# Impact of reformed RM Encoded data on PAPR of Multicode CDMA under MSK

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*Abstract* — **In this research work, the effect of Reformed Reed Muller Encoded Data (RRMED) on Peak to Average Power Ratio (PAPR) of Multicode Code Division Multiple Access (MC-CDMA) systems was studied under Minimum Shift Keying (MSK) modulation. Simulation studies revealed that implementation of RRMED on PAPR with MSK modulation can save up to 7dB of transmitter power compared to the un-coded PAPR of MC-CDMA systems.**

**Simulation results further proved that MSK modulation also plays an important role in reducing PAPR as compared to binary Phase Shift Keying (PSK).**

*Index Terms* –**MC-CDMA, MSK, PAPR, RM**

## I. INTRODUCTION

MC-CDMA is a multiple access technique, which include backward compatibility, simplicity, high data rates, error correcting capability and orthogonality. The concept behind MC-CDMA is to allocate several channels to a user who wants to relay at a desired data rates [1,7]. These several channels present at the base station as several users. Each channel is then multiplied by the standard data rates, which boost up standard data rates [1,2,3,8].

MC-CDMA depends on addition of n channels of standard data rates for transmission, from an orthogonal square matrix known as discrete WHT. This addition of n signals yields in high amplitude, which is n times the mean signal power. Normally, $n = 2^m$, where m is within limit of 2 and 6 [1-3]. Thus, transmission of MC-CDMA signals with no malformation requires a pricy power amplifier (PA), which should work in its linear region.

Because, MC-CDMA suffers from high peaks, which consequently degrades performance of the (PA) at the forward link and we know that PA works efficiently in its linear area. Hence, a procedure may be formulated for calculating the linearity of the PA [1,2,3,9,10].

A technique to gauge of high amplitude is known as PAPR – the amount of maximum power that a PA could generate versus its mean power [10, 11]. In order to maintain the linearity of PA, its Input Back Off (IBO) needs to be high.

### A. Related work and Motivation

There are several methods to reduce PAPR [1,3,7,9,12,21]. But, all of these methods to reduce PAPR are under binary PSK, 16-QAM, quaternary or octary signaling modulation. There are several advantages of MSK over the said modulation scheme, like spectral efficiency, constant envelope and low PAPR.

This provides obvious motivation to use MSK modulation, instead of binary PSK with RRMED sequence to evaluate PAPR of MCCDMA [18].

### B. Contribution and outline

In the next section-II we will introduce background. Section-III contains proposed methodology, which includes contribution. The main contribution of section-IV is simulation, which proves that MSK further reduces PAPR and section-V states conclusion and open issues.

## II. BACKGROUND

### A. Reed Muller codes

Reed Muller codes or RM codes are oldest, finest error correcting and easy to understand codes [19]. They are useful in telecommunication. The distinguish feature of RM codes is that they are easy to decrypt using majority logic circuits [22]. RM code may be defined as RM(r, m) of order r, where r = 0, 1 ….m; has the set of three parameters (n, k, d) as follows:-

$$\left[ n = 2^m, k = \sum_{i=0}^{r} \binom{m}{i}, d = 2^{m-r} \right] \quad (1)$$

Where m is varying, n denotes the size of the data, k is used to find out the number of rows in RM code and d is the minimum distance. Large order RM code can iteratively be formed from the lower order. They are often used as to construct different codes.

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### B. *Walsh Hadamard Transform (WHTn)*

WHTn of dimension n by n is a discrete orthogonal transform of matrix; 2m × 2m. Recursion is used to generate higher order matrices from the lower order as follows:-

$$WHT(2^m) = \begin{bmatrix} WHT(2^{m-1}) WHT(2^{m-1}) \\ WHT(2^{m-1}) WHT(2^{m-1}) \end{bmatrix},$$

$$WHT(1) = 1 \qquad (2)$$

### C. *PAPR*

Now we define PAPR as follows: - Let Di represents an i$^{th}$. encoded data (with RRMED), then PAPR can mathematically be (with the corresponding transmitted signal SDi(t)) stated as follows:

$$PAPR(Di) = (1/n)\max\left|Di \times SDi(t)\right|^2 \qquad (3)$$

Where, PAPR(Di) is the peak power of encoded data Di and n is length of WHT. For an uncoded data the maximum PAPR is equal to n (number of channels) and the output of WHT is also various level of signal varying from – n to + n .For un-coded data the maximum PAPR is equal to n [3]. The lower and upper problem was resolved by reducing the phase jump from 180 degree to 90 degree in Offset Quadrature Phase Shift Keying (OPQSK). But 90 degree phase difference was still there in OPQSK compare to Quadrature Phase Shift Keying (QPSK). This short phase jump problem of OQPSK was further rectified and the resultant modulation scheme is known as continuous phase modulation (CPM). Minimum shift Keying (MSK) is one of the scheme [23]. In MSK there are no phase discontinuities [24]. Since there is no phase discontinuities in MSK signal, therefore it shows reduced power spectrum than Binary Phase-Shift Keying (BPSK) [25].

