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# A COMPARATIVE INQUIRY OF PATH LOSS ANALYSIS FOR GSM NETWORK USING OKUMURA-HATA MODEL FOR SURULERE AREA IN LAGOS STATE, NIGERIA.

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## ABSTRACT

*Surulere, Lagos State have experienced rapid growth in GSM network, as the number of subscribers of GMS phone user increases the spectral efficiency becomes more critical because the frequency allocation is limited. This research is aimed at using a Model that can help in planning better GSM network and to address the defects and complains of the poor quality of GSM network services in Surulere area in Lagos State by consumers/subscribers.*

*In this research, comparison were made between measurement results and prediction model (Okumura - Hata Propagation Model) and was presented with the GSM network at a frequency of 1800MHz. The results shown are consistent with the Okumura - Hata Model for Path loss Propagation with a little deviation which might be due to some environmental terrain factors, this will provide a plat form that will aid system optimization process for improve performance and also for characterization of the quality of GSM coverage in the investigated area.*

**Keywords**: Drive test, Pathloss, Frequency, GSM Network, Okumura-Hata Propagation Model, Subscribers.

## 1. INTRODUCTION

Surulere, Lagos is an urban, residential and commercial area, and a Local Government Area located on the Lagos mainland in Lagos State, Nigeria, with an area of 23 km². It is part of Metropolitan Lagos. At the last census in the year 2006, there were 502,865 inhabitants, with a population density of 21,864 inhabitants per square kilometre.

Surulere, experience rapid growth of Global Mobile of Communication (GSM) telephone subscribers right from the time GSM license was auctioned by the Nigeria Communications Commission (NCC) in February 2001, as the number of subscribers of GSM phone user increases the spectral efficiency becomes more critical because the frequency allocation is limited. The smaller the frequency reuse the greater the network capacity, high spectral efficiency means great achievement by reusing frequency over irregular terrain such as buildings and other geographical features [7].

Urban areas have moderate climatic atmosphere, with most of the localities in flat surface terrains and suburban is the combination of the both [5]. GSM comes under wireless communication, which depends on the Propagation of waves in the free space and providing transmission of data [11], it extends service by providing mobility for users, which fulfils the subscribers demand at any terrain covered by wireless network. When we consider the earlier historical legacy, the growth in mobile communications field has now become less. Here, the paramount factor was to serve for high quality and high capacity networks. Estimated coverage precisely has become very pivotal. So, in lieu of accomplishing far more accurate design, coverage of modem cellular networks and signal strength measurements will be considered as source of data, in order to provide reliable and efficient coverage locality. This paper focuses on the comparisons between theoretical and experimental analysis, at channel Propagation Path loss Models at GSM frequency of 1800MHz for various terrains in Surulere. Here, the clutters show the vegetation of the different areas for propagation of RF signals [11]. Figure 1 shows the framework of GSM technology.

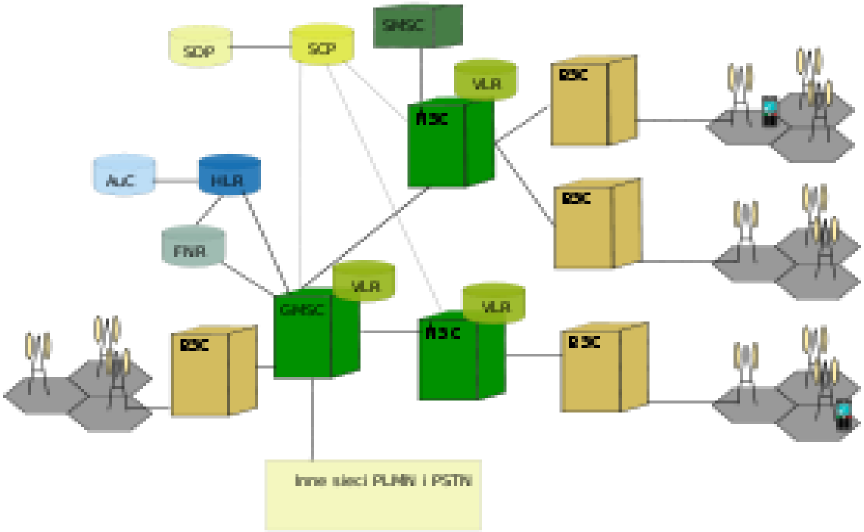


**Figure 1: GSM framework**

## 2. SIGNIFICANCE OF PROPAGATION FORECAST



Planning is the key before implementing designs, and also setting up of wireless communication systems. Precise propagation characteristics of the situation should be known. Usually propagation provides two types of data, corresponding to the large-scale path loss and small- scale statistics pertaining to fading issue. Information regarding path-loss is very pivotal, for knowing the coverage of a base-station (BS) and in tuning it. The statistics provided by the small-scale parameters pertain only to local field variations. Also in turn this helps to improvise receiver (Rx) design structure and counter the multipath fading [11].

