

**EC6801 WIRELESS COMMUNICATION**  
**UNIT I WIRELESS CHANNELS**

**PART A**

**1. Write the effects of fading.**

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

**2. Define coherence bandwidth. (May 2016)**

The coherence bandwidth is related to the specific multipath structure of the channel. The coherence bandwidth is a measure of the maximum frequency difference for which signals are still strongly correlated in amplitude. This bandwidth is inversely proportional to the rms value of time delay spread.

**3. What is coherence time?**

It is defined as the required time interval to obtain an envelope correlation of 0.9 or less.

**4. Define Doppler shift.**

The shift in received signal frequency due to motion is called the Doppler shift.

**5. What is Doppler spread?**

It is defined as the range of frequencies over which the received Doppler spectrum is essentially non-zero.

**6. What are the effects of multipath propagation?**

Slow fading and fast fading

**7. What is flat fading?**

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.

**8. Write the conditions for flat fading.**

BW of signal  $\ll$  BW of channel  $B_s \ll B_c$   
 Symbol period  $\gg$  Delay spread  $T_s \gg \sigma_\lambda$

**9. What is frequency selective fading?**

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.

**10. Write the conditions for frequency selective fading.**

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

**11. Define fast fading channel.**

The channel impulse response changes rapidly within the symbol duration. This type of channel is called fast fading channel.

**12. Define slow fading channel.**

The channel impulse response changes at a rate much slower than the transmitted baseband signal. This type of channel is called slow fading channel.

**13. What is meant by link budget?**

A link budget is the clearest and the most intuitive way of computing the required transmit power.

**14. 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 becomes possible to predict the SNR for a mobile communication system.

**15. What is ISI?**

Intersymbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols

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

The rapid fluctuations of the amplitudes, phases; or multipath delays of a radio signal over a short period of time or travel distance is known as small scale fading.

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

The rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a long period of time or travel distance is known as large scale fading.

**18. What are the factors influencing small scale fading?**

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

**19. What is meant by frequency dispersion?**

The received signal has a larger bandwidth than that of the transmitted signal, due to the different Doppler shifts introduced by the components of the multipath.

**20. What is free space propagation model?**

It is a model which is used to predict received signal strength, when unobstructed line of sight path

**21. 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  $\lambda/2$  for successive circles. These circles are called Fresnel zones.

**22. Explain knife-edge diffraction model.**

Knife edge is the simplest of diffraction models, and the diffraction loss can be readily estimated using the classical Fresnel solution for the field behind the knife edge.

**23. Find the far field distance for an antenna with maximum dimension of 2m and operating frequency 1 GHz?(Dec 2015)**

$$D_f = 2D^2/\lambda = 2 * 2 * 2/0.3 = 26.7 \text{ m}$$

**24. Define Snell's law. (May 2013)**

Snell's law states that the ratio of the sines 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:

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

**25. Calculate the Brewster Angle for a wave impinging on ground having a permittivity of  $\epsilon_r = 5$ .(May 2016)**

$$\sin \theta_B = \frac{\sqrt{\epsilon_r - 1}}{\sqrt{\epsilon_r^2 - 1}} = 0.409 \quad \text{Brewster Angle} = \sin^{-1}(0.409) = 24.14$$

**PART B -**

1. Discuss in brief about the Free-space and Two-Ray models.
2. Explain i) Fading and ii) Multipath propagation.
3. Write short notes on i) time-selective channels ii) frequency-selective channels
4. Differentiate narrowband and wideband channels.
5. What is link budget? Explain with an example how it can be computed for noise limited system.
6. Write short notes on WSSUS channels.
7. Explain coherence time and coherence bandwidth with expressions.
8. Explain in detail about the parameters of mobile multipath channels(May 2016).
9. Explain Okumura-Hata empirical and Nakagami model in detail.(May 2013)
10. Explain briefly on outdoor propagation model (Dec 2014)
11. Describe in detail Two Ray Rayleigh Fading Model. (Dec 2014)
- 12.(i) Explain on path loss estimation techniques using path loss models.  
 (ii) Describe on Ricean Distribution(Dec 2014)
13. In free space propagation describe how the signals are affected by reflection, diffraction and scattering. (May 2016)

**UNIT II CELLULAR ARCHITECTURE**

**PART A**

**1. What are the different types of multiple access schemes? (Dec 2013),(May 2016).**

FDMA-Frequency division multiple access-different frequencies are assigned to different users

TDMA-Time division multiple access-different time slots are assigned to different users.

