Analysis of techniques for peak- to- average power ratio (PAPR) reduction in OFDM-MIMO systems

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\textbf{ABSTRACT}

OFDM is multicarrier technique which divides the large data stream to small data stream & each stream is associates with single subcarrier. This wireless channel impairment improves bandwidth efficiency & provides high data rate communication. MIMO (multiple input multiple output) communication refers to system where multiple input at transmitter & multiple input at receiver side. Even though there is multiple transmit & receive, there is no interface between the signals. It improves the signal quality & significant capacity gain. Multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) & is combinable used for many advantageous effects like less non linear distortion, decrease receiver's complexity etc. same way they have some drawbacks & among all the (PAPR) peak to average power ratio is major drawback of MIMO-OFDM system. We have investigate the PAPR reduction techniques, as PAPR is the major drawback and due to which power amplifiers are carefully manufactured to have large input power back offs. We have studied different PAPR reduction techniques their importance and drawbacks.

\textbf{Keywords:} Multiple input multiple output (MIMO), orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), Companding technique

\section{INTRODUCTION}

In the present scenarios 3G is not enough as the ever growing demands of multimedia services, online gaming etc. needs higher speed of data. The need for more sophisticated technology is possible with higher and faster data transmission and reception. This can be achieved using 4G wireless technology. MIMO-OFDM is considered as one of the promising solution for increasing high data rates in wireless communication systems. The main limitation of MIMO-OFDM system is its high peak-to average power ratio (PAPR) of the transmitted signals which is required to be reduced [1]. The various PAPR reduction schemes have been proposed for OFDM systems. When considering a system with Transmitting power amplifier, Nonlinear Distortion and peak amplitude limiting introduced by the high power Amplifier will produce inter modulation between the different carriers and introduce additional interference into the system. This additional interference leads to increase in Bit Error Rate (BER) of the system. One way to avoid such nonlinear distortion and keep a low BER is by forcing the amplifier to work in its linear region. Unfortunately, such solution is not power efficient and thus not suitable for wireless communication. Hence there is a need to reduce PAPR of transmitting signal. To overcome this severe problem of OFDM system, many techniques have been proposed so far. Some techniques are designed based on employing redundancy; some are achieved by using extended signal constellation and some uses external coded sequence and interleaving. Coding , selective mapping , tone reservation , tone injection , multi-amplitude Continuous Phase Modulation (CPM) , interleaving are some of the examples of the cited types. The associated drawbacks of these techniques are reduction in transmission rates , increased power [7], implementation complexity [9] etc. But the simple PAPR reduction methods can be achieved by clipping and filtering [11] or companding [12, 13]. However, use of the clipping technique causes both inband and out-of-band distortion.
which results in an increased bit error rate (BER) in the system [14]. As an alternative approach, the companding technique shows better performance than the clipping technique, because the inverse companding transform (expanding) can be applied at the receiving end to reduce the distortion of signal.

2. OFDM SYSTEM ARCHITECTURE

OFDM is multicarrier modulation technique known for its capability to mitigate multipath. In OFDM, a high speed data stream is divided into “N” narrowband data streams and is modulated using subcarriers which are orthogonal to each other and the information is transmitted on each sub carrier. OFDM is well suited for transmission of high data rate applications in fading channels due to its robustness to inter symbol interference. IFFT is performed at the transmitter and FFT at the receiver, resulting in conversion of wideband signal affected by frequency selective fading, into “N” narrowband flat fading signals. Therefore, simpler equalizer is required at the receiver. OFDM is used for dedicated short-range communications (DSRC) for road side to vehicle communications and as a backbone for fourth generation (4G) mobile wireless systems. In the traditional frequency division multiplexing (FDM) system, signals are transmitted in different channels. Guard intervals are required for channel isolation and filtering to prevent interference and guarantee effective wireless communication. However, at receiving end a series of band-pass filters are required to separate and extract information which results in less frequency spectrum utilization. Figure 1 and 2 depict the frequency spectrum utilization efficiency in FDM and OFDM system, respectively. Each subcarrier in OFDM system signal has a very narrow bandwidth with low symbol rate. The signal therefore, has immunity on multipath delay spread. At the receiving end transmitted in low-speed parallel subcarriers, it has increased symbol period which help to reduce the time dispersion and ISI of the system.

![Figure 1: Spectrum of traditional FDM modulation scheme](image1)

![Figure 2: OFDM Spectrum](image2)

3. TRANSCEIVER OF OFDM

![Figure 3: Transceiver of OFDM](image3)
4. MIMO-OFDM ARCHITECTURE

MIMO-OFDM [4], technique is used in wireless communication systems to achieve gigabit transmission. It enables high capacities suited for internet and multimedia services which increase the range and reliability. It also increases diversity gain and enhance system capacity of application services on a time-varying multipath fading channel improving power-spectral efficiency in wireless communication systems besides optimizing the power efficiency. The technology guarantees each user’s quality of service (Qos) requirements that include low bit-error rate (BER) and high data rate and as a result ensures fairness to all the active users. It allows transmission over high frequency selective channels at a reduced Bit Error Rate with better quality signal. As MIMO can be combined with any modulation or multiple access technique, therefore the implementation of combination of MIMO and OFDM is more efficient. OFDM has the property of robustness against multipath delay spread. This is achieved by having a long symbol period, which minimizes the inter-symbol interference [5]. MIMO, on the other hand, either for improving the SNR or data rate. Therefore both these techniques result in a new mechanism which is very helpful in aiming at the design of high-rate data carrying wireless mobile systems. One of the advantages of this system is to achieve reduced BER. The BER of this system is quite less as compared to an OFDM system. For a fixed value of SNR possible to achieve less bit error rate, so can say that have an improvement in SNR or can say that have less error probability of bits resulting in higher data rate. On increasing the number of antennas on transmitter and receiver side, the BER is further reduced because of diversity. In the current paper an 8x8 MIMO-OFDM system is discussed for reduction of PAPR using SLM technique and enhanced channel capacity.

