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PAPR REDUCTION USING SCS-SLM TECHNIQUE IN STFBC MIMO-OFDM

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ABSTRACT

The combination of MIMO and OFDM gives a very attractive option for high data rate communication in wireless communication system over frequency selective fading. However, MIMO-OFDM also inherent the PAPR problem from OFDM system. We proposed our SCS technique and modified SLM technique to be applied in diversity MIMO-OFDM system for PAPR and BER performance improvement. The utilization of circulant shift codeword from SCS technique with multiplication of phase factor of SLM technique in preparing several candidates for interleaving technique is proposed in MIMO-OFDM system. This approach gave a new solution of reducing high PAPR in MIMO-OFDM system. Moreover, by using diversity MIMO-OFDM which is STFBC, the improvement of BER performance also can be improved until 55%.

Keywords: peak-average power ratio, MIMO-OFDM, space-time-frequency block codes, SCS.

INTRODUCTION

In recent years, information technology has progressively led to global energy consumption due to the demands of mobile communications around the world. In this level, the main component to reduce power consumption depends on the high-power amplifier (HPA) efficiency which is associated to the peak-to-average power ratio (PAPR). Unconstrained signalling technique in MIMO-OFDM represent by Bell Laboratories Layered Space-Time (BLAST) architecture aim to increase data rate through simultaneous transmission offering spatial multiplexing over multiple transmit antenna. The BLAST has a multiplexing capacity but lacks a diversity capacity. That means each antennas is independent like in the single input single output (SISO) case [1-2]. Thus, the PAPR value in BLAST MIMO-OFDM for each antennas in time domain are similar with SISO.

In order to achieve maximum diversity gain by improving BER performance at receiver, recently, joint technique using diversity scheme is widely discussed by researchers [3-4].

Selective Mapping (SLM) technique is widely used in OFDM system in order to reduce high PAPR because of its advantage of avoiding signal distortion [5]. However, a concern of these technique is the side information (SI) is transmitted together with the signal to allow for original data recovery. The erroneous of the SI could affect the BER performance at the receiver if it does not detect the correct SI[6].

In this paper, extending our work in [7], we proposed a modified SLM technique in MIMO-OFDM using diversity scheme space-time-frequency block codes (STFBC) to improve BER as well as to further improve the PAPR performance. This technique applied a circulant shift onto parallel bit data and embedded bit SI before digital modulation process in transmitter joint with SLM technique. The results shows the comparison of PAPR and BER performance between modified SLM, Method 1 of Data Position Permutation (DPP) [8], conventional SLM and Selective Codeword Shift (SCS) [7].

PEAK-AVERAGE POWER RATIO (PAPR)

In MIMO-OFDM system, the PAPR is calculated independently at each antenna. Thus, PAPR calculation for each antennas that using V-BLAST spatial multiplexing are similar with SISO case. The sums of a large number of modulated subcarriers may cause a high peak power values in the time domain instantaneously compare to single carrier system. Basically, PAPR of OFDM signals is determined by the ratio between the peak power and its average power,

$$\mathrm{PAPR} = 10\log\left\{\frac{P_{peak}}{P_{avg}}\right\}\ \mathrm{dB} \tag{1}$$

The complex baseband signal as in Equation. (1) is define over time interval, and mathematically, PAPR is given by

$$\mathrm{PAPR} = 10\log\left\{\frac{\max|s(t)|^2}{E|s(t)|^2}\right\}\mathrm{dB} \tag{2}$$

where $\max|s(t)|^2$ is maximum signal power and $E|s(t)|^2$ is the average signal power. Average signal power of OFDM system is thus calculated by

$$E = \frac{\text{Sum of the magnitude of all OFDM symbol}}{\text{No. of OFDM symbols (N)}} \tag{3}$$

The PAPR performance is commonly presented in Complementary Cumulative Distribution Function (CCDF). CCDF is defined as the probability of exceeded PAPR in a certain PAPR threshold, γ. CCDF of OFDM system can be expressed as

$$\mathrm{CCDF}(\gamma) = \Pr\{\mathrm{PAPR} > \gamma\} = 1 - (1 - \mathrm{e}^{-\gamma})^{\mathrm{N}} \quad (4)$$

SPACE-TIME-FREQUENCY BLOCK CODES (STFBC)

