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PERFORMANCE ANALYSIS AND BER COMPARISON OF VARIOUS CHANNELS IN OFDM SYSTEM

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ABSTRACT

In multi-carrier transmission, Orthogonal frequency division multiplexing (OFDM) is a unique case as it is capable of maintaining high data rate requirement of the present wireless communication systems. But a very important part regarding communication is the channel or we can say the path on which the signal travels up to long distances. The path itself has its own disadvantages. In wireless communication systems channel plays a very important role, since the estimation of channel is a crucial part in OFDM system, sometimes it becomes challenging to comprehend the appropriate channel evaluation method for OFDM systems so that an appropriate technique can be applied. In our paper we have investigated three different channels namely Raleigh , Rician and AWGN and evaluated their performance on the basis of BER comparison. For simplicity purpose estimation of channel at pilot frequencies is based on LS & MMSE estimation techniques by utilizing 16-QAM modulation scheme.

Keywords :***BER, ISI, OFDM, 16 QAM,ICI***

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has currently been used comprehensively in the sector of mobile communication due to its very high bandwidth efficiency and tremendous data rate transmission capability, also it is very robust to the problems like delay and multi-path fading[1][2] . It is been utilized in wireless LAN standards especially the popular IEEE802.11.It can be called as the essential technique for the fourth generation (4G) wireless communication systems[26]. It is been used in (DAB) digital audio broadcasting, digital video broadcasting (DVB), Asymmetric digital subscriber line (ADSL) standards, High bit rate digital subscriber line (HDSL) and wireless LAN standards such as the American **IEEE**® Std. 802.11™ (Wi-Fi)[4] and its European corresponding standard HIPRLAN/2. A suitable performance analysis of channel is necessary before the signal gets demodulated at the receiver side .As the channel is frequency selective and time-varying for mobile communication systems.

In OFDM closely spaced narrow band subcarriers are used for the transmission of the data, each of the carrier is closely spaced and every sub channel is orthogonal to each other[6][9]. The distance between each of the subcarrier is minimal for obtaining good spectral efficiency. Orthogonal FDM is basically used due to its capability of handling of multipath interference at the receiver side of the system. The multipath propagation is responsible for effects such as ISI (intersymbol interference) and frequency selective fading[7]. Disadvantages of OFDM are transmitted signals has a large dynamic range and it is very much sensitive to the frequency offset errors.Using MATLAB simulation we have implemented OFDM system to investigated three different channels namely Rayleigh , Rician and AWGN. For simplicity we will use the parameters of the European standard Hyperlan/2 and we will observe the performance of the OFDM system. The evaluation will be on the basis of performance of BER[11] .For simplicity purpose estimation of channel at pilot frequencies is based on LS & MMSE estimation techniques by utilizing 16-QAM modulation scheme.

The MATLAB Code in this paper is utilized for performance analysis and BER comparison of various channels in OFDM system. For simplicity purpose evaluation of channel at pilot frequencies is based on LS& MMSE estimation techniques by making use of 16-QAM modulation scheme for three main types of channels which are AWGN, Rayleigh & Rician. The arrangement of every block after implementation can be understood from the block diagram shown in Fig 1. Once the signal is received at the receiver end, comparison between the transmitted and the obtained signal is done just to calculate the performance and BER comparison of channel with two different types of channel estimators such as the LS (Least square) and the MMSE (Minimum mean square error) estimators. This work does not explain the MATLAB simulation Code, but it shows the performance analysis of various channels and their BER Comparison.

