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MC-CDMA Performance Analysis with RNS Precoding Under Different Radio Channels

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Abstract: *Multi carrier systems are more robust to noise and fading caused with multi path propagation channels and this is heavy when the data transmitted is of high data rate. This paper presents a speed and effective RNS precoding approach for MC-CDMA systems. This approach mainly concentrates to minimize the PAPR and to improve the BER performance which is analyzed under different radio channels. The main advantage of this method is that it doesn't require side lobe information and also mitigates the non linear distortions.*

Key words: MC-CDMA, Spreading codes, Residual number system, PAPR

I Introduction

Multi carrier code division multiple access (MC-CDMA) which is integration of OFDM with CDMA is introduced in 1993 [1]. The main idea of this technology relies in transmitting the high data rate stream into 'N' low data rate parallel streams in different sub carriers. Latest 4G and 5G technologies mainly concentrate on minimize the inter carrier interference and inter symbol interference in high data rate streams. MC-CDMA is one of the solutions for this problem which combines the benefits of both CDMA and OFDM technologies. In MC-CDMA, the data symbols are spreaded by different spreading codes like Pseudo Noise codes, Gold Codes, and Walsh Hadamard codes which are mapped for every symbol in the sub carrier [2].

MC-CDMA finds its own advantages in transmitting high speed data over fading channels but as in the case of OFDM this approach also suffers from PAPR which leads to the degradation of efficiency in transmitting the signal. Furthermore it introduces the complexity in designing the ADC which results in poor BER and high power consumption. So in this paper a fast and effective way of precoding approach is presented which mainly intends to decrease the PAPR and improves the performance of the MC CDMA system under different channeling environments.

This paper is organized as follows, section I , presents the brief introduction regarding the implication in MC CDMA systems, section II provides a brief literature on the work done so far in the related research area and their outcomes. Section III provides the information reading the concepts involved in analysis of the approach. Section IV presents the proposed approach to mitigate the PAPR and to enhance BER proceeding with the experimental values that are achieved.

II Related work

MC-CDMA is a very attractive technique for high speed data transmissions over multi path fading channels. It incorporates high security while minimizing the multipath fading effects [3]. There are certain technical issues in this technology such as Time-dispersion, Doppler-spreading, frequency and phase offset synchronization, sub carrier selection and PAPR. After all PAPR causes severe performance degradation in transmitting the signal. Many researchers have proposed several algorithms to mitigate this problem few of them which are correlated with the paper is presented.

A compression and expanding technique is proposed by Jiang et.al in [4], clipping and filtering is the simpler approach but increases in band distortions which in turn increases the BER. The use of companding finds good use rather than clipping, a similar approach with airy function is proposed by Yuan .J et.al in [5].Various coding mechanisms like use of Huffman coding [6], Zade-off-chu matrix [7]. In [8] Vijayarangan et.al , proposed pulse shaping raised cosine pulse waveform for minimizing PAPR without use of side information which seems to be more effective and simpler.

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Pre-coding approach is one of the solution to mitigate the raised PAPR using simpler linear methods without use of any side information , in [9] Baig et.al have proposed ZCT pre-coded based approach along with raised root cosine pulse shaping . In [10] Zhang et.al proposed different orthogonal bases, and introduced wavelet based multi carrier modulation scheme, however certain amount of distortion are introduced with the use of wavelet transforms. In [11] [12] Sarala et.al have proposed precoding approach for MC-CDMA systems using DCT and DWT transforms. This paper mainly focuses on reducing the PAPR using RNS precoding and thereby increases its performance.

III Background

a) PAPR of MC-CDMA

In MC-CDMA, 'k' number of user data is spreaded, pre-coded and modulated before it is passed for conventional OFDM operation. During the spreading operation the spreading sequences like PN, Gold, and Hadamard sequences are used to spread the message bits of the K^{th} user in time domain. Later these symbols are passed into precoding stage where a coding mechanism is used to change its format into encoded form. The PAPR is calculated after the IFFT operation, where the system consists of number of separately modulated sub carriers which in turn lead to high PAPR.

The PAPR of MC CDMA signal is defined as the ratio between instantaneous power and its average power of the signal

$$PAPR = \frac{\max\left[|x(t)|^2\right]}{E\left[|x(t)|^2\right]} \quad (1)$$

Where E [.] denotes expectation and complementary cumulative distribution function for MC-CDMA signal can be written as CCDF = probability (PAPR> P0), where P0 is the Threshold [12].
PAPR of MC-CDMA signal is mathematically defined as

$$PAPR = 10\, log_{10} \frac{\max\left[|x(t)|^2\right]}{\frac{1}{T}\int_0^T |x(t)|^2\, dt} \quad dB \quad (2)$$

b) Residual Number System

RNS is a parallel number system in which an integer of large word length is divided into several relatively small integers with a specific moduli set. In this number system the mathematical operations are performed in concurrent and independent which doesn't have carries among the residues [13]. RNS is extensively studied in the implementation signal processing applications like FFT, FIR, DWT and many other methods on VLSI domain. In spite of several advantages, it has some issues like magnitude comparison, scaling, division. These operations are not simpler to implement with this number system because of its non weight property [14].

