# Path Loss Propagation Model for Rural and Semiurban Mobile Environment

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## Abstract

**In order to estimate the signal parameters accurately for mobile systems, it is necessary to find a system's propagation characteristics through a medium. The path loss is one of such parameter which is associated with the design of base stations, as it tells us how much a transmitter needs to radiate to service a given region. Hence estimation of path loss becomes very important in initial deployment of wireless network and cell planning.**

**An attempt has been made to estimate and analyze the path loss for GSM system. This paper starts with the path loss characterization of mobile communication channel using empirical Hata ,LEE and COST231 model. These models are then compared with the measured data in rural and Semiurban non LOS environments.**

*Keywords-* **path loss models, empirical models, mobile communication channel**

### 1. INTRODUCTION

Mobile communication involves radio communication, in which at least one of the terminal can be in motion and include the technologies ranging from cordless telephones, digital cellular mobile radio and evolving personal communication services (PCS) to wireless data and networks. The dramatic increase in the demand for the cellular mobile communication requires highly efficient use of the limited available frequency spectrum, for the accommodation of large number of users.

Unlike wired channels that are stationary and predictable, radio channels are extremely random and do not offer easy analysis. The mechanisms, which govern radio propagation, are complex and diverse, and they can generally be attributed to three basic propagation mechanisms: reflection, diffraction and scattering.

**Path loss :** Signal propagation in wireless environment is characterized by path loss, which is the attenuation that the signal suffers from the transmitter to the receiver. Link budget calculations requires an estimate of the power level so that a signal to-noise ratio (SNR) or , similarly , a carrier-to-interference (C/I) ratio may be computed. Understanding the propagation mechanisms in wireless systems becomes important for not only predicting coverage to a particular mobile user, but also predicting the interfering signals that user will experience from other RF sources.

Path loss (PL) is used to denote the local average received signal power relative to the transmit power. It is defined by [1]:

$$PL(dB)=10\log(Pt/Pr) \qquad (1)$$

Where Pt and Pr are the transmitted and received power , respectively.In free space , the power reaching the receiving antenna which is separated from the transmitting antenna by a distance d is given by the Friss-space equation:

$$Pr=(d)[(PtGtGr\lambda^2)/(4\pi)^2d^2L] \qquad (2)$$

Where Gt and Gr are the gain of the transmitting and the receiving antenna,respectively.L is the system loss factor not related with the propagation. $\lambda$ is the wavelength .

This is useful quantity, since received power is usually measured as a local spatial average rather than instantaneous value. A general PL model that has been demonstrated through measurements uses a parameter, n, to denote the power law relationship between distance and received power. As a function of distance, d, PL (in decibels) is expressed as :

$$PL(d) = PL(d_o) + 10\, n \log (d/d_o) \qquad (3)$$

Where n is path loss exponent, which typically ranges from 2 (for rural) to 4 (for urban environment).The term $PL(d_o)$ gives PL at a known close in reference distance $d_o$ which is in the far field of the transmitting antenna. Path eloss is the main ingredient of a propagation model. It is related to the ares of coverage of mobile system.

### 2. HATA MODEL

Hata model [2] is based on extensive empirical measurements taken by Okumura in the city of Tokyo. It is widely used for path loss prediction in wireless systems. Hata presented the urban area propagation loss as standard formula and supplied correction equations for suburban and rural areas.
The formula for the median path loss in urban area is given by

$$Lp(urban)(d) = 69.55 + 26.16\log(fc) - 13.82\log(hb) - a(hm) + (44.9-6.55\log(hb))\log(d) \quad (4)$$

Where fc is the carrier frequency which varies from 150 MHz to 1500 MHz, hm is the mobile station height , hb is the base station height and d is the distance from the base station to the mobile antenna. a(hm) is the correction factor for the effective antenna height of the mobile unit which is given by

$$a(hm) = (1.1\log(fc)-0.7)hm-(1.56\log(fc)-0.8) \quad (5)$$

to obtain the path loss in suburban area, the standard Hata formula is modified as follows:

$$Lp(d) = Lp(urban)(d) - 5.4 - 2[\log(fc/28)]^2 \quad (6)$$

The path loss in open rural area is expressed through

$$Lp(d) = Lp(urban)(d) - 4.78(\log fc)^2 - 18.33 \log fc - 40.98 \quad (7)$$

**3. LEE MODEL**

Lee *area-to-area* mode median loss model is given by [3]

$$\text{Path Loss} = Lo + \gamma \log(d) - 10\log(Fo) \quad (8)$$

Where (Lo) is a median path loss at reference point (near zone). ($\gamma$) is the slope of the path loss curve in dB/decade. Fo is an adjustment term composed of several factors and can be calculated as

$$Fo = F_1 F_2 F_3 F_4 F_5 \quad (9)$$

Where the dependant factors are BS antenna height correction factor ($F_1$), BS antenna gain correction factor ( $F_2$ ), MS antenna height correction factor ($F_3$), MS antenna gain correction factor ($F_4$ ), and frequency adjustment factor ($F_5$).

