Interference

Introduction to Co-Channel Interference

CO-CHANNEL INTERFERENCE

- INTRODUCTION TO CO-CHANNEL INTERFERENCE
- PROCEDURE TO FIND NEAREST NEIGHBOURS OF A CELL
- CO-CHANNEL INTERFERENCE REDUCTION FACTOR
- DESIRED C/I FROM A NORMAL AND WORST CASE IN AN OMNI-DIRECTIONAL AND DIRECTIONAL ANTENNA SYSTEM
- IMPACT ON CO-CHANNEL INTERFERENCE BY LOWERING THE ANTENNA HEIGHT
- NON CO-CHANNEL INTERFERENCE

Interference: A process in which two or more waves are super-imposed in such a way that they produce higher peaks, lower troughs, or a new wave pattern.

In other word, it is the effect when the two or more waves overlap or intersect with each other, and the amplitude of the resulting wave depends upon the frequencies and phases of the individual waves.

Co-channel Interference: The interference between the signals from the co-channel cells is called the co-channel interference.

Adjacent channel Interference: The interference between the signals from the adjacent channel cell is called the adjacent channel interference.

MAJOR LIMITING FACTOR for Cellular System performance is the INTERFERENCE

Interferences can cause:

→ CROSS TALK

→ Missed and Blocked Calls.

SOURCES OF INTERFERENCE?

- Another mobile in the same cell (if distance & frequency are close)
- A call-in progress in neighboring cell (if frequency is close).
- Other base stations operating in the same frequency band (from co-channel cells)
- Non-cellular systems leaking energy into cellular frequency band

COCHANNEL INTERFERENCE

- The frequency-reuse method is useful for increasing the efficiency of spectrum usage but results in co channel interference because the same frequency channel is used repeatedly in different co channel cells.
- Co-channel cells $\rightarrow$ cells that share same set of frequencies
- The co channel interference reduction factor *$q = 4.6$ is based on the system required $C/I = 18$ dB of the AMPS system.*

Introduction to Co-Channel Interference

- The co channel interference is usually involved with **FDMA, TDMA,** and **OFDMA** systems.

- The interference occurred because the frequency reuse scheme is applied to those systems in which **the channels operate at the same frequency but repeatedly in separate locations.**

PROCEDURE TO FIND NEAREST NEIGHBOURS OF A CELL

- In most mobile radio environments, use of a seven-cell reuse pattern is not sufficient to avoid co channel interference for AMPS systems.
- Increasing *K > 7 would reduce the* number of co 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 co channel interference and use channel sharing and channel borrowing schemes to increase spectrum efficiency.

Determination of Co-channel Interference Area

- For detection of serious co channel interference in areas in a cellular system a test is conducted.
- Test: Find the co channel interference area from a mobile receiver.
- While performing this test we watch for any change detected by a field strength recorder in mobile unit and compare the data with the condition of no co channel interference.
- This test must be repeated as the mobile unit travels in every co channel cell.
- To facilitate the test, we can install a channel scanning receiver in one car.

- One channel f1 records the signal level and another channel f2 records the interference level while the third channel f3 is used to record only the noise level.
- 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.
- We can also obtain the carrier to noise ratio C/N by subtracting the result obtained from f3 from the result obtained from f1.
- Four conditions should be used to compare the results:

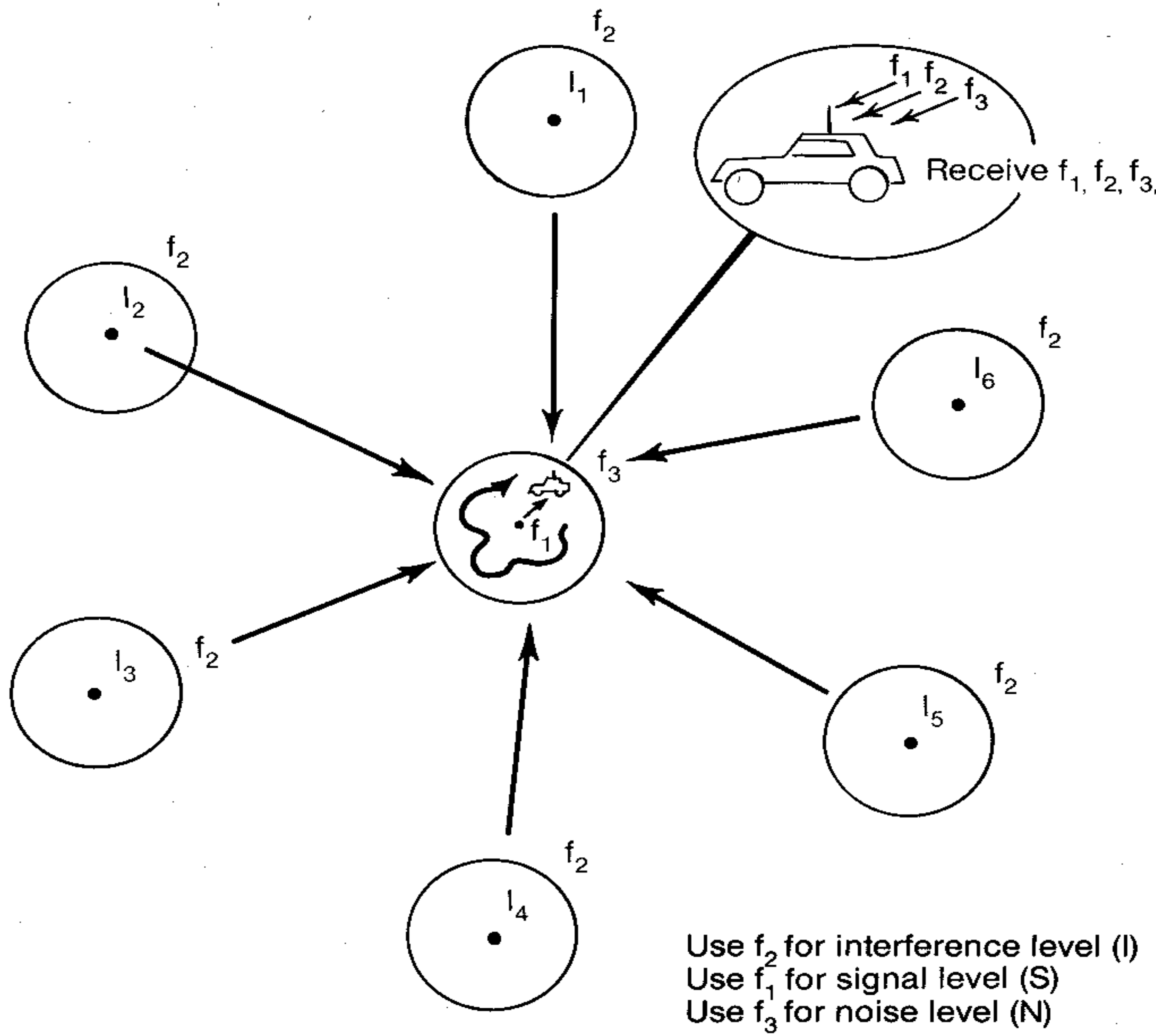
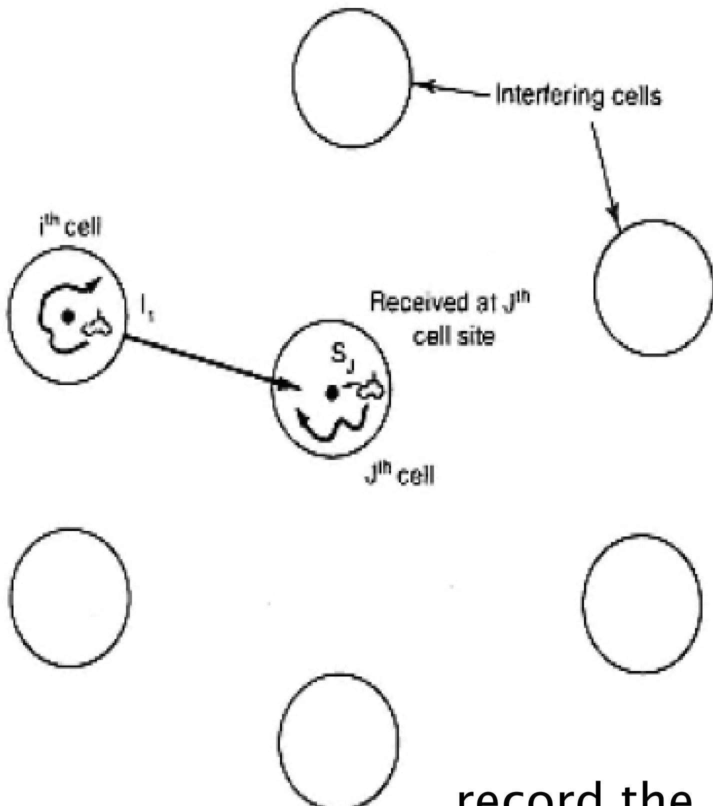


