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A Review Investigation on Outdoor and Indoor Propagation Models

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Authors' contributions

This work was carried out in collaboration between all authors. Author VOAA designed the study, performed the statistical analysis. Author SIU wrote the protocol and first draft of the manuscript. Authors FIA and AII managed the analyses of the study. Author OA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Path loss exponent has turned out to be one of the key challenges that are been faced in the telecommunications sector both in Nigeria and other countries. There is a great need to take a critical look at the various mathematical methods and techniques that have been developed by many researchers of which are used in the calculation of signal loss in telecommunication industry. This article draws the conclusion that all the methods are accurate depending on the condition(s) or factors after reviewing over fifty (50) journals. It was therefore concluded that the method that is applied to a particular situation depends on the surrounding environments.

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1. INTRODUCTION

Path loss is the decrease in power density (attenuation) of an electromagnetic wave as it travels through space. Path loss is a noteworthy part of the investigation and plan of the connection spending plan of a telecommunication framework. The term is generally utilized as a part of wireless communication and signal spread. Path loss could be due to impacts such as: free-space loss, absorption, reflection, diffraction, aperture-medium coupling loss and refraction. Path loss is also affected by shapes, territory, condition (urban or provincial, vegetation and foliage), spread medium (dry or wet air), the separation between the transmitter and the receiver, and the stature and area of the antennas [1-5,6]. Path loss typically incorporates propagation losses caused by the regular development of the radio wave front in free space, absorption losses (aka infiltration losses), when the signal goes through media not straightforward to electromagnetic waves, diffraction losses when part of the radio wave front is discouraged by a hazy deterrent, and losses caused by other wonders [7,8,9,6].

The multipath effect is a process in which a signal emanated by a transmitter may travel along a wide range of paths to a receiver concurrently. Multipath waves join at the receiver antenna, bringing about a resulting signal that may fluctuate generally, contingent upon the circulation of the force and relative engendering time of the waves and bandwidth of the transmitted signal. The aggregate power of meddling waves in a Rayleigh fading situation differs rapidly as a component of space (which is known as a small-scale fading). Small-scale fading alludes to the fast changes in radio signal abundancy in a brief timeframe or travel separate [10]

1.1 Path Loss Experiment

In wireless communication studies, path loss is spoken to by the path loss exponent, whose esteem is regularly in the scope of 2 to 4, where 2 is for propagation in free space, 4 is for moderately lossy conditions and for the instance of full specular reflection from the earth surface alluded to as the level earth display. In a few conditions, the path loss exponent can achieve values in the scope of 4 to 6. Then again, a passage may go about as a waveguide, bringing about a path loss exponent under 2.

Path loss is typically communicated in dB. In its most straightforward shape, the path loss can be computed utilizing the equation.

$$L = 10\,n + C \tag{1}$$

Where L is the path loss in decibels, n is the path loss exponent, d is the separation between the transmitter and the receiver, normally estimated in meters, and C is a consistent which represent framework losses.

The estimation of C typically fluctuates and is ordinarily reliant on the kind of demonstrating under thought. A rundown of run of the mill path loss exponents acquired in different versatile situations has appeared in Table 1.

Table 1. Path Loss Exponents for Different Environments [11,12,13,14,15]

Environment	Path loss exponent, n
Free space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

2. PATH LOSS PREDICTION TECHNIQUES

The process of calculating the path loss is usually called prediction. Exact prediction is plausible only for less complex cases, such as the previously mentioned free space propagation or the flat-earth model. In practical cases the path loss is calculated by using a number of approximations. Statistical methods (likewise called stochastic or empirical) depend on estimated and arrived at the midpoint of losses along typical classes of radio connections. Some of the most commonly utilized methods are Hata, Okumura-Hata, the COST Hata model, W.C.Y.Lee etc. which are otherwise known as radio wave propagation models and are typically utilized as a part of the plan of cellular networks and public land versatile networks (PLMN). The Okumura-Hata as refined by the COST-231 project is the method employed for wireless communications in the very high frequency (VHF) and ultra-high frequency (UHF) frequency band (the bands utilized by walkie-talkies, police, maneuvers and cellular telephones). For FM radio and the TV broadcasting, the path loss is most commonly predicted utilizing the ITU model as described in ITU-R P.1546 recommendation. Other well-known models are those of Walfisch-Ikegami, W.C.Y Lee, and Erceg.

