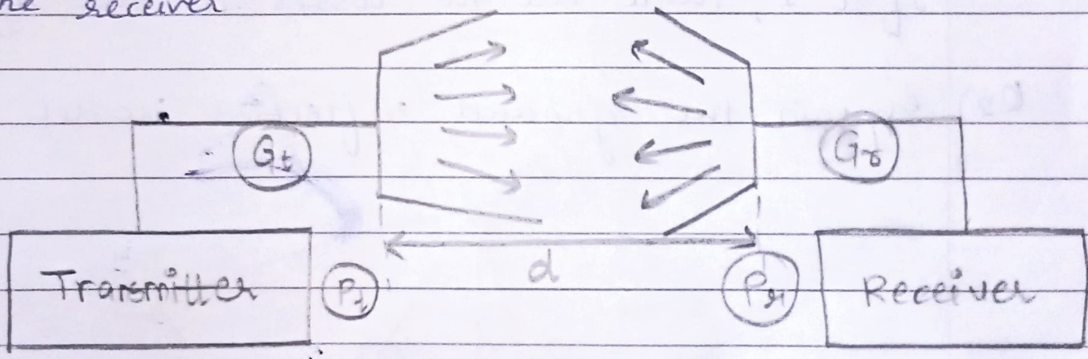
Name - Divyanshi Rathore
Class - TE ENTC B   Roll no - 61
Subject - Cellular Networks

Assignment 1 on Unit 1

Q1.) Explain the free space propogation model in detail.

→ Free space propogation model is used for predecting the receiving signal strength when the transmitter and receiver has a clear line of sight (LOS) path between them. The function of the free-space model is to predict the received signal strength as a function of the separation (d) between the transmitter & the receiver



The free space power received by a receiving antenna is given by free space equation as:-

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

where,

$P_r(d)$ = Received power
P_t = Transmitted power
G_t = Gain of transmitting antenna
G_r = Gain of receiving antenna
λ = wavelength

L = System loss factor

The value of L is greater than or equal to 1. The gain of an antenna is related to effective area Ae with the following expression,

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

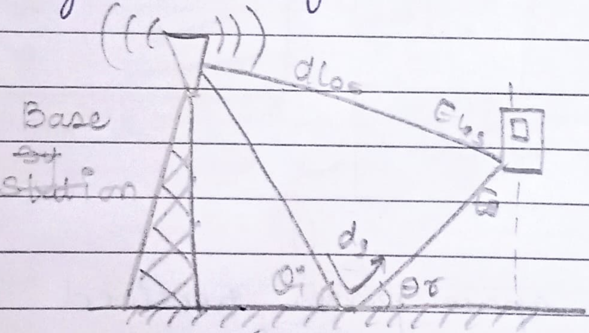
where, $\lambda = \frac{c}{f}$ &

f is carrier frequency in Hz.

The losses L ($L \geq 1$) are generally corresponding to the attenuation due to transmission line. After losses & antenna losses.

If L = 1, There are no losses in the system.

Q2.) Explain the ground reflection model in details.



→ ① In free space, the signal travels from the transmitter to receiver along the signal path but in realistic environment, the signal reaches the receiver through several different paths.

② The line of sight (LOS) component between base station & mobile terminal carries the signal similar as in free space.

③ Another path of signal is through the reflection of the earth's surface. These two paths travel differently distances based on height of base station antenna (h_t) & height of mobile terminal antenna (h_r)

4.) Ground reflection model is applicable when the distance between the transmitting & receiving antenna is greater that 10km.

5.) ~~Ang~~ And the height of the antenna is approximately 50m.