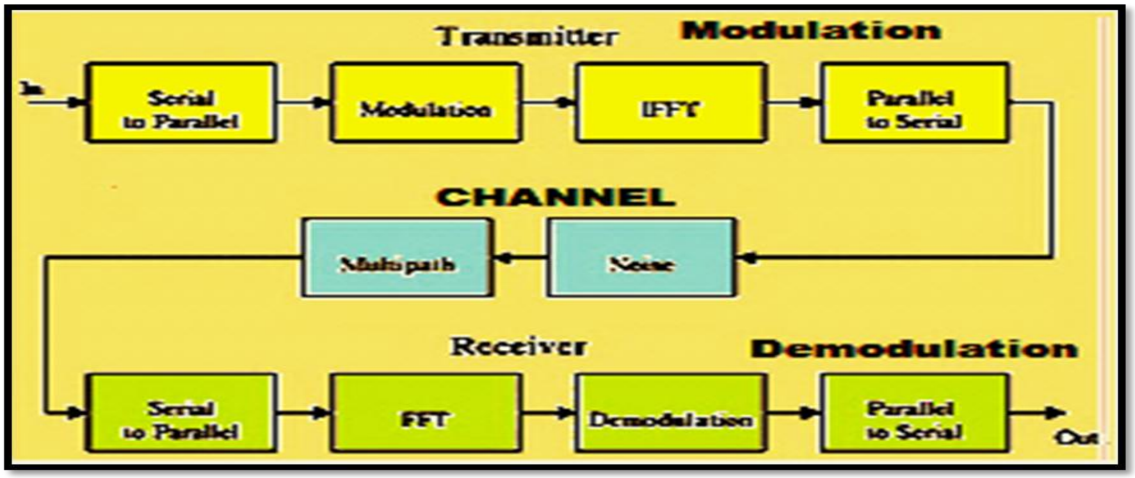

Fig.no1. OFDM System

II ESTIMATION OF CHANNEL

In Orthogonal frequency division multiplexing there are basically two types of channel estimation methods. Among the both the first is called as block type channel approximation which is shown in the figure no 2. The block type channel estimation method was developed for slow fading channel, which is achieved by insertion of pilot tones into the entire subcarriers of the OFDM symbols for a specific time period[12][18] . The next type is called as the comb-type channel estimation technique , which is basically implemented for to fulfillment of the approximation if the channel try's to changes even from one block to the subsequent. It is very easily done by introducing additive pilot tones into some subcarriers of every OFDM symbol, To estimate the condition of data subcarriers interpolation is needed[8][13].

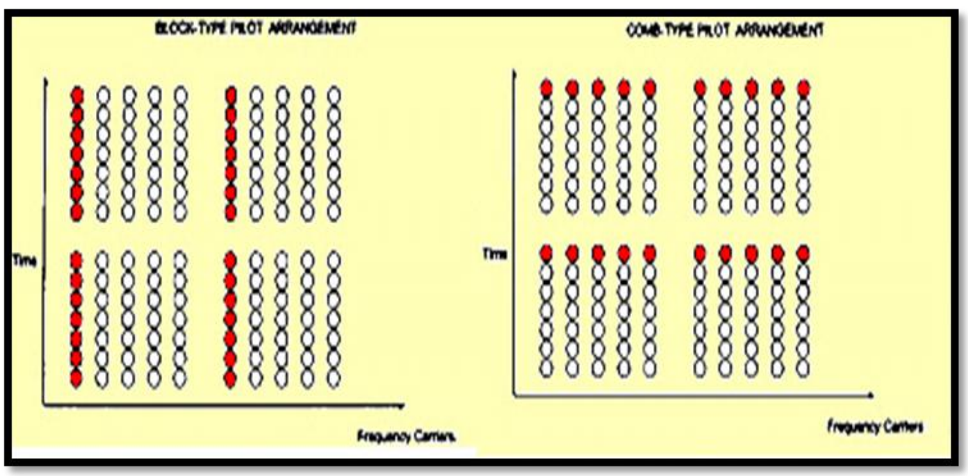

Fig.no.2 The Two Types Pilot Arrangement

In case of the block type arrangement of pilot as shown in figure above, the channel approximation is done by transmitting OFDM symbols periodically, were all the subcarriers are utilized as pilots[5]. As we know that Least square estimator is insusceptible to noise and inter carrier interference. Since in the case of MMSE is recommended while compromising the complication. As the MMSE the process of matrix inversion adopted at each iteration[24].

2.1 Least Square channel Estimator

The Least Square channel estimator minimizes the parameter $(\bar{Y} - \underline{X}\ \bar{H})^H(\bar{Y} - \underline{X}\ \bar{H})$ where $(\bullet)^H$ means the conjugate transpose operation[16]. It is shown that the LS estimator of $\bar{H}$ is displayed as below .

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$$\hat{H}_{LS} = \underline{X}^{-1}\overline{Y} = [(X_k / \ Y_k)]^T \qquad (k = 0, ..., N-1) \quad \textbf{(1)}$$

2.2 MMSE Estimator

The Minimum Mean Square Error channel estimator delivers the second order statistics of the channel conditions to minimize the mean-square error .Denoted by $\mathbf{\underline{R}}_{gg}$, R_{HH}, R_{YY} the auto covariance matrix of $\bar{g}$, $\bar{H}$ & $\bar{Y}$,respectively and $\underline{R}_{gy}$ is the cross covariance matrix between $\bar{\mathbf{g}}$ and $\mathbf{Y}$ [19][20] .Also is denoted by σ^2_N the noise variance $\mathbf{E\{(|\ \bar{N}\ |^2\}}$. **We** Assume the channel vector $\bar{g}$ and the noise $\bar{N}$ are uncorrelated so it is derived that

$$R_{HH} = E\{\overline{H}\overline{H}^H\} = E\{(E\bar{g})(E\bar{g})^H\} = ER_{gg}E^H \qquad (2)$$

$$R_{gY} = E\{\bar{g}\overline{Y}^H\} = E\{\bar{g}(XE\bar{g} + \overline{N})^H\} = R_{gg}E^HX^H \qquad (3)$$

$$R_{YY} = E\{\overline{Y}\overline{Y}^H\} = XER_{gg}E^HX^H + \sigma_N^2 I_N \qquad (4)$$

