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PEAK-TO-AVERAGE POWER RATIO REDUCTION USING CODING AND HYBRID TECHNIQUES FOR OFDM SYSTEM

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Abstract

In this article, the research work investigated is based on an error correction coding techniques are used to reduce the undesirable Peak-to-Average Power Ratio (PAPR) quantity. The Golay Code (24, 12), Reed-Muller code (16, 11), Hamming code (7, 4) and Hybrid technique (Combination of Signal Scrambling and Signal Distortion) proposed by us are used as proposed coding techniques, the simulation results shows that performance of Hybrid technique, reduces PAPR significantly as compared to Conventional and Modified Selective mapping techniques. The simulation results are validated through statistical properties, for proposed technique's autocorrelation value is maximum shows reduction in PAPR. The symbol preference is the key idea to reduce PAPR based on Hamming distance. The simulation results are discussed in detail, in this article.

Keywords:

Orthogonal Frequency-Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Selected Mapping (SLM), M-ary Phase Shift Keying (MPSK), Forward Error Correction (FEC), Bit Error Rate (BER)

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has become a good candidate for wireless multimedia communication by virtue of its excellent properties in frequency-selective fading environments. In OFDM, data is transmitted over several parallel low data rate, channels which provide data integrity due to fading, relative to modulation methods that employ a single channel for high data rate transmission. However, OFDM suffers from high Peak-to-Average Power Ratio (PAPR).

In the last two decades, many researchers has been evolved coding techniques as state-of-art to reduce undesirable quantity i.e. PAPR of OFDM systems (Viz. Coding techniques [1, 2, 3], tone reservation [4], tone injection [4], Active constellation [5], multiple signal representation techniques such as Partial transmit sequence(PTS) [6, 7]. Selected Mapping (SLM) based on a standard array coding method [8, 9, 10] and interleaving [11]. These techniques achieve good PAPR reduction at the expense of increase in transmitting signal power, decrease in bit error rate, loss of data rate, and increase in computational complexity many more [12].

Recently, researchers evolved, modified SLM technique based on standard array linear block coding [13, 24, 26, 27] technique (LBC (7, 4)) and Linear coding techniques [14].

It is proposed and investigated some coding techniques, namely Linear Block Codes (7, 4), Reed-Muller Code (16, 11), Golay Code (24, 12) and Hybrid Techniques (combination of signal scrambling and signal distortion techniques). These techniques reduce PAPR significantly, discussed more in section-3.0 and section 4.0.

2. PAPR OF OFDM SIGNAL

PAPR is defined as the ratio of the maximum power to average power of a system, the PAPR of a discrete-time signal is given by,

$$PAPR = \frac{\max_n \{x[n]^2\}}{E_n[x[n]^2]} \tag{1}$$

where, $E[.]$ denotes, expectation operator and $x[n]$, is the discrete time domain samples [4].

3. PAPR REDUCTION TECHNIQUES

As signal reshaping techniques suffer from in-band and out-of-band interference leads to degradation in system performance in terms of BER [1, 12, 23 and 25]. To reduce this effect Forward Error Correction (FEC) coding technique are applied across several OFDM symbols [12, 16-19, 24, 26 and 27]. Among these better techniques are, selective mapping, partial transmit sequence and block coding.

3.1 CODING TECHNIQUES

While dealing with the linear block code, it is convenient to use systematic encoder. A systematic encoder for block code is one that maps each data word (consists of data symbols) into a code word with the data symbols unmodified in the first symbols of the code word. The remaining symbols are called as the check symbols. Here redundant bits are used to spread the symbols in time domain before modulation this result in reduction of PAPR.

