MC CDMA PAPR Reduction Using Residue Coding

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ABSTRACT

High Peak to Average Power Ratio (PAPR) of the transmitted signal deteriorates Multi-Carrier CODE Division Multiple Access (MC CDMA) system performance, due to large number of subcarriers. This paper proposes a new technique to reduce PAPR of MC CDMA signal using Residue Number System (RNS) coding. Using this method PAPR reduces about 2dB to 2.5 dB and improves Bit Error Rate (BER). The proposed technique improves BER, Power Spectral density (PSD), spectral bandwidth and better spectral characteristics.

Keywords

PAPR, MC CDMA, RNS, BER.PSD.

1. INTRODUCTION

The growing demand for multimedia services requires high data rates for wireless digital communication. MC CDMA is currently dominating system for broadband wireless communication applications and personal communication systems. As air interface used as communication channel, the information of the communication may be exposed to an eavesdropper or system services can be fraudulently altered. In order to have good security over wireless channel, the Residue Number systems (RNS) coding is proposed for MC CDMA PAPR reduction and security measures [1]. MC CDMA transmits a data symbol of a user simultaneously on several narrow band subcarriers (sub channels). In MC CDMA, k user spread symbols are modulated and mapped in the frequency domain using Inverse Fast Fourier Transform (IFFT) [2]. It is very efficient for the synchronous downlink with high data rates. MC CDMA transmitted signals suffers from high PAPR, which degrades system performance and require high linear amplifiers. There has been a lot of research work done on PAPR reduction techniques in MCM systems. Several techniques are proposed for PAPR reduction [3].

A.S. Madhukumar et.al [4] has been proposed a new method to enhance the bandwidth efficiency of an MC CDMA system by using a residue number based representation for information symbols. A Multicarrier Modulation (MCM) scheme used for both transmission and reception of residue channels.

RNS has been effectively used in encryption and coding in the field of CDMA by many researchers. Watson and Hastings [5] have constructed a Redundant Residue Number System (RRNS) to detect and correct single errors. However, this method requires a correction table which may require large memory space. Jenn-Dong Sun and Harikrishna [6] proposed RRNS for correcting multiple errors, single burst error, and detecting multiple errors. The concept of Hamming weight, minimum distance, weight distribution, and error detection and correction capabilities in RRNS were introduced. RRNS systems widely used in high speed parallel signal processing structures, self-checking, error detection and error correction in digital processors, arithmetic units and data transmission.

A Residue Number Representation (RNS) is non-linear and non-weighted number system. RNS supports carry free arithmetic operations; parallel arithmetic operations between residue digits can increase the speed of computations. A RNS defined by a set of relatively prime integers called the moduli. The prime moduli set represented as {p1, p2, ---, pn}, where pi is the prime of ith modules. Each integer x is represented as a set of smaller integers called residues. The residue set represented as {r1, r2, ---, rn}. Where ri is the ith residue. The residue ri is defined as the least positive remainder, when x is divided by modulo pi. RNS are based on congruence relation, which is defined as follows.

X mod pi = ri. Where pi is the modulus, ri is the residue. The dynamic range determined by the product of modulo set {p1, p2, ---, pn} and represented by M=$\prod_{i=1}^{n} p_i$.

The RNS integer range is 0 to M-1, the RNS representation repeats itself. Hence, more than one integer might have the same residue representation. All elements of moduli set should be pair-wise relatively prime. The product of all moduli determines maximum number of bits possible in a symbol and is called the dynamic range of moduli set [7].

RNS offer high speed and significant power dissipation savings in the design of low power VLSI and wide range of DSP applications. RNS can reduce power dissipation since it reduces the hardware cost, switching activity, supply voltage.RNS advantages are Digital Signal Processing (DSP) based applications like FIR, IIR filter, adaptive system implementation, convolution, various transforms, digital frequency synthesizers, fault tolerant systems, RSA cryptography, FPGA based solution, Image processing. Error detection and correction properties can be introduced in the residue number system by inserting few redundant moduli in digital communication field. However, RNS not familiar due to magnitude comparison, sign detection, overflow detection and division. A RNS based spreading sequence is proposed for MC CDMA system to reduce PAPR and to enhance bandwidth efficiency. RNS reduce computation load in complex number processing, and provides serving at the algorithm level [8, 9, and 10].

RNS has two inherent features that render the RNS when compared with conventional weighted number systems. These two features are the carry-free arithmetic and lack of ordered significance amongst the residue digits. Introducing residue number systems to the spread spectrum communication system in order to add more features to the communication system [11].Using RNS system in wireless systems support increased channel bandwidth , improves Bit Error Rate (BER) probability and SNR , more security to the system, hardware complexity is reduced, spectrally efficient and higher throughput. Improves performance, saves area and power. Telecom media market demands for speed and low power consumption. Main problems while using RNS are difficult to detect overflow, division, square root, sign detection and comparison, conversion to conventional number system.