6.) The total electric field,

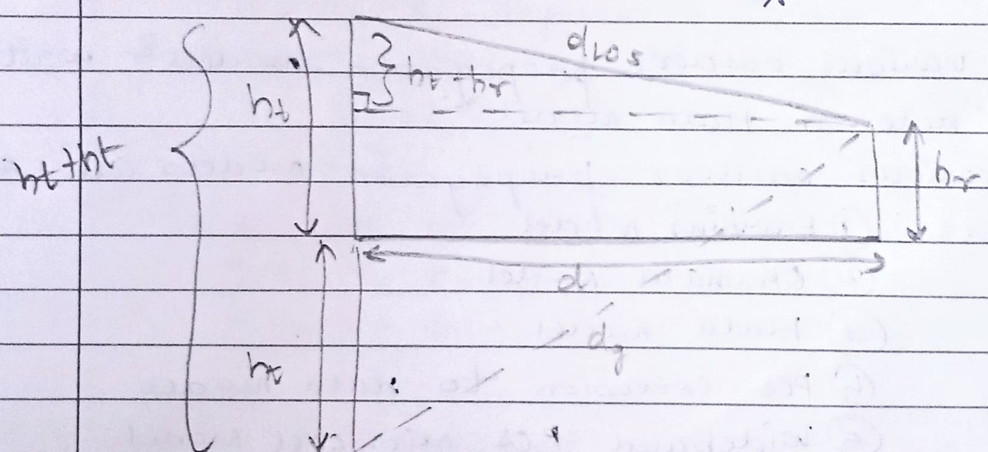
$$E_{TOTAL} = E_{LOS} + E_g$$

7.) The ~~toat~~ total electric field intensity depends on two factors,

① Path difference = d_{LOS}, d_g

$$\Delta = d_g - d_{LOS}$$

② ~~Patte~~ Phase difference $= \frac{2\pi}{\lambda}$



using pythagoras theorem,

$$d_{LOS} = \sqrt{(h_t - h_r)^2 + h^2}$$

$$d_g = \sqrt{(h_t + h_r)^2 + h^2}$$

$$\Delta = d_g - d_{LOS}$$

$$= \sqrt{(h_t + h_r)^2 + h^2} - \sqrt{(h_t - h_r)^2 + h^2}$$

$$\Delta = \frac{2h_t h_r}{d}$$

$$E_{total} = \frac{E_0 d_0}{2d} \cdot \frac{2\pi}{\lambda} \cdot \Delta d$$

$$\therefore E_{total} = \frac{E_0 d_0}{2d} \times \frac{2\pi}{\lambda} \times \frac{2h_t h_r}{d}$$

where d_0 = fraunfhoffer distance

Δd = path difference

$\frac{2\pi}{\lambda}$ = phase difference

$\frac{E_0 d_0}{2d}$: Electric field intensity at fraunhoffer distance.

Q3.) State various outdoor propogation models & write a short note on Hata model

→ The various outdoor propogation models are as follows:-
1. Durkin's model.
2. Okumara model.
3. Hata model
4. PCS extension to Hata model
5. Wideband PCS Microcell Model
6. Walfish & Bertoni Model (WBM)

Hata model:-
1. Hata model is an emperical formula for propogation loss which presents analytical approximation for graphical information based on Okumura model
2. It is valid in the frequency range from 150-1500 MHz only.
3. Height of transmitting antenna is 30m to 200m

CELEBRO
DATE
PAGE

& heigut of receiving antenna is 1m to 20m.

(4) Hata model is well suited for large cell mobile systems.

(5) The standard formula for median path loss in urban areas is given by the following equation

$$L_{50}(dB) = 69.55 + 26.16 \log f_c - 13.82 \log H_t - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d$$

where,

f_c = frequency in (MHz) from 150 MHz to 1500 MHz

h_{te} = effective transmitter (base station) antenna height ranging from 30m to 200m

h_{re} = Effective receiver (mobile) antenna height ranging from 1m to 10m.

d = $T_x - R_x$ separation in km.

$a(h_{re})$ = correction factor for effective mobile antenna height

(6) The mobile antenna correction factor for a large city is

$a(h_{re}) = 8.29 (\log 1.54\, h_{re})^2 - 1.1\,dB$ for $f_c < 300$ MHz

$a(h_{re}) = 3.2 (\log 11.75\, h_{re})^2 - 4.97$ for $f_c \geq 300$ MHz

Q4.) Explain the concept of diversity reception in wireless communication.

→ (1) Diversity technique is the most effective technique that can be used to nullify the effect of multipath fading.

(2) Diversity technique employ some form of time space or frequency diversity either or both the transmission & reception of desired signal.

(3) Any fading of the transmitted signal that occurs will not remain the same over time nor will it be

same over different signal paths or be the same for different frequencies. Therefore, if some form of time, space or frequency diversity is used, the effects of signal fading can be migrated.

(4) Diversity technique is a method for improving the ~~reat~~ redability of a message signal by utilizing two or more communication channels with different characteristics.

(5) The diversity technique provide two or more number of inputs at the mobile reception end such that fading among these two inputs are not co-related.

