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Experimental Study of Variation of Path Loss with Respect to Heights at GSM Frequency Band

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ABSTRACT

In wireless channels, path loss has a strong impact on the quality of the links and hence there is need for accurate estimation for the efficient design of GSM networks**.** In this paper, measurements campaign were conducted at different floor using the GSM frequencies 900MHz and 1800MHz in the tallest building in Tropical Africa (Cocoa house) located in Ibadan metropolis. Cost-231 and Erickson path loss models were used to predict path losses with respect to receiver heights at different floors and the accuracy of the experimental results was estimated by determine the MSE between the measured and estimated path loss. The lower frequency suffers less path loss with varying heights compared to higher frequency with mean path loss 70.25dBm and 77.44dBm respectively. The comparative analysis revealed that the mean square error (MSE) for Cost-231 and Erickson were 1.25dB and 3.37dB respectively. The results shows that Cost-231 is the most accurate and reliable path loss prediction model for urban area (Ibadan) with varying heights. The results is also in good agreement with the acceptable international standard range $1 \leq \mu \leq 15dB$.

Keywords: Cost-231, Erickson model, Mean square error, Path loss, Stairwells.

I. INTRODUCTION

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 [1].

Variation of transmitter and receiver height also produces path loss [2]. A fundamental element of wireless communication system planning is predicting the signal strength at same location that results from a transmitter at some other location over the years, a wide variety of approaches have been developed to predict coverage using what are known as propagation models. Propagation modeling is an effort to predict what happens to signals en route from the transmitter to the receiver. Obviously, the signal gets weaker with increase in distance. Prediction and estimation of path loss is an important and significant element of system design in any communication system. A propagation model is also called a "path-loss calculation". The best propagation model for a particular study depends on the type of type of communication system area where it will be used.

II. METHODS AND MATERIAL

1.1 LOSS EXPONENT

In the study of wireless communications, path loss can be represented by the path loss exponent, whose value is normally in the range of 2 to 4 (where 2 is for propagation in free space, 4 is for relatively lossy environments and for the case of full specular reflection from the earth surface - the so-called flat earth model) [2,3]. In some environments, such as buildings, stadiums and other indoor environments, the path loss exponent can reach values in the range of 4 to 6. On the other hand, a tunnel may act as a waveguide, resulting in a path loss exponent less than 2. Path loss is usually expressed in dBm. It is given by [3]

$$P_L = 10nlog_{10}(d) + C \qquad (1)$$

Where P_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.

2.0 Propagation Path Loss Models

A reliable propagation model is one which calculates the path loss with small standard deviation and this will help to optimize the coverage area, Transmitter power and eliminates undesirable phenomenon, (e.g. interference, noise), etc. of other Radio transmissions. This will equally help network engineers and planners to optimize the coverage area and to determine the correct transmitter power to be used for such an area.

2.1 Free space model (FSPL)

Free space model (FSPL) emphasizes on how much strength of signal transmission between transmitter and receiver lost. This can be determine by [3,4]

$$PL_{FSPL}\, 32.48\; 20log10(d) + 20log(f) \qquad (1)$$

Where f is the frequency in MHz, d is the distance between transmitter and receiver in metre and p is the power loss in *dBm.*

2.2 Ericsson model

Ericsson model developed software to predict the path loss. The path loss according to this model is given [3], [5], [6]

$$PL = a_0 + a_1.log(d) + a2\,log(h_t) + a3.log(h_t).log(d) - 3.3(\log(11.78h_r))^2\,) + g(f) \qquad (2)$$

Where: $g(f)$ is defined as:

$$g(f) = 44.51log(f) - 4.79\,(log(f)^2) \qquad (3)$$

f = frequency in MHz
ht = transmitter height (m)
hr = receiver height (m)

2.3 Okumura Model

Okumura model is an empirical model based on extension drive test measurements within the range of 150 to 1920MHz and further extrapolated up to 3000MHZ. He developed a set of curves which gives the median attenuation relative to free space (AMU) in an urban area. The path loss prediction according to Okumura is given by [3,7].

$$L_{50}\,(dB) = LF + Amu(fd) - G(h_b) - G(h_m) - G(Area) \qquad (4)$$

Where L_{50} (dB) = median value (i.e. 50^{th} percentile) of path loss propagation
LF = free space propagation

$$G(h_b) = 20log_{\,10} \quad 1000m > h_b > 30m \qquad (5)$$

$$G(h_m)10log_{\,10}\left(\frac{h_m}{3}\right) \quad h_m \leq 3m \qquad (6)$$

$$G(h_m)20log_{\,10}\left(\frac{h_m}{3}\right) \quad 10\; \leq h_m \leq 3m \qquad (7)$$

