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MIMO-OFDM : Foundation for Next-Generation Wireless Systems

Vaishali Bahl
Department of Electronics and Communications
Punjab Institute of Technology, PTU Main Campus
Jalandhar, India
vaishalibahl@rediffmail.com

Rakesh Dubey
Department of Electronics and Communication
Punjab Institute of Technology, PTU Main Campus
Jalandhar, India
rakeshdubey034@gmail.com

Dr. Dalvir Kaur
Department of Electronics and Communications
Punjab Institute of Technology, PTU Main Campus
Jalandhar, India
dn_dogra@rediffmail.com

Abstract—the conjunction of MIMO systems with OFDM has emerged as a promising technology in recent years. The use of multiple transmit and receive antennas forming MIMO-OFDM systems not only provide robustness against multipath fading impairments but also ensures significant increase in the rates over frequency selective channels. Furthermore this technology is now making possible to build high data rate communication systems with affordable receiver complexity. Because of these advancements, MIMO-OFDM has been widely adopted for different wireless standards all over the world and few names to mention are IEEE 802.11n (WLAN), IEEE 802.16e-2005(WiMAX), 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE).

Keywords—*Orthogonal Frequency Division Multiplexing(OFDM); Multiple Input Multiple Output(MIMO).*

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I. INTRODUCTION

The vital challenge faced by future wireless communication systems is to provide high-data rate wireless access at high quality of service (QoS) in addition to the facts that spectrum is a limited resource and propagation conditions are hostile because of fading caused by destructive addition of multipath components and interference from other users [1]. This requirement urges for an alternative to thoroughly increase the spectral efficiency and to improvise the link authenticity due to antenna gain diversity. The usage of multiple antennas at both ends of a wireless link (MIMO technology) holds the potential to radically improve the spectral efficiency and link reliability in upcoming wireless communication systems. An explicitly promising claimant for next-generation fixed and mobile wireless systems is the combination of MIMO technology with Orthogonal Frequency Division Multiplexing (OFDM) [2].

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM is a special case of multi-carrier modulation. The principle of OFDM is to divide a single high-data rate stream into a number of lower rate streams that are transmitted simultaneously over some narrower sub channels which are orthogonal to each other. Hence it is not only a modulation technique but a multiplexing technique too. The merits of this technique that make it a preferred choice over other modulation techniques are 1) It has high spectral efficiency. 2) Easy implementation of FFT. 3) Low receiver complexity. 4) Its robustness for high-data rate transmission over multipath fading channel. 5) Its high flexibility for link adaptation are few advantages to list. But every coin has two sides and same principle apply to this technique too. It has two basic disadvantages: 1) Sensitivity to frequency offsets, timing errors and phase noise. 2) Relatively higher peak to average power ratio (PAPR) as compared single carrier signal which tends to reduce the power efficiency of RF Amplifier. But numerous efficient techniques have already been developed to maintain this technique's fidelity. Fig (1) shows block diagram of baseband OFDM modem which is based on PHY (physical layer) of IEEE standard 802.11a [3].

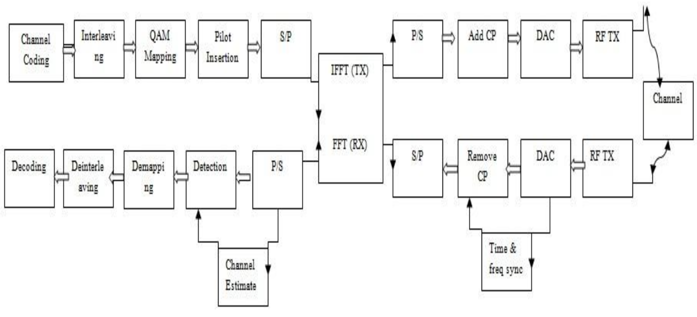

Fig 1. OFDM Baseband Model

III. MUTIPLE INPUT MULTIPLE OUTPUT – ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (MIMO-OFDM)

The primary encouragement to OFDM in a MIMO channel is the fact that OFDM modulation turns a frequency-selective MIMO channel into a set of parallel frequency-flat MIMO channels [2]. This yields multi-channel equalization specifically simple, since for each OFDM-subcarrier only a constant matrix has to be inverted.

