EC8652 WIRELESS COMMUNICATION L T P C
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OBJECTIVES:

- To study the characteristic of wireless channel
- To understand the design of a cellular system
- To study the various digital signaling techniques and multipath mitigation techniques
- To understand the concepts of multiple antenna techniques

UNIT I WIRELESS CHANNELS 9

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

UNIT II CELLULAR ARCHITECTURE 9

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

UNIT III DIGITAL SIGNALING FOR FADING CHANNELS 9

Structure of a wireless communication link, Principles of Offset-QPSK, p/4-DQPSK, Minimum Shift Keying, Gaussian Minimum Shift Keying, Error performance in fading channels, OFDM principle – Cyclic prefix, Windowing, PAPR.

UNIT IV MULTIPATH MITIGATION TECHNIQUES 9

Equalisation –Adaptive equalization, Linear and Non-Linear equalization, Zero forcing and LMS Algorithms. Diversity –Micro and Macro diversity, Diversity combining techniques, Error probability in fading channels with diversity reception, Rake receiver.

UNIT V MULTIPLE ANTENNA TECHNIQUES 9

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

TOTAL:45 PERIODS

OUTCOMES:

The student should be able to:

1. Characterize a wireless channel and evolve the system design specifications
2. Design a cellular system based on resource availability and traffic demands
3. Identify suitable signaling and multipath mitigation techniques for the wireless channel and system under consideration.

TEXT BOOKS:

1. Rappaport,T.S., ―Wireless communications‖, Pearson Education, Second Edition, 2010.(UNIT I, II, IV)
2. Andreas.F. Molisch, ―Wireless Communications‖, John Wiley –India, 2006. (UNIT III,V)

REFERENCES:

1. Wireless Communication –Andrea Goldsmith, Cambridge University Press, 2011
2. Van Nee, R. and Ramji Prasad, ―OFDM for wireless multimedia communications, Artech House, 2000
3. David Tse and Pramod Viswanath, ―Fundamentals of Wireless Communication, Cambridge University Press, 2005.
4. Upena Dalal, ―Wireless Communication‖, Oxford University Press, 2009.

Subject Code: EC8652 **Year/Semester: III /06**
Subject Name: WIRELESS COMMUNICATION **Subject Handler: Dr.R.Thandaiah Prabu**

UNIT I - WIRELESS CHANNELS

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

PART * A

Q.No.	Questions
1.	**Write the effects of fading. - BTL2** 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. - BTL1** 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? - BTL1** It is defined as the required time interval to obtain an envelope correlation of 0.9 or less.
4	**Define Doppler shift. - BTL1** The shift in received signal frequency due to motion is called the Doppler shift.
5	**What is Doppler spread? - BTL1** 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? – BTL2** Slow fading and fast fading
7	**Write the conditions for flat fading. – BTL3** BW of signal<<BW of channel $B_s << B_c$ Symbol period>>Delay spread $T_s >> \sigma\lambda$
8	**What is frequency selective fading? - BTL1** 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.
9	**Write the conditions for frequency selective fading. - BTL1** BW of signal>BW of channel $B_s > B_{c,}$ Symbol period< Delay spread $T_s < \sigma\lambda$
10	**What is meant by link budget? - BTL1** A link budget is the clearest and the most intuitive way of computing the required transmit power.
11	**What is the need of path loss models in link budget design? – BTL2** 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.

12 **What is the need of propagation model? – BTL2**

Propagation models have traditionally focused on predicting the average received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in close spatial proximity to a particular location. Propagation models that predict the mean signal strength for an arbitrary transmitter-receiver separation distance are useful in estimating the radio coverage area of a transmitter.

13 **What is ISI? - BTL1**

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

14 **Differentiate Flat fading & Frequency selective fading. – BTL3**

Flat Fading	Frequency Selective Fading
Bandwidth of the signal is lesser than the bandwidth of the channel.	Bandwidth of the signal is greater than the bandwidth of channel.
Delay spread is lesser than symbol period.	Delay spread is greater than symbol period.

15 **Differentiate Fast fading & slow fading. – BTL3**

Fast Fading	Slow Fading
High Doppler spread	Low Doppler Spread
Coherence time is lesser than symbol period.	Coherence time is greater than symbol period.
Channel variations faster than base band signal variations	Channel variations slower than base band signal variations

16 **What is meant by small scale fading? (May 2013) - BTL1**

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) - BTL1**

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? - BTL1**

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

19 **What is meant by time dispersion? - BTL1**

The received signal has a longer duration than that of the transmitted signal, due to the different delays of the signal paths. This is known as time dispersion.

20 **What is meant by frequency dispersion? - BTL1**

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. This is known as frequency dispersion.

21 **Classify the wireless channels. – BTL2**

Time-flat channels, Frequency -flat channels, Frequency-selective channels

22 **What is free space propagation model? - BTL1**

It is a model which is used to predict received signal strength, when unobstructed line of sight path between transmitter and receiver.

23 **What are Fresnel zones? - BTL1**

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

<table>
<tr><td></td><td>Fresnel zones.</td></tr>
<tr><td>24</td><td>Explain knife-edge diffraction model. - BTL1
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.</td></tr>
<tr><td>25</td><td>What is the need of path loss models in link budget design? – BTL3
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.</td></tr>
<tr><td>26</td><td>State the difference between small scale and large scale fading? (May/June2013) – BTL3
<table>
<tr><th>Small scale fading</th><th>Large scale fading</th></tr>
<tr><td>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.</td><td>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.</td></tr>
</table></td></tr>
<tr><td>27</td><td>State the difference between Narrow band and Wide band systems?(Nov/Dec 2013) – BTL3
<table>
<tr><th>Narrow band</th><th>Wide band</th></tr>
<tr><td>For a narrowband channel, the impulse response is a delta function with a time-varying attenuation</td><td>The most commonly used wideband model is an <i>N</i>-tap Rayleigh-fading model</td></tr>
<tr><td>The variations in amplitude over a small area are typically modeled as a random process, with an autocorrelation function that is determined by the Doppler spectrum</td><td>This is a fairly generic structure, and is basically just the tapped delay line structure with the added restriction that the amplitudes of all taps are subject to Rayleigh fading.</td></tr>
</table></td></tr>
<tr><td>28</td><td>Define Snell’s law. (May/June 2013) - BTL1
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:
$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$</td></tr>
<tr><td>29</td><td>What is fading and Doppler spread? (Nov/Dec 2013) - BTL1
In wireless communications, fading is deviation of the attenuation affecting a signal over certain propagation media. The fading may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel is a communication channel comprising fading.
The coherence time of the channel is related to a quantity known as the Doppler spread of the channel. When a user (or reflectors in its environment) is moving, the user's velocity causes a shift in the frequency of the signal transmitted along each signal path. This phenomenon is known as the Doppler shift.</td></tr>
<tr><td>30</td><td>What are the different fading effects due to Doppler spread?(Nov/Dec 2014) – BTL3
The fading effects due to Doppler spread are: Fast fading and slow fading
Fast fading (time selective fading): the channel impulse response changes rapidly within the symbol duration.</td></tr>
</table>

Slow fading: the channel impulse response changes at a rate much slower than the transmitted baseband signal s (t).

PART * B

1.

Explain the path loss model, and describe the following (1) – BTL2 (13)

a) Log-distance path loss model, (4)
b) Log-normal shading path loss model (4)
c) Indoor Propagation Mechanism (4)

free space path loss model (1)

path loss models to estimate the received signal level as a function of distance

Log Distance Path Loss Model (4)

The average large-scale path loss for an arbitrary T-R separation is expressed as a function of distance by using a path loss exponent, n.

$$\mathrm{PL(d)} \propto \left(\frac{\mathrm{d}}{d0}\right)^{n}$$

In dB format: $(\mathrm{PL})\mathrm{dB} = \mathrm{PL}(do) + 10n\log(d/do)$

Environment	Path oss Exponent, n
Free space	2
Urban area cellular radio	2.7 to 3.5

Log-Normal Shadowing (4)

The log-normal distribution describes the random shadowing effects which occur over a large number of measurement locations which have the same T-R separation, but have different levels of clutter on the propagation path. This phenomenon is referred to as log-normal shadowing.

$$[\mathrm{PL(d)}]\ \mathrm{dB} = \mathrm{PL}(d) + X\sigma = \mathrm{PL}(do) + 10n\log(d/do) + X\sigma$$

$$\mathrm{Pr(d)\ [dBm]} = \mathrm{P_t\ [dBm] - PL(d)[dB]}$$

Indoor Propagation Models (4)

The indoor radio channel differs from the traditional radio channel in two aspects:

1. The distances covered are much smaller.
2. The variability of the environment is much greater for a much smaller range of T - R separation distances.

Answer: Page No. 157-161 in Rappaport

2

Explain power delay profile, mean excess delay , RMS delay spread & Maximum excess delay. (13) – BTL2 (Each Type – 3 Marks + Diagram 1 Mark)

Power delay profile: Integrating the scattering function over the Doppler shift gives the **multipath intensity profile**, or **power delay profile** (PDP).

$$P_h(\tau) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |h(t,\tau)|^2\, dt$$

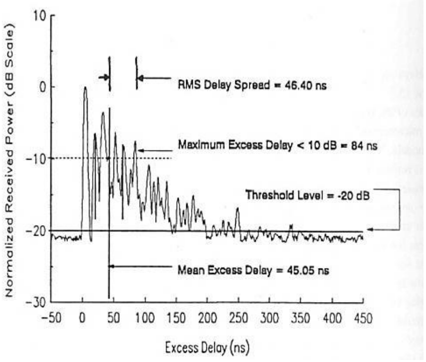
The **mean delay** or **mean excess delay** μ_τ is the first moment of the power delay profile and is defined to be

$$\bar{\tau} = \frac{\sum_k a_k^2 \tau_k}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)(\tau_k)}{\sum_k P(\tau_k)}$$

The **rms delay spread** σ_τ is the square root of the second central moment of the power delay profile and is defined to be

$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2}$$

$$\overline{\tau^2} = \frac{\sum_k a_k^2 \tau_k^2}{\sum_k a_k^2} = \frac{\sum_k P(\tau_k)(\tau_k^2)}{\sum_k P(\tau_k)}$$



Maximum Excess Delay (X dB):

Defined as the time delay value after which the multipath energy falls to X dB below the maximum multipath energy. It is also called ***excess delay spread*.**

Answer: Page No. 199 in Rappaport

3

Summarize the following (13)

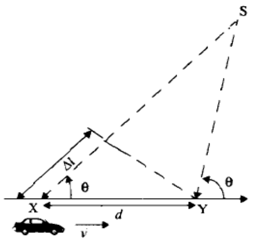
Doppler shift (5) , Doppler spread (4) and Coherence time (4) – BTL2

DOPPLER SHIFT

The phase change in the received signal due to the difference in path lengths is

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t\cos\theta}{\lambda}$$

(Dia- 2 M + Exp – 3 M)



Doppler shift is given by $f_d = \frac{1}{2\pi}\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cos\theta$

$f = f_c + f_d$, $f = f_c - f_d$

DOPPLER SPREAD & COHERENCE TIME *(Each – 4 M)*

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

Coherence time T_c is the time duration over which two received signals have a strong potential for amplitude correlation.

$$T_C \approx \sqrt{\frac{9}{16\pi f_m^2}} = \frac{0.423}{f_m}$$

Answer: Page No. 179, 202-203 in Rappaport

4

Assume a receiver is located 10 km from a 50 W transmitter. The carrier frequency is 900 MHz, free space propagation is assumed, $G_T = 1$, and $G_R = 2$, find (a) the power at the receiver, (b) the magnitude of the E-field at the receiver antenna. (c) The RMS voltage applied to the receiver input assuming that the receiver antenna has a purely real impedance of 50 Ω and is matched to the receiver. (13) – BTL4

a)

$$P_R(d) = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

$$= 50\times1\times2\left(\frac{0.33}{4\pi\times10000}\right)^2 = 7\times10^{-10}\text{ W}$$ (2)

$$P_R(d)\text{ dBm} = 10\log\left(\frac{P_R(d)}{1\times10^{-3}}\right) = -61.5\text{ dBm}$$ (2)

b) $$|E| = \sqrt{\frac{120\pi P_R(d)}{\lambda^2 G_R / 4\pi}} = \sqrt{\frac{120\pi\times7\times10^{-10}}{0.33^2\times2/4\pi}} = 0.0039\text{ V/m}$$ (5)

c) $v_{ant} = \sqrt{P_r(d) * 4R_{ant}} = \sqrt{7 * 10^{-10} * 4 * 50} = 0.374\, mV$ (4)

Answer: Page No. 112 in Rappaport

5 **If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna. What is P_r (10 km)? Assume unity gain for the receiver antenna. (13) – BTL3**

a) $$P_t\text{ (dBm)} = 10\log\left(\frac{P_t}{1\times10^{-3}}\right) = 10\log\left(\frac{50}{1\times10^{-3}}\right) = 47\text{ dBm}$$ (2)

b) $$P_t\text{ (dB)} = 10\log(P_t) = 10\log(50) = 47\text{ dBW}$$ (2)

$$P_R(d) = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

$$= 50\times1\times1\left(\frac{0.33}{4\pi\times100}\right)^2$$

$$= 3.5\times10^{-6}\text{ W}$$

$$P_R(d)\text{ dBm} = 10\log\left(\frac{P_R(d)}{1\times10^{-3}}\right) = 10\log\left(\frac{3.5\times10^{-6}}{1\times10^{-3}}\right) = -24.5\text{ dBm}$$ (5)

Now d=10km, d_0=100m (4)

$$P_r(d)\,\text{dBm} = 10\log\left(\frac{P_r(d_0)}{0.001\,\text{W}}\right) + 20\log\left(\frac{d_0}{d}\right) \qquad d \geq d_0 \geq d_f$$

$$P_r(10km) = p_r(100) + 20\ log\left(\frac{100}{10000}\right) = -24.5\ dBm - 40\ dBm = -64.5\ dbm$$

Answer: Page No. 109 in Rappaport

6 **Derive the final expression for the free space path loss model, and derive the Gain expression. (13) - BTL3**

Free Space Path Loss Model (2)

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them.

flux density $\Phi_R = \frac{P_T}{4\pi d^2}$ (1)

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

gain of the antenna

$$G = \frac{4\pi A_e}{\lambda^2}$$ (2)

Antenna Efficiency $\eta = \frac{A_e}{A}$

Effective isotropic radiated power (EIRP) $EIRP = P_t G_t$ (2)

Path loss for the free space model

$$PL(dB) = 10\log\frac{P_t}{P_r} = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right)$$ (1)

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

far-field distance = $2D^2/\lambda$ (1)

received power (2)

$$P_r(d)\,\text{dBm} = 10\log\left(\frac{P_r(d_0)}{0.001\,\text{W}}\right) + 20\log\left(\frac{d_0}{d}\right)$$

Answer: Page No. 107 in Rappaport

7

An aircraft is headed towards an airport control tower with a speed of 500 km/h at an elevation of 20°. safety communications between the aircraft tower and the plane occurs at a frequency of approximately 128 MHz. What is the expected Doppler shift of the received signal? (13) BTL – 4

Given Data (1)

$$\text{wavelength } \lambda = \frac{c}{f_c} = \frac{3\times10^8}{128\times10^6} = 2.34\text{m}$$ (4)

Aircraft speed v = 500 × 1000/3600 m/s = 138.89 m/s

(4)

The Doppler shift of the received signal is $f_d = \frac{v}{\lambda}\cos\theta = \frac{138.89}{2.34}\cos 20^\circ = 55.775$ (4)

8

Consider a transmitter which radiates a sinusoidal carrier frequency of 900 MHz. For a vehicle moving 70 km/h, compute the received carrier frequency if the mobile is moving (a) directly towards the transmitter, (b) directly away from the transmitter, (c) in a direction which is perpendicular to the direction of arrival of the transmitted signal. (13)

