International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-5, Issue-4, August 2016

# Effect of PAPR Reduction Using Companding Technique on Adaptive Modulation Based MIMO OFDM System

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***Abstract*— Wireless standards utilize the Orthogonal Frequency Division Multiplexing (OFDM) technique due to many advantage of this technique. One of the challenging issues for Orthogonal Frequency Division Multiplexing technique is high Peak-to-Average Power Ratio (PAPR). Due to high PAPR ratio, wireless communication system requires to handle large range of signal to noise ratio. Hence antenna design becomes complex for high PAPR based OFDM system. In this paper, we review and analysis different OFDM PAPR reduction techniques. The main emphasis of the researchers were developed a method to reduce Bit error rate and PAPR both simultaneously. In this paper, a companding based PAPR reduction technique is used along with MIMO technique to control BER and PAPR for OFDM system. The BER and PAPR parameters for various SNR value for this system are also discussed in this paper.**

***Index Terms*— Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio, Bit error rate, µ-law Campanding, Communication channel, etc.**

## I. INTRODUCTION

Wireless communication standards, existing and under development, adopt or consider adopting orthogonal frequency-division multiplexing (OFDM) as the modulation technique. It is

clear that OFDM has become the definitive modulation scheme in current and future wireless communication systems.zzThe OFDM is a multicarrier transmission technique, it divides available spectrum into many carriers. An Orthogonal Frequency Division Multiplexing (OFDM) uses spectrum much more efficiently by spacing the channels much closer to each other. This system has better properties such as high spectral efficiency, in robustness to channel fading, immunity to interference. There are some obstacles in OFDM. A major problem is that OFDM signal exhibits a very high peak to average power ratio. If large peaks cause saturation in power amplifiers, inter modulation amongst subcarriers, increases out of band interference. Therefore it is necessary to reduce PAPR.

The reduce the peak to average power ratio several method have been proposed such as clipping coding, tone reservation, peak windowing. But most of these technique are unable to achieve simultaneous a large reduction in PAPR (peak to average power ratio) with low complexity. Among all these techniques the simplest solution is to clip transmitted signal when its amplitude exceed a preferred threshold. Clipping highly non-linear process, it produces significant out of band interference. A good remedy for out of band interference is called companding. The scheme 'soft' compress, rather than 'hard' clips, in the signal peaks causes far less out of band interference. In proposed method in which employed in classical µ- law transform and showed effective. Since then many different companding algorithm with better performance have been published. This paper organized as follows: section 2, presents companding algorithms such as µ law campanding, the exponential, and companding using airy function. In section three these algorithms compared with non-companded. We use bit error rate and peak to average power ratio as a comparison parameter for companding algorithm. In section four we conclude.

## II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal frequency-division multiplexing in some cases known as multicarrier modulation (MCM) or discrete multi tone is a well known modulation technique that is tolerant to channel disturbances and impulse noise. The multi carrier modulation have been developed 1950's by introducing two modems, the Collins Kineplex system and the one so called Kathryn modem. OFDM has distinguished properties such as bandwidth efficiency, highly adjustable in terms of its adaptability to channels and robustness to multipath scheme. To achieve higher spectral efficiency in multicarrier method, the sub-carriers must have overlapping transmit spectra but at the same time they need to be orthogonal to avoid complex division and processing at the receiving end. As it is stated in, the orthogonal set can be represented as such

$$\left\{\frac{1}{\sqrt{T_s}}\exp^{jw_k t} \text{ for } t \in [0, T_s]\right\} \qquad (1)$$

With $w_k = w_0 + kw_s; \quad k = 0,1,\ldots,N_c - 1$

$w_0$ Is the lowest frequency used and $w_k$ is the subcarrier frequency.

As a substitute of bank of matched filters & baseband modulator, Inverse Fast Fourier Transform and Fast Fourier Transform is active method of OFDM system implementation.

