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CDMA2000 Radio Measurements at 1.9GHz and Comparison of Propagation Models in Three Built-Up Cities of South-South, Nigeria.

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Abstract: Radio propagation measurements and prediction, realized by the mobile terminal or the base station, is needed to guarantee quality of service and to supervise the planned coverage area. A wide variety of approaches have been developed over the years to predict signal pathloss using what are known as propagation models. In this paper, we compare the measured pathloss obtained for the urban areas with seven existing propagation models, that is, SUI, Lee, Hata, ECC and COST-231 W/I and W/B. Firstly, for both areas, the results show that the path loss is not constant at various locations for a constant distance around the respective base station (BS). This shows that the terrains of studied cities are irregular. Secondly, observations show that the W/B gives better agreement for all the studied three cities; hence, it can be used to model signal coverage area of cellular networks in any region of South-South Nigeria.

***Keywords**:* *CDMA2000, Radio measurements, Signal coverage area, Pathloss.*

I. INTRODUCTION

It is established that propagation phenomena can cause unexpectedly poor performance in cellular networks. These are manifested in reduced coverage, dropped calls and unexpected handovers [1]. The performance of the cellular network can be assessed, or new networks can be designed when deferent models are tested with observed measurement results.

Radio measurements, realized by the mobile terminal or the base station, are crucial to assess mobile network reliability as they are needed to guarantee quality of service and to supervise the planned coverage area. These measurements are standardized for each wireless radio technology (GSM, UMTS, EDGE, CDMA2000, HSDPA...) and are essentially used as input for Radio Resource Management (RRM) algorithms. According to current radio network standards such as (third generation partnership project (3GPP) which is the joint standardization body from Europe, Japan, Korea, USA and China, the available metrics in the network can be divided in several categories, depending on their target use:

- Intra frequency measurements: Measurements on the same frequency as the active set. An active set corresponds to the set of base stations (for example Node B in CDMA) to which the mobile terminal is connected,
- Inter RAT measurements: Measurements on channels belonging to other radio access technologies,
- Quality measurements: Measurements of quality of service and of comparison to requested QoS,
- Internal measurements: Measurements in the mobile terminal, on the transmitted and received signal level,
- Positioning measurements: Measurements of the mobile terminal position. These metrics are related to the chosen positioning technology. The widely used technique is the Global Positioning System (GPS),
- Synchronization measurements: Mainly mobile terminal synchronization measurements,
- Traffic volume measurements.

In this study, we focus on internal measurements in the mobile terminal, on the transmitted and received signal level. This type of measurements is characterized with interesting properties linked to the propagation phenomenon. The idea is to explore the hidden properties in the radio measurements of CDMA2000 1x network operating at a frequency of 1.9GHz in built-up areas, so as to obtain received signal level information and predict pathloss between the base station (BS) transmitter and the mobile station (MS) terminal.

II. RESEARCH MOTIVATION

Academically, built-up environments are interesting to study because of the complexity they present for the radio wave propagation. The many surfaces of buildings and objects in the streets produce reflections, diffraction, and shadowing of the signal, guiding it as it propagates from transmitter to receiver. Built-up environments are also of practical interest because these areas attract great concentrations of users. In fact, the popularity of wireless services in these areas is leading to network congestion. Since adding additional base stations to extend capacity is an expensive endeavor, system operators seek ways to extend the capacities of their existing systems.

Moreover, one way to extend capacity is through improved resource allocation methods. A resource is any shared commodity that the system provides to users on demand. Examples of such resources are frequency, timeslots, transmitted power, and modulation level/bandwidth. For example, in systems that spend less time performing unnecessary handoffs in regions where two base stations serve equally well, an improved handoff algorithm can use information from the propagation characteristics in the area to better refine the handoff location point [2-4].

Signal pathloss prediction models are important in this regard since they predict the received signal strength. Although other parameters may be used in resource allocation decisions, the received signal strength is the fundamental parameter by which these decisions are made. We study propagation models since they yield predictions of signal strength. The signal strength is the primary parameter by which resource allocation decisions are made in cellular systems.

III. MATREIAL AND METHODS MATERIALS

The materials used for field measurements are:

1. Accer compatible Laptop.
2. TEMS measurement software.
3. NOKIA 1265 CDMA test phone
4. External GPS antenna.
5. USB connector.

IV. METHODS

Field measurements were performed in the built-up city of Port Harcourt, Benin and Uyo for their CDMA2000 based system. All the measurements were taken for mobile terminal the NOKIA 1265 CDMA test phone systems (TEMS) operated in the active mode which was provided by the studied CDMA network service provider, accompanied with an Acer portable laptop and a MAP76CSX GPS receiver for accurate location. Measurements were taken in all three zones/sectors of studied BS sites. For macro cellular system, the reference distance is taken as d_0 = 100m. Starting from 100m, measurements were taken in intervals of 0.1 km, then up to a distance of 2 km from the transmitter in the three cities. In all, 9 cellular base stations were involved in the field measurements and their configuration parameters is shown in table 1.