BTL - 4

wavelength $\lambda = \frac{c}{f_c} = \frac{3\times10^8}{900\times10^6} = 0.33\text{m}$

Vehicle speed v = 70 × 1000/3600 = 19.44 m/s (2)

a) $$f_d = \frac{v}{\lambda}\cos\theta$$ (2)
$$= \frac{19.44}{0.33}\cos 0 = 58.9091$$

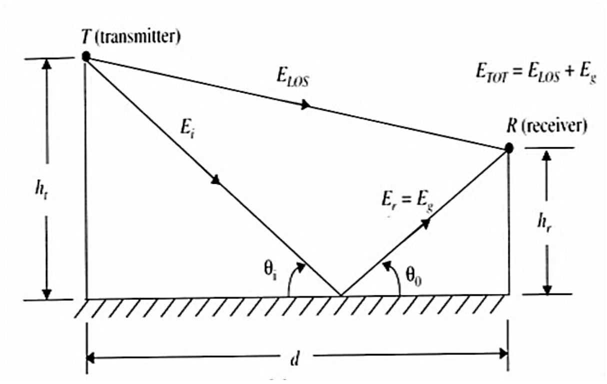
$$f = f_c + f_d = 900\times10^6 + 58.9091 = 900.0000589 \text{ MHz}$$ (3)

b) $$f = f_c - f_d = 900\times10^6 - 58.9091 = 899.9999411 \text{ MHz}$$ (3)

c) $\theta = 90°,\ \cos 90° = 0$,, and there is no Doppler shift. (3)

PART * C

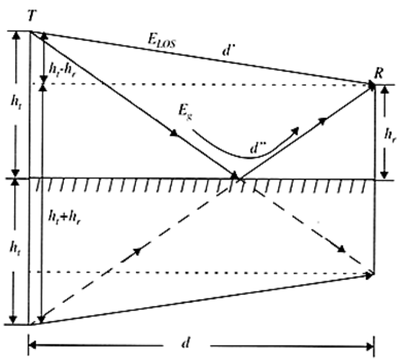
1. **Derive the final expression for Two Ray Model propagation mechanisms. (15)**



(2)

The 2-ray ground reflection model consists of both the direct path and a ground reflected propagation path between transmitter and receiver

$$\vec{E}_{TOT} = \vec{E}_{LOS} + \vec{E}_g$$ (4)



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

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

(2)

$$\left|\frac{E_0 d_0}{d}\right| \approx \left|\frac{E_0 d_0}{d'}\right| \approx \left|\frac{E_0 d_0}{d''}\right| \quad (1)$$

Diagram – 2

$$P_r\,(d) = P_r\,(d_0)\left(\frac{d_0}{d}\right)^4 (2)$$

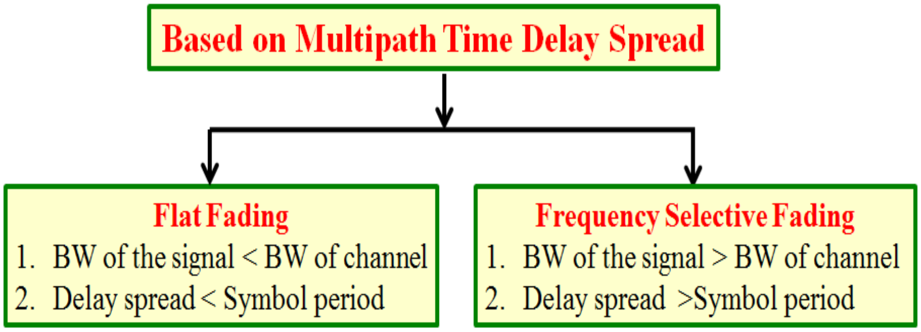
$$P_L\,(dB) = 40 \log d - [10 \log G_t + 10 \log G_r + 20 \log h_t + 20 \log h_r$$

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4} \quad (2)$$

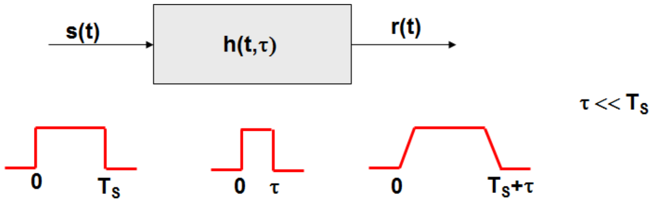
Answer: Page No. 120 in Rappaport

2

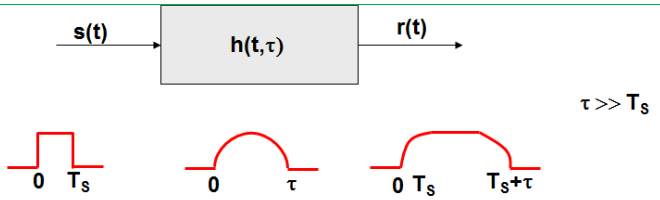
Describe in detail about small scale fading based on multipath delay spread and Doppler spread (15) – BTL2 (4 types (Dia 2 M) + Exp 7 M)

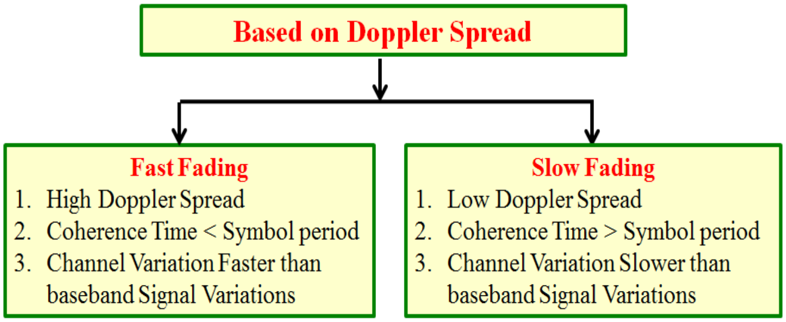


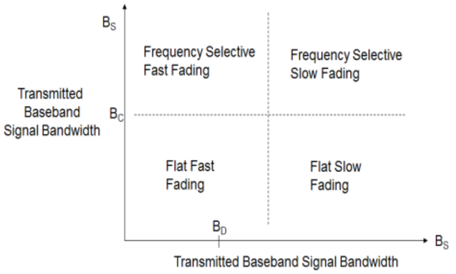
FLAT FADING CHANNEL

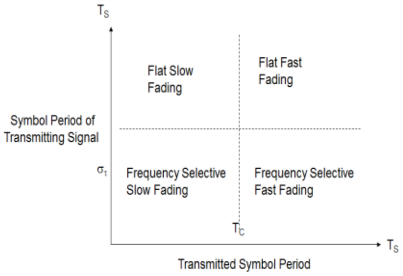


FREQUENCY SELECTIVE FADING CHANNEL









Answer: Page No. 205 in Rappaport

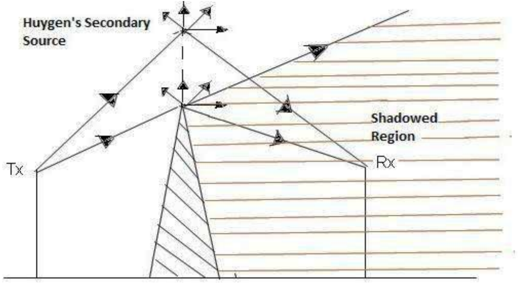
3

Describe the basic propagation mechanisms in detail. – BTL2 (15)

Reflection occurs when a propagating electromagnetic wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave. Reflections occur from the surface of the earth and from buildings and walls. (3)

The **Brewster angle** is the angle at which no reflection occurs in the medium of origin. $\theta_B = \sin^{-1}\sqrt{\frac{\varepsilon_1}{\varepsilon_1+\varepsilon_2}}$ (3)

Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp irregularities (edges). (2)



(2)

Fresnel-Kirchhoff diffraction parameter as $v = h\sqrt{\frac{2(d_1+d_2)}{\lambda d_1 d_2}}$ (2)

Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects, or by other irregularities in the channel. (2) $h_c = \frac{\lambda}{8\sin\theta_i}$ (1)

Answer: Page No. 113, 114, 126, 135 in Rappaport

UNIT II CELLULAR ARCHITECTURE

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

PART * A

Q.No.	Questions
1.	**What are the different types of multiple access schemes? (Nov/Dec 13) - BTL1** 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? - BTL1** The transmitter and receiver require much less digital signal processing, Synchronization is simple.
3	**What are the disadvantages of FDMA? - BTL1** 1. Sensitivity to fading 2. Sensitivity to random frequency modulation 3. Inter modulation
4	**Define SAMA. - BTL1** 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. - BTL1** 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? - BTL1** 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? - BTL1** 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 is guard space? - BTL1** Guard spaces are needed to avoid frequency band overlapping is also called channel interference.
9	**What is called burst and normal burst? - BTL1** Data is transmitted in small portions called bursts, normal burst are used for data transmission inside a slot (user and signalling data).
10	**What limits the number of user in TDM and FDM compared to CDM? – BTL3** 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.
11	**How does near and far effect influence CDMA? What are counter measurements? – BTL3** 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 λ. λ receive all senders with the same strength at a receiver**.**

12	**Define FCA and DCA. - BTL1** 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.
13	**What is meant by frequency reuse?(May/June2013) - BTL1** Cellular systems should rely on frequency reuse pattern, Band of frequencies should be allotted to each cell Use same frequency in nearby cells for multiple conversations. To avoid interference or cross talk different frequencies should be allotted to adjacent cells. *E.g.N* cells all using same number of frequencies, *K total* number of frequencies used in systems, Each cell has *K/N* frequencies
14	**When handoff occurs? - BTL1** 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.
15	**Differentiate soft and hard handoff. – BTL3** 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.
16	**What is the function of Medium Access Control Layer? - BTL1** The functions of Medium Access Control Layer are responsible for establishes, maintains, and releases channels for higher layers by activating and deactivating physical channels.
17	**What are the 2 sub layers in DLC? - BTL1** Logical Link Control(LLC), Media Access Control (MAC)
18	**What do you mean by Polling? - BTL1** Polling is a strictly centralized scheme with one master and several slave stations. The master can collect the list of stations during the contention phase and can poll these slaves according to many schemes like round robin, random access, reservation scheme etc.
19	**Define traffic multi frame and control multi frame? - BTL1** 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.
20	**How does near and far effect influence CDMA? What are counter measurements? – BTL4** 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.
21	**What is meant by vertical handoff? - BTL1** Moving between different wireless technologies.
22	**Differentiate inter and intra cell handoff. – BTL3** Inter-cell hand-off means in which present serving ant the new target cells are different cells. The purpose of this hand-off is to maintain the call as the mobile subscriber is moving out of the area covered by the present serving cell and entering the area of the new target cell. Intra-cell hand-off means in which present serving ant the new target cells are one and the same cell. The purpose of this hand-off is to change one channel, which may be interfered or affected by fading, with a new clearer or lest fading channel.

23	**How does a p-persistent CSMA different from non-persistent CSMA? – BTL4** In non-persistent CSMA, stations sense the carrier and start sending immediately if the medium is idle. If the medium is busy, the station pauses a random amount of time before sensing the medium again and repeating this pattern. In p-persistent CSMA systems nodes also sense the medium, but only transmit with a probability of p, with the station deferring to the next slot with the probability 1-p, i.e., access is slotted in addition
24	**What are the benefits of reservation schemes? - BTL1** The benefits of reservation schemes are reserves future slots, higher throughput, less collisions.
25	**What is the function of Medium Access Control Layer? - BTL1** 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.
26	**Define Set-up time. - BTL1** The time required to allocate a trunked radio channel to a requesting user.
27	**What is a blocked call? - BTL1** Call which cannot be completed at time of request, due to congestion.Also referred to as lost call.
28	**What is orthogonality? - BTL1** 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.
29	**Define Holding-time. - BTL1** Average duration of a typical call.Denoted by ‘H’ (in seconds).
30	**State advantages of CDMA over FDMA?(Nov/Dec2014) - BTL1** 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.
	PART * B
1.	**An urban area has a population of two million residents. Three competing trunked mobile networks (systems A, B, and C) provide cellular service in this area. System A has 394 cells with 19 channels each, system B has 98 cells with 57 channels each, and system C has 49 cells, each with 100 channels. Find the number of users that can be supported at 2% blocking if each user averages two calls per hour at average call duration of three minutes. Assuming that all three trunked systems are operated at maximum capacity, compute the percentage market penetration of each cellular provider. (13) – BTL5** **System A (3)** Probability of blocking = 2% = 0.02, C = 19, $Au = \lambda H = 2 \times (3/60) = 0.1$ Erlangs For GOS = 0.02 and C = 19, from the Erlang B chart, the total carried traffic, A, is obtained as

12 Erlangs. U = A/Au = 12/0.1 = 120

The total number of subscribers, supported by System A is equal to 120 × 394 = 47280

System B (3)

Probability of blocking = 2% = 0.02, C = 57, Au = λH = 2 × (3/60) = 0.1 Erlangs

For GOS = 0.02 and C = 57, from the Erlang B chart, the total carried traffic, A, is obtained as 45 Erlangs. U = A/Au = 45/0.1 = 450

The total number of subscribers, supported by System B is equal to 450 × 98 = 44,100

System C (3)

Probability of blocking = 2% = 0.02, C = 100, Au = λH = 2 × (3/60) = 0.1 Erlangs

For GOS = 0.02 and C = 100, from the Erlang B chart, the total carried traffic, A, is obtained as 88 Erlangs. U = A/Au = 88/0.1 = 880

The total number of subscribers, supported by System C is equal to 880 × 49 = 43,120

Total numbers of cellular subscribers 47,280 + 44,100 + 43,120 = 134,500 users. **(2)**

In System A the percentage market penetration is equal to 47,280/2,000,000 = 2.36%

Similarly, market penetration of System B is equal to 44,100/2,000,000 = 2.205%

and the market penetration of System C is equal to 43,120/2,000,000 = 2.156%

The market penetration of the three systems combined is equal to 134,500/2,000,000 = 6.725% **(2)**

Answer: Page No. 83 in Rappaport

2

Compare TDMA, FDMA and CDMA - BTL3 (Any 6 Points – 13 M)

	FDMA	***TDMA***	***CDMA***
Modulation	▪ Relies on bandwidth-efficient modulation	▪ Relies on bandwidth-efficient modulation	▪ Simple modulation
Diversity	▪ Requires multiple transmitters or receivers	▪ Requires multiple transmitters or receivers ▪ Can be frequency-hopped	▪ Includes frequency diversity when implemented with a RAKE receiver
User terminal complexity	▪ Simple	▪ Medium complexity	▪ More complex
Handover	▪ Hard	▪ hard	▪ Soft
System complexity	▪ Large number of simple components	▪ Reduced number of channel units	▪ Large number of complex interacting components
Multiple-Access interference	▪ Limited by system planning	▪ Limited by system planning	▪ Dynamic power control
Fading	▪ Flat-fading ▪ No diversity ▪ Simple to track	▪ May be frequency-selective ▪ May need equalizer	▪ Frequency-selective diversity via RAKE receiver

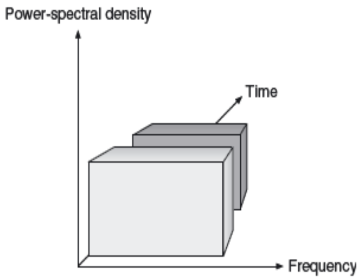
Answer: Page No. 447 - 458 in Rappaport

3

Write short notes on TDMA, FDMA CDMA in cell system. (13) – BTL2 3 Types (Exp - 7 M + Dia – 2M)

