Performance Analysis of OFDM-based Massive MIMO Downlink System

Padarti Vijaya Kumar, Venkateswara Rao Nandanavanam

Abstract: ***Massive MIMO systems are the key technology for evolution of 4G, 5G standards in telecommunication environment. One of the major limitations in OFDM based massive multiple-input multiple-output (MIMO) downlink system is peak to average power ratio (PAPR). Transmitting symbol vectors to different set of users, the main idea is estimate the low PAPR OFDM modulated signal with reduced multi user interference. Many techniques were used to mitigate the PAPR problem, but they consume more computational time, particularly in Massive MIMO systems. The proposed ETG (Expectation maximization Truncated Gaussian mixture Generalized approximate passing) employs truncated Gaussian mixture prior to get low PAPR signal. To understand the prior signal, expectation step helps in identifying hidden variables; maximization step helps in identifying deterministic parameters. Generalized approximate passing is applied to mitigate the computational complexity. Numerical simulated results in comparison with existing techniques suggests that desired level of PAPR is achieved with less computation time with minute degradation in symbol error rate(SER).By choosing proper normalization we can achieve same SER with reduced PAPR.***

Keywords: MIMO, PAPR, MASSIVE MIMO OFDM, ETG, MUI, OBR and CCDF

I. INTRODUCTION

Massive MIMO is the upcoming technology for next generation of wireless data networks and 5G communications. Massive MIMO technology, where the Base Stations (BSs) consists of huge number of antennas so as to reach multiple orders of spectral and energy efficiency gains will be a fundamental technology enabler for 5G. It enhances the spectral efficiency with more numbers of antennas located at the base station at a time, serving a much smaller number of single-antenna users sharing the same time-frequency bandwidth. These systems also substantially improve the energy efficiency which enables the use of less expensive and low-power components. In the future massive MIMO technology brings substantial changes to upcoming wireless systems. In practice the constraint frequency selective fading (FSF) severely deteriorates the Broadband wireless communications. OFDM modulation has the potential to combat FSF by transforming the digital symbol data on separate sub-carrier frequencies to communicate information among the users. The PAPR is one of the factors which severely reduces data rate of the OFDM systems, also it affects RF amplifier efficiency. To reduce inband and out-of-band radiation PAPR mitigation is essential. If antennas increase, it is highly impractical to implement. So reducing PAPR in Massive MIMO-OFDM systems can reduce the cost of hardware and also can improve power efficiency. To reduce PAPR several techniques were used at single-input single-output (SISO) OFDM wireless systems,. The techniques are clipping, filtering, tone reservation (TR) active constellation extension (ACE) , selected mapping (SLM), partial transmission sequence (PTS).The above mentioned schemes hold good for point-to-point MIMO systems, but not suitable for extending to the MU-MIMO systems. Straightforward implementation is not possible, practical implementation at the joint receiver-side is highly impossible, because the users are distributed. New techniques like FITRA were developed and used to control PAPR level in massive MIMO-OFDM systems .This FITRA algorithm exhibits good PAPR reduction, with low convergence rate. Peak signal clipping scheme gives low computational complexity but PAPR mitigation is not that efficient and reserved antennas using for back up can generate huge PAPR effect. ZF precoding and convex optimization exploits the null spaces of massive MU-MIMO OFDM channels based on a linear constrained optimization problem. We applied Bayesian process model to find the parameters automatically with a good balance between desired solution and data fitting error. Also we utilized quasi-constant magnitude solution with finite boundaries to reduce PAPR problem. Truncated Gaussian mixture model is applied as prior model for reducing PAPR followed GAMP strategy which has ability to reduce computational complexity. Expectation step is used to for updating of hidden parameters and maximization step is applied for updating of deterministic parameters. The hybrid algorithm set up is going to reduce PAPR level, so that data rate increases. The precoding helps in reducing MUI and OBR.The hybrid ETG algorithm works well under wireless indoor and outdoor environments where scattering level is high. Applying big O notation strategy to compute the computational complexity ETG is better compared to FITRA algorithm. We used CCDF function for measuring PAPR level which is used for computing PAPR level achievement in later part of the paper.ETG algorithm substantially reduces computation complexity and PAPR level.

