Reduced Complexity Max Norm based PAPR Optimization in OFDM systems

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Abstract :- Orthogonal Frequency Division Multiplexing (OFDM) is a suitable multicarrier modulation scheme for high speed broadband communication systems. OFDM provides bandwidth efficiency and robustness against multipath fading channels, but is sensitive to nonlinear effects due to the high Peak-to-Average Power Ratio (PAPR) of the transmitted signal. The reduction in PAPR is desirable in order to obtain power efficiency and to increase BER performance. This paper proposes an efficient Reduced Complexity Max Norm (RCMN) algorithm for optimizing the PAPR of the OFDM signals. The proposed technique avoids the use of additional Inverse Fast-Fourier Transform (IFFT) as compared to Selective Level Mapping (SLM) and Partial Transmit Sequence (PTS) and hence reduces the computational and phase search complexity. In addition, as compared to other probabilistic schemes such as SLM and PTS, the proposed scheme does not require the transmission of Side Information (SI) to the receiver, which provides better bandwidth utilization. The proposed scheme has been compared with SLM and PTS schemes and the results show that the RCMN improves PAPR optimization with less computational and phase search complexity.

Key-words:- OFDM, PAPR, IFFT, RCMN, IRCMN, CCRR

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a frequency division multiplexing scheme used for digital multi-carrier modulation method [1,2,3]. A large number of closely-spaced orthogonal sub-carriers are used to carry the data. OFDM consist of a block of 'N' data streams X_k (k=0, 1, …, N-1), of vector X, which will be transmitted in parallel [4,5]. These 'N' parallel data streams are then used to modulate 'N' orthogonal sub-carriers. Each baseband subcarrier is given as

$$\phi_k(t) = e^{j2\pi f_k t} \tag{1}$$

where, f_k is the k th subcarrier frequency.The subcarrier frequencies f_k are equally spaced as given by

$$f_k = \frac{k}{NT} \tag{2}$$

This makes the subcarriers $\phi_k(t)$ on $0 < t < NT$ orthogonal. One OFDM data symbol multiplexes N modulated subcarriers as given as,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \phi_k(t), \qquad 0 < t < NT \tag{3}$$

OFDM is widely used in broadband applications, such as Asymmetric Digital Subscriber Line(ADSL), Digital Audio Broadcasting(DAB), Digital Video Broadcasting(DVB), and Wireless LAN (IEEE 802.11a, g, n), Broadband Wireless Access (BWA) (IEEE 802.16e –WiMAX), Mobile Broadband Wireless Access (MBWA) (IEEE 802.20).

OFDM has several properties, which make it an attractive modulation scheme for high speed transmission links. OFDM is robust against narrow-band co-channel interference, Inter Symbol Interference (ISI) and fading. However, the main drawback of OFDM signal is that, it has high peak to average power ratio due to its nature of multicarrier modulation. This is widely believed as one of the most critical problem for OFDM systems. A larger PAPR requires a large Input Back-Off (IBO) of power amplifier and when OFDM signal passes through a non-linear amplifier the large PAPR may cause an increase in Bit Error Rate (BER) and Out-of-band distortion [6,7]. PAPR reduction is defined as the ratio of the maximum to the average power during an OFDM symbol period. For x(t), we therefore have

$$PAPR = \frac{\max_{0 \le t \le NT} [|x(t)|^2]}{P_{av}} \tag{4}$$

where p_{av} is the average power of x(t). In general, most of the systems deal with a discrete time signal, therefore we have to sample the continuous time signal x(t) by a oversampling factor of L, which is an integer greater than or equal to 1 [4]. The L-time oversampled samples can be obtained by performing LN point inverse FFT on the data block X, because Nyquist rate sampling probably misses some signal peaks. The L time oversampled signal can be given by (5)

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\Pi kn/LN} \quad (5)$$

For the discrete time signal x_n, the PAPR can be given as

$$PAPR = \frac{\max_{0 \le n \le LN-1} [|x_n|^2]}{E(|x_n|^2)} \quad (6)$$

where E(.) denotes ensemble average calculated over the duration of OFDM.

The Cumulative Distribution Function (CDF) and Complimentary CDF (CCDF) of PAPR are commonly used performance measures for PAPR reduction [8]. The probability that the PAPR given by equation (6) exceeds a threshold Po known as CCDF, can then be defined by(7) as in

$$P\,(PAPR > Po) = 1- (1-\exp(-Po))N \quad (7)$$

In this paper, we propose a new algorithm the Reduced Complexity Max Norm (RCMN) to optimize the PAPR. The proposed method also serves to reduce the computational complexity and search complexity of phase factors. The rest of the paper is organized as follows. In section 2, we briefly discuss the OFDM, PAPR and existing techniques for PAPR reduction. The proposed scheme based on RCMN is discussed in section 3. Section 4 shows the simulation results supporting the ideas presented. Finally conclusions are drawn in section 5.

