Beam forming and Papr Reduction using MRT and EGT in MIMO OFDM System

P. Revathi, P. Arul Marry
Department of Electronics and Communication Engineering, Oxford Engineering College, Trichy, Tamil Nadu, India

Article Info
Article history:
Received 3 February 2015
Received in revised form
20 February 2015
Accepted 28 February 2015
Available online 6 March 2015

Keywords
MIMO OFDM,
Beam forming,
Precoding,
Peak-to-Average Power Ratio,
PAPR,
Maximum ratio Transmission,
MRT,
Equal gain Transmission,
EGT

Abstract
In Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing system using beamforming improve the receive Signal to Noise Ratio. In the transmission signals after beam forming the Peak-to-Average Power Ratio (PAPR) is a major issue in Orthogonal Frequency Division Multiplexing systems, High Peak to Average Power Ratio is complicated to design the power amplifier and also increases the power consumption. Analysis of Peak to Average Power Ratio in Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing systems has beam forming schemes, MRT (Maximum Ratio Transmission) and EGT (Equal Gain Transmission). Maximum Ratio Transmission systems have better improvement compare to that of Equal Gain Transmission systems in Peak to Average Power Ratio reduction. In Maximum Ratio Transmission OFDM systems improve both PAPR and bit error rate, also EGT OFDM systems improves PAPR reduction and lesser improvement in bit error rate when compare to Maximum Ratio Transmission system.

1. Introduction

Multiple-input Multiple-output orthogonal frequency division multiplexing (MIMO OFDM) is widely used in current and next generation broadband wireless communications, because it can provide high data rate transmission over multipath fading channels [1], [2]. Among the MIMO techniques, beamforming (or precoding) has been widely adopted in communication standards, *e.g.*, LTE, Wi-MAX and Wi-Fi applications, because it can achieve full diversity, which results in a reliable transmission. It is known that OFDM systems suffer from high peak-to-average power ratio (PAPR). High PAPR leads to high effort in designing the power amplifier (PA) in order to maintain a wide linear region for preventing signal clipping, which therefore increases not only hardware complexity but also power consumption.

The PAPR issue is worse when beamforming is applied in OFDM systems, because the dynamic range of the signals increases after beamforming. Many methods have been proposed for reducing the PAPR including deliberate clipping, companding, probabilistic methods, and coding, these methods may more or less distort signals and decrease the data rate. For example, the most straightforward PAPR reduction method is via clipping peak signals before passing them to the PA [5].However, clipping signals induces in-band and out-of-band distortion and requires additional signal processing techniques to reconstruct the received signals. Another category of methods to reduce the PAPR is through probabilistic schemes such as partial transmit sequence (PTS) [6],selected mapping (SLM) [8] and sign adjustment [9].The objective of probabilistic methods is to reduce the probability that peak power exceeds a certain PAPR There hold. These methods demand that the transmitter sends side information to the receiver. Consequently, the data rate decreases due to the side information, and the transmitted signals cannot be correctly reconstructed if the transmitted side information is polluted. Moreover, although there has been extensive research for PAPR on OFDM systems in analyzing the PAPR for beamforming MIMO OFDM systems and developing corresponding PAPR reduction methods [11]

The PAPR increases if beamforming is adopted in OFDM systems, and then the corresponding PAPR mitigation methods. In this paper, we analyze the PAPR performance for single user MIMO OFDM systems adopting either one of the two most commonly used beamforming schemes, *i.e.,* maximum ratio transmission (MRT) [12] and equal gain transmission (EGT) [13]-[15]. MRT is the optimal beamforming scheme in terms of receives SNR, but the PA design for MRT is more complicated than EGT. It has been shown that the maximum SNR loss between MRT and EGT is only 1.05 dB under Rayleigh fading channels [16].The Extreme Value Theory and order statistics[20] to derive the CCDF (complementary cumulative distribution function) of PAPR for EGT and MRT OFDM systems, and make some insightful observations. EGT OFDM systems have constant power property for different OFDM blocks and different RF transmits branches.