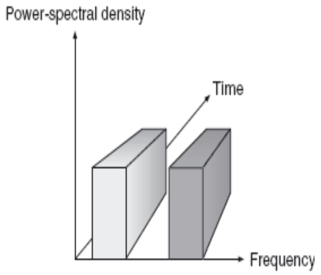
TDMA

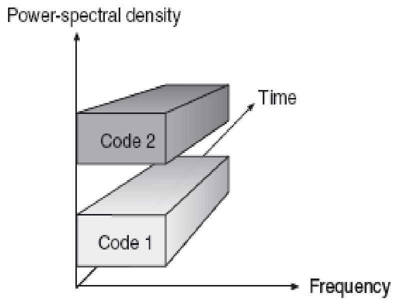
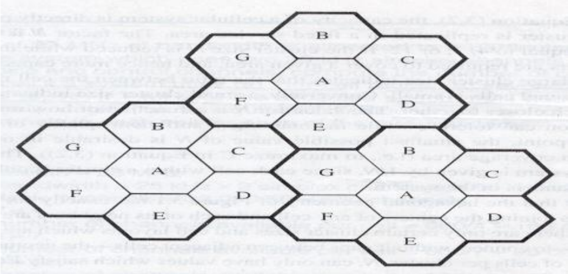
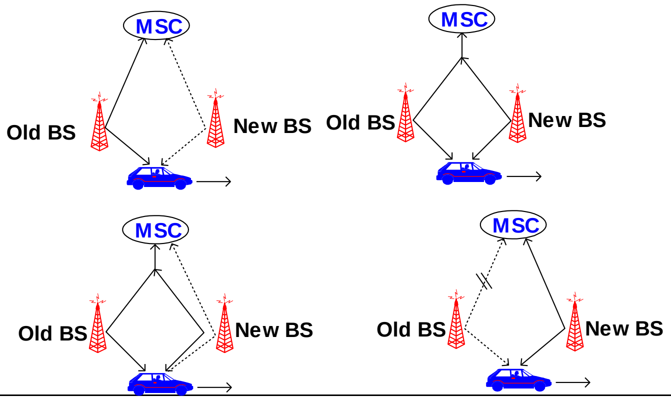
single carrier frequency with several users
System is not continuous, but occurs in bursts.
The handoff process is much simpler for a subscriber unit
Duplexers are not required.
High transmission rates compared to FDMA channels.
High synchronization overhead is required



FDMA

Channel carries only one phone circuit at a time.
If channel is not in use, then it cannot be used by other users
Continuous transmission scheme
Narrowband systems.
Inter-symbol interference is low.
Mobile unit uses duplexers.
Requires RF filtering to minimize adjacent channel interference



	CDMA Many users of a CDMA system share the same frequency. Soft capacity limit. Frequency-dependent transmission impairments Multipath fading may be substantially reduced Channel data rates are very high Macroscopic spatial diversity to provide soft handoff. The near-far problem occurs at a CDMA receiver. Answer: Page No. 447 - 458 in Rappaport 
4	**Write short notes on frequency reuse – BTL2 (13)** **(Diagram 3 M + Formula 4 M + Exp 6)** The design process of selecting and allocating channels groups for all of the cellular base stations within a system is called frequency reuse or frequency planning S=kN. C = MkN = MS. & $N=i^2 + ij + j^2$  $\frac{D}{R} = \sqrt{3N}$ Answer: Page No. 58 in Rappaport
5	**Describe channel assignment strategies in detail – BTL2 (13)** **Channel assignment strategies** can be classified as Static and Dynamic. (1) When fixed numbers of channels are assigned to a cell, it is called fixed channel assignment. (6) In case of dynamic channel assignment, voice channels are assigned by MSC based on request from the Base stations.(6) Answer: Page No. 62 in Rappaport
6	**Explain the process of Handoff and its strategies (13) – BTL2 (Dia 4 M + Exp 9 M)** Handoff process, which allows users to remain in touch, even while breaking the connection with one BS and establishing connection with another BS. (3) 

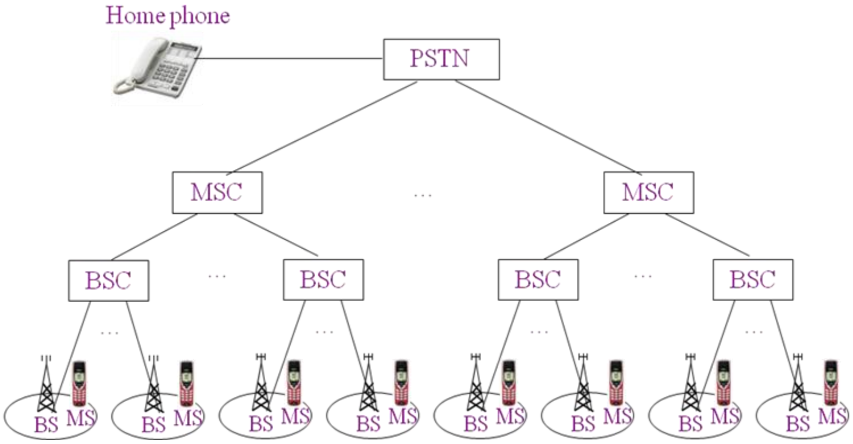
	(4) **Handoff detection strategies** (3) ❖ Mobile-Controlled handoff (MCHO) ❖ Network-Controlled handoff (NCHO) ❖ Mobile-Assisted handoff (MAHO) **Handoff types with reference to the network** (3) ❖ Intra-system handoff or Inter-BS handoff The new and the old BSs are connected to the same MSC. ❖ Intersystem handoff or Inter-MSC handoff The new and the old BSs are connected to different MSCs. Answer: Page No. 62 in Rappaport
7	**Drive the expressions for interference systems. (13) BTL - 3** **Interference** is the major limiting factor in the performance of cellular radio systems. (3) Several cell that use the same set of frequencies, these cells are called co channels cells and the interference form these cells called **co channel interference. (5)** $$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i=io} Ii}$$ The average power Pr α $\frac{1}{r^{n}}$ Interference resulting from signals which are adjusted in frequency to the desired signal is called **Adjacent channel interference. (5)** Answer: Page No. 67 in Rappaport
8	**If a signal to interference ratio of 15 db is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size should be used for maximum capacity if the path loss exponent is a) n = 4 and b.) n=3. Assume that there are six co channel cells in the first tier and all of them are at the same distance from the mobile. . Use suitable assumption. (13) (5 M + 8 M) – BTL4** a) **n= 4,** consider N=7, D / R = 4.583. (5) S / I = (1 / 6) * $(4.583)^4$ = 75.3 = 18.66 db Since this is greater than the minimum required S / I, N = 7 can be used. **b) n = 3, N=7, (8)** S / I = (1 / 6) * $(4.583)^3$ = 16.04 = 12.06 db Since this is less than the minimum required S / I , we need to use a larger N. Using the N = 12, D/ R becomes 6.0 S / I = (1 / 6) * $(6)^3$ = 36 = 15.56 db Since this is greater than the minimum required S / I, N = 12 is used. Answer: Page No. 72 in Rappaport

9

Illustrate the principles of cellular networks (13) – BTL – 3

Explanation of each blocks (7)

Diagram (6)



10

If a particular FDD cellular telephone system has a total bandwidth of 33mhz and if the phone system uses two 25khz simplex channel to provide the no/- of channels per cell if n=4,7,12 (13) – BTL 3

Formulas (3)

Channel bandwidth = 25 KHz x 2 = 50 KHz (2)

Total available channels = 33 MHz / 50 KHz = 660 (2)

N = 4 Channel per cell = 660 / 4 = 165 channels (2)

N = 7 Channel per cell = 660 / 7 = 95 channels (2)

N = 12 Channel per cell = 660 / 12 = 55 channels (2)

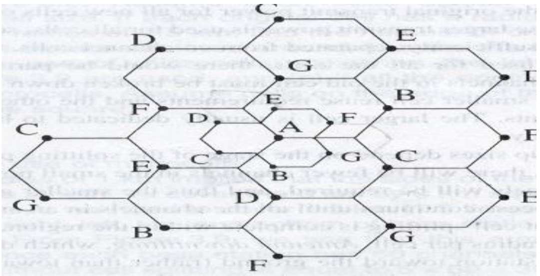
PART * C

1.

How to improve coverage and capacity of cellular system, analyze the concept. (15) – BTL4

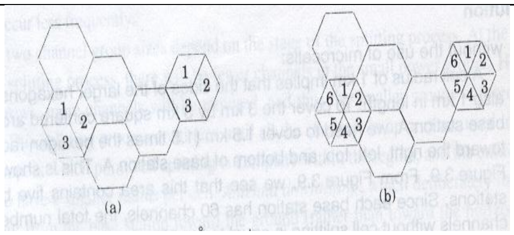
Cell Splitting: (5)

It is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power.



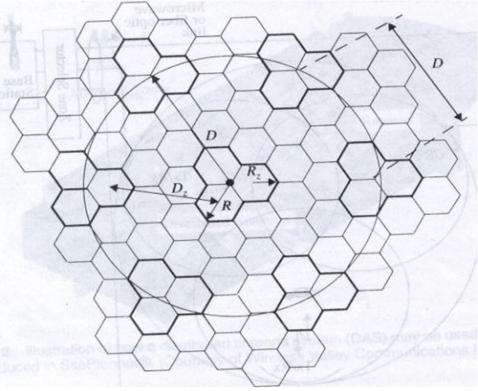
Sectoring: (5)

It replaces the omni directional antenna at the center or directional antennas at the corner with three directional antenna at the center if the cell is divided into three sectors. Each of the directional antennas covers a sector of 120 degrees as shown in the following figure



Microcell Zone: **(5)**

The advantage of the zone cell technique is that while the cell maintains a particular coverage radius, the co-channel interference in the cellular system is reduced such a large central base station is replaced by several lower powered transmitters on the edges of the cell.



Answer: Page No. 86 in Rappaport

2

Write short notes on

i. **Telephone Call Made To Mobile User (10)**

ii. **Telephone Call Placed by Mobile (5)– BTL3**

Telephone Call Made To Mobile User (Dia – 3m + Exp 7)

Step 1: The incoming telephone call to Mobile X,

Step 2: The MSC dispatches the request to all base stations

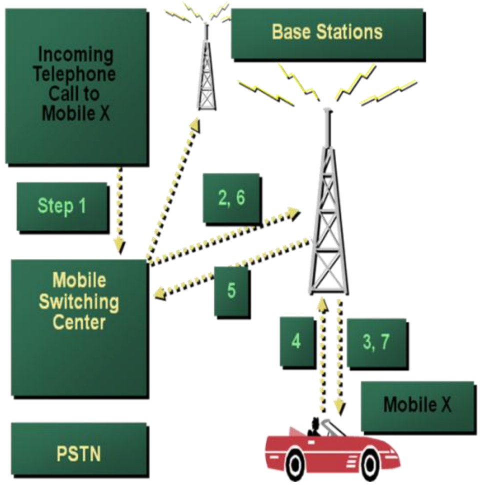
Step 3: The base stations broadcast paging message

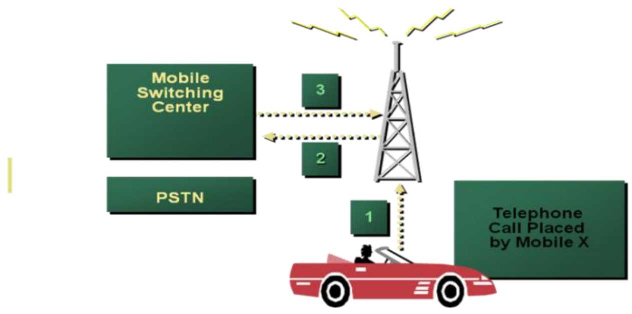
Step 4: The mobile receives the paging message

Step 5: The base station informs the MSC of the handshake.

Step 6: The MSC move the call to an available voice channel within the cell.

Step 7: The base station signals the mobile to change frequencies



	Telephone Call Placed by Mobile (Dia – 2 M+ Exp 3 M) **Step 1:** Mobile originates a call and it sends MIN, ESN, SCM **Step 2:** Cell base station receives the data and sends it to the MSC. **Step 3:** The MSC validates the request, and allow the conversation to begin.  Answer: Page No. 13 in Rappaport
3	**Write detail about trunking and grade of service of cell system (15) – BTL2** The concept of trunking allows a large number of users to share the relatively small number of channels in a cell by providing access to each user, on demand, from a pool of available channels. **(5)** **Parameters: (8)** **Set-up Time:** The time required to allocate a trunked radio channel to a requesting user. **Blocked Call:** Call which cannot be completed at time of request, due to congestion. **Holding Time:** Average duration of a typical call. Denoted by H **Traffic Intensity:** Measure of channel time utilization **Load:** Traffic intensity across the entire trunked radio system **Grade of Service (GOS):** A measure of congestion which is specified as the probability of a call being blocked (for Erlang B), or the probability of a call being delayed beyond a certain amount of time (for Erlang C). **Request Rate:** The average number of call requests per unit time. Denoted by λ seconds–1. **Erlangs formula** $A_u = \lambda H$ **(2)** Answer: Page No. 77 in Rappaport

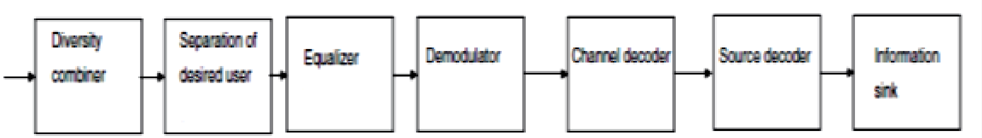
UNIT III - DIGITAL SIGNALING FOR FADING CHANNELS

Structure of a wireless communication link, Principles of Offset-QPSK, p/4-DQPSK, Minimum Shift Keying, Gaussian Minimum Shift Keying, Error performance in fading channels, OFDM principle – Cyclic prefix, Windowing, PAPR.

PART * A

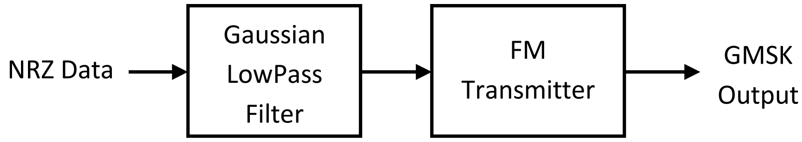
Q.No.	Questions
1.	**Define modulation. - BTL1** It is defined as the process by which some parameters of a high frequency signal termed as carrier, is varied in accordance with the signal to be transmitted.
2	**What is demodulation? - BTL1** It is the process of recovering the original modulating signal from a modulated signal.
3	**Write the advantages of digital over analog modulation. - BTL1** Greater noise immunity, Robustness to channel impairments, Easier multiplexing of various forms of information, Greater security
4	**What is meant by Amplitude shift keying? - BTL1** 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? - BTL1** 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? - BTL1** 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 - BTL1** In digital 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? - BTL1** 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 - BTL1** 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.
10	**What is QAM? - BTL1** 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? - BTL1** QPSK is a multi-level modulation in which four phase shifts are used for representing four different symbols.
12	**What is linear modulation? - BTL1** 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. - BTL1** Bandwidth efficient, Very attractive for use in wireless communication systems, Accommodate more and more users within a limited spectrum.

