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Study of the Radio Wave Propagation in Urban and Sub Urban Environment.

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ABSTRACT :-

In mobile communication, the cell phone needs adequate signal strength to properly place or receive calls. Signal strength varies based on location and multipath is one of the conditions that lead to signal variation in a given environment. In this paper, measurement of signal strength with increase in distance was made at two different environments. The plot of signal strength relative to median against distance revealed more random variation at location A suggesting the presence of multipath in that environment. It was also observed that in a real world environment with obstructions, shadowing can lead to loss of more than 13dBm signal strength. This investigation showed that small scale fading due to multipath is not a challenge in a "no obstruction environment" such as location B. Though the signal strength varies with distance, the variation is approximately linear in such environment. The paper recommends that network providers should make routine signal strength measurement in suburban and urban environments as this will guide them on how to maintain signal quality within cells.

INTRODUCTION

Radio waves propagating through a radio channel may undergo reflection, refraction, diffraction, interference and scattering. They may also be absorbed or attenuated. This is due to the fact that radio channels are not in free space (vacuum) but in earth's atmosphere. Therefore, mobile communication undergoes some particular propagation complication compared to the channel characteristics in radio systems within fixed and carefully positioned antenna (Gatarayiha, 2006). Since antenna height in mobile terminal is usually very small, obstacles and reflecting surfaces in the neighborhood of the user have substantial influence on the characteristics of the propagation path. More so, if the mobile unit moves, the propagation, characteristics changes from place to place and from time to time. (Gatarayiha, 2006). Hence the transmission path between the transmitter and the receiver can vary from simple direct line of sight to that with obstacles such as foliage, buildings and terrain. This implies that the performance of mobile communication systems depends largely on the medium through which the signal propagates.

In mobile radio environments, a lot of near objects create different paths for the transmitting signal giving rise to multipath propagation. These multiple signals (waves) arrive with variable delay at the receiver resulting to either constructive or destructive interference depending on their relative phase. This gives rise to fluctuation in the received signal strength known as fading. Signal strength in mobile communications is the magnitude of an electric field at a reference point which is located at a significant distance from the transmitting antenna. This is expressed as signal power of the receiver or the voltage per length received by the reference antenna (Techopedia, 2014) The main factors affecting signal strength in outdoor environment are;

- Local terrain: GSM signals can be impacted by solid objects such as buildings, trees, hills, walls and so on. The more obstructions there are between the base station and mobile station, the more the signal strength is affected (Tomasi, 2007).
- Network range and distance between devices: Even in free space propagation, as the distance between the base transceiver stations (BTS) and mobile station increases, the signal strength reduces.
- Signal sharing/congestion: Wireless networks allow more than one person to communicate with another network source at the same time. The more subscribers utilizing the network the more devices the access point has to try to communicate with. Ones there is congestion (overload) signal quality will diminish leading to dropped calls or busy signal
- Other factors: Technical issues such as BTS antenna direction and weather conditions affect GSM signal strength.

Network planners have a way of finding solution to the issue of range, signal sharing and other technical issues during design. However, the effects of local terrain (topography) on signal strength poses serious challenge to both network providers and subscribers: hence it requires more investigation.

The commercial success of cellular communication since its inception has led to an intense interest among the wireless engineers to understand and predict radio propagation characteristics in rural, urban and suburban environments (Tapan, Zhong, Kin, Abdullatif and Palma, 2003). With increase in number of subscribers and advancement in mobile technology, wireless engineering requirements have become more stringent necessitating not just detailed information on signal strength but also on the exact knowledge of fading statistics for all forms of propagation path (Tekle, 2011). This is because fading poses a serious challenge to the wireless engineer whose main goal is to establish high quality of service for the subscribers. Random small scale fading creates changes in received signal amplitude that can have a profound impact on the quality of reception and general performance of a mobile device. (Alvaro, David, Gullaume and Jie, 2009).

With increase dependence on Global System for Mobile Communication (GSM) cellular technology, it is important for subscribers to understand the reasons for signal strength changes in our immediate environment so as to plan on how to improve reception quality. Knowledge of variation of signal level in real environment will also guide network providers on how to design radio cell size for different environments.

