2022 International Conference on Computer Communication and Informatics (*ICCCI* -2022), Jan. 25 – 27, 2022, Coimbatore, INDIA

Modified Channel Estimation Techniques for DCT based OFDM Systems

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2022 International Conference on Computer Communication and Informatics (ICCCI) | 978-1-6654-8035-2/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICCCI54379.2022.9740842

Abstract— ***In the field of Wireless Communication many advancements are developed in past decade. The main requirements of are high data rates quality of service (QOS). In this paper Orthogonal Frequency Division Multiplexing (OFDM) is designed using discrete cosine transforms (DCT). The channel estimation techniques of Least Square (LS) and Minimum mean square error (MMSE) are analyzed with the help of DCT kernel matrix of DCT based OFDM systems. We will also compare the results of estimation techniques of DCT OFDM systems with the DFT based OFDM systems. It is required to investigate on DCT-OFDM system for better performance. The DCT-OFDM mainly concentrate on disposal of between block and intercarrier obstruction at a similar guard grouping overhead, contrasted and DFT-OFDM. DCT-based OFDM requires just a large portion of the subcarrier dispersing of OFDM, in this way permitting to twofold the quantity of subcarriers inside a similar data transmission***

Keywords-OFDM,DCT,LS,MMSE,DFT

I. Introduction

OFDM is frequency division multiplexing in which a one channel uses many of sub-carriers on different frequencies. Furthermore, in an OFDM system, the sub-carriers overlap to maximizes spectral efficiency. Normally, overlapping adjacent channels might cause interference. Sub-carriers in an OFDM system, on the other hand, are perfectly orthogonal to one another. As a result, they can overlap without interfering. As a result, OFDM systems can maximizes spectral efficiency without interfering with neighboring channels.

By suppressing time domain noise, traditional DFT-based channel predictions increase performance [1]. They may, however, necessitate information on channel impulse responses, and inaccurate channel information, such as channel delay spread, may result in a mean-square error (MSE) floor. DFT based schemes can be preferred because of availability of FFT[2]. The fractional based DCT proposed in [3], important parameters are compared in [4].

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The proposed channel estimation techniques of modified LS and MMSE using DCT improves SNR and reduces the MSE for different modulation schemes.

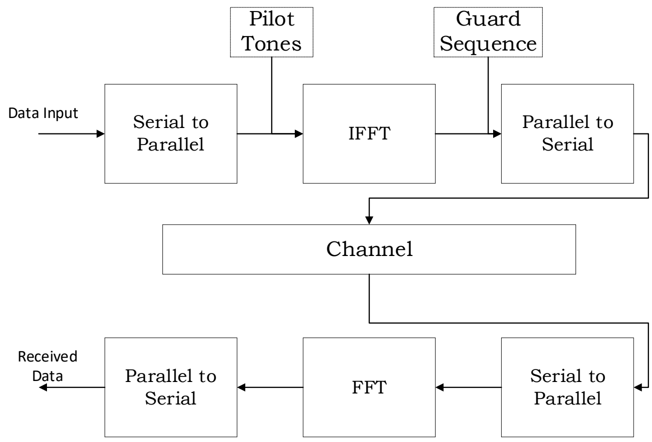

Figure 1 DFT-OFDM block diagram

As per the block diagram in figure 1, the data first enters the series to parallel block (SP) where data is converted from series to parallel. Then the pilot tones are added to the data which are used to estimate the channel. The data containing the pilot tones are sent to the IDFT block [5], later the guard sequence is added. Then the data is again converted from parallel to series. At the end of the PS block, the signal is ready to transmit into medium (such as air). In the medium some white gaussian noise is added.

At the receiver end, the data enters the parallel to series block (SP) where data is converted from parallel to series. Then the guard sequence is removed. The removed guard sequence signal is sent to the DFT block then the channel is estimated. Then the data is again converted from series to parallel. And then the transmitted data is obtained.

In the process of discrete Fourier transform based channel estimation channel taps are determined from the channel impulse response (CIR) and the channel taps are determined by the estimated CIR with a threshold value. The difference between estimated CIR and obtained CIR is the estimation error.

