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An Efficient Data compression Method for PAPR Redcution in OFDM Systems

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Abstract — *Orthogonal Frequency Division Multiplexing (OFDM) is one of the most widely used techniques in broadband communication. But main disadvantage of OFDM is high PAPR. Data compression coding can reduce PAPR significantly. There are many coding techniques used for data compression but here we compare two main coding for it i.e. Run-Length Coding and Arithmetic Coding. In this paper we compare PAPR of Run-Length Coded and Arithmetic Coded signal with original signal. Simulation results shows PAPR reduced of about 2 db for Run-Length Coding and 1.6 db for Arithmetic Coding.*

Keywords- *OFDM, PAPR, Run-length Coding, Arithmetic Coding*

I. INTRODUCTION

Single carrier modulation techniques which are used in 3G are not suitable for high data rate because they suffer from problems such as inter symbol interference, time dispersion, selective fading etc. To overcome this problems multicarrier modulation technique such as OFDM is used. OFDM is very attractive technique for high speed data transmission in mobile communications due to various advantages such as high spectral efficiency, efficiency, robustness to channel fading, immunity to impulse interference, capability of handling very strong multi-path fading and frequency selective fading without required powerful channel equalization [1]. OFDM is potential candidate for 4G, where speed of data up to 2 GBPS can be achieved. It is an efficient technology for wireless communications and used in many wireless standards like IEEE 802.11, Broadcast radio Access network (BRAN), Digital audio broadcasting, digital video broadcasting, WLAN, WIMAX and in military applications.

Apart from lots of advantages, some drawbacks become apparent, while using OFDM in transmission systems. A major obstacle is that the multiplex signal exhibits a very high peak-to-average power ratio (PAR). Therefore, nonlinearities may get overloaded by high signal peaks, causing intermodulation among subcarriers and more critical, undesired out-of-band radiation.

Large PAPR may cause nonlinear distortion in the high power amplifier (HPA) because HPA limits the output with certain value and reduces the power efficiency of the amplifier. Also, it increases complexity of the analog-to-digital and digital-to-analog converters [1]- [3]. The main objective of this paper is to find best data compression technique that can reduce PAPR significantly.

Data compression coding is one of the useful coding for reducing PAPR in multicarrier system. The primary encoding algorithms used to produce bit sequences are Huffman coding and arithmetic coding. Arithmetic coding achieves compression rates close to the best possible for a particular statistical model, which is given by the information entropy. Run-length encoding is a very simple form of data compression which runs of data are stored as a single data value and count, rather than as the original run. This is most useful on data that contains many such runs.

The paper is organized as follows. Section II discusses OFDM system model and PAPR problems. While Data compression methods are explained in section III, simulation results are presented in section IV. Finally, conclusion is drawn in section V.

II. PAPER OFDM SYSTEM MODEL AND PAPR PROBLEM

2.1 OFDM System Model

OFDM symbol consists of N subcarriers which have constant spacing Δf. Bandwidth of that signal is $B=\Delta f \cdot N$ and symbol time $T=1/\Delta f$. This leads to sum of N sinusoids in the time domain, that have exactly an integer number of cycles in the interval T. Each subcarrier is modulated by complex value $X_{m,n}$, where m denotes symbol index and n subcarrier index

M-th OFDM symbol can be written as:

$$x_m = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_{m,n} g_n(t - mT)$$

Where $g_n(t)$ means :

$$g_n(t) = \exp(j2\pi n\Delta f t) \text{ for } 0 \le t \le T$$

$$g_n(t) = 0 \text{ for other t}$$

Time domain signal can be written as sum of symbols:

$$x_m = \frac{1}{\sqrt{N}} \sum_{m=0}^{\infty} \sum_{n=0}^{N-1} x_{m,n} g_n(t - mT)$$

The complex value $X_{m,n}$, depends of partial modulation. Usually M-PSK or M-QAM is used[4].

