PAPR REDUCTION IN OFDM SYSTEM USING M2M DWT SCHEME

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Abstract - In this work OFDM system has been implemented with the distinguish wavelets with MSK modulation scheme, & named as M2M- DWT OFDM. Using the MSK modulation reduction in the implementation complexity is achieved, & also no need of channel estimation or equalization. Also, MSK is a minimum variation modulation and demodulation technique that compensates the channel effect on the signal without the need of any previous knowledge of the channel. AWGN channel model has been considered, since AWGN is a result of several independent noise sources which can be possibly added to the signal. Different wavelets sets have been taken & for them BER & PAPR analysis has been simulated. Simulation results shows that PAPR is reduced, with the use of DWT, instead of conventional DFT or FFT. Also, due to the inherit added advantage of wavelet based system, this system does require use of cyclic prefix, hence overall bandwidth efficiency is also more, as compared to the conventional FFT based OFDM.

Keywords—Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR),M-2M Mapping, Selected Mapping, DWT, FFT, AWGN.

I. INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is now a days widely used for wireless applications since it provides high data rate and also improves the spectral efficiency [1]. OFDM is a multicarrier digital communication technique in which the all available bandwidth is divided into many small streams of low data rate and then they are modulated with various different sub-carriers. One of the main shortcoming of OFDM is high PAPR (peak to average power ratio) [5]. To overcome this problem and to obtain efficient output power, generally the high power amplifier (HPA) is set to near the saturation region. The high PAPR mainly causes nonlinearity in the amplifier behavior. Due to this it works in the linear portion with large head-room and this tends to very inefficient amplification. So, it is customary to reduce the PAPR for making the system with less losses. The detailed analysis is given in the next sections.

OFDM signal generated by an N point Inverse Fast Fourier Transform (IFFT) in the transmitter, and the Fast Fourier Transform (FFT) can be used at the receiver to reform the signal. Now if the input complex-valued data of N subcarriers as: $X_N = X_K, K = 0,1,2 \ldots\ldots N-1$ is used to form with each of the symbol modulating the corresponding subcarrier from a set of opted orthogonal set, the discrete-time OFDM symbol can be written as:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{NL}kn}, 0 \le n \le NL-1$$

Where; X_K is the symbol carried by the K^{th}sub-carrier, L is the oversampling factor. An OFDM signal contains an "N" number of independently modulated subcarriers, which can be given a very large PAPR when added up coherently.

Further, one can also define PAPR for continuous time and discrete-time signals [6]. For a continuous-time OFDM signal, it can be defined at an instant as the ratio of the maximum power to the average power as:

$$PAPR\ [s(t)] = \frac{t \in \max_{[0,T_s]} |s(t)|^2}{E\{|s(t)|^2\}}$$

Where s (t) is the time-continuous type OFDM signal & in case of a discrete-time type signal, sampling is generally placed at a rate of Nyquist-rate to estimate true PAPR. But these samples which are taken here need not to be compulsorily overlapped with the time-continuous signal's peaks. To accurately estimate of PAPR, one need to perform oversampling of given OFDM signal. PAPR with oversampling factor L is given as [6];

$$PAPR[oversampling] = \max_{k\in[0,NL]} \frac{|x(k/L)|^2}{E\{|x(k/L)|^2\}}$$

Where, E [.] denotes the expected value, basically shows average power of the signal and x (k/L) are samples of the OFDM signal with oversampling and defined as:

$$x[k/L] = \sum_{n=0}^{N-1} s_n e^{i2\pi kn/N}$$

Where k=0, 1,……, LN-1. For the value L=1, the samples are called Nyquist-rate samples. PAPR with rate of Nyquist-rate sampling is:

$$PAPR[Nyquist - sampling] = \max_{k\in[0,NL]} \frac{|x(k/l)|^2}{E\{|x(l)|^2\}}$$

The rest of this paper is presented as follows. In Section II illustration of various PAPR reduction techniques. In Section III theoretically comparison of different PAPR reduction techniques including the advantages and disadvantages of these techniques are given. The next part concludes and give the briefs about the future possibilities to this work for implementations.

