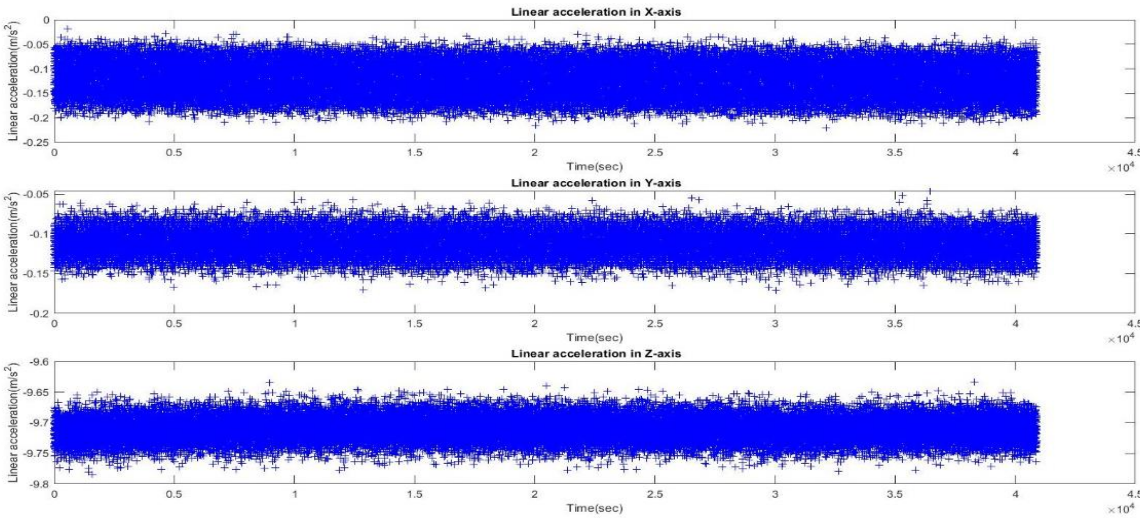
Report-3 IMU

Kshama Dhaduti

PART 1: Stationary IMU data collection for 10-15 minutes.

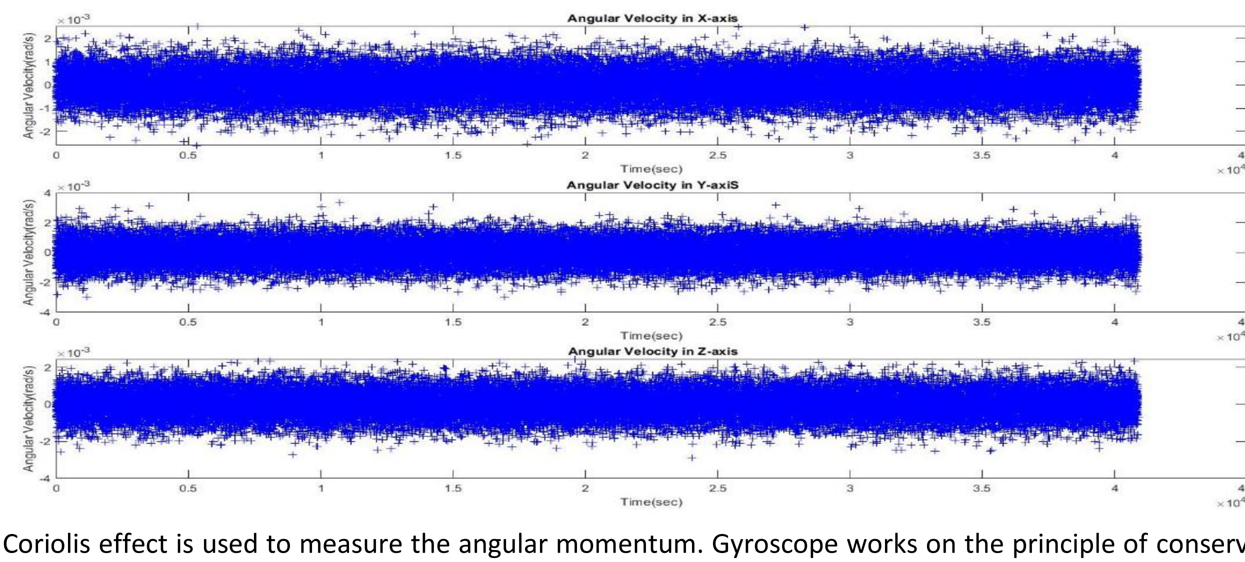
The static IMU data was collected using the device driver, the basement for an apartment. Since this data was collected on a snowy weekend, the heaters and washing machines were functioning in full swing. Lot of error and noise is being introduced into the readings collected due to the above reasons.

