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REVIEW ON ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING: STUDY AND SURVEY

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Abstract: This paper is a survey on the orthogonal frequency division multiplexing in the field of wireless communications. Nowadays the need for high data speed transmission of digital communication has increased, with the rapid growth in recent years. OFDM endeavor high data rates access for wireless communications and use for high speed applications as one of the efficient solutions as compared to other Technology. In OFDM, Demodulation and modulations of signal is done with the help of FFT/IFFT controller respectively. We have address basic OFDM and not only modulations, as well as specific techniques to improve the performance of OFDM, which includes channel estimation and signal detection also frequency and time offset estimation and correction, inter-carrier interference, multiple-input–multiple-output techniques and peak to average power ratio reduction. Applications of OFDM in current systems and standards are described.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), ultra-wide band (UWB), inter-carrier interference (ICI), multicarrier (MC), multiple input multiple outputs (MIMO).

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INTRODUCTION

The demand for broadband wireless communications is growing with an extremely rapid. These systems are required to be operating in an environment which is characterized by high carrier frequency, mobility, and data transmission rate; altogether such an environment can be modeled by a frequency selective fast time varying fading channel. The OFDM is a special case of multicarrier modulation in which serial stream of data is divided in parallel and then modulated by orthogonal sub-carriers with partial overlapping frequency bands. OFDM is a special multi-carrier modulation technique. It divides feasible spectrum into many carriers and used the spectrum efficiently in comparison to FDMA by spacing the channels close together and making all carriers orthogonal to each another which will minimized interference between closely spaced carriers. The advantage of OFDM is the ability to enhance the basic signals that overcome channel impairments. Multi-Band Orthogonal Frequency Division Multiplexing (MBOFDM) is a solution for implementation of high speed data transmission in UWB by dividing the spectrum available into multiple bands. [5]

OFDM provides high bandwidth efficiency because the carriers are orthogonal to each other and the data shared by multiple carriers. It has ability to cope with severe channel conditions and has high spectral efficiency in comparison to other double sideband spread spectrum, modulation schemes etc. OFDM has several advantages compared to other type of modulation technique implemented in wireless system. It combats the effect of frequency selective fading and burst error. It overcomes the effect of ISI, bandwidth efficiency etc.

In spite of distinct advantageous features, in OFDM systems have three major solicitous i.e. high PAPR of transmitted signal, synchronization (timing and frequency) and Noise (Impulse) at the receiver.

LITERATURE OVERVIEW

The review of literature gives a detailed study of existing material for clear understanding. This paper shows different Issues of OFDM system like high PAPR, Noise, synchronization etc.

OFDM is implemented using IFFT/FFT controller. Separate clock are used for modulator/demodulator in transmitter/receiver section respectively to improve the data rate. Multi-VTH principles and Clock are applied to reduced power consumption. Novel circuits designed have been employed for realization of optimal hardware and power efficient architecture. This enabled the high-speed transmission system. Implementing low power techniques, the hardware elements can be minimized and it leads to less power consumption.

Packet Error Rate (PER) measurement is done to analyze and evaluate the system performance based on different optical fiber lengths, data rates, transmitting UWB power levels.

OFDM BASIC MODEL

The OFDM system was modeled using the Communication and Signal Processing Toolbox, Simulink of the MATLABTM, and is shown in Figure below. A description of the model is provided below.

1) Serial/Parallel Conversion: The input serial data streams are formatted into the word size needed for transmission.

2) Data Modulation: The data transmitted on every carrier is differentially encoded with previous symbols, and mapped into PSK format. Differential encoding considering, it requires an initial phase reference as extra symbol is added at the start. Data on every symbol mapped to a phase angle which is based on method of modulation. E.g., for QPSK the phase angles used is 0, 90, 180, 270 degrees. The constant amplitude signals produced by the use of PSK were chosen to reduce problems with amplitude fluctuations because of fading.

3) Inverse Fourier Transform: After worked out of the required spectrum, an inverse Fourier transform is perform to find the corresponding time waveform. At the start of each symbol Guard period is added.

4) Channel: A channel is a medium or Model to Transmit data that allows for the signal to the noise ratio, multi-path, and peak power clipping which are to be controlled. By addition of white noise of known amount to the transmitted signal SNR ratio is set. The Multipath delay spread is added by simulating the delay spread with the help of filter FIR. The length of an FIR filter shows the maximum delay spread, and the coefficient of amplitude shows reflected signal magnitude.

5) Guard Period: The Guard period contains two sections. First zero amplitude transmission of 50% of guard period time and Secondly cyclic extension of symbol is to be transmitted in remaining 50% of guard time. This was allowing symbol timing to be easily recovered by scheme of envelope detection. Hence when the guard has been added, symbols converted back to serial time waveform which is the base band signal required for the OFDM transmission.

