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Comparison of Channel Estimation Techniques for OFDM

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is a unique case of multi-carrier transmission and it can maintain high data rate requirement of wireless systems. Since channel estimation is an essential part of OFDM systems, it is difficult to understand the basis of channel estimation techniques for OFDM systems, so that the most suitable method can be applied. The estimation of channel at pilot frequencies is based on LS and MMSE estimation techniques by using 16QAM modulation scheme. The purpose of this paper is to use MAT LAB simulation of OFDM to see how the Bit Error Ratio (BER) of a transmission varies when Signal to Noise Ratio (S/N Ratio) and Multi propagation effects are changed on transmission channel. Also to compare the Least Square & mean squared error performance for various channel models such as AWGN, Rayleigh & Rician using 16QAM modulation scheme.

***Index Terms*—** BER, ISI, OFDM, S/N,QAM

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has presently been used extensively in wireless communication due to its tall bandwidth efficiency, high data rate transmission capability and its robustness to multi-path delay. It has been used in wireless LAN standards such as IEEE802.11a and in multimedia wireless services such as Japanese Multimedia Mobile Access Communications. A appropriate estimation of channel is necessary before the demodulation of OFDM signals. Since the radio channel is time-varying and frequency selective for wideband mobile communication systems [1].

In an OFDM system a large number of sub-carriers are used to transmit data. Each sub-channel is orthogonal to every other. They are closely spaced and have narrow band. The parting of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability of handling multipath interference at the receiving end, The main effects of multi propagation are Frequency selective fading and Inter Symbol Interference (ISI) [2]. In OFDM the huge number of narrow sub-carriers provides sufficiently “flat” channels. Therefore the fading can be handled by simple equalizing techniques for each channel. Furthermore the large amount of carriers can provide same data rates of a single carrier modulation at a lower symbol rate. The two main disadvantages of OFDM are the large dynamic range of the signals being transmitted and the sensitivity to frequency errors.

Using MATLAB simulation we can apply an OFDM transmission. Using the simulation we can easily change the values of S/N ratio and change the multi propagation effects on the transmission. The modulation scheme used for the simulation is 16QAM, were we see the performance of LS & MMSE channel estimation techniques for various channel models such as AWGN, Rayleigh & Rician.

II. OFDM SIMULATION

Code in this paper is used for checking the performance of LS & MMSE channel estimation techniques. Modulation scheme used is 16QAM for various channel models such as AWGN, Rayleigh & Rician. A scheme of every part of the implementation can be seen in Fig 1. In the end of the transmission, when the receiver receives the data, a comparison of the transmitted and the received data is done in order to calculate the Bit Error Rate (BER).This paper does not explain the simulation Code, but it points towards the results which we get after simulation.

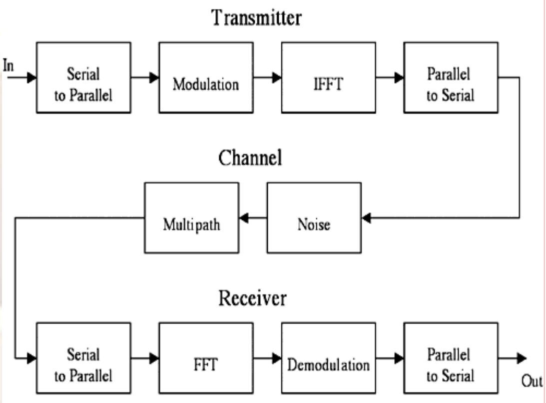

Fig.1: OFDM modulation scheme

III. CHANNEL ESTIMATION

The two basic channel estimation techniques in OFDM systems are illustrated in Figure 2. The first one, block-type pilot channel estimation, is developed under the guess of slow fading channel, and it is performed by inserting pilot tones into all subcarriers of OFDM symbols within a specific period. The second one, comb-type estimation, which is introduced to fulfill the need for equalizing when the channel changes even from one OFDM block to the subsequent one. It is thus performed by inserting

pilot tones into certain subcarriers of each OFDM symbol,
where the interpolation is needed to estimate the conditions of data subcarriers [1].

