International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 1, ISSN 2249 –071X

"Verification for PAPR Reduction of OFDM Signal Using Partial Transmit Sequences Technique"

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***Abstract* - In this paper we propose an algorithm for PAPR reduction in OFDM systems, based on a Partial Transmit Sequence Technique. In this present work an introduction to multi-carrier modulation emphasizing OFDM (Orthogonal Frequency Division Multiplexing) is given followed by mathematical and qualitative description of OFDM. This paper work presents an overview of the most popular OFDM PAPR-reduction techniques demonstrating that Partial Transmit Sequences (PTS) Technique is a particularly promising reduction technique. It achieves considerable PAPR reduction without distortion, but the high computational complexity of multiple Fourier transforms is a problem in practical systems. This new technique significantly decreases the computational complexity while providing comparable PAPR reduction to ordinary PTS (O-PTS), even with a small number of stages after PTS partitioning. All carriers are orthogonal to each other, which means when one particular subcarrier is at its peak other are at zero. It also requires less increase in SNR for the same BER compared to other methods. Numerical results are presented which confirm the PAPR improvements.**

***Keywords* - OFDM (Orthogonal Frequency Division Multiplexing), PAPR (Peak to Average Power Ratio), BER (Bit Error Rate), PTS (Partial Transmit Sequence)**

I. INTRODUCTION

Future mobile communications systems reaching for ever increasing data rates require higher bandwidths than those typical used in today's cellular systems. By going to higher bandwidth (for low bandwidth) the flat fading radio channel becomes frequency selective and time dispersive.

Due to its inherent robustness against time dispersion Orthogonal Frequency Division Multiplexing (OFDM) is an attractive candidate for such future mobile communication systems.

OFDM partitions the available bandwidth into many sub-channels with much lower bandwidth. Such a narrowband sub-channel experiences now due to its low bandwidth an almost flat fading leading in addition to above mentioned robustness also to simple implementations. However, one potential drawback with OFDM modulation is the high Peak to Average Power Ratio (PAPR) of the transmitted signal: The signal transmitted by the OFDM system is the superposition of all signals transmitted in the narrowband sub-channels. The transmit signal has then due to the central limit theorem a Gaussian distribution leading to high peak values compared to the average power.

A system design not taking this into account will have a high clip rate: Each signal sample that is beyond the saturation limit of the power amplifier suffers either clipping to this limit value or other non-linear distortion, both creating additional bit errors in the receiver.

One possibility to avoid clipping is to design the system for very high signal peaks. However, this approach leads to very high power consumption (since the power amplifier must have high supply rails) and also complex power amplifiers. The preferred solution is therefore to apply digital signal processing that reduces such high peak values in the transmitted signal thus avoiding clipping. These methods are commonly referred to as Peak to Average Power Ratio (PAPR) reduction.

II. MULTICARRIER MODULATION

Differently from satellite communication where we have one single direct path from transmitter to receiver, in the classical terrestrial broadcasting scenario we have to deal with a multipath- channel i.e. the transmitted signal arrives at the receiver in various paths of different length as shown in the figure below. Since multiple versions of the signal interfere with each other that means the Inter Symbol Interference (ISI) occurs and it becomes very hard to extract the original information.

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi carrier modulation, uses DSP algorithms like Inverse Fast Fourier Transform (IFFT) to generate waveform that are mutually orthogonal. After more than thirty years of research and development carried out in different places, OFDM is now being widely implemented in high-speed digital communications. Due to the recent advancements in digital signal processing (DSP) and very large-scale integrated circuits (VLSI) technologies, the initial obstacles of OFDM implementations do not exist anymore. Meanwhile, the use of fast Fourier transform (FFT) algorithms eliminates arrays of sinusoidal generators and coherent demodulation required in parallel data systems and makes the implementation of the technology cost effective. In recent years OFDM has gained a lot of interest in diverse digital communication applications. This has been due to its favorable properties like high spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density, capability of handling very strong echoes and less non-linear distortion.

Orthogonal frequency division multiplexing (OFDM) is the modulation technique used in many new broadband communication schemes including digital television, digital radio, ADSL and wireless LANs (HIPERLAN 2, IEEE 802.11a) and many other wireless communication systems. Even though there are many advantages of OFDM, it has two main drawbacks:

1. High Peak to Average Power Ratio (PAPR)
2. Frequency Offset.

IV. Peak-To-Average Power Ratio (PAPR) In OFDM

High PAPR causes saturation in power amplifiers, leading to inter-modulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR. In this work, I have focused on problem of high PAPR and various available methods for its reduction are discussed. I have also briefly discussed OFDM and its advantages and disadvantages as compared to single carrier modulation technique.

