

Evaluating Pathloss Propagation Using Okumura-Hata Model for Surulere Area in Lagos State, Nigeria.

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Abstract

Good network performance in any wireless network which is a measure of the strength of signal received is of a great concern to the network provider. The desire in this research work is to use a Path loss Propagation Model that can help in planning better Global System for Mobile Communication (GSM) network. The data used were collected via drive test. The down link signal level were collected using test phones, TEMs investigating software (Agilent technology) and info maps. The base station antenna height is 30m and mobile station antenna height is 1.5m and the average Path loss was measured to be 147.76dB.

Comparison was made between measurement results and Prediction Model (Okumura-Hata Propagation Model) with GSM network at a frequency of 1500MHz. The results were consistent with the Okumura-Hata Model for Path loss Propagation with a little deviation which is as a result some macroscopic parameters and this will provide a plat form to aid in system optimization process for improve performance also for characterization of the quality of radio coverage.

Key words: Drive Test, GSM, Path loss, Okumura-Hata Model, TEMs

1.0 Introduction

Since the launch of GSM in Nigeria in August 2001, it has changed the face of Information and Communication Technology (ICT) in the country. Mobile telephony has rapidly become the most popular method of voice communication in Nigeria. The growth has been so rapid that Nigeria has been rightly described in various forums as 'one of the fastest growing GSM markets in the world' [1].

Path loss (Path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a

telecommunication system. This term is commonly used in wireless communication and signal propagation. Path loss may be due to many effects, such as free space loss, refraction, diffraction, reflection, aperture-medium coupling loss and absorption. Path loss represents the mean signal attenuation at a certain distance from the transmitter and can be predicted by the distance and other macroscopic parameters such as carrier frequency, transmitter and receiver antenna heights, terrain, contour, and buildings concentration [2,3]. One of the main reason for understanding the various elements affecting radio signal Path loss is to predict the coverage area that may be achieve for a particular broadcast station and also to predict the suitability of Model as well.

Path loss is usually expressed in decibels (dB). In its simplest form, the Path loss can be calculated using the formula

$$L = 10n \log_{10}(d) + C \dots\dots\dots (1)$$

Where L is the Path loss in dB, n is the Path loss exponent, d is the distance between the transmitter and the receiver, usually measured in meters, and C is a constant which accounts for system losses.

Prediction of Path loss is a significant element of system design in any communication system. A reliable Propagation Model is one which calculates the Path loss with small standard deviation. Suitable Models must be chosen for measurements of field strength and Path loss as well as other parameters. An accurate and reliable prediction method helps to optimize the coverage area, transmitter power and eliminates interference problems of other radio transmitters as well. This will help network engineers and planners to optimise the coverage area and to use the correct transmitted powers. All the prediction methods are divided into empirical and physical model . The preference for the coverage Prediction Model depends on the propagation environment and the area to be covered. For this reason, Prediction Models have been developed using empirical or statistical methods. The critical factor that affects Path loss is the distance between the transmitter and receiver. It is known that signal power decreases as distance increases[4,5,6].

2.0 Propagation Models in Brief

The two basic Propagation Models (Free-Space and Plane Earth loss) have all the mechanisms which are encountered in macro cell prediction. Many researchers use these Models and predict the total signal loss. Other Models require detailed knowledge of the locations, dimensions and parameters for every tree or building and terrain features in the area to be covered. The Models are complex and yield an unnecessary amount of details as the network designer is not only interested in the particular locations covered, but mainly on the overall extent of the coverage area. One appropriate way of removing these complexities is to adopt an Empirical Model.

These Models use all the parameters like the received signal strength, frequency, antenna heights and terrain profiles which were derived from a particular environment by the use of extensive measurements and statistical analysis as well. These Models then can be used to design the system which operates on similar environmental condition as the original measurements [7].

2.1 Free Space Propagation Model

The free space Propagation Model is used to predict received signal strength when the transmitter and receiver have a clear and unobstructed line-of-sight path between them. Since in most large- scale radio wave Propagation Models, the free space Model predicts that received power decays as a function of the separation distance between Transmitter-Receiver raised to some power (i.e. a power law function). In this case free space power received by a receiver antenna which is separated from a radiating transmitter antenna by a distance d is given by the Friis free space equation [8].

$$P_r(d) = P_t G_t G_r \lambda^2 / (4\pi)^2 d^2 \dots\dots\dots(2)$$

Where $P_r(d)$ is the received power, P_t is the transmitted power, G_t is the transmitter antenna gain, G_r is the receiver antenna gain, d is the transmitter-receiver separation distance in meters and λ is the wavelength in meters.

$$PL = - 10\log_{10} G_t - 10\log_{10} G_r - 20\log_{10} [(c \times 10^3) / 4\pi \times f \times 10^6] - 20\log_{10}(1/d)$$

$$PL = -G_t - G_r + 32.44 + 20\log_{10}(d) + 20\log_{10}(f) \dots\dots\dots(3)$$

Where PL is the Path loss, f is the frequency in MHz and c is the speed of light ($3 \times 10^8 \text{ms}^{-1}$).