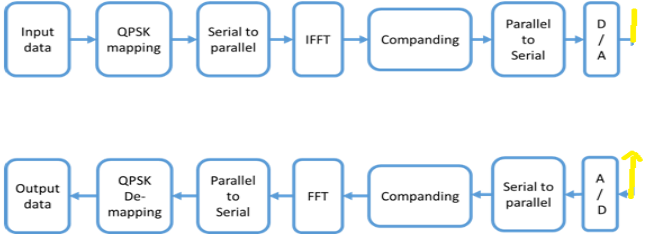

Fig. 1. Block diagram OFDM system with companding algorithm

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## III. Peak To Average Power Ratio Scheme

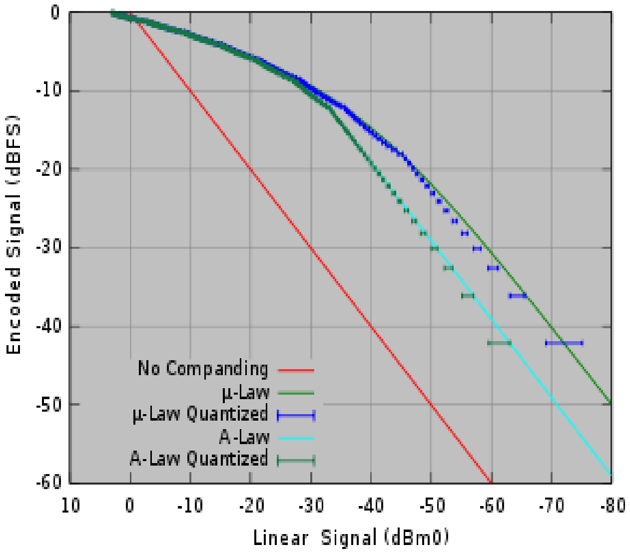
The peak-to-average power ratio (PAPR), defined as the ratio of the peak power to the average power, has been one weakness for OFDM communication systems. The PAPR formula is given by

$$PAPR = \frac{max|x(t)|^2}{E|x(t)|^2} \qquad (2)$$

In the extreme case, in which all the subcarriers are coherently and equally summed up, the time-domain OFDM signal can have a PAPR of about N. For example, the PAPR of a 256-subcarrier OFDM system can be as high as 256, or equivalently 24 dB. Such a high PAPR demands high dynamic range in the ensuing amplifier, especially the power amplifier (PA) in the transmitter. If not biased properly, the PA easily enters into saturation, causing nonlinear amplification of large-magnitude signals. To accommodate such large-dynamic-range signals linearly, the PA must work at an operating point, $P_{o,avg}$, that is quite inefficient in terms of power consumption. Namely, a large output back-off (OBO), must be implemented. The output back-off is defined as the output saturation power to the average output power of a PA,

$$OBO = 10\log_{10}\frac{P_{o,max}}{P_{o,avg}}(\mathrm{dB}) \qquad (3)$$

To reduce the PAPR, many approaches have been proposed. Clipping and windowing the peak signals exceeding some threshold are one of the possible solutions. However, they may introduce in-band distortion and out-of-band radiation. Some suggested using coding techniques. Depending on the input data, the signals to be modulated on all the subcarriers are chosen from a set of code words that corresponds to waveforms with a lower PAPR. The drawback of the coding techniques is the overhead in transmission efficiency. Scrambling codes can also be adopted to destroy signal regularity, which can incur a high PAPR. In yet another method, the transmitted signals are carefully adjusted by convex optimization to minimize APR under the constraints of allowable constellation error and out-of-band energy.



## IV. Companding Algorithm

### *µ-Law Companding*

µ −Law is a simple but effective companding technique to reduce the peak-to-average power ratio of orthogonal frequency-division multiplexing signal. The idea comes from the use of companding in speech processing. Since orthogonal frequency-division multiplexing signal is similar to speech signal in the sense that large signals only occur very infrequently, the same companding technique might be used to improve OFDM transmission performance.

A QAM-OFDM system diagram is shown in Figure .1. The incoming bit stream is packed into x bits per symbol to form a complex number $S_k$ where x is determined by the QAM signal constellation. For a real sequence output at the IDFT, the complex input to the IDFT has Hermitian symmetry and is constrained as follows

$$S_{N-K} = S_k \qquad (1)$$

Where k=0, 1, 2……… (N/2)-1, and S(0)=0.

