NAME : JOSE JOSEPH THANDAPRAL

NUID NO. : 002102407

COURSE CODE : EECE5554

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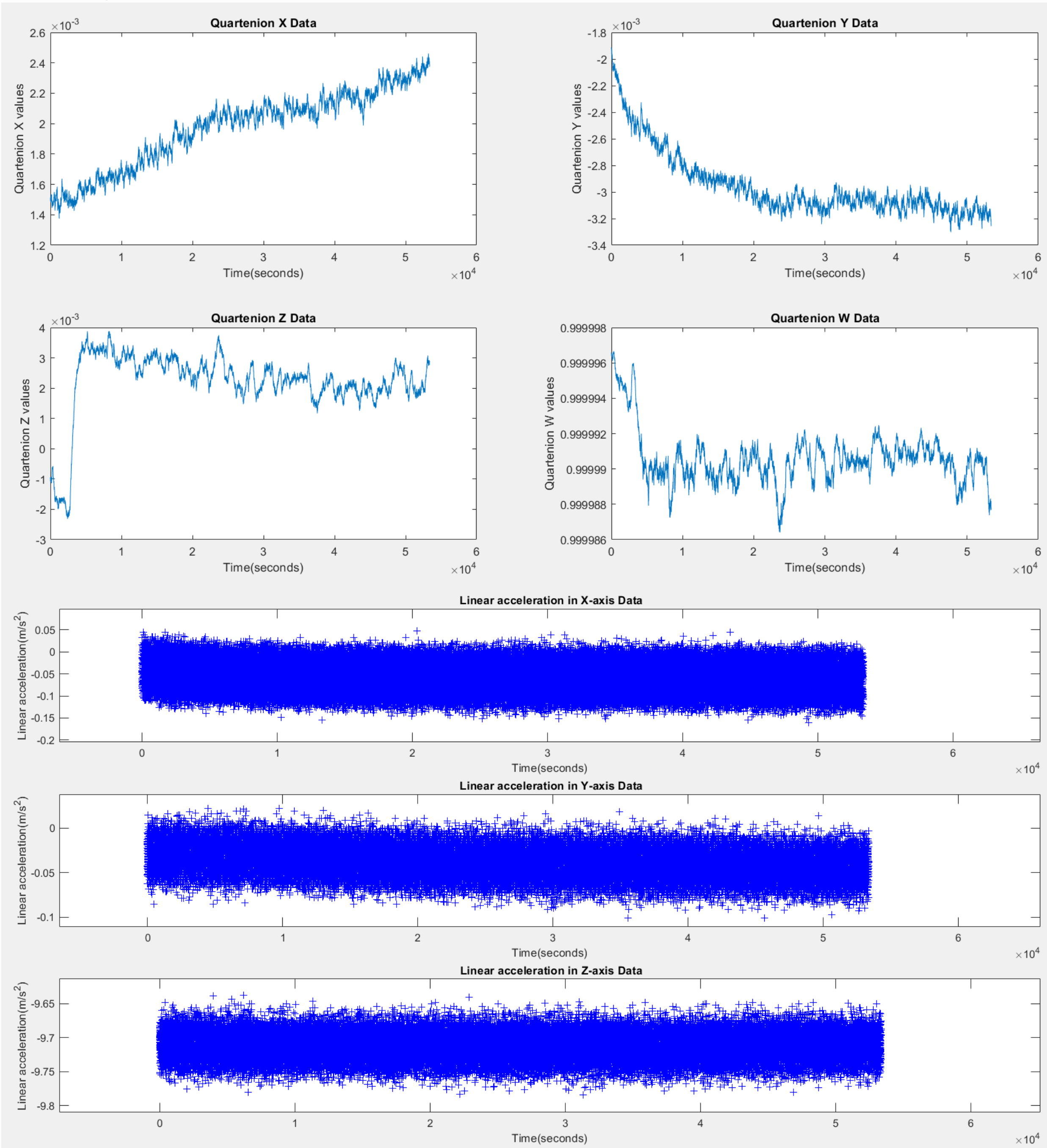
CRN : 33639

FACULTY : PROF. HANUMANT SINGH

NORTHEASTERN UNIVERSITY, BOSTON

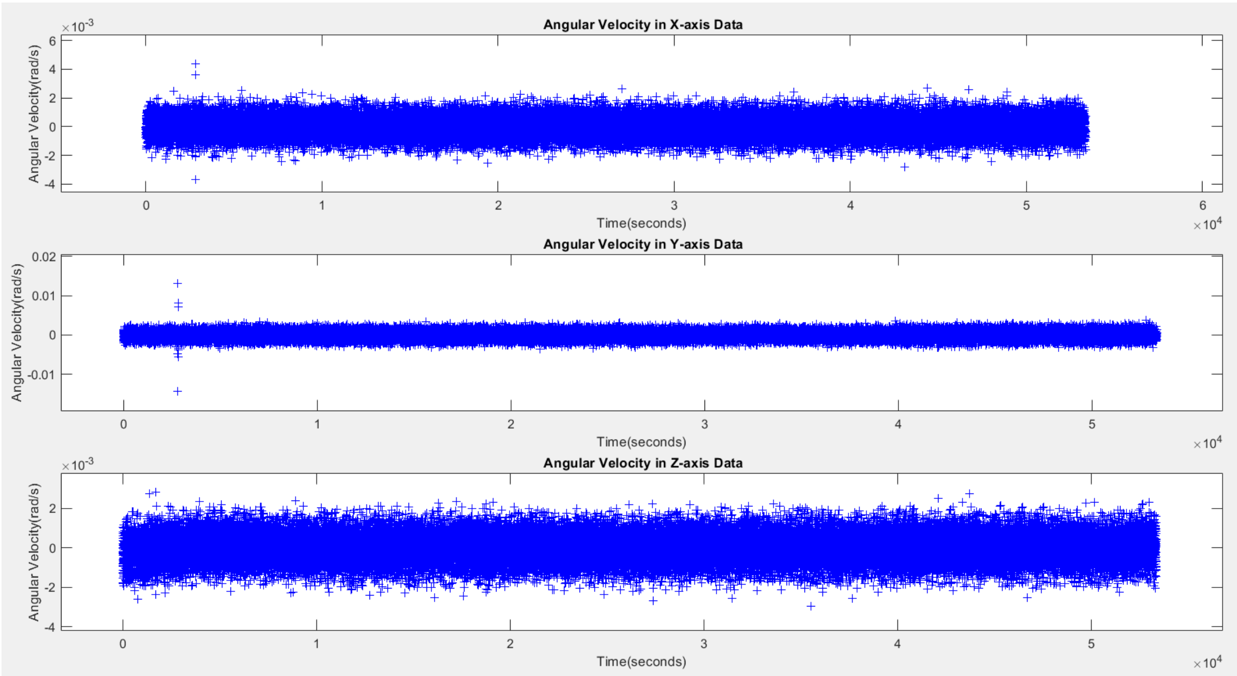
LAB-3 REPORT

Stationary IMU data collection for 15 minutes:

