A REVIEW ON OUTDOOR PROPAGATION MODELS IN RADIO COMMUNICATION

Govind Sati[1], Sonika Singh[2]
[1]Post Grad. Scholar, DIT University, Dehradun, India
[2]Associate Professor, DIT University, Dehradun, India

ABSTRACT

Radio propagation models focus on realization of the path loss with supplement task of predicting the area of coverage for a radio transmitter. Radio propagation models are empirical in nature. They are developed based on large collection of data for the specific scenario. The aim of this paper is study of different path loss models in radio communication at different frequency band. Like SUI model, Hata model, Okumura model, COST-231 model, ECC-33 model & W-I model.

KEYWORDS: *Empirical, Deterministic and Stochastic path loss models. Free space path loss models.*

1. INTRODUCTION

Radio propagation model is an empirical mathematical formulation for the characterization of radio wave propagation as a function of distance between transmitter and receiver, function of frequency and function of other condition. A propagation model is usually developed to predict the behavior of propagation in different environment. Radio propagation model are empirical in nature and are developed based on large collection of data collected for the specific scenario. For any propagation model the collection of data has to be sufficiently large to provide enough scope to all kind of situations in specific scenario.

Propagation models are very useful in network planning and performing interference studies as the deployment proceeds. These models can be broadly classified into three types- Empirical, Deterministic and Stochastic. [6]

Empirical:-

An empirical model is based on observed and measurements alone. These models are mainly used to predict the path loss. It can be further classified into two sub part- non time dispersive and time dispersive.

The Stanford University Interim (SUI) model is one of the perfect examples of time dispersive models. The models like Hata model, COST-231 Hata model, ITU – R model are the best example of non-time dispersive models.

Deterministic:-

Deterministic models are deployed laws of governing electromagnetic wave propagation for determination of received signal power at a particular location. These kinds of models often require a complete 3-D map of the propagation environment. Ray-tracing models are the best example of the deterministic model [10].

Stochastic:-

These models are used in terms of random variables. Stochastic models are the least accurate but require the least information about the environment and use much less processing power to generate predications. These are mostly used for predication at above 1.8GHz.

2. FREE SPACE PATH LOSS MODELS

Path loss in free space can be defined as the ratio of the transmitted power to receiver power in free air. It is expressed in decibels. Free space path loss is diverse on frequency and distance. Path loss is expressed as [1]

$PL = 10n\ \log_{10}(d) + 10n\ \log_{10}(f) + 32.44$ ….(1)
Where
n is the path loss exponent. The value of path loss exponent for free space model is always 2.[4]
$PL = 20\ \log_{10}(d) + 20\ \log_{10}(f) + 32.44$ ….(2)
F [MHz] Frequency of operation.
D [m] Distance between transmitter & receiver.

2.1 Stanford University Interim (SUI) models

Working group of IEEE 108.16 proposed this standard for the frequency range below 11GHz. The proposed standards for frequency range below 11GHz contain the channel models developed by Stanford University, namely the SUI models. This model has been derived as an extension to Hata model with 1900 MHz frequency band and above.
The SUI models are sub divided into three different types, namely A, B & C. Type A is associated with path loss and it is very useful for hilly terrain with moderate to heavy foliage densities. Type B is very useful for flat terrains with moderate to heavy tree densities or hilly terrains with light tree densities. Type C is associated with minimum path loss and applicable for flat terrain with light tree densities.
The fundamental path loss expression for the SUI model along with correction factors is as [4]
$PL = A + 10\,\gamma\ \log_{10}(\frac{d}{d_0}) + X_f + X_h + e\,; for\ d > d_0$ … (3)
Where the parameters are
D [m] Separation of transmitter and receiver
d_0 [m] 100
λ [m] Wavelength
X_f [MHz] Correction factor for frequency > 2GHz
X_h[m] Correction factor for receiving antenna height
S [dB] Correction factor for shadowing effect (value between 8.2dB to 10.6dB)
γ Path loss exponent

2.2 Hata Model

Hata model is simply the empirical formulation of the graphical path loss data produced by Okumura and is valid from 150MHz to 1500MHz frequency range. It predicted the median path loss for the distance d from transmitter to receiver antenna up to 20Km and the transmitter antenna height is considered 30m to 200m and receiver antenna height is 1m to 10m. It is presented in the urban area propagation loss as a standard formula and supplied provide correction equations for suburban and rural areas.
Median path loss (dB) of Hata model is given by [11]
$PL(dB) = 69.25 + 26.16\ \log(f_c) - 13.82\ \log(h_t) - a\ (h_r) + (44.99 - 6.55\ \log(h_t))(\log(I))$
…..(4)
Where
f_c [MHz] Frequency
h_t [m] Height of base station antenna
h_r [m] Height of mobile station antenna
I [Km] $T_x - R_x$ sepration
$a\ (h_r)$ Antenna height correction factor for the receiver antenna as a function of coverage area.

