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Channel Estimation Using DFT Based Automoly Classifying Neural Network

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ABSTRACT*:* Channel Estimation refers to the evaluation of the performance of a channel through which the data is sent. MIMO OFDM(Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing) systems are quite effective in terms of sending bulk data to the receiving end but it suffers with few problems also, like high amplification to noise ratio, etc. In such a scenario estimation techniques defines the ways of optimization against the data packets send and received through the channel. DFT is one of the effective techniques which can be used for the channel estimation. This paper focuses on the DFT based channel estimation technique and its comparison with other existing estimation techniques like MMSE, LS. This paper also includes a suggestion for the future enhancement of channel estimation techniques. An optimization technique like bacterial foraging optimization has been suggested here. The current paper focuses on the existing scenarios of channel estimation techniques. The current paper also describes that the future aspects of channel estimation may include variation in MMSE techniques. This paper gives a review of the initialization of the neural network through which the estimation can further be enhanced.

KEYWORDS: MIMO –OFDM, Channel Estimation, DFT, Neural Network, LS (Least Square), MMSE (Minimum Mean Square)

I. INTRODUCTION

For the past few years, advancement have been made by researchers in the field of wireless communication for achieving the data rate beyond 2Mbps range that can support a variety of multimedia applications. One of the optimistic approaches discussed so far is that OFDM stands for Orthogonal Frequency Division Multiplexing is a multicarrier modulation scheme where closely spaced subcarriers in a huge amount that are orthogonal in nature are used to carry data over various parallel data, streams or channels. Each subcarrier mapped onto a standard modulation scheme such as phase shift keying(PSK), or quadrature amplitude modulation (QAM) at a low symbol rate that preserve an entire data rate equivalent to a single carrier modulation scheme with the same bandwidth. This orthogonality helps in separation of signals from the receiver that may get overlapped at the transmitter that eliminates Intercarrier Interference (ICI) and parallel transmission ensures a low data rate that could diminish the probability of Intersymbol interference (ISI) thus it nearly doubles spectral efficiency [1]. By the efficient utilization of bandwidth OFDM has been accepted over numerous wireless standards such as digital video broadcasting (DVB-T), digital audio broadcasting (DAB), the IEEE local area network and the metropolitan area network (MAN) standard. Applications of OFDM make it a strong contender for upcoming 4G wireless communications [2]. Practically, OFDM works either as modulation or as the multiplexing technique. Advantages of OFDM make a reincarnation in the world of the next generation high-speed wireless and mobile communications systems. OFDM uses N overlapping (but orthogonal) subbands, where individual having a baud rate of 1/T and they are spaced 1/T intervals apart. DFT-based algorithm uses this feature to increase the performance of the LS and MMSE algorithms. Now-a-days different communication systems have come into the picture. One of the most optimistic communication schemes for high data rate is MIMO (Multiple Input Multiple Output) [3], [4], [5]. The MIMO concept was first introduced by Jack Winters in 1987 for two basic communication systems [6]. In wireless broadband systems, receiver complexity gets highly reduced by the application of Orthogonal Frequency Division Multiplexing (OFDM). However, in this case synchronization and channel estimation plays an important role. So a new scheme that allows multiple users to have access over the same channel by integrating TDM and FDM known as Multiple Input Multiple output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM). These features increase its popularity for the next generation wireless communication systems such as WLAN, WMAN, Wimax and the 3G-LTE standard that accustomed several users in the same channel at the same time without making use of extra bandwidth [6].