Ray tracing is one of the deterministic methods in view of the physical laws of wave propagation that are additionally utilized as they are expected to produce more accurate and solid predictions of the path loss than the empirical methods but are considerably more costly in computational exertion and rely upon the definite and accurate description of all objects in the propagation space, such as structures, rooftops, windows, entryways and walls. They are therefore employed predominantly for short propagation paths. Among the most commonly employed methods in the plan of radio gear such as antennas and bolsters is the limited difference time-space strategy.

Comparable methods are employed in predicting the path loss in other frequency bands (medium wave (MW), short wave (SW or HF), micro wave (SHF) although the actual calculations and equations may slightly be dissimilar to those for VHF/UHF. Dependable prediction of the path loss in the SW/HF band is particularly difficult, and its accuracy is comparable to weather predictions [16]. Easy approximations for calculating the path loss over distances significantly shorter than the distance to the radio skyline: In free space the path loss increases with 20 dB every decade (one decade is when the distance between the transmitter and the receiver increases ten times) or 6dB for every octave (one octave is when the distance between the transmitter and the receiver pairs). This can be utilized as a very harsh first request guess for (microwave) communication joins. The path loss increases with roughly 35-40 dB for each decade (10-12 dB for each octave) for signals in the UHF/VHF band spreading over the surface of the Earth which can be utilized as a part of cellular networks as a first figure. The estimation of the path loss in developed regions can reach 110-140 dB for the main kilometer of the connection between the base transmitter station (BTS) and the versatile in cellular networks, such as UMTS and GSM, which work in the UHF band. The path loss for the initial ten kilometers may be 150-190 dB. These qualities are very inexact and are given here only as a delineation of the range in which the numbers used to express the path loss esteems can eventually be; these are not authoritative or restricting figures. Studies have shown that the path loss may be very extraordinary for a similar distance along two unique paths and it can be distinctive even along a similar path if estimated at various circumstances.

In radio wave condition for versatile antennas is close to the ground. Viewable pathway propagation (LOS) models are highly altered. The signal path from the BTS antenna normally raised over the rooftop tops is refracted down into the local physical condition (slopes, trees, houses) and the LOS signal only here and there reaches the antenna. Nature will produce a few deflections of the direct signal unto the antenna, where typically 2-5 deflected signal components will be vectorially included. These refraction and deflection processes cause loss of signal strength, which changes when the versatile antenna moves (Raleigh fading), causing quick varieties of up to 20 db. The network is therefore intended to give an excess of signal strength compared to LOS of 8-25 db relying upon the idea of the physical condition, and another 10 db to maintain a strategic distance from the fading because of development. [16]

2.1 Propagation Models

A radio propagation model, otherwise called the Radio Wave Propagation Model or the Radio Frequency Propagation Model is an empirical mathematical plan for the characterization of radio wave propagation as a function of frequency, distance and other conditions. The conduct of propagation for every single comparable connection under comparable constraints is usually predicted with a solitary model is usually created with the objective of formalizing the way radio waves are proliferated starting with one place then onto the next, such models typically predict the path loss along a connection or the effective coverage region of a transmitter. As the path loss encountered along any radio connection fills in as the predominant factor for characterization of propagation for the connection, radio propagation models typically focus on the acknowledgment of the path loss with the auxiliary undertaking of predicting the territory of coverage for a transmitter or modeling the conveyance of signals over various areas. Because each individual telecommunication interface needs to encounter distinctive landscape, path, obstructions, atmospheric conditions and other marvels, it is intractable to detail the exact loss for all telecommunication systems in a solitary mathematical condition. Accordingly, extraordinary models exist for various types of radio connections under various conditions. The models rely on computing the middle path loss for a connection under a certain probability that the considered conditions will occur.

Radio propagation models are empirical in nature. For any model, the collected information must be sufficiently extensive to give enough likeliness (or enough scope) to all sort of circumstances that can occur in that specific scenario. Like every single empirical model, radio propagation models don't call attention to the exact conduct of a connection, rather, they predict the no doubt conduct the connection may show under the specified conditions.

Diverse models have been created to address the issues of understanding the propagation conduct in various condition. Types of models for radio propagation include the under recorded:

(i) Models for indoor applications
(ii) Models for outdoor applications
(iii) Ground wave propagation models
(iv) Sky-Wave propagation models
(v) Environmental Attenuation models
(vi) Point-to-Point propagation models
(vii) Terrain models
(viii) City models

3. MODELS FOR OUTDOOR ATTENUATIONS

Outdoor attenuations models are classified into four groups namely, Near-earth propagation models, Terrain models, City models and Band-specific models.

3.1 Near-Earth Propagation Models

Under this model, there are two distinct groups namely, Foliage and updated ITU model.