2. Related Work

To solve the PAPR reduction problem in OFDM, a number of solutions have been proposed. These solutions may be classified as statistical schemes and probabilistic schemes. Statistical techniques like Coding[9], Amplitude clipping and Filtering[9], modify the time domain signal but introduce distortion in signals. The probabilistic schemes include Partial Transmit Sequence (PTS) [10,11], Selective Mapping (SLM), Interleaving, tone reservation (TR)[9], tone injection (TI)[9], and Active constellation extension and these techniques reduce the PAPR with some loss of data rate but increase with the computational complexity.

SLM is one of the commonly used distortion less probabilistic schemes for PAPR reduction [12,13,14]. In SLM, the transmitter generates U number of data blocks all representing the same information as the original data block. Data blocks are multiplied by different phase sequences $\varphi_k^{(u)}$ and each transformed by U separate Inverse Fast Fourier Transform (IFFT) to obtain $x[n]^{(u)}$=IFFT$\{X_k^{(u)}\}$ where u=[0,1,2,…..U-1]. The U candidates $x[n]^{(u)}$ are analyzed and the lowest PAPR sequence is selected for transmission. In order to recover the original data sequence, $\log_2(U)$ bits should be transmitted to the receiver as Side Information (SI) which decreases the information throughput $X_k^{(u)} = X_k e^{j\varphi_k(u)}$. This scheme requires N number of IFFT blocks, which leads to higher computational complexity. Finding the phase sequence for multiplication is random, therefore phase search complexity is also high.

In PTS technique [14,15,16,17] data block of N symbols is partitioned into V number of disjoint sub blocks $X_m = [X_{m,0}, X_{m,1}, \ldots\ldots X_{m,v-1}]^T$, where m=1,2,3….M, such that $\sum_{m=1}^{M} X_m = X$ and the sub blocks are combined to minimize the PAPR in time domain. The L-times oversampled time domain signal X_m, m=1,2,3……M, is obtained by taking an IFFT of length VL on X_m concatenated with (L-1)V zeros. These are called partial transmit sequences. The time domain signal after combining is given by

$$x'(b) = \sum_{m-1}^{M} b_m \bullet x_m \quad (8)$$

The selection of phase factors is limited to a set with a finite number of elements to reduce the search complexity. The set of allowed phase factor is given as, $P = \{e^{j2\pi l/W}\}$, where l=0,1,2……W-1 and W is the number of allowed phase factors. Therefore exhaustive phase search is required for this scheme and hence phase search complexity increases exponentially to the number of sub-blocks. Also PTS requires M number of IDFT operations for each data block leads to higher computational complexity. The side information required in this scheme is $\log_2 W^{M-1}$, resulting in poor bandwidth efficiency.

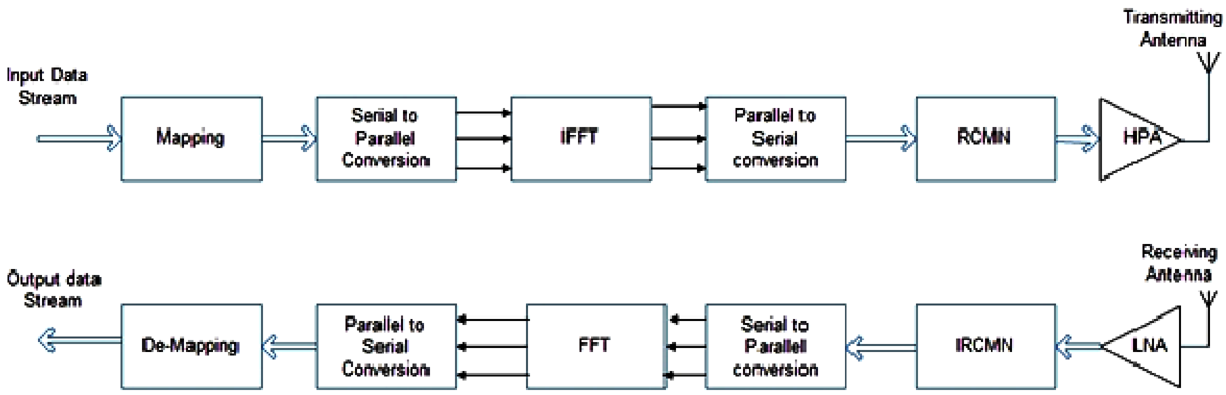

Fig 1 : Proposed OFDM system with RCMN algorithm for PAPR Optimization

3. Proposed Method

In this section, a novel Reduced Complexity Max Norm (RCMN) algorithm has been proposed, in order to optimize the PAPR of the OFDM signal. It is seen that this method greatly reduces the heavy computational complexity and phase search complexity. It is also not required to transmit the Side Information (SI), which is used to recover the data at the receiver end. The block diagram of the proposed OFDM system with RCMN algorithm for PAPR optimization is as shown in Fig 1.