II.RELATED WORK

In [1] author discussed about the number of PHY layer issues such as synchronization and channel estimation useful for the implementation of broadband MIMO-OFDM systems. Space time coding techniques and adaptive analog beam forming that can provide best path for MIMO channel environment. Then author discussed about error correction codes where he emphasized on high-rate LDPC codes. In [4] author implemented MIMO-OFDM system where they proposed enhanced MIMO detection algorithm based on per-antenna-coding (PAC) at the transmitter where PAC V-BLAST performs outstanding than the complex PAC soft output maximum likelihood detection (MLD) scheme in terms of Bit Error Rate (BER) and Packet Error Rate (PER).At the end by this algorithm throughput get enhanced by the factor of three. In [6] author compared the performance of MIMO-OFDM system using V-BLAST architecture in terms of BER(Bit Error Rate) by considering different modulation schemes by varying both transmitting and receiving elements on AWGN channel. As a result high spectral efficiency is achieved. In [8] Channel estimation based on comb type pilot arrangement with low pass interpolation performs best than block type arrangement with decision feedback equalizer whose BER is 10-15db higher for fast fading channels Thus comb type is more robust for increase in doppler frequencies. In [11] Optimized channel estimation for slow time varying channels has been achieved using optimal equipowered, equispaced and phase shift orthogonal training sequences in terms of MSE of the channel estimate and BER that has provided 3db gain in SNR at a BER of 10-2 and Doppler spread fd = 5 Hz where training has been shown over multiple OFDM symbols. RLS (recursive least square) algorithm used to obtain considerable gain of 2db in SNR with smaller Doppler spread. In [13] author compared the performance of LSE channel estimation based on linear pilot interpolation for OFDM system uplink. The results are tested under AWGN and SUI where it is clearly shown that known channel estimation is superior to linear interpolation channel estimation with the difference of more than 2db.

III. OFDM SYSTEMS

The method for generating an OFDM symbol is as follows:
Initially, N data complex symbols are cushioned with zeros to get N_S symbols that are utilized to compute the IFFT. The yield of IFFT is the essential OFDM symbol focused around the deferral spread of the multi-way channel; a particular gatekeeper time must be chosen (say T_G). Various specimens comparing to this gatekeeper time must be taken from the beginning of the OFDM symbol and added at the end of the symbol. Also, the same number of specimens must be chosen from the end of the OFDM symbol and must be embedded in the starting. The OFDM symbol must be increased with the raised cosine window to uproot the force of the out-of-band sub-bearers. The windowed OFDM symbol is then added to the yield of the past OFDM symbol with a deferral of T_R, so that there is a cover locale of bT_R between each symbol [8].

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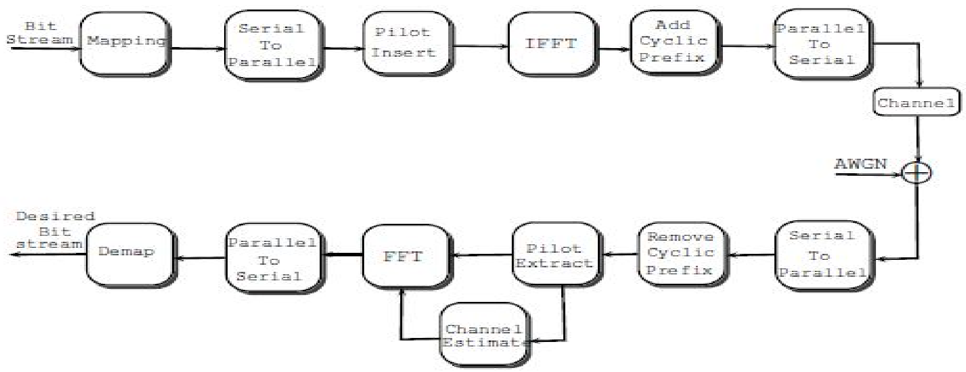

Figure 1: Block Diagram of the OFDM system [8]

III. MIMO SYSTEM

MIMO technology, a remarkable performer in the field of wireless communications, in light of the fact that it offers noteworthy expands in information throughput and connection range without extra transfer speed or expanded transmit power. It attains this objective by spreading the same aggregated transmit power over the receiving wires, so as to accomplish array gain that enhances the spectral efficiency (more bits for every second for every hertz of data transfer capacity) and then achieve a diversity gain that improves the link reliability (reduced fading). Functions of MIMO further classified into three main categories: Precoding, Space Time Coding (STC) and Space Division Multiplexing (SDM). STC enhanced the overall performance of the wireless network by coding over the different transmitter branches; whereas SDM attains an increased throughput by transmitting individual data streams over different transmit branches simultaneously having the same carrier frequency [4]. Precoding considered as the multi-stream beamforming. In more general terms, it reviewed as all spatial processing that occurs at the transmitter. In (individual-stream) beamforming, the same signal emitted from each transmit antennas with appropriate phase and gain weighting such that signal power maximized at receiver input.

