PAPR Reduction using SLM and Companding Technique

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ABSTRACT
Orthogonal frequency division multiplexing (OFDM) is an modulation and multiplexing technique preferred in present wireless environment. One of the issues to be addressed in OFDM is high peak to average power ratio (PAPR) of the received signal which may cause power amplifiers at receivers to go into saturation. In this paper a selective mapping technique (SLM) associated with Reed Solomon (RS) code and µ law Companding is proposed to reduce PAPR in OFDM system. The simulation results shown with CCDF graphs indicate improved performance in PAPR with RS coding and companding as compared to conventional method. Further the advantage gained with using Reed Solomon (RS) coding is good error correcting capability in multipath environment.

Keywords
PAPR Reduction; RS Coding; Companding Transform; CCDF.

1. INTRODUCTION
In modern communication systems need for bandwidth and high data rates is increasing, which requires efficient modulation and multiplexing techniques for better performance The Multicarrier data transmission, orthogonal frequency-division multiplexing (OFDM) is in use in present day's wireless applications [3] to meet this demand. In OFDM, the number of symbols is chosen to ensure that each sub-channel has a bandwidth less than the channel coherence bandwidth. As bandwidth of subcarriers are small, variation of channel frequency response over theses bandwidth becomes significantly flat and equalization required will be simple [1][2].

An OFDM signal consists of number of independently modulated subcarriers which form a composite signal with large peak to average power ratio (PAPR) [2]. This high peaks leads to an increased complexity in analog to digital (A/D) and digital to analog (D/A) conversion process and in addition reduces the efficiency of RF power amplifier at the receiver. Various methods to reduce the PAPR such as clipping, selective mapping, tone injection, active constellation extension, windowing, channel coding [1,3] has been suggested. Further use of BCH coding technique to reduce PAPR is proposed in [1]. Use of coding technique provides error correction in addition to reduction in PAPR. This motivates to use RS coding schemes for performance improvement of OFDM system in terms of error correction and PAPR reduction. In this paper selective mapping method with RS encoding and µ law companding has been proposed. Selective mapping method (SLM) , chooses the signal with lowest PAPR from a set of signals that contain the same information bits with different redundant bits added to them at the transmitter. At the receiving end, these redundant bits are removed while recovering the original information bits. The advantage of this technique is , no loss of data, no distortion associated. In addition, there is flexibility in selection of modulation scheme and number of subcarriers to be used.

Simulation results shows that the proposed scheme has improved performance in PAPR reduction than OFDM without coding and companding.

2. PEAK TO AVERAGE POWER RATIO
OFDM signal is the sum of many independent sub-carriers of equal bandwidth. The continuous time signal x (t)

$$x(t) = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} X_m \exp\left(\frac{j2\pi mt}{Ts}\right) \quad ,0 \le t \le Ts \quad [1]$$

Where T_S is the symbol period and X_m is the symbol on m^{th} subcarrier.

PAPR of transmitted signal x (t) is given by

$$PAPR = \frac{\max|x(t)|^2}{\frac{\int_0^{TS} |x(t)|^2}{T_S} dt} \quad [2]$$

Complementary cumulative distribution function (CCDF) indicates the probability of given data block that exceeds a given threshold of PAP Ratio.

$$P\,(PAPR \le Z) = F\,(Z)^N = (1 - \exp(-z))\,N \quad [3]$$

3. RS CODE
Reed-Solomon codes are non-binary cyclic codes with symbols made up of m bit sequences, where m is an any positive integer having a value greater than two.

RS (*n* , *k*) codes on m bit symbols exist for all n and k for which $0 < k < n < 2^{m+2}$ where *k* is the number of data symbols being encoded, and *n* is the total number of code symbols in the encoded block.

For the most conventional RS (n, k) code,

$$(n, k) = (2^m - 1, 2^m - 1 - 2t) \quad [4]$$

Where t is the symbol-error correcting capability of the code, and n - k = 2t is the number of parity symbols. An extended RS code can be made up with $n = 2^m$ or $n = 2^m + 1$. Reed-Solomon codes achieve the largest possible code minimum distance with the same encoder input and output block lengths. In addition it provides good burst error correcting capability. It is possible to code and interleave data up to 4 code words and are suitable when a code length is less than the size of the field.

