Apprise Education, Reprise Innovations

### 8.10.1 Effects of Cell-Site Antenna Heights

There are several points that need to be clarified concerning cell-site antenna-height effects.

***8.10.1.1 Antenna Height Unchanged.*** If the power of the cell-site transmitter changes, the whole signal-strength map (obtained from Sec. 8.9) can be linearly updated according to the change in power.

If the transmitted power increases by 3 dB, just add 3 dB to each grid in the signal-strength map. The relative differences in power among the grids remain the same.

***8.10.1.2 Antenna Height Changed.*** If the antenna height changes ($\pm\Delta h$), then the whole signal-strength map obtained from the old antenna height cannot be updated with a simple antenna gain formula as

$$\Delta g = 20 \log \frac{h_1'}{h_1} \tag{8.10-1}$$

where $h_1$ is the old actual antenna height and $h_1'$ is the new actual antenna height. However, we can still use the same terrain contour data along the radio paths (from the cell-site antenna to each grid) to figure out the difference in gain resulting from the different effective antenna heights in each grid.

$$\Delta g' = 20 \log \frac{h_e'}{h_e} = 20 \log \frac{h_e \pm \Delta h}{h_e} \tag{8.10-2}$$

where $h_e$ is the old effective antenna height and $h'_e$ is the new effective antenna height. The additional gain (increase or decrease) will be added to the signal-strength grid based on the old antenna height.

**EXAMPLE 8.12** *If the old cell-site antenna height is 30 m (100 ft) and the new one $h'_1$, is 45 m, the mobile unit 8 km (5 mi) away sees the old cell-site effective antenna height ($h_e$) being 60 m. The new cell-site effective antenna height $h'_e$ seen from the same mobile spot can be derived.*

$$h'_e = h_e + (h'_1 - h_1) = h_e + (h'_e - h_e) = h_e + \Delta h = 60 + (45 - 30) = 75 \text{ m}$$

*Since the difference between two actual antenna heights is the same as the difference between the two corresponding effective antenna heights seen from each grid, the additional gain (or loss) based on the new change of actual antenna height is*

$$\Delta g' = 20 \log \frac{h'_e}{h_e} = 20 \log \left(1 + \frac{h'_1 - h_1}{h_e}\right) \qquad \text{(E8.12-1)}$$

***8.10.1.3 Location of the Antenna Changed.*** If the location of the antenna changes, the point-to-point program has to start all over again. The old point-to-point terrain contour data are no longer useful. The old effective antenna height seen from a distance will be different when the location of the antenna changes, and there is no relation between the old effective antenna height and the new effective antenna height. Therefore, every time the antenna location changes, the new point-to-point prediction calculation starts again.

***8.10.1.4 Visualization of the Effective Antenna Height.*** The effective antenna height changes when the location of the mobile unit changes. Therefore, we can visualize the effective antenna height as always changing up or down while the mobile unit is moving. This kind of picture should be kept in mind. In addition, the following facts would be helpful.

> *Case 1: The mobile unit is driven up a positive slope (up to a high spot).* The effective antenna height increases if the mobile unit is driving away from the cell-site antenna, and it decreases if the mobile unit is approaching the cell-site antenna. (See Fig. 8.25*a*.)
>
> *Case 2: The mobile unit is driven down a hill.* The effective antenna height decreases if the mobile unit is driving away from the cell-site antenna, and it increases if the mobile unit is approaching the cell-site antenna. (See Fig. 8.25*a*.)

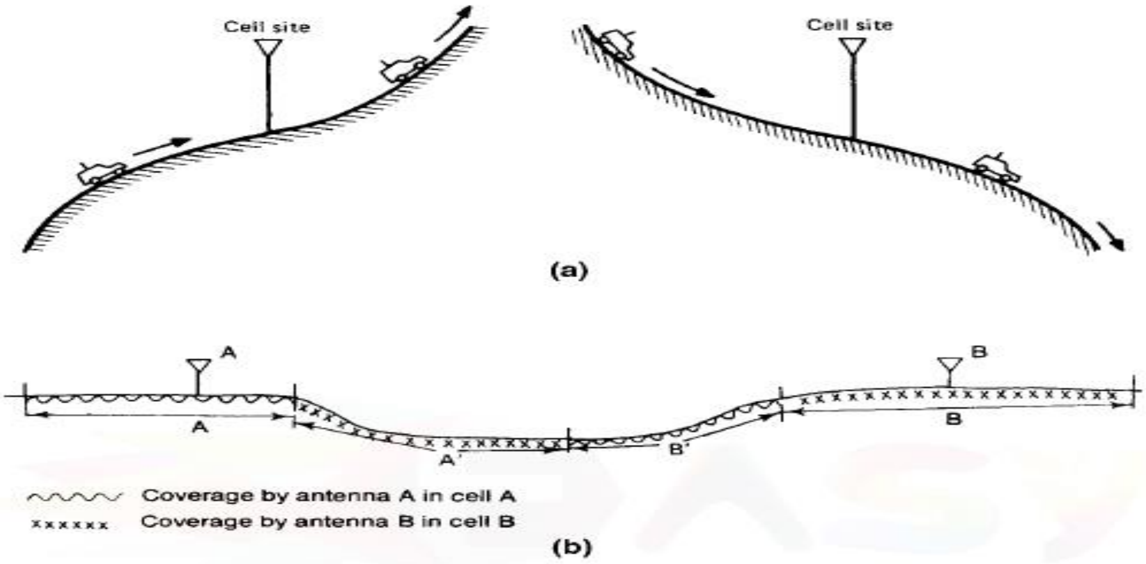
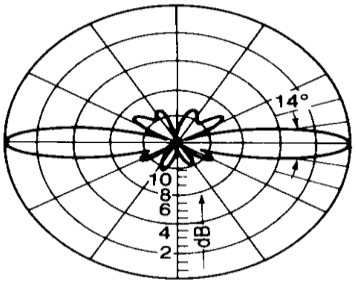


**FIGURE 8.25** Different coverage concept. (*a*) Signal coverage due to effective antenna heights. (*b*) Signal coverage served by two cell sites.

