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Investigation of Radio Waves Propagation Models in Benin City, Edo State

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Abstract

The effectiveness of Radio waves propagation models has been investigated inBenin City, Edo State.This was achieved by carrying out a drive test measurement in a live base transceiver station operating at 900MHz using TEMS Investigation Software.

There are several propagation models developed and currently deployed for use in mobile cellular network projects. However in this paper, the Free Space Path Loss model, Okumura- Hata model and ECC-33 model have been considered.

The measured data was collected over a distance starting from 200m-5km from the base station. Comparison of the measured path loss and the predicted path loss models considered in this paper, shows that only the Okumura-Hata Path loss models for mediumsized city (such as the study area) conforms closet to the measured path loss, and can thus be fully deployed to good effect in the study area and other macro cellular environment that have similar terrain features.

Key words: Radio waves Propagation, Measured Pathloss, Path loss models, Predicted path loss, Received signal strength, Transceiver.

1.0 Introduction

A very crucial factor in mobile cellular network projects is the ability to make an accurate predictionof propagation models within an environment. An accurate prediction model will assist tremendously inthe planning, designing and even implementation processes of a mobile cellular network project [1].

Propagation models are designed for specific types of environment and terrain, and as such, the accuracy in predicting signal attenuation (path loss) is largely affected by these two factors. Their efficiency in predicting the path loss suffers when they are used in an environment other than the one for which they are designed [2] because different types of terrain environment cause different attenuation levels in practice. The developing world has got its own unique type of environment different from the developed world. Most propagation models have been tested in different regions of the developed world but scarcely in the regions of the developing world.Moreso each model, can be useful for some specific environment and the accuracy of any specific technique depends on the fit between the parameters available for the area concerned and the parameters required for the model [2]. Furthermore most propagation models whichhave been used in developed world may not be suitable for use in developing world as it is a region different from the one it was built.

Prajesh and Singh [3] compared the measured path loss to various path loss prediction models to find the best fit model in kutch Bhuj area, India. They were motivated to carry out the study because the propagation models were giving unsatisfactory results when compared with measured data. They considered Free Space Path Loss Model, Okumura-Hata model,walfisch-ikegami model and ECC-33 model in their experiment. They found that ECC-33 model and Okumura- Hata were the best fit models for the area.

The aim of this study is toinvestigateradio waves propagation models in Benin City, Edo State by field measurements, and compare the measured path loss (attenuation)with three predictedpropagation models, in order to ascertain which of the existing propagation model(s) best suit Benin City environmental conditions, as some propagation models will perform woefully in predicting signal propagation if used in the study area.

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2.0 Radio Wave Propagation Models

Variouspropagation models have been developed over the years to estimate the propagation path loss atvarious receiver distances from a transceiver basestation. These models include the Free Space model,Okumura-Hata model, ECC-33 model Walfisch-Ikegami model, Cost-231 model, Longley- Rice model, Ericsson 9999 model and many others. Once thepropagation path loss can be predicted with a level ofaccuracy, then the received signal power distribution(P_r) at the respective distances can be easilyobtained.

The effective power radiated from the BTS antenna (P_t in dBm) is given as:

$$P_t = P_{BTS} - P_D - P_f + (A_{ms} + A_{BTS}) \quad (1)$$

Where

P_{BTS} = base transceiver station power

P_D = duplexer loss

P_f = feeder loss

A_{ms} = Mobile station(receiver) antenna gain

A_{BTS} = the base transciever stationantenna gain

The effective radiated power is subject to propagationloss (P_L) along its path due to reflection, diffraction, refraction, scattering, etc. Power at the receiverdistances from the base transceiver station is expressed as[4]:

$$P_L = P_t - P_r \text{ (in dBm)} \quad (2)$$

$$P_L \text{ (dB)} = 10 \log_{10} (P_t / P_r) \quad (3)$$

In this paper, three propagation models namely; free space propagation model, Okumura- Hata model and ECC- 33 model will be specifically considered for comparison with the measured path loss, and as such, they are discussed briefly.

