Q.2 An interconnected collection of piconet is called________ .

a scatternet b micronet c mininet d none of the mentioned

[Ans. : a]

Explanation : Piconet is the basic unit of bluetooth system having a master node and upto seven active slave nodes.

Q.3 Bluetooth uses ______ .

a frequency hoping spread spectrum

b orthogonal frequency division multiplexing

c time division multiplexing

d none of the mentioned

[Ans. : a]

Q.4 Bluetooth transceiver devices operate in _____ band.

a 2.4 GHz ISM b 2.5 GHz ISM c 2.6 GHz ISM d 2.7 GHz ISM

[Ans. : a]

Q.5 The bluetooth supports ________ .

a point-to-point connections b point-to-multipoint connection

c both (a) and (b) d none of the mentioned

[Ans. : c]

Q.6 Unauthorised access of information from a wireless device through a bluetooth connection is called ________ .

a bluemaking b bluesnarfing c bluestring d none of the mentioned

[Ans. : b]

Q.7 In the piconet of bluetooth one master device ________ .

a can not be slave b can be slave in another piconet

c can be slave in the same piconet d none of the mentioned

[Ans. : b]

Q.8 An interconnected collection of piconet is called ________ .

a scatternet b micronet c mininet d none of the mentioned

[Ans. : a]

2 The Cellular Concept-System Design Fundamentals

Syllabus

Cellular system, Hexagonal geometry cell and concept of frequency reuse, Channel Assignment Strategies Distance to frequency reuse ratio, Channel & co-channel interference reduction factor, S/I ratio consideration and calculation for Minimum Co-channel and adjacent interference, Handoff Strategies, Umbrella Cell Concept, Trunking and Grade of Service, Improving Coverage & Capacity in Cellular System-cell splitting, Cell sectorization, Repeaters, Micro cell zone concept, Channel antenna system design considerations.

Contents

2.1 Cellular System

- The cellular topology is dominant topology that is used in all large-scale terres and satellite wireless networks.
- A **cellular system** is a combination of a modulation and multiple access techniq this method is equally applicable to both analog and digital systems.
- Cellular systems are complex but a much more efficient. It includes seve disciplines of engineering and has taken much enterprise and development assemble into global systems. Cellular radio requires combination of many large sc technology e.g. HF semiconductor technologies, radio transmission planning a global fixed telecommunications networks.
- In cellular systems, improved spectral efficiency and ability to handle heavy traf demands can be achieved by frequency reuse and cell splitting techniques. **Frequen reuse** refers to the use of radio channels on the same carrier frequency to cov different areas which are separated from one another by a sufficient distance so th co-channel interference is not objectionable.
- **Cell splitting** is further dividing a cell into smaller cells a set of channel frequenci is reused more often, leading to a higher spectral efficiency.
- Higher spectral efficiency leads to more subscribers, cheaper equipment due to ma production, low call charges and, overall lower cost per subscriber.

2.1.1 Hexagonal Geometry

- The overall service area is divided into small cell, ideally with no gaps or overlap each cell being served by its own base station and a set of channel frequencies. Th power transmitted by each station is controlled in such a way that the local mobil stations in the cell are served, while co-channel interference, in the cells using th same set of radio channel frequencies is kept minimum.
- As shown in Fig. 2.1.1 the cells are hexagons with the repeater and base station at the centre. The N cells which collectively use the complete set of available frequencies is called a **cluster.**
- Cell sizes are made smaller at the centre of the city or area of occupation of most subscribers.

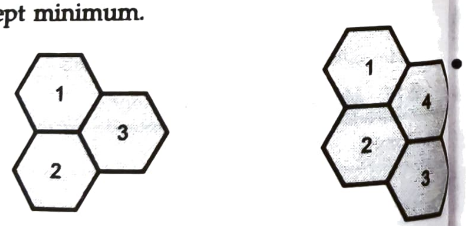
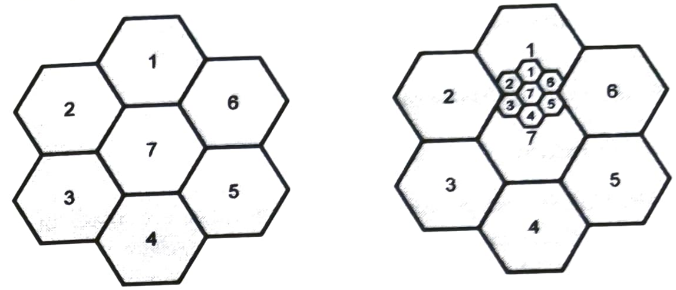


Fig. 2.1.1

- Cells are arranged in clusters. Only certain cluster sizes are possible, principally due t geometry of a hexagon and the allowable cluster sizes of 3, 4, 7 and 12 are shown b way of illustration.

- The hexagon shape permits easy and manageable analysis of a cellular system. The actual radio coverage of a cell is known as **footprint**. The footprint of cell is determined by field measurements or propagation prediction models.
- The hexagonal cells fit together to form a honey comb pattern. Fig. 2.1.2 shows seven cell honey comb pattern or seven cell cluster.



(a) Honey comb pattern or seven cell cluster

(b) Two sizes of cell

Fig. 2.1.2 The concept of cell

- The hexagonal shape of cell ensures the most effective transmission but in reality the antenna patterns will not achieve this pattern, the cells more likely takes the circular pattern with some overlap.
- When planning a system the aim must be to achieve the maximum use of the available radio spectrum. Also there must be low interference, good quality speech and an acceptable grade of service.
- The frequency channels are full duplex hence each conversation requires a pair of frequencies. The forward and reverse directions from the base station to the mobile are to different frequency band and the two frequencies are separated by 45 MHz.
- The factors affecting number of channels in a particular area :
  1. The available frequency spectrum.
  2. The cell size or transmitter power.
  3. The reduction in the quality of the link that can be tolerated due to co-channel interference.
- The normal maximum number of channels operating in a cell is limited to 120 and this occurs in places where the traffic is highest. The capacity of a system in an area is determined by the number of channels in a cell and the cell size.
- The number of simultaneous users is given by expression :

$$n = \frac{m\,(W / N)}{B}$$

Where,

W is total available spectrum,

B is bandwidth needed per user,

N is frequency reuse factor,

m is number of cell required to cover an area.

- Above expression indicates the capacity of network can be increased by :
  - i) Increasing m
  - ii) Decreasing frequency reuse factor

2.1.2 Cellular Hierarchy

- Hierarchical cellular infrastructures of different sizes are used in cellular netwo[rks] because of following reasons :
  - i) To extend the coverage to the areas those are difficult to cover by a large cell.
  - ii) To increase the capacity of the network for those areas that has a higher density [of] users.
  - iii) To provide coverage for specific application
- For deployment of cellular network numbers of cell sizes are used to provide comprehensive coverage supporting traffic fluctuations in different geographic are[a] and supporting a variety of applications.
- Different cell sizes are defined as following.

1. Femtocells

- Femtocells are the smallest unit of hierarchy used for connection of personal equipment such as laptops and cellular telephones.
- The femtocells cover only few meters where these devices are used within physical range of users.

2. Picocells

- Picocells are the small cells inside a building that support local indoor networks. For example, wireless LANs, Wi-Fi networks.
- The size of these networks is in the range of a few tens of meters.

3. Microcells

- The microcells cover the interiors of streets and its antenna is located at the heights lower than the rooftop of the building.
- The microcell covers range of few hundreds of meter. It is used for personal communication systems.

4. Macrocells

- Macrocells cover metropolitan areas and its antennas are mounted above the rooftop of the buildings in the coverage area.
- The macrocells cover areas on the order of several kilometres.

5. Megacells

- Megacells cover nationwide areas with satellites. It usually covers ranges of hundreds of kilometers.

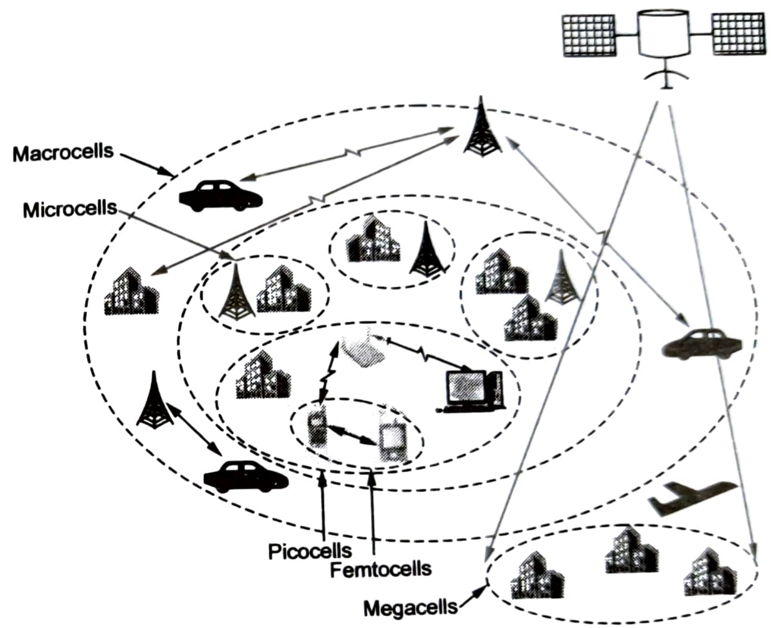


Fig. 2.1.3 Coverage areas of different cells

Solved Example

Example 2.1.1 *A service provider wants to provide cellular communication to a particular geographic area. The total bandwidth the service provider licensed is 5 MHz and system subscriber requires 10 kHz of bandwidth. Determine the system capacity, if the service provider implements a cellular system with 35 transmitter sites and cluster size of 7.*

Solution : Given : Cluster size N = 7

Total system bandwidth B = 5 MHz = 5000 kHz

Bandwidth per subscriber = 10 kHz

Total cell transmitter = 35

$$\text{Bandwidth per cell} = \frac{B}{N} = \frac{5000 \text{ kHz}}{7} \approx 714 \text{ kHz}$$

$$\text{Capacity of each cell} = \frac{714 \text{ kHz}}{10 \text{ kHz / user}} = 71 \text{ user}$$

Total system capacity = Total number of cells * Capacity of each cell

Total system capacity = 35 * 71 users = **2485 users**

2.1.3 Cell Fundamental

- The use of hexagon allows for the complete theoretical coverage of an area without any overlapping cells or gaps in the coverage area.
- The use of hexagons makes the theoretical calculations of system parameters much easier.
- There are a few geometrical figures which ensure full coverage of a given area without either overlapping or holes. These are equilateral triangles, squares and hexagons. Hexagons best approximate the circular shape of base station coverage in a flat terrain without obstacles and the hexagonal edges well approximate the borders between cells of the same size.
- In reality, the base station coverage does not have a regular circular shape because the coverage is a result of terrain architecture and obstacles such as houses, trees, etc.

2.2 Frequency Reuse

GTU : Summer-15, Winter-14,15

- In a cellular system, the frequency space allocated is insufficient. for a 7 cell cluster arrangement the allocation of frequencies into seven sets is required. The same frequency band or channel used in a cell can be reused in another cluster or cell i.e. frequency to be used for multiple simultaneous conversations. This is referred to as **frequency reuse.**
- Frequency reuse is the process of using the same set of frequencies to more than one cell. (See Fig. 2.2.1 on next page)
- However frequency reuse depends on various factors such as transmitter power of base station, antenna gain and height, distance between cells. The distance between the two cells using the same frequency is known as **reuse distance**, is denoted by D. A typical cluster of seven cells shows frequency reuse pattern and reuse distance.

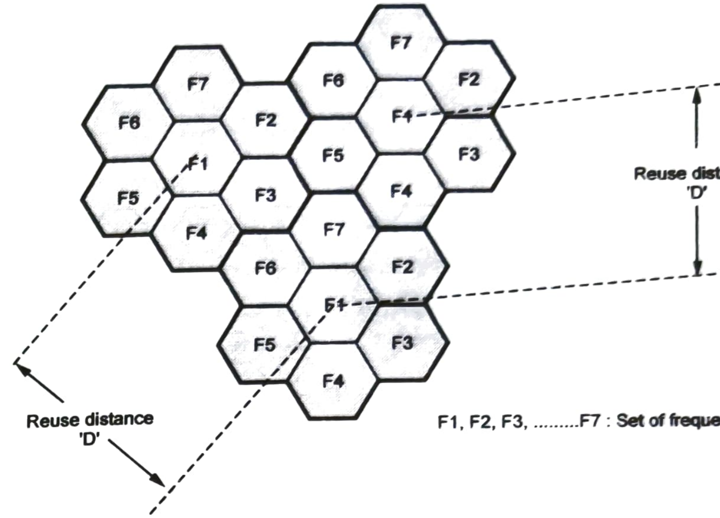


Fig. 2.2.1 Frequency reuse for 7 cell cluster

- Frequency reuse distance is decided by cluster size 'N'. In hexagonal cell pattern the cluster size (number of cells per cluster) is given by,

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

where N represents the cluster size.

i represents the number of cells to be transversed along direction qi from center of cell.

j represents number of cells in direction 60° to the direction of i.

Substituting different values of i and j (nonnegative integers)

N = 1, 3, 4, 7, 9, 12, 13 ....

Most popular value of N are 4 and 7.

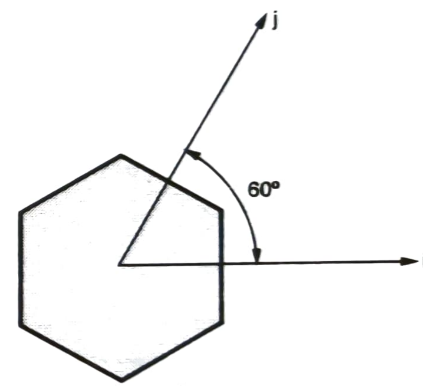


Fig. 2.2.2

- Due to hexagonal geometry, there are six equidistant neighbours and each neighbor is separated by multiples of 60°.

