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A Survey on PAPR Reduction Methods

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Abstract : *To support various wireless services and applications, a dramatic increase has been noticed over the decade for high data rate. To meet the requirements of high data rate, third generation partnership project (3GPP) has come across the development of long term evolution (LTE). Two techniques used in LTE are Orthogonal Frequency Division Multiple Access (OFDMA) and Single-Carrier Frequency Division Multiple Access (SC-FDMA). The main drawback of OFDMA over SC-FDMA is its high peak-to-average power ratio (PAPR). Therefore OFDMA is used in the downlink and SC-FDMA is used in the uplink of fourth generation (4G) wireless communication systems. To provide high data rate along with increased system capacity it is possible to extend Multiple-Input Multiple-Output (MIMO) to OFDMA and SC-FDMA. This paper surveys on PAPR problem and PAPR reduction methods.*

Keywords – *BER, MIMO, OFDMA, PAPR, SC-FDMA*

I. Introduction

Commercial cellular telecommunications from the early 1980s has grown rapidly through a sequence of generations along with the progress in technology with each new decade. The first generation systems in 1980 used frequency division multiple access (FDMA) to create physical channels. Digital transmission arrived in the early 1990s with the most popular systems employing time division multiple access (TDMA) and others relying on code division (CDMA). Third generation technology dating from 2000 uses code division whereas the next generation promises a return to frequency division. Three standard organizations, IEEE, 3GPP and 3GPP2 have worked in progress on advanced mobile broadband systems using frequency division transmission technology. To meet the requirements of high data rate and high throughput, third generation partnership project (3GPP) has developed long term evolution (LTE). The high data rate of LTE not only demands a wider bandwidth but also a more advanced modulation technique. OFDM was considered as an optimum solution for downlink transmission requirement. But this modulation scheme has some major limitations like high peak to average power ratio (PAPR) which can increase complexity and power of transmitter in uplink. To overcome the disadvantages of OFDM, 3GPP investigated a modified form for uplink transmissions in the long term evolution of cellular systems. The modified version of OFDMA is referred as single carrier FDMA (SC-FDMA).

Multiple Input Multiple Output (MIMO) means multiple antennas at both link ends of a communication system, i.e., at the transmit and at the receive side. The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO transmission can be used for both uplink and downlink. For wideband channels, orthogonal frequency division multiplexing (OFDM) has to be used with MIMO techniques for ISI mitigation and capacity improvement. Single-carrier FDMA (SC-FDMA) is a frequency division multiple access scheme that deals with the assignment of multiple users to a shared communication resource. MIMO SC-FDMA employs spatial multiplexing and dynamic bandwidth assignment [1]. Spatial multiplexing provides additional data capacity by making use of different paths which carries additional traffic. In other words it increases the data throughput capability. To achieve a better cellular coverage and power amplifier efficiency it is required to make use of MIMO SC-FDMA with low Peak to Average Power Ratio (PAPR).

The remainder of this paper is organized as: Section 2 gives an overview of OFDMA and SC-FDMA. Section3 discusses the PAPR problem. Section 4 describes PAPR reduction methods. Section 5 concludes the paper.

II. Overview of OFDMA and SC-FDMA

1.1 OFDMA

One of the key elements of LTE is the use of Orthogonal Frequency Division Multiple Access (OFDMA). OFDMA is a multiple access scheme that multiplexes the data on multiple carriers and transmits them in parallel. The assignment of subcarriers to individual users allows simultaneous low data rate transmission from several users. The basic idea of OFDMA is the division of a high speed digital signal into various slower signals and transmission of each slower signal in a separate frequency band. The slow signals are frequency multiplexed to create one waveform in such a way that the symbol duration in each one is long enough to eliminate inter-symbol interference (ISI). The basic block diagram of OFDMA is shown in Fig 1[2].