2.1 Free Space Propagation Model

Free space loss describes the ideal situation, where the transmitter and receiver have line-of- sight and no obstacles are around to create reflection, diffraction or scattering [5]. In this ideal case the attenuation of the radio wave signal is equivalent to the square of the distance from the transmitter.

When the signal has been transmitted in the free space towards the receiver antenna, the power density S at the distance from the transmitter,d,can be written as

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

Where P_t is the transmitted power and $G_t$is the gain of the transmission antenna.

The effective area A of the receiver antenna, which affects the received power, can be expressed as

$$A = \frac{\lambda^2 G_r}{4\pi} \quad (5)$$

Where $\lambda$is the wavelength and G_r is the gain of the receiver (RX) antenna. The received power density can also be written as

$$S = \frac{P_r}{A} \quad (6)$$

Combining equation (4), (5) and (6), we have

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \quad (7)$$

The free space path loss is the ratio of transmitted power and received power i.e.

$$L = \frac{P_t}{P_r} \quad (8)$$

Substituting equation (7) into (8) and excluding the antenna gains, we have

$$L = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (9)$$

And the free space loss converted in decibels is

$$L = 32.4 + 20\log(f) + 20\log(d) \quad (10)$$

Where f is the frequency in megahertz and dis the distance in kilometers.

2.2 Okumura–Hata Model

The Okumura–Hata modelis a well-known propagation model, which can be applied for a macro cell environment to predict median radio signal attenuation. Having one component the model uses free space loss. The Okumura–Hata model is an empirical model, which means that it is based on field measurements. Okumura performed the field measurements in Tokyo and published results in graphical format. Hata applied the measurement results into equations. The model can be applied without correction factors for quasi-smooth terrain in an urban area but in case of other terrain types correction factors are needed[5].

The weakness of the Okumura–Hata model is that it does not consider reflections and shadowing. The parameter restrictions for this model are:

Frequency f*:* 150–1500 MHz, extension 1500–2000 MHz

Distance between MS and BTS d: 1–20 km
Transmitter antenna height H_{BTS}: 3–200 m
Receiver antenna height H_{MS}: 1–10 m
The Okumura–Hata model for path loss prediction can by written as

$$L = A+B\log(f)-13.82\log(H_{BTS})-a(H_{MS})+ [44.9-6.55 \log(H_{BTS})]\log(d) + L_{other} \quad (11)$$

Where fis the frequency (MHz), H_{BTS} is the height base station (m), $a(H_{MS})$ is the mobile station antenna correction factor, *d* is the distance between the BTS and MS (km) and L_{other} is an additional correction factor for area type correction. The correction factor for the MS antenna height is represented as follows:
For a small or medium sized city,

$$a(H_{MS}) = [1.1 \log(f) - 0.7]H_{MS} - [1.56 \log(f) - 0.8] \quad (12)$$

And for a large city:

$$a(H_{MS}) = \begin{cases} 8.29 [\log(1.54 H_m)]^2 - 1.1 : & f \leq 200 \text{ MHz} \\ 3.2 [\log(11.75 H_m)]^2 - 4.97 : & f \geq 400 \text{ MHz} \end{cases} \quad (13)$$

Where

H_{MS} is the height of mobile station:

$1 \leq H_{MS} \leq 10$ (H_{MS} in metres)

The parameters A and B are dependent on the frequency as follows:

$$A = \begin{cases} 69.55, & f = 150 - 1500 \text{ MHz} \\ 46.30, & f = 1500 - 2000 \text{ MHz} \end{cases}$$

$$B = \begin{cases} 26.16, & f = 150 - 1500 \text{ MHz} \\ 33.90, & f = 1500 - 2000 \text{ MHz} \end{cases}$$

