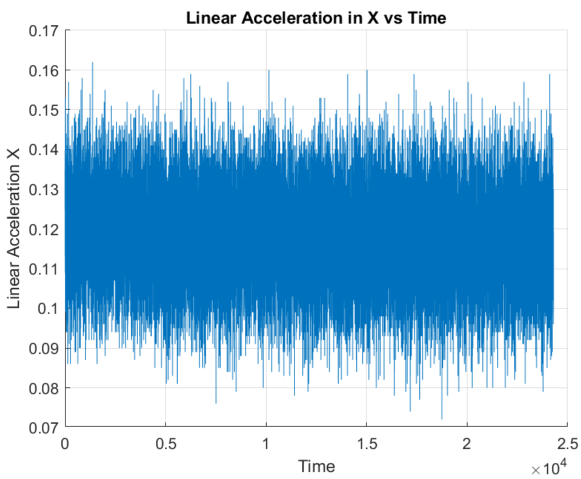
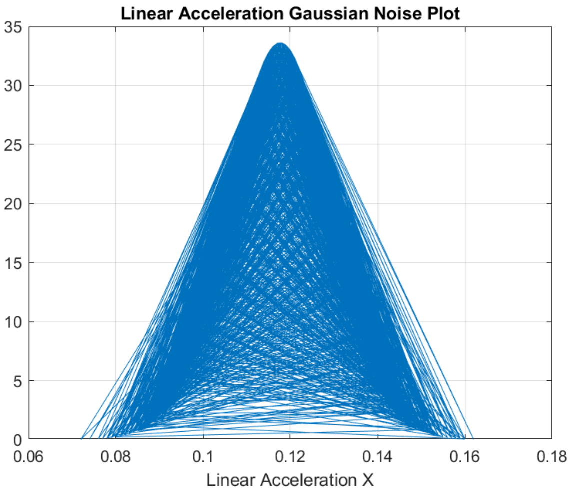
Lab3

IMU Noise Characterization with Allan Variance

1. 15 Minute Data Set Collected at West Village F Basement

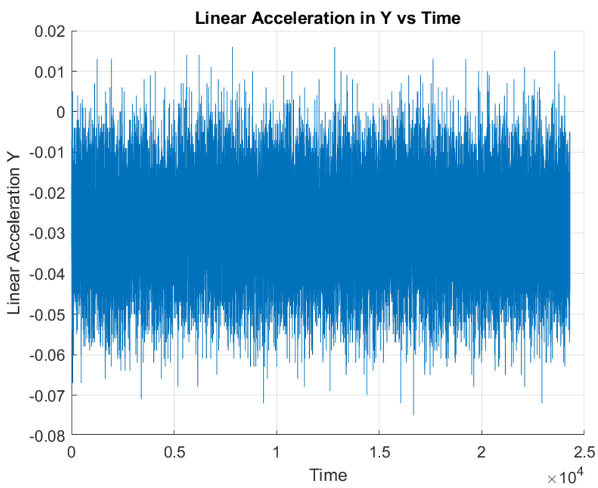
A. Linear Acceleration in X

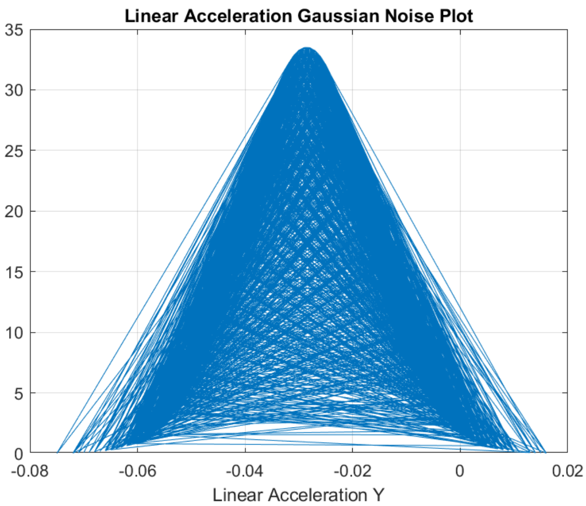




As we can see from the above plot even though the accelerometer was taped down to the floor we see a gaussian noise present in the measurements. They are verified to be white gaussian noise from the probability density function. Wit a mean value for x to be about 0.1176 which can be considered as a bias offset as x should have been 0. The standard deviation for the measurements is about 0.0118.

