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Implement PAPR Reduction in OFDM System Using SAS DCT with Companding

A. Kayalvizhi
Dept of ECE,
Annamalai University
Tamil Nadu, India

K. Thamizhmaran
Dept of ECE,
Annamalai University
Tamil Nadu, India

G. Ramprabhu
Dept of ECE,
Annamalai University
Tamil Nadu, India

Abstract**:** OFDM has been adopted as a standard for various high data rate wireless communication systems due to several benefits. One of the major drawbacks in OFDM system is its high Peak-to-Average Power Ratio (PAPR) of its transmitted signals thereby making transmitter amplifier to operate beyond its linear range of operation resulting in signal distortion. In this research work a simple method for reducing Peak-to-Average Power Ratio in OFDM is presented. The method is based on Discrete Cosine Transform (DCT) aided successive addition and subtraction (SAS) of data symbols within a single OFDM frame. Performance of the proposed method is evaluated and compared with the existing techniques. Joint reduction in PAPR by combining SAS preprocessed DCT technique and companding is also presented where system utilizes companding technique to further reduce the PAPR of the OFDM signal.

Keywords: OFDM; PAPR; DCT; SAS; Companding

I. INTRODUCTION

Globally, Multimedia plays a predominant role in this smart world with its introduction of 4th generation wireless communication with high demand butwhereas the spectrum for communication remains very less than the number of users. In Single carrier system, the single carrier engages the entire communication bandwidth whereas in multi carrier the available communication bandwidths are divided by many sub carriers. Due to this, each sub carrier gets smaller bandwidth than the bandwidth of single carrier system. To overcome this,OFDM can be used which comes up with best bandwidth efficiency, high speed data rates & its immune to frequency selective fading marks. The base of all 4G communication is OFDM due to its high speed data rate as high as 100Mbps,enormous capacity of number of sub carriers & widespread coverage with high mobility. OFDM are widely & majorly used in DAB,DVB& LTE & much more.

In OFDM, tight frequency synchronization, time offset, peak to average power ratio (PAPR) and channel estimation are the major disadvantages. The independent phases of sub-carriers lead to constructive effect when all sub carriers have same phase which results in high peak amplitude resulting in signal with high PAPR rate. So, the amplifier Q point operates in saturation region which results in nonlinear amplification due to greater amplitude of OFDM signal than the linear range of transmitter amplifier. In these dynamic range amplifiers the efficiency lacks by reducing the Battery Life & Carbon Foot print. Mitigation of such constructive & destructive effects is essential for improved system performance[1].

The increase in no. of sub-carriers also increases the PAPR of OFDM which degrades the system performance of power amplifier & its efficiency. To overcome the problem of High PAPR few PAPR reduction techniques are used called Distortion & distortion less techniques.The distortion technique includes clipping, filtering, peak windowing, and companding,where the information is distorted by several methods without affecting the date rate of the signal & without any rise in power of the signal.The Distortion less technique includes Selected Mapping (SLM), Partial Transmit Sequence (PTS), coding techniques, interleaving and tone reservation and injection method where the information undergoes scrambling process without any distortion in information[2,3].

This paper proposes about PAPR reduction based on iterative addition and subtraction of OFDM symbols followed by DCT. DCT is to reduce the autocorrelation between the signals which in turn reduces the PAPR of the OFDM signal. To improve the PAPR performance of SAS pre-processed DCT aided technique by adding companding technique.

II. LITERATURE SURVEY

DCT precoded SLM technique for PAPR reduction in OFDM systems was done by I. Baig et al.,(2010). MIMO-OFDM Wireless Communication with MATLAB was done by et al., Y.Cho(2010).Combined DCT and companding for PAPR reduction in OFDM signals was done by Wang (2011). A PAPR reduction scheme without side information for OFDM signal transmissions was done by Takeda and Adachi (2012).Low complexity PAPR reduction technique for OFDM systems using modified widely linear SLM scheme was done by L.Yang et al.,(2012).Precoded DCT and low complexity SLM for PAPR reduction in OFDM systems was done by Nugrohoand Kim (2013).PAPR reduction scheme with selective tone reservation for

OFDMsignals was done by C.-C. Chen et al.,(2013).Linear precoding schemes for PAPR reduction in mobile WiMAX OFDMA System was done by Jijina and Pillai (2014). A Review on PAPR Reduction Techniques was done by yogita et al.,(2014).

