SIGNAL STRENGTH EVALUATION OF A 3G NETWORK IN OWERRI METROPOLIS USING PATH LOSS PROPAGATION MODEL AT 2.1GHz

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CERTIFICATION

I certify that this work "Signal Strength Evaluation Of A 3G Network in Owerri Metropolis Using Path Loss Propagation Model at a Frequency Of 2.1GHz" was carried out by Nwaokoro Amaka Ann (20104885618) in partial fulfillment for the award of the degree of M.Eng in Communication Engineering in the department of Electrical/Electronic Engineering of the Federal University of Technology Owerri.

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DEDICATION

I dedicate this project work to God Almighty for the knowledge, wisdom, understanding, strength and grace to complete this project work.

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ABSTRACT

This work evaluated the path losses and strength of received signals of a 3G Network operating at frequency of 2.1GHz in Owerri metropolis using Drive test. There were serious cases of call drops and low Quality of signal (QoS) experienced within some part of the Owerri metropolis. This situation has been burdensome on the side of the network users, as that has made them incur a lot of financial losses and passed through pains. The network providers, on their side, also passed through pressures and financial losses. Through the use of Transmission Evaluation and monitoring system (TEMS 11) equipment, Global positioning system (BU353 GPS) and laptop, a drive test was carried out along the major streets in owerri metropolis categorized into urban and sub-urban areas. From data collected, Owerri sub-urban indicated poor received signal level compared to Owerri urban. Hence, path loss exponents were computed for the Owerri urban and sub-urban as 3.24 and 4.34 respectively, the mean squared error was calculated as 1.96 and 1.68, and a measurement-based path loss models were developed for Owerri urban and sub-urban areas, Imo State Nigeria as $\mathrm{Lp} = 111.33\mathrm{dB} + 32.4\log(\mathrm{D})$ and $\mathrm{Lp} = 111.45\ \mathrm{dB} + 43.4\log(\mathrm{D})$ respectively. The results from the MatLab software simulation showed a considerable drop in the Received Signal Level (RSL) in some of these studied areas which were as a result of multipath fading, inefficient call hand over scheme, among others. The results indicated a deviation between the compared existing models (Hata and Cost 231) and the proposed path loss models. However, the slope of the Hata plot is closer to the proposed model than that of Cost 231; hence, the proposed model will best represent the path loss within the environment under study, followed by Hata model.

Keywords: Pathloss, Quality of Signal, model, Drive Test.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Terrestrial and satellite communication systems radiate their signal at microwave frequencies in both fixed and mobile environment. The rapid advancement in these communication services as a result of the high quest for next generation services by mobile network subscribers arouse an ever increasing demand for hitch- free network coverage. Hence, satisfying this need require a proper awareness of the inherent restrictions posed by the environmental factors to microwave signal radiation.

The environmental factors influence the integrity of transmitted signals during signal propagation, especially in unbound media like global system for mobile communication (GSM). These factors include buildings, trees, rain, snow, dust, fog, vapor, and mist among others (Folaponmile, and Sani, 2011). The impact of building is felt much in the urban areas while that of the trees is more pronounced in the rural areas.

In the model for signal transmission, these factors are modeled under path loss (PL). Path loss constitutes a basic part in the design for a wireless communication system. Proper understanding of path loss facilitates the selection of the necessary network parameters such as the power of the transmitter, height of the antenna, gain of the antenna, distance between the transmitter and the receiver, including antenna location. Therefore in order to ensure the reception of signal of appropriate strength at the receiving antenna , care should be taken in conducting a proper feasibility studies of the signal limiting factors in order to design a radio communication path that will take accurate cognizance of the factors.

It is worth noting that these signal limiting factors, which are found in the media between the transmitting and receiving antennas, degrade the radiated signals through reflecting back some of the radiated signal into the initial medium, diffracting some of the signal, scattering some and / or causing the medium to absorb some signal.(Nwawelu, *et al.,* 2012)

Path loss occurs when the received signal level (RSL) fades away as a result of the distance between the base station and the base transceiver station. This happens despite the absence of obstacles between the transmitting antenna and the receiving antenna.

The efficiency of any wireless communication system is based on the propagation features of the medium or channel. The channel features have a great influence on the design of the propagation strategy.

This signal propagation models predict the received signal strength at a given distance from the transmitter, including the variability strength of the signal within a specific location. These propagation models are useful in predicting the signal coverage of a transmitter for any transmitter- receiver distance of separation. They predict signal attenuation or path loss whose knowledge serves as a controlling factor for system analysis. Received signal prediction models perform an essential function in the optimization of the signal coverage and optimal utilization of the available resources.

Hence, signal strength, signal propagation, signal predictions and signal measurements are very essential in analyzing the efficiency of GSM networks. The signal propagation models are defined as the mathematical algorithms that are utilized for the purpose of signal prediction. In as much as there are ever increasing demand of such issues from users, the network providers in Nigeria need to undergo in depth modifications and expansions in order to actualize the demand (Ogbulezie *et al.,* 2013).

The incessant drops in the level of received signal as experienced/witnessed in high rate of call drop and quality of service (QoS) within the Owerri metropolis prompted the need to carry out an evaluation of the strength of signal reception of a 3G network in Owerri using drive test. In this research work, the received signal level (RSL) of the connection that exist between the mobile station (MS) and Base Transceiver station were recorded in a log file during drive test performed with the aid of Global positioning system(GPS) receiver, laptop and Ericson's Transmission Evaluation and Monitoring System (TEMS) phone.

The study compares the path loss proposed models for Owerri urban and sub-urban with the classical Hata and COST 231 prediction models.

The results showed a considerable received signal level (RSL) drop in some part of the Owerri metropolis within the period of this research. The routes covered in the course of the research include: Akanchawa (Concord Hotel area), Imo state government house road, Wetheral road, Royce road, Bank road and Tetlow road categorized as urban. The suburban areas include Obinze- Owerri express way, FUTO and Ihiagwa road.

It was carried out using the microwave link of MTN, one of the Global System for mobile communication (GSM) companies in Nigeria. A computer program based on MatLab was used to simulate the results.

1.2 PROBLEM STATEMENT

Telecommunication systems should generate the expected effect (signal), maintain the integrity of the effect in the course of propagation, with the capacity to improve the effect of the message .This ensures effective communication.

However, the effects of the environmental factors through which signal are propagated, have some degradable influence on the radiating signal. These factors which are mainly buildings and trees do reflect, diffract, attenuate, absorb and even scatter the propagation signal in the medium.

The impact of this anomaly is that it cost the network providers a very huge amount of money to install and maintain more network devices to abate this problem. Also, some network subscribers who experience this hardship in the network, do abandon their service provider for alternative networks.

This research studies, analyzes and proffers solution to the hindrances / obstacles that undermine the level of signal strength received within Owerri metropolis.

1.3 OBJECTIVE OF THE STUDY

The main objective of this work is:

- To evaluate the received signal strength of a 3G network in Owerri metropolis using path loss propagation model at 2.1GHz.

The specific objectives are:

- To characterized the environment for the signal performances using Drive test tool.
- To determine the path loss exponent and the standard deviation for the proposed model.

- To develop the path loss model for the environment of study
- To compare the path loss models obtained with Hata and COST231 models
- To proffer a remedy to the factors that influence the integrity of the radiated signals within Owerri metropolis.

1.4 JUSTIFICATION OF THE STUDY

The study which evaluates the path losses and the strength of received signal within Owerri is very essential in determining the reduction in power of an electromagnetic wave as it propagates through space. These losses constitute a major component in analysis and design of the link budget of a system communication model.

This system model is dependent on antenna height, frequency, link distance, among other factors.

This study helps to ascertain the actual antenna height, link distance and so on, that will ensure optimum signal propagation. Hence, the waste of devices and cost is minimized.

1.5 SCOPE OF THE STUDY

This research focused on determining the Received Signal Levels (RSL) within Owerri metropolis. It engaged TEMS installed software system, mobile phone, Actix software, and the MatLab software in the study. The frequency of the network used is 2.1GHz, and the transmitting antenna height and power is 35m and 30W respectively.

The areas under study were Akanchawa road (Concord Hotel area), Imo state government house road, obinze- Owerri express way, wetheral road – Royce road – Bank road – Tetlow road, FUTO – Ihiagwa road.

CHAPTER TWO

LITERATURE REVIEW

2.1 VARIOUS TYPES OF PROPAGATION PATH-LOSS MODELS

Empirical model: This model is efficient and simple to use, as it is obtained from in-depth field measurement. The input data here are qualitative, though not very correct for area like dense urban area, rural area and others.

Site-specific models: These models are based on numerical methods and the finite difference time- domain (FDTD) technique. The input data here are very precise and in depth.

Theoretical model: These models are obtained from physical hypothetical assumption with inclusion of some moderate conditions. This can be seen when, for instance, considering the over-root top, the diffraction model here is obtained by the use of physical optics with the assumption of constant heights and buildings spacing. (Rakesh and Srivatsa, 2013).

2.1.1 FREE SPACE PROPAGATION MODEL:

Free space propagation model assumes that there is no obstacle between the transmitter and receiver during signal propagation. The transmitter radiates signal to an infinite distance without any issue of signal absorption or reflection. If the transmitter propagates signal at 360^0 using a fixed power with an ever increasing sphere, then the transmitter will have a power flux of

$$P_d=P_t/4\pi d^2 \tag{2.1}$$

Where P_t is the power transmitted (w/m^2)

P_d is the power obtained when the distance is d from antenna (Ubom, et al, 2011).

According to (Ayyappan, et al., 2014), free space propagation model shows that the signal received by the receiver decays with distance between the transmitter and receiver at a rate of 20dB/decade.

The path loss for free space model is given. Thus;

$$PL_{FSPL} = 32.45 + 20log_{10}(d) + 20log_{10}(f)\ [dB] \tag{2.2}$$

Where;

f is the frequency in MHz

d is the distance between transmitter and receiver km

(Alshami, et al.,2011), (Urban et al.,2011), (Rakesh, *et al.,*2013).

2.1.2 HATA PROPAGATION MODEL

The Hata model is a set of equations obtained on measurements and extrapolations taken from curves that are derived by Okumura (Ubom *et al.,* 2011). It is an empirical formular for graphical path loss. (Ayyappan, *et al.,* 2014).

Hata presented the prediction area into three divisions: Open, suburban and urban areas. This model is appropriate for frequency range of 150-1500 MHz (UHF) and for distance of 1km-20km. However, Hata model does not consider terrain profile like hills that are found between transmitter and receiver. (Ayyapan, 2014)

In the words of (Alshami, *et al.,* 2011), Hata model for calculation of path loss are used in three situations namely:

Situation1: Urban Hata pathloss

The urban Hata pathloss (PL) is expressed as

$$PL = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(h_b) + (44.9 - 6.55log_{10}(h_b))log_{10}(d) - a(h_m) + c_M \tag{2.3}$$

Where,

f is the frequency in MHZ

h_m is the height of the mobile antenna in meters

h_b is the height of the base station antenna in meters (Ubom *et al.,*2011), (Alshami *et al.,* 2011), (Rakesh *et al.,* 2013)

C_M is a constant (which is 0 for urban region and 3 suburban region)

$a(h_m)$ is the mobile station antenna correction factor expressed as

$a(h_m)$ =$1.11log_{10}(f) - 0.7h_m - (1.56log_{10}(f) - 0.8)$ in dB (2.4)

Situation 2: Suburban Hata pathloss

The Suburban Hata pathloss (PL) is expressed as

PL=PLUrban-2((log_{10}f/28))^2-5.4 (2.5)

Situation 3: Rural Hata pathloss

The Rural Hata pathloss (PL) is expressed as:

PL=PL(Urban) – $4.78(log_{10}(f)^2) + 18.33log_{10}(f) - 40.98$ (2.6)

2.1.3 SUI Model

This stands for Stanford university Interim model. It is developed by Stanford University for frequency band of 2.5GHZ. In this model, the height of the base station antenna can be any value between 10m to 80m while that of the receiver can be between 2m to 20m based on (Rakesh, *et al.,* 2013).

The SUI model listed out three classes of terrain namely: terrain A, B, and C. According to (Jadhav *et al.,* 2014) and (Raskesh, *et al.,* 2013), terrain A is suitable for dense urban locality, terrain B for hilly regions, while terrain C is appropriate for rural community with considerable vegetation. The authors also stated that the basic pathloss equation of the Stanford university interim model is thus:

$$PL = A + 10\gamma log_{10}\left({}^{d}/_{do}\right) + X_f + X_h + S \text{ for } d > d_o \qquad (2.7)$$

Where,

d is the distance between Base Station and Receiving antenna (m)

d_o is 100 meters

λ is wavelength in meters.

X_f is the correction for frequency

X_h is the correction for receiving antenna height in meters

S is the correction for shadowing in dB

γ Is the path loss exponent

(Rakesh, *et al.,* 2013) further stated that random variables can be taken as the path loss exponent γ while the weak fading standard should be derived. Hence, the parameter A, which is the Attenuation, is presented as,

$$A = 20log_{10}(^{4\pi d_o}/_{\lambda}) \qquad (2.8)$$

The path loss exponent γ, is expressed as

$$\gamma = a - bh_b + (^c/_{h_b}) \qquad (2.9)$$

Where;

h_b is base station antenna height which is between 10m to 80m.

a, b, and c are constant and depend on the terrain type.

The value of Υ is 2 for free space, $3<\gamma<5$ for urban Non-Line of Sight (NLOS) environment, and $\gamma>5$ for indoor propagation.

Also;

The correction for frequency, X_f is expressed as:

$$X_f = 6.2\ log_{10}(f/2000) \qquad (2.10)$$

2.1.4 ECC-33 Model

The ECC-33 model stands for Electronic communication committee-33 model. ECC extrapolated the Okumura measurements and amended its assumption to closely depict a fixed wireless access system (Ogbulezie *et al.,* 2013). This path loss model, otherwise known as ECC- 33 model, is suitable for suburban areas and urban areas and represented thus,

$$PL = PL_{fs} + PL_{bm} - G_b - G_m \qquad (2.11)$$

$$PL_{fs} = 92.4 + 20log_{10}(d) + 20log_{10}(f) \qquad (2.12)$$

$$PL_{bm} = 20.41 + 9.83log_{10}(d) + 7.894log_{10}(f) + 9.56\left(log_{10}(f)\right)^2 \quad (2.13)$$

$$G_b = log_{10}\left({}^{h_b}/_{200}\right)\{13.98 + 5.8[log_{10}(d)]^2\} \quad (2.14)$$

$$G_m = [42.57 + 13.7log_{10}(f)]\left[log_{10(hm)-} 0.585\right] \quad (2.15)$$

Where,

G_b = base station antenna gain

G_m = mobile station antenna gain

PL $_{fs}$ is the free space path loss

PL $_{bm}$ is the basic median path loss

(Alsami et al., 2011. ogbulezie et al,2013)

2.1.5 COST-231 Hata propagation model

This stands for Co-operative for Scientific and Technical research. It is an enhanced version of the Hata propagation model. That is, it employs suitable correction factors to improve the limitations of the Hata model. (Ubom *et al.,* 2011). COST-231 model makes use of four variables in predicting propagation loss. The variables are Frequency, height of base station, height of receiver's antenna and distance between base station and receiver antenna.

(Ayyappan and Dananyayan, 2014).

The COST 231 Path loss equation is given by

$$PL(dB) = 46.3 + 33.9log(f_c) - 13.82log(h_b) - a(h_m) + \left(44.9 - 6.55log(h_b)\right)log_{10}(d) + c_M$$

(2.16)

Where;

C_M is a constant which may be 0 for suburban city or 3 for metropolitan city

For urban environments,

$a(h_m)=3.20(\log(11.75h_r))^2-4.97$

For suburban or rural environments,

$ah_m = (1.1\log f - 0.7)hr - (1.56 \log f - 0.8)$

Where h_r is the mobile antenna height.

(ogbulezie, *et al.,* 2013: Nwalozie *et al.,* 2014)

2.1.6 LEE Propagation Model

According to (Alshami, *et al.,* 2011), this model predicts the pathloss in urban, suburban, rural and free space regions.

CASE 1:

For Urban region PL$= 123.77 + 30.5log_{10}(d) + 10nlog_{10}(^f/_{900}) - \alpha_o$ (2.17)

CASE 2: for suburban region

$$PL = 99.86 + 38.4log_{10}(d) + 10nlog_{10}(^f/_{900}) - \alpha_o \quad (2.18)$$

CASE 3: For Rural region

$$PL = 86.12 + 43.5log_{10}(d) + 10nlog_{10}\left(f/_{900}\right) - \alpha_o \qquad (2.19)$$

CASE 4: For free space region

$$PL = 96.92 + 20log_{10}(d) + 10nlog_{10}\left(f/_{900}\right) - \alpha_o \qquad (2.20)$$

Where n is an experimental value, say 3

α_o is the correction factor.

Hence;

$$\alpha_o = \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 \qquad (2.21)$$

Where;

$\alpha_1 = \left(h_b/_{30.48}\right)^2$

$\alpha_2 = \left(h_m/_{3}\right)^2$

$\alpha_3 = \left(P_t/_{10}\right)^2$

$\alpha_4 = \left(G_b/_{4}\right)$

$\alpha_5 = G_m$

2.1.7 Regression Models:

Regression models are used to predict one variable from one or more other variables. (Folapomile and Sani, 2011). These models are very powerful tools that help scientists forecast about past, present or future activities through the use of information from past or present happenings. According to these authors, a regression model can be represented as shown in the equation below,

$$\gamma = b_o + b_1 \tag{2.22}$$

$$b_1 = \frac{\sum (x_i - \overline{x})(\Upsilon_i - \overline{\Upsilon})}{\sum (x_i - \overline{x})^2} \tag{2.23}$$

$$b_o = \frac{1}{n}\left(\sum \Upsilon_i - b_1 \sum x_i\right)$$

$$= \overline{\gamma} - b_1 \overline{x} \tag{2.24}$$

Where;

Υ is the dependent variable which is the attenuation represented as A

x is the independent variable

b_o Is the intercept

b_1 is the slope calculated from equation (2.23)

In other words, equation (2.22) can be re-written as

$$A = b_o + b_1 D_d \tag{2.25}$$

Where;

D_d is the independent variable

Hence, equation (2.25) is used to calculate the empirical formular while equation (2.24) and (2.23) are used to determine the values of b_0 and b_1 in that order.

2.1.8 Least-Squares Formulation

According to Durgin *et al.* (1998), "Finer propagation models use partition-dependent attenuation factors, which assumes free space path loss exponent (n=2) with additional path loss based on the objects that lie between the transmitter and receiver". The author highlighted that for outdoor-to- indoor propagation environment, the object may consist of house exteriors, trees, wooded patches, plaster board walls, and so on. Then the path loss, for 1m free space at any given point, can be expressed by equation (2.26) below:

Pathloss, $PL(d) = 20log_{10}(d) + a \times x_a + b \times x_b + \cdots$ (2.26)

Where;

a, b,… are the quantities of each partition type between the receiver and transmitter.

x_a, x_b,… are their respective attenuation values in dB. When the data at a known site is measured, the unknown in equation (2.26) are the individual attenuation factors x_a, x_b etc. One of the methods suggested for the computation of the attenuation factors is to reduce or minimize the mean- square error of measured versus predicted data.

In the words of the author, if P_i stands for the path loss with respect to 1m Free Space measured at the ith location, it then means that N number of measurement will give rise to the system of equation written below:

$P_1 = 20l0g_{10}(d_1) + a_1 \times x_a + b_1 \times x_b$ (2.27)

$$P_2 = 20log_{10}(d_2) + a_2 \times x_a + b_2 \times x_b \tag{2.28}$$

$$P_N = 20log_{10}(d_N) + a_N \times x_a + b_N \times x_b \tag{2.29}$$

Putting this equation in a succinct form, that is using matrix notation.

$$A\vec{x} = \vec{p} - 20\log10(\vec{d}) \tag{2.30}$$

Where;

$$\vec{p} = \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_N \end{bmatrix}$$

$$\vec{d} = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_N \end{bmatrix}$$

$$\vec{x} = \begin{bmatrix} x_a \\ x_b \\ \vdots \\ x_z \end{bmatrix}$$

$$A = \begin{bmatrix} a_1 & b_1 \ldots & z_1 \\ a_2 & b_2 \quad \ldots & z_2 \\ \vdots & \vdots & \vdots \\ a_N & b_N \ldots & z_N \end{bmatrix} \tag{2.31}$$

(Durgin *et al.,* 1998)

There are more measured points in P compared to the unknown in X in equation (2.30), hence, it cannot be solved immediately. Therefore, multiplying both sides of equation (2.30) by the transpose of A produces a tractable linear matrix equation.

$$A^T A\vec{x} = A^T[\vec{p} - 20log(\vec{d})] \tag{2.32}$$

This equation is termed the “normal equation”. Solving the normal equations - taking the proper precaution against ill- conditioned matrices simultaneously minimizes the mean square error with respect to all values in X. Since these data represent large – scale path loss, which tends to a log – normal distribution, the mean –square error criterion, as well as mean and standard deviation comparisons are based on the dB values of path loss. Durgin *et al.* (1998) give the forecasts that match measurement with a non-zero mean and small standard deviation error.

2.1.9 Path loss Exponent Models With Aggregate Penetration Loss (APL)

“Adding penetration loss into the path loss exponent model increases its accuracy for outdoor –to- indoor propagation’’ Durgin, *et al*. (1998). The method used in this model is to first estimate the strength of the signal received using the outdoor in value. Following this is the addition of aggregate propagation loss (APL) to the outdoor result in order to obtain the indoor received power. The formular for this model is expressed in equation (2.33) below;

$$PR = P_T + G_T + G_R + 20log_{10}\left[\frac{1}{4\pi}\left(\frac{\lambda}{1m}\right)\right] - 10n_{out}log\left(\frac{d}{1m}\right) - APL \tag{2.33}$$

Where,

PR=received Power

P_T is transmitted Power

G_R is receiver gain

$G_T$is transmitter gain

λ=receiver power

d=distance

APL=Aggregate Penetration Loss

According to the authors, there is a difference between aggregate penetration loss and penetration loss of the partition - based model. Aggregate Penetration Loss (APL) stands for an average difference that exists between the indoor and outdoor path loss, not minding the location inside the house. It is worth to know that APL does not consider the particular number of wells or height above ground level. Also, the author defined partition based penetration loss as the difference in path loss between, two position or location that are positioned on the immediate inside and outside of the exterior wall.

2.1.10 Partition-Based Outdoor - Indoor Model

Durgin *et al.,* (1998) emphasized that pseudo deterministic methods do use the partition – based path loss model. This is because the standard deviation (error) encountered in path loss by the use of exponent models for outdoor to indoor propagation could be enormous due to wide spread neighborhood use of a wireless network. The partition-based path loss model is expressed as equation (2.34) below;

$$P_R = P_T + G_T + G_R + 20log_{10}\left(\frac{\lambda}{4\pi d}\right) - \sum_{i=1}^{N} xi \quad (2.34)$$

xi is the value for attenuation of the ith obstruction that is intersected by the line drawn from the transmitter to the receiver point.

This outdoor obstruction could be a deciduous or coniferous tree, an area of terrain, a building and so on.

Also, the indoor obstruction is usually a wall. Partition-based- outdoor to indoor model can be extended to three dimensions by taking cognizance of the high and low blocking of trees.

These authors (Durgin *et al.,* 1998), revealed that the partition based outdoor-to-indoor model performs better when the transmitter-receiver (TR) separation is less than 50m and for more distant transmitters, once the surrounding area has just a few scatterers. When the number of the surrounding scatterers is on the high side, this results to the domination of multipath penetration which leads to the loss of physical significance of the partition-based model. This could happen, for instance, when the model try to forecast propagation through a building. One of the disadvantages of the partition-based model is that it requires a site-specific database with outdoor site characteristic and indoor floor plans. There is also the possibility that some of the application might require such a detail and extra accuracy, according to the authors.

2.1.11 Partition- Based Outdoor Model

The partition-based outdoor model and the indoor-to-outdoor model are related except that the partition-based outdoor model does not take account of the internal layout of the individual houses. However, all the partition losses as used in equation (2.34) above correspond to outdoor elements. The partition –based outdoor model only require knowledge of the outdoor environment and can estimate signal levels in the shadow of buildings otherwise, it faces some of the same difficulties as the outdoor-to-indoor partition based model,'' Durgin *et al,* 1998.

2.1.12 Penetration Losses

Nwawelu *et al*., (2012) stated the losses that result from signal that comes into the building from outside are being categorized into two namely: window penetration loss and wall penetration loss. According to the authors, these losses were modeled using Fresnel transmission coefficient (FTC), which represents the level of signal strength that comes into the building from outside. The author gives the equation for the Fresnel transmission coefficient (FTC) as

$$T_s = \frac{2\cos\theta}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \tag{2.35}$$

ε_r= permeability

The relationship between the penetration losses and the Fresnel transmission coefficient is expressed in a normalized form as shown in equation (2.36)

$$L_{pen} = \frac{1}{T_s^{\ 2}} \tag{2.36}$$

"The penetration losses are the same both when the signal is coming from outside the building and when is coming from inside to outside of the building due to reciprocity law'', Nwawelu *et al.,* (2012) asserted. The authors made an assumption that the signal has to pass through windows and walls before reaching the receiving antenna.