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This approach utilizes the exploitation of extra degrees of freedom provided by the excess of service antennas.
Numerical simulated results in comparison with existing techniques suggests that desired level of PAPR is achieved with less computation time with minute degradation in symbol error rate(SER).By choosing proper normalization we can achieve same SER with reduced PAPR. The rest of paper is organized as follows, section 2 presents system model followed by algorithm and mathematical implementation, section 3 gives numerical simulations for a set of specifications performance analysis in terms of comparison parameters and section 4, eventually gives the conclusion part of the paper.

II. SYSTEM MODEL AND PROPOSED FORMULATION

Multiuser Massive MIMO downlink system is considered which serves M users at the output side. We have taken a model in which N transmitter antennas and M users (M<N).The block diagram model is used for exhaustive explanation of working model. Zero-Forcing precoding scheme is exploited to combat the level of multi-user interference (MUI). Wn is considered as the precoded vector, All the precoded vectors are reordered and converted into time domain with transform (IFFT) operation and added up by a cyclic prefix (CP) which can to control the intersymbol interference (ISI).All the symbols are converted into analog signals by DAC.Signals propagated over a FSF channel. At the receiver section the converse process is followed up and signals are transmitted among different M users.

2.1Peak to Average Power Ratio (PAPR)

PAPR provides the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. Simply PAPR is the ratio of peak power to the average power. The PAPR is one of the factors which severely reduces data rate of the OFDM systems, also it affects RF amplifier efficiency. Mathematically it is given as

$$PAPR = \frac{\max imum|\mathrm{mod}\, ulatedsignal|^2}{Expectation\{\|\mathrm{mod}\, ulatedsignal\|^2\}} \tag{1}$$

2.2 Bayesian Inference Methodology:

Multiuser Massive MIMO downlink system is considered which serves M users at the output side. We have taken a model in which N transmitter antennas and M users (M<N).The block diagram is shown which provide step by step process of our system. Zero Forcing precoding technique

is utilized in reducing multi user interferenceMUI and out of band radiation (OBR).

MUI is mathematically given as

$$MUI = \frac{\sum_N \|Modulatedsignals - \Pr ecodedsignals\|^2}{\sum_N \|Modulatedsignals\|^2} \tag{2}$$

OBR is mathematically given as

$$OBR = \frac{|OFDMtones| \sum_N \|\Pr ecodedsymbols\|^2}{\left| |OFDMComplementarytones| \sum_N \|\Pr ecodedsymbols\|^2 \right|} \tag{3}$$

The received vectors R_M consists of

$$R_M = H_N w_N + noise \tag{4}$$

Where H is MIMO channel matrix and w is preceded vectors. Noise vector is assumed as Gaussian distributed over the channel.We applied Bayesian process model to find the parameters automatically with a good balance between desired solution and data fitting error. Also we utilized quasi-constant magnitude solution with finite boundaries to reduce PAPR problem. Truncated Gaussian mixture model is applied as prior model for reducing PAPR followed GAMP strategy which has ability to reduce computational complexity. Expectation step is used to for updating of hidden parameters and maximization step is applied for updating of deterministic parameters. The hybrid algorithm set up is going to reduce PAPR level, so that data rate increases. The precoding helps in reducing MUI and OBR.The hybrid ETG algorithm works well under wireless indoor and outdoor environments where scattering level is high. Applying big O notation strategy to compute the computational complexity ETG is better compared to FITRA algorithm. We used CCDF function for measuring PAPR level which is used for computing PAPR level achievement in later part of the paper.ETG algorithm substantially reduces computation complexity and PAPR level. The specifications we applied in simulation in given in the later part of the paper.

