LAB 03 – REPORT

1. INTRODUCTION

IMU (Inertial Measurement Unit) noise characterization with Allan variance is a technique used to analyze and quantify the noise characteristics of accelerometer and gyroscope measurements. The Allan variance is a statistical tool that provides insights into the random noise sources affecting the IMU readings. By collecting a series of IMU measurements over a period and calculating the Allan variance, it is possible to determine different types of noise present in the IMU data. The Allan variance can reveal characteristics like random walk noise, bias instability, rate random walk, and white noise. Understanding the noise characteristics of an IMU is crucial for sensor fusion and navigation systems, as it helps in accurately estimating the orientation and position of a device. By analyzing the Allan variance curve, one can identify the optimal integration time for the IMU, which balances the reduction of noise and the increase of bias errors.

Overall, IMU noise characterization using Allan variance is an essential step in designing precise motion sensing systems, enabling accurate measurements and improving the overall performance of inertial sensors.

2. ANALYSIS PLOTS:

1. Analysis of Data Collected for a Short Interval (10-15mins)

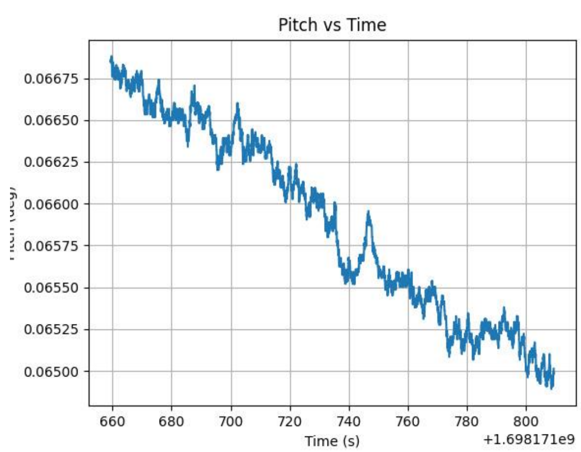

Fig.1: Pitch vs Time

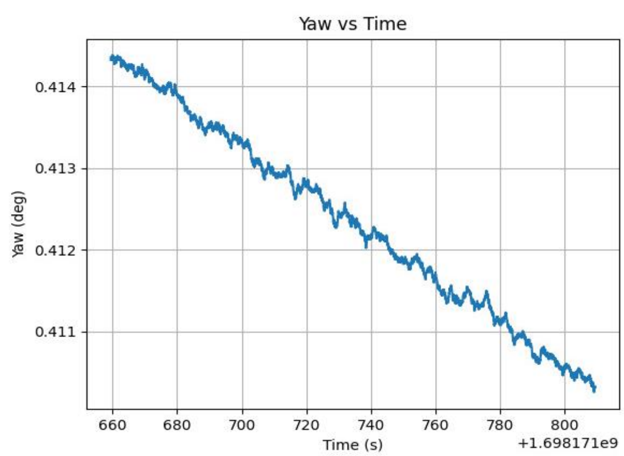

Fig.2: Yaw vs Time

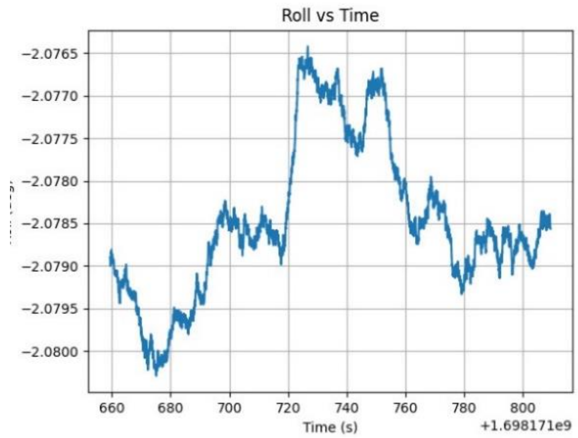

