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Radio wave propagation at 900 and 1800MHz bands in Lagos, Nigeria

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ABSTRACT

The role accurate measurement and reception of electromagnetic signal play in telecommunications cannot be over emphasized. These measurements and reception are a function of terrain/topology, level of infrastructural development, vegetation and other factors. Wave propagation models are very important and necessary tools for determining the radio wave propagation characteristics of a user environment or area. The research handles site specific measurements for Lagos at frequencies of 900MHz and 1800MHz and comparison done with standard calculated values. From the analysis of data collected, the mean square errors (μ_e) ranged from 5.39dB to 13.60dB for Okumura Hata at 900MHz. For COST 231 Hata at this frequency, it was from 5.06dB to 13.52dB. This agrees with the acceptable International range. The acceptable range lies between $1 \leq \mu \leq 15$dB (Wu and Yuan 1998). The mean square error at 1800MHz varied from 4.66dB to 5.06dB.

Introduction

Communication signals are degraded as they move from the transmitting antenna to the receiving antenna. This degradation comes in form of path loss, shadowing (slow fading) and fast fading (multipath fading). All of these processes vary as the relative positions of the transmitter and receiver change and as any contributing objects or material between the antennas are moved Saunders (2007).

In path loss, the signal strength is decreased as the distance between the receiver and the transmitter is increased. This is because waves spread outward as they leave the transmitting antenna due to the effect of obstruction like trees, bill board, tall buildings etc. Shadowing changes more rapidly with significant variations over distances of hundreds of metres. Shadowing generally involves variations up to around 20dB. Fast fading or multipath fading are as a result of the constructive and destructive interference between multiple waves reaching the mobile station from the base station Saunders (2007).

The Global System for Mobile communication (GSM) in Nigeria has become one of the fastest growing telecommunications industries in Africa. Daily, more subscribers are added to the existing network infrastructures thereby putting strain on the available bandwidth. These have given rise to many technical challenges on how to meet customer satisfaction. The GSM networks in Nigeria are plagued by high drop calls, high tariffs and other problems associated with poor coverage.

These problems are traceable to the fact that most of the path loss models implemented by GSM network operators in the country are models specifically developed for other lands like the Okumura- Hata and COST 231 Hata models. These models do not take into consideration the morphology and site specific terrain of a city like Lagos in Nigeria Bachir (2004), Kanagalu (1999), Anderson (2006) and Neskovic (2008). The necessary formulae for Okumura. -Hata and COST 231 Hata have been extensively shown in earlier write ups Ogbulezie (2013), Saunders (1980) and Ogbulezie (2013). The need for site specific measurements cannot be overemphasized.

The Okumura-Hata model is represented by the equations

$$P_L(dB) = A + B\log(d) \quad (1)$$

$$A = 69.55 + 26.16\log(f) - 13.82\log(h_b) - a(h_m) \quad (2)$$

$$B = 44.9 - 6.55\log(h_b) \quad (3)$$

where P_L= path loss in dB and d= distance in kilometers.

A is fixed loss that depends on frequency of the signal,

f = frequency measured in MHz, h_b = height of the base station antenna in meters

h_m = mobile antenna height in meters, $a(h_m)$ = correction factor in dB

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

$$a(h_m) = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8] \quad (4)$$

For COST-231 Hata model, the path loss is given by [7]

$$P_L(dB) = 46.33 + 33.9\log(f) - 13.82(h_b) - a(h_m) + [44.9 - 6.55\log(h_b)]\log(d) \quad (5)$$

where

$$a(h_m) = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8] \quad (6)$$

Materials and Method

Laptop with installed software Eriksson test mobile system (TEMS) software, handset complete with charger, headset, data cable and USB hub were used to take the necessary measurements. Data was obtained by conducting a drive test around the two routes selected for the research. The routes were selected based on the terrains and the density of clutter. GSM signals operating on the frequencies of 900MHz and 1800MHz were under investigation in this research. These are the two frequencies used by mobile operators in Nigeria. TEMS drive test is a method used in verifying the actual condition of radio frequency signals of a GSM operator. TEMS investigation is able to (a) find problems on base station transmitters (b) analyze

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obtained results (c) analyze the complaints from customers about an operator.