Statistically it can be possible to characterize the PAPR using Complementary Cumulative Distribution Function (CCDF). CCDF is a most common type of way to evaluate the PAPR by estimating the probability of PAPR, when this exceeds a particular level. The CCDF equation of the PAPR of OFDM signals with small subcarriers is written as:

$$CCDF = P(PAPR > PAPR_0) = 1 - (1 - exp(PAPR_O))^N$$

This equation is interpreted as the probability that the PAPR of a block symbol exceeds some threshold level $PAPR_O$.

PAPR is a measure of the envelope variations of a multicarrier signal and is used as FOM or figure of merit. Since OFDM signal consists of a number of independent modulated symbols, the sum of independently modulated subcarriers may have large amplitude fluctuations which causes in a large PAPR.

II. EFFECTS OF PAPR

As PAPR increases it results in the following effects [21]:

- Large dynamic range of the D/A and A/D converters will be required; if it is not increased then the peak values could be clipped, results in signal distortion.
- If A/D and D/A converters with large working ranges are taken, quantization noise will also increase and performance will degrade.
- Furthermore, the selection of power amplifier and up-converters will also be crucial when PAPR problem occurs. The working range of Power amplifier & up converters is required, so that the nonlinear distortion would not be introduced which results in decreasing the power efficiency of Power amplifier.

III. PAPR REDUCTION TECHNIQUES

PAPR reduction techniques can be mainly divided into two types. These are signal scrambling techniques and signal distortion techniques [24].

The signal scrambling techniques are classified as:

- Block Coding Techniques
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

The Signal Distortion Techniques are classified as:

- Peak Windowing
- Envelope Scaling
- Clipping

IV. PROPOSED PAPR REDUCTION TECHNIQUE

In this work the conventional IDFT & DFT blocks are replaced by IDWT & DWT respectively. The advantages of DWT are that there is no need of cyclic-prefix in DWT-OFDM systems because of the inherit overlapping properties of wavelet transform. Also, wavelets have one main advantage that its side lobs have less amount of data & that most of the data is contained in the main lobe, hence the chances of interferences are reduced. Also, in this work MSK modulation scheme is adapted for modulation & demodulation. The advantages of MSK is that it reduces interference, since it has minimum transitions. In this work use of different types of wavelet filters are used for simulation like 'Haar', 'Symlet', 'biorthogonal', 'Mayer' & 'coiflet'.

The proposed mapping scheme maps M-ary data points to 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme. The proposed mapping scheme completely eliminates the requirement of SI. The M-2M scheme utilizes (1, j) as phase rotation factors instead of the conventional pair of two phase rotation factors (1,-1) to map M data points to 2M constellation points. The reason behind this choice of the phase rotation factors is discussed by taking the examples of various mapping schemes using (1,-1) or (1, j) as phase rotation factors. This phase rotation factor is altered in this mapping of M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme.

As shown in Figure 5.1, the binary input signal is first converted into M-ary data signal and then M-2M mapping scheme is applied to obtain M initial mapped modulated data symbols. After this, these modulated data symbols are converted into N parallel sub-streams by using S/P converter and then a block of N parallel data symbols $\{X_k\}_{k=0}^{N-1}$ undergoes to IDWT operation; then each of these sequence is multiplied with the phase rotation factors and then combined to avoid the peak formation, internally as the mother wavelets are taken for decomposition. A phase optimization technique can be used to reduce the computational complexity [13] and at the same time to achieve good PAPR reduction capability.

Then discrete time domain OFDM signal is obtained at next stage. After this signal undergoes to P/S converter to obtain a serial OFDM signal. The obtained discrete time OFDM signal is passed through a digital to analog (D/A) converter to obtain the analog OFDM signal. Finally, the analog signal is amplified by using HPA to achieve the desired signal power level and finally transmitted over communication channel.

