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# Transmitter Design for LMS-MIMO-MCCDMA Systems with Pilot Channel Estimates and Zero Forcing Equalizer

S.M. Bahri, F.T. Bendimerad

***Abstract*****—**We propose a downlink multiple-input multiple-output (MIMO) multi-carrier code division multiple access (MC-CDMA) system with adaptive beamforming algorithm for smart antennas. The algorithm used in this paper is based on the Least Mean Square (LMS), with pilot channel estimation (PCE) and the zero forcing equalizer (ZFE) in the receiver, requiring reference signal and no knowledge channel. MC-CDMA is studied in a multiple antenna context in order to efficiently exploit robustness against multipath effects and multi-user flexibility of MC-CDMA and channel diversity offered by MIMO systems for radio mobile channels. Computer simulations, considering multi-path Rayleigh Fading Channel, interference inter symbol and interference are presented to verify the performance. Simulation results show that the scheme achieves good performance in a multi-user system.

***Keywords*****—**Adaptive Beamforming, LMS Algorithm, MC-CDMA, MIMO System, Smart Antenna.

## I. INTRODUCTION

IN recent years, adaptive antennas have been considered to be one of the most expected technologies, which are adapted to the demanding high-bit-rate or high-quality in broadband commercial wireless communication such as mobile internet or multi-media services [1]-[2]. Currently, MIMO systems, where array antennas are equipped at both the transmitter and receiver, have emerged as significant break-through in wireless communication systems. It has been improved to provide high-bit-rate transmission and increase system performance over multipath fading channels and interference [3]-[4].

In this paper, we propose a new MIMO scheme, namely LMS-MIMO-MCCDMA. The LMS-MIMO-MCCDMA is intended to use the conventional LMS technology for the problem solving [5] [6]. Here MC-CDMA and MIMO techniques are combined in order to increase the bandwidth efficiency while keeping robustness against channel selectivity. On the one hand MC-CDMA efficiently combines OFDM and CDMA techniques providing high spectral efficiency, good robustness against multipath effects, multiple access flexibility and low multi-user interference [1]. On the other hand, MIMO techniques offer efficient schemes to improve capacity thanks to spatial diversity.

A MIMO multi-user generalized system is investigated where the channel is assumed to be a multipath Rayleigh fading channel. Each user communicates through more than one transmitting antenna, each having its own spreading code where no orthogonality between codes is assumed and no pre-processing is required to combat the ISI.

Our proposed scheme is based on the beamforming approach to excluding interference emanating from a direction other than that of the desired signal. For MIMO system, there are a total of three different types of interference, which are Co-cannel interference (CCI), Interference Inter Symbol ISI and Multiple antenna interference (MAI). The MAI defined here is the interference from different transmits antennas in the MIMO system. We are targeting on the three interferences sources and aiming to provide a solution to the problems of resolving all ISI and MAI and canceling CCI effectively by employing LMS algorithm by adjusting both transmitter and receiver weights in the MIMO system.

Coherent MIMO MCCDMA requires channel state information at the receiver, when the channel is not known. Thus, pilot symbols are often periodically inserted into the transmitted signal to support channel estimation (CE). It is performed using the Zero forcing (ZF) equalizer on pilots only. The computer simulation with the AWGN, interference and multi-path Raleigh Fading channel are presented to verify its performance [6].

## II. PROPOSED LMS MIMO MCCDMA CONFIGURATION

Fig. 1 represents the block diagram of the downlink MIMO MC-CDMA system with LMS Algorithm. At the transmitter, the data symbols $\mathrm{U} = [\mathrm{u}_1, \ldots \mathrm{u}_\mathrm{i}, \ldots \mathrm{u}_{\mathrm{N}_\mathrm{u}}]^\mathrm{T}$ of the $\mathrm{N}_\mathrm{u}$ users are multiplied by their specific orthogonal Walsh-Hadamard spreading code $\mathrm{C} = [\mathrm{c}_1, \ldots \mathrm{c}_\mathrm{i}, \ldots \mathrm{c}_{\mathrm{N}_\mathrm{u}}]^\mathrm{T}$ where $c_i$ is the $\mathrm{i}^{\mathrm{th}}$ chip, and $[.]^\mathrm{T}$ denotes matrix transposition; the spread vector is simply expressed as:

$$S = C \cdot X \tag{1}$$

The result signals are summed and multiplexed together with pilot symbols where are inserted at the beginning of each frame. These result symbols S' are next QAM modulated and serial-to-parallel converted to $N_c$ *data* symbols per user in an

