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Analysis Of Radio Propagation Characteristics For An Operative GSM Network: A Case Study Of Makurdi

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***Abstract:** This research work seeks to analyze the radio propagation characteristics of a GSM operative network using Makurdi as a case study. The analysis of radio propagation by a GSM operative entails the characteristics/ behavior of the radio wave between the transmitter and the receiver. An understanding of the radio wave propagation characteristics of an environment is a necessary condition for effective radio network planning which translate to the determination of the coverage strength of the network (the transmitted power, the antenna gain, antenna height and general location), the radio-coverage prediction is still a topic of great interest, both in the scientific community and amongst technology users. This interest produced a great number of electromagnetic propagation models, from which several computing algorithms have been developed, each one fits to a different application environment. The Stanford university interim (SUI) model was used to predict and analyze the path loss of a service provider at six different locations in the town using the data collected, the path loss was greatest at the Nyiman Layout Base station (176.34dB) and least at the Conoil North Bank base station (157.10dB) at 10.87km (base station to mobile station distance). The received signal strength was computed for the six base stations and the Nyiman Layout base station had the least (-88.67dBm) while the Conoil North Bank base station had the greatest (-69.43dBm). All the received signal strengths were above the threshold level (-92dBm) which implied that the estimated coverage within the path length of 10.87km is satisfactory.*

***Keywords:** (MS) Mobile Station, (BSS) Base Station System, MSC: Mobile Service Switching Center, (PLMN) Public Land Mobile Network, (VLR) Visitor Location Register, (GMSC) Gateway Mobile Service Switching Center, (HLR) Home location Register, (CN) Core Network*

I. INTRODUCTION

An understanding of the radio wave propagation characteristics of an environment is a necessary condition for effective radio network planning. This becomes very important today with the ever-increasing demand for radio channels following explosion in demand for wireless services. The analysis of radio propagation of a GSM network cannot be discussed in isolation because in totality, it implies a communication system. A communication system is a mechanism that provides the information link between a source and a destination.

Some of the key words that apply to the research include: transmitter, free space medium, receiver, and radio frequency etc.

TERMS ASSOCIATED WITH GSM

- ✓ *Mobile Station (MS):* It can be referred to as the test mobile phone used (the GSM handset).
- ✓ *Base Station System (BSS):* It is composed of one or more base station controllers (BSC) and one or more base transceiver stations (BTS). The BTS contains one or more transceivers (TRX). The TRX (mounted on the mast) is

responsible for radio signal transmission and reception. BTS and BSC are connected through the Abis interface. The BSS is connected to the MSC through the A interface. Figure 1.2 shows a pictorial view of a base station.

Figure 1: Pictorial View of a Base Station System

- ✓ *Mobile Service Switching Center (MSC):* It is the core switching entity in the network. The MSC is connected to the radio access network (RAN); the RAN is formed by the BSCs and BTSs within the Public Land Mobile Network (PLMN). Users of the GSM network are registered with an MSC; all calls to and from the user are controlled by the MSC. A GSM network has one or more MSCs, geographically distributed.
- ✓ *Public Land Mobile Network (PLMN):* A GSM network is a PLMN.
- ✓ *Visitor Location Register (VLR):* It contains subscriber data for subscribers registered in an MSC. Every MSC contains a VLR. Although MSC and VLR are individually addressable, they are always contained in one integrated node.
- ✓ *Gateway MSC (GMSC):* It is the switching entity that controls mobile terminating calls. When a call is established towards a GSM subscriber, a GMSC contacts the HLR of that subscriber, to obtain the address of the MSC where that subscriber is currently registered. That MSC address is used to route the call to that subscriber.
- ✓ *Home Location Register (HLR):* It is the database that contains a subscription record for each subscriber of the network. A GSM subscriber is normally associated with one particular HLR. The HLR is responsible for the sending of subscription data to the VLR (during registration) or GMSC (during mobile terminating call handling).
- ✓ *Core Network (CN):* It consists of, amongst other things, MSC(s), GMSC(s) and HLR(s). These entities are the main components for call handling and subscriber management. Other main entities in the CN are the equipment identification register (EIR) and authentication centre (AUC).

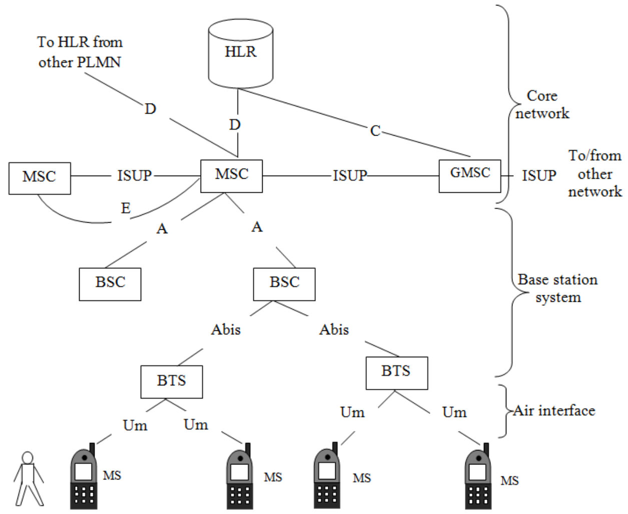

Figure 2: GSM Network Architecture

The various entities in the GSM network are connected to one another through signaling networks. Signaling is used for example, for subscriber mobility, subscriber registration, call establishment, etc. The connections to the various entities are known as 'reference points'. Examples include [1]:

- ✓ *A interface* – the connection between MSC and BSC.
- ✓ *Abis interface* – the connection between BSC and BTS.
- ✓ *D interface* – the connection between MSC and HLR.
- ✓ *Um interface* – the radio connection between MS and BTS.

II. CELLULAR NETWORK PLANNING AND OPTIMIZATION

The main aim of radio network planning is to provide a cost-effective solution for the radio network in terms of coverage, capacity and quality. The radio network planning process and design criteria vary from region to region depending upon the dominating factor, which could be capacity or coverage [8].

