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PAPR Reduction using PTS Technique in OFDM – MIMO System

Celina Antony[1] , Prof S.G. Hate [2]

Department of E&TC Engineering, G.H.Raisoni Institute of Technology, Pune[1,2]

Abstract: In the advancement of technology multicarrier transmission is of great importance. Orthogonal Frequency Division Multiplexing (OFDM) is a promising multicarrier technology for wireless communications. It facilitates high data rate for communication. The biggest drawback which OFDM encounters is high PAPR. The high PAPR results some interference to the system. This paper analyses the PAPR reduction technique called Partial Time Sequence (PTS) with different sub block and concludes that PTS technique is the most promising technique for PAPR reduction in OFDM system. OFDM – MIMO system with reduced PAPR is the best method for multicarrier transmission with higher data rate.

Keywords: OFDM, MIMO, PAPR, PTS.

I. INTRODUCTION

1.1 MIMO

Conventional antenna systems are employed using single antenna at the transmitter & receiver. Such systems are subject to fading. To overcome this fading, technique employed is MIMO. MIMO stands for Multiple Input Multiple Output. It is an antenna technology that is used both and receiver equipment for wireless radio communication. There can be various MIMO configurations. For example, a 2x2 MIMO configuration is 2 antennas to transmit signals (from base station) and 2 antennas to receive signals (mobile terminal). Fig 1 shows simple arrangement of MIMO system. It uses multiple antenna configurations at the transmitter & the receiver.

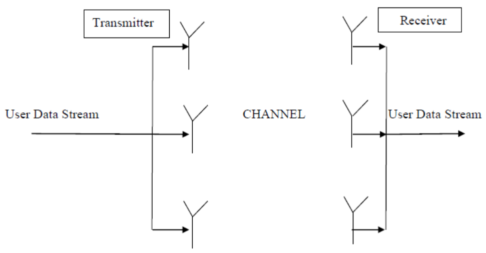

Fig 1. MIMO Systems

Attracted attention in wireless communications, because it It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution [1].

1.2 OFDM

OFDM is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower-rate subcarriers (SC) [2]. It is worth mentioning here that OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase robustness against frequency selective fading or narrowband interference. In a single-carrier system, a single fade or interference can cause the entire link to fail, but in a multicarrier system, only a small percentage of the SCs will be affected. Error-correction coding can then be used to correct for the few erroneous SC. The concept of using parallel-data transmission and frequency-division multiplexing (FDM) was developed in the mid-1960s [9].

In a classical parallel-data system, the total signal frequency band is divided into N non overlapping frequency sub channels. Each sub channel is modulated with a separate symbol, and then the N sub channels are frequency multiplexed [2]. Its good to avoid spectral overlap of channels to eliminate inter channel interference. However, this leads to inefficient use of the available spectrum. To cope with the inefficiency, the ideas proposed in the mid-1960s were to use parallel data and FDM with overlapping sub channels, in which each, carrying a signaling rate b, is spaced b apart in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion, as well as to use the available bandwidth fully. Figure 2 illustrates the difference between the conventional non overlapping multicarrier technique and the overlapping multicarrier modulation technique. By using the overlapping multicarrier modulation technique, we save almost 50% of bandwidth. To realize this technique, however, we need to reduce cross talk between SCs, which means that we want orthogonality between the different modulated carriers. The word “orthogonal” indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. In a normal FDM system, many carriers are spaced apart in such a way that the signals can be received using conventional filters and demodulators. In such receivers, guard bands are introduced between the different carriers and in the frequency domain, which results in a lowering of spectrum efficiency.

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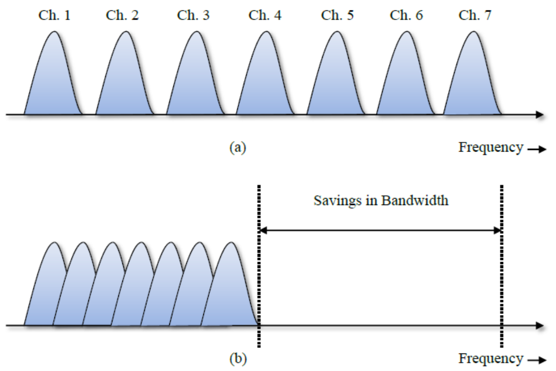

Fig 2 a) Conventional Multicarrier Technique (FDM)
b) OFDM technique

OFDM transmits data by using a large number of narrow-band subcarriers. These subcarriers are regularly spaced in frequency, forming a block of spectrum. The frequency spacing and time synchronization of the subcarriers is chosen in such a way that the subcarriers are orthogonal, meaning that they do not cause interference to one another. This is despite the subcarriers overlapping each other in the frequency domain. By selecting a special set of (orthogonal) carrier frequencies, high spectral efficiency is obtained because the spectra of the SC overlap, while mutual influence among the SC can be avoided. The derivation of the system model shows that by introducing a cyclic prefix, the orthogonality can be maintained over a dispersive channel. In OFDM, subcarrier spacing is kept at minimum, while still preserving the time domain orthogonality between subcarriers, even though the individual frequency spectrum may overlap [2]. The minimum subcarrier spacing should equal to 1/T, where T is the symbol period [1].