The input data streams are mapped onto Quadrature Amplitude Modulation (QAM) [3] constellation, then applied to IFFT. RCMN transformation is then performed on the time domain signal. The inverse transformation proposed at the receiver effectively recovers the original data blocks without SI. BER performance of the proposed scheme is evaluated and compared with the existing schemes such as PTS and SLM.

3.1 Reduced Complexity Max Norm

The RCMN algorithm steps at the transmitter is detailed as follows:

Step1: Generate the input data $x=(x_1, x_2, \dots, x_n)$ and map with the BPSK or QAM constellation and get the modulated data stream X,

Step2: Calculate IFFT for the mapped data stream x=IFFT(X),

Step3: Find the maximum value from the IFFT output.

$\|x\|_{max} = \max(x_1, x_2,\dots, x_i,\dots, x_N)$

$\|x\|_{max} = x_i$

Step 4: Define the parametric form of maximum norm by introducing the parameter α. Multiply $\|x\|_{max}$ with the value of α.

$\alpha^*\|x\|_{max} = \alpha^*\max(x_1, x_2,\dots, x_{i,\dots,} x_N)$

$\alpha^*\|x\|_{max} = \alpha^* x_i$

where ‘α’ is a parameter, that adjusts the PAPR of the transformed output. Optimized value of α ranges from 2 to 5.

Step5 : The output is transformed using RCMN technique

$y = x - \alpha^* x_i$

$$y = ((x_1- \alpha^*x_i), (x_2 - \alpha^*x_i),\dots, (x_i -\alpha^*x_i),\dots, (x_N- \alpha^*x_i)) \quad (9)$$

$y = ((x_1- \alpha^*x_i), (x_2 - \alpha^*x_i),\dots, (1- \alpha)^*x_i,\dots, (x_N- \alpha^*x_i))$

Step6: Transmit the transformed output which offers low PAPR.

The RCMN algorithm Transmitter steps are depicted as a flow diagram in Fig 2. The RCMN algorithm steps at the receiver are as follows:

Step1: Receive the transmitted data block y.

Step2: Find the minimum value of y,

$$\min(y) = \min((x_1- \alpha^*x_i), (x_2 - \alpha^*x_i),\dots, (1- \alpha)^*x_i,\dots, (x_N- \alpha^*x_i)) \quad (10)$$

$\min(y) = (1- \alpha)^*x_i$

Step 3: Divide min (y) by (1- α) to obtain x_i

$\min(y)/ (1- \alpha) = x_i$

Step 4: To obtain x, add α^*x_i with y. From equation (9),

$x = y + \alpha^*x_i$

$x = ((x_1 - \alpha * x_i + \alpha * x_i), (x_2 - \alpha * x_i + \alpha * x_i), \ldots, (x_i - \alpha * x_i + \alpha * x_i), \ldots, (x_N - \alpha * x_i + \alpha * x_i))$

$x = (x_1, x_2, \ldots, x_{i, \ldots,} x_N)$.

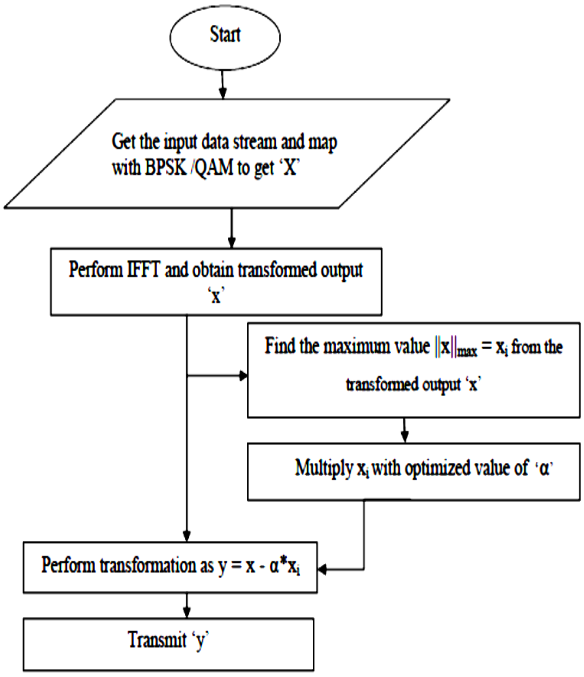

Fig 2. Flow diagram of RCMN algorithm at the transmitter

Step5: Calculate FFT for x, which gives the actual data block.

The RCMN algorithm Receiver steps are depicted as a flow diagram in Fig 3.