## 3. PATH LOSS IN GSM

Path loss (or 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 communications 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 is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas.



### 3.1 CAUSES OF PATH LOSS

Path loss normally includes Propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere), absorption losses (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radiowave front is obstructed by an opaque obstacle, and losses caused by other phenomena.

The signal radiated by a transmitter may also travel along many and different paths to a receiver simultaneously; this effect is called multipath. Multipath waves combine at the receiver antenna, resulting in a received signal that may vary widely, depending on the distribution of the intensity and relative propagation time of the waves and bandwidth of the transmitted signal. The total power of interfering waves in a Rayleigh fading scenario vary quickly as a function of space (which is known as *small scale fading*). Small-scale fading refers to the rapid changes in radio signal amplitude in a short period of time or travel distance.

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

$L = 10\, n\, \log_{10}(d) + C$ ............................ *(1)*

where *L* is the path loss in decibels, *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.

### 3.2 RADIO ENGINEER FORULAM

Radio and antenna engineers use the following simplified formula (also known as the Friis transmission equation) for the path loss between two isotropic antennas in free space:

Path loss in dB:

$$L = 20\ \log_{10}\left(\frac{4\pi d}{\lambda}\right)$$ ………………………………. **(2)**

where *L* is the path loss in decibels, λ is the wavelength and *d* is the transmitter-receiver distance in the same units as the wavelength.

### 3.3 PREDICTION

Calculation of the path loss is usually called *prediction*. Exact prediction is possible only for simpler cases, such as the above-mentioned *free space* Propagation or the *flat-earth model*. For practical cases the path loss is calculated using a variety of approximations.

*Statistical* methods (also called *Stochastic* or *Empirical*) are based on measured and averaged losses along typical classes of radio links. Among the most commonly used such methods are Okumura-Hata, the COST Hata model, W.C.Y.Lee, etc. These are also known as *Radio Wave Propagation Models* and are typically used in the design of cellular networks and PLMN. For wireless communications in the VHF and UHF frequency band (the bands used by walkie-talkies, police, taxis and cellular phones), one of the most commonly used methods is that of Okumura-Hata.

Other well-known models are those of Walfisch-Ikegami, W.C.Y. Lee, and Erceg. For FM radio and TV broadcasting the path loss is most commonly predicted using the ITU model.

## 3.4 EMPIRRCAL PROPAGATION MODEL

The three basic Propagation Model mainly use in Theoretical Model for path loss propagation are; free space, flat or smooth loss and the diffraction loss would requires detailed knowledge of the location, dimension and constitutive parameters of every buildings , trees and other geographical features in the investigation area or cell to be covered. This far complex, tedious and cumbersome to be practical and definitely it would yield unnecessary amount entails or it is difficult to gain an accurate bill of components in the investigation area but one obvious way for determining these complex effects is through Empirical Propagation Model, there are actually many types of Empirical Propagation Model among few are Okumura – Hata Model, Sakagami – Kuboi Model and Walfisch – Ikegami Model these models can solve the problems of the complexity effects, among the Models Okumura-Hata is chosen because of its suitability of general characteristics of the investigation area.

Comment [UE1]:

## 3.5 OKUMURA – HATA MODEL

Okumura Hata model is characterized by the following parameters; carrier frequency 900MHz and 1800MHz, the from the base station ranges from 1km to 20km, the height of the base station antenna ranges from 30m to 200m and height of mobile station ranges 1m to 10m.

Base on the field test predicted, Hata created a number of Representive Path loss Mathematical Model for different types of clusters as follows:

$$L_u = 69.55+26.16 \log_{10}(f) -13.82\log_{10}(h_b) - C_H +[44.9 - 6.55 \log_{10}(h_B)]\log_{10} d \quad \ldots (3)$$

Where $L_u$ is the path loss for urban area, $L_m$ is the path loss for medium size city like Surulere, $h_B$ is the height of base station (BS) antenna, $h_M$ is the height of mobile station (MS) antenna, f is the operating frequency, d is the distance between the BS and MS in km and $C_H$ is the antenna height correction factor.

The mean square error E, is given by;

$$E = \sigma / \sqrt{N} \quad \ldots\ldots (4)$$

**4. REVIEW OF RELATED WORKS**

Over the years, various Propagation Path loss Models have been developed for the assessment of the performance of wireless communication systems for high quality of service delivery. Various research studies have been carried out by different researchers on the behaviour of radio wave within different environments under diverse environmental and geographical conditions. The Models derived are specific for the respective environment [11].

