Pilot Based Channel Estimation In OFDM Using Time Domain Technique

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Abstract-**In wireless communication orthogonal frequency division multiplexing (OFDM) is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower rate subcarriers. This new standard is the first one to use OFDM in packet-based communications, while the use of OFDM until now was limited to continuous transmission systems .Channel estimation is very important in order to get original information at receiver side. In paper the BER is calculated using Rayleigh fading channel using AWGN noise. It is going to be compared the BER by channel estimation methods like LS (Least square), DFT (Discrete Fourier Transform) for DFT-OFDM and DCT-OFDM. And it would be concluded that DFT based channel estimation is better than LS in both DFT-OFDM and DCT_OFDM. And also concluded that DCT-OFDM is better than DFT-OFDM for low range of SNR.**

Keywords—DFT-OFDM, DCT-OFDM, pilot, channel estimation, LS, DFT.

I. Introduction

From last 20 years there is an abundant development in communication side. The especially in mobile communication. For mobile communication the technology used is OFDM (Orthogonal Frequency Division Multiplexing). OFDM is method of encoding digital data on to a large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data stream or channels [1]. From beginning many technologies like 1G, 2G, 3G and now a days 4G is used. OFDM is used for high volume and high speed wireless mobile communication systems [2].

In wireless communication the channel estimation is main part. Pilots may be inserted or not in channel. If the pilots inserted are of two types: comb type and block type [20]. In block type pilots are inserted in specific period of time and in comb type the pilots are inserted in each symbol. The comb type is suitable for fast fading. The BER is less in comb type as compare to block type. Cyclic prefix is added to increase the BER. As shown in Fig. 1 there are two portions: one is cyclic prefix and another is data or information. As the number of cyclic prefix is added as the probability of correct symbol receive at receiver is increases. But if more number of cyclic prefix is added is reduce the channel information carrying capacity is reduce [3].

There are basically two ways for inserting cyclic prefix. One way is *zero padding.* In this the zero is added in the portion of cyclic prefix. This is the simplest way for inserting cyclic prefix. Another way is *information.* In this mode the information is repeated from beginning. [19]

If the cyclic prefix is decided for 25% then the 25% of symbol from starting is repeated. As shown in figure 1 the block of dotted line from beginning is repeated at the cyclic prefix portion. In cyclic prefix the combination of both data and zeros can be used.[19]

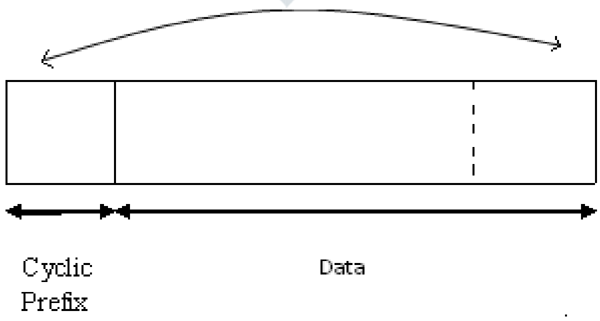

Figure 1: Cyclic prefix [3]

There are many channel estimation methods for channel estimation. Channel estimation is mostly done in frequency domain. LS estimator is good in terms of complexity i.e. it has very low complexity but the performance is not so good. The performance is in terms of BER with reference to SNR. But for better performance frequency domain based channel estimator which is DFT based channel estimation is used. In which the symbols are applied to IFFT first to convert frequency domain into time domain. Then according to threshold value the noise removed by further converting it to frequency domain by FFT [6].

Further in section II the brief overview of OFDM and basic introduction of two types of pilot based channel estimation. In section III basic simulation parameters to be calculated with different channel estimation techniques.

