Cellular Concept - System design fundamentals

Introduction - Frequency Reuse - Channel Assignment Strategies - Hand off strategies : prioritizing Hand offs, Practical Handoff Considerations. Interference and System capacity : Co-channel Interference and system Capacity - Channel Planning for wireless systems. Adjacent Channel Interference, Power Control for Reducing Interference, Trunking and Grade of service. Improving Coverage and capacity in cellular systems : cell splitting, sectoring.

Introduction :-

* Cellular System Solves the problem of Spectral Congestion.
* Offers high Capacity in limited Spectrum.
* High Capacity is achieved by limiting the coverage area of each BS to a small geographical area called cell.
* Replace high powered transmitter with several low power transmitters.
* Each BS is allocated a portion of total channels and nearby cells are allocated completely different channels.
* All available channels are allocated to small no. of neighbouring BS.

* Interference between neighboring BS's is minimized by allocating different channels.

* Same frequencies are reused by spatially separated BS's

* Interference between co-channels stations is kept below acceptable level.

* Additional radio capacity is achieved.

* Frequency Reuse - Fix no. of channels serve an arbitrarily large no. of subscribers.

<u>Frequency Reuse:</u>

* Each cellular base station is allocated a group of radio channels to be used within a small geographic area called cell.

* The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called freq. reuse (or) freq. planning.

* The actual radio coverage of a cell is known as the foot print and is determined from field measurements of propagation prediction models.

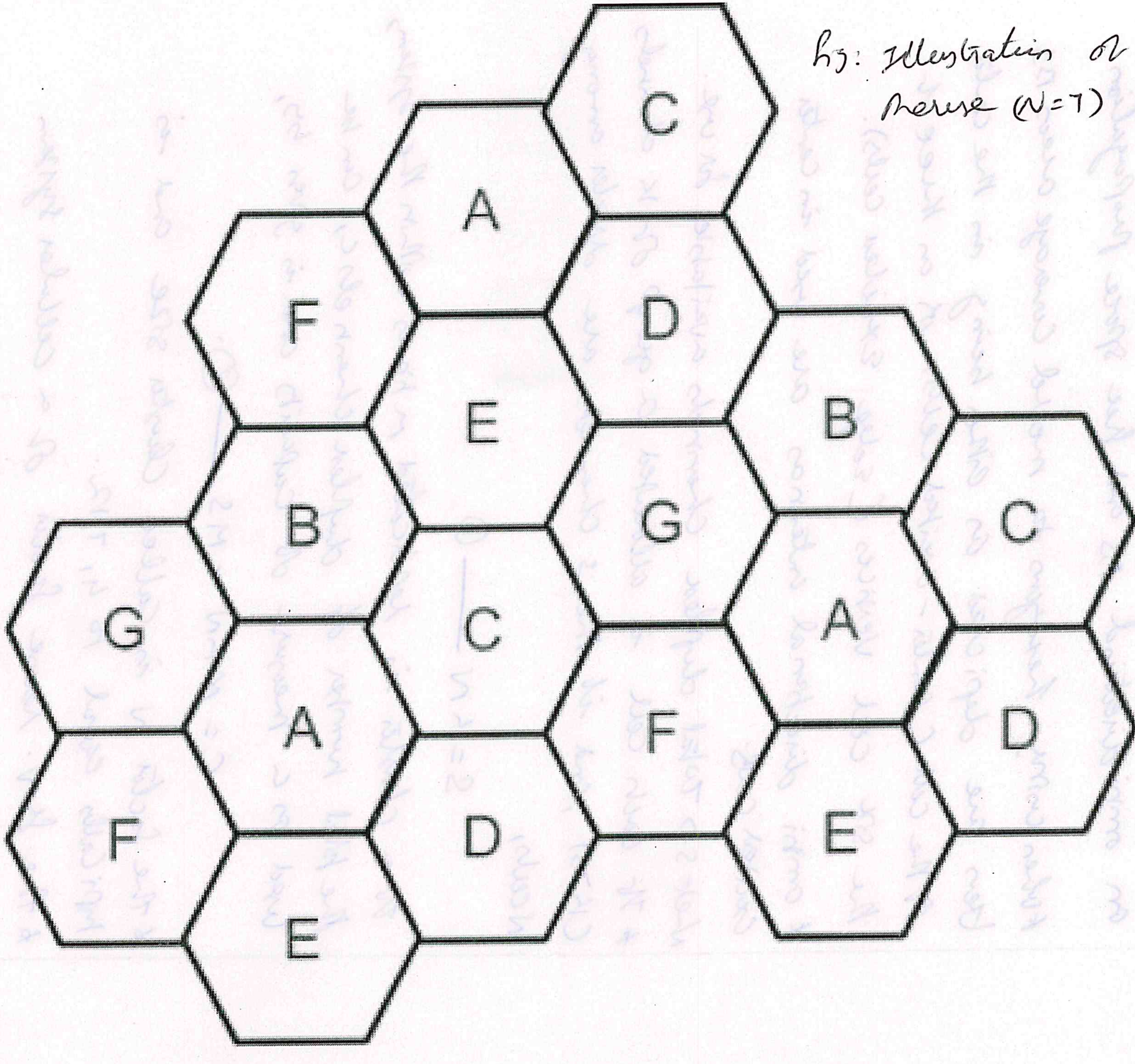


Fig: Illustration of frequency reuse (N=7)

* The fewer no. of cells can cover a geographic region and the hexagon closely approximates a circular radiation pattern would occur for an omni directional BS and free space propagation.

* When using hexagons to model coverage areas BS tiers are depicted as either being in the center of the cell (center-excited cells) or on three of the six cell vertices (Edge excited cells).

* omni directional antennas are used in center excited cells.

Let S -> Total duplex channels available for use.

* If each cell is allocated a group of K channels (K>S), and if the S channels are divided among N cells,

$$S = KN \text{ ——— } ①$$

If a cluster is replicated M times within the system, the total number of duplex channels C, can be used as a measure of capacity and is given by,

$$C = MKN = MS \text{ ——— } ②$$

* The factor N is called cluster size and is typically equal to 4, 7, 12.

* The freq. reuse factor of a cellular system is given by 1/N.

* The number of cells per cluster, N can only have values which satisfy the equation,

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

where i and j are non-negative integers.

To find the nearest co-channel neighbours of a particular cell.

① Move i cells along any chain of hexagons.

② Turn 60 degrees counter clockwise and move j cells.

Channel Assignment :-

For efficient utilization of the radio spectrum a frequency scheme that is consistent with the objectives of increasing capacity and min. interference is required.

Channel Assignment.
- Fixed channel Assignment.
- Dynamic channel Assignment.

* The choice of channel assignment strategy impacts the performance of the system.
* Particularly as to how calls are managed when a mobile user is hand off from one cell to another.

Fixed channel Assignment:-

* Each cell is allocated a predetermined set of voice channels.

* Borrowing strategy — a cell is allowed to borrow channels from a neighboring cell if all of its own channels are already occupied.
* The mobile switching center (MSC) supervises borrowing procedures.

Dynamic Channel Assignment:-

* Voice channels are not allocated to different cells permanently.
* Each time a call request is made, the serving BS requests a channel from the MSC.
* Dynamic channel assignment reduce the likelihood of blocking, which increases the trunking capacity of the system.
* Dynamic channel assignment strategies require the MSC to collect real time-data on channel occupancy, traffic distribution and radio signal strength indications (RSSI) of all channels on a continuous basis.

Hand off Strategies:-

* When a mobiles moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new basestation". This is called handoff.
* This handoff operation not only involves identifying a new BS, but also requires that the voice and control signal.

System designers must specify an optimum signal level at which to initiate a handoff.

Threshold level, $\Delta = P_{r\,handoff} - P_{r\,min.\,usable}$

* If Δ is too large, unnecessary handoffs which burden the MSC may occur.
* If Δ is too small there may be insufficient time to complete a handoff before a call is lost due to weak signal conditions.
* The length of time needed to decide if a handoff is necessary depends on the speed at which the vehicle is moving.

Dwell Time:-

The time over which a call may be maintained within a cell, without handoff is called the dwell time.

The factors that influence Dwell time are

1. Propagation
2. Interference
3. Distance.

MAHO:-

In second generation system, hand off are mobile assisted. In mobile Assisted handoff (MAHO) every mobile station measures the received power from surrounding BS and continually reports the results of these measurement to the serving base station.

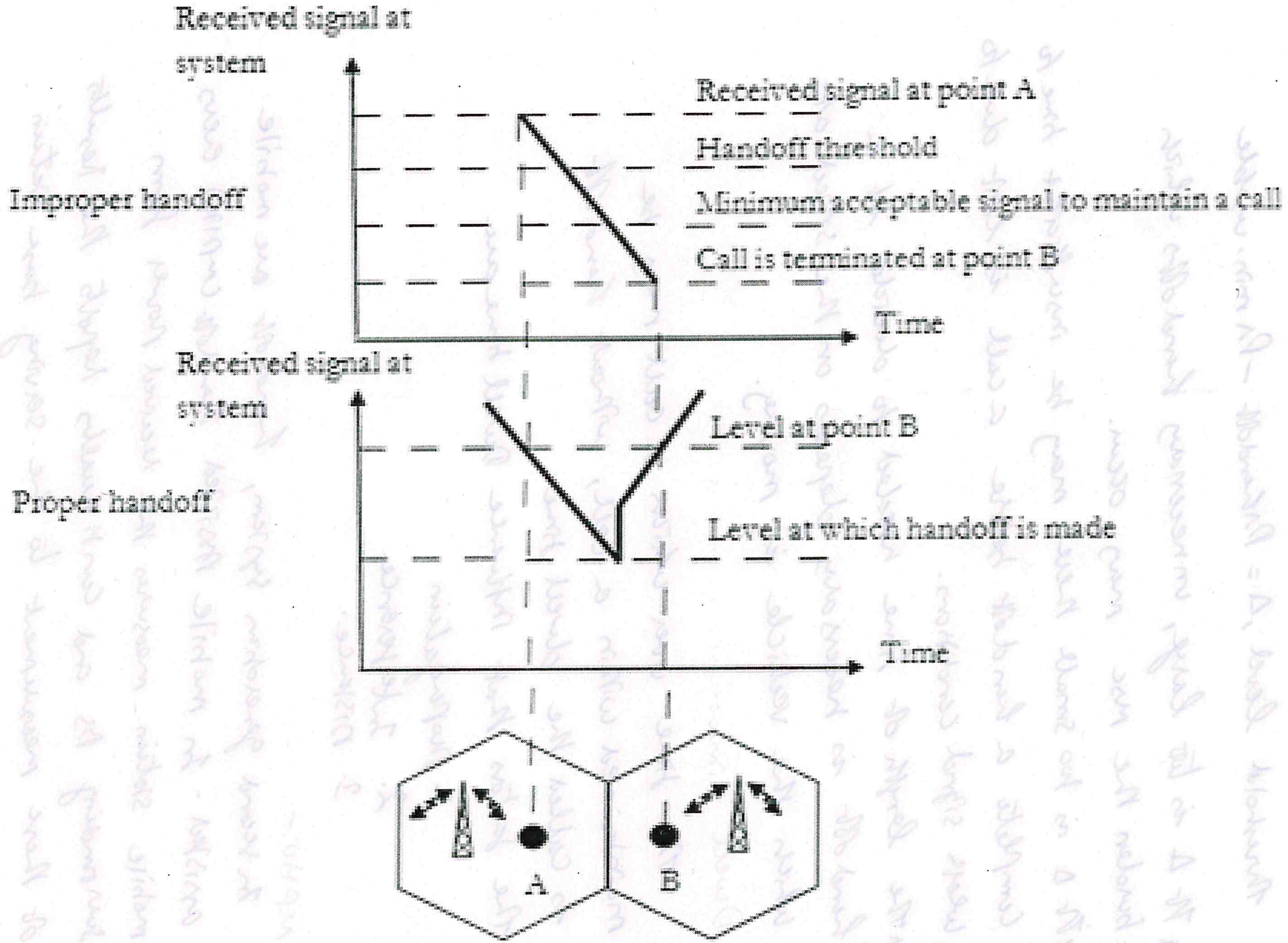


Fig: Proper and improper

Minimizing Hand offs :-

* Guard channel concept.

* Queuing of hand off request.

* Guard channel concept → A fraction of the total available channels in a cell is reserved exclusively for hand off requests from ongoing calls which may be handed off into the cell.

Practical Hand off Considerations :-

Umbrella cell approach :-

By using different antenna heights and different power levels, it is possible to provide "large" and "small" cells which are co-located at a single location. This technique is called umbrella cell approach.

* The number of handoffs is minimized for high speed users. and provides additional microcell channels for pedestrian users.

* The speed of each user may be estimated by the base station or MSC.

Cell dragging :-

* Cell dragging results from pedestrian users that provide a very strong signal to the base station.

* Cell dragging occurs when there is a LOS b/w the subscriber and the BS.

Umbrella Cells

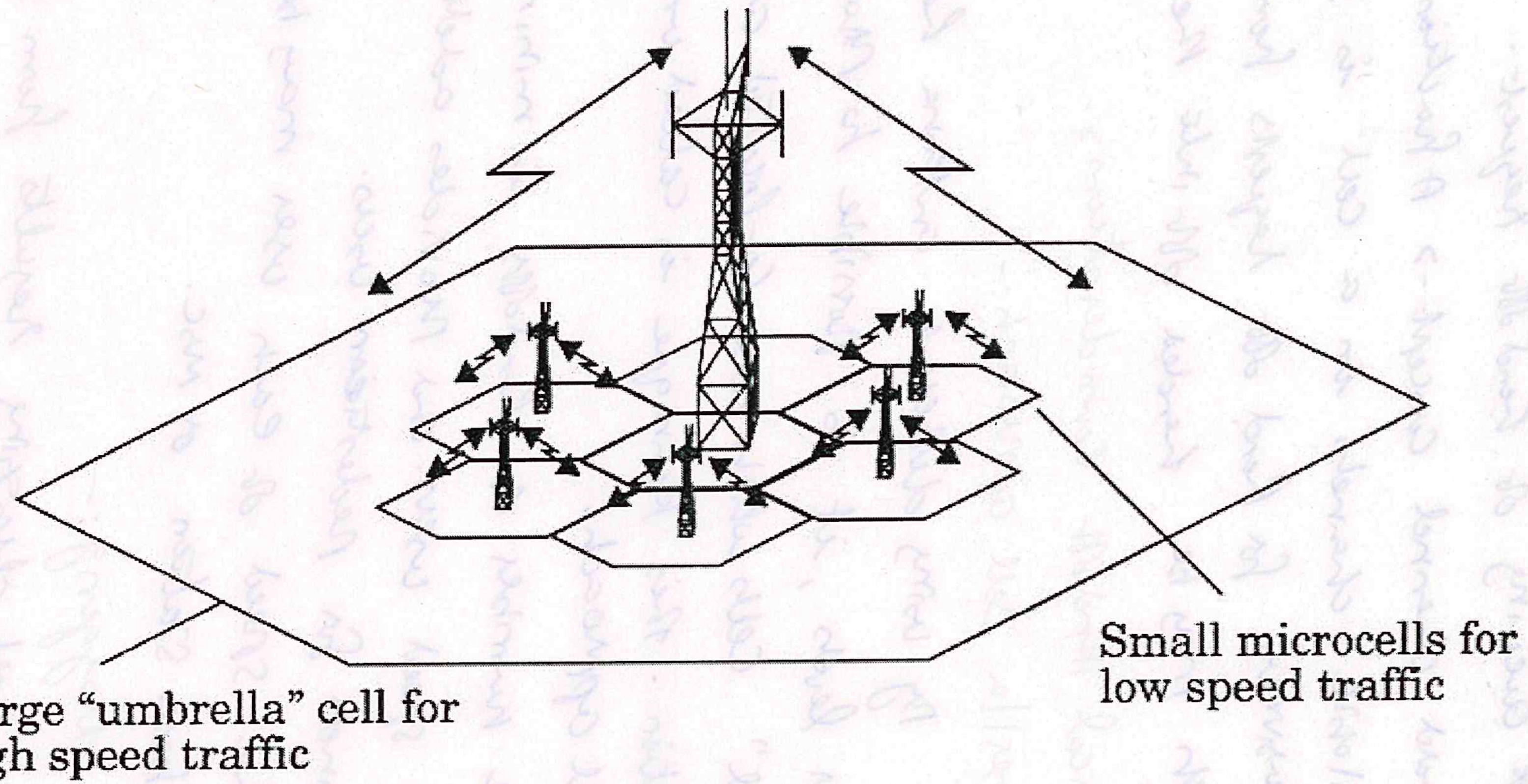


Figure 3.4 The umbrella cell approach.

* To solve the cell dragging problem, handoff thresholds and radio coverage parameters must be adjusted carefully.

Hard and Soft handoff:-

* Assign different radio channels during a hand off is called hard handoff.
* The ability to select b/w the instantaneous received signals from a variety of base stations is called soft handoff.

Interference & System Capacity:-

Interference is the major limiting factor in the performance of cellular radio systems.

Sources of interference:-

* Signal generated from other mobile.
* Call that is in progress in the neighbouring cell.
* BS operating in the same freq. range.
* Cross talk.

Types of interference:-

① Co-channel interference.
② Adjacent channel interference.

Co-channel interference and System capacity:-

* Freq. reuse implies that in a given coverage area there are several cells that use the same set of frequencies. These cells are called cochannel cells, and the interference signals from these cells is called co-channel interference.

* To reduce co-channel interference cochannels must be physically separated by a min. distance to provide sufficient isolation due to propagation.

R – Radius of the cell

D → Distance b/w centres of the nearest cochannel cells (D)

Q → Cochannel reuse ratio is related to cluster size.

* For a hexagonal geometry

$$Q = \frac{D}{R} = \sqrt{3N} \quad \text{——} \; (1)$$

* A small value of Q provides larger capacity since the cluster size N is small.

* Let i be the no. of cochannel interfering cells.

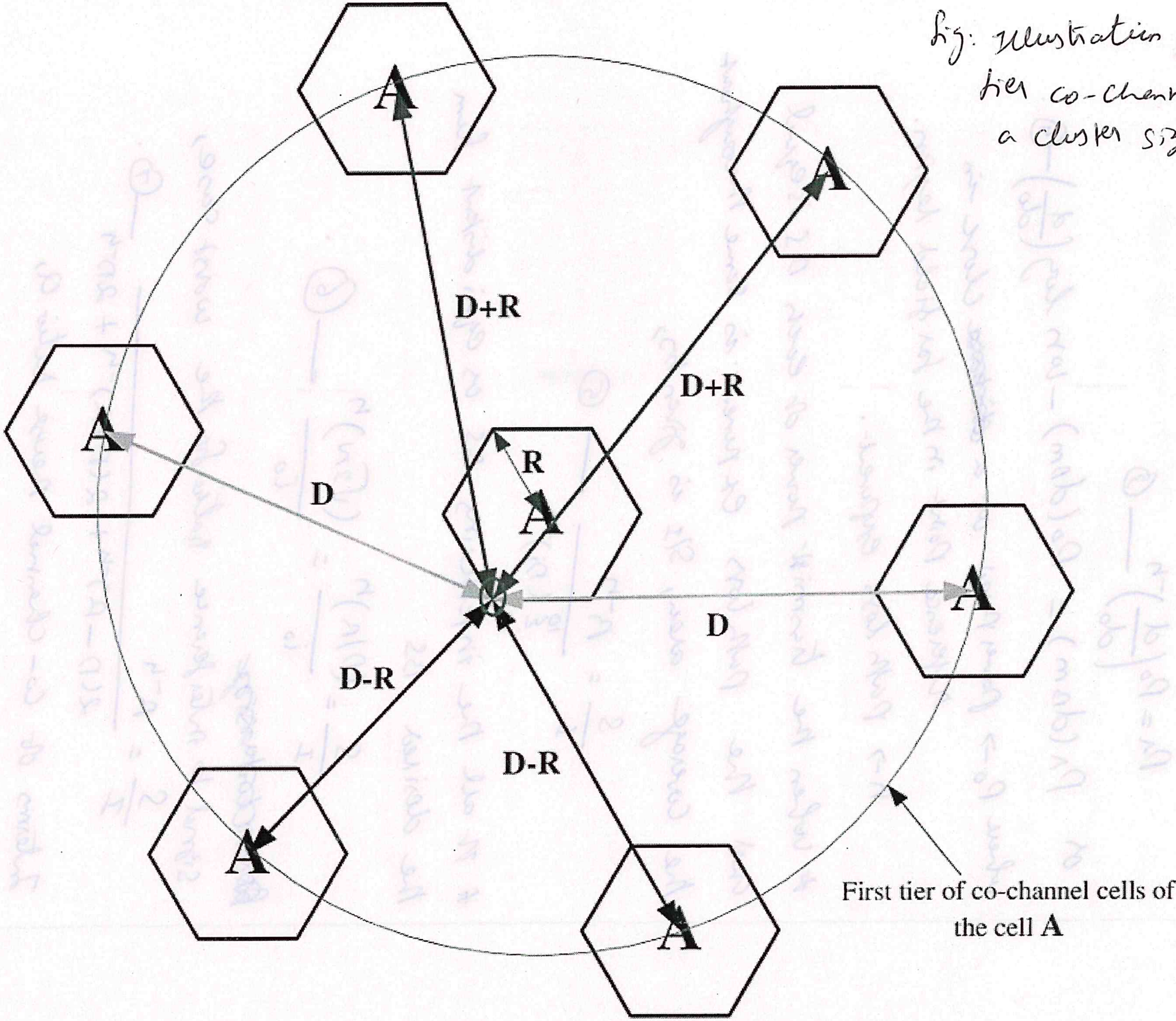
* Then the S/N ratio is given by.

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i} \quad \text{——} \; (2).$$

where S → Desired signal power from desired B.S.

I_i → Interference power caused by the ith interfering cochannel cell BS.

fig: Illustration of the first tier co-channel cell for a cluster size of N=7



* The average received power P_r at a distance d from the transmitting antenna is approximated by,

$$P_r = P_o\left(\frac{d}{d_o}\right)^{-n} \quad (3)$$

or

$$P_r(dBm) = P_o(dBm) - 10n\log\left(\frac{d}{d_o}\right) \quad (4)$$

where P_o → power received at a ~~distance~~ close-in reference point in the far field region.

n → path loss exponent.

* When the transmit power of each BS is equal and the path loss exponent is same throughout the coverage area, S/I is given by,

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0}(D_i)^{-n}} \quad (5)$$

* If all the interfering BS are equidistant from the desired BS

$$\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0} \quad (6)$$

~~[illegible]~~

Signal to interference ratio for the worst case,

$$\frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}} \quad (7)$$

In terms of co-channel reuse ratio Q,

$$\frac{S}{I} = \frac{1}{2(Q-1)^{-4} + 2(Q+1)^{-4} + 2Q^{-4}} \quad (8)$$

Adjacent channel interference:-

* Interference resulting from signals which are adjacent in freq. to the desired signal is called Adjacent channel interference.
* Rxer filters which allow near by frequencies to leak into the pass band.

Near far effect:-

If an user is transmitting in a range that is very close to another subscribers receiver then the Rxer will make an attempt to Receive the BS signal which will result in serious interference problem. Such an effect of interference due to distance/range is called "near-far" effect.

* Adjacent channel interference minimized by,
  * filtering
  * Channel Assignments.
  * Channel allocation schemes.
* If the freq. Reuse factor is large, the separation b/w adjacent channels at the BS may not be sufficient to keep the adjacent channel.
* For eg. If a close-in mobile is 20 times as close to the BS as another mobile, the signal to interference ratio at the BS,

$$S/I = (20)^{-n}$$

* For a path loss exponent n=4, this is equal to -52dB.

Trunking and Grade of service:-

Trunking:-

* to accomodate a large number of users in a limited radio spectrum.

* Trunking Theory - to determine the number of telephone circuits that need to be allocated for office buildings with hundreds of telephone.

* when a particular user request service and all of the radio channels are already in use, the user is blocked of access denied.

Grade of service (GOS):-

* GOS is a measure of the ability of a user to access a trunked system during the busiest hour.

* the busy hour for cellular radio systems are b/w 4pm and 6pm on thursday or friday.

* The grade of service is a benchmark used to define the desired performance of a particular trunked system by specifying a desired likelihood of a user obtaining channel access given a specific number of channels available in the system.

Definitions of common terms used in Trunking Theory:-

Setup time :-

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

Blocked Call or Lost Call :-

Call which cannot be completed at time of request due to congestion

Holding time :-

Average duration of a typical call denoted by H (in seconds).

Load :-

Traffic intensity across the entire trunkcated radio system, measured in Erlangs.

Grade of service (GOS) :-

A measure of congestion which is specified as the probability of call being blocked or the probability of a call being delayed beyond a certain amount of time (for Erlang C)

Request rate :-

The average no. of call request per time. Denoted by λ $seconds^{-1}$

Coverage and Capacity Improvement :-

* As the demand for wireless service increases the no. of channels assigned to a cell eventually becomes insufficient to support the required no. of users.
* For enhancing the cellular coverage & capacity the following techniques are used.

1. Cell splitting
2. Sectoring
3. Coverage zone approaches.
4. Repeaters.

* Cell splitting allows an orderly growth of the cellular system.

* Sectoring uses directional antennas to further control the interference and freq. reuse of channels.

* The microcell concept distributes the coverage of a cell and extends the cell boundary to hard-to-reach places.

Cell splitting:-

* Cell splitting 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 transmitted power.

* Cell splitting increases the capacity of a cellular system since it increases the no. of times that channels are reused.

* BS are placed at the corners of the cells.

* The area served by base station A is assumed to be saturated with traffic.

* The original BS A has been surrounded by six new microcells.

