A New Method of PAPR reduction in MIMO-OFDM System using combination of OSTBC Encoder and $T \times T$ Spreading Code Sequence

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is regarded as one of the most outstanding multicarrier modulation technique in fourth generation (4G) wireless networks, which makes it possible to transfer very high bit rates despite extensive multipath radio propagation (echoes). The use of smart antenna arrays both at transmitter and receiver further increases the bit rate and enhance the system diversity on time variant and frequency selective channels resulting in a multiple-input multiple-output (MIMO) configuration. However one of the main disadvantages associated with MIMO-OFDM is the high Peak-to-Average Power Ratio (PAPR) of the transmitter's output signal on different antennas. High Peak to Average Power Ratio (PAPR) for MIMO-OFDM system is still a demanding area and difficult issue. So far numerous techniques based on PAPR reduction have been proposed. In this paper a new method based on the combination of OSTBC Encoder and Spreading code sequence have been implemented and simulated. The results obtained are compared with earlier results based on transform techniques. Simulations show that better results are obtained in proposed technique.

Introduction

The International Telecommunication Union-Radio communications sector (ITU-R) specified a set of requirement for 4G standards, named the International Mobile Telecommunications Advanced (IMT-Advanced) specification, setting peak speed requirement for 4G services at 100 Megabits per second for high mobility communication and 1Gigabitper second for low mobility communication [1]. The spread spectrum radio technology used in 3G systems, is abandoned in all 4G candidate systems and replaced by OFDM multi-carrier transmission. The peak bit rate is further improved by smart antenna arrays for multiple-input multiple-output (MIMO) communications Multiple-input multiple-output (MIMO) wireless technology [2]seems to meet these specifications set by IMT-Advanced by offering increased spectral efficiency through spatial multiplexing gain, and improved link reliability due to antenna diversity gain. Even though there is still a large number of an open research problem in the area of MIMO wireless, both from a theoretical perspective and a hardware implementation perspective, the technology have reached a stage where it can be considered ready for use in practical systems. In fact, the first products based on MIMO technology have become available, for example, the pre-IEEE802.11n wireless local area network (WLAN) systems by Air go Networks, Inc., A theros Communications, Inc., Broad com Corporation, Marvell Semiconductor, Inc., and Metalink Technologies, Inc. Current industry trends suggest that large-scale deployment of MIMO wireless systems will initially be seen in WLANs and in wireless metropolitan area networks(WMANs). Corresponding standards currently under definition include the IEEE 802.11nWLAN and IEEE 802.16 WMAN standards. Both standards define air interfaces that are based on the combination of MIMO with Orthogonal Frequency Division Multiplexing (OFDM) modulation (MIMO-OFDM).In MIMO-OFDM system, a number of antennas are placed at the transmitting and receiving ends and the distances are separated far enough. The idea is to use spatial multiplexing and data pipes by developing space dimensions which are created by multi transmitting and receiving antennas. The transmitted signal bandwidth is so narrow that its frequency response can be assumed as being flat [3] The main advantage of using MIMO-OFDM system include high power spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density, capability of handling very strong echoes, lesser nonlinear distortion and use of small guard intervals [4]. This paper investigates one of the bottleneck problems that exist in OFDM wireless communication system i.e. High Peak-Average Power Ratio (PAPR of OFDM signal), and a new technique have been proposed to reduce it. The occurrences of high peaks in the transmitted OFDM signal gears the degradation of the system performance due to various non-linear effects like spectral spreading, intermodulation, and signal constellation that exist inherently in power amplifiers[5].In this paper a new technique based on the combination of OSTBC encoder and Spreading code sequence have been implemented thus concating the concept of MIMO with DS-CDMA. The OFDM modulator has been implemented by Inverse Fast Fourier Transform (IFFT).The output of IFFT is given to the OSTBC encoder with variable number of transmit and receive antennas and a spreading code is applied after that .The spreading code spreads the IFFT generated signal and then modulates a different subcarrier with each chip (spreading in Frequency domain).