The Okumura – Hata Model is very effective for radio wave propagation path loss prediction in suburban and urban areas in Nigeria. In view of finding an adaptable and suitable Propagation Path loss Models cities in Nigeria [11].

He emphasized the need to examine the prediction error variations of the Path loss Models over other environment in order to be useful in such areas.

He concluded that Propagation Path loss Models may give different results if they are used in different environment other than in which they were designed.



## 5. METHODOLOGY

The data used were collected via drive test. The down link signal level were collected using test phones, Transmission Evaluation and Monitoring System (TEMS) investigating software (Agilent technology) and info maps.

The drive test was conducted within Surulere, Lagos Nigeria with a vehicle driven along predefined routes with the Cluster DT defined by the following 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.

The drive test survey routes were carefully planned in such a way that the distance is long enough to allow the noise floor of the receiver to be reached. Typically, a distance of approximately 0.5 km was considered appropriate. TEMS was used on a laptop with a Global Positioning System (GPS) and a TEMS Mobile Station (Sony Ericsson K800i) connected through Universal Serial Board (USB) ports. The personal computer serves as the communication hub for all the equipments in the system. The GPS operates with global positioning satellites to provide the location tracking for the system during data collection. This enables the system to determine the position of the Mobile Station on a global map which is already installed on the laptop. The Mobile Station was used to initiate calls during data collection process. While driving was going on, the handset was configured to automatically make calls to a fixed destination number. Each call lasted for 30 seconds hold time and the call was dropped. The phone remained idle for some period of time then another call was made.

The Data shows the Rx Level, Rx Quality and FER as Recorded from the drive test and was analysed to provide the required solution.

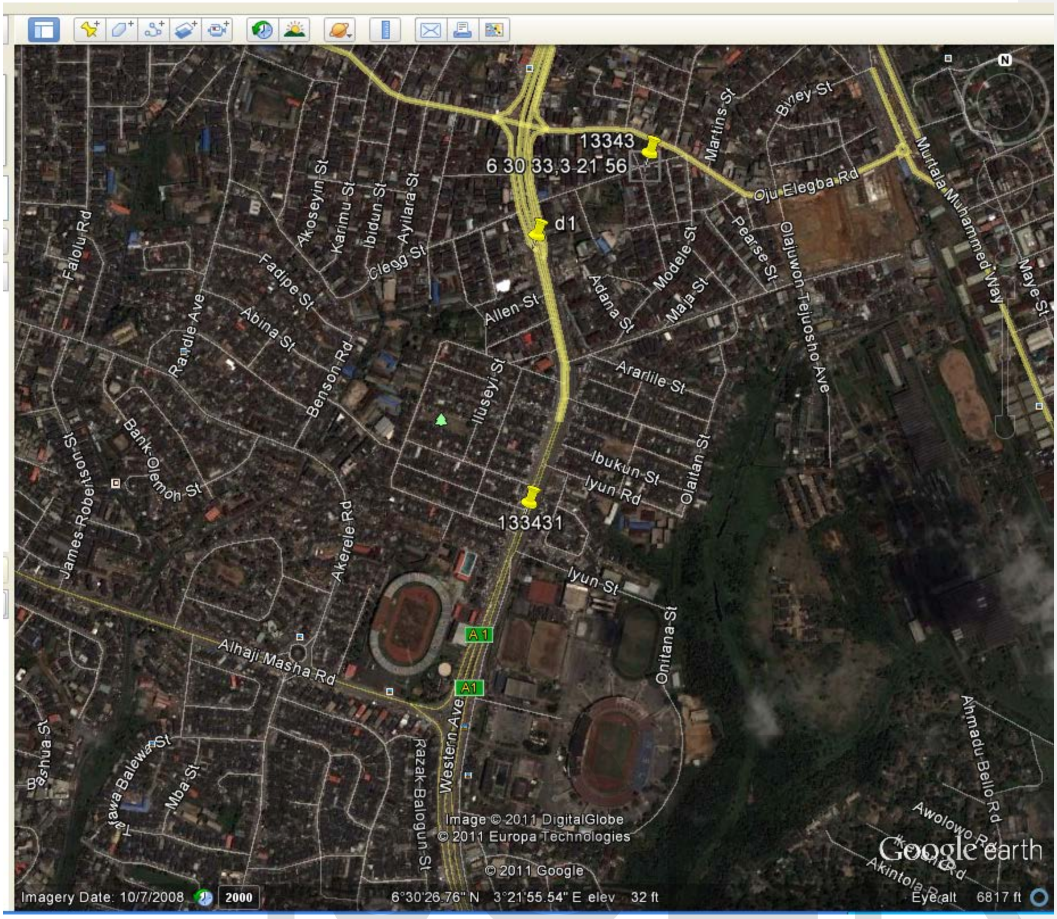


**Fig. 2: Google Earth map for Surulere, Lagos State.**

## 6. ANALYSIS OF DATA AND DISCUSSION OF RESULTS

The results of the measurement are shown in Table 1 below.

| S/no | 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 |

**Table 1: Rx Level (coverage) Data**

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The measurement were taken at an interval of 500m, 10 times for each measurement which is a summary and measured results from the data collected via drive test.

