UNIT III
INTERFERENCE

Cochannel Interference: The frequency-re method is useful for increasing the efficiency of spectrum usage but results in cochannel interference because the same frequency channel is used repeatedly in different cochannel cells. Application of the cochannel interference reduction factor q= D/R = 4.6 for a seven- cell reuse pattern (K = 7). In most mobile radio environments, use of a seven-cell reuse pattern is not sufficient to avoid cochannel interference. Increasing K > 7 would reduce the number of channels per cell, and that would also reduce spectrum efficiency. Therefore, it might be advisable to retain the same number of radios as the seven-cell system but to sector the cell radially, as if slicing a pie. This technique would reduce cochannel interference and use channel sharing and channel borrowing schemes to increase spectrum efficiency.

When customer demand increases, the channels which are limited in number, have to be repeatedly reused in different areas, which provides many cochannel cells, which increases the system's capacity. But co channel interference may be the result, in this situation the received voice quality is affected by both the grade of coverage and the amount of cochannel interference. For detection of serious channel interference areas in a cellular system, two tests are suggested.

Test 1—find the cochannel interference area from a mobile receiver:

Cochannel interference which occurs in one channel will occur equally in all the other channels in a given area. We can then measure cochannel interference by selecting any one channel (as one channel represents all the channels) and transmitting on that channel at all cochannel sites at night while the mobile receiver is traveling in one of the cochannel cells. While performing this test we watch for any change detected by a field-strength recorder in the mobile unit and compare the data with the condition of no cochannel sites being transmitted. This test must be repeated as the mobile unit travels in every cochannel cell. To facilitate this test, we can install a channel scanning receiver in one car. One channel (f1) records the signal level (no-cochannel condition), another channel (f2) records the interference level (six-cochannel condition is the maximum), while the third channel receives f, which is not in use. Therefore the noise level is recorded only in f3.We can obtain, in decibels, the carrier to interference ratio C/I by subtracting the result obtained from f2 from the result obtained from f1 (carrier minus interference C - I) and the carrier-to-noise ratio C/N by subtracting the result obtained from f3 from the result obtained from f2 (carrier minus noise C — N). Four conditions should be used to compare the results.

i. If the carrier-to-interference ratio C / I is greater than 18 dB throughout most of the cell, the system is properly designed.
ii. If C/I is less than 18 dB and C/N is greater than 18 dB in some areas, there is co channel interference
iii. If both C/N and C/I are less than 18 dB and C/N =C/I in a given area, there is a coverage problem.
iv. If both C/N and C/I are less than 18 dB and C/N> C/I in a given area, there is a coverage

problem and cochannel interference.

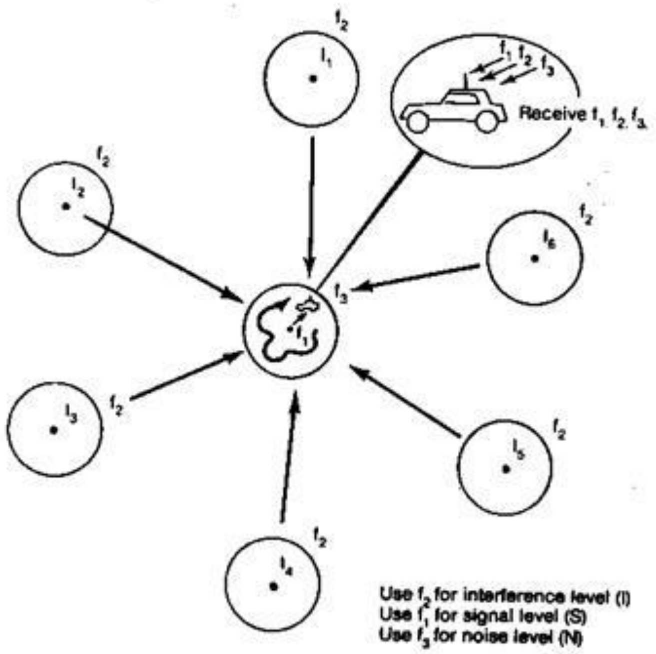

Fig.3.1 cochannel interference at mobile unit

Test 2—find the cochannel interference area which affects a cell site:

The reciprocity theorem can be applied for the coverage problem but not for cochannel interference. Therefore, we cannot assume that the first test result will apply to the second test condition. We must perform the second test as well. Because it is difficult to use seven cars simultaneously, with each car traveling in each cochannel cell for this test, an alternative app roach may be to record the signal strength at every cochannel cell site while a mobile unit is traveling either in its own cell or in one of the cochannel cells shown in Fig. 3.2.

