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Optimaization of PAPR using Non-Linear Companding with Weighting Function for MIMO-OFDM Systems

Rebba Chandra Sekhar, D. Nagamani

ABSTRACT--- *Orthogonal Frequency Division Multiplexing (OFDM) is a key wireless broadband technology employed in Long Term Evaluation (LTE), LTE -Advanced (LTE-A) and World Wide Interoperability for Microwave Access (WiMAX) cellular standards. Multi carrier modulated systems (MCM) is the fundamental principle for OFDM where the wideband frequency selective channels are splited into narrow band frequency flat faded channels, results in reducing Inter Symbol Interference (ISI). OFDM offers several advantages like orthogonality and low complexity at the transmitter and receiver by replacing number of modulators/de modulators by Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) respectively. The motivation behind MIMO is high data rate. High data rate communication link with transmission rates 1Gigabits/sec or more. That barrier can be achieved using the conventional SISO configuration at the cost of much power and much bandwidth. MIMO-OFDM is the solution to above problems and provides enormous data rates and channel quality without premium on bandwidth and power. One of the major drawbacks of MIMO-OFDM system is high Peak to Average Power Ratio. The high PAPR causes signal clipping which leads to information loss and inter carrier interference. In this paper weighting function with Non-linear companding technique (mu-law) is used to optimize the PAPR for MIMO-OFDM systems. Weighting function is pulse shaping function which consist of smooth shape with low frequency components and should not interfere with transmitted bits. Simulation results are performed in MATLAB; Results shown that by choosing proper weighting function with mu-law value the PAPR of OFDM system is effectively decreased.*

Keywords—MIMO, LTE, OFDM, LTE-A, PAPR, WIMAX, Precoding, BER, mu-law companding, CCDF

I. INTRODUCTION

Multipath fading and lower data rate are some of the key limitations in wireless communication. In typical outdoor conventional single carrier communication system produces large delay spread which increases inter symbol interference. The basic key principle for multi carrier modulation is reducing ISI by increasing symbol time. In conventional Frequency Division Multiplexing two or more number of signals is transmitted simultaneously through single communication channel [1, 2]. In order to reduce inter carrier interference and ISI at the receiver side in FDM we provide a guard band in between different symbols/carriers. This provision of extra guard band leads to inefficient bandwidth utilization. OFDM is a promising technique to increase the bandwidth utilization by orthogonality principle, where the wideband frequency selective channels are splited into narrow band frequency flat faded channels, results in reducing Inter Symbol Interference (ISI). Orthogonal carriers achieve spectral efficiency and multicarrier modulation combats over multipath fading effects. Eventually OFDM is one which provides high data rate transmission in multipath fading environment effectively [3, 4, 5].

MIMO is the theme of current research and it is a technology of next generation wireless networks. MIMO provides enormous data rates and channel capacity without increasing bandwidth and power. OFDM when combined with MIMO enhances the system performance on frequency selective fading environment and provides higher data rates. One of the applications of MIMO-OFDM is WIMAX [6].

The performance of OFDM is mainly limited by its large PAPR. When all the subcarriers are combined in phase results in high PAPR. Several PAPR reduction schemes were discussed in the literature. Some of the techniques are block coding, clipping with filtering, tone reservation and selected mapping [7, 8]. However, most of the techniques need coding overhead or side information at the transceiver. In this paper weighting with non linear companding technique is proposed to reduce high PAPR. Weighting function technique doesn't need any side information and also it preserves the character of OFDM.

The remaining paper is organized as follows. In section II system model is explained. Section III gives proposed method. The simulations results are analyzed in section IV. Conclusion remarks are given in section V.

II. SYSTEM MODEL

In this paper, MIMO-OFDM system with BPSK modulation and N modulated symbols per OFDM block is considered. The block diagram of weighting function MIMO-OFDM Transmitter and receiver sections are shown in fig.1.

