International Journal of Engineering Technology, Management and Applied Sciences

IJETMAS

www.ijetmas.com January 2017, Volume 5, Issue 1, ISSN 2349-4476

Survey on Different Types of Channel Estimation Techniques in MIMO-OFDM Communication Systems

Mr. Umesha G B
Research Scholar
Department of ECE
SJCE, Mysore
Karnataka, India

Prof. M .N Shanmukha Swamy
Professor and HOD
Department of ECE
SJCE, Mysore
Karnataka, India

Abstract— A Modern wireless broadband system of MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing) is more popular because of good data transmission rate and its robustness against multipath fading & good spectral efficiency. This system provides reliable communication & wide coverage. A main challenge to MIMO-OFDM system is retrieval of the channel state information (CSI)accurately and synchronization between the transmitter & receiver. The channel state information is retrieved with the help of various estimation algorithms such as training based, blind and semi blind channel Estimation. This paper describes the basic introduction of OFDM, MIMO-OFDM system and explains the different channel estimation algorithms, optimization techniques and their utilization in MIMO system for 4G wireless mobile communication systems.

Key Words— Channel Estimation, LS Estimation, MMSE Estimation, CSI, Mean Square Error.

I. INTRODUCTION

Fourth Generation Mobile system (4G) has very good features than previous generation networks such as 2G & 3G.Data transmission speed is very high when compared with previous generation mobile systems. It can fully supports multimedia services with extreme quality, audio, video files, wireless internet and other broadband services with superior quality. This technology provides the user to select any desired service with more freedom & flexibility Mobile communication systems transmit information by changing the amplitude or phase of radio waves. In the receiving side of mobile system, amplitude or phase can vary widely. This causes degradation in the quality of system since the performance of receiver is highly dependent on the accuracy of estimated instantaneous channel.

In a wireless link, channel state information (CSI) provides the known channel properties of the link. It provides the detail of signal propagation between transmitter and the receiver and tells about the effects of scattering, fading. The CSI can incorporate current channel conditions with transmission data for achieving reliable communication. This CSI should be estimated at the receiver and fed back to the transmitter. The channel state information can be obtained through different types of channel estimation algorithms. This estimation can be done with a set of well-known sequence of unique bits for a particular transmitter and the same can be repeated in every transmission burst. Thus the channel estimator estimatesthe channel impulse response for each burst separately from the well-known transmitted bits and corresponding received samples. This paper describes the fundamentals of MIMO-OFDM system and study of various channel estimation techniques and their performance.

II.ORTHOGONAL FREQUENCY DIVISION MULTIPLEXIN (OFDM)

A. *Over view of OFDM*

Orthogonal frequency division multiplexing (OFDM) is a type of frequency-division multiplexing (FDM) method which can be used as a digital multi-carrier modulation technique. Usually a large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is spliced into various parallel data streams or channels, one for each sub-carrier. Each subcarrier is modulated by digital modulation techniques such as quadrature amplitude modulation (QAM) or Quadrature phase-shift keying (QPSK) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The Modulator outputs are combined and the resulting signal is transmitted.

B. Features

In OFDM, the sub-carriers are orthogonal to each other. It avoids the interference between the sub-channels and hence no need of guard bands. Therefore the design of both the transmitter and receiver becomes easy .Unlike conventional FDM, a separate filter is not necessary for each sub-channel. The orthogonally also allows high spectral efficiency. But OFDM requires accurate frequency synchronization between the receiver and the transmitter it is easier to transmit a large number of low-rate data streams in parallel instead of a single high-rate stream. It is easy to insert a guard interval between the OFDM symbols if the symbol duration is high. By this way, the inter symbol interference is eliminated. The guard interval also eliminates the necessity of pulse-shaping filter.

C. Mathematical Description

If N sub-carriers are used, and each sub-carrier is modulated by M alternative symbols, the OFDM symbol alphabet consists of MN combined symbols.

The low pass equivalent of OFDM signal is given as

$$v(t) = \sum_{k=0}^{N-1} x^k e^{\frac{j2\pi kt}{T}} \qquad 0 \leq t \leq T \qquad (1)$$

Where X^k - Data Symbols

N- Number of Subcarriers

T- OFDM Symbol Time.

III. MIMO-OFDM SYSTEM

MIMO-OFDM (multiple input multiple output – orthogonal frequency division multiplexing) is a modern wireless broad band technology which has great capability of high rate data transmission and its robustness against multi-path fading and other channel impairments. In MIMO system, multiple number of transmitters at one end and multiple number of receivers at the other end are effectively combined to improve the channel capacity of wireless system. This technology highly improves the spectrum efficiency, reliability of system & coverage area. A simple MIMO system with $M_t$transmit antennas and $M_r$receiving antennas shown in Figure 1. Pre coding is one of the multi-stream beam forming technique which is employed at the transmitter .In beam forming, the same type of signal is emitted from each one of the transmitantennas with appropriate phase weighting such that the maximum received input signal power at the receiver. This technique increases the received signal gain, by employing signals emitted from multiple antennas and also reduces the multipath fading effects. It requires exact knowledge of channel state information (CSI) at the transmitter.

