A Hybrid PAPR Reduction Scheme for OFDM System

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is considered as most efficient technique for future wireless communication systems due to its higher spectral bandwidth efficiency, robustness to frequency selective fading channels, etc. However, the successful implementation of the OFDM system necessitates several difficulties. The biggest disadvantage to work with OFDM system is its high peak-to-average power ratio PAPR leadsto severe inter carrier interference, out-of-band radiation, and poor bit error rate performance due to the nonlinearity of the high power amplifier. In this paper, a novel hybrid technique is proposed to reduce PAPR further and comparison has been done with conventional techniques as well. Simulated results are presentedconfirm theoretical results.MATLAB 7.5 is used to simulate the results for system parametersconsidered.

KEYWORDS

Orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), selected mapping (SLM), partial transmit sequences (PTS), Convolutional encoding, Hamming Codes, RS coding.

1. INTRODUCTION

From past few years, research community has started considering orthogonal frequency division multiplexing (OFDM) as one of the core technologies for various communication systems and therefore it has been adopted as a standard for various wireless communication systems such as wireless LAN, wireless MAN and digital audio/videobroadcasting [1]. It is an efficient technique for achieving high data rate in wireless communication systems and performs better with frequency selective fading channels [2]. Despite its advantages, an OFDM signal experience high peak-to-average power ratio (PAPR) at the transmitter, which causes signal distortion due to the nonlinearity of the high power amplifier (HPA) and causes higher bit error rate (BER) [3]. The large PAPR also increase the complexity of analog-to-digital converter (ADC) and digital-to-analog converter (DAC). Thus, PAPR reduction for OFDM systems has become a topic of research to the academicians and researchers these days.

Many schemes have been proposed by researchers for reducing the PAPR of OFDM signals, which can be broadly put into two categories[4]–[11]. First, the PAPR schemes can be classified as multiplicative or additive schemes, where PAPR reduction is carried out in the OFDM modulator. Selected mapping (SLM) and partial transmit sequence (PTS) are multiplicative schemes because the phase sequences are multiplied with input symbol sequences or OFDM signal sequences [4-6], [8]. whereas, tone reservation (TR) and clipping are additive schemes because the reference signals are added [7], [9], [10]. In a second category, the PAPR schemes can be classified as deterministic and probabilistic scheme. Deterministic schemes includes clipping [11], limit the PAPR of the OFDM signals below a given threshold level. Probabilistic schemes modify the thecharacteristics of the PAPR distribution statistically for OFDM signals

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without signal deformation[12]. SLM and PTS are probabilistic in naturein which multiple signals are generated and the one withthe minimum PAPR is chosen for transmission. The computational complexity of SLM is larger than that of PTS still it outperforms over PTS if the amount of side information is limited.

In this paper, a novel hybrid scheme has been proposed to reduce PAPR value significantly by combining block coding scheme with selected mapping scheme. The simulated results are presented to strengthen the idea of proposed scheme over other conventional scheme of PAPRreduction.

2. OFDM SYSTEM MODEL

Fig. 1 shows the block diagram of typical OFDM system. A block of input bits (called symbols) are modulated using M-arymodulation scheme and then passed to the serial to parallel converter. Depending upon the system requirements different types of data modulator can be used e.g. M-QAM, M-PSK etc.) [45]. The complex parallel data symbols (X_k) obtained by using modulation techniques are given to N point IFFT block as shown in fig. 1.

The baseband transmitted OFDM signal envelope can be written as

$$y(t) = \frac{1}{\sqrt{N}} \sum_{L=0}^{N-1} Y_L \, e^{i2\pi f_L t} \qquad ; 0 \leq t \leq \leq NT \qquad (1)$$

where, N is the total number of subcarriers, Y_L, L= 0,1,2,…., N-1 block of N input bits (symbols), f_L=L f, where Δf=1/ (Nτ), τ=original symbol period.