The drive test started from the very busy Amadu Bello Road through Ozumba Mbadiwe Avenue as shown in figure 1. The area had various range of clutter.

The measurements were done in June during the rainy season. Analysis formats were done in accordance to Okumura-Hata and COST 231 Hata models. Acquired measurements were compared with theoretical values for the city. The equipment for the drive test was placed in a vehicle maintained at an average speed of 30km/h. The mobile antenna height was 1.5m.

The TEMS mobile phone was used to indicate the calls during the data collection stage. The data was collected starting from a distance of 0.5km from the selected base station. The vehicle was moved along the selected routes from the site up to a distance of five kilometers. Obstruction and terrain were observed. To improve on the accuracy of the measurements, the mean of the data from each route was obtained.

These values from the Okumura-Hata and COST-231 Hata models were compared with the measured values. The various standard deviations were calculated from the equation.

$$\sigma = \sqrt{\sum \frac{(P_m - P_r)^2}{N}} \qquad (7)$$

where

P_m = measured path loss (dB), P_r = predicated path loss (dB),

N = number of measured data points

The mean square error (μ_e) is also given by

$$\mu_e = \frac{\sigma}{\sqrt{N}} \qquad (8)$$

Table 1: Location of the routes, standard deviations (σ) and mean square errors (μ_e) of the Okumura and COST 231 models at 900MHz at 1800MHz for these routes

City	Location	Okumura (dB) at 900MHz	COST (dB) at 900MHz	COST231 (dB) at 1800MHz
		μ_e σ	μ_e σ	μe σ
Lagos	Victoria Island Lekki	13.60 42.98 5.39 17.02	13.52 42.73 5.06 15.99	4.66 14.73 5.06 8.86

Table 2: Proposed modified equations for both Okumura-Hata and COST 231 at 900MHz and 1800MHz for the cities.

City	Location	Okumura-Hata Equations (P_L=) at 900MHz	COST231 Equations (P_L=) at 900MHz	COST `231 Equations (P_L =) at 1800MHz
Lagos	Victoria Island Lekki	119.19+ 34.79 $\log_{10}(d)$ 120.64 + 35.04 $\log_{10}(d)$	111.62 + 34.79 $\log_{10}(d)$ 120.61 + 35.05 $\log_{10}(d)$	130.64 + 34.79 $\log_{10}(d)$ 132.74 + 45.86 $\log_{10}(d)$

The mean square error of each site was subtracted from the Okumura-Hata and COST 231 Hata models for the particular site to give the proposed model equations for the sites. These equations are written in the form of equation 1.

Results and Discussion

The measurements obtained are shown graphically in figures 2a to 3b. From these measured data, the standard deviations and mean square errors were calculated and tabulated in tables1 and 2 for the two frequencies under consideration. Tables 1 and 2 show the locations of the routes, standard deviations, mean square errors and modified equations. Figure 1 is a sketch of one of the routes.

