Review of Wireless OFDM and its Challenges

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Abstract— Current wireless OFDM system under AWGN channel are reviewed by the widely used choice of the researchers and wireless professionals. An OFDM is widely been used for the broadband high speed data and video transmission. There are many technical challenges while implementing the OFDM, the major challenge is problem of High PAPR which may leads to the non-linearity of the high power amplifier of the system and may cause distortion and less efficiency. Many researchers have designed methods to reduce the PAPR problem. The paper has broadly classified the PAPR reduction methods and then individually reviews the each category. Paper concludes that use of PAPR reduction methods may increase the efficiency of the OFDM system. Using hybrid combinations of the various methods may optimally improves the OFDM performance under large number of the sub carriers and different working environments.

Key words: OFDM, Wireless Communication, PAPR, AWGN, Selective Mapping, Clipping

I. INTRODUCTION

An OFDM is commonly used modulation technique for wireless broadband applications which offers the capabilities of multi-carrier communication. OFDM method actually sub-divides the total system bandwidth into N number of orthogonal carriers therefore it is also called as the Multi Carrier (MC) modulation. The information signal is petitioned to small blocks and transmitted simultaneously using these N sub parallel multi carriers without any overlapping each other thus OFDM significantly avoids the inter carrier interference ICI) due to orthogonality property.

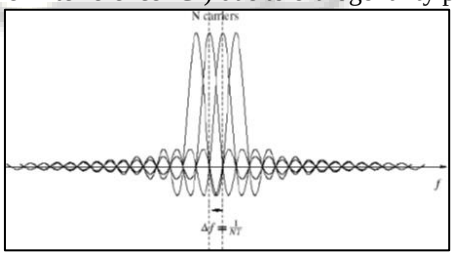

Fig. 1: OFDM Sub Carrier frequency responses

The concept of orthogonal sub carriers of OFDM system is shown in Figure 1.

This paper is aimed to design the wireless communication method capable of reducing the major OFDM challenges efficiently. The major advantages of modern wireless communications are its higher speed, flexibility, simplicity, and mobility. But simultaneously the high speed OFDM communication may suffers from challenges of Inter-Symbol Interference (ISI), Inter-Carrier Interference (ICI) under the AWGN and frequency selective fading environments. There are various challenges which have to be conquering for providing the quality transmission under AWGN and fading environments.

There are many advantages of modern day's wireless communications such as flexibility, simplicity, mobility and higher speed. At the same time high speed wireless communication suffers from challenges of Inter-Symbol Interference (ISI), Inter-Carrier Interference (ICI) and multipath frequency selective fading. There are many challenges which must be conquering for providing the quality transmission under fading environments. The challenges exist at OFDM system design are hardware issues, PAPR and communication link design challenges. Out of theses some of the major challenges are discussed in this paper.

II. PAPR REDUCTION METHODS CLASSIFICATION

PAPR reduction methods can be mainly divided into two domain methods: frequency domain method and time domain method [3] as shown in the Figure 2. The basic of frequency domain method is to increase cross correlation of the input signal before IDFT and decrease the output of the IDFT peak value or average value. Selective Mapping (SLM), Partial Transmit Sequence (PTS), Pre coding etc. schemes are example of frequency domain method. However, in time domain method PAPR is reduced by distorting the signal before amplification and added of extra signals which increase the average power. Clipping and filtering, Peak widowing etc. are examples of time domain method. It is very simple method because it requires very less computational time but introduces the distortion, increases out of band radiation and also degrades BER performance. On comparing between these two domain methods, frequency domain PAPR reduction technique is most efficient one because it compress the PAPR without distorting the transmitted signal, no production of in band distortion and out of band radiation in OFDM signals.

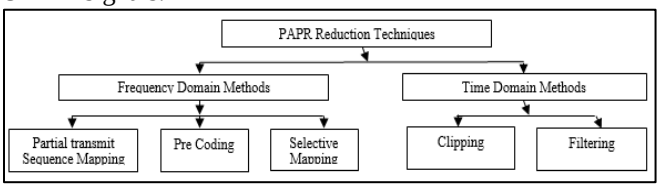

Fig. 2: Classification of PAPR reduction methods

III. IMPACT OF PAPR

The major impact of a high PAPR are-

1) Increased complexity in the ADC and DAC.
2) Reduced in efficiency of radio frequency (RF) amplifiers

The parameters that influence the PAPR are-

– The number of subcarriers (S) in OFDM system is directly proportional to the PAPR as shown observed. As S increases, PAPR of OFDM system also increases and decreasing on decreases PAPR but code rate also decreases.
– Modulation schemes shows that PAPR is linearly dependent on constellation of modulation schemes (C). It is known that is more for M-QAM than M-PSK.