To achieve maximum capacity while maintaining an acceptable grade of service and good speech quality is the main focus in radio network planning. Planning for a network with a limited number of subscribers is not the major problem. The difficulty is to plan for a network that allows future growth and expansion. The objectives of radio network planning [9] can be summarized as:

- ✓ To obtain sufficient coverage over the entire service area and to ensure that high quality voice services and data services with low error rates can be offered to the subscribers.
- ✓ To offer the subscriber traffic network capacity with sufficiently low blocking and call dropping rate.
- ✓ To enable an economical network implementation when the service is established and a controlled network expansion during the life cycle of the network.

For an operator, good network planning produces the following benefits:

- ✓ Less money will be spent on infrastructure.
- ✓ More satisfied customers (good service quality).
- ✓ Less need for adjustments.

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For an operator, network optimization produces the following benefits:

- ✓ Better return for investment.
- ✓ Less need for costly hardware updates.
- ✓ Less need for new sites (which are very expensive).

An understanding of the radio propagation characteristics of an environment is a necessary condition for effective radio network planning; the conventional planning approach which is widely used is called the analytical approach to cellular network planning. This approach is focused on the determination of the transmitter parameters like transmitter location, antenna type, or transmitter power. It obeys the RF objective but neglects the capacity and the network design objective during the engineering process [10].

In principle, the analytical approach consists of four phases: Radio Network Definition, Propagation Analysis, Frequency Allocation, and Radio Network Analysis [10]. Figure 3 shows the conventional approach for cellular planning.

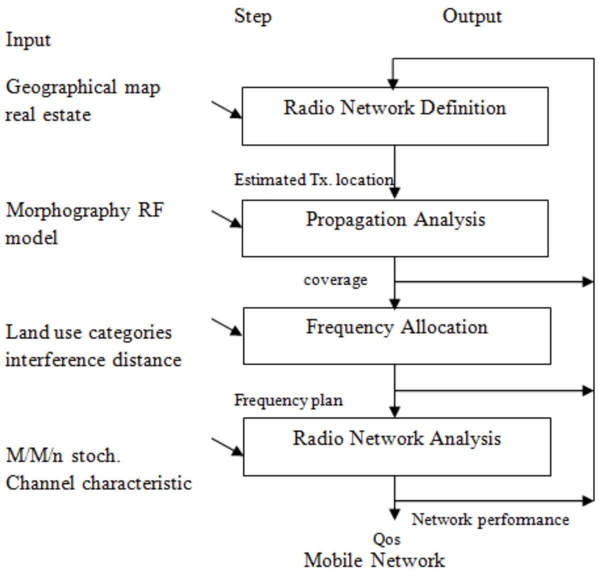

Figure 3: Conventional Approach of Cellular Network Planning [10]

- ✓ During the *Radio Network Definition* phase, a human expert chooses the cell sites. In order to obtain a regular structure, usually the popular concept of distributing the transmitters on a hexagonal grid is used in this step.
- ✓ Using these transmitter configurations, the *Propagation Analysis* of the area evaluates the radio coverage by field strength prediction methods. Here stochastic channel models as well as more sophisticated approaches like ray tracing techniques are applied. Usually, several field strength prediction methods are implemented but the tools offer little if any support in choosing the appropriate propagation model. If the planning expert decides that the coverage is not sufficient enough, new transmitter positions have to be chosen and the propagation has to be analyzed once again.
- ✓ The radio network capacity issues are addressed in the next phase, the *Frequency Allocation*. At first, the tele-traffic distribution within the planning region is derived based on rough estimates on the land use and the demographic structure of the area. The distribution is then stored in a traffic matrix. In the next step, a hexagonal grid representing the cells is superimposed on the entire planning region.

  If, for a given frequency reuse pattern and for given interference distance constraints, all the cells of the area can be supplied with the required number of channels, the algorithm proceeds to Radio Network Analysis. Otherwise the algorithm starts all over again.
- ✓ The *Radio Network Analysis* calculates the quality-of-service values of the area with regard to blocking and hand-over dropping probabilities. Again, stochastic channel characteristics as well as user demand estimates from the traffic data-base are used to calculate the network performance. If grade-of-service specifications are met, the task is accomplished; otherwise the algorithm has to be restarted.

The major disadvantage of the analytical approach is its restriction to the RF design objectives. Network and capacity issues are more or less neglected by the approach. The Integrated Approach to cellular network planning overcomes the shortcomings of the conventional approach by organizing the cellular design constraints and quality objectives.

In wireless communication systems, transfer of information between the transmitting antenna and the receiving antenna is achieved by means of electromagnetic radio waves. The interaction between the electromagnetic waves and the environment reduces the signal strength sent from transmitter to receiver, which causes path loss. The existing propagation model tries to evaluate this path loss as a means of improving the radio wave propagation during network planning.

A. TYPES OF PROPAGATION MODEL

Models for path loss can be categorized into three types Empirical Models, Deterministic Models, and Stochastic Models. Propagation models can further be classified into; Theoretical Models and Empirical Models as seen in figure 4. In general, path loss can be expressed as:

$$Pathloss(L_p) = \frac{PowerTransmitted}{PowerReceived} \text{ in dB} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

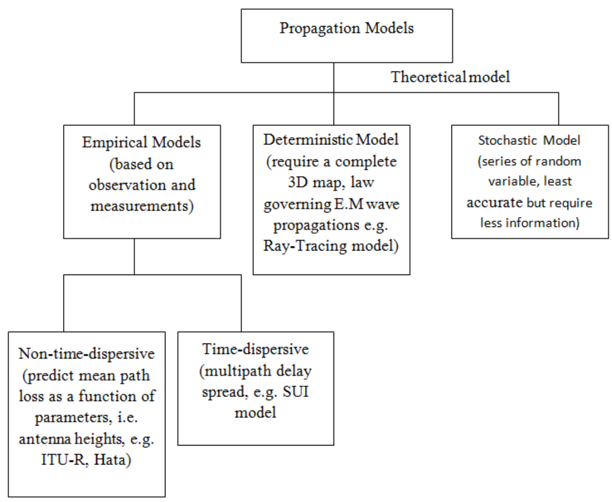

Figure 4: Categorization of Propagation Models

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THE EMPIRICAL PROPAGATION MODEL

At times it is impossible to explain a situation by a mathematical model. In that case, the use some data to predict the behavior approximately is applied. By definition, an empirical model is based on data used to predict, not explain a system and are based on observations and measurements alone. Common empirical propagation models include: The Okumura, Hata, Cost 231, Walfisch-Ikegami Model, and Stanford University Interim (SUI) Models etc.

