Logical Clipper and De-clipper Technique to Reduce PAPR from OFDM Signal

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***Abstract*—Orthogonal frequency-division multiplexing (OFDM) is the most effective technique for high speed wireless communication systems. The key challenge of OFDM based transceiver is its large peak to average power ratio (PAPR) due to non-linearity effects of power amplifier at final stage of OFDM transmitter. In this work performance of OFDM system using logical clipper and de-clipper in the OFDM transmitter and receiver respectively has been studied. In the proposed method the clipped portion of the signal is transmitted as side information which is subsequently used by the receiver to reproduce the original signal. The whole system was simulated in MATLAB environment considering AWGN channel. It is observed that the proposed system can significantly reduce PAPR of OFDM signal.**

Keywords—orthogonal frequency division multiplexing (OFDM); logical clipper; logical declipper; PAPR; complementary cumulative distribution function (CCDF).

I. INTRODUCTION

For fourth and fifth generation (4G and 5G) wireless communication systems orthogonal frequency division multiplexing (OFDM) is one of the most attractive techniques [1-2]. It effectively combats the multipath fading channel, improves the bandwidth efficiency and increases system capacity to provide reliable transmission [2-3]. One inherent problem of OFDM is its large peak to average power ratio (PAPR) due to non-linearity of power amplifier, phase noise problems of local oscillator, frequency offset due to Doppler shift or difference between transmitter and receiver. This peak to average power (PAP) ratio can distort the signal if the transmitter contains nonlinear components such as power amplifiers (PAs) [4]. Spectral spreading, inter modulation and changing of signal constellation of the OFDM symbols are some effects of the nonlinearity. The PAPR in dB of OFDM symbol is defined as a ratio of the peak power and average power of OFDM signals [5]:

$$PAPR(dB) = 10log_{10}\frac{P_{peak}}{P_{av}} = 10log_{10}\frac{\max[|x_n|^2]}{E[|x_n|^2]} \quad (1)$$

where P_{peak} is the output peak power of OFDM signal and P_{av} is the average power of the signal.

In this research, we have used logical clipping and de-clipping method to reduce PAPR from OFDM signal.

II. METHODOLOGY

A. *Clipping*

The basic functional block diagram of clipping technique is shown in Fig. 1. Clipping is the simplest way to reduce the peak signal to the desired level [6-7]. But its main drawback is self-interference generated by clipping operation that distorts signal amplitude.

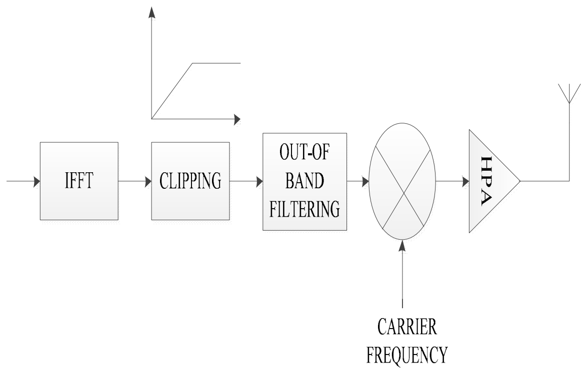

Fig. 1. OFDM transmitter including clipping scheme.

Due to this self-interference, clipping gives rise to re-growth of the high frequency components as a result spectral efficiency can be reduced. For overcoming such problems with clipping operation, several schemes have been developed. One such technique is the utilization of filtering to reduce or remove out-of-band radiation but it can also cause peak re-growth. Another technique is the iterative clipping and filtering that can reduce PAPR to the desired level, but this increases computational complexity [2, 7-9]. Peak windowing is a method to reduce the peak value by multiplying the correcting function by the original OFDM signal [7-8]. There

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are several schemes for reducing problems at the receiver, which are inherently generated by clipping with filtering [10].

In the present study peak signals will be removed by signal processing steps only and no filter will be utilized.

