Subject Name: **Cellular Mobile Communication**

Subject Code: **EC-6001**

Semester: **6th**

**EC-6001 Cellular mobile communication**
**Unit-III**

**Co channel interference reduction**
Co channel interference, real-time co channel interference measurement at mobile radio transceivers, design of antenna systems - Omni directional and directional, lowering the antenna height, reduction of co channel interference, umbrella-pattern effect, diversity receiver, designing a system to serve a predefined area that experiences co channel interference.
**Types of Non co channel interference**
Adjacent channel interference, near-end-far-end interference, effect on near-end mobile units, cross-talk, effects of coverage and interference by applying power decrease, antenna height decrease, beam tilting, effects of cell site components, interference between systems, UHF TV interference, long distance interference.

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## CO CHANNEL INTERFERENCE REDUCTION

Inference between two co channels is known as co channel interference. Frequency reuse technique is very useful for increasing the efficiency of spectrum utilization. But which results the co channel interference since the same frequency channel is repeatedly used in different co channel cells. To reduce the co channel interference need to find the minimum frequency reuse distance.

### 3.1 Real-time co channel interference measurement

When the carriers are angle modulated by the voice signal and if the frequency difference between them is much higher than the fading frequency. The signal carrier-to-interference ratio (C/ I) gives the signal as-

$$e_1 = S(t)\sin(\omega t + \emptyset_1) \qquad \text{..............................3.1}$$

And interference signal as

$$e_2 = I(t)\sin(\omega t + \emptyset_2) \qquad \text{..............................3.2}$$

Then the received signal is given by

$$e(t) = e_1 + e_2 = R\sin(\omega t + \varphi) \qquad \text{..............................3.3}$$

Where

$$R = \sqrt{[S(t)\cos\emptyset_1 + I(t)\cos\emptyset_2]^2 + [S(t)\sin\emptyset_1 + I(t)\sin\emptyset_2]^2} \qquad \text{..............................3.4}$$

$$\varphi = \tan^{-1}\frac{S(t)\sin\emptyset_1 + I(t)\sin\emptyset_2}{S(t)\cos\emptyset_1 + I(t)\cos\emptyset_2} \qquad \text{..............................3.5}$$

### 3.2 Design of an omni-directional antenna system

If the cluster size K is 7 the value of co channel reduction factor q is 4.6. The value of q is valid for a normal interference case in a K=7 cell pattern. Here we consider a case when the user is at the location where it receives the weakest signal from its own cell site but receives strong interferences from all the interfering cell sites. In the worst case the mobile unit is at the boundary cell as shown in figure 3.1.
The distances from all six co channel interfering sites are also shown in the figure 3.1 two distances of D - R, two distances of D, and two distances of D + R.

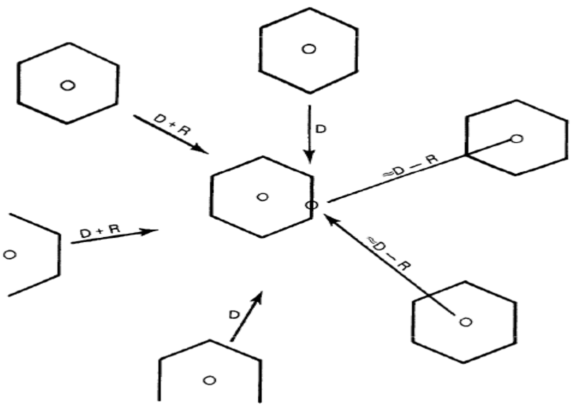

Figure 3.1 Co channel interference

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

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

Then the carrier-to-interference ratio is

 

$$\frac{C}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2D^{-4} + 2(D+R)^{-4}} \qquad \text{……………………3.6}$$

We know that co channel inference reduction factor is given by

$$q = D/R \qquad \text{…………………… 3.7}$$

Putting the value of q in equation 3.7 we get

$$\frac{C}{I} = \frac{1}{2(q-1)^{-4} + 2q^{-4} + 2(q+1)^{-4}} \qquad \text{……………………3.8}$$