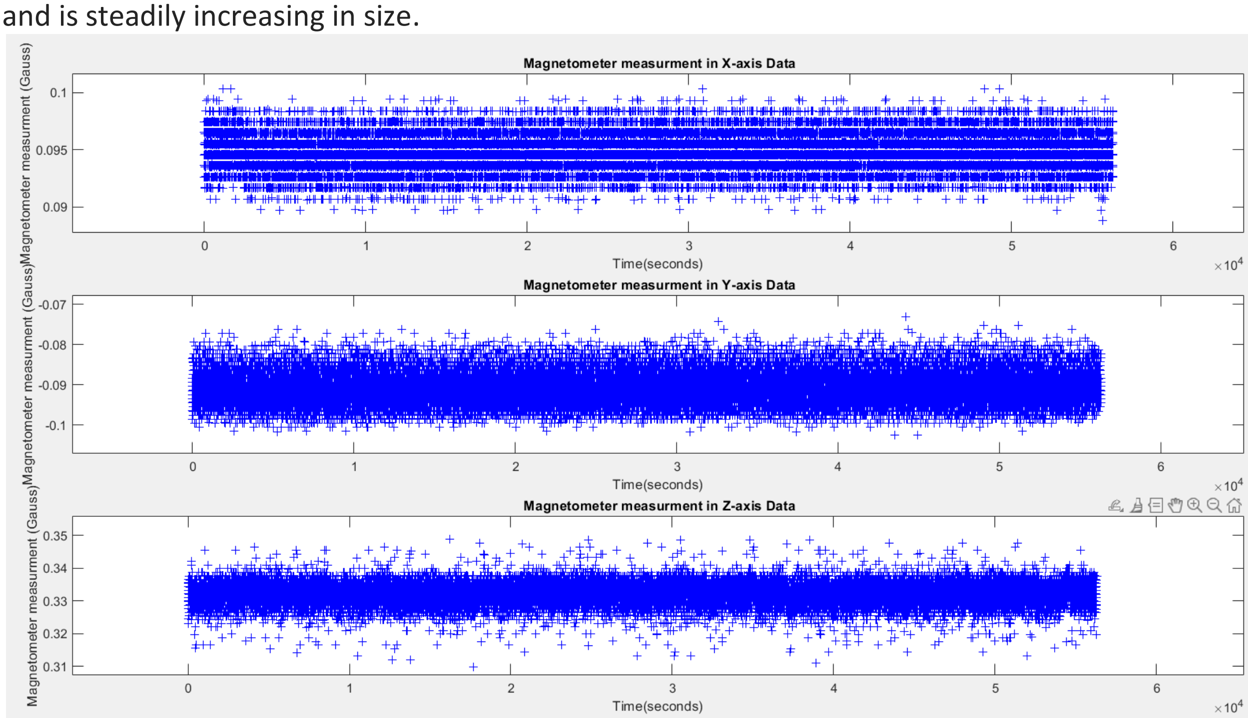


The heaters and washing machines were in full swing because the data was obtained on a snowy weekend. Because of the aforementioned reasons, an amount of noise has been induced into the readings gathered.

The IMU sensor is extremely sensitive to noise and any type of disturbance in the environment, as shown in the Time vs Acceleration graph above. Gravity is another component that will affect the z-axis, although gravity may have also influenced the x and y axes because the sensor was not completely balanced.

