PROPAGATION MODEL FOR HIGHWAY IN MOBILE COMMUNICATION SYSTEM

K.Ayyappan
Department of Electronics and Communication Engineering,
Rajiv Gandhi College of Engineering and Technology,
Pondicherry, India.

*P. Dananjayan
Department of Electronics and Communication Engineering Pondicherry Engineering College Pondicherry - 605014, India.
* pdananjayan@hotmail.com
*corresponding author

ABSTRACT

Radio propagation is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network. It is heavily site specific and can vary significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor. Accurate characterization of radio channel through key parameters and a mathematical model is important for predicting signal coverage, achievable data rates, specific performance attributes of alternative signaling and reception schemes. Path loss models for macro cells such as Hata Okumura, COST 231 and ECC 33 models are analyzed and compared their parameters. The received signal strength was calculated with respect to distance and model that can be adopted to minimize the number of handoffs and avoid ping pong effect are determined. This paper proposes a propagation model for highway environment between Pondicherry - Villupuram which is 40 kilometers spaced out .Comparative study with real time measurement obtained from Bharat Sanchar Nigam Limited (BSNL) a GSM based wireless network for Pondicherry, India has been implemented.

Keywords: Handoff, Path loss, Received signal strength, ping pong, cellular mobile.

1 INTRODUCTION

Propagation models have traditionally focused on predicting the received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in a close spatial proximity to a particular location. Propagation models that predict the signal strength for an arbitrary transmitter-receiver (T-R) separation distance are useful in estimating the radio coverage area of a transmitter. Conversely, propagation models that characterize the rapid fluctuations of the received signal strength over very short travel distances are called small-scale or fading models. Propagation models are useful for predicting signal attenuation or path loss. This path loss information may be used as a controlling factor for system performance or coverage so as to achieve perfect reception [1].

The common approaches to propagation modeling include physical models and empirical models. In this paper, only empirical models are considered. Empirical models use measurement data to model a path loss equation. To conceive these models, a correlation was found between the received signal strength and other parameters such as antenna heights, terrain profiles, etc through the use of extensive measurement and statistical analysis.

Radio transmission in a mobile communication system often takes place over irregular terrain. The terrain profile of a particular area needs to be taken into account for estimating the path loss. The terrain profile may vary from a simple curved earth profile to a highly curved mountainous profile. A number of propagation models are available to predict path loss over irregular terrain. While all these models aim to predict signal strength at a particular receiving point or in a specific location are called sector, the methods vary widely in their approach, complexity and accuracy. Most of these models are based on a systematic interpretation of measurement data obtained in the service area. In cellular mobile communication systems, handoff takes place due to movement of mobile unit and unfavorable conditions inside an individual cell or between a numbers of adjacent cells [2, 3]. It is a seamless service to active users while data transfer is in progress, so unnecessary handoffs should be avoided.

Hard handoff suffers from 'ping pong' effect when the mobile users are near the boundaries of adjacent cells and is a result of frequent handoffs. The parameters measured to determine handoff are usually the received signal strength, the signal to noise ratio and the bit error rate. However, a path loss model can increase the connection reliability. Hence, the choice of path loss model plays an important role in the performance of handoffs. In this paper different path loss models for macro cells such as Hata Okumura model, Cost 231 model and ECC 33 model are analyzed and compared their parameters. A propagation model for highway is proposed by modifying Cost 231 and Hata Okumura suburban model and it is implemented in Pondicherry – Villupuram highway and compared its parameters with experimental values.

The work is organized as follows. Section 2 describes the path loss models. Section 3 deals with the received signal strength for different path loss models. Section 4 discusses the models and the results are evaluated. Section 5 concludes with the performance of various path loss models.

2 PATH LOSS MODELS

Path loss is the reduction in power of an electromagnetic wave as it propagates through space. It is a major component in analysis and design of link budget of a communication system. It depends on frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors. 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. Among numerous propagation models, the following are the most significant ones, providing the foundation of mobile communication services. The empirical models are

i. Hata Okumura model
ii. COST 231 model
iii. ECC 33 model

These prediction models are based on extensive experimental data and statistical analysis, which enable us to compute the received signal level in a given propagation medium [5, 6]. The usage and accuracy of these prediction models depends on the propagation environment.