2.2.1 Frequency Reuse Factor

- The relationship between frequency reuse distance 'D', radius and cell 'R' and number of cells per cluster 'N' is represented by,

$$\boxed{D = \sqrt{3N}\,R}$$

The ratio $\frac{D}{R}$ is known as **reuse factor.**

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

- Fig. 2.2..3 shows various reuse patterns.

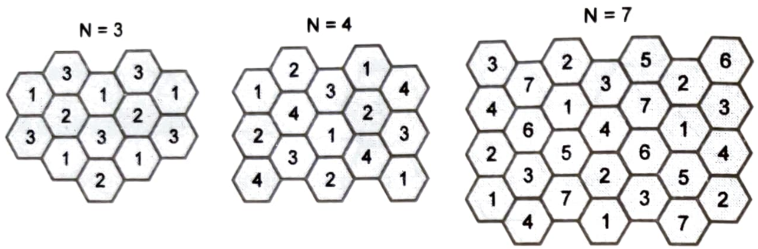


Fig. 2.2.3 Freuency reuse patterns for N = 3, N = 4 and N = 7

- If the system is not properly designed with respect to the number of cells in a cluster, topographic cell distribution and channel assignment, then it will experience excessive interference between the channels in different cells which use the same carrier frequencies.
- Co-channel Reuse Ratio for different values of N are summarised in table 2.2.1.

Sr No	Values of i and j	Cluster size (N)	Co-channel reuse ratio (Q=D/R)
1	i = 1 and j = 1	3	3
2	i = 1 and j = 2	7	4.583
3	i = 2 and j = 2	12	6
4	I = 1 and j = 3	13	6.24

Table 2.2.1

Solved Examples

Example 2.2.1 *For a mobile system of cluster size of 7, determine the frequency reuse distance if the cell radius is 5 km. Repeat the calculation for a cluster size of 4.*

Solution : Given : Cluster size N = 7

Cell radius R = 5 km

Frequency reuse distance is given by $D = \sqrt{3N}R$

$$D = \sqrt{3*7} * 5 = 4.5823*5$$

$$D = \mathbf{22.913\ km} \quad \textbf{... Ans.}$$

For cluster size N = 4

$$D = \sqrt{3*4} *5 = 3.464*5$$

$$D = \mathbf{17.32\ km} \quad \textbf{... Ans.}$$

Example 2.2.2 *Determine frequency reuse distance for a cell radius of 2 km and cluster size of 8.*

Solution : Given : Cluster size N = 8

Cell radius R = 2 km

Frequency reuse distance is given by $D = \sqrt{3N}.R$

$$D = \sqrt{3*8} *2 = 4.8989*2$$

$$D = \mathbf{9.7979\ km} \quad \textbf{... Ans.}$$

Example 2.2.3 *If 20 MHz of total spectrum is allocated for a duplex wireless cellular system and each simplex channel has 25 kHz RF bandwidth, find :*

(i) The number of duplex channels

(ii) The total number of channels per cell site, if N=4 cell reuse is used

GTU : Summer-15, Marks 7

Solution : Given : Total BW = 20 MHz

BW of channel = 25 kHz × 2 simplex channels = 50 kHz/duplex channel

i) Total number of available channels $= \frac{20000}{5} = 400$ channels.

ii) For N = 4, number of channels available per cell $= \frac{400}{4} =$ **100 Channels**

Example 2.2.4 *A cellular system has 32 cells; each cell has 1.6 km radius and the system reuse factor of 7. The system is to support 336 traffic channels in total. Determine the total geographical area covered, the number of traffic channels per cell and total number of simultaneous calls supported by this system.*

GTU : Winter-14, Marks 7

Solution : The area of a hexagon of radius R is given by -

$$\mathbf{A = 1.5\,R^2\sqrt{3}}$$

$$A = 1.5 \times 1.6^2\sqrt{3} = 6.65\ km^2$$

i) Total geographical area covered= $6.65 \times 32 = \mathbf{213\ km^2}$

ii) No. of traffic channels per cell

For N = 7, the number of channels per cell is $\frac{336}{7} = \mathbf{48}$

iii) Total channel capacity = $48 \times 32 =$ **1536 channels**

University Questions

1. *For a regular hexagonal geometry show that co-channel reuse ratio is $Q = (3N)^{1/2}$, where $N = i^2+ij+j^2$.* **GTU : Winter-14, Marks 7**
2. *With figure explain the concept of frequency reuse in detail.* **GTU : Winter-15, Marks 7**

2.3 Channel Assignment Strategies

- **Channel assignment** is process of allocating specific channels to cell sites and mobile units. Careful channel assignment eliminates the interference in the system. The channel assignment is done on short term and long term basis. The long term channel assignment is also called as fixed channel assignment.
- Channel assignment is applied for setup channels and voice channels.

Channel assignment to cell sites

- The channel assignment to the cell sites is considered with respect to fixed channel assignment. Here the concept of fixed channel assignment is that channels are assigned to cell sites for a long period. The two different types of channels assigned are :

  i) Voice channels ii) Set-up channels

) Voice channels

- The assignment of voice channels in every cell site is with idea of reducing the adjacent channel interference (ACI) and co-channel interference (CCI). As discussed earlier the voice channels is expressed as two groups named as A and B in the frequency management topic.

) Set-up channels

In each cell in the system is allocated with 21 set-up channels. The corresponding cluster sites are N = 4, N =7 or N = 12, reuse patterns.

- In case the antenna used is omnidirectional then one set-up channel is enough. It may lead to many unused set-up channels. But it is better not to use the set-up channel of neighbourhood of the block (from A to B or from B to A) so that it will avoid interference in the system.

Channel assignment to the mobile units in moving status :

- The channel assignment process to roaming mobile unit is high during peak hours, of morning and evening. But it is opposite during the night hours when traffic intensity reduces. In case the traffic is uniform in the system, there will be larger backward energy observed from the mobile unit also, the antenna pattern will not affect the system. But the case is reverse if the traffic is non-uniform.
- To have smooth call handling even for the cell sites away from city the transmit power should be low for voice and set-up channels for few cell-sites.
- For controlling the call acceptances and handoff calls three different methodologies are applied. They are given below,

  a) Frequency assignment

  b) Tilted assignment

  c) Underlay - overlay cell arrangement.

a) Frequency assignment

- The frequencies assigned to a cell is a part of one set or more than that of the total available 21 set-up channels. If necessary borrowing of channels is also permitted. In a sectored cell we can also assign required frequencies with no interferences with neighbouring sectors of the cell.

b) Tilted antennas

- The tilted directional antenna set is capable of eliminating interferences. It is a good design practice to tilt an antenna instead of reducing antenna height, particularly to handle foliage areas (with tall trees etc.)

  i) Also if the tilting angle (θ) is 22° a notch will be created in the horizontal antenna pattern. Due to of this there is an additional reduction of interference can which be achived.

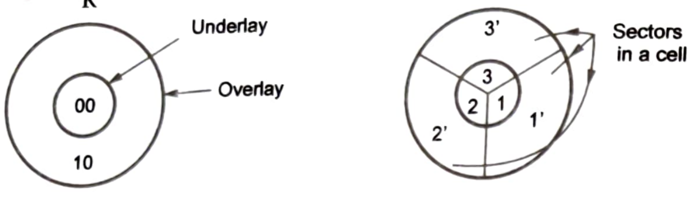
c) Underlay-overlay

- In the cellular arrangements shown below the inner circle represents underlay and the outer circle represents overlay structures. In these two areas the voice powers transmitted are slightly adjusted. To each area a unique voice frequency is assigned.
- For an omnidirectional cell, if N = 7 reuse pattern is used the radius is R then the reuse distance D is,

$$D = 4.6\ R$$

and cochannel interference factor reduction ratio q is,

$$q = \frac{D}{R} = 4.6$$



(a) In omni cells (b) In sectored cells

Fig. 2.3.1 Overlay-underlay cellular arrangement

- From Fig. 2.3.1, for sectorization in a cell different algorithms are applied. For example in Fig. 2.3.1 (b) there are six regions in total for overlay and underlay areas available.
- Overlay regions/areas - 3
    - Underlay regions/ areas - 3

    Total - 6 regions / areas.
- Thus the overlaid and underlaid cell arrangements are adopted in cell sites and its ultimate goal is to increase the traffic capacity in the system.

2.3.1 Fixed Channel Assignment

- Fixed channel assignment is the simplest strategy of system resources distribution.
- When distribution of carriers (channels) from the point of view of interchannel interference minimization. If this channel allocation is done once and kept constant, this type of assignment is called a **fixed channel assignment.**
- In fixed channel assignment each cell is permanently allocated predetermined group of channels. Any call attempt within cell can only be served by unused channels in that particular cell.
- In fixed channel assignment, setting a new connection in a given cell is possible only if there are unoccupied channels in that cell. In the case of a temporary lack of available channels, the user suffers from blocking of a connection.
- Fixed channel assignment can be an inefficient solution resulting in high probability of blocking during busy hours.
- There are more sophisticated channel assignment methods, which take into account a dynamically changing demand for channels such as channel sharing and channel borrowing.

2.3.1.1 Channel Sharing

- In a cell if the traffic is heavy it could share the channels of same cell. That is the channels of another face of the, same cell is shared. Such a channel sharing is done to handle short-term overload situations in the system as shown in the Fig. 2.3.2.

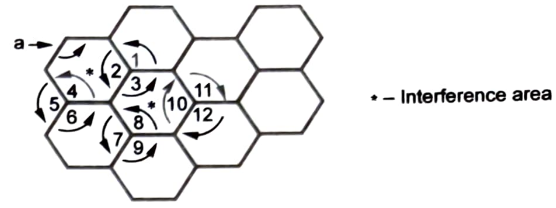


Fig. 2.3.2 Channel sharing concept

- It is considered that there are 21 channels sets, each set consisting of 16 channels. If one face of cell needs more channel it shares the channels of another face of same channel. In cell 'a' shown in Fig. 2.3.2, shares channel from one face to another and due to this channel sharing there will be interference developed in same channel marked with * symbol. In channel sharing concept it is flexible to use channel combiners and at one face of channel the combiner can handle upto 32 channels.

2.3.1.2 Channel Borrowing

- The concept of channel borrowing is done in long-term borrowing. The borrowing is done with other cells or borrowing channels from another face of same cell also can be done.
- This technique is suitable for slowly developing cellular systems. The cell-splitting technique is used in cells to handle different traffic densities. But implementation of cell-splitting technique is costly. Thus if it is badly required for the system, only then it should be used.
- The channel borrowing technique helps to avoid cell splitting in the system. It is a main advantage of channel borrowing technique.

Note The central cell in the cluster can borrow channels from its neighbouring cells.

2.3.1.3 Sectorization

- In a cellular system cell sectoring would help to delay cell splitting. The available channels are divided into groups. There are different types of sector system is available.

(a) 6 sectors of 60° each (b) 3 sectors of 120° each

Fig. 2.3.3 Cell sectorization concept

For example i) 120° sector system

ii) 60° sector system

iii) 45° sector system.

A 60° (6 sector) and 120° (3 sectors) sector systems are shown in Fig. 2.3.3.

- If the cluster N size is 7 then 3 sectors of 120° each in one cell is used. The total channel sets will be 21.
- In special case the sector angle can be narrowed/reduced for the purpose of assigning more number of channels in one sector. But this has to done carefully that the neighbouring channel interference should not increase. In general the cochannels interference is avoided in sectored cells than in the case of cell spliting.
- Comparison of sectorized and non-sectorized cells in the cellular system

i) Sectorized cells :

E.g. Omni cells

- Considering N = 7 frequency reuse pattern : The frequency allotted is based on frequency management chart.
- Terrain profile is assumed to be not flat.
- To reduce CCI cluster size should be N = 12 and cochannel reduction factor is q = 6.

ii) Sectorized cells :

- Three sectors in a cell each with 120° can be used for transmitting and receiving sectorization.
- Changing the sectors on call progress needs handoffs.
- Six sectors with 60° each, is also used for both transmission and receiving sectorization. But here in changing sectors for a call in progress needs more handoffs than 120° sectored cell.
- The 60° or 120° sector is used only for receiving sectorization. Thus an omni antenna should be used for transmitting.
- This method makes accurate decisions related to call handoffs but it does not reduce interference levels.

2.3.1.4 Advantages and Disadvantages of Fixed Channel Assignment

Advantages

1. Less load on Main Switching Center (MSC)
2. Simple to implement

Disadvantages

1. Blocking may happen

2.3.2 Dynamic Channel Assignment

- In the dynamic channel assignment strategy there are no channels permanently assigned to the cells. The channel is assigned to a particular call on a call-by-call basis.
- All channels are placed in a pool, and are assigned to new calls according to the reuse pattern. Signal is returned to the pool, when call is completed.
- MSC allocates frequency channels on dynamic basis if that frequency channel is not presently in use in the cell or any other cell which falls within the minimum restricted distance of frequency reuse to avoid co-channel interference.
- Decision upon the assigned channel can be made either by the mobile switching center or by the mobile station. It can be described as the distributed control of the channel assignment process.
- Dynamic channel assignment reduces chances of blocking which increases trunking capacity of system as all available channels are accessible to all cells.
- In Dynamic channel assignment MSC has to collect real time data on channel occupancy, traffic distribution, radio signal strength indication of all channels on continuous basis, thus increasing the computational load on MSC.

2.3.2.1 Advantages and Disadvantages of Dynamic Channel Allocation

Advantages

1. Voice channels are not allocated permanently. That is shared on need-basis.

Disadvantages

1. Requires MSC for processing resulting in burden on MSC
2. It is complicated system
3. Issues related to channel allocation are still under research.