2. Proposed System

PAPR reduction methods for both MRT OFDM and EGT OFDM systems. It is worth to emphasize that, unlike conventional PAPR reduction methods, there is no need to send side information from the transmitter to the receiver in the proposed algorithms. In addition, for MRT OFDM systems, the proposed algorithm not only can reduce the PAPR but also can improve the bit error rate performance.

Corresponding Author,
E-mail address: sureva24@gmail.com

Beam forming (or preceding) techniques have been widely adopted in modern MIMO OFDM systems. Using beam forming can significantly improve the receive SNR of OFDM systems. However, the combination of transmit signals after beam forming deteriorates the peak-to-average power ratio (PAPR), which has long been considered a major issue of OFDM systems. High PAPR not only complicates the design of the power amplifier, but also increases power consumption. In this paper, we theoretically analyze the PAPR performance of MIMOOFDM systems that adopt either one of the two popular beams forming schemes, *i.e.* MRT (maximum ratio transmission) and EGT (equal gain transmission). The analysis considers different numbers of channel taps after sampling. The results may provide important reference for practical designs when evaluating the required power amplifiers and power consumption.

2.1 Analysis of Peak to Average Power Ratio

MRT OFDM systems generally perform much worse than EGT OFDM systems in terms of PAPR, PAPR reduction algorithms are proposed for both MRT OFDM and EGT OFDM systems. It is worth to mention that for MRT OFDM systems, algorithm can improve both PAPR and bit error rate; for EGT OFDM, algorithm improves PAPR while it only slightly degrades bit error rate. In this paper, we analyze the PAPR performance for single user MIMO OFDM systems adopting either one of the two most commonly used beam forming schemes, *i.e.,* maximum ratio transmission (MRT) and equal gain transmission(EGT) [MRT is the optimal beam forming scheme in terms of receive SNR, but the PA design for MRT is more complicated than EGT. It has been shown that the maximum SNR loss between MRT and EGT is only 1.05 dB under Rayleigh fading channels. Two types of average power: one is block average power P_{av} and the other is long-term average power $\bar{P}_{av}$ the block average power is the average power of an OFDM block at a specific transmit branch, *i.e.*

$$P_{av} = \frac{1}{T}\int_0^T \left[S^{(i)}(t)\right]^2 dt$$

While the long-term average power is the expectation of the block average power, i.e.

$$\bar{P}_{av} = E[P_{av}]$$

The baseband PAPR of the beam forming OFDM system is defined as

$$\max_{0\le i\le M_{t-1}}\left\{PAPR^{(i)}\right\} = \max_{0\le i\le M_{t-1}}\left\{\max_{0<t\le T}\frac{S^{(i)}(t)^2}{\bar{P}_{av}}\right\}$$

2.2 Block Diagram Of PAPR Reduction

The data stream is converted into serial to parallel. Then preserve the signal power by using unit magnitude random phase vectors **U**m. Amplitude limiting devices such as DACs and PAs are potential sources of nonlinearity which may cause performance degradation in OFDM systems. We consider both the DAC and the PA as nonlinear.

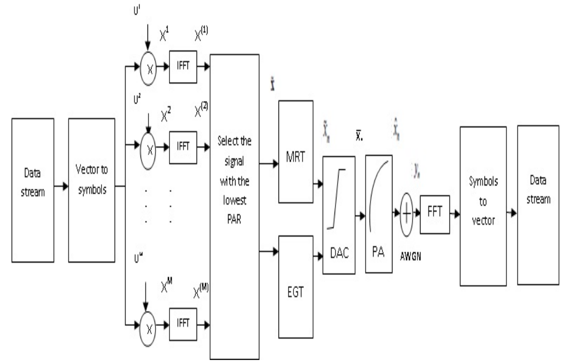

Fig: 1. PAPR reduction in MRT and EGT

Since the soft limiter is one of the most commonly used models for memory less nonlinear devices in a transmitter. In order to avoid unwanted nonlinear distortions, the output of the DAC should be adjusted to operate within the input range of the PA. Then, the output of the FFT demodulator is multiplied with the complex conjugate of the minimum PAR random phase vector**.**

