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Peak to Average Power Ratio (PAPR) Minimizing Techniques for Helical Interleaved OFDM System

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***Abstract:* Orthogonal frequency-division multiplexing (OFDM) is a multi-carrier, multi rate, multi symbol, frequency division multiplexing transmission system. In which a single high data rate stream is divided in to a number of low data rate streams. High spectral efficiency due to orthogonal subcarriers is the major advantage of this system. The major drawback of this system is high peak-to-average power ratio (PAPR) due to multiplexing of signals. The high PAPR reduces the system performance. This paper presents different PAPR reduction solutions for helical interleaved OFDM system. A current PAPR reduction technique reduces the PAPR to minimum of 12dB. Here we reduced PAPR to minimum of 8dB. The simulation for PAPR reduction has been done in MATLAB.**

***Keywords:* High-speed wireless; OFDM, peak- to-average power.**

I. Introduction

OFDM is a bandwidth efficient multicarrier modulation where the available spectrum is divided into subcarriers, with each subcarrier containing a low rate data stream [1]. OFDM has gained a tremendous interest in recent years because of its robustness in the presence of severe multipath channel conditions with simple equalization, robustness against Inter-symbol Interference (ISI), multipath fading, in addition to its high spectral efficiency. However, the PAPR [2] is a major drawback of multicarrier transmission system such as OFDM. Various techniques are available to reduce PAPR for OFDM system. In this paper, Selected Mapping (SLM) [3] and Partial Transmit Sequence (PTS) [4] are analyzed for the reduction of PAPR. Helical interleaving [5] is also proposed at the place of random interleaver for reduction of system complexity and memory requirement.

II. PAPR

Now here is the explanation of PAPR in Mathematical equation form. PAPR is defined as the maximum power occurring in the OFDM transmission to the average power of the OFDM transmission. Mathematical representation has been given below.

$$PAPR = \frac{P_{peak}}{P_{average}} = \frac{\max[|xn|^2]}{\mathrm{E}[|xn|^2]}$$

where, P_{peak} is Peak power of the OFDM system, $P_{average}$ is average power of the OFDM system and $E\ [\ \cdot\ ]$ is the expectation operator.

The PAPR of an oversampled version of x(t) is calculated as per the above equation. Here in this equation our main goal is to minimize the max $[|Xn|^2]$.

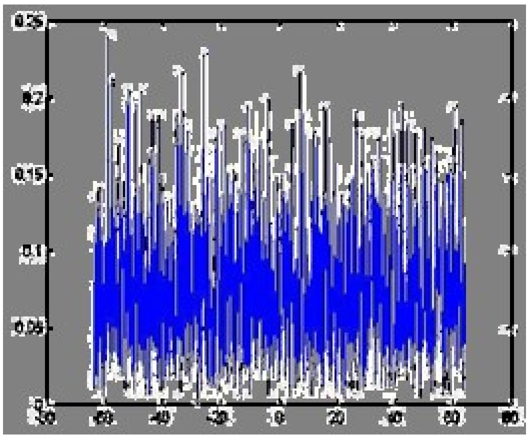

Fig 1. OFDM Signal containing sinusoidal high peaks

Figure 1 shows the OFDM Signal containing sinusoidal high peaks.

III. Interleaver For OFDM System

The Helical interleaver used in OFDM System specifies the order in which a modulator reads bits from an encoded data block [5]. The principle design rule of helical interleavers is to start off from a pre-defined interleaver as a master interleaver, from which the family of helical interleavers are generated by reading the interleaver indices in a deterministic order. The generation process can be described as follows:

1. Generate a one-dimensional master interleaver of length N_c (e.g, a pseudo-random interleaver) and write the interleaver indices of the master interleaver row-wise into a matrix with M_r rows and M_c columns.
2. The 1st helical interleaver is generated from the master interleaver by reading the interleaver indices column-wise from the matrix.
3. The remaining interleavers are generated by cyclically reading the interleaver indices from the diagonals of

the matrix. Different interleavers correspond to diagonals with different slopes; one can generate M_c helical interleavers from the master interleaver.

