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PAPR REDUCTION USING VLM PRECODING WITH COMPANDING TECHNIQUES FOR OFDM SYSTEMS

Surjeet Kumar*

Abstract: OFDM (Orthogonal Frequency Division Multiplexing) is a promising multicarrier (MC) modulation scheme which is suited for high speed communications such as LTE, WiMAX and WLAN etc. However, a major drawback of MC transmission is the high peak-to-average power ratio (PAPR) of the transmit OFDM signal. Since the high power amplifiers (HPAs) at the transmitter are limited by peak power, which causes distortion in modulated signal during amplification through HPA. The complexity of Digital to Analogue (D/A) and Analogue to Digital (A/D) converters are increased due to High PAPR and also the efficiency of RF High Power Amplifier (HPA) is reduced. Therefore, PAPR reduction is very necessary. In this paper, we review and analyze VLM pre-coding technique with A-law and μ-law companding over conventional OFDM system which gives better PAPR reduction in OFDMA System [14].

Key Words: OFDM (Orthogonal Frequency Division Multiplexing), PAPR reduction, Vandermonde-like matrix (VLM)

1. INTRODUCTION

OFDM is a multicarrier modulation technique, where a high speed data stream is further splited into number of parallel streams of low data rate and these low rates data streams are transmitted simultaneously over a number of orthogonal subcarriers. It provides the high data rate and high frequency spectral efficiency and low implementation complexity [2]. Because of these advantages, OFDM is used in systems such as wireless local area networks, LTE and WiMAX, digital audio broadcasting (DAB) and digital video broadcasting (DVB) [3],[4]. One of the major drawbacks of OFDM is the high Peak to Average Power Ratio (PAPR) value of the transmitted signals [5],[7]. This problem came into existence from modulation itself, it comes on adding multiple sub carriers while formulating the transmitting signal. On the other hand, when the numbers of subcarriers are increased with the same phases, then the OFDM signals will have a large envelope fluctuation which leads to high PAPR values. Due to this high PAPR, system requires large back-off; which creates a side effect of reducing efficiency of HPA. There are many PAPR reduction techniques, including SLM (selected mapping) [6], [8], PTS (partial transmit sequences) [9], [13], interleaving [10], TR (tone reservation), and TI (tone injection) [11]. However, these techniques provide different sets of tradeoffs that may include data rate, and BER (bit error rate) performance and computational complexity.

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In this paper, VLM pre-coding method with A-law and μ-law companding techniques is investigated which reduces significant PAPR of the OFDM signal. In this paper first of all, the VLM transform coding is applied on the modulated data stream, then the 'N' point IFFT is applied into the VLM pre-coded data. Finally, the companding techniques are applied on IFFT output then OFDM signal will be obtained and the PAPR parameter will be calculated.

2. SYSTEM MODEL

2.1 PAPR in OFDM System

In this system, the whole bandwidth (BW) of the system is divided into many narrow bandwidth of orthogonal sub-carriers and the input data symbols are typically mapped by Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM) are transmitted independently on the narrowband orthogonal sub carriers. In this paper, M-QAM modulation scheme is used for an OFDM system. An OFDM signal consists of N mapped symbols and each symbol is modulated by one of a set of N orthogonal sub carriers. In figure (1) an OFDM system first of all, the serial input baseband mapped symbols are converted in to parallel low data streams. The output data vector after the baseband mapping is assumed as $X = [\, X_1, X_{2,}, \ldots, X_N \,]^T$ and Xi is ith data symbol. Then OFDM signal is determined using the 'N' point IFFT (Inverse Fast Fourier Transform). Oversampling is done for the better approximation of the PAPR of the continuous-time OFDM signals. Oversampling can be implemented by determining an LN-point IFFT (Inverse Fast Fourier Transform) of the data block with zero-padding of (L - 1) N and the output of oversampled IFFT can be given as

$$x[n] \;=\; \frac{1}{\sqrt{LN}} \sum_{k=0}^{LN-1} X_k \, e^{\frac{j2\pi nk}{LN}}$$

$$n = 0, 1, 2 \ldots\ldots\ldots\ldots\ldots LN - 1 \qquad (1)$$

The oversample factor is considered as 'L' .The Peak to Average Power Ratio (PAPR) in any of OFDM symbols can be calculated with the help of given equation below

