PAPR reduction techniques in OFDM for Wireless Communication systems- A Study

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique which divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream. The subcarriers have proper spacing and pass-band filter shape to satisfy orthogonality. A main issues of OFDM is high Peak-to-Average Power Ratio (PAPR) of the transmitted signal that affects the complexity of power amplifiers. A number of techniques have been proposed and to reduce PAPR of OFDM signal. Some effective methods for mu PAPR reduction are discussed in this paper. Many protocols including Wi-Fi (Wireless fidelity), LTE (Long Term Evolution) , 4G and 5G uses OFDM (Orthogonal Frequency Division Multiplexing). Excellent spectrum efficiency and large transmission data rates are made possible by it. But OFDM's high peak-to average power ratio (PAPR) is one of its primary drawbacks. A few strategies for lowering the OFDM signal's PAPR is discussed in this study.

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier communication of encoding digital data on multiple carrier frequencies. This transmission scheme is used in the fourth generation of wireless communication systems and is used to lessen the spectral issue. The disadvantage of OFDM is the large PAPR affecting the OFDM.To lessen the PAPR effect in OFDM systems, a number of PAPR techniques exists in literature. This study uses a variety of PAPR control strategies. Because, OFDM uses a cyclic prefix and has a low symbol rate, it is known to be resistant to multipath interference. Consequently, in broadband high-speed data,

OFDM splits the wideband signal into narrow sub-carriers and the subcarriers are mutually independently orthogonal to each other which prevents interference. The data in each subcarrier are transformed from serial to parallel scheme for simultaneous transmission in different channel. The Inverse fast Fourier transform (IFFT) is used to produce orthogonal data subcarriers where the input data samples are modulated either by (e.g. QAM or PSK) and after they are jointly correlated. The major merit of OFDM systems are elimination of cross talk between the sub channels and that inter carrier bands are not required [1-3]. The signals transmitted in an OFDM system have high peak values in the time domain and subcarrier components are added by a IFFT operation. Hence OFDM systems are having a high PAPR (Peak -to-Average Power Ratio), when compared to single-carrier systems. The high PAPR is one among the most degrading aspects in the OFDM system since it decreases the Signal -to-Quantization Noise Ratio and the bit error rate [4-5]. OFDM has many advantages like robustness in the frequency selective fading channels and is more immune to ISI and fading, which causes multipath propagation. Some techniques like clipping, tone reservation, partial transmit sequence (PTS), and selective mapping (SLM) are discussed in this study.

The demand for lower power consumption and better spectral efficiency is highly significant in today's wireless communication. The peak-to-average power ratio (PAPR) reduction is hence, very crucial since Orthogonal frequency division multiplexing (OFDM) is a fundamental technology in 5G and Beyond 5G (B5G) wireless systems. Implementation of an efficient PAPR reduction technique is hence necessary for enhancing its performance.

2. PAPR Reduction Techniques

Many methods have been reported in literature to reduce PAPR. Various factors which are taken into consideration for adopting a PAPR reduction technique in an OFDM system includes loss of data rate, spectral efficiency, rise in transmit signal power, computational complexity and increase in bit-error rate etc. So PAPR reduction techniques depend on the requirement of the system. Signal scrambling techniques and signal distortion techniques are the two major classifications adopted for this purpose. Distortion method includes clipping and companding , distortion less methods also include clipping and filtering, selective mapping, partial transmit sequence, tone injection etc. Usually the complementary cumulative distributive function (CCDF) and bit error rate (BER) are considered as the performance parameters associated with PAPR reduction.

The ratio between the maximum power and the average power of the OFDM signal over a time interval T, is given by PAPR and can be expressed as in (1).

$$\text{PAPR(x(t))}=\frac{P_{max}}{P_{avg}} = \frac{\max(|x(t)^2|)_{0<t<T}}{\frac{1}{T}(\int_0^T |x(t)^2|dt)} \quad \text{----} \quad (1)$$

2.1 Clipping and Filtering

Clipping and Filtering is one among the simplest reduction techniques for PAPR. Amplitude Clipping lowers the peak level of the input signal to a predetermined value. According to [6-7] the idea behind this technique is to clip the signal parts that have high peak outside of the allowed band. In this method the high peaks of the OFDM signal are clipped before passing it through the power amplifier. Clipping leads to both in-band and out-of-band distortions In-band distortion can be eliminated by filtering the signal after clipping and out-of-band distortion can degrade the BER performance and cannot be reduced by filtering