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Rebba Chandra Sekhar Assistant Professor, Dept of ECE Anil Neerukonda Institute of Technology and Sciences (Autonomous) Sangivalasa, Bheemunipatnam Visakhapatnam, A.P, India.-531162 (E-mail: chandrasekhar.ece@anits.edu.in)

D. Nagamani Assistant Professor, Dept of ECE, Anil Neerukonda Institute of Technology and Sciences (Autonomous), Sangivalasa, Bheemunipatnam Visakhapatnam, A.P, India-531162 (E-mail: nagamani.ece@anits.edu.in)

K. Rushendra Babu Assistant Professor, Dept of ECE Gudlavalleru Engineering College (Autonomous), Gudlavalleru ,Gudivada Krishna District, A.P, India -521356 (E-mail: rushendrababu.k@gmail.com)

K.Yashoda Assistant Professor, Dept of ECE Anil Neerukonda Institute of Technology and Sciences (Autonomous) Sangivalasa, Bheemunipatnam Visakhapatnam, A.P, India -531162 (E-mail: yashoda.k225@gmail.com)

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Multi carrier modulated systems (MCM) is the fundamental principle for OFDM where the wideband frequency selective channels are splited into narrow band frequency flat faded channels, results in reducing Inter Symbol Interference (ISI). The information source generates random data this data is converted in to parallel streams using S/P.

$$X=[X_{0,} X_{1,} X_{2}\ldots\ldots, X_{N-1}] \tag{1}$$

Where X= Serial Data

The parallel converted data is modulated using BPSK modulator after that it is applied to a weighting function Weighting function is pulse shaping function which consist of smooth shape with low frequency components and should not interfere with transmitted bits.

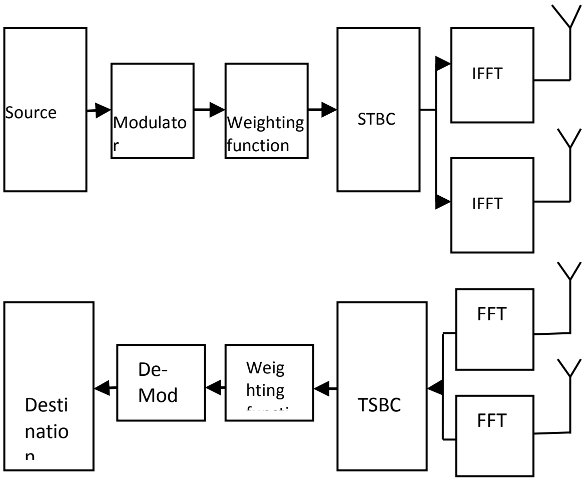

Fig.1. Block diagram of weighting function MIMO-OFDM System

A. Weighting function

Weighting function is pulse shaping function and obeys the following characteristics.

(i). should consist of smooth shape with low frequency components, and

(ii). should not interfere with transmitted bits (no inter symbol interference).

We have investigated some of the pulse shaping functions: Rectangular Weighting function, Sinc weighting function, raised cosine weighting function and square root raised cosine weighting function. Square root raised cosine function is a compromise in between rectangular weighting function and sinc function because it requires less bandwidth compared to rectangular weighting and it has smoother shape compared to sinc weighting function. The square root raised cosine function is given as

. (2)

$$P_{src}(f)=\begin{cases} T_s \sin\left(\frac{\Pi f T_s}{2\beta}\right), & 0 \prec f \le \frac{\beta}{T_s} \\ T_s, & \frac{\beta}{T_s} \le f \le \frac{1}{T_s} \\ T_s \sin\left[\frac{\Pi \left(f \quad T_s -1\right)}{2\beta} + \frac{\Pi}{2}\right], & \frac{1}{T_s} \prec f \le \frac{1}{T_s} \end{cases}$$

Where

T_s = OFDM symbol time period

f = Frequency of the OFDM signal

β = Roll off factor

B. Precoding matrix

A precoding matrix is formed by using square root raised cosine function. A precoding matrix is a matrix which satisfies the following properties. (i). It should be orthogonal, (ii).The origination of the precoding matrix are correlate to each other.

$$P{*}P=I \tag{3}$$

Where P^{*} represents Hermition transpose of 'P' matrix and 'I' is the N x N identity matrix and precoding matrix is given as

$$P=\begin{bmatrix} P_{0,0} & \cdots & P_{0,N-1} \\ . & . & . \\ . & . & . \\ . & . & . \\ P_{L-1,0} & \cdots & P_{L-1,N-1} \end{bmatrix} \tag{4}$$

Where $P_{i,j}$ show the origination of the precoding matrix. By using the SRRC weighting function the origination of the precoding matrix becomes,

$$P_{i,m}=P_{i,0} \quad e^{-j2\Pi \quad \frac{im}{N}} \tag{5}$$

Where

$$P_{i,0}=\begin{cases} \frac{(-1)^i}{\sqrt{N}}\sin\left(\frac{\Pi i}{2N_p}\right), & 0 \le i \prec N_p \\ \frac{(-1)^i}{\sqrt{N}}, & N_p \le i \le N \\ \frac{(-1)^i}{\sqrt{N}}\cos\left(\frac{\Pi(i-N)}{2N_p}\right), & N \le i \le L-1 \end{cases} \tag{6}$$

