A NOVEL DESIGN OF TIME VARYING ANALYSIS OF CHANNEL ESTIMATION METHODS IN OFDM

K.Murali*

M.Sucharitha**

T.Jahnavi**

N.Poornima**

P.Krishna Silpa**

ABSTRACT:

OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected. Error correction coding can then be used to correct for the few erroneous subcarriers.

In this paper, channel estimation for Spatial Multiplexing (SM) is investigated for MIMO-OFDM system. Due to the channel characteristic of the transmission system is always changed by the time and its importance in wireless transmission to reconstruct the transmitted signals, the channel needs to be known as well as possible. Pilot symbols are used to gather knowledge about the channel and try to estimate it. The channel estimation based on the pilot symbol is called pilot aided channel estimation. In this research, Least Square (LS) method was chosen for initial channel estimation. By using applicable proposed system design, channel state

---

* Assistant Professor Department of Electronics and Communication Engineering, Vijaya Institute of Technology for Women, Enikepadu, Krishna (Dt), Andhra Pradesh.

** IV/IV B.Tech – Department of Electronics and Communication Engineering, Vijaya Institute of Technology for Women, Enikepadu, Krishna (Dt), Andhra Pradesh.

information is estimated through the use of channel information before in subcarriers with no pilot symbols. Zero forcing (ZF) algorithms is used to detect and separate the received signal.

Keywords- MIMO, OFDM , pilot symbol, channel estimation, least square, minimum mean square ,zero forcing.

I. *INTRODUCTION*

OFDM is a multi-carrier transmission technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream. The subcarriers have appropriate spacing and passband filter shape to satisfy orthogonality. As compared to classical parallel data system, frequency division multiplexing (FDM), where a guard band is necessary between the subcarriers which results in an inefficient usage of spectrum, OFDM uses overlapping spectrum of orthogonal subcarriers which leads to effective usage of spectrum. Therefore, OFDM can be considered as a spectrally efficient version of FDM. The advantage of OFDM, especially in the multipath propagation, interference, and fading environment, makes the technology a promising alternative in digital broadcasting and communications. These systems suffer from two major impairments namely Inter Symbol Interference and Inter Subcarrier Interference. While insertion of guard band eliminates the former, a cyclic prefix in the guard band eliminates the later.

OFDM provides high spectral efficiency, Resiliency to RF interference, Lower multi-path distortion. OFDM is sometimes called multi-carrier or discrete multi-tone modulation. It is the modulation technique used for digital TV in Europe, Japan and Australia. In conjunction with differential modulation there is no need to implement a channel Estimator is less sensitive to sample timing offsets than single carrier systems and Provides good protection against co-channel interference and impulsive parasitic noise.

II. **PROBLEM FORMULATION**: In this section, we implement channel estimation in MIMO-OFDM system for Spatial Multiplexing technique with the aid of pilot symbols to estimate the channel. Least Square (LS) is used to get the initial estimation, whereas to define all of channel characteristics, we use the channel condition in the past in all subcarriers with no pilot symbols and estimate the best channel by using channel estimators like LSE,MMSE and ZF algorithms.

III. RELATED WORK:

OFDM TRANSMISION AND RECEPTION: OFDM, a high-data-rate stream is divided up into *K* parallel data streams of lower data-rate sub-carriers, which are transmitted simultaneously. OFDM sub-carriers are designed such that they are orthogonal to each other. This allows them to be used in a spectrally overlapped manner, which enables the maximum use of the available bandwidth. The choice of orthogonal sub-carriers allows the spectrum of each sub-carrier to have a null at other subcarrier frequencies so that ICI is avoided. Modulation by an orthogonal sub-carrier is easily implemented by the inverse fast Fourier transform (IFFT) operation.By turning a high-data-rate stream into parallel lower data rate streams, the symbol period is increased and frequency-selective fading becomes flat fading. In this way, the ISI caused by a frequency-selective fading channel is mitigated by OFDM. Multipath spread of the channel also causes ISI and this can be mitigated by adding a guard interval to the transmitted signal.