3.2 HAMMING CODE

In this paper $(n,k) = (7, 4)$ is used with parity check bits $m = 3$ along with the message bits. The parity check matrix H of size $(n - k)\times n$ is a very interesting, systematic parity check matrix is given by,

$$H = [I_{3\times 3}|P^T] \tag{2}$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}. \tag{3}$$

Thus the generator matrix of order 4×7 in the systematic form of the binary Hamming code is given by,

$$G = [I_{4\times 4}|P^T] \tag{4}$$

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}. \quad (5)$$

In the parity check matric H, it is observed that two columns are linearly dependent, three columns add up to zero thus the minimum distance of (n, k) Hamming $d_{\min} = 3$. The error detecting and correcting capability is given by,

$$t_d \leq d_{\min} - 1 = 2 \quad (6)$$

$$t_c = \frac{d_{\min} - 1}{2} = 1. \quad (7)$$

Hamming code decoding is performed by syndrome decoding technique, $S = rH^T$, if S is a null vector, means no error in the received data, if not corresponding syndrome error pattern will be selected, finally corrected code word is obtained by receiving bits, where r received code word and e is the error pattern [20, 24].

3.3 GOLAY CODE (24, 12)

For experimentation, extended Golay Code (24, 12) is considered, the generator matrix is given by,

$$G = [I_{12}|Q] \quad (8)$$

$$G = \begin{bmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&1&1&0&1&1&1&0&0&0&1&0&1 \\
0&1&0&0&0&0&0&0&0&0&0&0&1&0&1&1&1&0&0&0&1&0&1&1 \\
0&0&1&0&0&0&0&0&0&0&0&0&0&1&1&1&0&0&0&1&0&1&1&1 \\
0&0&0&1&0&0&0&0&0&0&0&0&1&1&1&0&0&0&1&0&1&1&0&1 \\
0&0&0&0&1&0&0&0&0&0&0&0&1&1&0&0&0&1&0&0&1&0&1&1 \\
0&0&0&0&0&1&0&0&0&0&0&0&1&0&0&0&1&0&1&1&0&1&1&1 \\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&1&0&1&1&1&1&1&1&1 \\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&1&0&1&1&0&0&1&1&0&1 \\
0&0&0&0&0&0&0&0&1&0&0&0&0&1&0&1&1&0&1&1&1&0&0&1 \\
0&0&0&0&0&0&0&0&0&1&0&0&1&0&1&1&0&1&1&1&0&0&0&1 \\
0&0&0&0&0&0&0&0&0&0&1&0&0&1&1&0&1&1&1&1&0&0&1&1 \\
0&0&0&0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1&0
\end{bmatrix}.$$

The Golay Code (23, 12) is a perfect code indicating that the code is having 23 bits, 12 information bits and 23-12 = 11 check bits and it is a sub-class of cylic code with a minimum hamming distance $d_{\min} = 7$. The distance between any two Golay Code (23, 12) codewords is always eight or more bits, the parity check matrix H shows that no six columns are linearly independent. The code rate is 0.52 and it is triple error correcting code [20]. The generator polynomial of the Golay Code (23, 12) is given by,

$$g(x) = x^{11} + x^{10} + x^6 + x^5 + x^4 + x^3 + x^2 + 1. \quad (9)$$

Authors [21] used the Golay complementary sequences to achieve the PAPR reduction, in which more than the 3-dB PAPR reduction had been obtained. Codes with error correcting capabilities has been proposed in to achieve more lower PAPR for OFDM signals by determining the relationship of the coset's of Reed-Muller codes to Golay complementary sequences. While these block codes reduce PAPR, they also reduce the transmission rate, significantly for OFDM systems with large number of sub-carriers.

3.4 REED-MULLER CODE (16, 11)

They were first introduced by Muller [22] and provided with a decoding algorithm by Reed in 1954. One reason that Reed-Muller codes are easy to implement and have a simple decoding algorithm. For decoding of $RM(r,m)$ code majority logic decoding is used.

The Reed-Muller codes holds following properties on:

i) $RM(m-2, m)$ are extended Hamming codes of length 2^m.

ii) $RM(1, m)$ consists of the rows of the Hadamard matrix $H_{2^m} = H_2 \otimes \ldots\ldots \otimes H_2$ where we change the 1 to 0 and -1 to 1, together with their complements.

