PATHLOSS DETERMINATION USING OKUMURA-HATA MODEL FOR ROURKELA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FORTHE DEGREE OF

Bachelor of Technology

In

Electronics & Communication Engineering

By

ASHISH EKKA

Department of Electronics & Communication Engineering

National Institute of Technology

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Under the guidance of

Prof. S.Maiti

Department of Electronics & Communication Engineering

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CERTIFICATE

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This is to certify that the work in this thesis entitled………………….

"**Pathloss Determination Using Okumura-hata Model for Rourkela**"

by Ashish Ekka has been carried out under my supervision in partial fulfillment of the requirements for the degree of Bachelor of Technology in 'Electronics &Communication' during session 2011-2012 in the Department of Electronics and Communication Engineering, National Institute of Technology,

Rourkela.

Place:

Dated:

Prof. S.Maiti
Dept. of ECE
National Institute of Technology, Rourkela

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ABSTRACT

In this article we aim to adopt a propagation model for Rourkela in which we examine the applicability of Okumura-hata model in Rourkela in GSM frequency band. We accomplish the investigation in variation in path loss between the measured and predicted values. Through MATLAB graph was plotted between path loss verses distance. The mean square error (MSE) was calculated between measured path loss values and those predicted on basis of Okumura-hata model for a sub-urban area.

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CHAPTER - 1

INTRODUCTION

Introduction:

Since the mid 1990’s the cellular communications industry has witnessed rapid growth. Wireless mobile communication networks have become much more pervasive than anyone ever imagined when cellular concept was first developed. High quality and high capacity network are in need today, estimating coverage accurately has become exceedingly important. Therefore for more accurate design coverage of modern cellular networks, measurement of signal strength must be taken into consideration, thus to provide efficient and reliable coverage area. In this clause the comparisons between the theoretical and experimental propagation models are shown. The more commonly used propagation data for mobile communications is Okumura’s measurements and this is recognized by the International Telecommunication Union (ITU).

The cellular concept came into picture which made huge difference in solving the problem of spectral congestion and user’s capacity. With no change in technological concept, it offered high capacity with a limited spectrum allocation. The cellular concept is a system level idea in which a single, high power transmitter is replaced with many low power transmitters. The area serviced by a transmitter is called a cell. Thus each cell has one transmitter. This transmitter is also called base station which provides coverage to only a small portion of the service area. Transmission between the base station and the mobile station do have some power loss this loss is known as path loss and depends particularly on the carrier frequency, antenna height and distance. The range for a given path loss is minimized at higher frequencies. So more cells are required to cover a given area. Neighbor base stations close are assigned different group of channels which reduces interference between the base stations. If the demand increases for the service, the number of base stations may be increased, thus providing additional capacity with no increase in radio spectrum. The advantage of cellular system is that it can serve as many number of subscribers with only limited number of channel by efficient channel reuse.

OBJECTIVE

- Comparisons between the theoretical and the empirical propagation models
- -Reasons for path loss
- -Understanding the cellular concept

CHAPTER - 2
LITERATURE REVIEW

Introduction

The mechanisms behind electromagnetic wave propagation are large it can generally be attributed to scattering, diffraction and reflection. Because of multiple reflection from various objects, they travel along different paths of varying lengths. Most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and where presence of high rise buildings causes severe diffraction loss. .

Basically propagation models are of two types:

1. Free space propagation
2. Plane earth propagation

Free space propagation : The wave is not reflected or absorbed in free space propagation model. The ideal propagation radiates in all directions from transmitting source and propagating to an infinite distance with no degradation. Attenuation occurs due to spreading of power over greater areas. Power flux is calculated by,

$$Pd = Pt / 4\pi \ d^2$$

Where P_t is transmitted power

P_d is power at distance d from antenna.

The power is spread over an ever-expanding sphere if radiating elements generates a fixed power. As the sphere expands the energy will be spread more thinly.

The power received can be calculated from the antenna if a receiver antenna is placed in power flux density at a point of a given distance from the from the radiation.