Figure 6.1 Test 1: cochannel interference at the mobile unit.

- 1. If the carrier- to- Interference ratio C/I is greater than 18 dB through out the cell, the system is properly designed.
- 2. If C/I is less than 18 dB and C/N is greater than 18 dB in some areas, there is no co channel interference.
- 3. If both C/I and C/N are less than 18dB and C/N=C/I in a given area there is a coverage problem.
- 4. If both C/I and C/N are less than 18dB and C/N>C/I in a given area there is a coverage problem and co channel interference.

Test 2
Find the Cochannel Interference Area Which Affects a Cell Site



$$\frac{C_J}{I} = \frac{C_J}{\sum_{\substack{i=1 \\ i \neq J}}^{6} I_i}$$

record the signal strength at every co channel cell site while a mobile unit is travelling either in its own cell or in one of the co channel cells show in fig.

REAL-TIME COCHANNEL INTERFERENCE MEASUREMENT AT MOBILE RADIOTRANSCEIVERS

- 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*

$$e_1 = S(t) \sin(\omega t + \phi_1)$$

- and the interference is

$$e_2 = I(t) \sin(\omega t + \phi_2)$$

REAL-TIME COCHANNEL INTERFERENCE MEASUREMENT AT MOBILE RADIOTRANSCEIVERS

- The received signal is

$$e(t) = e_1(t) + e_2(t) = R\ \sin(\omega t + \psi)$$

- Where

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

- And

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

The envelope *R can be simplified in Eq. and becomes*

$$R^2 = [S^2(t) + I^2(t) + 2S(t)I(t)\cos(\phi_1 - \phi_2)]$$

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

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

- the average processes on *X* and *Y* are

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

$$\overline{Y^2} = 4\overline{S^2(t)}\,\overline{I^2(t)}(1/2) = 2\overline{S^2(t)}\,\overline{I^2(t)} \qquad (6.3\text{-}10)$$

- The signal-to-interference ratio

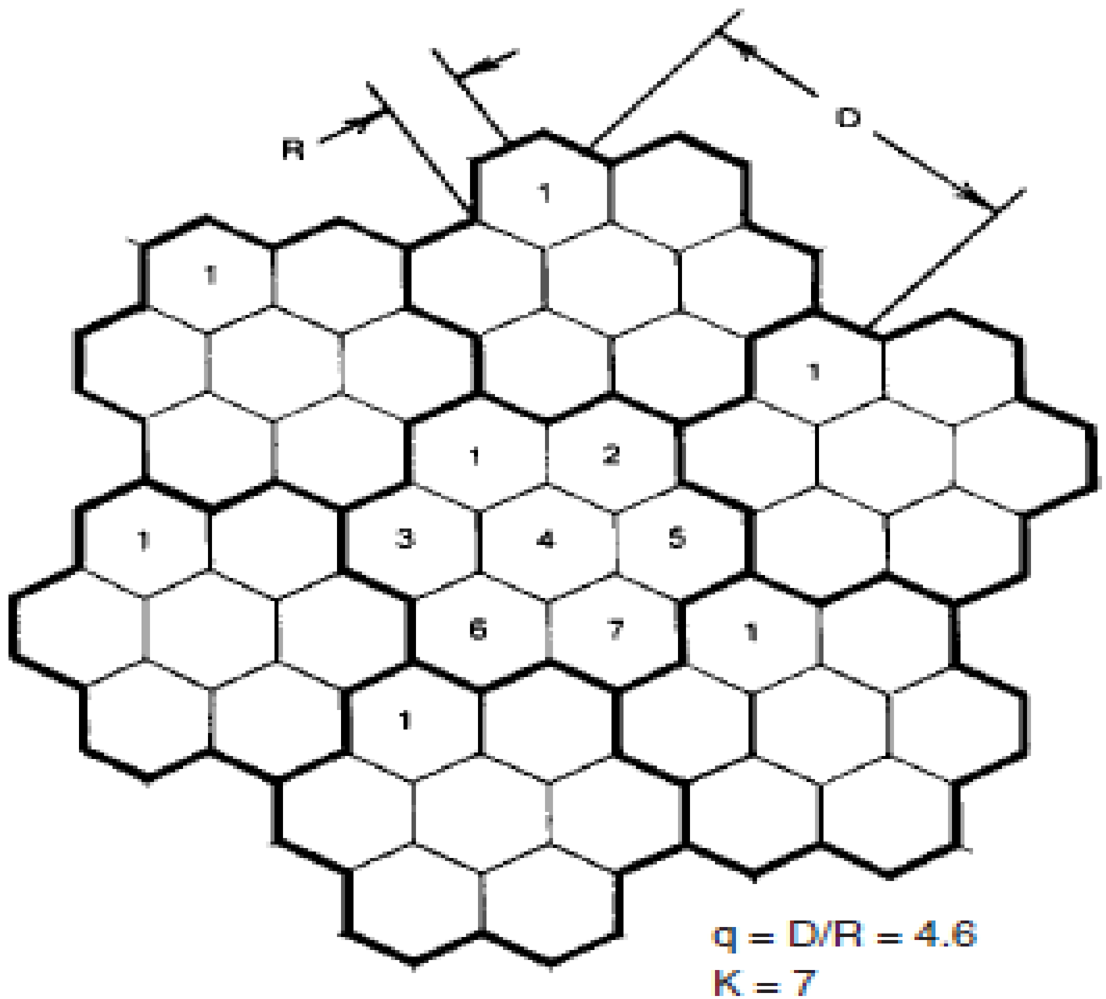
$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = k + \sqrt{k^2 - 1} \qquad (6.3\text{-}11)$$

where $$k = \frac{\overline{X}^2}{\overline{Y^2}} - 1$$

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.*
- The worst case is at the location where the mobile unit would receive the weakest signal from its own cell site but strong interferences from all interfering cell sites.
- a *$K = 7$ cell pattern does* not provide a sufficient frequency-reuse distance separation even when an ideal condition of flat terrain is assumed.

