UNIT-2

Mobile Radio Propagation-I

Free Space Propagation Model

- The mechanisms behind EM wave propagation are reflection, diffraction and scattering.
- For cellular systems there is no direct line of sight path between transmitter and receiver.
- Propagation models predict the average received signal strength for an arbitrary transmitter – receiver (T-R) seperation distances that are useful in estimating the radio coverage .

Free Space Propagation Model continued----

- If T-R separation distances are large they are called as large – scale propagation models.

- If T-R separation distances are small they are called as small – scale propagation models.

- Free space propagation model is used to predict the received signal strength when the transmitter and receiver have a clear, unobstructed LOS between them.
- Eg: Satellite communication systems

Free Space Propagation Model continued----

- The free space model predicts that the received power decays as a function of T-R separation distance increases.

- Free space power received by receiver antenna which is separated by a distance ‘d’ is given by “ Friis free space equation” given by

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

Free Space Propagation Model continued----

- Where ,

Pt is the Transmitted power

Pr(d) is the received power as a function of T-R separation distance.

Gt Transmitter antenna gain

Gr Receiver antenna gain

d is the T-R separation distance

L is the system loss factor

λ is the wavelength in meters.

Free Space Propagation Model continued----

- Gain of the antenna is related to the effective aperture 'Ae'

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

The effective aperture is related to physical size of antenna and

λ is related to its carrier frequency given by

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega_c}$$

Free Space Propagation Model continued----

- Where
- ‘f’ is the carrier frequency in ‘Hz’
- ω_c is the carrier frequency in radians per second
- C is the velocity of light.
- The system losses are usually due to the attenuation in transmission lines, filter losses, antenna losses.
- A value of L=1 indicates there are no losses in the system hardware.

Free Space Propagation Model continued----

- Path loss is defined as the difference(in decibels) between transmitted power and received power.
- Given by

$$PL\,(\mathrm{dB}) = 10\log\frac{P_t}{P_r} = -10\log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right]$$

Free Space Propagation Model continued----

- When antenna gains are assumed to have unity gain then path loss is given by

$$PL\,(\mathrm{dB}) = 10\log\frac{P_t}{P_r} = -10\log\left[\frac{\lambda^2}{(4\pi)^2 d^2}\right]$$

Free Space Propagation Model continued----

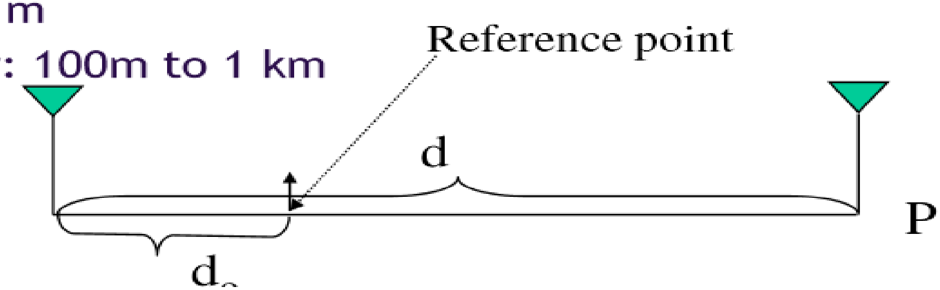
- The Friis free space model is only a valid predictor for "P_r" for values of "d" which are in the far-field of the Transmitting antenna
- Thus, in practice, power can be measured at d_0 and predicted at d using the relation

$$P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2$$

Free Space Propagation Model continued----

where $d >= d_0 >= d_f$

- Typical value for d_0:
  - Indoor: 1m
  - Outdoor: 100m to 1 km



d_f is Fraunhofer distance which complies:

$$d_f = 2D^2/\lambda$$

where D is the largest physical linear dimension of the antenna

Example 1

- Find the far-field distance for an antenna with maximum dimension of 1 m and operating frequency of 900 MHz.

Given;

Largest dimension of antenna, D = 1m

Operating freq, f = 900MHz, $\lambda = \frac{c}{f} = \frac{3\ X\ 10^8}{900\ MHz} = 0.33m$

Far-field distance $d_f = \frac{2D^2}{\lambda} = \frac{2(1)^2}{0.33} = 6\ m$

Example 2

- (a) If a transmitter produces 50 watts of power, express the transmit power in units of dB_m, and dB_W.
- (b) If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dB_m at a free space distance of 100 m from the antenna, What is P_r (10 km)? Assume unity gain for the receiver antenna.

Example 2 continued-----

Solution

(a) TX power in dBm = 10 $\log_{10}$ (Pt/1mW)

= 10 $\log_{10}$ (50/1mW)=47 dBm

Tx power in dBW = 10 $\log_{10}$ (Pt/1W)

= 10 log10(50)=17 dBW

(b)

Rx power = Pr(d) = Pt Gt Gr λ / $(4\pi)^2$ d^2 L

Wavelength, λ = 0.3333333 , GT=Gr = 1, D=100 m, L=1

Pr(100 m) = 3.52167x10^{-06} W = 3.5x10^{-3} mW =10log (3.5*10^{-3}) = -24.5 dBm

Pr(10*1000 m) = 3.5*10^{-3} /10^4 = 3.5*10^{-7} mW

Basic Propagation Mechanisms

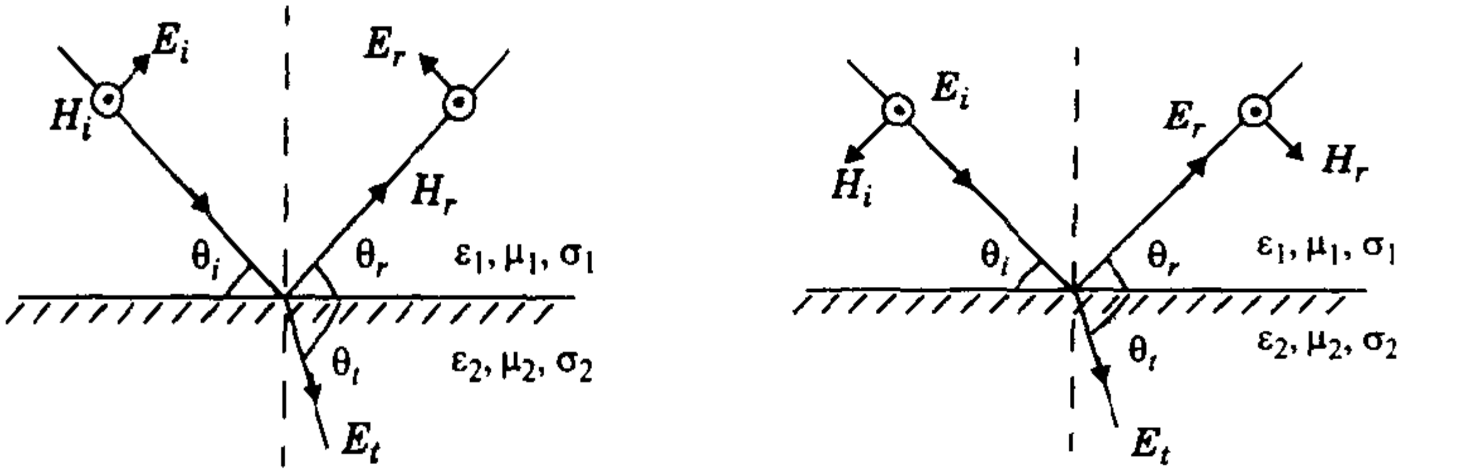
- There are three basic propagation mechanisms:

1. Reflection
2. Diffraction
3. Scattering

- Reflection occurs when an EM wave impinges on an object which has very large dimensions as compared to the wavelength
- Eg: surface of the earth, buildings, walls etc.

Basic Propagation Mechanisms continued-----

- If a radio wave incident on a perfect dielectric part f energy is reflected back and part of energy is transmitted into the dielectric.



