B.Tech. Major Project -

Channel Estimation in MIMO OFDM System in 5G using Deep Learning

Under Supervision of Prof. Purnendu Karmakar-

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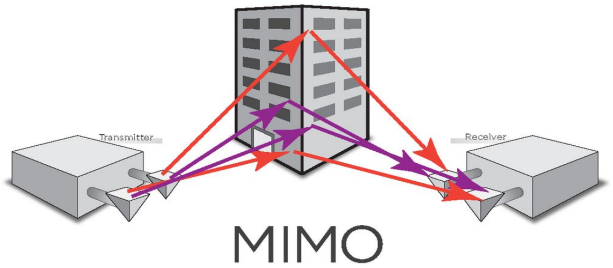
Introductions

01 We understand the basics of MIMO OFDM systems in brief.

02 Gaining insights in other theoretical concept like Cyclic prefix, LSE,MMSE,Pilots,Deep Learning,etc

03 Understanding various Estimation Techniques and Deep Learning Concept.

MIMO OFDM



Multiple Input Multiple Output(MIMO) system is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver).

Orthogonal frequency-division multiplexing (OFDM) is a method of digital signal modulation in which a single data stream is split across several separate narrowband channels at different frequencies.

Theoretical concepts

LSE

Least Square Error Estimator

Minimising the Euclidean square distance between the transmitted and received signal

- Easy to implement
- Less Complex
- More MSE

MMSE

Minimum Mean Square Error Estimator

Applies the channel statistics to minimise the MSE

- Difficult to implement
- More Complex
- Less MSE

Pilot

Pilot signal Addition

Comb type pilot signal is periodically added for channel clearance and control purpose.

- Added to Tx and Rx
- Comb type in frequency domain
- Periodically added

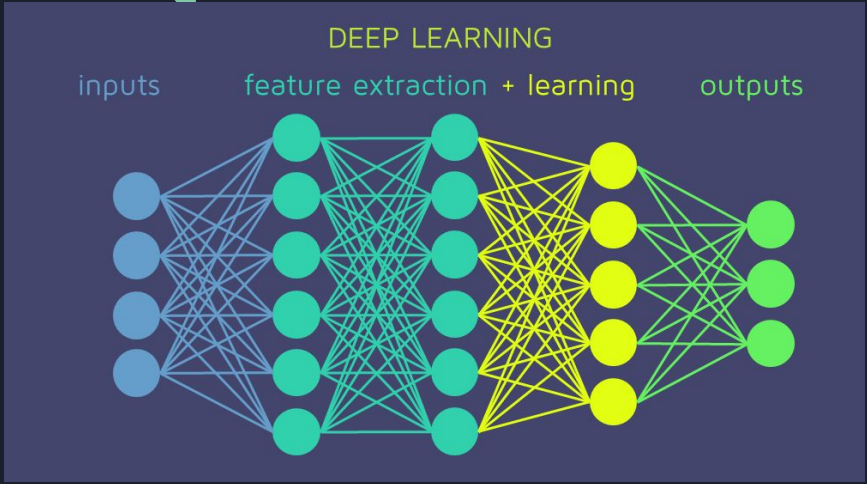
CP

Cyclic Prefix

Cyclic Prefix acts as a buffer that prevents OFDM signal from ISI and ICI or IBI.

- Cyclic Prefix can remove the frequency selective nature of OFDM and change into FLAT FADING.
- Length of the cyclic prefix can be varied

Deep Learning

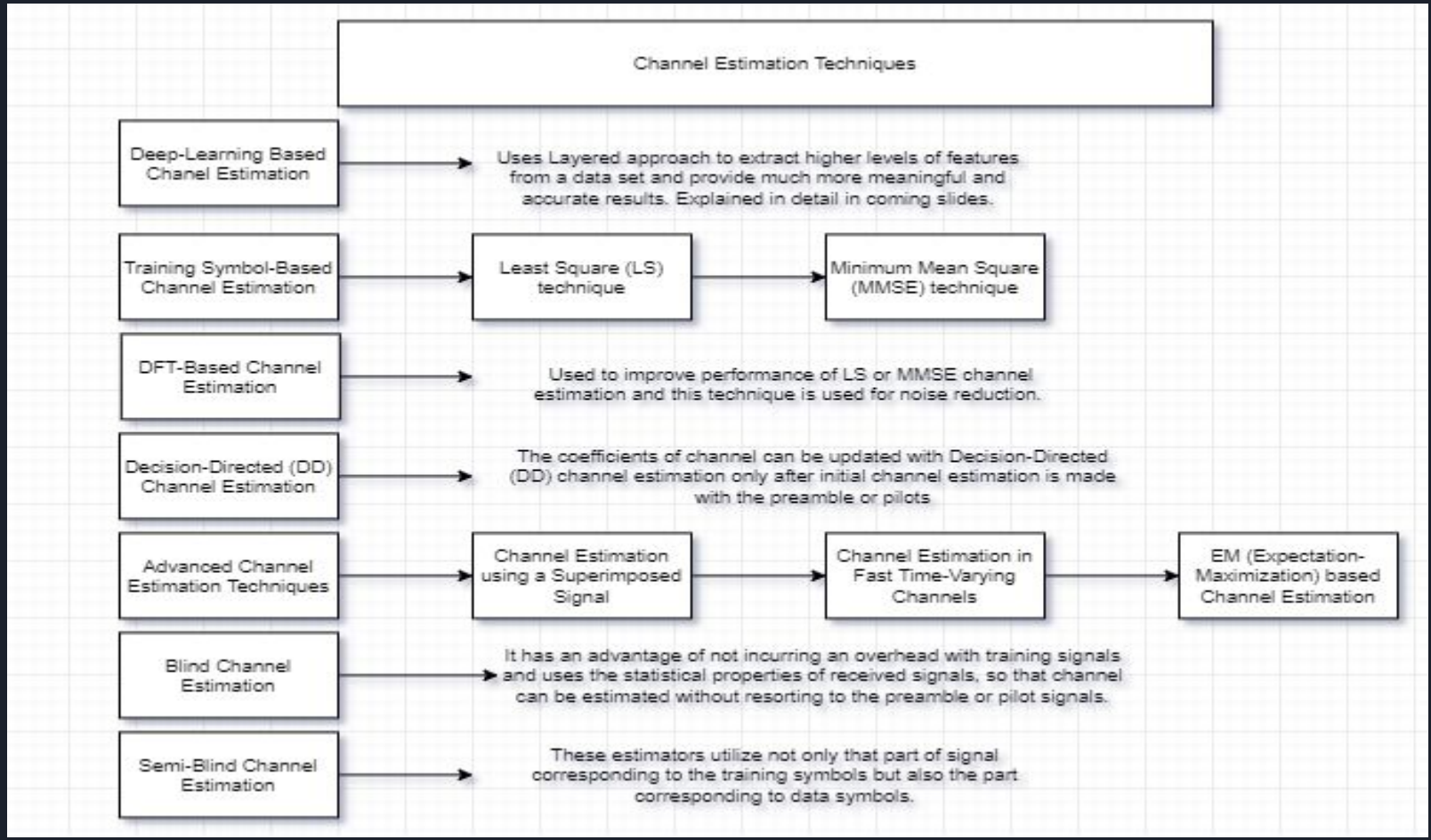


A basic deep learning model consists of three sections of Neural networks.