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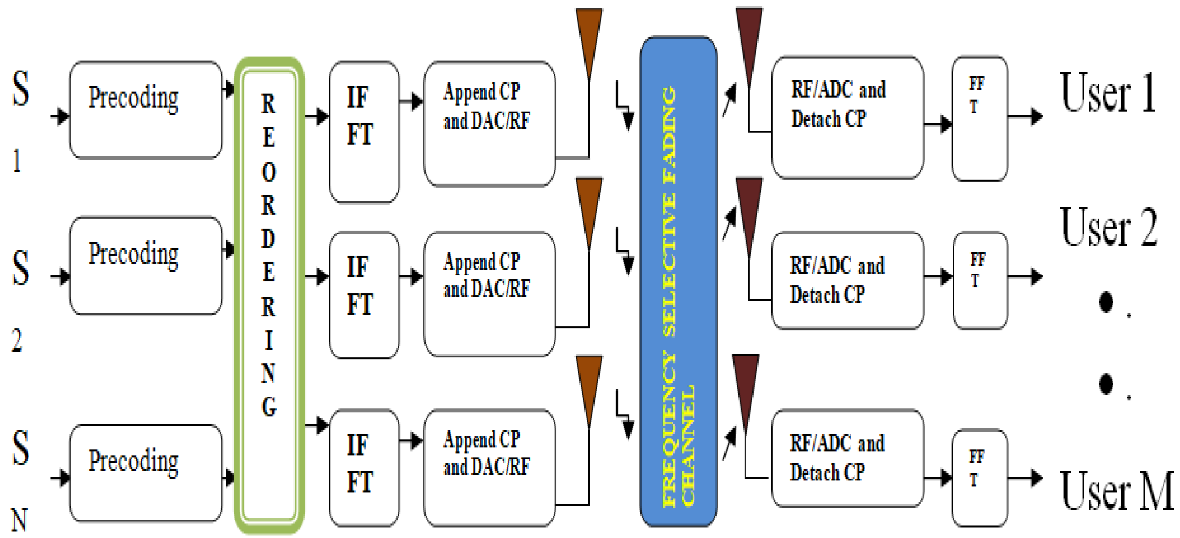

Fig. 1. Block diagram of OFDM based Massive MIMO Downlink System

Implementation of algorithm

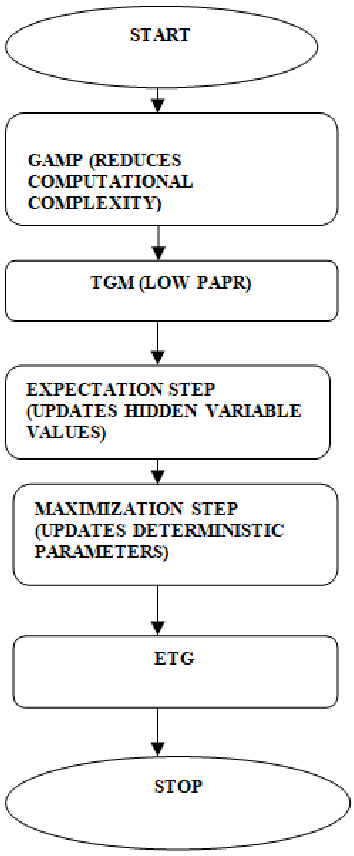

Fig. 2.Implemenation of algorithm

III. PERFORMANCE ANALYSIS

Specifications utilized

Number of antennas at BS	120
Modulation	16-QAM
OFDM Tones	128
Delay Taps	10
Channel	Frequency selective Fading Channel
Optimization algorithm	ETG Algorithm
No of iterations	200
Number of users	20
Software	MATLAB

