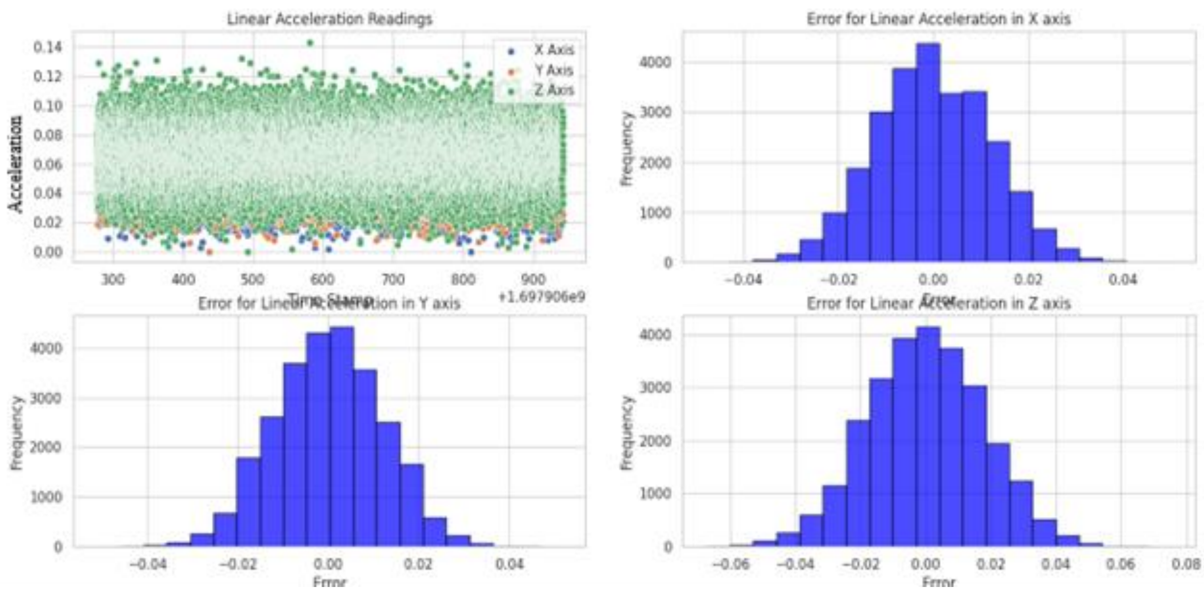
LAB#3 REPORT

Stationary Data Analysis

Accelerometer



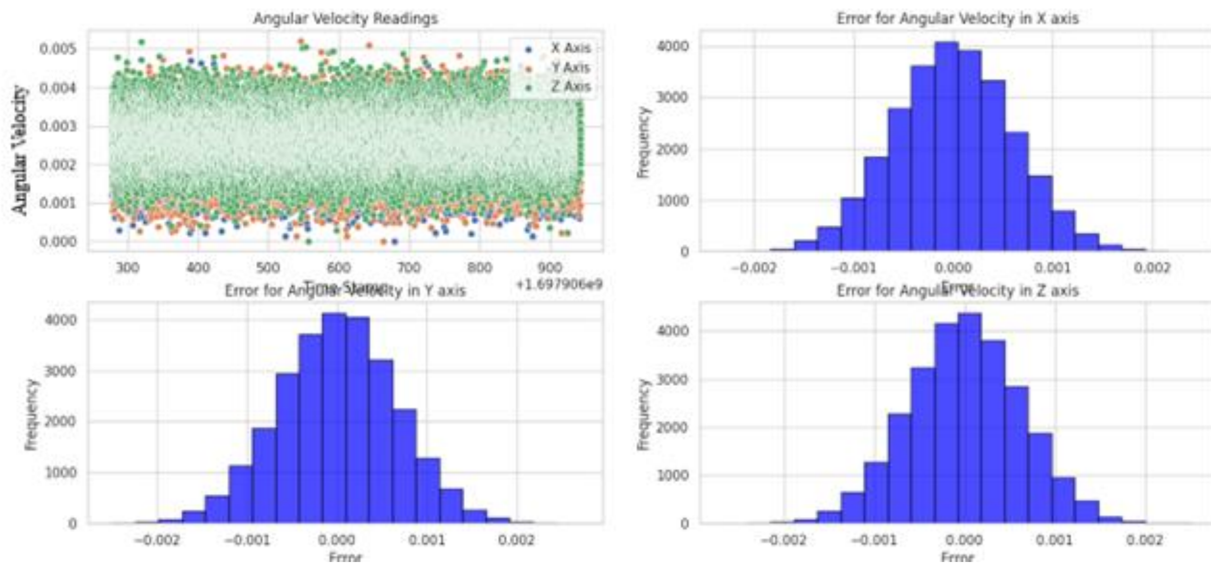
The distribution of the accelerometer readings as a time series plot is fairly constant as is expected while being stationary. The readings have been normalized using their minimum values and therefore they all are more or less accurately pointing towards the value of 0, rather than one (among, X, Y or Z) being inclined towards the value of acceleration due to gravity. The mean, median and Standard Deviation of the X, Y and Z values of the accelerometer readings are mentioned below –

Standard Deviation (X): 0.01202733697029911
Mean (X): 0.04772547765909434
Median (X): 0.04800000000000001

Standard Deviation (Y): 0.011796349808466474
Mean (Y): 0.051200616819617885
Median (Y): 0.05100000000000004

Standard Deviation (Z): 0.017742854299696326
Mean (Z): 0.06727978787422965
Median (Z): 0.06700000000000017

Gyroscope



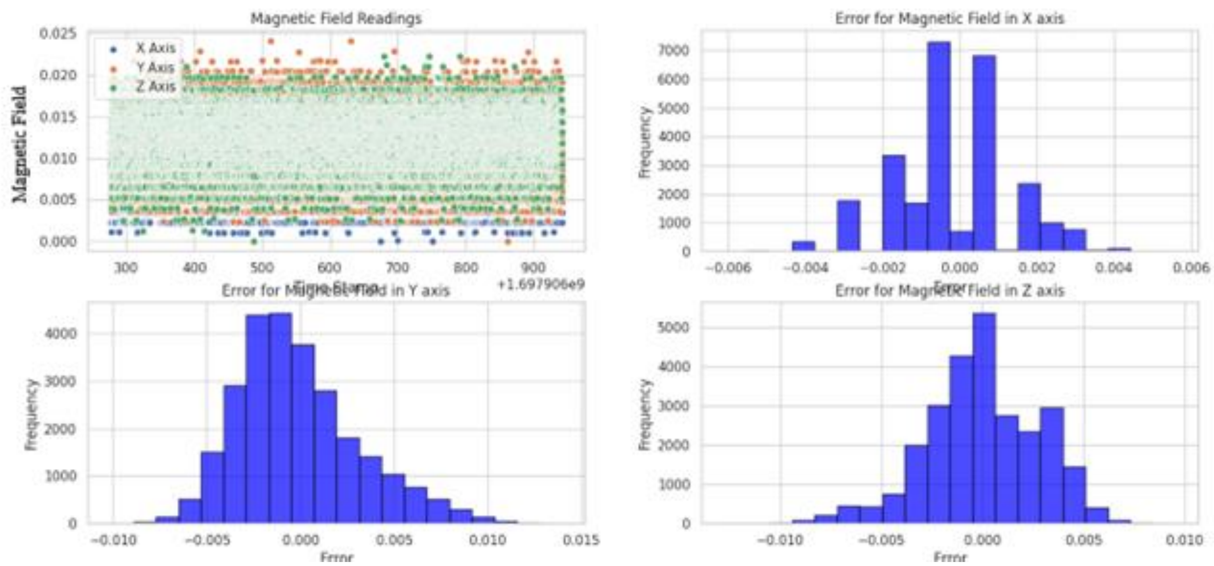
Like acceleration, we expect the angular velocity values recorded by a stationary IMU to be 0 as well, and this is what was observed in our time-series plot. Again, normalization brought the data points together towards the zero mark. The mean, median and Standard Deviation of the X, Y and Z values of the gyroscope readings are mentioned below -

Standard Deviation (X): 0.0006004162825780641
Mean (X): 0.0023027059575748457
Median (X): 0.0022990000000000003

Standard Deviation (Y): 0.0006571835176004376
Mean (Y): 0.002508268504588536
Median (Y): 0.0025139999999999997

Standard Deviation (Z): 0.0006254237511236518
Mean (Z): 0.0026639938694147736
Median (Z): 0.002665

Magnetometer



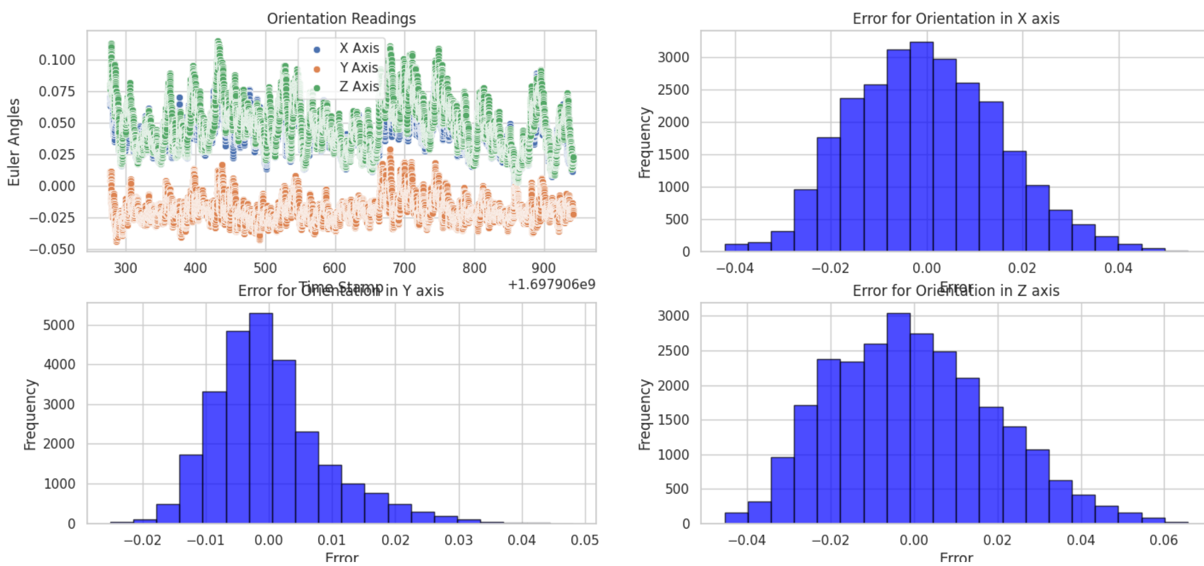
In contrast to the readings from the accelerometer and gyroscope within the IMU, the magnetometer readings cannot be “expected” as such as it depends more on the IMU’s surroundings rather than its own motion. However, as the data was collected at an area far from interferences incurring soft iron and hard iron interference errors, the distribution points were precisely closer to the accurate mark of 0. The mean, median and Standard Deviation of the X, Y and Z values of the Magnetometer readings are mentioned below -

Standard Deviation (X): 0.0015130014827943346
Mean (X): 0.006101782759139459
Median (X): 0.0058

Standard Deviation (Y): 0.003202544910454293
Mean (Y): 0.010142996840680003
Median (Y): 0.009599999999999997

Standard Deviation (Z): 0.0027329093339787977
Mean (Z): 0.012754332781706042
Median (Z): 0.0131

Orientation



The observations of the orientation values recorded by the IMU do not precisely match the true value which must be 0. Although, all the X, Y and Z distributions point towards 0, the X and Y axis of the orientation readings incur some noise in their recording which may attributed to the innate constant source of noise or bias. Moreover, the magnetometer readings illustrate more fluctuations in the time-series plots which may be reasoned back to the fact that no environment is free from magnetic interferences. The mean, median and Standard Deviation of the X, Y and Z values of the orientation readings are mentioned below -

Standard Deviation (X): 0.01542672296247196
Mean (X): 0.0427519792291255
Median (X): 0.04210447009347977

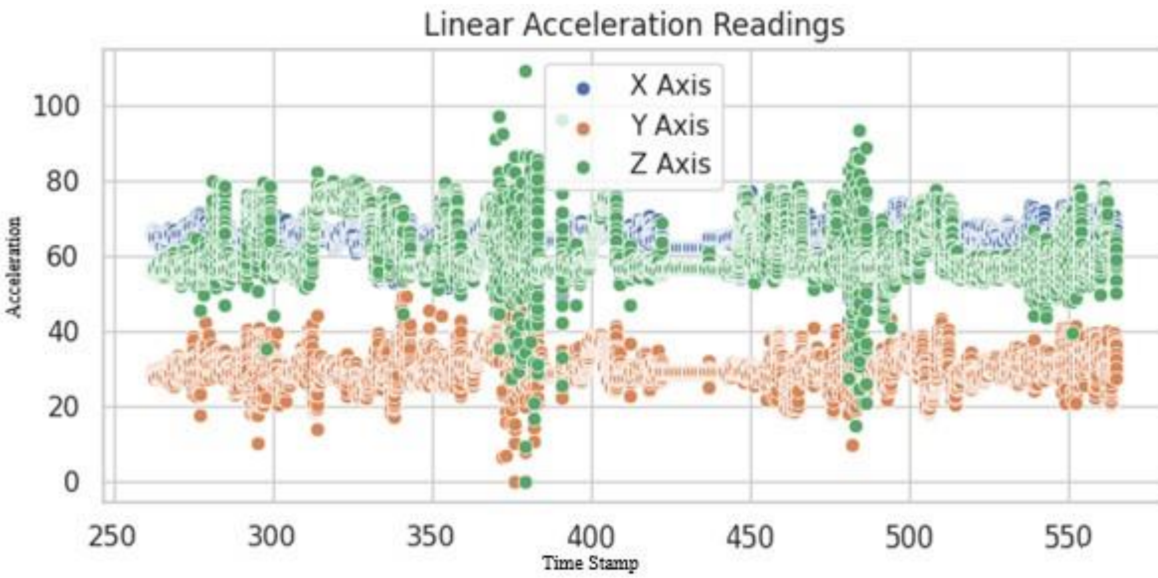
Standard Deviation (Y): 0.008955463436794918
Mean (Y): -0.01869528962666707
Median (Y): -0.01998364712225989

Standard Deviation (Z): 0.01955109821364446
Mean (Z): 0.04918256547532632
Median (Z): 0.04770326018879381

The distributions observed in this analysis display traits that align with a normal distribution, suggesting a symmetric and bell-shaped distribution centered around the mean. This consistency assists in quantifying the data's reliability and evaluating any random errors.