$$\text{PAPR} = \frac{\max|x[n]|^2}{\text{avg}[|x[n]|^2]} \qquad (2)$$

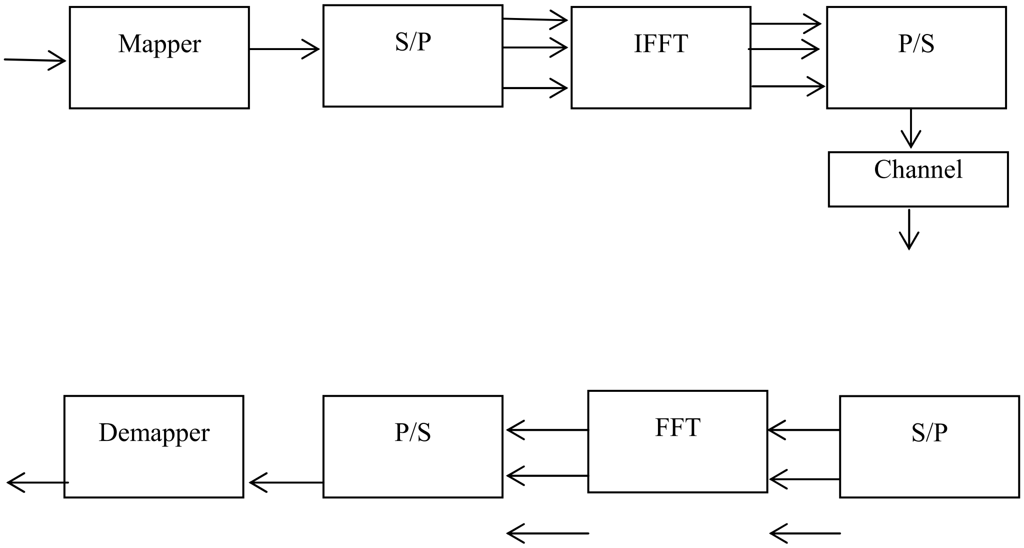

Figure 1: A simple block diagram of an OFDM system

The efficiency of PAPR techniques is measured by one of the most widely used parameter that is CDF (cumulative distribution function), which helps to measure PAPR of the OFDM system.

The performance of PAPR can be evaluated by using the cumulative distribution of PAPR of OFDM signal. The complementary cumulative distribution function (CCDF) is used in-stead of CDF, which helps in the measurement of the probability of the PAPR of a certain data block exceeds the given threshold value as

$$P\ (PAPR > PAPR0) = 1 - (1 - e\text{-}PAPR0)\ N \tag{3}$$

For the transmission of high power, High Power Amplifiers (HPA) employed in most of the radio systems at the transmitters for the achieving the maximum output power efficiency. Therefore, High Power Amplifiers (HPAs) are needed near the saturation region to operate and the I/O characteristic of HPA is non- linear. Because of this non linearity, the HPA becomes very sensitive to the variations of amplitude of the signal. Thus the spectral efficiency of the OFDM transmitter is reduced by HPA because of its operation in non-linear region. Due to non-linearity, the variations occur in the instantaneous power of the OFDM signals which result high value of PAPR. In order to improve spectral efficiency the HPA must be operated in its linear region. HPA has a large dynamic range in linear region. But unfortunately HPAs are more expensive and have poor efficiency in the linear.

In wireless communication, power efficiency is very necessary as it provides adequate coverage area, allows small size terminals and saves power consumption etc. So, it is necessary to resolve the non-linearity problem of the HPA and also the interference problem caused because of HPA. There is a good solution to reduce the interference by reducing PAPR of the transmitted signal. One of the PAPR reduction technique which is based on VLM pre-coding with companding as is illustrated in figure (2).

