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For the Lab3 experiment two separate data collections were needed to get statistics on the error of our VN-100s IMU device. One data set covers about 10 minutes of data while the other runs for around 5 hours. The smaller dataset gives us some insight on the short term errors the sensor may pick up while the larger dataset is tested for long term drift done by computing the Allan Variance of the sensor data. Both datasets were collected in a basement where the IMU was firmly locked into place. The basement was not near any trains or tunnels. But still the different sources of errors could be because of the different kinds of electrical machines in the basement, like water heating equipment,washing machines, etc,.

Orientation Data:

Orientation data was first measured directly using the IMU serial output then converted into a quaternion for our standard ros sensor_msg, then transformed back into yaw, pitch, roll orientation data. For orientation data we first look at the short-term data where error is shown by subtracting the first recorded value from every subsequent value, giving us the relative error.

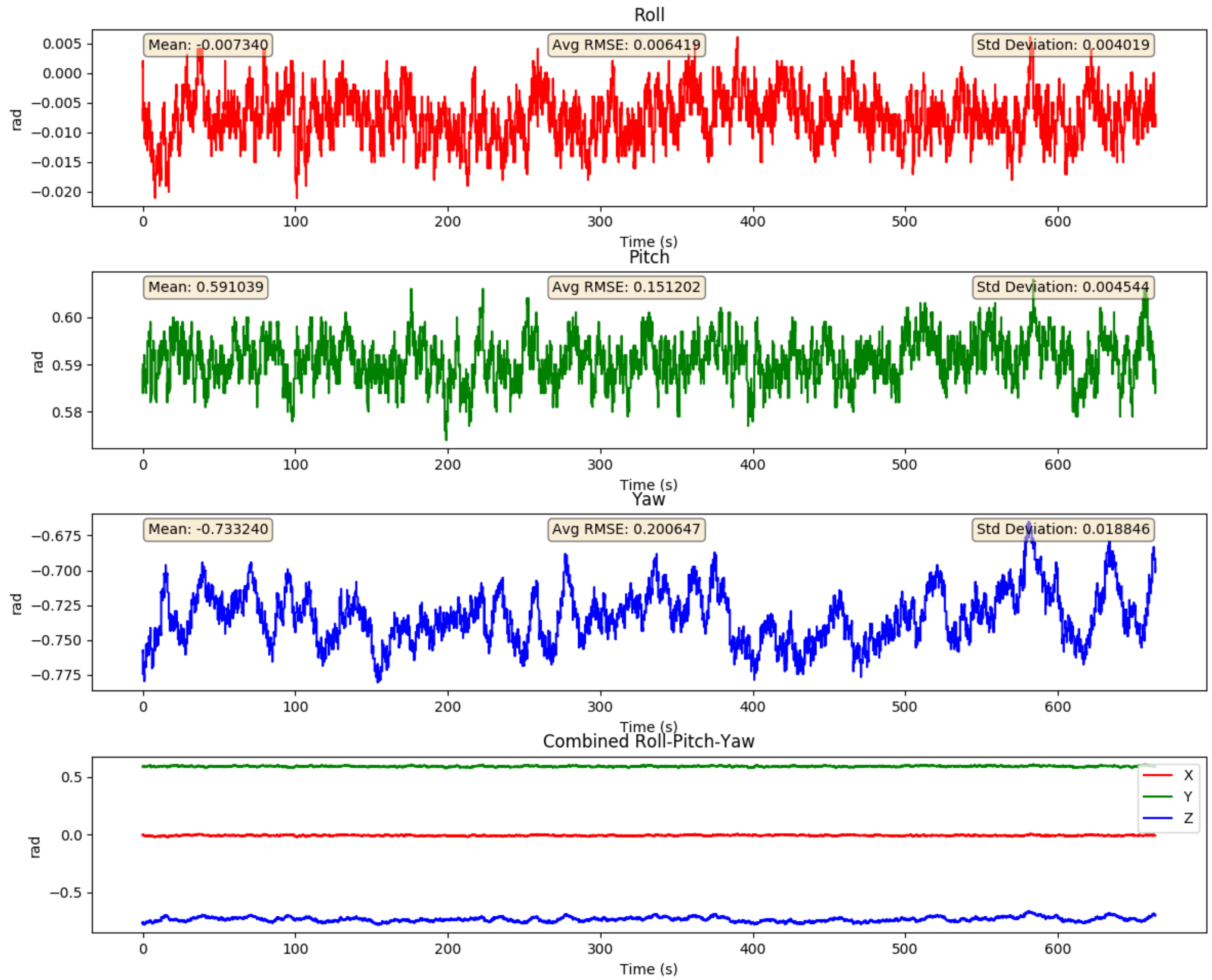

Figure_1.1 : Roll - Pitch - Yaw plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

