Channel Estimation on MIMO-OFDM System

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Abstract— Wireless communication systems face several problems. This includes frequency fading, multipath fading, Inter Carrier Interference (ICI), Inter Symbol Interference (ISI) etc. Requirement of larger transmit power at high rate, spectral efficiency and low bit rate capacity are other disadvantages. OFDM is an effective technique for high data rate wireless communication in multipath channels and fading environments at reasonable frequency in wireless channels. Because of the nature of its high speed data transmission and effectiveness in combating the frequency selective fading channel, it is adopted in recent days by many systems. Recently, multiple input multiple output (MIMO) channels have been introduced to achieve high data speed requisite by the next-generation communication systems. The channel characteristics can be estimated by using a preamble or pilot symbols known to both transmitter and receiver, which employ various interpolation techniques to estimate the channel response of the subcarriers between pilot tones. Generally, data signal as well as training signal, or both, can be used for channel estimation. This method can greatly reduce interference because the multiple antennas use the same frequency to transmit data in the OFDM transmission system, which can be applied to wireless mobile MIMO-OFDM communication system with double selective fading.

Key words: MIMO-OFDM, channel estimation, Pilot, interpolation

I. INTRODUCTION

Wireless communication system offers ubiquitous communication 'anytime, anywhere'. But however the wireless environment is hostile and communication signals subjected to frequency fading, multipath fading, ICI, ISI etc. Diversity is one of the methods adopted to combat these problems. By far the most promising multiple antenna technology today happens to be the so called multiple input multiple-output (MIMO) system. These MIMO systems are being considered to improve the range and performance of communication systems.

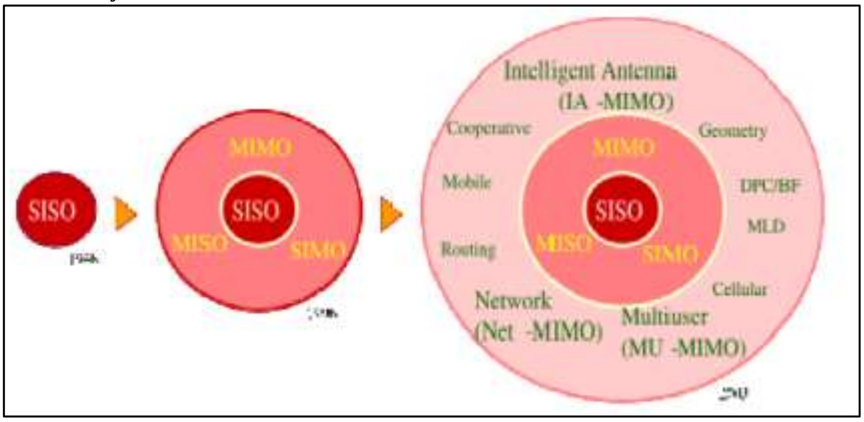

Fig. 1: MIMO Evolution

OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple orthogonal sub-carriers on adjacent frequencies. In addition the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency without interference.

For an OFDM based system under unknown narrow band interference [7] authors have proposed an iterative receiver to jointly estimate the channel information, which consists of channel coefficients and noise plus interference variances of each sub-carrier and detect the transmitted signal. The simulation outcomes show that proposed receiver provides an extremely close bit-error-rate (BER) to that of the case when perfect information is available at receiver. The channel estimation is a process of characterizing the effect of the transmission channel on the input signal. In this work authors compare the performance of Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) channel estimation technique for Wavelet based OFDM system.

The channel gain estimation algorithm [3] for the MIMO-OFDM system under the high speed movements has been analysed and simulated.. This method aims to achieve the robust MIMO-OFDM channel gain estimation by using only the Kalman filter from the canonical state space models. It consists of a state equation composed of channel gain and the colored driving source. It also includes an observation equation composed of the pilot symbols, channel gain and AWGN. The remarkable features of this method are that the channel gain estimation accuracy does not depend on the mobile speed, the number of channel paths and the number of transmitting antennas. Therefore, this method is the practical MIMO-OFDM channel gain estimation method. The proposed method estimates the channel gain with reduced computational complexity.

