JAET

Journal homepage: http://jae-tech,com

Journal of Applied Engineering & Technology

ISSN : 2523-6032 ISSN-L : 2523-2924

Review Paper on Peak Average Power Ratio Reduction in OFDM

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Abstract: In this paper, the peak average power reduction techniques are discussed that are utilized in Orthogonal Frequency Division Multiplexing (OFDM) signal. OFDM suffers from high peak to average power ratio (PAPR). This is a major drawback of the scheme and ways of minimizing the PAPR have been researched. The paper will be beneficial for the all the researcher, who are intended to initiate or develop some modified techniques from the existing on.

Keywords: Average Peak Power; OFDM; Channel Modeling

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream [1]. The OFDM technique divides the total bandwidth into many narrow sub-channels and sends data in parallel [2]. It has various advantages, such as high spectral efficiency, immunity to impulse interference and, frequency selective fading without having powerful channel equalizer [3]. But one of the major drawbacks of the OFDM system is high PAPR. OFDM signal consists of lot of independent modulated subcarriers, which would create the PAPR problem [4]. It is impossible to send this high peak amplitude signals to the transmitter without reducing peaks [5]. The high peak amplitude of the signal has to reduced, before transmitting the signal. The nature of Wireless Local Area Network (WLAN) applications demands high data rates. Naturally dealing with ever unpredictable wireless channel at high data rate communications is not an easy task [6]. The idea of multi-carrier transmission has surfaced recently to be used for combating the hostility of wireless channel as high data rate communications. OFDM is a special form of multi-carrier transmission where all the subcarriers are orthogonal to each other. OFDM promises a higher user data rate transmission capability at a reasonable complexity and precision [7]. At high data rates, the channel distortion to the data is very significant, and it is somewhat impossible to recover the transmitted data with a simple receiver. A very complex receiver structure is needed which makes use of computationally extensive equalization and channel estimation algorithms to correctly estimate the channel, so that the estimations can be used with the received data to recover the originally transmitted data [8]. OFDM can drastically simplify the equalization problem by turning the frequency selective channel to a flat channel. A simple one-tap equalizer is needed to estimate the

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channel and recover the data [9]. The subcarriers have proper spacing and pass-band filter shape to satisfy orthogonality as shown in Fig. 1. Inter-Symbol Interference (ISI) is reduced completely by using a guard band in every OFDM symbol. In OFDM, using guard band is cyclically extended in order to avoid Inter-Carrier Interference (ICI) [10].

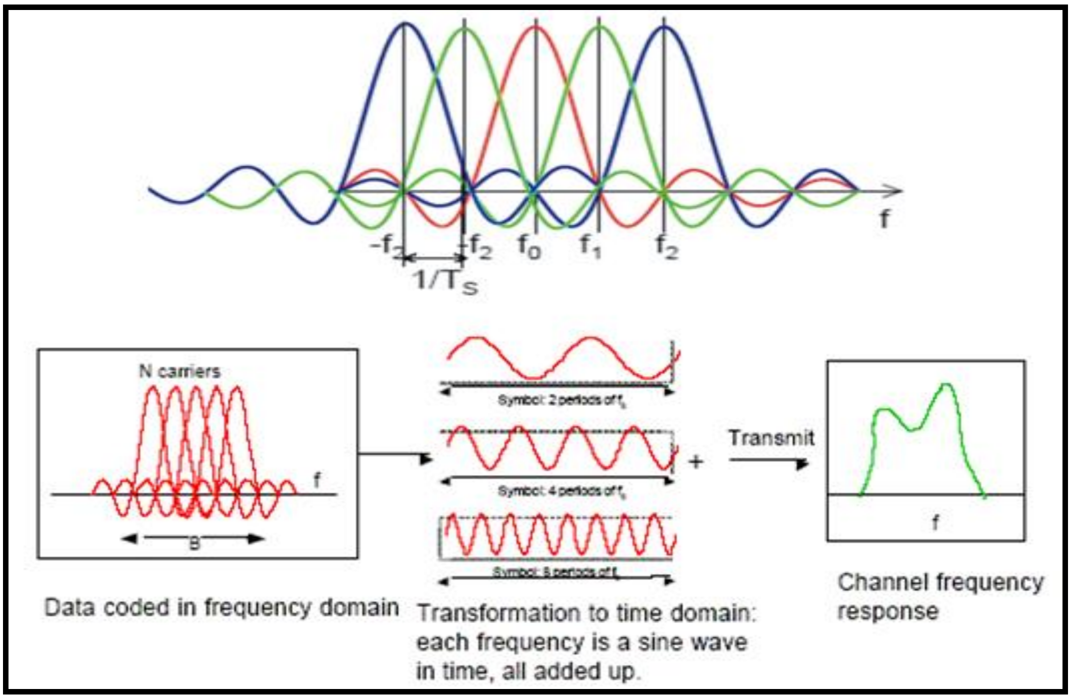

Fig. 1 - OFDM Subcarriers in Frequency Domain [9]