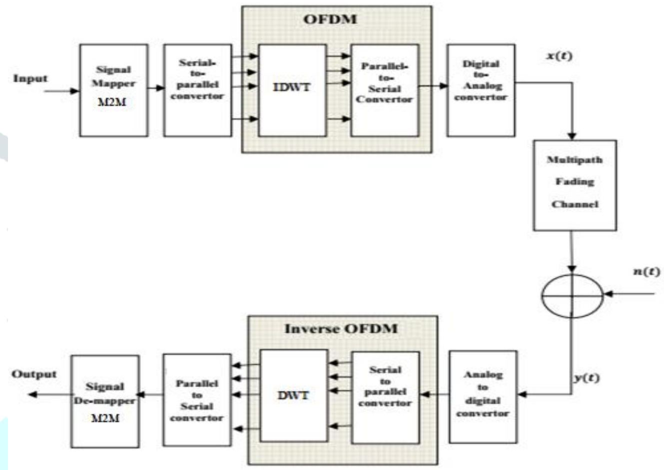

Figure 1: Block diagram of Proposed MSK DWT-OFDM Transceiver

Symbol	Phase factor sequence			
Si	1	-1	j	-j
±Si*	1	-1	-j	j

Table 1: Proposed Phase factor sequence mapping

MSK is a multilevel modulation technique. MSK is chosen as the modulation scheme as it doesn't require any channel estimation nor equalization at the receiver, which improves the complexity of the receiver compared to other modulation schemes. As MSK can be represented as follows:

$$Si,k = Bi,k.Si-1,k$$

Where; $S_{i,k}$ is the complex symbol, $B_{i,k}$ is the bit sequence to be modulated and $S_{i-1,k}$ is the previous modulated complex symbol. In this dissertation MSK was employed. MSK uses both amplitude and phase for modulation. For MSK the number of bits per modulated symbol or in other words the number of bits used to get $B_{i,k}$ in equation (5.1) is six. Those six bits are going to be referred to as b_0, b_1, b_2, b_3, b_4 and b_6. The first four bits are responsible for the phase modulation while the last two bits will be responsible for the amplitude part along with the previous modulated symbol.

V. SIMULATION RESULTS

In this work a model as an additive white Gaussian noise (AWGN) has been considered, since AWGN is a result of several independent noise sources which can be possibly added to the signal. Using the MSK modulation reduction in the implementation complexity is achieved, & also no need of channel estimation or equalization. Also, MSK is a minimum variation modulation and demodulation technique that compensates the channel effect on the signal without the need of any previous knowledge of the channel. For simulation use of wavelets has been done. Different wavelets sets have been taken & for them BER & PAPR analysis has been simulated. Simulation results shows that PAPR is reduced, with the use of DWT, instead of conventional DFT or FFT. The PAPR of conventional OFDM system without any PAPR reduction method is typically 10-15 dB.

7.1 BER

For evaluation of overall performance of any OFDM system, one of the parameter is Bit Error Rate, which is the ratio of number of bits in error in the received signal to the transmitted signal. BER is obtained at distinguish SNRs, & is used to obtain to check the robustness of the signal to the channel impairments. Figures below shows the BER at distinguish SNRs for proposed M2M-DWT OFDM system for distinguish wavelets for AWGN channel model.