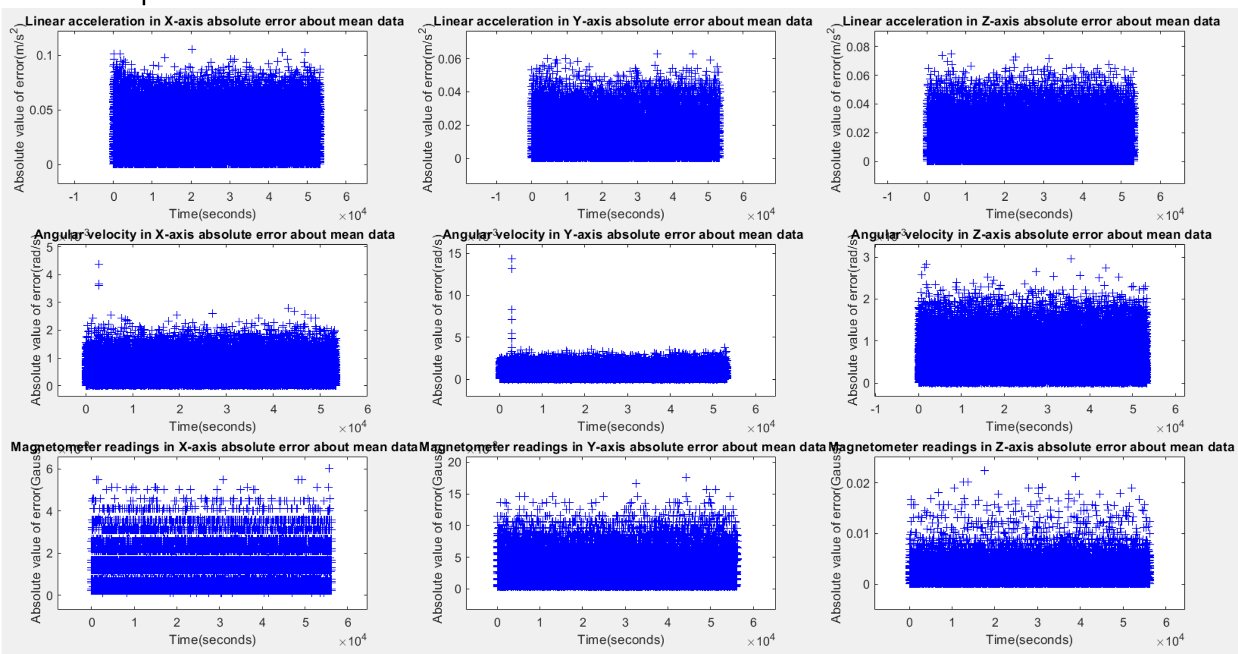


The angular momentum is calculated using the Coriolis effect. The gyroscope works on the idea of angular momentum conservation. Despite the fact that the gyroscope is fixed, the output fluctuates, which should be zero. We've noticed it wandering over time, resulting in bias instability. Heaters, washing machines, people walking, and sensor noise are all sources of noise in the data that we collected. White gaussian noise makes up the majority of the sensor noise. The gyro also exhibits a high-frequency white noise characteristic, which is caused by thermoelectrical reactions. This is an extra noise that affects the recorded gyro measurements and is steadily increasing in size.



The graph of Time vs Magnetometer shows that the reading is influenced by the presence of any type of magnetic field in the area. Since this data was collected in an apartment basement with high-power electric wires, electronic devices, and other metal objects, the induced magnetic field is distorting the magnetometer readings.

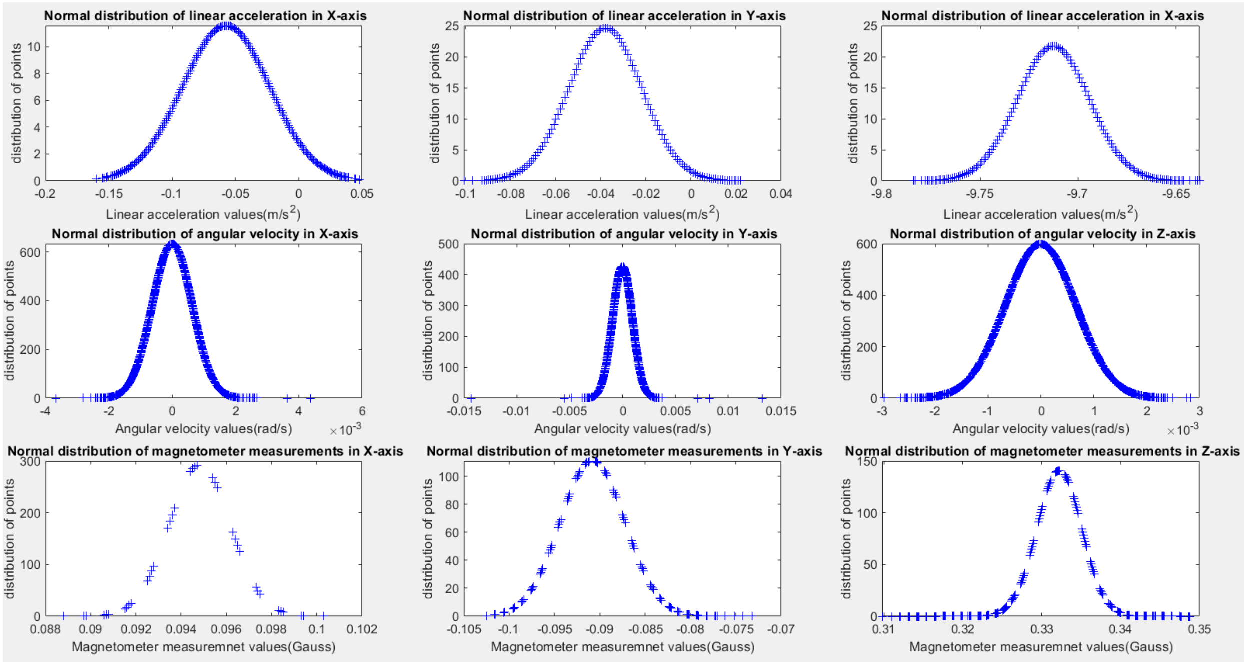
The below plot shows the distribution of absolute values of errors:



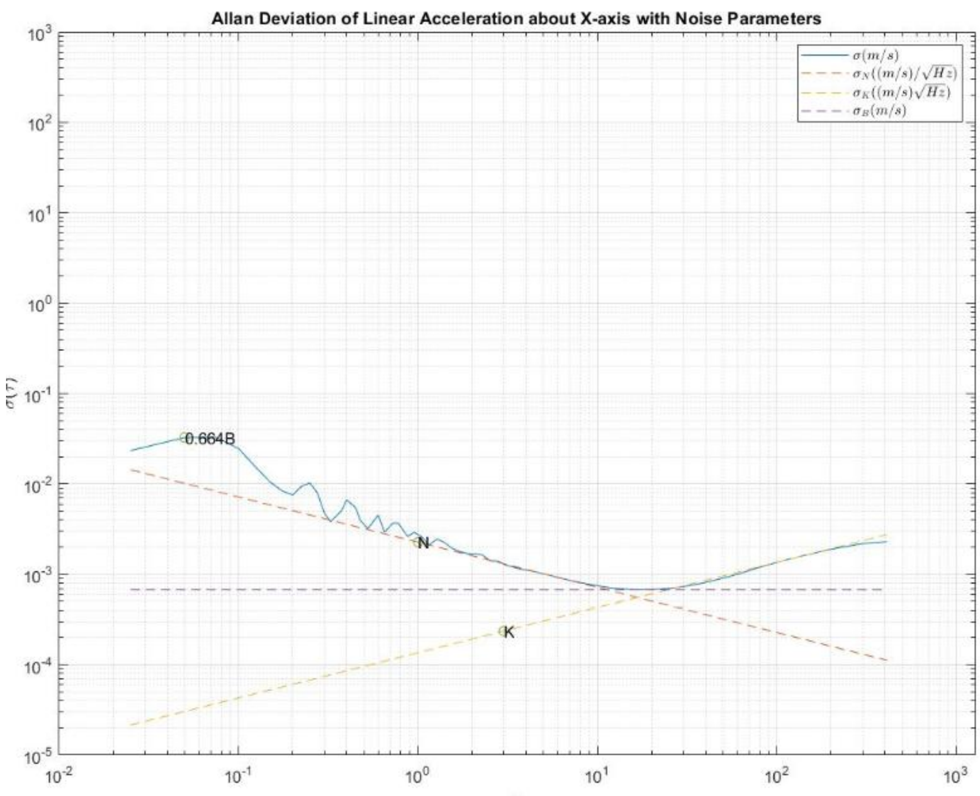
The statistics for the errors are as shown:

	Linear acceleration	Angular velocity	Magnetometer measurements
Mean(about x-axis)	-0.0574	0.000003296	0.0948
Mean(about y-axis)	-0.0381	-0.000001476	-0.0908
Mean(about z-axis)	-9.7126	-3.7053E-06	0.3322
S.D.(about x-axis)	0.0345	0.00062977	0.0014
S.D.(about y-axis)	0.0162	0.00093381	0.0036
S.D.(about z-axis)	0.0184	0.0006668	0.0028
Mean of abs. error(X axis)	0.0293	0.00050221	0.0011
Mean of abs. error(Y axis)	0.0131	0.00074604	0.0029
Mean of abs. error(Z axis)	0.0147	0.00053154	0.0022
S.D. of abs. error(X axis)	0.0182	0.00037999	0.0008064
S.D. of abs. error(Y axis)	0.0096	0.00056162	0.0021
S.D. of abs. error(Z axis)	0.0111	0.0004026	0.0018

Further, the normal distribution of the different parameters are plotted as shown:

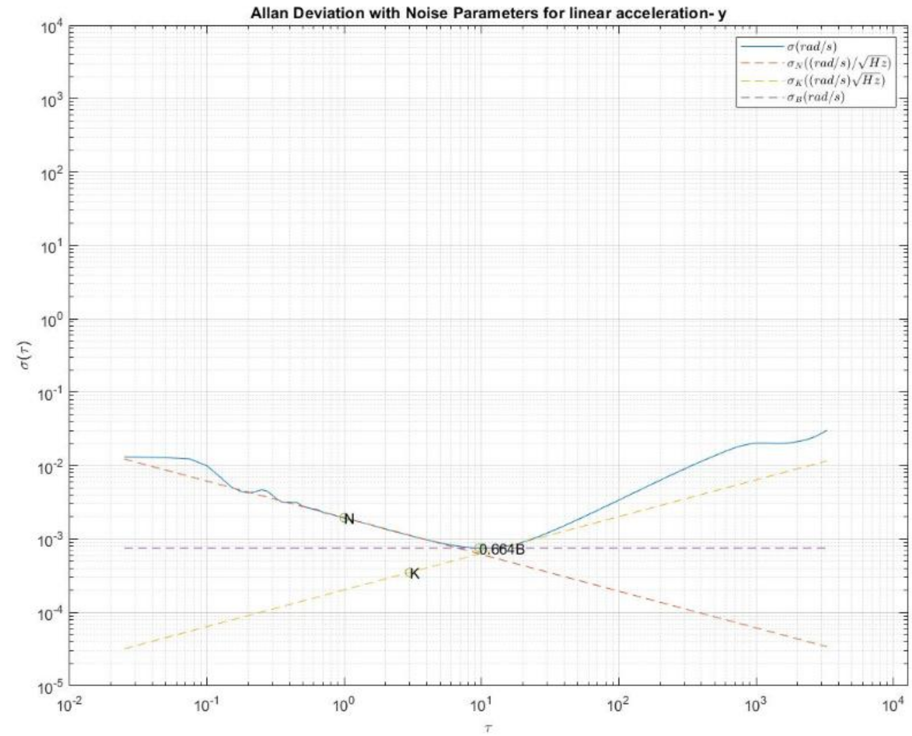


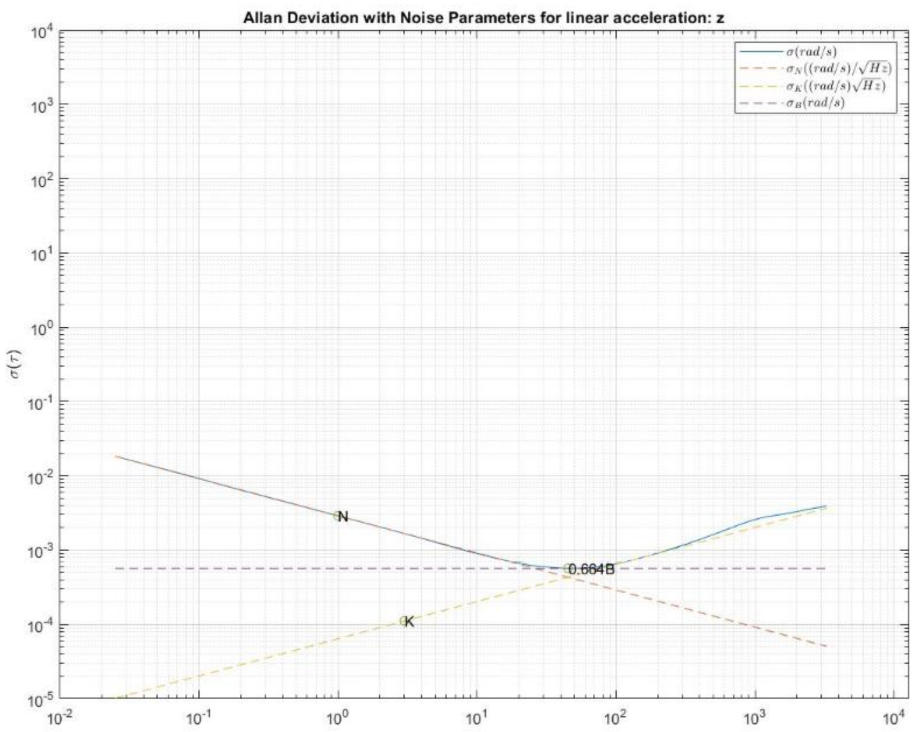
Allan deviation for 5 hours of data

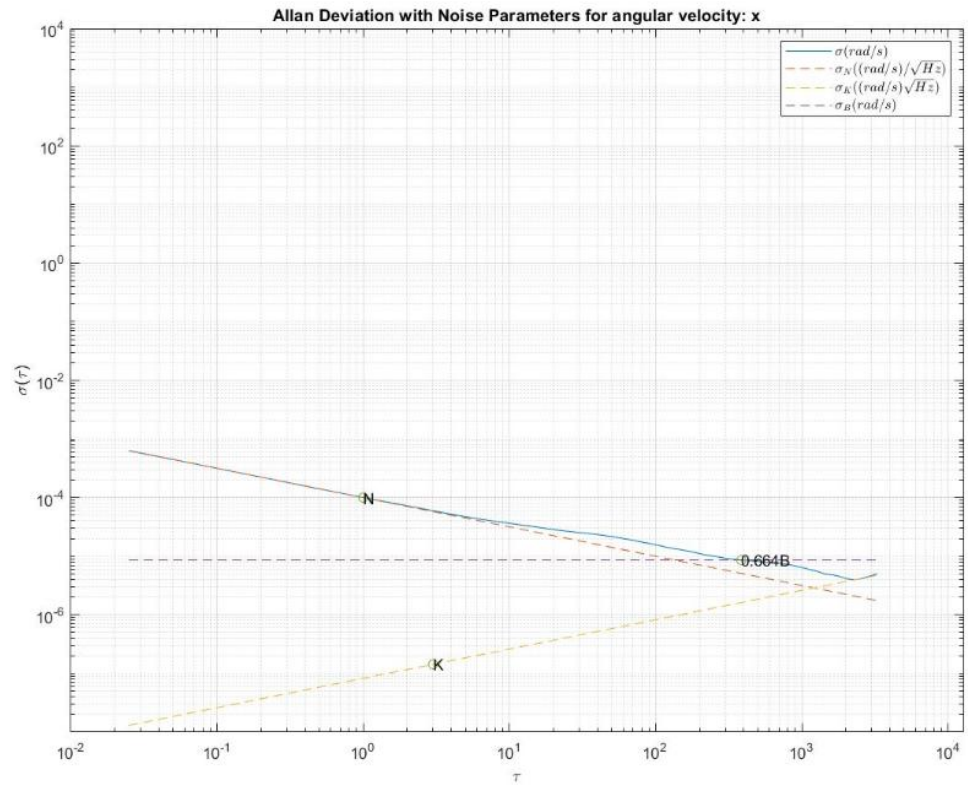


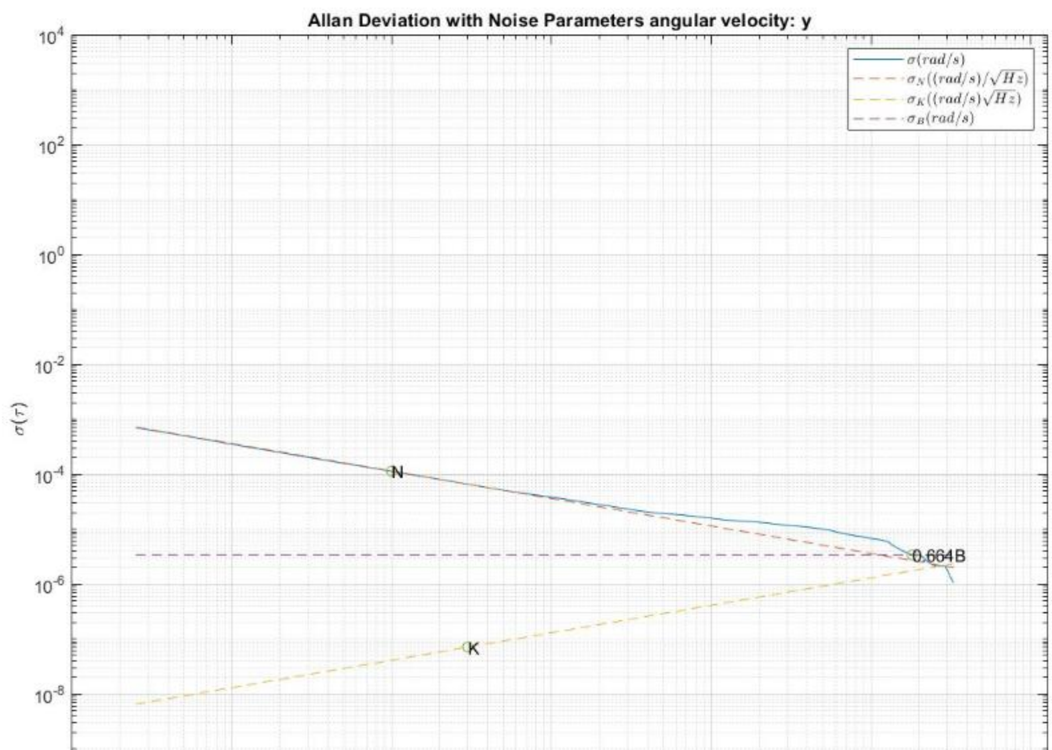
The data is exhibiting some disturbances in the Allan variance plot for the x and y axes, indicating that the accelerometer is largely impacted by the surrounding vibrations and noise. It can be reasonably assumed that the crinkle in the x and y is due to vibrations from the elevator and the washing machine running during the first few hours of the 5-hour reading. The Linear

