AN OVERVIEW AND MODELLING OF AMPLITUDE LIMITATION FOR OFDM SYSTEM

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ABSTRACT

The orthogonal frequency division multiplexing (OFDM) is a wideband wireless digital communication technique that is based on block modulation. It effectively improves the bandwidth and efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission. The OFDM scheme is mainly based on Digital signal processing (DSP) techniques. OFDM signals have a very large peak to average power ratio or one can say that amplitude limitation of OFDM system. This effect produces interference both within the OFDM band and in adjacent frequency bands. Coding, phase rotation, mapping, clipping and partial transmit sequence (PTS) etc. are among many PAPR reduction schemes that have been proposed to overcome this problem. In this paper an overview and modelling of OFDM system for amplitude limitation is given.

Keywords - TDM, FDM, OFDM, PAPR, PTS, DSP, MCS, ISI and MCM etc.

I. INTRODUCTION

1.1 Orthogonality and OFDM

Orthogonality between two signals means that the two coexisting signals are independent of each other in a specified time interval and do not interact with each other. The concept of orthogonal signals is essential for the understanding of OFDM system Orthogonality is a property that allows multiple information signals to be transmitted perfectly over a common channel and detected without interference. Loss of orthogonality results degradations in communication.

Many common multiplexing schemes are inherently orthogonal. Time division multiplexing (TDM) allows transmission of the multiple signals over a single channel by assigning unique time slots for each of the information signals. TDM is orthogonal in nature but time synchronization problem is the limitation.

In the frequency division multiplexing (FDM), most FDM systems are orthogonal in the sense that each of the separate transmission signals is well spaced out in frequency, preventing the interference but it consumes a lot of spectrum.

The above two methods preserve orthogonality with a compromise, the term OFDM reserves a special feature. It is orthogonal FDM in which the subcarriers are spaced as close as possible maintaining orthogonality between them and hence, saving of spectrum is achieved. The OFDM arranges the subcarriers in the frequency domain by allocating partly the information signals onto different subcarriers. Single information stream is split into multiple symbols and each symbol or a group of symbols will be assigned a separate carrier. All the split information is then transmitted in parallel through multiple carriers. Each carrier in an OFDM system is a sinusoidal with a frequency such that the spacing between two consecutive subcarriers depends upon the symbol rate and hence on the bit rate, which again can be derived from the condition of orthogonaltiy. If the OFDM symbol period is too long, the spacing between the carriers can be reduced to be as close as possible.

In OFDM, multiple carriers are used for the transmission of the multiplexed multi-user information in a frame and hence the carriers are related in one channel bandwidth. Figure 1.1 shows how OFDM is saving bandwidth as compared with conventional FDM.

