PAPR Reduction using Curve Fitting Based Modified Dynamic Tone Reservation Method in OFDM system

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***Abstract*— PAPR is one of the issues in the design of the OFDM system. In this paper we use a novel curve fitting based tone reservation method to reduce the PAPR of the OFDM system. The main idea of CF-TR method is to generate an ideal peak canceling signal by utilizing the clipping noise introduced by clipping. This method obtains a significant PAPR reduction with very few iteration by using only one IFFT operation in each iteration, thus the computational complexity is reduced to a greater extend. In this method tones are allocated in advance, but if there is no need for PAPR reduction those tones goes unused which can be used for data transmission. In this paper we propose dynamic tone allocation method based on the actual signal realization using an l1 norm minimization. Addition processing need to be done at the receiver as it does not know the position of the reserved tone this method is called modified tone reservation method. Simulation results shows that by using Modified Dynamic tone reservation method PAPR of the system gets reduced by 2 db at 10^{-2} symbol clip probability compared to a fixed reserved set**.

***Index Terms*—Tone reservation; papr; dynamic and modified dynamic tone reservation; PRT; ccdf**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is one of the widely used technique because of its robustness against inter symbol interference and frequency-selective fading channels. However there are some drawbacks of this technique, PAPR (peak to Average Power Ratio) is one of them. It occurs due envelope fluctuations of the OFDM signal.

There are several PAPR reduction techniques which are broadly classified into two types as Signal Scrambling Techniques and Signal Distortion Techniques. Block Coding Techniques, Block Coding Scheme with Error Correction, Selected Mapping (SLM), Partial Transmit Sequence (PTS), Interleaving Technique, Tone Reservation (TR), and Tone Injection (TI) comes under Signal Scrambling Techniques and Peak Windowing, Envelope Scaling, Peak Reduction Carrier, Clipping and Filtering comes under Signal Distortion Techniques.

In this paper, we use a curve fitting based modified dynamic tone reservation method to reduce the PAPR of the OFDM signal, in the curve fitting technique we use the clipping noise produced by the clipping to generate the peak cancelling signal as it uses only one IFFT operation during each iteration complexity of the system gets reduced to a greater extend. In this technique tone are allocated in advance but there may come a situation when PARP reduction is not required for a given block of OFDM signal in such case the reserved tone go unused which can be made use for data transmission so we propose a modified Dynamic Tone Reservation method in which the tones are reserved based on the signal realization

The rest of the paper is organized as follows In Section II, system model is given. Then, CF-TR is explained in Section III. Section IV, Dynamic and Modified Dynamic Tone Reservation is discussed. In section V Simulation results are provided, finally conclusions in Section VI.

II. SYSTEM MODEL

In an OFDM system, data is modulated using N orthogonal carrier and discrete time OFDM signal $x = [\, x(0), x(1), \cdot \cdot \cdot , x(N-1)]^T$ is generated. X is the N-point inverse fast Fourier transform (IFFT) of input data.

$$X(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x^k a^{\frac{j2\pi kn}{N}} \quad ,\ldots\ldots\ldots\ldots\ldots(1)$$

Where n = 0, 1 , ... N-1

Generally, the PAPR of an OFDM signal x is defined as

$$PAPR = \frac{\max_{0\le n\le N-1} [|x(n)|^2]}{E[|x(n)|^2]} \quad \ldots\ldots\ldots(2)$$

Where E[・] represents the expectation.

In Tone reservation technique some of the subcarriers are reserved for generation of peak cancelling signal $c = [\, c_0 , c_1 , \ldots , c_{N-1}]^T$ to reduce peak. These subcarriers are called peak reduction tones (PRT). These PRTs does not carry any data and they are used for peak reduction. C is added to x to obtain the peak reduced signal

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III. CURVE FITTING BASED TONE RESERVATION

For the CF-TR method, original time domain signal is added to the peak cancelling signal generated by the reserved tones by introducing clipping.

For a given clipping threshold A, the clipped OFDM signal

$$\tilde{X} = [\, \tilde{x}(0) , \tilde{x}(1) , \ldots\ldots \tilde{x}(N-1) \,]^T$$

Can be obtained by

$$\tilde{x}(n) = \begin{cases} x(n), & If\ |x(n)| < A \\ A\, e^{j\theta_n}, & If\ |x(n)| \geq A \end{cases} \quad \ldots\ldots\ldots\ldots(3)$$

Where x(n) = | x(n) | e j^{θ_n} and θ_n is the phase of x(n). Then the clipping noise F = [f(0) , f(1) , ... , f(N-1)]^T is defined as

$$f(n) = \tilde{x}(n) - x(n) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The waveform of the peak canceling signal c is fitted to the waveform of the clipping noise f. Here fitting c(n) to f(n) is meant to decrease the Euclidean distance between the points c(nl) and f(nl) for l = 0, 1, · · · , L – 1 , where L is the number of non-zero values of f(n).