In our experimentation $RM(16, 11)$ code generator matrix is used as given below,

$$G = \begin{bmatrix}
1&0&0&0&0&0&0&0&0&0&0 \\
1&0&0&0&1&0&0&0&0&0&0 \\
1&0&0&1&0&0&0&0&0&0&0 \\
1&0&0&1&1&0&0&0&0&0&1 \\
1&0&1&0&0&0&0&0&0&0&0 \\
1&0&1&0&1&0&0&0&0&1&0 \\
1&0&1&1&0&0&0&0&1&0&0 \\
1&0&1&1&1&0&0&0&1&1&1 \\
1&1&0&0&0&0&0&0&0&0&0 \\
1&1&0&0&1&0&0&1&0&0&0 \\
1&1&0&1&0&0&1&0&0&0&0 \\
1&1&0&1&1&0&1&1&0&0&1 \\
1&1&1&0&0&1&0&0&0&0&0 \\
1&1&1&0&1&1&0&1&0&1&0 \\
1&1&1&1&0&1&1&0&1&0&0 \\
1&1&1&1&1&1&1&1&1&1&1
\end{bmatrix}. \quad (10)$$

3.5 PROPOSED HYBRID TECHNIQUE

A combination of modified SLM [13] and µ-Law compander achieves better PAPR reduction as compared all other techniques as shown in Fig.1. In the companding technique compression of high peak OFDM signals done at the transmitter and expansion at the receiver side [23], its mathematical expression are given by,

$$y = V \frac{\log\left(1 + \mu \frac{|x|}{V}\right)}{\log(1+\mu)} \, sign(x) \quad (11)$$

where, V is the peak amplitude of the input and output signals specified for the µ-Law compander, and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of y [26].

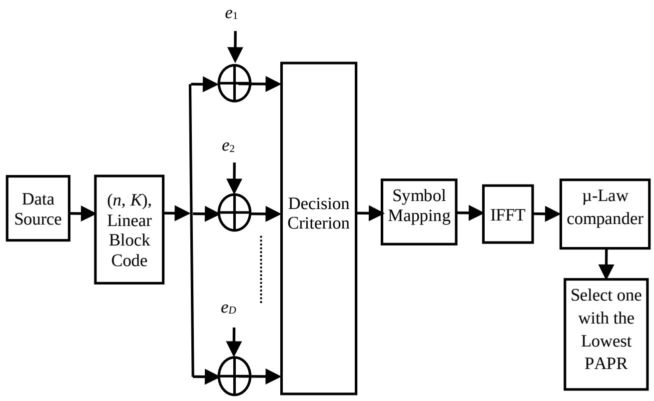

Fig.1. Block diagram of the Hybrid technique

4. RESULTS AND DISCUSSION

To verify the performance of the proposed methods to measure the PAPR reduction performance, Simulations are undertaken by using MATLAB R2013 by considering as per Table.1 simulation parameters. The performance of proposed systems has been evaluated and compared by plotting CCDF curves.

Table.1. Simulation parameters are considered to measure the PAPR performance

Sl. No.	Parameters	Value
1	Hamming Code	(7,4)
2	Primitive Polynomial Coefficients	[1 1 0 1]
3	Number of sub-Carriers	64
4	Size of FFT	256
5	Symbol Mapping	QPSK/DQPSK
6	Number of symbols	900
7	Type of Compander	Mu(μ)-Law
8	Extended Golay Code	(24,12)
9	Reed-Muller code	(16,11)

From Fig.2 to Fig.4 it is clear that, Hybrid technique (combination of SLM and Companding) performance is better than other techniques. Further, it is also observed that, Combination of SLM and Golay PAPR reduction performance is same as that of Hybrid technique. Hence linear code performance is better than other techniques, at the cost of bandwidth.