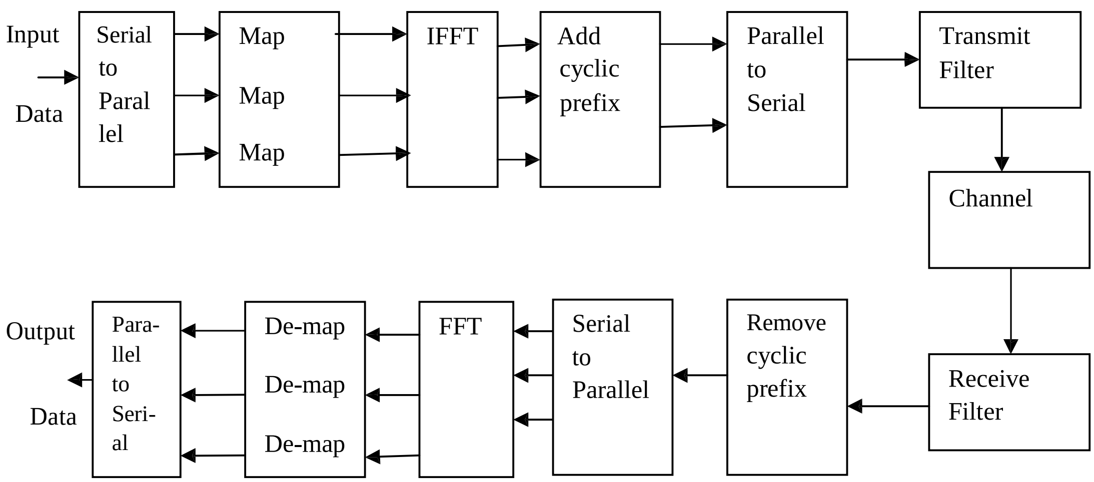

Figure - An OFDM System

Orthogonal Frequency Division Multiplexing (OFDM) belongs to the more general class of multicarrier modulation systems and has found its way to the high-speed wireless and mobile communications arena.

OFDM transmitters generate both the carrier and the data signal simultaneously with purely digital circuits residing in the specialized DSP (Digital Signal Processor) microchips. The specific process of digital signal generation used in OFDM is based on the series of mathematical computations known as an Inverse Fourier Transform, and the process results in the formation of a complex modulated waveform at the output of the transmitter. The incoming serial data is first converted from serial to parallel and grouped into x bits each to form a complex number. The complex numbers are modulated in a base band fashion by the IFFT and converted back to serial data for transmission. A guard interval is inserted between symbols to avoid inter-symbol interference (ISI) caused by multipath distortion. The discrete symbols are converted to analog and low pass filtered for RF up-conversion. The receiver performs the inverse process of the transmitter. One tap equalizer is used to correct channel distortion. The tap coefficients of the filter are calculated based on channel information

V. Expression Of Peak To Average Power Ratio

The most popular quantification metric of envelope variation is the peak-to-average ratio (PAPR). Rightfully so, as PAPR captures the most important aspect of a signal that has to pass through a peak-power limited device: the peak power.

PAPR is alternately referred to as the peak-to-average power ratio and PMEPR (peak to mean envelope power ratio). PAPR is also directly related to the crest factor (CF) of a signal where $CF = \sqrt{PAR}$

The PAR of an OFDM signal can be defined as,

$$PAPR = \frac{\text{Peak Power of the Signal}}{\text{Average Power of the Signal}}$$

$$PAPR = \frac{max|x|^2}{E[|x|^2]}$$

Where x be any signal representation (critically sampled baseband, oversampled baseband, continuous-time pass-band, etc.) defined over one symbol period.

Because the denominator of above equation is an expected value and, strictly speaking, not an “average”, it is true that the term PAPR is a bit of a misnomer. Despite this slight technical inaccuracy, PAPR is the most widely used term and we will keep with convention here. Also, note that the ensemble average power and the expectation in the denominator of above equation only differ for non-constant modulus constellations.

VI. Result

1. GENERATION OF DM SIGNAL

All carriers are orthogonal to each other, which means when one particular subcarrier is at its peak other are at zero as shown in the figure. Figure 1 shows OFDM signal for 4 subcarriers. All four carriers are orthogonal to each other that means when one particular subcarrier is at its peak other are at zero as shown in the figure.

