Pathloss Model Evaluation for Long Term Evolution in Owerri

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Abstract:- The investigation of propagation models in urban areas is vital because the surrounding is poised of diverse physical obstructions. These models are useful development tools that enable the network planner of wireless communication networks achieve optimal levels for the base station operation and meeting the anticipated service level requirements. This research examines five experimental broadcast models- FSPL, EGLI, ECC, COST 231 and ERICSSON Model for pathloss performance in Owerri, Imo State of Nigeria. A drive test was carried out to acquire the authentic field data on the LTE with a frequency of 700MHz network deployed within the study area. TEMS Investigation and Discovery network planning tool was used for the forecast calculations. Results obtained shows that Ericsson model was found to best predict the environment with a minimum deviation of 10.11dB being closest to measured pathloss with 2.01dB compared to the other models

Keywords:- *Pathloss, LTE, Base Station, Model, Broadcast.*

I. INTRODUCTION

Issues of poor capacity, low average, and attenuation when waves are propagated from one point to another are the reasons behind slow data rate and call drops experienced in broadband transmission [1]. Radio transmission planning is extremely important in wireless network development. Wireless network can be propagated through different mechanism such as scattering, diffraction and reflection. Pathloss is the power reduction of EM waves as it propagates through space [2]. Pathloss is simply the difference between the power transmitted and power received [3]. In planning 4G network, pathloss is a key component. It is the attenuation of EM waves as it propagate from one point to the other through space. Numerous factors such as environment (Urban, sub-urban, rural), distance between the transmitter and the receiver, the location and the height of the antenna can influence the pathloss. As signal passes through multi-path transmission, it tends to reduce due to density of electromagnetic waves and reduction of power. This poses a high challenge in the use of mobile radio communications and its effect can be felt in highly populated cities such as Owerri. Due to the various differences in city structures, local topography profiles, weather etc., predicting the pathloss with reference to the existing empirical path loss models such as the SUI, Ericsson model, Hata's model etc., may differ from the actual one. Therefore determination of pathloss for a particular terrain becomes highly necessary for network planning and optimization engineers.

II. EXPERIMENTAL METHOD OF PATHLOSS ANALYSIS

Models have been postulated considering different factors including geographical terrain, frequency of operation over a given distance. They could be applicable to other environment other than the one that was predicted but most times, they become less accurate.

A. Cost 231 Hata Model

COST 231 HATA model is used for predicting path loss in mobile wireless system is the COST-231 Hata model. It is a revised version and an extension to the Hata-Okumura model. The designated frequency of operation is between the range of 500 MHz to 2000 MHz. there are also provisions for antenna factor corrections for flat environment. Due to its provision for correction factor and simplicity, it is often used to predict pathloss. The basic equation for path loss in dB

$$PL = 46.3 + 33.9\log(f) - 13.82\log(h_b) - ah_m + (44.9 - 6.55\log(h_b)\ logd + C_n \qquad (1)$$

where, f is the frequency in MHz, d is the distance between AP and CPE antennas in km, and h_b is the AP antenna height above ground level in metres. C_n is 0dB for suburban and 3dB for urban region. ah can be defined for urban region as

$$ah_m = 3.20(\log(11.75hr))^2 - 4.97,\ for\ f > 400MHz \qquad (2)$$

And for sub-urban and rural environments,

$$ah_m = (1.1logf - 0.7)hr - (1.56logf - 0.8) \qquad (3)$$

B. Egli Model

This model is good in predicting point to point links. It is most preferred where the one antenna is mobile and the other fixed. It is not applicable in terrains where there is vegetation obstructing line of sight. Egli model is given by

$$(dB) = G_b G_m \left(\frac{h_b h_m}{d^2}\right)^2 \left(\frac{40}{f}\right)^2 \qquad (4)$$

Where
G_b is the BTS antenna gain
G_m is the mobile station antenna gain
h_b is the base station height
h_m is the obile station height
d is the distance in meters
f is the frequency in Hz