3.2 Computational and phase search complexity

In this paper, we consider the computational complexity of the PAPR reduction in terms of complex multiplications and complex additions required for IFFT. When the number of subcarriers $M=2^n$ and K the total number of IFFTs, the number of complex multiplications and complex additions required for K -IFFTs are *(M/2)nK* and *MnK* respectively. The proposed scheme requires only one IFFT block instead of K- IFFT's required for conventional SLM scheme. However, this scheme requires *2M+1* additional operations for finding maximum value and further distance findings. The Computational Complexity Reduction Ratio (CCRR) [18] of the proposed RCMN scheme as compared with conventional SLM and PTS scheme is given by,

$$CCRR = 1 - \frac{\text{complexity of the proposed scheme}}{\text{complexity of the conventional scheme}}$$

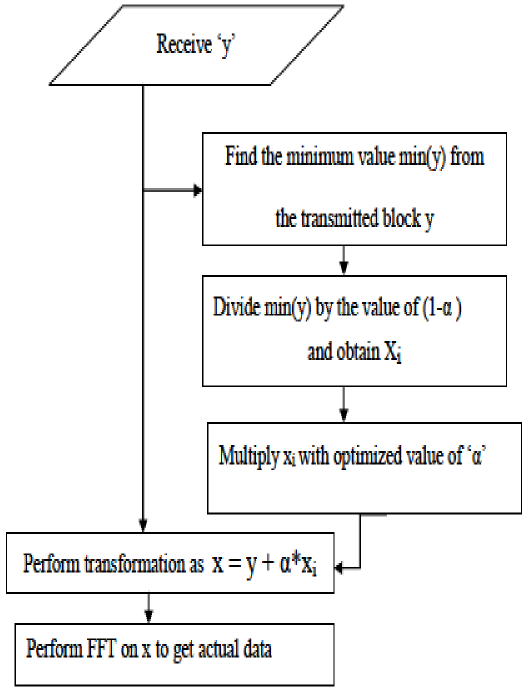

Fig 3. Flow diagram of RCMN algorithm at the Receiver

The CCRR of the proposed scheme over the SLM scheme with typical values of M=64 and 256 was given in Table 1.

The analysis shows that the proposed scheme becomes computationally more efficient than the conventional SLM as M increases. The proposed method satisfies the property of one-to-one transformation necessary for reconstruction [19]. Hence, there is no exhaustive phase search is needed as required in conventional PTS and SLM schemes.

3.3 Proof of reconstruction for RCMN

The reconstruction of the vector at the receiver is possible if and only if the proposed transform is one-to-one. In the original sequence after mapping and IFFT the sequences are given as

$$x = (x_1, x_2, x_3, \ldots, x_n) \qquad (11)$$

The transformed sequence vector is denoted as,

$$x' = (x_1', x_2', x_3', \ldots, x_n') \qquad (12)$$

Based on the proposed RCMN method the maximum value obtained from the vector x is denoted as x_i. Now the equations (11) and (12) are represented as a function of x and x' is given in terms of x_i and x_j is given by the equations (13) and (14).

$$f(x) = x(n) - \alpha x_i = (x_1 - \alpha x_i, x_2 - \alpha x_i, x_3 - \alpha x_i, \ldots, x_n - \alpha x_i) \qquad (13)$$

Table 1: Computational complexity of the conventional SLM and the proposed RCMN scheme

		Conventional SLM/PTS	RCMN	CCRR (in %)
Number of IFFT's		8	1	79.1%
Number of Complex Multiplication	M=64	1536	321	
	M=256	8192	1537	81.2%
Number of complex addition	M=64	3072	513	83.3%
	M=256	16384	2561	84.3%

$$f(x') = x'(n) - \alpha x_j'$$
$$= (x_1' - \alpha x_j',\ x_2' - \alpha x_j',\ x_3' - \alpha x_j', \ldots,\ x_n' - \alpha x_j') \quad (14)$$

To show one-to-one relationship, $f(x) = f(x')$; if $x = x'$. From equations (13) and (14) we get

$$x(n) - \alpha x_i = x'(n) - \alpha x_j'$$

$$(x_1 - \alpha x_i, x_2 - \alpha x_i, x_3 - \alpha x_i, \ldots, x_n - \alpha x_i) = (x_1' - \alpha x_j', x_2' - \alpha x_j', x_3' - \alpha x_j', \ldots, x_n' - \alpha x_j')$$

ie.,
$$x_1 - \alpha x_i = x_1' - \alpha x_j'$$
$$x_2 - \alpha x_i = x_2' - \alpha x_j'$$
$$x_3 - \alpha x_i = x_3' - \alpha x_j'$$
$$\ldots$$
$$x_n - \alpha x_i = x_n' - \alpha x_j'$$

Case 1:

The minimum value for the function f(x) occurred at position 'i', and minimum for f(x') will occur at position j, since f(x)= f(x') if i=j.