The main disadvantage of DFT is, it requires high bandwidth and less immune to noise. The Bit Error Rate (BER) and Mean Square Error (MSE) for DFT-Based OFDM is High and also the effect of noise reduction is dependent upon the no. of pilot signals. Based on the disadvantages of DFT-Based OFDM channel estimation we propose a new trigonometric transform-based estimation which has low BER, MSE from the simulation results.

II. Proposed Method

In this paper trigonometric transforms based OFDM is used which achieves improved noise immunity and better BER performance. The phase noise immunity is more in DCT OFDM compared to DFT OFDM. The block diagram of DCT-OFDM is shown in figure 2. The subcarrier spacing for DCT-based OFDM is half [6][7], so that it allows double the number of subcarriers within the same bandwidth [12][13].

DCT based pilot-image helped channel assessors depend on the property of channel recurrence reaction and the addition in change area. The DCT-Based OFDM is very similar to DFT-Based OFDM. The Only change is, the IDFT and DFT blocks are replaced with the IDCT and DCT blocks. As per the above block diagram, the data first enters the series to parallel block (SP) where data is converted from series to parallel. Then the pilot tones are added to the data which are used to estimate the channel [14][15]. The data containing the pilot tones are sent to the IDCT block, later the guard sequence is added [16]. Then the data is again converted from parallel to series. At the end of the PS block, the signal is ready to transmit into medium (such as air). In the medium some white gaussian noise is added.

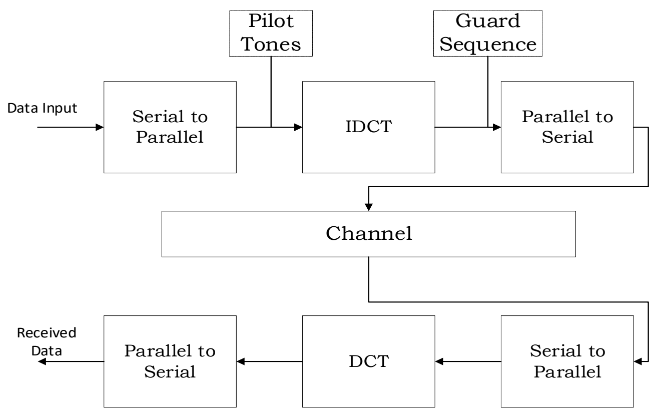

Figure 2 DCT-OFDM block diagram

A. Signal model

The DFT-OFDM block diagram is shown in figure, here the modulation and demodulation are done by DFT and IDFT respectively those are having different kernels. Whereas DCT-OFDM replaces with same IDCT or DCT module.
The expression for DCT-OFDM signal $x(t)$ is

$$x(t) = \sqrt{\frac{2}{N}}\sum_{n=0}^{N-1} d_n\beta_n \cos\frac{n\pi t}{T}$$

where $d_0, d_1, . . . ,d_{N-1}$ are N independent data symbols

$$\beta_n = \begin{cases} \frac{1}{\sqrt{2}}, & n = 0 \\ 1, & n = 1,2,3\ldots\ldots N-1 \end{cases}$$

Xm is the expression for discrete DCTOFDM signal

$$x_m = \sqrt{\frac{2}{N}}\sum_{n=0}^{N-1} d_n\beta_n \cos\frac{n\pi(2m+1)}{2N}$$

$$\mathrm{d} = [d_0, d_1,\ldots,d_{N-1}]^T,$$

The data symbols are feed serially $x = [x_0, x_1,\ldots,x_{N-1}]^T$ through a D/A converter. Assume channel impulse response is constant a frequency-selective multi path fading channel is used to transmit the signal. During one DCT-OFDM symbol, After matched filtering, the signal is sampled at rate 1/Ts and serial to parallel converted at the receiver seen in Figure 1. We denote with $h = [h_0, h_1,\ldots,h_{N-1}]^T$ the Tsspaced samples of the overall CIR

$$y = x \otimes h + w$$

Where,

h is the impulse response
$\otimes$ denotes cyclic convolution
w is additive white Gaussian noise (AWGN)