2.2 Okumura Model

The Okumura Model is an Empirical Model based on extensive drive test measurements made in Japan at several frequencies within the range of 150 to 1920 MHz and further extrapolated up to 3000 MHz. Okumura's Models is developed for macro cells with cells diameters in range from 1 to 100 km. The height of the base station antenna is kept between 30-100 m. The Okumura model has taken into account several propagation parameters such as the type of environment and the terrain irregularity. Okumura developed a set of curves which gives the median attenuation relative to free space (Amu), in an urban area over a quasi-smooth terrain with a base station effective antenna height (h_b) of 200m and a mobile antenna height (h_m) of 3 meters. These curves were developed from extensive measurements using vertical omni-directional antenna at both the base

and mobile. In this case curves are plotted as a function of frequency in the range of 100 MHz to 1920 MHz, and as a function of distance from the base station in the range from 1 km to 100 km.

$$PL_{50} = L_F + Amu(f,d) - G_{(hb)} - G_{(hm)} - G_{AREA} \dots\dots\dots(4)$$

Where $PL_{50}(\text{dB})$ is the median value (i.e. 50th percentile) of Path (propagation) loss, L_F is the free space loss and can be calculated using either Equation (6) or Equation (7). The value of Amu is the median attenuation relative to free space, $G_{(hb)}$ is the base station antenna height gain factor, $G_{(hm)}$ is the mobile antenna height gain factor, and G_{AREA} is the gain or correction factor owing to the type of environment. $Amu(f; d)$ and G_{AREA} are determined by observing the Okumura curves.

The term $G_{(hb)}$ and $G_{(hm)}$ can be calculated by using these simple formulas :

$$G_{(hb)} = 20 \log_{10} (1000m / h_b) \quad h_b > 30m \dots\dots\dots(5)$$

$$G_{(hm)} = 10 \log_{10} (h_m / 3) \quad h_m \leq 3m \dots\dots\dots(6)$$

$$G_{(hm)} = 20 \log_{10} (h_m / 3) \quad 10m \leq h_m \leq 3m \dots\dots\dots(7)$$

Okumura's Model is considered to be the simplest and most excellent in terms of accuracy in Path loss prediction for mature cellular and land mobile systems in cluttered environment. The main disadvantage of the Okumura Model is its sluggish response to rapid changes in terrain condition. Consequently the model is fairly good in urban and suburban areas but not as good (suited) for rural areas [9,10].

2.3 Okumura-Hata Path loss Model

The Okumura-Hata Model (1980) is an empirical formulation of the graphical Path loss data provided by Yoshihisa Okumura, and is valid from 150 MHz to 1500 MHz. This Model basically is a set of equations based on measurements and extrapolations from the curves derived by Okumura. Okumura-Hata presented the urban area Propagation loss as a standard formula, along with additional correction factors for application in other situations such as suburban and rural area. Only four parameters are required in this Model as a result the computation time is very short in this Model. This is one of the main advantages of this Model. However, the Model neglects the terrain profiles (conditions) between the transmitter and receiver i.e. hills or other obstacles that exist between the transmitter and receiver were not considered. This is because both Okumura-Hata and Okumura Models have made the assumption that the transmitters would normally be located on hills. The basic formula for the median Propagation loss given by Okumura-Hata is:

$$PL = 69.55 + 26.16 \log_{10} f_c - 13.82 \log_{10} h_1 - ah_2 + (44.9 - 6.55 \log_{10} h_1) \log_{10} d - K \dots\dots\dots (8)$$

where f_c is the carrier frequency (in MHz) from 150 MHz to 1500 MHz, h_b is the base station antenna height (in metres) ranging from 30m to 200m, h_m is the mobile antenna height (in metres) ranging from 1 m to 10 m, d is the base station to mobile separation distance (in km), and $a(h_m)$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area.[6]

Table 1: Okumura-Hata Model Parameters

Type of Area	$a(h_m)$	K
Open	$(1.1\log_{10}f_c - 0.7)h_m - (1.56\log_{10}f_c - 0.8)$	$4.7(\log_{10}f_c)^2 - 18.33\log_{10}f_c + 40.94$
Sub-Urban	$(1.1\log_{10}f_c - 0.7)h_m - (1.56\log_{10}f_c - 0.8)$	$2[\log_{10}f_c / (28)]^2 + 5.4$
Medium-Small City	$(1.1\log_{10}f_c - 0.7)h_m - (1.56\log_{10}f_c - 0.8)$	0
Large City ($f_c > 300$)	$3.2(\log_{10} 11.75h_m)^2 - 4.97$	0
Large City ($f_c < 300$)	$8.29(\log_{10} 1.54h_m)^2 - 1.10$	0

An Empirical formula for extending the Okumura-Hata Model range up to distances 20 to 100 km was developed by ITU-R also the Cost -231 Model can be use for small distances and also extend validity of the frequency range of Okumura-Hata Model to 1500-2000MHz [6].