2.3 ECC–33 Model

The ECC 33 path loss model, which is developed by Electronic Communication Committee (ECC), is extrapolated from original measurements by Okumura and modified its assumptions so that it more closely represents a fixed wireless access (FWA) system. The path loss model is defined as [6]:

$$P_L(dB) = A_{fs} + A_{bm} - G_b - G_r \quad (14)$$

Where A_{fs}, A_{bm},G_b and G_r are the free space attenuation, basic median path loss, the base station height gain factor and the receiver height gain factor. They are defined individually
as:

$$A_{fs} = 92.4 + 20\log(d) + 20\log(f) \quad (15)$$

$$A_{bm} = 20.41 + 9.83\log(d) + 7.894\log(f) + 9.56[\log(f)]^2 \quad (16)$$

$$G_b = \log(h_{BTS}/200)\{13.958 + 5.8[\log(d)]^2\} \quad (17)$$

And for medium city environments,

$$G_r = [42.57 + 13.7\log(f)][\log(h_{MS}) - 0.585] \quad (18)$$

Where
f is the frequency in GHz
d is the distance between base station and mobile station in Km
h_{BTS} is the height of base transceiver station in meters
h_{MS} is the height of mobile station in meters

3.0 Methodology

The procedure involves obtaining the mean receiver power distribution at specified receiver distances from a two sector GSM base transceiver station in Benin City,EdoState. The path loss value was then obtained.The values obtained from field measurements were then compared with those obtained from the aforementionedpredicted path loss models.
A site verification exercise was done using Ericsson k800i mobile station (MS) and a piece of compass. This is to ensure that the base transceiver station (BTS) used was performing optimally and meets up with all parameters as stated:
BTS power: 40W, BTS antenna height: 55m, MS Antenna height: 1.2m, Transmitter antenna height: 55m, Frequency band: 900MHZ, Connector loss: 3dB, Feeder loss: 2.58dB, Duplexer loss: 4.5dB
Data collection was performed thereafter using a test kit consisting of the following:

Ericsson TEMS investigation software 11.0.1 version, Sony Ericsson k800i mobile station with TEMSsoftware, Garmin GPS 76 with 0db loss antenna, Personal computer with the TEMS
Software and Radio works 2.0 software.
The schematic diagram for the field setup[7] is shown in figure 1**.**

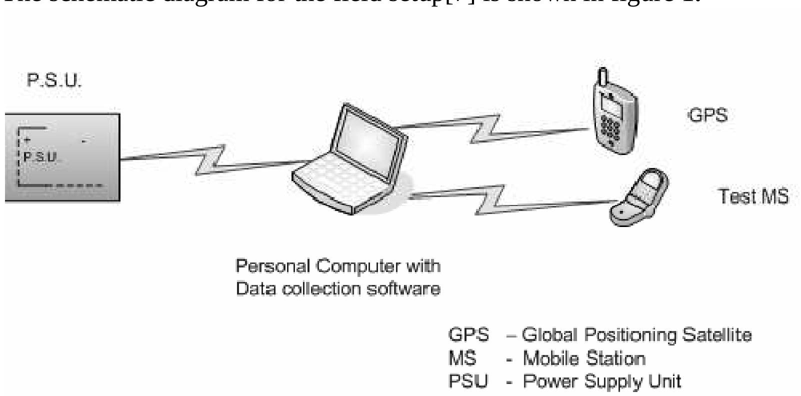

Figure 1: Schematic diagram of the Experimental Setup.

The functions of the various components of the field setup are as follows [7]:
(1) PSU: The power supply unit provides the source of power for the whole system. It is made up of an inverter which inverts the 12V dc power from the vehicle to 220Vac needed by the data collection device.
(2) Laptop: The laptop houses the operating system and the data collection software(Ericsson TEMS investigation 11.0.1).
(3) GPS: The global positioning system (GPS) helps to localise the position of quality degradation. It operates with global positioning satellites to provide the location tracking for the system during data collection. It enables the system to determine its position on a global map which has been installed on the laptop.
(4) TMS: Thetest mobile station phone connected to the laptop is used to initiate calls during the data collection. The behaviour of this mobile phone gives the behaviour of any mobile station within the network [7].