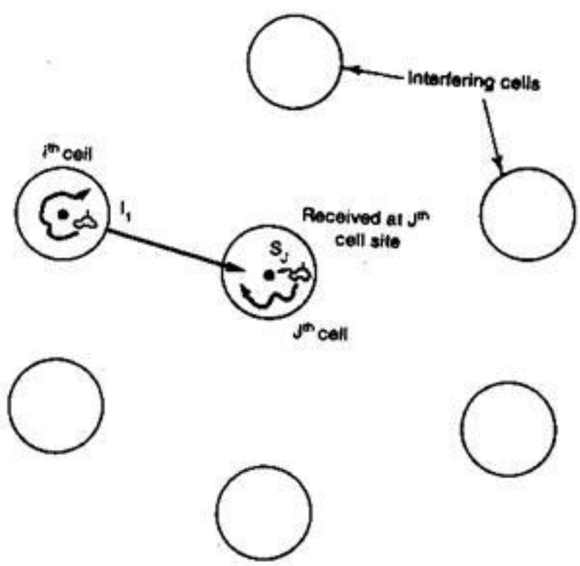

Fig.3.2: cochannel interference at the cell site

First we find the areas in an interfering cell in which the top 10 percent level of the signal transmitted from the mobile unit in those areas is received at the desired site (Jth cell in Fig. 1.1). This top 10 percent level can be distributed in different areas in a cell. The average value of the top 10 percent level signal strength is used as the interference level from that particular interfering cell. The mobile unit also travels in different interfering cells. Up to six interference levels are obtained from a mobile unit running in six interfering cells. We then calculate the average of the bottom 10 percent level of the signal strength which is transmitted from a mobile unit in the desired cell (Jth cell) and received at the desired cell site as a carrier reception level. Then we can reestablish the carrier-to-interference ratio received at a desired cell, say, the Jth cell site as follows.The number of cochannel cells in the system can be less than six. We must be aware that all Cj and Ii were read in decibels, Therefore, a translation from decibels to linear is needed before summing all the interfering sources. The test can be carried out repeatedly for any given cell. We then compare Cj/I and Cj/N and determine the cochannel interference condition, which will be the same as that in test 1. Nj is the noise level in the Jth cell assuming no interference exists.

Real-Time Co-channel interference measurement at Mobile Radio Transceiver

When the carriers are angularly modulated by the voice signal and the RF frequency difference between them is much higher than the

fading frequency, measurement of the signal carrier-to-interference ratio C/I reveals that the signal is

$$e_1 = S(t)\sin(\omega t + \phi_1) \tag{6.3-1}$$

and the interference is

$$e_2 = I(t)\sin(\omega t + \phi_2) \tag{6.3-2}$$

The received signal is

$$e(t) = e_1(t) + e_2(t) = R\sin(\omega t + \psi) \tag{6.3-3}$$

where

$$R = \sqrt{[S(t)\cos\phi_1 + I(t)\cos\phi_2]^2 + [S(t)\sin\phi_1 + I(t)\sin\phi_2]^2} \tag{6.3-4}$$

and

$$\psi = \tan^{-1}\frac{S(t)\sin\phi_1 + I(t)\sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2} \tag{6.3-5}$$

The envelope R can be simplified in Eq. (6.3-4), and R^2 becomes

$$R^2 = \{S^2(t) + I^2(t) + 2S(t)I(t)\cos(\phi_1 - \phi_2)\} \tag{6.3-6}$$

Following Kozono and Sakamoto's[2] analysis of Eq. (6.3-6) the term $S^2(t) + I^2(t)$ fluctuates close to the fading frequency V/λ and the term $2S(t)I(t)\cos(\phi_1 - \phi_1)$ fluctuates to a frequency close to $d/dt(\phi_1 - \phi_2)$, which is much higher than the fading frequency. Then the two parts of the squared envelope can be separated as

$$X = S^2(t) + I^2(t) \tag{6.3-7}$$

$$Y = 2S(t)I(t)\cos(\phi_1 - \phi_2) \tag{6.3-8}$$

Assume that the random variables $S(t)$, $I(t)$, ϕ_1, and ϕ_2 are independent; then the average processes on X and Y are

$$\overline{X} = \overline{S^2(t)} + \overline{I^2(t)} \tag{6.3-9}$$

$$\overline{Y^2} = 4\overline{S^2(t)}\,\overline{I^2(t)}(½) = 2\overline{S^2(t)}\,\overline{I^2(t)} \tag{6.3-10}$$

The signal-to-interference ratio Γ becomes

$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = k + \sqrt{k^2 - 1} \tag{6.3-11}$$

where $$k = \frac{\overline{X^2}}{\overline{Y^2}} - 1 \qquad (6.3\text{-}12)$$

Since X and Y can be separated in Eq. (6.3-6), the preceding computation of Γ in Eq. (6.3-11) could have been accomplished by means of an envelope detector, and analog-to-digital converter, and a microcomputer. The sampling delay time Δt should be small enough to satisfy

$$S(t) \approx S(t + \Delta t), \qquad I(t) \approx I(t + \Delta t) \qquad (6.3\text{-}13)$$

and $$\overline{\cos[\phi_1(t) - \phi_2(t)]\cos[\phi_1(t + \Delta t) - \phi_2(t + \Delta t)]} \approx 0 \qquad (6.3\text{-}14)$$

Determining the delay time Δt to meet the requirement of Eq. (6.3-13) for this calculation is difficult and is a drawback to this measurement technique. Therefore, real-time cochannel interference measurement is difficult to achieve in practice.

Design of an Omnidirectional Antenna System in the Worst Case

The value of q = 4.6 is valid for a normal interference case in a K=7 cell pattern. In this section we would like to prove that a K=7 cell pattern does not provide a sufficient frequency re-use distance separation eyen when an ideal condition of flat terrain is assumed. The worst case is at the location where the weakest signal from its own cell site but strong interferences from all interfering cell sites. In the worst case the mobile unit is at the cell boundary R, as shown in Fig. 3. The distances from all six cochannel interfering sites are also shown in the figure: two distances of D - R, two distances of D, and two distances of D + R.

