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EXPERIMENTAL STUDIES AND SIMULATIONS BASED PREDICTION OF A BETTER MIMO-OFDM COMBINED SYSTEM FOR BROADBAND WIRELESS MOBILE COMMUNICATION

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Abstract—Wireless technology offers new found freedom and the potential for 'anytime, anyplace' communications. Communication technology requires being sustainable in the sense of efficiency, not only to preserve the information within the quality requirements, but also to express the same contents with the minimum resources. The Code Division Multiple Access (CDMA) is an emerging technology for next generation multimedia information of real-time and non real-time traffic and various multi-source multi-traffic communication environments. Multiple inputs multiple output (MIMO) as an adaptive antenna based technology which can improves the capacity of wireless mobile communication. The combined technique has both the advantages of CDMA and MIMO systems. Below the jamming margin CDMA alone works up to satisfactory level but above jamming margin

CDMA along with MIMO may be a better proposition for anytime-anywhere communication.

1. INTRODUCTION

Broadband communication system can simultaneously accommodate television, voice, data, and many other services [1]. Broadband networks or the high-speed networks are not being designed as an exercise to demonstrate engineering capability. They are being developed and deployed only because network service providers increasing demand for communication services that can only be met with a low-latency, very fast, high-capacity network infrastructure [2].

Atmosphere is the main constraint to achieve high speed data communication [3]. In order to support peoples' appetite CDMA plays an important role in wireless communication. The third-generation (3G) and fourth-generation (4G) mobile communications are expected to provide a high-rate data services [4]. WCDMA (Wideband Code Division Multiple Access) is the dominant transmission technology for 3G and OFDM (Orthogonal Frequency Division Multiplexing) becoming very popular and other evolving technology is UWB (Ultra Wide Band). However, keeping in mind the spectral limitation as an effort to support such high rates, the multiple antennas [5] and multi-user detection algorithms [6] are used for the performance improvement in the DS-CDMA systems.

Data rate plays important role in wireless communication. Voice communication data rate is reduced to the minimum level for additional users [7]. But people are interested about the performance of a system. For higher data rate, enhancement of transmit power will cost more because of the logarithmic relationship between the capacity of a wireless link and signal-to-interference-and-noise-ratio (SINR) at the receiver end [8].

Recent studies have shown that high data rate is possible only under favourable conditions like near the base station and no other users competing for bandwidth [9]. In a multi-user environment the wireless transmission performance is fundamentally limited by interference due to the presence of signals from other users as well as from multipath. Specially, the performance of wireless communication systems is limited by time dispersion in the channel as a result of multipath. Dispersion gives rise to frequency-selective fading those results in a distorted frequency spectrum of the information signal [10]. It is usually assumed that the multipath delay spread is smaller than symbol duration [11] because larger values of delay spread cause significant intersymbol interference (ISI), which limits the achievable data rate. Fading, Jamming, Security are also the important issues in wireless communication.

2. HARDWARE SIMULATION EXPERIMENT TO STUDY JAMMING POWER DIRECT SEQUENCE SPREAD SPECTRUM (DSSS) SYSTEM ARCHITECTURE

The capability of a jamming (co-channel) source is the function of its jamming power and dwell time. Higher is the jamming power lower is the dwell time and vice-versa [15]. DSSS based frequency diversity transceiver system at unlicensed ISM band of 902–928 MHz has been developed. Hardware simulation experiment, system development and performance testing is conducted at Calcutta, India. The CDMA is utilized for multiple accesses of four such users with a centralized access point. The ProComm software has been utilized to communicate among the PC with the wireless LAN developed for this purpose. This is configured with the purpose of propagation effects on online multimedia data transmission .The simplified schematics of which are shown in the Figure 1.

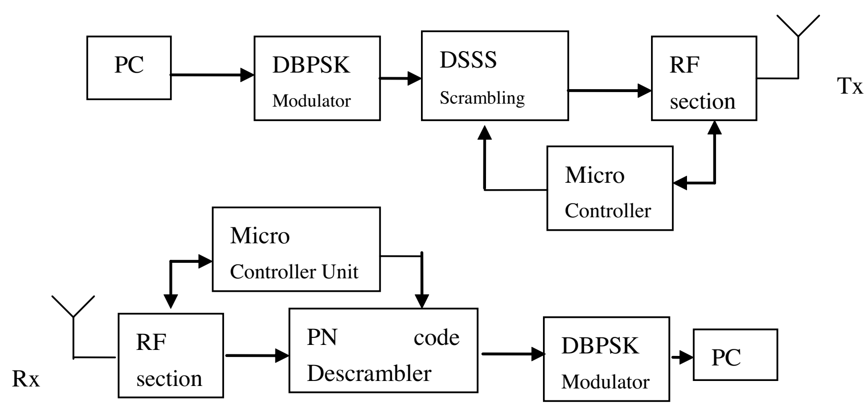

Figure 1. Schematic diagram of DSSS system.