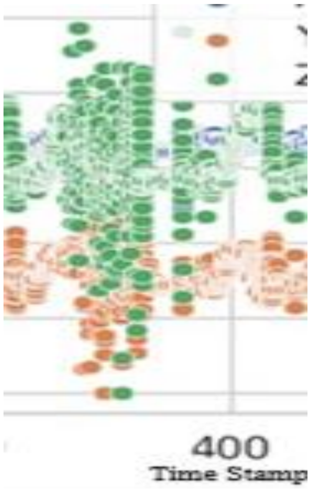
Action Data Analysis

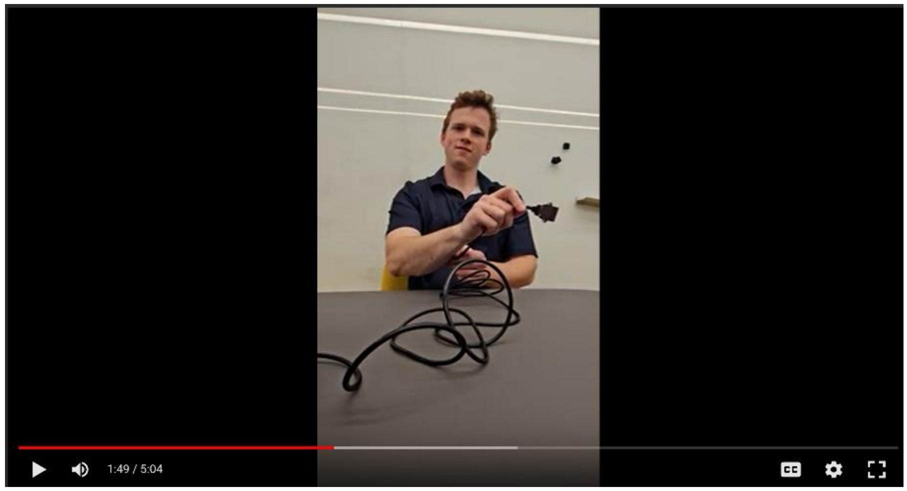
Accelerometer



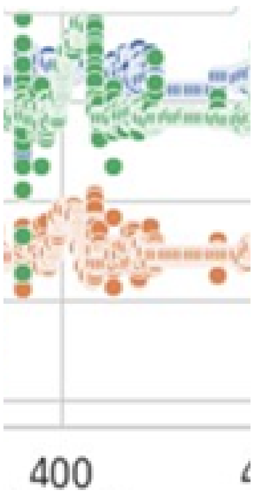
The distribution of the accelerometer readings as a time series plot has attained higher magnitudes as is expected while moving. The readings have been normalized using their minimum values and therefore they all are compensated for the value of acceleration due to gravity. However, there is a constant bias in the recorded values. The mean, median and Standard Deviation of the X, Y and Z values of the accelerometer readings are mentioned below -

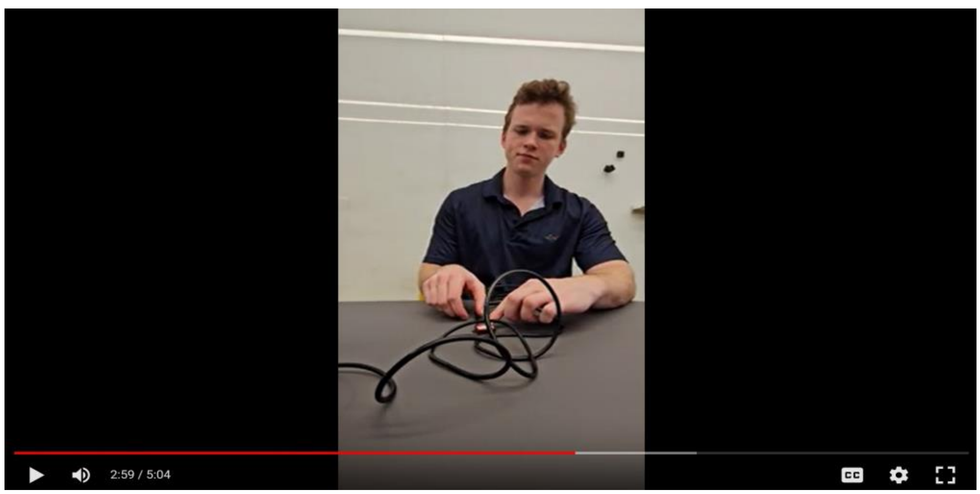
Standard Deviation (X): 3.939443393989412
Mean (X): 65.49248596665016
Median (X): 65.789
Standard Deviation (Y): 4.025966130047762
Mean (Y): 30.400576192834738
Median (Y): 29.824
Standard Deviation (Z): 7.366563439832987
Mean (Z): 61.337404573221065
Median (Z): 57.865





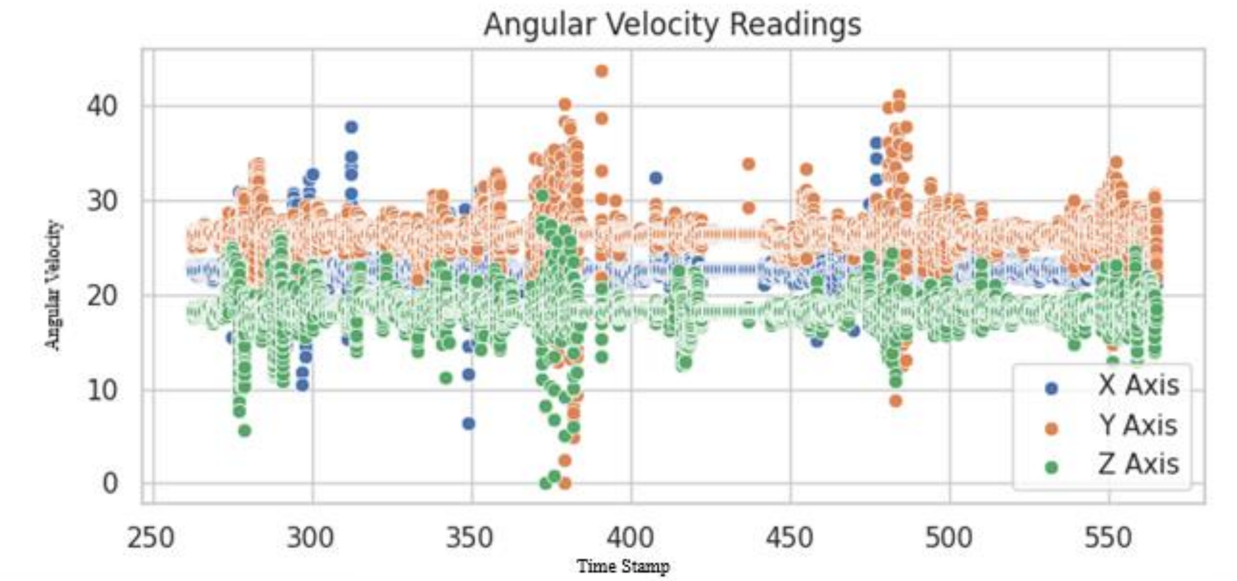
This portion of the plot can be matched with the sudden jerk in the Z Axis of the IMU recorded at 1:49. The screengrab of the portion is attached to the right.



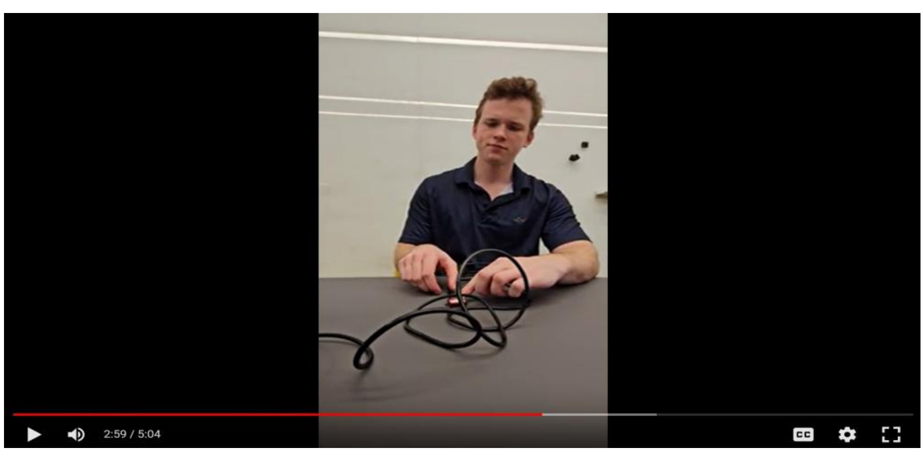


Additionally, this part of the plot corresponds to the time duration during which the IMU is kept stationary, and during this time we expect both the linear accelerations and the angular velocity readings to be 0. The screengrab of the portion is attached to the right.

Gyroscope

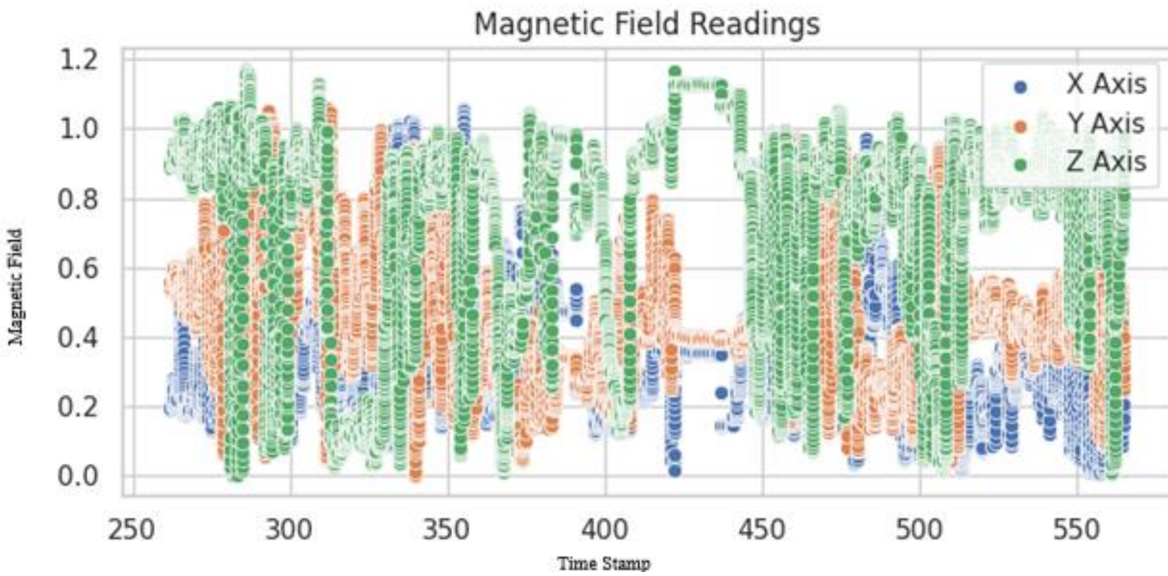


Standard Deviation (X): 1.361600645119942
Mean (X): 22.74001635463101
Median (X): 22.6520735
Standard Deviation (Y): 1.6006813837335652
Mean (Y): 26.377649565874197
Median (Y): 26.376839
Standard Deviation (Z): 1.3682211574986585
Mean (Z): 18.392449720983983
Median (Z): 18.241334