3.1 Data Collection

With the overall system in figure 1 mounted on a vehicle maintained atan average speed of 30km/h, data collection wasdone starting from a distance of less than 200m fromthe base station. The vehicle then moves along thedirection of the main lobes of each directionalantenna away from the site until it gets to the coverage border. This process was repeated for bothsectorsof the site under which the experiment was performed.

4.0 Results and Discussion

The received power level at various receiver distances from each sector of the base transceiver station and the calculated path loss is as shown in table 1;

Table 1: Mean Receive Level Distribution

Distances(km)	RX Power (dBm)			Path loss (dBm)
	Sector 1	**Sector 2**	**Mean RX-Power**	
0.2	-53.0	-67.0	-60.0	116.9
0.4	-64.0	-76.0	-70.0	126.9
0.6	-70.0	-82.0	-76.0	132.9
0.8	-74.0	-86.0	-80.0	136.9
1	-78.0	-89.0	-83.5	140.4
1.2	-81.0	-92.0	-86.5	143.4
1.4	-83.0	-94.0	-88.5	145.4
1.6	-85.0	-96.0	-90.5	147.4
1.8	-87.0	-97.0	-92.0	148.9
2	-88.0	-99.0	-93.5	150.4
2.2	-90.0	-100.0	-95.0	151.9
2.4	-91.0	-101.0	-96.0	152.9
2.6	-92.0	-103.0	-97.5	154.4
2.8	-94.0	-104.0	-99.0	155.9
3	-95.0	-105.0	-100.0	156.9
3.2	-96.0	-105.0	-100.5	157.4
3.4	-97.0	-106.0	-101.5	158.4
3.6	-97.0	-107.0	-102.0	158.9
3.8	-98.0	-108.0	-103.0	159.9
4	-99.0	-109.0	-104.0	160.9
4.2	-100.0	-109.0	-104.5	161.4
4.4	-100.0	-110.0	-105.0	161.9
4.6	101.0	-111.0	-106.0	162.9
4.8	-102.0	-111.0	-106.5	163.4
5	-102.0	-112.0	-107	163.9

The measured path loss at various distances from the base station in the study area and the predicted path loss of the 3 models described in section 2 are shown in table 2. From the table it is clearly seen that the free space and ECC- 33 propagation models deviate from the measured path loss. This is also evident in figure 2 which shows a graph of path loss against distances for the measured and predicted path loss models discussed in this paper.

Table 2: Measured and predicted Path loss

distance(km)	Measured path loss	Free space path loss	Okumura-Hata path loss	ECC-33 Pathloss
0.2	116.9	83.5	111.6	301.3076
0.4	126.9	89.5	122.2	308.7090
0.6	132.9	93.1	128.4	313.4401
0.8	136.9	95.6	132.8	316.9766
1	140.4	97.5	136.2	319.8226
1.2	143.4	99.1	139.0	322.2145
1.4	145.4	100.4	141.4	324.2836
1.6	147.4	101.6	143.4	326.1106
1.8	148.9	102.6	145.2	327.7488
2	150.4	103.5	146.8	329.2355
2.2	151.9	104.4	148.3	330.5975
2.4	152.9	105.1	149.6	331.8553
2.6	154.4	105.8	150.9	333.0244
2.8	155.9	106.4	152.0	334.1171
3	156.9	107.0	153.0	335.1432
3.2	157.4	107.6	154.0	336.1109
3.4	158.4	108.1	155.0	337.0268
3.6	158.9	108.6	155.8	337.8964
3.8	159.9	109.1	156.7	338.7243
4	160.9	109.5	157.4	339.5147
4.2	161.4	110.0	158.2	340.2708
4.4	161.9	110.4	158.9	340.9958
4.6	162.9	110.8	159.6	341.6922
4.8	163.4	111.1	160.2	342.3623
5	163.9	111.5	160.9	343.0082