We know that the value of q is 4.6 for K=7. Substituting q =4.6 into equation 3.8, we obtain C/ I = 54 or 17 dB, which is lower than 18 dB. In worst case we may use the shortest distance D–R for all six interferers then equation 3.8 is replaced by

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

**3.3 Design of a Directional Antenna System:**

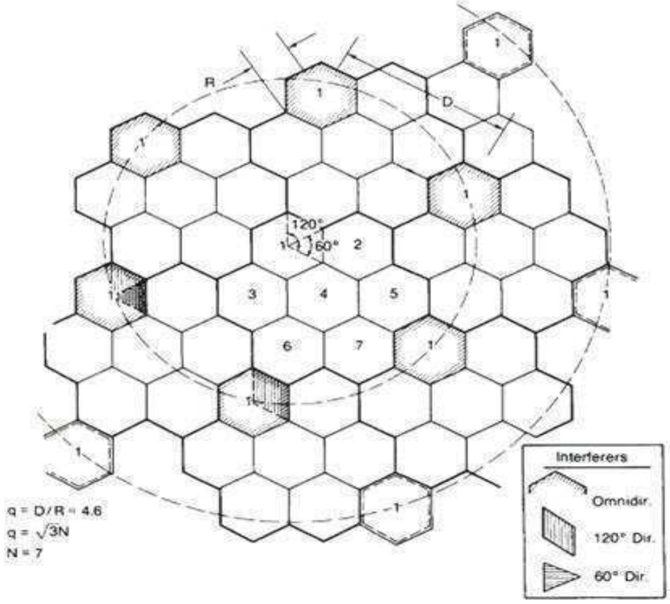


Figure 3.2 Interfering cells shown in a seven-cell system

When the call traffic increases we need to use the available frequency spectrum efficiently. To avoid increasing the number of cells in a seven-cell frequency reuse pattern. When K increases, the number of frequency channels assigned in a cell must become smaller and the efficiency of implementing frequency reuse scheme decrease.

In place of increasing the number K in a set of cells we can use a directional antenna arrangement. The co channel interference can be reduced by using directional antenna. It means that each cell is divided into 3 or 6 sectors and uses 3 or 6 directional antennas at the base station. Each sector is assigned a set of frequencies. The interference between two co channel cells decreases as shown figure 3.2.

**3.3.1 Directional antennas in K=7 cell patterns:**

**Three sector case:** The three-sector case is shown in figure 3.2. To show the worst case situation, two co channel cells are shown in figure 3.3(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 strong interference from the interfering cell.

In a three-sector case, the interference is effective in only one direction because the front-to-back ratio of a cell-site directional antenna is at least 10 dB or more in a mobile radio environment. The worst-case co channel interference in the directional-antenna sectors in which interference occurs can be calculated. Because of the use of directional antennas, the number of principal interferers is reduced from 6 to 2 as shown in figure 3.3(a). The worst case of C/I occurs when mobile unit is at position of E at this point the distance between the mobile unit and the two interfering antennas is nearly D + (R/2). The value of C/I can be obtained by the following expression

$$\frac{C}{I}(\text{worst case}) = \frac{R^{-4}}{(D+0.7R)^{-4} + D^{-4}} \qquad \text{……………………3.9}$$

$$\frac{C}{I}(\text{worst case}) = \frac{1}{(q+0.7)^{-4} + q^{-4}} \qquad \text{……………………3.10}$$

Let q=4.6 then equation 3.10 becomes

$$\frac{C}{I}(\text{worst case}) = 285 = 24.4 \text{ dB}$$

 