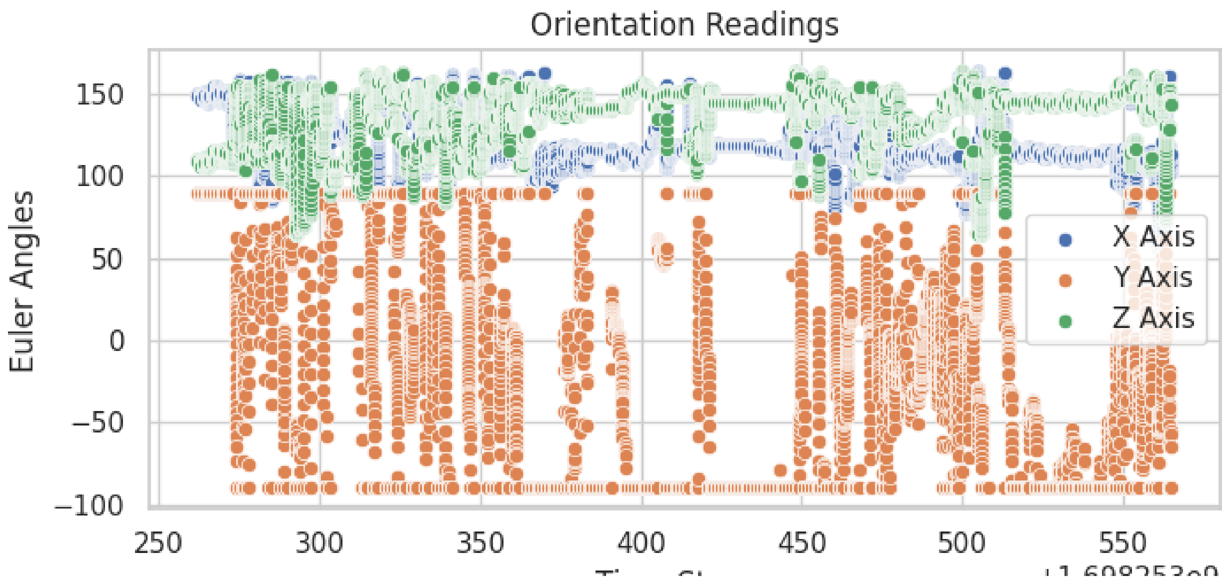
This portion of the plot corresponds to the time duration in which the IMU is kept stationary on the table. As observed, the values are fairly constant but with a bias. The screengrab of the portion is attached to the right.

Magnetometer



Standard Deviation (X): 0.20389227941981616
Mean (X): 0.3542805679379231
Median (X): 0.30690000000000006
Standard Deviation (Y): 0.19425886102031556
Mean (Y): 0.45438140993891357
Median (Y): 0.4305
Standard Deviation (Z): 0.30602182742777534
Mean (Z): 0.7338848192174343
Median (Z): 0.857

Orientation



Standard Deviation (X): 17.47436920769635
Mean (X): 123.6333141760062
Median (X): 117.2710471803924
Standard Deviation (Y): 78.50366323498379
Mean (Y): -16.971021096833017
Median (Y): -46.32703974959176
Standard Deviation (Z): 17.393816450116507
Mean (Z): 135.82883569529878
Median (Z): 143.2269435339536

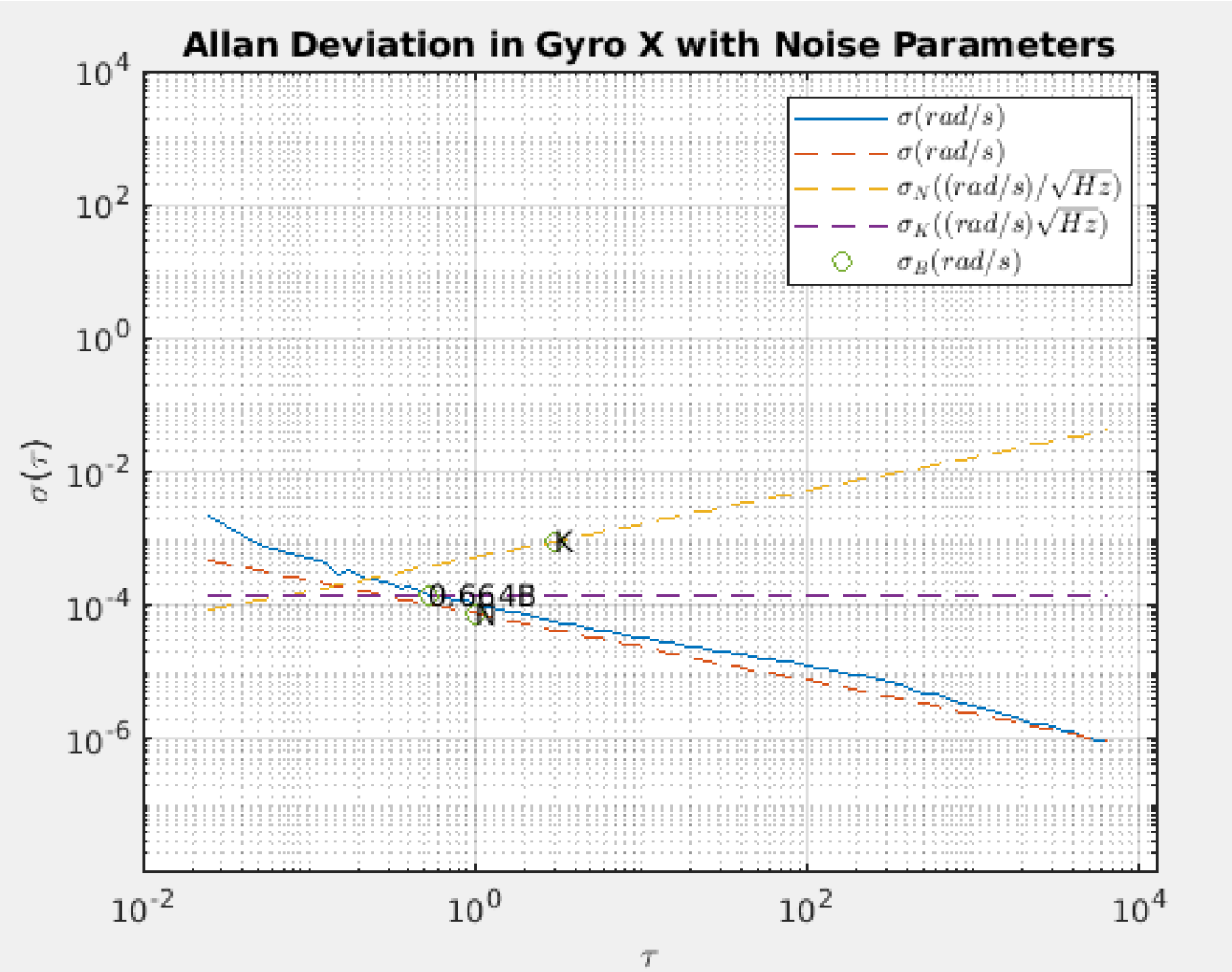
The alignment of the VectorNav data with the video was done with the help of key changes in the acceleration, angular velocities and rotational values of the sensor hardware, as observed in the video. For example,

1. When the IMU was kept stationary, the values of accelerations among two axes must be 0. Moreover, the angular velocities must be 0 as well.
2. When there was a sudden jerk in the Z Axis, the acceleration values in the Z Axis must shoot up.

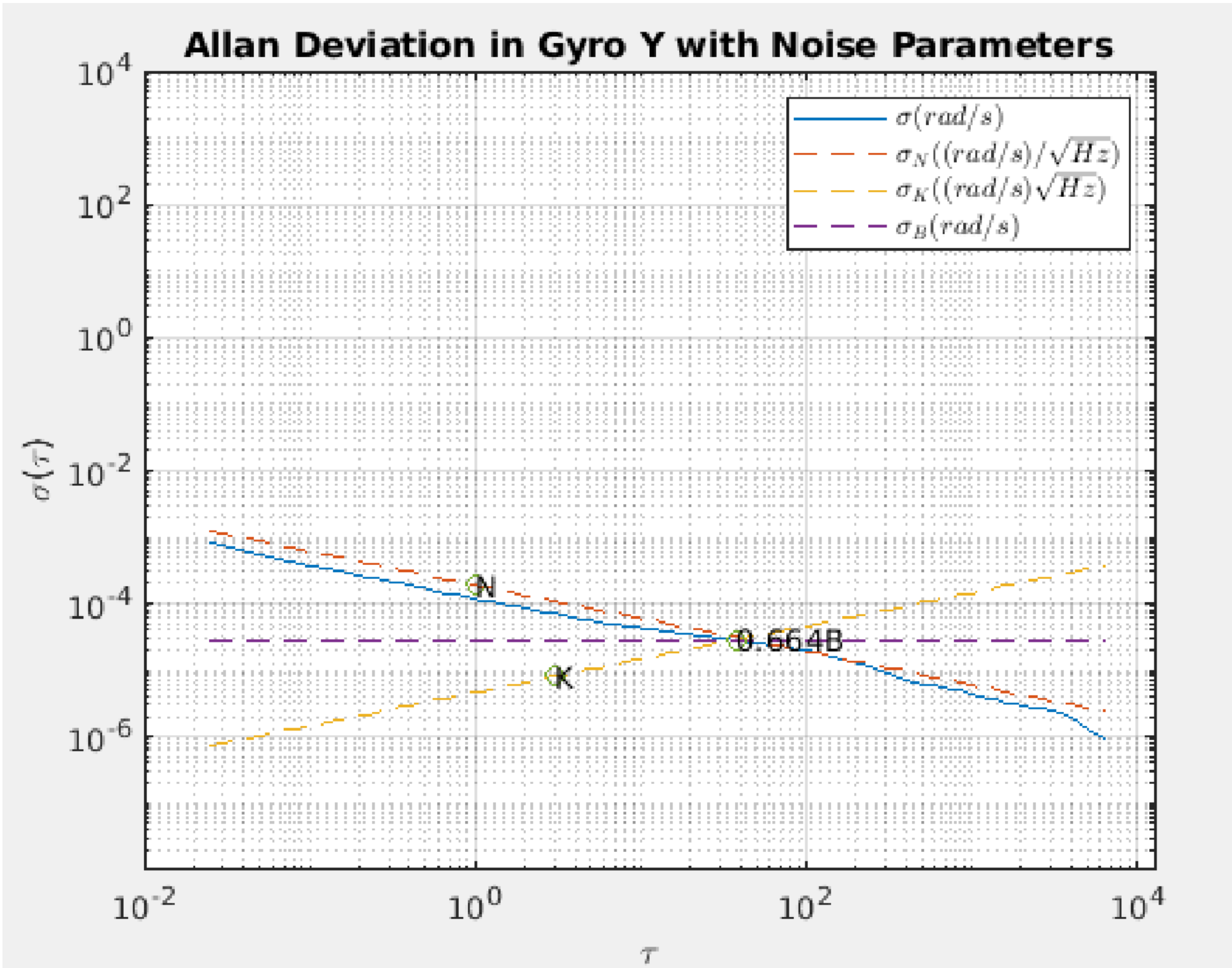
The VectorNav performance when compared to its specifications mentioned in the datasheet gave us mixed observations. The accuracies and resolutions mentioned in the datasheet closely match with the ranges and observed values in our datasets. However, the bias stability measures mentioned in the datasheet are far off my many orders of magnitude when compared to our calculations. Moreover, the noises incurred in the recording could be again attributed to electromagnetic interferences from the surrounding which may be dynamic.