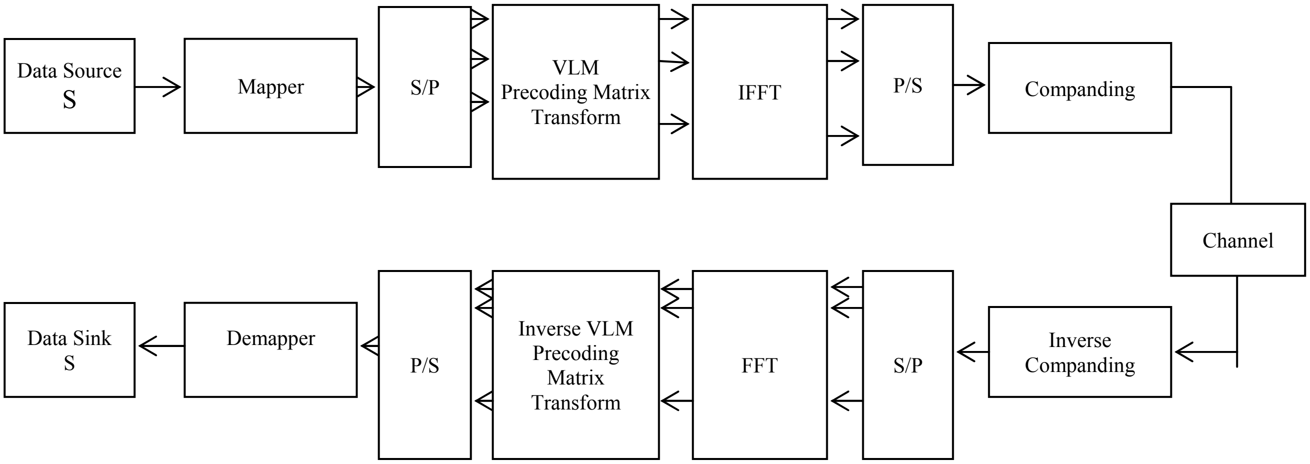

Figure 2: A simple block diagram of an OFDM system with VLM pre-coding and companding.

3. VLM PRECODING TECHNIQUE

The VLM pre-coding technique is used to obtain a signal with lower PAPR than in the case of conventional OFDM

It also compensates the nonlinearities of the HPA. The autocorrelation of the input sequence is reduced by applying the VLM transform to the input signal before IFFT operation thus the PAPR of the OFDM signal is also reduced. Vandermonde-Like Matrices can be defined as equation.

$$V\ (i, j) = \sqrt{\frac{2}{1+N}}\ (\cos\ (\frac{(i-1)(j-1)\pi}{N-1})) \tag{4}$$

scaling factor $\sqrt{\frac{2}{1+N}}$ is used to normalize the matrices. [16]

4. COMPANDING TECHNIQUES

We used the compander in order to reduce PAPR of OFDM signal because compander amplify the small signal and increase the average power of the OFDM signal and reduce the high peak value. In general a compander consists of a compressor and an expander. The compressor is a simple logarithm computation block. The inverse system of a compressor is called expander. In this paper, the compression is applied at the transmitter end, after the IFFT process and the expansion is applied at the receiver end prior to the FFT process. These two types are the μ- law and the A-law compander [15], [17].

(a) ***μ-law Compander***: It consists of the logarithmic function at the transmitting side. Generally a μ-law compression characteristic is defined as

$$Y = \frac{V \log_e\left(\frac{1+\mu|x|}{V}\right) \operatorname{sgn}(x)}{\log_e(1+\mu)} \tag{5}$$

Where μ is parameter of the μ-law compander which is used to control the compression of signal, where *x* is the input signal and *V* is the maximum value of *x*. For normalized input signal: $|x| \leq 1$, then the characteristics becomes:

$$Y = \frac{\log(1+\mu|x|)}{\log(1+\mu)} \operatorname{sgn}(x) \tag{6}$$

(b) ***A-law Compander:*** It consists of the logarithmic function at the transmitter side. Generally A-law compression characteristic is defined as:

$$Y = \begin{cases} \frac{A|x|}{1+\log A} \operatorname{sgn}(x) & \text{for} \quad 0 \leq |x| \leq \frac{V}{A} \\ \frac{V \log_e\left(\frac{A|x|\mu}{V}\right)}{1+\log A} \operatorname{sgn}(x) & \text{for} \quad \frac{V}{A} < |x| \leq V \end{cases} \tag{7}$$

Where A is parameter of the A-law companding which is used to control compression of input signal, *x* is the input signal and V is the maximum value of *x*.

5. SIMULATION RESULTS

In this section, the PAPR of OFDM using VLM precoding technique with the A-law and μ-law compandings has been evaluated by simulation. The results are obtained by modulating the signals using M-QAM (where M=8. 16, 128). A simple block diagram of an OFDM system with VLM pre-coding and companding is implemented where VLM precoding is used as a precoding matrix transform and A-law and μ-law compandings are used as companding used in simulations.