(a) E-field in the plane of incidence

(b) E-field normal to the plane of incidence

Basic Propagation Mechanisms continued-----

Γ

$$\Gamma_{\parallel} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_t - \eta_1 \sin\theta_i}{\eta_2 \sin\theta_t + \eta_1 \sin\theta_i}$$ (E-field in plane of incidence)

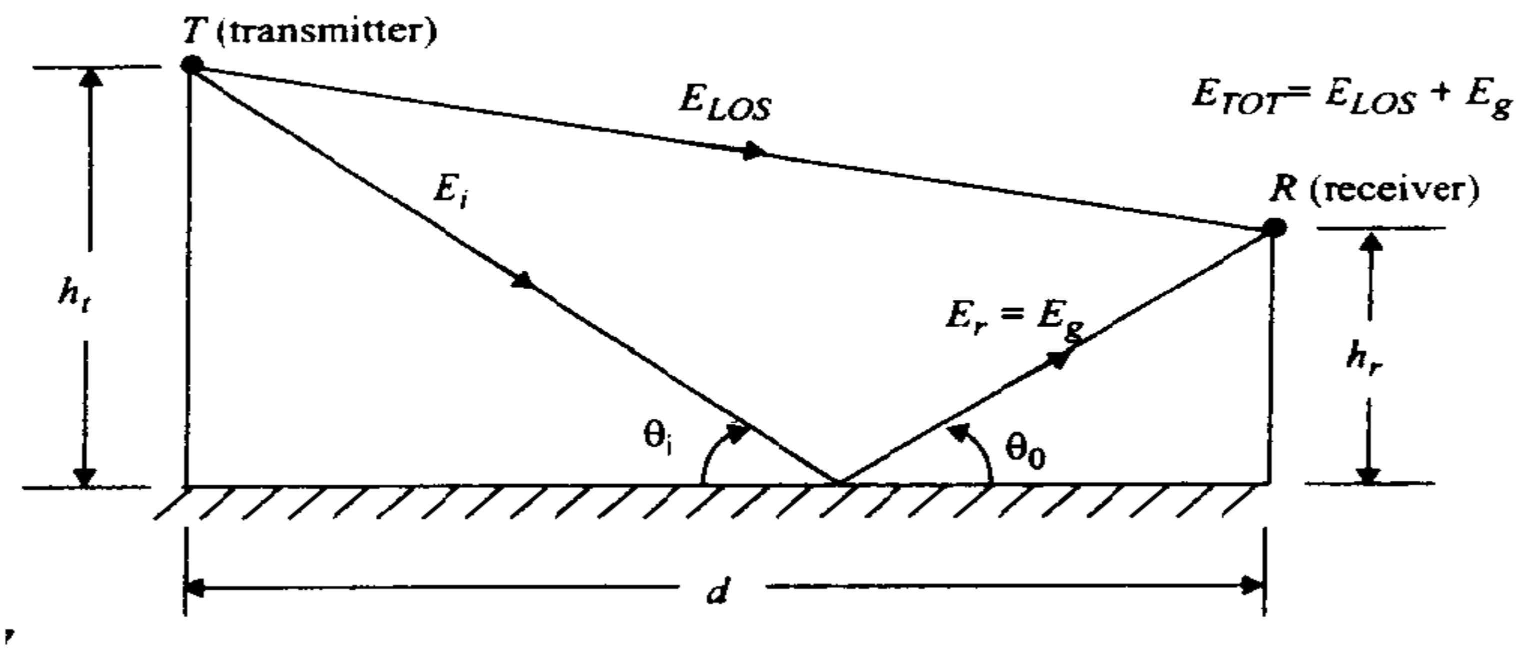
$$\Gamma_{\perp} = \frac{E_r}{E_i} = \frac{\eta_2 \sin\theta_i - \eta_1 \sin\theta_t}{\eta_2 \sin\theta_i + \eta_1 \sin\theta_t}$$ (E-field not in plane of incidence)

Basic Propagation Mechanisms continued-----

- Diffraction Occurs when the radio path between transmitter and receiver is obstructed by the surface that has sharp irregularities(edges).
- Scattering occurs when the medium has objects that has smaller or comprable wavelengths
- Eg:small objects, rough surfaces, water droplets, rain, snow, dust particles etc.

Ground Reflection Model
Classical 2-ray ground bounce model

- One line of sight and one ground reflected path.
- This is a large scale propagation model in which distance between transmitter and receiver is of several kilometers.



Ground Reflection Model continued-----------

- The received signal is effected by the path difference delta Δ
- Given by

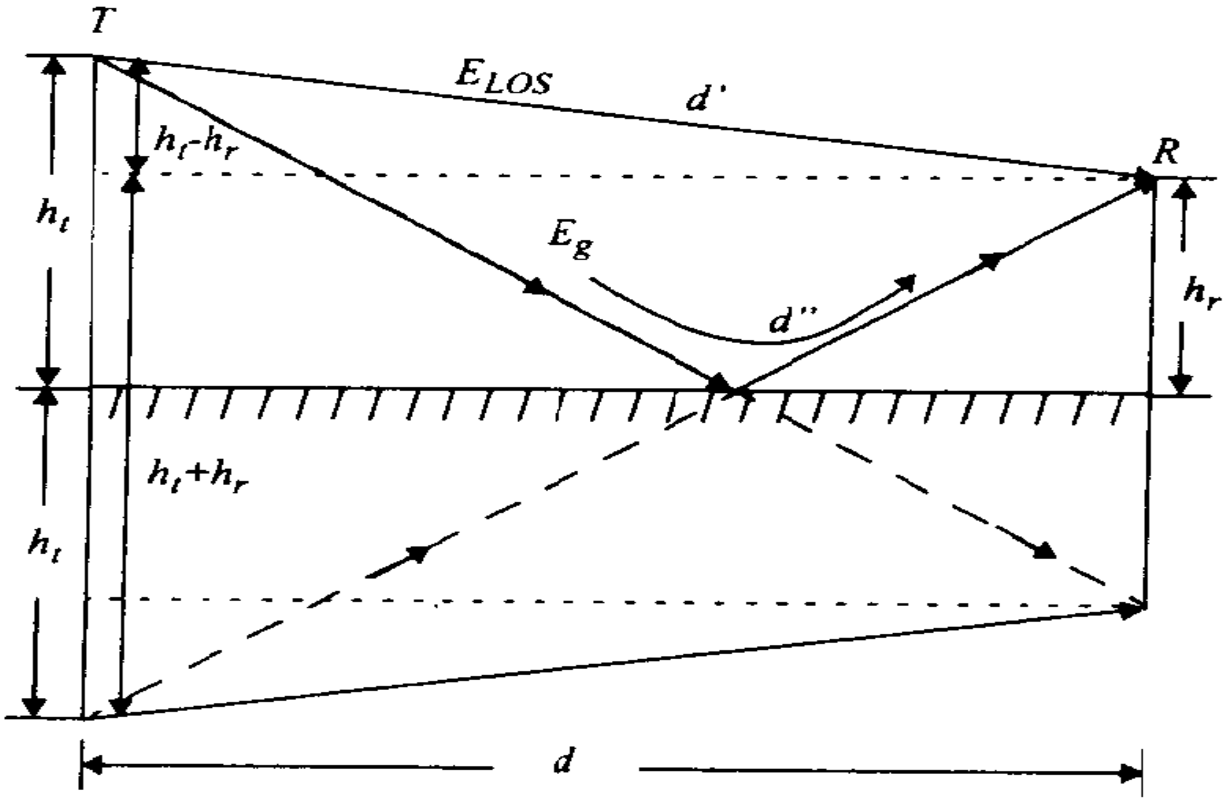
$$\Delta = d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}$$

After simplifying using taylor series appriximation the path difference is given below

$$\Delta = d'' - d' \approx \frac{2h_t h_r}{d}$$

Ground Reflection Model continued-----------

- The above expressions are obtained by using the *method of images as shown below*



Ground Reflection Model continued-----------

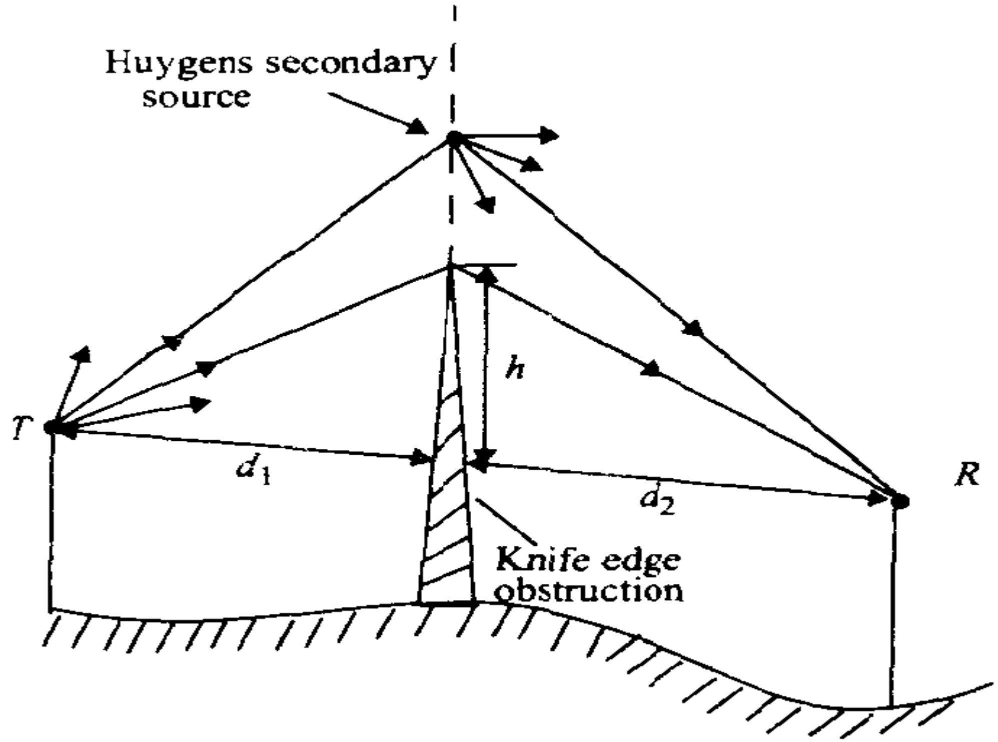
- The received power can be depend upon the path difference given by

$$P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$

Knife Edge Diffraction Model

- The phenomenon of diffraction can be explained by Huygens's principle, which states that all points on a wave front can be considered as point sources for the production of secondary wavelets.
- The field strength of a diffracted wave in the shadowed region is the vector sum of the electric field components of all the secondary wavelets in the space around the obstacle.