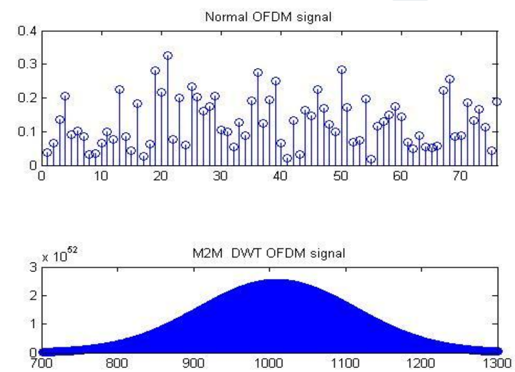

Figure 7.1: PAPR comparison of Proposed system with Normal OFDM

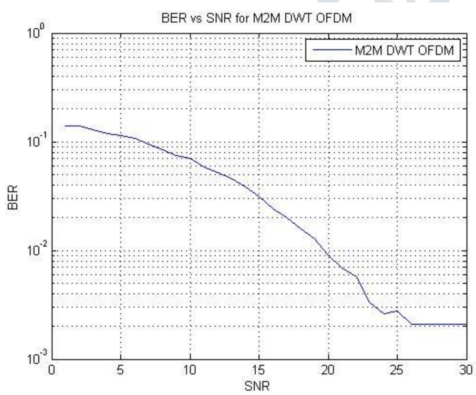

Figure 7.2: Performance of BER using 'Haar' wavelet at different SNR

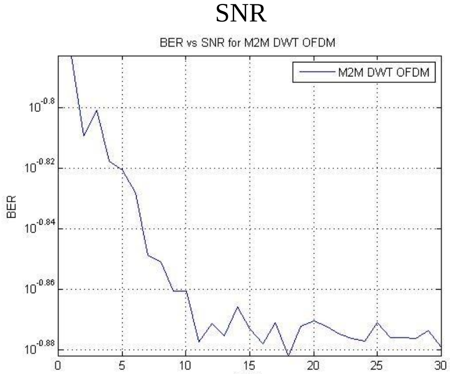

Figure 7.3: Performance of BER using 'Symlet' wavelet at different SNR

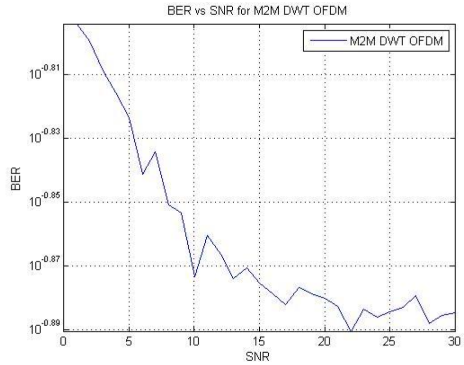

Figure 7.4: Performance of BER using 'dB2' wavelet at different SNR

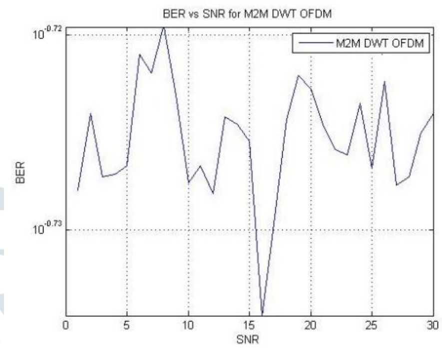

Figure 7.5: Performance of BER using 'Coiflet' wavelet at different SNR

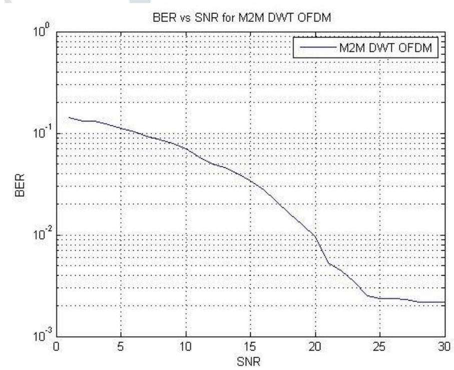

Figure 7.6: Performance of BER using 'Bior' wavelet at different SNR

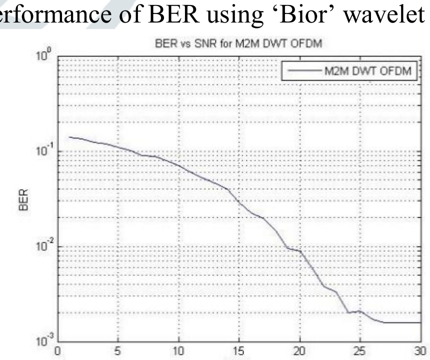

Figure 7.7: Performance of BER using 'Rbio' wavelet at different SNR

SNR (dB)	BER					
	'Haar'	'Symlets'	'Coiflets'	'dB2'	'Bior'	'Rbio'
5	0.100	0.148	0.250	0.147	0.100	0.100
10	0.075	0.134	0.280	0.132	0.073	0.071
15	0.061	0.127	0.186	0.125	0.058	0.056
20	0.001	0.120	0.253	0.118	0.001	0.001
25	0.008	0.111	0.259	0.109	0.007	0.006
30	0.007	0.100	0.260	0.100	0.006	0.004

Table 2.: BER analysis for different Wavelets of simulation results

From the above table 2, the BER results shows that for proposed M2M-OFDM, the performance of 'rbio' or Reverse Orthogonal wavelets, outperforms all other wavelets. Also, we can observe that Biorthogonal wavelets performs better than Haar wavelets. For the remaining other available wavelets the BER performance is not upto the mark, as for these mentioned wavelets. This shows that noise immunity of proposed system is more as compared to the conventional DFT based system. It is because of the fact the side lobes of the sub-carriers generated by DWT are less than as compared to DFT which makes it more immune to ISI.

7.2 PAPR

The other parameter of performance of any OFDM system is the peak to average power ratio (PAPR), which is a measurement of the variations in the peak values of signal's envelope. Figures shows the CCDF of the PAPR for the proposed system.

