Characterization of Mobile Radio Propagation Channel using Empirically based Pathloss Model for Suburban Environments in Nigeria

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Abstract: This paper focused on characterizing mobile radio propagation channel using empirically based pathloss model for suburban environments in Nigeria. In this paper, field data were collected from a CDMA20001x network which included measurement of received signal strength over several distances from the transmitting base station. The averages of the measured data were used in determining the pathloss exponent of the propagation environment. Also, an empirical based pathloss model was developed for the testbed environment using the field data and the pathloss exponent. The developed pathloss model and the computed pathloss exponent of 3.63 were used in characterizing the testbed environment in order to determine the efficiency and link quality of the network under consideration.

Key words*:Pathloss,propagation,CDMA20001x,*

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I. INTRODUCTION

In mobile communication network, the radio channel is characterized by multipath signal between the transmitter and the receiver which result in multipath interference on the network. The multipath interference arises due to reflection, diffraction and scattering of signal in the process of transmission [1].This phenomenon adversely affects the quality of wireless communication signal. For example, when a radio frequency signal is transmitted towards the receiver, the general behaviour of the signal is to grow wider as it transmits further. In this manner, the radio frequency signal encounters objects that reflect, refract and interfere with the signal. When such signal is reflected off an obstacle, multiple wave fronts are created so that new duplicate wave fronts reach the receiver. However, multipath distortion occurs due to radio frequency interference when a radio signal has more than one path to travel between the transmitter and the receiver. The extent to which signal attenuation occurs in a communication channel can be determined by the pathloss exponent [2]. Thus, pathloss refers to the difference between the transmitted power and the received power and is measured in decibel [3].Therefore, it is always important to characterize the propagation environment used as the testbed environment using the pathloss exponent obtained from the field data in order to ascertain the signal attenuation of the area.

II. MOBILE RADIO PROPAGATION PATHLOSS MODELS

Path loss is defined as the difference in decibel between the effective transmitted power and the received power and it includes the effect of antenna gains. It can also be defined as signal attenuation as a positive quantity measured in decibel (dB).There are some empirical pathloss models which can be used to predict both large-scale and medium-scale coverage for mobile communication system design. These pathloss models include [4]:

i. The log-distance path loss model.

ii. The log-normal path loss model.

(i) The log-distance path loss model

Both theoretical and measurement based propagation models indicate that the coverage received signal power decreases logarithmically with distance, whether in outdoor or indoor radio channels. The average large-scale path loss for an arbitrary Transmit-Receiver (T-R) separation is expressed as a function of distance by using path loss exponent (n) as:

$$PL(d)\alpha(d/d_o)^n$$

Or,

$$PL(dB) = PL(d_0) + 10n\log(d/d_0)$$

Where n, is the path loss exponent, d_0 is the closed-in reference distance which is determined from measurements closed to transmitter and *d* is the T-R separation distance. The value of *n* depends on the specific propagation environment. For example, if free space is 2 and when obstructions are present, *n* will have a larger value [5].It is important to select a *close in* reference distance that is appropriate for the propagation environment. In large coverage cellular systems, 1km reference distance is commonly used, whereas in microcellular systems smaller distance such as 100m is commonly used [6]. The reference distance should always be in the far field of the antenna so that near field effect does not alter the reference path loss.

The reference path loss, PL (d_o), is calculated through field measurement at distance (d_o).

(ii) The log-normal shadowing model

The log-normal distribution describes the random shadowing effects which occur over a large number of measurement locations which have the same T-R separation, but have different levels of clutter on the propagation path. This phenomenon is referred to as log-normal shadowing. Log-normal shadowing implies that measured signal level at a specific T-R separation have a Gaussian (normal) distribution about the distance-dependent mean of equation (2) where the mean signal levels have values in dB. The standard deviation of the Gaussian distribution that describes the shadowing is also in dB.

Measurements have shown that at any value of *d*, the path loss ,PL(d), at a particular location is random and distributed log-normally (normal in dB) about the mean distance dependent value.i.e.

$$PL(d)[dB] = PL(dB) + x_\sigma \quad (11)$$

$$PL(d)[dB] = PL(d_0) + 10n\log\left(\frac{d}{d_0}\right) + x_\sigma \quad (12)$$

And,

$$\Pr(d)[dBm] = Pt[dBm] - PL(d)[dB] \quad (13)$$

Where, X_σ is a zero-mean Gaussian distributed random variable (dB) with standard deviation σ also in dB.

The closed in reference distance (d_0), the path loss exponent (*n*), and the standard deviation (σ) statically describe the path loss model for an arbitrary location having a specific T-R separation and this model may be used in computer simulation to provide received power levels for random locations in communication system design and analysis [7].