2.4 Interference

GTU : Winter-15, Summer-15,16

- A cellular telephone system suffers from two kinds of interferences.
  1. Co-channel interference 2. Adjacent channel interference

2.4.1 Co-channel Interference

- With frequency reuse, many cells at a distance will be using the same frequency bands within a given area. These cells are called as co-channels. There is possibility of interference between them since they are operating at same frequency, th interference between them is called as **co-channel interference.** For a 7 cell cluste there could be up to six immediate interferers as shown in Fig. 2.4.1.

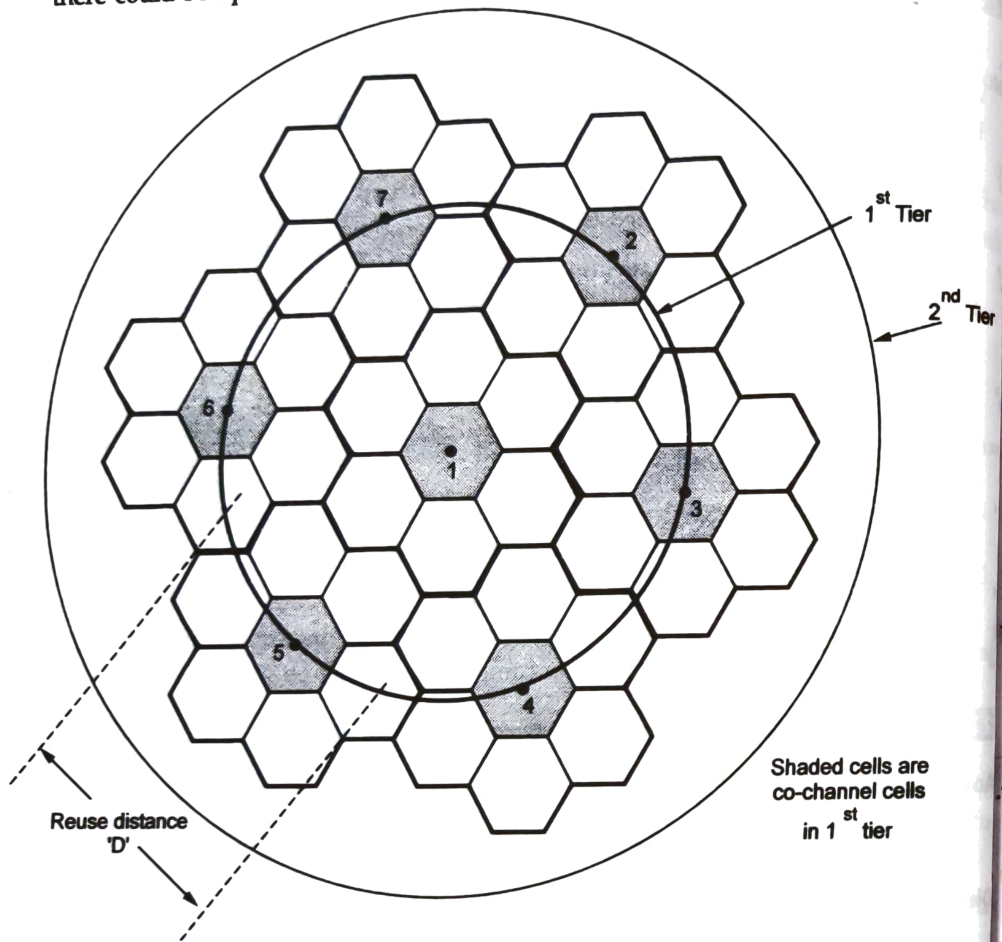


Fig. 2.4.1 Interfering cells in a 7 cell cluster pattern

- The co-channel interference exists even after the power levels of the interfering cell are low enough. The co-channel interference can be experienced by mobile unit and within cell site also.
- The co-channel interference is measured by the ratio of carrier to interference (C/I) at the cell site.
- For measuring carrier to interference ratio consider two cells using the same frequencies at a reuse distance ' D ' as shown in Fig. 2.4..2.

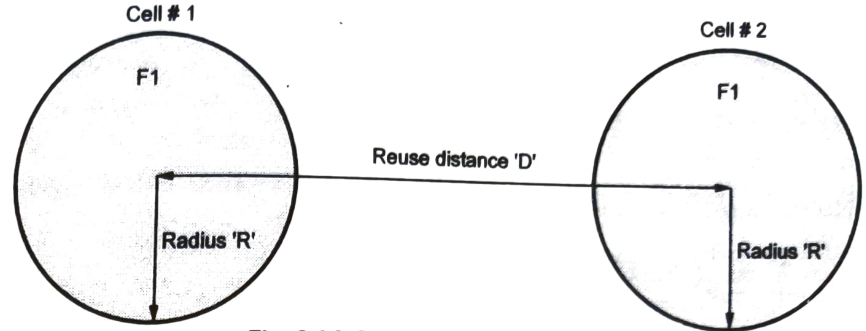


Fig. 2.4.2 Carrier to interference ratio

- Let the power transmitted by each base station is fixed. Then the received power by mobile at a distance from the base station is proportional to $r^{-\gamma}$ where γ is propagation constant.
- Typical value of γ for free space is 2 and for urban area it is 4.

Co-channel Interference Ratio (CIR) is given by

$$\frac{C}{I} = \frac{\text{Carrier}}{\text{Interference}} = \frac{C}{\sum_{k=1}^{m} I_k}$$

where I_k represents co-channel interference.

m represents number of interfering cells.

For 7-cluster size, m=6

$$\therefore \quad \frac{C}{I} = \frac{C}{\sum 6\, I_k}$$

$$\frac{C}{I} = \frac{C}{6\left(\frac{D}{R}\right)^{\gamma}} = \frac{C}{6\left(\frac{D}{R}\right)^{4}}$$

- The co-channel interference is a function of a parameter, q

$$\boxed{q = \frac{D}{R}}$$

The parameter 'q' is called the **co-channel interference reduction factor.**

- Factor q is independent of actual power level P_0 which is assumed the same for all cells. Let all the cells contribute interference equally.

$$\frac{C}{I} = \left(\frac{R}{6D}\right)^{-4} = \frac{R^{-4}}{6D^{-4}} = \frac{1}{6q^4}$$

Now reuse factor $\frac{D}{R} = \sqrt{3N}$

$\therefore$ $\frac{R}{D} = \frac{1}{\sqrt{3N}} = (3N)^{-1/2}$

Substituting in above equation

$$\frac{C}{I} = \frac{1}{6}(3N)^{\frac{-1}{2}\times -4} = \frac{1}{6}\left(3N^2\right)$$

$$\frac{C}{I} = 1.5\ N^2$$

i.e. The C/I ratio is a function of cluster size.

- In the cellular environment it is normal practice to specify that CIR should be greater than 18 dB for acceptable performance.

$\because$ 18 dB = 63.1

Also $\frac{C}{I} = \frac{q^4}{6}$

$$63.1 = \frac{q^4}{6}$$

$$q^4 = 6 \times 63.1$$

Hence $q = 4.41$

Again reuse factor $\frac{D}{R} = \sqrt{3N}$

$\therefore$ $q = \sqrt{3N}$

Substituting value of q = 4.41

$$4.41 = \sqrt{3N}$$

$$N = 6.48$$

Hence cluster size for this CIR is 7, note that this is approximate analysis.

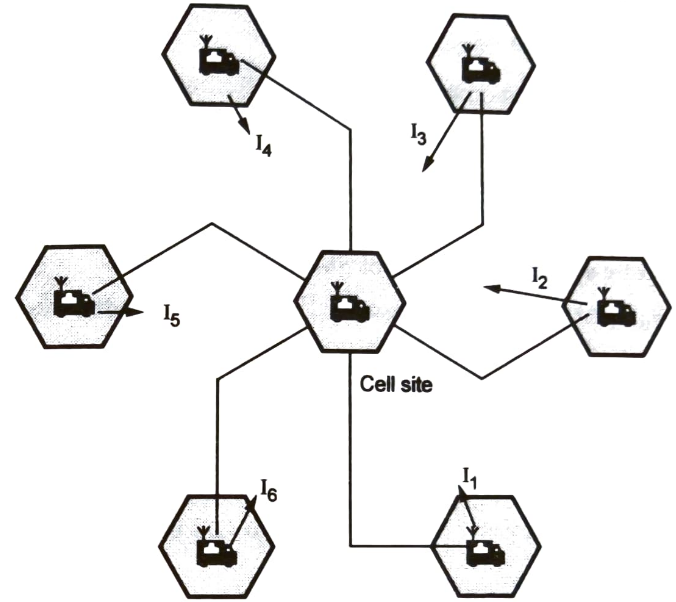
2.4.1.1 Desired C/I from a Normal Case in an Omni-directional Antenna System

- The desired carrier to interference ratio is related with the co-channel reuse factor Q. For an omni-directional antenna system the desired C/I can be found with a simple analytic solution in which two cases are considered

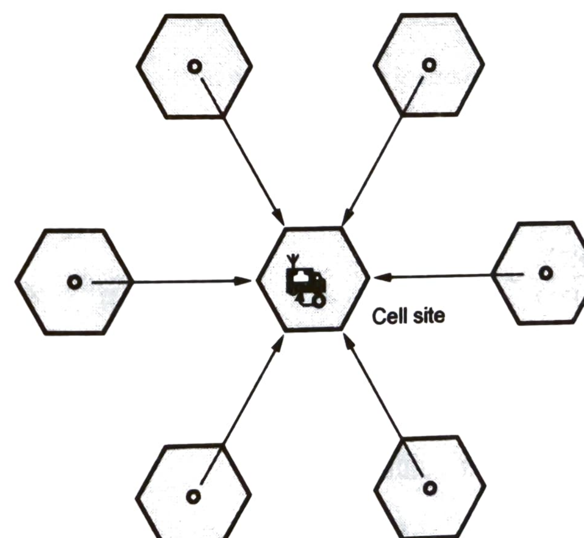
Case 1 : The signal received by the mobile unit along with co-channel interference signal if any.

Case 2 : The signal received by the cell site along with co-channel interference signal if any.

If frequency reuse technique is applied in a cellular system there is an advantage of bandwidth saving but at the same time the risk of interference generated by co-channel cells is high. If the distance between the co-channel cells is less then co-channel



(a) CCI at a desired cell site



(b) CCI at a desired mobile unit

Fig. 2.4.3 Co-channel interference in cellular mobile environment - considering six interferers

interference will be more. It is the problem of repeting the same frequency in differe cells.

- In co-channel environment consider that desired signal is x(t) and interferring sig is i(t).

$$x(t) = \exp j(\omega_c t+\phi(t)) \ldots$$

$$i(t) = a \exp j(\omega_c t+\phi_i(t)+\phi_0(t)) \ldots$$

where $\phi(t)$ is phase-modulation component of the desired signal x(t).

$\phi_i(t)$ is phase-modulation component of the interferring signal i(t).

$\phi_0(t)$ is the phase difference between the signals x(t) and i(t).

'a' is the amplitude of the interferring signal i(t) to that of the x(t).

- Then the composite signal at the input of FM receiver will be

$$V_c(t) = x(t) + i(t) = \exp j[\omega_c t+\phi(t)]\{1 + a \exp j[\phi_i(t)-\phi(t)+\phi_0(t)]\}$$

Balanced System :

- If the carrier to interference (C/I) ratio level received is same at both the mobile u and the cell site then such a system is called as balanced system.
- Considering a two tier of cells (twelve cells) arrangement under co-chan interference analysis the carrier to interference ratio C/I is,

$$\frac{C}{I} = \frac{1}{\sum_{k=1}^{k_I}(q_k)^{-\gamma}} \quad ; \text{ where } q_k = \left(\frac{D_k}{R}\right)$$

in which 1) q_k is the co-channel interference reduction factor.

2) k represents the k^{th} cell and

3) γ represents the propagation path-loss slope that is calculated b the terrain development.

$$\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^\gamma}{6}$$

and $\boxed{q^\gamma = 6\,C/I}$ $\rightarrow q = \left(6\frac{C}{I}\right)^{1/\gamma}$

For finite set of cells (N) in the cellular system

$$q = \sqrt{3N} \quad \text{or} \quad q = \sqrt{3K}$$

where N or K is the cluster size.

For the C/I = 18 dB from the simulation results

1) D = 4.6 R 2) $q = \frac{D}{R} = 4.6$

2.4.2 Adjacent Channel Interference

- **Adjacent channel interference** occurs from channels in adjacent neighbouring cells. This is worse in small cell clusters. Adjacent channel interference results from imperfect filters in receivers that allow nearby frequencies to enter the mobile unit.
- Interference can be observed when an adjacent channel is transmitting and the mobile unit is receiving at an adjacent frequency. This is called as **near-far effect.** Both mobile unit and base station receiver will tend to cancel the adjacent channel spectral component but due to near-far effect and propagation path loss can add a very large number of dBs to the adjacent channel interference compared to the on-channel signal.
- Adjacent channel interference can be reduced by designing precise filtering in receivers and assigning frequency channels. The best that one can do is to keep adjacent channels as far apart. The voice channels in cells are chosen to be far away from those in their adjacent cells, from the channel set available in the frequency plan, because of adjacent channel interference and bandwidth overlap problems.

Example 2.4.1 *If a signal to interference ratio of 15 dB is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is (1) n= 4, (2) n = 3? Assume that there are six co-channels cells in the first tier and all of them are at the same distance from the mobile.*

GTU : Winter-15, Marks 7

Solution : (1) For n = 4

Considering a 7-cell reuse pattern.