Following the mobile radio propagation rule of 40 dB/dec, we obtain

$$C \propto R^{-4} \qquad I \propto D^{-4}$$

Then the carrier-to-interference ratio is

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

$$= \frac{1}{2(q-1)^{-4} + 2(q)^{-4} + 2(q+1)^{-4}}$$

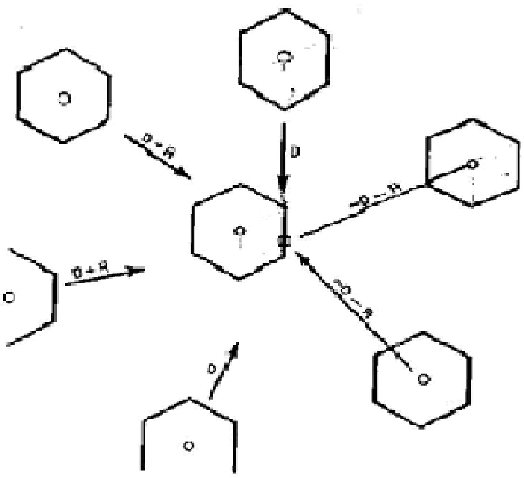

Fig.3.3. Cochannel interference (a worst case)

Where q=4.6 is derived from the normal case. Substituting q=4.6 into above eqn. we obtain C/I =54 or 17 dB, which is lower than 18 dB. To be conservative, we may use the shortest distance D – R for all six interferers as a worst case; then we have

$$\frac{C}{I} = \frac{R^{-4}}{6(D-R)^{-4}} = \frac{1}{6(q-1)^{-4}} = 28 = 14.47 \text{ dB}$$

In reality, because of the imperfect site locations and the rolling nature of the terrain configuration, the C/I received is always worse than 17 dB and could be 14 dB and lower. Such an instance can easily our in a heavy traffic situation; therefore, the system must be designed around the C/I of the worst case. In that case, a cochannel interference reduction factor of q=4.6 is insufficient.

Therefore, in an omnidirectional-cell system, K = 9 or K 12 would be a correct choice. Then the values of q are

$$q = \begin{cases} \frac{D}{R} = \sqrt{3K} \\ 5.2 & K = 9 \\ 6 & K = 12 \end{cases}$$

Substituting these values in Eq. (6.4-1), we obtain

$$\frac{C}{I} = 84.5 \ (=) \ 19.25 \text{ dB} \qquad K = 9$$

$$\frac{C}{I} = 179.33 \ (=) \ 22.54 \text{ dB} \qquad K = 12$$

Design of a Directional Antenna System:

When the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid increasing the number of cells K in a seven-cell frequency reuse pattern. When K increases, the number of frequency channels assigned in a cell must become smaller (assuming a total allocated channel divided by K) and the efficiency of applying the frequency reuse scheme decrease.

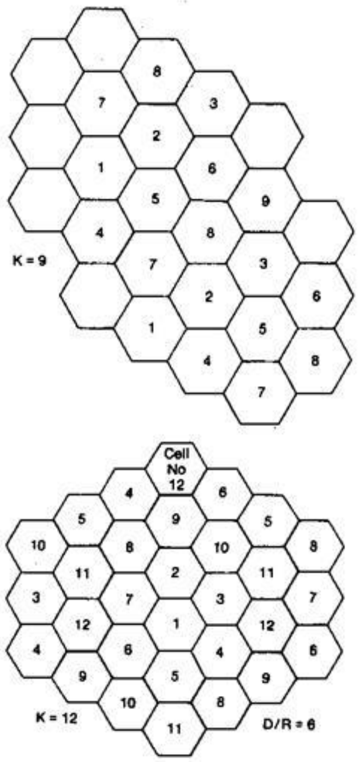

Fig.3.4: Interference with frequency-reuse patterns K=7 and K=12

Instead of increasing the number K in a set of cells, let us keep K =7 and introduce a directional antenna arrangement. The cochannel interference can be reduced by using directional antenna. This means that each cell is divided into three or six sectors and uses three or six directional antennas at a base station. Each sector is assigned a set of frequencies (channels). The interference between two cochannel cells decreases as shown Fig.3.5.

Directional antennas in K=7 cell patterns:

Three sector case: The three-sector case is shown in Fig.3.5. To illustrate the worst case situation, two cochannel cells are shown in Fig. 3.6(a) . The mobile unit at position E will experience greater interference in the lower shaded cell sector than in the upper shaded cell-sector site. This is because the mobile receiver receives the weakest signal from its own cell but fairly strong interference from the interfering cell.

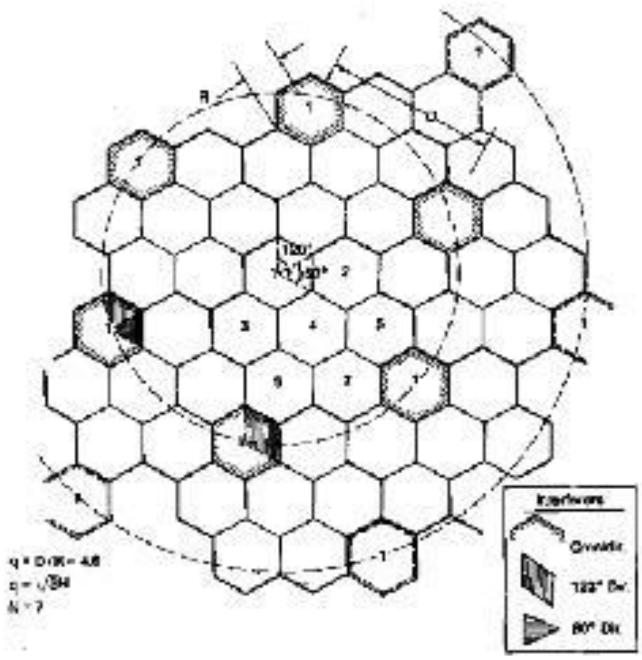

Fig.3.5: Interfering cells shown in a seven cell system (two-tiers)