ALLAN VARIANCE ANALYSIS

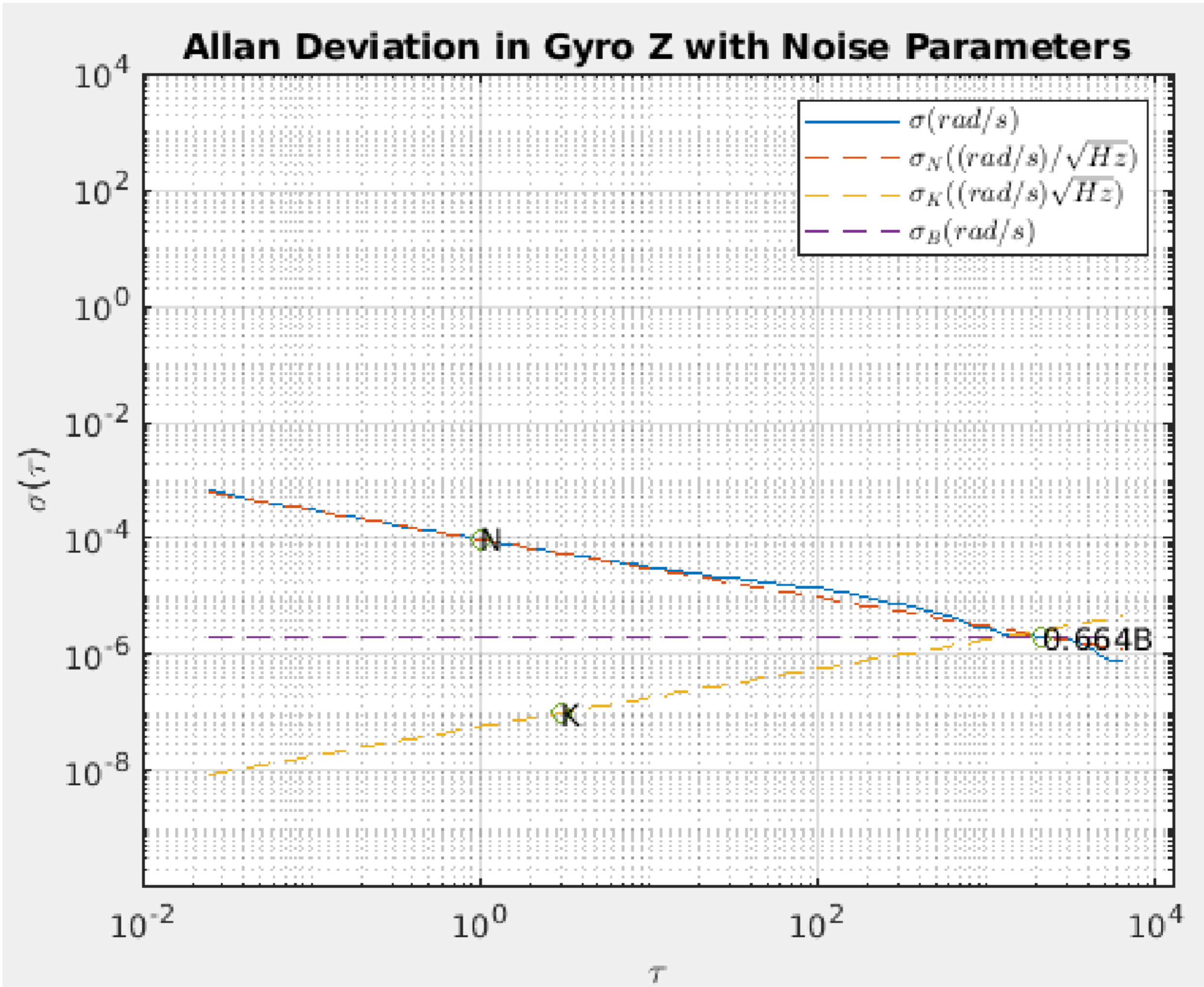
Location C (My Analysis)



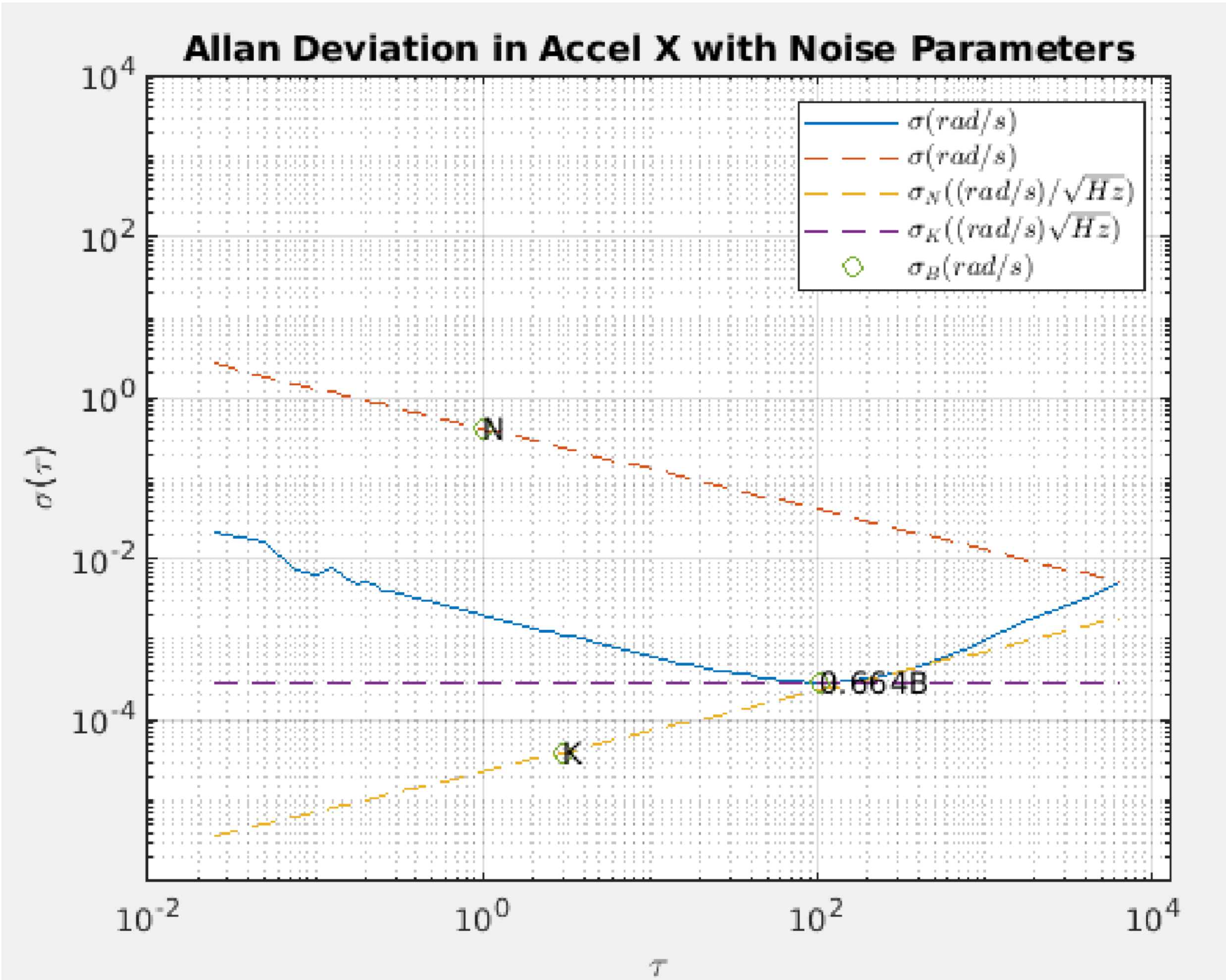
N = 7.4822e-05
K = 9.0026e-04
B = 2.1290e-04



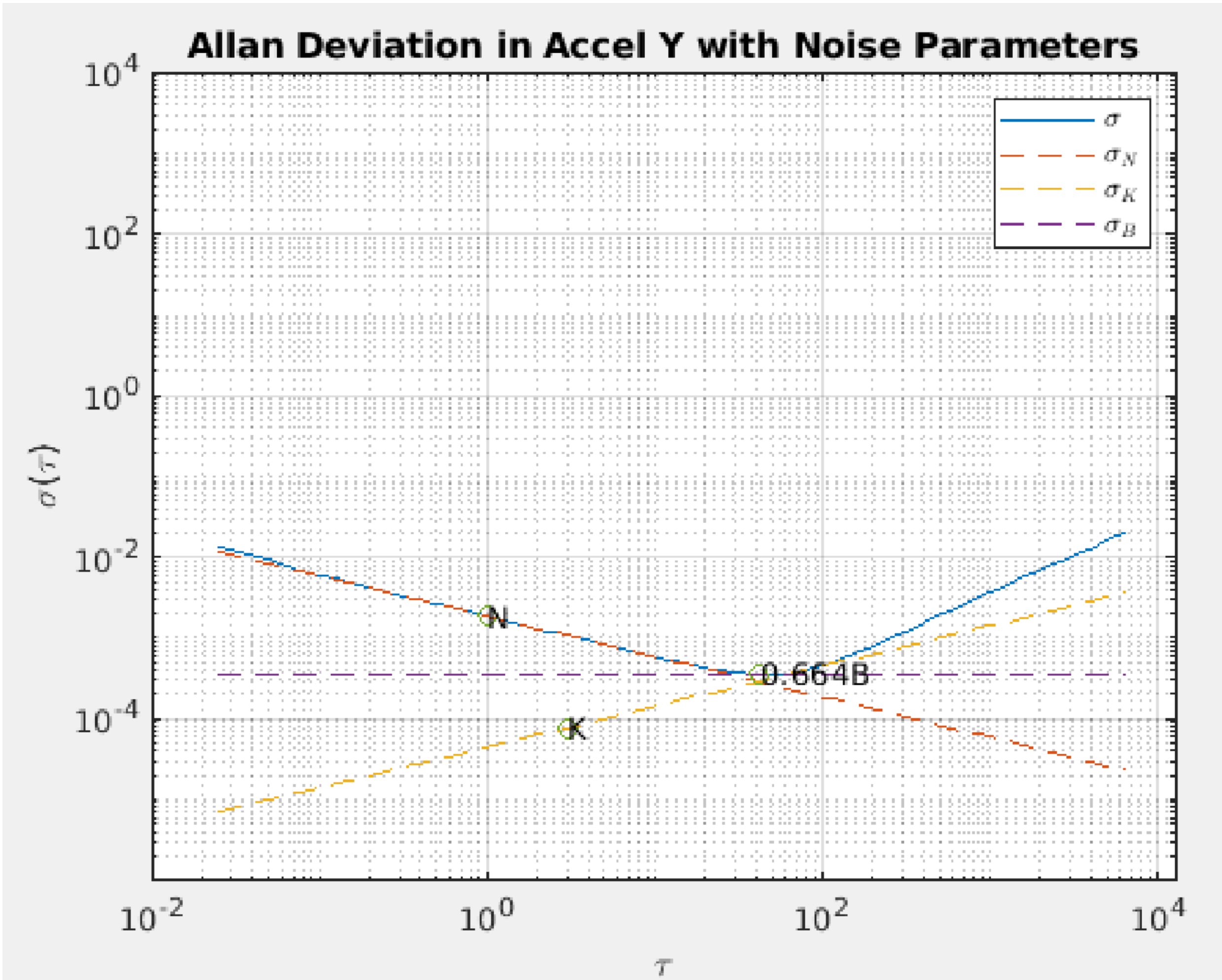
N = 1.9149e-04
K = 7.9209e-06
B = 4.2087e-05



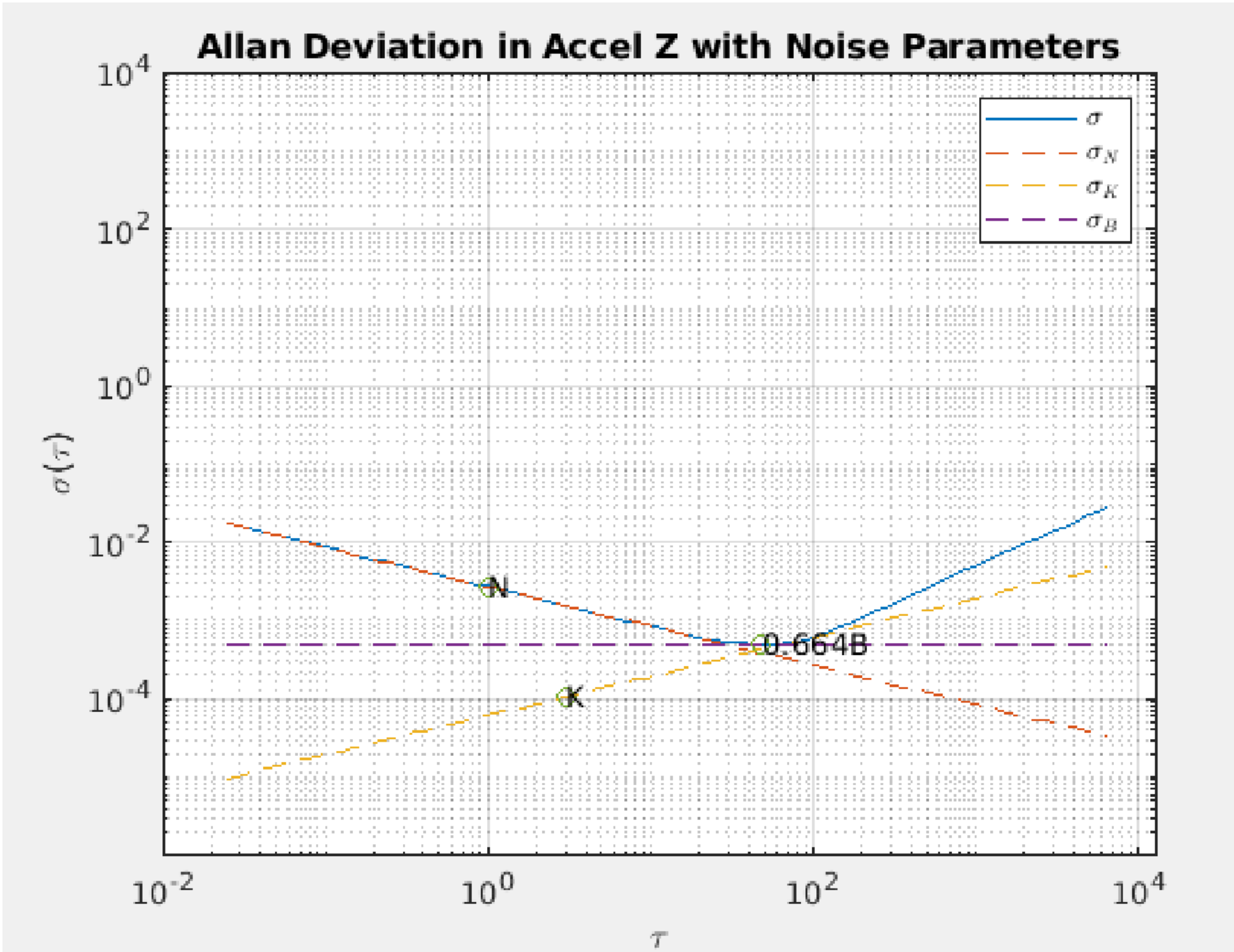
N = 9.8138e-05
K = 9.7200e-08
B = 2.9252e-06