This paper discusses the impact of radio propagation in outdoor environment on the amplitude of received signal at two different locations. More random variation was observed in an environment with structures such as buildings and trees.

I. SIGNAL TRANSMISSION IN SPACE

Poynting vector represents the energy flux in Watts/m^2 of an electromagnetic field. It gives the actual power propagated in space. The magnitude of the poynting vector S is given as (Carpenter, 2004)

$$S = E \times H \qquad (1)$$

where E and H are electric and magnetic field intensity

$$E = E_o \, Cos\,(\phi)\,x \;\; and \;\; H = H_o \, Cos\,(\phi)\,y \qquad (2)$$

respectively. The solutions to Maxwell's equation for a plane wave are (Willis, 2007)

If $\phi = \omega t + kz$ then equation 2 can be expressed as

$$E = E_o \, Cos\,(\omega t + kz)\,x \;\; and \;\; H = H_o \, Cos\,(\omega t + kz)\,y \qquad (3)$$

Where x and y are unit vectors, $\omega = 2\pi f$ (angular frequency), k = wave number (the rate of change of phase with distance)

E and H can be expressed in exponential notation as

$$E\,(z,t) = E_o \, x \,.R_e \left\{e^{j(wt-kz)}\right\} \qquad (4)$$

All materials that are not free space are lossy to an extent (Willis, 2007). Hence the amplitudes of E and H fields decay exponentially with distance along the direction of

$$E\,(z,t) = E_o \, x \, e^{j(wt-kz)} \, e^{-Lz} \qquad (5)$$

propagation. Putting this into account, equation 4 transforms to equation 5, thus

Where Lz represents the loss with distance

Equation 5 reveals that a wave propagating through a lossy medium has a specific attenuation in decibel per meter (Willis, 2007). Therefore, it implies that in free space (where there is nothing to obstruct the progress of the radio wave) radio waves decay proportionally with the square of the distance and inversely with the square of the radio waves. Hence, the propagation loss L (dB) is given by

$$10 log_{10} \frac{w_t}{w_r}$$

$$L = 10 log_{10} \frac{w_t}{w_r} \qquad (6)$$

$$= 10 log_{10} \left[\frac{4\pi d}{\lambda}\right] - (10 log_{10} G_t + 10 log_{10} G_r) \qquad (7)$$

where w_t and w_r are effective transmitted power and received power respectively d: = distance, λ: = wavelength, G_t and G_r are absolute gains of transmitting and receiving antennas respectively. When antenna performance is not considered (isotropic antennas), $G_t = G_R = 1$ in equation 7. Hence, the path loss L can be obtained thus (Huang and Boyle, 2008):

$$L = 10 \log_{10}\left(\frac{P_T}{P_R}\right) = 20 \log_{10} f + 20 \log_{10} d - 147.6 \qquad (8)$$

However in an environment where there is an impact from terrain and buildings and

$$L = 20 log_{10} \left[\frac{4\pi d}{\lambda}\right] - log_{10} \left\{1 + \gamma^2 + 2\gamma cos\left(\frac{2\pi \Delta 1}{\lambda} + \phi\right)\right\} \qquad (9)$$

where weather conditions has an effect, propagation loss is given as)

For very high values of ¢L becomes

$$L = 20log_{10}\left\{\frac{d^2}{h_t . h_r}\right\} \quad (10)$$

where d = communication distance, h_t = transmitting antenna height h_r = receiving antenna height.Equation 10 known as Plane Earth Model can be rewritten as (Huang and Boyle, 2008)

$$L = 40 \log_{10} (d) – 20 \log h_t h_r \quad (11)$$

II. MATERIALS AND METHOD

Materials used for the measurement include tape rule and Cornet Electromog Radiofrequency (Rf) meter. The portable hand held cornet Electrosmog radiofrequency meter hasthe following specification; (Osuagwu and Joseph, 2013)

Model: ED15CV30L Frequency range: 100MHZ - 3GHZ Sensor type: Electric field sensor Sensitivity: - 55dBm to 0dBm.

Since measurement is within a short distance of few meters, the handy survey meter was appropriate. At each location, signal level measurement was made at interval of 10m from the foot of the base stations to about 130m. The two base stations are sited in suburban environment.