III. EXPERIMENTAL EQUIPMENT SETUP

A typical setup for such an experiment will involve the following instruments: a power supply unit, a personal computer, GPS, and a test mobile station. The value of the signal strength (received power) at various locations can be used to calculate the path loss as shown in equation (3.1 –3.4):

A. HATA'S PROPAGATION MODEL

Hata model was based on Okumura's field test results and predicted various equations for path loss with different types of clutter. The limitations on Hata Model due to range of test results from carrier frequency (f) 150MHz to 1500MHz, the distance from the base station ranges from 1Km to 20Km, the height of base station antenna (h_b) ranges from 30m to 200m and the height of mobile antenna (h_m) ranges from 1m to 10m. Hata created a number of representative path loss mathematical models for each of the urban, suburban and open country environments, as illustrated in equations (2.11-2.14), respectively.

Path Loss for urban clutter:

$$L_p(Urban) = 69.55 + 26.16log_{10}(f) - 13.82log_{10}(h_b) - a(h_m) + [44.9 - 6.55log_{10}(h_b)]log_{10}(d) \ldots\ldots\ldots\ldots\ldots (2.11)$$

$where, a(h_m) = antennacorrectionfactor, L_p = medianpathlossindB$

$$a(h_m) = 0.8 + (1.1log_{10}(f) - 0.7)h_m - 1.56log_{10}(f) \ldots\ldots\ldots\ldots\ldots (2.12)$$

Path loss for suburban clutter:

$$L_p(suburban) = L_p(urban) - 2\{log_{10}(f/28)\}^2 - 5.4 \quad \ldots\ldots\ldots\ldots\ldots (2.13)$$

Path loss for the open country is:

$$L_p(opencountry) = L_p(urban) - 4.78\{log_{10}(f)\}^2 + 18.33log_{10}(f) - 40.94 \quad \ldots. (2.14)$$

Hata model is not suitable for micro-cell planning where antenna is below roof height and its maximum carrier frequency is 1500MHz. It is not valid for 1800 MHz and 1900 MHz systems.

B. THE OKUMURA MODEL

The Hata model for suburban Areas, also known as the Okumura-Hata model for being a developed version of the Okumura model, is the most widely used model in radio frequency propagation for predicting the behavior of cellular transmissions in city outskirts and other rural areas. This model incorporates the graphical information from Okumura model and develops it further to better suit the need. This model also has two more varieties for transmission in urban areas and open areas [4].

Okumura define path loss as;

$$L_p = L_{50} + L_f + A_{mu}(f,d) - G(h_b) - G(h_m) - G_{AREA} \ldots\ldots\ldots\ldots\ldots (2.15)$$

where,
L_{50} *is the* 50^{th} *percentile(i.e.media) loss,*
A_{mu} *is the median free space,*
L_f is the free space path loss,
$G(h_b)$ *is the base station antenna height gain factor,*
$G(h_b)$ *is the mobile antenna height gain factor,*
G_{AREA} *is the gain due to thet ype of environment.*
f: *Frequency [MHz]*
h_b: *Transmitter antenna height [m]*
h_m: *Receiver antenna height [m]*
d: *Distancebetweentransmitterandreceiverantenna [km]*

A_{mu} and G_{AREA} are obtained from relevant curves, developed by Okumura relating median attenuation and area gain to frequency respectively. He predicted that:

$$\left.\begin{aligned} G(h_b) &= 20log\, {h_b}/{200}, \quad 1000m > h_b > 10m \\ G(h_m) &= 10log\, {h_m}/{3}, \quad h_m \leq 3m \ldots\ldots\ldots \\ G(h_m) &= 20log\, {h_m}/{3}, \quad 10m > h_m > 3m \end{aligned}\right\} \ldots (2.16)$$

Figure 5 provides the values of *Amu (f, d)* and G_{AREA} (from set of curves).

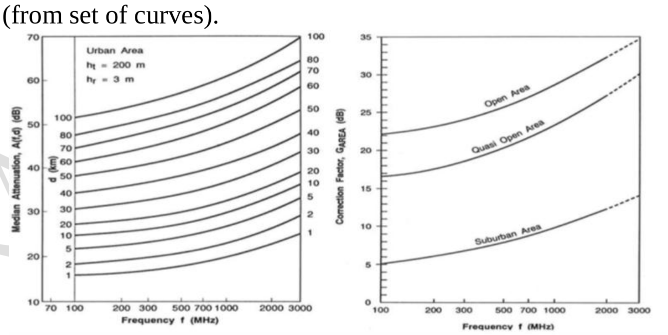

Figure 5: Median Attenuation and Area Gain Factor [13]

C. THE COST 231 MODEL

The European Co-operative for Scientific and Technical Research formed the COST 231 committee to develop an extended version of the Hata model such that applicability to 2 GHz is possible [3]. The model is applicable for mobile station antenna height up to 10m, base station antenna height of 30m to 100m and link distance up to 20km. Path loss in this model is computed as:

$$L_p = 46.3 + 33.9\log(f) - 13.82\log(h_b) - a(h_r) + [44.9 - 6.55\log(h_b)]d + C \quad \ldots\ldots (2.17)$$

Where,

L_p *is the median pathloss* (L_{50}) *indB*

$C =$ *0dB for medium sized city and suburban areas and 3dB for metropolitan centers,*
h_b *is the height of the transmitter(m),*
h_r *is the height of the receiver(m),*
d is the separation distance between the transmitter and receiver (km),
$a(h_r)$ *is the mobile station antenna height correction factor as described in the Hata model ,*
and f is the carrier frequency in MHz.