B. Proposed Logical Clipper

The model of the proposed Logical Clipper is shown in Fig. 2. This unit is placed after final stage of parallel to serial (P/S) converter of OFDM transmitter. P/S converter has added N discrete time OFDM signal after successful operation of IFTT/IDFT and cyclic prefix (CP) operation (N is the number of IFFT/IDFT points in that transmitter). As a result, it delivers discrete time OFDM signal with high PAPR. In this proposed technique, every N point discrete time domain OFDM signal is considered as a single segment that may pass through the first step of Logical Clipper known as comparator. This comparator will compare the amplitude of every segment of OFDM signal with the threshold value (VT). Where VT to be equal to the average value of OFDM signal. If amplitude of the signal is greater than VT then position & over threshold value counter (POTVC) will count the time domain position and over threshold value for every segment of OFDM signal. With the help of POTVC, the position & over threshold value selector (POTVS) will select the fixed number (two in this case) of time domain position corresponding over threshold value of every segment for clipping operation. After that, the

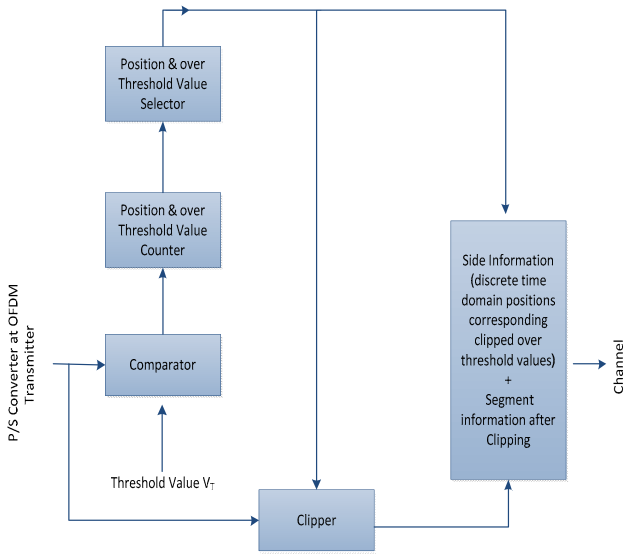

Fig. 2. Model of Logical Clipper at OFDM Transmitter.

clipper clips twice of the over threshold value from every segment of OFDM signal at selected position. Finally this portion of the signal is inserted as side information at the front of the corresponding segment. In this technique length of every segment increases by the factor two because POTVS select only two positions.

Here goes a brief description of the main technical function of the logical clipper. For simplicity let us consider the case of single segment and also consider the value of V_T is Vx, the length of segment is L, time domain positions P_n, P_{n+1} and P_{n+2} are containing the values Vx +3ΔVx, Vx +2ΔVx and Vx +ΔVx respectively and rest of the position of that segment contains the values lower than Vx. Where n is a positive integer, $0 \leq$ [n± positive integer] $\leq$ L and ΔVx represents smallest unit value for the corresponding positions.

Therefore, POTVS will select the position P_n and $P_{n+1}$with over threshold value of 3ΔVx (Vx +3ΔVx – Vx) and 2ΔVx (Vx +2ΔVx – Vx) respectively. Finally, clipper clips the values 2×3ΔVx and 2×2ΔVx from corresponding selected positions P_n and P_{n+1} respectively. After clipping operation, the positions P_n and P_{n+1} of the segment contain the values Vx -3ΔVx (Vx +3ΔVx- 2×3ΔVx) and Vx -2ΔVx (Vx +2ΔVx- 2×2ΔVx) respectively and these positions are put in front of that segment. So segment length will be L+2.

