Implementation of Tone- Reservation Technique for PAPR Reduction in OFDM

Nilesh M. Prajapati and Priyanka P Prajapati

Abstract—**One of the major drawbacks of OFDM is high Peak to-Average Power Ratio (PAPR) which can result in poor power efficiency and serious distortion in the transmitter amplifier. Tone Reservation (TR) is a technique designed to combat this problem by reserving a number of carriers (tones) in the frequency domain to generate a cancellation signal in the time domain to remove high peaks. However TR can have a high associated computational cost due to the difficulties in finding an effective cancellation signal in the time domain by using only a few tones in the frequency domain. In this paper ,we propose a novel approach to overcoming this problem by creating a Gaussian pulse as the cancellation signal from only a small number of reserved tones .This facilitates a simple and effective algorithm for reducing peak values while minimizing the occurrence of secondary peaks, the latter being a key factor in contributing to the high computational complexity of tone reservation algorithms**

Index Terms—Orthogonal Frequency Division Multiplexing (OFDM) ,Peak To Average Power Ratio(PAPR),Selective Mapping(SLM), Tone Reservation. CCDF (Complementary Cumulative Distribution Faction).

I. Introduction

Orthogonal Frequency –Division Multiplexing (OFDM) offer many well-documented advantages for multi-carrier transmission at high data rates, including high spectral efficiency, simple implementation using the Fast Fourier transform (FFT), immunity to multi-path fading etc. [1-4].

However, one of major drawbacks of OFDM is the high peak-to-average power ratio (PAPR) of the transmitted signal. This occurs due to the large number of the independent sub-carriers with random phase that are added together at the modulator.

The high peaks occur very rarely, but the power amplifier (PA) may be overdriven deep into saturation on this rare occurrence since we might normally wish to operate the PA under reasonably strong drive conditions to maintain high power efficiency .During the overdrive event the distortion that is generated results in very high instantaneous spectral re-growth which can cause serious adjacent channel interference.

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Several technique have been developed to address the PAPR problem .The simplest is clipping, but it causes in-band and out-of-band distortion .Filtering can be used to alleviate out-of-band distortion but result in peak re-growth. Repeated clipping and filtering can lead to serious degradation in bit-error- rate(BER) The use of windowing technique involves multiplying large signal peak by a non –rectangular window such as a Gaussian pulse to minimize the out-of –band interference. Ideally the window should be as narrow –band as possible but it should not have too long an extension in the time domain ,otherwise more signal sample are affected, which would result in an Increase in BER.[5].

Selective Mapping (SLM) is another approach, which is implemented by generating a set of sufficiently different candidate signals from the original data signal .The transmitter selects and submits the candidate signal which has the lowest PAPR. Partial Transmit Sequencing (PTS) is a similar technique in which sub-blocks of the original signal are optimally combined at the transmitter for generating a transmitted signal with low PAPR .Although SLM and PTS are effective at reducing the PAPR, they require the use of side information to the receiver in order to decode the signal [6].

The tone reservation (TR) algorithm was developed by Tellado [7], whereby a small number of sub-carriers (tones) are reserved to create a signal which can cancel the high peaks in the information –carrying signal at the transmitter .this approach can reduce the PAPR of the OFDM signal without introducing any additional distortion to the information data and does not require side information. However TR can have high computational cost due to the difficulties of fading an effective cancellation signal in the time domain from only a small number of reserved tones in the frequency domain .In this paper ,we propose a novel approach for overcoming this difficulty by creating a Gaussian –pulse –like cancellation signal which facilitates a simple procedure for reducing peak values ,while minimizing the occurrence of secondary peaks.

II Overview of Tone Reservation

In an OFDM system with N sub-carriers, the transmitted base band signal can be written as

$$X(\mathrm{t}) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X_K e^{J(2\pi k \Delta f t)}, 0 \le t \le T \qquad (1)$$

Where X_k is the symbol carried by the kith sub-carrier, Δf is the frequency difference between sub-carriers,

and T is the OFDM symbol duration .in the transmitter ,the transmitted signal or sequence may be generated by the Inverse Fast Fourier Transform (IFFT) of the N-point $\{X_k\}$sequence , and at the receiver, the Fast Fourier Transform(FFT) is employed to restore the signal ,e.g.,

$$X_n = \text{IFFT}(X_k) \text{ and } X_k = \text{FFT}(X_n) \quad (2)$$

Because the continuous –time peak power can be significantly higher than in the discrete –time domain, it is necessary to over sample the signal by factor of at least four (8).For an oversampling factor of l, the input signal to the IFFT is extended by including N(l-1)zeros in the center of the signal

The PAPR of the transmitted signal can be expressed as:

$$\text{PAPR(X)} = 10\log 10\left(\frac{\max|x(n)|^2}{E[x(n)]^2}\right) \quad (3)$$

Where $|x(n)|$ return the magnitude of x(n), and E[.] denotes the expectation operation. As more sub-carriers are added, higher peak values may occur, hence the PAPR normally increases proportionality with the number of sub-carriers.