The digital base band signal coming out from PC is first fed to the DBPSK modulator and then scrambled by PN sequence generator. It is then Up-converted to the RF level by using synthesized RF unit — which is connected to the Tx antenna shown in Figure 1. Both PN sequence generator and RF unit is controlled by a micro controller unit to have different code for different users as well as to have different free radio channels within the permissible band of 902 to 928 MHz. After receiving the composite RF signal the original base band multimedia signal is retrieved by using PN code descrambler and DBPSK demodulator respectively. It is then fed to another distant PC.

3. SIMULATION OF EXTERNAL INTERFERENCE USING SWEEP GENERATOR (PERFORMANCE STUDY)

With the rapid growth of CDMA communication systems, the jamming at the RF level is a serious problem as all user use the same RF frequency at the same time. The remedial measure can only taken by addition of proper circuit or DSP in the system only after proper jamming performance study is carried out repeatedly. This also needs proper simulation experiment. With those above facts in mind, the RF sweep generator with variable sweep time as well as variable power level has been utilized to radiate the CW power within the specified band and acts as a jamming power source. The physical placement of the sweep generator is very near to the Base station as shown in the Figure 2. A spectrum analyzer is used to monitor the various signal conditions which helps the authors to explore the performance study of the system. The Sweep generator is also replaced by using synthesized signal generator with adjustable modulation depth and the jamming condition is also tested.

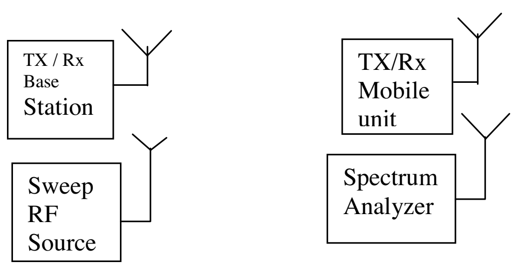

Figure 2. Extended experimental setup for study of Jamming performance.

4. RESULTS AND OBSERVATION

The system is working satisfactory as the intended data is received through a remote mobile PC while the data is sent through a base station PC. This has been achieved by putting off the sweep RF source. As soon as the sweep RF source is turned on the intended data is lost for a period of time. The data lost period is highly dependable on the sweep time as well as on the power level of the sweep generator. As the sweep time varies the relative dwell time also varies; resulting different jamming occurrences of the radio channel at different power level. Table 1 shows some experimental data regarding dwell time vs. required jamming power whereas Figure 3 shows its graphical representation. It is evident from the plot that as dwell time increases the required jamming power decays exponentially following some empirical formula like this — Fit equation is

$$y_0 + A_1 e^{\{-(x-x_0)/t_1\}} + A_2 e^{\{-(x-x_0)/t_2\}} \tag{1}$$

where co-efficient are shown in the plot itself (Figure 3).

Table 1. Experimental data — Dwell time vs. jamming power.

Dwell Time (sec)	Increasing Jamming Power (dBm)	Decreasing Jamming Power (dBm)
0.1	−5.4	−8
0.2	−10.6	−12.2
0.3	−11.9	−13.1
0.5	−13.0	−14.9
0.7	−13.5	−14.4
1.0	−14.3	−14.9

In other way the system jamming performance can be improved by offsetting the jamming margin in the upward direction as shown in the Figure 4. So jamming free region will be increased. This can be done in different way, like using DSP technique in WCDMA. However, here we are concentrating on multiple Antenna system to achieve the desired performance.

5. ANTENNA ARRAY

The co-channel interference is suppressed in CDMA system satisfactory up to the jamming margin level above which it is prone to Interference. This may be the situation when the cars stop at the crossing of roads and the mobile units at the cars face infinite dwell time. Additionally the limitations of data rate arise from different speed of the user. Higher data rate is well supported for the user under low mobility condition like walking etc. But while moving in a high speed vehicles, the multipath fading is accentuated, again at high data rate multipath

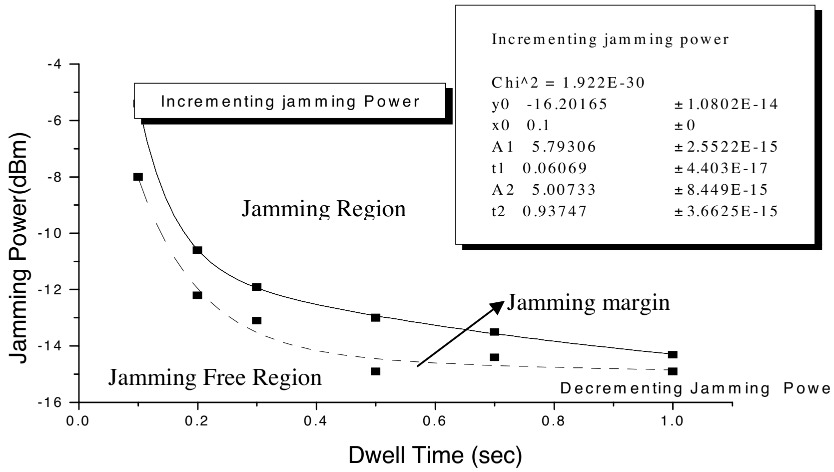

Figure 3. Dwell time vs. jamming power graph.