B. Linear Acceleration in Y

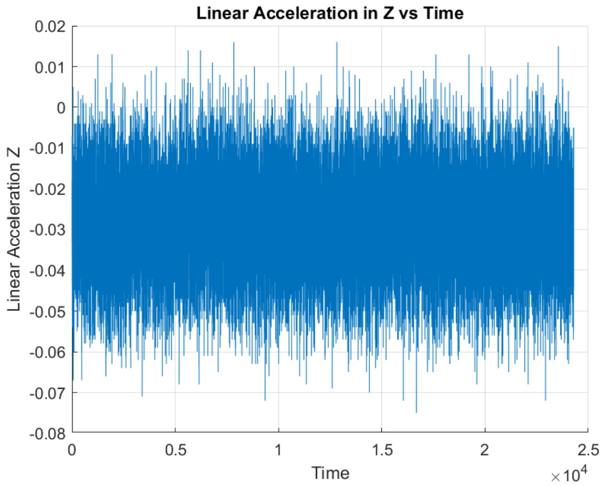


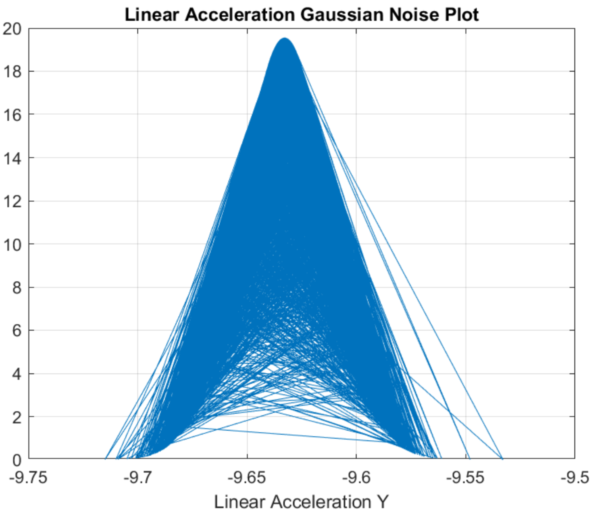


As we can see from the above plot even though the accelerometer was taped down to the floor we see a gaussian noise present in the measurements. They are verified to be white gaussian noise from the probability density function. Wit a mean value for x to be about -

0.0285 which can be considered as a bias offset as x should have been 0. The standard deviation for the measurements is about 0.0119.

C. Linear Acceleration in Z

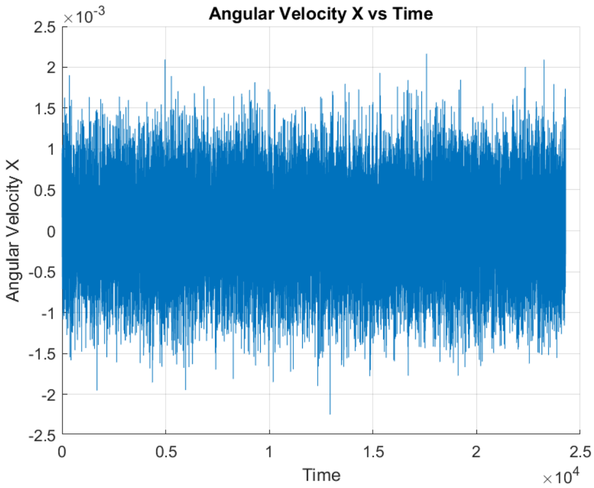


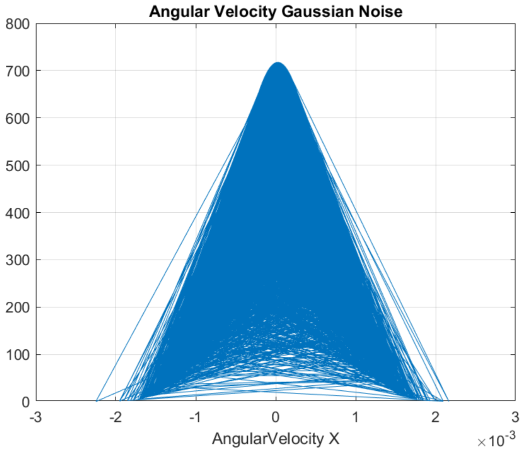


As we can see from the above plot even though the accelerometer was taped down to the floor, we see a gaussian noise present in the measurements. They are verified to be white gaussian noise from the probability density function. With a mean value for x to be about -9.632 which can be considered as a bias offset as x should have been -9.81. The standard deviation for the measurements is about 0.0204.

So for Linear Acceleration data we can conclude that a White Gaussian noise is present with a standard deviation of about approximately 0.02 is present in all the 3 Axed meaning that the sensor is consistent with the errors.

