An Overview of MIMO OFDM System

Prof. Monica Khanore*, Ms. Quanitah Shaikh**

*(A.P- Department of Electronics ,Frcrce, Mumbai
Email:khanore@frcrce.ac.in)
** (M.E student - Department of Electronics, Frcrce, Mumbai
Email: click.kanata@gmail.com)

ABSTRACT

In this paper, orthogonal frequency division multiplexing (OFDM) along with MIMO (MIMO - OFDM) is considered to mitigate intersymbol interference and enhance system capacity. The main goal of use of multiple antennas at both ends of a wireless link (MIMO technology) is to improve the spectral efficiency and link reliability in future wireless communications systems. The goal of this paper is to improve the concept of increasing the link throughput by extending an OFDM-based system with MIMO.Since synchronization is an essential task for any digital communication system and required for reliable reception of the transmitted data, this paper provides an overview to the preamble, synchronization, channel estimation , time and frequency synchronization.

Keywords- **Multiple Input Multiple Output (MIMO) System, Orthogonal Frequency Division Multiplexing (OFDM), Preamble, Synchronization**.

1. INTRODUCTION

The main reasons why orthogonal frequency division multiplexing (OFDM) was adopted in the wireless communication are its high spectral efficiency and ability to deal with frequency selective fading and narrowband interference. The requirement for wide bandwidth and flexibility imposes the use of efficient transmission methods especially in wireless environment where the channel is very challenging. In wireless environment the signal is propagating from the transmitter to the receiver along number of different paths, collectively referred as multipath. While propagating the signal power drops of due to three effects: path loss, macroscopic fading and microscopic fading. Fading of the signal can be mitigated by different diversity techniques. To obtain diversity, the signal is transmitted through multiple (ideally) independent fading paths e.g. in time, frequency or space and combined constructively at the receiver. Multiple input-multiple-output (MIMO) exploits spatial diversity by having several transmit and receive antennas.However "MIMO principles" assumed frequency flat fading MIMO channels.OFDM is modulation method known for its capability to mitigate multipath. In OFDM the high speed data stream is divided into Nc narrowband data streams, Nc corresponding to the subcarriers or subchannels i.e. one OFDM symbol consists of N symbols modulated for example by QAM . As a result the symbol duration is N times longer than in a single carrier system with the same symbol rate. The symbol duration is made even longer by adding a cyclic prefix to each symbol. As long as the cyclic prefix is longer than the channel delay spread OFDM offers inter-symbol interference (ISI) free transmission. The combination MIMO-OFDM is very natural and beneficial since OFDM enables support of more antennas and larger bandwidths since it simplifies equalization in MIMO systems. This paper provides a general overview of this promising transmission technique.

2. MIMO

In MIMO system multiple antennas are employed at the transmitter and the receiver. MIMO transmits and receives two or more data streams through a single radio channel. Thereby the system can deliver two or more times the data rate per channel without additional bandwidth or transmit power [4],[5]. The addition of multiple antennas at the transmitter combined with advanced signal processing at the transmitter and the receiver yields significant advantage in terms of capacity and diversity. Space-time block coding and spatial multiplexing are MIMO based techniques that provide link quality and high capacity in the system.

3. OFDM

As applications move to higher and higher data rates over wireless channels, ISI becomes more of a problem. To eliminate this problem multicarrier modulation is used.In MCM scheme such as FDM the channel bandwidth is divided into subchannels and transmits multiple relatively low rate signals by carrying each signal on a separate carrier frequency. To facilitate separation of the signals at the receiver, the carrier frequencies are spaced sufficiently far apart so that signal spectra do not overlap.Because of which, the resulting spectral efficiency of the system is quite low.
prefix (CP) before the final TX signal is upconverted to radio frequency (RF).

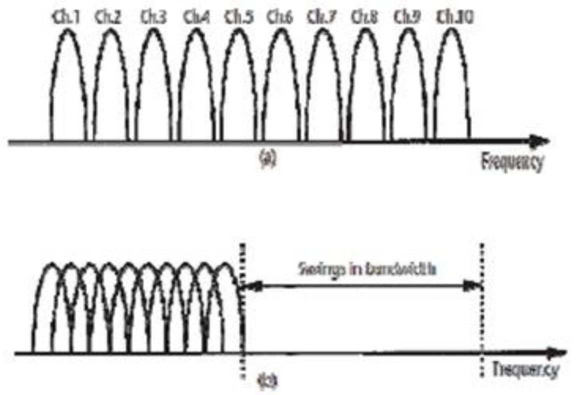

Fig.1. Multicarrier modulation scheme
a)FDM
b)Orthogonal Frequency Division Multiplexing.