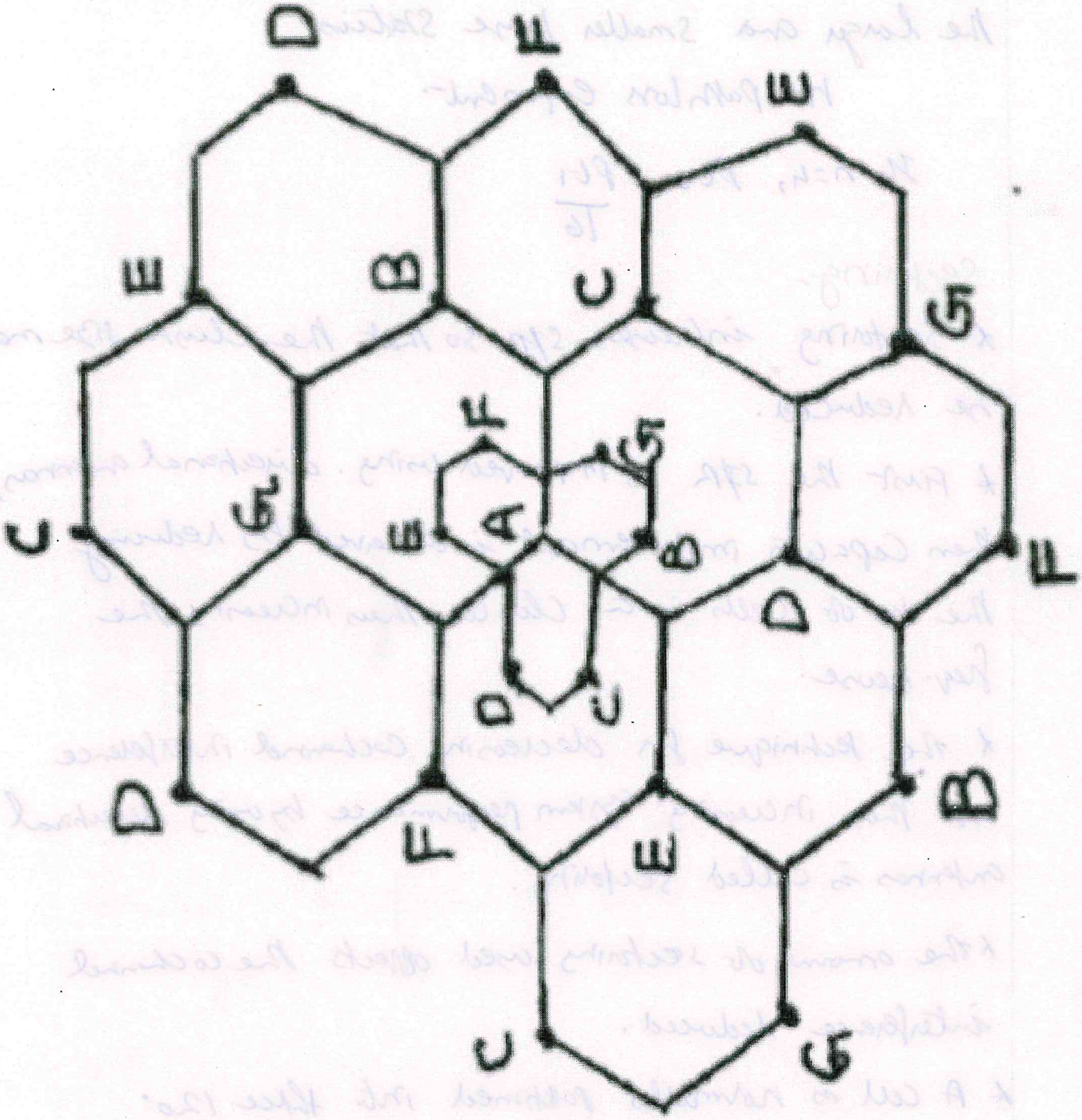


Fig. Illustration of cell splitting.

* P_r [at old cell boundary] ∝ $P_{t1} R^{-n}$

and P_r [at new cell boundary] ∝ $P_{t2} (R/2)^{-n}$

where, P_{t1} & P_{t2} are the transmit powers of the larger and smaller base stations.

$n \rightarrow$ path loss exponent.

If $n=4$, $P_{t2} = \frac{P_{t1}}{16}$

Sectoring:-

* Sectoring increases S/R so that the cluster size may be reduced.

* First the S/R is improved using directional antennas, then capacity improvement is achieved by reducing the no. of cells in a cluster, thus increasing the freq. reuse.

* The technique for decreasing cochannel interference and thus increasing system performance by using directional antennas is called sectoring.

* The amount of sectoring used affects the cochannel interference reduced.

* A cell is normally partitioned into three 120° sectors or six 60° sectors.

* In 120° sectors the no. of interferences in the first tier is reduced from six to two.

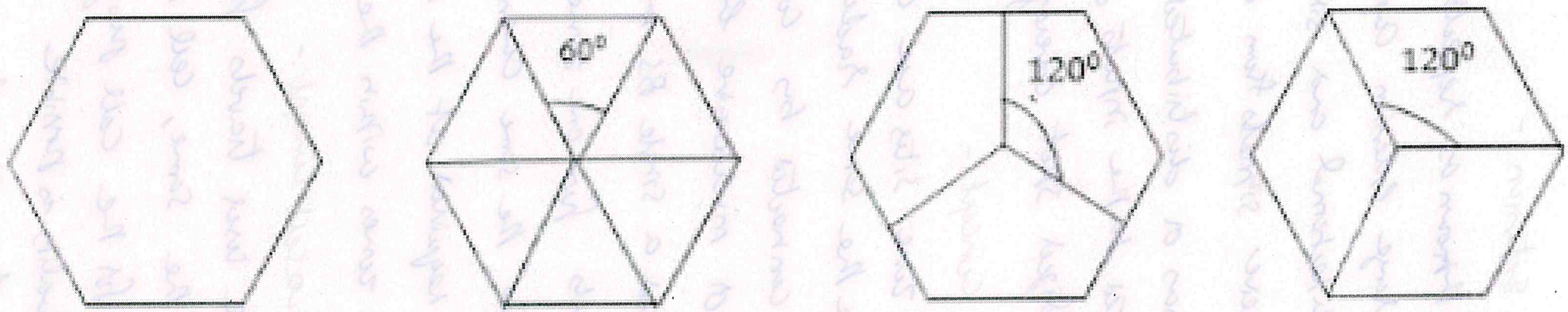


Fig: omni-directional 60° sectoring 120° sectoring

Repeaters for Range Extension:-

* Radio transmitters known as repeaters are often used to provide such range extension capabilities.

* Repeaters are Bidirectional and simultaneously send signals to and receive signals from a serving BS.

* Directional antennas or distributed Antenna Systems (DAS) are connected to the inputs or outputs of repeaters for localized spot coverage.

A Microcell zone concept:-

* Each of the 3 zone sites are connected to a single BS and share the same radio equipment.

* The zones are connected by coaxial cable, fiber optic cable or microwave link to the BS.

* multiple zones and a single BS make up a cell.

* As a mobile travels from one zone to another within the cell it retains the same channel.

* Hand off is not required at the MSC when the mobile travels b/w zones within the cell.

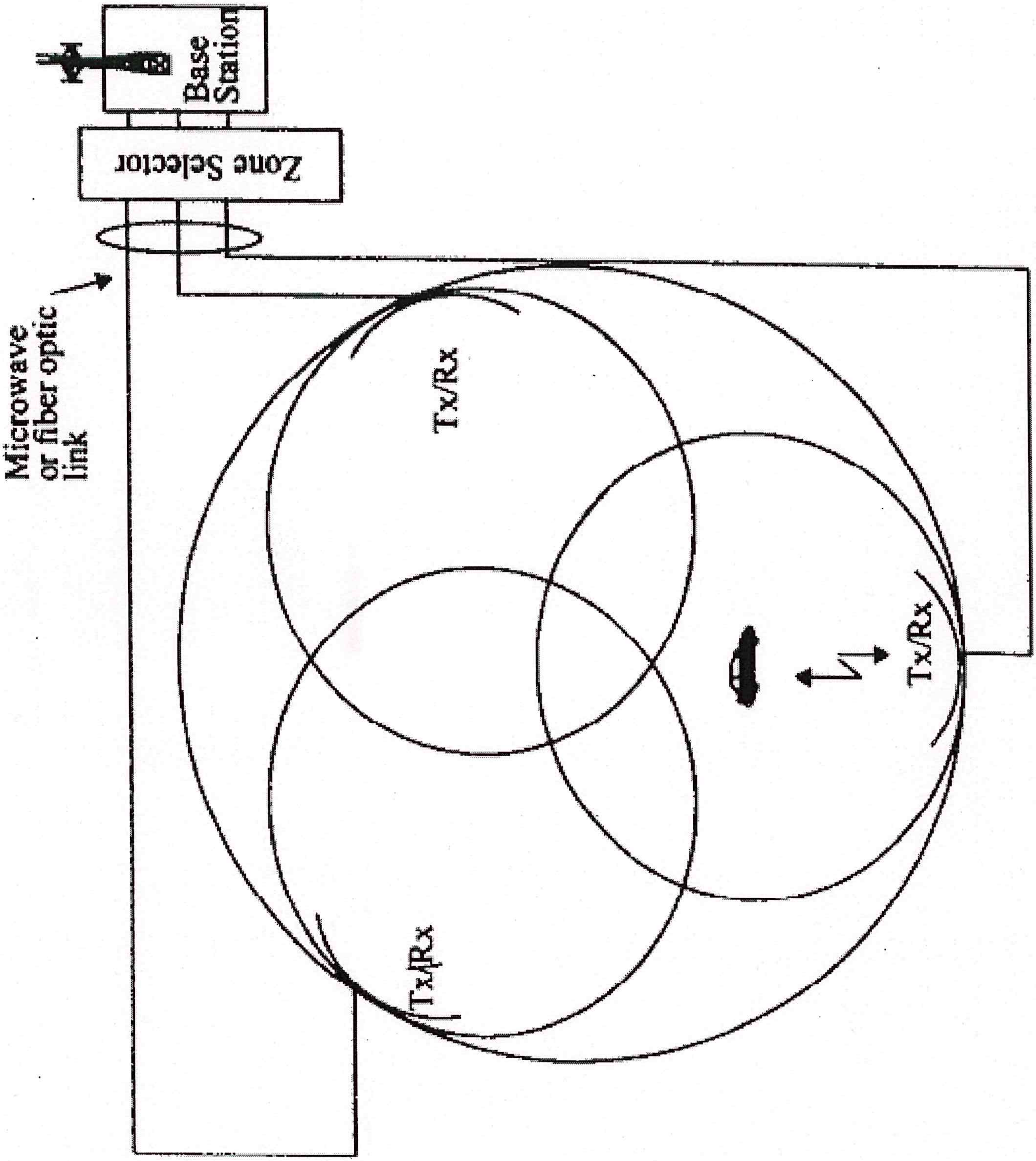
Advantages of microcell concept:-

* When the mobile user travels from one zone to another zone within the same, cell the same channel is still maintained for the call progress.

* Improved signal quality is possible

* Reduced no of handoffs when a call is in progress.

Fig: The micro cell concept:-



Application:-

It is used in urban traffic (or) in high ways traffic conditions.

Unit II

Mobile Radio Propagation.

Large Scale Path Loss: Introduction to Radiowave Propagation - Free Space Propagation model - Three Basic Propagation Mechanism: Reflection - Brewster Angle - Diffraction - Scattering. Small Scale fading and multipath. Small scale multipath Propagation, Factors Influencing Small-Scale Fading, Doppler Shift, Coherence Bandwidth, Doppler Spread and Coherence time, Types of Small-Scale fading: Fading effects due to multipath time delay spread, fading effects due to doppler spread.

Introduction:

* The radio wave propagation is influenced by the mechanisms namely scattering, reflection and diffraction.
* Most cellular radio systems operate in urban areas where there is no direct Line-of-sight path b/w the transmitter and the Receiver.
* Due to multiple reflections from various objects, the electromagnetic waves travel along different paths of varying lengths.
* As the distance is very large the probability of level of signal fade would be more.

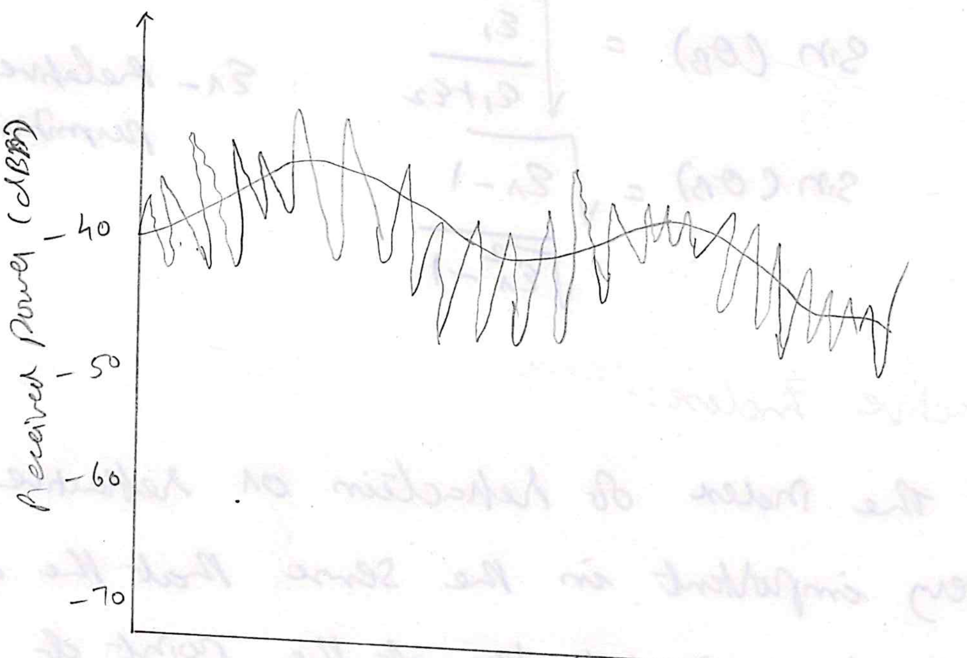
* Estimation of T-R separation helps in determining the radio coverage
* The propagation models are useful in calculation of the mean signal strength in transmission & these models are known as large scale propagation models.
* The characterization of fluctuations of Rxed signal over shorter time periods or shorter distances like few wave lengths by the models are known as small scale propagation models.

Large scale path loss:-

* The signal strength in wireless communication varies as it propagates and it is closely related to the location through which it travels.

* The propagation models predicts mean signal strength for a transmitter-Receiver separation (T-R) distance.
* The radio coverage area in this communication is also calculated and usually they are called as Large scale propagation models.
* This is due to signal strength calculations for larger T-R separation distance.

* The propagation models predict rapidly fluctuating received signal strength.
* The T-R seperation is of shorter distances.
* This kind of models are said to be small scale fading models.



* From fig the attenuation gets varied as the distance gets changed.

The three Basic propagation Mechanism:-

Basic three propagation Mechanisms are
* Reflection
* Diffraction
* Scattering.

Brewster angle:-

* The Brewster angle is the angle at which no reflection occurs in the medium of origin.

* It occurs when the incident angle θ_B is such that the reflection co-efficient $\Gamma_{\parallel}$ is equal to zero.

$$\sin(\theta_B) = \sqrt{\frac{\varepsilon_1}{\varepsilon_1+\varepsilon_2}}$$

ε_r - Relative permittivity.

$$\sin(\theta_B) = \frac{\sqrt{\varepsilon_r - 1}}{\sqrt{\varepsilon_r^2 - 1}}$$

Refractive Index:-

The index of refraction or refractive index is very important in the sense that the amount of bending or refraction at the point of interface of two materials of different density depends on this refractive index.

Refractive index $n = c/v$

$c \rightarrow$ speed of light (3×10^8 m/s)

$V \rightarrow$ speed of Light in a particular given material (m/sec).

Rayleigh Criterion:-

$$\cos\theta_i > \lambda/8D.$$

Path loss model :-

Free space propagation model :-

Definition :-

The term "free space propagation model" refers to the measurement of Received signal strength when the transmitter and receiver of the communication system have clear line of sight in b/w the two i.e. there is no obstacle in b/w the Txer and Rxer.

Application areas :-

The free space propagation is useful in areas of (a) Microwave Radio Link (b)

Analysis :-

* The free space propagation model predicts the received power delay level and for this prediction method the distance / range b/w receiver antenna and transmitter antenna is measured.

* The power received by the receiver antenna is denoted as $P_r(d)$ and it is known as "Friis free space equation"

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

P_t → transmitted power
$P_r(d)$ → Received power
G_t → transmitter antenna gain
G_r → Receiver antenna gain
d → T-R distance
L → system loss
λ → wave length

* The gain of an antenna is related to its effective aperture Ae by

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

* The effective aperture Ae is related to the physical size of the antenna, λ is related to the carrier frequency by

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$$

where, f → Carrier frequency in Hertz

ω_c → Carrier frequency in radians per sec.

c → Speed of light in meters/s.

* An "isotropic radiator" is an ideal antenna which radiates power with unit gain uniformly in all directions.

* The "effective isotropic radiated power [EIRP]" is defined as

$$EIRP = P_t G_t.$$

and represents the max. radiated power available from a txer in the direction of max. antenna gain as compared to an isotropic radiator.

* The "path loss" which represents signal attenuation as a positive quantity measured in dB, is defined as the difference (in dB)

* the path loss for the free space model when antenna gain are included is given by

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

* The antenna gains are assumed to have unity gain, the path loss is given by,

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

* The "far field (or) Fraunhofer region" of a txing antenna is defined as the region beyond the far-field distance d_f, which is related to the largest linear dimension of the txer antenna aperture and the carrier wave length.

* The fraunhofer distance is given by,

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

where, $D \rightarrow$ Largest physical linear dimension of the antenna.

d_f must satisfy,

① $d_f >> D$

② $d_f >> \lambda$

* Let 'd_0' be the reference 'close-in' distance. Such that d_0 is selected to be a smaller value than the practical distance under mobile communication.

* The received power in free space at a distance greater than d_0 is given by,

$$P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2 \qquad d \geq d_0 \geq d_f$$

* P_r is in units of dBm, the received power is given by,

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

$$d \geq d_0 \geq d_f$$

where, $P_r(d_0)$ is in units of watts.

Ground Reflection (Two-Ray) model:-

* Two ray Ground reflection model is more accurate than free space propagation model.
* The two ray model considers the direct path, reflected path and geometric optics
* This method is used for predicting the large scale signal strength over distances of several kilometers and line-of-sight microcell channels in urban environments.

E_{TOT} → Total Received E-field
E_{LOS} → Direct Light of sight component.
E_g → Ground Reflected Component
h_t, h_r → height of Txa & Rxa.

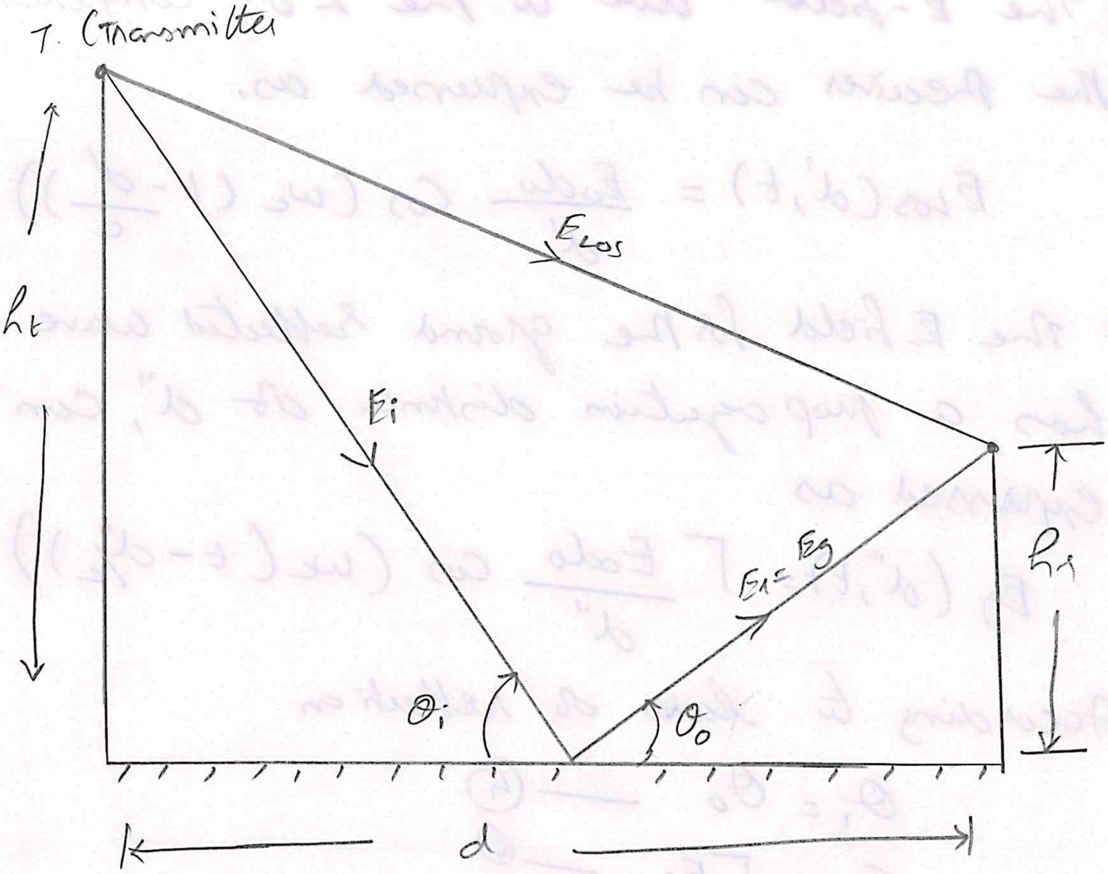


fig: Two-ray Ground Reflection model.

* If E_0 is the free space E field at a reference distance d_0 from the transmitter, then for distance d_0, the free space propagating E field is given by

$$E(d,t) = \frac{E_0 d_0}{d} \cos\left(\omega_c\left(t - \frac{d}{c}\right)\right) \quad (d > d_0) \quad \text{--- ①}$$

where $E(d,t) = \frac{E_0 d_0}{d}$ represents the envelop of the E field at d meters from the transmitter.

Two propagating waves arrive at the receiver.

① The direct wave that travels a distance d'.

② The reflected wave that travels a distance d''.

* The E-field due to the LOS component at the Receiver can be expressed as,

$$E_{LOS}(d',t) = \frac{E_0 d_0}{d'} \cos\left(\omega_c\left(t-\frac{d'}{c}\right)\right) \quad (2)$$

* The E field for the ground reflected wave which has a propagation distance of d'', can be expressed as

$$E_g(d'',t) = \Gamma \frac{E_0 d_0}{d''} \cos\left(\omega_c\left(t-d''/c\right)\right) \quad (3)$$

According to laws of reflection

$$\theta_i = \theta_0 \quad (4)$$

$$E_g = \Gamma E_i \quad (5)$$

$$E_t = (1+\Gamma)E_i \quad (6)$$

where $\Gamma \rightarrow$ reflection Co-efficient.

The resultant total E field envelope is given by, $|E_{TOT}| = |E_{LOS} + E_g|$

* The electric field $E_{TOT}(d,t)$ can be expressed as the sum of eqn (2) & (3)

$$E_{TOT}(d,t) = \frac{E_0 d_0}{d'} \cos\left(\omega_c\left(t-\frac{d'}{c}\right)\right) + (-1)\frac{E_0 d_0}{d''} \cos\left(\omega_c\left(t-\frac{d''}{c}\right)\right) \quad (8)$$

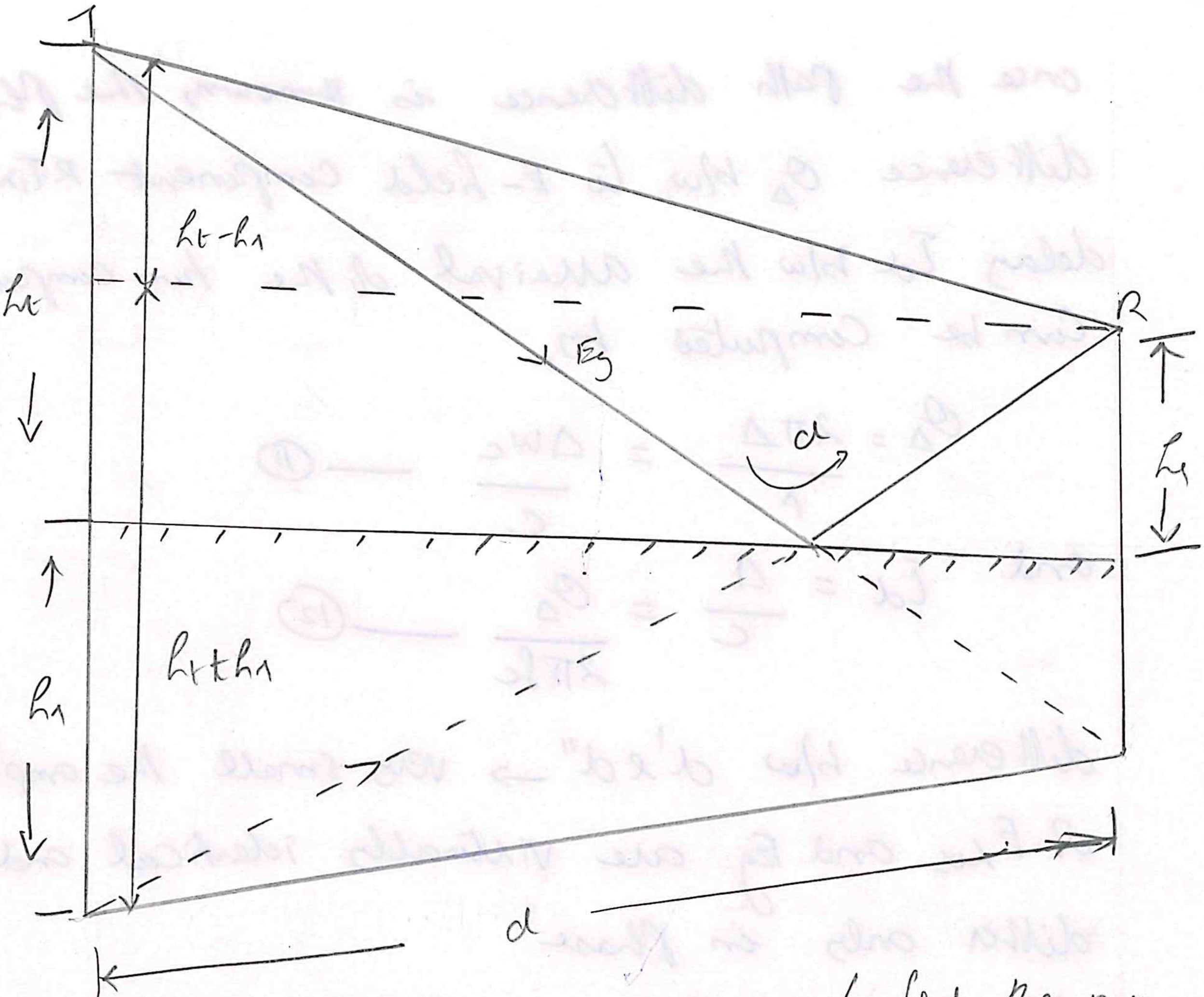


fig: The method of images is used to find the path difference b/w the LOS and the ground reflection paths.

Using method of images, the path difference Δ, b/w the LOS and the ground reflected paths can be expressed as

$$\Delta = d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2} \quad \text{— (9)}$$

when the T-R separation distance d is very large compared to $h_t + h_r$, eqn (9) can be simplified using a Taylor series approximation

$$\Delta = d'' - d' \approx \frac{2 h_t h_r}{d} \quad \text{— (10)}$$

once the path difference is known, the phase difference θ_Δ b/w to E-field component & Time delay τ_d b/w the arrival of the two components can be computed by,

$$\theta_\Delta = \frac{2\pi\Delta}{\lambda} = \frac{\Delta \omega_c}{c} \quad \text{—— (11)}$$

and

$$\tau_d = \frac{\Delta}{c} = \frac{\theta_\Delta}{2\pi f_c} \quad \text{—— (12)}$$

difference b/w d' & d'' → very small the amplitudes of E_{LOS} and E_g are virtually identical and differ only in phase

$$\left|\frac{E_0 d_0}{d}\right| \approx \left|\frac{E_0 d_0}{d'}\right| \approx \left|\frac{E_0 d_0}{d''}\right| \quad \text{—— (13)}$$

* If the received E-field is evaluated at $t = d''/c$, eqn (8) can be expressed as a phasor.

$$E_{TOT}(d, t = d''/c) \approx \frac{E_0 d_0}{d}\left[\angle \theta_B - 1\right] \text{—— (14)}$$

<u>Link Budget Design</u>:-

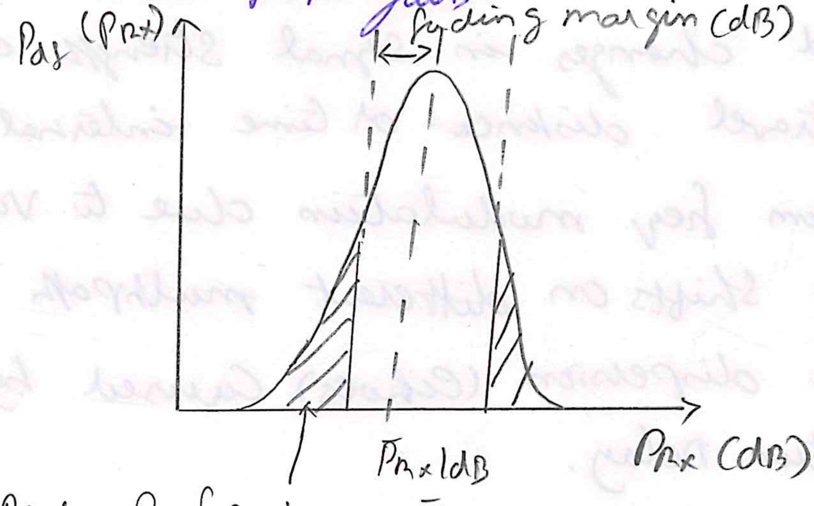
* A link budget is the clearest and most intuitive way of computing the required Tx power
* It tabulates all equations that connect the Tx power to the received SNR.

