ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.3

Analysis and Prediction of Telecommunication Medium Pathloss in Urban Areas

Dr. Ugochukwu Kamalu[1], Innocent. O. Dibie[2]
Senior Lecturer[1], ME Student[2]
Department of Electrical & Electronic Engineering
University of Portharcourt, Nigeria

Abstract:
Telecommunications medium characteristics influence the development and deployment of communication systems. Unlike wired medium that are stable and predictable, wireless/radio channels are extremely random and do not offer easy analysis and prediction. Pathloss results when an electromagnetic wave travels though space from transmitter to receiver. A pathloss propagation model is a mathematical formulation for the description of radio wave propagation as a function of frequency, distance and other conditions. Prediction of telecommunications medium pathloss is a fundamental requirement for designing any mobile/wireless communication system. It facilitates appropriate planning, interference estimations, frequency assignments etc. Several pathloss models are available, such as: Okumura-Hata model, COST231model, Ericsson model and Stanford University Interim (SUI) model etc. Propagation models that predict the pathloss for an arbitrary transmitter (base station) – receiver (mobile station) separation distance which is useful in estimating the radio coverage area of a transmitter are called large-scale propagation models, because they define pathloss over large transmitter (base station) – receiver (mobile station) separation distances. Our aim, in this paper, is to simulate the propagation pathloss models of Okumura-Hata, COST231, Ericsson and SUI using MATLAB software. The simulation is done for varying Mobile Station (MBS) antenna height, Transmitter (BTS)-Receiver (MBS) distance and Base Station (BTS) antenna height, assuming a hypothetical telecommunication network/system operating at 2000 MHz., and simulation carried out specifically for urban environment. The simulation results of the chosen models are analyzed to identify a suitable model in the urban environment. The analysis is done based on the effect of variation of the distance between the transmitter and receiver, the transmitter and receiver antenna height on the prediction of path loss.

Keywords: Radio Propagation Model, Multipath, Medium, Wired, Wireless, Path, Interference, Coverage Area, Antenna, Transmitter, Receiver.

1.0 INTRODUCTION

Telecommunication medium refers to the channel through which electromagnetic signals embedded with information is propagated or transmitted. It encompasses the intervening region between the transmitter and the receiver. This medium can be fixed (wired) as in copper cables or wireless as in free space. Whichever medium of propagation is involved, there would exist some amount of signal degradation (path loss) as it travels from transmitter to receiver. While analysis and prediction of the path loss experienced with fixed medium is quite deterministic, the contrary is true for wireless medium. In view of the above, analysis and prediction of telecommunication medium path loss in this paper, invariably refers to that of the wireless or mobile system. The ability to build and understand wireless networks hinges on the understanding of how wireless signals are attenuated over distances in realistic environments. Appropriate prediction of the attenuation of a radio signal, can result to a better planning and diagnosis of networks as well as building networks that can adapt to the real radio environment. Propagation models are useful for analyzing and predicting signal attenuation or path loss which may be used as a controlling factor for system performance or coverage so as to achieve perfect reception. It has been found that the mechanisms behind electromagnetic wave propagation are diverse and characterized by certain phenomena such as reflection, refraction and diffraction of waves. These phenomena induce signal scattering, fading and shadowing along the signal path as it propagates from the transmitter to the receiver. “Propagation of the radio waves in urban areas is quite complex because it consists of reflected and diffracted waves produced by multipath propagation. In general, radio wave propagation consists of three main modes; (a) Reflection: It occurs when radio wave propagation in one medium impinges upon another medium with different electromagnetic properties. Part of radio wave energy may be absorbed or propagated through the reflecting medium, resulting in the reflected wave that is attenuated. (b) Diffraction: It is a phenomenon by which propagating radio waves bend or deviate in the neighborhood of obstacles. (c) Scattering: It occurs when radio waves hit a rough surface or an object which is having a size much smaller than the signal wave length” (Pardeep, Parveen & Shashi 2014, p.335). A radio pathloss model is an empirical mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance another conditions. Path loss model describes the signal attenuation from transmitter to receiver antenna as a function of distance, carrier frequency, antenna heights and other significant parameters like terrain profile such as urban, suburban and rural(Nafaa et al 2014, p.693). Most radio propagation models are derived using a combination of analytical and empirical methods. In general, most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and where the presence of high rise buildings causes severe diffraction loss. In this paper, the path loss applicable to urban environment is analyzed and predicted using MATLAB simulation of Okumura-Hata model, COST231 model, Ericson mode land SUI model. These models were used to analyze and predict varying Mobile Station (MS) antenna height, propagation distance, and Base Station (BTS) antenna height considering the hypothetical telecommunication network/system to operate at 2000 MHz carrier frequency.

2.0 PATH LOSS PREDICTION MODELS AND SIMULATION FOR URBAN AREAS

Pathloss characteristics of a medium are important in wireless telecommunication and signal propagation. Path loss may result from different circumstances, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss and absorption. Path loss is also affected by terrain contours, environment(urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height of the base station (transmitter) and mobile station(receiver)antennas."Theurban environment is the most common and unpredictable propagation environment in cellular communication systems which is characterized by dense urban, urban, and suburban environments with the density of civil structure variation. The signal received at the receiver is aresult of direct rays, reflected rays, and shadowing" (Rony2016, p.9)The signal radiated from a transmitter may travel along several and different paths to a receiver simultaneously, a term referred as multipath propagation. Multipath propagation can either increase or decrease received signal strength, depending on whether the individual multipath wave fronts interfere constructively or destructively. The calculation of path loss is usually termed prediction. It is not that much easy because the path loss depends on many parameters during the signal propagation from the transmitter to receiver but we can predict the path loss by considering some important factors. Exact prediction is possible only for simpler cases, such as the free space propagation or the flat-earth model. For practical cases the path loss is calculated using a number of approximations called models. These models can be broadly categorized into three types; empirical, deterministic and stochastic. Empirical models are those based on observations and measurements alone. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Stochastic models, on the other hand, model the environment as a series of random variables. Macro cells are generally large, providing a coverage range in kilometers and used for outdoor communication. Several empirical path loss models have been determined for macro cells. The empirical models use existing equations obtained from results of several measurement efforts. Among numerous propagation models are; Okomura– Hata Model, COST 231 Model and Ericson Model and SUI model etc.

2.1OKOMURA-HATA MODEL

One of the most general models for pathloss prediction in large urban macro cells is Okumura's model. This model is applied for frequency ranges of 150-1920 MHz and over distances of 1-100 km. Okumura used extensive measurements of base station-to-mobile signal attenuation to develop a set of curves giving median attenuation relative to free space of signal propagation in irregular terrain. The base station heights for these measurements were 30-100m. Hata Model otherwise called Okomura-Hata model is based on the Okumara's model with some correction factors. It works within the frequency range of 150 MHz to 1500 MHz. According to Alim et al (2010)this model, which is the most widely used in urban area, is given as below in equation1:

$PL(dB) = 69.55+26.16\log10\ (f)-13.82\log10\ (hb)-(ahm) + (44.9-6.55\log10\ (hb))\ \log10(d)$........... (1)

$ahm=3.2(\log\ (11.75hm))2 - 4.97$

in urban, f> 400MHz

where:

PL = path loss in decibel(dB)

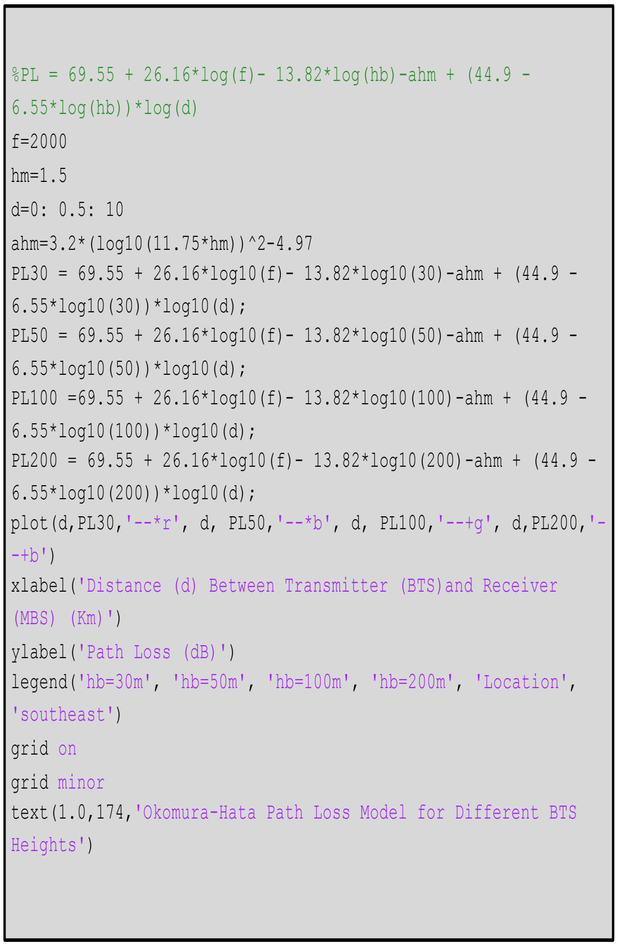
f = frequency in megahertz (MHz)

d= Distance between transmitter and receiver antennas in kilometers (km)

hb= Base station antenna height in meters (m)

hm=Mobile station antenna height in meters(m)

