Comparative analysis of UC-CMA and SD-CMA for Reduction of PAPR above 90 percent in MIMO-OFDM/A

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Abstract: OFDM have a several attractive features which give many advantages for transmission of fast and reliable data, high spectral efficiency, and easy equalization. During the transmission of this OFDM signal PAPR is a major practical problem involving OFDM modulation. PAPR in signal is usually undesirable because it usually strains the analog circuitry. To overcome this problem constant modulus algorithm is an efficient scheme which can decreases PAPR (Peak to average power ratio) gradually. In this paper, SD-CMA (Steepest Descent constant modulus algorithm) and UC-CMA (Unit circle constant modulus algorithm) are used for the reduction of PAPR. OFDM signals are generated by using these two algorithms and then compared with the originally generated signal the comparison gives an idea for the algorithm more efficient for data transmission with above 90 percent PAPR.

Keywords: OFDM, PAPR, SD-CMA, UC-CMA

1. Introduction

Orthogonal multicarrier modulation is an efficient method for data transmission in channels with fading and multipath. This method has a relatively simple implementation, based on fast discrete Fourier transform (DFT) allowing avoidance of complicated equalization algorithms. Such an approach appears in several wire line and wireless communication standards, and is also adopted in OFDM and discrete multi-tone (DMT) systems. The main disadvantage of multicarrier modulation is that it exhibits a high peak-to-average power ratio (PAPR). Namely, the peak values of some of the transmitted signals can be much larger than the typical values. This could lead to necessity of using circuits with linear characteristics within a large dynamic range; otherwise the signal clipping at high levels would yield a distortion of the transmitted signal and out-of-band radiation. Though PAPR reduction is not possible up-to 100 percent but it can be reduced gradually by using different techniques. In this paper, reduction of PAPR is aimed above 90 percent by using SCCMA and UCCMA. Selection of appropriate algorithm is done after weighting the two algorithms mentioned above, using graphical representation.

A well-known drawback of OFDM is that the amplitude of the time domain signal varies strongly with the transmitted symbols modulated on the subcarriers in the frequency domain. If the maximum amplitude of the time domain signal is too large, it pushes the transmit amplifier into a non-linear region which distorts the signal resulting in a substantial increase in the error rate at the receiver. To eliminate the error rate here we propose the PAPR reduction.

2. Proposed System

Here we provide the novel method to reduce the Peak to average power ratio (PAPR) by using Constant Modulus algorithm. In first step, time domain signals from resource blocks may be linearly combined using pre-coding weights, transparent to the receiver. Next the pre-coding weights can be designed to minimize the modulus variations of the resulting signal, leading generally to a reduction in PAPR. In CMA, we formulate this problem, by replacing the infinity norm by the average deviation of the OFDM block from a constant modulus signal.

2.1 Signal Generation

OFDM is the abbreviation for Orthogonal Frequency Division Multiplexing. Thus describes a digital modulation scheme that distributes a single data stream over a large number of carriers for parallel transmission. These carriers are called the subcarriers of the signal. In the frequency domain, they are equally spaced around a central RF carrier. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal.

2.2 Packet allocation

An OFDM block with subcarriers is transmitted from each antenna. The subcarriers include useful subcarriers surrounded by two guard bands with zero energy. The useful subcarriers are further grouped into resource blocks (RBs) each consisting of subcarriers. Data of one or more users is placed in these RBs and mapped into the space-time domain using an inverse discrete Fourier transform (IDFT) and space-time block coding (STBC). To allow channel estimation at the receivers (mobile stations), each RB also contains several pilot subcarriers that act as training symbols.

2.3 Signal scrambling technique

Partial transmit sequence (PTS) combining can improve the PAPR statistics of an OFDM signal. The input data vector is partitioned into disjoint sub blocks. Simple portioning mechanisms are used to split the data vector into sub blocks which consists of contiguous set of subcarriers. They are combined to minimize the PAPR.

