Influence of Utilizing the Selective Mapping Technique for PAPR Reduction in SC-FDMA Systems

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ABSTRACT
In this paper, the influence of the use of the selective mapping technique in SC-FDMA systems has been investigated for various modulation schemes in order to reduce the values of the Peak-to-Average-Power-Ratio. In fact, single carrier frequency division multiple access (SC-FDMA) scheme has not only utilized the frequency-domain equalization, and has the most features of OFDMA, but it has an outstanding feature. It has low PAPR values due to its single carrier structure. However, localized frequency division multiple access (LFDMA) still needs more PAPR reduction since the pulse shaping process has not a reasonable effect on its PAPR performance. Accordingly, we propose a scheme that's combining the selective mapping technique besides SC-FDMA. Afterwards, we numerically discuss PAPR characteristics according to the complementary cumulative distribution function (CCDF). The results demonstrate that the proposed scheme has a significant PAPR reduction.

Keywords: SC-FDMA; Time domain selective mapping; Peak-to-average power ratio; side information.

1. INTRODUCTION
The prominent advantage of SC-FDMA over OFDMA is the outstanding PAPR reduction. However, as a result of a numerous number of subcarriers and the accumulation of multiple component carriers, the PAPR of SC-FDMA signal consequently increases [1]. In this point of view, the PAPR issue is still a problem that decreases the power efficiency.SC-FDMA is a promising scheme for high data rate uplink communication systems. This scheme has many approaches, among the potential sub-carrier mapping approaches. The LFDMA scheme with channel-dependent scheduling (CDS) produces a higher throughput than IFDMA. However, the PAPR performance of IFDMA is much better than that of LFDMA by up to 7dB [2].

Note that the effect of pulse shaping on the PAPR performance for the IFDMA scheme is much greater than the LFDMA scheme [3]. An investigation for the effect of the time domain selective mapping on both LFDMA and IFDMA will be presented in the upcoming sections.

2. SELECTIVE MAPPING
Unlike clipping techniques [4], [5], the most famous distortionless PAPR reduction schemes are Selective Mapping (SLM) and Partial Transmit Sequence (PTS) [6], [7], [8]. In fact, SLM has higher computational complexity than PTS; however, it has a significant PAPR reduction [9]. In SLM scheme, the input data block

$$\mathbf{X}=[X[0], X[1], \ldots, X[N-1]]^T \quad (1)$$

is multiplied with U different phase sequences,

$$P^{\boldsymbol{u}}= [P_{\mathbf{0}}^{\boldsymbol{u}}, P_{\mathbf{1}}^{\boldsymbol{u}}, \ldots\ldots, P_{N-1}^{\boldsymbol{u}}]^T \quad (2)$$

, where $P_v^u = e^{\phi_v^u}$ and $\phi_v^u \epsilon [0, 2\pi]$ for v = 0, 1, ……, N-1 and u = 1, 2, ….., U, which produce a modified data block,

$$x^u= [x^u[0], x^u[1], \ldots\ldots, x^u[N-1]]^T \quad (3)$$

Afterwards, the independent sequences are inserted into IFFT to produce time domain sequences

$$x^u= [x_{\mathbf{0}}^{\boldsymbol{u}}, x_{\mathbf{1}}^{\boldsymbol{u}}, \ldots\ldots, x_{\boldsymbol{N-1}}^{\boldsymbol{u}}]^T \quad (4)$$

, among which the one $\tilde{X}= X^{\tilde{u}}$ with the lowest PAPR is selected for transmission [10][11], as shown as:

$$\tilde{u} = \underbrace{argmin}_{u=1,2,\ldots,u}\left(\max_{n=0,1,\ldots,N-1} |x^u[n]|\right) \quad (5)$$

Note that SLM technique requires side information (SI), so that the data can be recovered in the mapping stage [12]. The side information is a drawback because it is considered as overhead and it reduces the spectral efficiency.