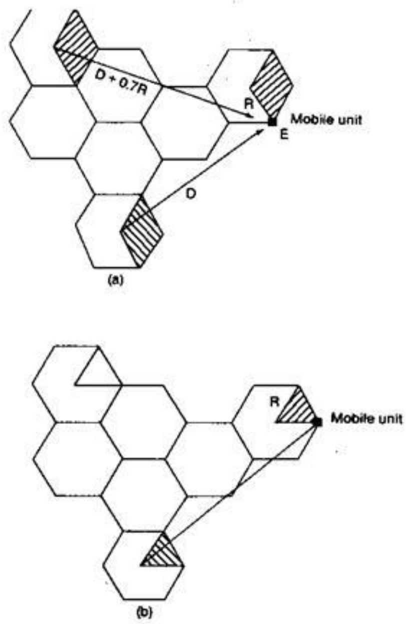

Fig.3.6: Determination of C/I in a directional antenna system. (a)Worst case in a 120 directional antenna system(N=7); (b) worst case in a 60 directional antenna system(N=7)

Let q=4.6; then we have

$$\frac{C}{I}\text{ (worst case)} = 285 \; (=) \; 24.5 \text{ dB}$$

The C/I received by a mobile unit from the 120° directional antenna sector system expressed in Eq. above greatly exceeds 18 dB in a worst case. Equation above shows that using directional antenna sectors can improve the signal-to-interference ratio, that is, reduce the cochannel interference. However, in reality, the C/I could be 6 dB weaker than in Eq. given above in a heavy traffic area as a result of irregular terrain contour and imperfect site locations. The remaining 18.5 dB is still adequate.

Six-sector case: We may also divide a cell into six sectors by using six 60°-beam directional antennas as shown in Fig.4.2. In this case, only one instance of interference can occur in each sector as shown in Fig, 4.2. Therefore, the carrier-to -interference ratio in this case is which shows a further reduction of cochannel interference. If we use the same argument as we did for Eq. above and subtract 6 dB from the result of Eq. the remaining 23 dB is still more than adequate. When heavy traffic occurs, the 60°-sector configuration can be used to reduce cochannel interference. However, fewer channels are generally allowed in a 60° sector and the trunking efficiency decreases. In certain cases, more available channels could be assigned in a 60° sector.

Directional antenna in K = 4 cell pattern:

Three -sector case: To obtain the carrier- to-interference ratio, we use the same procedure as in the K = 7 cell-pattern system. The 120° directional antennas used in the sectors reduced the interferers to two as in K = 7 systems, as shown in Fig.4.4. We can apply Eq. here. For K = 4, the value of q = 3.46; therefore, Eq. becomes

$$\frac{C}{I}\text{ (worst case)} = \frac{1}{(q + 0.7)^{-4} + q^{-4}} = 97 = 20 \text{ dB}$$

If, using the same reasoning used with Eq. above, 6 dB is subtracted from the result of Eq. above, the remaining 14 dB is unacceptable.

Six-sector case: There is only one interferer at a distance of D + R shown in Fig.4.4. With q=3.46, we can obtain

$$\frac{C}{I}\text{ (worst case)} = \frac{R^{-4}}{(D + R)^{-4}} = \frac{1}{(q + 1)^{-4}} = 355 = 26 \text{ dB}$$

If 6 dB is subtracted from the above result, the remaining 20 dB is adequate.

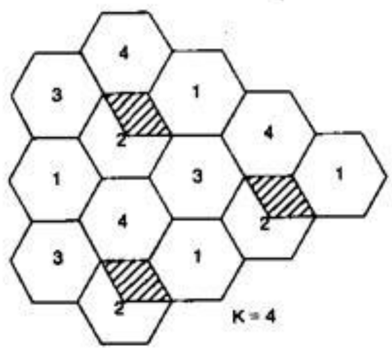

Fig. 3.7: Interference with frequency reuse pattern K=4

Under heavy traffic conditions, there is still a great deal of concern over using a K =4 cell pattern in a 60° sector.

Comparing K =7 and N =4 systems:

A K =7 cell pattern system is a logical way to begin an omnicell system. The co-channel reuse distance is more or less adequate, according to the designed criterion. When the traffic increases, a three sector system should be implemented, that is, with three 120° directional antennas in place. In certain hot spots, 60° sectors can be used locally to increase the channel utilization.

If a given area is covered by both K=7 and K=4 cell patterns and both patterns have a six-sector configuration, then the K=7 system has a total of 42 sectors, but the K=4 system has a total of only 24 sectors and, of course, the system of K=7 and six sectors has less cochannel interference.

One advantage of 60° sectors with K=4 is that they require fewer cell sites than 120 sectors with K=7. Two disadvantages of 60 deg sectors are that (1) they require more antennas to he mounted on the antenna mast and (2) they often require more frequent handoffs because of the increased chance that the mobile units will travel across the six sectors of the call.

Furthermore, assigning the proper frequency channel to the mobile unit in each sector is more difficult unless the antenna height at the cell site is increased so that the mobile unit can be located more precisely. In reality the terrain is not flat, end coverage is never uniformly distributed; in addition, the directional antenna front-to-back power ratio in the field is very difficult to predict. In small cells, interference could become uncontrollable; then the use of a K = 4 pattern with 60 deg sectors in small cells needs to be considered only for special implementations such an portable cellular systems or narrow beam applications. For small cells, a better alternative scheme is to use a K =7 pattern with 120° sectors plus the underlay-overlay configuration.