II. LITERATURE SURVEY

In 2014, Takahiro Natori, Nari Tanabe and Toshihiro Furukawa presented the channel gain estimation algorithm for the MIMO-OFDM system under the high speed movement environments. This method aims to achieve the robust MIMO-OFDM channel gain estimation by using only the Kalman filter from the canonical state space models. It consists of a state equation composed of channel gain and the colored driving source. It also includes an observation equation composed of the pilot symbols, channel gain and AWGN. The remarkable features of this method are that the channel gain estimation accuracy does not depend on the mobile speed, the number of channel path and the number of transmitting antennas. The proposed method can estimate the channel gain with reduced computational complexity of the traditional. Therefore, this method is the practical MIMO-OFDM channel gain estimation method

In 2013, Peng Cheng, Zhuo Chen and Yun Rui discovered Channel estimation technique for an orthogonal frequency division multiplexing broadband system over a doubly selective channel that is very challenging. This is mainly due to the significant Doppler shift, which results in a time-frequency doubly-selective (DS) channel. Authors proposed a novel channel estimation system based on distributed compressive sensing (DCS) theory. The special decoupling form originating from a novel sparse pilot pattern is designed for such estimation, which results in an ICI-free structure and enables the DCS application to make joint estimation of these vectors accurately. Combined with a smoothing treatment process, the proposed scheme can achieve significantly higher estimation accuracy than the existing ones, although with a much smaller number of pilot subcarriers. Results confirm its performance merits.

In2012, The hanh Pham and ying –chang Liang presented on OFDM based system under unknown narrow band interference author proposed an iterative receiver in jointly estimate the channel information, which consists of channel coefficients and noise plus interference variances of each sub-carrier and detect the transmitted signal. The simulation outcomes show that proposed receiver provides an extremely close bit-error-rate (BER) to that of the case when perfect information is available at receiver.

In 2011, M K Gupta, S Shrivastava, and Raghuvanshi, presented the channel estimation is a process of characterizing the effect of the transmission channel on the input signal. In this research work authors compare the performance of Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) channel estimation technique for Wavelet based OFDM system.

In 2010, LI Yuhong, GE Ning and LU Jianhua proposed a Single carrier Ultra-wideband (SC-UWB) transmission scheme with MSE channel estimation. Mainly, a direct sequence Binary phase shift keying (DSBPSK) has been used by this scheme to support high to moderate data rate applications that differentiates from Multi-band OFDM and Impulse radio (IR) UWB systems.

III. MIMO OFDM

System model for MIMO OFDM shows that the MIMO-OFDM processing transfers the wideband frequency-selective MIMO channel into a number of parallel flat-fading MIMO sub channels. Consider a MIMO OFDM system as shown in figure 2 with Nt transmit (TX) and Nr receive (RX) antennas. In addition to the spatial and temporal dimension of MIMO, OFDM adds one extra dimension to exploit, namely, the frequency dimension. In general, the incoming bit stream is first encoded by a one-dimensional encoder after which the encoded bits are mapped onto the three available dimensions by the Space-Time-Frequency (STF) mapper. After the STF mapper, each TX branch consists of almost an entire OFDM transmitter.

On the receiver side as shown in figure 3, the CP is removed and the FFT is performed for every receiver branch. In the context of the unified view, overall STF detection and decoding must be performed to recover the binary data stream. In general, however, because the MIMO algorithms are single carrier algorithms, MIMO detection is performed per OFDM subcarrier. The received signals of subcarrier i are routed to the i-th MIMO detector to recover the Nt QAM symbols transmitted on that subcarrier. Next, the symbols per TX stream are combined and, finally, STF demapping and decoding are performed on these Nt parallel streams and the resulting data are combined to obtain the binary output data.

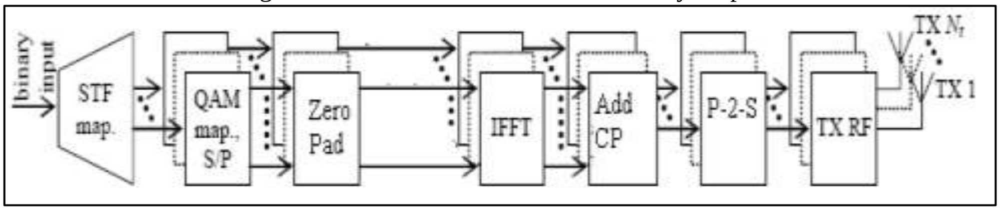

Fig. 2:

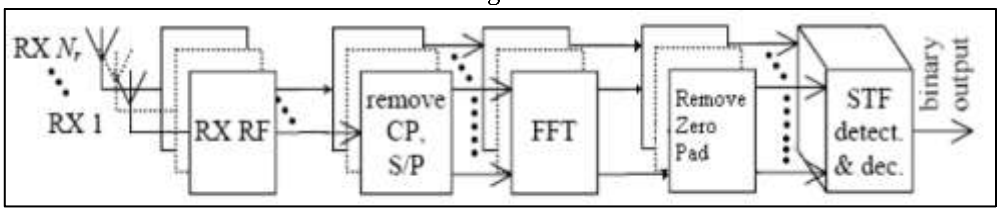

Fig. 3:

It is also seen that OFDM has the advantage that it introduces a certain amount of parallelism by means of its Nc subcarriers. This fact can be exploited by MIMO OFDM i.e., if MIMO detection is performed per subcarrier, then a given detector is allowed to work Nc times slower than the MIMO detector of an equivalent single carrier system with comparable data rate. However Nc such detectors are required and they can work in parallel, which might ease the implementation.

IV. CHANNEL ESTIMATION

Channel Estimation is the process of characterizing the effect of the physical medium o the input sequence. Even with a limited knowledge of the wireless channel properties, a receiver can gain insight into the data sent over by the transmitter. The main goal of Channel Estimation is to measure the effects of the channel on known or partially known set of transmissions.
Two types of channel estimation techniques in practice are:

1) Pilot based channel Estimation
2) Blind Channel Estimation
3) Pilot based channel Estimation

The general block diagram of the baseband processing of an OFDM transceiver is shown in Figure: 4 following the data-stream from transmitter to receiver. In the transmitter, a convolutional encoder encodes the binary input data. After interleaving, the binary values are mapped on Quadrature Amplitude Modulation (QAM) values. In order to correct the signal in the receiver for a possible phase drift, pilot carriers can be introduced. But in this work we assume optimal timing and, thus, no pilot carriers will be used. In the Serial to Parallel block, the serial QAM input symbol-stream is converted to a parallel stream with width equal to the number of sub carriers. These parallel symbols are modulated onto the sub carriers by applying the Inverse Fast Fourier Transform. In order to get an output spectrum with a relative low out of-band radiation, the size of the IFFT can be chosen larger than the number of sub carriers that is actually used to transmit the data[10].