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Bahri Sidi Mohammed is with the Chlef University, Chlef, Algeria
e-mail: sm_bahri@yahoo.fr

OFDM symbol using the IFFT operator. In order to combat the effect of multipath, the cyclic prefix is added to an OFDM symbol after parallel to serial conversion, the cyclic prefix maintains orthogonality between the subcarriers in a multipath channel. Each data symbol is then transmitted by a MIMO beamforming combining system with $M_t$ transmit antennas and Mr receive antennas. Assuming a narrowband channel, the combining vector at the transmitter is denoted as Z and the receiver is denoted by Y while the additive white Gaussian noise (AWGN) at the receiver is denoted as N with zero mean and power $\sigma_n^2$. The uncorrelated Rayleigh channel assumption implies that the entries of H are distributed as (O, 1). Let *hij* be the coefficient of H representing the link between antenna *i* and antenna *j*.

In order to detect the transmitted signal at the receiver we multiplied the transmitted and the received signal by transmitted weights $W_T$ and received weights $W_R$ respectively, the received signal is given as

$$Y = W_R \cdot H \cdot W_T \cdot Z + W_T \cdot N \tag{2}$$

The calculation of the weights is explained in the section III. The result symbols are shortened by the GI and OFDM demodulated by an FFT operation of the received symbols and brings them back to the frequency domain. Then, the received pilot symbols are separated from the received data symbols, and fed into the CE (Channel Estimation). The CE only uses pilot symbols to estimate the CSI (channel symbol Interference) using ZFE (Zero Forcing Equalizer) given as

$$Z_{ZF}(k) = \frac{1}{G(k)} \tag{3}$$

Where $G(k)$ is the multipath channel estimation. The $N_c$ results sequence are then, parallel to serial converted and QAM demodulated. The pilots symbols are then demultiplexing from the demodulated signal and the output of the pilot DEMUX is dispreading with Walsh code $c_1$, representing the code of the desired signal.

## III. LMS MIMO algorithm

Fig. 3. is the model of MIMO system considered in this paper. The number of antennas of the transmitter array and the receiver array are $M_t$ and $M_r$ respectively. The received signal is expressed as in equation (4) [9].

$$x(t) = H \cdot W_T \cdot z(t) + \sum_{l=1}^{L} H_l \cdot W_{Tl} \cdot z_l(t) + n(t) \tag{4}$$

The received signal $x(t)$, the channel matrix *( H* ), and transmission weight vector ($W_T$) are defined as the following vector equations

$$x(t) = [x_1(t), x_2(t), \ldots., x_{Mt}(t)]^T \tag{5}$$

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdot & \cdot & \cdot & h_{1Mr} \\ h_{21} & h_{22} & & & & h_{2Mr} \\ \cdot & \cdot & \cdot & & & \cdot \\ \cdot & \cdot & & \cdot & & \cdot \\ \cdot & \cdot & & & \cdot & \cdot \\ h_{Mt1} & h_{Mt2} & \cdot & \cdot & \cdot & h_{MtMr} \end{bmatrix} \tag{6}$$

$$W_T = [W_{T1}, W_{T2}, \ldots, W_{TMr}]^T \tag{7}$$

Where, $h_{nm}$ is the channel response between *m-th* transmitter antenna and *n-th* receiver antenna. And, z(t) is source data signal, n(t) is AWGN (additive white Gaussian noise). L is the number of interferences. $H_l$, is the channel matrix of the *1-th* interference signal similarly composed of equation (6) and $W_{Tl}$ is the transmitter weight vector of *l-th* interference composed of the same manner as equation (7). And, in this paper, the symbols, $[.]^*$, $[.]^T$, and, $[.]^H$, are conjugate, transpose and, conjugate transpose operators, respectively.