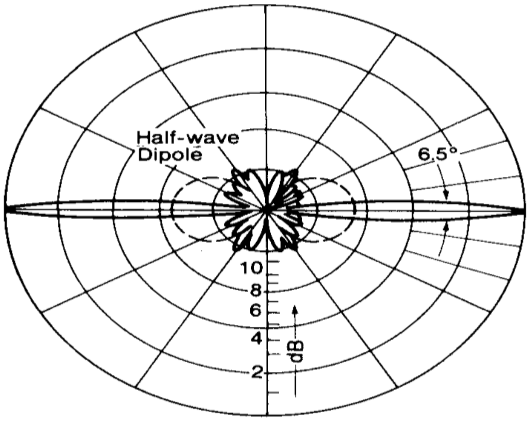
ANTENNAS AT CELL SITE:

High gain antennas:

There are standard 6db and 9 db gain Omni directional antennas. The antenna patterns for 6 db gain and 9 db gain are shown in figure.



Vertical
(a)

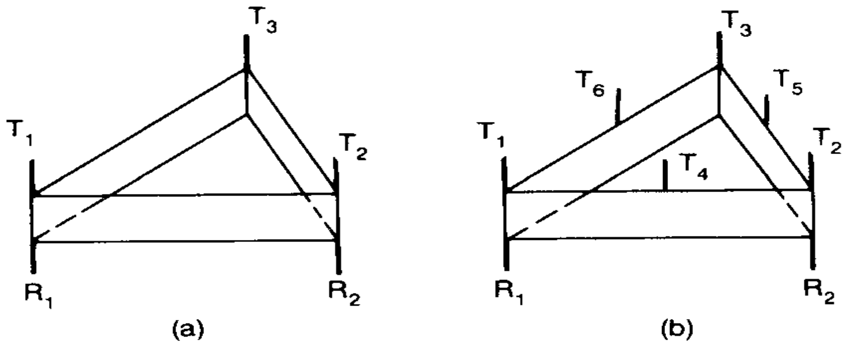


Vertical
(b)

**Start up system configuration**: In this omnicell consisting of omnidirectional transmitting antennas are used. Each antenna can transmit signals from 16 radio transmitters have three transmitting antennas which serve 45 voice radio transmitters simultaneously. Each sending signal is amplified by its own channel amplifier in each radio transmitter, then 16 channels pass through a 16 channel combiner and transmit signals means of a transmitting antenna.

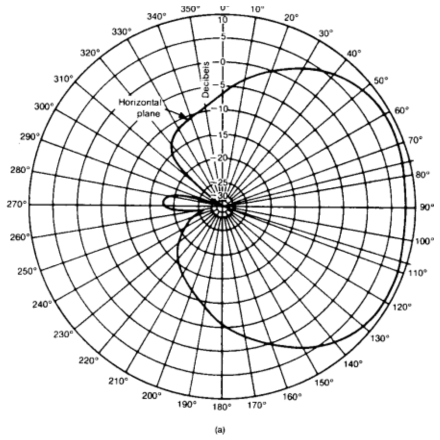
Two receiving antennas are commonly can receive all 45 voice radio signals simultaneously. Then in each channel, tow identical signals received by two receiving antennas pass through a diversity receiver of that channel. The receiving antenna configuration on the antenna must is shown in figure.

**Abnormal antenna configuration**: Usually, the call traffic in each cell increases as the number of customers increases. Some cells require a greater number of radios to handle the increasing traffic. An omnicell site can be equipped with up to 90 voice radios. In such cases six transmitting antennas should be used as shown in figure . In meantime, receiving antennas is still two. In order to reduce the number of transmitting antennas, a hybrid ring combiner to combine two 16 channels is found.



Cell site antennas for omnicells (a) for 45 channels (b) for 90 channels

**For interference reduction use – directional antennas**: when the frequency reuse scheme must be used, cochannel interference will occur. The co channel interference reduction factor q = d/r = 4.6 is based on the assumption that the terrain is flat. A 120 corner reflector or 120 place reflector can be used in a 120 sector cell. A 60 corner reflector can be used in a 60 sector cell. A typical pattern for a directional antenna of 120 is shown in the figure.



Azimuthal pattern of 8 db directional antenna.

**Location antennas**: In each cell site a location receiver connects to the respective location antenna. This antenna can be either omnidirection or shared directional . The location receiver can tune a channel to one of 333 channels either upon demand or periodically.

**Setup channel antennas**: It is used to page a called mobile unit or to access a call from a mobile unit. It transmits only data. The setup channel antenna can be an omnidirectional antenna or consist of several directional antennas at one cell site. In general, in both omnicell and sector-cell systems, one omnidirectional antenna is used for transmitting signals and another for receiving signals in each cell site.

