Performance Evaluation of Channel Estimation Methods in OFDM Systems

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ABSTRACT:
In the communication sector, a large amount of data needs to be transmitted very quickly with an increasing user demand. To accommodate these demands, single carrier systems leave their place to multiple carrier systems. The transmission of large amounts of data at high speed requires high-quality radio access over multi-way damped channels. The amplitudes of the signals reaching the receiver at different times and paths are caused by fluctuations in the signal strength, this is called damping effect. The received signal is weaker than the transmitted signal due to the average transmission loss and damping. The adverse effects such as the damping effect on the communication channel greatly affect the performance of the wireless communication and prevent to reach high transmission speeds. In addition to multipath demodulation, multipath propagation also extends the time required for the transmitted signal to reach the receiver. In wireless communication systems, the best way to mitigate the damping effect on the channel is to take advantage of diversification techniques. OFDM, one of the multi-carrier systems, provides efficient channel capacity enhancement. In this study, the performances of least squares (LS) and minimum mean square error (MMSE) estimation methods, which are channel estimation methods, required to remove the interchannel interference in the OFDM technique are investigated by computer simulations. In interchannel interference in the OFDM technique is analyzed with LS and MMS estimation methods and results are compared with respect to Signal to Noise Ratio aspect. The results are promising.

KEYWORDS: Orthogonal frequency division multiplexing(OFDM), Multi input multi output (MIMO), Least Square (LS), Minimum Mean-Square Error (MMSE).

1. INTRODUCTION

The low frequency information signals which are to be transmitted in the data communication are transported to the distant places by superimposing on a carrier signal or modulated signal of high frequency. This process is called modulation. Because of the high speed and low cost of data transmission, broadband wireless communication has become popular in recent years. Researchers have also sought to develop effective coding and modulation techniques to enhance the quality of communication. In wireless communication systems, when the channel delay passes the decreasing symbol duration, then inter-symbol interference will occur. Thus the frequency selectivity of the channel will increase and the efficiency of the system will decrease considerably. [1] Although such distortions in the channel can be rectified by systems called channel compensators, the complexity and processing load of these systems is undesirable. By using OFDM systems that divide the current band width into subbands perpendicular to each other and send the signal in parallel from these subbands, interference between the symbols can be prevented and the frequency selectivity can be removed so that a frequency-selective channel can be converted into a channel with a damped channel. To illustrate this, the basic structure of a MIMO OFDM system is shown in figure1.

If the channel model is considered to be double-fading in broadband wireless communication, another system is needed to enable these codes to operate on the frequency-selective channel. This system is a system called orthogonal frequency division multiplexing (OFDM), which divides the available bandwidth into sub-bands perpendicular to each other. OFDM is a system that reduces the transmission rate in the lower bands so as not to reduce the total transmission rate, thereby extending the symbol duration to make the frequency selective channel flat damping channel. Integrated transmit diversity OFDM systems perform well on frequency selective channels. [1, 2] However, the system needs channel parameters in decoding in the receiver. In this article, channel estimation methods and computer simulation and performance analysis are performed to obtain the damping and interchannel interference (ICI) in OFDM systems. Also, some suggestions were made.

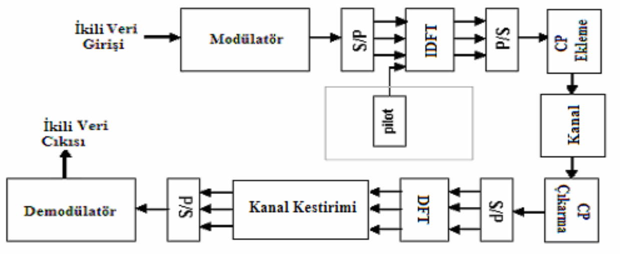

Fig. 1. A MIMO System

2. OFDM PRINCIPLE

With this technique, data is modulated numerically and high-speed data symbols are divided into sub-channels. With Inverse Fast Fourier Transform (IFFT), low speed sub-symbols are generated. Orthogonal Frequency Division Multiplexing (OFDM) symbol is obtained by adding sub-symbols. Briefly, OFDM divides the data stream into low-speed subcarriers, which are transmitted in parallel channels.[3]

In order to separate the signals from each other on the receiver side, carrier frequency gaps must not overlap each other. This obligation prevents precise efficiency from the frequency spectrum. Orthogonal Frequency Division Multiplexing (OFDM) has been proposed to make more use of bandwidth.

OFDM is a modulation and multiplexing technique that divides a communication channel into low-speed subcarriers and transmits them in parallel channels. The main difference between OFDM and FDM is that, In the OFDM system, the carrier spectra overlap each other, and these carriers are perpendicular to each other, resulting in spectral efficiency. The bandwidth savings achieved at this point are evident in Figure 2. In this technique; Because the information signal is transmitted at low speed, the signal period will be large and the inter-signal interference (ISI) problem will be resolved. In addition, the low speeds of the subcarriers in this system will provide more resistance to the negative effects that the multiple pathway will bring[4].