2.1.13 Distance Dependence Losses

These losses are dependent on the distance that exists between the building and the receiving antenna. According to Nwawelu *et al.,* (2012), the path loss dependence with the distance of separation between the building and the receiver is taken as 2 just like that of free-space loss due to the fact that it obeys the law of power decays. This expression is represented as:

$$L_{dd} = \left(\frac{d_t + d_{in} + d_r}{d_t + d_{in}}\right)^2 \tag{2.37}$$

Where d_r= length of path between the building and the receiving antenna in the direction of signal propagation.

2.1.14 Two Ray Ground Model.

In two ray ground model, an assumption is made that the total power received by the receiver is the total sum of the powers due to double paths. The first path is the direct path between the transmitter and the receiver. The second path is the path obtained through a ground reflection between the transmitting and receiving stations with equal distance of separation just like in the direct path case (Joshi, 2012). There is one essential parameter that is found in this model which is the height at which the receiver and transmitter is positioned with respect to the ground level. For a distance L, the received power can be computed using the formular below.

$$P_r(1) = \frac{P_t G_t G_r h_t^2 h_r^2}{l^4 L} \tag{2.38}$$

Where;

$P_r(1)$ is the power received through path 1, which is distance between the transmitter and the receiver

P_t is the transmitter power

I is the current value at the receiver antenna

h_t is the transmitter height

h_r is the height of the receiver

L is distance between transmitter and receiver

$G_t G_r$ is the transmitter and receiver gain respectively

The diagram indicating a two ray ground model is shown in Fig. 2.1 below. LOS stands for Line of Sight while NLOS stands for Non Line of Sight;

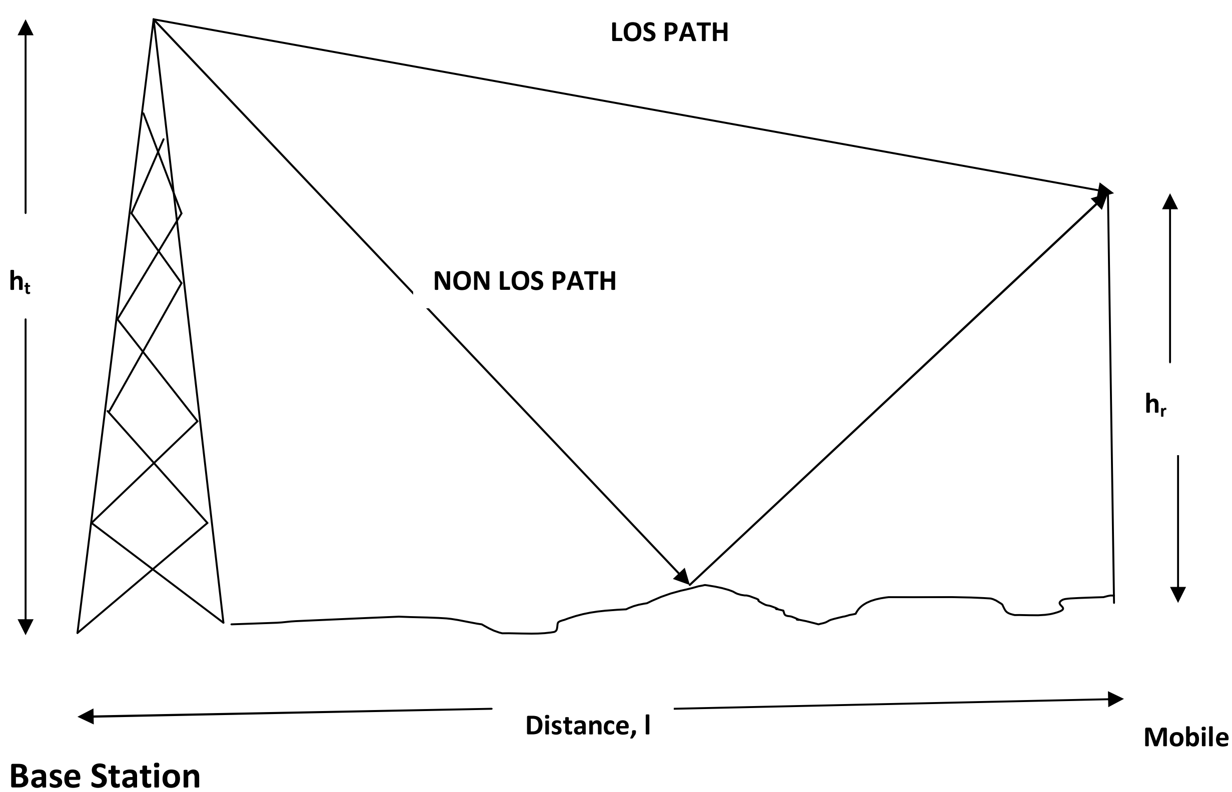

Fig. 2.1: Diagram of a Two Ray Ground Model

2.1.15 Bertoni's Model

The essence of using any model is to effectively predict or forecast the strength of signals for various surroundings. Bertoni's model ensures the following:

1. Facilitation of low building environment through the use of uniform radio absorbers array to replace the row of buildings.
2. Ensure suitability of street grid organization by taking cognizance of intra-building spacing and back to back spacing.
3. It deploys simple geometric method for tall building situation
4. Bertoni's model considers propagation as a root top occurrence. (Joshi and Gupta, 2012)

2.1.16 COST 231 WALFISCH- Bertoni's model

This model came into existence through the combined effort of J.Walfisch and F. Ikegami. They suggested physical modeling called COST 231 Walfisch- Bertoni model due to the contribution and the research work carried out by Bertoni as regards low roof top buildings. This COST 231 model produces a more concise path loss among other models and is most appropriate model for flat sub-urban and urban areas with uniform building height. This is because COST 231 Walfisch – Bertoni model possess extra parameters that distinguish various surroundings. This model also takes account of the variation in the features or characteristics of the terrain. Under this model, the path loss equation is as listed in equations below:

For line of sight (LOS) scenario

$$PL_{los} = 42.6 + 26log(d) + 20log(f) \qquad (2.39)$$

For Non-line of sight (NLOS) Scenario:

$$PL_{Nlos} = \begin{Bmatrix} L_{FSL} + L_{rts} + L_{msd}\ for\ urban\ and\ sub - urban \\ L_{FSL}\ if\ L_{rts} + L_{msd} > 0 \ldots \end{Bmatrix} \tag{2.40}$$

Where,

L_{FSL}= Free space loss

L_{rts}= Roof top to street diffraction

L_{msd}= Multi screen diffraction loss

(Joshi and Gupta, 2012).

2.1.17 COST Walfisch-Ikegami Model

In order to enhance the computation of path loss, Walfisch Bertoni technique is emerged with the Ikegami model through the addition of additional data. The factors that were added to this model are:

1. Height of buildings
2. Width of roads
3. Separation distance between buildings
4. Road orientation with respect to the line of sight (LOS) path.

Also added are the multiple screen diffraction loss L_{msd} and the roof top to street diffraction and scatter loss L_{rts}. Hence, for non line of sight path loss L, the equation is expressed below:

$$L = \begin{cases} L + L_{rts} + L_{msd} & L_{rts} + L_{msd} > 0 \\ L & L_{rts} + L_{msd} < 0 \end{cases} \tag{2.41}$$

The technique given in Ikegami model is deployed in finding the L_{rts} though with a different function of street orientation. Thus the expression for L_{rts} is given in equation below.

$$L_{rts} = -16.9 - 10log_{10}w + 10log_{10}f_{MHZ} + 20log_{10}(h - h_m) + L_{ori}$$

(2.42)

Where,

w is spacing between building

h is the height of the building

h_m is the height of mobile station

$$L_{ori} = \begin{cases} -10 + 0.354\varphi & 0° \le \varphi < 35° \\ 2.5 + 0.07(\varphi - 35) & 35° \le \varphi < 55° \\ 4.0 - 0.114(\varphi - 55) & 55° \le \varphi < 90° \end{cases} \tag{2.43}$$

Where;

L_{ori} is a factor estimated from only a small number of measurements

φ is street angle of orientation

For multiple screen diffraction loss, Walfisch and Bertoni model is used to complete it when the base station antenna is above the roof tops.

The necessary equation required here are:

$$L_{msd} = L_{bsh} + k_{a} + k_{d} log_{10} \ dkm + k_{f} log_{10} fMHz - 9 log_{10} b \qquad (2.44)$$

$$L_{bsh} = \begin{cases} -18 log_{10}[1 + (h_b - h)] & h_b > h \\ 0 & h_b \leq h \end{cases} \qquad (2.45)$$

Where;

$$k_a = \begin{cases} 54 & h_{b>} h \\ 54 - 0.8(h_b - h) & h_{b>} h \ and \ d_m \geq 0.5km \\ 54 - 0.8(h_b - h)\frac{d}{0.5} & h_{b>} h \ and \ d_m \geq 0.5km \end{cases} \qquad (2.46)$$

$$k_d = \begin{cases} 18 & h_b > h \\ 18 - 15\frac{(h_b - h)}{h} & h_b > h \end{cases} \qquad (2.47)$$

$$k_f = -4 + \begin{cases} 0.7\left(\frac{fmhz}{925} - 1\right) \ for \ medium \ sized \ cities \\ 1.5\left(\frac{fmhz}{925} - 1\right) \ for \ urban \end{cases} \qquad (2.48)$$

Where,

K_a increase an path loss when the base station antenna is below roof top height

K_d allows for the dependence of the diffraction loss on range

K_f allows for the dependence of the diffraction loss a frequency (Jadhav and kale, 2014)

2.1.18 Ricean and Rayleigh Model

Ricean and Rayleigh model are deployed where there are multiple propagation paths between the transmitting and receiving stations. There are two conditions here:

The first condition is where there are multiple indirect paths, with no direct path between the transmitting and the receiving stations. In this case, the Rayleigh fading is said to have occurred.

However, the second case is where there is existence of multiple indirect paths, with one direct path between the transmitting and receiving station. Here, Ricean fading occurs. In other words, the implication is that the occurrence of multipath propagation result to another effect called fading in radio signal propagations. The consequences of this fading are that several signals that are radiated from the same transmitter to a particular receiver reached the receiver but with different time delay. According to Jashi(2012),''In order to get an idea of measure of fading it is needed to correlate different signals received at the receiver in time domain known as time –correlation".

2.1.19 Shadowing Model

An assumption at the shadowing model is that the power received at the receiving station differs logarithmically with distance of separation between the transmitting and receiving stations. This simply means that the power received by the receiver is a logarithmic function of the distance of separations between the transmitting and receiving stations.

Shadowing model also contain a normalized random variable that takes cognizance of the path loss experienced where the habitants vary. In the words of Joshi (2012), it assumes a close in distance of ℓ_0. It takes ℓ_0 as a reference point with respect to which received power is calculated at different distances. Thus, a relativistic measurement is carried out as;

$$P_r(\ell_0) = \frac{\left(\frac{\ell}{\ell_0}\right)^{\mu}}{P_r(\ell)} \tag{2.49}$$

Where:

ℓ is the distance covered, P_r is the received power, μ is the factor which account for the path loss and is generally determined using empirical methods or using realistic field measurement.

According to the author, some of the different path loss exponent values at various frequencies of measurement and variable environment are shown in the table 2.1 below:

Table 2.1: Different path loss exponent values at various frequencies of measurement and variable environment profiles (Joshi, 2012)

Habitat (niche characteristics)		μ (pathloss Exponent)
Outdoor Environments	Free space	2
	urban area cellular radio	2.7 -3.5
	obstructed in factories	2 – 3

	shadowed urban areas	3 – 5

2.1.20 Longley Rice Model

Longley Rice Model is deployed only when considering point to point communication. This model considers a broad range of terrain profile together with the terrain geometry and the refractivity of troposphere. Also, it makes use of geometrical optics together with two –ray ground reflection model.

Longley- Rice Model account for the parametric condition like terrain, climatic conditions, subsoil conditions and curvature of ground. It is implemented in the form of an algorithm which accepts different parameters to give the path loss data because of much detailed outlook it poses. It is implemented in two configurations, namely: point to point and area configuration, Joshi (2012). The author stated that the model rely on measurement that are taken in the frequency range of 40MHz to100MHZ within the distance of 1-2000km. It is not suitable for mobile communication. The main shortcoming of the Longley Rice model is its inability to take cognizance of building and foliage. (Joshi, 2012)

2.1.21 Near Earth Propagation Models

An environment where many obstacles abound, radio wave propagation near the earth surface is needed by many applications in their point to point communications. These application models takes into account the effect of the land profile, foliage, buildings and so on which can influence signal reflection , signal absorption, signal diffraction among others. Near earth propagation models are very essential for very high frequency (VHF) channels as they take cognizance of the reasonable quantity of data that is being collected within this specific range. Examples of Near Earth Propagation Models are as listed below

- **Foliage models**: Foliage models highlight an additional signal loss that happen as a result of thick foliage hindrance on the line of sight (LOS) of signal propagation. The foliage model cover a frequency band of 230MHz-95GHz, and the thickness of the foliage is represented in meter while the frequency of operation is in GHz.
- **Weiss Berger's model**: This model is dependent on exponential decay model. It is a modification of the exponential decay model, and it is expressed as shown in equation below. Weise Berger's model covers frequency range of 230MHz-95GHz.

$$L(dB) = \begin{cases} 1.33F^{0.284} I_f^{0.588}, 14 < I_f < 400m \\ 0.45F^{0.284} I_f, 0 < I_f < 14m \end{cases} \quad (2.50)$$

Where;

I_f =Depth of foliage in meters

f=Frequency in GHz

- **Early ITU vegetation model:** According to Joshi (2012) Early ITU vegetation model produces result which is in fine coincidence with the Weise Berger's model. The model is expressed as shown in equation below,

$$L(dB) = 0.2F^{0.3} I_f^{0.6} \quad (2.51)$$

Where;

f =Frequency in MHz

I_f = Depth of foliage in meters along LOS.

- **Updated ITU Vegetation Model**: Though all models are efficient one way or the other, majority of the models were not convenient for the specificity based nature of all earlier ITU models. Updated ITU vegetation model possess a limit to the magnitude of attenuation due to consideration of foliage along with diffraction paths that has a close proximity. With the actual vegetation, model becomes a function of foliage type, foliage depth and area under consideration.

- **Terrestrial path with one terminal in woodland:** This model takes care of the situation where there is excess attenuation loss which is as a result of one terminal that is located among woodland or vegetation. This model is mathematically expressed as:

$$A_{ev} = A_m \left[\mathbf{1} - \frac{e^{I}_{\alpha}}{Am} \right] \quad (2.52)$$

Where;

l=Length of path within the woodland in meters

α=attenuation specific to short vegetative path (dB/m)

A_m= Maximum attenuation for single terminal within specific vegetation type (dB)

- **Single Vegetation obstruction**: This model is deployed in a situation where none of the terminals is located within a vegetation zone but there are existences of some vegetation between the two terminals. The formula for the vegetation loss model, for frequency equals 3GHZ or below is expressed in equation below:

$$A_{e-l} = l.\propto \quad (2.53)$$

Where,

$\propto$= Specific attenuation for short vegetation paths (dB/m)

l = Length of path within the vegetation in meters.

A_{e-l}= Lowest excess attenuation for any other path in dB

A situation where the vegetation loss is enormous, an alternate path is used in computing the path loss such as diffraction path (Joshi, 2012).

2.1.22 Terrain Modeling

Terrain is that part of the earth (natural geography) over which signal propagation takes place. Terrain profile excludes artificial objects and vegetation. Joshi (2012) maintained that terrain modeling improves the calculation of median path loss proportional to the distance of separation and variation in the terrain. There are good numbers of well known terrain models which include Egli model, Longley-Rice model, ITU terrain model among others.

Egli model: Egli model helps in the computation of median path loss on an irregular terrain. This model is expressed mathematically in equation below:

$$L_{50} = G_b G_m \left(h_b h_m / \ell^2\right)^2 \beta \quad (2.54)$$

Where,

L_{50}=median path loss

G_b= gain of base station antenna

G_m= gain of mobile antenna

h_b= height of base station antenna

h_m = height of mobile antenna

ℓ = propagation distance

β= $(40/f)^2$

f= frequency in MHz

- **ITU Terrain Model:** This model according to the author is dependent on the effect of diffraction which is evaluated under wave optics. The author stressed that this model serve as a faster technique for calculating median path loss. The model is expressed mathematically as shown in the equation below;

$$A_d = -{}^{20h}/_{F_1} + 10\,dB \qquad (2.55)$$

Where,

h= the difference in height between most concerned path blockage and loss between transmitter and receiver

A_d stands for signal attenuation

F1 = radius of first fresnel zone

Hence,

$$F_1 = 17.3\sqrt{\left(\frac{d_1 d_2}{f_d}\right)}m \tag{2.56}$$

Where;

d_1 and d_2 = distances from each of the terminals to the obstruction in km

d=distance between terminal in km

f_d= frequency of operation in GHz

2.2 Wireless Local Area Network (WLAN) Elements

There are four main components that make up the wireless local Area Networks. These include the Station, Access point, Medium, and distribution system.

Station: This means the device that contains the wireless network interfaces.

Access point: Access point is simply the wireless device (router or bridge) that is used to interface the wired network with the wireless network.

Medium: Wireless medium represents the physical layer standard which is used while conveying frames from one station to another station.

Distribution system: This is best defined as the logical device that is used to convey frames from one access point (AP) to another within a broad area of coverage. In other words distribution system is also referred to as the backbone network

Antennas

According to Stallings (2004), an antenna is “an electrical conductor or system of conductors used for either radiating electromagnetic energy or for collecting it’’.

Antenna is very essential components used in wireless communication. In the course of signal radiation, the antenna converts the radio frequency electrical energy from the transmitter into the electromagnetic energy form before radiating it into the surrounding medium. Also, during signal reception at the receiving end, the receiving antenna converts the received electromagnetic energy into the initial radio frequency electrical energy.

Antennas are grouped into two major types namely Omni-directional antenna and directional antennas.

Omni- directional antennas: These are ideal antennas that radiate signals in all directions. They are suitable for signal radiation in a large room or floor where the access point is positional at the middle of the room. Example is dipole antennas

Directional antenna: Directional antenna is mainly deployed for point to point signal transmission. These antennas use narrow beam to radiate radio frequency for a long distance unlike the Omni-directional antennas. Examples of these antennas include dish antenna.

Radio Frequency Component

Radio communication is made up of two or more components that are tuned to the same frequency. These devices are mainly the transmitting and receiving component. While the transmitting station (transmitter) produces the radio frequency and is made up of transmitter, antennas and transmission line, the receiving station is made up of a receiver, an antenna and a transmission cable.

Radio frequency communication takes place when the transmitter radiates an oscillating signal whose frequency is constant to the receiving station. The transmitter and the receiver must be tuned to the same frequency before radio frequency communication occurs.

Wireless Local Area Network Topology

There are two major categories of wireless network topologies. Which are the independent Basic Service Set (IBSS) or Ad-hoc Network and the infrastructural Basic Service Set. (www.ciscopress.com/articles/article.asp?p=1876001)

1. **Independent Basic Service Set topologies**: Here the components communicate directly with each other and there is no connection to a wired infrastructure. They are easy to set up though very tedious to maintain

2. **Infrastructure Basic Service Set**: this topologies posse a gateway to the wired infrastructure and permits communication between different stations of service area. Thus Gateway, which is the access point, is required in every communication because it makes a connection to the wired network.

2.3 Multi-Path Propagation

Multi-path propagation occurs in wireless telecommunication when the radio signals are received by the receiving antenna through two or more paths. This phenomenon is as a result of factors like ionospheric reflection and refraction, atmospheric ducting, and reflecting due to water bodies and terrestrial materials like mountains, buildings, trees and so on. It is worth mentioning here that radio wave propagation is made up of three major features which are Reflection, Diffraction and Scattering. As the transmitting signal leaves the transmitting antennas from different angles, the radiated signal propagates not only through the direct line of sight (LOS) but over a range of angles depending on the type of antenna deployed. The consequences of this effect is that the radiated signals reach the receiving antenna at varying times, this is because the transmitted signals may have to be reflected on several objects within the medium thereby following or propagating through different paths before it gets to the antenna . When the reflected received signals are in phase with the main signal, the signal adds to increase its strength.

However, when the signal are out of phase or are interfering with the main signal, the total strength of the signal reduced (Popoola, 2009).

There are situations where the relative signal path length do change as a result of the shift or movement of transmitter, receiver or any of the object at which signal reflect at. The consequence of this is that the phases at which the signals do get to the receiver alter, thereby causing variation in the strength of the received signal. A situation where the antenna at the receiving station receives many reflected and scattered signals, the instantaneous received power at a moving antenna becomes a random variable which is a function of the antenna location; this is as a result of signal cancellation effect. Under this condition, there are many fading that occur which include:

1. **Rayleigh fading**: This is caused by the reception of multipath signal
2. **Nakagami fading**: This happens in multi path scattering that has relatively larger time-delay spreads with cluster of different reflected signals
3. **Rician fading**: Rician fading happens as a result of propagation of multi-path and when the signal path are of varying strength

Other effects of multipath propagation are: occurrence of construction and destructive interference, signal phase shifting among others. Hence the mathematical expression of the total signal received, y (t), at time t is known in equation below

$$y_t = \sum_{n=0}^{N-1} p_n e^{j\varphi n} \ \delta(t - \tau_n) \qquad (2.57)$$

Where;

N= Number of received signal or electromagnetic path to the receiver

τ_n=Time delay of the generic nth signals

$p_n e^{j\varphi n}$=The complex amplitude of the generic received signal (Popoola, 2009)

2.4 RELATED WORKS

Nwalozie *et al.* (2014) researched on path loss prediction for GSM Mobile Network for urban Region of Aba, South East Nigeria using site-specific measurement approach. The authors obtained their received signal strength through the use of Global com limited (GLO) Network operating at 900MHz. The authors developed a path loss model for the Aba urban environment which indicated the path loss increased by 3.10dB per decade. However, the authors did not employ the use of regression method as that is known for its accuracy in path loss exponent derivation.

Sharma and Singh (2010) worked on the cooperative analysis of propagation path loss model with field measured data. The authors compared different path loss propagation models with measured field data in India environment at frequency of

900MHz and 1800MHz using spectrum analyzer. The result obtained showed that COST231 and SUI models exhibited better performances in the environment under study. The authors failed to develop their own path loss model based on the obtained measured field data for the environment.

Wang et al. (2012) research a Near-Ground path loss measurement and modeling for wireless sensor Network at 2.4 GHz. The authors presented three (3) near-ground scenarios whose path loss values were obtained through measurement. The authors used a least square linear regression approach in the analysis. The predicted and measured far field path losses were compared and the result obtained indicated that the proposed model performs better in near-ground scenarios than the compared generic models. There was no evidence of calculated standard deviation between the prediction and the measured path losses.

From the above related works, Nwalozie *et al*. (2014) did not make use of regression analysis in carrying out their analysis. Sharma and Singh (2012) failed to develop a path loss model for the environment under study, and Wang *et al.* (2012) did not show the standard deviation that existed between the predicted and the measured path losses.

This work fills the gap by evaluating the received signal of 3G Network in Owerri metropolis using path loss propagation model at a frequency of 2.1GHz. The pathloss models for Owerri metropolis at the measured frequency, using linear regression approach were developed. The standard deviation that exists between predicted and measured path losses were calculated.

CHAPTER THREE

MATERIALS AND METHOD

3.1 MATERIALS

This research was carried out in Owerri metropolis during dry season. The key materials used for this investigative research are: Ericsson Transmission Evaluation and Monitoring System (TEMS 11) mobile station, a global positioning system (BU353 GPS), and a laptop with TEMS software installed in it, power supply unit and a vehicle as sketched in Fig 3.1 below.

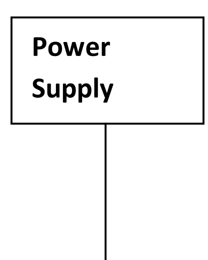

Fig. 3.1: The Block diagram representing the Setup of the field experiment.

As shown in Fig. 3.1, the Laptop computer is connected to an external power source, while the TEMS mobile phone and GPS are all connected to the Laptop through its USB ports. The 3G network, operating at the frequency of 2.1GHz, was under investigation in this research within the Owerri metropolis in Imo state. TEMS drive test is a technique that is deployed in assessing the state of radio frequency signal of the operator.

3.2 METHOD

Before the drive test commenced, all the needed configurations on the Transmission Evaluation and Monitoring System (TEMS 11) equipment were carried out. The drive test readings at each case begin whenever “record” is clicked on the start command.

The TEMS handset was set in such a way that it initiated calls that lasted for 10 seconds each before the calls got terminated and then the calls commenced again. This call process continued all through the routes under the study. The investigations were carried out into six (6) phases which covered the major routes under consideration. The areas covered were categorized into two which are: urban area and Sub-urban area.

The urban area comprises:

i. Log1: Govt house Imo state, Works layout , Okigwe road.
ii. Log2: Wethedral road, Nekede road,Royce road, Bank road, Tetlow road
iii. Log3: Akanchawa new road, World Bank road, new Owerri.

While the Sub-urban area is comprised of:

i. Log4: Owerri-Obinze Express road
ii. Log5: FUTO community
iii. Log6: Ihiagwa road.