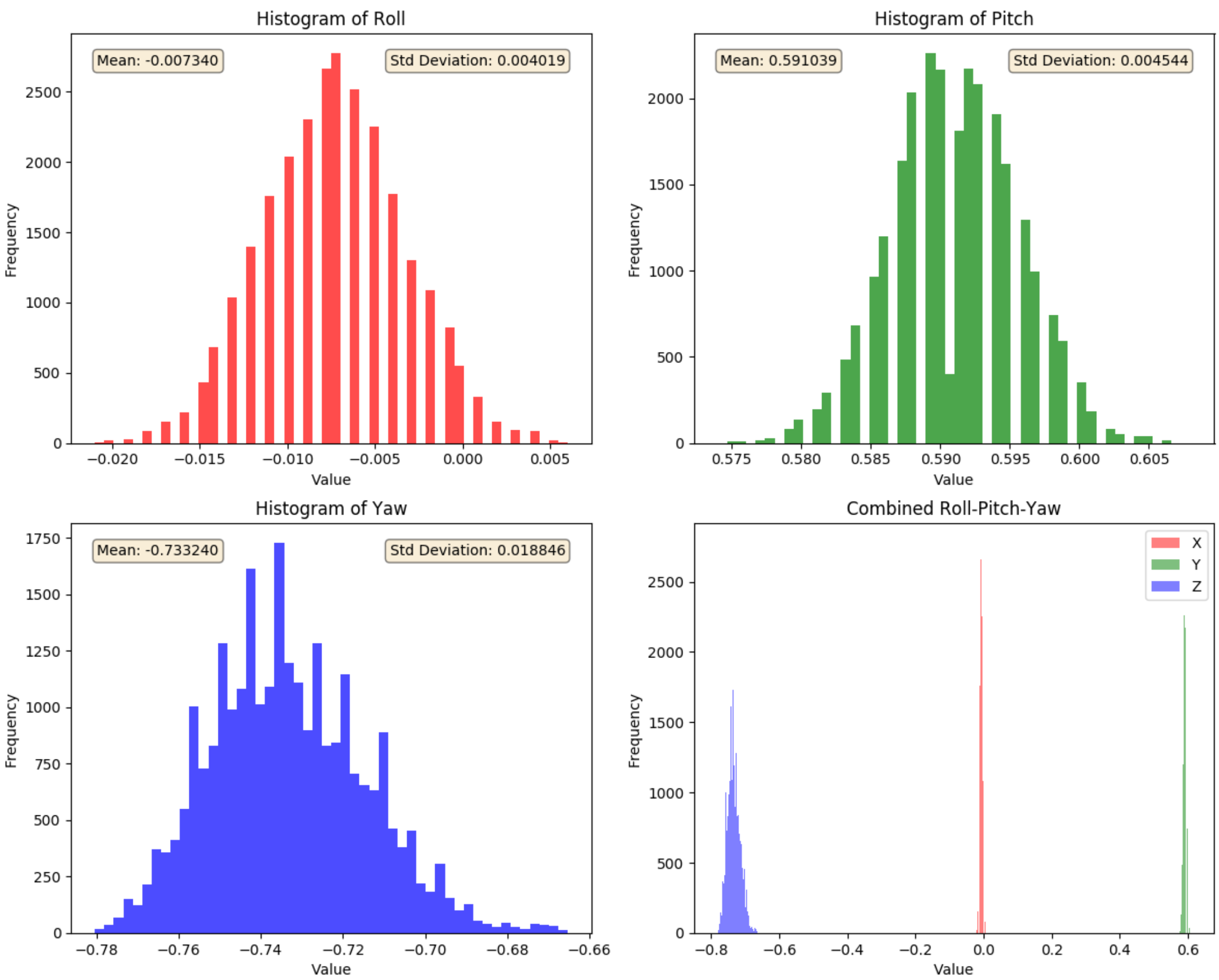

Figure_1.2 : Histograms of Roll - Pitch - Yaw plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

From the figure we see that the error in Roll orientation is very less, possibly stating that the floor was slightly uneven. All three rotation angles (Roll, Pitch, Yaw) exhibit some level of variability over the span of 600 seconds. The Pitch data seems relatively more stable compared to Roll and Yaw, given its smaller standard deviation. The Yaw data exhibits the most variability. The combined graph at the bottom aids in visualizing the simultaneous behavior of all three rotational components. The error and Standard Deviation for each component can be seen on the respective graphs.

Below are the graphs plotted for Allan Deviation for R P Y and W for the data collected for 5 hrs in MATLAB and the respective Bias instability is below its figure.

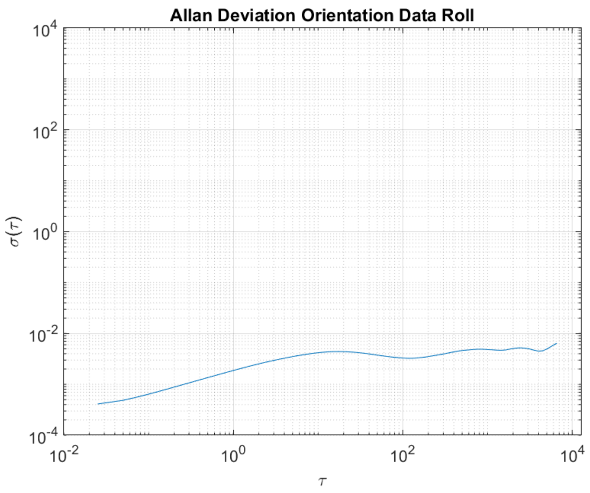

Fig 1a : Angle random walk = 0.2769
Rate random walk = 0.0034
Bias instability = 0.0074

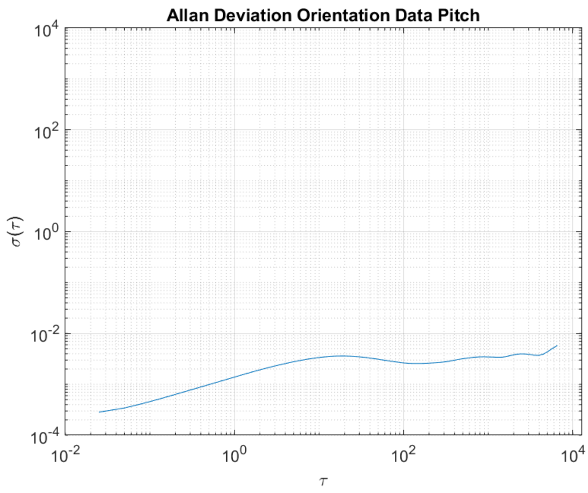

Fig 1b : Angle random walk = 0.2148
Rate random walk = 0.0024
Bias instability = 0.0054