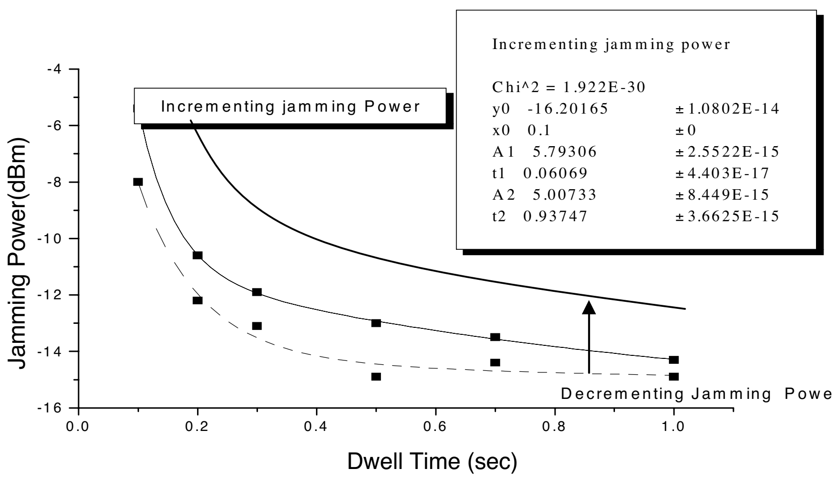

Figure 4. Offsetting jamming margin.

distortion is more disturbing at high data rate (as described in the Figure 5) which in turn degrades the quality of service. Frequency Diversion Technique provides a solution [16] but for very high data rate but it is not the ultimate solution.

Adaptive Antenna Array system plays an important role for mitigation of channel impairments like multipath effects [17]. The capacity improvement of wireless network has drawn considerable

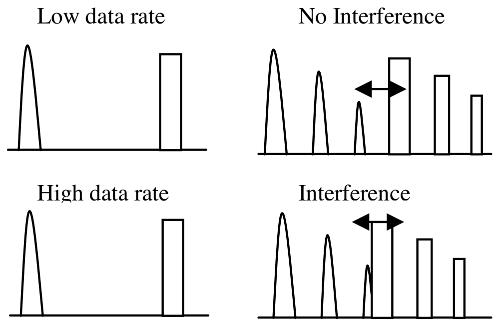

Figure 5. Multipath distortion at different data rate.

attention to multiple-input multiple-output (MIMO) system. That is multiple antenna arrays at both the transmitter and receiver side of a communication link significantly improve the capacity over the single antenna system [18]. MIMO link can provide multiplexing gain over the SIMO channels. Capacity gain in MIMO link is proportional to the minimum number of transmitting and receiving antennas [19]. Researchers have studied using multiple transmit antennas for diversity in wireless systems. Transmit diversity may be based on linear transforms [20] or space-time-coding [21]. The system capacity can be improved if multiple transmit and receive antennas are used to form MIMO channels [18, 19, 22, 23]. It is evident from [18] that compared with a single-input single-output (SISO) system with flat Rayleigh fading or narrowband channels. For wideband transmission [24], space-time processing must be used to mitigate ISI. However, complexity of the space-time processing increases with the bandwidth, and the performance stability degrades when estimated channel parameters are used [25].

A detailed treatment of array gain and capacity of MIMO channels for the case where both the transmitter and receiver know the channel can be found in [26]. An Antenna Array System for Wireless Communications is shown in Figure 6.

For many years adaptive antenna array systems have been proposed to achieve reliable, robust high speed wireless data communication [27, 28], however research and development has increased significantly in this area [29, 30] and recently there has been important development in space-time coding and SDM antenna systems. Antenna array becoming so popular for increasing the data rate because they mitigate major impairments like fading, delay spread, co-channel interference. The antenna diversity which is commercially used at base station mitigates the effects of fading. An important research area for antenna system is the processing block which consists of weight. In this work we have calculated the weights and multiplying with the incoming signal to get only the desired signal.

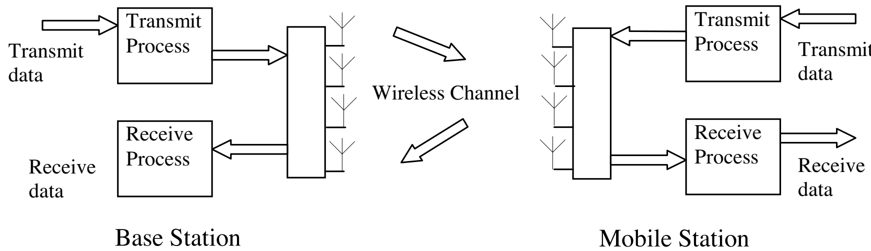

Figure 6. Antenna array system for wireless communications.