II. SYSTEM DISCRIPLTION

A. Basic block diagram of pilot based OFDM:

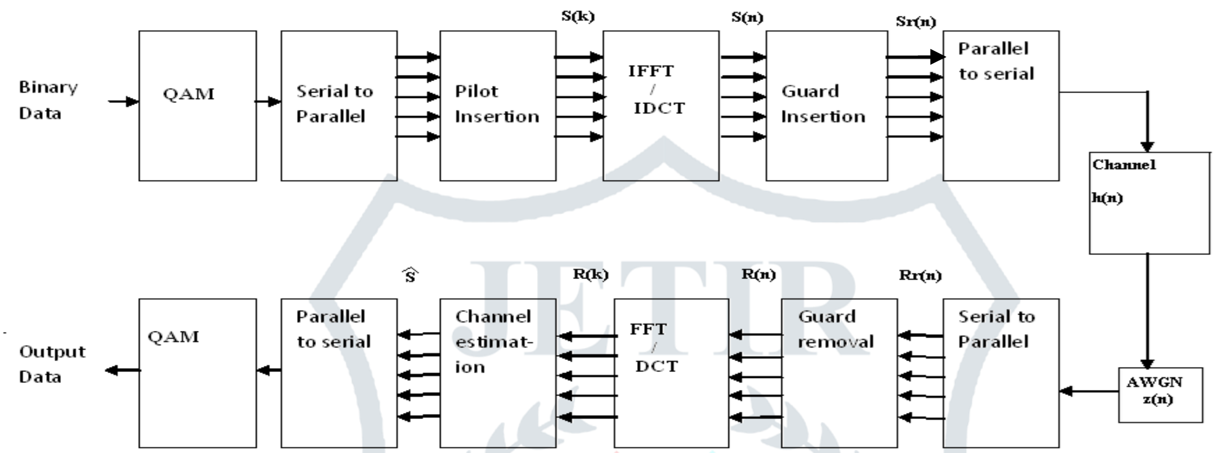

Figure 2: Block Diagram of OFDM [6]

The Fig. 2 shows the basic block diagram of OFDM system. In which first the symbols are modulated using various modulation schemes like BPSK/QAM/QPSK etc. After converting data into parallel from serial form the pilots are inserted. Then these symbols passed through IFFT block for DFT-OFDM and through IDCT for DCT-OFDM. All these are done at the transmitter side. After inserting guard interval it is converted into serial form [5].

Then at receiver the information passed through different channel and noise is added through environment is first converted into parallel form. Then exactly reverse procedure is performed. The FFT/DCT is done followed by guard interval removal. And after performing P/S and demodulation the output is gained [5].

B. Channel Estimation in OFDM:

There are different channel estimation methods for estimation of a channel. Basic channel estimation methods are based on in frequency domain and in time domain. The LS based channel estimation method is of frequency domain where as DFT-based channel estimation and DCT-based channel estimation is based on time domain.

C. System Discription:

The basic OFDM system based on pilot arrangement is as shown in fig. First the data sequence is modulated using BPSK modulation method. For fast data transmission serial data is converted into parallel form using serial to parallel block. The IFFT is done followed by pilot insertion. For N- point IFFT block use to transform the S(k) into time domain signal s(n) as follow [6]:

$$s(n)=IFFT(S(k)), \quad n=0,1,2..N-1$$

$$s(n)= \sum_{k=0}^{N-1} s(k)e^{j2\pi kn/N} \qquad \ldots (1)$$

After IFFT the guard band is inserted in data sequence. The guard band is inserted by two ways as discus before. The guard band is inserted to remove or reduce ISI and ICI. Let L_{gi} is the length of guard interval and $s(f)_n$ is the resultant OFDM symbol after inserting guard interval.

$$s\,(f)_n = \begin{cases} s(n+k), \; n=-N_{gi}, -N_{gi}+1,\ldots,-1 \\ s(n), \quad n=0,1,2,\ldots,N-1 \end{cases} \qquad \ldots (2)$$

This signal will pass through Rayleigh fading channel by adding AWGN noise in it. The received signal is given by:

$$Y_f(n)=s_f(n)*h(n)+z(n) \qquad \ldots (3)$$

Where z(n) is AWGN (Additive White Gaussian Noise) and h(n) is the channel impulse response. Lets denote the complex impulse response h(n) of flat fading channel as follows[19]:

$h(t)=h_I(nT_s)+jh_Q(nT_s)$ ... (4)