N = 0.4162
K = 3.9045e-05
B = 4.3992e-04



N = 0.0019
K = 7.6865e-05
B = 5.3425e-04



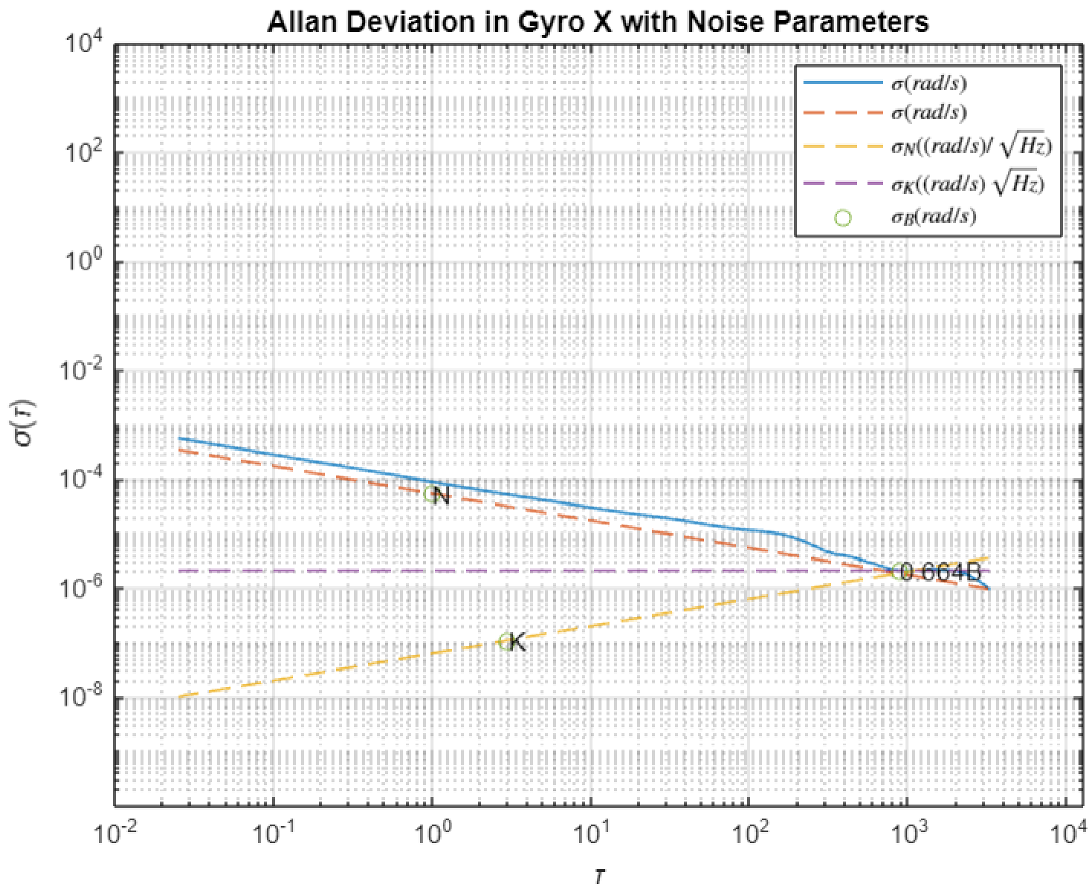
N = 0.0027
K = 1.0507e-04
B = 7.5436e-0

I would say that we could match the Allan variance plots with the situations in which they were recorded, only given that we have different plots of datasets recorded at different places. Then comparing the relative amounts of errors in each of those plots would land us with accurate correspondence of the locations with their plots. The noises present in the environment would vary according to the environment in which the data was recorded, for example,
At a stationary place – There would be dynamic noises of error such as electromagnetic interferences, temperature fluctuations, magnetic noise from nearby instruments and devices.

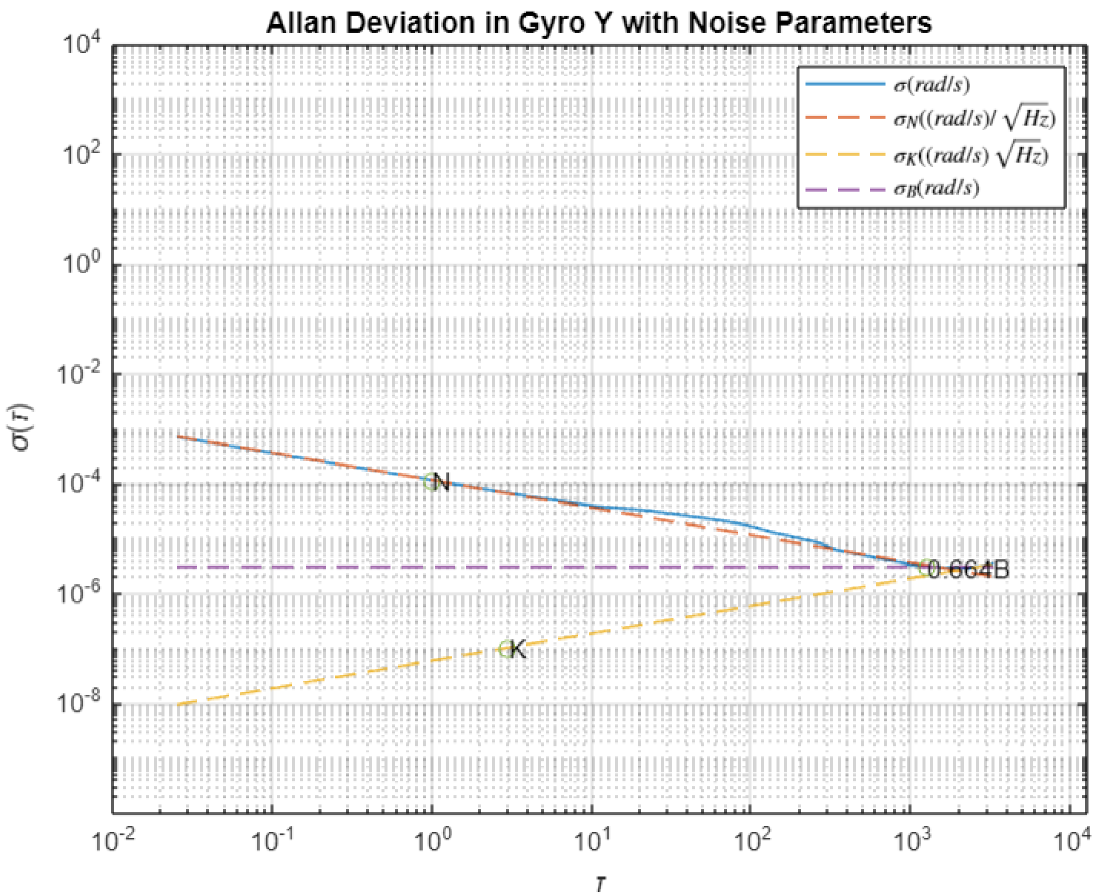
The best conditions to measure Allan Variance would be one with the least environmental noise sources. Additionally, best sensor performance would be observed when the sensor is calibrated for all forms of internal noises.

If I were to characterize a new sensor with unknown performance, I would measure the internal noises of the sensor using the parameters of N (angle random walk), K (rate random walk) and B Bias instability relates to the sensor's inherent systematic errors, causing deviations from the true value over time. Rate noise, conversely, introduces random fluctuations in the measurements, contributing to the linear trend seen in the graph.

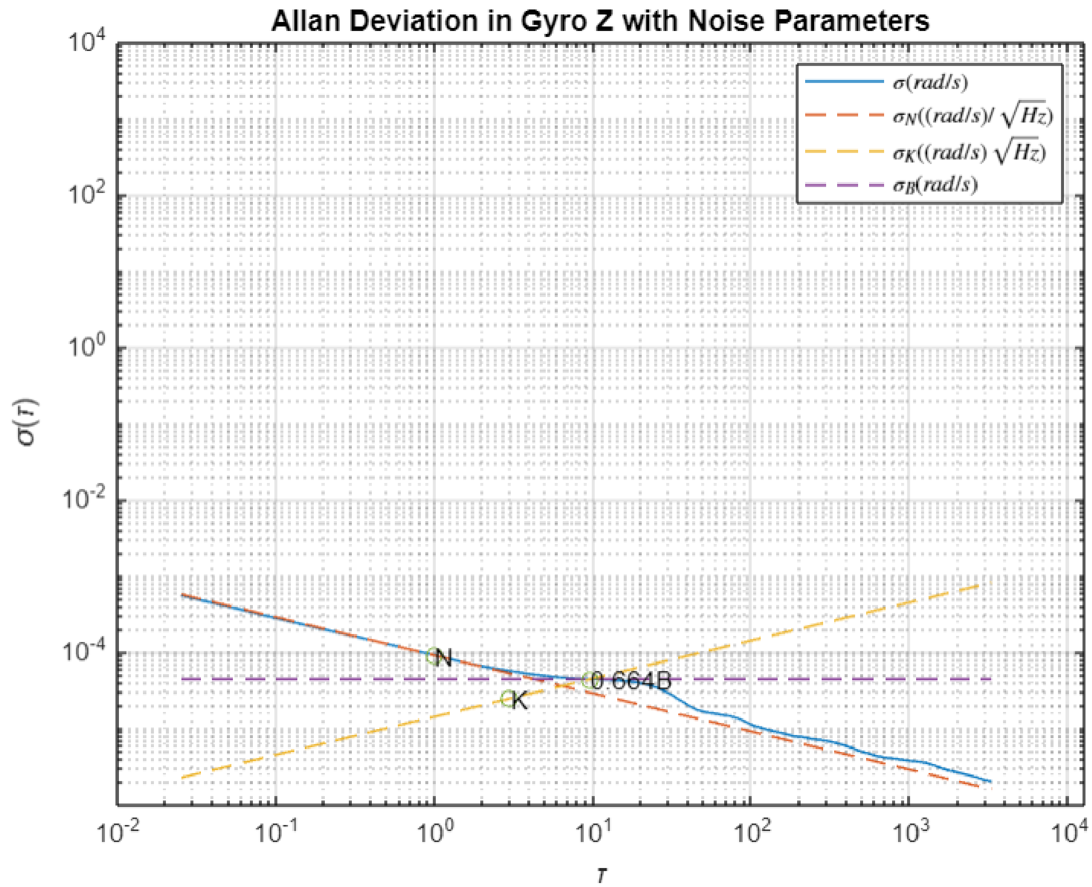
Location B



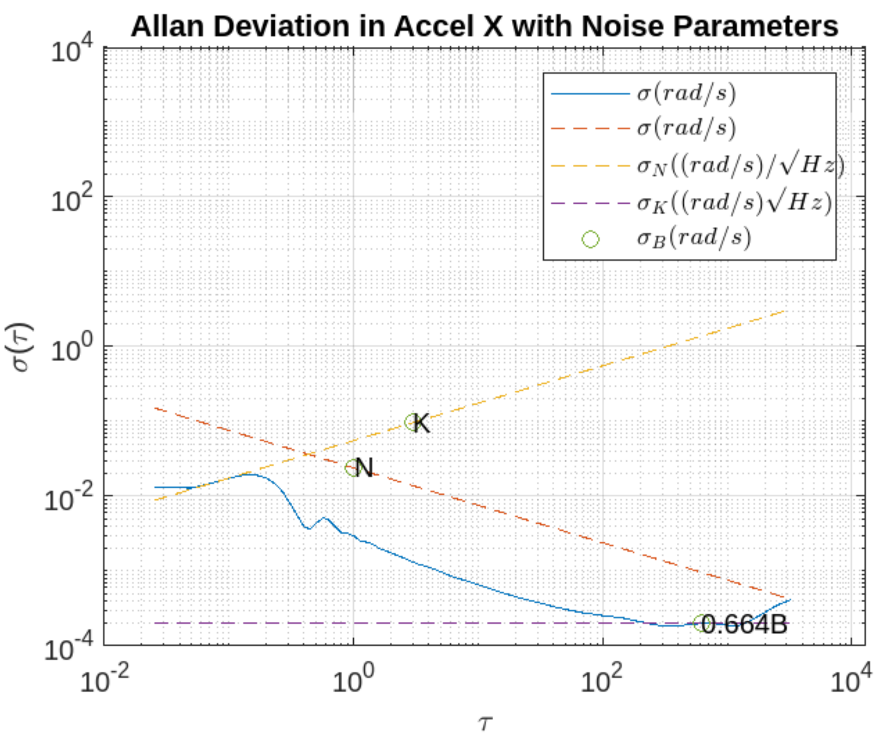
N = 5.3858e-05
K = 1.0811e-07
B = 3.1026e-06