Suppose N is even and $S_k = a_k - jb_k$

$$S(n) = \frac{1}{\sqrt{N}}\sum_{k=1}^{\frac{N}{2}-1}\left(a_k\cos\frac{2\pi kn}{N} + b_k\sin\frac{2\pi kn}{N}\right) \qquad (4)$$

$$n = 0, 1, 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots, N-1$$

The µ law companding technique can be then introduced. The samples of OFDM signal s(n) are companded before it is converted into analog waveform. The signal after companding is given by

$$S_c(n) = \frac{A sgn(s(n)) ln\left[1+\mu\left|\frac{s(n)}{A}\right|\right.}{\ln(1+\mu)} \qquad (5)$$

'A' is normalization constant, after D/A conversion the signal transmitted through channel. At the receiver end, received signal first converted into digital form, the sampling result is

$$s(n) = S_c(n) + q(n) + w(n) \qquad (6)$$

Where q is analog to digital conversion error and w is AWGN channel factor. The expanded signal can be approximated as:

$$S'(n) \approx s(n) + \frac{[q(n)+w(n)]AB}{\mu} + S(n)[q(n) + w(n)]B \qquad (7)$$

## V. Results And Discussion

The parameter of simulation are given without companding as follows

- Modulation scheme : BPSK ,QPSK,QAM-8
- MIMO encoding scheme : Alamouti
- No. of transmitter antenna :2
- No. of receiver antenna :2
- Channel coding : Convolution code
- Channel : Rayleigh fading channel
- Equalizer : Zero forcing
- Performance parameter: BER, spectral efficiency and CCDF with SNR and PAPR respectively.
- BER threshold for Adaptive Modulation scheme : 10-2

The various results are obtained after the simulation. The results are given as follows,

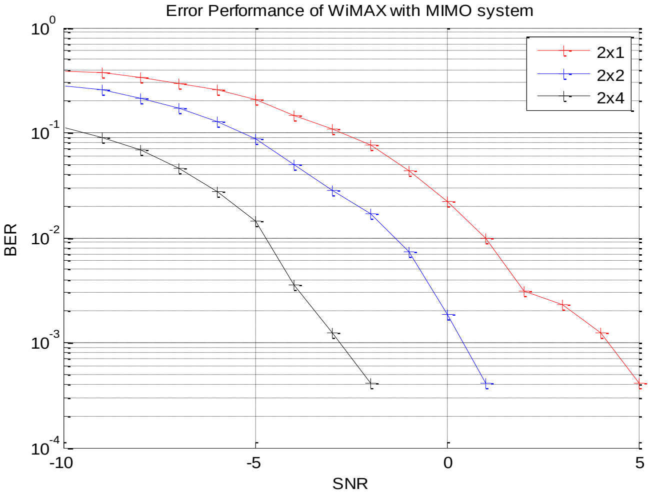


**Fig. 2. BER for different modulation scheme for MIMO WiMAX for 2x2 antenna scheme**

These graph shows performance of BER over Snr. Snr increases BER is decreases when the no. of anteena is incereases by keeping BER threshold for Adaptive Modulation scheme : 10-2 constant

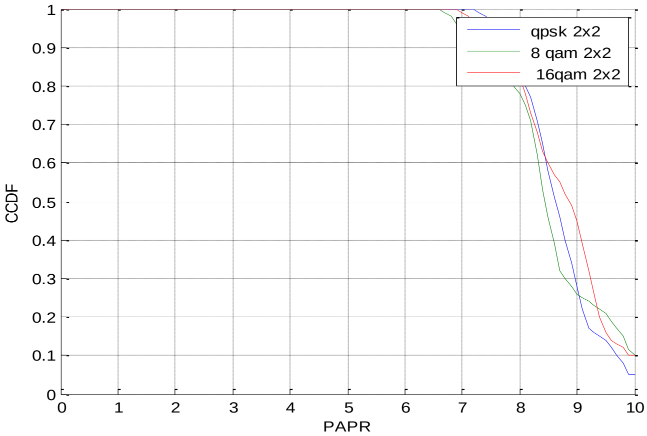


**Fig. 3. CCDF vs PAPR for different modulation scheme for WiMAX**

These Figure Shows that if some variation occur in CCDF for different modulation Scheme like Qpsk,8QAM,16QAM for Same anteena then PAPR is reduce .when we compare these modulation Scheme we find that maximum reduction of PAPR in 16QAM modulation scheme for same anteena

