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Bit Error Rate Reduction in Code Division Multiple Access (CDMA) 20001x Mobile Communication Network Using Antenna Diversity Technique

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ABSTRACT:- This paper is aimed at reducing Bit Error Rate (BER) performance in Code Division Multiple Access (CDMA) 20001x mobile radio network using base station antenna diversity technique. In this paper, a mathematical model was developed from the measured received signal strength for the characterization of the mobile radio propagation environment and prediction of the received signal strength as well as the pathloss exponent of the characterized environment. Field measurements of Received Signal Strength (RSS) were carried out on a CDMA20001x based mobile radio network belonging to Visafone network Nigeria Limited, located in Asaba, the capital of Delta State of Nigeria. These data were measured for several months using spectrum analyzer, made by Agilent, of model B4407 ESA-E Series. The Global Positioning System (GPS) was used in measuring angular co-ordinates, elevation of the measurement points, as well as the distances in meters between the transmitting base station and mobile station. The result obtained from the measured data showed that the pathloss exponent of the characterized environment was 3.63 and the result obtained from CDMA20001x network using the antenna diversity showed pathloss exponent of 2.51 as compared to the conventional antenna system. The Bit Error Rate (BER) performance of the CDMA20001x network using antenna diversity was of the order 10^{-2} which is within the acceptable and standard value for efficient voice and data transmission while the BER of the network using conventional antenna system was 10^{-1}.

Keywords: **Bit Error Rate, CDMA20001x, antenna diversity, pathloss exponent.**

I. INTRODUCTION

There is an ever-increasing demand on mobile wireless operators to provide efficient voice and high speed data services. At the same time, these operators support more users per base station in order to reduce overall network cost and make services available to subscribers. Unfortunately, because the available broadcast spectrum is limited, attempts to increase subscriber's density within a fixed bandwidth create more traffic, interference in the system and degrade the signal quality. Code Division Multiple Access (CDMA) 20001x is prone to this phenomenon. Code Division Multiple Access 20001x is one of the third Generation (3G) network that uses pseudo-random code to identify different users on the network unlike the second Generation(2G) network such as Global System for Mobile (GSM) communication that make use of Time Division Multiple Access (TDMA).The second Generation (2G) wireless communication systems, which make up most of today's cellular networks, use digital modulation formats and Time Division Multiple Access/Frequency Division Duplex (TDMA/FDD) [2]. Examples of 2G systems include Interim Standard-95 Code Division Multiple Access (IS-95 CDMA) which is used in American, Asian and Pacific countries including USA, South Korea and Australia [3] and Global System for Mobile communications (GSM) which is widely used in European and Asian countries including China and Australia [4]. This increasing demand for high data rate mobile communication services, without a corresponding increase in radio frequency spectrum allocation, motivates the need for new techniques to improve spectrum efficiency of the wireless network. One of such new techniques is known as antenna diversity. Diversity is a means of reducing the effect of multipath fading in wireless network. The various types of diversity include: antenna diversity, time diversity, and frequency diversity. Antenna diversity involves making use of two or more equally spaced antennas in order to combat the effect of multipart fading in wireless network. Time diversity requires the transmitter to re-transmit the information again at a later time giving the receiver two channels to acquire the signal and properly decode it. In frequency diversity, the system transmits the message simultaneously at two or more different frequencies, which combine at the receiver using a pre-determined algorithm [5]. This paper concentrates on using antenna diversity to reduce the bit error rate of the network in order to improve the performance of the network.