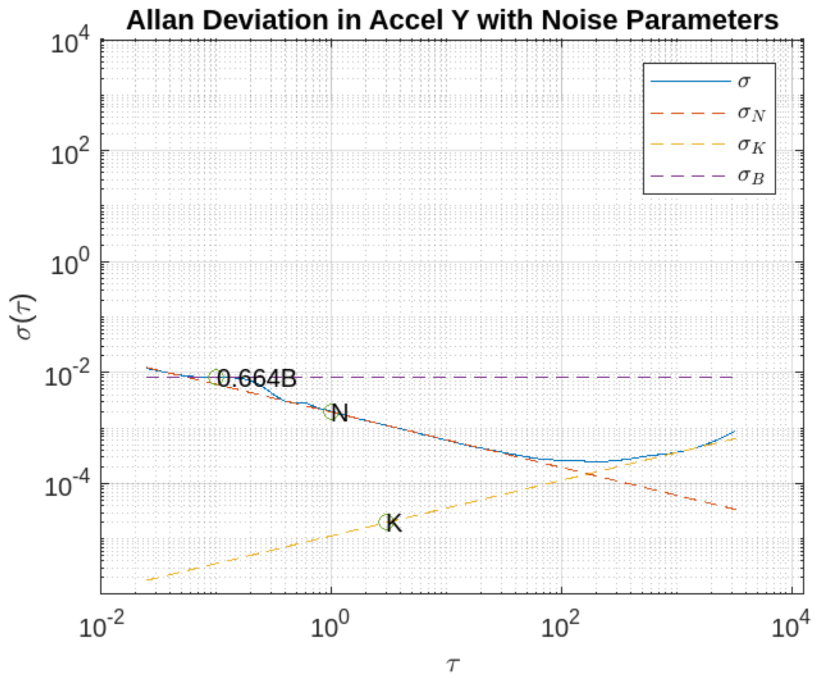
N = 1.1353e-04
K = 1.0157e-07
B = 4.5021e-06



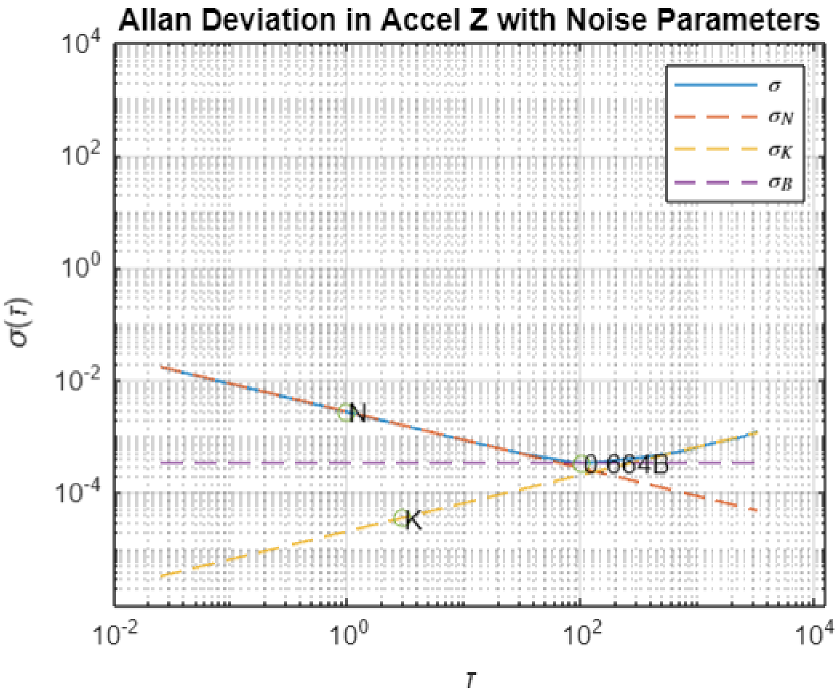
N = 9.0601e-05
K = 2.4620e-05
B = 6.6385e-05