The RS code is capable of correcting any combination of t or fewer errors, where t can be expressed as

$$t = \frac{d\min - 1}{2} \quad [5]$$

4. PROPOSED TECHNIQUE

The block diagram of proposed scheme is shown in **Figure 1** and **Figure 2.** At the transmitter, random bits are generated and scrambled into a group of 45 bits. U different and statistically independent sequences of same data are generated. Each data block is then applied to 3 different branches. The first data branch is encoded using RS (63, 45) code. Second branch is added with 6 zeros as the redundant bits to reduce PAPR. Then encoding is done to this block using RS (63, 51) code. For the third branch 6 ones are added as redundant bits and is encoded using RS (63, 51) code. After encoding, each block is modulated using 64 PSK modulations to produce sequence of symbols X0, X1…X_{N-1} where N is the number of subcarriers used. The advantage offered by SLM technique is that it supports any modulation technique like PSK or QAM. After modulation each block is interleaved, using random interleaving technique to avoid the burst errors distributed across the length of data. After interleaving each data block is converted in to a time domain signal using IFFT and transmitted. Due to large PAPR, peak values of some transmitted signals is much greater than the normal values, causing inter modulation between different subcarriers leading to additional interference causes an increase in the bit error rate (BER) of the system. In order to combat this large peak of sub carriers, in addition to RS codes companding technique is employed. This technique does not impose any restrictions in selecting parameters such as number of sub carriers, frame format and constellation [3]. In the proposed technique µ law companding is employed, after IFFT block. The companding of subcarriers using µ law companding is given by the equation

$$y = xp \frac{\ln\left[1 + \frac{|x|}{xp}\right]}{\ln[1+\mu]} \operatorname{sgn}(x) \quad [6]$$

Where x is the instantaneous input signal, y is the companded output signal, xp is the maximum input /output signal and sgn is the signum function.

After taking the µ law companding of each data block the value of PAPR is calculated and the block with the lowest PAPR is selected for transmission.

In order to decode the transmitted data blind estimation is employed, which is based on calculation of hamming metric. In traditional SLM technique a side information is sent in order to provide the receiver with the data corresponding to particular data block transmitted among U different blocks. But in the proposed method , no side information is used to decode the data.

At the receiving end, µ law expansion of received data is performed followed by N point FFT to get the data back to frequency domain. Then resultant data is deinterleaved and decoded using 64 PSKdemodulation. At this point data block received would be of length 63 bits. In the blind estimation technique first 45 bits out of 63 bits are extraced and are encoded as done at transmitter side, to get the block of RS(63,45) code. For second branch 6 zeros are added and encoded using RS(63,51) code.Similarly for third branch 6 ones are added and encoded using RS(63,51) code. Output from each block is compared with decoded 63 bits and hamming distance is calculated. The block with less hamming distance is considered as the data block which is being transmitted.Finally decoding is done by removing the redundant bits to get back estimation of transmitted bits. The above procedure is continued till entire data that is transmitted is decoded successfully. The advantage of proposed technique is that no signal distortion is introduced and no side information required during transmission. But the receiver has to estimate out of U different sequences, the correct one which has been transmitted with least PAPR [1], and demanding additional computation. However use of RS codes with good error correcting capability and no additional side information along with reduction in PAPR is the advantage gained by the proposed method.