CDMA-Code division multiple access-each user is assigned a different code.

**2. What are the advantages of FDMA?**

The transmitter and receiver require much less digital signal processing, Synchronization is simple.

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

1. Sensitivity to fading
2. Sensitivity to random frequency modulation
3. Inter modulation

**4. Define SAMA.**

Spread Aloha Multiple Access is a combination of CDMA and TDMA. The CDMA better suits for connection oriented services only and not for connection less burst data traffic because it requires to program both sender and receiver to access different users with different codes.

**5. Define CDMA.**

Code Division Multiple Access systems use codes with certain characteristics to separate different users. To enable access to the shared medium without interference. The users use the same frequency and time to transmit data. The main problem is to find good codes and to separate this signal from noise. The good code can be found the following 2 characteristic 1. Orthogonal. 2. Autocorrelation.

**6. What is SDMA?**

Space Division Multiple Access (SDMA) is used for allocating separated spaces to users in wireless networks. The basis for the SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure implementing space division multiplexing (SDM).

**7. What is FDD?**

In FDMA, the base station and the mobile station establish a duplex channel. The two directions, mobile station to base station and vice versa are separated using different frequencies. This Scheme is called Frequency Division Duplex (FDD)

**8. What limits the number of user in TDM and FDM compared to CDM?**

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 TDM and FDM are limited.

**9. How does near and far effect influence CDMA? What are counter measurements?**

The near and far effect is a server problem of wireless networks using CDM. All signals should arrive at the receiver with more or less the same strength. Precise power control is needed to receive all senders with the same strength at a receiver.

**10. Define FCA and DCA.**

Allocating a fixed frequencies for a channel is called as Fixed channel Allocation (FCA). In Dynamic Channel Allocation (DCA) scheme frequencies can only be borrowed, but it is also possible to freely allocate frequencies to cells. With dynamic assignment of frequencies to cells, the danger of the interference with cells with same frequency exists. Thus the borrowed frequencies in the surroundings cells can be blocked.

**11. What is guard space?**

Guard spaces are needed to avoid frequency band overlapping is also called channel interference.

**12. What is guard space?**

Guard spaces are needed to avoid frequency band overlapping is also called channel interference.

**13. 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 its assigns one of them to the handed-off call.

**14. Differentiate soft and hard handoff. (May 2016).**

Hard handoff mode is characterized by a mobile having a radio link with only AP at any time. Thus, the old connection is terminated before a new connection is activated. This mode of operation is referred to as break before make.

In Soft handoff, the mobile can simultaneously communicate with more than one AP during the handoff. This new connection is made before breaking the old connection, and is referred to as make before break.

**15. What is the function of Medium Access Control Layer?**

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

**16. What are the 2 sub layers in DLC?**

Logical Link Control(LLC), Media Access Control (MAC)

**17. Define traffic multi frame and control multi frame?**

The periodic pattern of 26 slots occurs in all TDMA frames with a TCH. The combination of these frames is called traffic multi frame TDMA frames containing data for the other logical channels are combined to a control multi frame.

**18. 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.

**19. What is orthogonality?**

Orthogonality mean if we have “n” users and n-bit sequences, then a set of vectors in n-space are orthogonal if any point in n-space may be expressed as only linear combination of these vectors.

