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Outdoor Propagation Path Loss Models: A Review

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Abstract— This paper characterize different propagation path loss models as they are vary from one destination to another destination. The propagation path loss models is an important issues in desiging of a telecommunication system in wireless communication. Telecommunication sector is growing per day by day. The evolution of mobile service are growing with faster rate from 2nd generation GSM service to 3rd generation UMTS service to 4thgeneration LTE network. This paper begins with a review of the information available on the various propagation path loss models for outdoor models. The main characteristies of radio channels is path loss, fading and time delay spread. Effeciency of path loss models vary as the environment is change. The propagation model are useful for predicting the signal attenuation or path loss between the transmitter and receiver. This path loss information may be used as a controlling factor for wireless communication system performance to achieve the perfect network planning.

Index Terms— Propagation model,Path loss,Free space,Received signal strength, Wireless communication,Okumara,Hata,cost-231

1 INTRODUCTION

Propagation models predict the mean signal strength for an arbitrary transmitter separation distance[6].In wireless communication signal is transmitted by transmitting antenna and received by receiving antenna any distortion in signal strength at receiver is known as path loss[7].

Path loss arise when the electromagnetic wave propagates through space from transmitter to receiver. In general

PL=Power transmitted/Power received (db)

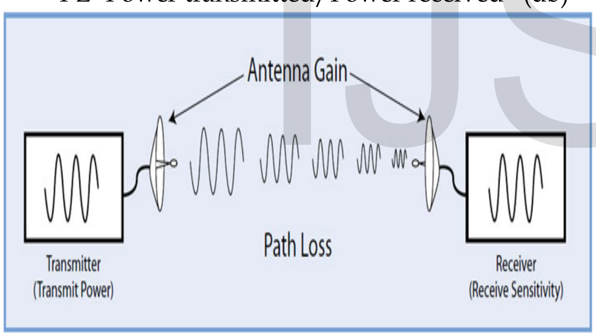

Fig.1 Basic Path loss Model

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There are many factors which is responsible for path loss. Some causes of path loss is:-

- Free space
- Absorption
- Diffraction
- Multipath
- Atmosphere

The propagation path loss model is an empirical mathematical formulation to characterize behaviour of the radio Waves as a function of the radio waves as a function of frequency, surrounding environment and distance[9].

2. Propagation Path Loss Model

The propagation path loss model basically of two types:-

- Empirical(Statistical) models
- Physical(Determinstic) models

The Empirical models are based on practically measured data. This models are simple but not very accurate. The empirical model include Hata model, okumara model and cost 231 model. On the other way deterministic models are very accurate.for example Ray tracing and Ikegami model

A propagation model describes the average signal propagation and it provides the maximum cell range with respect to the maximum propagation loss. It depends on the following:-

- Environments(such as urban, sea, rural, forest, dense)etc.
- Distance
- Frequency
- Atmospheric conditions.
- Indoor/Outdoor

2.1 Okumara Model

Okumara's model is empirical models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHZ to 1920 MHZ(extended upto 3000MHZ) and distances of 1Km to 100 Km.[6]Okumara is the model to find path loss in urban area. The basis of the method is that the free space path loss between the transmitter and receiver is added

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to the value of Amu (f,d), where Amu is the median attenuation, relative to free space in the urban area with a base station effective antenna height G(htr) 200 meter and mobile station height G(htt) is 3 meter as shown in fig2. To determine path loss between the points of interest is first determined, and then the value of Amu(f,d) is added to it along with correction factors to account for the type of terrain as expressed in:-