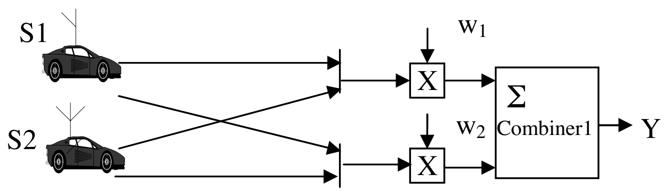

Figure 7. Interference rejection using adaptive antenna.

A set of antenna elements are arranged in space and the output of each element is multiplied by a complex weight and combined by summing as shown in the Figure 7. The output (y) can be written as

$$\begin{aligned} Y &= x_1 w_1 + x_2 w_2 \\ &= s_1(\alpha_{11} w_1 + \alpha_{12} w_2) + s_2(\alpha_{21} w_1 + \alpha_{22} w_2) \end{aligned} \tag{2}$$

where

$$\begin{aligned} x_1 &= s_1 \alpha_{11} + s_2 \alpha_{21} \quad \text{for antenna 1} \\ x_2 &= s_1 \alpha_{12} + s_2 \alpha_{22} \quad \text{for antenna 2} \end{aligned}$$

α_{ij} = Fading effects from mobile i to element (antenna) j

$$\begin{aligned} s_i &= \text{signal from mobile } i \\ w_1 &= \text{complex weight for mobile } i. \end{aligned}$$

The output is forced to be the same as the signal from the desired mobile i.e., $y = S_1$ i.e.,

$$\alpha_{11} w_1 + \alpha_{12} w_2 = 1. \tag{3}$$

And

$$\alpha_{21}w_1 + \alpha_{22}w_2 = 0. \tag{4}$$

This analysis shows that we can use weighting to completely remove interfering co-channel signals [31]. In practical cases, the optimum weights would have to be estimated in presence of noise, so an interferer is not removed completely.

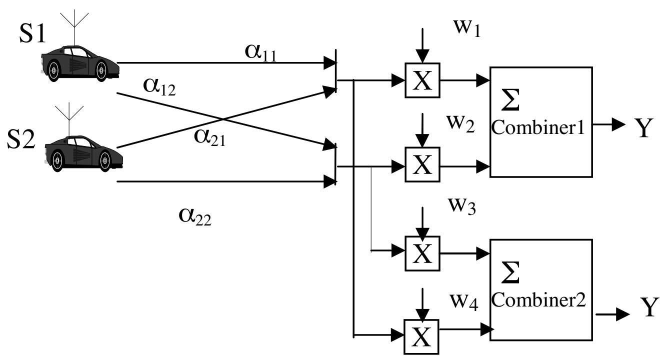

Figure 8. Dual combining for two-channel SDMA.

Instead, the weights are chosen to maximize the signal-to-noise ratio (SINR). A second combiner has been added with input from same antenna elements (Figure 8). The second combiner weights are chosen to eliminate the signal from mobile 1 and retain the signal from mobile 2. This idea can be explored to have a new multiple access schemes termed as Space Division Multiple Access (SDMA). Using these scheme two mobiles in the same cell can communicate on the same frequency/time/code. Thus SDMA will offer the potential for greatly increasing system capacity in future mobile systems [32]. Figure 8 shows a pictorial representation of the idea described in Equation (2). We have generalized the Equation (2) in matrix form as given below.

$$AW = B \begin{pmatrix} \alpha_{11} & \alpha_{11} & \alpha_{11} & \alpha_{11} & \dots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \dots & \alpha_{2n} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \dots & \alpha_{2n} \\ \vdots & \vdots & \vdots & \vdots & & \vdots \\ \alpha_{m1} & \alpha_{m2} & \alpha_{m3} & \alpha_{m4} & \dots & \alpha_{mn} \end{pmatrix} \tag{5}$$

where A is the free space loss matrix and B is the column matrix whose all elements are zero except the element corresponding to desired signal. When S1 is the desired signal then 1st element of matrix B will be 1 and the rest are zero. Similarly for $S2$, the desired signal then 2nd element will be one and rests are zero and so on. In this work we have considered 8 mobile units and 8 antennas at the base station. We calculated the weights and multiplied with the incoming signal and then combined to get the desired signal. We studied this using a MATLAB program and at the output we got the input signal. In order to substantiate our present model, we consider the cell size of 2 km radius and the transmitting power of 1000 mw respectively.

Here we have studied a MIMO system on MATLAB based simulation technique and revealed that MIMO system is better than a SISO system. First we compared the fading loses with distances (d) for both SISO and MIMO system as depicted in Figure 8. For unity gain the free space loss (α) expressed in dB is given by $(32.4 + 20 * \log(d) + 20 * \log(f))$ [32] where d is the distance in kilometer and f is the carrier frequency in MHz. Here we have considered at the 900 MHz frequency band, however it can be calculated for 2.4 GHz also. However for different areas this equation will deviate from the present form.