II. DETERMINATION OF PATHLOSS EXPONENT OF MOBILE RADIO PROPAGATION ENVIRONMENT

Pathloss occurs when the received signal becomes weaker and weaker due to increasing distance between the mobile station and base station. The extent to which signal degradation occurs in a communication channel can be known by determining the pathloss exponent of the environment. Therefore, pathloss exponent, n, of an environment shows the variation of signal loss in an environment. The pathloss exponent, n, and the received signal strength obtained from field measurement can be

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used to completely characterize a propagation environment under consideration. The mean path loss measured in decibel, $P_L(d_i)$ [dB] at a transmitter receiver separation, d_i , is given as [6]:

$$P_L(d_i) = P_L(d_0) + 10n\log_{10}\left(\frac{d_i}{d_0}\right) \quad (1)$$

Where n = pathloss exponent,
$P_L(d_0)$ = pathloss at known reference distance d_0 and measured in dB
For free space model, n, is regarded as 2. The free-space model however is an over idealization, and the propagation of a signal is affected by reflection, diffraction and scattering. These effects are environment (indoors, outdoors, rain, buildings, etc.) dependent. However, it is accepted on the basis of empirical evidence that it is reasonable to model the pathloss, $P_L(d_i)$ at any value of d at a particular location as a random and log-normally distributed random variable with a distance-dependent mean value [7].
That is:

$$P_L(d_i) = P_L(d_0) + 10n\log_{10}\left(\frac{d_i}{d_0}\right) + S \quad (2)$$

Where S, the shadowing factor is a Gaussian random variable with values in dB. The path loss exponent, n, is an empirical constant which depends on propagation environment.
In order to determine the pathloss coefficient, n, of the test bed environment, equation (1) can be used to manually compute it as:

$$n = \frac{\{P_L(d_i) - P_L(d_0)\}}{10\log_{10}\left(\frac{d_i}{d_0}\right)} \quad (3)$$

But, using linear regression, the value of n can be determined from the measured data by minimizing total error R^2 as follows:

$$R^2 = \sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right]^2 \quad (4)$$

Differentiating equation (4) with respect to n,

$$\frac{\partial R^2(n)}{\partial n} = -20\log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (5)$$

Equating $\frac{\partial R^2(n)}{\partial n}$ to zero,

$$0 = -20\log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (6)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - 10n\log_{10}\left(\frac{d_i}{d_0}\right) = 0 \quad (7)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - \sum_{i=1}^{M}\left[10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] = 0 \quad (8)$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] = \sum_{i=1}^{M}\left[10n\log_{10}\left(\frac{d_i}{d_0}\right)\right] \quad (9)$$

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

Equation (10) can be used in determining the pathloss exponent,n, of the test bed environment which is essential in characterizing the propagation environment.

A. FADING

The received signal exhibits fluctuations in signal level called fading. As these variations represent the change of the strength of the electrical field as a function of the distance from the transmitter, a mobile user will experience variation in time. The signal level of the continuous time received signal called signal fading is composed of two multiplication component, α_s, and and α_r, as follows [8]:

$$\alpha(t) = \alpha_s(t)\,\alpha_r(t) \quad (11)$$

where, $\alpha_s(t)$ is called slow fading and represents the long time variations of the received signal, whereas $\alpha_r(t)$ represents the short-term (or multipath) fading.

(I) SLOW FADING

This fading is caused by long-term shadowing effects of building or natural features in the terrain. It can be described as the local mean of fast fading signal. The statistical distribution of the local mean has been studied experimentally and was shown to be influenced by the antenna height, the operating frequency and the type of environment [9].

(II) FAST FADING

The fast fading also called short-term fading results from rapid fluctuations of the received signal in space. It is caused by scattering of the signal off objects near the moving mobile. Fast fading is also called Rayleigh fading because it is modelled by Rayleigh statistical distribution. Multipath propagation creates the most threat to signal degradation in wireless communication system. Signals that are reflected off other surface may combine with the desired signal but be out of phase. The multipath channel impulse response is given by:

$$h(\tau,t) = \sum_{i=1}^{N} \beta_i(t)\,\delta(\tau - \tau_i(t)) \quad (12)$$

Where, N is the number of paths, β_i is the complex gain and the subscript, $_i$, is the delay of the ith arriving path [10].