For confidential and legal purposes, the name of the service provider used for the study will be designated as Operator A throughout the research.

The values of the signal strength level measured were converted into pathloss using the expression in equation (1):

$$PL = P_T + G_T + G_R - L_T - L_R - RSS_{(measured)} \quad (1)$$

where P_T is BS transmitted power, $RSS_{(measured)}$ is measured received signal strength, G_T and G_R are the gain of transmitting and receiving antenna, and L_T and L_R are feeder losses of the transmitter and the receiver, all in dB scale.

Table 1: Base station and CDMA network specification

Parameter	Specification for Operator A
Carrier Frequency in the Downlink	1900MHz
Bandwidth	1.25MHz
Modulation/Data Spreading	QPSK
Antenna Height	45m
Antenna Type	Directional (3-Sectored Antenna)
Antenna Gain	17dBi
Vertical Beam width	6.5°
Transmit Power	43dBm

Table 2: Environmental parameters for the pathloss calculation in the study location

Environmental parameters	Benin	Port Harcourt	Uyo
Average Height of Building (m)	6	5	7
Average space between building (m)	2.5	3	3
Average Street width (m)	9	9	10
Average root height (m)	2	2.5	2
Environment	Built-up city	Built-up city	Built-up city
City type	Large	Large	Medium large

EXISTING PROPAGATION MODELS

Here, some key city models available in existing literature for network planning are chosen and analysed relative to actual measured path loss to see how accurate they are for path loss prediction for CDMA2000 in the different locations of study. The chosen models which are Walficsh-Bertoni (W/B), Hata, ECC, SUI, COST-231(W/I), Lee and Egli model and their input environmental parameters used are summarized in table 1 and table 2

.

HATA PROPAGATION MODEL

The propagation model known as Hata -model, is based on Okumura's measurements in Tokyo [5], which were fitted into a mathematical model by Hata. The original Okumura-Hata formula is given in Equation (2) [6]:

$$L = 69.55+26.16\log10 (f)-13.82\log10 (h_{BS})-a (h_{MS}) + [44.9-6.55\log10 (h_{BS}) \log10 (d) \qquad (2)$$

where a is defined as:

$$a(h_{MS}) = [1.1 \log10(f) – 0.7]\ h_{MS} - [1.56 \log10(f) – 0.8] \qquad (3)$$

$$a(h_{MS}) = 3.2 [\log10(11.75h_{MS})]^2 – 4.97 \qquad (4)$$

Equation (2) is used for small and medium cities and Equation (3) for large cities.

Other definitions used in Equation (1) are:

L= Path loss (dB)

F= Frequency (150 - 1500 MHz)

h_{BS} = Base station effective antenna height (20 - 200 m)

h_{MS}= Mobile station antenna height (1 - 10 m)

d =Distance between base and mobile station (1 - 20 km)

The original Okumura-Hata has some limitations. The most restrictive is that Okumura's measurements were made at 1920 MHz, and Hata's formulas cover only frequencies range from 150 to 1500 MHz. Also antennas have been over average rooftop level.

The original formula has been modified by COST-231 -project, which resulted in extending Okumura-Hata formula to cover frequencies from 1500 to 2000 GHz. This makes it possible to use the formula in simulations for 3G-networks for a reasonable accuracy [7]. Constants *A* and *B* are redefined, and distance dependence parameter *C* is recommended to be defined by measurements, but value 44.9 is still often used. The COST-231-Hata –formula is given in Equation 2.69. Constants A and B are chosen from the Table 3 [8]. Also an additional environment dependent parameter, area type correction factor, *Cm*, is given. It is above 0 dB in urban areas, but in rural areas it can be even below -15 dB [7].

$$L = A+B \log_{10}(f)-3.82\log_{10}(h_{BS})-a (h_{MS})+[C-6:55 \log_{10}(h_{BS})] \log10(d)+C_m \qquad (5)$$

New definitions in the formula are:

A Constant, see Table 2.2

B Constant, see Table 2.2

C User defined value for distance dependence (slope factor) Cm Area correction factor.