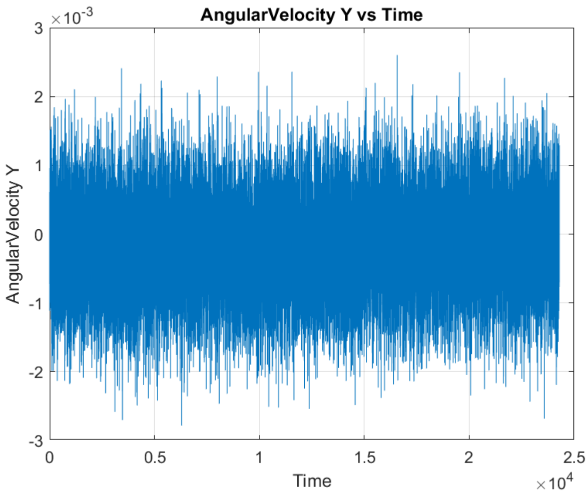
D. Angular Velocity in X

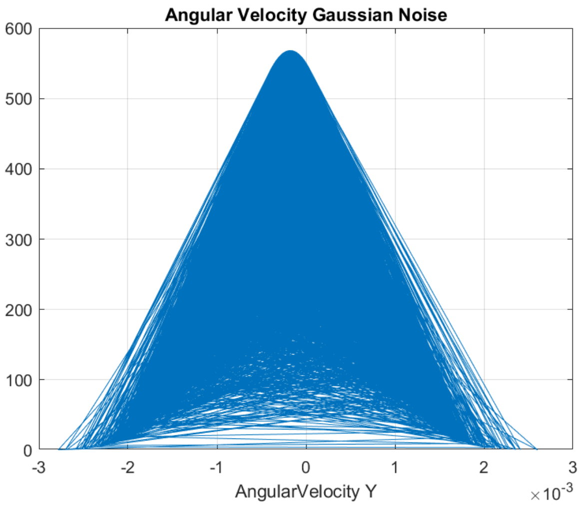




From the graoh we can see that a stationary IMU gives us a mean angular velocity in x to be about 0.0000276 m/ s2. And a standard deviation of 0.0005. This shows that the IMU gives us a very accurate reading upto 6 decimal places. We see a presence of White Gaussian Noise and the Bell Curve Plot shows us how the values are spaced out over the probability density function. From the curve we can also see a slight downward drift but can be validated by taking data over a longer period