$$H_n = \sqrt{\frac{2}{N}}\sum_{n=0}^{N-1} h_k \cos\frac{\pi k(2n+1)}{2N}$$

Let h is the channel response or channel impulse response. The DFT of h is H which is the channel frequency response. The signal at the receiver end passes through N-point DCT. The response is given by

$$z_n = d_n H_n + w_n,$$

$$z = [z_0, z_1, \ldots, z_{Np-1}]^T,$$

From above equations, we have

$$z = DFh + w = DH + w,$$

Where $w=[w1, w2, \ldots, wL-1]$ is the AWGN noise matrix in DCT domain

$$D = \mathrm{diag}\{c_0, c_1, \ldots, c_{Np-1}\}$$

$$F(k,n) = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} \beta_k \cos \frac{\pi k(2n+1)}{2N}$$

B. Mathematical equations for LS channel estimation

The basic expression for LS channel estimation transfer function[8][9] is

$$H_{LS} = D^{-1}z$$

$$\text{W.K.T,}\ \ z = DFh + w$$

The modified LS estimation for DCT OFDM is given by

$$H_{LS} = D^{-1}(DFh + w) = H + D^{-1}w$$

Where, D^{-1} denotes the inverse of diagonal matrix containing pilot symbols and w denotes the channel noise.

C. Mathematical equations for MMSE channel estimation

The basic expression for LS channel estimation transfer function [10][11] is

$$h_{MMSE} = Z_{hr}Z_{rr}^{-1}z$$

Where,

$$Z_{hr} = \{hz^H\} = Z_{hh}F^H D^H$$
$$Z_{rr} = \{rr^H\} = DFZ_{hh}F^H D^H + \sigma_w^2 I_N,$$
Z_{rr} = auto covariance matrix of ‘z’
Z_{hh} = auto covariance matrix of ‘h’
Z_{hr} = cross covariance matrix b/w ‘h’ and ‘z’

The modified channel estimation H_{MMSE} for DCT-OFDM given by

$$H_{MMSE} = Fh_{MMSE}$$

III. SIMULATION RESULTS

A. BER vs SNR for DFT-Based OFDM

The simulation results for BER vs SNR or DFT-OFDM with LS and MMSE estimation is shown in figure 3 , figure 4, figure 5 and figure 6

These are plots drawn with SNR on X-axis and BER on Y-axis for DFT-Based OFDM in four different modulation schemes i.e., BPSK, QPSK, QAM and PAM.