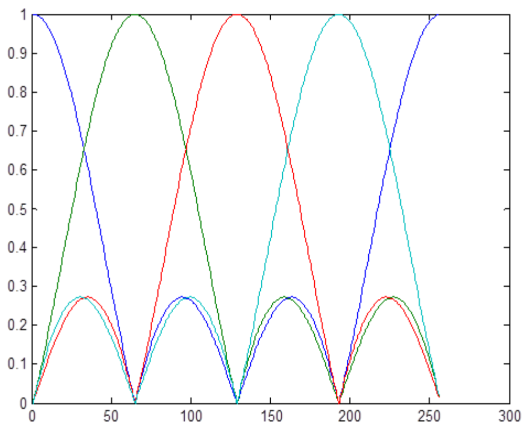

Fig – 1 OFDM signal

2. CCDF OF PAPR OF OFDM

A. For N=16

The CCDF of PAPR of OFDM for N=16 is as shown in figure 2. The horizontal and vertical axes represent the threshold for the PAPR and the probability that the PAPR of a data block exceeds the threshold, respectively.

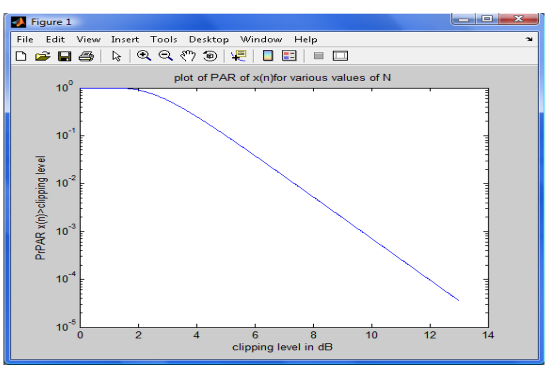

Fig-2 CCDF of PAPR of OFDM for N=16

B. For Various Values of N

The CCDF Of PAPR Of OFDM For N =16:

The CCDFs are usually compared in a graph such as Figure 3, which shows the CCDFs of the PAPR of an OFDM signal with 16,128,256 and 1024 subcarriers (*N* =16,128, 256,1024) for quaternary phase shift keying (QPSK) modulation. The horizontal and vertical axes represent the threshold for the PAPR and the probability that the PAPR of a data block exceeds the threshold, respectively.

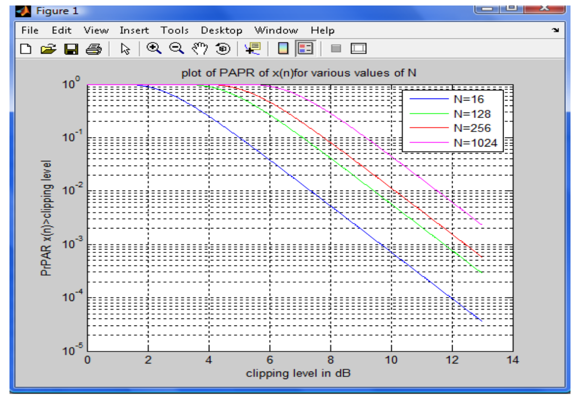

Fig -3 CCDF of PAPR of OFDM for Various N

It is shown that the unmodified OFDM signal has a PAPR that exceeds 10 dB for less than 1 percent of the data blocks for *N* = 256. OFDM signal has a PAPR that exceeds 12 dB for less than 0.1 percent of the data blocks for *N* = 1024

C. Comparison of CCDF of PAPR of Unmodified OFDM and OFDM with PTS Technique

The figure 4 shows that when is used as a PAPR reduction technique, the 0.1 percent PAPR reduce to 8.8 dB, resulting in 1.8 dB reductions. Speaking roughly, the closer the CCDF curve is to the vertical axis, the better its PAPR characteristic.

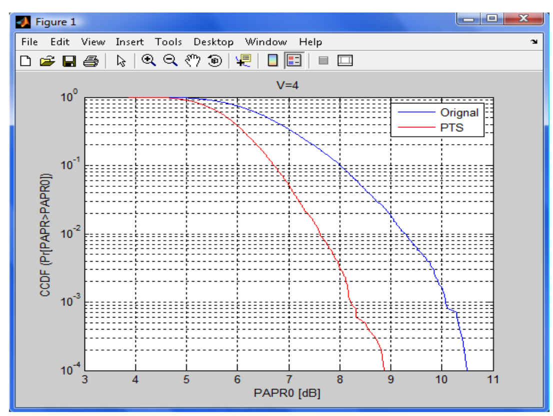

Fig – 4 Comparison of CCDF of PAPR of Unmodified OFDM and OFDM with PTS

D. PTS For 36 Phase Sequences

Figure 5 shows the Comparison of CCDF of PAPR of unmodified OFDM and OFDM with PTS technique with 36 phase sequences. The figure shows that when is used as a PAPR reduction technique, the 0.1 percent PAPR reduce to 7.6 dB, resulting in 2.8 dB reductions.

