Empirical Path Loss Model
(Okumura Model)

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ABSTRACT

Radio propagation prediction is one of the fundamentals of radio network planning. It is therefore vital that the propagation prediction models are as accurate as possible. Propagation path loss is major in the analysis and design of the link budget of telecommunication system.

Calculation of the path loss is usually called prediction. Exact prediction is possible only for simpler cases, such as free space propagation or the flat-earth model. For practical cases the path loss is calculated using a variety of approximations.

In this report we will discuss Empirical path loss model and then mainly focus on Okumura model used for the signal prediction. Okumura model is one of the most widely used empirical propagation prediction models used in Urban Areas. It was developed through works of Y. Okumura and is based on the results of extensive measurements in certain urban and suburban areas of Japan. We will consider the parameters causing losses in propagation such as Free space propagation loss, Base station antenna height factor, Mobile antenna height gain factor, Basic median attenuation and Environment gain.

To check the practical implementation and working some demonstrational view can be created on MATLAB by writing some code to see actual graph of relation between the received power and the distance, relation between transmitter height and propagation path loss.

OBJECTIVE

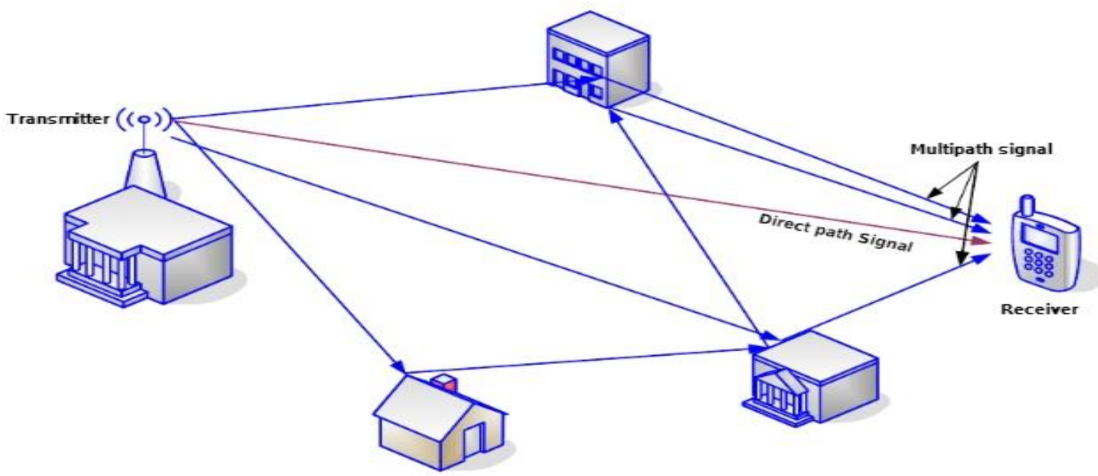
Main objective of this Report is to illustrate the basic ideology of Empirical path losses. To Serve this purpose we have selected an Okumura model and consider every aspect of predication model. It describes some advantages of its usage and suitability criteria under which this is superior option to be used through observation of parameters.

INTRODUCTION

Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Free-space loss, refraction, diffraction, reflection, aperture-medium loss, and absorption are main causes for the path loss .Path loss is also influence by terrain contours, environments, propagation medium, distance between transmitter and receiver and the height and location of the antenna .

Mathematical formulation for the characterization of the radio wave propagation as a function of transmission, distance and other conditions that influence the behavior of radio channel in each propagation environment is called as Radio propagation model. Models are usually developed to predict the nature of propagation for the all similar links under similar constrains. It provides platform to simulate the behavior characteristics of radio channel before deployment. These characteristics helps to tackle any deficiency in the network planning to reduce delay and any unnecessarily cost expenses as a corrective measure. Empirical, Deterministic and Semi deterministic models are generally used.

The Models which are based on measured data, few simple parameters, uses measured properties and are less accurate are called as empirical model. Models which requires enamors no of geometry information about the cite very important computational efforts, site -specific and so accurate are called as deterministic models. Semi deterministic models are based on empirical models and deterministic aspects.



Cells are another aspect of path loss modelling. These are basically classified into four major categories named Large macro Cells (1 to 30 km), Small Macro Cells (0.5 to 3 km), Micro cells (up to 1km) and Pico Cells (up to 500m). In large Macro cells and Small Macro Cells typical base station antenna installation height is above medium roof top level and all surrounding building are below antenna height whereas Microcell installation height is below medium roof top level. Base Station antenna installation height is below roof top level in Pico-cell. Large Micro cell, Small Micro cell and Micro Cell are in outdoor environment whereas Pico cell can be used in indoor as well.