Spatial multiplexing requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into several low rate data streams and each stream is transmitted with the help of different transmit antennas which are having the same frequency. If these signals receive at the receiver antenna array with different spatial signatures, the receiver can easily separate this stream of data into parallel channels. It is one of the excellent technique to increase the channel capacity and improves high signal to noise ratio. Diversity Coding techniques are used when there is no channel knowledge at the transmitter. In diversity coding a single data stream is transmitted with a coding technique called as space-time coding. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Diversity coding exploits the independent fading in the multiple antenna links to enhance signal diversity.

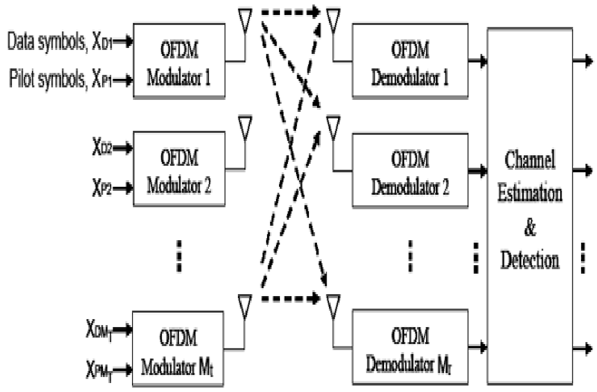

Figure1: TypicalMIMO system Model.

Spatial multiplexing can also be combined with precoding when the channel is known at the transmitter or combined with diversity coding when decoding reliability is in trade-off. Spatial multiplexing techniques makes the receivers very complex.Therefore it is usually combined with orthogonal frequency-division multiplexing (OFDM) or with Orthogonal Frequency Division Multiple Access (OFDMA) modulation, where the problems created by multi-path channel are handled efficiently.

A. Mathematical Description

A narrowband flat-fading channel with multiple transmit and receive antennas (MIMO), the system is modeled as

$$y = Hx + n \qquad (2)$$

Where y and x are receive and transmit vectors respectively and H, n are the channel matrix and the noise vectors. Ideally the channel matrix H is known perfectly due to channel estimation errors, the channel information can be represented as

$$\text{vec}\,(H) \sim \text{CN}\,(\text{vec}\,(Hestimate), Rerrorr) \qquad (3)$$

Where $Hestimate$ is the channel estimate and $Rerror$ is the estimation error covariance matrix.CN is the circular symmetric complex normal.

B. Channel Estimation

In a wireless communication link, channel state information (CSI) provides the known channel properties of the link. This CSI should be estimated at the receiver and usually fed back to the transmitter. Therefore, the transmitter and receiver can have different CSI. The Channel State information may be instantaneous or statistical. In Instantaneous CSI, the current channel conditions are known, which can be viewed by knowing the impulse response of the transmitted sequence. But Statistical CSI contains the statistical characteristics such as fading distribution, channel gain, spatial correlation etc. The CSI acquisition is practically limited by how fast the channel conditions are changing.

In fast fading systems where channel conditions vary rapidly under the transmission of a single information symbol, only statistical CSI is reasonable. But, in slow fading systems instantaneous CSI can be estimated with reasonable accuracy. So channel estimation technique is introduced to improve accuracy of the received signal.

C. Classification of Channel Estimation

Basic classification of channel estimation algorithm is shown in Figure2. They are training based, blind channel estimation or semi blind channel estimation. The training-based channel estimation can be performed by either block type pilots or comb type pilots. In block type pilot estimation, pilot tones are inserted into all frequency bins within the periodic intervals of OFDM blocks. But in comb type pilot estimation, pilot tones are inserted into each OFDM symbol with a specific period of frequency bins. This type of channel estimation is very much suitable where the changes even in one OFDM block.The blind channel estimation is carried out by evaluating the statistical information of the channel and particular properties of the transmitted signals. This blind channel estimation has no overhead loss and it is only suitable for slowly time varying channels. But in training based channel estimation, training symbols or pilot tones that are known to the receiver, are multiplexed along with the data stream for channel estimation. The Semi-blind channel estimation algorithm is a hybrid combination of blind channel estimation and training based channel estimation which utilizes pilot carriers and other natural constraints to perform channel estimation.