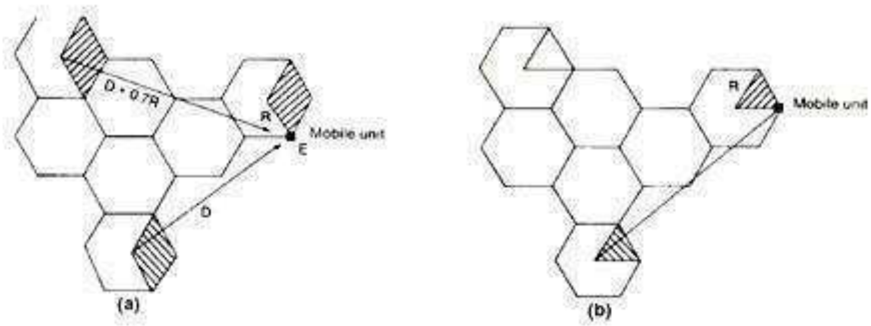


Figure 3.3 (a) In a 120◦ directional antenna system (b) In a 60◦ directional antenna

**Six-sector case:** We can also divide a cell into six sectors by using six 60° beam directional antennas as shown in figure 3.3(b). In this case, only one instance of interference can occur in each sector as shown in figure 3.2. Therefore, the carrier-to-interference ratio in this case is

$$\frac{C}{I} = \frac{R^{-4}}{(D + 0.7R)^{-4}}$$

$$= \frac{1}{(q + 0.7)^{-4}} \qquad \text{……………………3.11}$$

For q= 4.6 we get

$$\frac{C}{I} = 794 = 29 \ \text{dB}$$

This shows a further reduction of co channel interference.

**3.4 Lowering the antenna height:**

Lowering the antenna height does not always reduce the co channel interference. In some cases such as on flat ground or in a valley situation, lowering antenna height will be very useful for reducing the co channel and adjacent channel interference. There are three cases where lowering the antenna height may or may not effectively help in reduction of interference.

- **On a high hill or a high spot:**

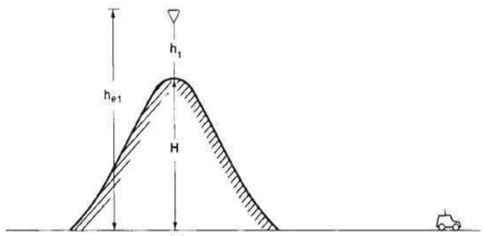


Figure 3.4 lowering the antenna height on a high hill

In the system design the effective antenna height is always considered rather than the actual height. Therefore, the effective antenna height varies according to the location of the mobile unit. When the antenna site is on a hill, as shown in figure 3.4 the effective antenna height is $h_1 + H$.

If we reduce the actual antenna height to $0.5h_1$, the effective antenna height becomes $0.5h_1 + H$. The reduction in gain resulting from the height reduction is

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

$$= 20 \ \log(1 - \frac{0.5 \ h_1}{h_1 + H})$$

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

$$G = 20 \ \log 1 = 0 \ \text{dB}$$

This simply proves that lowering antenna height on the hill does not reduce the received power at both end i.e. the cell site or the mobile unit.

- **In a forested area:**

In a forested area, the antenna should clear the tops of any trees in the area, especially when trees are closer to the antenna. In this case decreasing the height of the antenna would not be the proper procedure for reducing co channel 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

 

➢ **In a valley:**

The effective antenna height as seen from the mobile unit shown in figure 3.5 is $h_{e1}$, which is less than the actual antenna height $h_1$. If $h_{e1}$ = 2/3 $h_1$, and the antenna is lowered to ½ $h_1$, then the new effective antenna height is

$$h_{e1} = \frac{1}{2}h_1 - \left(h_1 - \frac{2}{3}h_1\right) = \frac{1}{6}h_1$$

Then the antenna gain is reduced by

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

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.

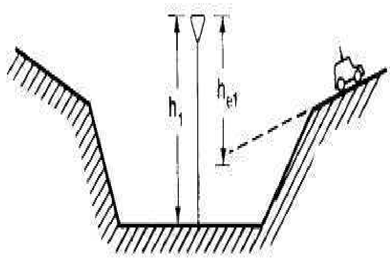

Figure 3.5 Lowering the antenna height in a valley.