This pathloss model desribed in equation 1 is simulated in MATLAB using the code listing in figure1.It represents the relationship between pathloss and the distance between transmitter and receiver at varying transmitter antenna heights. The simulation result is as shown in figure2.



```
%PL = 69.55 + 26.16*log(f)- 13.82*log(hb)-ahm + (44.9 -
6.55*log(hb))*log(d)
f=2000
hm=1.5
d=0: 0.5: 10
ahm=3.2*(log10(11.75*hm))^2-4.97
PL30 = 69.55 + 26.16*log10(f)- 13.82*log10(30)-ahm + (44.9 -
6.55*log10(30))*log10(d);
PL50 = 69.55 + 26.16*log10(f)- 13.82*log10(50)-ahm + (44.9 -
6.55*log10(50))*log10(d);
PL100 =69.55 + 26.16*log10(f)- 13.82*log10(100)-ahm + (44.9 -
6.55*log10(100))*log10(d);
PL200 = 69.55 + 26.16*log10(f)- 13.82*log10(200)-ahm + (44.9 -
6.55*log10(200))*log10(d);
plot(d,PL30,'--*r', d, PL50,'--*b', d, PL100,'--+g', d,PL200,'-
-+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver
(MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hb=30m', 'hb=50m', 'hb=100m', 'hb=200m', 'Location',
'southeast')
grid on
grid minor
text(1.0,174,'Okomura-Hata Path Loss Model for Different BTS
Heights')
```

Figure1: Code Listing for Okomura-Hata Model (hm = 1.5m and hb =30m, 50m, 100m and 200m)

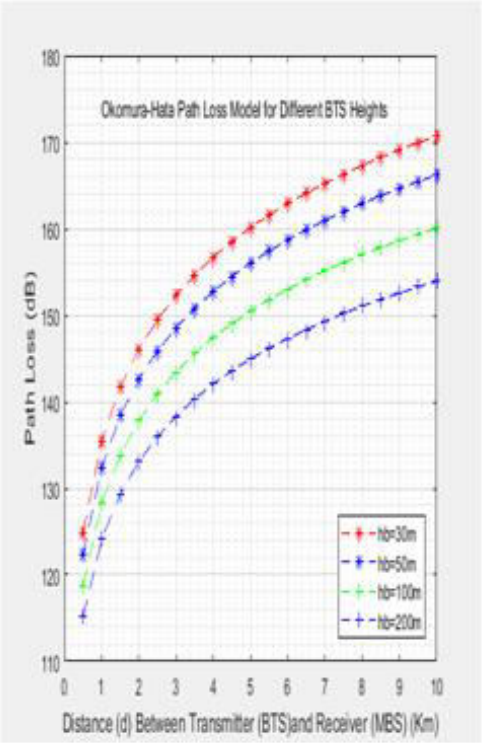
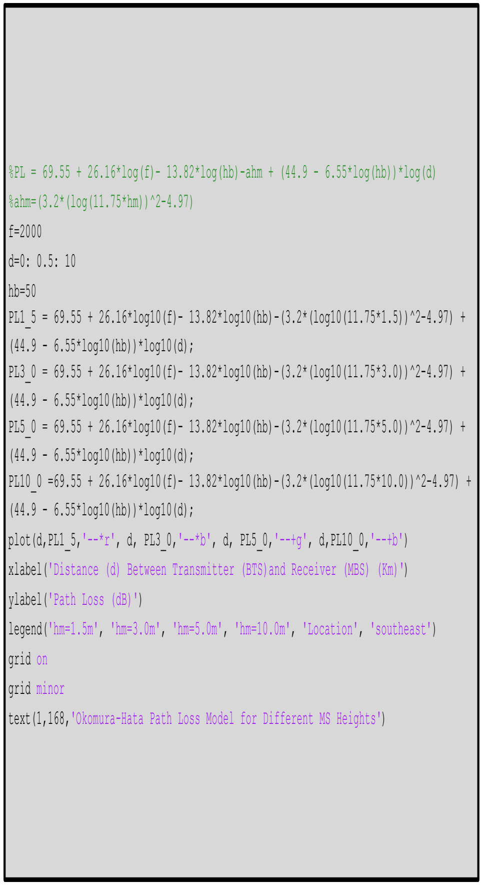


Figure.2.Path loss versus BTS- MBS distance with different base station antenna heights(Okumura-Hata Model)

In order to establish the relationship between pathloss and transmitter-receiver distance as receiver antenna height varies in line with equation 1, a MATLAB code listing in figure3 is used. The simulation result is as shown in figure4.



```
%PL = 69.55 + 26.16*log(f)- 13.82*log(hb)-ahm + (44.9 - 6.55*log(hb))*log(d)
%ahm=(3.2*(log(11.75*hm))^2-4.97)
f=2000
d=0: 0.5: 10
hb=50
PL1_5 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-(3.2*(log10(11.75*1.5))^2-4.97) +
(44.9 - 6.55*log10(hb))*log10(d);
PL3_0 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-(3.2*(log10(11.75*3.0))^2-4.97) +
(44.9 - 6.55*log10(hb))*log10(d);
PL5_0 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-(3.2*(log10(11.75*5.0))^2-4.97) +
(44.9 - 6.55*log10(hb))*log10(d);
PL10_0 =69.55 + 26.16*log10(f)- 13.82*log10(hb)-(3.2*(log10(11.75*10.0))^2-4.97) +
(44.9 - 6.55*log10(hb))*log10(d);
plot(d,PL1_5,'--*r', d, PL3_0,'--*b', d, PL5_0,'--+g', d,PL10_0,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hm=1.5m', 'hm=3.0m', 'hm=5.0m', 'hm=10.0m', 'Location', 'southeast')
grid on
grid minor
text(1,168,'Okomura-Hata Path Loss Model for Different MS Heights')
```

Figure3: Code Listing for Okomura-Hata Model (hb = 50m and hm =1.5m, 3.0m, 5.0m and 10.0m)

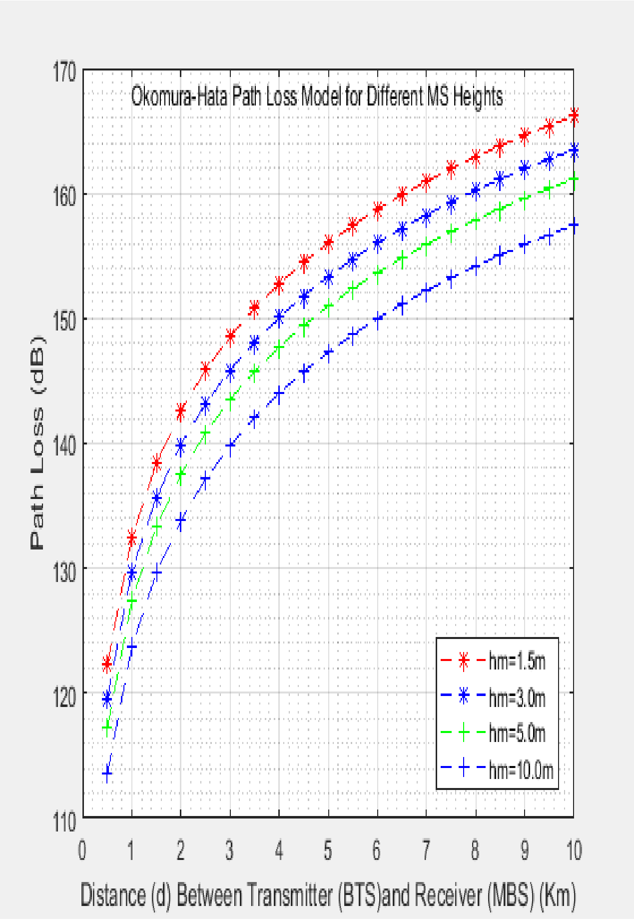


Figure.4.Path loss versus BTS- MBS distance with different mobile station antenna heights(Okumura-Hata Model)

2.2COST 231 MODEL

This model is also called Personal Communication System (PCS) Extension. It is an extension of the Okumura-Hata model designed for use in the frequency band of 1500MHz to 2000MHz, base station height ranges from (30 – 200metres) and receiver antenna height (1- 10m) with distance between two antennas from 1- 2km. “COST231 model is a combination of empirical and deterministic model for estimating the pathloss in an urban area over the frequency range of 800MHz to 2000MHz” (Saptarshi Gupta, 2013). It is applied widely for calculating path loss prediction mobile wireless communication system. It also contains correction factors for urban, suburban and rural (flat) environments, which allows its use for wide application in path loss prediction at the above stated frequency band. The pathloss equation, as given in (Sonia Sharma and Sunita Parashar, 2014) and (Nwalozie Gerald.C et al, 2014)is as follows.