2.3 Maximum ratio transmission(MRT)

MRT is the optimal beam forming scheme in terms of receive SNR, but the PA design for MRT is more complicated than EGT. It has been shown that the maximum SNR loss between MRT and EGT is only 1.05 dB under Rayleigh fading channels. It is worth to emphasize that, unlike Conventional PAPR reduction methods, there is no need to send side information from the transmitter to the receiver in the proposed algorithms. In addition, for MRT OFDM systems, the proposed algorithm not only can reduce the PAPR but also can improve the bit error rate performance. This satisfying result is obtained thanks to the motivation from the derived results. The proposed algorithm attempts to adjust the power at some subcarriers after beam forming as closely as possible. Since the subcarrier power is equalized in a certain level, both the PAPR and the bit error rate performance are improved simultaneously.

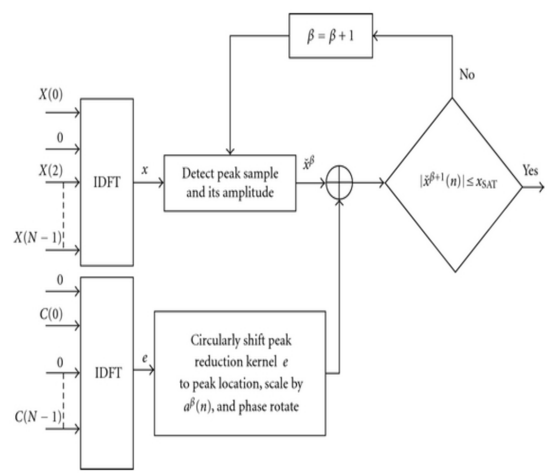

Fig: 2. Flow diagram of MRT

2.4 PAPR Reduction Algorithm For MRT OFDM System

MRT is the optimal beam forming scheme, and can achieve 1.05 dB better receive SNR than EGT. Unlike the for mentioned desirable property of EGT in Lemma 1, MRT has different average power for different transmit branches and different OFDM blocks. Hence MRT does not have constant block average power and the long-term average is needed to identify the operation region of power amplifier. The power variation of MRT unavoidably increases the PAPR. As a result, it complicates the design of the PA and increases power consumption. Moreover, the PAPR analysis for MRT OFDM systems is more complicated than that for EGT OFDM systems because *1*) *Pav*is no longer a constant, and *2*) different numbers of channels taps after sampling *L* lead to different MRT vectors and consequently different PAPR values. To obtain the PAPR of MRT OFDM systems, again, we first focus on a specific transmit branch, and then extend the results to all transmit branches. The MRT beamforming vector can be obtained from the right singular vector corresponding to the maximum singular value in MIMO/MISO channels. The PAPR statistics for MIMO and MISO channels should be the same, because their right singular vectors are both with the conditional Haar distribution.

2.5 Equal Gain Transmission (EGT)

The proposed algorithm attempts to adjust the power at some subcarriers after beamforming as closely as possible. Since the subcarrier power is equalized in a certain level, both the PAPR and the bit error rate performance are improved simultaneously. For EGT OFDM systems, the proposed algorithm can reduce the PAPR, while at the same time it only slightly degrades bit error rate performance. Finally, simulation results are provided to show the accuracy of the derived theoretical PAPR results and the performance improvement achieved when using the proposed PAPR mitigation algorithms.