1.1. Accelerometer Data Analysis:



In the above graph Time vs Acceleration, the IMU sensor is very sensitive to noise and any form of vibrations in the environment. Gravity is another factor that will be affecting the z – axis but since the sensor was not perfectly leveled, gravity might have influenced x and y axes too.
The environmental conditions introduce noise in the data collected, in our case the heaters, washing machines, people walking and the sensor noise itself are the major source of noise. The sensor noise is mainly white gaussian noise.

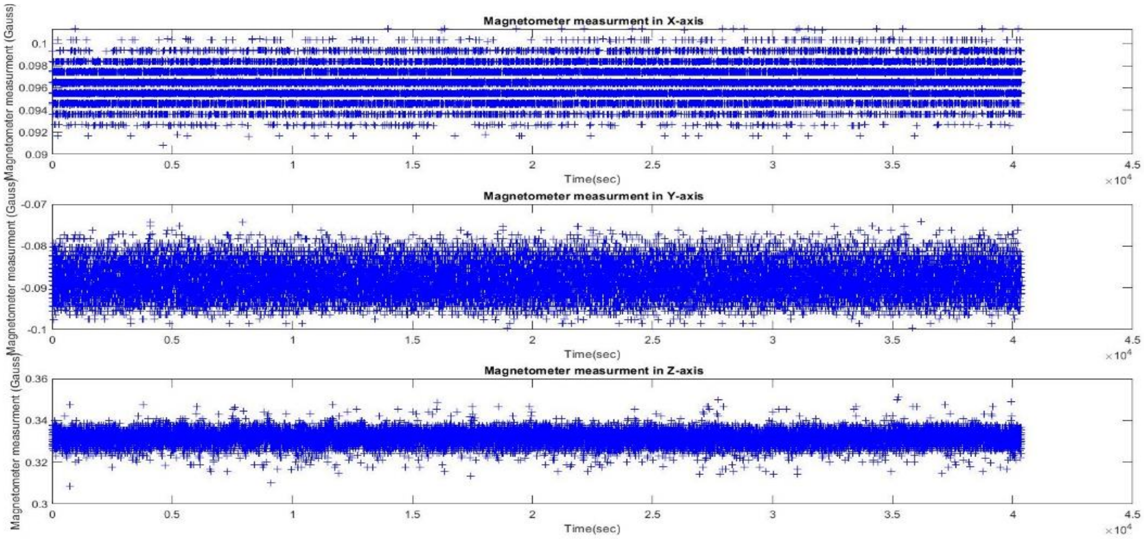
1.2. Gyroscope Data Analysis:



The Coriolis effect is used to measure the angular momentum. Gyroscope works on the principle of conservation of angular momentum. The gyroscope although being fixed the output is observed to be fluctuation, which ideally should have been zero. We are observing it to be drifting over a period, resulting in bias instability.

