MIMO-OFDM

Shweta[1], Priyanka Mavi[2]
UG, [1,2] Department of Electronics and Communication Engineering,
Raj Kumar Goel Institute Of Technology For Women, UP (India)

ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is used for transmitting a number of data messages simultaneously through a linear band-limited transmission medium at a maximum data rate without inter-channel and inter-symbol interferences. The use of multiple antennas at both ends of a wireless link (MIMO technology) holds the potential to drastically improve the spectral efficiency and link reliability in future wireless communications systems. A particularly promising candidate for next-generation fixed and mobile wireless systems is the combination of MIMO technology with Orthogonal Frequency Division Multiplexing (OFDM). The main motivation for using OFDM in a MIMO channel is the fact that OFDM modulation turns a frequency - selective MIMO channel into a set of parallel frequency-at MIMO channels.This paper provides an overview of the basic principles of MIMO-OFDM. This Paper describes how MIMO-OFDM (Multiple Input Multiple Output- Orthogonal Frequency Division Multiplexing) technology delivers significant performance improvements for wireless LANs, enabling them to serve existing applications more cost-effectively as well as making new, more demanding applications possible.

***Keywords:* Diversity, Spatial Multiplexing, Inter Symbol Interference, Multi Input Multi Output (MIMO), OFDM, Bit Error Rate.**

I INTRODUCTION OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) SYSTEMS

Orthogonal frequency division multiplexing (OFDM) has become a popular technique for transmission of signals over wireless channels. In recent years, orthogonal frequency division multiplexing (OFDM) technique has attracted a lot of attention in the standardization of broadband wireless systems. OFDM technique is a multicarrier modulation technique with a rather simple implementation performed using FFT/IFFT algorithms, and robust against frequency-selective fading channels which is obtained by converting the channel into flat fading sub-channels. Our information society today is marked by an increasing need for mobility and permanent accessibility. At the same time, the desire for ever higher data transfer rates is also increasing. The greatest current challenge for future wireless communication systems is therefore to provide broadband mobile (or at least portable) data access with a quality of service (QOS) as high as possible. Even in the wireless LAN area the necessary data transfer rates and the quality of service for implementing new applications such as home entertainment, home TV broadcasting or streaming are lacking in the current IEEE 802.11a/g standards as well as the basic IEEE802.11 and IEEE802.11b standards. OFDM converts a frequency-selective channel into a parallel collection of frequency flat sub-channels. The subcarriers have the minimum frequency separation required to maintain orthogonally of their corresponding time domain waveforms, yet the signal spectra corresponding to the different subcarriers overlap in frequency. Hence, the available bandwidth is used very efficiently.

If knowledge of the channel is available at the transmitter, then the OFDM transmitter can adapt its signalling strategy to match the channel. Due to the fact that OFDM uses a large collection of narrowly spaced sub-channels, these adaptive strategies can approach the ideal water pouring capacity of a frequency- selective channel. In practice this is achieved by using adaptive bit loading techniques, where different sized signal constellations are transmitted on the subcarriers. Theoretically, MIMO technique to be efficient the antenna spacing needs to be at least half the wavelength of the transmitted signal, even though, in some recent research this theoretical bound has been conquered and recently some broadband mobile phones support more than one antenna. In this paper, a new transmission scheme for MIMO-OFDM systems is proposed. The new transmission approach reduces significantly the complexity of the conventional MIMO-OFDM systems for the symmetric channel. The principal of the proposed scheme is based on channel coding which make use of the estimated channel parameters extracted from a pilot signal transmitted by the destination receiver. Thus, the transmitted signal is very much adapted to the channel impairments and variations.

1.1 MIMO SYSTEM

Multipath propagation is a feature of all wireless communication environments. There is usually a primary (most direct) path from a transmitter at point “A” to a receiver at point “B.” Inevitably, some of the transmitted signal takes other paths to the receiver, bouncing off objects, the ground, or layers of the atmosphere. Signals traversing less direct paths arrive at the receiver later and are often attenuated. A common strategy for dealing with weaker multipath signals is to simply ignore them—in which case the energy they contain is wasted. The strongest multipath signals may be too strong to ignore, however, and can degrade the performance of wireless LAN equipment based on existing standards.

