PAPR Reduction Techniques in OFDM

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Abstract : The Orthogonal frequency division multiplexing (OFDM) is the most commonly used digital communication technique for transmitting large data over radio waves. Although OFDM is the most commonly efficient method of transmission, a drawback emerges from the mode of transmission which is the PAPR (peak to average power ratio). The peak to average power ratio goes high when the partially transmitted waves of OFDM are added up. These peaks cause many issues which are discussed here in this paper. This paper also gives a detailed outline of OFDM. The method to overcome the PAPR effect is also discussed.

IndexTerms - **OFDM (orthogonal frequency multiplexing), PAPR (peak to average power ratio), signal scrambling, signal distortion, coding techniques.**

I. INTRODUCTION

With the growth of communication technology, necessity for the mode of propagation satisfying the requirements is becoming mandatory. An efficient system must be able to provide high bit rate, low bit error rate, essential bandwidth and spectral efficiency. The destructive impact of fading environment and bandwidth has become the limitations of the communication system. Advance modulation formats with competing bandwidth and spectral efficiency required to support higher data rates are emerging which are actually not supported by the current systems. OFDM has drawn much attention as it attains the maximum transmit diversity. It is the most commonly used strands of the broadband wireless communication technology. The key challenges of future communication advancements have dropped their way through OFDM. It uses a smart adaptive technique which is detailed in this paper. This paper gives the boon and bane of OFDM. It briefly discusses on the methodologies reducing the most important disadvantage (PAPR effect) with its detailed study.

II. OFDM

OFDM (Orthogonal frequency division multiplexing) is the most widely used method of transmission in digital communication on trend. It is used as the digital multi-carrier modulation method. Earlier mode of transmission resulted in the increase of interface which paved the way for emergence of OFDM technique [3]. In OFDM the signals are driven orthogonally in order to avoid interference. Hence it could transmit multiple information signal and large data over radio waves at a high bit rate. OFDM increases the robustness against selective fading or narrow band interference.

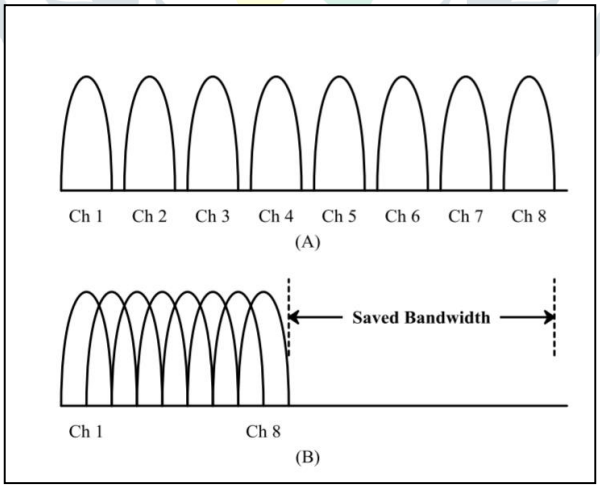

Fig 1 FDM subcarrier vs OFDM subcarrier

This technique initially divides the available spectrum into many subcarriers and each subcarrier will modulate by a low data stream rate. It breaks the wideband channel into several narrowband sub-channels and transfers parallel information.

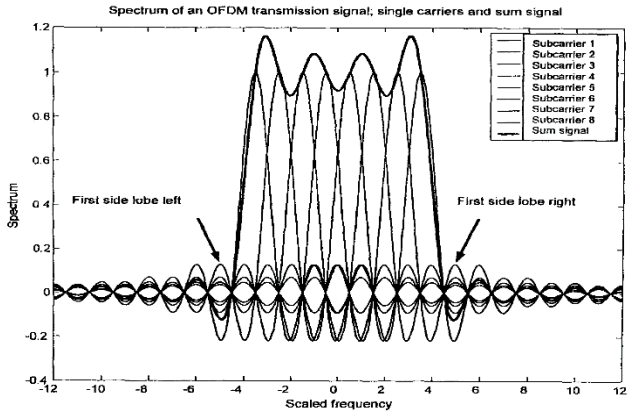

Fig 2 Spectrum of an OFDM transmission signal

In OFDM systems, each subcarrier is orthogonal to the other subcarrier because with minimum frequency spacing the spectrum of individual subcarrier is overlapped. A guard interval is inserted between the OFDM symbols. The purpose of the guard interval is to eliminate inter symbol interference. Hence it proves to replace the pulse shaping filters and also reduces the sensitivity to time synchronization problems.

Advantages of OFDM:

1. Immunity to selective fading.
2. Resilience to interference.
3. Spectrum efficiency.
4. Resilient to ISI (inter symbol interference).
5. Simpler channel equalization.

III. PAPR EFFECT

OFDM is an efficient method of transmission as discussed earlier. But the major disadvantage of OFDM is high PAPR (high peak to average power ratio) [5]. OFDM uses IIFT method for addition of the parallel projecting signals. The use of IIFT gives a resulting signal with large peaks and dynamic range in time. A serious issue that is nonlinear input output characteristics are got when high value PAPR is passed through non-linear devices such as 4G systems and high-power amplifier. These signals would also require dynamic linearity from the analog circuit which makes us to design expensive devices but then gives lower efficiency with high power consumption. The non-linear distortions due to high peaks also causes in-band and out of band interference to signals wherein in-band interference cause a increase in the Bit error rate (BER) of the received signal, while the out-of-band interference causes adjacent channel interference through spectral spreading [5].
Here are certain basic techniques to reduce PAPR effect.