2.1 Free Space Propagation Model

In radio wave propagation models, the free space model predicts that received power decays as a function of T-R separation distance. This implies that received power decays with distance at a rate of 20 dB/decade.

The path loss for free space model when antenna gains are included is given by

$$PL(dB) = -G_t - G_r + 32.44 + 20\log(d) + 20\log(f) \quad (1)$$

where

G_t is the transmitted antenna gain in dB,
G_r is the received antenna gain in dB,
d is the T-R separation distance in kilometers and
f is the frequency in MHz.

2.2 The Hata Okumura model

The Hata-Okumura model is an empirical formula for graphical path loss data provided by Yoshihisa Okumura, and is valid from 150 MHz to 1500 MHz. The Hata model is a set of equations based on measurements and extrapolations from curves derived by Okumura. Hata presented the urban area propagation loss as a standard formula, along with additional correction factors for application in other situations such as suburban, rural among others. The computation time is short and only four parameters are required in Hata model [7]. However, the model neglects terrain profile between transmitter and receiver, i.e. hills or other obstacles between transmitter and receiver are not considered. This is because both Hata and Okumura made the assumption that transmitter would normally be located on hills. The path loss in dB for the urban environment is given by

$$PL(dB) = A + B\log(d) \quad (2)$$

where

d is distance in kilometer,
A represents a fixed loss that depends on frequency of the signal.
These parameters are given by the empirical formula

$$A = 69.55 + 26.16\log(f) - 13.82\log(h_b) - a(h_m)$$

$$B = 44.9 - 6.55\log(h_b)$$

where,

f is frequency measured in MHz,
h_b is height of the base station antenna in meters,
h_m is mobile antenna height in meters and
$a(h_m)$ is correction factor in dB
For effective mobile antenna height $a(h_m)$ is given by

$$a[h_m] = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8]$$

The path loss model for highway is given by
For without noise factor

$$PL(dB) = PL(dB)_{urban} - 2\left[\log\left(\frac{f}{28}\right)\right]^2 - 5.4 \quad (3)$$

For with noise factor

$$PL(dB) = PL(dB)_{urban} - 2\left[\log\left(\frac{f}{28}\right)\right]^2 \quad (4)$$

2.3 COST-231 Hata model

To extend Hata-Okumura- model for personal communication system (PCS) applications operating at 1800 to 2000 MHz, the European Co-operative for Scientific and Technical Research (COST) came up with COST-231 model. This model is derived from Hata model and depends upon four parameters for prediction of propagation loss: frequency, height of received antenna, height of base station and distance between base station and received antenna [8].
The path loss in urban area is given by

$$PL(dB) = 46.33 + 33.9\log(f) - 13.82\log(h_b) - a(h_m) + [44.9 - 6.55\log(h_b)]\log(d) \quad (5)$$

where $a(h_m) = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8]$

The path loss calculation for highway is similar to Hata-Okumura model.

2.4 ECC-33 model

The ECC 33 path loss model, which is developed by Electronic Communication Committee (ECC), is extrapolated from original measurements by Okumura and modified its assumptions so that it more closely represents a fixed wireless access (FWA) system. The path loss model is defined as,

$$PL(dB) = A_{fs} + A_{bm} - G_t - G_r \quad (6)$$

where,
A_{fs} is free space attenuation,
A_{bm} is basic median path loss,
G_t is BS height gain factor and
G_r is received antenna height gain factor.
They are individually defined as,

$A_{fs} = 92.4 + 20\log(d) + \log(f)$ and

$$A_{bm} = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56[\log(f)]^2$$

$$G_t = \log\left(\frac{h_b}{200}\right)[13.958 + \{5.8\log(d)\}]^2$$

for medium city environments,

$$G_r = [42.57 + 13.7\log(f)][\log(h_m) - 0.585]$$

where,
f is frequency in GHz,
d is distance between base station and mobile (km)
h_b is BS antenna height in meters and
h_m is mobile antenna height in meters.