* It is convenient to write all the equations in a logarithmic form - specifically in dB.
* The link budget gives only an approximation for the total SNR, because some interactions b/w different effects are not taken into account.
* For distances $d < d_{break}$, the received power is proportional to d^{-n}, where $n = 3.5$ to 4.5

The received power is thus,

$$P_{Rx}(d) = P_{Rx}(d_{break})\left(\frac{d}{d_{break}}\right)^{-n} \text{ for } d > d_{break}.$$

* wireless systems, especially mobile systems suffer from temporal and spatial variations of the transmission channel (fading)
* The ratio of the transmit power to this mean received power is also known as the path loss converse of the path gain



$P_{out} = P_r\{P_{Rx}|dB < \bar{P}_{Rx}|dB - \text{Fading margin}|dB\}$

fig: fading margin to guarantee a certain outage probability.

* If the mean received power is used as the basis for the link budget, then the transmission quality will be above the threshold only in approximately 50% of the times and locations.

* we have to add a fading margin, the minimum received power is exceeded in atleast eg: 90% of all cases.

* The value of the fading margin depends on the amplitude statistics of the fading.

* uplink (ms to BS) and down link (BS to ms) are reciprocal, the voltage and currents at the antenna ports are reciprocal.

<u>Small scale</u> multipath propagation:-

* multipath in the radio channel creates small scale fading effects.

* The three most important effects are

* Rapid changes in signal strength over a small travel distance or time interval.

* Random freq. modulation due to varying Doppler shifts on different multipath signals.

* Time dispersion (echoes) caused by multipath propagation Delay.

* Fading occurs because the height of the mobile antennas, so there is no LOS path to the base station.
* The incoming radio waves arrive from different directions with different propagation delays.
* Even when a mobile Rxer is stationary the received signal may fade due to movement of surrounding objects in the radio channel
* The spatial variations of the resulting signal are seen as temporal variations by the receiver as it moves through the multipath field.
* Due to constructive and destructive effect of multipath waves summing at various points in space, a receiver moving at high speed can pass through several fades in a small period of time.

Factors influencing <u>Small</u> <u>Scale fading</u>:-

* multipath propagation
* Speed of mobile
* speed of surrounding objects
* The transmission bandwidth of the signal.

Doppler shift :-

* "Due to the relative motion b/w the mobile and the base station, each multipath wave experiences an apparent shift in freq. The shift in received signal freq. due to motion is called doppler shift".

* Doppler shift is directly proportional to the velocity and direction of motion of the mobile.

* Consider a mobile moving at a constant velocity 'v', having length 'd' b/w points x & y while it receives signal from a remote source 'S'.

* Path difference $\Delta L = d \cos\theta = V \Delta t \cos\theta$,

$\Delta t \rightarrow$ time required for the mobile to travel from x to y

* The phase angle change is received signal,

$$\Delta\phi = \frac{2\pi \Delta l}{\lambda} = \frac{2\pi V \Delta t}{\lambda} \cos\theta \quad \text{--- (1)}$$

* Doppler shift is given by f_d,

$$f_d = \frac{1}{2\pi} \cdot \frac{\Delta\phi}{\Delta t} = \frac{V}{\lambda} \cos\theta \quad \text{--- (2)}$$

* If the mobile is moving toward the direction of arrival of the wave the Doppler shift is positive

* If the mobile is moving away from the direction of arrival of the wave the Doppler shift is negative.

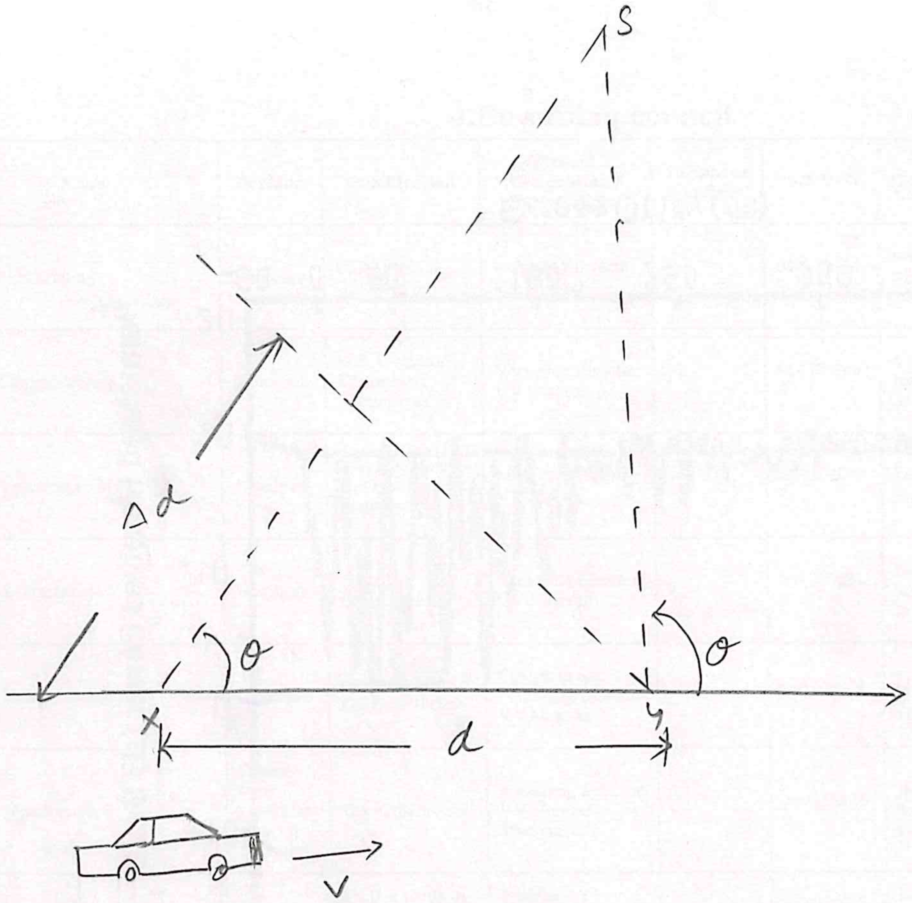
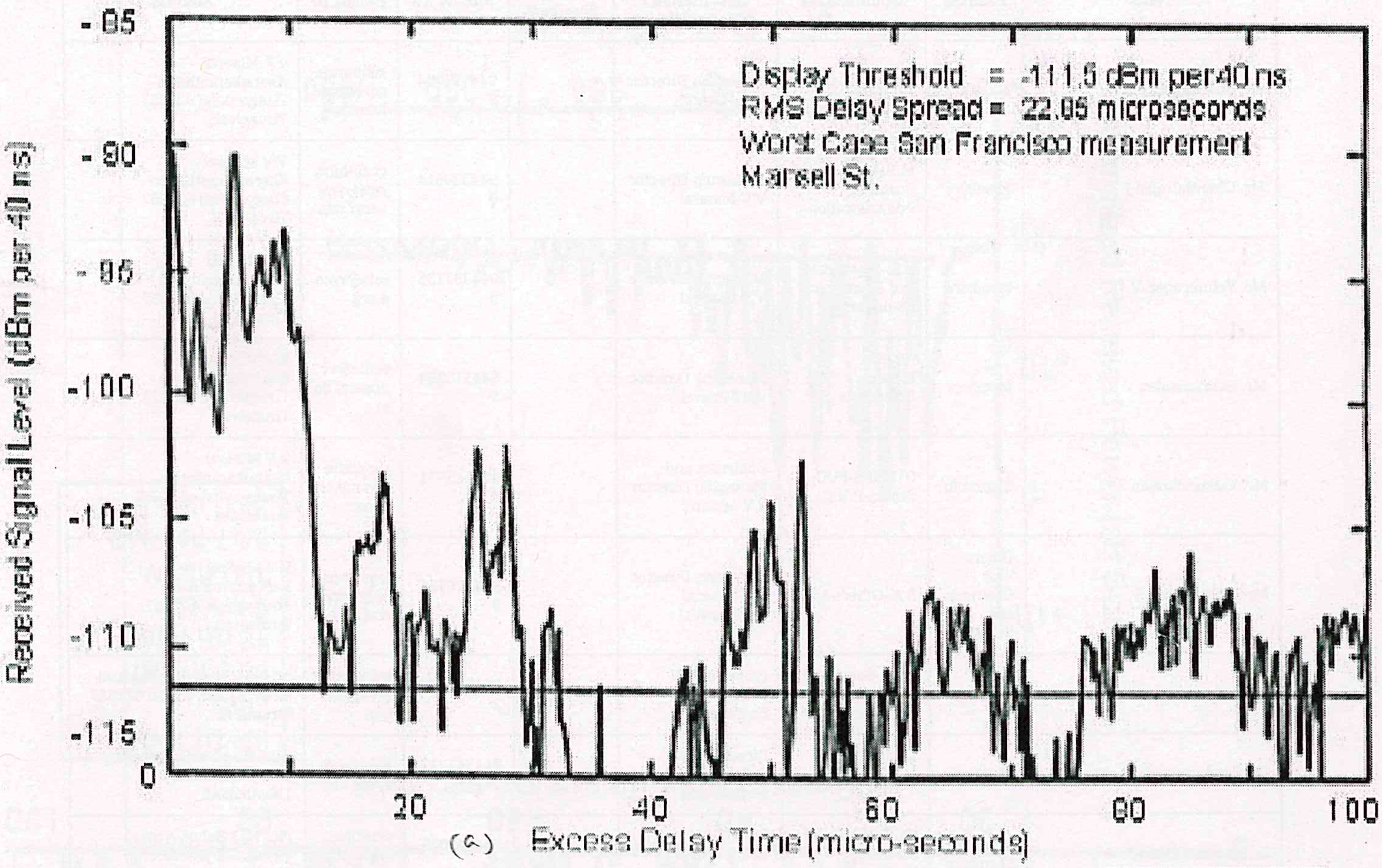


fig: Illustration of Doppler effect.

Parameters of mobile multipath channels:-

* power delay profiles are found by averaging instantaneous power delay profile measurements over a local area in order to determine an average small scale power delay profile
  * Time Dispersion parameters
  * Coherence Bandwidth.
  * Doppler spread & Coherence Time.

* small scale sampling avoids large scale averaging bias in the resulting small scale statistics.



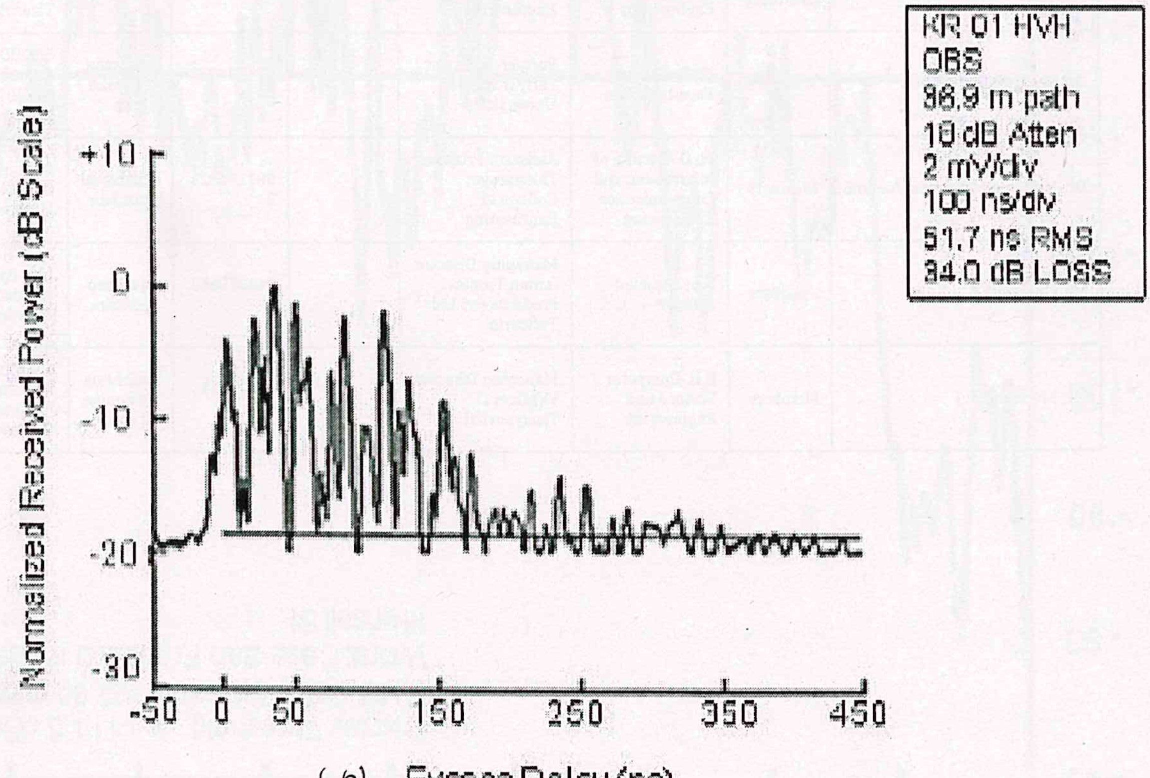


Fig: Measured multipath power delay profiles
(a) From a 900MHz cellular system in San Francisco
(b) Inside a grocery store at 4GHz.

Time Dispersion Parameters:-

* The mean excess delay, rms delay spread and excess delay spread are multipath channel parameters that can be determined from a power delay profile

* The mean excess delay ($\bar{\tau}$) is the first moment of the power delay profile and is defined to be

$$\bar{\tau} = \frac{\sum_K a_K^2 \tau_K}{\sum_K a_K^2} = \frac{\sum_K P(\tau_K)\,\tau_K}{\sum_K P(\tau_K)} \quad \text{--- (1)}$$

* 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

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

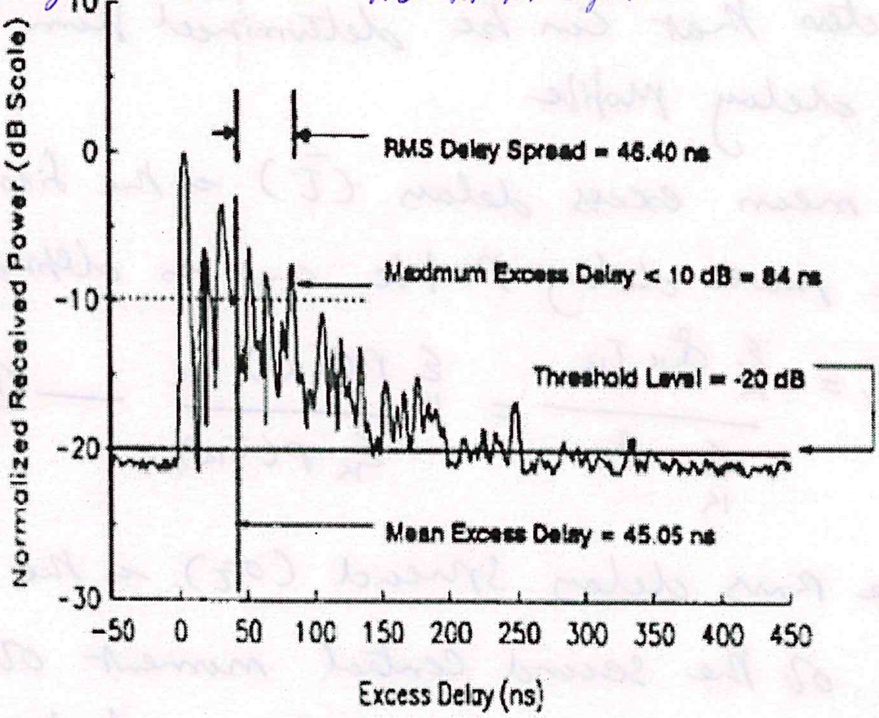
where,

$$\overline{\tau^2} = \frac{\sum_K a_K^2 \tau_K^2}{\sum_K a_K^2} = \frac{\sum_K P(\tau_K)\,\tau_K^2}{\sum_K P(\tau_K)} \quad \text{--- (3)}$$

* Typical values of rms delay spread are on the order of micro seconds in outdoor mobile radio channels and on the order of nano seconds in indoor radio channels.

* The max. excess delay (X dB) of the power delay profile is defined to be the time delay during which multipath energy falls to X dB below the maximum.

* The max. excess delay is defined as, $\tau_x - \tau_0$, where τ_0 is the first arriving signal and τ_x is the max. delay at which a multipath component is within X dB of the strongest arriving multipath signal.



Environment	Frequency (MHz)	Rms delay spread (σ_τ)
Urban	892	10 to 25 μs
Suburban	910	200 to 310 ns
Indoors	1500	10 to 50 ns.

* Analogy to the delay spread parameters in the time domain, Coherence Bandwidth is used to characterize the channel in frequency domain.

Coherence Bandwidth:-

* Coherence Bandwidth is a Statistical measure of the range of frequencies over which the channel can be considered "flat".
* Coherence Bandwidth is the range of frequencies over which two frequency components have a strong potential for amplitude correlation.
* If Coherence Bandwidth is defined as the bandwidth over which the frequency correlation fn. is 0.9, then the coherence Bandwidth is,

$$B_C \approx \frac{1}{50\,\sigma_\tau} \quad \text{—— (1)}$$

* Freq. correlation fn. is above 0.5, then the Coherence Bandwidth is,

$$B_C \approx \frac{1}{5\sigma_\tau} \quad \text{—— (2)}$$

Eqn (1) & (2) are "Ball park estimates".

* Spectral analysis techniques and simulation are required to determine the exact impact that time varying multipath has on a particular transmitted signal.

Doppler Spread and Coherence Time:-

* Doppler spread B_D is a measure of the spectral broadening caused by the time rate of change of the mobile radio channel and is defined as the range of frequencies over which the received Doppler spectrum is essentially non-zero.
* When a pure sinusoidal tone of freq. f_c is transmitted, the received signal spectrum called the Doppler spectrum, will have components in the range $f_c - f_d$. where f_d is the Doppler shift.
* If the baseband signal bandwidth is much greater than B_D, the effects of Doppler spread are negligible at the receiver.
* Coherence Time T_c is the time domain dual of Doppler spread and is used to characterize the time varying nature of the freq. dispersiveness of the channel in the time domain.
* The Doppler spread and coherence time are inversely proportional to one another.

$$T_c \approx \frac{1}{f_m}$$

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

* If the coherence time is defined as the time over which the time correlation function is above 0.5, then coherence time is,

$$T_c \approx \frac{9}{16\pi f_m}$$

where $f_m \to$ max. Doppler shift.

$$f_m = v/\lambda$$

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

* The definition of coherence time implies that two signals arriving with a time separation greater than T_c are affected differently by the channel.

Types of Small Scale Fading:-

While multipath delay spread leads to time dispersion and frequency selective fading, Doppler spread leads to frequency dispersion and time selective fading.

Small-Scale Fading
(Based on multipath time delay spread)

Flat Fading
1. BW of signal < BW of channel
2. Delay spread < Symbol period

Frequency Selective Fading
1. BW of signal > BW of channel
2. Delay spread > Symbol period

Small-Scale Fading
(Based on Doppler spread)

Fast Fading
1. High Doppler spread
2. Coherence time < Symbol period
3. Channel variations faster than baseband signal variations

Slow Fading
1. Low Doppler spread
2. Coherence time > Symbol period
3. Channel variations slower than baseband signal variations

Fig: Types of small scale fading.

Fading effects due to multipath time delay spread:-

Time dispersion due to multipath causes the transmitted signal to undergo either flat or frequency selective fading.

Flat fading:-

* "If the mobile radio channel has a constant gain and linear phase response over a bandwidth which is greater than the bandwidth of the transmitted signal then the received signal will undergo flat fading"

* spectral characteristics of the transmitted signal are preserved at the receiver.
* the strength of the received signal changes with time, due to fluctuations in the gain of the channel caused by multipath.

* over time, the received signal r(t) varies in gain, but the spectrum of the transmission is preserved.

* The Reciprocal Bandwidth is much larger than the multipath time delay spread of the channel.

* Flat fading channels are also known as amplitude varying channels and are sometimes are referred to as narrow band channels, since the Bandwidth of the applied signal is narrow as compared to the channel flat fading bandwidth

A signal undergoes flat fading if,

$$B_S << B_C \quad \text{—— (1)}$$

and

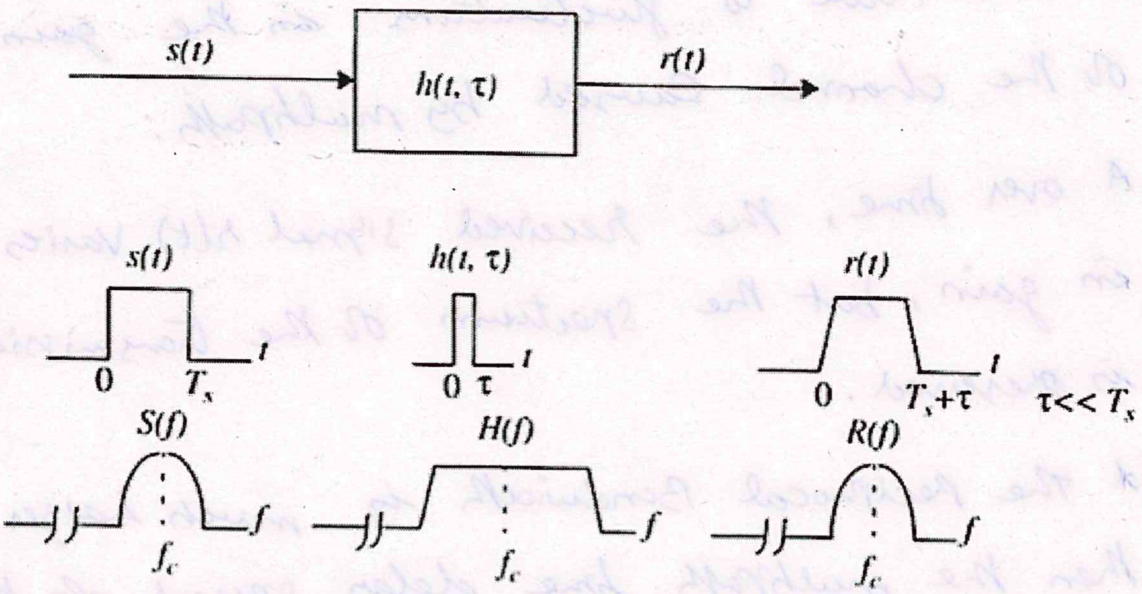
$$T_S >> \sigma_\tau \quad \text{—— (2)}$$

where, $T_S \rightarrow$ Reciprocal Bandwidth

$B_S \rightarrow$ Bandwidth

σ_τ & $B_C \rightarrow$ Rms delay spread & Coherence Bandwidth.

Fig: Flat fading characteristics.

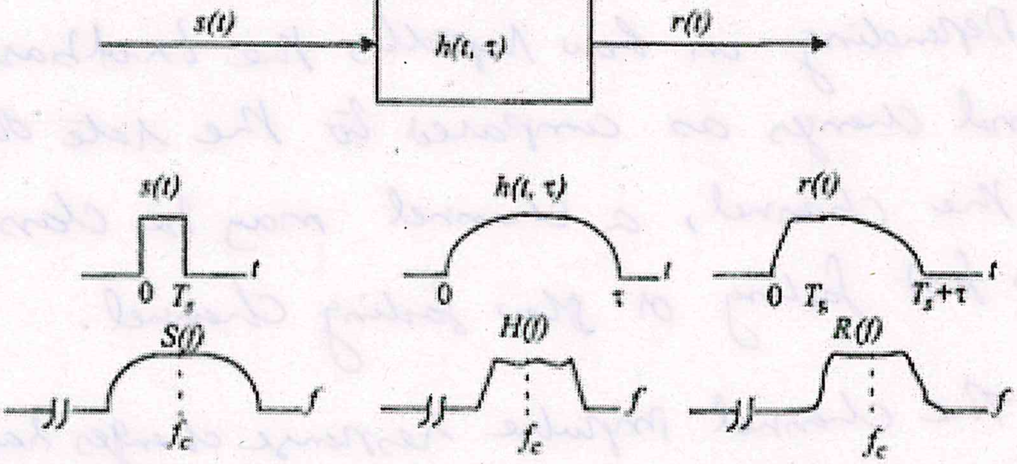


Frequency Selective fading:-

* "If the channel possess a constant gain and linear phase response over a bandwidth that is smaller than the bandwidth of transmitted signal, then the channel creates freq. selective fading on the received signal".
* Freq. selective fading is due to time dispersion of the transmitted symbols within the channel.
* Thus the channel induces Intersymbol interference (ISI)
* Freq. selective fading channels are much more difficult to model than flat fading channels.
* When analyzing mobile comm. systems, statistical impulse response models such as the two-ray Rayleigh fading model (or)

Computer generated or measured impulse responses are generally used for analyzing freq. selective small scale fading.

Fig. freq. selective fading channel characteristics.



* For freq. selective fading, the spectrum S(f) of the transmitted signal has a bandwidth which is greater than the coherence bandwidth B_c of the channel.
* ~~Freq~~. Signal undergoes freq. selective fading

$$B_S > B_C \quad \text{—} (1)$$

and

$$T_S < \sigma_\tau \quad \text{—} (2).$$

* A channel is flat fading if $T_s \geq 10\sigma_\tau$ and a channel is freq. selective if $T_s < 10\sigma_\tau$.

Fading Effects Due to Doppler Spread:-

* Fast fading
* Slow fading.

Fast fading:-

* Depending on how rapidly the txed base band signal changes as compared to the rate of change of the channel, a channel may be classified as fast fading or slow fading channel.

* The channel impulse response changes rapidly within symbol duration.
* Coherence time of the channel is smaller than the symbol period of the transmitted signal.
* This causes freq. dispersion due to Doppler spreading, which leads to signal distortion.
* A signal undergo fast fading if

$$T_S > T_C$$

and

$$B_S < B_D.$$

* Fast fading only deals with the rate of change of the channel due to motion.
* The amplitude of the delta fn. varies faster than the rate of change of the txed baseband signal.
* Fast fading only occurs for very low data rate.