14	**What is nonlinear modulation? - BTL1** 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. – BTL2** 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 providesHigh 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, constantEnvelopemodulation is not well suited.
16	**What is the advantage of MSK over QPSK? – BTL2** 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? – BTL3** 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. - BTL1** Constant envelope, Spectral efficiency, Good BER performance, Self-synchronizing capability
19	**Why MSK cannot be directly used in multi user communications? - BTL3** 1. The main lobe of MSK is wide. This makes MSK unsuitable for the applications where extremely narrow bandwidths and sharp cutoffs 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? (Nov/Dec 13) – BTL3** Gaussian filters used before the modulator to reduce the transmitted bandwidth of the signal. It uses less bandwidth than conventional FSK.
21	**Give some examples of linear modulation. - BTL1** Pulse shaped QPSK, OQPSK, and π/4QPSK
22	**Give some examples for constant envelope modulation. - BTL1** BFSK, MSK, GMSK
23	**Define QAM. - BTL1** Quadrature amplitude modulation is in which both the amplitude and phase of the transmitted signals are varied by the baseband signal.
24	**Define M-ary FSK. - BTL1** In M-ary system, M=2N different symbols are used and N no of bits per symbol. Every symbol uses separate frequency for transmission.
25	**Write the applications of MFSK and OFDM. – BTL2** They are used for high speed data connections as part of the IEEE 802.11a standards activities to provide 54mbps WLAN connections, as well as for high speed line of sight and non-line of sight connections for Multi-channel Multipoint Distribution service (MMDS) operation.

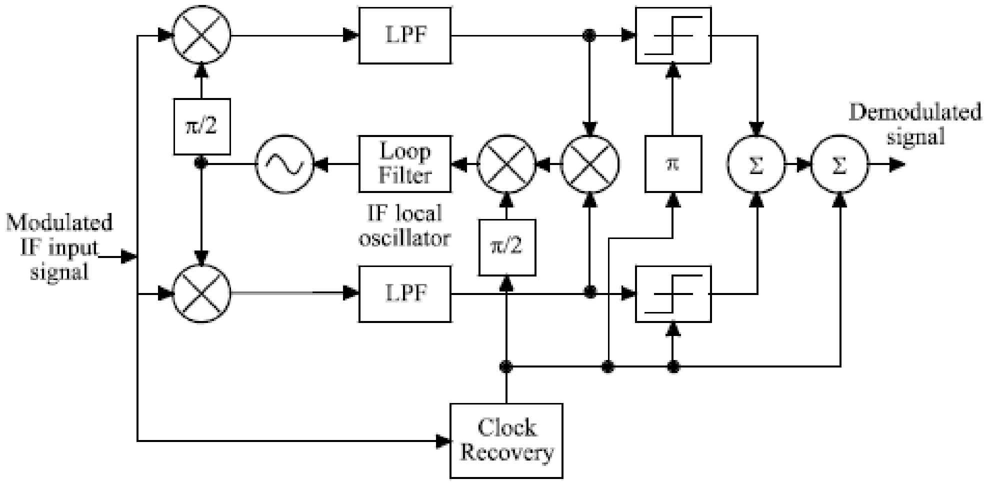
26	**What are the modulations suitable for frequency selective mobile channels? - BTL1** Both filtered and unfiltered BPSK, QPSK, OQPSK and MSK modulations are suitable for frequency selective mobile channels.
27	**Mention any two criteria for choosing a modulation technique for a specific wireless application? (May/June 2013) - BTL1** 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.
28	**Draw the structure of generic optimum receiver? (May/June 2013) – BTL3** 
29	**Define cyclic prefix. - BTL1** 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.
30	**Define Windowing. - BTL1** 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.
31	**Define PAPR. - BTL1** 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.
32	**State advantages of Offset-QPSK.(Nov/Dec 2014) - BTL1** i. OQPSK is close to a constant envelope modulation scheme that is attractive for systems using nonlinear transponders, e.g., satellite communication ii. Envelope fluctuations in OQPSK is much smaller than in QPSK iii. Since sudden 180 degree phase changes cannot occur in OQPSK, this problem is reduced to a certain extent.
33	**List the advantages of GMSK.(Nov/Dec 2014) - BTL1** Modulated carrier in MSK contains no phase discontinuities and frequency changes occur at zero crossing of carrier. This helps in keeping PAPR low hence do not require highly linear power amplifier. GMSK spectral efficiency is better than MSK. Also it has reasonably less demodulator complexity.
	PART * B
1.	**Explain GMSK transmitter and receiver with signal spacing diagram and give an expression for spectral efficiency (13) – BTL2** **GMSK** **(3)** GMSK is a simple binary modulation scheme which may be viewed as a derivative of MSK. The GMSK premodulation filter has an impulse response given by

$$h_G(t)=\frac{\sqrt{\pi}}{\alpha}\exp\left(-\frac{\pi^2}{\alpha^2}t^2\right)$$

GMSK TRANSMITTER **(Diagram 2 M+ Exp 3 M)**



GMSK RECEIVER **(Diagram 2 M+ Exp 3 M)**

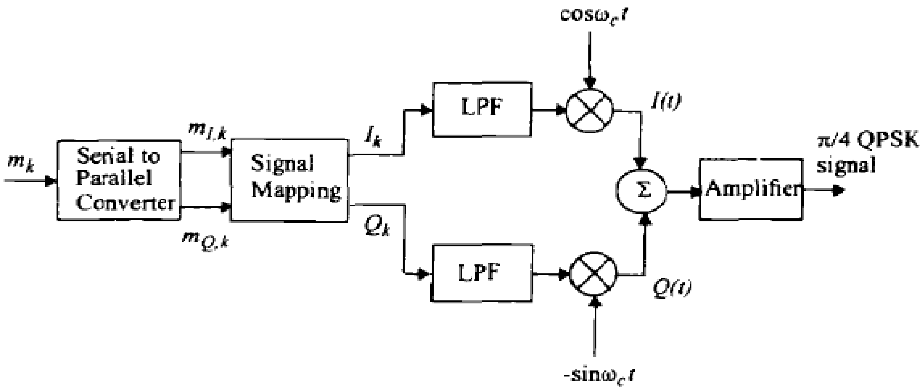


Answer: Page No. 318 in Rappaport

2 **Describe π/4 QPSK and its advantages with neat block diagram. (13) – BTL2**

Even though QPSK is a constant envelope format, it has amplitude dips at bit transitions. This can be reduced by using ***π/4*-DQPSK** (3)

***π/4* QPSK transmitter** (Diagram 2 M+ Exp 3 M)



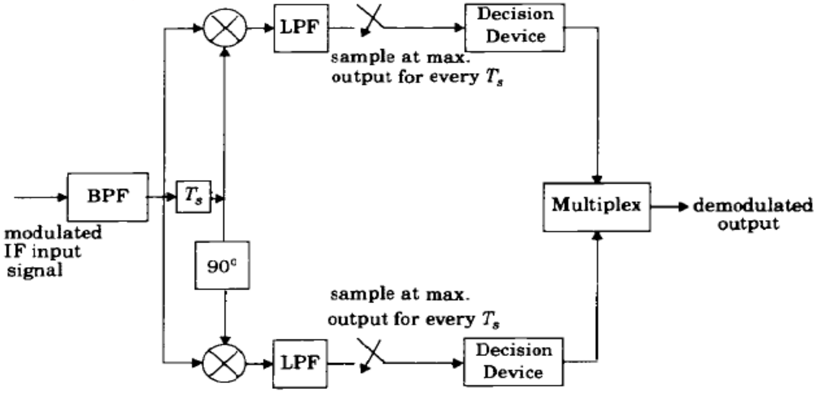
$I_k = \cos\theta_k$ $Q_k = \sin\theta_k$ $\theta_k = \theta_{k-1} + \phi_k$

Information bits $m_{I,k}, m_{Q,k}$	Phase shift ϕ_k
11	$\pi/4$
01	$3\pi/4$
00	$-3\pi/4$
10	$-\pi/4$

QPSK waveform given by

$$S_{\pi/4-DQPSK} = I(t)\cos\omega_c t - Q(t)\sin\omega_c t$$

π/4 QPSK Detection(Diagram 2 M+ Exp 3 M)



The received signal is converted to IF and is bandpass filtered. The bandpass filter is designed to match the transmitted pulse shape, so that the carrier phase is preserved and noise power is minimized. The received IF signal is differentially decoded using a delay line and two mixers.

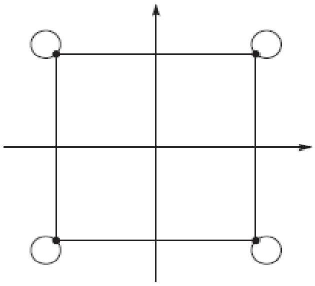
Answer: Page No. 305 in Rappaport

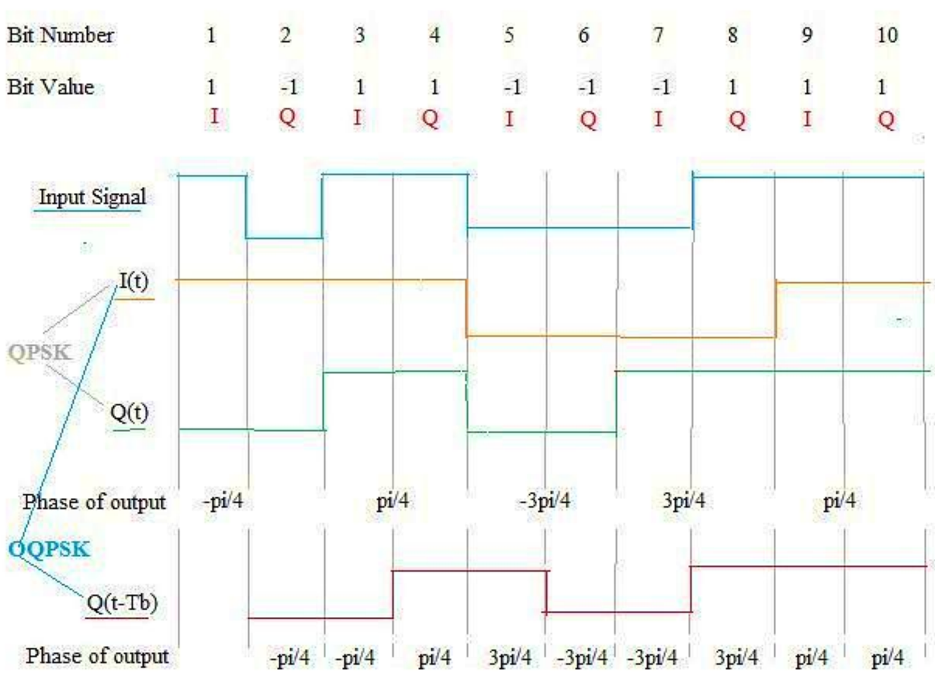
3 **Describe the OFFSET QPSK (OQPSK)with suitable diagrams** *(13)* – **BTL2**

(Diagram 6 M+ Exp 7 M)

A modified form of QPSK, called offset QPSK (OQPSK) or staggered QPSK is less susceptible to these deleterious effects. The 180° phase transition in QPSK causes abrupt changes in the signal, resulting in large spectral side lobes. To prevent 180° phase changes in QPSK, **offset QPSK (OQPSK)** or **staggered QPSK (SQPSK)** is used.

The phase transition diagram for OQPSK is shown in figure below. It is clear that there are no transitions passing through the origin of the coordinate system. Maximum phase transition is ±90°





QPSK and OQPSK Time Domain Waveforms

Advantages of offset QPSK: maximum phase shift 90 degree, nonlinear amplification does not generate high frequency side lobes, spectral occupancy is reduced.

Answer: Page No. 303 in Rappaport

4

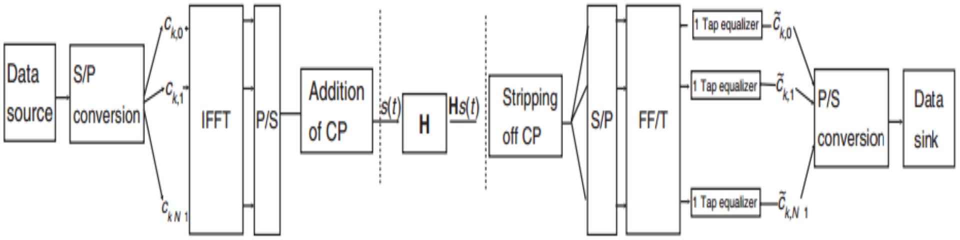
Briefly explain Peak Average Power Ratio(PAPR) and cyclic prefixing in OFDM (13) – BTL2

Cyclic Prefix (Diagram 3 M+ Exp 4 M)

Delay dispersion leads to

1. appreciable errors even when delay spread < symbol duration.
2. loss of orthogonality between the subcarriers, and thus leads to **Inter Carrier Interference.**

The cyclic prefix converts this linear convolution into a cyclical convolution.



Peak-to-Average Power Ratio (PAPR) (6 M)

Peak-to-average power ratio (PAPR) is proportional to the number of subcarriers used for OFDM systems.

An OFDM system with large number of subcarriers will thus have a very large PAPR when the subcarriers add up coherently.

Large PAPR of a system makes the implementation of digital-to-analog converter (DAC) and analog-to-digital converter (ADC) extremely difficult.

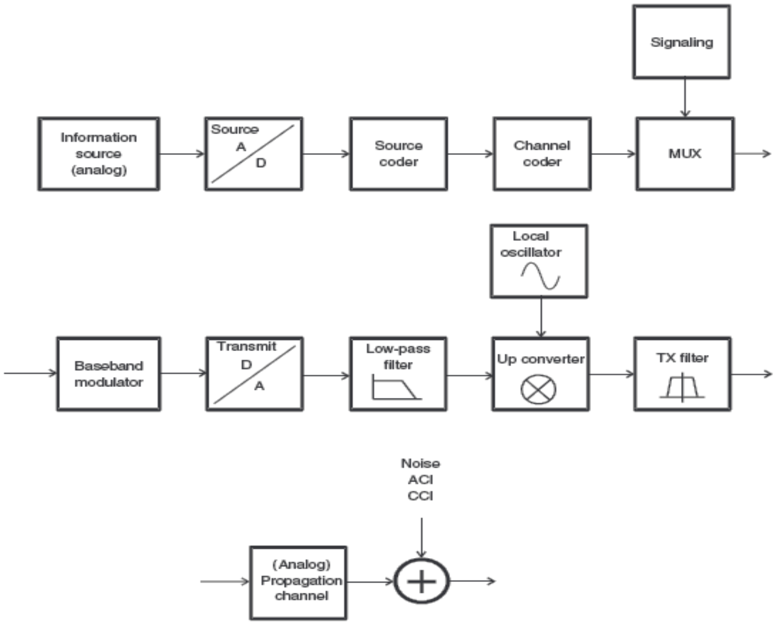
The design of RF amplifier also becomes increasingly difficult as the PAPR increases.