2.4 COST-231 Hata model

COST stands for European Co-operative for Scientific and Technical Research. Cost 231 Hata model is widely used for predicting path loss is mobile wireless systems. It is an extension of the Okumura – Hata model. The COST 231 Hata model is designed to be used in the frequency range of 500MHz to 2000MHz. It has correction for urban, suburban, and rural (flat) environments. Because of its simplicity and correction factors, it is widely used for path loss predictions at these frequency bands COST (1999), Hata (1981), Okumura (1968).

The path loss in urban area is given by

$$Pl\,(dB)[46.33\;33.9\,log\,(f)]\,[13.82\,log\,(hb)] - a(hm)\,[44.9 - 6.55\,log\,(hb)]\,log\,(d) \qquad (8)$$

Where:

$$a\,(hm)\,1.1\,log\,(f) - 0.7hm - 1.56log\,(f)\,0.8 \qquad (9)$$

The path loss for highway calculations is similar to Okumura-Hata models.

hb is the height of base antenna station; hm is the height of mobile antenna in meters

$$a\,(h) = correction\ factor\ in\ dB$$

3.0 Experimental Method And Campaign

Measurements campaign was conducted at different floor using the GSM frequencies 900MHz and 1800MHz in the tallest building in Tropical Africa (Cocoa house) located in Ibadan metropolis. The measurements were carried out in the month of October, November and December 2015, under no wind and no rain. The daily ambient temperature ranges between 29^{o}C to 32^{o}C.

The measurement setup consists of the following: An Agilent 895BD signal generator and vertically polarized Omni directional antenna –AR-68B which has typical gain of 1.9dB. The receiver used is HP8547E spectrum analyzer for the measurement of signal strength at 900MHz and 1800MHz. The received signal passes through the same vertically polarized antenna to spectrum analyzer. The measured data was stored in a computer via a GPIB interface through a LABVIEW control program and post-processing of the data were performed offline using MATLAB R2015a.

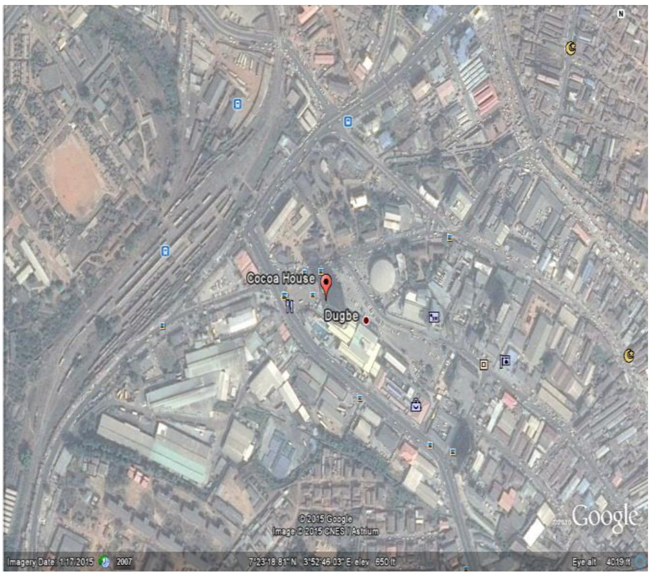

Figure 1: Google map of measurement campaign.

III. RESULTS AND DISCUSSION

Figures 2 and 3 shows the experimental variation of the path loss (dBm) and the models considered against the receiver heights. The path loss of all the measured and the models considered shows decreasing trends with respect to receiver height, that is, path loss is inversely proportional to heights.

At 900MHz frequency, when the receiver was placed at 4.0m, the path loss was around 97.00dBm and it was around 53.5dBm when the receiver was placed at 80.0m. At 1800MHz frequency, when the receiver was placed at 4.0m height, the path loss was found to be around 105dBm whereas when the receiver height was around 80.0m, the path loss was found to be 60.0dBm.

Figure 4 shows the bar chart of path loss variation with frequency used. It could be seen clearly that even with varying height, lower frequency (900MHz) suffers less loss compared with higher frequency (1800MHz) used in this work.

