Study and Analyze the PAPR Performance in Asterisk QAM and Square QAM SC-FDMA Systems

Hsin-Ying Liang, Wei-Chih Yeh and Chia-Hsuan Chen
Dept. Of Information and Communication Engineering, Chaoyang University of Technology
168, Jifeng East Road, Wufeng Dist., Taichung City 41349, Taiwan
hyliang@gm.cyut.edu.tw

Abstract— The single carrier frequency division multiple access (SC-FDMA) technology has been selected as the uplink transmission technology by the long term evolution (LTE). Although the SC-FDMA technology already becomes a popular transmission technology, it still has many defects under improvement; for example, the SC-FDMA signal has high peak to average power ratio (PAPR). This paper mainly studies and analyzes the PAPR performance in asterisk QAM and square QAM SC-FDMA systems. Moreover, this paper finds out the reachable efficiency improving fact and features while applying the partial transmit sequence (PTS) technology on this systems.

Keywords— SC-FDMA, PAPR, PTS, Asterisk QAM.

1. INTRODUCTION

Nowadays the quadrature amplitude modulation (QAM) technology is the modulating technology used widely, on particular, the square QAM is commonly used in various communication systems. As compared to the asterisk QAM technology, since the performance of square QAM technology may be affected by the coherent detection, the asterisk QAM [1-6] thus get more attention worldwide, and the asterisk QAM is one among the constellation QAM. At present, many ways of improving PAPR have been published; such as the partial transmit sequence (PTS) [7-9], selective mapping (SLM) [10-12] and tone reservation (TR) [13-18], etc. the PTS technology is the popular technique and applied in the orthogonal frequency division multiplexing (OFDM) system. PTS makes multi-sub-block-dividing on the block signals inputted, in which the block-dividing should satisfy two conditions: the sum of all sub-blocks is the block data originally inputted; and no intersection occurs among the sub-blocks. PTS is to multiply a phase factor on each sub-block after being converted to multi-time-domain signal, which can change the phase change of time-domain signals; and finally makes a linear combination on these time-domain signals with phase-change. PTS is the picked minimum PAPR signal, in the prospective of lowering the possibility of making PAPR during signal transmission.

This paper bases on the SC-FDMA system of asterisk and square QAM, analyze the PAPR performance; try using the PTS technology to observe the PAPR performance being improved. Finally, follow the simulation data to provide the analysis result and respective solution.

1. SC-FDMA SYSTEM and PAPR

In Fig. 1, data transmitted is modulated first; modulation methods include the M-ary phase shift keying (PSK) or M-ary QAM, etc.; then, use the M-point discrete Fourier transform (DFT) converting the modulated result into the time-domain signal. Next, send the time-domain signal to the N-point inverse discrete Fourier transform (IDFT), transmitted to the SC-FDMA signal. Fig 2 shows the laying way of input-data under IDFT; it normally is divided into either the distributed or localized type, called the distributed DFT spread OFDM and localized DFT spread OFDM. The distributed DFT spread OFDM lays the IDFT input-data with a specific time-interval; when the time-interval is fixed, the distributed DFT spread OFDM is called the interleaved DFT spread OFDM. The Localized DFT spread OFDM lays the IDFT input-data at the IDFT input end consecutively. For example, we express M symbols under transmission by

$$\mathbf{a} = [a_1, a_2, \cdots, a_M],$$

after IDFT, it becomes

$$X_k = \sum_{i=0}^{M-1} a_i e^{-j\frac{2\pi ik}{M}}, \quad k = 0,1,\ldots,M-1.$$

