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LMS Channel Estimation in OFDM System by Using Pilot Based Technique

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Abstract
Orthogonal Frequency Division Multiplexing (OFDM) is predominantly chosen because of its high robustness to multipath fading at high data rate transmission, ease for implementation. Pilot Assisted Channel Estimation (PACE) techniques have been successfully applied to OFDM systems for obtaining a remarkable enhancement. This paper analyzes the degradation effect of null subcarriers in OFDM systems on the time-domain based on the estimation performance. The splitting process decreases the rate of the data stream associated with each subcarrier and thus reducing the effect of inter symbol interference (ISI).Here we have studied and implemented OFDM in MATLAB using pilot based techniques. This paper starts with implementation of OFDM using QAM followed by modelling the LMS estimators on MATLAB and finally concluded the importance of estimation based on the performance we achieved.

Index terms: OFDM, multipath fading, maximum likelihood,ISI, LMS.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is most commonly employed in wireless communication systems because of the high rate of data transmission potential with efficiency for high bandwidth and its ability to combat against multi-path delay. It has been used in wireless standards particularly for broadband multimedia wireless services [1]. In OFDM-based systems, pilot-assisted schemes are commonly employed for channel estimation and tracking in fast fading channels. The performances of various pilot assignments using different modulation scheme and interpolation techniques are provided in [8]. Since in wireless communication systems, channel response is time variant, channel estimation is an essential part of the receiver .Hence effective channel estimation algorithms are required to guarantee the performance of communication. There are numerous methods to estimate the channel response among which Pilot-Aided or Training-Based Channel Estimation (TBCE) [11] schemes rely on training sequences that are known *a priori* to the receiver are multiplexed along with the data stream for channel estimation. Blind Channel Estimation (BCE) method identifies the channel only from the received data and is evaluated from the statistical information of the channel and transmitted signals. Here it doesn’t suffer from overhead loss and is suitable for only slowly time-varying channels. Semi-Blind Channel Estimation (SBCE) approaches as a combination of blind and training technique, utilizes pilots and other natural constraints to perform channel estimation, and Decision Directed channel Estimation (DDCE) could be viewed as Pilot-Aided Channel Estimation scheme that employs approximately full pilot information symbols for channel estimation in comparison with the purely pilot-aided scheme with sparse available pilot symbols for the same estimation. In particular, the task of the channel estimation in a pilot-aided OFDM system has been widely investigated based on the maximum likelihood estimator (MLE) and the minimum mean square error estimator (MMSEE).The constellation of the channel for comb-type based channel estimation [2] can depend on linear interpolation, second order interpolation, low-pass interpolation, spline cubic interpolation, and time domain interpolation. In this paper, our aim is to study the performance of all equalization techniques, pilot arrangements [3] and applying it in OFDM by using QAM (Quadrature Amplitude Modulation) as modulation schemes with zero fading technique.

In this paper, we analyse this effect by looking at the ratio of the number of pilot subcarriers to the number of parameters needed for channel estimation, and then proceed to propose a new channel estimation method designed to overcome the performance degradation caused by the null subcarriers. This method consists of expanding the channel information by effectively using constellated information. Further our work is organised and presented with the description of the system model in section II .And section III gives the study and description of the channel based on pilot arrangement. In Section IV, the simulation environment and results are described and sectionV concludes the paper