STFBC is a diversity scheme which is performed using space time (ST) and space frequency (SF), where the symbols are sent through multiple of antennas at different frequency and different times. The encoding of STFBC is generated by following Alamouti code as in [9]. The STFBC with two symbol blocks is design as

$$\mathrm{X}_{\mathrm{STF}} = \begin{bmatrix} s_{1,1} & s_{2,1} \\ -s_{2,1}^{*} & s_{1,1}^{*} \end{bmatrix}^{\mathrm{T}} \quad (5)$$

The design of STFBC is based on the full diversity SFBC. Thus, STFBC code can be simply generated by repeating SFBC multiple times. PAPR for diversity MIMO-OFDM has been discussed to be calculated in each time slot [10]. PAPR for next time slot is reported to have a same property with first time slot because of the repeating codes. As such, the PAPR for STFBC and SFBC for two symbol block is similar for each time slot.

SCS-SLM TECHNIQUE

The baseband model of SCS-SLM OFDM system is depicted in Figure-1. At the transmitter, binary data stream is duplicated in several number of candidates, m, where m is obtained from number of bits per symbol ($\log_2$ M-ary QAM). Each candidates of data are then embedded with bit SI as in Figure-2. The data is shifted into desired SCS shift factor as in [7]. The shifted binary data codeword is given as

$$C^{\zeta} = \prod_{k=1}^{K} C_k \otimes S^{\zeta}, \quad 0 \le \zeta \le m-1 \quad (6)$$

After that, the binary data are modulated using QAM modulation to produce complex number of OFDM symbols as a preparation to be modulated by IFFT. The outputs of the symbol sequences are$\mathrm{X}^{S} = [\mathrm{X}_{1,\zeta}, \mathrm{X}_{2,\zeta}, \ldots, X_{K,\zeta}]$. Before the data is undergoing for IFFT modulation, the multiplication of data and desired phase factor is carried out to perform SLM. The new alternatives OFDM symbol for modified SLM is given by

$$\mathrm{X}^{S,u} = \prod_{k=1}^{K} X_k^{S} \otimes \mathrm{P}^{u}, \qquad 0 \le u \le U-1 \quad (7)$$

The process is followed by IFFT modulation for each candidates. Therefore, the alternative OFDM signals in the time domain is represented as

$$x^{S,u}(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} \mathrm{X}^{S,u} \cdot e^{j2\pi f_k t} \quad (8)$$

Finally, the minimum PAPR among those candidates is selected for transmission. The minimum PAPR for alternative OFDM signals are obtained by

$$s^{S,u}(t) = argmin_{0 \le u \le U-1} \left\{ \frac{\max\left|x^{S,u}(t))\right|^2}{E\left|x^{S,u}(t)\right|^2} \right\} \quad (9)$$

As given in Equation. (4), CCDF of OFDM system in this technique can be expressed as

$$CCDF(\gamma) = \{Pr\{PAPR > \gamma\}\}^{S} = \{1 - (1 - e^{-\gamma})^{N}\}^{S} \quad (10)$$

At receiver part, the received signals are demodulated using FFT as given as

$$\mathrm{Z(k)} = \frac{1}{\mathrm{T}} \int_0^{\mathrm{T}} \mathrm{z(t)} \cdot \mathrm{e}^{-\mathrm{j}2\pi \mathrm{f_k t}}\, \mathrm{dt}, \quad \mathrm{k} = 0,1,..\mathrm{N}-1 \quad (11)$$

The symbols are then undergoing SLM decode process base on side information index received together with the data. Finally, the output data can be retrieved after demodulation by QAM or PSK and SCS decoding which is the backward process of SCS encoding.