### A. Receiver Antenna Weight Vector

Basically, the algorithm is based on the conventional LMS algorithm. Considering a simplified MIMO model in Fig. 3. The received signal is as following

$$x(t) = H \cdot W_T \cdot z(t) + n(t) \tag{8}$$

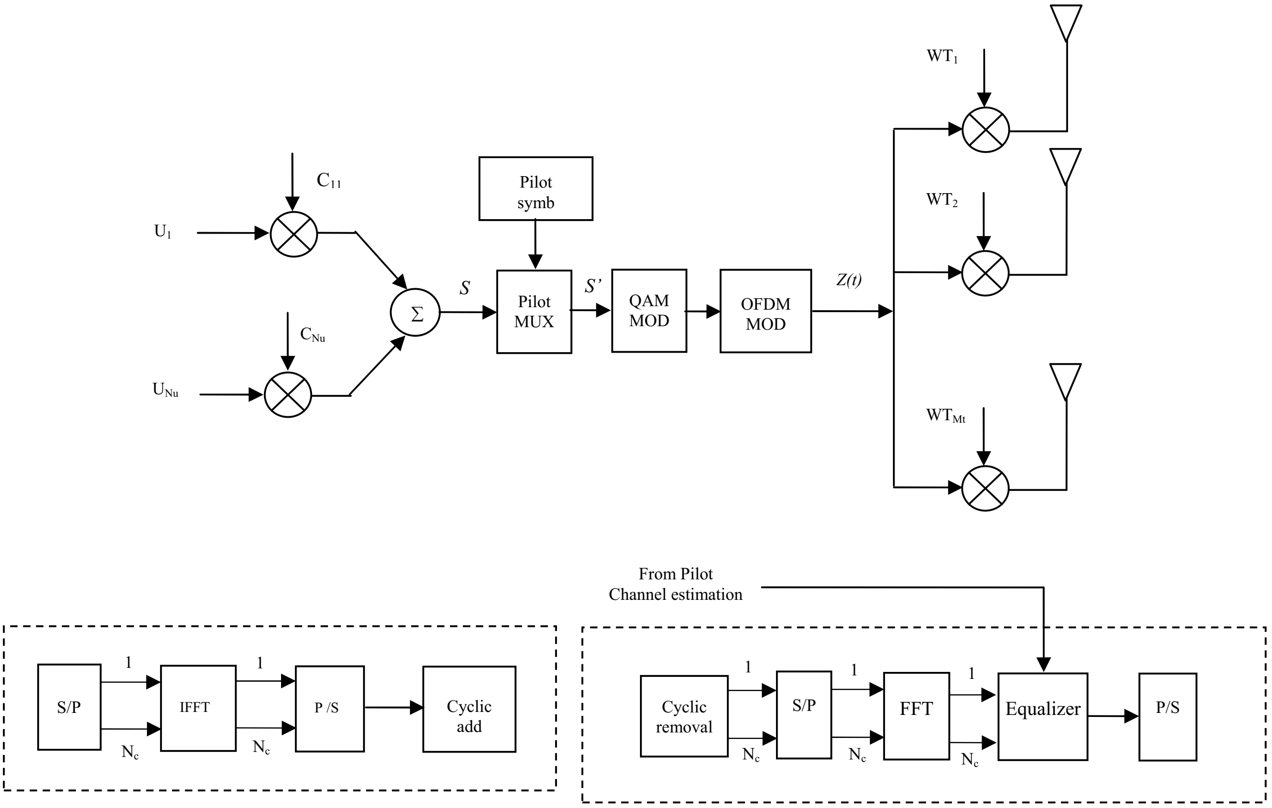
By the receiver adaptive beamforming, the output signal is

$$y(t) = W_R^H \cdot H \cdot W_T \cdot z(t) \tag{9}$$

Here the noise component is omitted for the simplicity of calculation. The error signal of the k-th sample is defined by following

$$\varepsilon_k = d_k - y(k) = d_k - W_R^H(k) \cdot H \cdot W_T(k) \cdot z(k) \tag{10}$$

Here, $d_k$ is reference signal defined by projecting the output signal y(k) to the nearest signal constellation. Now, the