Table 3.1 is the transmission parameters for the Network. This is a 3G based network, and it is used for the drive test.

Table 3.1: Transmission Parameters for the Network

S/N	**Transmission parameters**	**Values**
1	Transmitter power	30W
2	Transmitter height	35m

3	Mobile Station height	1.5m
4	Gain of transmitter	18dB
5	Gain of receiver	1.76dB
6	Frequency of operation	2.1GHz

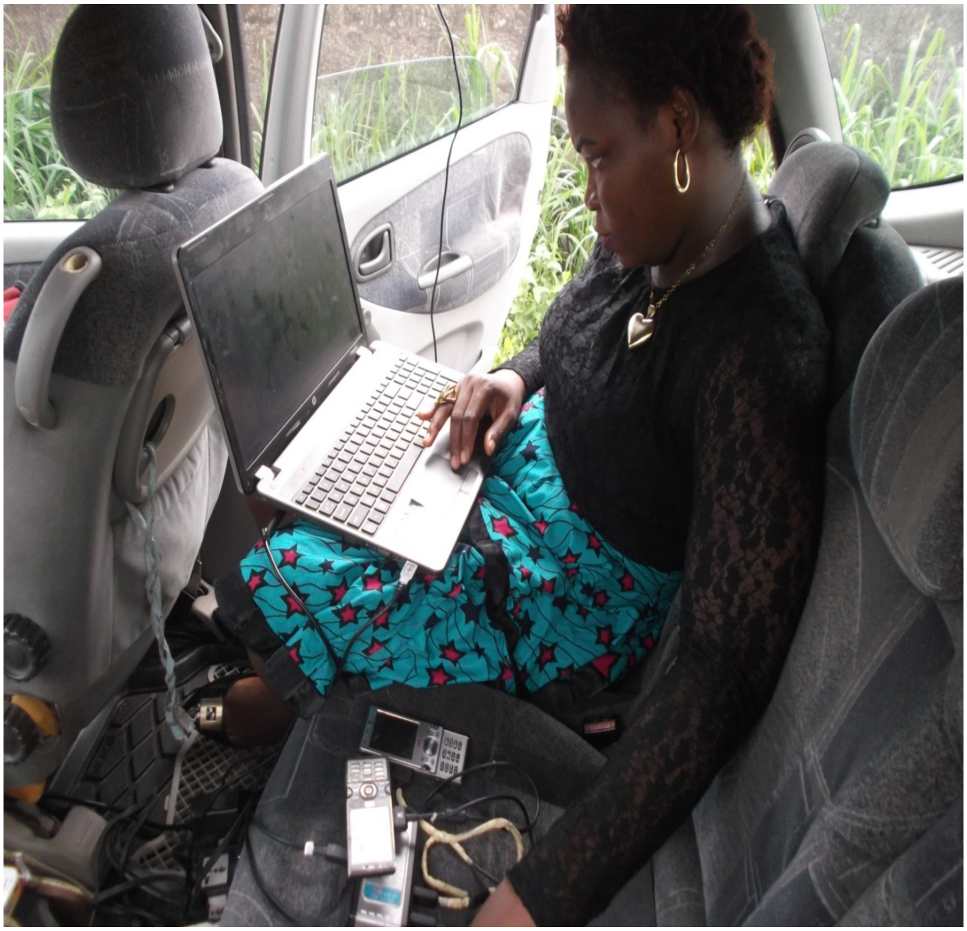

Fig. 3.2: The picture for the Setup of the field experiment

These measurements were carried out in a car with the speed limit kept as constant as possible in order to ensure accuracy of signal recordings. In the course of the drive test, the received signal level (RSL) that existed between the mobile station (MS) and Base transceiver station (BTS) were recorded in a log file of the laptop with TEMS 11 investigation software. The Global positioning system (BU 353 GPS) indicated the distance and location with regard to the base station which was also recorded on the laptop. Figs. 3.3 to 3.13 below represent the log of the field work along various routes. The curves stand for the routes followed during the drive test in the areas while the colour variations indicate the strength of the received signals as shown in the legend.

Fig. 3.3 indicates the log of measurement along Wetheral-Nekede-Royce Tetlow Road. The various colours across the log paths signify the strength of the received signal as shown in the legend. The light blue colour represents the best received signal level while the red colour indicates the worst state in that order at the legend. The modal value of the aggregate received signal level here is 728dB which is 32.5% of the total received signal. Hence, this shows that Wetheral-Nekede-Royce Tetlow Road have a good quality of signal coverage within the area. In the plots, RSCP stands for the Received Signal Code Power.

WETHERAL-NEKEDE-ROYCE-TETLOW ROAD BY RSCP

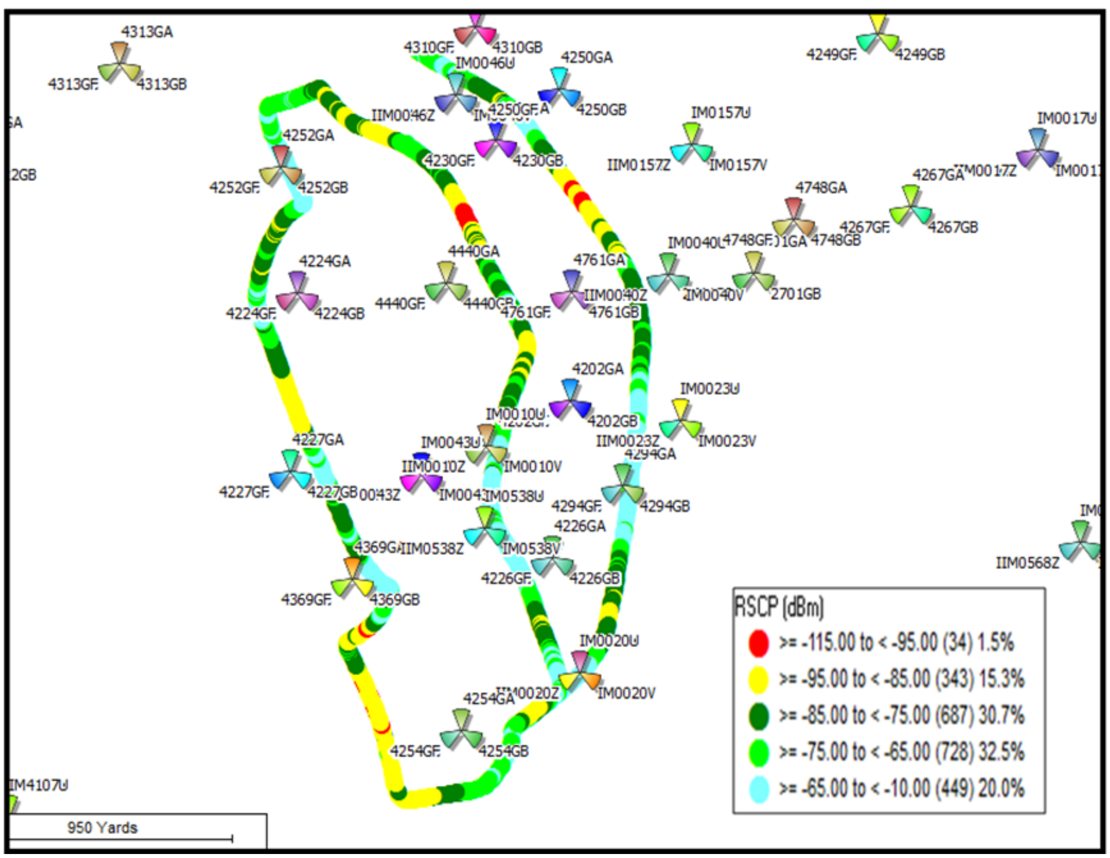

Fig. 3.3: The log of measurement along Wetheral-Nekede-Royce Tetlow Road.

Fig. 3.4 shows the log of measurement along Government House- Okigwe Road. The modal value of the aggregate received signal level here is 317dB which is 39.2% of the total received level. Hence, this shows that Government House- Okigwe Road has a poor quality of signal coverage within the zone.

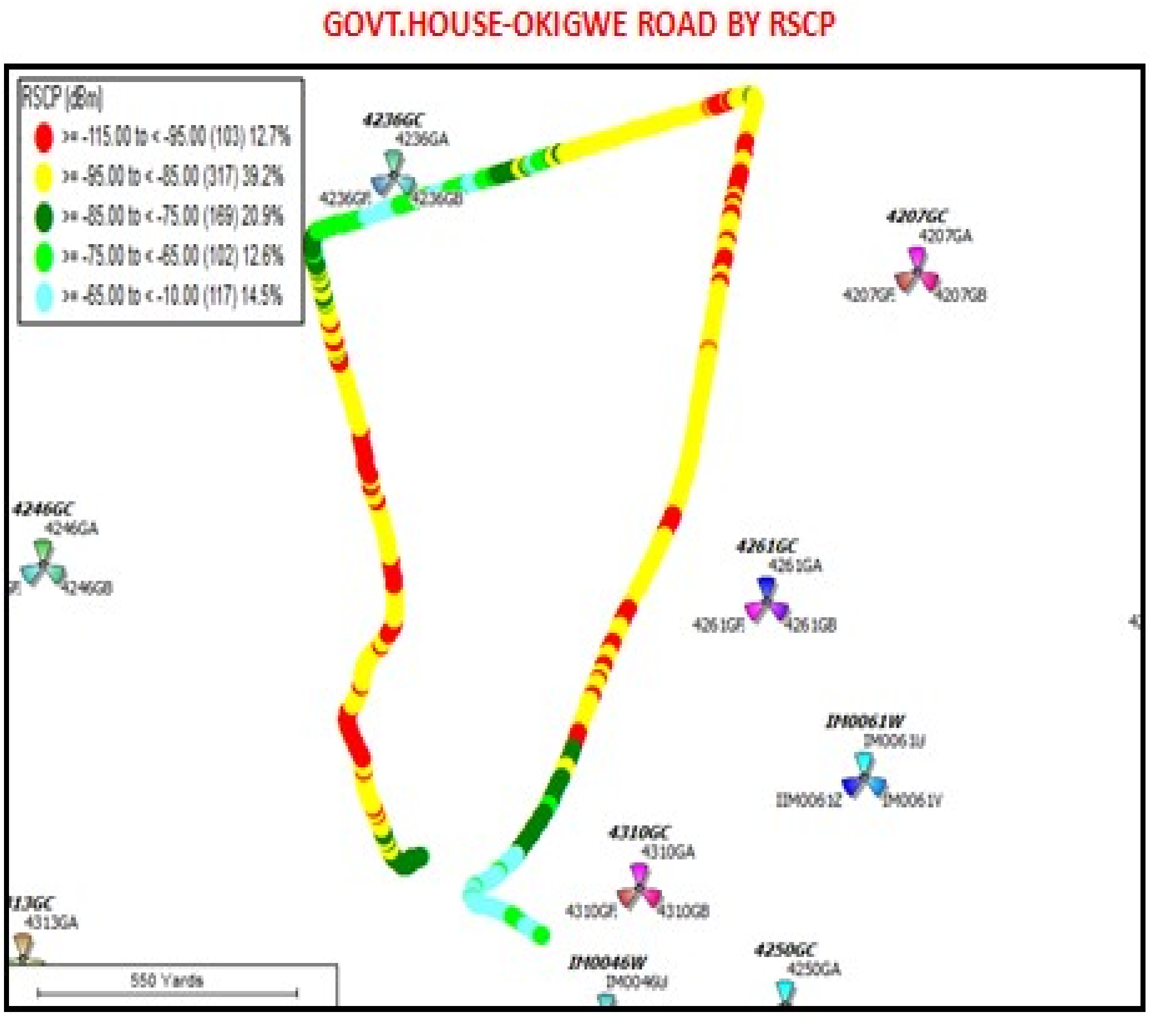

Fig. 3.4: The log of measurement along Government House- Okigwe Road.

Fig. 3.5 shows the log of measurement along Akanchawa New Owerri- World bank Road. The modal value of the aggregate received signal level here is 364.2dB which is 28.6% of the total received level. Hence, this shows that Akanchawa New Owerri- World bank Road have a good quality of signal coverage within the area.

AKANCHAWA-NEW OWERRI-WORLD BANK ROAD BY RSCP

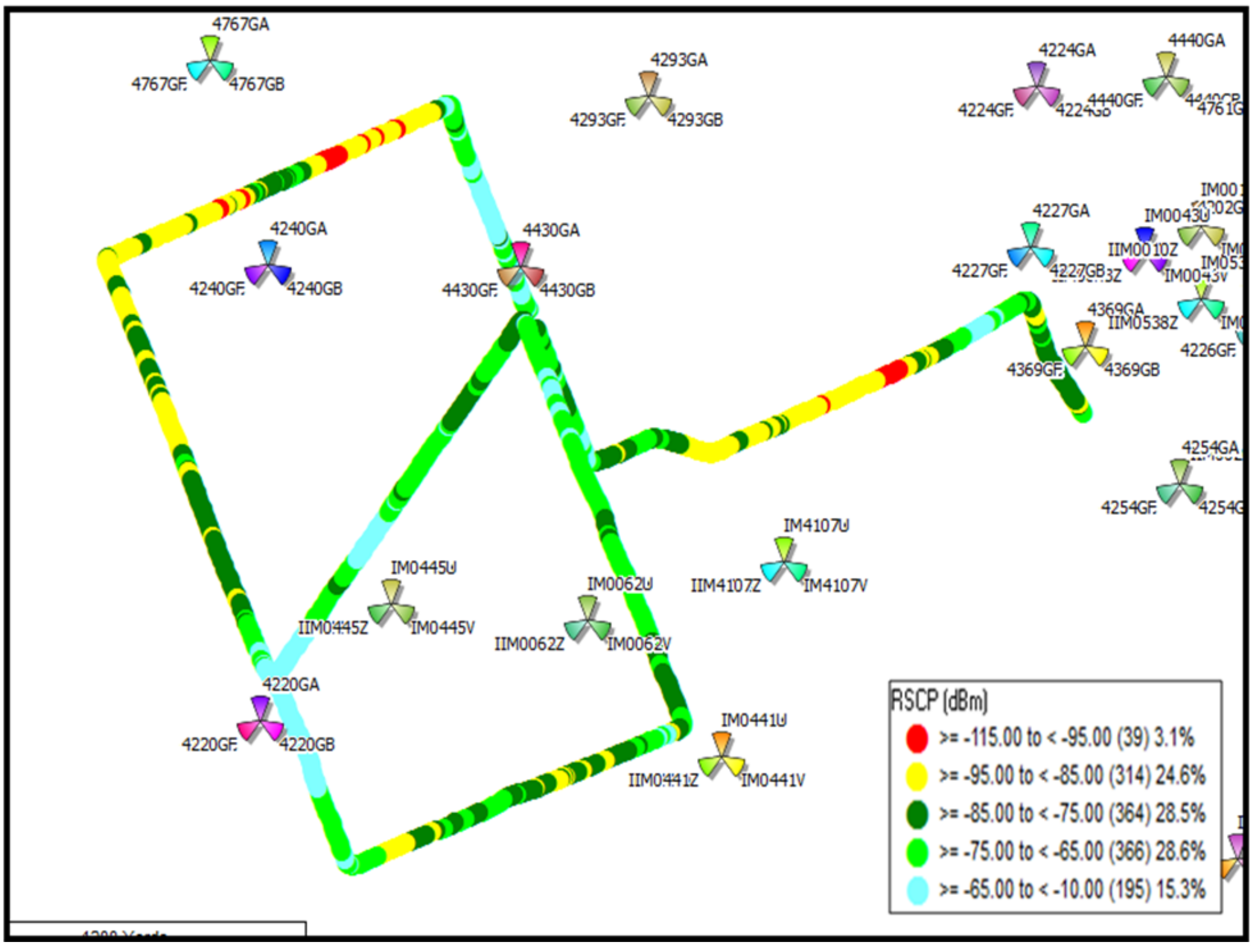

Fig. 3.5: The log of measurement along Akanchawa New Owerri- World bank Road.

Fig. 3.6 represents the log of measurement along Obinze-Owerri Express Road. The modal value of the aggregate received signal level here is 162dB which is 24.6% of the total received level. In other words, Obinze-Owerri Express Road has a very poor quality of signal coverage within the area.

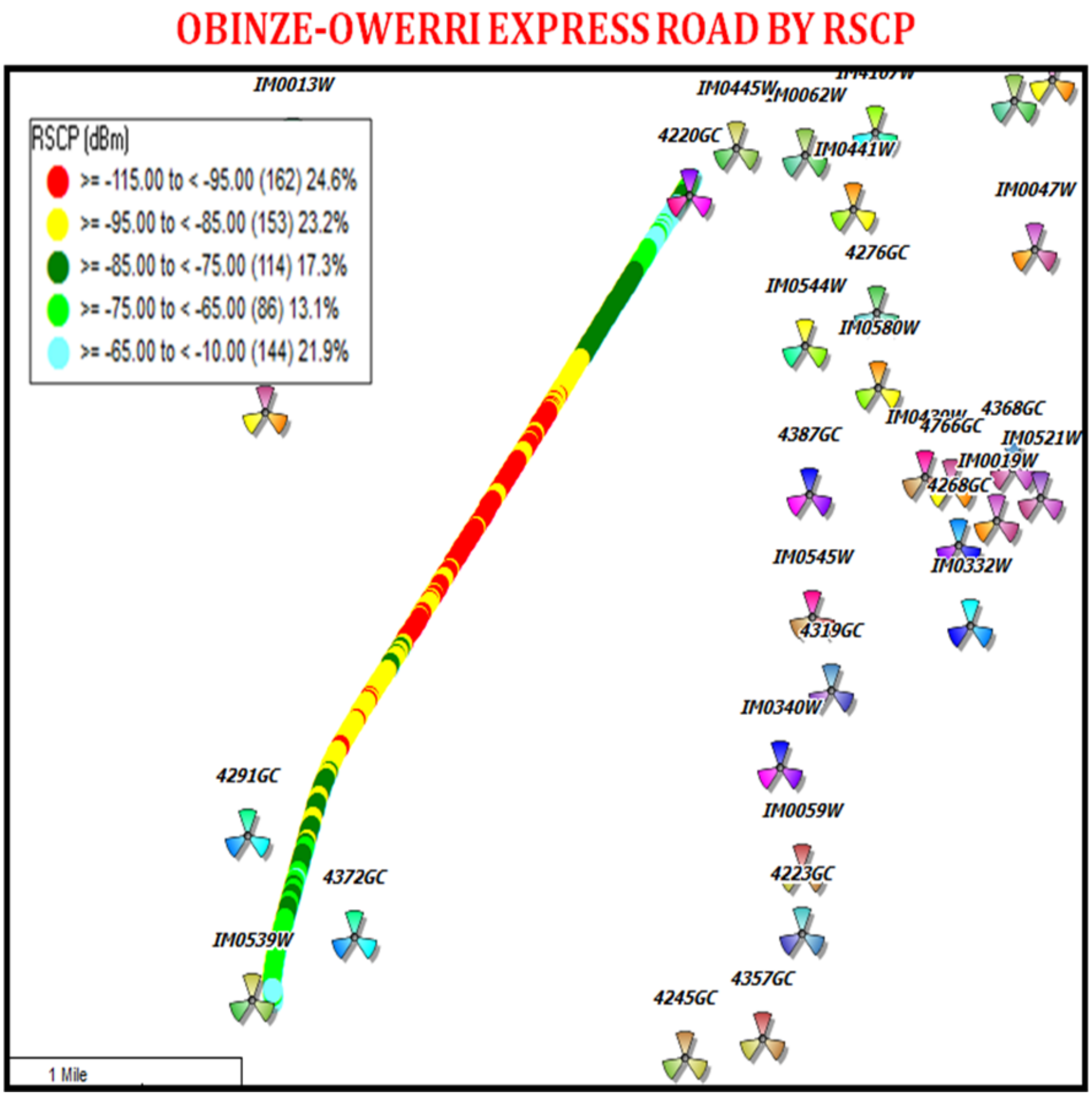

Fig. 3.6: The log of measurement along Obinze-Owerri Express Road.

Fig. 3.7 represents the log of measurement along FUTO1 road. The modal value of the aggregate received signal level here is 208dB which is 41.6% of the total received level. Hence, this shows that FUTO1 road has poor quality of signal coverage within the area.

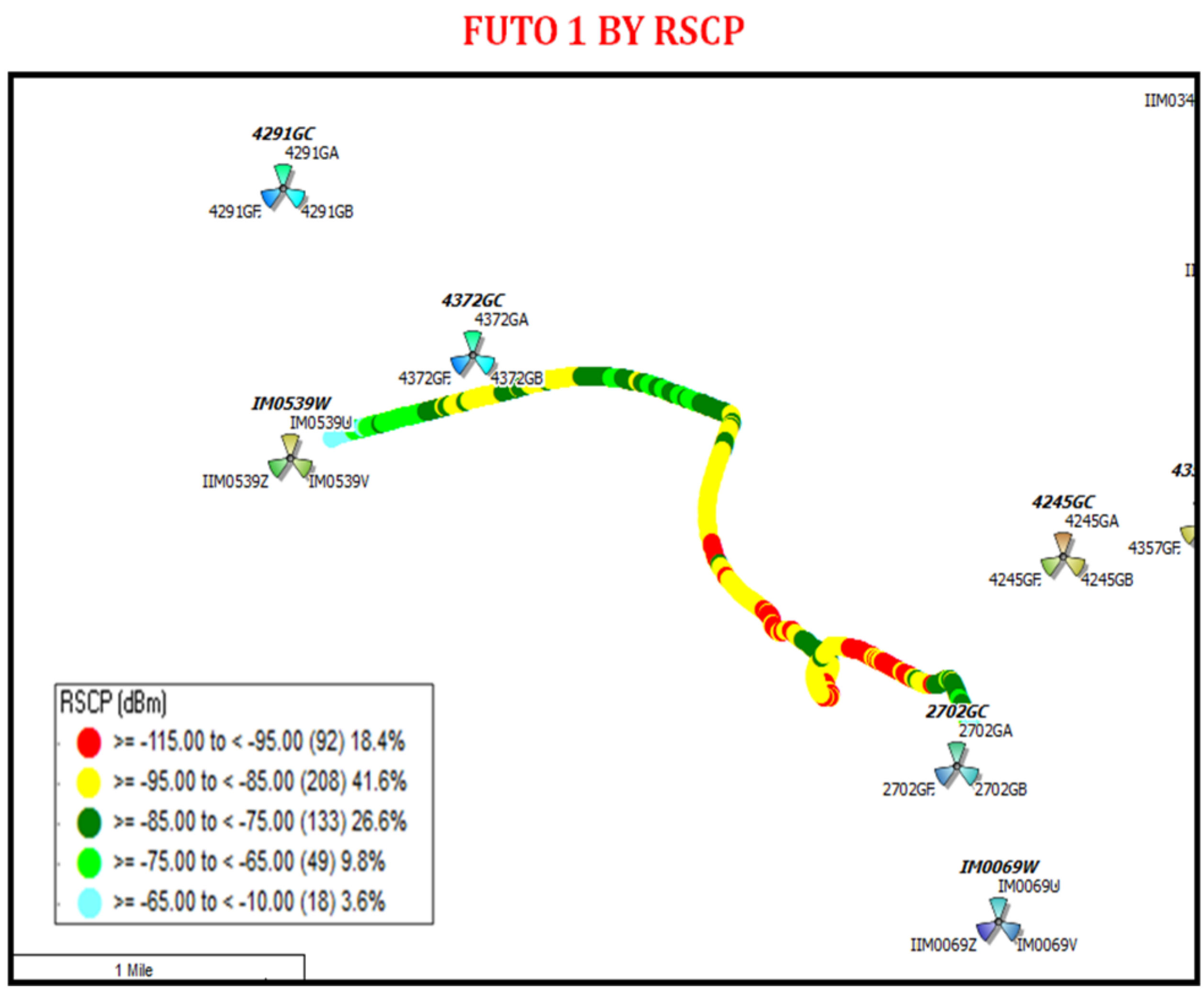

Fig. 3.7: The log of measurement along FUTO1 road.

Fig. 3.8 is the log of measurement along FUTO2 road also. The modal value of the aggregate received signal level here is 311dB which is 32.7% of the total received level. Hence, this shows that FUTO2 road has the poorest quality of signal coverage within the area.