CDMA is a communication technique that allows multiple users to communicate over one frequency. This is achieved through the use of spreading codes, whereby a single data bit is spread over a longer sequence of transmitted bits. These codes known as chip sequence, must be carefully chosen so that data may be correctly despread at the receiver. Such codes are known as orthogonal codes.

**20. Define Set-up time.**

The time required to allocate a trunked radio channel to a requesting user.

**21. What is a blocked call?**

Call which cannot be completed at time of request, due to congestion. Also referred to as lost call.

**22. Define Holding-time.**

Average duration of a typical call. Denoted by ‘H’ (in seconds).

**23. State advantages of CDMA over FDMA?(Dec2014)**

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.

**24. Define co-channel reuse ratio?(Dec2015)**

Co-channel reuse ratio Q is given as

$$Q = D/R, D - \text{is the distance between centres of cells, } R - \text{radius of the hexagonal cell}$$

**25. Define Grade of Service?(Dec2015)**

Grade of Service in Wireless communication can be defined as ability of the user to connect on a call when the cell is being used by multiple users. It can be given by the ratio of number of blocked calls to the number of offered calls.

**PART B**

1. Compare and Contrast the TDMA,FDMA and CDMA techniques. (May 2016) (June 2013).
2. Describe the Channel Assignment Strategies.
3. Describe the Operations of Cellular systems and Explain it steps with a neat sketch(June 2013)
4. Explain in detail about multiple accesses with collision avoidance scheme. Also explain the advantages of the same. (Dec 2013) .
5. Explain the concept of cell planning with relevant diagrams and expressions.
6. Explain the various methods that increase the channel capacity and coverage. (May 2016).
7. Explain the principle of cellular networks and various types of Handoff techniques.(Dec 2013)(Dec 2014).
8. Write a note on trunking and grade of service.
9. A spectrum of 30MHZ 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 1MHZ 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 three systems.
10. Illustrate Cellular Frequency Reuse with a neat sketch.

**UNIT III DIGITAL SIGNALLING FOR FADING CHANNELS**

**PART A**

**1. Define modulation.**

It is defined as the process by which some parameters of a high frequency signal termed as carrier, is varied in accordance with the signal to be transmitted.

**2. What is demodulation?**

It is the process of recovering the original modulating signal from a modulated signal.

**3. Write the advantages of digital over analog modulation.**

Greater noise immunity, Robustness to channel impairments, Easier multiplexing of various forms of information, Greater security

**4. What is meant by Amplitude shift keying?**

If amplitude of the carrier is varied depending on the incoming digital signal, then it is called Amplitude shift keying.

**5. What is meant by Frequency shift keying?**

If the frequency of the sinusoidal carrier frequency is varied depending on the incoming digital signal, then it is called Frequency shift keying.

**6. 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.

**7. Define M-ary transmission system,**

Indigital modulation instead of transmitting one bit at a time, two or more bits are transmitted simultaneously. This is called M-ary transmission.

**8. What is Quadrature modulation?**

Sometimes two or more Quadrature carriers are used for modulation. It is called Quadrature modulation.

**9. 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

**10. What is QAM?**

At high bit rates, a combination of ASK and PSK is employed in order to minimize the errors in the received data. This method is known as Quadrature amplitude modulation.

**11. What is meant by QPSK?**

QPSK is a multi-level modulation in which four phase shifts are used for representing four different symbols.

**12. What is 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.

**13. Write the merits of linear modulation.**

Bandwidth efficient, Very attractive for use in wireless communication systems, Accommodate more and more users within a limited spectrum.

**14. What is nonlinear modulation?**

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

**15. 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 high immunity 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.

**16. 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.

**17. 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.

**18. Mention some merits of MSK.**

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

**19. 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.

**20. What is the need of Gaussian filter? (Dec 13)**

Gaussian filters used before the modulator to reduce the transmitted bandwidth of the signal. It uses less bandwidth than conventional FSK.

**21. Define M-ary FSK.**

In M-ary system,  $M=2^N$  different symbols are used and N no of bits per symbol. Every symbol uses separate frequency for transmission.