Answer: Page No. 420, 431 in Andreas F Molisch

5

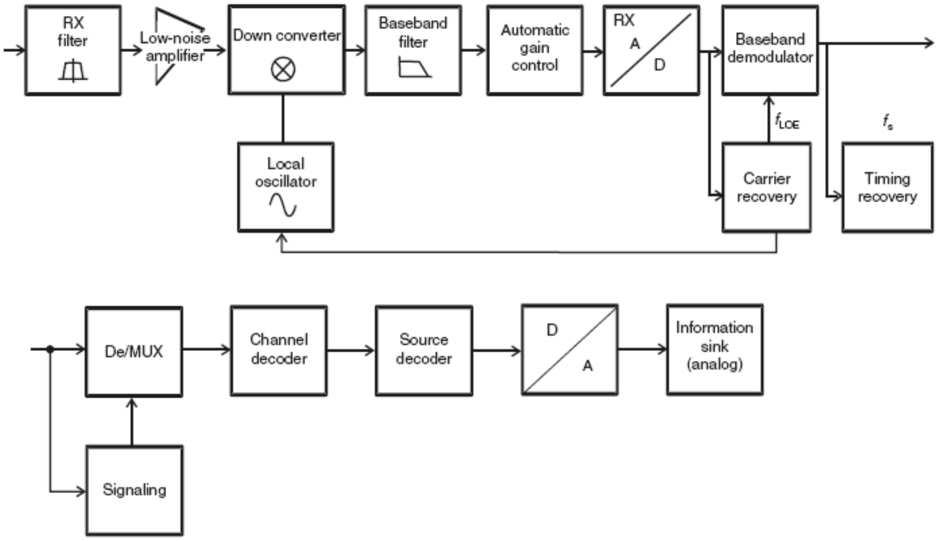
Describe the block diagram of transmitter and receiver block diagram in detail. (13) – BTL2

Transmitter: (Diagram 3 M+ Exp 4 M)



Explanation of each blocks

Receiver: (Diagram 3 M+ Exp 3 M)



Explanation of each block

Answer: Page No. 181 in Andreas F Molisch

6 **Compare QPSK, OQPSK and QPSK (13) – BTL 3 Any 6 points – 13 M**

QPSK	**OQPSK**	**pi/4 QPSK**
phase changes of +/- 90 and +/-180 degrees	phase changes of +/- 90 exist	+/-45 and +/-135
+/-180 degree transitions of the both bits change the phase at the same time.	one of the bits changes the phase at a time and occurs twice during the symbol period with half the intensity of QPSK	Phase transitions avoid zero crossing.
Null Bandwidth is 1.0 X Data rate	Same as QPSK	Same as QPSK
Bandwidth containing 90% of power is in 0.8 X Data rate	Same as QPSK	Same as QPSK
Power spectral density falls of as inverse second power of frequency	Same as QPSK	Same as QPSK
Amplitude variations are of the order of 30dB	Amplitude variation are of the order of 3 Db	-
Main lobe to side lobe suppression is poor	Same as QPSK	Same as QPSK

7 **Assume that $\Theta_0 = 0^{\Theta}$. The bit stream 0 0 1 0 1 1 is to be sent using Π/4 DQPSK. The leftmost bits are first applied to the transmitter. Determine the phase of Θ_K and the values of I_k, Q_k during transmission. (13) – BTL 4**

Formula used $I_k = \cos\theta_k$ $Q_k = \sin\theta_k$ (2)

$\theta_k = \theta_{k-1} + \phi_k$ Table (2)

Information bits $m_{I,k}, m_{Q,k}$	Phase shift ϕ_k
11	$\pi/4$
01	$3\pi/4$
00	$-3\pi/4$
10	$-\pi/4$

The first two bits are 0 0, which implies that $\phi_1 = -3\pi/4$ (3)

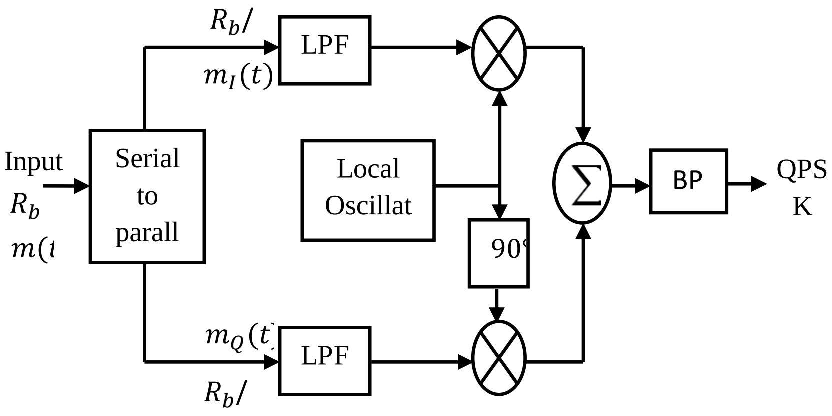
$$\theta_k = \theta_{k-1} + \phi_k$$

$$\Theta_1 = \Theta_0 + \phi_1 = -3\pi/4 \text{ (from table)}$$

	$I_k = \cos\theta_k$ $Q_k = \sin\theta_k$ $I_1 = -0.707$ $Q_1 = -0.707$ The second two bits are 10, which implies that **$\phi_2 = -\pi/4$** (3) **$\Theta_2 = \Theta_1 + \phi_2 = -3\pi/4 - \pi/4 = -\pi$** $I_2 = -1$ $Q_2 = 0$ The third two bits are 11, which implies that **$\phi_3 = \pi/4$** (3) **$\Theta_3 = \Theta_2 + \phi_3 = -\pi + \pi/4 = -3\pi/4$** $I_3 = -0.707$ $Q_3 = -0.707$ Answer: Page No. 307 in Rappaport
8	**Identify the Methods for Computation of Error Probability *(13)* – BTL 1 (Any 4 Types With Formula 13 M)** Error Probability for Coherent Receivers – General Case Error Probability for Coherent Receivers – Binary Orthogonal Signals Error Probability for Coherent Receivers – Antipodal Signaling Error Probability for Differential Detection Error Probability for Noncoherent Detection
9	**Drive the Error Probability In Flat-Fading Channels *(13)* – BTL 3** For a mathematical computation of the BER in a channel, (6) 1. Determine the BER for any arbitrary SNR. 2. Determine the probability that a certain SNR occurs in the channel. 3. Average the BER over the distribution of SNRs $\overline{BER} = \int pdf_{\gamma_B}(\gamma_B)BER(\gamma_B)\, d\gamma_B$ (7) $pdf_{\gamma_B}(\gamma_B) = \frac{1}{\bar{\gamma}_B}\exp\left(-\frac{\gamma_B}{\bar{\gamma}_B}\right)$ $\overline{BER} = \frac{1}{2+\bar{\gamma}_B} \cong \frac{1}{\bar{\gamma}_B}$
10	**Enumerate the Advantages and Disadvantages of OFDM *(13)* – BTL 2** Advantages (7) • Immunity to selective fading • Resilience to interference • Spectrum efficiency • Resilient to ISI • Resilient to narrow-band effects • Simpler channel Equalization Disadvantages (6) • High peak to average power ratio • Sensitive to carrier offset and drift
	PART * C
1.	**Discuss about QPSK transmitter and receiver with signal space diagram and give an**

expression for spatial effect (15) – BTL2

QPSK TRANSMITTER (Diagram 3 M+ Exp 3 M)

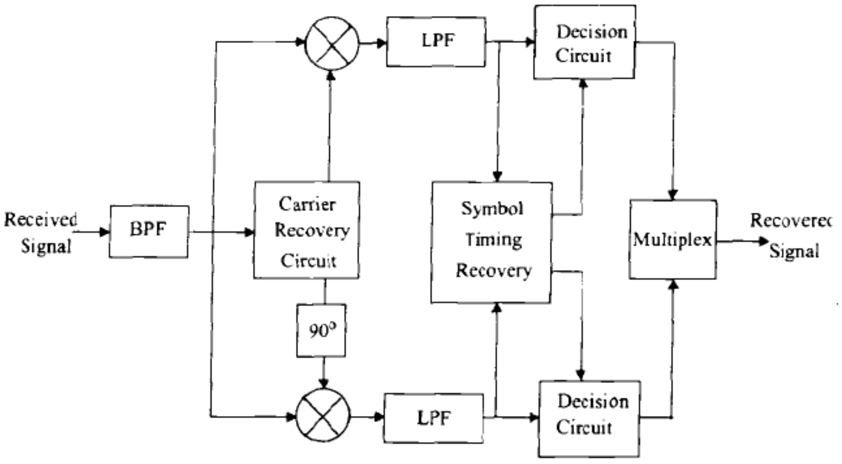


$$S_{QPSK}(t)=\sqrt{\frac{E_b}{T_b}}\left\{p1_D(t)\cos(2\pi f_c t)-p2_D(t)\sin(2\pi f_c t)\right\}$$

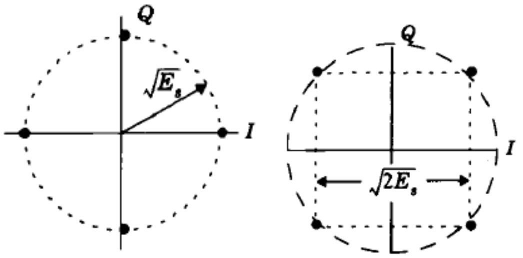
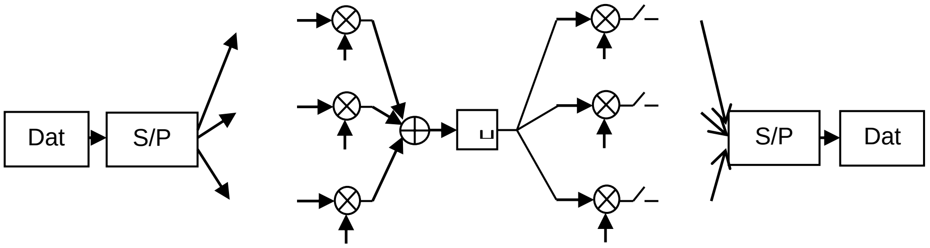
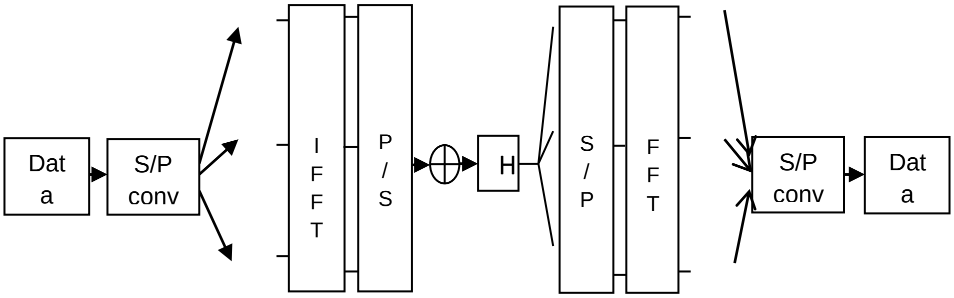
The baseband signal is

$$S_{QPSK}(t)=\sqrt{\frac{E_b}{T_b}}[p1_D(t)+jp2_D(t)]$$

QPSK RECEIVER (Diagram 3 M+ Exp 3 M)



The constellation diagram of QPSK **(3)**

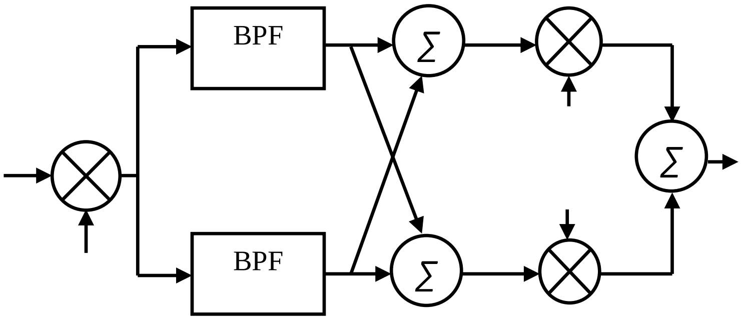
	 $P_{e,\,QPSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$ Answer: Page No. 300 in Rappaport
2	**Interpret the implementation of transceivers in OFDM (15) – BTL2** (Diagram 8 M+ Exp 7 M) The OFDM scheme differs from traditional FDM in the following interrelated ways: Multiple carriers carry the information stream, The subcarriers are orthogonal to each other, and guard interval is added to each symbol to minimize the channel delay spread and intersymbol interference **Analog implementation**  **Digital implementation**  Answer: Page No. 417 in Andreas F Molisch
3	**What is MSK , explain with transmitter and receiver diagram . Explain the various types of demodulation of MSK. (15) – BTL2** 1. Minimum shift keying (MSK) is a special type of continuous phase FSK **(4)** $\Delta f = \frac{1}{4} R_b = \frac{1}{4T_b}$ MSK is sometimes referred to as **fast FSK**

2. MSK signal, where the baseband rectangular pulses are replaced with half-sinusoidal pulses.

$$S_{MSK} = \sum_{i=0}^{N-1} m_I(t)g(t-2iT_b)\cos(2\pi f_c t) + \sum_{i=0}^{N-1} m_Q(t)g(t-2iT_b-T_b)\sin(2\pi f_c t)$$

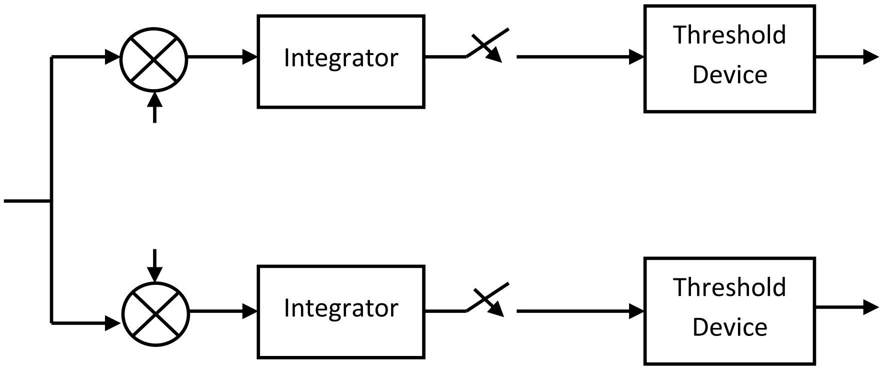
$$g(t) = \begin{Bmatrix} \sin\left(\dfrac{\pi t}{2T_b}\right) & 0 \le t \le 2T_b \\ 0 & elsewhere \end{Bmatrix}$$

MSK Modulator (Diagram 3 M+ Exp 3 M)



Demodulation of Minimum Shift Keying (3)

1. ***Frequency discriminator detection***
2. ***Differential detection:***
3. ***Matched filter reception***



Properties of MSK (2)

- constant envelope
- good spectral efficiency
- good BER performance
- self-synchronizing capability
- relatively narrow bandwidth
- coherent detection performance equivalent to that of QPSK

Answer: Page No. 314 in Rappaport

UNIT IV MULTIPATH MITIGATION TECHNIQUES

Equalisation – Adaptive equalization, Linear and Non-Linear equalization, Zero forcing and LMS Algorithms. Diversity – Micro and Macrodiversity, Diversity combining techniques, Error probability in fading channels with diversity reception, Rake receiver

PART * A

Q.No.	Questions
1.	**What are the techniques used to improve the received signal quality? - BTL1** Equalization, Diversity and Channel coding
2	**What is the need of equalization? - BTL1** Equalization is used to compensate the inter-symbol interference created by multipath within time dispersion channel.
3	**Write the functions of diversity. (Nov/Dec 13) - BTL1** 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.
4	**Define spatial diversity. - BTL1** 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.
5	**What is equalizer? (Nov/Dec 13) - BTL1** The device which equalizes the dispersive effect of a channel is referred to as an equalizer.
6	**Define adaptive equalizer. - BTL1** 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.
7	**What are the operating modes available in an adaptive equalizer? - BTL1** Training and tracking modes.
8	**What is training mode in an adaptive equalizer? - BTL1** 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.
9	**What is tracking mode in an adaptive equalizer? - BTL1** 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.
10	**Write a short note on i) linear equalizers ii) non-linear equalizers - BTL1** 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 nonlinear equalizers.
11	**Write the advantages of lattice equalizer. - BTL1** 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	**Mention the disadvantages of lattice equalizer. - BTL1** i. If the channel is not very time dispersive, only a fraction of stages are used. ii. It is more complicated than a linear transversal equalizer.
13	**Why nonlinear equalizers are preferred? - BTL1** 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? - BTL1** Decision feedback equalization (DFE), Maximum likelihood symbol detection and Maximum likelihood sequence estimation (MLSE).
15	**Where DFEs are used? - BTL1** DFE is particularly useful for channels with severe amplitude distortions and is widely used in wireless communications.
16	**What are the factors used in adaptive algorithms? - BTL1** Rate of convergence, Misadjustment, Computational complexity and numerical properties.
17	**Define rate of convergence. - BTL1** The no of iterations required for the algorithm in response to stationary inputs to converge close enough to the optimum solution.
18	**Write the basic algorithms used for adaptive equalization. - BTL1** Zero forcing algorithm (ZF), least mean square algorithm (LMS) and recursive least square algorithm (RLS).
19	**Write the advantages of LMS algorithm. - BTL1** It maximizes the signal to distortion at its output within the constraints of the equalizer filter length, Low computational complexity and Simple program
20	**Write the advantages of RLS algorithm. - BTL1** Fast convergence, Good tracking ability
21	**Explain Diversity concept. - BTL1** 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.
22	**List out the types of Diversity. - BTL1** Space diversity, Polarization diversity, Time diversity, Frequency diversity
23	**What is the need for diversity schemes? - BTL1** To increase signal to noise ratio, for error free digital transmission, to degrade the bit error probability.
24	**What are the two main classifications of diversity techniques? - BTL1** Microscopic diversity and Macroscopic diversity
25	**List out the four types of Combining Methods. - BTL1** Selection combining, switched combining, Equal gain combining, Maximum ratio combining
26	**Define Hamming distance. (May/June 2013) - BTL1** The Hamming distance between two strings of equal length is the number of positions at which the corresponding symbols are different. In another way, it measures the minimum number of substitutions required to change one string into the other, or the minimum number of errors that could have transformed one string into the other

27 **State the principle of diversity.(May/June 2013) - BTL1**

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.

