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# Enhancing the performance of CDMA 20001x in Rayleigh fading Channel using Space Diversity Technique

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## ABSTRACT

This paper is aimed at enhancing the performance of CDMA20001x using antenna diversity technique in order to accommodate much subscribers on the network. Real time measurement involving measurement of received signal strength and signal to interference and noise ratio were carried out on a CDMA20001x network in Asaba, Delta state of Nigeria. This paper also presents simulations that were done on Matlab version 7.5 to determine the BER performance of the CDMA20001X with and without antenna diversity. Results obtained from the real time measurements showed that CDMA20001x as one of the 3G network is prone to the effect of multipath fading and multiple access interference and these effect need to be minimized using antenna diversity. The results of the BER performance of CDMA20001x with antenna diversity showed a significant improvement on the performance of the network compared to the result without antenna diversity.

**Keywords:** Antenna diversity, CDMA20001x, Rayleigh Fading, Diversity

## I. INTRODUCTION

In wireless communication systems, the received signal can be exposed to both short-term fading, which is the result of multipath propagation, and long term fading (shadowing), which is the result of large obstacles and large deviations in terrain profile between transmitter and receiver [1]. The reliability of communication over the wireless channels can be improved using diversity techniques, such as space diversity techniques [2]. The most popular space diversity combining techniques are selection combining (SC), equal gain combining (EGC), and maximal ratio combining (MRC) [3]. Maximal ratio combining is optimal combining technique in the sense that it achieves the best performance regardless of the fading statistics on the best performance regardless of the fading statistics on the diversity branches. However, MRC requires the knowledge of the channel fading amplitudes and phases of each diversity branch which must be continuously estimated by the receiver. These estimations require separate receiver chain for each branch of the diversity system increasing complexity. Equal gain combining provides performance comparable to MRC, but with simpler implementation complexity. EGC does not require the estimation of the channel fading amplitudes since it combines signals from all branches with the same weight factor. Selection combining (SC) is the least complicated technique. It works on processing only one of the diversity branches. Selection combining combiner chooses the branch with the highest signal value. Diversity techniques at single base station (micro diversity) reduce the effects of short term fading. Impairments due to shadowing can be mitigated using macro diversity techniques which employ the processing of signals from multiple base stations. The use of composite micro- and macro diversity has received considerable interest due to the fact that it simultaneously combats both short term fading and shadowing. Rayleigh, Rician and Nakagami statistical models are the most frequently used to describe fading envelop of the received signal. The Rayleigh distribution is frequently used to model multipath fading with no direct line-of-sight (LOS) path. The Rician distribution is often used to model propagation paths consisting of one strong direct line of sight component and many random weaker components.

## II. METHODS AND MATERIAL

**Rayleigh fading channel.**

The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal. The Rayleigh flat fading channel model assumes that all the components that make up the resultant received signal are reflected or scattered and there is no LOS path from the transmitter to the receiver. When the channel impulse response *x* (*t*) is modelled as a zero-mean complex-valued Gaussian process, the envelope at any instant is Rayleigh-distributed. The Rayleigh distribution of a received complex envelope of a signal *z* (*t*) = |*x* (*t*)| at any time *t* is given as [4],

$$p_z(x) = \begin{cases} \frac{x}{\sigma^2} e^{-\left(\frac{x^2}{2\sigma^2}\right)} & ,0 \leq x < \infty \\ 0 & ,x < 0 \end{cases} \quad (1)$$

Where, $\sigma^2$ is the root mean square value of the received voltage signal before envelope detection. For a Rayleigh distributed envelope, the average power is $2\sigma^2$.

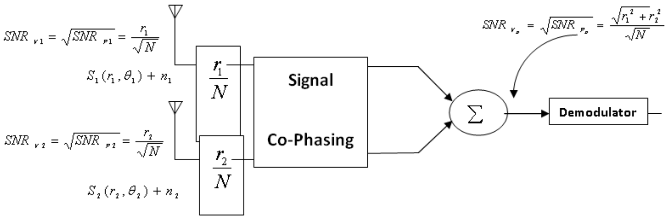


Fig 1: Block diagram of a two-branch maximum ratio combiner for equal noise powers in both branches.