In a MIMO-OFDM system with N subcarriers, the individual data streams are primarily passed through OFDMmodulators which perform an IFFT on blocks of length

N followed by a parallel to serial conversion. A cyclic prefix (CP) of length Lcp ≥ L containing a copy of last Lcp samples of parallel to serial converted output of N-point IFFT is then speculated. The resulting OFDM symbols of length N+Lcp are released simultaneously from the individual transmit antennas. The cyclic prefix is essentially a guard interval whose function is to eliminate interference between OFDM systems and convert linear convolution into circular convolution so that the channel gets diagonalized by the Fast Fourier Transform (FFT). In the receiver section the individual signals are passed through OFDM demodulators which foremost discard the CP through OFDM demodulator and then perform an N-point FFT. The outputs of OFDM demodulators are convincingly separated and decoded. Fig (2) shows the MIMO-OFDM system model [2].

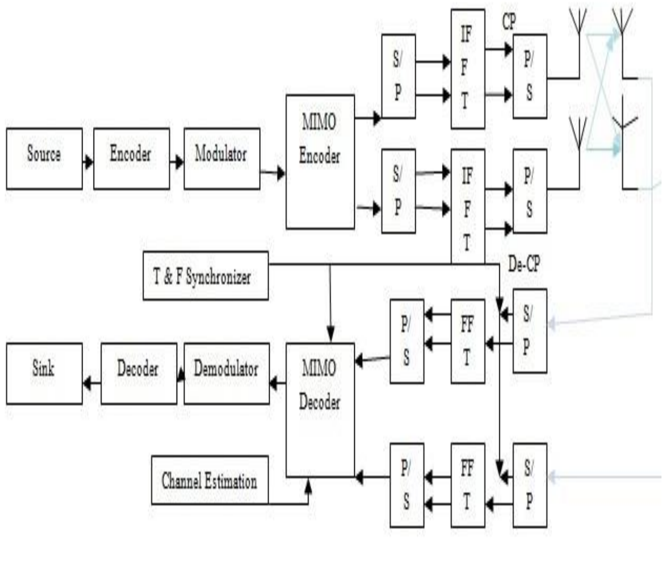

Fig 2. MIMO-OFDM Model

A. ISSUES IN MIMO-OFDM

The implementation of MIMO-OFDM in the presence of multiple users increases the benefits followed by issues [4].

- The multiuser and multi-cell interference occurs [4].
- Resource Allocation becomes crucial [4].
- Antenna issues arise as both the antenna element numbers and the inter-element spacing are the prime requirements for high spectral efficiencies but base stations with large number of antennas pose environmental threat [5].
- Precoding schemes are required for multi user MIMO that make each layer of MIMO linear and make beam formingpossible [5].
- The complexity is enhanced in the system [5].

B. PROGRESS IN MIMO-OFDM

The OFDM has been considered as a contender standard by a no. of standardization groups of IEEE like-

- IEEE 802.11a which is an extension to IEEE 802.11[39] that is considered for WLANs and provides a bit rate up to 54Mbps in 5 GHz band in comparison to IEEE 802.11. IEEE 802.11a uses OFDM scheme which applies to wireless asynchronous transfer mode (WATM) networks and access link [6].
- IEEE 802.11g provides wireless transmission over short distance at 20-54 Mbps in 2.4 GHz band also employs OFDM scheme [6].
- IEEE 802.11nis the promising candidate for next generation WLANs, which was a formed from previous IEEE 802.11 standard by integrating MIMO techniques. It provides high throughput at 100-200 Mbps bit rate [6].
- IEEE 802.16 depicts the wireless services operating in the 2-11 GHz band in combination with WMANs to provide link between subscriber and a core network are the few to mention [6].

Table 1 shows some of the main contributions in field of OFDM systems [6].

As a prominent building block of next generation wireless communication systems, MIMOs are proficient in supporting data rates higher than UMTS and HSPDA based 3G networks. Since the information is transmitted via different paths a MIMO system exploits transmit and receive diversity thereby maintain the promising communication [6].

With the onset of MIMO assisted OFDM systems the transmission rate, range and reliability have been improvised.

