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PAPR Reduction in OFDM

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Abstract-

The term OFDM is a special type of FDM which has very vast application in the field of wired and wireless communication systems. In this paper we are discussing about the main problem of OFDM i.e. Peak to Average Power Ratio (PAPR) which affects the performance and efficiency of Power Amplifier. Partial Transmit Sequence (PTS) is an attractive scheme for PAPR reduction without distortion, but to obtain preferable PAPR performance it needs many Inverse Fast Fourier Transforms (IFFTs) which results in high complexity. In this paper, a single IFFT block is implanted in to PTS technique for reduction of PAPR in OFDM. The scheme is very efficient and avoids the use of any extra IFFTs as was done in PAPR reduction by ordinary PTS technique.

Key Words: 4G, OFDM, PAPR, PTS, IFFT.

I. INTRODUCTION

OFDM is a multicarrier modulation technique which seems to be an attractive candidate for fourth generation (4G) wireless communication systems. OFDM offer high spectral efficiency, immune to the multipath delay, low inter-symbol interference (ISI), immunity to frequency selective fading and high power efficiency. Due to these merits OFDM is chosen as high data rate communication systems such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile Wi-MAX). OFDM faces several challenges. The key challenges are large peak to average power ratio (PAPR) due to nonlinearity of amplifier, phase noise problems of local oscillator, frequency offset due to Doppler shift or difference between transmitter and receiver.

Techniques such as clipping, interleaving method, selective mapping (SLM), and partial transmit sequence (PTS) were proposed by researchers to control the PAPR of the transmitted signals in OFDM systems.PTS could be an effective technique for PAPR reduction, However the technique suffers from an acute problem of very high computational complexity. This complexity can be reduced by replacing multiple numbers of IFFT blocks by a single block and the parallel processing has been replaced by serial processing.

II. PAPR OF OFDM SIGNALS

Any multi-carrier signal is the summation of a large number of independent or orthogonal signals. Hence the envelope of the MC signal may vary extensively. This variation is quantified by the ratio of the peak value to the average value of the MC signal and is termed as peak-to-average-power-ratio (PAPR).An OFDM symbol is made of sub-carriers modulated by constellations mapping. OFDM symbols can be given as the sum of a numbers of independent symbols which are modulated onto sub channels of equal bandwidth Let $X_k(k = 0, 1, \ldots, N-1)$ denote the input data symbol whose period is *T*. The complex baseband representation of an OFDM signal with N sub-carriers is:

$$x(t)=\frac{1}{\sqrt{N}}\sum_{n-0}^{N-1} X_n\, e^{j2\pi n\Delta f t} \qquad ,0\leq t < NT$$

where Δf is the subcarrier spacing and T is the period for pulse-shaping symbol.
For this signal, PAPR can be defined as follows:

$$\text{PAPR}=\frac{\max_{0\leq t\leq NT} |x(t)|^2}{\frac{1}{NT}\int_0^{NT} |X(t)|^2 dt}$$

III. PARTIAL TRANSMIT SEQUENCE

The principle of the original PTS technique is to divide the incoming parallel block of data into sub-blocks; perform IFFT on each of these sub-blocks to generate partial transmit sequences, rotate the PTSs by a pre-defined phase factor and sum up the rotated PTSs in a manner such that the overall PAPR value of this particular OFDM block reduced to an acceptable limit. This process is repeated for W^{M-1} times using different combinations of phase factors and the candidate signal with the minimum PAPR is chosen as the OFDM symbol to be transmitted. Figure-1 illustrate the block diagram of PTS.

Let the incoming serial stream of data be represented as X. If the number of sub-carriers be N, then let the parallel block of data obtained after serial to parallel conversion be represented as:

$$X=[X_0, X_1, \ldots\ldots, X_{N-1}]$$

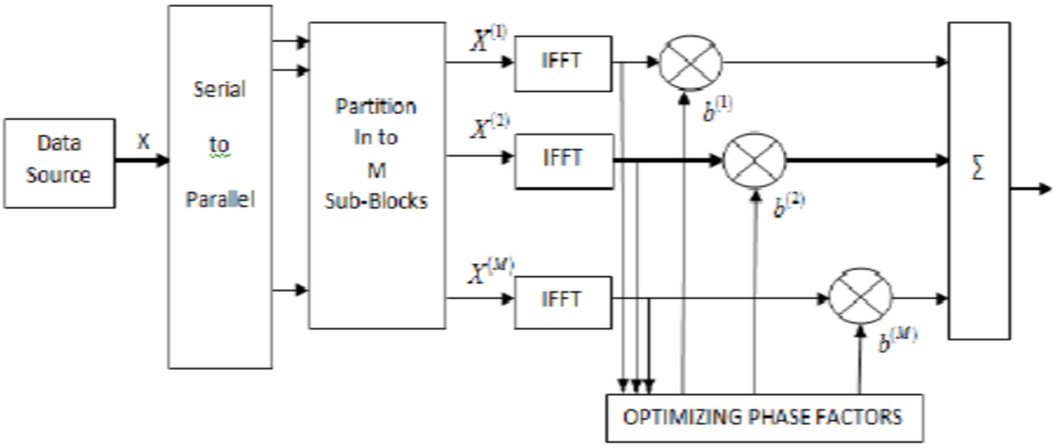

Figure 1: Block Diagram of PTS Technique

If the number of sub-blocks be M, then for convenience let us assume that [N/M] elements in each sub-block will be non-zero. T. So the sub-blocks can be expressed as **X**m where:

$$X=\sum_{m=0}^{M-1} Xm$$

Each of the sub-blocks is then passed through an N-point IFFT block to obtain the corresponding PTS given by:

$$x_m=\text{IFFT}\{X_M\} \qquad m=0,1,.....M-1$$

Let the number of allowed phase factors be W. So the phase factors can be expressed as:

$$b_w=e^{j\,\theta_w},\ w=0,1,.......W-1$$

Generally the first sub-block is left as it is, and rest is rotated. The modified OFDM symbol is:

$$\tilde{x} = \sum_{m=0}^{M-1} b^{(m)}\, Xm$$

The optimum OFDM symbol to be transmitted is expressed as:

$$\tilde{\boldsymbol{x}}_{opt} = \min_{0\le c\le C-1} \frac{\max_{0\le k\le NL-1} |\tilde{\boldsymbol{x}}_{k,c}|}{E[|\tilde{\boldsymbol{x}}_{k,c}|]}$$