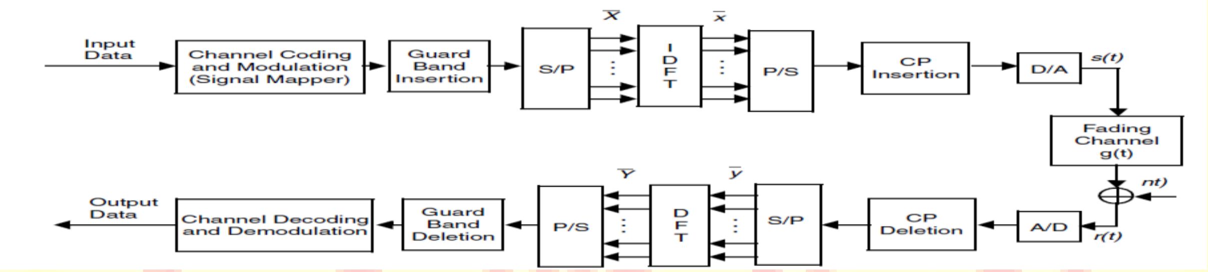


Fig:1 Basic OFDM system

CHANNEL ESTIMATION METHODS: Coherent modulation allows arbitrary signal constellations, but efficient channel estimation strategies are required for coherent detection and decoding.There are two main problems in designing channel estimators for wireless OFDM systems. The first problem is the arrangement of pilot information, where pilot means the reference signal used by both transmitters and receivers. The second problem is the design of an estimator with both low complexity and good channel tracking ability. The two problems are interconnected.

Least-Square (LS) Channel Estimation

Channel estimation is based on standard LS techniques. We can write the transmitted and the received signals in vector form as

$$r\ n\ = \left[r\ n,0\ ,r\ n,1\ ,\ldots\ldots,r\ n,k-1\ \right]$$
$$s\ n\ = \left[s\ n,0\ ,s\ n,1\ ,\ldots\ldots,s\ n,k-1\ \right] \qquad (1)$$

where $r\ n$ and $s\ n$ are the vectors containing samples $r\ n,k$ and $s\ n,k$ respectively for $k = 0,1,\ldots.,k-1$, and K is the total number of sub-carriers in an OFDM symbol. By simply dividing $r\ n,k$ and $s\ n,k$ we get the frequency response of the channel plus some noise. In this way, we can express the estimated channel frequency response by [5] –

$$\hat{H}\ n,k\ = \frac{r\ n,k}{s\ n,k}, \qquad for\ k = 0,1,\ldots,K-1 \qquad (2)$$

Since the transmitted signal is QPSK with unit magnitude

$$\frac{1}{s\ n,k} = s^{*}\ n,k \qquad (3)$$

and we can rewrite the above Equation as

$$\hat{H}\ n,k\ = r\ n,k\ s^{*}\ n,k\ , \qquad for\ k = 0,1,\ldots,K-1$$

While implementing this estimation technique, the frequency responses of the channels corresponding to different OFDM blocks and sub-carriers are assumed to be independent of each other. Consequently, none of the correlation properties of the channel is used and the estimation is based on a Gaussian channel model. The block diagram of the LS channel estimator is shown in Figure 2.

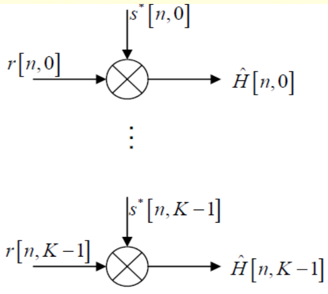


Figure 2. LS channel estimator

We need knowledge of the transmitted OFDM symbol in order to get the LS estimate of the channel frequency response. During the preliminary training period, we use symbols known at the receiver while during data transmission we use the reconstructed data symbols.

