Experiment-1

1.1 Aim of the Experiment:

To analyse the characteristics of (i) Friis free space path loss model (ii) Log distance path loss model and (iii) Hata path loss model.

1.2 Hardware and Software Required:

- Personal Computer (PC)
- MATLAB Software

1.3 Theory

- Path loss (PL) refers to the loss or attenuation a propagating electromagnetic wave or signal encounters along its path from transmitter to the receiver.
- In linear scale, it is defined as the ratio between Transmitted power (P_t) and Received power (P_r).

$$P_L = \frac{P_t}{P_r} \tag{1.1}$$

- In Logarithmic scale, it is defined as the difference between Transmitted power in dB (P_t) and Received power in dB (P_r).

$$P_L \text{ dB} = 10 \log_{10} \frac{P_t}{P_r} \text{ dB} \tag{1.2}$$

1.3.1 Friis Free Space Path loss Model:

- It is used to predict the path loss when there is a clear Line of Sight (LOS) path exists between transmitter and receiver. .
- The receiver power is obtained at the receiver due to this path loss model is given as

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L} \tag{1.3}$$

P_r = Received signal power in Watts

d=Distance between transmitter and receiver in meter

P_t= Transmitted signal power in Watts

G_t = Gains of the transmitter antennas

G_r= Gains of the receiver antennas

λ = Wavelength of transmitted signal in meters

L= System losses

- In logarithmic scale, Eq^n (1.3) can be represented as

$$P_r = 10log_{10}(P_t) + 10log_{10}(G_t) + 10log_{10}(G_t) + 20log_{10}(\lambda) - 20log_{10}(4\pi d) - 10\ log_{10}\ (L) \quad (1.4)$$

1.3.2 Log distance path loss model:

- Log distance path loss model is a generic model and an extension to Friis Free space model. It is used to predict the propagation loss for a wide range of environments which includes shadowing.
- It is represented as

$$PL(d) = PL(d_0) + 10\ \eta\ log_{10}\left(\frac{d}{d_0}\right) + \chi \quad (1.5)$$

d_0= Reference distance

η = Path Loss exponent.

χ = A zero-mean Gaussian distributed random variable with standard deviation σ. This variable is used only when there is a shadowing effect.

1.3.3 Hata Path loss Model:

- The Hata model is an empirical formulation of the graphical path loss data provided by Okumura and is valid from 150 MHz to 1500 MHz.
- Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations.
- The standard formula for median path loss in urban areas is given by

$$PL_{Hata} = 69.55 + 26.26log_{10}(f_c) - 13.82\ log_{10}(h_{te}) - a(h_{re}) + (44.9 - 6.55h_{te})log_{10}\ (d) \quad (1.6)$$

Where

f_c is the frequency (in MHz) from 150 MHz to 1500 MHz

h_{te} is the effective transmitter antenna height ranging from 30 m to 200 m

h_{re} is the effective receiver antenna height ranging from 1 m to 10 m

d is the distance between transmitter and receiver (in km)

$a(h_{re})$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area.

For a small to medium sized city, the mobile antenna correction factor is given by.

$$a(h_{re}) = (1.1\ log_{10}\ (f_c) - 0.7)h_{re} - (1.56\ log_{10}\ (f_c) - 0.8) \quad (1.7)$$

For a large city, it is given by

$$a(h_{re}) = 8.29(log_{10}(1.54)\, h_{re})^2 - 1.1 \quad for\ fc \leq 300MHz \qquad (1.8)$$

$$a(h_{re}) = 3.2(log_{10}(11.75)\, h_{re})^2 - 4.97 \quad for\ fc \geq 300MHz \qquad (1.9)$$