5.1 CCDF Performance with A-law Companding

The computer simulated results are described in this section to evaluate capability of PAPR reduction of proposed technique. In this simulation, an OFDM system with orthogonal sub-carriers of N = 64 and *M*-QAM = 8, 16 and 128 modulation techniques are used. The performance of the proposed PAPR reduction technique can be analyzed with the help of CCDF parameter of the PAPR of the OFDM signal at various values of the A parameter of A-law compander.

$$\text{CCDF} = 1 - \text{CDF} \tag{8}$$

$$\text{CCDF} = \Pr\,(\text{PAPR} > \text{PAPR0}) \tag{9}$$

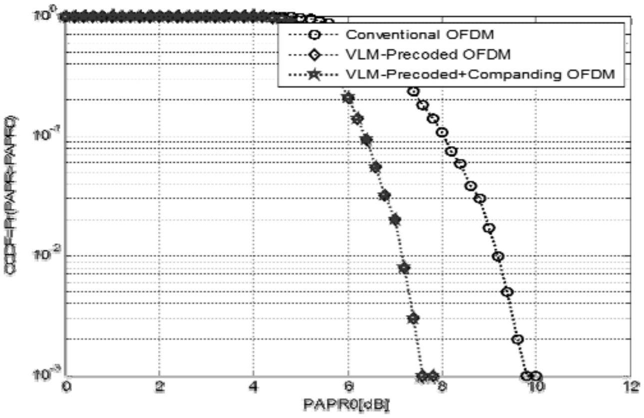

Figure 3: CCDF for VLM pre-coding with A- law companding, technique at A=5 for 8 QAM

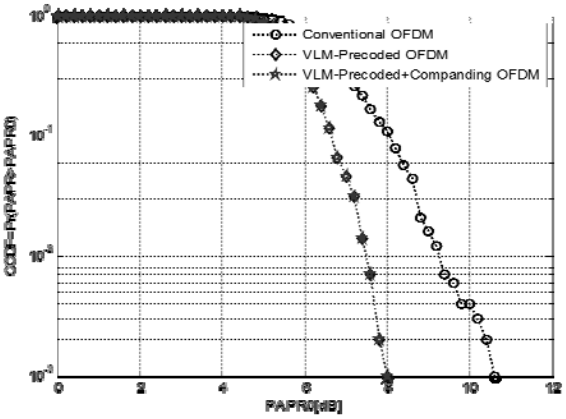

Figure 4: CCDF for VLM pre-coding with A- law companding, technique at A=5 for 16 QAM

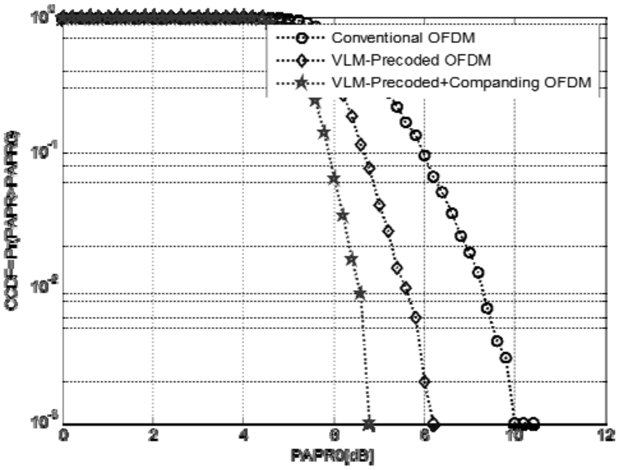

Figure 5: CCDF for VLM pre-coding with A- law companding,technique at A=10 for 16 QAM

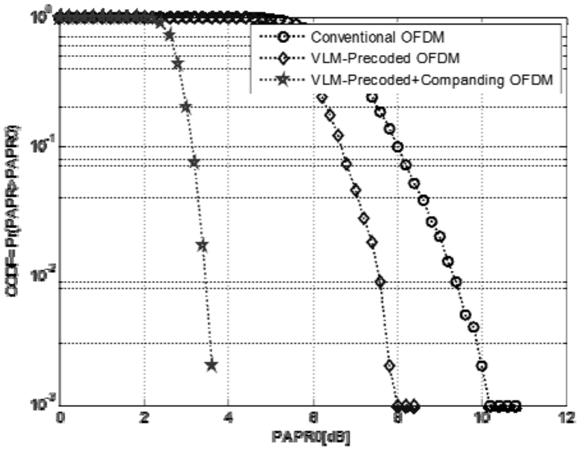

Figure 6: CCDF for VLM pre-coding with A- law companding, technique at A=50 for 16 QAM