In order to solve the bandwidth efficiency problem, Orthogonal Frequency Division. Multiplexing (OFDM) was proposed, which employs orthogonal tones to modulate the signals [2],[3]. The tones are spaced at frequency intervals equal to the symbol rate and are capable of separation at the receiver. This carrier spacing provides optimum spectral efficiency. It has been found that the OFDM symbols can actually overlap in the frequency domain and still be separated at the receiver.

4. MIMO OFDM System description

4.1 MIMO OFDM Transmitter

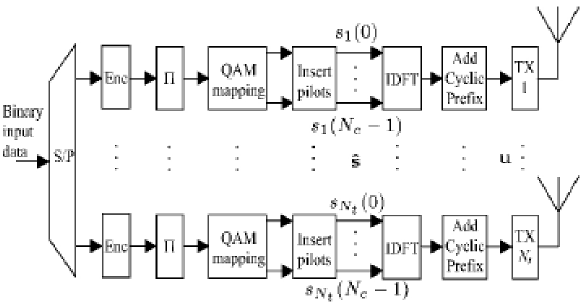

Fig. 2.MIMO OFDM transmitter scheme.

Fig. 2.MIMO OFDM transmitter scheme.

Consider a MIMO OFDM system with transmit (TX) and receive (RX) antennas. When the MIMO technique of spatial multiplexing is applied [8], encoding can be done either jointly over the multiple transmitter branches or per branch [2].The MIMO OFDM transmitter consists of OFDM transmitters
[1],[2] in which the incoming bits are multiplexed, and then, each branch in parallel performs encoding, interleaving, QAM mapping, and -point inverse discrete fourier transformation (IDFT) and adds a cyclic

4.1.1 Cyclic Prefix

The cyclic prefix(also called guard interval or zeropadding) is added to an OFDM symbol in order to combat the effect of multipath. ISI is avoided between adjacent OFDM symbols by introducing a guard period in which the multipath components of the desired signal are allowed to die out, after which the next OFDM symbol is transmitted. However, in order for this technique to work, the guard interval should be greater than the channel delay spread.

4.2 MIMO OFDM Receiver

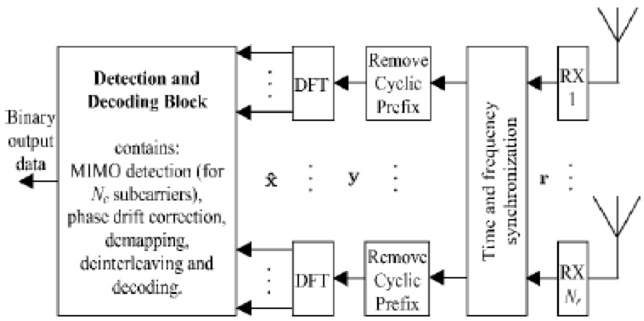

Fig. 3. MIMO OFDM receiver scheme

Fig. 3. MIMO OFDM receiver scheme

The receiver first estimate and correct for the frequency offset and the symbol timing, e.g., by using the training symbols in the preamble. After the channel, the cyclic extension is removed as it just contains the channel spread. Then the N-point discrete Fourier transformation (DFT) is performed per receiver branch. Each antenna receives a different noisy superimposition of the faded versions of the N transmitted signals (Figure 2).If the transmit and receive antennas are sufficiently spatially separated, and there is a sufficiently rich scattering propagation environment, the transmitted signals arriving at different receive antennas undergo uncorrelated fading. Moreover, if the channel state is perfectly known at the receiver, receiver is able to detect the N transmitted sub streams. Then, the symbols per TX stream are combined, and finally, demapping, deinterleaving , and decoding are performed for the parallel streams and the resulting data are combined to obtain the binary output data.

5. Synchronization

Synchronization is a key issue in the design of a OFDM receiver.Time and frequency synchronization is used for the start of the OFDM symbol and to align the modulators and the demodulators local oscillator frequencies. If any of these synchronization tasks is not performed with sufficient accuracy, then the orthogonality of the SCs is(partly) lost. That is, ISI and ICI are introduced.