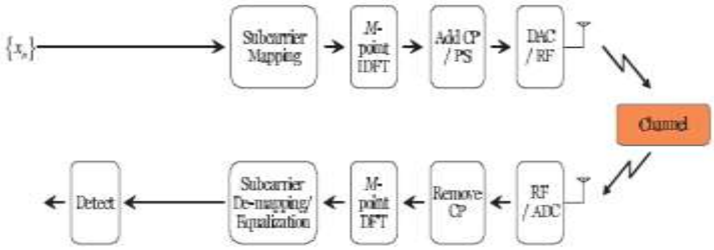

Figure 1 Block diagram of OFDMA [2]

The other main advantages of OFDMA [3] include:

a). For a particular channel delay spread, the receiver complexity is much lower than that of a single carrier system.

b). Spectral efficiency is high since it uses overlapping orthogonal subcarriers.

c). Capacity can be increased by adapting the data rate per subcarrier according to the signal-to-noise ratio (SNR) of the individual subcarrier.

Besides these advantages, the main drawback of OFDMA is the high peak-to-average power ratio (PAPR). Since the transmitted signal is the sum of many modulated subcarriers, at certain point of time the sum may be larger than the average value and at other times it may be smaller which points to the fact that the peak value is larger than the average value [4]. The result of high PAPR is low power efficiency, increase in the complexity of analog-to-digital and digital-to-analog converter, degradation in BER performance of the system etc. To overcome these problems, Third Generation Partnership Project (3GPP) has introduced a modified form of OFDMA known as Single Carrier Frequency Division Multiple Access (SC-FDMA). OFDMA transmits a multi-carrier signal whereas SC-FDMA transmits a single carrier signal. Because of this, SC- FDMA has a lower peak-to-average power ratio (PAPR) than OFDMA.

2.2 SC-FDMA

Single Carrier Frequency Division Multiple Access (SC-FDMA) is a technique used for high data rate uplink transmission. SC-FDMA is a modified form of OFDMA with similar throughput performance and complexity. It can be considered as DFT-coded OFDM where discrete Fourier transform (DFT) block in the transmitter side which is absent in OFDMA converts the time domain signal to frequency domain signal. This is illustrated in Fig 2 [2].

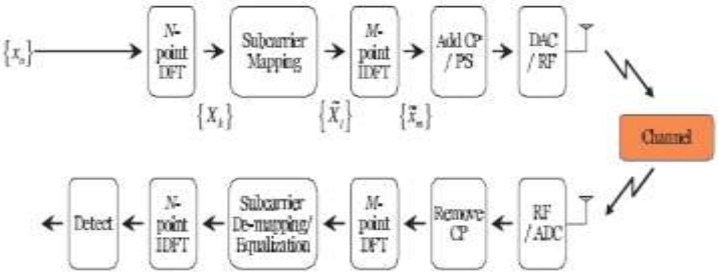

Figure 2 Block diagram of SC-FDMA [2]

Similarly, in the receiver IDFT block present helps in the transformation of frequency domain symbols back to time domain. SC-FDMA has the same advantage as OFDMA like its robustness against multipath signal propagation. An additional advantage of SC-FDMA is its low peak-to-average power ratio (PAPR) compared to OFDMA making it suitable for uplink transmission by user-terminals.

III. PAPR Problem

Apart from low bit error rate (BER), high data rate, high spectral efficiency, high power efficiency and low computational complexity which constitutes the main requirements of a mobile user [4], low peak to average power ratio (PAPR) is an important factor to be considered. The peak-to-average power ratio (PAPR) is defined as the ratio of peak power to average power of the transmitted signal in a given transmission block. High PAPR may result in a situation where the system performance may degrade. Hence it is essential to reduce the PAPR. The problem of high PAPR arises in multicarrier communication system whereas it is low for single carrier communication system because of its single-carrier structure.

3.1 Causes of high PAPR

PAPR occurs during the summation of carriers together. Multicarrier signals like OFDM signals have modulated subcarriers with different amplitude and phase. These subcarriers are all transmitted at the same time. When these subcarriers get added up, sometimes the peak power becomes greater than the average power and results in high PAPR. Due to high PAPR in OFDMA signals, the signals will be clipped when passed through nonlinear power amplifier resulting in signal distortion. The intermodulation distortion caused due to signal distortion can be avoided by using highly linear power amplifiers operating with a large backoff [2]. But the result is low power efficiency.