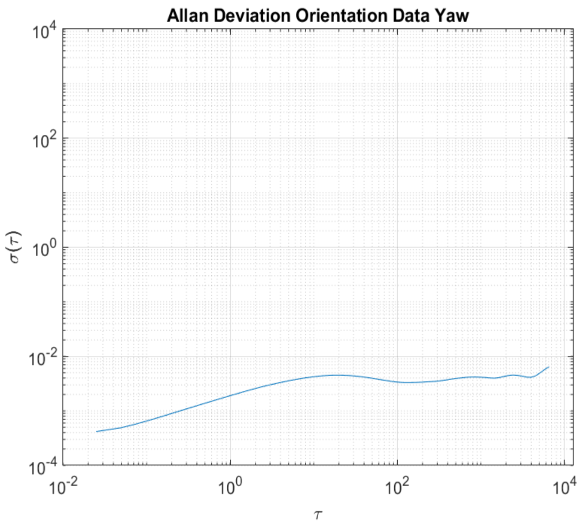

Fig 1c : Angle random walk = 0.2418
Rate random walk = 0.0035
Bias instability = 0.0068

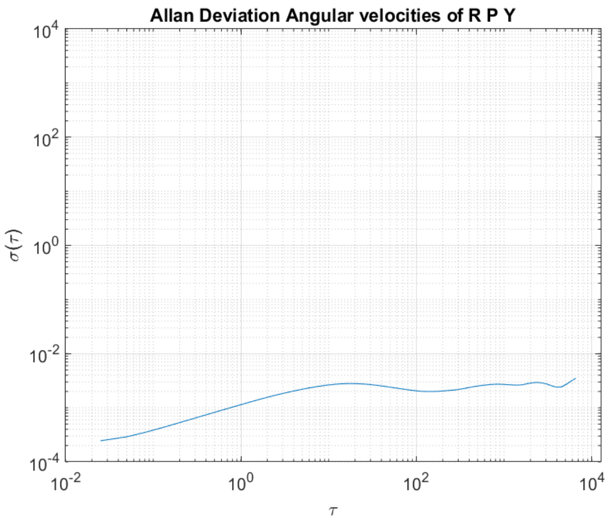

Fig 1d : Angle random walk = 0.1503
Rate random walk = 0.0021
Bias instability = 0.0030

Accelerometer Data :

For accelerometer data we first look at the short-term data where error is shown by subtracting the first recorded value from every subsequent value, giving us the relative error.
The error and Standard Deviation for each component can be seen on the respective graphs.