5.1 Preamble

The preamble is used for both frequency synchronization and channel estimation. For the proposed frequency synchronization algorithm a repetition of the training symbol is required. For the estimation of the MIMO channel, it is important that the subchannels from the different TX antennas to every RX antenna can be uniquely identified. To achieve that, the preambles on the different TX antennas have to be orthogonal and shift-orthogonal for at least the channel length.

5.2 Time Synchronization

5.2.1 Frame Detection

The task of the frame detection (FD) is to identify the preamble in order to detect packet arrival. This preamble detection algorithm can also be used as a coarse timing (CT) algorithm, since it inherently provides a rough estimate of the starting point of the packet.

5.2.1 Symbol Timing

The symbol timing in an OFDM system decides where to place the start of the FFT window within the OFDM symbol. Although an OFDM system exhibits a guard interval(GI), making it somewhat robust against timing offsets, a nonoptimal symbol timing will cause more ISI and inter-carrier interference (ICI) in delay spread environments. This will result in a performance degradation.

5.3 Frequency Synchronization

The frequency synchronization has to correct for the frequency offset, which is caused by the difference in oscillator frequencies at the transmitter and the receiver. We estimate this frequency offset and compensate the received signals for it. The frequency offset can be estimated using the phase of the complex correlation between the two consecutive received training symbols [6],[7].

5.4 Channel Estimation

When time synchronization is performed at the receiver and after the received signals are corrected for the frequency offset, the channel can be estimated using the known training symbols within the preamble. When the timing is performed correctly ,we know which received samples correspond to the training part [6],[7].

CONCLUSION

Since radio resources are scarce and data rate requirements keep increasing, spectral efficiency is a stringent requirement in present and future wireless communications systems. MIMO-OFDM increase spectral efficiency and provides high data rate. In this technique different signals are transmitted simultaneously on different transmitting antennas. These parallel stream of data are mixed up in the air, the transmitted signal can still be recovered at the receiver.

ACKNOWLEDGMENTS

Our thanks to the experts who have contributed towards development of the MIMO OFDM system.

REFERENCES

Journal Papers

[1] G.J. Foschini and M.J. Gans , "On limits of wireless communications in a fading environment when using multiple antennas", Wireless Personal Communications, vol. 6, no. 3, pp. 311-335, March 1998.

[2] Allert van Zelst and Tim C. W. Schenk"Implementation of a MIMO OFDM-Based Wireless LAN System", IEEE Transactions on Signal Processing, VOL. 52, NO. 2, Feb 2004.

[3] Helmut Bölcskei, "MIMO-OFDM Wireless Systems:Basics, Perspectives, and Challenges", Communication Technology Laboratory ETH Zürich 2007.

[4] H. Sampath, S. Talwar, J. Tellado, V. Erceg, and A.Paulraj, "A fourth generation MIMO-OFDM:Broadband wireless systems," IEEE Commun. Mag., vol. 40, no. 9, pp.143-149, Sept. 2002.

[5] Arogyaswami J. Paulraj, Dhananjay A. Gore, Rohit U.Nabar, and Helmut Bolcskei, "An Overview of MIMO Communications—A Key to Gigabit Wireless," in IEEE proc. Vol. 92, No. 2, 2004.

[6] Schenk, T. and van Zelst, "A Frequency Sychronization for MIMO OFDM wireless LAN systems,"Proc. of IEEE Veh. Technol.Conf., 509-513, Florida, USA, 2003.

[7] Y. G. Li, J. H. Winters, and N. R. Sollenberger, "Signal detection for MIMO-OFDM wireless Communications ," IEEE Int. Conf. Commun.,June 2001.

Books

[8] J. G. Proakis, *Digital Communication* (New York: McGraw- Hill,4th ed., 2001).

[9] T. Rappaport, *Wireless Communications Principles and Practice* (Prentice Hall, 1996).

[10] R. van Nee and R. Prasard, *OFDM for Wireless Multimedia Communication* (Norwell , MA: Artech House, 2000)

Chapters in Books:

[11] J. G. Proakis, Multichannel and Multicarrier systems, *Digital Communication* (New York: McGraw-Hill,4th ed., 2001) 709-724.

[12] T. Rappaport,Mobile radio propogation:small scale fading and multipath, *Wireless Communications Principles and Practice* (Prentice Hall, 1996) 177- 248.