2.3 Okumura model

The Okumura model is classical empirical model to measure the radio signal strength in built up areas. This model is perfect in those cities which having dense and tall structure. This model was framed on the basis of accumulated data from Tokyo city of Japan [6]. This model is applicable for less than 3GHz frequency range. By using this model we calculate the path loss in urban, sub-urban and rural area.
Median path loss model can be expressed as [13]
$PL\ (dB) = L_f + A_{mn}(f, d) - G(h_{te}) - G(h_{re}) - G_{AREA}$.….(5)

Where
L_f [dB] Free space path loss
$A_{mn}(f, d)$ [dB] Median attenuation relative to free space
$G(h_{te})$ [dB] Base station antenna height gain factor
$G(h_{re})$[dB] Mobile station antenna height gain factor
h_{te} [m] Transmitter antenna height
h_{re} [m] Receiver antenna height
G_{AREA} [dB] Gain due to type of environment
F [MHz] Operation frequency
d [km] Distance between T_X & R_X

2.4 Cost 231 Hata model

Cost 231 Hata model is widely used for predicting path loss in mobile wireless system. Cost 231 Hata model is initiated as an extension of Hata model. It is used for predicted the path loss in different environments like urban, sub urban and rural. It is designed for 500MHz to 2000MHz frequency range. The basic path loss equation in dB is[2] [12]

$$PL = 46.3 + 33.9\ \log_{10}(f) - 13.82\ \log_{10}(h_b) - ah_m + n(44.9 - 6.55\ \log_{10}(h_b)) \log_{10} d +\ c_m \quad (6)$$

Where,
f: [MHz] Frequency
d :[Km] Distance between transmitter and receiver antenna
h_b [m] Height of transmitter antenna
The parameter ah_m is defined for urban environments as

$$ah_m = 3.20\ (\log_{10}(11.75h_r))^2 - 4.97, for\ f > 400MHz$$

And for suburban or rural environments

$$ah_m = (1.1\ \log_{10} f - 0.7)h_r - (1.56\ \log_{10} f - 0.8)$$

Where
h_r Antenna height in meters.

2.5 Hata – Okumura Extended model or ECC-33 model

Hata – Okumura model is most usable in empirical propagation model, which is based on the Okumura model. It is well established model for the UHF band. Recent recommendations of ITU-R i.e. P.529, this model use up to 3.5GHz but data greater than 3GHz is not yet provided. Path loss of the ECC-33 model is defined as- [2]

$$PL =\ A_{fs} +\ A_{bm} -\ G_b -\ G_r \quad .....(7)$$

Where
A_{fs} [dB] Free space attenuation
A_{bm} [dB] Basic median path loss
G_b Transmitter antenna height gain factor
G_r Receiver antenna height gain factor
They are individually defined as

$$A_{fs} = 92.4 + 20\ \log_{10}(d) +\ 20\ \log_{10}(f)$$

$$A_{bm} = 20.41 + 9.83\ \log_{10}(d) + 7.894 \log_{10}(f) + 9.56\ [\log_{10}(f)]^2$$

$$G_b = \log_{10}(h_b/200)\ \{\ 13.958 + 5.8\ [\log_{10}(d)]^2\}$$

$$G_r = [42.57 + 13.7\ \log_{10}(f)][\ \log_{10}(d_r) - 0.585]$$

2.6 Walfisch - Ikegami Propagation Model

It the combination of the models from J. Walfisch and F. Ikegami. This empirical model was developed by the COST-231 project. It is also called Empirical COST- Walfisch- Ikegami.[6]
The accuracy of the model is quite high because in urban environments especially the propagation over the rooftops is the most dominant part. This empirical model considers only the buildings in the vertical place between the transmitter and the receiver.
This model is applicable for the frequency range of 800 to 2000MHz, height of the transmitter "h_{TX}" is 4 to 50m, height of the receiver "h_{RX}" is 1 to 3m and distance “d” between transmitter and receiver.

This model distinguishes between two situations, the "line of sight (LOS)" and the "non-line of sight (NLOS)" situations.

