Development of Matrix Exponentiation Based PAPR Reduction Algorithm in OFDM System

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Abstract - Transmission of signals for communication is not possible without power and wireless communication is possible just because of microwave/radio power. Signal carrying information usually transmitted on different powers as per their applications like GSM, WLAN, Wi-MAX, 3G, 4G and now 5G. Due to various operators such communication scenarios create various interference points and create peak power of the signals and reduce average power, which causes to increase PAPR. Peak to Average Power Ratio is the parameter to analyze the power ratio. Various algorithms have been developed to reduce the PAPR and achieved significant level. In this work a matrix exponential based scheme is used to suppress the peak power of the signals and conclude to maintain average power hence reduces PAPR. From the simulation results it concludes that the proposed matrix exponential based solution is performing better than previous algorithm.

Keywords - matrix exponential suppression, PAPR, OFDM, m-array QAM.

I. INTRODUCTION

Wireless communications is one of the fastest growing segments of the communications industry. As such, it has captured the attention of the media and the imagination of the public. Wireless communication mainly categorized for media (voice and video), and data. Under media, cellular systems have experienced exponential growth over the last decade and there are currently about two billion users worldwide. Indeed, cellular phones have become a critical business tool and part of everyday life in most developed countries, and they are rapidly supplanting antiquated wire line systems in many developing countries. For data applications, wireless local area networks currently supplement or replace wired networks in many homes, businesses, and campuses. Many new applications – including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine – are emerging from research ideas to concrete systems. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers suggests a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure.

However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. The gap between current and emerging systems and the vision for future wireless applications indicates that much work remains to be done to make this vision a reality.

Multi-carrier modulation (MCM) has recently gained fair degree of prominence among modulation schemes due to its intrinsic robustness in frequency selective fading channels. This is one of the main reason to select MCM a candidate for systems such as Digital Audio and Video Broadcasting (DAB and DVB), Digital Subscriber Lines (DSL), and Wireless local area networks (WLAN), metropolitan area networks (MAN), personal area networks (PAN), home networking, and even beyond 3G wide area networks (WAN). Orthogonal Frequency Division Multiplexing (OFDM), a multi-carrier transmission technique that is widely adopted in different communication applications. OFDM systems support high data rate transmission.

However, OFDM systems have the undesirable feature of a large peak to average power ratio (PAPR) of the transmitted signals. The transmitted signal has a non-constant envelope and exhibits peaks whose power strongly exceeds the mean power. Consequently, to prevent distortion of the OFDM signal, the transmit amplifier must operate in its linear regions. Therefore, power amplifiers with a large dynamic range are required for OFDM systems. Reducing the PAPR is pivotal to reducing the cost of OFDM systems.

In this work, main focus is given for the multi-carrier modulations along with PAPR suppression method. This is one of the useful solutions in building the wireless or other LAN based systems with better operating conditions bit error rate. This work reported a development simulation of matrix exponential based PAPR reduction algorithm in OFDM system in MATLAB simulation environment. Performance of proposed algorithm is examined based on CCDF and PAPR.

II. PEAK TO AVERAGE POWER RATIO

High PAPR is an important issue in communication system which reduces the efficiency of power amplifier used in the circuit. PAPR problem in any MCM system arises because of the fact that the output symbol of MCM system is the summation of symbols modulated on different subcarriers and there is a probability that all symbols have same phase which leads to a very high peak compared to the average value of the symbol. PAPR of an FBMC system is defined as the ratio of peak power to the average power[7].

In general, the PAPR of a complex envelope d[n] with length N can be written as

$$PAPR = \left(\frac{\max\{|d[n]|^2\}}{\mathrm{E}\{|d[n]|^2\}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where d[n] is amplitude of d[n] and E denote the expectation of the signal. PAPR in dB can be written as:

PAPR(dB) = 10log10(PAPR)

Effect of High PAPR

The linear power amplifiers are used in the transmitter side of any communication system. For linear power amplifier the operating point should be in the linear region of operation. Because of the high PAPR the operating point moves to the saturation region hence[8], the clipping of signal peaks occurs which generates in-band and out-of-band distortion. So we should increase the dynamic range of the power amplifier to keep the operating point in the linear region which reduces efficiency and enhances the cost of the power amplifier. Hence, a trade-off exists between nonlinearity and efficiency. So we should reduce PAPR value to improve the efficiency of the power amplifier.