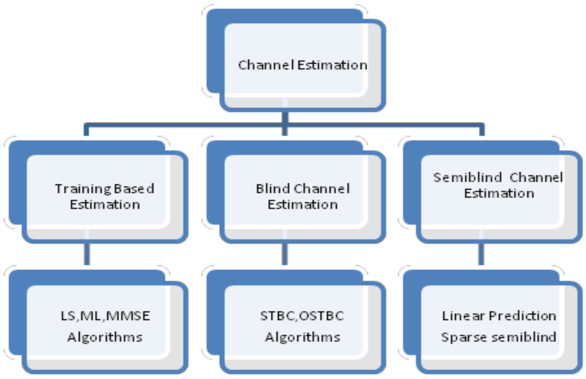

Figure2: classification channel estimation algorithms

IV. CHANNEL ESTIMATION ALGORITHMS

Channel estimator using neural network is presented by A.Omri for Long Term evolution (LTE) uplink. This method uses knowledge of pilot channel properties to estimate the unknown channel response at non-pilot subcarriers. This type of estimator learns to adapt to the channel variations and then it estimates the channel frequency response. This method is less complex and high quality than conventional methods such as least Square (LS), Minimum Mean Square Error

(MMSE). Also this method has more mobility. Ahamed Gomaa presented a novel approach based on compressive sensing (CS) theory to estimate and mitigate synchronous narrow band interference (NBI) in MIMO-OFDM system. Compressive sensing theory showed how to reconstruct a sparse vector from a noisy environment. In this approach, NBI is first estimated and cancelled before channel estimation. This technique has less performance loss due to the channel estimation errors. This approach is studied for time varying & frequency selective channels.

A semi blind algorithm is presented by Feng Wan for the estimation of sparse MIMO-OFDM system. In this approach, a second order statistics of signal received through sparse channel is expressed in terms of most significant taps (MSTs) of the sparse channel. Blind constraint for the channel is derived from the MST position and this constraint is then combined with the training based least square method to develop a semi blind algorithm.

Nima Sarmadiproposed a new blind channel estimation algorithm for MIMO-OFDM system. This method uses specific properties of orthogonal space time block codes to estimate the finite impulse response channel parameters in time domain. A semi definite relaxation technique is used for estimation in this approach. This technique has less complexity and good performance than existing blind channel estimation techniques.

A. Training Based Channel Estimation Techniques

The training-based channel estimation can be performed by either block type pilots or comb type pilots. LeastSquare (LS), Minimum Mean Square Error estimation techniques and their performance is discussed. In block type pilot estimation, pilot tones are inserted into each OFDM symbol with a specific period of frequency. This type of channel estimation is very much suitable where the changes even in one OFDM block. In this fast fading, the pilots are transmitted at all times but with an even spacing on the sub carriers, representing a comb type pilot placement which is shown in Figure3(a)MIMO-OFDM system performance is evaluated by means of the plot of Mean Square Error (MSE) and Bit Error Rate (BER). Block-type and comb type pilot based channel estimation using LS and MMSE algorithms are used to model Rayleigh fading channel of MIMO-OFDM system and Mean square error is estimated. The MMSE channel estimation has low Mean Square Error than LS channel estimation algorithm.A block fading channel is a channel which is constant over a few OFDM symbols. In this channel, pilots are transmitted on all sub carriers in periodic intervals of OFDM blocks. This type of pilot arrangement is shown in Figure 3(b) is called as block type arrangement.

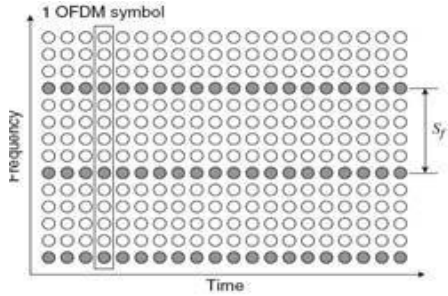

Figure3 (a): Comb type pilot

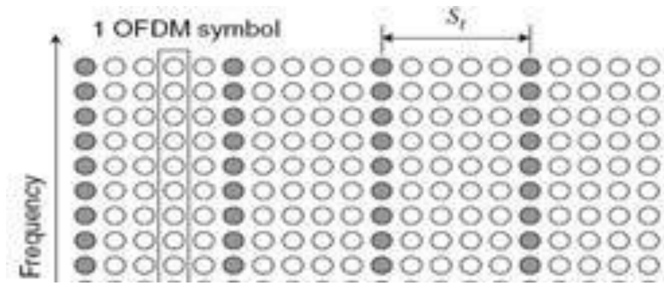

Figure3 (b): Block type pilot

B. Optimization Techniques

Various optimization techniques are used to optimize the placement of pilots, power and LS & MMSE algorithms. Muhammet Nuri Seyman proposed particle swarm optimization (PSO) to optimize the placement and power of comb-type pilot tones used for LS channel estimation in MIMO-OFDM system.Mean square error is used as an objective function of PSO in this technique. This approach has less complexity and better placement of pilot tones with minimum error. K.Vidhya proposed evolutionary programming technique to optimize LS & MMSE algorithms for better results. In this approach, evolutionary programming method of mutation & crossover operations are applied to the existing algorithms and best channel estimation matrix is derived.