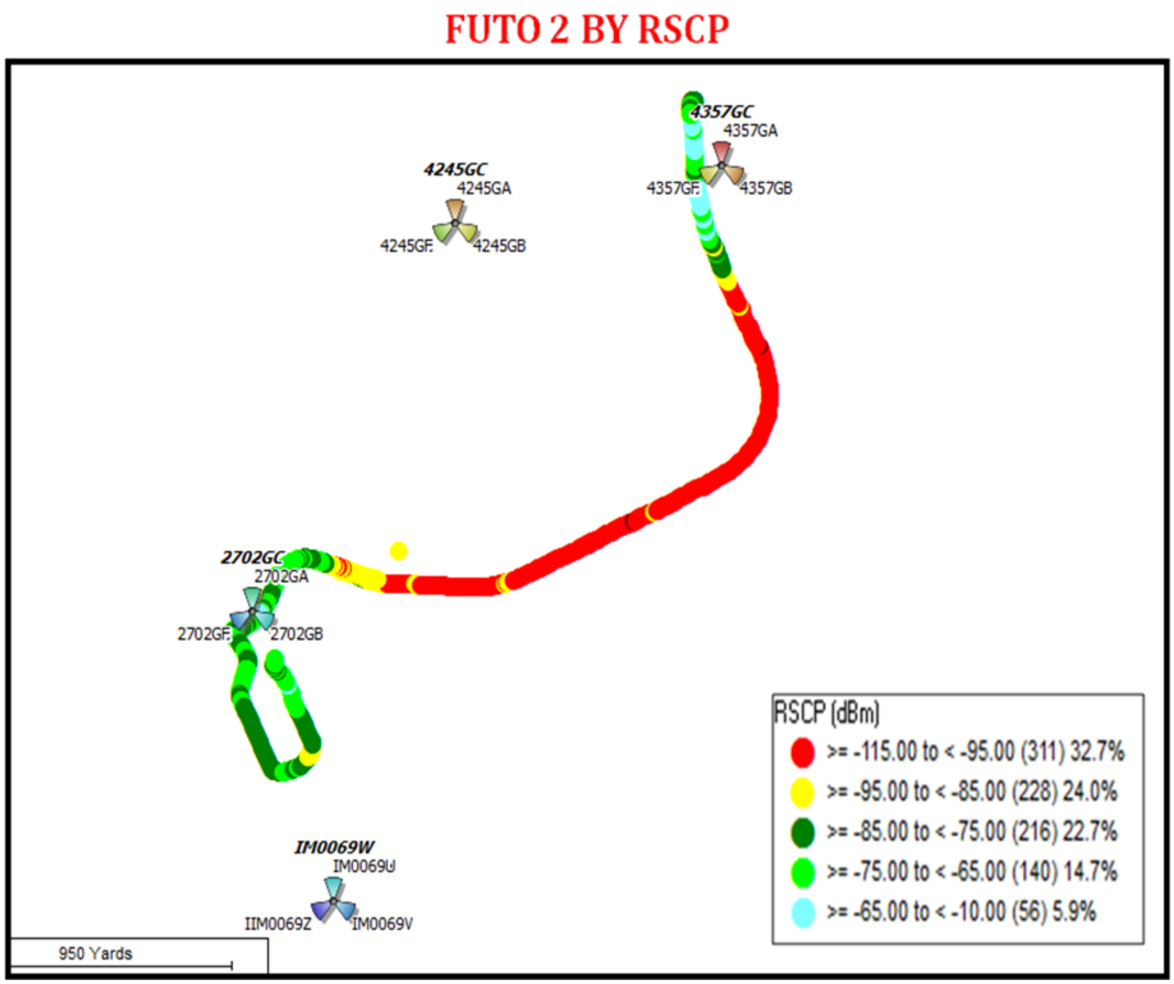

Fig. 3.8: The log of measurement along FUTO 2.

Fig. 3.9 represents the log of measurement along FUTO route. The map indicates a serious degradation on the level of the total received signal level as indicated in red colour shown in the map.

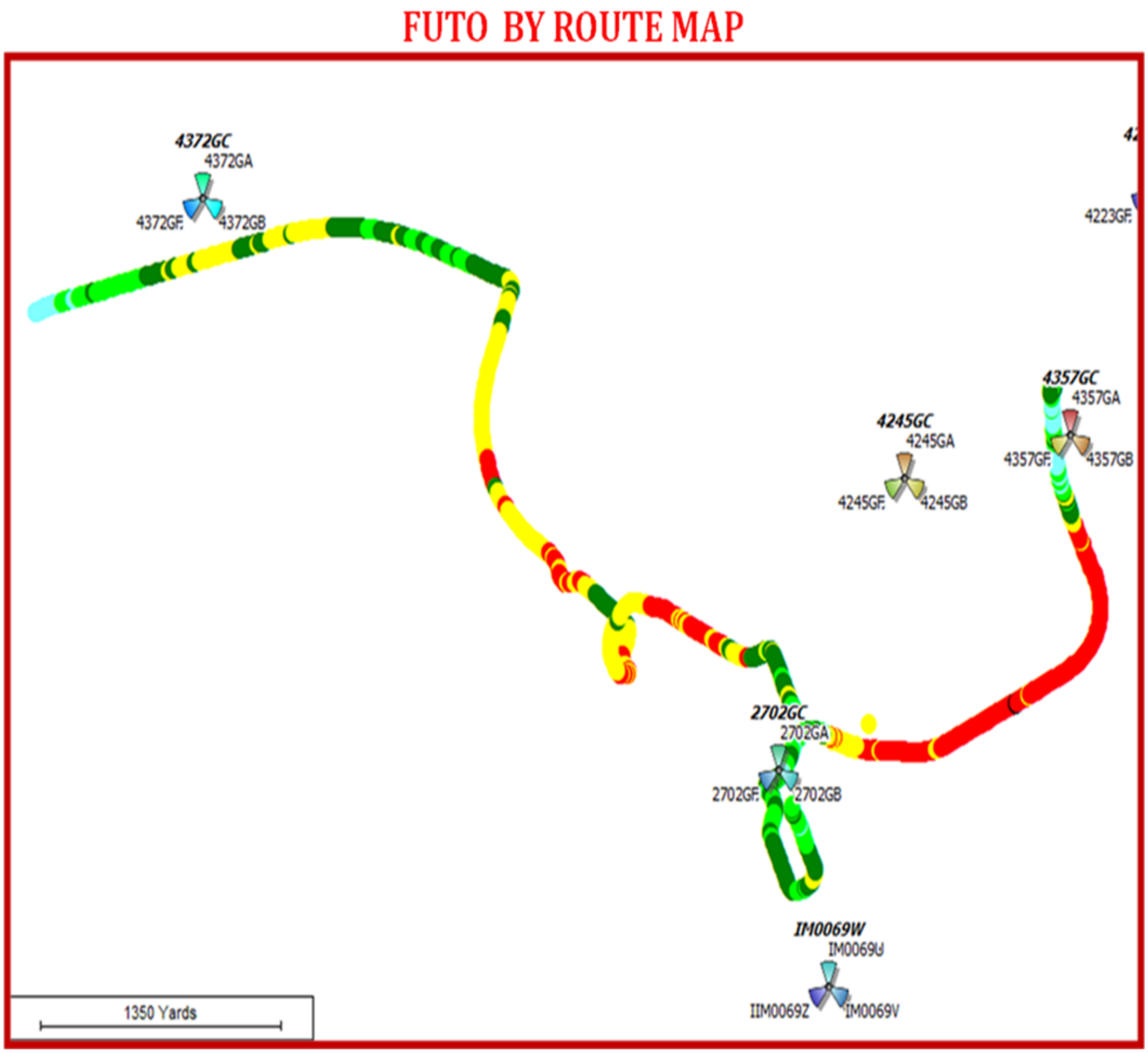

Fig. 3.9: The log of measurement along FUTO Route.

Fig. 3.10 represents the log of measurement along FUTO Community, taking off from the Potluck supermarket to the senate building. The received level was seriously degraded as one drives past the FUTO senate building.

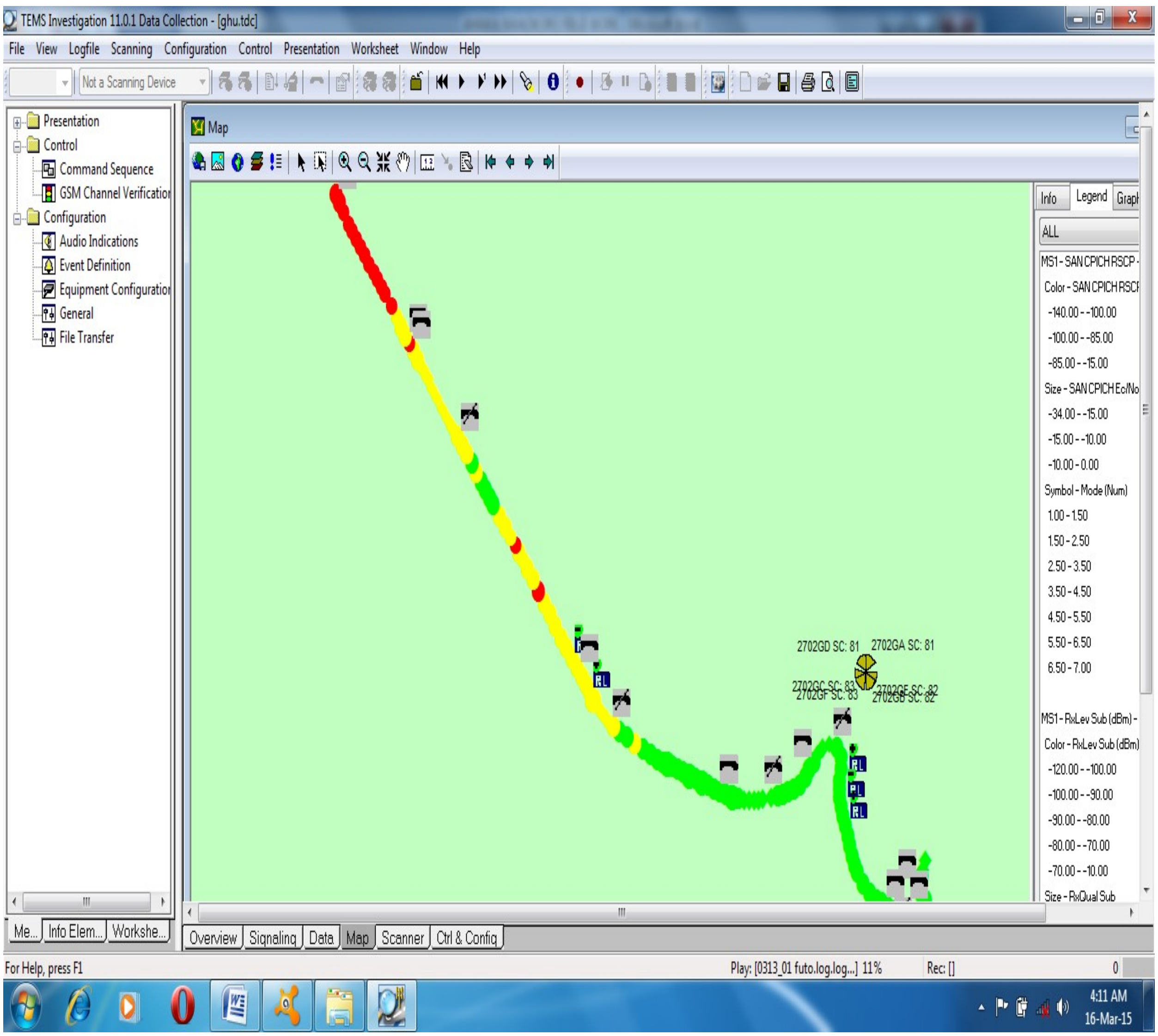

Fig. 3.10: The log of measurement along FUTO Community, taking off from the Potluck supermarket to the senate building.

Fig. 3.11 stands for the log of measurement along Obinze – Owerri road. The plot indicates a signal hand – over as observed from the play of the log video. There was a transfer of service from the antenna at the lower base station to the antenna at the upper base station.

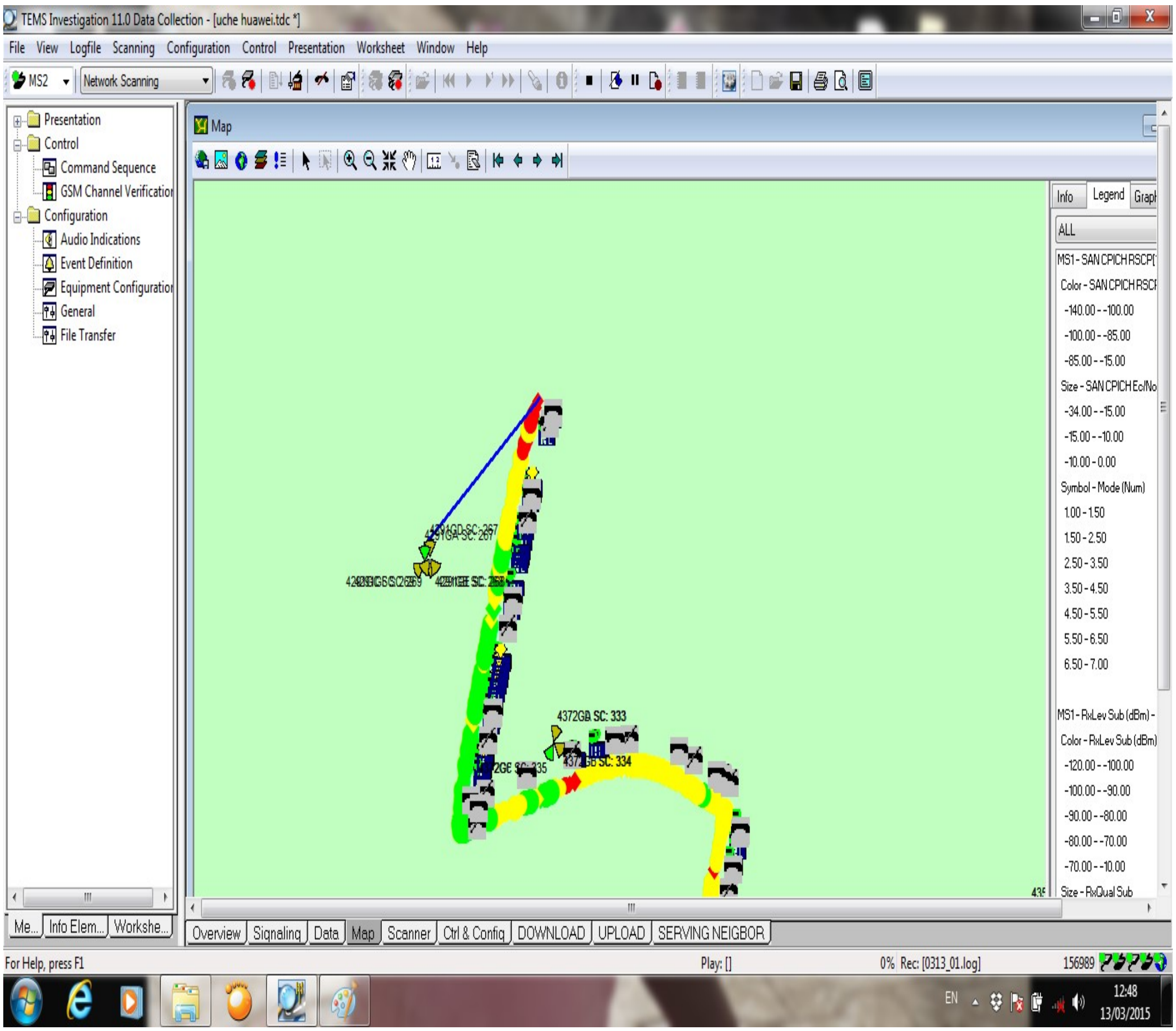

Fig. 3.11: The log of measurement along Obinze – Owerri road indicating Network Hand – over.

Fig. 3.12 stands for the log of measurement along New Owerri zone. There is good signal coverage across the region. This is as observed from the green colour of the signal path that dominated the signal path on the diagram.

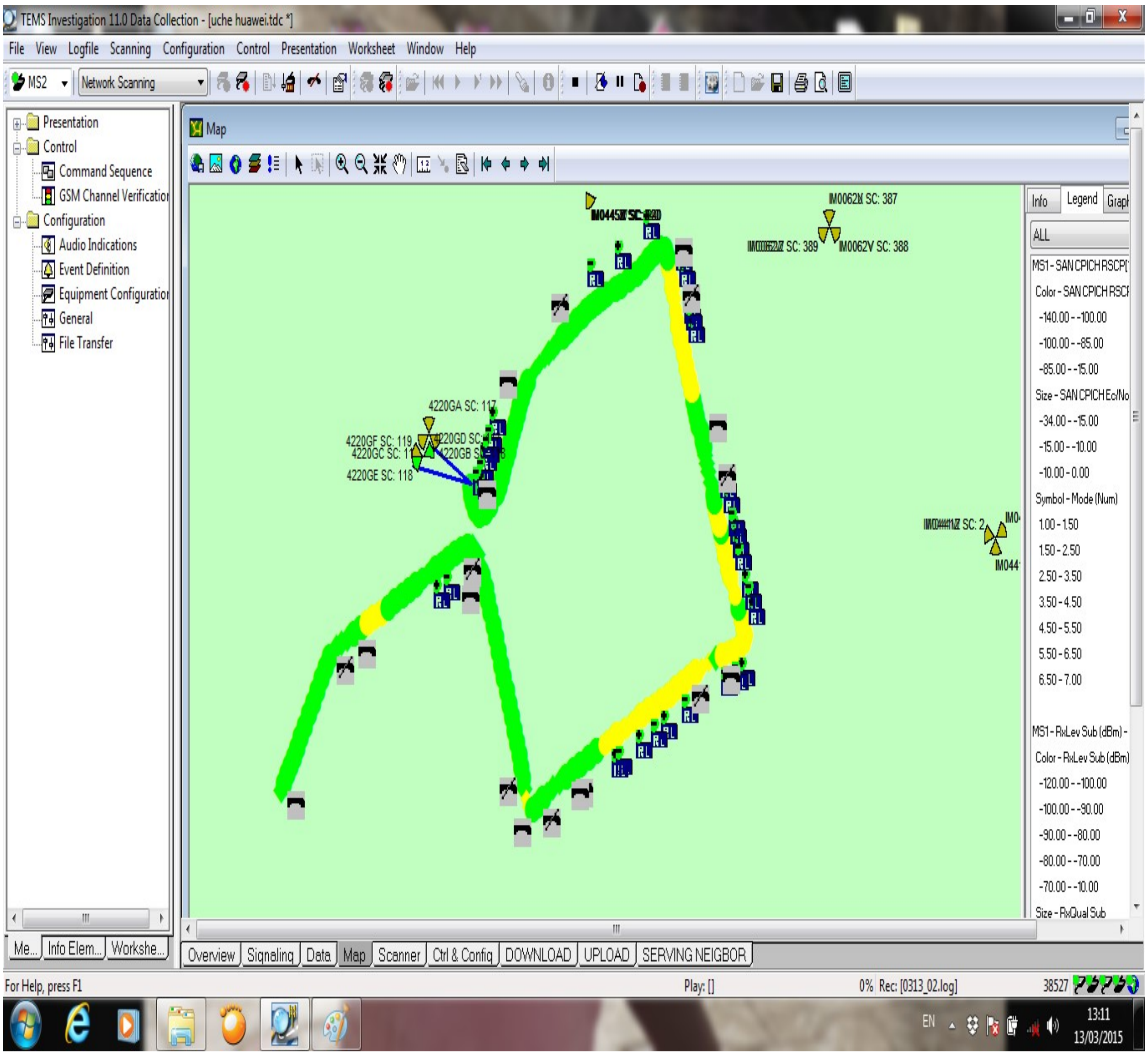

Fig. 3.12: The log of measurement along New Owerri zone.

Fig. 3.13 stands for the log of measurement along Owerri main town around concord hotel. The signal coverage across this area is also appropriate. This is also observed from the green colour of the signal path indicated on the diagram, with scanty patches of yellow path.

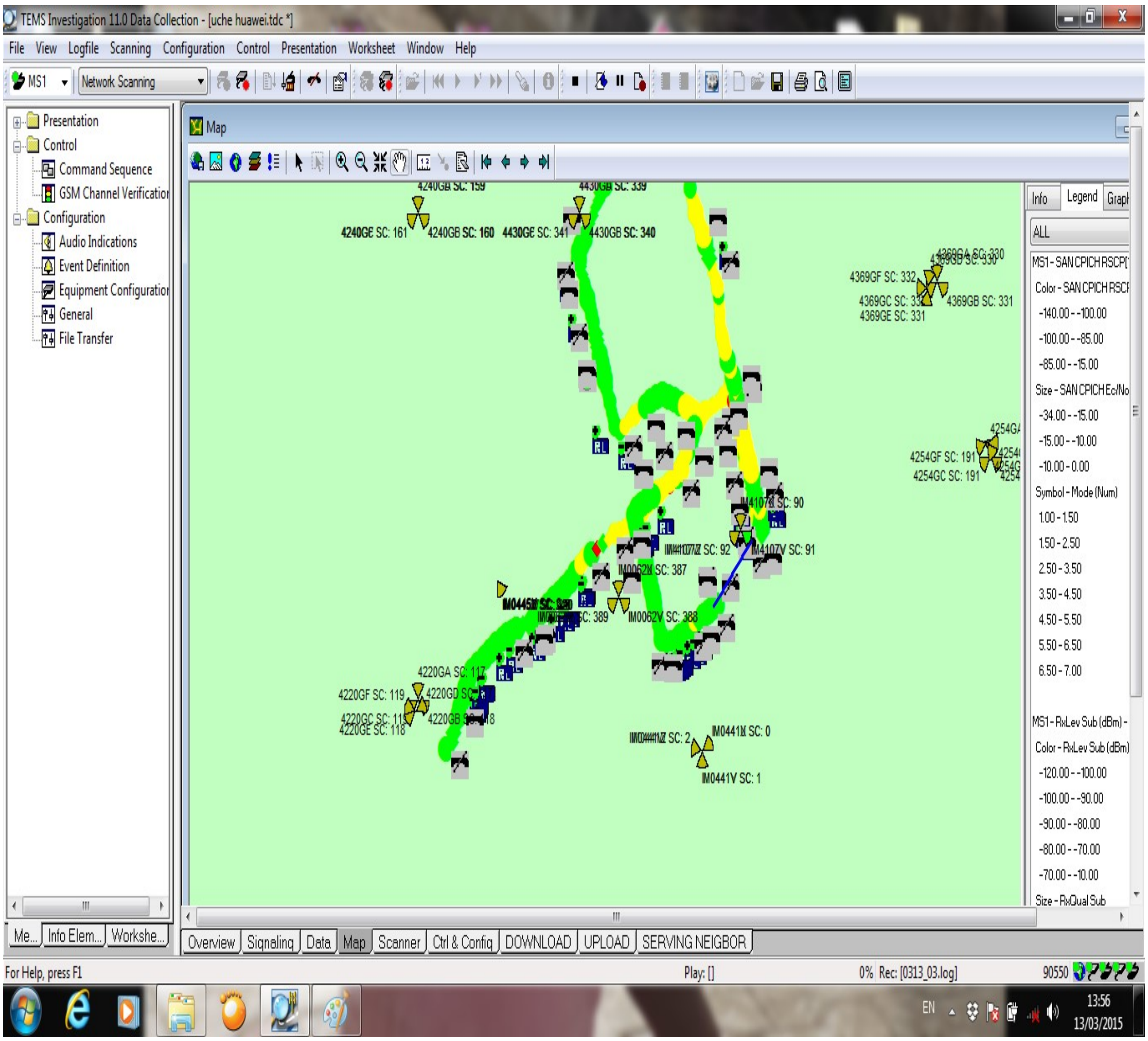

Fig. 3.13: The log of measurement along Owerri main town around concord hotel.

During the drive test, it was closely observed that the urban section of the area under study had a fair signal received level whereas the sub-urban area had poor signal received level. Therefore, this work resolved to generate separate path loss models that will describe the signal path loss at Owerri urban and sub-urban regions, so as to assist the network operators that are operating within the area or that may wish to site their network within the area ascertain the challenges in the study area, and then plan for the way to tackle them.

To develop the proposed models, the following under-listed parameters should be obtained accordingly.

i. the path loss exponent,
ii. reference path loss,
iii. predicted path losses, and
iv. standard deviation

In order to determine the Path Loss within Owerri metropolis, the data obtained from the field experiment on the path loss was collected and has its validity tested in order to derive an appropriate model that best predict the signal pathloss within Owerri metropolis. Tables 3.2 and 3.3 below indicate the median values of the measured Received Signal Levels (RSL) and corresponding values of measured Path Losses for specified distances, 0.1km≤ di ≤1.0km of the routes as generated from the analysis of actix software. The values did not ultimately follow a decreasing order with distance which could possibly be as a result of interferences from other transceiver stations other than the reference transmitting station at the start of the drive test.

Equation 3.1 below is the path loss model for predicting the Path loss. Substituting the values of the path loss exponent, reference path loss, and standard deviation that will be computed from the field measurements into equation 3.1 below gives the path loss model of Owerri metropolis.

$$Lp = Lp(d_0) + 10nxlog\left(\frac{d_i}{d_o}\right) + \delta \quad (3.1)$$

Where;

Lp=Path loss,

di = distance for i equal 1, 2, 3, …

Lp (do) = Reference path loss at a close-in distance of do

nx=Path loss exponent (Path Loss exponent shows the rate at which Path Loss varies with distance) and

δ=standard deviation, and

(Nwalozie, *et al.,* 2014)

Table 3.2: Median Receive Signal Levels (RSL) and corresponding measured path loss for Owerri urban.

Distance(km)	Median RSS (dBm)	Measured Path loss (dB)
0.10	-54	85
0.20	-57	96
0.30	-62	97
0.40	-97	158
0.50	-66	99
0.60	-83	113
0.70	-66	148
0.80	-76	109
0.90	-80	112
1.0	-81	113

Table 3.3: Median Receive Signal Levels (RSL) and corresponding measured path loss for Owerri sub-urban.