2.4CMA Algorithm

The Constant Modulus Algorithm (CMA) is a method to update the covariance matrix of this distribution. This is particularly useful, if the function is ill-conditioned. Adaptation of the covariance matrix helps in learning a second order model of the underlying objective function. In contrast to most classical methods, fewer assumptions on the nature of the underlying objective function are made. Only the ranking between candidate solutions is exploited for learning the sample distribution and neither derivatives nor even the function values themselves are required by the method.

2.5 PAPR reduction

PAPR is reduced by designing pre-coding weights that minimize the modulus variations of the resulting signal. For this Steepest-Descent CMA (SDCMA) and Unit-Circle CMA (UC-CMA) algorithm is used. The SDCMA is a block-iterative algorithm in which we act on the full data matrix and update until it converges.

3. Performance ANALYSES

The performance is analyzed using Complementary Cumulative Distribution Function (CCDF) Plot. The CCDF graph displays the probability of the generated waveform's calculated peak-to-average power ratio meeting or exceeding a certain level.

3.1Block diagram

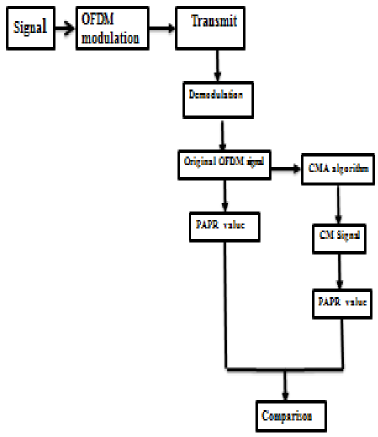

FIGURE 1: MODULE 1

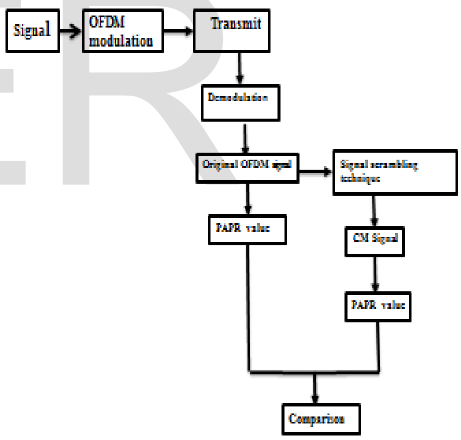

FIGURE 2: MODULE 2

3.2Quantifying the PAPR

Since multicarrier systems transmit data over a number of parallel-frequency channels, the resulting wave form is the superposition of L narrowband signals. In particular, each of the L-output samples from an L-pt. IFFT operation involves the sum of L complex numbers, because of the central limit theorem, the resulting output values

$$\{x_1, x_2, ..., x_L\}$$

Can be accurately modelled, particularly for large L, as complex Gaussian random variables with zero mean and variance, which is Rayleigh distributed, with parameter σ^2. The output power is

$$|x[n]|^2 = (\mathrm{Re}\{x[n]\})^2 + (lm\{x[n]\})^2$$

The PAPR of transmitted analog signal can be defined as

$$\mathrm{PAPR} = \frac{P_{peak}}{P_{average}} = 10\log_{10}\frac{\max[|x_n|^2]}{E[|x_n|^2]}$$

The complex envelope of the transmitted OFDM signal is given by

$$x(t) = \frac{1}{\sqrt{N}}\sum_{K=1}^{N-1} Y_K e^{j2\pi k\Delta f t} \quad (3)$$

The complementary cumulative distribution function (*CCDF=1-CDF*) of the PAPR is the most commonly used measure [2, 3].
Van Nee and de wild introduced a simple and accurate approximation of the CCDF for large L (≥ 64).

$$CCDF(L,\varepsilon_{\max}) = 1 - G(L,\varepsilon_{\max})^{\beta L} = 1 - \left(1 - \exp\left(\frac{\varepsilon_{\max}}{2\sigma^2}\right)\right)^{\beta L}$$

The CDF of the Nyquist-sampled signal power can be obtained by

$$G(L,\varepsilon_{\max}) = P(\max\|x(t)\| \leq \varepsilon_{\max}) = F(L,\varepsilon_{\max})^L$$

3.3Preamble and pilot

There are two ways to transmit training symbols: preamble or pilot tones. Preamble entails sending a certain number of training symbols prior to the user data symbols. Pilot tones are for tracking the time-varying channel in order to maintain accurate channel estimates.