**22. Mention any two criteria for choosing a modulation technique for a specific wireless 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.

**23. Define cyclic prefix.**

In OFDM, delay dispersion leads to a loss of orthogonality between the subcarriers and thus leads to Inter Carrier Interference (ICI). These negative effects can be eliminated by a special type of guard interval called the cyclic prefix.

**24. Define Windowing. (May 2016).**

Windowing is a technique proposed to help 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 function.

**25. Define PAPR.**

The peak to average power ratio PAPR is an important attribute of a communication system. A low PAPR allows the transmit power amplifier to operate efficiently, whereas a high PAPR forces the transmit power amplifier to have a large backoff in order to ensure linear amplification of the signal.

**PART B**

1. Explain QPSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(Dec 2013)(Dec 2014)**
2. Explain  $\pi/4$  Differential QPSK & OQPSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(June 2013)(May 2016).**
3. Explain BFSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(Dec 2014)**
4. Explain MSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(June 2013),(Dec 2015)**
5. Explain GMSK transmitter and receiver with signal space diagram and give an expression for spectral efficiency. **(Dec 2015)(May 2016).**
6. Discuss about the performance of digital modulation in fading channels. **(Dec 2013)**
7. Explain the Nyquist criterion for ISI cancellation. **(Dec 2013)**
8. Explain in detail about OFDM modulation technique with necessary diagrams.
9. (i) Describe with a block diagram  $\pi/4$  Quadrature phase shift keying and its advantages.  
 (ii) What is MSK? Explain its power spectral density. **(Dec 2014)**

**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?**

Rate of convergence, Misadjustment, Computational complexity and numerical properties.

**3. What is the need of equalization?**

Equalization is used to compensate the inter-symbol interference created by multipath within time dispersion channel.

**4. Write the functions of diversity. (Dec 2013)**

- i. Diversity is used to compensate for fading channel impairments, and is usually implemented by using two or more receiving antennas.
- ii. Diversity improves transmission performance by making use of more than one independently faded version of the transmitted signal.

**5. Define spatial diversity.**

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.

**6. What is equalizer? (Dec 2013)**

The device which equalizes the dispersive effect of a channel is referred to as an equalizer.

**7. What are the operating modes available in an adaptive equalizer?**

Training and tracking modes.

**8. Define adaptive equalizer. (May 2016).**

To combat ISI, the equalizer coefficients should change according to the channel status so as to track the channel variations. Such an equalizer is called an adaptive equalizer since it adapts to the channel variations.

**9. 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, where the training sequence is pseudorandom binary signal or a fixed and prescribed bit pattern.

**10. What is tracking mode in an adaptive equalizer?**

Immediately following the training sequence, the user data is sent, and the adaptive equalizer at the receiver utilizes a recursive algorithm to evaluate the channel and estimate filter coefficients to compensate for the distortion created by multipath in the channel.

**11. Write a short note on i) linear equalizers ii) non-linear equalizers**

If the output is not used in the feedback path to adapt, then this type of equalizer is called linear equalizer. If the output is fed back to change the subsequent outputs of the equalizer, this type of equalizer is called

**12. 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.

**13. 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.

**14. What are the nonlinear equalization methods used?**

Decision feedback equalization (DFE), Maximum likelihood symbol detection and Maximum likelihood sequence estimation (MLSE).

**15. Where DFEs are used?**

DFE is particularly useful for channels with severe amplitude distortions and is widely used in wireless communications.

**16. 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.

**17. 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

**18. What is the need for diversity schemes?**

To increase signal to noise ratio, for error free digital transmission, to degrade the bit error probability.

**19. 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.

**20. List out the four types of Combining Methods.**

Selection combining, switched combining, Equal gain combining, Maximum ratio combining.