## SPACES-DIVERSITY ANTENNAS

Two-branch space-diversity antennas are used at the cell site to receive the same signal with different fading envelopes, one at each antenna. The degree of correlation between two fading envelopes is determined by the degree of separation between two receiving antennas. When the two fading envelopes are combined, the degree of fading is reduced. Here the antenna setup is shown in Fig. 5a.

Equation is presented as an example for the designer to use.

$\eta = h/D = 11$ (8.13-1)

Where h is the antenna height and D is the antenna separation. From Eq., the separation $d \geq 8\lambda$ is needed for an antenna height of 100 ft (30 m) and the separation $d \geq 14\lambda$ is needed for an antenna height of 150 ft (50 m). In any Omni cell system, the two space-diversity antennas should be aligned with the terrain, which should have a U shape as shown in Fig.5b. Space-diversity antennas can separate only horizontally, not vertically; thus, there is no advantage in using a vertical separation in the design.

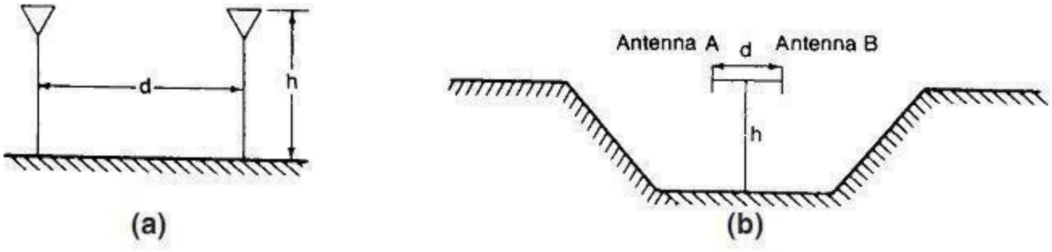


Fig.6.10.Diversity antenna spacing at cell site: (a) n=h/d (b) Proper arrangement with two antennas

## UMBRELLAS-PATTERN ANTENNAS

In certain situations, umbrella-pattern antennas should be used for the cell-site antennas.

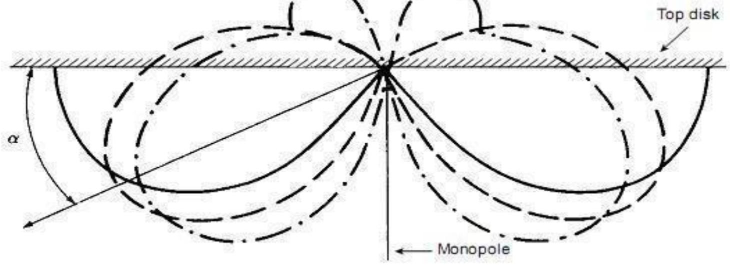


Fig. Vertical-plane patterns of quarter-wavelength stub antenna on infinite ground plane (solid) and on finite ground planes several wavelengths in diameter (dashed line) and about one wavelength in diameter (dotted line).

**i) NORMAL UMBRELLA-PATTERN ANTENNA:**

For controlling the energy in a confined area, the umbrella-pattern antenna can be developed by using a monopole with a top disk (top-loading) as shown in Fig. The size of the disk determines the tilting angle of the pattern. The smaller the disk, the larger the tilting angle of the umbrella pattern.

**ii) BROADBAND UMBRELLA-PATTERN ANTENNA:**

The parameters of a Discone antenna (a bio conical antenna in which one of the cones is extended to 180◦ to form a disk) are shown in Fig. The diameter of the disk, the length of the cone, and the opening of the cone can be adjusted to create an umbrella-pattern antenna.

**iii) INTERFERENCE REDUCTION ANTENNA:**

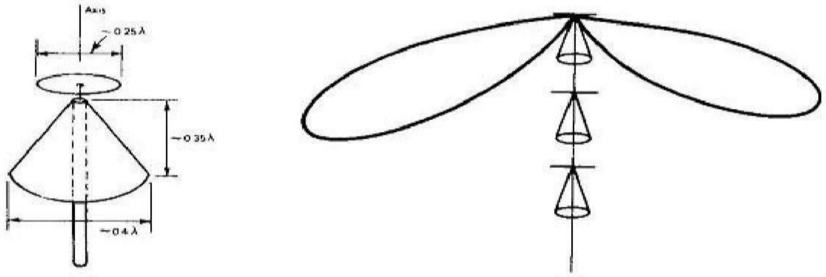
A design for an antenna configuration that reduces interference in two critical directions (areas) is shown in Fig.6.3. The parasitic (insulation) element is about 1.05 times longer than the active element.

**iv) HIGH-GAIN BROADBAND UMBRELLA-PATTERN ANTENNA**:

A high-gain antenna can be constructed by vertically stacking a number of umbrella-pattern antennas as shown in Fig.

$$E_0 = \frac{\sin[(Nd/2\lambda)\cos\phi]}{\sin[(d/2\lambda)\cos\phi]} \cdot \text{(individual umbrella pattern)}$$

where $\phi$ = direction of wave travel
$N$ = number of elements
$d$ = spacing between two adjacent elements



(a) (b)

Fig. Discone antennas (a) Single antenna; (b) An array of antenna

## MINIMUM SEPARATION OF CELL-SITE RECEIVING ANTENNAS

Separation between two transmitting antennas should be minimized to avoid the inter modulation. The minimum separation between a transmitting antenna and a receiving antenna is necessary to avoid receiver desensitization. Here we are describing a minimum separation between two receiving antennas to reduce the antenna pattern ripple effects. The two receiving antennas are used for a space-diversity receiver.