There are many modulation techniques which have been used to design the OFDM by the researchers. M-PSK and M-QAM modulations are most popular modulation techniques used for OFDM. The choice of modulation

techniques depends opens the data transmission speed and the capacity of the communication system also affects the PAPR issues. Since the Bit Error Rate (BER) performance of the transmission and reception various with the order of the modulation therefore, it is required to observe the performance of the high speed wireless OFDM system under different order of modulation.

Quadrature Amplitude modulation (QAM) is used for high speed wireless digital transmission with OFDM [8, 11, and 14]. Combining QAM with OFDM improves the efficient and performance of QAM modulation under multipath flat fading environment. Also using OFDM along with QAM the ISI removed and the bandwidth efficiency of the wireless system is also improved

IV. CHALLENGES IN OFDM IMPLEMENTATION

There are many reasons due to which OFDM implementation may be a complex in nature and same time high speed wireless communication suffers from challenges which makes it difficult to track few of them are Inter-Symbol Interference (ISI), Inter-Carrier Interference (ICI) and multipath frequency selective fading. There are many challenges which must be conquering for providing the quality transmission under fading environments. The challenges exist at OFDM system design are hardware issues, networks issues, and communication link design and application design challenges. Out of theses some of the major challenges are discussed in this paper.

Although there are many challenges for the implementing the OFDM system including cyclic prefix insertion, FFT implementation and Fading effects of channel. But High Peak-to-Average Power Ratio (PAPR) is a major drawback of OFDM modulation systems. High PAPR forces final High Power Amplifier (HPA) to work in its linear region along with its wide dynamic range therefore its power efficiency is reduced significantly. This creates the need of PAPR reduction more essential in OFDM modulation systems.

There are many methods [1, 2, 4 and 5] which have been designed in order to reduce this problem. Among these methods Selected Mapping (SLM) [3] and Clipping [1] are widely used techniques for PAPR reduction. But the efficiency of the PAPR reduction methods varies with the different modulation conditions and rate. Therefore this dissertation proposed an adaptive hybrid technique which combines the existing method to address the better PAPR reduction problem.

There are two basic types of the wireless communication channels defined as;

A. AWGN Channel

Usually the communication channel is modelled with the Additive White Gaussian Noise (AWGN) [3, 5, and 19]. The AWGN channel model is one in which the only harm to communication channel is the linear addition of wideband or white noise with a flat power spectral density articulated with watts per hertz of bandwidth and a Gaussian distribution of amplitude. The term noise is defined as an unwanted signal that are always present in channel and systems and the additive means the noise is superimposed to the signal that tends to limit the receiver ability to take the correct symbol decisions [5].

The AWGN channel is a good approximation for the Satellite and Space communication links with BPSK modulation techniques. The AWGN channel adds white Gaussian noise to the input signals. Therefore the transmitted signal, white Gaussian noise and received signal are expressed as $s(t), n(t),$ and $y(t)$ respectively [5]. Where $n(t)$ is a sample function of the AWGN process with probability density function (pdf) and power spectral density as,

$$N_{nm}(f) = \frac{1}{2}N_0 \left|\frac{w}{H_z}\right| \qquad (1)$$

But this model does not described phenomena like frequency selectivity, fading, interference, dispersion or nonlinearity. However, it defined simple, tractable mathematical models which are useful for achieving insight into the primary behaviour of a system before considering all of these other phenomena. AWGN model is commonly used to simulate environmental noise of the channel under observation, in addition to multipath, terrain ground clutter, blocking, interference, and self-interference encountered by the modern radio systems in terrestrial operation.

B. Fading Channel

Since the wireless channel environment is a time-varying environment. So signal transmitted in a wireless channel suffers from multipath fading, interference, and delay spread and propagation path losses When any object comes across the path between a wireless transmitter and a receiver, it stops the signal and generates number of signal paths known as multi path. A wireless channels may be statistically model in number of ways in order to represent the random nature of multipath fading. A most simple and popular channel model as shown in the Figure 3 which represents the fading channel with a linear and time-varying Channel Impulse Response (CIR) represented by the function $\square(t, \tau)$.

$$r(t) = h(t, \tau) * s(t) \qquad (2)$$

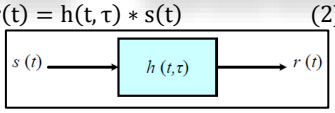

Fig. 3: Modelling channel by the Channel Impulse Response

OFDM contains some inbuilt benefits useful for improving the performance of wireless communications channels. This section deals with few most important benefits due to which OFDM is becoming widely popular in the wireless communication field. Using the cyclic insertion process and proper design, it is possible to completely eliminate ISI from the system.

OFDM modulated systems are intrinsically robust against the impulsive noises generated by channels, since the symbol period of the OFDM signal is much larger than that of the respective single carrier modulation system. Therefore, it is less likely that impulse noise might cause (even single) symbol errors in OFDM systems. Thus, complicated error-control coding and interleaving schemes for handling burst-type errors are not really required for OFDM Systems simplifying the transceiver design.

