ARPN Journal of Engineering and Applied Sciences

MITIGATION OF INTERFERENCES IN LTE SYSTEMS

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ABSTRACT

A channel independent pre-coding for MIMO-OFDM systems with insufficient cyclic prefix (CP) is proposed by using the notion of interference nulling. The proposed pre-coding is more bandwidth efficient than the conventional zero-padded (ZP) or CP added MIMO systems, such as, ZP-only and CP-OFDM, when the number of receiver antennas is not more than the number of transmitting antennas. OFDM is an enticing modulation technique for transmitting large amounts of digital data over radio waves. Peak to Average Power Ratio (PAPR) for MIMO-OFDM system is still a demanding area and a difficult issue. A novel phase offset scheme to reduce PAPR in Alamouti coded OFDM systems without side information (SI) is by multiplying different phase rotation sequences by their corresponding phase offsets at the transmitter. Moreover, at the receiver, a MED decoder is also proposed, and the phase offset with the minimum Euclidian distance is selected as the sign of phase rotation sequence used at the transmitter. In this way, the SI can be obtained by estimating the phase offset, since they are one-to-one correspondence. Therefore, the proposed scheme does not need to reserve bits for the transmission of the SI, resulting in an increased data rate.

Keywords: pre-coding, MIMO-OFDM, BER, PAPR.

INTRODUCTION

The use of multiple antennas at the transmitter and receiver in wireless systems, popularly known as MIMO (multiple-input multiple-output) technology, has rapidly gained in popularity over the past decade due to its powerful performance-enhancing capabilities. MIMO technology with space division multiplexing, called Bell Labs layered space-time (BLAST) system achieves a high throughput of wireless links by transmitting independent data streams on the different transmit branches simultaneously [G. Foschini., 1996]. MIMO technology constitutes a breakthrough in wireless communication system design, offering a number of benefits that help meet the challenges posed by both the impairments in the wireless channel as well as resource constraints. The advantages of MIMO systems have been widely acknowledged to the extent that certain transmit diversity methods like Alamouti signalling have been incorporated into wireless standards. Specifically, due to size, cost, or hardware limitations, a wireless agent may not be able to support multiple transmit antennas. A proposed novel frequency domain turbo equalizer for MIMO-OFDM transmission in channels where the maximum excess delay exceeds the length of the guard interval was studied [S. A. Jafar., *et al.,* 2008]. A non-cyclic prefixed MIMO-OFDM system based on a recursive algorithm of joint channel estimation and data detection. Unlike the traditional cyclic prefixed MIMO-OFDM system, the transmitted sequence of the proposed system is given in a way that the block-type pilot sequences and OFDM symbols have been arranged alternately without any CP before each OFDM symbol was used [J. Guo., *et al.,* 2008]. [S. Chern., *et al.,* 2009] presents a new receiver framework for the CP-free MIMO-OFDM system, equipped with the space-time block codes (STBC), over time varying multipath channels. Usually, without CP in the OFDM system, the inter channel interference could not be removed effectively at the receiver when the inter symbol interference has to be taken into account. A general criterion for STBC to achieve full diversity with a linear receiver for a wireless communication system having multiple input and single output (MISO) antennas, particularly, the STBC with Toeplitz structure satisfies this criterion, and therefore, enables full diversity [J. Liu., *et al.* 2009].

PROPOSED SYSTEM MODEL

The received signal is split into different frequencies and merged with their respective phase rotation sequences. These signals enter the Space Frequency Block Coding (SFBC) and each signal is split into two signals. The first signal of each output is $X_1$and the second output is X_2. Each of these signals is then passed through the Inverse Fast Fourier Transform (IFFT) filter and PAPR is also calculated before transmitting the data.

