UNIT I WIRELESS CHANNELS

PART A

1. What is meant by link budget Equation/ Friss Equation / Free space equation?

A link budget is the clearest and the most intuitive way of computing the required received power of the signal with respect to the 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 ISI?

Intersymbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. It happens mainly due to multipath propagation and fading.

5. What is meant by small scale fading? (May 2013)

The rapid fluctuations of the received signal strength of a radio signal over a smaller distanceor a short period of time is known as small scale fading.As the Receiver moves away from transmitter over smaller distance (100m-10 km), received signal strength will decrease very slowly.

6. What is meant by large scale fading? (May 2013)

The rapid fluctuations of the received signal strength of a radio signal over a larger distance or a long period of time is known as small scale fading.As the Receiver moves away from transmitter over larger distance (1m-10m), received signal strength rapidly decrease.

7. 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.

8. What is path Loss?

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

PL (dB) = $10\log(\frac{P_t}{P_r})$

9. What is EIRP?

Isotropic Radiator is an ideal antenna which radiates power uniformly in all directions and is often used to reference antenna gains in wireless systems.EIRP is an Effective Isotropic Radiator is nothing but maximum power is radiated in the direction of maximum gain.

$$EIRP = P_t * G_t$$

10. Give the equation for average large scale path loss between transmitter and receiver as a function of distance? (Dec 2016)

It is simply a link budget equation used to predict received signal strength, when unobstructed line of sight 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

11. 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.

12. 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

13. 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. It is the largest linear dimension of the antenna and the aperture length.

$D_f = 2D^2 / \lambda$

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

$D_f = 26.7$ m

14. Define Snell's law. (May 2013)

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:

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

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

$Sin\ \theta_B = \frac{\sqrt{\varepsilon_r - 1}}{\sqrt{\varepsilon_r{}^2 - 1}}$ = 0.409 Brewster Angle = sin $^{-1}$ (0.409) = 24.14

16. 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)

17. What are the factors influencing small scale fading?

Speed of surrounding objects, Multipath propagation, Speed of the mobile, Transmission bandwidth of the signal.

18. what are the causes of small scale multipath propagation?

1. Random frequency modulation due to varying Doppler shifts on multipath signals.
2. Time dispersion caused by multipath propagation delays.

19. Define coherence bandwidth. (May 2016) (Dec 2015)

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.

$$B_c = \frac{1}{50\sigma_t}$$

20. What is coherence time? (Dec 2015) ? In what way does this parameter decide the behaviour of wireless channel? (May 2017)

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.

21. 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

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

22. 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)

23. 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.

24. What is flat fading? (Nov 2017)

If the mobile radio channel has a constant gain and linear phase response over a bandwidth which isgreaterthan 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.

25. Write the conditions for flat fading.

BW of signal<<BW of channel $B_s << B_c$
Symbol period>>Delay spread $T_s >> \sigma\lambda$

26. What is frequency selective fading? (Dec 2016)

Ifthechannel 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.$B_{signal} > B_{coherence}$

27. Write the conditions for frequency selective fading.

Bandwidth of Signal> Coherence Bandwidth($B_{signal} > B_{coherence}$)
Symbol period< Delay spread ($T_s < \sigma_t$)

28. Define fast fading channel.

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.

29. Define slow fading channel

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.

30. 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($T_{signal} < T_{coherence}$)

31. 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 - unlike communication that entails the use of connection wires, this type of communication does not require elaborate physical infrastructure or maintenance practices.

Flexibility - wireless communication enables people to communicate regardless of their location. It is not necessary to be in an office or some telephone booth in order to pass and receive messages

Convenience - wireless communication devices like mobile phones are quite simple and therefore allow just about anyone to use them wherever they may be. There is no need to physically connect anything in order to receive or pass messages

Constant connectivity - whether someone is traveling or seated at the beach, he or she can still stay in touch with loved ones or important business contacts. Constant connectivity also ensures that people can respond to emergencies relatively quickly

PART B

1. Explain in detail about free space propagation model.

2. Explain in detail about two ray ground reflection model. **(May 2017)**

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)**

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.Explaini) Fading and ii) Multipath propagation.