OKUMURA MODEL

Okumura model today is one of the most widely used empirical propagation prediction models used in Urban Areas. It was developed through works of Y**.** Okumura and is based on the results of extensive measurements in certain urban and suburban areas of Japan. The model served as a base for Hata models. Recently a wider use of the Okumura model was further encouraged with its formal recognition by the International Telecommunications Union (ITU) through the ITU-R Recommendation. Okumura model was built into three modes. The ones for urban, suburban and open areas. The model for urban areas was built first and used as the base for others.

Okumura Model is applicable for frequency range of 150Mhz to 1920Mhz which can be typically expandable up to 3000Mhz. I

t can cover distance from 1 Km to 100 Km. Transmitter antenna effective height must be 30 m to 1000m and receiver antenna height is 1m to 10 m.

Mathematical Formulation:

The Okumura model is formally expressed as:

Lm = LF+ Amu(f,d) – G(Hre) – G(Hte) – GAREA

Where;

Lm = 50 th Percentile (i.e., median) value of propagation path loss between transmitter and receiver expressed in dB.

LF = Free space propagation path loss in dB.

Amu(f,d) = Median attenuation relative to free space in db.

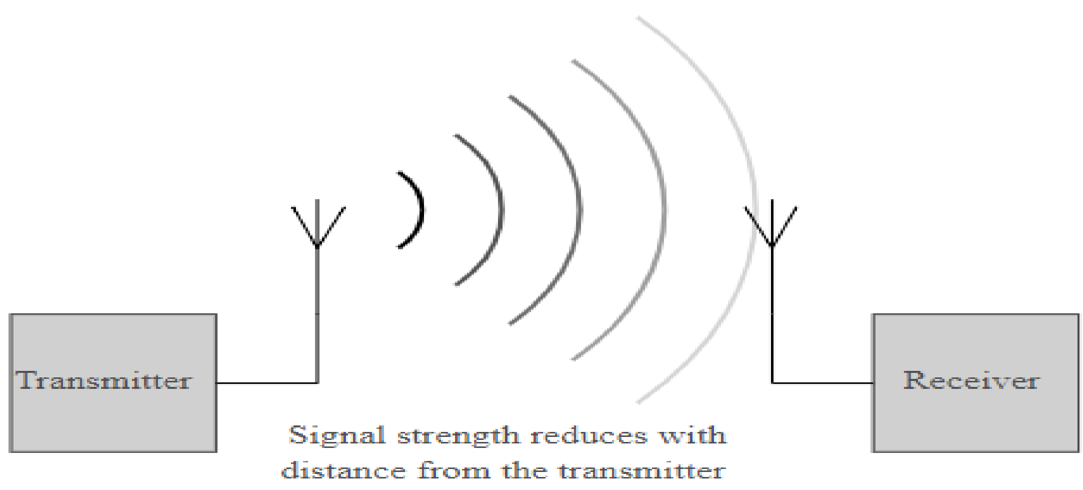
G(Hte) = Base station antenna height gain factor in db.

G(Hre) = mobile antenna height gain factor in dB.

GAREA = gain due to type of environment given in suburban, urban or open areas Correction factors.

Free Space Propagation Path Loss (LF)

The free space propagation model is the simplest scenario for the propagation of radio signals. Here they are considered to travel outwards from the point where they are radiated by the antenna. The way in which they propagate can be likened to the ripples of waves on a pond that travel outwards from the point where a stone is dropped into a pond.