5. SIMULATION RESULTS

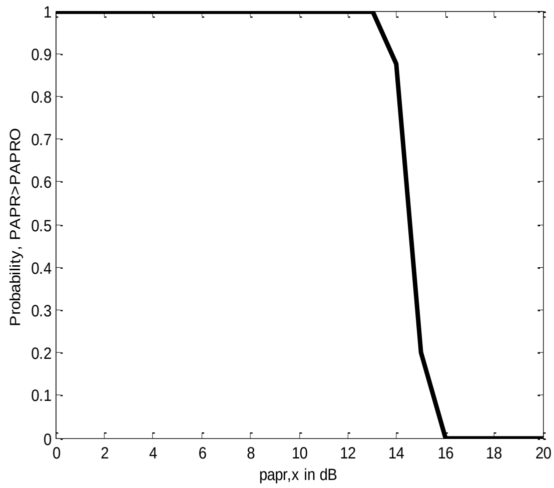

Figure 3: PAPR Plot without companding With 64 subcarriers

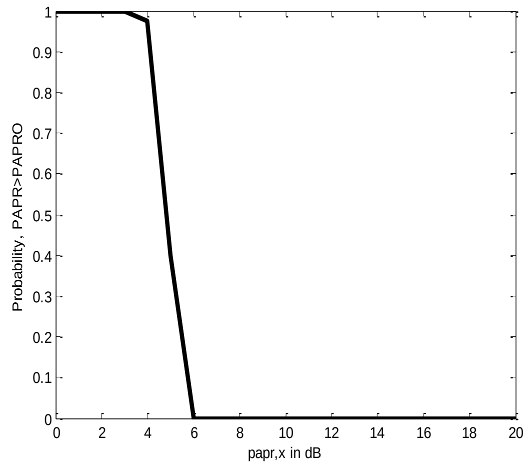

Figure 4: PAPR Plot with companding With 64 subcarriers

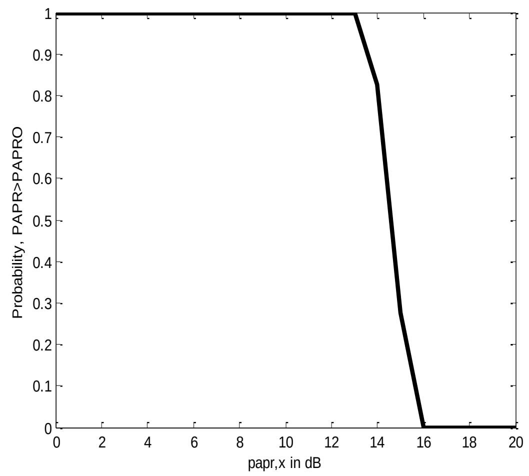

Figure 5: PAPR Plot without companding With 128 subcarriers

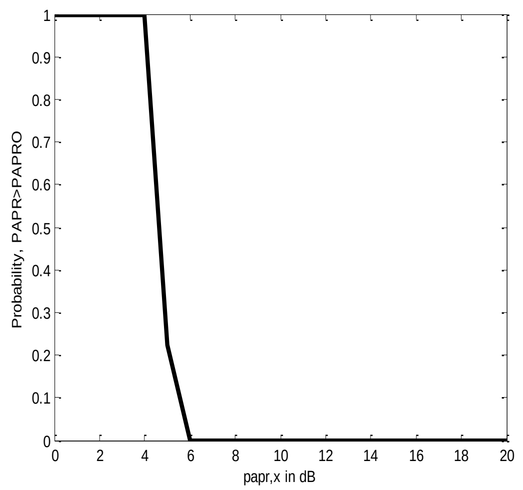

Figure 6: PAPR Plot with companding With 128 subcarriers

FLOW CHART:

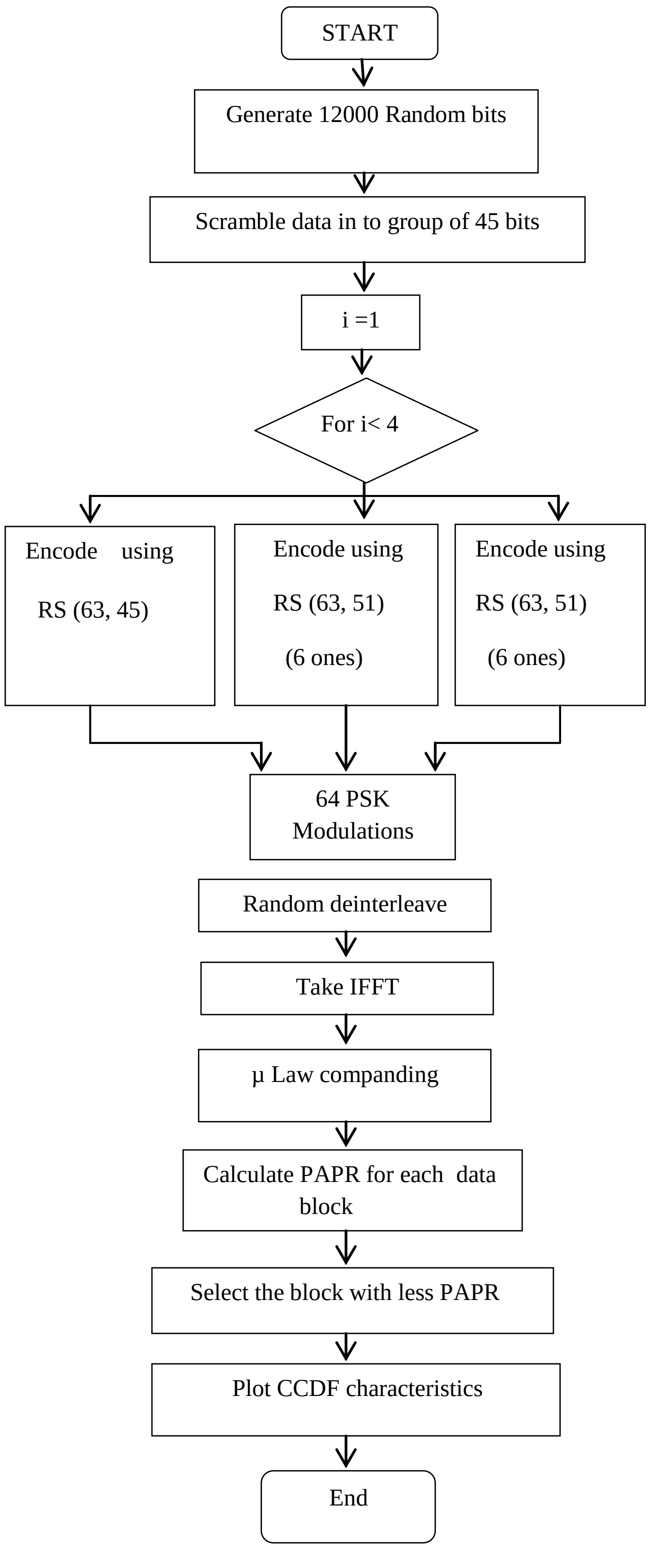

Figure 7: Transmitter side

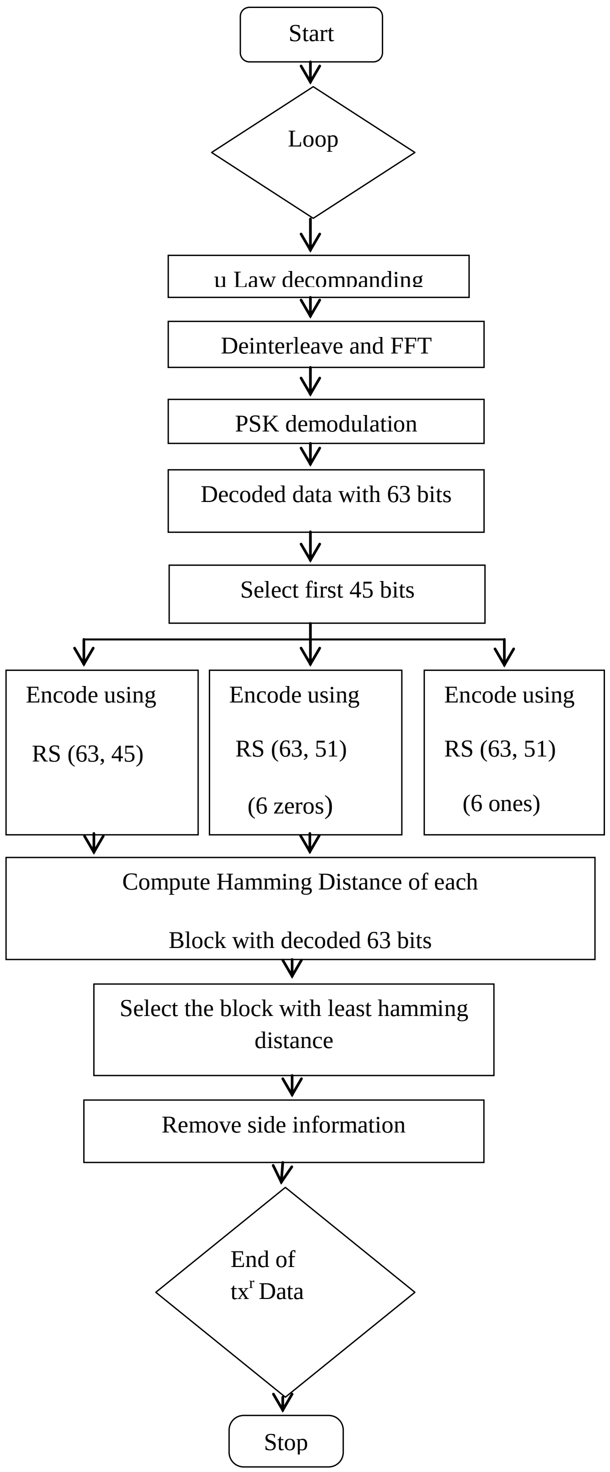

Figure 8: Receiver side

Table 1. Simulation Parameters

Simulated Bits	12000
Encoding Technique	RS Code
Modulation scheme used	64 PSK
Type of companding	μ Law with μ=100
Channel Type	AWGN