IV. MIMO-OFDM SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM) whose vigor towards frequency selective fading,, a proficient utilization of spectral proficiency, and low computational multifaceted nature satisfied it as great physical layer innovation for high-bit rate remote correspondence. The amalgamation of multiple-input multiple-output, (MIMO) and orthogonal frequency-division multiplexing, (OFDM) technologies, known as MIMO-OFDM, is right away under study as a standout amongst the most yearning hopefuls for cutting edge interchanges frameworks, floating from remote LAN to broadband access. It expands the diversity gain alongside the framework limit by misusing spatial area. Since the OFDM framework guarantees different parallel narrowband channels, MIMO-OFDM analyzed as a key engineering in a rising high-information rate frameworks, for example, 4G, IEEE 802.16, and IEEE 802.11n[3]. MIMO frameworks join different receiving wires at both the transmitter and recipient that use the spatial space for spatial multiplexing alongside spatial diversity.

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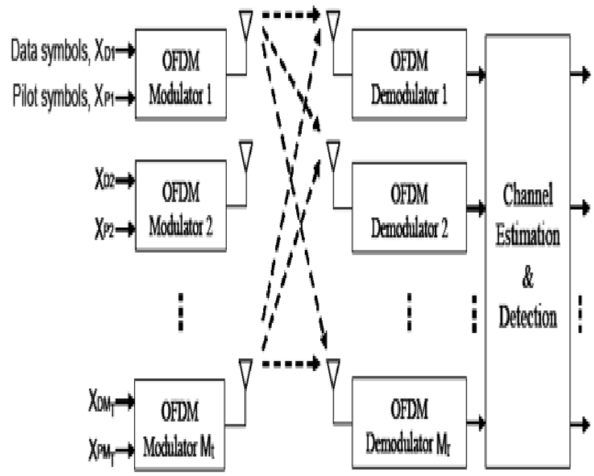

Figure 2: MIMO OFDM System [3]

Figure 2 shows the MIMO OFDM system. OFDM defined as multi-carrier modulation where the selection of spacing among the carriers is done to make them properly orthogonal to each
other. Two input sequences are orthogonal if their dot product is zero. That is; by assuming two different sequences and multiplied them together [3]. On the off chance that their indispensable over an interim is zero, then those two sequences are orthogonal in that interim. Orthogonality might be attained via precisely selecting carrier spacing, for example, guaranteeing the carriers dispersing between them be equivalent to the equal of the helpful symbol period. As the subcarriers are orthogonal, the range of every carrier has an invalid at the core recurrence of each of alternate transporters in the framework [3], [7], [8]. That results in no obstruction between the carriers, permitting them to be divided in close closeness to one another. It sections the entire recurrence range into sub-groups little enough with the goal that the channel impacts are consistent (level) over a given sub-band. At that point a traditional IQ (In stage Quadrature stage) regulation (BPSK, QPSK, QAM, and so forth.) is sent over the sub-band [9]. An extensive number of nearly dispersed orthogonal subcarriers are utilized to convey information. The information is partitioned into a few parallel information streams or channels, one for every subcarrier. OFDM converts the recurrence particular blurring channels into parallel even blurring a sub channel, as long as the cyclic prefix (CP) embedded at the start of every OFDM sequence is longer than or equivalent to the channel length[10].

V. CHANNEL ESTIMATION

For extenuating, the result of channel distortion channel estimation employed over wireless communication systems considered as one of the challenges in MIMO-OFDM systems. It gives an idea how the physical channel responds to an input sequence. In other words, it predicts the impulse response of the system in the form of the mathematical model that shows what is happening. It has been evaluated from a number of researches that more the accurate channel state information better will be the coherent detection of data symbols at the receiver [11]. Channel estimation algorithms classified into three main categories, training based, semi-blind and blind methods. The blind channel estimation method depends on the received symbols that are completely unknown to the transmitter. It exploits the use of training symbols that extract the Channel state information (CSI) on the basis of evaluating statistical information and hence saves the bandwidth [11], [12]. While in training based, MIMO systems extract CSI before the transmission of data where training sequences or pilot symbols used for channel identification introduced at the starting of each frame for synchronization. When the CSI varies crucially over a time varying channel, a retraining sequence is transmitted [11]. The use of Blind methods together

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with training data to have better prediction on the channel variations known as semi-blind methods. This process highly removes the effect over the convergence period of blind subspace algorithm that became unreliable in real-time systems [12].

