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PAPR Reduction in MIMO OFDM System Using Improved Constant Modulus Algorithm

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Abstract— MIMO OFDM has gained importance with the increase in demand of high speed data communication .MIMO OFDM also qualifies 4G standard due to high bandwidth frequency. Despite of many merits MIMO OFDM suffers from high peak to average power ratio problem. This paper proposes a new technique based on continuous modulus algorithm to eliminate the problem of inter-carrier interference (ICI), high out-of-band radiation, and degradation of bit error rate performance. Proposed algorithms are simulated in matlab and parameters like bandwidth requirement and error is calculated. These parameters are compared with contemporary techniques to validate the proposed algorithm.

Keywords— Orthogonal frequency division multiplexing (OFDM), Peak-to-average power ratio (PAPR), constant modulus algorithm (CMA).Complementary cumulative distribution function (CCDF)

I. INTRODUCTION

Growing demand of high speed communication has evolved various multicarrier modulation techniques, few notable among them being Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). Orthogonal Frequency Division Multiplexing is a frequency division multiplexing (FDM) scheme utilized as a digital multi carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data. The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining total data rates similar to the conventional single carrier modulation schemes in the same bandwidth. In OFDM system, a stream containing high-speed data is transmitted using a number of parallel lower data rate subcarriers. As the individual data rate is much less the total data rate, ISI is avoided owing to the long symbol duration [2].

OFDM modulation has been incorporated in many wireless applications such as Wireless Personal Area, Local Area and Metropolitan Area Networks, Digital Audio and Video Broadcasting [3]. It is employed as a modulation technique for IEEE 802.20, IEEE 802.16 and 3GPP-LTE [3]. A simple one tap equalizer is required at the receiver side as the effect of ISI is eliminated by introducing cyclic prefix (CP) [2].

In contradiction to these advantages some problems still persist in the design of OFDM systems. One of the major problems is high Peak-to-Average Power Ratio (PAPR) of the transmitted OFDM signals. The transmitted signals in an OFDM system can have high peak values in the time domain as many subcarriers are added due to IFFT operation at the transmitter. Therefore, OFDM systems have a high PAPR as compared with single-carrier communication systems. As a result of this problem, the Signal-to-Noise Ratio of Analog-to-Digital Converter and Digital-to-Analog Converter is reduced, which further degrades the efficiency of the high power amplifier at the transmitter side. As more efficient Power Amplifier is essential in a mobile terminal due to the limited battery power, the PAPR problem is more troublesome in the uplink design. Hence it is essential to reduce PAPR in OFDM based systems. Over the past decade, an extensive amount of literature has been dedicated to PAPR reduction techniques. These techniques are associated with cost in terms of bandwidth and transmit power. Also, most of them require modifications to both the transmitter and the receiver which makes them non-compliant to existing standards. A new technique is proposed and the simulation results are compared using complementary cumulative Distribution function. Performance comparison, complexity comparison, BER performance and PAPR reduction performance are among them[11].

The idea of using Multiple receive and multiple transmit antennas has emerged as one of the most significant technical breakthroughs in modern wireless communications.[6] Theoretical studies and initial prototyping of these MIMO system have shown order of magnitude spectral efficiency improvements in communications. As a result, MIMO is considered a key technology for improving the throughputs of future wireless broadband data systems. The simplest way to reduce the PAP ratio is to clip the signal, such that the peak amplitude becomes limited to some desired maximum level. Although clipping is definitely the simplest solution, there are a few problems associated with it. First by distorting the OFDM signal amplitude, a kind of self-interference is introduced that degrades the BER. Second it increases the level of out–of-band radiation. The latter effect can be understood easily by viewing the clipping operation as a multiplication of the OFDM signal.[7]

II. SYSTEM MODEL

We have considered a generic MIMO-OFDM/A downlink scenario with one base station (BS) employing M_t antennas. An OFDM block with subcarriers is transmitted through each antenna. The subcarriers include useful subcarriers surrounded by two guard bands with zero energy. The useful subcarriers are also further grouped into resource blocks (RBs) each consisting of subcarriers. Data of one or more users is placed in these RBs and mapped into the space-time domain using an inverse discrete Fourier transform (IDFT) and space-time block coding (STBC). To allow channel estimation at the receivers (mobile stations), each RB also contains several pilot subcarriers that act as training symbols.[9]

