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MIMO-MC CDMA System for Mobile Communication Systems

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Abstract. Multiple-Input Multiple-Output (MIMO) technology is today considered one of the most promising systems for high data transmission in wireless communications works. Its implementation with MC-CDMA scheme can provide optimized transmission performance to the mobile users. But the presence of High Peak to Average Power Ratio (PAPR) during the transmission constitutes an obstacle in its use by causing signal distortion and producing an inefficient amplification power in the transmission system. This paper introduces the Companding Transform technique based on Hyperbolic Sine System and the Revised Exponential Companding. After having reviewed and established the comparative study with the current systems performances based on PAPR reduction techniques, we analyze the adjustability in Companding function and the effective trade-off between the PAPR and the bit rate error (BER) performance. This new approach offers a stable high power amplified (HPA) and the non affectation of cost in the new transmission system. Moreover, the simulation works with Matlab are implemented; the results show an outperformed technique for PAPR signal reduction in MIMO- MC CDMA.

Keywords: BER, HPA, MC-CDMA, MIMO, OFDM

1 Introduction

MIMO technology is used today in mobile high data systems for good transmission performance. Its insertion with the Multi Carrier Code Division Multiple Access (combination between orthogonal frequency division multiplexing and code division multiple access) can provide optimized transmission. The use of MC-CDMA presents more advantages: In the context of broadband wireless communications, MC-CDMA provides high spectral efficiency, the lower implementation complexity by the presence of multi carrier adaptation, it participate to built high multi-path fading reducing co-channel interference and the impulsive parasitic noise.

However, the MIMO-MCDMA couple presents an essential disadvantage which consists of the presence of high Peak-to-Average Power Ratio (PAPR) during the transmission step. When the transmission signal passes through the High Power Amplifier, the presence of the high Peak-to-Average Power Ratio is observed. It causes the peaks to enter into saturation region and that situation will bring out two new phenomenon: the In-band radiation (IBR) phenomenon and the Out-of-band radiation (OBR) phenomenon; the In-band radiation will considerably increasing the bit error rate and the interferences are observed from transmission channel; all these inconvenient are responsible of the degradation of the transmission signal in mobile communication environment.

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The high PAPR into MIMO-MC CDMA are also responsible of the critical system malfunction aspects in the system: the design complexity of Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) which plays an important role in the transmission interface by converting and realizing reverse function performance during data processing. The high PAPR also affects the power efficiency by increasing the power consumption, increasing the cost, reducing the battery life.

This paper analyses a new idea which is the combination of inverse hyperbolic sine function namely $C-1$ (.) [8] and the clipping concept function two revised exponential Companding transform [9].

The remainder of this paper is organized as follows: We present the MC-CDMA PAPR system Analysis in Section 2. Section 3 presents the paper contributions, Section 4 describes the new Algorithm based MIMO MC-CDMA. And finally in Sections 5 and 6 we present respectively simulation results and conclusions.

2 MIMO-MC CDMA PAPR System Analysis

2.1 The Motivation of PAPR Reduction

The non companding transform (NCT) technique is very attractive and revolutionary way due to its good system performance including its integral simplification in the case of the implementation without restriction of the number of subcarriers, the type constellation, and the presence of the full use of band expansion in the transmission system. Following the Inverse Fast Fourier Transform (IFFT) at the sender side and the Fast Fourier Transform (FFT) at the receiver side, the MC-CDMA system bandwidth passes through several orthogonal subcarriers with narrow bandwidth, and an number of K users data symbols are modulated by the use of

Quadrature Amplitude Modulation (QAM) and transmitted independently on subcarriers where the signal will be converted from parallel to serial (P/S). According to its calculation, the MIMO-MC CDMA signal other the symbol interval can be determined as follows:

$$Sn = \frac{1}{\sqrt{n}} \sum_{K=0}^{N-1} SK.\exp\left(\frac{j.2\pi kn}{N}\right), 0 \le n \le N-1 \quad \textbf{(1)}$$

Where $j = \sqrt{-1}$ is oversampling ratio, and n=0, 1….N-1is the time index; In this case, considering N values which is the number of subcarrier used. Sn is is based on central limited theorem and it is a complex Gaussian process with a large value of N (e,g. $N \ge 64$). The signal symbol SN automatically becomes the Gaussian distribution function with Zero mean and a common variance $\delta_2 = \mathrm{E}\{|\mathrm{kx}|2\}/2$, and in this process, the Gaussian Distribution function is write with the probability density as follows:

$$Fsn(S) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(\frac{S^2}{2\sigma}\right) \quad \textbf{(2)}$$