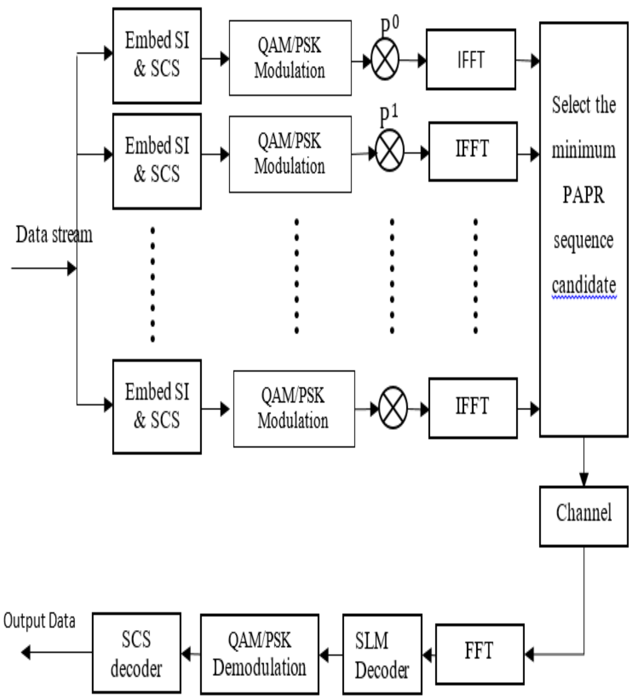

Figure-1. Block diagram of proposed SCS-SLM technique in OFDM systems.

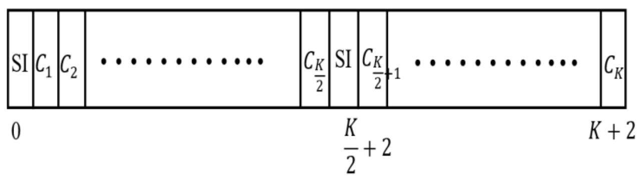

Figure-2. Sub-block sequence with m bits of embedded bit side information.

RESULTS AND DISCUSSIONS

An OFDM system of 128 subcarrier and 64 QAM has been considered in the simulation. There were 10^4 of

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OFDM signals which have been considered to calculate the PAPR complementary cumulative distribution functions (CCDF) for PAPR performance investigation using SCS, SCS-SLM, conventional Selective Mapping (SLM) and method 1 of Data Position Permutation (DPP). Table-1 shown the OFDM system parameter used in the simulation.

Table-1. Simulation parameters for the 3rd generation partnership project long term evolution (3GPP-LTE) system [11].

Parameter	Value
Bandwidth (BW)	1.25 MHz
Sampling frequency	1.92 MHz
Sampling time	5.208×10^{-7} sec
IFFT size	128
Used subcarrier	76
Modulation technique	64 QAM
Guard interval	1/4
Chanel model	Rayleigh Fading

Firstly, performance of PAPR is investigated between SISO and STFBC MIMO-OFDM. The results obtained are shown in Figure-3. STFBC scheme shows an increment of PAPR CCDF value for original OFDM and SCS-SLM. The increment is about 0.1 dB and 0.5 dB respectively. On the other hand, SCS technique shows a slightly decreasing pattern between SISO and STFBC. The difference is about 0.2 dB. These results can conclude two findings. First, the application of STFBC MIMO-OFDM can cause a degradation of PAPR CCDF performance. Second, the SCS and SCS-SLM technique show the potential in mitigating high PAPR problem in SISO and V-BLAST MIMO-OFDM compare with STFBC MIMO-OFDM. The best performance can be achieved when using SCS-SLM in SISO OFDM system with PAPR 7.6 dB at clip rate10^{-3}.

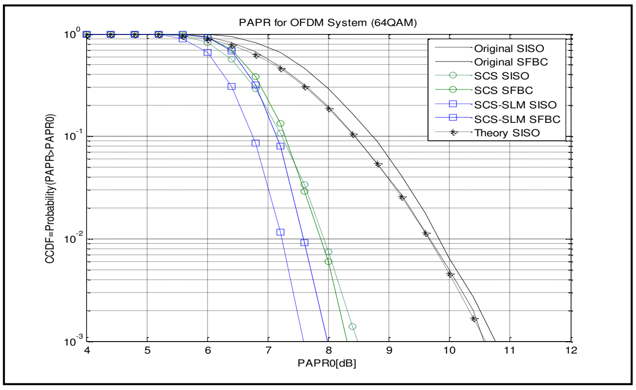

Figure-3. PAPR performance of SCS and SCS-SLM in SISO and STFBC MIMO OFDM.