IV. SINGLE IFFT BLOCK PTS TECHNIQUE

However PTS technique have a major drawback of computational complexity, to reduce this complexity we replace many IFFT blocks with single IFFT block and parallel processing replaced by serial processing. In this paper a single IFFT block PTS technique is used for PAPR reduction.

This technique is modified to incorporate only one IFFT block in place of multiple ones and replace the parallel processing with serial processing. Figure-2 illustrates the Single IFFT block PTS.

The design approach has been concentrated on two major factors:

1. Reducing the number of IFFT blocks
2. Reducing the number of candidate signals.

The technique does not need a predefined threshold value to reduce the number of candidate signals. Hence the dependency of the performance of the technique on the choice of the threshold is removed. Mathematical complicacy has been avoided by keeping the mathematical principle same. The reduction in the number of IFFT blocks is from M to 1, unlike a reduction by half. This reduces the complexity even further. The optimization of the phase factor has been done in the same way as original PTS does. Added complexity due to extra logic and computation is avoided. Also the basic principle of PTS is maintained; hence the PAPR reduction performance is not degraded.

Let the incoming serial stream of data be represented as X. If the number of sub-carriers be N, then let the parallel block of data obtained after serial to parallel conversion be represented as:

$$X=[X_0, X_1, \ldots\ldots, X_{N-1}]$$

If the number of sub-blocks be M, the parallel data block **X** is divided such that at least $[N/M]$ elements in each sub-block will be non-zero. So the sub-blocks can be expressed as **X**m where:

$$X=\sum_{m=0}^{M-1} X_m$$

Each of the sub-blocks is then passed through an N-point IFFT block to obtain the corresponding PTS given by:

$$x_m = IFFT\{X_m\} \qquad m=0,1,......M-1$$

Let the number of allowed phase factors be W. So the phase factors can be expressed as:

$$b_w = e^{j\theta_w},w=0,1,......w-1$$

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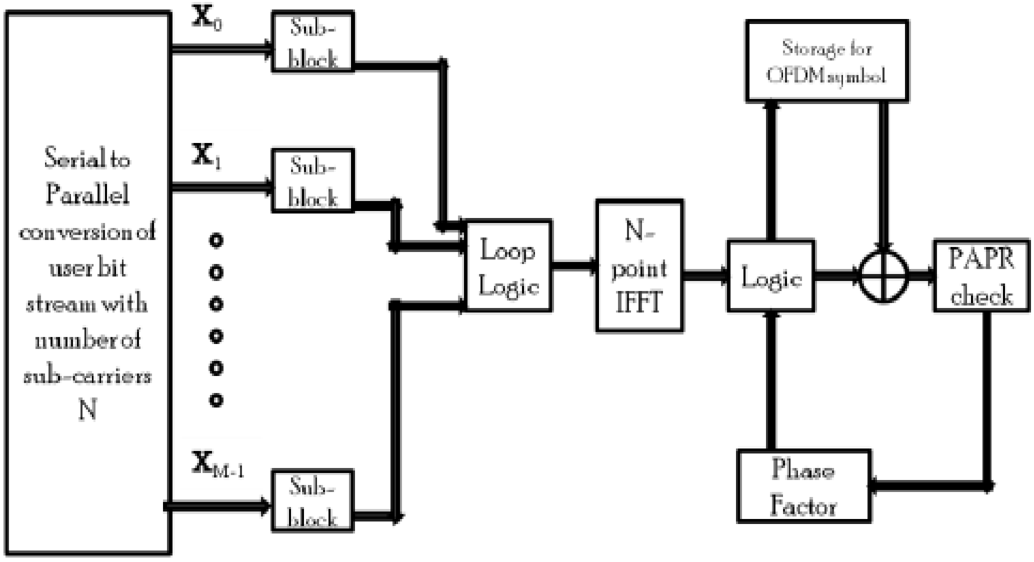

Figure 2: Block Diagram for Single IFFT Block PTS

The OFDM symbol formed after the (m+2)th iteration when m = [0, M-1] by choosing the optimum phase factor for each PTS can be hence expressed as:

$$\hat{\boldsymbol{x}}_m = \min_{0\le w\le W-1}\left(\frac{\max_{0\le k\le N-1}\left|x_k b_w^{(m)} + \hat{x}_{m-1}\right|}{E\left[\left|x_k b_w^{(m)} + \hat{x}_{m-1}\right|\right]}\right)$$

V. CONCLUSION

This paper discussed a single IFFT block PTS technique which reduces the computational complexity of PTS by reducing number of IFFT blocks and by reducing numbers of candidate signals. PAPR reduction performance is improved by this technique. The choice of the phase factor has been done by simply checking with the preceding PTSs. This techniques delivers performance significantly better than PTS technique. The hardware requirement has been reduced significantly by cutting down multiple IFFT blocks to one, only with the addition of smaller loop control logical blocks which do not contribute to complexity as much as the IFFT blocks. The performance has been effectively better as PAPR has been reduced in every step of formation of the OFDM symbol from the PTSs.

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