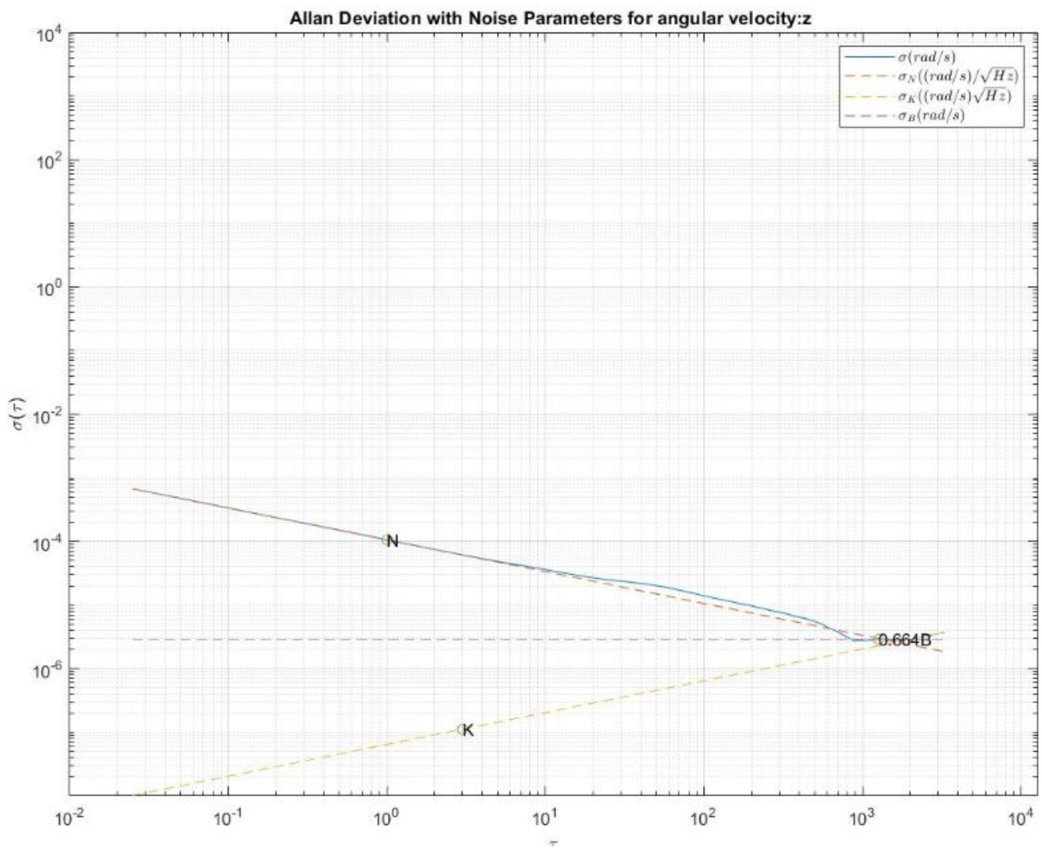
Acceleration about the z-axis, on the other hand, does not cause as much disruption as the other two. The X, Y, and Z plots are drifting and rising over time and are depicted at tau. We might claim that the performance of the accelerometer sensor varies with time.






Allan Deviation with Noise Parameters for angular velocity: x
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
$\sigma(\tau)$
τ
N
K
0.664B


Allan Deviation with Noise Parameters angular velocity: y
$\sigma(rad/s)$
$\sigma_N((rad/s)/\sqrt{Hz})$
$\sigma_K((rad/s)\sqrt{Hz})$
$\sigma_B(rad/s)$
$\sigma(\tau)$
N
K
0.664B



The statistics of the data are as follows:

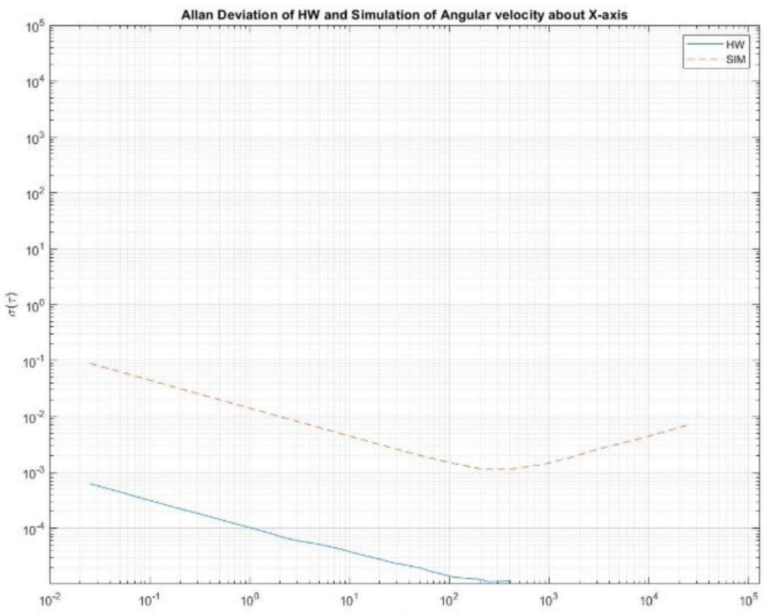
	Angular velocity	Linear acceleration
N About x-axis	0.00010018	0.0023
N About y-axis	0.0001136	0.002
N About z-axis	0.00010615	0.0029
B About x-axis	0.000012909	0.017
B About y-axis	5.0667E-06	0.0011
B About z-axis	4.3643E-06	0.00085681
K About x-axis	5.0667E-06	0.2502
K About y-axis	7.0851E-08	0.00035106
K About z-axis	1.1177E-07	0.00011129

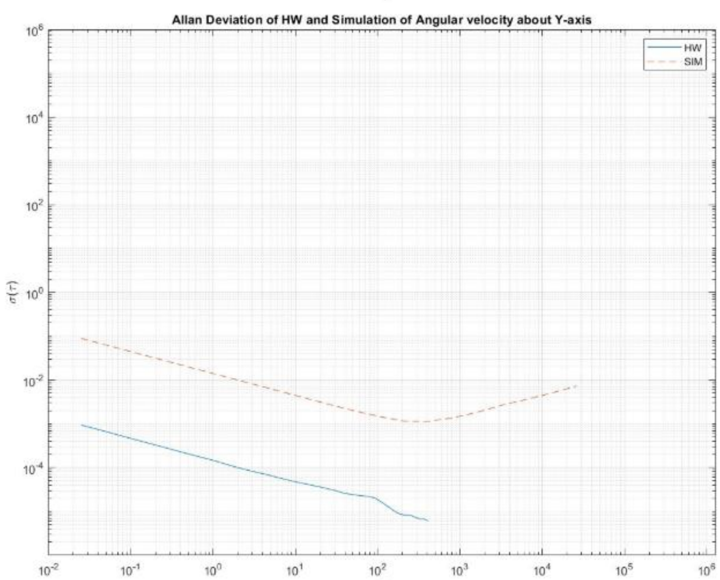
The comparison of the data values with VN100 spec sheet as shown below shows that witht eh available data, N,B and K values are comparable to that of a ‘Navigation Grade sensor’:

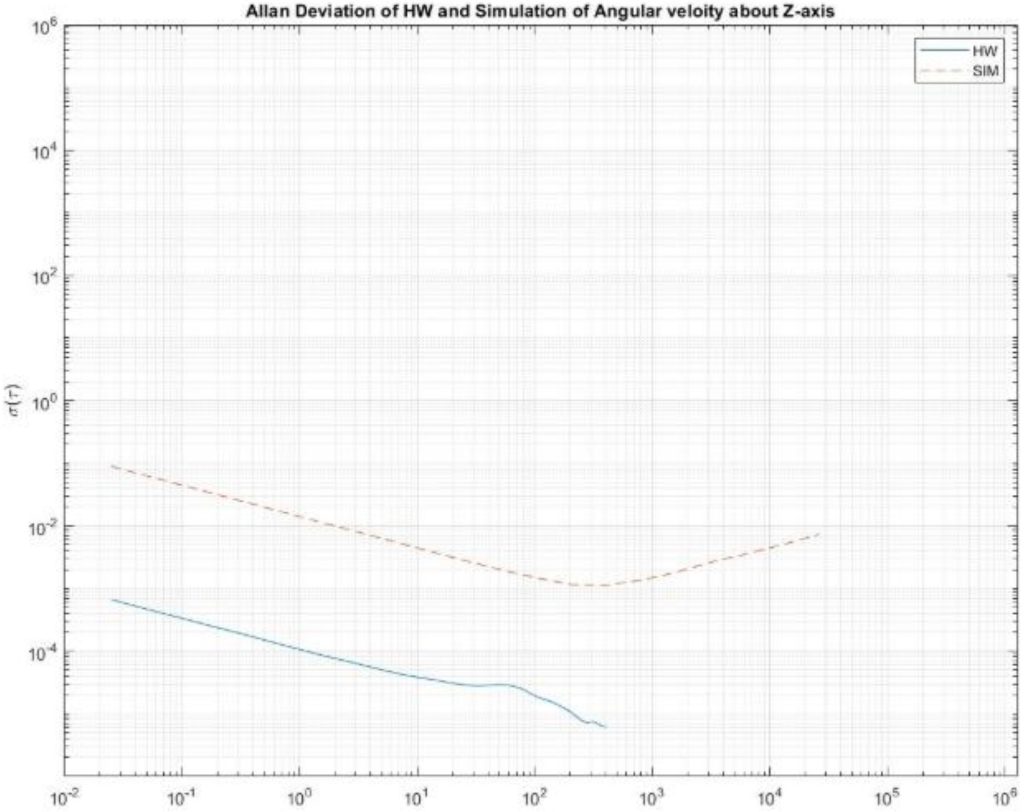
Error Terms by Sensor Grade

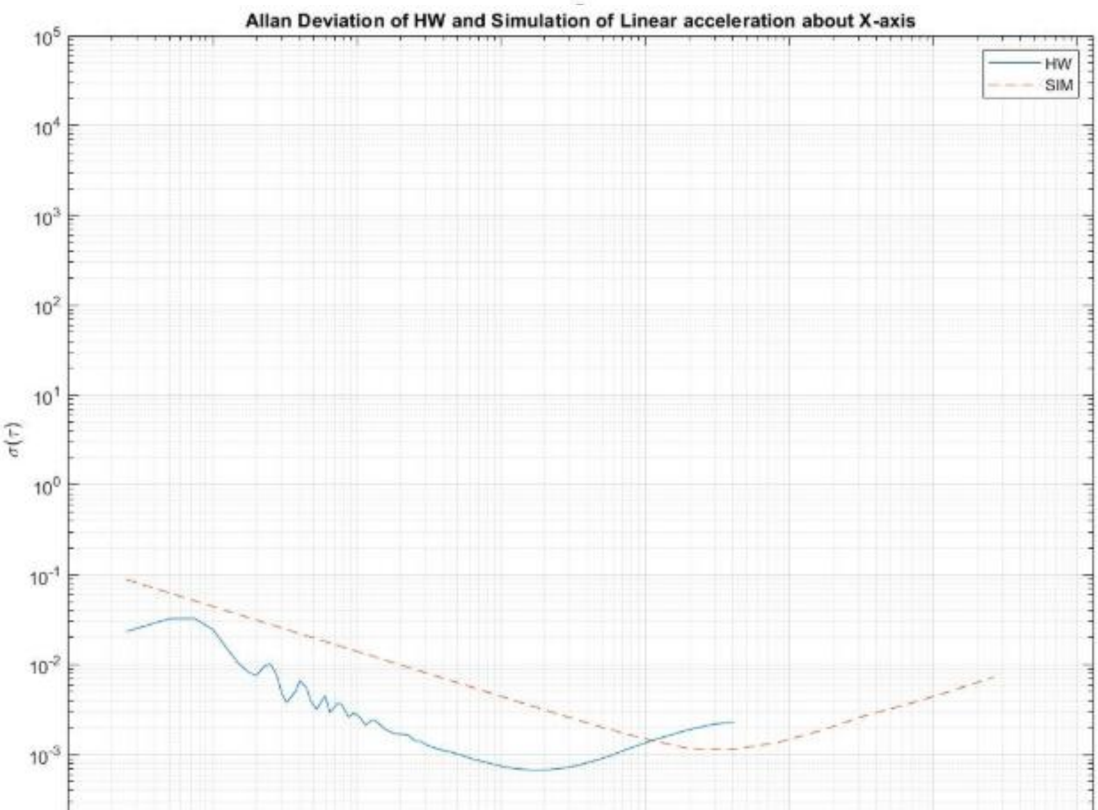
GRADE	ACCELEROMETER BIAS (mg)	VELOCITY RANDOM WALK (m/s/$\sqrt{hr}$)	GYRO BIAS (deg/hr)	ANGLE RANDOM WALK (deg/$\sqrt{hr}$)
Consumer	10	1	100	2
Industrial	1	0.1	10	0.2
Tactical	0.1	0.03	1	0.05
Navigation	0.01	0.01	0.01	0.01

