PATHLOSS PREDICTION FOR SUBURBAN ENVIRONMENTS IN ACDMA 20001X NETWORK

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ABSTRACT

This paper focuses on the performance analysis of a Rayleigh fading channel characterization of the CDMA20001x network environments in Nigeria. Experimentation and field data measurement of the received signal strengths were obtained from a CDMA20001x network in a multipath fading environment of the suburban region of Awka, the Capital of Anambra state of Nigeria. The measured field data were used to determine the pathloss exponent of the environment. The propagation model for the multipath fading environment was also developed. Results obtained from the measured field data of received signal strengths showed that the propagation environment has a pathloss exponent of 4.6. Also, result showed that the developed model for the multipath fading environment in Awka, $Y = 100.93 + 46\log_{10}X$ can be used in determining the reliability of the investigative wireless network.

Keywords: Pathloss exponent, Rayleigh fading channel, multipath fading, Pathloss, CDMA

1.0 INTRODUCTION

In a wireless communication channel, the transmitted signal generally propagates to the receiver antenna through different paths. This phenomenon is called multipath propagation (Foschini and Gans, 2009). Multipath propagation is due to the multiple reflections caused by reflectors and scatterers in the environment. These reflectors and scattereres include mountains, hills, trees, buildings etc. The receiver antenna will therefore receive multiple copies of the transmitted signal (Bjerke and Proakis, 2010). Different versions of the signal propagates through different paths they will have different attenuations, phase shifts, time delays and angles of arrival.

Code Division Multiple Access (CDMA) is a form of multiplexing and a method of multiple access that divides up a radio channel not by time nor frequency, but instead by using different pseudo-random code sequence for each user such that the transmitting end modulates the signals that it sends using the pseudo-random codes, and the receiving end detects the corresponding signals by demodulating the mixed signals using the same pseudo-random code. Here, the users spread across both frequency and time in the same channel. The pseudo-random code is a periodic binary sequence with a noise-like waveform. It is also called pseudo-noise codes and is used to differentiate subscribers. The codes are shared by both the Mobile Station (MS) and the Base Station (BS). Thus, CDMA20001X is one of the third generation (3G) wireless communications networks and it provides a variety of new services with different data rate requirements under different traffic conditions, while maintaining compatibility with 2G

systems. Networks like Visafone Nigeria limited is one of CDMA20001X network which is prone to multipath fading.
Multipath fading produces three effects which are signal fading, delay spread and Doppler spread (Yumin and Donal, 2014). These effects combine to produce a faded signal at the receiving end of the communication link. Signal fading occurs due to the addition of multipath components which result in constructive interference if they are in phase or destructive interference if they are out of phase during unfavourable conditions. The delay spread causes the mobile channel to be selective in the urban environment where there are clusters of buildings and moving objects. The resulting effect of frequency selectivity is the Inter Symbol Interference (ISI) distortion. The Doppler spread determines how fast or slow the fading is; the effect is significant when mobiles are at highway speeds and the mobile communication link exhibits Doppler fading rates of up to about 100 Hz (Norm, *2010*). A simple transmission model system of multipath channel is presented in Figure 1.

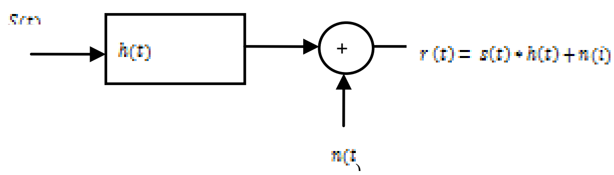

Figure 1: *A simple transmission model*

The output signal, $r(t)$, at a receiver can be expressed as:

$$r(t) = s(t) * h(t) + n(t). \quad (1)$$

Where; $s(t)$ is the input signal, (*) is the convolution process, $h(t)$ is the channel attenuation coefficient and $n(t)$ is the additive random noise process.

2.0 RAYLEIGH FADING CHANNEL

The Rayleigh fading channel is commonly used to describe multipath fading channels when there is no Line-Of-Sight (LOS) component. The number of independent copies (multipath) of the signal arriving at the receiver is large and the coherence bandwidth of the channel is greater than the bandwidth of the signal itself (Skler, 2007). If $s(t)$ is the transmitted symbol then the received symbol is given as:

$$r(t) = s(t) * h(t) + n(t) \quad (2)$$

where; $n(t)$ is the Additive White Gaussian Noise (AWGN) and $h(t)$ is Rayleigh coherence attenuation channel variable, $r(t)$ is distributed by using Rayleigh distribution function as shown in equation (3). The Rayleigh distributions has a Probability Density Functions (PDF) according to (Skler, 2007), given by:

$$p_{(r)} = \left\{\frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right)\right\} for\ 0 \le r \quad (3)$$