$$x_i - \alpha x_i = x_i' - \alpha x_j' \quad (15)$$
$$x_i - x_i' = \alpha x_i - \alpha x_j'$$
$$x_i - x_i' = \alpha(x_i - x_i')$$
$$(1-\alpha)(x_i - x_i') = 0$$

The optimum value of α range from 2 to 4, therefore (1-α) is not equal to zero.
Hence $x_i - x_i' = 0$ i.e. $x_i = x_i'$

Case 2:

If $x_i = x_j'$, maximum values are equal. Therefore from equation (15)

$$x_i - \alpha x_i = x_i' - \alpha x_j'$$
$$x_i - x_i' = \alpha(x_i - x_j')$$
$$x_i - x_i' = 0$$
$$x_i = x_i'$$

4. Results and Discussions

To compare and evaluate the PAPR optimization performance, extensive simulations have been performed based on RCMN algorithm using MATLAB. In simulations, an OFDM system has been considered with N=64 and 128, L=4 and Quadrature Amplitude Modulation (QAM) is implemented. The simulation parameters used are given in Table 2.

Table 3 compares the PAPR values for original OFDM with SLM and with RCMN for various types of data blocks. It is seen that, highest PAPR results when all the bits in a data block are same and orthogonal. It can be seen from the results that OFDM with RCMN works effectively gives reduced PAPR for all types of data blocks where the data bits may be same, orthogonal or random.

In the simulation we used 16-QAM baseband modulation scheme. Each modulated symbol is transmitted through N=64 sub carriers by 64-point IFFT and L=4 oversampling is employed to estimate PAPR precisely. To analyze PAPR reduction and power amplifier efficiency, we consider class A power amplifier which is the most linear with power efficiency [20]. In practical OFDM systems, even linear amplifiers impose a nonlinear distortion if excited by a large input, causes the out-of-band radiation that affects signals in adjacent bands, and in-band distortion that results in rotation, attenuation, and offset on the received signal. The maximum possible output P_{Out}^{Max} is limited by saturation point when the corresponding input power is given by P_{In}^{Max}.

Table 2: Simulation Parameters

Parameter	Specifications
Modulation	QAM
Number of data subcarriers M	64, 128
Number of FFT/IFFT points(N)	64,128
Number of data symbols	16
Over sampling factor	L=4
Bandwidth, BW	1MHz
Sampling Frequency, (BW x L)	4 MHz
Number of Guard Interval Samples	32

The input must be backed-off so as to operate the PA in linear region. Therefore, the nonlinear region can be described by Input Back-Off (IBO) or Output Back-Off (OBO) is given in equations (16),(17).

$$IBO=10\log_{10}P_{In}^{Max}/P_{in} \quad (16)$$

$$OBO=10\log_{10}P_{Out}^{Max}/P_{out} \quad (17)$$

In this paper, we assume a fixed probability of clipping to $1x10^{-4}$ therefore PA is adjusted by required IBO according to PAPR of the input signal to ensure that the clipping will not exceed $1x10^{-4}$, also the analysis will be performed on a fixed Bit Error Rate (BER).Table 4 summarizes the relation between probability of clipping and corresponding PAPR (dB) for different number of sub carriers.

In Class-A PA, the overall efficiency is defined as $\eta_A=\frac{Pout}{P_{DC}}$, where $\overline{P_{out}}$ and P_{DC} are the average output power and total DC power consumed by the PA. Power amplifier efficiency in terms of OBO is given in Eq. (18) [20].

$$\eta_A=0.5/OBO, \quad (18)$$

In Table 4, OFDM signal with 128 subcarriers exhibits PAPR of 11.2 dB (13.18) at the probability of clipping level of $1x10^{-4}$ .The PA should be forced with an IBO equal to PAPR which results in a power efficiency of η_A =0.5 / 13.18=3.79%; the loss in efficiency should be noted from the results. From equations (16), (17), we obtain,

$$P_{DC}=2*\overline{P_{out}}*PAPR \quad (19)$$

From equation (19), if PAPR is reduced, the consumed DC power P_{DC} also reduced for the same level of $\overline{P_{out}}$ [20]. Therefore from equation (19), power saving

$$P_{saving}=2*\overline{P_{out}}(PAPR_b-PAPR_a) \quad (20)$$

where $PAPR_b$ is the DC power consumed by PA before PAPR reduction and $PAPR_a$ is the DC power consumed
by PA after PAPR reduction. In [20], saving gain is shown in equation (22) using equation(20).

$$G_{saving}=P_{saving}/\overline{P_{out}} \quad (21)$$

$$G_{saving}=2(PAPR_b-PAPR_a) \quad (22)$$

To investigate saving gain, the BER is set to 1×10^{-4} and corresponding SNR is calculated using the formula in equation (21)[19,21].

$$BER=\frac{4}{k}\,Q\left(\sqrt{\left(\frac{3}{M-1}\right)SNR}\right) \quad (23)$$

where M is the modulation level and 'k' denotes the number of bits per symbol. Saving gain of the proposed method is defined in equation (22).