C. Proposed Logical De-clipper

The first block of the receiver for the proposed method is Logical De-clipper (Fig. 3.). Its working principle is just the reverse of Logical Clipper in OFDM transmitter. The first stage of Logical De-clipper, called position signal collector (PSC), removes time domain position signals (side information) that were placed in front of every segment at logical clipper in OFDM transmitter. Also PSC stores the side informations and subsequently passes these to Threshold Value Regenerator and Combiner. Clipped over Threshold Value Regenerator (CoTVR) compares VT with the value of every segment at selected position provided by PSC and identify the difference value at selected position. After that it multiplies the difference value by two and regenerate clipped over threshold corresponding time domain position for every segment of OFDM received signal. CoTVR, the final stage of Logical De-clipper (Combiner), adds clipped over threshold with every segment of discrete time OFDM signal at desired position. Thus the process generates original unclipped OFDM signal for further processing in OFDM receiver.

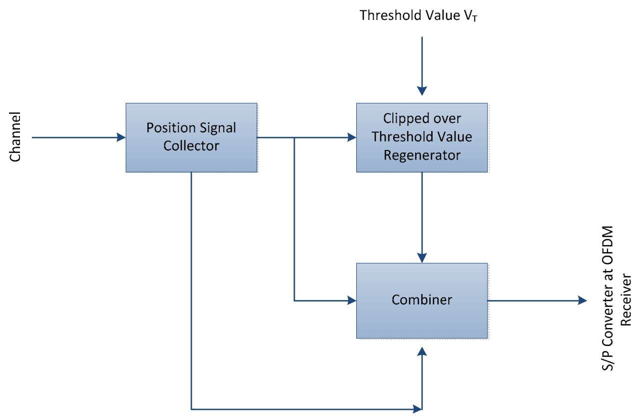

Fig. 3. Model of Logical De-clipper at OFDM Receiver.

III. SIMULATION RESULT

In this research work, performance of Logical Clipper with OFDM transmitter and De-Clipper with OFDM receiver in reducing PAPR have been studied for different numbers of subcarriers and modulation schemes.

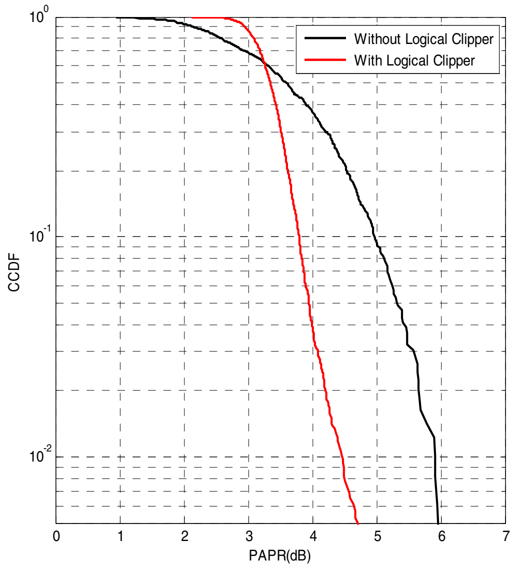

Fig. 4. CCDF Corresponding the PAPR for 64 Subcarriers and 4-QAM modulation scheme.

The whole process was simulated using MATLAB simulator. Here AWGN channel was used taking randomly generated data bits.

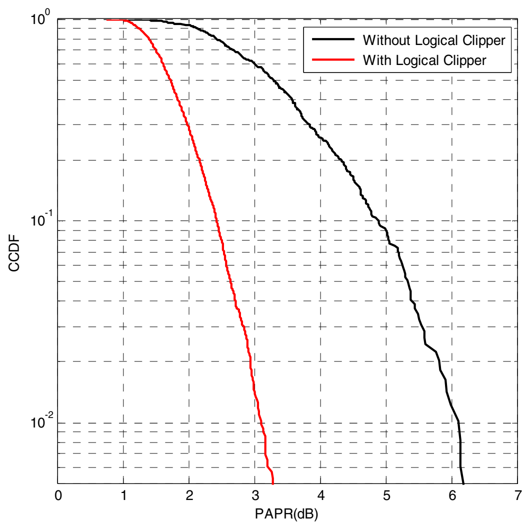

Fig. 5. CCDF Corresponding the PAPR for 32 Subcarriers and 4-QAM modulation scheme.