The rest of the paper is organized as follows: Section 2 describes PAPR of MC CDMA signal and Complementary Cumulative Distribution Function (CCDF) of the PAPR. Section 3 describes related work. Proposed PAPR models are discussed in section 4 with the help of a suitable algorithm and block diagram. In section 5 results are discussed. Conclusions are presented in section 6.

2. MC CDMA SYSTEM & PAPR REDUCTION

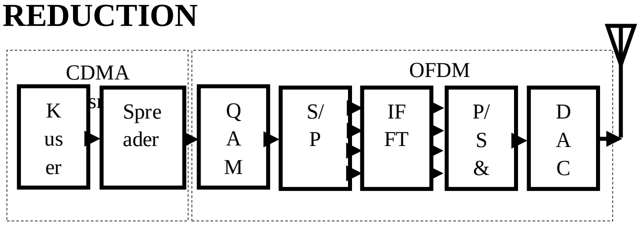

Figure1 MC CDMA Transmitter

Figure 1 shows the MC CDMA transmitter for kth user. It transmits each data symbol of a K user simultaneously on several narrow band sub channels. In MC CDMA K user data symbols are spread, then modulated and mapped in the frequency domain using Inverse Fast Fourier Transform (IFFT). At the spreader the k user data spread in the time domain by kth users spreading sequence, then applied to Quadrature Amplitude Modulation (QAM) mapper followed by serial to parallel (S/P) converter and then applied to IFFT in the frequency domain.

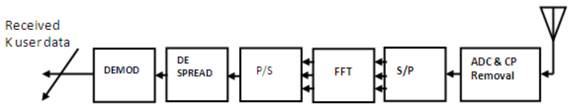

Figure 2. Block Diagram of MC CDMA Receiver

The MC CDMA receiver model for kth user is shown in figure (2). The received signal is first down converted, and the cyclic prefix or guard interval is removed. Then, the data is fed to serial to parallel converter. After that, the signal is transformed using FFT and applied to dispreading and demodulation blocks to recover the original binary information [12].

Generally, the PAPR of the MC CDMA signal x (t) is defined as the ratio between maximum instaneous power and its average power during the MC CDMA signal as shown in equation (1)[13].

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

Where E [.] denotes expectation and complementary cumulative distribution function for MC CDMA signal can be written as CCDF = probability (PAPR> x0), where x0 is the Threshold.

PAPR of MC CDMA signal is mathematically defined as

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

An additional measure to determine the envelope variation is the crest factor (CF), which is Cf = √PAPR.

3. RELATED WORK

Earlier we proposed a new technique for reduction in PAPR of the Multicarrier Code Division Multiple Access (MC CDMA) signals based on combining the Discrete Cosine Transform (DCT) /multi-resolution Discrete Wavelet Transform (DWT) with companding is proposed [12]. It is analyzed and implemented using MATLAB. This paper proposes a new technique to reduce PAPR of the MC CDMA signal using residue number system.

4. PROPOSED MC CDMA SYSTEM

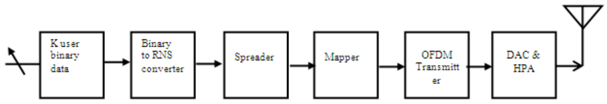

Figure 3. MC CDMA Transmitter with RNS.

Figure (3) shows proposed system for PAPR reduction of MC CDMA transmitted signal. K user binary information x is equal to b(n) converted into set of residues using forward converter. Summation of RNS based residues {r1, r2, ---, rn} are spread by using appropriate spreading codes such as Pseudo Noise (PN) codes, Walsh Hadamard codes and Gold codes. Spreading signal is modulated using Quadrature Phase Shift Keying (QPSK) modulation and transmitted over Orthogonal Frequency Division Multiplexing (OFDM) followed by Digital to Analog Converter (DAC) and High Power Amplifier (HPA).

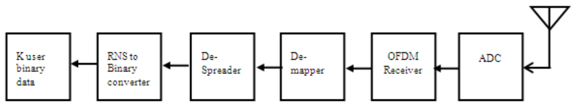

Figure 4. Block Diagram of MC CDMA Receiver with RNS

The received signal can be represented as a sum of delayed, phase shifted and attenuated versions of the input signal from all users. Figure 4 Shows that the blocks diagram of MC CDMA with RNS receiver. The spread signal received over a multipath channel. After proper synchronization, the signal is received from OFDM receiver, and fed to the de-mapper followed by de-spreader. The output of the de-spreader converted back from RNS to binary to recover original binary information.