**21. Differentiate between Macrodiversity and Microdiversity. (Dec 2014)**

Macrodiversity	Microdiversity
In antenna (or micro) diversity the signal from antennas mounted at separate locations are combined	In site (or macro) diversity the receiving antennas are located at different receiver sites
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

**22. 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.

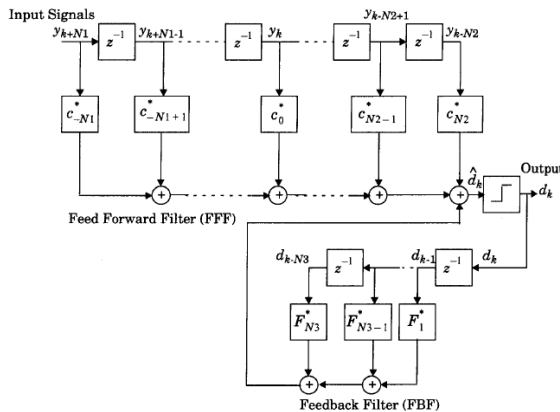
**23. State the principle of diversity.(June 2013)**

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.

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

1. Rake receiver gives the best performance among all the CDMA receivers.
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**25. Draw the structure of a linear transversal equaliser (Dec 2015)**



**PART B**

1. Explain the classification of equalizers.
2. Briefly explain about linear and non-linear equalizers. **(Dec 2013)(May 2016).**
3. Discuss about DFE.
4. Explain about MLSE equalizer. **(Dec 2013)**
5. Discuss in detail about the different micro diversity concepts. **(May 2016).**
6. Explain about theoretical model for polarization diversity.
7. Discuss the performance of a RAKE receiver with a neat diagram. **(Dec 2013)**
8. Explain any two diversity techniques to combat small scale fading **(June 2013)**
9. Describe any two adaptation algorithms for Mean square error Equalizers **(June 2013)**
10. (i) With a neat block diagram explain the principle of Macrodiversity  
 (ii) Explain the operation of an adaptive equalizer at the receiver side **(Dec 2014)**
11. (i) Explain with block diagram Maximal ratio combiner  
 (ii) Describe on Polarization and space diversity. **(Dec 2014)**
12. Derive the mean square error for a generic adaptive equaliser **(Dec 2015).**

**UNIT V MULTIPLE ANTENNA TECHNIQUES**

**PART A**

**1. What is Beamforming?**

The multiple antennas at the transmitter and receiver can be used to obtain array and diversity gain instead of capacity 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 beamforming.

**2. What are the advantages of Beamforming?**

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

**3. What is multiplexing gain?**

Multiple antennas are used to improve wireless system performance. One option is to obtain capacity gain by decomposing the MIMO channel into parallel channels and multiplexing different data streams onto these channels. This capacity gain is also referred to as multiplexing gain.

**4. 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.

**5. What is RAKE receiver?**

A more complicated receiver can have several branches, with each branch synchronized to a different multipath component. This structure is called a RAKE receiver, and it assumes there is a multipath component at each integer multiple of a chip time.

**6. Write the advantages of RAKE receiver.**

RAKE's provide a simple mechanism to obtain diversity benefits. When spread spectrum signalling is chosen for its other benefits such as multiuser or interference rejection capabilities.

**7. Explain the concept of Rake receiver.**

In Multipath environment, if the multiple versions of the signal arrive more than one chip interval apart from each other. The receiver can recover the signal from multiple paths and then combine them with suitable delays. This method achieves better performance than simply recovering dominant signal and treating remaining signals as noise.

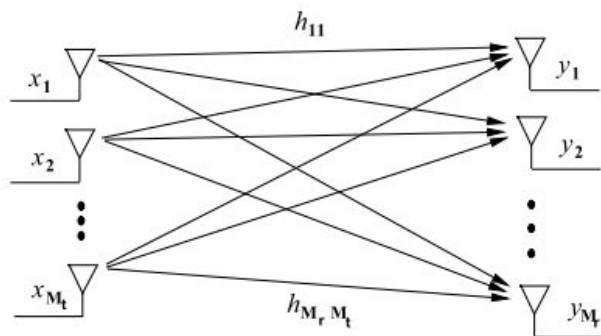
**8. What are MIMO systems? (May 2016).**

Systems with multiple antennas at the transmitter and 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.