Q5.) Explain the time Diversity, frequency diversity & space diversity in detail. also write difference between Microscopic & Macroscopic diversity.

→ Time Diversity:-

(1) In the method, the information is transmitted repeatedly at specific time spacing that would exceed the coherence time of the mobile channel & this will lead to repeatition of signals at several times, irrespective of fading conditions.

(2) When an identical information is sent for different time slots, it is possible to obtain diversity branch signals.

(3) The time diversity techniques is suited for spread spectrum CDMA system, in which RAKE receiver is used for reception.

Frequency Diversity:-

(1) Frequency diversity utilizes transmission of same signal at different spaced frequency carriers acheiving two independently fading versions of a signals

CELEBRO
DATE
PAGE

(2) Frequency diversity is a costly mechanism to use because of the difficulties to generate several transmitted signals & combining signals received at several different frequencies simultaneously.
(3) There are two types of frequencies diversity:-
  (1) Frequency hop spredd spectrum (FHSS)
  (2) Direct sequence spread spectrum (DSSS)

Space Diversity-
(1) In Space Diversity, two antennas are separated by a distance 'd' so as to get the two input signal with low correlation among fading aspects
(2) Space Diversity is used to improve signal to noise ratio (SNR)
(3) Variations in Space Diversity are 3-
  a.) Multiple Input Single Output (MISO)
  b.) Single Input multiple Output (SIMO)
  c.) multiple Input multiple output (MIMO)
(4) MISO & SIMO will provide better SNR with low cost as compared to MIMO

Macroscopic Diversity
(1) Prevents large scale fading
(2) Large scale fading is caused by shadowing due to variation in both the terrain profile & the nature of surrounding
(3) Large scale fading is log normally distributed signal

Microscopic Diversity
(1) Prevents Small Scale fading
(2) Small scale fading is caused by multiple reflections from the surrounding.
(3) It is characterized by deep & rapid amplitude ~~fra~~ fluctuations which occurs as the mobile moves

CELEBRO

DATE
PAGE

	over distances of a few wavelength.
(ii) This fading is prevented by selecting an antenna which is not shadowed when others are, this allows increase in the signal to noise ratio	(ii) This fading is prevented by selecting an antenna which gives a strong signal that mitigates this small signal fading effect.

Q7.) Find the far-field distance for an antenna with maximum dimension of 1m & operating frequency of 900MHz. If the antennas have unity gain. Calculate the path loss.

→ Given :- Maximum dimension = 1m

Operating frequency = 900 MHz
= 900×10^6 Hz

$G_r = G_t = 1$

(1) Fraunhofer distance.

$$R = \frac{2D^2}{\lambda}$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = 0.333$$

$$\therefore R = \frac{2(1)^2}{0.333} = 6.006 \approx 6$$

(2) $$PL(dB) = -10\log\left(\frac{\lambda^2}{(4\pi)^2 d^2}\right)$$

$$= -10\log\left(\frac{(0.333)^2}{(4\pi)^2\times(6)^2}\right)$$

$$= 47.17\,dB$$

$\therefore PL(dB) = 47.17\,dB$.

Q8.) If a transmitter ~~powi~~ produces 50 watts of power, express the transmit power in units of (a) dBm & (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency find the received power in dBm at a free space distance of 100 m from the antenna. What is Pr (10 km)? Assume unity gain for the receiver antenna.

→ Given :-

$P_t = 50\,W$, unity gain $= G_r = G_t = 1$

$f = 900\,MHz = 900 \times 10^6\,Hz$

$d = 100\,m$

(1) Pt in dB watt $= 10 \log (P_t)$

$= 10 \log (50)$

$= 16.989\,dB$.

(2) Pt in dBm $= 10 \log \left(\frac{P_t}{1\,mW} \right)$

$= 10 \log \left(\frac{50}{10^{-3}} \right)$

$= 10 \log (50 \times 10^3)$

$= 46.98\,dBm$.