The signal matrix $S1 = [30\ 31.3\ 28.3\ 27.9\ 29\ 30.6\ 29.2\ 30.4]$. We have got the free space loss matrix as below for different distance within 1 km.

$$A = \begin{pmatrix} 167.4699 & 152.8176 & 156.0083 & 114.2330 & 154.3382 & 150.9804 & 143.8455 & 143.6672 \\ 162.7966 & 121.7448 & 117.1473 & 161.9032 & 163.0880 & 160.0752 & 164.2436 & 148.7909 \\ 144.7796 & 148.6006 & 161.5062 & 132.8156 & 164.3251 & 153.1863 & 161.9412 & 168.3450 \\ 148.1534 & 162.1764 & 159.8220 & 160.7740 & 70.8871 & 159.9595 & 167.3215 & 158.6689 \\ 163.5536 & 53.2630 & 163.9088 & 159.5788 & 133.9822 & 155.7277 & 138.0508 & 156.4202 \\ 111.5833 & 157.8133 & 150.9115 & 134.8555 & 113.4425 & 116.5845 & 145.0267 & 167.2971 \\ 168.0587 & 156.6763 & 168.2171 & 161.0718 & 140.0435 & 164.2289 & 167.0933 & 127.4585 \\ 160.9344 & 144.1839 & 159.7465 & 153.0801 & 166.8408 & 140.0485 & 160.1423 & 146.4128 \end{pmatrix}$$

The corresponding distance matrix d is given by

$$R = \begin{pmatrix} 0.9523 & 0.4577 & 0.5369 & 0.0665 & 0.4939 & 0.4175 & 0.2923 & 0.2897 \\ 0.7538 & 0.0968 & 0.0769 & 0.7209 & 0.7649 & 0.6579 & 0.8104 & 0.3742 \\ 0.3062 & 0.3707 & 0.7067 & 0.1684 & 0.8137 & 0.4662 & 0.7223 & 0.9949 \\ 0.3625 & 0.7308 & 0.6497 & 0.6813 & 0.0076 & 0.6541 & 0.9452 & 0.6133 \\ 0.7829 & 0.0032 & 0.7970 & 0.6418 & 0.1785 & 0.5294 & 0.2187 & 0.5481 \\ 0.0582 & 0.5876 & 0.4161 & 0.1864 & 0.0639 & 0.0748 & 0.3100 & 0.9441 \\ 0.9807 & 0.5551 & 0.9885 & 0.6916 & 0.2417 & 0.8098 & 0.9345 & 0.1288 \\ 0.6868 & 0.2972 & 0.6472 & 0.4638 & 0.9228 & 0.2417 & 0.6602 & 0.3323 \end{pmatrix}$$

The weight (Wi's) matrices for different desired signals (Si's) are calculated and at the output we got the values of (Y's)

$$W1 = \begin{pmatrix} 0.0169 \\ 0.0150 \\ -0.0054 \\ 0.0033 \\ 0.0008 \\ 0.0110 \\ -0.0483 \\ 0.0104 \end{pmatrix} \quad Y1 = 30\,\mathrm{dB}, \quad W2 = \begin{pmatrix} -0.0035 \\ 0.0087 \\ -0.0195 \\ 0.0176 \\ 0.0057 \\ 0.0170 \\ -0.0284 \\ 0.0064 \end{pmatrix} \quad Y2 = 31.3\,\mathrm{dB}$$

$$W3 = \begin{pmatrix} -0.0184 \\ -0.0223 \\ 0.0091 \\ -0.0405 \\ -0.0004 \\ -0.0009 \\ 0.0762 \\ -0.0073 \end{pmatrix} \quad Y3 = 28.3\,\mathrm{dB}, \quad W4 = \begin{pmatrix} 0.0207 \\ -0.0151 \\ -0.0019 \\ -0.0287 \\ -0.0190 \\ -0.0273 \\ 0.0652 \\ 0.0008 \end{pmatrix} \quad Y4 = 27.9\,\mathrm{dB}$$

$$W5 = \begin{pmatrix} -0.0017 \\ -0.0034 \\ 0.0055 \\ 0.0090 \\ 0.0009 \\ 0.0080 \\ -0.0214 \\ 0.0044 \end{pmatrix} \quad Y5 = 29.0\,\mathrm{dB}, \quad W6 = \begin{pmatrix} -0.0215 \\ 0.0277 \\ -0.0020 \\ 0.0458 \\ 0.0122 \\ 0.0288 \\ -0.0951 \\ 0.0131 \end{pmatrix} \quad Y6 = 30.6\,\mathrm{dB}$$

$$W7 = \begin{pmatrix} -0.0332 \\ 0.0192 \\ 0.0091 \\ 0.0354 \\ 0.0134 \\ 0.0465 \\ -0.0657 \\ -0.0173 \end{pmatrix} \quad Y7 = 29.2\,\mathrm{dB}, \quad W8 = \begin{pmatrix} 0.0408 \\ -0.0261 \\ 0.0052 \\ -0.0363 \\ -0.0122 \\ -0.0793 \\ 0.1066 \\ -0.0069 \end{pmatrix} \quad Y8 = 30.4\,\mathrm{dB}$$

