
It is suitable for large scale fading channels.	It is suitable for small scale fading channels
It is caused by shadowing due to variation in both the terrains and nature of	It is caused by multiple reflections from the surroundings in the vicinity of the

	surroundings	mobile.
	These antennas are located on the vehicle or at the same base station tower and their spacing is a few wavelengths. The received signal amplitude is correlated, depending on the antennas separation *d* relative to the wavelength.	Signals from within a cell may be received at the different corners of the hexagonal area. The advantage is that not only the multipath fading attenuation is independent at each branch but that the shadowing and path losses are also uncorrelated to some extent
18	**What are the benefits of Rake Receiver? (May 2016).** ❖ Rake receiver gives the best performance among all the CDMA receivers. ❖ Since, correlators form the main working system of the receiver, The best version of the received signal is selected and given as output.	
19	**List out the four types of Combining Methods.** Selection combining, switched combining, equal gain combining, maximum ratio combining.	
20	**Why is an adaptive equaliser is required? (May 2017)** Since the channel is random and time varying, adaptive equalization can be used to compensate the inter-symbol interference created by multipath environment.	
21	**State the principle of diversity. (June 2013)** Diversity: It is the technique used to compensate for fading channel impairments. It is implemented by using two or more receiving antennas. While Equalization is used to counter the effects of ISI, Diversity is usually employed to reduce the depth and duration of the fades experienced by a receiver in a flat fading channel. These techniques can be employed at both base station and mobile receivers. Spatial Diversity is the most widely used diversity technique.	
22	**Define STCM. (Nov 2017)** STCM stands for Space-Time Coded Modulation. Channel coding can also be combined with diversity a technique called Space-Time Coded Modulation. The space-time coding is a bandwidth and power efficient method for wireless communication.	
23	**List different types of diversity schemes. (April 2018)** ❖ Time diversity ❖ Frequency diversity ❖ Space diversity ❖ Polarization diversity ❖ Multiuser diversity ❖ Co-operative diversity	
24	**What is Macro diversity? (Nov/Dec 2018, April 2019)** It is suitable for large-scale fading channels. These antennas are located on the vehicle or at the same base station tower and their spacing is a few wavelengths. The received signal amplitude is correlated, depending on the antennas separation d relative to the wavelength. It is caused by shadowing due to variation in both the terrains and nature	

	of surroundings
25	**Assume 5 branch diversity is used, where each branch receives an independent Rayleigh fading signal. If the average SNR is 20 dB, determine the probability that the SNR will drop below 10 dB. (May 2021)** γ = 10 dB Γ = 20 dB $\gamma/\Gamma = 0.1$ P_5 (10dB) =$[1 - e^{-.01}]^5$= .0000078
	UNIT-IV / PART-B
1	What is equalization? Why equalization in a wireless system required to be adaptive? **(Nov/ Dec 2018)**
2	Derive the mean square error for a generic adaptive equaliser **(Dec 2015).**
3	Briefly explain about linear and non-linear equalizers. **(Dec 2013) (May 2016) (Nov 2017)**
4	Write a brief note on space diversity reception techniques. **(April 2019)**
5	Describe any two adaptation algorithms for Mean square error Equalizers **(June 2013)**
6	Briefly explain and about linear equalization procedure with neat diagram. **(Nov/ Dec 2018)**
7	Explain in detail the various factors to determine the algorithm for adaptive equaliser. Also derive the Least Mean Square Algorithm for adaptive equaliser. **(Dec 2016)**
8	Discuss in detail about the micro diversity concepts. 1. Spatial diversity 2. Frequency Diversity 3. Time Diversity 4. Polarization Diversity/ Explain any two diversity techniques to combat small scale fading **(June 2013) (May 2016) (Nov 2017)**
9	With relevant diagrams explain the RAKE Receiver. **(Nov/ Dec 2018)** Also discuss how time diversity is achieved in CDMA technique using RAKE Receiver? **(Dec 2016) (April 2018) (April 2019)**
10	Draw and explain a simplified communication system using an adaptive equalizer at the receiver. **(April 2019)**
11	**(i)** Describe any two diversity combining techniques. Stating their merits **(Nov/ Dec 2018)** **(ii)** Explain the operation of an adaptive equalizer at the receiver side **(Dec 2014)**
12	(i) Describe the role played by Equalisation and diversity as multipath mitigation techniques. Compare and contrast these two techniques. (ii) Consider the design of US digital cell equaliser, where f= 900 MHz and the mobile velocity v= 80 km/hr, determine the maximum Doppler shift, the coherence time of the channel and the maximum number of symbols that could be transmitted without updating the equaliser assuming that the symbol rate is 24.3 k symbols / sec. **(May 2017)**
13	**(i)** What is zero forcing algorithm and explain. **(Nov/ Dec 2018)** (ii) Assume the four-branch diversity is used, where each branch receives an independent Rayleigh fading signal. if the average SNR is 20 dB, determine the probability that the SNR will drop below10 dB. Compare this with the case of a single