Table 1: Measured signal strength with distance and signal strength relative to median at location A

Median = - 33.5dBm		
S(m)	Signal strength P_r (dBm)	P_{rm}(dBm)
10	-33.8	-0.3
20	-32.9	+0.6
30	-32.6	+0.9
40	-29.5	+4.0
50	-43.1	-9.6
60	-38.2	-4.7
70	-37.7	-4.2
80	-33.0	+0.5
90	-33.5	0.0
100	-28.8	+4.7
110	-31.7	+1.8
120	-38.8	-5.3
130	-40.8	-7.3

At Location A, measurement of signal strength with distance was carried out in a space before and after a Storey building (office/shopping complex) situated 40m from a base station with walls and low level buildings on both sides of the office complex and trees some meters away from it. The complex is situated along Samaru road before Kwangila Bridge, Zaria. Measurements were also carried out in an open farmland with scanty foliage opposite a base station beside Shirash filling station Basawa, Zaria. This is termed location B. These sites were chosen due to the presence of open space that will enable measurements to be made in an orderly manner.

III. DATA PRESENTATION

To observe the variation of signal at each of the locations, the median of the measured signal levels at each of the locations was evaluated. Subsequently, signal level with respect to median (P_{rm}) was evaluated for each set of data as shown in tables 1 and 2. The values of P_{rm} obtained were plotted against distance (S) for each location as shown in figures 1 and 2. Equations 8 and 11 were also used to calculate signal loss in free space and real environment as shown in tables 3 and 4 respectively.

Table 2: Measured signal strength with distance and signal strength relative to median at location B

Median= -25.2dBm		
S(m)	Signal strength P_r (dBm)	P_{rm} (dBm)
10	-44.0	-18.8
20	-40.2	-15.0
30	-27.9	-2.7
40	-33.1	-7.9
50	-27.8	-2.6
60	-34.0	-8.8
70	-25.2	0.0
80	-19.9	5.3
90	-19.5	5.7
100	-20.4	4.8
110	-18.2	7.0
120	-20.6	4.6
130	-21.4	3.8