Also, a de-multiplexer selects the minimum PAPR signal from N number of data before transmitting. There are two transmitting antennas, T$X_1$and TX_2. TX_1 keeps the data unchanged, while the data at TX_2 is multiplied by the phase offset $\boldsymbol{e}^{\frac{j2\pi u}{U}}$. The receiving antenna Rx receives the signal and then performs FFT and the signals Y_e and $Y_0$are used in the above equations to get X_e andX_0. It is then passed through MED (Minimum Euclidean Distance) decoder to minimize the distance in the Euclidian space to get the output signal D.

VOL. 12, NO. 21, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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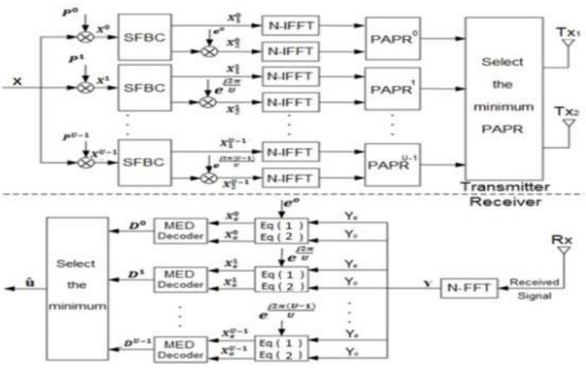

Figure-1. Block diagram of the proposed system.

$$\overline{X}_e^u(l) = H_{1,e}^*(l)Y_e(l) + e^{\frac{j2\pi u}{U}} H_{2,o}(l)Y_o^*(l) \qquad (1)$$

PERFORMANCE ANALYSIS

$$\overline{X}_o^u(l) = e^{\frac{-j2\pi u}{U}} H_{2,e}^*(l)Y_e(l) - H_{1,o}(l)Y_o^*(l) \qquad (2)$$

A. Bit Error Rate (BER) analysis

BER is a key parameter that is used in assessing systems that transmit digital data from one point to another. When data is transmitted over a data link, there is a possibility of errors being introduced into the system, which might cause the integrity of the system to be compromised. Hence, it is necessary to assess the performance of the system and BER provides an ideal way in which this can be achieved.

BER = (Number of errors) / (Total number of bits sent) (3)

B. PAPR in Alamouti MIMO OFDM system

The Alamouti space-frequency block coding (SFBC) is employed for Alamouti MIMO-OFDM systems with two transmit antennas. Therefore, the input data block is encoded into two vectors X_1 and X_2.

$$X_1 = [X(0), X^*(1), \ldots, X(N-2), -X^*(N-1)] \qquad (4)$$

$$X_2 = [X(1), X^*(0), \ldots, X(N-1), -X^*(N-2)] \qquad (5)$$

Where X (K) is modulated by a given signal constellation, N is the number of sub-carriers, and (.)* denotes the complex conjugate operation. After inverse fast Fourier transforms (IFFT) operation, the time domain signal,

$$x_i(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_i(k) e^{\frac{j2\pi kn}{jN}} \qquad (6)$$

C. Existing technique

For successful generation of the relationship between all the carriers in OFDM, they must be carefully controlled to maintain the orthogonality of the carriers [Vijayarangan, V., *et al* 2009]. The multiple orthogonal subcarrier signals, which are overlapped in spectrum mathematically, resemble to N-point IDFT of the transmitted symbols. Thus an OFDM symbol is generated by computing the IDFT of the complex modulation symbols to be conveyed in each sub-channel. Selected mapping (SLM) is a well-known technique of PAPR reduction and it provides the reliable performance of diversity and spatial multiplexing [Yang, Hongwei, 2005]. However this system suffer from high PAPR and inter-symbol interference (ISI), which occurs due to loss of orthogonality due to channel effects. It also requires time and frequency synchronization to get a low bit error rate [Wu, Yiyan. *et al* 1995].