3.2 Effects of high PAPR

For signals with high PAPR, if the input power is not decreased it may cause signal distortion which inturn produce intermodulation distortion. A large PAPR increases the complexity of the analog-to-digital and digital-to-analog converter and reduces the efficiency of the radio frequency (RF) power amplifier [2]. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi-carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi-carrier transmission can be out-weighed by a high PAPR value. Other than this, high PAPR may degrade bit error rate (BER) performance of the system. If the BER degradation is only negligible, it may cause performance degradation of the system [1].

IV. PAPR Reduction Methods

PAPR is an important factor to be considered in the design of mobile terminals especially in the uplink of the communication system. The PAPR of the signal to be transmitted will reduce significantly by using single carrier transmission instead of multi-carrier modulation scheme. The transmitters in an SC-FDMA system use different orthogonal frequencies to transmit information symbols. They transmit the subcarriersbsequentially rather than in parallel. This arrangement reduces the envelope fluctuations in the transmitted waveform. Therefore, SC-FDMA signals have lower PAPR than OFDMA signals. High PAPR may cause poor amplifier power efficiency, increased complexity of the system, shorter battery life etc. Thus it is essential to reduce PAPR inorder to achieve a better performance for the system.

Different PAPR reduction methods have been developed for MIMO SC-FDMA systems. One method to decrease PAPR is to use pulse shaping filters. Ref [5] gives such a method. The two forms of SC-FDMA i.e. localized FDMA (LFDMA) and interleaved FDMA (IFDMA) are compared with OFDMA. Fig 3 shows the plots of CCDF of PAPR for IFDMA, LFDMA and OFDMA. It can be observed that in case of no pulse shaping, IFDMA has lower PAPR than OFDMA. Also with pulse shaping with roll-off factor, SC-FDMA has low PAPR than OFDMA.

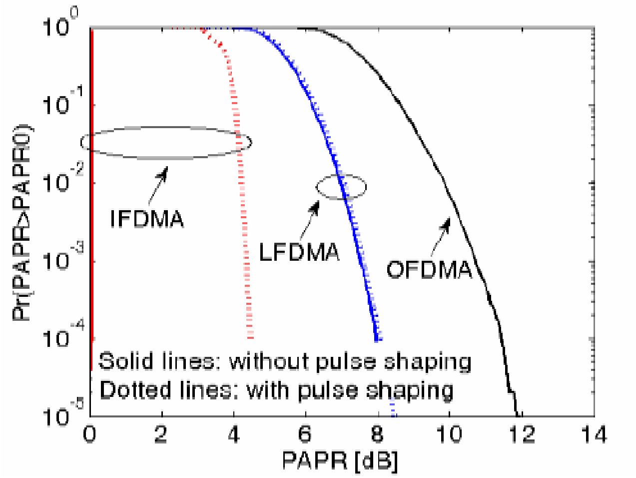

Figure 3. Comparison of PAPR for IFDMA, LFDMA and OFDMA [5]

Other than this, two codes used for PAPR reduction are Space-Frequency Block Code (SFBC) and Space-Time Block Code (STBC). Ref [6] shows a better PAPR reduction using an innovative mapping method with SFBC. For this, two schemes developed are orthogonal single-carrier SFBC and quasi-orthogonal single-carrier SFBC. In the first scheme, a matrix corresponding to Alamouti based SFBC scheme is obtained in a way that PAPR of obtained signal ia same as PAPR of original signal. In the second scheme, QO code is obtained such that it preserves the SC like nature of the signal along with low PAPR. Hence the use of innovative mapping methods helps to provide a good PAPR performance and preserve the single-carrier nature of SC-FDMA signal as shown in Fig 4. But a limitation is performance degradation due to non-adjacent subcarriers.