The generic idea that they placed was to use cyclic extension of OFDM symbols instead of using empty guard spaces in frequency domain [11]. This effectively turns the channel as performing cyclic convolution, which provides orthogonality over dispersive channels when CP is longer than the channel impulse response. It is obvious that introducing CP causes loss of signal energy proportional to length of CP compared to symbol length, but, on the other hand, it facilitates a zero ICI advantage which pays off [12]. By this time, inclusion of Fast Fourier Transform (FFT) and CP in OFDM system and substantial advancements in Digital Signal Processing (DSP) technology made it an important part of telecommunications landscape. In the 1990s, OFDM was exploited for wideband data communications over mobile radio FM channels, High-bit-rate Digital Subscriber Lines (HDSL at 1.6Mbps), Asymmetric Digital Subscriber Lines (ADSL up to 6Mbps) and Very-high-speed Digital Subscriber Lines (VDSL at 100Mbps) [13]. Digital Audio Broadcasting (DAB) was the first commercial use of OFDM technology. Development of DAB started in 1987. By 1992, DAB was proposed and the standard was formulated in 1994. DAB services came to reality in 1995 in United Kingdom (UK) and Sweden [14]. The development of Digital Video Broadcasting (DVB) started in 1993. DVB along with High-Definition TeleVision (HDTV) terrestrial broadcasting standard was published in 1995. At the dawn of the 20th century, several WLAN standards adopted OFDM on their physical layers. Development of European WLAN standard HiperLAN started in 1995. HiperLAN/2 was defined in June 1999 which adopts OFDM in physical layer. Recently IEEE 802.11a in USA has also adopted OFDM in their PHY layer. Perhaps of even greater importance is the emergence of this technology as a competitor for future 4th Generations (4G) wireless systems [14-15]. These systems, expected to emerge by the year 2010, promise to at last deliver on the wireless Nirvana of anywhere, anytime, anything communications. Should OFDM gain prominence in this arena, and telecom giants are banking on just this scenario, then OFDM will become the technology of choice in most wireless links worldwide.

2. Spectral Efficiency

In the case of OFDM, a better spectral efficiency is achieved by maintaining orthogonality between the subcarriers [16]. When orthogonality is maintained between different subchannels during transmission, then it is possible to separate the signals very easily at the receiver side. Classical Frequency Division Multiplexing (FDM) ensures this by inserting guard bands between sub channels. These guard bands keep the subchannels far enough so that separation of different subchannels are possible. Naturally inserting guard bands results to inefficient use of spectral resources. Orthogonality makes it possible in OFDM to arrange the subcarriers in such a way that the sidebands of the individual carriers overlap and still the signals are received at the receiver without being interfered by ICI [17].

3. Energy Loss

Unlike CDMA, OFDM receiver collects signal energy in frequency domain, thus it is able to protect energy loss at frequency domain [18]. OFDM can be used for high-speed multimedia applications with lower service cost. The OFDM transmitter simplifies the channel effect, thus a simpler receiver structure is enough for recovering transmitted data. A very simple channel estimation (and/or equalization) is needed, if coherent modulation schemes are used. Channel estimator is not needed if differential modulation schemes are used

4. Disadvantages of OFDM

Some of the disadvantages of an OFDM system are as follows:

4.1 Peak-to-Average Power Ratio(PAPR)

Peak to Average Power Ratio (PAPR) is proportional to the number of sub-carriers used for OFDM systems [19]. An OFDM system with large number of sub-carriers will thus have a very large PAPR when the sub-carriers add up coherently. Large PAPR of a system makes the implementation of Digital-to-Analog Converter (DAC) and Analog-to-Digital Converter (ADC) to be extremely difficult. The design of Radio Frequency (RF) amplifier also becomes increasingly difficult as the PAPR increases [20].