C. Stanford University Interm (Sui) Model

The Stanford University Interm (SUI) model development took place under the institute of Electrical and Electronic Engineers (IEEE) 802.16 broad band wireless access working group. This model takes into consideration correction factors for the Hata model with frequencies above 1900MHz. This model consist of three terrains; A, B and C. Type A is for hilly terrains, type C is for areas with reduced pathloss and densities. Type B is with flat terrains with light tree densities [9]. SUI equation model is given by

$$(dB) = A + 10\gamma\, log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s \quad for\ d > d_0 \tag{5}$$

where, d is the distance between the BTS and the mobile device in m, d0 = 100 m and s takes the effect of shadowing into consideration and is a log normally distributed factor and has a value between 8.2 dB and 10.6dB . Other parameters are defined as

$$A = 20\, log_{10}\left(\frac{4\pi d_0}{\lambda}\right) \tag{6}$$

$$\gamma = a - bh_b - c/h_b \tag{7}$$

where, the h_b is the base station height in metres. The constants a, b and c are defined in the table 1 below. The parameter γ in is equivalent to the exponent of the pathloss.

Model Parameters	Terrain A	Terrain B	Terrain C
a	4.8	4.2	3.8
b	0.0095	0.0085	0.007
c	12.8	12.8	20.2

Table 1:- SUI Constants

The antenna correction factors for the frequency and for the mobile equipment antenna height for the SUI model are

$$X_f = 6.0\, log_{10}\left(\frac{f}{2000}\right) \tag{8}$$

$$X_f = -10.8\, log_{10}\left(\frac{h_r}{2000}\right) \quad for\ Terrain\ A\ and\ B \tag{9}$$

$$= 6.0\, log_{10}\left(\frac{f}{2000}\right) \quad for\ Terrain\ C \tag{10}$$

D. Ericsson Model

The modification of the Okumura hata Model according to a propagation environment gave room for change in parameters which eventually lead to Ericsson model. Network engineers used a software to actually develop this model. According to this model, the pathloss is given by

$$Pl = a_0 + a_1 \log_{10} d + a_2 \log_{10} h_b + a_3 \log_{10} h_b \log_{10} d - 3.2(\log_{10}(11.75 h_r))^2 + g(f) \tag{11}$$

$$\text{Where } (f) = 44.50 \log_{10} f - 4.80(\log_{10} f)^2 \tag{12}$$

Where f is the frequency in Mhz

h_b is the distance in m
hr is the receiver antenna height in m

The default values of these parameters (a_0, a_1, a_2 and a_3) for different terrain are given in Table 2 below

Environment	a_0	a_1	a_2	a_3
Urban	36.4	30.4	12.2	0.3
Sub-Urban	43.4	69.15	12.2	0.3
Rural	46.13	100.8	12.2	0.3

Table 2:- Ericsson Constants

The value of parameter a_0 and a_1 in suburban and rural area are based on the Least Square (LS) method [10]

III. DESIGN METHODOLOGY

A. Drive Test

A drive test was conducted with the aid of a laptop with TEMS investigation 15.3.3. the mobile device is a Samsung S5 galaxy pre installed with TEMS pocket and GLO LTE enabled sim. An inverter provided power supply for the laptop and a GPS was used to record coordinate of site. The BTS antenna was located at 25m height while the mobile station height is 1m. the car was driven at a speed not more than 45km/hr while the TEMS recorded the received power(RSRP). Measurements were taken twice in a day for a period of four month and mean average values of received signal strength obtained for this work.