2.1 DETERMINATION OF PATHLOSS EXPONENT OF THE MOBILE RADIO PROPAGATION ENVIRONMENT

In order to completely characterize the mobile radio propagation environment under consideration, the received signal strength from the field measurement, pathloss exponent and propagation model for the test bed environment must be known. The pathloss exponent,n, for the testbed environment is obtained using equation(14) given as[8]:

$$\text{Therefore, } n = \frac{\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)]}{\sum_{i=1}^{M}\left[10\log_{10}\left(\frac{d_i}{d_0}\right)\right]} \quad (14)$$

where, Pathloss $P_{L(di)}$, is the difference between the transmitting power, P_t , in dB and power received, P_r , in dBm, $P_L(d_o)$is the pathloss at close in reference distance otherwise known as reference pathloss , d_o is close in reference distance, d_i is distance at intervals from the BS to MS.

2.2 EMPIRICAL PATH LOSS MODEL FOR TEST BED ENVIRONMENT.

The path loss model for free space is given by equation (15) as [9]:

$$LP_{fs}\text{ (dB)} = 32.44 + 20\log_{10}(f_c) + 20\log_{10}(d_i) \quad (15)$$

Where, LP_{fs} is the free space path loss, f_c is the carrier frequency in (MHz), d_i is the distance between the Base Station (BS) and Mobile Station (MS) in (Km).

The Hata path loss model for urban and suburban environment is given in equation (16) and (17) respectively as:

$$L_{Pu}\text{ (dB)} = 69.55 + 26.16\,\mathrm{Log}_{10}(f_c) + (44.9 - 6.55\log_{10}h_b)\log(d_i) - 13.82\log_{10}(h_b) - \alpha(h_m) \quad (16)$$

$$L_{Ps} = Lp_u - 2[\log_{10}(\frac{fc}{28})]^2 - 5.4 \quad (17)$$

Where ;LP_u is the pathloss prediction for urban area in dB, L_{ps} is the pathloss prediction for suburban area in dB, α (h_m) is the correlation factor for mobile station antenna height in dB, h_b is the height of BS (km),h_m is the height of MS. The correlation factor α (h_m) for suburban is given as:

$$\alpha(h_m) = [1.1\log_{10}f_c - 0.7]h_m - [1.56\log f_c - 0.8] \quad (18)$$

III. DATA COLLECTION

The field measurements of received signal strength were carried out from a CDMA 20001x base station of height 36m, and transmitter frequency 878.87MHz located at Asaba, a suburban environmnent and the capital of Delta State of Nigeria as indicated in the measurement environment of Figure 1. The field measurement were carried out using 3G CDMA technology rather than the GSM because of its advantages such as higher bandwidth capacity, high-speed packet data and multipath fading reduction. The field measurements were carried out using a radio propagation simulator called debug access equipment (i.e Grayson receiver) and Global Positioning System (GPS).The GPS data were recorded which made it easier to determine the T-R separation distances associated with each power measurement while the debug access equipment measured received power levels at various distances away from a CDMA 20001x base transmitter station. The experimental data were taken at distances ranging from 100 metres to 700metres as shown in Table 1.

Figure 1: Test bed Environment

IV. DATA PRESENTATION AND ANALYSIS

The measured field data obtained during the experimentation is shown in Table 1 and the average of the measurements were used to compute the pathloss exponent.

Table1:RSS during experimentation: Time of Measurement: 8.00am-6.00pm

(Cell Site: Asa001, Frequency, F=878.87MHz, Transmitted Power, Tx =44.4dBm)

Distance(m)	RSS(dBm) (1/10/2011)	RSS(dBm) (3/11/2011)	RSS(dBm) (4/11/2011)	RSS(dBm) 6/1/2012	RSS(dBm) (3/2/2012)	RSS(dBm) (10/3/2012)	RSS(dBm) (5/4/2012)	RSS(dBm) (8/5/2012)	RSS(dBm) (15/6/2012)	RSS(dBm) 26/7/2012
100	-68.51	-68.42	-69.23	-68.40	-69.12	-68.60	-68.19	-68.73	-67.98	-69.22
200	-75.10	-75.62	-75.10	--76.20	-75.50	-75.49	-76.00	-75.55	-75.00	-76.94
300	-94.25	-94.79	-93.86	-94.80	-94.95	-93.00	-94.92	-94.10	-94.51	-100.72
400	-94.80	-94.73	-93.00	-94.20	-95.00	-96.00	-94.76	-94.83	-95.25	-96.33
500	-98.72	-98.91	-98.25	-98.00	-98.10	-97.95	-96.53	-98.99	-98.41	-103.44
600	-103.80	-104.25	-104.00	-105.10	-103.29	-103.95	-104.10	-104.21	-104.30	-103.90
700	-106.30	-107.00	-107.30	-107.41	-107.50	-106.79	-106.89	-105.30	-107.40	-111.01

Let X and Y represents the numerator values and denominator values respectively in equation (14), then, we determine the pathloss exponent of the propagation environment as follows:

d_i= [100, 200,300,400,500,600,700]

P_t = 44.4dB

P_r = [-67.94 -74.16 -86.84 -87.04 -91.64 -99.33 -103.13]