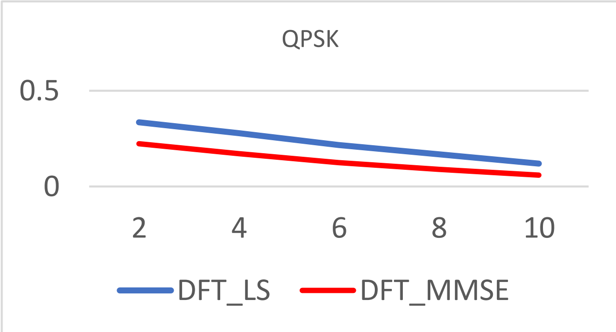

Figure 3 BER vs SNR for DFT using QPSK

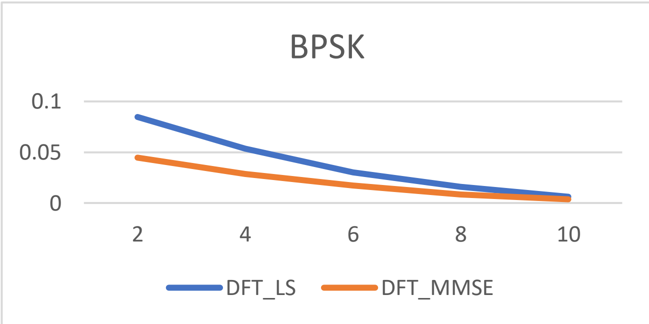

Figure 4 BER vs SNR for DFT using BPSK

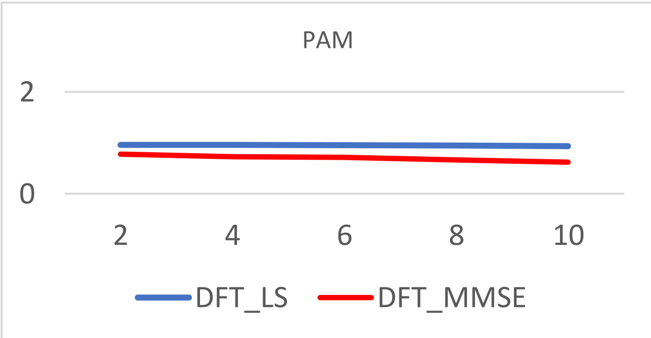

Figure 5 BER vs SNR for DFT using PAM

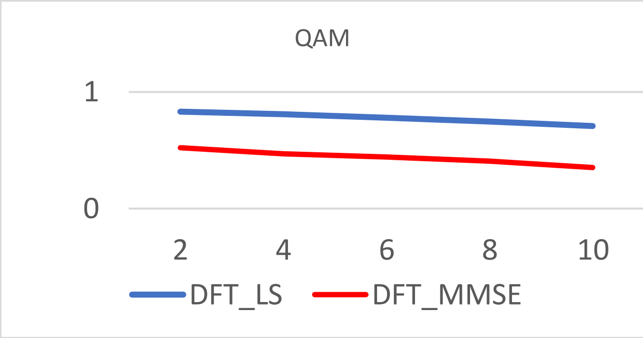

Figure 6 BER vs SNR for DFT using QAM

From the plots, we can clearly observe that LS has high BER compared to MMSE. So it has high accuracy but implementation complexity of MMSE is high.

B. BER vs SNR for DCT-Based OFDM

The simulation results for BER vs SNR or DCT-OFDM with LS and MMSE estimation is shown in figure 8 , figure 9, figure 10 and figure 11

These are plots drawn with SNR on X-axis and BER on Y-axis for DCT-Based OFDM in four different modulation schemes i.e BPSK, QPSK, QAM and PAM.

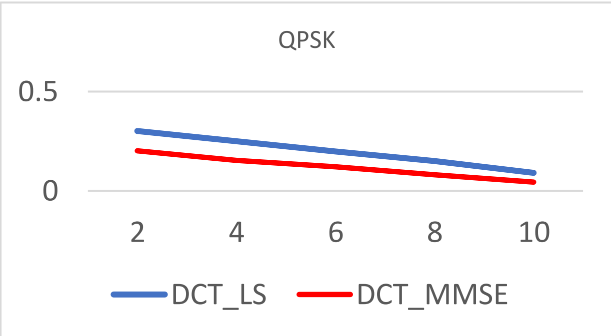

Figure 7 BER vs SNR for DCT using QPSK

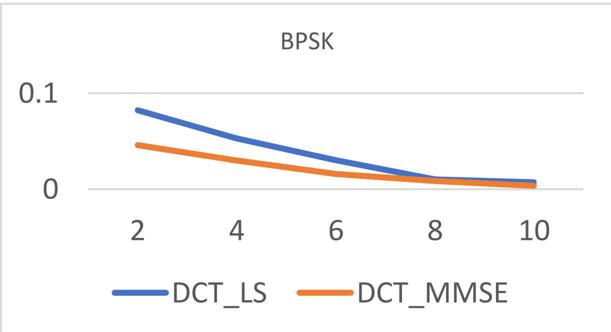

Figure 8 BER vs SNR for DCT using BPSK

From the plots, we can clearly observe that LS has high BER compared to MMSE. So, it has high accuracy but implementation complexity of MMSE is high.