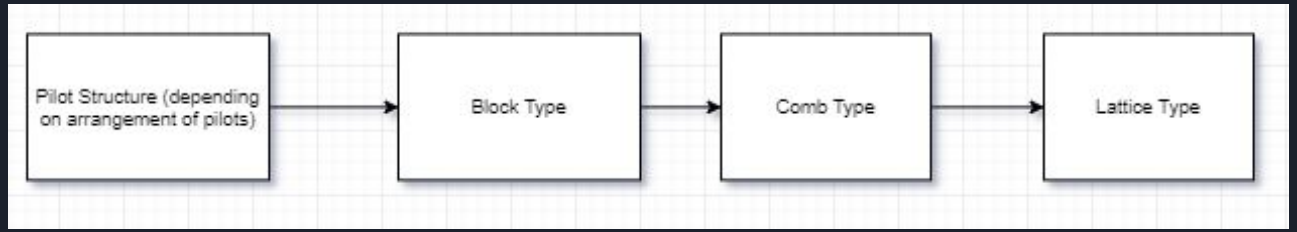
- Input Layer - Takes raw data input
- Hidden Layer - Uses algorithm to find trends in data
- Output Layer - Generates output based on calculations

Our Classification Model used a variety of basic DL NN like LSTM, Softmax layer, fully connected layers, etc. All these layers interact to minimise the loss function for lower BER values and hence better accuracy.

Literature survey of Estimation Techniques



Understanding Various Estimation Techniques



In this project, so far we've implemented Channel Estimation based on Block Type Pilot arrangement where we've performed estimation using LS (Least Square) estimator and MMSE (Minimum Mean Square Estimator) which comes under Training Symbol-based channel estimation technique. For LS estimation we've used Linear Interpolation.

Further, in the next phase of this project, we will be using Deep Learning technique as it provides result better than other traditional estimators which is explained in the next slide.

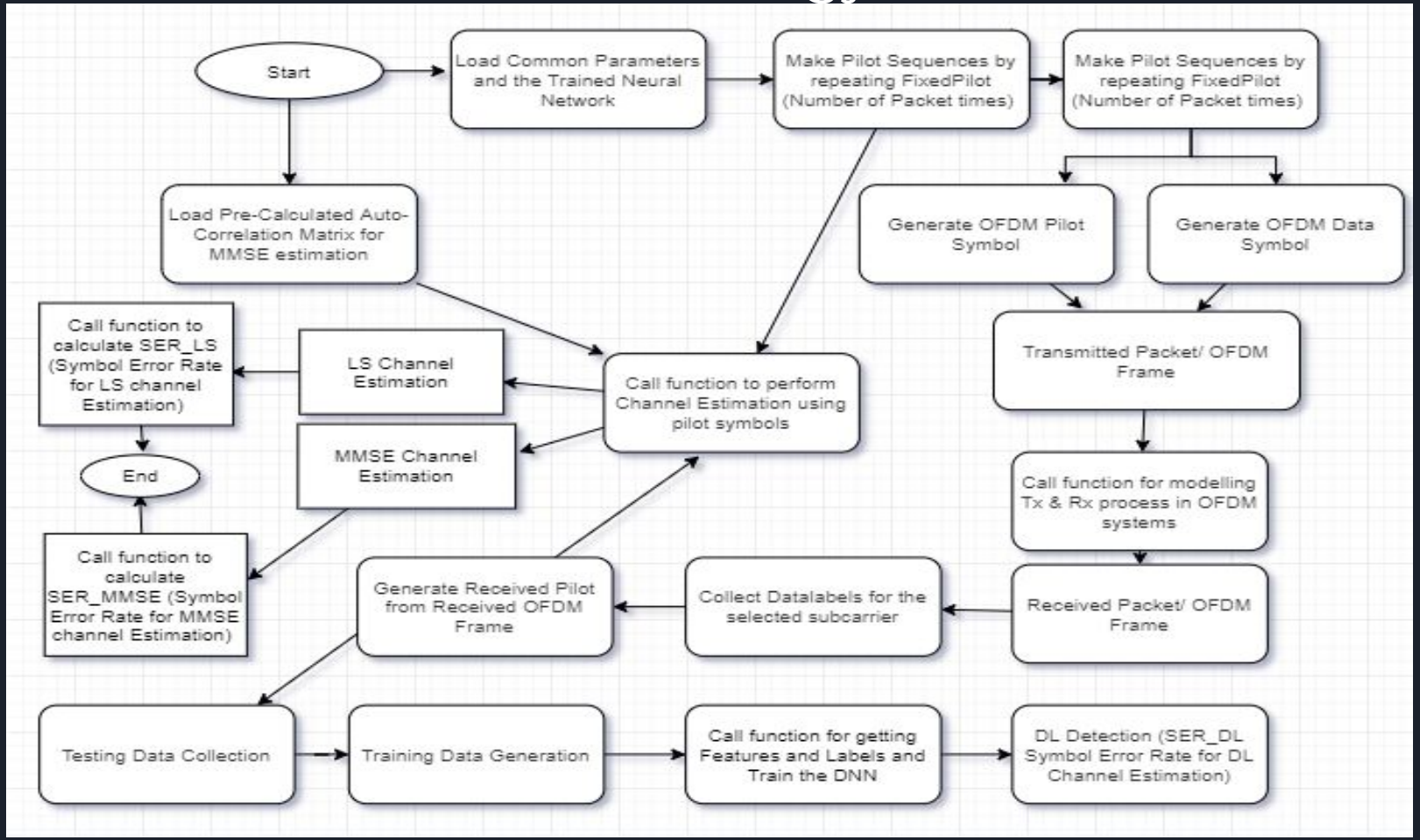
Problem In Literature and Improvements

01	Most researches didn't compare all three estimators (LSE, MMSE, DL) simultaneously	We were able to integrate the three estimators seamlessly into finding reliable results
02	Most researches did not focus on improving accuracy. They varied cyclic prefix or pilot symbols to see changes.	We exclusively tried to improve accuracy by reducing BER. Our efforts led to slightly better error rates
03	Many researches led to MMSE bearing better results or having highly complex DL models	We created a simple DL model which nearly mapped the results of MMSE.