Slow fading:-

* In a slow fading channel, the channel impulse response changes at a rate much slower than the transmitted base band signal $s(t)$.
* In freq. domain, the Doppler spread of the channel is much less than the bandwidth of the base band signal
* A signal undergoes slow fading if

$$T_s \ll T_c$$

and $B_s \gg B_D$

* The velocity of the mobile and the base band signaling determines whether a signal undergoes fast fading or slow fading.

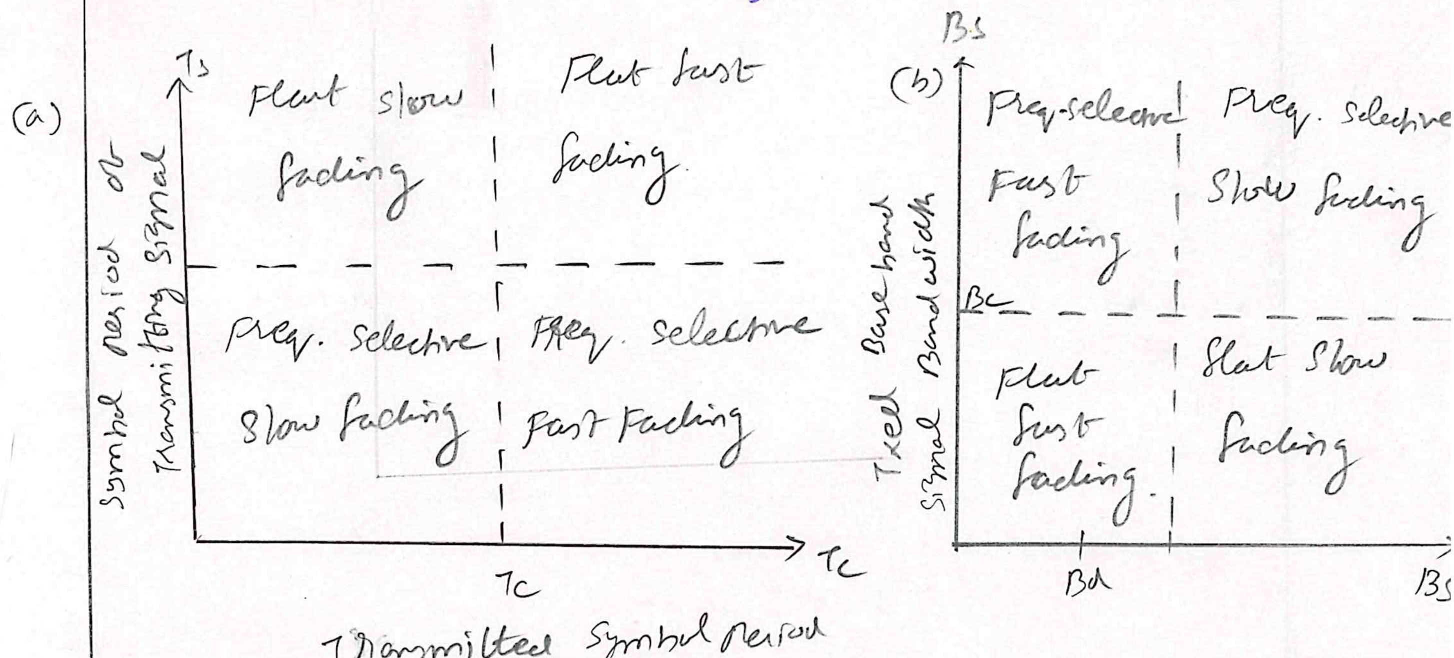


Fig: matrix Illustrating type of fading experienced by a signal as a function of (a) Symbol period (b) base band signal bandwidth.

Unit III Modulation Techniques And Equalization And Diversity.

Digital Modulation - An overview: Factors that Influence the choice of Digital modulation, Linear Modulation Techniques: Minimum Shift Keying (MSK), Gaussian minimum shift keying (GMSK), Spread spectrum modulation techniques: Pseudo. noise (PN) sequences, Direct Sequence Spread Spectrum (DS-SS) - Modulation performance in fading and multipath channels - Equalization, Diversity and channel Coding: Introduction. Fundamentals of Equalization - Diversity Techniques: Practical Space Diversity Considerations, Polarization Diversity, Frequency Diversity, Time Diversity.

Digital modulation - An overview:-

Modern mobile Communication Systems use digital modulation techniques. The advancements in very large scale Integration (VLSI) and Digital Signal processing technology that makes the digital modulation more cost effective than analog transmission systems.

Advantages:-

The digital modulation offers many advantages over analog modulation.

(i) Greater noise immunity (ii) Robustness to channel impairments

(iii) Easier multiplexing of various forms of information such as voice, data and video.

(iv) Greater Security.

Factors that influence the choice of Digital modulation:

Depending on the demands of the particular application, trade offs are made when selecting a digital modulation. The performance of a digital modulation scheme is often measured in terms of its power efficiency and bandwidth efficiency.

(1) Power efficiency (or) Energy efficiency:-

The power efficiency is defined as, "the ratio of the signal energy per bit (E_b) to noise power spectral density (N_0) which is required at the input for a certain probability of error"

$$\eta_p = \frac{E_b}{N_0}$$

(2) Bandwidth Efficiency:-

Bandwidth efficiency reflects how efficiently the allocated bandwidth is utilized and it is defined as, "the ratio of the throughput data rate per Hertz in a given bandwidth".

$$\eta_B = \frac{R}{B} \text{ bps/Hz}$$

(3) Other factors:-

* For all Personal Communication Systems (PCSs) which serve a large user community, here the cost and complexity of the subscriber receiver must be minimized and modulation scheme will be simple and more attractive.

* The performance of the modulation scheme under various types of channel impairments such as Rayleigh and Ricean fading and multipath time dispersion a given particular demodulator implementation is another key factor in a selecting a modulation.

* In cellular systems, interference is a major issue and the performance scheme in an interference environment is extremely important.

* Sensitivity to detection or timing jitter, caused by time varying channels is also an important consideration in choosing a particular modulation scheme.

* In general the modulation, interference and implementation of the time varying effects of the channel as well as the performance and the specific demodulator are analyzed as a complete system using simulation to determine relative performance and select the best one.

* The two D-flip flops act as a quadrature product demodulator and the XOR gates act as baseband multipliers.

* The mutually orthogonal reference carriers are generated using two D flip flops.

* VCO center freq. is set equal to four times the carrier center freq.

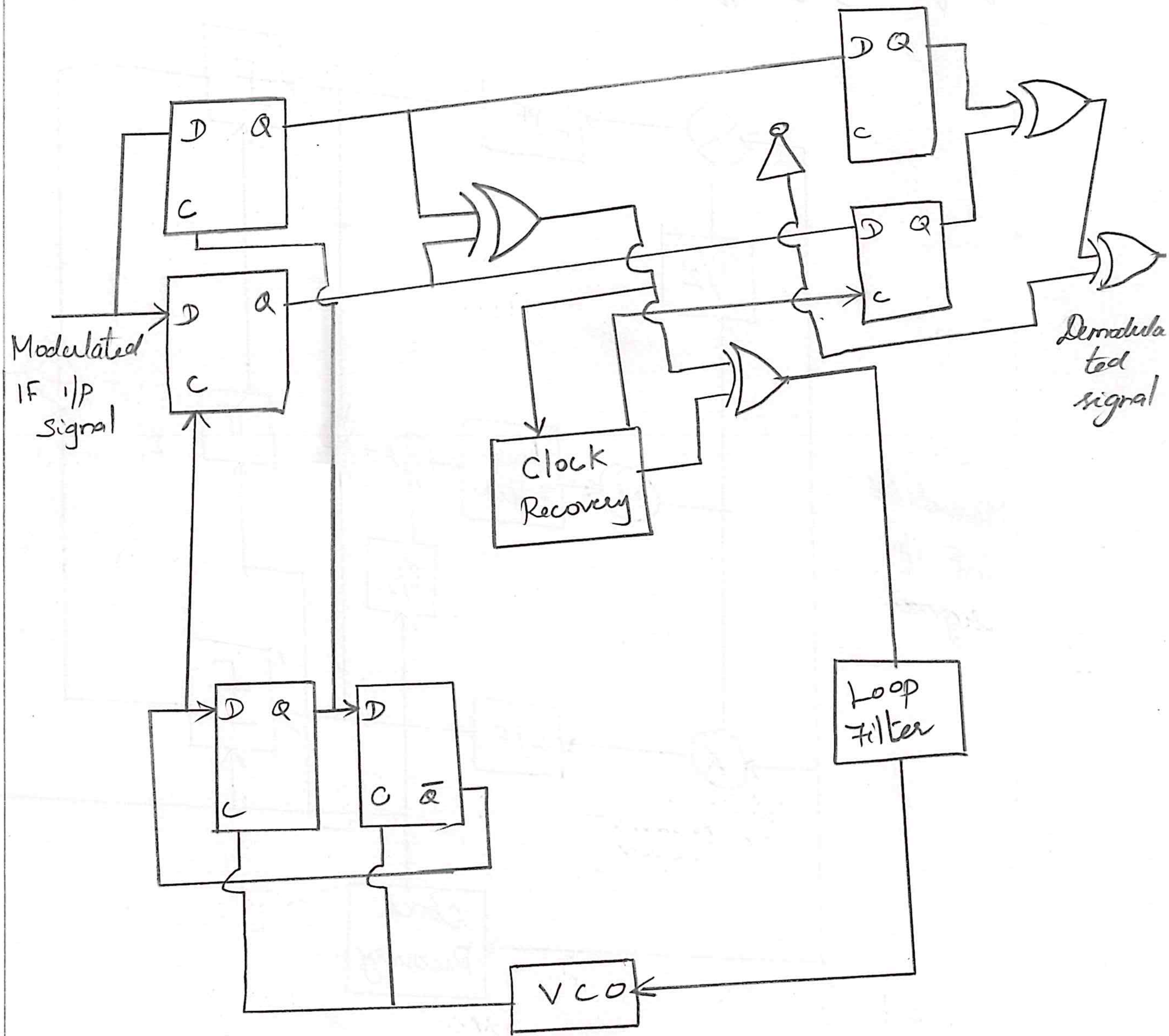


Fig:- Digital logic circuit for GMSK Demodulation

* GMSK signals can be detected using orthogonal coherent detectors or non coherent detectors such as standard FM discriminators.

* The sum of two discrete freq. component centered at the o/p of a freq. doubler is dived by four.

* De Buda's method is similar to the Costas loops and is equivalent to that of a PLL with a frequency doubler.

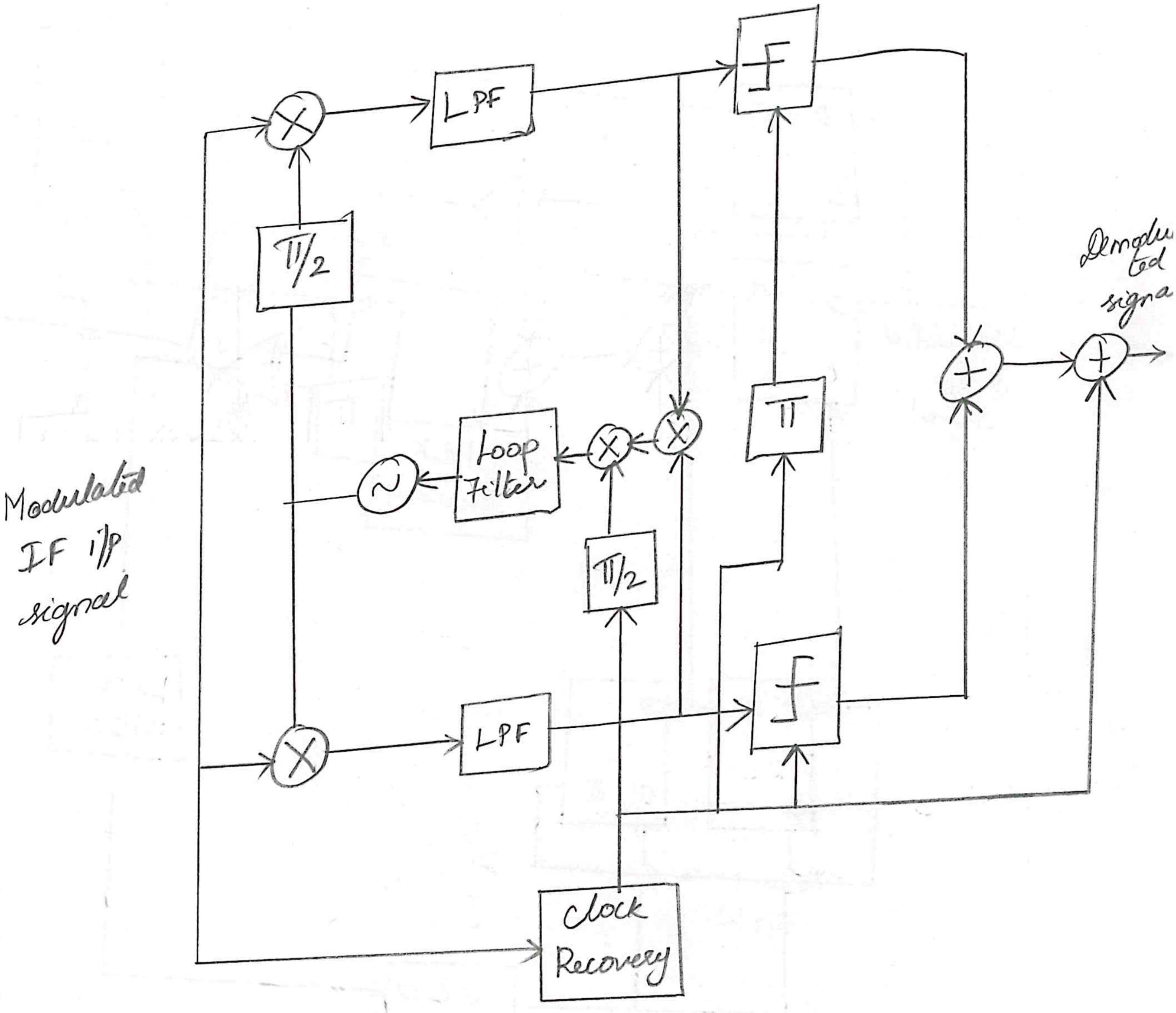


fig:- Block Diagram of a GMSK Receiver

GMSK Bit Error rate:-

* The bit error probability is a fn of BT, since the pulse shaping impacts ISI
* The bit error probability for GMSK is given by,

$$P_e = Q\left\{\sqrt{\frac{2\gamma E_b}{N_0}}\right\} \quad \text{—— (11a)}$$

where γ is a constant related to BT by

$$\gamma = \begin{cases} 0.68 & \text{for GMSK with } BT = 0.25 \\ 0.85 & \text{for simple MSK } (BT = \infty) \end{cases} \longrightarrow (11b)$$

GMSK Transmitter and Receiver:-

* The simplest way to generate a GMSK signal is to pass a NRZ message bit stream through a Gaussian baseband filter, followed by FM modulator.
* It is used in US cellular digital packet data (CDPD) & Global System for mobile (GSM) system.
* Fig. below may also be implemented digitally using a standard I/Q modulator.

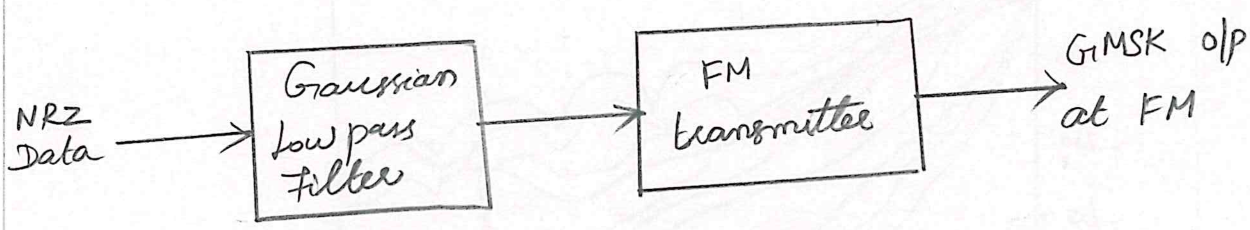


fig:- Block Diagram of a GMSK transmitter using Direct FM generation

* the parameter α is related to B, the 3dB baseband Bandwidth of H(f) by

$$\alpha = \frac{\sqrt{\ln 2}}{\sqrt{2}\, B} = \frac{0.5887}{B} \quad \text{--- (10)}$$

and the GMSK filter may be completed defined from B and the base band symbol duration T.

Power spectrum of GMSK:-

* the power spectrum of MSK, which is equivalent to GMSK with a BT product of infinity.
* BT product decreases, the sidelobe levels fall off very rapidly.
* GMSK irreducible error rate is less than that produced by the mobile channel, there is no penalty in using GMSK.

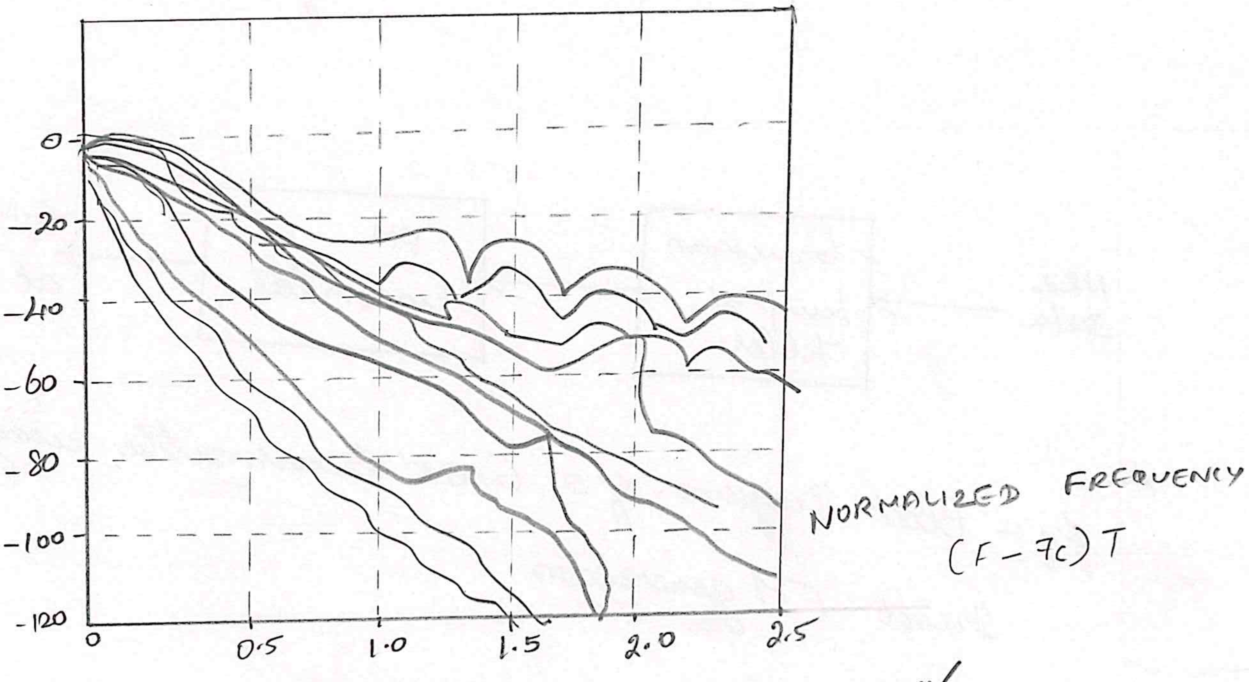


fig:- Power spectral density of a GMSK signal

Gaussian minimum shift keying (GMSK):-

* GMSK is a simple binary modulation scheme which may be viewed as a derivative of MSK.

* Premodulation Gaussian filtering converts the full response message signal into a partial response scheme where each transmitted symbol spans several bit periods.

* GMSK can be coherently or non coherently detected.

* GMSK is most attractive for its power efficiency and spectral efficiency.

* The premodulation Gaussian filtering introduces ISI in the transmitted signal.

GMSK properties:-

* Irreducible error rate.
* Partial response signaling.
* Good spectral efficiency
* Constant envelope properties
* The GMSK premodulation filter has an impulse response given by.

$$h_G(t) = \frac{\sqrt{\pi}}{\alpha} \exp\left(-\frac{\pi^2}{\alpha^2} t^2\right) \quad \text{——} \ (8)$$

and the transfer fn is given by,

$$H_G(f) = \exp(-\alpha^2 f^2) \quad \text{——} \ (9)$$

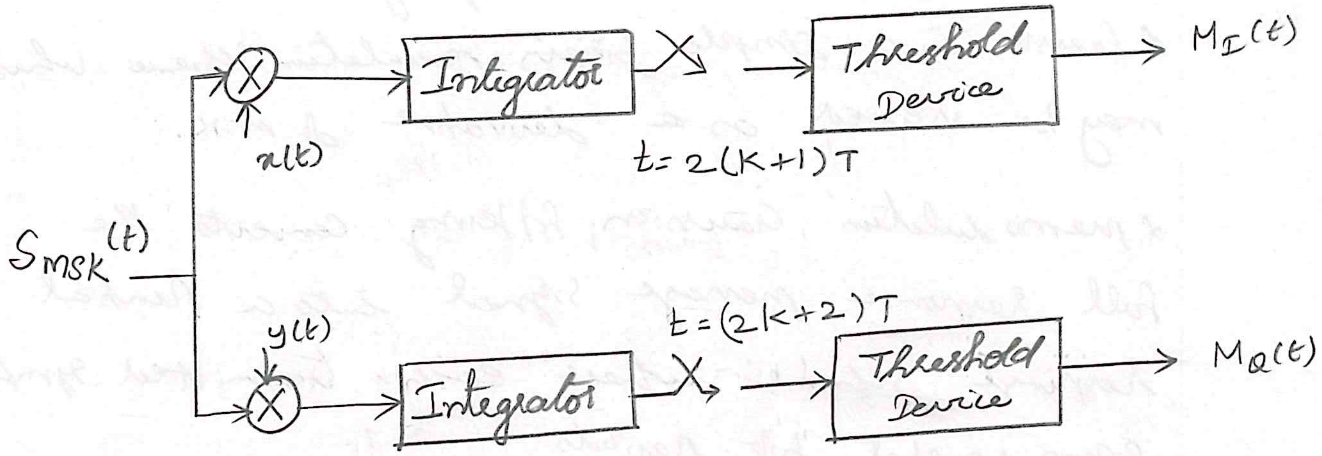


fig:- Block Diagram of MSK Receiver

* multiplying a carrier signal with $\cos(\pi t/2T)$ produces two phase coherent signals at $f_c + 1/4T$ and $f_c - 1/4T$
* two FSK signals are separated using two narrow BPF & combined to form inphase and quadrature phase carrier component $x(t)$ and $y(t)$.
* These carrier are multiplied with odd & even bits streams $m_I(t)$ & $m_Q(t)$ to produce $S_{msk}(t)$.
* The o/p of the multipliers are integrated over 2 bit periods and dumped to a decision ckt.
* The threshold detector decides whether the signal is a 0 or a 1.
* The o/p data streams correspond to $m_I(t)$ and $m_Q(t)$ which are offset combined to obtain the demodulated signal.

* MSK is popular modulation scheme for mobile Radio Communication : Reasons are

* The envelope is kept more or less constant even after band limiting

* Any small variations in the envelope level can be removed by hard limiting at the receiver without raising the out of band radiation levels.

* The continuous phase property makes it highly desirable for highly reactive loads.

* MSK has simple demodulation and Syn. circuits.

MSK Transmitter and Receiver:-

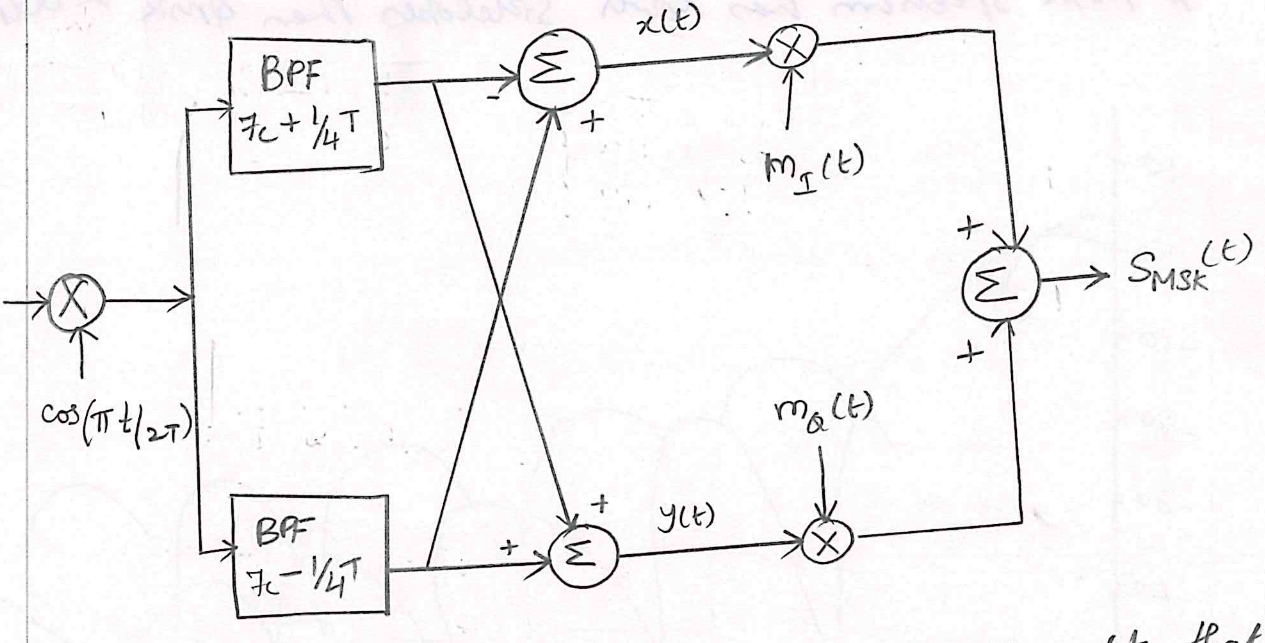


fig:- Block diagram of an MSK Transmitter. Note that $m_I(t)$ and $m_Q(t)$ are offset by T_b

MSK Power spectrum:-

* RF power spectrum is obtained by freq. shifting the magnitude squared of the fourier transform of the base band pulse shaping function.

* For MSK the base band pulse shaping fn. is given by

$$P(t) = \begin{cases} \cos\left(\frac{\pi t}{2T}\right) & |t| < T \\ 0 & \text{o.w} \end{cases} \quad \text{—— (6)}$$

* Thus the normalized power spectral density for MSK is given by.

$$P_{MSK}(f) = \frac{16}{\pi^2}\left(\frac{\cos 2\pi (f+f_c) T}{1.16 f^2 T^2}\right)^2 + \frac{16}{\pi^2}\left(\frac{\cos 2\pi (f-f_c) T}{1.16 f^2 T^2}\right)^2 \quad \text{—— (7)}$$

* MSK spectrum has lower sidelobes than QPSK & OQPSK.