The computation using this number system is very fast which makes it more feasible to be incorporated with many of the signal processing application. In this paper this system is used as a precoding mechanism to minimize the symbols which are the reason for obtaining high PAPR. The number system representation is presented below.

The residue number system uses positional bases which are relatively prime to each other, for instance consider {2, 3, 5}. If a number 8 is to be represented with this co prime set then it is divided with the respective prime base which results in { 0, 2, 3 } and the number of unique representation is 2x3x5=30. Below table gives us a clear view of the decimal and RNS representation.

Table1: Decimal to RNS conversion

Residue to Base			
N	**5**	**3**	**2**
0	0	0	0
1	1	1	1
2	2	2	0
3	3	0	1
4	4	1	0
5	0	2	1
6	1	0	0
7	2	1	1
8	3	2	0
9	4	0	1

To convert a decimal X to residue number system, simply take the residue of X with respect to the positional moduli.

III Proposed Approach

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The below block diagram depicts the proposed approach followed in this work. At the first step the data for 'K' number of users is generated which is then converted into RNS number system using co prime set. The residues are up sampled by a factor of number of co-primes in the moduli set , for instance let 512 samples for 3 users i.e; 512x3, and the moduli set is {2,3} then the resultant is 1024x3. This data is spreaded using Hadamard spreading sequence which is followed by IQ modulation.

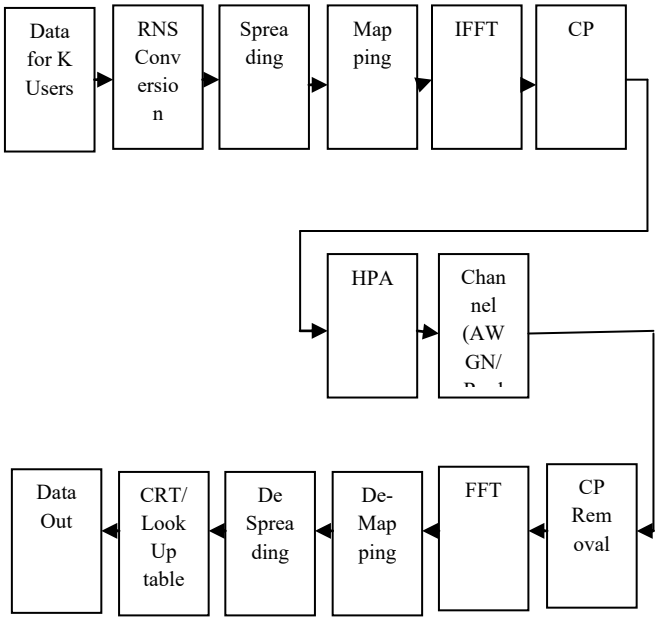

Figure 1: Block diagram of the proposed approach

The modulated symbols which are complex in nature are fed to IFFT transform are been transformed into orthogonal symbols in time domain. In this paper, the effect of high power amplifier (HPA) is not considered as it will be presented in the later papers. Three radio channels are considered to analyze the performance of the proposed approach by varying the attenuation of the channel. At the receiver, the RNS number system values are reconverted into decimal values either by using Chinese reminder theorem [15] or customized look up table [16].

IV Experimental Results

To analyze the performance of the proposed approach 1024 samples per user and 16 users were considered. The experiments were conducted using Matlab 2013a version on core Duo processor with 4Gb Ram. The method is validated in terms of CCDF (complementary cumulative distribution function), BER (bit error rate), and OBI (out of band interference). It is evident from the graphs that PAPR is decreased by 1.2 dB for RNS system with 64-QAM modulation scheme. The BER analysis is slightly increased by 0.1-0.2dB which is practically feasible result for fading channels. The experiment is carried out in comparing the analysis with and without RNS system and also comparing the BER with and without decoding. From the results it is clear that though there is no decoding at the receiver it yields almost similar performance when evaluated with decoding which is the key advantage in including RNS for MC-CDMA. It provides more security with lesser computations.