The proposed model for balancing SER and joint-PAPR in Massive MIMO OFDM downlink system was implemented MATLAB 2018a, and the performance analysis was carried out. For optimizing the SER, joint PAPR, MUI and OBR we have taken the above mentioned simulated parameters. Moreover the performance of the proposed ETG algorithm was compared with existing ZF, Clipping and FITRA algorithms. Our simulated results indicates better balance between joint PAPR and SER and moreover the computation complexity is also minimized .Our algorithm achieved the convergence rate with less number of iterations. Along with the statistical analysis and algorithm analysis was given for final affirmation. Different types of plots were plotted between CCDF and PAPR, SER and SNR, PAPR and number of iterations, MUI and number of iterations and OBR and number of iterations. Performance analysis is compared with different algorithms represented in the form of tables and graphs. CCDF is used as a performance measure for evaluation of PAPR problem. CCDF gives the probability that the PAPR of the signal obtained exceeds a given threshold value mathematically given as

CCDF (PAPR) = Probability (PAPR > Threshold Value) (5)

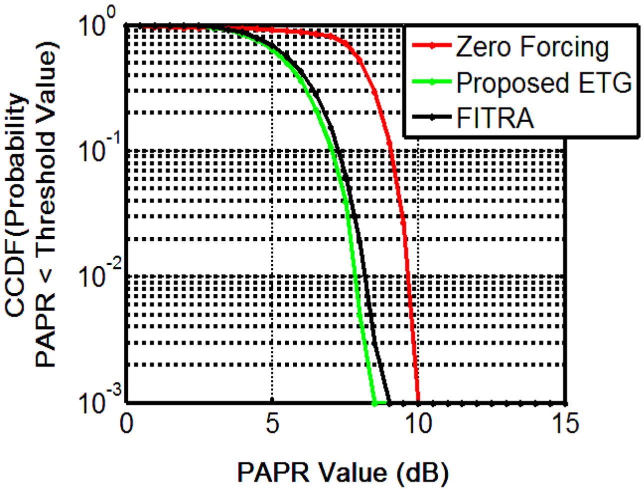

Fig. 3.Complementary Cumulative Distribution Function plots

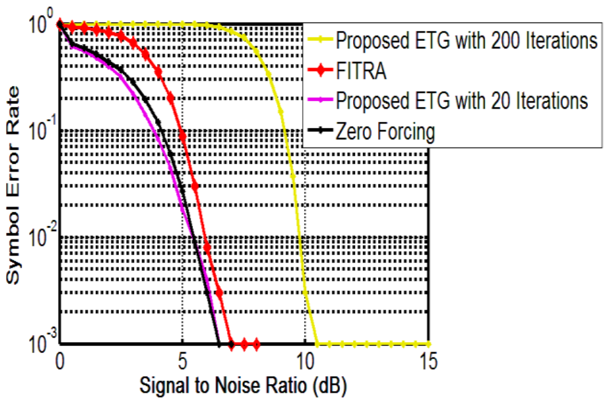

Fig. 4.SER vs SNR

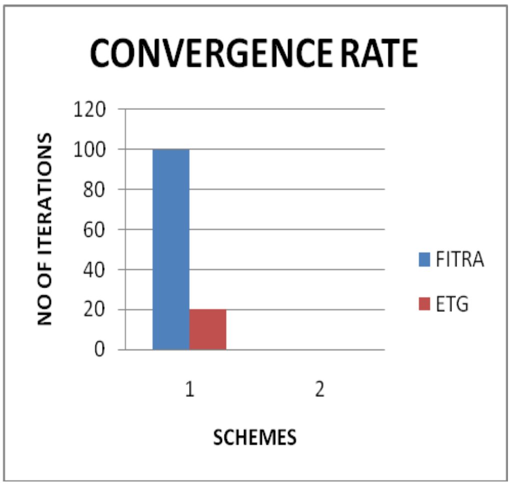

Fig. 5.Convergence rate vs no of iteratons

Table1: Convergence rate for different techniques

PARAMETER	ZF []	FITRA[]	PROPOSED ETG
CONVERGENCE RATE	150 iterations	100 iterations	20 iterations

