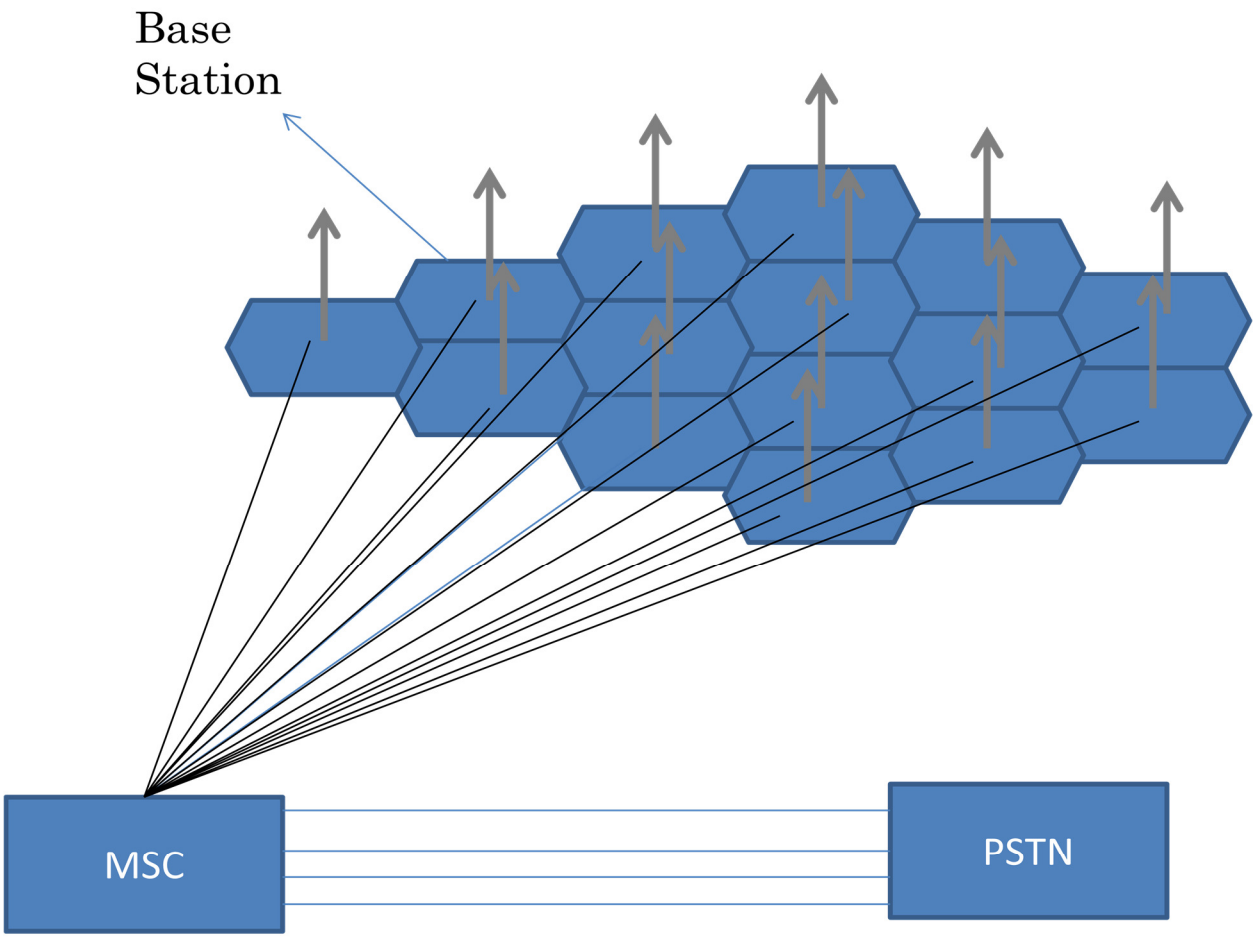
Cellular Concepts and System Design Issue

Basic Requirements:

- Same frequencies/time slots/codes are reused by spatially separated base stations.
- High capacity is achieved by limiting the coverage of each base station to a small geographic region called a cell.
- A switching technique called hand off enables a call to proceed uninterrupted when one user moves from one cell to another.

Basically this approach resolves the problem of limited radio spectrum.

- Neighboring base stations are assigned different group of channels so as to minimize the interference.
- By systematically spacing base stations and the channel groups may be reused as many number of times as necessary.
- As demand increases , the no. of base stations may be increased thereby providing additional capacity.
- Cell size is also dependent on radiated power of base station transmitter. For reducing cell size transmitted power of base station is also controlled.
- Highly populated areas are broken into smaller cells to cover large no. of customers.
- Every base station is connected with the Mobile Switching Center (MSC).
- In real life cells may overlap and size is not exactly hexagonal.



(Cellular Telephone System)

Forward & Revue Channels:

- Forward Voice Channel (FVC) from base station to mobile set.
- Reverse Voice Channel (RVC) from mobile station to base station.
- Forward Control Channel (FCC) used for initialing a call from base station to mobile station.
- Reverse Control Channel (RCC) used for initiating a call from Mobile station to Base Station.
- FCC & RCC are also called setup Channels. They use 5% of band width as an over head.

ANATOMY OF A CELLULAR CALL:

- A cell phone, when turned on, (through not yet engaged in a call) scams the group of FCC to determine the one with the strongest signal.

Two factors concerned the battery power one is during talk, i.e., talk time and another is during stand by mode when it is continuously communicating with the base station to find its existence in a cell & is monitoring the signal strength continuously.