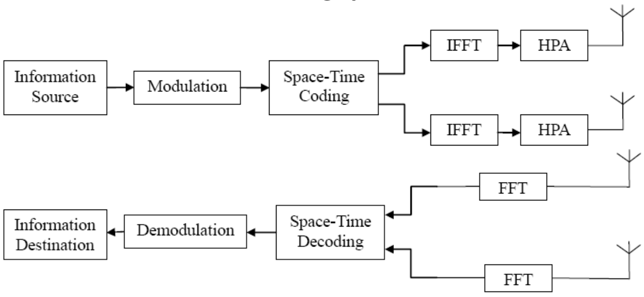

Figure 1. Basic Structure of MIMO OFDM System

Figure 1 shows basic structure of MIMO OFDM System. A number of transmission antennas are used at the transmitting end. An input data bit stream is supplied into space time coding, then modulated by OFDM and finally fed to antennas for sending out (radiation). At the receiving end, incoming signals are fed into a signal detector and processed before recovery of the original signal is made.

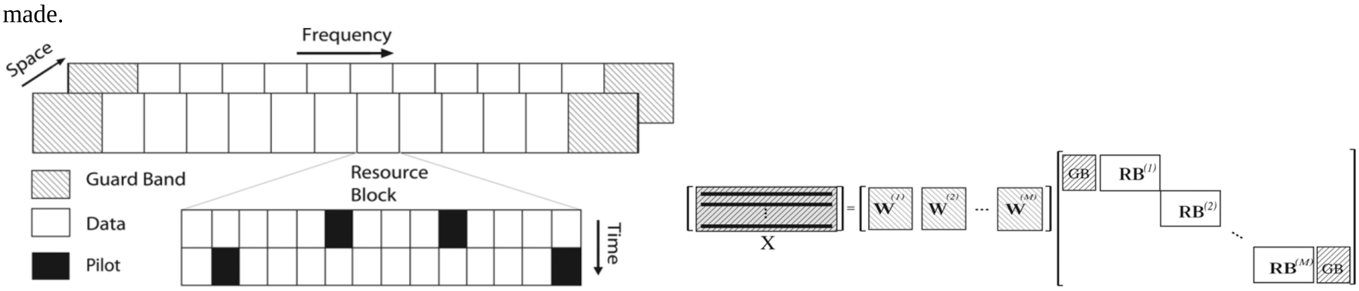

Figure 2. Data structure of an OFDM block for a MIMO-OFDM/A downlink

A generic MIMO-OFDMA with one base station employing Mt antennas is considered. An OFDM block with N subcarrier is transmitted from each antenna. The N subcarriers include Nu useful subcarriers surrounded by two guard bands with zero energy. The useful subcarriers are further grouped in to M resource blocks, each consisting of Nb = Nu/M subcarriers. Data of one or more users is placed in these resource blocks and mapped in to space time domain using an inverse discrete Fourier transform. Channel estimation is done at receivers. In MIMO transmit data model.[11]

The Beamformed Data Matrix X is given by

$X = W^H D$……………………(i)

Where W and D is a block-diagonal matrix with guard bands as shown in Figure 2.

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The IFFT of the beamformed data matrix is given by

$Y = X F^H = W^H DF^H$ …………………..(ii)

Where F^H denoted the IFFT matrix and Y contains the resulting transmit OFDM sequences. The resulting MIMO OFDM transmit matrix is

$S = W^H \Omega DF^H$ ………………………………………..(iii)

Where Ω is a diagonal (unimodular) precoding matrix and by applying Kronecker products, we can rewrite S as

$S = A \omega$ ……………………………………………(iv)

Where ω is the vecdiag(Ω) and the cost function is given by

$\omega\ J(\omega)$ min , where $J(\omega) = E[(|S|2 - \alpha^2]$ ………..(v)