6) Receiver: The receivers basically do the reverse operation in case of transmitter. Then the guard periods are removed and FFT of each symbol is performed to know the original spectrum

through demodulating the received phase, then Phase angle of each carrier which was transmitted is examined and converted back to data.

7) Generation of OFDM: To generate OFDM well, relationship between all carriers must be controlled carefully in order to control the orthogonality of carriers. For this motive, OFDM is generated by 1st choosing the spectrum required, depends on data input, and scheme of modulation used. For transmission, data is assign to every produced carrier. The required phase and amplitude of carrier is calculated and with the help of IFT converted back to its time domain. However in many applications, IFFT is used. IFFT performs the transformation efficiently.

8) Guard Period added to OFDM: One of the properties of OFDM transmissions is its robustness in comparison with multipath delay spread. This is the result of the symbol periods which are used, that minimize the inter-symbol interference. The level of multipath robustness can be increased further by addition of guard period between the symbols transmitted. The most effective usable period is a cyclic extension of symbol. At the end of the symbol waveform if mirror in time, is put at the beginning of the symbol as guard period, which effectively extends the length of symbol. For performance of the FFT, the cyclic extended symbol can be used and taken anywhere over the symbol length. It provides multipath immunity and also symbol time synchronization tolerance.

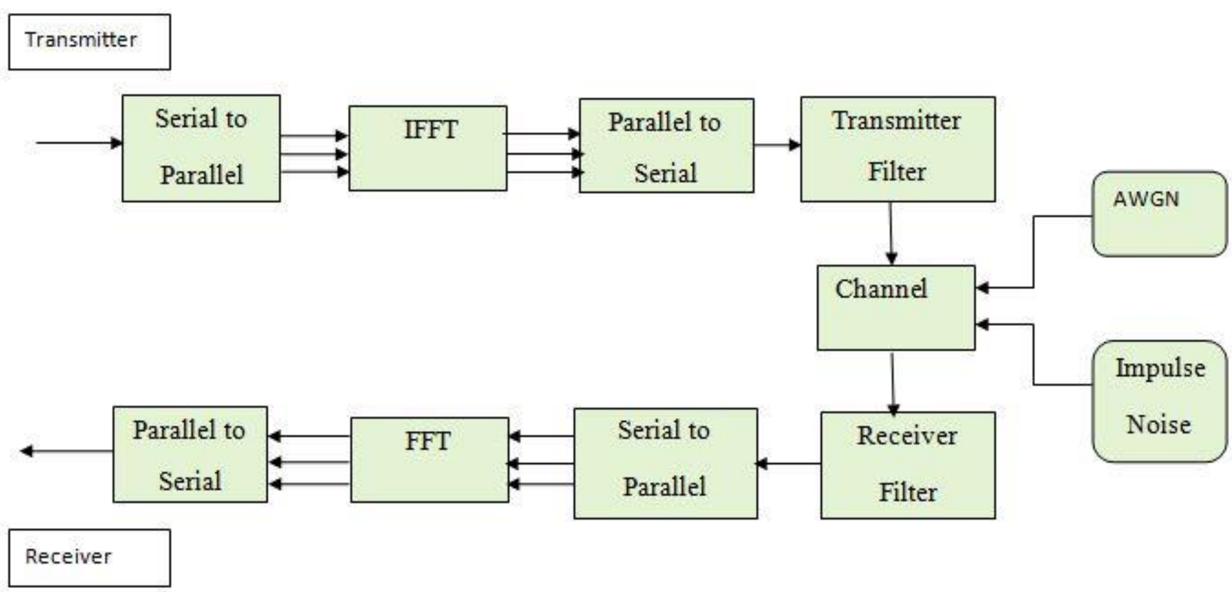

Fig. 1. Block diagram of OFDM system

I. PARAMETERS OF AN ACTUAL OFDM SYSTEM

Table I: Parameters of IEEE 802.11which is a system based on OFDM.

Data rate	6 Mbps to 48 Mbps
Modulation	BPSK, QPSK, 16 QAM, 64 QAM
Coding	Convolution concatenated with Reed solomon
Coding rate	1/2, 2/3, 3/4
FFT Size	64
FFT period	3.2 μs
No.of Subcarriers	52
No. of Pilots	04
Symbol time	4 μs
Guard interval	0.8 μs
Sub-Carrier spacing	0.3125 MHz
Channel spacing	20 z

ISSUES WITH OFDM

There are many issues with OFDM, having significant impact on it. [1]

A) Orthogonality

It is difficult to preserved Orthogonality entirely, but by adopting guard intervals and the forward error correction techniques it can be improved. Also every carrier operates at low bit rates. Linear equipment should be used in OFDM to eliminate any other phase alteration. Cyclic prefix is added before transmission. When FFT path delay is done it will reflect only phase at the receiver. Hence, Orthogonality will be preserved.