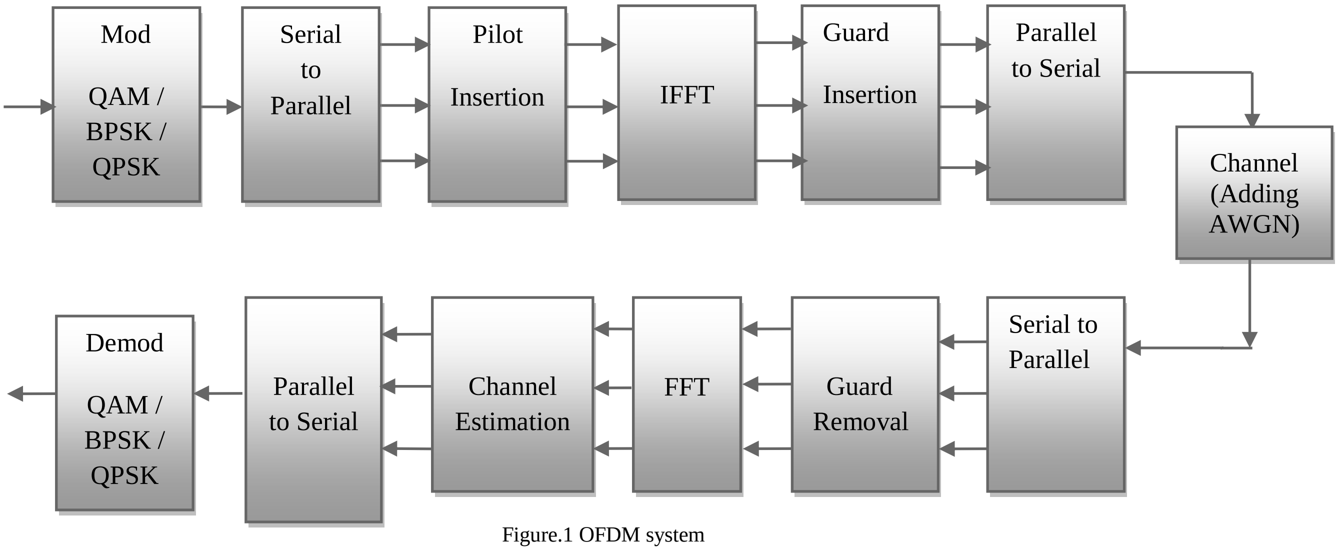


Figure.1 OFDM system

II.SYSTEM MODEL

The “orthogonal” part of the OFDM name indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system [5]. In a normal FDM system, the many carriers are spaced apart in such way that the signals can be received using conventional filters and demodulators. In such receivers, guard bands have to be introduced between the different carriers and the introduction of these guard bands in the frequency domain results in a lowering of the spectrum efficiency [6]. It is possible, however, to arrange the carriers in an OFDM signal so that the sidebands of the individual carriers overlap and the signals can still be received without adjacent carrier interference. In order to do this the carriers must be mathematically orthogonal. The receiver acts as a bank of demodulators, translating each carrier down to DC, the resulting signal then being integrated over a symbol period to recover the raw data. If the other carriers all beat down to frequencies which, in the time domain, have a whole number of cycles in the symbol period (t), then the integration process results in a zero contribution from all these carriers. Thus the carriers are linearly independent (i.e. Orthogonal) if the carrier spacing is a multiple of 1/t.

$$\int \Psi_p(t)\Psi_q^*(t)dt = \begin{cases} K & for \quad p = q \\ 0 & for \quad p \neq q \end{cases} \quad \text{……1}$$

Where the * indicates the complex conjugate and the interval [a b] is a symbol period. A fairly simple mathematical proof exists, that the series *sin* (*mx*) for *m*=1, 2… is orthogonal over the interval -p to p.

A. Mathematical description of OFDM system:

This allows us to see how the signal is generated and how receiver must operate, and it gives us a tool to understand the effects of imperfections in the transmission channel. As noted above, OFDM transmits a large number of narrowband carriers, closely spaced in the frequency domain. In order to avoid a large number of modulators and filters at the transmitter and harmonizing filters and demodulators at the receiver, it is desirable to be able to use modern digital signal processing techniques, such as Fast Fourier Transform (FFT)

The input signal is given as a random signal by using Random Data Generator. It is represented as

$$\{x_k(i)\}_{i-1}^{n} \quad \text{..……2}$$

Let ‘n’ represent the total number of bits to be transmitted.

The modulation techniques which are used here are BPSK, QAM, and QPSK.