TABLE 3: CONSTANTS A AND B FOR HATA MODEL

	150-1000MHz	1500-2000MHz
A	69.55	46.3
B	26.16	39.9

STANFORD UNIVERSITY INTERIM (SUI) MODEL

The SUI model was developed under the institute of Electrical and Electronics Engineers (IEEE) 802.16 working group for prediction of path loss in urban, suburban and rural environments [9]. The applicability of this model in the 800 MHz and 1900MHz band has not been validated. However, due to the availability of correction factors for the operating frequency, this model is selected. The SUI models are divided into three types of terrains 1, namely, A, B, and C. Type A is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities. Type C is associated with minimum path loss and applies to flat terrain with light trees densities. Type B is associated characterized with either mostly flat terrains with moderate to heavy three density or hilly terrains with light tree densities. The basic path loss equation with correction factors is presented in [9]:

$$L(dB) = A + 10n\log_{10}\left(\frac{d}{do}\right) + X_f + X_b + S \quad for \quad d > do \qquad (6)$$

Where d is the distance between the Access Point (AP) and mobile station in meters, $do = 100m$ and S is a log normally distributed factor that is used to account for the shadow fading owning to tree and other cluster and has a valued between 8.2 dB and 10.6dB [10]. The other parameters are defined as

$$A = 20\log_{10}\left(\frac{4\pi d_o}{\lambda}\right) \qquad (7)$$

$$n = a - bh_b + C/h_b \qquad (8)$$

where the parameter h_b is the base station height above the ground in metres and should be between 10m and 80m. The constants used a, b, and c is given in Table 4. The parameter n in (8) is equal to the pathloss exponent. For a given terrain type the pathloss exponent is determined by h_b

TABLE 4: SUI MODEL PARAMETERS IN DIFFERENT TERRAIN [10]

Model arameter	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b (m^{-1})	0.0075	0.0065	0.005
c (m)	12.6	17.1	20

The correction factors for the operating frequency and the mobile station antenna height for the model are [10].

$$X_f = 6.0\log_{10}\left(f/2000\right) \qquad (9)$$

and

$$X_h = -10.8\log_{10}\left(\frac{hr}{2000}\right) \quad for \ Terrain \ A \ and \ B \qquad (10)$$

$$= -20.0\log_{10}\left(\frac{hr}{2000}\right) \text{ for Terrain type C} \qquad (11)$$

where, f is the frequency in MHz and hr is the mobile antenna height above the ground in metres. The SUI model is used to predict the path loss in all three environments, namely rural, suburban and urban.

THE LEE MODEL

This is a 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 terrain. It can be expressed in the simplified form [11]:

$$L = 10n\log(d) - 20\log(h_{BS}) - P_o - 10\log(h_{MS}) + 29 \qquad (12)$$

where n and P_o are given in table 5 below

TABLE 5: PARAMETERS FOR LEE'S PATH LOSS MODEL

Environment	P_o	n
Free space	80	2.0
Open Area	89	4.35
North American Suburban	101.7	3.85
North American Urban	110	3.68
North American Urban	104	4.31
Japanese Urban	124	3.05

THE EGLI FACTOR MODEL

The Egli Model is a terrain model for radio frequency propagation. This model consists of the plane earth loss plus an extra loss component called the clutter factor. An example of clutter factor model is the method due to Egli, which is based upon a large number of measurements taken around American cities.
The formulas for the Egli's propagation loss prediction model are as below [12]:
For $hms \leq 10$,

$$PL\,(dB) = 20\log_{10} f_c + 40\log_{10} R + 20\log_{10} hbs + 76{:}3 - 10\log_{10} hms \qquad (13)$$

For $hms \geq 10$,

$$PL\,(dB) = 20\log_{10} f_c + 40\log_{10} R + 20\log_{10} hbs + 85{:}9 - 10\log_{10} hms \qquad (14)$$

ECC-33 MODEL

ECC-33 is a model from Electronic Communication Committee based on analysis in 3.4 and 3.8 GHz band. The path loss is obtained from de following equations[13]:

$$L = A_{fs} + A_{bm} - G_b - G_r \qquad (15)$$

A_{fs}: Free space attenuation (dB)
A_{bm}: Basic median path loss (dB)
G_b: Transmitter antenna height gain factor
G_r : Receiver antenna height gain factor

$$Afs = 92.4 + 20\log(d) + 20\log(f) \qquad (16)$$

$$Abm = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56[\log(f)]^2 \qquad (17)$$

When dealing with gain of the cities, G_b and G_r is be expressed as [13]:

$$G_b = \log10(h_b/200)\{13.958 + 5.8[\log(d)]^2\} \qquad (18)$$

$$G_r = 42.57 + 13.17\log(f)][\log(h_{MS}) + -0.585] \qquad (19)$$

Where d: Distance between transmitter and receiver antenna (km)
f: Frequency (GHz)
h_{BS}: Transmitter antenna height (m)
h_{MS}: Receiver antenna height (m)

COST 231(WALFISCH - IKEGAMI)