L = Actual number of subcarrier + Extra number of subcarriers

N = Actual number of subcarrier

N_p =Extra number of subcarriers(overhead)

Mapped data is multiplied by weighting function matrix P, then Y become

$$Y = P\times X = [Y_{0,} Y_{1,} Y_{2}\ldots\ldots, Y_{N-1}] \tag{7}$$

Where Y = precoded data

P = precoding matrix X = Modulated data

Space time block coder improves bit error rate performance and provides high data rate by using spatial multiplexing and spatial diversity.

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C. Spatial diversity

In spatial diversity, redundant information is transmitted through different transmitting antennas which lead to increase the diversity of the MIMO

D. Spatial multiplexing

In spatial multiplexing, total transmitted data is divided into several sub data's every sub data is transmitted by using different transmitting antennas in the same frequency slot. Spatial multiplexing improves data through put and channel capacity.

After multiplying the modulated data with a precoding matrix the same is applied to IFFT. The equation of IFFT is given as

$$Y(n) = \frac{1}{N}\sum_{k=0}^{N-1} Y(k)\, e^{j2\pi nk/N} \tag{8}$$

Finally the PAPR of modulated data is calculated by using following equation

$$PAPR\{Y(n)\} = \frac{\max\left|Y(n)\right|^2}{E\left[\left|Y(n)\right|^2\right]} \tag{9}$$

E. Non Linear Companding

Large PAPR and dynamic range of the transmitted signal caused very high distortion across the channel. Companding technique is one which compressing or reducing the large signals and expansion small signal before it pass through channel. In this paper companding with weighting function technique is proposed to reduce the high PAPR of the transmitted signal and at the receiver side replica operation (expanding) is performed to extract the original information. The following fig.3 shows the non-linear companding scheme for MIMO-OFDM.

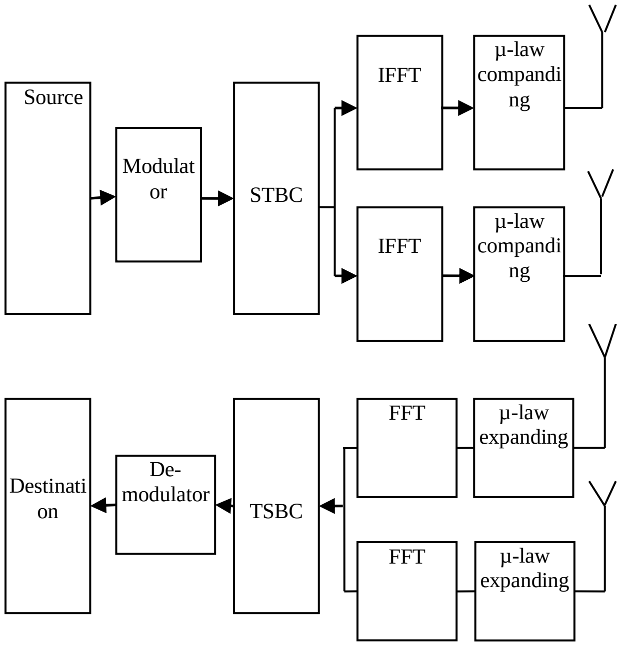

Fig.2. Non-linear companding scheme for MIMO-OFDM

The Non-linear companding property of mu-law can be expressed as,

$$\mathrm{C}_u(t) = \frac{In\left[1+\mu\frac{\|c(t)\|}{c_{\max}(t)}\right]}{In[1+\mu]} * c_{\max}(t) * \mathrm{sgn}(c(t)) \tag{10}$$

At the receiver compressed signal is expanded using following formula,

$$C'_u(t) = \left[\exp\left(\frac{\left(\left|c_u(t)\right|\log(1+\mu)\right)}{c_{\max}(t)}\right) - 1\right] * \frac{c_{\max}(t)}{\mu} * \mathrm{sgn}(c_u(t)) \tag{11}$$

Where, mu is the comparator value larger the value high compression is possible and lower the value low compression is possible.

C (t) is input signal instantaneous amplitude

$C_{\max}$ (t) is the peak amplitude of C (t)

Sgn is a Sign function.