$PL_{OK}(50)(db)=L_a+A_{ma}(f,d)-G(h_{tr})-G(h_{tt})-Garea$

Where

$G(h_{tt})=10\log_{10}(h_{tt}/200)$ $h_{tt}<3m$

$G(h_{tt})=20\log_{10}(h_{tt}/200)$ $10m>h_{tt}<3m$

$G(h_{tr})=20\log_{10}(h_{tr}/3)$

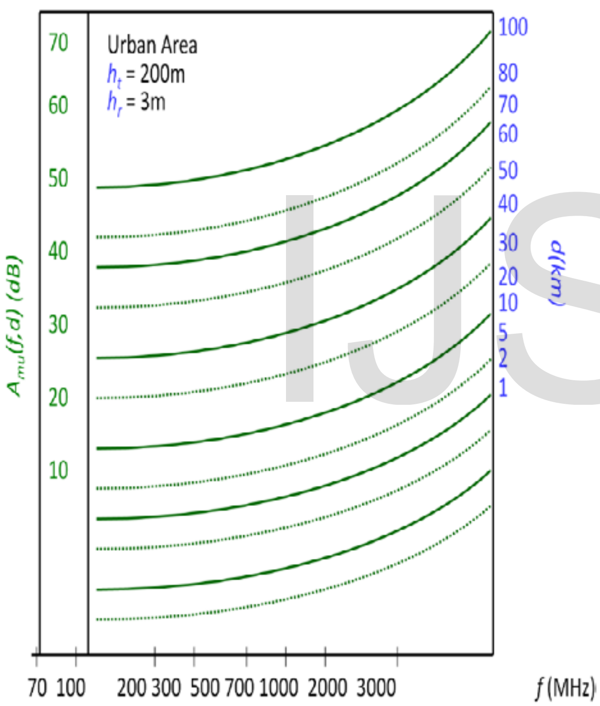

Fig.2 Median attenuation relative to free space(Amu(f,d)),over a quasi-smoth terrain{from[oku68]@IEEE}

PL $_{OK}$(db) is the percentile value of propagation path loss, L_a is propagation loss of free space,A_{ma} is the median attenuation relative to free space, $G(h_{tr})$, $G(h_{tt})$, Garea are BTS antenna height gain factor, mobile antenna height gain factor, mobile antenna height gain factor and gain due to the type of environment. Correction factors can be added using a graphical form to allow for transmission in suburban and open areas and irregular terrain. The parameter which is related to determine the various correction factors as shown in fig3.

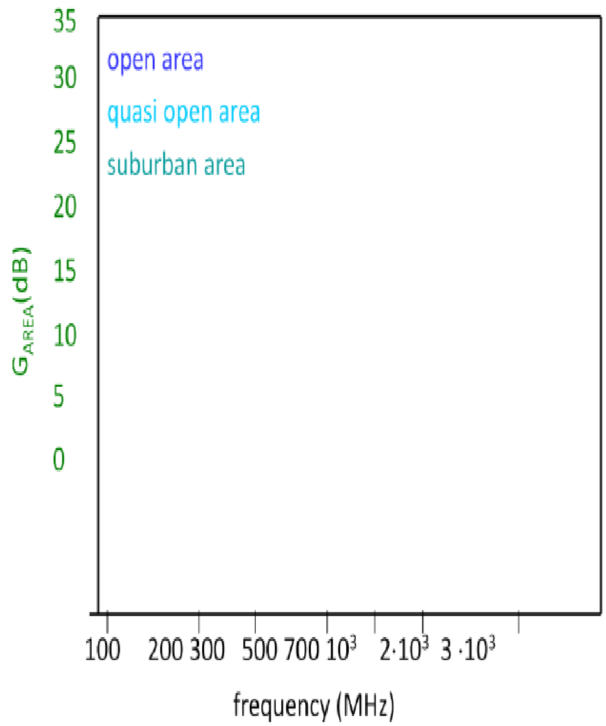

Fig.3 Correction factor Garea for different types of terrain{from[oku68]@IEEE}

2.2 Hata Model

The hata model is the empirical mathematical relationship to describe the graphical path loss data provided by okumara's model. The formula for the median path loss is:-

$PL_{HA}(urban)(db)=69.55+26.16\log_{10} fc-13.82\log_{10} h_{tr}-a(h_{tt})+(44.9-6.55\log_{10} h_{tr}).\log_{10}D$