LOS situation:-

In this case the path loss predication is very easy. Equation for the path loss predication is.

$$I_P = 42.6 + 26\ \log\left(\frac{d}{km}\right) + 20\ \left(\frac{f}{MHz}\right) \qquad \ldots(8)$$

N-LOS situation:-

$$PL_{LOS} = \{\, L_{FSL} +\ L_{rts} +\ L_{msd}\ for\ urban\ \&\ sub-urban\ L_{FS}\ if\ L_{rts} +\ L_{msd} > 0\, \}$$

Where,

L_{FSL} Free space loss

L_{rts} Roof top to street diffraction

L_{msd} Multiscreen diffraction loss

3. COMPARISON

From the above study all outdoor propagation models can compare on the basses of their frequency band and terrain.

Table1 – Comparison of various outdoor propagation models.

S. No	MODELS	FREQUENCY BAND	TERRAIN
1	SUI	Below 11GHz	Hilly Terrain
2	HATA	150MHz to 1500MHz	Urban, Suburban & Rural
3	OKUMURA	Up to 3GHz	Urban, Suburban & Rural
4	COST-231	500MHz to 2000MHz	Urban, Suburban & Rural
5	ECC-33	Up to3.5GHz	Urban, Suburban & Rural
6	COST-231 W-I	800 to 2000MHZ	Buildings in the vertical place

4. CONCLUSIONS

This study has given the brief introduction of radio propagation models. The major parameters which characterize the radio propagations models h, f, T_x, R_x were introduced. Each model has its own characteristic to use in the different environment. Free space path loss model is basic models for finding the path loss in free space. SUI models showed quite large path loss prediction errors. Hata model predicted the median path loss at 20Km distance from T_x toR_x. COST-231 Hata model generally predicate the path loss at greater antenna heights. ECC-33 model highly recommended for urban environments. WI models have high accuracy and generally use in urban environment.

REFERENCES

[1] Yih-Guang Jan, Yang-Han Lee, Hsien-Wei Tseng, Ming Hsueh Chuan, Jheng Yao Lin, Chih-Weisu, "comparison of propagation path loss models" IEEE-C802.16m-07/121, call for comments, 2007.

[2] V.S Abhaywardhana, I.J Wassell, D. Crosby, M.P Sellars, M.G Brown, 'Comparison of empirical propagation path loss models for fixed wireless access systems' IEEE Conference, 2005.

[3] Theodore S. Rappaport, Susumu Yoshida, 'propagation measurement & models for wireless communication channels' IEEE, Communication Magazine 1995.

[4] Magdy F. Iskander, Zhengquing Yun, ' Propagation predication models for wireless communication systems', IEEE Transactions on microwave theory & techniques, March 2012.

[5] V.S Abhaywardhana, I.J Wassell, D. Crosby, M.P Sellars, M.G Brown, 'time variability of the foliated fixed wireless access channel at 305GHz', IEEE Conference, 2005.

[6] Jhon S. Seybold, 'introduction to rf propagation', John Wiley & Sons., 2005

[7] F.M Landstorfer, 'wave propagation models for the planning of mobile communication networks', GAAS Munich, 1999.

[8] V. Erceg, K. V. S. Hari, et al., 'Channel models of fixed wireless applications' tech. rep. IEEE 802.16 Broadband Wireless Access Working Group, January 2001.

[9] T. K. Sarkar, Z. Ji, K. Kim, A. Medouri, M. Salazar – Palma. 'A Survey of Various Propagations Models for Mobile communication'. IEEE Antennas and Propagation Magazine, 45, 3(2003), pp.51-82N
[10] http://www.radioelectronics.com/info/propagation/path-loss/rf-siganl-loss-Tutorial.php
[11] M Hata, 'Empirical formula for propagation loss in land mobile radio services' IEEE Transactions on vehicular technology, Vol 29,No 3, August 1980, P317
[12] Cost action 231, 'Digital mobile radio towards future generation systems, final report' tech rep, European communities, EUR 18957, 1999.

AUTHOR

Govind Sati became a Member (M) of IAENG in 2013. He presently lives in Dehradun and completed his Diploma in the field of Electronics Engineering from Govt. Poly. Gauchar, Chamoli, Uttarakhand, India in 2009. Then he completed his Graduation as a B.Tech graduate in the field of Electronics and communication from Uttar Pradesh Technical University, Lucknow, UP, India in 2012. He is a post-graduate scholar in the field of Wireless & Mobile Communications from Dehradun Institute of Technology, Dehradun, Uttarakhand, India in 2013. Presently he is working on "radio propagation at 1.8GHz"