Signals reduce in intensity as they travel from the transmitter

$LF = 10 * \log ((4*pi)^2*d^2)/(lamda^2)$

Where,

d= distance between transmitter and receiver

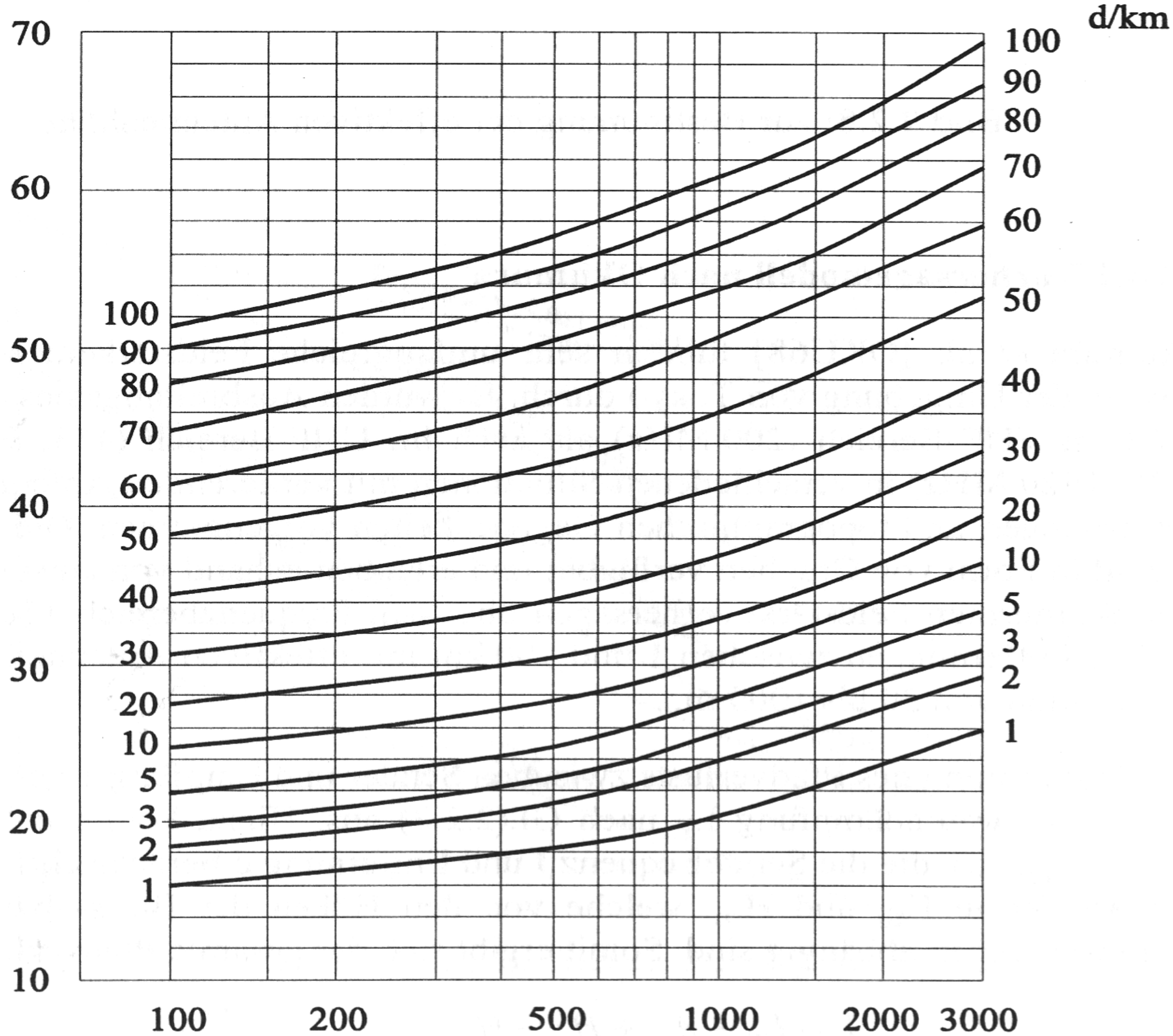
lamda= c/f

c=Speed of Light

f= Frequency of transmission of signal in Mhz.