**3.5 Reduction of co channel interference**

Reduction of co channel interference in a cellular mobile system is always a challenging problem. A number of methods can be considered, such as

- Increasing the separation between two co channel cells
- Using directional antennas at the base station
- Lowering the antenna heights at the base station.

Method 1 is not advisable because as the number of frequency-reuse cells increases, the system efficiency, which is directly proportional to the number of channels per cell, decreases. Method 3 is not recommended because such an arrangement also weakens the reception level at the mobile unit. However, method 2 is a good approach, especially when the number of frequency-reuse cells is fixed.

There are different techniques available to generate directional antennas

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

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

I. 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 disc one 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 Omni directional antenna pattern. In the hilly areas to cover the weak spot area we cannot increase the height of antenna which may increase the 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 co channel interference.

**3. Parasitic Elements:** The use of parasitic elements provides the desired pattern and hence we can avoid the co channel interference. This antenna combination has a parasitic antenna and a driving antenna. Driving antenna is the source of current flowing in the parasitic antenna. The different combinations of their arrangements produce different patterns. When the lengths of the elements are identical and closely spaced the current flowing through the parasitic element is strong. This creates equal level of patterns. When the length of parasitic element is more than drive antenna, the parasitic element act as reflector and the pattern in the reflected direction is more. When the length of parasitic element is less than drive antenna, the parasitic elements acts as a director and the pattern is more inclined in the forward direction.

**3.6 Types of non co channel interference**

There are different types of non co channel interferences that can degrade the performance of the cellular mobile system. Basically interference is classified into two categories as follows

A. Co channel interference
B. Non Co channel interference

Inference between two co channels is known as co channel interference and interference between to non co channels is known as non co channel interference. Types of non co channel interference are as follows

1. Adjacent-Channel Interference
2. Near-End-Far-End Interference
3. Cross Talk
4. Interference between systems
5. UHF TV Interference
6. Long distance interference

**3.6.1 Adjacent-Channel Interference**:

The adjacent channel interference is the interference that generated by the adjacent cells of the desired cell site. The ACI has better control than the co channel interference .It can be eliminated/ reduced on the basis of the channel assignment, the filter characteristics, and the reduction of near-end-far-end interference. It includes

A. Next-Channel (channel next to the operating channel)
B. Neighboring-channel Interference(channel away from the operating channel)

➢ **Next-Channel Interference:**

- Next-channel interference will arrive at the mobile unit from other cell sites if the system is not designed properly.
- Mobile unit initiating a call on a control channel in a cell may cause interference with the next control channel at another cell site.
- The filter with a sharp falloff slope can help to reduce all the adjacent-channel interference, including the next-channel interference.

➢ **Neighboring-channel Interference:**

- The channels which are several channels away from the next channel will cause interference with the desired signal.
- A fixed set of serving channels is assigned to each cell site.
- If all the channels are simultaneously transmitted at one cell site antenna, a sufficient amount of band isolation between channels is required for a multi-channel combiner to reduce inter-modulation products

**3.6.2 Near-End Far-End Interference:**

When the vehicles are in movement some of the mobile units are closer to the cell site while some of them would be at a distance from the cell site. Hence the mobile units which are very close will possess stronger signal than the mobile units that are in further place and thus the closer units will induce interference.

In short the near-end-to-far-end ratio can be defined as the power difference due to the path loss (PL) available between the receiving end and the two transmitters.

$$\text{Near end far end ratio} = \frac{\text{Path loss due to near end}}{\text{Path loss due to far end}}$$

Consider the two cases shown in figure 3.6. The first case is the interference due to near-end-far-end in one cell. In second case two cell sites A and B are shown/ where interference will occur at the reception point in the cell.