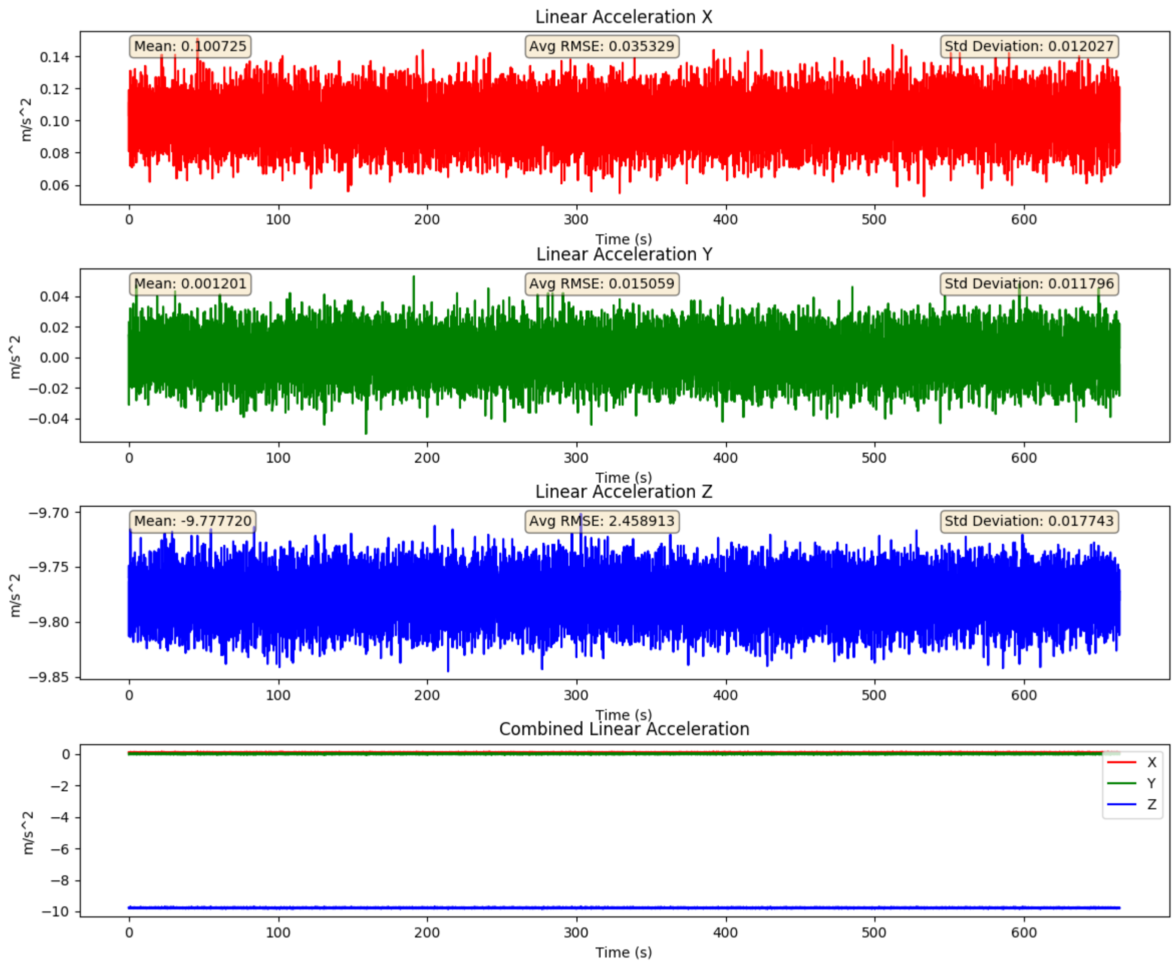

Figure_2.1 : Linear Acceleration in X Y Z plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

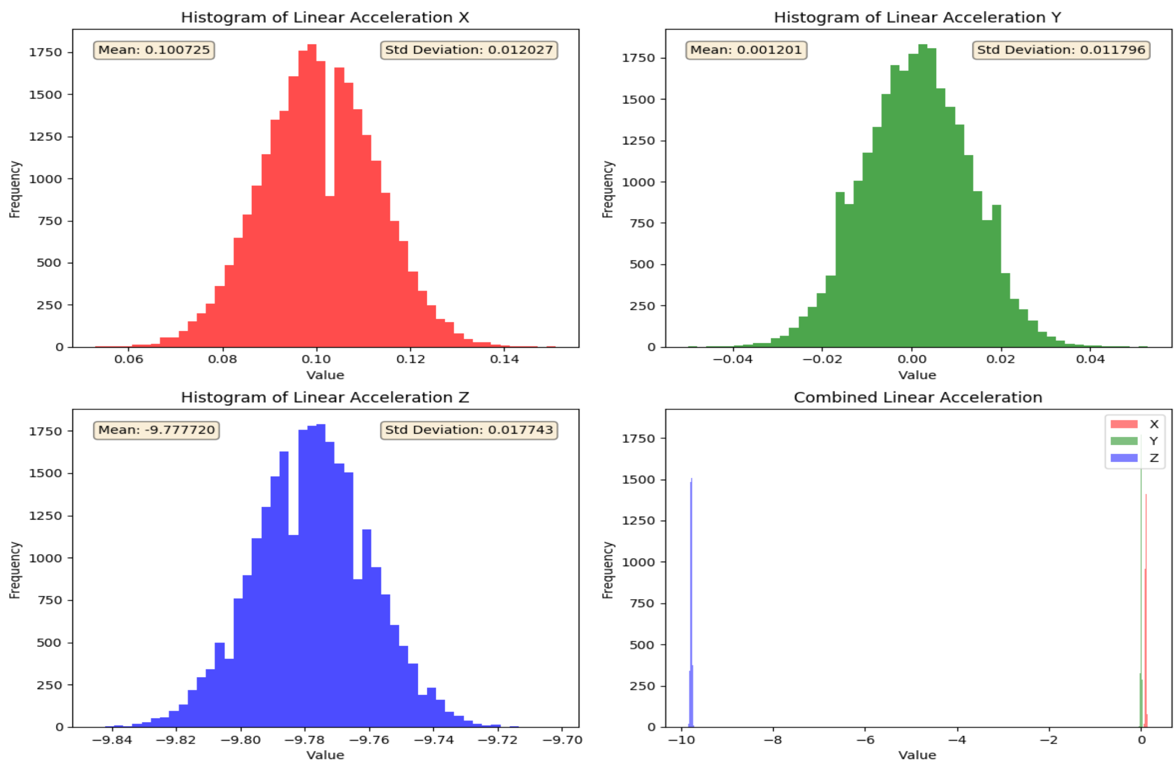

Figure_2.2 : Histograms of Linear Acceleration in X Y Z plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

To further analyze where the IMU begins to drift, the Allan Variance is also plotted for a 5 hour data collection.

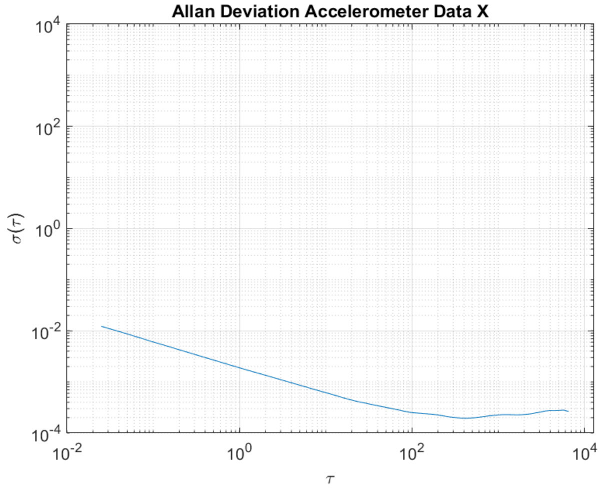

Fig 2a : Angle random walk = 0.0019
Rate random walk = 8.0037e-06
Bias instability = 3.4386e-04