The parameters, excess path loss from Walfisch-Bertoni model and final building path loss from Ikegami Model are combined in this model with a few empirical correction parameters. This model is statistical and not deterministic because you can only insert a characteristic value, with no considerations of topographical database of buildings. The model is restricted to flat urban terrain.
The parameters used in Cost 231 Walfisch- Ikegami are denoted figure 1

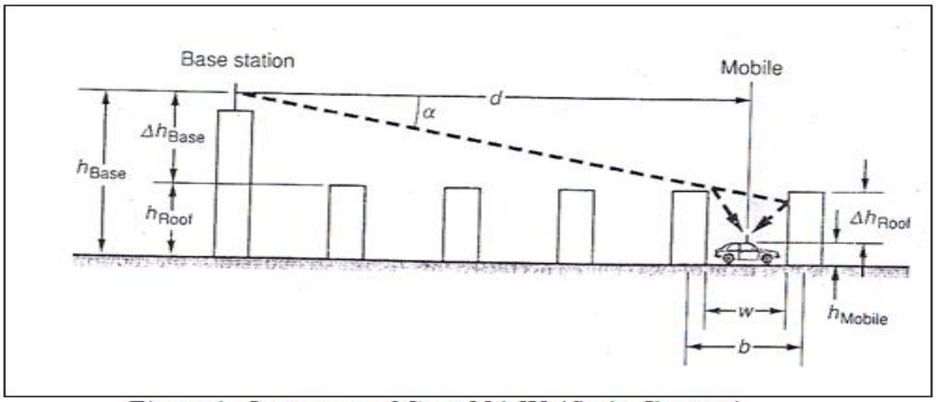

Figure 1: Geometry of Cost 231 Walfisch- Ikegami

The formulation of the model is given as follow
If a free LOS exists in a street canyon then, path loss defined as[2] :

$$L_{los}=42.6+26\log d+20\log f \qquad d \geq 20m \tag{20}$$

WALFISCH IKEGAMI (NLOS)
Restrictions of the model are given as follow [2]:

TABLE 6 RESTRICTIONS OF THE COST 231 W-I MODEL

Frequency (MHz)	800-2000 MHz
Base Station Height (h_{base})	4-50 m
Mobile Height (h_{mobile})	1-3 m
Distance d,km	0.02-5 km

If a non-LOS exists, path loss defined as follow:

$$L_b = \begin{cases} L_{FS} + L_{rts} + L_{msd} & \\ L_{FS} & \text{If } L_{rts} + L_{msd} < 0 \end{cases} \tag{21}$$

L_{FS} represents free space loss, L_{rts} is rooftop to street diffraction and scatter loss, L_{rts} is the multi-screen loss. The rooftop to street diffraction and scatter loss L_{rts} represents the coupling of wave propagating along the multi-screen path into the street mobile located.

$$L_{rts} = \begin{cases} -16.9 - 10\log w + 10\log f + 20\log \Delta h_{mobile} + & h_{roof} > h_{mobile} \\ 0 & L_{rts} < 0 \end{cases} \tag{22}$$

$$L_{ori} = \begin{cases} -10 + 0.354\,(\varphi/\deg) & 0 \leq \varphi < 35 \\ 2.5 + 0.075\,[(\varphi/\deg) - 35] & 35 \leq \varphi < 55 \\ 4 - .114[(\varphi/\deg) - 55] & 55 \leq \varphi \leq 90 \end{cases} \tag{23}$$

Where φ is the angle between incidences coming from base station and road, in degrees shown in following figure 2.

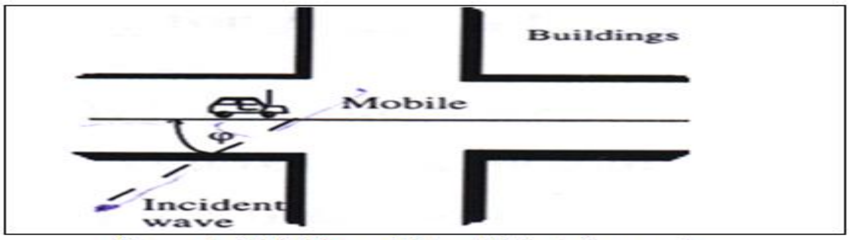

Figure 2: Definition of Street Orientation angleφ.