$PL=46.3+33.9\log10\ (f)-13.82\log10(hb)-ahm\ +(44.9-6.55\log10\ (hb))\ \log10(d)+Cm$.......(2)

$ahm = 3.2(\log10(11.75hm))^2-4.97$

in urban, f > 400MHz

where:

Pr = path loss in decibel(dB)

f = frequency in megahertz (MHz)

d = Distance between transmitter and receiver antennas in kilometers (km)

hb= Base station antenna height in meters (m)

hm=Mobile station antenna height in meters(m)
Cm = 3dB for urban environment
ahm = Mobile antenna height correction

Figure 5 is the code listing for the MATLAB simulation of equation2. This gives the relationship between pathloss and transmitter-receiver distance for different transmitter antenna height as modeled by cost231. Figure 6 is the result of the simulation.

```
%PL = 46.3+33.9*log(f)-13.82*log(hb)-ahm+(44.9-6.55*log(hb))*log(d)+3
%ahm = 3.2*(log(11.75*hm))^2-4.97;
f = 2000
hm = 1.5
d = 0:0.5:10
ahm = 3.2*(log10(11.75*hm))^2-4.97;
PL30 = 46.3+33.9*log10(f)-13.82*log10(30)-ahm+(44.9-
6.55*log10(30))*log10(d)+3;
PL50 = 46.3+33.9*log10(f)-13.82*log10(50)-ahm+(44.9-
6.55*log10(50))*log10(d)+3;
PL100 = 46.3+33.9*log10(f)-13.82*log10(100)-ahm+(44.9-
6.55*log10(100))*log10(d)+3;
PL200 = 46.3+33.9*log10(f)-13.82*log10(200)-ahm+(44.9-
6.55*log10(200))*log10(d)+3;
plot(d,PL30,'--*r', d, PL50,'--*b', d, PL100,'--+g', d,PL200,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hb=30m', 'hb=50m', 'hb=100m', 'hb=200m', 'Location',
'southeast')
grid on
grid minor
text(1.4,178,'COST231 Path Loss Model for Different BTS Heights')
```

Figure5: Code Listing for Cost231 Model (hm = 1.5m and hb =30m, 50m, 100m and 200m)

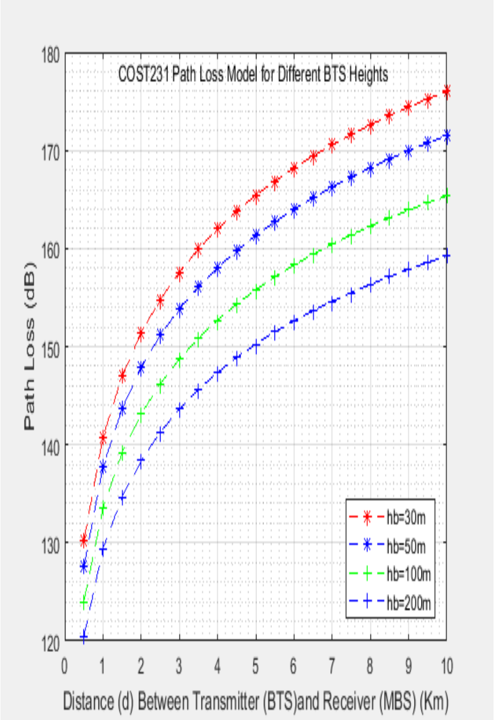


Figure.6. Path loss versus BTS- MBS distance with different base station antenna heights (COST231 Model)

Figure 7 is the code listing for the MATLAB simulation of equation2 depicting the relationship between pathloss and transmitter-receiver distance for different receiver antenna height as modeled by cost231. Figure 8 is the result of the simulation.

```
f = 2000
hb = 50
d = 0:0.5:10
%PL = 46.3+33.9*log(f)-13.82*log(hb)-ahm+(44.9-6.55*log(hb))*log(d)+3
%ahm = 3.2*(log(11.75*hm))^2-4.97;
PL1_5 = 46.3+33.9*log10(f)-13.82*log10(hb)-(3.2*(log10(11.75*1.5))^2-
4.97)+(44.9-6.55*log10(hb))*log10(d)+3;
PL3_0 = 46.3+33.9*log10(f)-13.82*log10(hb)-(3.2*(log10(11.75*3.0))^2-
4.97)+(44.9-6.55*log10(hb))*log10(d)+3;
PL5_0 = 46.3+33.9*log10(f)-13.82*log10(hb)-(3.2*(log10(11.75*5.0))^2-
4.97)+(44.9-6.55*log10(hb))*log10(d)+3;
PL10_0 = 46.3+33.9*log10(f)-13.82*log10(hb)-(3.2*(log10(11.75*10.0))^2-
4.97)+(44.9-6.55*log10(hb))*log10(d)+3;
plot(d,PL1_5,'--*r', d, PL3_0,'--*b', d, PL5_0,'--+g', d,PL10_0,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hm=1.5m', 'hm=3.0m', 'hm=5.0m', 'hb=10.0m', 'Location',
'southeast')
grid on
grid minor
text(1.8,176,'COST231 Path Loss Model for Different MS Heights')
```

Figure7: Code Listing for Cost231 Model (hb = 50m and hm =1.5m, 3.0m, 5.0m and 10.0m)

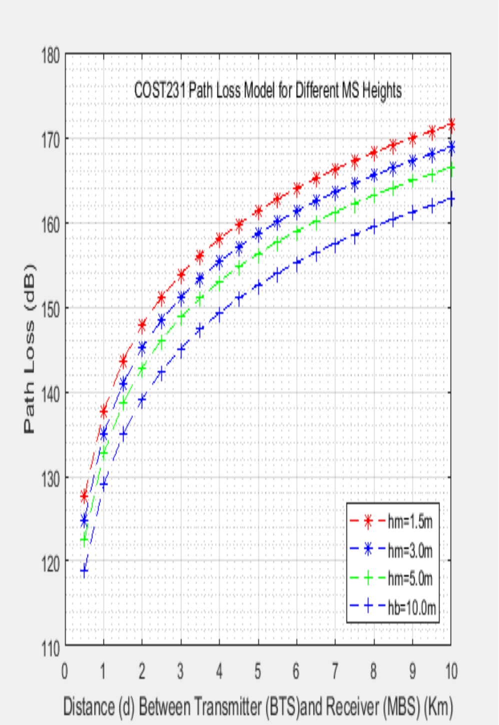


Figure.8.Path loss versus BTS- MBS distance with different mobile station antenna heights (COST231 Model)

2.3ERICSSON MODEL

This model was developed based on the adjusted Okumura-Hata model for use in different propagation environments according to the parameters a_0, a_1, a_2 and a_3.This path loss model was created by Ericsson for use in network planning and deployment process of mobile communication network. Path loss according to this model is given by Nafaa etal (2013)as below:

$$PL=a_0+a_1\log10(d)+a_2\log10(h_b)+a3\log10(h_b).\log10(d)-3.2[\log10(11.75hm)]^2+44.49\log10(f)-4.78[\log10(f)]^2 \ldots\ldots\ldots\ldots\ldots (3)$$

f = carrier frequency (MHz)
h_b = transmitter antenna height (m)
hm = receiver antenna height (m)
d = transmitter-receiver separation distance

parameters a_0, a_1, a_2 and $a_3$are as given for urban environment in the table below

Parameter	a_0	a_1	a_2	a_3
Value	36.20	30.20	12	0.1

Figure 9 is the code listing for the MATLAB simulation of equation3 showing the relationship between pathloss and transmitter-receiver distance for different transmitter antenna height as modeled by Ericsson. Figure 10 is the result of the simulation.

```
%PL = a0+a1*log(d)+a2*log(hb)+a3*(log(hb))*log(d)-
3.2*(log(11.75*hm))^2+44.49*log(f)-4.78*(log(f))^2
f = 2000
hm = 1.5
d = 0:0.5:10
a0=36.20
a1=30.20
a2=12
a3=0.1
g(f)=44.49*log10(f)-4.78*(log10(f))^2
PL30 = a0+a1*log10(d)+a2*log10(30)+a3*(log10(30))*log10(d)-
3.2*(log10(11.75*hm))^2+g(f)
PL50 = a0+a1*log10(d)+a2*log10(50)+a3*(log10(50))*log10(d)-
3.2*(log10(11.75*hm))^2+g(f)
PL100 = a0+a1*log10(d)+a2*log10(100)+a3*(log10(100))*log10(d)-
3.2*(log10(11.75*hm))^2+g(f)
PL200 = a0+a1*log10(d)+a2*log10(200)+a3*(log10(200))*log10(d)-
3.2*(log10(11.75*hm))^2+g(f)
plot(d,PL30,'--*r', d, PL50,'--*b', d, PL100,'--+g', d,PL200,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS)
(Km)')
ylabel('Path Loss (dB)')
legend('hb=30m', 'hb=50m', 'hb=100m', 'hb=200m',
'Location','southeast')
grid on
grid minor
text(1.2,184,'Ericsson Path Loss Model for Different BTS Heights')
```

Figure9: Code Listing for Ericsson Model (hm = 1.5m and hb =30m, 50m, 100m and 200m)