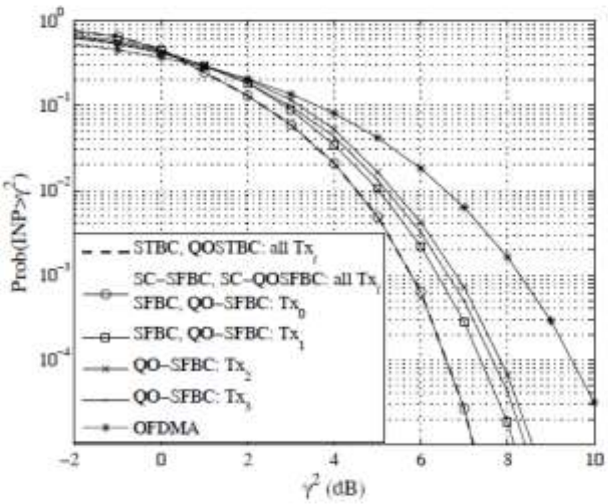

Figure 4. PAPR performance of SC-QOSFBC, SC-SFBC and other schemes [6]

A novel space-frequency block coding also helps to reduce PAPR [7]. The mapping of data symbols to subcarriers as the original symbols on DFT output of the transmitter block causes the reduction in PAPR. From Fig 5, it is clear that for classical SFBC scheme PAPR increases since the mapping changes the structure of original DFT output symbols. For the proposed SFBC scheme, reduction in PAPR is noticed.

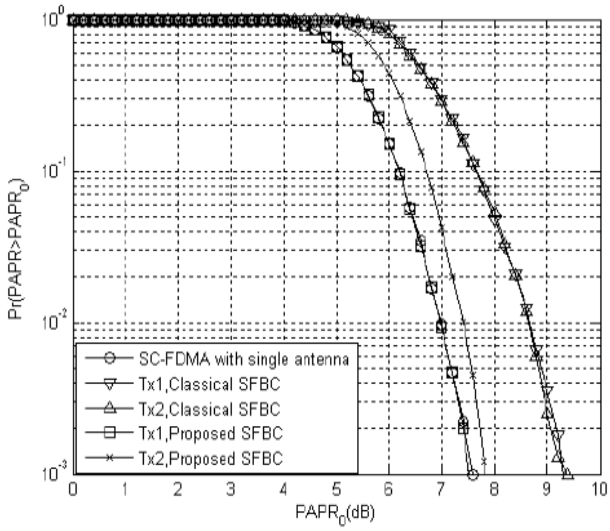

Figure 5. CCDF of PAPR for QPSK [7]

Here, the scheme divides the data transmitted into two sub-groups such that the symbols of first group are Alamouti coded with the corresponding symbols of the next adjacent group. Hence, the original symbols in each group are mapped to the subcarriers of one antenna and the conjugates are mapped to another antenna. Other advantages like improved power amplifier efficiency and enhanced cellular coverage are also obtained.

A good PAPR reduction is also obtained by the use of modified SFBC instead of conventional SFBC [1]. Space-frequency block coding is a coding for OFDM systems with multiple transmit antennas, where coding is applied in the frequency domain (OFDM carriers).

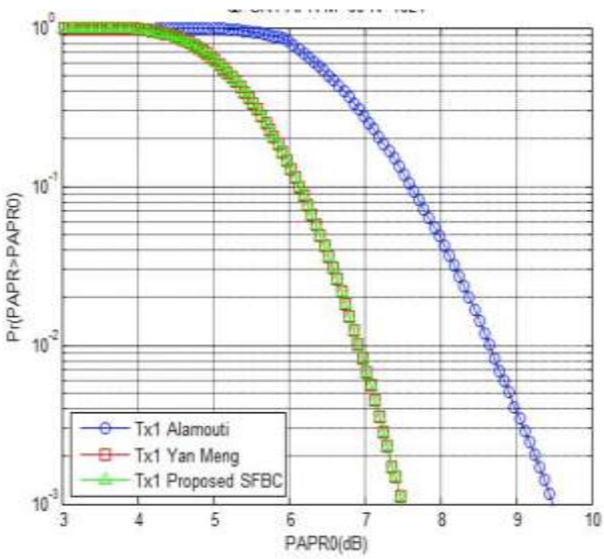

Figure 6. PAPR performance for T_{x1} in two ransmit antennas [1]