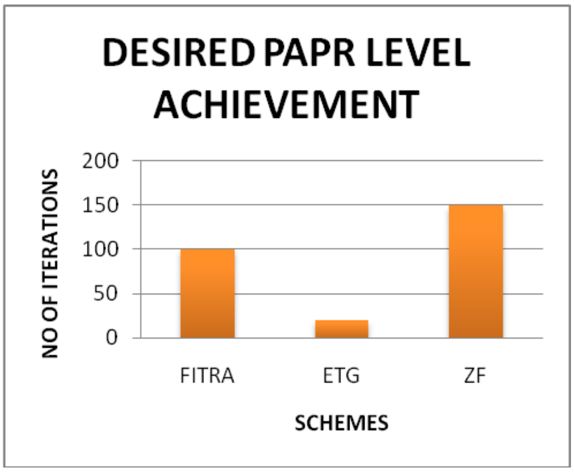

Fig. 6.No of iteratons taken by different schemes to achieve desired papr level

Table2: PAPR achievement in terms of no of iterations

PARAMETER	ZF []	FITRA[]	PROPOSED ETG
DESIRED PAPR LEVEL ACHIEVEMENT	10	9	8

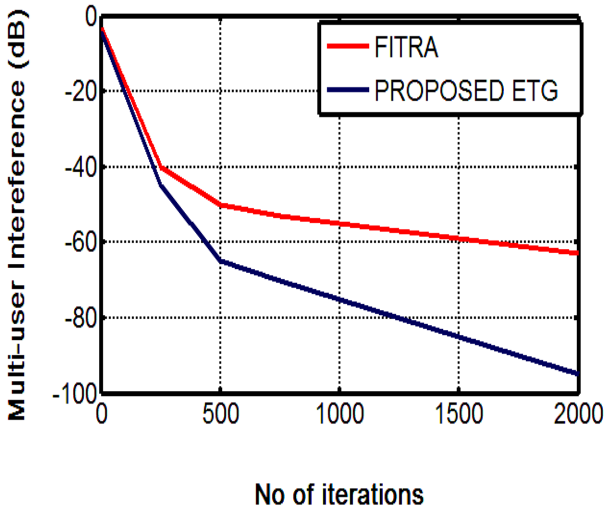

Fig. 7.MUI vs no of iteratons

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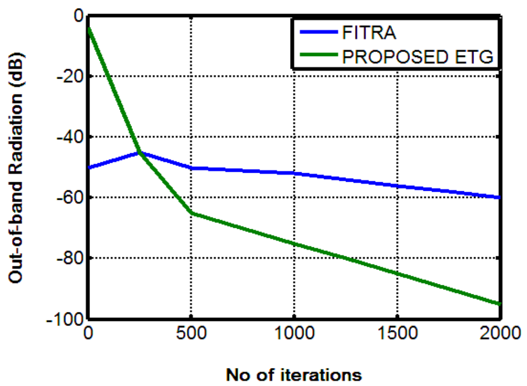

Fig. 8. OBR vs no of iterations

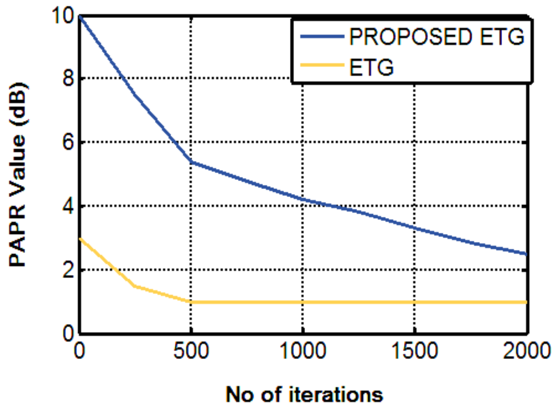

Fig. 9.PAPR vs no of iterations

Table 3: Comparison of algorithms

Scheme	Zero Forcing[6]	FITRA[6]	Proposed ETG
PAPR(dB)	10.11	7.67	5.33

Graphical simulated and statistical results shows that our proposed ETG algorithm exhibits lowest PAPR of 0.65 dB FITRA PAPR is 2.24dB and clipping PAPR is 4.23dB and ZF scheme PAPR of 9 dB.