Mathematically, each carrier of a BPSK signal can be described as a complex wave,

$$S_c(t) = b(t)Acos(2\Pi f_0 t) \quad \text{…….3}$$

The general BPSK signal can be expressed as,

$$S_n(t) = \sqrt{\frac{2E_b}{T_b}}cos\{2\Pi f_c t + \Pi(1-n)\}, n = 0,1.. \quad \text{……..4}$$

Where, A is the peak value of sinusoidal carrier. It is denoted as,

$$A = \sqrt{2p} \quad \text{…….5}$$

B (t) = +1, when binary ‘1’ is transmitted

= -1,when binary ‘0’ is transmitted

For the QAM the transmitted signal is expressed as the following,

$$S(t) = I(t)cos2\Pi f_0 t - Q(t)sin2\Pi f_0 t \qquad \ldots\ldots 6$$

Where I (t) and Q (t) modulate signals.

The demodulated signal is given by multiplying the transmitted signal with a cosine signal.

$$r(t) = I(t)cos2\Pi f_0 cos2\Pi f_0 - Q(t)sin2\Pi f_0 cos2\Pi f_0 \quad \ldots.7$$

QPSK signal is mathematically expressed as,

$$S_n(t) = \sqrt{\frac{2E_s}{T_s}}\, cos\left(2\Pi f_c t + \frac{\Pi}{4}(2n-1)\right) \text{n=0,1,.....8}$$

Serial to parallel conversion is done by extracting the data. After extraction the serial data is converted as $x_k(1)$, $x_k(2)$, ……$x_k(n)$.

We have to design the number of pilot clusters (Nc) in the frequency domain to be greater than the length of the CIR vector, i.e.*Nc> length of CIR.*

We showed that the pilot cluster size (Np) must satisfy $M \leq Np \leq 2M - 1$; where

$M = 2, 4$…….

Hence, the period of pilot clusters Lc is given by

$$L_c = \frac{NN_p}{N_T} \qquad \ldots\ldots.9$$

Where $N_T = NcNp$ is the total number of pilot subcarriers and N is the total number of symbols.

The progression of transforming from the time domain representation to the frequency domain representation uses the Fourier transform itself, whereas the reverse process uses the inverse Fourier transform. At the transmitter, the signal is defined in the frequency domain. It is a sampled digital signal, and it is defined such that the discrete Fourier spectrum exists only at discrete frequencies. The amplitudes and phases of the carriers depend on the data to be transmitted. The data transitions are harmonized at the carriers, and can be processed together, symbol by symbol.

FFT is mathematically described as,

$$X(k) = \sum_{j=1}^{N} x(j)_{\omega} N^{(j-1)(k-1)} \qquad \ldots\ldots.10$$

Where,

$\omega_N = e^{(-2\Pi i)/N}$, N is the number of output points.

Guard interval is inserted by using the formula

$$x_n^g = A\sum_{k=0}^{N-1} S_k exp\left\{j\frac{2\Pi kn}{N}\right\} \qquad \ldots\ldots.11$$

Where ‘n’ is the total number of bits.The parallel data is converted back into serial data as

$$\{x_n^g(i)\}_{i=1}^{n} \qquad \ldots\ldots..12$$

The AWGN Channel block relates E_s/N_0 and SNR according to the following equation:

$$\frac{E_s}{N_0} = SNR(T_{sym}/T_{samp}) \qquad \ldots\ldots.13$$

Where E_s is Signal energy (Joules), N_0 is Noise power spectral density (Watts/Hz), T_{sym} is the Symbol period of the block in Es/No mode (s), T_{samp} is the inherited Sample time of the block.

The Bit Error Rate (BER) is calculated by using the formula,

$$BER = 0.5erfc\sqrt{s/2} \qquad \ldots\ldots14$$

A natural consequence of this method is that it allows us to generate carriers that are orthogonal. The members of an orthogonal set are linearly independent. According to the pilot position, frequency response of corresponding sub-channel is calculated in the receiver.

$$\hat{H}_P(m) = \frac{Y_p(mN_f)}{X_p(mN_f)} \qquad m = 0,1,\ldots.N_p - 1 \qquad \ldots\ldots15$$

Where Y_p and X_p are the output and input of pilot subcarriers, respectively.