Assume using the Localized DFT spread OFDM

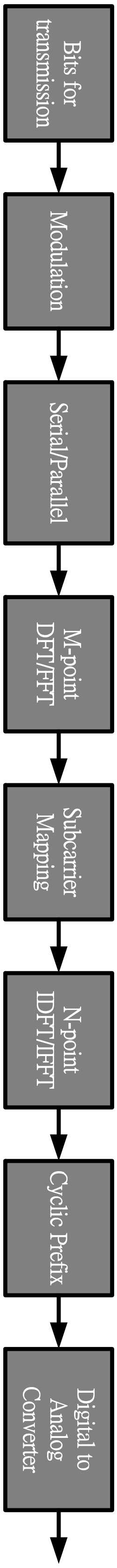

Fig. 1 SC-FDMA system block diagram at transmission end

technology, the input-data of N-point IDFT is expressed as

$$\bar{X}_p = \begin{cases} X_p,\ p = 0,1,\ldots,M-1 \\ 0,\ p = M, M+1,\ldots,N-1 \end{cases}, \qquad (1)$$

If using the Distributed DFT Spread OFDM technology, and set the input-interval amount to Q, we can use the example shown in below:

$$\bar{X}_p = \begin{cases} X_p,\ p = 0, Q, 2Q,\ldots, MQ \\ 0,\ p \neq 0, Q, 2Q,\ldots, MQ \end{cases} \qquad (2)$$

where $QM \le N$. In order to facilitate the nomenclature, we also call the Localized DFTS-OFDM the SC-LFDMA, and call the Interleaved DFTS-OFDM the SC-IFDMA. Next, after N-point IDFT operation, the generated DFTS-OFDM signal is expressed as

$$x_s = \frac{1}{N}\sum_{p=0}^{N-1} \bar{X}_p e^{\frac{j2\pi sp}{N}}, \quad s = 0,1,\ldots,N\text{-}1 \qquad (3)$$

The PAPR of DFTS-OFDM is defined and expressed as:

$$\text{PAPR}=10\log_{10}\left(\frac{\max|\bar{x}_s|^2}{E\{|\bar{x}_s|^2\}}\right),\ s = 0,1,\ldots,N$$

where E{u} means the expected value of u. in other words, the PAPR of any signal is defined as the ratio of its peak instantaneous power to the average power. Normally, we use the complementary cumulative distribution function (CCDF) to analyze the technologic effect of deducting PAPR. Assume the referenced level of PAPR is $PAPR_0$, then, CCDF(PAPR) is the possibility of PAPR > $PAPR_0$ in signal transmission, expressed as

$$\text{CCDF(PAPR)} = P_r(\text{PAPR} > \text{PAPR}_0)$$

2. PTS

Fig. 3 shows the transmission end of OFDM system that applies PTS technology. In Fig 3. In Fig 3, PTS divides the inputted modulation data block $\mathbf{X}=[X_0, X_1,\cdots,X_{N-1}]$ into U sub-blocks $\mathbf{X}^{(i)} = \left[X_0^{(i)}, X_1^{(i)},\cdots, X_{N-1}^{(i)}\right]$; each sub-block should satisfy the following two formulas:

1. $\mathbf{X}^{(i)} \cap \mathbf{X}^{(j)} = \phi$, where $i \neq j$;
2. $\mathbf{X} = \sum_{i=1}^{U} \mathbf{X}^{(i)}$;

Make Inverse Fourier transformation to the U sub-blocks and transform them into U time-