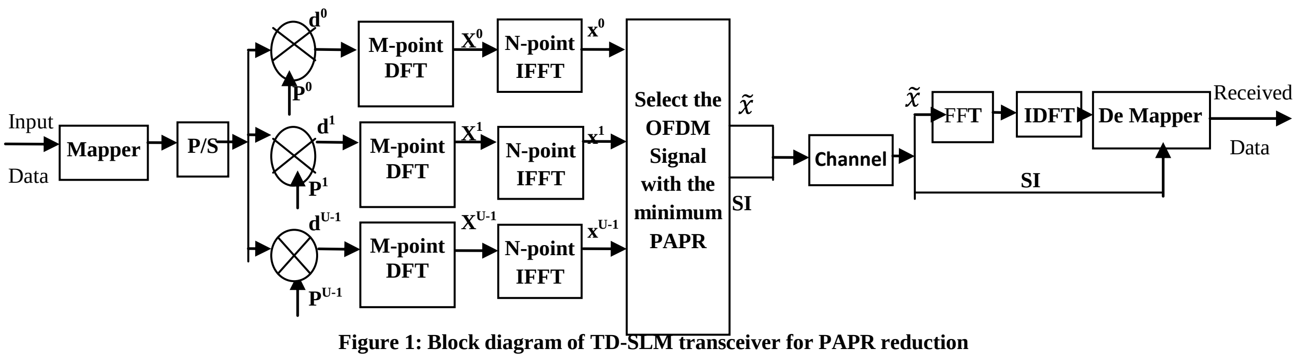

Figure 1: Block diagram of TD-SLM transceiver for PAPR reduction

3. PROPOSED TD-SLM SCHEME

We name our proposed scheme as Time-Domain Selective Mapping (TD-SLM), mainly because the selective mapping process is taken a place in the time domain. The PAPR of the transmitted signal can be written as follows,

$$\textbf{PAPR (dB)} = \mathbf{10 \log_{10}} \frac{max\{|x(t)|^2\}}{E\{|x(t)|^2\}} \quad (6)$$

In TD-SLM scheme, a block of M mapped symbols,

$$\mathbf{d}=[d[0], d[1], \ldots, d[M\text{-}1]]^T \quad (7)$$

,is multiplied by U different phase sequences,

$$P^{u} = [P_0^u, P_1^u, \ldots\ldots, P_{M-1}^u]^T \quad (8)$$

, where $P_v^u = e^{\phi_v^u}$ and $\phi_v^u \epsilon\ [0, 2\pi]$ for v = 0, 1, ……, M-1 and u = 1, 2, ….., U, which produce a modified data block

$$d^u = [d^u[0], d^u[1], \ldots\ldots, d^u[M-1]]^T \quad (9)$$

Afterwards, each block is transformed into the frequency-domain signals by the application of the M-point discrete Fourier transform (DFT),

$$X^u = F_M\, d^u = [X_0^u, X_1^u, \ldots\ldots, X_{N-1}^u]^T \quad (10)$$

, In which $[\mathbf{F}_m]_{k,m} = e^{\frac{j2\pi km}{M}}$

Afterwards, the M-points X is inserted to N-points inverse discrete Fourier transform (IDFT), which produces:

$$x^u = (F_N)^{-1}\, G\, F_M\, d^u = [x_0^u, x_1^u, \ldots\ldots, x_{N-1}^u]^T \quad (11)$$

,where G represents the sub-carrier mapping transform matrix.

Among which the one $\tilde{x} = x^{\tilde{u}}$ with the lowest PAPR is selected for transmission.

$$\tilde{u} = \underbrace{argmin}_{u=1,2,\ldots,u}\left(\max_{n=0,1,\ldots,N-1} |x^u[n]|\right) \quad (12)$$

Note that there is a proportional relationship between the number of phases and the number of DFT and IFFT machines, i.e. if we use U phases; we have to implement U DFT and IFFT blocks. Therefore, a compromise between the cost, complexity and the PAPR performance should be taken into account.

Due to the side information which is a must for a correct recovery of the data block in de-mapping stage, the bit error rate will be increased. This is due to the loss or the distortion of the SI during the transmission process. So that securing the side information from the channel impairments will be ultimately desired, however, this will increase the size of this overhead.