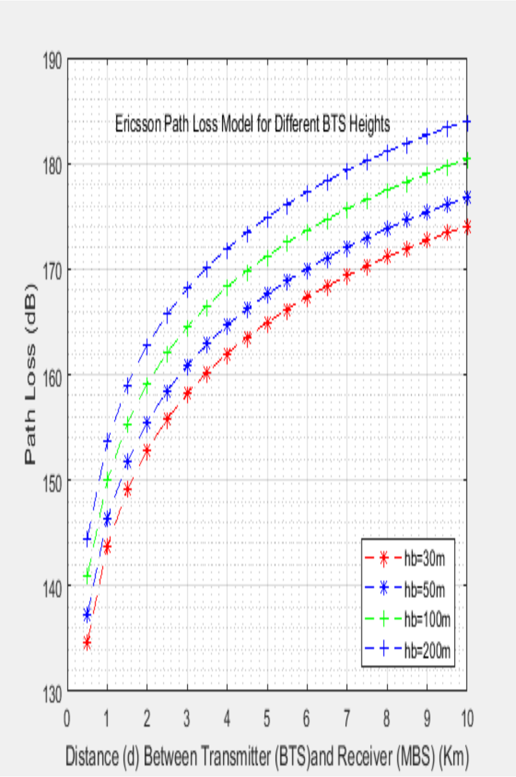


Figure.10.Path loss versus BTS- MBS distance with different base station antenna heights (Ericsson Model)

Figure 11 is the code listing for the MATLAB simulation of equation3 showing the relationship between pathloss and transmitter-receiver distance for different receiver antenna height as modeled by Ericsson. Figure 12 is the result of the simulation.

```
%PL = a0+a1*log(d)+a2*log(hb)+a3*(log(hb))*log(d)-
3.2*(log(11.75*hm))^2+44.49*log(f)-4.78*(log(f))^2
f = 2000
hb = 50
d = 0:0.5:10
a0=36.20
a1=30.20
a2=12
a3=0.1
PL1_5 = a0+a1*log10(d)+a2*log10(hb)+a3*(log10(hb))*log10(d)-
3.2*(log10(11.75*1.5))^2+44.49*log10(f)-4.78*(log10(f))^2;
PL3_0 = a0+a1*log10(d)+a2*log10(hb)+a3*(log10(hb))*log10(d)-
3.2*(log10(11.75*3.0))^2+44.49*log10(f)-4.78*(log10(f))^2;
PL5_0 = a0+a1*log10(d)+a2*log10(hb)+a3*(log10(hb))*log10(d)-
3.2*(log10(11.75*5.0))^2+44.49*log10(f)-4.78*(log10(f))^2;
PL10_0 = a0+a1*log10(d)+a2*log10(hb)+a3*(log10(hb))*log10(d)-
3.2*(log10(11.75*10.0))^2+44.49*log10(f)-4.78*(log10(f))^2;
plot(d,PL1_5,'--*r', d, PL3_0,'--*b', d, PL5_0,'--+g', d,PL10_0,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hm=1.5m', 'hm=3.0m', 'hm=5.0m', 'hm=10.0m', 'Location', 'southeast')
grid on
grid minor
text(1.6,178,'Ericsson Path Loss Model for Different MS Heights')
```

Figure11: Code Listing for Ericsson Model (hb = 50m and hm =1.5m, 3.0m, 5.0m and 10.0m)

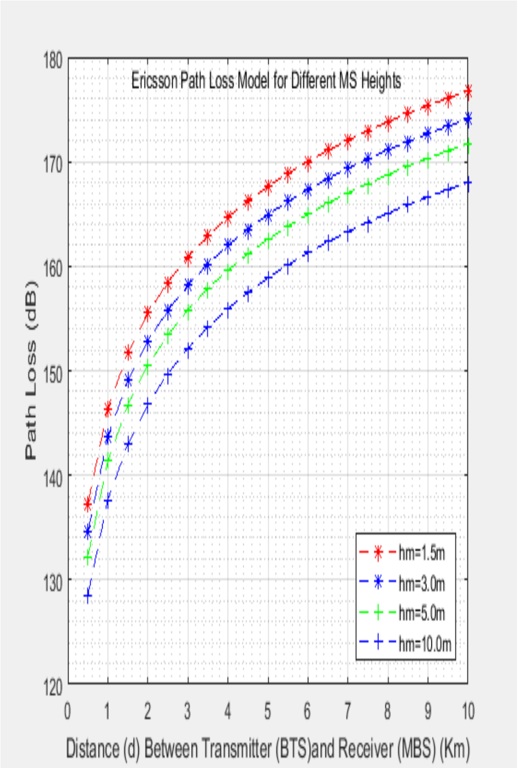


Figure.12.Path loss versus BTS- MBS distance with different mobile station antenna heights (Ericsson Model)

2.4 SUI (Standard University Interim) Model

This prediction model come from the extension of Hata model with frequency larger than 1900MHz (Nafaa etal, 2013). However, its use on higher frequencies is possible by introducing correction factors. SUI models are divided into three types of terrains namely A, B and C. Type A is related with maximum path loss and is also known as urban area. Type C is related with minimum path loss and also known asrural area. Type B is related with suburban area. The basic path loss equation is given by:

PL(dB) = A + $10\gamma\log_{10}(d/do)$ +X_f+X_h+ S --------------(4)

Where,

d = distance between transmitter and receiver inkm

$X_{f=}$ correction factor for frequencies above 2GHz

X_h= correction factor for receiving antenna height in meter

S =correction factor for shadowing, its value in urban area is 10.6.

A = $20\log_{10}(4\pi do/\lambda)$

λ= wavelength in meter

do= reference distance of 100 meter.

Path loss exponent is given by:

$\gamma= a - bh_b + (c / h_b)$

Here h_b is height of transmitter antenna in meter. a, b, c are constants. Value of constants a, b and c is given for urban terrain as below:

Parameter	a	b	c
Value	4.6	0.0075	12.6

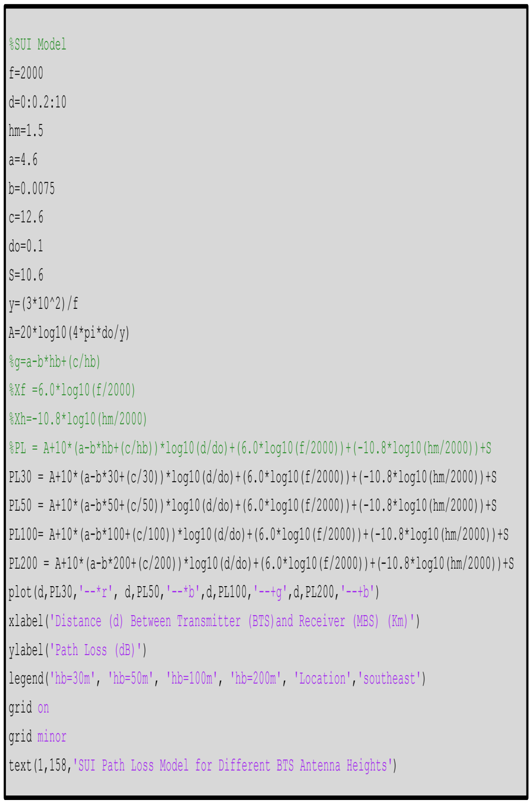
Frequency correction factor and correction factor for receiverantenna height are given by:

X_f= 6.0log(f/2000)

X_h = -10.8log (hm/ 2000)

Where, f is frequency in MHz and hm is receiver antennaheight in meter.

Figure 13 is the code listing for the MATLAB simulation of equation4 which describe the relationship between pathloss and transmitter-receiver distance for different transmitter antenna height as modeled by SUI. Figure 14 is the result of the simulation.



```
%SUI Model
f=2000
d=0:0.2:10
hm=1.5
a=4.6
b=0.0075
c=12.6
do=0.1
S=10.6
y=(3*10^2)/f
A=20*log10(4*pi*do/y)
%g=a-b*hb+(c/hb)
%Xf =6.0*log10(f/2000)
%Xh=-10.8*log10(hm/2000)
%PL = A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
PL30 = A+10*(a-b*30+(c/30))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
PL50 = A+10*(a-b*50+(c/50))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
PL100= A+10*(a-b*100+(c/100))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
PL200 = A+10*(a-b*200+(c/200))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
plot(d,PL30,'--*r', d,PL50,'--*b',d,PL100,'--+g',d,PL200,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hb=30m', 'hb=50m', 'hb=100m', 'hb=200m', 'Location','southeast')
grid on
grid minor
text(1,158,'SUI Path Loss Model for Different BTS Antenna Heights')
```

Figure13: Code Listing for SUI Model (hm = 1.5m and hb =30m, 50m, 100m and 200m)