Where S^2 is the variance of the original of multi-carrier modulation signals, and the constant *sn* the distribution with cumulative function (CDF); the new calculation of the *Sn* function is as follow:

$$Fsn(S) = \frac{1}{2}\left(1 + erf\left(\frac{S}{2\sigma}\right)\right),\ erf(s) = \int_0^x \frac{2}{\sqrt{\pi}} e^{-y2} dy \quad \textbf{(3)}$$

We can then define the PAPR of MCM signal *Sn* into a constant symbol period as follows:

$$PAPR(sn) = 10\log\frac{Max\{|sn|^2\}}{\sigma^2}(dB) \quad \textbf{(4)}$$

From equation (3) it is observed that PAPR reduction of MC-CDMA signals is mainly obtained by MC-CDMA signals is mainly obtained by decreasing the maximum instantaneous signal power. for this reason, the new PAPR defined in relation with multi carrier signal is determined as follows:

$$PAPR = \frac{\max |X_m|^2}{\frac{1}{Nerf \int_0^{N_{erf}} |x(d)|^2 dt}} \quad \textbf{(5)}$$

Where $|x_m|^2$, $|x(d)|^2$, *Nerf* are the new factors and we adopt the companding transform, and *sn* signal is companded befor converted to analog waveforms and amplified by the high power average. And $S_c(n)$ is given by

$$S_c(n)=V_c(n),\ (n=0,\ 1,\ldots,\ N-1) \quad \textbf{(6)}$$

where *C(.)* is the companding transform function adopted in the case of MIMO MC-CDMA. We define X_m as the time samples of an MC-CDMA symbol in the system. And for this affirmation, m=0, 1 ...considering that our work is give in the context of downlink, the PAPR of MIMO MC-CDMA in downlink context is given by the relation between *L* users $N_C=L$ which can be calculate as follow:

$$PAPR = 2\max \frac{\left\{ \sum_{k=0}^{k-1} \left| \sum_{l=0}^{l-1} C_L^k e^{j.\frac{2\pi}{T_s}} \right| \right\}^2}{L} \quad \textbf{(7)}$$

Then, MC-CDMA signals are transmitted into the radio channel. After have passing through both AWGN and the frequency selective fading channel.

Fig. 1. shows the block diagram of MC-CDMA system based on NCT technique [2], which combines the revised NCT and the Inverse Hyperbolic Sine Function.

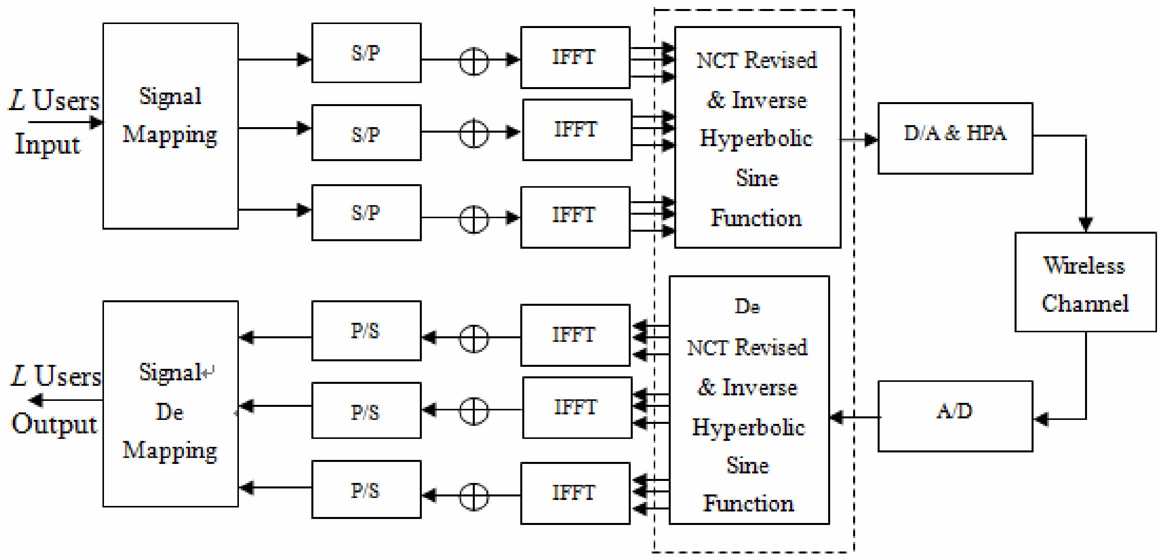

Fig. 1. MC-CDMA system based Revised NCT and the Inverse Hyperbolic Sine Function technique