III. PROBLEM

PEAK -TO - AVERAGE POWER RATIO

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[5, 10].

Peak to Average Power Ratio (PAPR) is defined as ratio of maximum power to the average power of complex signal. Mathematically it is given by

$$\mathrm{PAPR}\{x(t)\} = \frac{\max |x(t)|^2}{E\{|x(t)|^2\}} \qquad (1)$$

The PAPR is usually calculated through CumulativeDistribution Function (CDF) which is a probabilistic approach. A complex OFDM symbols is composed of real parts and imaginary parts. These real and imaginary parts are asymptotically Gaussian distribution for a large number of subcarriers. Hence, the amplitude of OFDM symbols followsRayleigh distribution. Assuming average power of s(t) is equal to one, E{|s(t)|2} = 1; then $z_n$are i.i.d. Rayleigh random variables normalised with its own average power will have Probability density Function (PDF)[4,6].

$$f z_n(z) = \frac{z}{\sigma^2} e^{\frac{-z^2}{2\sigma^2}} = 2ze^{z^2}$$

Where Z_n is the magnitude of complex samples $\{ s(nTs(N) \}_{n=0}^{N-1}$ and $E\{{z_n}^2\} = 2\sigma^2 = 1$

Now CDFZ_{max} is given as

$$FZ_{\max}(z) = P(z_{\max} < z)$$
$$= P(Z_0 < z), P(Z_1 < z), P(Z_{N-1} < z),$$
$$= (1 - e^{z^2})^N \qquad (2)$$

Where $Z_{\max} = \max_{n=0,1,2,\ldots\ldots N-1} Z_n$ is called crest factor (CF).

To find the probability that CF exceeds z we consider Complementary CDF (CCDF). CCDF can be given as

$$FZ_{\max}(z) = P(z_{\max} > z)$$
$$= 1 - P(Z_{\max} \le z)$$
$$= 1 - F_{\max}(z)$$
$$= 1 - (1 - e^{z^2})^N \qquad (3)$$

IV. PAPR REDUCTION METHODS

This section describes PTS and the proposed method. PTS scheme is seen to minimize PAPR effectively. So, performance of proposed method will be compared against PTS scheme.

PARTIAL TRANSMIT SEQUENCE (PTS) TECHNIQUE

In PTS scheme the input data block of length N is divided into V disjoint sub blocks. V number of sub blocks can be given as$X=[X^1 X^2 \ldots X^V]$ Where X^i, for I =1,2, . . . V , are sub blocks that arelocated consecutively and are of equal length. In PTS scheme scrambling is applied to a set of subcarrier which constitutes sub block.It is shown in Figure.1Each of the sub block is multiplied by a phase factor $b^v = e^{j\phi_v}$ for$v = 1,2,\ldots V$ subsequently, the IFFT of each sub block is computed[8, 11, 12]. Hence, the time domain signal after IFFT operation is given by

$$x = \mathrm{IFFT}\left\{\sum_{v=1}^{v} b^v X^v\right\}$$
$$= \sum_{v=1}^{v} b^v \,\mathrm{IFFT}\,(X^v)$$
$$= \sum_{v=1}^{v} b^v x^v$$

x^v is called the partial transmit sequence. The phase vector for minimum PAPR is given by

$$\widetilde{b^1}\ \widetilde{b^2} \ldots \widetilde{b^v} = \frac{\arg\min}{[b^1 b^2 \ldots b^v]}\left(\frac{\max}{n = 0,1,\ldots N-1}\left|\sum_{v=1}^{v} b^v x^v(n)\right|\right)$$