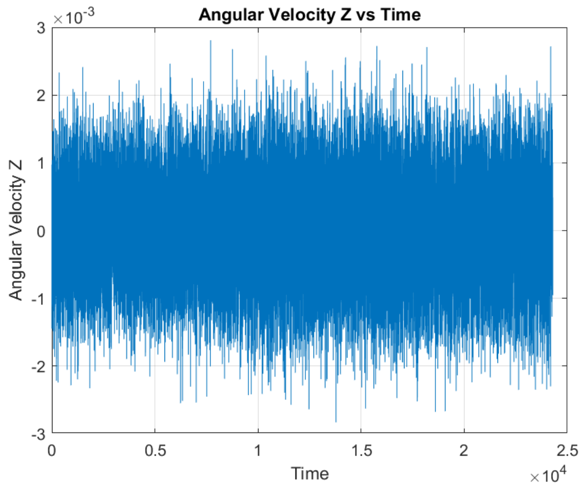
E. Angular Velocity in Y

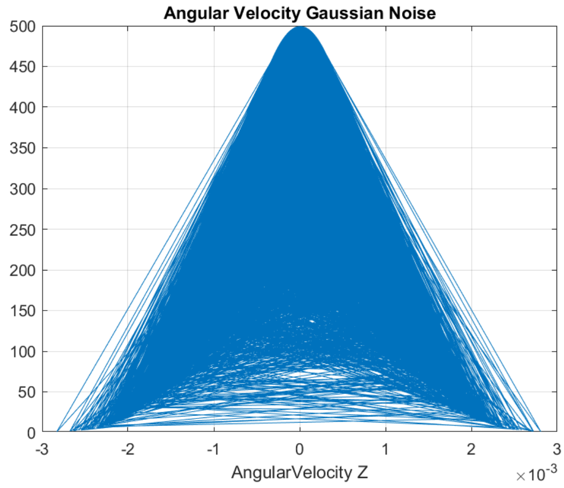




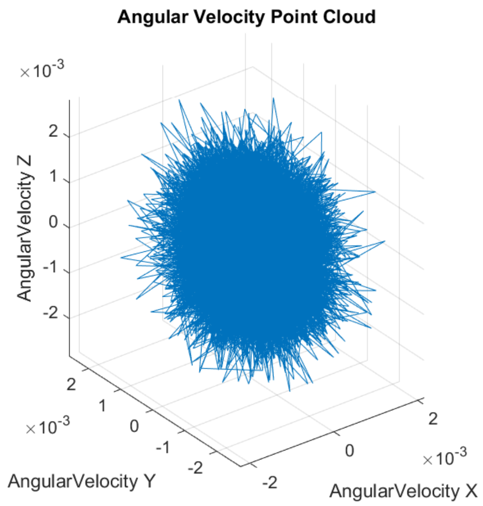
From the graph we can see that a stationary IMU gives us a mean angular velocity in y to be about -0.0001759m/ s2. And a standard deviation of 0.0007. This shows that the IMU gives us a very accurate reading upto 6 decimal places. We see a presence of White Gaussian Noise and the Bell Curve Plot shows us how the values are spaced out over the probability density function. From the curve we can also see a slight upward drift but can be validated by taking data over a longer period

F. Angular Velocity in Z





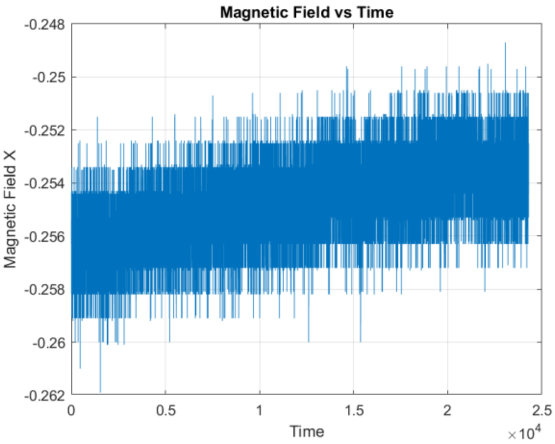
From the graph we can see that a stationary IMU gives us a mean angular velocity in z to be about 0.000007309m/ s2. And a standard deviation of 0.00079. This shows that the IMU gives us a very accurate reading upto 6 decimal places. We see a presence of White Gaussian Noise and the Bell Curve Plot shows us how the values are spaced out over the probability density function. From the curve we can also see a slight downward drift but can be validated by taking data over a longer period

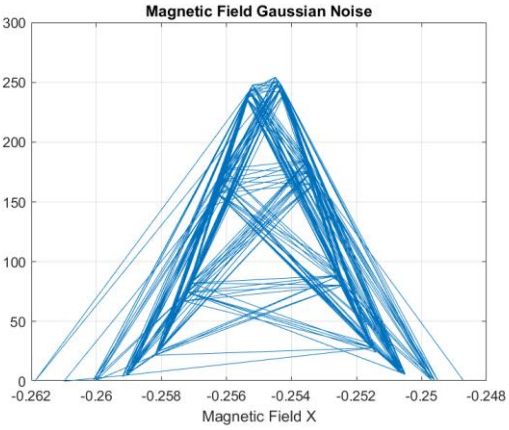


The Point cloud just verifies that we have most of data in the variance of 0.002 within the mean value.

The White gaussian Noise is present and can be due to Vibrations of the building, People walking around the area, Cars and other environmental factors. This can be validated from the plots above.