Problem Statement ?

Minimization of channel estimation error using Deep learning Technique for MIMO OFDM 5G system.

Methodology



Understanding Code Flow

As can be seen from the code flow, we have called four functions in order to achieve our desired result. These functions serve the following purpose:

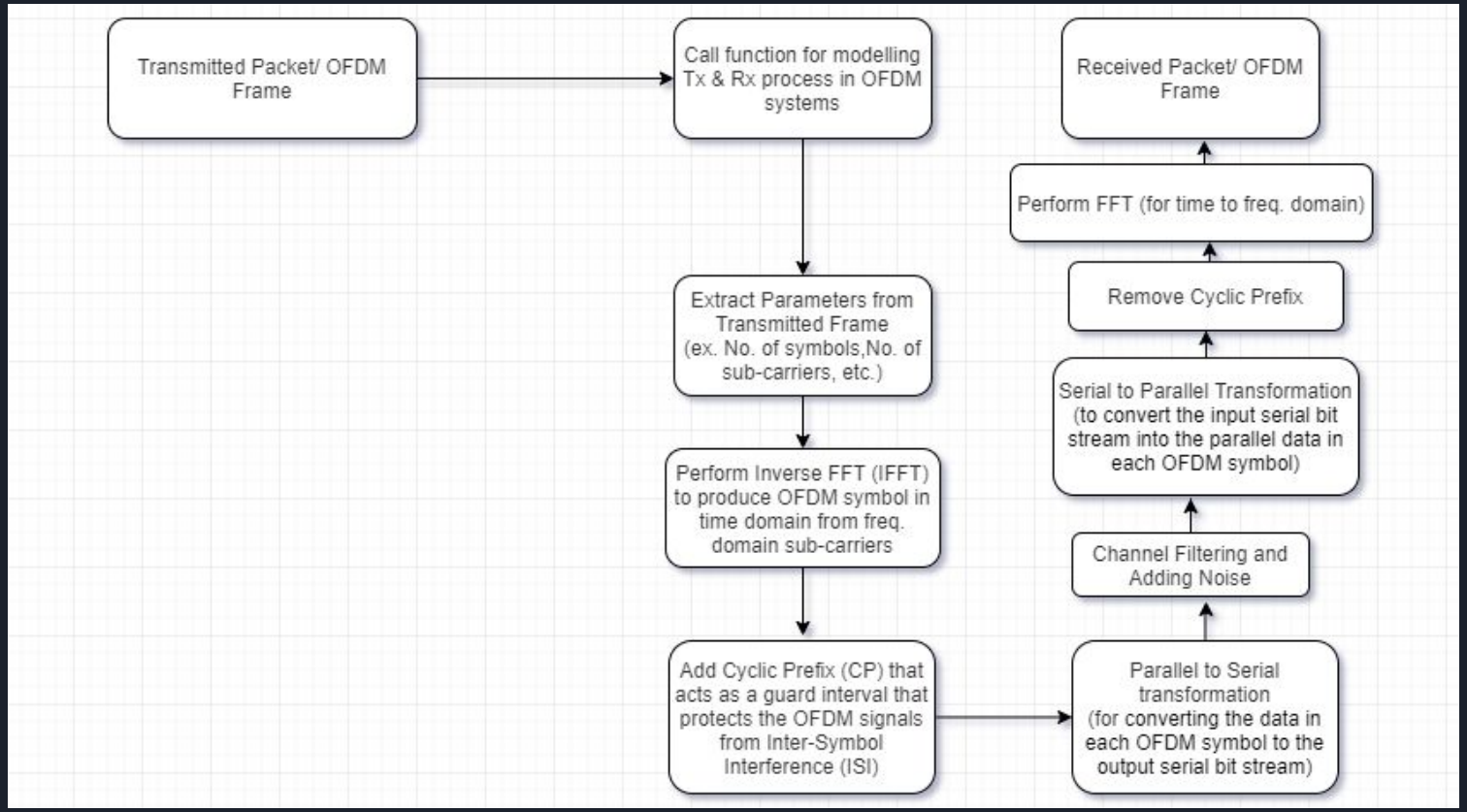
- **Function-1**: for modelling Transmission and Receiver process in OFDM systems.
- **Function-2**: for performing LSE and MMSE channel estimation.
- **Function-3**: for calculating SER (Symbol Error Rate) of LSE and MMSE channel estimation.
- **Function-4:** for obtaining features and labels

Apart from these functions we have also written codes serving the following purpose:

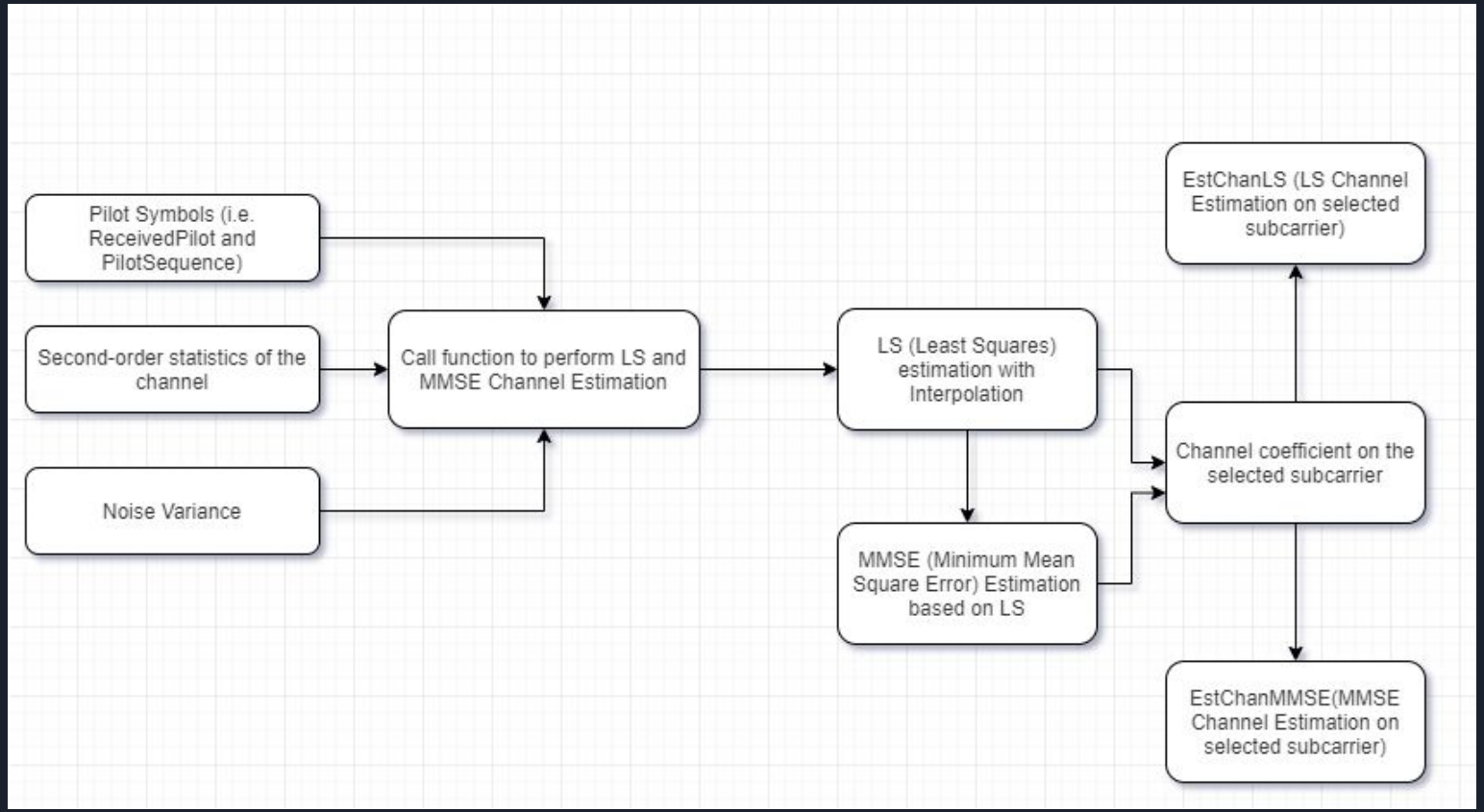
- Training Data generation and collection.
- Deep Learning model which takes the input and predicts labels (set-up parameters for training the DNN).

In next few slides we present a code flow for these functions and codes...

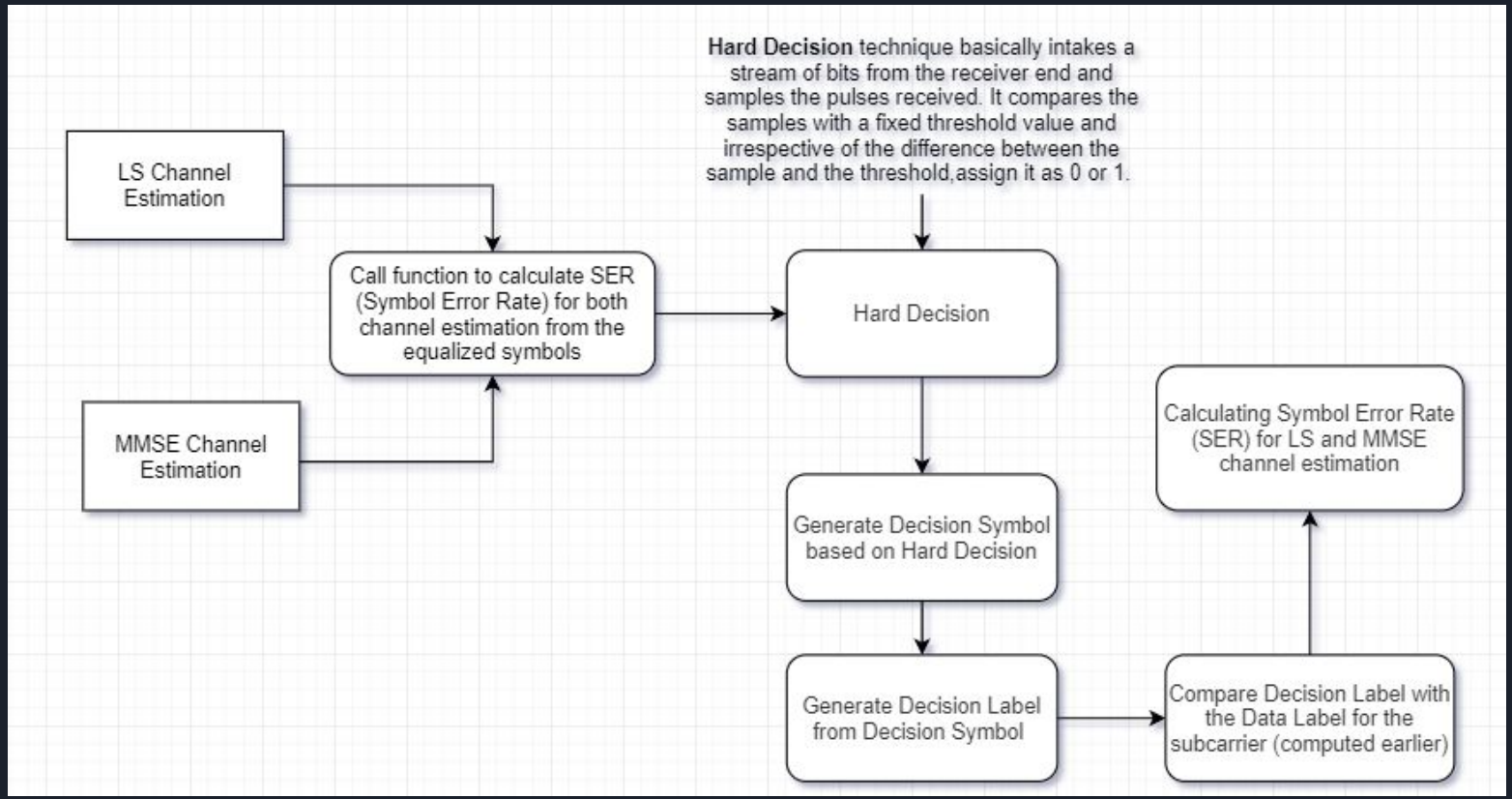
Function-1 (for modelling Tx and Rx process in OFDM systems).