Co-channel reuse ratio : $Q = \frac{D}{R} = \sqrt{3} = 4.583$

The signal-to-noise interference ratio is given by

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

$$\frac{S}{I} = (1/6) \times (4.583)^4 = 75.3 = 18.66 \text{ dB.}$$

Since this is greater than the minimum required S/I, therefore, N = 7 can be used.

2) For n = 3

Considering a 7-cell reuse pattern.

The signal-to-interference ratio is given by

$$S/I = (1/6) \times (4.583)^4 = 16.04 = 12.05 \text{ dB.}$$

Since this is less than the minimum required S/I, we need to use a larger N.

University Questions

1. *How co-channel interference and system capacity arc related ?* **GTU : Summer-15, Marks 7**
2. *With respect to mobile networks, explain co channel and adjacent channel interference.* **GTU : Summer-16, Marks 7**

2.5 Handoff Strategies

GTU : Winter-15

- The limited available power transmitted by the mobile subscriber determined the ce size. As the subscriber moves (roams) between cells during a journey, th communication with the base station of the departing cell ceases and communicatio with the base station of the entering cell commences. This process is known a **handoff or handover.**
- Each adjacent base station transmits a frequency that is different from its neighbou The handoff is accomplished when the received signal from the base station is lo enough to exceed a predetermined threshold. At the border between two cells th subscriber is under the influence of two or even three base stations, and th communication link can pass back and forth between base stations as the movin subscriber receiver experiences a fluctuating field strength depending upon th immediate environment such as being surrounded by tall buildings. Hence th carrier-to-interference ratio (C/I) on its allocated channel will vary, this is monitore by main switching center,the mobile can be instructed to hand over the strongest ba station.
- Handoff mechanism is shown in Fig. 2.5.1 as the mobile unit passes through adjace cell sites maintained by local base stations.
- Handoff assures the continuity of calls. Handoff of a call to a new connection implie transfer of security functions also.
- The handoff algorithm must be able to cope with-

a) Whether the current loss in channel quality is due to short term fading.

b) Whether a simple increase in power would be sufficient to restore the chann quality (it can produce an unacceptable co-channel interference in other cells usin the same frequency).

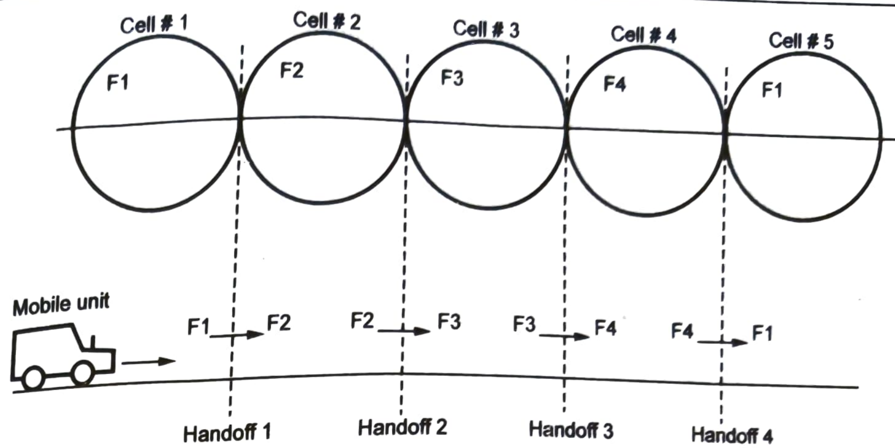


Fig. 2.5.1 Handoff mechanism

c) Whether the measurements from adjacent cells are valid.

d) Whether the cell chosen for handover has spare channels available.

- In some systems the mobile unit continuously monitors the signals of surrounding base stations and initiates the process of hand off when required. Such systems are known as **mobile controlled handoff (MCHO).**
- In analogue systems such as in AMPS the base stations performs the radio channel measurments and the mobile terminal is totally passive it is known as **network-controlled handoff (NCHO)**
- In digital systems, both mobile terminals and base stations make measurements and report these to fixed networks for handover decisions, it is known as **mobile assisted handoff (MAHO).** It is used in GSM and IS 95.
- The handoff without interruption is called a **soft handoff,** it takes normally 0.2 sec to switch over. A handoff which that is broken momentarily during call transfer is called **hard handoff.** During handoff, the information about the user stored in the earlier base station is transferred to the new base station.
- On receipt a command to 'handover' the mobile stores the new channel number, power level and signalling tone for ms before handing over. For AMPS/TACS the duration time for confirmation of handoff mechanism is 50 msec.
- Whenever handoff occurs communication is interrupted and voice channels are muted. This interruption is usually short and unnoticed during voice communications. After the completion of calls these channels are reallocated to other users.

2.5.1 Reasons of Handoff

- Handoff is required for any of reasons.

1. The mobile unit moves out of range of a base station.
2. Traffic in one cell is too high in order to balance the traffic in each cell hand off is initiated.
3. In noise limited system when the signal strength goes below the threshold of – 100 dBm.
4. When the signal strength is not at all reaching within the cell site. This happens because of geographical locations and the portion where the signal is not available is called as **holes or gaps.**
5. When the capacity for connecting new calls of a given cell is used up.
6. When there is interference in the channels due to the different phones using the same channel in different cells.

2.5.2 Types of Handoff

- Handoff is the mechanism which transfers an ongoing call from one cell to another cell as users are near to the coverage area of the neighbouring cell. If handoff does not occur quickly, the Quality of Service (QoS) will degarde below an acceptable level and the connection will be lost.
- There exists two types of handoff -
  1. Handoff based on signal strength.
  2. Handoff based on carrier-to-interference ratio (C/I).
- While designing the mobile system the minimum acceptable level of signal strength is decided. For noise-limited system the signal strength is –100 dBm and for interference limited system the threshold is – 95 dBm. When the signal level in any situation goes below the threshold level, the hand is initiated.
- Also for an acceptable quality of voice the value of carrier-to-interference ratio is decided within cell boundary. When the C/I ratio drops below 18 dB with cell area handoff initiated.

Sr. No.	Based on SS	Based on C/I
1.	Threshold level i) – 100 dB M in noise limited systems ii) – 95 dB M in interference limited systems	At cell boundary C/I = 18 dB
2.	Easy implementation	Not easy to implenent

- Received Signal Strength (RSS) = C + I

where C → Carrier signal power

I → Interference level

- If C/I drops in a cell and if the occurance of handoffs is dependent on C/I then in this case as a response to drop C/I either the propagation distance or interference will increase.

2.5.3 Dropped Call

- When a mobile unit moves into a cell where all the channels are busy, there is possibility that the call may be dropped because of lack of free channels, it is called as **blocked call**. The reason of blocked call is non-availability of voice channels.
- The call may drop because of poor signal of the assigned voice channel the termination of call due to weak signal is referred to as **dropped call**. The signal becomes weak because of fading phenomena. The dropped call rate should be minimum to achieve the maximum efficiency of the system.

  Dropped call rate is given by

$$p = \sum_{n=0}^{N} \alpha_n \cdot P_n$$

where P_n represents probability of dropped call after n handoff.

α_n represents weighted value for calls having n handoff.

N represents the maximum number of handoff.

2.5.4 Handoff Initiation

- In the cell site the signal strength is continously monitored using a reverse voice channel. Depending on the strength the decision for handoff is made.
- If the signal strength reaches a level that is higher than the threshold level set for minimum voice quality, cell site will request the switching office (MTSO) for handoff to continue the call. Occurance of handoff either earlier or later can be determined by intelligence within the call site also.
- Two points have to be considered and they should be avoided,
  1) An unneccessary handoff will be requested if the handoff decision is very early.
  2) A failure handoff would result if the handoff decision is very late.
- Thus the decision for a handoff on call should be perfect depending on accuracy of signal strength measurements. The threshold can be determined by two parameters namely velocity of vehicle 'V' and the pathloss slope γ in the pathloss curve.
- Assume the threshold level is – 100 dBm at cell boundary. To have a handoff here the signal strength level should be higher than – 100 dBm (Δ).

- If signal strength is = – 100 dBm + ΔdB then a request for handoff will be initiate The value of Δ should not be too large or too small so that proper handoff initiatio at right time will be made.

Note

Handoff may be necessary but cannot be done at following cases

1) Mobile is at signal strength hole and not at cell boundary.

2) If the mobile is at cell boundary but no channel in the new cell is available t make handoff

- In these cases MTSO has to take step to make handoff faster before a dropped cal occurance.

Number of handoffs

- If the call size is smaller the number of handoffs taking place will be high. The number of handoffs for one call progress depends on the size of the cell.

e.g.

Cell area	Number of handoffs
16 to 24 km cell	0.2 handoff / call
3.2 to 8 km cell	1 - 2 handoffs / call

2.5.5 Delaying Handoff

- In simple case of handoff we have an efficient call communication withou disturbance inspite of the moving mobile unit's status.
- There is also another handoff called as two-handoff-level that is applied to have successive handoff of a call.
- The use of this algorithm allows two request handoffs so as to provide more chances to have a successful handoff.

2.5.6 Delayed Handoff

- When a base station wants to handover the call to the base station of new cell where the subscriber enters, the new base station will accept it and takes call control. This smooth handoff is possible only if the new cell is free to take it. If there the cell not available (free) then the handoff will be delayed. This is known as delayed handoff scenario.
- A simple two-level handoff technique is shown below with a graph mentioning threshold level.

There are two cases 1 and 2 as shown.

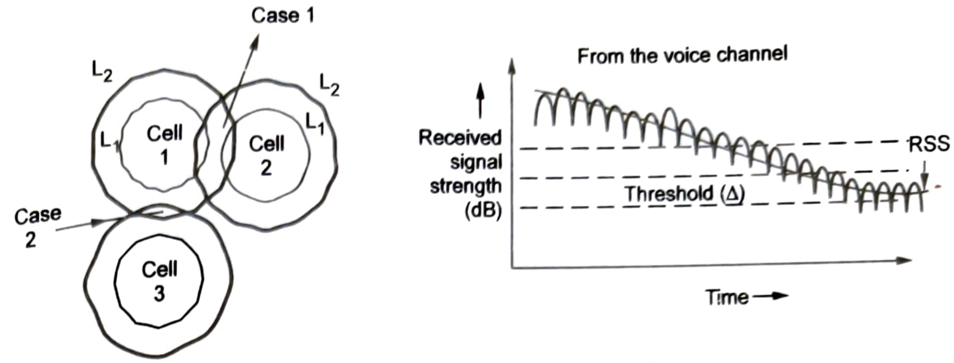


Fig. 2.5.2 Two level handoff technique

Assume that the mobile unit is in a hole or a weakspot or the neighbouring cell of it would be busy. Then handoff will be periodically requested say for every 5 sec.

- Consider the case 1. During first handoff level there will be successful handoff if the new signal is very strong. In case 2 the second handoff level is shown. Here the call in progress is handed it to new cell with no restricted conditions.
- When there are both handoff request and originating call request comes present at same time to MTSO, the MTSO will attend to the handoff call first. The originating new call will be given second priority. The call will be allowed to continue smoothly till the allowed threshold level is reached, as in the graph. Once the threshold level (Δ) is reached the call will be dropped.

Note If the SAT tone is not sent from mobile unit within a time of 5 sec, then cell site will turn off the transmitter unit. Thus receiving of SAT tone from mobile unit is closely monitored.

Advantages of delayed handoff

1) If the neighbouring cells are busy delayed handoff helps to continue the call in progress smoothly till the new cell gets free.

2) In two-handoff-level alogorithm only after the second handoff the call will be dropped. Thus probability of call blocking is very less.

3) This algorithm also makes handoff to take place at correct location.

4) The algorithm avoids interference in the system .

2.5.7 Forced Handoffs

- A forced handoff technique can be explained with two different definitions

1) Forced handoff is a technique that is defined as a handoff which should not occur but it is forced to occur.

2) Forced handoff is a technique that is defined as a handoff that would occur normally but it is prevented to occur.

- In forced handoff two important aspects are :
  i) Controlling a handoff and ii) Creating a handoff

I) Controlling a handoff

- If handoff should occur earlier then handoff threshold level should be high. On the otherhand if handoff should occur later the handoff threshold level should be low.
- Depending upon these criteria a cellsite has to plan a low handoff threshold or high handoff threshold level in the cellsite.
- The Mobile Switching Office (MSC) can also control the handoff and make it to occur either earlier or later, after receiving a handoff request from the cell site in the system.

II) Creating a handoff

- The concept of creating a handoff is dependent on the cell congestion due to mobile traffic.
- If a cell is too congested then mobile switching office decides to create handoffs.
- It informs the cellsite those that are heavily congested due to mobile traffic to create early handoffs. If so some calls will be handed over to neighbour cells and the congested cell will be reaching a moderate mobile traffic.
- Thus handoff threshold level in cell site may be high or low according to the order of MTSO given to cellsites. Depending upon the instructions of MTSO either earlier or delayed handoff would take place in the cell.
- The advantage of this method is to have an efficient mobility management.

2.5.8 Handoff Prioritization

- Handoff fails for many reasons like, if no channel is available in the candidate cell. One of the ways to reduce the handoff failure rate is to prioritize handoff.
- Handoff algorithms try to minimize the number of handoffs which give poor performance in heavy traffic situations. In such situations, a significant handoff performance improvement can be obtained by prioritizing handoff.
- Two basic methods of handoff prioritization are guard channels and queuing of hand off.

1. Guard Channels

- Guard channels improve the probability of successful handoffs by reserving a fixed or dynamically adjustable number of channels exclusively for handoffs.

- An adaptive number of guard channels can help reduce this problem.

2. Queuing of Handoff

- Queuing is a way of delaying handoff. The MSC queues the handoff requests instead of denying access if the candidate BS is busy.
- The probability of a successful handoff can be improved by queuing handoff requests at the cost of increased new call blocking probability and a decrease in the ratio of carried-to-admitted traffic since new calls are not assigned a channel until all the handoff requests in the queue are served.