5. PAPR REDUCTION TECHNIQUES

5.1 Signal distortion techniques

OFDM signal having high peak so, clipping & filtering is used in this system. 1st generated OFDM signal transferred to clipping block. In dipping part if amplitude exceeds the threshold then amplitude is hard –clipped & phase is saved. The clipping cause in band & out of band distortion because of non linear operation of clipping. In band distortion causes degradation of BER while distortion causes out of band emission.

5.2 Signal scrambling techniques

PTS (partial transmit sequence)

In PTS technique generally have input data block of N symbols which are partitioned into disjoint sub blocks & the serial data is converted in to parallel. Then the sub carriers of each sub block are weighted by phase factor & each phase factors are selected such a way that PAPR of external signal is lower down.

SLM (selected mapping)

Here the transmitter generates the set of sufficiently different candidate data blocks & which represent the same information as original data blocks & they are partitioned into sub blocks & they multiply with different phase factor & then IPFT of the combined sub block & phase factor is performed & then select the favourable among all sub blocks.

5.3 Proposed Companding technique

Pulse code modulation (PCM) is a common method of digitizing or quantizing an analog waveform. For any analog-to-digital conversion process, the quantization step produces an estimate of the waveform sample using a digital codeword. This digital estimate inherently contains some level of error due to the finite number of bits available. In practical terms, there is always tradeoff between the amount of error and the size of the digital data samples [19]. The goal in any system design is quantizing the data in smallest number of bits that results in a tolerable level of error. In the case of speech coding, linear quantization with 13 bits sampled at 8 KHz is the minimum required to accurately produce a digital representation of the full range of speech signals. For many transmission systems, wired or wireless, 13 bits sampled at 8 KHz is an expensive proposition as far as bandwidth is concerned. To address this constraint, a companding system is often employed.

Companding is simply a system in which information is first compressed, transmitted through a bandwidthlimited channel, and expanded at the receiving end. It is frequently used to reduce the bandwidth requirements for transmitting telephone quality speech, by reducing the 13-bit codewords to 8-bit codewords.

Two international standards for encoding signal data to 8-bit codes are A-law and µ-law. A-law is the accepted European standard, while µ-law is the accepted standard in the United States and Japan. A-law companding
A-law is the CCITT recommended companding standard used across Europe. Limiting the linear sample values to 12 magnitude bits, the A-law compression is defined by below Equation, where $A$ is the compression parameter ($A=87.7$ in Europe), and $x$ is the normalized integer to be compressed.

$$F(X) = \frac{A|x|}{1+\ln(A)} \quad 0 \leq |x| < \frac{1}{A} \quad (1)$$

$$F(X) = \frac{\text{sgn}(x)\times(1+\ln(A|x|))}{1+\ln(A)} \quad \frac{1}{A} \leq |x| \leq 1 \quad (2)$$

μ-law companding

The United States and Japan use μ-law companding. Limiting the linear sample values to 13 magnitude bits, the μ-law compression is defined by below equation, where $\mu$ is the compression parameter ($\mu=255$ in the U.S. and Japan) and $x$ is the normalized integer to be compressed.

$$Y = -\frac{1}{1+\mu} \ln \left(1 + \frac{\mu}{\text{x}_{\text{max}}} |x| \right) \frac{x}{|x|} \quad (3)$$

SIMULATION AND RESULTS

Simulation Parameters

<table>
<thead>
<tr>
<th>Table 1 Parameters used in OFDM</th>
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<tr>
<td>PARAMETERS</td>
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<tr>
<td>FFT size</td>
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<tr>
<td>Subcarrier</td>
</tr>
<tr>
<td>No of bits</td>
</tr>
<tr>
<td>Modulation</td>
</tr>
<tr>
<td>Block size</td>
</tr>
<tr>
<td>N=number of Carriers</td>
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<tr>
<td>M=Size of Signal Constellation</td>
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<tr>
<td>C=number of Channel</td>
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<tr>
<td>QPSK set</td>
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<td>Avg (Clipping level set)</td>
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Fig 4. PAPR of SLM method for OFDM
Fig 5. PAPR of μ-law Companding method for OFDM

Fig 6. PAPR of A-law Companding method for OFDM

Fig 7. PAPR of SLM, Clipping and filtering, A-law and μ-law companding
TECHNIQUES | PAPR
---|---
Original | 5.5 – 11db
SLM | 5.2 – 7 db
Clipping & filtering | 5.1 – 5.4 db
μ-law companding | 3.8 – 5 db
A-law companding | 2 – 4.2 db

CONCLUSION
In this paper, a promising technique for PAPR reduction has been proposed and numerically analyzed. The main attraction of this technique is to keep the PAPR at a level which is lower than or equal to the pre-specified PAPR level, by performing multiple companding. However, multiple companding may not be required if the signal is already within the level of PAPR. The proposed technique is based on conventional companding scheme and the implementation complexity is relatively simple than the other PAPR reduction techniques.

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