Fig.3: Roll vs Time

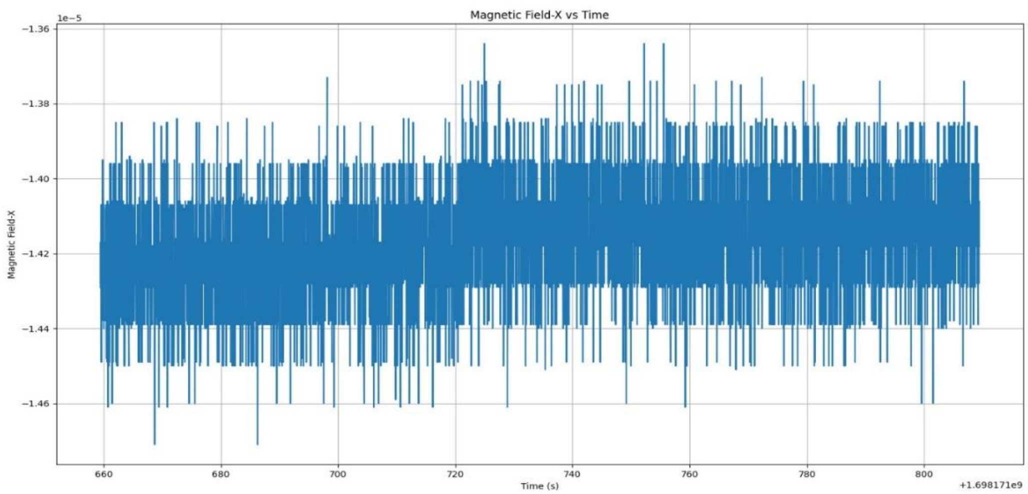

Fig.4: Magnetic Field - X vs Time

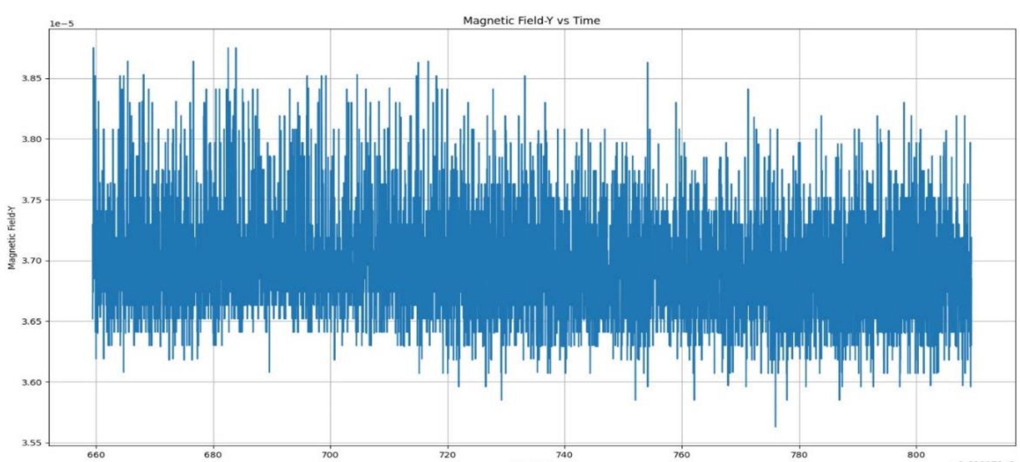

Fig.5: Magnetic Field - Y vs Time

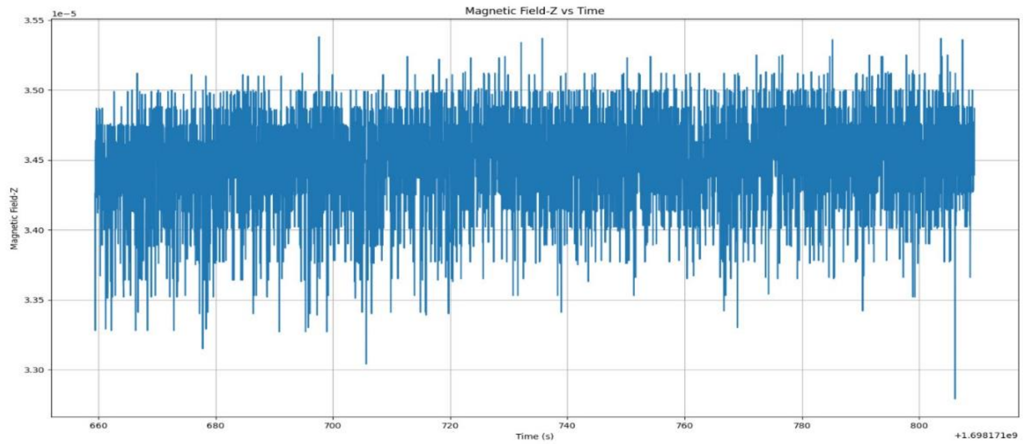

Fig.6: Magnetic Field - Y vs Time

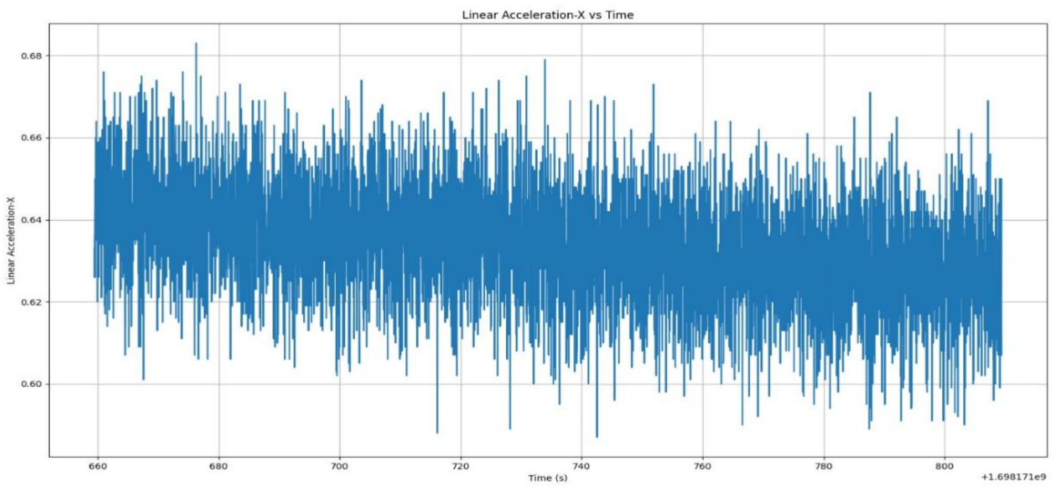

Fig.7: Linear Acceleration- X vs Time

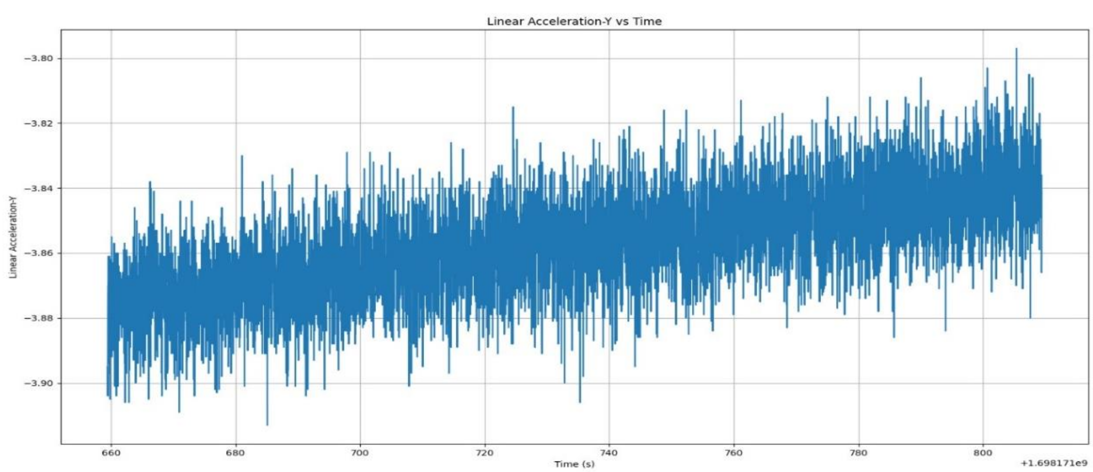

Fig.8: Linear Acceleration- Y vs Time

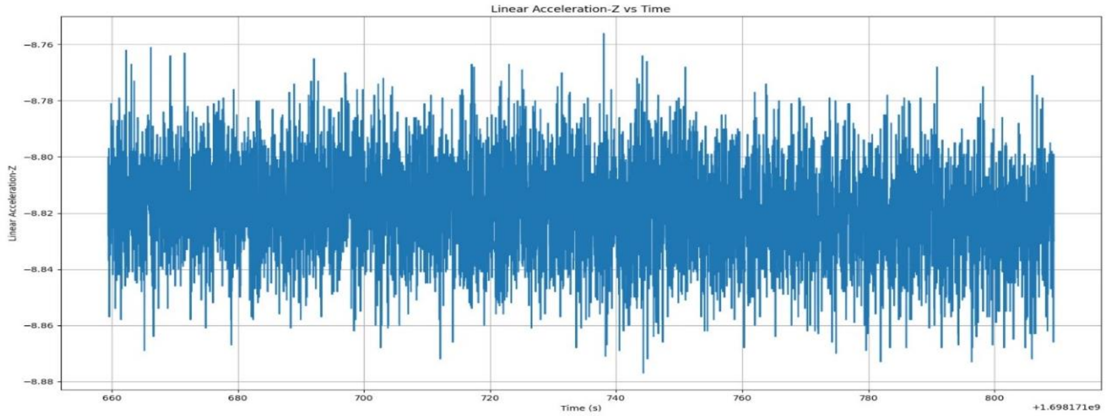

Fig.9: Linear Acceleration- Z vs Time

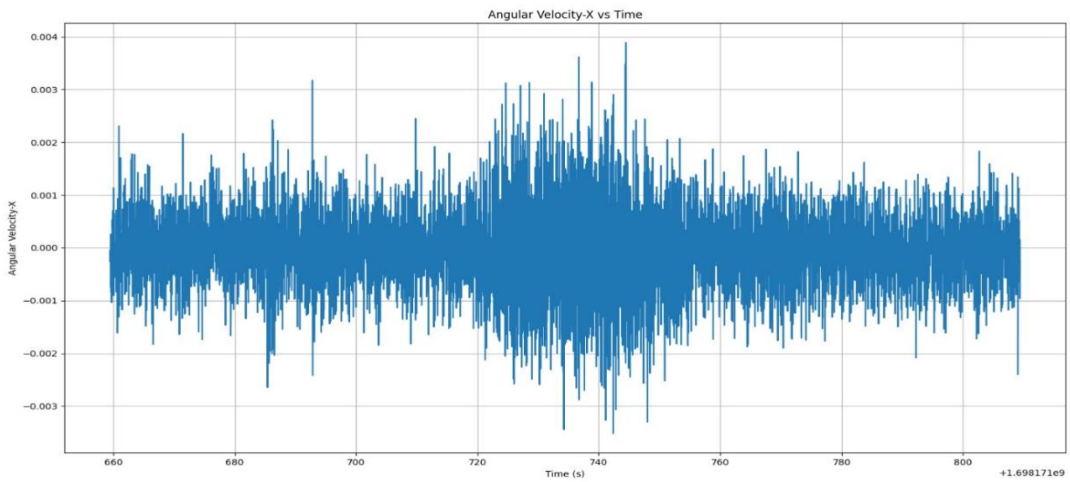

Fig.10: Angular Velocity- X vs Time

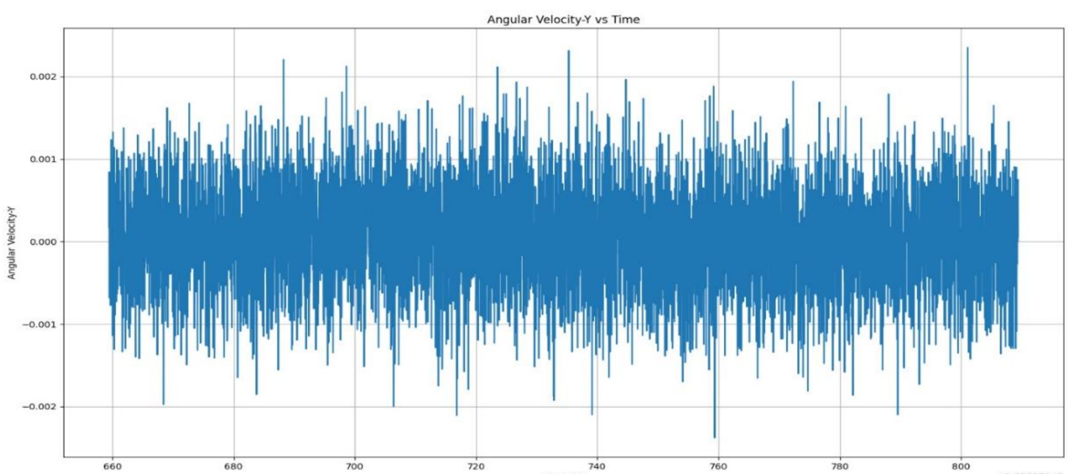

Fig.11: Angular Velocity- Y vs Time

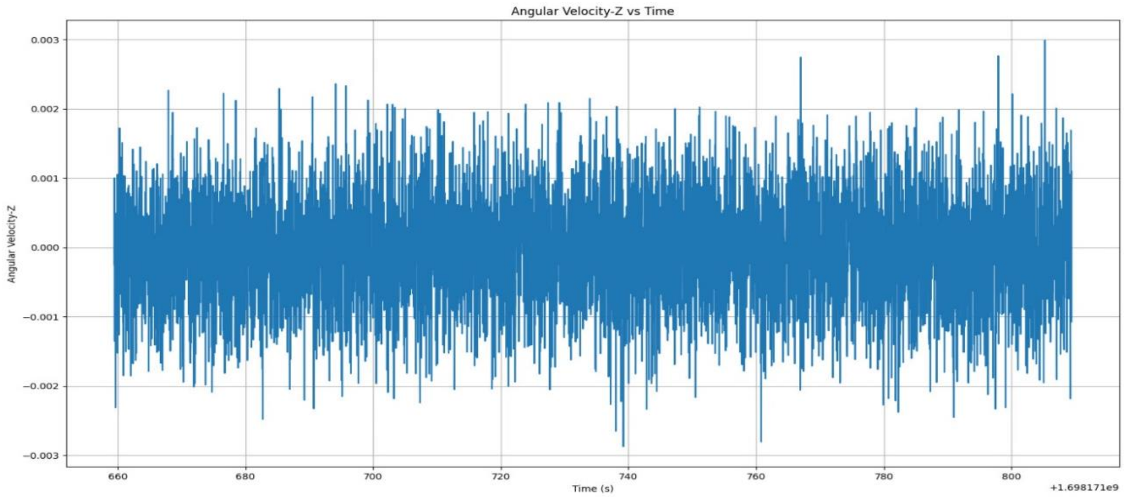

Fig.12: Angular Velocity - Z vs Time

	Mean	Standard Deviation
Roll	**1.31496921e-01**	**2.25269614e-04**
Pitch	**-1.60030054e-01**	**1.71775033e-04**
Yaw	**-8.46720460e-01**	**9.48839642e-05**
Magnetic Field – X	**-1.41667873e-05**	**6.65280357e-08**
Magnetic Field – Y	**3.69666822e-05**	**1.93834867e-07**
Magnetic Field – Z	**3.44950409e-05**	**1.42526838e-07**
Linear Acceleration – X	**6.33836697e-01**	**6.05082134e-03**
Linear Acceleration – Y	**-3.85737848e+00**	**7.27889976e-03**
Linear Acceleration – Z	**-8.81879783e+00**	**7.77579354e-03**
Angular Velocity - X	**-1.89114262e-05**	**3.57433783e-04**
Angular Velocity – Y	**4.01793161e-05**	**2.81817279e-04**
Angular Velocity - Z	**-4.61090909e-05**	**3.52156125e-04**

