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A Review on Channel Estimation in Mimo-Ofdm Wireless Communication System

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Abstract: *In today's Broad band wireless communication system, Orthogonal Frequency Division Multiplexing (OFDM) is used to improve spectral efficiency and Multiple Input Multiple Output (MIMO) is used to improve spatial diversity. This system is just popular because of good data transmission rate, good spectral efficiency and its robustness against multipath fading. This system provides wide coverage and reliable communication. Therefore channel estimation techniques play an important role for proper detection of all data symbols to system performance. This paper provides channel estimation technique for MIMO-OFDM systems.*
Keywords- *MIMO, OFDM, CSI, ISI, LS*

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I. Introduction

MIMO-OFDM (Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing) is a broad band wireless communication technology. It has great capability of high data rate transmission and its robustness against multipath fading and other channel impairments [1].

As shown below in MIMO system, multiple numbers of transmitters at one end and multiple numbers of receivers at another end are effectively combined to improve the channel capacity of broad band wireless system. This technology highly improves the reliability of system, spectrum efficiency and coverage area.

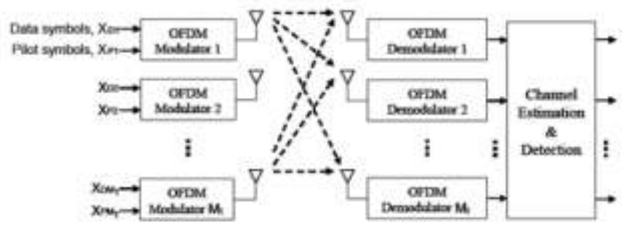

Figure 1 Block Diagram of MIMO-OFDM System

II. Overview of the Wireless Communication System

Over the old traditional wired communication system, wireless communication has rapidly become the preferred communication technique [3]. Its explosion in the use of mobile phones and other portable communication devices for voice and data communication has further contributed to the process on Broad band wireless communication systems.

On wireless systems in light of the heavy traffic for voice and data (i.e. broad band) communication they are expected to achieve low delay, high data rates. Primarily, broad band wireless systems are governed by the wireless channel characteristics and the environment [2]. Contrary to a wired channel is typically static and predictable, while the wireless channel is rather dynamic and unpredictable which makes it pretty daunti
ng.

2.1. On Wireless Signal Propagation Effect of Environment

Over wireless links (channels) the frequency Spectrum allotted to communication is in the Inverse gigahertz (GHZ) range, and given the inverse relationship between frequency and wavelength i.e. from

$V=f\lambda$

$F=v/\lambda$

Here v=velocity (constant at 3 million/sec)

Transmitted signals at this high frequencies propagation wavelength is in the range of millimeter range. Extremely short wavelength signals makes the signals propagating the wireless channel susceptible to diverse environment conditions [4]. Principal among these are refraction, reflection, diffraction and scattering from various physical objects-buildings, trees, water bodies, vehicles etc are always present in any wireless communication environment. Then these bodies cause effect to significant attenuation, phase shift and delay in the signals propagating from the transmitter to receiver. Hence at receiver, these signals arrive at different times with varying signal strengths and may be combining either constructively or destructively, resulting in attenuation, and amplification in transmitting signal. This is called as Multipath Propagation. This propagation causes certain frequency components of the transmitted signal to be affected more than others i.e. Frequency Selective Fading. It prevents total recovery of the transmitted signal at the receiver. It is a fading mechanism peculiar to broad band signals [5].

2.2. On Wireless signal propagation effects of channel characteristics

In addition to the effect of multipath propagation induced frequency selective fading, it is also induced by the effects of channel characteristics on the propagation signals. In broad band wireless communication, the delay spread of the channel is the maximum time delay which takes place during transmission of the signal through the channel, and it varies directly with changes in the environment conditions. For low rate narrow band signals, the pulse durations or symbol periods are large compared to the channel delay spread, thus they undergo flat fading but not frequency selective fading. Within the transmitted signal band, Flat Fading affects all the frequency components equally. In contrast broad band signal have Pulse duration that are nearly small relative to channel delay spread. This causes a multiple delayed paths that acts like a filter on the transmitted signal sequence leading to fading at selected frequencies i.e. frequency selective fading. In broad band high frequency transmission Frequency-selective fading creates inter-symbol interference (ISI) in the received signal.