The signal matrix $S2 = [30.7\ 31.0\ 29.2\ 28.9\ 29.7\ 30.2\ 28.9\ 30.8]$. We have got the free space loss matrix as below for different distance within

1 km.

$$A = \begin{pmatrix} 143.8455 & 120.5731 & 154.8538 & 165.9849 & 158.7437 & 107.0354 & 167.4625 & 132.8944 \\ 164.6409 & 158.6071 & 165.1339 & 125.0383 & 159.8082 & 125.1592 & 153.4921 & 160.8280 \\ 128.1446 & 153.0939 & 115.6167 & 157.5953 & 157.0639 & 141.1386 & 139.7797 & 85.6867 \\ 149.3444 & 162.8880 & 157.3858 & 150.5223 & 135.8253 & 155.0661 & 161.6921 & 165.6025 \\ 162.4745 & 168.3443 & 165.5878 & 154.0093 & 166.4140 & 90.5195 & 159.4215 & 167.2965 \\ 104.4567 & 143.3897 & 160.6537 & 157.7653 & 113.7712 & 165.8733 & 154.0954 & 166.1504 \\ 163.0195 & 159.9948 & 167.8692 & 133.1423 & 128.5408 & 162.8327 & 145.2307 & 153.0582 \\ 146.8384 & 75.5735 & 146.5037 & 140.4662 & 168.3288 & 166.4640 & 147.4382 & 142.8535 \end{pmatrix}$$

The corresponding distance matrix d is given by

$$R = \begin{pmatrix} 0.2923 & 0.0913 & 0.5068 & 0.8841 & 0.6156 & 0.0464 & 0.9519 & 0.1690 \\ 0.8267 & 0.6114 & 0.8473 & 0.1141 & 0.6492 & 0.1148 & 0.4734 & 0.6832 \\ 0.1333 & 0.4641 & 0.0713 & 0.5812 & 0.5660 & 0.2553 & 0.2385 & 0.0160 \\ 0.3847 & 0.7573 & 0.5752 & 0.4081 & 0.1957 & 0.5122 & 0.7133 & 0.8674 \\ 0.7418 & 0.9948 & 0.8667 & 0.4858 & 0.9033 & 0.0203 & 0.6368 & 0.9441 \\ 0.0408 & 0.2857 & 0.6773 & 0.5862 & 0.0650 & 0.8792 & 0.4879 & 0.8915 \\ 0.7623 & 0.6553 & 0.9715 & 0.1711 & 0.1360 & 0.7552 & 0.3132 & 0.4633 \\ 0.3394 & 0.0096 & 0.3338 & 0.2468 & 0.9941 & 0.9056 & 0.3498 & 0.2781 \end{pmatrix}$$

The weight (Wi's) matrices for different desired signals (Si's) are calculated and at the output we got the values of (Y's)

$$W1 = \begin{pmatrix} 0.0021 \\ -0.0074 \\ 0.0130 \\ -0.0052 \\ -0.0128 \\ -0.0065 \\ 0.0334 \\ -0.0183 \end{pmatrix} \quad Y1 = 30.7\,\text{dB}, \quad W2 = \begin{pmatrix} -0.0251 \\ 0.0081 \\ 0.0154 \\ -0.0463 \\ 0.0182 \\ 0.0020 \\ 0.0389 \\ -0.0126 \end{pmatrix} \quad Y2 = 31\,\text{dB}$$

$$W3 = \begin{pmatrix} -0.0053 \\ 0.0069 \\ -0.0021 \\ 0.0027 \\ 0.0092 \\ 0.0038 \\ -0.0067 \\ -0.0070 \end{pmatrix} \quad Y3 = 29.2\,\text{dB}, \quad W4 = \begin{pmatrix} 0.0216 \\ -0.0004 \\ -0.0579 \\ -0.0028 \\ -0.0197 \\ 0.0022 \\ 0.0391 \\ 0.0205 \end{pmatrix} \quad Y4 = 28.9\,\text{dB}$$

$$W5 = \begin{pmatrix} 0.0078 \\ 0.0010 \\ -0.0042 \\ 0.0299 \\ 0.0057 \\ -0.0078 \\ -0.0485 \\ 0.0188 \end{pmatrix} \quad Y5 = 29.7\,\text{dB}, \quad W6 = \begin{pmatrix} -0.0242 \\ 0.0031 \\ 0.0209 \\ -0.0005 \\ 0.0082 \\ 0.0021 \\ -0.0088 \\ -0.0008 \end{pmatrix} \quad Y6 = 30.2\,\text{dB}$$