Where α is the average transmit power. , μ is the step size and ɵ is the point wise division The resulting transmit sequence is $X(q)=W(q)^H D(q)$. Together with guard intervals, they are collected in a matrix X X∈CMt×N where the Mt rows of this represent the N symbols to be transmitted from the Mt antennas. The data model is $X=W^H D$. Matrix X represents the spatial data in the frequency domain. taking the IDFT of the data matrix X, resulting in

$Y=XF^H=W^H DF^H$ ………………………………..(vi)

Y Contains the resulting transmit OFDM sequence for each of the Mt antennas. Denoting the total power in the data matrix D by $Pd=\|vec(D)\|^2=\alpha Nt$. Nt is the total number of subcarrier or samples to be sent from all Mt antennas, and α is defined as the average transmit power per sample.[11]

III. METHODOLOGIES

The PAPR reduction is achieved using constant modulus algorithm, steepest descent algorithm and unit circle CMA.

A. Constant Modulus Algorithm- The most commonly used adaptive algorithm is constant modulus algorithm, which uses the constant modularity of the signal as the desired property. CMA assumes that the input to the channel is a modulated signal that has constant amplitude at every instant in time. Any deviation of the received signal amplitude from the constant value is considered a distortion, introduced by channel. The distortion is mainly caused by band-limiting or multi-path effects in the channel. Both this effects results in inter-symbol interference and thus distorts the received signal. CMA can also used for QAM signals where the amplitude of modulated signal is not the same at every instant. The error e(n) is then determined by considering the nearest valid amplitude level of the modulated signal as the desired value. The most commonly used blind equalization is constant modulus algorithm which uses constant modularity as the desired property of the output. [13]

B. Steepest-Descent CMA

The SDCMA is a block-iterative algorithm in which we act on the full data matrix and update until it converges. The derivation of the block SDCMA is straightforward when the statistical expectation in original formula in [7] is replaced by an average over a block. For the -th iteration, we start from the
current estimate and compute:

$$\overbrace{S}\, i = A\, \omega^i \qquad \text{(vii)}$$

$$e^i = (\overbrace{S}\, i \odot \overline{\overbrace{S}}\, i) - \alpha\, 1\, N_i \qquad \text{(viii)}$$

$$\overbrace{S}\, e = \overbrace{S}\, i \odot ei \qquad \text{(ix)}$$

$$\omega^{i+1} = \omega^i - \mu \Delta J(\omega^i) = \omega^i - \mu A^T \overbrace{S}\, e \qquad \text{(x)}$$

Here, μ is a suitable step size, and S_e is the update error. The maximal step size μ could be defined as a scale independent parameter α^2 .To keep the solution unchanged as scales, needs to be divided by factor. For convergence, the algorithm is initialized. The algorithm should be run until the cost function converges; convergence is fast and the algorithm is run for a fixed small number of iterations. To satisfy the power constraint, we can simply scale the resulting after convergence. A difference with the standard CMA is that, here, a good solution does not necessarily exist. The usual application of CMA is for a linear combination of constant modulus sources for which without noise, a perfect beam former exists. The present situation could be said to correspond to a very noisy source separation situation. [8, 9, 14].

C. Unit-Circle CMA

In SDCMA, the computed ω has no constraints and may have some small entries. These are equivalent to a (broad) null in the channel which will affect the BER performance. Ideally, we should restrict the entries of ω to take only unimodular values In order to restrict the solution to be on the unit circle, a normalization step is added to each iteration. This alternative updating algorithm is called Unit Circle CMA (UC-CMA) since projects the solution of CMA to a unit circle at each iteration.[7]

IV. SIMULATION

Simulation was done considering Wimax standard in which one RB represents 14 subcarriers over two OFDM symbols in time, containing 4 pilots and 24 data symbols. We have considered 10 MHz system with total 60 RBs. Size of OFDM block is considered to be 1024 including data subcarriers with QPSK modulation and 92 guard subcarriers at each end of the band. MIMO transmit antennas is either, 2 or 4, as will be indicated. A total number of 10,000 OFDM blocks are randomly generated to produce the CCDF curves. For each block, a random complex fading channel is generated, and the beam forming matrices are chosen as the right singular vectors of these channel matrices.

