ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

TRAINING BASED CHANNEL ESTIMATION IN OFDM SYSTEMS

Shridhar B Devamane, Trupthi Rao, Ramesh K.P
Email Id: [1]shri.git@gmail.com, [2]trupthiraob@gmail.com, [3]rameshkp1@gmail.com
Assistant Professor, ECE Department, APS College of Engineering, Bangalore, Karnataka, India

Abstract- In this paper the Proposed new scheme in order to implement an MMSE Channel estimator for an OFDM System we know that the time domain maximum likelihood estimators (MSE) Can achieve highly accurate impulse response estimation by using time domain long preamble of an OFDM frame. The Least Square algorithm is easier for the channel estimation. The impulse response estimation based on the minimum mean square error (MMSE) Criterion can achieve superior channel estimation in low SNR conditions.

Key Words: Channel Estimation, OFDM, Training Symbol, Pilot Structure, Bit error rate

1. INTRODUCTION

The concept of using parallel data transmission by means of frequency division multiplexing (FDM) was published in mid 60s. Some early development can be traced back in the 50s. A U.S. patent was filled and issued in January, 1970. The idea was to use parallel data streams and FDM with overlapping sub channels to avoid the use of high speed equalization and to combat impulsive noise, and multipath distortion as well as to fully use the available bandwidth. The initial applications were in the military communications. In the telecommunications field, the terms of discrete multitone (DMT), multichannel modulation and multicarrier modulation (MCM) are widely used and sometimes they are interchangeable with OFDM. In OFDM, each carrier is orthogonal to all other carriers. However, this condition is not always maintained in MCM. OFDM is an optimal version of multicarrier transmission schemes. For a large number of sub channels, the arrays of sinusoidal generators and coherent demodulators required in a parallel system become unreasonably expensive and complex. The receiver needs precise phasing of the demodulating carriers and sampling times in order to keep crosstalk between sub channels acceptable. Weinstein and Ebert applied the discrete Fourier transform (DFT) to parallel data transmission system as part of the modulation and Demodulation process. In addition to eliminating the banks of subcarrier oscillators and coherent demodulators required by FDM, a completely digital implementation could be built around special-purpose hardware performing the fast Fourier transform (FFT). Recent advances in VLSI technology enable making of high-speed chips that can perform large size FFT at affordable price. In the 1980s, OFDM has been studied for high-speed modems, digital mobile communications and high-density recording. One of the systems used a pilot tone for stabilizing carrier and clock frequency control and trellis coding was implemented. Various fast modems were developed for telephone networks. In 1990s, OFDM has been exploited for wideband data communications over mobile radio FM channels, high-bit-rate digital subscriber lines (HDSL, 1.6 Mb/s), asymmetric digital subscriber lines (ADSL, 1,536 Mb/s), very high-speed digital subscriber lines (VHDSL, 100 Mb/s), digital audio broadcasting (DAB) and HDTV terrestrial broadcasting.

2. MINIMUM MEAN SQUARED ERROR ESTIMATOR (MMSE)

The best linear estimator in terms of Mean Squared Error is the Linear Minimum Mean Squared Error Estimator (LMMSE). Given the transmitted symbols X and recieved symbols Y, under certain conditions the simplified MMSE estimation of the channel h can be expressed as

$$\hat{h}_{mmse} = R_{hh}\left(R_{hh} + \frac{\beta}{SNR} I\right)^{-1}\hat{h}_{ls}$$

where $\hat{h}_{ls} = X^{-1}Y$ is the Least Squares estimate of the channel attenuations h, R_{hh} is the auto-correlation of the channel, $SNR = E\frac{|x_k|^2}{\sigma^2}$ is the signal-to-noise ratio and β is a constant.

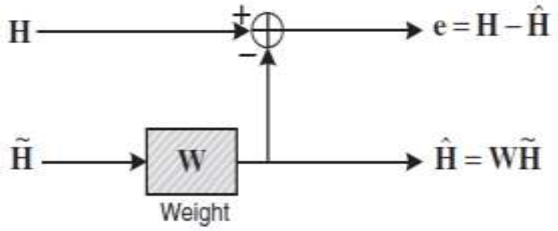
3. MMSE CHANNEL ESTIMATION

Consider the LS solution,

$$\hat{H}_{LS} = X^{-1}Y \triangleq \hat{H}$$

Using the weight matrix w, define

$$\hat{H} \triangleq W\tilde{H}$$



Referring to Figure, MSE of channel estimate H is given as orthogonality principle states estimation error vector

$$\mathbf{J}(\hat{\mathbf{H}}) = \mathbf{E}\{\|\mathbf{e}\|^2\} = \mathbf{E}\left\{\|\mathbf{H} - \hat{\mathbf{H}}\|^2\right\}$$

$$\mathbf{e} = \mathbf{H} - \hat{\mathbf{H}}$$

is orthogonal to $\hat{H}$ such that $E\{e\tilde{H}^H\} = E\{(H - \hat{H})\tilde{H}^H\}$

$$\begin{aligned} &= E\{(H - W\tilde{H})\tilde{H}^H\} \\ &= E\{H\tilde{H}^H\} - WE\{\tilde{H}\tilde{H}^H\} \\ &= R_{H\tilde{H}} - WR_{\tilde{H}\tilde{H}} \\ &= 0 \end{aligned}$$