Where M is the l and k denote the number of subcarriers used during the parallel transmission process, and by calculation we consider k with condition S_k (0 < K < n-1) as the K^{th} the complex modulated symbol in a block of N information symbols; the Inverse Fast Fourier Transform IFFT which is used to convert the P/S is into the frequency interleaving block.

2.2 Existing Method Limitation

Over the last five years, a variety of techniques based PAPR reduction techniques have been proposed to optimize MC-CDMA signal; comparing with current techniques, clipping & filtering technique approach is considered as the more widely adopted technique but its main drawback is the presence of an additional clipping noise resulting in significant out-of-band interference (OBI). The clipping will select the optimum clipping ratio to remove the high amplitude peak; in the processing, the system performance is considerably affected by a drawback performance [1].

Recently, the use of Nonlinear approach is more introduced to fix the performance issue in signal; a new promising technique called Nonlinear Companding Transform (NCT) has been introduced [2]. In this evaluation, several methods have been proposed by different authors including SML in [3] which proposed the selective mapping method working with two main advantages such as the use of only one IFFT algorithm at the transmitter side, and the no need of side information for the transmission.

The Partial transmit sequence has be introduced by Choe, Kim and Park [4]. The author uses a combination of DSI and PTS to perform the profitability of data rate. Another technique called active constellation extension has been used in [5] based on pre-scrambling method. And the tone reservation (TR) method and tone injection (TI) have been proposed to eliminate clipping noise [6-7].

Nevertheless, most of works introduced in related works cited above still present varieties of key research problems; the high peak to average still more sensitive because these proposed approaches outperform uniquely the clipping: This new observation opened a new challenge to find an appropriate NCT technique capable to provide proper and sufficient non companding transform technique, and finally resolve the key research problem announced in this paper.

Following this new observation, two propositions are more efficient: the first one is based on OFDM scheme and the statistical distribution, and the second is especially focused on the optimization technique to perform NCT drawback characteristics. In this work, the use of a novel NCT scheme based on the inverse hyperbolic sine function is proposed, and according to this approach, the Companded signal can be reallocated more reasonably while maintaining an unchanged average power level, a significant PAPR reduction result can improve the bit error rate performance to achieve a coherent transmission simultaneously.

3 Paper Contributions

The first contribution in this paper consist to propose a system criteria for PAPR reduction which is based in a scalable of MC-CDMA PAPR and HPA; and most of criteria include High capability of PAPR reduction, low average power, low implementation complexity, no bandwidth expansion, no BER performance degradation, no need of additional power needed, no spectral spillage.

The design criteria of the nonlinear companding transforms is proposed. It is based on the combination of two recent NCT based techniques which are inverse hyperbolic sine function and the revised exponential companding transform. The proposed novel nonlinear companding transforms can effectively reduce the PAPR of the MCM signals after passing through both AWGN and the frequency selective fading channel, by transforming the power of the original MCM signals into uniform distribution. This novel scheme can also maintain a constant average power level in the nonlinear companding operation. And the strict linearity requirement on HPA can then be partially relieved.

4 Algorithm based MIMO MC-CDMA

The new approach generates an algorithm which can be given as below:

Step 1. Calculation of threshold value at the transmitter can be given as follow:

$$T_1 = \frac{median(|X_n|)}{\delta^2_{x_n}} \quad \textbf{(8)}$$

where $\delta^2_{x_n}$ is the variance of standard deviation at standard deviation[2], the modulus symbol of MC-CDMA is given by $|X_n|$, with T_1 as the threshold value;

Step 2. Calculation of new modulus based combination of HIS-RECT approach can be calculated as follow:

$$X_n^{'} = T_1 + \log(|X_n| - T_1 + 1) \quad \textbf{(9)}$$

Step 3. Calculation of Inverse Hyperbolic Syn Function:

The signal at the receiver:

$$x_m = x_n \text{ where } 0 \le |x_n| \le T_1,\ x_n^{'},\ \text{when } |x_n| \ge T_1 \quad \textbf{(10)}$$

The revised exponential companding transform algorithm is given as follow:

Step1. Calculation of threshold value (at the receiver side) T_2:

$$T_2 = \frac{median(|r_n|)}{\sigma_{x_n}^2} \quad \textbf{(11)}$$

where $\sigma_{x_n}^2$ is a variance of standard deviation, and $|r_n|$ is Modulus of MC-CDMA a received symbol which is the threshold value at the receiver.