PAPR Reduction Techniques

There are so many techniques presents for the reduction of PAPR. Some of the important PAPR reduction techniques are illustrated below:

1. Clipping and Filtering

This is one of the simplest technique used for PAPR reduction. Clipping is a technique in which the amplitude of the input signal is limited to a predetermined value[9].

- Clipping causes signal distortion, which results in degradation of Bit Error Rate performance.
- Out-of-band radiation also occurs in clipping, which is responsible for interference between adjacent channels. Filtering can be used to reduce this out-of-band radiation.
- Filtering of the clipped signal brings the peak regrowth. That means the signal level may exceed the clipping level after filtering operation because of the clipping operation.

2. Coding

In the coding technique, some code words are used to minimize or reduce the PAPR of the signal. It does not cause any distortion and also no out-of-band radiation produces, but it has a drawback of reduced bandwidth efficiency as the data rate is reduced.

3. Partial Transmit Sequence

In the Partial Transmit Sequence (PTS) technique [11], an input data block of N symbols is partitioned into disjoint sub-blocks. A phase factor weights the sub-carriers in each sub-block for that sub-block. The phase factors are selected in such a way that the PAPR of the combined signal is reduced.

4. Selected Mapping (SLM)

In the SLM technique, a number of alternative FBMC signals are generated from the input data block and one with minimum PAPR is chosen for transmission. Complexity and data rate loss are two drawbacks of this technique.

5. Tone Reservation

Tone reservation and tone injection are two efficient PAPR reduction techniques. In these techniques, a data block dependent time domain signal is appended to the original signal in such a way that peaks of the original signal will reduce. [14]This time domain signal can be easily computed at the transmitter side and can be easily removed at the receiver side.

6. Tone Injection

The basic idea in TI technique is to increase the constellation size so that each of the points in the original basic constellation can be mapped into several equivalent points in the expanded constellation[15]. Here equivalent constellation points are added in original constellation point in a way that PAPR will reduce. These time domain signals for PAPR reduction is calculated for the sub-carrier which gives minimum PAPR. In this technique no data rate loss or distortion occurs but power increase in this technique.

7. Active Constellation Extension (ACE)

ACE technique is similar to Tone Injection technique. According to this technique [12], some of the outer signal constellation points in the data block are dynamically extended towards the outside of the original constellation such that PAPR of the data block is reduced. In this method also power increase of transmitted signal takes place.

8. Companding

In Companding technique, we enlarge the small signals while compressing the large signals so that the immunity of small signals from noise will increase[13]. This compression is carried out at the transmitter end after the output is taken from IFFT block. There are two types of companders: µ-law and A-law companders. Compression of the signal reduces high peaks, so in this way PAPR reduction of input signal take place. This is a simple and low complexity method for PAPR reduction.

III. PROPOSED METHODOLOGY

Development of matrix exponential based PAPR reduction algorithm in OFDM System has carried out in this examination. Fig. 3.1 shows the block representation of proposed algorithm in MATLAB. In communication, modulation is the method of changing a regular waveform so that a high frequency waveform is used as a carrier signal to transmit a message. A sine wave's three main parameters are frequency, amplitude and phase, all of which can be altered to achieve a modulated signal according to a low frequency information signal.

OFDM is a digital carrier modulation approach used in the proposed examination using a big amount of orthogonal subcarriers that are tightly spaced. Each sub carrier is modulated with a traditional modulation approach at small symbol rates; it conspires in a comparable bandwidth to maintain information rates like standard single carrier modulation.