MIMO wireless communication refers to the transmissions over wireless links formed by multiple antennas equipped at both the transmitter and receiver. In MIMO "multiple channels" is often interchanged with "multiple antennas". A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. Generally, there are three categories of MIMO techniques. The first aims to improve the power efficiency by maximizing spatial diversity. The key advantages of employing multiple antennas lie in the more reliable performance obtained through diversity and the achievable higher data rate through spatial multiplexing. These concepts are briefly discussed below.

1.1.1 Diversity : The signal transmission over broadband wireless channels always suffers from attenuation due to the detrimental effect of multipath fading, and this can severely degrade the reception performance. In MIMO systems, the same information can be transmitted from multiple transmit antennas and received at multiple receive antennas simultaneously. Since the fading for each link between a pair of transmit and receive antennas can usually be considered to be independent, the probability that the information is detected accurately is increased.

Apart from the spatial diversity, other forms of diversity are commonly available, namely, temporal diversity and frequency diversity, if the replicas of the faded signals are received in the form of redundancy in the temporal and frequency domains, respectively. The simplest way of achieving diversity in MIMO systems is through repetition coding that sends the same information symbol at different time slots from different transmit antennas. A more bandwidth efficient coding scheme is ST coding [4], where a block of information symbols are transmitted in a different order from each antenna.

1.1.2 Spatial Multiplexing — It is widely recognized that the capacity of a MIMO system is much higher than a single-antenna system. For a rich scattering environment, in a MIMO system with *Mt* transmit antennas and *Mr* receive antennas, the capacity will grow proportionally with min (*Mt*, *Mr*). MIMO systems provide more spatial freedoms or spatial multiplexing, so that different information can be transmitted simultaneously over multiple antennas, thereby boosting the system throughput. Spatial multiplexing needs a dedicated detection algorithm at the receiver to sort out different transmitted signals from their mixed one. V-BLAST is an example of such an algorithm and it can be realized in an efficient way with a series of ordering and successive cancellation.

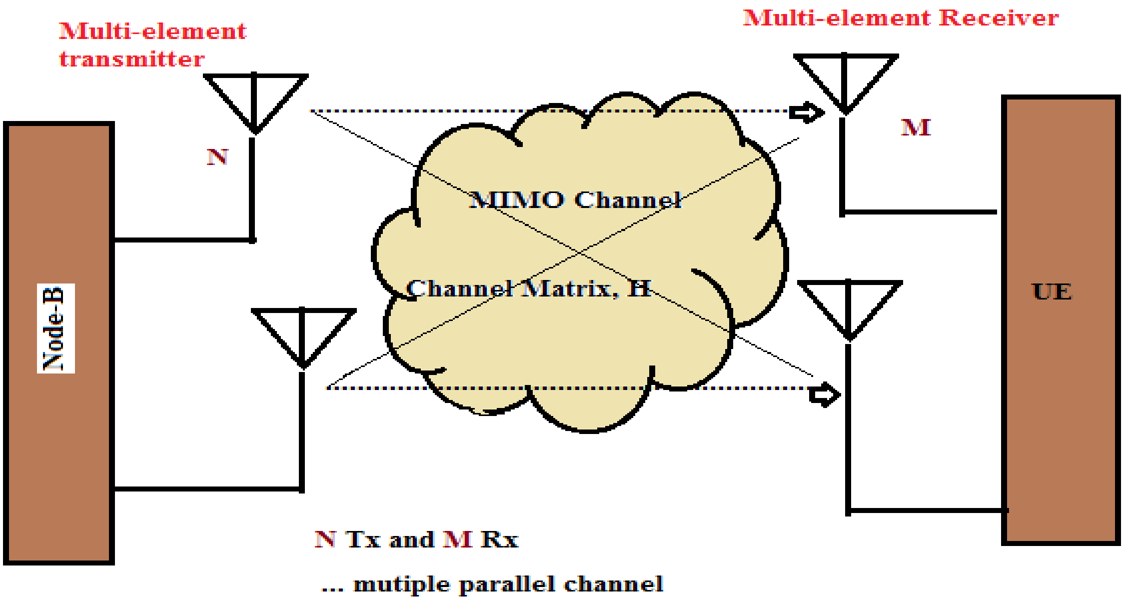

Fig 1: MIMO

II NEED OF MIMO-OFDM

MIMO can be used with any modulation or access technique. Today, most digital radio systems use Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), or Orthogonal Frequency Division Multiplexing (OFDM). Time division systems transmit bits over a narrowband channel, using time slots to segregate bits for different users or purposes. Code division systems transmit bits over a wideband (spread spectrum) channel, using codes to segregate bits for different users or purposes. OFDM is also a wideband system, but unlike CDMA which spreads the signal continuously over the entire channel, OFDM employs multiple, discrete, lower data rate sub-channels.