B) Synchronization

One of the typical difficulties in the receiver is to sample the signals which are incoming into correct format. If it goes wrong, then it would be difficult to recover correctly the received data on the carriers by Fast Fourier Transform. When the receiver is switched on, the problem is more embarrassing. Hence there is a need for acquiring timing lock and time shift theorems in convolution transform theory.

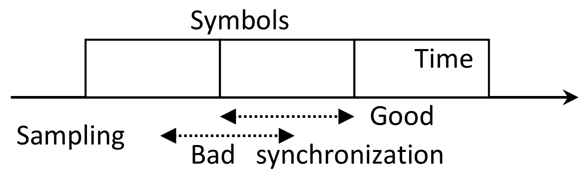

Fig. 2. Synchronization

The effect of time shift would be to add the phase shift including some inter-symbol interference with adjacent symbols. Interference degrades reception hardly. To avoid these problems, it needs to transmit more number of complete sequence of time samples to increase tolerance in timing.

To obtain good synchronization one of the main techniques is to add null (zero samples) symbol between each OFDM symbol. This technique used in DAB for time synchronization.

C) Channel Estimation

In OFDM systems, using known training symbols at both the transmitter and receiver CSI can be estimated.

1) DACE: In data aided channel estimation, complete OFDM symbol / a portion of a symbol, which is known at the receiver (pilot information), is transmitted so that the receiver could easily estimate the radio channel by demodulating the received samples. There are two main issues which affect the performance of any data aided channel estimators. Basic issue is of design and arrangement of pilot information. After that second issue is design of an estimator or an interpolator with both low complexity and good channel tracking ability. These two issues are interconnected. The two basic 1D data aided channel estimations are block-type pilot channel estimation and comb-type pilot channel estimation, in this the pilots are inserted into the frequency and time direction.

2) Pilot-Aided Channel Estimation: With the help of pilot tones to estimate channel coefficients was first proposed. The two major concern of pilot-aided estimation of channels are pilot design and interpolation.

3) DDCE: For DDCE, CSI at the preamble blocks is first estimated and used to demodulate as well as detect the symbols at the next block. It can be tracked by using detected symbols, either hard or soft decision. For systems with error-correction coding, redundancy in coding could be took advantage by performing iteratively soft symbol decision and estimation of channel.

D) Peak to Average Power Ratio (PAPR)

An important complication comes in OFDM systems when the phase of different subcarriers gets add up to form a large peaks. This problem is known as Peak Average Power Ratio (PAPR). a time interval [n, n+Ts] is represented by the following formula for every OFDM signal:

For continuous signals

$$\chi_n = \frac{\max\limits_{t\in[n,n+T_s]} |x(t)|^2}{\int_n^{n+t_s} |x^2(t)| dt}$$

For sampled signals

$$\chi_n = \frac{\max\limits_{k} |x_n[k]|^2}{E\{|x_n[k]|^2\}}$$

In OFDM systems PAPR have very high values for certain input sample and overload the non-linear characteristics, results in inter-modulations on different carriers. The quantization noise domination towards the performance of the system can be seen as a major drawback of PAPR.

Table II: Comparison between different PAPR reduction Techniques.

Methods	Average Power	Bandwidth Expansion	BER Degradation
Clipping	No	No	Yes
Coding	No	Yes	No
PTS/SLM	No	Yes	No
Pre-coding	No	Yes	No

To reduce PAPR in OFDM signals various techniques are proposed which are as follows:

1) Signal Distortion: These methods reduce the PAPR by distorting the OFDM signal non-linearly. The methods like clipping, filtering, peak windowing& non-linear commanding are the example of these techniques. These techniques are applied after the generation of OFDM signal (after the IFFT).

2) Coding Methods: The coding methods employed some error correcting codes for the PAPR reduction. These methods applied before the generation of OFDM signal (before IFFT). The

basic idea of all coding schemes for the reduction of PAPR is to reduce the occurrence probability of the same phase of N signals.

3) Probabilistic Techniques: The probabilistic methods are based on scrambling of each OFDM symbol with different scrambling sequences and selecting that sequence which gives smallest PAPR. The methods like Selective Mapping (SLM) and Partial Transmit Sequence (PTS) are the example of probabilistic techniques.

4) Pre-distortion Methods: The pre-distortion methods are based on the re-orientation or spreading the energy of data symbol before taking IFFT. The pre-distortion schemes have discrete spreading, pulse shaping and constellation shaping.

E) Time and frequency varying impairment mitigation

In this section, we will address time and frequency-varying impairment mitigation. Frequency-varying impairments are caused by the timing offset between the transmitter and the receiver or the delay spread due to a multipath of wireless channels.