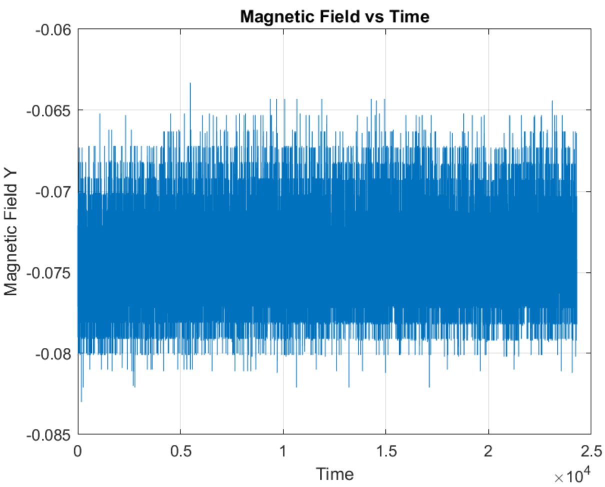
G. Magnetometer Data in X

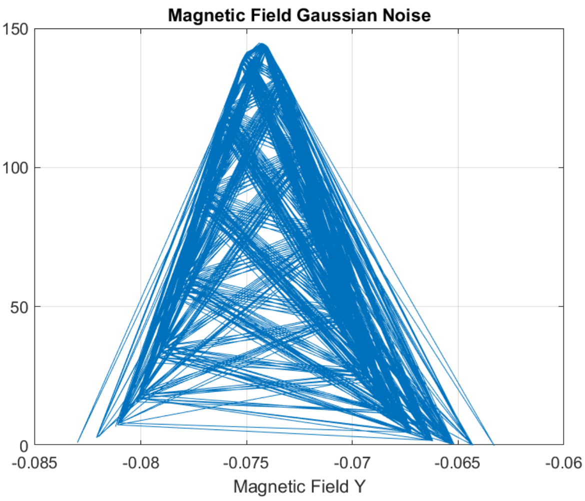




We can see a huge drift in the magnetometer X data as it varies from -0.256 to -0.252. The mean of the data is at -0.2547 and the standard deviation comes to be about 0.00154. The gaussian noise plot is not a clean plot as we can see multiple points probability at multiple “means”. This is a data set full of errors and could be due to environmental factors. Further investigation or repeatability is needed to rate the sensor.

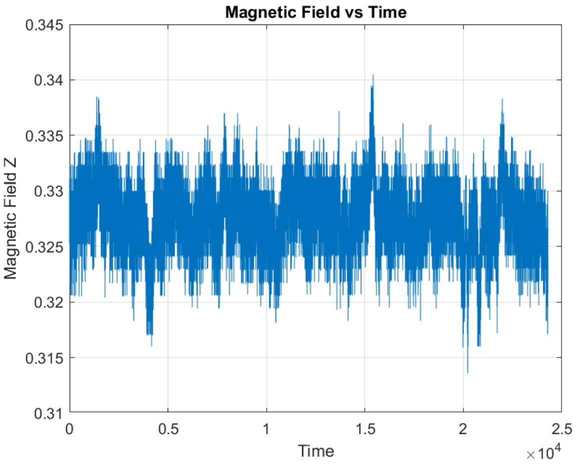
H. Magnetometer Data in Y

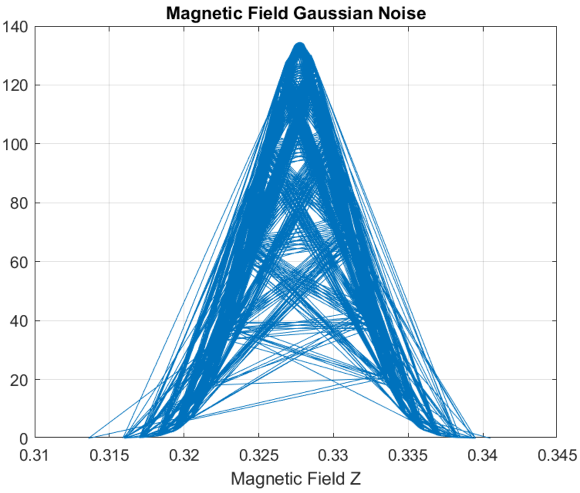




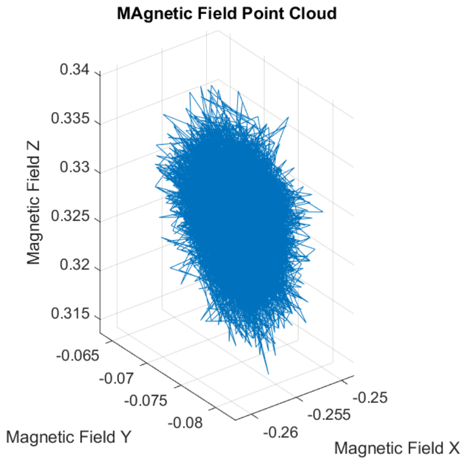
We see that the magnetometer Y vary about 0.074 ie the mean of the data and the standard deviation comes to be about 0.0027. The gaussian noise plot is not a clean plot as we can see multiple points probability at multiple “means”. This is a data set full of errors and could be due to environmental factors. Further investigation or repeatability is needed to rate the sensor.

I. Magnetometer Data in Z,





We can see a resonant frequency in this plot. This could be due to magnetic fluctuations around the sensor and need to be further investigated by taking multiple data sets. The mean of the data is at 0.327 and the standard deviation comes to be about 0.0029. The gaussian noise plot is well distributed but not clean. This is a data set full of errors and could be due to environmental factors. Further investigation or repeatability is needed to rate the sensor.



2. 5 Hour Data Set Collected at West Village F Basement

A. Angular Acceleration Allan

The white noise could be considered as too small to create significant difference in the final solution but a drift in the measurement would lead to a huge difference in the final solution and hence need to be modeled or cancelled out.