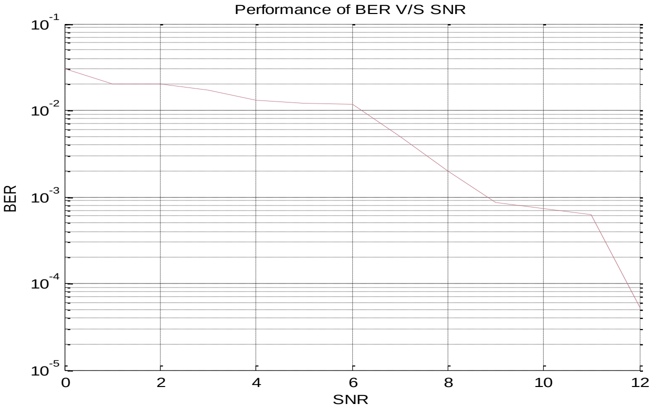


**Fig. 4. Spectral efficiency for Adaptive modulation scheme for MIMO WiMAX for 2x2 antenna scheme**

These graph shows that variation in SNR with BER. BER is reduce when SNR is increases so Spectral efficiency for Adaptive modulation Scheme is increases.

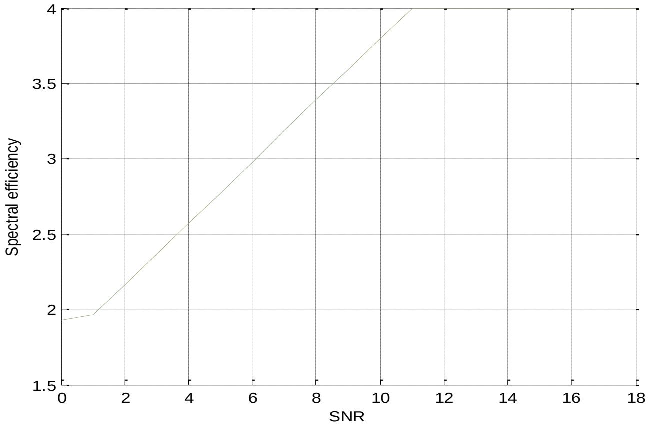


Fig. 5. **Performance of spectral efficiency Vs SNR**

These graph shows performance of Spectral efficiency over Snr. Snr increases Spectral efficiency is increases by keeping BER threshold for Adaptive Modulation scheme : 10-2 constant

PERFORMANCE OF ADAPTIVE MODULATION FOR MIMO WIMAXFOR 2X2 ANTENNA SCHEME

| S.No. | Modulation Scheme | SNR range |
|---|---|---|
| 1 | QPSK | Less than4 |
| 2 | QAM-8 | Between4and 10 |
| 3 | QAM-16 | Greater than 10 |

## VI. DISCUSSION WITH COMPANDING

The parameter of simulation are given as follows

- Modulation scheme : BPSK ,QPSK,QAM-8
- MIMO encoding scheme : Alamoutis
- No. of transmitter antenna :2
- No. of receiver antenna :2
- Channel coding : Convolution code
- Channel : Rayleigh fading channel
- Equalizer : Zero forcing
- Performance parameter: BER, spectral efficiency and CCDF with SNR and PAPR respectively.

- BER threshold for Adaptive Modulation scheme : $10^{-2}$

The various results are obtained after the simulation. The results are given as follows,

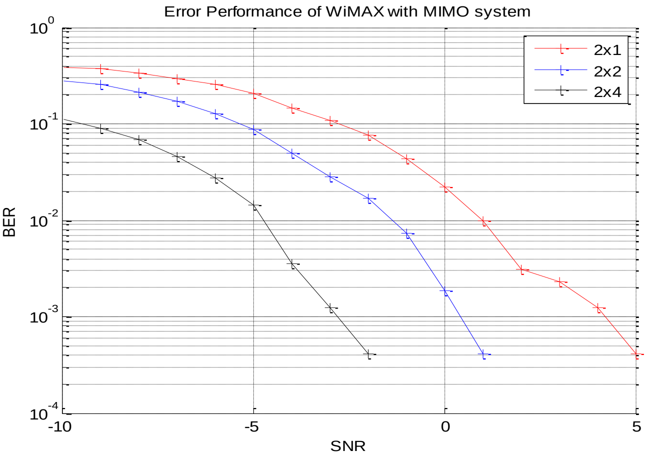


**Fig. 6. BER for different modulation scheme for MIMO WiMAX for 2x2 antenna scheme**

These graph shows performance of BER over Snr. Snr increases BER is decreases when the no. of anteena is inceases by keeping BER threshold for Adaptive Modulation scheme : 10-2 constant with companding

