RSN Lab-3 Report

Location of individual data (15 min) collection: Parker Hill Avenue, Basement of an apartment.

Location of team data (5 hrs.) collection: Parker Hill Avenue, Basement of an apartment.

The units for data collected and represented are as follows:

Acceleration: m/s^2

Magnetic Field: Gauss

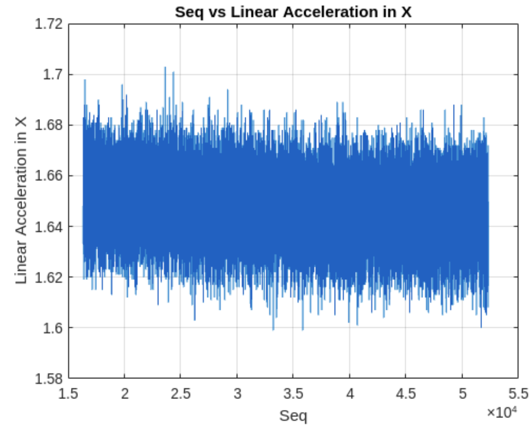
Gyroscope: rad/s

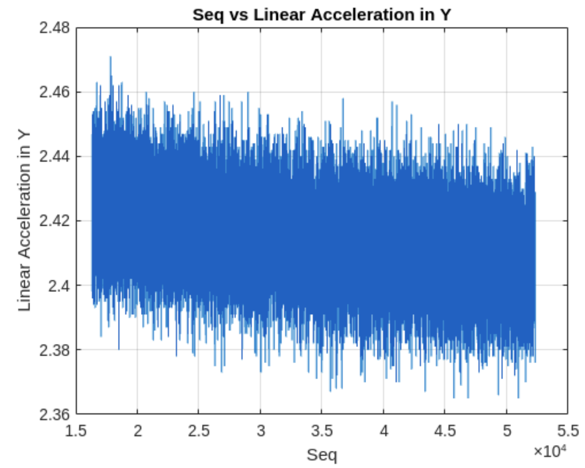
Time (Seq): seconds

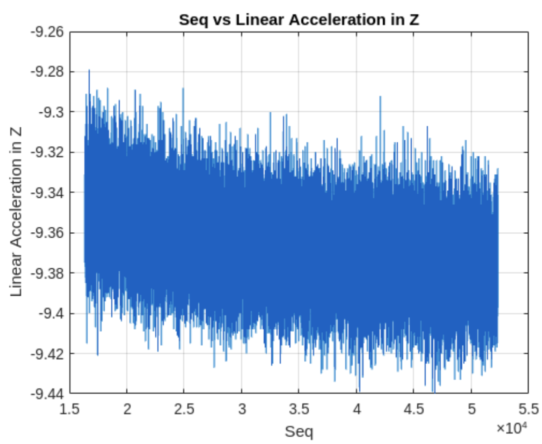
All the graphs use the same convention.

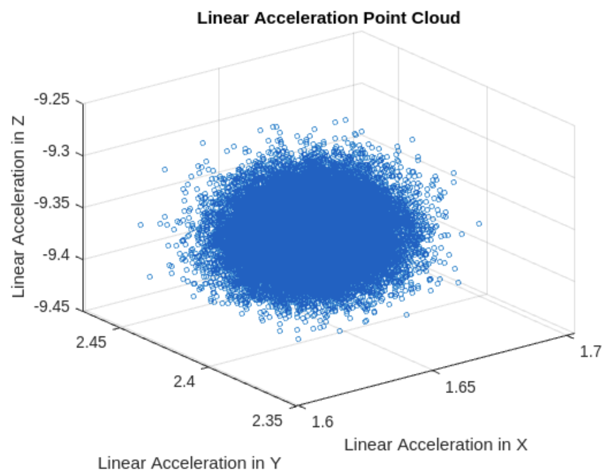
Analysis of Accelerometer Data:

This 15 min data is collected in the basement of an apartment on parker hill avenue. It is considerably distant from the T-line and the traffic was nearly nonexistent on the road in front of the apartment. No noise from other external factors was observed except for a little noise from the plastic that was moving the sensor a little which was then taken out during the collection of the long duration data.







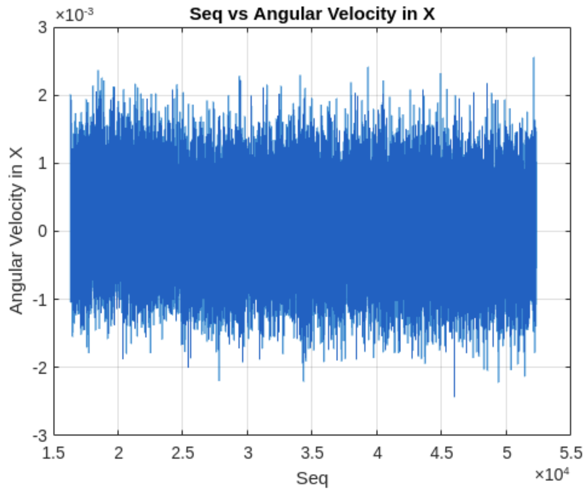


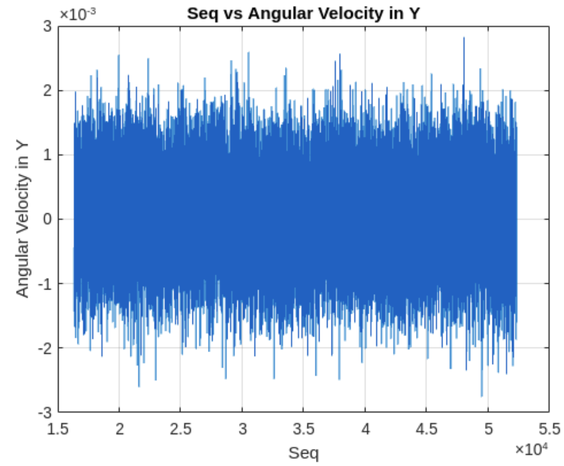
The acceleration in X direction looks more stable than that in the Y and Z directions while the acceleration in Y and Z is found to be drifting in the slightest. The point cloud shows the acceleration along the axes plotted in 3-Dimensions giving us a general idea of the distribution of our data.