	receiver without diversity. (iii) Derive an expression for the performance improvement due to maximal ratio combining. **(May2017)**
14	Analyze and compare the error performance in fading channels with and without diversity reception techniques **(Nov 2017)(April 2018)**
15	With valid statements, analytically prove that the adaptive equalizers exhibit superior performance over the conventional equalizers. **(Nov 2017)**
16	(i) Write short notes on zero forcing and LMS algorithm. **(ii)** Draw the block diagram of simplified communication system using an adaptive equalizer at the receiver. **(April 2021)**
17	(i) Discuss any two receiver diversity technique **(ii)** Draw the structure of RAKE receiver. **(April 2021)**

UNIT V MULTIPLE ANTENNA TECHNIQUES

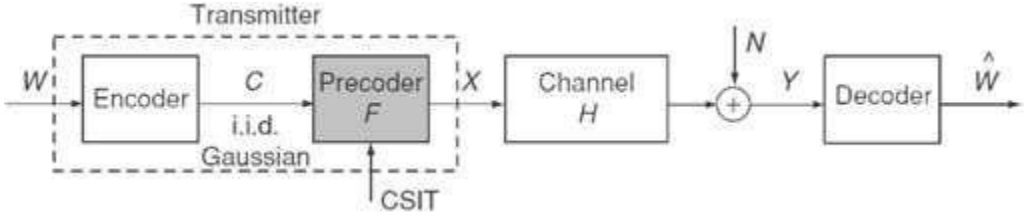
MIMO systems–spatial multiplexing-System model -Pre-coding- Beam forming-transmitter diversity, receiver diversity-Channel state information-capacity in fading and non-fading channels.

UNIT-V / PART-A

1	**What are MIMO systems? (May 2016).** Systems with multiple antennas at the transmitter and multiple antennas at the receiver, are commonly, referred to as multiple-input multiple-output (MIMO) systems. The multiple antennas can be used to increase data rates through multiplexing or to improve performance through diversity.
2	**Write the advantages of MIMO systems.** ❖ Multiple-input multiple-output systems can significantly enhance the performance of wireless systems through multiplexing, diversity gain and array gain. ❖ For a given transmit energy per bit, multiplexing gain provides a higher data rate whereas diversity gain provides a lower BER in fading channels. ❖ Support a higher data rate for a given energy per bit, so it transmits the bits more quickly and can then shut down to save energy.
3	**Write the disadvantages of MIMO systems.** ❖ The resource requirements and hardware complexity is higher compared to single antenna based system. ❖ Cost of MIMO based system is higher compared to single antenna based system due to increased hardware and advanced software requirements. ❖ Signal processing associated with MIMO is highly complex.
4	**Mention the applications of MIMO systems.** ❖ MIMO can reliably connect devices in home, such as computer networking devices, cabled video devices, phone lines, music, storage devices etc. ❖ The IEEE 802.16e standard and the IEEE 802.11n standard also use MIMO system. ❖ MIMO is used in mobile radio telephone standard such as 3GPP and 3GPP2 standard.

	❖ 3GPP High Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standard use MIMO.
5	**What are smart antennas in MIMO systems?** Smart antennas (also known as adaptive array antennas, digital antenna arrays) are antenna arrays with smart signal processing algorithms used to identify spatial signal signatures such as the direction of arrival (DOA) of the signal, and use them to calculate beam forming vectors which are used to track and locate the antenna beam on the mobile/target. Smart antenna techniques are used mostly in cellular systems like W-CDMA, UMTS, and LTE. Smart antennas have many functions: DOA estimation, beam forming, interference nulling, and constant modulus preservation.
6	**What is Beam forming? (May 2021)** Beam forming or spatial filtering is a signal processing technique used for directional signal transmission or reception. This is achieved by combining elements in an antenna array in such a way that signals at particular angles experience constructive interference while others experience destructive interference. Beam forming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity.
7	**What are the advantages of Beam forming?** Following are the benefits or advantages of Beam forming: ❖ It boosts the power of beams in the desired direction and hence farthest subscribers can also be reached by telecom cell towers or base stations. This increases supporting capacity of a cellular tower in terms of number of subscribers. ❖ It can also reduce the power of the beam for nearby subscribers and hence interference issues near to the cell towers can be avoided. ❖ It increases C/N ratio of the signal and hence the signal can withstand against noisy and attenuating channel environment. This increases coverage capacity of the cell tower or base station.
8	**What is multiplexing Gain/ capacity gain?** MIMO channels offer a linear increase in capacity without additional power or bandwidth. This gain is referred as spatial multiplexing gain. The spatial multiplexing gain is realized by transmitting independent data signals from individual antennas. This multiplexing gain is also referred to as capacity gain. It is also used to increase the data rate; since independent data streams are send through independent paths between multiple transmitters and multiple receivers. In other words if there are M transmit antennas and N receive antennas, the increase in the data rate is min (M, N) fold.
9	**Distinguish between diversity gain versus array gain. (April 2018)** In MIMO communication systems, array gain means a power gain of transmitted signals that is achieved by using multiple-antennas at transmitter and/or receiver, with respect to single-input single-output case. It can be simply called power gain. Diversity gain is the increase in signal-to-interference ratio due to some diversity scheme, or how much the transmission power can be reduced when a diversity scheme