The objective of digital modulation is to transfer a digital bit stream over a channel or radio frequency band passing an analog band. Changes are selected from a finite amount of alternative symbols in the carrier signal. QAM is the most important system of digital modulation. In QAM, the modulation letters in order is helpfully represented on a constellation diagram, demonstrating the amplitude of inphase (I) segment on x-pivot and the amplitude of Quadrature (Q) part on y-hub, for every symbol. 'I' and 'Q' signals can be joined into a complex esteemed signal called the comparable baseband signal. This is a representation of the value modulated physical signal.

As shows in Fig. 3.1 there are three fundamental blocks are there in proposed methodology which is implemented and simulated in MATLAB. The input data is first modulated using QAM modulation scheme and a Matrix exponential algorithm is applied on it to suppress PAPR and again modulated with IDFT OFDM modulation scheme. At the receiver end a PAPR suppressed signal is arrived functionality of each block in Fig. 3.1 is briefed as follows

a. Quadrature Amplitude Modulation (QAM)

M-array QAM or QAM is a modulation approach. For higher data rates, PSK has restrictions. QAM gives the higher throughput rate required for data transfers by combining ASK and PSK. Two unique signals are sent at the same time on a similar carrier frequency. The result of this combination provides two variable (amplitude and phase of the signal) to assign binary values. As the number of states is increasing, greater throughput is achieved.

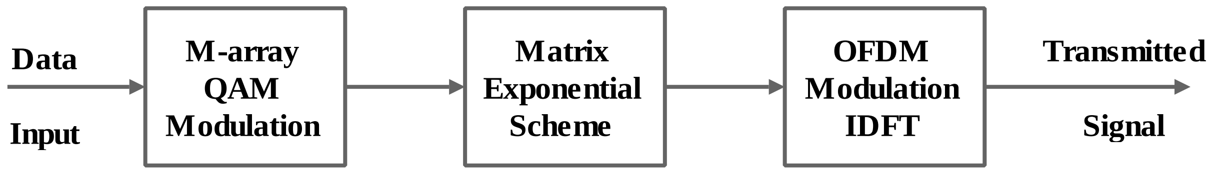

Fig.3.1 Block representation of proposed approach

b. Matrix Exponential Algorithm

In However, this algorithm requires that each transmitter understand an estimate of the local utility gradient matrix. The understanding of the gradient matrix in the transmitters entails a high overhead signaling, particularly that the matrix size rises with the action matrix dimension. Each receiver sends portion of the gradient matrix components with regard to a certain probability at each iteration and each receiver feeds the entire gradient matrix "sporadically." This is a very efficient strategy to eliminating PAPR.

c. OFDM Modulation/IDFFT

The portion of the transmitter transforms digital data for transmission into a mapping of the amplitude and phase of the subcarrier. It then uses an Inverse Discrete Fourier Transform (IDFT) to transform this spectral representation of the information into the time domain. The Inverse Fast Fourier Transform (IFFT) conducts the same activities as an IDFT, except it is much more efficient in computational terms and is used in all practical processes. IDFT as a linear transformation can be readily introduced to the scheme and DFT can be used at the receiver end to recover the initial information in the receiver's frequency domain. Since Fourier transform is based on orthogonal parameters, the time domain of the OFDM signal can be obtained from its frequency parts.

Fig. 3.2 shows the process flow of proposed approach in MATLAB the steps of simulation of proposed algorithm in MATALB are as follows