8. What are the factors influencing small scale fading? **(Dec 2016)**

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)**

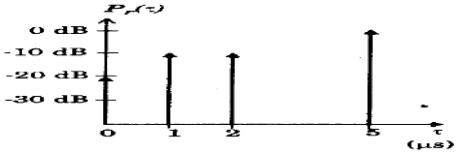
10. Consider transmitter which radiates the sinusoidal carrier frequency of 1850 MHZ for a vehicle Moving at 60 km/hr. Compute the Received carrier frequency if (i) the vehicle is moving towards the transmitter (ii)the vehicle is moving away from transmitter (iii) the vehicle is moving the direction of transmitter.

11. Determine the proper spatial sampling interval required to make small scale propagation measurements which assume that consecutive samples are highly correlated in time. How many samples will be required over 10 m travel distance if f_c= 1900 MHz and v= 50 m/s. How long would it take to make these measurements, assuming they could be made in real time from a moving vehicle? What is the Doppler spread of the channel? **(May 2017)**

12. Relation between bandwidth and power of a wireless propagation channel.**(Dec 2015)**

13. Explain in detail about the various parameters involved in mobile multipath channels **(May 2016/17)**

14. 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.



15. Explain coherence time and coherence bandwidth with expressions.

16. Write the short notes on small scale multipath measurements.

17. Explain fading effects due to multipath time delay spread and fading effects due to Doppler spread. **(Dec 2016)**

18. Write short notes on i) Frequency -selective fading ii) frequency-non- selective (Flat)fading/ Fading effects due to multipath time delay spread

19. Write short notes on i) Time-selective fading (Fast Fading) ii) Time-Non-Selective channels (Slow Fading) (or)

Compare and contrast fast and slow fading. "In practice fast fading occurs for very low data rate Communications: Why? **(May 2017)(Nov 2017)**

20. What do you mean by path loss model? Explain in detail about log-distance path loss model.**(Nov 2017)**

UNIT II CELLULAR ARCHITECTURE

PART -A

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

Multiple Access: 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).

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 frequencieswithin 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)−SDMA transmits different information in different physical areas.

3. What are the different modes of Communication?

Simplex: Communication happens on only one direction. It doesn't require any acknowledgement.

Half Duplex: Allows two way communications. But uses same radio channel for both transmission & reception.

Full Duplex: Allows Simultaneous transmission and reception between Transmitter and receiver. It uses different channel for transmission and reception.

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 allows Single channel and doesn't any duplexer.

5. What do you mean by narrow band system?

Generally total spectrum is divided into a number of relatively narrow radio channels (e.g. FDMA). If all the channels are being used, call blocking occurs. Unused bandwidth in each channel cannot be used by other users. Transmission experiences non selective fading. This means that when fading occurs, whole of the information (i.e. the whole channel) is affected.

6. What do you mean by wide band system?

The main feature of wide band systems is that either complete spectrum is available (e.g. CDMA, TDMA) or a considerable portion of it is used by each user (e.g. TDMA+FDMA).The advantage of wideband systems is that the transmission bandwidth always exceeds the coherence bandwidth for which the signal experiences only selective fading. That is, only a small fraction of the frequencies composing the signal is affected by fading.

7. 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 synchronisation.

ISI (Inter Symbol Interference) is low. Complexity of FDMA is also very low.

8. 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 then there is no user can share the same channel. It leads to essentially a waste source.
- Sensitivity to fading
- Sensitivity to Inter modulation

9.What are the features of TDMA?

In TDMA a single carrier frequency with a wide bandwidth is shared among multiple users. Each user is assigned 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.

10. Mention the applications of multiple access techniques in wireless communication.

- It shares many users at same time
- Share a finite amount of radio spectrum
- High performance

11. Define CDMA and mention its significance.

Code Division Multiple Access systems uses unique codes with certain characteristics to different users.Each user employs a unique spread spectrum signaling code. It provides communication privacy between users with different spreading signals. The main problem is to find good codes and to separate this signal from noise. The good code can be found the following characteristics 1.Orthogonal. 2. Autocorrelation.

12. What is SDMA? What are the advantages of SDMA?

Space Division Multiple Access (SDMA) is used for allocating separated spaces to different users in wireless environment. The basis for the SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure for implementing the space division multiplexing (SDM). **T**he same frequency can be reused multiple times and signals on the same frequency do not interfere with one another.

13. What limits the number of user in TDMA and FDMA compared to CDMA?

The code space is huge compared to the frequency space and time space. Because of the limited time space and frequency space, the number of user in TDMA and FDMA are limited.