In OQPSK, the rectangular shape pulses are used. If these rectangular shape pulses are replaced by sinusoidal pulse shapes i.e. by Cos(π/2T) and Sin(π/2T) for the in-phase (I) and quadrature (Q) component respectively. This is also known as MSK [26]. MSK provides constant envelope and low PAPR. Its application ranges from Global System for Mobile Communication (GSM) to micro satellite communication, positioning and navigation system, hybrid optical / wireless communication system, and deep space communication [27].

## III. PROPOSED METHODOLOGY

We would like to propose Minimum Shift Keying (MSK) to add to the above contributions as mentioned in motivation and related work. Our communication model is depicted in Fig. 1, which consists of data ‘D’, data encoder with RRMED, MSK (for spectral efficiency and low power), WHT and finally signal, SDi(t) is relayed to the receiver over the wireless interface. At the receiver end inverse transformation and decrypting is performed to recover the un-coded data ‘D’.

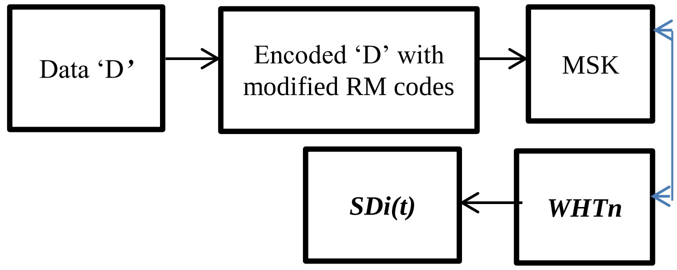


Fig. 1. MC-CDMA transmitter

## IV. SIMULATION

### A. *Discussion*

Table I shows simulation parameters we used to design the MC-CDMA transmitter. We start our discussion first for effect of RRMED on PAPR under MSK modulation and second PAPR for MSK vs. PSK.

For RM code and un-coded message length, we produce 10,000 random data segments. As shown in Fig. 1, Encoded data ‘D’ with RRMED is modulated under MSK. The modulated data is transformed into orthogonal signal using WHT. The resultant PAPR is constant and reduced. But for un-coded data, PAPR is variable and high.

TABLE I
Simulation parameters

| |
|---|
| Simulation tool : MATLAB |
| Multi Access Technique : MC-CDMA |
| WHT (n x n) : n=4,8,16,32 and 64 |
| Modulation: MSK |
| Channel Coding : RM (0,2);(0,3);(0,4);(0,5);(0,6);(1,2);(1,3);(1,4);(1,5);(1,6); (2,2), (2,3),(2,4),(2,5) and 2,6) |
| Random data blocks : 10,000 for each message length of 3,4,5,6,7, and 8 corresponding to RM codes(1,2);(1,3);(1,4);(1,5);(1,6);(2,3) |

Table II, shows the comparison of maximum PAPR under MSK for RM codes of order 0, 1st and 2nd. All of the said orders has constant and low PAPR, except RM(2,4), RM(2,5) and RM(2,6), which has low PAPR compare to original PAPR, but not constant. Verification of constant PAPR, only shown in figures 3 and 4 for RM(1,6) and RM(2,3). Table II and Fig. 2, 3 and 4 also demonstrates that RRMED with MSK modulation provides minimum and unvarying PAPR. In some cases PAPR is much lower for e.g. RM(0.2), RM(0,3), RM(04), RM(0,5), RM (1,2), RM(1,3), and RM(1,5) as shown in figures 2 and 3 respectively.

TABLE II
Maximum PAPR (dB) for coded (with modified RM codes) and uncoded data under MSK modulation

| WHT (4x4) | | WHT (8x8) | | WHT (16x16) | | WHT (32x32) | | WHT (64x64) | |
|---|---|---|---|---|---|---|---|---|---|
| Zero Order Reed-Muller Codes | | | | | | | | | |
| original | RM(0,2) | original | RM(0,3) | original | RM(0,4) | original | RM(0,5) | original | RM(0,6) |
| 3 | 0 | 6 | 0 | 7 | 0 | 10 | 6 | 9.6 | 9 |
| First Order Reed-Muller Codes | | | | | | | | | |
| original | RM (1,2) | original | RM(1,3) | original | RM(1,4) | original | RM(1,5) | original | RM(1,6) |
| 3 | 0 | 6 | 0 | 9 | 6.5 | 9.7 | 6 | 11.5 | 9 |
| Second Order Reed-Muller Codes | | | | | | | | | |
| original | RM(2,2) | original | RM(2,3) | original | RM(2,4) | original | RM(2,5) | original | RM(2,6) |
| 3 | 3 | 6 | 4 | 8 | 6.5 | 9.67 | 7 | 10.23 | 9 |