4.1 RNS Encoding/Decoding

Data conversion can be divided into two type's namely forward conversion and reverse conversion. The process of converting the binary to RNS representation is called forward conversion or RNS encoding (1) RNS encoding are usually classified based on moduli-sets using look-up tables. This paper uses existing special moduli-set, such as {2n-1, 2n, 2n +1}, makes forward conversion process fast and simple. Forward converter is efficient in terms of area, power, and speed. After the data is processed using forward converter, they have to convert back to binary data. The process of converting RNS to binary data is called reverse conversion or decoding. RNS to binary conversion process is complex when compared with forward conversion process.

5. SIMULATION RESULT

Original MC CDMA, MC CDMA with RNS systems are implemented using MATLAB with the following specifications: number of symbols are 256, IFFT size is 128, and number of subcarriers are 64, spreading codes are PN codes, Gold codes, Walsh Hadamard codes and modulation used Quadrature Phase Sift Keying (QPSK). We can evaluate the performance of PAPR using complementary cumulative distribution of PAPR of MC CDMA with RNS and MC CDMA original. The results are compared with original MC CDMA (without RNS), MC CDMA with RNS.

5.1 CCDF Performance

We can evaluate the performance of PAPR using cumulative distribution of PAPR of MC CDMA signal. The Complementary Cumulative Distribution Function (CCDF) is one of the most regularly used parameters, which is used to measure the efficiency of PAPR technique.

Figures 7, 8, 9 show that the CCDF performance of a MC CDMA original system, MC CDMA with RNS for PAPR reduction for different spreading codes. At CCDF = 10-2 in MC CDMA with the RNS the PAPR is reduced by 2.0 dB to 2.5 dB for different spreading codes such as Gold codes, PN codes, Walsh codes respectively, when compared to original MC CDMA system. The simulation results show that the MC CDMA with RNS scheme resulted in about 2.0 dB to 2.5 dB PAPR reduction when compared with original MC CDMA system.

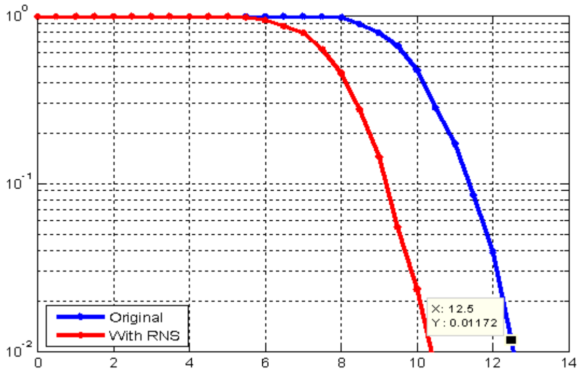

Figure 7 MC CDMA PAPR performances with RNS and Gold codes

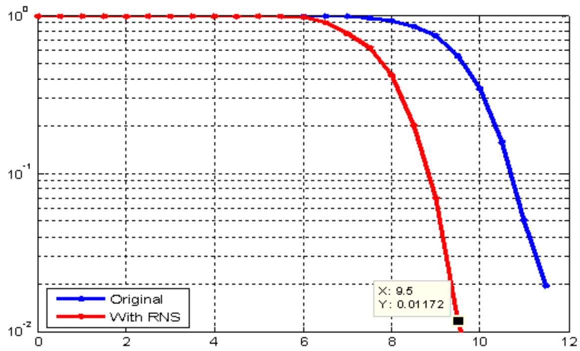

Figure 8 MC CDMA PAPR performances with RNS and PN codes

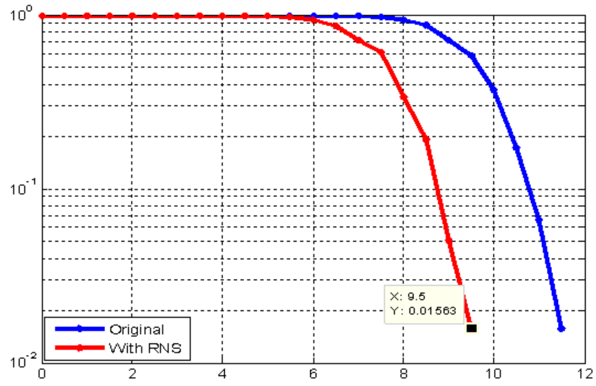

Figure 9 MC CDMA PAPR performances with RNS and Walsh codes

6. CONCLUSION

MC CDMA is used to combat channel distortion, and improves the spectral efficiency, supports high data rate, robust against multipath fading. In this paper, we implemented a MC CDMA system using RNS to reduce the PAPR. Proposed technique reduces PAPR more when compared to other conventional MC CDMA techniques.

The simulation results show that the PAPR reduction is improved by using RNS based MC CDMA when compared with MC CDMA original system. MC CDMA with RNS scheme obtained about 2 dB to 2.5 dB PAPR reduction when compared with MC CDMA. The proposed technique reduces PAPR, and improves the spectrum efficiency and provides moderate security. Proposed system has superior performance in terms of power spectral density and low PAPR.

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