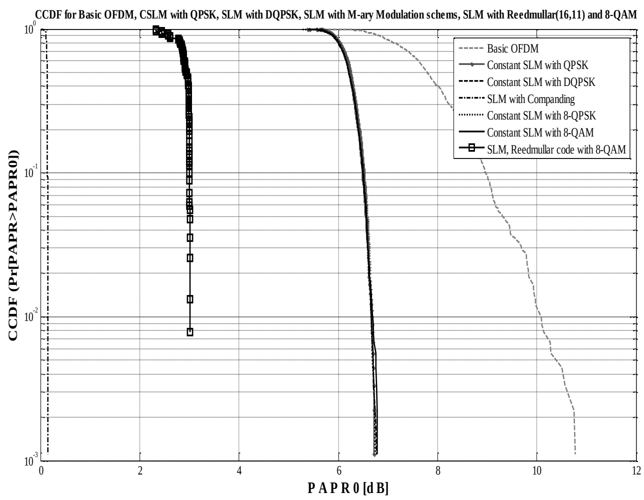

Fig.2. CCDF curve for Basic OFDM, conventional SLM, SLM with Companding and SLM with Reed-Muller code

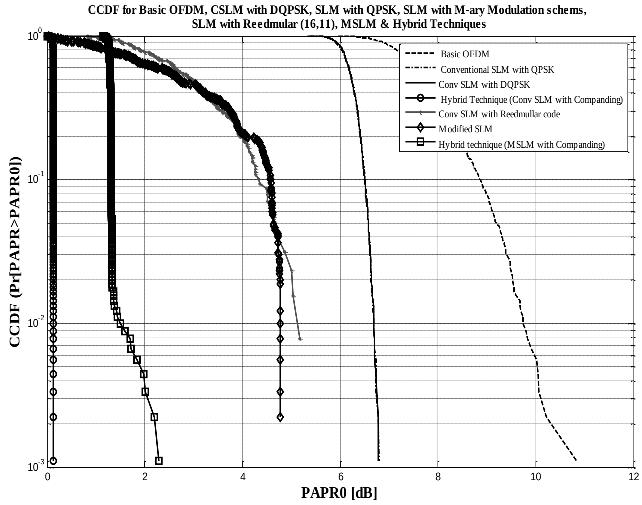

Fig.3. CCDF curve for Basic OFDM, conventional SLM, and SLM with Companding, MSLM with Companding, Modified SLM and SLM with Reed-Muller code

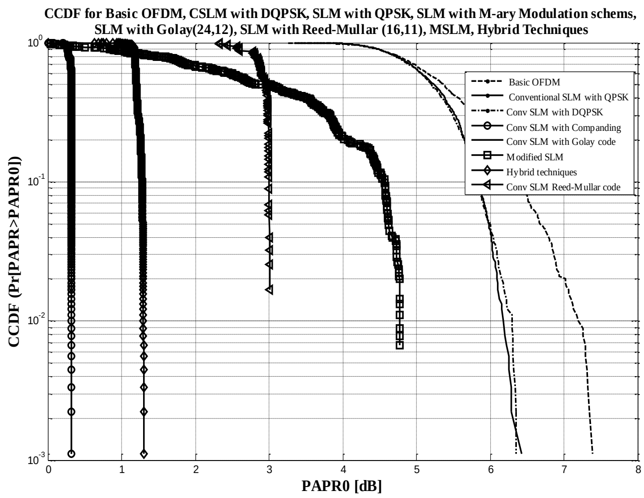

Fig.4. CCDF curve for basic OFDM, SLM, SLM with Companding, SLM with Golay Code, Modified SLM, MSLM with Companding, and SLM with Reed-Muller code