OFDM is the major technique which saves bandwidth & improves spectral efficiency of the signal. But OFDM is effected with Peak-To-Average power ratio (PAPR). If the peak transmit power is limited by either regulatory or application constraints, the effect is to reduce the average power allowed under multicarrier transmission relative to that under constant power modulation techniques. This in turn reduces the range of multicarrier transmission. Moreover, to prevent spectral growth of the multicarrier signal in the form of inter modulation among subcarriers and out-of-band radiation, the transmit power amplifier must be operated in its linear region (i.e., with a large input back off), where the power conversion is inefficient. PAPR will affect the OFDM by distorting the orthogonality & not allowing the signal to operate in the high power zone. Hence its mandatory to reduce the effect of PAPR. Many techniques have been employed for reduction of PAPR [3].

II. PAPR

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole System. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal [4]. The major disadvantages of a high PAPR are, increased complexity in the analog to digital and digital to analog converter & reduction in efficiency of RF amplifiers. PAPR equation is given by:

$$\text{PAPR}= {}^{Ppeak}/_{Paverage} = 10\log_{10}\frac{max[|x(t)|^2]}{E[|x(t)|^2]}$$

Reducing the max|x(t)| is the principle goal of PARP reduction techniques. Since, discrete- time signals are dealt with in most systems, many PAPR techniques are implemented to deal with amplitudes of various samples of x(t). Due to symbol spaced output in the first equation we find some of the peaks missing which can be compensated by oversampling the equation by some factor to give the true PAPR value.

III. LITERATURE REVIEW

In the paper "Evaluation of Clipping Based Iterative PAPR Reduction Techniques for FBMC Systems" by Zsolt Kollar, Lajos Varga presents novel clipping based PAPR reduction techniques, evaluated and compared by simulations and measurements, with an emphasis on spectral aspects. The paper gives an overall comparison of PAPR reduction techniques, focusing on the reduction of the dynamic range of signals without increasing out-of-band radiation. An overview is presented on transmitter oriented techniques employing baseband clipping, which can maintain the system performance with a desired bit error rate (BER). This approach could achieve PAPR reduction by enhancing the transmitter & not the receiver. A PAPR reduction of upto 5db could be possible by the approach (the actual simulation results showed lower values) [5].

"MIMO-OFDM Wireless Communications with MATLAB" states that the simplest approach of reducing the PAPR is to clip the amplitude of the signal to a fixed level. The pseudo-maximum amplitude in this approach is referred to as the clipping level and denoted by m. In other words, any signal whose amplitude exceeds m will saturate its amplitude to the clipping level m. While reducing PAPR, the clipping approach helps improve the signal-to-quantization noise ratio (SQNR) in analog-to-digital conversion (ADC) [10]. If the clipping level is low, the signal will suffer from a clipping distortion while the PAPR and quantization noise will decrease. If the clipping level is high, a clipping distortion decreases while it suffers from the PAPR and quantization noise. The Complication in construction of filters in clipping & increase in the SQNR is the biggest drawback of this technique [1].

"New Codes from Dual BCH Codes with Applications in Low PAPR OFDM" by Maryam Sabbaghian, Yongjun Kwak and Vahid Tarokh propose an advanced approach to solve the afore mentioned problems. We construct a new code with favourable PAPR properties based on dual

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BCH codes and develop the associated maximum a posterior (MAP) decoding algorithm. By exploiting this code as the frequency domain constituent code in a time-frequency turbo structure, we reduce the gap between the performance and Shannon limit while the bounded PAPR of OFDM symbols is guaranteed. By comparative performance evaluation we illustrate that the performance of this system is comparable with that of capacity approaching codes while it has 7 dB lower PAPR [6]. "MIMO-OFDM Wireless Communications with MATLAB" sates that coding technique works efficiently for low sub-carrier systems otherwise it leads to complexity [1].

"SOCP Approach for Reducing PAPR for MIMO-OFDM via Tone Reservation" by Emna Hajlaoui and Mahmoud Abdellaoui proposes a novel method to reduce the PAPR based on the use of unused subcarriers. Accordingly, we formulated the reduction of the PAPR problem as space-time block codes approach (convex optimization). The reduction method is originally based on a particular case of Tone Reservation approach which uses the unused carriers of standards. Indeed, this approach does not degrade the bit-error-rate or the data rate and no side information is required. Besides, our approach is relatively simple, robust and precise and it achieved significant reduction in PAPR. In fact, we validated our approach on the WiMax systems and we compared our results with those found in the literature. Consequently, our proposed approach improved a PAPR reduction about 5 dB at the 10-3 probability level. In addition, and precisely when using CCDF of signal technique optimized with constraint mean power. The PAPR was reduced about 6dB. However and with previously works, a PAPR reduction has been obtained about 2.5 dB [7].