III.PILOT Based ARRANGEMENT

OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI). It also allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI) as long as the modulated carriers are orthogonal.

A.Cyclic prefix:

The concept of cyclic prefix (CP) was introduced to combat the problem of ICI and ISI. Cyclic prefix is a copy of the last part of the OFDM symbol that is pre-appended to the transmitted symbol, as shown in Figure.2, and removed before demodulation.

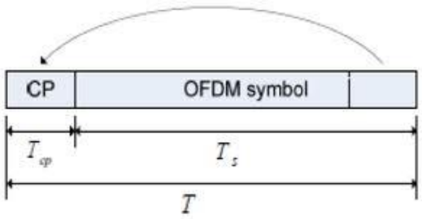


Figure.2 Cyclic prefix

B.Channel Estimation:

The channel estimation can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol [7]. There are basically two types of classification of Channel estimation in OFDM

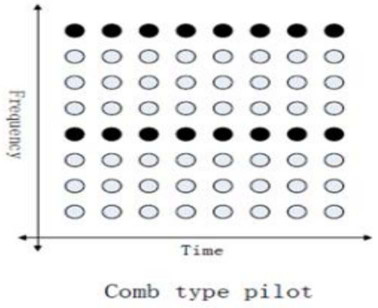
Pilot Based Channel Estimation: Known symbol called pilots are transmitted.

Blind Channel Estimation: No pilots required. It uses some underlying mathematical properties of data sent.

The Blind channel estimation methods are computationally complex and hard to implement [8]. The Pilot based channel estimation methods are easy to implement but they reduces the bandwidth efficiency and in order to obtain the channel information, pilot symbols are inserted in the information from the transmitter, and the receiver gets the channel information by using pilot symbols received. if the pilot is not inserted means it might result in phase error [9][10]. In essence, the problem of pilot pattern design is to determine where to insert the pilot and how closely between pilots. A suitable way of inserting could be calculated according to the known communication environment and estimated speed from the terminal.

Pilot type channel estimation is performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers[3]. Block type pilot insertion is done by inserting pilot tones into all subcarriers of OFDM symbols with a specific period of time. The pilot symbols covers all frequencies which could be effective against the selected frequency fading, but more sensitive to the impact of fast fading channel. Therefore, the block-type pilot is developed under the assumption of the slow fading channel. Comb-type pilot is performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers. It is introduced to satisfy the need for equalizing when the channel changes even from one OFDM block to the subsequent one. The comb type pilot performs better since it tracks fast fading channels.

Comb-type pilot channel estimation is introduced to satisfy the need for equalizing when the channel changes even from one OFDM block to the subsequent one [11]. In case of the same number of pilots, the performance is decided by channel multipath time delay, known as coherent bandwidth. The comb type pilot performs better since it tracks fast fading channels. Since LMS estimate is susceptible to noise and ICI, the MMSE is proposed while compromising complexity [12]. Since MMSE includes the matrix inversion at each iteration. In this simplified version, the inverse only needs to be calculated once. In the complexity is further reduced with a low-rank approximation by using singular value recombination.



● Pilot ○ Information

Figure.3 Comb type pilot arrangement

IV.SIMULATION RESULTS

The simulation is done using MATLAB with Communication toolbox. This Paper simulates the OFDM signal transmission for the parameters listed as per the specified data in the table 1. The Paper carries OFDM transmission for 64 subcarrier with 5 symbols. The modulation carried for OFDM transmission is QAM with N=4 and hence 16 QAM. Though we studied about different pilot arrangement, here comb type arrangement is followed.