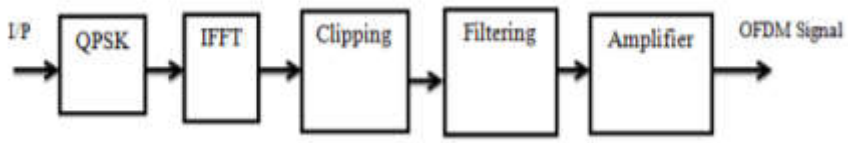

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Fig. 1 Block Diagram of Clipping and filtering process

2.2 WEIGHTED OFDM Technique

A typical signal is used as a weight in this method. This signal is chosen in such a way that the Fourier transform of this signal has no zero on the real line. The convolution of this weight signal with the modulated signal is taken. The weighted OFDM signal is the given convoluted

signal. The weighted modulated signal is given to the IFFT block [2] which converts the signal from frequency domain to time domain. Then ISI is reduced by adding cyclic prefix.

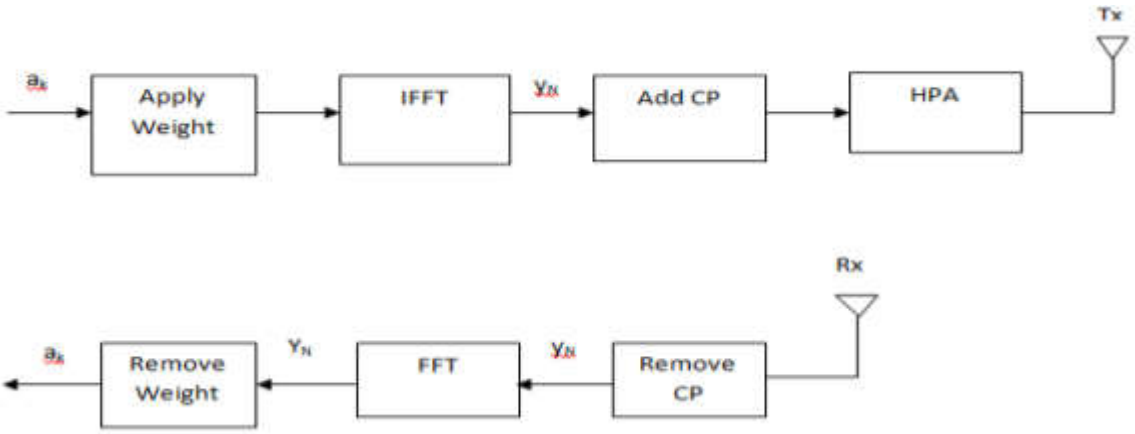

Fig.2 Weighted OFDM Technique

2.3 Partial Transmit Sequence

In this method an input data block with length N is partitioned by pseudo-random method into a number of disjoint sub blocks. The IDFT is computed for each of these sub-blocks and then weighted by a phase factor. The PF are selected in such a way that the PAPR of the combined signal of all the sub-blocks is minimized. Fig.4. shows a block diagram of the OFDM transmitter using this technique.