Assume $\underline{R}_{gg}$ thus (R_{HH}) and σ^2_N are known as receiver in advance, MMSE estimator of $\bar{g}$ is given $\hat{g}_{MMSE} = R_{gY} R_{YY}^{-1} \bar{Y}^{HH}$ note that $\bar{g}$ is not Gaussian ,$\hat{g}_{MMSE}$ it is not necessarily a minimum mean-square error estimator, but it is still the finest linear estimator in the mean-square error sense. At last, it is calculated that

$$\begin{aligned} \hat{H}_{MMSE} &= \underline{F}\hat{g}_{MMSE} = \underline{F}[(\underline{F}^H\underline{X}^H)^{-1}\underline{R}_{gg}^{-1}\sigma_N^2 + XF]^{-1}\overline{Y} \qquad (5) \\ &= ER_{gg}[(E^H X^H X E)^{-1}\sigma_N^2 + R_{gg}]E^{-1}\hat{H}_{LS} \\ &= R_{HH}[R_{HH} + \sigma_N^2(XX^H)^{-1}]^{-1}\hat{H}_{LS} \end{aligned}$$

III CHANNEL TYPES

Fading can be divided into two parts small scale and large scale fading. If the transmitter and receiver have large distance between each other it can be called as a large signal fading[17]. But when the distance between transmitter and the receiver is small then it results in small scale fading channel[3][25]. It has three typesof channels mainly Rayleigh , Rician and AWGN channel.

3.1 THE AWGN CHANNEL

The simple wireless communication channel is the AWGN Channel ,in which linear addition of white noise with spectral density which is constant along with Gaussian distribution of amplitude which don't relies on selective frequency , multipath fading, interference or dispersion. 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[10][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 .

3.2 RAYLEIGH FADING CHANNEL

In the case of wireless communication system ,the 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 ionosphere reflection ,ducting, refraction, and reflection due to the irregular terrain profile of place[23]. Rayleigh channel is a frequently usedmodel to describe the geometric time varying nature of the envelope of the flatfading signal or envelope of an individual multipath component[14][15].This type of channel is used when there is no direct path between transmitter & receiver. If there is no LOS then the beneficial and vicious nature of Multipath Signal flat fading can be approximated by Rayleigh channel[21].

The signal can be given as

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

Where h(t) is the random channel matrix ,r(t) is the received signal, and n(t) is the Additive White Gaussian Noise. We can say that the Rayleigh distribution is fundamentally the magnitude of the summation of two identical independent orthogonal Gaussian random variables and the probability density function

3.3RICIAN FADING CHANNEL

Rician model is identical to the Rayleigh model.This channel is used to study the OFDM when line of sight is accessible means the transmitter & receiver have straight path between them. This type of signal is estimated by Rician distribution in which the dominating component run into more fade the signal characteristic goes from Rician to Rayleigh distribution[22]. This type of signal can be given by

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

Hereh(t) is the random channel matrix with Rician distribution , r(t) is the received signal and n(t) is Additive White Gaussian Noise. The Rician distribution can be given as below:

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

Were 'I_0'is the improved Bessel function of the first kind andof zerothorder and 'A' is the peak amplitude of the dominant signal .The K-factor can be given as the ratio of signal power to the scattered power. Which is denoted as below