	is introduced, without a performance loss. Diversity gain is usually expressed in decibels, and sometimes as a power ratio.
10	**How does spatial multiplexing work? (Dec 2016) (May 2017)(Nov 2017)** ❖ Spatial multiplexing uses MEAs at the TX for transmission of parallel data streams . ❖ An original high-rate data stream is multiplexed into several parallel streams, each of which is sent from one transmit antenna element. ❖ The channel "mixes up" these data streams, so that each of the receive antenna elements sees a combination of them. If the channel is well behaved, the received signals represent linearly independent combinations. ❖ Appropriate signal processing at the RX can separate the data streams. ❖ A basic condition is that the number of receive antenna elements is at least as large as the number of transmit data streams. ❖ It is clear that this approach allows the data rate to be drastically increased – namely, by a factor of min (Nt, Nr).
11	**Define Diversity gain.** Diversity gain is the increase in signal-to-interference ratio due to some diversity scheme, or how much the transmission power can be reduced when a diversity scheme is introduced, without a performance loss. Diversity gain is usually expressed in decibels, and sometimes as a power ratio.
12	**Define short term CSI and long term CSI** Instantaneous CSI (or short term CSI) ❖ Instantaneous CSI means current channel condition ❖ This gives an opportunity to adapt the transmitted signal to the channel impulse response and thereby optimize the received signal for spatial multiplexing or to achieve low BER. Statistical CSI (or long term CSI) - ❖ Statistical characterization of the channel. ❖ Statistical characterization includes the type of fading distribution, the average channel gain, line of sight component and the spectral correlation. Statistical CSI can be used for transmission optimization.
13	**State the importance of spatial multiplexing.** ❖ Spatial multiplexing offer a linear increase in capacity without additional power or bandwidth. ❖ It is also used to increase the data rate; since independent data streams are send through independent paths between multiple transmitters and multiple receivers. In other words if there are M transmit antennas and N receive antennas, the increase in the data rate is min (M, N) fold.
14	**Define Transmitter diversity. (May 2016).** In transmit diversity there are multiple transmit antennas, and the transmit power is divided among these antennas. Transmit diversity is desirable in systems where more space, power and processing capability is available on the transmit side than on the

	receive side. Transmit diversity design depends on whether or not the complex channel gain is known to the transmitter.
15	**Define Receiver diversity. (Nov 2017)** In Receive diversity there are multiple Receive antennas, and the receive power is divided among these antennas. Receive diversity is desirable in systems where more space, power and processing capability is available on the receive side than on the Transmitter side. Receive diversity design depends on whether the channel gain is known (or) unknown to the receiver.
16	**Define channel capacity of MIMO system.** Two different definitions of capacity exist for MIMO systems: (i) Ergodic (Shannon) capacity (ii) Outage capacity Ergodic (Shannon) capacity: this is the expected value of the capacity, taken over all realizations of the channel. This quantity assumes an infinitely long code that extends over all the different channel realizations. Outage capacity: this is the minimum transmission rate that is achieved over a certain fraction of the time – e.g., 90% or 95%. This quantity assume that data are encoded with a near-Shannon-limit achieving code that extends over a period that is much shorter than the channel coherence time.
17	**What is Precoding? (April 2019)** ❖ Precoding is a processing technique that makes use of channel state information of the transmitter (CSIT) before the signal is transmitted. ❖ Precoding is done inorder to optimize the beams transmitted in intended areas. Precoding system structure 
18	**What is Ergodic capacity? (Dec 2016)** Ergodic capacity is related to channel capacity. It is same as Shannon channel capacity. It is the average capacity of the channel (irrespective of deep fading or slow fading).The Shannon capacity of a fading channel with receiver CSI for an average power constraint $\bar{P}$ is given by $C_{ergodic} = \int_0^{\infty} \mathrm{B}\log_2(1+\gamma).\mathrm{P}(\gamma).\mathrm{d}\gamma$ where B is the received signal bandwidth. This is also referred to as Ergodic capacity since it is the average of the instantaneous capacity for an AWGN channel with SNR γ given by $\mathrm{B}\log_2(1+\gamma)$.
19	**What is outage capacity? (Dec 2016)** Capacity with outage is define as the maximum rate that can be transmitted over a channel with some outage probability corresponding to the probability that the transmission cant be decoded with negligible error probability.