Knife Edge Diffraction Model continued------



Consider a receiver at a point R is located in the shadowed region .

The field strength at point R in the above figure is the vector sum of fields due to all of the secondary Huygen's sources in the plane above the knife edge.

Knife Edge Diffraction Model continued------

- The diffraction gain due to the presence of a knife edge, as compared to the free space E-field ,is given by

$$G_d(\text{dB}) = 20\log|F(v)|$$

Wher v Is the Fresnal – Kirchoff diffraction parameter given by

$$v = h\sqrt{\frac{2(d_1+d_2)}{\lambda d_1 d_2}} = \alpha\sqrt{\frac{2d_1 d_2}{\lambda(d_1+d_2)}}$$

Here 'h' is the effective height of obstructing screen as shown in above figure.

Knife Edge Diffraction Model continued------

- An approximate solution for diffraction gain $G_d\,(\text{dB})$ Is given by Lee is shown below

$$G_d\,(dB) = 0 \qquad \upsilon \le -1$$

$$G_d\,(\text{dB}) = 20\log\,(0.5 - 0.62\upsilon) \qquad -1 \le \upsilon \le 0$$

$$G_d\,(\text{dB}) = 20\log\,(0.5\,\exp\,(-0.95\upsilon)) \qquad 0 \le \upsilon \le 1$$

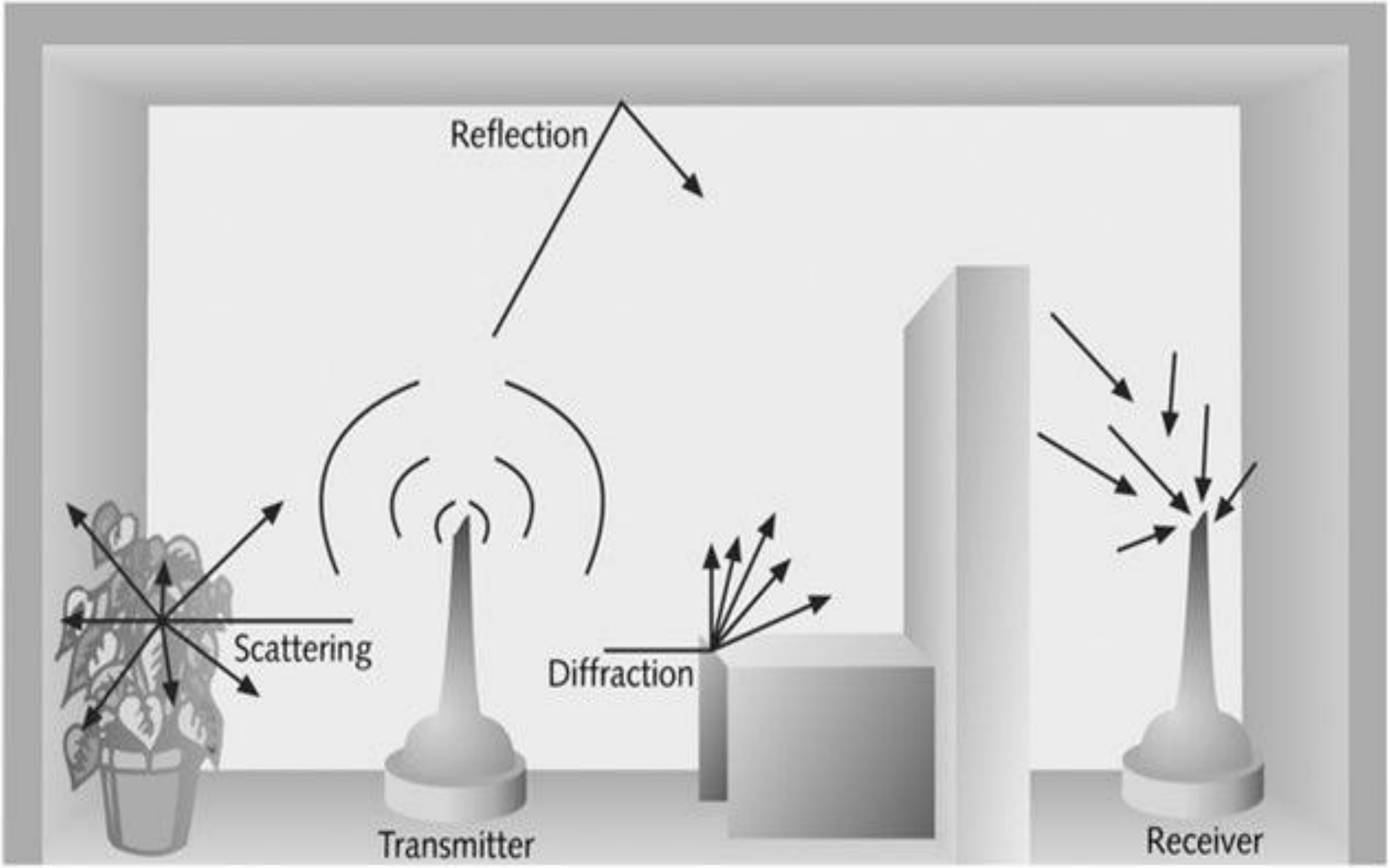
$$G_d\,(\text{dB}) = 20\log\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1\upsilon)^2}\right) \qquad 1 \le \upsilon \le 2.4$$

$$G_d\,(\text{dB}) = 20\log\left(\frac{0.225}{\upsilon}\right) \qquad \upsilon > 2.4$$

Scattering

- The medium which the wave travels consists of objects with dimensions smaller than the wavelength and where the number of obstacles per unit volume is large – rough surfaces, small objects, foliage, street signs, lamp posts.
- Generally difficult to model because the environmental conditions that cause it are complex
- Modeling “position of every street sign” is not feasible.

Illustration ..



Link Budget Design Using Path Loss Models

- A calculation of signal powers, noise powers, and/or signal-to-noise ratios for a complete communication link is called link budget.
- It is a useful approach to the basic design of a complete communication system.
  - The performance of any communication link depends on the quality of the equipment being used.
  - ***Link budget*** is a way of quantifying the link performance.

Link Budget Design Using Path Loss Models continued-------------

- The received power in a link is determined by three factors: ***transmit power***, ***transmitting antenna gain***, and ***receiving antenna gain***.
- If that power, minus the ***free space loss*** of the link path, is greater than the ***minimum received signal level*** of the receiving radio, then a link is possible.
- The difference between the minimum received signal level and the actual received power is called the ***link margin***.

Link Budget Design Using Path Loss Models continued------------

- Practical path loss estimation techniques are given below:

1. Log-distance Path Loss Model
2. Log normal Shadowing

Log-distance Path Loss Model:

- Both theoretical and measurement based propagation models indicate that average received signal power decreases logarithmically with distance

Link Budget Design Using Path Loss Models continued------------

- Log-distance Path Loss Model continued-------
- The average large-scale path loss for an arbitrary T-R separation is expressed as a function of distance by using path loss exponent, *n*

$$\overline{PL}(d) \propto \left(\frac{d}{d_0}\right)^n$$

or

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right)$$

Link Budget Design Using Path Loss Models continued------------

- Log-distance Path Loss Model continued-------
- Where *n* is the path loss exponent which indicates the rate at which the path loss increases with distance.

d_0 Is the reference distance which is determined from measurements close to the transmitter .

- *d* is the T-R separation distance
- The bars in the above equations denote the ensemble average of all possible path loss values for a given value of *d* .

Link Budget Design Using Path Loss Models continued------------

- Log-distance Path Loss Model continued-------
- The Path Loss exponents for different environments is shown below

Environment	Path Loss Exponent, n
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Link Budget Design Using Path Loss Models continued------------

- Log-normal Shadowing:
- Log-normal Shadowing implies that the measured signal levels at a specific T-R separation have a normal (Gaussian) distribution about the distance.
- Measurements have shown that at any value of 'd' the path loss PL(*d*) at a particular location is random and distributed log-normally(normal in dB) about the mean distance.

Link Budget Design Using Path Loss Models continued------------

- Log-normal Shadowing continued--------
- That is as shown below

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma$$

where X_σ is a zero-mean Gaussian distributed random variable (in dB) with standard deviation σ (also in dB).

•Thus the close in reference distance *do*, the path loss exponent *n* and standard deviation *σ* statistically describe the path loss model for an arbitrary location having specific T-R separation distance.