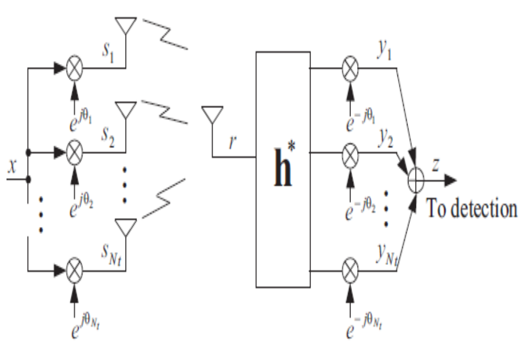

Fig: 3. Flow diagram of equal gain Pre-coder

2.6 PAPR Reduction Algorithm For EGT OFDM System

The PAPR of one specific transmit branch for EGT OFDM systems is the same as that for unprecoded OFDM systems. Hence, the PAPR reduction algorithms for unprecoded OFDM systems can be applied to EGT OFDM systems. EGT already has constant power for different OFDM blocks and transmit branches; also it is known that changing subcarrier phases can reduce the PAPR of OFDM systems Therefore, we change the subcarrier phases corresponding to the largest effective channel gains, because the error rate performance is dominated by the subcarriers corresponding to the smallest effective channel gains. By doing this, we can effectively reduce the PAPR, yet the error rate performance is only slightly degraded.

3. Results

The proposed PAPR reduction algorithms can effectively reduce the PAPR for both MRT and EGT OFDM systems. At the same time the performance is improved for MRT OFDM systems and is only slightly degraded for EGT OFDM systems.

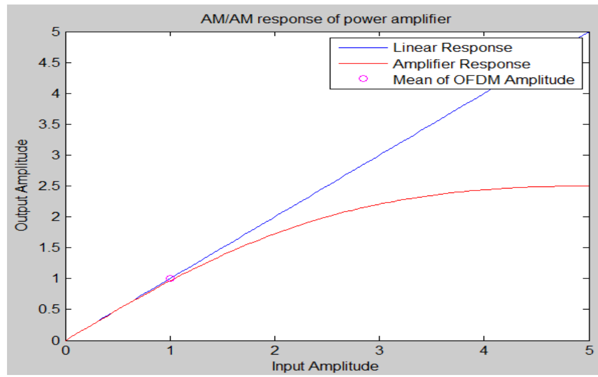

Fig: 4. AM/AM Response of Power Amplifier

In the result the comparison of input and output amplitude response of power amplifier where linear and amplifier response is obtained,also mean of OFDM amplitude is determined.

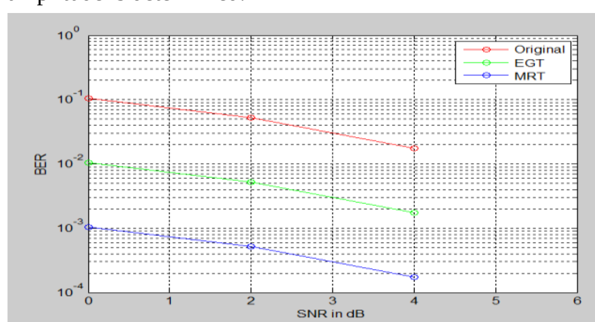

Fig: 5. BER for both MRT and EGT

In the result bit error calculation for overall Maximum Ratio Transmission system and Equal Gain Transmission system. In MRT system has better improvement when compare to EGT system.

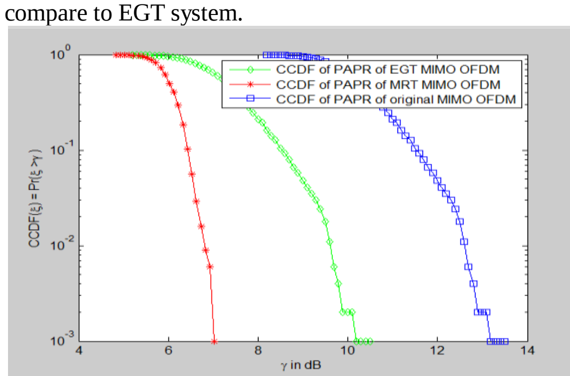

Fig: 6. CCDF of PAPR reduction for MRT and EGT system

In the result CCDF complementary cumulative distribution function of PAPR reduction for both MRT and EGT in MIMO OFDM system.MRT has better improvement compare to EGT system.