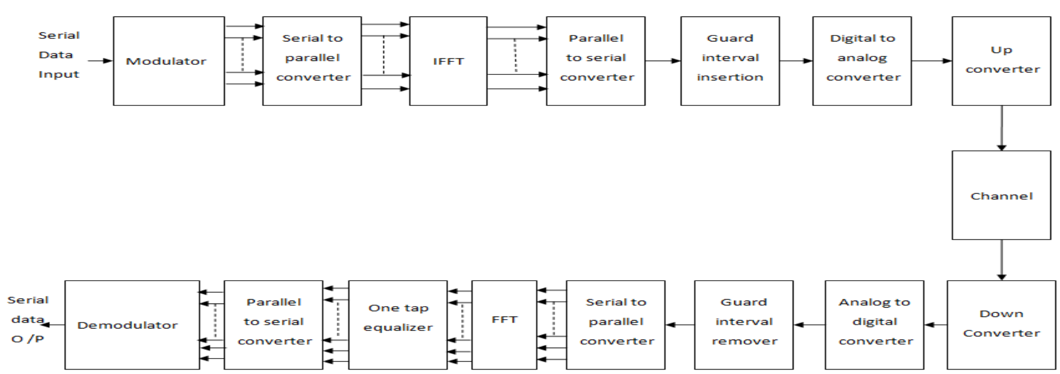

Fig.1: Typical OFDMSystem

$$E[X_k X_l] = \begin{cases} 1 & \forall\, k = l \\ 0 & \forall\, k \neq l \end{cases} \qquad (2)$$

The discrete form of OFDM signal x(n) is given by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}} for n = 0,1,2, \ldots\ldots, N-1 \qquad (3)$$

(3)shows that a signal $x(n)$can be extracted by performing inverse discrete Fourier transform (IDFT) operation on the modulated input bits. Generally, IDFT operation can be performed by using inverse fast Fourier transform (IFFT).

To remove ISI introduced due to delay spread,guard interval is used which is generally interleaved between consecutive OFDM symbols. To remove ISI completely a guard band interval with no signal transmission can be used. However, it may produce ICI due to high frequency components. The guard interval can be introduced in the form of zero padding (ZP) and cyclic extension. Cyclic extension can be extended in two ways-cyclic prefix or cyclic suffix.

On contrary to the transmitter, at receiver side, the guard interval of OFDM symbol is removed and then unguarded OFDM symbol undergoes serial to parallel conversion. After this, FFT operation is performed to converts parallel OFDM data streams into frequency domain. Therefore, the output of FFT block can be expressed as-

$$\mathrm{X(n) = F(n).x(n) + \ w(n)} \forall\ 0 \leq \mathrm{n} \leq \mathrm{N} - 1 \qquad (4)$$

Where, W (n) is the additive white Gaussian noise (AWGN) component in frequency domain and (.) denotes frequency response of the multipath fading channel at the sub channel

$$F(m) = \frac{1}{\sqrt{N}} \sum_{l=0}^{L-1} h_l\, e^{\frac{-i2\pi mn}{N}} \forall\ \mathrm{m} = 0,1, \dots \dots .., N-1 \qquad (5)$$

3. PAPR

The biggest hurdle to implement OFDM system successfully is its high PAPR value of transmitted signal thatseverely degrades the system performance. The PAPR of the continuous time OFDM transmitted signal x (t) may be defined as the ratio of the maximum instantaneous power and the average power of OFDM signal.

$$\mathrm{PAPR} = \frac{\max[\mathrm{Y(t)}]^2}{\mathrm{E}\{|\mathrm{Y(t)}|^2\}} \forall\ 0 \leq \mathrm{t} \leq \mathrm{NT} \qquad (6)$$

Where, E denotes expectation operator and $\mathrm{E}\{|\mathrm{Y(t)}|^2\}$ is average power of Y(t) as well as T is an original symbol period. PAPR mainly occurs due to large dynamic range of OFDM symbol waveforms. High PAPR in OFDM fundamentallytake place because of IFFT pre-processing (i.e. OFDM signal consists of a multiple independently modulated sub-carriers which can give a large peak when added up with same phases). The discrete time baseband OFDM signals are transformed to continuous time baseband OFDM signals by a low-pass filter called DAC, where the peak power can be increased while maintaining a constant average power. Generally, the PAPR of the continuous time baseband OFDM signals is larger than that of the discrete time baseband OFDM signals by 0.5-1.0 dB [13-14].