Because of the near field disturbance due to the close spacing, ripples will form in the antenna patterns (Fig.). The difference in power reception between two antennas at different angles of arrival is shown in Fig. . If the antennas are located closer; the difference in power between two antennas at a given pointing angle increases. Although the power difference is confined to a small sector, it affects a large section of the street as shown in Fig. .

If the power difference is excessive, use of space diversity will have no effect reducing fading. At 850 MHz, the separation of eight wavelengths between two receiving antennas creates a power difference of ±2 dB, which is tolerable for the advantageous use of a diversity scheme.

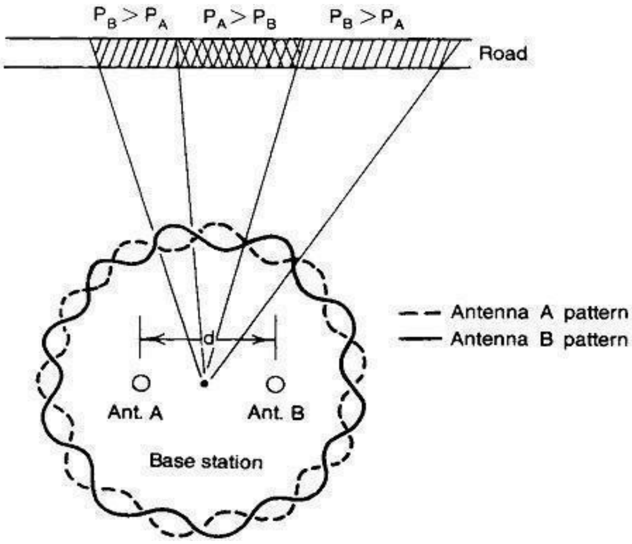


*Fig. Antenna pattern ripple effect*

## MOBILE ANTENNAS

The requirement of a mobile (motor-vehicle–mounted) antenna is an Omni-directional antenna that can be located as high as possible from the point of reception. However, the physical limitation of antenna height on the vehicle restricts this requirement. Generally, the antenna should at least clear the top of the vehicle. Patterns for two types of mobile antenna are shown in Fig.

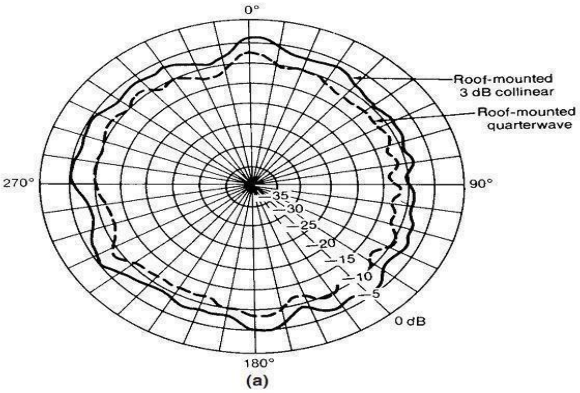


**Fig. Mobile antenna patterns (a) Roof mounted 3-dB-gain collinear antenna versus roof-mounted quarter-wave antenna, (b) Window-mourned "on-glass" gain antenna versus roof-mounted quarter-wave antenna.**

**ROOF-MOUNTED ANTENNA:**

The antenna pattern of a roof-mounted antenna is more or less uniformly distributed around the mobile unit when measured at an antenna range in free space as shown in Fig.9.2. The 3-dBhigh-gain antenna shows a 3-dBgain over the quarter-wave antenna. However, the gain of the antenna used at the mobile unit must be limited to 3 dB because the cell-site antenna is rarely as high as the broadcasting antenna and out-of-sight conditions often prevail. The mobile antenna with a gain of more than 3 dB can receive only a limited portion of the total multipath signal in the elevation as measured under the out-of-sight condition.

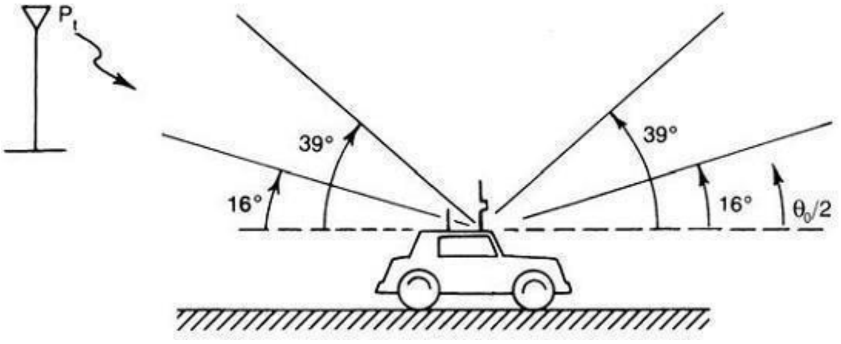


**Fig. Vertical angle of signal arrival**

**GLASS-MOUNTED ANTENNAS:**

There are many kinds of glass-mounted antennas. Energy is coupled through the glass; therefore, there is no need to drill a hole. However, some energy is dissipated on passage through the glass. The antenna gain range is 1 to 3 dB depending on the operating frequency. The position of the glass-mounted antenna is always lower than that of the roof-mounted antenna; generally there is a 3-dBdifference between these two types of antenna. Also, glass mounted antennas cannot be installed on the shaded glass found in some motor vehicles because this type of glass has a high metal content.