K = 7 cell pattern

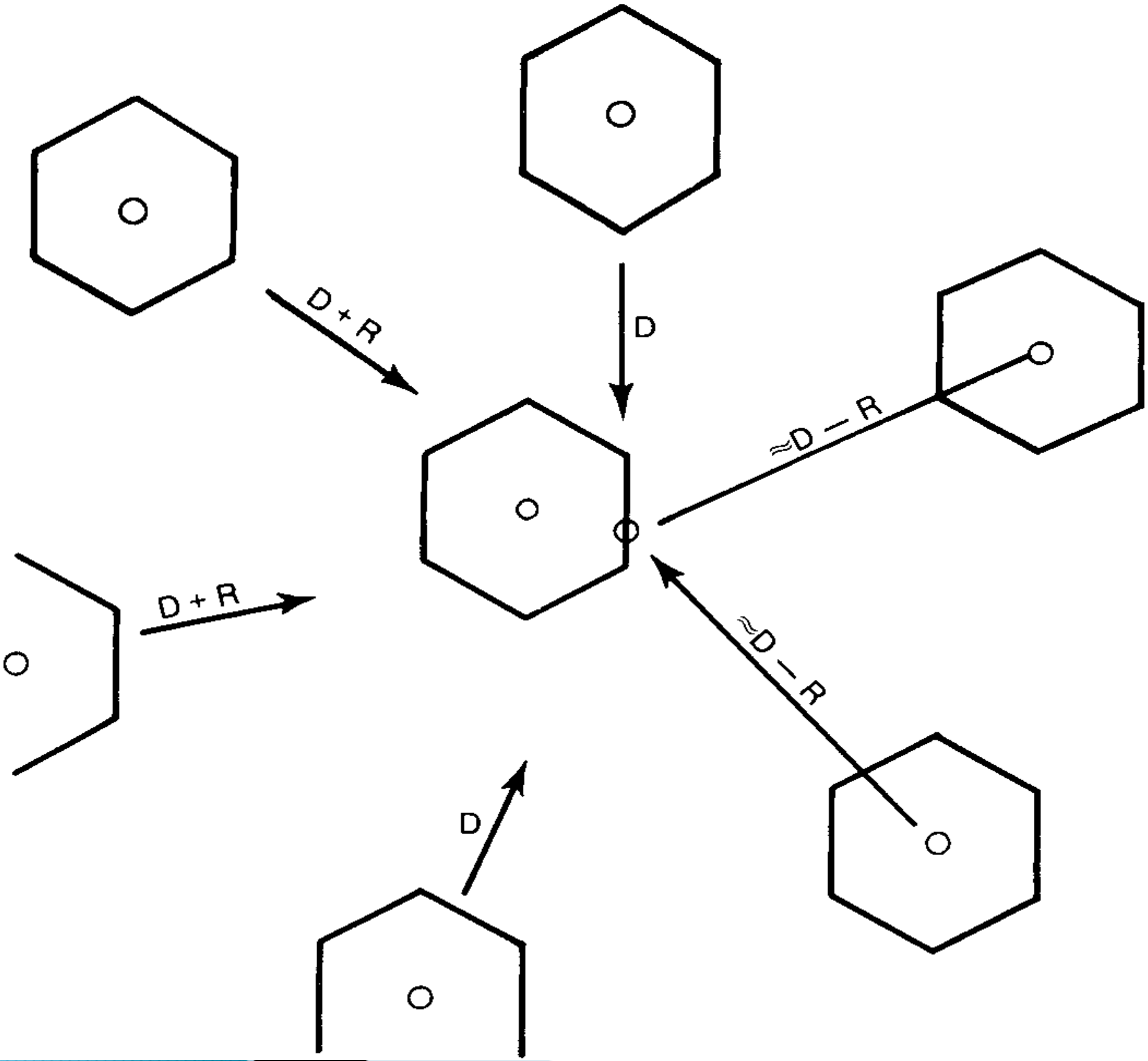


Carrier-to-Interference ratio

- In the worst case the mobile unit is at the cell boundary *R, as shown in Fig.*
- *The* distances from all six co channel 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

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

FIGURE .Co channel interference (a worst case).



Carrier-to-Interference ratio

- Then the carrier-to-interference ratio is

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

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

- where *q = 4.6 is derived from the normal case.*
- *Substituting q =4.6 into Eq.,*
- *we obtain C/I = 54 or 17 dB, which is lower than 18 dB.*

K = 9 and K = 12 cell patterns

- In that case, a co channel interference reduction factor of *q = 4.6 is insufficient.*
- Therefore, in an Omni directional-cell system, *K = 9 or K = 12 would be a correct* choice.

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

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

- The *K = 9 and K = 12 cell patterns, are shown in Fig.*

Carrier-to-Interference ratio

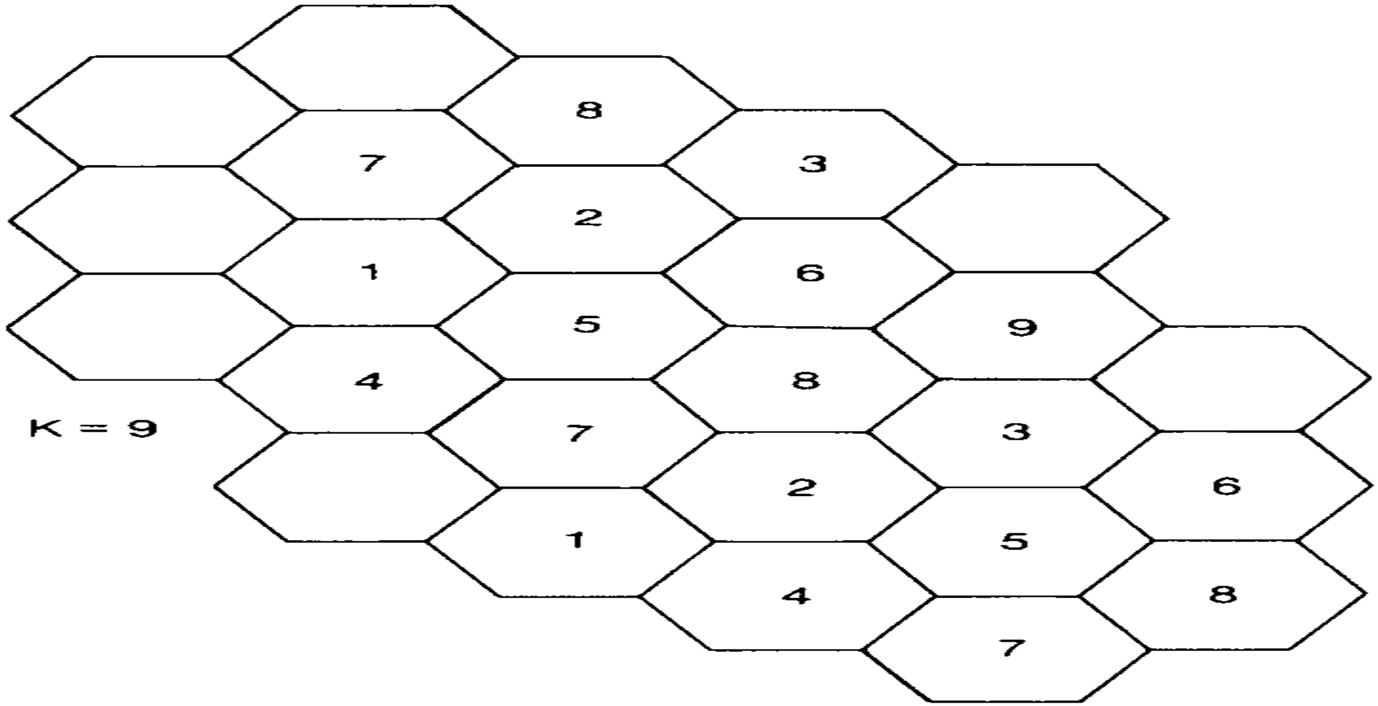
$$q = \begin{cases} \frac{D}{R} = \sqrt{3K} \\ 5.2 & K = 9 \\ 6 & K = 12 \end{cases}$$

