Field strength predicting outdoor models

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Abstract—*The main objective of this paper is a comprehensive review of outdoor propagation model in different geographical areas. A wide variety of radio propagation models for different wireless services that specifically address varying propagation environments and operating frequency bands are generally known. A large number of propagation prediction models have been developed for various terrains Irregularities, tunnels, urban streets and buildings, earth curvature, etc*

Keywords— outdoor, propagation model, path loss

I. Introduction

Radio Propagation is essential to understand the upcoming any wireless network with its deployment, design and management strategies. Wireless network are more complicated than its wired countered part .due to the nature of the radio channels. Some factors effected radio propagation as it is heavily site specific and varies due to frequency of operation, depends on terrain, mobile terminal velocity, interference due to sources etc. Radio channels characteristics must be accurate by controlling some key parameters. Also by mathematical model some parameters can be predicted such signal as coverage, data which can be achievable, performance parameters of alternative signalling and also its reception schemes.

Signal strength and transmission power are the two important concepts of mathematical modelling. Radio propagation is the term related to the transfer of the energy which is measured in power or watts. The power which is measured at transmitter is the transmission power and this power is measured at the transmitter as well as receiver. The total amount of the power measured as the receiver is also known as the strength of the signal (signal strength). The letter measurement is less than the former; it is due to the nature of the radio wave propagation because when the signal moves through the air in the form of radio waves it loses its power.

Path Loss

The primary factor which is considered in wireless communication system is the free space propagation. As there are no obstacles or obstruction due earth's surface in the case of LOS propagation. A term known as friss free space propagation is used to determine the received power (P_r), at the receiving antenna which is located from a transmitter at a distance d is given by

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \quad (1)$$

For friss space model, the equation of path loss can be written as

$$L_f = \frac{P_t}{P_r} = \frac{1}{G_t G_r}\left(\frac{\lambda}{4\pi d}\right)^2 \quad (2)$$

Where

P_r = received power
P_t = transmitted power
λ = wavelength = c/f
c = speed of light (3×10^8 m/s)
f = carrier frequency in Mega Hertz
G_t = gain of the transmitter
G_r = gain of the receiver
d = antenna separation distance in kilometre
L_f = free space loss

The above equations show that the free space path loss is increasing with distance and also frequency depended. Whenever the frequency or length of the path is doubled there is an increase of 6dB in the free space attenuation.

II. MOBILE RADIO PROPAGATION ENVIRONMENT

The signal that is transmitted from the transmitting antenna (BTS/MS) and received by the receiving antenna (MS/BTS) travels a small and complex path. This signal is exposed to a variety of man-made structures, passes through different types of terrain, and is affected by the combination of propagation environments. All these factors contribute to variation in the signal level, so varying the signal coverage and quality in the network. Some phenomenon associated with the radio wave propagation is briefly described below.

(1) Diffraction
(2) Reflection
(3) Refraction
(4) Scattering

III.OUTDOOR PATH LOSS PREDICTION MODEL

The prediction of path loss is a very important step in planning a mobile radio system, and accurate prediction methods are needed to determine the parameters of a radio system which will provide efficient and reliable coverage of a specified service area. A path loss prediction or propagation model is the fundamental tool for designing any wireless communication system. Since it become very costly if we use site measurements to design a system, so as an alternative propagation model has been developed which are more suitable, convenient and low cost. These models typically focus on path loss realization and predict what will happen to the transmitted signal as it travel from transmitter to the receiver.

The outdoor propagation model can be classified as:

(1) Empirical model
(2) Physical model
(3) Theoretical model

A. Empirical Model

The Experimental measurement data is used by empirical model to produce a relationship between propagation circumstances and expected field strength or time dispersion result. Development of empirical model can do by laboratory measurement or with scale models of propagation environment. This type of approach can achieve by using fitting curve or analytical expression that recreate set of measured data. When we talking about propagation factor, it include both known and unknown, through actual field measurement. However, establishment of validity of empirical model at transmission frequency or other than model driven environment can be done by adding data which is measured at new environment at the required transmission frequency.