Basic Median Attenuation

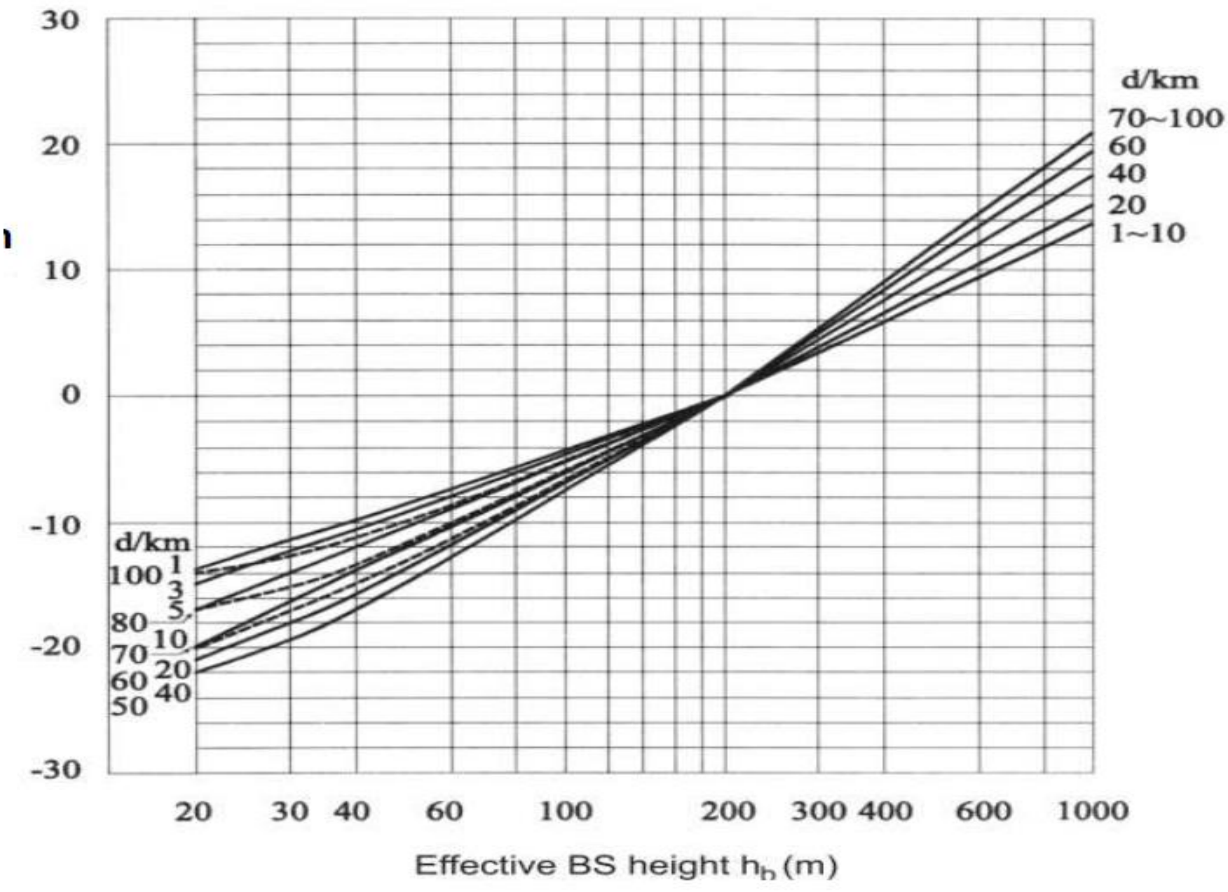
- It models additional propagation losses due to the signal propagation with these reference condition:
- Terrestrial urban environment over a squsi -smooth terrains.
- Base station effective antenna height =200 m
- Mobile antenna height =3 m
- If actual height of transmitter and receiver antenna or the propagation area type differ from those reference the appropriate correction needs to be added.



Base Station Antenna Effective Height Gain Factor G(Hte)

- At the effective height of 200m, all curves meet, and no correction gain is required.
- Base station antennas above 200m introduces positive gain and antennas lower than 200m have negative gain Factor.
- The parameters of a family of the curve is the distance between the transmitter and receiver.
- Okumura found that G(Hte) varies at the rate of 20dB/decade for effective height between 30m and 1000 m.

$$G(H_{te}) = 20 \log (H_{te}/200) \qquad \text{for } 1000 > H_{te} > 30 \text{ m}$$