**MOBILE HIGH-GAIN ANTENNAS:**

A high-gain antenna used on a mobile unit has been studied. This type of high-gain antenna should be distinguished from the directional antenna. In the directional antenna, the antenna beam pattern is suppressed horizontally; in the high-gain antenna, the pattern is suppressed vertically.

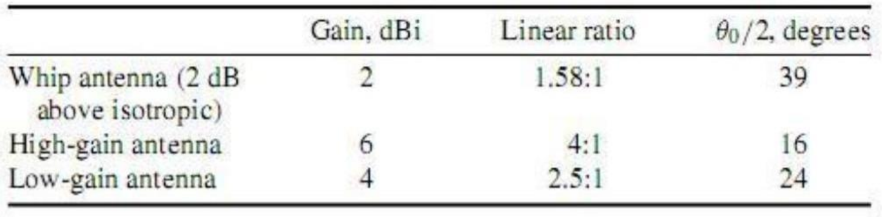
To apply either a directional antenna or a high-gain antenna for reception in a radio environment, we must know the origin of the signal. If we point the directional antenna opposite to the transmitter site, we would in theory receive nothing. In a mobile radio environment, the scattered signals arrive at the mobile unit from every direction with equal probability. That is why an Omni directional antenna must be used.

The scattered signals also arrive from different elevation angles. Lee and Brandt used two types of antenna, one $\lambda/4$ whip antenna with elevation coverage of 39◦ and one 4-dB-gain antenna (4-dB gain with respect to the gain of a dipole) with elevation coverage of 16◦ and measured the angle of signal arrival in the suburban Keyport-Matawan area of New Jersey. There are two types of test: a line-of-sight condition and an out-of-sight condition. In Lee and Brandt’s study, the transmitter was located at an elevation of approximately 100 m (300 ft) above sea level.

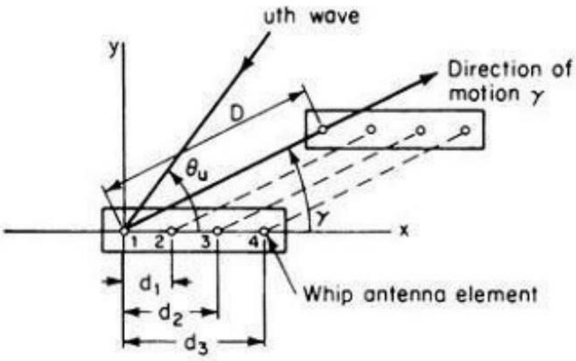
The measured areas were about 12 m (40 ft) above sea level and the path length about 3 mi. The received signal from the 4-dB-gain antenna was 4 dB stronger than that from the whip antenna under line-of-sight conditions. This is what we would expect.

However, the received signal from the 4-dB-gain antenna was only about 2 dB stronger than that from the whip antenna under out-of-sight conditions. This is surprising. The reason for the latter observation is that the scattered signals arriving under out-of- sight conditions are spread over a wide elevation angle. A large portion of the signals outside the elevation angle of 16◦ cannot be received by the high-gain antenna. We may calculate the portion being received by the high-gain antenna from the measured beam width. For instance, suppose that a 4:1 gain (6 dBi) is expected from the high-gain antenna, but only 2.5:1 is received. Therefore, 63 percent of the signal is received by the 4-dB-gain antenna (i.e., 6 dBi) and 37 percent is felt in the region between 16 and 39◦

Therefore, a 2- to 3-dB-gain antenna (4 to 5 dBi) should be adequate for general use. An antenna gain higher than 2 to 3 dB does not serve the purpose of enhancing reception level. Moreover, measurements reveal that the elevation angle for scattered signals received in urban areas is greater than that in suburban areas.



| | Gain, dBi | Linear ratio | $\theta_0/2$, degrees |
|---|---|---|---|
| Whip antenna (2 dB above isotropic) | 2 | 1.58:1 | 39 |
| High-gain antenna | 6 | 4:1 | 16 |
| Low-gain antenna | 4 | 2.5:1 | 24 |



**Minimum separation between cell site receiving antennas:**

- The minimum separation between a transmitting antenna and a receiving antenna necessary to avoid receiver desensitization.
- Here we are describing a minimum separation between two receiving antennas to reduce the antenna pattern ripple effects.
- The two receiving antennas are used for a space-diversity receiver.
- Because of the near field disturbance due to the close spacing, ripples will form in the antenna patterns as shown in below fig4.
- The difference in power reception between two antennas at different angles of arrival is shown in Fig 4.