MMSE Estimator

The MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error. Denote by $\underline{R}_{gg}, \underline{R}_{HH}, \underline{R}_{YY}$ and the auto-covariance matrix of $\overline{g}, \overline{H}, \overline{Y}$, and Respectively, and by $\underline{R}_{gY}$ the cross covariance matrix between $\overline{g}$ & $\overline{Y}$. Also denote by σ_N^2 the noise variance $E\ |\overline{N}|^2$. Assume the channel vector $\overline{g}$ and the noise $\overline{N}$ are uncorrelated, it is derived that

$$\underline{R}_{HH} = E\ \ \overline{H}\,\overline{H}^H\ \ = E\ \ (\underline{F}\overline{g})^H\ \ = \underline{F}\,\underline{R}_{gg}\,\underline{F}^H \qquad (4)$$

$$\underline{R}_{gY} = E\ \ \overline{g}\overline{Y}^H\ \ = E\ \ \overline{g}(\underline{X}\,\underline{F}\,\overline{g}) + \overline{N}^H\ \ = \underline{R}_{gg}\,\underline{F}^H\,\underline{X}^H$$

$$\underline{R}_{YY} = E\ \ \overline{Y}\overline{Y}^H\ \ = \underline{X}\,\underline{F}\,\underline{R}_{gg}\,\underline{F}^H\,\underline{X}^H + \sigma_N^2\,\underline{I}_N \qquad (5)$$

Assume $\underline{R}_{gg}$ (thus $\underline{R}_{HH}$) and σ_N^2 are known at the receiver in advance, the MMSE estimator of $\overline{g}$ is given by $\hat{g}_{MMSE} = \underline{R}_{gY}\,\underline{R}_{YY}^{-1}\overline{Y}^{HH}$. Note that if $\overline{g}$ is not Gaussian $\hat{g}_{MMSE}$ is not necessarily a minimum mean-square error estimator, but it is still the best linear estimator in the mean-square error sense. At last, it is calculated that

$$\hat{H}_{MMSE} = \hat{\underline{F}}_{g\,MMSE} = \underline{F}\left[(\underline{F}^H\,\underline{X}^H)^{-1}\underline{R}_{gg}{}^{-1}\sigma_N^2 + XF\right]^{-1}\overline{Y} \qquad (6)$$

$$= \underline{F}\,\underline{R}_{gg}\left[\ \ \underline{F}^H\,\underline{X}^H\,\underline{X}\,\underline{F}\ \ ^{-1}\sigma_N^2 + \underline{R}_{gg}\right]\underline{F}^{-1}\,\overset{\square}{H}_{LS}$$

$$= \underline{R}_{HH}\left[\underline{R}_{HH} + \sigma_N^2\ \ \underline{X}\,\underline{X}^H\ \ ^{-1}\right]^{-1}\hat{H}_{LS} \qquad (7)$$

The MMSE estimator yields much better performance than LS estimators, especially under the low SNR scenarios. A major drawback of the MMSE estimator is its high computational complexity, especially if matrix inversions are needed each time the data in $\underline{X}$ changes.

ZERO FORCING:

The zero forcing algorithm (ZF) is used, where multiplier matrix W is an inverse or pseudo inverse (PI) matrix of the channel matrix H, namely:

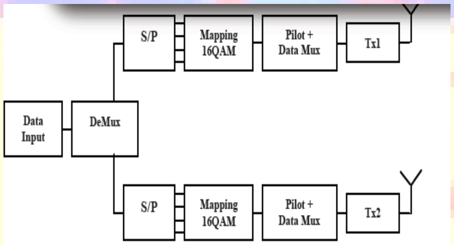
$$\begin{aligned} W &= \mathrm{H}^{-1} && \text{for } M = N \\ W &= \mathrm{H}^{\mathrm{H}}\mathrm{H}^{\;-1}\mathrm{H}^{\mathrm{H}} && \text{for } M \neq N \end{aligned} \quad (8)$$

with $^{\mathrm{H}}$ is complex conjugate transpose matrix H.