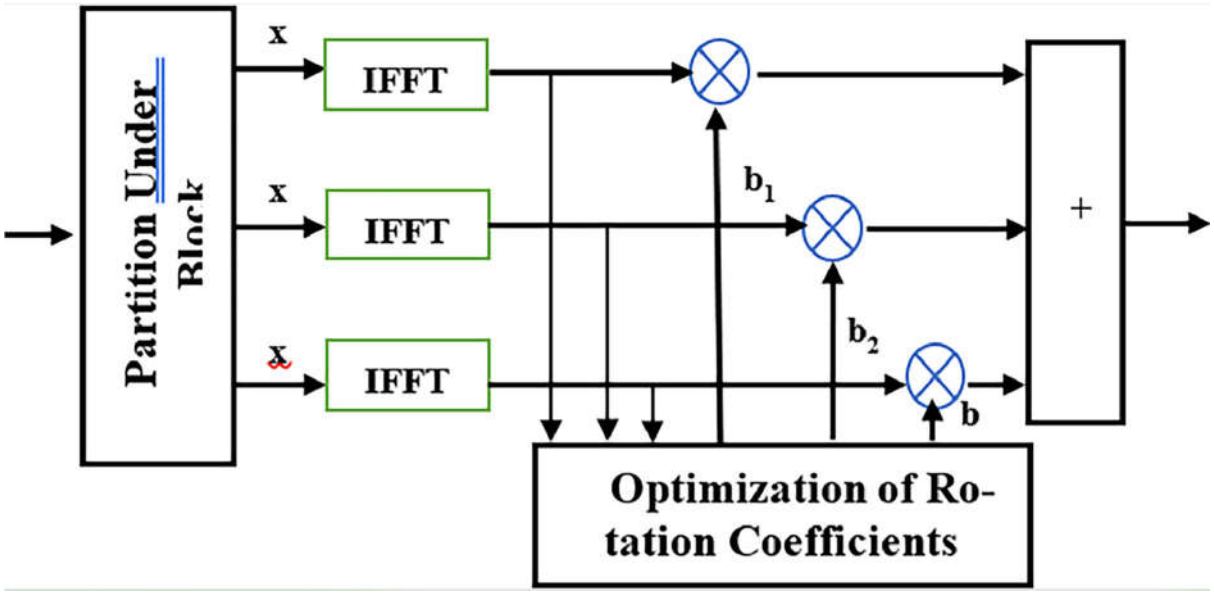

Fig.4 Techenique of Partial Transmit Sequence [8]

2.4 Selective mapping (SLM)

Multiple versions of the OFDM signal at various phases are produced by increasing the input symbols that emerge from digital modulation using a sequence of distinct vectors. The signal variant that exhibits the highest PAPR performance is kept. This approach is complicated, particularly because it calls for running the IFFT as many times as possible due to the large number of variations. The foundation of this approach is the application of the best PAPR among many. The premise is straightforward: run the signal through the IFFT after multiplying it by L distinct P. The SLM (Selected Mapping) technique's primary goal is to find the binary

sequence that reduces the OFDM signal's PAPR (Peak-to-Average Power Ratio). The OFDM signal with lower PAPR is obtained by applying this binary sequence to the modulated signal, then carrying out the IFFT and appending the cyclic prefix. To determine the optimal binary sequence that minimizes the PAPR, the procedure is carried out multiple times[7].

2.5 Linear Block Coding Method

Coding techniques can be applied for signal scrambling, M sequences, Golay complementary sequences, Shapiro-Rudin sequences codes can be used to reduce the PAPR efficiently. This Block coding technique has been proposed by Wilkinson and Jones in 1965 for the minimization of the peak to mean envelope power ratio of multicarrier communication systemTo enhance BER performance instead of dedicating some bits of the code word, these bits are now dedicated to reduce PAPR. The code words having low PAPR have to be chosen for transmission. A linear block coding scheme was proposed in [5], here 4 bits are mapped into 5 bits by adding a parity bit. It is based on the fact that irrespective of code word length, four specific code words will always have disproportionately large PAPR values. These are the code words where the odd and even bit values are equal. The PAPR can hence be very easily reduced by eliminating these code words using a simple added bit code.

Table-1 Comparison of PAPR Reduction Techniques [6-10]

3. PAPAR reduction techniques- Performance parameters

When choosing a particular method for PAPR reduction, several considerations need to be taken into account. These elements include the capacity to reduce PAPR, signal distortion, rate hit, and side information, complexity, the transmit signal's power increase, the rise in receiver's BER etc., the computation complexity increase, etc. There is interdependence among the requirements. Every criterion has a corresponding value. The method chosen for PAPR reduction affects each of these factors.

4. Conclusion

OFDM is a technique for multicarrier transmission and has become one of the best choices for high speed data transmission over a communication channel. It has a lot of advantages; but also has one major drawback of high PAPR. In this paper, some of the techniques for reducing the PAPR of the OFDM system are studied. Even though non-linear transformation techniques provides low PAPR, it degrades the bit error rate (BER) performance. Deep learning based architectures have been proposed in recent works. Computational overheads makes practical difficulties for. So an architecture to efficiently reduce PAPR along with a a good BER performance need to be evolved.

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PAPR Reduction Technique	**Performance parameters**					
	PAPR Reduction capabilities	**Side Information**	**Rate hit**	**BER degradation**	**Distortion**	**Power Increase**
Clipping and Filtering	High	No	Low-Medium	Medium	Yes	No
WEIGHTED OFDM Technique	Medium	No	Low-Medium	No	No	No
Partial Transmit Sequence	Medium	Yes	Low-Medium	High	No	No
Selective mapping (SLM)	Medium	Yes	Low-Medium	High	No	No
Linear Block Coding Method	High	No	High	No	No	No

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