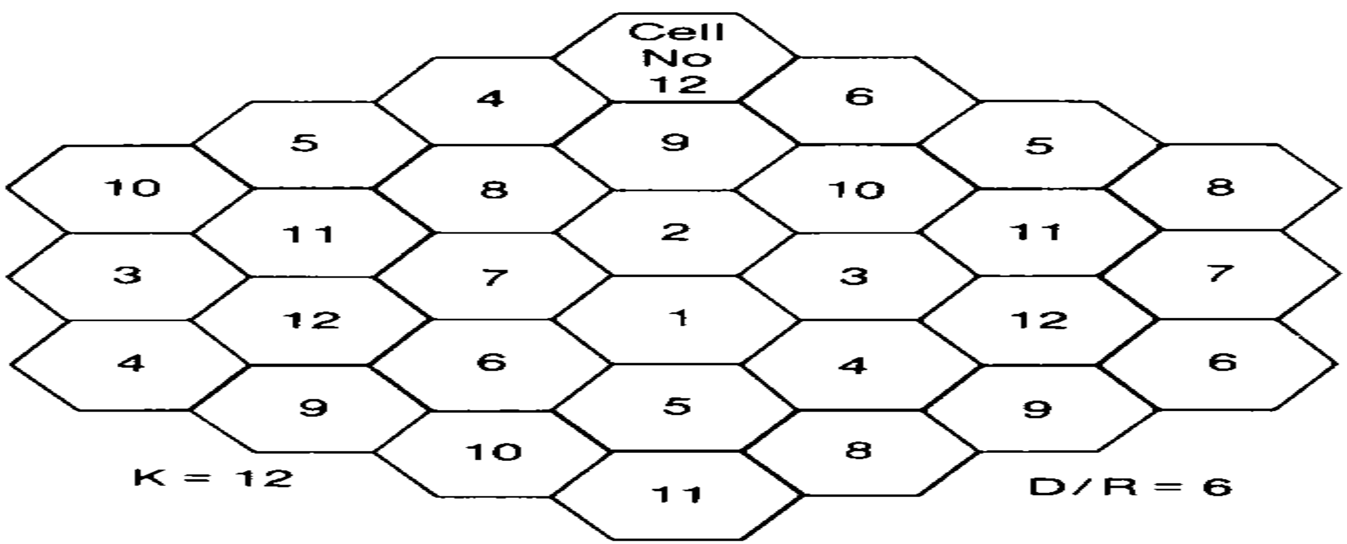
Substituting these values in Eq. (6.4-1), we obtain

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

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

frequency-reuse patterns *K = 9 and K = 12.*





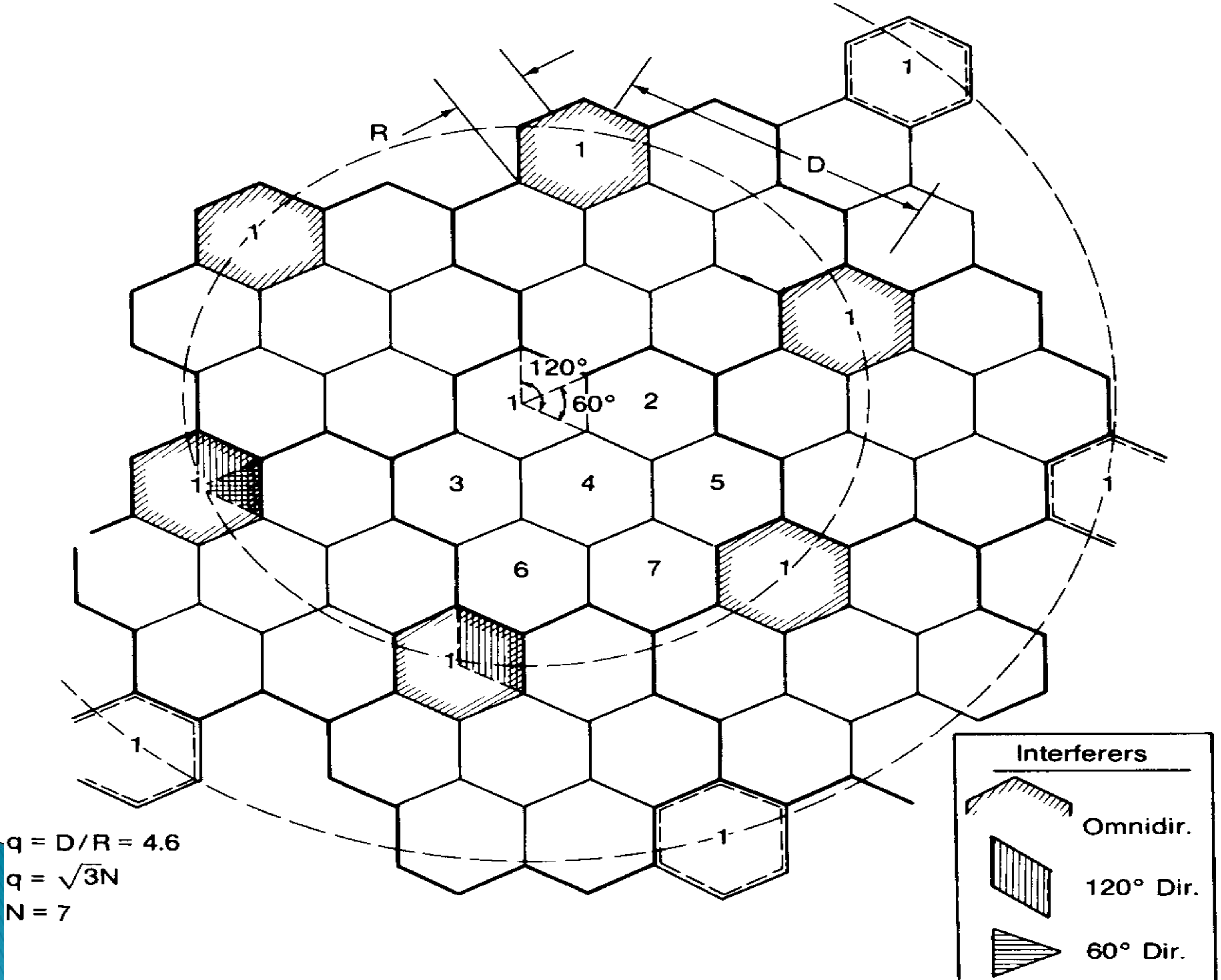
DESIGN OF A DIRECTIONAL ANTENNA SYSTEM

- 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 decreases.