Outdoor Propagation Models

- There are many empirical Outdoor propagation models such as Longley-Rice model, Durkin's model, Okumura model, Hata model, and so on.
- **Longley-Rice Model:**
- Longley-Rice model is the most used model within a frequency band of 40MHz to 100GHz over different terrains.
- Certain modifications over the rudimentary model like an extra urban factor (UF) due to an urban clutter near the receiver are also included in this model.

Longley-Rice Model continued---------

- The Longley- Rice model is also available as a computer program to calculate large scale transmission loss relative to free space loss over irregular terrain for frequencies between 20MHz to 10GHz.
- The Longley- Rice model operates in two modes

a) When a detailed terrain path profile is available the prediction is called *point to point mode* prediction.

b) If the terrain path profile is not available, the prediction is called *area mode* prediction.

Okumura Model

- It is one of the most widely used models for signal prediction in urban areas, and it is applicable for frequencies in the range 150 MHz to 1920 MHz
- Based totally on measurements (not analytical calculations)
- Applicable in the range: 150MHz to ~ 2000MHz, 1km to 100km T-R separation, Antenna heights of 30m to 100m

$$L_{50}(dB) = L_F + A_{mu}(f,d) - G(h_{re}) - G(h_{te}) - G_{AREA}$$

Where

L_{50} is the median path loss (50%)

L_F is the free space path loss

$A_{mu}(f,d)$ is the median attenuation relative to free space

$G(h_{re}), G(h_{te})$ are antenna height gain factors

G_{AREA} is the gain due to the type of environment

Okumura Model

- The major disadvantage with the model is its low response to rapid changes in terrain, therefore the model is fairly good in urban areas, but not as good in rural areas.
- Common standard deviations between predicted and measured path loss values are around 10 to 14 dB.
- G(hre) :

$$G(h_{te}) = 20\log\left(\frac{h_{te}}{200}\right) \qquad 1000\text{m} > h_{te} > 30\,\text{m}$$

$$G(h_{re}) = 10\log\left(\frac{h_{re}}{3}\right) \qquad h_{re} \leq 3\,\text{m}$$

$$G(h_{re}) = 20\log\left(\frac{h_{re}}{3}\right) \qquad 10\text{m} > h_{re} > 3\,\text{m}$$

Hata Model

- The **Hata model** is a radio propagation **model** for predicting the path loss of cellular transmissions in exterior environments, valid for microwave frequencies from 150 to 1500 MHz.

- It is an empirical formulation based on the data from the Okumura **Model**, and is thus also commonly referred to as the Okumura–**Hata model**.

The following classification was used by Hata:

Hata Model

- Urban area $L_{dB} = A + B\log d - E$
- Suburban area $L_{dB} = A + B\log d - C$
- Open area $L_{dB} = A + B\log d - D$

$$A = 69.55 + 26.16\log f - 13.82 h_b$$

$$B = 44.9 - 6.55\log h_b$$

$$C = 2(\log(f/28))^2 + 5.4$$

$$D = 4.78\log(f/28)^2 + 18.33\log f + 40.94$$

$$E = 3.2(\log(11.75 h_m))^2 - 4.97 \quad \text{for large cities, } f \geq 300 MHz$$

$$E = 8.29(\log(1.54 h_m))^2 - 1.1 \quad \text{for large cities, } f < 300 MHz$$

$$E = (1.11\log f - 0.7) h_m - (1.56\log f - 0.8) \quad \text{for medium to small cities}$$

Indoor Propagation Models

- The distances covered are much smaller
- The variability of the environment is much greater
- Key variables: layout of the building, construction materials, building type, where the antenna mounted, …etc.

- The losses between floors of a building are determined by the external dimensions and materials of the building, as well as the type of construction used to create the floors and the external surroundings.

- Floor attenuation factor (FAF)

Partition losses inside a floor(intra-floor)

- Internal and external structure of a building formed by partitions and obstacles vary widely.
- partitions that are formed as a part of building structure are called Hard partitions.
- partitions that can be moved and which do not span to the ceiling are called Soft partitions.
- Partitions vary widely in physical and electrical characteristics, making it difficult to apply general models to specific indoor installations.

Partition losses between floors

Table 4.4 Total Floor Attenuation Factor and Standard Deviation σ (dB) for Three Buildings. Each Point Represents the Average Path Loss Over a 20λ Measurement Track [Sei92a]

Building	915 MHz FAF (dB)	σ (dB)	Number of locations	1900 MHz FAF (dB)	σ (dB)	Number of locations
Walnut Creek						
One Floor	33.6	3.2	25	31.3	4.6	110
Two Floors	44.0	4.8	39	38.5	4.0	29
SF PacBell						
One Floor	13.2	9.2	16	26.2	10.5	21
Two Floors	18.1	8.0	10	33.4	9.9	21
Three Floors	24.0	5.6	10	35.2	5.9	20
Four Floors	27.0	6.8	10	38.4	3.4	20
Five Floors	27.1	6.3	10	46.4	3.9	17
San Ramon						
One Floor	29.1	5.8	93	35.4	6.4	74
Two Floors	36.6	6.0	81	35.6	5.9	41
Three Floors	39.6	6.0	70	35.2	3.9	27

Partition losses between floors

Table 4.5 Average Floor Attenuation Factor in dB for One, Two, Three, and Four Floors in Two Office Buildings [Sei92b]

Building	FAF (dB)	σ (dB)	Number of locations
Office Building 1:			
Through One Floor	12.9	7.0	52
Through Two Floors	18.7	2.8	9
Through Three Floors	24.4	1.7	9
Through Four Floors	27.0	1.5	9
Office Building 2:			
Through One Floor	16.2	2.9	21
Through Two Floors	27.5	5.4	21
Through Three Floors	31.6	7.2	21

Log-distance Path Loss Model

- The exponent n depends on the surroundings and building type
  - X_σ is the variable in dB having a standard deviation σ.

Table 4.6 Path Loss Exponent and Standard Deviation Measured in Different Buildings [And94]

Building	Frequency (MHz)	*n*	σ (dB)
Retail Stores	914	2.2	8.7
Grocery Store	914	1.8	5.2
Office, hard partition	1500	3.0	7.0
Office, soft partition	900	2.4	9.6
Office, soft partition	1900	2.6	14.1
Factory LOS			
Textile/Chemical	1300	2.0	3.0
Textile/Chemical	4000	2.1	7.0
Paper/Cereals	1300	1.8	6.0
Metalworking	1300	1.6	5.8
Suburban Home			
Indoor Street	900	3.0	7.0
Factory OBS			
Textile/Chemical	4000	2.1	9.7
Metalworking	1300	3.3	6.8

$$PL(d) = PL(d_0) + 10n\log(d/d_0) + X_\sigma$$

Small-Scale Multi-path Propagation

- Small-scale Fading:
- Small-scale fading, or simply fading describes the rapid fluctuation of the amplitude of a radio signal over a short period of time or travel distance.
- It is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at different times