B. Pathloss Equation Analysis

Path loss can be defined as the ratio of the transmitted to received power, usually expressed in decibels. The equation for the Least Square (LS) regression analysis shows the path loss at distance d in the form

$$10 \log (mw) = (dBm) \tag{13}$$

Where P_r is the receive power

$$(d_i)(dB) = (d_0) + 10n \log(\frac{d}{d_0}) \quad (14)$$

Where
(d_i) is the measured pathloss with respect to distance
(d_0) is the predicted pathloss with respect to reference distance $d_0 = 0.1$km

Log Normal Shadowing Model

During transmission, obstructions are caused by objects such as buildings and trees thus causing some part of the signal being lost via diffraction, scattering, absorption and reflection. This effect is referred to as shadowing. Based on this, equation 14 above can be modeled into

$$PL(d_i) = PL(d_o) + 10_n \log\left(\frac{d}{d_o}\right) + \chi_\sigma \quad (15)$$

Where χ_σ is a Gaussian distributed random variable with standard deviation σ

$PL(d_o)$ is the pathloss at reference distance
$PL(d_i)$ is the measured pathloss at various distances n is the pathloss exponent

$$n = \frac{PL(d_i) - PL(d_o)}{10\log(\frac{d}{d_o})} \quad (16)$$

In the above equation, we can analyse it with linear regression where pathloss exponent n can be evaluated by obtaining the mean square error and minimizing it.

$$\eta = \frac{\sum_{i=1}^{K} PL(d_i) - PL(d_o)}{\sum_{i=1}^{k} 10 \log\left(\frac{d_i}{d_o}\right)} \quad (17)$$

The standard deviation σ can be obtained via the formula below

$$\sigma = \sqrt{\sum_{i=1}^{k} \frac{PL(d_i) - PL(d_o)^2}{N}} \quad (18)$$

Where N is the number of set points

SITE NAME	EIMO_102(OWERRI)
BTS power	45dB
BTS antenna height	25m
LTE Operating frequency	700Mhz
Mobile station height	1m

Table 3:- Site Parameters

Distance	EIMO_102(OWERRI)
(Km)	Measured RSRP (dBm)
0.1	-75.9
0.2	-78.3
0.3	-81.3
0.4	-83.5
0.5	-85.9
0.6	-87.7
0.7	-89.5
0.8	-91.2
0.9	-94.2
1.0	-96.2

Table 4:- Reference Power Received Signal (RSRP)

From table 4, we can calculate the average power received Pr at various distances

$$P_r\,(dBm) = 10 \log P\,(mW) \quad (19)$$

$$Pl(d_o) = 10\log(\frac{P_t}{P_r}) \quad (20)$$

where
Pt is the BTS transmit power at 45dBm
$P\,r$ is the RSRP in dBm
$Pl(d_o)$ is the measured pathloss value in dB

Distance	EIMO_102(OWERRI-Urban)	PLm
(Km)	Measured RSRP(dBm)	dB
0.1	-75.9	120.2
0.2	-78.3	123.2
0.3	-81.3	126.5
0.4	-83.5	128.9
0.5	-85.9	130.9
0.6	-87.7	132.7
0.7	-89.5	134.6
0.8	-91.2	136.1
0.9	-94.2	139.2
1.0	-96.2	141.5

Table 5:- Measured Pathloss and the Received Power for the Various Distances

Based on table 5, it can be deduced that the pathloss measurement increases as distance increases. The rate at which the pathloss increases exponentially (n) with respect to distance can be computed taken into consideration the effect of log normal shadowing

$$Pl(d_i) = Pl(d_o) + 10n \log\left(\frac{d_i}{d_o}\right) \quad (21)$$

Where $Pl(d_o)$ is 120.8 and d_o is the reference distance 0.1Km.

Distance	EIMO_102	Measured PLm	Predicted PL
(Km)	Measured RSRP(dBm)	dB	
0.1	-75.9	120.2	120.7
0.2	-78.3	123.2	120.7+3.02n
0.3	-81.3	126.5	120.7+4.57n
0.4	-83.5	128.9	120.7+6.01n
0.5	-85.9	130.9	120.7+6.69n
0.6	-87.7	132.7	120.7+7.58n
0.7	-89.5	134.6	120.7+8.25n
0.8	-91.2	136.1	120.7+9.13n
0.9	-94.2	139.2	120.7+9.84n
1.0	-96.2	141.5	120.7+10.10n