3.1.1 Foliage models

Foliage models are sub divided into Weissberger's modified exponential decay model and Early ITU model.

(a) Weissberger's Modified Exponential Decay Model

Weissberger's adjusted exponential decay model, or simply, Weissberger's model is a radio wave propagation model that gauges the path loss because of the presence of at least one trees in a point-to-point telecommunication connect. This model has a place with the category of Foliage or Vegetation models with profundity of foliage of up to 400 m, for the cases of observable pathway propagation as utilized as a part of microwave transmission. This model is only applicable when there is an obstruction made by some foliage in the connection i.e. in between the transmitter and receiver.

It is perfect for application in the circumstance where the LOS path is blocked by thick, dry and leafy trees. It is appropriate for application in the frequency scope of 230 MHz to 95 GHz [17]. Defined in 1982, this model is an improvement of the ITU Model for Exponential Decay (MED). Weissberger's model is formally communicated as:

$$L = \begin{cases} 1.33 f^{0.284} d^{0.588}, & if \ 14 < d \leq 400 \\ 0.45 f^{0.284} d, & if \ \ 0 < d \leq 14 \end{cases} \qquad (2)$$

where,

L = The loss due to foliage in decibels (dB).
f = The transmission frequency in gigahertz (GHz).
d = The depth of foliage along the path in meters (m).

Unfortunately, this model has the following limitations.

(i) The equation is scaled for frequency specified in GHz range.
(ii) Depth of foliage must be specified in meters (m).
(iii) It is significant for the frequency range of 230 MHz to 95 GHz only, as pointed out by Blaunstein [17]
(iv) The model does not define the operation if the depth of vegetation is more than 400m.
(v) The model predicts the loss due to foliage; hence the path loss must be calculated with the inclusion of the free space loss [17]

(b) Early ITU Model

The ITU vegetation model is a radio propagation model that gauges the path loss encountered because of the presence of at least one trees inside a point to point telecommunication connect. The predictions found from this model is congruent to those found from Weissberger's adjusted exponential decay model in low frequencies. It was subsequently embraced late 1986.

The model is applicable to the circumstances where the telecommunication interface has a few obstructions made by trees along its way; it is, therefore, reasonable for point-to-point microwave connects that has vegetation in their path. The typical application of this model is to predict the path loss for microwave joins. Below is the mathematical expression of the model:

$$L = 0.2\, f^{0.3} d^{0.6} \tag{3}$$

Where,

L = The path loss in decibels (dB).
f = The frequency of transmission in megahertz (MHz).
d = The depth of foliage along the link in meters (m).

Equation (2.3) is scaled for frequency specified in megahertz (MHz) only while the depth of foliage must be in the units of meter. Unfortunately, the result of this model gets impractical at high frequencies [18-24]

3.2 Updated ITU Model

The Early ITU model described above was updated in early 2002; this gave rise to two other models described below.

3.2.1 One woodland terminal model

The ITU earthly model for one terminal in woodland is a proportion propagation model having a place with the class of foliage models. This model is a successor of the early ITU model. It is applicable to the scenario where one terminal of a connection is inside foliage and the flip side is free. It is very valuable for frequencies below 5 GHz. Below is the mathematical expression of the model;

$$AV = A \tag{4}$$

where

AV= Attenuation because of vegetation in decibel (dB)
A = Maximum attenuation for one terminal caused by a certain foliage in decibel (dB)
D = Depth of foliage along the path in meter (m)
Γ = Specific attenuation for short vegetations in decibel/meter (dB/m).

The estimation of γ is reliant on the frequency and is an empirical constant. The model expects that exactly one of the terminals is located inside some backwoods or manor and the term profundity applies to the distance from the terminal inside the ranch to the finish of estate along the connection. It is additionally appropriate for frequencies below 5 GHz [25-30]

3.3 Single Vegetative Obstructive Model

The ITU Single Vegetative Obstructive Model is a Radio propagation model that quantitatively approximates the attenuation because of the vegetation amidst a telecommunication connect. The model is relevant to scenarios where no finish of the connection is totally inside foliage, yet a solitary plant or tree remains amidst the connection. It is discovered valuable in the recurrence go beneath 3GHz and more than 5GHz. Below is the mathematical expression of the model;

$$A = \begin{cases} \delta\gamma, \; frequency < 3GHz \\ R_f d + k\left[1 - e^{(R_f - R_i)\frac{d}{k}}\right], \; frequency > 5GHz \end{cases} \tag{5}$$

Where,

A = The Attenuation due to vegetation in decibel (dB)
D = Depth of foliage in meter (m)
Γ = Specific attenuation for short vegetations in decibel/meter (dB/m).
R_i = The initial slope of the attenuation curve
R_f = The final slope of the attenuation curve
f = The frequency of operations in gigahertz (GHz)
k = Empirical constant

3.3.1 The calculation of slopes

For the calculation of slopes, the initial slope is calculated as:

$$R_i = a^f \tag{6}$$

And the final slope as:

$$R_f = bf^c \tag{7}$$

where a, b and c are empirical constants given in Table 2.2.