	$C_{outage} = (1 - P_{out}) \text{Blog}_2 (1 + \gamma_{min})$ Where P_{out} is the probability with outage= $P(\gamma < \gamma_{min})$
20	**What is Channel state information? (Nov/ Dec 2018) Mention its benefits. (May 2017)** In wireless communications, channel state information (CSI) refers to known channel properties of a communication link. This information describes how a signal propagates from the transmitter to the receiver and represents the combined effect of scattering, fading, and power decay with respect to the distance. The CSI makes it possible to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication with high data rates in multi antenna systems.
21	**What is meant by spatial multiplexing? (Nov/ Dec 2018)** Spatial multiplexing employs MEA‟s (Multiple element antennas) at the transmitter for transmission of data streams. An original high-rate data stream is multiplexed into several parallel streams, each of which is sent from one transmit antenna element. A basic condition is that the number of receive antenna elements (Nr) is at least as large as the number of transmit data streams (Nt). This approach allows the data rate to be drastically increased – namely, by a factor of min (Nt,Nr).
22	**What is meant by spatial diversity?** In spatial diversity, many signal copies are transmitted from different antennas and are received at more than one antenna. This redundancy is provided by employing an array of antennas, with a minimum separation of half wavelength between neighboring antennas. Spatial diversity technique is used to mitigate the effect of fading in wireless communication systems.
23	**Differentiate transmit diversity from random beam forming.(April 2019)** In **transmit diversity** there are multiple transmit antennas, and the transmit power is divided among these antennas. Transmit diversity is desirable in systems where more space, power and processing capability is available on the transmit side than on the receive side. Transmit diversity design depends on whether or not the complex channel gain is known to the transmitter. **Beamforming** or spatial filtering is a signal processing technique used in wireless communication systems for directional signal transmission or reception. This is achieved by combining elements in an antenna array in such a way that signals at particular angles experience constructive interference while others experience destructive interference. Beam forming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity.
	UNIT-V / PART-B
1	Briefly explain Multiple-input multiple output systems. **(Dec 2016) (May 2017) (Nov 2017)**
2	Explain Pre-coding and Beam forming with neat diagram. **(May 2017) (Nov/Dec 2018)**
3	Discuss in detail the classification of algorithms for MIMO based system. **(Dec 2016)**
4	Define Beam forming and briefly explain MIMO diversity gain.**(May 2016) (Nov 2017)**

5	Discuss on the capacity of MIMO system in flat fading and non-fading channels. **(Dec 2016) (May 2017)**
6	Determine the capacity of frequency selective fading and explain the concept of water filling/Water pouring models. **(Dec 2015)**.
7	Determine the capacity of a slow fading channel and prove that the outage probability for Receiver diversity system with L receives antennas. **(Dec 2015)**
8	Derive an expression for the capacity of the following systems: (i) SIMO system assuming that the channel is known at Receiver. (ii) MISO system assuming that the channel is known at Transmitter. **(iii)**MIMO system assuming that the channel is known at Transmitter. **(April 2018)**
9	Explain the types of CSI and their significance in wireless communication.
10	Explain Shanon‟s water filling power allocation strategy.
11	Derive and explain the capacity of non-fading channels with related sketches. **(Nov/Dec 2018)**
12	Explain transmitter diversity and receiver diversity in detail. **(Nov/Dec 2018)**
13	Explain MIMO system and its role in improving wireless communication system. **(Nov/Dec 2018)**
14	Explain clearly how spatial multiplexing works with a neat diagram and write down the expression for the channel matrix and received signal vector. **(April 2019)**
15	Explain the concept of diversity with CSI at the transmitter and derive the expression for the capacity. **(April 2019)**
16	(i) Discuss a 2 x 2 MIMO system and provide your understanding on Alamouti Code (ii)Write short notes on spatial multiplexing **(May 2021)**
17	(i) Mention the importance of channel state information **(ii)** How MIMO creates performance gains in a fading channel **(May 2021)**