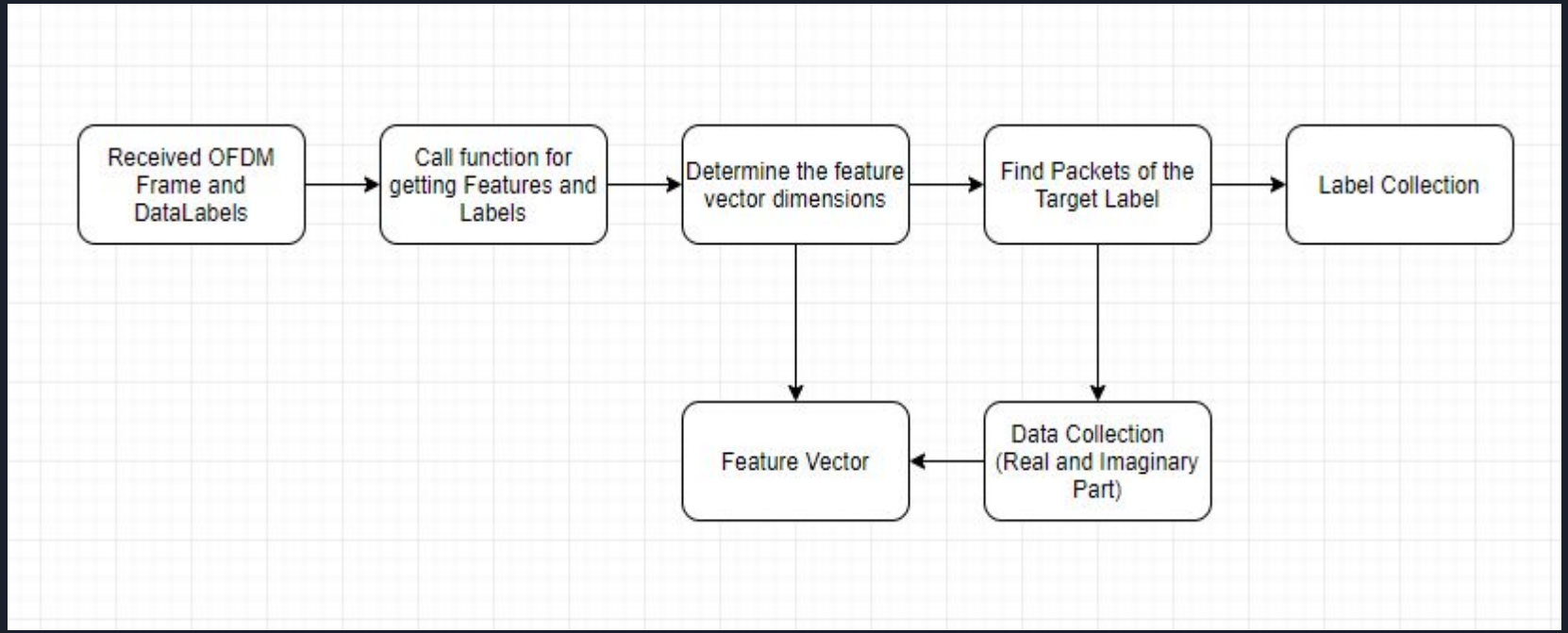
Function-2 (for performing LSE and MMSE channel estimation)



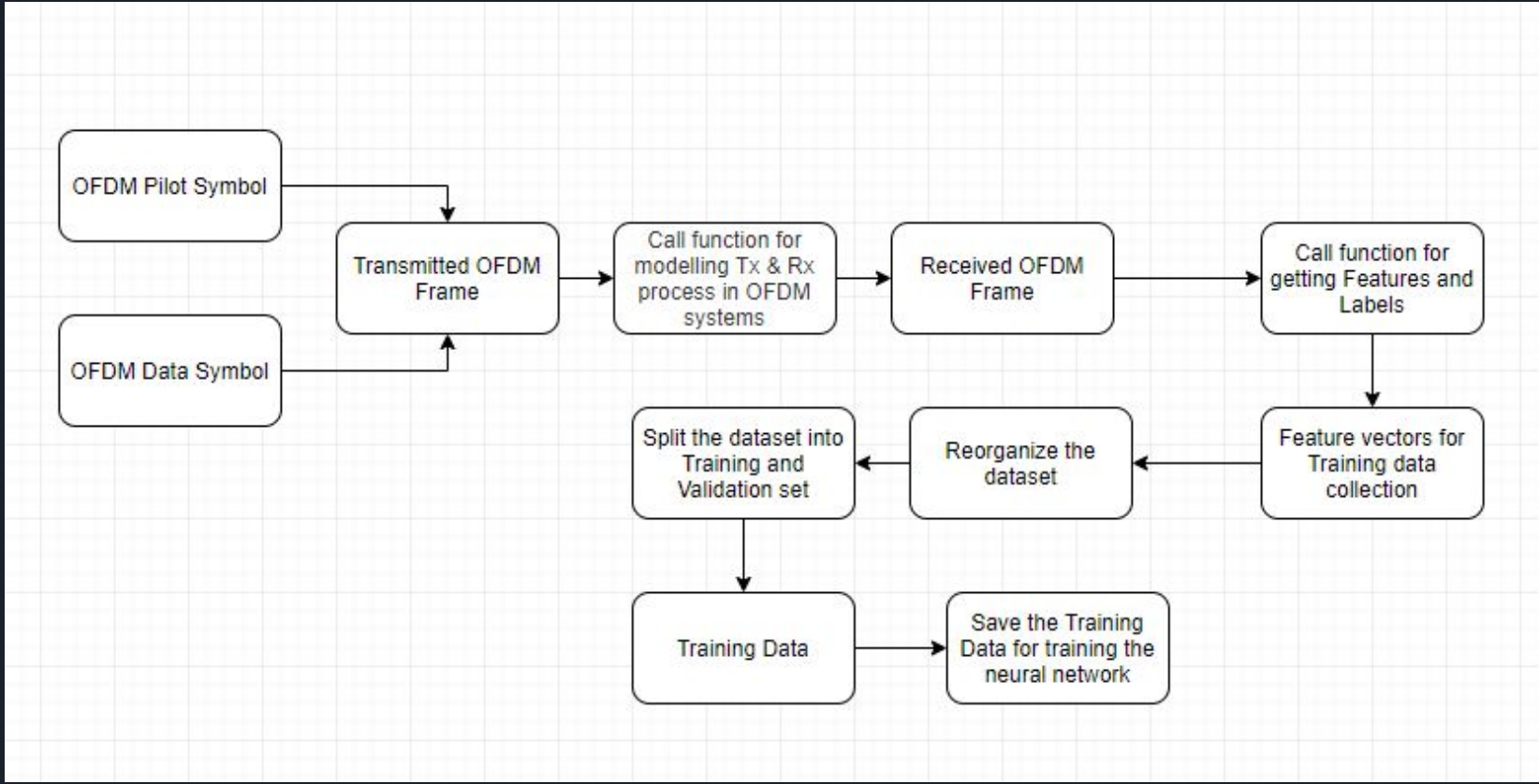
Function-3 (for calculating SER of LSE and MMSE channel estimation)