Table 2. Simulated Results

Number of subcarriers(N)	PAPR Without companding in db	PAPR With companding in db	Reduction of PAPR in db
64	**14**	**4**	**10**

6. CONCLUSION

In this paper selective mapping method with RS coding and companding is applied for FFT based OFDM system. With RS encoding and μ law companding better PAPR performance is obtained, as compared to one without using Companding. The PAPR reduction is shown in the Table2, which is around 10dB. Further as the number of subcarriers is increased from 64 to 128, PAPR is increased by about 2dB.Therefore the method used in this paper gives better PAPR performance with reduced burden of side information transmission.

8. REFERENCES

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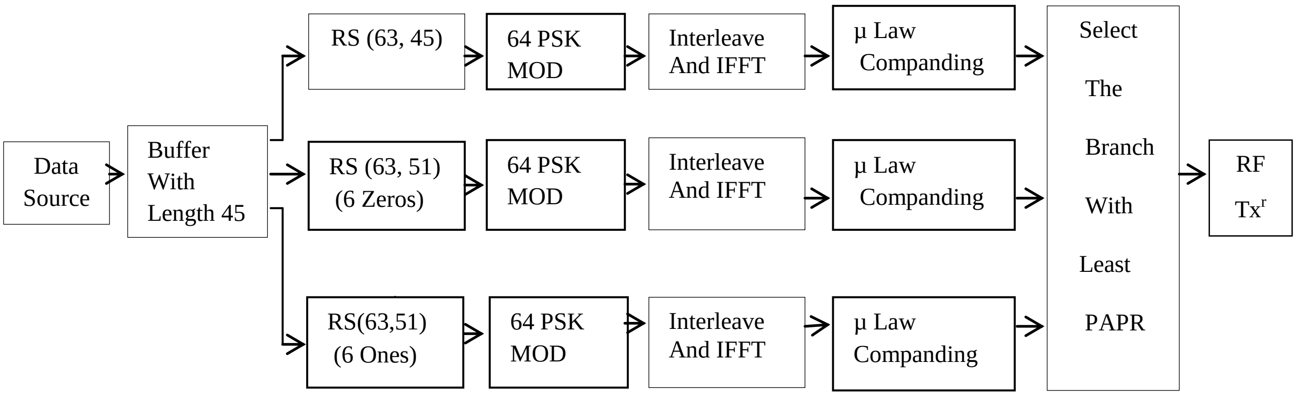

Figure 1: Block diagram of Transmitter

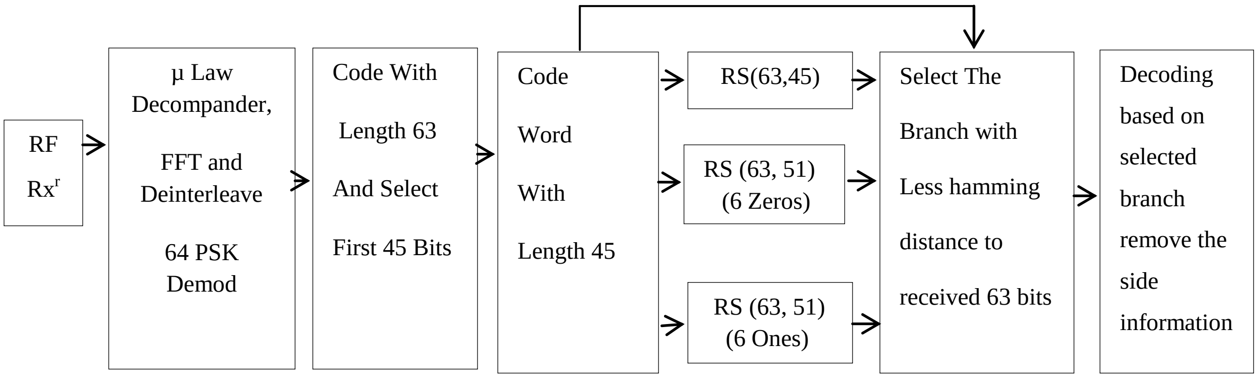

Figure 2: Block diagram of Receiver