1.4 Code

1.4.1 Friis Free Space Path loss Model:

```
clc;
clear all;
close all;
%-----------Input section-----------------------
Pt=5; % Transmitted power in dB
Gt=2; % Gain of the Transmitted antenna in dBi
Gr=3; % Gain of the Receiver antenna in dBi
d =1:10:100; % Distance in meters
L=2; % Other System Losses
f=2.4e9; % Transmitted signal frequency in Hertz
lambda=(3*10^8)/f; % Wavelength in meters
Pr=Pt+Gt+Gr+(20)*log10(lambda)-(20)*log10(4*pi*d)-L;
PL=Pt-Pr;
plot(d,PL,'b-*','LineWidth',2);
xlabel("Distance between Transmitter and Receiver (d) in meters");
ylabel("Path loss in dB");
grid on;
```

1.4.2 Log distance path loss model:

```
clc;
clear all;
close all;
Pt=5; % Input transmitted power in dB
Gt=3; % Gain of the Transmitted antenna in dBi
Gr=2; % Gain of the Receiver antenna in dBi
f=2.4e9; % Transmitted signal frequency in Hertz
d0=1; % Let’s assume reference distance = 1Km
d=1:0.1:50; % Array of distances to simulate
L=2; % Other System Losses, No Loss case L=1
sigma=2;% Standard deviation of log Normal distribution
n=2; % path loss exponent
lambda=3*10^8/f; % Wavelength in meters
Pr_d0=Pt+Gt+Gr+((20)*log10(lambda))-(20*log10(4*pi*d0))-(10*log10(L));
     % Received power at reference distance
PL_d0=Pt-Pr_d0;       % Path loss at reference distance
X = sigma*randn(1,numel(d)); % Normal random variable
PL_d1=PL_d0+10*n*log10(d/d0);% Mean Path loss
```

```
PL_d2=PL_d0+10*n*log10(d/d0)+X;% Log Distance path loss
plot(d,PL_d1,'r-o');
hold on;
xlabel("Distance between Transmitter and Receiver (d) in Km");
ylabel("Path loss in dB");
plot(d,PL_d2,'b-o');
grid on;
legend('Median Path loss','Path loss due to shadowing');
```

1.4.3 Hata Path loss Model:

```
clc;
clear all;
close all;
ht=30; % Height of the transmitter
hr=3; % Height of the receiver
d=1:5:100; % Distance in Km

%---------------------------For small and medium city------------------
--%
f1=100; % Frequency in MHz
cf_medium=((1.1)*log10(f1)-0.7)*hr-((1.566)*log10(f1)-0.8); %
Correction factor
PL_medium=69.55+((26.26)*log10(f1))-((13.82)*log10(ht))-
           (cf_medium)+(44.9-6.55*log10(ht))*log(d); % Path loss
figure(1);
plot(d,PL_medium,'b-*','LineWidth',1)
xlabel("Distance between Transmitter and Receiver (d) in Km");
ylabel("Path loss in dB");
title("Path loss with Hata model for small or Medium city");
grid on;

%----------- For Large city with Frequency<=300MHz---------------------
------------------------------------------------%
f2=200; % Frequency in MHz
cf_large1=(8.29*(log10(1.54)*hr).^2-1.1);  % Correction factor
PL_large1=69.55+(26.26)*log10(f2)-(13.82)*log10(ht)-cf_large1+((44.9-
(6.55)*log10(ht)))*log10(d); % Path loss
figure(2);
plot(d,PL_large1,'r-o','LineWidth',1)
xlabel("Distance between Transmitter and Receiver (d) in Km ");
ylabel("Path loss in dB");
title("Path loss with Hata model for Large city for frequency
<=300MHz");
grid on;


%--------------------For Large city with Frequency >=300MHz
f3=350; % Frequency in MHz
cf_large2=(3.2*(log10(11.75)*hr).^2-4.97); % Correction factor
```

```
PL_large2=69.55+(26.26)*log10(f3)-(13.82)*log10(ht)-cf_large2+((44.9-(6.55)*log10(ht)))*log10(d); % Path loss
figure(3);
plot(d,PL_large2,'m-+','LineWidth',1)
xlabel("Distance between Transmitter and Receiver (d) in Km");
ylabel("Path loss in dB");
title("Path loss with Hata model for Large city for frequency >=300MHz");
grid on;
```