Table 6:- Predicted Pathloss

Applying least square method of regression analysis, we can obtain the mean square error by applying the formula below

$$MSE = e(n) = \sum_{i=1}^{k}[Pl(d_i) - Pl(d_o)]^2 \qquad (22)$$

$$= 523.40n^2 - 1763.16n + 1529.79$$

Since the MSE is a function of n, we can obtain n by minimizing the equation above and equating it to zero.

$$\frac{\partial e(n)}{\partial n} = 2[523.40] - 1763.16 = 0$$

$1044.8n = 1763.16$

$n = 1.69$

Substituting n in the equation below

$$PL(d_i) = PL(d_o) + 10n\log\left(\frac{d}{d_o}\right)\chi_\sigma \qquad (23)$$

$$Pl(d_i) = 120.8 + 16.9\log\left(\frac{d}{d_1}\right) + \chi_\sigma$$

To obtain the standard deviation σ we use the formula

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{k}(Pl(d_i) - Pl(d_o))^2} \qquad (24)$$

$$\sigma = \sqrt{\frac{1}{10}((523.40n^2 - 1763.16n + 1529.79))}$$

$\sigma = 2.03dB$

The resultant model will be

$$Pl(d_i) = 120.8 + 10(1.69)\log\left(\frac{d_i}{d_o}\right) + 2.03$$

$$Pl(d_i) = 124.82 + 16.9\log(D) \qquad (25)$$

where

$D = \frac{d_i}{d_o}$

di is the distance at any point

$d0$ is the reference distance point

The pathloss model of YENAGOA town Bayelsa can be predicted by equation (25)

To give room for comparism, we need to compare the measured pathloss model against empirical pathloss models.

D(Km)	Measured (dB)	Free space (dB)	Egli model (dB)	Cost 231 (dB)	Ecc33 (dB)	Ericsson (dB)
0.1	120.2	71.54	78.36	91.12	98.84	102.87
0.2	123.2	76.39	89.43	102.28	105.06	113.24
0.3	126.5	80.18	97.18	108.13	109.38	118.72
0.4	128.9	83.17	102.86	112.66	112.52	122.35
0.5	130.9	85.69	106.55	116.50	114.75	125.86
0.6	132.7	86.74	109.43	119.87	117.23	127.52
0.7	134.6	88.26	112.81	120.46	118.99	129.66
0.8	136.1	89.45	114.17	122.90	119.72	131.01
0.9	139.2	90.48	116.53	125.72	122.05	132.59
1	141.5	91.76	118.90	127.21	123.73	134.31

Table 7:- Measured and Calculated Empirical Pathloss Values

	$(pL_m - PL_{FSPL})^2$	$(PL_m - PL_{EGIL})^2$	$(PL_m - PL_{COST231})^2$	$(PL_m - PL_{ECC})^2$	$(PL_m - PL_{ERICSSON})^2$
D(Km)	FSPL	EGIL	COST231	ECC	ERICSSON
0.1	2650.55	1959.18	980.68	579.89	357.52
0.2	2281.25	1192.21	524.48	402.00	146.19
0.3	2241.12	935.47	389.82	360.80	97.40
0.4	2260.33	800.34	323.54	345.35	77.88
0.5	2265.96	697.92	273.42	325.72	61.82
0.6	2286.78	627.50	240.98	312.29	52.76
0.7	2350.32	594.25	229.21	317.40	52.56
0.8	2400.91	559.77	215.33	315.51	50.70
0.9	2579.51	599.99	247.80	367.34	69.99
1.0	2681.34	604.65	256.47	388.79	79.86
	$\sum = 23984.07$	$\sum = 8566.19$	$\sum = 3676.70$	$\sum = 3713.09$	$\sum = 1042.68$

Table 8:- Mse Evaluations for Various Empirical Method

To obtain the standard deviation

$$\sigma = \sqrt{\frac{1}{N}\sum(Pl_m - Pl_{emptricat})^2} \qquad (26)$$

$\sigma_{measured}$	$\sigma_{ericsson}$	$\sigma_{COST231}$	σ_{ECC}	σ_{EGLI}	σ_{FSPL}
4.03dB	12.25dB	20.16dB	19.26dB	33.08dB	49.57dB