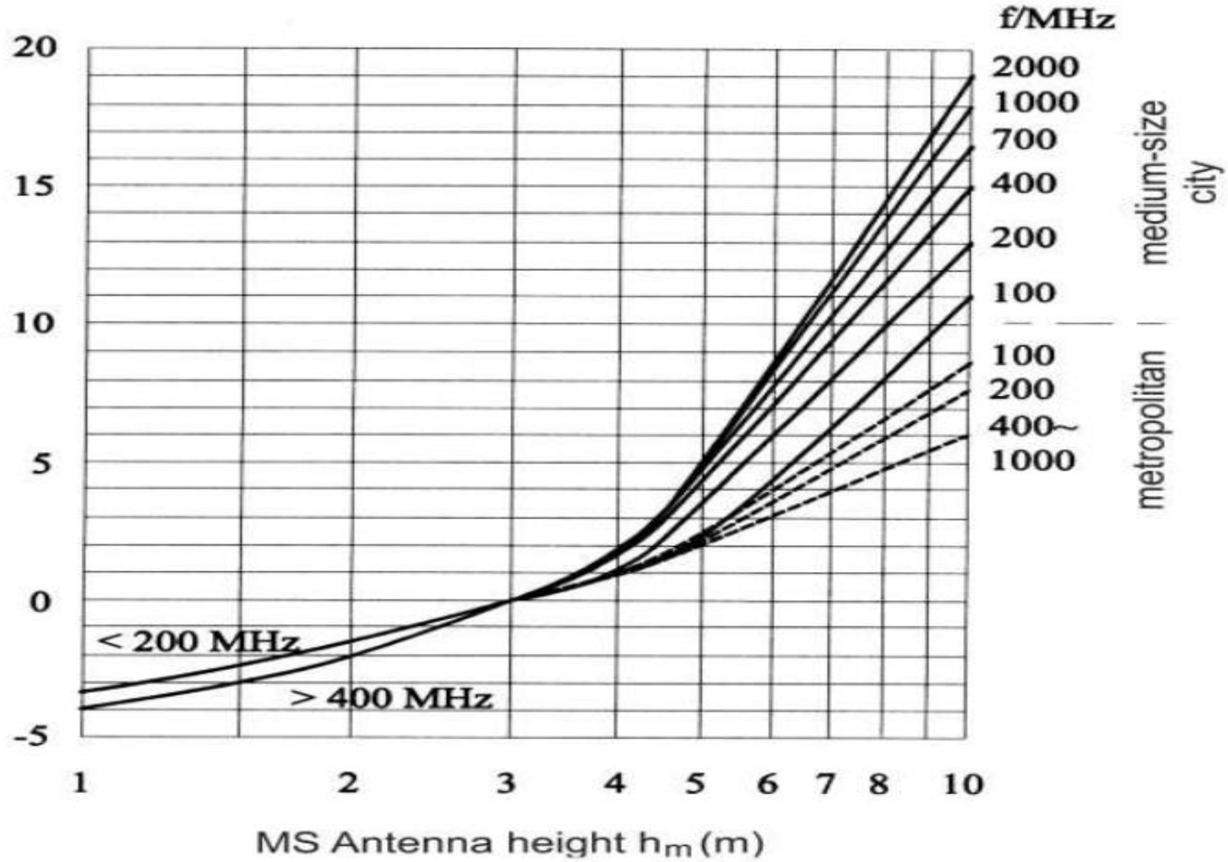


Mobile Antenna Height Gain Factor (G(Hre))

- All the curves at the reference 3m horizontal coordinate.
- Higher antennas introduce gain and lower cause loss of reference signal level.
- Mobile antenna Hight gain factor is also separated according to the size of the city in two clusters: medium and large cities.
- Okumura found that G(hre) varies at a rate of 10 dB/decade for mobile height less than 3m and varies at a rate of 20 dB/decade for mobile heights between 10m and 3m.