- It monitors that channel until it drops below a threshold. It then scams for another channel which is the strongest.
- Control channels are defined and standardized over the entire area of service. Typically the control channels use up 5% of the total number of channels.

A Call to a Mobile User:

- MSC dispatches the request to all base stations. The mobile identification no. (MIN) is broadcast as a paging message over all FCC through out the service area.
- The MS receives the paging message from the BS it is monitoring. It responds by identifying it self over the RCC.
- The BS conveys the handshake to the MSC. The MSC instructs the BS to move to an unused voice channel. Basically in GSM phones, MSC holds the mobile phone no. and mobile identification no. for every user. In case any phone gets lost or stolen that phone can be deactivated by the MIN available in the look table of MSC so no call can be sent up.
- There are few no. such as SIM card no., hard ware no (MIN) & logical no. So valid phone no is a combination of all these nos.
- The BS signals the MS to change over to an unused FVC & RVC.
- A data message (called alert) is transmitted over the FVC to instruct the mobile to ring.
- All of these sequences of events occur in just a few seconds, are not noticeable to the user.
- While the call is in progress the MSC adjusts the transmitted power in order to maintain the call quality.
- Now days many features of MSC are take care by BS. e.g. power control management. For call quality so as to reduce the over head of MSC.

A Call from a mobile user:

- A call initiation request is sent to the RCC.

- Along with this, the MS transmits its MIN, Electronic Serial Number (ESN) and the phone no. of the called party.
- The MS also transmits the station class mark (SCM) which indicates the maximum transmitter power level for the particular uses.(Basically used to control transmitted power).
- The BS forwards the data to the MSC, which validates the data and makes connection to the called party through the PSTN.

FREQUENCY REUSE: THE NEED

- Fixed telephone network runs wires to every household.
- Suppose we give every household their own allocation of radio spectrum for analog speech of 4 KHz bandwidth.
- 125 million household (say Delhi) * 4 KHz = 50 GHz.
- Charily impractical: -
    - ❖ No other services possible using radio transmission.
    - ❖ Most of the spectrum unused most of the time.
- Cellular radio system really on intelligent allocation and reuse of channels through the coverage area.
- Each base station is allocated a group of radio channels to be used within the small geographic area of its cell.
- Neighboring base stations are given different channel allocation from each other. GSM phone monitors power level 800 times a second.
- By design of antennas , the coverage area is limited within the cell and the same group of frequencies is reused to cover another all separated by a large enough distance to keep co-channel interference within limits.

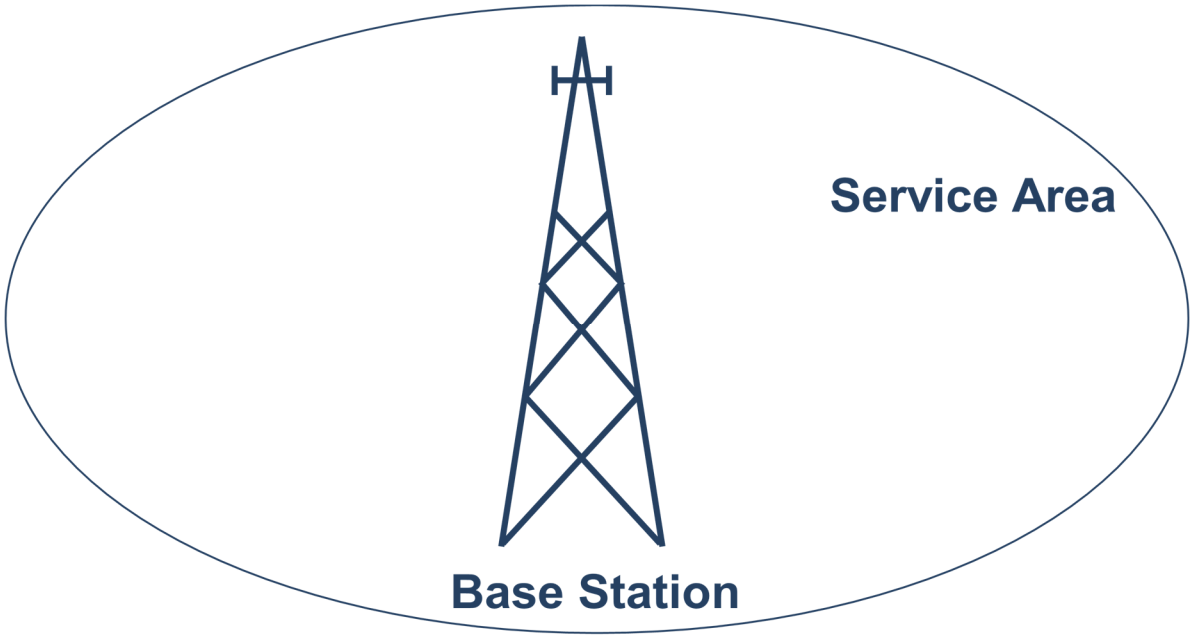
Basically co-channel cell should be far located to reduce interference . But when co-channel cells are far located, channel capacity will be affected. So there is a trade off while selecting the distance between co-channel cells & capacity contained by the cell.

- The design procedure of allocating channel groups for all of the cellular BS within a system is called frequency reuse or frequency planning.

For frequency reuse a cluster of cells are required to repeat Co-channel cells.

What is cell?

- Cell is an area covered by one base station (BS) to use of radio communication by Mobile Station (MS).