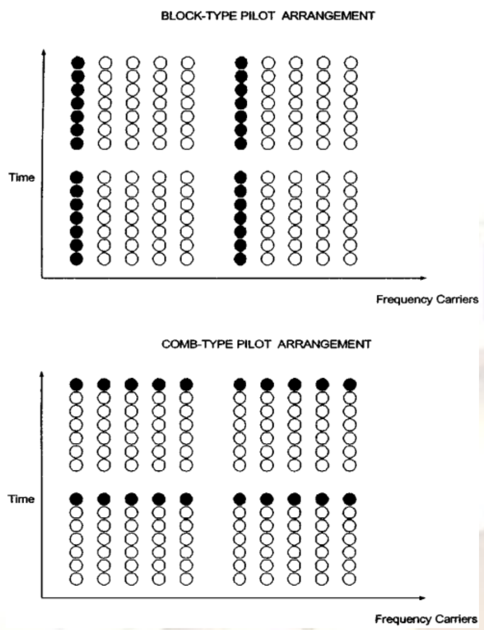

Fig.2: Pilot arrangement.

In block-type pilot-based channel estimation, as shown in Figure 2, OFDM channel estimation symbols are transmitted periodically, and all subcarriers are used as pilots. Since LS estimate is prone to noise and ICI, MMSE is proposed while compromising complication. Since MMSE includes the matrix inversion at each iteration [3].

3.1 LS Estimator

The LS estimator minimizes the parameter $(Y\square - X\square H\square)^H (Y\square - X\square H\square)$ where $(\bullet)^H$ means the conjugate transpose operation. It is shown that the LS estimator of $H\square$ is given by [1].

$$\hat{H}_{LS} = X\square^{-1} Y = [(X_K / Y_K)]^T \quad (1)$$

3.2 MMSE Estimator

The MMSE estimator employs the second-order statistics of the channel conditions to minimize the mean-square error .Denoted by $R\square_{gg}$, $^{R\square}{}_{HH}$, $^{R\square}{}_{YY}$ the auto covariance matrix of $g\square$, $H\square$ and $Y\square$,respectively and $R\square_{gy}$ the cross covariance matrix between $g\square$ and $Y\square$.[1]Also denoted by σ^2_N the noise variance $E\{(| N\square|^2\}$.Assume the channel vector $g\square$ and the noise $N\square$ are uncorrelated so it is derived that

$$^{R\square}{}_{HH} = E\{H\square H\square^H\} = E\{(F\square g\square)(F\square g\square)^H\} = F\square R\square_{gg} F\square^H \quad (2)$$

$$R\square_{gY} = E\{g\square Y\square^H\} = E\{ g\square (X\square F\square g\square + N\square)^H\} = R\square_{gg} F\square^H X\square^H \quad (3)$$

$$^{R\square}{}_{YY} = E\{Y\square Y\square^H\} = X\square F\square R\square_{gg} F\square^H X\square^H + \sigma^2_N I\square_N \quad (4)$$

Assume $R\square_{gg}$ thus $(^{R\square}{}_{HH})$ and σ^2_N are known as receiver in advance, MMSE estimator of $g\square$ is given $g\square_{MMSE} = {}^{R\square}{}_{gY}\, {}^{R\square}{}_{YY}{}^{-1}\, Y\square^{HH}$ note that $g\square$ is not Gaussian , $g\square_{MMSE}$ it 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

$$H\square_{MMSE} = F\square\, g\square_{MMSE}\;\; F\square[(F\square^H X\square^H)^{-1} R\square_{gg}{}^{-1} \sigma^2_N + XF]^{-1} Y\square$$

$$= F\square R\square_{gg}[(F\square^H X\square^H X\square F\square)^{-1} \sigma^2_N + R\square_{gg}] F\square^{-1} H\square_{LS} \quad (5)$$

$$= R\square_{HH}[R\square_{HH} + \sigma^2_N (X\square X\square^H)^{-1} H\square_{LS}$$

IV. TYPES OF CHANNELS

Different type of channel that can be utilized for the Modulation and Propagation of radio signal are AWGN, Rayleigh and Rician Channel.

4.1 AWGN Channel

Additive White Gaussian Noise channel (AWGN) is used for analyzing modulation schemes used for transmission of OFDM signal. In this the channel inserts a white Gaussian noise to the OFDM signal which is fleeting through it. By this the signal achieves two properties. Amplitude frequency response is plane, means signal pass through channel without any height loss and having infinite bandwidth. Phase frequency response is linear, so no phase distortion[4]. In AWGN channel the Received Signal is simplified to

$$r(t) = s(t) + n(t) \quad (6)$$

Where r(t) is received signal and n(t) is the Additive White Gaussian Noise .

4.2 Rayleigh Fading Channel

In wireless communications, multipath propagation is the phenomenon that causes radio signal to reach the receiving antenna by two or many paths. Causes of multipath propagation which include ducting, ionosphere reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. This type channel is used when there is no direct path between transmitter and receiver. If there is no LOS then the beneficial and vicious nature of Multipath Signal flat fading can be approximated by Rayleigh channel.