We use Least Square channel estimation technique and Zero Forcing symbol detection method in this study due to more emphasis on analysis of channel characteristic that influence on the capacity of the system with known channel that compared to the systems with estimated channel.

System Design of MIMO-OFDM Spatial Multiplexing

The channel estimation system design for a 2x2 MIMO-OFDM Spatial Multiplexing in the frequency domain with 128 subcarriers, so that the model does not need the IFFT/ FFT. Channel estimation system design, in detail, is shown in Fig.



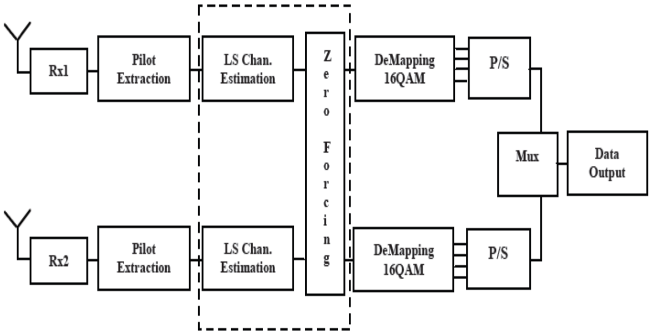


Fig:3 Channel estimation scheme in OFDM-MIMO using LSE Method

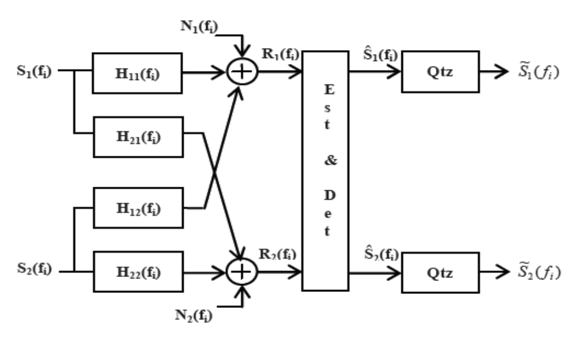


Fig:4 Design of a 2x2 MIMO-OFDM models in frequency domain

Propagation channel matrix contained in each signal path generated by the channel coefficient for Rayleigh model and assuming that the cyclic prefix is always sufficient in every OFDM symbol transmission, to avoid interference. In the data transmission, each output data symbol in all transmitters is multiplied by the channel matrix H. For the proposed 2x2 MIMO-OFDM in frequency domain shown in Fig 4, channel matrix H consists of 4 elements such as H11, H12, H21, and H22. This process is performed simultaneously for all data in each OFDM symbol transmission with AWGN noise addition.