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MIMO-OFDM System

Traditionally, multiple antennas (at one side of the wireless link) have been used to perform interference cancellation and to realize diversity and array gain through coherent combining. The use of multiple antennas at both sides of the link offers an additional fundamental gain — spatial multiplexing gain, which results in increased spectral efficiency. The signaling schemes used in MIMO system scan be roughly grouped into spatial multiplexing [1], which realizes the capacity gain, and space time coding[6], which improves link reliability through diversity gain. Most multi-antenna signaling schemes, in fact, realize both spatial-multiplexing and diversity gain.

A framework for characterizing the trade-off between spatial-multiplexing and diversity gains in flat-fading MIMO channels was proposed in 2003 [7]. In an OFDM-based MIMO system, spatial multiplexing is performed by transmitting independent data streams on a tone-by-tone basis with the total transmit power split uniformly across antennas and tones. Although the use of OFDM eliminates ISI, the computational complexity of MIMO-OFDM spatial-multiplexing receivers can still be high. This is because the number of data-carrying tones typically ranges between 48 (as in the IEEE 802.11a/g standard)and 1728 (as in the IEEE 802.16e standard)and spatial separation has to be performed for each tone. Recently, a new class of algorithms that alleviate this problem was proposed in 2004 [8]. The basicidea underlying these algorithms is to exploit thefact that the matrix-valued transfer function in a MIMO-OFDM system is "smooth" across tones because the delay spread in the channel is limited. Computational complexity reductions areobtained by performing channel inversion in the case of a minimum mean-squared error (MMSE)receiver. While spatial multiplexing aims at increasing spectral efficiency by transmitting independent data streams, the basic idea of space-time coding[6] is to introduce redundancy across space and time to realize spatial diversity gain at the transmitter. This is achieved by applying forward-error-correction coding and interleaving across tones; most practical systems employ bit-interleaved coded modulation [9].

The problem can, however, be approached in a more systematic fashion through space-frequency codes [10], which essentially spread the data symbols across space (antennas) and frequency(tones), Figure 1shows a MIMO-OFDM system with N subcarriers (or tones). The individual data streams are first passed through OFDM modulators. Each modulator performs an IFFT on block of length N. Then, it is followed by a parallel to serial conversion. After that, a cyclic prefix of length cp $L \geq M$ is appended. The CP contains a copy of the last cp L samples of the output of the N-point IFFT, where M denotes the length of the discrete-time channel impulse response. The resulting OFDM symbols with length cp $N + L$ are launched simultaneously from the individual transmit antennas. The CP is a guard interval that serves to eliminate interference between OFDM symbols. It also turns the linear convolution into circular convolution such that the channel is diagonalzed by the FFT. At the receiver, the individual signals are passed through OFDM demodulators. Each modulator removes the CP and then performs an N-point FFT. The outputs of the OFDM demodulators are finally separated and decoded.
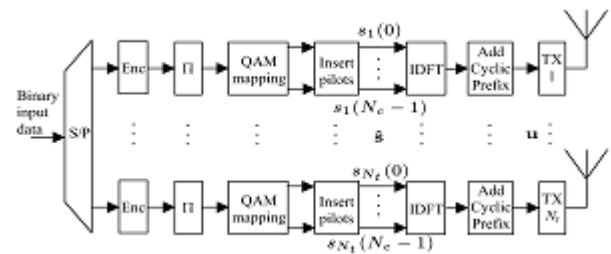

Figure 1: Block Diagram for Simplified MIMO-OFDM System.

High value of PAPR brings disadvantages like an increased complexity of A/D and D/A converters and a reduced efficiency of RF power amplifiers. In a practical system, before transmission, OFDM signal is passed through a power amplifier that is always peak power limited. If the squared magnitude of the OFDM signal is larger than the saturation point of the power amplifier at any time instant, then the signal will be clipped. Clipping destroys the orthogonality between subcarriers resulting in an increase in the Bit Error Rate (BER) when compared with the non-clipped case [4]