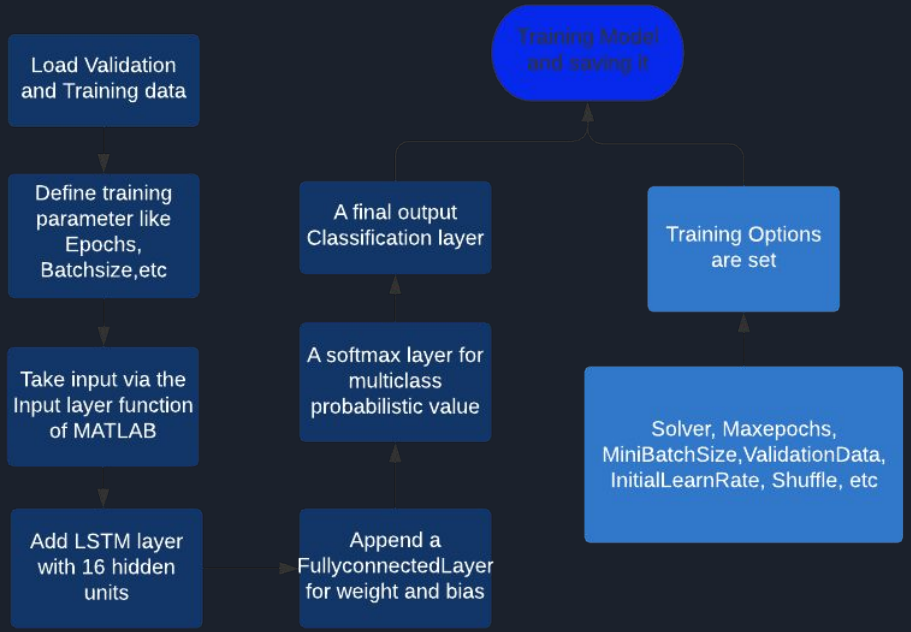
Function-4 (for obtaining Features and Labels)