Fig. 4 shows saving gain at different values of α. From the figure, α=3 is selected because it satisfies the required BER values and a high saving gain of 8.06 dB. If the value of α greater than 4, P_{saving} will be greater than 9 dB, however these higher gains is achieved with the expense of BER degradation. Fig. 5 shows the PAPR reduction performance of RCMN at α=[0:1:10].

The proposed method offers better reduction at α=3 and above, however α=3 is the one at which required BER of 1x 10^{-4} is obtained.

Table 3: Comparison of PAPR for various data blocks using RCMN and SLM

Data Block	PAPR (dB)		
	Original	SLM	RCMN
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	12.0412	3.5218	0.2085
1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 1 -1	12.0412	2.9269	0.2085
-1 -1 1 -1 1 -1 -1 1 1 -1 -1 -1 1 1 1 -1	5.8971	3.7298	2.9480
1 -1 1 1 1 -1 -1 1 -1 -1 -1 -1 1 1 1 -1	2.9269	2.9269	2.1530
1 1 1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 -1 1 -1	3.4952	3.0103	2.9013

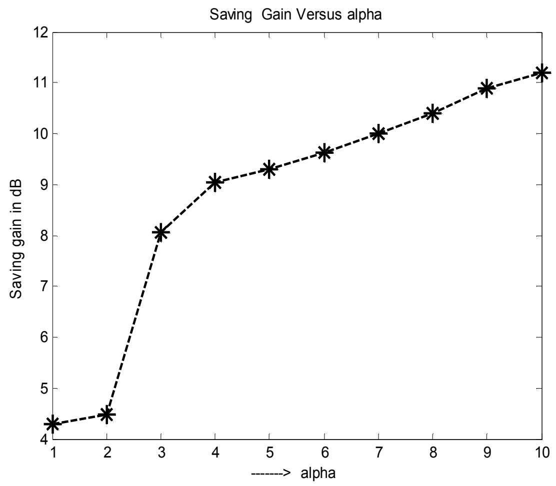

Fig 4. Saving Gain Versus 'α'

The average signal power for various values of α is listed in Table 5. For the value of α greater than 4, it may be observed that average signal power is high and the PAPR is too low, however this increase in signal power limits the system performance.

It is also observed that, if α<2, the average signal power is low, causes high value of PAPR which affects the performance of power amplifier (PA). Therefore it is found that, the optimum PAPR result is obtained for α = 3.

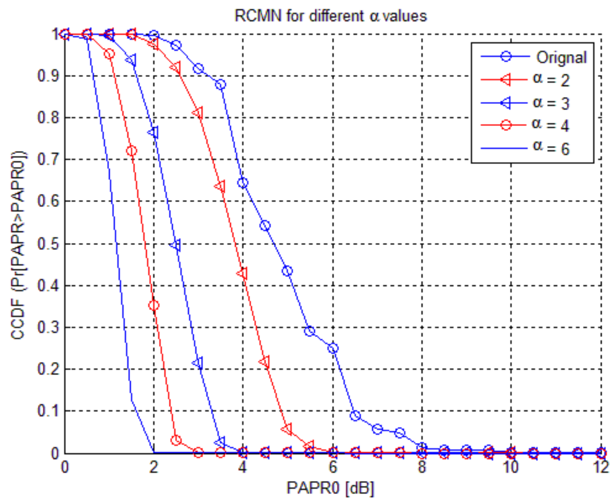

Fig 5: PAPR reduction performance of RCMN

Table 4: Comparison of PAPR values for RCMN with Existing schemes.

No. of sub carriers	PAPR Reduction schemes (with PAPR in dB)		$P=10^{-2}$	$P=10^{-3}$	$P=10^{-4}$
64	PTS	Original	9.8	10.4	11.4
		PTS	8.8	9.6	10.2
		RCMN	7.0	8.0	8.4
	SLM	Original	9.2	10	10.8
		SLM	7.0	7.8	8.0
		RCMN	5.2	5.8	6.0
128	PTS	Original	10.0	10.6	11.2
		PTS	9.0	9.8	10.4
		RCMN	7.0	7.8	8.2
	SLM	Original	9.6	10.2	11.0
		SLM	7.8	8.0	8.5
		RCMN	5.0	5.2	5.6

Fig.6 shows the CCDF of PAPR in the RCMN scheme with M=64 with QAM modulation scheme.

