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An Empirically Base Path Loss Model for GSM Fixed Wireless Access

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ABSTRACT

This work aim at developing model for Gombi town with the view to address the complain of the GSM telephone subscribers. A measurement campaign was accomplished along the major road that divides Gombi into almost two equal parts. The empirical data measured were analyzed using significant statistical functions, the mean square error obtained between the predicted and the measured data range between 1.5 to 3.5dB. The model developed is efficient for under taking any future network planning in the investigated area.

Keywords: *Network quality, subscribers, environment, empirical measurement, measured data, predicted data and model.*

I. INTRODUCTION

Radio path loss is a particularly important element in the design of any radio communication system or wireless network, the radio path loss will determine many elements of radio communication system especially the transmitter power, antenna gain, antenna height and general location [3]. Radio path loss also affects other element such as the required receiver antenna sensitivity, form of transmission used and several other factors [5]. As a result it is necessary to understand the reason for radio path loss in relation to coverage area and to be able to determine the level of the signal loss for a given radio at a particular distance.

Propagation model are widely used extensively in network planning, particularly for conducting feasibility studies and during deployment. These models are also useful for performing interference studies as the deployment proceeds [1].

Gombi experience rapid growth of global system for mobile communication (GSM) telephone subscribers' right from the day the GSM operators came into operation in Gombi, as the number of subscribers of GSM phone user increases the spectral efficiency becomes more critical because the frequency allocation is limited resource. The smaller the frequency reuse the greater the network capacity [10], high spectral efficiency means great achievement by reusing, frequency over irregular terrain such as trees, building and other geographical features.

Subscribers in Gombi experience some call difficulties more especially from 2006 to date Field survey (2010), such as frequent call drop, network busy, poor intra and inters connectivity, cross talk during call conversation.

According to [4] attenuation from trees or buildings/trees are usually of order of 0.05dM/m for 200MHz, since Gombi used 900MHz as the carrier frequency the minimum expected attenuation may be approximately in order of 0.0125dB/m this depend strictly on distance where the power density is detected, received or the complexity of the environment .

GSM signal strength usually suffers losses due free space, diffraction, refractions, human activities, and others this is because the signal are geographically dispersed over wide area within the macro cell [9]. Efforts have been made to see how to reduce these effects in Europe, America, part of Asia and very little in Africa but, GSM signal is still much more associated with these losses in Africa which depend strictly on the environment.

This study aim at measuring path loss along the main street that divides Gombi town into almost equal part and developing a model that may probably address the complains of the GSM subscribers in Gombi town.

II. MEASUREMENT CAMPAIGN AND STUDY AREA

Gombi falls within the sudan savannah belt of Nigerian vegetation zone in the north east of the country, the zone is made of dry land weeds interspaced by shrubs and woody plants, the plants are divided into two categories; indigenous and exotic woody plants. The indigenous woody plants are Tamarin, Shear butter, Locust bean, Barasus aethiopus "Giginya" their height ranges between 7m – 12m and exotic woody plants are Neem, Mahogany, cashew and Guava almost of the same height [2]. Gombi has hills of approximately 20m – 25m high above the sea level in the eastern part of the town which is roughly few meters away from the main settlement. There are only 3 GSM base station (BS) planted and functional in the town in different locations of different GSM Operators namely ZAIN, MTN and GLO. These BSs were installed at 35, 30 and 35m above the sea level for ZAIN, MTN and GLO respectively. In the area were the measurement was conducted the highest building is about 9.5m, trees and building are scattered round the settlements. To generate measurements of signal strength (power density) level for the uplink and the down link within the coverage area, cell TEM instrument was used on vehicle to cover the desired distance.

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III. THE MODEL

The model incorporates the following parameters in equation (1) which consider related parameter like free space, diffraction due to buildings, trees, movements of vehicle, human activities and others factors as early discussed.

$$L_p = L_f + 10n\log\left(\frac{d_i}{d}\right) + L_d + G_{ah} + X_\sigma + C \quad (1)$$

Where L_p is the path loss model, L_f is the free space loss, n is the attenuation factor, d_i is the distance between the antenna and the receiver antenna, d is the reference distance, G_{ah} is gain height of the antenna, Xσ is the log normally distributed variable, C is the empirical constant or the Rayleigh fading of signal and L_d id the loss due diffraction. We analyzed the data obtained mostly by statistical approached as given in the following equations.

- ### Free Space Loss

It is generally accepted that free space can be obtained using equation (2) given by;

$$L_f = 32.44 + 20\log f + 20\log d - G_T - G_R \quad (2)$$

Where, f is the carrier frequency, G_T is the transmitter gain and G_R is the receiver gain [8].

