CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

A human can send information in various forms viz., text, images and videos over a long distances through a digital communication system. In a recent past, single carrier schemes were very popular in communication systems due to its easy implementation and less bandwidth requirement. Unfortunately, it suffers with low data rate transmission. In the further enhancement of wireless communication system, single carrier scheme are replaced by multi-carrier techniques. Orthogonal frequency division multiplexing (OFDM) is generally utilized multi-carrier scheme for achievement of high speed data transmission rate.

Nowadays, consumer demands for high data rates under noisy and congested environment, which led researchers to look into upcoming techniques that could help to fulfill the customer demands. The utilization of multiple antennas at the transmitter and receiver end is the viable solution to achieve higher data rates under fading environment. Multiple-input multiple-output (MIMO) integrated with OFDM provides higher data rate without any additional power requirement and bandwidth expansion. The major issue across MIMO-OFDM system are encoders complexity, high peak-to-average power ratio (PAPR), antennas design, equalization, channel estimation and so on. MIMO-OFDM signals with a high envelope fluctuation require highly linear power amplifiers to evade excessive inter-modulation distortion. Equalization of MIMO-OFDM signal is also important to mitigate the impact of ISI brought on because of channel delay spread. *This work focuses on the development of efficient algorithms for reduction of peak-to-average power ratio (PAPR) and inter symbol interference (ISI) for MIMO-OFDM system. To further diminish the computational complexity of PAPR reduction algorithms the soft-computing models has been employed.*

1.2 NEED OF MIMO-OFDM SYSTEM

In general, as the communication traffic increases, the spectrum allocation among users becomes very difficult [Nee and Prasad (2000)]. It infers that more bandwidth is required to support higher information rate application. With the constrained frequency range and the unfaltering increment in the quantity of new wireless applications or extension of existing ones. There is a issue in begin able to oblige all of them. In the recent years various multimedia and high data rate applications require multi-carrier transmission scheme [Bahai *et. al.* (2004)]. The generation of multi-carrier scheme can be done through the Discrete Fourier Transform (DFT) [Sklar (2001)]. The basic concept behind the Fourier Transform (FT) is to generate different frequencies for each subcarrier. One of the example of multi-carrier scheme is orthogonal frequency division multiplexing (OFDM) [Prasad (2004)]. The working principle of the OFDM is to divide the entire spectrum into spectrum narrowband subchannel through which parallel data are transmitted. OFDM is preferred in many communication system because of several features which attract to developer to design various standard applications. The main objective of standards is to give the specifications of particular system, in fact Institute of Electrical and Electronics Engineers (IEEE) develops several standards such as IEEE 802.11a, HIPERLAN/2, digital video broadcasting (DVB), IEEE 802.16e and digital audio broadcasting (DAB) for communication technology. In present scenario, OFDM is one of the major component in Fourth Generation (4G) mobile broadband standard which is known as Third Generation Partnership Project Long Term Evolution (3GPP LTE) [Hara and Prasad (2003)].

Multiple-input multiple-output (MIMO) system is an effective techniques to accomplish these requirements in present wireless systems [Gupta and Saini (2013)]. In MIMO system, instructions can be transmitted and got through multiple antennas simultaneously. The key advantages of utilizing MIMO-OFDM system are (a) the performance improvement in diversity and reliability, and (b) increment in data rate through spatial multiplexing. Diversity depicts the available degree of freedom present in the MIMO-OFDM faded channel.

1.3 CHRONOLOGICAL DEVELOPMENT

The next-generation wireless systems are required to have good voice quality as compared to present cellular mobile radio standards and give high rate data service. Simultaneously, the remote units are should be small lightweight pocket communicators. Hence, researchers have centered their attention on the upcoming era of wireless communication systems, which go for conveying multimedia services requiring data rates beyond 2 Mbps [Jiang and Hanzo (2007)]. In 1960's the first OFDM schemes were proposed by Chang and Saltzberg [Chang (1966); Saltzberg (1967)]. In the parallel data transmission systems, the frequency-domain (FD) bandwidth is partitioned into various non-overlapping sub-channels, each of which has a particular carrier broadly referred to as a sub-carrier. The OFDM scheme required banks of sinusoidal sub-carrier generators and demodula-

Table 1.1: Design parameters of Wireless Local Area Network [IEEE 802.11a].

Parameters	**Specification**
Data rate	6, 9, 12, 18, 24, 36,48,and 54 Mbps
Coding rate	1/2, 2/3, and 3/4
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Number of Pilot sub-carrier	4
Number of Data sub-carriers	48
Total number of sub-carrier (Pilot + Data)	4 + 48 = 52
OFDM Symbol Duration	4 μs
Sub-carrier spacing	312.5 KHz
Guard Interval	800 ns
Channel Spacing	20 MHz

tors with high implementation complexity. Weinstein and Ebert in 1971 proposed that the discrete fourier transform (DFT) can be utilized for the OFDM modulation and demodulation processes, which efficiently minimizes the implementation complexity of OFDM [Weinstein and Ebert (1971)]. In 1980's Peled and Ruiz suggested a easier Frequency Domain data transmission scheme using a cyclic prefix aided technique with lower computational complexity than that of classic single-carrier time-domain QAM modems [Peled and Ruiz (1980)]. Cimini explored the performance of OFDM system in wireless communication channels [Cimini (1985)]. Raleigh and Cioffi in 1996, developed new schemes for upgrading the efficiency of MIMO systems, which inspired various further contributions [Raleigh and Cioffi (1996); Foschini (1996)].