14. What is near and far effect? How it influence CDMA? What are counter measurements?

For the detection of message signal, receiver needs to know about the transmitted information. Each user is operated with no knowledge of other users. If the Power of each user within a cell is not controlled, they don't appear as equal in receiver base station which will cause near and far effect. To combat the near and far effect power control is used at the receiver in CDMA systems.

15. Define FCA.

Fixed channel Allocation (FCA): Each cell is assigned with predetermined set of voice channels. If all the channels in the cell is occupied, then the call is blocked. The user doesn't get service. In variation of a fixed channel assignment, a cell can borrow from the channel from its neighbouring cells, if its own channels are full

16. Define DCA.

In**Dynamic Channel Allocation (DCA)**: In this scheme, Voice channels are not allocated to different cells permanently. Each time 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 the frequency reuse distance. Thus DCA reduces the likelihood of call blocking which can improve the capacity of a cellular system.

17. What is guard bandwidth?

It is the minimum frequency spacing used to separate transmitter and receiver. It is useful to avoid the frequency band overlapping/ channel interference during transmission.

18. When handoff occurs?

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.

19. 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.

20. Difference between adjacent channel interference and Co-channel interference?

adjacent channel interference	**Co-channel interference**
It is caused due to the 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 can't be overcome by the increasing the carrier power of the transmitter.

21. What is meant by frequency reuse and mention its significance(Nov 2017)

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.

22. Why the cell shapes are hexagons?

- Hexagons are geometric shapes that approximates a circle.(for Omni directional radiation) Moreover Circle, 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.

23. How to improve the capacity of a cell?

- As the cluster size is increased (N) to cover the entire area of interest which will increase the value of M .Thus increases the capacity of a cell.
- Higher the value of N will also reduce the co channel interference&improve the systemcapacity.

24. 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)

$$S = KN$$

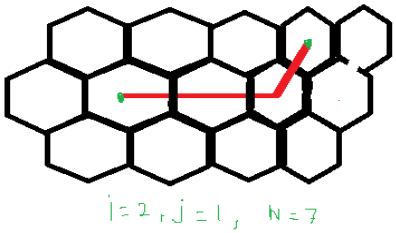
If a cluster of N cell is replicated M types in the system, the total number of duplex channels C can be used to measure the cell capacity**$C = MS = MKN$**

25. What are the steps to locate co channel cells in a cluster?

- 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.



26. What is the function of Medium Access Control Layer?

The functions of Medium Access Control Layer which are responsible for establishes, maintains, and releases channels for higher layers by activating and deactivating physical channels.

27. Define Set-up time and Holding-time.

Set-up time: The time required to allocate a trunked radio channel to a requesting user.

Holding time: Average duration of a typical call.Denoted by 'H' (in seconds).

28. What is a blocked call and Request Rate?

Blocked call: Call which cannot be completed at time of request, due to congestion is referred to as lost call/Blocked call. **Request Rate:** The average number of calls per unit time. (λ)

29.What is meant byTraffic intensity/ one erlang?

Erlang is the measure of channel utilization time.

A channel kept busy for one hour is defined as having a load of one Erlang.

30. 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.

31. Define co-channel reuse ratio? (Dec2015)

Co-channel reuse ratio Q is given as

$$Q = \frac{D}{R} = \sqrt{3N}$$

Where D= $\sqrt{3N}R$ It is the Reuse distance between center of cells,

And R is the radius of the hexagonal cell

32. 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 the 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)

33. Why the cellular concept used for mobile telephony? (May 2017)

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, the more number of users can use the service with high coverage and maximum capacity.

34.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.

35. 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.

PART B

1. Compare and Contrast the TDMA, FDMA and CDMA techniques. **(May 2016)**

2. Explain in detail about the Channel Assignment and Handoff Strategies. **(May 2017)**

3. Describe the Operations of Cellular systems and Explain it steps with a neat sketch**.**

4. Explain in detail about FDMA Techniques.

5. Explain in detail about TDMA Techniques.**(Nov 2017)**

6. Explain in detail about CDMA Techniques.

7. Explain the concept of cell planning with relevant diagrams and expressions.

8. Illustrate Cellular Frequency Reuse with a neat sketch.

9. Explain the various methods that increase the channel capacity and coverage area of a cellular system. **(May 2016).**

10. Explain the principle of cellular networks and various types of Handoff techniques.**(Dec 2013) (Dec 2014).**

11. Explain Hand off process in detail.

12. Explain the co channel interference and adjacent channel interference of a cellular system. Describe the techniques to avoid the interference. **(Dec 2016)**

13. (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)**

14. 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)**

15. 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)

16. 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)**

17.(a) Derive the expressions for cellular CDMA Schemes for both noise limited and interference limited scenarios.