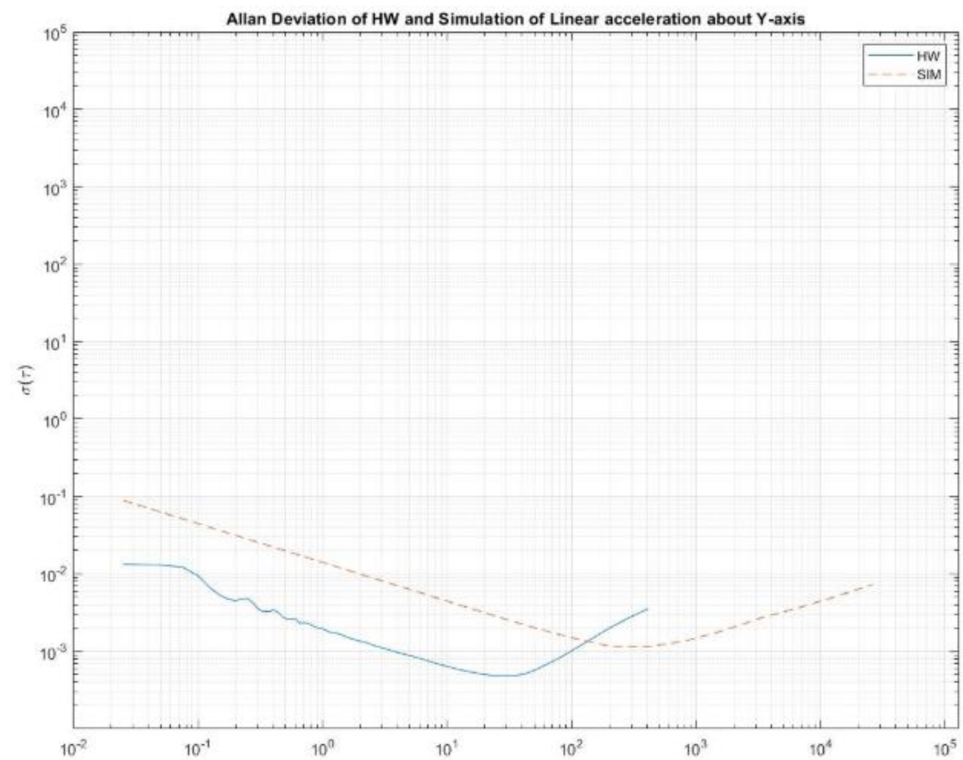
Further, the gyroscope simulation model creation and comparison with the actual data gives the following plots:

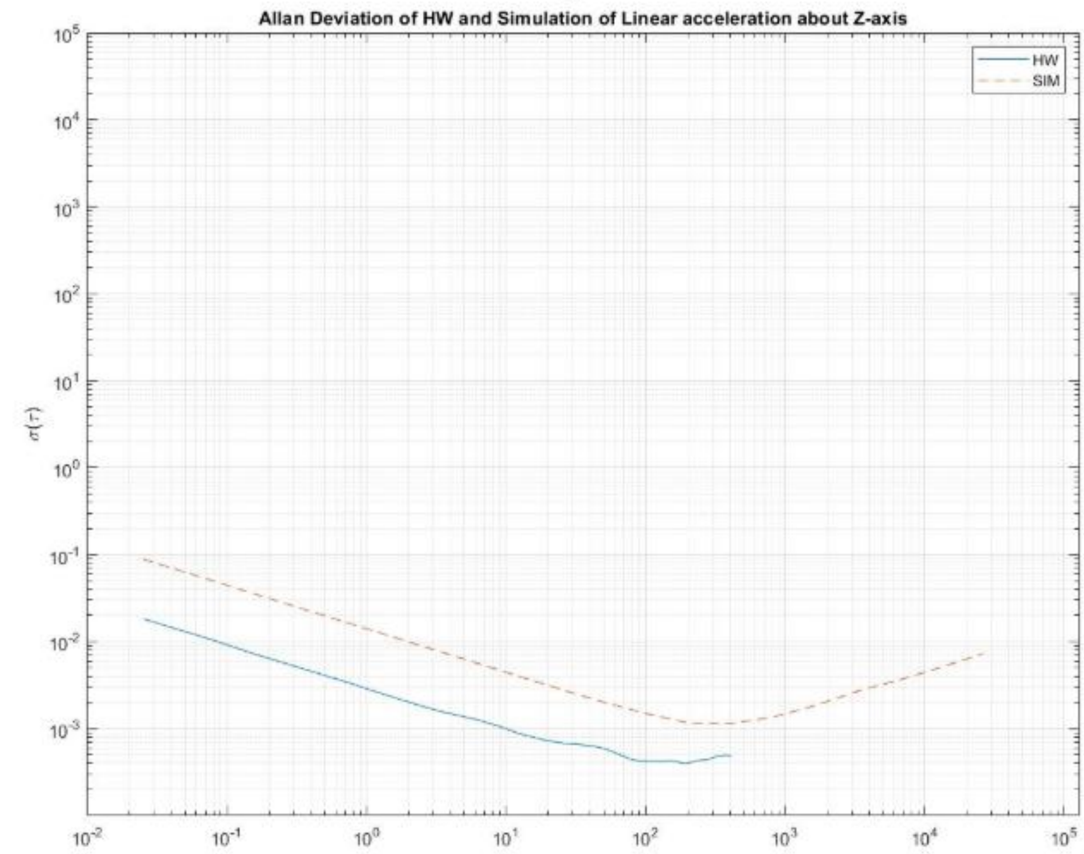





Allan Deviation of HW and Simulation of Angular veloity about Z-axis
HW
SIM
$\sigma(\tau)$
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}


Allan Deviation of HW and Simulation of Linear acceleration about X-axis
HW
SIM
$\sigma(\tau)$
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5}
τ


Allan Deviation of HW and Simulation of Linear acceleration about Y-axis
HW
SIM
σ(τ)
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
10^5


Allan Deviation of HW and Simulation of Linear acceleration about Z-axis
HW
SIM
σ(τ)
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
τ

The simulated value is calculated by not considering the variations in temperature and other parameters as it says in the mathworks documentation:

"The model measurements contain slightly less noise since the quantization and temperature-related parameters are not set using `gyroparams`. The gyroscope model can be used to generate measurements using movements that are not easily captured with hardware."

https://www.mathworks.com/help/nav/ug/inertial-sensor-noise-analysis-using-allan-variance.html

Hence, it shows a deviation from the actual data calculated.

References:

- https://www.vectornav.com/products/detail/vn-100
- https://www.vectornav.com/resources/inertial-navigation-primer/specifications--and--error-budgets/specs-imuspecs
- https://www.vectornav.com/resources/inertial-navigation-articles/what-is-an-inertial-measurement-unit-imu