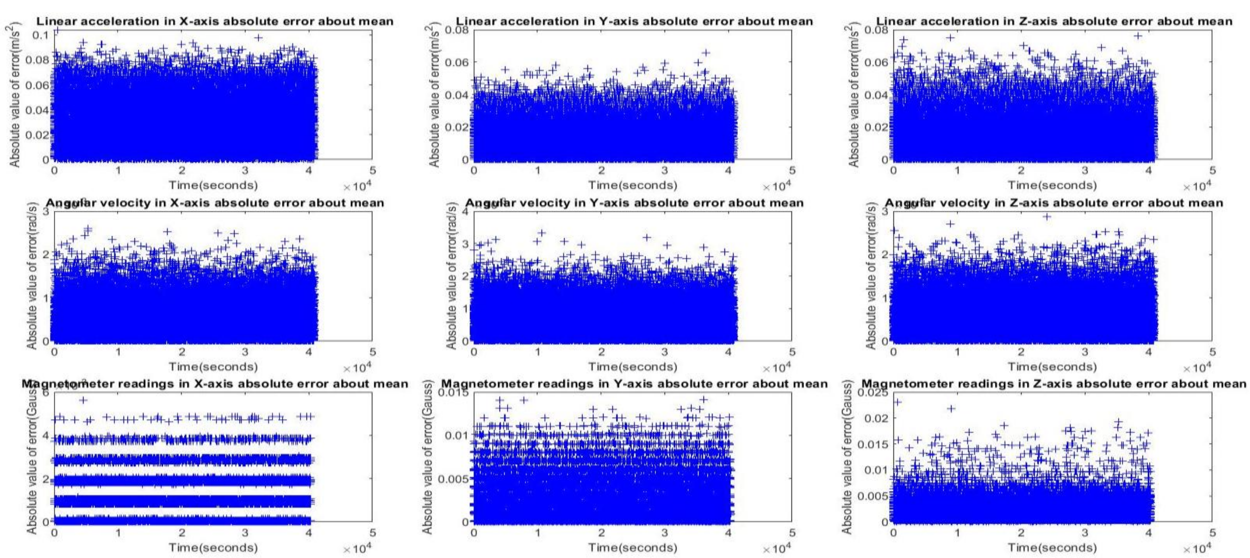
The gyro also exhibits a high frequency white noise, thermoelectrical reactions. This is an additional noise affecting the recorded gyro readings and keeps growing in proportion.

1.3. Magnetometer Data Analysis:



Looking at the graph of Time vs Magnetometer, we can infer that the reading is affected by the existence of any type of magnetic field in the surroundings. Since this data was collected in an apartment basement with high power electric lines, electronic devices, and other metal objects, the indued magnetic field is affecting the magnetometer readings.

1.4. Absolute error about mean data:

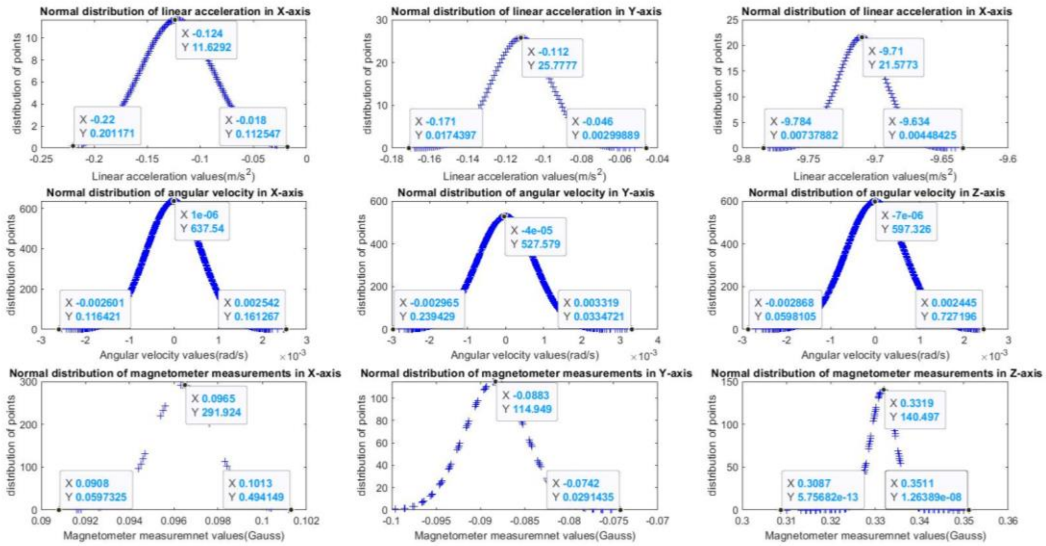


We are plotting absolute error about mean data along each axis for

1. Linear Acceleration
2. Angular Velocity
3. Magnetic Field

Comparatively less error is observed in angular velocity amongst the three.

