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# Channel Characterization of a Dense UMTS and LTE Network for Improved Services in South-West, Nigeria

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***Abstract-*** The need for excellent delivery in wireless communication and the demand for high data rate transmission have resulted in the investigation of propagation mechanisms for higher-order frequencies, with enormous prospects in increasing data rate with respect to higher bandwidth. Deficiencies in the wireless channel such as poor signal quality, blocked calls, dropped calls, interference problems, etc make it eminent for the development of path loss prediction and estimation models that predict the signal strength of any given terrain. This research is focused on determining the mathematical model that characterizes the propagation environment of a dense urban area in Lagos, Nigeria (Festac town). The RSS measured was used to characterize the environment and a path loss model was developed for both UMTS and LTE in the test environment as $Lp$ (d) = 77 + 32 $Log$ $(D)$ and $Lp$ $(di)$ = 81 + 26 $Log$ $(D)$ respectively. The path loss model developed was tested and its goodness of fit $(R^2)$ was found to be 0,83 for both UMTS and LTE network respectively. This serves as a basis for predicting the path loss of measured data in the environment under research with greater precision and helps in optimizing the overall performance of the wireless mobile network in proffering seamless services in Lagos, Nigeria.

***Keywords***- Path-loss, Channel Characterization, LTE, UMTS, Lagos

## 1. INTRODUCTION

In wireless communications, the signal is transmitted by electromagnetic waves to a receiver which currently suffers from propagation [1]. The signal is radiated by a transmitter and may also travel along many different paths to a receiver simultaneously, this effect is called multipath. Multipath waves are combined at the receiver antenna. The growing need for excellent performing wireless infrastructure, high data rate transmission has also resulted in the investigation of propagation mechanisms of higher-order frequencies, with enormous prospects in increasing data rate with respect to higher bandwidth. To combat wireless channel deficiencies such as poor signal quality, blocked calls, dropped calls and interference problems, path loss prediction estimation provides an approximation used for the development of models that predicts the signal strength of any given terrain. The Path loss models are important for predicting coverage area, interference analysis, frequency assignments and cell parameters which are basic elements for network planning process in mobile radio.

Path loss refers to electromagnetic wave attenuation between transmitter and receiver in the communication system. It could be due to effects such as diffraction, refraction, reflection, free space loss, coupling loss and absorption. Path loss depends on the condition of the environment (sub-urban, urban, rural, dense, open, etc), operating frequency, and atmospheric conditions. This environmentally induced attenuation can be characterized by the path loss model of such terrain. The average large-scale path loss for an arbitrary transmitter to receiver separation is expressed as a function of distance [2] as:

$$L_p(d) = L_p(d_o) + 10n\,Log\left[\frac{d_i}{d_o}\right] \quad (1)$$

The problem of channel efficiency often results in the poor quality of service (QoS) to their network subscribers, most of the times if operators take for granted the plight of their subscribers they stand the chances of losing them and once they lose customer their revenue generation drops therefore no operator play with the nature of services they provide to their customers. That is what necessitates the consistent evolutions that have been taken place over the years from first generation (1G) to fifth Generation (5G), but this study specifically concentrates on Third Generation (3G) and Fourth Generation (4G) generally known as Long Term Evolution (4G LTE). The universal mobile Telecommunication System (UMTS) generally known as 3G network technology has its challenges that necessitate the improvement made on it in 4G LTE. LTE is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) which was introduced in 3rd Generation Partnership Project (3GPP) Release 8. The main advantages with LTE are high throughput, low latency, plug and play. The focus of this study is on a suitable propagation model for path loss estimation at 2100MHz and 2600MHz for UMTS and LTE respectively, in an urban environment. The data of the received signal strength (RSS) and other parameters were taken using TEMS tools at 2100MHz and 2600MHz in the trade fair (Festac – Town) area of Lagos, Nigeria.

This research work focuses on determining the mathematical model that can characterize the channel in the trade fair (Festac – Town) a dense urban area of Lagos, Nigeria. This will serve as a basis for predicting the path loss of measured data in the environment under research with greater precision. The Channel characterization includes coverage prediction, pilot pollution estimation and frequency management which are vital for network planning. This will help in optimizing the overall performance of the wireless mobile network in proffering seamless services in Lagos, Nigeria.

## 2. REVIEW OF RELATED WORKS

According to [2], and [3], as wireless mobile networks become all-pervasive, the need to improve on the wireless channel becomes a necessity as signals propagate through a variable non-ideal radio environment. Besides, the deployment of efficient and cost effective infrastructure rollout depends largely on the understanding of the intended propagation channel. Hence, the characterization of the dynamic channel via the use of statistical techniques has been well validated in the research community [4].