(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)**

18. Explain in detail Trunking and Grade of Service of Cellular System. **(Nov 2017)**

UNIT III DIGITAL SIGNALLING FOR FADING CHANNELS

PART A

1. Define Digital modulation.

Modulation is nothing but mapping the digital data into the analog waveform for transmitting the signal via channel is called modulation. E.g.: Binary Modulation (two bits), M-ary Modulation.

Data ----------→Symbol-------→ Signal

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. Mention any two criteria for choosing a modulation technique for a specificwireless application? (June 2013)

The spectral efficiency of the modulation format should be as high as possible. This can best be achieved by a higher order modulation format. This allows the transmission of many data bits with each symbol. Adjacent channel interference must be small. This entails that the power spectrum of the signal should show a strong roll-off outside the desired band. Furthermore, the signal must be filtered before transmission.

5. What is linear modulation? Mention the merits of linear 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: Bandwidth efficient, Very attractive for use in wireless communication systems, Accommodate more and more users within a limited spectrum.

6. What is nonlinear modulation?

In nonlinear modulation, the amplitude of the carrier is constant regardless of the variation in the modulating signal.

7. Mention the merits and demerits of nonlinear modulation.

Merits:

a. Lower efficient class c amplifiers can be used without introducing degradation in the Spectrum occupancy of the transmitted signal.

b. Low out of band radiation of the order of -60dB to -70dB can be achieved.

c. Limiter-discriminator detection can be used, which simplifies receiver design and provides highImmunity against random FM noise and signal fluctuations due to Rayleigh fading.

Demerits:

a. Constant envelope modulations occupy a larger bandwidth than linear modulation scheme

b. In situations where bandwidth efficiency is more important than power efficiency, constant Envelope modulation is not well suited.

8. What do you meant by signal constellation diagram?

Mapping the infinite dimension signal into a finite dimension signal as a vector space to find the error probabilities.

9. 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.

10.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.

11. 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.

12. 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.

13. 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 135^o as compared to 180^o for BPSK and 90^o for QPSK.

14. 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.

15.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^oat a time.

16. What is MSK?

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.

17. What are the features of offset QPSK?

- 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.

18. What is the advantage of MSK over QPSK?

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.

19. Why MSK is called as fast FSK? (May 2016).

MSK is called fast FSK, as the frequency spacing used is only half as much as that used in conventional non-coherent FSK.

20. Mention some merits of MSK. (May 2017)

- Constant envelope,
- Self-synchronizing capability
- Spectral efficiency, Good BER performance,

21. 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.

22. What is the need of Gaussian filter in GMSK? (Dec 13)(Dec 2016)

Gaussian filters used before the modulator 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.

23. What is GMSK?

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.

24. What are the advantages and disadvantages of GMSK?

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.

25. 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.

26. What is the principle behind OFDM?

As the bandwidth of the channel increases, Symbol time decreases which leads to ISI (Inter Symbol Interference). To overcome this, divide the total bandwidth into N smaller bands. In each sub bands place the subcarrier which will make **symbol time > delay spread** to avoid the interference.

27. Define cyclic prefix. (Dec 2016)

When the two consecutive blocks of OFDM symbols are transmitted, it will create the Inter Block Interference (IBI). To remove this, $\bar{L}$ 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)

28. Define PAPR.(Nov 2017)

The ratio between maximum instantaneous Power 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.