OFDM Modulation

OFDM démodulation

Fig. 1 LMS-MIMO-MCCDMA Transmitter

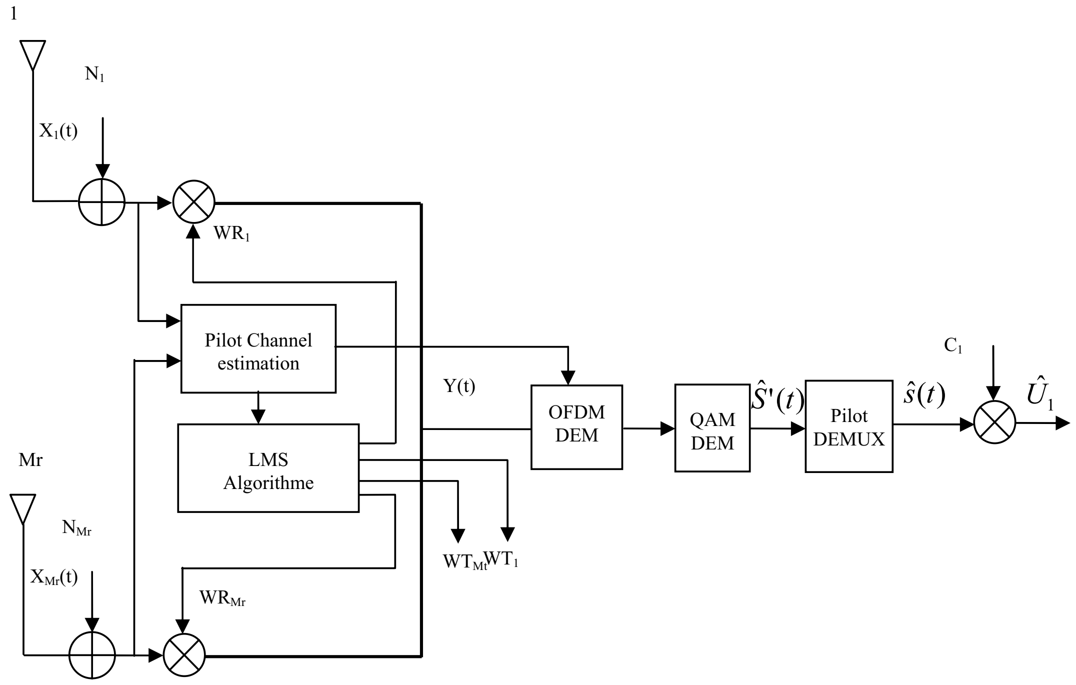


Fig. 2 LMS-MIMO-MCCDMA receiver

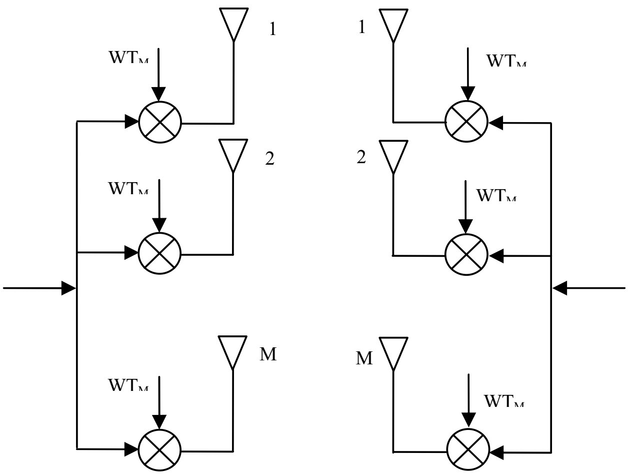


Fig. 3 A MIMO system model

gradient is obtained by differentiating the square error by the receiver antenna weight,

$$\frac{d\varepsilon_k^2}{dW_R^*(k)} = -2\varepsilon_k \cdot x(k) \tag{11}$$

Consequently, the weight of the receiver antenna is upgraded by following [10]

$$W_R(k+1) = W_R(k) - 2\mu\varepsilon_k x(k) \tag{12}$$

### *B. Transmitter Antenna Weight Vector*

Differentiating the square error by the transmitter antenna weight is,

$$\frac{d\varepsilon_k^2}{dW_T(k)} = -2\varepsilon_k \frac{d\varepsilon_k}{dW_T(k)} \tag{13}$$

Here, $\varepsilon_k = d_k - W_R^H(k) \cdot H \cdot W_T(k) \cdot z(k)$, the error signal is differentiated as following

$$\frac{d\varepsilon_k}{dW_T(k)} = -z(k) \cdot H^T \cdot W_R^*(k) \tag{14}$$

Therefore the transmitter antenna weight vector is,

$$W_T(k+1) = W_T(k) - 2\mu\varepsilon_k z(k) H^T W_R^*(k) \tag{15}$$

Multiplying the transmitter weight by the equation (8)

$$x(k) W_T^H(k) = H \cdot z(k) \cdot W_T(k) \cdot W_T^H(k) \tag{16}$$

Applying vector inversion to the equation (16), the following equation is obtained

$$H \cdot z(k) = x(k) w_T^H(k) \tag{17}$$

Taking transpose operation and multiplying by the receiver weight vector to the equation (17),

$$z(k) \cdot H^T \cdot W_R^*(k) = y(k) \cdot W_T^*(k) \tag{18}$$

Finally, the transmitter antenna weight vector of equation (15) is modified as following [10]

$$W_T(k+1) = W_T(k) - 2\mu \cdot \varepsilon_k \cdot y(k) \cdot W_T^*(k) \tag{19}$$