3.3.2 Calculation of k

For the calculation of k, it is computed as:

$$k = k_0 - 10\log\left[1 - e^{\frac{-A_i}{A_0}}\right]\left[1 - e^{R_f f}\right] \tag{8}$$

where,

k_0 = Empirical constant given in Table 2.2
R_f = Empirical constant for frequency dependent attenuation
A_0 = Empirical attenuation constant is given in Table 2.2
A_i = Illumination area

3.3.3 Calculation of A_i

Ai is computed in utilizing any of the conditions 2.9 and 2.10, taking note of that, the terms h, hT, hR, w, wT and wR are characterized opposite to the expected level line joining the transmitter and recipient. The initial three terms are estimated vertically and the other three are estimated on a level plane [31-34]

$$A = min(w_T w_R w)\ x\ min(h_T h_R h) \tag{9}$$

$$A_i = min\left(2d_T tan\frac{\propto_T}{2}, 2d_R tan\frac{\propto_R}{2}, w\right)$$
$$xmin\left(2d_T tan\frac{e_T}{2}, 2d_R tan\frac{e_R}{2}, h\right) \tag{10}$$

where,

w_T = Width of illuminated area as seen from the transmitter in meter (m).
w_R = Width of illuminated area as seen from the receiver in meter (m).
w = Width of the vegetation in meter (m).
h_T = Height of illuminated area as seen from the transmitter in meter (m).
h_R = Height of illuminated area as seen from the receiver in meter (m).
h = Height of vegetation in meter (m).
α_T = Azimuth beam width of the transmitter in degree or radian.
α_R = Azimuth beam width of the receiver in degree or radian.
e_T = Elevation beam width of the transmitter in degree or radian.
e_R = Elevation beam width of the receiver in degree or radian.
d_T = Distance of the vegetation from transmitter in meter (m).
d_R = Distance of the vegetation from receiver in meter (m).

The empirical constants *a*, *b*, *c*, k_0, R_f and A_0 are used as tabulated in Table 2.

Tragically, the model predicts the express path loss because of the presence of vegetation along the connection. The aggregate path loss incorporates different components like free space loss which is excluded in this model. More than 5 GHz and beneath 3 GHz, the conditions all of a sudden turn out to be greatly perplexing in light of the conditions. Likewise, this model does not work for frequency between 3 GHz and 5 GHz.

Table 2. Empirical constants a, b, c, k_0, R_f and A_0 used for Single Vegetation Obstruction Model [35]

Parameter	Inside leaves	Out of leaves
A	0.20	0.16
B	1.27	2.59
C	0.63	0.85
k_0	6.57	12.6
R_f	0.002	2.1
A_0	10	10

3.4 Terrain Models

Terrain models are generally subdivided into three models, namely Egli Model, Longley-Rice Model and ITU terrain loss model.

3.4.1 Egli Model

The Egli model is a terrain model for radio frequency propagation. The model was gotten from true information on UHF and VHF TV transmission in a few expansive urban communities. It predicts the aggregate path loss for a point to point interface. The model is regularly utilized for outdoor observable pathway transmission and it gives the path loss as a solitary amount. It is ordinarily reasonable for cellular communication scenarios where one radio wire is settled and another is portable. The model is likewise relevant to scenarios where the transmission needs to go over a sporadic terrain. Shockingly, the model has two noteworthy impediments:

(a) It does not consider travel through some vegetative obstruction, such as trees or shrubbery [36-40]
(b) It predicts the path loss all in all and does not subdivide the loss into free space loss and different losses. Below is the mathematical expression of the model;

$$P_R = G_B G_M \left[\frac{h_B h_M}{d^2}\right]^2 \left[\frac{40}{f}\right]^2 P_T \tag{11}$$

where,

P_{R50} = 50th percentile receive power (W).
P_T = Transmit power (W).
G_B = Absolute gain of base station antenna.
G_M = Absolute gain of mobile station antenna.
h_B = Height of the base station antenna (m).
h_M = Height of the mobile station antenna (m).
d = distance from the base station antenna (m).
f = frequency of transmission (MHz).