IV. CONCLUSION

OFDM based massive mimo downlink model has been implemented by balancing the tradeoff joint PAPR and SER using ETG algorithm. The fundamental objective is to minimize MUI, OBR, joint-PAPR and SER. is being considered. The optimal solution has been found by applying hybrid ETG algorithm .From the performance analysis, hybrid ETG able to converge in less iteration when compared with existing algorithms. And also achieved low PAPR solution proposed ETG algorithm exhibits lowest PAPR of 0.65 dB FITRA PAPR is 2.24dB and clipping PAPR is 4.23dB and ZF scheme PAPR of 9 dB compared with other techniques. This proposed model utilized DOF from several numbers of antennas at the base station to reduce PAPR in the signal. Hence it is concluded that proposed ETG algorithm performed well for balancing better tradeoff between SER and joint-PAPR.

REFERENCES

1. S.H.Muller and J.B.Huber, "OFDM with reduced Peak to average power ratio by optimum combination of partial transmit sequences," IEEE.Letters, Vol.33, no.5, pp.368-369, 1997.
2. S.H.Han and J.H.Lee, "An overview of peak to average power ratio reduction techniques for multicarrier transmission," IEEE Wireless Comm., Vol,.12,no.2,pp.56-65,Apr.2005.
3. J.Vila and P.Schinter, "Expectation- maximization Gaussian –Mixture approximate message passing," IEEE Trans. Signal..Process.., vol 61, no.19, pp.4658- 4672, oct, 2013.
4. Bao, Hengyao, Jun Fang, Zhi Chen, Hongbin Li, and Shaoqian Li. "An Efficient Bayesian PAPR Reduction Method for OFDM-Based Massive MIMO Systems", IEEE Transactions on Wireless Communications, 2016.
5. T. Tsiligkaridis and D. L. Jones, "PAPR reduction performance by active constellation extension for diversity MIMO-OFDM systems," J. Electrical and Computer Eng., Sep. 2010.
6. M. Tipping, "Sparse Bayesian learning and the relevance vector machine,"Journal of Machine Learning Research, vol. 1, pp. 211–244, 2001.
7. D. G. Tzikas, A. C. Likas, and N. P. Galatsanos, The variational approximation for Bayesian inference, IEEE Sig. Process. Mag.25 (2008), no. 6, 131–146.
8. Shruti S Bhagawati, T S Indumati. "PAPR and MUI reduction using novel Bayesian approach in OFDM based MIMO", 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2016.
9. S.Rangan, "Generalized approximate message passing for estimation with linear random mixing,"IEEE ISIT,Full version at arXiv: 1010.5141,pp.2168-2172, Aug, 2011.
10. J. C. Chen, M. H. Chiu, and Y. S. Yang, A suboptimal tone reservation algorithm based on cross-entropy method for PAPR reduction in OFDM systems, IEEE Trans. Broadcast. 57 (2011), no. 3, 752–756.
11. J. P. Vila and P. Schniter, An empirical-bayesian approach to recovering linearly constrained non-negative sparse signals, IEEE Trans. Sig. Process. 62 (2014), no. 18, 4689–4703.
12. J. Yang et al., A modified selected mapping technique to reduce the peak -to- average power ratio of OFDM signal, IEEE Trans. Consumer Electr. 53 (2007), no. 3, 846–851.
13. L. Wang and C. Tellambura, A simplified clipping and filtering technique for PAR reduction in OFDM systems, IEEE Sig. Process Lett. 12 (2005), no. 6, 453–456.

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