Small-Scale Multi-path Propagation continued---------

- The three most important fading effects are

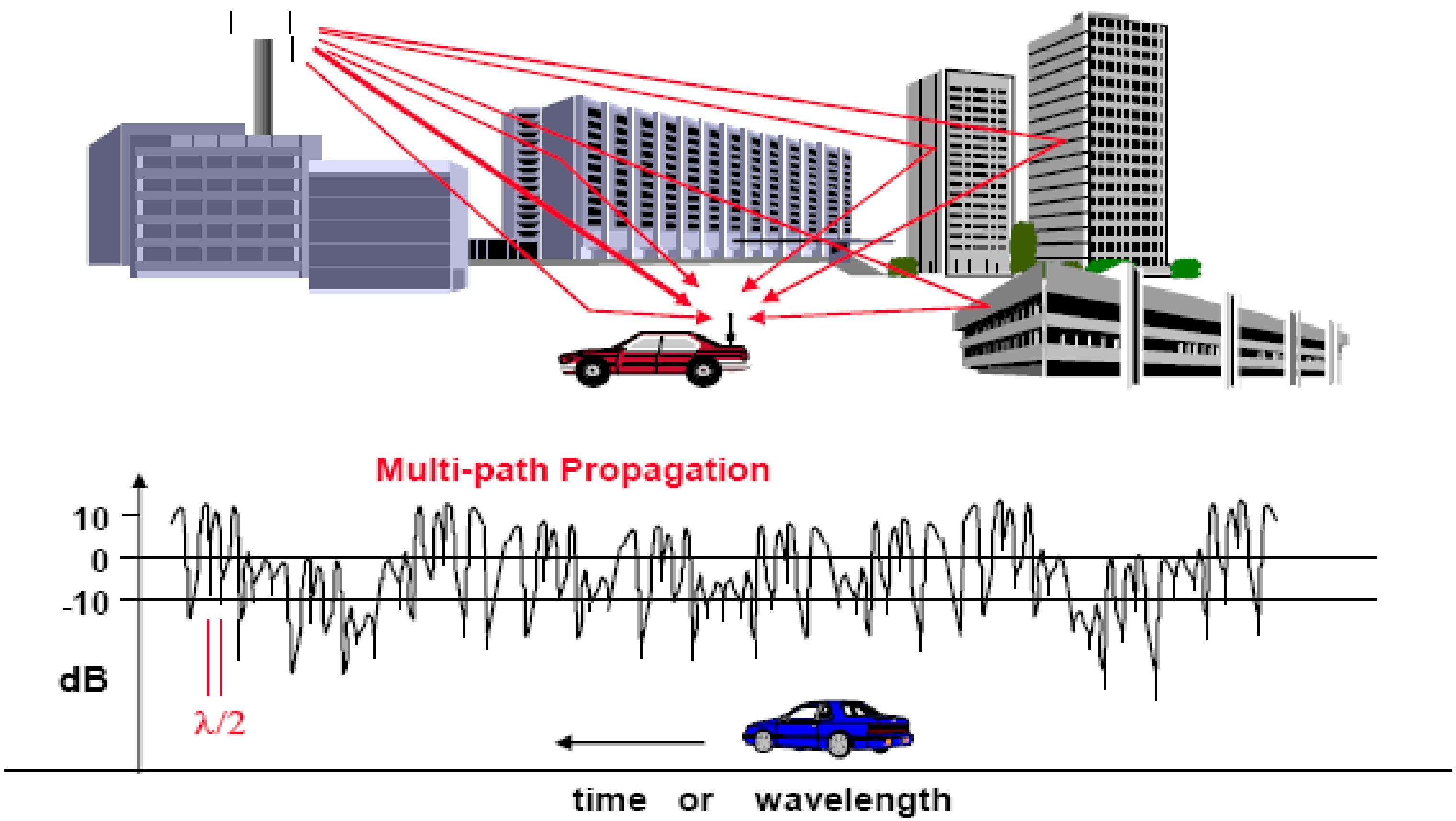
1. Rapid changes in signal strength over a small travel distance or time interval.
2. Random frequency modulation due to varying Doppler shifts (described later) on different multi-path signals.
3. Time dispersions (echos) caused by multi-path propagation delays.

Small-Scale Multi-path Propagation continued----------

- Factors Influencing Small-scale Fading:
- The following physical factors in the radio propagation channel influence small-scale fading
- multi-path propagation
- speed of the mobile
- speed of the surrounding objects
- the transmission bandwidth of the signal

- Multi-path Propagation:
- The presence of reflecting objects and scatterers in the channel creates a constantly changing environment
- This results in multiple versions of the transmitted signal that arrive at the receiving antenna, displaced with respect to one another in time and spatial orientation

Multipath propagation



- Speed of the mobile:
- The relative motion between base station and mobile results in random frequency modulation due to different Doppler shifts.
- Doppler shift will be positive or negative depending on whether the mobile receiver is moving towards or away from the base station.
- Speed of the surrounding objects:
- If the speed of the surrounding objects is greater than mobile, the fading is dominated by those objects.
- If surrounding objects are slower than mobile, then their effect can be ignored.

- The transmission bandwidth of the signal:
- Depending on the relation between signal bandwidth and coherence bandwidth of the channel, the signal can be either distorted or faded.
- If signal bandwidth is greater than coherence bandwidth it creates distortion.
- If signal bandwidth is smaller than coherence bandwidth it creates small scale fading.
- Coherence bandwidth of wireless channels is the range of frequencies that are allowed to pass through the channel without distortion.

Doppler Shift:

- The Doppler effect (or Doppler shift) is the change in frequency of a wave for an observer moving relative to the source of the wave.

- A mobile moves at a constant velocity v, along a path segment having length d between points X and Y.
- Path length difference

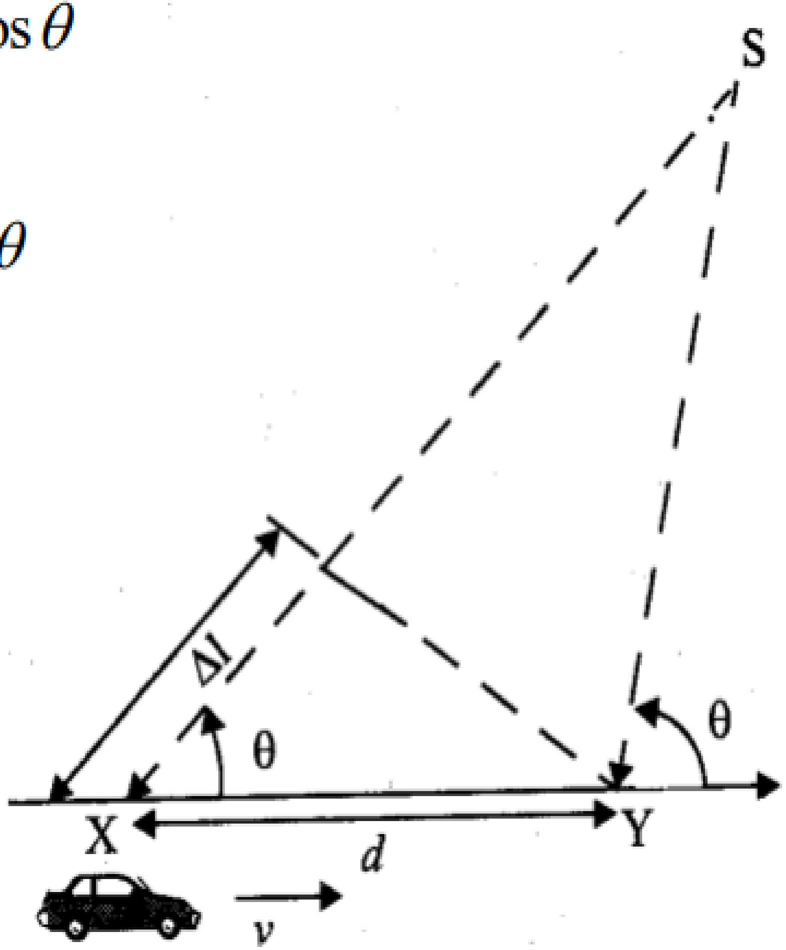
$$\Delta l = d\cos\theta = v\Delta t\cos\theta$$

- Phase change

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v\Delta t}{\lambda}\cos\theta$$

- Doppler shift

$$f_d = \frac{1}{2\pi}\cdot\frac{\Delta\phi}{\Delta t} = \frac{v}{\lambda}\cos\theta$$



Types of Small Scale Fading

Small-Scale Fading
(Based on multipath time delay spread)

Flat Fading

1. BW of signal < BW of channel
2. Delay spread < Symbol period

Frequency Selective Fading

1. BW of signal > BW of channel
2. Delay spread > Symbol period

Small-Scale Fading
(Based on Doppler spread)

Fast Fading

1. High Doppler spread
2. Coherence time < Symbol period
3. Channel variations faster than baseband signal variations

Slow Fading

1. Low Doppler spread
2. Coherence time > Symbol period
3. Channel variations slower than baseband signal variations

Flat Fading:

- Such types of fading occurs when the bandwidth of the transmitted signal is less than the coherence bandwidth of the channel. Equivalently if the symbol period of the signal is more than the rms delay spread of the channel, then the fading is flat fading.
- So we can say that flat fading occurs when

$$B_S \ll B_C$$

- where *Bs is the signal bandwidth and Bc is the coherence bandwidth. Also*

$$T_S \gg \sigma_\tau$$

- where *TS is the symbol period and στ is the rms delay spread. And in such a case,* mobile channel has a constant gain and linear phase response over its bandwidth.

Frequency Selective Fading:

- Frequency selective fading occurs when the signal bandwidth is more than the coherence bandwidth of the mobile radio channel or equivalently the symbols duration of the signal is less than the rms delay spread.

$$B_S \gg B_C$$

and

$$T_S \ll \sigma_\tau$$

Frequency Selective Fading continued-------------

- At the receiver, we obtain multiple copies of the transmitted signal, all attenuated and delayed in time. The channel introduces inter symbol interference. A rule of thumb for a channel to have flat fading is if

$$\frac{\sigma_{\tau}}{T_S} \leq 0.1$$

Fast Fading:

- In a fast fading channel, the channel impulse response changes rapidly within the symbol duration of the signal.
- Due to Doppler spreading, signal undergoes frequency dispersion leading to distortion. Therefore a signal undergoes fast fading if

$$T_S \gg T_C$$

where T_C *is the coherence time and*

$$B_S \gg B_D$$

- where B_D *is the Doppler spread. Transmission involving very low data rates suffer* from fast fading.

Slow Fading:

- In such a channel, the rate of the change of the channel impulse response is much less than the transmitted signal. We can consider a slow faded channel in which channel is almost constant over at least one symbol duration. Hence

$$T_S \ll T_C$$

$$B_S \gg B_D$$

•We observe that the velocity of the user plays an important role in deciding whether the signal experiences fast or slow fading.