$PL_{HA}(suburban)(db)=69.55+26.16\log_{10}fc-13.82\log_{10}h_{tr}-a(h_{tt})+(44.9-6.55\log_{10}tr).\log_{10}D-5.4+2[\log_{10}(fc/28)]2$

$PL_{HA}(open)(db)=69.55+26.16\log_{10}fc-13.82\log_{10}h_{tr}-a(h_{tt})+(44.9-6.55\log_{10}h_{tr}).\log_{10}D-40.99+4.78[\log_{10}(fc)2]-18.33\log_{10}(fc)$

Where

carrier frequency(fc):150 MHZ<fc<1500 MHZ
The effective base station antenna height(h_{tr}):$30m<h_{tr}<200m$
The effective mobile antenna height(h_{tt}):$1m<h_{tt}<10m$
The transmitter-receiver distance(D): km
The correction factor for effective mobile antenna height $a(h_{tt})$:km

This model gives the better result in urban and suburban area but in the rural areas its efficiency decreases.This model is not suitable for personal communication systems.

2.3 ECC 33 Model

The ECC model is electronics communication system developed for fixed wireless access system.The path loss model is defined as

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$PL_{ECC}(db)=A_{sf}+A_{mb}-G_d-G_s$

Where

A_{sf} , A_{mb} , G_d and G_s are the free space attenuation, the basic medium path loss, the BS height gain factor and the terminal height gain factor.
where

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

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

G_d =$\log_{10}(h_a/200)\{3.958+5.8[\log_{10}(d)]2$

And for medium city environments

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

Where
f is the frequency in GHZ,d is the distance between transmitter and receiver in km,h_a is the BS antenna height in meters and h_c is the CPE antenna height in meters. The ECC 33 model compared the medium city data with the suburban and urban data.

2.4 COST- 231 Model

The COST-231 hata model extended hata's model for use in the 1.5-2MHZ frequency range. This model is used in base station antenna is above the roof tops and is widely used in radio transmission in mobile telephony. The model is expressed in terms of the following parameters

$PL_{231}(db)=46.3+33.9\log_{10}(f_c)-13.28\log_{10}(h_{bh})-a(h_{mh})+44.9-6.55\log_{10}(h_{bh})+C_c$

$PL_{231}(db)=46.3+33.9\log_{10}(f_c)-13.28\log_{10}(h_{bh})-a(h_{mh})+44.9-6.55\log_{10}(h_{bh})+C_c$

C_c =0 (for medium city and suburban areas)
=3(for meteropolitan areas)
Carrier frequency(f_c)=1.5-2MHZ
BS antenna height(h_{bh})=30-200m
MS antenna height(h_{mh})=1-10m
Transmission distance(D)=1-20km

2.5 LEE Model

Lee path loss model is known more of a "North American Model".Lee model is based on flat terrain.
An error will take place when the model is applied to a non-terrain.The propagation path loss will be calculated as:

$PL_{LEE}(db)=124+30.5\log_{10}(d_0/d_{00})+10k \log_{10}(f_c/f_{cc})-a_0$

Where
d is in km, f_c and f_{cc} is in MHZ,k=2 for f_{cc}<450MHZ and in suburban/open area and 3 for f_{cc}>450 MHZ and in urban area,d_{oo}=1.6 km.f_c is transmitted frequency,d_o is the transmitter-recevier distance and a_0 is the correction factor to account for BS and MS antenna heights.

2.6 Walfish And Bertoni Model

A model which using the diffraction to predict the avg. signal strength at a street level is known as walfish- bertoni model.
$PL_{W\text{-}B}(db)= I_0 R_2 I_1$
Where
I_0 is the free space path loss for isotropic antennas, R_2 gives the signal power reduction due to buildings which provides images at receiver at street level, and I_1 is based on signal loss from the rooftop to the street due to diffraction.

The model reduces the path loss in three factors:-
(i)free space loss
(ii)loss along the building
(iii)loss down at the street along

2.7 Longley Rice Model

This Longley rice model is a radio propagation model.This model is also known as ITS irregular terrain model operates in two modes.First modes is path specific parameter and second is area mode prediction.
The Longley rice model is generally used for point to point communication in frequency range of 40MHZ to 100MHZ in different regions. This model is not use for mobile communications. The one shortcoming is that it does not count the account of building and forest or foliage.