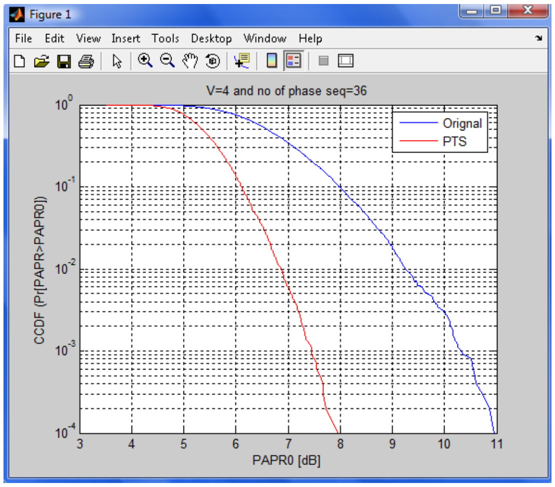

Fig – 5 Comparison of CCDF of PAPR of Unmodified OFDM and OFDM with PTS for 36 Phase Sequences

E. PTS With Variable V

Now I try to show that the PAPR reduction process can be made more efficient by increasing the number of phase sequences and the number of sub blocks, although there may be a little bit increment of calculation complexity. Figure 6 shows the Comparison of CCDF of PAPR of unmodified OFDM and OFDM with PTS technique with variable V. The figure shows that when is used as a PAPR reduction technique, the 0.1 percent PAPR reduce to 8.6 dB and 7.5 dB, resulting in 1.5 dB and 2.6 dB reductions for V=4 and V=8 respectively.

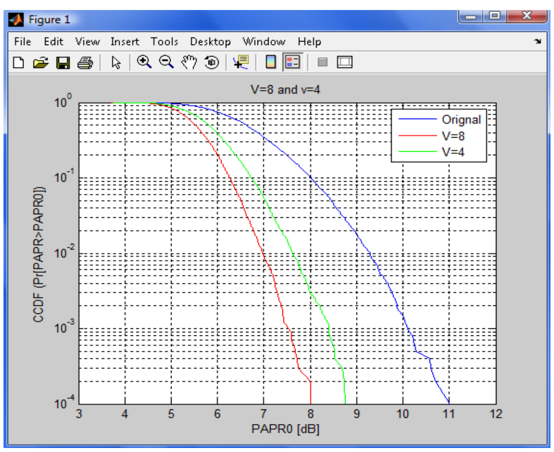

Fig – 6 Comparison of CCDF of PAPR of Unmodified OFDM and OFDM with PTS for Variable V

These results shows that the PAPR reduction process can be made more efficient by increasing the number of phase sequences and the number of sub blocks, although there may be a little bit increment of calculation complexity. Following figure shows the comparison of PAPR for original unmodified OFDM signal and by using PTS technique for different phase sequences and variation in number of sub blocks.

VII. Conclusion

In this paper, we considered partial transmit sequence (PTS) in OFDM systems. In PTS, the receiver must know which vector had actually been used at transmitter to recover the data at receiver correctly. Therefore, the phase factors must be transmitted as side information, resulting in some loss of band efficiency. However to reduce the inter-modulation distortion in high power amplifiers or active devices reduction in PAPR is unavoidable.

The PAPR reduction with the PTS technique is about 1.8 dB for 0.01 % of input symbols. This reduction in PAPR with PTS can be increased by increasing the number of phase sequences and the size of input data block. The simulation results show that PAPR is reduced to 2.8 dB for 0.01 % of input symbols for increasing the number of phase sequences from 16 to 36. Also, PAPR is reduced to 2.7 dB for 0.01 % of input symbols for increasing the size of input data block from 4 to 8. But the cost paid for this reduction in PAPR is increase in calculation complexity.

S. No	*'PAPR0 [dB]*	*'CCDF (Pr[PAPR>PAPR0]) of Original*	*CCDF (Pr[PAPR>PAPR0]) of PTS for 16 Phase Sequences*	*CCDF (Pr[PAPR>PAPR0]) of PTS for 36 Phase Sequences*	*CCDF (Pr[PAPR>PAPR0]) of PTS with Variable V=8*
1.	*4*	*1*	*1*	*1*	*1*
2.	*6*	*0.8*	*0.3*	*0.7*	*0.1*
3.	*8*	*0.1*	*0.02*	*0.0004*	*0.0007*
4.	*8.2*	*0.09*	*0.016*	*0*	*0*
5.	*9.3*	*0.08*	*0*	*0*	*0*
6.	*11*	*0*	*0*	*0*	*0*

Table 1 : Comparison PAPR

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