29. 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

30. 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

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)**
3. Explain π/4 Differential QPSK & OQPSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(June 2013)(May 2016)**
4. Explain OQPSK.? What is its advantage ? Describe the offset- QPSK Scheme. **(May 2017)**
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. Derive the expression of probability of error of slow flat fading (Rayleigh fading) channels.
9. Draw the basic arrangement of OFDM transceivers and discuss its overall operation. (**Dec 2016**)**(May 2017)**
10. Write the short notes on PAPR reduction techniques. **(May 2017)**
11. (i)Describe with a block diagram π/4 Quadrature phase shift keying and its advantages.
    (ii)What is MSK? 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.**(Nov 2017)**

UNIT IV MULTIPATH MITIGATION TECHNIQUES

PART A

1. What are the techniques used to improve the received signal quality?

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)
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. Write the advantages of lattice equalizer.
It is simplest and easily available, Numerical stability, Faster convergence, Unique structure of the lattice filter allows the dynamic assignment of the most effective length of the lattice equalizer and When the channel becomes more time dispersive, the length of the equalizer can be increased by the algorithm without stopping the operation of the equalizer.

12. 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.

13. What are the types of nonlinear equalization methods used?
Decision feedback equalization (DFE), Maximum likelihood symbol detection and Maximum likelihood sequence estimation (MLSE).

14. Where DFEs are used?
Decision Feedback Equalisers are particularly useful for channels with severe amplitude distortions and is widely used in wireless communications.

15. Define rate of convergence.
The no of iterations required for the algorithm in response to stationary inputs to converge close enough to the optimum solution.

16. 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

17. 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

18. 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.

19. 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.

20. 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 surroundings	It is caused by multiple reflections from the surroundings in the vicinity of the 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

21. What are the benefits of Rake Receiver? (May 2016).

1. Rake receiver gives the best performance among all the CDMA receivers.

2. since correlators form the main working system of the receiver. The best version of the received signal is selected and given as output.

22. List out the four types of Combining Methods.

Selection combining, switched combining, equal gain combining, maximum ratio combining.

23. Why is an adaptive equaliser is required?. (May 2017)

Equaliser should be adaptive since the channel is unknown and time varying. Then only Equalization can be used to compensate the inter-symbol interference created by multipath environment.

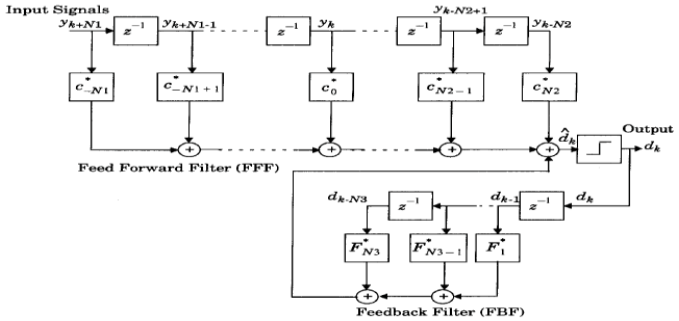
24. State the principle of diversity. (June 2013)

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.

25. 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.

26. Draw the structure of a linear transversal equalizer (Dec 2015)



PART B

1. Briefly explain about the adaptive equalisation procedure.

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. Discuss about DFE and MLSE Equaliser.

5. Describe any two adaptation algorithms for Mean square error Equalizers **(June 2013)**

6. Explain in detail about LMS algorithm.

7.Explain in detail about RLS Algorithm.

8.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)**

9. Discuss in detail about the micro diversity concepts. 1. Spatial diversity 2. Frequency Diversity 3. Time Diversity 4. Polarization Diversity **(May 2016).(Nov 2017)**

10.With relevant diagrams explain the RAKE Receiver. Also discuss how time diversity is achieved in CDMA technique using RAKE Receiver?**(Dec 2016)**

11. Explain any two diversity techniques to combat small scale fading **(June 2013)**

12.(i) With a neat block diagram explain the principle of Macro diversity

(ii)Explain the operation of an adaptive equalizer at the receiver side **(Dec 2014)**

13. Derive the expression of bit error rate of QPSK under diversity reception and compare the Performances using AWGN Channel.

14. (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)**

15.(i) With a neat diagram, Explain RAKE Receiver.

(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)

16. Analyze and compare the error performance in fading channels with and without diversity reception techniques**(Nov 2017)**

17. With valid statements, analytically prove that the adaptive equlaisers exhibit superior performance over the conventional equalisers. **(Nov 2017)**

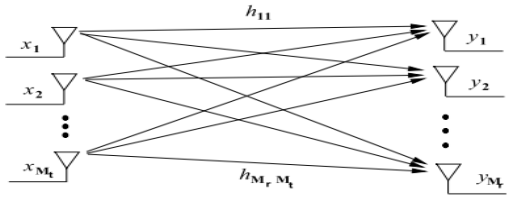
UNIT V MULTIPLE ANTENNA TECHNIQUES

PART A

1. What are MIMO systems?(May 2016).

Systems with multiple antennas at the transmitter and multiple antennas at the receiver, which 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. Draw the MIMO model.