- ### Attenuation Factor

This factor was realized using regression coefficient from the empirical data as given in equation (3);

$$n = I\sum_{i=1}^{I} \log d_i L_p - \frac{\left(\sum_{i=1}^{I} \log d_i\right)\left(\sum_{i=1}^{I} \log L_p\right)}{I\sum_{i=1}^{I} (\log d_i)^2 - \left(\sum_{i=1}^{I} \log d_i\right)^2} \quad (3)$$

Where I is the number of the measurement conducted.

- ### Diffraction Loss

The diffraction loss due the mention obstacles was obtained from equation (4);

$$L_d = 20\log\left(\frac{0.225}{v_0}\right) \quad (4)$$

$$v_0 = \sqrt{2}\left[(h_0 - 2h_R) - \frac{w(h_T - h_R)}{d+w}\right]\sqrt{\frac{d\cos^2\theta}{\lambda(d\cos - w)w}} \quad (5)$$

For obstacle with height lower than the transmitter antenna defines the parameter of equation (5), h_T=height of the transmitter h_R is the height of the receiving antenna and θ = angle of elevation [6] while the medium height of the obstacle is also

$$h_0 = \sqrt{r^2 + (K_e a_e)^2 + 2rK_e a_e \sin\theta}) - K_e a_e + h_T \quad (6)$$

Where, r = the hypotenuse distance between the transmitter and the receiver, a_e = the radius of the earth, K_e=4/3 (Standard refraction coefficient).

- ### Gain Height

The transmitter gain height is also an important parameter in developing a model for path loss, it be determine using the parameters in equation (7) [6].

$$G_T = 20\log\left[\frac{(h_0 - h_R)h_R}{h_T}\right] \quad (7)$$

- ### Gaussian random Variable

Here we use Gaussian Distribution, to examined the temporal variation of the signal induced due to human activities

$$X_\sigma(L_p) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(L_p - \overline{L_p})^2}{2\sigma^2}} \quad (8)$$

Where σ is the standard deviation of the signal.

- ### Rayleigh Random Variable

Here we also use Rayleigh Ditribution to analysed the fast fading signal due to vehicle and objects that caused strong attenuation of the signal.

$$C(L_p) = \frac{L_p}{\sigma^2} e^{-\left(\frac{L_p^2}{2\sigma^2}\right)} \quad (9)$$

IV. RESULTS AND DISCUSSION

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 into consideration in order to provide an efficient and reliable coverage area [7].

The standard deviation and the mean square error of the empirical data measured were obtained using expression (10) and (11) respectively.

$$\sigma^2 = \frac{\sum_{i=1}^{I}\left[L_p - a + n\log d_i\right]^2}{I-2} \qquad (10)$$

$$MSE = \left[P_D - M_D\right]^{\frac{1}{2}} \qquad (11)$$

Where MSE is the mean square error, P_D is the predicted data, M_D is the measured data and a is a constant.

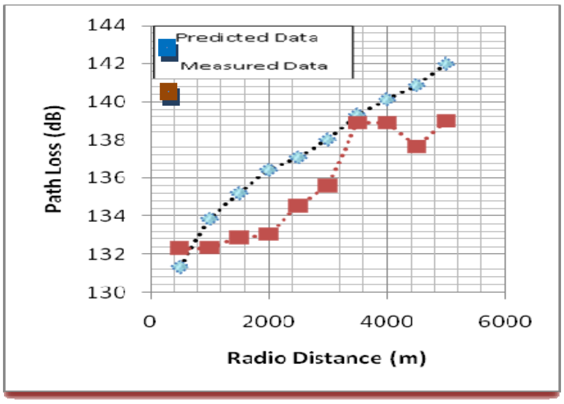

Figure 1: Propagation path loss

Figure 1, presents the results of measured and the predicted data, as we can clearly see from the plots the path loss of the measured data is less than the predicted data by the difference ranging between 1.5 <L_p ≤ 3.5dB. However, they may be seasons for this significant difference which could be due geographical difference. The empirical model is a more suitable model for the environment investigated as it requires no constitutive parameter of the geographical environment and less tedious.

CONCLUSION

The desire in this work is to develop a model that may help in addressing the complains of the GSM subscriber in Gombi town and provide better planning for GSM network in terms of future plan since Gombi is a prospecting developing city. The mean square error obtained range between 1.5 to 3.5dB, We hope this model had exposed some approached to the GSM company on how to study path loss and implement it while developing a network plan, if this model can be adapted by GSM operators in Gombi we believe that it will tremendously provide sufficient, efficient and qualitative signal to the GSM subscribers.

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