1.5. Plot of Normal Distribution:



Above are the plots of Normal distribution of:

1. Linear Acceleration
2. Angular Velocity
3. Magnetometer

We can observe the distribution of the collected data is gaussian and the range of it.

1.6. Standard Deviation and Mean:

Tabulating the Mean and Standard deviation of the 15minutes stationary data.

	Linear acceleration	Angular velocity	Magnetometer measurements
Mean(about x-axis)	-0.0574	-4.69E-06	0.0964
Mean(about y-axis)	-0.1119	-1.57E-06	-0.0883
Mean(about z-axis)	-9.7101	-1.79E-06	0.3318
S.D.(about x-axis)	0.0343	6.26E-04	0.0014
S.D.(about y-axis)	0.0155	7.55E-04	0.0035
S.D.(about z-axis)	0.0185	6.68E-04	0.0028
Mean of abs. error(X axis)	0.0291	4.98E-04	0.0011
Mean of abs. error(Y axis)	0.0125	6.01E-04	0.0029
Mean of abs. error(Z axis)	0.0148	5.33E-04	0.0022
S.D. of abs. error(X axis)	0.018	3.78E-04	8.61E-04
S.D. of abs. error(Y axis)	0.0091	4.57E-04	0.0021
S.D. of abs. error(Z axis)	0.0111	4.03E-04	0.0018

2. Stationary IMU data collection for 5 hours.

Allan Variance used for identifying noise properties of inertial sensor. This is used to model gyroscope in simulation as:

$$\Omega(t) = \Omega_{Ideal}(t) + Bias_N(t) + Bias_B(t) + Bias_K(t)$$

N = angle random walk

K = rate random walk

B = bias instability

2.1 Noise

2.1.1 Angle Random walk(N):

It is defined by the white noise observed in the output. The Power Spectral Density according to Allan Variance MathWorks: $S_\Omega(f) = N^2$ The units of *N* are $(rad/s)/\sqrt{Hz}$.

White noise shows up on the Allan Variance as a slope gradient -0.5. The random walk is obtained by fitting a straight line through the slope at τ = 1.

2.1.2 Rate random walk(K):

Represents the red noise (Brownian noise) in the data collected. The PSD is

$$S_\Omega(f) = (\frac{K}{2\pi})^2 \frac{1}{f^2}$$

The units of *K* are $(rad/s)\sqrt{Hz}$.

2.1.3 Bias instability(B):

Represents the pink noise (flicker noise) in the data collected.

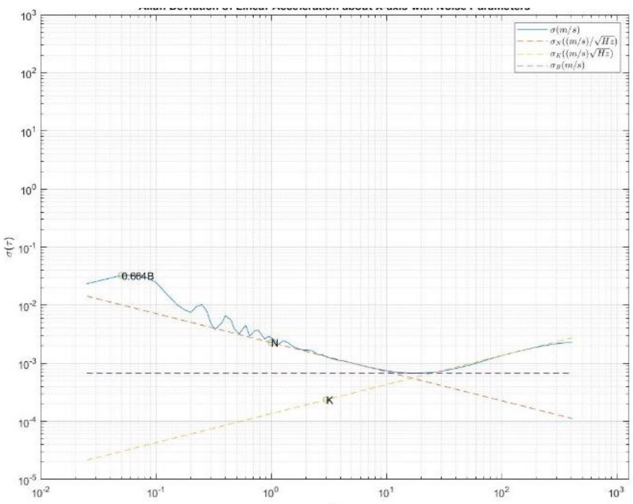
Bias stability is a measure of change over a specific period with constant surrounding conditions. It is the min value on the graph plotted.

$$S_\Omega(f) = \begin{cases} (\frac{B^2}{2\pi})\frac{1}{f} & : f \le f_0 \\ 0 & : f > f_0 \end{cases}$$