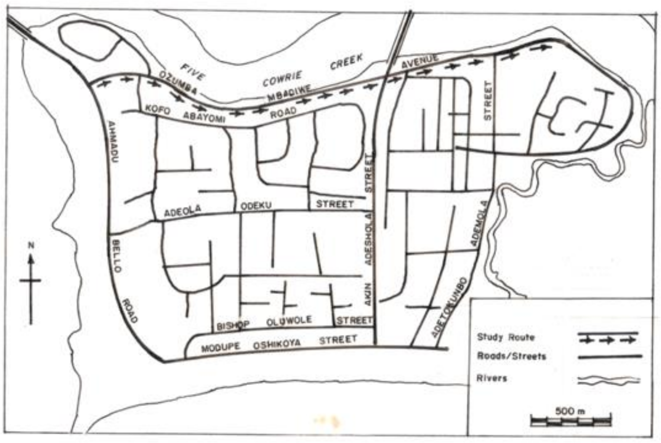

Fig.1: Sketch showing Victoria Island and one of the study routes

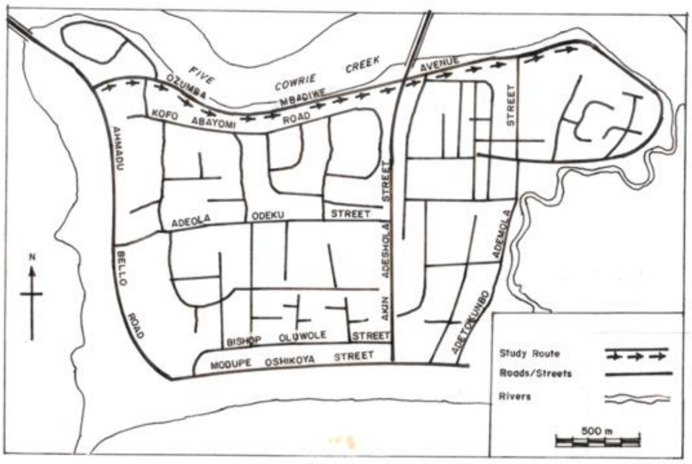

Fig.1: Sketch showing Victoria Island and one of the study routes

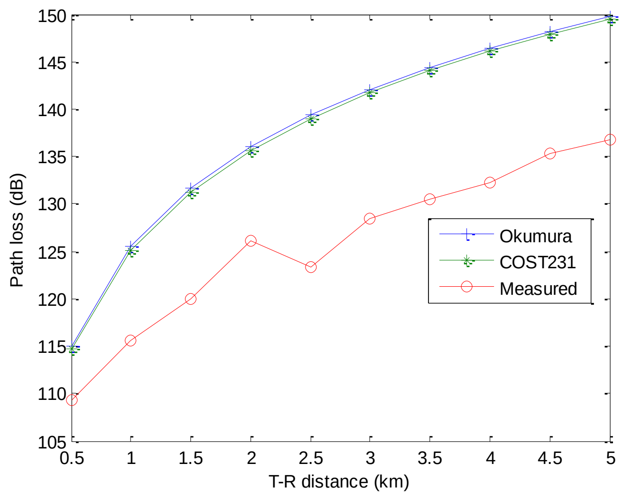

FIG. 2a :Path loss at 900MHz for classics and measured for Victoria Island, Lagos

Victoria Island links Ikoyi and Lagos Island through bridges. This area has many high-rise buildings such as the 1004 flats etc. Due to its well planned nature and high heights of BTS, the values obtained were low. The test drive was along Ozumba Mbadiwe Avenue which is a very busy area close to Five Cowrie Creek. The mean square errors were 13.60dB and 4.66dB for 900MHz and 1800MHz respectively.

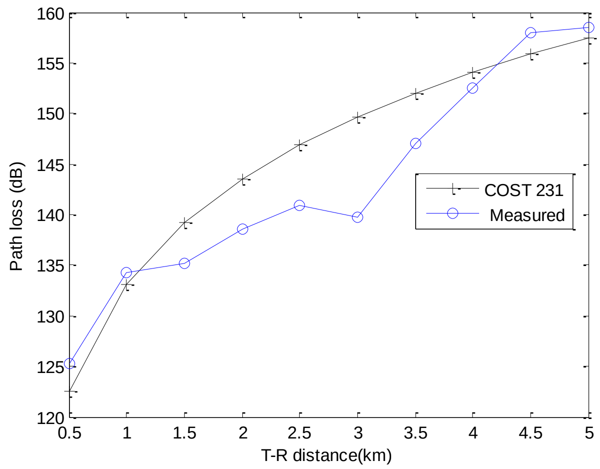

Fig. 2b:Path loss at 1800MHz for COST 231 and measured for Victoria Island, Lagos