Power conversion from Watt to dBm is done using the expression:

$$PdBm = 10LogPmW \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

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Then, the effective power radiated from the BTS antenna (Pt in dBm) is given as:

$$P_t = P_{BTS} - P_{con} - P_D - P_f + (A_{ms} + A_{BTS}) \ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Where; P_{BTS} = basestationpower, P_{con} = connectorloss, P_D = duplexerloss
P_f = feederloss,
A_{ms} = Mobilestation(receiver)antennagainA_{BTS} = thebasestationantennagain.

The effective radiated power is subject to propagation loss (P_L) along its path due to reflection, diffraction, retraction, scattering, etc. Power at the receiver distances from the base station is expressed as:

$$P_L = P_t - P_r (indBm) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3.3)$$
$$P_L(dB) = 10 \log_{10}(P_t/P_r) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

D. APPLICATION OF THE PROPAGATION MODELS

The general Path loss equation is given by (Okumura-Hata Urban Propagation Model)

$$L_p = Q_1 + Q_2 \log(f) - 13.82\log(h_b) - a(h_m) + \{44.9 - 6.55\log(h_b)\}\log(d) + Qo \quad \ldots\ldots\ldots\ldots\ldots (3.5)$$

Where,
L_p = path loss in dB
f = Frequency in MHz
d = distance between BTS and the mobile (1 – 20 Km)
h_b = base station height in meters (30 to 100m)
$a(h_m)$ = Correction required if mobile height is more than 1.5 meters and is given by:
$a(h_m) = \{1.1 \log(f) - 0.7\}h_m - \{1.56 \log(f) - 0.8\}$ for urban areas and
$= 3.2\{\log(11.75h_m)\}^2 - 4.97$ for Dense urban areas
h_m = mobile antenna height (1 – 10m)
Q_1 = 69.55 for frequencies from 150 to 1000MHz
= 46.3 for frequencies from 1500 to 2000MHz
Q_2 = 26.16 for 150 to1000 MHz
= 33.9 for 1500 to 2000 MHz
Q_o = 0 dB for urban
= 3 dB for Dense urban

From equation (5), when the values of parameters like the height of mobile antenna (h_m), the height of base station (h_b), distance of base station from mobile station (d) and the frequency of propagation (f) are stated (collected from GSM operator in the case of this research), the value of the path loss can be calculated by adequate substitutions and mathematical manipulations.

E. HATA-OKUMURA EXTENDED MODEL OR ECC-33 MODEL

One of the most extensively empirical propagation models is the Hata-Okumura model which is based on the Okumura model. This model is a well-established model for the ultra-high frequency (UHF) band. Based on prior knowledge of Okumura model an extrapolated method is applied to predict the model for higher frequency greater than 3 GHz [13].

$$L_p = A_{fs} + A_{bm} - G_b - G_r \quad \ldots\ldots (3.6)$$

Where,

$$A_{fs}(\text{free space attenuation}) = 92.4 + 20\log_{10}(d) + 20\log_{10}(f)$$
$$A_{bm}(\text{Basic median path loss}) = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56[\log_{10}(f)]^2$$
$$G_b(\text{Transmitter antenna height gain factor}) = \log_{10}\left({}^{h_b}/_{200}\right) \times \{13.958 + 5.8[\log_{10}(d)]^2\}$$
$$G_r(\text{Receiver attenna height gain factor})$$
$$\begin{cases} = [42.57 + 13.7\log_{10}(f)][\log_{10}(h_r) - 0.585] & : \text{for a meduim city,} \\ = 0.759h_r - 1.862 & : \text{for a large city} \end{cases}$$

d: Distance between transmitter and receiver antenna [km]
f: Frequency [GHz]
hb: Transmitter antenna height [m]
hr: Receiver antenna height [m]

F. STANFORD UNIVERSITY INTERIM (SUI) MODEL

IEEE 80.16 Broadband Wireless Access working group proposed the standard for the frequency band below 11 GHz containing the channel model developed by Stanford University, namely SUI model. Thus prediction model come from the extension of Hata model with larger than 1900 MHz [1].

The base station height of SUI model can be used from 10m to 80 m. Receiver antenna height is from 2m to 10m. The cell radius from 0.1 km to 8 Km [5] the SUI model describes three types of terrain; they are terrain A, terrain B and terrain C. There is no declaration about any particular environment. Terrain A can be used for hilly area with moderate or very dense vegetation. This terrain presents the highest path loss. In our research work, we consider terrain A as a dense populated urban area. Terrain B is characterized for the hilly terrains with rare vegetation, or flat terrains with moderate or heavy tree densities. This is the intermediate path loss scheme. We consider this model for suburban environment. Terrain C is suitable for flat terrains or rural with light vegetation, here path loss is minimal.

The SUI model is widely used in calculating the path loss for the following reasons:

- ✓ Simplicity in computing path loss.
- ✓ Extended range of carrier frequency.
- ✓ Applicable for higher base and mobile station height as compared to the isolated models.

The basic path loss expression of the SUI model with correction factors is presented as [5].

$$PL = A + 10\gamma \log_{10}\left({}^{d}/_{d_o}\right) + X_f + X_h + s \quad for\ d > d_o \ldots (3.7)$$

Where the parameters are;

d: Distance between BS and receiving antenna	[m]
d_o: 100	[m]
λ : Wavelength	[m]
X_f : Correction for frequency above 2 GHz	[m]
X_h: Correction for receiving antenna height	[MHz]
s: Correction for shadowing	[dB]
γ : Path loss exponent	

The parameter A is defined as [5]

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

And the path loss exponent γ

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$$\gamma = a - bh_b + \left(C/h_b\right)$$

Where the parameter h_b, is the base station antenna height in meters, this is between 10 and 80 m. the constant a, b, and c depend upon the types of terrain that are given in table 3.1.

Model Parameter	Terrain A	Terrain B	Terrain C
A	4.6	4.0	3.6
b (m^{-1})	0.0075	0.0065	0.005
c (m)	12.6	17.1	20

Table 3.1: Parameters for Different Terrain

The frequency correction factor X_f and the correction for receiver antenna height X_h for the model is expressed in [5];

$$X_f = 6.0 \times log_{10}\left(f/2000\right)$$

$$X_h = -log_{10}\left(h_r/2000\right) \quad \text{For terrain type A and B}$$

$$X_h = -20.0 log_{10}\left(h_r/2000\right) \quad \text{For terrain type C}$$

Where, f is the operating frequency in MHz, and h_f is the receiver antenna height in meter. For the above the correction factors this model is extensively used for the path loss prediction of all three types of terrain in rural, urban and suburban environments.