1.5 Simulation Results:

1.5.1 Friis Free Space Path loss Model:

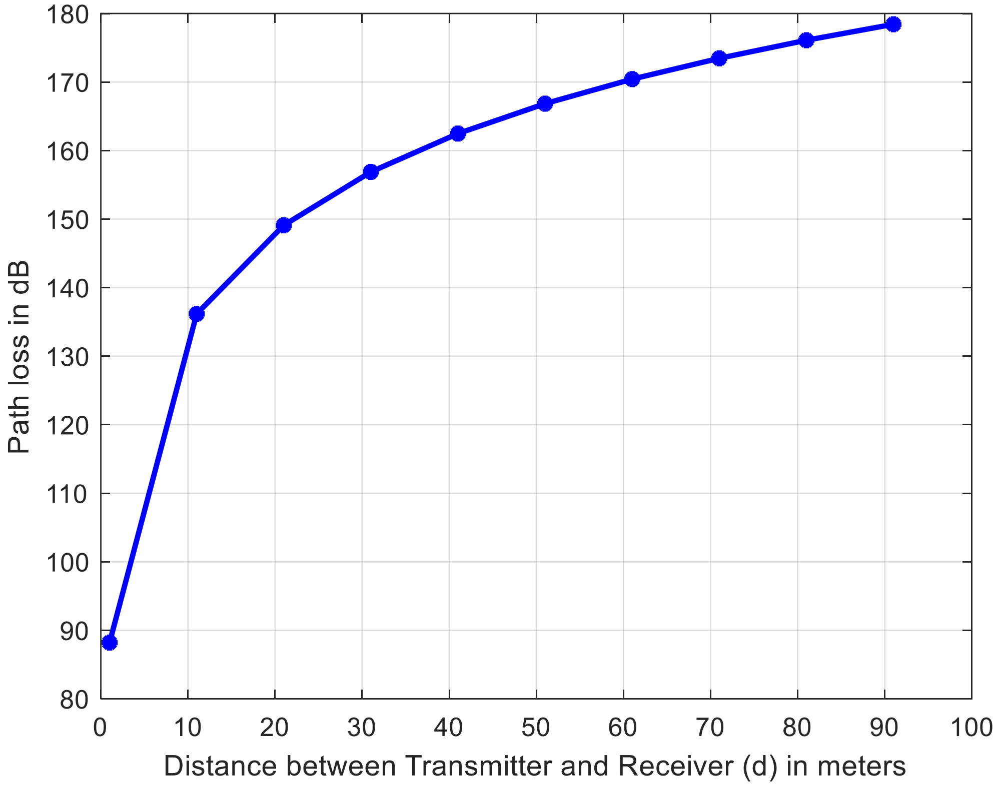

Fig.1.1 Path loss with Friis Free Space Path loss model

1.5.2 Log distance path loss model:

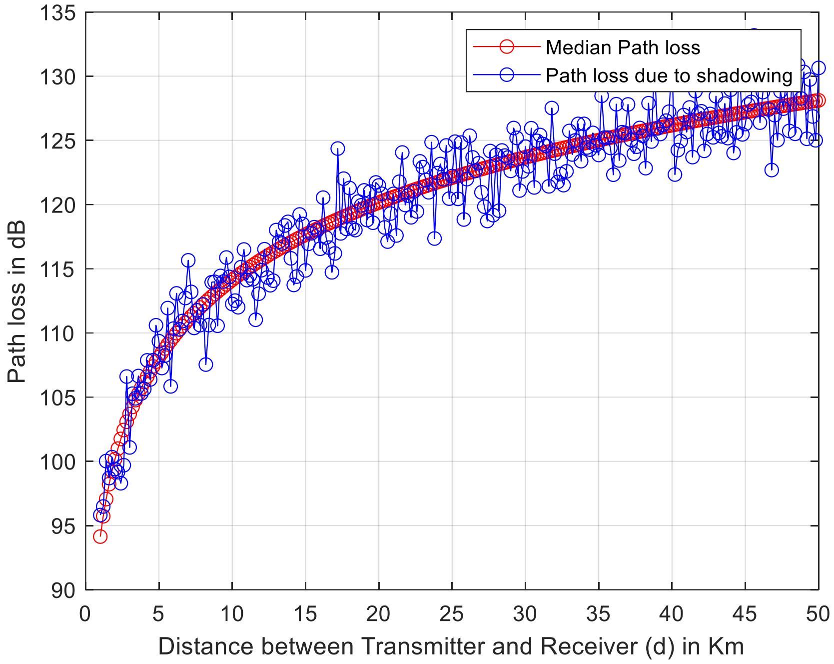

Fig.1.2 Path loss with Log distance Path loss model