The configuration of Figure 1 is for a two-branch diversity system. Both branches are weighted by their respective instantaneous voltage-to-noise ratios. The branches are then co-phased prior to summing in order to ensure that all branches are added in phase for maximum diversity gain. The summed signals are then used as the received signal and connected to the demodulator.

The inputs to the maximal ratio combiner are both Rayleigh distributed signals $s_1$ and $s_2$ received with envelopes $r_1$ and $r_2$, and with phase $\theta_1$ and $\theta_2$ respectively. In the presence of additive independent noise voltage sources $n_1$ and $n_2$. Both $n_1$ and $n_2$ are zero mean white Gaussian random variables with a variance of N;

The signal-to-noise ratio at the input of each diversity branch is the ratio of instantaneous signal power to noise power, or $SNR_{P1,2}$ ($t_0$). At time $t_0$, the $SNR_P$ received by each antenna elements is therefore given by[6]

$$SNR_{P_{1,2}}(t_0) = \frac{Power_{Signal}(t_0)}{Power_{Noise}(t_0)} = \frac{r_{1,2}(t_0)^2}{E\left[n_{1,2}^2\right]} = \frac{r_{1,2}(t_0)^2}{N} \quad (2)$$

$$SNR_{P_{1,2}} = \frac{r_{1,2}^2}{N} \quad (3)$$

$$But, SNR_{V_{1,2}} = \sqrt{SNR_{P_{1,2}}} = \frac{r_{1,2}}{\sqrt{N}} \quad (4)$$

The amplitude of the signal of interest after MRC can be evaluated by multiplying the received signal envelopes $r_1$ and $r_2$ at $t_0$, by their instantaneous voltage to noise power ratios which when summed gives:

$$V_{S,M}(t0) = r_1(t_0)\left(\frac{r_1(t_0)}{N}\right) + r_2(t_0)\left(\frac{r_2(t_0)}{N}\right) = \frac{r_1(t_0)^2 + r_2(t_0)^2}{N} \quad (5)$$

The instantaneous signal power after maximal ratio combining, $P_{S,M}$ ($t_o$), is defined as the voltage signal squared

$$P_{S,M}(t_0) = V_{S,M}(t_0)^2 = \left(\frac{r_1(t_0)^2 + r_2(t_0)^2}{N}\right)^2 \quad (6)$$

The noise component after MRC at $t_0$, $V_{N,M}(t_0)$, is also multiplied by the gains in both branches and evaluates after co-phasing and branch addition to;

$$V_{N,M}(t_0) = n_1\left(\frac{r_1(t_0)}{N}\right) + n_2\left(\frac{r_2(t_0)}{N}\right) = \frac{n_1 r_1(t_0)^2 + n_2 r_2(t_0)^2}{N} \quad (7)$$

While the output noise power, $P_{N,M,}$ can be found by evaluating the expected value of the noise voltage squared expression as;

$$P_{N,M}(t_0) = E\left[V_{N,M}(t_0)^2\right] = E\left[\frac{n_1^2 r_1(t_0)^2}{N^2} + \frac{2n_1 n_2 r_1(t_0) r_2(t_0)}{N^2} + \frac{n_2^2 r_1(t_0)^2}{N^2}\right] \quad (8)$$

$$P_{N,M}(t_0) = E\left[\frac{n_1^2 r_1(t_0)^2}{N^2}\right] + E\left[\frac{2n_1 n_2 r_1(t_0) r_2(t_0)}{N^2}\right] + E\left[\frac{n_2^2 r_1(t_0)^2}{N^2}\right] \quad (9)$$

The middle term evaluates to zero since each noise source is independent of all other signals and has a mean of zero. Simplifying (8) further, by noting that the expected value is formed given steady signals $r_1(t_0)$ and $r_2(t_0)$ which factor out of the operator as constants and produce the following result for the noise power at the output of the maximal ratio combiner at time $t_0$.