R_{AB} is the cross-correlation matrix i.e., $R_{AB} = E[AB^H]$ $\tilde{H}$ is the LS channel estimate given as

$$\tilde{H} = X^{-1}Y = H + X^{-1}Z$$

Solving the Equation for W yields

$$w = R_{H\tilde{H}}{R_{\tilde{H}\tilde{H}}}^{-1}$$

where $R_{\tilde{H}\tilde{H}}$: auto-correlation matrix of $\tilde{H}$ is

$$\begin{aligned} R_{\tilde{H}\tilde{H}} &= E\left\{\widetilde{\tilde{H}\tilde{H}^H}\right\} \\ &= E\{X^{-1}Y(X^{-1}Y)^H\} \\ &= E\{(H + X^{-1}Z)(H + X^{-1}Z)^H\} \\ &= E\{HH^H + X^{-1}ZH^H + HZ^H(X^{-1})^H + ZZ^H(X^{-1})^H\} \\ &= E\{HH^H\} + E\{X^{-1}ZZ^H(X^{-1})^H\} \end{aligned}$$

$R_{H\tilde{H}}$**:** Cross-correlation matrix.

Using the Equation above, the MMSE channel estimate follows as

$$\begin{aligned} \hat{H} &= W\tilde{H} \\ &= R_{H\tilde{H}}{R_{\tilde{H}\tilde{H}}}^{-1} \\ &= R_{H\tilde{H}}\left(R_{HH} + \frac{\sigma_Z^2}{\sigma_X^2} I\right)^{-1} \tilde{H} \end{aligned}$$

4. PILOT STRUCTURES FOR CHANNEL ESTIMATION

4.1 Block Type Pilot Scheme

In this type, OFDM symbols with pilots at all subcarriers (referred to as pilot symbols herein) are transmitted periodically for channel estimation. Using these pilots, a time-domain interpolation is performed to estimate the channel along the time axis. Let st denote the period of pilot symbols in time. In order to keep track of the time-varying channel characteristics, the pilot symbols must be placed as frequently as the coherence time is. As the coherence time is given in an inverse form of the Doppler frequency $fdoppler$ in the channel. The pilot symbol period must satisfy the following Inequality:

$$S_t \le \frac{1}{f_{\text{dopple}}}$$

Since pilot tones are inserted into all subcarriers of pilot symbols with a period in time, the block type pilot arrangement is suitable for frequency-selective channels. For the fast-fading channels, however, it might incur too much overhead to track the channel variation by reducing the pilot symbol period.

4.2 Comb type Pilot Scheme

In Comb type of pilot arrangement, every OFDM symbol has (N_P) pilot tones which are periodically inserted into the input signal (X) with pilot subcarrier spacing (S_f). A frequency domain interpolation along the frequency axis is performed using the pilots to estimate the channel. In order to keep track of the frequency-selective channel characteristics, the pilot subcarrier spacing (S_f) must be such that it is less than the coherence bandwidth. As the coherence bandwidth is equivalent to the inverse form of the maximum delay spread (σ_{max}), the pilot subcarrier spacing (S_f) must satisfy the following inequality Comb type pilot arrangement gives better performance for fast fading channels as each OFDM symbol contains known pilot signals at some of the subcarriers. However, this type of pilot arrangement is not suitable for frequency-selective channels. As the receiver knows the pilot locations for each OFDM symbol, it estimates the channel conditions at the pilot subcarriers which are then interpolated over the total subcarrier length (N) to get the overall channel frequency response at each OFDM symbol. As described above for Block type pilot arrangement, the same channel estimation techniques namely LS, MMSE and Modified MMSE channel estimation are used to estimate the channel response at the pilot subcarriers. It is then interpolated using different interpolation techniques to get the channel frequency response.

4.3 Lattice type Pilot Scheme

In lattice type of pilot arrangement, pilots are inserted along both the time and the frequency axes for channel estimation. A frequency-domain interpolation along the frequency axis and a time domain interpolation along the time axis are performed using the pilots to estimate the channel. In order to keep track of the frequency-selective and the time varying channel characteristics, the pilot subcarrier spacing (S_f) must be less than the coherence bandwidth and the pilot symbol period (S_t) must be less than the coherence time. The pilot symbol arrangement must satisfy the following inequality

$$S_t \le \frac{1}{f_d} \text{ and } S_f \le \frac{1}{\sigma_{max}}$$

Depending on the pilot arrangement and also the channel characteristics, lattice type pilot arrangement can be used to estimate the channel in case of both frequency selective as well as fast fading channels.