**9. Draw the MIMO model.**



Mt transmit antenna and Mr receive antennas.

**10. Write the advantages of MIMO systems.**

- i. Multiple-input multiple-output systems can significantly enhance performance of wireless systems through multiplexing or diversity 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.

**11. Write the disadvantages of MIMO systems.**

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

**12. 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.

**13. How does spatial multiplexing work?**

Spatial multiplexing uses MEA's (Multiple element antennas) at the transmitter for transmission of data streams. An original high-rate datastream is multiplexed into several parallel streams, each of which is sent from one transmit antenna element. The channel mixes up these datastreams 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 transmit diversity?**

In transmit diversity more antennas are used on the transmitter side than on the receiver side. Transmit diversity is used to reduce the effect of fading. In transmit diversity the same information is transmitted from two different antennas. Data from the second antenna is encoded differently to differentiate it from the first antenna. This can be done to enable the user equipment on the receiver side to identify that the information is coming from the different locations and properly decode it. Space-time coding is used to create redundant signals.

**16. What are smart antennas and 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.

**17. What is array gain?**

Array gain is defined as the average increase in the SNR and depends on the number of transmit and receive antennas. 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.

**18. What is diversity gain?**

Diversity is a powerful technique to reduce fading effect in wireless communications. Diversity gain is defined as the reduction in the probability of error due to multiple independent paths produced

between the transmitter and receiver. 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.

**19. What is multiplexing gain?**

Multiplexing gain is defined as the increase in the data rate; since independent data streams are send through independent paths between multiple transmitters and multiple receivers. In other words if there are  $M$  (&gt; 1) transmit antennas and  $N$  (&gt; 1) receive antennas, the increase in the data rate is  $\min(M, N)$ -fold

**20. What is meant by co-phasing?**

“Co-phase the signals” means that we need to multiply signals by  $e^{j\phi_i}$  for some constant phase angle  $\phi_i$  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.

**21. 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  $\gamma_T$ . As in SC, co-phasing is not required because only one branch output is used at a time. Hence this technique can be used with either coherent or differential modulation.

**22. 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.

**23. What is Precoding.**

Pre-coding is generalized to allow multi-layer transmission in MIMO systems. As conventional beamforming 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 beamforming to increase the throughput performance of a multiple receive antennas. In pre-coding the transmit antennas transmit the multiple streams with independent and suitable weighting per each antenna such that higher link throughput is obtained at the receiver output

**24. 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 symbols  $S_1$  and  $S_2$  (each with energy  $E_s/2$ ) 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  $E_s/2$ .

**25. 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.

**PART B**

1. Briefly explain Multiple-input multiple output systems.
2. Explain Pre-coding and Beam forming.
3. Define Beamforming and briefly explain MIMO diversity gain. (May 2016).
4. Discuss transmit diversity with channel known at transmitter.
5. Discuss transmit diversity with channel unknown at transmitter – The Alamouti scheme.
6. Explain receiver diversity in detail.
7. Discuss receiver diversity with selection combining and threshold combining.
8. Briefly discuss Maximal-Ratio combining and Equal-Gain combining.
9. Discuss the capacity of time-varying frequency-selective fading channels with respect to time-

- invariant channels and time-varying channels.
10. Discuss the capacity in fading and unfading channels.
  11. Explain parallel decomposition of the MIMO channel.
  12. Explain the architectures of spatial multiplexing with neat diagram. **(May 2016).**
  13. Determine the capacity of frequency selective fading and explain the concept of waterfilling/waterpouring models. **(Dec 2015).**
  14. Explain with relevant diagrams the layered space time structure with respect to MIMO systems. **(May 2016).**