Step 2. the New Companding received signal can be described as:

$$\hat{x}_n = r_n \quad \textbf{(12)}$$

where $|r_n| \le T_2|$

5 Simulation Results

The evaluation of the new MIMO signal performance is made by using Cumulative Distribution Technique and the Complementary Cumulative Distribution Function (CCDF). We consider the main constant parameter to measure the efficiency of the PAPR scheme. The proposed MIMO based HIS-RECT with the revised exponential companding transform and newly introduced Inverse Hyperbolic Sine (HIS-RECT) Technique systems is implemented by using MATLAB software. The specification parameters are given as follow:

The number of symbols are 254, 510, 1022 and 4094 symbols; the Inverse Fast Fourier Transform (IFFT) size is 254, the number of subcarriers are respectively 126, 62, 31; to transmit the signal into the bandwidth we use Pseudo Noise (PN) codes and Reed Solomon code. The modulation process is made with 16-Quadrature Amplitude Modulation (16-QAM) and Amplitude Shift Keying (ASK). The simulations are performed for an MIMO-MC CDMA system with PAPR using cumulative distribution with different codes and companding techniques. And the results are compared with original MC-CDMA scheme with Liner companding, and exponential companding.

The result of MC-CDMA simulation from Fig. 2 to Fig. 4 show that HIS RECT technique combine to PN/Reed Solomon codes a reduction of the PAPR EFFECT by 2 dB, and 2.5 dB when compared with the original MC-CDMA (traditional companding), and MC-CDMA with exponential companding techniques. Therefore, if we increase the number of symbols, we automatically also increase the PAPR signal (up to 2.5 dB).

The Fig. 5 to Fig. 7 show that, using MC-CDMA with PN code and HIS-RECT technique, PAPR is reduced by 2.5 dB, and 2.0dB by comparing with the traditional Non Companding technique used in the same context.

