International Journal of Information Sciences and Techniques (IJIST) Vol.4, No.3, May 2014

SIDELOBE SUPPRESSION AND PAPR REDUCTION FOR COGNITIVE RADIO MIMO-OFDM SYSTEMS USING CONVEX OPTIMIZATION TECHNIQUE

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is deployed to overcome the interference. However, OFDM has a relatively large OOB emissions. In spectrum sharing approaches such as dynamic spectrum access networks, the OOB power levels of secondary transmissions should be kept below a certain level, in order not to interfere with primary transmissions. . The difficulties such as sidelobes and PAPR caused by OFDM is reduced by convex optimization and PTS technique respectively. In this technique each OFDM subcarrier is multiplied with a real-valued weight that is determined in order not to interfere with adjacent users. The problem with the SW technique is involving a very complex optimization. We propose a heuristic approach called convex optimization. It can achieve considerable sidelobe suppression while requiring significantly less computational resources than the optimal solution. Implementation results prove that it can be introduced for real-time transmissions. Optimizing the subcarrier weights and SINR is complex, for which we use the technique of convex optimization. For reducing the PAPR we use Partial Transmit Sequence (PTS) technique.

Index terms : *OFDM (Orthogonal Frequency Division Multiplexing), PAPR (Peak Average Power Ratio), OOB (Out Of Band), IFFT (Inverse Fast Fourier Transform).*

I.INTRODUCTION:

OFDM makes efficient use of the spectrum by allowing overlap of channels. By dividing the channel into narrowband flat fading subchannels, OFDM is more resistant to frequency selective fading than single carrier systems. It eliminates ISI and IFI through use of a cyclic prefix. But still the use of OFDM introduces the sidelobes and the PAPR effect. Sidelobes is caused by the multiple subcarriers of OFDM . In OFDM the single broad band frequency is divided into large number of parallel narrow band of frequencies. OFDM inbuilt scheme produces orthogonal carriers by using the Inverse Fast Fourier Transform (IFFT). In addition to that IFFT is also used to raise the frequency used in the baseband to that of transmittable high frequency. Thus this reduces the interference between the carriers of nearer frequencies. Moreover the cyclic prefix addition makes us to reduce the most important problem of the digital communication that is the Inter Symbol Interference (ISI). By using the frequency response of sub-carrier used for transmission, the amount of information for each subband can be altered. On the other hand these narrow bands have less frequency selective fading. But performing IFFT in the OFDM block the peak amplitudes occur in the signal.

Though OFDM has a very high advantage over other techniques the major shortcoming involved

DOI : 10.5121/ijist.2014.4309

here is the high Peak to Average Power Ratio. The transmit signals in an

OFDM system can have high peak values in the time domain since many subcarrier components are added via an IFFT operation. So there is a need for the reduction in this detrimental factor .In the PTS technique, an input data block of N symbols is partitioned into disjoint sub-blocks. The sub carriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. The sidelobes caused by OFDM is reduced by multiplying OFDM subcarrier with real valued weight that is determined in order not to interfere with adjacent users. The problem with the SW technique is involving a very complex optimization that has to be performed for each OFDM symbol. It can achieved through convex optimization where considerable sidelobe suppression while requiring significantly less computational resources than the optimal solution**.**

II. EXISTING METHODS:

A. Sidelobe Suppression by Multiple-Choice Sequences (MCS)

A set of sequences $d^{(P))}$= $(d_1(\mathrm{p}), d_2(\mathrm{p})\ldots\ldots d_n(\mathrm{p}))^T$; p = 1,2.....P , is produced from the sequence d. For each sequence $d^{(p)}$ the average sidelobe power, is denoted with $A^{(p)}$; p = 1,2......P , is calculated. To determine $A^{(p)}$, a certain frequency range spanning several OFDM sidelobes, called optimization range, is considered using discrete frequency samples. Recalling that the spectrum of an individual subcarrier equals a si-function si(x) = sin(x)=x, $A^{(p)}$ is given by,

$$A^{(p)} = 1/k \sum_{k=1}^{k} \{ \sum_{n=1}^{N} d_n^{(p)} si(\pi(y_k - x_n)) \}^2$$

$$p = 1,2...............P$$

where x_n, n = 1,2...... N, are the normalized subcarrier frequencies and y_k; k = 1, 2.....K, are normalized frequency samples within the optimization range. The index Q of the sequence with maximum sidelobe suppression is given by

$$Q = \arg\min A^{(p)};\ p = 1, 2......\ P$$

Thus the sequence$\bar{d} = d^{(q)}$ is chosen for transmission and output from the MCS unit. To enable successful data detection, the received sequence has to be de-mapped onto the original sequence at the receiver. The MCS set is constructed such that the knowledge about the index Q of the selected sequence is suffcient to perform this de-mapping. Thus, the index Q is coded in bits, passed from the MCS unit to the signalling channel, and sent to the receiver.