5. RESULTS

In this work the Simulation Results of the Comparison of LS and MMSE algorithms of SNR V/S BER for an OFDM system with MMSE/LS Estimation. The simulation results for BER Comparison between LS and MMSE from which it is clear that MMSE technique is better technique than LS which does not utilize the channel statistics.at high SNR values the performance gap is more than low SNR. but for improved performance in MMSE we have to pay for more complexity which results in increased computational time and high implementation cost of hardware to have a priori knowledge of channel behaviour.

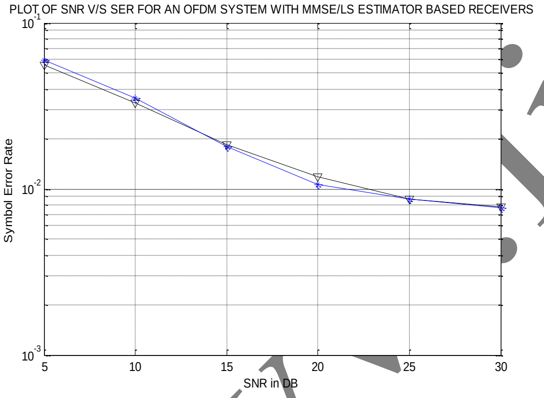


Fig. 5.1 Graph of SNR V/S MSE for an OFDM System

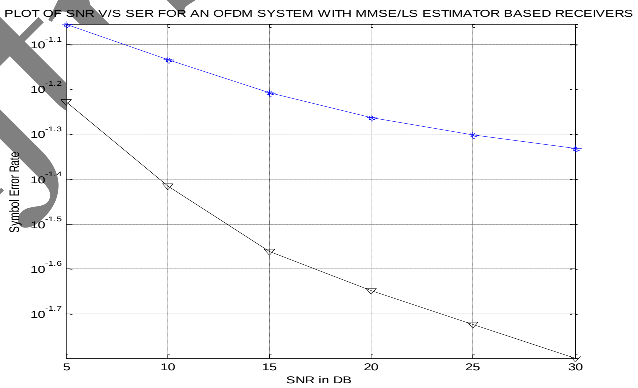


Fig. 5.2 Graph of SER V/S SNR for an OFDM System

CONCLUSION

LS method offers accurate estimation of channel.in this paper LS method was used for initial channel estimation.LS algorithm does not require correlation function calculation nor does it require matrix inversion. MMSE estimator is complex as MMSE algorithm require both correlation function calculation and matrix inversion from simulation results it is clear that MMSE estimator provides better performance than LS estimator in terms of Mean Square Error (MSE) and Bit Error Rate (BER) whereas implementation of LS algorithm is much easier than MMSE algorithm.

REFERENCES

[1] MIMO-OFDM Wireless Communications with MATLAB: Yong Soo Cho, Jaekwon Kim, Won Young Yangand Chung G. Kang_ 2010 John Wiley & Sons (Asia) Pte Ltd.

[2] A Survey on Channel Estimation Techniques in MIMO-OFDM Mobile Communication Systems R.S.Ganesh, Dr. J.Jaya Kumari

[3] Coleri, S., Ergen, M., Puri, A., and Bahai, A. (2002) Channel estimation techniques based on pilot arrangement in OFDM systems. IEEE Trans. on Broadcasting, 48(3), 223–229.

[4] Heiskala, J. and Terry, J. (2002) OFDM Wireless LANs: A Theoretical and Practical Guide, SAMS.

[5] Hsieh, M. and Wei, C. (1998) Channel estimation for OFDM systems based on comb-type pilot arrangement in frequency selective fading channels. IEEE Trans. Consumer Electron .44(1), 217 228. Ding, Z. and Li, Y. (2001) Blind Equalization and Identification, Marcel Dekker.

[6] Sato, Y. (1975) A method of self-recovering equalization for multilevel amplitude-modulation systems. IEEE Trans. Communication, 23(6), 679–682.

[7] OFDM Based WLAN Systems, Muhammad Imadur Rahman, Suvra Sekhar Das, Frank H.P. Fitzek.

[8] M.Pukkila, Channel Estimation Modelling, Postgraduate Course in Radio-Communication, Nokia Research Center, Fall 2000.

[9] George Tsoulos, MIMO System Technology For Wireless Communications, Revised Edition, CRC Publisher, 2006.

[10] Li, Ye. Simplified channel estimation for OFDM systems with multiple transmit antennas. Wireless communication, IEEE Transactions on 1.1(2002):67-75.