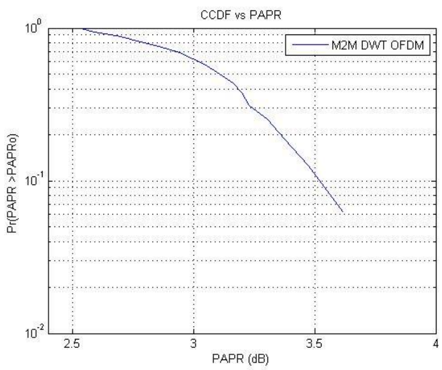

Figure 7.8: PAPR of the proposed M2M-DWT OFDM using 'Haar' wavelet

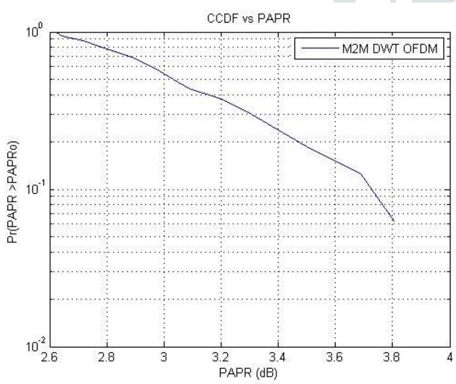

Figure 7.9: PAPR of the proposed M2M-DWT OFDM using 'Symlet' wavelet

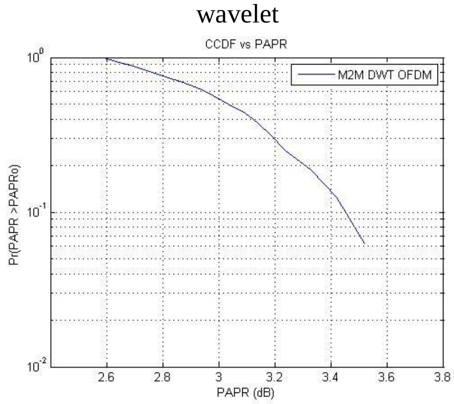

Figure 7.10: PAPR of the proposed M2M-DWT OFDM using 'dB2' wavelet

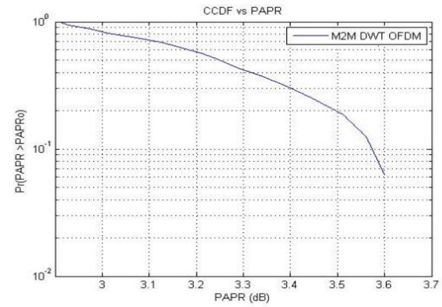

Figure 7.11: PAPR of the proposed M2M-DWT OFDM using 'Coiflet' wavelet

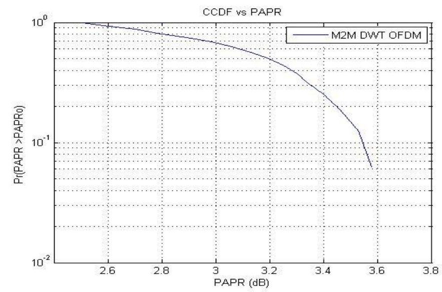

Figure 7.12: PAPR of the proposed M2M-DWT OFDM using 'Bior' wavelet

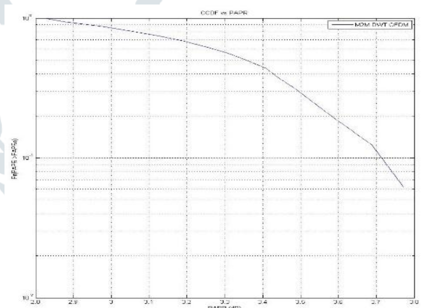

Figure 7.13: PAPR of the proposed M2M-DWT OFDM using 'Rbio' wavelet

CCDF (PAPR>PAPRo)	PAPR (dB)					
	'Haar'	'Symlet'	'Coiflet'	'dB2'	'Bio'	'Rbio'
0.01	3.5	3.6	3.6	3.5	3.6	3.7

Table 3: CCDF of the PAPR analysis for different Wavelets of simulation results

From the above table 3, PAPR vs CCDF simulation results are interpreted that, for Haar wavelets, PAPR is minimum equals to 3.5 dB. Also, using biorthogonal wavelets PAPR is 3.6 dB. Hence, we can conclude that both the wavelets can be used for PAPR reduction effectively.

7.3 Results Comparison

For the sake of comparison of simulation results of proposed work are tabulated with reference work in table 4.

PAPR>PAPRo (CCDF)	Original OFDM	Dummy signal Insertion [2]	Conventional Hybrid [2]	Modified Hybrid [2]	Hybrid with dummy signal insertion [2]	Improved Low Complexity 4 PTS [1]	Proposed M2M DWT OFDM