Step:1 Start simulation in MATLAB

Step:2 Define simulation environment variables

Step:3 Generate data for system analysis

Step:4 Modulate with M-array QAM

Step:5 Apply matrix exponential scheme for peak suppression

Step:6 Apply OFDM modulation

Step:7 Calculate different powers , PAPR, CCDF

Step:8 Compare and display results

Step:9 End process in MATLAB

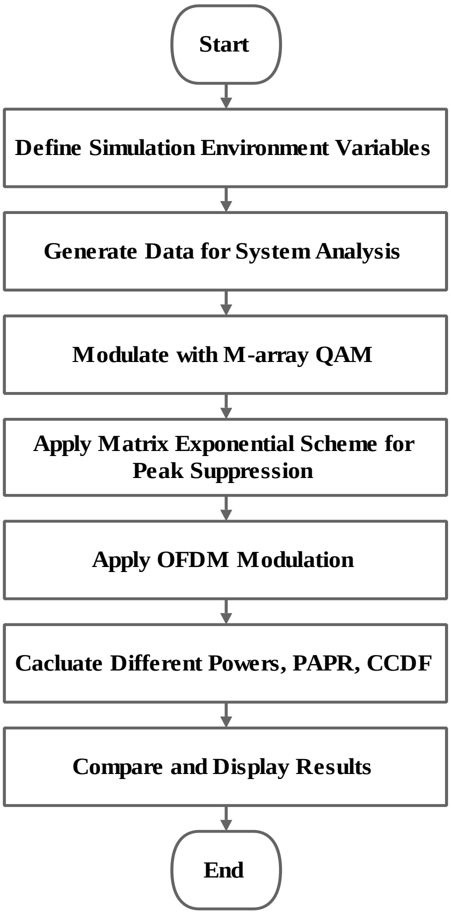

Fig.3.2 Process Flow of Proposed approach in MATLAB

IV. SIMULATION AND RESULTS ANALYSIS

An OFDM signal is made up of a number of separately modulated sub-carriers that can deliver a big PAPR when consistently added up. They generate a maximum strength that is N times the average signal power when N signals are added with the same stage. OFDM has a very big PAPR, which is very susceptible to the non-linearity of the high-performance amplifier. To overcome this examination introduced an effective approach to eliminate PAPR. To verify the performance of proposed approach a MATLAB based simulation and results analysis is carried out. The performance of proposed algorithm is examined based on PAPR analysis using CCDF.

Analysis of PAPR using CCDF

If Z is a random variable, the z Cumulative Distribution Function (CDF) is defined as the { zz } event probability. The Complementary Cumulative Distribution Function is therefore defined as the { Z > z } event probability. The complementary feature of cumulative density (CCDF) is the probability that PAPR will exceed some limit. The PAPR efficiency of the PAPR decrease method is measured using the CCDF plot. Let's consider x as the signal transmitted, then PAPR's theoretical CCDF implies the probability of the case $\{PAPR\{x\} > PAPR_0\}$ is given as

$$Pr\ (PAPR\{x\} > PAPR_0) = 1 - (1 - e^{-PAPR_0})^N \ \ldots..(2)$$

Where N is the subcarrier number. However, the PAPR may not be the same as for the continuous-time baseband signal x (t) for the discrete-time baseband signal x[n].

The PAPR for the continuous-time signal can be evaluated in practice only after the real hardware has been implemented. The PAPR can therefore be estimated in some way from the x[n] discrete-time signal. It is realized that x[n] can display virtually the same PAPR as x (t) when it is interpolated (over-sampled) U times.. Where U ≥ 4 [1]. The estimated value of the CCDF is provided for the over-sampled signal as

$$Pr\ (PAPR\{x\} > PAPR_0) = 1 - (1 - e^{-PAPR_0})^{\alpha N} \ldots(3)$$

Where α has to be determined by the actual fitting of the theoretical CCDF.

Fig. 4.1 PAPR vs CCDF Performance with oversampling factor 2 shows the complementary cumulative distribution function of the oversampled signal. In this case the modulation used is QAM. It is seen from the graph that proposed algorithm significantly reduces the PAPR and the performance.

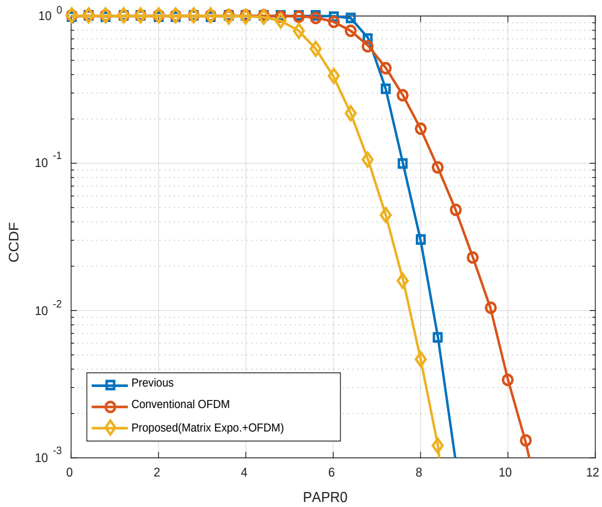

Fig.4.1 PAPR vs CCDF Performance with oversampling factor 2

Fig.4.2 PAPR vs CCDF Performance with oversampling factor 4 shows the complementary cumulative distribution function of the oversampled signal. In this case the modulation used is QAM. It is seen from the graph that proposed algorithm significantly reduces the PAPR and the performance.