### 2.1 Overview of Radio Propagation Models

Propagation models are mathematical representations used to plan, design and optimize wireless networks. These models are useful for coverage prediction, spectrum allocation and pilot pollution studies. They are also used in network planning, particularly for conducting preliminary studies during initial rollout. Propagation models are useful for predicting signal attenuation or path loss which is the reduction in power of an electromagnetic wave as it propagates through space. It is a major component in analysis and design of link budget of a communication system. These models can be categorized as empirical, deterministic or stochastic models.

Empirical models result from measurement and observations and find wide application in the prediction of path loss while the deterministic model takes its reference from the governing laws of electromagnetic wave propagation in determining the received signal strength of a particular coverage area. Stochastic models predict the investigated environment in terms of a set of random variables. The mean path loss is predicted in terms of transmitter – receiver separation distance, frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors. Macro cells are generally large, providing a coverage range in kilometers and used for outdoor communication. Several empirical path loss models have been determined for macro cells. Among numerous propagation models, the propagation models commonly in use are;

#### a. Free space model

In free space there are no obstacles, the propagated wave radiates freely to an infinite distance without being absorbed or reflected [5]. In radio wave propagation models, the free space model predicts that received power decays as a function of Transmission-Receiver separation distance, the path loss in dB for free space model when antenna gains are included is given by [5].

Power flux at the transmitter can be calculated using equation (2).

$$P_d = \frac{P_t}{4\pi d^2} \quad (2)$$

Where;

$P_d$ is the power density at a distance d from an isotropic source, in watts/square meter.

$P_t$ is the transmitted power in watts, d is the distance in meters, from the source. The power is spread over an ever-expanding sphere if radiating elements generate a fixed power. As the sphere expands, the energy spreads more thinly. The power received can be calculated from the antenna if a receiver antenna is placed in power flux density at a point of a given distance from the radiation. To calculate the effective antenna aperture and received power, the formulas are shown in equations below.

The amount of power captured by the antenna at the required distance, d, depends on the effective aperture of the antenna and the power flux density at the receiving element. There are mainly three factors by which the actual power received depends upon the antenna:

(a) The aperture of receiving antenna (b) The power flux density (c) and the wavelength of received signal.

For isotropic antenna, effective coverage area is given by

$$A_e = \frac{\lambda^2}{4\pi} \quad (3)$$

Power received is given by.

$$P_r = P_d \times A_e = \frac{P_t \times \lambda^2}{(4\pi d)^2} \quad (4)$$

Pathloss $L_P$ is,

$L_P$ = power transmitted ($P_t$ ) − power received($P_r$) (5)

Therefore, $L_P = Pt - Pr$

$$L_P(dB) = -Gt - Gr + 32.44 + 20log(d) + 20\ log(f) \quad (6)$$

where;

$G_t$ is the transmitter antenna gain in dB,

$G_r$ is the receiver antenna gain in dB,

d is the T-R separation distance in kilometres and

$f$ is the operating frequency in MHz

$L_P$ *(dB)* =$20\log_{10}(4\pi)$ + $20\log_{10}$(d) + $20\log_{10}(\lambda)$ (7)

Substituting [λ (in km) = 0.3/$f$ (in MHz)], the generic free space path loss formula is stated in equation.

$L_P$ *(dB)*=32.5 + 20Iog$_{l0}$(d) + 201og$_{l0}$ $f$ (8)

**b. Hata Okumura model**

The Hata-Okumura model is an empirical formula for graphical path loss data provided by Yoshihisa Okumura, and is valid from 150 MHz to 1500 MHz. The Hata model is a set of equations based on measurements and extrapolations from curves derived by Okumura. Hata presented the urban area propagation loss as a standard formula, along with additional correction factors for application in other situations such as suburban, rural among others. The computation time is short and only four parameters are required in Hata model.

However, the model neglects terrain profile between transmitter and receiver, i.e. hills or other obstacles between transmitter and receiver are not considered.

- This is because both Hata and Okumura made the assumption that transmitter would normally be located on hills.
- Okumura Hata Model

The Okumura Hata Model for path loss prediction in different radio propagation environment is given as;

✓ For Urban Area

$$L_{P(\text{URBAN})}\ (dB) = A + B\log(d) \quad (9)$$

where;

$L_{P\ (\text{URBAN})}$ (dB) is the path loss for urban area in Db, d is distance between transmitter (Tx) and receiver (Rx) in kilometre,

'A' represents a fixed loss that depends on frequency of the signal.

