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Performance of Tone Reservation (TR) method for reducing PAPR in OFDM Systems

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Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique possessing higher data rates with several advantages such that immune to frequency selective fading, elimination of Inter Symbol Interference (ISI), good computational efficiency, good protection against co-channel interference etc. On the other hand, OFDM suffers from various disadvantages like High Peak-to-Average Power Ratio (PAPR), more sensitive to carrier frequency offset etc. In this paper, we propose the Tone Reservation technique in order to reduce the PAPR of OFDM signal. We use QPSK modulation and Radix-2 FFT operations for propose work. Simulation results show that there is a sufficient reduction in PAPR.

Keywords*— OFDM, QPSK, PAPR, Reserved Tones.

I. INTRODUCTION

In recent years, the requirement of high speed data goes on increasing. To fulfil this requirement, many multiplexing techniques have been developed. The OFDM is one of them and is special form of multi-carrier modulation. It has many advantages such that high spectral efficiency, immunity to frequency selective fading, removal of Inter-Symbol Interference (ISI) with delay spread reduction etc. But, OFDM suffers from the drawbacks such that Doppler shifts, carrier frequency offsets etc. One of the most severe drawbacks of OFDM is high Peak-to-Average Power Ratio (PAPR). The OFDM has large number of sub-carriers with varying amplitudes which results in high PAPR of the system. As a result, the efficiency of HPA gets reduced [1]. To reduce the high PAPR value, various techniques such as Clipping, Selected Mapping (SLM) [3][4], Partial Transmit Sequence (PTS), Tone Injection (TI) and Tone Reservation (TR) are studied.[2] In this paper, we focus on the Tone Reservation (TR) technique [5][6] with QPSK modulation to reduce the PAPR value.

II. PEAK-TO-AVERAGE POWER RATIO (PAPR)

The OFDM signal consists of large number of independent modulated sub-carriers. Sometimes, the peak value of power of any sub-carrier can be very much higher than average power of remaining sub-carriers. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio (PAPR). A coherent addition of N signals of same phase produces a peak which is N times the average signal. A large PAPR increases the complexity of the analog–to–digital and digital–to–analog converter and reduces the efficiency of the radio – frequency (RF) power amplifier. The PAPR is defined as

$$\text{PAPR} = \frac{\max_{0\le t<NT} |x(t)|^2}{1/_{NT} \int_0^{NT} |x(t)|^2 \, dt}$$

There are number of techniques to deal with the problem of PAPR. Some of them are Amplitude Clipping, Partial Transmit Sequence (PTS) and Selected Mapping (SLM). These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on.

III. TONE RESERVATION

In this paper, we propose the Tone Reservation technique in order to reduce the PAPR of OFDM system. In this method, the original signal is added with an approximate signal so that the PAPR of original signal is reduced. The basic requirement of this technique is the original signal and the approximate signal both should lie in disjoint frequency subspaces. i.e some tones in original signal are reserved to reduce the peaks in signal. The reserved tones do not contain data. Fig. 1 shows the basic block schematic of proposed scheme. From figure, we consider a time domain signal x[n] which suffered from PAPR problem. The basic task is to find the approximate signal c[n] that will be added in the original signal to reduce the peaks in the original suffered signal. Therefore, the resultant signal is obtained as

$$x^*[n] = x[n] + c[n]$$

But the generation of c[n] signal is difficult as it contains data symbols in frequency domain. Therefore, a corresponding frequency domain signal C[k] is constructed and added in the frequency domain signal X[k] i.e

$$X^*[k] = X[k] + C[k]$$

The equivalent time domain signal is obtained by taking IFFT of the above sum. The resultant OFDM signal after applying the Tone Reservation method is obtained as

$$x^*[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X[k] + C[k]\, e^{\frac{j2\pi kn}{N}}$$