V.CONCLUSION

In this paper, the basic concepts of Orthogonal Frequency Division Multiplexing (OFDM), Multiple Input Multiple Output (MIMO) systems are discussed. The various channel estimation techniques such as training based, blind channel, semi blind channel based algorithms and their performance are also discussed. Also different optimization techniques such as particle swarm optimization, evolutionary programming is reviewed to optimize LS & MMSE algorithms.

ACKNOWLEDGMENT

Authors are thankful to Prof.M.N Shanmukha Sawmy and Prof. Veena M.B for their encouragement and valuable guidance for all the time.

REFERNCES

[1] A. Razavi, P. Xiao, and R. Tafazolli, "Information theoretic analysis of ofdm/oqam with utilized intrinsic interference," IEEE Signal Processing Letters, 2015.

[2] A.Omri , R.Bouallegue, R.Hamila and M.Hasna " Channel Estimation for LTE Uplink System by perceptron Neural Network" in International Journal of Wireless & Mobile Networks, Vol.2, No.3, Aug .2010, pp. 155-165.

[3] AhamedGomaa,"A Sparsity-Aware Approach for NBI Estimationin MIMO-OFDM" in IEEE Transaction on Wireless communications. Vol.10. No.6. June 2011. pp. 1854- 1862.

[4] Feng Wan, Wei-Ping Zhu, M.N.S.Swamy,"Semiblind Sparse Channel Estimation for MIMO-OFDM Systems", in IEEE Transaction on Vechicular Technology, Vol.60, No.6 July 2011.

[5]Nima sarmadi, Shahram Shahbazpanahi,Alex B.gershman "Blind channel Estimation in Orthogonally coded MIMO-OFDMSystems, A Semi definite Relaxation Approach" IEEE Transaction on Signal Processing, vol.57, No.6, June 2009, pp.2354-2364.

[6] Kala Praveen Bagadi,Susmita Das,"MIMO-OFDM Channel Estimation Using Pilot Carriers"in International Journal of Computer Applications,Vol.2,No.3,May2010,pp.81-86.

[7] R.S.Ganesh,J.Jaya Kumari,Akhila I.P,"Channel Estimation Analysis in MIMO-OFDM Wireless System" in Proceedings of 2011 IEEE International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN 2011),pp.467- 471

[8] Muhammet Nuri Seyman,, Necmi taspinar " Particle Swarm Optimization for Pilot Tones design in MIMO-OFDM Systems" in Eurasip Journal on Advances in Signal Processing 2011.

[9] K.Vidhya K.R.Shankar Kumar " Enhanced Channel Estimation Technique for MIMO-OFDM Systems with the aid of EP Techniques" in European Journal of Scientific Research .Vol.67,No.1,2011 pp. 140156.

[10]Muhammet Nuri Seyman"Optimization of Pilot tones using differential evolution algorithm in MIMO-OFDM Systems" in Turk Journal of Elec Engg & Comp Science. Vol.20. No.1, .2012, pp. 15-23.

[11] J. M. Periera, "Balancing Public and Private in Fourth Generation," The 12th IEEE International Symposium, Indoor and Mobile radio Communications, vol. 12, pp. 125–132, September/October 2001.

[12] M. L. Moher and J. H. Lodge, "TCMP- a modulation and coding stretegy for Rician fading channels," IEEE Trans. Commun. Tech., pp. 805–813, December 1967

[13] Bria, F. Gessler, O. Queseth, R. Stridh, M. Unbehaun, J. Wu and J. Zander, "Fourth Generation Wireless Infrastructure: Scenarios and Research Challenges," IEEE Personal Communications, vol. 8, pp. 25–31, December 2001.

[14] MEng-Han Hieh and Che-Ho Wei, "Channel Estimation for OFDM Systems based on COMBType Pilot arrangement in frequency selective fading channels," IEEE Trans. on Commun., 1998.

[15] M.sandell and O.Edfors, "A comparative study of pilot-based channel estimators for wireless OFDM" Research report TULEA, Div. of signal processing, LULEA University of Tech, September 1996.

[16] M. Julia Fernandez-Getino Garcia, Ove Edfors and Jose M. Paez-Borrallo, "Frequency offset correction for coherent OFDM in mobile cellular systems ," Procc. Of IEEE, 2001.