While frequency selective fading and multipath propagation are the major mechanisms that determine accurate signal detection and recovery in static scenario. A relative mobility between transmitter and receiver also affects the channel characteristics and hence signal recovery is possible. We can say that this is a Doppler shift which changes the channel characteristics to change rapidly at every instant of time and it may lead to minor to severe attenuation of transmitted signal. The relative speed of motion between transmitter and receiver increases then its effects actually becomes more significant. Thus in the high mobility environment, the wireless channel becomes frequency selective and highly time variant, i.e. the channel characteristics changes very rapidly with time. The receiver in the wireless channel needs to accurately estimate the channel characteristics in order to fully recover the transmitted signals. Because of the channel varies rapidly with time so this estimation has to be carried out as frequently as possible in high mobility environment. At every instance of time for accurate signal detection at the receiver the channel matrix coefficients have to be computed just in order to feed back accurate channel state information (CSI) to the transmitter [6].

III. Channel Estimation Techniques

In MIMO-OFDM system, estimation of channel state information (CSI) constitutes a bottleneck. To enhance accurate recovery of the transmitted signals at the receiver under the prevailing channel conditions CSI entails identifying information about the channel. To provide known channel properties for a wireless link, it is estimated at the receiver and fed back to the transmitter. Thus the rate of acquisition of CSI is determined b the rate of change of the channel conditions with time.

Channel state information (CSI) can either instantaneous or statistical [5]. In the former, the impulse response of the transmitted sequence is used to obtain the current channel condition. While in the latter, statistical characteristics of channel-fading distribution, channel gain, spatial correlation etc. are obtained and frequently used for estimating CSI. For slow fading systems, instantaneous CSI is well estimated where the channel conditions vary with a period higher than the symbol duration while in fast fading systems statistical CSI can be reasonably estimated where the channel conditions vary with a period less than the symbol duration. The CSI changes rapidly with time in a high mobility wireless environment, and statistical CSI are most useful to estimate such channel.

In reality, full knowledge of the CSI is never at the receiver prior to transmission and due to noise and other factors or conditions during transmission the estimation of the channel is not perfect. Based on this quality and availability of CSI at receiver, CSI can be further categorized into three types as follows:-

1. Perfect CSI: - In this case receiver has a perfect knowledge of the instantaneous channel realization and detection of symbols. It is known as a coherent detection. When analyzing wireless channel. It is the most common assumed scenario, but it is not achievable in reality.
2. Imperfect CSI: - In this case receiver as an incomplete or inaccurate knowledge about the parameters that describe the channel. Hence the estimator relies on the partial information obtained about the system for its estimation.

3. No CSI:- The estimator relies on other means of information about the entire system to reasonable estimate the channel, where there is no information about the state of the channel or its statistics. This is known as non-coherent detection.

The techniques or algorithms for channel estimation can be broadly categorized into parts as follows:-

1. Pilot Symbol or Training based Channel Estimation.
2. Blind Channel Estimation.
3. Semi-Blind Channel Estimation.

3.1. Pilot Symbol or Training Based Channel Estimation

This estimation involves the insertion of pilot symbols into all subcarriers on an OFDM transmitter with in a specific time period [5]. These pilot symbols are also known as the training symbols, and are the reference signals used by both the transmitter and receiver for estimating the channel. Firstly, the CSI symbol corresponding to the pilot symbols are estimated, the information obtained is than extended to the adjoining data symbols for estimating the channel.

The pilot symbol based estimation techniques assumes that all subcarriers in the OFDM block are orthogonal and free of inter channel interference (ICI). Hence for an OFDM block of N subcarriers, the pilot symbols are given by the diagonal matrix, X given by:-

$$\mathbf{X} = \begin{bmatrix} X[0] & 0 & \cdots & 0 \\ 0 & X[1] & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & X[N-1] \end{bmatrix}$$

Here X (k) represents a pilot tone at the K^{th} subcarrier and E {X (k)} = 0; k=0, 1…N-1.