1.5.3 Hata Path loss Model:

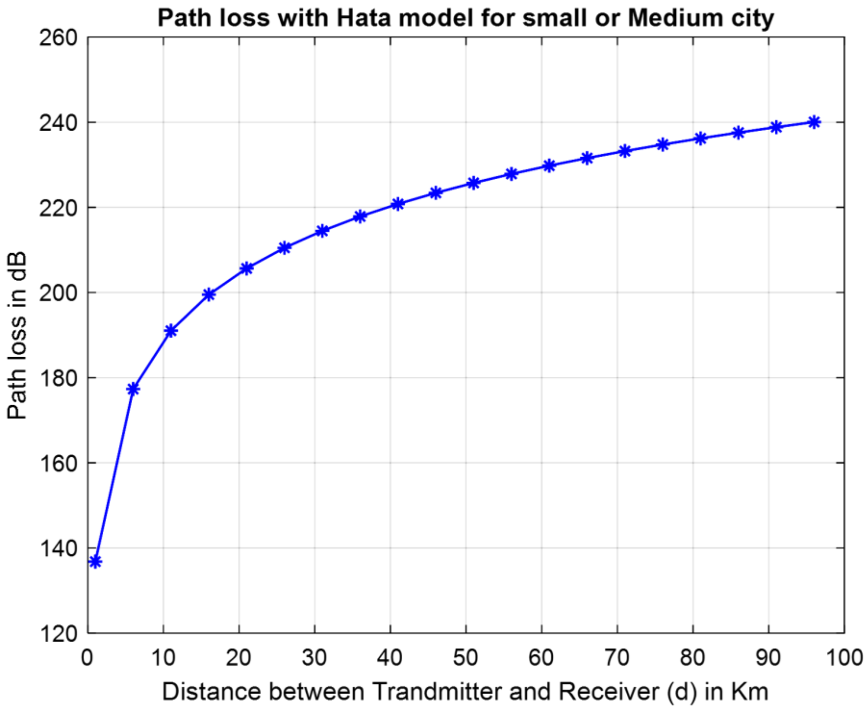

Fig.1.3 Path loss with Hata model for small or medium city

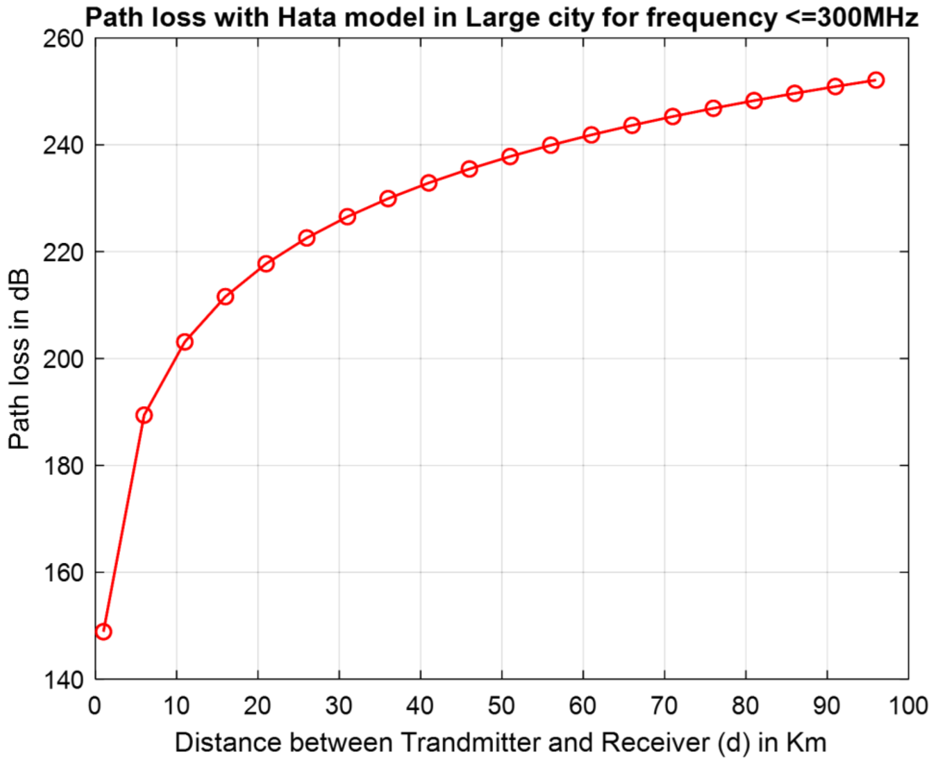

Fig.1.4 Path loss with Hata model in large city for frequency <=300MHz