4.2 Strict Synchronization Requirement

OFDM is highly sensitive to time and frequency synchronization errors, especially at frequency synchronization errors, everything can go wrong [21]. Demodulation of an OFDM signal with an offset in the frequency can lead to a high bit error rate. The source of synchronization errors are two, first, one being the difference between local oscillator frequencies in transmitter and receiver, secondly, relative motion between the transmitter and receiver that gives Doppler spread. Local oscillator frequencies at both points must match as closely as they can [21]. The matching should be even more perfect for higher number of subchannels. Motion of transmitter and receiver causes the other frequency error. OFDM may show significant performance degradation at high-speed moving vehicles.

4.3 Co-Channel Interference (CCI) in Cellular OFDM

In cellular communications systems, CCI is combated by combining adaptive antenna techniques, such as sectorization, directive antenna, and antenna arrays. Using OFDM in cellular systems will give rise to CCI [22]. Similarly with the traditional techniques, with the aid of beam steering, it is possible to focus the receiver's antenna beam on the served user, while attenuating the co-channel interferers. This is significant since OFDM is sensitive to CCI.

5. Problem due to PAPR

An important limitation of OFDM is that it suffers from a high PAPR resulting from the coherent sum of several carriers [23]. This forces the power amplifier to have a large input backoff and operate inefficiently in its linear region to avoid intermodulation products.

5.1 The Effects of PAPR

The large variation in signal power affects both the transmitter and receiver design. This is because a very linear power amplifier with a large dynamic range is required at both the transmitter and the receiver. Any amplifier nonlinearity will result in a significant signal distortion. OFDM must keep its average power below the nonlinear region to accommodate the infrequent signal power peaks. But this result in a lower output power and also affects the efficiency and the range of the signal. Thus a careful design will compensate the distortion and the output power. In order to select an average input level, it must be assured that the average input level is possible of generating sufficient output power with no interference. Higher number of subcarriers used also will increase the value of PAPR. PAPR depends on the number of subcarriers and the level of SNR that must be maintained at the receiver. High PAPR also affects Digital/Analog (D/A) converters negatively and may lower the range of transmission [24]

5.2 PAPR Reduction Schemes

There have been many new approaches developed during the last few years. To minimize the OFDM system performance degradation due to PAPR, several techniques has been explored, each with varying degrees of complexity and performance enhancements. [1][2] These schemes can be divided into three general categories:

5.2.1 Signal Distortion Techniques

It reduces the peak amplitudes simply by nonlinearly distorting the OFDM signal at or around the peaks. Clipping and Peak Windowing is the simplest way to reduce the PAPR, such that the peak amplitude becomes limited to some desired maximum level. Other method is peak cancellation, where the out of time band radiation (undesirable effect) can be achieved by performing a linear peak cancellation technique, whereby a time shifted and scaled- reference function is subtracted from the signal [25].

5.2.2 Symbol Scrambling Technique

It scrambles each OFDM symbol with different scrambling sequences and selecting the sequence that gives the smallest PAPR. For each OFDM symbol, the input sequence is scrambled by a certain number of scrambling sequences. The output signal with the smallest PAPR is transmitted [26]. For uncorrelated scrambling sequences, the resulting OFDM signals and corresponding PAPR will be uncorrelated, so, if the PAPR for one OFDM symbol has a probability p of exceeding a certain level without scrambling, the probability is decreased to p by using k scrambling codes. Hence, symbol scrambling does not guarantee a PAPR below some level, rather, it decreases the probability that high PAPR will occur. Scrambling techniques were first proposed in under the names selected mapping and partial transmit sequences.

6. Existing Work Discussion

Hideki Ochiai et.al, 2019, in their journal has developed a system named “Performance of Block Codes with Peak Power Reduction for Indoor Multicarrier Systems”. In this journal, the performance of block coding scheme based on complementary sequences, which allows coding gain and reduction of peak to average power ratio (PAPR) of multicarrier signals, is evaluated over frequency selective Rayleigh fading channel, employing the efficient soft decision decoding method. Above all, 8-carrier Quadrature Differential Phase Shift Keying (QDPSK) and 8 Differential Phase Shift Keying (DPSK) systems exhibit good performance in terms of bit error rate improvement, feasibility of practically optimal decoding with a moderate coding rate, and the resultant PAPR at most 3dB. Coding method based on the connection of Golay complementary sequences and Reed-Muller code is proposed. Though this method may certainly offer flexibility for the system requirements, we will focus on the coding strategy of linear block codes since encoding is straightforward and computationally efficient yet practically optimal decoding algorithm is available. This paper describes the performance of the peak reduction block codes with differential detection over frequency selective fading channel and discusses the performance in terms of frequency diversity for indoor mobile radio environment, though this system may be also applicable to other applications. (Hideki Ochiai et.al, 1998)