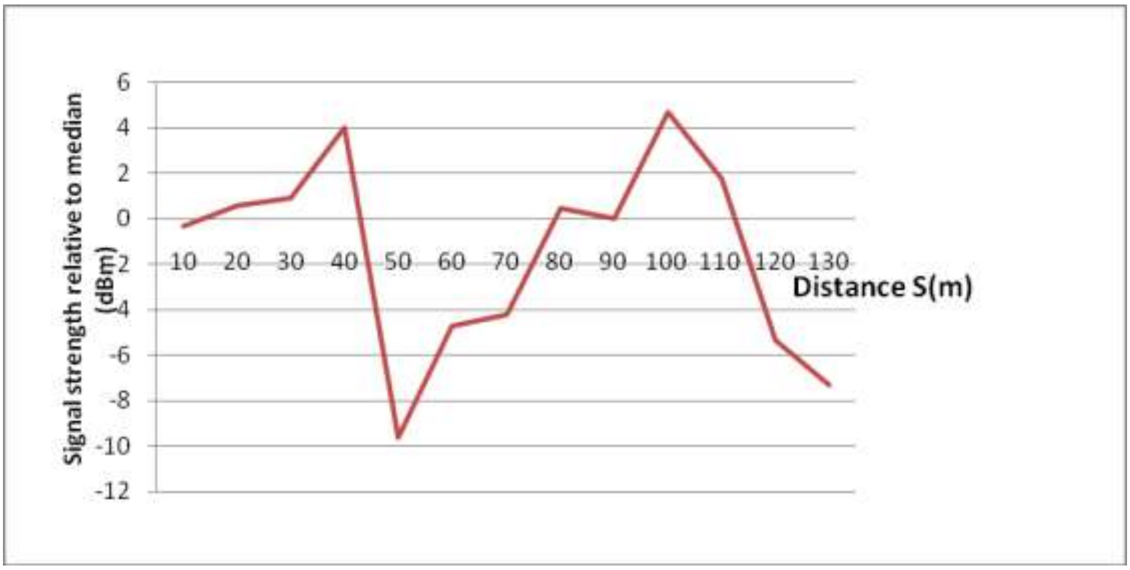

Fig.1 Plot of signal level relative to median against distance for location A

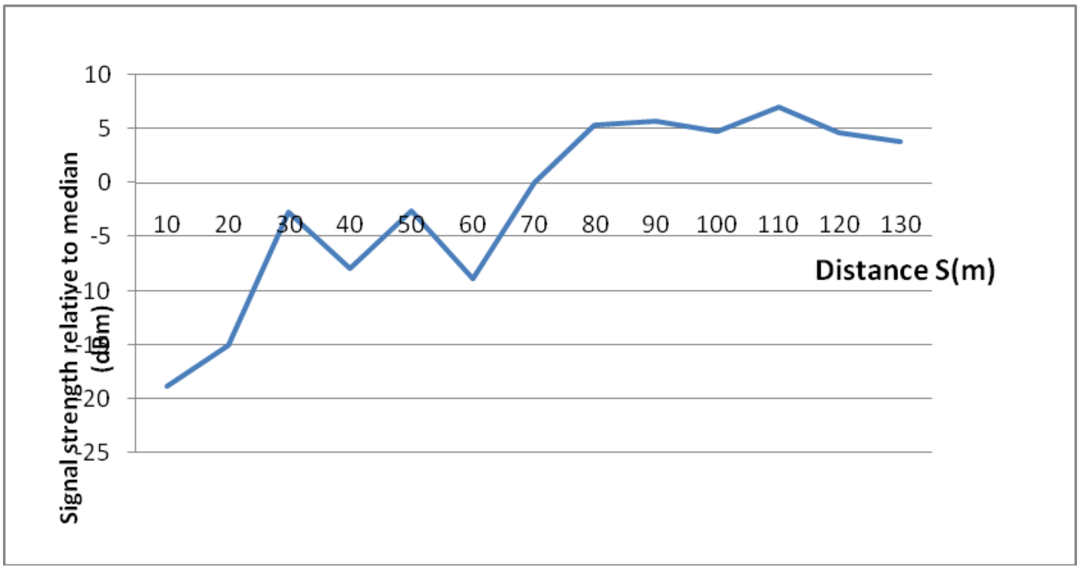

Fig.2 Plot of signal level relative to median against distance for location B

Table 3: Calculated Signal loss using free space model

Median= 68.3dB		
S(m)	Loss in Signal strength L (dB)	L_m (dB)
10	52.4	-15.9
20	57.4	-10.9
30	60.9	-7.4
40	63.4	-4.9
50	65.4	-2.9
60	67.0	-1.3
70	68.3	0.0
80	69.5	1.2
90	70.5	2.2
100	71.4	2.8
110	72.2	3.9
120	73.0	4.7
130	73.7	5.4

Table 4: Calculated Signal loss using Plane Earth model

Median= 32.2dB		
S(m)	Loss in Signal strength L (dB)	L_m (dB)
10	-1.6	-33.8
20	10.4	-21.8
30	17.5	-14.7
40	22.5	-9.7
50	26.4	-5.8
60	29.5	-2.7
70	32.2	0.0
80	34.5	2.3
90	36.6	4.4
100	38.4	6.2
110	40.1	7.9
120	41.6	9.4
130	42.3	10.1