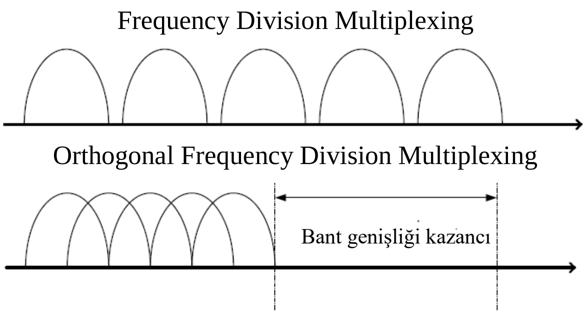

Fig. 2. Bandwidth savings provided by using OFDM.[1]

In Figure 2, the multi-carrier system technique, which overlaps with each other and does not overlap with each other, is compared. Thanks to the OFDM technique, more than half of the bandwidth is achieved.

Due to the OFDM technique, inter-symbol interference (ISI) can be eliminated which is caused by the adverse effects occurring in the channel. This process; cyclic prefix(CP) to be selected to be larger than the channel delay is provided between the successive OFDM packets. The orthogonality between sub-carriers in OFDM is provided using the Inverse Fourier Transform technique, which is a digital signal processing technique [3, 4].

2.1 Advantages of OFDM

The advantages of the OFDM technique over other techniques include, for example:

• High availability in a multi-path environment

• Flexibility to delay propagation:

- Due to the use of more than one subcarrier, the duration of the symbol on the subcarriers increases with the delay spread.

- Simpler mathematical operations are required when compared to a single carrier spectrum

• More effective against possible damping. Error correction techniques can be used to correct sub-carriers that are damaged by the damping effect.

• Resistant to narrow band interference.

• Can be adapted to channels that change slowly over time.

Using OFDM, the capacity can be increased by adjusting the data rate of each subcarrier according to the signal to noise ratio. [4]

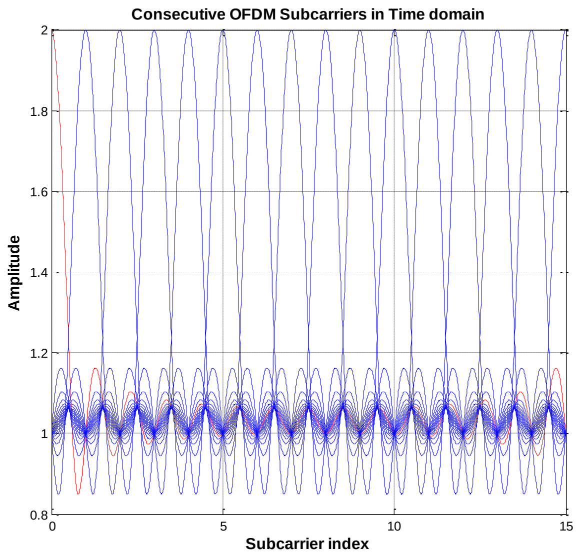

Fig. 3. Computer simulation showing the density of carriers of OFDM signal in time domain

2.2. Channel Estimation for Wireless OFDM Systems

In wireless communication systems, channel estimation should be performed to identify the parameters between the transmitter and receiver antennas, i.e. the communication channel. Training tones are used for this. Each transmitting antenna can be identified as a single channel, as the training tones transmitted from each antenna are perpendicular to each other. The training tones to be selected are placed at smaller values than the frequency response of the communication channel, so that the channel can be interposed between training tones.[5, 6] The channel interpolation process can be adapted to the delay propagation occurring in the channel and can be further improved with the time domain filtering technique. In the satellite-to-terrestrial communication channel, the dedicated channel identification parameters are continuously and regularly broadcast to all users.

Since multiple carriers are used in the OFDM technique and transmission from different channels is ensured, the correct receipt of the transmitted information by the receiver depends on the correct detection of the channel status information (CSI) on the receiver side by means of channel estimation methods.[7, 8]

Failure to correctly identify the channel state information in the receiver will result in Interchannel Interferences (ICI), and therefore the information to be transmitted will not be transmitted correctly. There are two different methods for channel state information, namely these are; Blind channel estimation (BCE) and Pilot tone additive estimation techniques.

In the blind channel estimation technique, the estimation process is performed without any tone addition. The estimation of the pilot tone additive channel estimation technique is carried out by using all known pilot symbols on the transmitter and receiver side. Two different channel estimator techniques, named least squares (LS) or minimum mean square error (MMSE), are used in the pilot tone articulation method. [9]

The LS channel estimator technique is unsuccessful in channels with low signal-to-noise ratio. however, it is simple in structure and small in size and easy to apply.

The MMSE channel estimator technique is more successful in channels with low signal-to-noise ratio. However, its structure is a bit more complex and its application is more difficult. [6, 8]

This technique was later extended for OFDM systems using transmitter diversity and space time coding.