Table 9:- Calculated Standard Deviation of Pathloss Models

IV. RESULTS AND DISCUSSIONS

The measured pathloss and empirical values were used to plot graphs with the aid of MATLAB

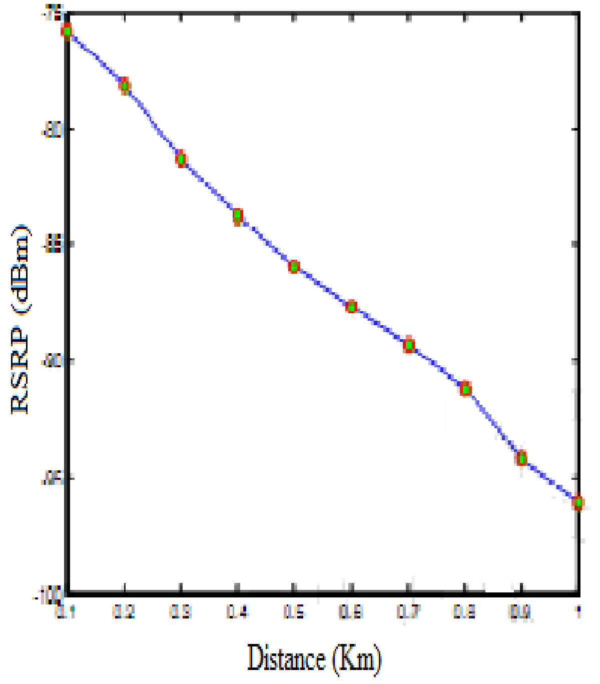

Fig 1:- Plot of Received Power against Distance

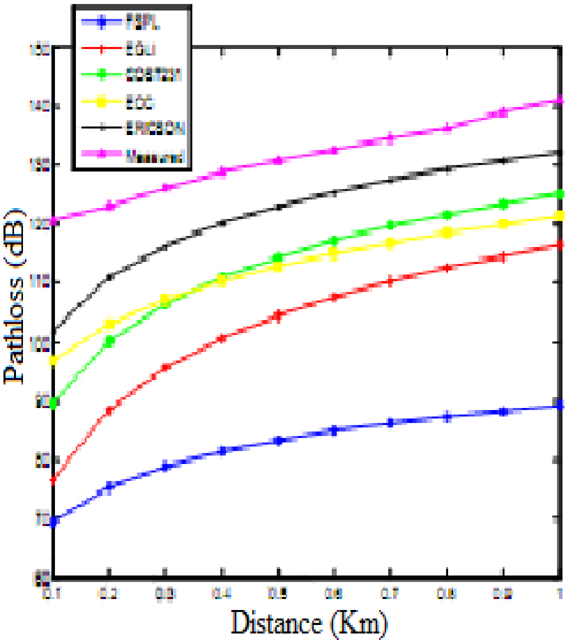

Fig 2:- Plots of Measured and Empirical Pathloss against Distance

A joint plot of measured pathloss and empirical pathloss model against distance is shown in fig 4. It is observed that the free space pathloss(FSPL) prediction of the urban environment falls below standard. This is attributed to the fact that the FSPL does not take into consideration, correction factors for base station height hb and receiver station height hr. Also we notice the FSPL has the highest standard deviation of value 49.57dB. The EGLI model shows a standard deviation of 33.08dB. Based on its deviation, it truly shows it is more conservative when compared to FSPL. COST 231 and ECC shows a standard deviation of 20.16dB and 19.26dB respectively. Both values were close and it could also be observed from the plot in fig.4 above as both curves lie side by side. Ericsson show the best prediction of the environment when compared to the measured pathloss model as seen from the plot. Also, the standard deviation shows minimum deviation with a value of 12.25dB as compared to the measured pathloss with 4.03dB. In predicting the value of n for the measured pathloss, we adopted the log normal shadowing effect which can be analyzed using least square method(LS). Ericsson model constant a0 and a1 were also obtained using LS method thus best predicting the measured pathloss for the environment as seen from the plots and the deviation compared to other models.

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