By using Clarke's Rayleigh Fading model for flat fading channel [24],

$$h_I(nT_s)=\frac{1}{\sqrt{M}}\sum_{m=1}^{M}\cos\{2\pi fD\cos[\frac{(2\pi-1)+\theta}{4M}]*nTs+\alpha m\}$$

$$h_Q(nT_s)=\frac{1}{\sqrt{M}}\sum_{m=1}^{M}\sin\{2\pi fD\cos[\frac{(2\pi-1)+\theta}{4M}]*nTs+\beta m\}$$

Where θ, α_m and β_m are uniformly distributed over [0,2π) for all n and are mutually distributed, f_D= maximum Doppler spread, T_s =sampling period, n= sample index.

Now at the receiver side same procedure follows but in reverse order. FFT of an received signal done after removing guard band. Then after channel estimation is done and demodulated signal receive at receiver after demodulation,

III. PILOT BASED CHANNEL ESTIMATION

For pilot based channel estimation, there are basically three types: I) Blind channel estimation, II) Semi-blind channel estimation and III) Decision Direct channel estimation. The blind channel estimation identifies the channel only from the received data and is evaluated from the statistical information of the channel and transmitted signals. It doesn't suffer from overhead loss and is suitable for only slow time varying channels. In semi-blind channel estimation approaches as a combination of blind and training technique, utilizes pilots and other natural constrains to perform channel estimation. And in decision direct channel estimation 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. This is very vast description of channel estimation. But basically there are two types of channel estimation named: block type channel estimation and comb type channel estimation. Both of these types come under decision direct channel estimation.

A. *Block Type Channel Estimation:*

In Block type channel estimation all subcarrier uses pilot in it. In this the pilots are added in specific period of subcarrier.

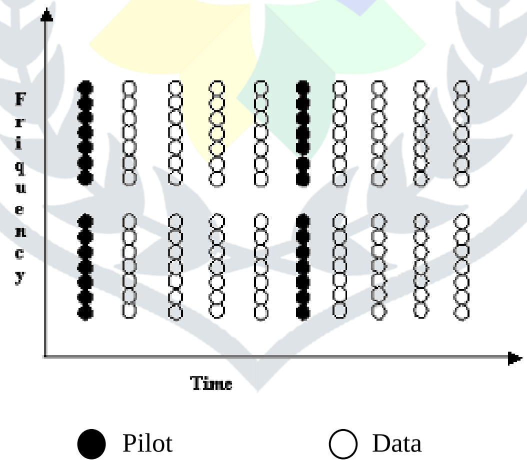

Figure 3: Block type channel estimation [12]

Generally block type is used in slow fading, where channel impulse response is not changing very fast [3]. The estimation of channel response is usually obtained by LS or MMSE estimator of training pilots.

B. *Comb Type Channel Estimation:*

In comb type channel estimation unlike block type, the part of all sub-carrier always reserved as pilot for each symbol. This is suited for fast fading channel. It requires fewer pilots as compare to block type and also gives better performance in terms of BER [3].

Figure.4 shows the comb type pilot arrangement for channel estimation in OFDM. In which black part shows the pilot and white portion shows the data which is to be transmitted.

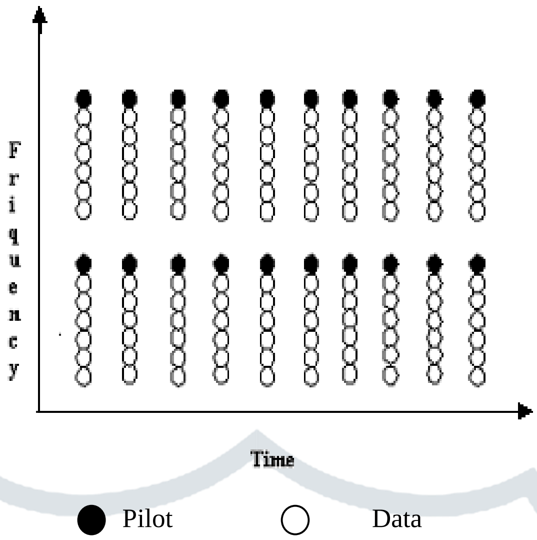

Figure 4: Comb type channel estimation [12]

The comb type pilot arrangement is given by:

$$S(k) = S(mL+l)$$

$$= \begin{cases} s_p(m), & l=0 \\ Info, & l=1, 2, \ldots, L-1 \end{cases} \quad \ldots (5)$$

Where L is number of carrier / Np and Sp (m) is the mth pilot carrier value, then $\{H_p(k) \quad k=0,1,\ldots,N_p\}$ define as the channel frequency response at pilot sub-carriers.