4. PAPR REDUCTION SCHEME

The numbers of schemes have been developed to reduce the PAPR of OFDM signals. In this section, we overview the conventional PAPR reduction schemes their advantages and disadvantages.

4.1 Clipping

Signal clipping is one of the most commonly used technique to reduce the peak signal to a desired signal level [12], [13]. The output signal of a Hard/soft limiter can be written as

$$\overline{x_n} = \begin{Bmatrix} x_n|x_n| < X_{th} \\ X_{th}e^{j\emptyset(x_n)}|x_n| \geq X_{th} \end{Bmatrix} \quad (7)$$

WhereX_{th} is the clipping level and φ (x_n) represents the phase. Thoughthe scheme guarantees peak reduction but has fewdisadvantages. For example, clipping distort the signal shape that is treated as an interference and results increases in BER. Moreover, spectral efficiency of OFDM system also reduced due to high frequency components regrowth. Various techniques have been proposed by researchers time to time to overcome these shortcomings of the clipping method. For example filtering method is most commonly employed to reduce out-of-band emission but, at same time it cause peak regrowth. [14]–[16]. Peak windowing is another important technique in whichsignal peak value is reduced by multiplying it with a correcting function like Gaussian, Kaiser, and cosinewith original OFDM signal [11], [17].

4.2 Nonlinear Processing

Nonlinear processing of OFDM signal includes companding and decompanding the input signal with an aid of digital to analog converter (DAC) in which signal amplitudes are nonlinearly scaled by suppressing signals with large amplitudes and amplifying signals with smaller amplitudes. At the receiver, the original signal is recovered from the companded signal by a reverse process known as decompanding[18].

4.3 Coding

Recently, coding has evolved as one of the popular scheme to reduce PAPR. The most widely used Golay complementary sequence is an example which ensures that the OFDM signals may not exceed PAPR value equals to 3 dB [19-20]. The advantage of using Golay complementary sequences is not only their small PAPR value but also theirexcellent error correction properties. The main drawback of using these sequences is their significantrate loss during transmission.

4.4 Partial Transmit Sequence (PTS)

As the name suggest, in PTS scheme, signal's high PAPR issue is resolved by dividing the input data block into independent sub blocks which are further processed by converting them into time-domain partial transmit sequences [16]. These partial sequences are thereafter rotated with different phase factorsto combine optimally to obtain OFDM signals with lowest PAPR value. To find optimal phase factors is a cumbersome process and requires high computational complexity to the system. Moreover, it requires side information to be transmitted at receiver side for appropriate decoding and demodulation of the transmitted bit sequence[17].

4.5 Selected Mapping (SLM)

Similar to the PTS scheme, in SLM scheme the input data sequences are multiplied by each of the phase sequences to generate alternative input symbol sequences [18]. IFFT operation is performed on each of these alternative input data sequences and then the sequence with the lowest PAPR is transmitted. For the successful implementation of SLM OFDM systems, the SLM technique multiple IFFT operations and side information for each data block[19].

4.6 Tone Rejection (TR)& Tone Injection (TI)

Both, tone rejection (TR) and tone injection (TI) schemes work on the same principle of keeping a subset of tones reserve at the transmitter and receiver side to generating PAPR reduction signals. In TR, the time domain signal is identified to add to the original time domain signal to reduce the PAPR. Similarly, in TI scheme the constellation size is extended by replacing same data point with multiple possible constellation points by duplicating the original constellation into various alternative ones [21- 22].