1) Timing-Offset Estimation and Correction: The timing offset can be estimated with pilot and non-pilot-aided techniques. After the timing offset is estimated, its integer part, which is a multiple of the sampling interval, is used to adjust the starting position of FFT window and its (residual) fractional part will generate a phase offset and can be compensated at each sub-channel when we cancel the impact of the delay spread of wireless channels.

2) Frequency-Offset Estimation and Correction: From the perspective of its impact and signal processing, the CFO can be divided into integer and fractional parts. The integer part of the CFO is a multiple of the sub-channel space, which will cause a symbol or sub-channel shift, that is, the transmitted symbol in one sub-channel is shifted to another at the receiver. The fractional part results in the loss of orthogonally among sub-channels and generates ICI. Once the CFO is estimated, its impact can completely be canceled in the time domain by multiplying the received signal by the frequency shift factor.

3) Mitigation of ICI Caused by the Doppler Spread: ICI may be caused by the CFO, phase noise, timing offset, and Doppler spread. However, ICI induced by the first three impairments can completely be compensated or corrected. Since the Doppler spread or shift is random, we can only mitigate its impact. The existing ICI mitigation techniques include frequency equalization, ICI self-canceling, time-domain windowing, coding etc.

F) Phase noise

At the receiver, phase noise is added by a local oscillator to OFDM signal, e.g. The phase noise could have two effects are as Common Phase Error (CPE) and ICI, similar to the additive Gaussian noise. In fact, the signal constellation within a specific given symbol is subject to same rotation for all the carriers and the effect of this can be corrected with the help of reference information within the same symbol. But, ICI is more difficult to overcome, because of additive noise, which is not same for all carriers' results in loss of orthogonality.

G) Frequency error

An OFDM system is subjected to two types of error in frequency. They are Frequency offset and Error in the receiver master clock. Before finding solutions to those problems, the system designer need to know limit of residual frequency error if it is permissible, and get how errors affect the received signal and studied, so a frequency offset affects equally most carriers, with a very edge carrier minimum affected. ICI results from a fixed absolute frequency offset rise with number of carriers, if the system bandwidth is maintain a constant.

I. OFDM RELATED MODULATION AND ACCESS TECHNIQUES

There are many modulation or access techniques linked to OFDM. Multicarrier modulation is a general category throughout all to which OFDM belongs. The two block transmission arrangement that exploit the Cyclic Prefix to reduce the delay spread of wireless channels are single-carrier system with frequency-domain equalization (SC-FDE) and Energy spreading transform (EST) based modulation. Moreover, many access techniques have been developed based on OFDM like MC-CDMA and OFDM access (OFDMA) are two examples.

II. MIMO TECHNIQUES IN OFDM

MIMO techniques can be used in wireless communications for diversity gain and capacity improvement. Recent Books, Magazines have given a complete introduction of MIMO techniques. Here, we focus on special issues when MIMO techniques are used with OFDM. Most of MIMO techniques are developed for flat fading channels. However, multipath will cause frequency selectivity of broadband wireless channels. Therefore, MIMO-OFDM, proved to be very promising choice for future high data rate transmission over broadband wireless channel. [3]

III. RESULT AND DISCUSSION

The overall survey Results are given below in short which defines the ultimate threats to OFDM system.

Table III: Survey on Impact of Different Issues on OFDM

Issues	Impact on OFDM System
Orthogonality	High
Synchronization	Medium
Channel Estimation	Medium
PAPR	High
Noise (Impulse)	High

IV. APPLICATION

During past few years, OFDM have started being used in many wireless communication standards such as European digital audio broadcasting and in China for satellite terrestrial interactive Multi-service infra-structure. Many IEEE standard working groups have approved OFDM. The groups are IEEE 802.11a/g/n, IEEE 802.16d/e and IEEE 802.15.3a. The applications consist of wireless personal area networks, wireless LAN, and metropolitan networks etc. Presently, OFDMA is being reviewed as one of the most gifted radio transmission techniques for Long Term Evolution of the 3rd Generation Partnership Project and International Mobile Telecommunications advanced Systems.

V. CONCLUSION

Orthogonal frequency division multiplexing (OFDM) plays a vital role in the Field of wireless Communication that has been described briefly in this paper. Since the Technology has been invented over 40 years ago and still in a hunt for an area of active research for the past decade. OFDM has high spectral efficiency, robustness all over the world Mobile Wireless Communication. OFDM proves to be one of the best digital communication systems if it overcomes the three main drawbacks as PAPR, Synchronization and Noise (Impulse). Many researchers have devoted their time and worked hard on it to minimized the effects to an extent, Still a long way to go to make it perfect system for long term goals in future for mankind.

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