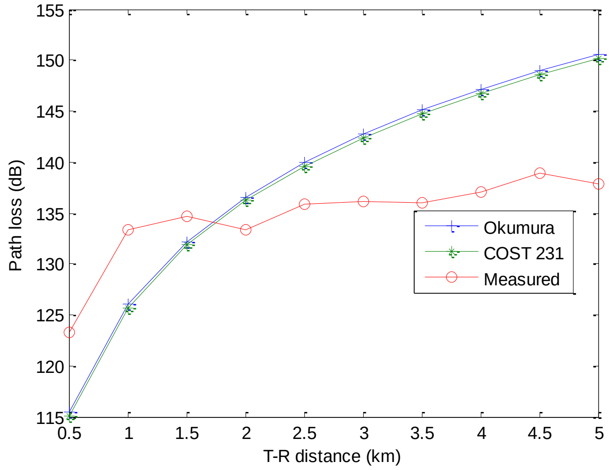

Fig.3a: Path loss at 900MHz for classic models and measured for Lekki, Lagos

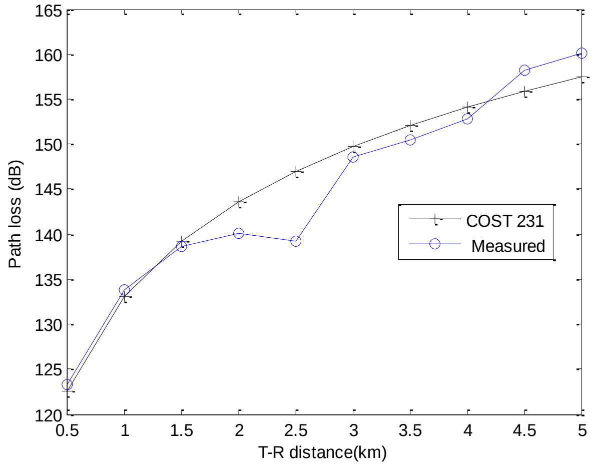

Fig.3b: Path loss at 1800MHz for COST231 and measured for Lekki, Lagos

Signal reception was quite okay as the BTS towered above the buildings. The body of water around the area made the values at 4.5km (157.93dB) and 5km (158.45dB) above the classical values of the COST231 at 1800MHz.

Lekki peninsula is an exclusive area of Lagos under massive development. The area is planned with many estates. The drive test started at Ajah Junction to Badore. The highest building is three storeys high. Badore is very close to the sheltered waters of the peninsula. The values of path loss were higher than those classical models for the first half kilometres due to higher clutter at Ajah Junction. The standard deviation and mean square errors were 17.02dB and 5.392dB, 15.99dB and 5.06dB for Okumura and COST231 respectively at 900MHz.

Summary and conclusion

The basic mechanism of planning a network is to ensure that the right type and size of equipment are provided to meet the needs of the customer in the most economical way. To make this procedure to function, there must be a measure of equipment usage and a measure of the service the customer receives Ogbulezie (2008).

From the measurements and analysis carried out in this work, it can be seen that the classical models for path loss determination over estimated the path loss for the two routes considered in this work. The average path loss values for Victoria Island were 138.49dB and 143.00dB at 900MHz and 1800MHz respectively while for Lekki the values were 135.01dB and 144.52dB.

Path loss determination are required for the coverage planning, determination of multipath effects as well as interference and cell calculations The overall network plan must ensure appropriate design, implementation and maintenance of the entire segments of the network. With these segments having appropriate circuit equivalents, the assurance of quality can be guaranteed. Planning and cell dimensioning should always be in advance of traffic demand. These variables are dependent on reliable growth and prediction of future traffic trend.

Measurements taken in this work were compared against predictions made by the Okumura Hata and COST 231 Hata models. These classical models over estimated the path loss. The measurements were taken during the rainy season and hence thicker foliage contributing to the high values in some areas.

The proposed modified Okumura Hata and COST 231Hata models could be fully adapted for Lagos because amongst other considerations, they make provision for rain attenuations as well as the unique features of the city. By adopting these modified propagation equations and increasing the number of base stations, coverage by the network operators will be greatly improved. The cell size will decrease; call dropping rates reduced and customer satisfaction guaranteed.

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