Lowering the Antenna Height:

Lowering the antenna height does not always reduce the co-channel interference. In some circumstances, such as on fairly flat ground or in a valley situation, lowering the antenna height will be very effective for reducing the cochannel and adjacent-channel interference, However, there are three cases where lowering the antenna height may or may not effectively help reduce the interference.

On a high hill or a high spot: The effective antenna height, rather than the actual height, is always considered in the system design. Therefore, the effective antenna height varies according to the location of the mobile unit. When the antenna site is on a bill, as shown in Fig. 5.1(a), the effective antenna height is h1 + H.

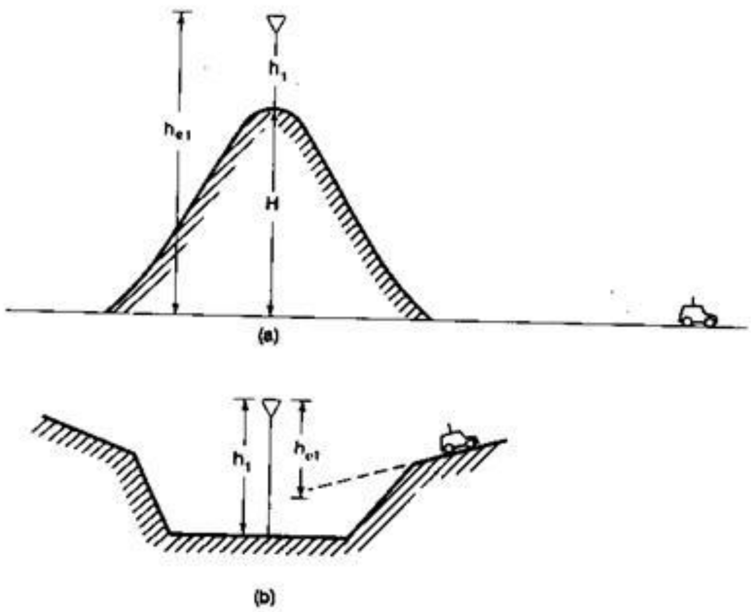

Fig 3.8: Lowering the antenna height (a) on a high hill and (b) in a valley

If we reduce the actual antenna height to 0.5h1, the effective antenna height becomes 0.5h1 + H. The reduction in gain resulting from the height reduction is

$$G = \text{gain reduction} = 20 \log_{10} \frac{0.5h_1 + H}{h_1 + H}$$

$$= 20 \log_{10} \left(1 - \frac{0.5h_1}{h_1 + H}\right)$$

If $h_1 << H$, then the above equation becomes

$$G \approx 20 \log_{10} 1 = 0 \text{ dB}$$

This simply proves that lowering antenna height on the kill does not reduce the received power at either the cell site or the mobile unit.

In a valley: The effective antenna height as seen from the mobile unit shown in Fig. 5.1(b) is he1, which is less than the actual antenna height h1. If he1= 2/3 h1, and the antenna is lowered to ½ h1, then the new effective antenna height is

$$h_{e1} = \tfrac{1}{2}h_1 - (h_1 - \tfrac{2}{3}h_1) = \tfrac{1}{6}h_1$$

Then the antenna gain is reduced by

$$G = 20 \log \frac{\tfrac{1}{6}h_1}{\tfrac{2}{3}h_1} = -12 \text{ dB}$$

This simply proves that the lowered antenna height in a valley is very effective in reducing the radiated power in a distant high elevation area. However, in the area adjacent to the cell-site antenna the effective antenna height is the same as the actual antenna height. The power reduction caused by decreasing antenna height by half is only

$$20 \log \frac{\tfrac{1}{2}h_1}{h_1} = -6 \text{ dB}$$

In a forested area: In a forested area, the antenna should clear the tops of any trees in the vicinity, especially when they are very close to the antenna. In this case decreasing the height of the antenna would not be the proper procedure for reducing cochannel interference because excessive attenuation of the desired signal would occur in the vicinity of the antenna and in its cell boundary if the antenna were below the treetop level.

Antenna Parameters and their effects

The different methods used to reduce co-channel interference are broadly classified into three. They are

1. By providing large separation among the two co-channel cells.
2. By reducing the antenna heights at the base station.
3. By the usage of directional antennas at the base station.

The first two techniques ne not employed because they have disadvantageous effects i.e., method 1 is responsible for reducing the system efficiency for increase in number for frequency range channels. While method 2 is responsible for reducing the reception level at the mobile unit. The method 3 is most commonly used because, along with reducing co-channel interference, it also increases the channel capacity (during heavy traffic).

There are different techniques to generate directional antennas

Tilting the antenna and creating a notch along the unwanted space.
Using umbrella patterns.
Using parasitic elements.

1. **Tilting the Antenna: T**he tilting of an antenna in a desired manner produces an energy pattern with a notch in the desired direction. Hence, ibis notch prevents the co-channel interference problem. The tilting of the antenna is done in two ways.

(1) Electrically
(ii) Mechanically

In the electronic down tilting, the phases between the elements of a co-linear array antenna are varied. In the mechanical down tilting the physical rotation of antenna is occurred.

2. Umbrella Pattern: The umbrella pattern is obtained with the help of a staggered discone antenna. The umbrella pattern reduces the long distance co-channel interference problems, particularly cross talk. Even though, the umbrella pattern is not used for a directional antenna pattern, it can be used for an omnidirectional antenna pattern. In hilly areas, where the height of antenna cannot be increased to cover weak signal spots, results in co-channel interference. In this case also we can use umbrella pattern. The umbrella pattern allows us to increase the antenna height but, we can still decrease cochannel interference.