$$W7 = \begin{pmatrix} 0.0176 \\ -0.0024 \\ 0.0250 \\ 0.0156 \\ -0.0140 \\ 0.0015 \\ -0.0303 \\ -0.0118 \end{pmatrix} \quad Y7 = 28.9\,\text{dB}, \quad W8 = \begin{pmatrix} 0.0044 \\ -0.0081 \\ -0.0073 \\ 0.0075 \\ 0.0076 \\ 0.0042 \\ -0.0166 \\ 0.0101 \end{pmatrix} \quad Y8 = 30.8\,\text{dB}$$

The signal matrix

$$S3 = [30.1\ 29.8\ 30.2\ 28.3\ 28.7\ 30.4\ 28.2\ 30]$$

We have got the free space loss matrix as below for different distance within 1 km.

$$A = \begin{pmatrix} 120.9284 & 139.9497 & 166.3772 & 145.9228 & 157.3001 & 134.7069 & 162.3692 & 124.6192 \\ 149.2927 & 165.4864 & 165.3635 & 164.4633 & 140.3746 & 166.2870 & 158.3684 & 129.0872 \\ 131.9583 & 165.9628 & 168.0149 & 158.2753 & 148.1150 & 139.1761 & 152.4658 & 159.6188 \\ 140.3357 & 153.2627 & 154.4820 & 116.6332 & 163.1320 & 106.5886 & 132.4253 & 163.4067 \\ 137.0770 & 140.8636 & 149.9475 & 153.7972 & 154.9532 & 159.0413 & 159.0653 & 168.2704 \\ 147.9716 & 142.7002 & 160.6792 & 154.9324 & 142.7630 & 157.5133 & 164.5479 & 167.2413 \\ 152.2236 & 151.2511 & 168.3717 & 158.6965 & 167.2967 & 166.6074 & 164.3560 & 161.0161 \\ 144.9372 & 156.7870 & 159.4206 & 163.1967 & 110.0840 & 125.1621 & 165.1030 & 133.2872 \end{pmatrix}$$

The corresponding distance matrix d is given by

$$R = \begin{pmatrix} 0.0929 & 0.2405 & 0.9016 & 0.3242 & 0.5727 & 0.1851 & 0.7379 & 0.1118 \\ 0.3838 & 0.8624 & 0.8571 & 0.8194 & 0.2457 & 0.8976 & 0.6041 & 0.1397 \\ 0.1613 & 0.8832 & 0.9786 & 0.6013 & 0.3618 & 0.2314 & 0.4497 & 0.6431 \\ 0.2452 & 0.4680 & 0.4974 & 0.0750 & 0.7666 & 0.0454 & 0.1651 & 0.7772 \\ 0.2083 & 0.2518 & 0.3965 & 0.4807 & 0.5093 & 0.6248 & 0.6255 & 0.9912 \\ 0.3592 & 0.2760 & 0.6781 & 0.5088 & 0.2769 & 0.5788 & 0.8228 & 0.9415 \\ 0.4443 & 0.4232 & 0.9962 & 0.6141 & 0.9441 & 0.9121 & 0.8150 & 0.6896 \\ 0.3087 & 0.5582 & 0.6368 & 0.7691 & 0.0540 & 0.1148 & 0.8460 & 0.1724 \end{pmatrix}$$

The weight (Wi's) matrices for different desired signals (Si's) are calculated and at the output we got the values of (Y's)

$$W1 = \begin{pmatrix} -0.0227 \\ 0.0109 \\ 0.0048 \\ -0.0341 \\ 0.0001 \\ 0.0062 \\ 0.0398 \\ -0.0072 \end{pmatrix} \quad Y1 = 30.1\,\mathrm{dB}, \quad W2 = \begin{pmatrix} -0.0137 \\ 0.0531 \\ -0.0202 \\ -0.0640 \\ -0.0155 \\ 0.0357 \\ 0.0358 \\ -0.0101 \end{pmatrix} \quad Y2 = 29.8\,\mathrm{dB}$$

$$W3 = \begin{pmatrix} -0.0198 \\ -0.0120 \\ 0.0380 \\ 0.0383 \\ -0.0053 \\ -0.0049 \\ -0.0496 \\ 0.0136 \end{pmatrix} \quad Y3 = 30.2\,\mathrm{dB}, \quad W4 = \begin{pmatrix} 0.0043 \\ 0.0243 \\ -0.0146 \\ -0.0362 \\ 0.0010 \\ 0.0005 \\ 0.0217 \\ 0.0004 \end{pmatrix} \quad Y4 = 28.3\,\mathrm{dB}$$