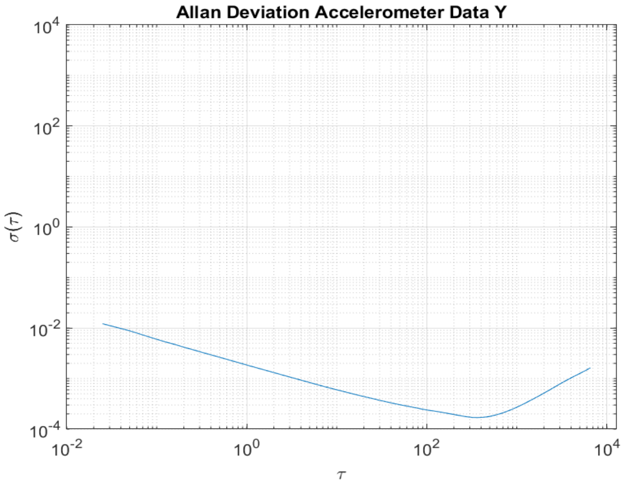

Fig 2b : Angle random walk = 0.0019
Rate random walk = 1.3662e-05
Bias instability = 2.5630e-04

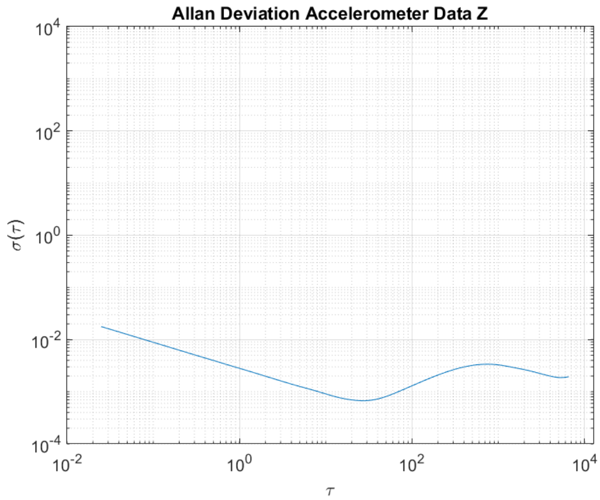

Fig 2a : Angle random walk = 0.0029
Rate random walk = 2.6325e-04
Bias instability = 0.0010

In datasheet the Random Walk and Bias are:
0.14 mg/ $\sqrt{}$ Hz and <0.04 mg respectively.

Above are the graphs plotted for Allan Deviation for Accelerometer in X Y Z for the data collected for 5 hrs in MATLAB and the respective Bias instability is below its figure.
For the accelerometer data we can see a much more distinct inflection point in our confidence level data pointing to a clear running time when drift over time builds up and becomes present in our accelerometer data. This was not nearly as prominent in our gyroscope data.
In terms of accelerometer output out measured data the provided MATLAB code also computes some error and noise statistics. These can be compared to the specifications listed on the VN100 datasheet.

Magnetometer Data :

For gyroscope data we first look at the short-term data where error is shown by subtracting the first recorded value from every subsequent value, giving us the relative error.

The error and Standard Deviation for each component can be seen on the respective graphs.