A more accurate comparative analysis for determining the best path loss prediction model for macro environments is the use of the mean square error (MSE) approach. The MSE is the ratio of dispersion of measured path loss values and describes how good the propagation model matches experimental data. It is commonly used to verify the accuracy of path loss models. The standard deviation and MSE according to [3] [7] [8] is given by:

$$\sigma = \frac{\sqrt{\boldsymbol{\Sigma}(p_{\boldsymbol{m}} - \boldsymbol{p_r})^{\boldsymbol{2}}}}{N} \qquad (10)$$

Where P_m = measured path loss (dB)

P_r = predicted path loss (dB)

$$\mu = \frac{\sigma}{\sqrt{N}} \qquad (11)$$

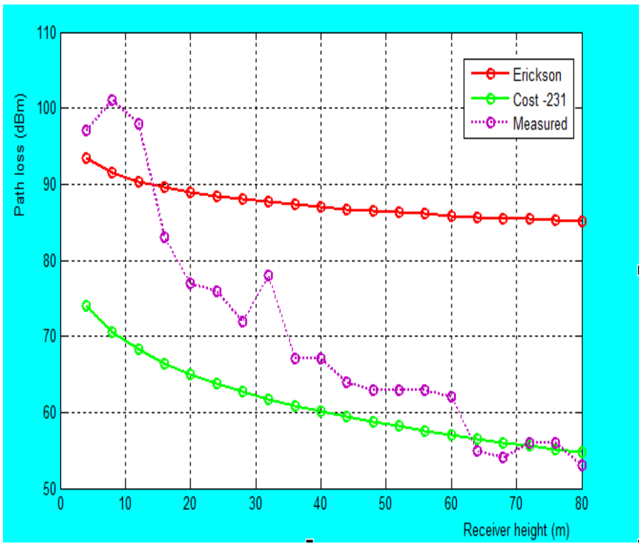

Figure 2: Variation of path loss with height at 900MHz

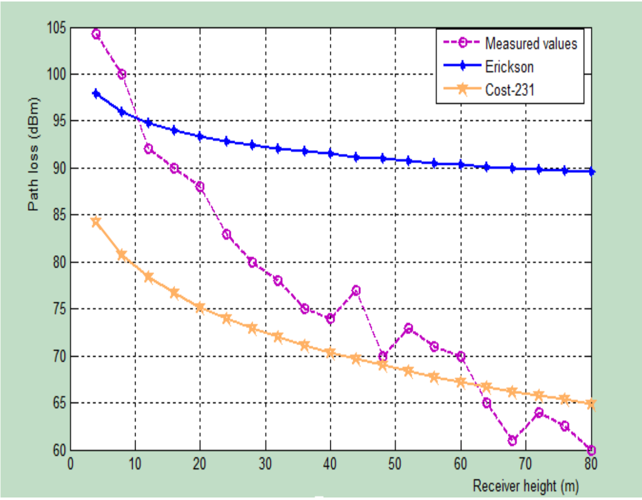

Figure 3: Variation of path loss with heights at 1800MHz

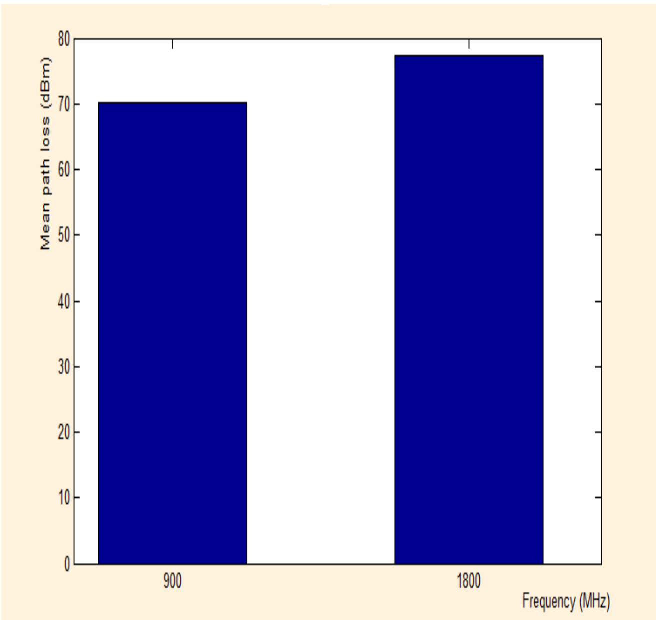

Figure 4: Comparison of measured mean path loss at 900 and 1800MHz

The goodness of fit is given by the following parameters in the table below

Table 1: Statistical comparison between measured values at 900 and 1800MHz

Parameters	900MHz	1800MHz
Sum of square errors, SSE	500.10	211.50
R-Square	0.8815	0.931
Adjusted R-Square	0.875	0.927
Root mean square error	5.271	3.428

Newly Proposed Model

We applied power law model 1 fitting by employing the non-linear least squares method and used the Algorithm in Trust-region with robust at off region.