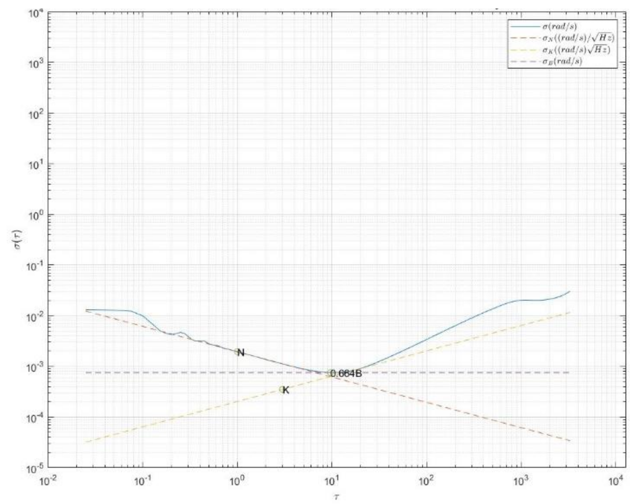
The units of *B* are rad/s

2.2 Allan Deviation for Linear Acceleration

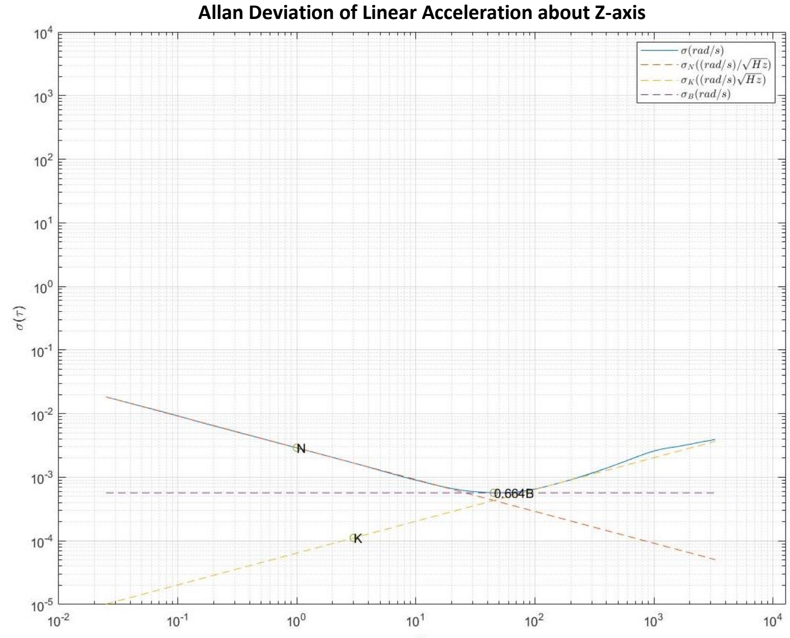
Allan Deviation of Linear Acceleration about X-axis



Allan Deviation of Linear Acceleration about Y-axis



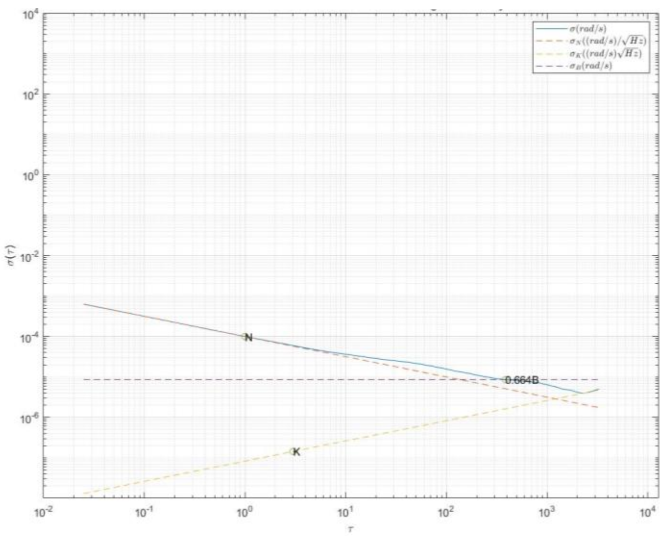
Allan Deviation of Linear Acceleration about Z-axis