P_L (d_i) =P_t-P_r=44.4 - [-67.94 -74.16 -86.84 -87.04 -91.64 -99.33 -103.13]

P_L (d_i) = [112.34 118.56 131.25 131.44 136.04 143.73 147.53]

But, substituting, X= [$P_L(d_i)$-$P_L(d_o)$] in equation (14)

= [112.34 118.56 131.25 131.44 136.04 143.73 147.53]-[112.34]

= [0 6.22 18.91 19.10 23.70 31.39 35.19]

X =134.51

Also, substituting, Y =10log $_{10}(\frac{di}{do})$ in equation (14) where d_o=100

Y=∑ [10 $\log_{10}$ [1 2 3 4 5 6 7]]

Y=0+3.01+4.77+6.02+6.99+7.78+8.45

=37.02

Therefore, pathloss exponent, n, = $\frac{X}{Y} = \frac{134.51}{37.02}$ = ***3.63***

The pathloss exponent, n, which helped in characterization of the mobile radio propagation environment under consideration as computed from the measured data is 3.63.

4.1 PROPAGATION PATHLOSS MODEL FOR THE TESTBED ENVIRONMENT

Using equation (16) and equation (17) and substituting f_c =878.87MHz, h_b= 0.036,

h_m =0.0018,and α (h_m)=3.99,we obtain the pathloss model for Asaba as:

L_{Pu}(dB) = 69.55 + 26.16$\log_{10}$(878.87)+(44.9-6.55$\log_{10}$(0.036)) log(d_i)-13.82$\log_{10}$(1.8x10^{-3}) - 3.99 (19)

L_{Pu}(dB) =104.63+54.36Log(d_i) (20)

Substituting equation (20) into equation (17), we obtain:

L_{Ps} = 104.63+54.36Log (d_i) – 2[$\log_{10}$ ($\frac{878.87}{28}$)]^2 – 5.4 (21)

L_{Ps} (d_o) =94.74dB.

But, re-arranging equation (2), so that:

P_L [dB]= Lp(d_i)= empirical pathloss model for Asaba

$P_L(d_0)$ = $L_{Ps}(d_o)$ = pathloss for Asaba at known reference distance d_0

n = 3.63 =pathloss exponent.

Therefore, the empirical path loss model for Asaba is :

$$Lp(d_i)=94.74 + 36.3Log(d_i) \quad (22)$$

The pathloss exponent of 3.63 and the pathloss model as indicated in equation (22) are used in the characterization of a mobile radio propagation environment so as to determine the efficiency of the network. The pathloss exponent as obtained from the field data is a good indicator of how accurate the link quality of the communication network is. Since it is always difficult to obtain field data from the network operators, the developed pathloss model in equation (2) can be used for accurate pathloss prediction of the testbed environment in order to avoid constant measurement of field data.

V. GRAPHICAL PRESENTATION OF DATA

The graphical presentation of the field data is shown in Figure 2, which shows the plot of received signal strength against various distances. Figure 2 shows the rate at which pathloss increases as the distance from the base station increases. It equally shows that the received signal strength varies log normal with distance in the testbed environment. As observed from Figure 2, the pathloss exponent of the testbed is 3.63 and this shows how signal attenuation affects the quality of services rendered to the subscribers. The pathloss exponent of the testbed environment when compared with free space pathloss exponent of 2, informs the network operators the rate at which attenuation occurs in that network.

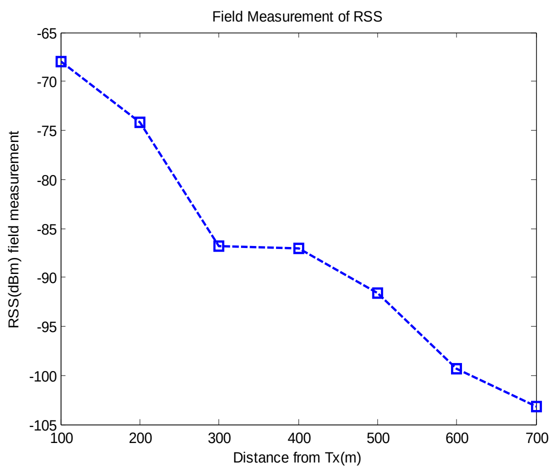

Figure 2: RSS vs. distance for the characterized environment

VI. CONCLUSION

In this paper, it was shown that pathloss characterization of the radio propagation channel in the 800MHz band over Asaba, the capital of Delta State of Nigeria is achieved. The mean pathloss exponent of 3.63 was computed from the measured field data and an empirical pathloss model was developed from the data collected in measurement environment of Asaba using the existing CDMA 20001x cellular network. The developed pathloss model can be used for accurate pathloss prediction of the received signal strength of the CDMA20001x based network. Therefore, for accurate pathloss prediction in these environment, the developed pathloss model can be used as a correction factor, else field measurement must be performed.

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