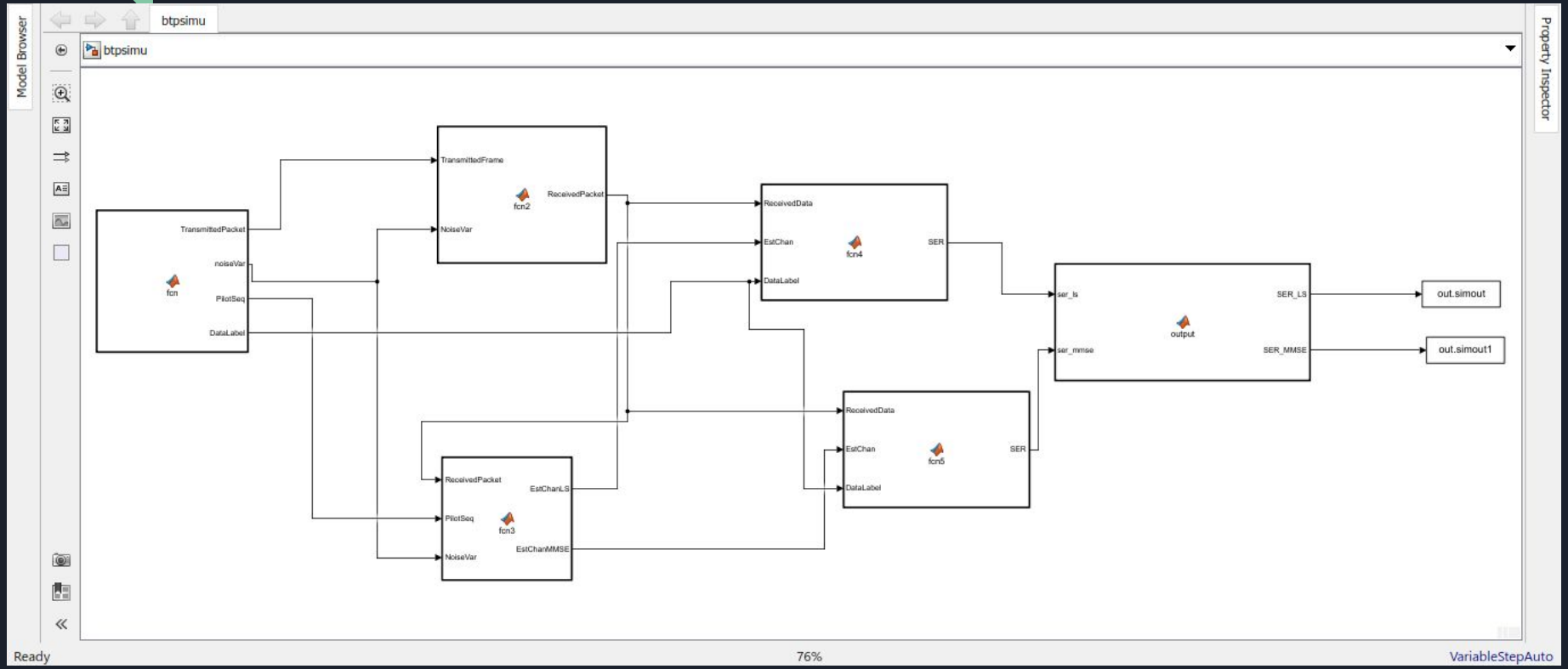
Training Data Generation and Collection



Deep Learning Model

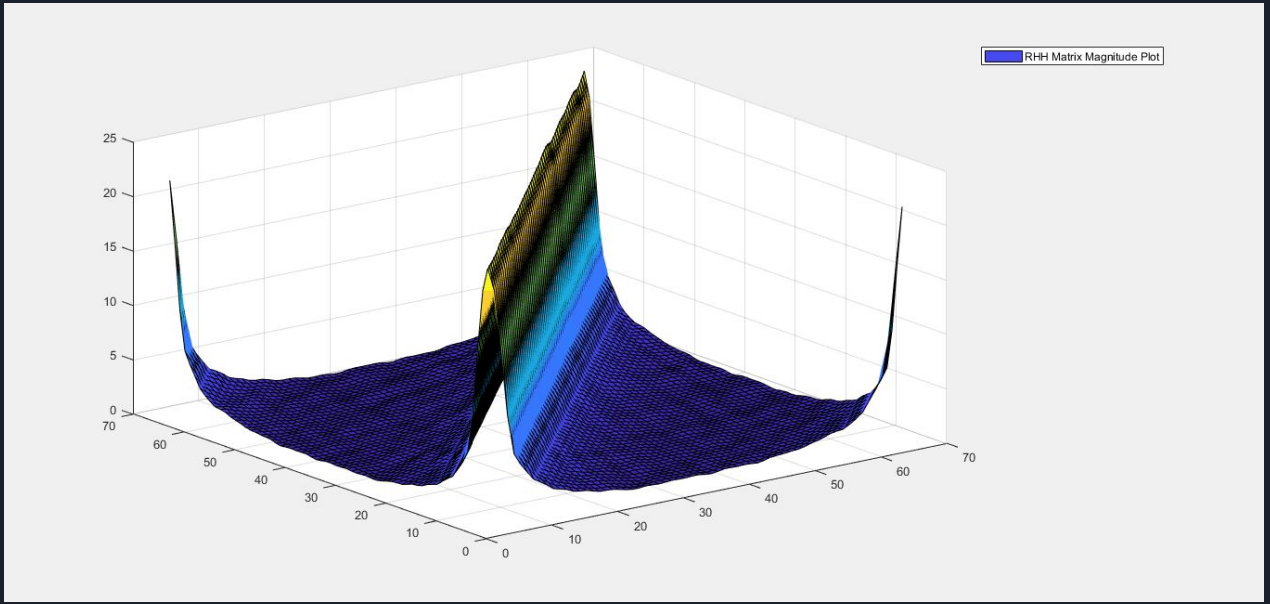


Simulation (Simulink Model)