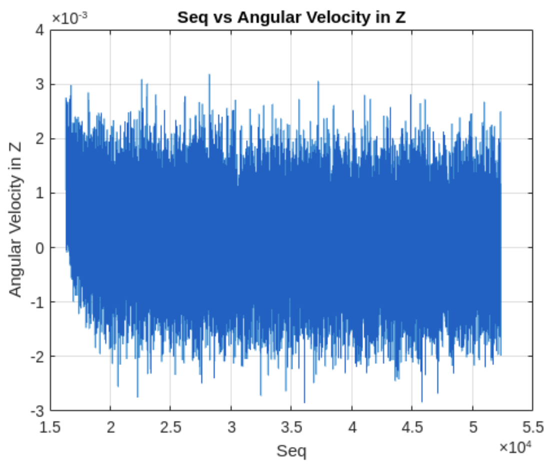
```
mean_imu_ax = 1.6475
mean_imu_ay = 2.4146
mean_imu_az = -9.3663
std_imu_ax = 0.0125
std_imu_ay = 0.0131
std_imu_az = 0.0203
```

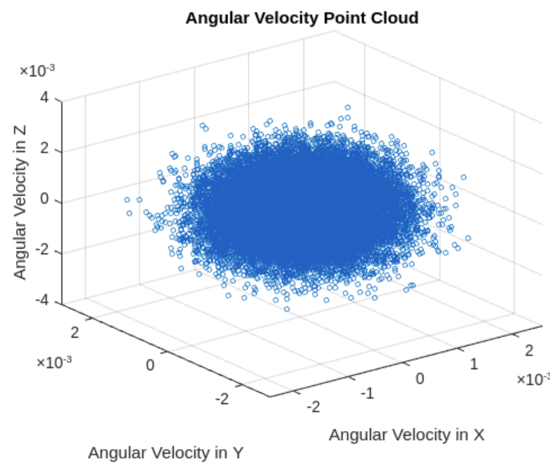
The noise in the given data is analyzed by calculating the mean and the standard deviation of the acceleration along the 3 –axes. The standard deviation in X is found to be the lowest and the overall values are low which suggests that 15 minutes is probably a very less duration to actually get a sense of the drift in acceleration along the various axes.

Analysis of Gyroscope Data:









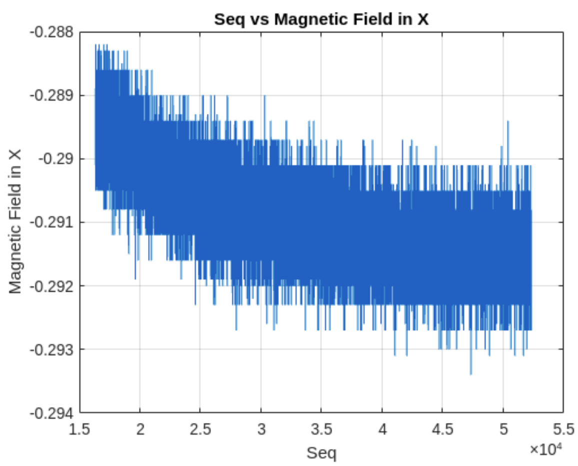
The data from the gyroscope looks the most stable among all the three data collected and it can also be observed from the statistical data that is displayed below this text. When compared to the drift in the accelerometer and as we will see of magnetometer in the next section, we can clearly say that the data from the gyroscope has the least standard deviation among all three sets and is the most stable with the least drift. We can also observe from the graphs that the angular velocity in the Z direction is the least at first but gets larger gradually which could be because of the vibrations due to people walking in the apartment or could be because of gravity as well. This won't affect the values of the X and Y direction as much and we can see in the below-given statistics that the Z direction has the highest standard deviation.

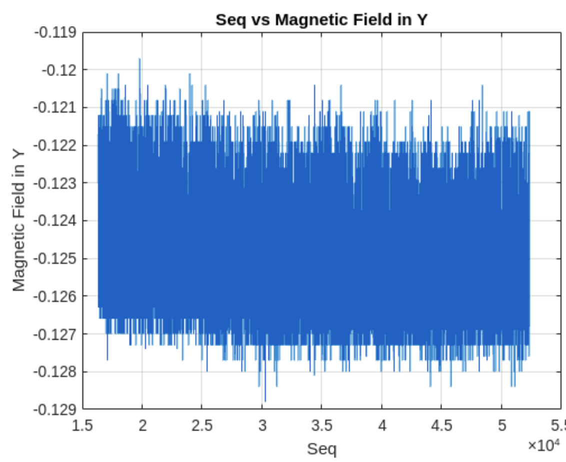
We can also have a look at the point cloud to get a visual understanding of how the data varies in 3 directions simultaneously. It is clear that the most standard deviation is in the Z direction.

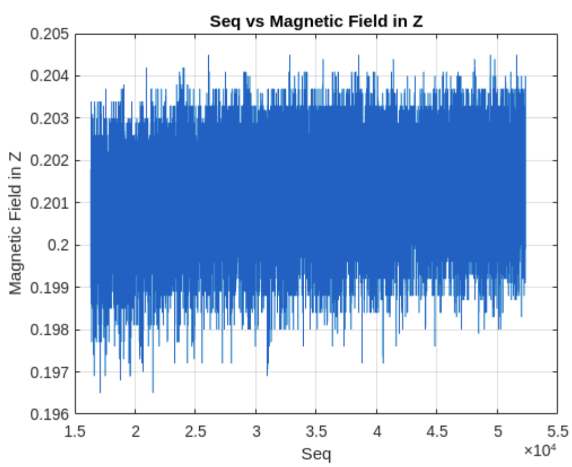
```
mean_imu_gx = 9.1167e-05
mean_imu_gy = 6.3811e-05
mean_imu_gz = 1.4938e-04
std_imu_gx = 6.1624e-04
std_imu_gy = 6.6552e-04
std_imu_gz = 7.7699e-04
```