Mt transmit antenna and Mr receive antennas.

3. Write the advantages of MIMO systems.

i. Multiple-input multiple-output systems can significantly enhance the performance of wireless systems through multiplexing, diversity gain and array gain.

ii. For a given transmit energy per bit, multiplexing gain provides a higher data rate whereas diversity gain provides a lower BER in fading.

iii. 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.

4. Write the disadvantages of MIMO systems.

- MIMO systems entail significantly more circuit energy consumption than their single antenna counterparts, because separate circuitry is required for each antenna signal path.
- Signal processing associated with MIMO can be highly complex.

5. Mention the applications of MIMO systems.

i. MIMO can reliably connect devices in home, such as computer networking devices, cabled video devices, phone lines, music, storage devices etc.

ii. The IEEE 802.16e standard and the IEEE 802.11n standard also use MIMO system.

iii. MIMO is used in mobile radio telephone standard such as 3GPP and 3GPP2 standard.

iv. 3GPP High Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standard use MIMO.

6. What are smart antennas in MIMO systems?

A MIMO system consists of several antenna elements, plus adaptive signal processing at both transmitter and receiver, the combination of which exploits the spatial dimension of the mobile radio channel. A smart antenna system is a system that has multiple antenna elements only at one link end

7. What is Beam forming?

The multiple antennas at the transmitter and receiver can be used to obtain array and diversity gain. In this setting the same symbol weighted by a complex scale factor is sent over each transmit antenna, so that the input covariance matrix has unit rank. This scheme is also referred to as MIMO beam forming.

8. What are the advantages of Beam forming?

Beam forming provides diversity and array gain via coherent combining of the multiple signal paths.

9. What is multiplexing Gain/ capacity gain?

It is the gain at which the MIMO Channel can be decomposed into a large number of parallel independent fading channels. It improves the wireless system performance. 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 (> 1) transmit antennas and N (> 1) receive antennas, the increase in the data rate is min (M, N)-fold

10. What is array gain?

Array gain is defined as the ratio of output SNR to the input SNR. Transmit/Receive array gain needs channel

information in the transmitter and receiver respectively. Channel information is typically available in the receiver whereas the channel state information in the transmitter is more difficult to maintain in general. In other words, it represents the number of receiver antennas in MIMO system.(Since Receiver only produces SNR)

11. What is diversity gain?

Diversity is a powerful technique to reduce fading effect in wireless communications. It is the gain due to the multiple antennas at the transmitter and receiver. (Product of transmitting Antenna and Receiving Antenna) In other words if there are M transmits, N receive antennas, the order of diversity is M*N. There is no diversity gain if the medium is line of sight channel.

12. What is the tradeoff between multiplexing gain and diversity Gain?

It happens due to two reasons.

1. Data rate 2. Probability of error.

As the data rate increase s in multiplexing gain, the probability of Error also increases on diversity gain.

13. How does spatial multiplexing work? (Dec 2016) (May 2017)(Nov 2017)

Spatial multiplexing uses 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. The channel mixes up these data streams so that each of the receive antenna elements sees a combination of them.

14. State the importance of spatial multiplexing.

The basic premise of spatial multiplexing is to send Mt independent symbols per symbol period using the dimensions of space and time. To obtain full diversity order, an encoded bit stream must be transmitted over all Mt transmit antennas. This can be done through serial encoding.

15. What is meant by co-phasing?

"Co-phase the signals" means that we need to multiply signals by $e^{j\varphi_i}$ for some constant phase angle φ_i on channel i, so that the (otherwise random) phases of the signals on the different channels line up. If we don't co-phase the signals before combining them, we end up with the multipath fading problem signals sometimes add together destructively. Without co-phasing, the branch signals would not add up coherently in the combiner, so the resulting output could still exhibit significant fading due to constructive and destructive addition of the signals in all the branches.

16. Describe threshold combining.

Selection combining for systems that transmit continuously may require a dedicated receiver on each branch to continuously monitor branch SNR. A simpler type of combining, called threshold combining, avoids the need for a dedicated receiver on each branch by scanning each of the branches in sequential order and outputting the first signal whose SNR is above a given threshold γT . As in SC, co-phasing is not required because only one branch output is used at a time.