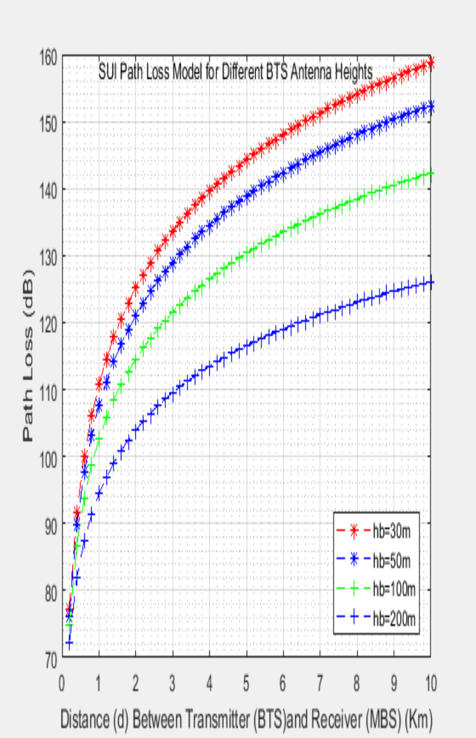
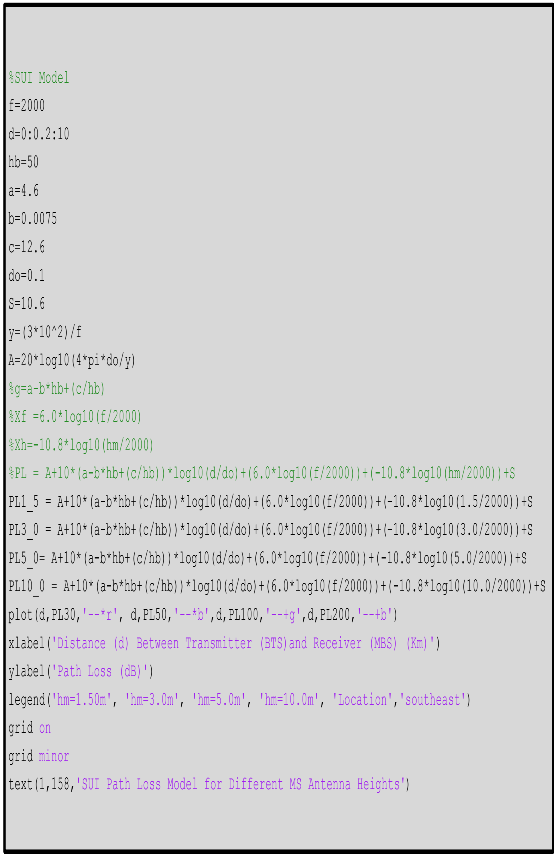


Figure.14.Path loss versus BTS- MBS distance with different base station antenna heights (SUI Model)

Figure 15 is the code listing for the MATLAB simulation of equation4 which describe the relationship between pathloss and transmitter-receiver distance for different receiver antenna height as modeled by SUI. Figure 16 is the result of the simulation.



```
%SUI Model
f=2000
d=0:0.2:10
hb=50
a=4.6
b=0.0075
c=12.6
do=0.1
S=10.6
y=(3*10^2)/f
A=20*log10(4*pi*do/y)
%g=a-b*hb+(c/hb)
%Xf =6.0*log10(f/2000)
%Xh=-10.8*log10(hm/2000)
%PL = A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(hm/2000))+S
PL1_5 = A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(1.5/2000))+S
PL3_0 = A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(3.0/2000))+S
PL5_0= A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(5.0/2000))+S
PL10_0 = A+10*(a-b*hb+(c/hb))*log10(d/do)+(6.0*log10(f/2000))+(-10.8*log10(10.0/2000))+S
plot(d,PL30,'--*r', d,PL50,'--*b',d,PL100,'--+g',d,PL200,'--+b')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
legend('hm=1.50m', 'hm=3.0m', 'hm=5.0m', 'hm=10.0m', 'Location','southeast')
grid on
grid minor
text(1,158,'SUI Path Loss Model for Different MS Antenna Heights')
```

Figure15: Code Listing for SUI Model (hb = 50m and hm =1.5m, 3.0m, 5.0m and 10.0m)

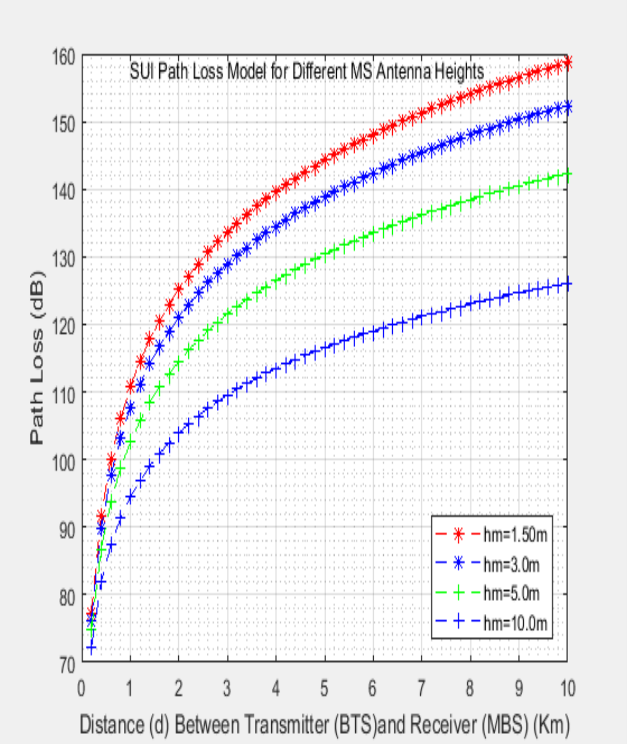


Figure.16.Path loss versus BTS- MBS distance with different mobile station antenna heights (SUI Model)

3.0 ANALYSIS OF SIMULATION RESULTS

The MATLAB simulation of the different models, Okomura-Hata Model, Cost231 Model and Ericsson Model and SUI Model was carried out in section2, the simulation parameters as shown in table1.

Table.1. Pathloss Models Simulation Parameters

Transmitter Heights	30m, 50m, 100m and 200m
Receiver Height	1.5m, 3m, 5m and 10m
Carrier frequency	2000MHz
Distance between Transmitter and receiver	0-10km
Shadowing factor	10.6

The simulation results are graphical displays of the relationship between pathloss and transmitter(BTS)-receiver(MS) separation (d), transmitter(base station) antenna height (h_b), receiver(mobile station) antenna height (h_m).

With carrier frequency f=2000 MHz, pathloss simulation was done for(BTS-MS) distance range 0-10km, base station antenna heights(h_b)range(30m, 50m, 100m and 200m) and mobile station antenna height fixed at h_m=1.5m for the respective prediction models are simulated and shown in figures 2, 6, 10and 14, for Okomura-Hata, Cost231, Ericsson and SUI models respectively.

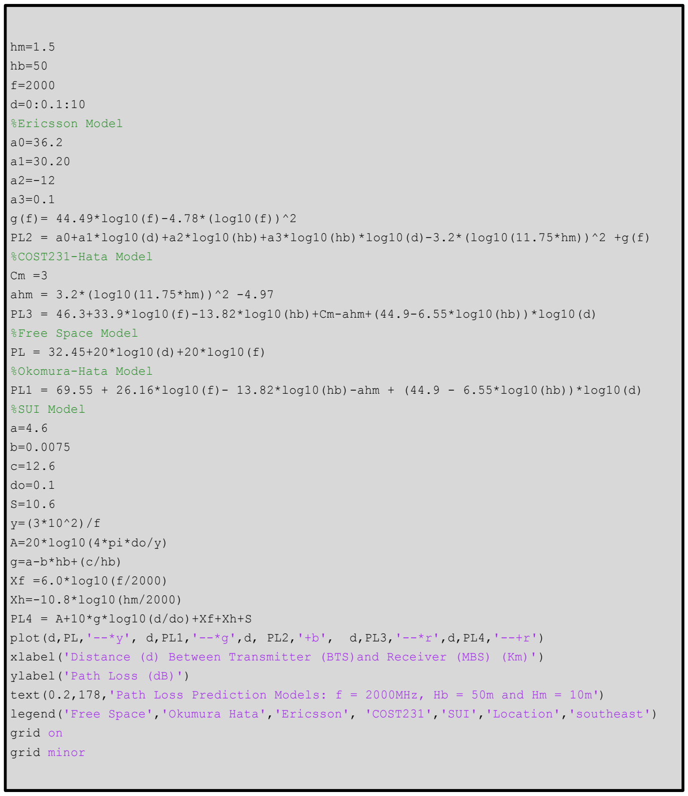
The simulation results show that pathloss increases with increasing distance of separation between transmitter and receiver. Similarly, pathloss simulation was carried out at same carrier frequency of 2000MHz to show the relationship between pathloss and (BTS-MBS) separation distance range, 0-10km, mobile station antenna height (h_m) range(1.5m, 3.0m, 5.0m and 10.0m) and base station antenna height fixed at hb=50m for the respective prediction models.

The results are depicted in figures 4, 8, 12and 16, for Okomura-Hata, Cost231, Ericsson and SUI models respectively.

The various results show that pathloss increases with increasing distance of separation between transmitter and receiver. Also, at given distance and fixed transmitter antenna height, pathloss increases with reducing receiver antenna height.