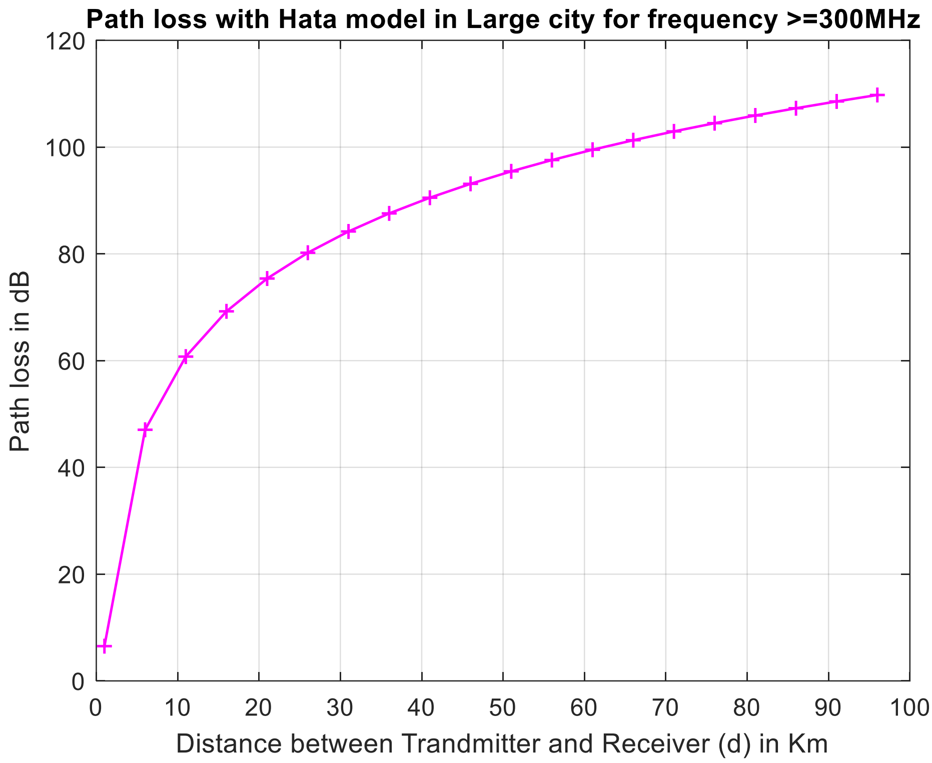

Fig.1.5 Path loss with Hata model in large city for frequency >=300MHz

1.6 Conclusion:

The characteristics of Friis free space path loss model, Log distance path loss model, and Hata path loss model were analysed with MATLAB simulation software.