3 RECEIVED SIGNAL STRENGTH

In mobile communication, received signal strength is a measurement of power present in a received radio signal. Signal strength between base station and mobile must be greater than threshold value to maintain signal quality at receiver [9]. Simultaneously signal strength must not be too strong to create more co-channel interference with channels in another cell using same frequency band. Handoff decision is based on received signal strength from current base station to neighbouring base stations. The signal gets weaker as mobile moves far away from base station and gets stronger as it gets closer. The received signal strength for various path loss models like Hata Okumura model, Cost 231 model, and ECC-33 model are calculated as

$$P_r = P_t + G_t + G_r - PL - A \quad (7)$$

where,
P_r is Received signal strength in dBm,
P_t is transmitted power in dBm,
G_t is transmitted antenna gain in dB,
G_r is received antenna gain in dB,
PL is total path loss in dB and
A is connector and cable loss in dB.

4 PERFORMANCE ANALYSIS

The performance analysis is based on the calculation of received signal strength, path loss between the base station and mobile from the propagation model. The GSM based cellular network specification obtained from Bharat Sanchar Nigam Limited (BSNL), India shown in Table 1 is used for evaluating the performance of path loss models.

Table 1: Simulation parameter

Parameters	Values
Base station transmitter power	43dBm
Mobile transmitter power	30dBm
Base station antenna height	35m
Mobile antenna height	1.5m
Transmitter antenna gain	17.5dB
Threshold level for mobile	-102dBm
Threshold level for base station	-110dBm
Frequency	900 MHz
Connector loss	2 dB
Cable loss	1.5dB
Duplexer loss	1.5dB
Maximum uplink loss	161.5dB
Maximum downlink loss	161.8dB

4.1 Path losses for various models

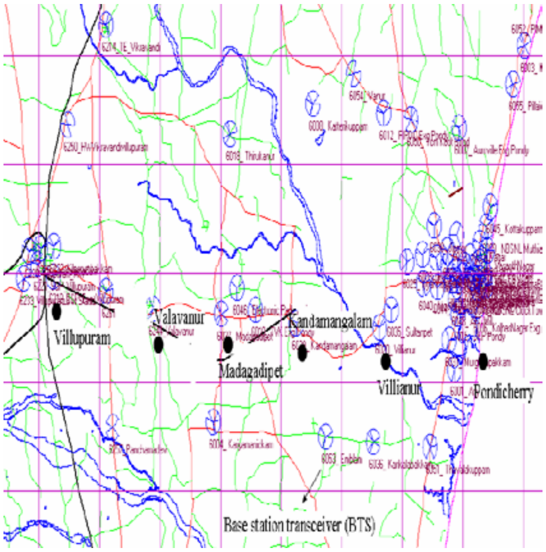

Fig.1 Pondicherry- Villupuram highway map

Table 2 Path loss for various models

Distance (km)	COST 231(dB)	HATA OKUMURA (dB)	ECC33 (dB)
0.5	104.7	105.1	130.7
1	115.2	115.5	139.3
1.5	121.3	121.7	144.7
2	125.6	126.0	148.6
2.5	129.0	129.4	151.8
3	131.7	132.1	154.5
3.5	134.1	134.5	156.8
4	136.1	136.5	158.8

The path losses for various models are calculated using eq (2),(5) and (6) between Pondicherry-Villupuram highway as shown in Fig.1 which is connected via Villianur, Kandamangalam, Madagadipet and Valavanur. The circle shown in this figure are the base station transceiver (BTS) and identified by BTS number.The path loss values are calculated and given in Table 2 and the comparison for various models are given in Fig.2.The maximum allowable uplink loss for Nortel S8K base station transceiver is 161.5 dB and maximum allowable downlink loss is 161.8 dB.