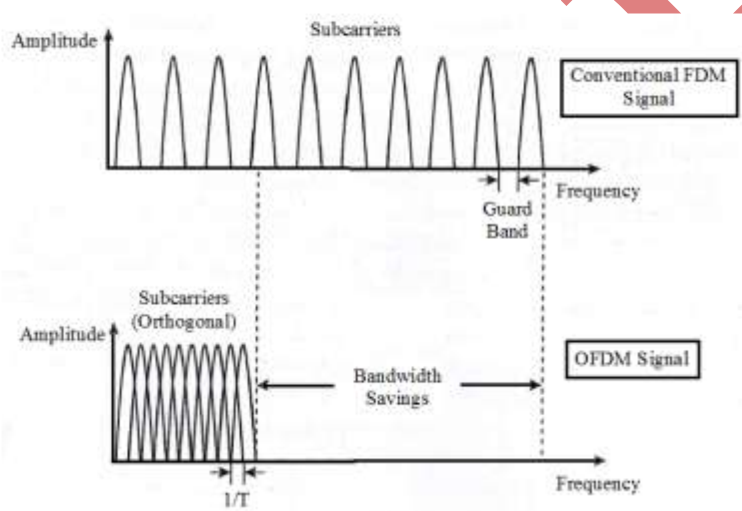

Fig.1.1 Conventional FDM and OFDM signal showing saving of bandwidth

1.2 Basic Structure of a Multicarrier System

The basic idea of OFDM is to divide the available spectrum into several sub-channels (or subcarriers). By making all sub-channels narrowband, they experience almost flat fading, which makes equalization very simple. The OFDM provides a DSP-based technique allowing the bandwidths of modulated carriers to overlap without interference. To obtain a high spectral efficiency, the frequency responses of the sub-channels are overlapping and orthogonal. Orthogonality can be completely maintained, even though the signal passes through the time-dispersive channel, by introducing cyclic prefix. It also supports a high data rate due to serial-to-parallel conversion of symbols acquiring long symbol duration, thus helping eliminate inter-symbol interference (ISI). Input signals which are divided by a multiplexer are applied to pulse-formed $h_t(t)$ filters before being transmitted through multipath environment. Correspondingly, the receiving ends consist of N parallel paths. Each one is passed through a respective match filter $h_r(t)$ to realize maximum signal to noise ratio. The basic structure diagram of a multicarrier system is shown in Figure 1.2.

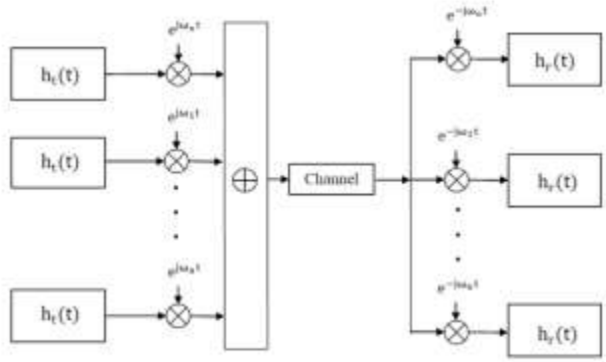

Fig. 1.2 Basic structure of a multicarrier system

In this system, the original data stream multiplexed into parallel data streams. Each of the sub streams is modulated with a different subcarrier frequency and all the data streams are transmitted in the same band. In this case, the inter-symbol interference of each sub-system are reduces. As the value of parallel path increases, inter-symbol interference becoming decreases. In a single carrier system, fading or interference can make the entire link fail. However, in a multicarrier system, only a small part of subcarriers will be affected. Error correction coding methods can be employed to correct the errors which were happened in subcarriers. OFDM is a special form of MCM, in which a signal is transmitted over a number of lower rate subcarriers. Time and frequency synchronization is the main limitation of multicarrier systems.

1.3 Amplitude Limitation in OFDM

An OFDM signal is the sum of many subcarrier signals that are modulated independently by different modulation symbols. As the amplitude of the OFDM signal is a stochastic process and according to the central limiting theorem, it obeys a complex Gaussian distribution if the number of subcarriers is large. Thus, OFDM signals have a very large peak to average power ratio (PAPR). In the transmitter, the maximum output power of the amplifier therefore limits the peak amplitude of the signal. This effect produces interference both within the OFDM band and in adjacent frequency bands. Hence, a modification of the OFDM system is done to remove the signal peaks or PAPR that exceed a given amplitude threshold. The out-of-band interference produced by these corrections can be kept within clearly defined limits while minimum interference within the OFDM band is obtained.

II OFDM SYSTEM MODEL

Let $\mathbf{A} = [A_0\, A_1 \cdots A_{N-1}]^T$ denote an input symbol vector in the frequency domain, where A_k represents the complex data of the k^{th} subcarrier and N is the number of subcarriers. The input symbol vector is also called the input symbol sequence. The OFDM signal is generated by summing all the N modulated subcarriers each of which is separated by $1/Nt_s$ in the frequency domain, where t_s is the sampling period. Then, a continuous time baseband OFDM signal is written as:

$$a_t = \frac{1}{\sqrt{N}} \sum_{k=1}^{N-1} A_k e^{j2\pi \frac{k}{Nt_s} t}, 0 \leq t < Nt_s \quad 1$$

The discrete time baseband OFDM signal a_n sampled at the Nyquist rate $t = nt_s$ can be written as:

$$a_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} A_k e^{j2\pi \frac{k}{N} n}, n = 0,1, \ldots, N-1 \quad 2$$

Let $a = [a_0\ a_{N-1}]T$ denote a discrete time OFDM signal vector. Then, corresponds to the inverse fast Fourier transform (IFFT) of A, that is, a = QA, where Q is the IFFT matrix. The block diagram of OFDM transmitter is described in Fig.2.1 as -

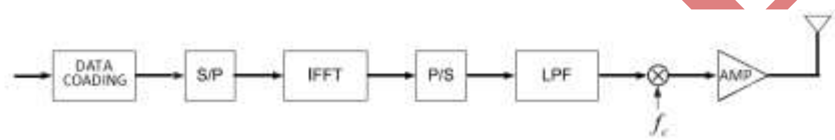

Fig. 2.1 OFDM transmitter.