DESIGN OF A DIRECTIONAL ANTENNA SYSTEM

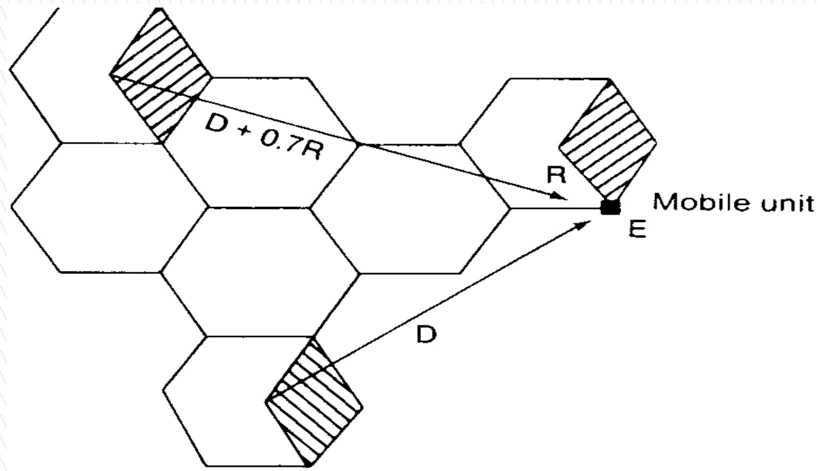
- Instead of increasing the number *K in a set of cells, let us keep K = 7 and introduce a* directional-antenna arrangement.
- The co channel interference can be reduced by using directional antennas.
- This means that each cell is divided into three or six sectors and uses three or six directional antennas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

FIGURE .Interfering cells shown in a seven-cell system (two-tiers).



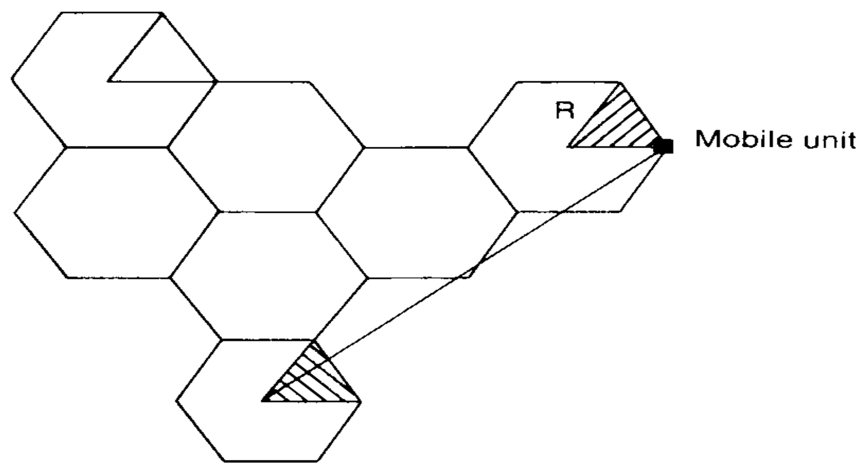
Determination of carrier-to-interference ratio *C/I in a* directional antenna system

- (a)Worst case in a 120∘ directional antenna system (N = 7);



(a)

- (b) worst case in a 60∘ directional antenna system(N = 7).



(b)

Directional Antennas In *K = 7 Cell Patterns*

- ***Three-Sector Case:*** *The three-sector case is shown in Fig.*
- *To illustrate the* worst-case situation, two co channel cells are shown in Fig. 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.

Directional Antennas In *K* = 7 *Cell Patterns*

- Because of the use of directional antennas, the number of principal interferers is reduced from six to two (Fig. 9.5).
- The worst case of ***C/I*** *occurs when the mobile unit is* at position *E*, *at which point the distance between the mobile unit and the two interfering* antennas is roughly $D + (R/2)$;
- *C/I can be calculated more precisely as follows.*

Directional Antennas In *K = 7 Cell Patterns*

- The value of *C/I can be obtained by the following expression (assuming that the worst case* is at **position** *E at which the distances from two interferers are D + 0.7 and D).*

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

$$= \frac{1}{(q+0.7)^{-4} + q^{-4}}$$

- Let *q = 4.6; then Eq. becomes*

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

- The *C/I received by a mobile unit from the 120◦ directional antenna sector system expressed* in Eq.
- $$\frac{C}{I}(\text{worst case}) = 285\ (=)\ 24.5\ \text{dB}$$
-

greatly exceeds 18 dB in a worst case.
- Equation shows that using directional antenna sectors can improve the signal-to-interference ratio, that is, reduce the co channel interference.
- However, in reality, the *C/I could be 6 dB weaker than in Eq.* 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. *b.*
- *In this case, only one instance of interference* can occur in each sector as shown in Fig. 9.5.
- Therefore, the carrier-to-interference ratio in this case is

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

- For *q = 4.6, Eq. becomes*

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

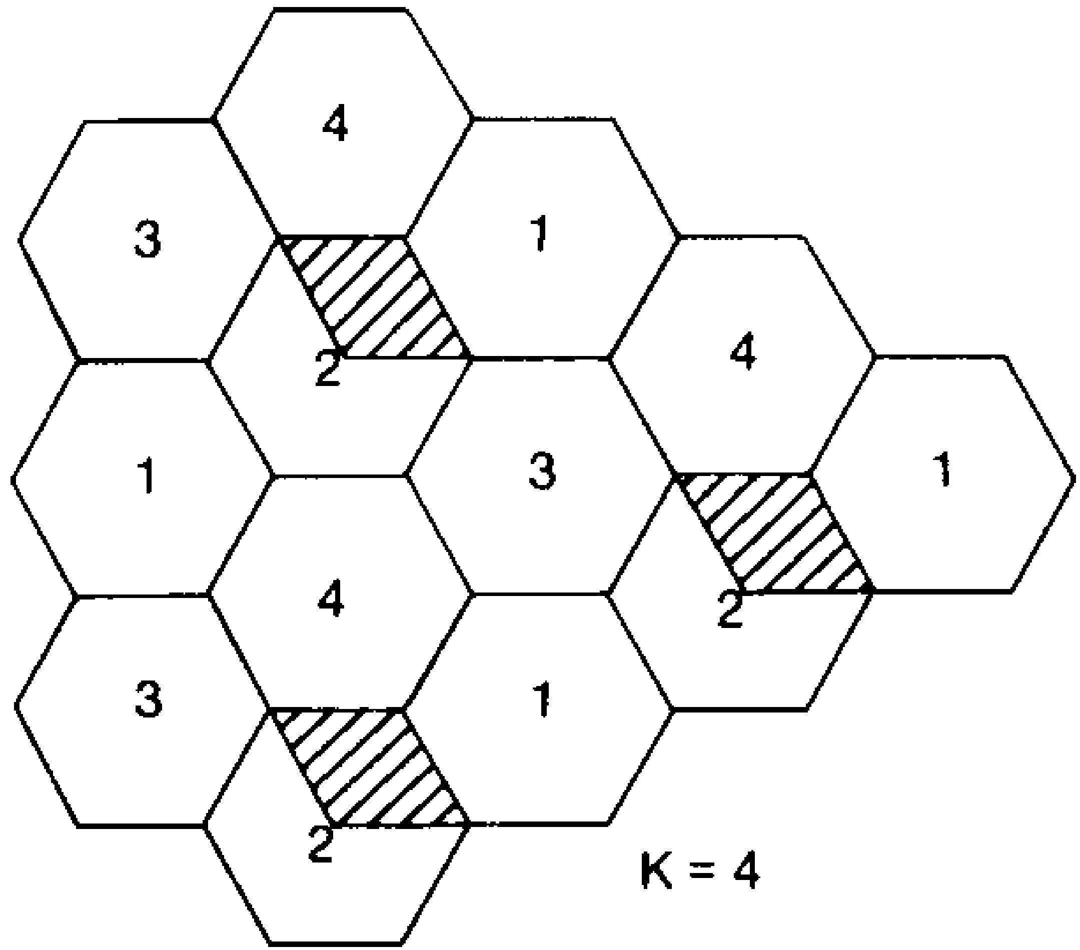
- which shows a further reduction of co channel interference.