3.4.2 Longley-Rice Model

The Longley-Rice model (LR) is a radio propagation model: a strategy for foreseeing the attenuation of radio signs for a telecommunication link in the frequency scope of 20MHz to 20 GHz (Seybold, 2005). Longley-Rice is otherwise called the irregular terrain model (ITM). It was made for the requirements of frequency arranging in TV broadcasting in the United States in the 1960s and was widely utilized for setting up the tables of channel designations for VHF/UHF broadcasting there.

Longley-Rice has two sections: a model for expectations over a zone and a model for point to point interface forecasts. The Longley-Rice model was proposed for frequencies between 20 MHz and 40 GHz for various scenarios and distinctive statures of transmitting and accepting receiving wires. The model displays a speculation of the got signal control without an itemized portrayal of the channel, which relies upon the factors of every situation and condition [41-43]

The variety of the signal is dictated by the forecast model as indicated by the air changes, topographic profile and free space. These varieties are depicted with the assistance of factual evaluations which have deviations that add to the aggregate attenuation of the signal. The statistical appraisals or attenuation factors of this forecast model are: I) Situation inconstancy (YS); II) Location changeability (YL). The reference attenuation (W) is resolved as an element of the separation, attenuation factors and an urban factor for a region or point-to-point. In light of this fluctuation, there could be deviations (δ) pretty much huge to the attenuation of the transmitted signal. The got signal (W) is acquired signal level constricted in free space (W0) weakened by the aggregate of the lessened shaped by irregular factors. On the off chance that transmitter and beneficiary are at known focuses, the area variable has an estimation of zero.

The reference attenuation characterized as an element of separation additionally includes 3 territories for expectation: I) observable pathway; ii) diffraction; iii) diffuse. For every one of these reaches, there are attenuation coefficients characterized by connecting geometry. These factors additionally consider the geology that is characterized as terrain sporadically parameter Δh(d) for a reference separate (D0). A few applications utilize the Longley-Rice Model. Illustrations are CRC-COVWEB, SPLAT!, Radio Mobile, QRadioPredict, Pathloss5 [44-45]

3.4.3 ITU Terrain Loss Model

The ITU terrain loss model is a radio propagation model that gives a technique to anticipate the middle path loss for a telecommunication connection. The model was produced based on diffraction hypothesis and it predicts the path loss as an element of the stature of path blockage and the First Fresnel zone for the transmission connect (Seybold, 2005). The model records for hindrances amidst the telecommunication connection. It is in this manner reasonable to be utilized inside urban areas and in open fields. The model has the benefit of being reasonable for use in any terrain and any frequency. Below is the mathematical expression of the model;

$$A = 10 - 20\, C_N \tag{12}$$

Where,

A = Additional loss (in excess of free-space loss) due to diffraction (dB)
$C_N = \frac{h}{F_1}$ = Normalized terrain clearance
$h = h_L - h_0$
$F_1 = 17.3\sqrt{\frac{d_1 d_2}{fd}}$

3.4.4 City models

City models include Young Model, Okumura Model, Hata Model for Urban Areas, Hata Models for Suburban Areas, Hata Model for Open Areas, COST Hata Model, Area to Area Lee Model and Point to Point Lee Model. Some of these models that are close to the area under study are selected for presentation in this section.

3.4.4.1 Young Model

The young model is a proportion propagation model that was based on the information gathered on New York City in 1952. It regularly models the conduct of cellular communications in urban communities. It is perfect for modeling the conduct of cellular communications in substantial urban areas with tall structures. The model gives a valuable device in the frequency scope of 150 MHz to 3700 MHz. Below is the mathematical expression of the model;

$$G_B G_M \left(\frac{h_B h_M}{d^2}\right)^2 \beta \tag{13}$$

where,

L = Path loss in decibel (dB)
G_B = Gain of base transmitter in decibel (dB)
G_M = Gain of mobile transmitter in decibel (dB)
h_B = Height of base station antenna in meter (m).
h_M = Height of mobile station antenna in meter (m).
d = Link distance in kilometer (km).
β = Clutter factor

3.4.4.2 Hata Model for Urban Areas

The Hata model for urban zones, otherwise called the Okumura-Hata model for being an advancement adaptation of the Okumura model, is the most generally utilized radio frequency propagation model for anticipating the conduct of cellular transmissions in developed territories. This model fuses the graphical data from Okumura model and creates it further to understand the impacts of diffraction, reflection and disseminating caused by city structures. This model additionally has two more assortments for transmission in rural territories and open zones [46,47,8,9,6,48]