Table 1: Mean & Standard Deviation

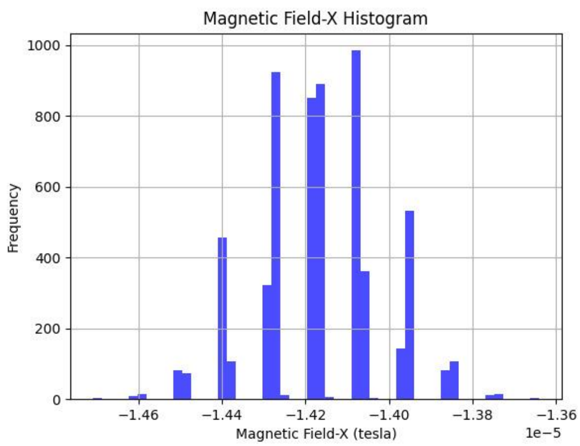

Fig.13: Magnetic Field -X

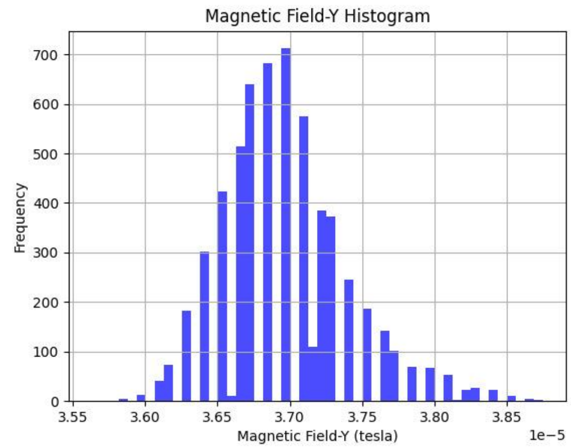

Fig.14: Magnetic Field -Y

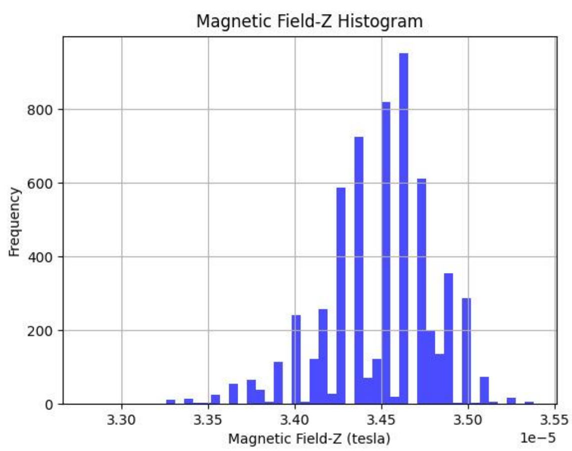

Fig.15: Magnetic Field -Z

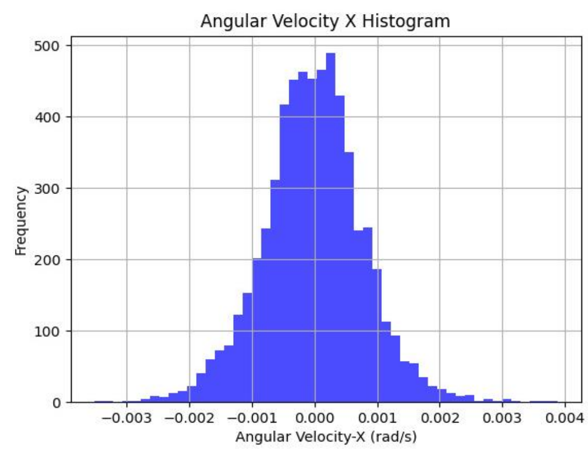

Fig.16: Angular Velocity - X

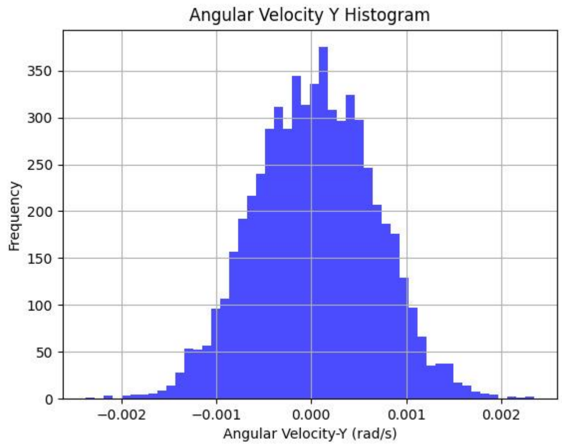

Fig.17: Angular Velocity - Y

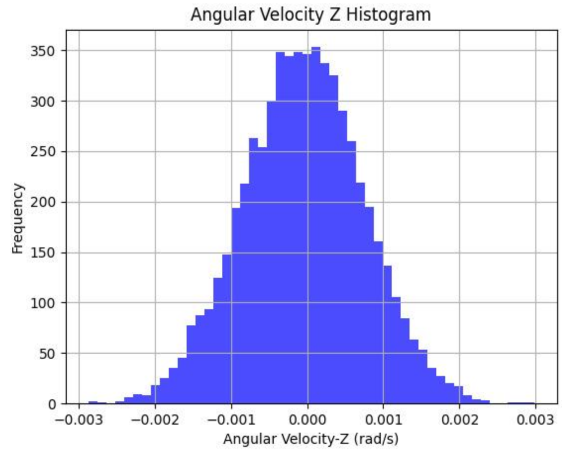

Fig.18: Angular Velocity - Z

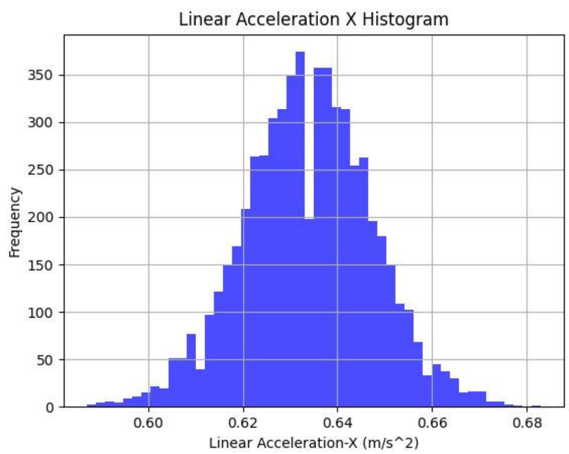

Fig.18: Linear Acceleration - X

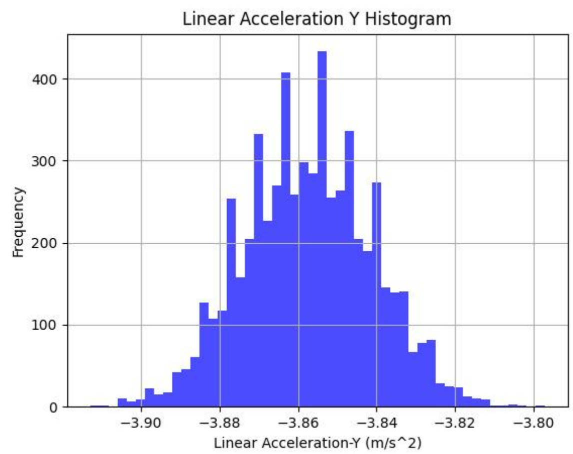

Fig.19: Linear Acceleration - Y

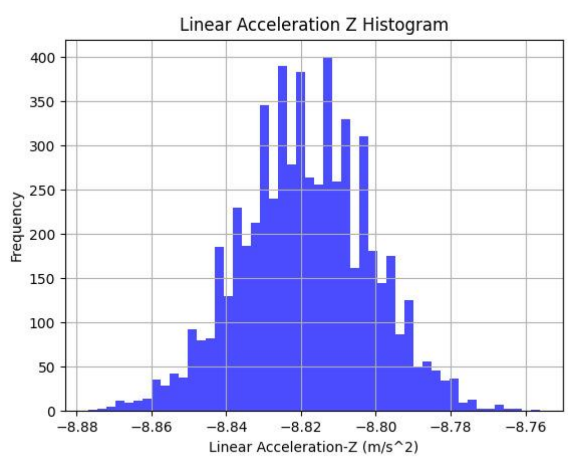

Fig.20: Linear Acceleration - Z

ERROR ANALYSIS:

A significant portion of the errors in the data can also be attributed to setup and data-collection errors that naturally occur during testing. The test configuration that was used caused differences in the findings because this IMU device is quite sensitive to changes in motion. The equipment should have been more firmly fixed to the steady surface, to reduce error. Due to its lack of a foundation, the surface that the device was placed on also serves as an additional cause of error.

It is evident from the histogram plots that the IMU data has a gaussian distribution, which supports the presence of Gaussian error. The time series plots further confirm this result because the data is scattered around the mean and most part lies within the +/- Standard deviation indicating that the data is gaussian distributed.

In terms of orientation, the mean indicates the sensor's orientation at the point in time the data was collected.

In terms of linear acceleration, the mean for the y and z axis are negative. This could mean that the errors are due to sensor biases, misalignments, or external forces such as gravity acting on the IMU in the opposite direction of the respective axes.

In terms of angular velocity, the mean for x and z axis are negative. If the angular velocity in the Y axis is positive, this means that the IMU is rotating counterclockwise around the Y axis. However, if the angular velocity in the X and Z axes is negative, this means that the IMU is rotating clockwise around the X and Z axes. This is physically impossible, so it indicates that there is an error in the data.

In terms of magnetic field, a positive magnetic field in the Y and Z axes indicates that the IMU is oriented correctly with respect to the Earth's magnetic field. A positive mean value for the magnetic field in the Y and Z axes and a negative mean value for the magnetic field in the X axis for IMU signals tells us that the IMU is flipped around the X axis and is not oriented correctly with respect to the Earth's magnetic field.

With respect to the IMU most errors are due to:

1. Sensor Noise
2. Calibration Error
3. Magnetic Interference
4. Mounting and Installation Errors
5. Sensor Drift

2. Analysis of Data Collected in the Basement for a Long Time Interval (5hrs)
ALLEN DEVIATION PLOTS:

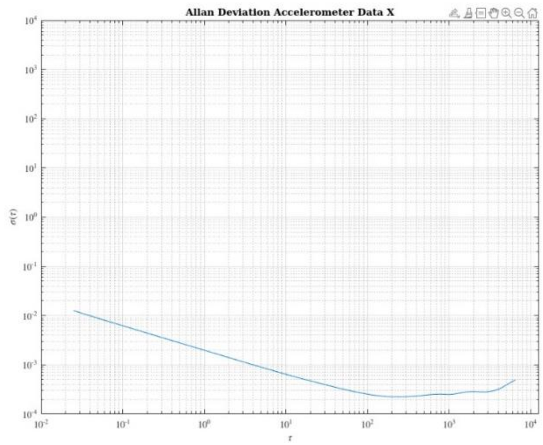

Fig.21: Accelerometer X-axis

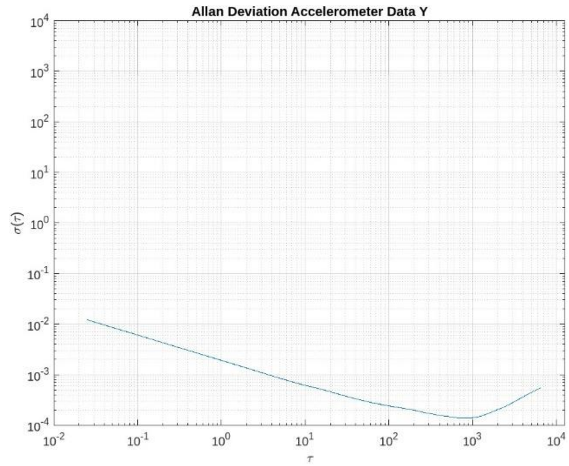

Fig.22: Accelerometer Y-axis

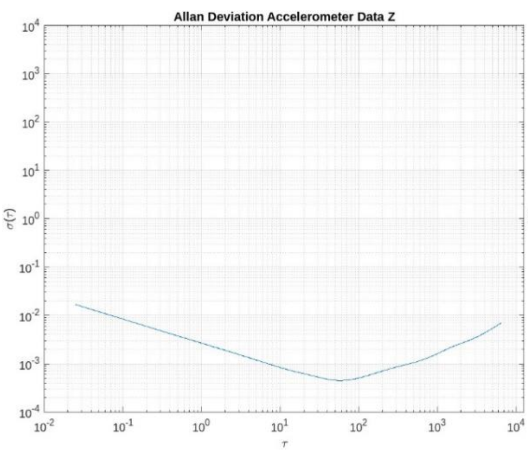

Fig.23: Accelerometer Z-axis

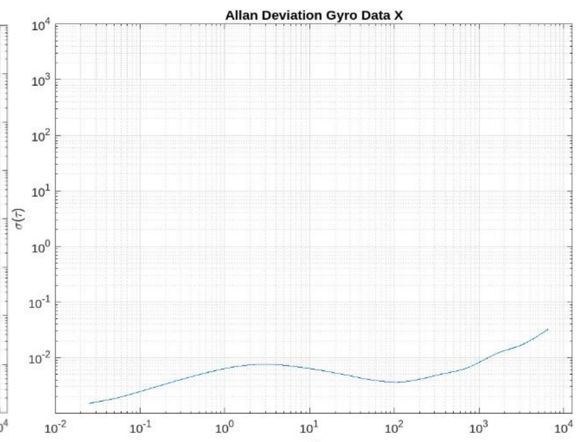

Fig.24: Gyro X-axis

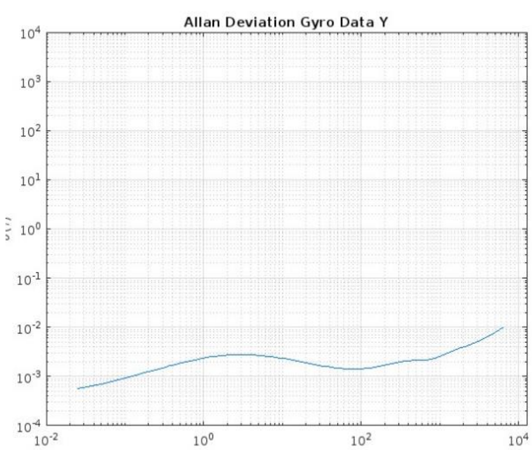

Fig.25: Gyro Y-axis

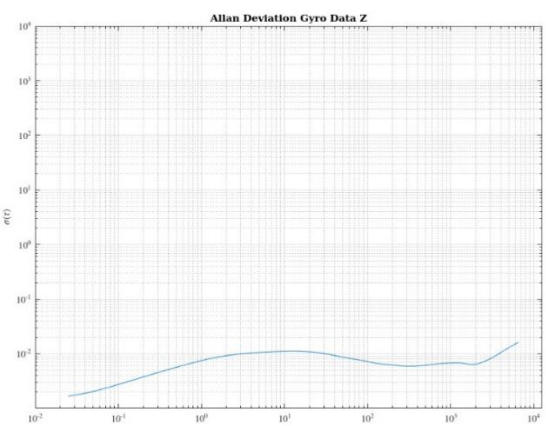

Fig.26: Gyro Z-axis

ERROR ANALYSIS:

The Allan Deviation is used to model and display the presence of noise in a dataset and neglect the presence of other systematic errors. It is calculated using the number of samples in a dataset, time frequency of those samples, and the total collection time.

Gyroscope noise:

Bias instability: Even when there is no rotation, gyroscopes have a bias, or an offset in the output. Bias instability may result from these biases gradually shifting over time. This can be modeled as a random walk process with a gradually changing bias.

White Noise: Random noise that exists in all frequency components is also a feature of gyroscopes. A zero-mean Gaussian noise can be used to model this noise.

Accelerometer noise:

Bias instability: An accelerometer's bias instability is comparable to that of a gyroscope. Gradually changing bias can have an impact on accelerometer measurements. Another way to express this is as a random walk process.

White Noise: Like gyroscopes, accelerometers also contain white noise components. Zero-mean Gaussian noise is commonly used to model this type of noise.

Magnetometer Noise:

Bias instability: Just like gyroscopes and accelerometers, magnetometers are susceptible to bias instability. Modeling the bias instability in magnetometers as a random walk process is possible.

White Noise: Modeled as zero-mean Gaussian noise, magnetometers also contain white noise components.

3. CONCLUSION:

Both time series and histogram charts demonstrated that the errors have a Gaussian distribution, and the Allan Deviation plot was used to identify and quantify the noise parameters. With the use of an IMU device and a mathematical and graphical analysis of the Allan Deviation, we were able to detect and simulate the noise measurements through this lab.