V. RESULTS

The performance of PAPR reduction is analyzed using MATLAB simulation .We assumed number of sub-carriers N = 1024, number of sub blocks V=4, oversampling factor L=4 and applying pseudorandom partition scheme, for each carrier, adopting QPSK constellation mapping weighting factor bv € [±1,±j] .The plot of Complementary Cumulative Distribution Function (CCDF) is drawn to compare the effect of PAPR reduction.

Table-1(PAPR Caculation)

Iteration	PAPR (CMA)	PAPR (Modified)
1	1.043113e+001	5.177351e+000
2	8.399582e+000	4.876617e+000
3	9.407558e+000	4.911971e+000
4	8.449497e+000	5.961661e+000
5	8.077563e+000	4.952112e+000
6	9.015796e+000	5.274559e+000
7	8.895236e+000	5.372887e+000
8	1.007338e+001	5.307861e+000
9	9.197113e+000	4.884317e+000
10	9.601901e+000	5.037950e+000

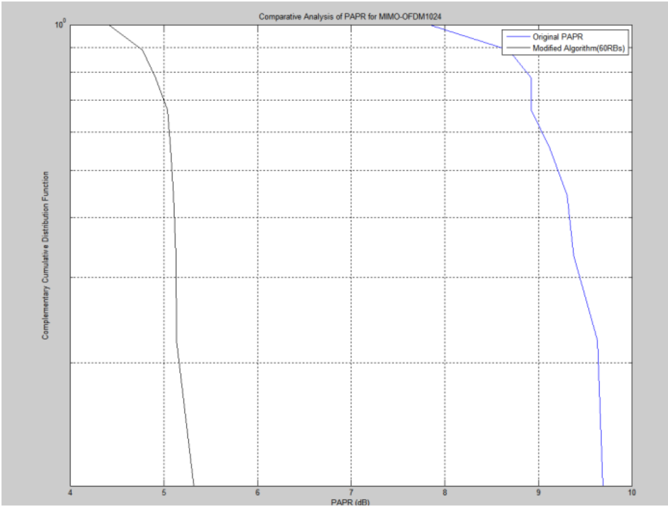

Figure 3. Comparative Analysis of PAPR with CMA

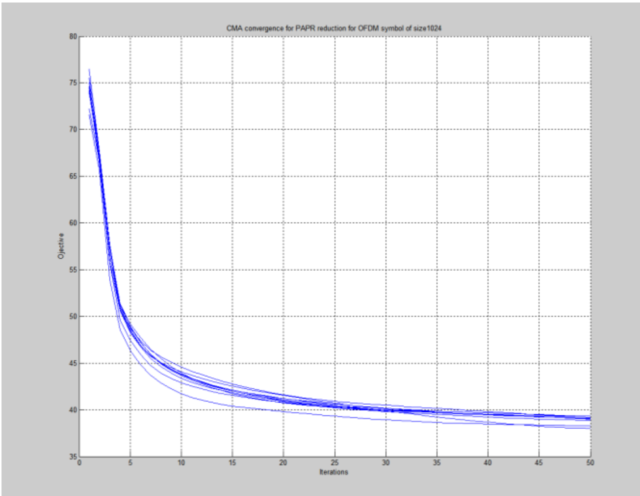

Figure 4. CMA Convergence plot for iterations

Figure 3 and figure 4 shows the superior performance improved CMA approach as compare to PAPR reduction given system. The above curve shows the performance of UC-CMA for various number of transmit antennas. The convergence curve shows the measurement of objective function fo the given iteration.

VI. Conclusion

MIMO OFDM has gained interest due to spectrum efficiency and channel robustness but it suffers from drawback of high PAPRF. Efficient technique is being implemented using modified continuous modulus algorithm using unit circle approach which resulted in increase in reduction of PAPR. Results can be further improved by comparing the algorithm with contemporary PAPR reduction techniques and analyzing efficiency. Increase in iteration number also improved the reduction efficiency of PAPR.MIMO OFDM model and PAPR reduction techniques using modified CMA approach has been successfully simulated and verified using matlab environment.

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