These parameters are given by the empirical formula

$$L_{P\ (\text{URBAN})} = 69.55\ 4 - 26.161\log_{10}(f) - 13.82\log_{10}(h_b) - a(h_m) + (44.9 - 6.55\log_{10}(h_b)\log_{10}(d). \quad (10)$$

A = 69.55 + 26.16 log (f) -13.82 log ($h_b$) - a ($h_m$).

B = 44.9 - 6.55 log ($h_b$).

Where,

f is the operation frequency measured in MHz,

$h_b$ is height of the base station antenna in meters,

$h_m$ is mobile antenna height in meters and

a($h_m$) is correction factor in dB

For effective mobile antenna height, a($h_m$) is given by

✓ For small and medium size cities

$a[h_m] = (1.1 \log(f) - 0.7)\ h_m - (1.56\log(f) - 0.8)$,

✓ For large cities,

$a[h_m] = 8.29(\log 1.54h_m)^2 - 11,\ f \leq 200\text{MHz}$

$a[h_m] = 3.2(\log 11.75h_m)^2 - 4.97,\ f \geq 400\text{MHz}$

✓ For Sub-Urban Area the path loss is given as

$$P_{L(SUB-URBAN)}\ (dB) = L_{P(\text{URBAN})} - 2[log(f/28)2 - 5.4]dB \quad (11)$$

✓ For Rural Area the path loss is given as

$$L_{P(\text{URBAN})}\ (dB) = L_{P(\text{URBAN})} - 4.78log(f)2 + 18.33logf - 40.94dB \quad (12)$$

The range of value for validity of Hata model is

$150 \leq f \leq 1500MHz$

$30 \leq hb \leq 200m$

$1 \leq hm \leq 10m$

$1 \leq d \leq 20km. \leq 20\text{km}.$

**c. Cost - 231 Model**

To extend Hata-Okumura- model for personal communication system (PCS) applications operating at 1800 to 2000 MHz, the European Co-operative for Scientific and Technical Research (COST) came up with COST-231 model. This model was derived from Hata model and depends upon four parameters for prediction of propagation loss: frequency, height of received antenna, height of base station antenna and distance between base station and received antenna.

The path loss in urban area is given in equation For Urban Area the path loss is given as [5]

$$L_P\ (dB) = 46.33 + 33.9\ log(f) - 13.82\ log(hb) - a(hm) + [44.9 - 6.55\ log(hb)]log(d) \quad (13)$$

$a[hm] = (1.1\ log(f) - 0.7)\ hm - (1.56log(f) - 0.8)$

Applying linear regression formulae, [8]

$$e(n) = \sum_{i=1}^{K}\{L_P(d_i) - \widehat{L_P}(d_o)\}.^2 \quad (14)$$

Where;

$L_P(d_i)$is the measured path loss at distance $d$ and $\widehat{L_P}(d_o)$ is the estimated path loss using equation

$$e(n) = \sum_{i=1}^{K}\left\{L_P(d_i) - \widehat{L_P}(d_o) - 10n\ Log\left[\frac{d_i}{d_o}\right]\right\}.^2 \quad (15)$$

Differentiating equation (14) with respect to n, and Equating $\frac{\partial e(n)}{\partial n}\ to\ zero$

$$\sum_{i=1}^{K}\{L_P(d_i) - L_P(d_o)\}\sum_{i=1}^{K}\left\{10n\ Log\left[\frac{d_i}{d_o}\right]\right\} = 0 \quad (16)$$

$$\sum_{i=1}^{K}\{L_P(d_i) - L_P(d_o)\} = \sum_{i=1}^{K}\left\{10n\ Log\left[\frac{d_i}{d_o}\right]\right\} \quad (17)$$

$$n = \frac{\sum_{i=1}^{K}\{L_P(d_i) - L_P(d_o)\}}{\sum_{i=1}^{K}\left\{10n\ Log\left[\frac{d_i}{d_o}\right]\right\}} \quad (18)$$

It is shown by [6], that for any value of $d$, the path loss $L_p(d_i)$ is a random variable with a log-normal distribution about the mean value $\overline{L_P}(d_o)(dB)$ due to shadowing. Therefore, to compensate for shadow fading, the path loss beyond the reference distance can be written as

$$L_P(dB) = L_P(d) + 10n\ Log\left[\frac{d_i}{d_o}\right] + S \quad (19)$$

Where S is the shadow fading variation about the linear relationship and has a $r.m.s$ value that reduces the Error as seen below in the given equation.

$$\sqrt{\sum_{i=1}^{K}\frac{(P_m - P_r)^2}{N}} \quad (20)$$

 

### 2.2 Review of related works

[6], carried out a study on "An Empirical Propagation Model for Path Loss Prediction at 2100MHz in a Dense Urban Environment", they found out that the Ericsson model showed a better fit for the measured path loss data with root mean squared errors of 5.86dB, 5.86dB and 5.85dB at 1.0m, 1.5m and 2.0m mobile antenna heights respectively in comparison with Okumura model which is currently in use. It also outperformed other investigated models which are; Hata, COST 231, and Stanford University Interim (SUI) models at 2100MHz. These findings helps in revamping radio frequency planning and system design of the investigated and similar terrains thereby optimizing overall system performance while minimizing dropped calls, handover/quality issues and other network inherent failure.