The number of handoffs per call is relative to cell size, smaller the cell size maximum the number of handoff and the path loss model which cover maximum distance will minimize the number of handoff. The path loss calculation using Hata-Okumura and COST 231 model are less than the threshold value up to 19 km and ECC 33 model exceed the threshold value at 5km.

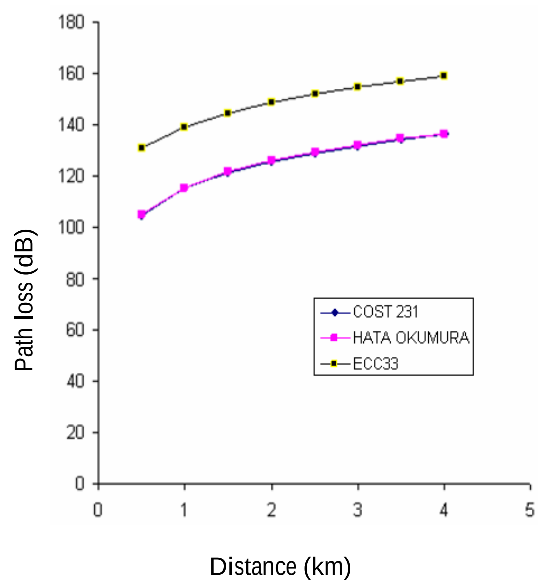

Fig.2 Comparison of Path loss

4.2 Received signal strength for various models

Table 3: BS to MS received power

Distance (km)	COST 231 (dBm)	HATA OKUMURA (dBm)	ECC 33 (dBm)
0.5	-49.2	-49.6	-75.2
1	-59.7	-60.0	-83.8
1.5	-65.9	-66.1	-89.2
2	-70.1	-70.5	-93.2
2.5	-73.5	-73.9	-96.3
3	-76.2	-76.6	-99.0
3.5	-78.6	-79.0	-101.3
4	-80.6	-81.0	-103.3

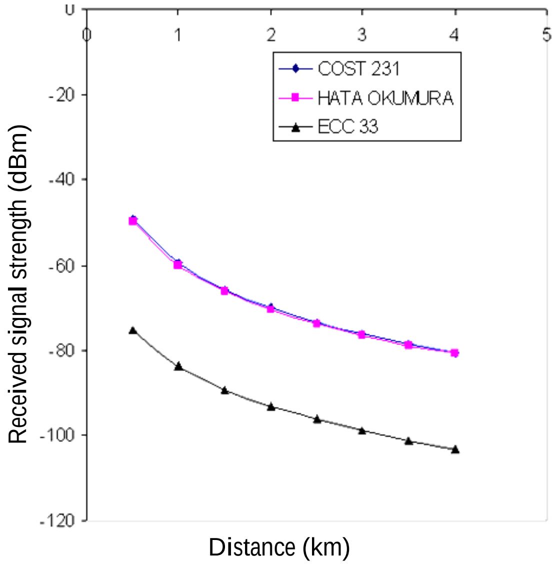

Fig.3 Received signal strength for suburban models

The received signal strength for COST 231, Hata-Okumura and ECC 33 models are calculated using eq (7) shown in Table.3 for suburban area and the comparison shown in Fig.3. The received signal strength using ECC 33 model is -103.3 dBm at four kilometers which is greater than threshold level of mobile receiver -102 dBm. The received signal strength using COST 231 and Hata-Okumura model values are less than the sensitivity threshold of mobile. So these two models are preferred for maximum coverage area and reduce the number of handoff.

4.3 Highway propagation model

Table 4: BS to MS received power

Distance (km)	COST 231 (dBm)	HATA OKUMURA (dBm)	Experiment Value (dBm)
0.5	-49.2	-49.6	-50
1	-59.7	-60.0	-57
1.5	-65.9	-66.1	-65
2	-70.1	-70.5	-68
2.5	-73.5	-73.9	-74
3	-81.6	-82.0	-82
3.5	-84.0	-84.4	-84
4	-86.0	-86.4	-86