But , $p_{(r)} = 0$ for $r < 0$ Where, r is the Root Mean Square (RMS) values of voltage in a received signal, and σ^2 is the time-average power of the received signal. The Cumulative Distribution Function (CDF) is defined to specify the probability that the received signal does not exceed a specific threshold R. The CDF is given by,

$$p(R) = p(r \le R) = \int_0^R P(r)dr = \exp(-\frac{R^2}{2\sigma^2}) \quad (4)$$

3.0 MATERIALS AND METHOD

3.1. Materials:

3.1.1. Determination of the Reliability of Propagation Channel in a Multipath Fading Environment:

The reliability of a wireless communication system can be primarily determined by its multipath fading characteristics (Coulson, 2012). Pathloss exponent is a vital parameter that can be used in determining the efficiency or reliability of the propagation channel in multipath environment. Pathloss can be defined as the difference between the transmitted power (in dBm) and the received signal power (dBm).. The path loss for an arbitrary Transmit-Receiver (T-R) separation is expressed as a function of distance and path loss exponent (n) as (Bultitude and Bedal, 2012):

$$P_L(d) \alpha (d_i / d_o)^n \quad (5)$$

where, Pathloss $P_L(d)$, is the difference between the transmitting power, P_t, in dB and power received, P_r, in dBm, d_i is the distance at intervals from the base station to mobile station, d_o is the reference distance, n, is the path loss exponent.
Taking logarithms of both sides of equation (5),we obtain equation (6) which include the term , $P_L(d_o)$, which is the pathloss at close in reference distance otherwise known as reference pathloss ,(Rappaport,1999).

$$P_L(d_i) = P_L(d_0) + 10n\log(d_i / d_0) \quad (6)$$

But, using linear regression, the value of n can be determined from the measured data and given as (Azubogu et al., 2011):

Therefore, $n = \frac{\sum_{i=1}^{M}[P_L(d) - P_L(d_0)]}{\sum_{i=1}^{M}\left[10\log_{10}\left(\frac{d_i}{d_0}\right)\right]}$ (7)

3.1.2 Propagation Model for the Multipath fading Environment:

The developed propagation model for the multipath channel was obtained from the Hata pathloss model for urban and suburban environment as shown in equation (8), (9) and (10) respectively (Lee and Miller,2013).

$$L_{pu}(\text{dB}) = 69.55 + 26.16\log_{10}F_c + (44.9 - 6.55\log_{10}h_b)\log(d_i) - 13.82\log_{10}h_b - a(h_m) \quad (8)$$

where ; L_{pu} is the pathloss prediction for urban area in dB, F_c is the carrier Frequency in Mega Hertz (MHz), h_b is the height of base station in Kilometers (Km), h_m is the height of mobile station in (Km). $\alpha(h_m)$ is the correlation factor for mobile station antenna height in dB. The correlation factor $\alpha(h_m)$ for the suburban environment is given as:

$$\alpha(h_m) = [1.1\log_{10}F_c - 0.7]h_m - [1.56\log_{10}F_c - 0.8] \quad (9)$$

The pathloss prediction for suburban area in, L_{ps}, takes into consideration the pathloss prediction for urban area in dB and is given as:

$$L_{ps} = L_{pu} - 2[\log_{10}(\frac{F_c}{28})]^2 - 5.4 \quad (10)$$

where L_{ps} is the pathloss prediction for the suburban environment in dB

3.2 METHOD

3.2.1 Drive Test Method of measurement of Received Signal Strength:

The method employed for the data collection of received signal strength used in the analysis of the multipath propagation environment is the drive test method. The network under consideration is a Visafone network located in Awka, the capital of Anambra State of Nigeria at a location with Longitude 13.1572^o and Latitude 11.8606 ^{o}. The Awka environment consisted of a scarcely built up environment and small houses with two to three floors and back yards. The houses were of clay bricks and metal roofs. The environment is made up of farm lands and few bushes around. The parameters of the Visafone (CDMA20001x) network include: carrier Frequency: 800MHz,Transmitting power : 40.4dB,: base station height: 38m, mobile antenna height: 1.6m,channel bandwidth: 5MHz. Using the drive test method, the received signal strengths data were measured from the base station at a 100metres intervals up to 700m from a reference point on the transmitting base station. The measurement was done with the help of a spectrum analyzer made by Gilat. The spectrum analyser was mounted on a monitoring Van with antenna of height 1.6m. A summary of the field data measurement of received signal strengths is shown in Table 1.

4.0 MEASURED RESULT ANALYSIS

4.1 Results:

The result of the field data measurement is shown in Table 1 while the pathloss obtained in the multipath fading environment is shown in Table 2. The graphical presentations of the results in Table 1 and Table 2 are shown in Figure 2 and Figure 3 respectively.