2.8 Standard University Intersim Model

The proposed standards for the frequency bands below 11GHZ contain the channel developed by standard university, namely the SUI models[7]. The SUI models are considered into three types of terrains, namely X,Y,Z. Type X is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities. Type Z is associated with minimum path loss and applies to flat terrain with light tree densities. Type Y is characterized with either mostly flat terrains with moderate to heavy tree densities or hilly terrains with light tree densities. The path loss equation with correction factor is

$PL_{SUI}(db)=\alpha+10\beta\log_{10}d_0/d_{00}+A_a+B_b+C$ for $d_0>d_{00}$

Where

d_0 is the distance between the AP and the CPE antennas in meters,d_{00} =100m and C is a log normally distributed factor that is used to account for the shadow fading owing to trees and other clutter and has a value between 8.2db and 10.6 db.

The
$\alpha =20 \log10(4\pi d_{00}/\lambda)$
$\beta=x-yb_h+z/h_b$
Where b_h is the base station height above ground in meters and should be between 10 m and 80 m.For a given terrain type

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the path loss exponent is determined by h_b.

2.9 Egly Propagation Model

Egly propagation model is frequency range approximately 50 feet in hill areas. Egli is based on measured propagation paths and then reduced to mathematical model[7]. In case of Egli, the model consist of propagation path equation

$PL_{EG}=117+40\log_{10}d+20\log_{10}f-20\log_{10}(h_t-h_r)$

Where

PL_{EG} is attenuation in db(between dipole),d is the path distance in miles,f is the frequency in mega hertz, h_t is the transmitter antenna height above ground level(in feet) ,h_r is the receiver antenna height above ground level(in feet)

The free space loss between half wave dipole antenna(in db) is

$PL_{FS}=32.27+20\log d+20\log f$

To isolate the propagation of the loss

$PL=PL_{EG}-PL_{FS}$

$=84.73+20\log_{10}d20\log(h_t*h_r)$

Egli propagation model is applicable only on short over water and very flat barren land paths and it is not applicable on foliage area.

2.10 Cost-231 Walfish-Ikagami Model(W-I)

This model is combination of two model first is J. Walfish and f.Ikegami model. This is most suitable for flat suburban and urban areas.This model is most suitable for flat suburban and urban ares. Among other models like hata model this model is more precise path loss model. This is a result of additional parameters introduced which characterized in a different environments. So for LOS condition the path loss equation is

$PL_{COST-231}$ LOS$=42.6+26\log_{10}D+20\log_{10}F$

For NLOS condition

$PL_{COST-231}$ NLOS= {$PL_{FSL}+PL_{RTS}+PL_{MSD}$ (for urban and suburban)

{PL_{FS} (if $PL_{RTS}+PL_{MSD}>0$)

Where

PL_{FSL}=free space loss

PL_{RTS}=roof top to street diffraction

PL_{MSD}=multiscreen diffraction loss.

2.11 Bullington Model

This model is used the multiple knife edges to compute the diffraction loss. It defines the new apperature at the point where the line of sight from two antenna crosses.[7]

2.12 Epstein Peterson Model

This model is similar to bullington model but the major difference is that in Epstein model it takes to draw line of sight between relevant obstacles and add it to the diffraction loss at each obstacles.

3 Conculsion

In this paper we surveyed the different types of propagation model with their path loss equation . Some propagation path loss model used in urban, suburban while some is used in rural areas.For example Hata, okumara model are better in suburban area and the Longley rice model in rural areas.The accuracy of evey model in any given condition will depend on the suitability among parameter required by the model.The Hata okumara model has widespread application in open environment but is severely limited in built up areas.The path loss of okumara,Hata and cost 231 model decrease as the transmitter antenna height and received antenna height but increase as the transmission distance.The okumara model is short path loss whereas the cost 231 model is largest path loss.

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