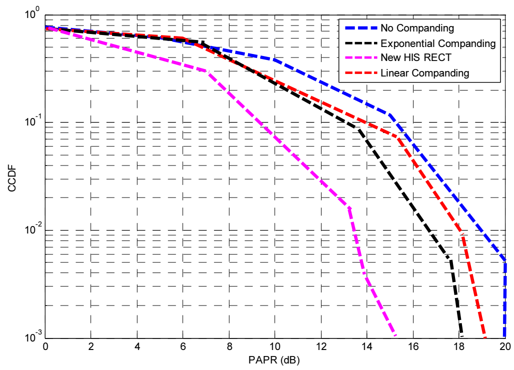

Fig. 2. Nsym=510, nfft=254, nsub=62, ų=0.825, d=1.1, 16QAM, Reed Solomom Codes

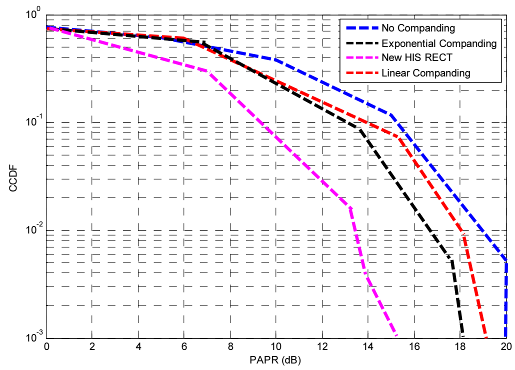

Fig. 3. Nsym=510, nfft=254, nsub=126, ų=0.825, d=1.1, 16QAM, Reed Solomom Codes

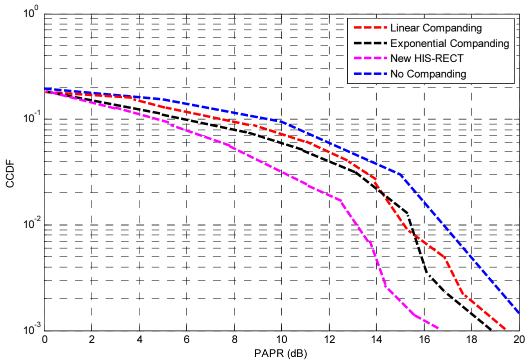

Fig. 4. Nsym=1022, nfft=254, nsub=126, ɥ=0.825, d=1.1, 16QAM, Reed Solomom Codes

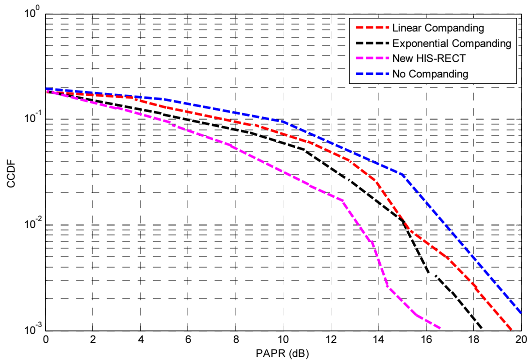

Fig. 5. Nsym=510, nfft=254, nsub=62, ɥ=0.825, d=1.1, 16QAM, PN Codes

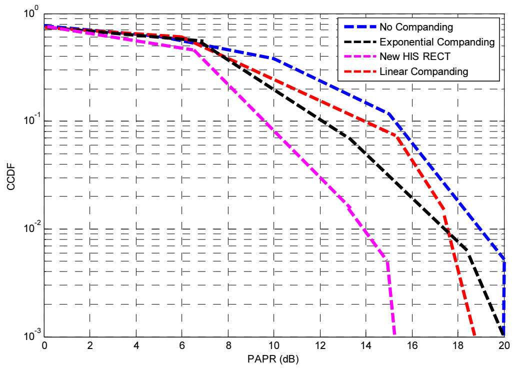

Fig. 6. Nsym=4094, nfft=254, nsub=126, ɥ=0.825, d=1.1, 16QAM, NC Codes

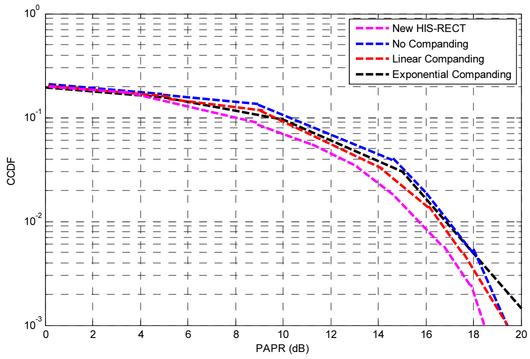

Fig. 7. Nsym=254, nfft=254, nsub=62, ɥ=0.825, d=1.1, 16QAM, NC Codes

The use of Reed Solomon Codes combined to MC-CDMA with HIS-RECT technique show in Fig. 8 to Fig. 11 that the PAPR phenomenon can be reduced by 1.5 dB and 1.75 dB when compared with traditional MC-CDMA companding techniques, the no companding technique and the MC-CDMA with Exponential Companding. And if the number of symbols is increased, the PAPR is further reduced by 0.5dB. If we double the number of subcarriers we got a PAPR which is increased by 2.5dB