3. Parasitic Elements: The use of parasitic elements provides the desired pattern and hence we can avoid the cochannel interference. This antenna combination has a parasitic antenna and a driving antenna, the driving antenna is the source of current flowing in the parasitic antenna. The different combinations of their arrangements produce different patterns as described below.

When the lengths of the elements are identical and closely spaced the current flowing through the parasitic clement is strong. This creates equal level of patterns.

When the length of parasite is more than drive antenna, the parasite act as reflector and the pattern in the reflected direction is more.

When the length of parasite is less than drive antenna, the parasite acts as a director and the pattern is more inclined in the forward direction. These three patterns are illustrated in figure (a) figure (b) and figure (c) respectively.

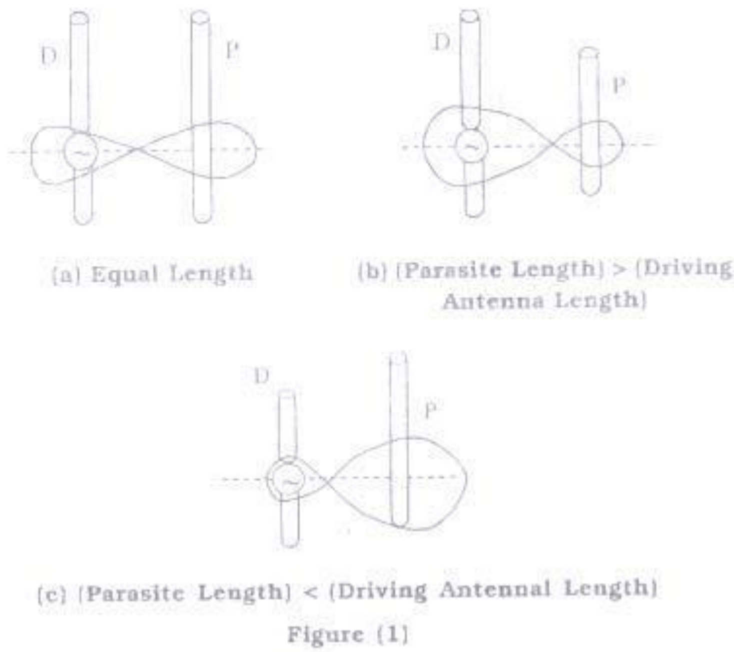

Fig 3.9: Antenna patterns with different parasite lengths

Channel Combiner:

1. A Fixed Tuned Channel Combiner: At the travelling side, a fixed tunable combined unit is used. In every cell site, a channel combiner circuit is installed. The transmitted channels have to be combined based on the following two criteria,

a) The signal isolation between the radio channels must be maximum
b) The insertion loss should be minimum. However, the usage of channel combiner can be avoided by feeding each channel to its corresponding antenna.

But, if there are I6 channels available in a cell site, there will be requirement of 16 antennas for operation which is bottle neck for real time functionalities. It is not economical to hive huge hardware setups. Thus, a conventional combiner can he used, which has 16 channel combining capacity and it is based on the frequency subset of 16 channels of cell site.

The channel combiner would be responsible for each of the 16 channels to exhibit a 3 dB loss due to the signal insertion in to the channel combiner. The signal isolation would be 17dB, if every channel is separated from its neighboring channels by 630 kHz frequency.

2. Tunable Combiner: Tunable combiner is also referred as frequency agile combiner. The frequency agile combiner is an advanced combiner circuit with additional features. It can return any frequency in real time by remote control device, namely microprocessor. This combiner is essentially a waveguide resonator with a tuning bar facility. A motor makes the tuning bar to rotate and once the motor starts rotating, the Voltage Standing Wave Ratio (VSWR) can be measured.

The controller unit has self-adjusting feature and it accepts an optimum value of VSWR as the motor complete, a full turn. The controller is compatible only with dynamic frequency assignment. The cell-sites should be flexible to change their operating frequency 'f' that is controlled by MTSO/MSC. Thus, we can use this frequency agile combiner in the cell site transceiver setup.

3. Ring Combiner: Ring combiner is used to combine two groups of channels to give one output. This combiner has an insertion loss of 3 dB. For example, using a ring combiner two 16 channel groups into one 32 channel output. Even 64 channels can be used with this combiner if two antennas arc available in the cell site. In case of low transmitter power more than one ring combiner can be used for combining. However, the demerits of ring combiners are.

a) It reduces adjacent-channel separation.
b) They may be affected from the problem of power limitations

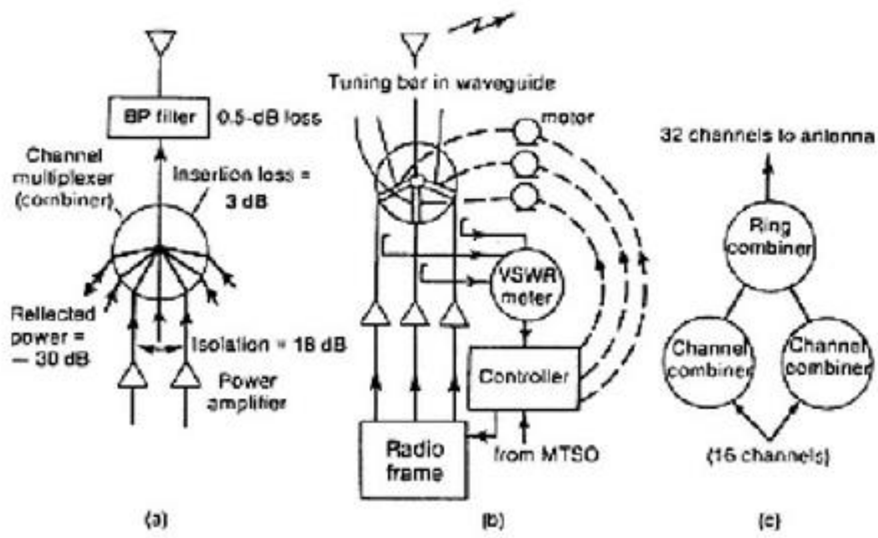

Fig 3.10: Channel Combiners

Demultilexer at the receiver end:

The main theme of using demultiplexer at the receiver end is to reduce the non co-channel interference. A 1:16 demultiplexer is used in between the pre-amplifier stage and filter stage as shown in figure below. Particularly, 1:16 demultiplexer is used in order to receive 16 channels from a single antenna. The output of each antenna reaches demultiplexer after passing through a 25 dB gain amplifier. The total split loss of demultiplexer output and due to 16 channels is given by.

$$S = 10 \log 16$$

$$= 12.04$$

$$S = 12.04 \text{ dB}$$

Care must be taken such that the intermodulation product at the demultiplexer output is 65 dB down and the space diversity antennas connected to an umbrella filter must have a 55 dB rejection from other systems band, otherwise in case. if a dummy mobile unit is close to the cell site then the preamplifier generates intermodulation frequency at the amplifiers output which may lead to cross talk.

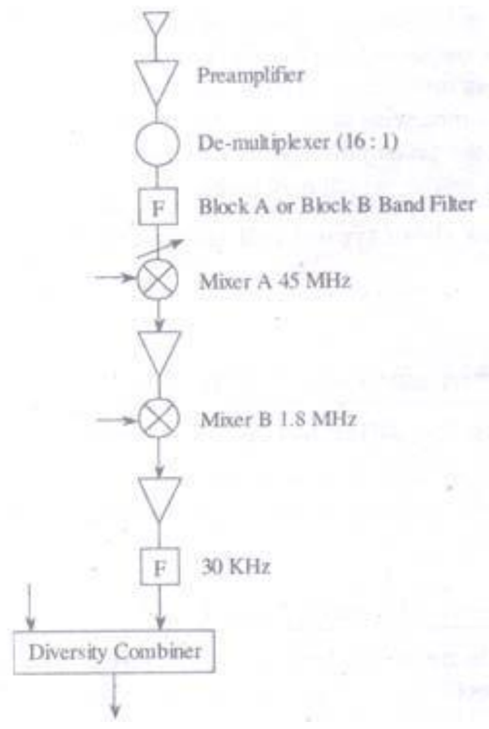

Fig 3.11: A typical Cell Site Channel Receiver

Diversity Receiver:

The diversity scheme applied at the receiving end of the antenna is an effective technique for reducing interference because any measures taken at the receiving end to improve signal performance will not cause additional interference. The diversity scheme is one of these approaches. We may use a selective combiner to combine two correlated signals as shown in Fig. 3.12. The performance of other kinds of combiners can be at most 2 dB better than that of selective combiners. However, the selective combining technique is the easiest scheme to use.

Figure 7 shows a family of curves representing this selective combination. Each curve has an associated correlation coefficient p; when using the diversity scheme, the optimum result is obtained when p = 0.

At the cell site the correlation coefficient p < 0.7 should be used for a two-branch space diversity; with this coefficient the separation of two antennas at the cell site meets the requirement of h / d= 11, where h is the antenna height and d is the antenna separation.

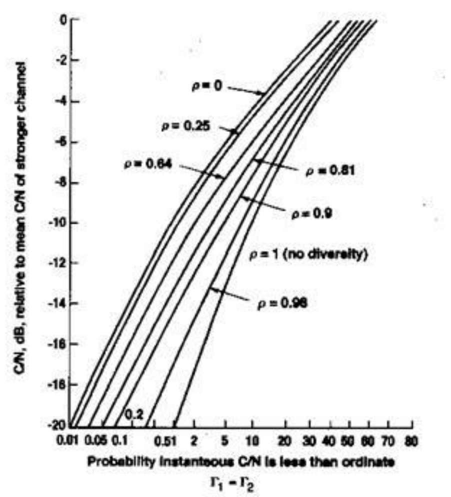

Fig. 3.12: Selective combining of two correlated signals

At the mobile unit we can use p =0, which implies that the two roof-mounted antennas of the mobile unit are 0.5 Lambda or more apart. This is verified by the measured data shown in Fig. 3.13. Now we may estimate the advantage of using diversity. First, let us assume a threshold level of 10 dB below the average power level.

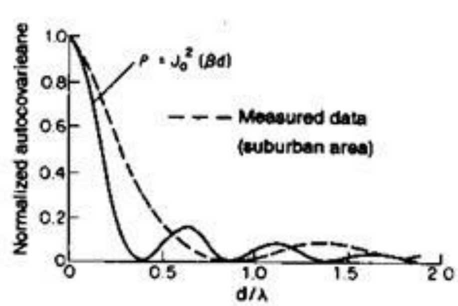

Fig. 3.13 Autocorrelation coefficient versus spacing for uniform angular distribution (applied to diversity receiver)

Then compare the percent of signal below the threshold level both with and without a diversity scheme.