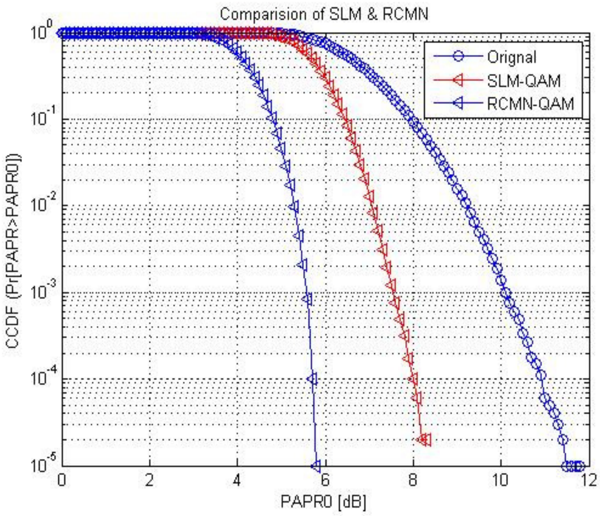

Fig 6: CCDFs of PAPR in RCMN with SLM at M=64

It is easy to observe that at 0.0001% of CCDF the conventional SLM scheme offers 2.8dB reduction and the proposed scheme offers 5.2dB reduction when compared to the original values. Fig.7 shows the CCDF of PAPR in the RCMN scheme with M=128 with QAM modulation scheme.

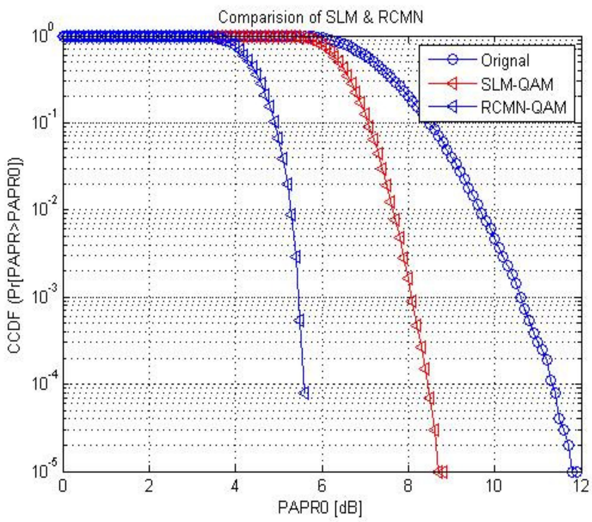

Fig 7: CCDFs of PAPR in RCMN with SLM at M=128

Fig.8 shows the CCDF of PAPR in the RCMN and PTS scheme with M=64 with QAM modulation scheme.

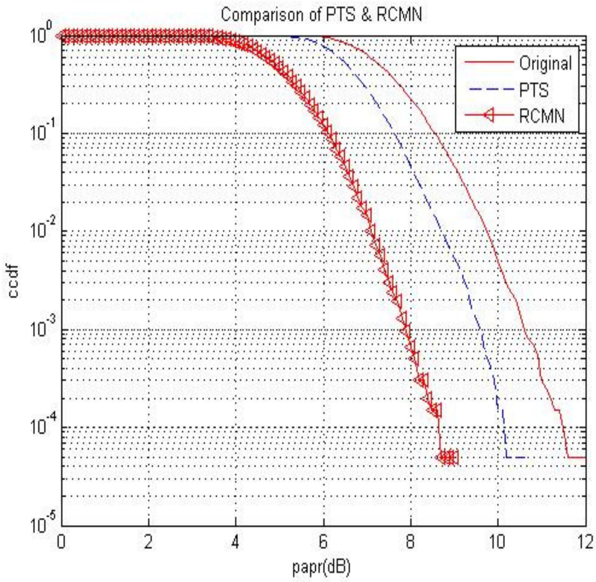

Fig 8: Comparison of CCDF plots of PAPR in RCMN with PTS at M=64

It is observed that at 0.0001% of CCDF the conventional SLM scheme offers 3.2dB reduction and the proposed scheme offers 6.2dB reduction when compared to the actual values.

It is observed that at 0.0001% of CCDF the conventional PTS scheme offers 1.5dB reduction and the proposed scheme offers 3.5dB reduction for M=64. Fig.9 shows the CCDF of PAPR in the RCMN and PTS scheme with M=128 with QAM modulation scheme.