## IV. SIMULATIONS

This section presents simulation results for a downlink MIMO MC-CDMA system applying WH spreading and the LMS beamforming Algorithm with five transmit and five receive antennas, spaced d= 0.5 wavelengths apart.

In this section, we provide some simulation results of our proposed MIMO Beamforming, which we briefly call, LMS-MIMO-MCCDMA and compare its performance to an STBC-MIMO-MCCDMA, the most important difference is that the proposed hybrid LMS-MIMO-MCCDMA technique is capable of performing co-channel interference and Multiple antenna interference cancellation and inter-symbol interference (ISI) equalization. The performance is also evaluated over number of antennas at transmitter and receiver.

### *A.* Simulation Parameters

At a carrier frequency of fc = 5.2 GHz, the MC-CDMA systems transmits 32 OFDM symbols per frame divided into 768 useful data subcarriers over a bandwidth of 46.2 MHz resulting in a subcarrier spacing of  f = 60 kHz. The size of the fast Fourier transforms in the OFDM modulation and demodulation is 1024. The guard interval TGI is set to 256 Tspl, where the sampling duration is Tspl = 1/61.44 MHz =16.276 ns.

The system uses a modulator of 16-QAM symbols and WH spreading codes of length L = 32. A 128 pilot symbols are inserted into the frame.

We consider the received desired signal arrive at angle 45° with 16 multi-path Rayleigh fading channel and interferences at 135° and 300°.

We plot the simulation results in terms of bit error ratios (BER) versus signal to noise power ratio (SNR).We consider for all simulation the channel coefficients for individual users $h_{ij}(k)$ are generated using uncorrelated Rayleigh channel distributed as (O, 1). In order to apply LMS algorithm we assume that the channel is stationary over each block of 768 symbols and is different from block to block. Also, for simplicity we assume that the transmitted data is known.

The initial transmit weight vector is used to calculate the optimal receive and transmit weight vectors $\mathbf{w}_R^{opt}$ , $\mathbf{w}_T^{opt}$ alternately by using the iterative update weight LMS algorithm. The updated $\mathbf{w}_T^{opt}$ is used in the transmitter as a fixed weight vector and updated $\mathbf{w}_R^{opt}$ is used in the receiver to detect the received signal X(*t*) at the receiver. Although the received weight vectors are estimated based on an iterative update LMS algorithm to overcome the interferences, only the error between the reference and the output signal obtained from the received signal Y(*t*) is less than all the rest. It is clear that the DOA of both the transmitter and the receiver antennas sides are exploited to suppress interferences for the received signal X(*t*).

In our simulations, 3 iterations are sufficient to obtain the best performance.

As shown in the Fig. 4., the BER performance of the proposed system is much better than STBC-MCCDMA system with RMSE algorithm [7]. However, at high SNR, the degradation gets down above 5 dB for BER ≤ $10^{-3}$.

Fig. 5 shows the system performance in term of the beampattern of the LMS-MCCDMA algorithm in the presence of two interferences. It is noted that patterns main lobes exactly oriented toward the direction of the desired user (45°) and nulls toward the interferers (135°, 300°).

Fig. 6 shows that as a number of antennas at transmitter and receiver increases, the performance also improves. Therefore, the two receive antenna system does not have sufficient degree of freedom to fight multipath and interference. However, the results of link level performance show clearly that 6 transmitter and receiver antennas provide significant result. The performance improvement of our proposed scheme belongs to the number of transmitter and receiver antennas because the DOA of both the transmitter and receiver antennas is used to suppress the interferences of the signal X(t).

From the Fig. 7., it can be seen that, as the number of interferences increase as the performance of the system is less than that obtained without interferences.