CHANNEL ESTIMATION ALGORITHMS

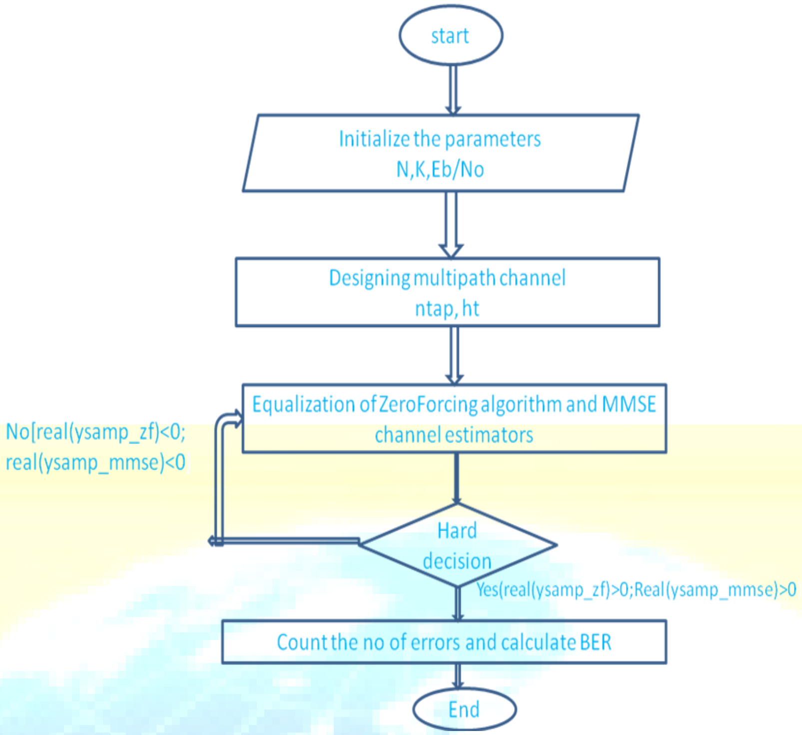


Fig: 5 ZF and MMSE Channel Estimators Flowchart

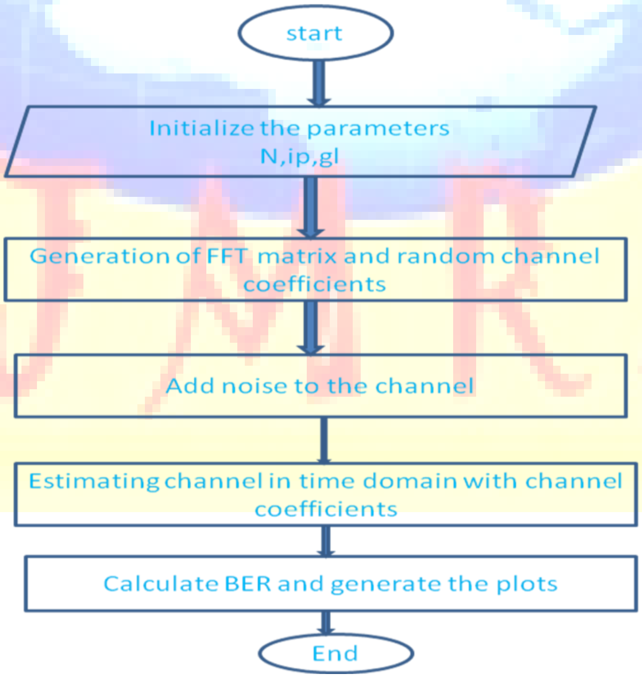


Fig:6 LSE Flowchart

IV.SIMULATION RESULTS:

The original channel is multiplied by the data symbols from both of the transmitter including a pilot symbols. Estimated channel which is obtained by using Least Square method is called as the initial estimated channel. It said the initial estimated, because only a few channel characteristic are known at the receiver, based on pilot symbols subcarrier. Furthermore, based on the initial estimated channel, we can obtain the overall channel estimation through the use of channel information before, in all subcarriers with no pilot symbols. Channel estimation performance is also measured based on the value of Bit Error Rate (BER). The greater the SNR is given then the smaller the BER values obtained. The result of channel estimation is affected by the SNR value. The larger the SNR the higher accuracy of the estimation will be. It relates to the selection of channel estimation and detection techniques. The estimation results also affect the value of BER that would be decrease by increasing the value of SNR.