Nam Yul Yu, 2018, in journal has developed a system named “A Theoretical Study of Peak-to-Average Power Ratio in Reed-Muller Coded Multicarrier CDMA”. Reed-Muller codes are studied for peak power control in multicarrier code-division multiple access (MC-CDMA) communication systems. In a coded MC-CDMA system, the information data multiplexed from users is encoded by a Reed-Muller subcode and the codeword is fully-loaded to Walsh-Hadamard spreading sequences. The polynomial representation of a coded MC-CDMA signal is established for theoretical analysis of the peak-to-average power ratio (PAPR). The Reed-Muller subcodes are then defined in a recursive way by the Boolean functions providing the transmitted MC-CDMA signals with the bounded PAPR as well as the error correction capability. A connection between the code rates and the maxim urn PAPR is theoretically investigated in the coded MC-CDMA. The theoretical study shows that the Reed-Muller subcodes are effective coding schemes for peak power control in MC-CDMA with small and moderate numbers of users, subcarriers, and spreading factors. In this journal, he proposes a binary Reed-Muller coded MC-CDMA system employing the Walsh-Hadamard spreading sequences, and theoretically study its PAPR properties. Most of the efforts on PAPR reduction of MC-CDMA have been verified mainly by statistical experiments, where it has never been addressed whether it is theoretically bounded. A recursive construction of Boolean functions is then presented for the Reed-Muller subcodes, where the PAPR of the MC-CDMA signal encoded by the subcode is proven to be theoretically bounded. In conclusion, the Reed-Muller codes can be effectively utilized for peak power control in MC-CDMA with small and moderate numbers of users, subcarriers, and spreading factors.(Nam Yul Yu, 2010)

7. Summary

Both of the journals use Reed Muller code as the reduction technique for PAPR. In this project, Reed Solomon (RS) code is used. Reed Solomon code has the same characteristic as Reed Muller code which is less distortion, no power increase but slightly power rate loss.

Acknowledgement

I would like to thank my supervisor, Dr. Mohammad Faiz Liew bin Abdullah, for his guidance and help in my final project.

References

[1] Wen, M., Basar, E., Li, Q., Zheng, B., & Zhang, M. (2017). Multiple-mode orthogonal frequency division multiplexing with index modulation. IEEE Transactions on Communications, 65(9), 3892-3906.

[2] Gade, S. H., Sinha, M., Rout, S. S., & Deb, S. (2018, July). Enabling reliable high throughput on-chip wireless communication for many core architectures. In 2018 IEEE Computer Society Annual Symposium on VLSI (ISVLSI) (pp. 591-596). IEEE.

[3] Saci, A., Al-Dweik, A., Shami, A., & Iraqi, Y. (2017). One-shot blind channel estimation for OFDM systems over frequency-selective fading channels. IEEE Transactions on Communications, 65(12), 5445-5458.

[4] Rajasekaran, A. S., Vameghestahbanati, M., Farsi, M., Yanikomeroglu, H., & Saeedi, H. (2019). Resource allocation-based PAPR analysis in uplink SCMA-OFDM systems. IEEE Access, 7, 162803-162817.

[5] Sandoval, F., Poitau, G., & Gagnon, F. (2019). On optimizing the PAPR of OFDM signals with coding, companding, and MIMO. IEEE Access, 7, 24132-24139.

[6] Basar, E., Di Renzo, M., De Rosny, J., Debbah, M., Alouini, M. S., & Zhang, R. (2019). Wireless communications through reconfigurable intelligent surfaces. IEEE access, 7, 116753-116773.

[7] Hussein, Y. S., Alias, M. Y., Abdulkafi, A. A., Omar, N., & Salleh, M. K. B. (2018). Expectation-maximization-based channel estimation algorithm for OFDM visible light communication systems. International Journal of Engineering & Technology, 7(4), 2638-2645.

[8] Panayirci, E., Altabbaa, M. T., Uysal, M., & Poor, H. V. (2019). Sparse channel estimation for OFDM-based underwater acoustic systems in Rician fading with a new OMP-MAP algorithm. IEEE Transactions on Signal Processing, 67(6), 1550-1565.

[9] Cheng, X., Liu, D., Wang, C., Yan, S., & Zhu, Z. (2019). Deep learning-based channel estimation and equalization scheme for FBMC/OQAM systems. IEEE Wireless Communications Letters, 8(3), 881-884.