[7], researched on the "Performance Analysis of Path loss Prediction Models in Wireless Mobile Networks in Different Propagation Environments" Their study analyzed six different path loss prediction models: free space, extended COST-231 Hata, empirical Hata, Walfisch-Ikegami, Stanford University Interim (SUI) and Ericson (9999). The article showed that SUI, Ericsson and Empirical Hata are the overall best choice for the new generation of mobile networks regardless of distance and type of environment. However, SUI performed better than Ericsson and Empirical Hata for 3.5 GHz for both urban and suburban environments. For higher frequencies (28 GHz), which was required for the new generation of mobile networks like 5G, it showed that Ericsson model gave better results for path loss in urban area compared with SUI which gave better results in suburban environment. This conclusion was confirmed by introducing the average of path loss.

## 3. METHODOLOGY

Using the net monitor application on TECHNO L8 LTE and INFINIX PRO 6 phone operated in the active mode and MAP76CSX GPS to determine the distance from Base Stations, the received signal strength was measured from existing UMTS and LTE base station at 2100MHz and 2600MHz frequencies respectively. Readings were taken at intervals of 100m from the BTS at a near constant MS height of 1.5meters.

The MTN network operator was adopted for the field work, at trade fair in festac town in Lagos, South-West region of Nigeria. Base Station Antenna heights range from 30 meters to 50 meters. The BTS were selected to cover the Urban and the trade fair base stations with following coordinates, Cell ID LG402111 $6.45996166^{0}$, $3.2304233^{0}$ Cell ID LG346911, $6.4576066^{0}$, $3.2519650^{0}$ and Cell ID LG439600 $6.4575245^{0}$, $3.2458317^{0}$ in Lagos, South-West region of Nigeria. The area of measurement consisted of sites located near tall, closely built buildings, factories, offices with communication towers and high density of both human and vehicular traffic at trade fair in festac town in Lagos, South-West region of Nigeria.

### 3.1 Path loss characterization of the test-bed.

To completely characterize the propagation path loss model of the test-bed, values should be established for all the parameters namely; path loss at a reference distance, $L_P$ ($d_o$), the measured path loss, the predicted path loss, the path loss exponent n, and shadowing factor X, which is a Gaussian random variable with standard deviation (values in dB) Since the gradual reduction of the signal strength (power), as the transmitter and receiver (T-R) distance increases is called path loss as expressed in the equation 3.4;

Path loss = $L_P(d_i)dB = 10\ Log\left[\frac{P_t}{P_r}\right](dB)$ (21)

The equation is then evaluated using measured data (Average received Power from the Table 1. From equation (21) at a close-in distance, $d_o$ of 100m medean received power is;

The received signal strength average ($RSS_{ave}$) which is the mean obtained from the measured field data from the site (test-bed). The field measurements were taken from three base stations of MTN were considered for this work. The readings were taking and the average was taken.

e.g. $\frac{((-62)+(-49)+(-51))}{3}$ = -54 dBm

Power ($R_{Xav}$) = $P_r(dBm)$ = -54 dBm

That is -54 = 10 Log $P_r$ = -5.4

Hence $P_r = 10^{-5.4} = 3.981 \times 10^{-6}\ dB$

Transmitter power for LTE $P_t = 46W = 10\ Log\ 46$

$P_t = 16.628\ dB$

Transmitter power for UMTS $P_t = 30W = 10\ Log\ 30$

$P_t = 14.77\ dB$

Table 1: LTE and UMTS Median RSS and Median Path Loss for the Measured Sites

| Distance (Km) | Median$\boldsymbol{R_{Xav}}$ (dBm) LTE | Measured PL(dB)LTE | Median$\boldsymbol{R_{Xav}}$ (dBm) UMTS | Measured PL(dB) UMTS |
|---|---|---|---|---|
| 0.10 | -54 | 66 | -57 | 69 |
| 0.20 | -60 | 72 | -67 | 79 |
| 0.30 | -82 | 94 | -65 | 77 |
| 0.40 | -82 | 94 | -69 | 81 |
| 0.50 | -87 | 99 | -69 | 81 |
| 0.60 | -70 | 82 | -91 | 82 |