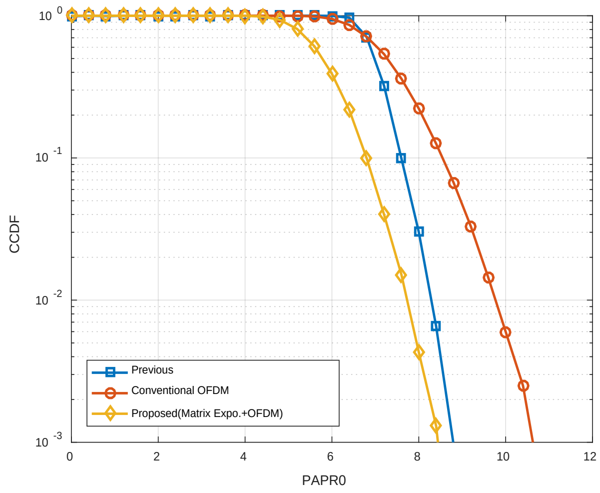

Fig.4.2 PAPR vs CCDF Performance with oversampling factor 4

Fig.4.3 PAPR vs CCDF Performance with oversampling factor 8 shows the complementary cumulative distribution function of the oversampled signal. In this case the modulation used is QAM. It is seen from the graph that proposed algorithm significantly reduces the PAPR and the performance.

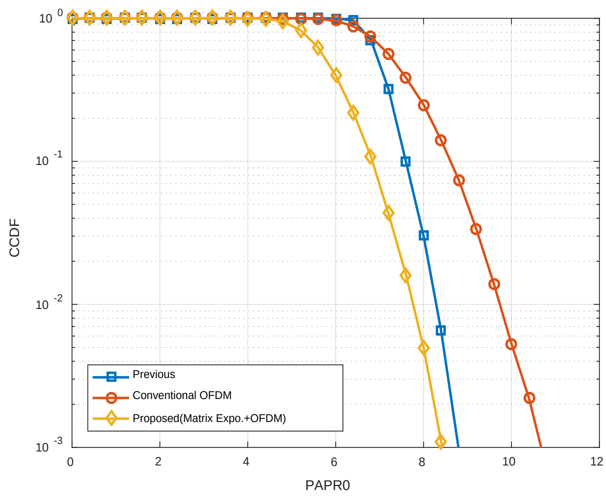

Fig.4.3 PAPR vs CCDF Performance with oversampling factor 8

V. CONCLUSION

OFDM is a highly appealing multi-carrier transmission method and has become one of the standard high-speed data transmission options across a communication channel. It has different benefits; but it also has one significant drawback: it has a very elevated PAPR. This examination presents introduction to orthogonal frequency division multiplexing technology with its application, advantages and limitations. Also the OFDM system simulation model and the PAPR performance of OFDM have been analyzed. The review of PAPR reduction methods such as clipping and filtering, selected mapping (SLM), partial transmission sequence (PTS) etc. is presented as a whole study job conducted in this examination. Design parameters of proposed matrix exponential based PAPR reduction algorithm in OFDM system which are incorporated in the basic OFDM system are studied and optimized. CCDF of PAPR, performance evaluations are carried out using proposed system. Examination results shows proposed work has better performance as compared to previous one. The following are some pointers for scope of further research.

Proposed technique can be applied for PAPR reduction in MIMO-OFDM, which is the key technology for further 4G applications.

Design of optimal pulse shapes with minimum interference power may be tried to provide further improvement in performance.

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