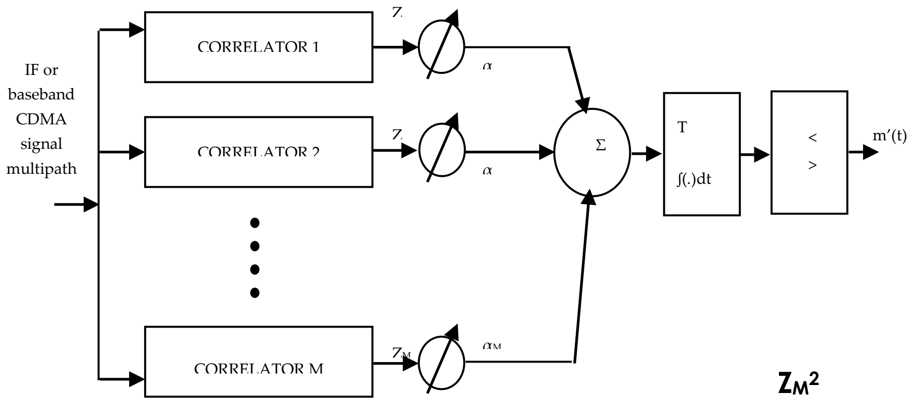
28 **Differentiate between Macrodiversity and Microdiversity. (Nov/Dec 2014) – BTL3**

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

PART * B

1\. **Illustrate the concepts of Rake receiver (13) – BTL3 (Dia – 5 M + Exp – 8 M)**

A RAKE receiver utilizes multiple correlators to separately detect the M strongest multipath components. The outputs of each correlators are then weighted to provide a better estimate of the transmitted signal than is provided by a single component. Demodulation and bit decisions are then based on the weighted outputs of the M correlators.



$$a_M = \frac{Z_M^2}{\sum_{m=1}^{M} Z_M^2}$$

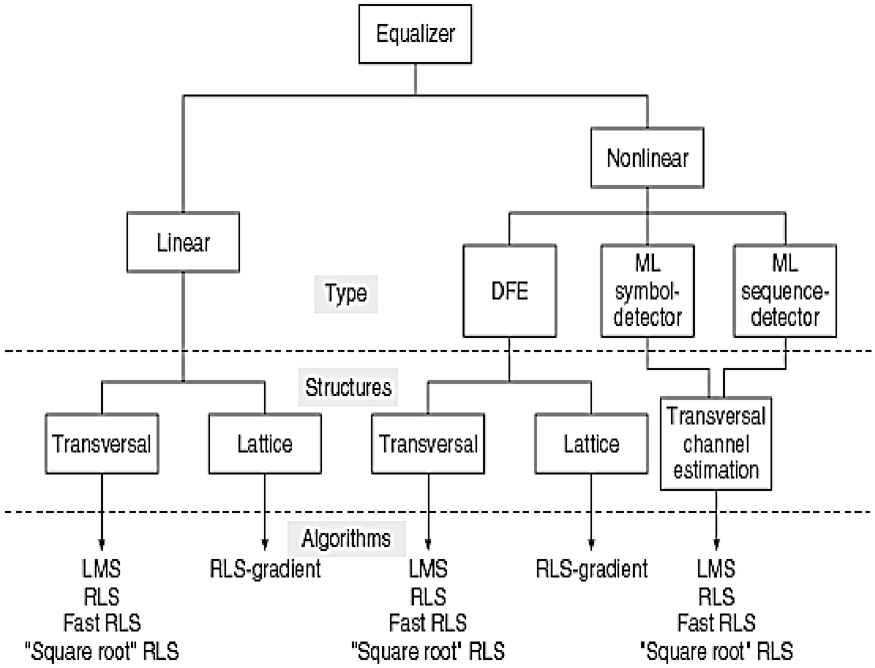
$$Z' = \sum_{m=1}^{M} a_M Z_M$$

The basic idea of a RAKE receiver was first proposed by Price and Green.

Answer: Page No. 391 in Rappaport

2

Describe the Algorithms used for the Adaptive Equalization (13) – BTL2



(Types -10 + Difference 3 M)

LMS Algorithm	RLS Algorithm
The LMS algorithm usually converges too slowly.	The RLS algorithm converges faster, but has a larger residual error.
The LMS algorithm requires fewer (complex) operations than RLS algorithm.	The RLS algorithm requires more (complex) operations than LMS algorithm.

Answer: Page No. 372 in Rappaport

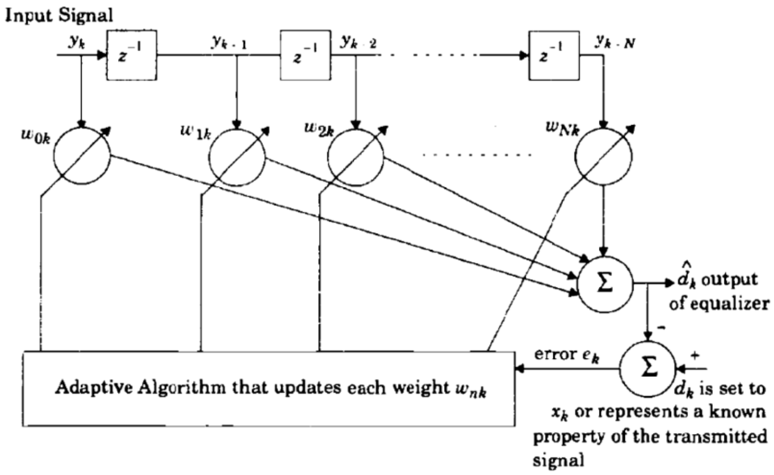
3

Derive the mean square error for a generic adaptive equalizer. (13) – BTL3

(Dia – 5 M + Exp – 8 M)

A Generic Adaptive Equalizer

An adaptive equalizer is a time-varying filter which must constantly be retuned.



The adaptive equalizer structure shown above is called a transversal filter.

New weights = Previous weights + (constant) x (Previous error) x (Current input vector)
Previous error = Previous desired output — Previous actual output

A more recent class of adaptive algorithms are able to exploit characteristics of the transmitted signal and do not require training sequences.

These modern algorithms blind algorithms, constant modulus algorithm (CMA) and the spectral coherence restoral algorithm (SCORE)

$$e_k = d_k - \overline{d_k} = x_k - \overline{d_k}$$

Answer: Page No. 359 in Rappaport

4

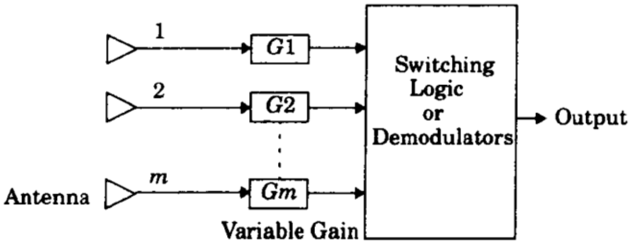
Illustrate the classification of Space/ Spatial Diversity Techniques (13) – BTL3

(4 Types – 1M + Each Type – 3M)

Space diversity reception method can be classified into four categories.

- Selection diversity
- Feedback Diversity
- Maximal Ratio Combining
- Equal Gain Diversity

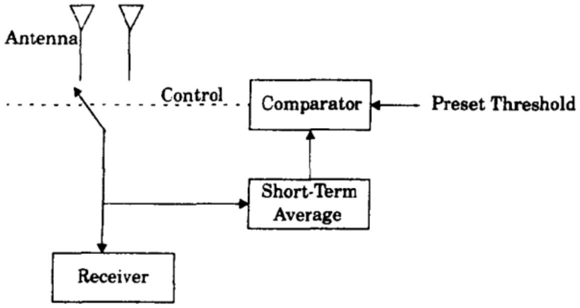
Selection diversity:



The receiver branch having the highest instantaneous SNR is connected to the demodulator.

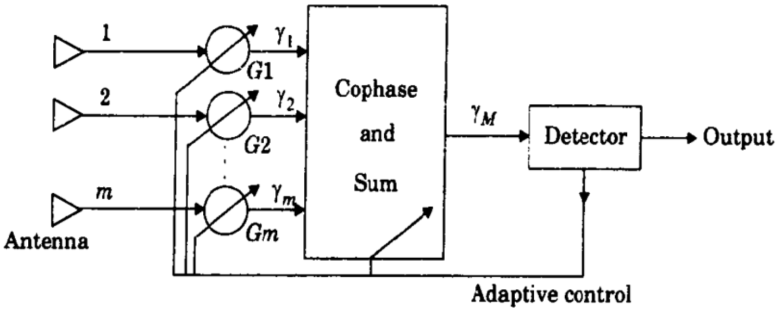
Feedback Diversity or scanning diversity

The M signals are scanned in a fixed sequence until one is found to be a above predetermined threshold.



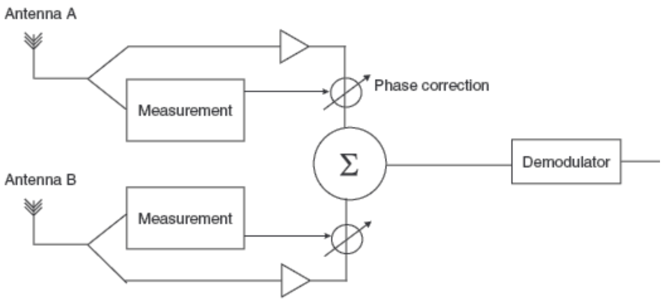
Maximal Ratio Combining

The M branches are weighted according to their individual signal voltage to noise power ratios and summed.



Equal Gain combining:

In certain cases it is not convenient to provide for the variable weighting capability required for true maximal ratio combining. In such cases, the branch weights are all set to unity, but the signals from each branch are co phased to provide the equal gain combining diversity.



Answer: Page No. 385 in Rappaport

5

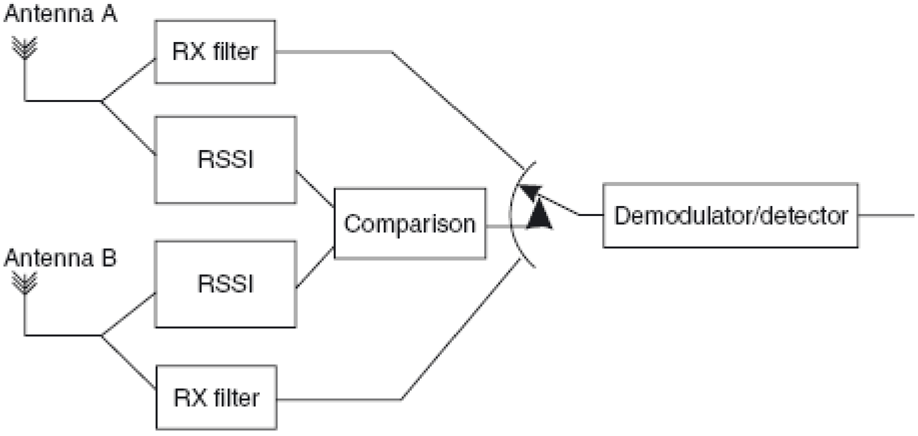
Explain the selection diversity and its types *(13)* – **BTL2**

(2 Types – 1M + Each Type – 6M)

In selection diversity the best signal copy is selected and processed, while all other copies are discarded.

Received-Signal-Strength-Indication-Driven Diversity

In this method, the RX selects the signal with the largest instantaneous power, and processes it further.

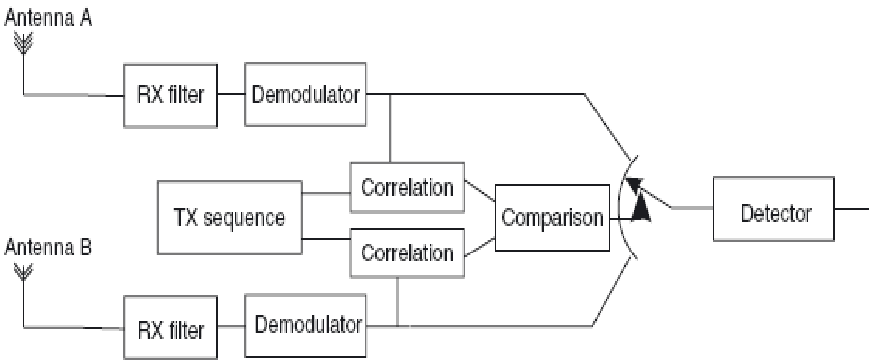


$$pdf_{\gamma_n}(\gamma_n) = \frac{1}{\bar{\gamma}} \exp\left(-\frac{\gamma_n}{\bar{\gamma}}\right)$$

$$cdf_{\gamma_n}(\gamma_n) = 1 - \exp\left(-\frac{\gamma_n}{\bar{\gamma}}\right)$$

Bit-Error-Rate-Driven Diversity

The antenna whose signal results in the smallest BER is judged to be the best, and used for the reception of data signals.



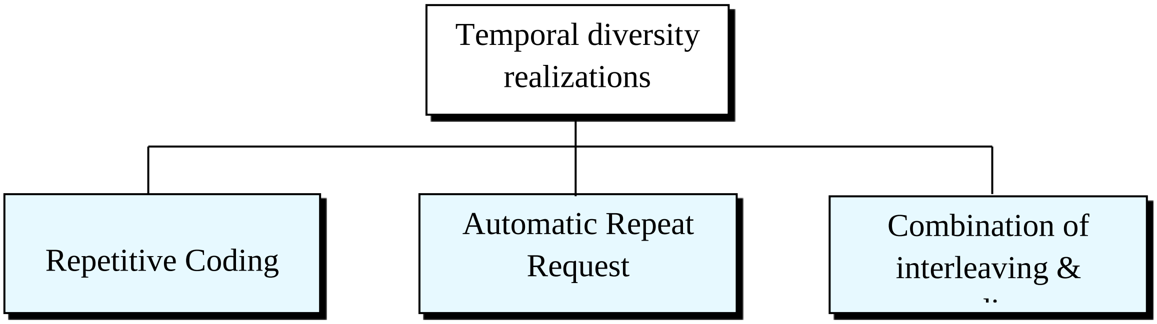
Drawbacks:

1. The RX needs either *N*r RF chains and demodulators
2. If the RX has only one demodulator, then it is not possible to continuously monitor the selection criterion of all diversity branches.
3. Since the duration of the training sequence is finite, the selection criterion

Answer: Page No. 259 in Andreas F Molisch

6

Classify the time diversity in detail (13) – BTL 2 3 TYPES – 12 M + LIST 1 M



Signal is repeated several times

Rx sends a message to TX to indicate whether it received the data with sufficient quality

Different symbols of a codeword are transmitted at different times

PART * C

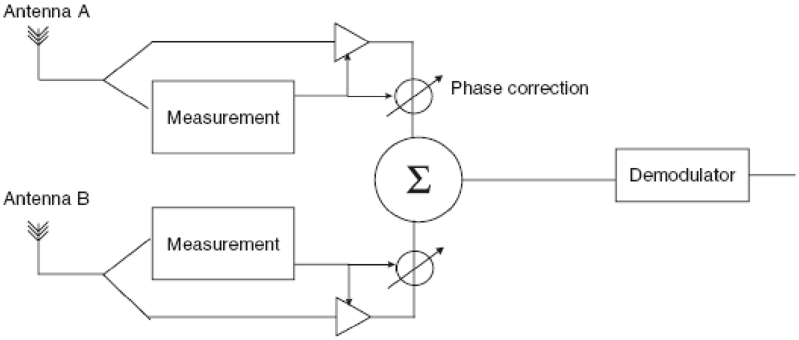
1.