Adaptive MIMO System With OSTB Encoder

The OSTBC Encoder block encodes an input symbol sequence using Orthogonal Space-Time Block Code (OSTBC). The block maps the input symbols block-wise and concates the output code word matrices in the time domain. The block supports time and spatial domain for OSTBC transmission. The system uses variable number of transmit and receive antennas. The number of transmit and receive antennas are adaptive and change either manually or according to an adaptation algorithm, based on the difference between target and actual frame –error rates of the overall system. OSTBCs are attractive techniques for MIMO wireless communications. They exploit full spatial diversity order and employ symbol-wise maximum likelihood (ML) decoding. The OSTBC Combiner block at the receiver side provides soft information of the symbols that the system transmits, which can be utilized for decoding or demodulation of an outer code. The OSTBC Encoder block encodes the information symbols from the QPSK Modulator by using complex orthogonalcodes for two, three, and four transmit antennas. The number of transmit antenna is given to this block as an input. The output of this block is an (Ns×Nt) variable-size matrix, where the number of columns (Nt) corresponds to the number of transmit antennas and number of rows (Ns) corresponds to the number of orthogonal code samples transmitted over each transmit antenna in a frame. The Adaptive MIMO channel is a variable-size MATLAB function block with variable-size signal implementation. The maximum Doppler shift property of the system object is set to 100.The object uses this value so the MIMO channel behaves like a quasi-static fading channel, i.e., it keeps relatively constant during one code block transmission and varies along multiple blocks.

The input of this block is an (Ns×Nt) variable-size matrix, where the number of columns (Nt)correspond to the number of selected transmit antennas and number of rows (Ns) corresponds to the number of orthogonal code samples that the system transmits over each transmit antenna in a frame. The first output of this block, the signal chGain, is an (Ns× Nt× Nr) variable-size channel gain array, where the third dimension (Nr) corresponds to the number of selected receive antennas. The second output of

this block, the signal chOut, is an (Ns× Nr) variable-size channel output matrix.

Algorithm for proposed Scheme for PAPR reduction in MIMO- OFDM systems

The algorithm for the proposed scheme is summarized as below.

i. firstly Choose the no of sub-carriers 'N'(say) and oversampling factor 'of' (say)

ii. Multiply both to obtain K (in this work k=512)

iii. Select the QPSK constellation symbols and define the rotation factor value range

iv. Generate the OFDM symbols in the frequency domain as an array of 0's and 1's

v. Take the IFFT of generated OFDM symbols.

vi.Pass the IFFT generated signal through the OSTBC Encoder having variable number of transmit antennas (in this work we take numTx=2,3,4)

vii. Calculate the PAPR for each transmit antenna path(numTx=2,3,4)

viii. Apply the T×T Spreading code (PN) to each antenna path

ix. Calculate the Complementary Cumulative Distribution Function (CCDF) of original signal.

x. Define the different M-ary phase modulations (M=2,4,8,16)

xi. Calculate the PAPR using Selective Level Mapping (SLM) with different M values.

xii. Calculate the signals CCDF with M=2,4,8,16 and for each transmit antenna path.

xiii. Plot the CCDF values with different M values and compare the results

Results and Discussions

In this work a new method based on the combination of OSTBC Encoder and Spreading code sequence have been implemented. Sixty four carriers have been used and oversampling factor is eight. The specifications in this work has been made as per International Telecommunication Union (ITU).The following simulation results illustrate the effect of implementing basic SLM (without OSTBC Encoder), OSTBC Encoder with number of transmit antennas=2,3,4 for various M-Ary phase modulations (M=2,4,8,16) and compares it with original signal. The graphs are plotted between CCDF and PAPR0 (db)

The simulation result for basic SLM(without OSTBC Encoder) have been shown in figure2. With CCDF (Pr[PAPR>PAPR0]) equal to max (i.e 1), it can be shown that PAPR decreases with increasing values of M .For M=16 PAPR reduces to 7.1db as compared to original signal of 10.3db, thus there is a reduction of 3.2 db.
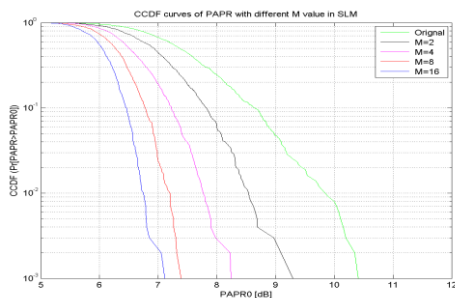
Figure 2: Plot for conventional SLM(without OSTBC Encoder)