To calculate the effective antenna aperture and received power the formulas are shown in equation. The amount of power captured by the antenna at the required distance d, depends on the effective aperture of the antenna and the power flux density at the receiving element. There are mainly three factors by which the actual power received depends upon by the antenna: (a) the aperture of receiving antenna (b) the power flux density (c) and the wavelength of received signal.

For isotropic antenna effective area is given by,

$$Ae = \lambda^2 / 4\pi \quad (2)$$

Power received is given by,

$$Pr = Pd \times Ae = Pt \times \lambda^2 / (4\pi) \quad (3)$$

Path loss is,

$$Lp = \textit{Power transmitted}\ (Pt) - \textit{Power received}\ (Pr) \quad (4)$$

Now substituting equation (3) in equation (4) we get,

$$Lp\ (dB) = 20 \log10\ (4\pi) + 20 \log10\ (d) - 20 \log10\ (\lambda) \quad (5)$$

Then substituting (λ (in km) = 0.3 / f (in MHz)) and rationalizing the equation produces the generic free space path loss formula,

$$Lp\ (dB) = 32.5 + 20 \log10\ (d) + 20 \log10\ (f) \quad (6)$$

Plane earth propagation model:

The affects of propagation model on ground is not considered for the free space propagation model. Some of the power will be reflected due to the presence of ground and then received by the receiver when a radio wave propagates over ground. The free space propagation model is modified and referred to as the ‘Plain-Earth’ propagation model by determining the effect of the reflected power. Thus this model suits better for the true characteristics of radio wave propagation over ground. This model computes the received signal to be the sum of a direct signal which reflected from a smooth, flat earth. The relevant input parameters include, the length of the path, the antenna heights, the operating frequency and the reflection coefficient of the earth. The coefficient will vary according to the type of terrain either water, wet ground, desert etc.

For this the path loss equation is given by,

$$L_{pe} = 40\log10(d) - 20\log10(h1) - 20\log10(h2) \qquad (7)$$

Here ‘ d’ is the path length in meter *h1* and *h2* are the antenna heights at the base station and the mobile,respectively. The plane earth model in not appropriate for mobile GSM systems as it does not consider the reflections from buildings, multiple propagation or diffraction effects. Furthermore, if the mobile height changes (as it will in practice) then the predicted path loss will also be changed.

EMPIRICAL PROPAGATION MODELS

Okumura and hata are among the two empirical propagation models.

The two basic propagation models are free space loss and plane earth loss would be requiring detailed knowledge of the location and constitutive parameters of building, terrain feature, every tree and terrain feature in the area to be covered. It is too complex to be practical and would be providing an unnecessary amount of detail therefore appropriate way of accounting for these complex effects is by an empirical model. There are many empirical prediction models like, Cost 231 – Hata model,Okumura – Hata model,Sakagami- Kuboi model, Cost 231 Walfisch – Ikegami model.

Okumura Model – wholly based on measured data - no analytical explanation

- among the simplest & best for in terms of path loss accuracy in cluttered mobile environment
- **Disadvantage**: slow response to rapid terrain changes
- common std deviations between predicted & measured path loss ≈ 10dB - 14dB
- widely used for urban areas
- useful for

- Frequencies ranging from 150MHz-1920MHz

- **Frequencies** can be extrapolated to 3GHz

- Distances from 1km to 100km

- Base station antenna heights from 30m-1000m

Okumura developed a set of curves in urban areas with quasi-smooth terrain

- effective antenna height:

  - Base station h_{te} = 200m

  - Mobile: h_{re} = 3m

- Gives median attenuation relative to free space (A_{mu})
- Developed from extensive measurements using vertical Omni-directional antennas at base and mobile
- Measurements plotted against frequency

• Estimating path loss using Okumura Model

- 1. determine free space loss, $A_{mu}(f,d)$, between points of interest
- 2. add $A_{mu}(f,d)$ and correction factors to account for terrain

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

L_{50} = 50% value of propagation path loss (median)