2.2 PAPR Problem

OFDM consists of lots of independent modulated subcarriers. That leads to problem with peak to average power ratio. If N subcarriers are in phase (same symbols modulated on all subcarriers), the peak power is N times average power. For sampled signal, PAPR is defined

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

where $E\{\cdot\}$ denotes statistical expectation. The cumulative distribution function (CDF) of the PAPR is one of the most frequently used criteria for PAPR reduction. The complementary of CDF (CCDF) is commonly used instead of the CDF itself. The CCDF of the PAPR denotes the Probability that the PAPR of a data block exceeds a given threshold[4]. Due to high PAPR linearity of Power Amplifier is disturb.

III. DATA COMPRESSION METHODS

3.1 Arithmetic Coding

The idea of arithmetic coding was suggested by Rissanen [1975] from the theory of enumerative coding by Pasco [1976]. Arithmetic coding is a form of entropy encoding used in lossless data compression. For understanding of arithmetic coding we take one example. Suppose we have six symbols and probability respectively shown in table below. And their distribution also given as,

Table 1:Example of Arithmetic Coding

Symbols	Probability	Interval
A	0.2	[0,0.2)
E	0.3	[0.2,0.5)
I	0.1	[0.5,0.6)
O	0.2	[0.6,0.8)
U	0.1	[0.8,0.9)
!	0.1	[0.9,1)

We have message "eaii!" that can be transfer. For arithmetic coding all these symbols is divided into intervals according to their probability as shown in table. After that we check message that want to transfer, first symbol in message is 'e' therefore we concentrate on interval between 0.2 to 0.5. After 'e' second symbol is 'a', for that we divide interval of 0.2 to 0.5 in same probability and so on.

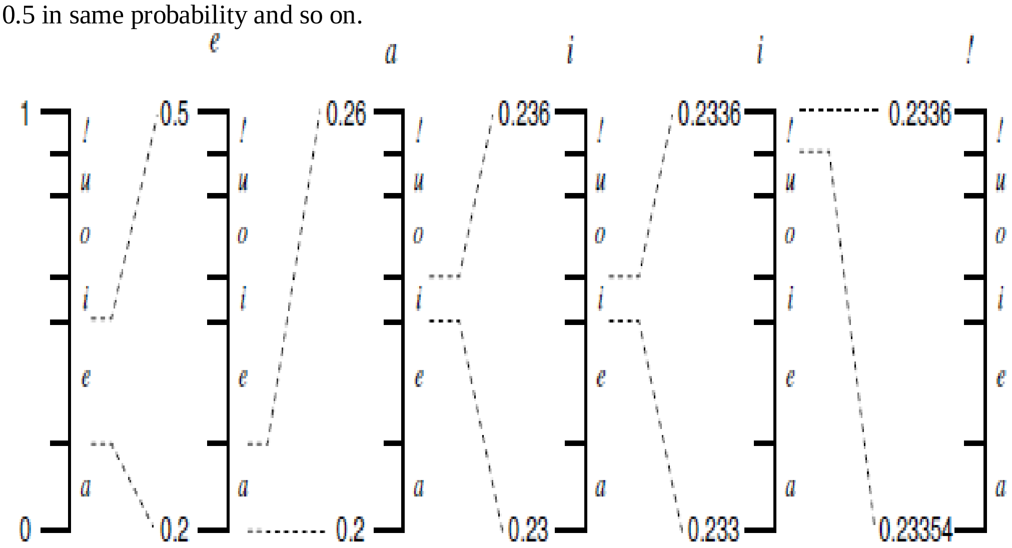

Figure 1: Arithmetic Coding

Figure 1 shows the detail procedure for the coding of message "eaii!'. After coding we get two values (0.2336,0.23354). Received signal having value in between this interval indicate the message "eaii!'. But for transmission we need binary data for that we have to convert this interval into binary expansion. For this interval binary expansion is 001111 and we only need to transmit this sequence.

When we apply this coding to OFDM system, data can be compressed significantly because here for whole message we send single string that can reduce data size and as the data size is reduced the PAPR also reduced. Because the PAPR reduction is depend on the compression ratio.