III. PROPOSED METHOD

Weighting function with non-linear companding method is introduced to mitigate large PAPR. The generated data from the source is in serial form, Serial to parallel converter converts this serial data into multiple parallel streams, this parallel data streams are modulated by modulator then it is precoded and passed to STBC coder finally it is passed through IFFT block which gives equation (8).

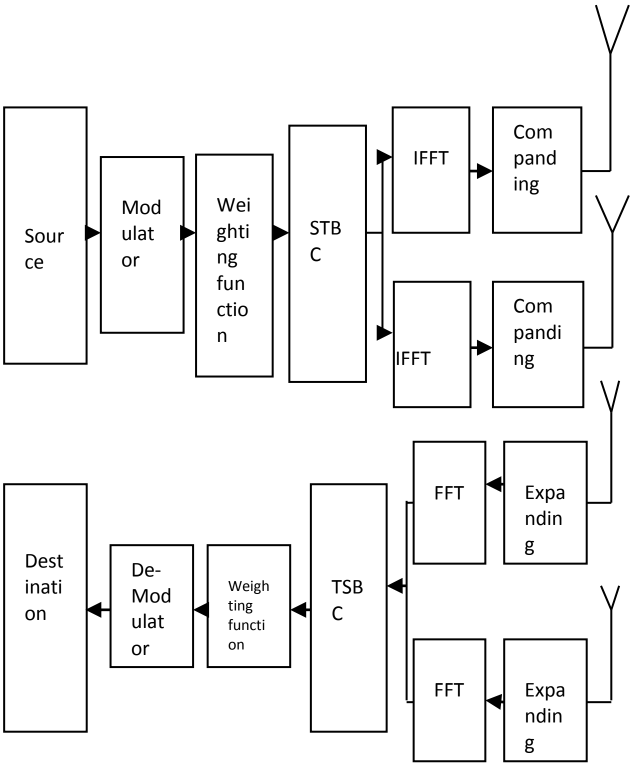

Fig.3. Block diagram of weighting function with mu-law companding MIMO-OFDM System

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Now this complex signal is passed through a mu law comparator which compress the high dynamic and PAPR of the signal at desired level. From equation (9), the new compressed signal is expressed as (let assume S(t) is the complex signal)

$$S_u(t) = \frac{In\left[1+\mu\frac{\|s(t)\|}{s_{\max}(t)}\right]}{In[1+\mu]} * s_{\max}(t) * \operatorname{sgn}(s(t)). \qquad (12)$$

At the receiver compressed signal is expanded using following formula,

$$S'_u(t) = \left[\exp\left(\frac{\left(|S_u(t)|\log(1+\mu)\right)}{S_{\max}(t)}\right) - 1\right] * \frac{S_{\max}(t)}{\mu} * \operatorname{sgn}(S_u(t)) \qquad (13)$$

This expanded signal is passed through FFT and STBC which provides space diversity and time synchronization. Finally it is multiplied by inverse whieghting function followed by demodulation using demodulator and original information received at the destination side.

IV. SIMULATION RESULTS

MATLAB simulation tool is used to evaluate the MIMO-OFDM system with different techniques. The following table shows the simulation parameters

Parameter	Value
Total Number of sub carriers	128
NIFFT Size	128
Modulation Type	BPSK
Weighting Function (Beta values)	0.1&0.5
Comapnding Ratio (mu values)	25,50,75&100
SNR Range	0-25

Table.1 Simulation parameters

A. CCDF plots

A Complementary cumulative distribution function curve is basically a plot of average power levels versus probability. CCDF curves are used to know the power characteristics of a signal. In this paper CCDF curves have been plotted to know the power distributions and PAPR values of OFDM signals and are shown in below.

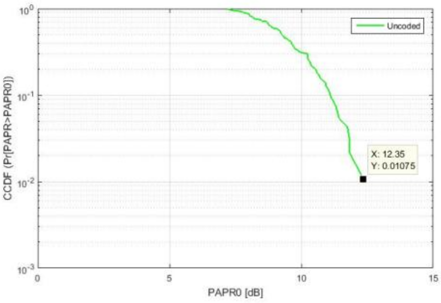

Fig.4. Conventional MIMO-OFDM System (Uncoded)

Fig.4 Illustrates the CCDFs of conventional MIMO-OFDM system. From the figure it is clearly observed that in Conventional MIMO-OFDM system produces large PAPR value. For example at CCDF=10^{-2} the PAPR value in Conventional MIMO-OFDM system is 12.35 dB.