MIMO can be used with any modulation or access technique. However, research shows that implementation is much simpler particularly at high data rates for MIMO-OFDM. Specifically, MIMO-OFDM signals can be processed using relatively straightforward matrix algebra.

III SYNTHESIS OF OFDM SIGNALS FOR MULTI-CHANNEL DATA TRANSMISSION

In this section it is shown that by using a new class of band-limited orthogonal signals, the channels can transmit through a linear band-limited transmission medium at a maximum possible data rate without inter-channel and inter-symbol interferences. A general method is given for synthesizing an infinite number of classes of band-limited orthogonal time-functions in a limited frequency band. This method permits one to synthesize a large class of transmitting filter characteristics for arbitrarily given amplitude and phase characteristics of the transmission medium. The synthesis procedure is convenient. Furthermore, the amplitude and the phase characteristics of the transmitting filters can be synthesized independently, i.e., the amplitude characteristics need not be altered when the phase characteristics are changed, and vice versa. The system can be used to transmit not only binary digits or m-array digits, but also real numbers, such as time samples of analogy information sources. As will be shown, the system satisfies the following requirements.

i. The transmitting filters have gradual cut-off amplitude characteristics. Perpendicular cut offs and linear phases are not required.

ii. The data rate per channel is 2fs bauds, where fs is the centre frequency difference between two adjacent channels. Overall data rate of the system is [N/(N+1)] Rmax, where N is the total number of channels and Rmax, which equals two times the overall base band bandwidth, is the Nyquist rate for which unrealisable rectangular filters with perpendicular cut-offs and linear phases are required. Thus, as N increases, the overall data rate of the system approaches the theoretical maximum rate Rmax, yet rectangular filtering is not required.

iii. When transmitting filters are designed for an arbitrary given amplitude characteristic of the transmission medium, the received signals remain orthogonal for all phase characteristics of the transmission medium. Thus, the system (orthogonal transmission plus adaptive correlation reception) eliminates inter channel and inter symbol interferences for all phase characteristics of the transmission medium.

iv. The distance in signal space between any two sets of received signals is the same as if the signals of each channel were transmitted through an independent medium and inter symbol interference in each channel were eliminated by reducing data rate. The same distance protection is therefore provided against channel noise (impulse and Gaussian noise). For instance, for band-limited white Gaussian noise, the receiver receives each of the overlapping signals with the same probability of error as if only that signal were transmitted. The distances in the signals space are also independent of the phase characteristics of the transmitting filters and the transmission medium.

v. When signalling intervals of different channels are not synchronized, at least half of the channels can transmit simultaneously without inter-channel and inter-symbol interference.