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

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{900 \times 10^6} = 0.333$

$P_r(d) = \frac{50 \times 1 \times 1 \times (0.333)^2}{(4\pi)^2 \times d^2}$

CELEBRO

DATE

PAGE

$$= \frac{50 \times 1 \times 1 \times (0.333)^2}{(4\pi)^2 \times (100)^2}$$

$= 3.5 \times 10^{-6} W$

$= 3.5 \mu W$

$P_r(d)$ in dBm $= 10 \log (3.5 \times 10^{-6} \times 10^3)$

$= -24.55$ dB

Q9) A mobile is located 5km away from a base station and uses a vertical $\lambda/4$ Monopole antenna with a gain of 2.55 dB to receive a cellular radio signal. The electric field at 1km from the transmitter is measured to be 10^{-3} V/m. The carrier frequency 900MHz used for the system.

a) Find the length & effective apperiture of the receiving antenna.

b.) Find the received power at the mobile using 2 ray ground reflection model assuming the height of the transmitting antenna is 50m & the receiving antenna is 1.5m above ground.

→ (a) Given:-

$F = 900 MHz = 900 \times 10^6 Hz$

$G_r = 2.55 dB$

$$l = \frac{\lambda}{4}$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{900 \times 10^6} = 0.333 m$$

1) $$l_r = \frac{0.33}{4} = 0.083 m$$

$l_r = 0.083$ m.

$\therefore l_r = 8.3$ cm

2) $$A_e = \frac{G_r \times \lambda^2}{4\pi}$$

CELEBRO
DATE
PAGE

$G(dB) = 10\log(G_{nor})$

$\therefore \text{Antilog}_{10}\left(\frac{2.55}{10}\right) = G_{nor}$

$\therefore G_{nor} = 1.798$

$A_e = \frac{1.798 \times (0.33)^2}{4 \times 3.14}$

$\therefore A_e = 0.0155 m^2$

(b) Given:-

$E_o = 10^{-3}$, $d_o = 10^3$, $d = 5km = 5\times10^3 m$

$h_t = 50m$, $h_r = 1.5m$

$E_{total} = \frac{E_o d_o}{2d} \times \frac{2\pi}{\lambda} \times \frac{2h_t h_r}{d}$

$= \frac{10^{-3}\times10^3\times 2\times3.14\times2\times50\times1.5}{2\times(5\times10^3)^2\times0.33}$

$\therefore E_{total} = 114.18\times10^{-6} V/m$

$P_r = \frac{E^2}{\eta} \cdot A_e$

$= \frac{(114.18\times10^{-6})}{120\times\pi} \times 0.0155$

$P_r = 5.36\times10^{-3}$ watt

$P_r(dB) = 10\log(P_r \text{ in watt})$

$= 10\log(5.4\times10^{-10}) m$

$P_r(dB) = -92.67 m$

Q10) Employing Hata model compute the median loss at a distance $d = 8km$. when carrier frequency $f_c = 2.1GHz$ $H_t = 40m$, $H_{re} = 2m$ for a large city.

→ Given:- $f_c = 2.1GHz = 2100$; $H_t = 40m$, $H_r = 2m$

$d = 8km = 8\times10^3 m$

Area = Large city

$a(h_{re}) = 3.2(\log 11.75 h_{re})^2 - 4.97$

$= 3.2(\log(11.75)(2))^2 - 4.97$

$= 1.045$

$L_{50}(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_t - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d.$

$= 69.55 + 26.16 \log(2100) - 13.82 \log(40) - 1.045 + (44.9 - 6.55 \log(40)) \times \log 8$

$\therefore L_{50}(dB) = 164.35 \, dB$

Q6.) Consider a transmitter which radiates a sinusoidal carrier frequency of 1850 MHz. for a vehical moving 60 mph. Compute the received carrier frequency ~~is~~ if the mobile is moving
(a) directly towards the transmitter.
(b) directly away from the transmitter.
(c) in a direction which is perpendicular to the direction of arrival of the transmitted signal.

→ Given:-

Carrier frequency $f_c = 900 \, MHz = 900 \times 10^6 \, Hz$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{900 \times 10^6} = 0.33 \, m.$$

Vehicle speed, $V = 70 \times \frac{1000}{60} \times 60 = 19.44 \, m/s$

(a) The vehicle is moving directly towards the transmitter.

$$f = f_c + f_d = 900 \times 10^6 + \frac{19.44}{0.33}$$

$= 900 \, MHz$

(b) The vehicle is moving directly away from the transmitter.

The received frequency is given by,

$$f = f_c - f_d = 900 \times 10^6 - \frac{19.44}{0.33} \approx 899.9 \, MHz$$

(c) The vehicle is moving perpendicular to the angle of arrival of transmitted signal
In this case, $\theta = 90°$, $\cos\theta = 0$ & there is no doppler shift.
The received signal frequency is the same as the transmitted frequency of 900 MHz.