$\Delta h_{mobile}=h_{roof} - h_{mobile}$
$\Delta h_{Base}= h_{base} - h_{roof}$

The multiscreen diffraction loss L_{msd} is an integral for which Walfisch-Bertoni model approximate a solution to this for the cases base station antenna height is greater than the average rooftop. COST 231 extended this solution to the cases base station antenna height is lower than the average rooftop by including empirical functions.

$$L_{msd} = L_{bsh} + k_a + k_d \log (d/km) + k_f \log (f/MHz) - 9\log (b/m) \tag{24}$$

$$L_{bsh} = \begin{cases} -18\log (1+ \Delta h_{base}) & \text{for } h_{base} > h_{roof} \\ 0 & \text{for } h_{base} \leq h_{roof} \end{cases} \tag{25}$$

$$kf = -4 + \begin{cases} 0.7\,[(f/925)-1] & \text{Medium sized cities and suburban centers with moderate tree density} \\ 1.5\,[(f/925)-1] & \text{Metropolitan centers} \end{cases} \tag{26}$$

$$k_a = \begin{cases} 54 & \text{for } h_{base} > h_{roof} \\ 54 - 0.8\Delta h_{base} & \text{for } d \geq 0.5 \text{ km and } h_{base} \leq h_{roof} \end{cases} \tag{27}$$

$$k_d = \begin{cases} 54 - 0.8\Delta h_{base} R/0.5 & \text{for } d < 0.5 \text{ km and } h_{base} \leq h_{roof} \\ 18 & \text{for } h_{base} > h_{roof} \\ 18 - 15\,\Delta h_{base} / h_{roof} & \text{for } h_{base} \leq h_{roof} \end{cases} \quad (28)$$

The term k_a denotes the increase of the path loss for base station antennas below the rooftops of adjacent buildings. The terms k_d and k_f control the dependence of the multi screen diffraction loss versus distance and radio frequency.

In case of that data on the structure of buildings and roads are not available; following values could be taken as default [14]:

b= 20 ~ 50m

w= b/2

h_{roof}= 3m x (number of floors)+roof height

roof=3 m for pitched 0 m for flat

$\varphi = 90^0$

WALFICSH-BERTONI MODEL

Bertoni and Walfisch [15] proposed a semi-empirical model that is applicable to propagation through buildings in built-up environments. The model assumes building heights to be uniformly distributed and the separation between buildings are equal. Propagation is then equated to the process of multiple diffractions past these rows of buildings. The Walficsh-Bertoni reduces path loss model to three elements: Free space loss, PL_{fs}, diffraction from the rooftops, $PL_{rooftops}$ and diffraction and scatter loss from rooftop down the street, Pl_{down}

Free space loss,

$$PL_fs = -10\log_{10}\left(\frac{\lambda}{4\pi r}\right)^2 \quad (29)$$

Diffraction and scatter loss from rooftop down the street, Pl_{down}

$$PL_{down} = \frac{\lambda \rho_1}{2\pi^2 (H_b - h_m)} \quad (30)$$

Diffraction from the rooftops, $PL_{rooftops}$

$$PL_{rooftops} = P(g)^2 = \left[0.1\left(\frac{\sin\delta\sqrt{\frac{d}{\lambda}}}{0.03}\right)^{0.9}\right]^2 \quad (31)$$

Here, $\sin\delta$ can be written in terms of BS height h_T, the building height H_B, and the distance R as,

$$\sin\delta = \frac{h_T - H_g}{R} \quad (32)$$

Equation (31) becomes,

$$PL_{rooftops} = P(g)^2 = 0.01\left(\frac{h_T - H_B}{0.03R}\right)^{1.8}\left(\frac{d}{\lambda}\right)^{0.9} \quad (33)$$

The total loss is thus given by:

$$PL_{total} = \log\left(\frac{\lambda}{4\pi R}\right)^2 P(g)^2 \frac{\lambda \rho_1}{2\pi^2 (H_b - h_m)} \quad (34)$$

$$= \frac{5.51}{32\pi^4}\frac{(h_r - H_g)^{1.8}\rho_1 d^{0.9}}{(H_B - h_m)^2}\frac{\lambda^{21}}{E^{3.8}}$$

Equation (34) can be expressed in decibels as:

$$PL_{total} = 89.5 - 10\log\left[\frac{\rho_1 d^{0.9}}{(H_B - h_m)^2}\right] + 21\log f_m - 18\log(h_T - H_B) + 38\log R_k \quad (35)$$

Where

and $$\rho_1 = \sqrt{\left(\frac{d}{2}\right)^2 + (H_B - h_m)^2} \qquad (36)$$

f_m: Frequency in MHz.
h_T: Antenna Height in meters.
H_b : Building height in meters.
h_m : Mobile height in meters.
d: Space between buildings in meters.
R: Distance between base station transmitter and mobile station in meters.
Given in table 5 and 6 are the definition of the basic parameters/ specification of the CDMA networks of the two operators in the chosen area of study.

V. RESULTS AND DISCUSSION

In figure 3-5, the measurement pathloss data is examined with the existing models based on the separation distance between the mobile and base station, for comparison.