$$P_{N,M}(t_0) = E\left[\frac{n_1^2 r_1(t_0)^2}{N^2}\right] + E\left[\frac{n_2^2 r_1(t_0)^2}{N^2}\right] \quad (9)$$

$$P_{N,M} = \frac{r_1(t_0)^2}{N^2} E\left[n_1^2\right] + \frac{r_2(t_0)^2}{N^2} E\left[n_2^2\right] = \frac{r_1(t_0)^2 + r_2(t_0)^2}{N} \quad (10)$$

The output signal to noise ratio, $SNR_{P,M,}$ at $t_0$ after maximal ratio combining is given by the ratio of signal to noise power or the division of (5) and (7) which gives

$$SNR_{PM}(t_0) = \frac{Power_{Signal}(t_0)}{Power_{Noise}(t_0)} = \frac{P_{S,M}(t_0)}{P_{N,M}(t_0)} = \frac{V_{S,M}(t_0)^2}{E\left[V_{N,M}(t_0)^2\right]} \quad (11)`$$

$$SNR_{p_M}(t_0) = \frac{r_1(t_0)^2 + r_2(t_0)^2}{N} = \frac{1}{N}\left(r_1(t_0)^2 + r_2(t_0)^2\right) \quad (12)$$

The output voltage signal-to-noise ratio after MRC, allows for a direct comparison between theory and measured data and is given by[7].

$$SNR_{V_M}(t_0) = \sqrt{SNR_{p_M}(t_0)} = \sqrt{\frac{r_1(t_0)^2 + r_2(t_0)^2}{N}} = \frac{1}{\sqrt{N}}\sqrt{r_1(t_0)^2 + r_2(t_0)^2} \quad (13)$$

The goal of this paper is to quantify the improvement between systems using two branch diversity over ones with just a single branch in a Rayleigh fading channel. The gain (as a ratio) between the signal to noise ratio after maximal ratio combining and a single branch is independent of the noise power N. From (1) and (11), and (12) for the $SNR_V$) the factor 1/N (1/√N for $SNR_V$) will cancel when dividing these two equations. The gain is not a function of N and therefore depends solely on the distributions of $r_1$ and $r_2$ when both branches have equal noise power. The signal-to-noise ratio of two-branch maximal ratio combining with N set to unity can be computed from (12) and (13) and are given by

$$SNR_{P_M}\Big|_{N=1} = r_1^2 + r_2^2 \quad (14)$$

$$SNR_{V_M}\Big|_{N=1} = \sqrt{r_1^2 + r_2^2} \quad (15)$$

## III. RESULTS AND DISCUSSION

The equipment specifications are as follows:

**(A) Spectrum analyzer:**
Type: bench top
Model: Agilent: 8563E Series
Frequency range: 9 KHz - 26.5GHz
Resolution bandwidth (RBW): 30 KHz
Video bandwidth (VBW): 8 KHz
Sweep time: 10ms

**(B) Mobile station (MS) antenna**:
Type: horn antenna: Dorado GH42-25
Model: Schwarz Beck BBHA9120 E0899 D69250 schonau
Frequency range: 450 – 6000MHz
Gains isotropic: 5.73 – 18.77dBi
Antenna factor: 17.55 – 27.01dB/m

**(C) Base Station parameters (BS)**
BS height = 36m
Reference Power level = -40dBm
Centre frequency = 881.27MHz
Transmit power: 44.4W
Antenna gain=20dB

### 3.1 Data collection

The researcher was part of the four man team of three Engineers (2 from Visafone, 1 from Huawei Technologies) that carried out the drive test in the city of

Asaba in Delta state of Nigeria. The received signal strength from the reference transmitting base station (ASA001) was recorded at intervals of 100m using a spectrum analyzer. All the measurements for distances were taken for mobile terminal using a radio propagation simulator called the Global positioning system (GPS). The GPS indicates the transmitter – receive (T–R) separation distances. The reference distance is taken as $d_o$ = 100m, thus starting from 100m, measurements were taken in intervals of 100m and these measurements were performed up to a distance of 700m from the transmitter and the average of the measurements in a day is recorded in a table. The distances of these points from the reference point of the base station were also recorded using the Global positioning system (GPS). Specifically, signal strength measurements were made by monitoring and recording the signal received by a mobile unit as it moves away from the base station along the test driven route. The measurements were conducted between 10.00am till 4.00pm daily for an average of Ten days.