However, to comfortably analyze pathloss in the urban environment as regards the chosen models, we consider a combined/comparative simulation of the various models. With carrier frequency 2000MHz, BTS-MB Separation distance range 0m to 10km, fixed transmitter antenna height of 50m,

We undertake three comparative simulations for the chosen models at respective receiver antenna heights of 1.5m, 5.0m and 10m. These comparative simulation results are shown in figures 18, 20 and 22 for receiver antenna heights of 1.5m, 5.0m and 10.0m respectively.



```
hm=1.5
hb=50
f=2000
d=0:0.1:10
%Ericsson Model
a0=36.2
a1=30.20
a2=-12
a3=0.1
g(f)= 44.49*log10(f)-4.78*(log10(f))^2
PL2 = a0+a1*log10(d)+a2*log10(hb)+a3*log10(hb)*log10(d)-3.2*(log10(11.75*hm))^2 +g(f)
%COST231-Hata Model
Cm =3
ahm = 3.2*(log10(11.75*hm))^2 -4.97
PL3 = 46.3+33.9*log10(f)-13.82*log10(hb)+Cm-ahm+(44.9-6.55*log10(hb))*log10(d)
%Free Space Model
PL = 32.45+20*log10(d)+20*log10(f)
%Okomura-Hata Model
PL1 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-ahm + (44.9 - 6.55*log10(hb))*log10(d)
%SUI Model
a=4.6
b=0.0075
c=12.6
do=0.1
S=10.6
y=(3*10^2)/f
A=20*log10(4*pi*do/y)
g=a-b*hb+(c/hb)
Xf =6.0*log10(f/2000)
Xh=-10.8*log10(hm/2000)
PL4 = A+10*g*log10(d/do)+Xf+Xh+S
plot(d,PL,'--*y', d,PL1,'--*g',d, PL2,'+b',  d,PL3,'--*r',d,PL4,'--+r')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
text(0.2,178,'Path Loss Prediction Models: f = 2000MHz, Hb = 50m and Hm = 10m')
legend('Free Space','Okumura Hata','Ericsson', 'COST231','SUI','Location','southeast')
grid on
grid minor
```

Figure17: Code Listing for Free Space, Okomura-Hata, Ericsson, Cost231 and SUI Urban Models (hb = 50m and hm =1.5m)

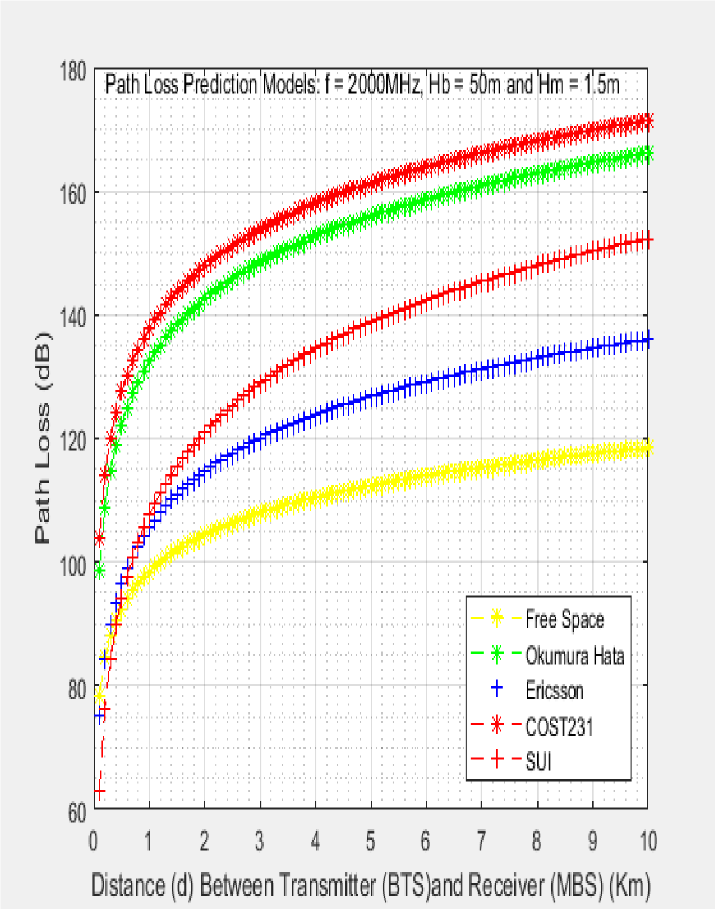
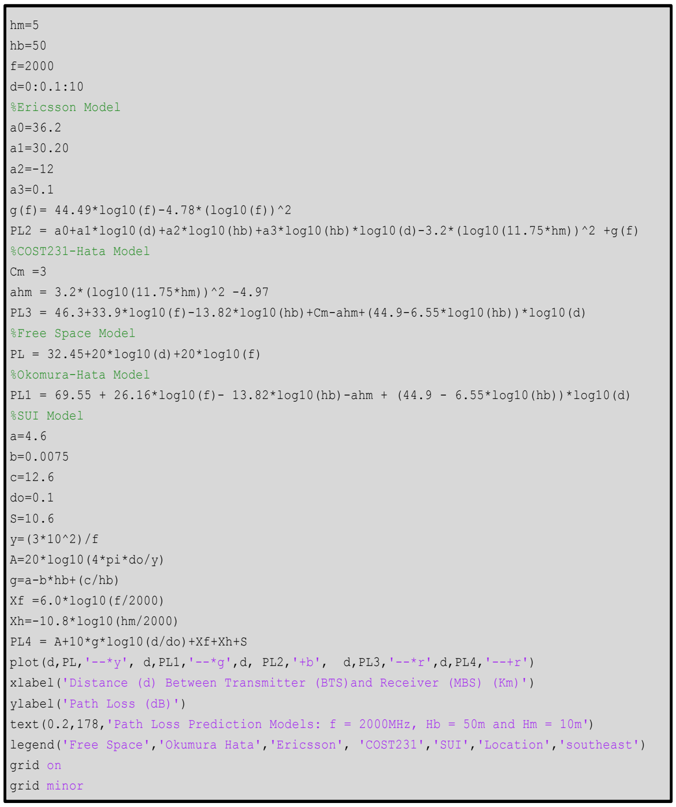


Figure.18. Simulation of Models in Urban Environment at 1.5m Height of Receiver Antenna



```
hm=5
hb=50
f=2000
d=0:0.1:10
%Ericsson Model
a0=36.2
a1=30.20
a2=-12
a3=0.1
g(f)= 44.49*log10(f)-4.78*(log10(f))^2
PL2 = a0+a1*log10(d)+a2*log10(hb)+a3*log10(hb)*log10(d)-3.2*(log10(11.75*hm))^2 +g(f)
%COST231-Hata Model
Cm =3
ahm = 3.2*(log10(11.75*hm))^2 -4.97
PL3 = 46.3+33.9*log10(f)-13.82*log10(hb)+Cm-ahm+(44.9-6.55*log10(hb))*log10(d)
%Free Space Model
PL = 32.45+20*log10(d)+20*log10(f)
%Okomura-Hata Model
PL1 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-ahm + (44.9 - 6.55*log10(hb))*log10(d)
%SUI Model
a=4.6
b=0.0075
c=12.6
do=0.1
S=10.6
y=(3*10^2)/f
A=20*log10(4*pi*do/y)
g=a-b*hb+(c/hb)
Xf =6.0*log10(f/2000)
Xh=-10.8*log10(hm/2000)
PL4 = A+10*g*log10(d/do)+Xf+Xh+S
plot(d,PL,'--*y', d,PL1,'--*g',d, PL2,'+b',  d,PL3,'--*r',d,PL4,'--+r')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
text(0.2,178,'Path Loss Prediction Models: f = 2000MHz, Hb = 50m and Hm = 10m')
legend('Free Space','Okumura Hata','Ericsson', 'COST231','SUI','Location','southeast')
grid on
grid minor
```

Fiure19: Code Listing for Free Space, Okomura-Hata, Ericsson, Cost231 and SUI Urban Models (hb = 50m and hm =5m)