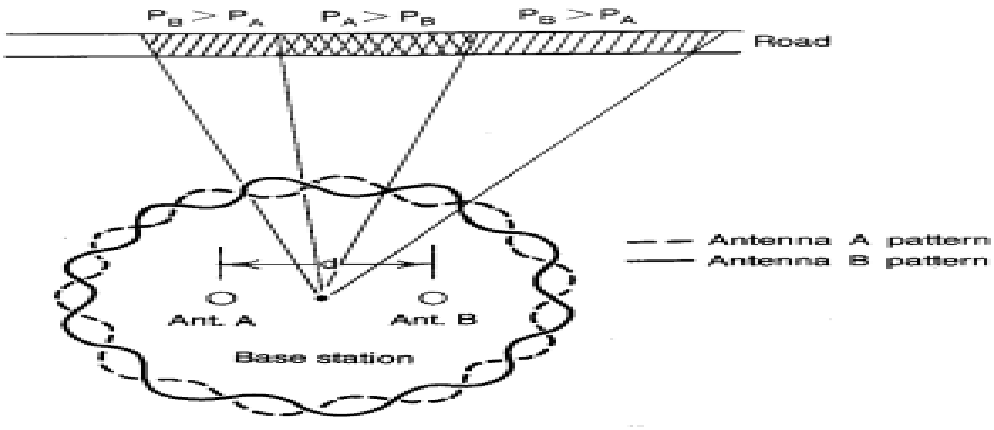


Fig 4:Cell site receiving antenna pattern ripple effect

- If the antennas are located closer, the difference in received power between two antennas at a given pointing angle increases.
- If the power difference is excessive, use of a space diversity will have no effect reducing fading.
- At 850 MHz, the separation of eight wavelengths between two receiving antennas creates a power difference of ±2 dB, which is tolerable for the advantageous use of a diversity scheme.

## Concept of Sum and Difference patterns:

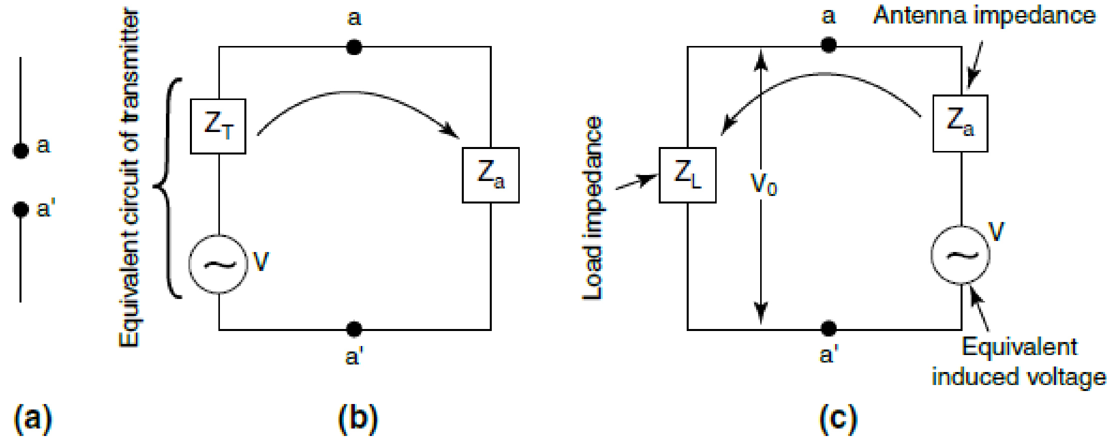


**FIGURE D.1** An actual antenna and its equivalent circuit. (*a*) An actual antenna; (*b*) equivalent circuit of a transmitting antenna; (*c*) equivalent circuit of a receiving antenna.

In the circuit,

$Z_T$ → Transmitter impedance.
$Z_A$ → Antenna impedance
V → Voltage
A, A' → Antenna.

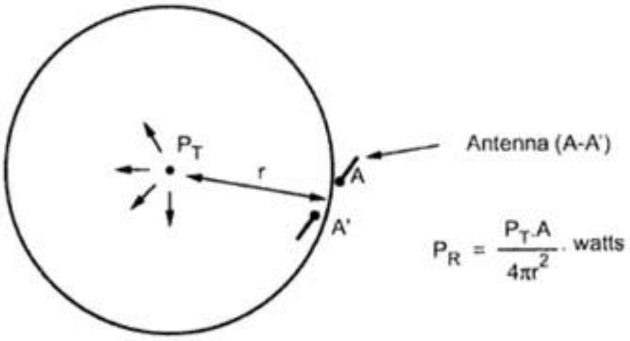


**Fig. 5.2 Example of power received in space**

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

The power received at receiving antenna is $P_R$ Watts measured as above.

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

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

The gain G is unity for a short dipole.

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

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

Now substituting the value of antenna aperture in the equation of received power '$P_R$', we get