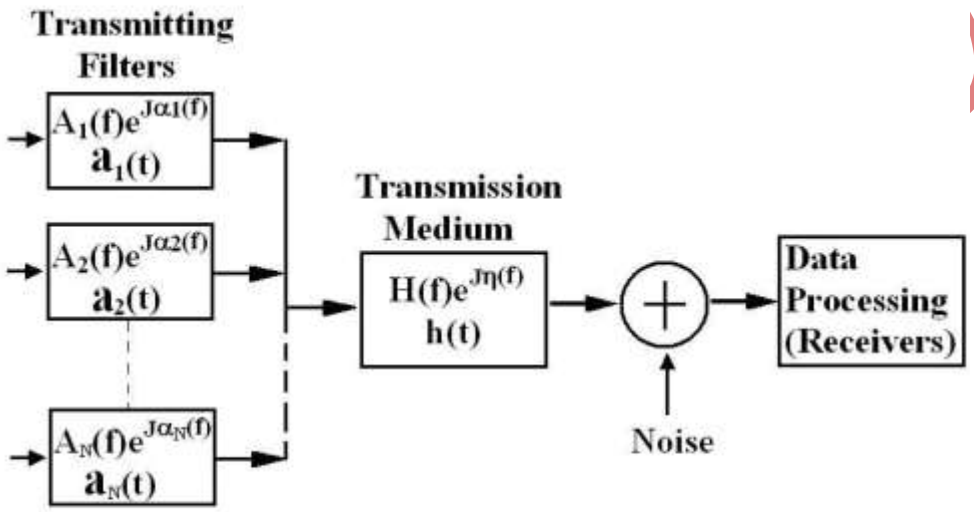

Fig 2: N data channels transmitting over one transmission medium

IV OFDM MODEL SYSTEM

Recent developments in MIMO techniques promise a significant boost in performance for OFDM systems. Broadband MIMO-OFDM systems with bandwidth efficiency of the order of 10 b/s/Hz are feasible for LAN/MAN environments. The physical (PHY) layer techniques described in this paper are intended to approach 10 b/s/Hz bandwidth efficiency.

The general structure of MIMO-OFDM system is shown in figure 1. The proposed system consists of 2 transmit and 2 receive antennae. The OFDM signal for each antenna is obtained by applying the inverse Fast Fourier transform (IFFT) and can be detected using Fast Fourier transform (FFT) [5]. A pilot sequence is inserted and used for the channel estimation. Also, a cyclic prefix is inserted in front of the OFDM symbol at the last step of OFDM modulation block. The time length of the cyclic prefix should be greater than the maximum delay spread of the channel. The main function of the cyclic prefix is to guard the OFDM symbol against Inter Symbol Interference (ISI), hence, this cyclic prefix is called the guard interval of the OFDM symbols [Ref]. The MIMO coding can use several encoders such as STBC, VBLAST and Golden coding. In this paper, the conventional MIMO-OFDM system is implemented using Alamouti STBC with two transmits and two receive antennas

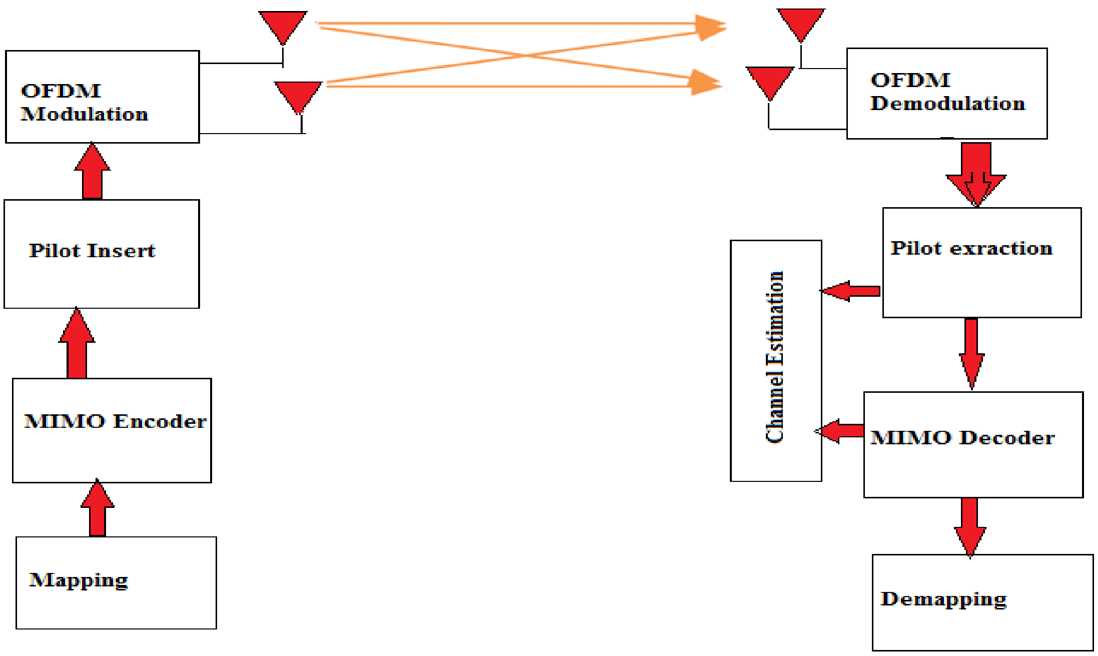

Fig 3. MIMO-OFDM system model.