 

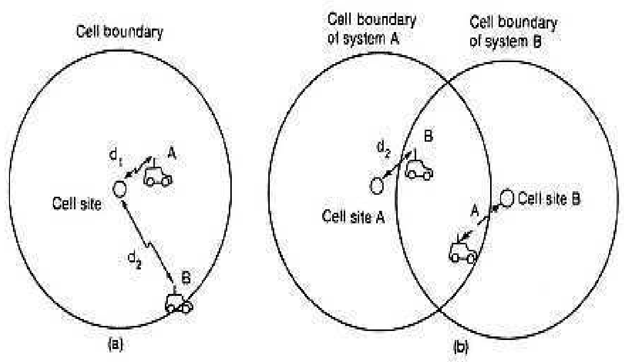


Figure 3.6 (a) In one cell; (b) in two cell

- **In One Cell :**

• The close-in mobile unit has a strong signal which causes adjacent-channel interference

• In this situation, near-end-far-end interference can occur only at the reception point in the cell site as shown in figure 3.6 (a)

- **In Cells of Two Systems:**

• The frequency channels of both cells of the two systems must be coordinated in the neighborhood of the two- system frequency bands. The situation can be seen in figure 3.6 (b)

**3.6.3 Cross Talk:**

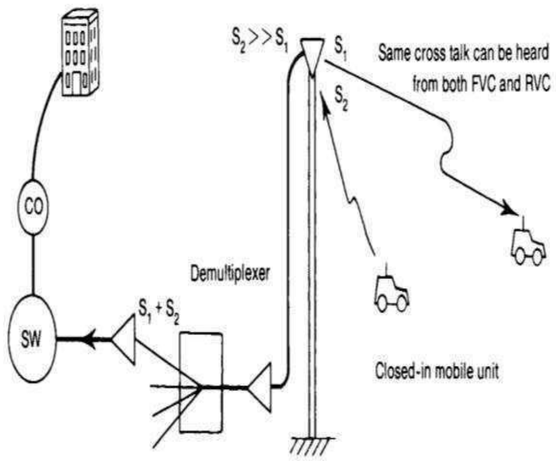


Figure 3.7 Cross-talk phenomenon.

The cellular radio system was designed like a telephone wire line. In telephone wire line a wire pair serves both directions of traffic at the line transmission. Similarly in a mobile cellular system there is a pair of frequencies used occupying a bandwidth of 60 KHz which is known as channel. A frequency of 30 KHz is used for received path and the other 30 KHz used for transmitted path. Because of paired-frequency coupling through the two wire four wire hybrid circuitry at the telephone central office, it is possible to hear voices in both frequencies simultaneously while scanning on only one frequency in the air.

Therefore, just as with a wire telephone line, the full conversation can be heard on a single frequency. This phenomenon does not annoy cellular mobile users; when they talk they also listen to themselves through the phone receiver. They are not even aware that they are listening to their own voices.

This unnoticeable cross-talk phenomenon in frequency pairs has no major impact on both wire telephone line and cellular mobile performance. But when real cross talk occurs it has a larger impact on the cellular mobile system than on the telephone line, because the amount of cross talk could potentially be doubled since cross talk occurring on one frequency will be heard on the other (paired) frequency. Cross talk occurring on the reverse voice channel (RVC) can be heard on the forward voice channel (FVC), and cross talk occurring on the forward voice channel can be heard on the reverse channel.

**3.6.4 Interference between Systems:**

- **In One City:**

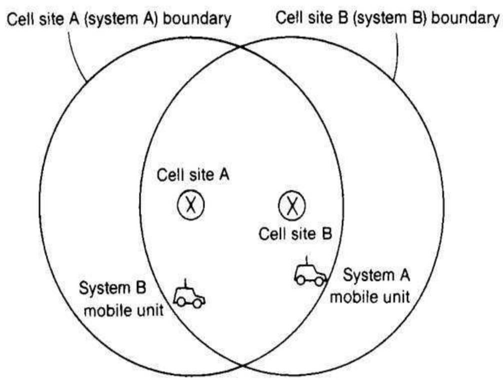


Figure 3.8 Interference in one city

Assume that there are two systems operating in one city or one metropolitan area. If a mobile unit of system A is closer to a cell site of system B while a call is being initiated through system A, adjacent channel interference or intermediation (IM) can be produced if the transmitted frequency of mobile unit A is close to the covered band of the received preamplifier at cell site B as shown in figure 3.8. These IM products will then leak into the receiving channel of system B and cross talk will occur. This cross talk can be heard not only at the land-line side but also at the mobile unit.