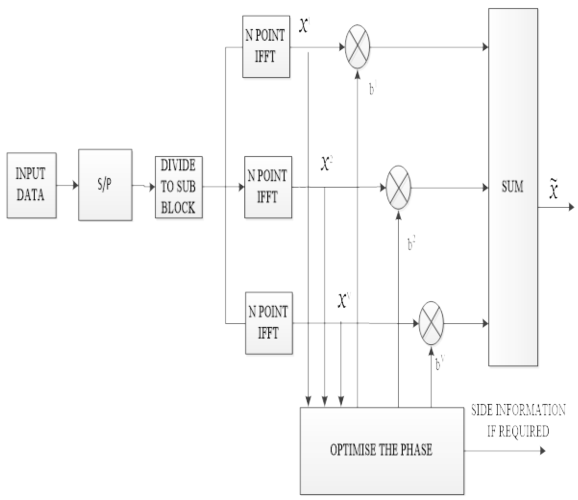

Fig 1.Partial Transmit Sequence Scheme for PAPR reduction

V. PROPOSED METHOD

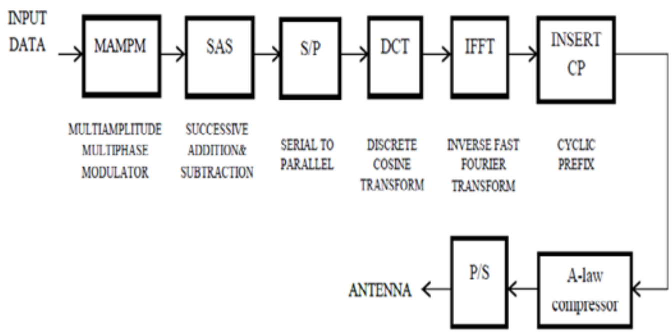

Fig 2.Transmitter using the SAS preprocessed DCT technique with companding.

The basic principle of this method is to change the phase of each successive sample inside the OFDM frame, based on Discrete Cosine Transformation technique aided with successive addition & subtraction of symbols inside the single Orthogonal Frequency Division Multiplexing Frame.[7,9].For N number of sub-carriers there are N samples denoted as n=0,1,2…..N-1 OFDM symbols. Each odd OFDM sample is multiplied by +1and each even OFDM symbol is multiplied by -1. First OFDM sample to be transmitted as it is. The second OFDM sample to be transmitted is addition of first two OFDM symbols (after multiplication by either +1 or -1). Similarly, the process goes on for N number symbols. Once, after the transformation of N OFDM symbols the DCT signal is taken. Then it is passed through IFFT block. Mathematically the transformed X(K) is given by

$$X_t(k)= \begin{cases} X(k) & \text{for } k = 0 \\ \sum_{i=\text{even}}^{K=k} X(i) - \sum_{i=\text{odd}}^{K=k} X(i) & k = 1,2,\ldots, N-1 \end{cases}$$
(4)

where $X_t(k)$ is the transformed signal.

A-law COMPANDING

In Companding method, the characteristic of compressor is piecewise which is made up of a linear segment for low level inputs & a logarithmic segment for high level inputs. The A-law companding is used for PCM telephone systems. The linear segment of the characteristic is for low level inputs whereas the logarithmic segment is for high level inputs. Significantly, this technique is used further to reduce the PAPR to the most in OFDM.A-law compressor output F(x) for input x is given by

$$F(x) = \operatorname{sgn}(x) \begin{cases} \dfrac{A(\max)}{1+\log(A)} & |x| < \dfrac{1}{A} \\ \dfrac{1+\log(A|x|)}{1+\log(A)} & \dfrac{1}{A} \le |x| \le 1 \end{cases} \quad (5)$$

V. SIMULATION RESULTS & DISCUSSION

The results are simulated using MATLAB and OFDM Parameters chosen for simulating the results are

- Number of sub-carriers: 128.
- FFT length: 128.
- Number of OFDM frames: 200.
- Channel model: Rayleigh multi-path fading channel.

CCDF (Complementary Cumulative Distribution Function) computes the power complementary to complementary distribution function from a time domain signal. The CCDF curve shows the average power level of the measured signal, or equivalently, the probability that the signal power will be above the average power level. CCDF can be computed using equations 2 and 3.

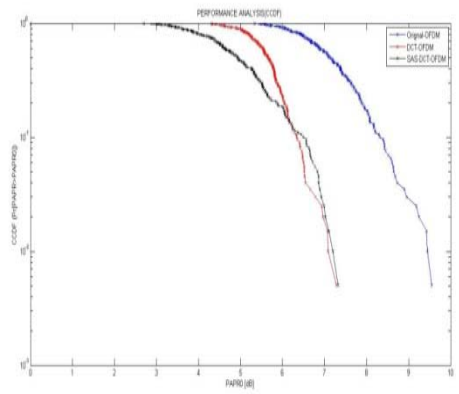

Figure 3 PAPR performance (CCDF) comparison using QPSK modulation.

