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Design of OFDM Transceiver to Improve PAPR using Clipping Technique

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Abstract

Although OFDM is an efficient multi-carrier technique, it has a major limitation. The PAPR of a conventional OFDM signal is naturally high. In order to reduce it, many different techniques have been proposed and clipping is one of them.

In this paper, we employ clipping as the PAPR reduction technique and propose a block diagram designed to reduce PAPR and improve the BER performance.

Keywords: OFDM- Orthogonal Frequency Division Multiplexing, PAPR- Peak-to-Average Power-Ratio. QAM- Quadrature Amplitude Modulation, FFT- Fast Fourier Transform, IFFT- Inverse Fast Fourier Transform, BER- Bit Error Rate, HPA- High Power Amplifier, ADC- Analog to Digital Converters, and DAC- Digital to Analog Converters, S-P- Serial to Parallel, P-S- Parallel to Serial, ICI- Inter Carrier Interference, ISI- Inter symbol Interference, AWGN- Additive White Gaussian Noise.

Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is an attractive multi-carrier modulation technique as it is immune to frequency selective fading channels, offers high spectral efficiency and offers many other advantages. Hence, it is widely opted for high data rate communication and implemented in many wireless standards [1].

Along with its share of advantages, it has a major disadvantage in the form of high PAPR. This is due to the occasional long peak signals present in a block. These signals can lead to complexity of analog to digital converters (ADCs) and digital to analog converters (DACs) and in-band and out-of-band radiations due to the non-linearity of high power amplifier (HPA). Thus, it is important to reduce the PAPR of the OFDM signal [2].

The organisation of rest of the paper is as follows. Section II focuses on the persistent PAPR problem in OFDM. In section III, we concentrate on proposed system model of the OFDM transceiver. Section IV discusses the transceiver design in brief. Section V presents the simulation results obtained and in section VI contains the conclusion of this paper.

The Papr problem

The PAPR of an OFDM signal is defined as the ratio of maximum peak power to the average power.

PAPR = Peak power/average power

This PAPR problem exists both in continuous base band and discrete base band signals. The PAPR of continuous base band OFDM is marginally greater than discrete band OFDM by a figure of 0.5-1 [2].

This paper concentrates on discrete band OFDM signal in its approach.

If the PAPR of OFDM is very high, then the variation of amplitudes is very wide and these affect the non-linearities of HPA. Additional interference is also introduced as a result of high PAPR. This also leads to a higher BER. Since power efficiency is necessary in HPA, it is advisable to try and reduce the PAPR [3].

OFDM system model

The proposed block diagram of OFDM transceiver employing the PAPR technique clipping is described in the figure. The transmitter section consists of the blocks data source, encoding, zero padding, S-P, modulation, IFFT, P-S, cyclic prefix and clipping.

The signal is then passed through the channel.

The receiver block contains the blocks of removing cyclic prefix, P-S, FFT, demodulation, P-S, decoder and then the data is received at the destination [6] [7] [9].

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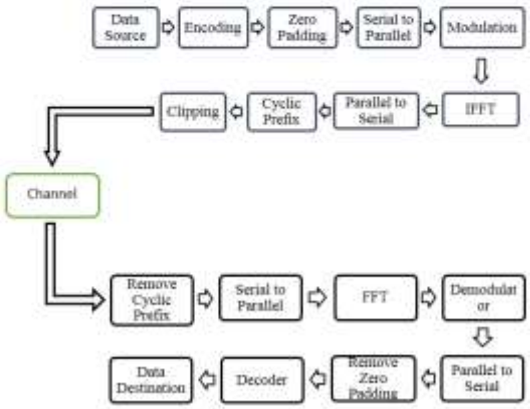

Figure 1. Block diagram of OFDM transceiver

Transceiver design

The transceiver is consisting of 3 sections; transmitter, channel and the receiver. These sections are described below.

Transmitter

The design of the proposed transmitter can be seen from the block diagram. The different blocks present are described below.

The first block in the transmitter is the data source where the data is generated and it is then convolutionally encoded in the encoder block. The encoded data is then zero padded to eliminate ICI and then its converted into a parallel stream. It is then modulated using PSK technique and IFFT is performed to obtain the OFDM symbol. The parallel data is then converted back into a serial stream and then cyclic prefix is added at the head of stream. This helps in eliminating the ISI [5]. The proposed PAPR reduction technique, clipping, is then introduced.

Clipping As The PAPR Reduction Technique

The proposed clipping technique is the simplest PAPR reduction technique. It is employed to reduce the PAPR of OFDM signals [4].

A suitable value is taken as a threshold value and signals above this value are clipped to this threshold value. Thus the large peak signals are eliminated. The signals before and after clipping are shown in figure 4 and figure 5 [5].

If we consider the clipping output of a signal X to be C(X), then

$$C(X) = \begin{cases} x & , \quad |x| \leq A \\ A & , \quad |x| > A \end{cases}$$

where A is the chipping threshold and X is the signal amplitude [8].

Channel

The clipped signals are fed into a channel made up of Additive White Gaussian Noise (AWGN) with a pre-defined SNR of 30.