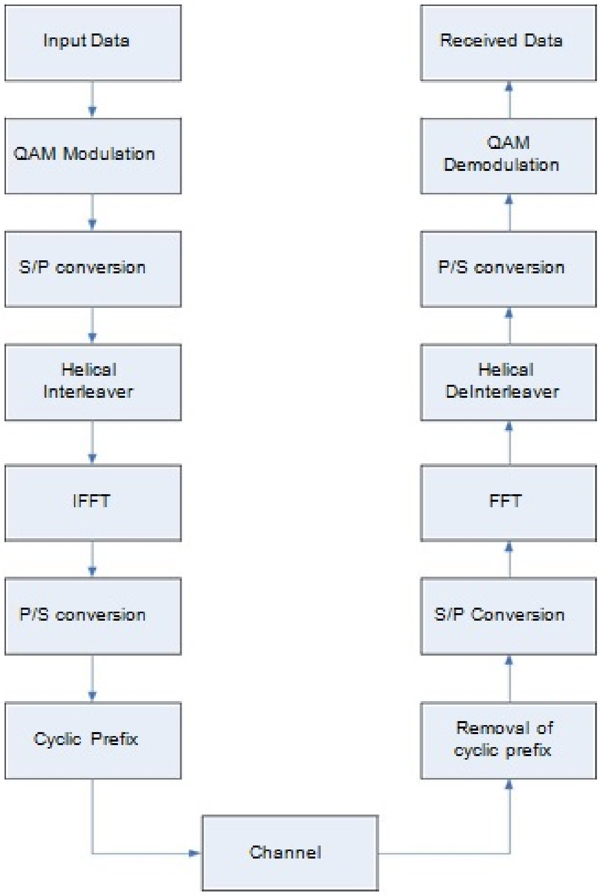

Fig 2. Block diagram OFDM system with helical interleaver

Figure2 shows the simple block diagram OFDM system with helical interleaving scheme, useful for easy designing of system. This scheme also reduces complexity and the memory requirement of the OFDM System.

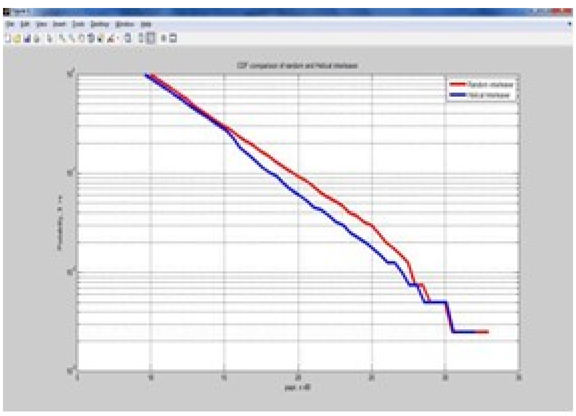

Fig 3. Comparison of Helical interleaver and random interleaver performance against PAPR.

Figure 3 shows the performance of randomly interleaved and helical interleaved OFDM.

IV. Algorithms Used For Reduction Of PAPR

A. Selective mapping

The Complementary Cumulative Distributive Function (CCDF) of the original signal sequence PAPR above threshold PAPR is written as $P_r\{PAPR > PAPR_0\}$ Thus for K statistical independent signal waveforms, CCDF can be written as $[P_r\{PAPR > PAPR_0\}]R$, so the probability of PAPR exceeds the same threshold [3]. Assuming that M-OFDM symbols carry the same information and that they are statistically independent of each other [6]. In this case, the probability of PAPR greater than Z is equal to the product of each independent probability.

In selection mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks $Sm = [Sm_0, Sm_1, Sm_{N-1}]T$ for m=1,2,...,M are then forwarded into IFFT operation simultaneously [7]. $Xm=[X_1, X_2, X_N]T$ in discrete time-domain are acquired and then the PAPR of these M vectors are calculated separately. Eventually, the sequences xd with the smallest PAPR is selected for final serial transmission [8]. Figure 4 shows the basic block diagram of selection mapping technique for suppressing the high PAPR.

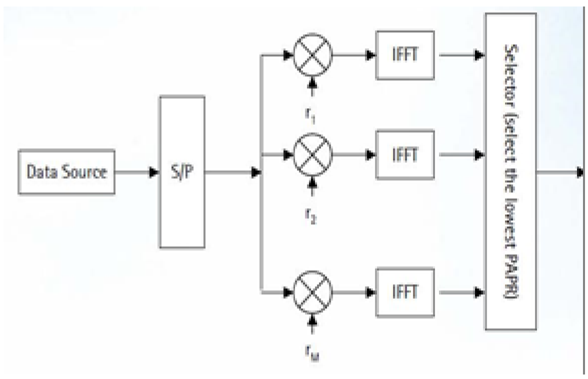

Fig 4. Block diagram of selective mapping algorithm in OFDM System.