According to MATLAB

The angle random walk is characterized by the white noise spectrum of the gyroscope output. The PSD is represented by:

$$S_{\Omega}(f) = N^2$$

Where;

N = angle random walk coefficient

Substituting into the original PSD equation and performing integration yields:

$$\sigma^2(\tau) = \frac{N^2}{\tau}$$

The above equation is a line with a slope of -1/2 when plotted on a log-log plot of $\sigma(\tau)$ versus τ. The value of *N* can be read directly off of this line at $\tau = 1$. The units of *N* are $(rad/s)/\sqrt{Hz}$.

The rate random walk is known as the red noise. represented by:

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

The above equation is a line with a slope of 1/2 when plotted on a log-log plot of $\sigma(\tau)$ versus τ. The value of *K* can be read directly off of this line at $\tau = 3$. The units of *K* are $(rad/s)\sqrt{Hz}$.

The bias instability is characterized by the pink noise (flicker noise) spectrum of the gyroscope output. The PSD is represented by:

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

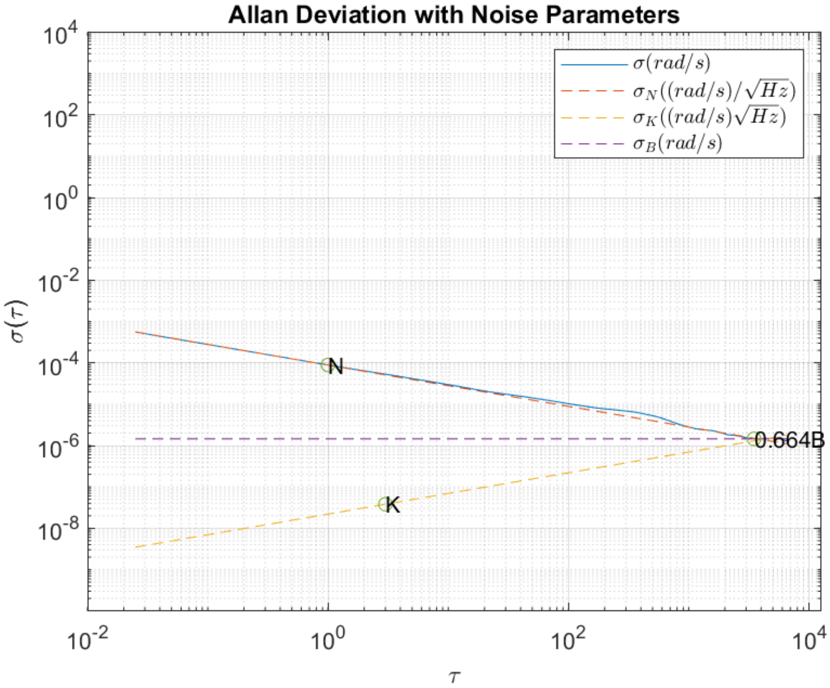
where

B = bias instability coefficient

The above equation is a line with a slope of 0 when plotted on a log-log plot of $\sigma(\tau)$ versus τ. The value of *B* can be read directly off of this line with a scaling of $\sqrt{\frac{2\ln 2}{\pi}} \approx 0.664$. The units of *B* are rad/s