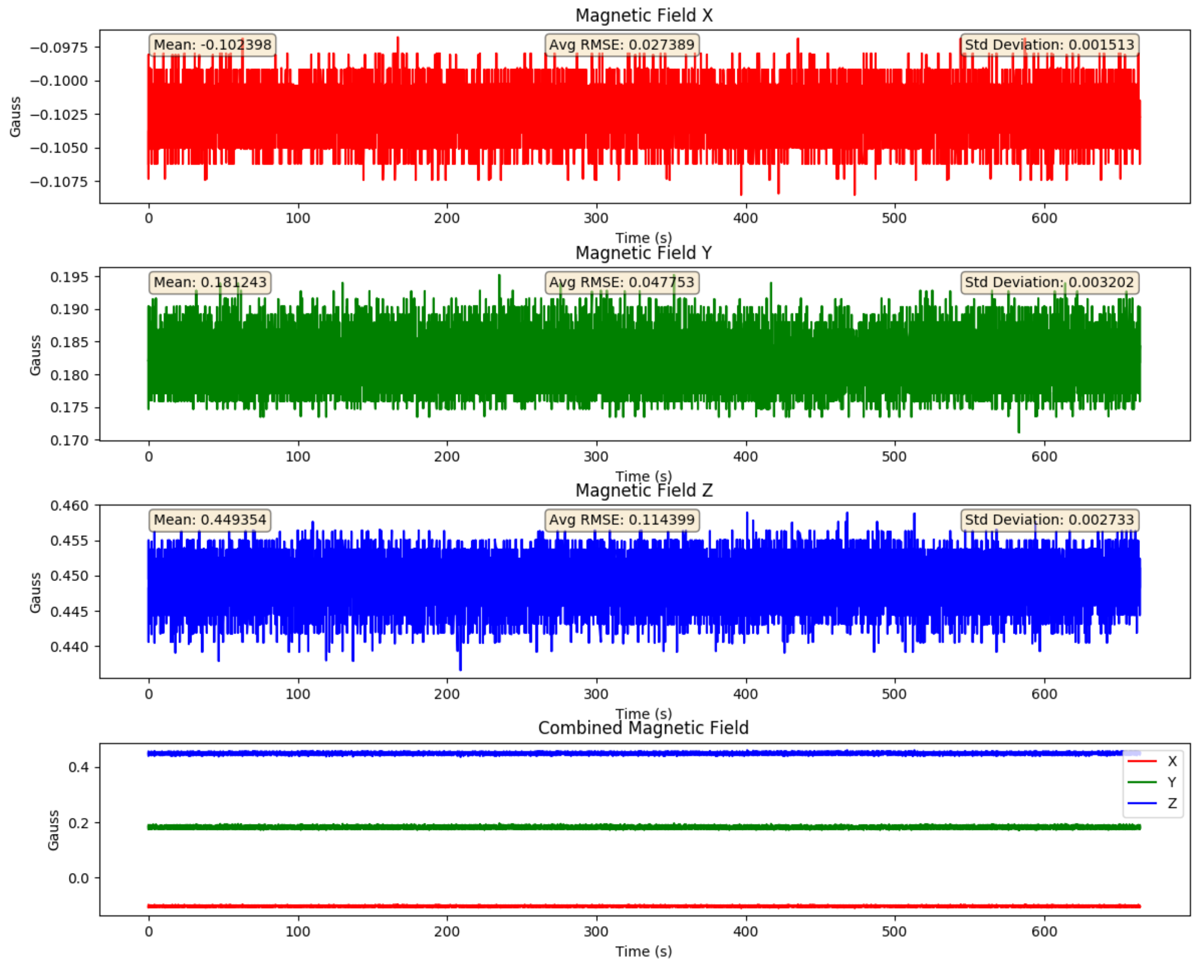

Figure_3 :Magnetic Field in X Y Z plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

Below are the graphs plotted for Allan Deviation for Magnetic Field in X Y Z for the data collected for 5 hrs in MATLAB and the respective Bias instability is below its figure. Although Allan Deviation is **not** considered a valid estimator for scaling of magnetic field intensity, the plotted graphs are just for understanding the shift in magnetic field.

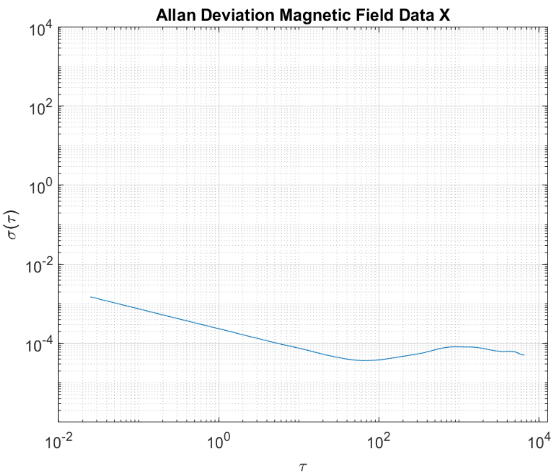

Fig 3a : Angle random walk = 2.3783e-04
Rate random walk = 5.2664e-06
Bias instability = 5.4943e-05

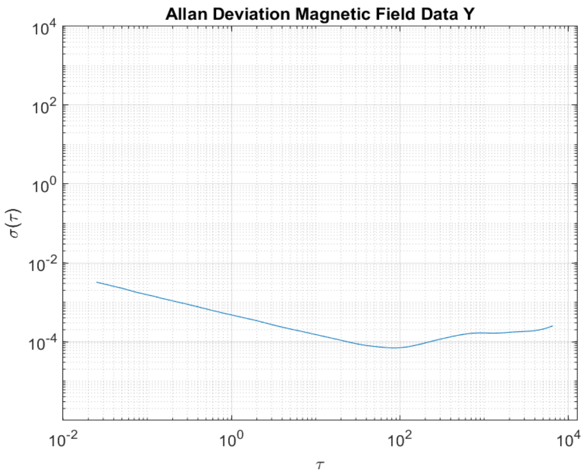

Fig 3b : Angle random walk = 4.6594e-04
Rate random walk = 1.1509e-05
Bias instability = 1.0411e-04

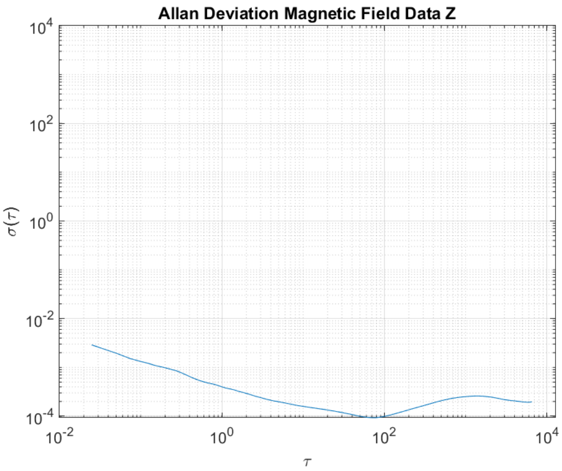

Fig 3a : Angle random walk = 4.1533e-04
Rate random walk = 1.6579e-05
Bias instability = 1.4024e-04

Gyroscope Data :

For gyroscope data we first look at the short-term data where error is shown by subtracting the first recorded value from every subsequent value, giving us the relative error.