Distance(km)	Median RSS (dBm)	Measured Path loss (dB)
0.10	-58	91
0.20	-64	97
0.30	-76	115
0.40	-90	158
0.50	-87	137
0.60	-79	112
0.70	-87	120
0.80	-89	123
0.90	-84	120
1.0	-90	158

3.2.1 MODELING OF MEASURED PATH LOSS FOR OWERRI URBAN

3.2.1.1 Computation of the Path Loss Exponent for Owerri Urban:

The value of the path loss exponent, n_x for the Owerri Urban is calculated from the measured data using linear regression method as shown in Table 3.4.

Table 3.4: Computation of path loss exponent for Owerri urban using regression method.

Distance (d(km))	Xi =10*Log10(d/do)	Yi =PL(dB)	Xi^2	XiYi	Yi^2
0.10	0.0000	85	0.0000	0	7.225
0.20	3.0103	96	9.0619	288.9888	9.216
0.30	4.7712	97	22.7645	462.8064	9.409
0.40	6.0206	158	36.2476	951.2548	24.964
0.50	6.9897	99	48.8559	691.9803	9.801
0.60	7.7815	113	60.5519	879.3095	12.769
0.70	8.4510	148	71.4191	1250.748	21.904
0.80	9.0309	109	81.5572	984.3681	11.881
0.90	9.5424	112	91.0579	1068.7488	12.544
1.00	10.0000	113	100.0000	1130	12.769
SUM	65.5976	1130	521.5159	7708.2047	132.482

Where, do is the close in distance = 0.10km

Yi is the measured path loss

Path loss exponent for urban region,

$$nx_{urban} = \frac{\left(N\sum_{i=1}^{n}(XiYi) - \left(\sum_{i=1}^{n} Xi\right)\left(\sum_{i}^{n} Yi\right)\right)}{N\left(\sum_{i}^{n} Xi^2\right) - \left(\sum_{i=1}^{n} Xi\right)^2} \tag{3.2}$$

$$\text{nx}_{\text{urban}} = \frac{(10 * 7708.2047) - (65.5976) * (1130)}{10 * (521.5159) - (65.5976)^2}$$

$$= \frac{(77{,}082.047) - (74{,}781.264)}{(5215.159) - (4{,}303.0451)}$$

$$= \frac{(2{,}956.759)}{(912.1139)}$$

$$= 3.2417$$

$$\approx 3.24$$

3.2.1.2 Computation of the Reference Path Loss for Owerri urban:

The reference path loss is computed from Table 3.4 above using equation below

$$\text{Reference path loss, L (d)} = \frac{(\sum_{i=1}^{n} Y_i - nx \sum_{i=1}^{n} X_i)}{N} \tag{3.3}$$

Where nx is the path loss exponent for Owerri urban

$$\text{The reference path loss, L (d)} = \frac{1130 - 3.24 * 65.5976}{10} \tag{3.4}$$

$$\text{The reference path loss, L (d)} = \frac{917.4638}{10}$$

$$\mathbf{Lp\ (do) \approx 91.75}\ \boldsymbol{dB}$$

3.2.1.3 Computation of the standard deviation for Owerri urban

Standard deviation of the distribution can be evaluated via the mean squared error method as shown below;

$$e(nx) = \sum_{i=1}^{k} [L_m(d) - L_p(d)]^2 \tag{3.5}$$

Where;

Lm = measured path loss

Lp = predicted path loss

To obtain the standard deviation, the values for the measured path losses and predicted path losses shown in Table 4.8 were substituted in equation 3.5, in order to get the Mean Squared Errors (MSE) of the system. This is as represented in equation (3.6) below.

$$\text{The sum of Mean Squared Error}, e(nx) = \quad 3{,}833.5248 \tag{3.6}$$

Hence, the standard deviation is calculated using equation 3.8 below.

$$\delta = \sqrt{\sum \frac{[(L_m)-(L_p)]^2}{N}} \tag{3.7}$$

Where: $\delta =$ Standard deviation, L_m= measured path loss, = predicted path loss,

N=total number of data points (10)

$$\delta = \left[\frac{3{,}833.5248}{10}\right]^{\frac{1}{2}} \tag{3.8}$$

$$\delta = \left[\pm 383.35248\right]^{\frac{1}{2}} \tag{3.9}$$

$$\boldsymbol{\delta = 19.58\ \mathrm{dB}}$$

The standard deviation is 19.58 dB.

Thus, the predicted path loss model for the 2.1GHz 3G network in Owerri urban under investigation is as shown in equation (3.10) by substituting the reference path loss , path loss exponent and standard deviation into equation (3.1):

$$\mathrm{Lp} = 91.75 + 32.4 * \log_{10}\left(\frac{d}{d_o}\right) + 19.58\mathrm{dB} \tag{3.10}$$

$$Lp = 111.33\,dB + 32.4\log\left(\frac{d_i}{d_o}\right) \quad (3.11)$$

$$\mathbf{Lp = 111.33\,dB + 32.4\log(D)} \quad (3.12)$$

Where,

$$D = \frac{d_i}{d_o} \quad (3.13)$$

To obtain the Mean Squared Error, e, of the distribution, equation 3.15 is used;

$$e = \frac{\delta}{N} \quad (3.14)$$

(Nwalozie *et al*, 2014)

$$e = \frac{19.58}{10} \approx 1.96$$

3.2.2 MODELING OF MEASURED PATH LOSS FOR OWERRI SUB-URBAN

3.2.2.1 Computation of the Path Loss Exponent for Owerri sub-urban:

The value of the path loss exponent, nx, for the Owerri suburban is calculated from the measured data using linear regression as shown in Table 3.5.

Table 3.5: Computation of path loss exponent for Owerri sub-urban using regression method.

Distance (d(km))	Xi =10*Log10(d/do)	Yi =PL(dB)	Xi^2	XiYi	Yi^2
0.10	0.0000	91	0.0000	0	8.281
0.20	3.0103	97	9.0619	291.9991	9.409
0.30	4.7712	115	22.7645	548.688	13.225
0.40	6.0206	158	36.2476	951.2548	24.964
0.50	6.9897	137	48.8559	957.5889	18.769
0.60	7.7815	112	60.5519	871.528	12.544
0.70	8.4510	120	71.4191	1014.12	14.400
0.80	9.0309	123	81.5572	1110.8007	15.129
0.90	9.5424	120	91.0579	1145.088	14.400
1.00	10.0000	158	100.0000	1580	24.964
SUM	65.5976	1231	521.5159	8471.0675	156.085

Where, do is the close in distance = 0.10km

Yi is the measured path loss

The path loss exponent for Owerri sub-urban is obtained using equation 3.2 above:

$$n_{suburban} = \frac{(10 * 8471.0675) - (65.5976) * (1231)}{10 * (521.5159) - (65.5976)^2}$$

$$= \frac{(84{,}710.675) - (80{,}750.6456)}{(5215.159) - (4{,}303.0451)}$$

$$= \frac{(3{,}960.0294)}{(912.1139)}$$

$$= 4.3416$$

≈ 4.34

3.2.2.2 Computation of the Reference Path Loss for Owerri Sub-urban:

The reference path loss is computed from Table 3.5 using equation (3.3)

$$\text{The reference path loss, Lp (do)}_{\text{ sub-urban}} = \frac{1231 - 4.34 * 65.5976}{10} \quad (3.15)$$

$$\text{The reference path loss, Lp (do)}_{\text{ sub-urban}} = \frac{946.3064}{10}$$

$$\textbf{Lp (do)} \approx \mathbf{94.63}\ \boldsymbol{dB}$$

3.2.2.3 Computation of the standard deviation for Owerri Sub-urban:

Standard deviation of the distribution can be evaluated using the mean squared error method of equation (3.5);

To obtain the standard deviation, the values for the measured path losses and predicted path losses shown in Table 4.9 were substituted in equation 3.5, in order to get the Mean Squared Errors (MSE) of the system. This is as substituted in equation below.

$$\text{The sum of Mean Squared Error}, e(nx) = 2{,}829.6148 \quad (3.16)$$

Also, the standard deviation is calculated using equation 3.7 above.

$$\delta = \left[\frac{2{,}829.6148}{10}\right]^{\frac{1}{2}} \quad (3.17)$$

$$\delta = [\pm 282.96]^{\frac{1}{2}}$$

$$\delta = 16.82 \text{ dB}$$

The standard deviation is $16.82\ dB$.

Thus, the predicted path loss is as shown in equation (3.18) by substituting the obtained reference pathloss, pathloss exponent and standard deviation for Owerri sub-urban into equation (3.1):

$$Lp = 94.63 + 43.4 * \log_{10}\left(\frac{d}{d_0}\right) + 16.82dB \quad (3.18)$$

$$Lp = 111.45\ dB + 43.4 \log\left(\frac{d_i}{d_0}\right) \quad (3.19)$$

$$Lp = 111.45\ dB + 43.4 \log(D) \quad (3.20)$$

Where,

$$D = \frac{d_i}{d_o} \quad (3.21)$$

To obtain the Mean Squared Error, e, of the distribution, equation 3.14 is used;

$$e = \frac{16.82}{10} \approx 1.68$$

3.3 CALCULATION OF PATH LOSS FROM THE EXISTING MODELS

Two (2) existing models were considered for modeling the Owerri Metropolis 3G network: Hata model, and COST 231 model, with distance in Km, frequency in MHz, the antenna height in meters.

3.3.1 Calculation of Hata Path Loss model for Owerri urban

Using the transmission parameters given in Table 3.1 and equation (2.3), the Hata model is computed as shown below:

$$PL(Hata)_{urban} = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(h_b) - a(h_m) + (44.9 - 6.55log_{10}(h_b))log_{10}(d) + c_M$$

(3.22)

The correction factor for the receiving antenna height is calculated using equation (3.23),

a(hm) = (1.11*$\log_{10}$ (2100) - 0.7) 1.5 - (1.56* $\log_{10}$ (2100) - 0.8) (3.23)

The c_m for the environment is given as 0dB. Therefore, by substituting equation (3.23), into equation (3.22), the path loss for this environment is calculated as,

$$PL(Hata)_{urban} = 69.55 + 26.16log_{10}(2100) - 13.82log_{10}(35) - (1.11 * \log 10\ (2100) - 0.7)\ 1.5 - (1.5 * \log 10\ (2100) - 0.8) + (44.9 - 6.55log_{10}(35))log_{10}(d)$$

(3.24)

$$PL(Hata)_{urban} = 69.55 + 86.91 - 21.34 - 4.4815 - 4.1833 + (44.9 - 10.11)log_{10}(d)$$

(3.25)

$$PL(Hata)_{urban} = 126.46 + 34.79log_{10}(d) \quad (3.26)$$

3.3.1 Calculation of Hata Path Loss model for Owerri sub-urban

For sub-urban area, the path loss is obtained from equation 2.5 thus;

$$PL\text{Hata (suburban)} = PL\text{Hata (urban)} - (2(\log 10(f/28))^2 - 5.4$$

(3.27)

Given that;

$$PL(Hata)_{urban} = 126.46 + 34.79log_{10}(d) \quad (3.28)$$

$$PL(Hata)_{suburban} = 126.46+34.79log_{10}(d) - (2(\log 10(f/28))^2 - 5.4)$$

(3.29)

$$PL(Hata)_{suburban} = 126.46+34.79log_{10}(d) - 1.6317 \text{ dB} \quad (3.30)$$

$$PL(Hata)_{suburban} = 124.83+34.79log_{10}(d) \quad (3.31)$$

3.3.2 COST 231 Extension of Hata Model for Owerri urban:

From equation (2.16) the COST 231 Path loss equation is given by

$$PL(COST\ 231)_{urban} = 46.3 + 33.9log(f_c) - 13.82log(h_b) - a(h_m) + [44.9 - 6.55log(h_b)]log_{10}(d) + c_M$$

(3.32)

Using the transmission parameters given in Table 3.1 and equation for the correction factor below, the COST 231model is computed as shown below:

$$a(h_m)=3.20(\log(11.75*1.5))^2-4.97 \quad (3.33)$$

The COST 231path loss for the Owerri urban is determined by substituting equation (3.33) with the c_M of 3dB for urban into equation (3.32) as shown in equation (3.34),

$$PL(COST\ 231)_{urban} = 46.3 + 33.9log(f_c) - 13.82log(h_b) - [3.20(\log(11.75*1.5))^2 - 4.97] + (44.9 - 6.55log(h_b))log_{10}(d) + c_M$$

(3.34)

$PL(COST\ 231)_{urban}$= 46.3 + 33.9 * $\log_{10}$ (2100) - 13.82 * $\log_{10}$ (35) – [3.2 ($\log_{10}$ (11.75x1.5))^2- 4.97] + [44.9 - 6.55*$\log_{10}$(35)] $\log_{10}$ (d)+3dB

(3.35)

$PL(COST\ 231)_{urban}$= 46.3 + 112.62 – 21.34 – [4.97 - 4.97] + [34.7863] $\log_{10}$ (d)+3dB (3.36)

$PL(COST\ 231)_{urban}$=140.58+34.7863$\log_{10}$ (d) (3.37)

$PL(COST\ 231)_{urban}$=140.58+34.79 $\log_{10}$(d) (3.38)

3.3.2 COST 231 Extension of Hata Model for Owerri sub-urban:

From equation (2.16) the COST 231 Path loss equation is given by

$$PL(COST\ 231)_{suburban} = 46.3 + 33.9log(f_c) - 13.82log(h_b) - a(h_m) + [44.9 - 6.55log(h_b)]log_{10}(d) + c_M \quad (3.39)$$

Using the transmission parameters given in Table 3.1 and equation for the correction factor below, the COST 231model is computed:

a(hm) =(1.11*log10 (2100) - 0.7) 1.5 - (1.5*log10 (2100) - 0.8) (3.40)

The COST 231 path loss for the Owerri metropolis is determined by substituting equation (3.40) with the correction factor of 0dB for Sub-urban into equation (3.39) as shown in equation (3.41),

$$PL(COST\,231)_{suburban} = 46.3 + 33.9log(f_c) - 13.82log(h_b) - [(1.11 * \log10\,(2100) - 0.7)\,1.5 - (1.5 * \log10\,(2100) - 0.8)] + \left(44.9 - 6.55log(h_b)\right)log_{10}\,(d) + c_M$$

(3.41)

$$PL(COST\,231)_{suburban} = 46.3 + 33.9 * \log_{10}(2100) - 13.82 * \log_{10}(35) - [(1.11*\log10\,(2100) - 0.7)\,1.5 - (1.5*\log10\,(2100) - 0.8)] + [44.9 - 6.55*\log_{10}(35)]\log_{10}(d) + 0dB \quad (3.42)$$

$$PL_{COST231}\,(suburban) = 46.3 + 112.62 - 21.34 - [0.297] + [34.7863]\log_{10}(d) + 0dB \quad (3.43)$$

$$PL(COST\,231)_{suburban} = 137.28 + 34.7863\log_{10}(d)$$

$$PL(COST\,231)_{suburban} = 137.28 + 34.79\log_{10}(d) \quad (3.44)$$

CHAPTER FOUR

RESULTS AND DISCUSSION

Simulations were carried out on the measured values obtained during the drive test conducted on the major streets/roads of the Owerri metropolis. These major routes include: Akanchawa- world bank-new Owerri road, Imo state government house-works layout-okigwe road, wetheral road-Royce- World Bank road- Tetlow road, Owerri- Obinze express road, and FUTO - Ihiagwa. The path loss and the received signal level along these mentioned routes were simulated and plotted as shown in Figs. 4.1 to 4.10 using the MatLab codes shown in the Appendices A to H. The proposed models for the Owerri urban and Owerri sub-urban are shown in figures 4.11 and 4.12 respectively using the MatLab codes in Appendices I and J.

To give room for comparison, the path loss models: Hata model and COST 231 model of equations (2.3) and (2.16) were also simulated using MatLab software tools. These models were used to compare the proposed models for Owerri urban and Owerri sub-urban respectively.

Fig. 4.1 is the plot of the signal path loss as measured along Akanchawa- new Owerri-world bank road during the drive test.

There was a gradual but irregular change of signal loss with distance up till distance of about 0.4km before the sharp rise in the pathloss again. Between the distances of about 0.42km to 0.6km, the pathloss was almost constant at about 158dB. This irregular behavior could be attributed to interference of intervening transceiver within, and lack of proper signal handover.

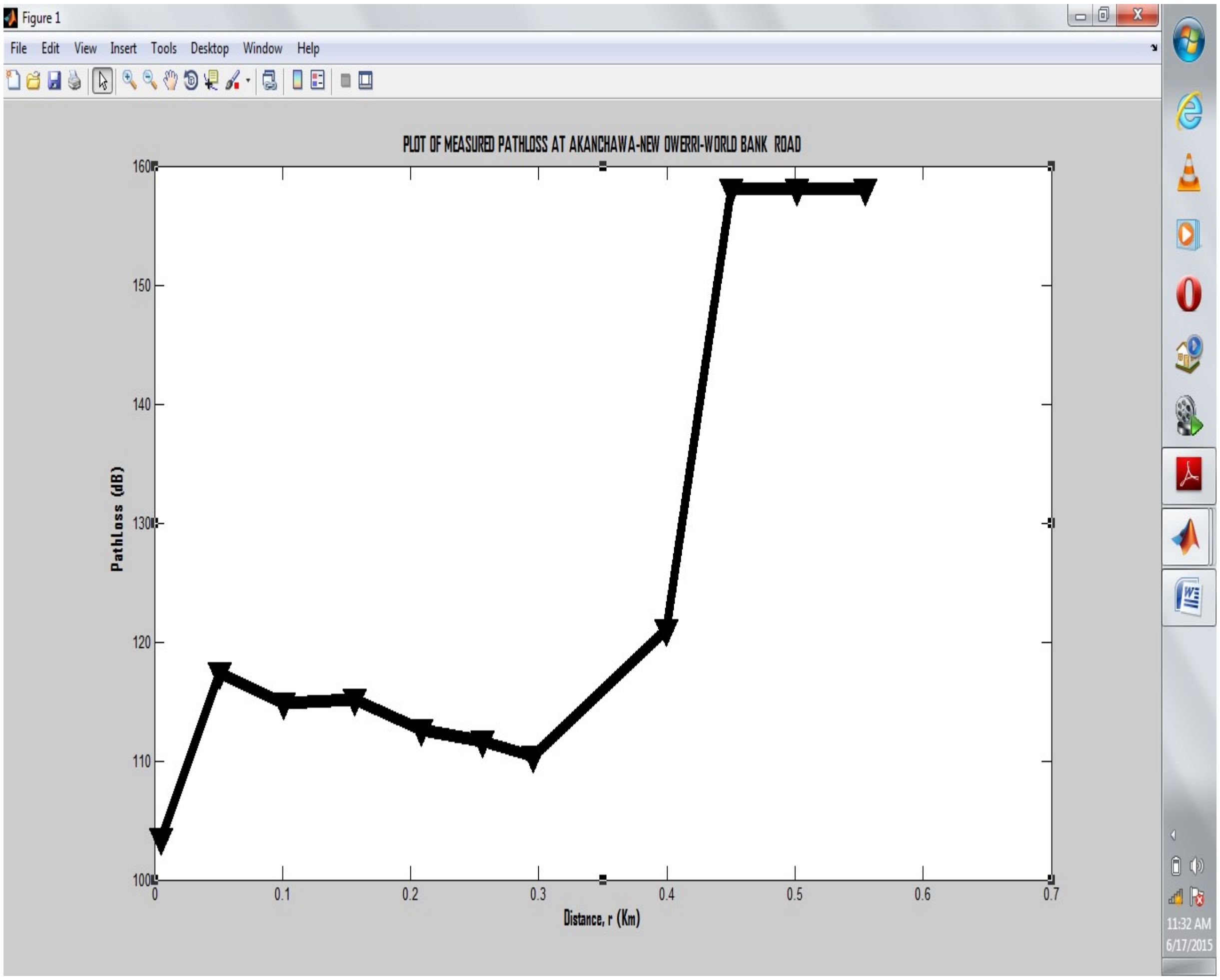

Fig. 4.1: Akanchawa-New Owerri-World Bank Pathloss.

Fig. 4.2 represents the corresponding plot of the received signal level (RSL) along Akanchawa- new Owerri-world bank road.

The received signal level decreased constantly with distance up till 0.05km and decreases again from distance of about 0.3km after some irregular variation of the received level within distance range of about 0.05km to 0.3km.

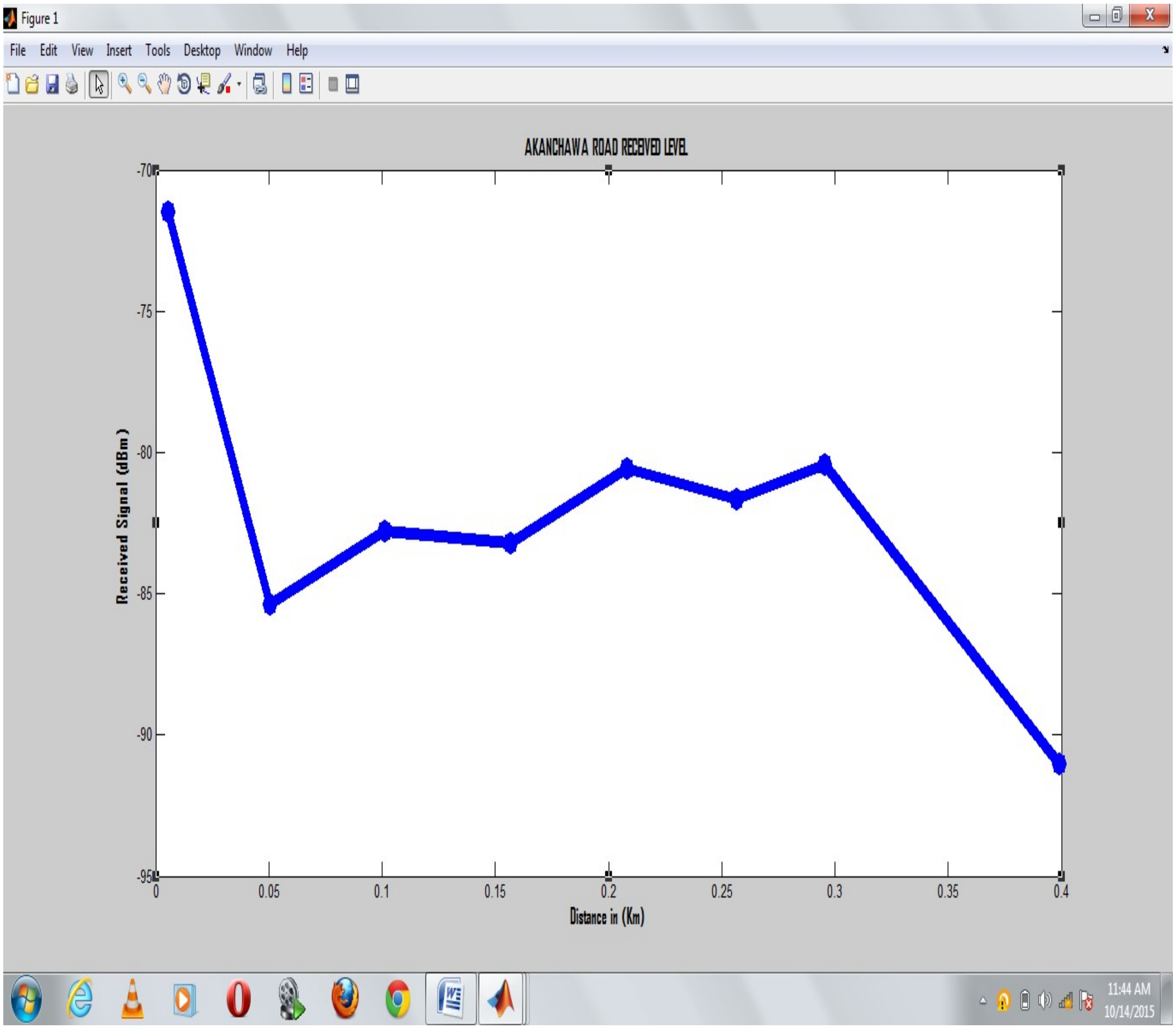

Fig. 4.2: Akanchawa-New Owerri-World Bank Received Level.

Fig. 4.3 represents the plot of the measured signal path loss along Owerri government house-works layout-okigwe road. . The MatLab program for this plot is as shown in Appendix C.

The pathloss indicates a gradual increase with distance uptill about 0.3km and pathloss of about 125dB. After this point, there was irregular but consistent increase in distance without a corresponding increase of the path loss. This could be attributed to the interference of other transceiever stations along the route.