| | | | | |
|---|---|---|---|---|
| 0.70 | -72 | 84 | -73 | 85 |
| 0.80 | -80 | 92 | -77 | 89 |
| 0.90 | -88 | 100 | -87 | 100 |
| 1.00 | -89 | 101 | -95 | 101 |
| 1.10 | -89 | 101 | -97 | 107 |
| 1.20 | -100 | 112 | -85 | 97 |
| 1.30 | -95 | 107 | -83 | 95 |
| 1.40 | -84 | 96 | -85 | 96 |
| 1.50 | -97 | 109 | -81 | 109 |
| 1.60 | -96 | 108 | -91 | 108 |
| 1.70 | -80 | 92 | -83 | 95 |
| 1.80 | -83 | 95 | -83 | 95 |
| 1.90 | -98 | 110 | -98 | 110 |
| 2.00 | -106 | 118 | -103 | 118 |

The received signal strength was used to calculate where $P_m$ the measured path loss (dB), $P_r$ is the predicted path loss (dB) from equation (1) and N is the number of measured data points. Applying equation (15) and equation (17) to Table 1, and median path loss data for the LTE and UMTS using calculations to obtain the Path loss exponent for LTE was found to be 3.2 with a Shadow factor of 11 $dB$ and that of UMTS was calculated to be 2.6 and a shadowed factor of 12 $dB$ and $L_P\ (d_o)$ in table1 for both LTE and UMTS are 66 dB and 69 dB respectively.

Therefore, the Path loss for LTE Network is given as

$$L_P(dB) = L_P(do) + \ 10n\ Log\left[\frac{d_i}{d_o}\right]\ S$$

Substituting $S$ and ($L_p(d_o)$ and calculating the result; the Path loss at a distance $d$ is given as

$$L_P\ (dB)\ =\ L_P(do) +\ 10nLog\ (\frac{di}{do})\ +\ 11dB.$$

$$L_P\ (dB) =\ \ 66\ +\ 32Log\ (\frac{di}{do})\ +\ 11dB. \quad (22)$$

Therefore, the resultant path loss model for shadowed urban Trade fair Lagos for LTE is;

$$L_P\ \text{(dB)} = 77 + 32\ Log\ \left(\frac{di}{do}\right).$$

$$L_P\ \text{(dB)} = 77 + 32\ Log\ (D). \quad (23)$$

And the Path loss for UMTS Network is given as;

Hence;$L_P\ (dB)\ = 69\ +\ n10Log\ \left(\frac{di}{do}\right) + 12dB. \quad (24)$

$$L_P\ (dB)\ \ \ =\ \ 69\ +\ 26\ Log\ \ \left(\frac{di}{do}\right)\ +\ 12dB.$$

Therefore, the resultant path loss model for shadowed urban Trade Fair Environment in Lagos is; $L_P\ (dB)\ =$ $81\ +\ 26\ Log\ \left(\frac{di}{do}\right)$ Log di/do

$$L_P\ (dB)\ =\ 81\ +\ 26\ Log\ (D). \quad (25)$$

**3.2 Free-space model at LTE and UMTS frequencies**

Recall that from equation (8), the free-space model was given as:

$L_P$ *(dB)* = 32.5 + 20Iog$_{l0}$(d) + 201og$_{l0}$ $f$

At Frequency of 2600 Mhz for LTE 4G Network Technology

This gives:

$L_P$ *(dB)* = 100.75 + 20Iog$_{l0}$(d) (26)

At Frequency of 2100 Mhz for UMTS Network Technology

$L_P$ *(dB)* = 98.94 + 20Iog$_{l0}$(d) (27)

Tables 2 and 3, shows the comparison between the Developed LTE and UMTS, Hata and Free Space Models using equation 23, 25, 8 & 10 of measured data at Frequency $2600\ MHz\ and\ 2100\ MHz$ 2100 MHzand UMTS respectively.

**3.3 Hata's Model at LTE and UMTS Frequencies**

Recall that from equation (10), the Hata's model for an urban environment was stated as:

$L_{P(\text{URBAN})}$= 69.55 4- 26.161og10($f$) -13.82 log10*(hb)* - *a(hm)* + (44.9 - 6.55 log10($hb$)log10(d), *where:*

*a{hm)* = (1.1log10($f$)- 0.7*) hm* - (1.56 Iog$_{l0}$(d))

Where *hm is* the mobile antenna height, *hb is the* Base station antenna height and $f$ is the frequency in $MHz$.