3.4 Channel Estimation

When OFDM is used with a MIMO transceiver, channel information is essential at the receiver in order to coherently detect the received signal and for diversity combining or spatial-interference suppression. Accurate channel information is also important at the transmitter for the closed-loop MIMO. Channel estimation can be performed in two-ways: training-based and blind. In training-based channel estimation, known symbols are transmitted specifically to aid the receiver's channel estimation-algorithms. In a blind channel-estimation method, the receiver must determine the channel without the aid of known symbols.
The signals of each residue sub channel share the original frequency band through FDM. The set of V parallel residue signals is superimposed in the transmitter expressed as

$$S_{TX}(k) = \mathrm{Re}\left[\sum_{v=1}^{V} s_{k,m_v}\exp(j2\pi f_v)\right]$$

Channel–estimation methods based on the preamble and pilot tones are different due to the difference in the number of known symbols. For preamble-based channel estimation in the time domain with a cyclic prefix, the received OFDM symbol for training signal can be represented in a circulant matrix as

$$\boldsymbol{y} = \begin{bmatrix} \boldsymbol{h}(0) & \cdots & \boldsymbol{h}(v) & 0 & \cdots & 0 \\ 0 & \boldsymbol{h}(0) & \cdots & \boldsymbol{h}(v) & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \boldsymbol{h}(1) & \cdots & \boldsymbol{h}(v) & 0 & \cdots & \boldsymbol{h}(0) \end{bmatrix} \begin{bmatrix} \boldsymbol{x}(L-1) \\ \vdots \\ \boldsymbol{x}(0) \end{bmatrix} + \boldsymbol{n}$$

$$= \begin{bmatrix} x(0) & x(L) & x(L-1) & \cdots & x(L-v+1) \\ x(1) & x(0) & x(L) & \cdots & x(L-v+2) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x(1) & x(L-1) & \cdots & \cdots & x(L-v) \end{bmatrix} \begin{bmatrix} h(0) \\ \vdots \\ h(v) \end{bmatrix} + n$$

$$= Xh + n$$

Channel estimation is simpler in the frequency domain than in the time domain. The received symbol of the lth subcarrier in the frequency domain is

$$Y(l) = H(l)X(l) + N(l)$$

H and Y are the L point DFT of H and received signal on each output subcarrier, and the estimation matrix A is

$$A = R_H\left(R_H + \sigma^2\left(X^*X\right)^{-1}\right)^{-1} X^{-1}$$

The PAPR of the OFDM can be presented by

$$PAPR_{OFDM} = 10\log\frac{\max\left\{\left|\sum_{i=0}^{N-1} d_i \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}{E\left\{\left|\sum_{i=0}^{N-1} d_i \exp\left(j\frac{2\pi ik}{N}\right)\right|^2\right\}}$$

4. Simulation Results

The relative analysis of UC-CMA and SDCMA is shown in the graphs obtained for comparison of capacity, BER and CCDF.
The capacity and CCDF is plotted relative to a rayleigh fading as well, wherein the SDCMA fairs well than the remaining two, but UC-CMA underperforms compared to rayleigh fading scenario.

Fig3. Shows the plot of amplitude vs time for original OFDM signal, estimated channel, channel allocation and received data. The original signal varies largely in amplitude and received data uniformly distributed with the sudden peak near 500 data points.