[10] Fathima, S. Y., Rahman, M. Z. U., Krishna, K. M., Bhanu, S., & Shahsavar, M. S. (2017). Side lobe suppression in NC-OFDM systems using variable cancellation basis function. IEEE Access, 5, 9415-9421.

[11] Melki, R., Noura, H. N., Mansour, M. M., & Chehab, A. (2018). An efficient OFDM-based encryption scheme using a dynamic key approach. IEEE Internet of Things Journal, 6(1), 361-378.

[12] Hamamreh, J. M., Furqan, H. M., & Arslan, H. (2018). Classifications and applications of physical layer security techniques for confidentiality: A comprehensive survey. IEEE Communications Surveys & Tutorials, 21(2), 1773-1828.

[13] Hadi, I., & Thussyadiyah, R. H. (2019, February). MIMO Printed Dipole Antenna for Wimax Network Usage Application. In Journal of Physics: Conference Series (Vol. 1167, No. 1, p. 012014). IOP Publishing.

[14] Lax, S. (2017). Different standards: Engineers' expectations and listener adoption of digital and FM radio broadcasting. Journal of Radio & Audio Media, 24(1), 28-44.

[15] Jauert, P., Ala-Fossi, M., Föllmer, G., Lax, S., & Murphy, K. (2017). The future of radio revisited: Expert perspectives and future scenarios for radio media in 2025. Journal of radio & audio media, 24(1), 7-27.

[16] Ghannam, H., & Darwazeh, I. (2018). SEFDM over satellite systems with advanced interference cancellation. IET Communications, 12(1), 59-66.

[17] Sofi, N., Bendimerad, F. T., & Debbat, F. (2017, May). Compromise between spectral efficiency and interference cancellation in OFDM system. In 2017 International Conference on Engineering & MIS (ICEMIS) (pp. 1-7). IEEE.

[18] Liu, Z., Zhang, L., Wu, Z., & Bian, J. (2019). A secure and robust frequency and time diversity aided OFDM–DCSK modulation system not requiring channel state information. IEEE Transactions on Communications, 68(3), 1684-1697.

[19] Singh, M., & Patra, S. K. (2018). On the PTS optimization using the firefly algorithm for PAPR reduction in OFDM systems. IETE Technical Review, 35(5), 441-455.

[20] Abdelali, H., Bachir, S., & Oumsis, M. (2018). New Technique Combining the Tone Reservation Method with Clipping Technique to Reduce the Peak-to-Average Power Ratio. International Journal of Electrical & Computer Engineering (2088-8708), 8(6).

[21] Cortés, J. A., Aguayo-Torres, M. C., Cañete, F. J., Gómez, G., Martos-Naya, E., & Entrambasaguas, J. T. (2019). Vehicular channels: Characteristics, models and implications on communication systems design. Wireless Personal Communications, 106(1), 237-260.

[22] Jasim, M. (2018). Initial Beam Access Schemes for Millimeter Wave Cellular Networks. University of South Florida.

[23] Yao, M., Carrick, M., Sohul, M. M., Marojevic, V., Patterson, C. D., & Reed, J. H. (2018). Semidefinite relaxation-based PAPR-aware precoding for massive MIMO-OFDM systems. IEEE Transactions on Vehicular Technology, 68(3), 2229-2243.

[24] Singh, V. K., & Dalal, U. D. (2017). Abatement of PAPR for ACO-OFDM deployed in VLC systems by frequency modulation of the baseband signal forming a constant envelope. Optics Communications, 393, 258-266.

[25] Azizipour, M. J., & Mohamed-pour, K. (2017). Clipping noise estimation in OFDM systems: A greedy-based approach. AEU-International Journal of Electronics and Communications, 80, 36-42.

[26] Zhao, N., Cheng, F., Yu, F. R., Tang, J., Chen, Y., Gui, G., & Sari, H. (2018). Caching UAV assisted secure transmission in hyper-dense networks based on interference alignment. IEEE Transactions on Communications, 66(5), 2281-2294.

[27] Hama, Y., & Ochiai, H. (2019). Performance analysis of matched-filter detector for MIMO spatial multiplexing over rayleigh fading channels with imperfect channel estimation. IEEE Transactions on Communications, 67(5), 3220-3233.

[28] Yu, N. Y. (2019). Multiuser activity and data detection via sparsity-blind greedy recovery for uplink grant-free NOMA. IEEE Communications Letters, 23(11), 2082-2085.