This specific adaptation of the Hata model is relevant to the radio propagation inside urban zones. It is suited for both point-to-point and communicates transmissions and it depends on broad experimental estimations taken. It is appropriate to be connected in the frequency scope of 150 MHz to 1500 MHz. The model was created for Mobile Station Antenna Height of between 1 to 10km, and Base Station Antenna Height of range 30 to 200 meters [46, 49]. Equation 14 shows the mathematical expression of the model:

$$L = 69.55 + 26.16 log_{10} f - 13.82\ log_{10} h_B - C_H + [44.9 - 6.55 log_{10} h_B] log_{10} d \tag{14}$$

For small or medium sized city,

$$C_H = 0.8 + \ 1.1\ log_{10} f - 0.7) h_M - 1.56 log_{10} f \tag{15}$$

And for large cities

$$C_H = \begin{cases} 8.29(log_{10}(1.54 h_M))^2 \quad - 1.1, \ if\ 150 \le f \le 200 \\ 3.2(log_{10}(11.75 h_M))^2 \ - \ 4.97, \ if\ 200 \le f \le 1500 \end{cases} \tag{16}$$

where,

L = Path loss in urban areas in decibel (dB).
h_B = Height of base station antenna in meter (m).
h_M = Height of mobile station antenna in meter (m).
f = Frequency of transmission in Megahertz (MHz).

Though based on Okumura model, the Hata model does not provide coverage to the whole range of frequencies covered by Okumura model. Hata model does not go beyond 1500 MHz while Okumura provides support for up to 1920 MHz.

3.4.4.3 Hata Model for Suburban Areas

The Hata model for rural territories, otherwise called the Okumura-Hata model for being a created adaptation of the Okumura model, is the most broadly utilized model in radio frequency propagation for anticipating the conduct of cellular transmissions in city edges and other rustic regions. This model fuses the graphical data from Okumura model and creates it further to better suit the need. This model additionally has two more assortments for transmission in urban zones and open territories; these are not investigated in this work [50,10]

The Hata model predicts the aggregate path loss along with a connection of earthbound microwave or other sort of cellular communications and is a component of transmission frequency and the normal path loss in urban zones. The Hata model for rural zones, otherwise called the Okumura – Hata model, for being a created form of the Okumura model is the most generally utilized as a part of radio frequency propagation for foreseeing the conduct of cellular transmission in city edges and other rustic zones. This model consolidates the graphical data from Okumura model and creates it further to better suit the need. It additionally has two more assortments for transmission in urban zones and open zones.

The Hata model predicts the aggregate path loss along with a connection of earthly microwave or other sort of cellular communications. It also serves as a function of transmission frequency and the average path loss in urban areas. Below is the mathematical expression of the model; [45]

$$L_{SU} = L_U - 2\left[\log_{10}\frac{f}{28}\right]^2 - 5.4 \qquad (17)$$

where,

L_{SU} = Path loss in suburban areas in decibel (dB)
L_U = Average path loss in urban areas for small sized city in decibel (dB)
f = Frequency of transmission in Megahertz (MHz)

3.5 Models for Indoor Attenuations

In indoor radio channels, the propagation is firmly impacted by the format of structures, development materials and building compose, e.g. kind of parcels, delicate or hard segments and multi-floor structures. As a rule, it is hard to foresee the correct model for indoor conditions where infiltration from outside is included. Thus, a speculation is generally made, e.g. the flag quality got inside building increments with height, because of urban group impact [46-47]

3.5.1 ITU Model for Indoor Attenuation

The ITU indoor propagation model, otherwise called ITU model for indoor attenuation, is a radio propagation model that gauges the path loss inside a room or a shut zone inside a building delimited by dividers of any shape. Appropriate for machine intended for indoor utilize, this model approximates the aggregate path loss an indoor connection may understanding. The model is pertinent to just the indoor situations. Normally, such apparatuses utilize the lower microwave groups around 2.4 GHz. Nonetheless, the model applies to a significantly more extensive territory, with better outcomes between the frequencies of 900 MHz to 5.2 GHz. [20-22, 8-9,6]. The model is also found suitable for multi floor attenuation predictions when the number of floors less than or equal to 3 (ITU-R, 2001). The ITU indoor path loss model is formally expressed as (ITU-R, 2001):

$$L = 20\log f + N\log d + L_f(n) - 28 \qquad (18)$$

where,

L = The total path loss in decibel (dB)
f = Frequency of transmission in megahertz (MHz)
d = Distance between base station and portable terminal in meter (m).
N = The distance power loss coefficient
n = Number of floors between the transmitter and portable terminal ($n \geq 0$), $L_f = 0$ dB for $n = 0$
$L_f(n)$ =The floor loss penetration factor