However, the PAPR in STFBC MIMO-OFDM when comparing SCS and SCS-SLM with the other probabilistic technique such as DPP and SLM has shown a competitive result in improving PAPR problem. As we can see in Figure-4, SCS-SLM technique achieved the best PAPR CCDF performance with 7.8 dB which is about 2.9 dB improvement. Then, PAPR CCDF for SCS technique and DPP are about 8 dB and 8.5 dB respectively. The PAPR CCDF for conventional SLM technique is 9.8 dB. This result proof that SCS-SLM technique has improve the conventional SLM PAPR performance about 2 dB. The PAPR CCDF results are summarized in Table-2.

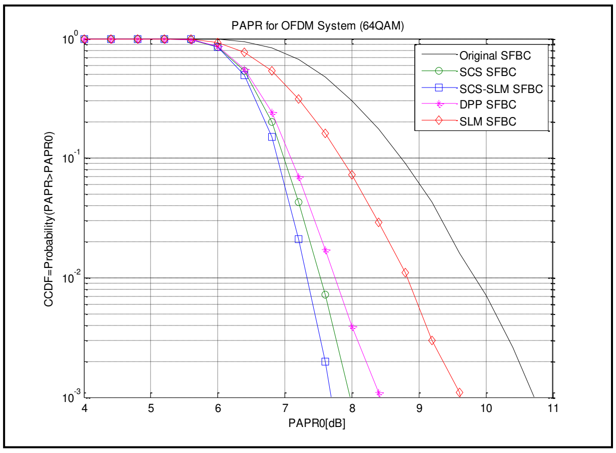

Figure-4. PAPR performance for SCS, SCS-SLM, DPP and SLM in MIMO-OFDM.

Table-2. Summary of PAPR reduction.

	PAPR (dB)				
OFDM System	**original**	**SCS**	**SCS-SLM**	**DPP**	**SLM**
SISO	10.7	8.5	7.6	9.2	9.6
STFBC	10.8	8.0	7.8	8.5	9.8

In Figure-5, the robustness of BER performance in the system is investigated by comparing SCS-SLM technique in both SISO/V-BLAST and STFBC MIMO-OFDM system. In the graph, we can see that, there is a significant improvement of BER performance using SCS-SLM STFBC compare with SCS-SLM SISO/V-BLAST system. The maximum BER improvement using SCS-SLM STFBC is achieved when utilizing 2 received antennas. The result shows an improvement about 55%. The more antennas used at receiver, the better BER performance can be achieved.

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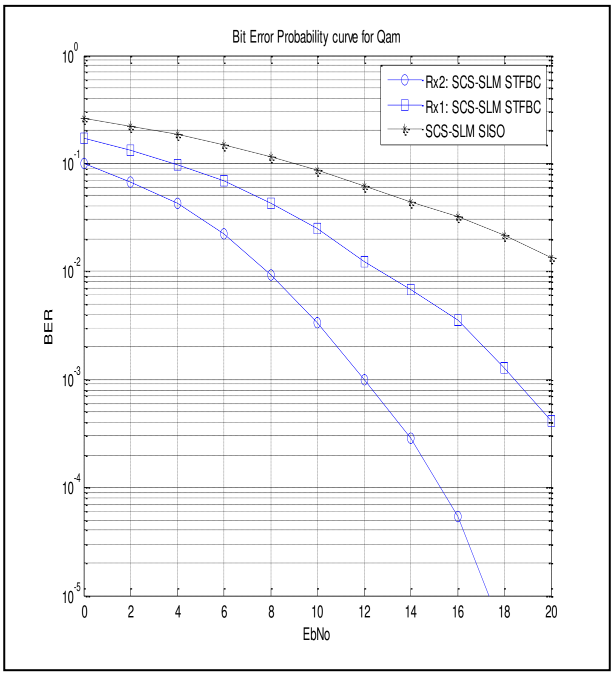

Figure-5. BER performance for SISO/V-BLAST and SCS-SLM.

CONCLUSIONS

MIMO-OFDM systems also inherit the PAPR problem in its system. In this paper, utilizing SCS and SCS-SLM in MIMO-OFDM system using diversity scheme STFBC are proposed. The results show a potential of these technique to reduce PAPR in SISO OFDM, BLAST MIMO-OFDM and STFBC MIMO-OFDM. The best performance can be achieved when utilizing SCS-SLM technique in SISO or BLAST MIMO-OFDM system. Furthermore, the application of STFBC in MIMO-OFDM can improved about 55% of the BER performance when compare with BLAST MIMO-OFDM.

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