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

Were scattered power can be given as

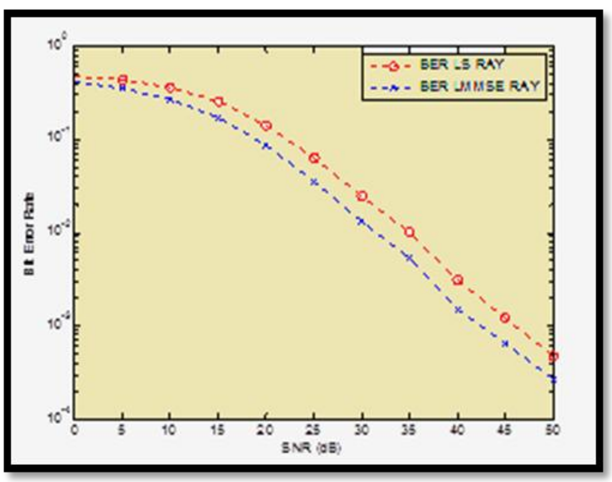
$$\sigma^2 = P/(K+1) \qquad (11)$$

were the amplitude of the LOS is

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

IV SIMULATION RESULTS

Using MATLAB simulation we have verified the performance of OFDM system to investigated three different channels namely Rayleigh , Rician and AWGN. For simplicity purpose we have used the parameters of the European standard Hyperlan/2 standard for wireless LAN transmissions in the 5.2 GHz frequency band . We assume that we have FFT size as N= 64 sampling frequency as 20MHz. Number of data sub-carriers 48, Number of pilot sub-carriers 4, Total sub-carriers 52, Sub-carrier spacing 0.3MHz, Nominal bandwidth 16 MHz, The Data symbol constellations lengths 16 QAM. Assigning data onto the sub-carriers is also subject of discussion. In case of European standard Hyperlan/ 2 . four subcarriers are used for pilot tones ,48 sub carriers are used to carry data and the remaining are left unused for an FFT size of 64. For our simulation, we will utilize the entire 64 carriers for carrying the data information. The channel response will be verified on the basis of BER comparison and performance analysis of three different channels such as Rayleigh ,Rician and AWGN. we will also check the performance by introducing the estimators such as LS and MMSE.



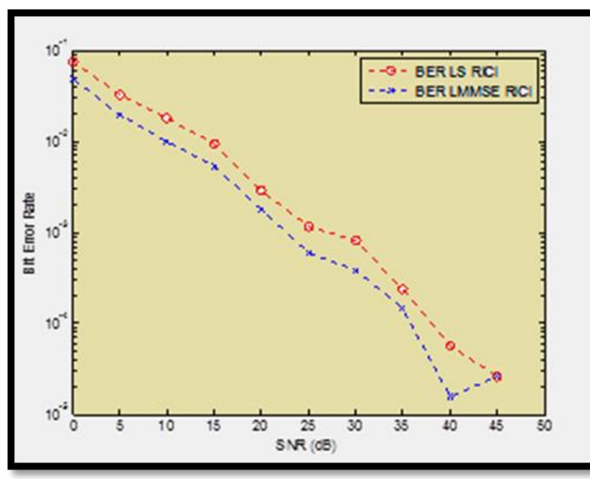


Fig.no.3.BER Comparison of Rayleigh channel Fig.no.4.BER Comparison of Rician channel

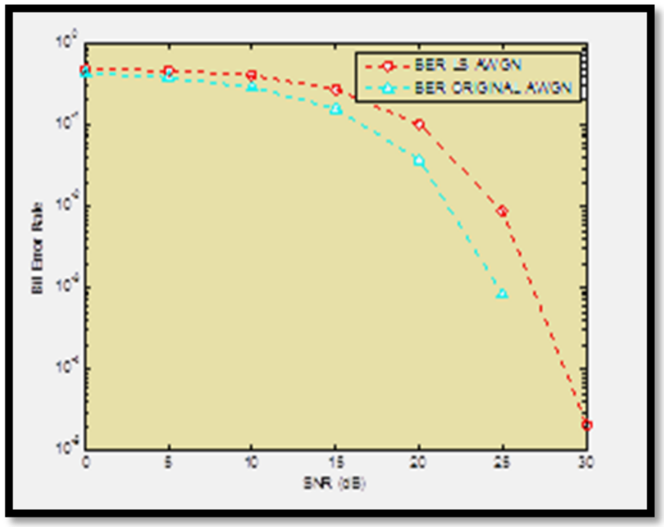


Fig.no.5.BER Comparison of AWGN channel

V CONCLUSION

The above simulation results demonstrate the performance analysis and BER comparison of various channels in the implemented OFDM system. Above simulation results we have utilized 16-QAM modulation scheme. The results clearly demonstrate that if channel estimator is not used the performance degrades and BER rises. From fig 3 it is clear that the performance of Rayleigh channel is better in the case of MMSE estimator as compared to LS estimator. In the second case we can say that the performance of Rician channel is better as compared to the Rayleigh channel, both the channel estimators show a better performance in Rician as compared to the Rayleigh channel, the third case AWGN is far most better in both conditions as compared to the Rician and Rayleigh channel performances.The performance of Rayleigh fading channel is the worst of all channels as BER of this channel has been much affected by noise under 16-QAM modulation scheme. In this paper we have demonstrated Least square and Minimum Mean Square Error estimators for both block type & comb type pilot tone arrangement. Thechannel estimatorsin this paper can be used to efficiently to evaluate the channel performance in an OFDM system demonstrating certain information about slowly fading channel statistics. LS estimator is both simple and satisfactory. In case of MMSE channel estimator it has excellent performance but more complex.

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