Figure 5 shows the CCDF as a function of PAPR distribution when SLM method is used with 64 numbers of subcarrier. Figure 5 shows the same result for 128 numbers of subcarrier. M takes the value of 1 (without adopting SLM method), 2, 4, 8 and 16. It is seen in Figure 5 that with increase of branch number M, PAPR's CCDF gets smaller. It indicates the reduction of PAPR about 8dB.

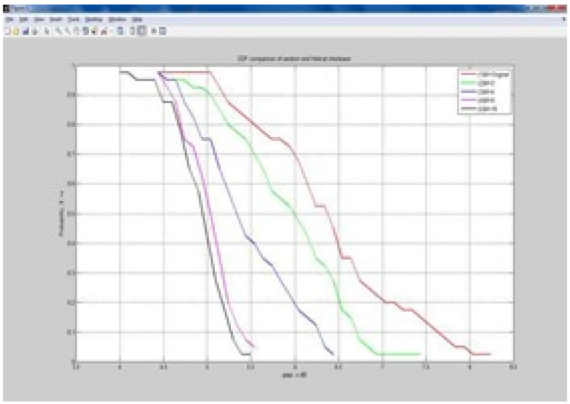

Fig 5. Comparison of PAPR reduction performances with different values of M for helical interleaved OFDM

B. *Partial transmit sequence*

Partial Transmit Sequence algorithm is a technique for improving the statistics of a multicarrier signal. The basic ideas of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen.

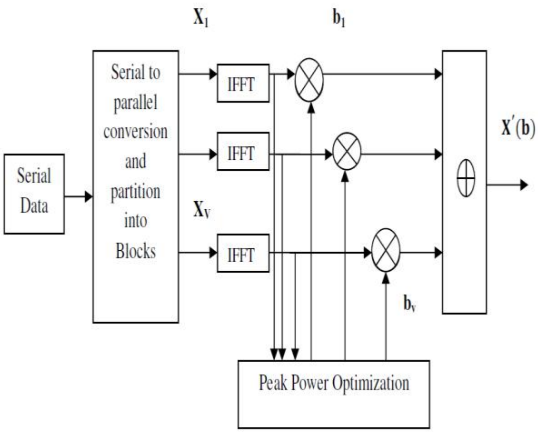

Fig 6. Block diagram of Partial Transmit algorithm in OFDM System

Figure 6 is the block diagram of PTS technique. From the left side of diagram, the data information in frequency domain X is separated into V non-overlapping sub-blocks and each sub block vectors has the same size N [9]. So for each and every sub-block it contains N/V nonzero elements and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other. The sub-block vector is given by $X=\sum b_v X_v$ where b_v is a weighting factor been used for phase rotation. The signal in time domain is obtained by applying IFFT operation on, that is $X=IFFT(x)= \sum b_v IFFT(x_v)= \sum b_v X_v$.

For the optimum result one of the suitable factor from combination $b = [b_1, b_2,.., b_v]$ is selected [10].

Fig 7. Comparison of PAPR reduction performances with different values of W for helical interleaved OFDM.

Fig. 7 shows that there are varying parameters which impact the PAPR reduction performance these are: 1) The number of sub-blocks V, which influences the complexity strongly; 2) The number of possible phase value W, which impacts the complexity; and 3) The sub-block partition schemes. Here, only one parameter is considered that is sub-block size V. Figure 7 shows that PTS technique improves the performance of OFDM system, moreover, it can be shown that with increasing the value of V the PAPR performance becomes better.

Fig 8. Comparison of PAPR reduction performance between SLM and PTS algorithm for helical interleaved OFDM

In Figure 8, it is clear that PTS method provides a better PAPR reduction performance compared to SLM method.

V. Conclusion

OFDM is a very attractive technique for wireless communications due to its spectrum efficiency and channel robustness. One of the serious drawbacks of OFDM systems is that the composite transmit signal can exhibit a very high PAPR when the input sequences are highly correlated. In this paper, Layer Specific Helical Interleaver is used to reduce the memory requirement of the OFDM System and several important aspects are described as well as mathematical analysis is provided, including the distribution of the PAPR used in OFDM systems. Two techniques, SLM and PTS are used to reduce PAPR, which have the potential to provide substantial reduction in PAPR. PTS method performs better than SLM method in reducing PAPR in OFDM systems.

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