3.0 Methodology

Surulere is a residential and commercial area, it is part of Metropolitan Lagos City and a Local Government Area located on the Lagos mainland in Lagos State, Nigeria, with an area of 23 km². At the last census in the year 2006, there were 502,865 inhabitants, with a population density of 21,864 inhabitants per square kilometre. The data used for this work was collected via the Drive Test, the down link signal level were collected using test phones, TEMs investigating software (Agilent technology) and info maps carried out for sites around Surulere, from GSM network along major streets in Surulere (Funsho Williams Avenue, Alhaji Masha Street, Lawanson, Itire Road, Akerele Road, Randle Avenue, Ogunlana Drive, Adeniran Ogunsanya, Bode Thomus and Sab Animashaun Street) as shown in the Google Earth map in Figure 1. The Data shows the Rx Level, Rx Quality and FER as recorded from the drive test (Table 2) and were analysed.

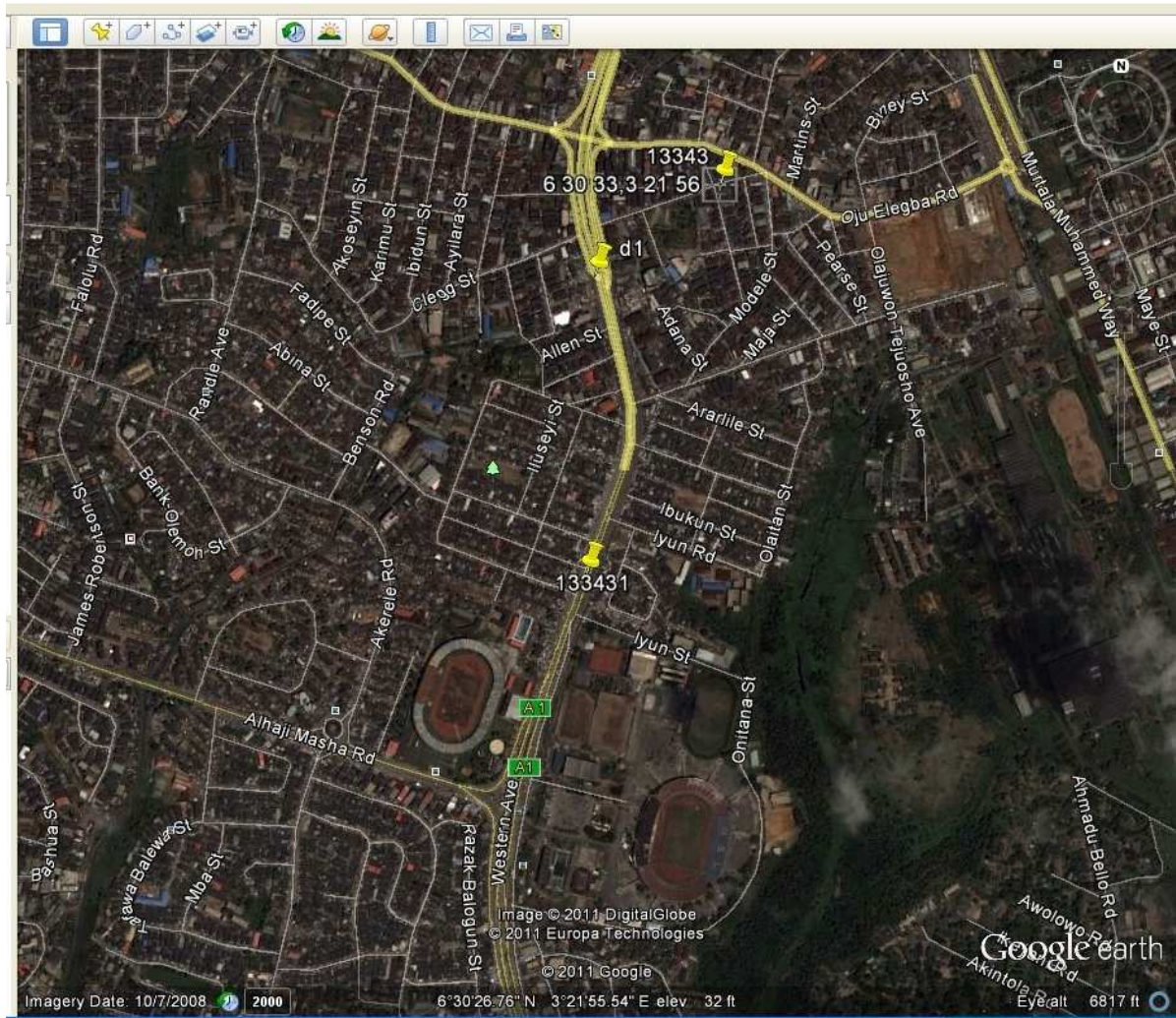


Figure 1: Google Earth map for Surulere, Lagos State

Table 2: Rx Level (coverage) Data

S/N	Latitude	Longitude	Cell ID	Rx Level (Full)	Rx Level (Sub)	Rx Quality (Full)	Rx Quality (Sub)
1	6.51267	3.34944	11146	-72	-77	1	0
2	6.51266	3.34946	11146	-72	-73	3	2
3	6.51266	3.34953	11146	-76	-76	2	2
4	6.51266	3.34966	11146	-77	-80	4	3
5	6.51266	3.34966	11146	-70	-76	3	0
6	6.51266	3.34977	11146	-79	-78	5	3
7	6.51266	3.34994	11146	-79	-78	4	4
8	6.51266	3.36033	11165	-74	-72	3	0
9	6.48898	3.35602	11165	-76	-74	3	0
10	6.48898	3.35603	11165	-72	-72	2	0

4.0 Results

The measurements were taken at an interval of 500m, 10 times for each measurement which is a summary and measured results from the data collected. Table 3 contain the measured Path loss and theoretical value for Okumura-Hata Model with the same distance interval.