All The conversions are carried out using the VN100 Vectornav primer databook

A1. Angular Velocity in X

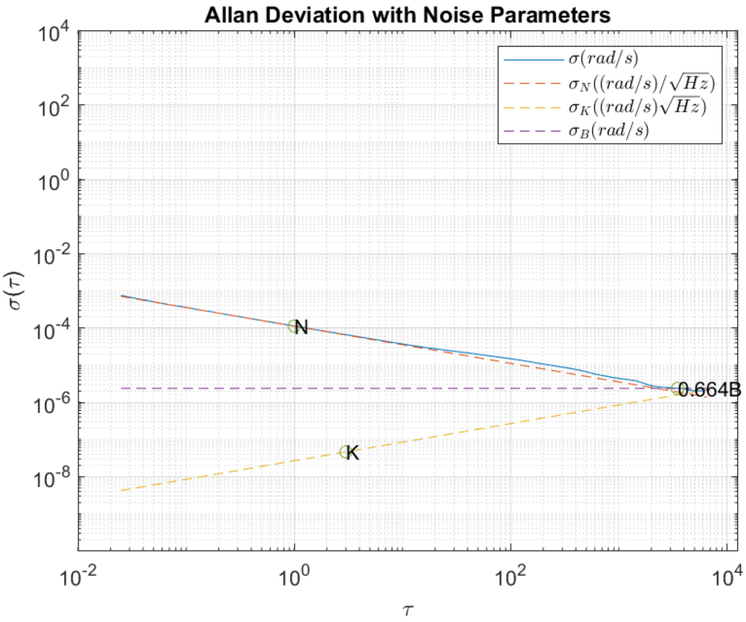


According to the plot we have N =8.858211836469779e-05, which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the rad/s/sqrt(Hz) to deg/sqrt(Hr) we need to multiply the N value by a factor of 60 after converting rad/s to deg/s, we see that this value is equal to 0.29 which suggests that the sensor is of either industrial grade or consumer grade.

K = 3.804891256855273e-08 . This value is also very small which suggests that the rate random walk does not appear to be a significant source of noise in the data set that we have collected. If we are to collect a larger data set then we can comment on this. But as of the data set collected the red noise sources and effects are less.

According to the gyro bias B =2.187472354808633e-06 rad/sec when converted to deg/hr gives us a value of 0.446 which when compared to the data sheet equivalent to a tactical grade sensor.

A2. Angular Velocity in Y

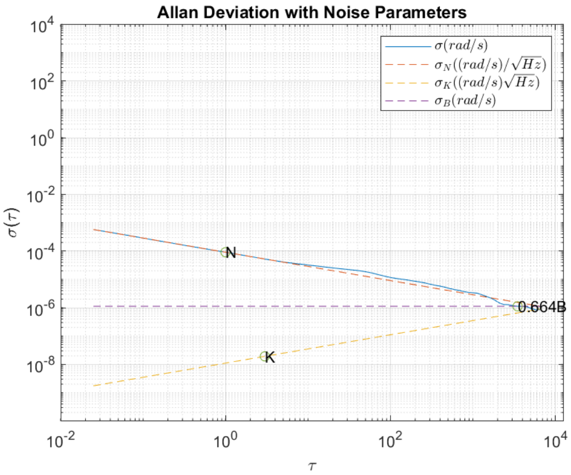


According to the plot we have N =1.118982270722039e-04 , which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the rad/s/sqrt(Hz) to deg/sqrt(Hr) we need to multiply the N value by a factor of 60 after converting rad/s to deg/s, we see that this value is equal to 0.378 which suggests that the sensor is of either industrial grade or consumer grade.

K =4.635862147297426e-08 This value is also very small which suggests that the rate random walk does not appear to be a significant source of noise in the data set that we have collected. If we are to collect a larger data set then we can comment on this. But as of the data set collected the red noise sources and effects are less.

According to the gyro bias B =3.558918644938269e-05 rad/sec when converted to deg/hr gives us a value of 7.219 which is again when compared to the data sheet equivalent to an industrial grade sensor.

A3. Angular Velocity in Z



According to the plot we have N =9.042853866968627e-05, which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the rad/s/sqrt(Hz) to deg/sqrt(Hr) we need to multiply the N value by a factor of 60 after converting rad/s to deg/s, we see that this value is equal to 0.3102 which suggests that the sensor is of either industrial grade or consumer grade.

K =1.914897842543661e-08This value is also very small which suggests that the rate random walk does not appear to be a significant source of noise in the data set that we have collected. If we are to collect a larger data set then we can comment on this. But as of the data set collected the red noise sources and effects are less.

According to the gyro bias B =1.683075710026665e-06rad/sec when converted to deg/hr gives us a value of 0.3465 which is again when compared to the data sheet equivalent to a tactical grade sensor.

	N(rad/s/sqrt(hz))	B(rad/s)	B(deg/hr)	N(deg/sqrt(hr))	Grade
X	8.8582118e-05	2.18747e-06	0.446	0.29	
Y	1.1189822e-04	3.55891e-05	7.219	0.378	Industrial
Z	9.0428538e-05	1.68307e-06	0.3465	0.3102	
Grade			Tactical	consumer	

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

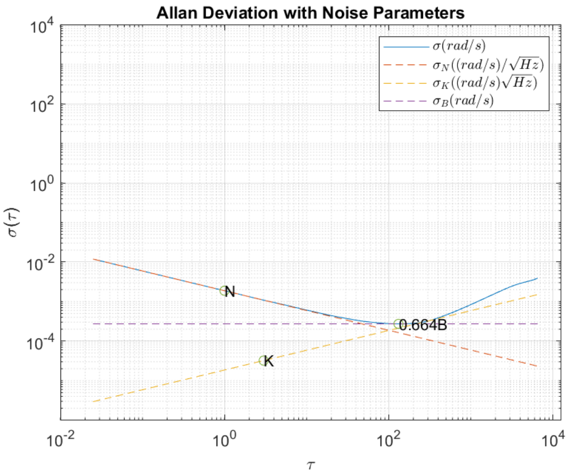
TABLE 3.1

We only consider the Gyro Bias and Angle Random Walk data for Angular Velocity.