PARAMETER	SPECIFICATION
M	4
Block size	8
Sampling Frequency	1KHz
Number of data points	64
Pilot arrangement	No pilot, block, comb
Modulation	QAM
FFT size	512
Guard band	8

Table 1 Simulation parameters

The Figure-4 describes transmitted and received OFDM signal, which is given as input to QAM modulator and received OFDM signal is taken from QAM demodulator.

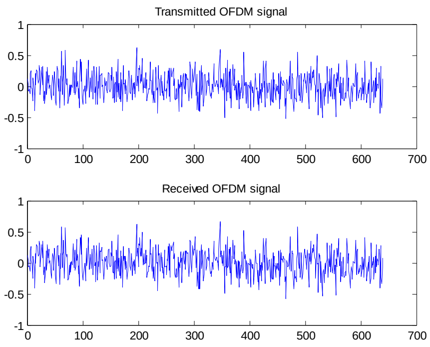


Figure.4: Transmitted and received OFDM signal

The Figure 5 describes received signal constellation, which compares the performance of both the proposed system and a system using comb type pilot arrangement.

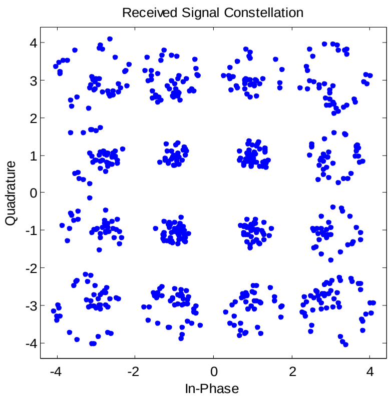


Figure.5: Received Signal Constellation

Figure 6 describes estimated signal constellation which uses estimated techniques to decrease BER performance and to increase SNR.

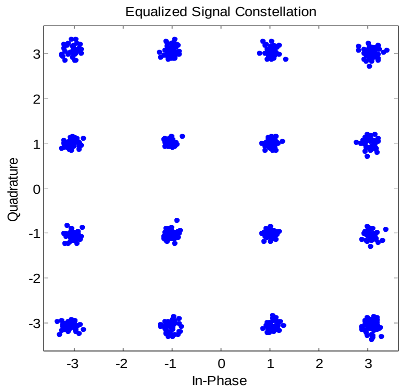
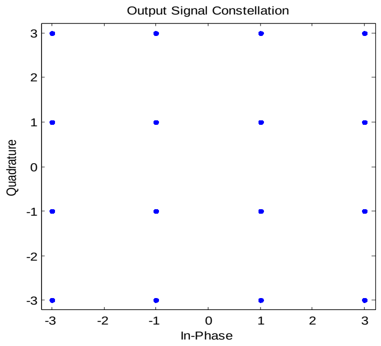


Figure.6: Estimated signal constellation

Figure-7 describes Output signal constellation, which gives output with less error



Figure,7: Output signal constellation

Figure 8 shows the simulation curve for LMS based channel estimation for three case of pilot arrangements and shows at 10^0 the BER for comb type as considerably 10 db than block and no pilot mode of pilot arrangement.

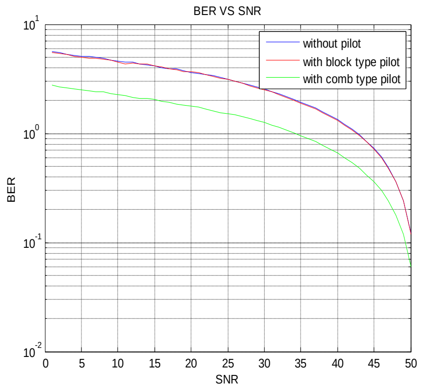


Figure 8: Error vs Iteration

V.CONCLUSION

In this paper, channel estimation based on comb type pilot arrangement is presented and it is shown to have 10 db improvements over other pilot arrangement for a rapidly varying changing channel. Channel estimation based on comb-type pilot arrangement utilizes LMS scheme. From the simulation results, we have shown the transmitted and received OFDM signal shows the data is achieved perfectly in multipath propagation environment with estimated signal than with received signal without estimation.

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