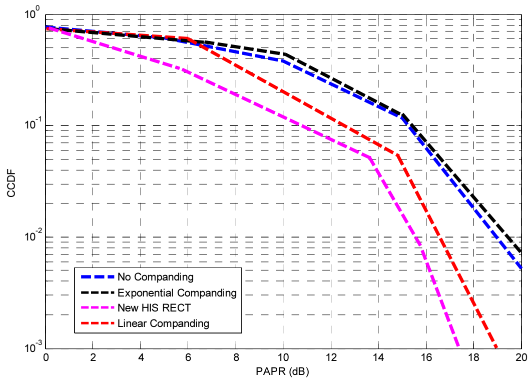

Fig. 8. Nsym=254, nfft=254, nsub=30, ɥ=0.825, d=1.1, 16QAM, Reed Solomon Codes

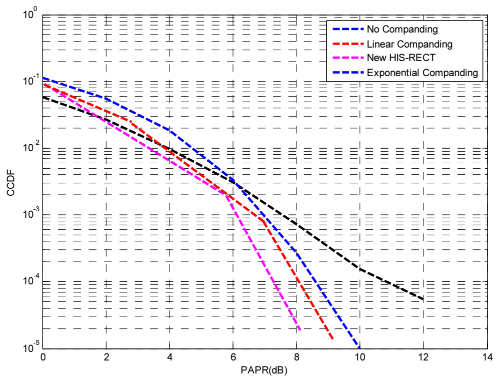

Fig. 9. Nsym=4094, nfft=254, nsub=30, ɥ=0.825, d=1.1, 16QAM, Reed Solomon Codes

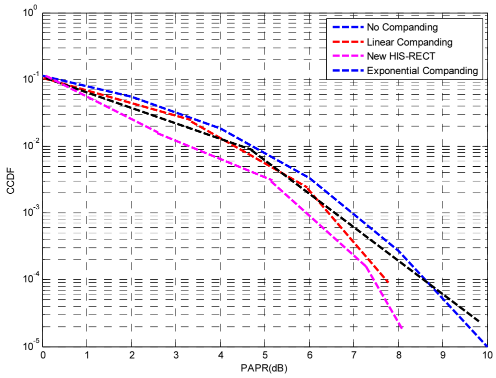

Fig. 10. Nsym=4094, nfft=254, nsub=62, ɥ=0.825, d=1.1, 16QAM, Reed Solomon Codes

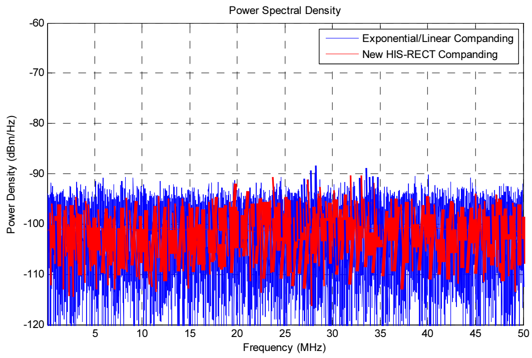

Fig. 11. Power Spectral Density Comparison

The simulation results of Power Spectral Density shows in Fig. 12. that the HIS-RECT based MC-CDMA technique has 11dB less in lower side and main lobe when compared with the traditional MC-CDMA technique, linear technique and exponential technique. The MC-CDMA with linear system has less mean amplitude and the system maintains constant the main lobe bandwidth compared to other MC-CDMA systems implemented in the same conditions.

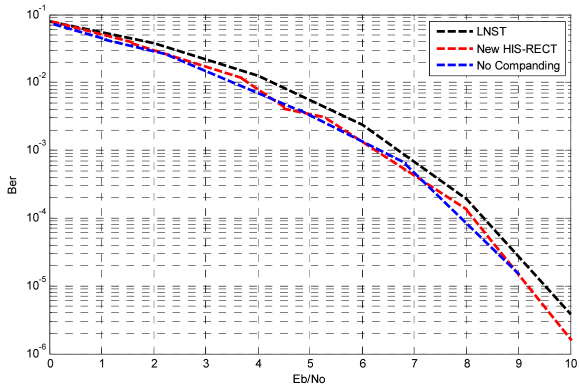

Fig. 12. BER analysis of new introduced HIS-RECT with Linear Companding technique

The result of BER simulations by using Reed Solomon/PN codes and HIS-RECT combined to MC-CDMA system with AWGN channel is shown in the Fig. 12. Found BER 9.2 at 10.1dB, the MC-CDMA with linear companding found BER is 0.8* 9.2 at 10.1 Db. And a newly introduced HIS-RECT with MC-CDMA technique obtains better BER when compared with the traditional combined MC-CDMA with linear companding technique.

6 Conclusions

The PAPR reduction and moderate BER performance degradation are a critical challenge for a well-designed HIS-RECT in MIMO MC-CDMA system. In this paper, the problem performance of high peak to average has been analyzed. To improve the limitation of the performance inside the signal transmission, a novel system based Hyperbolic Sine System and the Revised Exponential Companding is introduced to reduce PAPR effect. The performance and quality of clipping behavior is enhanced. The simulation analysis show normal high data rate transmission process with a reduction by 2.5 dB using Reed Solomon codes and a performance of 1.5dB with NC codes. The BER has been decreased over linear companding technique with an improvement of the spectrum efficiency. By compared with the MC-CDMA based traditional linear companding, the new approach found that the HIS-RECT based MIMO-MC CDMA has 11dB less inside the main lobe. The BER performance is improved and PAPR is also reduced. The design of this new technique does not require the use of any sophistic program. Therefore, it represents a suitable option for mobile high data transmission design scenarios.

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