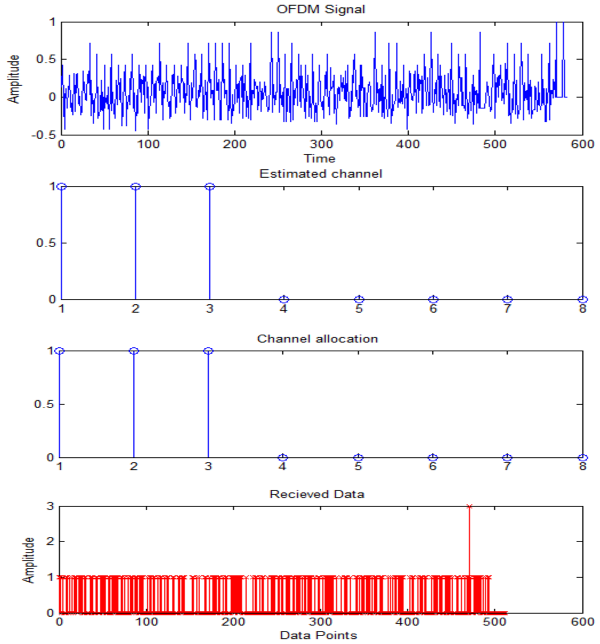

Figure 3: OFDM SIGNAL, CHANNEL ALLOCATION AND RECEIVED DATA

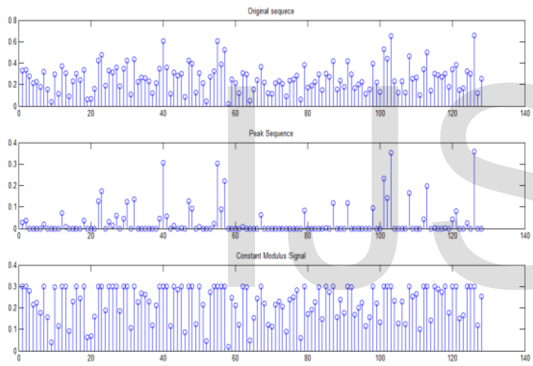

FIGURE 4: CONSTANT MODULO SIGNAL

Fig4. Shows the stem plot of OFDM signal along with peak sequences on application of CM Algorithm the received CM-Signal is more uniformly distributed peaks smoothing out the average amplitude of the original signal.

Fig5. Shows the comparison of SNR and BER for Rayleigh fading, UC-CMA, SD-CMA, the performance is comparable For Rayleigh fading and UC-CMA till SNR of four as we increase the SD-CMA gives less error rate for the same signal to noise ratio.

Fig6. Shows that SD-CMA has better capacity vs. SNR Result compared to Rayleigh fading and UC-CMA all though UC-CMA under performs even though Rayleigh fading channel

Fig7. Shows the CCDF plot such as better reduction of PAPR compared to UC-CMA there by increasing the efficiency of data transmitted.