IV. LS CHANNEL ESTIMATION

In simple case, the channel estimation can be found by straight forward multiplying the received pilot by the inverse of known transmitted pilot. This method is known as Least Square (LS) based channel estimation. And it is given by:

$$H_e^{LS}(k) = S_p(k)^{-1}\, R_p(k) \qquad \text{For } k=0,1,\ldots,N_p\text{-}1 \quad \ldots (6)$$

Where $R_p(k)$ and $S_p(k)$ are output and input data at the kth pilot sub-carrier respectively.

V. DFT BASED CHANNEL ESTIMATION

In DFT based channel estimation FFT is used to improvise the results of LS and LMMSE channel estimators. There are three basic steps for performing DFT channel estimation.

Step: 1: Perform the FFT of LS channel estimator.

$$\widehat{H}_{LS} = IDFT(H_e^{LS}) \quad \ldots (7)$$

Step: 2: Do the zero padding of the output of FFT LS.
It is done by following equation.

$$\begin{cases} \widehat{H}_{LS,ZP} = IDFT(H_e^{LS}) & ,0 \le n \le L-1 \\ 0 & , \text{else} \end{cases} \quad \ldots (8)$$

Step: 3: Perform IFFT of that padded symbol.

$$H_{DFT} = DFT(\widehat{H}_{LS,ZP}) \quad \ldots (9)$$

After performing these three steps we get DFT output for LS channel estimator.

VI. SIMULATION PARAMETERS AND RESULTS

The simulation parameters are very important while simulation. Because by changing any parameter the results are going to be different. So, the simulation parameters are:

SIMULATION PARAMETERS	VALUE
No. of subcarriers	1024
Guard Interval	≈30%
Channel Used	Rayleigh fading
Noise	AWGN (Additive White Gaussian Noise)
Modulation Method	16-QAM

Table.1: Simulation Parameters

The simulation result shows for comparison of LS and DFT based channel estimation for DFT-OFDM for 16-QAM modulation technique.

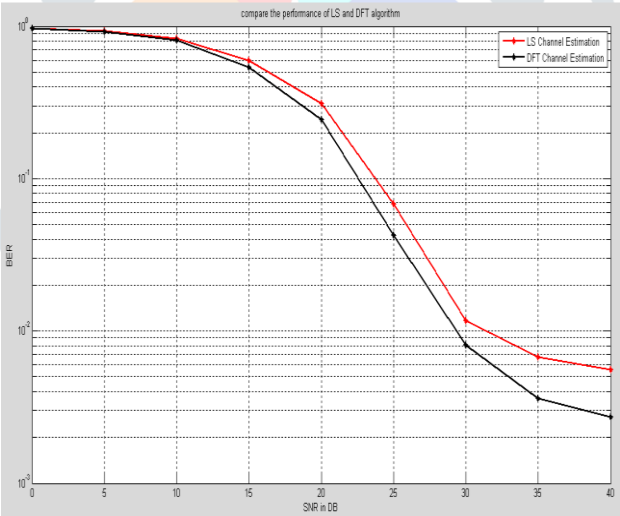

Figure 5: DFT-OFDM

According to results shown in Fig.5 it can be say that the DFT based channel estimation is better than LS based channel estimation for DFT-OFDM.

The following Table.2 shows the various values of BER for different values of SNR for LS and DFT channel estimation for DFT-OFDM.