Receiver Design

In the receiver section, we first start off by removing the cyclic prefix. Then, the serial data is converted into parallel and then FFT is performed. The data is then demodulated and converted back to serial stream where the zero padding is removed, then the data is decoded by passing it through a Viterbi decoder. This is used as the signal is corrupted by AWGN in the channel. The data is then received at the destination.

IV. Simulation results

The code for this design was tested on MATLAB by generating 512 bits random data at the source and 16 – PSK was employed. The simulation results include the Scatterplot in figure 2, BER vs SNR curve in figure 3, the signal amplitudes before and after clipping in figure 4 and 5 respectively. The clipping threshold was taken to be 0.105. The improvement in PAPR is also seen in figure 6.

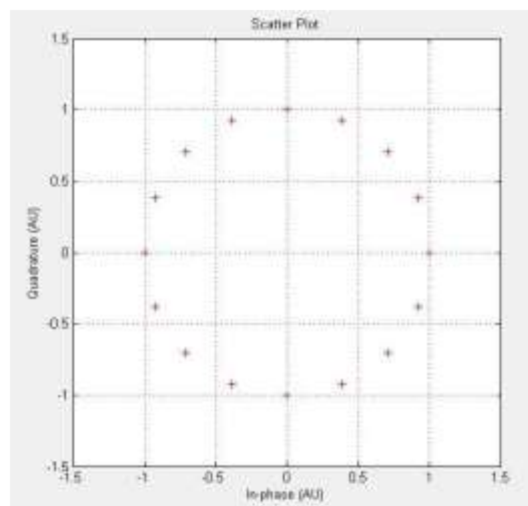

Figure 2. Scatterplot

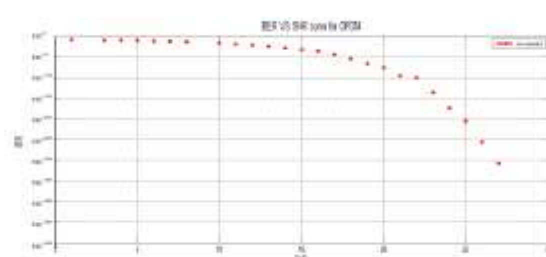

Figure 3. SNR vs BER curve

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In figure 3, the SNR vs BER performance is seen. The value of BER for different SNR values is given in the table below.

SNR	BER
0	10^{0}
5	10^{-1}
10	10^{-2}
15	10^{-3}
20	10^{-7}
25	10^{-20}

Table 1. SNR vs BER values from the curve

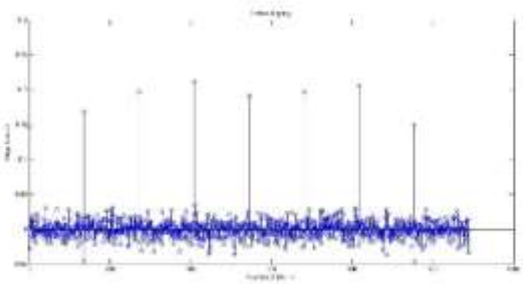

Figure 4. Signal before clipping

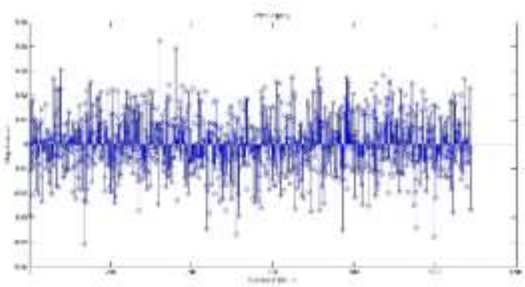

Figure 5. Signal after clipping

The clipping effects is seen from figure 4 and figure 5. The high peak signals are clipped to the desired threshold value.

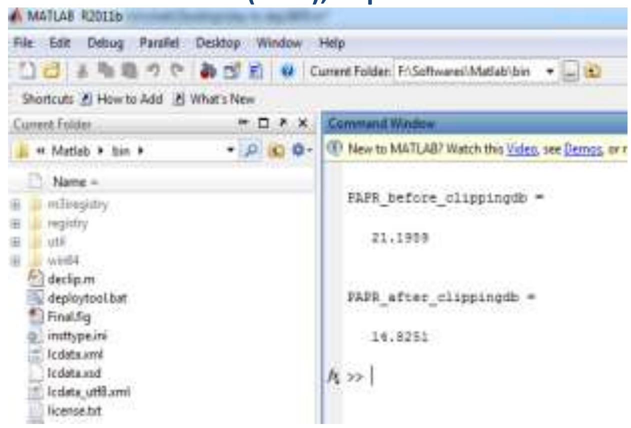

Figure 6. PAPR improvement

The PAPR has been reduced from 21.19 to 14.82 as seen in the figure above.

Conclusion

From the proposed design of the OFDM transceiver by employing clipping as the PAPR reduction technique, we can conclude that the proposed technique has been successful in improving the PAPR performance by a significant margin using PSK modulation and also the BER performance of the signal has improved compared to conventional OFDM.

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