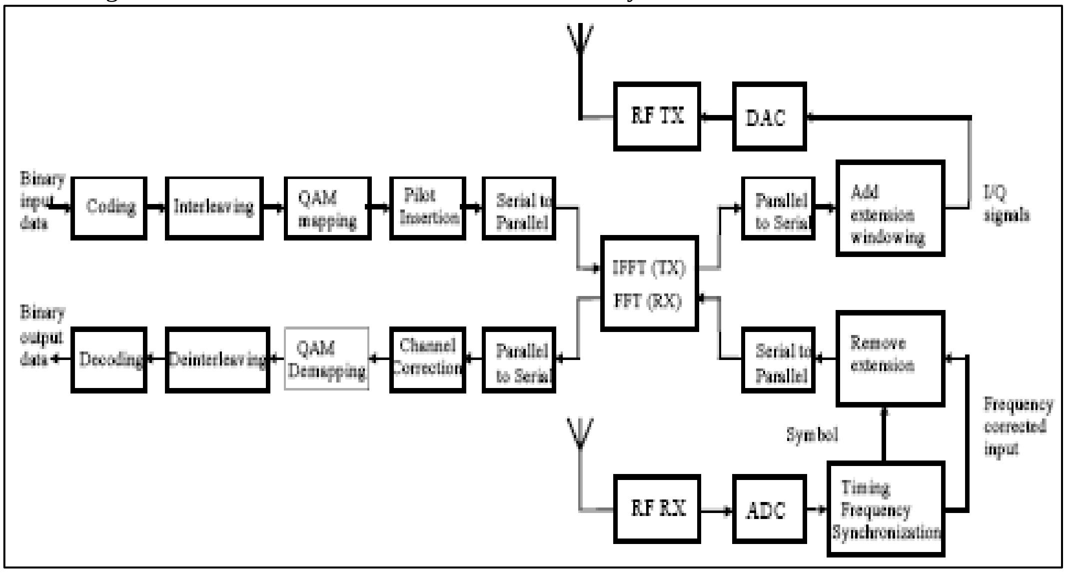

Fig. 4: Channel estimation by pilot carrier technique using MIMO-OFDM system

In the output of IFFT block, the parallel output is converted to serial output. To make the system robust to multipath propagation, a cyclic prefix is added. Further, windowing is applied to get a narrower output spectrum. After this, the digital output signals are converted to analog signals. These analog signals are then up converted to the RF band, amplified and transmitted through an antenna. The OFDM receiver basically performs the reverse operations of the transmitter, together with additional training tasks. First, the receiver has to estimate frequency offset and symbol timing, using special training symbols in a preamble. Then, it can do a Fast Fourier Transform for every symbol to recover the QAM values of all sub carriers. The training symbols and pilot sub carriers are used to correct for the channel response as well as the remaining phase drift. The QAM values are then demapped into binary values and de-interleaved, after which a Viterbi decoder can decode the information bits [10].

V. SIMULATION RESULTS AND ANALYSIS

A. *Pilot Based Estimation*

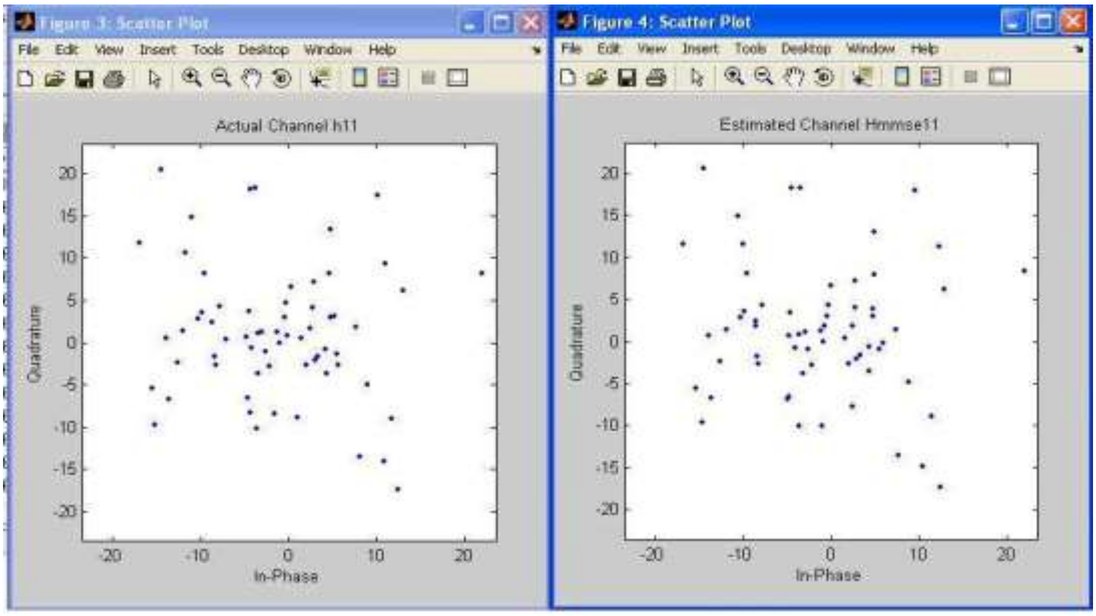

Fig. 5: MIMO channel Scatter Plots

VI. CONCLUSION

The OFDM-MIMO technique has been chosen for various current and future communication systems for many applications that need high speed data transmission. In this paper, OFDM, channel estimation is done for suppressing the interference and ensuring signal detection. Due to accurate channel estimation, OFDM is able to use the coherent detection for 3-dB signal to Noise ratio (SNR) gain over differential detection. MIMO transmission greatly improves the capacity of wireless communications. Since OFDM can convert a frequency selective channel into parallel flat fading channels, it is natural to combine MIMO with OFDM to provide high rate data transmission over frequency selective channels. However, channel estimation in MIMO-OFDM systems is challenging due to the presence of multiple transmits antennas. The implemented channel estimation algorithm is seen to greatly reduce interference because the different antennas use the same frequency to transmit data in the OFDM transmission system, which can be applied to wireless mobile MIMO-OFDM communication system with double selective fading.

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