$$P_R = eA$$

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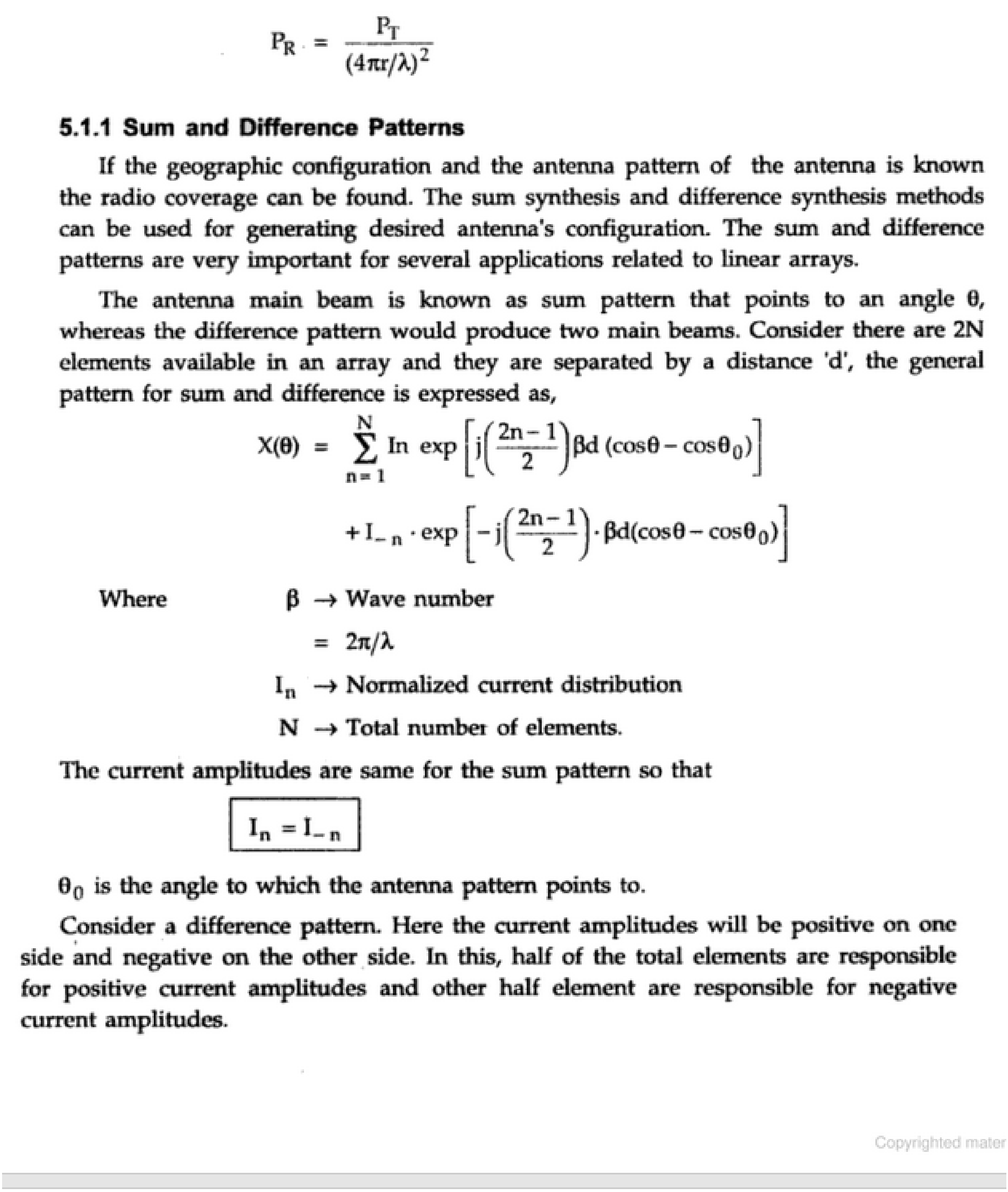
$$= \frac{P_T\ A}{4\pi r^2}$$

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

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



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

### 5.1.1 Sum and Difference Patterns

If the geographic configuration and the antenna pattern of the antenna is known the radio coverage can be found. The sum synthesis and difference synthesis methods can be used for generating desired antenna's configuration. The sum and difference patterns are very important for several applications related to linear arrays.

The antenna main beam is known as sum pattern that points to an angle θ, whereas the difference pattern would produce two main beams. Consider there are 2N elements available in an array and they are separated by a distance 'd', the general pattern for sum and difference is expressed as,

$$X(\theta) = \sum_{n=1}^{N} \text{In} \exp\left[j\left(\frac{2n-1}{2}\right)\beta d\,(\cos\theta - \cos\theta_0)\right]$$

$$+ I_{-n}\cdot\exp\left[-j\left(\frac{2n-1}{2}\right)\cdot\beta d(\cos\theta - \cos\theta_0)\right]$$

Where $\beta \rightarrow$ Wave number

$= 2\pi/\lambda$

$I_n \rightarrow$ Normalized current distribution

$N \rightarrow$ Total number of elements.

The current amplitudes are same for the sum pattern so that

$$\boxed{I_n = I_{-n}}$$

$\theta_0$ is the angle to which the antenna pattern points to.

Consider a difference pattern. Here the current amplitudes will be positive on one side and negative on the other side. In this, half of the total elements are responsible for positive current amplitudes and other half element are responsible for negative current amplitudes.

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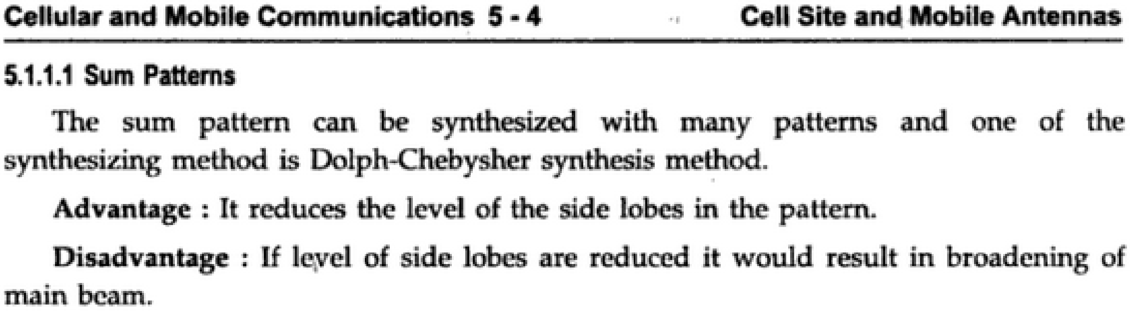


#### 5.1.1.1 Sum Patterns

The sum pattern can be synthesized with many patterns and one of the synthesizing method is Dolph-Chebysher synthesis method.