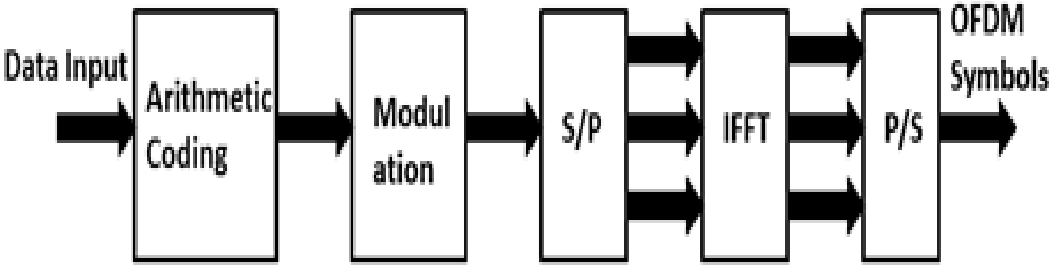

Figure 2 OFDM Transmitter Using Arithmetic Coding

Above Figure 2 shows the OFDM transmitter using Arithmetic Coding. In that firstly input data is encoded by arithmetic encoding. Encoding string is modulated using mapper like M-QAM, M-PSK, QPSK, BPSK etc.. After mapping it is converted to parallel stream and IFFT is done on that. And finally OFDM symbols we get by transfer parallel to serial stream.

3.2 Run-Length Encoding(RLE)

RLE is a lossless compression method that is used as source coding. RLE codes are divided into two sections which are run length and the data themselves. A special character such as $ is usually used. The format of RLE is (Sc, Y, D) where Sc is the special character, Y is the run length, and D is the data [7], [8]. For the simulation we omit the special character because there is no need to use the special character. The function of the special character is just to separate between RLE codes.

For example, a source emits the following data: ffffaaaaahhhhh. The RLE codes for the data is: $4f$5a$5h. If a symbol is represented by one byte, the original message contains 14 bytes while the coded message just contains 9 bytes. Thus, the compression ratio is 14/9 = 1.6. The compression ratio is not too significant because of lossless compression.[9]

When we applied RLE to OFDM system. After modulation symbols send are encoded by using RLE. After encoding we get two information one is ‘run length’ and second is ‘data’ that repeated. We transmit ‘run length’ as side information. The ‘run” is sent in line with the “data” so that they can be decoded at the receiver.

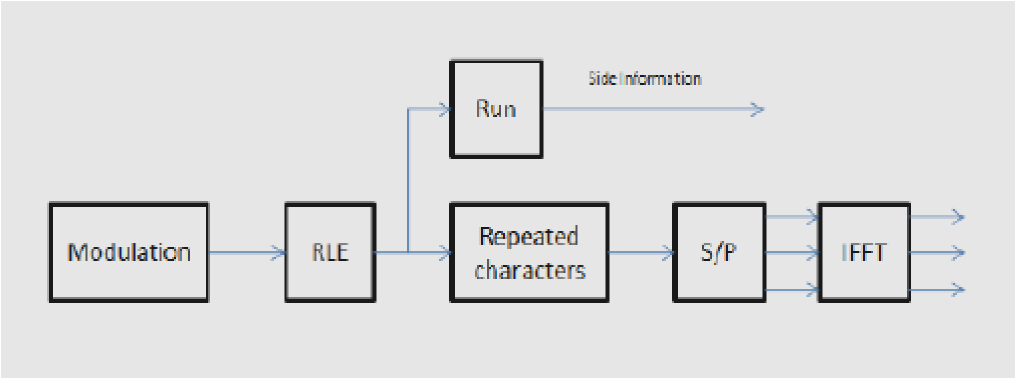

Figure 3: OFDM Transmitter Using RLE

OFDM transmitter using RLE is shown in Figure 3. In that repeated data converted to parallel stream and IFFT is carry over there. After IFFT symbols can be transmit as OFDM symbols.

From above discussion, the main part of this coding is compression ratio. Comparatively compression ratio for Huffman coding is better than for Arithmetic coding and for RLE. Because in arithmetic coding as the message length increases the binary expansion value also increases. But in Huffman coding, that symbols having more probability we assign small bit symbol and for low probability we assign large bit symbols because of that compression ratio for Huffman coding is better. And in RLE the main problem is as there are continuous stream that can be compressed but if there is message that continuously changing for that compression using RLE is not significant. Figure 4 shows the relation of compression ratio and PAPR. As the compression ratio increases the PAPR reduces. But compression of certain data have also some limit, and we need lossless data compression therefore up to certain limit we can compress data.

