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MITIGATING MULTIPATH FADING IN CDMA WIRELESS NETWORK USING SPACE DIVERSITY SCHEME

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Abstract

*This paper focused on the mitigation of multipath fading in Code Division Multiple Acess(CDMA) wireless network using space diversity technigue. During experimentation, Multilink CDMA based station of antenna height 32m with ID number HT/SE/NE/008 located at longitude N06*27'53.2" and E007* 33'09.6 in Emene Enugu State Nigeria was considered. With a transmission power (Tx power) of 35dBw and transmission frequency of 900MHz in our testbed, a TEMS investigation software running on two pilot laptops configured for drive test setup was used for the network metrics (ie. RSSI, node distance, sensitivity, etc and the data were obtained over a period of time. A characteristic plot of the service provider network testbed showed that multipath fading index in all cases is above 50% revealing a dissatisfactory response for future generation wireless communication systems. Consequently, a generic model was proposed and implemented with a prototyping environment based on MATLAB Simulink, 2011b. Using the OSTBC model, we evaluated the array pattern (AP) and the Bit Error Rate (BER) performance over multipath communication channel conditions, while showing how optimized receiver diversity can improve channel interference with polar diagrams. Multiple Correspondence Analysis (MCA) validated our model showing 87.4% diversity gain recovery. BER performances evaluated for the channel conditions demonstrate the merits of the generic model offering over 90% efficiency.*

Keywords:CDMA 20001x, Psudo Code, Diversity, Space Diversity

1.0 Introduction

A radio channel is characterized by multipath signal between the transmitter and the receiver. Multipath fading arises due to reflection, diffraction, and scattering of signal in the process of transmission. This behaviour adversely affects the quality of wireless communication signal. Multipath reception is the combination of the original direct Line of Sight (LoS) signal plus the duplicate wave fronts that result from reflection of the wave off obstacles as it travels between the transmitter and the receiver. When a radio frequency signal is transmitted towards the receiver, the general behaviour of the signal is to grow wider as it transmits further [1]. On its way, 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. As a result new duplicate wave fronts reach the receiver. Under this condition multiple propagation occurs when radio frequency signals take different paths from source to destination. A part of the signal travels direct to the destination while another bounces off an obstruction to travel a longer distance to the destination. 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.

Most wireless communication systems, however, are low power and do not have the dynamic range available to counter the effects introduced by the propagation environment (distortion). An increase in reliability in multipath fading environment without increasing transmit power can be efficiently achieved using a receive antenna diversity system. Multiple antennas at the receiver have been used successfully in operational systems to diminish the variance of local signal strength fluctuation by using the signals on all antenna elements to reduce the incidence of severe signal degradation that occur during a fade. Using several antenna increases the probability that one or more of the elements will receive signals with adequate signal strength. Reducing the occurrence of fades improves the overall reliability of the received information and therefore allows for greater coverage distance.

In present cellular mobile radio communications, the use of multiple antennas was almost exclusively limited to base stations where sufficiently large areas are available to place several bulky antennas. It is well known that the size of antenna is directly proportional to its operation wavelength [2]. The increase in communication frequencies, as a consequence, was accompanied by a reduction in size of the antenna elements. In addition, at personal communication services (PCS) frequencies (1850-1900MHz) or higher, it has become feasible to have multiple antennas not only at the base station but also at the handset [3]. Diversity is an effective method for increasing the received signal-to-noise ratio in a flat fading environment [4]. The mobile radio channel varies with time and at times a receiver might receive a signal that is indistinguishable from the noise. Diversity is meant to provide the receiver with alternate paths to the transmitted signal to ensure the signal is reliably received.

Due to size constraints, antenna elements on a handset are closely spaced (less than λ). When identical elements are closely spaced, the signal envelope received by both elements can exhibit a large degree of correlation. A large correlation implies that when one antenna receives a low signal level, the second element most likely also attains a similar degraded signal level. It is also common for an antenna diversity system to use different antennas at each diversity branch. Using non-identical elements at the receiver (e.g. antennas with different polarizations or patterns) could lead to the average power imbalances between branches of a diversity system. Antennas that are different usually receive unequal average signal levels depending on which antenna is better matched to the received signal environment. The performance of any diversity system also depends on the combining technique used to merge the signals received by the antenna elements [5]. Among the most popular combining schemes are selection, equal gain and maximal ratio [6]. Some combining techniques outperform others under certain conditions and implementation issues usually determine which method is preferred. This research works, will adopt space-time diversity scheme in other to solve multipath related problems such as fading.