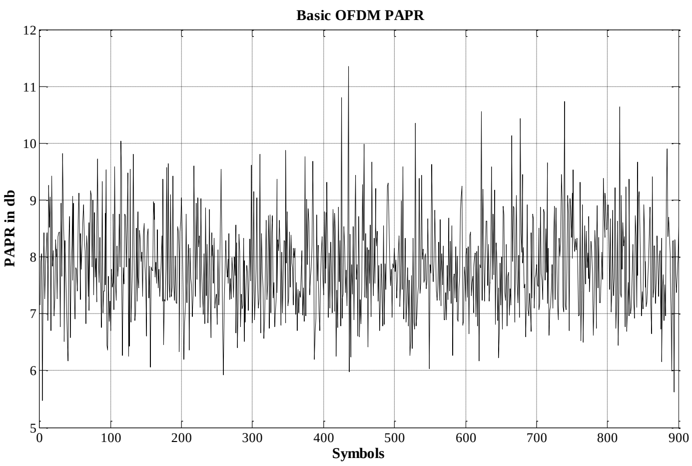

Fig.5(a). PAPR of basic OFDM system

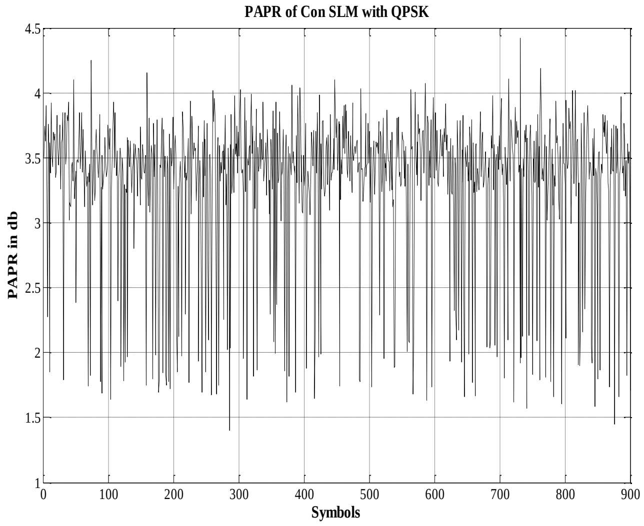

Fig.5(b). PAPR of the conventional SLM system using QPSK

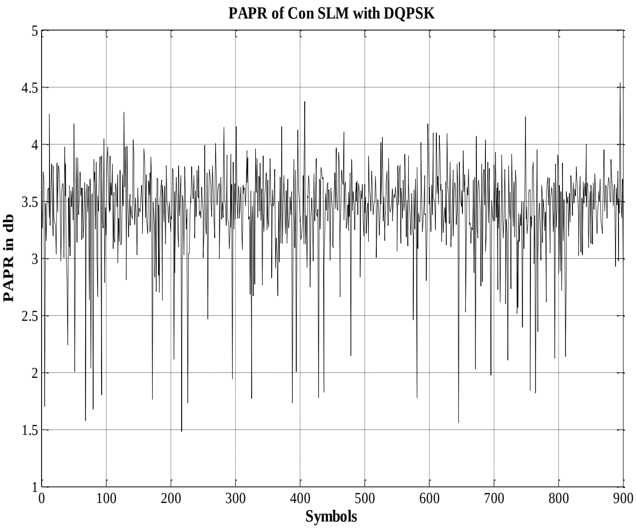

Fig.5(c). PAPR of the conventional SLM system using DQPSK

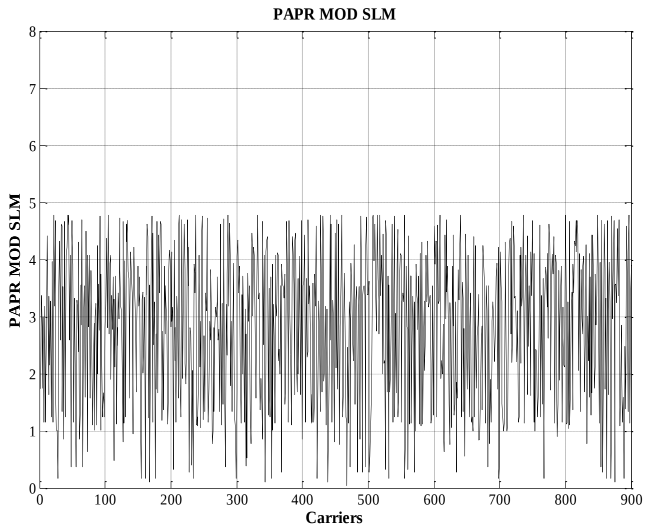

Fig.5(d). PAPR of the MSLM technique

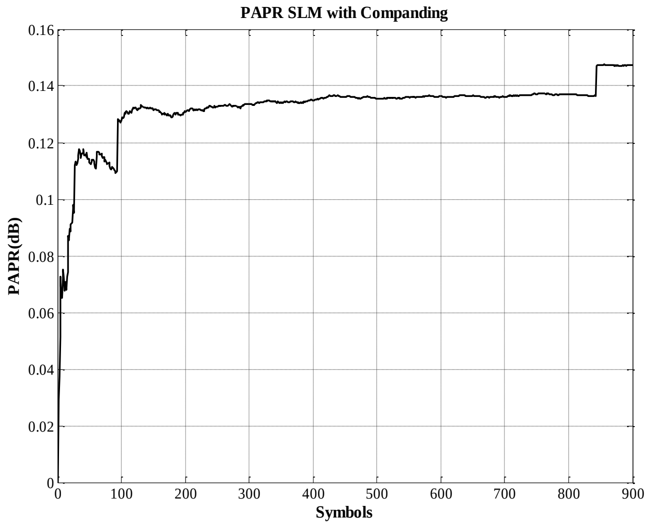

Fig.5(e). PAPR of the Hybrid technique

From Fig.5(a) to Fig.5(e) it is clear that more than 50% of PAPR reduction using modified SLM as compared to conventional techniques. However, Hybrid technique and Golay codes with SLM performance is better in terms of PAPR reduction.

From Table.2 it is clear that by use of test matrix in experimentation is to scramble the data symbols. It is possible to reduce PAPR significantly, among six test matrix; Orthogonal, Hadmard, Cauchy and Hilbert transform perform better than other four as shown in Table.2. The Choice of symbol mapping technique is also important for the reduction of PAPR, observe that small amount of PAPR reduction can be achieved by DQPSK.

The proposed Hybrid technique which is a combination of SLM and Companding method improves the reduction of PAPR as compared to other conventional coding techniques. It is further important to note, Golay Code performance is better than Reed-Muller code.

Table.2. PAPR value for SLM, Hybrid, Reed-Muller code, Golay code techniques

Sl. No.	Type of test Matrix	PAPR (dB) by considering test matrix's using Hamming Code (7,4)						PAPR (db) without test matrix's