L_F = free space propagation loss

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

$G(h_{te})$ = base station antenna height gain factor

$G(h_{re})$ = mobile antenna height gain factor

G_{AREA} = gain due to environment

$A_{mu}(f,d)$ & G_{AREA} have been plotted for wide range of frequencies

Antenna gain varies at rate of 20dB per decade or 10dB per decade

Model corrected for

- Δh = terrain undulation height
- isolated ridge height
- average terrain slope
- mixed land/sea parameter

Median Attenuation Relative to Free Space = $A_{mu}(f,d)$ *(dB)*

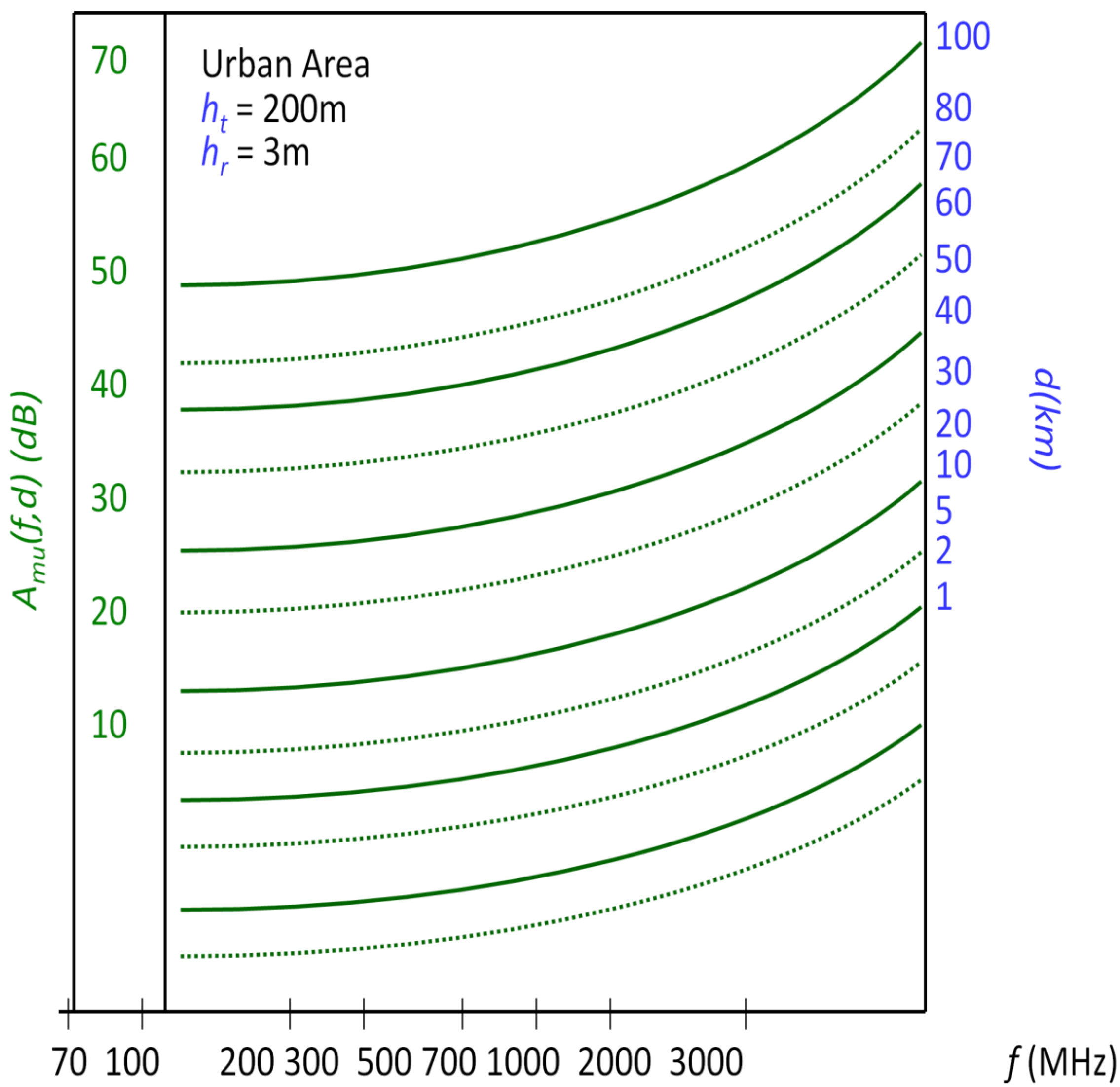

Figure 1: Median Attenuation Relative to Free Space

Correction Factor = G_{AREA}(dB)

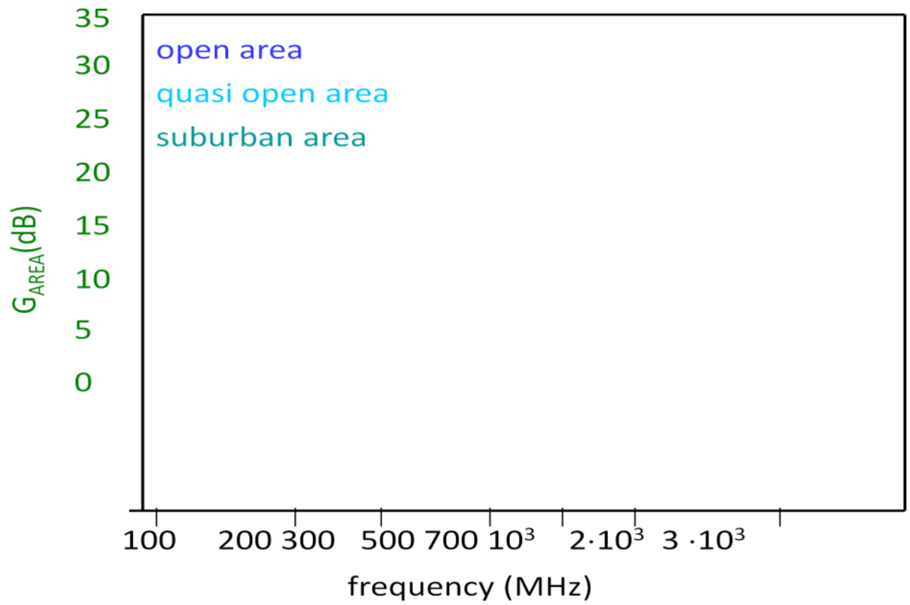

Figure 2:Correction Factor

Hata propagation model

- Most famous model: Okumura-Hata
- Okumura made extensive measurements
- Hata transformed Okumura's plots to an empirical model
- Valid for 150-1500 MHz
- Model takes the effect of
  - Transmitter height h_b in m
  - receiver height h_m in m
  - frequency f_c in MHz
  - Distance d in km
  - different environments

$$L(dB)=\begin{cases} A+B\log d & Urban \\ A+B\log d - C & Suburban \\ A+B\log d - D & open \end{cases}$$

$$A = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) - a(h_m)$$
$$B = 44.9 - 6.55\log(h_b)$$
$$C = 5.4 + 2\left[\log(f_c/28)\right]^2$$
$$D = 40.94 + 4.78\left[\log(f_c)\right]^2 - 19.33\log(f_c)$$

$$a(h_m) = \begin{cases} (1.1\log(f_c) - 0.7)h_m - (1.56\log(f_c) - 0.8) & \text{Medium or small city} \\ 8.28(\log(1.54h_m))^2 - 1.1 & f_c \geq 400Mhz, \text{large city} \\ 3.2(\log(11.75h_m))^2 - 4.97 & f_c < 400Mhz, \text{large city} \end{cases}$$

RESULTS AND DISCUSIONS

TEMS tool was used to measure the signal strength level for uplink and downlink at coverage areas for a cell in the road of Rourkela. The road of Rourkela can be considered as an sub-urban and therefore equivalent equations of Okumura-hata models were used. Pathloss was determined by practical measurement for each distance, then on that basis a comparison was done between theoretical and experimental values by MATLAB as show in next page.