In Tone Reservation ,a small number of sub-channels(tones), which do not carry any information data ,are reserved for peak cancellation .This restricts the data –bearing vector X, and the reserved tone vector C to lie in disjoint frequency subspaces ,i.e., they cannot both be nonzero at given tone, which require that

$$X_k + C_K = \begin{cases} C_K, \text{K} \in \text{L} \\ X_k, \text{K} \in L \end{cases} \text{c} \quad (4)$$

The subset of reserved tones can be denoted by L= $\{i_0, \ldots i_L\}$ with L ≤ N, where N represent the set of all tones in the multi carrier symbol L^C IS the complement of L in N and represent information carriers. The addition of these reserved tones c to a data-bearing signal x a new composite signal

$$\bar{X}[n] = x[n] + c[n] = \text{IFFT}(X_K + C_K) \quad (5)$$

Since symbol demodulation is performed in the frequency domain on a tone-by-tone basic, the reserved sub-channels can be discarded at the receiver, and only the data-bearing sub-channels are used to determine the transmitted bit stream. The PAPR becomes

$$\text{PAPR(x)} = 10\log 10\left(\frac{\max|x(n)+\text{c(n)}|^2}{E[x(n)]^2}\right) \quad (6)$$

Where we can see that the PAPR can be reduced by optimizing c(n) so that $\max|x(n)+\text{c(n)}|^2$ can be smaller Than max $\max|x(n)|^2$.

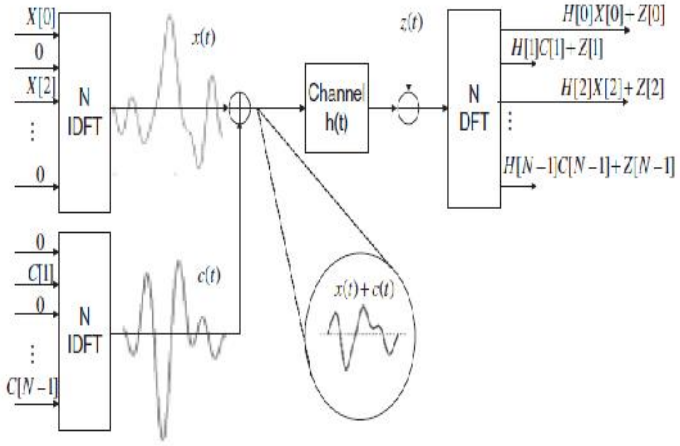


Fig1 Block diagram of Tone-Reservation

III Generation Gaussian Pulses for Reserved Tones

In the tone reservation approach, a small number of sub-carriers (tones) are reserved to create a signal which cancels the high peak of information –carrying signal in the transmitter. This cancelation signal must be generated in the frequency domain using the minimum number of tones to maximize data throughput, however it is also preferable to have narrow time domain signal to prevent the generation of secondary peak .In other peak , the PAPR reduction approach in tone reservation is a constrained signal –design problem :a signal must be designed in the frequency domain but its effect is evaluated in the time domain .in current time domain approaches ,the cancellation signal mainly generated from either trial and error processes or involves computationally complex optimization procedures[7][8].

In this paper, we propose a simple algorithm, in which Gaussian window-like signal is employed in the frequency domain to from the canceling pulse in the time domain. Since

Gaussian pulse can be optimized in both the time domain and frequency domain [9].

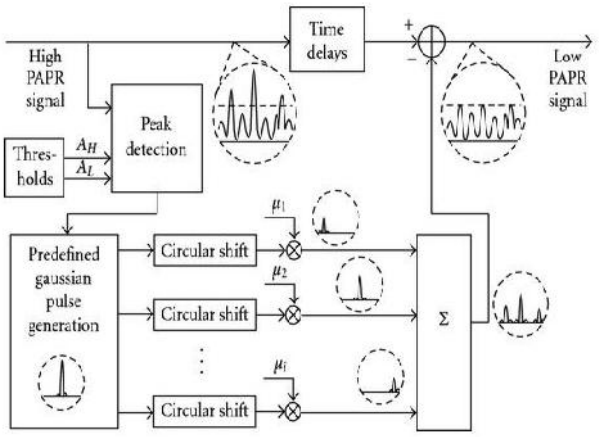


Fig.2.Gaussian pulse based Tone Reservation for Reducing PAPR of OFDM signal.