N = 0.0240
K = 0.0962
B = 3.0139e-04



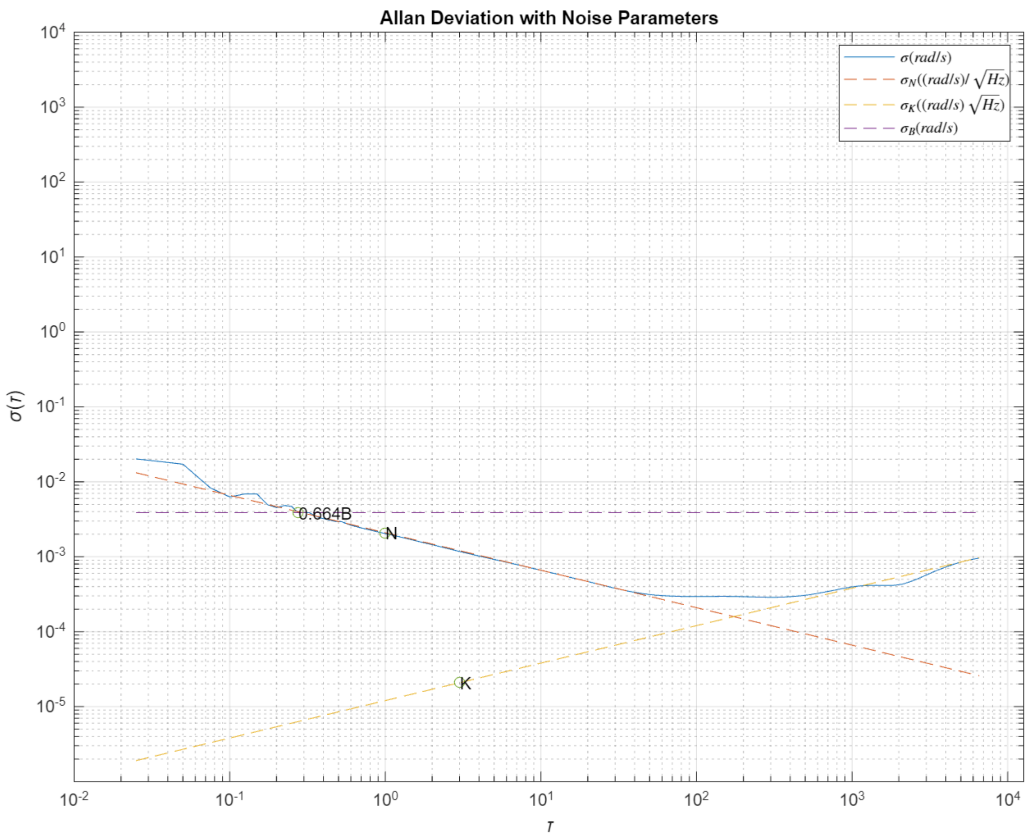
N = 0.0019
K = 1.9716e-05
B = 0.0122



N = 0.0027
K = 3.5605e-05
B = 5.0781e-04

Location D

Accelerometer X

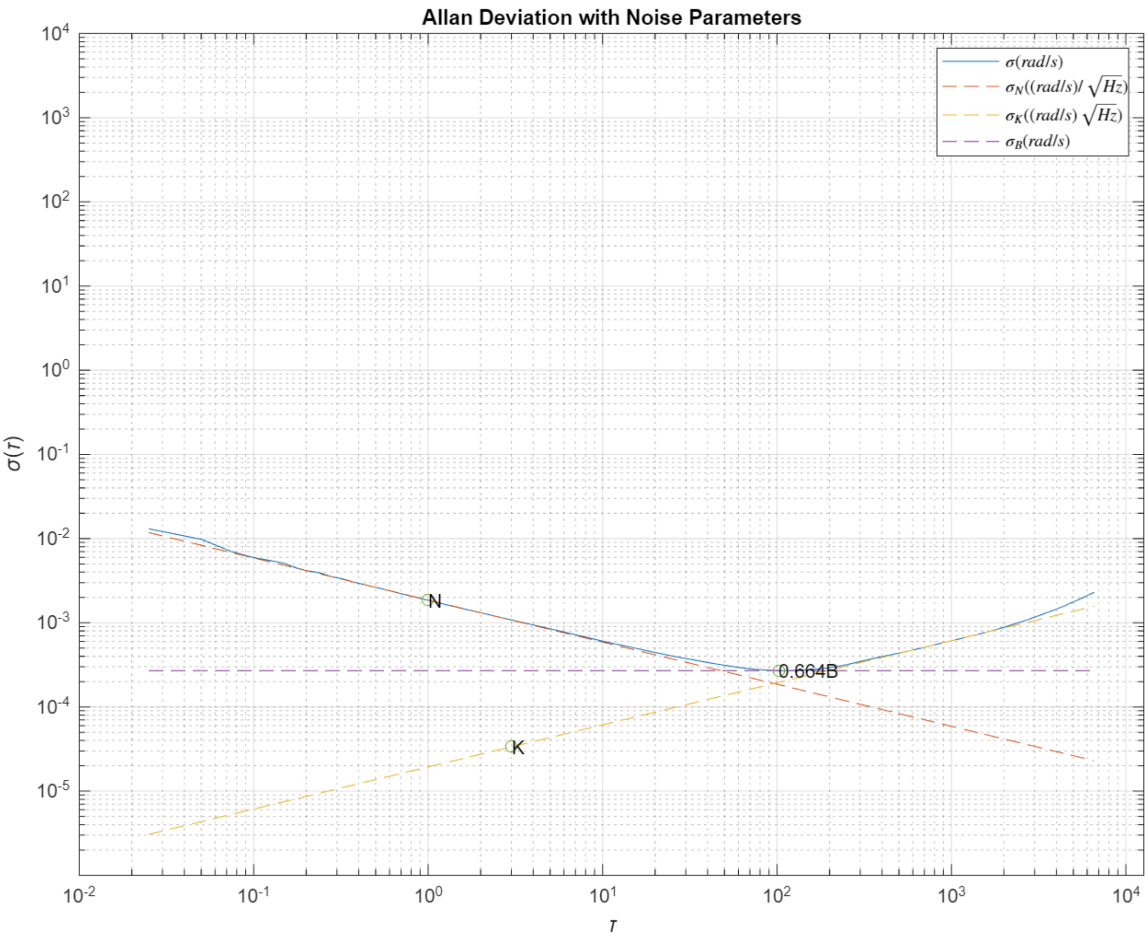


N = 0.0021

K = 2.0842e-05

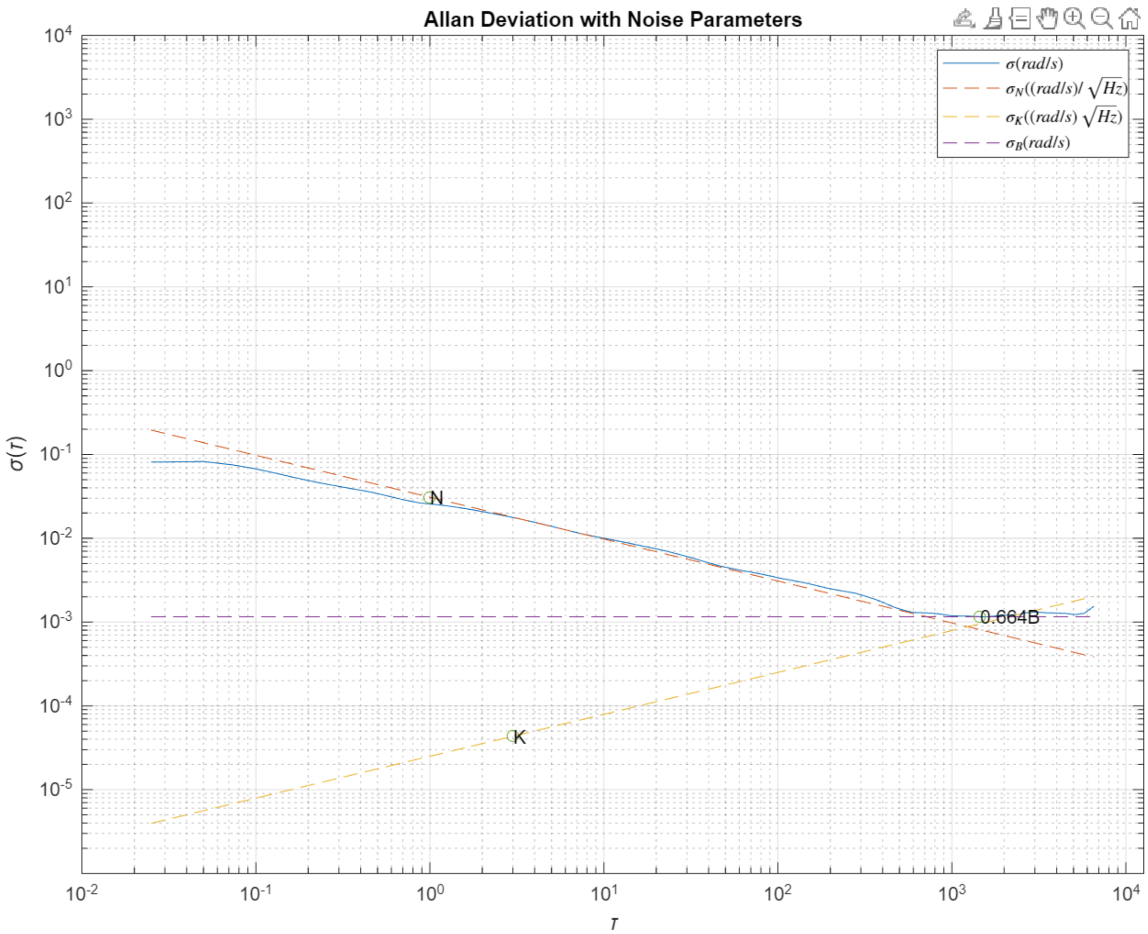
B = 0.0058

Accelerometer Y



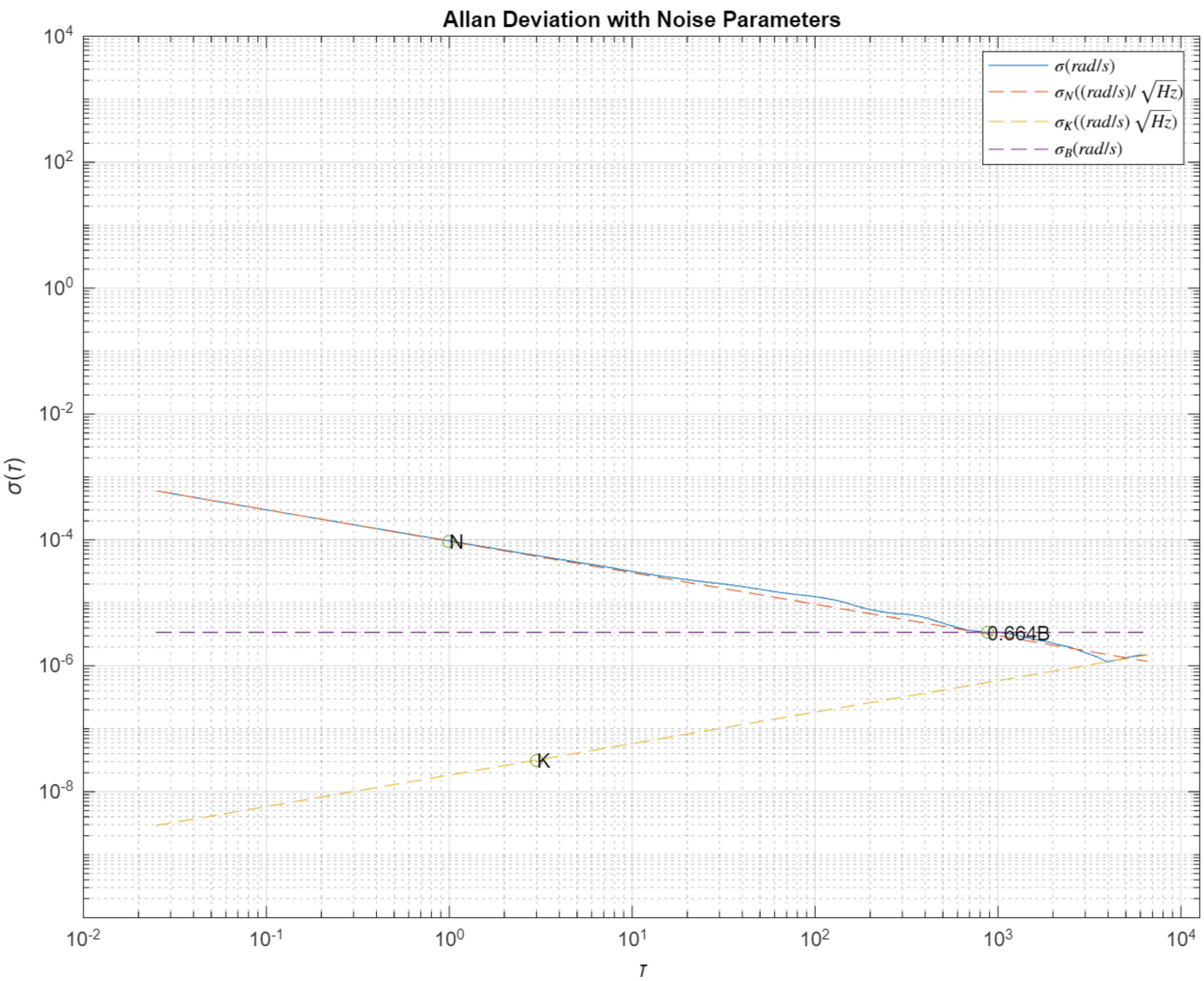
N = 0.0019
K = 3.3554e-05
B = 4.0730e-04

Accelerometer Z



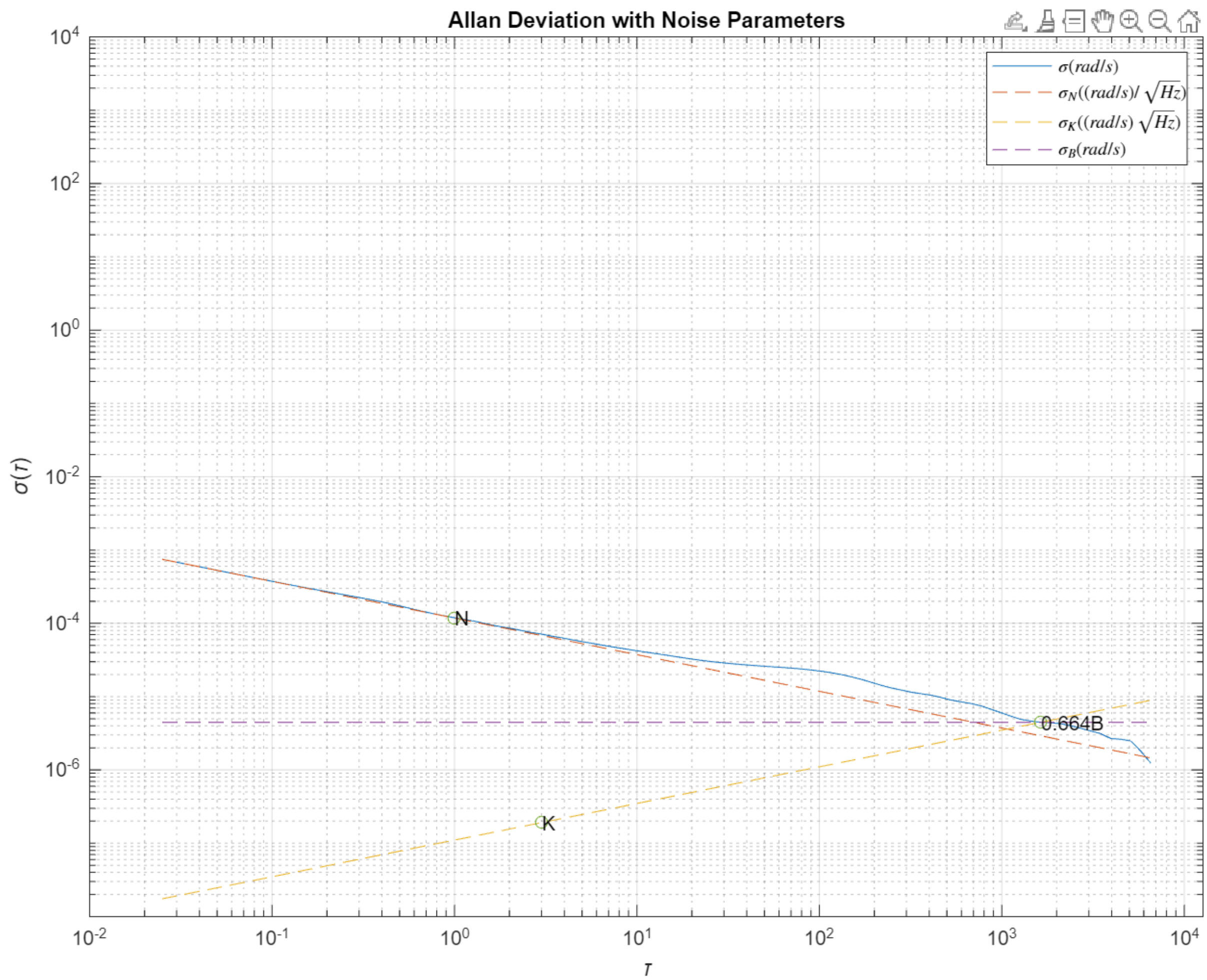
N = 0.0309
K = 4.3375e-05
B = 0.0017

Gyroscope X



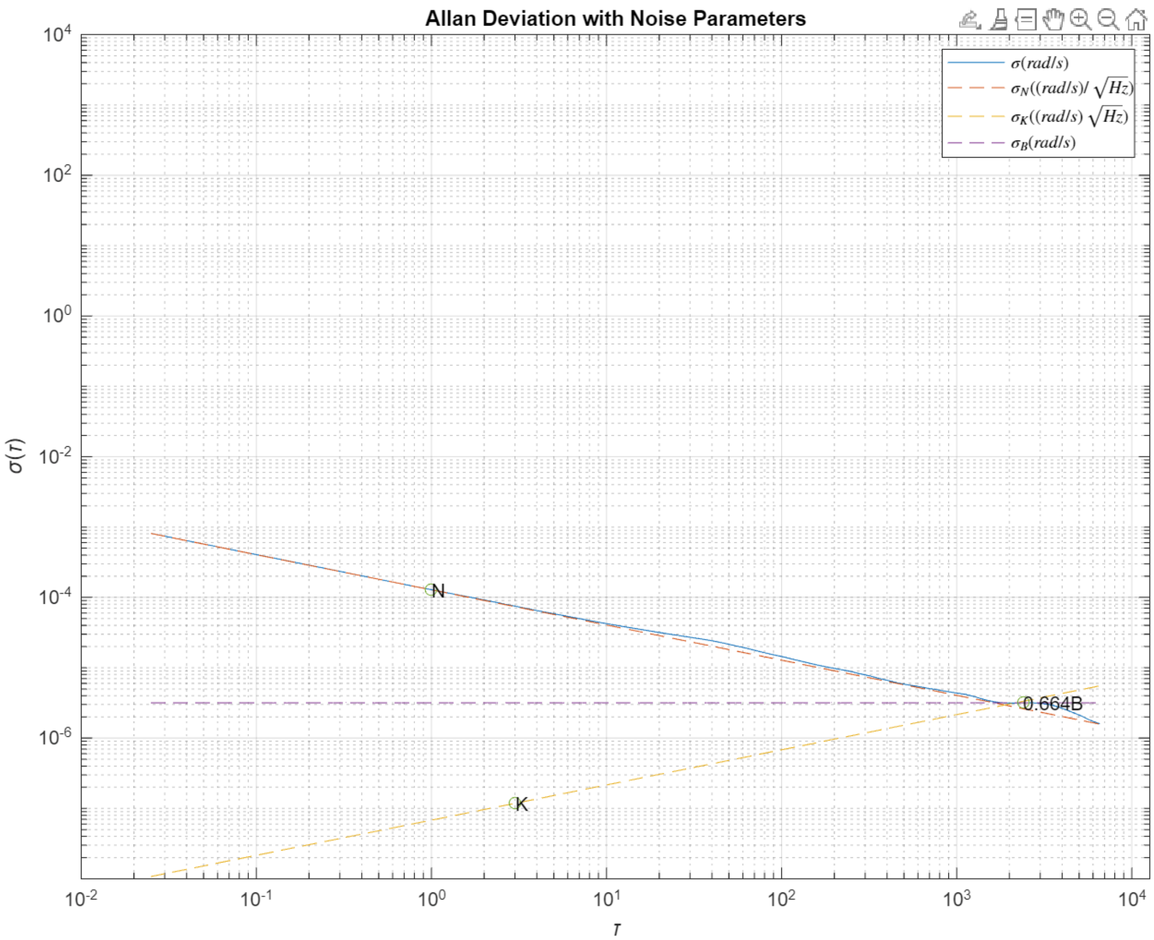
N = 9.5110e-05
K = 3.1830e-08
B = 5.1225e-06