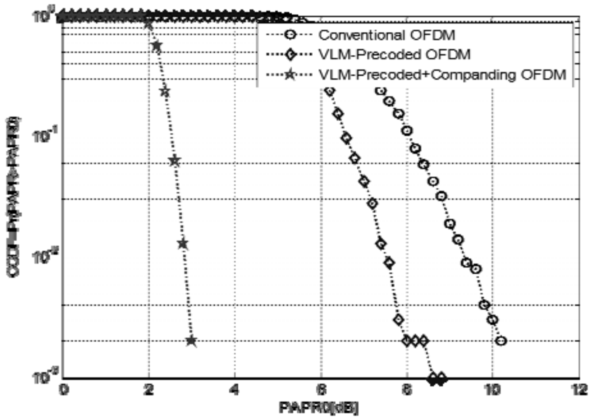

Figure 7: CCDF for VLM pre-coding with `A- law companding technique at A=100 for 16 QAM

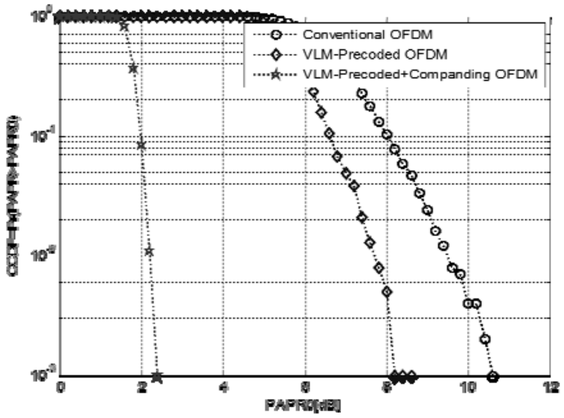

Figure 8: CCDF for VLM pre-coding with A- law companding, technique at A=100 for 128 QAM

5.2 CCDF Performance with μ -law Companding

The computer simulated results are described in this section to evaluate capability of PAPR reduction of proposed technique. In this simulation, an OFDM system with orthogonal sub-carriers of N = 64 and *M*-QAM = 8, 16 and 128 modulation techniques are used. The performance of the proposed PAPR reduction technique can be analyzed with the help of CCDF parameter of the PAPR of the OFDM signal at various values of the μ parameter of μ-law compander.

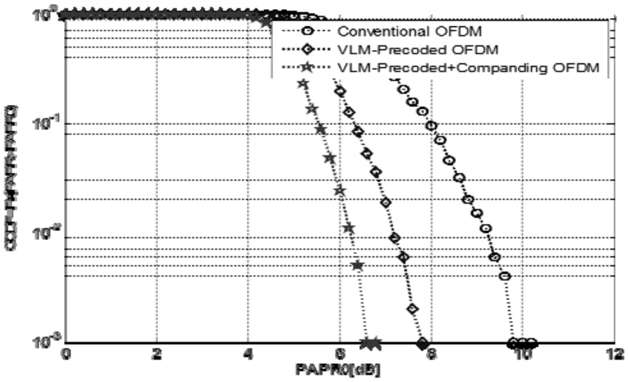

Figure 9: CCDF for VLM pre-coding with
μ- law companding technique at μ =5 for 8 QAM

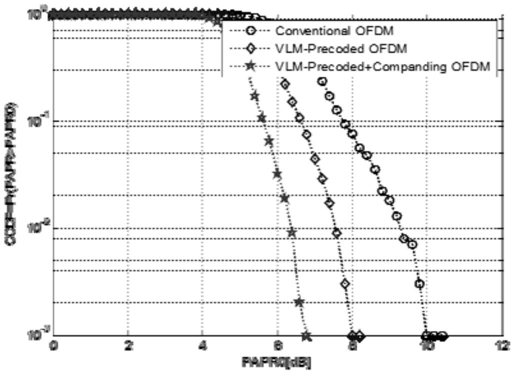

Figure 10: CCDF for VLM pre-coding with
μ- law companding technique at μ =5 for 16 QAM

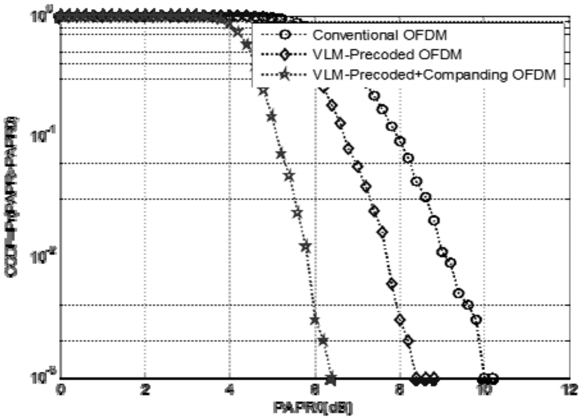

Figure 11: CCDF for VLM pre-coding with
μ- law companding technique at μ =10 for 16QAM.