Mathematical model fails to explain every situation; in this situation approximation is done to protect same data. To overcome this problem empirical model was introduced, which is totally base on the observation and measurements. Data was predicted but it has limitation that this model is not able to explain.

It has two subcategories time dispersive and non-time dispersive.

The time dispersive model detail it data is the form of time – dispersive characteristics such as delay spread of channel during multipath. Examples are SUI model. Whereas COST 231 Hata model. Hata and ITU –R model are falls under the example of non time dispersive empirical model.

B. Theoretical Model

Theoretical model are based on assumption that taken about environment of propagation. These are also known as statical model. These models are used for analyze the behavior of communication system having various channel response circumstances. Through, they are not able to deal with specific propagation information. They are not employed to plane a communication system use to serve a particular area. Hence they are used to relay an assumption for mathematical formulation.

Example of these models are..
(1) The geometrically based signal bomer macrocell (GBSBM) channel model by perturs.
(2) Quassi wide sense stationary uncorrelated scalling (quassi-wssus) channel model by bellow.

C. Physical Model

Physical model are based on basics of physics and deals with propagation environment. This model can either site specific or not site specific. A not site specific physical model based on the propagation principle of electromagnetic wave that predict signal level in generic environment to take account of development of relation shift between characteristics of environment and propagation.

Example of these model by W.I Kegami and H.L Beritoni for mobile radio system in urban area, where series of diffraction screen considered by roof edge with including diffraction from building roof to the select level.

In other way, a physical and site specific model uses physical low of electromagnetic wave propagation as well as have technique from which mapping of real propagation as well have technique from which mapping of real propagation environment can be done into model propagation environment. Prediction of presence of attenuation in a signal is achieved by Epstein-Peterson method, Deygent method, Longely rice method and Anderson 2-dimensional model. Example of physical and site specific model is ray tracing model which proves dispersion information and angle of arrival information.

D. Okumura Model

Okumura model is generated by empirical method in which various test are conducted to collect the data in different situation like irregular terrain and other environmental obstacles. This collected data was analyzed and checked in form of Diagrams. In the urban areas the quasi smooth terrain gives the information about median field strength. Along with urban area, an open area or suburban are requires the correction factors. Like rolling hilly terrain an isolated mountain mixed land sea paths, direction of streets, slope of terrain and it predicts the actual field strengths.

In the area of urban environment many studies have been done up to 1935 about the losses arises in the radio wave propagation, but the study of Yoshihisa okumura was widely focused on the above. In 1968 Tokoyo, Japan Yoshihisa okumura tested the propagation between the mobile station & base station. With a variation in the urban geometry many tests were conducted for the transmission of signal. Different frequencies were used in the measurement like 200, 453, 922, 1310, 1430 & 1929 Mhz. graph is plotted between path distances & varying condition in terms of measured field value curve for each frequency. For the representation of the median attenuation which is extended along the transmission path as a function of frequency which fits this plotted data for a series of curves was developed by Okumura & his colleagues.

A propagation model was developed by okumura which is based on the calculations &the collection of data by him, this model incorporates the correction factors for the locations of transmit & receive antenna, type of environment, city size, terrain type. The model proposed by okumura has disadvantage as it was complex & time consuming as the user has to refer to the okumura mathematical curves for the calculations of losses & correction factors.

(i) Generally Okumura illustrate correction factors for open area & suburban area.
(ii) Its model can predict the path loss up to 3 GHz in urban, suburban & Rural Area.

$$PL(dB)= L_f + A_{mn}(f,d) - G(h_{te}) - Gh_{re} - G_{AREA} \quad (4)$$

Where
PL=Media path loss [dB]
L_f= Free space path loss [dB]
A_{mn} (f,d)= Media attenuation relative to free space [dB]
$G(h_{te})$= Base station antenna height gain factor [dB]
Gh_{re} = Mobile station antenna height gain factor [dB]
G_{AREA}=Gain due to the type of environment [dB]
F= Frequency [MHz]
h_{te}=Transmitter antenna height [m]
kh_{re}=Receiver antenna height [m]
d=Distance between transmitter and receiver [km]