In our work, each data block just needs additionally, 6 bits as maximum, and 1 bit as minimum to represent its phase rotators (SI). Therefore, the spectral efficiency is slightly reduced.

4. SIMULATION RESULTS

In [13], it is mentioned that in case of LFDMA with N = 256, M = 64, and S = 4, the values of PAPR for QPSK, 16-QAM and 64-QAM are 7.7dB, 8.3dB and 8.4dB respectively, for CCDF of 10^{-3}. The following figures show a comparison of PAPR performances when the TD-SLM for DFT-spreading technique is applied to the LFDMA and IFDMA. Here, QPSK, 16-QAM, and 64-QAM are used 256 sub-carriers in a transmission bandwidth of 5 MHZ, M = 64, with Spreading factor of 4. The total number of the data blocks which were used in the simulation is 5,000 data blocks. It can be concluded; from the following figures, the PAPR performance of the TD-SLM varies depending on the sub-carrier allocation method and the number of phases, U. For instance, in the case of QPSK, with the LFDMA allocation scheme, the values of PAPRs with U= 4, 8, 64 are 4.5dB, 5.3dB, and 6dB respectively. Accordingly, when the number of phases U increased, this will lead to significant enhancement to the PAPR performance for the LFDMA allocation scheme.

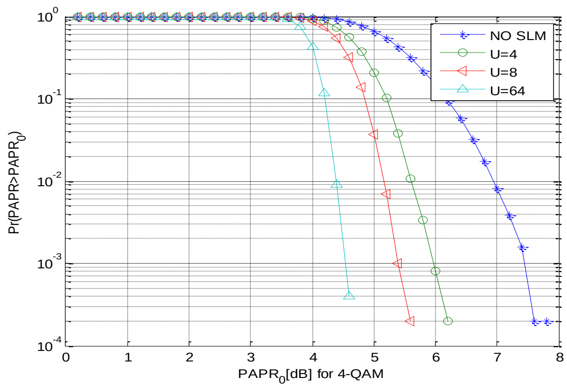

Figure 2, PAPR performance of QPSK for LFDMA

Figure 3 shows that the most of data blocks, that utilize a large amount of phases tend to produce a lower PAPR. Moreover, the figure raises a significant issue, i.e. if we want to utilize a clipping technique to assist the TD-SLM in gaining more PAPR reduction, e.g. 2dB; the number of the clipped signals for those which use a small amount of U, e.g. U=2 is much lesser than for those that use a large amount of U. Therefore, it is not recommended to use clipping techniques besides TD-SLM in case of the use of large number of phase rotators. Note that much clipped signals produce a high degradation in BER performance, which must be avoided.

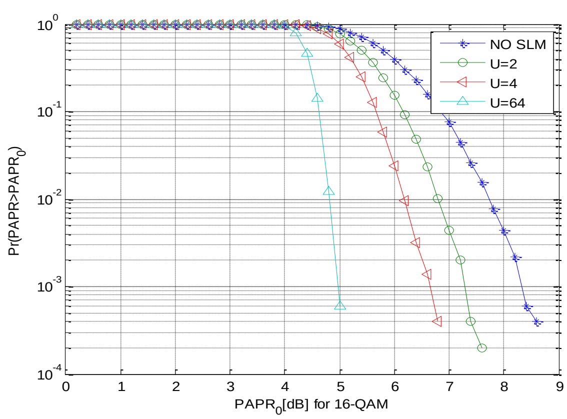

Figure 3, PAPR performance of 16-QAM for LFDMA

According to Figures 3 and 4, it is shown that at high modulation orders schemes, i.e. 16 QAM and 64 QAM there is a slight PAPR reduction (0.2 dB) for the benefit of the former modulation scheme. So that considering low modulation order to minimize the PAPR is not a good idea at all. Therefore, it is recommended to utilize high modulation schemes in case of the transceiver has the capabilities to encode and decode them according to the available channel. High modulation order schemes can significantly assist in gaining high channel capacity.