Now taking the channel gain of each of the subcarriers as H[k] and also given the channel vector, H= H[0], H[1], ..$H[N-1]^T$ And noise vector, Z= Z[0] ,Z[1],. $Z[N-1]^T$ And E {Z (k)} = 0; k=0, 1…N-1. At last the received training signal can be represented by a vector, Y [K].

$$\mathbf{Y} \triangleq \begin{bmatrix} Y[0] \\ Y[1] \\ \vdots \\ Y[N-1] \end{bmatrix} = \begin{bmatrix} X[0] & 0 & \cdots & 0 \\ 0 & X[1] & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & X[N-1] \end{bmatrix} \begin{bmatrix} H[0] \\ H[1] \\ \vdots \\ H[N-1] \end{bmatrix} + \begin{bmatrix} Z[0] \\ Z[1] \\ \vdots \\ Z[N-1] \end{bmatrix}$$

Y=XH+Z

However this technique is not very efficient in terms of bandwidth, due to the overhead incurred by the pilot symbols.

3.1.1 Least –Square Channel Estimation

This technique estimates the channel without any knowledge of the channel statistics. It relies on pilot signals and received signals for channel estimation. Although it has low computational complexity and their computation have high mean square error.

3.1.2 Minimum Mean Square Error Channel Estimation

This estimator performs better than the channel estimator, mainly in the low signal to noise ratio environment; by using the second order statistics of the channel conditions they minimize the mean square error. The major drawback of this system is the high computational complexity.

3.2. Blind Channel Estimation

This technique involves using the statistical properties of the received signal to estimate the channel without any reference to the pilot symbols. It has an advantage of incurring no overhead by virtue of the training symbols [5]. However for proper functioning it requires a large number of received symbols to extract statistical properties of the channel. Hence this scheme is rather complex and the performance is not as good as pilot-based channel estimation.

3.2.1 Sub-Spaced Based Channel Estimation

This technique is well suited for OFDM systems [10] [11]. It uses orthogonal properties and second order statistical properties of the received signals. As the received signal space consist of the noise subspace and signal subspace [5]. The properties of noise subspace are orthogonal to the signal subspace are basically used to estimate the channel. A large number of received signals are needed to accurately estimate the statistical properties of the received signals. The task of accurately separating the signals subspace from the noise subspace involves a high complexity computation.

3.2.2 Semi-blind Channel Estimation

This estimation technique combines the blind channel estimation technique and pilot based channel estimation technique [5]. It can be implemented where information on the input signals i.e. transmits and pilot symbols are not available. Then this estimation precedes using "unknown" factors that affect the channel characteristics. Using the same set of training symbols, when this technique is compared to the pilot based method, based on the mean square error (MSE) and Bit Error Rate (BER), then semi-blind channel estimation provides less BER and MSE than the pilot based approach.However this technique is very inefficient in a time varying channel like a high mobility situation.

3.3 Decision Directed Channel Estimation

This estimation is used to find data and apply it to estimate the channel in the last snapshot is called Decision Directing [7]. In this technique complete transmission session may be used to transfer data symbols. The received information symbol and the statistical properties of the communication channel are used to estimate the CSI in the direction directed channel estimation method. It is a bandwidth efficient technique. The main demerit of this method is that in real communication systems it is impractical to implement the DDCE and received signal is highly complicated.

IV. Conclusion

The performance of MIMO-OFDM wireless communication system channel estimation plays a very important role-especially, in high mobility environment where the channel characteristics very highly with time and becomes unstable. Hence an efficient channel estimation algorithm deployment occurs which will reduce the effects of channel variation. Hence allow appreciable detection and recovery at the receiver is important. To obtain perfect or non perfect channel state information such algorithm may involve the use of instantaneous or statistical information of the channel or combination of both, or even some novel channel estimation techniques to obtain a non-perfect channel state information. To achieve optimum performance in MIMO-OFDM wireless system the semi blind channel estimation combined the advantage of training based and blind based estimation techniques.

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