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Research Paper

PAPR REDUCTION IN OFDM SYSTEMS USING SIGNAL PROCESSING ALGORITHMS

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Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique which is very much popular in new wireless networks of IEEE standard, digital television, audio broadcasting and 4G mobile communications. The main benefit of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. It has improved the quality of long-distance communication by eliminating InterSymbol Interference (ISI) and improving Signal-to-Noise ratio (SNR). The main drawbacks of OFDM are its high peak to average power ratio and its sensitivity to phase noise and frequency offset. This paper deals with the PAPR reduction in OFDM systems using signal processing algorithms

Keywords: PAPR reduction, Signal processing, OFDM system

INTRODUCTION

Spread spectrum modulation has been the basis for majority of proprietary communication and boadcasting technology including IEEE 802.11 wireless local Area Networks (WLANs), ZigBee, Ultra Wide Band (UWB) and others. Through the use of frequency hopping and direct sequence, these WLANs provide data rates from 1 to 11 Mbps. Regardless of these relatively high data rates, there there has been an increasing demand of higher data rate for wireless broadband Local Area Networks (LANs) and Metropolitan Area Networks (MANs). Because of relatively inefficient use of bandwidth, spread spectrum systems did not satisfy the even higher data rates that multimedia applications required. In addition, multimedia applications operating outdoors or within industrial environments require a wireless network capable of operating more effectively in “RF hostile” areas. Consideration of more efficient and robust OFDM technology became a viable option for high data rate multimedia implementations. OFDM, sometimes referred to as multi-carrier or discrete multitone modulation utilizes multiple sub-carriers to transport information from one user to another.

OFDM SYSTEMS: CONCEPTS AND CHALLENGES

Orthogonal Frequency Division Multiplexing

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(OFDM) is a multi-carrier communication system. OFDM extends the concept of single sub-carrier modulation by using parallel multiple sub-carriers within a channel. It uses a large number of closely separated orthogonal sub-carriers that are transmitted in parallel. Each of the sub-carrier is modulated with any conventional digital modulation scheme (such as QPSK, 16QAM, etc.) at low symbol rate. The combination of all sub-carriers enables data rates equivalent to conventional single-carrier modulation schemes. Thus OFDM can be considered as similar to the Frequency Division Multiplexing (FDM). In FDM different streams of information are mapped onto separate parallel frequency channels. Each FDM channel is separated from the others by a frequency guard band to reduce the possible interference between adjacent channels.

PAPR REDUCTION

In the process of data transmission, signal after modulation is amplified in transmitter. This demands transmitter to operate in linear region, conversely, amplitude of data should lie in linear range of transmitter power amplifier. Also, communication system's performance heavily depends on the faithful amplification of transmitter power amplifier. The transmitter power amplifiers are high power amplifier used to transmit the signal. At any point of time, if the input power of the signal crosses the operation range then it will be going to non-linear range resulting in non-linear amplification including out of band radiation. Non-linearly amplified signal can not be easily retrieved in the receiver. Quantitatively, the ratio of peak power to the average power of a transmitter should be maintained low for faithful amplification. Furthermore, the reduction in PAPR results in a system that can either transmit more bits per second with the same hardware, or transmit the same bits per second with lower-power hardware (and therefore lower electricity costs [30]) (and therefore less expensive hardware), or both. To mitigate this effect many methods have been investigated. Few of the techniques involve clipping, clipping and filtering, coding and scrambling.

The OFDM Scheme Differs from the Traditional FDM in Following Ways:

Multiple carriers carry single information stream

ii. Sub-carriers are orthogonal to each other

iii. A guard interval is added between adjacent symbols to minimize the channel delay spread and inter symbol interference (ISI).

Figure 1 shows main concepts of an OFDM signal and the inter relationship between the frequency and time domains. The frequency axis contains N number of information carrying orthogonal sub-carriers. In the frequency domain, sub-carriers are independently modulated with complex data. Inverse FFT operation is performed on the frequency domain sub-carriers to produce the OFDM symbol in the time-domain. After IFFT operation, guard intervals are inserted to each symbols to prevent ISI at the receiver.Without ambiguity, it can be noted that ISI is caused by multi-path delay spread in the radio channel. At the receiver FFT operation is carried out on the OFDM symbols to recover the original transmit data bits.