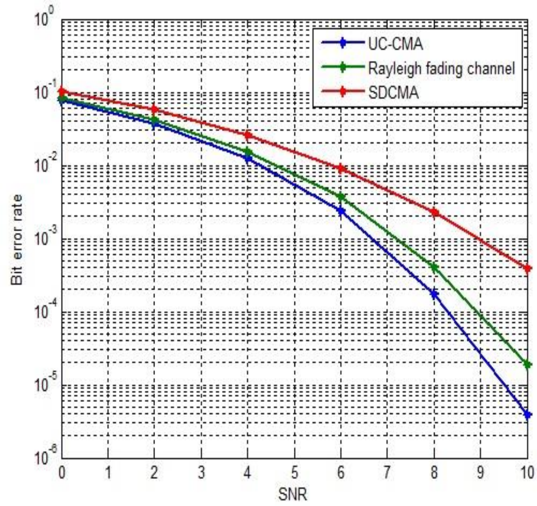

FIGURE 5: COMPARISON OF SNR AND BER FOR RAYLEIGH FADING, UC-CMA AND SDCMA

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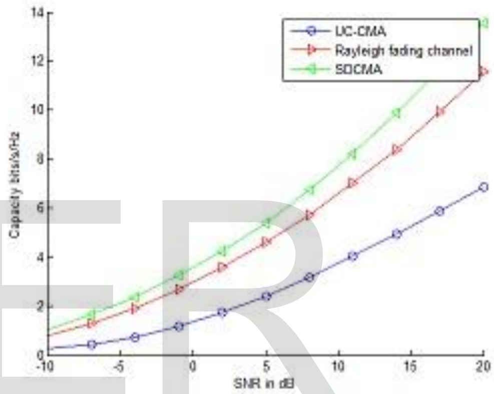

FIGURE 6: CAPACITY VS SNR

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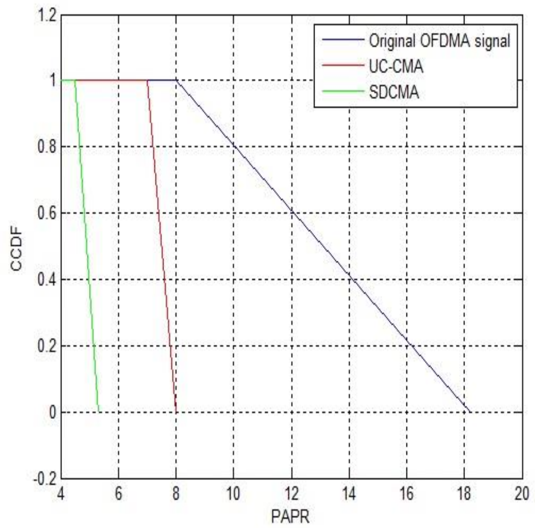

FIGURE 7: PERFORMANCE ANALYSIS OF UC-CMA AND SDCMA

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5 .Conclusion

This paper investigates the results obtained on applying a SD-CMA & UC-CMA for reducing PAPR in OFDM systems. It has been observed from the results that SD-CMA provides a better PAPR reduction performance compared to UC-CMA although above 90 percent of PAPR reduction is obtained from both the algorithms but SD-CMA is better than UC-CMA for higher capacity and signal-to-noise ratio scenarios.

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References

[1] S. H. Han and J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Wireless Commun. Mag., vol. 12, pp. 56–65, Apr. 2005.

[2] S. Khademi, T. Svantesson, M. Viberg, and T. Eriksson, "Peak-to-average- power-ratio (PAPR) reduction in WiMAX and OFDM/A systems," EURASIP J. Adv. Signal Process., Aug. 2011.

[3]Y. Shen and E. Martinez, "WiMAX channel estimation: Algorithms and implementations," Application Note, Freescale, 2007.

[4] J. Wang, Z. Lan, R. Funada, and H. Harada, "On scheduling and power allocation over multiuser MIMO-OFDMA: Fundamental design and performance evaluation WiMAX systems," in IEEE Int.Symp. Personal, Indoor and Mobile Radio Communications, 2009,pp. 2752–2756

[5] OFDM Baseband Receiver Design for Wireless Communications Tzi-Dar Chiueh National Taiwan University, Taiwan Pei-Yun Tsai National Central University, Taiwan John.

[6] P. Sunil Kumar, M.G. Sumithra, M. Sarumathi, E. Praveen Kumar, "Performance Analysis for PAPR Reduction using SLM technique in 2 x 1 and 2 x 2 Differential STBC MIMO RS OFDM Systems in Rayleigh Fading Channel" 2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE) Vol.14, No 3, April 2013.

[7] Dae-Woon Lim, Seok-Joong Heo, and Jong-Seon No, "An Overview of Peak-to-Average Power Ratio Reduction Schemes for OFDM Signals", Journal of Communications and Networks, VOL. 11, NO. 3, JUNE 2009.

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