For the multipath environment used in our simulations, it is shown that the 5x5 system can support properly four interferences with 16 multipaths and AWGN, the desired signal is well separated from the rest of the signals. In contrast, for tree interferences with 16 multipaths, the system causes performance improvement (around 4dB at $10^{-2}$ of BER ). Therefore, the four receive antenna system does not have sufficient degree of freedom for nulling; part of array gain has been spared to suppress each of interferences leading to reduced performance. However, the results of the link level performance show clearly that the proposed LMS-MIMO-MCCDM provides significant achievement while a failure occurs to a normal MIMO detection without the adaptive array to cancel the interferences.

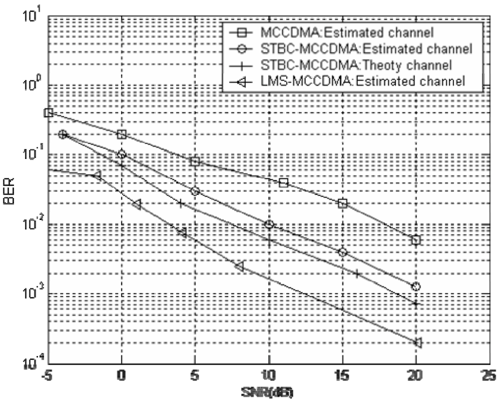


Fig. 4 Performance comparison between LMS-MIMO-MCCDMA system and STBC-MIMO-MCCDMA system (For MIMO $M_t$=$M_r$=3)

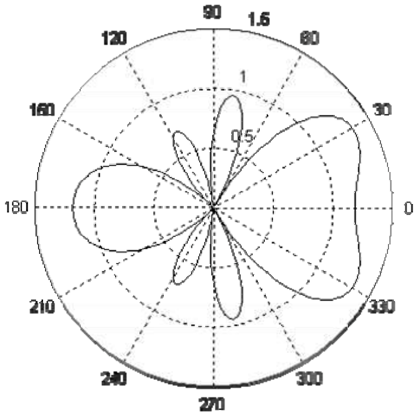


Fig. 5 Beampattern response for two interferences (at 135° and 300°) and desired signal at 45°

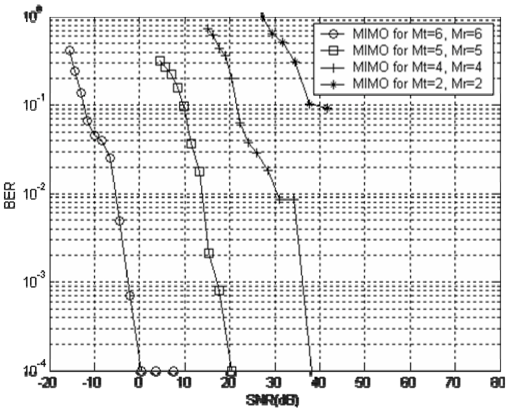


Fig. 6 LMS-MIMO-MCCDMA performance in the AWGN with multi-path Rayleigh Fading channel (with the variation of the transmitter and receiver antenna elements).

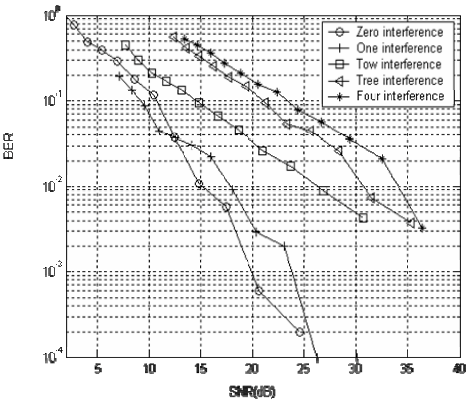


Fig. 7 LMS-MIMO-MCCDMA performance in the AWGN with multi-path Rayleigh Fading channel (With increase number of interferences)

## V. CONCLUSION

In this paper, we have proposed a MCCDMA MIMO adaptive beamforming LMS algorithm for smart antennas. The performance of the proposed system is much better than STBC-MIMO-MCCDMA system with RMSE algorithm. The performance also improves as the array antennas at the transmitter and receiver have more elements.

The proposed scheme is to target multipath and interference for efficient interference cancellation. The simulation results demonstrate a significant performance improvement using our proposed system with the presence of large interferences. It is worthwhile to note here that more receive antennas will be required to provide the degree of freedom to mitigate a higher number of effective multipath for improved system performance. The complexity of the proposed system is another issue for future investigation.

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