Orthogonal Frequency Division Multiplexing and its applications

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Abstract — Orthogonal Frequency Division Multiplexing (OFDM) is well known Technique for transmitting large data Over Radio waves. OFDM has become popular in wireless communication. It is a digital modulation technique based on parallel transmission of information. It is a multicarrier transmission where single data is transmitted over number of lower rate subcarriers. In this paper we review OFDM and its applications.

Keywords — Orthogonal Frequency Division Multiplexing (OFDM), Inter-carrier Interface (ICI), Applications.

I. INTRODUCTION

A multicarrier system, such as FDM divides the total available bandwidth in the spectrum into sub-bands for multiple carriers to transmit in parallel [1]. An overall high data rate can be achieved by placing carriers closely in the spectrum. However, ICI will occur due to lack of spacing to separate the carriers [2]. To avoid ICI, guard bands will need to be placed in between any adjacent carriers, which results in lowered data rate. OFDM is a multicarrier digital communication scheme to solve both issues. It combines a large number of low data rate carriers to construct a composite high data rate communication system. Orthogonality gives the carriers a valid reason to be closely spaced, even overlapped, without inter-carrier interference. Low data rate of each carrier implies long symbol periods, which greatly diminishes inter-symbol interference(ISI). Although the idea of OFDM came in 1960. It has never been widely utilized until the last decade.

A. OFDM

Multi-carrier transmission has been a promising technique for the high rate transmission over wireless radio channels [3] and it is robust to frequency selective fading and narrow band interference. So, OFDM has been adopted as wireless mobile communication systems such as Hiperlan2, IEEE802.1 la, etc. OFDM is used in many applications such as wireless LAN [4], digital audio broad-casting (DAB), digital video broadcasting (DVB), 4G and WiMax [5].

OFDM has some advantages and disadvantages:

Advantages of OFDM systems:

- OFDM systems are more resistant to frequency selective fading than single carrier systems.
- ICI and ISI are eliminate by using cyclic prefix.
- OFDM systems are more resistant to frequency selective fading than single carrier systems.
- In OFDM systems frequency band spectrums are used efficiently by allowing overlapping and orthogonality in subcarrier.
- Using adequate channel coding and interleaving one can recover symbols lost due to the frequency selectivity of the channel.
- The orthogonality preservation procedures in OFDM are much simpler compared to CDMA/TDMA technique in multipath conditions.

Disadvantages of OFDM systems:

- OFDM have high peak. High peak is occur in OFDM when subcarrier having same phase, are added in time domain.
- The OFDM signal has a noise like amplitude with a very large dynamic range therefore it requires RF power amplifiers with a high peak to average power ratio.
- Due to high amplitude of peak, OFDM has high PAPR.
- It is more sensitive to carrier frequency offset and drift than single carrier systems. Orthogonality may be lost due to carrier frequency offset.
- It is more complex than single carrier modulation.
B. INTER-CARRIER INTERFACE

Presence of Doppler shifts and frequency and phase offsets in an OFDM system causes loss in orthogonality of the sub-carriers. As a result, interference is observed between sub-carriers. This phenomenon is known as ICI [6].

C. APPLICATIONS

The OFDM has been applied in several fields. Some applications are discussed in this paper:

1) ADSL

Asynchronous Digital Subscriber Lines (ADSL) utilizes OFDM over wired links. Data rates for ADSL standards are 1.54 Mbps to 6.1 Mbps in the downlink and 9.6 to 192 Kbps in the uplink over several kilometres of ordinary twisted pair telephone line [7], while still supporting the standard telephone. The unbalanced data rates make ADSL particularly applicable to internet type applications where the downlink rate is typically much larger than the uplink rate.