IV. TECHNIQUES FOR PAPR REDUCTION

4.1) Signal scrambling:

Coding techniques can be used for signal scrambling. More practical solutions of signal scrambling techniques are mentioned below

1. Block coding
2. Selective level mapping
3. Partial transmit sequence
4. Inter leaving.

4.1.1) Selective level mapping:

The basic idea of SLM technique (selective level mapping) is to generate or setoff sufficiently different candidate data blocks by the transmitter, where all the data blocks represents the same information as the original data block and select the favorable having the least PAPR effect. Computational complexity, PAPR reduction capability and avoiding SI are the key issues in SLM. There are various methods available in literature to modify SLM.

4.1.2) Partial transmit sequence:

The concept used in partial transmits sequence (PTS) is that the data blocks are partitioned into non-overlapping sub blocks and each sub block is rotated with a independent factor. The rotation factor is transmitted to the receiver as side information. It should be noted that the time domain data with the lowest peak amplitude is generated by rotating factor. PTS performs much better when compared to selective mapping.

4.1.3) Inter leaving:

Highly correlated data frames have larger effects. It can be reduced if long correlation patterns were broken. The paper [2] proposes a adaptive technique to reduce the complexity of the scheme. The main idea in adaptive interleaving is to establish a early terminating threshold that is, the search is terminated as soon as the PAPR value reaches below the threshold rather than searching all the interleaved sequence. The low threshold will force the adaptive interleaving (AIL) to search for all the interleaved sequence. Whereas for a large threshold value, AIL will reach only the fraction of the interleaved sequence. It is less complex than the PTS method but achieves comparable results. It is found that the PAPR can be reduced to about 2db in 16 QAM OFDM without any increase in power but with a slight increase in the system complexity.

4.2) Tone reservation:

The concept of tone reservation deals with the reservation of the set of tones which is used in PAPR reduction. These tones carry no information data but are added to the existing OFDM symbols so that the summation of signals has lower PAPR values [7]. The amount of PAPR reduction depends on the number of reserved tones, their location within the frequency vector and the amount of complexity. The main advantage of the tone reservation technique is that no process is necessary at the receiver end. And also there is no necessity to transmit the side information along with the transmitted signal. In this method peak is reduced by adding the block to the time domain signal.

4.3) Signal scrambling

4.3.1) Peak window:

In windowing technique, some windows like Gaussian shaped window, cosine, Kaiser and Hamming window are multiplied with large signal peak [8]. Since several windows are multiplied with OFDM signal, the outcome of the spectrum will be the convolution of the original OFDM spectrum with the spectrum of the applied window. Even though the window is a narrow band in the time domain, the window must not be too long because many signal samples are affected by increasing the BER. With windowing method, PAPR can be reduced down to about 4dB, independent of the number of sub carriers. The signal distortion which causes the loss in SNR is limited to about 0.3dB. A back off relative to maximum output power of about 5.5dB is required in order to keep undesired spectra distortion at least 30dB below the in-band spectral density.

4.3.2) Clipping & filtering:

The correction of OFDM signal is done by adding it with a corrective function k(t). This method causes interference of the OFDM signal with minimal power. If there is no over sampling of OFDM signal, then the correction scheme is identical with clipping and an interference occurs on each sub carrier for each correction in the amplitude peak and the power of the correcting function is distributed evenly to all sub carriers. To correct the signal by correcting factor, the signal s(t) is oversampled by a factor of four and normalized so that the signal power is one. Then the signal is corrected with k(t). The amplitude threshold A0 is set according to the input bakeoff for the correction. After the correction, the limitation of amplitude peaks is taken into account by limiting the signal amplitude to A0which may have remained. The multiplicative Gaussian function or additive sinc function can be used for correction of signal. The scheme does not require any redundancy and, so it can be used for any number of subcarriers. Minor increase in the total in-band distortion reduces the PAPR effect.

4.3.3) Envelope scaling:

In this method, the envelopes of all the subcarriers input with PSK modulation are equal. The envelope of the input in some subcarriers can be scaled to obtain the minimum PAPR at the output of IFFT. The final input that gives the lowest PAPR will be sent to the system. The input sequence has the same phase information as the original one, but the envelopes are different. So, the receiver can decode the received sequence without any side information.
The main idea behind the scheme is that to obtain the minimum PAPR at the output of the IFFT the envelope of the input in some subcarriers is scaled.
In PSK modulation, the envelope of all subcarrier inputs are equal, hence the scheme supports PSK modulation [10].The carrier envelope scaling will result in the serious BER degradation due to the implementation of QAM modulation scheme in the OFDM system. To limit the BER degradation, amount of the side information would also be excessive when the number of subcarriers is large.

4.4) Coding techniques:

The main idea behind the coding techniques is to select those code words that reduce the PAPR effect and transmit the signals. Forward error correction (FEC) is defined by (n,k), where n is the data bit and k is the redundant bit.
FEC are further classified as:

- Block codes
- Run length codes

In block codes, a block of data is used to encoder whereas run length codes employ memory and lower values of n.

- Few block code techniques are:
- Linear block codes
- Golay complementary codes.
- Reed mullar.
- Bose chaudhari hochquenghen (BCH)
- Low density parity checker.

The superior performance at the cost of coding rate is the main disadvantage on considering the characteristics of these coding techniques.

V. CONCLUSION

As OFDM is used as the major technique for digital communication, it is chosen as the area of research by many research scholars. Many researches are done in accordance with issues but then it remains complicated which means the issues are not fully recovered. It is the state of research with many open issues. Basic requirements of practical PAPR techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency and low complexity. Even though various techniques were introduced to reduce the PAPR in OFDM, none of the techniques proves to be a perfect solution. The corresponding reduction technique have chosen for various system requirements. In future even more PAPR reduction technique can be introduced depending on the demand.

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