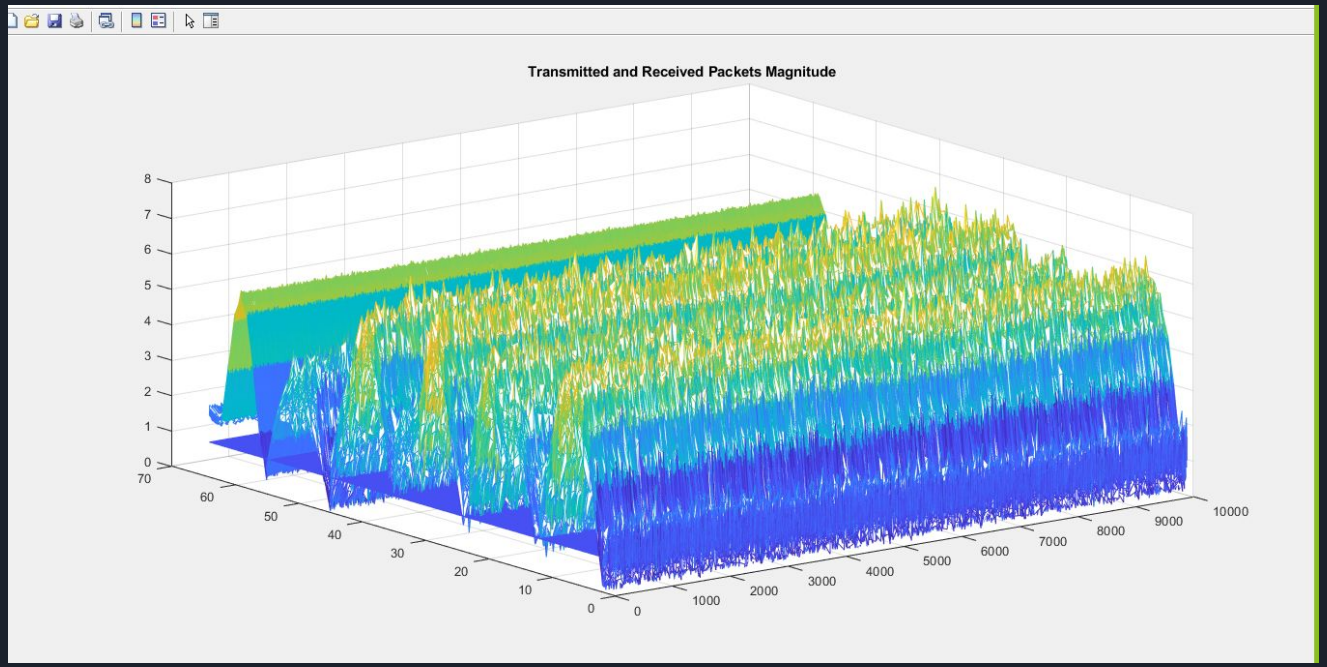
Results

Auto-Covariance of the channel frequency response



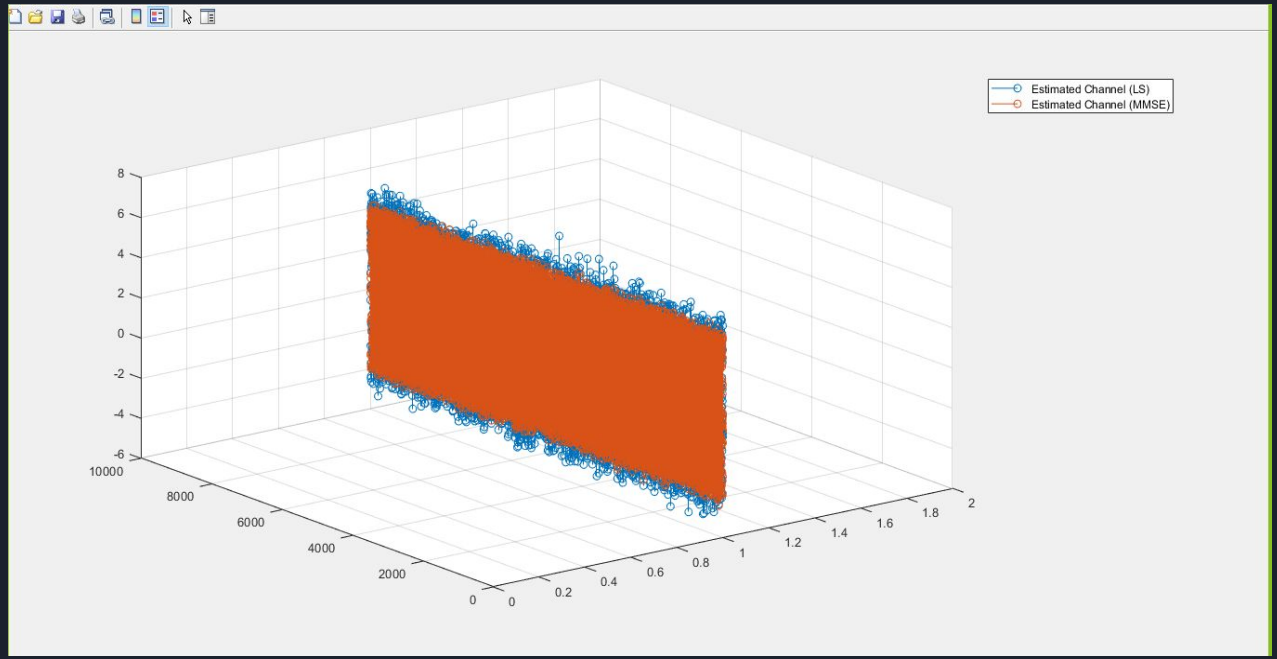
Results

Transmitted and Received packets Magnitude



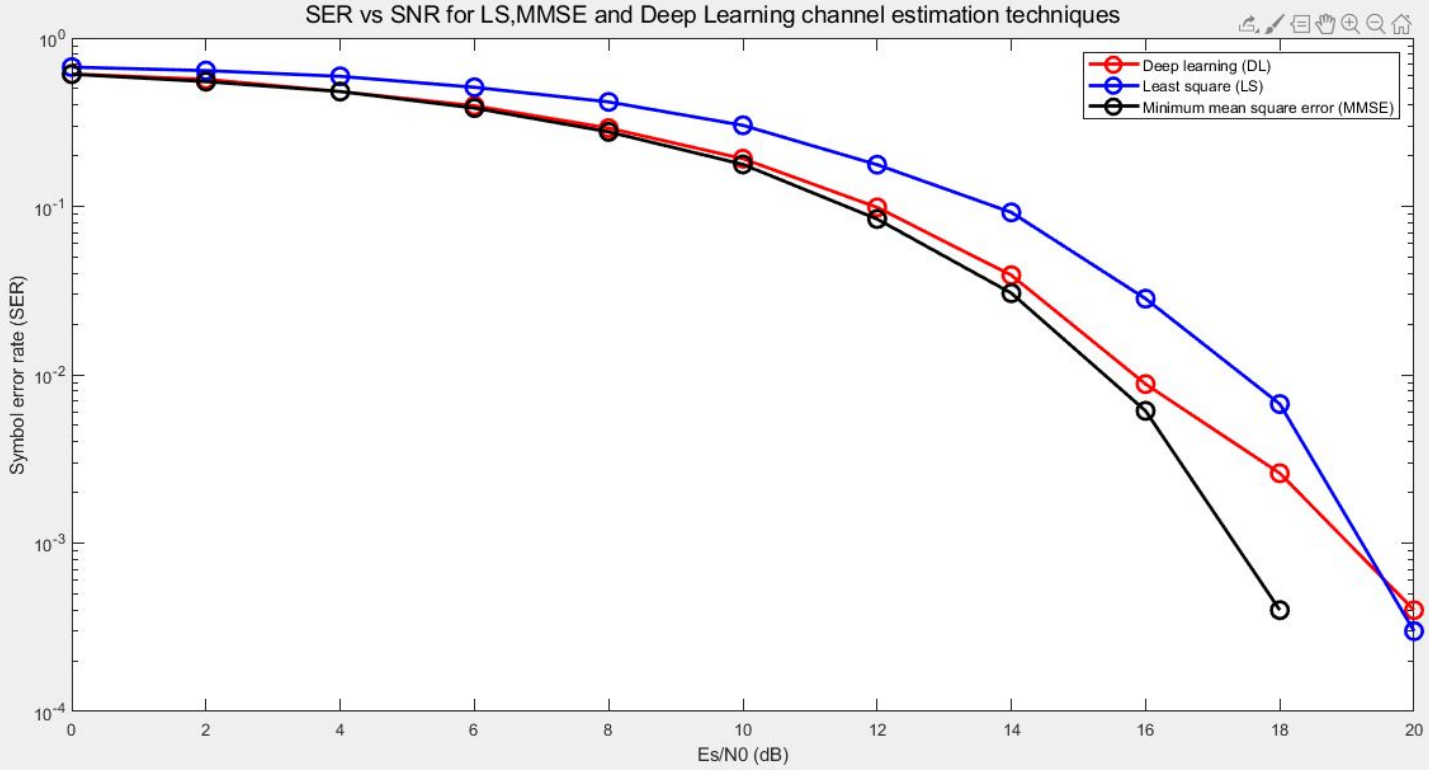
Results

3D plot of Channel Estimation in LS and MMSE



Results

Channel Estimation Plot of LS,MMSE and DL



Conclusion

The deep learning model performs significantly better than the LSE estimator as it takes into account system interferences and better noise handling capabilities. As MMSE has high complexity problems deep learning models provide comparable yet less taxing solution to channel estimation problem. It would be interesting to see the inverting points of these three estimators as at high snr values the graphs start to diverge. It would be interesting to find the inversion point of this trend.

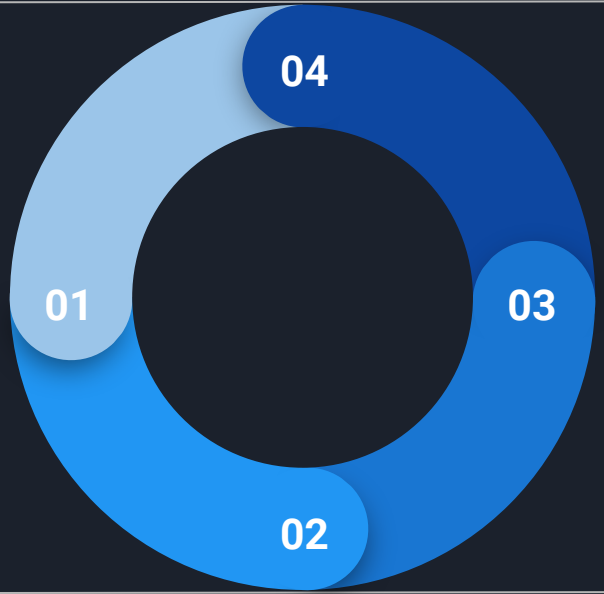
Project flow

Understanding Concept

Theoretical and mathematical abstractions

MATLAB/ Python Coding

Implementing in python or MATLAB



Deep Learning Estimation

Employ DL for better estimations and results.

Simulink Implementation

In MATLAB create a Simulink Model

Future Scope

The project only compares MMSE ,LSE and DL estimators . Further is coded in MATLAB only .

We have been in correspondence with Mr. Rahul Makkar for sorting errors in Simulink Model.

We were able to create a MIMO OFDM model in python and modulate, demodulate signals.

Furthermore better fine tuning of Deep learning models can be done for improved accuracy

Acknowledgement

We would like to take this opportunity to thank our Mentor **Prof. Purnendu Karmakar** for his guidance and support

Finally to us,the team members whose cooperation and hard work has made this Term paper a success.

Individual Contribution Note - All parts of this project were made by coordination and cooperation between all three team members. Hence all of us were able to understand all subparts and tasks in depth. We kindly request you to grade us equally.