OFDM is used in numerous wireless transmission standards nowadays (DAB, DVB-T, WiMAX IEEE 802.16, ADSL, WLAN IEEE 802.11a/g, Home Plug AV or DS2 200 aka "Home Bone"). The OFDM modulation transforms a broadband, frequency-selective channel into a multiplicity of parallel narrow-band single channels. A guard interval (called Cyclic Prefix CP) is inserted between the individual symbols. This guard interval must be temporally long enough to compensate for jitter in the transmission channel. Transmitted OFDM symbols experience different delays through the transmission channel. The variation of these delays at the receiving location is called jitter. The appearance of inter-symbol interference (ISI) can thus be prevented. It has been shown in that OFDM can be favourably combined with multiple antennas on the sending side as well as the receiving side to increase diversity gain and/or transmission capacity in time-varying and frequency-selective channels. The result is the MIMO OFDM systems now crowding the market. In a differentiation is made between Spatial Multiplexing MIMO (SM-MIMO) transmission systems with per-stream coding (PSC) and those with *per*-antenna coding (PAC*)*. In PSC the entire data stream is first encoded, the code bits are scrambled and then divided into parallel data streams according to the number of antennas. In PAC the encoding is done per sending antenna by all sub carriers.

V MULTIUSER SPACE-FREQUENCY CODING FOR OFDMA

Recently, the issue of increasing the information rate of multiuser MIMO-OFDM systems was considered without CSIT by Gärtner and Bölcskei. Their results show that joint code designs are necessary whenever multiple users transmit concurrently at high rates. Otherwise, employing the traditional single-user ST/SF codes for each of the users is optimal. It should be noted that the joint code design across transmit antennas has been widely used in point-to- point MIMO systems. However, in the multiple access case the individual users cannot coordinate their transmission. In for a specific case of 2-user multi-access channels (MAC), a simple design of multiuser SF codes was given by swapping and rotating one column of the Alamouti code matrix. The essence of the multiuser SF coding is to allow the users to choose their unique codebooks such that the error rate of the concurrent transmission is minimized. But this previous work is limited to a 2- user case and no explicit systematic code design was given. More recently, in we have shown that the achievable diversity gain of a multiuser MIMO OFDM system is not larger than that of a single user MIMO-OFDM system if each user is independently encoded. We have also found that multiuser interference can be minimized by applying a multiuser SF code. We then proposed a systematic design of multiuser SF codes for any number of users in MIMO frequency selective fading MAC. The proposed code for each user is structured as a constellation rotation followed by a unique phase rotation. The signal space diversity resulting from the constellation rotation can guarantee the full diversity for each user while the unique phase rotation for each user can ensure that multiuser interference is minimized. After employing a unique SF coding at each user, the coded symbols are allocated over all OFDM subcarriers, thereby increasing the data rate of each user. Assuming perfect CSI at the receivers and ML detection, it was shown that the proposed multiuser SF codes can achieve the diversity gain of *MtMrL* for every user and the minimal multiuser interference as well as a high data rate.

VI CONCLUSION

The combination of MIMO and OFDM has emerged as a promising solution for future high-rate wireless communication systems. We pointed out that in the open literature there was a paucity of information on multiuser MIMO OFDM detectors, which are capable of supporting a higher number of users than the number of receiver antennas. This scheme is based on channel coding using estimated channel parameters from a transmitted pilot data at the receiver end. Consequently, the prior information used by the coding scheme, will help the transmitted signal to adapt to the channel impairments and be more resilient to noise and interference. 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 un-casting represents real business logic also for broadcasting corporations because of the possible reduction in transmission stations. Unlike point-to-point MIMO-OFDM systems where the coding across transmit antennas is possible, coding across a group of uncoordinated users is generally impractical. In this article, we have shown that by applying signal space diversity and a unique phase rotation to each user, the proposed multiuser SF coding can guarantee the maximum diversity and high bandwidth efficiency as well as minimum multi-user interference.

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