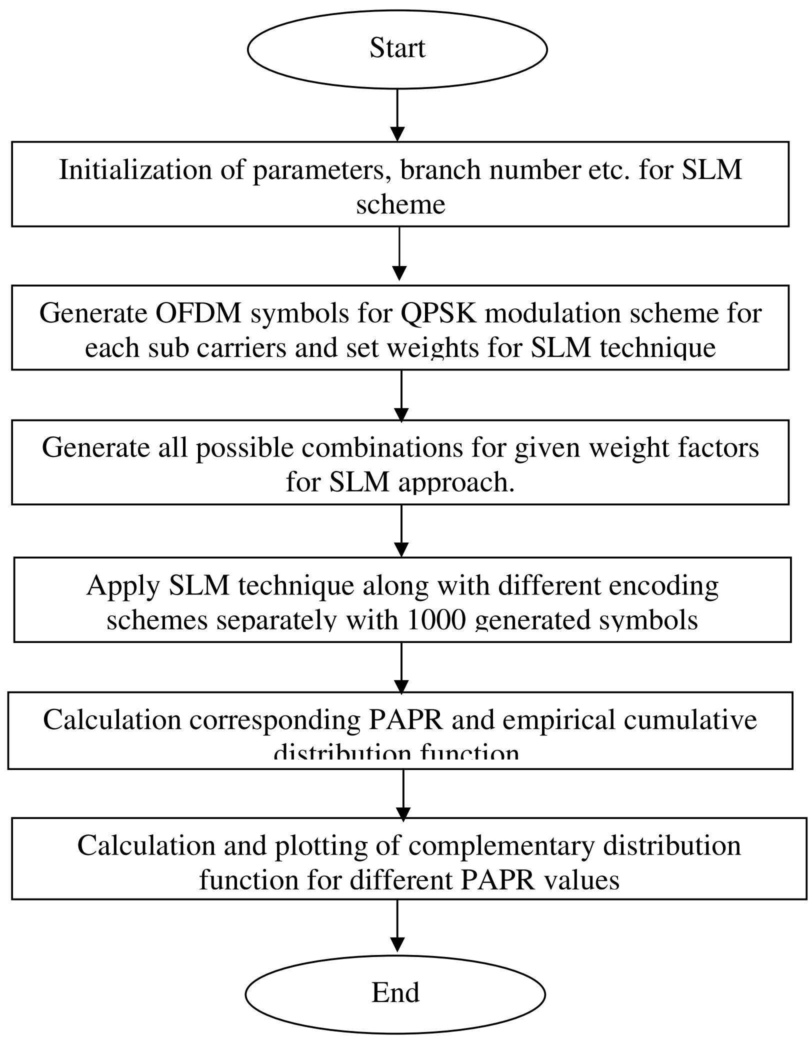

Fig.2: Flow Diagram of Proposed Scheme

The TI technique is more challenging than the TR technique since the injected signal occupies the frequency band as the information bearing signals. Moreover, the alternative constellation points in TI technique possess increased energy which results increase in the implementation complexity for the computation the optimal translation vector [23].

5. PROPOSED SCHEME

Many techniques have been proposed by the researchers time to time to overcome PAPR problem associated with OFDM systems. For examples, novel coding schemes, SLM, PTS schemes etc. In this thesis, a hybrid scheme has been proposed by combining SLM technique and different encoding schemes together to reduce PAPR value. The idea is to find the best encoding scheme that helps in reducing PAPR significantly when combined with SLM approach. To so, the encoding schemes taken into consideration are Convolution Encoding, Hamming Encoding and Reed Solomon Encoding. Fig. 2 is shows the flow diagram of proposed Technique.

6.RESULTS & DISCUSSIONS

In this paper, a novel hybrid technique is proposed to overcome the PAPR of OFDM system. The performance evaluation of the proposed schemes has been done through MATLAB simulations for parameters enlisted in table 1. The PAPR reduction performance of the proposed technique is evaluated in terms of Complementary Cumulative Distribution Function (CCDF) which may be defined as the probability that the PAPR of a block is larger than a certain level.