The coefficient of the Gaussian window G,can be calculated from the equation

$$G_{[m+1]=e^{-\frac{1}{2}\left(\alpha\frac{m-\frac{L}{2}}{L/2}\right)}} \quad \text{where } 0<m<L-1 \qquad (7)$$

Where α represent the reciprocal of the standrad deviation,and the width of the window is inversely related to α .These values reperesent the amplitude of the gussian window and the phase has value of zero.The valus of L reperesent the number of tones reserved to generate the cnacellation signal .Typically,a value of 16 or 32 provides sufficiently narrow Signal in the time domain to avoid the occurrence of secondary peak.Unlike previously proposed method ,the generation of this cancellation signal does not require complicated peak searching of optinization procedures [7[8].This signal peak signal is easily optimized both in the time and the frequency –domains..just one time IFFT operation is required ,and very few tones are needed.For example ,in a WiMax system with over-sampling by a factor of four,a
Selection of 16 tones only occupies 1.5% of the available bandwith.

IV. Algorithm For Reducing PAPR.

Once an efficient cancellation signal is obtained ,a fast conversion algorithm can be applied to the OFDM system to cancel the high peak so that the transmitted signal does not exceed the required threshold A.The algorithm employed is implemeted as follows:

I. A pre-defined cancellation signsl is generated by using the Gaussian pulse describe in section III.This cancellation signal only has non-zero value in the reserved tone location in the frequency domain and has one sharp peak in time domain.
II.We frist check if there are peak exceeding the required threshold A in the information –carrying signal. If there are ,the magnitude of the peaks and their crrespoing location are detected.
III.for each peak detected in the information data ,the peak of the pre-defined cancellation signal is circulaly shifted to the peak location and scaled by the value of the difference between the peak and the threshold so that power of the peak tone can be reduce to the desired target level.All of the appropriately scaled and phase shifted cancellation signals are then subtracted from the original information signal
IV.Ater the peak cancellation ,the compossite signal will be detected again since some secondary peak may appear during the previous peak-canceling operation .The process is continued untill all the peaks are below the require thershold or until a maximum number of iteration are exceeded as show in Fig.2

Since the Gaussian –pulse based peak cancellation signal has a very sharp shape in the time domain , the occurence of secondary peak is minimized .Typically only a signal iteration is required to remove each peak detected in the original time-domain signal in this approach ,when the pulse cancellation signal is circularly shifted ,scaled and phase-rotated in the time-domain, the value of the frequency –domain signal only change at the resereved tone location but remain unchaged at the other tones.The data vector X is not affected by the peak canceling opearation ,so that it does not need any side iformation or any receiver operation.

V. SIMULATION RESULTS.

To verify the approach proposed, we first simulated it in a WiMax system, which contain 256 data carriers with 16-QAM modulation and a bandwidth of 16 MHz The cancellation signal was generated by using 16 tones .A sample of the time domain signal is shown in Fig.3 where we can clearly see the high peak were effectively removed after three iteration

As per the technique Fig.4 shows the previous simulation by keeping CR = 1, that why reduction in the PAPR can be done up to 1.5dB only but the times always wants some changes so by this technique due to some Changes better result can be display. In table the data shows reduction in CCDF of PAPR.