Fig. 4 shows the plot of complementary cumulative distribution function (CCDF) of PAPR of OFDM signal for 64 subcarrier and 4-QAM modulation scheme. From the figure it was observed that the value of PAPR of OFDM without applying Logical Clipper was 6.0dB and it was reduced by approximately 1.3dB when Logical Clipper was employed in transmitter.

Fig. 5 presents the plot of CCDF of PAPR of OFDM signal for 32 subcarriers and 4-QAM modulation scheme. In this case PAPR of OFDM signal without applying logical clipper was 6.2dB which was seen to reduce by approximately 3 dB after applying logical clipper in the transmitter.

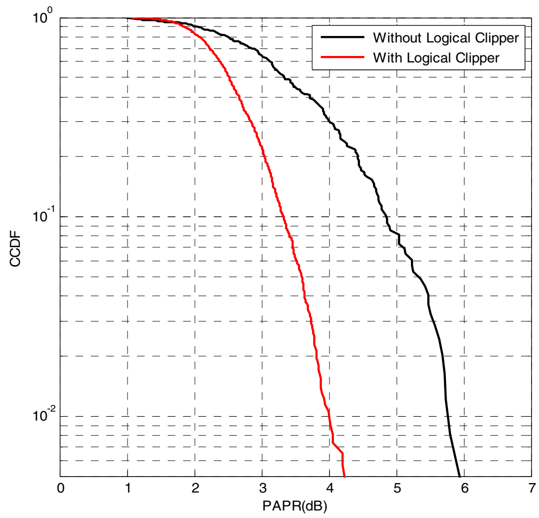

Fig. 6. CCDF Corresponding the PAPR for 64 Subcarriers and 16-QAM modulation scheme.

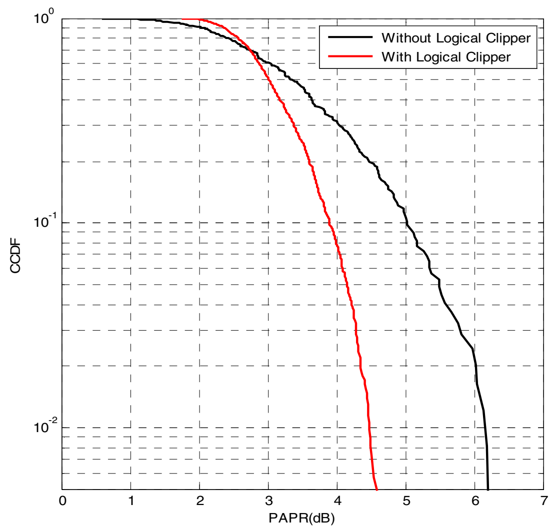

Fig. 7. CCDF Corresponding the PAPR for 32 Subcarriers and 16-QAM modulation scheme.

Fig. 6 shows the same type of plot for 64 subcarriers and 16-QAM modulation scheme. The PAPR of OFDM signal in this case was 5.9 dB without applying of clipper and was seen to reduce by approximately 1.7dB with logical clipper.

Fig. 7 gives the plot of CCDF of PAPR of OFDM signal for 32 subcarriers and 16-QAM modulation scheme. In this case PAPR was 6.2 dB without clipper and that was reduced to 1.6 dB with using clipper.

IV. CONCLUSION

In this study a technique named 'logical clipper and de-clipper' was applied to the OFDM system and its effect on the efficiency of OFDM transceiver in reducing PAPR from the signal was observed. The whole process was simulated using MATLAB simulator considering AWGN channel for communication. Performance of the OFDM system was evaluated by determining CCDF of PAPR from OFDM signal using 64 and 32 subcarriers and 4-QAM and 16-QAM modulation schemes respectively. From the obtained results it was seen that the proposed system performs well in reducing PAPR. Highest PAPR reduction was observed for 4-QAM modulation technique with 32 subcarriers.

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