(III) RAYLEIGH FADING CHANNELS

The probability density function of the signal, $f_R(r)$ can be described using a Rayleigh distribution given by [11]:

$$f_R(r) = \frac{r}{\sigma^2}e^{-\frac{r^2}{2\sigma^2}} \quad for\ r \geq 0 \quad (13)$$

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Where σ^2 is the variance, r is the signal, and $f_R(r)$ is the probability density function. The value , σ is a function of the average power of the envelope received by the antenna. Often the cumulative distribution function of the received signal can be the integral of equation (12) or the probability that the envelope is less than a certain value, r. In a Rayleigh channel, the cumulative distribution function is given by $F_R(r)$ and mathematically expressed as [12]:

$$F_R(r) = \int_{-\infty}^{r} f_R(r)dr = 1 - e^{-\frac{r^2}{2\sigma^2}} \quad for \ r \geq 0 \qquad (14)$$

(IV) FLAT FADING

Flat fading refers to the cases where latest copy of the signal arrives at base station after a time duration that is smaller than symbol bit period [13]. When the time difference becomes an appreciable percentage of the symbol bit period, Inter Symbol Interference (ISI) can occur. Flat fading is typical in large cells under FDMA and TDMA schemes and may require additional 20 or 30dB transmitter powers to maintain efficient transmission during deep fade.

III. DATA COLLECTION

The received signal strength data used for the experimentation were obtained from a CDMA20001x network located in Asaba, the Capital of Delta State of Nigeria and the base station was designated ASA001.The received signal strength was measured and analyzed using the spectrum analyzer, made by Agilent, of model B4407 ESA-E Series. The spectrum analyzer was installed on a spectrum monitoring van made available by the Nigeria Communication Commission at the time of the experimentation as shown in Figure1. The base station under consideration is of height 37m and has a carrier frequency of 876.78MHz. The base station from where the transmitted signals emanate is regarded as the network under consideration and it belongs to Visafone network. The received signal strengths were measured at intervals of 100 meters up to 700meters from the transmitting base station. The distances of these measurement points from the reference point of the base station were recorded using the Global Positioning System (GPS).The GPS showed the distance of the mobile unit or another transmitting base station from the base station under consideration. The global positioning system was also used to measure the angular locations of the mobile unit with respect to the transmitting base station. The measurement was done from the period of 29th August 2011 to 26th July 2012. In each month an average of 12 measurements of received signal strength were carried out (three measurement of RSS per week).For a day, measurement of RSS was done from 8.00am to 6.00pm.The entire data measured, were recorded and analyzed using spectrum analyzer and the average of the received signal strength was used for the experimentation as shown in Table 1.

Distance(m)	Measured RSS (dBm)	Predicted RSS(dBm)
100.00	-67.94	-67.94
200.00	-74.16	-78.85
300.00	-86.84	-85.26
400.00	-87.04	-89.79
500.00	-91.64	-93.31
600.00	-99.33	-96.18
700.00	-103.13	-98.61

Fig 1: Measurement Setup

Fig 2: Base station used for the experiment: ASA 001

IV. DATA PRESENTATION

Table 1 shows a comparison between the average measured received signal strength and the predicted received signal strength obtained from the developed mathematical signal model. The comparison is necessary in order to shown if the predicted received signal strength agrees with the measured received signal strength.

Table 1: Measured Received Signal Strength compared with predicted Received Signal Strength for Test Bed Environment Figure 3 show how received signal strength varies log normal with distance in the characterized environment and also the rate at which pathloss increases with distance as the mobile unit move away from the transmitting base station.