We denote

$$R = \begin{bmatrix} r_0(n_0) & \cdots & r_{M-1}(n_0) \\ \vdots & \ddots & \vdots \\ r_0(n_{L-1}) & \cdots & r_{M-1}(n_{L-1}) \end{bmatrix},$$

$$\hat{f} = \begin{bmatrix} f(n_0) \\ \vdots \\ f(n_{L-1}) \end{bmatrix}$$

Where $r_m(n) = \frac{1}{\sqrt{N}}\, e^{\frac{j2\pi k_m n}{N}}$

Therefore, the optimal value of $\hat{c}$, denoted as $\hat{c}^{opt}$ is calculated using

$$\hat{c}^{opt} = arg \overset{min}{\hat{c}} \left\| R\,\hat{c} - \hat{f} \right\|_2^2 \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Then the peak canceling signal is found by $c_i^{opt} = IFFT\{\hat{c}_i^{opt}\}$ this peak cancelling signal is added to the original time domain signal and transmitted. In case there is no clipping noise then the original time domain signal is transmitted

IV. DYNAMIC AND MODIFIED DYNAMIC TONE RESERVATION

A. Dynamic Allocation

In this based on the actual realization of the time domain signal the reserved tone set Sr is dynamically selected using l_1 norm minimization to achieve a good PAPR reduction. Considered that initially all N tones are loaded with data, now a small subset of data – carrying tones among the N tones is selected based on the l_1 norm minimization of the time domain signal.

$$\underset{C}{\text{Minimize}}\quad t$$

$$\text{Subject to}\quad |Q(X+C)|_\infty \leq t, \quad |C|_1 \leq \gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

B. Modified Dynamic Allocation

Dynamic selection of reserved tones brings complexity in the receiver as the receiver does not know the position of the reserved tone, to solve this problem Modified dynamic tone reservation is used. Points of reserved tones are kept in a proper distance so that the receiver can make a decision. Above equation is solved to find the position of the reserved tones, if the distance between the reserved point and the constellation point is smaller than a certain distance then the MDTR method modifies the value reserved tones so that receiver can identify the reserved tones.

V. STIMULATION AND RESULTS

A. PAPR reduction using CF-TR

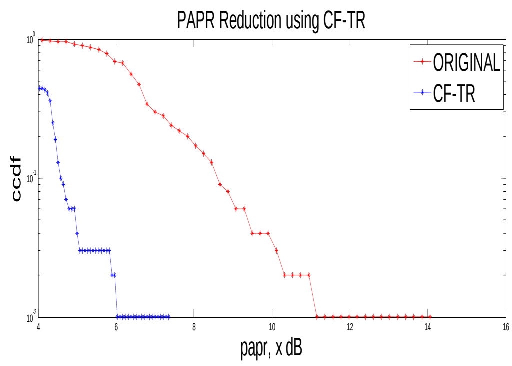

Fig.5.1 PAPR reduction using CF-TR

In the above graph to demonstrate the performance gain due to the CF-TR the Complementary Cumulative Distribution Function (CCDF) is shown. We use 4 reserved tones and 64 OFDM tones. We can clearly see that there is 2 db gain while using CF-TR as compared to the original signal

B. PAR reduction gains with dynamic allocation

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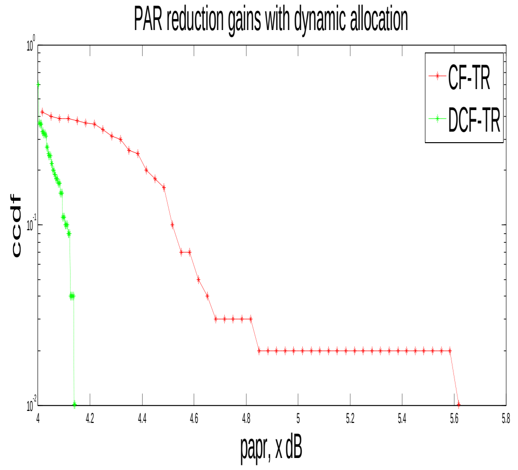

Fig 5.2 PAR reduction gains with dynamic allocation

In the above graph we compare the dynamic allocation of reserved tone with the standard allocation of reserved tones in CF-TR method. As seen the dynamic allocation provides a better performance gain as compared to the standard allocation.

C. PAR reduction gains of modified dynamic tone reservation

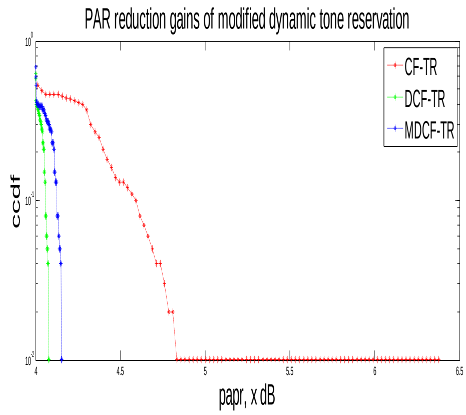

Fig:5.3 PAR reduction gains of modified dynamic tone reservation

The above ccdf plot shows the performance of modified dynamic tone reservation in comparison to the dynamic and standard tone reservation. From the above graph we can infer that the modified dynamic tone offers a better PAPR reduction performance as comparison to the standard tone reservation .One more advantage of using modified dynamic tone reservation is that it provides information about the position of the reserved tones to the receiver but a little compromise with the PAPR reduction has to be done as compared with dynamic tone reservation.

VI. CONCLUSION

In this work, we use a curve fitting based tone reservation method to generate the peak canceling signal also we propose modified dynamic tone reservation method to reduce the PAPR of the OFDM system. CF-TR method uses only one IFFT which results a significant reduction the in computational complexity also by choosing the reserved tones dynamically maximum utilization of tones are possible. Simulation results shows that by implementing CF-TR method through dynamic allocation of tones PAPR reduction performance can be improved to a greater extend.

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