3. RESULTS

In this study, the performance of the LS and MMSE channel estimators, which are the most important channel estimation methods and the channel estimation methods used, in the damped channel have been investigated in the OFDM technique, which is a multipath multi-carrier system that offers the advantage of more efficient use of the transmission channel bandwidth and thus the channel capacity.

With simulations made with Matlab program in computer environment; the minimum mean square error (MMSE) channel estimator technique is more successful than the least squares (LS) channel estimate. As shown in the graphs, the MSE and the symbol error rate (SER) values are obtained with the MMSE technique at both low and high signal to noise ratios, as compared to the LS technique. Along with that; The MMSE technique is more complex than the channel parameters and statistical information needed and is more difficult to implement. The LS estimation method is simpler than the MMSE estimation technique and its applicability is simple. The use of MMSE estimator in wireless communication systems, which are widely used today and have damped channel structure, will be more efficient in terms of performance. This is because, when the LS channel estimator is used in low signal-to-noise ratios in damped channels, the transmitted data may be erroneous.

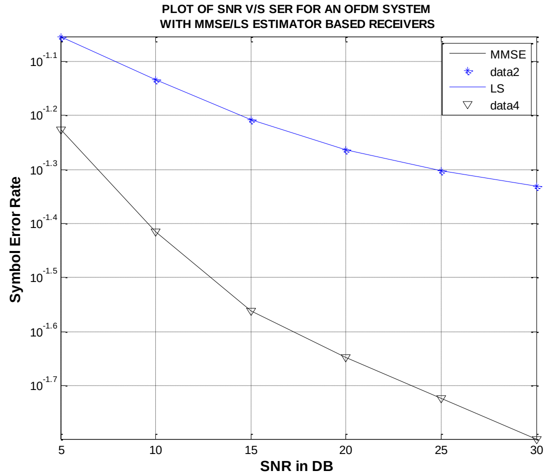

Fig. 4. Computer Simulation showing the SNR performances of MMSE and LS Channel Estimation Methods in OFDM systems on the receiver side.

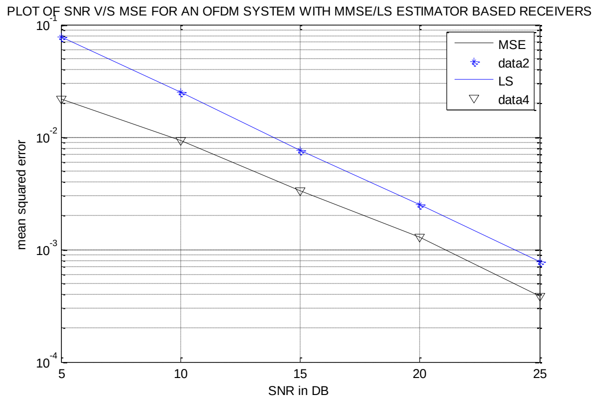

Fig. 5. Computer Simulation showing the SNR performances of the MMSE and LS Channel Estimation Methods on the receiver in a 64-carrier OFDM system.

Values used for Figure 6:

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nCP = 8;%round(Tcp/Ts);     nFFT = 64;
NT = nFFT + nCP;
F = dftmtx(nFFT)/sqrt(nFFT);
MC = 1500;     L = 5;
EsNodB = 0:5:40;
snr = 10.^(EsNodB/10);
beta = 17/9;   M = 16;
modObj = modem.qammod(M);
demodObj= modem.qamdemod(M);
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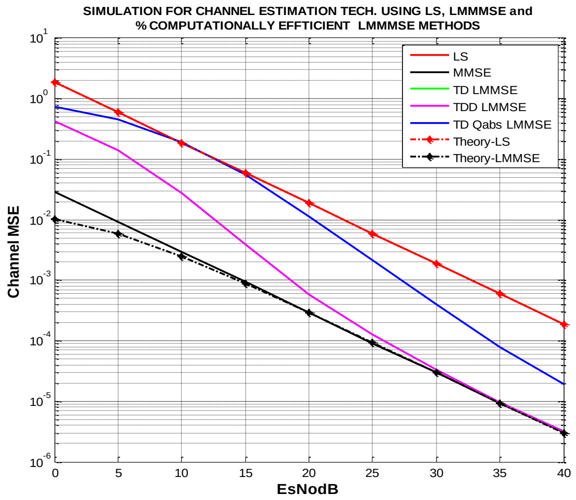

Fig. 3. Computer simulation showing the performance of Channel Estimation Methods used in OFDM system.

4. NOMENCLATURE

OFDM : Orthogonal Frequency-Division Multiplexing
MIMO : Multi Input Multi Output
LS : Least Square
MMSE : Minimum Mean-Square Error
ICI : Inter-Carrier Interference
ISI : Inter-Symbol Interference
SNR : Signal to Noise Ratio
CP : Cyclic Prefix
BER : Bit Error Rate.

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