Cell Design: Idea

- Idea of Cell design is taken from :

  Honey Bees Colonies & Hives

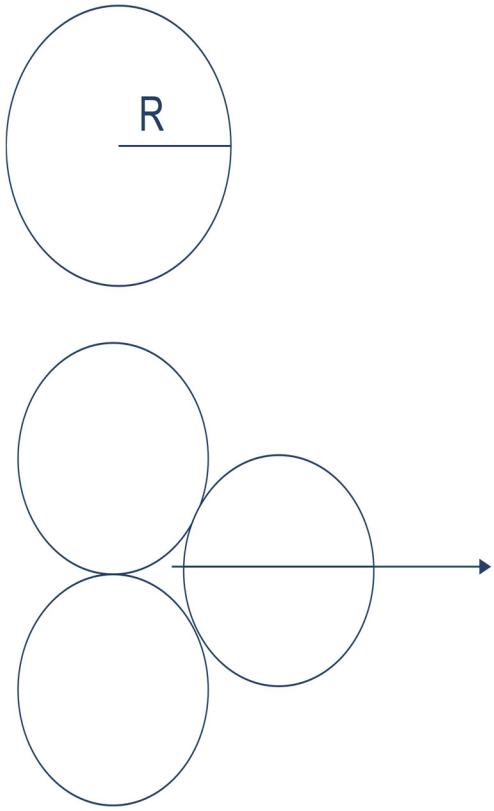
Each Hole of this Bees Hive is a cell which provides the Ideas of Cellular Mobile Communication

Cell Boundary:

- There are many possible models that can be used, to represent a cell boundary .
- The most popular cell boundaries are:
  1. Circle
  2. Square
  3. Equilateral triangle
  4. Hexagon

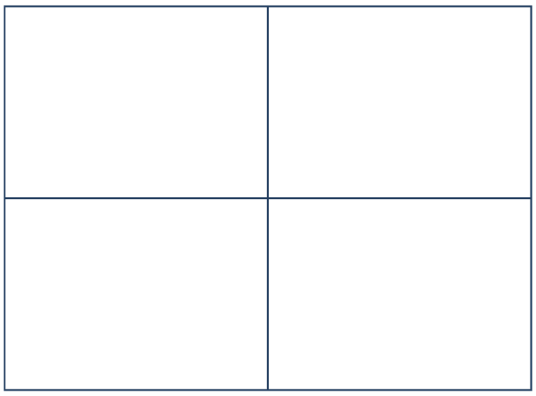
Circular Cell:

- Circle is one approximation of cell boundary.
- Problem with circular Cell is uncovered gap amongst Circles .


R

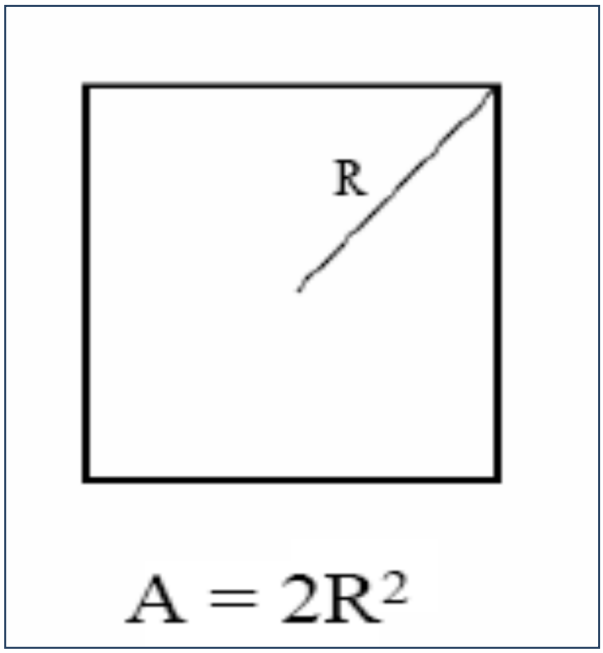
Square Cell:

- Square cell is another cell structure.
- Problem with Square Cell is Over lapping of R.F Radiated Signal