10^{-1}	9-11 dB	6 dB	8 dB	7.7 dB	5.8 dB	4 dB	**3.5 dB**

Table 7.3: Simulation Results Comparison

From the above table 4, we can observed that the proposed system has very less PAPR, as compared to previous work. An improvement of 2.1 dB with [2] & 0.5 dB improvement with [1].

VI. CONCLUSION

OFDM is the efficient modulation technique for multi-carrier transmission and high data rate transmission and it is also spectrally efficient. Major limitation of this scheme is PAPR. In this paper, new algorithms are proposed by mapping of phase rotation factor, by the mapping of M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme. With this property, the proposed algorithms can reduce half of the computational complexity compared with the conventional algorithms. BER performance of Biorthogonal wavelet is better than Haar, but PAPR using Haar wavelet is 0.1 dB less than the Bior wavelet. The results of the PAPR showed that the proposed system has lower PAPR when compared to the conventional DFT based OFDM system. The PAPR of the proposed system is 3.5-3.7 dB. Based on these two parameters, i.e. BER & PAPR we can say that for better BER & PAPR performance Biorthogonal wavelet & Haar wavelets, both can be adapted according to requirements.

Also, due to the inherit added advantage of wavelet based system, this system does require use of cyclic prefix, hence overall bandwidth efficiency is also more, as compared to the conventional FFT based OFDM.

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