G. DATA COLLECTION

The design values consist of the data collected from a GSM operator (GLO) in Makurdi town. These data consist of the various height of the base station and the frequency of propagation of each of the base station.

Globalcom Nigeria limited (Makurdi branch) comprises of 26 base stations according to the rollout engineer contacted during this research work. Table 3.1 gives the name of each of the base station, their height, and frequency of propagation.

S/No	Name	Location	Height(m)	Frequency(GHz)
1	MAK 001	Ankpa close H/L	36	13
2	MAK 002	Con oil BSU	36	18
3	MAK 003	Con oil N/B	70	13
4	MAK 004	Pila Village UAM	36	13
5	MAK 005	Ankpa road	50	18
6	MAK 006	Rice mill Wurukum	36	18
7	MAK 007	Sokoto st. Wadata	36	18
8	MAK 008	Catungo junction N/B	36	13
9	MAK 009	Top choice bakery Yema layout	36	18
10	MAK 010	Km 3 Judges Qtrs.	36	13
11	MAK 011	NAFE Base	36	18
12	MAK 012	New GRA	50	13
13	MAK 013	Gbonkon villa behind modern mkt.	50	13
14	MAK 014	Behind Zenith Bank	36	18
15	MAK 015	Off, Old Lafia rd. N/B	24	18
16	MAK 016	Ikpayongo	36	13
17	MAK 017	Behind BENADA	36	18
18	MAK 018	Int. mkt. behind vitia college	36	13
19	MAK 019	Behind Fed. Pay Office, Yema layout.	24	18
20	MAK 020	Mopo Barack, Naka rd.	36	13
21	MAK 021	Gbajimba rd.	36	18
22	MAK 022	Little angle schl. UAM rd.	36	18
23	MAK 023	Lower Benue	36	13
24	MAK 024	Tile Gyado college N/B	36	13
25	MAK 025	Comm. Qtrs.	36	13
26	MAK 026	Lobi Qtrs.	36	13

Table 3.2: Base Station Parameters for Globalcom Makurdi

IV. SIMULATION AND PRESENTATION OF RESULTS

Parameters	Values
TX power (watts)	0.25
TX power (dBm)	24.00
RX threshold level (dBm)	-92.00
Maximum receive signal (dBm)	-15.00
RX signal (dBm)	-39.29
Frequency (MHz)	13000 and 18000
Path length (Km)	10.87
Free space loss (dB)	135.47
Antenna height (m)	24, 36, 50 and 70
Reference mobile station height (m)	2

Table 4.1: Parameters and Values Used in Simulation

The SUI model of path loss prediction can be stated as follows;

$$PL = A + 10\gamma\, log_{10}\left(d/d_o\right) + X_f + X_h + s \quad \ldots\ldots\ldots \quad (4.1)$$

The following parameters will be varied at a fixed value of h_r (mobile antenna height [m]) to obtain a given path loss for such a variation:

- ✓ d: Distance between transmitter and receiver antenna [km]
- ✓ f: Frequency [GHz]

A. VARIATION OF PATH LOSS WITH DISTANCE

Simulation will be done using MATLAB for a distance of 0 – 12 km, (the distance between mobile station (RX) and transmitter TX) in order to ascertain the effect of path loss with varying RX to TX distance. All other parameters like frequency and base station height will be kept constant. The frequency for the Ideal Situation is 10 GHz while that for the Practical Situations is 13 or 18 GHz (depending on the base station considered). Appendix III gives more detail of the MATLAB simulation code. The selected base stations are.

- ✓ MAK 026: Lobi Quarter
- ✓ MAK 013: Behind Modern Market
- ✓ MAK 002 Con Oil, North Bank
- ✓ MAK 019: Yema Layout
- ✓ MAK 007: Sokoto Street, Wadata
- ✓ MAK 005: Ankpa Road

a. 13 GHz FREQUENCY AND 36 m BASE STATION HEIGHT (LOBI QUARTERS, MAKURDI)

The Lobi Quarters base station transmits at 13 GHz, and uses a 36 m antenna for transmission, the mobile antenna height is 2 m, and figure 6 shows the variation of the path loss with variation in mobile station to base station distance.

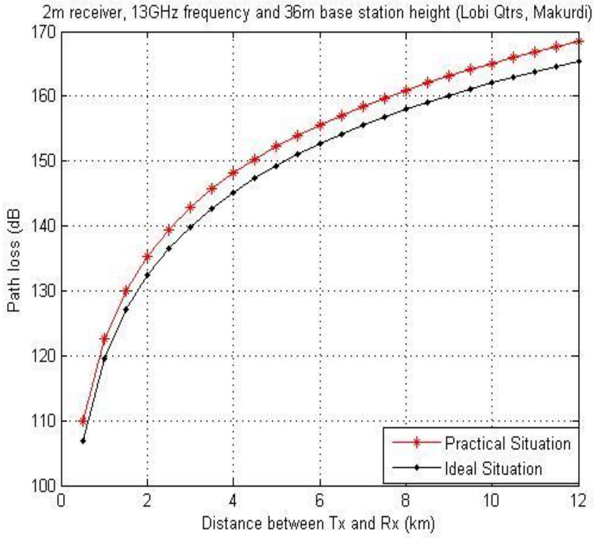


Figure 6: Change in Path Loss with Distance (Lobi Quarters, Makurdi)

b. 13 GHz FREQUENCY AND 50 m BASE STATION HEIGHT (BEHIND MODERN MARKET)

This base station transmits at 13 GHz with an antenna height of 50 m; figure 7 shows the variation of the path loss with variation in mobile station to base station distance