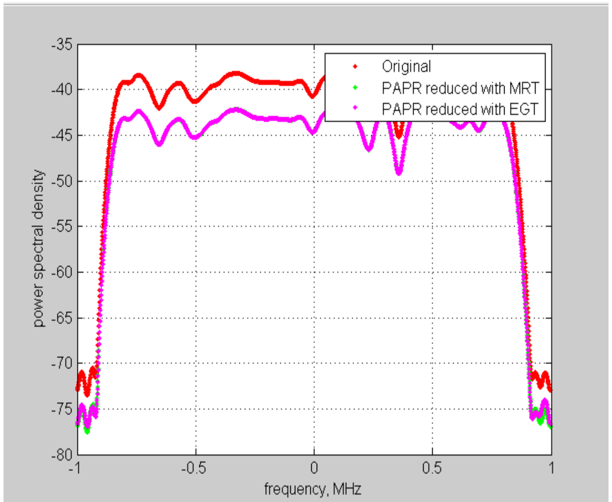

Fig: 7. Power spectral density function

In the result comparison of original, MRT and EGT system for power spectral density function.

4. Conclusion

The PAPR performance and corresponding mitigation algorithms for beamforming OFDM systems. We analytically derive the PAPR distribution for EGT OFDM and MRT OFDM systems. The theoretical results show that generally MRT OFDM systems perform much worse than EGT OFDM systems in terms of PAPR. Therefore, although MRT is the optimal beamforming scheme, which can achieve 1.05 dB more receive SNR than EGT, when the cost of the PA and the better power consumption are of concern, EGT may be a preferred solution due to its superior PAPR performance in OFDM systems. Moreover, we propose PAPR reduction algorithms for both MRT OFDM and EGT OFDM systems.

The performance improvement using the proposed algorithm is more pronounced in MRT OFDM systems; that is, both the PAPR and the bit error rate performance can be improved simultaneously. If a more aggressive PAPR improvement is needed, by carefully determining the design parameters, the proposed algorithms can greatly improve PAPR performance, yet the bit error rate performance is slightly degraded. Simulation results show that the proposed PAPR mitigation algorithms indeed significantly boost the PAPR performance. Also, the analytical results for the PAPR match simulation results well. Consequently, the derived outcomes could beused to evaluate the required PA specification and the power consumption for beamforming OFDM systems in practical designs. An interesting extension of this work is to analyze the PAPR for multi-stream and SDMA system, combine MRT and EGT to reduce PAPR and BER upto 90%.to increase the reduction of PAPR and BER ,combine the MRT and SLM method . By using this method, reduce PAPR and BER up to 95%.

References

[1] A. J. Paulraj, D. A. Gore, R. U. Nabar, H. B¨olcskei, An overviewof MIMO communications—a key to gigabit wireless, 92(2), 2004, 198–218

[2] K. F. Lee, D. B. Williams, A space-frequency transmitter diversity technique for OFDM systems, IEEE GLOBECOM, 2000, 1473–1477.

[3] S. Khademi, A.-J.van der Veen, T. Svantesson, Precodingtechnique for peak-to-average-power-ratio (PAPR) reduction in MIMO OFDM/A systems, IEEE ICASSP, 20, 2012, 3005– 3008

[4] S. H. Han, J. H. Lee, An overview of peak-to-average power ratio reduction techniques for multicarrier transmission, IEEE Wireless Commun., 12(2), 2005, 56–65

[5] U.-K. Kwon, D. Kim, G.-H.Im, Amplitude clipping and iterative reconstruction of MIMO-OFDM signals with optimum equalization, IEEE Trans. Wireless Commun., 8(1), 2009, 268–277

[6] S. H. M¨uller, J. B. Huber, OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequences, Electron. Lett., 33(5), 1997, 368–369

[7] L. Wang and J. Liu, Cooperative PTS for PAPR reduction in MIMOOFDM, Electron. Lett., 47(5), 2011, 351–352

[8] R. W. B¨auml, R. F. H. Fischer, J. B. Huber, Reducting the peak-to average power ratio of multicarrier modulation by selected mapping, Electron. Lett., 32(22), 1996, 2056–2057