D. Proposed technique

The pre-coding scheme is insertion of one or more zeros between each two sets of K consecutive information symbols. This pre-coding scheme may be able to remove the spectral nulls of an ISI channel without knowing the ISI channel [Xia, Xiang-Gen., 2001]. When no zero is inserted between each two sets of K consecutive information symbols and only each K consecutive symbols are blocked together, we obtain vector OFDM systems. A pre-coded OFDM system that may improve the performance of the OFDM systems for spectral null channels is proposed [Xia, Xiaiig-Gen., 2000]. Size K×1 vector OFDM systems that reduce the cyclic prefix length by K times compared to the conventional OFDM systems is also proposed. This technique has shown significant improvements in BER performance. The spectral efficiency is increased by the use of OFDM and a reduced CP length is obtained. Also, the interference is less in low SNR region.

RESULTS AND DISCUSSIONS

Simulations are carried out to evaluate the ability of the proposed scheme including the PAPR reduction and the BER performance, where 104 data blocks are generated with N=1024 and the oversampling factor J=4. The phase factors are chosen from {-1, 1} while Quadrature Phase Shift Keying (QPSK) and 16-QAM modulation are employed, and the saturation point of the solid-state power amplifier (SSPA) is C=0.1.

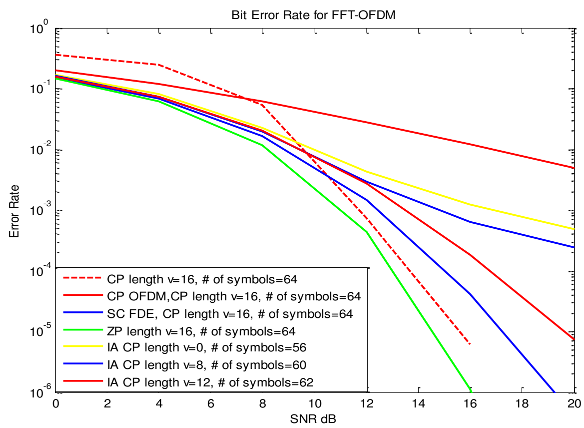

Figure-2. BER performances of the IA based pre-coding, SC-FDE, CP-OFDM, ZP-only.

VOL. 12, NO. 21, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Figure-2 includes the cases of Interface Alignment, CP-OFDM, ZP-only and SC-FDE systems. The order of the CIR is L = 16. The ZP-only scheme performs the best, since it achieves the full multipath diversity with the MMSE or ZF receiver.

Table-1. 16 QAM, Block size N= 8, with varying CP length.

	0dB	4dB	8dB	12dB	16dB	20dB
L=8	0.4	0.25	0.05	0.0008	0.000006	-
L=16	0.4	0.25	0.05	0.0008	0.000010	-
L=32	0.4	0.25	0.05	0.0009	0.000015	0.0000015
L=64	0.4	0.25	0.05	0.0008	0.000019	-

The Block Size is kept Constant for 16 QAM with varying CP length. It shows that as CP length increases, Bit Error Rate (BER) also increases and BER is least when V=8. So, the performance is better for minimum CP length.

Table-2. 16QAM, CP length = 16 with varying Block size.

	0dB	4dB	8dB	12dB	16dB	20dB
N=8	0.35	0.25	0.05	0.0008	0.00001	-
N=16	0.40	0.30	0.12	0.0045	0.000045	-
N=32	0.42	0.35	0.20	0.025	0.00007	-
N=64	0.45	0.40	0.30	0.08	0.0005	-

Now, the CP length is kept constant for 16 QAM with varying block size. It shows that as Block size increases, BER also increases and BER is least when N=8. So, the performance is better when block size is minimum.

Table-3. 64 QAM, Block size N= 8, with varying CP length.

	0dB	4dB	8dB	12dB	16dB	20dB
L=8	0.35	0.12	0.05	0.0008	0.000010	-
L=16	0.35	0.12	0.05	0.0007	0.000015	-
L=32	0.35	0.12	0.05	0.0006	0.000010	-
L=64	0.35	0.12	0.05	0.0007	0.000015	-

The Block Size is kept Constant for 64 QAM with varying CP length. It shows that as CP length increases, BER also increases and BER is least when V=8. So, the performance is better when CP length is minimum.