On the basis of training sequences or pilot assisted there are two kinds of channel estimation, one is a Block type where pilot insertion performed in the frequency domain using all the subcarriers. The Pilot's insertion is not at all the OFDM symbols, instead covering all the frequencies that do not require interpolation as shown in Figure 3 [13].

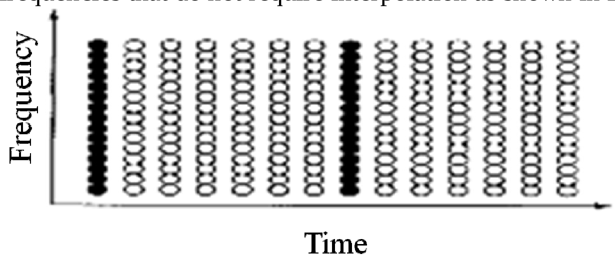

Figure 3: Block type Pilot Arrangement,

Another one is Comb Type where pilot insertion performed in the time domain by using a set of subcarriers and, therefore, needs interpolation. The Pilot's insertion carried out at all of the OFDM symbols as shown in Figure 4 [13].

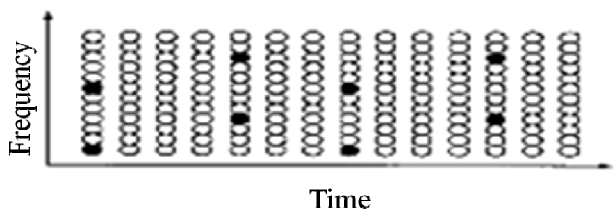

Figure 4: Comb Type Pilot Arrangement

VI. METHODS OF CHANNEL ESTIMATION

A. Least Square Channel Estimation

In comb, type pilot arrangement if N_p pilot symbols are inserted into X (k) in accordance with the equation [8] written below:

$$\mathbf{X(k) = X(mL + l)} \qquad l = 1, 2\ldots\ldots\ldots L-1 \qquad \text{(i)}$$

Where L = No. of Subcarriers / N_p and m is Pilot Carrier Index.

By the use of guard interval for the elimination of Intersymbol interference, the equation analyzed in the matrix notation is as described below:

$$\mathbf{Y = XFh + W} \qquad \textbf{(ii)}$$

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Where

$\mathbf{X} = \mathbf{diag\{X\ (0),\ X\ (1)\ldots\ldots\ldots\ldots X\ (N\text{-}1)\}}$ is transmitted vector

$\mathbf{Y = [Y\ (0),\ Y\ (1)\ldots\ldots Y\ (N\text{-}1)]^T}$ is received vector

$\mathbf{W = [W\ (0),\ W\ (1)\ldots\ldots\ldots W\ (N\text{-}1)]^T}$ is AWGN (Additive white Gaussian noise) vector

$$\mathbf{DFT\ (h) = H = [H\ (0),\ H\ (1)\ldots\ldots\ldots H\ (N\text{-}1)]^T}$$

$$\mathbf{F} = \begin{vmatrix} \mathbf{TW^{00}{}_N} & \cdots & \mathbf{TW^{0\ (N-1)}{}_N} \\ \vdots & \ddots & \vdots \\ \vdots & & \vdots \\ \mathbf{TW^{(N-1)0}{}_N} & \cdots & \mathbf{TW^{(N-1)\ (N-1)}{}_N} \end{vmatrix}$$

is the DFT matrix with

$$\mathbf{TW^{ik}{}_N} = \frac{1}{\sqrt{N}}\ e^{-j2\pi \mathrm{ik}/N}$$ defined as the **twiddle factor**

Now by applying LS Channel estimation for MIMO-OFDM lessens the error between estimated values and standard values. LS does not consider the distribution of channel noise and channel statistical characteristics. Therefore channel estimation between n_{th} transmit and m_{th} receive antenna in the matrix notation [8] represented as

$$\widehat{\boldsymbol{H}}_{\mathbf{LS}} = (\mathbf{X^{(n)}})^{-1}\,\mathbf{Y^{(m)}} \qquad \textbf{(iii)}$$

Where $\widehat{\boldsymbol{H}}_{\mathbf{LS\ represents}}$ the LS Channel Estimate

The plot for LS channel estimation among BER, MSE and SNR are discussed in the 'results' section.