Gyroscope Y



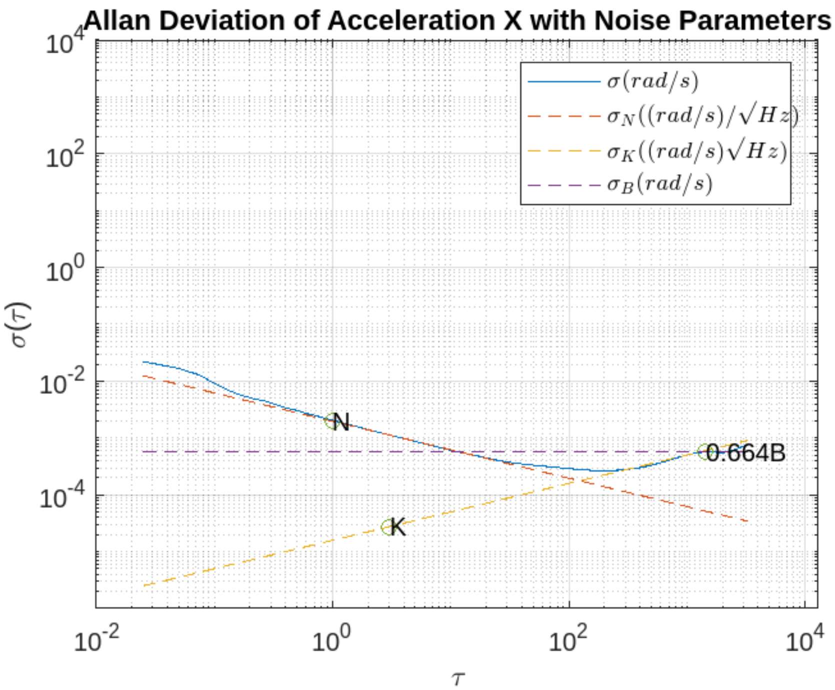
N = 1.1811e-04
K = 1.9097e-07
B = 6.7183e-06

Gyroscope Z

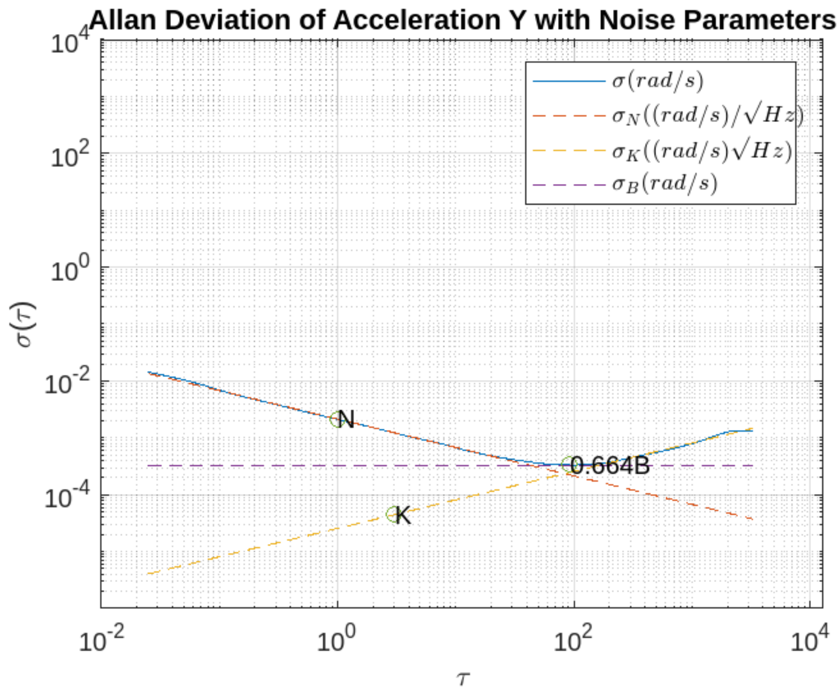


N = 1.2796e-04
K = 1.1802e-07
B = 4.7675e-06

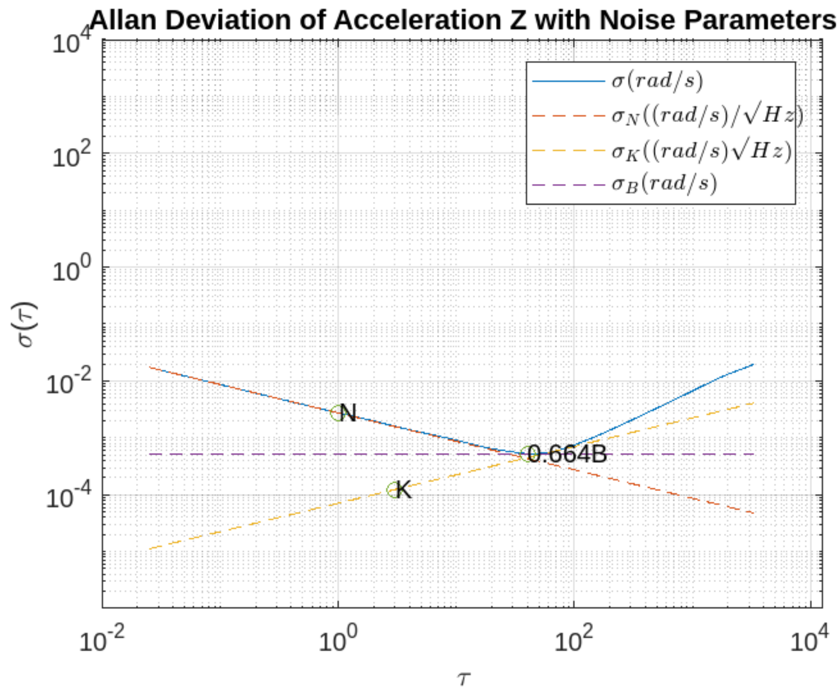
Location A



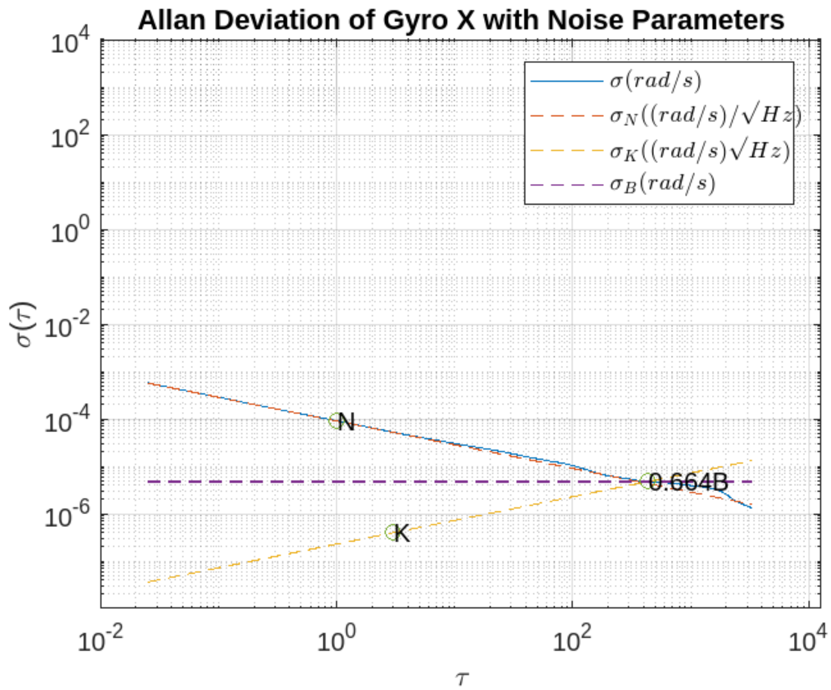

```
N = 0.0020
K = 2.7509e-05
B = 8.5466e-04
```



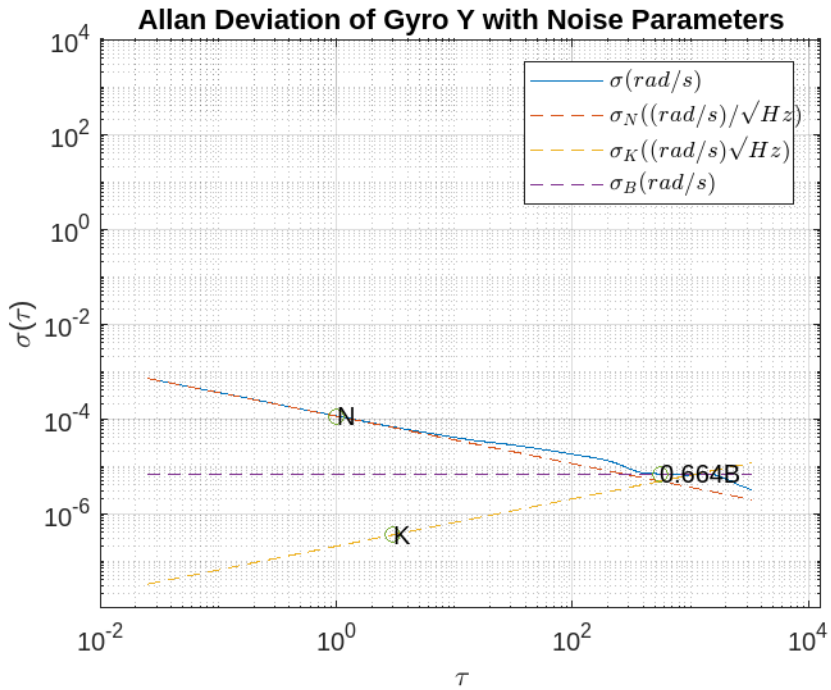

```
N = 0.0021
K = 4.4462e-05
B = 5.0139e-04
```



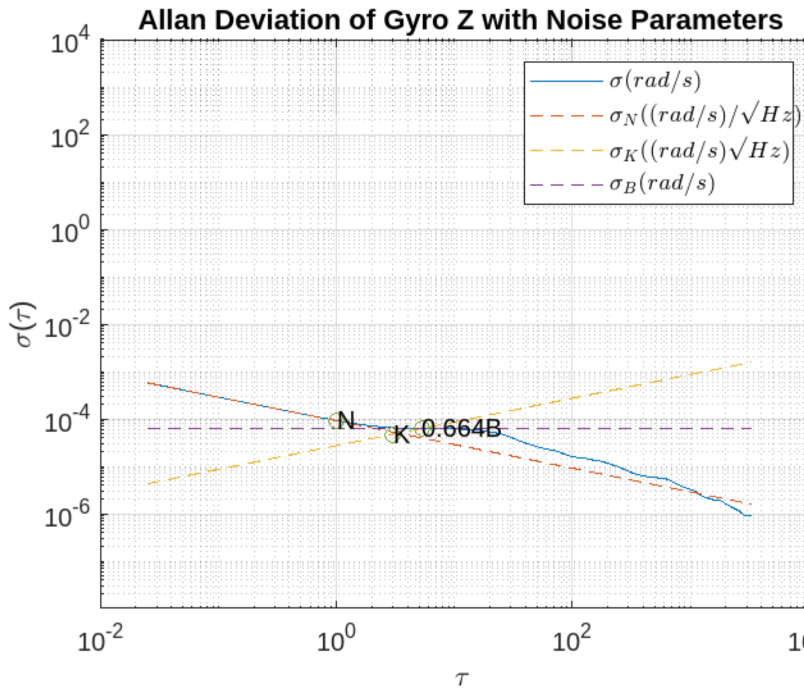

```
N = 0.0027
K = 1.2282e-04
B = 7.9223e-04
```




```
N = 9.0084e-05
K = 3.9555e-07
B = 7.1553e-06
```




```
N = 1.1251e-04
K = 3.5289e-07
B = 1.0239e-05
```




```
N = 9.1164e-05
K = 4.7209e-05
B = 9.4461e-05
```

Deciding between 5th floor of ISEC, 3rd floor of wooden house, ISEC basement, Snell library Basement,

Comparing the corresponding plots of C, B and D, we can say that the noise is maximum in Location A, followed by Locations D, C and B. In light of this, the matching correspondences are as follows -

Location A - ISEC Basement
Location D - Snell Library Basement
Location C – 3rd Floor of Wooden House
Location B - 5th Floor of ISEC