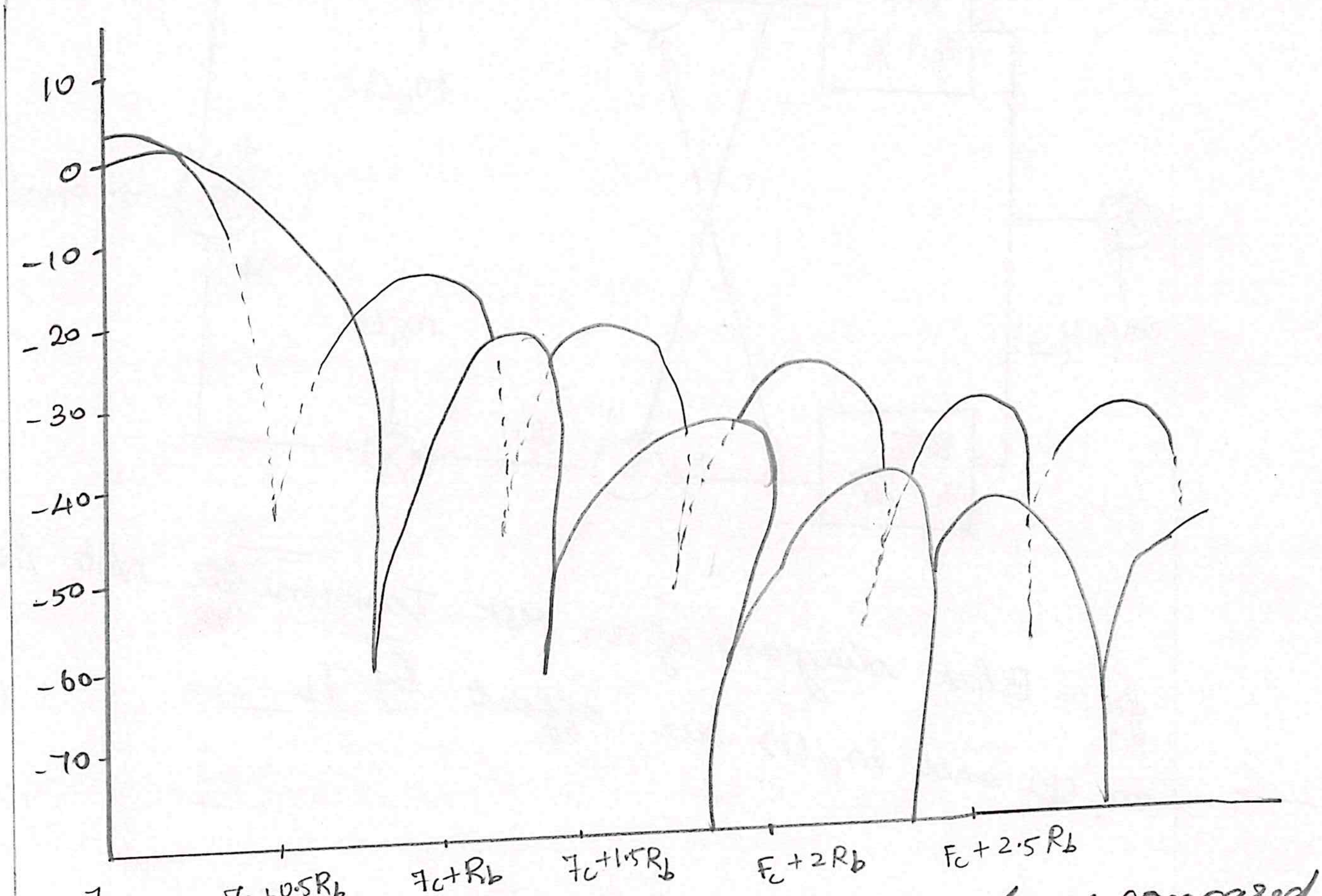


fig:- Power spectral density of MSK signals as compared to QPSK and OQPSK signals

* MSK sometimes referred to as fast FSK, as the freq. spacing used is only half as much as that used in conventional non coherent FSK.

MSK properties:-

* Constant envelope
* spectral efficiency.
* good BER performance.
* self-synchronizing capability.

* If half sinusoidal pulses are used instead of rectangular pulses, the modified signal can be defined as MSK and for an N bit stream is given by,

$$S_{MSK}(t) = \sum_{i=0}^{N-1} m_I(t)\, p[t-2iT_b]\cos 2\pi f_c t + \sum_{i=0}^{N-1} m_Q(t)\, p(t-2iT_b-T_b)\sin 2\pi f_c t \quad \text{--- (2)}$$

where
$$p(t) = \begin{cases} \sin\left(\frac{\pi t}{2T_b}\right) & 0 \le t \le 2T_b \\ 0 & \text{o.w} \end{cases} \quad \text{--- (3)}$$

* The MSK waveform can be seen as a special type of a continuous phase FSK.

$$S_{MSK}(t) = \sqrt{\frac{2E_b}{T_b}}\cos\left(2\pi f_c t - m_I(t)\, m_Q(t)\frac{\pi t}{2T_b} + \phi_k\right) \quad \text{--- (5)}$$

where ϕ_k is 0 or π depending on whether $m_I(t)$ is 1 or -1

* MSK signal is an FSK signal with binary signaling frequencies of $f_c + 1/4T$ and $f_c - 1/4T$.

* The i/p signal is first filtered using a band pass filter that is matched to the transmitted signal.
* The FM discriminator extracts the instantaneous freq. deviation of the received signal.
* when integrated over each symbol period gives the phase difference b/w two sampling instants.
* The modulo-2π phase detector improves the BER performance and reduces the effect of click noise

Minimum Shift Keying (MSK):-
* MSK is a special type of continuous phase freq. shift keying (CPFSK).
* The peak freq. deviation is equal to 1/4 the bit rate.
* The modulation index of an FSK is similar to the FM modulation index.

$$k_{FSK} = (2\Delta F)/R_b;$$

where $\Delta F \rightarrow$ peak RF freq. deviation.

$R_b \rightarrow$ bit rate.

* The name MSK implies the min. freq. separation that allows orthogonal detection.
* Two FSK signals $V_H(t)$ and $V_L(t)$ are said to be orthogonal if,

$$\int_0^T V_H(t) V_L(t)\, dt = 0 \quad \text{— (1)}$$

Spread Spectrum (SS) modulation Techniques:-

* Spread Spectrum modulation is a technique where by a modulated signal is modulated second time in such a way so as to generate an expanded bandwidth (wideband) signal, that does not significantly interfere with the other signal.

* Spreading is achieved by a Pseudo-Noise (PN) code which is independent of the data sequence. The same code is used at the receiver to de spread the received signal.

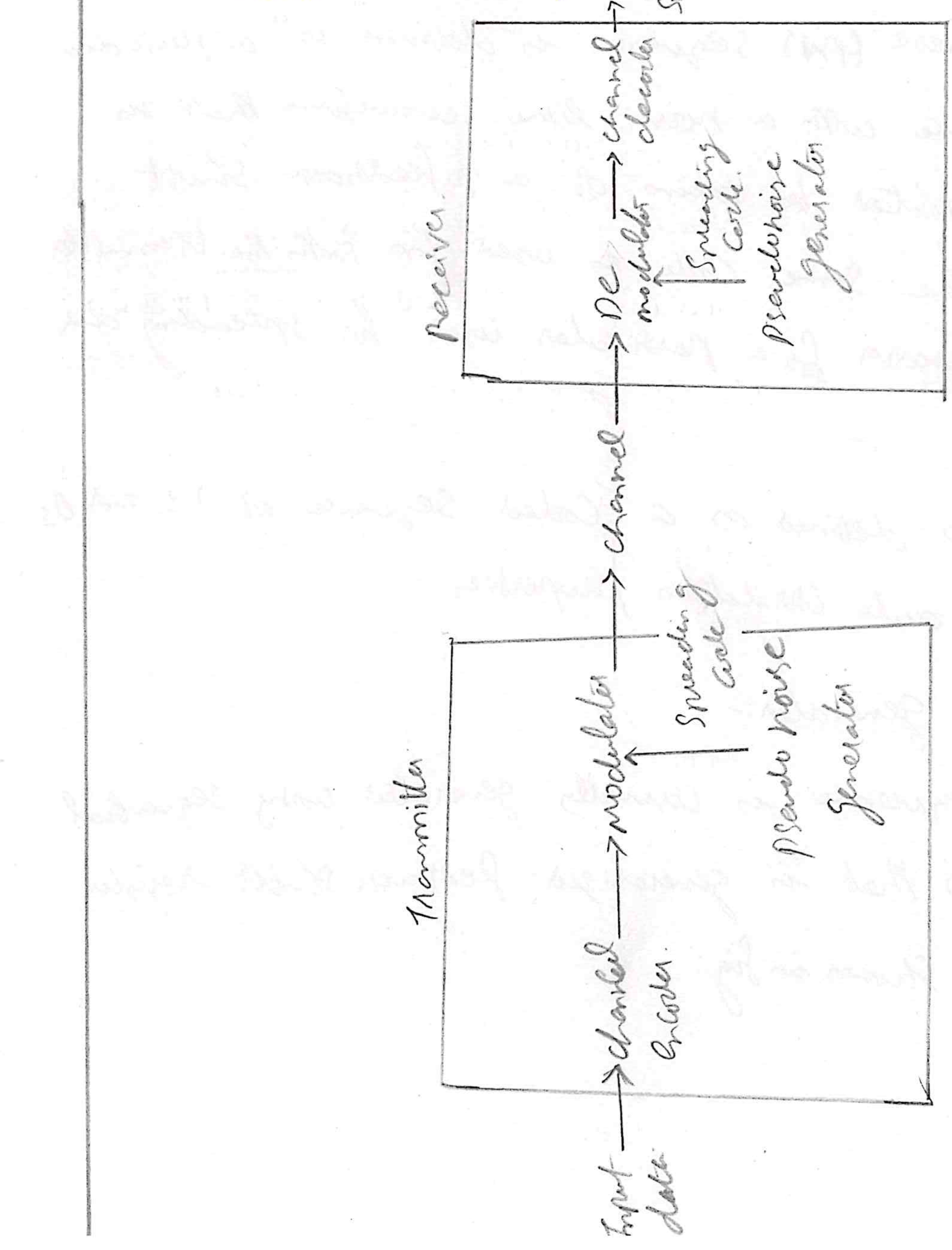


Fig: model of Spread Spectrum technique

Classification of Spread Spectrum (SS)

SS modulation.

- Direct Sequence Spread Spectrum (DS-SS)
- Frequency hop Spread Spectrum (FH-SS)

Pseudo-Noise (PN) Sequences:-

* A pseudo noise (PN) sequence is defined as "a periodic binary sequence with a noise like waveform that is usually generated by means of a feedback shift register". The same code is used for both the transmitter and the receiver for a particular user for spreading and despreading.
* It is also defined as a coded sequence of 1s and 0s with certain auto correlation properties.

PN sequence generator:-

* The PN sequence is usually generated using sequential logic circuits that is generalized feedback shift register with m stages shown in fig.

* It consist of consecutive stages of two-state memory devices and feedback logic. The binary sequences are shifted through the shift registers in response to clock pulse and the output of the various stages are logically combined and feedback as the input to the first stage.

* When the feedback logic consists of exclusive-OR gates, then the shift register is called as linear PN sequence generator.

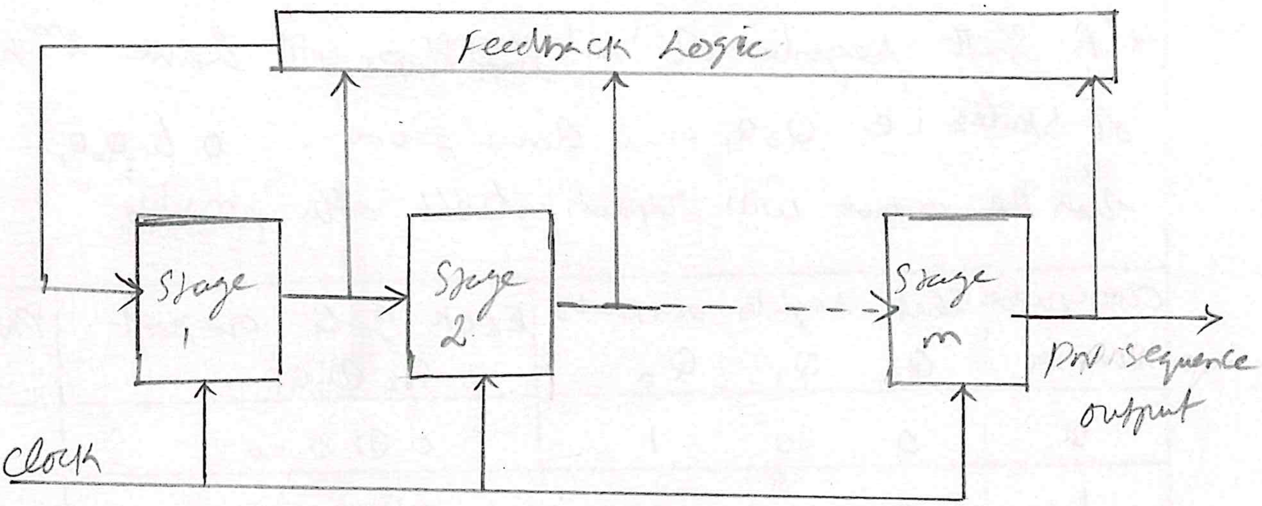


Fig. Block diagram of a generalized feedback shift register with m stages.

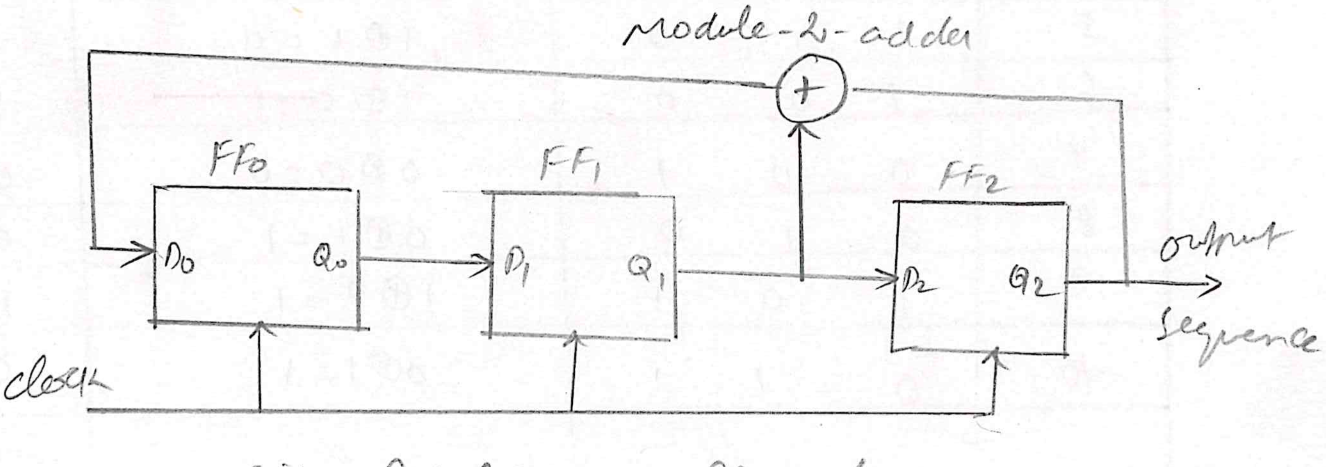


Fig. PN sequence generator.

* An Example of a PN Sequence generator is shown in fig. This is basically a shift register. Type D-flipflops are being connected such that the Q output of ~~previous~~ previous flip flop is connected as input to D.

* To obtain the PN sequence, assume initial state of $Q_2Q_1Q_0$ to 100. The output Q_1 and Q_2 are connected to a modulo-2 adder. i.e., an EX-OR gate. The following table summarizes the operation of the PN generator.

* A shift register of 'm' flip flops will have 2^m number of states i.e $Q_0Q_1 \ldots Q_{m-1} = 000 \ldots 0$ to $Q_0Q_1 \ldots Q_{m-1} = 111 \ldots 1$. Thus the output will repeat itself after 2^m bits.

Clock pulse Number	Shift register outputs Q_2	Q_1	Q_0	EXOR gate output $Q_2 \oplus Q_1$	PN sequence Q_2
0	0	0	1	$0 \oplus 0 = 0$	0
1	0	1	0	$0 \oplus 1 = 1$	0
2	1	0	1	$1 \oplus 0 = 1$	1
3	0	1	1	$0 \oplus 1 = 1$	0
4	1	1	1	$1 \oplus 1 = 0$	1
5	1	1	0	$1 \oplus 1 = 0$	1
6	1	0	0	$1 \oplus 0 = 1$	1
7	0	0	1	$0 \oplus 0 = 0$	0
8	0	1	0	$0 \oplus 1 = 1$	0
9	1	0	1	$1 \oplus 0 = 1$	1
10	0	1	1	$0 \oplus 1 = 1$	0

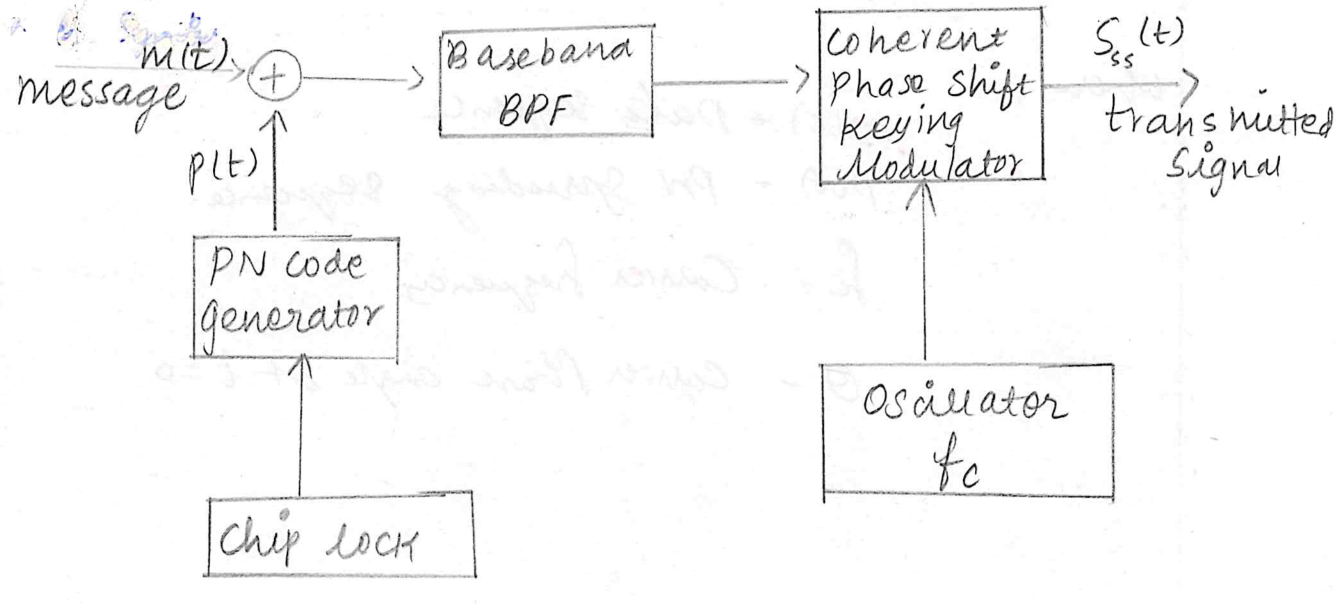
Table: operation of the PN sequence generator.

* The character generated by a PN sequence generator depends on the number of flip flops (m) used and on the selection of which flip flops outputs are connected to the inputs of modulo-2 adder.

* The state of each flip flop changes and gets shifted to the next flip flops corresponding to each pulse of the clock. The maximum length of the sequence will be $2^m - 1$. This is because the state 000...0 must be excluded.

Direct Sequence Spread Spectrum (DS-SS) :-

A Direct sequence spread spectrum (DS-SS) system spreads the base band data by directly multiplying the base band data pulses with a pseudo noise sequence which is produced by a pseudo-noise code generator.



Transmitter.

* A single pulse or symbol of the PN waveform is called a chip. Fig. shows a functional block diagram of a DS system with binary phase modulation.

* A synchronized data symbols, which may be information bits or binary channel code symbols, are added in modulo 2 fashion to the chips before being phase modulated.

* A coherent or differentially coherent phase shift keying (PSK) demodulation may be used in the receiver. The received spread spectrum signal for a single user can be represented as,

$$S_{ss}(t) = \sqrt{\frac{2E_s}{T_s}}\, m(t)\, p(t) \cos(2\pi f_c t + \theta)$$

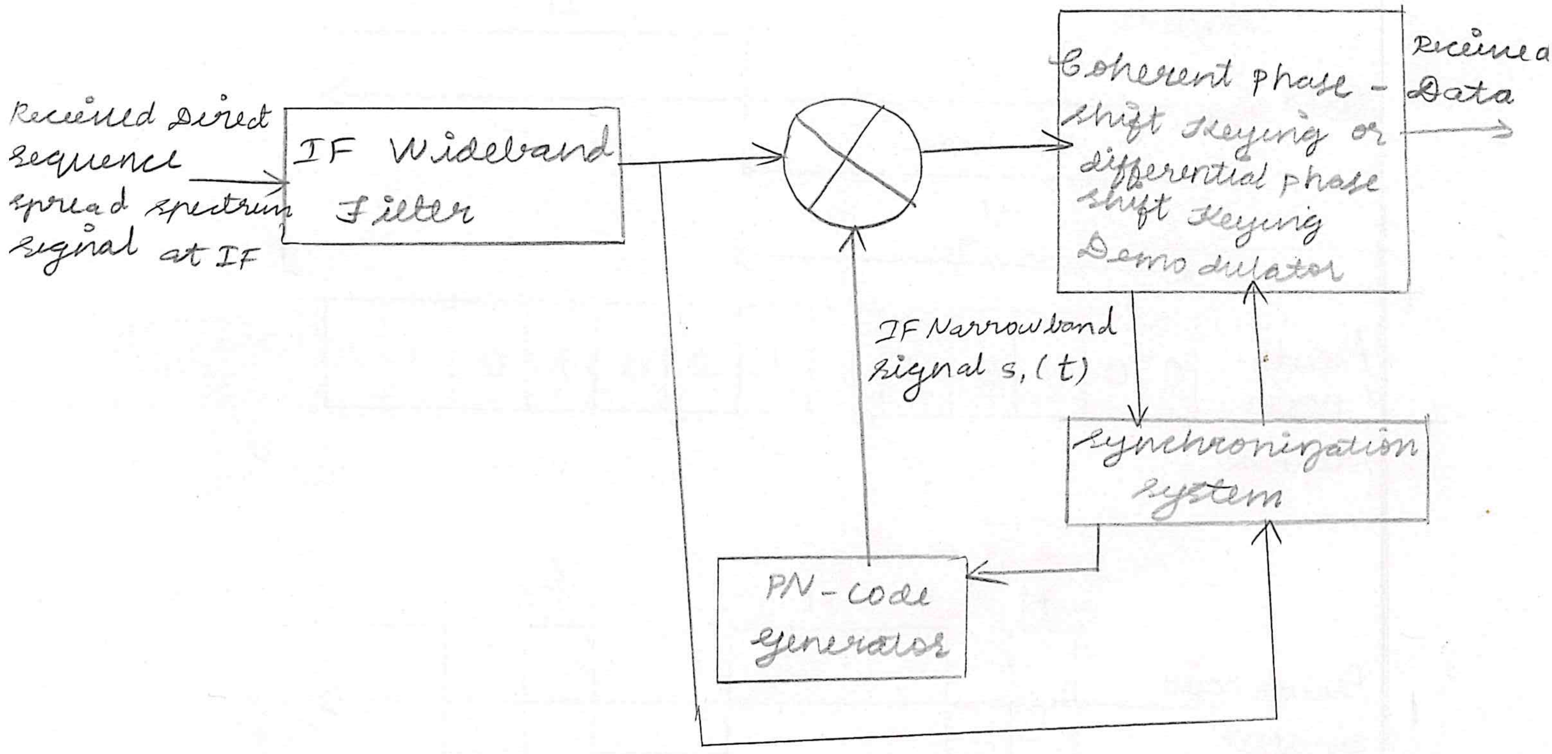
where,

m(t) = Data sequence

p(t) - PN spreading sequence.

f_c = Carrier frequency

θ - Carrier phase angle at $t=0$

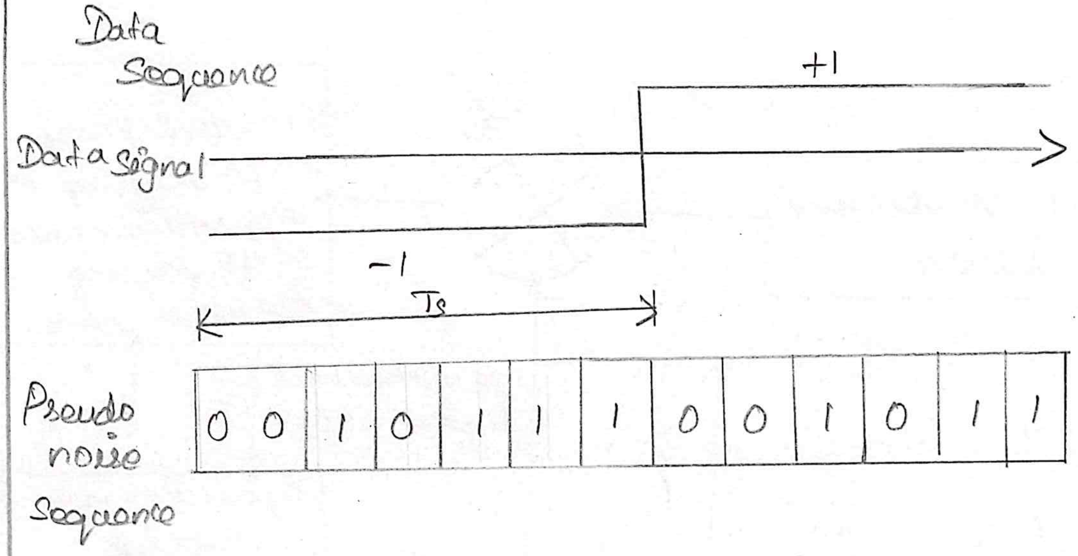


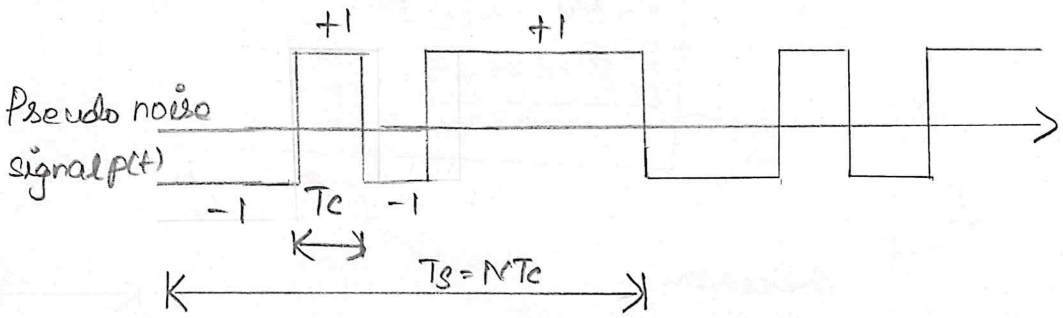
Receiver.

DS-SS Waveforms:-

* The data waveform is a time sequence of non-overlapping rectangular pulses and each has amplitude equal to +1 or -1. Each symbol in m(t) represents a data symbol and has duration T_s

* If B_{ss} is the bandwidth of $S_{ss}(t)$ and B is the bandwidth of a conventionally modulated signal $m(t)\cos(2\pi f_c t)$. The spreading due to p(t) gives $B_{ss} >> B$.