In the conventional scheme, frequency inversion between subcarriers changes the frequency structure of the transmitted signals thereby destroying the single carrier property of the signal and SC-FDMA loses its low PAPR advantage. In the case of modified schemes, the data symbols are mapped as original symbols on DFT output and therefore provide a good PAPR performance. In case of two transmit antennas, performance of first antenna shows that proposed SFBC has low PAPR same as [7] and better than [8]. Similarly, performance of second antenna concludes that proposed scheme has low PAPR than other methods. Figures 6 and 7 shows that the proposed modified scheme is better than conventional schemes in terms of PAPR reduction.

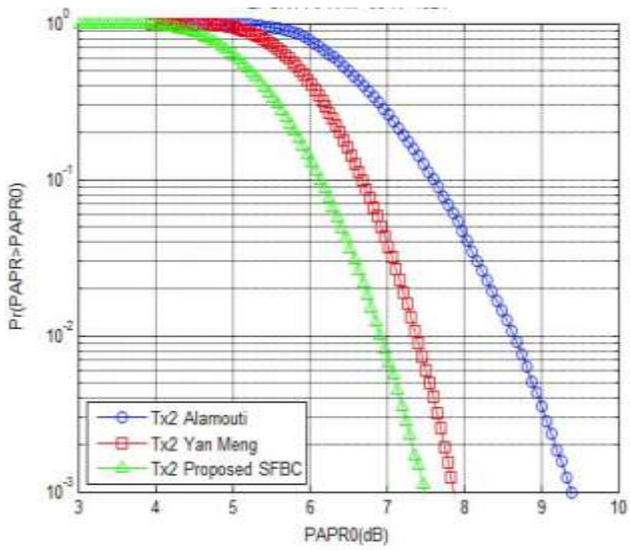

Figure 7. PAPR performance for T_{x2} in two transmit antennas [1]

But BER degradation is negligible as shown in Fig [8]. All proposed methods shows only negligible BER degradation. It is necessary to reduce the BER, which inturn helps to improve the system peformance. Therefore it is essential to look for a modified scheme that reduces BER, at the same time decreasing PAPR.

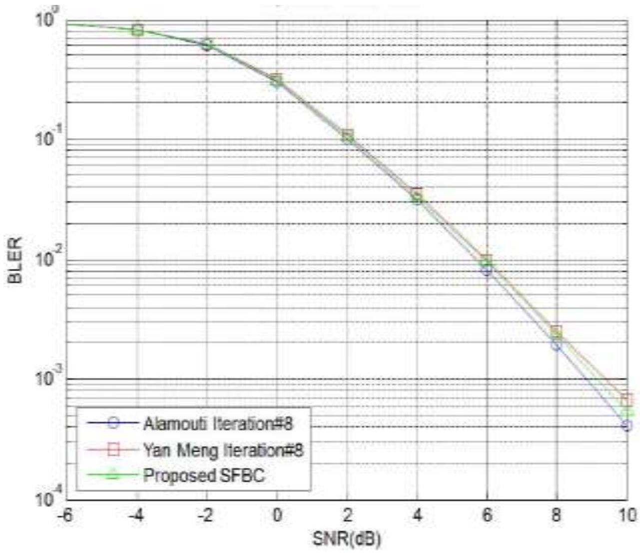

Figure 8. BLER performance for two transmit antennas[1]

Since BER is influenced by coding and modulation techniques, a good degradation along with low PAPR can be obtained by changing the coding and modulation techniques. Lower order modulation techniques like BPSK, QPSK etc and coding schemes like space-time block codes (STBC) are preferred.