- At Frequency of 2600 $Mhz$ for LTE 4G Network Technology.

Substituting the values: *f =2600 MHz, hm=1.5m and hb=32m into* the equation above yields:

$L_{P(\text{URBAN})}\ =\ 138.03\ +\ 35.0\ Iogl0(d)$ (28)

- At Frequency of 2100 Mhz for UMTS Network Technology.

Substituting the values: *f=2600 MHz, hm=1.5m and hb=32m into* the equation above yields:

$L_{P(\text{URBAN})}\ \ =\ 135.167\ +\ 35.4\ Iogl0(d)$ (29)

 

Table 2; LTE (4G) Network Path Loss Model Comparison.

| D(Km) | LTE Developed Model (dBm) | Free Space Model (dBm) | Hata Model (dB) |
|---|---|---|---|
| 0.1 | 45,00 | 80.75 | 103.03 |
| 0.2 | 54.63 | 86.77 | 113.57 |
| 0.3 | 60.27 | 90.29 | 119.73 |
| 0.4 | 64.27 | 92.79 | 124.10 |
| 0.5 | 67.37 | 94.73 | 127.50 |
| 0.6 | 69.90 | 96.31 | 130.27 |
| 0.7 | 72.04 | 97.65 | 132.61 |
| 0.8 | 73.90 | 98.81 | 134.64 |
| 0.9 | 75.54 | 99.83 | 136.34 |
| 1.0 | 77.00 | 100.75 | 138.03 |
| 1.1 | 78.32 | 101.85 | 139.48 |
| 1.2 | 79.53 | 102.33 | 140.80 |
| 1.3 | 80.65 | 103.03 | 142.02 |
| 1.4 | 81.68 | 103.67 | 143.14 |
| 1.5 | 82.63 | 104.27 | 144.20 |
| 1.6 | 83.53 | 104.83 | 145.17 |
| 1.7 | 84.37 | 105.36 | 146.10 |
| 1.8 | 85.17 | 105.86 | 146.96 |
| 1.9 | 85.92 | 106.33 | 147.97 |
| 2.0 | 86.63 | 106.77 | 148.57 |

Table 3; UMTS (WCDMA) Network Path Loss Model Comparison.

| D(Km) | UMTS Developed Model (dBm) | Free Space Model (dBm) | Hata Model (dB) |
|---|---|---|---|
| 0.1 | 55.00 | 78.94 | 99.77 |
| 0.2 | 62.83 | 84.96 | 110.42 |
| 0.3 | 67.41 | 88.48 | 116.66 |
| 0.4 | 70.65 | 90.98 | 121.08 |
| 0.5 | 73.17 | 92.92 | 124.51 |
| 0.6 | 75.23 | 94.50 | 127.31 |
| 0.7 | 76.97 | 95.84 | 129.68 |
| 0.8 | 78.48 | 97.00 | 131.74 |
| 0.9 | 79.81 | 98.02 | 133.55 |
| 1.0 | 81.00 | 98,94 | 135.17 |
| 1.1 | 82.08 | 99.77 | 136.63 |
| 1.2 | 83.06 | 100.52 | 137.97 |
| 1.3 | 83.96 | 101.22 | 139.20 |
| 1.4 | 84.79 | 101.86 | 140.34 |
| 1.5 | 85.58 | 102.46 | 141.40 |
| 1.6 | 86.31 | 103.02 | 142.39 |
| 1.7 | 86.99 | 103.55 | 143.32 |
| 1.8 | 87.64 | 104.05 | 144.20 |
| 1.9 | 88.25 | 104.52 | 145.03 |
| 2.0 | 88.83 | 104.96 | 145.82 |

## 4. RESULTS AND ANALYSIS

Recalling equation (28) and (29) for the Urban path loss determination of the Hata model, equation (26) and (27) for the free space model and equation (23) and (25) for the LTE and UMTS Developed Models respectively, and substituting the test parameters (*f=26600 MHz, hm=1.5m and hb=32m*) into the equations, produced plots shown in figure 1.

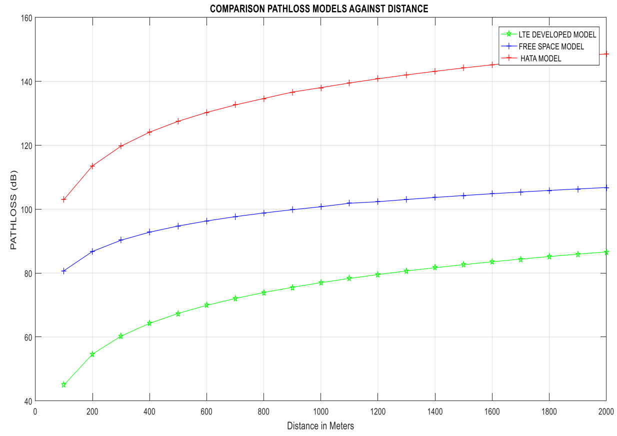


Figure 1. Comparison of path loss models with LTE Developed model and existing models.