2.5.9 Handoff Failures

- The reason of handoff failures :
  1. No channel is available on selected BS.
  2. Handoff is denied by the network for reasons such as lack of resources. For example, no bridge or no suitable channel card; the MS has exceeded some limit on the number of handoffs that may be attempted in some period of time. It takes the network too long to set up the handoff after it has been initiated.
  3. The target link fails in some way during the execution of handoff.

2.5.10 Types of Protocols

- In cellular wireless networks, it is very important to deal with Mobile Station (MS) handoff between cells in order to maintain a continuous and QOS-guaranteed service.
- There are four basic types of handoff protocols which help in providing continuous and QOS-guaranteed service. Namely :
  1. Network-Controlled Handoff (NCHO)
  2. Mobile-Assisted Handoff (MAHO)
  3. Soft HandOff (SHO) and
  4. Mobile-Controlled HandOff (MCHO)

University Question

1. *With figure explain hand off scenario at cell boundary.* GTU : Winter-15, Marks 4

GTU : Winter-15

2.6 Cell Splitting

- Cell splitting is a popular technique to expand the capacity of cellular system. Cells in area of high usage can be split into smaller cells.

- **Cell splitting** is the process of subdividing congested cells into smaller cells with their own Base Station (BS); corresponding reduction in antenna height and a corresponding reduction in transmitting power. Fig. 2.6.1 shows cell splitting technique.
- Cell splitting is achieved through reducing cell radius and keeping the D/R ratio unchanged.
- These smaller cells within the large cell have very interesting characteristics. All of them have their own base stations but these base stations are not so high. The antennas are shorter and they also transmit less power.

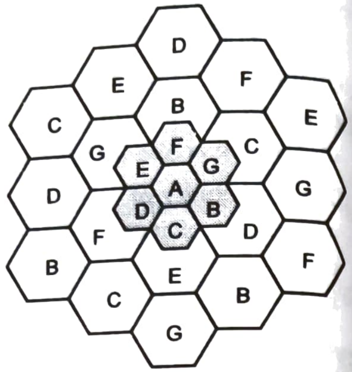


Fig. 2.6.1 Cell splitting

- Splitting the cell reduces the cell size thus more number of cells is to be used. More number of cells implies more number of clusters, more number of clusters implies more number of channels because number of channels per cell is fixed and ultimately it leads to a higher capacity.
- Cell splitting allows a system to grow by replacing large cells by smaller cells without upsetting the channel allocation. Frequency planning requires a lot of effort and resource allocation.

Features of Cell Splitting

- Important features of cell splitting are as under :
  1. Cell splitting enables more spatial use i.e. greater system capacity.
  2. Cell splitting preserves original frequency reuse plan.
  3. Cell splitting cause increased frequency handoffs.

2.6.1 Problems in Cell Splitting

- The problems of cell splitting can be categorised in to two categories : Channel assignment and handoff.

Channel Assignment

1. Not all cells are split at the same time.
2. It is often difficult to find real estate that is perfectly suitable for cell splitting.
3. Different cell sizes will exists simultaneously.
4. Special care needs to be taken to keep distance between co-channel cells at the required minimum, and hence channel assignments become more complicated.

5. High speed and low speed traffic needs to be accommodated simultaneously. For this , umbrella cell approach is commonly used.

2.6.2 Types of Cell Splitting

- In cells splitting we divide the original cell into small cells so as to handle different mobile traffic weather high or low. The small cells of the original cell is called as micro cells.
- In cell splitting technique there are two types :

1) Permanent cell splitting

- In premanent cell split the new cells are planned in a head. The number of channels to be assigned to each cell is pre-planned. Also the transmitted power, allocation of frequency, selection of cell site and the nature of traffic are considered. The lowest traffic in the cell-site is midnight and the call services during this period is very less. Thus the frequency channels are assigned permanently to the channel during system design itself.

2) Dynamic cell splitting

- It is also known as real-time cell splitting. This technique allocates channels to the cell depending upon traffic availability. As demand is more during busy hours many number of channels are assigned to cell, as per the requirement. It works in real time. But the complexity involved is complexity, in design involved.

Cell size issues in cell splitting

- The size of cell splitting depends on two factors :
  1. **Radio aspect :** The size of a small cell depends on the capacity of system to control coverage pattern and vehicle locating methods.
  2. **Capacity of switching processor :** If the size of cell is small then for call communications more number of handoffs will be required. Comparing the coverage handling problem is an important factor while dealing cell splitting technique.

2.6.2.1 Micro Cells

- When size of cell is very small the vehicle locating process is difficult because for handling every call more number of handoffs are required. Also control of radiation pattern is has to be considered for deciding the size of cell. For this installation of a mastless antenna is used.

Antenna structures and existing building structure

- If antenna is a roof-top mounted antenna on buildings then the height of post (h) shown below should be

$$h = d_1 \tan\left(\frac{\phi}{2}\right)$$

where ϕ is the vertical beamwidth of antenna, d_1 is distance between antenna po and roof.

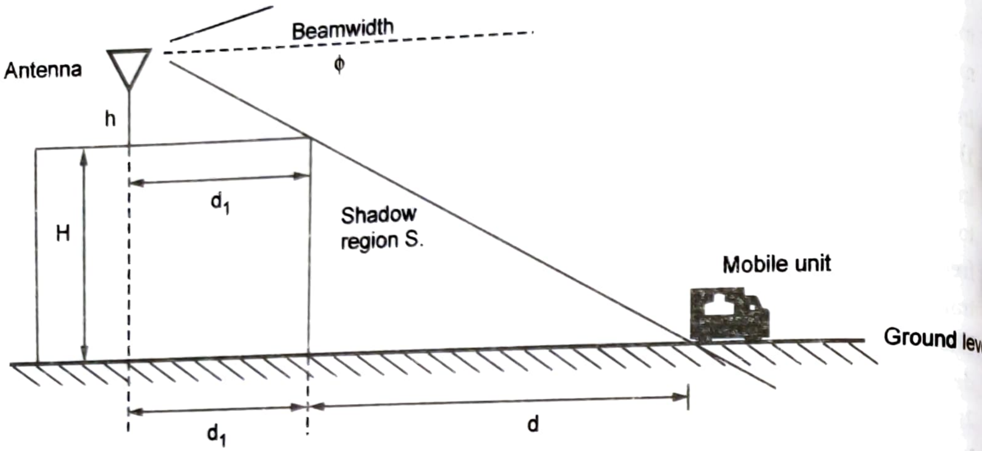


Fig. 2.6.2 Antenna mounted on roof top of building

- Consider antenna with vertical beamwidth as 28° gain is 6 dB distance d_1 is 31 m then the height of antenna h will be

$$h = (31\text{ m}) \tan\left(\frac{28^\circ}{2}\right).$$

It will be approximately 7.5 m.

Note *The shadow region (S) shown in Fig. 2.6.2 will depend on the height of the building structure.*

- A panel-type antenna can be used for antenna structures that can be hanged on the side walls. For example four-panel antennas would be mounted on walls for an omni-directional configuration, and mounted on building walls.
- If cell sectorization is used in every sector one antenna can be placed.

Effects of micro Cells

i) If cell splitting technique is applied in a cellular system there will be an unbalanced condition in the system. There will be changes in frequency reuse distances, power level etc. that results in unbalanced system condition.

ii) Due to cell splitting there will be both larger cells and small cells available. A group of frequencies should be maintained as barrier between those two cells so that interference can be avoided.

Parameters for micro cells

Cell radius	0.1 - 1 km
Delay spread (average value)	10 - 100 msec
Max bit rate	1 Mb/sec.
Transmission power P_T	0.1 - 1 watt

University Question

1. *Explain the concept of cell splitting in detail with figure.* **GTU : Winter-15, Marks 7**

2.7 Cell Sectoring

GTU : Winter-15

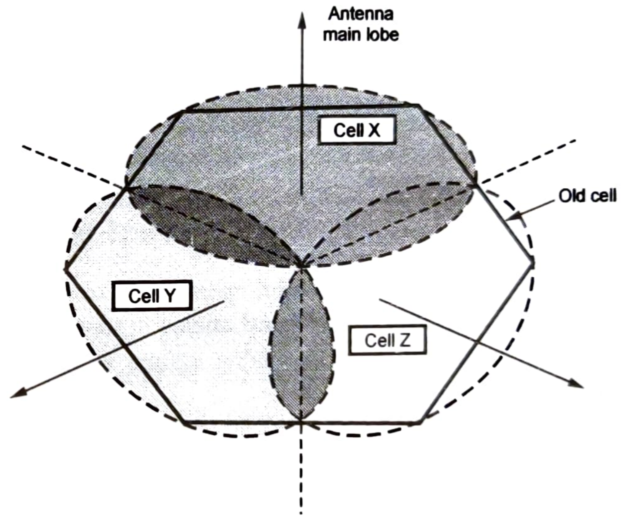


Fig. 2.7.1 Cell sectoring

- Cell sectoring uses directional antennas to effectively split a cell into three or sometimes six new cells.
- The new cell structure now uses three directional antennas with 120 o beam widths to illuminate the entire area previously serviced by a single omnidirectional antenna.

Sectoring of a cell results in a direction in the amount of interference that the sector experiences from its co-channel neighbors in adjacent clusters and conversely the amount of interference that the sector supplies to its co-channel neighbours.

Fig. 2.7.1 illustrates cell sectoring for increasing capacity.

2.7.1 Comparison of Cell Splitting and Cell Sectoring

Sr. No.	Cell splitting	Cell sectoring
1.	This method uses cell splitting from large cells into smaller cells to increase capacity in the over burdened areas.	This method uses cell sectoring to increase cellular system capacity by using three directional antennas.
2.	New cells require one quarter area of the large cells.	New cell structure requires 120° or 60° beam width.
3.	Transmit power reduced by a factor of 16 or 12 dB.	It reduces the amount of interference.
4.	Cell splitting effectively increases system capacity by reducing the cell size.	Cell sectoring effectively increases signal to noise ratio.
5.	Splitting process requires new cell sites.	It does not require new cell sites only additional antennas and triangular platforms are required.
6.	It is very difficult to implement.	It is easy to implement.
7.	It reduces the frequency range distance and permits to use more channels.	It can reduce the carrier size and gain more system capacity.

2.7.2 Overlaid Cells

- By using overlaid cell, the operational wideband analog system could be upgraded to increase its capacity by overlaying another analog system with a narrow bandwidth requirement over it.

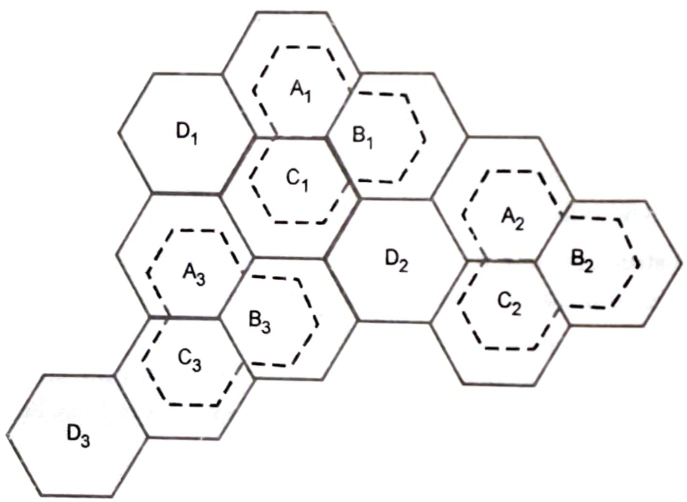


Fig. 2.7.2 Overlaid cells in split-band system

- The channels are divided between a larger macro cell and the overlaid micro cell that is contained in its entirely within a macro cell.
- The channels assigned to microcell are used to service users in the area between the microcells and the channels assigned to microcells service the microcells.

University Question

1. *Explain the concept of sectoring in detail with figure.* **GTU : Winter-15, Marks 7**

2.8 Trunking and Grade of Service

- **Trunking** is defined as a network that handles multiple signals simultaneously. The data transmitted through trunking can be audio, video, controlling signals or images. Trunking reduces the size of a telecom network and increases bandwidth.
- Trunking is the mechanism used to form an internetwork, or Internet, comprised of Local Area Networks (LANs), Virtual LANS (VLANs) or Wide Area Networks (WANs). The switches are interconnected to establish these networks using trunking. Trunking is not limited to any medium since its main purpose is to maximize the bandwidth available in any type of network.

2.8.1 Terminology in Trunking Theory

- The traffic is defined as the average number of calls in progress.
- Traffic is a dimensionless quantity but a name given to unit of traffic is Erlang (abbreviation E) named after A. K. Erlang, a Danish pioneer of traffic theory.
- Traffic is sometimes expressed in terms of hundreds of call seconds per hour (CCS).

$$\boxed{1 \text{ erlang} = 36 \text{ CCS} = 3600 \text{ CS} = 60 \text{ CM}}$$

1. **Busy Hour**

   The busy hour of an exchange is chosen 60 minute interval in which the telephone traffic is highest. The busy hour varies from exchange to exchange.

2. **Busy Hour Calling Rate (BHCR)**

   Busy Hour Calling Rate (BHCR) is defined as the average number of calls per subscriber during the busy hour.

   If the number of calls during busy hour be 6000 in an exchange serving 5000 subscribers, then BHCR is given as -

$$\boxed{BHCR = \frac{\text{Average busy hour calls}}{\text{Total number of subscribers}}}$$

$$BHCR = \frac{6000}{5000} = 1.2$$

$$\boxed{\text{Average Busy Hour Calls} = BHCA \times CCR}$$

3. Holding Time

- The holding time of a call is the time from which the first selector is seized to set up to call up to the time when all the selectors are released.

or

- The duration of a call is called as holding time.
- From the definition of erlang, the traffic carried by a group of trunk is given by :

$$\boxed{A = \frac{Ch}{T}}$$

where,

A is traffic in erlangs.