Figure 2 shows the block diagram of an OFDM communication system. In the transmitter binary data from a data source coded inside the channel coding block. Channel coded serial data are then converted from serial data to parallel data. These parallel data are then mapped to multi amplitude

Figure 1: Frequency Time Representative of an OFDM

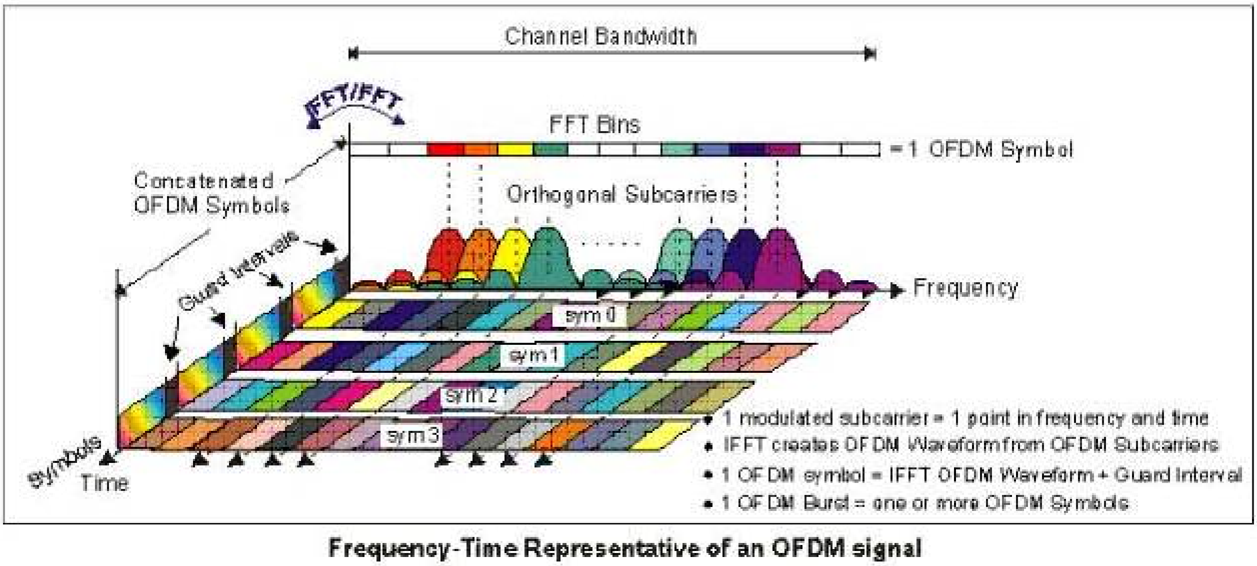
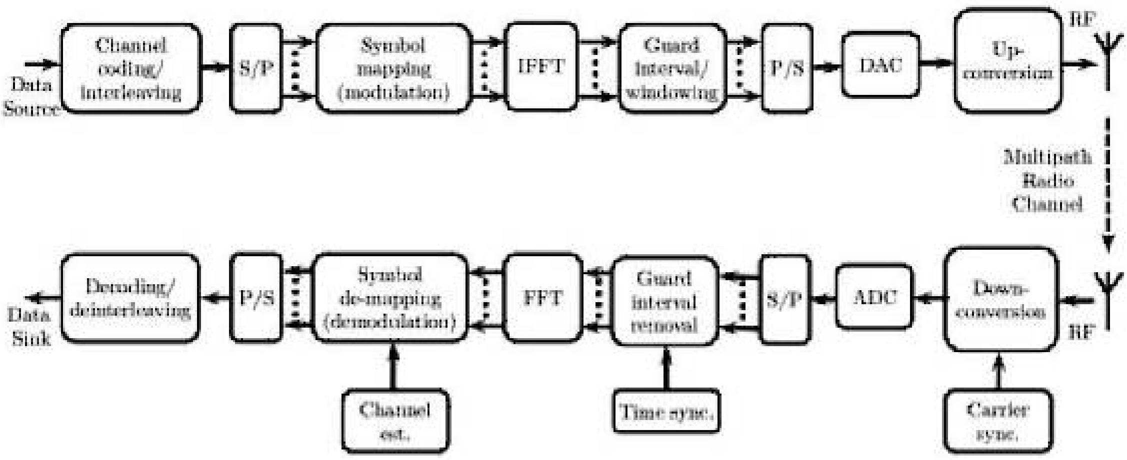


Figure 2: Block Diagram of OFDM System



multi phase modulation schemes (like QPSK, QAM4 etc.) in the symbol mapping block. Modulated parallel symbols are then converted to time domain signal through IFFT block. A guard interval signal equivalent to maximum channel delay is appended in the time domain signal to avoid inters symbol interference. The parallel data is then converted to serial data by converting them from digital to analog signal through DAC block. The analog signal is then transmitted through the transmitter antenna. In the receiver side the signal is received and carrier synchronization carried out by carrier synchronizer. These signal are the converted back to digital data through through DAC converter. Guard removal and time synchronization is carried out by guard removal block and time synchronizer block respectively. The signal is transformed from time domain to frequency domain by FFT block. Channel estimation and subsequent symbol demapping is done through channel estimation block and symbol demapping block respectively. Parallel data are then converted to serial data through parallel to serial block. Finally bit decoding is carried out through decoding block.