2) Cognitive Radio

Cognitive radio [8] has emerged as a promising technology to solve the current spectrum scarcity problem. Dynamic spectrum management and access is one of the key functions of cognitive radio. OFDM can be used to construct the transceiver of cognitive radio by virtue of its flexibility for subchannel assignment and power allocation. Secondary (unlicensed) users in cognitive radio exploit spectrum holes [9], which are bands that are not used by primary (licensed) users, and should not interfere with the operation of the primary users. Therefore, the available spectrum for the secondary users is usually disjoint bands. Furthermore, the available bands change with the activities of the primary users, which require the secondary users to flexibly adjust the frequency bands of their modulated signals.

3) HiperLAN2/802.11a

Wireless networking standards such as HIPERLAN2 and 802.11a use OFDM as the physical layer modulation scheme and operate in the unlicensed 5 GHz frequency band [10]. Hiperlan2 promises to deliver raw data rates of up to 56 Mbps.

4) Digital Audio Broadcasting

Digital audio broadcasting is a European standard for digital broadcasting that is intended to replace the analog technology such as AM and FM. Firstly, the analogue signals are converted to digital (a string of zeros and ones). That digital information is then compressed to an audio format known as MPEG-1 Layer 2 (sometimes referred to as MP2 or MUSICAM). Compressing audio to MP2 involves removing sounds that are unperceivable to the human ear, doing so reduces the size of transmitted data while maintaining sound quality. With the use of a multiplexer, the digital audio is then supplemented with information such as Programme Associated Data (PAD) [11]. Information included in PAD can consist of useful data such as song titles, artist names and general radio station details. The multiplexer then takes the digitized signal and combines it with the digital signals of other radio stations, creating a single group transmission called a DAB ensemble. This ensemble is then modulated using Coded OFDM.

5) MB-OFDM for UWB Systems

Multiband OFDM (MB-OFDM) [9] was once a standard candidate for the IEEE 802.15.3a working group for ultra-wideband (UWB) systems. The basic idea of MB-OFDM is to divide the spectrum into several sub-bands, and a data stream is transmitted over each band by OFDM. It should be noted that the actual bandwidth of the OFDM signal is 409.6 MHz although the bandwidth of each sub-band is 528 MHz. Interleaving is used to exploit frequency diversity. The MB-OFDM-based UWB system achieves data rates ranging from 55 to 480 Mb/s over distances up to 10 m. The combination of MIMO and MB-OFDM has also been investigated for high-data-rate transmission. However, there is some argument on whether we need multiple antennas in a UWB system because it should be with low complexity and low cost, whereas multiple antennas required by MIMO increase the cost of transceivers and obviously contradict them.

6) Mobile and Fixed Wireless Systems

OFDM has been adopted in IEEE 802.16 standards to support peak data rate up to 75 Mb/s at the frequency bands under 11 GHz. OFDMA in IEEE 802.16-2004 fixes the size of Fast Fourier transformation (FFT) to be 256 and varies the sub-channel space according to the bandwidth of the system [8]. Different from IEEE 802.16-2004, OFDMA in IEEE 802.16e-2005 maintains the same table some parameters of IEEE 802.16. Parameters of MB-OFDM-BASED UWB sub-channel space, $\Delta f = 10.94$ kHz, and changes the sizes of FFT according to the bandwidth of the system.. In both OFDM and OFDMA modes, the ratio of the length of the CP to the symbol duration may be 1/4, 1/8, 1/16, or 1/32, and the modulation scheme may be QPSK, 16 quadratic amplitude modulation (16QAM), or 64QAM, depending on the channel environments and the targeted data rate. In addition, antenna arrays may be used for diversity.
and interference suppression. STC is also optional in IEEE 802.16 to increase the data rates and extend the coverage. In the downlink of 3GPP LTE, OFDMA is a basic modulation scheme, which is with the length of the CP $T_g = 4.7/16.74$ $\mu$s (short/long CP) and the sub channel space $\Delta f = 15$ kHz.

**CONCLUSION**

OFDM provides many advantages for multi-carrier transmission at high data rates, including simple implementation using FFT. The main advantage of OFDM system is that it enables high data rate transmission and combat multipath fading by a simple equalization scheme at receiver. In this paper some applications of OFDM are discussed.

**REFERENCES**