[9] M. Sharif, B. Hassibi, Existence of codes with constant PMEPR and related design, IEEE Trans. Signal Process., 52(10), 2004, 2836–2846

[10] M. Sharif, V. Tarokh, B. Hassibi, Peak power reduction of OFDM signals with sign adjustment, IEEE Trans. Commun., 57(7), 2009, 2160–2166

[11] J. Joung, E.-R.Jeong, Y. H. Lee, Beam forming and PAPR reduction for MISO-OFDM systems, in Proc. 2007 IEEE ICASSP, 3, 377–380

[12] J. B. Andersen, Array gain and capacity for known random channels with multiple element arrays at both ends, IEEE J. Sel. Areas Commun., 18(11), 2000, 2172–2178

[13] D. J. Love, R. W. Heath, Equal gain transmission in multiple-input multiple-out wireless systems, IEEE Trans. Commun., 51(7), 2003, 1102–1110

[14] C. R. Murthy, B. D. Rao, Quantization methods for equal gain transmission with finite rate feedback, IEEE Trans. Signal Process., 55(1), 2007, 233–245

[15] X. Zheng, Y. Xie, J. Li, P. Stoica, MIMO transmit beamformingunder uniform elemental power constraint, IEEE Trans. Signal Process., 55(11), 2007, 5395–5406

[16] S.-H. Tsai, Transmit equal gain precoder in Rayleigh fading channels, IEEE Trans. Signal Process., 57(9), 2009, 3717–3721

[17] S.-H. Tsai, Equal gain transmission with antenna selection in MIMO communications, IEEE Trans. Wireless Commun., 10(5), 2011, 1470–1479

[18] M. R. Leadbetter, H. Rootzen, An extremal theory for stochastic processes, Annals Probability, 16, 1988, 431–478
[19] A. Papoulis, S. U. Pillai, Probability, Random Variables and Stochasitic Process. McGraw-Hill, 2002
[20] H. A. David, H. N. Nagaraja, Order Statistics, 3rd ed. John Wiley & Sons, Inc., 2003
[21] S. Wei, D. Goeckel, P. Kelly, A modern extreme value theory approach to calculating the distribution of the peak-to-average power ratio in OFDM Systems, in IEEE ICC, 3, 2002, 1686–1690
[22] T. Jiang, M. Guizani, H.-H. Chen, W. Xiang, Y. Wu, Derivation of PAPR distribution for OFDM wireless systems based on extreme value theory, IEEE Trans. Wireless Commun., 7(4), 2008, 1298–1305
[23] H. Ochiai, H. Imai, On the distribution of the peak-to-average power ratio in OFDM signals, IEEE Trans. Commun., 49(2), 2001, 282–289
[24] S. Wei, D. Goeckel, P. Kelly, Convergence of the complex envelope of bandlimited OFDM signals, IEEE Trans. Inf. Theory, 56(10), 2010, 4893–4904
[25] T. W. Anderson, An Introduction to Multivariate Statistical Analysis, 2nd ed. John Wiley & Sons, Inc., 1984
[26] T. G. Pham, N. Turkkan, Reliability of a standby system with beta distributed component lives, IEEE Trans. Reliability, 43(1), 1994, 71–75
[27] C. Tellambura, Computation of the continuous time PAR of an OFDM signal with BPSK subcarriers, IEEE Commun. Lett., 5(5), 2001, 185–187
[28] Y.-P. Lin, S.-M. Phoong, P. P. Vaidyanathan, Filter Bank Transceivers for OFDM and DMT Systems.Cambridge University Press, 2011
[29] Y.-P. Lin and S.-M.Phoong, Statistical bit allocation and statistical precoding for correlated MIMO channels with decision feedback, IEEE Signal Process. Lett., 19(11), 2012, 761–764
[30] T. Hu, J. Hu, Comparison of order statistics between dependent and independent random variables, Statist. Probab. Lett., 37, 1998, 1–6