In this paper, the possibility of offering efficient power control with reduced transmitting power which translates into increased coverage, increased system capacities and support for higher data rates is proposed for future wireless communication systems. In these systems, the RF antenna modules should be able to automatically track the desired signal and null the interfering signal by adjusting the gain and phase of weights, which control the output array element. Therefore, with OSTBC in space-time diversity context, multiple access interference and multipath fading issues faced by CDMA, LTE, etc systems can be mitigated by the higher reception sensitivity and interference cancellation benefits of OSTBC, without impacting on the RF spectrum as well as other requirements of the wireless communication systems.

2.0 Space Diversity

This is an approach used to achieve diversity. It involves the use M antennas to receive M copies of the transmitted signal. The antennas should be spaced far enough apart so that different received copies of the signal undergo independent fading. This method is different from frequency diversity and temporal diversity as no additional work is required on the transmission end, and no additional bandwidth or transmission time is required. However, physical constraints may limit its applications. Though, there are various types of diversity schemes.

2.1 Maximum Ratio Combining Technique

Figure 1 shows the baseband representation of an OSTD scheme that has one transmitter and three receiving antennas. At a time t_0, a signal S_0 is sent from a transmitter.

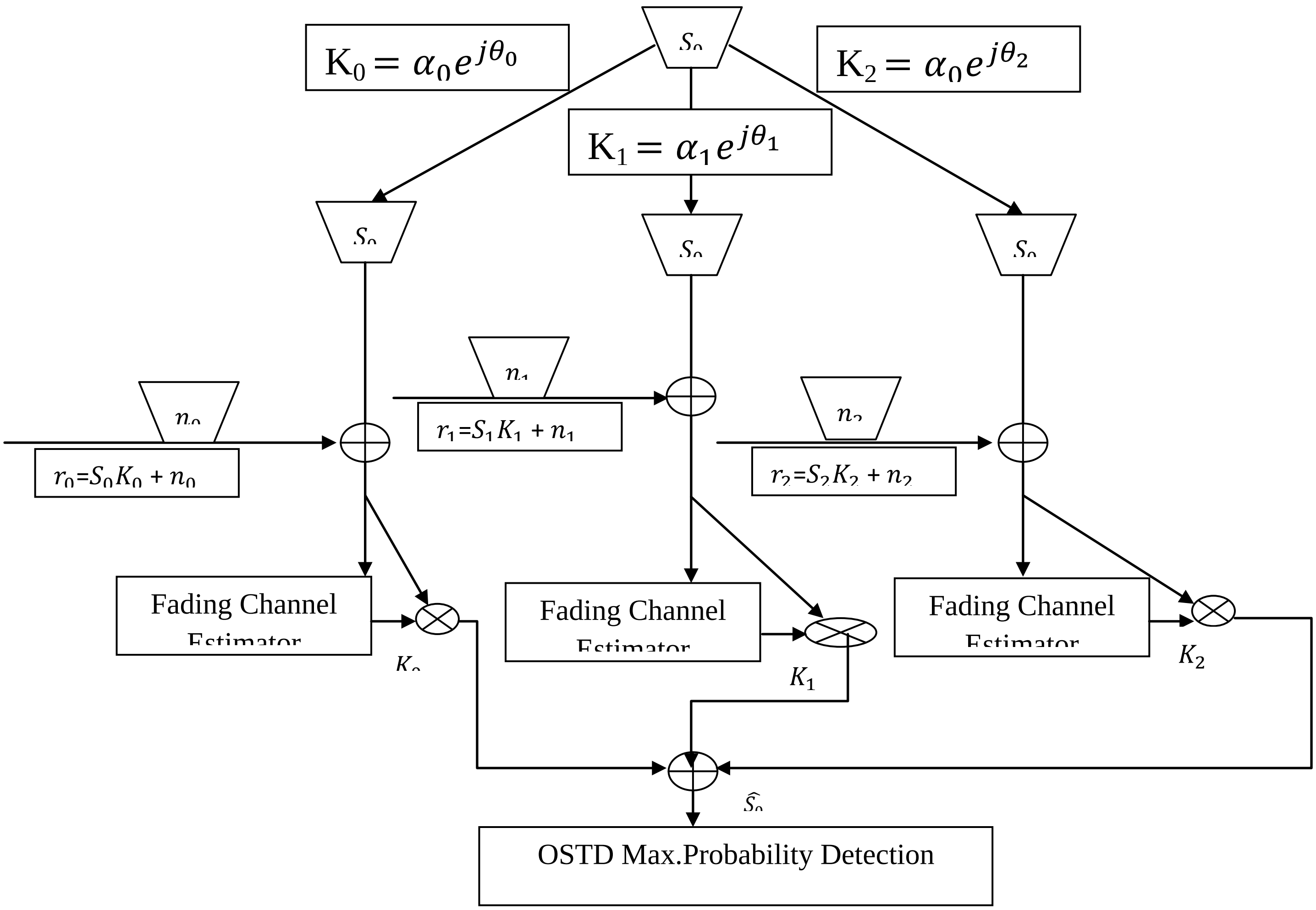

Figure 1: Analytical Model for CDMA OSTD

Let the characteristics of the channel between the transmitters antenna Tx_a and first receiver antenna be denoted by $K_{0,}$ that between the transmitters antenna Tx_a and the second receiver antenna be denote by K_1 and those between the Tx_a and the third receiver antenna be denoted by K_2.

Where,

K_0
$= \alpha_0 e^{j\theta_0}$ (1)

K_1
$= \alpha_1 e^{j\theta_1}$ (2)

K_2
$= \alpha_0 e^{j\theta_2}$ (3)

Where, α_{n+1} and $j\theta_{n+1}$ are the magnitude and the phase of the OSTD channel between the transmitter and the receiver antenna.

From figure 1, the resulting baseband signals is as follows:

$r_0 = S_0 K_0 + n_0$ (4)

$r_1 = S_1 K_1 + n_1$ (5)

$r_2 = S_2 K_2 + n_2$ (6)

Where $n_0, n_{1,} n_2$ represent complex noise and interference which are added at the receivers,

Hence,

Total $r_n = \sum_{i=0}^{n} (S_n K_n + n_{n+1})$ (7)

Assuming$n_0, n_{1,} n_2$, have Gaussian distribution, the max probability decision rule at the receiver for these received signals is choose signal S_i if and only if

$d^2(r_0, K_0, S_0) + d^2(r_1, K_1, S_i) + d^2(r_2, K_2, S_i) \leq d^2(r_0, K_0, S_k) + d^2(r_1, K_1, S_k) + d^2(r_2, K_2, S_k)$ (8)

Where d^2(x, y) is the squared Euclidean distance between signals x and y calculated using the following expression:

$$d^2(x,y) \triangleq (x-y)(\hat{x}-\hat{y}) \quad (9)$$

The receiver combining for OSTD scheme for the three branch framework is given as follows:

$$\widehat{S_0} = K_0 r_0 + K_1 r_1 + K_2 r_2 \quad (10)$$

$$\widehat{S_0} = K_0(K_0 S_0 + n_0) + K_1(K_1 S_1 + n_1) + K_2(K_2 S_2 + n_2) \quad (11)$$

$$\widehat{S_0} = ({\alpha_0}^2 + {\alpha_1}^2 + {\alpha_2}^2)\, S_0 + K_0 n_0 + K_1 n_1 + K_2 n_2 \quad (12)$$

Where ${\alpha_0}^2 = |K_0|^2$, ${\alpha_1}^2 = |K_1|^2$ and ${\alpha_2}^2 = |K_2|^2$

By expanding Equation 9 to Equation 12, we choose S_i if and only if

$$({\alpha_0}^2 + {\alpha_1}^2 + {\alpha_2}^2)\, |S_i|^2 - \widehat{S_0}\widehat{S_\iota} - \widehat{S_0}\widehat{S_\iota} \leq ({\alpha_0}^2 + {\alpha_1}^2 + {\alpha_2}^2)\, |S_k|^2 - \widehat{S_0}\widehat{S_k} - \widehat{S_0}\widehat{S_k} \quad (13)$$

Now, for OSTD signals as applied in CDMA,

$$|S_i|^2 = |S_k|^2 = E_s (\text{Equal Energy Constellations}) \quad (14)$$

Where E_s is the energy of the signals,

Hence, for the OSTD signals, the decision rule in Equation 13 is to simplify to

$$d^2(\widehat{S_0}, S_i) \leq d^2(\widehat{S_0}, S_k),\ \text{K} \neq 0 \quad (15)$$

3.0 Methodology and Result Analysis

During the experimentation, several network operators thriving on 3G services were visited, while finally using Multilinks Nigeria for the research testbed. A Multilink base station (mast) of height 32m with ID number HT/SE/NE/008 located at longitude N06*27’53.2” and E007*33’09.6 at Emene, Enugu (Enugu state of Nigeria) with transmission power (TX power) 35dBw and transmission frequency 900MHz was considered.