 

### ➢ In Adjacent Cities

Two systems operating at the same frequency band and in two adjacent cities or areas may interfere with each other if they do not coordinate their frequency channel use. Most cases of interference are due to cell sites at high altitudes as shown in figure 3.9. In any start-up system, a high-altitude cell site is always attractive to the designer. Such a system can cover a larger area, and, in turn, fewer cell sites are needed. However, if the neighboring city also uses the same system block, then the result is strong interference, which can be avoided by the following methods.

1. The operating frequencies should be coordinated between two cities. The frequencies used in one city should not be used in the adjacent city. This arrangement is useful only for two low-capacity systems.

2. If both systems are high capacity, then decreasing the antenna heights will result in reduction of the interference not only within each system but also between the two systems.

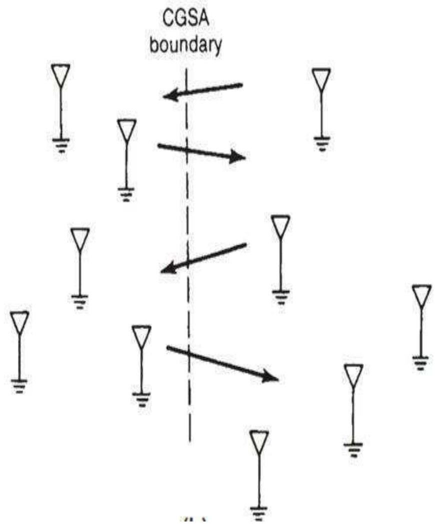


Figure 3.9 Interference between two cellular geographic service area (CGSA) systems

3. Directional antennas may be used. For example, if one system is high capacity and the other is low capacity, the low-capacity system can use directional antennas but still retain the high tower. In this situation frequency coordination between the two systems has to be worked out at the common boundary because all the allocated frequencies must be used by the high-capacity system in its service area but only some frequencies are used by the low-capacity system.

### 3.6.5 UHF TV Interference:

Two types of interference can occur between UHF television and 850-MHz cellular mobile phones.

- Interference to UHF TV Receivers from Cellular Mobile Transmitters
- Interference of Cellular Mobile Receivers by UHF TV Transmitters

Because of the wide frequency separation between cellular phone systems and the media broadcast services (TV and radio) and the significantly high power levels used by the UHF TV broadcast transmitters, the likelihood of interference from cellular phone transmissions affecting broadcasting is very small.

There is a slight probability that when the cell- site transmission is 90 MHz above that of a TV channel, it can interfere with the image- response frequency of typical home TV receivers. Interference between TV and cellular mobile channels is illustrated in figure 3.10.

Some UHF TV channels overlap cellular mobile channels. There two types of service can interfere with each other only under following conditions.

1. Band region with overlapping frequencies. Two services have been authorized to operate within the same frequency band region.

2. Image interference region. This is explained as follows. The TV receiver or the cellular receiver (mobile unit or cell site) can receive two transmitted signals, for instance, one from a TV channel and one from a cellular system, and produce a third-order inter modulation product that falls within the TV or the mobile receive band.

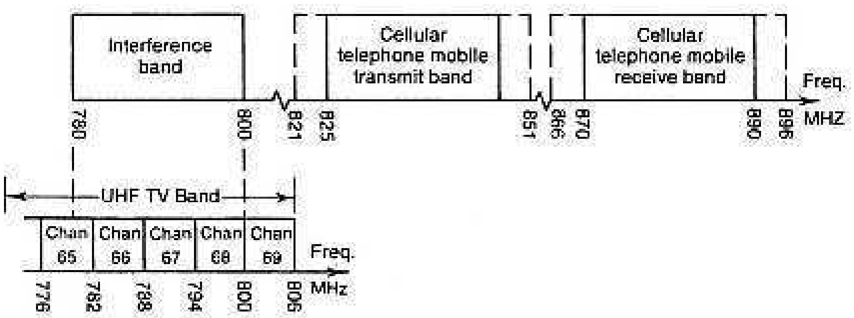


Figure 3.10 Cellular telephone frequency plan.