V. REVIEW OF MODULATION TECHNIQUES

Dua and Yadav [5] in year 2012 studied digital modulation schemes, such as PSK (Phase Shift keying) and QAM (Quadrature Amplitude Modulation) over an additive white Gaussian Noise (AWGN) channel to analyze the performance

of an OFDM system in terms of bit error rate (BER). The simulation result shows that, for high-capacity data rate transmission, QAM modulation performs better than the PSK modulation. Neetu sood et al. [3] has used BPSK and QPSK modulation techniques with OFDM over Gama fading channel. Mangal Singh et al.[2] in 2013 have analyzed the performance of OFDM techniques for the application in LTE technology. there main work is on to reduce the PAPR in OFDM system and they have compared the performance of the Selective Mapping (SLM) and Partial Transmit Sequence (PTS) method of PAPR reduction.

Surekha et al [4] 2011 performed a simulink based simulation system using Additive White Gaussian Noise channel (AWGN) to study the performance analysis of Bit Error rate (BER) Vs. Signal to Noise ratio (SNR).The effect of noise over AWGN channel was observed by using Constellation diagrams and results were concluded by comparing the simulated data with BER Tool, as it plays an important role in characteristic performance analysis of QAM –OFDM system.

VI. Review of OFDM Based Wireless WiMax

The OFDM transmission over wireless mobile communications channels can mitigate the problem in the multipath propagations [21]; current research efforts have focused on solving a set of inherent challenges associated to OFDM, namely the effect of cyclic prefix extension, time and frequency synchronization, and alleviating effects of the frequency selective fading channel. These issues are addressed below in slightly more depth, while a treatment is given in WiMAX (Worldwide Interoperability for Microwave Access), is the commercialization of the IEEE 802.16 standards [9]. Method aims to provide consumer and big business wireless broadband services on the scale of the Metropolitan Area Network (MAN). In June 2004, the 802.16 working group have got an approval for the latest 802.16 standard [9] known as IEEE802.16-2004 applicable for fixed wireless access,. In December 2005, an extended version is approved as IEEE802.16e-2005 that addresses mobility also. IEEE802.16-2004 acts as backhaul for Wi-Fi hot spots and potentially provides last-mile broadband wireless access to internet. IEEE802.16e-2005, the mobile version of WiMAX, is optimized for dynamic mobile radio channels and supports handoffs and roaming at vehicular speeds of up to 75 mph.

In IEEE 802.16e standard, an orthogonal frequency division multiple access (OFDMA) technique [1, 2] is used for multiple access scheme and multiple-input multiple-output (MIMO) system is applied to increase data rate. In reality, WiMAX is a 4G wireless technology that enhances broadband wireless access [11]. To meet the requirements of different types of access, the WiMAX Forum has two different system profiles: fixed system profile based on IEEE 802.16-2004 OFDM PHY (orthogonal frequency division multiple access) PHY; the other is mobility system profile based on IEEE 802.16e-2005 scalable OFDMA PHY. WiMAX applications are to convey broadband wireless services at a low cost.

Zhou et al [17] in 2007 given the overview of specifications of IEEE802.16e PHY and also performance of IEEE802.16e PHY was obtained using link level simulation by MATLAB. Reference value of PUSC gain is presented in the simulation results. And also the link performance with QPSK and 16 QAM modulations were presented.

Yoo et al [16] 2007 implemented a fixed-pFoint DSP algorithm for K-BEST lattice decoding algorithm in IEEE 802.16e 2 × 2 MIMO-OFDMA systems. Using fixed-point simulation the system performance of K-BEST algorithm was compared with ZF (zero-forcing) receiver. The computational complexity and the ability of real-time process of K-BEST algorithm was measured using DSP evaluation board. The paper concludes that ZF receiver requires lower computational complexity, but that showed poor BER (bit error rate) performance. Therefore, it is not suitable for implementation. K-BEST, on the other hands, showed reasonable BER performance, realistic computational complexity, and ability of real-time process. The author suggested that the complexity of existing computational of K-BEST algorithm for real-time process can be reduced by adopting K more than 2.

Sharef et al [14] in 2012 studied a link level simulation and also optimized the physical layer performance of WiMAX IEEE 802.16e system for the AWGN and multipath Rayleigh fading channels. Two 802.16e based OFDMA transceivers were designed using MATLAB Simulink. The effect of fading channel, Doppler shift and cyclic prefix on the system design performance were analyzed and investigated. The simulation shows that channel estimation improves the system performance, but the investigated system suffers from severe performance degradation and high probability of error whenever channel estimation was not applied.