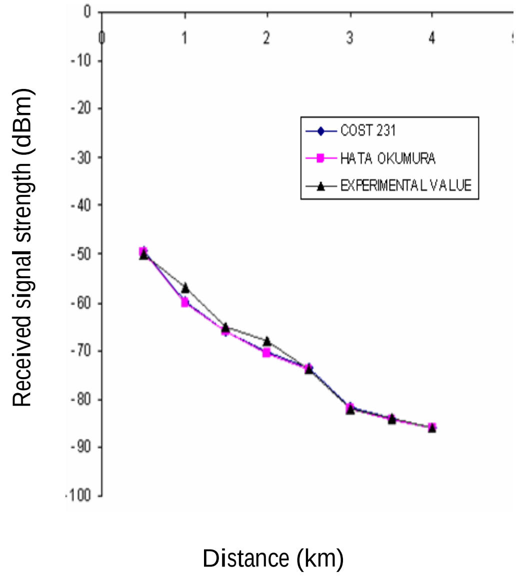

Fig. 4 Received signal strength for highway models

The general area around highway could be suburban because of location. The path loss calculation is a major concern in highways with and without noise level. In this paper the suburban model is modified to highway with small correction factor with respect to the location. RSS value for highway without noise factor was calculated using suburban model but highway with noise factor was calculated using additional correction factor of 5.4 with suburban model. Here up to 2.5 km the received signal strength was calculated using suburban model and beyond 2.5 km it was calculated with additional noise factor of 5.4.

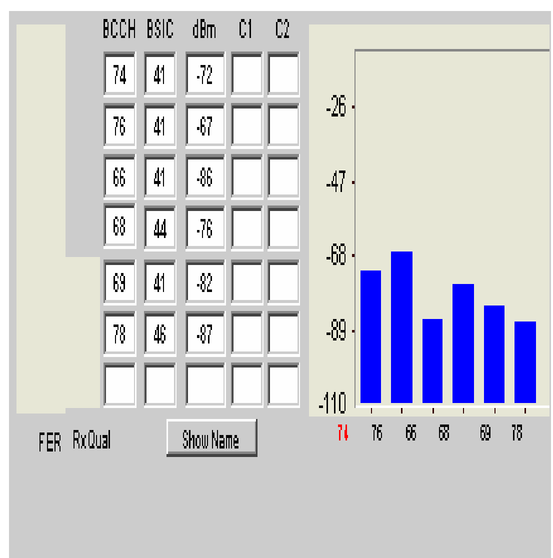

Fig.5 Adjacent cell RSSI

The Agilent Technologies provides Drive Test solution for GSM networks. The Agilent Drive Test E6474A model is used to calculate the amount of signal received by a mobile in Pondicherry - Villupuram highway as shown in Table 4.The received signal strength for COST 231, Hata-Okumura models are calculated and compared with experimental value are shown in Fig 4. The modified COST 231, Hata-Okumura suburban models for highway are matches with the experimental values.

High RSS handover margins can result in poor reception and dropped calls, while very low values of handover margin can produce ping pong effects as mobile switches frequently between cells. The existing cell broadcast control channel (BCCH-74) and adjacent cells (BCCH-76, 66, 68,69and 78) received signal strengths are shown in Fig.5. The optimum handover decision taken from drive test adjacent cell received signal strength indicator (RSSI) as shown in Fig.5.For BCCH-74 the corresponding base station identification code (BSIC) is 41 and the received signal strength is -72 dBm. Consecutively, mobile user receives adjacent inter and intra cell received signal strengths from BSIC 44,46and 41. The optimum handover decision taken from the drive test adjacent cell received signal strength indicator (RSSI) to improve the signal reception and reduce the number of dropped calls and also the ping-pong effect

5 CONCLUSION

In this paper, different path loss models for macro cells were used. The calculated path loss is compared with existing model like Hata-Okumura model, COST 231model and ECC 33 model. The received signal strength from base stations was calculated and the calculated values are compared with observed value between Pondicherry and Villupuram highway. The result shows that modified suburban model for highway using Hata-Okumura and COST 231 model is closer to the observed received signal strength and predicted to be suitable model for highway received signal strength calculation.

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