Write combining techniques using combination of signal (15)

- **a. Maximum ratio combining (4)**
- **b. Equal gain combining (4)**
- **c. optimum combining(4)**
- **d. Hybrid selection -maximum ratio combining – BTL2 (3)**

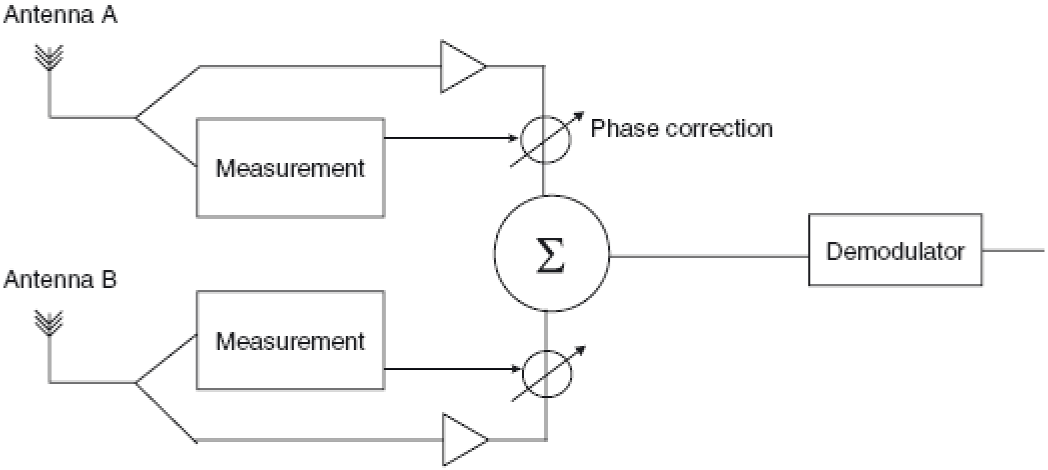
Maximum ratio combining

MRC compensates for the phases, and weights the signals from the different antenna branches according to their SNR.



Equal Gain Combining

In Equal Gain Combining, all amplitude weights are the same (in other words, there is no weighting, but just a phase correction



Optimum Combining

In order to maximize the Signal-to-Interference-and-Noise Ratio (SINR), the weights should then be determined according to a strategy called **optimum combining.**

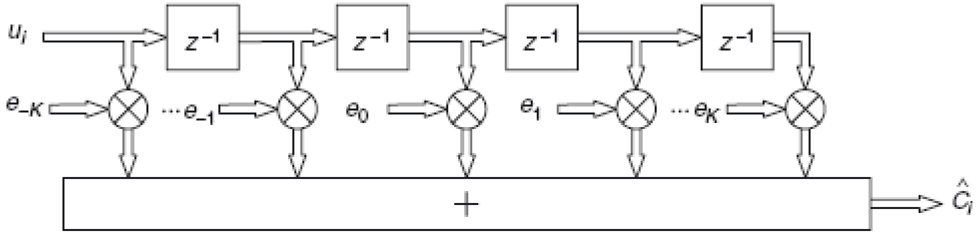
Hybrid Selection – Maximum Ratio Combining

In hybrid selection scheme, the best *L* out of *N*r antenna signals are chosen, downconverted, and processed. This reduces the number of required RF chains from N_r to *L*, and thus leads to significant savings.

Answer: Page No. 259-263 in Andreas F Molisch

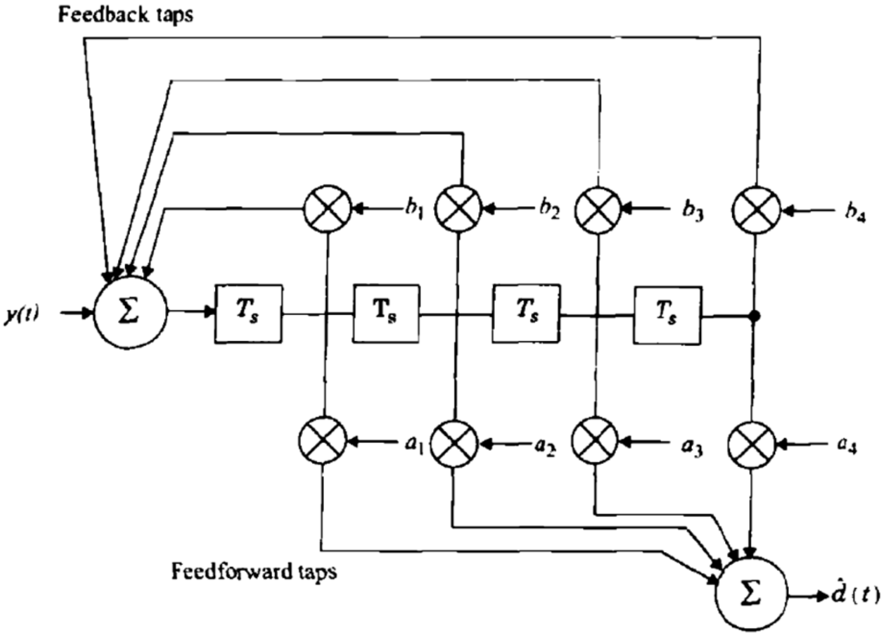
2 **Derive for the mean square error for linear equalizer during training adaptive equalizer (15) – BTL3 (Diagram – 8 M + Explanation – 7 M)**

Linear equalizers are simple linear filter structures. Linear equalizers try to invert the channel in the sense that the product of the transfer functions of channel and equalizer fulfills a certain criterion.



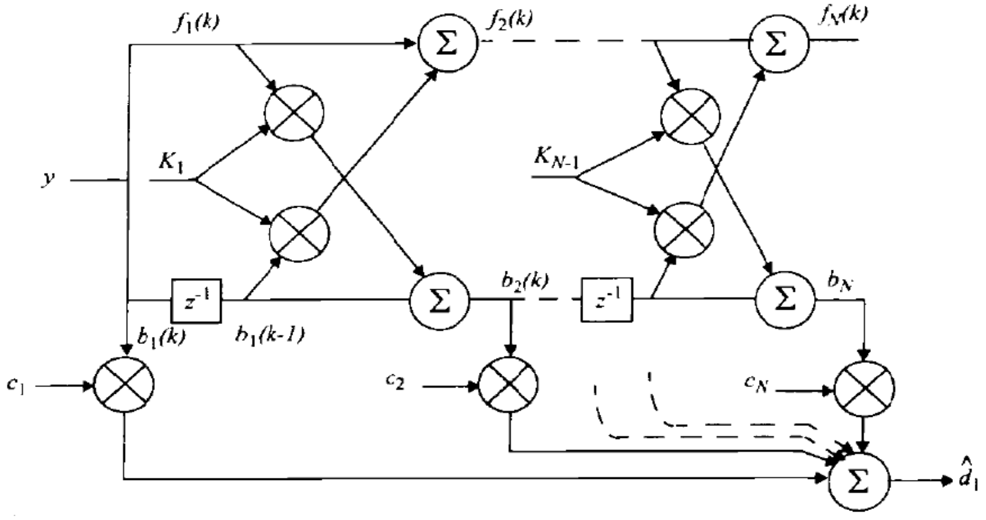
Minimum Mean Square Error (MMSE) equalizer.

Transversal Linear Equalizer



Lattice Equalizer

Two main advantages of the lattice equalizer is its numerical stability and faster convergence.

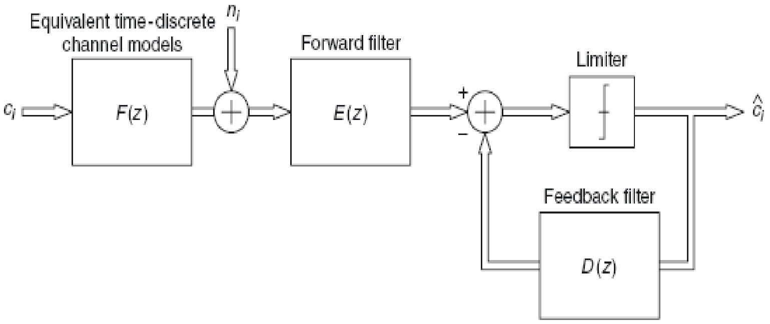


Answer: Page No. 359 in Rappaport

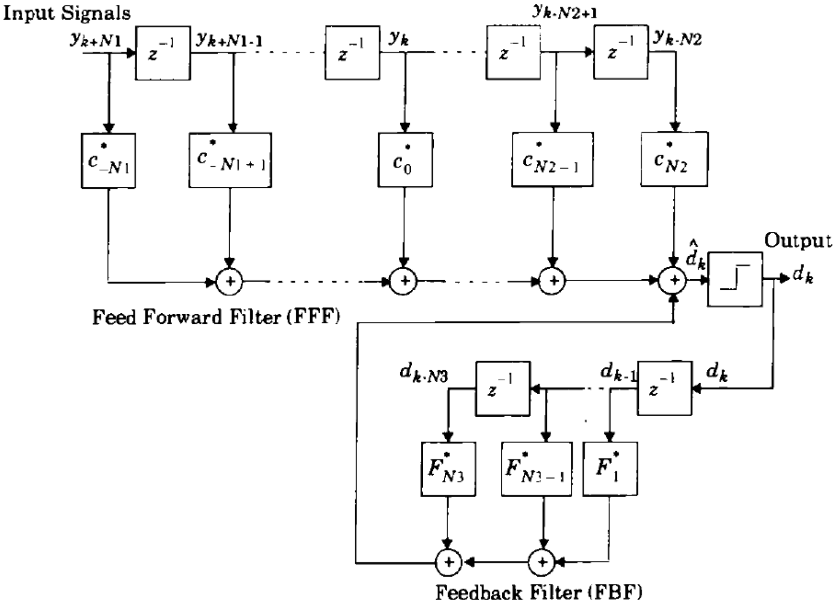
3

Explain the working principle of nonlinear equalizer based on decision feedback equalizer (15) – BTL2 (Diagram – 8 M + Explanation – 7 M)

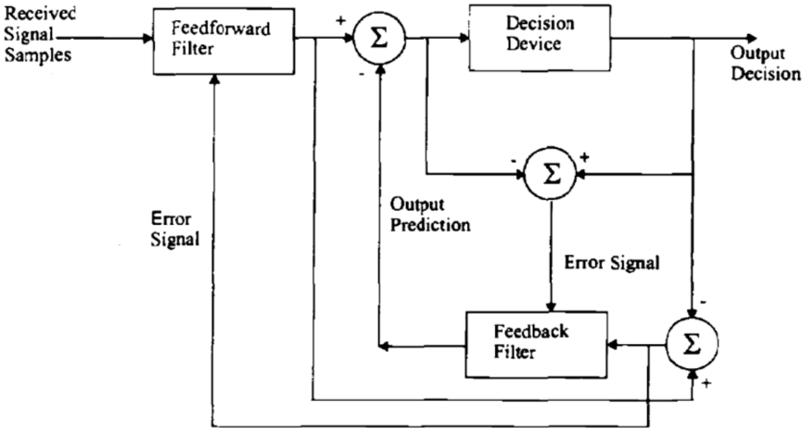
In decision feedback equalization, once a bit is correctly detected, the effect this bit on subsequent bit is determined. The ISI caused by each bit is then subtracted from these later samples.



It consists of a feedforward filter (FFF) and a feedback filter (FBF).



Another form of DFE proposed by Belfiore and Park is called a predictive It consists of a feed forward filter (FFF) as in the conventional DFE.



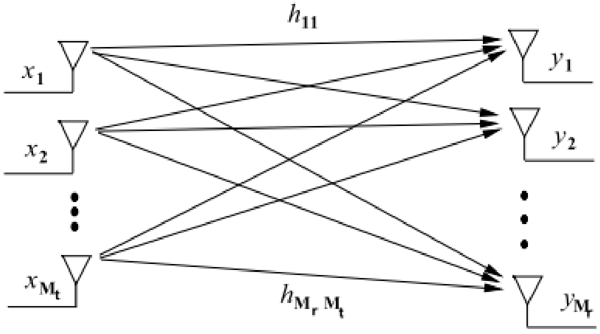
Answer: Page No. 369 in Rappaport

UNIT V - MULTIPLE ANTENNA TECHNIQUES

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

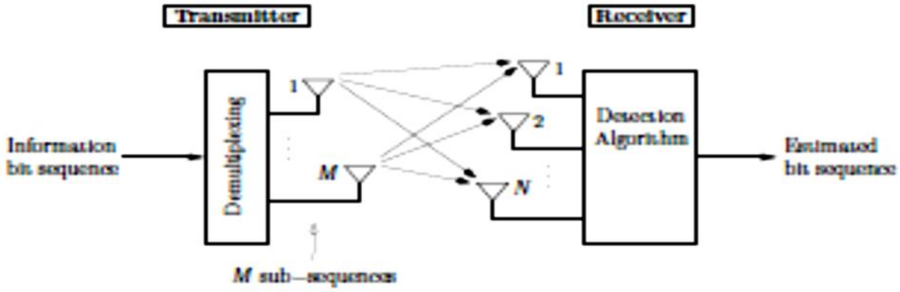
PART * A

Q.No.	Questions
1.	**What is Beamforming? - BTL1** 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? - BTL1** Beamforming provides diversity and array gain via coherent combining of the multiple signal paths.
3	**What is multiplexing gain? - BTL1** Multiple antennas are 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. - BTL1** 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? - BTL1** 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. - BTL1** 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. - BTL1** 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? - BTL1** 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. – BTL3**  Mt transmit antenna and Mr receive antennas.
10	**Write the advantages of MIMO systems. - BTL1** 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. - BTL1** 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**. **- BTL1** 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? – BTL2** 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. - BTL1** 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? - BTL1** 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 able 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? - BTL1** 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? - BTL1** 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? - BTL1** 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? - BTL1** 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 transmit antennas and N receive antennas, the increase in the data rate is min (M, N)-fold
20	**What is meant by co-phasing? - BTL1** “Co-phase the signals” means that we need to multiply signals by ejϕi for some constant phase angle ϕi 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	**What is Selection Combining? - BTL1** Selection combining assumes we know all signal amplitudes so that we can take the maximum.Scanning combining is a simplification which says that we only have one receiver, so we can only know the signal to noise ratio on one channel at a time. But we can switch between them when one channel’s SNR drops too low. We can often achieve nearly the same results using a scanning combiner as with selection combining.
22	**What is maximal ratio combining? - BTL1** For maximal ratio combining, we still co-phase the signals. But then, we weight the signals according to their SNR. The intuition is that some channels are more reliable than others, so we should “listen” to their signal more than others. The outage probability improves compared to equal gain combining.
23	**Describe threshold combining. - BTL1** 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. Hence this technique can be used with either coherent or differential modulation.