DS_SS Receiver:-

* The fig illustrates a DS receiver and assumes that code sync. has been achieved at the receiver. The received signal passes through the wide band filter and it is multiplied by a local replica of the PN code sequence p(t)

* If $p(t) = \pm 1$ then $p^2(t) = 1$ and this multiplication gives the despread signal $s(t)$ at the input of demodulator as,

$$s_1(t) = \sqrt{\frac{2E_s}{T_s}}\, m(t) \cos(2\pi f_c t + \theta)$$

Processing gain:-

The processing gain is the gain achieved by processing a spread spectrum signal over an unspreaded signal.

It is defined as "the ratio of the bandwidth of the spread spectrum signal to the bandwidth of the unspreaded signal"

$$\text{processing gain (PG)} = \frac{\text{BW of spread spectrum signal}}{\text{BW of unspreaded signal.}}$$

$$PG = \frac{B_{ss}}{B} = \frac{\frac{1}{T_c}}{\frac{1}{T_s}} = \frac{T_s}{T_c}$$

Modulation performance in fading and multipath channels:

* The mobile radio channel is characterized by various impairments such as fading, multipath and Doppler spread.
* BER does not provide information about the bursty errors in modulation scheme.
* In a mobile radio environment to study the effectiveness of any modulation scheme, it is necessary to evaluate the performance of the modulation scheme over mobile channel conditions.

* Bit error rates and probability of outage for various modulation schemes under various types of channel impairments can be evaluated either through analytical techniques or through simulations.

* Analytical techniques are used for BER in slow fading channels while the performance in freq. selective channel & computation of probability of outage are often done through computer simulation.

1. Performance in slow fast fading channels:-

* The probability of error of the particular modulation in AWGN channels over the possible ranges of signal strength due to fading is averaged out.

* The probability of error in a slow flat fading channel is given by $P_e = \int_0^\infty P_e(X)\, p(X)\, dX$.

where, $P_e(X)$ is the probability of error for an arbitrary modulation at a specific value of SNR ration α.

and $X = a^2 E_b/N_0$

* For Rayleigh fading channels, α has a Rayleigh distribution, so α^2 and consequently X have chi-square distribution with two degrees of freedom. Hence

$$p(X) = \frac{1}{\Gamma} \exp\left(-\frac{X}{\Gamma}\right) \quad X \geq 0$$

where $\Gamma = \frac{E_b}{N_o}\alpha^2$ is the average value of the SNR.

* the probability of error in a slow, flat fading channel can be expressed for coherent binary PSK and coherent binary FSK as:

For coherent binary PSK:

$$P_{e,PSK} = \frac{1}{2}\left[1 - \sqrt{\frac{\Gamma}{1+\Gamma}}\right]$$

For coherent binary FSK:

$$P_{e,FSK} = \frac{1}{2}\left[1 - \sqrt{\frac{\Gamma}{2+\Gamma}}\right]$$

For differential binary PSK:

$$P_{e,DPSK} = \frac{1}{2(1+\Gamma)}$$

For non-coherent orthogonal binary FSK:

$$P_{e,NCFSK} = \frac{1}{2+\Gamma}$$

For coherent GMSK:

$$P_{e,GMSK} = \frac{1}{2}\left(1 - \sqrt{\frac{\delta\Gamma}{\delta\Gamma+1}}\right) = \frac{1}{4\delta\Gamma}$$

where δ is ranging between 0.68 and 0.85

2. Performance in frequency selective mobile channels:

* The irreducible error floor in a freq. selective channel is primarily caused by the errors due to the ISI, which interferences with the signal component at the receiver sampling instants.

* This occurs in following situations:

(a) The main signal component is removed through multipath cancelation

(b) A non zero value of d causes ISI or

(c) The sampling time of a receiver is shifted as a result of delay spread.

* These factors impose bounds on the data rate and BER that can be transmitted reliably over a freq. selective channel.

* Simulation is the major tool used for analysing freq. selective fading effects.

Diversity Techniques:-

* Diversity technique is the most effective technique that can be used to nullify the effect of multipath fading.

* The basic theory behind the use of diversity in a wireless system is as follows: Any fading of the transmitted signal that occurs will not remain the same over time nor will it be the same over different signal paths or be the same for different frequencies.

* Diversity plays an important role in combating fading, co-channel interference, avoiding error bursts and it may exploit the multipath propagation resulting in a diversity gain.
* The diversity techniques provide two or more number of inputs at the mobile reception end such that fading among these two inputs are not correlated.

Types of diversity:-

There are several different kinds of diversity which are commonly employed in wireless communication system as follows.

1. Time diversity:-

* In time diversity method, the information is transmitted repeatedly at specific time spacings that would exceed the coherence time of the mobile channel and this will lead to repetition of signals for several times, irrespective of fading conditions.
* When an identical information is sent for different time slots, it is possible to obtain diversity branch signals.
* The time diversity technique is well suited for spread spectrum CDMA systems, in which, RAKE receiver is used for reception.

2. Frequency diversity:-

* Fading is a major problem and in order to reduce it, diversity is being used.

* Diversity techniques are used in wireless communications to mitigate the effect of fading over a radiochannel.

* Freq. diversity is a costly mechanism to use because of the difficulties to generate several transmitted signals and the combining signals received at several different frequencies simultaneously.

There are two types of freq. diversity.

(a) Frequency hop spread - spectrum.

(b) Direct sequence spread - spectrum.

3. Space diversity:-

* In space diversity technique two antennas are separated by a distance 'd' so as to get two i/p signal with low correlation among fading effects.

* The antenna would be at a height of 'h' from ground level at the cell site. As the distance 'd' between antennas varies with change in antenna height for both cell site and mobile antenna.

Equalization and diversity:-

Mobile communication systems require signal processing techniques that improve the link performance in hostile mobile radio environments.

Three popular techniques are

1. Equalization : Compensates for ISI.
2. Diversity : Compensates for channel fading.
3. Channel coding: Detects or Correct Errors.

* Equalization refers to any signal processing technique that eliminates or reduces this ISI before symbol detection.
* If the modulation bandwidth exceeds the coherence bandwidth of the radio channel, ISI occurs and modulation pulses are spread in time.
* Equalization compensates for ISI created by multipath within time dispersive channels.
* The o/p of an equalizer should be a Nyquist pulse for a single symbol case from which digital data can be recovered.
* Equalizer work by keeping the bit error rate as low as possible and SNR as high as possible

Equalization Categories:-

In general, equalization is partitioned into two broad categories.

1. Maximum Likelihood sequence Estimation (MLSE):
which entails making measurement of channel impulse response and then providing a means for adjusting the receiver to the transmission environment.

2. Equalization with filters:- It uses filters to compensate the distorted pulses. A pair of general channel and equalizer is used.

Depending on the time nature:-

* these types of equalizers can be grouped as preset or adaptive equalizers.

* Preset equalizers:- assume that the channel is time invariant and try to find H(f) and design equalizer depending on H(f)
* Adaptive equalizers:- assume channel is time varying channel and try to design equalizer filter whose filter coefficients are varying in time according to the change of channel and try to eliminate ISI and additive noise at each time.

Structure of a linear Transversal Equaliser:-

* when feed back path to adapt the equalizer is not used, the equalization is not said to be linear equalization and equalizer is called non-linear equalizer.
* the Linear Transversal Equalizer (LTE) is most common equalizer structure.

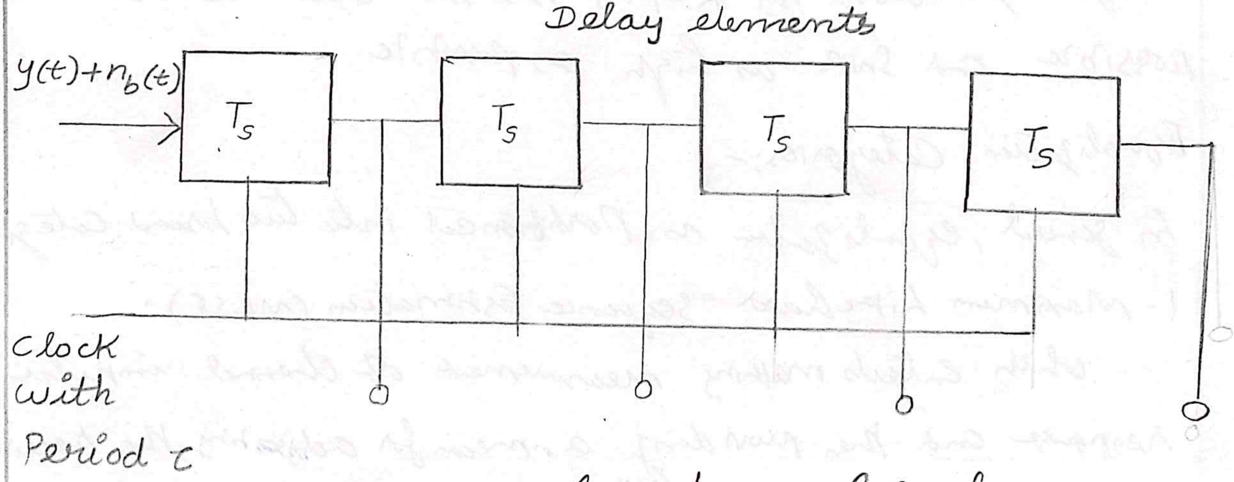


Fig: Basic linear transversal equalizer

* A simple LTE uses only feed forward taps and the transfer function of the equaliser filter is a polynomial in z^{-1}. Also it has many zeroes but poles only at $z=0$ and is called a finite impulse response (FIR) filter, or simply a transversal filter.

* In Linear Transversal Equalizer, the current and past values of the received signal are linearly weighted by the filter co-efficient and summed to produce the output.

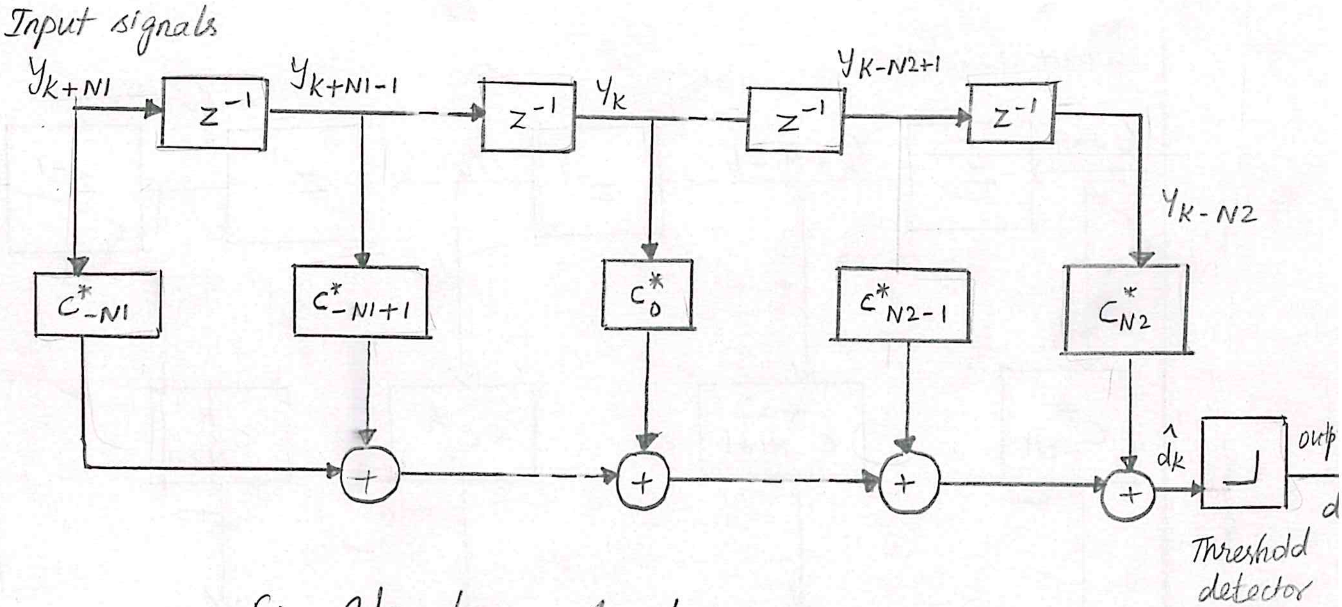


Fig: Structure of LTE.

* The output of this transversal filter before decision making is expressed by

$$\hat{d}_K = \sum_{n=-N_1}^{N_2} C(n^*) y_{K-n}$$

C_n^* - Complex filter co-efficients.

$\hat{d}_K$ - o/p at time index K,

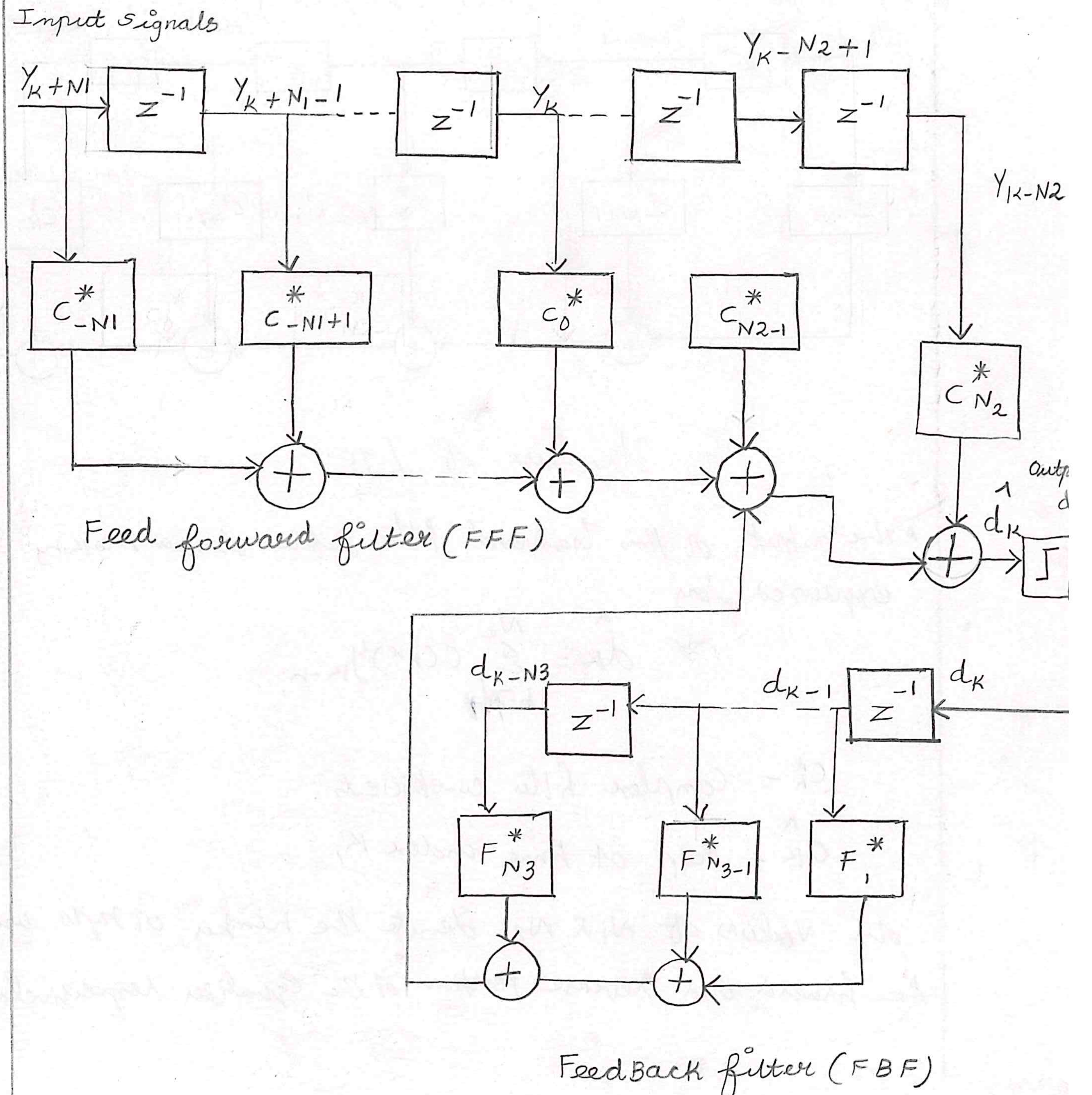
the values of N_1 & N_2 denote the number of taps used in the forward and reverse portions of the equalizer respectively.

The minimum mean squared error for LTE is:

$$E[|e(n)|^2] = \frac{T}{2\pi} \int_{-\pi/T}^{\pi/T} \frac{N_0}{|F(e^{j\omega T})|^2 + N_0} d\omega$$

where $F(e^{j\omega T})$ is the frequency response of the channel and N_0 is the noise spectral density.

Decision feedback Equalizer (DFE):-



* A DFE is a non linear equalizer that uses previous detector decisions to eliminate the ISI on pulses that are currently being demodulated.

* The basic idea of a DFE is that if the values of the symbols previously detected are known, then the ISI contributed by these symbols can be cancelled out exactly the o/p of the forward filter by subtracting past symbols values with appropriate weighting

* The DFE can be realized in either the direct transversal form or as a lattice filter.

* The DFE ~~can be realized in either~~ consist of a feed-forward filter (FFF) and a feed back filter (FBF).

* Adaptive DFE algorithm is similar to stochastic gradient algorithm, with the important difference that the i/p to the casual portion of the filter is the decisions rather than the o/p of the precursor equalizer filter.

* This difference will obviously change the desired tap co-efficients as well as reduce the noise enhancement due to equalization

Channel Coding :-

* Channel coding is used to improve mobile communication link performance by adding redundant databits in the transmitted message.

* Channel coding is mostly accomplished by selectively introducing redundant bits into the transmitted information stream.

these additional bits allow detection and collection of bits errors then originally received date stream and provide more reliable information transmission.

* The cost of using channel coding to protect information is a reduction in data rate or an expansion in bandwidth.

* The coded message then modulated for transmission in the wireless channel.

* Two general types of channel codes: Block codes convolution codes

* Commonly used block codes are Hamming codes, Golay codes, BCH codes and Reed Soloman codes. There are many ways to decode block codes and estimate the K-information bits.

* Convolution codes convert the entire data stream into one single code word. The encoded bits depend not only on the current K bits but also on past i/p bits. The main decoding strategy for convolution code is based on the widely used Viterbi algorithm.

Unit IV

Multiple Access Techniques.

Introduction: Introduction to multiple Access – Frequency Division multiple Access (FDMA) – Time division multiple Access (TDMA) – Spread Spectrum multiple Access – Code division multiple Access (CDMA) – Space division multiple Access (SDMA) – Capacity of cellular systems: capacity of cellular CDMA, Capacity of CDMA with multiple Cells.

Multiple Access techniques:

"Multiple Access Schemes are used to allow many users to share simultaneously a finite amount of radio spectrum"

* The Sharing of Spectrum is required to achieve high capacity by simultaneously allocating the available Bandwidth to multiple users.
* "It is possible to talk and listen simultaneously and this effect" is called duplexing.
* Duplexing may be done using freq. or time domain techniques.
* Freq. division duplexing provides two distinct bands of frequencies for every user.
* Forward band – provides traffic from the BS to MS
* Reverse band – provides traffic from the MS to BS.

* Time division duplexing (TDD) uses time instead of freq. to provide both forward & Reverse Link.

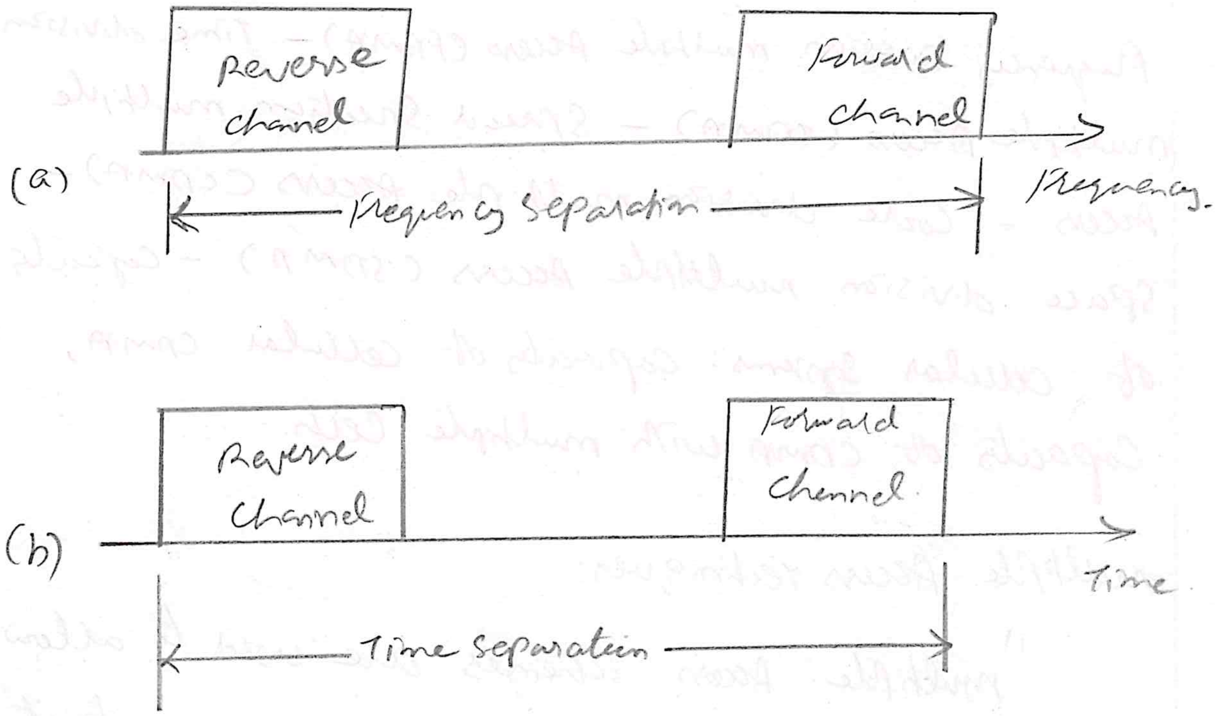


Fig (a) FDD (b) TDD.

* There are 3 major access techniques used to share the available bandwidth in a wireless communication

1. Frequency division multiple Access (FDMA)
2. Time division multiple Access (TDMA)
3. Code division multiple Access (CDMA).

These techniques can be grouped as Narrow band and wideband systems. depending upon how the available bandwidth is allocated to the users.

Frequency Division multiple Access (FDMA):-

Freq. division multiple Access (FDMA) assigns individual channels to individual users.

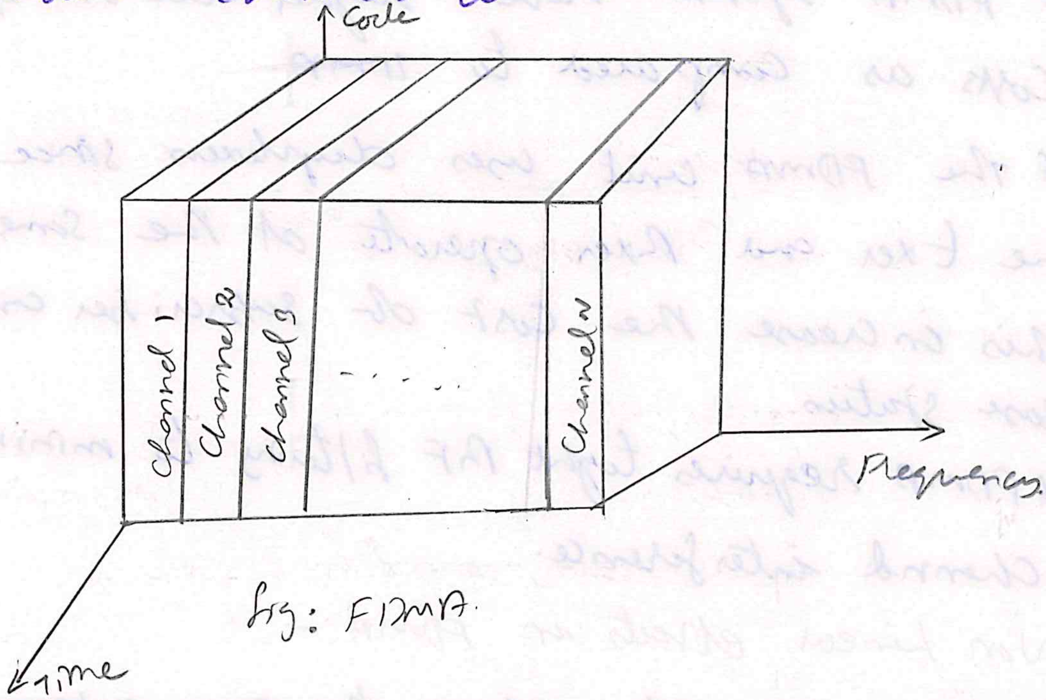


fig: FDMA.

* During the period of the call, no other user can share the same channel.
* In FDD systems, the users are assigned a channels as a pair of frequencies.
  - one freq. is used for forward channel
  - other freq. is used for reverse channel.

Features of FDMA:-

* The FDMA channel carries only one phone circuit at a time.
* After the assignment of a voice channel the BS and the mobile transmit simultaneously and continuously.
* The Bandwidth of FDMA channels are narrow (30KHZ in AMPS).

* The amount of ISI is Low.

* No equalization is required in FDMA narrow systems.

* FDMA system have higher cell site system costs as compared to TDMA.

* The FDMA unit uses duplexers since both the txer and Rxer operate at the same time. This increase the cost of subscriber unit and Base station.

* FDMA requires tight RF filtering to minimize channel interference.

Non Linear effects in FDMA:-

* Many channels share the same antenna of the BS.

* The non-linearities cause signal spreading in the freq. domain and generate Inter modulation freq.

* The first US analog cellular system, the AMPS is based on FDMA / FDD.

* The no. of channels that can be simultaneously supported in a FDMA system is given by.

$$N = \frac{B_t - 2B_{guard}}{B_c} \quad (1)$$

where B_t → Total spectrum allocation.

B_{guard} → Guard Band

B_c → Channel Bandwidth.

Time Division Multiple Access (TDMA):-

* "Time Division Multiple Access (TDMA) System divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive".