		Basic OFDM	Conv. SLM (QPSK)	Conv. SLM (DQPSK)	Conv. SLM (S-QPSK)	Hybrid Techniques		Reed-Muller Code
						SLM with Compandar	MSLM with Compandar	
1	-	10.70	5.35	5.16	5.41	1.75	4.77	
2	Riemann	11.25	4.63	4.63	4.58	0.55	1.25	
3	Orthogonal	11.24	6.93	6.93	5.07	0.15	2.15	
4	Binomial	10.33	5.17	5.17	3.13	0.31	1.21	3.01
5	Hadamard	10.97	6.85	6.85	5.37	0.15	1.45	
6	Hilbert	7.54	6.46	6.46	3.52	0.32	1.31	
7	Cauchy	9.04	6.53	6.53	4.26	0.22	1.44	

Table.3. Statistical properties of basic OFDM with conventional SLM, MSLM and proposed techniques

Sl. No.	Statistical Properties	PAPR (dB)					
		Basic OFDM	SLM (DQPSK)	SLM (QPSK)	Hybrid Tech (SLM+Comp)	Hybrid Tech (MSLM+Comp)	RM Code
1	Avg. of Auto Correlation	0.04	0.04	0.06	0.87	0.04	0.05
2	Covariance	0.705	0.053	0.059	0.0004	1.973	0.028

3	Standard Deviation	0.839	0.229	0.243	0.019	1.405	0.168
4	Minimum	5.477	5.414	5.317	0	0.041	2.330
	Maximum	11.346	6.781	6.890	0.154	4.771	3.008
5	Mean	7.839	6.22	6.229	0.141	2.656	2.882
6	Entropy	0	0	0	2.386	1.264	0

The Table.3 results analysis shows that the statistical properties of basic OFDM with conventional SLM, MSLM and proposed techniques. The average auto correlation, and Entropy value for Hybrid technique is maximum as compared other techniques. However covariance, standard deviation, minimum, maximum and mean statistical values are minimum as compared other techniques. This shows that proposed Hybrid techniques achieves minimum power.