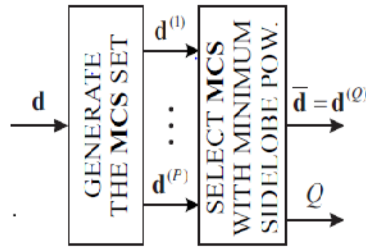

Fig 1: Block diagram of the MCS sidelobe suppression unit

For example, assuming an OFDM system with *N* subcarriers modulated with *M*-ary phase-shift-keying (*M*-PSK) or *M*-ary quadrature amplitude modulation (*M*-QAM) symbols, the overhead needed for the signalling information is

$$[\log_2(p)]/(\log_2(m).N + [\log_2(P)])$$

which is negligible for large *N* and/or *M*. $[x]$denotes the smallest integer greater than or equal to *x*. At the receiver, an estimate $\tilde{d}^{(q)}$ of the transmitted sequence $d^{(q)}$ is obtained which is transformed into an estimate $\tilde{d}$ of the original sequence d using the signalling information. Note that the signalling information is the index Q which indicates that the sequence $d^{(Q)}$ out of the MCS set has been chosen for transmission . In the following several computationally effective, but yet effcient algorithms steps to generate MCS sets are proposed and analyzed. The proposed methods do not degrade the bit-error rate performance at the receiver and require only a slightly increased signalling overhead.

III. PROPOSED METHOD

A. To reduce sidelobes

To overcome the large computational complexity problem, we propose a heuristic approach to perform optimization with power constraints. The basic idea of this approach is checking the contribution of each weighted subcarrier in the OOB regions for $\beta_{min}$and β_{max}.The one that results in lower OOB emissions is chosen for transmission. To understand the proposed algorithm, let us assume that only the subcarriers at the borders of each OFDM symbol are to be weighted while the remaining subcarriers are kept unweighted. Let M_l and M_r are the numbers of the weighted subcarriers to the left and to the right of OFDM spectrum . We assume that M_l and M_r are used to reduce the OOB emission the left and right of OFDM spectrum respectively. This assumption is reasonable as the subcarrier closer to the edge of OFDM spectrum have impact in the OOB region . First of all, the total OOB emission due to the unweighted subcarrier (N- M_l- M_r) can be obtained from,

$$Z_{0=\sum_{k=M_l+1}^{N-M_r} a_k x_k}\ (y)$$

The total OOB emissions will be only calculated at certain points (frequencies). Each subcarrier has sidelobes in the OOB regions and the highest peak in the OOB region has the most significant contribution in the OOB emissions. Therefore, the OOB emissions are calculated only at the highest peak point of each subcarrier in the OOB region. It is assumed that each weighting factor β_i can be either β_{min} or β_{max} .The weighting factor are determined one after other by calculating the OOB emission using β_{min} and β_{max}. Then the result in lower OOB emission is chosen for transmission.

For illustration, consider weighting M_l subcarriers. Define R_i as the frequency domain representation of the ith weighted subcarrier at the location of the highest peak in the OOB region. Defined P_i as the contribution of the ith weighted subcarrier at R_i while Q_i is defined as the total OOB emission at R_i before assigning β_i. The proposed algorithm can be described as follows:

a) Calculate the OOB emissions due to the unweighted subcarrier at R_i in OOB region.
b) Set i=1.
c) Calculate the OOB emission using β_{min} and β_{max} as:

$$S_1 = Q_i + (\beta_{min})(\alpha_{M_l-(i-1)}) P_i$$

$$S_2 = Q_i + (\beta_{max})(\alpha_{M_l-(i-1)}) P_i$$

d) If($S_1^2 < S_2^2$) , then $\beta_i = \beta_{min}$. Otherwise, $\beta_i = \beta_{max}$
e) Calculate the total OOB emission at the location R_k ,(i + 1 ≤ k ≤ M_l) by adding the contribution of the ith weighted subcarrier using:

$$Z_i = Z_{i-1} + \beta_i(\alpha_{M_l-(i-1)})(X_{M_l-(i-1)})$$

f) Increment i.
g) If (i ≤ M_r). Go to step c.

The same procedure can be applied for the remaining subcarriers taking into account that these subcarriers will be weighted to reduce the OOB emissions to the right of OFDM spectrum.

B. To reduce PAPR

This system is the incorporation of all the above mentioned techniques. The bandwidth is been conserve d by the M-ary modulation techniques. The errors are minimized and optimized data speed is achieved using MIMO antenna without any compromise for the bandwidth using OFDM.