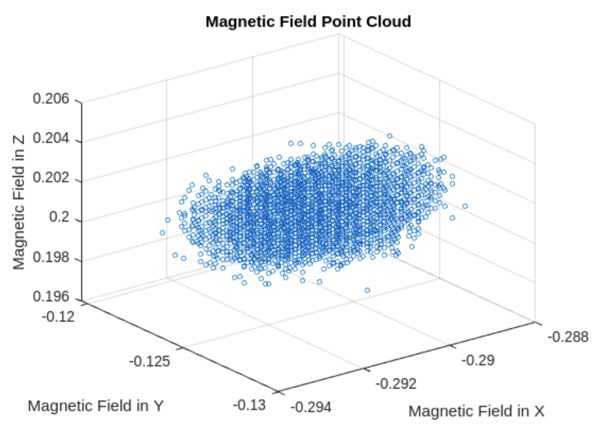
We can observe from the above statistical data that these readings have the least standard deviation of all and the deviation in the Z direction is the highest which matches our above reasoning. As the data was collected in the basement to reduce the vibrational noise, we have reduced noise in our data.

Analysis of Magnetometer Data:









It can be inferred from the above plots that the readings of the magnetometer or magnetic field in X, Y and Z have a certain drift. We can observe from the graphs that the values of X are decreasing over time and stabilizing. The values of Y and Z look more stabilized and have a lesser drift in values than in the X but observing the noise can tell us that they infact have a larger value of standard deviation than the magnetic field along X axes. This drift can be attributed to the presence of pink and white noise.

```
mean_mag_x = -0.2909
mean_mag_y = -0.1253
mean_mag_z = 0.2014
std_mag_x = 7.4901e-04
std_mag_y = 0.0011
std_mag_z = 0.0010
```

Mean and standard deviation are used to determine the noise in the values received over time. We can observe that the standard deviation in Y and Z direction is slightly greater than that of the magnetic field in X direction. It can also be observed from the point cloud that there is less variation along the X-axis than and the variation along Y and Z axis is nearly similar. We can also observe that the data which results in the higher standard deviation in Y and Z is sparsely distributed and if we can clean it up, we could probably bring it to a lower value.

Allan Deviation Analysis:

The data collected for the purpose of performing Allan Deviation Analysis is collected in the basement of an apartment on Parker Hill Avenue. The data is collected at 40 Hz and is collected for the duration of 5 hrs. Allan deviation graphs are plotted to model the noise which gets accumulated over time and affects the final result.

Allan deviation is a method of analyzing and measuring the frequency stability of the data. It is versatile in the sense that it is efficient in determining the different noise sources that may have been present in the stationary gyroscope measurements.

The three most important noises that are modelled using Allan Deviation Analysis are White noise, Red noise and Pink noise.

White Noise:

The angle random walk is determined by the spectrum of white noise from the output of gyroscope. The parameter N that will be visible in subsequent graphs signifies the angle random walk coefficient.

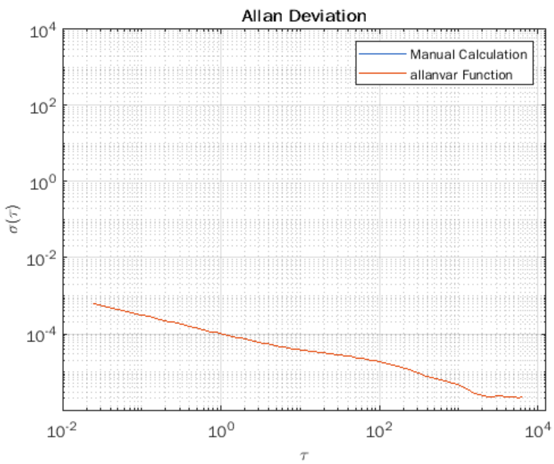
Red Noise:

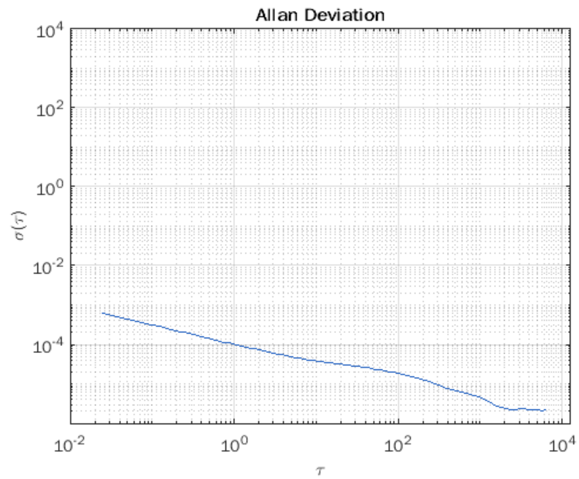
The rate random walk which we will see in subsequent plots is also called red noise or Brownian noise. The parameter K is the rate random walk coefficient.

Pink Noise:

The instability of bias is a characteristic of pink noise which is also known as flicker noise and is observed from the spectrum of gyroscope output as well. The parameter B is the bias instability coefficient.

Angular Acceleration:



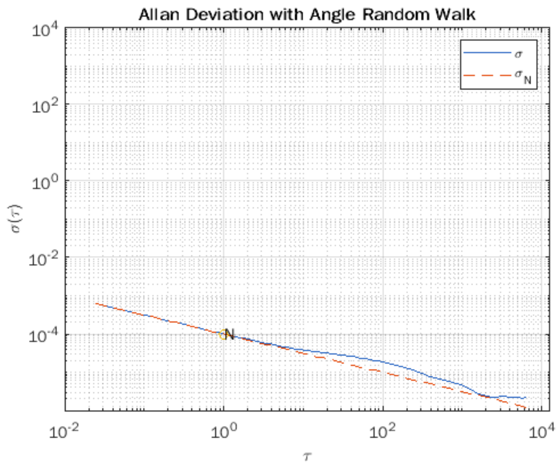


N value needs to be converted from rad/s to deg/root(hr.).