4. CONCLUSION

From these models analysis both the outdoor and indoor, it was observed that all models can perform better depending on the condition(s) that is involved. That is, the type of model used in analysis depends on the area where the experiment is to be carried out and as such, model A could perform better than model B, etc. Therefore, it is highly recommended that before a mathematical model can be chosen for any experiment, the surrounding environment have to be considered.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ajakaye TA. Telecommunication business in Nigeria University of Lagos. 2005;1:37-51.
2. Ajay Mishra. Advance cellular network planning and optimization. John Wiley and Sons. 2007;28:402-411.
3. Amitay N. Modeling and computer simulation of wave propagation in lineal line-of sight microcell. IEEE Trans. Veh. Tech. 1992;337-342.
4. Anderson JB, Rappaport TS, Yoshida S. Propagation measurements and models for wireless communication channels. IEEE Communication Magazine. 1995;42-49.
5. Anderson HR. A ray-tracing propagation model for digital broadcast systems in urban area. IEEE Trans. Broadcasting. 2001;39:309-317.

6. Uzairue Stanley et al. Experimental analysis of cable distance effect on signal attenuation in single and multimode fiber optics. International Journal of Electrical and Computer Engineering (IJECE). 2018; 8(3):1577~1582
7. Andrea Goldsmiths. Wireless communications Cambridge University Press. 2005;7:43-67
8. Victor O. Matthews et al. An Analytics enabled wireless anti-intruder monitoring and alarm system. International Journal of Scientific Research in Science, Engineering and Technology (ijsrset.com). 2018;4(9):05-11
9. Anyasi Francis et al. Design and analysis of a broadcast network using logical segmentation. TELKOMNIKA. 2018;16(2): 803~810
10. Uzairue Stanley et al. A Review: The past, present and future of radio frequency spectrum in Nigeria, Canada, United Kingdom, Ghana. International Research Journal of Engineering and Technology (IRJET). 2018;5(3):1034-1039
11. Andrea G. Wireless communications. Cambridge University Press. 2005.
12. Anyasi FI, Yesufu AK. Indoor propagation modeling in brick, zinc and wood buildings in Ekpoma. Journal of Engineering and Applied Sciences. Medwell Journals. ANSINET building, Pakistan. 2007;2(9): 1408-1413.
13. Anyasi FI, Yesufu AK, Akpaida VOA, Evbogbai MJE, Erua JB. Indoor modeling for determination of G. S. M. signal penetration level. A case study of mud, block, and steel building materials in Ekpoma. Journal of engineering and Applied Sciences. Medwell Journals, ANSINET Building, Pakistan. 2007;2(9): 1443-1449.
14. Armogum V, Soyjaudah KMS, Fogarty T, Mohamudally N. Comparative Study of Path loss using existing models for digital television broadcasting for summer, Mauritius. Season in the north of Mauritius, Proceeding of Third Advanced IEEE International Conference on Telecommunication. 2007;4:34-38.
15. Baccelli F, Blaszczyszyn B, Mühlethaler P. An aloha protocol for multihop mobile wireless networks. IEEE Transactions on Information Theory. 2006;52(2):421-436.
16. Bettstetter C. On the connectivity of ad Hoc networks. The Computer Journal, Special Issue on Mobile and Pervasive Computing. 2004;47(4):432-447.
17. Carlson AB, Crilly PB, Rutledge JC. Communication systems, an introduction to signal and noise in electrical communication. 4th Edition, McGraw-Hill; 2002.
18. Clint Smith, Daniel Collins. 3G Wireless Network. 2000;136.
19. Domazetovic A, Greenstein LJ, Mandayan N, Seskar I. A modeling approach 50 for wireless channels with predictable path geometrics. IEEE Beh. Tech. Conf; 2002.
20. Durgin GD, Rappaport TS, Xu H. Measurements and models for radio path loss and penetration loss in and around homes and trees at 5.85 GHz. IEEE Transactions on Communications. 1998; 46(11):1484-1496.
21. Erceg V, Greenstein LJ. An empirically path loss model for wireless channels in Suburban environments. IEEE Journal on Selected Areas in Communication. 1999; 17:1205-1211.
22. Erceg V, Fortune SJ, Ling J, Rustako AJ Jr, Valenzuela. Comparisons of a computer-based propagation prediction tool with experimental data collected in urban microcellular environments. IEEE Journal on Selected Areas in Communications. 1997;15))4:677-684.
23. Erceg V, Greenstein LJ, Tjandra SY, Parkoff SR, Gupta A, Kulic B, Julius Bianchi AA. An Empirically Based Path Loss Model for Wireless Channels in Suburban Environments. IEEE Journal on Selected Areas in Communication. 1999;17:1205-1211.
24. Hung HuyKhong, Bing W. Kwan, Leonard J. Tung. A physics-based path-loss model for UWB (Ultra-WideBand) Systems. Proc. International Conference on Wireless Networks (ICWN); 2008.
25. Idim AI, Anyasi FI. (a) Determination of building penetration loss of gsm signals, using selected buildings in Orhuwhorun, Delta State, Nigeria: As a Case Study. Journal of Electronics and Communication Engineering. 2014;9(5):1-5.
26. Idim AI, Anyasi FI. (b) Determination of path loss exponent using GSM in Orhuworun Environ, Delta State. Journal of Electronics and Communication Engineering. 2014;9(5):15-20.
27. International Engineering Consortium. Global System for Mobile Communication (GSM), IEEE. 2005;5(23):56-70.