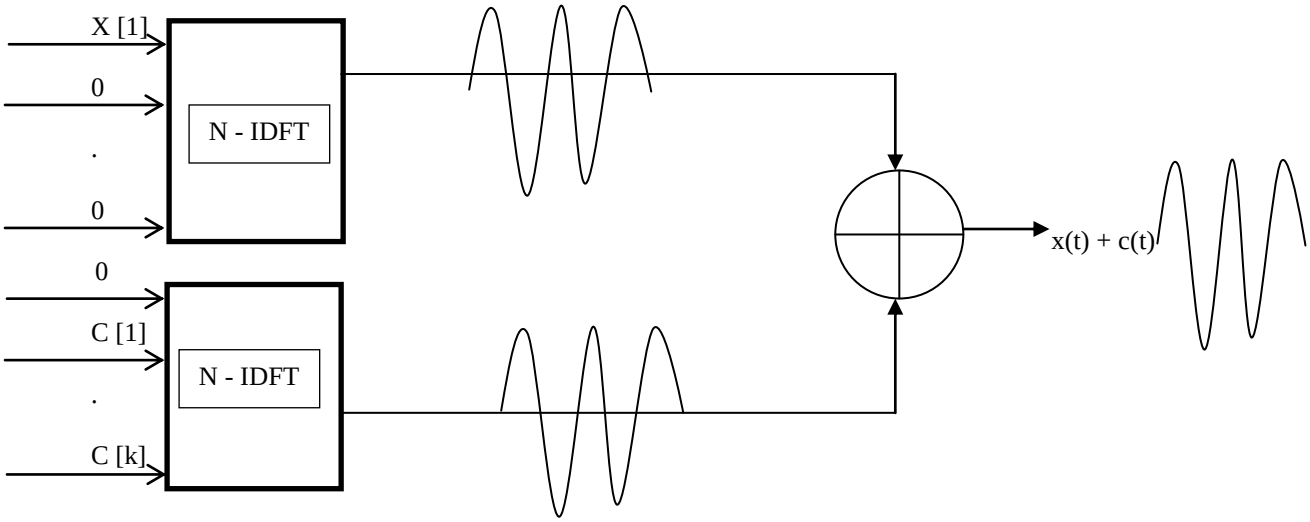

Fig. 1 Block schematic of Basic Tone Reservation

To implement the proposed scheme, we use the Radix – 2 IFFT computations which can be formulated as complex multiplication and complex addition. The mathematical expression for Radix-2 IFFT is as below.

$$\text{Complex Multiplication} = {}^{N}/_{2} \log_2 N$$

and

$$\text{Complex Addition} = N \log_2 N$$

PARAMETERS CONSIDERATION

TABLE.1 CONSIDERED PARAMETERS FOR PROPOSED WORK

FFT Size	256
Total Number of Subcarriers	128
Total Number of Reserved Subcarriers	30, 40, 50
Maximum Symbols	10000
Modulation	QPSK

IV. SIMULATION RESULTS

The simulation results are shown in figure 2 and figure 3. The figure 2 shows the results regarding to reserved subcarriers (R). As the number of reserved subcarriers increases, the effect of PAPR on OFDM signal decreases.

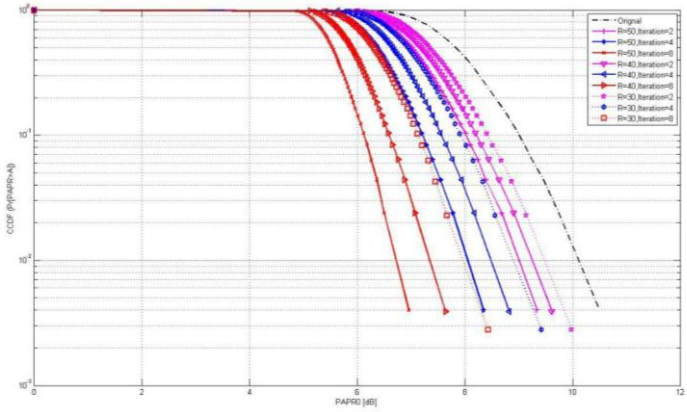

Fig. 2 CCDF Plot for various numbers of reserved subcarriers

From the simulation results of figure 3, we observed that for the highest number of reserved tones, the PAPR is reduced up to 6.98dB. The table no. 2 shows the obtained values of PAPR.

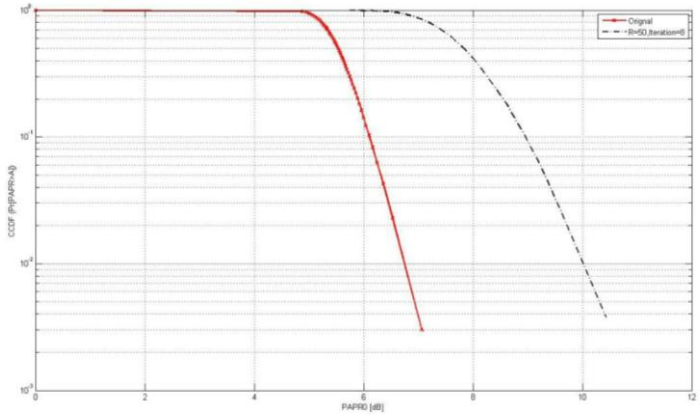

Fig.3 Performance of Basic Tone Reservation method

Table.2 Obtained values of reduced PAPR using TR

Original PAPR Value	**Reduced PAPR with Tone Reservation**
10.42 dB	6.98 dB

V. CONCLUSIONS

OFDM is a very attractive technique for wireless communications due to spectrum efficiency and channel robustness. One of the serious drawbacks of in OFDM systems is that the composite transmit signal can exhibit a very high PAPR when the input sequences are highly correlated. We have considered QPSK modulation for the performance of basic Tone Reservation. The simulation results show that there is a better PAPR reduction of 3.4dB with QPSK modulation. The PAPR reduction using Tone Reservation depends on number of reserved subcarriers and the IFFT iterations. The tone reservation can be applied to OFDM signal only and it does not require the side information for receiver operation.

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