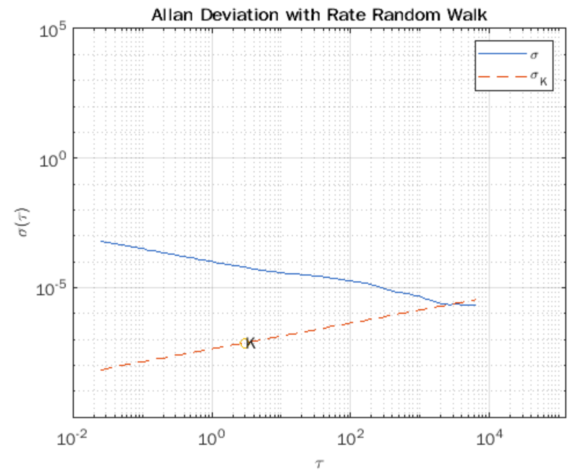
Bias needs to be converted from rad/s to deg/hr.

Angular Acceleration in X:

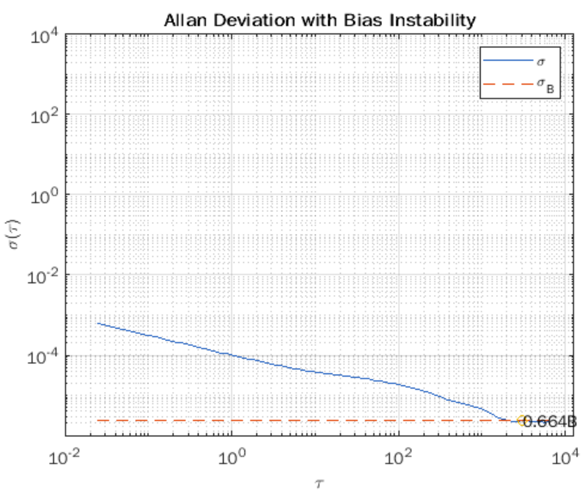
N = 9.9470e-05

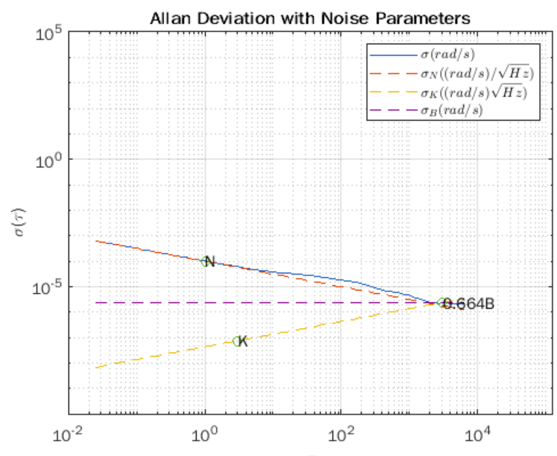


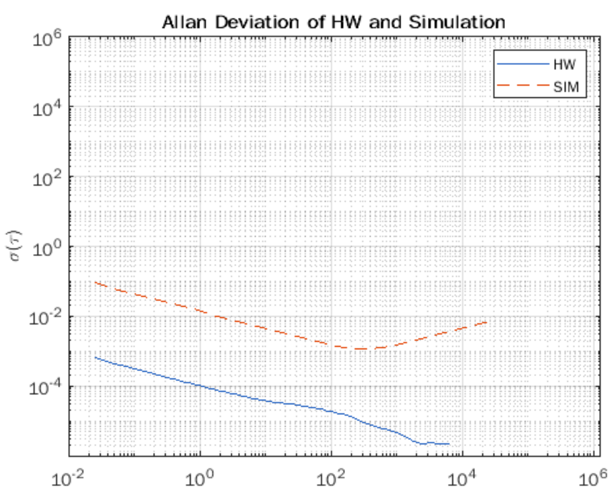
K = 7.3958e-08



B = 3.4518e-06



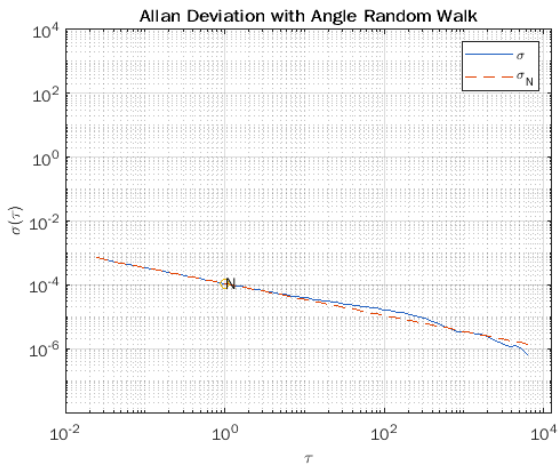




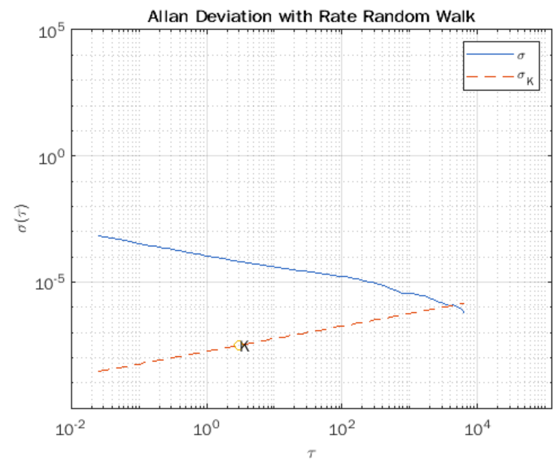
It is clear from the above plots showing deviation that the graph is closely following the slope line with a slope of 0.5. This is a characteristic of white noise and we can see that from the value of N. In the second plot, we can see the lines are intersecting and then following it. This is a characteristic of red noise. The third plot can be observed to infer that the line follows the slope zero line as well which marks the presence of pink noise. The above graphs are plotted from the data collected for a duration of 5 hrs. It has higher noise since other parameters like the temperature are not measured. The drift is not that significant as well which might be the reason that even 5 hrs of data is not enough for rate random walk.