Table 1: Field data measurement of received signal strength

Distance from Tx [m]	**Received Signal Strength power, P_{rss} [dBm]**
100	-67.70
200	-74.05
300	-86.00
400	-92.00
500	-96.50
600	-97.50
700	-105.00

Using the measured received signal strength, the value of the pathloss exponent ,n, can be obtained from equation (7) as follows:

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

P_t = 40.4dB

P_{rss} = [-67.70 -74.05 -86.00 -92.00 -96.50 -97.50 -105.00]

$P_L(d)$ = [108.10 114.45 126.40 132.40 137.00 137.90 145.40]

Substituting , y = [$P_L(d)$ - $P_L(d_o)$] in equation (7) = [0 6.35 18.30 24.30 28.90 28.90 36.90]

$\sum[P_L(d) - P_L(d_o)]$ = 172.55

Also, substituting, x = $\sum 10log_{10}(d_i/d_o)$ in equation (7) where d_o = 100

x =∑ [$10log_{10}$ [1 2 3 4 5 6 7]]

x =0+3.01+4.77+6.02+6.99+7.78+8.45 =37.02

The pathloss exponent , $n = \frac{y}{x}$

Pathloss exponent , n, = 4.6

Using equation (9) and equation (10) and substituting F_c = 800MHz, h_b = 0.038, h_m = 0.0016, α ($h)_m$ = 3.7155, we obtain the propagation pathloss model for the multipath fading channel in Awka as:

L_{pu}(dB)=69.55+ $26.16log_{10}(800) + (44.9 - 6.55log_{10}(0.038))log_{10}(d_i)$- $13.82log_{10}(0.0016) + 3.7155$ (11)

L_{pu}(dB)= 110.5705+ 54.20 $log_{10}(d_i)$ (12)

Substituting equation (12) into equation (13), we obtain:

$L_{ps} = 110.5705 + 54.20log_{10}(d_i)$– $2[log_{10}(\frac{800}{28})]^2 - 5.4$ (13)

L_{ps} = 100.93 + $54.20log_{10}(d_i)$ (14)

$L_{ps}(d_o)$ =100.93

But, re-arranging equation (6), so that:

$P_L(d_i)$ [dB]= Y = propagation pathloss model for multipath fading channel

$P_L(d_0)$ = X = pathloss at known reference distance d_0

n = 4.6 = pathloss exponent.

Therefore, the empirical path loss model for Awka is :

$$Y = 100.93 + 46log_{10}X \quad (15)$$

Equation (15) represents the propagation model for the multipath fading environments in Awka. This equation was used to obtain the pathloss at all measurement points as shown in Table 2 and Figure 3.

Table 2: Pathloss obtained in the measurement environment

Distance from Tx [m]	**Pathloss [dB]**
100	100.93
200	114.78
300	122.87
400	128.63
500	133.12
600	136.72
700	139.80

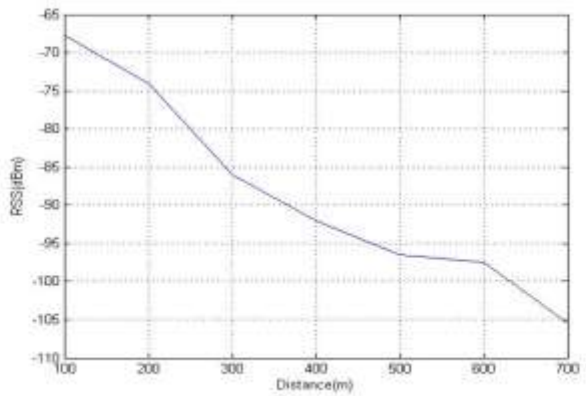

Figure 2: *Field data measurement of received signal strength*

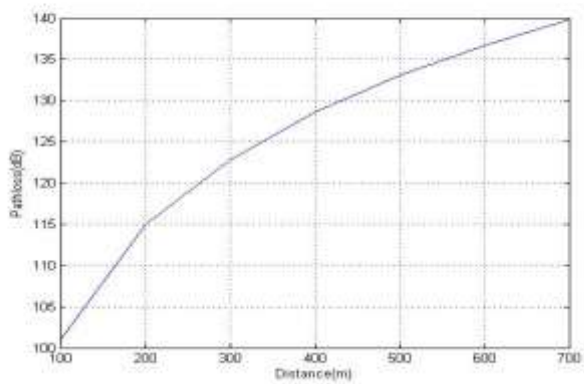

Figure 3: *Pathloss along measurement routes*

5. DISCUSSION

Table 1 showed the measurement data of received signal strength obtained from field measurement and its graphical presentation is shown in Figure 2. Figure 2 showed that the received signal strength decreases as the distance from the transmitter increases. The received signal strength values aid in determining the pathloss exponent of the environment. The pathloss exponent of 4.6 obtained showed that the environment is under heavy multipath fading. The pathloss exponent of 4.6 obtained from the field data is not within the standard range of between 2.0- 4.0 for (surburban region) that will guarantee reliable communication in CDMA20001x network.

The developed model of in equation 15 was used in obtaining the pathloss at all distances from the transmitter as shown in Table 2 and Figure 3. The model showed that the pathloss increases at the rate of 46.0dB which is very high as a result of multipath fading on the environment. Figure 3 showed that more pathloss occurred in the propagation environment due to multipath fading phenomenon. The developed model will help network operators to ascertain the reliability and performance of the wireless network before any optimization action will be taken.

5.0 CONCLUSION

The mobile radio channel places fundamental limitations on the performance of the wireless communication system. This paper has shown that field measurement of received signal strength can be used in the characterization of the multipath fading channel of the CDMA2001x network. The pathloss exponent and the developed propagation model will help network operators to ascertain the reliability and performance of the wireless network before any optimization action takes place.

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