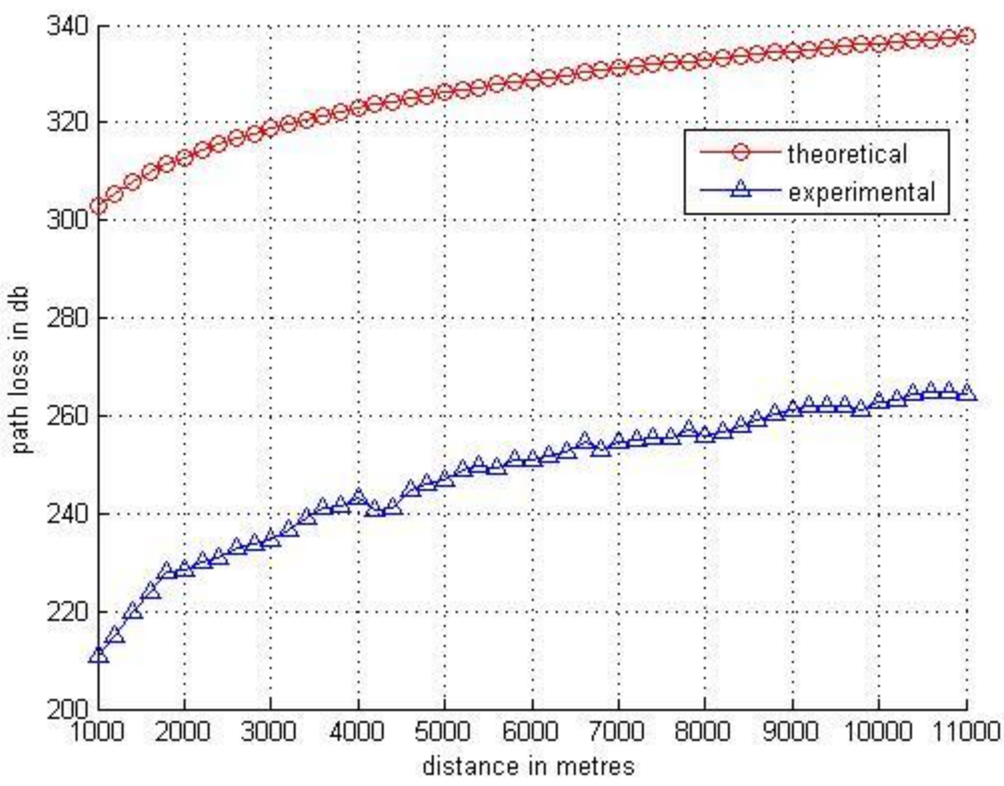

Figure 3:Path loss verses distance

This clearly shows that measured path loss is less than predicted pathloss which vary from 4 to 20 dB. This difference is because of many reasons one of the reason is the geographical situation of Rourkela is different from that of Japan. Now , mean square error (*MSE*) was calculated between measured path loss value and those predicted by Hata model using the following equation,

$$MSE = \sqrt{(\sum(Pm-Pr)^2/(N-1)}$$

Where Pm is measured path loss

Pr is predicted path loss

N is number of measured data points

The MSE was found to be around 110.23dB but the acceptable range is upto 6 dB. Therefore the MSE was subtracted from the Hata equation and the modified equation will be,

$$Lp_{Modified}\ (open\ area) = Lp(\ urban) - 4.78\{\log_{10}(f)\}^2 + 18.33\log(\ f) - 40.94\ 113.459$$

The modified result of Hata equation in sub-urban area is shown below using modified equation and the *MSE* in this case is less then 6dB, which is acceptable.