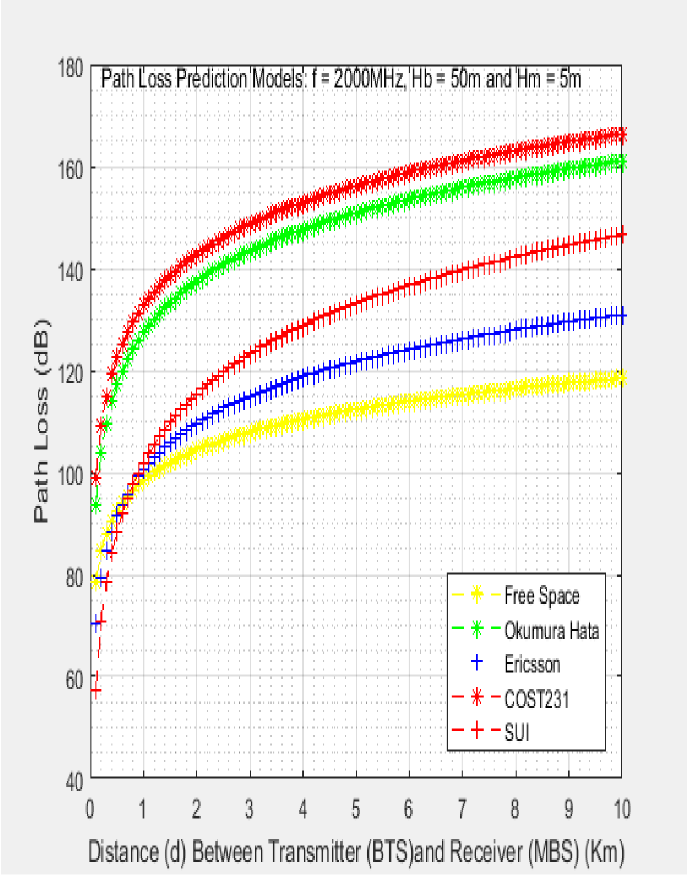
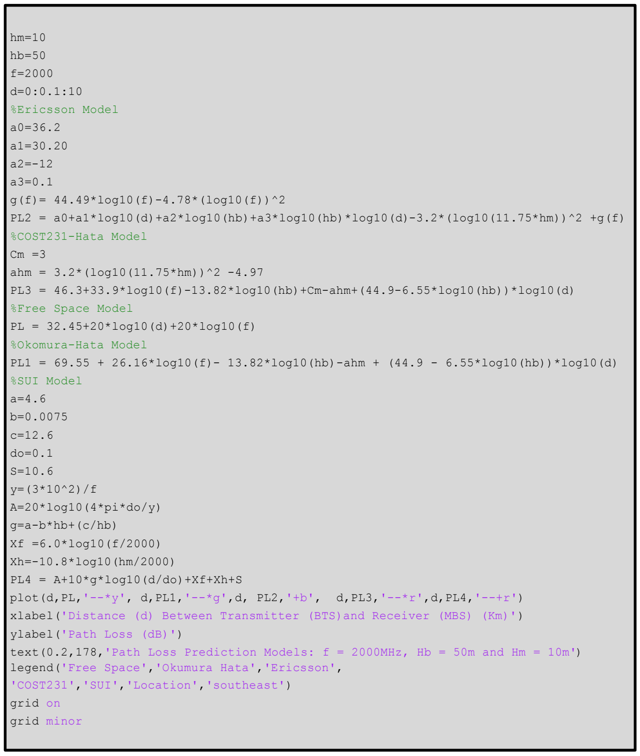


Figure.20. Simulation of Models in Urban Environment at 5m Height of Receiver Antenna



```
hm=10
hb=50
f=2000
d=0:0.1:10
%Ericsson Model
a0=36.2
a1=30.20
a2=-12
a3=0.1
g(f)= 44.49*log10(f)-4.78*(log10(f))^2
PL2 = a0+a1*log10(d)+a2*log10(hb)+a3*log10(hb)*log10(d)-3.2*(log10(11.75*hm))^2 +g(f)
%COST231-Hata Model
Cm =3
ahm = 3.2*(log10(11.75*hm))^2 -4.97
PL3 = 46.3+33.9*log10(f)-13.82*log10(hb)+Cm-ahm+(44.9-6.55*log10(hb))*log10(d)
%Free Space Model
PL = 32.45+20*log10(d)+20*log10(f)
%Okomura-Hata Model
PL1 = 69.55 + 26.16*log10(f)- 13.82*log10(hb)-ahm + (44.9 - 6.55*log10(hb))*log10(d)
%SUI Model
a=4.6
b=0.0075
c=12.6
do=0.1
S=10.6
y=(3*10^2)/f
A=20*log10(4*pi*do/y)
g=a-b*hb+(c/hb)
Xf =6.0*log10(f/2000)
Xh=-10.8*log10(hm/2000)
PL4 = A+10*g*log10(d/do)+Xf+Xh+S
plot(d,PL,'--*y', d,PL1,'--*g',d, PL2,'+b',  d,PL3,'--*r',d,PL4,'--+r')
xlabel('Distance (d) Between Transmitter (BTS)and Receiver (MBS) (Km)')
ylabel('Path Loss (dB)')
text(0.2,178,'Path Loss Prediction Models: f = 2000MHz, Hb = 50m and Hm = 10m')
legend('Free Space','Okumura Hata','Ericsson',
'COST231','SUI','Location','southeast')
grid on
grid minor
```

Figure21: Code Listing for Free Space, Okomura-Hata, Ericsson, Cost231 and SUI Urban Models (hb = 50m and hm =10m)

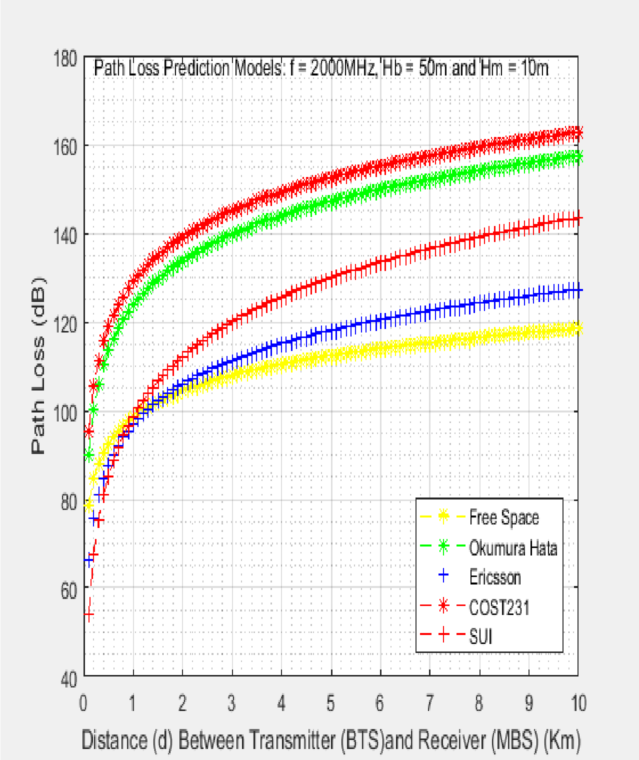


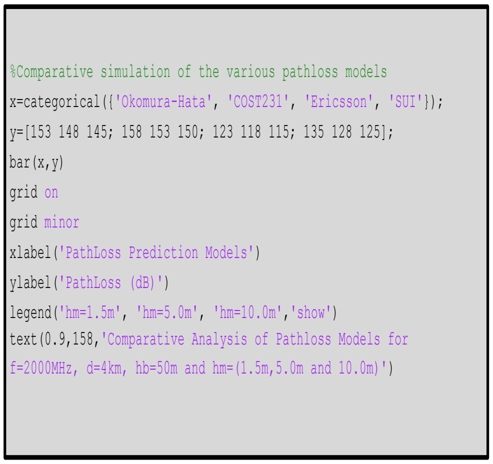
Figure.22. Simulation of Models in Urban Environment at 10m Height of Receiver Antenna

Influence of receiver antenna height

Choosing a refence transmitter-receiver distance of 4km, we can read the simulation result of figures 18, 20 and 22 and present the data as in table2. These can further be analyzed in bar chart as depicted in figure 24.

Table.2. Pathloss simulation result read from figures 18, 20 and 22 at d=4km.

Receiver Antenna Height (hm) in meters	Pathloss (dB) at f=2000MHz, d=4km, hb =50m			
	Okomura-Hata Model	COST231 Model	Ericsson Model	SUI Model
1.5	153	158	125	135
5.0	148	153	118	128
10.0	145	150	115	125



```
%Comparative simulation of the various pathloss models
x=categorical({'Okomura-Hata', 'COST231', 'Ericsson', 'SUI'});
y=[153 148 145; 158 153 150; 123 118 115; 135 128 125];
bar(x,y)
grid on
grid minor
xlabel('PathLoss Prediction Models')
ylabel('PathLoss (dB)')
legend('hm=1.5m', 'hm=5.0m', 'hm=10.0m','show')
text(0.9,158,'Comparative Analysis of Pathloss Models for
f=2000MHz, d=4km, hb=50m and hm=(1.5m,5.0m and 10.0m)')
```

Figure23: Code Listing for Bar Chart Analysis of Okomura-Hata, Ericsson, Cost231 and SUI Urban Models (d =4km, hb = 50m and hm =1.5m, 5.0m and 10m)

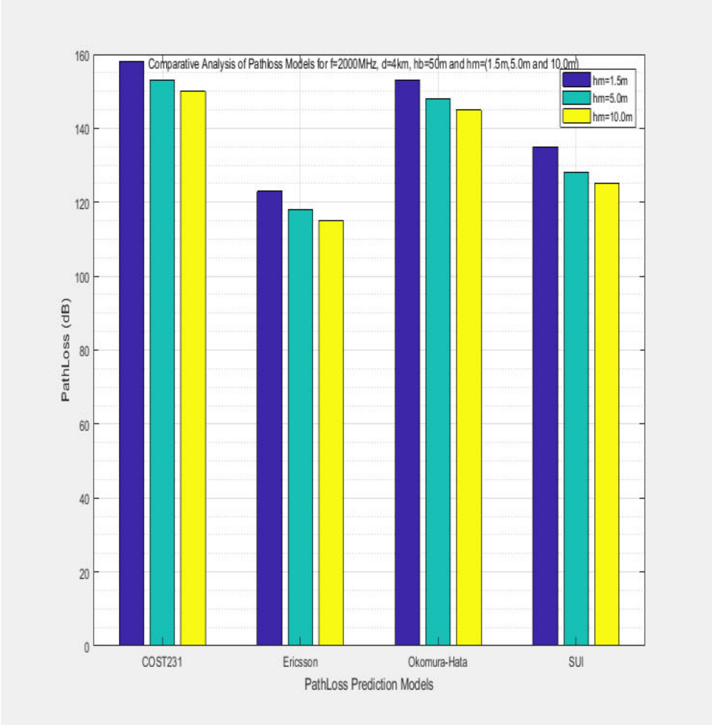


Figure.24. Comparative Analysis of Pathloss Models for f= 2000 MHz, d=4km, hb=50m and hm=(1.5m,5.0m and 10.0m)