The Fig.6 represents the constellation plot for conventional SLM (CSLM) and Modified SLM (MSLM), it is observed that before and after phase rotation, there is no change in OFDM symbol constellation point for the QPSK scheme (as shown by magenta diamond and red asterisk). Whereas for CSLM with DQPSK before phase rotation OFDM symbol points are away from the origin (Black square box) and after phase rotation symbols are near to the origin (magenta circle). However, for MSLM techniques, symbols points are nearest to the origin (green triangle). This signifies the symbols near to origin consume less power than far away symbols with respect to the origin.

In Fig.7 it is important to note that, Hybrid technique (SLM with Golay code) certain symbols are too closer to origin as compared to all other coding techniques. Hence, the lower hamming distance ($d_{\min}$) symbols consume lesser power as compared to larger Hamming distance ($d_{\max}$) symbols. This resulting into a reduction in PAPR as compared to other techniques. This signifies such minimum Hamming distance symbols consumes lesser power are selected for transmission. Thus the resultant reduction in PAPR is observed as compared to other techniques.

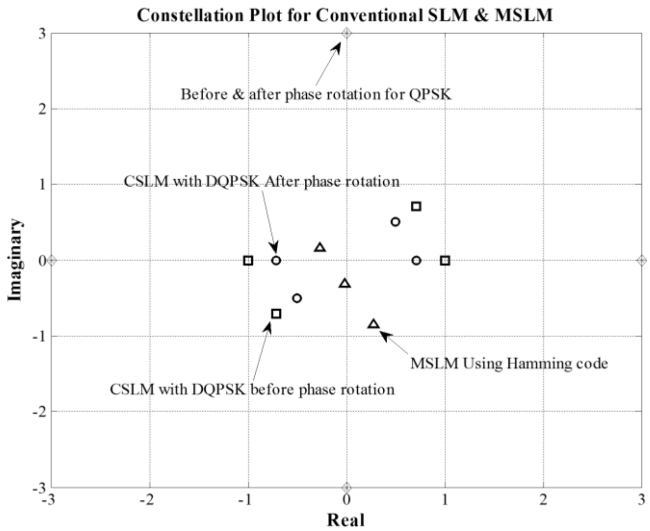

Fig.6. Constellation plot for conventional SLM and Modified SLM

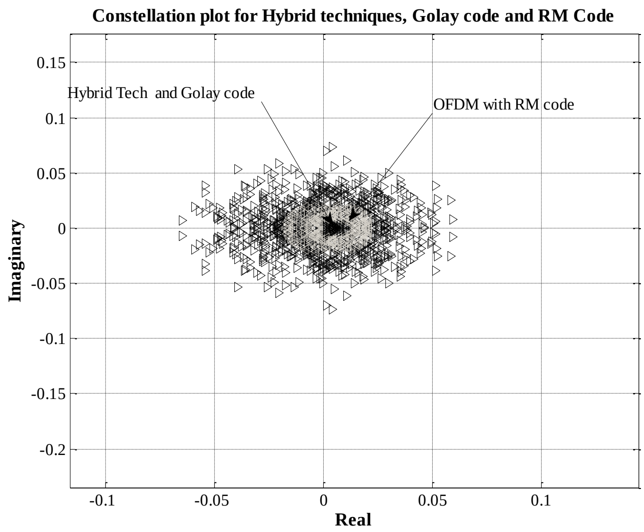

Fig.7. Constellation plot of OFDM system with Hybrid Technique, Golay Code and RM Code

5. CONCLUSION

In the proposed system, Hybrid technique gives a greater reduction in PAPR as compared to other conventional techniques (SLM, MSLM, Golay and Reed-Muller codes). The Choice of modulation scheme (DQPSK) and scrambling of data by test matrix viz. Orthogonal Matrix, Hilbert, Cauchy and Hadmard-transform in Hybrid technique results in significant reduction of PAPR.

Further results of the proposed technique have been validated by statistical properties and Constellation plot. The Hybrid technique have maximum average autocorrelation value 0.87 as compared to other techniques. Thus the introduction of phase rotation for proposed coding technique reduces the constellation points near to origin, resulting in reduced PAPR.

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