Table 3: Measured Path loss and Okumura-Hata Model Path loss in dB

Distance (m)	Path loss (dB)	Okumura-Hata Model Path loss (dB)
500	140.12	123.66
1000	139.88	134.26
1500	142.32	140.46
2000	144.32	144.86
2500	145.42	148.28
3000	147.43	151.06
3500	150.13	153.42
4000	154.12	155.47
4500	155.53	157.27
5000	158.34	158.88
Overall average	147.76	146.76

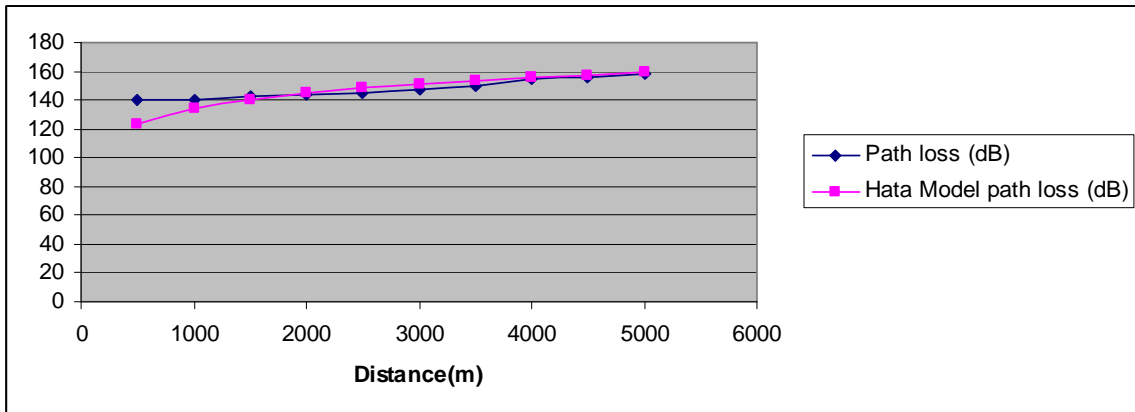


Figure 2: Path loss (measured and that of Okumura-Hata Model) versus distance

5.0 Discussion of Results

From Figure 2 which is the graph that compares the Path loss for the measurement results and that of the Okumura-Hata Model, it is obvious that there is a significant relationship between the measured and the Model results (both of them have almost the curve) which made it clear that Okumura-Hata Model is a suitable Model that can be use for estimating the propagation of Path loss in urban area like the area under investigation.

6.0 Conclusion

The overall average Path loss was 147.76dB and 146.76dB for the measured Path loss and Okumura-Hata Model Path loss respectively with a mean square error of 3.0dB. These results thus show that the Okumura-Hata Model for radio wave propagation is very effective and will be useful in planning and optimizing of GSM services in the investigated environment.

The need for high quality and high capacity network, estimating coverage accurately has become extremely significant. Therefore, for more accurate design coverage of modern cellular networks the signal strength measurements must be taken into consideration in order to provide an efficient and reliable coverage area.

7.0 References

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