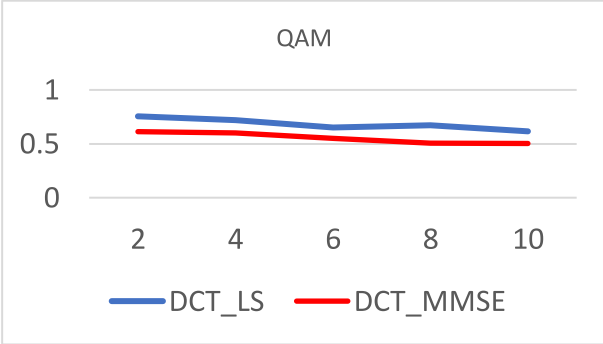

Figure 9 BER vs SNR for DCT using QAM

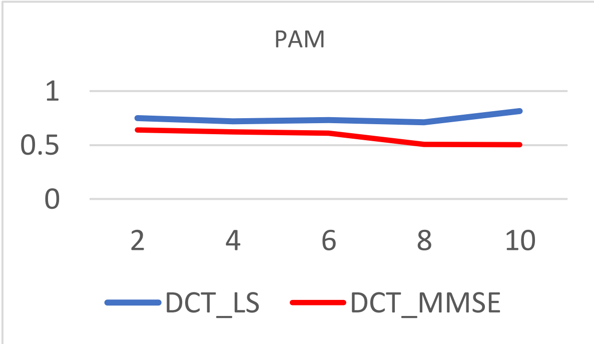

Figure 10 BER vs SNR for DCT using PAM

C. Comparison for DCT and DFT on BER vs SNR

The comparison results of BER vs SNR for DCT and DFT is shown in figure 11, figure 12 and figure 13.

These are comparisons for DCT and DFT Based OFDM in terms of BER for different SNR values. For example, we can clearly observe that in QPSK modulation with SNR value as 2, the BER for LS Estimation using DFT-Based OFDM is around 0.33 But BER for LS Estimation using DCT-Based OFDM is less than 0.3. Hence DCT-Based OFDM has less BER compared to DFT-Based OFDM.