**Table 1:** Simulation parameters under consideration

| | |
|---|---|
| Propagation environment | Multipath fading+AWQN |
| Modulation | QPSK |
| Chip rate | 3.84MCP |
| BS synchronization | Synchronous operation |
| Receiver | Rake receiver |
| Channel bit rate | 5.76Mbps |
| Power control | Ideal |
| Eb/no | 0.1-1.0 |

**Table 2 :** Average of all the measurements carried out for ten days on Visafone network at Asaba in Delta State (scenario 1).

| **Distance(m)** | **RSS (dBm)** | **Cell Site** | **Tx Power(dBm)** | **Tx Freq.(MHz)** | **SINR** |
|---|---|---|---|---|---|
| 100.00 | -67.94 | ASA001 | 44.4 | 881.27 | -6.54 |
| 200.00 | -74.16 | ASA001 | 44.4 | 881.27 | -6.61 |
| 300.00 | -86.84 | ASA001 | 44.4 | 881.27 | -5.17 |
| 400.00 | -87.04 | ASA001 | 44.4 | 881.27 | -5.68 |
| 500.00 | -91.64 | ASA001 | 44.4 | 881.27 | -7.62 |
| 600.00 | -99.33 | ASA001 | 44.4 | 881.27 | -4.27 |
| 700.00 | -103.13 | ASA001 | 44.4 | 881.27 | -8.64 |

**Table 3 :** Results for CDMA20001x with and without rake receivers

| **Eb/No(dB)** | **BER(Without antenna diversity** ) | **BER(with 2 RAKE)** | **BER(3RAKES)** With antenna diversity |
|---|---|---|---|
| 0.1 | 0.5364 | 0.4890 | 0.00184 |
| 0.2 | 0.5278 | 0.4800 | 0.00183 |
| 0.3 | 0.5227 | 0.4762 | 0.001673 |
| 0.4 | 0.5206 | 0.4758 | 0.001673 |
| 0.5 | 0.5185 | 0.4758 | 0.001673 |
| 0.6 | 0.5149 | 0.4730 | 0.001673 |
| 0.7 | 0.5114 | 0.4615 | 0.001673 |
| 0.8 | 0.5093 | 0.4508 | 0.001673 |
| 0.9 | 0.5081 | 0.4278 | 0.000418 |
| 1.0 | 0.5057 | 0.4124 | 0.000410 |