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. 9.7.*
- *We can* apply Eq. $\frac{C}{I}(\text{worst case}) = \frac{R^{-4}}{(D+0.7R)^{-4} + D^{-4}}$ here.
- For *K = 4, the value of* $q = \sqrt{3K} = 3.46$ *;*
- *therefore, Eq.* becomes

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

FIGURE . Interference with frequency-reuse pattern *K = 4.*



Six-Sector Case.

- *There is only one interferer at a distance of $D + R$ shown in* Fig.
- 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 result of Eq., the remaining 20 dB is adequate.

2.Smaller Cells:

In case of k=4 then cells are placed very closer.
In case of smaller cells we use 3sector case i.e it is better.

Comparing K=7 and K=4 systems:

A K=7 cell-pattern system is a logical way to begin an omnicell system.

- The cochannel reuse distance is more or less adequate,according to the desired criterion.
- When the traffic increases,a three sector system should be implemented,that is, with three 120 degrees directional antennas in place.
- In certain hotspots, 60 degree 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 sector , but the k=4 system has a total of only 26 sectors and the system of k=7 and six sectors has less cochannel interference.

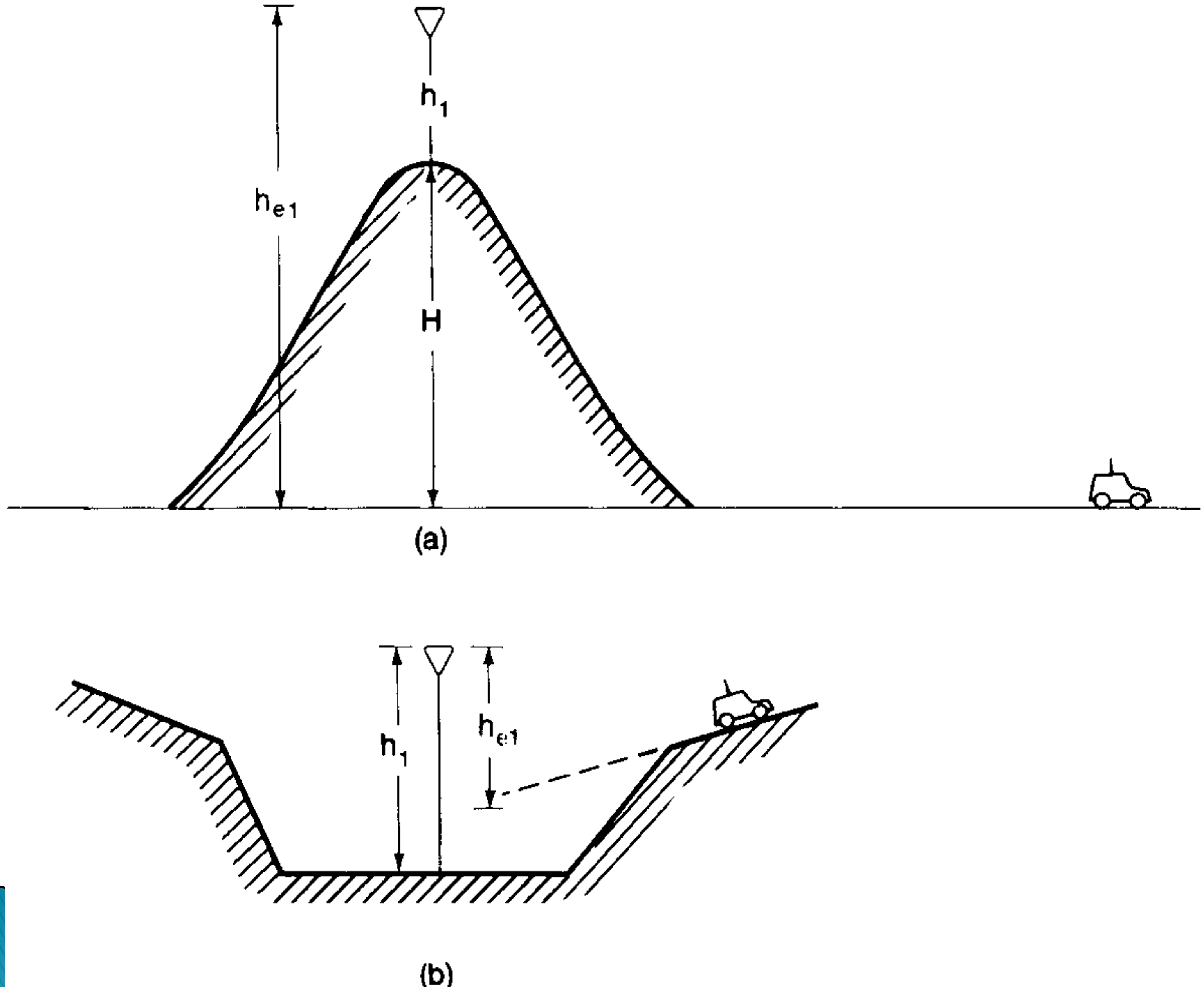
Antenna Parameters and their effects

- *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 co channel and adjacent-channel 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 hill, as shown in Fig. *a, the effective antenna height is* $h1 + H$.

FIGURE . Lowering the antenna height



On a High Hill or a High Spot

- If we reduce the actual antenna height to 0.5*h1, the effective antenna height becomes* 0*.5h1 + H.*
- *The reduction in gain resulting from the height reduction is*

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

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

On a High Hill or a High Spot

- If *h1 << H, then Eq. becomes*

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

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

In a Valley

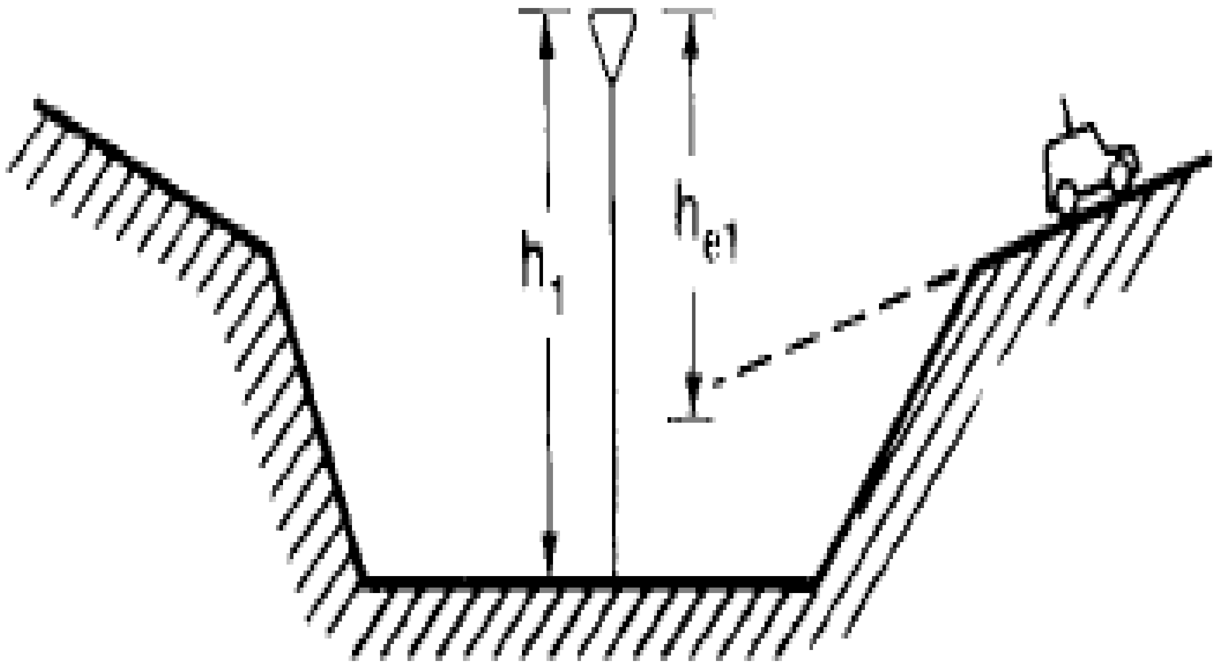
- The effective antenna height as seen from the mobile unit shown in Fig. *b is he1, which is* less than the actual antenna height *h1.*
- *If he1 = 2/3 h1 and the new antenna height is lowered* to ½ *h1, then the new effective antenna height, is*