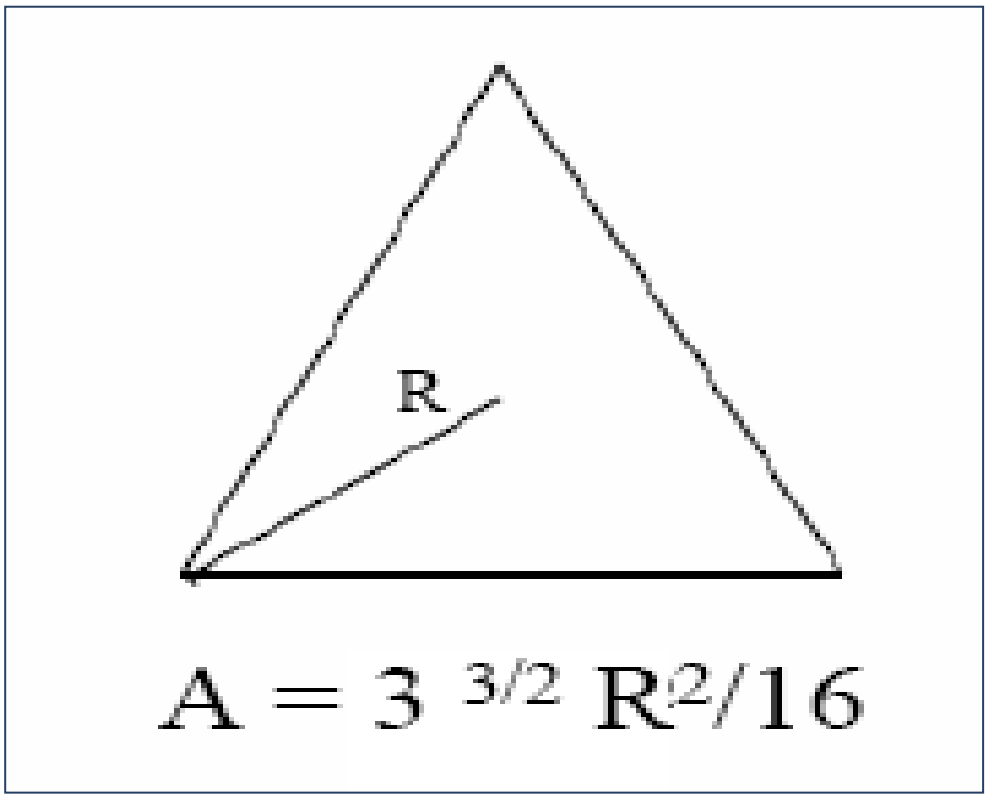


Square Cell:

Area of square cell is twice the square of radius of cell R.

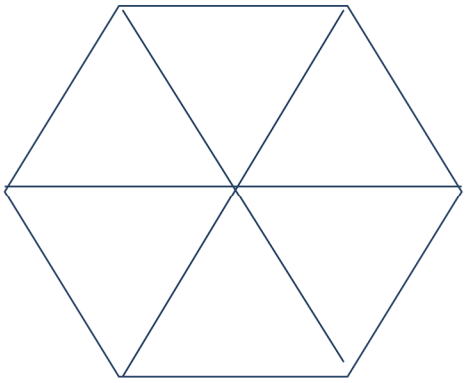


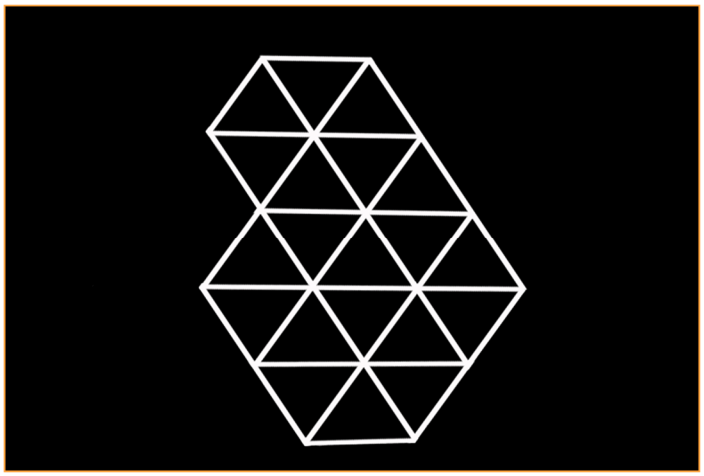
Triangular Cells:



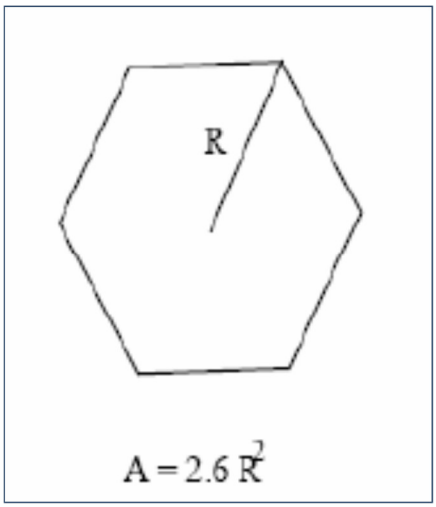
Hexagonal Cell:

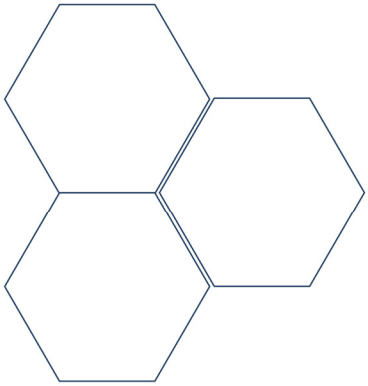
- **Multi triangles makes Hexagonal Cluster Formation.**

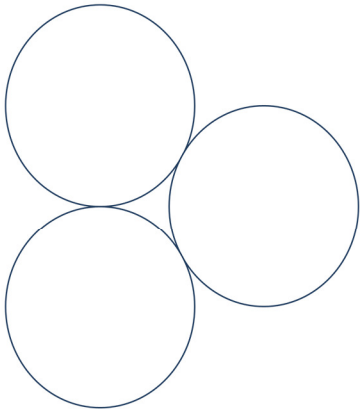




Cell: Why hexagonal?







Cell: Why hexagonal?

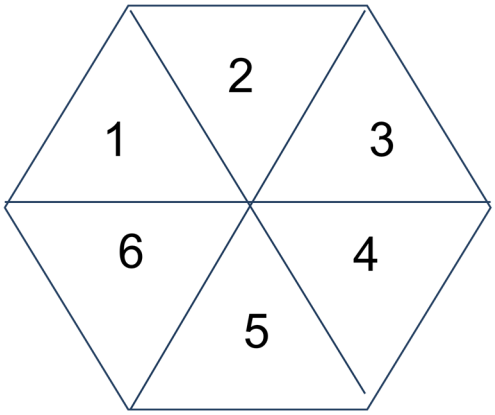
- In most modeling and simulation, hexagons are used, while a square is employed as the second choice.