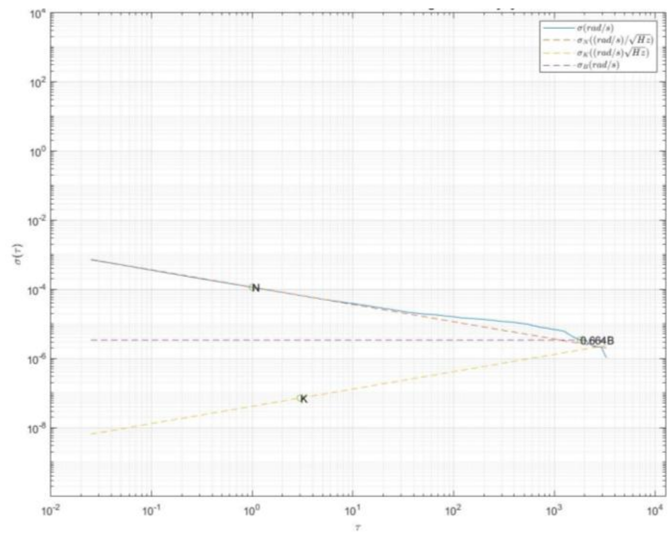
We are plotting Allan Variance for Linear Acceleration about X, Y and Z axis.
The Allan variance plot for x and y axis are showing some disturbances in the data, the accelerometer is mostly affected by the surrounding vibrations and noise. The crinkle observed in the x and the y, I suspect it to be vibrations sourcing from the elevator, washing machine running during the initial few hours of the 5-hour reading taken. On the other hand the Linear Acceleration about z – axis, we are not observing as much disturbance we are observing on the other two. We are observing the X,Y, & Z plot drifting and rising over time and is plotted at tau. We can say that the accelerometer sensor performance is fluctuating over time.

2.3 Allan Deviation for Angular velocity:

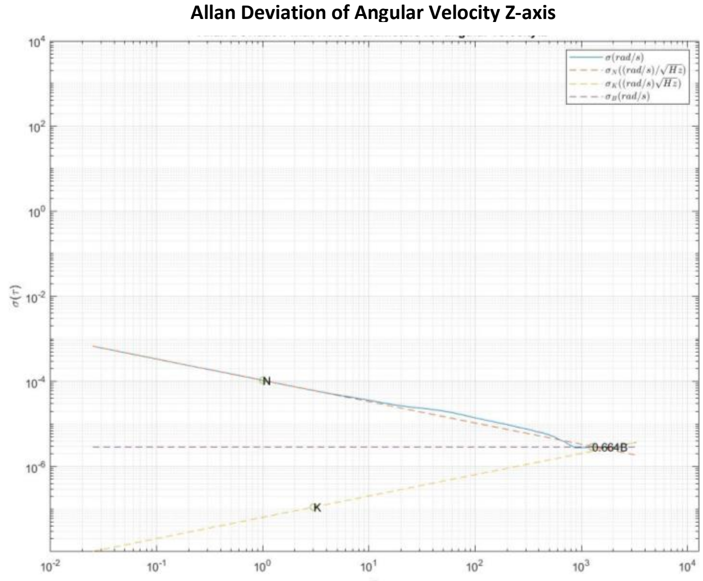
Allan Deviation of Angular Velocity about X-axis



Allan Deviation of Angular Velocity Y-axis



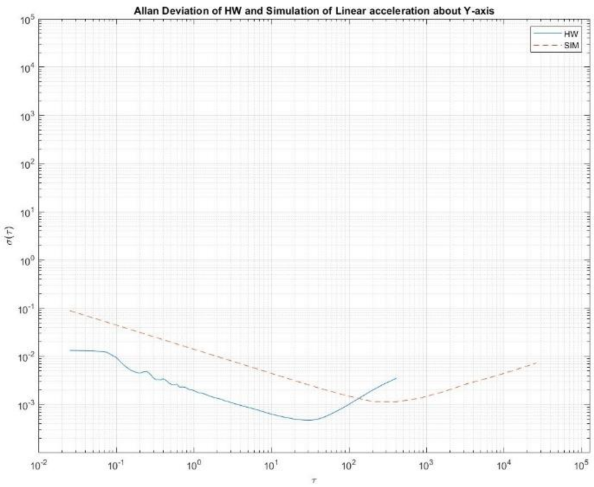
Allan Deviation of Angular Velocity Z-axis