Table 4 contain the theoretical value for Okumura - Hata Model with the same distance interval.

| **Distance (m)** | **Path loss (dB)** |
|---|---|
| 500 | 140.12 |
| 1000 | 139.88 |
| 1500 | 142.32 |
| 2000 | 144.32 |
| 2500 | 145.42 |
| 3000 | 147.43 |
| 3500 | 150.13 |
| 4000 | 154.12 |
| 4500 | 155.53 |
| 5000 | 158.34 |
| Overall average | 147.76 |

**Table 3: Measured Pathloss in (dB)**

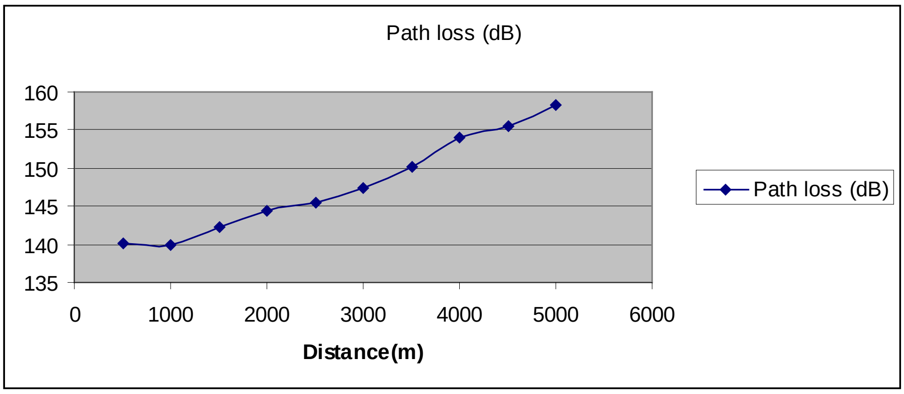


**Fig. 3: Path loss versus Distance**

| Distance (m) | Path loss (dB) | 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 |

**Path loss and Table 4: measured Hata model path loss in dB**

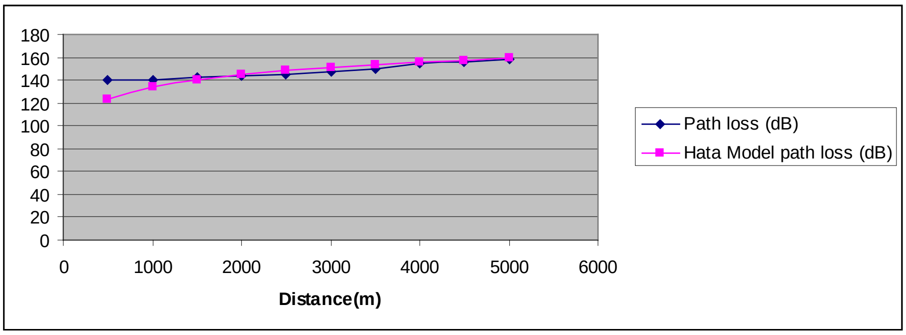


**Figure 4: Path loss (Measured and that of Okumura-Hata Model) versus Distance**

From Figure 4 which is the graph that compares the Path loss for the measurement results and that of the Okumura - Hata model, it is obvious that both of them have almost the curve which made it clear that Okumura - Hata Model is a well-known Model that can suit in for estimating the propagation of Path loss in urban area like the area under investigation, the average path loss is 147.76dB.

In this research, an Empirical Okumura - Hata Propagation Model was presented with the GSM network at a frequency of 1800MHz and will provide a plat form to aid in system optimization process for improve performance also for characterization of the quality of radio coverage in the investigated area.

The needs 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 in consideration in order to provide an efficient and reliable coverage area.

**7. SUMMARY AND RECOMMENDATIONS**

Measurements were conducted to precision, the overall average Path loss for the GSM used for the investigation for this research work is 147.76dB and if compare with the Okumura - Hata Model (which is 146.76dB) is so close the little different may be attributed to the nature of the environment or the location or height of the base stations (BSs).

Base on this result we can now recommend the use of Okumura – Hata Model for planning and optimization of GSM network. This will help radio network planners and engineers to accurately design GSM network with optimal network performance and better quality of service for the large populace of Surulere, Lagos State.

We suggest that any GSM network service provider that wants to deploy a radio network to an environment that has similar terrain features as that of Surulere area, to resort to this (Okumura _Hata) Propagation Model for Path loss analysis.

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