E.Hata Model

The limitations of okumura model was corrected in 1980 by Masaharu Hata who simplified it & reduces the user input to only four parameters by developing a set of equations. A fairly accurate prediction of propagation loss is obtained with only frequency, transmitted distance height of the base station antenna, height of mobile antenna in the earlier Okumura model. Hata model has limiting factors that it predicts only a short range of transmitted distance & frequencies. The limitations are overcome by the modification of Hata model into many models to extend the output over greater transmission distance & frequencies more accurately. The combination of a scaling term independent of distances, correction factors logarithmic like, open air, suburban urban is given by Hata model. Up to the transmission distances of 30 km. Other studies show that the curves match for Hata & Okumura model within the acceptable parameters. Beyond 30km both the curves approximately separated by 15db difference near about 100km. Today the most widely used loss model for urban propagation is Hata model in comparison with the other loss model.

A. ECC-33 Path Loss Model

The model is a systematic arrangement of Okumura Hata model as this was formed in Tokyo City so urban area is subdivided into large and medium city. This model is generally beneficial for macro cellular system.
Few specification of this model is:-

i. 30-200m, Antenna height of the base station
ii. 1-10m antenna height of the mobile station
iii. 1-20 km distance between Base station & mobile station

The path loss model presented in is referred to here as the ECC-33 model. The path loss is defined as,

$$PL(dB)= A_{fs} + A_{bm} - G_b - G_r$$

where, A_{fs}, A_{bm}, $G_b$and $G_r$are the free space attenuation, the basic median path loss, the BS height gain factor and the terminal (CPE) height gain factor. They are individuallydefined as,

$$A_{fs}= 92.4 + 20 \log_{10}(d) + 20 \log_{10}(f)$$
$$A_{bm}= 20.41 + 9.83 \log_{10}(d) + 7.894 \log_{10}(f) + 9.56[\log_{10}(f)]^2$$
$$G_b= \log_{10}(h_b/200)\{13.958 + 5.8[\log_{10}(d)]^2\}$$

and for medium city environments,

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

where, f is the frequency in GHz, d is the distance between base station and CPE in km, $h_b$is the BS antenna height in meters and $h_r$is the CPE antenna height in meters. The medium city model is more appropriate for European cities whereas the large city environment should only be used for cities having tall buildings. It is interesting to note that the predictions produced by the ECC-33 model do not lie on straight lines when plotted against distance having a log scale.

B. COST -231-Hata Model

COST-231 Hata model generally follows empirical model due to this the frequency range of Hata model is increased to 1500-2000MHz. it is applicable for suburban an urban area so called as outdoor propagation model. This model is used for flat terrain and base on huge measurement. Limitation of this model is that it fails to situation where node's antenna height is above top level adjacent to the node. This model gives accurate prediction within 1 dB for distance ranging 1 to 20Km.

The basic equation for path loss in dB is

$$PL(dB)= 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(h_{te}) - a(h_m) + (44.9 - 6.55 \log_{10}(h_{te})) \log_{10}d + c_m$$

where, f is the frequency in MHz, d is the distance between base station and mobile antennas in km, and $h_{te}$is the base station antenna height above ground level in meters. The parameter $c_m$is defined as 0 dB for suburban or open environments and 3 dB for urban environments. The parameter $a(h_m)$is defined for large area as

$$a(h_m)\ [dB] = 8.29 (\log 1.54\, h_{re})^2 - 1.1 \text{ for } f \geq 300 \text{ MHz}$$

$$a(h_m)\ [dB] = 3.2 (\log 11.75\, h_{re})^2 - 4.97 \text{ for } f \leq 300 \text{ MHz}$$

and for medium or small city area,

$$a(h_m)\ [dB]= (1.1 \log_{10}f - 0.7)h_{re} - (1.56 \log_{10}f - 0.8)$$

where, $h_{re}$is the mobile antenna height above ground level in meters.