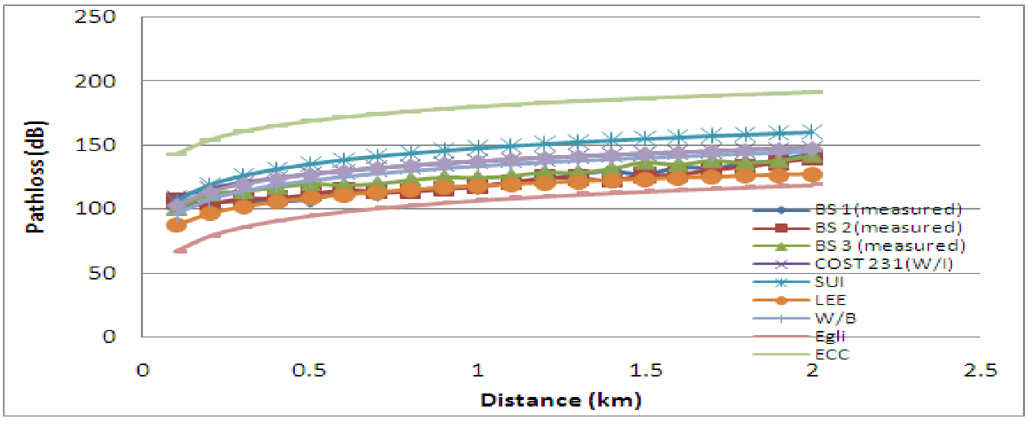

Figure 3: Comparative pathloss model for operator A, location 1

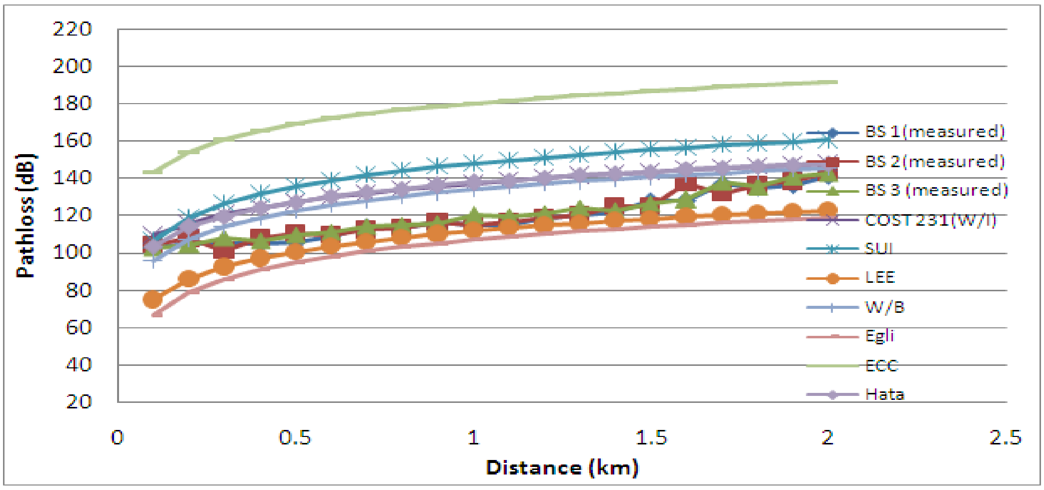

Figure 4: Comparative pathloss model for operator A, location 2

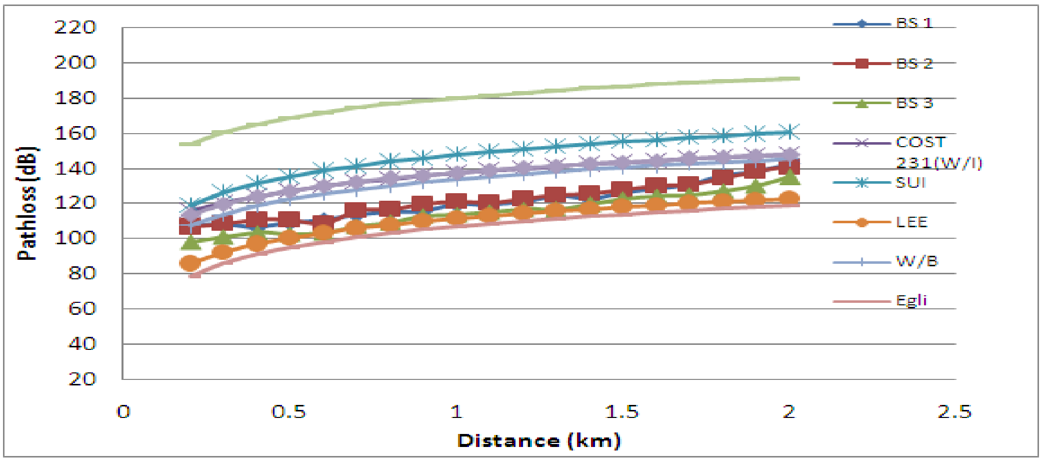

Figure 5 : Comparative pathloss model for operator A, location 3

As can be clearly observed from the above plots, the measured path loss is over predicted by W/B, Hata, ECC, SUI, and COST-231(W/I) models and under predicted by Lee and Egli model. Such performances can be ascribed to the differences in city structures and local terrain profiles.