These are expressed as follows:
$F_1 = (hb/30.48)^2$
$F_2 = (Gb/4)$
$F_3 = (hm/3)^2$
$F_4 = Gm/1$
$F_5 = (fc/900)^{-n}$ (10)

Gb and Gm are the gain of base and mobile station antenna respectively.

**4. COST-231 MODEL [4]**

It is also called as the PCS extension of Hata Model. It is a radio propagation model that extends the Hata model to cover the more elaborated range of frequencies which varies from 150 MHz to 2000 MHz . This model is applicable to Open, Suburban and Urban areas.

Other specifications of this model are

- Transmitter Height: 30m to 100 m
- Receiver Height: up to 10m
- Link Distance (d): up to 20 km

The COST 231 model is formulated as [4]:

$$Lp(d) = 46.3+33.9\log(fc)-13.82\log(hb)-a(hm) + (44.9-6.55\log(hb))\log(d) + C \quad (11)$$

Where,
C = 0 dB for medium cities and suburban areas and 3dB for urban areas.
a(hm) is the correction factor for the effective antenna height of the mobile unit as described in Hata model and given by equation (5).

**5. PATH LOSS BASED ON FIELD MEASUREMENTS [5]**

Field measurements were peformarmed in the suburban city of Nagpur and nearby rural area for BSNL GSM system at 950MHz at transmitted power of 10watts (40dBm). The received signal and the corresponding path loss for suburban and rural areas are given in Table1and Table2 respectively.

TABLE1: FOR SUB URBAN AREA

| Distance from base station in meters | Received signal strength (dBm) | Path loss (dBm) |
|---|---|---|
| 260 | -58 | 98 |
| 280 | -59 | 99 |
| 390 | -64 | 104 |
| 450 | -60 | 100 |
| 500 | -65 | 105 |
| 580 | -70 | 110 |

| | | |
|---|---|---|
| 650 | -75 | 115 |
| 750 | -70 | 110 |
| 765 | -74 | 114 |

TABLE2: FOR RURAL AREA

| Distance from base station (Km) | Received signal strength (dBm) | Path loss (dBm) |
|---|---|---|
| 1.0 | -60 | 100 |
| 1.5 | -65 | 105 |
| 2.0 | -72 | 112 |
| 2.5 | -75 | 115 |
| 3.0 | -80 | 120 |
| 3.5 | -85 | 125 |
| 4.0 | -90 | 130 |
| 4.5 | -95 | 135 |
| 5.0 | -110 | 150 |

## 6. CONCLUSION

In this article, path loss model based on the field measurements for suburban city of Nagpur is presented. The figure 1-3 shows the comparison of measured data with Hata, Lee and COST models which are generally used for path loss prediction in GSM based system applicable to given terrain scenario. A comparison of the developed model with above cited models gives large difference because of different geographical conditions in India. Therefore for accurate path loss prediction, field measurements must be performed and the measured data can be used to correct the existing model or to develop a new model [6].

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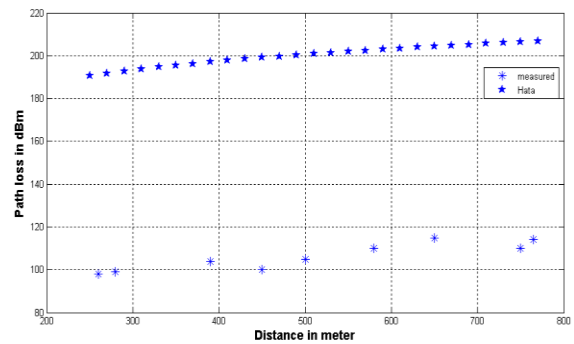


Figure 1. measured Vs Hata path loss

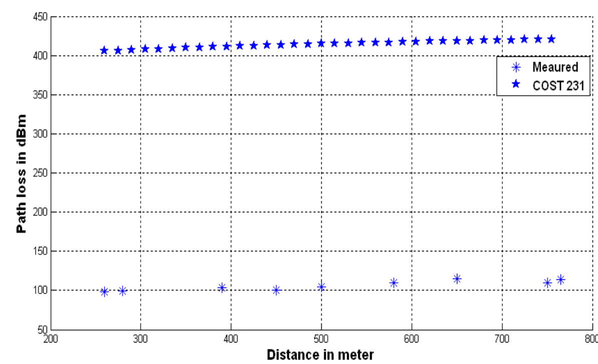


Figure 2. measured Vs COST 231 path loss

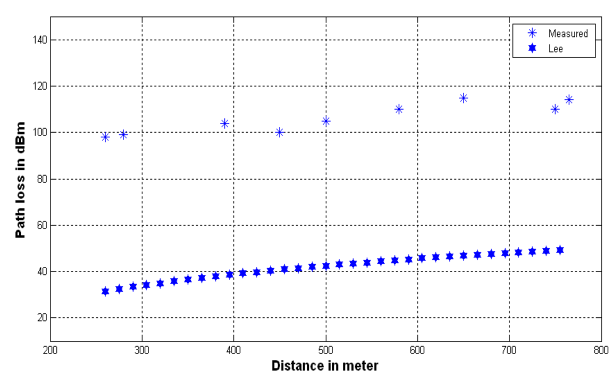


Figure 3. measured Vs Lee path loss