Angular Acceleration in Y:

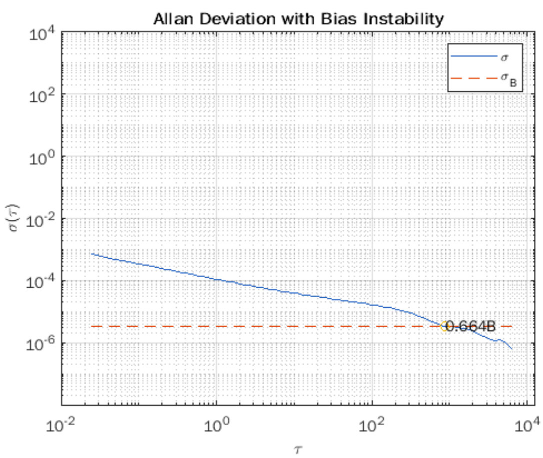
N = 1.0950e-04

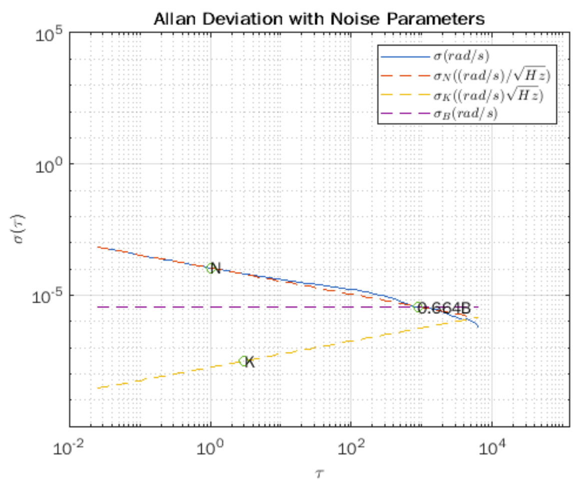


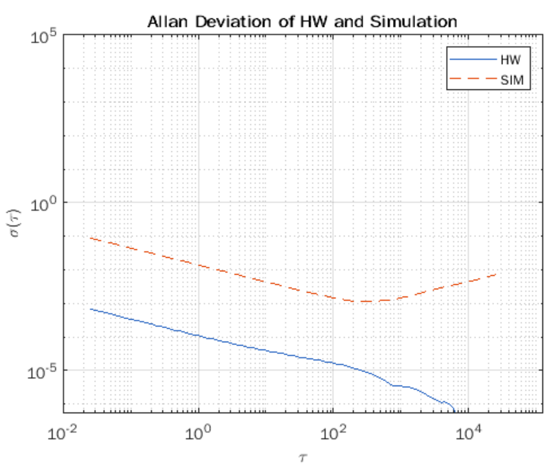
K = 3.1020e-08



B = 5.1516e-06



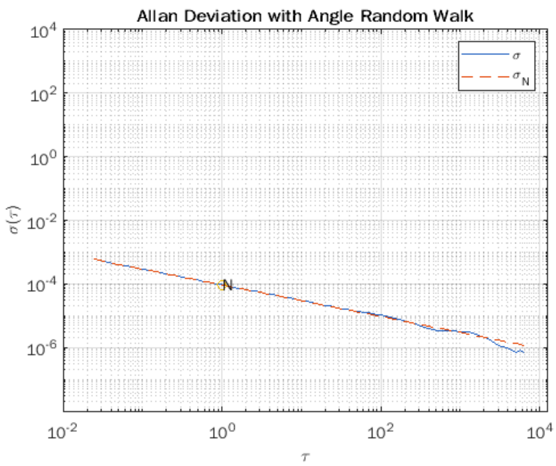




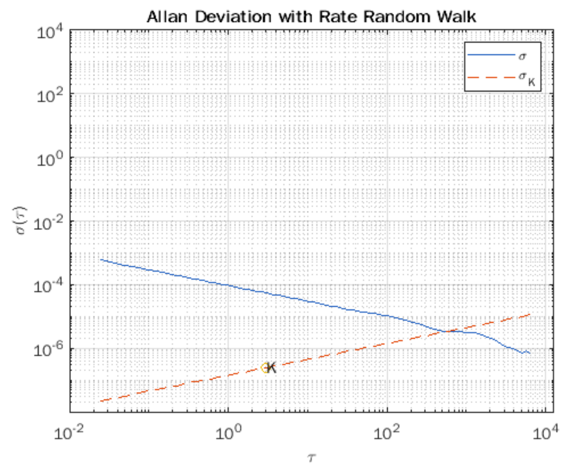
The observations can be made from the above graphs that white, red and pink noise are present in this scenario as well. While the graph follows the line in the first plot, it is unable to do so for the second and third which might be because the data of 5 hrs. is not enough for it to stabilize. The error can be observed to reduce, reach zero at the intersection and then start growing again as the lines move away.

Angular Acceleration in Z:

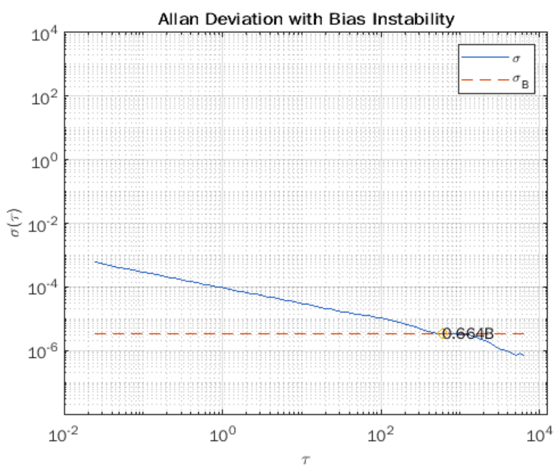
N = 9.3382e-05

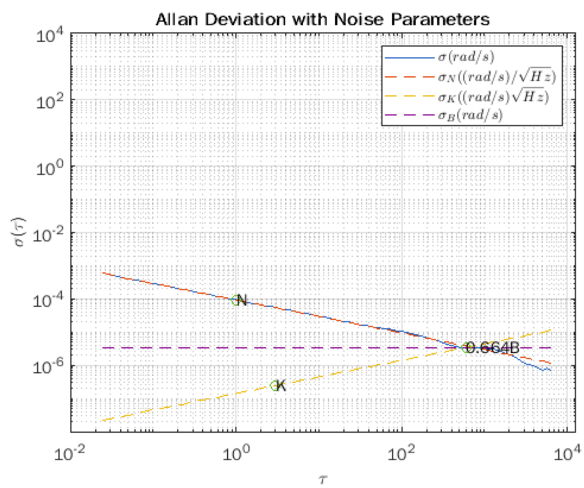


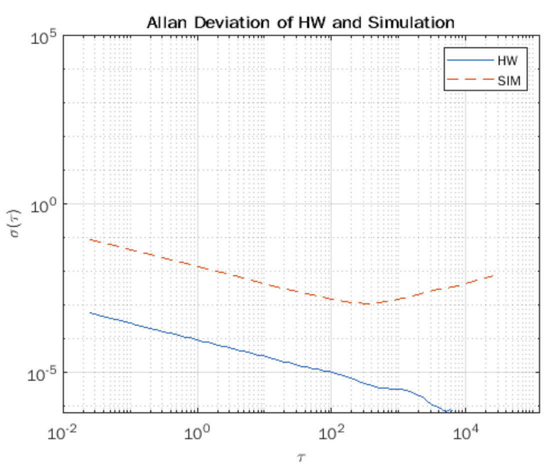
K = 2.4189e-07



B = 5.1404e-06

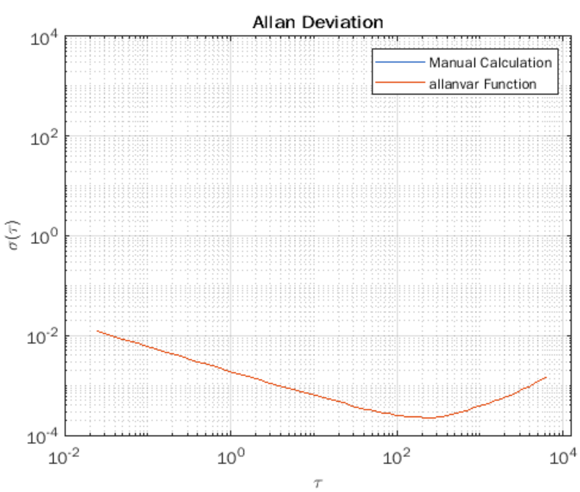


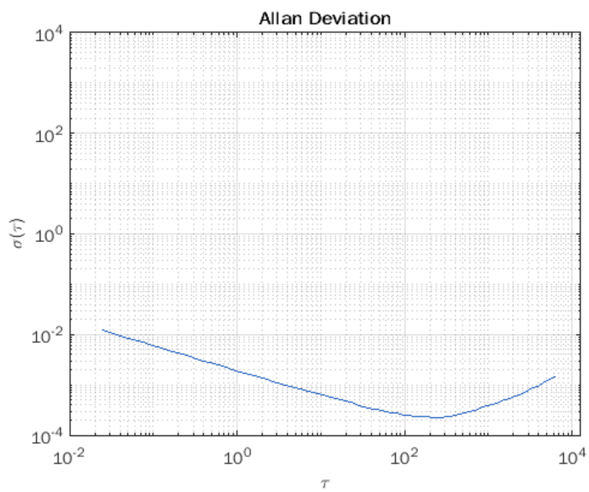




The noise in this case seems to worse than both X and Y combined. The lines are not able to follow except for the white noise which is still diverging from the looks of it. The error reduces gradually and start increasing again.

Linear Acceleration:





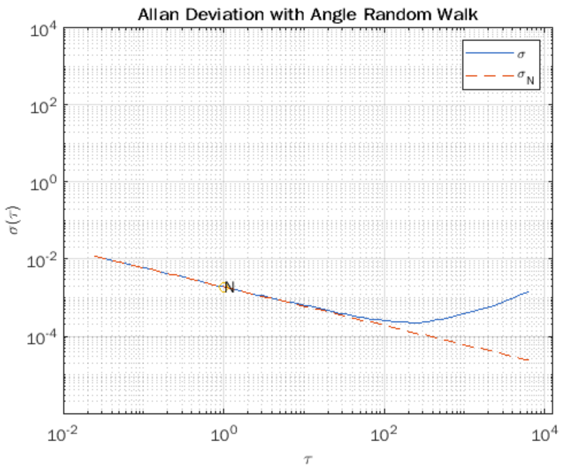
The parameter N needs to be converted from m/s to m/s/root(hr.).

The Bias parameter needs to be converted from m/s^2 to mg.

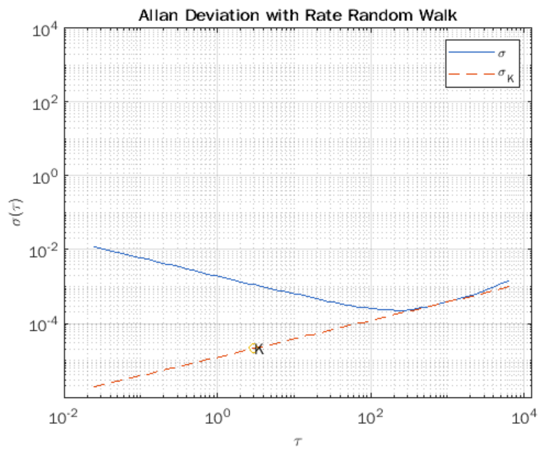
The analysis corresponds to that given in the VN100 data sheet concluding that it is accurate and the measurements look near to ideal as well though could still be improved.