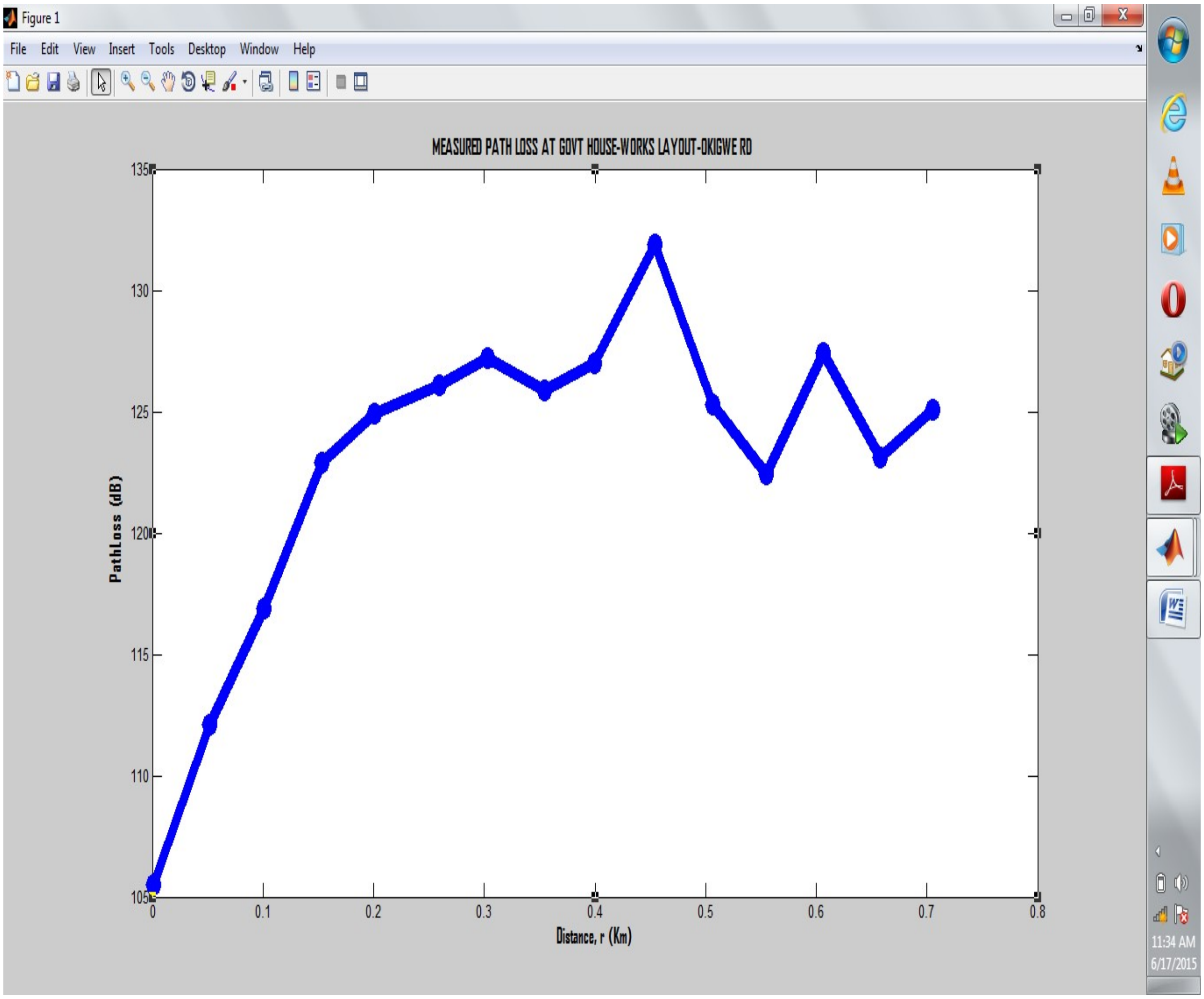

Fig. 4.3: Govt House-Works Layout-Okigwe Rd Pathloss.

Fig. 4.4 represents the corresponding plot of the received signal level (RSL) along the Govt House-Works Layout-Okigwe route. The MatLab program for this plot is as shown in appendix D. The plot of received signal level across the government house-works layout-okigwe road shows a gradual decrease of received signal level with distance up till about a distance of 0.15km and corresponding received level of about -95dBm. After this stage, there was also a gradual and irregular increase of distance at a fairly constant received signal level.

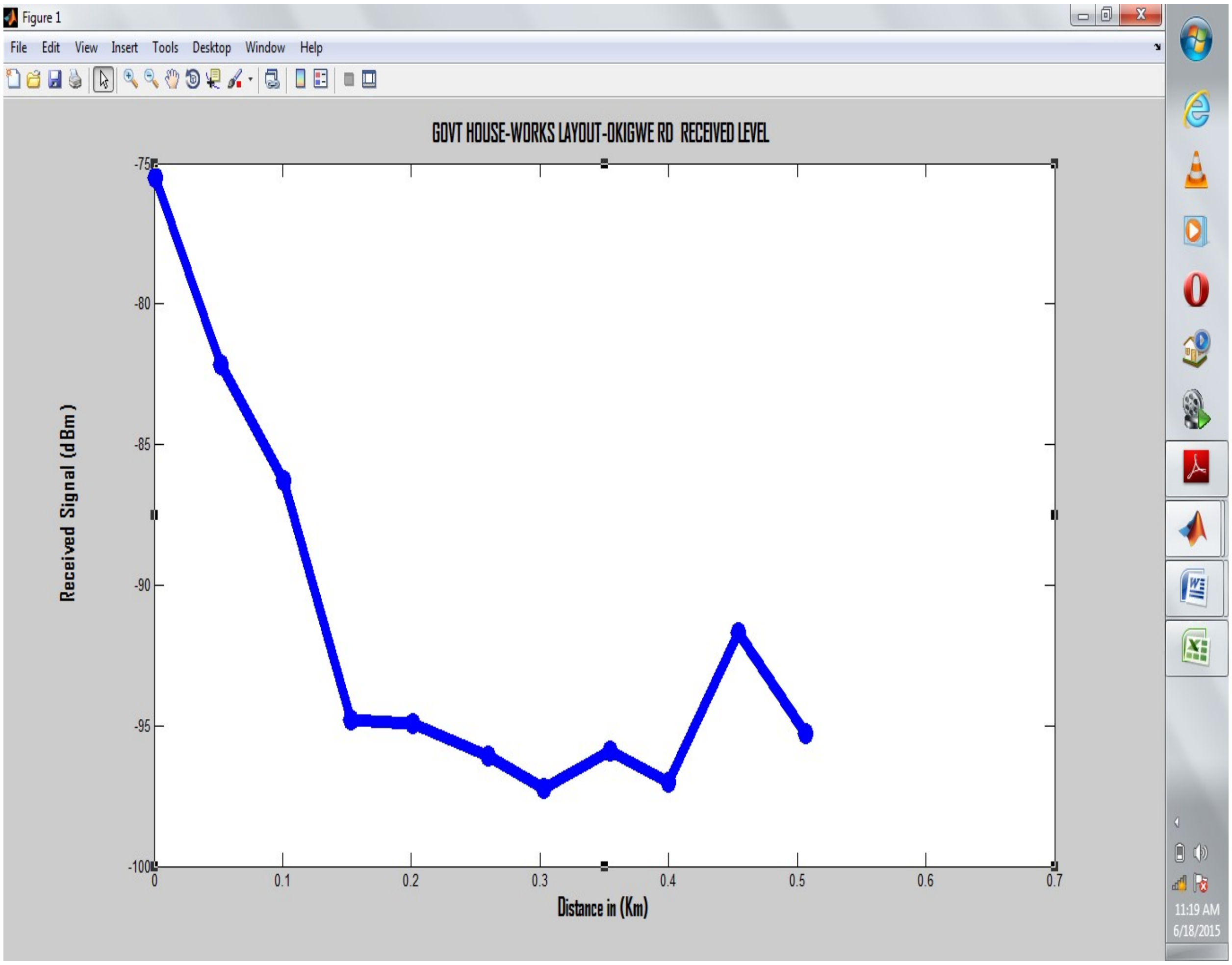

Fig. 4.4: Govt House-Works Layout-Okigwe Rd Received Level.

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Fig. 4.5 stands for the Cartesian plot of the measured pathloss, which was carried out along Obinze-Owerri Expressway. The Matlab program for this plot is as shown in appendix E.

The pathloss across Obinze-Owerri express way reveals a very rapid increase and decrease of pathloss across the route with distance. The pathloss was about 110dB at a distance of about 0.2km, and 65dB at a distance of about 0.4km. A rapid change in pathloss is witnessed within this little change in distance. This could be as a result of signal handover among the transceiver stations within the route.

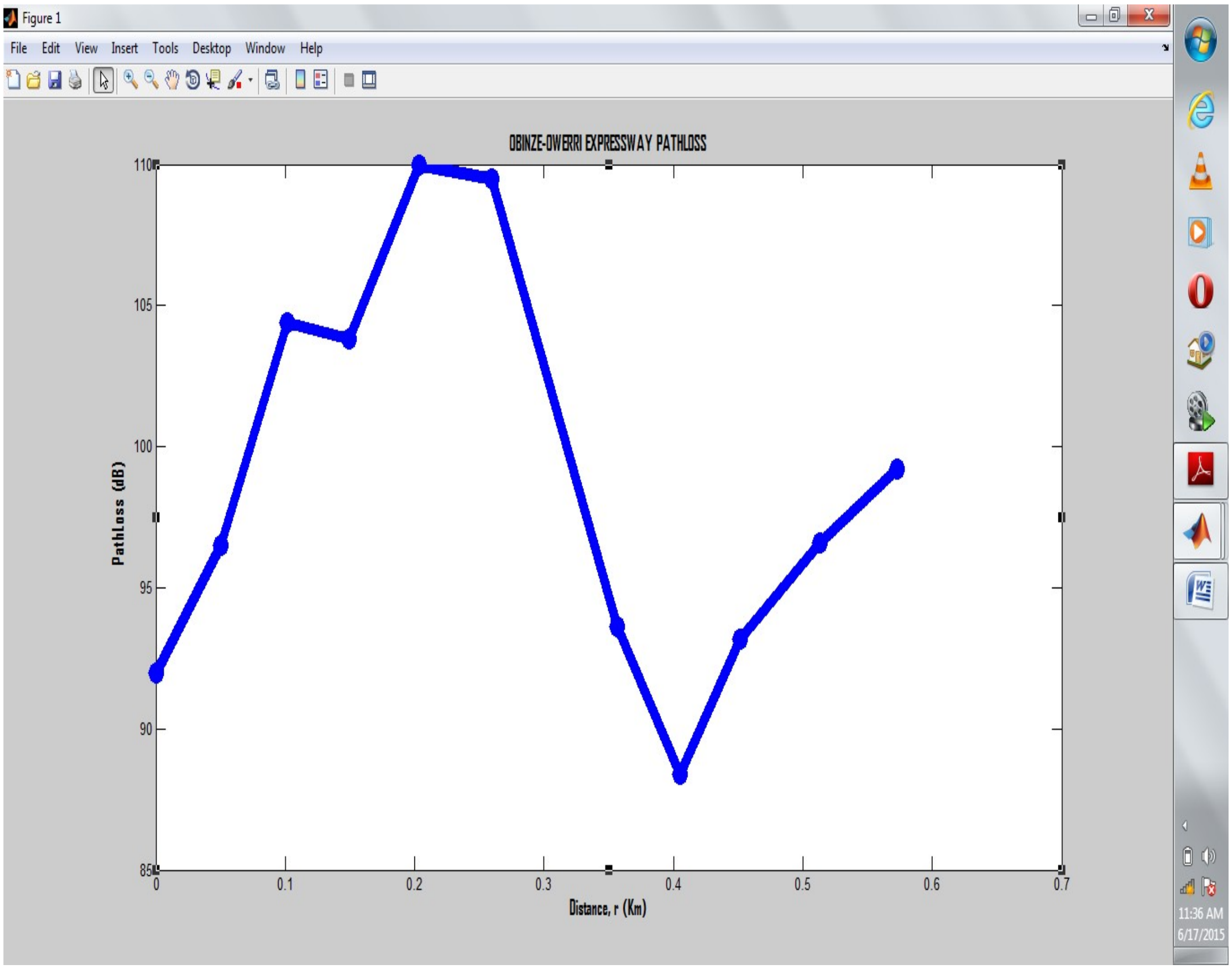

Fig. 4.5: Obinze-Owerri Expressway Pathloss.

Fig. 4.6 represents the corresponding plot of the received signal level (RSL) along the same route. The Matlab program for this plot is as shown in appendix F.

The received signal level along Obinze-Owerri express way indicates similar changes like its pathloss counterpart. There was rapid flip and flop of the received signal level within the route, and this could be attributed to the influence of other transceiver stations as observed from the log.

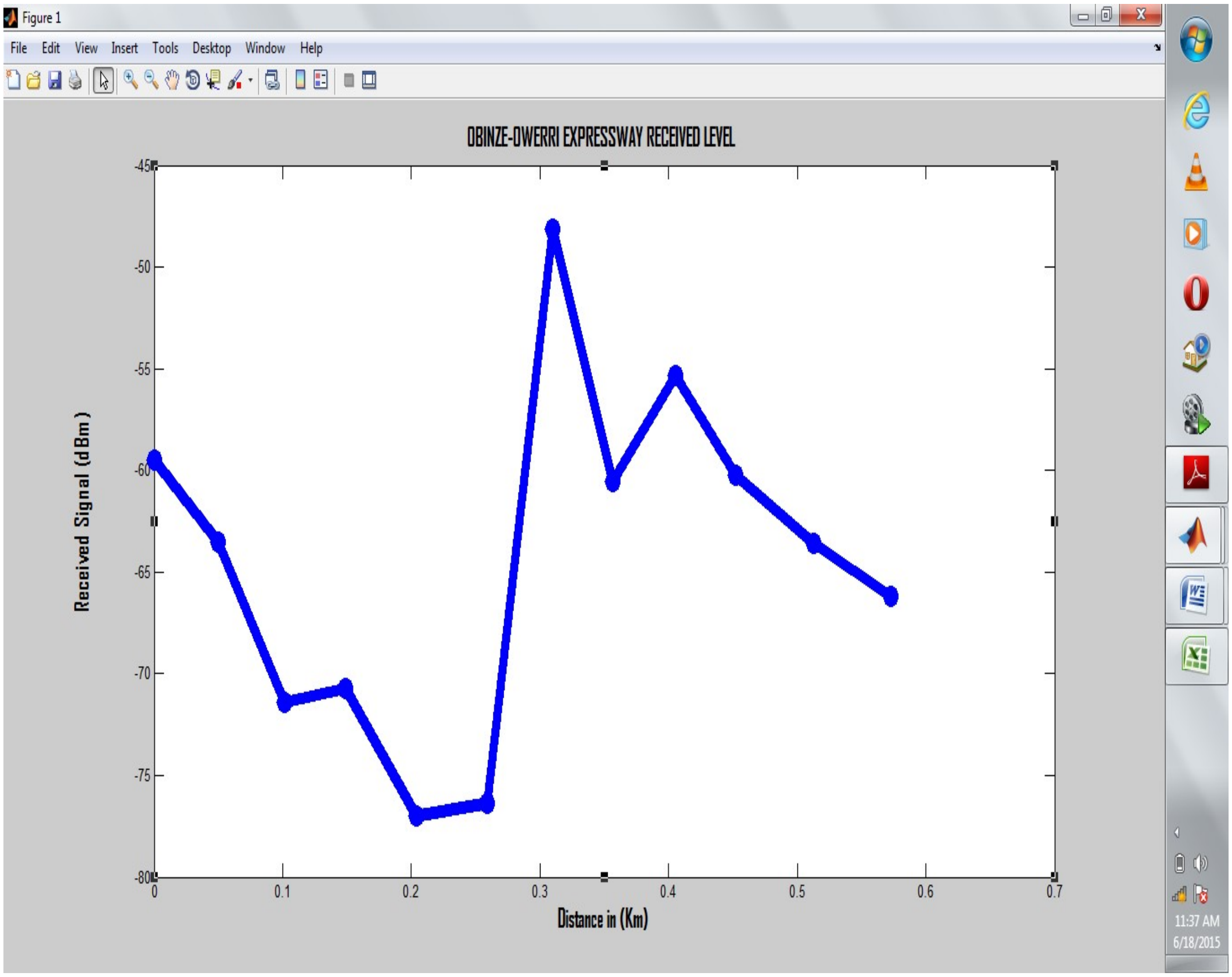

Fig. 4.6: Obinze-Owerri Expressway Received Level.

Fig. 4.7 is the plot of the pathloss experienced along Wetheral- Royce- Nekede- Bank road-Tetlow roads. . The Matlab program for this plot is as shown in appendix G.

There is a very little increase of path loss against distance in the log shown in this figure. This shows a very small rise in path loss with increase of distance, and this scenario could be witnessed in an area where there is a good quality of signal coverage.

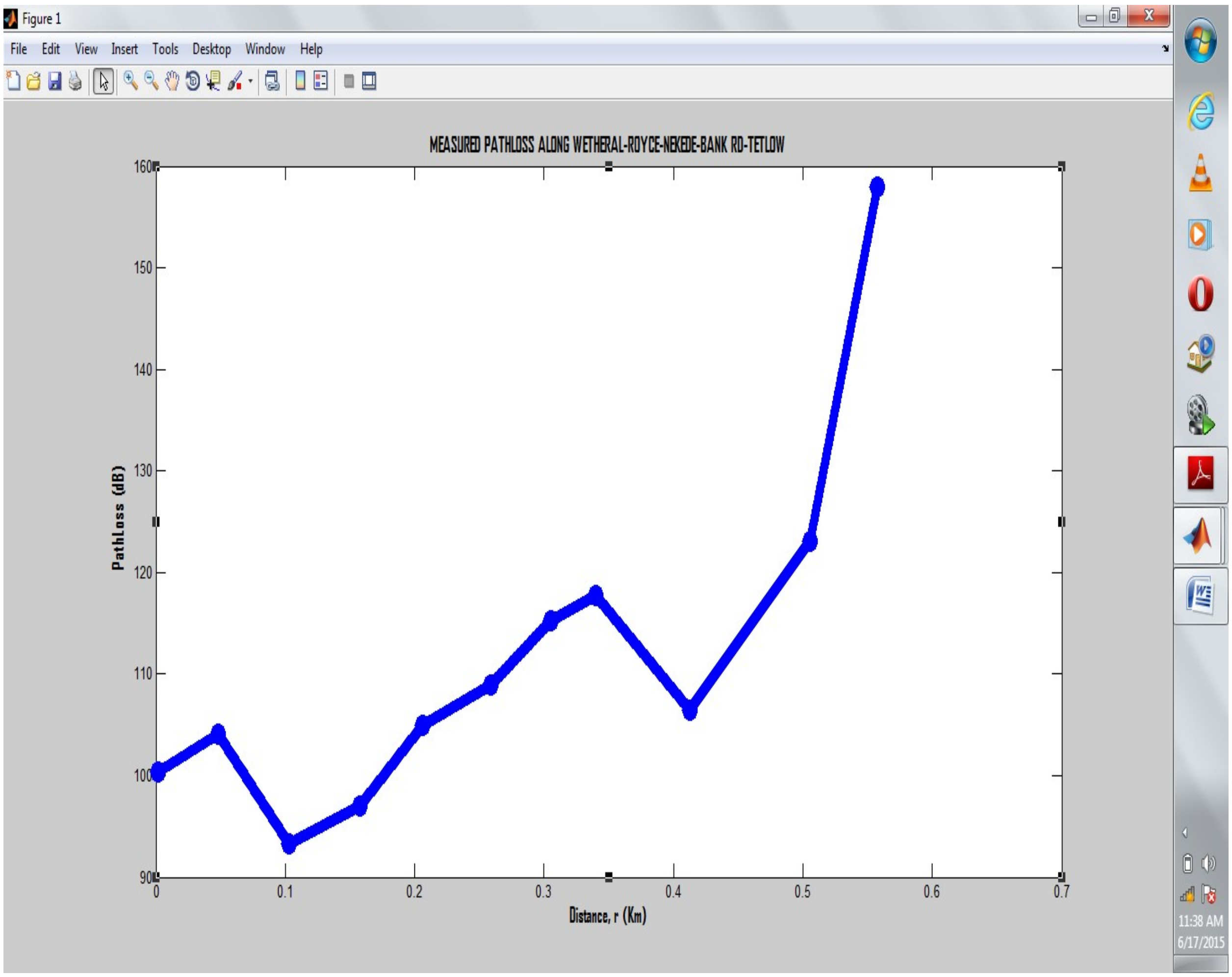

Fig. 4.7: Wetheral-Royce-Nekede-Bank Rd-Tetlow Path loss.

Fig. 4.8 represents the corresponding plot of the received signal level (RSL) along the route. . The MatLab program for this plot is as shown in Appendix H.

The received signal level along this route indicates a rapid increase of signal level with a little change in the distance. The sharp fall in the received level at a point may be as a result of improper signal handover among the cells.

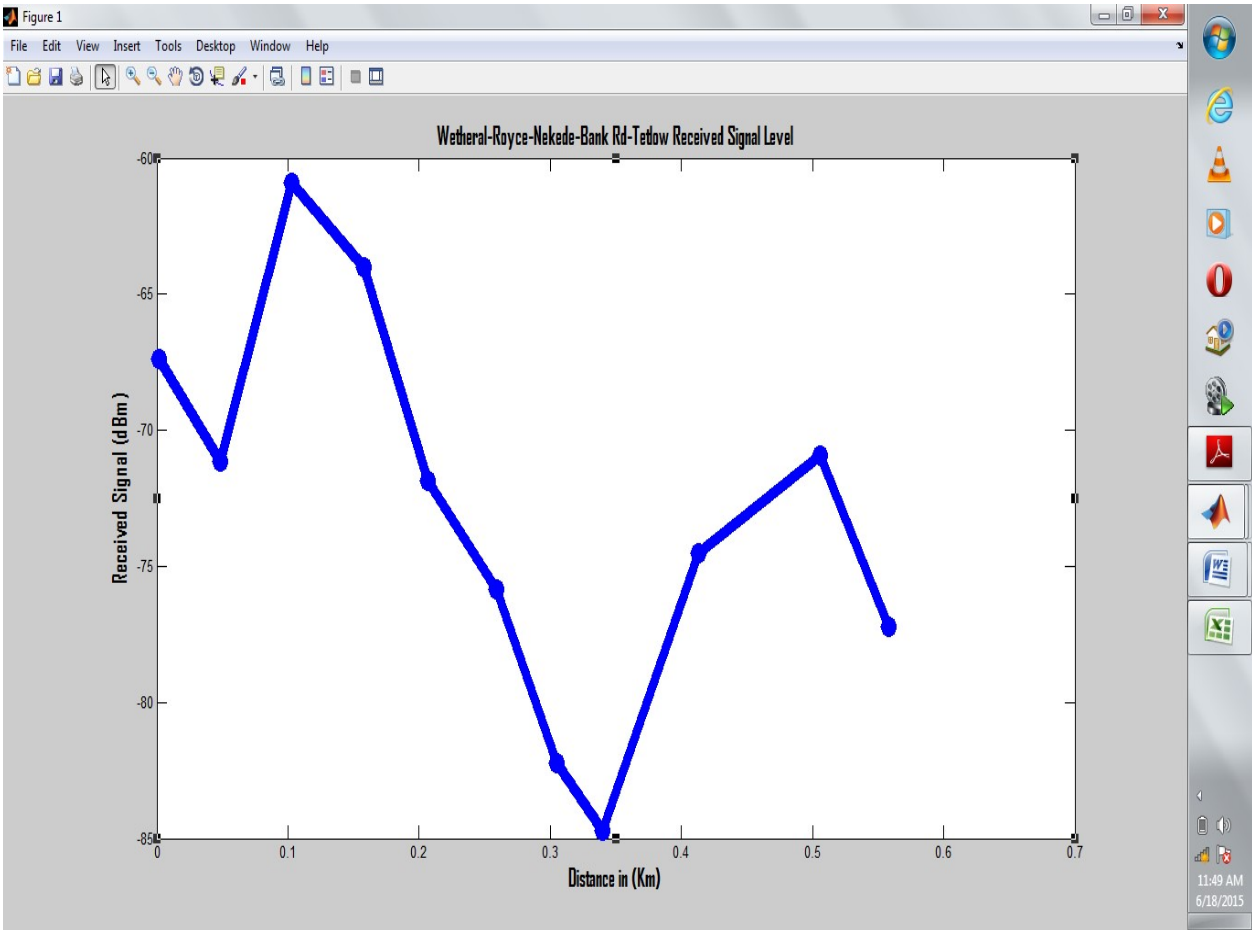

Fig. 4.8: Wetheral-Royce-Nekede-Bank Rd-Tetlow Received Level.

Fig. 4.9 denotes the Cartesian plot of the pathloss experienced within FUTO.

This route indicates appreciable increase of signal loss along the path. At a distance of about 0.43km to 0.47km, the path loss rose from about 135dB to about 158dB. It indicates poor level in the received signal level.