CELL SITE ANTENNAS and MOBILE ANTENNAS

ANTENNAS AT CELL SITE

For Coverage Use: Omni directional Antennas

For Interference Reduction Use: Directional Antennas

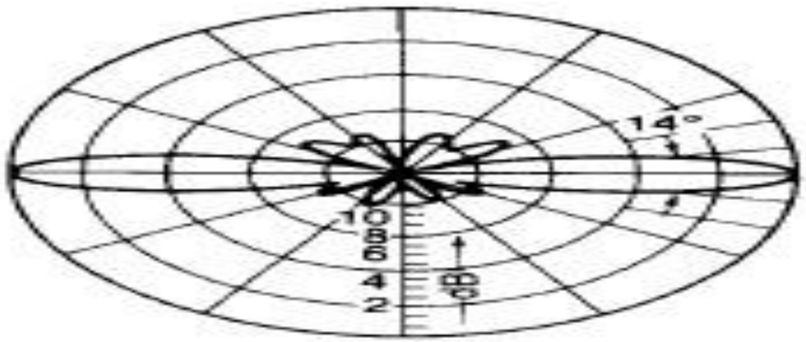
For Coverage Use: Omni directional Antennas

- Antennas used for cellular radio systems must fulfill the requirement of sufficient radio coverage and reducing the co- channel interference due to frequency reuse.

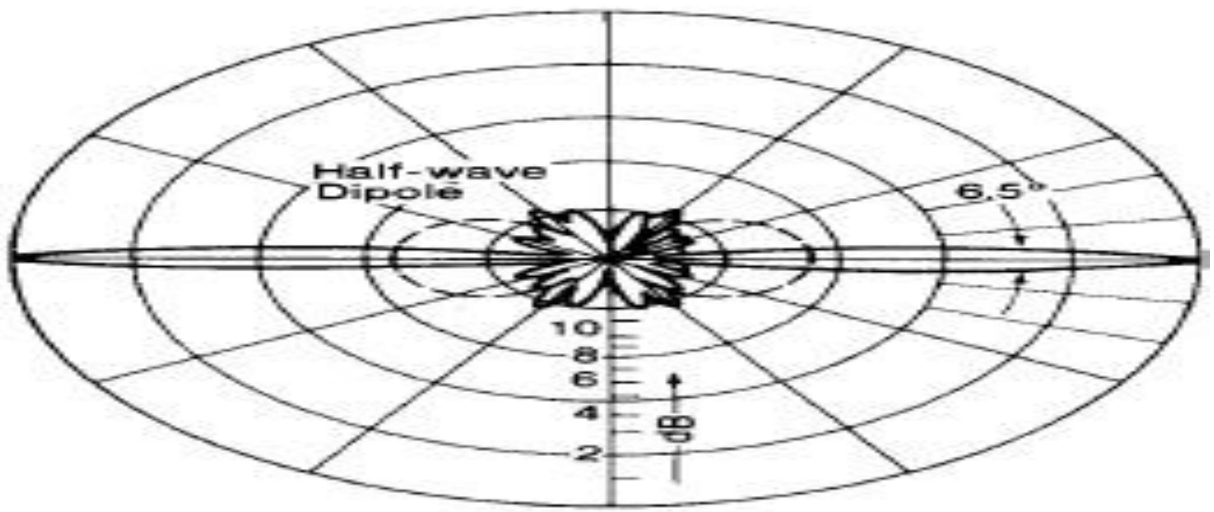
- Hence there is a need for high gain usually 6dB or 9dB Omni directional antennas.

- Antenna patterns for 6dB and 9dB gain is shown blow in which high gain omni directional antennas with reference to dipole.

Antenna patterns for 6dB & 9dB gain:



Vertical
(a)



Vertical
(b)

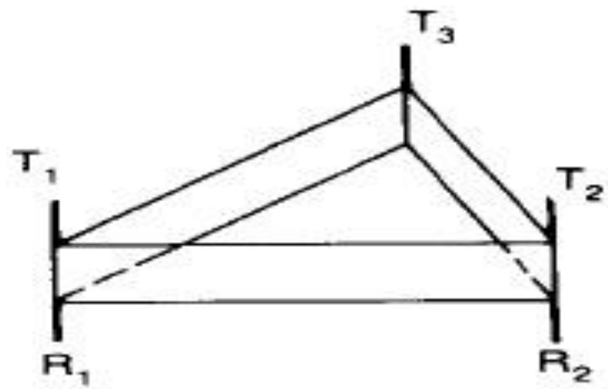
Start-Up System Configuration

- Start-Up System Configuration.
- In a start-up system, an Omni cell is one in which all the transmitting antennas are omni directional.
- In a start up system, an Omnicell is used.
- Each transmitting antenna can transmit signals from 16 radio transmitters simultaneously using a 16 -channel combiner.

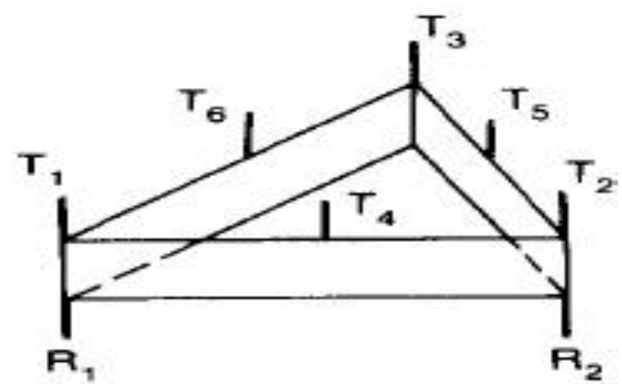
Start-Up System Configuration continued………….

- Each cell normally can 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 (radio signals) pass through a 16-channel combiner and transmit signals by means of a transmitting antenna (see Fig. a).

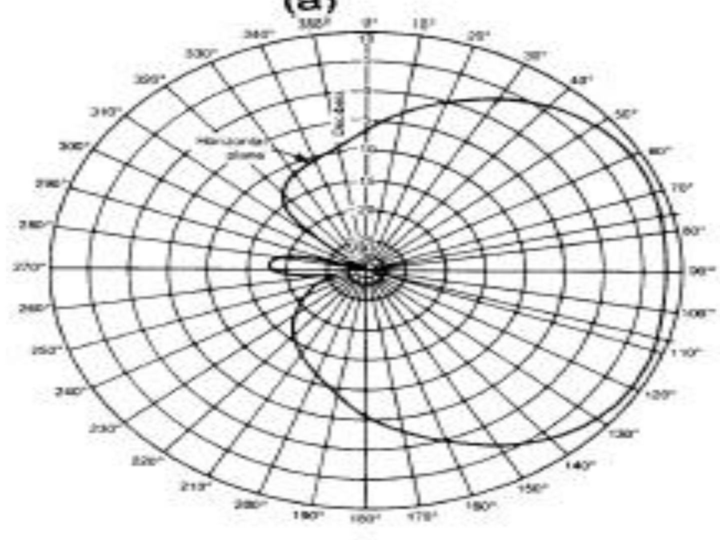
Cell site Antennas for Omni-cells



(a)



(b)



Start-Up System Configuration continued…………

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

For Interference Reduction Use: Directional Antennas

- When the frequency reuse scheme must be used , co channel interference will occur.

- The co channel interference reduction factor q = D/R = 4.6 is based on the assumption that the terrain is flat.

- To reduce the co channel interference, either we must increase the q or use directional antennas.

Directional Antennas.

- A 120◦-corner reflector or 120◦-plane 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◦beam width is shown in above figure.

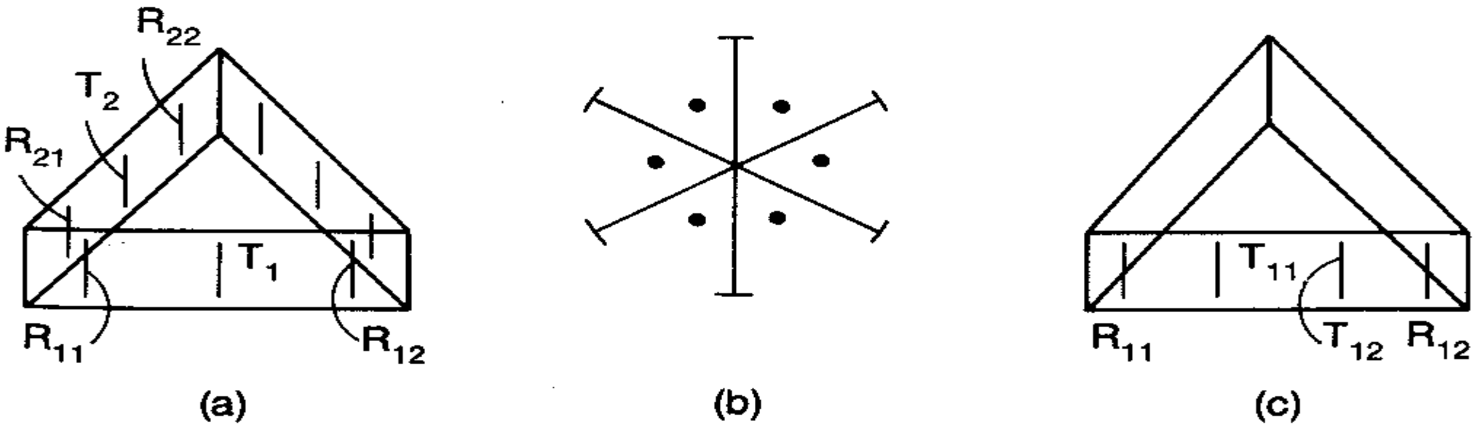


Figure 5.10 Directional antenna arrangement: (*a*) 120° sector (45 radios); (*b*) 60° sector; (*c*) 120° sector (90 radios).