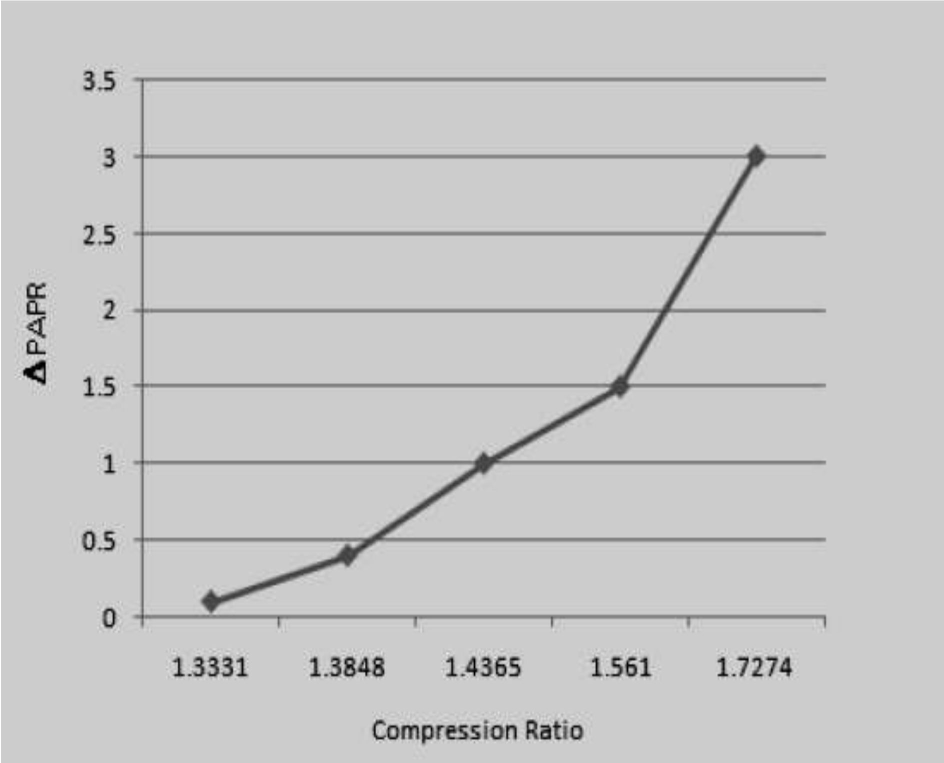

Figure 4 Compression ratio Vs PAPR

IV. SIMULATION RESULTS

For all simulation we take 512 subcarriers and we check results for that.