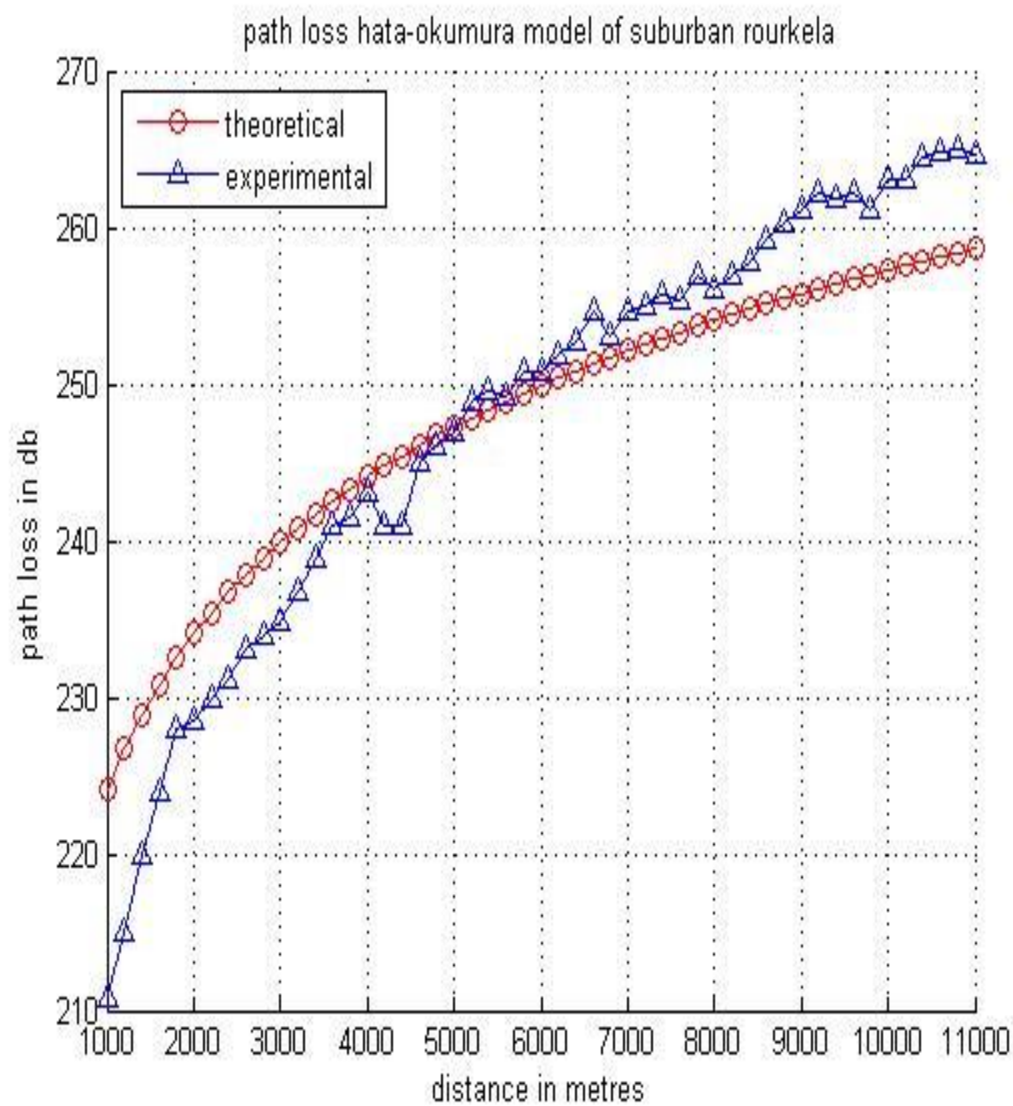

Figure 4 : Path loss verses distance after MSE

CONCLUSION

This work was aimed on predicting the mean signal strength of rourkela. However, most propagation models aim to predict the median path loss. Today’s predictions models differ in their applicability over different environmental and terrain conditions. There are many predictions methods based on deterministic processes through the availability of improved data values, but still the Okumura-Hata model is most commonly used empirical propagation model. That is because of the ITU-R recommendation for its proven reliability and its simplicity.

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