24	**What is equal-gain combining? - BTL1** Here, we simply co-phase the signals and then add them together.The outage probability improves compared to selection combining.
25	**Define channel capacity of MIMO system. - BTL1** 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.
26	**What is Precoding. - BTL1** 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
27	**What is Alamouti's scheme? - BTL1** 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 S1 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.
	PART * B
1.	**i) Discuss about the operation of spatial multiplexing systems. (6)** **ii) Using diagrams explain transmit diversity and receive diversity.(7) – BTL2 (13)** **Spatial Multiplexing** defines the system is able to carry more than one data stream over one frequency, simultaneously. At the **transmitter**, the data sequence is split into M sub-sequences that are transmitted simultaneously using the same frequency band At the **receiver**, the sub-sequences are separated by means of **interference cancellation** algorithm used



Spatial Diversity Techniques

- Signal copies are transferred from multiple antennas or received at more than one antenna
- redundancy is provided by employing an array of antennas, with a minimum separation of λ/2 between neighbouring antennas

Receive diversity:

In receiver diversity, one transmitting antenna and many receiving antennas are used. It is also called space diversity.

Types of Space Diversity:

1. Selection Diversity
2. Feedback Diversity
3. Maximal Ratio Combining
4. Equal Gain Diversity

Transmit diversity:

In transmitter diversity, multiple antenna elements are required at the transmitter and one antenna element at the receiver end and provide better performance. The transmit power is divided among these antennas.

Types of Transmitter Diversity:

1. Transmitter Diversity with Channel state Information
2. Transmitter Diversity without Channel state information

Delay Diversity

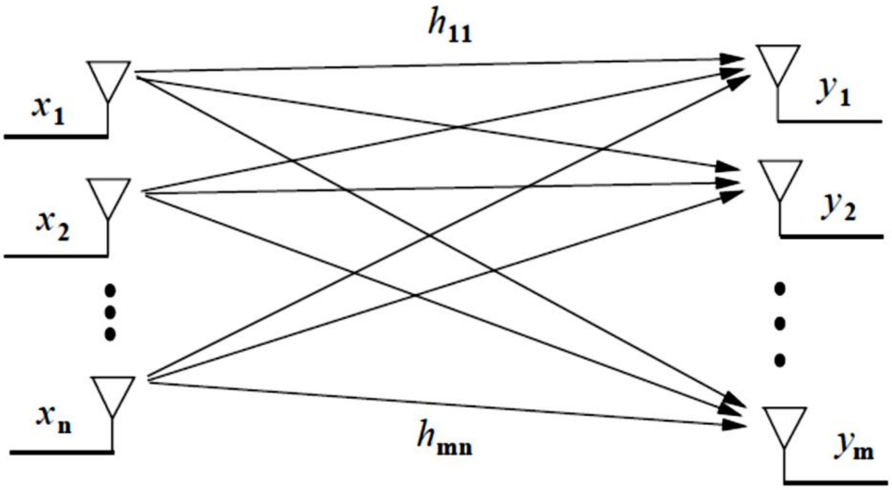
The transmit data streams with the delay of one symbol duration from each of the transmit antennas.

Answer: Page No. 480 in Andreas F Molisch

2

Describe the MIMO system model with necessary diagrams in detail (13) – BTL2

(Diagram – 5 M + Explanation – 8 M)



This system can be represented by the following discrete time model:

$$\begin{bmatrix} y_1 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} h_{11} & \cdots & h_{1n} \\ \vdots & \ddots & \vdots \\ h_{m1} & \cdots & h_{mn} \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} N_1 \\ \vdots \\ N_m \end{bmatrix}$$

or simply as $y = Hx + N$.

Important parameters in MIMO system:

CSIT – Channel Side Information at the Transmitter
CSIR – Channel Side Information at the Receiver

For Static Channel

- CSIR is assumed
- Pilot sequence used for channel Estimation

If feedback path is available:

- CSIR sends feedback to CSIT

If CSIT may be available in Bidirectional system without feedback

- When reciprocal properties
- Propagation are exploited

If channel not known to Transmitter and Receiver

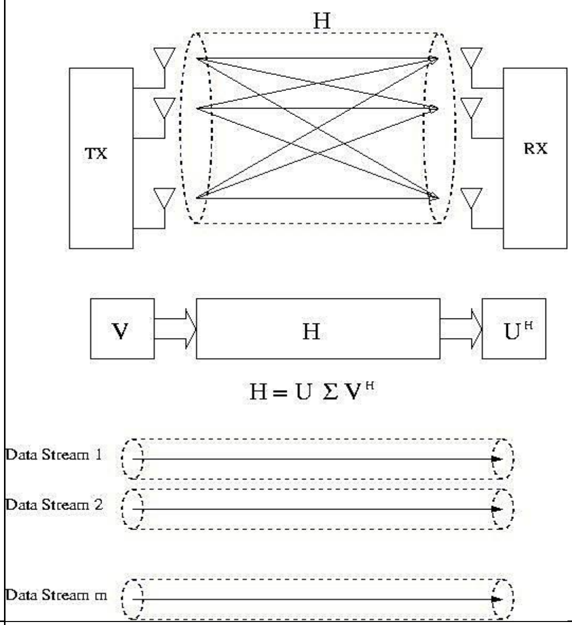
Some distribution on the channel matrix gain must be assumed.
Common Model: Zero Mean Spatially White Model (ZMSW)

Answer: Page No. 466 in Andreas F Molisch

3 **Illustrate the parallel decomposition of the MIMO model (13) – BTL3**

(Diagram – 6 M + Explanation – 7 M)

The increased data rate is called the **Multiplexing Gain.**



singular value decomposition (SVD)

$$\boldsymbol{H = U \in V^H}$$

Properties of Singular Values

$$\boldsymbol{\sigma_i = \sqrt{\lambda_i}}$$

Rank of Matrix (R_H)

$$R_H \leq \min(M_t, M_r)$$

The parallel decomposition of the channel is obtained by transformation on the channel input and output x and y via transmit precoding and receiver reshaping.

Answer: Page No. 466 in Andreas F Molisch

4 **What are smart antennas? Why are they required for and what are the different approaches for capacity gains? (13) – BTL2**

In actual, antennas are not Smart Antenna, systems are smart. **(4)**
Limited by two major impairments multipath and co-channel interference.

TYPES OF SMART ANTENNA SYSTEMS (4)

Direction-of-Arrival (DOA)
Switched Beam Antennas
Adaptive Array Antennas

Benefits of Smart Antennas: (5)

(a) Reduction in Co-Channel Interference
(b) Range Improvement
(c) Increase in Capacity
(d) Reduction in Transmitted Power
(e) Reduction in Handoff

Answer: Page No. 445 in Andreas F Molisch

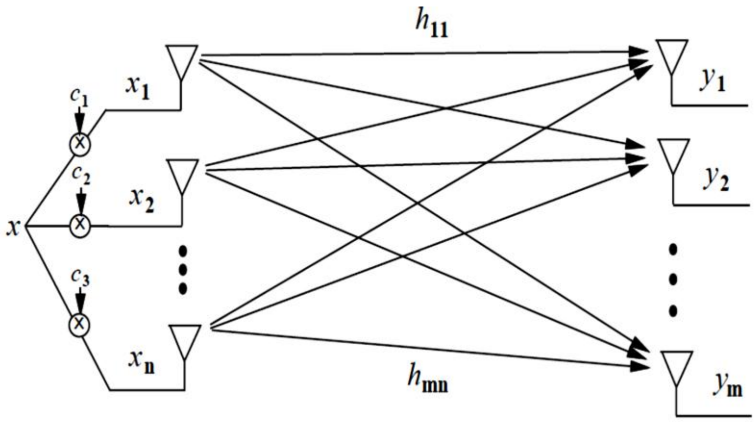
5 **Why beamforming is important for wireless systems, With illustration explain transmit beamforming, receive beamforming and opportunistic beamforming. (13) – BTL2**

(Diagram – 6 M + Explanation – 7 M)

A transmit strategy where the input covariance matrix has unit rank is called ***beamforming.***

Aligning the transmit signal in the direction of the transmit antenna array pattern is called

transmit beamforming. It takes advantages of an interference to change the directionality of the antenna.



$$||u|| = ||v|| = 1$$

$$C = B\ \log_2(1 + \sigma_{max}{}^2 \rho\ )$$

If H not known to Transmitter
Alamouti scheme used
Advantages of Beamforming Antenna:
Increase SNR and support higher user densities.
Answer: Page No. 484 in Andreas F Molisch

PART * C

1. **Derive the capacity of a Non fading channel for information transmitted from a wireless system. (15)– BTL3 (3 Types – 5 M)**

Shannon capacity of a MIMO channel, which equals the maximum data rate that can be transmitted over the channel will arbitrary small error probability.

STATIC CHANNEL

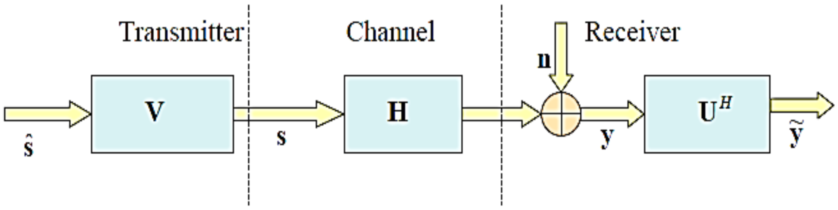
Condition: Channel unknown at transmitter

$$\mathbf{C = B\ \log_2(1 + \gamma)}$$

$$I(X\!:\!Y) = H(Y) - H\left(\frac{Y}{X}\right)$$

Zero Mean Circularly Symmetric Complex Gaussian (ZMCSCG)

$$\mathrm{C} = \frac{max}{p(x)}\ B\ \log_2 \det[I_{mr} + HR_xH^H]$$



CHANNEL KNOWN AT TRANSMITTER – WATTER FILLING METHOD

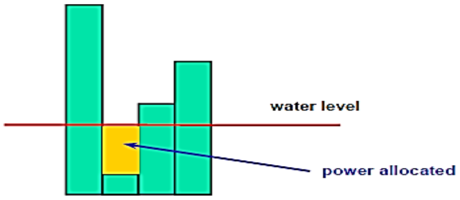
Condition: Channel (H) known to the both transmitter and receiver

$$C = \max_{\rho_i : \varepsilon_i \rho_i \le \rho} \sum_{i=1}^{R_H} B \ \log_2 \det[1 + {\sigma_i}^2 p_i]$$

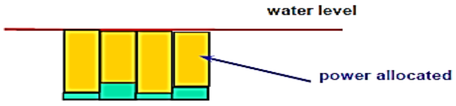
The capacity formula is similar to **flat fading & frequency selective fading**

Optimally allocating the power to several parallel channels is difficult because each has different SNR. This issue can be overcome by using **Water Filling Method.**

$$\frac{p_i}{p} = \begin{cases} \frac{1}{\gamma_0} - \frac{1}{\gamma_i} & \gamma_i \ \ge \ \gamma_0 \\ 0 & \gamma_i \ < \ \gamma_0 \end{cases}$$



Case I: Low SNR



Case II: High SNR

CHANNEL UNKNOWN AT TRANSMITTER UNIFORM POWER ALLOCATION

Condition:

- Receiver knows H
- Transmitter does not knows H

$$I(X\colon Y) = \ B \ \log_2 \det\left[IM_t + H\frac{\rho}{M_t}H^H\right]$$

$$I(X\colon Y) = \sum_{i=1}^{R_H} B \ \log_2\left(1 + \frac{\gamma_i}{M_t}\right)$$

Transmitter don't know what rate it want to transmit to reach receiver. This is called as **channel outage.**

$$R_H = M = Min\ (M_t, M_r)$$

Types:
Ergodic - expected value of the capacity taken over all realization of the channel.
Outage Capacity is minimum transmission rate that is achieved over a certain fraction of time.

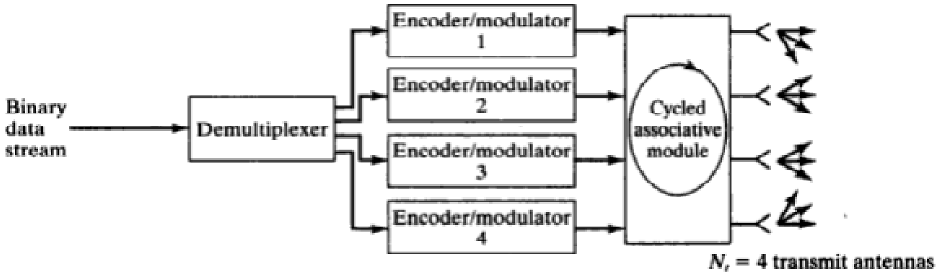
Answer: Page No. 467 in Andreas F Molisch

2 **Demonstrate the BLAST architectures used in MIMO systems (15) – BTL3**

(Types – 1 m + 2 Types – 7 M)

Three specific implementations of BLAST, depending on the type of coding employed:
1. Diagonal-BLAST (D-BLAST)
2. Vertical-BLAST (V-BLAST)

D-BLAST

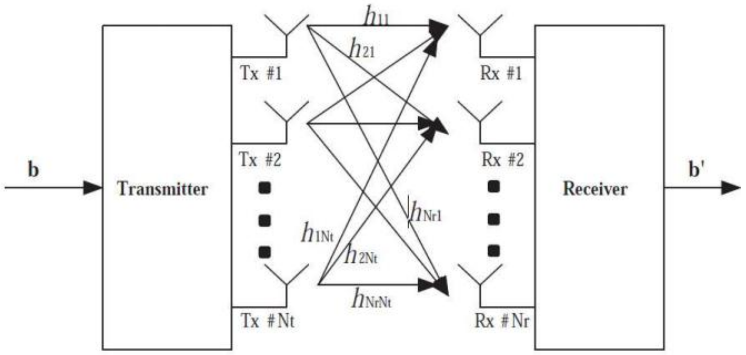


V-BLAST

V-BLAST architecture is a simplified version of D-BLAST

All the symbols of a certain stream are transmitted through the same antenna

A single data stream is demultiplexed into M sub streams.



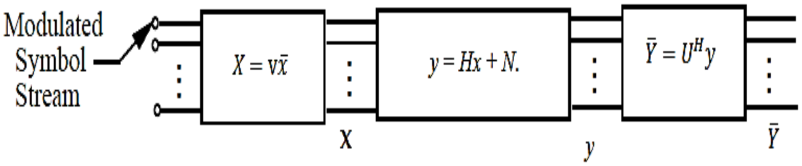
Answer: Page No. 479 in Andreas F Molisch

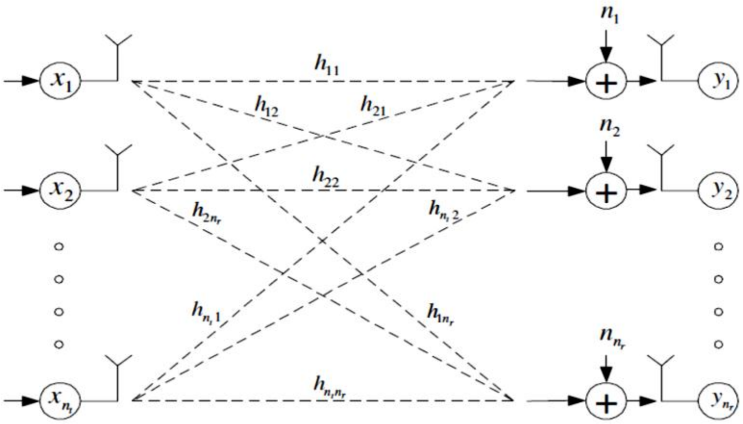
3 **Explain the operation of transmit precoding and receiver precoding schemes? (15) – BTL2**

(Diagram – 7 m + Exp – 8 M)

In transmit precoding the input x to the antennas is generated by linear transformation on input vector $\bar{x}$ $X = \mathrm{v}\bar{x}$

This operation is sometimes called transmit precoding. $\bar{Y} = U^{H} y$





$$\bar{Y} = \in \bar{x} + \boldsymbol{U^{H}} n$$

Answer: Page No. 490 in Andreas F Molisch