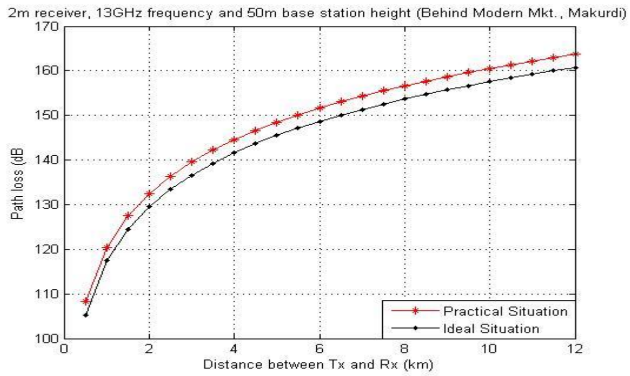


Figure 7: Change in Path Loss with Distance (Behind Modern Market)

c. 13 GHz FREQUENCY AND 70 m BASE STATION HEIGHT (CON OIL NORTH BANK, MAKURDI)

This base station transmits at 13 GHz with an antenna height of 70 m; figure 8 shows the variation of the path loss with variation in mobile station to base station distance.

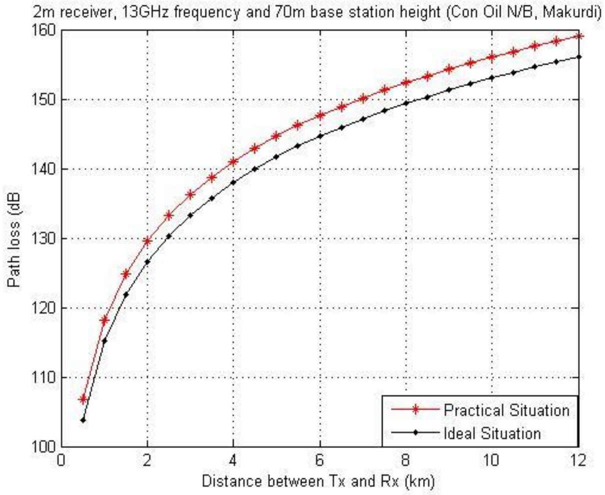


Figure 8: Change in Path Loss with Distance (Con Oil North Bank, Makurdi)

d. 18 GHz FREQUENCIES AND 24 m BASE STATION HEIGHT (YEMA LAYOUT, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 24 m; figure 9 shows the variation of the path loss with variation in mobile station to base station distance

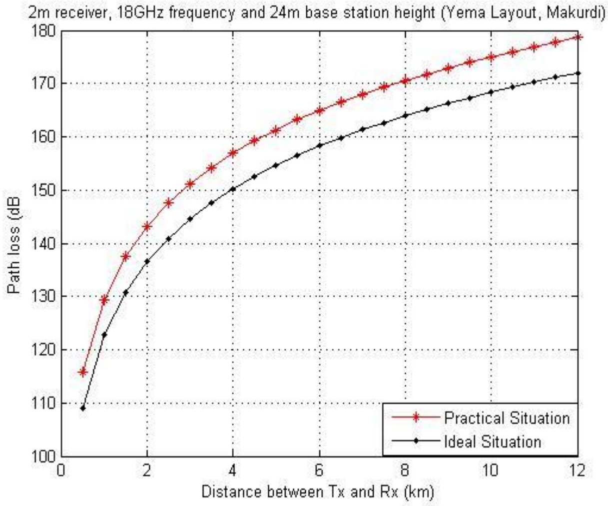


Figure 9: Change in Path Loss with Distance (Yema Layout, Makurdi)

e. 18 GHz FREQUENCIES AND 36 m BASE STATION HEIGHT (SOKOTO STREET WADATA, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 36 m; figure 10 shows the variation of the path loss with variation in mobile station to base station distance

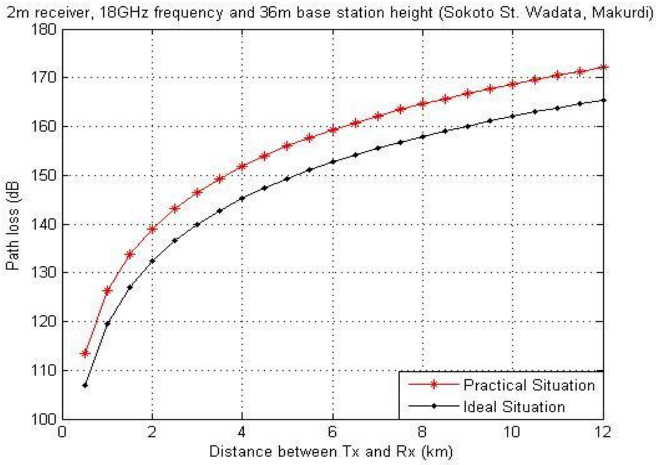


Figure 10: Change in Path Loss with Distance (Sokoto Street Wadata, Makurdi)

f. 18 GHz FREQUENCIES AND 50 m BASE STATION HEIGHT (ANKPA ROAD, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 50 m; figure 11 shows the variation of the path loss with variation in mobile station to base station distance

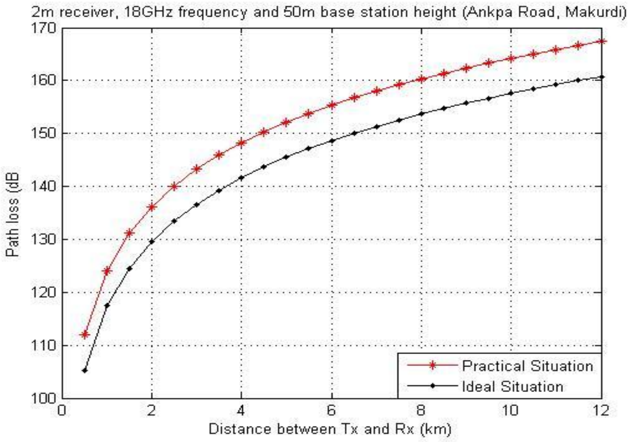


Figure 11: Change in Path Loss with Distance (Ankpa Road, Makurdi)