The plot in figure 1 shows that the developed model tilts close to the free space model and thus would serve as a good estimation model for determining the path loss model for this environment. The Hata model shows a wider variation from the free space model since it is not adapted for this environment. A Similar comparison for UMTS Network Technology is shown in figure 2.

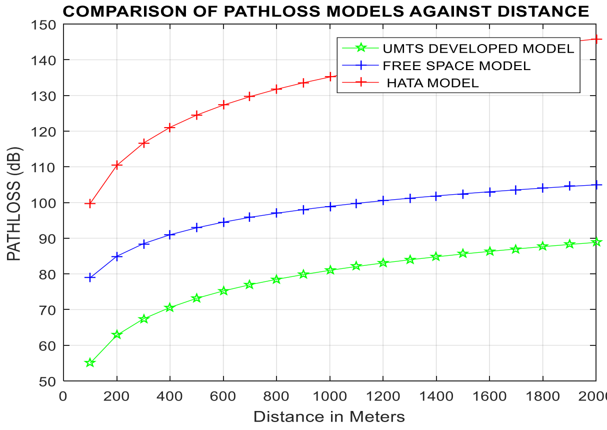


Figure 2. Comparison of path loss models with UMTS Developed model and the existing models

Figure 2 also shows that the UMTS developed model for Festac town, Lagos tilts close to the free space model and thus serves as a good estimation model for determining the path loss model for this environment. The Hata model shows a wider variation from the free space model since it is not adapted for this environment.

 

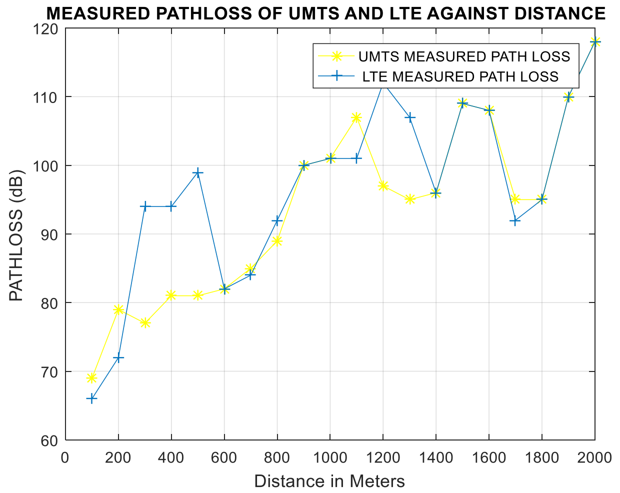


Figure 3. Comparison of Measured path loss between LTE and UMTS.

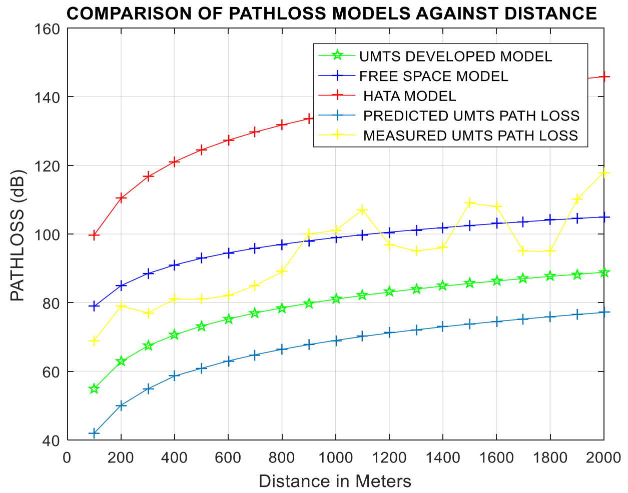


Figure 6. Comparison of UMTS Developed model, UMTS Predicted and UMTS Measured Path loss with existing models.