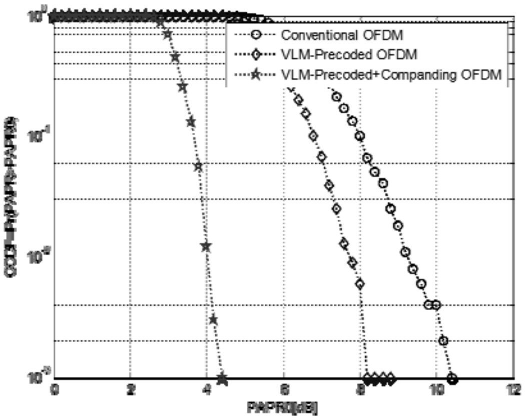

Figure 12: CCDF for VLM pre-coding with
μ- law companding technique at μ =50 for 16QAM.

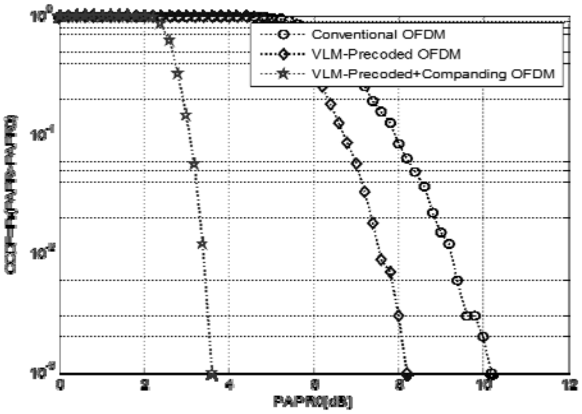

Figure 13: CCDF for VLM pre-coding with
μ- law companding technique at
μ =100 for 16QAM.

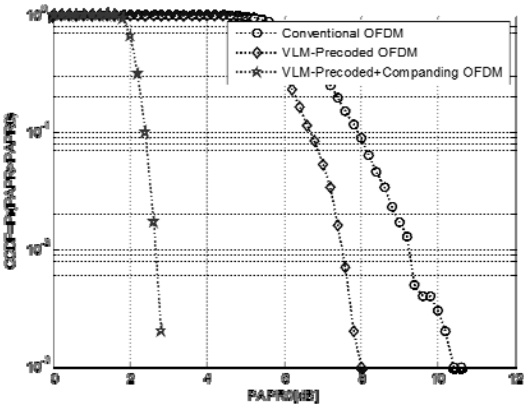

Figure 14: CCDF for VLM pre-coding with
μ- law companding technique at
μ =100 for 128QAM.

The figures 3, 4, 5, 6, 7 and 8 represent the CCDF performance of VLM pre-coding technique with and without A-law companding, for 8, 16 and 128 QAM and the Figures 9, 10, 11, 12, 13 and 14 represent the CCDF performance of VLM pre-coding technique with and without μ-law companding for 8, 16 and 128 QAM .It can be observed in figures 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 that using VLM pre-coding technique at CCDF = 10^{-3} the PAPR is reduced up to near around 8.1dB. And using the VLM pre-coding technique with μ-law companding, at CCDF=10^{-3}, the PAPR is reduced up to near around 2.4 dB for 128 QAM at μ =100. And using the VLM pre-coding technique with A-law companding, at CCDF=10^{-3}, the PAPR is reduced up to near around 2.1 dB for 128 QAM at A =100.

6. CONCLUSION

In this paper, the performance in terms of PAPR for OFDMA system is analyzed by using VLM pre-coding technique along with companding techniques. The VLM pre-coding technique reduces the PAPR as compare to its conventional OFDM system. The VLM pre coding technique with A-law and μ-law companding techniques further reduces PAPR of OFDM system. The VLM pre-coding technique with companding does not introduce any degradation in signal. It is better PAPR reduction technique than other techniques because VLM pre-coding technique with companding does not require any kind of side information which is required to send at the receiver. . A –law and u-law companding further reduce PAPR of OFDM signal and as increasing A or μ value PAPR reduces. The obtained results approved that the proposed method gives the better results than without companding and its conventional OFDM.

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