Lahcen et al. [8] in 2016 have investigated the Peak to Average Power Ration reduction method with the varied phase for designing the efficient the MIMO-OFDM system they have proposed a PTS scheme along with the solid state power amplifier for the reduction of PAPR.

Mingxi Wang [26] in (2011) gives an overview of the physical layer of the WiMAX standard IEEE802.16-2009. A simulation system with LDPC coded MIMO-OFDM was also established for analyzing the performance of the OFDM WiMAX transceiver. The simulations results show that the iterative receiver structure can achieve good performance. The bit error rate (BER) versus SNR (Es/No, db), for different channels and LDPC coding rates were plotted.

Patidar et al [7] in 2012 have developed the model of WiMAX physical layer using Simulink in MATLAB. The model was used for BER performance evaluation of WiMAX physical layer for real time audio data communication under different digital modulation scheme, channel encoding rate, and channel conditions. To evaluate the performance, for each SNR (signal to noise ratio) level, the received signal was demodulated and the received data was compared to the original information. The bit error rate (BER) versus SNR (Es/No, db), which provide information about the systems performance were plotted.

Amit et al. [13] in 2013 have presented a simulation of PAPR reduction method using the selective mapping method. They have used the IFFT along with the Selective mapping to improve the PAPR performance. They have modeled the OFDM based WIMAX system using Simulink in MATLAB with channel estimation and equalization sub system. Then performance of the MIMO receivers over the

Rayleigh flat fading channel with channel estimation errors is investigated.

Han Wang et al. [6] in 2016 have investigated the hybrid PAPR reduction method used for the FBMC/OQAM systems. The method was hybrid combination of partial transmit sequence (PTS) and method of tone reservation (TR) techniques. Th0e hybrid method exploits the multi overlapped adjacent blocks for increasing the efficiency. The bit-error rate (BER) performance of the multilevel Quadrature amplitude modulation (M-QAM) is analyzed

Tariq et al.[12] in 2011, have proposed the transmission of BPSK signals using OFDM system with 64-point FFT and using convolution coding. They have used cyclic prefix of length 16 for higher bandwidth efficiency. Banerji et al. [18] have presented a comparison of WiMAX and Wi-Fi technologies

VII. PAPR REDUCTION

Factors for selecting the PAPR reduction technique
Several factors should be considered for selecting the technique that can reduce the PAPR effectively as well as can maintain high quality performance. These following factors are to be considered [2, 6, 8, and 15] as:

- Without introducing in-band distortion and out-of-band radiation, PAPR reduction techniques should be enable to reduce the PAPR.
- Low average power: The raise in power requires a high linear operation region in HPA and hence degrades the BER performance. \
- No BER performance degradation: The motive of PAPR reduction is to get better system performance as well as BER than that of the original OFDM system.
- Addition power: Power efficiency should be considered while reducing the PAPR. If the operation of the technique which reduces the PAPR needs more additional power, then it degrades the BER performance when the transmitted signals are normalized back to the original power signal.
- No spectral spillage: The PAPR reduction technique should not destroy the inherent feature (orthogonality) of OFDM signal.

The widely used technique of PAPR reduction is amplitude clipping. This technique can be implemented by clipping parts of the OFDM signals (after IFFT) that are greater than a threshold level. If OFDM signals are clipped, it will introduce in-band distortion and out-of-band radiation (adjacent channel interference) into the communication system as a result BER performance of the system degrades. Hence, the best solution is to reduce the PAPR before formation of OFDM symbols as well as prior transmitted OFDM symbols into nonlinear HPA and DAC [15].

VIII. CONCLUSIONS

This paper has focused to review the various challenges in the designing of OFDM based WiMAX communication systems. It has been concluded that designing the OFDM system is a challenging problem due to major problem of the Higher PAPR of the system, random impulsive noise and temporal variation of the wireless channels. The challenge varies with respect to types of the wireless communication channels. The efficiency of WiMAX is essential based on the efficiency of OFDM modulation systems. After reviewing the work on PFDM following conclusions are drawn:

- The OFDM is widely used for wireless communication and attracted attentions of many researchers. OFDM has many application Viz. Broadband Internet, Digital Audio and Video Broadcasting, WiMAX, Wi-Fi, and in mobile application.
- Paper concludes that to generate efficient OFDM system with large traffic data and faster speed is a still challenging field of research.
- The efficiency of OFDM depends on the efficiency of the channel performance therefore many techniques are designed for channel fading reduction and for coding.
- The major problem with OFDM system is Higher PAPR and many methods have been designed to improve the performance of PAPR Viz. Clipping and Filtering, selective mapping, coding methods. But there performance is not consistent with different amount of noise. Therefore, it is required to improve efficiency of PAPR reduction methods..
- It is also require evaluating the performance of the PAPR reduction methods for different symbol rates and sizes.

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