- The hexagon is a good approximation of a circular region (for omnidirectional radiation). Moreover, it allows a larger region to be divided into non overlapping hexagonal sub regions of equal size, with each one representing a cell area.
- Using a hexagon geometry , fewest no. of cells can cover the entire area.

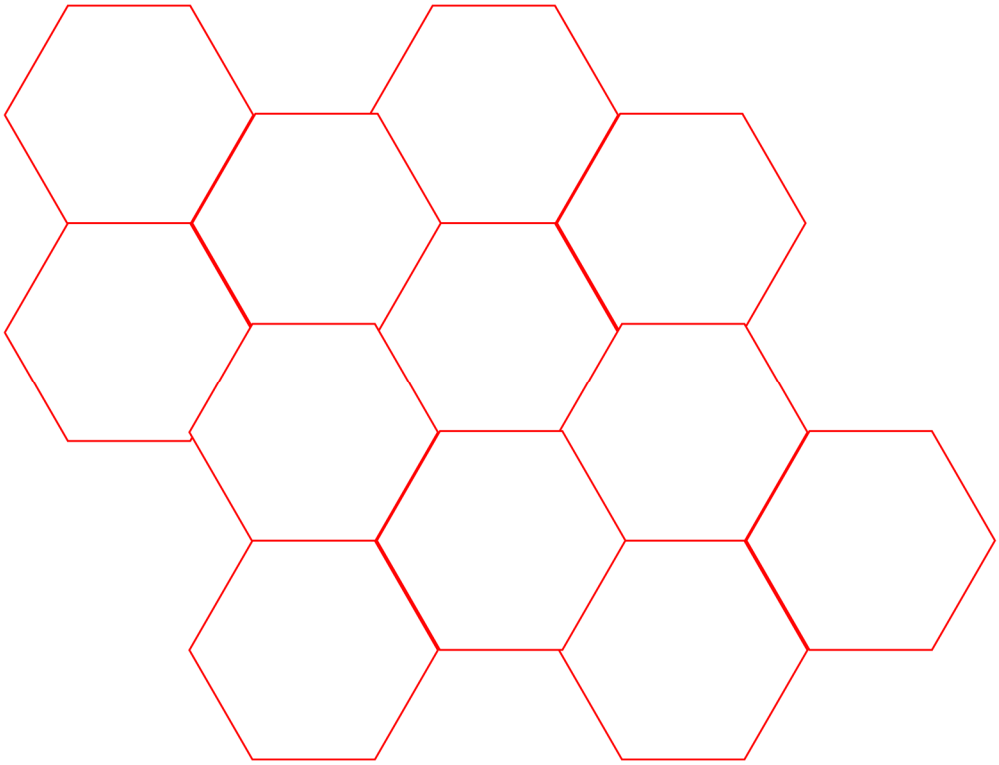
- Hexagonal Cell has the largest area amongst other Polygons.

Cell	Area	Perimeter
Square	R^2	4R
Hexagonal	$3/2 \times 3^{1/2}R^2$	6R
Circular	$3.14R^2$	(2x3.14)R
Triangular	$3^{1/2}/4R^2$	3R

Cell Coverage:

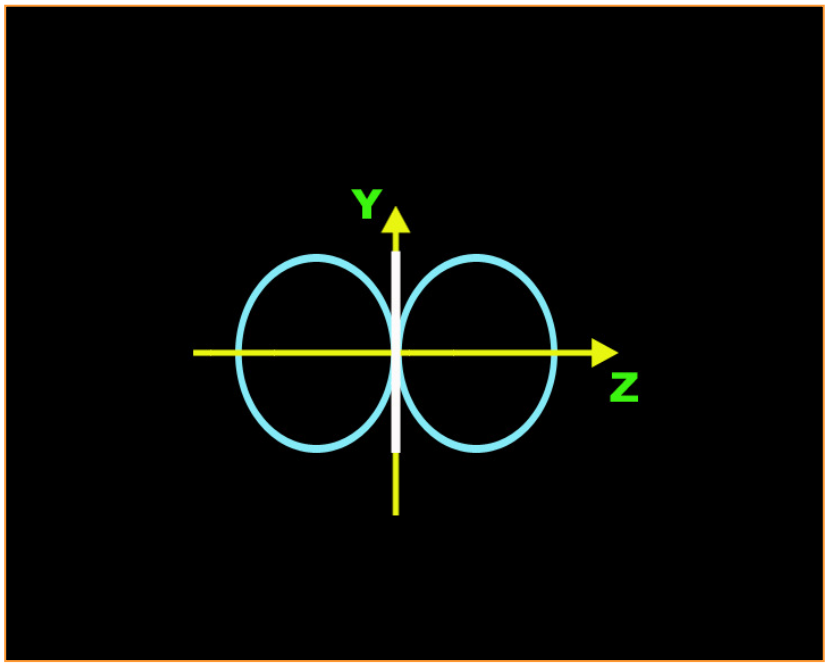


Comparison:



Radiation Pattern:

- Simple half dipole : It has omni directional radiation pattern in one plane and a figure of 8 in other two planes.



Signal Strength:

- It goes down as one moves away from Base Station .
- The variation of received power is a function of distance.