Linear Acceleration in X:

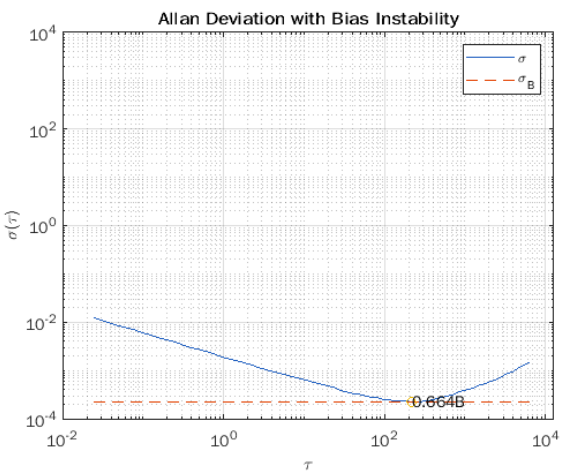
```
N = 0.0019
```

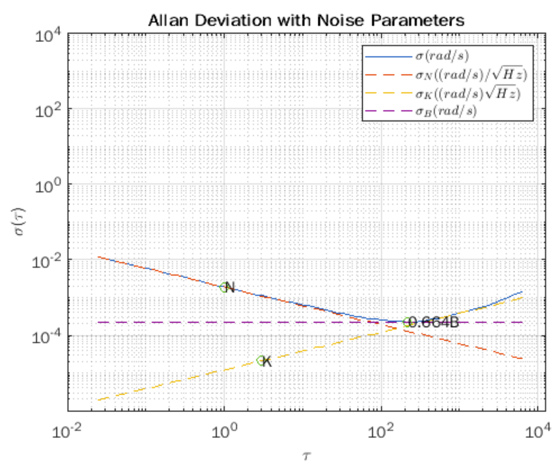


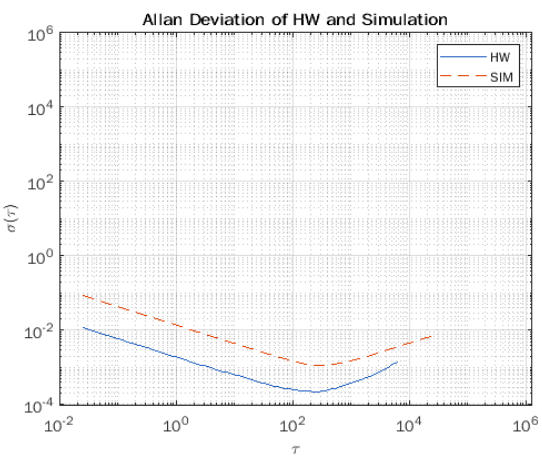

```
K = 2.0735e-05
```




```
B = 3.3919e-04
```



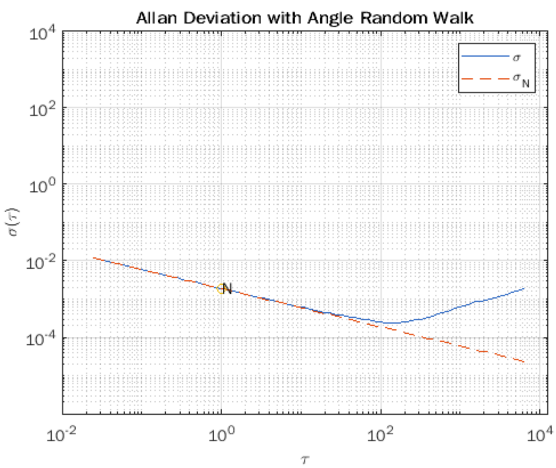




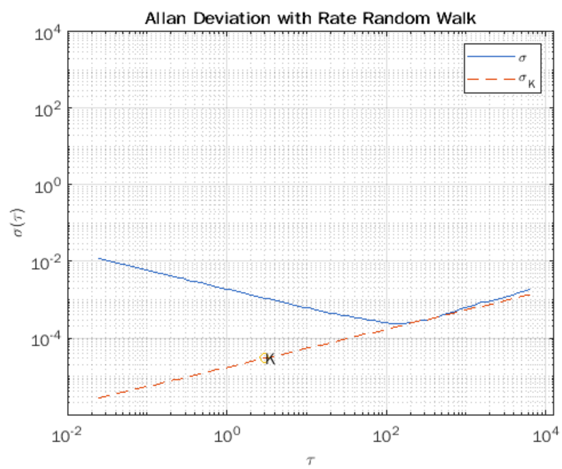
It can be seen from the graphs that there is the presence of white, red and pink noise the first plot follows the line almost overlapping but then diverges while the second plot is converging initially and then finally merges. The only graph that does not follow the line is the pink noise which might not have much significance in this case. The plots and ergo the data seems to be precise and smooth when compared to the results of angular acceleration but can still be improved. The simulation follows the line but has an offset which can be due to various factors like environmental conditions, temperature, etc.

Linear Acceleration in Y:

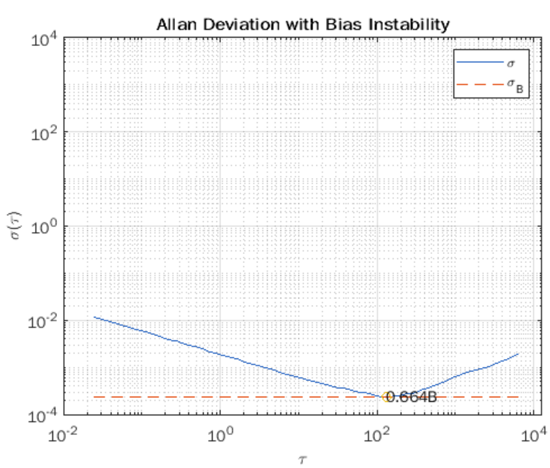
N = 0.0019

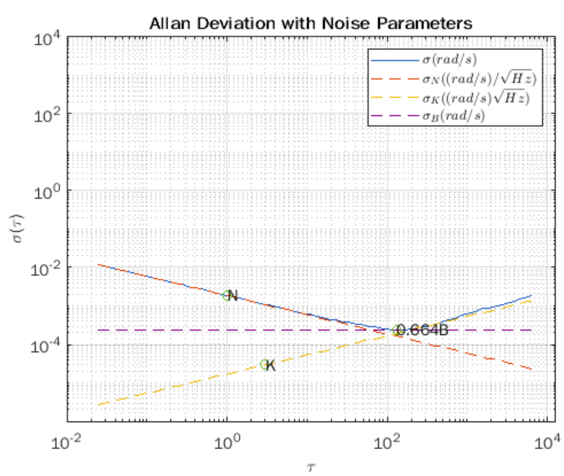


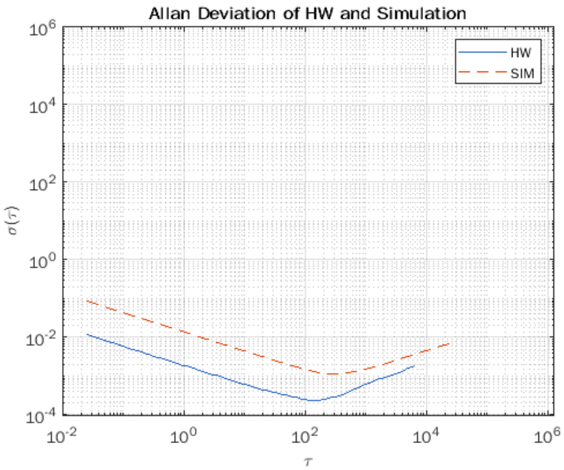
K = 2.9078e-05



B = 3.5764e-04



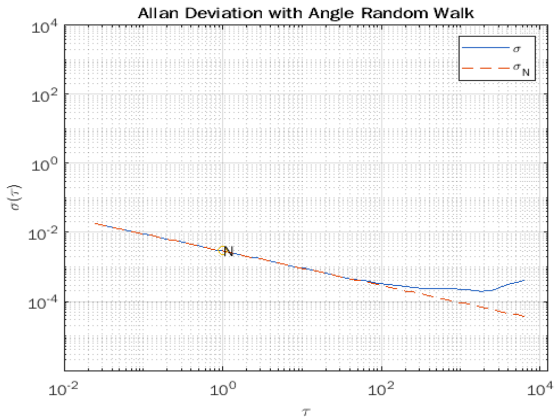




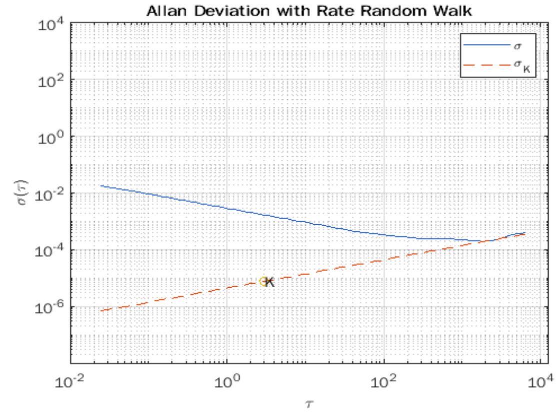
Similar observations and conclusions can be made about linear acceleration in Y axis as were made for linear acceleration in X axis.

Linear Acceleration in Z:

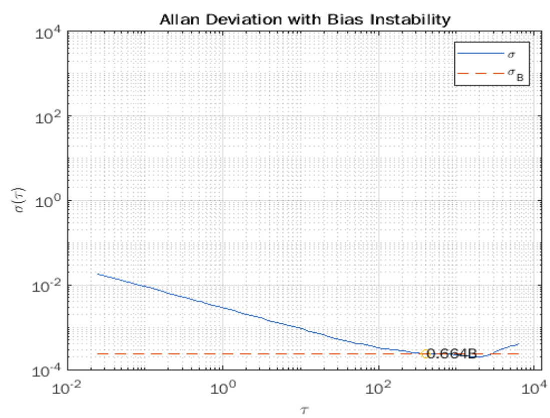
N = 0.0029

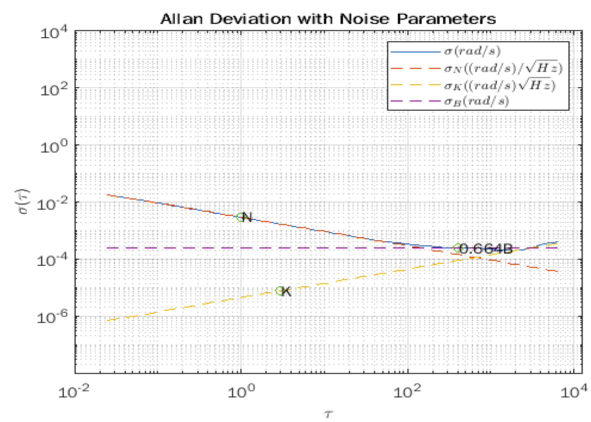


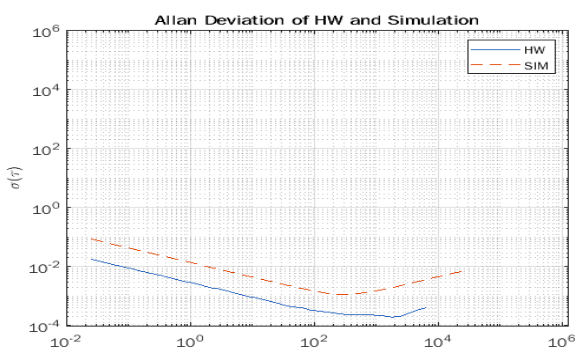
K = 7.5423e-06



B = 3.5700e-04







The linear acceleration in Z axis differs from the ones that we saw for the X and the Y axis. The lines are pretty much overlapping till the end and then diverges so we can say that it has white noise. The lines in the second graphs are converging and finally manage to overlap at the end. On interpolation we can find that the lines would continue to overlap but 5 hrs. of data is probably not enough to make that conclusion. The lines converge for pink noise as well in the third plot and then closely follow.

The given model predicts the behavior of data following the conventional path but the few errors could be a result of always varying environmental conditions or the disturbances caused by other factors like vibrations (even though complete attention and care was given to minimize external influence).