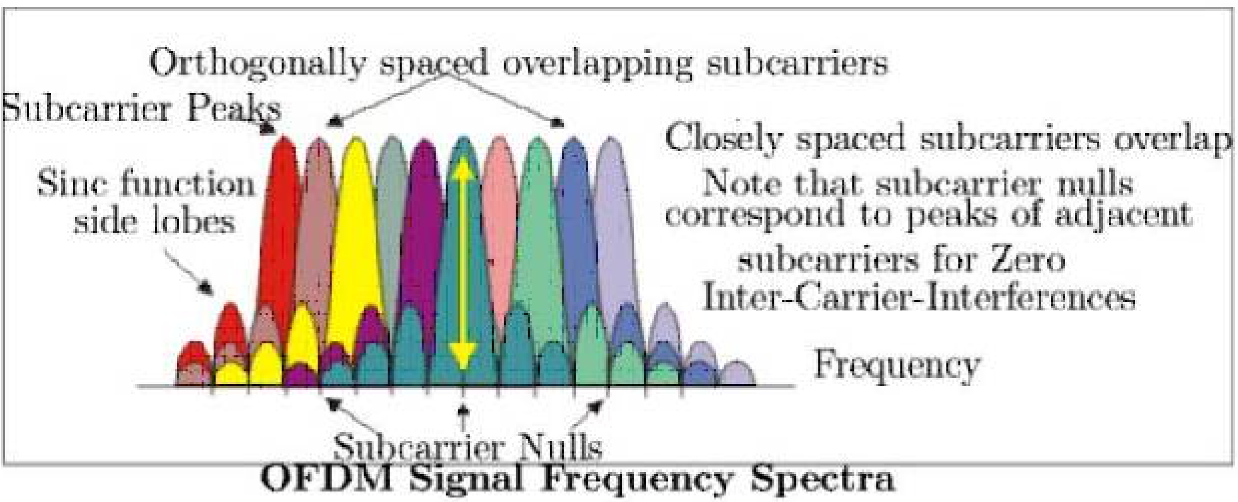
IMPORTANCE OF ORTHOGONALITY

The OFDM signal can be viewed as a set of closely separated FDM sub-carriers. In the frequency domain, each transmitted sub-carrier results in a sinc function spectrum with side lobes that produce overlapping spectra between sub-carriers. This is presented in Figure 3.This results in sub-carrier interference except at orthogonally spaced frequencies. At orthogonal frequencies, the individual peaks of sub-carriers align with the nulls of all other sub-carriers. This overlap of spectral energy does not interfere with the system's ability to recover the original signal. The receiver multiplies the incoming signal by the known set of sinusoids to recover the original set of bits sent. The use of orthogonal sub-carriers facilitates large number of sub-carriers per bandwidth resulting in an increase in spectral efficiency. In a perfect OFDM signal, orthogonality prevents interference between overlapping carriers which is also known as Inter Carrier Interference (ICI). In OFDM systems, the sub-carriers interfere with each other only if there is a loss of orthogonality.

MATHEMATICAL DESCRIPTION

If N sub-carriers are used, and each sub-carrier is modulated using M " ary signalling, the OFDM symbol alphabet consists of one out of M N

Figure 3: OFDM Signal Frequency Spectra



number of combined symbols. The low-pass equivalent OFDM signal can be represented as:

$$x(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T_s}, \quad 0 < t < T_s$$

where X_k are the data symbols, *N* is the number of sub-carriers, and Ts is the OFDM symbol time. The sub-carrier spacing of 1 Ts makes the symbols orthogonal over each symbol period; this property can be expressed as:

$$\frac{1}{T_s}\int_0^{T_s} \left(e^{j2\pi k_1 t/T_s}\right) * \left(e^{j2\pi k_2 t/T_s}\right) dt$$

$$\frac{1}{T_s}\int_0^{T_s} e^{j2\pi(k_1-k_2)t/T_s}\ dt = \delta_{k_1 k_2}$$

To avoid inter symbol interference in multipath fading channels, a guard interval of length Tg is inserted prior to the OFDM block.