The signal can be given as

$$r(t) = s(t)*h(t) + n(t) \quad (7)$$

Where r(t) is the received signal, h(t) is the random channel matrix and n(t) is the Additive White Gaussian Noise. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function

4.3 Rician Fading Channel

This channel is used to study the OFDM when line of sight is available means the transmitter and receiver have direct path between them[5]. This type of signal is approximated by Rician distribution in which the dominating component run into more fade the signal characteristic goes from Rician to Rayleigh distribution. This type of signal can be given by

r(t) = s(t)*h(t) + n(t) (8)

Here r(t) is the received signal and h(t) is the random channel matrix having Rician distribution and n(t) is Additive White Gaussian Noise. Now we study about the Rician distribution which is given by

$$p(r) = \frac{r}{\sigma^2} e^{\frac{r^2+A^2}{2\sigma^2}} \; Io\left(\frac{Ar}{\sigma^2}\right) \qquad for \qquad A \geq 0, \geq 0 \tag{9}$$

Here A is the peak amplitude of the dominant signal and I0 is the modified Bessel function of the first kind and zero-order. Rician K-factor can be defined as the ratio of signal power to the scattered power. So it can be given as

$K=c\,^2\alpha / 2\sigma^2$ (10)

And the scattered power equals

$\sigma^2=P/(K+1)$ (11)

And amplitude of the line-of sight is

$C=\sqrt{(2KP/(K+1))}$ (12)

We can clearly say that the BER is reducing by increase the SNR. by changing the value of Rician K-factor the BER can also be controlled[5].

V. SIMULATION RESULTS

Here we have simulated the systems using MATLAB 7.0 and by help of it we have generated the BER v/s SNR graph for various channels. Also we have introduced the Channel estimators such as least square (LS) and Minimum mean square error (MMSE) estimators. Here we can see clearly that the BER is reduced as we increase the SNR. In this paper the code used is for checking the performance of LS & MMSE channel estimation techniques by using 16QAM modulation scheme. We assume that we are using 64 lengths FFT with 64 subcarriers all carrying data. So there are no carriers specifically assigned to pilot. We have considered the guard interval length as 16, in the code we have considered the Rayleigh variance=0.001, the symbol count used in our code is 5. The frame count used for simulation is 300, but we can increase it as per requirements. The sampling frequency is 20MHz. The results shown in fig 3 are showing the performance of Rayleigh channel for 16-QAM modulation scheme by using estimators such as LS & MMSE estimators.

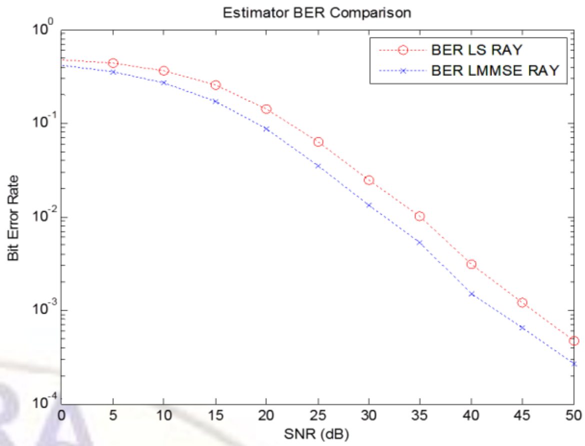

Fig.3 Bit error rate (BER) performance of Raleigh channel for 16-QAM modulation technique with using estimators such as LS &MMSE

We can see that the performance of the LS estimator is poor as compared to the MMSE .We can also see from the graph that the BER reduces as SNR increases in the case of the MMSE estimator, thus we can say that the BER is more in the case of the LS estimator.

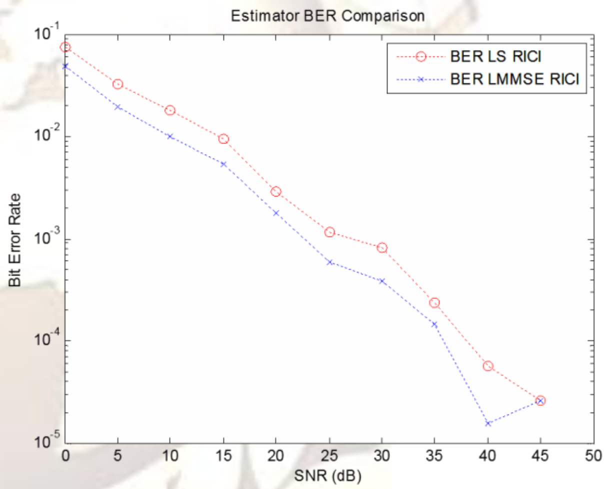

Fig.4 Bit error rate (BER) performance of Rician channel for 16-QAM modulation technique with using estimators such as LS &MMSE

As we can see from fig 4 is showing the performance of Rician channel for 16-QAM modulation scheme by using estimators such as LS & MMSE estimators. We can see that the performance of the LS estimator is poor as compared to the MMSE . From the graph it is clear that the BER reduces as SNR increases in the case of the MMSE estimator, thus we can say that the BER is more in the case of the LS estimator. The performance of Rician channel improves when we use the estimator, as it is said that the performance of the Rician is good as compared to the Rayleigh channel.