Let $\mathbf{a}_L = [a_{0,L}\ a_{1,L} \cdots a_{LN-1,L}]^T$ be an oversampled discrete time OFDM signal vector where $a_{n,L}$ is the oversampled discrete time OFDM signal sampled at $t = nt_s/L$ and written as:

$$a_{n,L} = \frac{1}{\sqrt{N}} \sum_{k=0}^{LN-1} A_k^1 e^{j2\pi \frac{k}{n}}, n = 0,1, \ldots LN-1 \quad 3$$

where A_k^1 is define as-

$$A_k^1 \begin{cases} A_k = & 0 \leq k \leq N-1 \\ 0 = & N \leq K \leq LN-1 \end{cases}$$

2.1 PAPR System Model

The PAPR of the discrete time baseband OFDM signal is defined as the ratio of the maximum peak power divided by the average power of the OFDM signal and written as:

$$PAPR(a_n) \triangleq \frac{\max\limits_{0 \leq n \leq N-1} |a_N|2}{P_v(a_n)} \quad 4$$

where $p_{av}(a_n)$ is define as-

$$P_{av}(a_n) = \frac{1}{N} \sum_{n=0}^{N-1} E\{|a_1|2\}$$

For the un-coded OFDM system, we can assume that the input symbols are identically and independently distributed and given by the expression-

$$E\{A_i A_j^*\} = \begin{cases} 0^2 & i = j \\ 0 & i \neq j \end{cases} \quad 5$$

From Parseval's theorem, the average power $P_{av}(a_n)$ is σ^2. An alternative measure of the envelope variation of the OFDM signals is the crest factor φ which is the ratio of the maximum instantaneous power to the root mean square of the signal envelope and written as:

$$\varphi(a_n) \triangleq \frac{\max\limits_{0\le n\le N-1} |a_N|1}{P_{av}(a_n)} \quad 6$$

The PAPR of the continuous time baseband OFDM signal a_t defined as the ratio of the maximum instantaneous power divided by the average power of the OFDM signal and written as:

$$PAPR\ (a_t) \triangleq \frac{\max\limits_{0\le t<Nt_s} |at|\ 2}{P_{av(gt)}} \quad 7$$

where $p_{av}\ (g_t)$ is define as-

$$P_{av}(g_t) = \frac{1}{Nt_s}\int_0^{Nt_s} e\{|a_t|2\}dt$$

And the PAPR of the continuous time pass-band OFDM signal g_t is also defined as:

$$PAPR\ (g_t) \triangleq \frac{\max\limits_{0\le t<Nt_s} |gt|2}{P_{av(gt)}} \quad 8$$

The discrete time baseband OFDM signals, which constitute the output of the IFFT block, are transformed to continuous time baseband OFDM signals by a low-pass filter called DAC, where the peak power can be increased while maintaining a constant average power. Usually, the PAPR of the continuous time baseband OFDM signals is larger than that of the discrete time baseband OFDM signals. Mixing the continuous time baseband OFDM signal with the radio frequency generates the continuous time pass-band OFDM signal. It does not change the peak power but the average power of the passé-band OFDM signal is half the average power of the continuous time baseband OFDM signal. Thus, the PAPR of the continuous time pass-band signal is generally larger than that of the continuous time baseband OFDM signal. The relationship between different PAPRs is given as:

$$PAPR(a_n) \le PAPR(at) < PAPR\ (g_t)$$

III CONCLUSION

In all the PAPR reduction techniques, it is seen that the amplitude limitation are not solved completely. In this paper, an overview and modeling of amplitude limitation for OFDM system is introduced to reduce the PAPR in multicarrier system. Also, the OFDM significantly reduces receiver complexity in wireless broadband system. The use of OFDM system with minimum peak to average power ratio seems to be an attractive solution for fourth generation wireless systems.

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