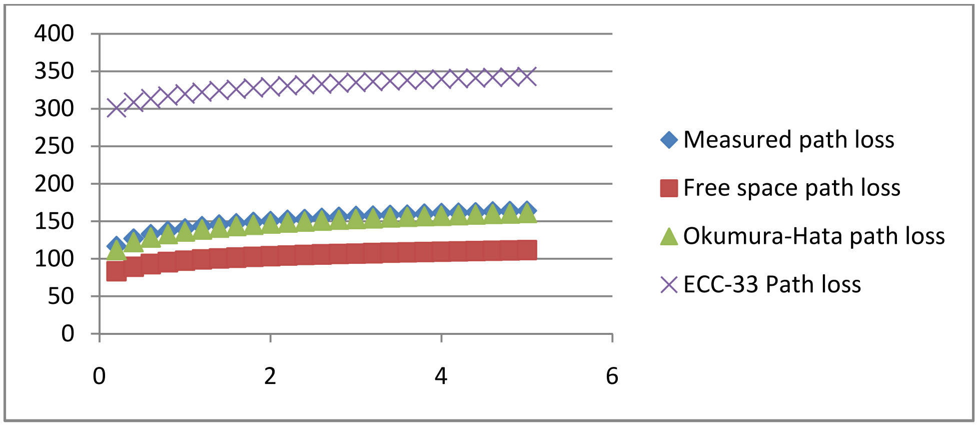

Figure 2: A graph of path loss against distances for measured and predicted path loss

5.0 Conclusions

Indesigning, planning and implementation of a mobile cellular network, an accurate and appropriate model for predicting radio waves propagation path loss within a specific environment is of utmost importance.

The aforementioned path loss models for medium sized cityhave been compared with measuredpath loss from a live base transceiver station in Benin City, Edo State.The analysis of the result and the graph shown in figure 2 shows that the free space and ECC- 33 path loss models showed large deviation from the measured path loss and as such these models will not perform effectively if used in predicting signal propagation in the study area.

However, the okumura-Hata model is the best fit as its predicted path loss values were closet to the measured data. Thus, the Okumura- Hata model can therefore be fully deployed in the study area and other macro cellular environment that have similar terrain feature.

Finally, similar drive test measurements should be carried out in any specific environment to determine suitable propagation models before planning and executing any mobile cellular network project. As this paper has shown for example that, not all models can be deployed in the study area.

6.0 References

[1] T.L. Adebayo and F.O. Edeko (2006) “Characterization of Propagation Path Loss at 1.8GHz: ACase study of Benin City, Nigeria.”Research Journal of Applied sciences: Vol. 1(1-4): Page 92- 96, 2006.

[2] J. Chebil, A.K. Lawas and M. D. Islam, “Comparison between measured and predicted path loss for mobile communication in Malaysia” World applied Sciences Journal Vol. 21, 2013, Page 123-128.

[3] P. Prajesh, and R. K. Singh, “ Investigation of outdoor path loss models for wireless communications in bhuj.” International Journal of Electronics and Communication Engineering and technology (IJECET) Vol. 3, Issue 2, Page 171- 178, 2012

[4] T. S. Rappaport, “Wireless communications, principles and practice” Prentice hall 2002

[5] Mishra A. R. Advanced cellular Network planning and optimization – Willey and sons, Inc., Page 40-41, 2007.

[6] V.S. Abhayawardhana, I.J. Wassell, D. Crosby, M.P. Sellars, M.G. Brown, Comparison of empirical propagation path loss models for fixed wireless access systems. Vehicular Technology Conference, IEEE, 30 May-1 June, Vol.1, page 73- 77, 2005.

[7] Shoewu O. and Adedipe, A. Investigation of Radio wave propagation models in Nigeria Rural and Suburban Areas. American Journal of scientific and industrial Research, Vol.1(2) Page 227- 232, 2010