C is average number of call arrivals during time 'T'.

h is average call holding time.

4. Occupancy

- A single trunk can carry only one call at a time i.e. $A \leq 1$. It means that the traffic a fraction of an erlang equal to the average proportion of time for which the trunk busy. This is referred as **occupancy** of the trunk.

5. Call Completion Rate (CCR)

- The Call Completion Rate (CCR) is defined as the ratio of the number of successful calls to the number of call attempts.

$$\boxed{CCR = \frac{\text{Number of successfull calls}}{\text{Number of call attempts}}}$$

- CCR and BHCR are related by -

$$\boxed{CCR = \frac{\text{Average busy hour calls}}{BHCA}}$$

6. Busy Hour Call Attempts (BHCA) : The number of call attempts in the busy hour called **Busy Hour Call Attempts (BHCA).**

7. Set-up Time :

- The time required to allocate a trunked radio channel to a requesting user is called as **set-up time.**

8. Blocked Call :

- Call which cannot be completed at time of request, due to congestion is called **blocked call.** It is also referred to as a lost call.

9. Traffic Intensity:

- Measure of channel time utilization, which is the average channel occupancy measured in Erlangs. This is a dimensionless quantity and may be used to measure the time utilization of single or multiple channels. Denoted by A.

10. Load :

- Load is traffic intensity across the entire trunked radio system, measured in Erlangs.

11. Grade of Service (GOS) :

- The **grade of service (GOS)** is a measure of congestion which is specified as the probability of a call being blocked (for Erlang B), or the probability of a call being delayed beyond a certain amount of time (for Erlang C).

12. Request Rate:

- The average number of call requests per unit time is called **request rate.** It is denoted by λ seconds^{-1}.

2.8.2 Grade of Service and Blocking Probability

1. Grade of Service (GOS)
2. Blocking probability

- It is theoretically possible for every subscriber to make a call simultaneously in an telephone exchange.
- The situation is that all the trunks in a group of trunks are busy and so it can accept no further calls. This state is known as "congestion". In a message switched system, calls that arrive during congestion wait in a queue until an outgoing trunks becomes free. Thus they are delayed but not lost. Such systems are therefore called queuing systems or delay systems.

Traffic carried = Traffic offered – Traffic lost.

Traffic lost = Traffic offered – Traffic carried

$$\text{Traffic lost} = A - A_0$$

Grade of Service (G.O.S.)

- The proportion of calls that is lost or delayed due to congestion is a measure of the service provided. It is called the grade of service.

$$\text{G.O.S.} = \frac{\text{Number of calls lost}}{\text{Number of calls offered}}$$

$$\boxed{\text{G.O.S.} = \frac{\text{Traffic lost}}{\text{Traffic offered}} = \frac{A - A_0}{A}}$$

Blocking Probability

- The blocking probability (P_B) is defined as the probability that all the servers in system are busy. Under such condition, no further traffic can be carried by the system.
- The probability that all the servers are busy may well represent the fraction of calls lost, which is GOS. But fundamental difference is that GOS is a measure from subscriber point of view whereas the blocking probability is a measure from network or switching system.

2.8.3 Comparison of GOS and Blocking Probability

Sr. No.	GOS	Blocking probability
1.	GOS is index of quality of service offered by network.	It is the probability that all the servers in system are busy.
2.	GOS can be zero.	It is always non-zero value.
3.	GOS is measured from subscriber point of view.	Blocking probability is measured from switching point of view.
4.	GOS is referred as call congestion or loss probability.	Blocking probability is referred as time congestions.

Useful Results

Sr. No.	FORMULA FOR	FORMULA
1.	Traffic carried by a group of trunk is given.	$A = Ch/T$ where A = Traffic in Erlangs, C = Average number of call arrivals during time 'T' h = Average holding time

2.	Average Busy Hour Calls (ABHC)	ABHC = Busy hour calling attempts × Call completion rate
3.	Busy Hour Calling Rate (BHCR)	$\text{BHCR} = \frac{\text{Average busy hour calls}}{\text{Total number of subscribers}}$
4.	Grade of Service (B)	$B = \frac{\text{Traffic lost}}{\text{Traffic offered}}$
5.	Traffic Carried (TC)	TC = Traffic offered − Traffic lost
6.	Traffic Offered (TO)	TO = Traffic carried + Traffic lost

Distribution of Traffic Over Trunks of a Group with Sequential Search

- In many switching systems, trunks in a group are selected by means of sequential search. A call is not connected to trunk numbered 2 unless 1 is busy. It is not connected to 3 unless both the previous trunks 1 and 2 are busy and so on. Calls finding the last choice trunks busy are lost. As a result, the 1st trunk has a very high occupancy and traffic carried by subsequent trunks is less. The last choice trunk is very lightly loaded. This behaviour is illustrated in the following Fig. 2.8.1.

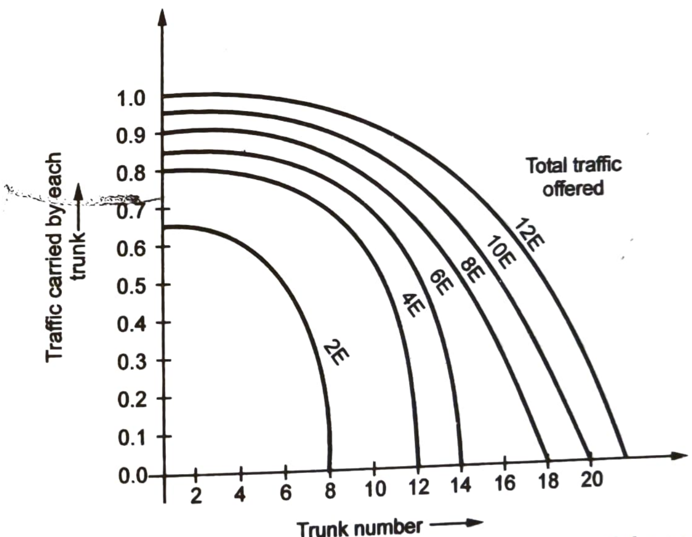


Fig. 2.8.1 Traffic distribution of a group with sequential search

- The performance of such an arrangement can be analyzed as follows : Let traffic 'A' E be offered to a group of trunks. Consider Erlang's lost call formula.

$$B = E_{IN}(A) = \frac{\frac{A^N}{N!}}{\sum_{K=0}^{N} \frac{A^K}{K!}} \qquad \text{... (2.8.1)}$$

The grade of service for a single trunk group is put N = 1, in equation (2.8.1).

$$\Rightarrow \quad E_{1,1}(A) = \frac{\frac{A^1}{1!}}{\sum_{K=0}^{1} \frac{A^K}{K!}} = \frac{A}{\frac{A^0}{0!}+\frac{A^1}{1!}} = \frac{A}{1+\frac{A^1}{1!}}$$

$$\Rightarrow \quad E_{1,1}(A) = \frac{A}{1+A}$$

Traffic overflowing from 1st trunk to 2nd is ;

$$A\,E_{1,1}(A) = \frac{A^2}{1+A}$$

$$\therefore \quad \text{Traffic carried by 1st trunk} = \text{Traffic offered} - \text{Traffic lost}$$

$$= A - \frac{A^2}{1+A}$$

$$= \frac{A + A^2 - A}{1+A} = \frac{A}{1+A}$$

In general,

Traffic carried by K^{th} trunk = Traffic lost from group of 1st (K – 1) trunks – traffic lost from group of 1st K trunks.

$$\therefore \quad \text{Traffic offered} = A\,\{E_{1,(K-1)}(A) - E_{1,K}(A)\}$$

2.9 Channel Antenna System and Design Consideration

GTU : Summer-16

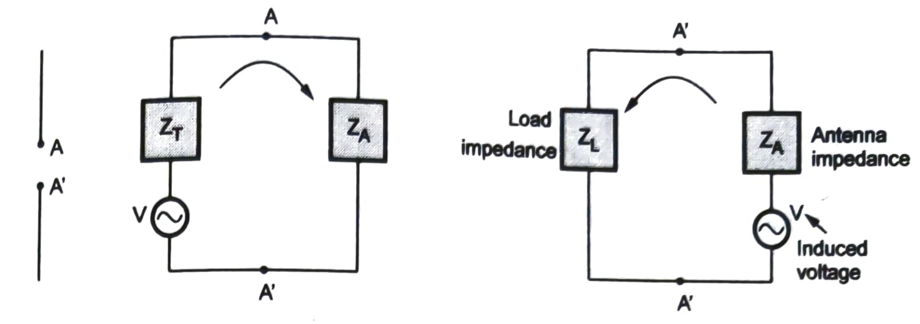
2.9.1 Equivalent Circuit of Antenna

- Consider an antenna and its equivalent circuits for transmitter and receiver (setups). Let Z_A be the antenna impedance, Z_L be the load impedance and Z_T be the impedance at the transmitter end.
- At the transmitting end of antenna the power P_t originates and it radiates into the space. If an isotropic antenna source P_T is used then power available in spherical space could be measured as power/unit area. Such a power density is known as outward flow of the energy or the poynting vector 'e', in a given surface area.

$$\text{Poynting vector} = e = \frac{P_T}{4\pi r^2}\ \text{W/m}^2$$

- The power will be received by the receiver antenna that is at a distance 'r' from the source antenna and with aperture A.

The received power is = $P_R = eA$



(a) Antenna (b) Equivalent circuit of transmitting antenna (c) Equivalent circuit of receiving antenna

Fig. 2.9.1 An antenna with equivalent circuits

$$= \left(\frac{P_T}{4\pi r^2}\right) A \cdot \text{watt}$$

- The three antennas and its equivalent diagrams are shown here.

In the circuit,

$Z_T \rightarrow$ Transmitter impedance

$Z_A \rightarrow$ Antenna impedance

$V \rightarrow$ Voltage

A, A' $\rightarrow$ Antenna.

- A simple diagram of power received in space is shown here. The antenna is A-A' and it is at a distance 'r' from the source transmitting. The signal emerges in many directions as it propagates from source.
- The power received at receiving antenna is P_R watts measured as above.

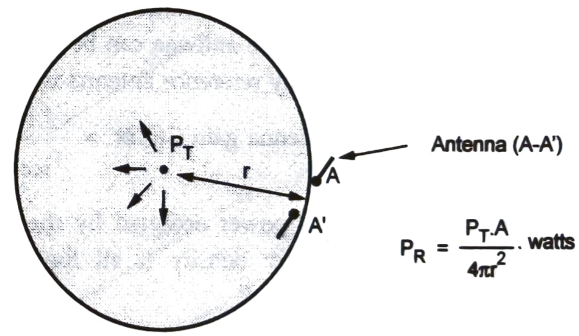


Fig. 2.9.2 Example of power received in space

The gain G and antenna aperture are related in the equation,

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

where λ is the wavelength in 'm'.

The gain G is unity for a short dipole.

Then $\frac{4\pi A}{\lambda^2} = 1$

Aperture is $\boxed{A = \frac{\lambda^2}{4\pi}}$

Now substituting the value of antenna aperture in the equation of received pow 'P$_R$', we get,

$$P_R = eA = \frac{P_T A}{4\pi r^2}$$

$$= \frac{P_T}{4\pi r^2} \cdot \frac{\lambda^2}{4\pi} = \frac{P_T \cdot \lambda^2}{(4\pi r)^2}$$

$$P_R = \frac{P_T}{(4\pi r/\lambda)^2}$$

2.9.2 Gain and Pattern Relationship

2.9.2.1 Antenna Gain

- **Antenna gain** is a gain relative to a reference antenna (isotropic radiator). Antenn gain is a measure of directional capabilities and efficiency of antenna.
- Antenna gain is defined as the ratio of the radiation intensity in a given direction t the radiation intensity by a reference (isotropic) antenna for similar power input t both antenna. The reference antenna can be short dipole or horn antenna whose gai can be calculated. Usually reference antenna is lossless isotropic source.

$$\text{Antenna gain } G(\theta, \phi) = \frac{P(\theta, \phi)}{P_{acc} / 4\pi r^2}$$

where P_{acc} is the total power accepted by the antenna from the transmitter (watts and $\mathbf{P_{acc}}$ is radiated power density if all the $4\pi r^2$ power is radiated isotropicall (watts/metre^2).

- The power accepted by the antenna is greater than the actual radiated power becaus of reflection (mismatch) efficiency and polarization loss factor.
- Antenna gain can be expressed interms of electric field.

$$G(\theta, \phi) = \frac{4\pi \text{ (Maximum radiated intensity)}}{\text{Total power radiated}}$$

$$G(\theta, \phi) = \frac{E^2_{max} (\theta_m, \phi_m)}{E^2 (\theta, \phi)} \quad \dots(2.9.1)$$

where,

E represents electric field

E_{max} represents maximum value of E.

E^2 represents average value of E^2 which is related to radiation intensity.

θ, ϕ represents radiation angles on azimuth and elevation planes.

- The antenna pattern E can be obtained either by measurement or in analytic form. The antenna gain G is calculated from E pattern.

Effective Radiated Power

When the gain of an antenna is multiplied by its power input, the result is termed as effective radiated power (ERP).

2.9.2.2 Pattern and Gain of an Antenna Array

- In certain communication systems a highly directive beam of radiation is needed. The conventional antennas and other elementary radiators cannot provide the highly directive beam of radiation because of low gain. This can be achieved by antenna arrays.
- An **antenna array** is a transmitting system consists of group of radiators arranged in specific manner.
- All the radiating elements of the arrays are placed close to each other so that they are within the induction field of each other. They interact with each other so that the resulting radiation pattern is the vector sum of individual patterns. The resulting radiation pattern is dependent on the characteristics of individual elements and the spacing between them. The antenna array also provides higher gain to the antenna.