Table 1: Parameters for the Proposed Scheme

S. No.	PARAMETER	NOTATION	VALUE
1	Number of sub carriers	N	16
2	Over sampling factors	Z	8
3	Modulation Scheme	-	QPSK, QAM
4	No. of sub blocks	Ψ	4 to 6
5	Total no. of IFFT combinations	X	16,256
6	Total no. of OFDM signal generated	Ξ	1000
7	SNR 16 dB QAM	P	15 Db
8	SNR 16 dB QPSK	Λ	20 dB
9	Clipping Ratio	Θ	4 dB

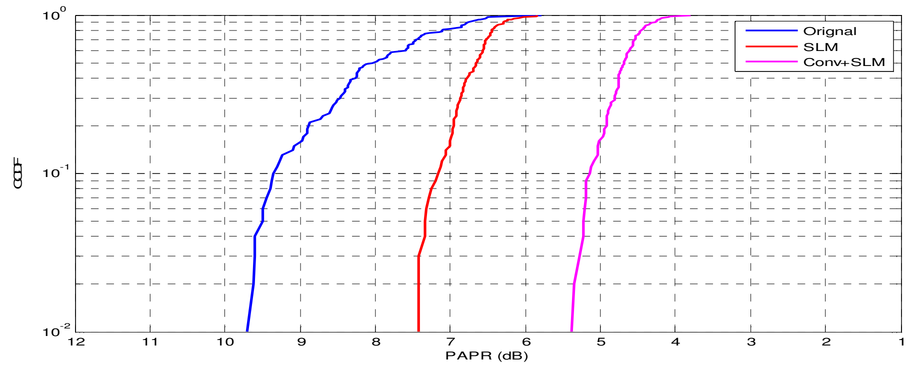

Figure 2: Impact of Convolution Encoding on PAPR

The comparison of CCDFs with respect to the PAPR distribution for original OFDM scheme without any PAPR reduction scheme is done with SLM technique and proposed hybrid (EncodedSLM) scheme. The modulation type considered here is QPSK for N=16. It has been observed that original PAPR for OFDM is very high. For example with CCDF equals to 10^{-2}, the PAPR values standard OFDM is 10.2 dB. The value of PAPR reduces significantly i.e. to 6.9 dB with proposed scheme when compared for the same value of CCDF by employing SLM technique. As expected, for the proposed hybrid scheme, the PAPR reduces further to 5.2 dB for CCDF equals to 5.2 dB.