So we can conclude on the estimation that by collecting a longer data set that our sensor is an industrial grade sensor

B. Linear Acceleration Allen Variance

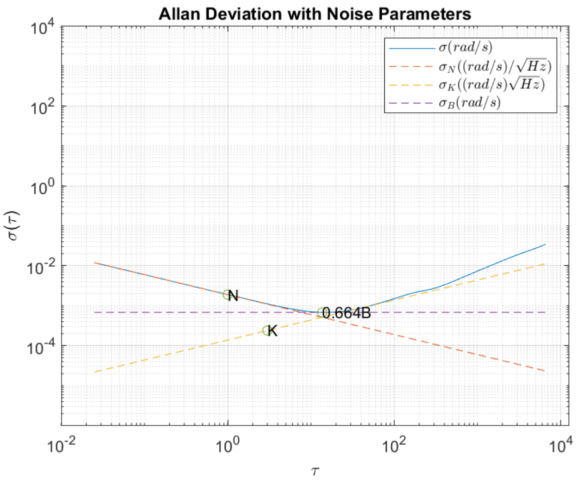
B1. Acceleration in X



According to the plot we have N =0.001876856697026, which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the m/s/sqrt(Hz) to m/s/sqrt(Hr) we need to multiply the N value by a factor of 60), we see that this value is equal to 0.112 which suggests that the sensor is of either industrial grade or consumer grade.

According to the gyro bias B =4.102051157211426e-04 m/s2 when converted to mg gives us a value of 0.041 which is again when compared to the data sheet equivalent to either industrial grade sensor or a tactical grade sensor.

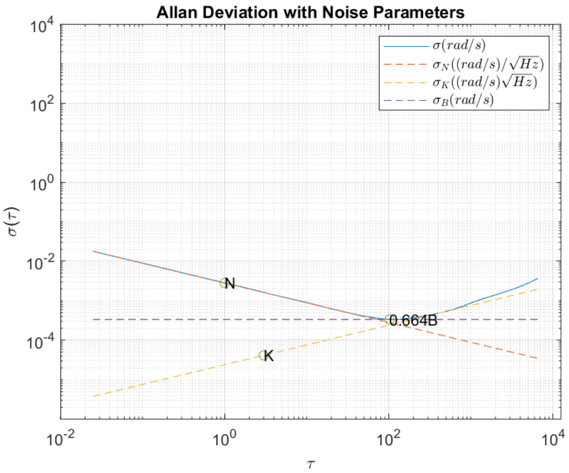
B2. Acceleration in Y



According to the plot we have N =0.001896141910733, which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the m/s2/sqrt(Hz) to m/s/sqrt(Hr) we need to multiply the N value by a factor of 60, we see that this value is equal to 0.1134 which suggests that the sensor is of either industrial grade or consumer grade.

According to the gyro bias B =0.001026494646724 m/s2 when converted to mg gives us a value of 0.1 which is again when compared to the data sheet equivalent to either industrial grade sensor or a tactical grade sensor.

B3. Acceleration in Z



According to the plot we have N =0.002811394406225, which is a very small value. To comparing it with the VN100 primer data sheet we need to convert the m/s2/sqrt(Hz) to m/s/sqrt(Hr) we need to multiply the N value by a factor of 60, we see that this value is equal to 0.16866 which suggests that the sensor is of either industrial grade or consumer grade.

According to the gyro bias B =5.055396828094319e-04 m/s2 when converted to mg gives us a value of 0.05 which is again when compared to the data sheet equivalent to either industrial grade sensor or a tactical grade sensor.

	N(m/s2/sqrt(hz))	B(m/s2)	B(mg)	N(m/s/sqrt(hr))	Grade
X	0.001876856697026	4.10205e-04	0.041	0.112	
Y	0.001896141910733	0.001026494	0.1	0.1134	Industrial
Z	0.002811394406225	5.05539e-04	0.05	0.16866	
Grade			Industrial	Industrial	

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

TABLE 3.1

We only consider the Accelerometer bias and the Velocity Random Walk for Liner Acceleration data. So we can conclude on the estimation that by collecting a longer data set that our sensor is an industrial grade sensor