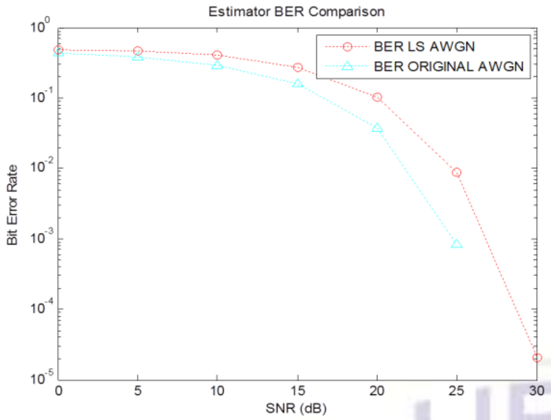

Fig.5 Bit error rate (BER) performance of AWGN channel for 16-QAM modulation technique with using LS estimator

As we can see from fig 5 is showing the performance of AWGN channel for 16-QAM modulation scheme by using estimator such as LS estimator. We can see that the performance of the LS estimator is good as compared to the output without estimator .We can also see from the graph that the BER reduces as SNR increases in the case when we use the LS estimator, thus we can say that the BER is more in the case of not using the LS estimator .we can see the comparison graph from which it is clear that the performance is excellent. Among all the channels the AWGN channel provides a good response after applying the estimator.

VI. CONCLUSION

The results show us the SNR vs. BER plot for with and without MMSE/LS based receiver using 16-QAM modulation scheme. The performance of AWGN channel is the best of all channels as it has the lowest bit error rate (BER) under QAM, 16-QAM & 64-QAM modulation schemes. The amount of noise occurs in the BER of this channel is quite slighter than fading channels. The performance of Rayleigh fading channel is the worst of all channels as BER of this channel has been much affected by noise under QAM, 16-QAM & 64-QAM modulation schemes. The performance of Rician fading channel is worse than that of AWGN channel and better than that of Rayleigh fading channel. Because Rician fading channel has higher BER than AWGN channel and lower than Rayleigh fading channel. BER of this channel has not been much affected by noise under QAM, 16-QAM & 64-QAM modulation schemes. In this work, we have studied LS and MMSE estimators for both block type and comb type pilot arrangement. The estimators in this study can be used to efficiently estimate the channel in an OFDM system giving certain knowledge about channel statistics. The MMSE estimators assume a priori knowledge of noise variance and channel covariance. Moreover, its complexity is large compare to the LS estimator. For high SNR the LS estimator is both simple and adequate. The MMSE estimator has good performance but high complexity. The LS estimator has low complexity, but its performance is not as good as that MMSE estimator basically at low SNRs.

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REFERENCES

[1] Sinem Coleri,Mustafa Ergen," Channel Estimation Techniques Based on Pilot Arrangement in OFDM Systems," *IEEE Transactions on Broadcasting,* "vol. 48, no. 3, September 2002 .

[2] Orlandos Grigoriadis, H. Srikanth Kamath," Ber Calculation Using Matlab Simulation for OFDM Transmission," *IAENG Proceedings of the International MultiConference of Engineers and Computer Scientists* 2008 vol. II, IMECS 2008, 19-21 March, 2008.

[3] Jan-Jaap van de Beek, Ove Edfors, Magnus Sandell, Sarah Kate Wilson and Per Ola B.rjesson," On Channel Estimation In OFDM Systems," *In Proceedings of Vehicular Technology Conference (VTC Ô95),* vol. 2, pp. 815-819, Chicago, USA, September 1995.

[4] Chaudhari Sachin, A.M Deshmukh,"Channel Estimation in OFDM," *International Journal of Engineering Research and Applications* (IJERA) Vol. 3, pp.512-515, Issue 1, January -February 2013.

[5] Rashi , Devendra Soni," Study of Performance of OFDM over Various Channels," *International Journal of Electronics and Computer Science Engineering(* IJECSE),vol.1,no.3,pp. 1254-1259.