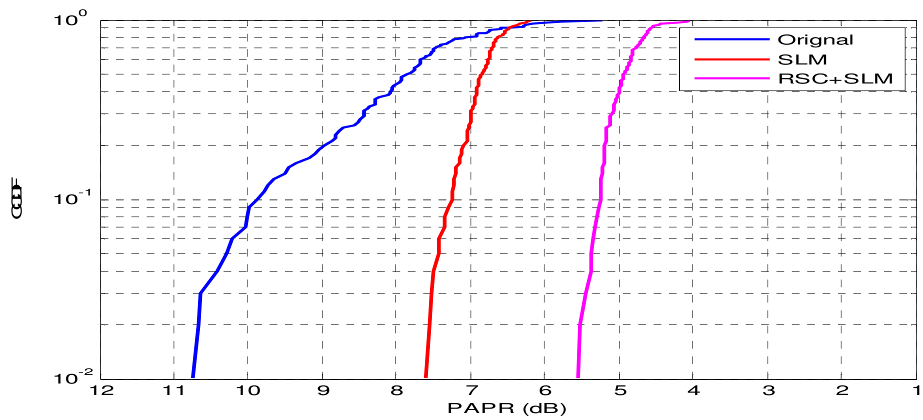

Figure 3: Impact of Reed Solomon Encoding on PAPR

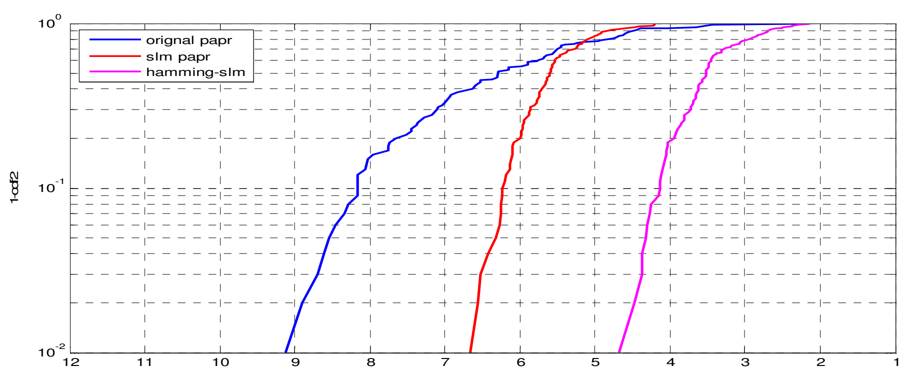

Figure 4: Impact of Hamming Encoding on PAPR

For parameters given in table 1 for OFDM system, the impact of Reed Solomon codes along with SLM technique is observed in fig. 3. The CCDF graph shows that SLM technique helps in reducing PAPR significantly. In proposed hybrid technique, Reed Solomon code is applied along with SLM technique, PAPR can be reduced further up to 2 dB and therefore improve the OFDM system performance further.

Fig. 5: Comparison of different encoding schemes for SLM based OFDM with N= 16

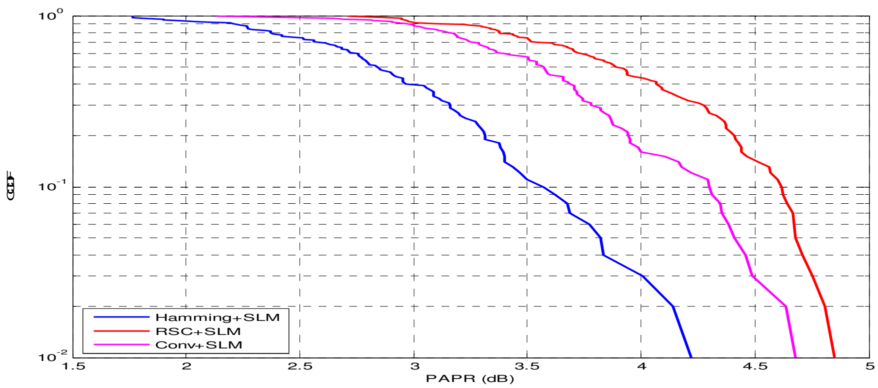

Fig. 6: Comparison of different encoding schemes for SLM based OFDM with N= 64

Figure 4shows the result PAPR analysis of Hamming Encoded OFDM. The results are compared for standard PAPR with SLM based PAPR reduction and with Hamming Encoded OFDM. The modulation type is QPSK and it is taken for N=16. It can be observed that at CCDF equals to 10^{-2}, PAPR values of standard OFDM filter is approximately 9.3 dB and for SLMbased PAPR, it is about 6.4. For Hamming encoded SLM OFDM it can be reduced further to 4.6.

The comparison of all three encoding schemes for encoded SLM based OFDM system is given in fig. 5. The modulation scheme is QPSK and N=16. It could be observed that with proposed hybrid scheme hamming encoding perform well in comparison with rest schemes. For example, at CCDF equals to 10^{-2} for Reed Solomon codes PAPR equals to 5.4 dB, for Convolutional encoding it is equals to 4.9 dB and for Hamming encoding it reduces to 4.4 dB. The impact of number of sub carriers could also be observed for the proposed scheme and is given in fig. 6. The curve becomes bit smoother in comparison with fig. 5 because more number of sub carriers and therefore symbols that have been generated.

5. Conclusion

In this paper, PAPR problem of OFDM system is addressed. Many PAPR reduction techniques have been overviewed and a hybrid scheme for reducing PAPR further is proposed by combining SLM approach with different encoding schemes. The different encoding schemes considered in this work are Convolutional Encoding, Reed Solomon Encoding and Hamming Encoding for QPSK modulation scheme. The simulated results are showing that proposed idea of combining encoding schemes along with SLM technique performs well and helps in reducing PAPR value significantly. The comparative analysis amongst three encoding schemes is done and it has been observed that hamming encoding scheme performs extremely well when combined with SLM approach to reduce PAPR significantly. Approximately 2dB improvement has been observed for proposed scheme for individual encoding scheme and a comparative analysis has also been given amongst encoding schemes.

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