V. Conclusion

In this paper we have done a survey on the works done by various researches for PAPR reduction. PAPR problem is more of a concern in uplink since efficiency of power amplifier is critical due to the limited battery power in a mobile terminal. Hence it is essential for the uplink of the communication system to achieve a low PAPR property. Many works pointed out the ways to obtain low PAPR. Through this paper, the causes and effects of high PAPR are studied along with various PAPR reduction methods. Besides PAPR, to improve the system performance it is essential to decrease BER. Other than the proposed methods, PAPR reduction can also be achieved by the use of lower order modulation techniques like BPSK or QPSK and coding schemes like space-time block codes (STBC).

References

[1] Chang-Ju Lin, Li-Chung Chang and Chih –Yao Huang, "Efficient PAPR Reduction Schemes for MIMO SC-FDMA with Space Frequency Block Codes," International Conference on Communication and Networking Technologies pp. 1-5 2014.
[2] H. G.Myung, J. Lim and D. J. Goodman, "Single Carrier FDMA for Uplink Wireless Transmission," IEEE Vehicular Technology Mag, vol.1, no. 3, Sep 2006, pp. 30-38.
[3] Hyung.G. Myung and David. Goodman, "Single carrier FDMA – A new air interface for long term Evolution", Wiley Publications,2008.
[4] Dr. G. Indumathi and D. Allin Joe, "Design of Optimum Physical Layer Architecture for a High Data Rate LTE Uplink Transceiver," IEEE International Conference on Green High Performance Computing, pp. 1-8, 2013.
[5] Hyung G. Myung, Junsung Lim and David J. Goodman, "Peak-to-Average Power Ratio of Single Carrier FDMA Signals with Pulse Shaping", International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'06) pp 1-5, 2006.
[6] C.Ciochina, D.Castelain, D.Mottier and H.Sari, "New PAPR-Preserving Mapping Methods for Single-Carrier FDMA with Space-Frequency Block Codes," IEEE Trans. On Wireless Communications, vol. 8, no. 10, pp. 5176-5186, October 2009.
[7] Yan Meng, Mingli You, Jin Liu and Hanwen Luo "A Novel Space-Frequency Block Coding Scheme for SC-FDMA," IEEE 70th Vehicular Technology Conference Fall, VTC 2009-Fall,pp. 1-5, September 2009.
[8] S. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE Journal on Selected Areas in Communications, vol. 16, pp. 1451-1458, October 1998.
[9] Harsha Prakash, Dr. Prof. Suriyakala C D " PAPR Reduction in MIMO SC-FDMA-A Survey ", International Journal of Recent Advances in Science and Technology (IJRAST), Vol. 2, Sep 2015.
[10] Prittu Ann Thomas and Prof M. Mathurakani, "Effects of Different Modulation Schemes in PAPR Reduction of SC-FDMA System for Uplink Communication", International Journal of Advanced Research in Electrical, electronics and Instrumentation Engineering Volume:03, Special Issue: 4, pp-8531-8539, April 2014.
[11] Jim Zyren and Dr. Wes McCoy, "Overview of the 3GPP Long Term Evolution Physical Layer", 2007.
[12] H. Ekström, A. Furuskär, J. Karlsson, M. Meyer, S. Parkvall, J. Torsner, and M. Wahlqvist, "Technical Solutions for the 3G Long–Term Evolution," IEEE Communications Magazine,vol. 44, no. 3, pp. 38–45, March 2006.
[13] A. Wilzeck, Q. Cai, M. Schiewer and T. Kaiser, "Effect of Multiple Carrier Frequency Offsets in MIMO SC-FDMA Systems," Proceedings of the European Association for Signal Processing 2007.
[14] N. Tavangaran, A. Wilzeck and T. Kaiser, "MIMO SC-FDMA system performance for space time/frequency coding and spatial multiplexing", International ITG Workshop on In Smart Antennas, 2008, pp. 382-386.
[15] GE Quan, JIN Yan-liang, SHI Zhi-dong and MIAO Hui-jun, "PAPR Analysis for Single-Carrier FDMA MIMO Systems with Space-Time/Frequency Block Codes", Second Internation*al Conference on Networks Security, Wireless Communications and Trusted Computing, vol. 2, pp 126-129, 2010.*