As a important building block of upcoming wireless communication systems, MIMO-OFDM are fit for supporting significantly higher data rates than the high-speed down-link packet access (HSDPA) based 3G networks and the universal mobile telecommunication system (UMTS) [Zu and Murch (2004)].

The three fundamental parameters that describes the quality of wireless link are

Table 1.2: Design parameters of Worldwide interoperability Microwave Access (WiMAX) [IEEE 802.16e].

Parameters	**Specification**
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Coding rate	1/2, 2/3, 3/4 and 5/6
FFT Size	256
Sampling Frequency (MHz)	2, 4, 6.32, and 8
Symbol Duration (T_u μsec	128, 64, 40, and 32
Duration of Guard Interval	$T_u/4, T_u/8, T_u/16$, and $T_u/32$
Sub-carrier Spacing (KHz)	7.81, 16.6, 25.0, and 31.3
Bandwidth (MHz)	1.75, 3.5, 5.5, and 7

the transmission rate, range and reliability [Jiang and Hanzo (2007)]. MIMO-OFDM is guaranteed to be discovered by Airgo Networks by George Raleigh in 2001 [Airgo (2001)]. However, with the approach of MIMO-OFDM systems, the aforementioned three parameters may be simultaneously improved. It has been formed the foundation of various IEEE standards viz., IEEE 802.11a/n [IEEE Standard 802.11a (1999)] and IEEE 802.16e [IEEE Standard 802.16 (2004)].

1.4 APPLICATIONS AND LIMITATIONS

MIMO-OFDM systems have discovered their way into several standards for future wireless communication systems, examples are IEEE 802.11a/n, 802.16 and the 3rd Group Partnership Project (3GPP) [Duman and Ghrayeb (2007)]. The IEEE 802.11a standard has been developed for WLAN (wireless local area network). WLAN is widely used in corporate workspace. It works in the 5 GHz band with a extreme net transmission data rate of 54 Mbps. The main parameter of WLAN is specified in Table 1.1. The IEEE 802.11a standard uses the same in-