For instance, the LEE pathloss model was designed based empirical data chosen from a flat terrain. Large errors arise when the model is applied to a non flat terrain. Also, Hata model, which is based on extensive empirical measurements taken by OKumura in city of Tokyo, Japan does not account for clutter factors [2]. In general, such outsized differences between the measured and predicted values can be explained by the fact the expression for pathloss calculation by the existing models were designed in an environment where the definition for urban, suburban and rural areas is not the same in Nigeria. Also, choosing the appropriate propagation model for application depends on system and terrain parameters. Thus, the accuracy of pathloss models suffers when they are used in an environment other than for which they have been developed. Therefore, performing in-field measurements in the environment of interest, and applying necessary corrections to the existing models, or developing a new model from the site-specific measured data is the only solution.

THE MODEL'S GOODNESS OF FIT STATISTICS

In order to examine the goodness of logarithmic fit of existing pathloss model to field data, root mean squared error (RMSE) and relative error (RE) have been calculated. These two statistical parameters are defined as:

Rmse: This statistic gives a quantitative measure on how close (on the average) are the predicted pathloss values, which are estimated using the existing models, to the measured pathloss values. RMSE value closer to 0 indicates a better fit.

Re: This statistic measures the largest error in predictions

Mathematically, the following equations define RMSE and RE:

$$\text{RMSE} = \sqrt{\frac{\sum (Pm - Pr)2}{N}} \qquad (37)$$

$$\text{RE} = \frac{\sum (Pm - Pr)}{Pm} x100 \qquad (38)$$

where,

P_{m} = measured Pathloss (dB)

Pr = Predicted Pathloss (dB)

N = Number of measured data points

. $\check{y}$ =Mean of measured pathloss (dB)

The deduced errors are summarized in figure 6-8.

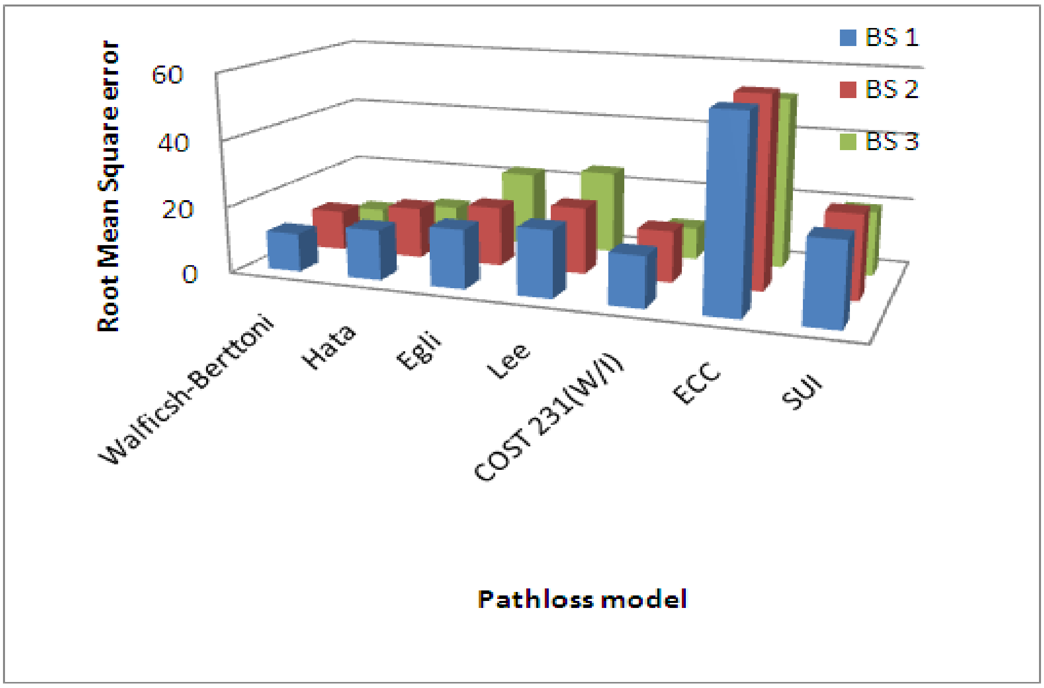

Table 6: The relative errors of the measurement path loss to the path loss of the existing path loss models for operator A, location 1