Normal Antenna (Mature System) Configuration

- 1. K = 7 cell pattern (120◦sectors).
- In a K = 7 cell pattern for frequency reuse, if 333 channels are used, each cell would have about 45 radios.
- Each 120◦sector would have one transmitting antenna and two receiving antennas and would serve 16 radios.
- The two receiving antennas are used for diversity .

2. K = 4 cell pattern(60◦sectors).

- We do not use K = 4 in an Omni cell system because the co channel reuse distance is not adequate.
- Therefore, in a K = 4 cell pattern, 60◦sectors are used. There are 24 sectors.
- In this K = 4 cell-pattern system, two approaches are used.

a. Transmitting-receiving 60◦sectors.

- Each sector has a transmitting antenna carrying its own set of frequency radios and hands off frequencies to other neighboring sectors or other cells.
- This is a full K = 4 cell-pattern system.
- If 333 channels are used, with13 radios per sector, there will be one transmitting antenna and one receiving antenna in each sector.
- At the receiving end, two of six receiving antennas are selected for an angle diversity for each radio channel.

b. Receiving 60◦sectors.

- Only 60◦-sector receiving antennas are used to locate mobile units and handoff to a proper neighboring cell with a high degree of accuracy.
- All the transmitting antennas are Omni directional within each cell.
- At the receiving end, the angle diversity for each radio channel is also used in this case.

Abnormal Antenna Configuration.

- If the call traffic is gradually increasing, there is an economic advantage in using the existing cell systems rather than the new splitting cell system (splitting into smaller cells).
- In the former, each site is capable of adding more radios.
- In a K = 7 cell pattern with 120◦sectors, two transmitting antennas at each sector are used (Fig. 8.34c).
- Each antenna serves 16 radios if a 16-channel combiner is used.

- The two transmitting antennas in each sector are placed relatively closer to the receiving antennas than in the single transmitting antenna case.
- This may cause some degree of desensitization in the receivers.
- The technology in 32-channel combiner can combine 32 channels in a combiner;
- therefore, only one transmitting antenna is needed in each sector.
- However, this one transmitting antenna must be capable of withstanding a high degree of transmitted power.

- If each channel transmits 100 W, the total power that the antenna terminal could withstand is 3.2 kW.
- The 32-channel combiner has a power limitation which would be specified by different manufacturers.
- Two receiving antennas in each 120° sector remain the same for space diversity use.

Directional/Sector Antenna for interference reduction

Space-Diversity Antennas Used at Cell Site

- 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.

Space-Diversity Antennas Used at Cell Site continued-------

- Here the antenna setup is shown in Fig.a.
- Equation $\eta = h/D = 11$ is presented as an example for the designer to use.
- $\eta = h/D = 11$
- where h is the antenna height and D is the antenna separation.
- From Eq. $\eta = h/D = 11$, 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).

Space-Diversity Antennas Used at Cell Site continued--------

- In any omnicell system, the two space-diversity antennas should be aligned with the terrain, which should have a U shape as shown in Fig b.
- Space-diversity antennas can separate only horizontally, not vertically; thus, there is no advantage in using a vertical separation in the design.

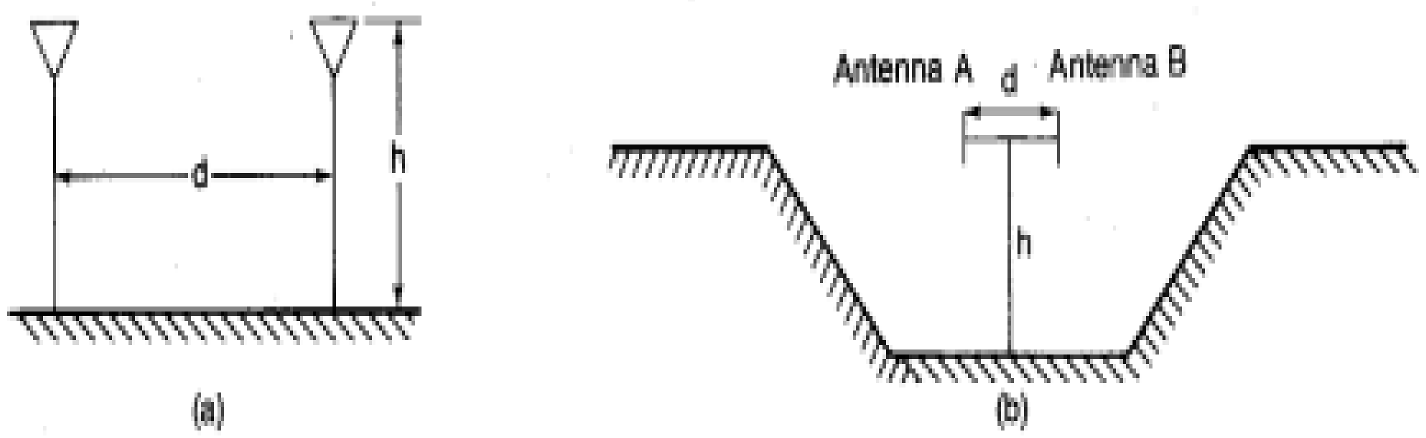


Fig:Space diversity antennas used at cell sites

Umbrella-Pattern Antennas

- In certain situations, umbrella-pattern antennas should be used for the cell-site antennas.
- **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 Fig1
- 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.

Normal Umbrella-Pattern Antenna continued-------

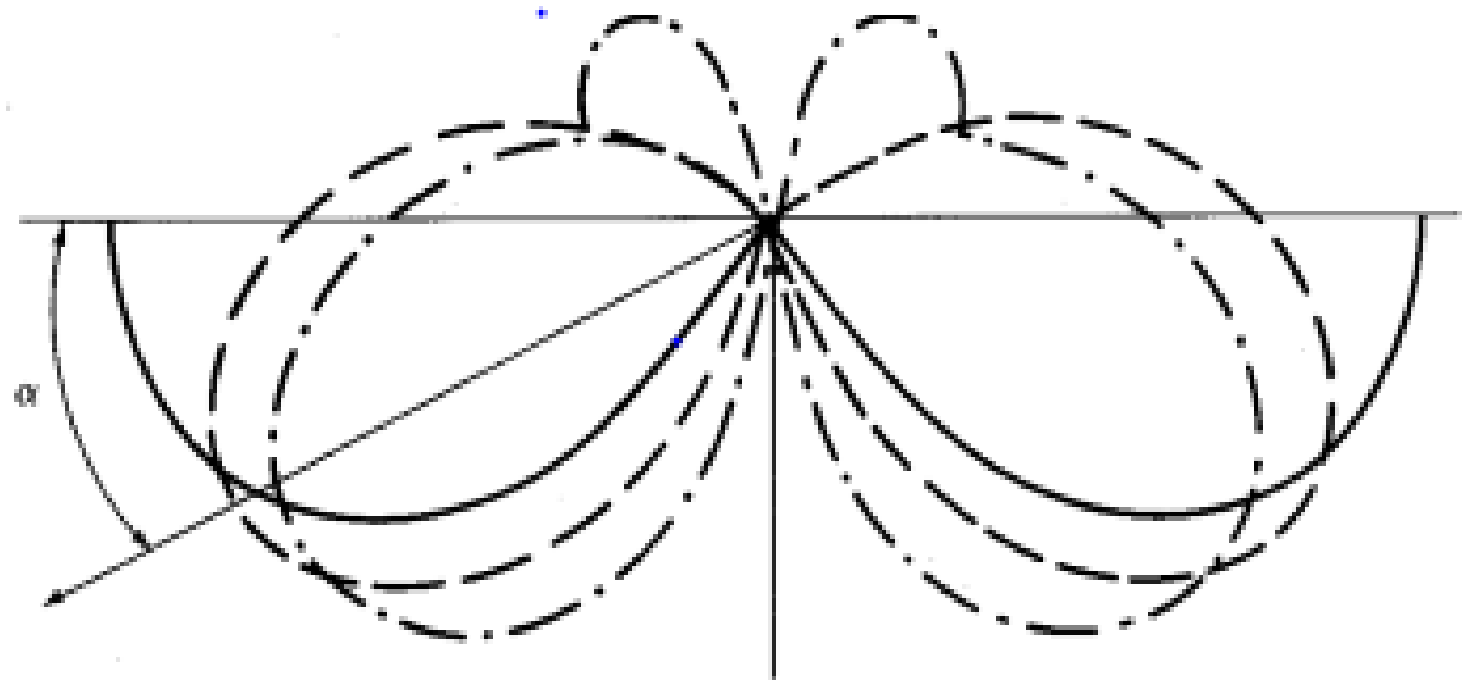


Fig:1 A monopole with a top disk

Broadband Umbrella-Pattern Antenna:

- The parameters of a discone antenna (a bioconical antenna in which one of the cones is extended to 180◦to form a disk) are shown in Fig.2
- 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.