17. 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.

18. 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.

19. Define channel capacity of MIMO system.

A very important factor for the profitability of a wireless networks is its capacity. MIMO system provides high capacity by using multiple antennas at both the transmitter and receiver end of the radio link. Multiple antennas are used to improve the capacity over SISO system when operated in multi-path environment. MIMO system capacity is measured in bits per second per hertz and is bounded by Shannon Hartley capacity. But it has become apparent that MIMO system can exceed the Shannon Hartley limit of SISO depending on the channel properties and the number of antennas.

20. What is Precoding?

Pre-coding is generalized to allow multi-layer transmission in MIMO systems. As conventional beam forming considers as linear single layer pre-coding, increasing the signal power at the output of the receiver by emitting the same signal from each of the transmit antennas with suitable weighting. When multiple antennas are used at the receiver, the signal level is not maximized simultaneously at all of the multiple receive antennas, so in that case pre-coding is used for multi-layer beam forming to increase the throughput

performance of a multiple receive antennas.

21. What is Alamouti's scheme?

Alamouti's scheme is designed for a digital communication system with two-antenna. Transmit diversity. The scheme works over two symbol periods and it is assumed that the Channel gain is constant over this time. Over the first symbol period, two different symbolsS1 and S2 (each with energy Es/2) are transmitted simultaneously from antennas 1 and 2, respectively. Over the next symbol period, symbol −S*2 is transmitted from antenna 1 and symbol S*1 is transmitted from antenna 2, each again with symbol energy Es/2.

22. What is Antenna Diversity? (Dec 2015)

Antenna Diversity or Space Diversity or Spatial Diversity can be given as the diversity scheme followed in wireless communications to overcome multipath fading. More than one antenna are used for transmission and reception, and the main concept behind this method is the signals transmitted by different antennas undergo different fading and there is at least one robust version of the signal being received. This method requires more sophisticated hardware for synchronisation.

23. 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

$$C_{ergodic} = \int_0^{\infty} \mathrm{Blog}_2(1+\gamma).\mathrm{P}(\gamma).\mathrm{d}\gamma$$

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 $\mathrm{Blog}_2(1+\gamma)$.

24. What is outage capacity? (Dec 2016)

Capacity with outage is define d as the maximum rate that can be transmitted over a channel with some outage probability corresponding to the probability that the transmission can't be decoded negligible error probability.

$$C_{outage} = (1 - \mathrm{P}_{out})\ \mathrm{Blog}_2(1+\gamma_{min})$$

Where P_{out} is the probability with outage= $\mathrm{P}(\gamma < \gamma_{min})$

25. What is Outage Probability?

If the received SNR is below γ_{min} then the bits received over that transmission burst cannot be decoded correctly with probability approaching one, and the receiver declares an outage.

P_{out} is the probability with outage= $\mathrm{P}(\gamma < \gamma_{min})$

26. What is Channel state information? 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 method is called Channel estimation.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.

PART B

1. Briefly explain Multiple-input multiple output systems. **(Dec 2016) (May 2017)(Nov 2017)**
2. Explain Pre-coding and Beam forming.**(May 2017)**
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 transmit diversity with (i) channel known at transmitter. (ii) Channel unknown at transmitter –The Alamouti scheme.
6. Explain receiver diversity with selection combining ,threshold combining, maximal-Ratio Combining in detail.
7. Discuss the capacity of time-varying frequency-selective fading channels with respect to Time- invariant channels and time-varying channels.
8. Discuss the capacity of MIMO system in flat fading and non-fading channels. **(Dec 2016) (May 2017)**
9. Explain parallel decomposition of the MIMO channel.
10. Explain the architectures of spatial multiplexing with neat diagram.**(May 2016).**
11. Determine the capacity of frequency selective fading and explain the concept of water filling/ Water pouring models.**(Dec 2015).**

12. Explain with relevant diagrams the layered space time structure with respect to MIMO systems **(May 2016).**

13. Determine the capacity of a slow fading channel and prove that the outage probability for a Receiver diversity system with L receives antennas $P_{out}(R) = \frac{(2^R - 1)^L}{L!\text{SNR}^L}$. **(Dec 2015)**