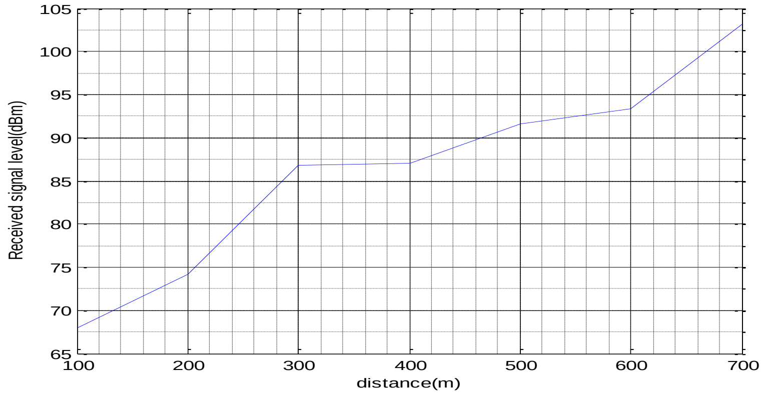


**Figure 1.** RSS Vs Distance for CDMA20001x

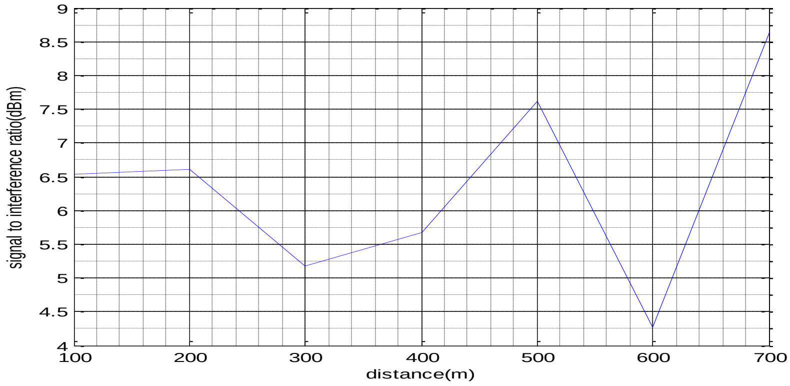


**Figure 2.** SINR Vs distance for CDMA20001X:ASA001.

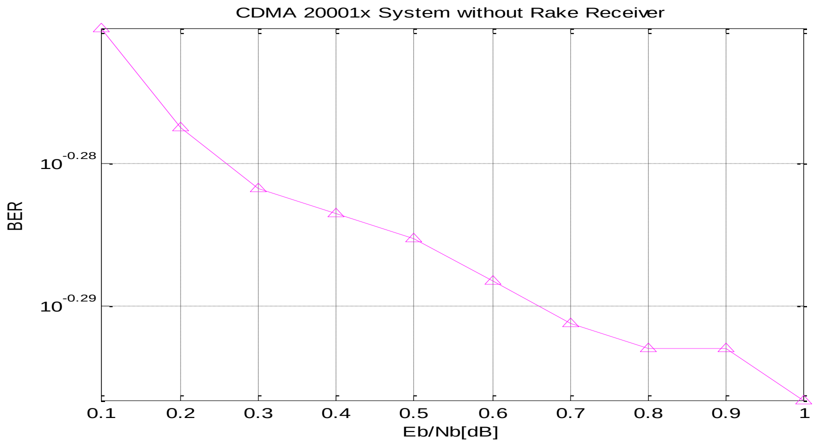


**Figure 3.** CDMA 20001x system without rake receiver

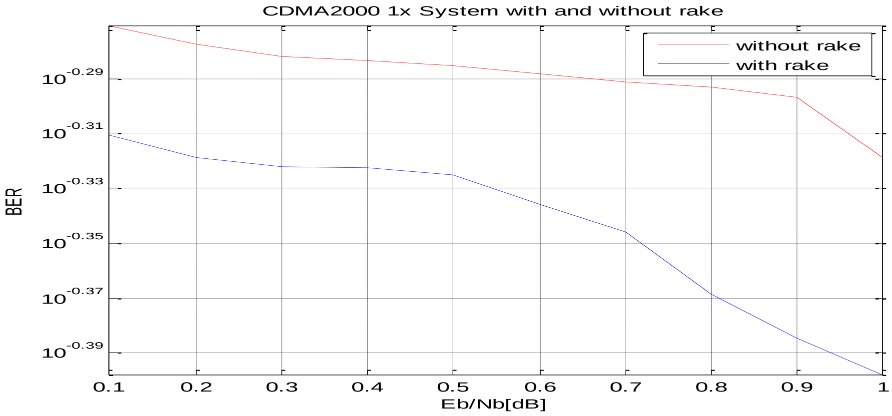

**Figure 4.** CDMA 20001x system with and without rake receiver(antenna diversity).

### 3.2 Summary of Results

Figure 1 showed the plot of received signal strength versus distance while Figure 2 showed the plot of signal to interference and noise ratio versus distance for the data obtained from the real time measurement. The two graphs showed that the received signal strength decreases with distance. Figure 3 showed BER versus Eb/No performance of CDMA20001x without rake receiver while Figure 4 showed BER performance of CDMA20001x with antenna diversity. It is observed from Figure 3 and Figure 4, that the bit error rate reduced drastically especially as indicated in Figure 4. This showed an improvement on the performance of CDMA20001x using antenna diversity.

## IV. CONCLUSION

The simulation results showed that RAKE receiver is very important technique in improving CDMA20001x system performance and channel capacity. The more the number of rake fingers, the lower the BER and the higher the performance of the system. This can be shown from the significant improvement in BER performance of CDMA20001x system when more than one rake receivers were used. This has shown that as antenna diversity increases at the receiver end of the CDMA20001X, the BER is reduced.

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