28. Iskander MF, Yun Z. Propagation prediction models for wireless communication systems. IEEE Transaction on Microwave Theory and Techniques. 2002;50(3):662-673.
29. ITU. What really is a third generation (3g) mobile technology. IEEE. 2009;6(28):57-87.
30. Kagan AM, Linnik YV, Rao CR. Characterization problems in mathematical statistics. Wiley; 1973.
31. King RJ. Electromagnetic wave propagation over a constant impedance plane. Radio Science. 1969;4:225-268.
32. Lee WCY. Mobile communications fundamentals. Second Edition; 1993.
33. Lee WCY. Mobile Communications Engineering. McGraw-Hill; 1998.
34. Leveque O, Tse D. Hierarchical cooperation achieves optimal capacity scaling in Ad Hoc networks. IEEE Transactions on Information Theory. 2007; 53(10):3349-3572.
35. Li HJ, Chen CC, Liu TY, Lin HC. Applicability of ray-tracing techniques for prediction of outdoor channel characteristics. IEEE Trans. Veh. Tech. 2000;2336-2349.
36. Li R. The accuracy of Norton’s empirical approximations for ground wave attenuations. IEEE Trans. Ant. Prop. 2000; 31:624-628.
37. Lichun L. IEEE Ant. Prop. Magazine. 2000; 21-33.
38. Longley AG. Radio propagation in urban area OT report New York, Propagation. 1998;42(2):78-144.
39. Schaubach KR, Davis IV, Rappaport TS. A ray tracing method for predicting path loss and delay spread in microcellular environments. IEEE Veh. Trans. Tech. 1992;932-935.
40. Seidel SY, Rappaport TS. 914MHz Path loss prediction models for indoor wireless communications in multifloored buildings. IEEE Transactions on Antennas and Propagation. 1992;40(2):207-217.
41. Idim AI, Anyasi FI. Determination of building penetration loss of gsm signals. IOSR Journal of Electronics and Communication Engineering. 2014;9(5):1-5
42. Francis Idachaba, etal. Future trends in fiber optics communication proceedings of the World Congress on Engineering. 2014;2-4.
43. Nsikan Nkordeh et al. The Nigerian telecommunication industry: Analysis of the first fifteen years of the growths and challenges in the GSM market (2001–2016) proceedings of the world congress on engineering and computer science 2017;25-27.
44. Sharma HK, Sahu S, Sharma S. Enhanced Cost 231 W.I propagation model in wireless network. International Journal of Computer Applications. 2011;19:6.
45. Sharma PK. International Journal of Engineering Science and Technology. 2010,2008-2013. 2013:2(6).
46. Skidmore RR. A comprehensive in building and microcellular wireless communication system design tool. M.S thesis, Dept. Elect. Eng, Virginia Polytechnic Inst. And State University Blacksburg, V.A.; 1997.
47. Sommerfeld AN. Propagation of waves in wireless telegraphy II. Ann. Phys. 2000; 81:1135-1153.
48. Anyasi FI, Uzairue SI. Determination of GSM signal strength level in some selected location in EKPOMA. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735. 2014;9(2):08-15
49. VOA Akpaida et al. Determination of an outdoor path loss model and signal penetration level in some selected modern residential and office apartments in Ogbomosho, Oyo State, Nigeria. Journal of Engineering Research and Reports. 2018; 1(2):1-25,
50. Uzairue Stanley et al. A review: Evolution of 5G, security and multiple access schemes in mobile communication. International Research Journal of Engineering and Technology (IRJET). 2017;04(12):1277-1279

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