Table-4. 64 QAM, CP length = 32 with varying block size.

	0dB	4dB	8dB	12dB
N=8	0.35	0.22	0.05	0.0006
N=16	0.37	0.28	0.10	0.004
N=32	0.40	0.32	0.20	0.02
N=64	0.42	0.38	0.25	0.07

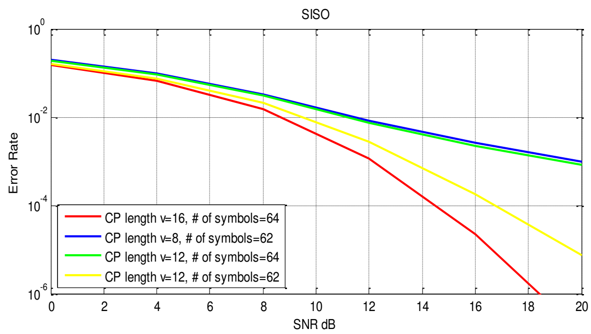

Figure-3. SISO case: BER performances of different CP lengths and different numbers of information symbols.

The CP length is kept constant for 64 QAM with varying block size. Table-4, shows that as Block size increases, BER also increases and BER is least when N=8 till 15dB. At 16dB, BER is least at N=16. So, the overall performance is better when block size is minimum.

In Figure-3, with SISO case, when v = 8 and v = 12 and the numbers of transmitted independent information symbols in one block are 62 and 64 respectively. In BER performances, the error floors occur when SNR becomes high because the IBI cannot be completely eliminated. It is inferred that when insufficient CP/ZP is added for CP-OFDM, ZP-only or SCFDE, error floor will also occur due to the residual IBI occurrence

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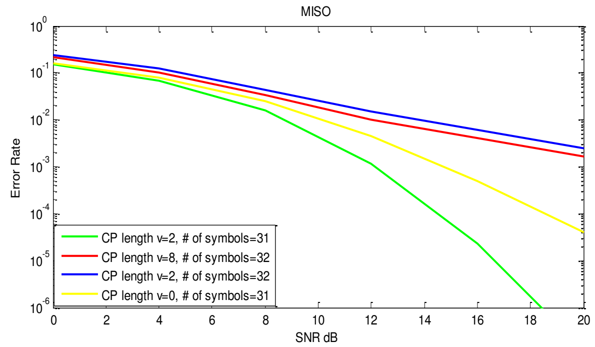

Figure-4. MISO case: BER performances of different CP lengths and different numbers of information symbols.

In Figure-4, the IA based pre-coding scheme with different CP lengths and different numbers of information symbols for the MISO configuration of n_t= 2 and n_r= 1 are shown.

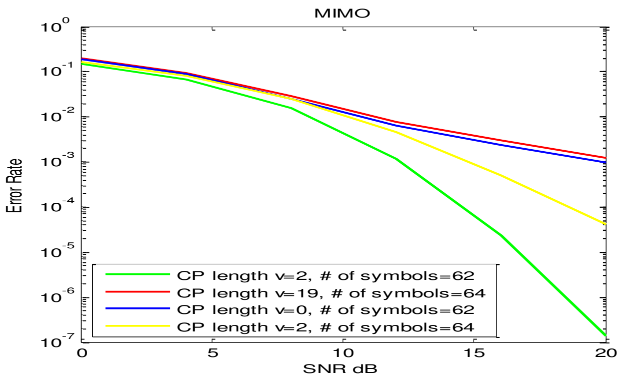

Figure-5. MIMO case: BER performances of different CP lengths and different numbers of information symbols.

In Figure-5, the IA based pre-coding scheme proposed for a MIMO configuration of four transmit and two receive antennas is simulated, i.e., n_t= 4 and n_r= 2.