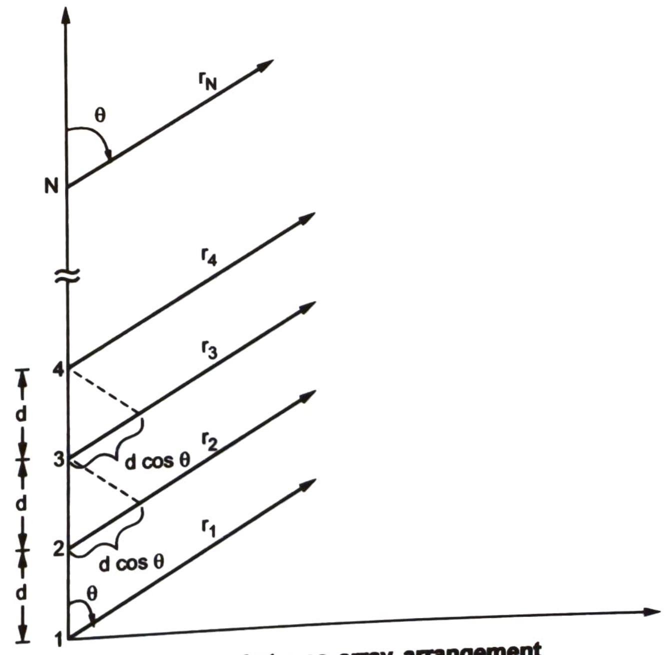


Fig. 2.9.3 Antenna array arrangement

- A simple and most practical array can be formed placing the radiating elements along a line. Fig. 2.9.3 shows N isotropic radiators forming an array. All the sources are equally spaced.
- The general field pattern of an antenna array is given as :

$$E(\theta, \phi) = \frac{\sin[N\pi(d\cos\phi \cdot \sin\theta + \psi)]}{N\sin[\pi(d\cos\phi \cdot \sin\theta + \psi)]} \times \begin{pmatrix}\text{Individual antanna} \\ \text{element pattern}\end{pmatrix} \quad \ldots(2.9.2)$$

where,

N represents number of elements in an array.

d represents spacing between adjacent elements in wavelength.

ψ represents phase difference between two adjacent elements.

θ, ϕ represents radiation angles.

$\theta = 90°$ for direction perpendicular to array axis.

- The gain of an array can be obtained by substituting equation (2.9.2) in equation (2.9.1).

2.9.2.3 Beamwidth

- Usually a directional antenna emits a beam of radiation in one or more directions. Various parts of radiation patterns are referred as **Lobes**.

1. Major Lobe :

- It is the radiation lobe in the direction of maximum radiation.

2. Minor Lobe :

- These are the lobes other than major lobe. A minor lobe is radiation in undesired direction hence it should be minimized.

3. Side Lobe :

- It is the lobe in any direction other than the major or intended lobe.

4. Back Lobe :

- It is a radiation whose axis makes an angle of approximately 180° with respect to beam of antenna.
- The **beamwidth of an antenna** is defined as the angle between its half power points in major lobes. These are also the points where power density is 3 dB less than it is at its maximum point.

2.9.2.4 Relation between Gain and Bandwidth

- Assuming gain G and directivity D are same,

$$\boxed{G = (D) = \frac{32{,}400}{\phi°\ \theta°}} \quad \text{For small } \phi \text{ and } \theta$$

where, $\phi°$ and $\theta°$ are 3 dB beamwidths in two planes.

$$\boxed{G = \frac{41{,}253}{\phi°\ \theta°}} \quad \text{For large } \phi° \text{ and } \theta°$$

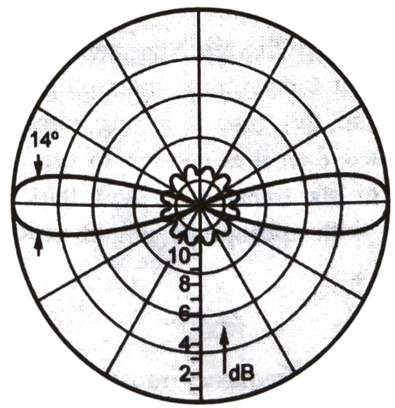
2.9.3 Antenna at Cell Site

2.9.3.1 For Coverage Use - Omnidirectional Antennas

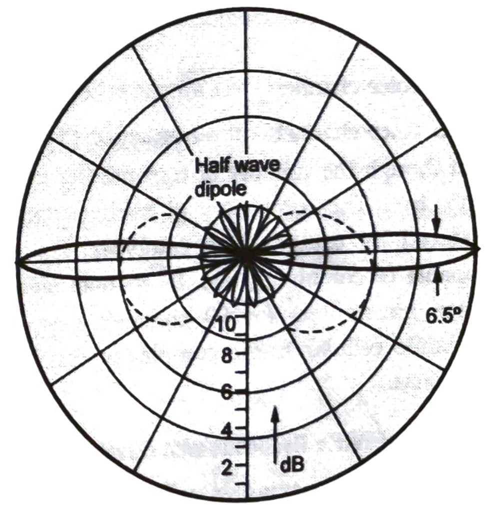
- The Omnidirectional antennas have the characteristics of radiating uniformly in all directions. The standard high gain omnidirectional antennas are 6 dB and 9 dB gain antennas. It is always suggested that in a startup cellular system omnidirectional antennas should be used. Some of detailed design features of handling a start-up system configuration are discussed here.

2.9.3.2 Start-up Cellular System Configuration

- For omnicells in start-up systems the cell-site antennas should be omnidirectional. Every transmitting antenna has to be capable of transmitting signals simultaneously from 16 transmitters with the help of a channel combiner. In general every cell will have three transmitting antennas that could serve 45 voice transmissions at a time.

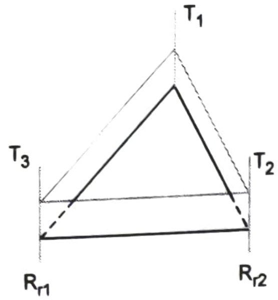


(a) Vertical high gain omnidirectional antenna of gain 6 dB

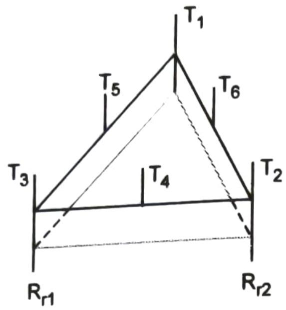


(b) Vertical high gain omnidirectional antenna of gain 9 dB

Fig. 2.9.4 High-gain omnidirectional antenna



(a) Used for 45 channels



(b) Used for 90 channels

Fig. 2.9.5 Cell-site antennas used for omnicells

- Channel amplifiers are used for amplifying its own signal that has to be sent. After 16 radio signals (16 channels) are passed through the channel combiner unit, at the receiving end, two antennas can receive all the 45 voices which were transmitted.
- In case two identical signals are received by these two receiving antennas then they would be sent to the diversity receiver of the corresponding channel. Thus receiving the different voice signals is done.

2.9.3.3 Abnormal Antenna Configuration

- In cellular mobile system if the number of subscribers increase there will be more call traffic. In particular some cells would require more channels than other cells to meet the increasing call traffic. In general the omnicells will be provided with 90 voice channels.

  90 voice channels - six antennas (T_1 to T_6) have to be used.

  45 voice channels - three antennas (T_1 to T_3) have to be used.
- But though the number of transmitting antennas are more the receiving antennas are only two. The complexity of having more number of transmitting antennas can be reduced by using a ring combiner. For example, in this case if a ring combiner capable of combining two 16 channel signals is used then it is enough to use only three transmitters for 90 channels case instead of six transmitters and thus the dynamic cellular traffic complexity can be solved with appropriate omnidirectional antennas.

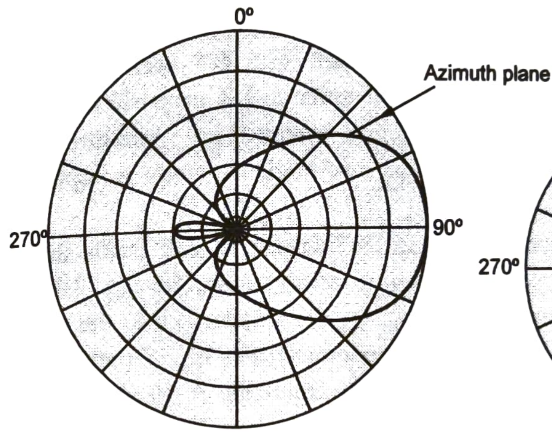
2.9.3.4 Interference Reduction with Directional Antennas

- For bandwidth saving in cellular mobile communication frequency reuse concept is used. But when reuse technique of repeatedly using same frequency is done there is a risk of cochannel interference. A standard value of cochannel interference reduction factor $q = D/R$ is applied but it suits for a flat terrain only.

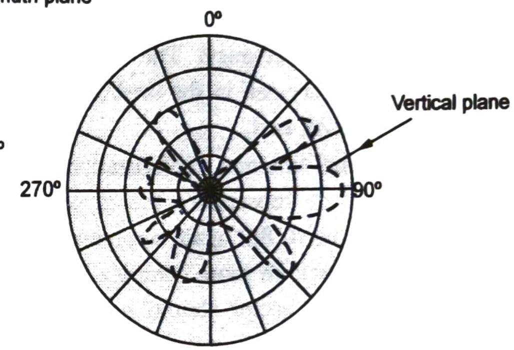
- In mobile environment a flat terrain cannot be guaranteed. As the subscriber moves the signal has to propagate through different terrain contour a standard cochannel reduction factor is not suitable.
- Thus to handle the interference problem either an increase in reduction factor q or usage of directional antennas should be done in system design. Using directional antennas is a better method to reduce interference.

1. Directional Antenna Setup

- In cellular system using sectorization concept assume a 120° sectored cell. For this cell a 120° corner reflector can be used. Likewise in a 60° sectored cell a 60° corner reflector can be used. An antenna of 120° beamwidth pattern is shown in Fig. 2.9.6.



(a) Azimuth pattern

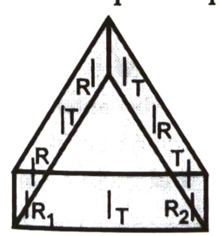


(b) Vertical pattern

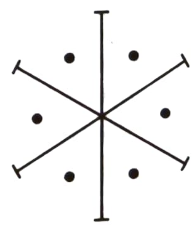
Fig. 2.9.6 8 dB directional antenna pattern

2. Normal Antenna System Configuration

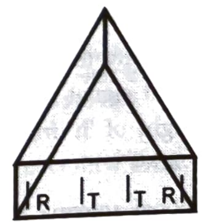
- If the cluster size N = 7 pattern then it means the 120° sectored cell. If frequency reuse technique is applied in this cell then 333 channels can be used here. Every



(a) 120° sector for 45 channels



(b) 60° sector



(c) 120° sector for 90 channels

Fig. 2.9.7 Directional antennas for different sectors

sector of 120° is capable of serving 16 channels with one transmitting and two receiving antennas, as in Fig. 2.9.7 (a).

- On the otherhand if a cluster size of N = 4 pattern is used, 60° sectored cell is considered. For omni cell systems the cluster size of N = 4 cannot be used because of its inadequate reuse distance. In such 60° sectored cell two different approaches are used.
  - i. Both transmitting and receiving are of 60° sectors. Each sector has an antenna that can carry its own set of frequency channels. It is known as N = 4 cellular pattern. In case 333 channels with 13 channels in one sector are used then one transmitting and one receiving antenna are used in one sector.
  - ii. At the receiving end two receiving antennas out of six are selected so as to have angle diversity. It is shown in Fig 2.9.7 (b).
  - iii. Finally consider a 'Receiving 60°' sectored case. The 60° sector receiving antennas are being applied for locating mobile units and it properly hand offs with high accuracy. The transmitting antenna systems are omnidirectional within every cell in the area. As the previous case angle diversity is applied at the receiver end.
- Under abnormal antenna configuration if there is an increase in call traffic due to more number of subscribers the directional antenna arrangement in Fig. 2.9.7 (c) shown can be used. But again applying cell splitting for the smaller cell in the system is not good. It will be more complex and also not economical. For N = 7 pattern with 120° sectors, each sector should have two transmitting antennas. A 16 channel ring combiner can be used in a system with two transmitting antennas. But now-a-days 32 channels combiners are being applied for effective reception and here only one transmitting antenna is enough instead of two transmitting antennas (Fig. 2.9.7 (c)) in 16 channel combiner case.

3. Space-Diversity Antennas at Cell Site

- 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.
- In space diversity technique two antennas are separated by a distance 'd' so as to get the two input 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.
- The directional antenna array elements will combine at radio frequency Fig. 2.9.8 (a). Its antenna pattern can be directed to an endfire or broadside array by design.