 

### 3.6.6 Long-Distance Interference:

Under the long distance interference two things has to be analyzed

1. Overwater Path
2. Overland Path

- Both, the over water path and over land paths would cause interference. But in case of 41 miles over water path that is operating at 1.5 GHz frequency had clear steady signal above the normal level at low ducts( < 50 feet thickness) and at high ducts ( >= 100 feet thickness) it received high signal level with deep fading effects.
- Under overland path the tropospheric scattering takes place over the path and it varies from one time to another. It is not persistent as in the case of underwater path. The amount of interference would be more in long-distance overland path considerations.

## 3.7 Effects on coverage and interference

In some conditions where the amount of interference is higher than system engineers reduce the coverage to compensate for interference. There are several ways to overcome this problem like reorienting the directional-antenna patterns, changing the antenna beamwidth, or synthesizing the antenna pattern, decreasing the power and decreasing the antenna height.

➢ **Power Decrease**

If the setup of the antenna arrangement at the cell site remains the same and if the cell-site transmitted power is decreased by 3 dB, then the reception at the mobile unit is also decreased by 3 dB. This is a one-on-one (i.e., linear) correspondence and thus is easy to control.

➢ **Antenna Height Decrease**

When antenna height is decreased in cellular mobile communication then received power is also decreased. The below formula of antenna gain shows the effect of antenna height on gain

$$\text{Antenna Height gain/loss} = 20 \log \frac{h'_{e1}}{h_{e1}}$$

This formula based on the difference between the old and new effective antenna heights and not on the actual antenna heights. Therefore, the effective antenna height is the same as the actual antenna height only when the mobile unit is traveling on flat ground. It is easy to decrease antenna height to control coverage in a flat-terrain area. For decreasing antenna height in a hilly area, the signal-strength contour is different from the situation of power decrease flat ground. Therefore, a decrease in antenna height would affect the coverage; thus, antenna height becomes very difficult to control in an overall plan. Some area within the cell may have a high attenuation while another may not.

## 3.8 Effects of cell-site components

Cell-site components include channel combiner unit, de-multiplexer used at the receiver and some of the functionalities of supervisory audio tone (SAT).

### 3.8.1 Channel combiner:

At the transmitter side a fixed tuned channel combiner unit is used. In every cell site a channel combiner is installed at each cell site. Then all the transmitted channels can be combined with minimum insertion loss and maximum signal isolation between channels. We eliminate the channel combiner by letting each channel feed to its own antenna. The transmitted channels-has to be combined with two main criteria namely,

i) Maximum signal isolation between the radio channels.

ii) Minimum insertion loss.

• But in such case if there are 16 channels available in a cell site there will be requirement of 16 antennas for operation which is a bottle neck for real time functionalities. It is not economical to have a huge hardware set ups. Thus a conventional" combiner can be used here that has 16-channel combining capacity and it is based on the frequency subset of the 16 channels of the cell site.

• The channel combiner would cause each of the 16 channels would face a 3 dB loss due to the signal insertion into the channel combiner, and the signal isolation would be 17 dB, if every channel is a part from its neighboring channels by 630 kHz frequency.

• There is inter modulation present at the multiplexer and it has to be controlled. For this ferrite isolators can be applied in design that would provide 30 dB reverse loss.