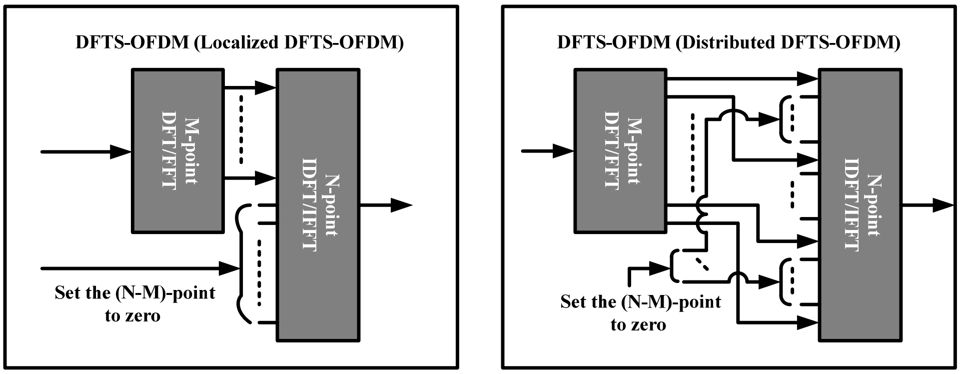

Fig 2. Distributed DFTS-OFDM and Localized DFTS-OFDM

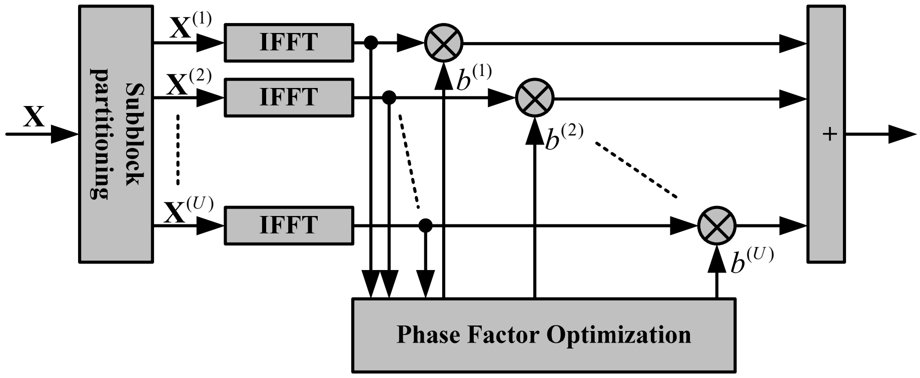

Fig 3. The transmission end of OFDM system that applies PTS

domain signals (also called PTS). Then, multiply U phase factors $b^{(i)}$ to each of the U PTS respectively to disturb the phases in the PTS, the phase factors can be expressed as:

$$b^{(i)} = \exp(i\frac{2\pi l}{Q}),\ l = 0,1,\cdots Q-1,$$

where Q is the allowable phase change amount. Finally, the different phase-disturbed PTS are associated into a signal candidate; follow the change amount of Q & U, there are totally Q^U signal candidates generated; pick the one with minimum PAPR as the signal under transmission. Since the receiving end cannot acknowledge which one is the transmitted signal among the Q^U signal candidates at the transmission end, it thus needs to transmit additional $\lfloor \log_2 Q^U \rfloor$ digits to the receiving end, informing the receiving end how to undo the data transmitted. But, since the PTS technology will elevate the PAPR efficiency along with the increasing of signal candidate amount, it also will extend the operating amount required in PTS technology.

3. SIMULATION and ANALYSIS

In this paper, we use 10,000 SC-LFDMA signals and SC-IFDMA signals generated randomly to make simulation, where M=256 and N=128. The PTC technology uses Q=2, U=2, 4. Fig 4 shows PAPR improvement in the SC-IFDMA system by using square QAM and asterisk QAM technology respectively, plus PTS technology. From Fig 4 we can see that under PTS technology application, square QAM makes better PAPR improvement than asterisk QAM case. On the other hand, Fig 5 shows PAPR improvement in the SC-LFDMA system by using square-QAM and asterisk-QAM technology respectively, plus PTS technology. As the simulating result indicated in Fig 4, Fig 5 also displays that under PTS technology application, square-QAM makes better PAPR improvement than asterisk-QAM case. As a conclusion, although using asterisk-QAM can effectively protects signals against noise, it also will lower PAPR. This paper uses PTS technology to associate the PAPR-improvement efficiency made from two different QAM methods; study result shows