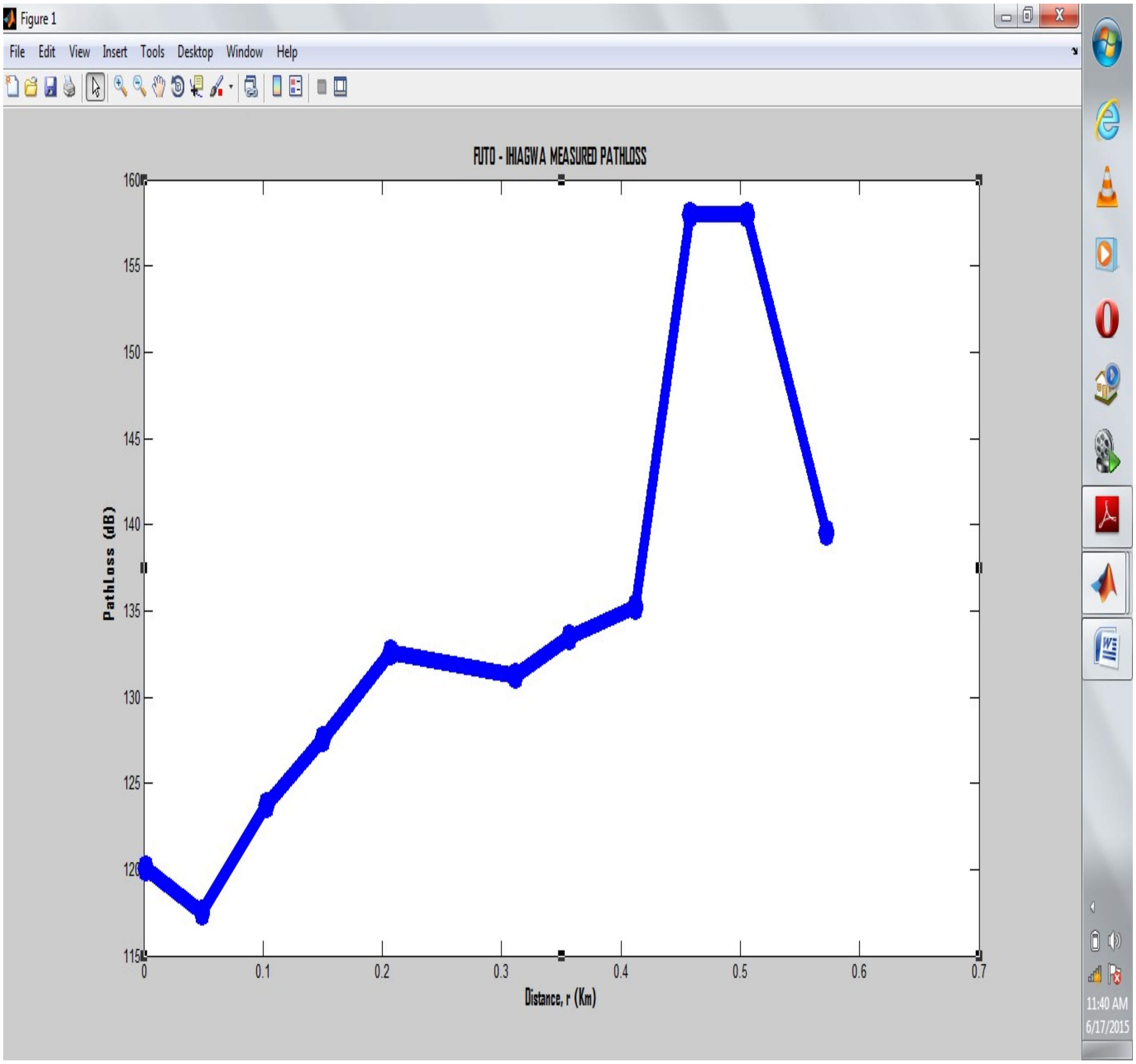

Fig. 4.9: The Plot of Path loss experienced along FUTO – Ihiagwa Road.

Fig. 4.10 represents the corresponding plot of the received signal level (RSL) along FUTO – Ihiagwa Road.

The log shows that the received signal level decreases irregularly but constantly with distance up till about 0.3km before the received level rise and falls again with distance.

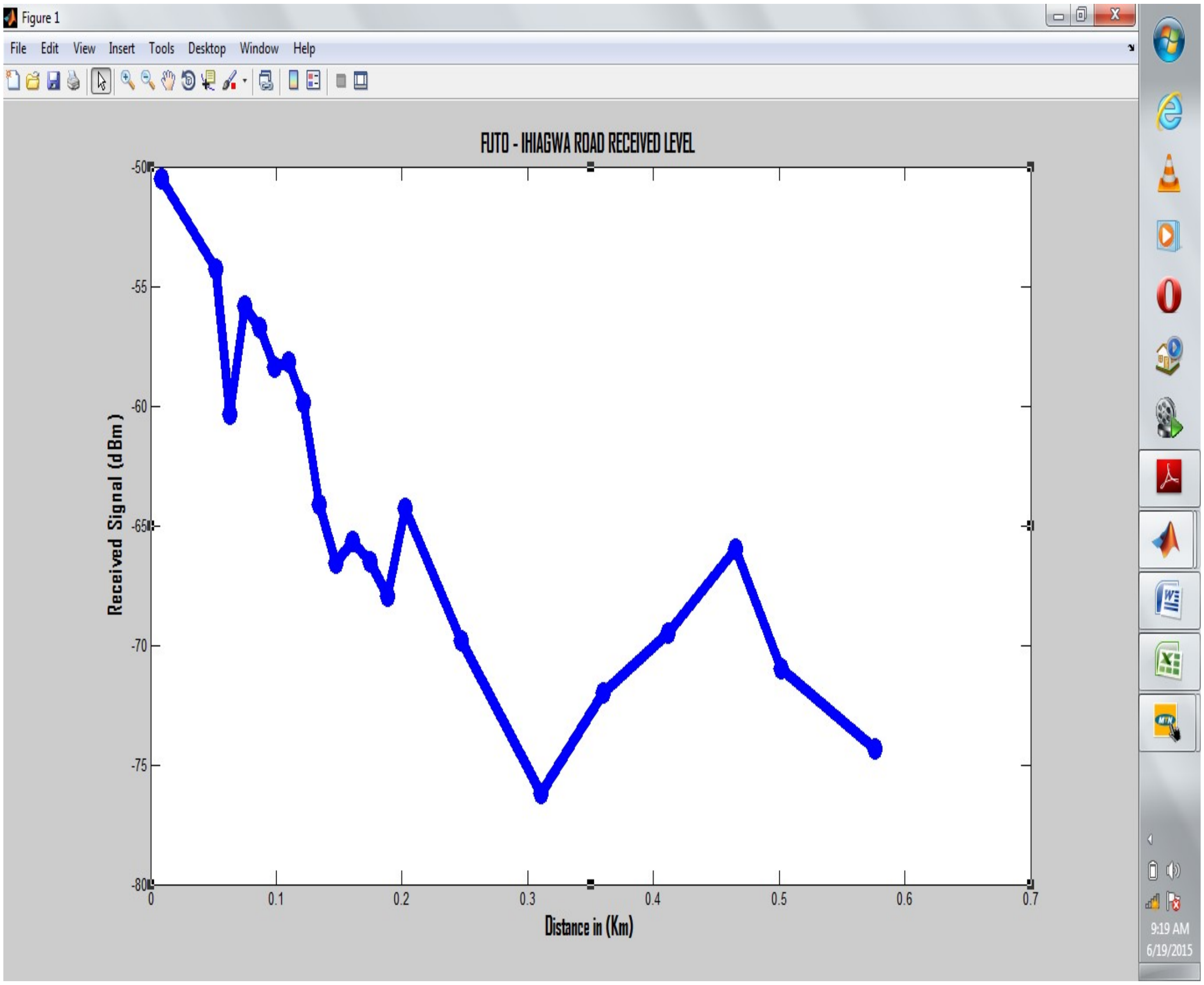

Fig. 4.10: FUTO – Ihiagwa Road Received Signal Level.

Figs. 4.1 to 4.10 clearly showed from their slopes that while FUTO environment indicated the worst case of signal degradation, Wetheral- Royce- Nekede- Bank road-Tetlow roads showed the best quality of signal coverage.

Table 4.1 is used in computing the Mean Squared Error and standard deviation.

Table 4.1: Mean Squared Error calculation for Owerri urban.

Distance(km)	Measured Path loss $L_m(d)$ (dB)	Predicted path loss $L_p(d)$ (dBm)	$[L_m(d) - L_p(d)]^2$
0.10	85	91.7500	45.5625
0.20	96	101.5033	30.2863
0.30	97	107.2086	104.2155
0.40	158	111.2566	2184.9454
0.50	99	114.3965	237.0522
0.60	113	116.9619	15.6967
0.70	148	119.1310	833.4192
0.80	109	121.0099	144.2377
0.90	112	122.6673	113.7913
1.00	113	124.1498	124.3180

Table 4.2 is also used in computing the Mean Squared Error and standard deviation for the Owerri sub-urban area. The last column of the table is computed using equation (3.6) above.

Table 4.2: Mean Squared Error calculation for Owerri sub-urban.

Distance(km)	Measured Path loss $L_m(d)$ (dB)	Predicted path loss $L_p(d)$ (dBm)	$[L_m(d) - L_p(d)]^2$
0.10	91	94.6300	13.1769
0.20	97	107.6946	114.3745
0.30	115	115.3369	0.1135
0.40	158	120.7592	1,386.8772
0.50	137	124.9651	144.8388
0.60	112	128.4015	269.0092
0.70	120	131.3070	127.8483
0.80	123	133.8239	117.1568
0.90	120	136.0439	257.4067
1.00	158	138.0297	398.8129

Fig. 4.11 is the Plot of Proposed Model for the Path loss in Owerri urban. The plot showed a gradual but persistent rise in path loss with increase of distance. At distance of 0.1km, 0.5km, 1km; the path losses were 111.3300 dB, 133.9765 dB, and 143.7298 dB respectively.

The proposed model indicates a gradual increase in path loss with distance measured in Km. The MatLab program for this plot is as shown in Appendix I.

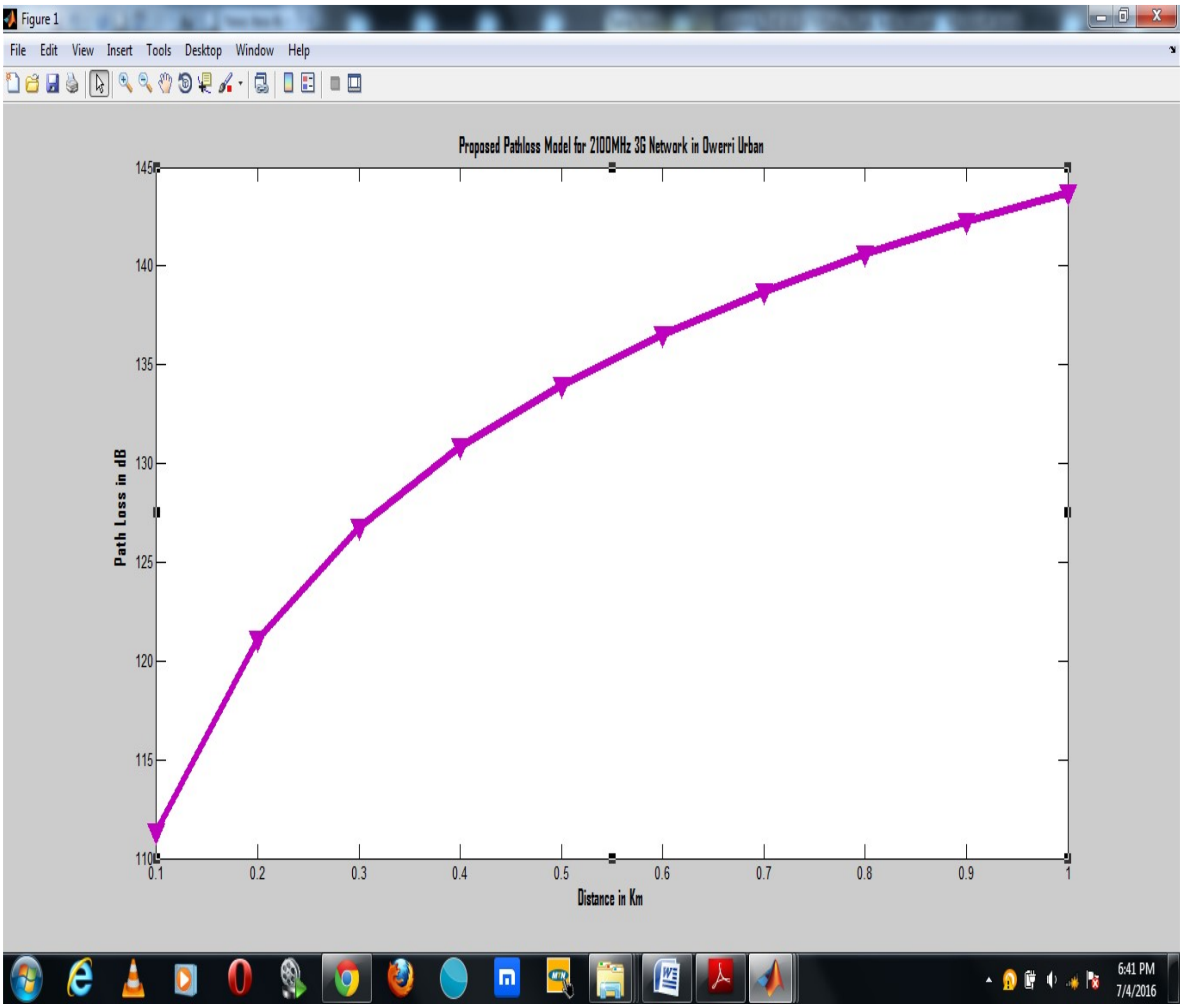

Fig. 4.11: Proposed Model for Owerri urban.

Fig. 4.12 is the Plot of Proposed Model for the Path loss in Owerri sub-urban. The plot showed a gradual but persistent rise in path loss with increase of distance. At distance of 0.1km, 0.5km, 1km; the path losses were 111.4500 dB, 141.7851 dB, and 154.8497dB respectively.

The proposed model indicates a gradual increase in path loss with distance measured in Km. The MatLab program for this plot is as shown in Appendix I.

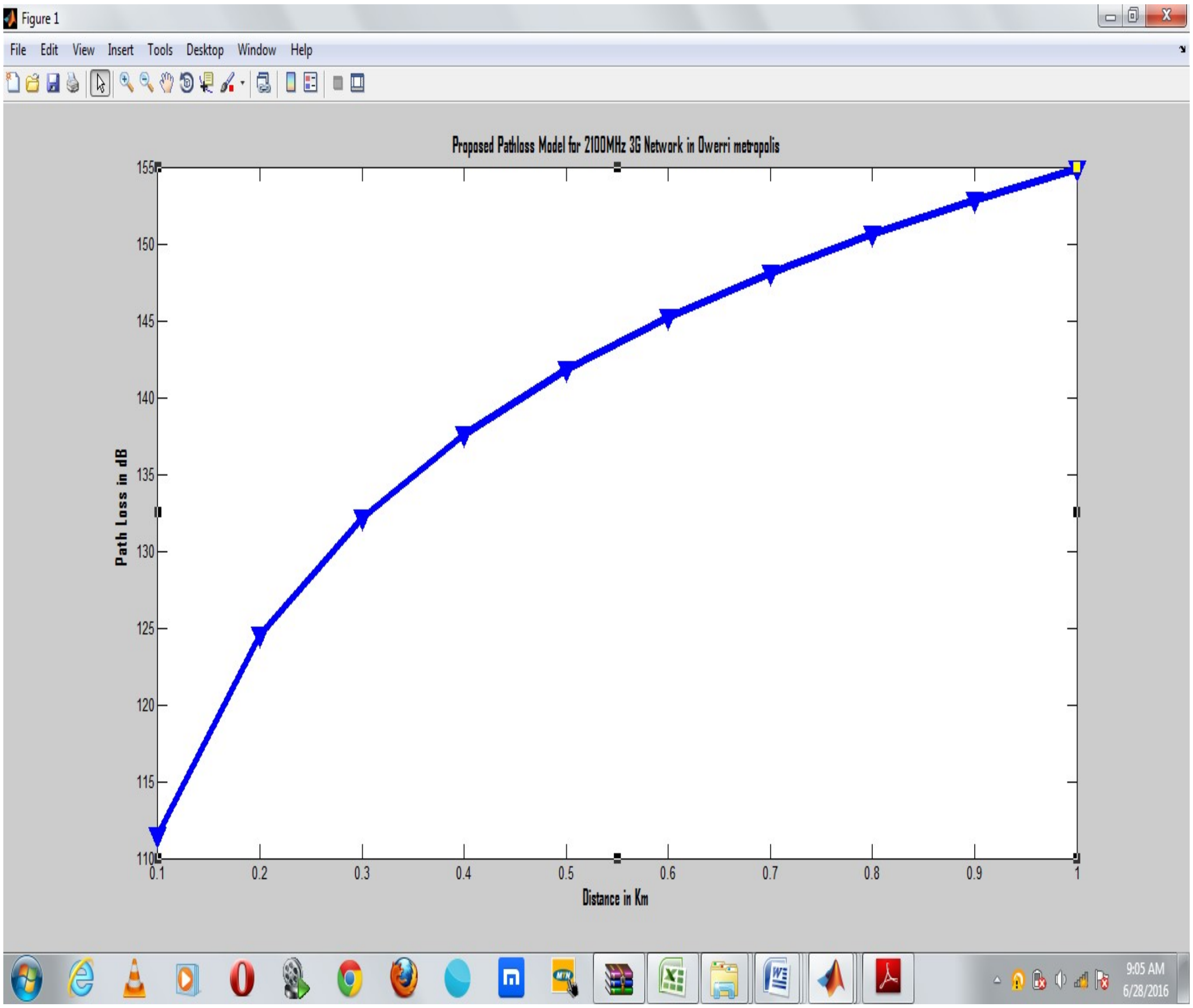

Fig. 4.12: Proposed Model for Owerri Sub-urban.

Fig. 4.13 is the plot that compared the Hata Model and COST 231 Model with the proposed path loss model for Owerri urban. At a distance of 0.1km, the path losses were 111.3300 dB, 137.5800 dB and 140.5800 dB for proposed model, Hata model, and Cost 231 model respectively, while at a distance of 1km, the path losses were 143.7298 dB, 172.3698dB and 175.3698dB in that order.

Hence, from this plot, the COST-231 model indicates the highest increase in path loss with distance, followed by the Hata model, and then the proposed model. The Matlab program for this plot is as shown in Appendix O.

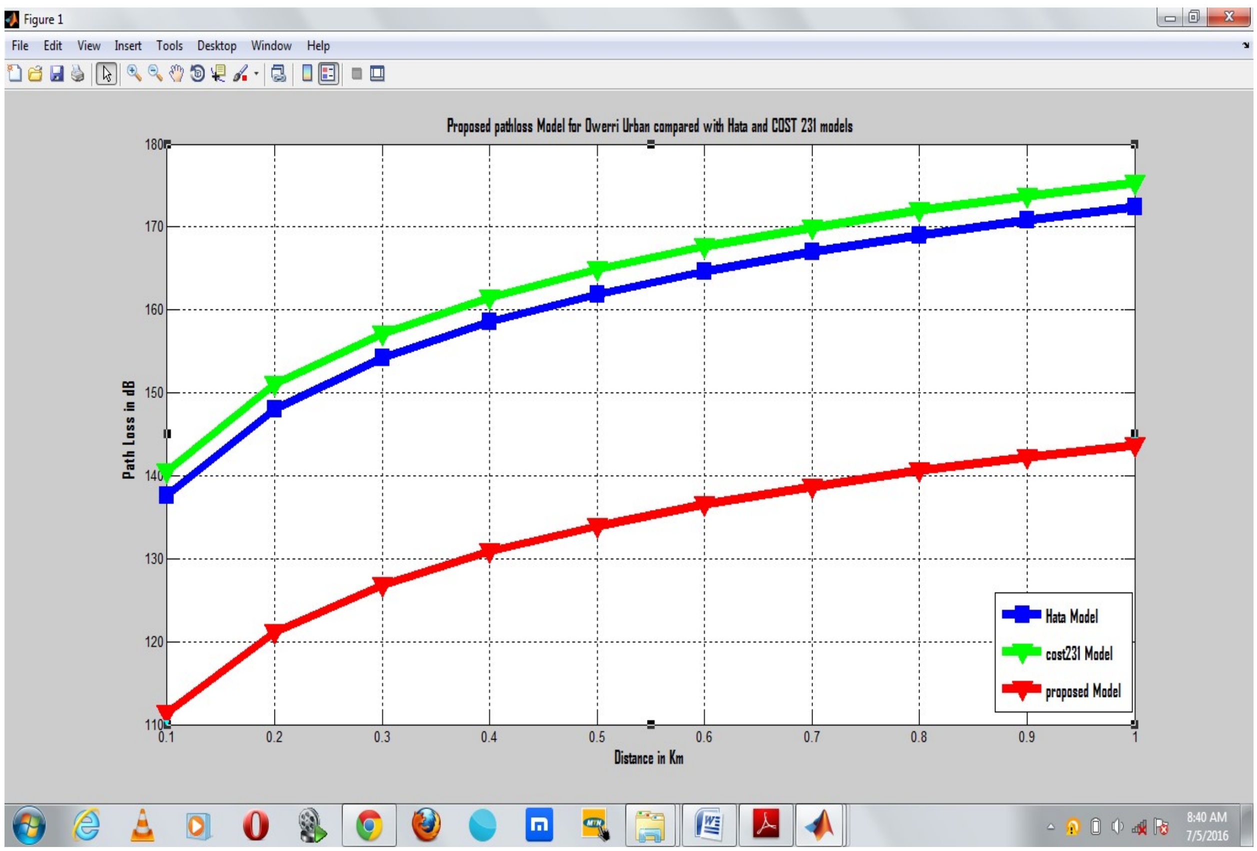

Fig. 4.13: Comparison of Hata Model, COST 231 Model, and Proposed Model for Owerri urban.

Fig. 4.14 is the plot that compared the Hata Model and COST 231 Model with the proposed path loss model for Owerri sub-urban. At a distance of 0.1km, the path losses were 111.4500 dB, 124.8300 dB and 137.2800 dB for proposed model, Hata model, and Cost 231 model respectively, while at a distance of 1km, the path losses were 54.8497dB, 159.6198dB and 172.0698dB in that order.

Hence, from this plot of the comparison in Fig. 4.14, the COST-231 model also indicates the maximum increase in path loss with distance. This is then followed by the Hata model, and the proposed model for Owerri sub-urban. The Matlab program for this plot is as shown in Appendix P.

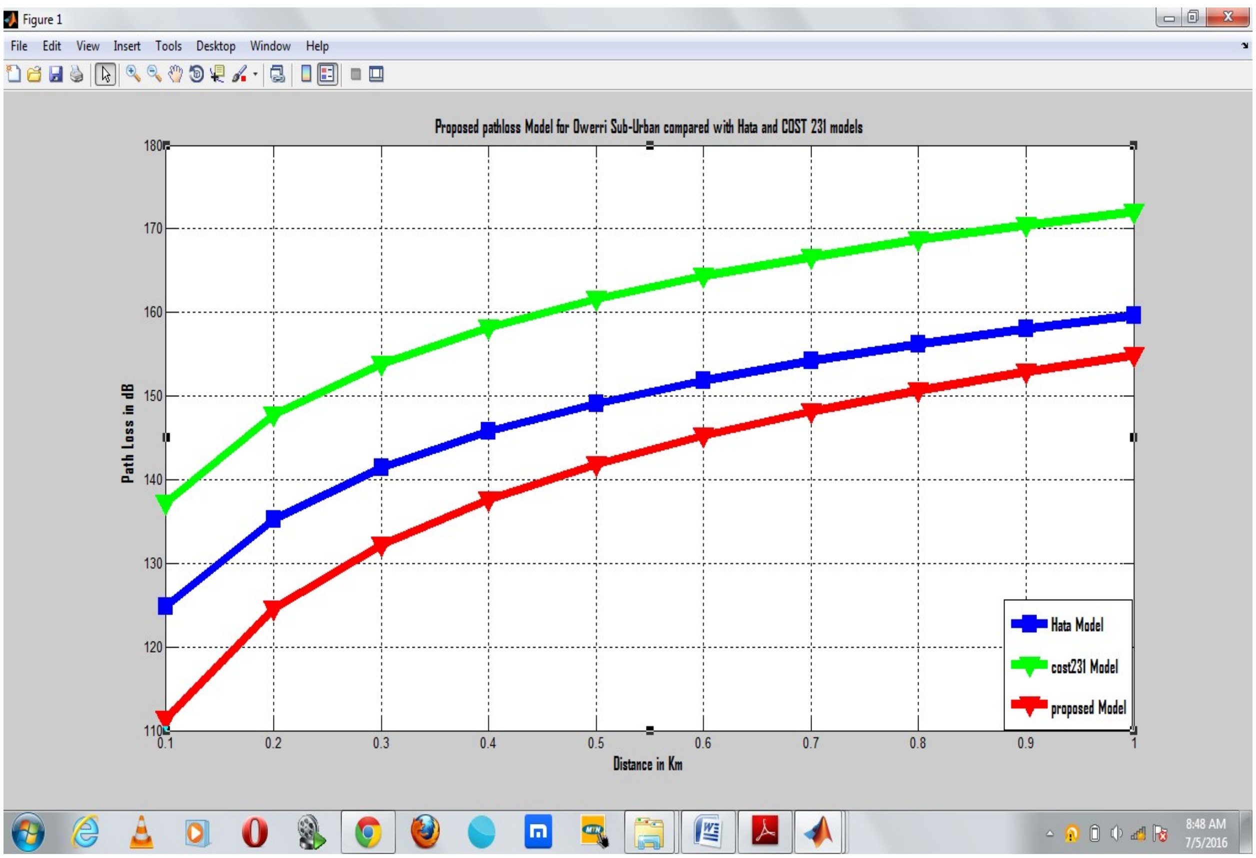

Fig. 4.14: Comparison of Hata Model, COST 231 Model, and Proposed Model for Owerri sub-urban.