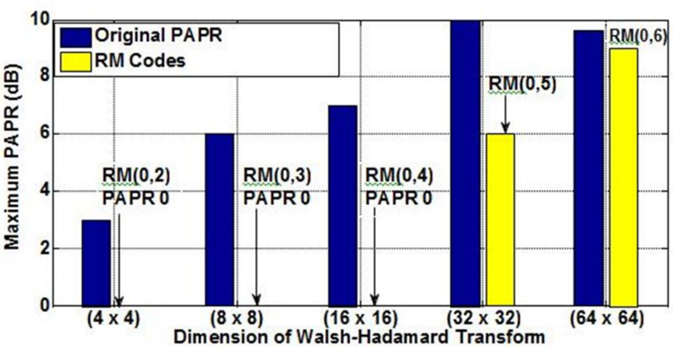


Fig. 2. PAPR Original vs. Coded for RM zero order

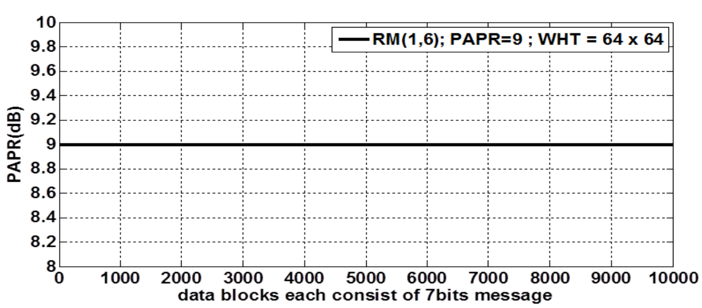


Fig. 3. Constant PAPR for RM(1,6)

Table III
PAPR (dB) for MSK vs. PSK

| WHT | RMC | MSK | PSK |
|---|---|---|---|
| 4 x 4 | RM(1,2) | 0 | 0 |
| 8 x 8 | RM(1,3) | 0 | 3 |
| 16 x 16 | RM(1,4) | 6.5 | 9.5 |
| 32 x 32 | RM(1,5) | 6 | 9 |
| 64 x 64 | RM(1,6) | 9 | 12 |
| 8 x 8 | RM(2,3) | 4 | 6.5 |
| 8 x 8 | RM(2,4) | 6.5 | 6 |
| 8 x 8 | RM(2,5) | 7 | 9 |
| 8 x 8 | RM(2,6) | 9 | 12 |

For PSK simulation, we have followed similar approach as described in discussion of simulation for MSK. From Table III and Fig. 5, note that PAPR for MSK is lower except for RM(1,2), where it is 0dB for both modulation. The reason for lower PAPR of MSK is its phase continuity, constant envelope and spectral efficiency.

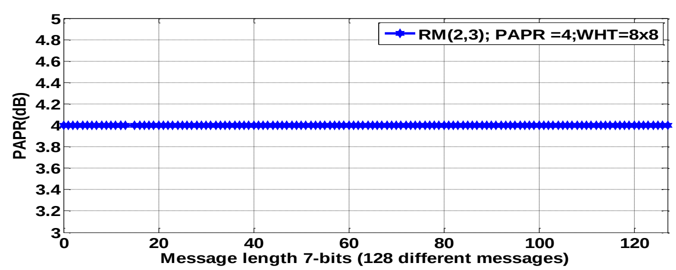


Fig. 4. Constant PAPR for RM(2,3)

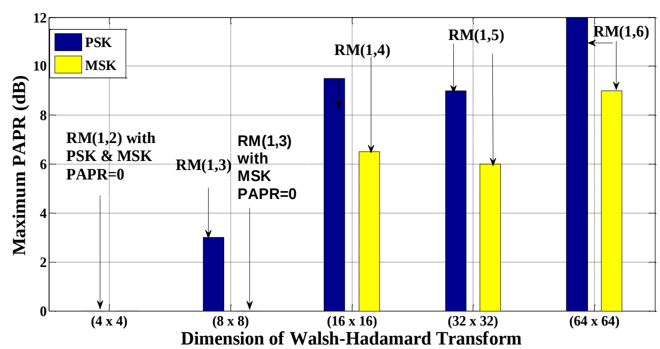


Fig. 5. MSK vs. PSK

## V. CONCLUSION

It is concluded that further low and constant PAPR under MSK modulation compared to binary PSK modulation is possible. This reduced PAPR is due to the fact that MSK modulation has phase continuity, which is not achievable in binary PSK. In future, MRMED may be tried to implement for high orders RM codes such as RM (2,6) and more block codes under MSK modulation.

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