Figures 6, 7, 8 show the complementary cumulative distribution functions (CCDF) of the PAPR for original signals. It is shown that the P-SLM scheme can offer the same PAPR reduction performance as that of C-SLM scheme, and P-SLM scheme can offer better PAPR reduction performance than B-SLM scheme. QPSK is employed and for U=4, U=8 and U=16, both of the P-SLM and C-SLM scheme can provide the PAPR reduction of 2.6 dB, 3.1 dB and3.6 dB at CCDF = 10^{-4}, respectively; however, the B-SLM scheme can only provide the PAPR reduction of 2.3 dB, 2.8 dB and 3.4 dB at CCDF = 10^{-4}respectively.

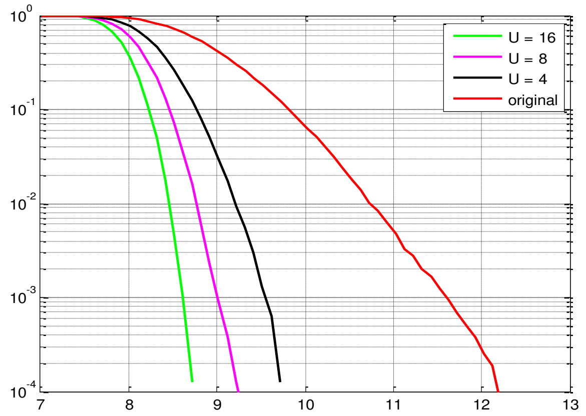

Figure-6. Comparison of the PAPR reduction with QPSK.

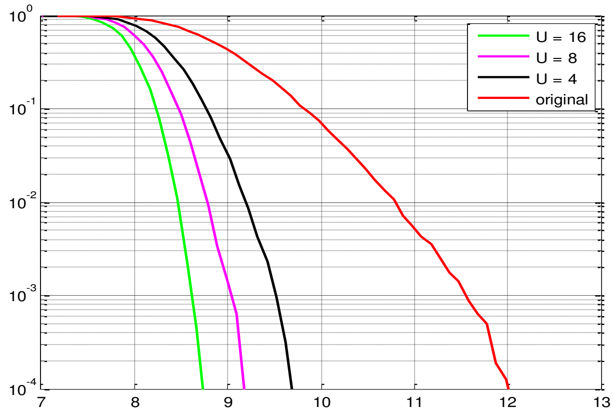

Figure-7. Comparison of the PAPR reduction with 16-QAM.

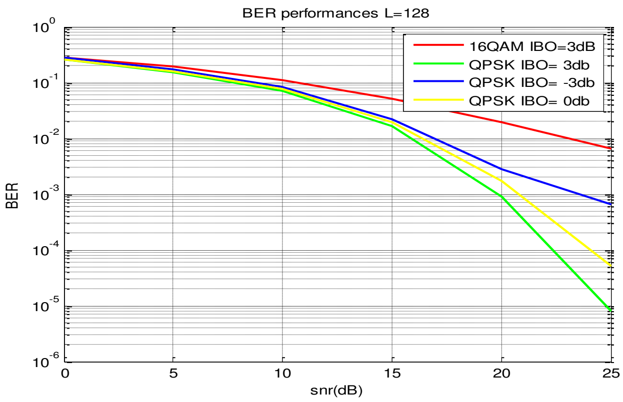

Figure-8. BER Performance with QPSK and 16 QAM (L=128).

CONCLUSIONS

A channel independent pre-coding is proposed for MIMO-OFDM systems with insufficient CP by using the notion of interference nulling that has been also actively used in interference alignment lately. It is shown that the proposed pre-coding is more bandwidth efficient than the conventional zero-padded or CP added MIMO systems, such as, ZP-only, CP-OFDM and SC-FDE systems, when the number of receive antennas is not more than the number of transmit antennas. Also, a novel phase offset scheme is proposed to reduce the PAPR in Alamouti MIMO-OFDM systems without SI. The proposed scheme utilizes the phase offsets as the sign of phase rotation sequences in the C-SLM scheme.

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