In the below system, the signal is M-ary modulated and transmitted in MIMO antenna using OFDM techniques where the factor of PAPR reduction is also considered for a better performance than the present existing models

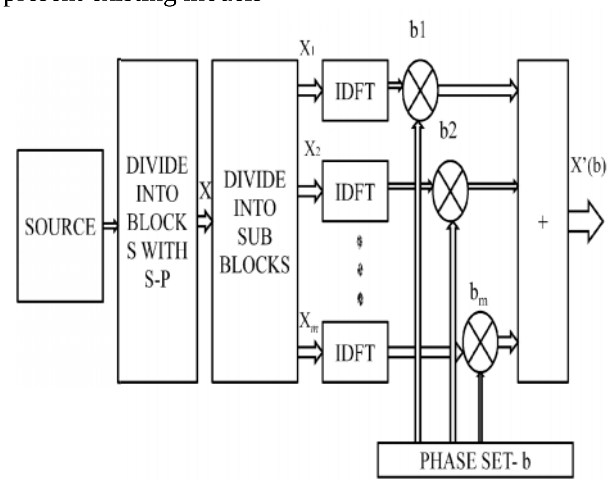

Fig 2 :The block diagram representing the combination of all the techniques is shown.

C. Combined model

The QAM modulated signal is converted from serial to parallel subject to the changes made by subcarrier weighting. We select a minimal value for the weight vector based on the basic criterion on SINR. This when done manually is a very tedious process, thus we do it using the technique of convex optimization. OFDM has a main disadvantage of OOB emissions. To reduce interference caused by OOB emissions, Cancellation Carriers are used. They are carriers added on either side of the OFDM spectrum which can be calculated and cancelled on the receiver side. Then normal process of OFDM is done by applying IFFT. The PAPR effect will affect the efficiency of the communication system and thus we use Partial transmit sequence method to distribute the signal in time domain. The parallel signals thus obtained are again converted into serial signal suitable for transmission. Weighting is done accordingly during the transmission.

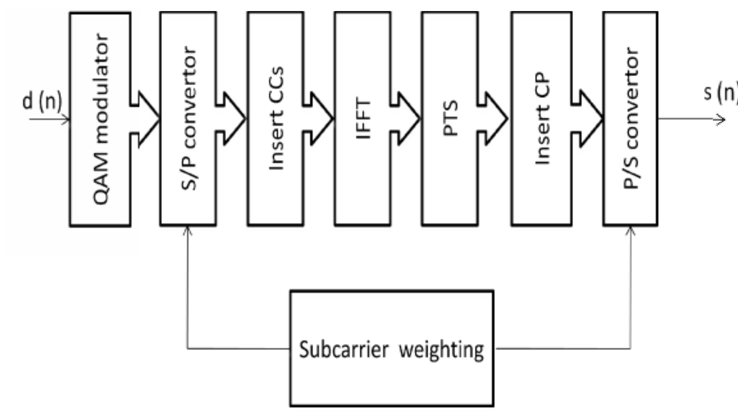

Fig 3: Proposed model

On the receiver side, the cyclic prefix is removed after converting it into a parallel signal. Then the phase set is removed so that the signal is grouped in same time domain. The normal processes of OFDM in a receiver like FFT are done and the cancellation carriers are calculated and cancelled to obtain the original signal back. Then the signal obtained is converted again into a serial signal and demodulated. The results have been analysed by comparing the original signal with the received signal.

IV. RESULTS AND DISCUSSION

If the number of subcarriers increases, then the occurrence of the error decreases. This makes OFDM more suitable for MIMO systems. The orthogonal carriers cause less interference in a MIMO antenna that is closely placed. MIMO-OFDM gives more capacity than the conventional MIMO in presence of multipath as shown.

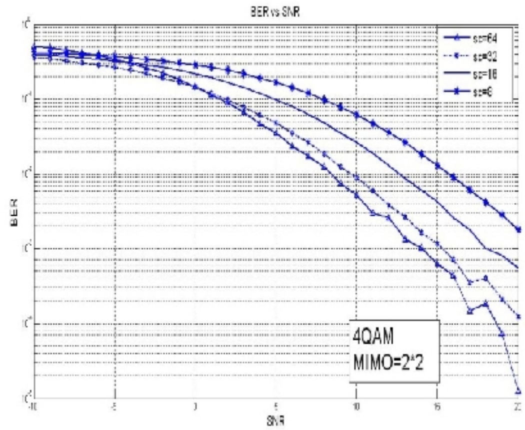

Fig 4: BER vs. SNR for 4-QAM for various subcarrier with dimensions of MIMO as 2×2

In the above proposed system including the MIMO-OFDM schemes we find PAPR to be a factor that need to be considered. So the extension of this system for a better performance will be possible by reducing this PAPR to the minimal value possible by a suitable technique. Analysis can be done on the system based CDF. The initial analysis here is done for an untrained system involving different subcarriers without any technique to reduce PAPR. The estimation of PAPR for the system with different subcarriers is shown below.