From the results presented in table 2 and figure 24, we note that, for the three receiver antenna heights (1.5m, 5.0m and 10m), the

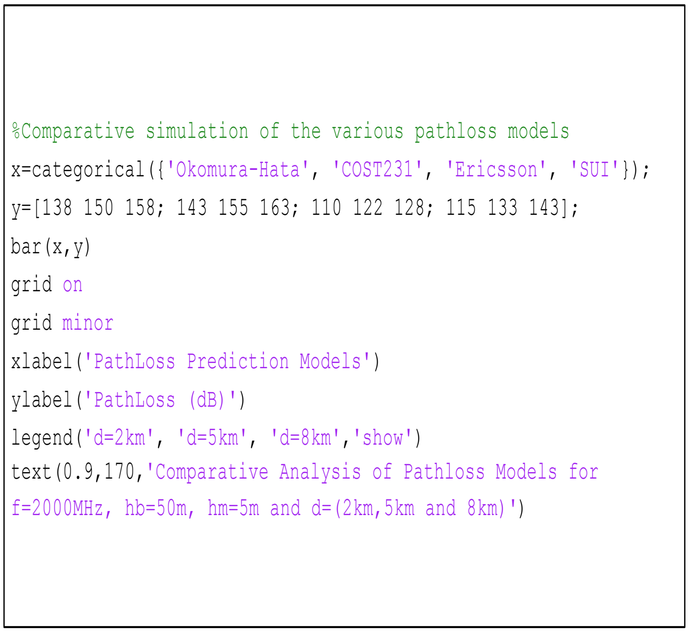
Ericsson model shows the lowest path loss values (125dB, 118dB and 115dB), and the Cost 231 model shows the highest path loss (158dB, 153dB and 150dB). As the receiver antenna height varied from 1.5m to 10m, the Ericsson and SUI models had a reduction in pathloss of (10dB) each while the Okomura-Hata and Cost231 models had the effect of their pathloss is decreased by (8dB) each.

Influence of distance

Choosing a reface transmitter antenna height of 50m and receiver antenna height of 5m, we can read the simulation result of figure 20 and present the data as in table3. These can further be analyzed in bar chart as depicted in figure 26. From the results presented in table 3 and figure 26, we note that, for the three transmitter-receiver distances (2km, 5km and 8km), the Ericsson model shows the lowest path loss values (110dB, 122dB and 128dB), and the Cost 231 model shows the highest path loss (143dB, 155dB and 163dB). As the transmitter-receiver distances varied from 2km to 8km, the Ericsson model had the lowest increase in pathloss of (18dB) while the SUI model recorded the highest increase in pathloss of (28dB).

Table.3. Pathloss simulation result read from figure 20 at hb=50m and hm=5m.

Transmitter-Receiver Distance (d) in kilometers	Pathloss (dB) at f=2000MHz, hb =50m, hb = 5m			
	Okomura-Hata Model	COST231 Model	Ericsson Model	SUI Model
2	138	143	110	115
5	150	155	122	133
8	158	163	128	143



```
%Comparative simulation of the various pathloss models
x=categorical({'Okomura-Hata', 'COST231', 'Ericsson', 'SUI'});
y=[138 150 158; 143 155 163; 110 122 128; 115 133 143];
bar(x,y)
grid on
grid minor
xlabel('PathLoss Prediction Models')
ylabel('PathLoss (dB)')
legend('d=2km', 'd=5km', 'd=8km','show')
text(0.9,170,'Comparative Analysis of Pathloss Models for f=2000MHz, hb=50m, hm=5m and d=(2km,5km and 8km)')
```

Figure25: Code Listing for Bar Chart Analysis of Okomura-Hata, Ericsson, Cost231 and SUI Urban Models (hb = 50m, hm=5m and d =2km, 5km and 8km)

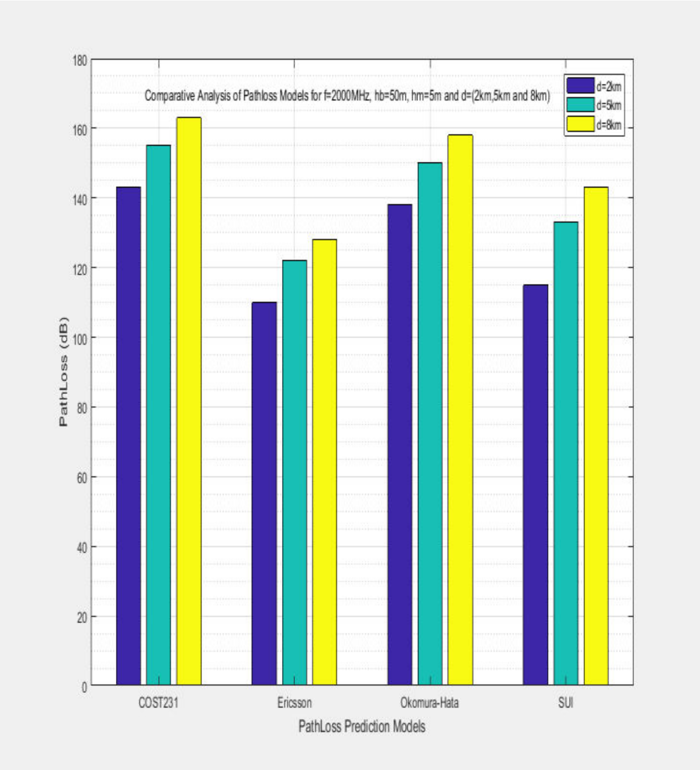


Figure. 26. Comparative Analysis of Pathloss Models for f= 2000MHz, hb=50m, hm=5m and d=(2km,5km and 8km)

4.0 CONCLUSION

In this paper, we have discussed and presented simulation results of some pathloss prediction models under the urban environment. The simulation and analysis were done to predict the pathloss by varying the receiver (mobile station)antenna height, hm and the transmitter (base station)-receiver (mobile station) separation distance, d. The simulation results were analyzed based on the influence of varying the propagation conditions, basically of, distance, receiver antenna height, on the pathloss prediction. For the different models, path loss was seen to increase with increasing transmitter receiver (base station)-receiver (mobile station) separation, d. The opposite is true for the relationship between pathloss and the antenna heights. Thus, pathloss was seen to decrease with increasing receiver (mobile station) antenna heights. With respect to the effect of changing of propagation conditions, we found that, the Ericsson model represent the lowest pathloss values due to change of distance and the receiver antenna height in the urban environment.

4.0. REFERENCES

[1]. Akujobi Ekeocha, Nosiri Onyebuchi and Lazarus Uzoechi 2016, Path loss characterization of 3G wireless signal for urban and suburban environments in Portharcourt City, Nigeria, International Research Journal of Engineering and Technology (IRJET)Volume: 03 Issue: 03, pp16-22.

[2]. Alim M. A., Rahman M. M., Hossain M. M., Al-Nahid A. 2010, Analysis of Large-Scale Propagation Models forMobile Communications in Urban Area, International Journal of Computer Science and Information Security, Volume 7, Issue 1, pp135-139.

[3]. Haider Kadhim Hoomod, Intisar Al-Mejibli and Abbas Issa Jabboory2018, Analyzing study of path loss propagation models in wireless communications at 0.8 GHz, IOP Conf. Series: Journal of Physics: Conf. Series 1003.

[4]. Masoud Dao Hamid 2014, Measurement based statistical model for path loss prediction for relaying systems operating in 1900 MHz band, College of Engineering, Florida Institute of Technology.

[5]. Nafaa M. Shebani, Abdulati E. Mohammed, Mohammed A. Mosbah, Yousra A. Hassan2013, Simulation and analysis of path loss models for WiMax communication system, viewed 26 October 2018,www.researchgate.net/publication, pp692-703.

[6]. Nwalozie Gerald .C, Ufoaroh S.U, Ezeagwu C.O, Ejio for A.C, 2014, Path loss prediction for GSM mobile networks for urban region of aba, south-east Nigeria, International Journal of Computer Science and Mobile Computing, Vol.3 Issue.2, pg. 267-281.

[7]. Pardeep Pathania, Parveen Kumar and Shashi B. Rana, (2014), Performance evaluation of different path loss models for broadcasting applications, American Journal of Engineering Research (AJER) Volume-03, Issue-04, pp-335-342.

[8]. Rony KumerSaha2016, Comparative analysis of path loss models in mobile communications for urban case, A Contribution of R&D NextEvolution.

[9]. Saptarshi Gupta2013, Comparative path loss analysis of okumura & cost 231 models for wireless mobile communication using matlab simulation, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, pp1-4.

[10]. Sonia Sharma and Sunita Parashar 2014, Analysis of path loss models at 3.3GHz to determine efficient handover in Wimax, International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 7, pp45-51.