Broadband Umbrella-Pattern Antenna continued---------

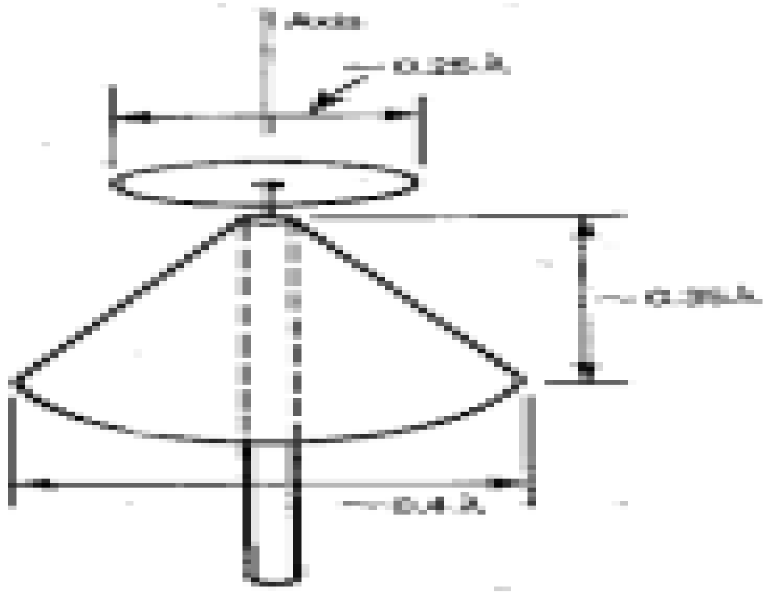


Fig2: Single Discone antenna

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 Fig3.

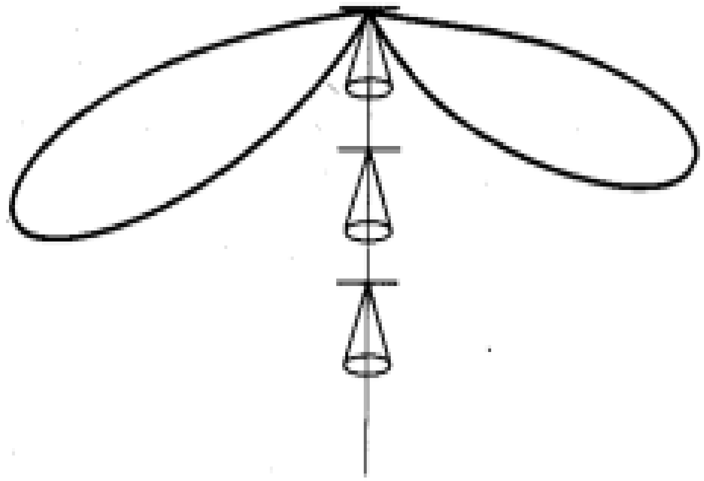


Fig3:An Array of Discone Antennas

Mobile Antennas

Mobile High Gain Antennas:

- A high gain antenna used on a mobile unit should be distinguished from the directional antenna.
- In the directional antenna, the antenna beam pattern is suppressed horizontally.
- In the high gain antenna, the antenna beam pattern is suppressed vertically.
- If we point the mobile antenna opposite to the cell site transmitter, in theory we would receive nothing.

Images of Whip Antennas

Mobile High Gain Antennas continued------

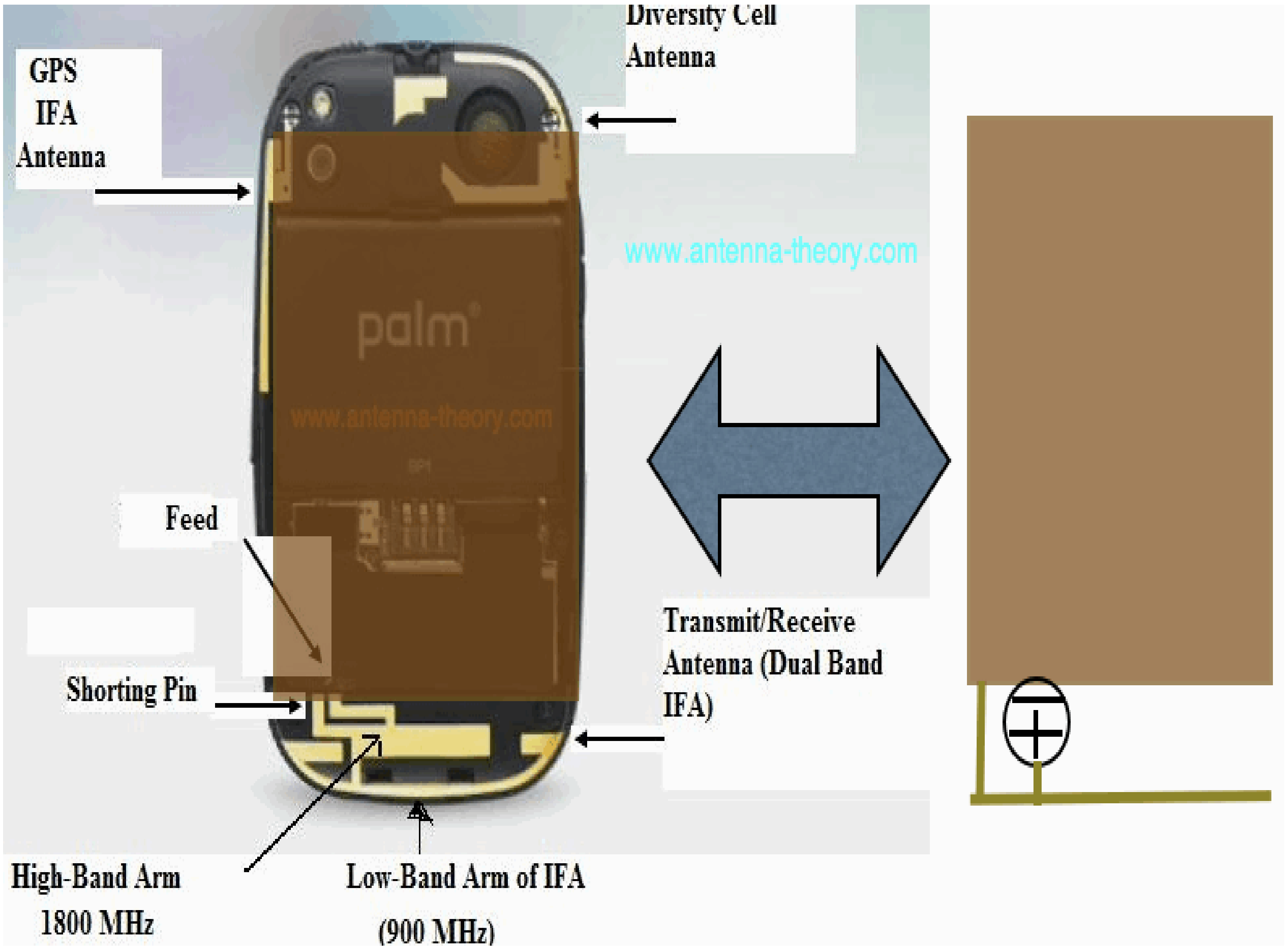
- There are two types of tests:

1. A line of sight condition
2. An out of sight condition

- In Lee and Brandt's Test the transmitter was located 100 m above sea level and measured areas were about 12 m above sea level.
- The received signal from 4-dB gain antenna was 4-dB stronger than that from whip antenna under line-of-sight conditions.
- The received signal from 4-dB gain antenna was 2-dB stronger than that from whip antenna under out of sight conditions.

Mobile High Gain Antennas continued------

- Therefore a 2-dB or 3-db gain antenna is sufficient for general use.
- An antenna with gain higher than 2-dB or 3-dB does not serve the purpose of enhancing reception level.
- Moreover, measurements reveal that elevation angle for scattered signals received in urban areas is greater than that in suburban areas.



GPS
IFA
Antenna
Diversity Cell
Antenna
www.antenna-theory.com
palm
www.antenna-theory.com
Feed
Shorting Pin
Transmit/Receive
Antenna (Dual Band
IFA)
High-Band Arm
1800 MHz
Low-Band Arm of IFA
(900 MHz)