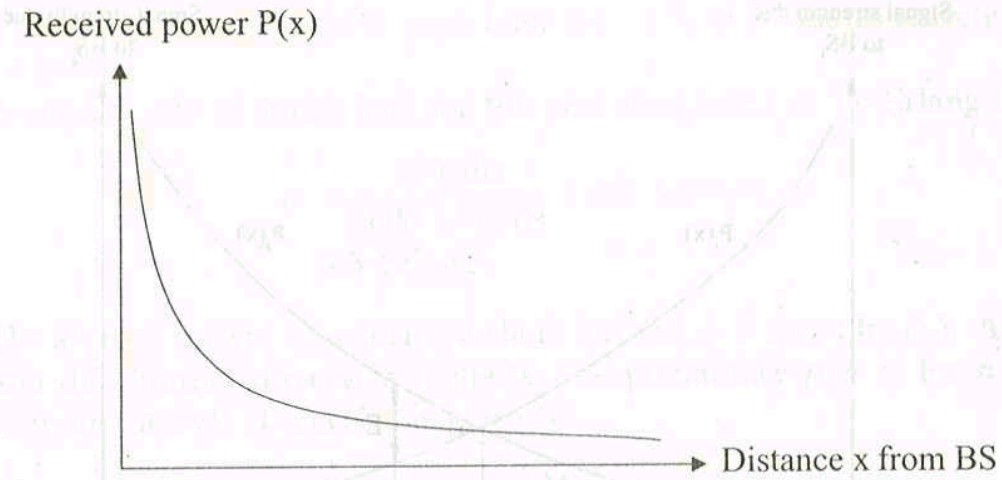
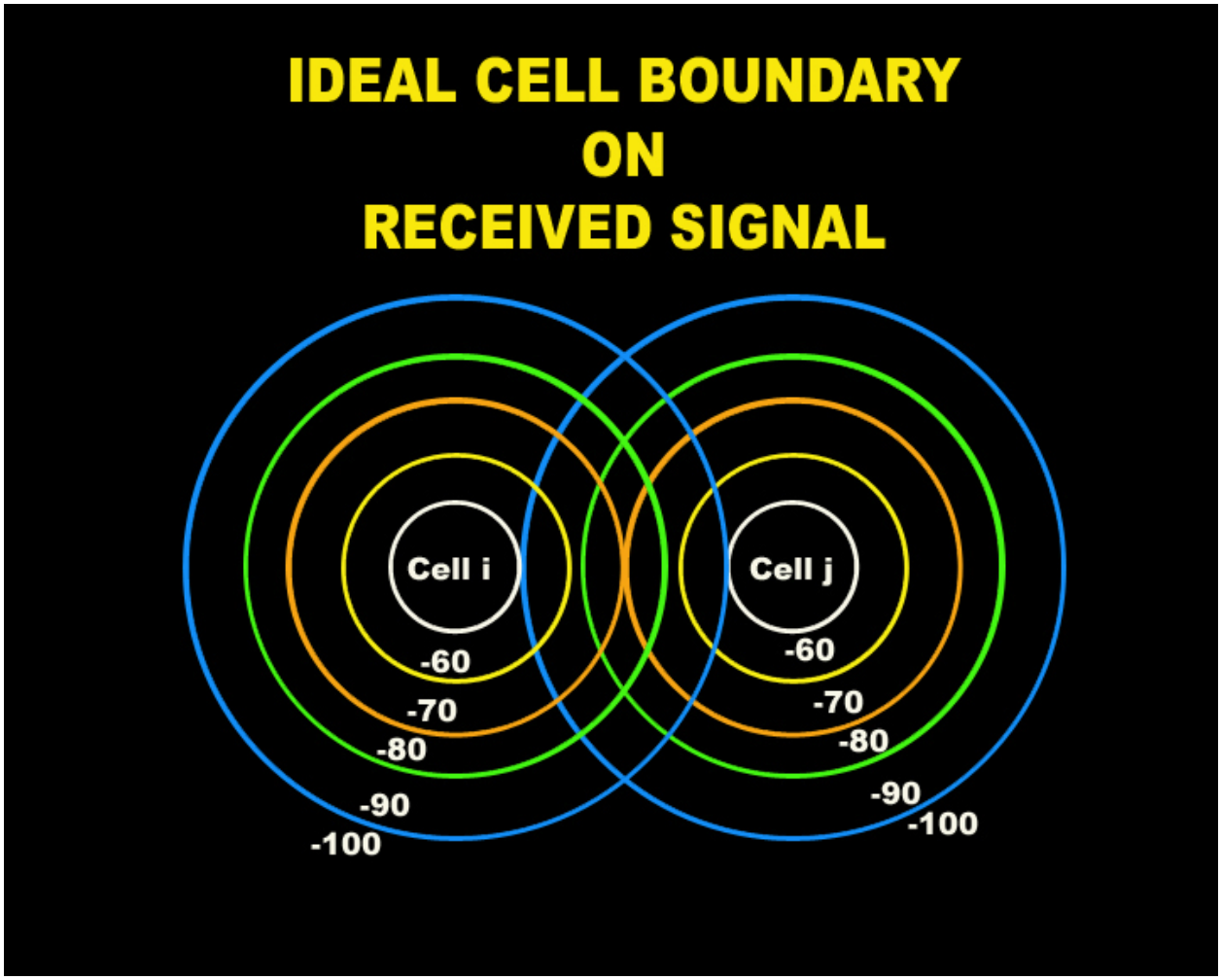
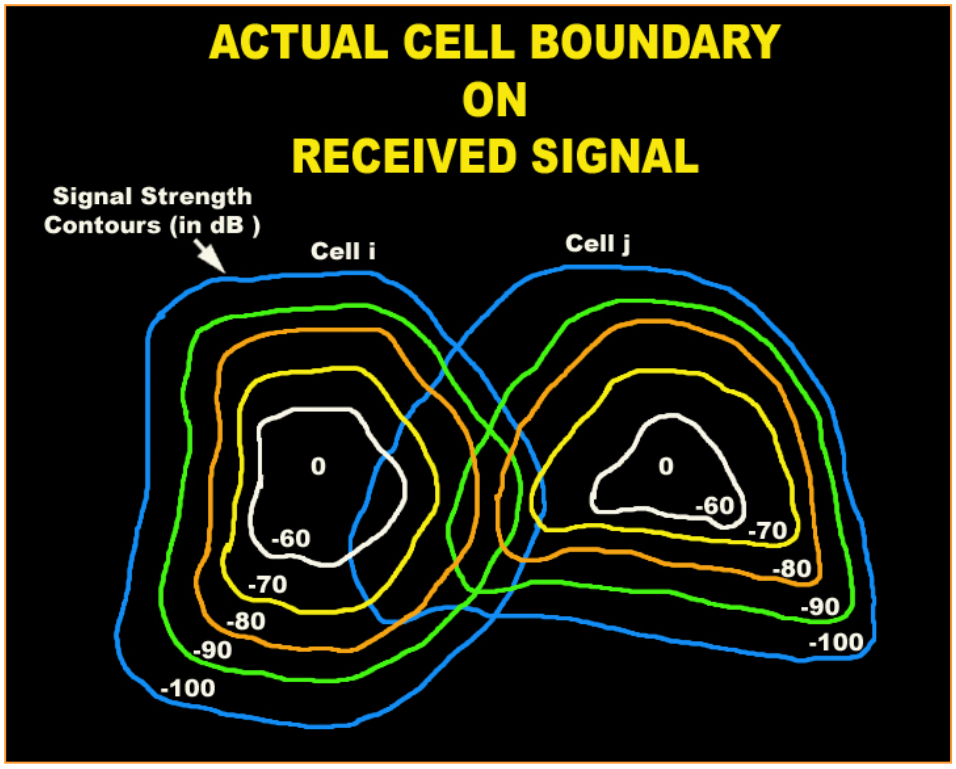