Different types of channel combiners are used at cell site. Figure 3.11 shows types of channel combiners

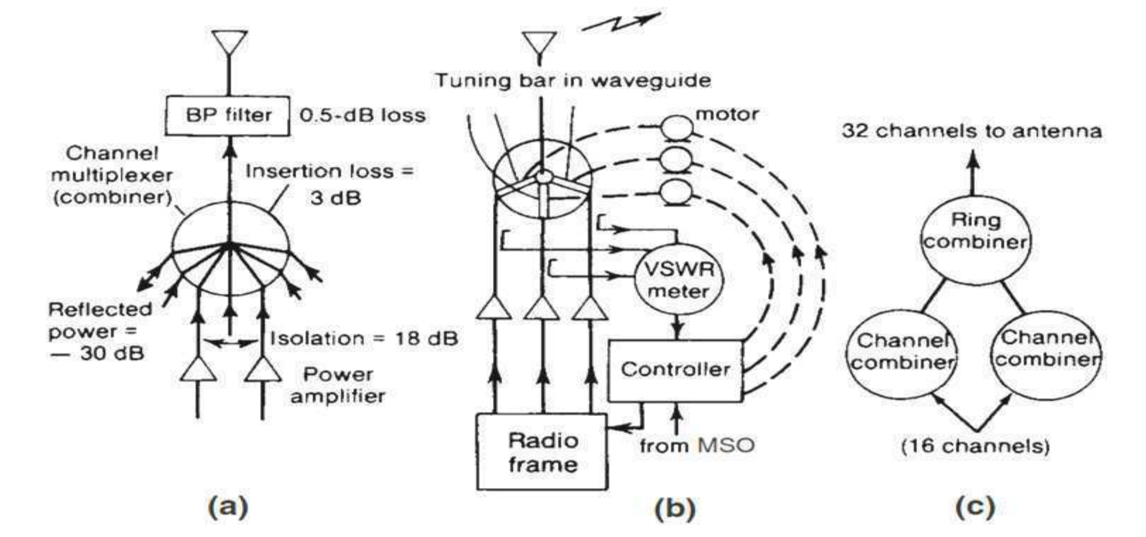


Figure 3.11 (a) Fixed-tuned combiner (b) tunable combiner (c) ring combiner.

**10.7.2 De-multiplexer at the Receiving End**

A de-multiplexer is commonly used to receive 16 channels from one antenna. The de-multiplexer is a filter bank as shown in figure. 3.12. Then, each receiving antenna output passes through a 25-dB-gain amplifier to a de-multiplexer. The de-multiplexer output has a 12-dB loss from the split of 16 channels and the IM product at the output of the de-multiplexer should be 65 dB down.

$$\text{Split loss} = 10 \log N$$

Where N is the number of channels and for N=16 the value of split loss is 12 dB.

The inter modulation effects takes place whenever the input signal applied is a summation of N frequencies while passing the signal through the power amplifier unit or a hard limiter circuit would produce the inter modulation effects.

• To avoid 1M products it is to have a wide radio frequency bandwidth for few channels alone. Only if large frequency spectrum is sacrificed the inter modulation spreading can be avoided.

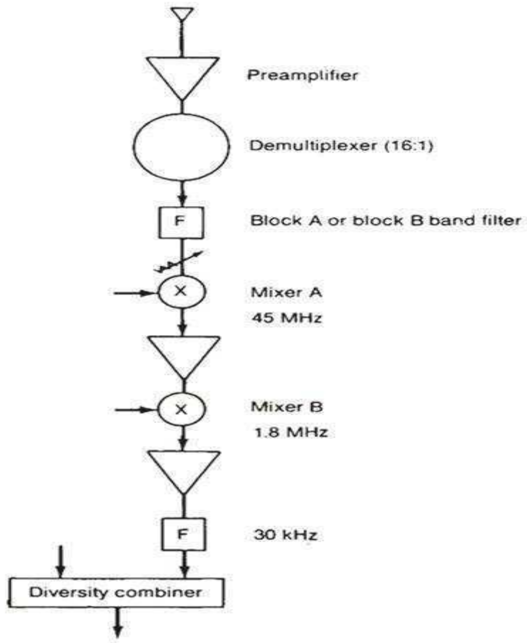


Figure 3.12 A typical cell-site channel receiver.