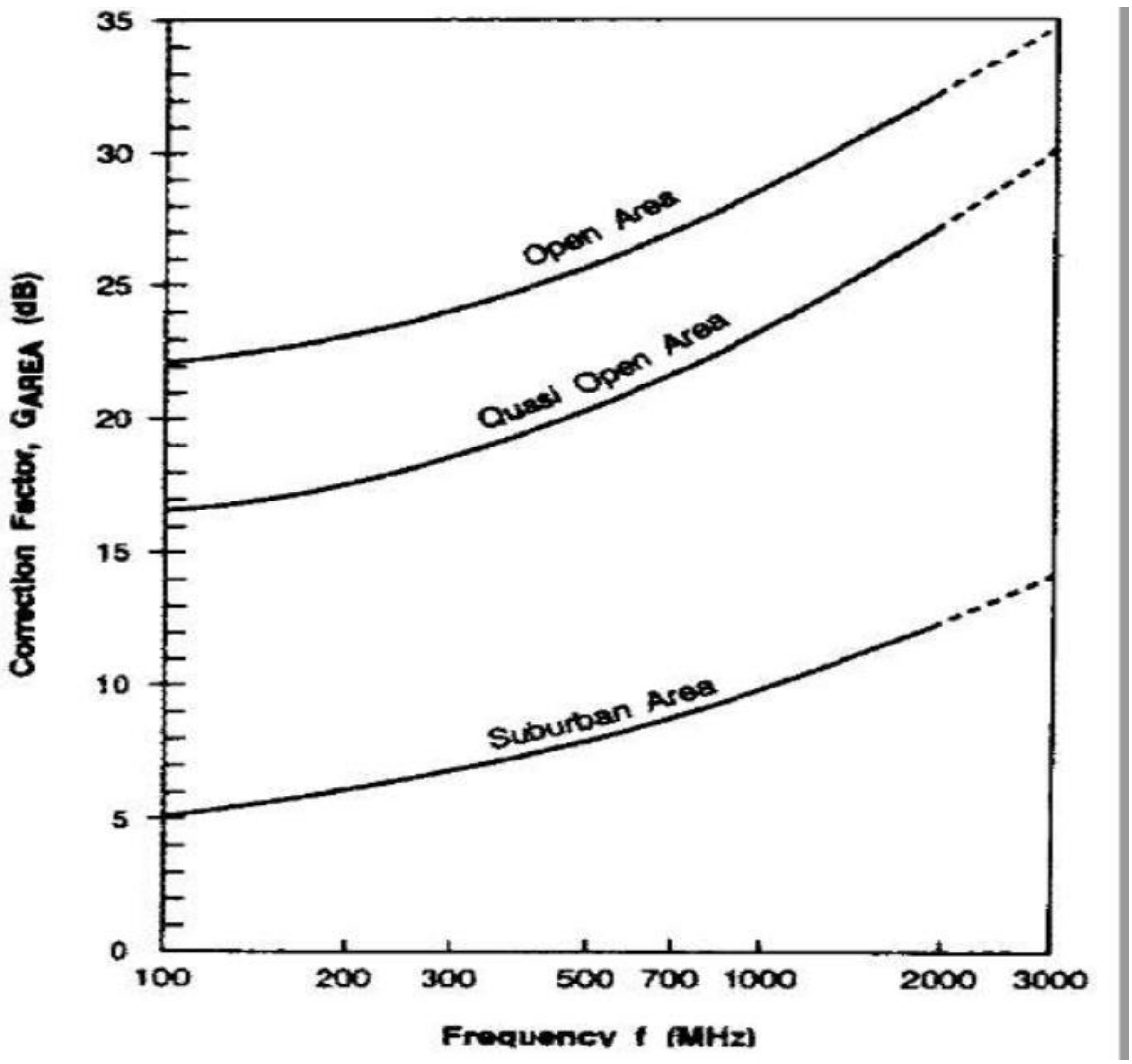
❖ G (Hre) = 10log (Hre/3) Hre < 3m

❖ G (Hre) = 20log (Hre/3) 10m>Hre >3m



Environment Gain $GAREA$

- For the referent Urban terrain environment, the value of $GAREA = 0\ dB$.
- For Other terrain types; such as Suburban, Quasi-Open and Open Areas, the value of $GAREA$ can be read the curves.
- $GAREA$ values represent an additional loss correction factor due to propagation in different than Urban environment.



Methodology

- Find the Free Space Path Loss Using Equation
- Determine the median attenuation relative to free space Amn (f,d) using Curves
- Determine the Correction Gain Factors from transmitter and received antenna height by using their equation or Curves.
- Determine area Gain Factor from Curves
- Substitute the Value in equation to find the path Loss.
- Compute Received Power from equation.

SIMULATION

MATLAB CODE

C: ▸ Users ▸ 11011726 ▸ Desktop ▸ SRP ▸ OKUMURA

Editor - C:\Users\11011726\Desktop\SRP\OKUMURA\OKUMURA_2.m

```matlab
% This program will plot the relationship Between Received Power with respect to Distance
clc;
clear ;

% Transmitting  Antenna Height
Hte=30:1:100;
% Input of Parameters
Hre=input('Enter the receiver antenna height 3m<hre<10m : ');
f=input('Enter the frequency 150Mhz<f<1920Mhz : ');
Pt=input('Enter the Transmitter power watts :  ');
Pt1=10*log10 (Pt);
fprintf('The Transmitted power in db is :%i\n',Pt1)

% Basic Calculation
x1=((4*pi)^2);
%lamda Calculation
c=3*10^8;
lamda=(c)/(f*10^6);
lamda1=lamda*lamda;

% Median Attenuation Assumtion Amu (f,d) in dB
Amu = 35;
%Gain Due to Type of Terrain in dB
Garea = 9;
%Base Antenna Height Gain Factor in dB
Ghte = 20*log(Hte/200);
% Mobile a Antenna Height Gain Factor in dB
if(Hre>3)
Ghre = 20*log(Hre/3);
else
Ghre = 10*log(Hre/3);
end
```

```matlab
% Continue .......
% Free Space Loss
d=1:1:71;
d1=d.*d;

Lf = 10*log ((d1.*x1)/(lamda1));
% 50 th  Percentile (Median Value of Propogation Path Loss
for n=1:1:d ...
% Plotting of Graphes
fprintf('\n############################################################################################');
fprintf('\nCaclulating Received Power Vs Distance Graph for Receiver antena Height of:%i m\n',Hre);
fprintf('Frequency:%i Mhz ,Transmitter Power:%i Watt (%i dB )\n',f,Pt,Pt1);
fprintf('###############################################################################################\n');
plot(d,Pr,'LineWidth',1.5);
title('Okumura Model Analysis');
xlabel('Distance between Transmitter and Receiver');
ylabel('Received Power in dB1');
grid on;