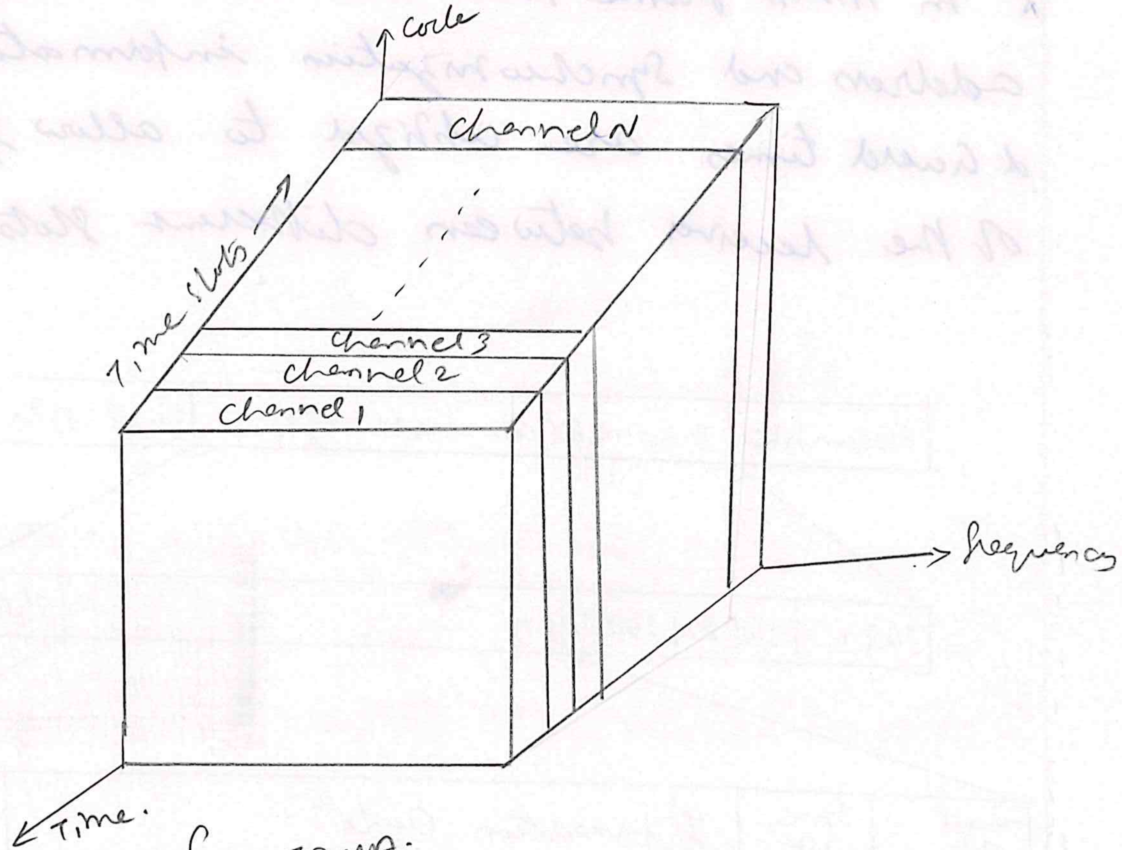


fig: TDMA.

* N time slots comprise a frame.
* TDMA systems transmit data in a buffer and burst method, thus the transmission for any user is non-continuous.
* A frame consist of a number of slots.
* Each frame is made up of a preamble an information, message and tail bits.

* In TDMA/TDD, half of the time slots in frame information message would be used for forward link channels and half would be used for reverse channels.
* In TDMA frame, the preamble contains the address and synchronization information.
* Guard times are utilized to allow synchronization of the receiver between different slots and frames.

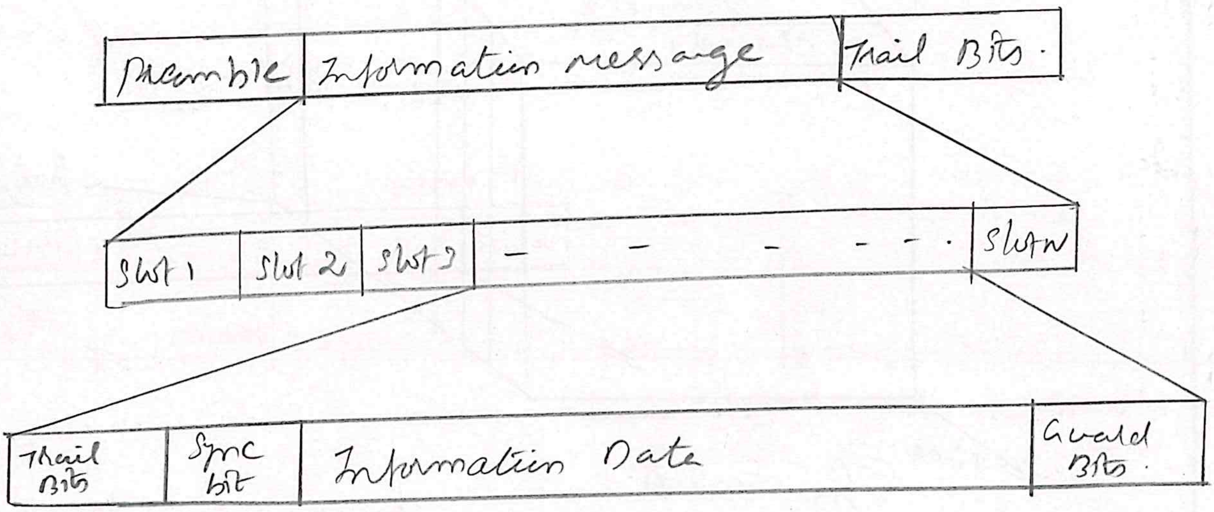


fig. TDMA frame structure.

Features of TDMA :-

* TDMA shares a single carrier freq. with several users, where each user makes use of non-overlapping time slots.
* Data transmission for users of a TDMA system is not continuous, but occurs in bursts.
* TDMA uses different time slots for trans & reception thus duplexers are not required.

* An enhanced link control, such as that provided by mobile assisted hand off (MAHO) can be carried out by a subscriber by listening on an idle slot in the TDMA frame.

* In TDMA, guard time should be minimized

* Higher synchronization overhead is required in TDMA systems because of burst transmission.

* TDMA has an advantage in that it is possible to allocate different numbers of time slots per frame to different users.

Efficiency of TDMA:-

* "The efficiency of a TDMA system is a measure of the percentage of tred data that contain information as opposed to providing overhead for the access scheme"

* The frame efficiency η_f, is the percentage of bits per frame which contain tred data".

* The number of overhead bits per frame

$$b_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g.$$

where;

$N_r \rightarrow$ Number of reference burst per frame.

$N_t \rightarrow$ Number of traffic bursts per frame.

$b_r \rightarrow$ No. of overhead bits per reference burst.

$b_p \rightarrow$ No. of overhead bits per preamble in each slot.

$b_g \rightarrow$ No. of equivalent bits ~~per preample~~ in each guard time interval. ~~each slot~~

* The total number of bits per frame, b_T is

$$b_T = T_f R$$

where $T_f \rightarrow$ frame duration

$R \rightarrow$ channel bit rate.

* The frame efficiency η_f is,

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\%$$

Number of channels in TDMA system:-

The number of TDMA channel slots that can be provided in a TDMA is found by multiplying the number of TDMA slots per channel by the no. of channels available is given by,

$$N = \frac{m(B_{tot} - 2 B_{guard})}{B_c}$$

where $m \rightarrow$ max. number of TDMA users supported on each radio channel.

Code division multiple Access (CDMA):-

* In code division multiple access (CDMA) systems, the narrow band message signal is multiplied by a large bandwidth signal called the spreading signal.
* The spreading signal is a pseudonoise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message

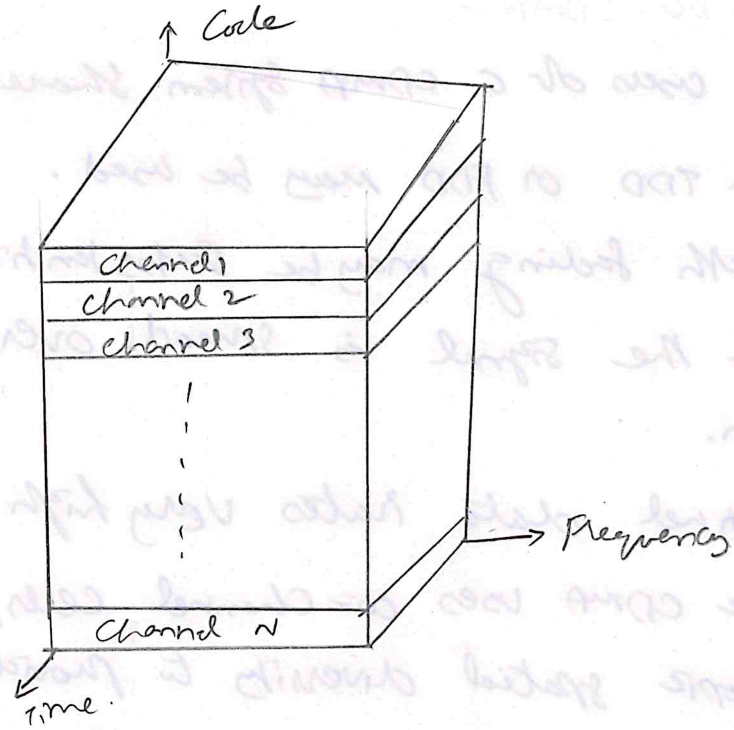


Fig: Spread spectrum multiple access.

* Each user has its own pseudorandom code word which is approximately orthogonal to all other code words.
* The receiver performs a time correlation operation to detect only the specific desired code word.
* All other code words appear as noise due to decorrelation.
* To combat the near far problem, power control is used in most CDMA implementations.
* Power control is implemented at the base station by rapidly sampling the radio signal strength indicator (RSSI) levels of each mobile and then sending a power change command over the forward radio link.

Features of CDMA:-

* Many users of a CDMA system share the same freq.
* Either TDD or FDD may be used.
* Multipath fading may be substantially reduced because the signal is spread over a large spectrum.
* Channel data rates very high in CDMA systems.
* Since CDMA uses co-channel cells, it can use macroscopic spatial diversity to provide soft handoff.
* Self jamming is a problem in CDMA system.
* The near far problem in CDMA system occurs CDMA receiver if an undesired user has a high detected power as compared to the desired user.

Capacity Calculations:-

* "Channel capacity for a radio system can be defined as the max. number of channels or users that can be provided in a fixed freq. band".
* "Radio capacity is a parameter which measure spectrum efficiency of a wireless system. This parameter is determined by the required C/I and the channel Bandwidth Bc.
* The interference at a BS Rxer will come from the subscriber units in surrounding cells - Reverse channel interference.

* The desired BS will provide the desired forward channel while the surrounding co-channel BS will provide the forward channel interference.

Let D → Distance b/w two co channel cells.

R → Cell Radius.

* The min. ratio of D/R that is required to provide a tolerable level of co-channel interference is called cochannel reuse ratio

$$Q = D/R \quad \text{—— (1)}$$

* M closest co-channel cells may be considered as first order interference in which case C/I is given by,

$$\frac{C}{I} = \frac{D_0^{-n_0}}{\sum_{K=1}^{M} D_K^{-n_K}} \quad \text{—— (2)}$$

where n_0 → path loss exponent in the desired cell.

D_0 → distance from the desired BS to mobile

D_K → Distance of the K^{th} cell from the mobile.

n_K → path loss exponent to the K^{th} interfering BS.

* If only the six closest interfering cells are considered, then C/I is given by,

$$\frac{C}{I} = \frac{D_0^{-n}}{6D^{-n}} \quad \text{—— (3)}$$

Carrier-to-Interference Ratio

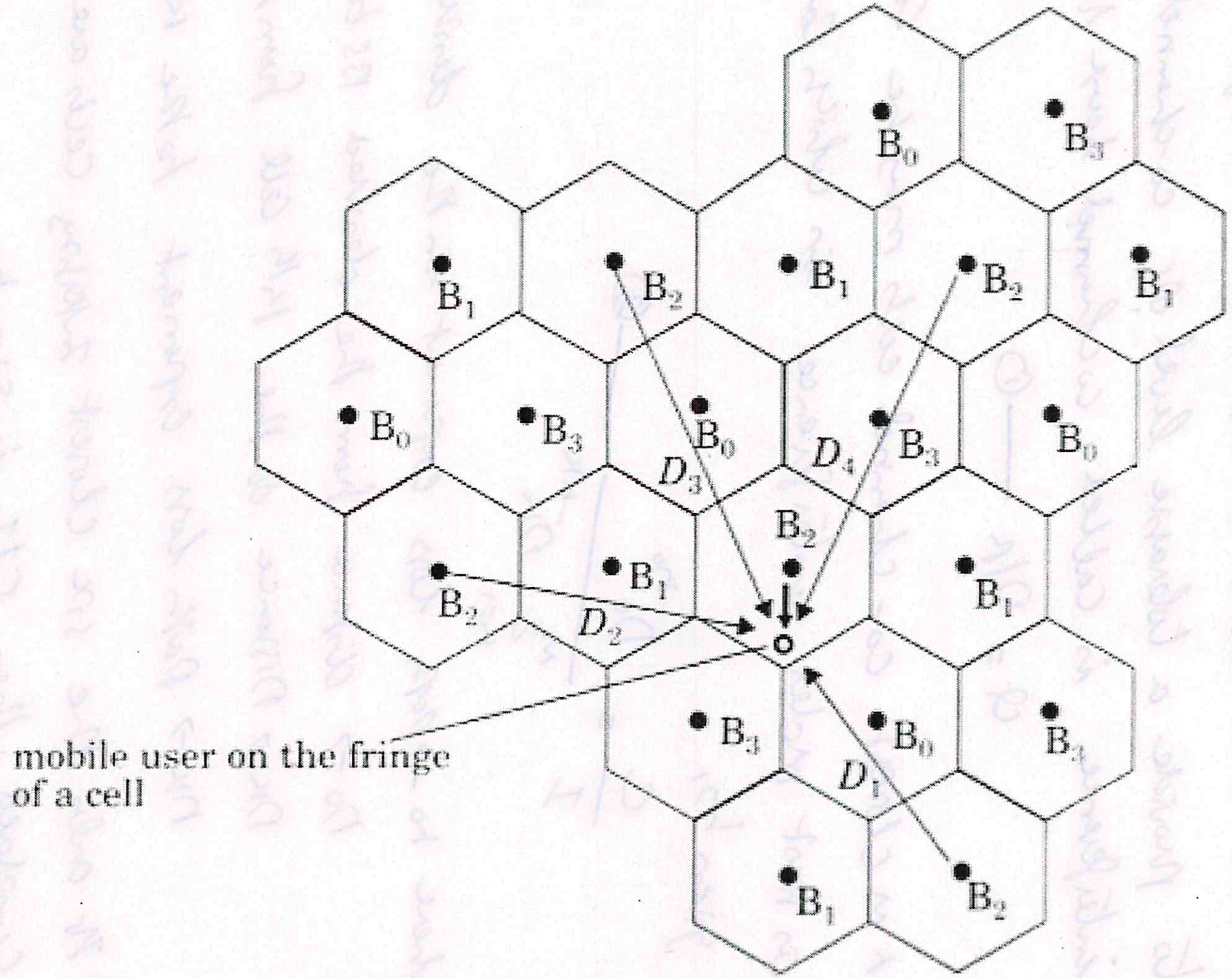


Figure 9.11 Illustration of forward channel interference for a cluster size of $N = 4$. Shown here are four co-channel base stations which interfere with the serving base station. The distance from the serving base station to the user is D_0, and interferers are a distance D_k from the user.

& the following eqn must hold for acceptable performance.

$$\frac{1}{6}\left(\frac{R}{D}\right)^{-n} \geq \left(\frac{C}{I}\right)_{min} \quad (4)$$

Cochannel reuse factor is,

$$Q = \left(6\left(\frac{C}{I}\right)_{min}\right)^{1/n} \quad (5)$$

The radio capacity of a cellular system is defined as,

$$m = \frac{B_t}{B_c N} \text{ radio channels / cell} \quad (6)$$

m → radio capacity metric,

B_t → total allocated spectrum for the system.

B_c → Channel Bandwidth

N → No. of cells in a freq. reuse pattern

The cochannel reuse factor Q by,

$$Q = \sqrt{3N} \quad (7)$$

from (5) (6) (7) the radio capacity is,

$$m = \frac{B_t}{B_c \frac{Q^2}{3}} = \frac{B_t}{B_c \frac{6}{3^{n/2}}\left(\frac{C}{I}\right)_{min}^{2/n}} \quad (8)$$

where n=4, the radio capacity is given by

$$m = \frac{B_t}{B_c\sqrt{\frac{2}{3}\left(\frac{C}{I}\right)_{min}}} \text{ Radio Channels/Cells} \quad (8)$$

$$\left(\frac{C}{I}\right)_{eq} = \left(\frac{C}{I}\right)_{min} \left(\frac{B_c}{B_i}\right)^2 \quad \text{——— (9)}$$

Capacity of Digital cellular TDMA:-

* TDMA Systems improve capacity by a factor of three to six times as compared to analog cellular radio systems.
* TDMA also makes it possible to introduce Adaptive channel Allocation (ACA).
* ACA eliminates system planning since it is not required to plan frequencies.

Capacity of Cellular CDMA:-

* The capacity of CDMA systems is interference limited, while it is bandwidth limited in FDMA & TDMA.
* The link performance for each user increases as the no. of users decreases.
* Another way of increasing CDMA capacity is to operate in a discontinuous transmission mode (DTX).
* The average capacity of a CDMA system can be increased by a factor inversely proportional to the duty factor.
* CDMA can reuse the entire spectrum for all cells and this results in an increase of capacity by a large percentage over the normal freq. reuse factor.

The signal to noise ratio is

$$SNR = \frac{S}{(N-1)S} = \frac{1}{N-1} \quad \text{——— (10)}$$

R → base band information bit rate,
W → Total RF band width, w.

$$E_b/N_o = \frac{S/R}{(N-1)(S/W)} = \frac{W/R}{N-1} \quad \text{——— (11)}$$

η → spread bandwidth.

* E_b/N_o can be represented as.

$$\frac{E_b}{N_o} = \frac{W/R}{(N-1)+(\eta/S)} \quad \text{——— (12)}$$

The no of users that can access the system is given as,

$$N = 1 + \frac{W/R}{E_b/N_o} - (\eta/S) \quad \text{——— (13)}$$

where, W/R is called the processing gain.

The back ground noise determines the cell radiation for a given transmitter power.

Two techniques to reduce interference,

① Antenna sectorization.
② monitoring of voice activity (α)

N_s → No. of users per sector.

α the new average value of E_b/N_o' within a sector is given as,

$$E_b/N_o' = \frac{W/R}{(N_s-1)\alpha + (\eta/S)} \quad \text{——— (14)}$$

when the no. of users is large and the system is interference limited rather than noise limited, the no. of users can be shown to be,

$$N_s = 1 + \frac{1}{\alpha}\left[\frac{W/R}{E_b/N_0'}\right] \quad \text{—— (15)}$$

Cellular Concept:-

Some of the important cellular concepts are,

(a) freq. reuse
(b) channel Assignment.
(c) Hand off
(d) Interference and system capacity.
(e) Trunking and Grade of service (GOS)
(f) Improving coverage and capacity.

Frequency Reuse:-

* Each cellular base station is allocated a group of radio channels to be used within a small geographic area called a cell.

* The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called freq. reuse or freq. planning.

* The actual radio coverage of a cell is known as the foot print and is determined from field measurements or propagation prediction models.

Space division multiple Access (SDMA):

Space division multiple Access (SDMA) is a channel access Method used in mobile communication Systems which reuses the Same set of cell phone frequencies in a given service area. two cells or two small regions can make use of the same set of frequencies if they are separated by an allowable distance.

It is defined as "assigning space to each channel with a minimum interference and a maximum medium utilization.

* In a cellular communication systems, the space division multiple access (SDMA) controls the radiated energy for each user in space.

* SDMA serves different users by using spot beam antennas. These different areas covered by the antenna beam may be served by the Same frequency or different frequencies.

* In SDMA, all users within the systems would be able to communicate at the Same time using the Same channel.

* SDMA is generally used in conjunction with FDMA, TDMA or CDMA, SDMA is mainly used for Satellite Systems.

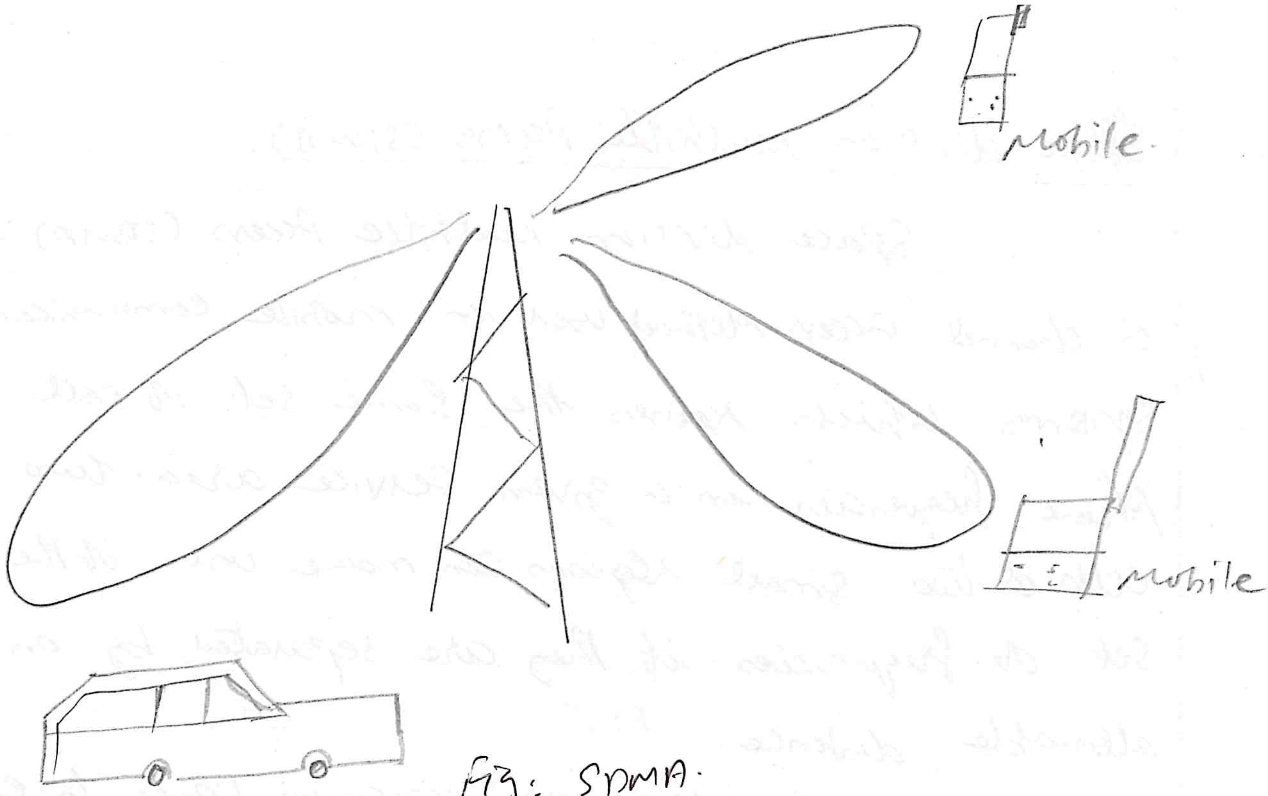


Fig: SDMA.

Advantages:

By maintaining separate space it easily avoids interference.

Disadvantages:

* separate space for each channel results in a waste of space, similar to the old analog telephone system.
* Many FM radio stations around the world can be use the same freq. without interference, if two or more channels were established within the same space that is several radio stations want to broadcast in the same city, will create a problem.

Unit - V - Wireless Networking

Introduction: Difference Between wireless and Fixed Telephone Networks, the public Switched Telephone Network (PSTN), Development of wireless Networks: First Generation wireless Network, Second generation wireless Networks, Third Generation wireless Networks, Fixed Network Transmission Hierarchy, Traffic Routing in wireless Networks: Circuit switching, Packet Switching - personal Communication services / networks (PCS/PCNS): Packet VS Circuit switching for PCN, cellular Packet - Switched Architecture - Packet Reservation multiple Access (PRMA) - Network Data bases: Distributed Data base for mobility management - Universal mobile Tele communication System (UMTS)

Introduction:-

* To provide wireless communications within a particular geographic region, an integrated network of base stations must be deployed to provide sufficient radio coverage to all mobile users.
* The base stations must be connected to a central hub called the mobile switching Center (MSC)
* The PSTN forms the global telecommunications grid, which connects conventional telephone switching centers with MSCs world wide.

* Radio links are established using a carefully defined communication protocol called the standard air interface or the handshake communication protocol.

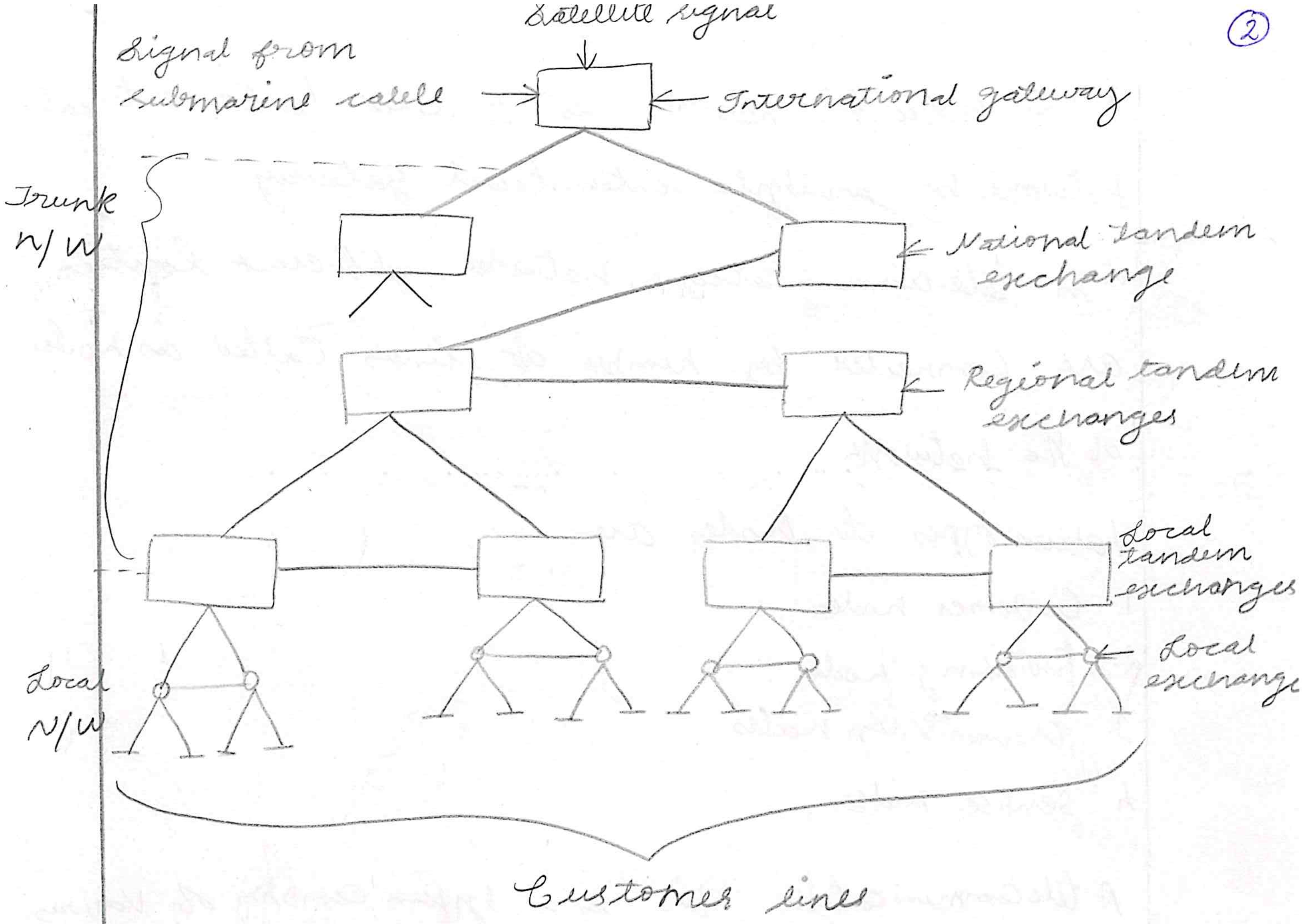
Differences between wireless and fixed telephone networks.