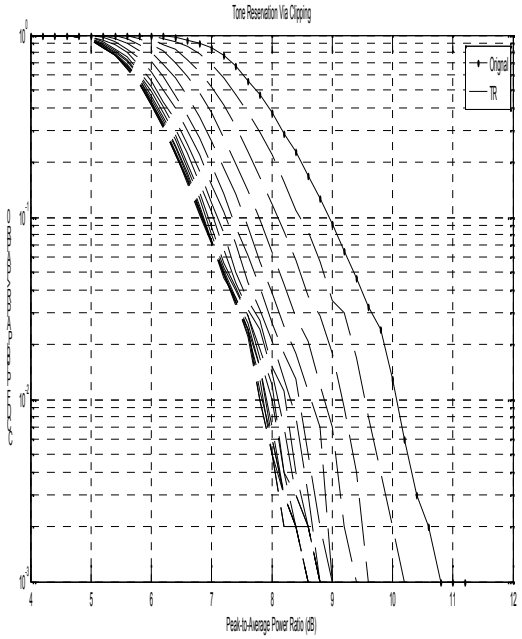


Fig.3 Shows PAPR reduction of TR up to 1.5dB CR=1

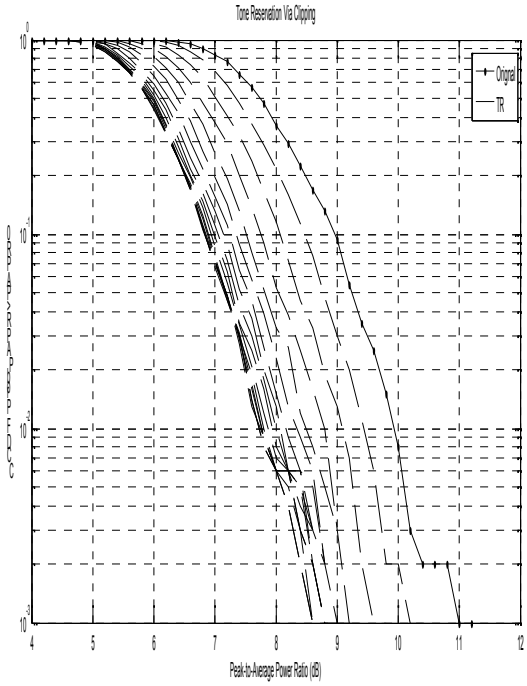


Fig .4 PAPR Reduction of TR when CR=2

The signal generated in BPSK modulation signal then signal passed from 1000 loops. OFDM signal's peaks can be remove at some level by using this technique. In this technique by using previous reservation terms further Can be evaluating. Now as per shown the Fig.4 this is the simulation result by using the tone reservation technique

To reduce the PAPR at CR=2 .This proposed technique includes signal power and mean power. Now in this technique OFDM signal is transmitted after performing IFFT $X = IFFT(\mathrm{X}^{*}\mathrm{TR})^{*}\sqrt{N}$ here the value of CCDF is checked for 32 times because here M= 32

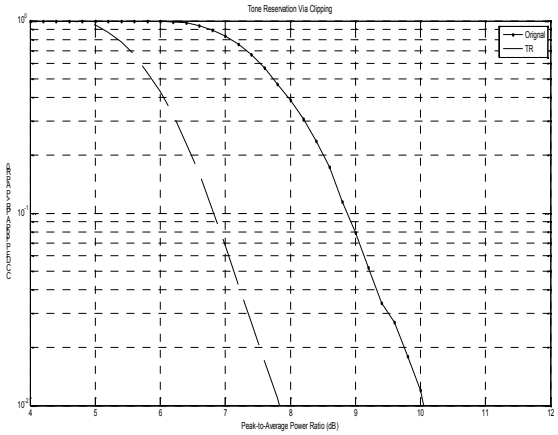
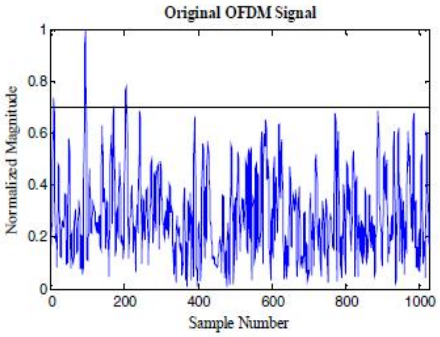
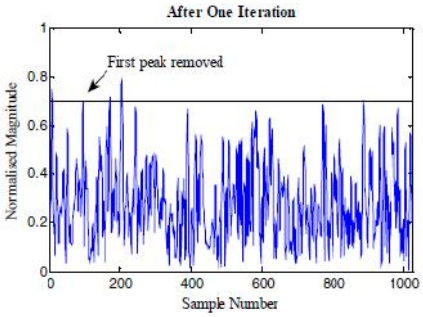
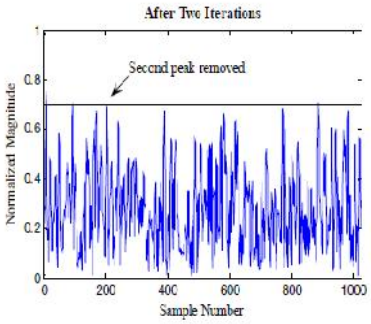


Fig.5 Tone reservation via Clipping







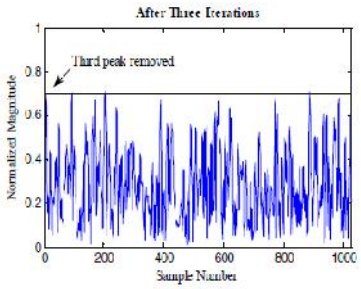


Fig 6. Time domain Tone Reservation

VI. CONCLUSION

In this paper , we have proposed an effective solution for generating peak cancellation signals in which only one IFFT operation and simple iterative operation are needed ,This dramatically reduce the computational complexity of conventional tone reservation operations. Significant PAPR reduction can be achieved by using only small number of tones in the frequency domain. This technique can be applied to any communication system where is employed, such as wireless LAN or WiMax.

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