$$h_{e1} = {}^1\!/_2 h_1 - (h_1 - {}^2\!/_3 h_1) = {}^1\!/_6 h_1$$

- Then the antenna gain is reduced by

$$G = 20 \log \frac{{}^1\!/_6 h_1}{{}^2\!/_3 h_1} = -12 \text{ dB}$$

In a Valley



(b)

In a Valley

- 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

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

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 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 level.

Non Co Channel Interference

Types of Non Co-channel Interference

ADJACENT-CHANNEL INTERFERENCE

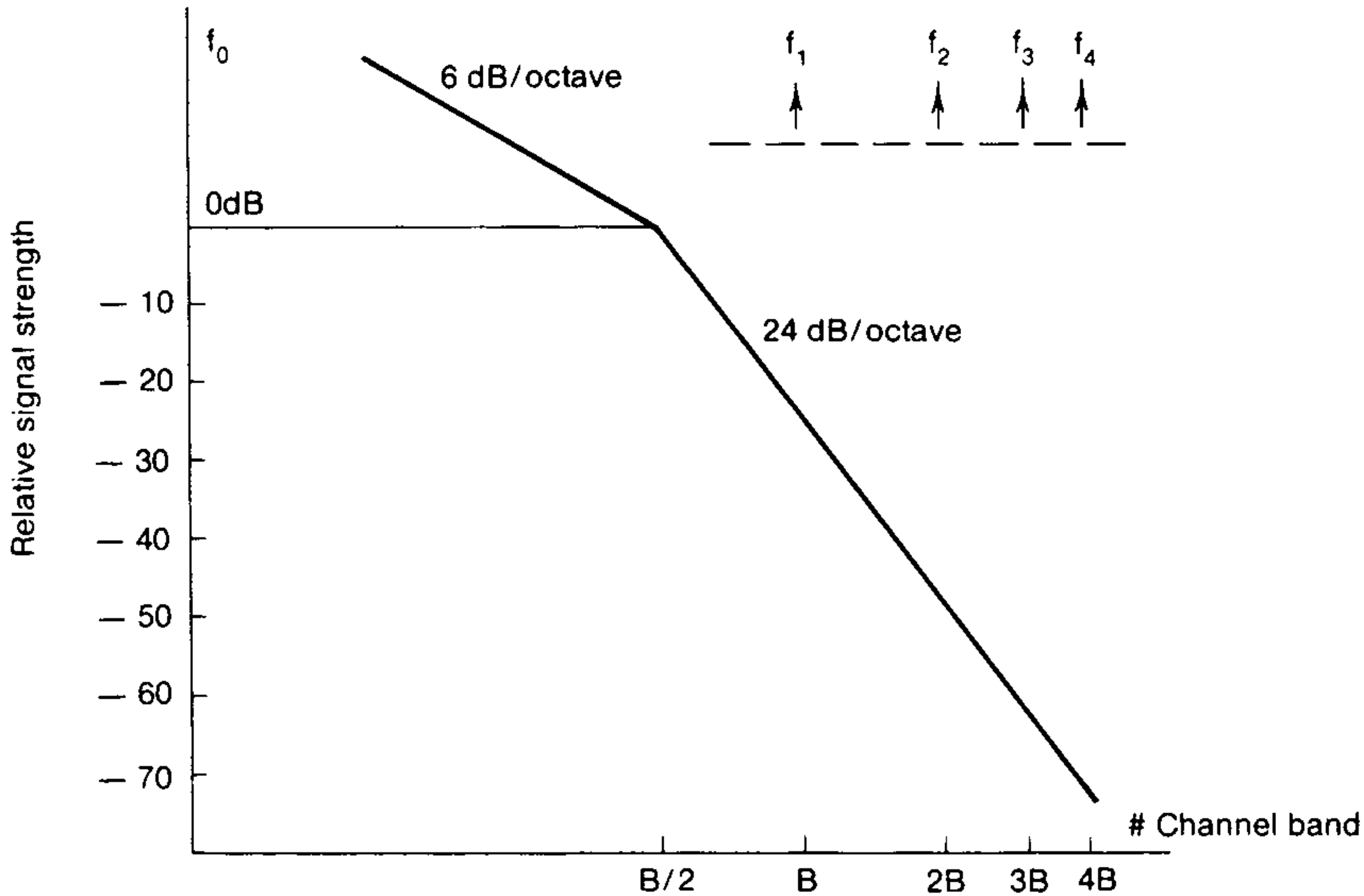
"Adjacent-channel interference"

- Interference from channels that are adjacent in frequency is called adjacent channel interference.
- The primary reason for that is Imperfect Receive Filters which cause the adjacent channel energy to leak into your spectrum
- "Adjacent-channel interference" is a broad term.
- It includes next-channel (the channel next to the operating channel) interference and neighboring-channel (more than one channel away from the operating channel) interference.
- Adjacent-channel interference can be reduced by the frequency assignment.

Next-Channel Interference

- Next-channel interference in an AMPS system affecting a particular mobile unit cannot be caused by transmitters in the common cell site but must originate at several other cell sites.
- This is because any channel combiner at the cell site must combine the selected channels, normally 21 channels (630 kHz) away, or at least 8 or 10 channels away from the desired one.
- Therefore, next-channel interference will arrive at the mobile unit from other cell sites if the system is not designed properly.

FIGURE . Characteristics of channel-band filter.



next-channel interference

- The methods for reducing this next-channel interference use the receiving end.
- The channel filter characteristics are a 6 dB/oct slope in the voice band and a 24 dB/oct falloff outside the voice-band region (see Fig.).
- If the next-channel signal is stronger than 24 dB, it will interfere with the desired signal.
- The filter with a sharp falloff slope can help to reduce all the adjacent-channel interference, including the next-channel interference.