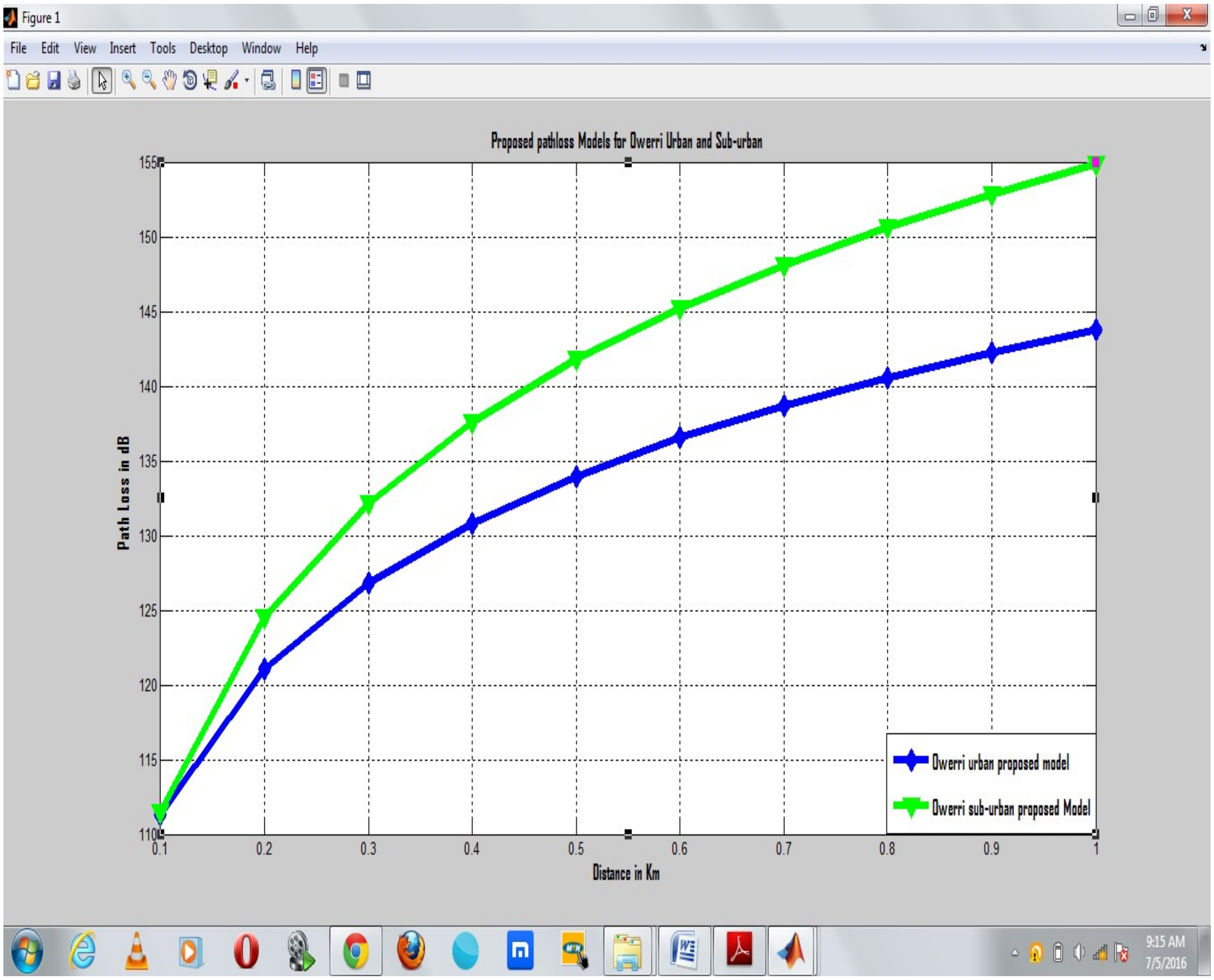

Fig. 4.15: Comparison of the proposed models for Owerri urban and sub-urban.

Fig. 4.15 compared the two generated models for Owerri metropolis (sub-urban and urban). The graph shows that both models possess similar close-in path losses of 91.75dB and 94.63 at a distance of 100m (0.1Km) for sub-urban and urban regions respectively. However, the path loss exponent for the Owerri suburban is 4.34 while that of Owerri urban is 3.24 indicating that the rate at which path loss for the sub-urban area varies with distance is greater than that experienced in the Owerri urban.

It can be seen from all the compared models that while there was clear deviation of the Hata model from the proposed path loss models for Owerri urban and sub-urban; there was however a larger separation between the proposed models and Cost 231 model as represented in Figs. 4.13 and 4.14. The slope of the Hata model plot is closer to the proposed model compared to that of Cost 231 model especially for the Owerri sub-urban model; hence, Hata model will best describe the path loss experienced in the Owerri suburban than the Cost 231 model, after the proposed model.

Also, there was continuous variation of the Received Signal Levels (RSL) right from the starting point of the drive test as depicted in the Figs 4.2, 4.4, 4.6, 4.8 and 4.10

Many factors account for these fluctuations in the received signal level which include:

i. Multipath fading: This is a situation where the transmitter signal takes various or multiple paths to arrive at the mobile station (MS) receiver.
ii. Change of mobile station positions: the amplitude of the received signal vary with its position. It decreased as the MS moves away from the transmitter.
iii. Instant cut-off of signals as a result of improper or inefficient hand over of signals between transceiver stations as experience in some areas.
iv. Issues of antenna azimuth - wrong positioning of the BTS antennas as observed from the log- video of the drive test carried along SEET Engineering complex to FUTO back gate.
v. Cable/sector swap problem as observed at the site along the FUTO main gate to senate building. The outcome of this is that an antenna that is facing

a particular sector refused to pick-up from serving antenna during a handover. This resulted to a failure in signal hand off.

It was also observed that the BTS site serving at the Government house area is very far and hence resulted to poor received signal strength.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Drive test was carried out within Owerri metropolis categorized into urban and sub-urban regions. Observations showed that there were much signal loss in the sub-urban region comprising Owerri-Obinze Express road, FUTO community, and Ihiagwa road than the Owerri urban which comprises Govt house Imo state, Works layout , Okigwe road; Wethedral road, Nekede road, Royce road, Bank road, Tetlow road; and Akanchawa new road, World Bank road, new Owerri.

The results obtained along these routes in Owerri metropolis were used to compute the path loss exponents as 3.24 and 4.34 for Owerri urban and sub-urban, standard deviations that exist between the measured and predicted path losses as 19.58 and 16.82 for Owerri urban and sub-urban, and mean squared error of 1.96 and 1.68in that order. These parameters were used to develop suitable path loss models for Owerri urban and sub-urban. Thereafter, the proposed models were compared with Hata model and COST 231 model. From all indications, these classical models did over estimate the path losses within the Owerri urban and suburban environments. Thus, the proposed models are best deployed in the environment under study for 2.1GHz Communication networks, followed by Hata model.

The result clearly demonstrated that the strength of signal reduction depends not only on distance of separation between the mobile station (MS) and the Base Transceiver station (BTS) but also on the height of the base station and frequency of signal radiated as witnessed in the computer programs formulated and simulated in MATLAB.

5.2 RECOMMENDATIONS

Based on the observation made on this research work, this study therefore recommends that:

i. The cells of 3G Network operating at a frequency of 2.1GHz in Owerri sub-urban should be planned in such a way that they intersect one another in order to facilitate call hand offs
ii. 3G Network operators at the stated frequency should mount Bi-sector high gain antenna that will ensure wide and all round signal coverage.
iii. A rigger with a Drive Test (DT) engineer should be sent to the BTS around senate building to FUTO main gate; the rigger will correct swap while DT engineer will do the drive to check if everything is fine.
iv. The network under study should also resolve the issue of antenna azimuth encountered along FUTO Engineering complex-FUTO back gate by adjusting the antenna properly.

5.3 CONTRIBUTIONS TO KNOWLEDGE

i. The research realized path loss exponents for the Owerri urban and sub-urban at frequency of 2.1GHz. This enables the 3G network operators to understand the rate at which the signal loss varies with distance.

ii. The research developed a measurement-based path loss models for Owerri urban and sub-urban regions, Imo State Nigeria as $Lp = 111.33dB + 32.4\log(D)$ and $Lp = 111.45\ dB + 43.4\log(D)$ respectively. This models will assist the 3G Network operators using frequency of 2.1GHz in Owerri metropolis understand that the path loss experienced in the environment, at a close-in distance of 0.1km is about 111.33dB and 111.45 dB for Owerri urban and sub-urban, while subsequent signals received at intervals of this distance is dependent on the factors "$32.4\log(D)$" and "$43.4\log(D)$" respectively.

iii. It also generated the standard deviations between the measured path losses and the predicted path losses. This helps to envisage the extent the predicted path losses deviated from the measured path loss values.

The above information can be used as a platform and benchmark to aid in the 3G system optimization process for improved performance for service providers in Owerri metropolis

5.4 RECOMMENDATION FOR FURTHER WORK.

This work was carried out during the dry season. Since external factors such as rain, wind, etc are found to influence path loss, further study and verification should be done on the empirical modeling of the path loss during the rainy and harmattan seasons to improve the reliability of the model.

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APPENDIX A

```
% AKANCHAWA-NEW OWERRI-WORLD BANK PATHLOSS
pathloss=[103.5,104,103,102.5,100.5,102.1,108,114.9,118.4,119.9,119.8,117.4,114
.8,115.7,111.9,108.6,111.3,112.7,114.8];

dist= [5.401401, 8.529413, 14.149593, 18.486332, 22.870235,
27.229605,31.233669,34.978436,38.3414,41.756657,45.684418,50.652176,56.438
95,62.939297,69.885262,77.014755, 84.654144,92.737457,101.137283];


size (dist);
size (pathloss);

disp (dist);
disp (pathloss);

plot(dist, pathloss, 'bo-')
title('PLOT OF MEASURED PATHLOSS AT AKANCHAWA-NEW OWERRI-
WORLD BANK  ROAD')


xlabel('Distance, r (meters)')
ylabel ('PathLoss (dB)')
```

APPENDIX B

```
% AKANCHAWA-NEW OWERRI-WORLD BANK RECEIVED SINNAL LEVEL

rsla =[-71.47,-85.36,-82.79,-83.21,-80.57,-81.67,-80.43,-91];

da= [5.4014,50.6522,101.1373,156.5340,208.0046,256.4350,295.3261,399.2364];
 size (da);
size (rsla);

disp (da);
disp (rsla);

plot(da/1000, rsla, 'bo-')
title('AKANCHAWA ROAD RECEIVED LEVEL ')

xlabel('Distance in (Km)')
ylabel ('Received Signal (dBm)')
```

APPENDIX C

```
% GOVT HOUSE-WORKS LAYOUT-OKIGWE RD PATHLOSS
% f=1200;
% h=35;

 pathloss3=[104,105.5,107.5,110,109,106,107.5,108,107.5,107,
106,105,104,104,106,105.7,105.2,107.6,107.6,108.4,108.6,
108.6,109.9,108.7,110,111.1,113,114.5,114,112,112,106,107.5,
112.5,115,110,107.4,109.7,106.6,107.3,106.7,104.7];

 dist3= [0,0.961498,1.199391,1.516061,1.648226,1.780392,2.391112,
2.575837,3.357264,3.735176,4.873357,5.443923,5.804107,
5.88364,6.969015,7.445905,7.815354,7.92091,8.145347,
8.884244,10.326859,12.123505,14.037891,16.0287,18.781355,
19.991815,20.44043,20.519598,20.598766,21.325741,
22.040158,22.823044,23.087376,23.513372,24.064604,25.038,
26.008968,27.382143,28.951628,29.728964,30.051575,
30.163793];


size (dist3);
size (pathloss3);

disp (dist3);
disp (pathloss3);
```

```
plot(dist3, pathloss3, 'bo-')
title('GOVT HOUSE-WORKS LAYOUT-OKIGWE RD')

 xlabel('Distance, r (meters)')
ylabel ('PathLoss (dB)')
```

APPENDIX D

```
% GOVT HOUSE-WORKS LAYOUT-OKIGWE RD RECEIVED LEVEL

rsl3(1)=-75.5;
rsl3(2)=-82.14;
rsl3(3)=-86.29;
rsl3(4)=-94.79;
rsl3(5)=-94.94;
rsl3(6)=-96.07;
rsl3(7)=-97.21;
rsl3(8)=-95.88;
rsl3(9)=-97;
rsl3(10)=-91.71;
rsl3(11)=-95.29;

 dg(1)=0.9615;
dg(2)=51.8613;
dg(3)=100.7704;
dg(4)=153.0571;
dg(5)=201.0411;
dg(6)=259.7570;
dg(7)=302.6775;
dg(8)=354.2890;
dg(9)=399.6489;
dg(10)=454.3367;
```

```
dg(11)=506.3093;
 plot(dg/1000, rsl3, 'bo-')
title('GOVT HOUSE-WORKS LAYOUT-OKIGWE RD  RECEIVED LEVEL')

 xlabel('Distance in (Km)')
ylabel ('Received Signal (dBm)')
```

APPENDIX E

```
% OBINZE-OWERRI EXPRESSWAY PATHLOSS
% f=1200;
% h=35;
  pathloss4=[92.5,92,90.7,90.9,92.4,94,91.2,87.3,86.8,90.3,94,
92.6,88.9,88.6,91,93.9,93.6,90.6,90.9,91.4,95,96.5,100.5,105,
103,100,104.4,103.1,99.3,102.4,103.8,101.8,105.4,108.3,110,
111.9,112.3,109.7,109.4,109.9,108.1,80.4,81.1,81.3,83,84.9,
88.9,93.6,94.7,93.7,93.4,91.9,92.1,92.6,92.3,87.4,88.4,89.2,
87.4,89.5,91.6,90.8,97,95.5,92,90,89,89.5,90.4,92.1,90.2,
88.7,91.2,92.2,91.7,90.3,85.2,87.4,91.5,90.1,93.2,97];


dist4= [0,0.523698,0.523698,0.788374,0.946716,0.946716,0.946716,
1.158804,1.682501,2.327742,3.442539,4.815768,6.545053,
8.550722,10.830042,13.92559,17.981127,23.188478,29.232813,35.183907,41.984
634,49.960739,58.663578,68.621841,
79.005356,90.126053,101.242447,112.358849,124.216347,
136.497208,149.20166,162.310257,175.660629,189.540359,
203.673935,218.148712,232.250626,245.900558,259.262177,
272.581329,285.910461,294.380107,310.250031,320.774261,
330.461792,339.472015,348.081696,356.796112,365.149231,
372.264038,378.639832,384.198029,389.110382,393.461792,
397.813232,401.911926,405.274933,407.551971,409.534454,
411.561127,413.54361,415.618774,418.043762,420.151581,
421.886261,423.648865,425.249542,427.148041,429.265442,
```

```
431.427032,433.015076,434.532684,436.267365,437.731079,
439.02356,440.624268,442.47699,444.31015,447.254364,
449.283386,451.835581,454.031443];

size (dist4);
size (pathloss4);

disp (dist4);
disp (pathloss4);

plot(dist4, pathloss4, 'bo-')
title('GOVT HOUSE-WORKS LAYOUT-OKIGWE RD')

 xlabel('Distance, r (meters)')
ylabel ('PathLoss (dB)')
```

APPENDIX F

```
% OBINZE-OWERRI EXPRESSWAY RECEIVED LEVEL
  rslo(1)=-59.5;
rslo(2)=-63.5;
rslo(3)=-71.43;
rslo(4)=-70.75;
rslo(5)=-77;
rslo(6)=-76.36;
rslo(7)=-48.14;
rslo(8)=-60.57;
rslo(9)=-55.36;
rslo(10)=-60.21;
rslo(11)=-63.57;
rslo(12)=-66.2;

do(1)=0.5237;
do(2)=49.9607;
do(3)=101.2425;
do(4)=149.2017;
do(5)=203.6739;
do(6)=259.2622;
do(7)=310.2500;
do(8)=356.7961;
do(9)=405.2749;
do(10)=451.8356;
do(11)=513.1217;
```

```
do(12)=573.0805;

 plot(do/1000, rslo, 'bo-')
  size (do);
size (rslo);

disp (do);
disp (rslo);

plot(do/1000, rslo, 'bo-')
title('OBINZE-OWERRI EXPRESSWAY RECEIVED LEVEL')

 xlabel('Distance in (Km)')
ylabel ('Received Signal (dBm)')
```

APPENDIX G

```
% WETHERAL-ROYCE-NEKEDE-BANK RD-TETLOW PATHLOSS
% at a distance of 650m
% f=1200;
% h=35;

 pathloss5=[99,100.4,101.5,98.9,97.7,98.8,101.2,100.8,102.5,
98.5,97.3,101.4,104.9,104.1,105.4,105,103.9,103.8,107.4,
93.3,93.9,96.7,92.6,99.4,100.8,94.5,97,100,100,100,103.5,
104.9,107.1,110.1,111.1,109.9,108.9,109.9,110,111.1,112.9,
115.2,114.7,113.4,116.4,118.7,119.2,119.6,119.4,117.3,
118.5,117.7,93.6,98.1,103.3,105.1,104.1,102.2,104.3,106.4,
107,106.5,106,97,93,92.7,93,96.5,102,123.1,158,158,158,
158,158,135.8,120.5,117.1,114.5,115.4,119,120];

 dist5=
[0,1.730998,3.544262,7.832789,9.736717,13.598445,17.460173,21.376157,25.436
407,29.588695,36.224586,38.594416,
43.389143,48.344048,53.643038,59.607002,66.466219,
74.069286,82.229061,94.707741,103.14962,111.730438,
120.388069,129.155151,138.238754,147.794373,157.600052,
162.417198,177.222412,182.177238,196.725891,206.460236,
216.631805,227.334946,238.148651,248.746216,259.056091,
264.154922,279.322144,284.193268,293.454742,305.33606,
311.756927,316.624298,318.412018,321.447388,323.687622,
325.737534,328.900574,331.534668,335.490112,340.227844,
```

```
345.31488,350.78299,356.543915,362.100006,367.947357,
374.091675,381.428009,385.411911,393.773315,412.811844,
417.926788,428.680908,445.876709,457.708511,469.726059,
487.929535,493.936539,505.868942,523.303101,534.940491,
546.575378,557.913879,569.380371,580.592041,592.058533,
603.174744,614.291016,625.070313,635.766357,646.263916];

 size (dist5);
size (pathloss5);

disp (dist5);
disp (pathloss5);

plot(dist5, pathloss5, 'bo-')
title('MEASURED PATHLOSS VALUE AT GOVT HOUSE-WORKS LAYOUT-
OKIGWE RD')

xlabel('Distance, r (meters)')
ylabel ('PathLoss (dB)')
```

APPENDIX H

```
%WETHERAL-ROYCE-NEKEDE-BANK RD-TETLOW RECEIVED LEVEL
rslw(1)=-67.4;
rslw(2)=-71.14;
rslw(3)=-60.93;
rslw(4)=-64;
rslw(5)=-71.86;
rslw(6)=-75.86;
rslw(7)=-82.21;
rslw(8)=-84.73;
rslw(9)=-74.5;
rslw(10)=-70.93;
rslw(11)=-77.2;

dw(1)=1.7310;
dw(2)=48.3441;
dw(3)=103.1496;
dw(4)=157.6001;
dw(5)=206.4602;
dw(6)=259.0561;
dw(7)=305.3361;
dw(8)=340.2278;
dw(9)=412.8118;
dw(10)=505.8689;
dw(11)=557.9139;
```

```
  plot(dw/1000, rslw, 'bo-')

size (dw);
size (rslw);

disp (dw);
disp (rslw);

title('Wetheral-Royce-Nekede-Bank Rd-Tetlow Received Signal Level')

 xlabel('Distance in (Km)')
ylabel ('Received Signal (dBm)')
```

APPENDIX I

```
% Plot of Proposed Model for the Path loss in Owerri urban

distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

for chv=1:1:10;

propmodel(chv)=(111.33 +(32.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (propmodel)
plot(distaav,propmodel, 'v')
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed Pathloss Model for 2100MHz 3G Network in Owerri Urban')
```

APPENDIX J

```
% Plot of Proposed Model for the Path loss in Owerri sub-urban
distin=0.100;
 distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

for chv=1:1:10;

propmodel(chv)=(111.45 +(43.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (propmodel)
plot(distaav,propmodel, 'v')
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed Pathloss Model for 2100MHz 3G Network in Owerri metropolis')
```

APPENDIX K

```
% Proposed pathloss Model for Owerri Urban compared with Hata and COST 231
%models at a distance of 1.0Km with an interval of 100m.

distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

 for chv=1:1:10;

   hata(chv)=137.58  +(34.7864*((log((distaav(chv)/distin)))/2.3026));

    cost231(chv)=140.58 +(34.79*((log((distaav(chv)/distin)))/2.3026));

    propmodel(chv)=(111.33 +(32.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (hata)
disp (cost231)
disp (propmodel)

plot(distaav,hata)
hold on
plot(distaav,cost231, 'gv')
```

```
hold on
plot(distaav,propmodel, 'rv')
hold off
grid on
legend ('Hata Model','cost231 Model','proposed Model');
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed pathloss Model for Owerri Urban compared with Hata and COST
231 models')
```

APPENDIX L

```
% Proposed pathloss Model for Owerri Urban compared with Hata and COST 231 models
distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

 for chv=1:1:10;

   hata(chv)=124.83  +(34.7864*((log((distaav(chv)/distin)))/2.3026));

    cost231(chv)=137.28 +(34.79*((log((distaav(chv)/distin)))/2.3026));

    propmodel(chv)=(111.45  +(43.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (hata)
disp (cost231)
disp (propmodel)

 plot(distaav,hata)
hold on
plot(distaav,cost231, 'gv')
hold on
```

```
plot(distaav,propmodel, 'rv')
hold off
grid on
legend ('Hata Model','cost231 Model','proposed Model');
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed pathloss Model for Owerri Urban compared with Hata and COST 231 models')
```

APPENDIX M

```
% Predicted path loss for Owerri urban


distin=0.100;


distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

for chv=1:1:10;

pred(chv)=(91.75 +(32.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (pred)
plot(distaav,pred, 'v')
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Predicted Model for 2100MHz 3G Network for Owerri urban')
```

APPENDIX N

```
% Predicted path loss for Owerri sub-urban
distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

for chv=1:1:10;

pred(chv)=(94.63 +(43.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (pred)
plot(distaav,pred, 'v')
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Predicted Model for 2100MHz 3G Network for Owerri metropolis')
```

APPENDIX O

```
%Proposed pathloss Model for Owerri Urban compared with Hata and COST 231
%models

distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;
 for chv=1:1:10;

   hata(chv)=137.58  +(34.7864*((log((distaav(chv)/distin)))/2.3026));

    cost231(chv)=140.58 +(34.79*((log((distaav(chv)/distin)))/2.3026));

    propmodel(chv)=(111.33 +(32.4*(log((distaav(chv))/distin))/2.3026));

end;
disp (distaav)
disp (hata)
disp (cost231)
disp (propmodel)

plot(distaav,hata)
hold on
plot(distaav,cost231, 'gv')
hold on
```

```
plot(distaav,propmodel, 'rv')
hold off
grid on
legend ('Hata Model','cost231 Model','proposed Model');
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed pathloss Model for Owerri Urban compared with Hata and COST 231 models')
```

APPENDIX P

```
%Proposed pathloss Model for Owerri sub-urban compared with Hata and COST
% 231 models

distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;

for chv=1:1:10;

   hata(chv)=124.83  +(34.7864*((log((distaav(chv)/distin)))/2.3026));

    cost231(chv)=137.28 +(34.79*((log((distaav(chv)/distin)))/2.3026));

    propmodel(chv)=(111.45  +(43.4*(log((distaav(chv))/distin))/2.3026));
 end;
disp (distaav)
disp (hata)
disp (cost231)
disp (propmodel)

plot(distaav,hata)
hold on
plot(distaav,cost231, 'gv')
```

```
hold on
plot(distaav,propmodel, 'rv')
hold off
grid on
legend ('Hata Model','cost231 Model','proposed Model');
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed pathloss Model for Owerri Urban compared with Hata and COST 231 models')
```

APPENDIX Q

```
distin=0.100;

distaav=[0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0];
nk=10;
 for chv=1:1:10;

    urbanpropmodel(chv)=(111.33 +(32.4*(log((distaav(chv))/distin))/2.3026));

   suburbanpropmodel(chv)=(111.45  +(43.4*(log((distaav(chv))/distin))/2.3026));

end;

disp (urbanpropmodel)
disp (suburbanpropmodel)

 plot(distaav,urbanpropmodel)
hold on
plot(distaav,suburbanpropmodel, 'gv')
hold off
grid on
legend ('Owerri urban proposed model','Owerri sub-urban proposed Model');
xlabel('Distance in Km')
ylabel('Path Loss in dB')
title('Proposed pathloss Models for Owerri Urban and Sub-urban')
```