MIMO-OFDM which is claimed to be invented by Airgo Networks has built the foundation of standards proposed for IEEE 802.11n. Extensive research has taken place in this field addressing aspects like capacity, space/time/frequency coding, PAPR control, channel estimation, receiver design etc.[6]. The table 1 illustrates some of the contribution in the field of MIMO-OFDM systems[6].

IV. DISSCUSSION

After studying several research works in the direction of MIMO-OFDM, it can be analyzed that MIMO has advantages of beam forming technology; the spatial diversity based on space-time coding can be used for attaining high diversity gains of MIMO systems, symbol error probability due to channel fading and noise can be reduced by joint coding of data streams. It can also enhance the redundancy of signal by joint coding and gain to improvise the fidelity of communication links. Further, data transfer rate and spectral efficiency can be magnified by the use of higher order modulation under same links.

A table (table I) has been composed comprising some of the major breakthrough in the territory of MIMO-OFDM systems.

A. Tables

TABLE I. CONTRIBUTIONS TO OFDM AND MIMO-OFDM SYSTEMS

Year	Milestones in OFDM and MIMO-OFDM Systems	
	AUTHOR	**CONTRIBUTION**
1966	Chang [6]	Proposed first OFDM scheme.
1993-1995	Warner, Moose & Pollet	Conducted studies on time and frequency synchronization.
2000	Van Nee and Prasad	OFDM for wireless multimedia communications
2001	Li	Exploited optimum training sequence design & simplified channel estimation for improving the performance & for reducing channel estimation for improving performance.
2003	Song and Li	Developed a technique based on auto correlation function for estimating for Doppler spread in Rayleigh fading channels for mobile OFDM systems using multiple antennas.
2004	J. Jhany	Adopted an ICI cancellation scheme in OFDM system.
2007	Ming-Xan Chang [7]	Developed a novel algorithm of inter sub channel ISI for OFDM systems.
2002	Li, winters [6]	Invoked Space Time coding & SIC in MIMO-OFDM systems.
2005	Sun, Xiong & Way	Targeted at designing CFO estimator aided expectation maximization based iterative receiver for MIMO-OFDM systems.
2006	Liew	Investigated a variation space time codes for ofdm systems.
2007	Yu fu witold A. krymien [8]	Worked for multiuser and ICI reduction in multiple antenna multiuser OFDM downlink.

Year	Milestones in OFDM and MIMO-OFDM Systems	
	AUTHOR	**CONTRIBUTION**
2008	Hyuwg joon song [9]	Used hybrid interference cancellation for Joint Doppler-Frequency Diversity for OFDM systems in time-varying multipath fading channel.
2009	Jing-Mao Lin [10]	High performance baseband transceiver for MIMO-OFDMA uplink communication.
2011	Doywook choi [11]	Obtained the resource allocation for CoMP with multiuser MIMO-OFDM.
2012	Xian – tao sun, Qi wang [12]	ICI/ISI aware Beam forming for MIMO-OFDM wireless systems.
2013	Pawandeep S. Taluja, Brian L. Hughes [13]	Obtained the diversity limits of compact broadband multi-antenna systems.

CONCLUSION

The MIMO-OFDM is influential in achieving the high-spectral efficiency required for transformation of mobile communication system. Since radio resources are limited and data rate requirements keep increasing, spectral efficiency is an unavoidable requirement in present and future wireless communications systems. MIMO-OFDM has become a new star in the constellation of wireless and mobile communications. In addition to increasing spectral efficiency, MIMO can also be used to reduce transmitting power while keeping coverage areas constant. The use of MIMO technique in future transmission systems for broadcasting, multicasting and unicasting represents real business logic also for broadcasting corporations because of possible reduction in transmission stations. Due to these properties MIMO is a vital part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), IEEE 802.16e (WiMAX) , 3GPP Long Term Evolution (LTE) , 3GPP HSPA+ , 4G systems and further new systems to come.The implementation of MIMO-OFDM will require efficient designs of channel estimation and synchronization techniques for working in fast fading conditions. MIMO-OFDM system will employ cooperative communications through relays to enhance authenticity and widen the coverage.

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