$$W5 = \begin{pmatrix} -0.0197 \\ 0.0438 \\ -0.0879 \\ -0.0114 \\ 0.0175 \\ 0.0024 \\ 0.0566 \\ 0.0021 \end{pmatrix} \quad Y5 = 28.7\,\mathrm{dB}, \quad W6 = \begin{pmatrix} -0.0227 \\ 0.0091 \\ 0.0542 \\ -0.0927 \\ -0.0528 \\ 0.0425 \\ 0.0362 \\ 0.0216 \end{pmatrix} \quad Y6 = 30.4\,\mathrm{dB}$$

$$W7 = \begin{pmatrix} 0.0676 \\ -0.1054 \\ 0.0398 \\ 0.1464 \\ 0.0450 \\ -0.0499 \\ -0.1238 \\ -0.0134 \end{pmatrix} \quad Y7 = 28.2\,\mathrm{dB}, \quad W8 = \begin{pmatrix} 0.0246 \\ -0.0163 \\ -0.0178 \\ 0.0462 \\ 0.0098 \\ -0.0313 \\ -0.0063 \\ -0.0063 \end{pmatrix} \quad Y8 = 30\,\mathrm{dB}$$

Figure 9 represents the variation of Signal Strength with the distance. For MIMO system Signal level is almost constant with distance. Figure 10 represents the variation of Carrier to interference (C/I) ratio with the number of interfering signals. For SISO it is not possible to establish a connection even with the presence of another co-channel interfering signal only. This is because the C/I value goes below 18 dB which is the minimum level for acceptable

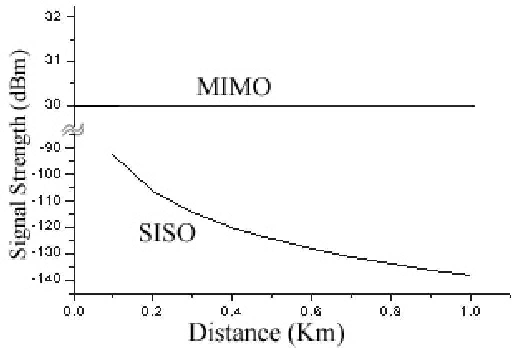

Figure 9. Comparison of Signal strength with distance.

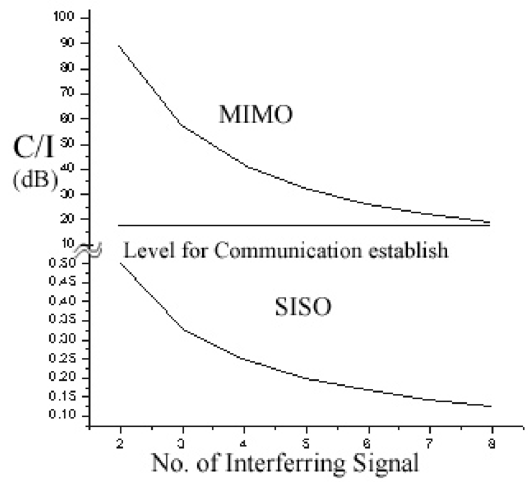

Figure 10. Comparison of C/I with no. of interfering signal.

voice quality [33]. However, for MIMO system it is evident from the Figure 10, that it is possible to setup communication link with 8 interfering co-channel signals for systems with 8 antenna elements.

Variation of C/I with distance for MIMO and SISO systems are depicted in Figure 11. It is also based on matlab simulation systems. Simulated results show that C/I level remain constant for both SISO and MIMO systems but C/I levels are not the same in both the cases. For SISO the level is much below the threshold level of 18 dB [33]. Here we have considered that the co-channel interfering signal will vary with distance similar to signal loss and hence ratio will remain constant.

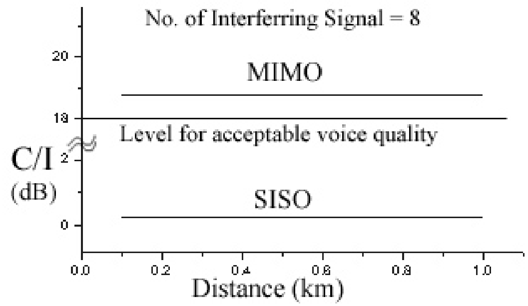

Figure 11. Comparison of C/I with distance.

6. CONCLUSION

From the above studies, we can say that the combined application of multiple-antenna technology and CDMA (MIMO-CDMA) technique will be very good solution for multipath effects. This combined technique has both the advantages of CDMA and MIMO systems. Below the jamming margin CDMA alone works up to satisfactory level but above jamming margin CDMA along with MIMO system may be a better proposition. We have practically studied the CDMA system and also performed computer simulation on MIMO system. From both the practical experiment and simulation results we propose the combined system which will work satisfactorily to support wireless mobile communication with full mobility in noisy environment, thereby establishing strong situation for any-time any-where communication. Again here we have studied the MIMO system on computer simulation, the practical result may vary from this simulation result.

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