Fig.5 Illustrates the CCDFs of weighting function (Beta=0.1) with companding (mu=25 and 50) MIMO-OFDM system. From the figure we can observe that weighting function technique with beta=0.1 produce large PAPR value when compared to combination of weighting function with mu law technique. For example at CCDF=$10^{-2.4}$ the PAPR value in weighting function with beta=0.1 MIMO-OFDM system is 9.92 dB, at same CCDF=$10^{-2.4}$ the PAPR value in weighting function with mu law companding for mu=25 and mu=50 are 4.468dB and 2.701dB respectively.

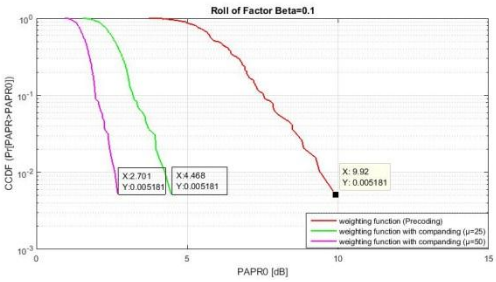

Fig.5. Weighting Function (Beta=0.1) with Companding (mu=25 and 50) MIMO-OFDM System

Scheme	PAPR in dB
Weighting Function with Beta=0.1	9.92 dB
Combination of weighting function with mu law companding mu=25	4.468dB
Combination of weighting function with mu law companding mu=50	2.701dB

Table.2 Optimized PAPR values of MIMO-OFDM System by weighting function (Beta=0.1) and Combination of weighting function with non linear companding (mu=25 & 50)

Fig.6 shows the CCDFs for weighting function (Beta=0.5) with companding (mu=25 and 50) MIMO-OFDM system. From the figure we can observe that weighting function technique with beta=0.5 produce large PAPR value when compared to combination of weighting function with mu law technique. For example at CCDF=10^{-2} the PAPR value in weighting function with beta=0.5 MIMO-OFDM system is 4.809 dB, at same CCDF=10^{-2} the PAPR value in weighting function with mu law companding for mu=25 and mu=50 are 2.068dB and 1.438dB respectively.

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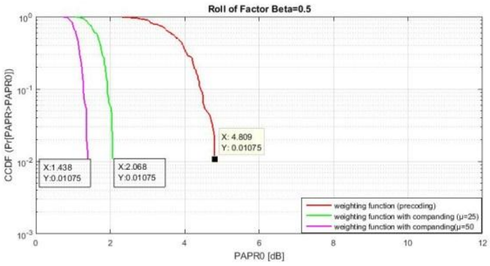

Fig.6. Weighting Function (Beta=0.5) with Companding (mu=25 and 50) MIMO-OFDM System

Scheme	PAPR in dB
Weighting Function with Beta=0.5	4.809 dB,
Combination of weighting function with mu law companding mu=25	2.068dB
Combination of weighting function with mu law companding mu=50	1.438dB

Table.3 Optimized PAPR values of MIMO-OFDM System by weighting function (Beta=0.5) and Combination of weighting function with non linear companding (mu=25 & 50)

Fig.7 shows the CCDFs for weighting function (Beta=0.1) with companding (mu=75 and 100) MIMO-OFDM system. From the figure we can observe that weighting function technique with beta=0.1 produce large PAPR value when compared to combination of weighting function with mu law technique. For example at CCDF=10^{-2} the PAPR value in weighting function with beta=0.1 MIMO-OFDM system is 8.505 dB, at same CCDF=10^{-2} the PAPR value in weighting function with mu law companding for mu=75 and mu=100 are 3.361dB and 1.985dB respectively.

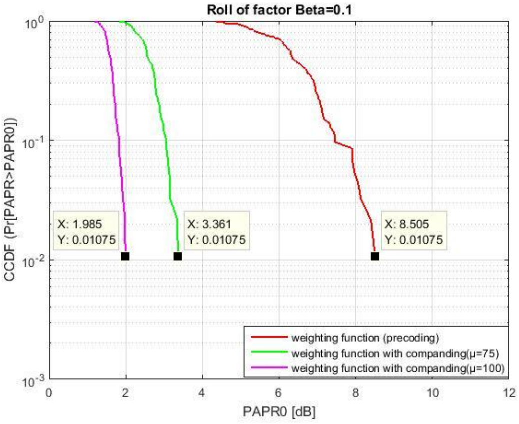

Fig.7. Weighting Function (Beta=0.1) with Companding (mu=75 and 100) MIMO-OFDM System