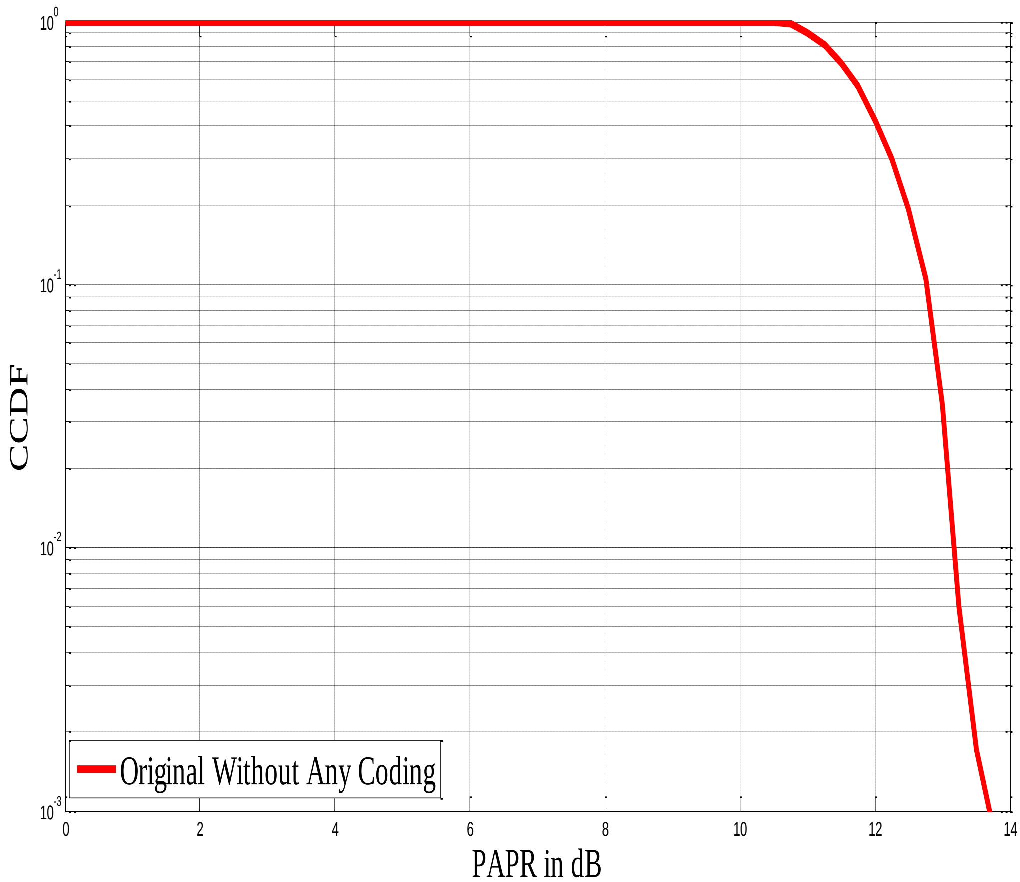

Figure 5 PAPR for Original Signal

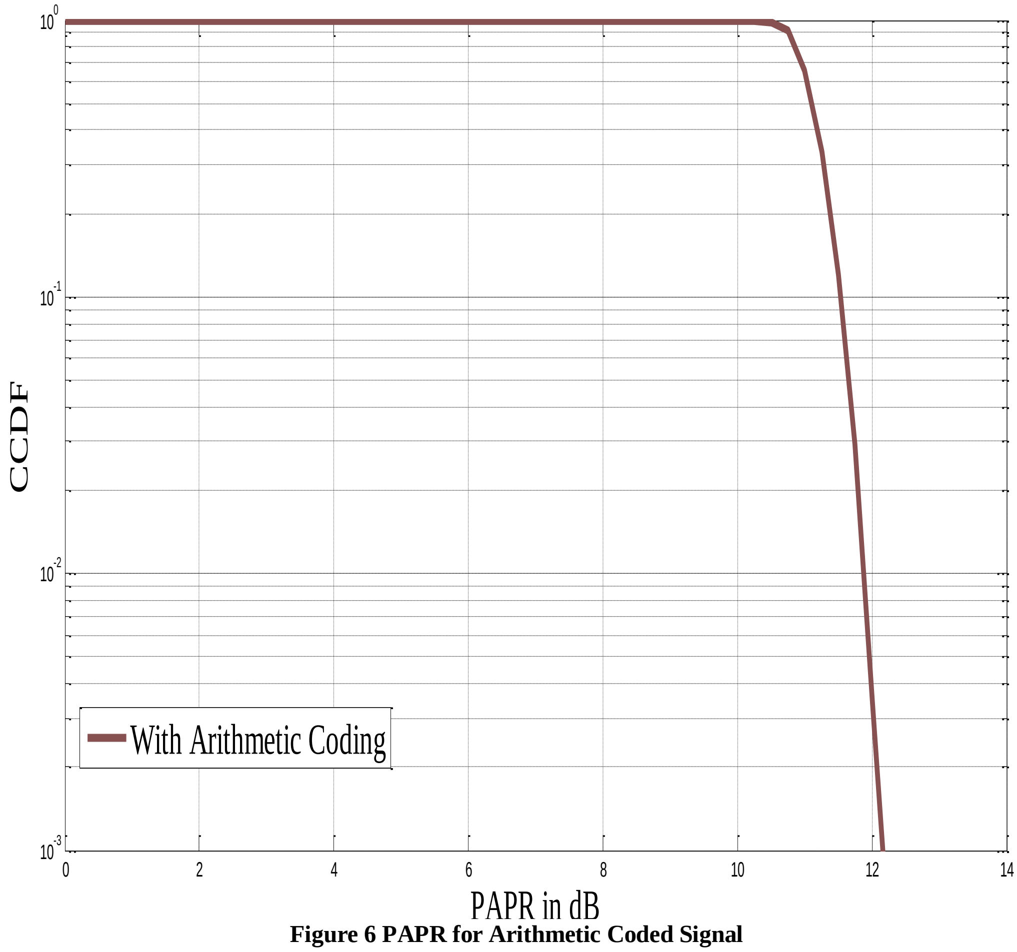

Figure 6 PAPR for Arithmetic Coded Signal

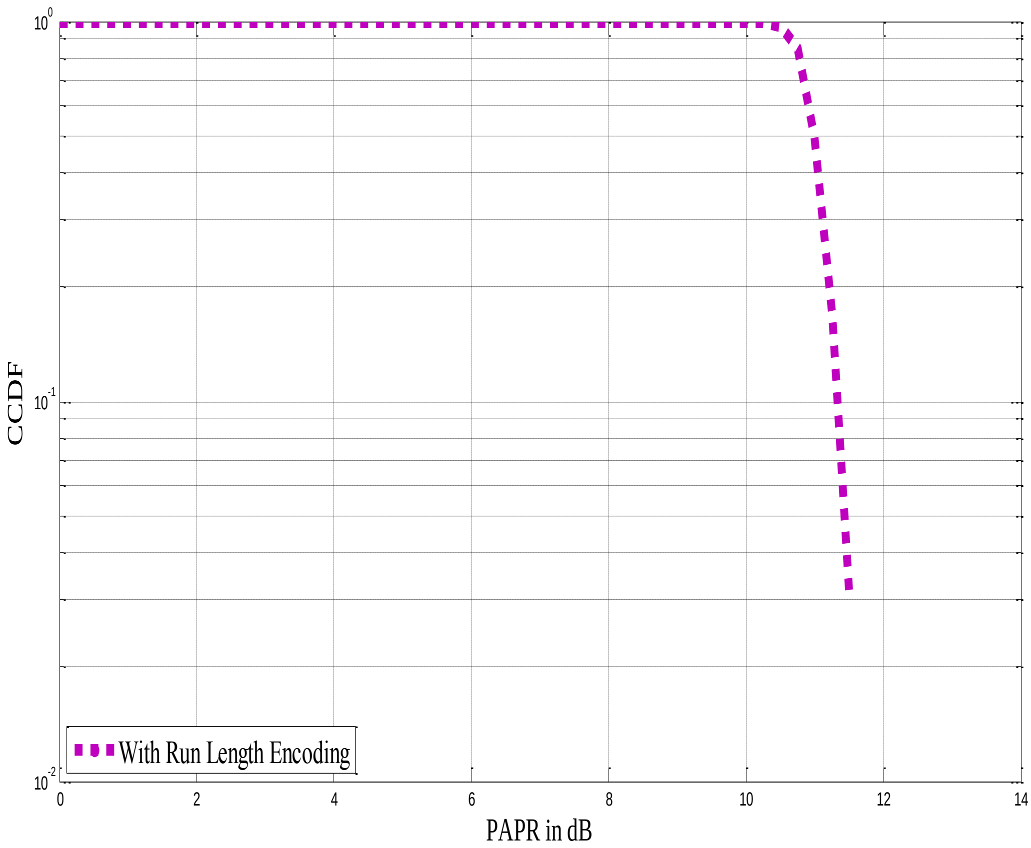

Figure 7 PAPR for Run-Length Encoded Signal

Figure 6 shows the results for Arithmetic Coding. For this PAPR reduced about 1 db for CCDF ≤ 10^{-1} and about 1.6 db for CCDF ≤ 10^{-2} and CCDF ≤ $10^{-3.}$ In Figure 7 shows the results for Run Length Encoding. For this PAPR reduced about 1.2 db for CCDF ≤ 10^{-1} and about 2 db for CCDF ≤ 10^{-2} and CCDF ≤ 10^{-3}.

V. CONCLUSION

We have concluded that the use of Run Length coding greatly reduce the PAPR of the OFDM system by about 0.4 db as compare to the Arithmetic coding. PAPR reduction is depend on compression ratio of encoding and compression ratio may vary according to the message that we want to transmit. But compression ratio also has certain limitation. Therefore for more reduction in PAPR Huffman coding or RLE will combine with another method of PAPR reduction.

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