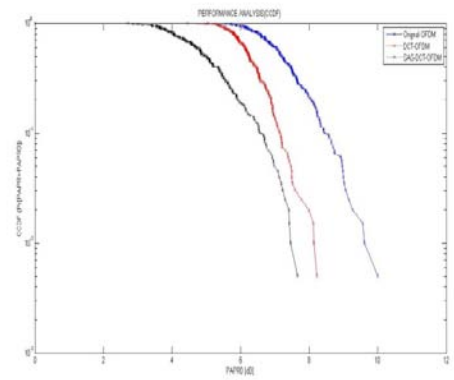

Figure 4 PAPR performance(CCDF) comparison using 16-QAM modulation.

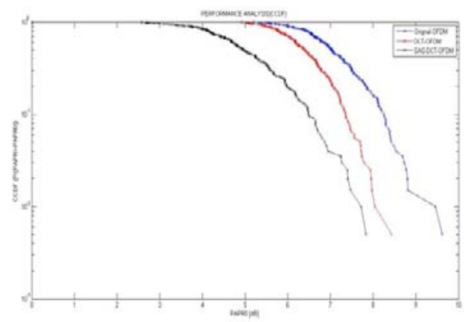

Figure 5 PAPR performance (CCDF) comparison using 64-QAM modulation.

Figure 3, 4 and 5 presentsPAPR performance comparison (CCDF) for SAS preprocessed DCT aided OFDM using QPSK,16-QAM and 64-QAM modulation.The performanceof SAS preprocessedDCTtechnique is asymptoticallysameas DCTmethod for QPSK. The performance of SAS preprocessed DCT method is better for higher level modulation(16-QAM and 64-QAM). PAPR can be further reduced by adding compression coding in SAS Preprocessed DCT. Here A-law compression is used.

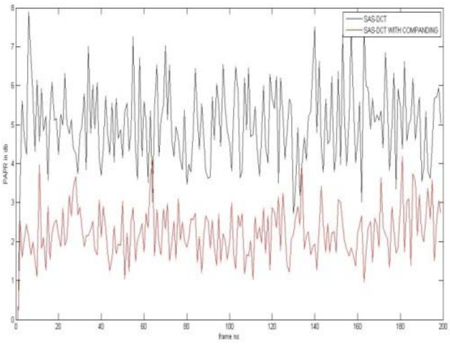

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Figure 6 PAPR of SAS preprocessed DCT aided OFDM with A-law companding usingQPSK modulation.

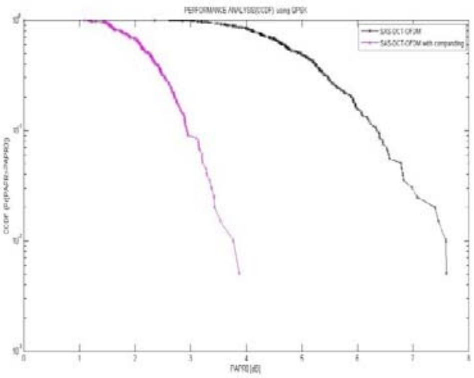

Figure 7 PAPR performance (CCDF) comparison of SAS preprocessed DCT aided OFDM with A-law companding using QPSK modulation.

Figure 7 shows PAPR performance can be improved using A-Law compression technique along with SAS preprocessed DCT aided PAPR reduction technique.

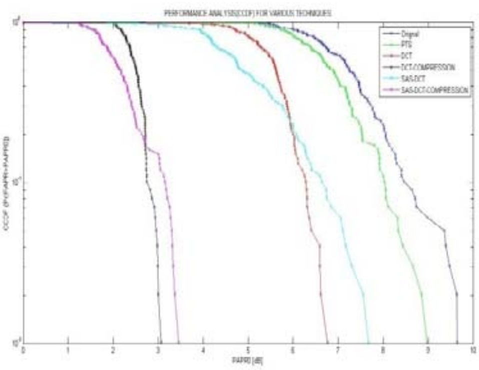

Figure 8 PAPR performance (CCDF) comparisons for various PAPR reduction techniques using QPSK modulation.

CONCLUSION

This method based on successive addition subtraction aided DCT for PAPR reduction and was presented and performance in term of CCDF was evaluated. The performance was further improved by adding compression technique. SAS preprocessed DCT is found to be simpler better than other algorithms. Using thismethod, in the receiver side, transmitted symbols can be will be decoded by taking simply the differentiation after IDCT. One more advantage of the proposed method is that sideinformation is not required to receive the signal at the receiverside. This work will be extended to implement receiver with better BER performance.

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