Scheme	PAPR in dB
Weighting Function with Beta=0.1	8.505 dB
Combination of weighting function with mu law companding mu=75	3.361dB
Combination of weighting function with mu law companding mu=100	1.985dB

Table.4 Optimized PAPR values of MIMO-OFDM System by weighting function (Beta=0.1) and Combination of weighting function with non linear companding (mu=75 & 100)

Fig.8 Illustrates the CCDFs of weighting function (Beta=0.5) with companding (mu=75 and 100) MIMO-OFDM system. From the figure we can observe that weighting function technique with beta=0.5 produce large PAPR value when compared to combination of weighting function with mu law technique. For example at CCDF=10^{-2} the PAPR value in weighting function with beta=0.5 MIMO-OFDM system is 4.752 dB, at same CCDF=10^{-2} the PAPR value in weighting function with mu law companding for mu=75 and mu=100 are 1.668dB and 1.163dB respectively.

Scheme	PAPR in dB
Weighting Function with Beta=0.5	4.752 dB
Combination of weighting function with mu law companding mu=75	1.668dB
Combination of weighting function with mu law companding mu=100	1.163dB

Table.4 Optimized PAPR values of MIMO-OFDM System by weighting function (Beta=0.5) and Combination of weighting function with non linear companding (mu=75 & 100)

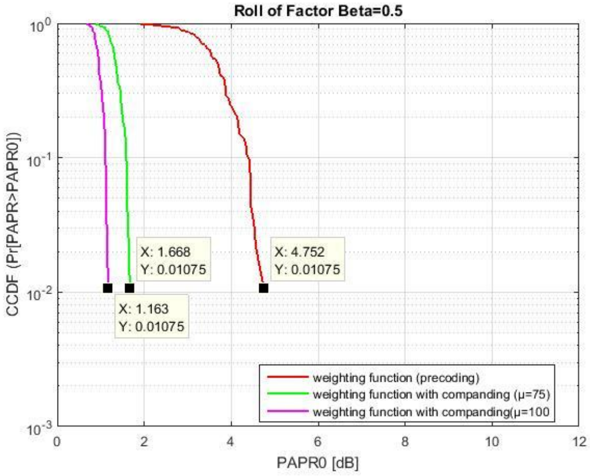

Fig.8. Weighting Function (Beta=0.5) with Companding (mu=75 and 100) MIMO-OFDM System

B. BER Performance

Fig.9 Illustrates the BER Performance of MIMO-OFDM System with different techniques as a function of Signal to Noise Ratio in X-axis and Bit Error Rate in Y-axis. From the figure we can observe that BER somewhat effects when we increasing the compression ratio. For example at E_b/N_o=10 the Conventional or Theoretical or uncoded BER is 0.02327, at same E_b/N_o=10 the BER value in weighting function with beta=0.1and weighting function beta=0.1 with companding technique mu=25 are 0.006636 and 0.001599. It clearly shows that there is a small BER decrement when compression mu value and weighting function beta value increment. But the users/designers use the optimized mu and beta value for high reduction in PAPR with less BER effect.

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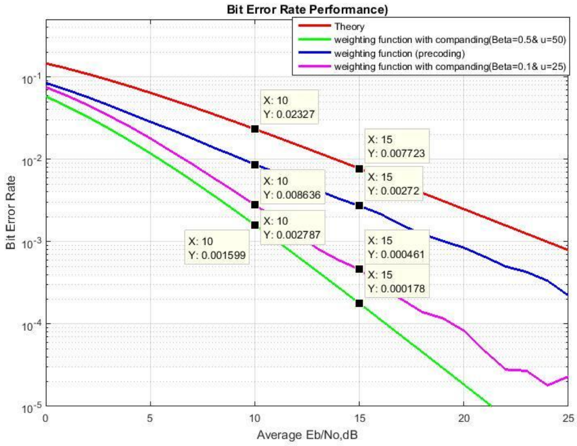

Fig.9. BER Characteristics of MIMO-OFDM System with different techniques

V. CONCLUSION

In this paper a new technique named as weighting function with companding is proposed to reduce high PAPR. From the analysis of the simulation results we can observe that uncoded MIMO-OFDM system produces large PAPR value when compared to weighting function and combination of weighting function with comapanding techniques, when Beta and mu value increases the PAPR decreases. From BER point of view it clearly shows that there is a small BER decrement when compression mu value and weighting function beta value increment. But the users/designers use the optimized mu and beta value for high reduction in PAPR with less BER effect.

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