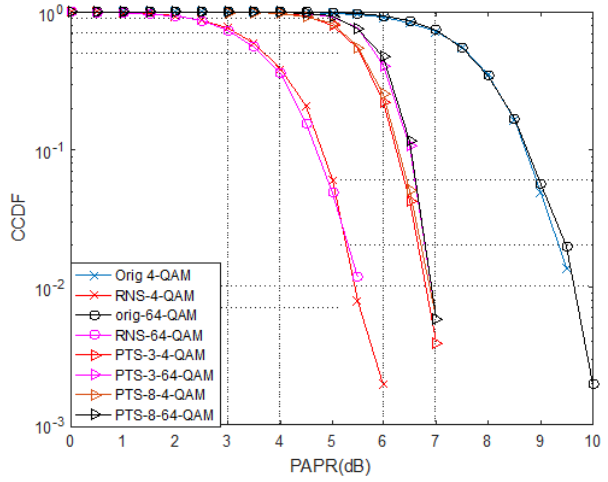

Figure 2: CCDF Vs PAPR for the proposed approach compared against PTS scheme [17]

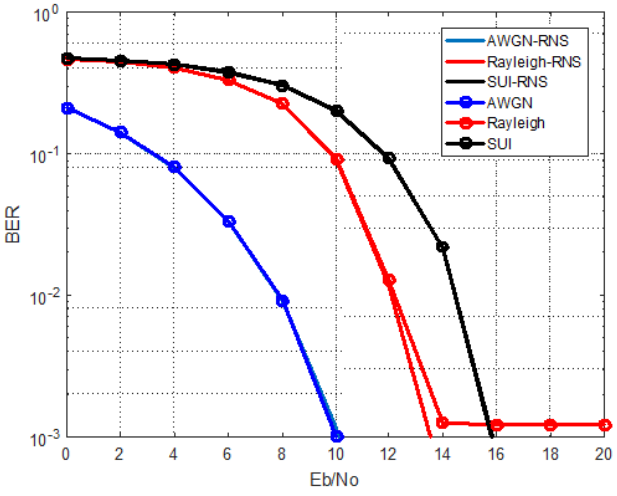

Figure 3: BER analysis with and without RNS precoding

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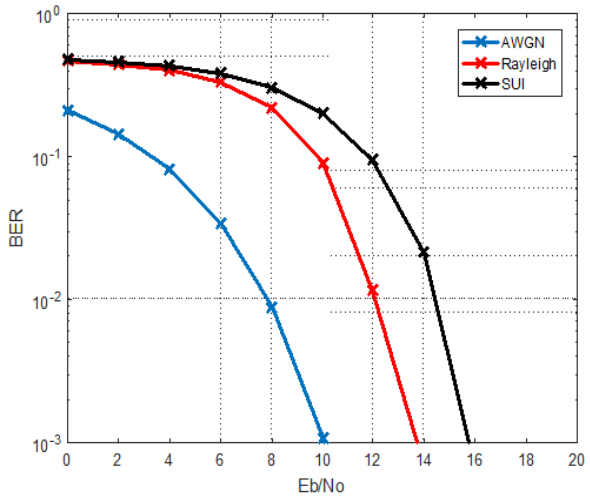

Figure 5: BER analysis with RNS pre coding without decoding

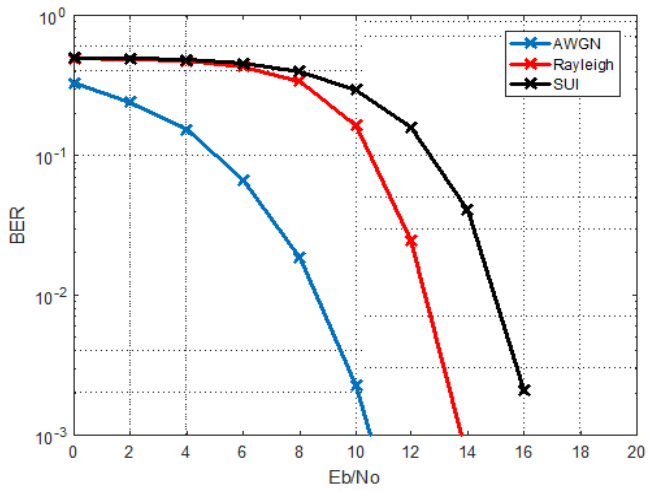

Figure 6: BER analysis with RNS pre coding with decoding

V Conclusion

A fast and secure precoding mechanism is proposed in this paper to obtain a low PAPR and to increase the BER for various channeling environments. This approach could attain a considerable decrease in PAPR on the other hand it also provides a better BER even with no decoding. This makes it meeting the requirement of providing the faster numerical method for decreasing the PAPR in MC-CDMA system. As there is high demand for the high data rate signal this approach can be one of the solution to meet the speed requirements.

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