APPLICATION OFDM

A formidable growth of demand for high data rate multimedia based services and high spectral efficiency are the key requirements for the continued technology evolution in future wireless communications. In recent past, several advancements have been incorporated for 3G wireless communication systems for enhancement of the data rate and the system performance (e.g., high speed downlink packet access (HSDPA) in wideband code division multiple access (WCDMA) systems, 1x evolution-data and voice (1xEV-DV) for cdma2000 systems). Continuous proliferation of wireless multimedia applications and services such as video teleconferencing, network gaming, and high quality audio/video streaming requires very high data rate. At present, it is apparent that the existing 3G wireless systems with its optimum capacity will be unable to support with this ever increasing demand for broadband wireless services.

The next generation wireless communication systems (namely, fourth generation (4G) or beyond 3G (B3G) systems, LTE, and fifth generation (5G)) are expected to support much higher data rate services compared to evolving 3G systems (up to 100 Mbit/s in outdoor environments and up to 1 Gbit/s in indoor environments). LTE-A is supposed to support up to 1Gbit/s data rate and gigabit wireless communication for millimeter wave communication known as 5G is expected to support data rate of beyond 1 Gbit/s. In order to achieve this high data rate, the major technical challenges will be achieving high spectral efficiency, handling high frequency-selectivity due to the use of large bandwidth, handling high PAPR as more number of subcarrier are to be introduced, and choosing an efficient signaling scheme for higher data rate. Hence, it has become crucial to incorporate the recent technical advances in the physical layer into the future wireless systems.

ADVANTAGE AND DISADVANTAGE OF OFDM SYSTEM

OFDM is a modulation technique comprised of high data capacity and resilience to interference. These factors are highly essential in todays's high capacity communications scene. Moreover, orthogonality is the basic principle of the OFDM system. Any deviation or loss of orthogonality will deteriorate the OFDM system performance.

OFDM has been used in many high data rate wireless systems because numerous advantages it possesses. Some of the advantages include

- Immunity to selective fading: OFDM is more resistant to frequency selective fading than single carrier systems because it divides the overall channel into multiple narrow-band channels. These channels being narrowband suffer from flat fading and appear robust than wide-band channel
- Resilience to interference: Interference appearing on a channel may be bandwidth limited and in this way it does not affect all the sub-channels. This reduces the channel fluctuation.
- Spectrum efficiency: Use of closely-spaced overlapping orthogonal sub-carriers enables data transmission with low bandwidth channels and hence it makes efficient use of the available spectrum.
- Resilient to ISI: OFDM is very resilient to inter-symbol and inter-frame interference. This is due to the fact that each of the sub-channel carries low data rate data stream.
- Resilient to narrow-band effects: Use of adequate channel coding and interleaving make it possible to recover symbols lost due to the frequency selectivity of the channel and narrow band interference.
- Simpler channel equalization: In conventional digital communication and spread spectrum communication channel equalization has to be applied across the whole channel bandwidth. So channel equalization complexity increases. In contrast, only a one tap equalizer is required for OFDM channel equalization as it uses multiple sub-channels. This reduces equalization complexity in OFDM .

OFDM DISADVANTAGES

Whilst OFDM has been widely used, there are still a few disadvantages which need to be addressed when considering its use.

- Sensitive to carrier offset and drift: OFDM is sensitive to carrier frequency offset and drift compared to single carrier system .
- High peak to average power ratio: OFDM signals are characterized by noise like amplitude variation in time domain and have relatively large dynamic range leading to high peak to average power ratio (PAPR). This impacts the RF amplifier efficiency as the amplifiers need to be linear and accommodate the large amplitude swings and these factors mean the amplifier cannot operate with a higher efficiency level.

LIMITATION AND FUTURE WORK

Few of the limitations of the work are

1. The use of adaptive Boosting algorithm needs very high number samples to be trained in the training period. Once the training is over the complexity is less.
2. In the SDMA MUD system, we assumed the channel statistics are known to the receiver.
3. Computational complexity associated with GA and Bat algorithm is very high (considering they run for large number of iterations). Though theoretically evolutionary algorithms finds the global solution, but it is not true alway. Some times GA and Bat algorithm stuck into local minima. Under this circumstance proper bit detection is not possible.
4. Converging speed of both GA and Bat algorithm is very high and time consuming.

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