***B*. Minimum Mean Square Estimation (MMSE)**

The MMSE estimator incorporates the second order statistics of the channel conditions that minimize Mean Square Error (MSE). The time domain correlation exploitation of the channel and then analyzing the impact of noise the estimation so obtained from the LS passed through the MMSE filter. Let $\mathbf{R_{hh}}$, $\mathbf{R_{HH}}$, and $\mathbf{R_{YY}}$ be the auto-covariance matrix of h, H, and Y, respectively and $\mathbf{R_{hY}}$ be the covariance matrix between h and Y. Then the MMSE Channel estimation $\widehat{\boldsymbol{H}}_{\mathbf{MMSE}}$ for the MIMO-OFDM system between n_{th} transmitter and m_{th} receiver analyzed [8] as below:

$$\widehat{\boldsymbol{H}}_{\mathbf{MMSE}} = \mathbf{F\ R_{hY} R_{yy}{}^{-1}\ Y} \qquad \textbf{(iv)}$$

$$\mathbf{R_{hY} = E\ \{hY\} = R_{hh}\ F^H\ X^H} \qquad \textbf{(v)}$$

$$\mathbf{R_{YY} = E\ \{YY\} = X\ FR_{hh}\ F^H\ X^H + \sigma^2\ I_N} \qquad \textbf{(vi)}$$

Where $\boldsymbol{\sigma}^2$ is noise variance $\mathbf{E\ \{|W\ (k)\ |^2\}}$ and $\mathbf{I_N}$ is the N×N identity matrix.

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Sometimes, the channel statistics are not available, so it becomes difficult to estimate the channel in this situation. However, in OFDM systems the signal can be available at the receiver via pilot carriers.The plot for MMSE channel estimation among BER, MSE and SNR are discussed in the 'results' section.

C. DFT based channel estimation

DFT requisition over LS, MMSE channel estimation, enhances the general execution of estimators by removing the impact of noise. In an OFDM framework, the length of the channel motivation reaction is normally short of what the length of cyclic prefix L. DFT-based calculation utilizes this gimmick to build the execution of the LS and MMSE calculations [14]. It changes the recurrence channel estimation into time channel estimation utilizing IDFT, considers the part that is bigger than L as commotion, and afterward treats that part as zero so as to wipe out the effect of noise. Let H[k] indicate the assessment of channel increase (gain) at the kth subcarrier, acquired by either LS or MMSE channel estimation system. Taking the IDFT of the channel estimate [14]

$$\{\hat{H}[k]\}^{N-1},$$

$$\mathrm{IDFT}\{\widehat{H}[k]\} = h[n] + z[n] \;\; \hat{h}[n] \qquad n=0, 1\ldots N-1 \qquad \text{(vii)}$$

Where,
Z[n] depicts the noise component in the time domain.
The estimation accuracy increased by removing the effect of noise from the time domain.

$$\hat{h}_{DFT}[n] = \{h[n] + z[n], \; n==0, 1, 2\ldots\ldots L-1$$

$$0 \quad , \quad \text{otherwise}\} \qquad \text{(viii)}$$

Taking the DFT of the remaining L elements that transform the resulting equation into the frequency domain.

$$\hat{H}_{DFT}[k] = \mathrm{DFT}\{\hat{h}_{DFT}[n]\} \qquad \text{(ix)}$$

The plot for DFT based channel estimation among BER, MSE and SNR are discussed in the ' results' section.

VII. NEURAL NETWORK

Neural systems, with their striking capacity to determine significance from entangled or uncertain information, might be utilized to concentrate examples and locate slants that are so intricate, there is no option be perceived by either people or other workstation methods. A prepared neural system might be considered a "master" in the classification of data it has been given to dissect. This master can then be utilized to give projections given new circumstances of investment and reply "what if"questions[15].

Different peculiarities include:

Adaptive Learning: The capacity to figure out how to do assignments focused around the information given for preparing or beginning knowledge.

Self-Organisation: ANN can make its own particular association or representation of the data it gets throughout learning time.

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Real Time Operation: ANN processing may be done in parallel, and extraordinary fitting gadgets are continuously outlined and produced which exploit this competence.