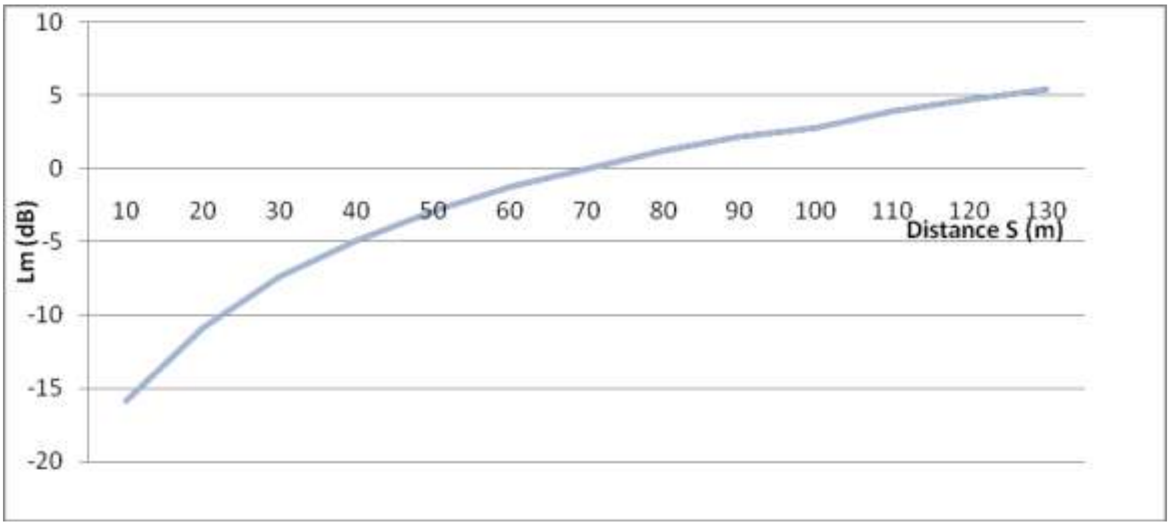

Fig. 3 Plot of signal loss relative to median against distance for plane earth model

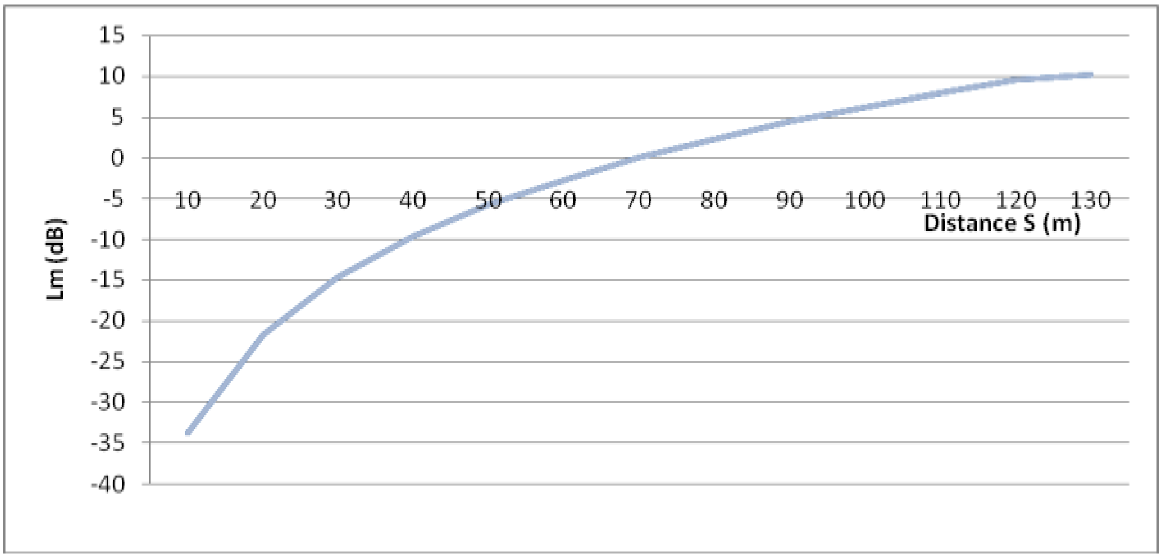

Fig. 4 Plot of signal loss relative to median against distance for free space model.

IV. DISCUSSION

The plots in figures 1 and 2 show that signal strength varies with distance. However, the signal strength received at location A (Fig. 1) showed more random variation above and below the zero level than that at location B. The variation at A is due to multipath propagation as a result of presence of buildings, wall, and trees. Also, a wide difference was observed between signal strength at 40m with measured value of -29.5 dBm and that at 50m distance with measured value of -43.1 dBm at location A. The 40m position falls within the space before the office/shopping complex while 50m position falls immediately after the shopping complex. Hence, the wide difference (above 13dBm) between the two positions is largely due to shadowing effect of the building. This effect continued to about 20m from the building (table 1). Large variation also occurred between 110m position and 120m position at location A (table 1) due to the presence of trees between the two positions. Hence, depending on one's position in such an environment fading may be in form of multipath fading, shadowing, or both.