C. Egli Model

Egli model is not a universal model but ease of implementation and agreement with the empirical data makes it a popular choice for a first analysis. Egli model for path loss over irregular terrain is

$$PL(dB) = G_B G_M \left(\frac{h_B h_M}{d^2}\right)^2 \left(\frac{40}{f}\right)^2$$

where
G_B: is gain of base station antenna
G_M: is gain of mobile station antenna
h_B: is height of base station antenna in meters
h_M: is height of mobile station antenna in meters
d:is distance from base station antenna in km and
f: is frequency of transmission in MHz

Egli model provides the entire path loss, whereas the Okumura model discussed below provides the path loss in addition to free space loss. This model is empirical in nature and applicable to scenarios where the transmission has to pass an irregular terrain. Egli model is not applicable to scenarios where some vegetative obstruction is in the middle of the link.

D. Lee Model

In 1982 a model was given by W.C.R Lee. This model becomes very popular due to its parameters which are easily adjustable among researches and system engineers. This model has faster prediction rate and has greater accuracy.

The Lee model is a modified power law model, with parameters taken from measurements in a number of locations, together with a procedure for calculating an effective base station antenna height which takes account of the variations in the terrain. Lee model can be expressed in the simplified form as

$$PL\ (dB) = 10n \log d - 20 \log h_b(eff) - P_0 - 10 \log h_m + 29$$

where n and $P_0$are given by measurements as shown in table 3.1,h_b(eff) is the effective base station antenna height in meter,$h_m$is the mobile antenna height in meter and d is the distance between base station and mobile station in km.

E. Cost 231 Walfisch-Ikegami Model

The most accurate propagation loss prediction model recognized was the Walfisch-Ikegami model but other than previous model. The range of parameters is for accurate calculation was very small. It has two different cases. A simple equation with transmission distance and frequency as two input parameter is called Line Of Sight. This case produces slightly greater losses in comparison with free space losses. But if an unobstructed signal would encounter a qualitative check validate that it has a similar loss as those in free space.

Other cases are much more complex in nature and called as non-line of sight, the equation is complicated and various factor affect like a multi-screen diffraction, average root top height, building separation, street width, roof top to street orientation and street angle of orientation. 800-2000MHz is the acceptable input frequency range and 0.02 to 5 km is the transmission distance range for this model.

F. Stanford University Interim (SUI) Model

SUI prediction model is developed under the Institute of Electrical and Electronic Engineers (IEEE) 802.16 Broadband Wireless Access Working Group.This prediction model comes from the extension of Hata model with frequency larger than 1900 MHz. The correction parameters are allowed to extend this model up to 3.5 GHz band. In the USA, this model is defined for the Multipoint Microwave Distribution System (MMDS) for the frequency band from 2.5 GHz to 2.7 GHz. The base station antenna height of SUI model can be used from 10 m to 80 m. Receiver antenna height is from 2 m to 10 m. The cell radius is from 0.1 km to 8 km. The SUI model describes three types of terrain, they are terrain A, terrain B and terrain C. There is no declaration about any particular environment. Terrain A can be used for hilly areas with moderate or very dense vegetation. This terrain presents the highest path loss. Terrain B is characterized for the hilly terrains with rare vegetation, or flat terrains with moderate or heavy tree densities. This is the intermediate path loss scheme. This terrain can be considered for suburban environment. Terrain C is suitable for flat terrains or rural with light vegetation, here path loss is minimum. The basic path loss expression of The SUI model with correction factors is presented as

$$PL(dB) = A + 10\gamma \log_{10}(d / d_o) + X_f + X_h + s for d > d_o$$

where the parameters are
d: distance between BS and receiving antenna in meter
d_0: 100 m
λ: Wavelength in meter
X_f: Correction for frequency above 2 GHz
X_h: Correction for receiving antenna heights
s: Correction for shadowing in dB
γ: Path loss exponent

IV. Conclusions

Due to the recent interest in propagated signals, models have been developed and currently exist that predict path losses associated with the urban environment, but the accuracy of each model generally exists only in a small window of specific parameters that are involved. An accurate radio propagation model is essential for coming up with appropriate design, deployment, and management strategies for any wireless network. It is also important for predicting signal coverage, achievable data, specific performance attributes of alternative signaling, reception schemes, analysis of interference from different systems and determining the optimum location for installing base station antennas.

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