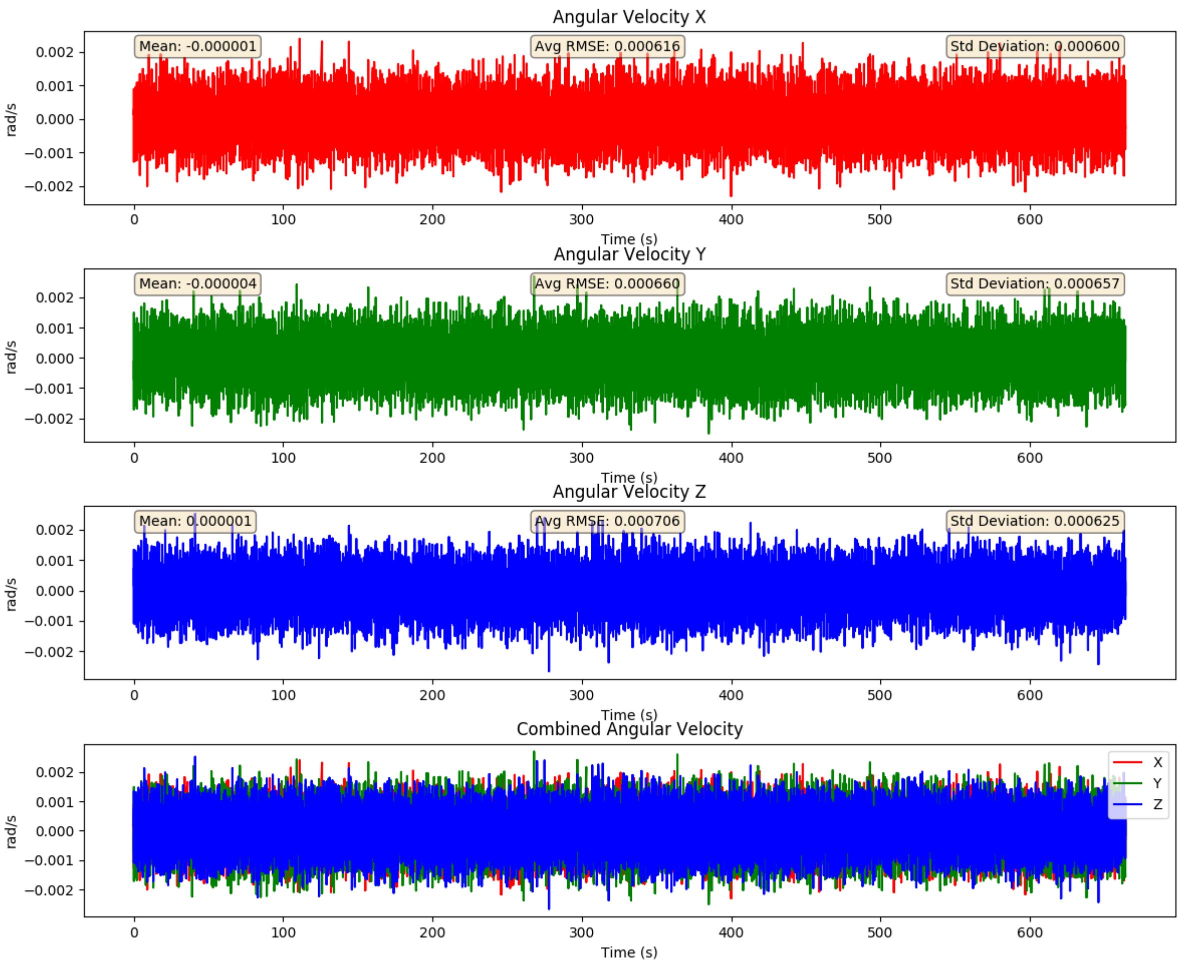

Figure_4.1 : Angular Velocity in X Y Z plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