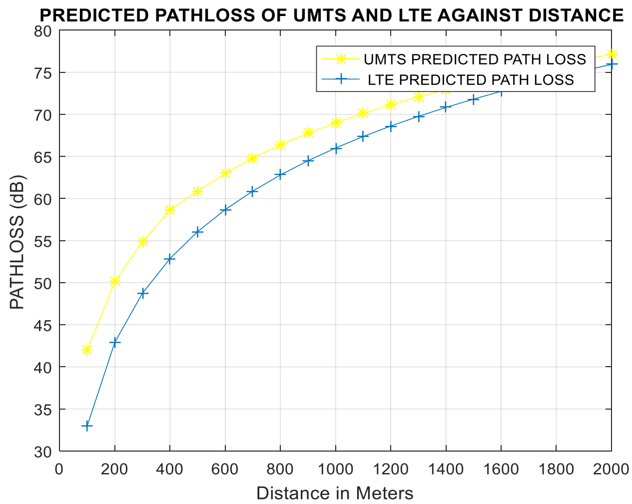


Figure 4. Comparison of Predicted path loss between LTE and UMTS

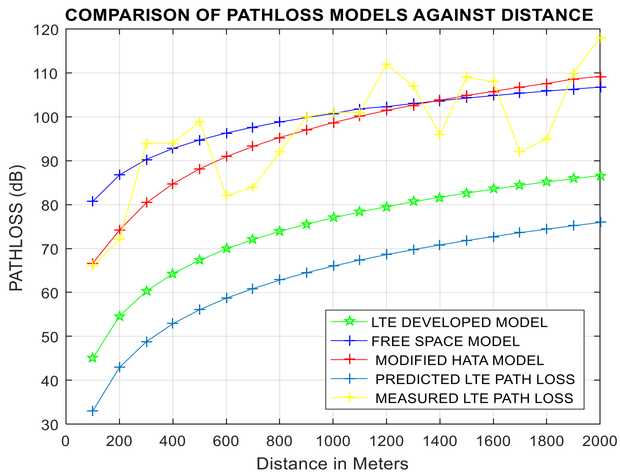


Figure 7. show comparison between the measured Models and Modified Hata Model for LTE

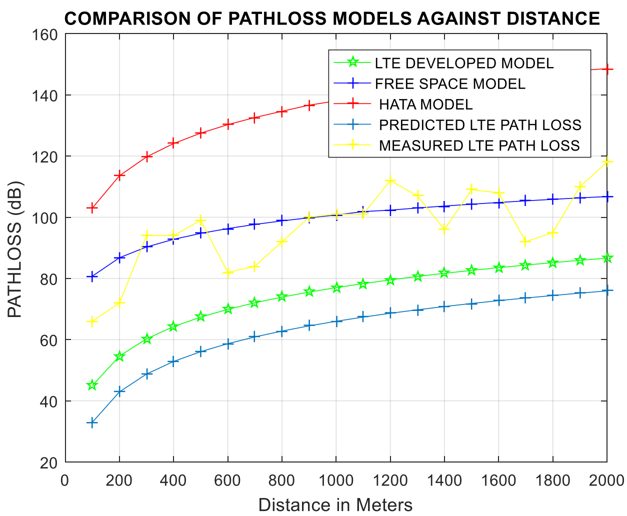


Figure 5. Comparison of LTE Developed model, LTE Predicted and LTE Measured Path loss with existing models.

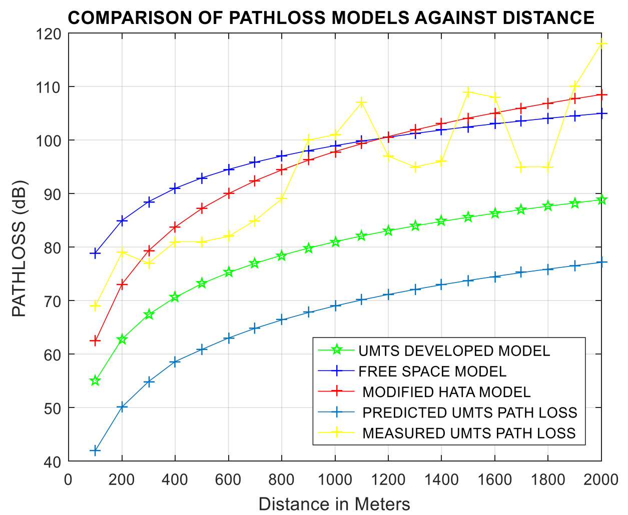


Figure 8. show comparison between the measured Models and Modified Hata Model for UMTS

As seen in the plots shown from figure 5 to 8, the developed models tilts and adapts closely to the free space model for both LTE and UMTS.

## 5. CONCLUSION

The Path loss models are important for predicting coverage area, interference analysis, frequency assignments and cell parameters which are basic elements for network planning process in mobile radio. From the MATLAB plots shown for the developed models, it is clearly demonstrated that the developed model from this work serves as a good index to characterize the test environment. This model is recommended to service providers who would want to carefully get propagation channel data for this location.

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