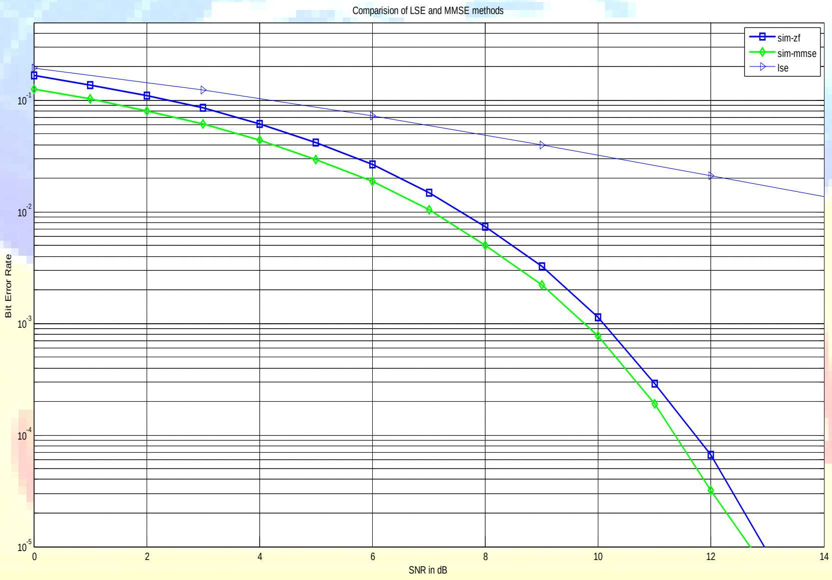


Fig:7 Comparison of LSE ,MMSE and ZF methods

The following estimators are used:

Estimator	Notation	Taps used	Size Q_0
MMSE	MMSE	0...63	64x 64
LS	LS.	0...63	N.A
Modified MMSE	MMSE-0	0...4	5 x 5
	MMSE-5	0...9, 59...63	15x15
	MMSE-10	0…14,54..63	25x25
Modified LS	LS-0	0...4	5 x 5
	LS-5	0...9, 59...63	15 x15
	LS-10	0…14,54…63	25x25

:

IV. CONCLUSIONS

The estimators in this study can be used to efficiently estimate the channel in an OFDM system given a certain knowledge about the channel statistics. The MMSE estimator assumes a priori knowledge of noise variance and channel covariance. Moreover, its complexity is large compared to the LS estimator. For high SNRs the LS estimator is both simple and adequate. However, for low SNRs, the presented modifications of the MMSE and LS estimators will allow a compromise between estimator complexity and performance. Even relatively low-complex modified estimators, however, perform significantly better than the LS estimator for a range of SNRs. The result of channel estimation is affected by the SNR value. The larger the SNR the higher accuracy of the estimation will be.

FUTURE SCOPE: The channel estimation algorithms studied in this thesis represent a specific subset of all available estimation methods, based on frequency correlation and time-domain properties of the channels. Other estimation algorithms can be found in the literature based on time correlation of the channel, other time-domain approaches or blind channel estimation techniques. These channel estimation methods may be investigated in future studies.

REFERENCES

[1] I-Tai Lu and Kun-Ju Tsai, “Channel Estimation in a Proposed IEEE802.11n OFDM MIMO WLAN System”, Sarnoff Symposium, IEEE, 2007

[2] A. A. Quadeer and Muhammad S. Sohail, “Enhanced Channel Estimation Using Cyclic Prefix in MIMO STBC OFDM Sytems”, IEEE,2011

[3] Andrew, J.G., A. Ghosh, and R. Muhammed, 2007, Fundamental of WIMAX, Prentice Hall

[4] Moon Jaekyun; Hui Jin; Jeon Taehyun; & Lee Sok-Kyu, “Channel Estimation for MIMO-OFDM Systems Employing Spatial Multiplexing”, IEEE Vehicular Technology Conference No60, Los Angeles CA , ETATS-UNIS, 2004

[5] Fabien Delestre and Yichuang Sun, “A Channel Estimation Method for MIMO-OFDM Mobile WiMax Systems”, IEEE, 2010

[6] Bagadi, K.P., S. Das,”MIMO-OFDM Channel Estimation using Pilot Carriers”,International Journal of Computer Applications, Vol.2-No.3, May 2010

[7] G. L. Stüber, J. R. Barry, S. W. McLaughlin, Y. Li, M. A. Ingram, and T. G. Pratt, “Broadband MIMO-OFDM wireless communications,” Proceedings of the IEEE, vol. 92, no. 2, pp. 271–294, 2004.

[8] Cho,Y.S., J. Kim “MIMO OFDM wireless communication with MATLAB,” John Wiley & Sons, 2010

[9] Rumney, M., “LTE and the Evolution to 4G Wireless: Design and Measurement Challenges”, Agilent Technology, 2009

[10] Alex Dowler, and Andrew Nix, “Performance Evaluation of Channel Estimation Techniques in a Multiple Antenna OFDM System, IEEE,2003