Figure 2: Snapshot of Tesebed mast with the Antennas: Base station CDMA 2000 1x
(Source: Multilinks Enugu base Station)

The measurements was carried out with the following tools: GPS, TEMS equipment comprising of two TEMS-phones (special mobile test-phones with TEMS software).The GPS and Modem all connected to a Laptop computer runing TEMS software. The test was carried out for several weeks and this readings which was taken repeatedly for six months (Monday to saturday) out of 28 week month reading time budget for this work.

The drive test log file shows the receive signal strengh with the distance from the base station, so the readings were taken from 100m, 200m, 300m, 400m, 500m, 600, 700m, 800m and 900m respectively.Table 1 shows the average of the RSS values.

Table 1 : Average of the measurement RSS values (from June to November)

Distance (m)	RSS (dBm)	TX Frequency (MHz)	Cell Site	Longitude	Latitude
100	-65	900	HT/SE/NE/008	N 6*27’52.43”	E7*33’06.42”
200	-69	900	HT/SE/NE/008	N 6*27’52.83”	E7*33’05.23”
300	-80	900	HT/SE/NE/008	N 6*27’53.19”	E7*33’02.67”
400	-82	900	HT/SE/NE/008	N 6*27’52.82”	E7*32’59.19”
500	-84	900	HT/SE/NE/008	N 6*27’52.41”	E7*32’57.15”
600	-87	900	HT/SE/NE/008	N 6*27’52.24”	E7*32’54.58”
700	-89	900	HT/SE/NE/008	N 6*27’52.00”	E7*32’52.31”
800	-90	900	HT/SE/NE/008	N 6*27’51.38”	E7*32’49.29”

900	-92	900	HT/SE/NE/008	N 6*27'50.90"	E7*32'43.46"

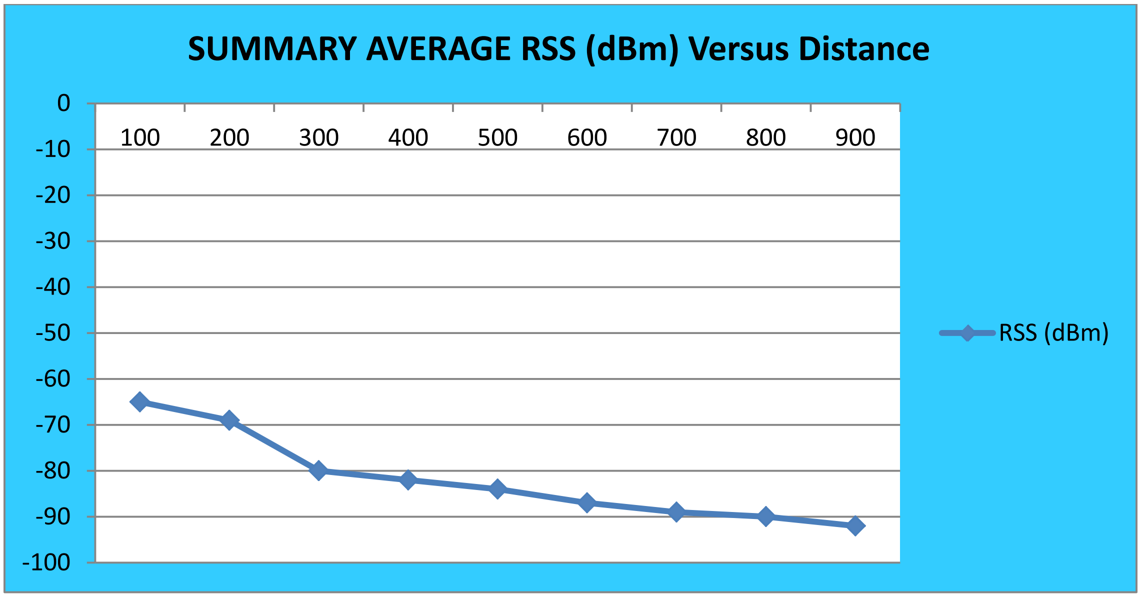

Figure 3: Average drive test signal quality

4.0 Conclusion

This paper developed and presents wireless communication system model that fits well into resource constrained bandwidth and power drain for CDMA service providers, hotspots, etc. The model addressed multipath fading and system capacity limitations in mobile infrastructures. The developed GWCS will scale in hotspots wireless systems (CDMAs). We used OFDM Space diversity gain amplifier in space-time diversity context. This addresses channel fading issues without altering RF spectrum allocation and bandwidth limits.

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