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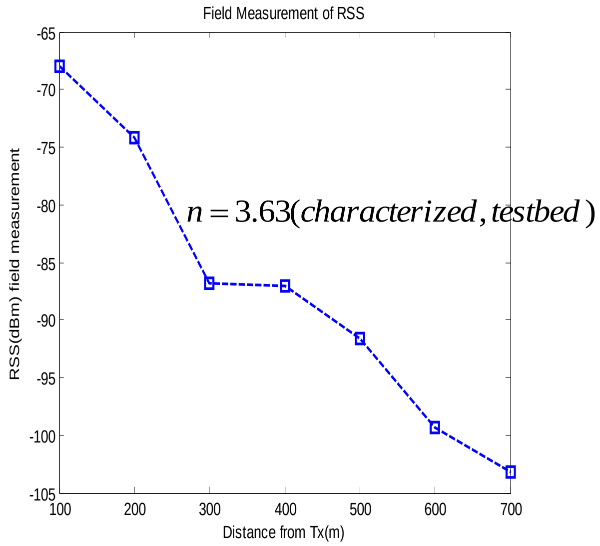

Fig 3: RSS vs. distance for the characterized environment

Fig 4 shows that there is a good agreement between the measured received signal strength and predicted received signal strength using the developed mathematical signal for predicting the received signal strength in the test bed environment.

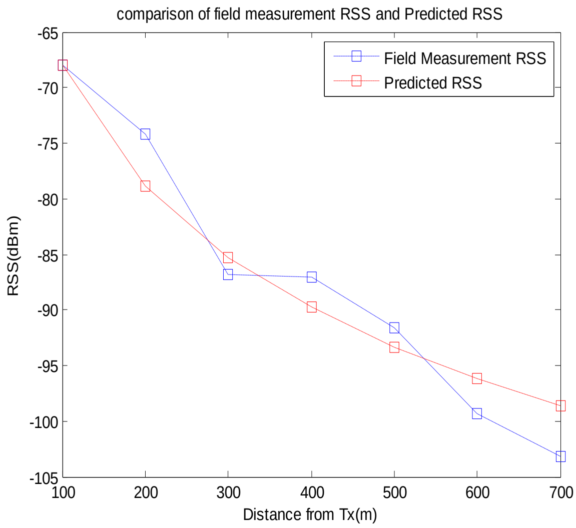

Fig 4: RSS (field) and RSS (predicted) vs. distance

Figure 5: Response of antenna diversity in minimizing BER of the network Figure 5 show the response of the antenna diversity technique in minimizing the Bit Error Rate (BER) of the CDMA20001x network. Also Figure 5 show that there is a greater improvement on the performance of the CDMA20001x network using antenna diversity in minimizing BER of the network, multiple access interference and multipath fading effect in the network as observed from the value of pathloss exponent of 2.51 obtained using antenna diversity unlike that of 3.63 obtained from the characterized test bed environment.

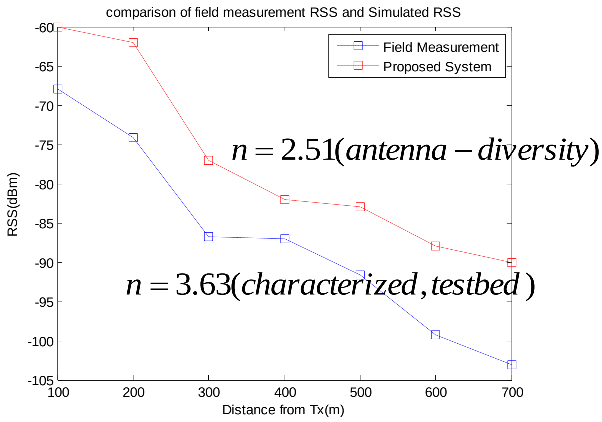

Fig 5: Response of antenna diversity in minimizing BER of the network

V. CONCLUSION

In communication network, the major problem is how to convey the information efficiently as possible within limited bandwidth, although most of the information bits are lost through fading. In order to minimize the bit error rate on the network, the loss of information and signal fading should be minimized. In this paper, we considered using antenna diversity to reduce the bit error rate performance of the signal and compared the technique with that of conventional antenna system. It was observed that using base station antenna diversity on the wireless network resulted in bit error rate that lied within the acceptable value for effective voice and data transmission as compared to the bit error rate of the conventional antenna system.

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