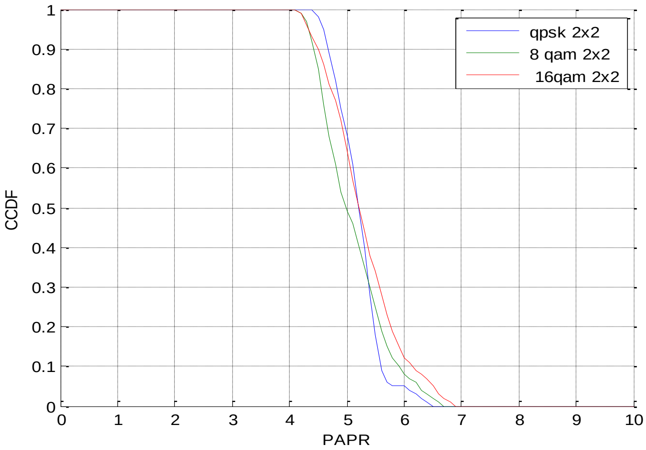
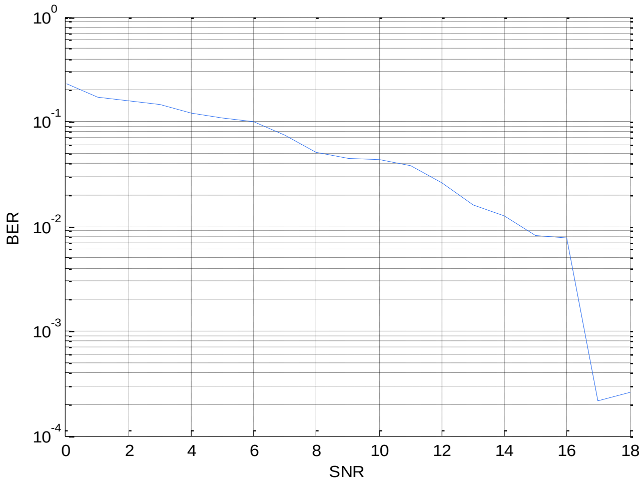


**Fig. 7. CCDF vs PAPR for different modulation scheme for WiMAX.**

These Figure Shows that if some variation occur in CCDF for different modulation Scheme like Qpsk,8QAM,16QAM for Same anteena then PAPR is reduce .when we compare these modulation Scheme With companding we find that maximum reduction of PAPR in 16QAM modulation scheme for same anteen



**. Fig. 8. BER curve for Adaptive modulation scheme for MIMO WiMAX for 2x2 antenna scheme**

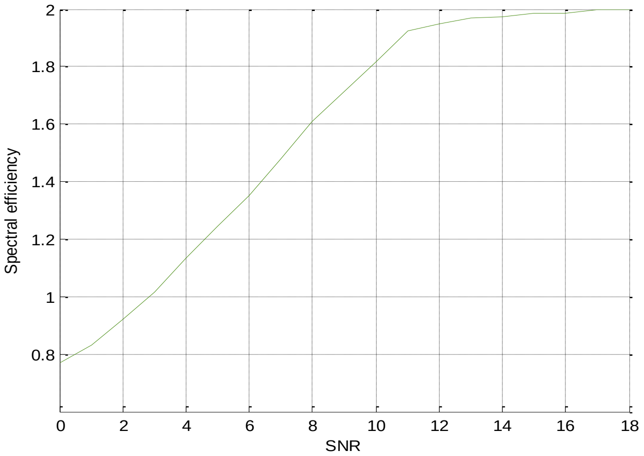


**Fig. 9. Spectral efficiency for Adaptive modulation scheme for MIMO WiMAX for 2x2 antenna scheme**

These graph shows performance of Spectral efficiency over Snr. Snr increases Spectral efficiency is increases by keeping BER threshold for Adaptive Modulation scheme : 10-2 constant with companding

**Table II Performance of adaptive modulation for MIMO WiMAX for 2x2 antenna scheme**

| S. No. | Modulation Scheme | SNR range |
|---|---|---|
| 1 | QPSK | Less than5 |
| 2 | 8QAM | Between4and 9 |
| 3 | 16QAM | Greater than 11 |

## VII. CONCLUSION

In this paper, performance enhancement of OFDM system is done with PAPR Companding algorithm. We present in the first part an analysis of the PAPR reduction method which isμ-law Companding algorithm. μ-law companded signal shows improvement in PAPR than non-companded signal. Exponential companding scheme offers better improvement in PAPR among all these techniques as it adjusts both large and small peaks. Thus by using airy companding scheme we can offer improved BER while reducing PAPR effectively.

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