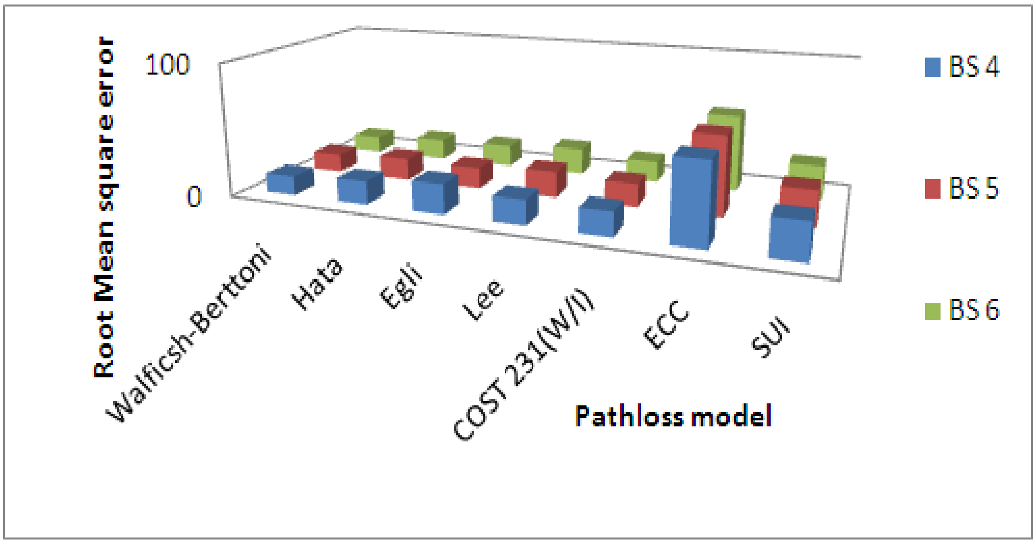

Table 7): The relative errors of the measurement path loss to the path loss of the existing path loss models for operator A, location 2

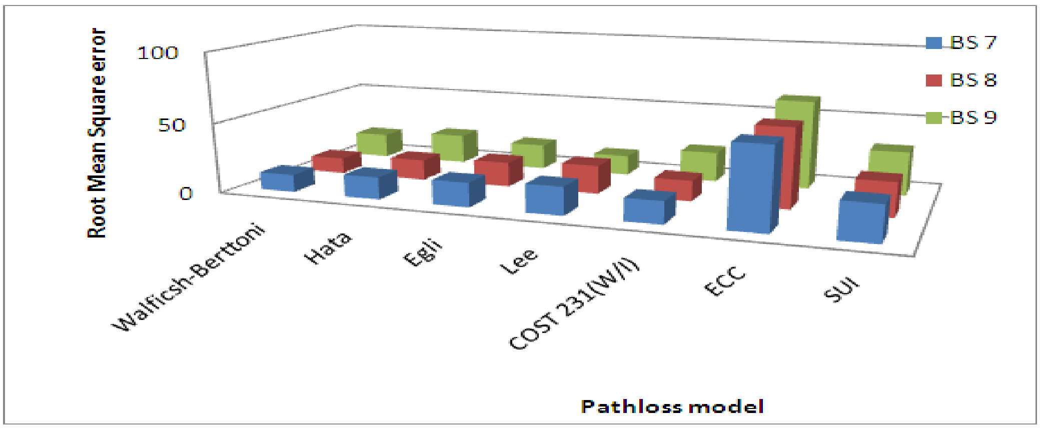

Table 8: The relative errors of the measurement path loss to the path loss of the existing path loss models for operator A, location 3

From the plots in figure 6-8, the measurement data are more close to the Walficsh-Bertoni (W/B) model with RMSE and RE of 6.5279- 17.6577 and 5.4965-15.4049 and more far from ECC model with RMSE and RE of 43.67169-63.26773 and 35.79981-54.20873 respectively. Based on closest agreement to field data, the W/B model is selected as the best model for signal coverage prediction for the studied environment.

VI. CONCLUSION

This study aims to measure and predict the signal path loss for built-up areas of South-South, Nigeria and to compare with different empirical models. The practical measurements that are collected over different distances from the base stations are used to estimate the path loss. Though propagation models are available to predict the losses, they are not very accurate in determining the coverage area of a system. This is due to the fact that these models have been designed based on measurements elsewhere. Therefore, in-field measurements must support the path loss prediction models for better and accurate results. Firstly, the effects of different parameters, such as distance from base stations have been studied and it is observed that path loss increases with distance due to a corresponding decrease in field strength. Secondly, observations show that the W/B gives better agreement for all the studied three cities; hence, it can be used to model any region in South-South Nigeria. Based on the obtained results, a proposal for future works can consider an adjustment of W/B Model by changing some parameters or adding a term which is related to some new environment feature.

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