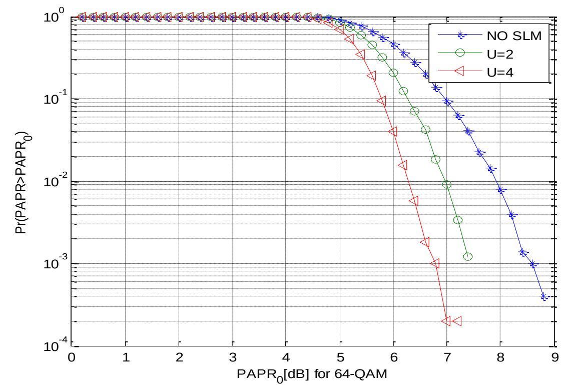

Figure 4, PAPR performance of 64-QAM for LFDMA

IFDMA is another allocation scheme in SC-FDMA systems with a significant low PAPR values compared with LFDMA. However, we still need more PAPR reduction to minimize the power consumption of the amplifier, especially for handheld terminals, which use batteries. We examine the PAPR performance for the 16-QAM-IFDMA scheme by applying TD-SLM technique, in the case of U= 4, 64. The resulting PAPR values were 2.2dB, and 2.8dB in case of CCDF of 10^{-3}. Note that IFDMA is significantly hard to be implemented, so that it is suggested to utilize TD-SLM besides LFDMA scheme as a possible solution for the current wireless systems.

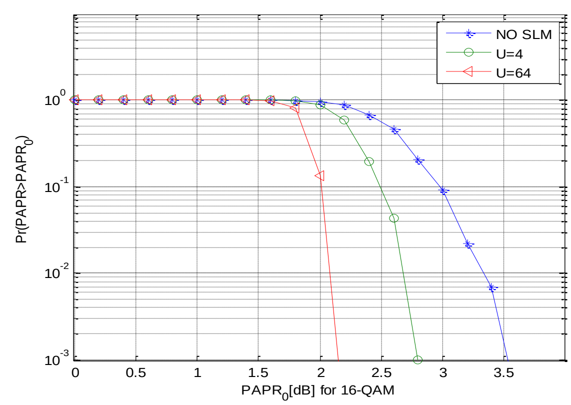

Figure 5, PAPR performances of 16-QAM for IFDMA

Evaluating the BER performance is a must and it considerably taken into account in the matter of design. Figure 6 visualizes the BER performance of 4-QAM for LFDMA over Additive White Gaussian Noise (AWGN) channel. Eight SLM phases are utilized to evaluate the performance, i.e., the size of side information (SI) is three bits per data block. Unfortunately, as shown in figure 6, there's a slight degradation in the BER performance for the proposed TD-SLM scheme. This might be happened due to the loss or the distortion of the side information during the transmission process.

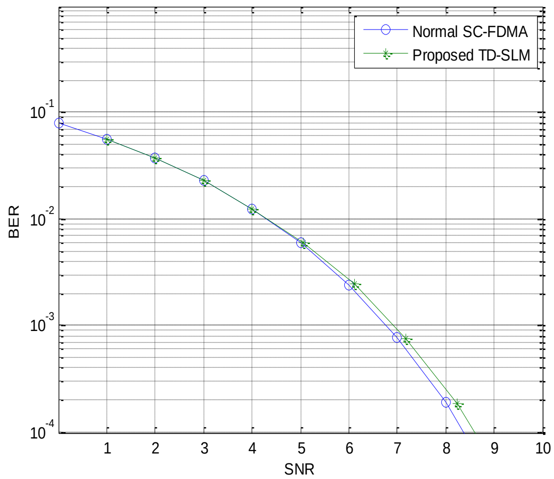

Figure 6, BER performance over AWGN channel

5. CONCLUSION

The time domain selective mapping technique (TD-SLM) shows significant enhancements in the PAPR performance in SC-FDMA, especially for LFDMA allocation scheme, but it causes a slight BER degradation. TD-SLM could reduce the PAPR more than 3.5dB. However, the uplink transmitter's computational complexity will be going up. Therefore, a compromise between (the circuit's cost; the computational complexity) and (PAPR performance) should be taken into design considerations.

6. REFERENCES

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