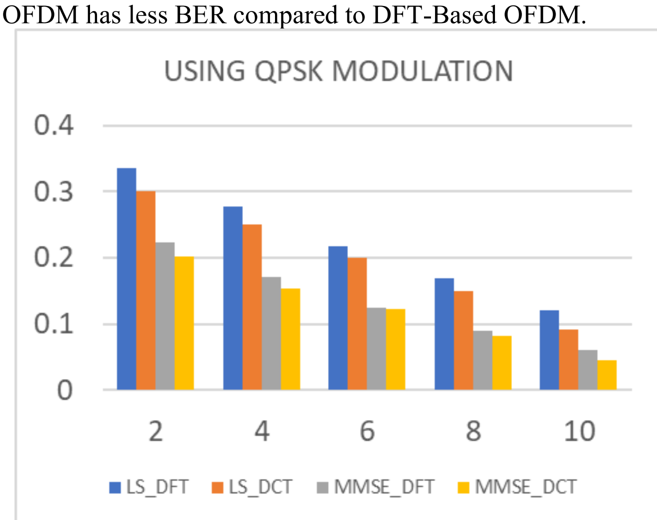

Figure 11 BER vs SNR comparison of DCT & DFT using QPSK

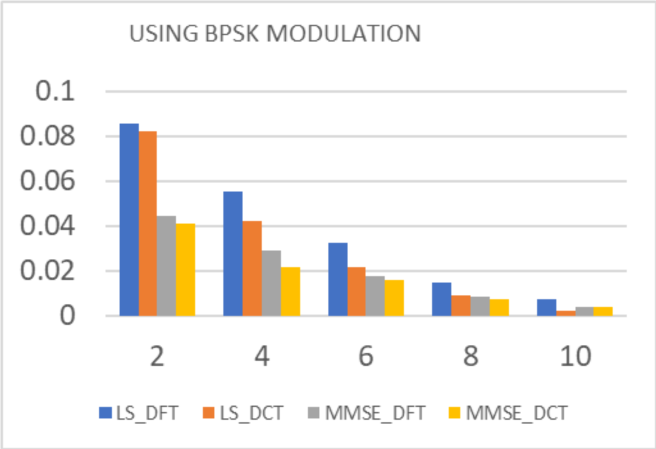

Figure 12 BER vs SNR comparison of DCT & DFT using BPSK

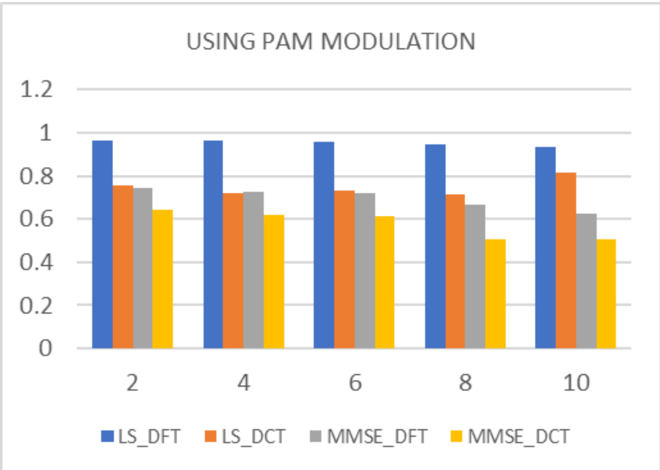

Figure 13 BER vs SNR comparison of DCT & DFT using PAM

D. MSE vs SNR for DFT-Based OFDM

The comparison results of MSE vs SNR for DCT and DFT is shown in figure 14, figure 15, figure 16 and figure 17.

These are plots drawn with SNR on X-axis and MSE on Y-axis for DFT-Based OFDM in four different modulation schemes i.e., BPSK, QPSK, QAM and PAM.

From the plots, we can clearly observe that LS has high BER compared to MMSE. So it has high accuracy but implementation complexity of MMSE is high.

E. MSE vs SNR for DCT-Based OFDM

The comparison results of MSE vs SNR for DCT and DFT is shown in figure 18 and figure 19.

These are plots drawn with SNR on X-axis and MSE on Y-axis for DCT-Based OFDM in four different modulation schemes i.e., BPSK, QPSK, QAM and PAM.