1. **At the mobile unit:** The comparison is between curves p = 0 and the p=1. The signal below the threshold level is 10 percent for no diversity and 1 percent for diversity. If the signal without diversity were 1 percent below the threshold, the power would be increased by 10 dB. In other words, if the diversity scheme is used, the power can be reduced by 10 dB and the same performance can be obtained as in the non diversity scheme. With 10 dB less power transmitted at the cell site, cochannel interference can be drastically reduced.

2. **At the cell site:** The comparison is between curves of p=0.7 and p =1. We use curve p=0.64 for a close approximation as shown in Fig. 7.1. The difference is 10 percent of the signal is below threshold level when a non diversity scheme is used versus 2 percent signal below threshold level when a diversity scheme is used. If the non diversity signal were 2 percent below the threshold, the power would have to increase by 7 dB (see Fig.7.1). Therefore, the mobile transmitter (for a cell-site diversity receiver) could undergo a 7dB reduction in power and attain the same performance as a non diversity receiver at the cell site. Thus, interference from the mobile transmitters to the receivers can be drastically reduced.

Non Cochannel Interfernces – Subjective Vs Objective
Adjacent Channel Interferncces

Near-End—Far-End Interference:

In one cell: Because motor vehicles in a given cell are usually moving, some mobile units are close to the cell site and some are not. The close-in mobile unit has a strong signal which causes adjacent-channel interference (see Fig. 3.14(a)). In this situation, near-end-far-end interference can our only at the reception point in the cell site.

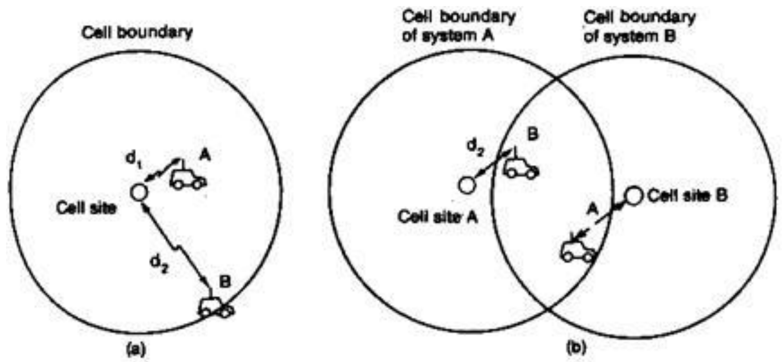

Fig.3.14: Near-end-far-end interference (a) In one cell (b) In two-systems.

If a separation of 5dB (five channel bandwidths) is needed for two adjacent channels in a cell in order to avoid the near-end -far-end interference, it is then implied that a minimum separation of 5dB required between each adjacent channel used with one cell.Because the total frequency channels are distributed in a set of N cell, each cell only has I/N of total frequency channels. We denote {Fl}, {F2},{F3},{F4} for the sets of frequency channels assigned in their corresponding cells C1.,C2, C3, C4.The issue here is how can we construct a good frequency management chart to assign the N sets of frequency channels properly and thus avoid the problems indicated above. The following section addresses how cellular system engineers solve this problem in two different systems.

In cells of two systems: Adjacent-channel interference can occur between two systems in a duopoly -market system. In this situation, adjacent-channel interference can occur at both the cell site and the mobile unit.

For instance, mobile unit A can be located at the boundary of its own home cell A in system A but very close to cell B of system B as shown in the figure 3.14(b). The other situation would occur if the mobile unit B were at the boundary of cell B of system B but very close to cell A of system A. Following the definition of near-end-far-end interference , the solid arrow indicates that interference may our at cell site A and the dotted arrow indicates that interference may occur at mobile unit A. Of course, the same interference will be introduced at cell site B and mobile unit B.

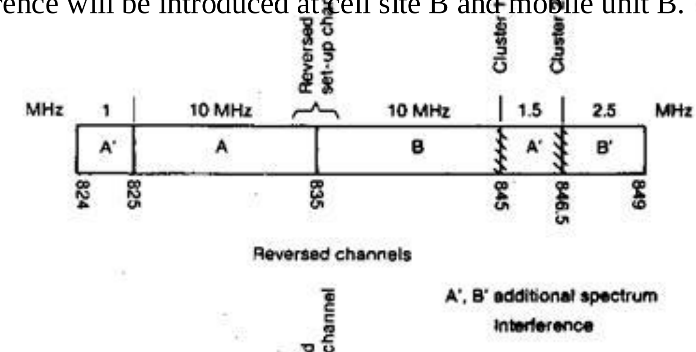

Fig. 3.15 Spectrum allocation with new additional spectrum.

Thus, the frequency channels of both cells of the two systems must be coordinated in the neighborhood of the two-system frequency bands. This phenomenon will be of greater concern in the future, as indicated in the additional frequency-spectrum allocation charts in Fig. 3.15.

The two causes of near-end—far-end interference of concern here are

1. Interference caused on the set-up channels. Two systems try to avoid using the neighborhood of the set-up channels as shown in Fig. 3.15.
2. Interference caused on the voice channels. There are two clusters of frequency sets as shown in Fig.3.15 which may cause adjacent-channel interference and should be avoided. The cluster can consist of 4 to 5 channels on each side of each system, that is, 8 to 10 channels in each cluster. The channel separation can be based on two assumptions.

a. Received interference at the mobile unit. The mobile unit is located away from its own cell site but only 0.25 ml away from the cell site of another system.

b. Received interference at the cell site. The cell site is located 10 ml away from its own mobile unit but only 0.25 mi from the mobile unit of another system.