	Fixed telephone networks	Wireless telephone networks.
1.	Transfer of information takes place through trunk lines.	Transfer of information takes place wireless radio links.
2.	The n/w configurations in the PSTN are virtually static.	Wireless n/ws are highly dynamic as the n/w configuration being rearranged everytime a subscriber moves into the coverage region of a different base station.
3.	Fixed networks are difficult to change	Wireless n/ws reconfigure themselves for users within intervals.
4.	Transmission delay is high	Transmission delay is less.
5.	Channel B/W can be increased by additional cables.	RF Channel B/W has constraint.

Public Switched Telecommunication Network (PSTN):-

A national PSTN is a hierarchical n/w. The major components of its hierarchy are

1. Local networks.
2. Junction networks.
3. Trunk networks.



1. Local networks:

Local network connects customer's station to their local exchanges.

2. Junction networks:-

Junction network interconnect a group of local exchanges serving an area and a tandem or trunk exchange.

3. Trunk Network:-

* Trunk network provides long-distances circuits b/w local areas throughout the country.
* the international network provides circuit linking with national networks of different countries.

* The national network is connected to the international network by multiple international gateway.

* In telecommunications network, different locations are connected by number of links called as nodes of the network.

Various types of nodes are

1. Customer nodes
2. Switching nodes
3. Transmission nodes
4. Service nodes

A telecommunications n/w is a system consisting of various interacting subsystems.

1. Transmission subsystem
2. Switching subsystems.
3. Signalling subsystems.

Development of Wireless Networks:-

First generation Wireless Networks:-

* The first analog, voice oriented cellular telephone system launched during 1970's and 1980s is referred to as first generation of 1G cellular technology.

* The first generation cellular system used analog freq. modulation schemes for transmission with two isolated bands downlink and uplink transmission. It uses FDM to increase system capacity.

Different 1G cellular technologies are

1. Advanced mobile Phone System (AMPS)
2. Total Access Communication System (TACS)
3. Nordic mobile telephone (NMT – 450)
4. Nippon Telegraph and Telephone (NTT)
5. Japanese TACS (JTACS).

Second generation wireless Networks:-

* 2G Standards rely on digital formats TDMA/FDD and CDMA/FDD multiple access techniques. 2G cellular Systems provide more facilities and attractive features than 1G Systems.

1. Better speech quality.
2. High speed data application
3. Efficient spectrum utilization.
4. Supports multiple users.

TDMA:-

IS-136, GSM, PDC (pacific Digital cellular).

CDMA:-

Interim Standard – 95 (CDMA – one).

2.5 Generation wireless Networks:-

* 2.5 G is an upgradation of existing 2G cellular system without any additional freq. spectrum and change in technology.

* Different 2.5 G cellular system standards are

1. CDPD (Cellular Digital Packet Data)
2. HSCSD (High Speed Circuit switched data)
3. GPRS

Third Generation wireless Networks:-

* 3G is a cellular system that supports higher data services, advanced multimedia services and global roaming. The 3G system ensures an efficient wireless access with high performance quality by using intelligent new protocols.

* Different 3G cellular system standards include.

1. IMT 2000 & UMTS
2. CDMA 2000

Fixed Network Transmission Hierarchy:-

* wireless n/w's rely on landline connections. for example the MSC connects to the PSTN and SS7 n/w's using fiber optic, copper cable or microwave links.

* Base Stations within a Cellular System are connected to the MSC using LOS microwave links or copper or fiber optic cables.

* The most basic DS formats form a DS-0, which represents one duplex voice channel digitized into a 64 kbps binary PCM format.

* The T(N) designation is used to denote transmission line compatibility for a particular DS format DS-1 signaling is used for a T1 trunk, which is a popular point to point n/w design signaling format used to connect base stations to the MSC.

* Co-axial or fiber optic cable or wideband microwave links transmit data rates over 10 Mbps. In contrast, inexpensive wire or co-axial cable used for slower data transfer.

* When connecting BS to MSC or distributing trunked voice channels throughout a wireless n/w, T1 (DS1) or level 1 links are most commonly used and utilized standard twisted pair wiring.

* DS-3 and higher rate circuits connect MSCs and COs to the PSTN.

Traffic Routing in Wireless Networks:-

* The amount of traffic capacity required in a wireless n/w depend upon the type of traffic carried.

* A subscribers voice telephone call requires dedicated n/w access for real time communications

* Control and signaling traffic may be bursty and may be able to share n/w resources with other bursty users.

* The type of traffic a n/w carries determines the routing services, protocols, and call handling techniques.

* Two general routing services are provided by n/w's these are 1. Connection - oriented services
  2. Connectionless services.

Circuit Switching :-

* In telephone n/w's, there is requirement of two way communication. It is necessary to connect the circuit of a calling telephone to the called telephone on demand to maintain its connection during call.

* The message switching cannot fulfill this requirement because of inherent delays. Circuit switching is most preferred in telephone n/w's. A temporary link is established for the duration of the call.

* In circuit switching, if a route is selected for establishing a call and if outgoing circuit from a switch is busy, the new call offered to it cannot be connected i.e. call is lost. A circuit switched system is an example of lost call system.

Advantages of Circuit Switching:

* Real time transfer of voice signal.
* Technology is mature.
* Lowest end to end delay.

Disadvantages:

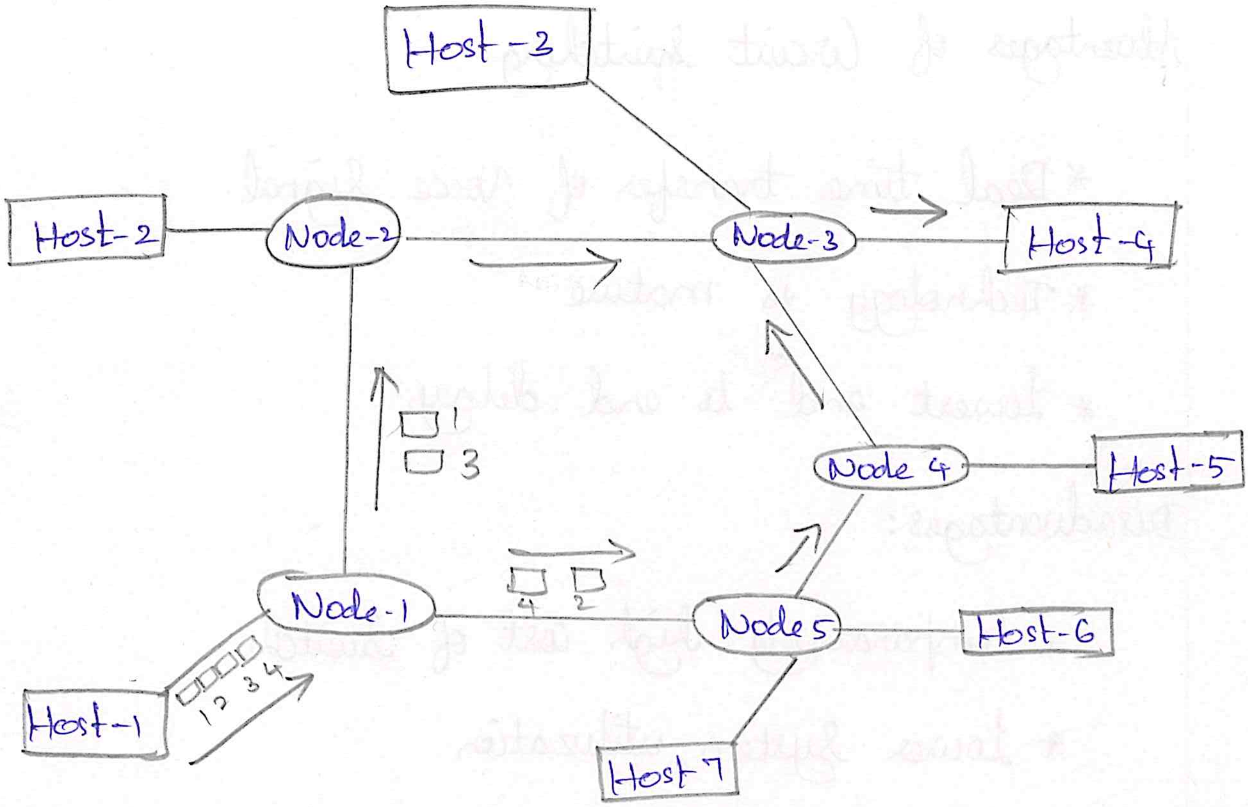
* Comparatively high cost of switch.
* Lower system utilization
* Call may be lost in busy network.

Packet Switching:

* It is a form of store and forward network. The message is split into number of packets of fixed size and these packets are transmitted in store and forward (S & F) format.

* Each packet transmission is independent of others. The packet may travel via different route with different delays. At destination host, these packets are reassembled.

* Each packet contains destination host id, source id, message id and packet id.



* Host-1 wants to send message to Host-4, the message is divided into packets 1, 2, 3 and 4. These packets may take different path and at destination they may arrive at out of sequence. It is responsibility of network to resequence the packets before delivery to the destination.

* Packet network offers forms at services.

1) Datagram Service.

2) Virtual Circuit Service.

Advantages of packet switching:

* Packet switching is cost effective, because switching devices do not need massive amount of secondary storage.

Personal Communication Services/ Network (PCS/ PCNs)

* PCS (Personal Communication Services) is a wireless access services but emphasizing personal service and extended mobility.

* Personal mobility is the ability of users to access any telecom service at any terminal based on personal identifiers, the networks ability and user profile.

* Terminal mobility is the wireless subscriber units ability to access services from different locations while in motion.

* Service mobility is the use of vertical features provided by landlines, users at remote locations or while in motion.

* PCS is a general term of a variety of voice, data and multimedia services. (GSM is a kind of PCS system)

* Such a personal communication service can be accessed at any time, place or form (They are mobile/ portable/ ubiquitous)

* Packet Switching offers improved delay characteristics because there are no long messages in the queue (maximum packet size is fixed).

* Packet can be rerouted if there is any problem, such as, busy or disabled links.

* The advantage of packet Switching is that many network users can share the same channel at the same time. Packet switching can maximize link efficiency by making optimal use of link bandwidth.

Disadvantages of packet Switching:

* Protocols for packet switching are typically more complex.

* It can add some initial costs in implementation

* If packet is lost, sender needs to retransmit the data. Another disadvantage is that packet-switched system still can't deliver the same quality as dedicated circuits in applications requiring very little delay - like voice conversations or moving images.

* PCS lays the foundation architecture - GSM and GPRS build upon and extend the PCS architecture to achieve new functionality.

* The Communication Services provided through a Small terminal, with a goal of enabling Communications at any time, at any place, and in any form.

* PCS is an integrated network as the ability to Contact to PSTN, wi-fi and Worldwide Introperability for Microwave Access (Wi-Max) Systems.

* PCS requires a number of antennas to blanket an area of Coverage. As a user moves around, the user's phone Signal is picked up by the nearest antenna and then forwarded to a base station that connects to the Wired network.

Types of PCS:

1) Narrowband PCS

2) Broadband PCS.

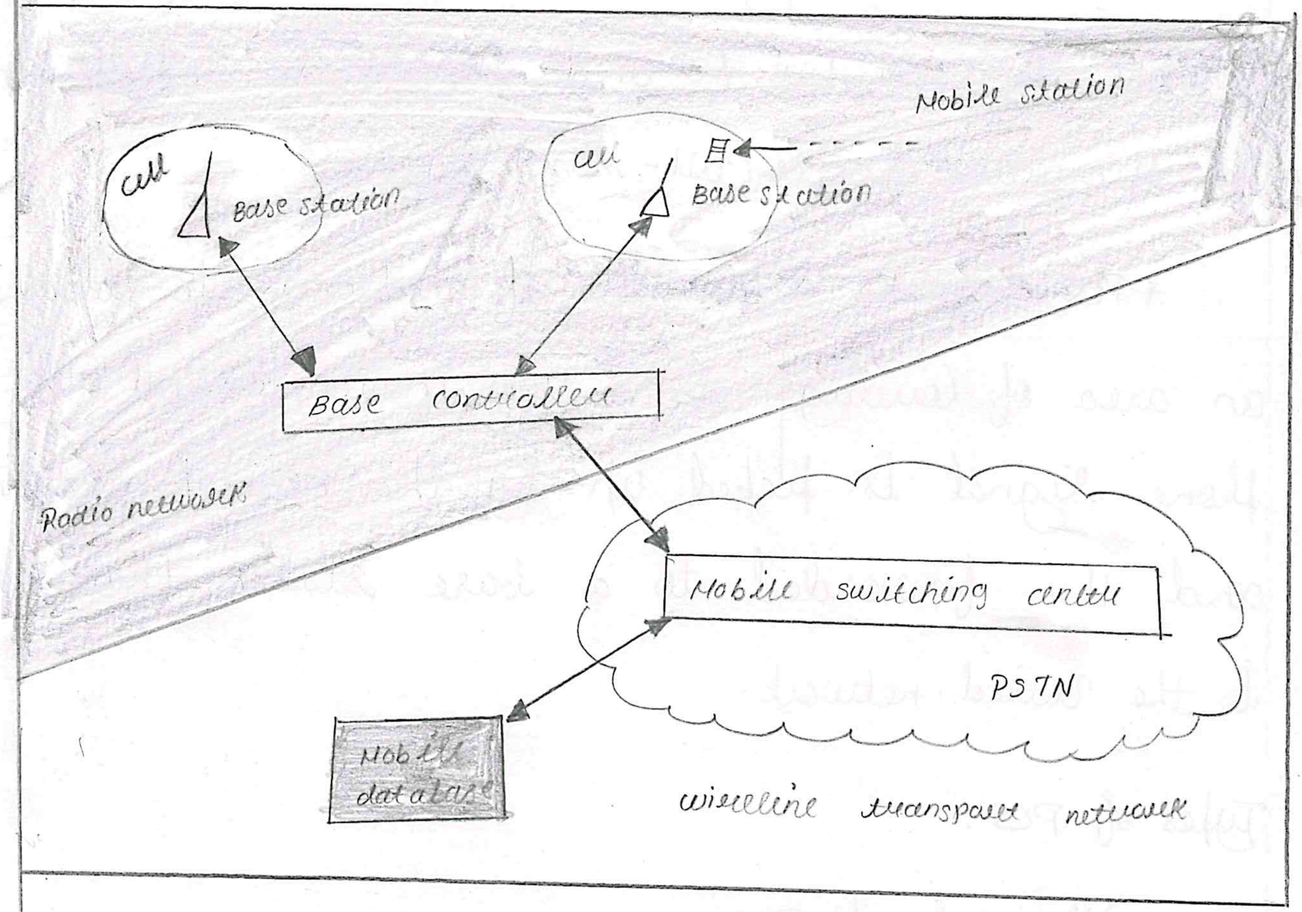
Narrowband PCS:

Narrowband of 3MHZ radio spectrum was used primarily for data transmissions. These Services were paging short message Systems.

Broadband PCS:

Broadband PCS is used for multimedia transmissions such as Voice, data, Internet, sms, image and in the future full motion Video. This obviously requires more channel capacity and is set aside on the 140 MHZ radio spectrum.

Architecture of PCS:



Two major parts of PCS architecture are,

1) Radio network 2) Wireline transport network.

* Parts of radio networks are mobile stations and base stations (BSs) controlled by base station controllers.

* Wireline transport network consists of Mobile Switching Centre (MSC) which is updated by mobility database.

PACKET RESERVATION MULTIPLE ACCESS [PRMA]

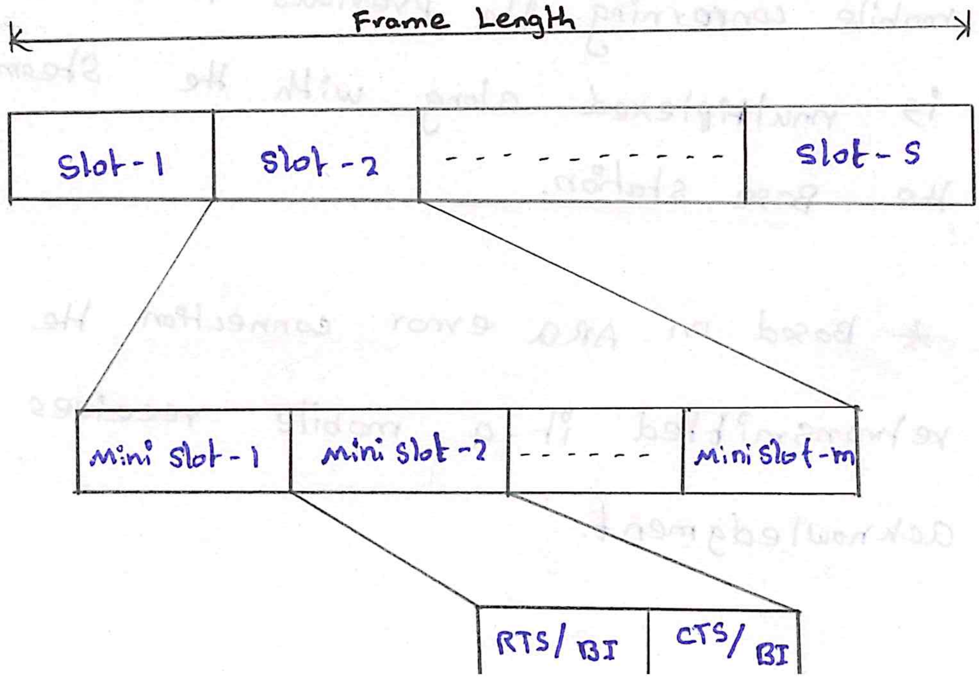
* Packet Reservation Multiple Access [PRMA) is a transmission protocol for packet voice terminals in a cellular system. PRMA is a Time Division Multiplex (TDM) based multiple access protocol that allows a group of spatially dispersed.

* The key feauter of PRMA protocol is the utilization of user transmission to gain access to the radio resources. PAMA is a dervation of reservation ALOHA, which is a combination of TDMA and slotted ALOHA.

Advantages :

* PRMA can utilize the discontinous nature of speech with the help of a voice Activity Detector (VAD) to increase capacity of the radio channel.

* The input to a voice terminal follows a pattern of talk spurt and silent gaps. Both digital packet data and speech data are simultaneously supported with PRMA.



* The raw channel bit stream is divided into time slots with each slot designed for a single packet of information. The time slot are generated as frames, which are repeated cyclically over the channel.

* A successful call SETUP ensures that the particularely mobile is given a reservation in a slot which is at the some position to succeeding frames.

* selection of frame duration is based on that a speech terminal can generated exactly one packet per frame. The allocated time slot is fixed within the frame untill be conversation is over.

* when the speech terminals has completed its communications it hals transmission that the base station receives a null packet and the time slot in the frame is unreserved once again and becomes avalible for use by other mobiles.

* A feed back signal from the base station to the mobile concerning the previous transmitted packet which is multiplexed along with the steam of data from the Base station.

* Based on ARQ error connection the packets are retransmitted if a mobile receives a negative acknowledgment.

Network Databases

1. In first generation wireless network the network, the network control was limited to the MSC and the MSCs of Neighbouring system were not able to communicate easily with each other.

2. In second and third generation wireless networks the distributed network controls among several processors.

3. The visitor location Database home location Database and the authentication centre are the major databases that are accessed by various processing elements.

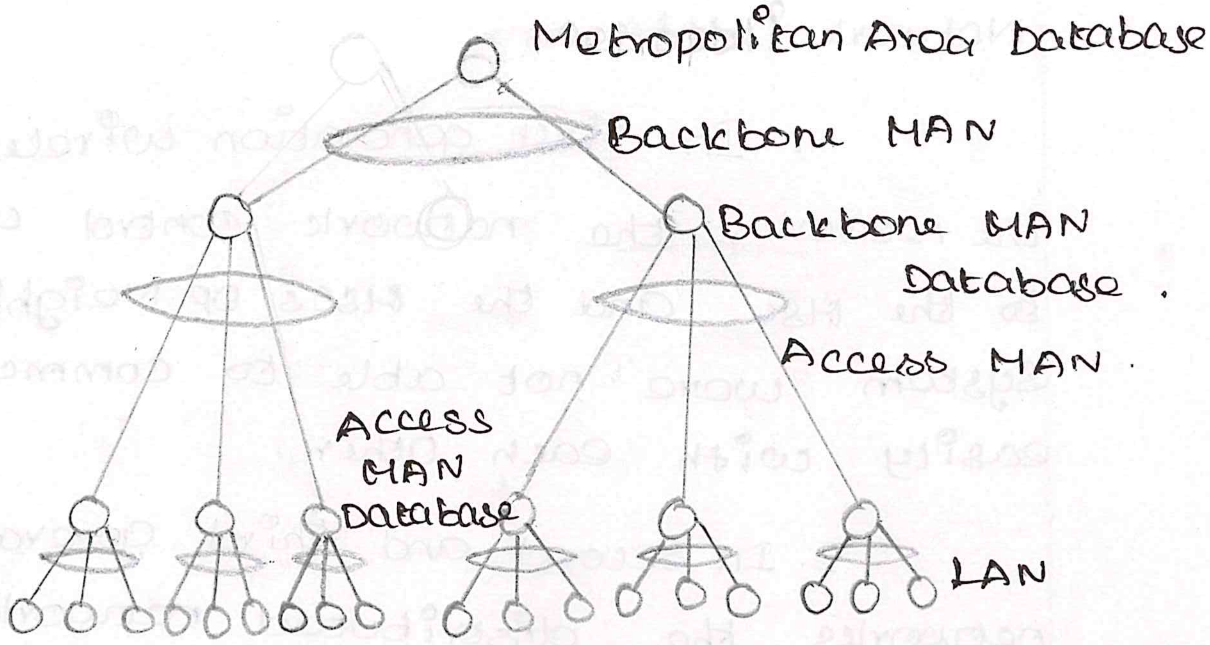
Distributed Database for Mobility Management.

1. The distributed hierarchical database architecture can be proposed to faciliate tracking and location of subscriber.

2. Higher level databases at the backbone MAN level enables subscriber tracking areas

3. The access MAN Databases indicates the mobile's BSC area location and the backbone MAN databases indicates the MAN access. Location

4. The Method of partitioning is an efficient technique because it reduces the time required to locate any mobile no



Base stations, LANs and Local Database

5. Each subscriber to cellular service has associated home access MAN, backbone MAN and a MAN Database. Home and visitor databases are logically distinctive but physically integrated in a single Database.

6. The CCITT recommendations E.164 suggest a Network address that is based on a hierarchical distribution such that the address indicates the access MAN node backbone MAN and MAN associated with a BSC.

7. Based on this type of format a roaming subscriber can be identified with its home base so that the new BSC can update it database for the visiting subscriber.

Universal Mobile Telecommunication System

Definition :

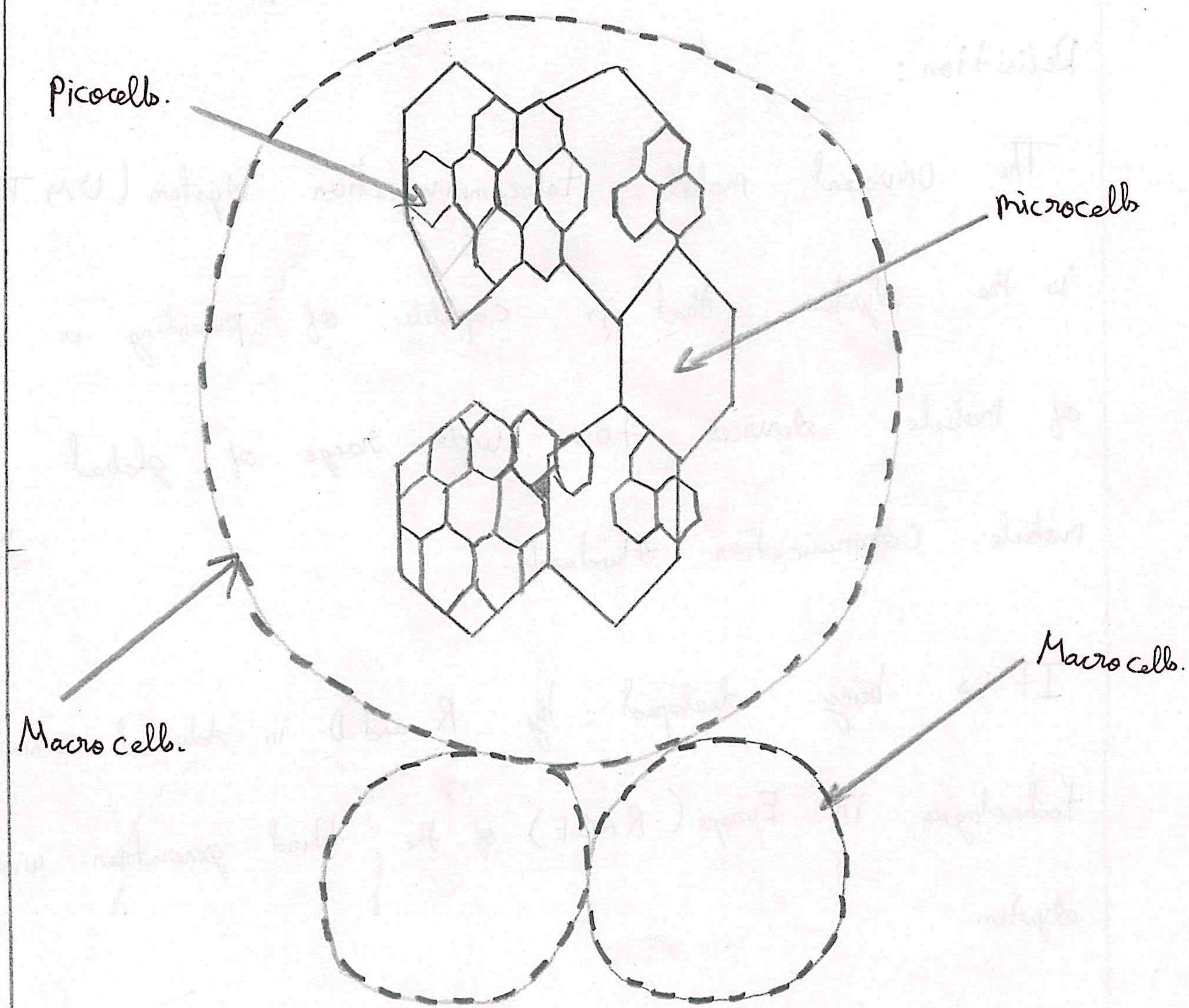
The Universal mobile telecommunication System (UMTS) is the System that is capable of providing a variety of mobile Services to a wide range of global mobile communication Standards.

It is being developed by R and D. in Advanced Communication technologies in Europe (RACE) of the third generation wireless System.

* In UMTS to handle a mixed range of traffic, a mixed cell layout that would consists of macrocells overlaid on micro and picocells. in a network architecture.

* This type of network distributes the traffic with the local traffic operating on the micro and pico cells, while the highly mobile traffic is operated on macro cells. thus reducing the number of handoffs required for the

fast moving traffic.



Network Architecture of UMTS

* The macrocells cover the spots not covered by other cells and also provide redundancy in certain areas. Thus, macrocells will also be able to avoid the failures of the overlapped cells.

* The major draw back of the overlaid architecture is the reduced spectrum density. The UMTS architecture will provide radio coverage with a network of base stations inter connected to each other and to a fixed network exchange.