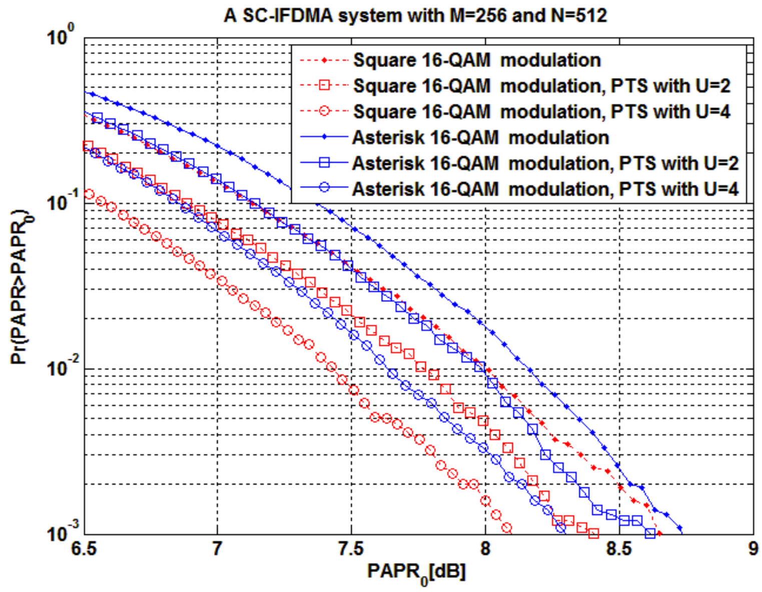

Fig 4. PAPR comparison under two QAM types under PTS technology in SC-IFDMA system

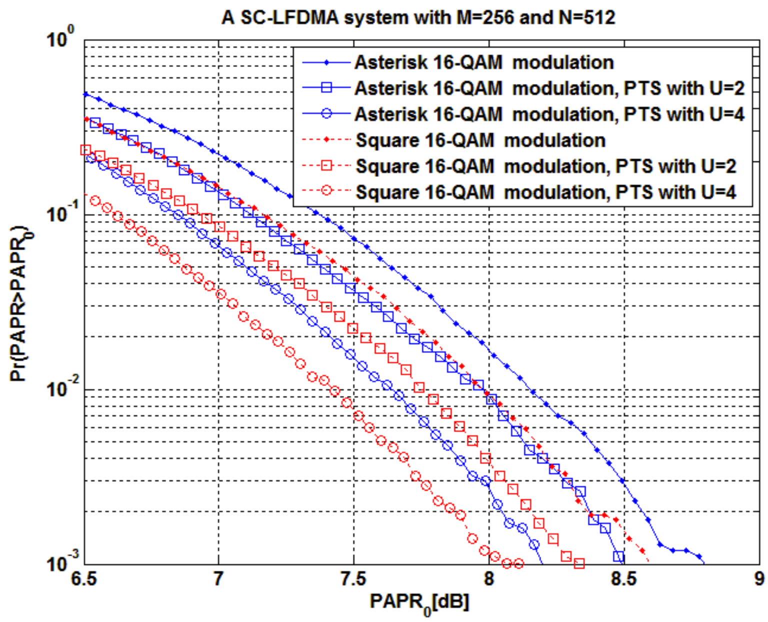

Fig 5. PAPR comparison under two QAM types under PTS technology in SC-LFDMA system

that PTS technology can improve the PAPR values effectively.

4. CONCLUSION

In this study paper, we provide the comparison & analysis chart of PAPR values under PTS technology in both SC-IFDMA system and SC-LFDMA system, and make observation on using square-QAM and asterisk-QAM methods. Simulation result indicates that while under PTS technology, no matter in SC-IFDMA or SC-LFDMA system, the PAPR values of using square- QAM is higher than using asterisk QAM. Therefore, using asterisk-QAM can effectively protect signals against noise, yet, it will lower down PAPR. How to follow the access-way characters to conditionally select the modulation method becomes another important issue for further study.

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