The model equation is given as follows:

For 900MHz.

$$PL(h) = 147.9 \times h^{-0.2167}$$

$$Coefficients\ (with\ 95\%\ confidence\ bounds)$$

For 1800MHz

$$PL(h) = 142 \times h^{-0.178}$$

$$Coefficients\ (with\ 95\%\ confidence\ bounds)$$

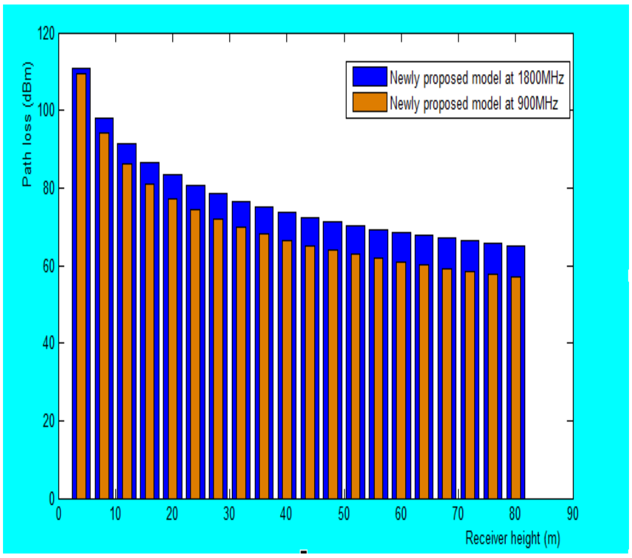

Figure 5: Newly proposed model for path loss against heights at 900 and 1800MHz

IV. CONCLUSION

In this work, the variation of path loss with respect to heights at GSM frequency band has been study so as to give accurate estimation for the efficient design of GSM network in this area. Different Empirical models have been analyzed and compared with experimental results at 900 and 1800MHz. the results shows that, lower frequency suffers less path loss with varying heights compared to higher frequency. The mean path loss for various heights considered at 900 and 1800MHz are 70.25dBm and 77.44dBm respectively. The work also revealed that path loss decreases as height increases, that is, at higher heights, receiver provides better signal; this is because interference occurs at higher heights.

Our results are in fairly good agreement with Cost-231 Hata model and a newly model is proposed for this region.

V. REFERENCES

[1] B. Castrol, M.Pinheiro, G.Canalcante, "Comparison between known comparison models, using least square tuning algorithm on 5.8GHz in Amazon region cities", Journal of Microwaves, Optoelectronics application, vol.10,No.1, June 2011.

[2] N. Rakesh and Strivasta S.K, " An Investigation on propagation path loss in Urban Environments for various models transmitter Antenna height 50m and different Receiver Antenna height" International Journal of Receiver and reviews in Computer Science", vol.3, No.4. pp 1761-1 August 2012.

[3] Yuvraj Singh "Comparison of Okumura, Hata and Cost-231 Models on the Basis of Path Loss and Signal Strength" International Journal of Computer Applications, vol.59-No.11, December 2012.

[4] S. R Saunders, M.Hata, Empirical formula for Propagation loss in Land Mobile Radio Services, IEEE Transaction on Vehicular Technology, Vol. V7 29 August 1980, pp 317-32

[5] N. Shabbir, M.Sadiq, T. Kashif, and R. Ullah, "Comparison of Radio Propagation Models for Long Term Evolution (LTE) Network", International Journal of Next generation networks, vol.3, No. 3, September, 2011

[6] V. Erceg, L. Greenstein, "An Empirical Based Path Loss Model for Wireless Channels in Suburban Environments "IEEE Journal on Selected Areas of Communication, vol.17, pp/ 1205-1211, July 1999.

[7] Yu-Huel, T., Wen-Shyang, H., and Ce-Kuen, S. "The Influence of Propagation Environment in a Live GSM Network. Research Paper, Department of Electrical Engineering, National Kaohsiung University of Applied Sciences, Kaohsiung, R.O.C.3-5.

[8] Z. Nadir and M.Idrees Ahmad "Path loss Determination Using Okumura-Hata Model and Cubic Regression for Missing Data for Oman", Proceedings of IMECS, vol.2, 2010