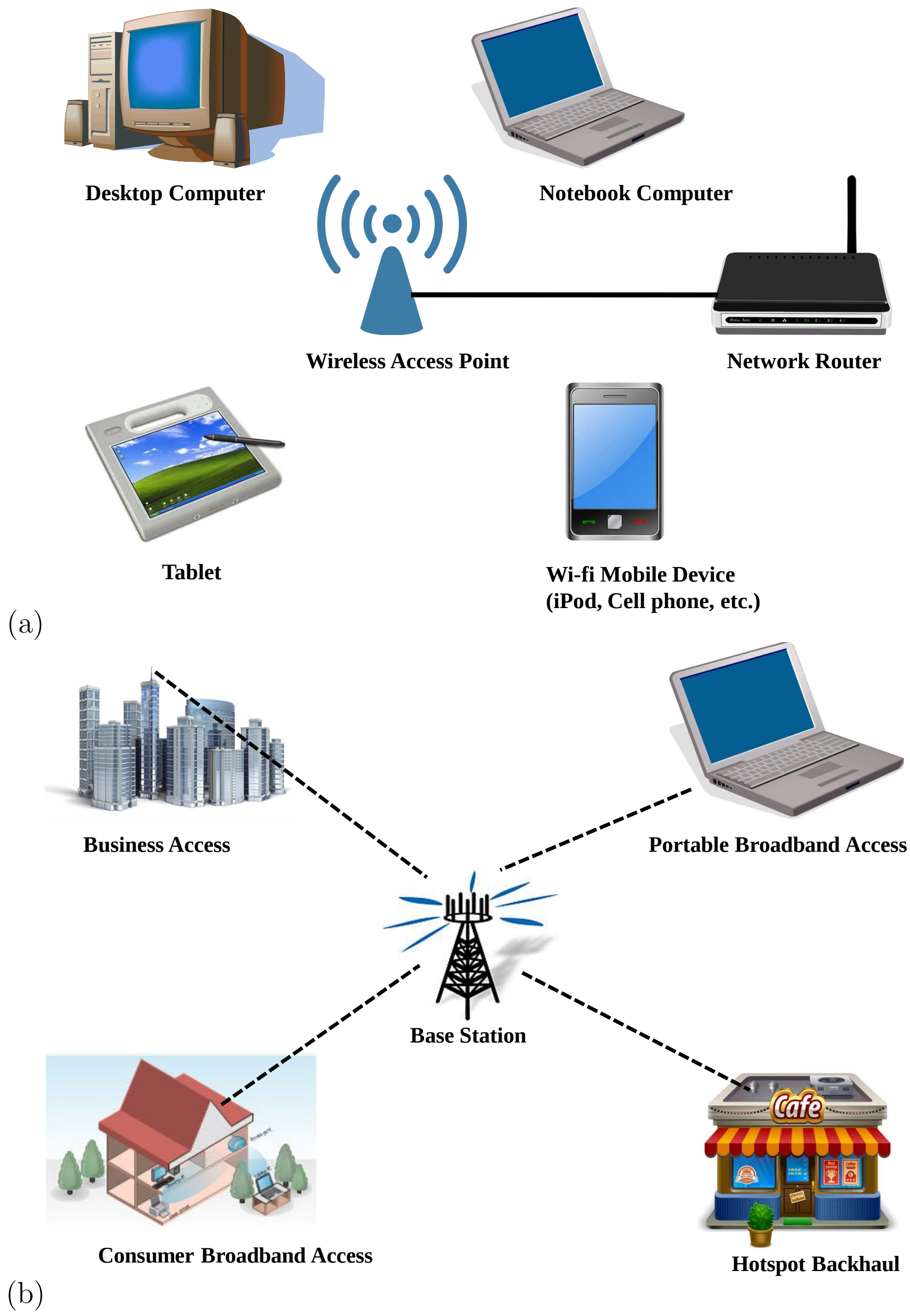

Figure 1.1: IEEE Standards (a) Wireless local area network (WLAN) (b) World-wide interoperability microwave access (WiMAX).

formation link layer protocol and frame format as the original standard. Several MIMO-OFDM configurations are being considered for WLAN applications with space-time block coding schemes. The IEEE 802.16 standard also-called WiMAX (World interoperability for Microwave Access), has been designed to deliver high data rates over long distances. The main parameters of IEEE 802.16 are given in Table 1.2. The IEEE 802.16e uses scalable OFDM to support channel bandwidths of between 1.25 MHz and 20 MHz, with up to 2048 subcarriers. Although MIMO-OFDM transmission can alleviate the issue of multipath propagation, but recently researchers focused on solving a set of inherent difficulties in MIMO-OFDM system. Figure 1.1 (a) IEEE 802.11a and (b) IEEE 802.16e depicts the practical applications of IEEE standarda. The various issues of MIMO-OFDM as discussed as below -

- Peak-to-average power ratio (PAPR) : MIMO-OFDM exhibits a high peak power after adding signal in same phase due to IFFT at the transmitter. When these signals excite the nonlinear characteristics of the HPA, it causes out-of-band radiation, which further distorts the signals in adjacent bands and in-band regions. This high peak power reduces the efficiency of HPA and degrades the performance of the MIMO-OFDM system.

- Symbol timing offset (STO) and Carrier frequency offset (CFO) : The symbol timing offset (STO) requires proper timing of fast fourier transform (FFT) at receiver; otherwise mismatching arises in MIMO-OFDM symbol detection. The orthogonality is destroyed due to carrier frequency offset arise between carriers. Doppler shift (due to relative motion between transmitter and receiver) is the major cause of CFO.

- Inter symbol interference (ISI) : The result of PAPR problem and channel delay under fading environment will appear in form of ISI at the receiver. It decreases the signa-to-noise ratio (SNR) and degrades the bit error rate

(BER) performance of MIMO-OFDM system. Equalization techniques are used to mitigate the problem of ISI at the receiver.

- Computational complexity : The complexity of MIMO-OFDM system increases with increase in number of antennas at transceiver end.
- Cost : Cost of the MIMO-OFDM system is directly affected by the increment in the number of antennas.

1.5 MOTIVATION

Increasing the spectral efficiency of wireless communication systems is one of the greatest challenges faced by wireless communication engineers. The huge demand for data rate with large number of subscribes and increase in multimedia applications require large bandwidth. OFDM, with its spectral efficient versions like MIMO-OFDM and multiple access versions like OFDMA are under active consideration to fulfill the requirements of present and next generation wireless systems.

In the modern era the requirement of internet, mobile and TV is drastically increasing because in general, human being adopted all such services as common routing life. Nowadays, many wireless services are affected by data traffic management due to a large number of subscribers. Therefore, the data management or simply data rate is the biggest challenge of today's world. Wireless communication puts a platform for users to perform many tasks simultaneously on the same bandwidth. This can be possible by using Wireless LAN, WiMAX. Both technologies help users to work with high speed better data security, such as net banking transaction, online railway ticket booking, filling of forms and online shopping, etc.

The major advantage of using MIMO-OFDM technology includes increase in diversity and array gain which enhances the coverage area and enhances quality of service (QoS) of a communication system. It also suffers with a major drawback viz., high PAPR and ISI. These drawback degrades the efficiency of the HPA in the transmitter and causes inter symbol interference (ISI) at receiver.

In this thesis, the motivation of research work is to propose an efficient scheme to reduce PAPR and ISI of MIMO-OFDM system. The proposed scheme is not only reduces the PAPR, but also maintain the spectral spreading. The new efficient channel equalization is also proposed to diminish the effect of ISI caused by channel delay, and maintain the BER performance. Moreover, the computational complexity of the system should be kept as low as possible using soft-computing scheme. The performance of the proposed schemes must be analyzed and compared with an existing conventional scheme based on different parameters.