PAPR Reduction Effect of Selective Mapping for Single-Carrier Joint Transmit/Receive Frequency-Domain Equalization

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1. Introduction

Joint transmit/receive frequency-domain equalization based on minimum mean-square error criterion (joint Tx/Rx MMSE-FDE) [1] was introduced as a promising technique combating with inter-symbol interference (ISI) in single-carrier (SC) transmission. However, it increases the peak-to-average power ratio (PAPR) of the transmitted signal. In this paper, we introduce the selective mapping (SLM) [2], which was proposed for orthogonal frequency division multiplexing (OFDM), to SC with joint Tx/Rx MMSE-FDE for PAPR reduction.

2. SC transmission

Figure 1 shows SC transmission model employing both joint Tx/Rx MMSE-FDE and SLM module. The transmission is conducted as N_c-length block transmission with N_g-length cyclic prefix insertion. Tx-FDE weight $W_t(k)$ and Rx-FDE weight $W_r(k)$ are multiplied in frequency domain. In addition, a selected phase sequence is also introduced at the transmitter. The transmitted signal vector **s** can be written as

$$\mathbf{s} = \mathbf{F}_{N_c}^H \mathbf{P}_{\hat{u}} \mathbf{W}_t \mathbf{F}_{N_c} \mathbf{d}\ , \tag{1}$$

where $\mathbf{P}_{\hat{u}} = diag[p_{\hat{u}}(0),...,p_{\hat{u}}(N_c-1)]$ is the phase sequence matrix. **d** is the time-domain modulated transmit symbol vector. $\mathbf{F}_{N_c}$ is an N_c-point discrete Fourier transform (DFT) matrix, where its Hermitian transpose represents inverse operation. $\mathbf{W}_t = diag[W_t(0),...,W_t(N_c-1)]$ is Tx-FDE weight matrix.

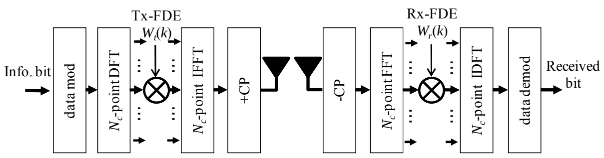


Fig. 1 Transmission system model.

3. PAPR Reduction Using SLM

With the aid of DFT, SLM can be directly applied to SC transmission in frequency-domain approach. Here, frequency-domain filtered signal vector $\mathbf{S} = \mathbf{W}_t \mathbf{F}_{N_c} \mathbf{d}$ is introduced. A set of U different unit-magnitude phase sequences $\mathbf{p}_u$ is defined. The first candidate $\mathbf{p}_0$ is set to all "1" sequence as a representative of original signal, where the other candidates is randomly generated as $\{p_u(k) = \pm 1 \mid k = 0,1,\ldots,N_c-1\}$. The instantaneous PAPR of transmitted signal block $\mathbf{s}_u = \mathbf{F}_{N_c}^H \mathbf{P}_u \mathbf{S}$ for all u are calculated from 0 to U–1, and the phase sequence index $\hat{u}$ which provides the minimum PAPR is selected by

$$\hat{u} = \arg \min_{u=0,1,\ldots,U-1} PAPR(\mathbf{s}_u = \mathbf{F}_{N_c}^H \mathbf{P}_u \mathbf{S})\ . \tag{2}$$

4. Tx-FDE and Rx-FDE weights

Using phase sequence may lead to modifications on Tx-FDE and Rx-FDE weights in [1]. By using MMSE criterion between frequency-domain signals, Rx-FDE weight can be expressed by

$$W_r(k) = \frac{H^*(k)\, p_{\hat{u}}^*(k) W_t^*(k)}{\left|H(k)\, p_{\hat{u}}(k) W_t(k)\right|^2 + \left(E_s/N_0\right)^{-1}}\ . \tag{3}$$

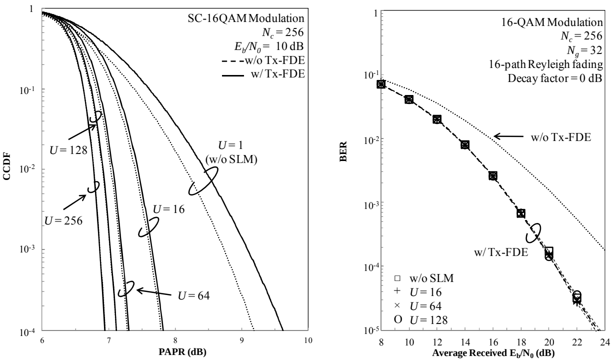
If the derived $W_r(k)$ is substituted back to the objective function (i.e., mean-square error), the MSE can be rewritten as

$$MSE = \sum_{k=0}^{N_c-1} \frac{\left(E_s/N_0\right)^{-1}}{\left|H(k)\right|^2 \left|p_{\hat{u}}(k)\right|^2 \left|W_t(k)\right|^2 + \left(E_s/N_0\right)^{-1}}\ . \tag{4}$$

Since $\left|p_{\hat{u}}(k)\right|^2 = 1$, (4) is exactly the same as MSE in [1], implying that there is no change on Tx-FDE. In addition, if the equivalent channel $H(k)\,p_{\hat{u}}(k)W_t(k)$ is accurately estimated, the transmission with SLM does not affect the bit-error rate (BER).

5. Simulation Results

Figure 2 shows the PAPR and BER performances of SC transmission with joint Tx/Rx MMSE-FDE and SLM. 16-QAM modulation is used. U=1 corresponds to no SLM. It can be also observed that the increasing of number U of phase sequence candidate also reduces PAPR, however, computational complexity also increases. As shown in Fig. 2(b), there is no significant impact on BER in case of perfect channel estimation.



(a) PAPR performance　(b) BER performance

Fig. 2 Performance comparison.

6. Conclusion

In this paper, SLM was introduced to SC transmission with joint Tx/Rx MMSE-FDE in order to reduce the PAPR. Simulation results confirmed that the SLM can reduce the PAPR, while it does not affect BER in case of perfect channel estimation.

References

[1] K. Takeda, and F. Adachi, IEICE Trans. Commun., vol. E94-B, no. 5, pp. 1396-1404, May 2011.

[2] H. Gacanin, and F. Adachi, Proc. VTC2008-Fall, Sept. 2008.