**Advantage :** It reduces the level of the side lobes in the pattern.

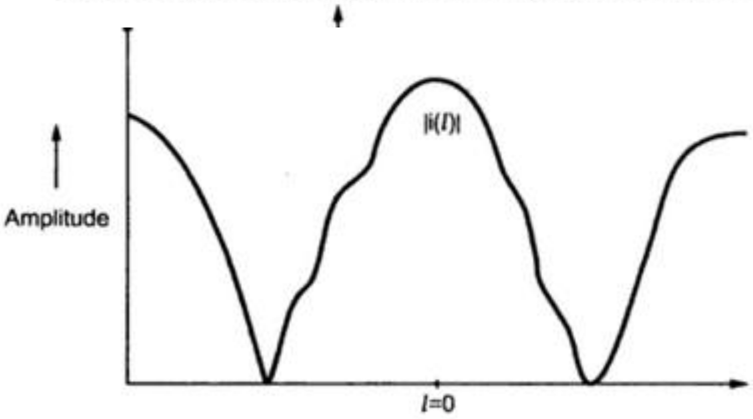
**Disadvantage :** If level of side lobes are reduced it would result in broadening of main beam.

Next the Taylor synthesis method can also be applied for sum pattern synthesis.

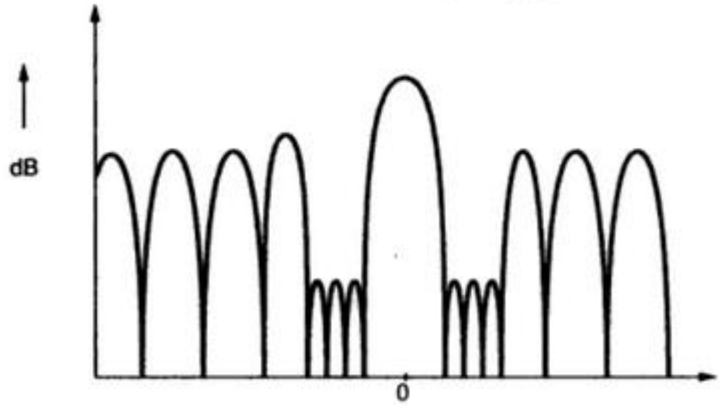
A distribution for the discrete arrays will give a desired pattern that contains a single mainbeam and delobes at specified level. Let the aperture current distribution of antenna be i($l$) and the antenna pattern A(θ) can be obtained from it. It is given as,

$$A(\theta) = \int_{-a}^{a} i(l)\, e^{j\beta l \cos\theta} \cdot dl$$

Both the symmetrical pattern and asymmetrical pattern can be obtained.



(a) Aperture distribution
for antenna setup in fig (b)



(b) Symmetrical sum pattern
including inner lobes

Fig. 5.3 Sum patterns (symmetrical)

For producing the symmetrical pattern at mainbeam, the current amplitude distribution $|i(l)|$ has to be found. Because the phase of current distribution remains constant. the desired pattern $|i(l)|$ of Fig. 5.3 (a) can be obtained from the current amplitude distribution shown in Fig. 5.3 (b).

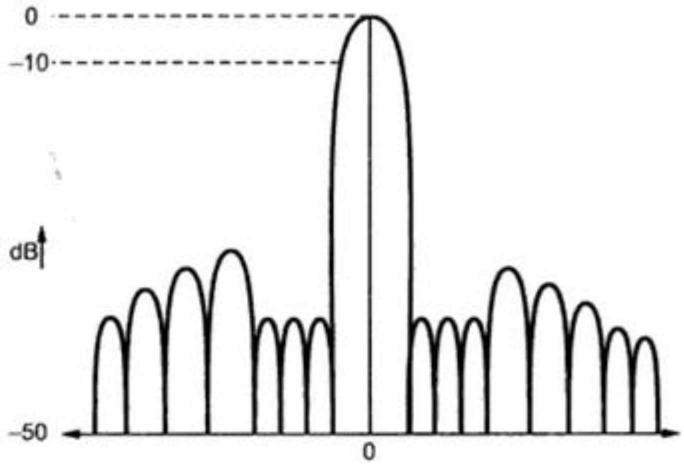
For generating an asymmetrical pattern, it is important to consider both current amplitude $|i(l)|$ and the phase value.

### 5.1.1.2 Difference Patterns

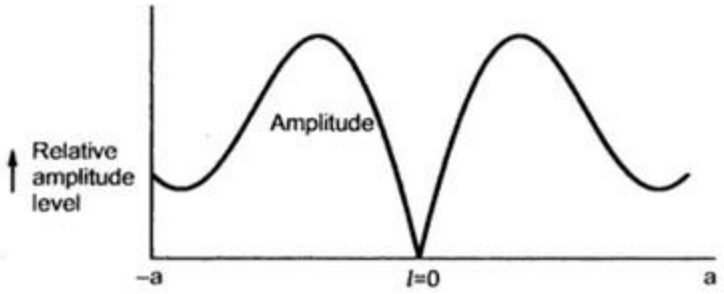
There are many synthesis schemes available for generating difference pattern. The Bayliss is one of them. In the Bayliss synthesis method one should calculate continuous line source from which symmetrical difference pattern can be found that has two mainbeam patterns. It also has some sidelobes. Let the pattern of Bayliss synthesis method be $B(\theta)$ and it is given as,

$$B(0) = \int_{-a}^{a} i(l) \cdot e^{j\beta l \cos\theta} \cdot dl$$

where $i(l)$ is current amplitude distribution.



(a) Inner side lobes reduced in symmetrical Bayliss difference method



(b)