B. VARIATION OF PATH LOSS WITH FREQUENCY

Simulations will be carried out to investigate the effect of varying frequency with path loss while maintaining every other parameter constant. Appendix IV gives more information of the MATLAB code. In the Ideal Situation the distance between mobile to base station is 8 Km while in the Practical situation, it is 10.7 Km (Path Length, see Table 4.1).

a. YEMA LAYOUT, MAKURDI (24 m TX ANTENNA)

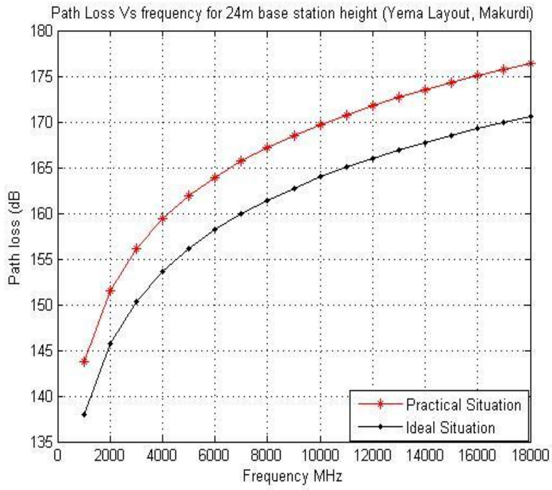


Figure 12: Change in Path Loss with Frequency (24 m TX Antenna)

b. LOBI QUARTERS MAKURDI (36 m TX ANTENNA)

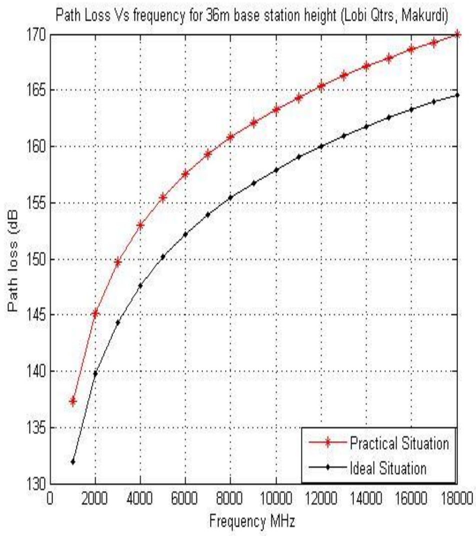


Figure 13: Change in Path Loss with Frequency (36 m TX Antenna)

c. ANKPA ROAD MAKURDI (50 m TX ANTENNA)

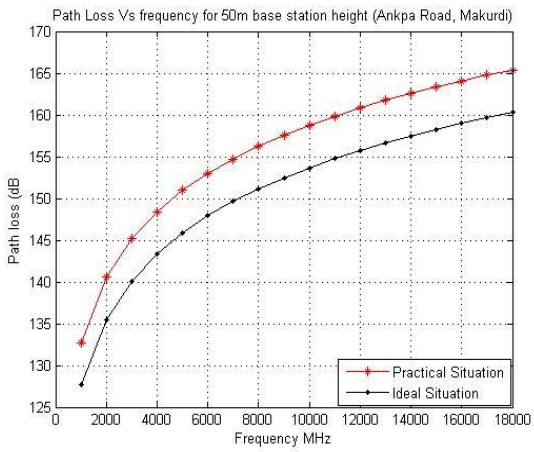


Figure 14: Change in Path Loss with Frequency (50 m TX Antenna)

d. CON OIL NORTH BANK, MAKURDI (70 m TX ANTENNA)

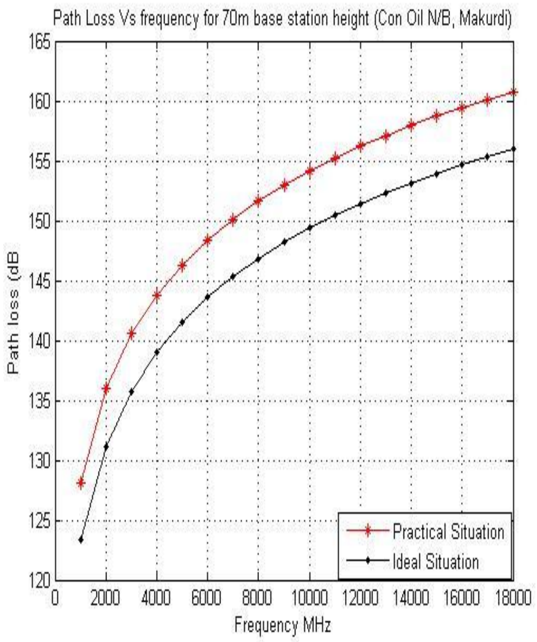
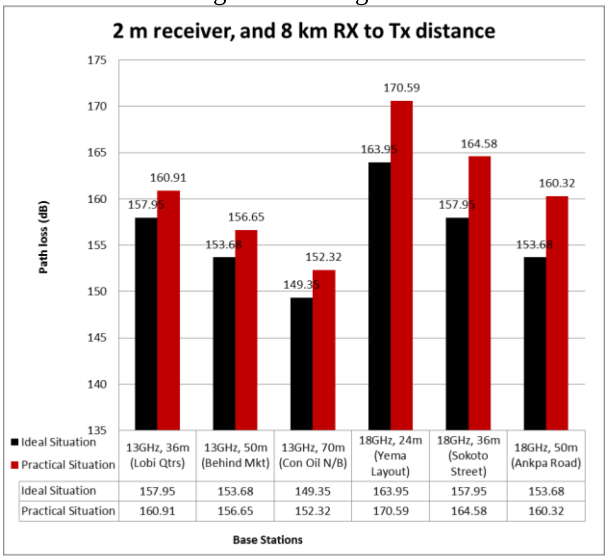


Figure 15: Change in Path Loss with Frequency (70 m TX Antenna)

C. ANALYSIS OF SIMULATED RESULTS

a. A 2 m MOBILE STATION AT A DISTANCE OF 8KM FROM TRANSMITTER

The accumulated result for the simulations can be shown in figure 17, and figure 18 shows a plot of the base station parameters for both Ideal and Practical Situations with path loss at 8 Km distance. It is worth noting that the Path loss is lowest when transmitting at a frequency of 13 GHz using an antenna of 70 m and highest when using a frequency of 18 GHz with a transmitting antenna height of 24 m.