Nevertheless, at location B, the variation of the received signal is close to that obtained using Plane Earth model. That is, the reduction in signal level is with increase in distance. At distances below the median distance, all values of signal level relative to median are negative while all the values of signal strength with respect to median at distances above 70m are positive. Hence, the absence of buildings and trees and other structures also resulted to the absence of multipath propagations. This explains the discrepancy of signal strength values at locations A and B (-31.7dBm and -18.2dBm respectively) measured at 110m distance from the foot of the base stations.

The free space model assumes an ideal situation where there are no obstacles that could cause reflection, diffraction, refraction or scattering within the line of sight between the transmitting and the receiving stations (Shoewu and Adedipe, 2010). Hence, the attenuation of the radio wave signal is proportional to the distance from the transmitter.

V. CONCLUSION AND RECOMMENDATION

Global System Mobile communication (GSM) signal strength was investigated at two different locations: one with obstructions (location A), and the other without obstructions (Location B).

The two channels investigated show that small scale fading due to mutipath is more in an environment with diverse forms of obstructions (location A). The result confirmed that the type of fading experienced by a signal propagating through a mobile wireless channel depends on the nature of the transmitting signal with respect to the characteristics of the channel. The increase in small scale fading must be due to the existence of various propagating paths (reflected, diffracted, and direct path). This implies that a single measurement of signal strength might not be sufficient since different measurements can lead to quite different results due to changing conditions. Based on the findings made in this work, the paper recommends that network designers should make routine practical measurements of signal strength especially in dense suburban and urban environment where building structures are erected regularly so as to ascertain what improvement they need to make to maintain high quality of service. Network designers should use Smart and Adaptive antenna systems in base stations and stake holders should ensure that such technologies are employed considering the poor signal quality being experienced all over the nation even after thirteen years of mobile communication existence in Nigeria. More research should be carried out to proffer solution to Smart antenna design complexities vis-à-vis cost of handsets, power dissipation and size of handsets.

REFERENCE

[1]. Alvaro V., David L. Gullaume R. and Jie Z (2009) Predicting Small-Scale Fading Distributions with Finite-Difference Methods in Indoor-to-Outdoor Scenarios. 69thIEEE Vehicular Technology Conference, Barcelona. June 2009, pp. 1 -5.

[2]. Carpenter K (2004) The Poynting Vector: Power And Energy in Electromagnetic Fields. [3]. http://www.ece.ksu.edu/~khc/notes/emt/pointing.pdf . Retrieved 09th October 2011.

[4]. Circuit Design Inc (2011). What are Radio Waves?

[5]. http://www.cdt21.com/resources/guide2.asp. Retrieved 2nd Oct. 2011.

[6]. Gatarayiha F. (2006) Improved Radio Propagation Modeling for Cellular Network in Rolling Hill Environment. M. Eng. Thesis. Pretoria: Tshawane University of Technology.

[7]. Huang Y and Boyle K . (2008) Antennas: From Theory to Practice. U.K: John Wiley and sons Ltd. [8]. Osuagwu,F.andEmmanuel.J. (2013).

[9]. Measured and Estimated Values ofRadiofrequency Radiation PowerDensity in theVicinity of Mobile Base Stations in Gaskiya.International Journal of Advances in Scienceand Technology vol. 7 No. 4 p. 1 – 8.

[10]. Shoewu O. and Adedipe A. (2010) Investigation of Radio waves Propagation models in NigerianRural and Sub-urban areas American Journal of Scientific and Industrial Research. 1(2):227-232.

[11]. Tapan K, Zhong J, Kim K, Abdellatif M., and Palma M. (2003). A survey of variouspropagatio models for mobile communication. IEEE Antenna and propagationmagazine. Vol. 45 No.3 pp 51-60.

[12]. Techopedia (2014) Definition of Signal Strengthwww.techopedia.com/definition/9366/signalstrength. Retrieved 4th Feb, 2014.

[13]. Tekle B. (2011) Statistical Modeling and Simulation of Small Scale Fast Fading WirelessChannel.M.sc Thesis.School of Graduate Studies. Addis Ababa: University of Addis Ababa.

[14]. Tomasi W. (2008) Electronic Communications Systems: Fundamental through Advance.Fifth edition. India: Pearson Education Inc.

[15]. Willis M (2007) Propagation Tutorial.http://www.mikewillis.com/Tutorial/PF3.htm.Retrieved 9th Oct. 2011