"MIMO-OFDM Wireless Communications with MATLAB" puts forward the drawback for tone reservation; it states that additional power is required to transmit the PRT symbols & the effective data rate decreases since the PRT tones work as an overhead [1].

In the paper "Performance Improvement of MIMO-OFDM Wireless Systems using PAPR Reduction Techniques" a method named as Selective Mapping (SLM) is proposed. The parallel input data vector is multiplied with V different phase sequences (each of length N) to create V modified data blocks with different phases before the IFFT operation. Then after the IFFT operation, among the modified data blocks the block having minimum PAPR is selected for tranmission. Information about the selected phase sequence should be transmitted to the receiver as side information and this is the reason for complexity. SLM can be used for any number of sub-carriers and for any signal constellation. It provides significant gain with moderate complexity. Channel coding is needed to protect the side information [8]. The SLM technique proposed in the current paper will degrade the PAPR performance if the number of subcarrier increases & hence PTS (Partial transmit Sequence) technique is proposed to be better than the SLM technique.

IV. PROPOSED APPROACH

In the Proposed approach Partial Transmit Sequence (PTS) technique is used for PAPR reduction. A number of approaches have been considered for PAPR reduction. Among which PTS technique was found to be the most promising technique [9s]. These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on. PAPR gives the maximum PAPR reduction with least complexities. We propose to partition the data blocks into 64 sub blocks which gives a better PAPR performance.

4.1 Algorithm:

1) Partition the input data block into V sub blocks as in Equation (1).

$$X = [X^0, X^1, X^2 \ldots\ldots X^{v-1}]^T \qquad (1)$$

2) Set all the phase factors $b^v = 1$ for $v = 1 : V$, find PAPR of Equation (2), and set it as PAPR_min.

$$IFFT \sum_{v=1}^{V} b^v X^v = \sum_{v=1}^{V} b^v x^v \qquad (2)$$

3) Set v = 2
4) Find PAPR for $b^v = -1$
5) If PAPR > PAPR _ min, switch sb^v back to 1. Otherwise, update PAPR _ min =PAPR
6) If v < V increment v by 1 & repeat step 4.

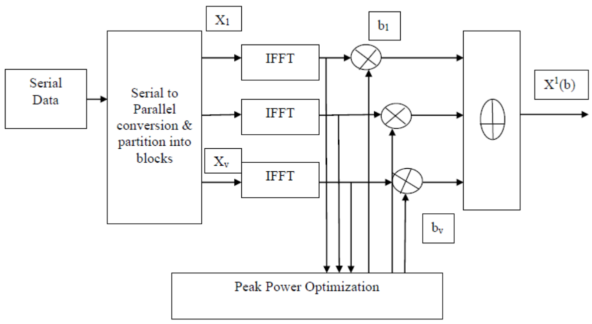

Fig3. Block Diagram of proposed PTS technique

V. SIMULATION RESULTS

Simulation results of Fig 4 shows that as the sub blocks i.e. 64 blocks of data increases there is an improvement in PAPR performance as compared to the conventional method of 4 sub blocks [1].

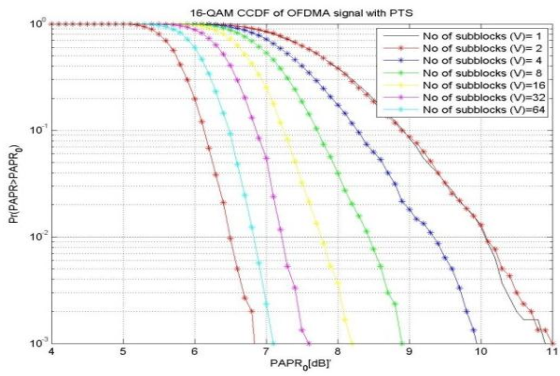

Fig s4. Simulation result of the Proposed Approach.

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VI. CONCLUSION

The proposed PAPR reduction method Partial Transmit Sequence (PTS) is the most promising technique for PAPR reduction. The simulation result shows that division of sub blocks from 8 sub blocks [1] as in the traditional methodology to 64 sub blocks as in the proposed approach gives a better PAPR reduction. Each of the methods discussed in the literature review has drawbacks and these effects need to be considered for a real performance measurement. In the proposed approach the PAPR reduction was found to be the most significant in reduction of PAPR.

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