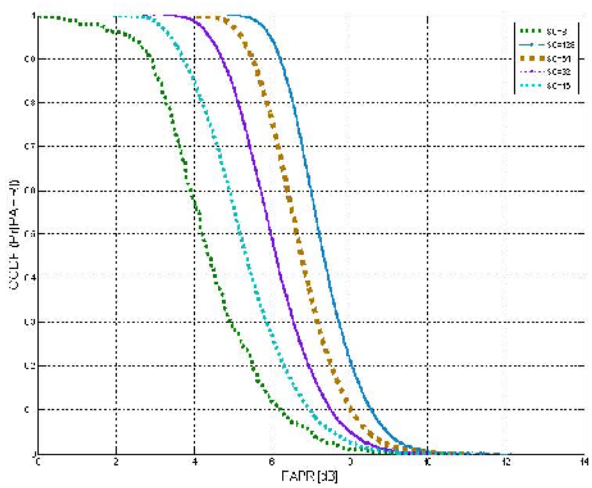

Fig 5: Effect of PAPR for Different Subcarriers using PAPR (dB) vs. CDF

The system with increased number of subcarriers shows an increase in the PAPR of the system. So a power reduction technique is adopted to improve the performance of the proposed system. PTS technique which is compatible with the above system is used.

PTS due to the moderate complexity and a better performance it is thus an attractive candidate for PAPR reduction

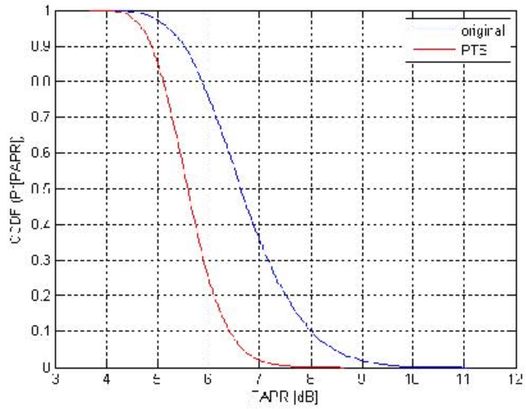

Fig 6: Comparison of PAPR for system with PTS and without PTS techniques

An improved performance is thus obtained by using a Peak Power Reduction technique along with the present system.

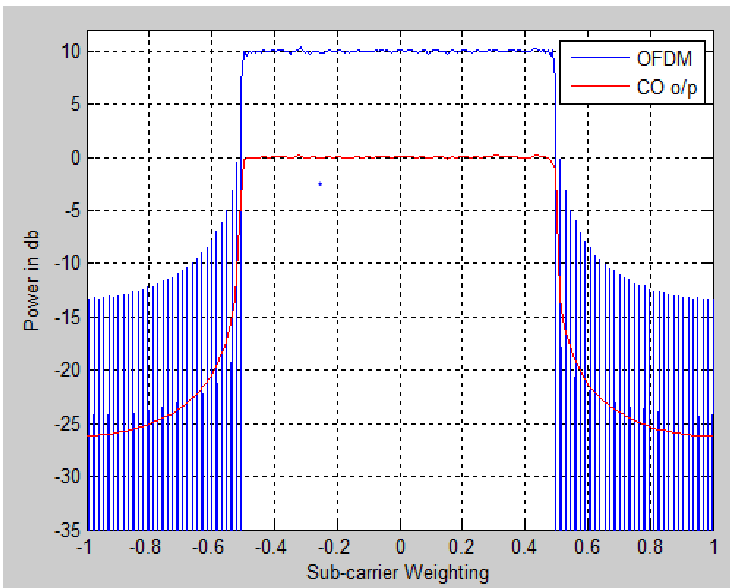

Fig 7 :Comparison of normal OFDM with Constellation Expansion method

This plot shows the spectrum of normal OFDM process compared with the constellation expansion. It has reduced sidelobes. When subcarrier weighting is done, the sidelobe is even more reduced.

V. CONCLUSION

The results shown above give an increase in the performance when an MIMO-OFDM system uses QAM modulation along with PTS method implemented in it. By this way we can efficiently communicate with low inter-channel interference and have minimal bit error rate. The high PAPR is the detrimental aspect in this system. The SINR of the system is also optimized. Subcarrier weighting and convex optimization technique is done to reduce sidelobe and interference. This will form the Most Efficient Way of Communication.

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