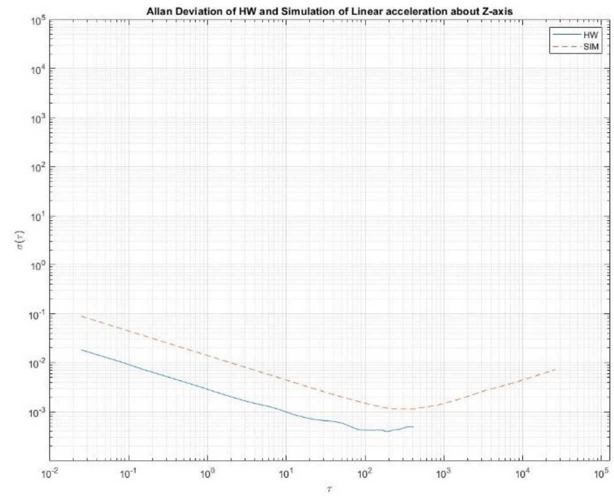


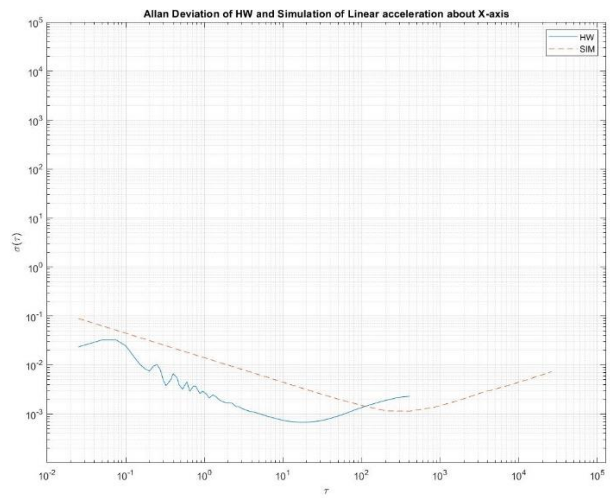
We are plotting Allan Deviation for Angular Velocity about X, Y and Z axis.
From the above graph, we don't see the angular velocity to be rising again. Its drifting away and does not rise back to anything close to it initial values. We can deduce that the sensor angular velocity parameter is near perfect, and the performance does not fluctuate but it drifts over time.

2.3 Allen Deviation of Hardware and Simulation:

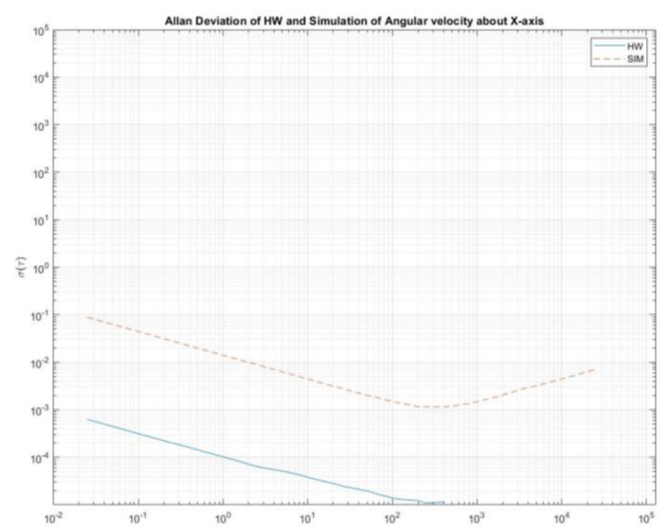
2.3.1 HW and Simulation of Linear Acceleration:

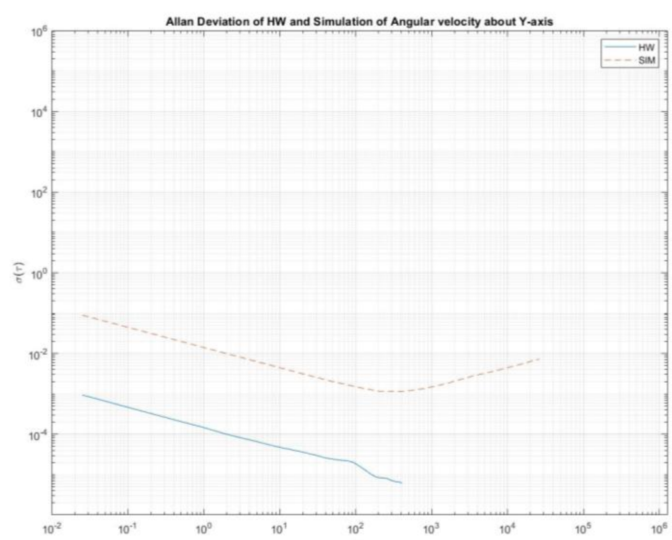


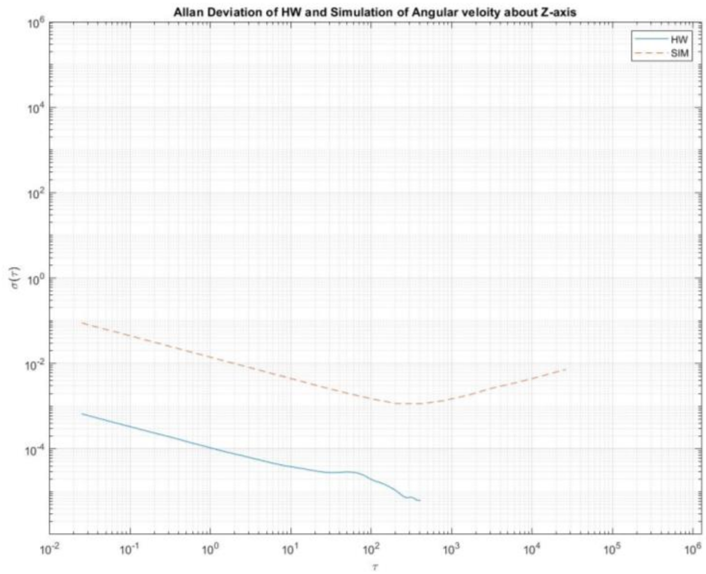




2.3.2 HW and Simulation of Angular Velocity:







The above plot shows us a simulated model of gyroscope and accelerometer compared along side actual hardware collected data. The simulated plot is independent of temperature related parameters, and noise. It is close to ideal expected data plot. We can deduce the difference being observed in the hardware collected data which is affected by noise, temperature and other parameters and the simulated data.

2.4 Comparing N, K & B values from the Allen Deviation with Error Terms by Sensor Grade:

Error Terms by Sensor Grade

GRADE	ACCELEROMETER BIAS (mg)	VELOCITY RANDOM WALK (m/s/$\sqrt{hr}$)	GYRO BIAS (deg/hr)	ANGLE RANDOM WALK (deg/$\sqrt{hr}$)
Consumer	10	1	100	2
Industrial	1	0.1	10	0.2
Tactical	0.1	0.03	1	0.05
Navigation	0.01	0.01	0.01	0.01

	Angular velocity	Linear acceleration
N about x-axis	1.00E-04	0.0023
N about y-axis	1.14E-04	0.002
N about z-axis	1.06E-04	0.0029
B about x-axis	1.29E-05	0.017
B about y-axis	5.07E-06	0.0011
B about z-axis	4.36E-06	8.57E-04
K about x-axis	5.07E-06	0.2502
K about y-axis	7.09E-08	3.51E-04
K about z-axis	1.12E-07	1.11E-04

Looking at the N, B and K values deduced after plotting the Allen Deviation for Angular velocity and Linear acceleration and comparing it with the available data, we can say that it is a 'Navigation grade sensor'.