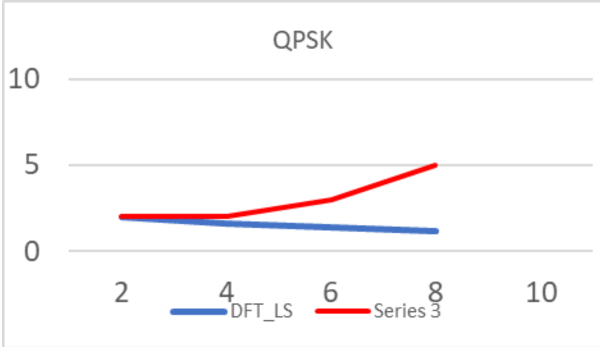

Figure 14 MSE vs SNR for DFT using QPSK

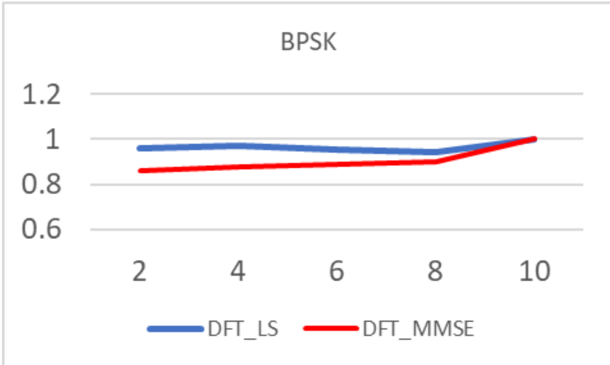

Figure 15 MSE vs SNR for DFT using BPSK

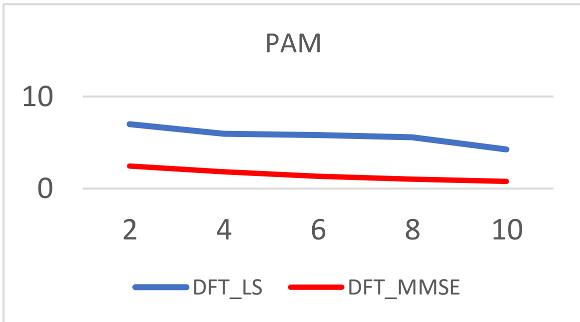

Figure 16 MSE vs SNR for DFT using PAM

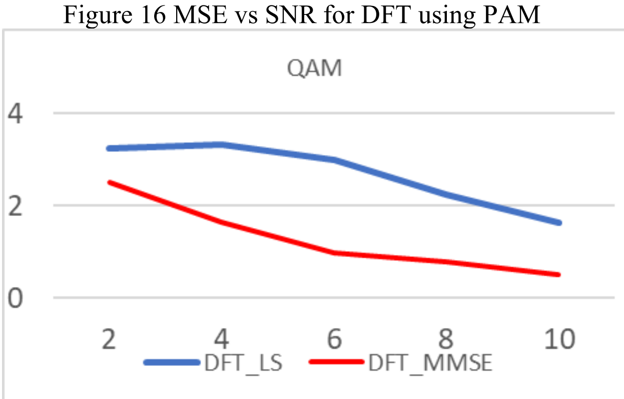

Figure 17 MSE vs SNR for DFT using QAM

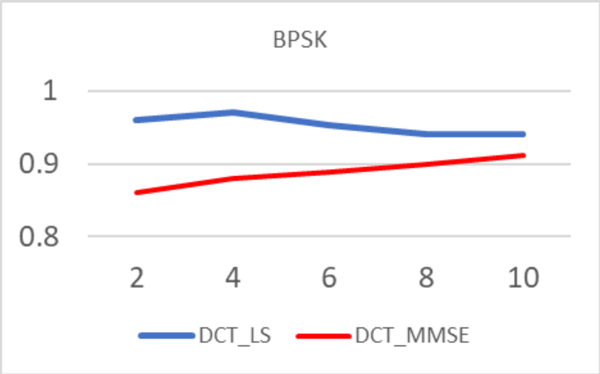

Figure 18 MSE vs SNR for DCT using BPSK

From the plots, we can clearly observe that LS has high BER compared to MMSE. So, it has high accuracy but implementation complexity of MMSE is high.

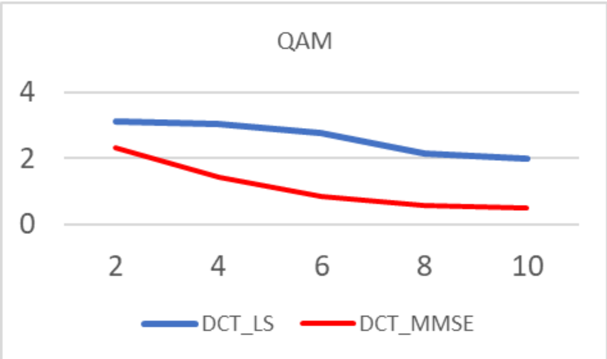

Figure 19 MSE vs SNR for DCT using QAM

F. Comparison for DCT and DFT on MSE vs SNR

These are comparisons for DCT and DFT Based OFDM in terms of MSE for different SNR values. For example, we can clearly observe that in QPSK modulation with SNR value as 2, the BER for LS Estimation using DFT-Based OFDM is around 2 But BER for LS Estimation using DCT-Based OFDM is less than 2. Hence DCT-Based OFDM has less MSE compared to DFT-Based OFDM.

IV. CONCLUSIONS

This paper gives a brief analysis of channel estimation techniques for DCT based OFDM using different modulation techniques such as QPSK, BPSK, PAM and QAM. The simulated results show that, there is a clear decrease in the graphs for BER and MSE. It concludes that the DCT based OFDM estimation techniques show a better BER and MSE over DFT based OFDM. The plots of the BER of DCT based OFDM is better i.e. less than that of DFT based OFDM techniques. The MSE plots also proved that the DCT based OFDM estimation techniques are better than DFT based OFDM.

So, in this paper we found that the DCT based OFDM has a better performance and less noise interference when compared to DFT based OFDM. The better results are because of the trigonometric transforms which has greater noise immunity, less noise interference and requires less bandwidth than DFT based OFDM. In future the DCT based OFDM techniques can also implemented for MIMO OFDM systems.

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