	13GHz, 36m (Lobi Qtrs)	13GHz, 50m (Behind Mkt)	13GHz, 70m (Con Oil N/B)	18GHz, 24m (Yema Layout)	18GHz, 36m (Sokoto Street)	18GHz, 50m (Ankpa Road)
Ideal Situation	157.95	153.68	149.35	163.95	157.95	153.68
Practical Situation	160.91	156.65	152.32	170.59	164.58	160.32

Figure 17: Analysis of Simulated Results at 8 km RX to TX Distance

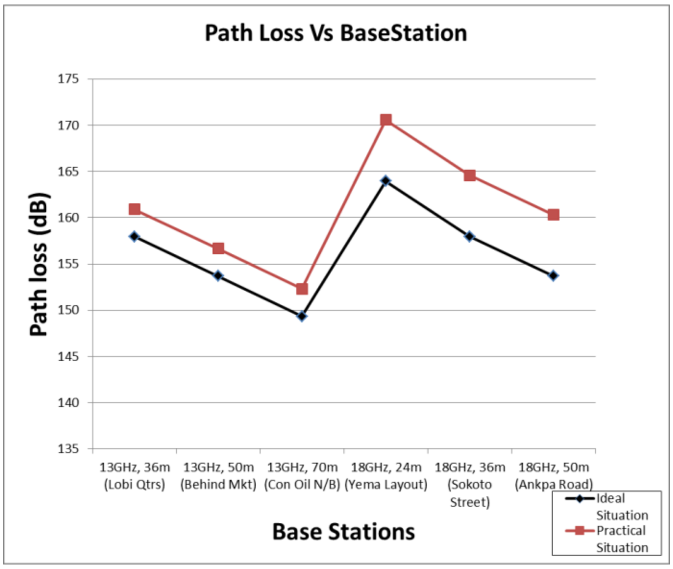
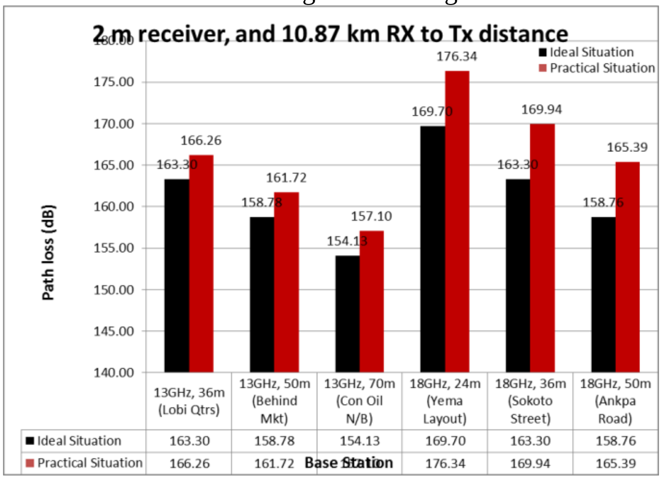


Figure 18: Path loss Against Base Stations at 8 Km.

b. A 2 m MOBILE STATION AT A DISTANCE OF 10.87 KM FROM TRANSMITTER

Similarly, the accumulated result for the simulations can be shown in figure 19, and figure 20 shows a plot of the base station parameters for both Ideal and Practical Situations with path loss at 10.7 Km distance. It is worth noting that the Path loss is lowest when transmitting at a frequency of 13 GHz using an antenna of 70 m and highest when using a frequency of 18 GHz with a transmitting antenna height of 24 m.



	13GHz, 36m (Lobi Qtrs)	13GHz, 50m (Behind Mkt)	13GHz, 70m (Con Oil N/B)	18GHz, 24m (Yema Layout)	18GHz, 36m (Sokoto Street)	18GHz, 50m (Ankpa Road)
Ideal Situation	163.30	158.78	154.13	169.70	163.30	158.76
Practical Situation	166.26	161.72	157.10	176.34	169.94	165.39

Figure 19: Analysis of Simulated Results at 10.87 km RX to TX Distance

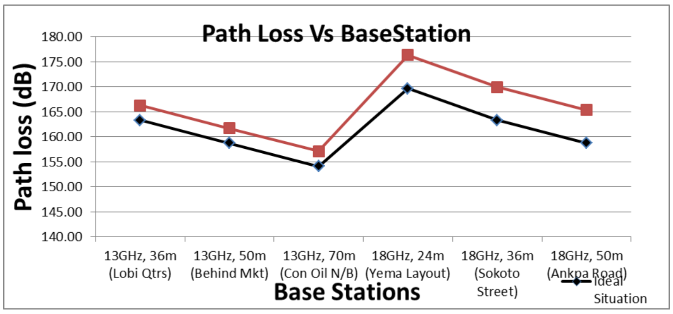


Figure 20: Path loss Against Base Stations at 10.87 Km

V. CONCLUSION

The following could be deduced from the simulation results in chapter IV.

- ✓ From figure 6 – 12, it can be concluded that the radio Path loss increases with increasing distance between the mobile station and the base station. Using the SUI model, the Path loss is least when transmitting at 13 GHz using a 70 m antenna (Con Oil base station) and it is greatest when transmitting at 18 GHz using a 24 m antenna (Yema base station).
- ✓ From figure 13 - 16 it can be concluded that the radio Path loss increases with increasing frequency of propagation using the SUI model. The Path loss is least at the Con Oil base station (70 m base station antenna) and it is greatest at the Yema base station (24 m base station antenna).
- ✓ From figure 18 and 20, it can be concluded that the Path loss decreases with increasing base station height when using the SUI model.

Since the aim of network optimization is to achieve a cost-effective radio network in terms of coverage, capacity and quality, we can say that the network of the GSM operator contacted during this research work is optimized in terms of cost because transmission at the SHF range leads to reduced antenna height, smaller antenna installation and other accessories etc. in spite of the Path loss experienced, the received signal is still of good quality within the 10.87km path length.

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