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Performance Analysis of Low-Complexity System for PAPR Reduction in OFDM Communication System

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***Abstract*-To reduce the peak OFDM signals that can be distorted by the nonlinearity of power amplifiers, this project has proposed an efficient structure for implementing the tone reservation method that assigns appropriate data to reserved tones. In the proposed structure, a new binary search algorithm is proposed for the peak OFDM signal Clipping, and the FFT is replaced with an approximate DFT in which complex multiplications are replaced with shift operations.The proposed system is simulated using modelsim and syntheized in Xilinx project navigator.**

I. INTRODUCTION

The orthogonal frequency division multiplexing (OFDM) system places data information into a large number of closely spaced orthogonal subcarriers to transmit data efficiently. Since the time-domain OFDM signal is generated by adding a number of subcarriers modulated independently, its value can be very high sometimes. Such a high peak signal is usually distorted by the non-linearity of power amplifiers. High peak-to-average-power ratio (PAPR) results in three major degradations: increment of symbol error rate (SER), loss of signal power called in-band distortion, and increment of interferences among subcarriers
referred to as out-of-band distortion [1], [2]. Previous PAPR reduction methods can be classified into two groups depending on the necessity of side information. The selected mapping (SLM) [3] and the partial transmit sequence (PTS) [4] modify frequency-domain symbols and time-domain signals, respectively.

To prevent the OFDM system from burst errors, the transmitter delivers side information to the receiver. The other group working with no side information includes clipping and filtering (CF) [5], peak windowing (PW) [6], active constellation extension (ACE) [7], and tone reservation [8], [9]. The TR method reserves a small number of subcarriers and assigns appropriate values to reduce PAPR. This approach is also iterative like the ACE, but it does not change data symbols at all. Based on the TR method, this paper proposes a new structure that can lower hardware complexity and power consumption. In the proposed structure, the fast Fourier transform (FFT) is replaced with the discrete Fourier transform (DFT), as the number of reserved tones is much smaller than that of subcarriers.

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II. TONE RESERVATION FOR PAPR REDUCTION

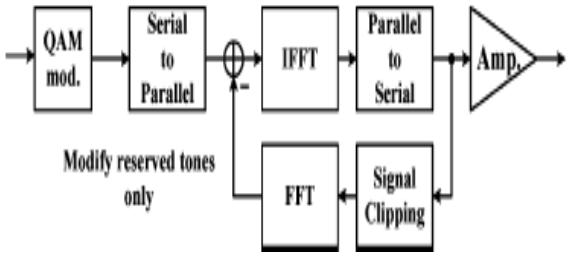

Fig. 1. Iterative FFT/IFFT processing for tone reservation

Let 'Lmax' be the input threshold voltage that forces the power amplifier to be saturated. If the time-domain signal values are all less than 'Lmax' the reserved-tone values are eventually allocated to the reserved tones. Otherwise, we modify the reserved-tone values with considering the effects of the current values. The time-domain signal exceeding 'Lmax' is clipped. The clipped samples are decomposed into frequency-domain values by conducting FFT. Then, we subtract the frequency components from the current reserved-tone values so as to update them. As the subtraction is performed only for the reserved tones, data symbols allocated to data subcarriers are not changed at all. To reduce the number of signal peaks exceeding 'Lmax' as many as possible, we have to perform the above procedure iteratively. However, the iterative computation increases the computational complexity as well as the hardware complexity. To clip the time-domain signal exceeding 'Lmax' , the approach called projection onto convex set (POCS)is usually used owing to its good theoretical properties. If the magnitude of an OFDM sample is greater than 'Lmax' , the sample should be scaled to 'Lmax' . For a time- domain sample x(n), the surplus portion to be clipped off, 'Xclip(n)' is computed as follows:

$$x_{\text{clip}}[n] = \begin{cases} \left(\frac{L_{\max} - |x[n]|}{|x[n]|}\right) \cdot x[n], & \text{if } |x[n]| > L_{\max} \\ 0, & \text{if } |x[n]| \le L_{\max}. \end{cases}$$

The POCS-based clipping expressed in this equation is difficult to implement, because of the magnitude computation of the sample and the complex domain multiplication involved in equation.

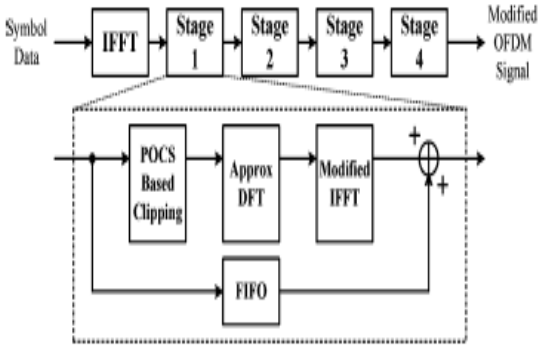

Fig 2. Proposed structure for the tone reservation method

In the proposed structure, the four iterations are pipelined using four stages each of which is in charge of one iteration. One stage consists of a FIFO buffer and three computational blocks for POCS-based clipping, approximate DFT, and modified radix-2 IFFT.Note that the approximation and modification applied to the DFT and IFFT are specific only for the TR method. The FIFO buffer is needed to temporarily store the input signals. The modified OFDM signal is generated by adding the incremental signal resulting from the approximate DFT to the input OFDM signal read from the FIFO buffer.

A. Binary Search for POCS-Based Clipping

The previous approach for the POCS-based clipping is to transform the rectangular coordinate to the polar coordinate (R2P) [11], which can be achieved

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by rotating the time-domain sample to the horizontal axis. The coordinate rotation can be realized by employing the coordinate rotation digital computer (CORDIC) approach [11] that computes the magnitude and angle of a complex value. However, the CORDIC computation is iterative and associated with a long latency.