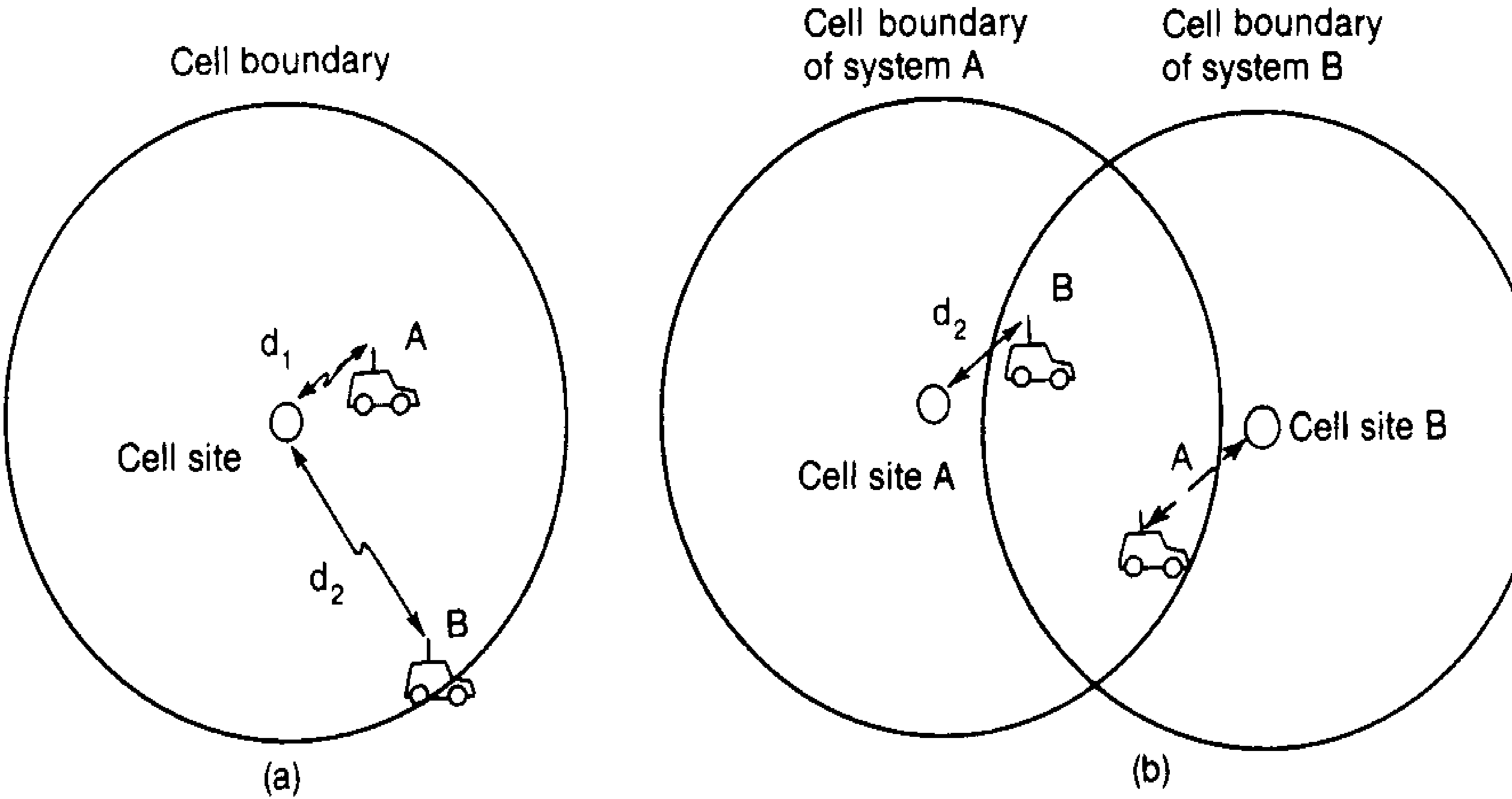
Neighboring-Channel Interference

- The channels that are several channels away from the next channel will cause interference with the desired signal.
- Usually, 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 multichannel combiner to reduce inter modulation products.
- Can be reduced if we use multiple antennas

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 that causes adjacent channel interference (see Fig. a*).*
- *In this situation, near-end-far-end interference can* occur only at the reception point in the cell site.
- If a separation of 5*B (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 5*B is required between each adjacent channel used with one cell.*

NEAR-END-FAR-END INTERFERENCE



NEAR-END-FAR-END INTERFERENCE

- **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 Fig *b.*
- *The other situation* would occur if mobile unit B were at the boundary of cell B of system B but very close to cell A of system A.

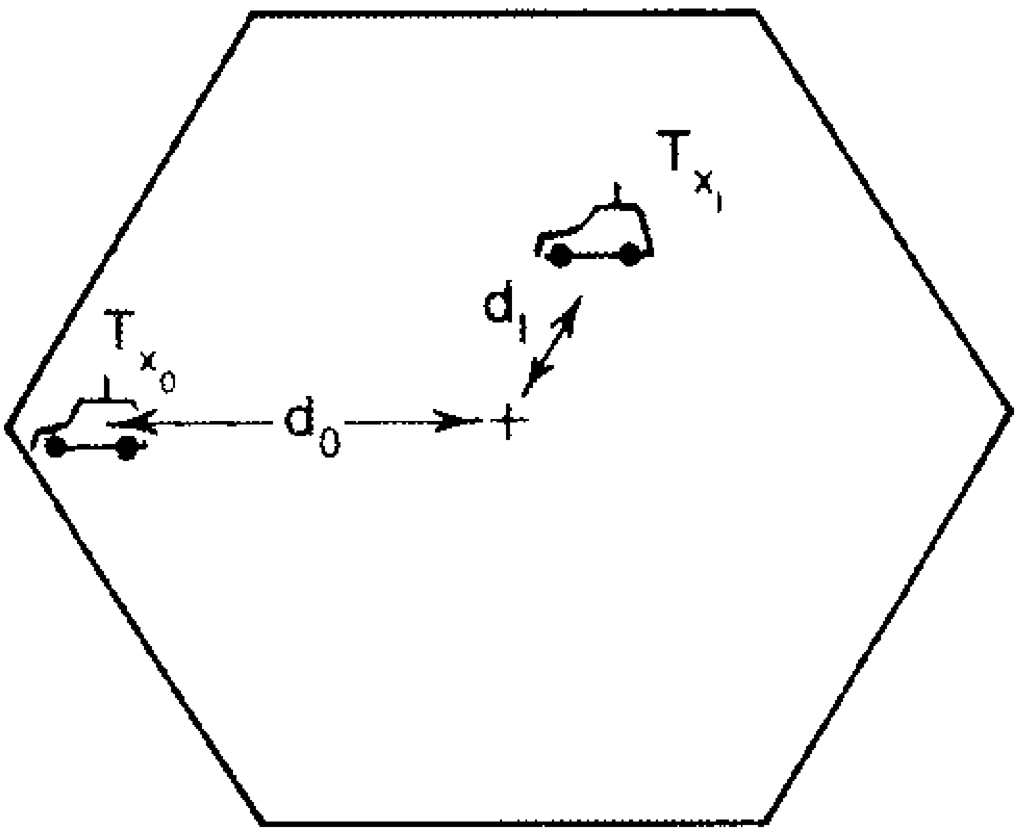
In Cells of Two Systems:

- Following the definition of near-end-far-end interference, the solid arrow indicates that interference may occur 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.

EFFECT ON NEAR-END MOBILE UNITS

- **Avoidance of Near-End-Far-End Interference:**
- The near-end mobile units are the mobile units that are located very close to the cell site.
- These mobile units transmit with the same power as the mobile units that are far away from the cell site.
- The situation described below is illustrated in Fig.
- The distance *d0 between a calling mobile transmitter and a base-station receiver is much larger than the* distance *dI between a mobile transmitter causing interference and the same base-station* receiver.

FIGURE.Near-end-far-end ratio interference.



d_0 = 10 miles

d_I = 0.25 miles

T_{x_0} = the desired signal

T_{x_I} = the interferred signal