SNR	LS_BER	DFT_BER

0	0.9646	0.9646
5	0.9204	0.9200
10	0.8086	0.8080
15	0.5956	0.5389
20	0.3122	0.2442
25	0.06833	0.04257
30	0.01174	0.008056
35	0.006736	0.003611
40	0.005556	0.002708

Table.2: Simulated values for DFT-OFDM

Now, Fig.6 shows the comparison of LS and DFT based channel estimation is shown for DCT-OFDM. All the simulation parameters are same as DFT-OFDM.

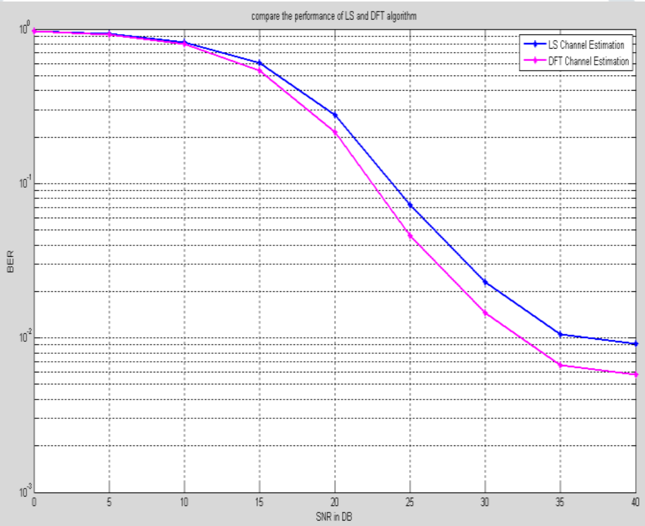

Figure 6: DCT-OFDM

From above fig.6 and following Table.3 it can say that for DCT-OFDM also the performance of DFT based channel estimation is better than LS based channel estimation.

SNR	LS_BER	DFT_BER
0	0.9695	0.9695
5	0.9239	0.9239
10	0.8018	0.8018
15	0.6014	0.5394
20	0.2782	0.2146
25	0.07271	0.04583
30	0.02292	0.01444

35	0.01049	0.006667
40	0.009167	0.005764

Table.3: Simulated values for DCT-OFDM

Figure 7 shows the comparison of LS based channel estimation with DFT- based channel estimation for DFT-OFDM and DCT-OFDM. In which it also seen that the LS for DCT-OFDM is better than DFT-OFDM. Same way for DFT based channel estimation DCT-OFDM gives better performance than DFT-OFDM.

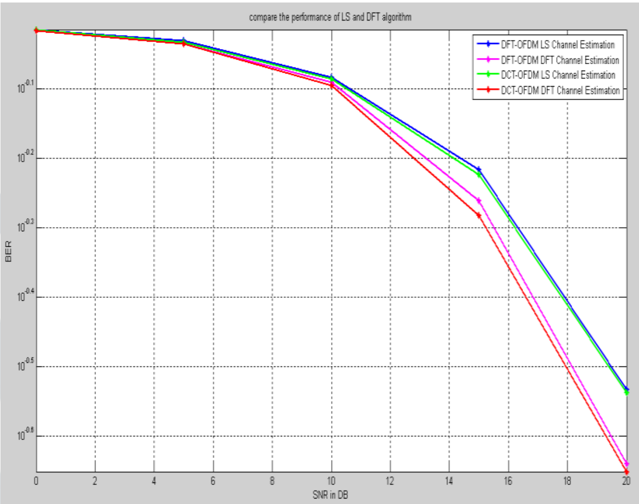

Figure 7: Comparison of DFT-OFDM and DCT-OFDM

VII. CONCLUSION

In this paper LS and DFT based channel estimation is compared for DFT-OFDM and DCT-OFDM. LS based channel estimation is very simple channel estimation method for computing. But it gives not good results. For better results DFT based channel estimation is used. So, by performing this it can be concluded that the DFT based channel estimation is better than LS based channel estimation for both DFT-OFDM and DCT-OFDM.

By comparing the performance of DFT-OFDM and DCT-OFDM it can be concluded that the DCT-OFDM gives better results than DFT-OFDM for only low range of SNR.

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