Shortcoming Tolerance by means of Redundant Information Coding: Partial demolition of a system prompts the comparing debasement of execution. Notwithstanding, some system capacities may be held even with significant system harm[15].The description of Neural Network based channel estimation for MIMO-OFDM systems is discussed in the next section.

VIII. RESULTS AND DISCUSSIONS

Training of the system using neural network: The OFDM system has been trained using a neural network in order to optimize the estimation model designed previously. The model contains guard band interval values which would be optimized using NEURAL NETWORK. The neural network takes two inputs: First, the general OFDM-MIMO architecture and second an Initial guard band with the data to be sent. The guard band is checked in the iterations that whether the current guard band is suitable for the data transmission or not. If the guard band is less than the appropriate guard band according to the architecture system, it is increased by a ratio, and when the neural propagates back, it checks that whether the threshold band is fit or not. In terms of BFO, the guard band is not termed as a simple one input value, rather it comes in the range to save the iteration. The BFO method picks an optimal value for the transfer. The procedure is repeated for the FFT range also as if the data FFT is not optimal, the BFO method generates a range for the same and the FFT length is enhanced according to BFO outcome values.The results of this experimental work are described below:

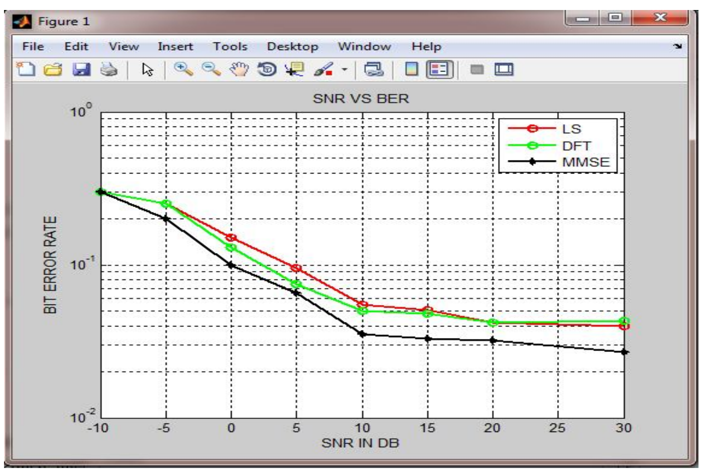

Figure 5: Graph between BER vs. SNR for LS, MMSE and DFT channel estimators

Figure 5 represents the comparison of DFT, LS and MMSE in terms of the Bit Error Rate (BER) and Signal to noise ratio (SNR). Figure 5 depicts that SNR is directly proportional to the signal strength whereas the Bit error rate reduces the effectiveness of the data packets sent. From the above graph, it is quite clear that DFT has an edge over the LS mechanism in improvisation of the bit error rate.

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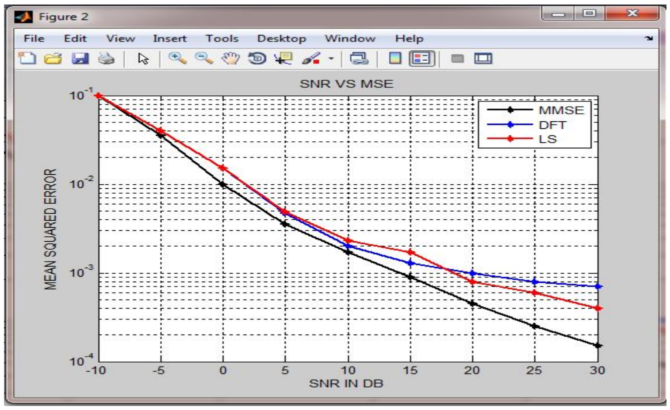

Figure 6: Graph between SNR vs. MSE for LS, MMSE and DFT Channel estimators

Figure 6 represents the SNR vs. MSE graph which states that MSE for DFT technique is more in comparison to the LS and MMSE.

IX. CONCLUSIONS

With the observed results above, it could be inferred that the channel estimation is a unique method to identify the capacity of the channel and predict that how much error would occur if the data propagates through the channel. It is also observed that the estimation techniques can be optimized. The current experiment opens up lots of gates for future research works as the current system does not include the types of MMSE technique or any optimization technique like GA, ACO, and BFO.

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