```

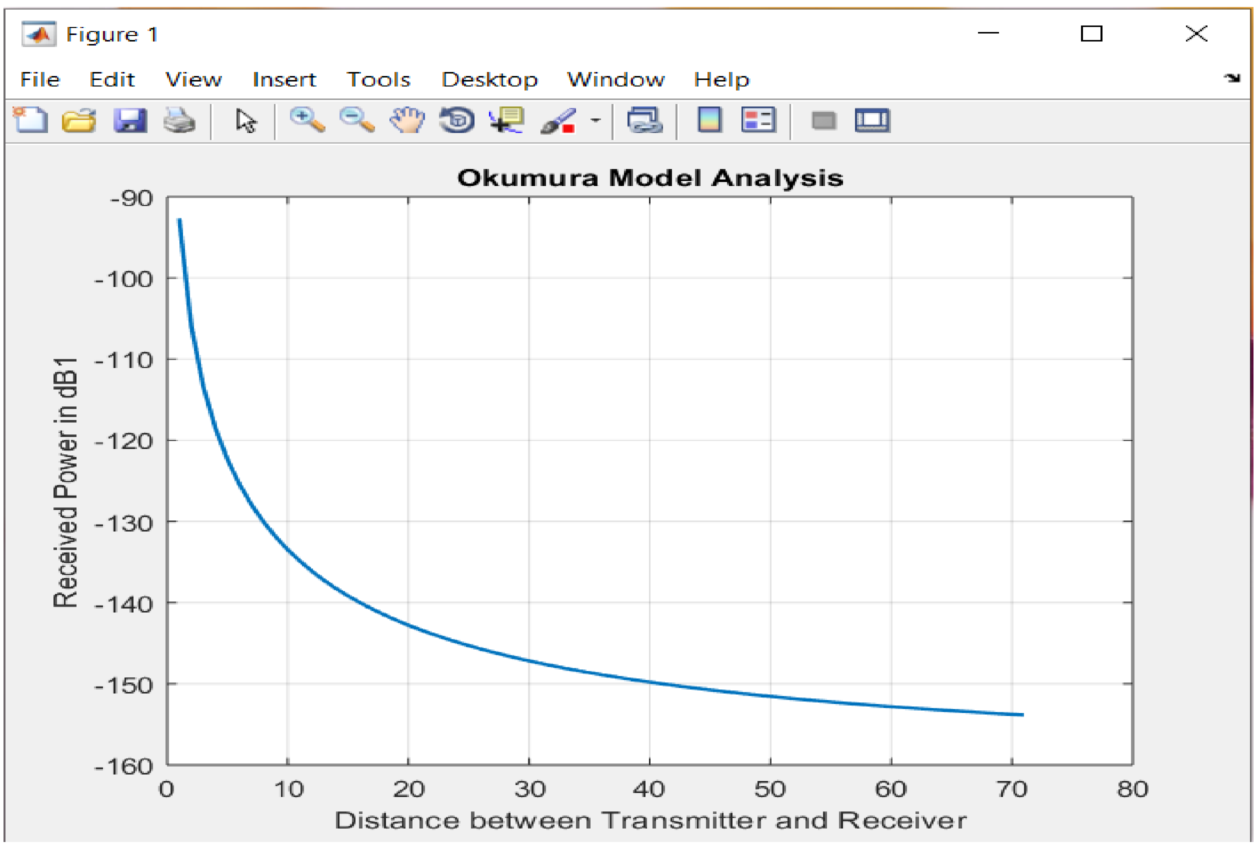
RESULTS

Relation Between Received Power and Distance

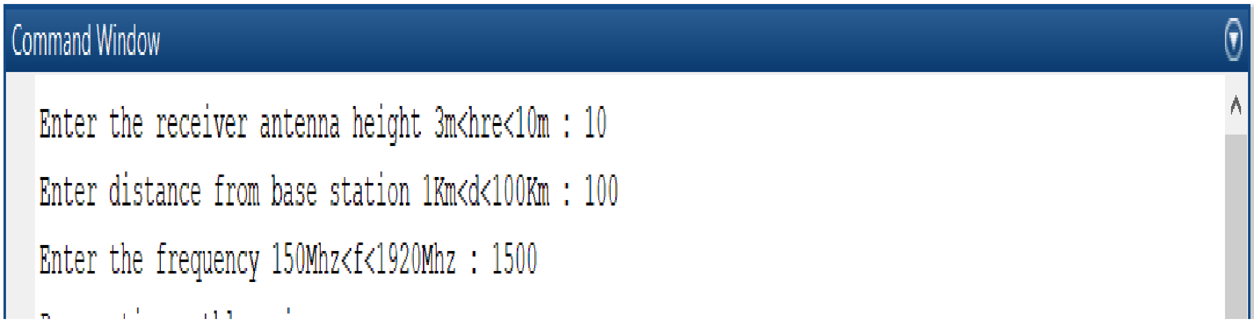
Command Window

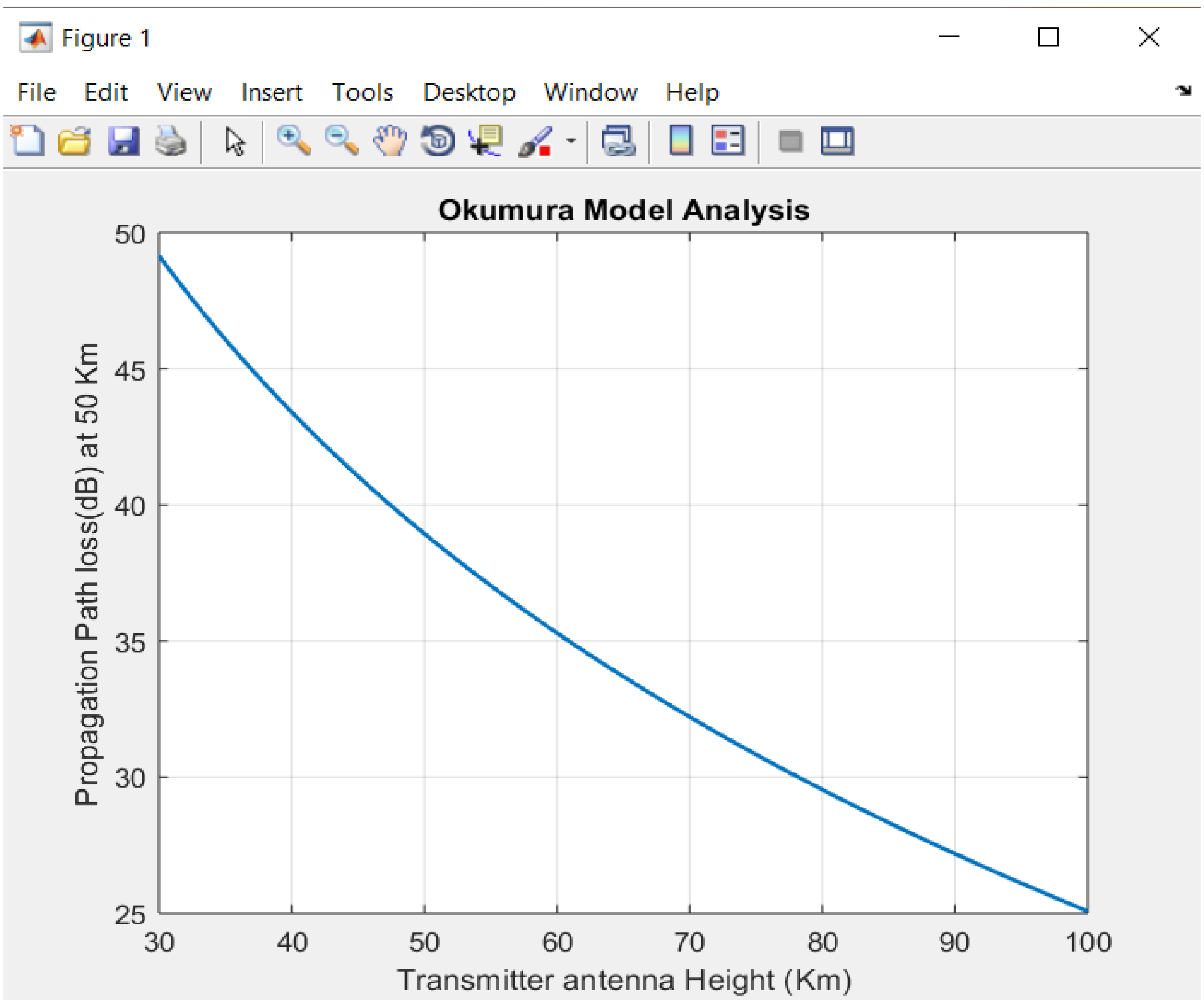
```
Enter the receiver antenna height 3m<hre<10m : 10
Enter the frequency 150Mhz<f<1920Mhz : 1500
Enter the Transmitter power watts :  1000
The Transmitted power in db is :30

######################################################################################
Caclulating Received Power Vs Distance Graph for Receiver antena Height of:10 m
Frequency:1500 Mhz ,Transmitter Power:1000 Watt (30 dB )
#########################################################################################
fx >>
```



Relation Between Transmitter Height and Propagation Path Loss





ANALYSIS & CONCLUSION

Okumura's model is wholly based on measured data and does not provide any analytical explanation. For many situations, extrapolations of the derived curves can be made to obtain values outside the measurement range, although the validity of such extrapolations depends on the circumstances and the smoothness of the curve in question.

Okumura's model is among the simplest and best in terms of accuracy in path loss prediction for mature cellular and land mobile radio systems in cluttered environments. It is very practical and has become a standard for system planning in modern land mobile radio systems in Japan. The major disadvantage with the model is its slow response to rapid changes in terrain, therefore the model is good in urban and suburban areas, but not as good in rural areas. Common standard deviations between predicted and measured path loss values are around 10 dB to 14 db.

References

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