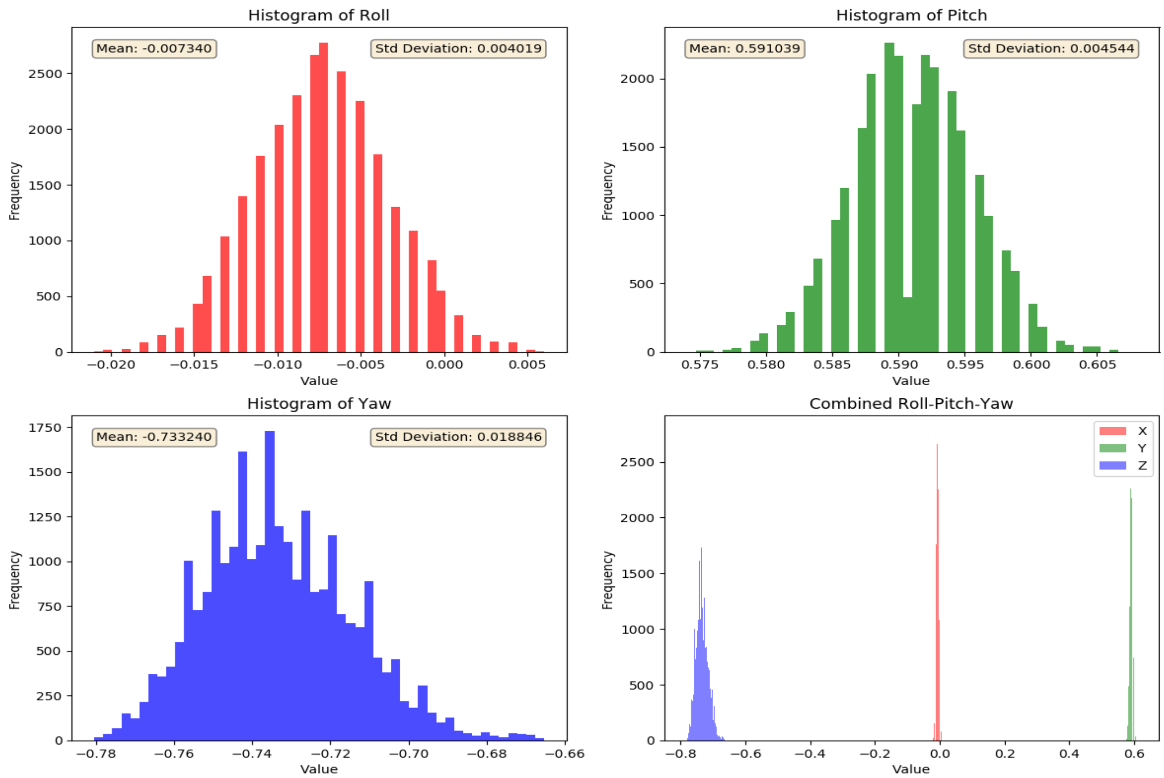

Figure_4.2 : Histograms of Gyroscope in X Y Z plot for 10 min data with Mean, Ang RMSE and Std. Dev on the respective graphs

The angular velocity seemed pretty constant throughout the time data was collected with very little error which can be seen on the respective graphs.

To further analyze where the IMU begins to drift the Allan Variance is also plotted for a 5 hour data collection.

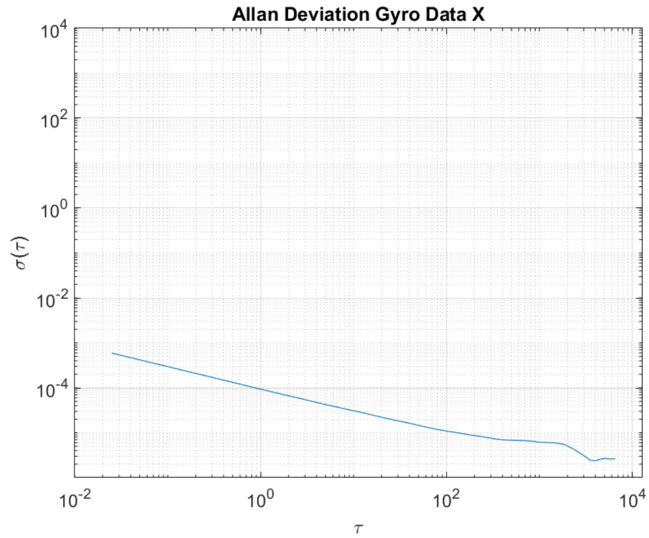

Fig 4a : Angle random walk = 9.3838e-05
Rate random walk = 6.5360e-08
Bias instability = 1.0153e-05

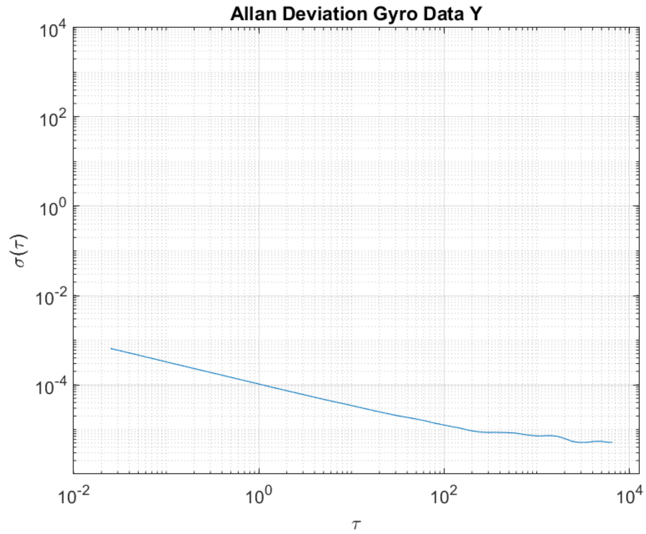

Fig 4b : Angle random walk = 1.0333e-04
Rate random walk = 1.5101e-07
Bias instability = 7.7732e-06

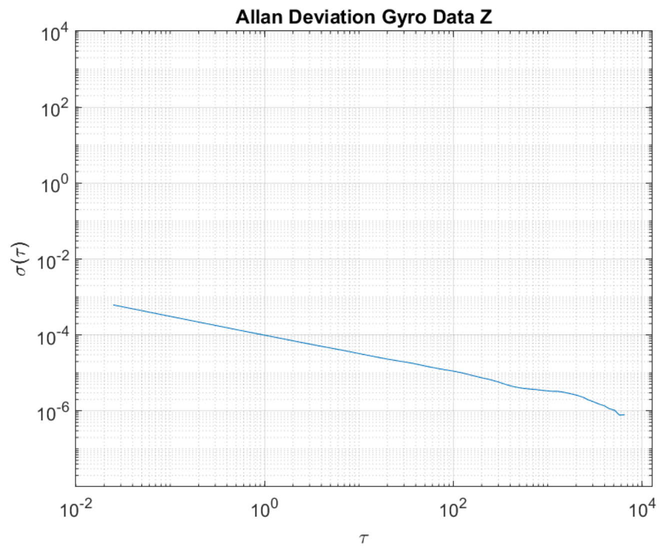

Fig 4a : Angle random walk = 9.7816e-05
Rate random walk = 1.7666e-08
Bias instability = 4.9511e-06

In datasheet the Random Walk and Bias are: 0.0035 °/s / √ Hz and <10° hr respectively.

As shown in the plots we can see there is no large spike against our confidence level meaning there is little drift in the gyroscope output even over a long time period.

In terms of gyroscope output out measured data the provided MATLAB code also computes some error and noise statistics. These can be compared to the specifications listed on the VN100 datasheet.