Figure 3 shows the simulation result for new proposed method based on the combination of OSTBC Encoder and Spreading code sequence with number of transmit antennas equal to

2.Simulation results show the huge variation in the reduction of PAPR as compared to the original signal with the increasing values of M. For M=16 PAPR reduces to 6.82db as compared to original signal of 10.55db, thus there is a reduction of 3.73db, which is a significant development
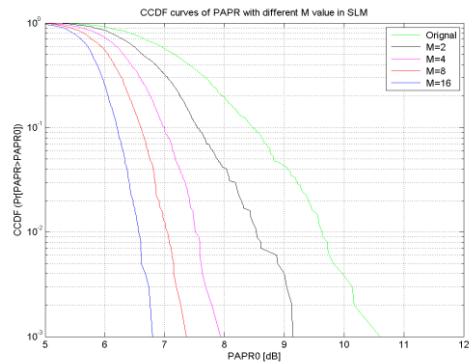
Figure 3: Plot for combination of OSTBC Encoder and Spreading code sequence(numTx=2)

Figure 4 shows the simulation results when number of transmit antennas are changed to 3.Again it is shown that PAPR decreases with the increasing values of M. For M=16 PAPR reduces to 6.8 as compared to original signal of 10.2 showing a reduction of 3.4db
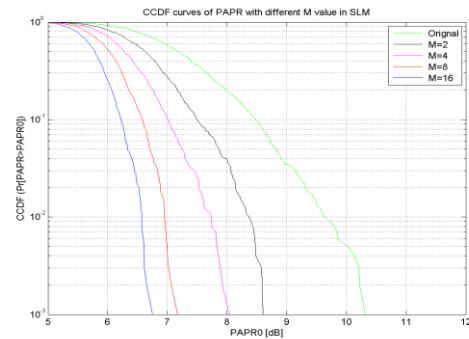
Figure 4 Plot for the combination of OSTBC Encoder and Spreading code sequence (numTx=3)

Figure 5 shows the simulation results when the number of transmit antennas are changed to 4.Simulations show a greater reduction in PAPR with the increasing values of M .For M=16 PAPR reduces to 6.75db as compare to original signal of 10.5db showing a reduction of 3.75db.
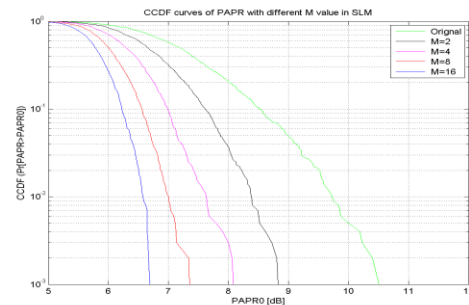
Figure 5 Plot for the combination of OSTBC Encoder and Spreading code sequence (numTx=4)

The above results have been more precisely given in tabular form for different M values and is shown in table 1. The PAPR of the original OFDM signal is calculated using the conventional techniques. Subsequently, the PAPR for different values of M is calculated using the proposed technique. It has been observed

that for the higher values of M there is significant reduction in PAPR.

Table 1. PAPR comparison for various M-ary Phase modulations and original OFDM signal for different proposed techniques

M	PAPR of Conventioanl Scheme	Proposed Scheme for nTx=2	nTx=3	nTx=4
1	10.3	10.55	10.2	10.5
2	9.2	9.1	8.7	8.85
4	8.2	7.79	8.05	8.1
8	7.4	7.2	7.15	7.3
16	7.1	6.82	6.8	6.75

Conclusion

The paper investigates one of the bottleneck problem that exist in MIMO-OFDM systems i.e high peak to average ratio and suggests a new technique to overcome it. The new technique is based on the combination of OSTBC encoder and Spreading code sequence. The proposed OSTBC Encoder uses variable number of transmit antennas that are adaptive and change either manually or according to an adaptation algorithm. Simulation results show a greater reduction in PAPR for the proposed scheme as compared to earlier conventional SLM technique. Also the PAPR decreases significantly for higher values of M as compared to original signal OFDM signal. The proposed scheme has a lot of scope in next generation network systems. Moreover with this improvement it can be considered as a potential candidate for high speed data transmission systems especially 4G systems

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