Figure 5.4: Variation of received power from a base station.

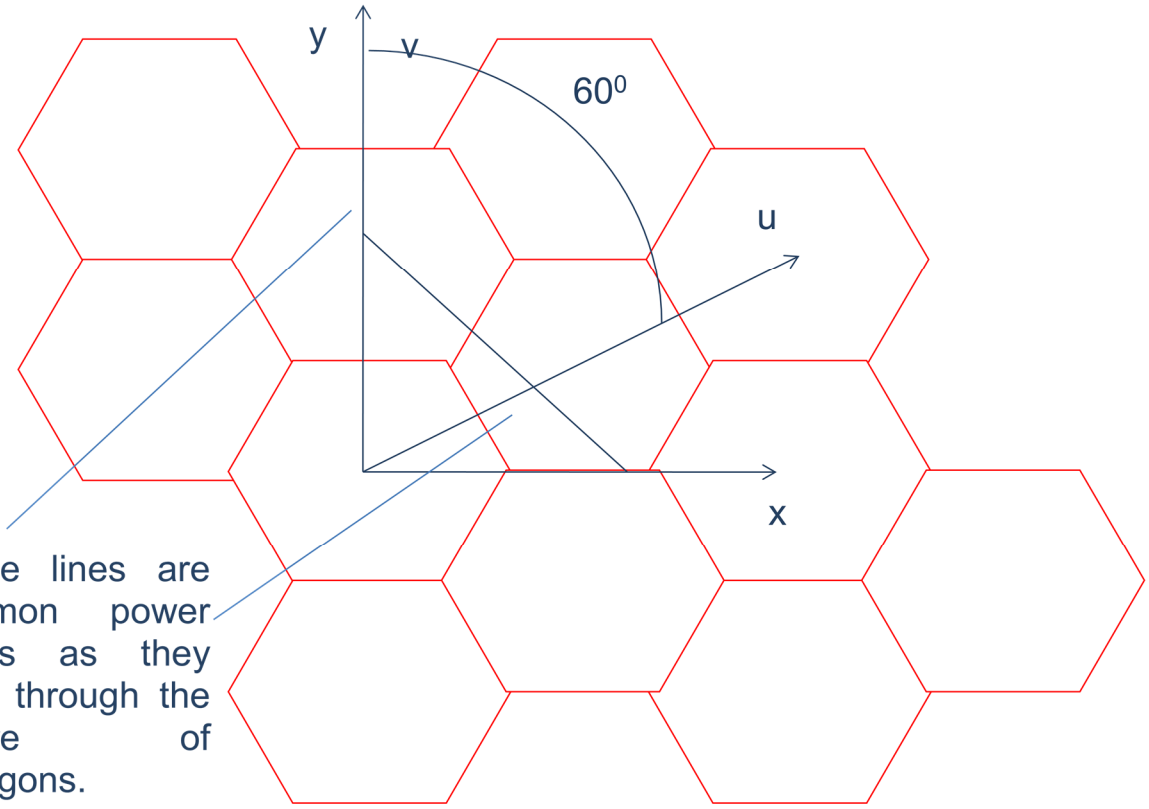


Actual Cell Boundary:

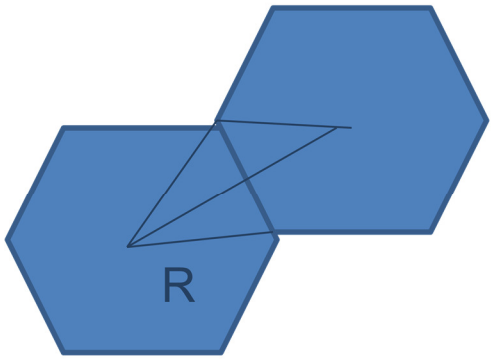
- ❖ Distorted by:
- Atmospheric conditions
- Topographical contours
- Signal strength contours indicates actual cell coverage. This depends on terrain, presence of obstacles and signal attenuation in the atmosphere.
- Ideal cell size is 2 – 10 Km radius.



Geometry of Hexagons:



- Axes u, v intersect at 60.
- Unit scale is distance between all centers.



$$\cos 30^0 = \frac{1}{2R}$$

$$2R \cos 30^0 = 1$$

$$R = \frac{1}{\sqrt{3}}$$

- If cell radius to the point of hexagon is R , then to find the distance of a point P(u , v) from the origin ,use x-y to u-v coordinate transformation :

$$r^2 = x^2 + y^2$$

$$x = u \cos 30^0$$

$$y = v + u \sin 30^0$$

$$r = (v^2 + uv + u^2)^{\frac{1}{2}}$$

- Using this equation, to locate co-channel cells, we start from a reference cell and move i hexagons along the u- axis then j-hexagons along the v-axis.
- Hence the distant cells in adjacent clusters is given by

$$D = (i^2 + ij + j^2)^{\frac{1}{2}}$$

- The no of cells in a cluster N is given by

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

Where i & j are integers.

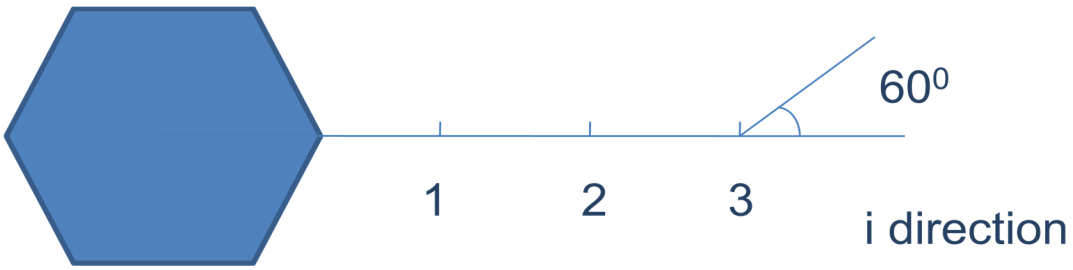
- Hence the possible value of N are 1,3,4,7,12,--------

Example:

Reuse co-ordinates		**No of cells in reuse pattern**	**Normalized Repeat Distance**
i	**j**	**N**	**D=SQRT (N)**
1	0	1	1
1	1	3	1.732
1	2	7	2.646
2	2	12	3.464
1	3	13	3.606
2	3	19	4.359
1	4	21	4.583

Co-channel Cell Location:

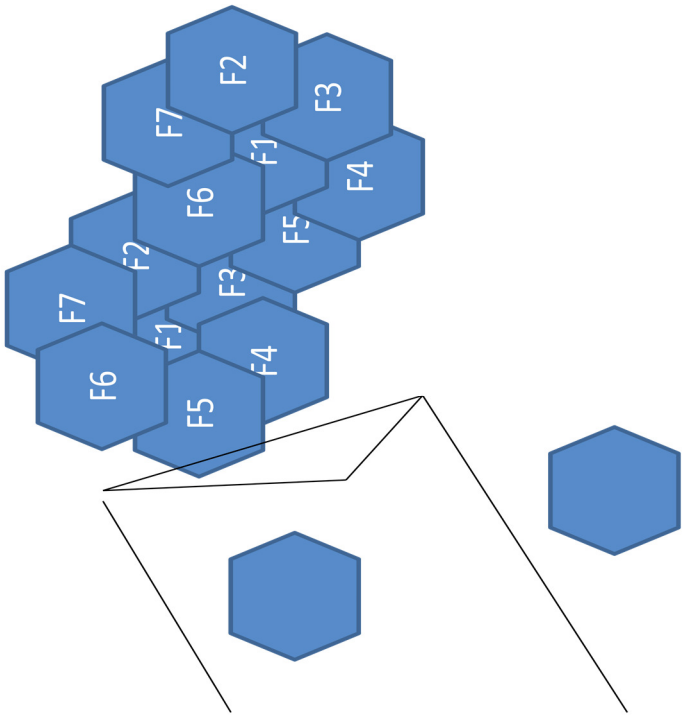
- Methods of locating co-channel cells.



- Finding the centre of an adjacent cluster using integers i and j (direction of i & j can be interchanged.)

e.g. for i=2 & j=1

i.e. N = 7



Co-channel Cell Location:

- In General , in GSM , we use N = 7 but sometimes N = 4 or even N = 3 also.
- For hexagonal cells the reuse distance is given by

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

R-cell side

N- Cluster size

Reuse factor

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