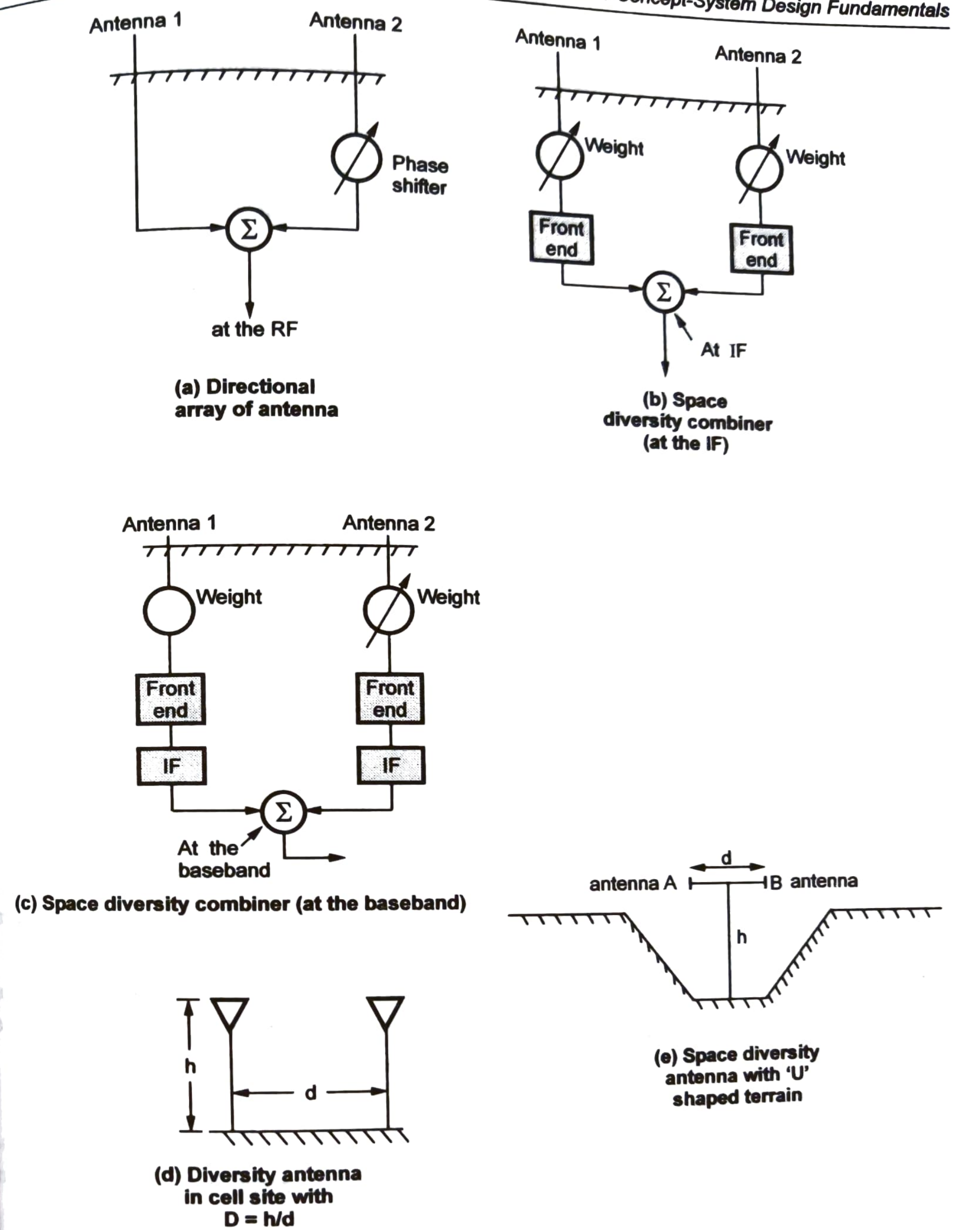


Fig. 2.9.8 Space diversity antenna concepts

- But the space diversity technique is combined either at baseband or at IF as Fig. 2.9.8 (b) and (c). For combining either maximal ratio combining or the equal-ga technique can be applied. Equal gain combining technique can co-phase the rando phase of all individual branches at IF level.
- The Maximal ratio combining can obtain maximum SNR at the output of IF. Th summation of power outputs at baseband is equivalent to the maximal rati combining method.
- The switch combined technique uses one RF signal only at a time for desired outpu signal. Also the selection-combined technique can select the strongest signal availab among the inputs of two antennas.
- A simple two-branch diversity antenna with spacing 'd' is shown in Fig. 2.9.8 (d). receives the same signal but with different fading envelopes, with different antenna.

Degree of correlation between two fading signals	$\propto$	Degree of separation distance between antennas.

- The fading is somewhat reduced when the two fading envelopes are combined.

$$\eta = \frac{h}{d} \; ; \quad \begin{array}{l} h \rightarrow \text{height of antenna} \\ d \rightarrow \text{separation distance} \end{array}$$

Sr. No.	Separation distance 'd'	Antenna height required
1.	$d \geq 14\lambda$	150 feet (50 m)
2.	$d \geq 8\lambda$	100 feet (30 m)

- In an omnicell the two space-diversity antennas has to be aligned with the terrai area. It should have a 'U' shape as in Fig. 2.9.8 (e).
- The space-diversity antennas separates only horizontally and hence horizont separation should be done in the design. Comparing to other diversity antennas spac diversity antenna configuration reduces fading in mobile transmissions.

4. Umbrella Pattern Antennas

- In cell-site antennas used in mobile communication can be umbrella pattern antenna For certain situations these antennas are much useful to meet the mobile traffic i busy hours.
- There are many types of umbrella pattern antennas available. They are
  i) Broadband umbrella-pattern antenna.
  ii) Normal umbrella-pattern antenna.

  iii) High-gain broadband umbrella-pattern antenna.
  iv) Interference reduction antenna.

i) Broadband umbrella-pattern antenna

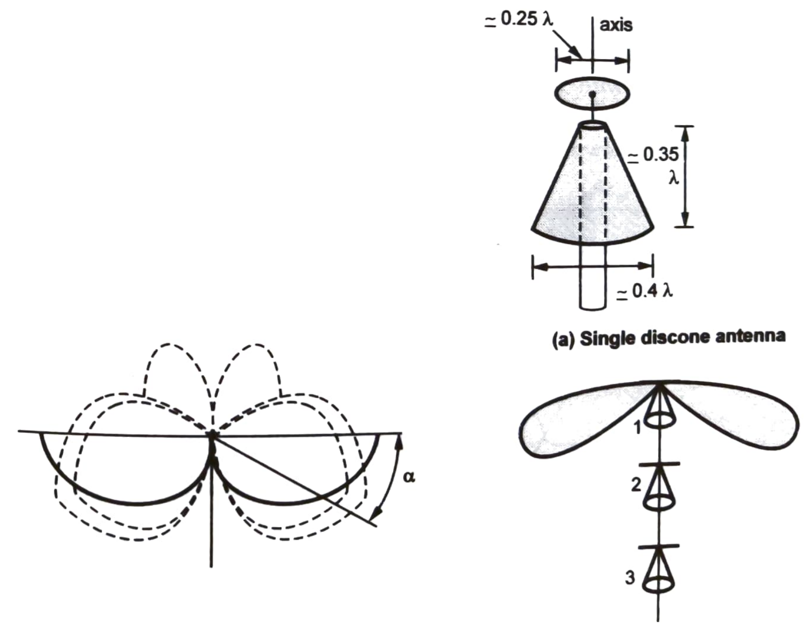
- Consider a bioconical antenna. One of its cones is extended to 180° so as to form a disk. It is called as discone antenna and acts as broadband umbrella-pattern as shown in Fig. 2.9.9 (a).

ii) Normal umbrella-pattern antenna

- The energy present in confined area should be controlled and for this an umbrella-pattern antenna (Fig. 2.9.9 (b)) can be designed, by using a monopole with top disk (top-loading) arrangement. The tilting angle of the radiation pattern is determined by the size of the top disk used. They are inversely proportional.
- If a larger disk is used as top disk, smaller will be the tilting angle of the pattern. If a smaller disk is used as top disk of monopole, then larger will be the tilting angle.

iii) High-gain broadband umbrella-pattern antenna

- A vertical stacking of number of umbrella-pattern antennas forms a high-gain antennas applicable for mobile transmissions.



(a) Single discone antenna

(b) Normal umbrella pattern antenna

(c) Discone antenna an array of antennas

Fig. 2.9.9 Umbrella pattern antennas

- If M is the number of antenna elements, ϕ is the direction of the wave travel and d is the spacing observed between elements then E_0 for one umbrella pattern will be

$$E_0 = \frac{\sin\left(\frac{Md}{2\lambda}\right)\cdot\cos\phi}{\sin\left(\frac{d}{2\lambda}\right)\cdot\cos\phi}$$

- All the above umbrella pattern antennas are useful in increasing coverage for wirele communication.

iv) Interference reduction antenna

- The parasitic elements can be used for antenna configurations to reduce interferenc Here the parasitic elements are longer (1.05 times approx) than the active element that reduction in interference is observed.

Minimum separation of cell-site receiving antennas

- To avoid the intermodulation problems the separation distance 'd' between tw transmitting antennas has to be minimized. In addition to this receiver desensitizatio is also minimized by reducing separation distance between transmitting and receivin antennas.
- Consider a space-diversity receiver unit where two receiving antennas are used. Th antennas are placed with minimum separation distance. There will be near-fiel disturbance generation because of the close spacing and ripples formed in th radiation patterns as shown in Fig 2.9.10.

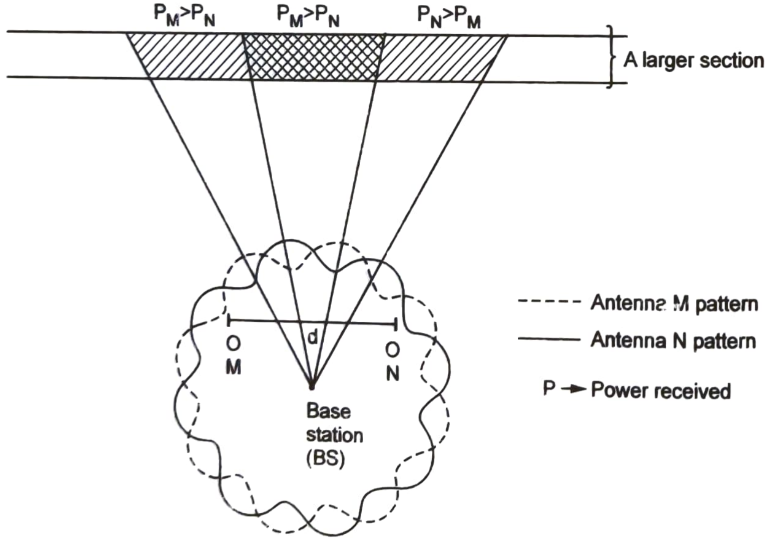


Fig.2.9.10 Antenna pattern of antennas M, N

- The difference in the received power at different angle for the antennas M and N are shown in the antenna pattern.
- The difference in the power received at a point for the two antennas will be high if the antennas are closely spaced. This power reception now is not only confined to a smaller sector but a large area (a section of road) is noted. Now fading cannot be reduced by using space diversity antennas due to close spacing.
- For a separation distance of 8λ between the two receiving antennas at 850 MHz frequency there will be a $\pm$ 2 dB power difference and it is tolerable for obtaining reasonable voice quality. If the antennas at receiver are not closely spaced, fading can be controlled.

University Question

1. *Explain the antenna design systems for mobile networks.* **GTU : Summer-16, Marks 7**

2.10 Short Questions and Answers

Q.1 Define telecommunication traffic.

Ans. : In telecommunication system, traffic is defined as the occupancy of the server in the network. There are two types of traffic viz. voice traffic and data traffic. For voice traffic, the calling rate is defined as the number of calls per traffic path during the busy hour. In a day, the 60 minutes interval in which the traffic is highest is called busy hour (BH).

Q.2 Define a cell.

Ans. : The smallest geographical area covered by wireless communication is said to be a cell. A base station is located in every cell. The shape of a cell is hexagon.

Q.3 What is Handoff ?

Ans. : Handoff is a process of transferring frequency channel from a cell site to other cell site.

Q.4 When Handoff is required ?

Ans. : Handoff is required in two situations -

1. At cell boundary, where signal strength becomes weak.
2. When mobile unit reaches to signal strength holes (gaps) within **cell site.**

Q.5 What is a dropped call ?

Ans. : A telephone connection that is unintentionally terminated while in progress is called as **dropped call.**

Q.6 State the causes of dropped call.

Ans. : Coverage problem, handoff problem, poor signal strength, fading.

Q.7 What is frequency-reuse concept ?

Ans. : Using same frequency channels in different geographic location is referred as frequency-reuse.

Q.8 Define a microcell.

Ans. : In cellular radio, a small cell designed to cover a high-traffic area is called as microcell.

Q.9 What is soft handoff ?

Ans. : In soft handoff mobile communicates simultaneously with two cells instead of switching from one cell to other.

Q.10 Give an example for Non-co-channel interference.

Ans. : Adjacent Channel Interference (ACI). The adjacent cells are very close than the co-channel cells and the interference due to these cells is called as ACI.

Q.11 What is an umbrella all pattern ?

Ans. : In a biggest cellular region say 'macrocell', there may be many small cells called as microcells and this is known as umbrella cell pattern.

Q.12 What is the use of an umbrella cell ?

Ans. : In umbrella cell design, signal strength is more and coverage of radio signal is high. Macro cells are used for high speed traffic and Micro cells are used for low speed traffic in the umbrella cellular pattern.

2.11 Multiple Choice Questions

Q.1 Radio capacity may be increased in cellular concept by

a Increase in radio spectrum

b Increasing the number of base stations & reusing the channels

c Both a and b

d None of the above

[Ans. : b]

Q.2 The shape for the cellular region for maximum radio coverage is

a Circular b Square c Oval d Hexagon

[Ans. : d]

Q.3 Hexagon shape is used for radio coverage for a cell because

a It uses the maximum area for coverage

b Fewer number of cells are required

c It approximates circular radiation pattern

d All of the above

[Ans. : d]

Q.4 Centre excited hexagonal cells use

a Sectored directional antennas

b Omni directional antennas

c Yagi uda antennas

d None of the above

[Ans. : b]

Q.5 The advantage of using frequency reuse is

a Increased capacity

b Limited spectrum is required

c Same spectrum may be allocated to other network

d All of the above

[Ans. : d]