To reduce the complexity of the POCS-based clipping, we propose a new approximation method based on the binary search. The first step is to compute the squared magnitude of the sample.

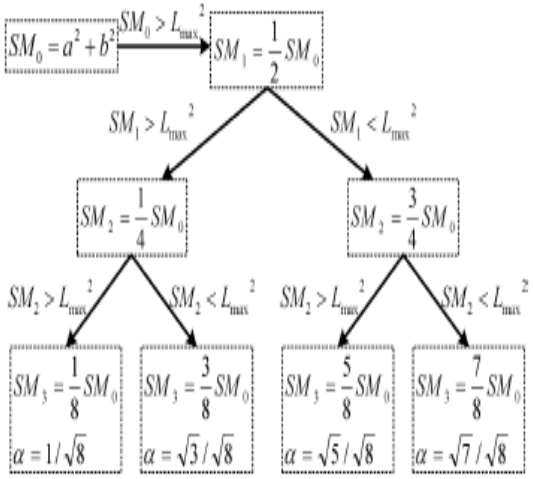

Fig 3. Two step Binary search

As the binary search is conducted only if the scaling factor is always less than 1. The pre-computed scaling factors are stored into a LUT. After we read a scaling factor from the LUT by using the whole comparison results as an index, we compute the scaled values of and by multiplying the scaling factor. The scaled values should be subtracted from the sample values to derive the clipped values.

B. Approximate DFT

In the conventional TR method, the FFT is directly used to decompose the clipped samples into frequency components. As the TR method concerns only the reserved tones, applying the DFT only to the reserved tones can result in a computational complexity lower than that of the FFT.

C. Modified Radix-2 IFFT

For real-time processing, the IFFT processing block is designed based on the structure of radix-2 single-path delay feedback (R2SDF).In the R2SDF structure, one of the two butterfly outputs is stored into the feedback shift register, and only a single data stream goes through the multiplier at every stage. Initial OFDM signal is produced by using the conventional R2SDF IFFT, because most of the input data are non-zero at that time. In the iterative IFFT for the TR method, however, the input data are zero except for reserved tones. When the reserved tones are fixed to specific subcarrier locations, we can further reduce the FIFO buffers and the LUT of twiddle factors, because there is no need to store the zero inputs and their corresponding twiddle factors.

III.PERFORMANCE ANALYSIS

The proposed architecture is designed using verilog HDL,simulated using modelsim software and synthesized using Xilinx project navigator.The RTL schematic view is illustrated in fig and its technology schematic view is displayed in fig.

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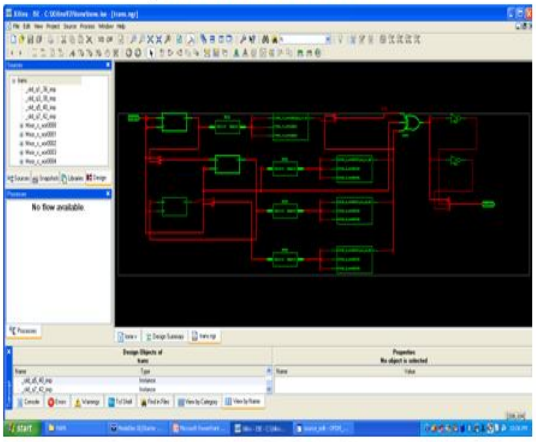
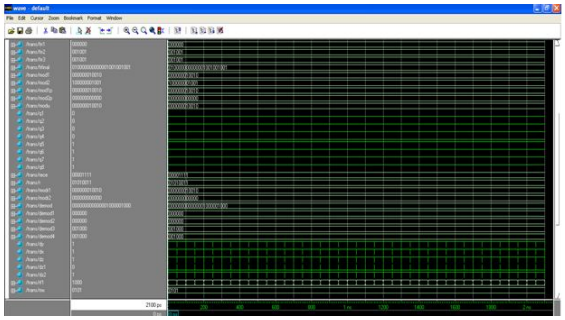
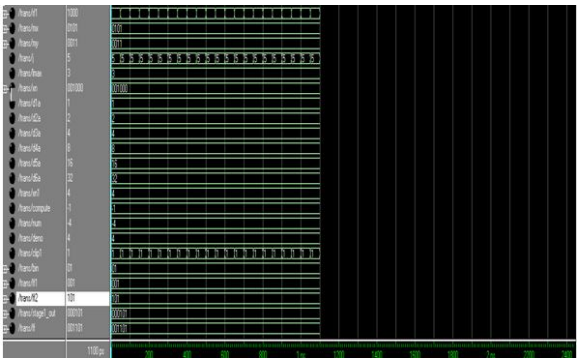
RTL Schematic view:



Simulation Result





Performance Evaluation

Performance Evaluation Parameters	Estimated Values
Power Consumption	160mw
Latency	6.23ns
Gate Count	400

V. CONCLUSION

To reduce the peak OFDM signals that can be distorted by the nonlinearity of power amplifiers, this paper has proposed an efficient structure for implementing the tone reservation method that assigns appropriate data to reserved tones. In the proposed structure, a new binary search algorithm has been proposed for the POCS-based Clipping, and the FFT is replaced with an approximate DFT in which complex multiplications are replaced with shift operations. In addition, the IFFT is minimized by reducing the FIFO size and the corresponding twiddle factors. The proposed structure reduces hardware complexity and power consumption significantly, while achieving almost the same performance as the conventional structure.

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