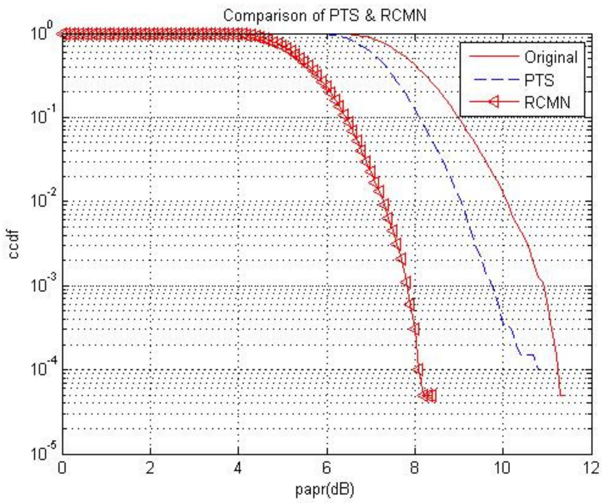

Fig 9: Comparison of CCDF plots of PAPR in RCMN with PTS at M=128

Table 5. Average signal power for various values of α

Data Block	Average Signal Power				
	α = 1	α = 2	α = 3	α = 5	α = 6
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0.8750	3.6250	8.3750	23.8750	34.6250
1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 1 -1	0.8750	3.6250	8.3750	23.8750	34.6250
-1 -1 1 -1 1 -1 -1 1 1 -1 -1 -1 1 1 1 -1	0.2500	0.8750	2.0000	5.7500	8.3750
1 -1 1 1 1 -1 -1 1 -1 -1 -1 -1 1 1 1 -1	0.5000	2.0000	4.6250	13.2500	19.2500
1 1 1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 -1 1 -1	0.2500	0.8750	2.0000	5.7500	8.3750

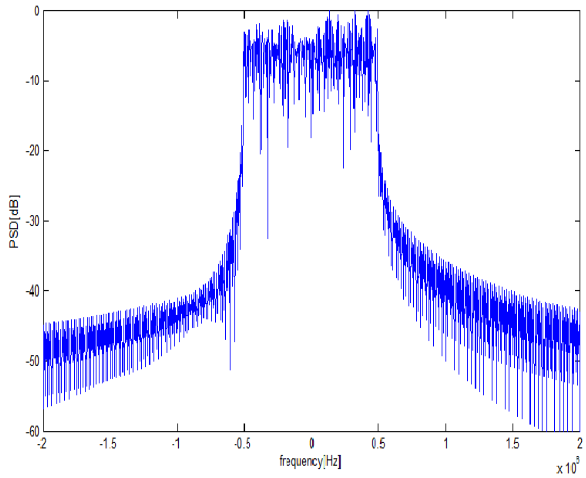

Fig 10:Power spectral density of OFDM with RCMN

It is observed that at 0.0001% of CCDF the conventional PTS scheme with M=128, offers 1.0dB reduction and the proposed RCMN scheme offers 3.5dB reduction under QAM mapping. Further it has been observed that the RCMN algorithm with QAM, with M=64 & 128 offers almost similar optimization performance. This justifies that the proposed algorithm can be implemented in various number of sub carriers.

The out-of-band (OBO) distortion is also investigated in the simulation by estimating power spectral density (PSD) of the signal at the output of Power Amplifier in Fig 10. The PSD is computed by means of averaged periodograms of the signal.

Fig.11 shows the BER performance in AWGN channel obtained for the proposed RCMN and Conventional PTS, SLM schemes. We conclude that BER performance of RCMN is better in comparison with conventional schemes at BER = 10^{-4}.

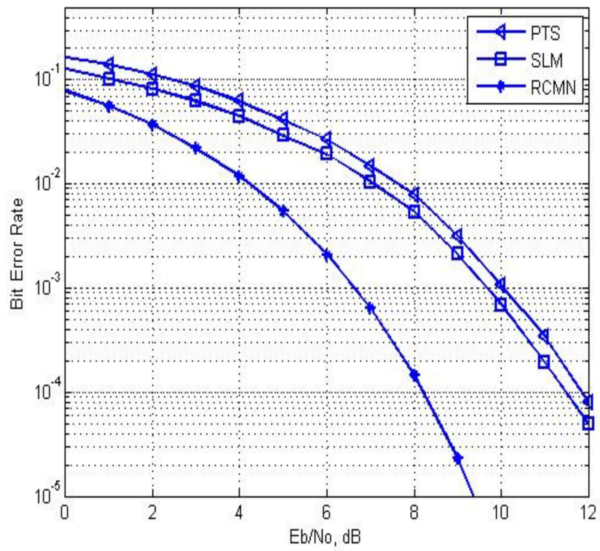

Fig 11: BER performance of OFDM with RCMN: FFT=64; QAM=16; α=3

5. Conclusion & Future Work

This paper proposes a new Reduced Complexity max Norm algorithm for PAPR optimization. It is seen from the simulation results that the proposed method offers better PAPR reduction performance than the conventional SLM and PTS schemes with reduced computational and phase search complexity. One of the main advantages of the proposed algorithm is the ability to reconstruct the original signal using one-to-one transform property at the receiver. Hence it is not required to transmit side information to reconstruct the signal at the receiver end. The proposed method works effectively for high data rates and suitable for OFDM based wireless communication systems such as IEEE 802.11a,b,g, 802.16e,n, DAB/DVB and HiperLAN/2. As future work it is proposed to extend to MIMO-OFDM systems.

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