EECE 5554 Robotics Sensing and Navigation
Lab-3 Report

Introduction

The Third Lab concentrated on collecting the imu data from Vectornav VN-100 IMU. Suitable driver was written to collect and parse the data which would later be published on to the imu topic. Once the data is collected it is analyzed for the three noise parameters N (angle random walk), K (rate random walk), and B (bias instability) which are estimated using the stationary data of gyroscope and accelerometer. Later the sources of noise in IMU and magnetometer measurements were analyzed.

Data Collection

As the VN-100 IMU is very sensitive and tends to detect even minute vibrations adn disturbances, the west village F basement was chosen to collect the 5 hour stationary data for the group. The 10 minute data was also collected in the first floor of the snell engineering center.

Data analyses:

The following data was collected from the IMU sensor VN-100 :

- Roll angle
- Pitch angle
- Yaw angle
- Angular velocity in x,y,z directions
- Linear acceleration in x,y,z directions
- Magnetic field in x,y,z directions

Time series and frequency distribution graphs were plotted for each data-set and noise characteristics of the same are obtained.

Time series and frequency plots for the stationary data would give us an understanding of the noise characteristics. Hence they were plotted, standard deviation and Mean were calculated.

Time series and Frequency plots:

Roll:

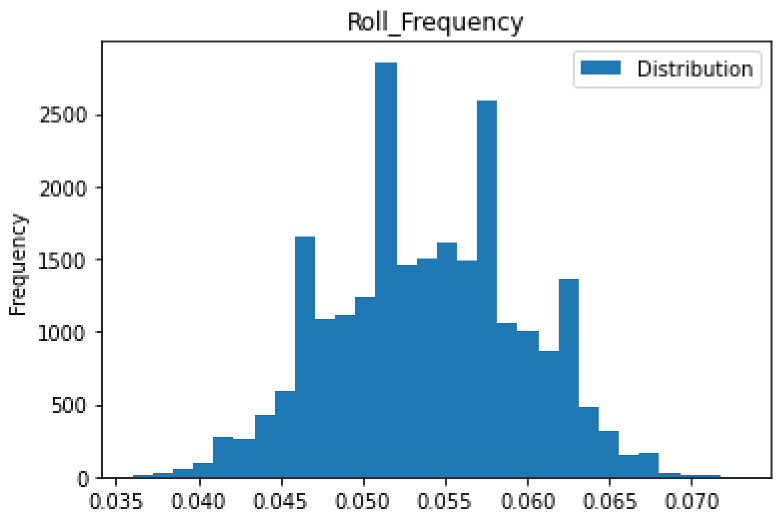

Fig-1 Histogram plot of Roll frequency

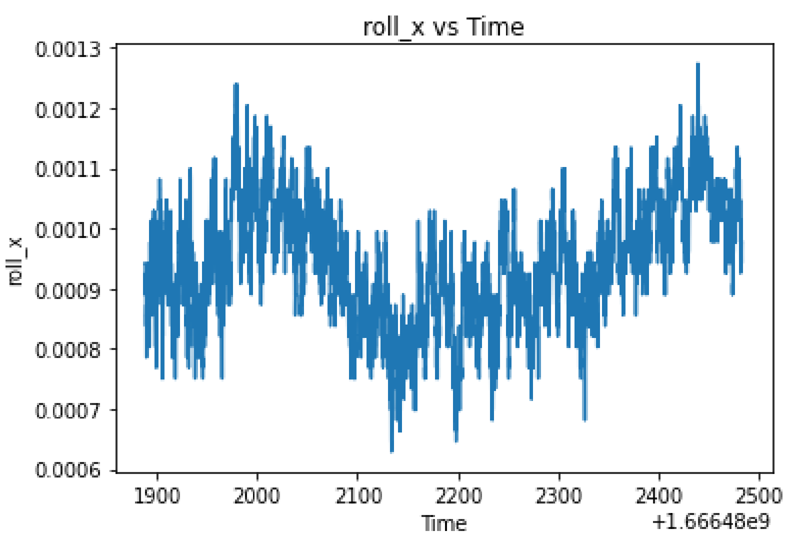

Fig-2 Time series plot of Roll angle

Noise characteristics:

The Standard Deviation in the roll angle is 0.005789832371404328 and Mean in the roll angle is 0.053962737355069415**.**

Distribution followed: Gaussian/ Normal Distribution

Pitch:

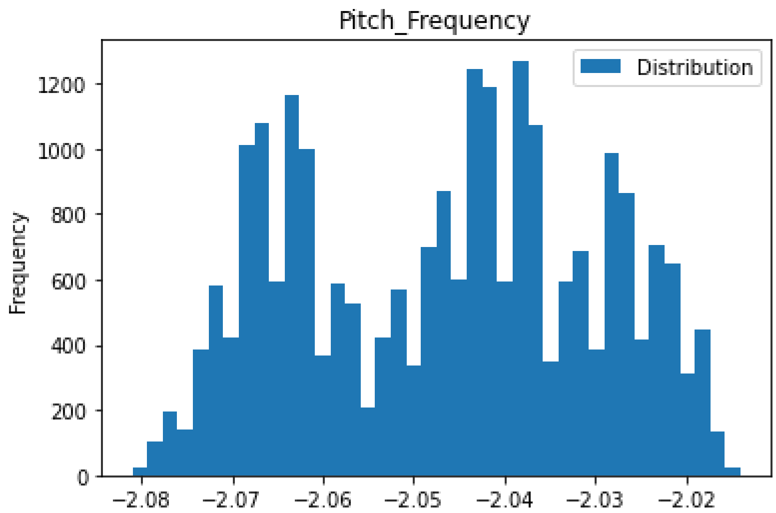

Fig-3 Histogram plot of Pitch frequency

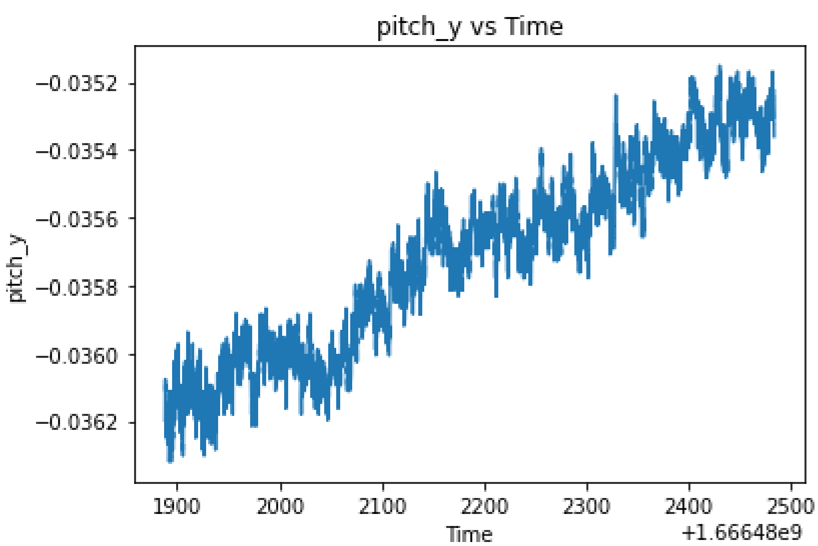

Fig-4 Time series plot of Pitch angle

Noise characteristics:

The Standard Deviation of the pitch angle is 0.016206876011980707 and the mean of the pitch angle is -2.0439999999999999

Distribution followed: Gaussian/ Normal Distribution

Yaw:

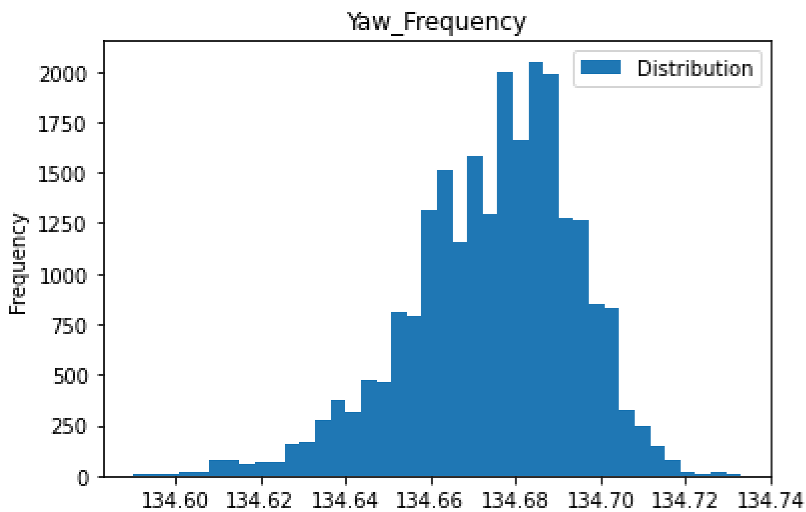

Fig-5 Time series plot of Pitch angle

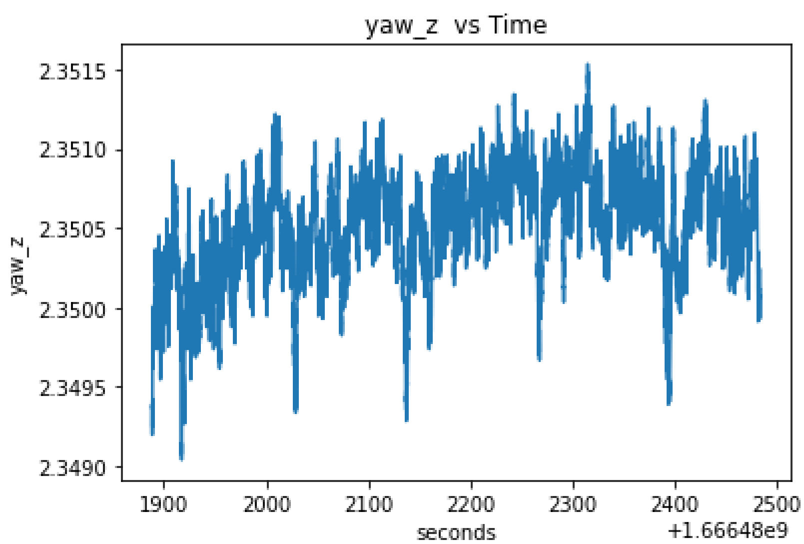

Fig-6 Time series plot of Pitch angle

Noise characteristics: The Standard Deviation of yaw angle is 0.01953962351534442 and the Mean of yaw is 134.67476768610317

Distribution followed: Gaussian/ Normal Distribution

Angular velocity in x,y,z directions:

Angular velocity in x:

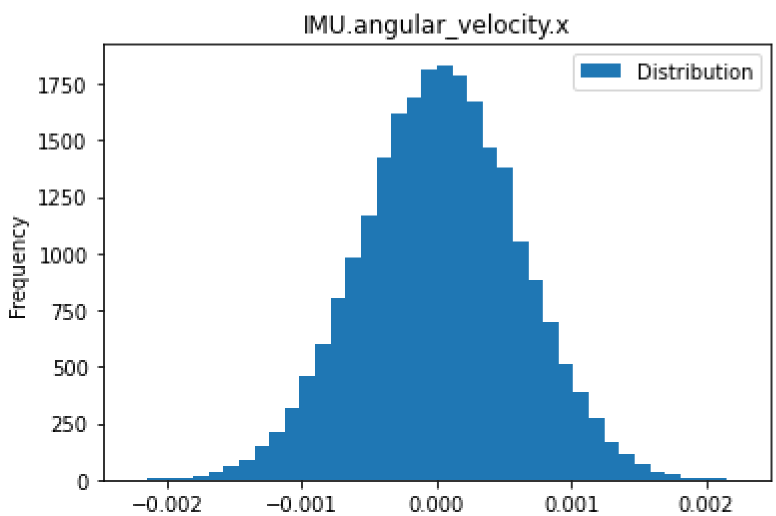

Fig-7 Time series plot of Pitch angle

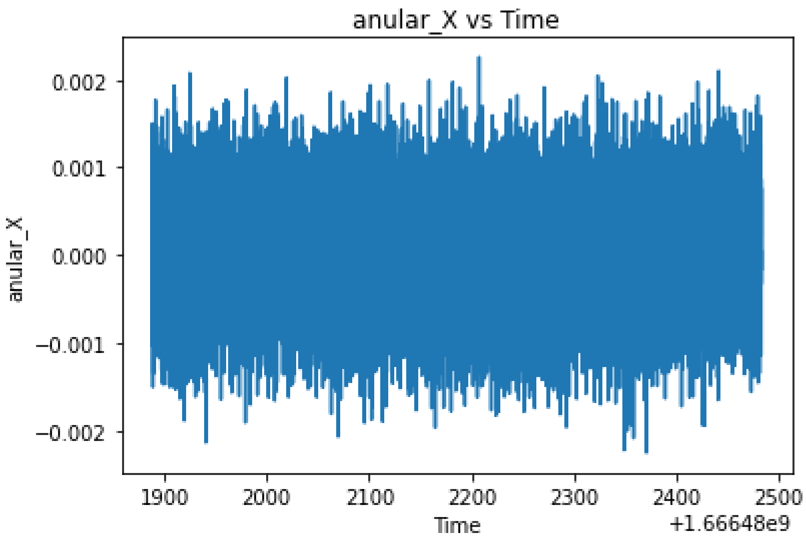

Fig-8 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of angular-velocity in x direction is 0.0005844614758752385 and the Mean of angular-velocity in x-direction is 3.2295454545455e^-05

Distribution followed: Gaussian/ Normal Distribution

Angular velocity in y:

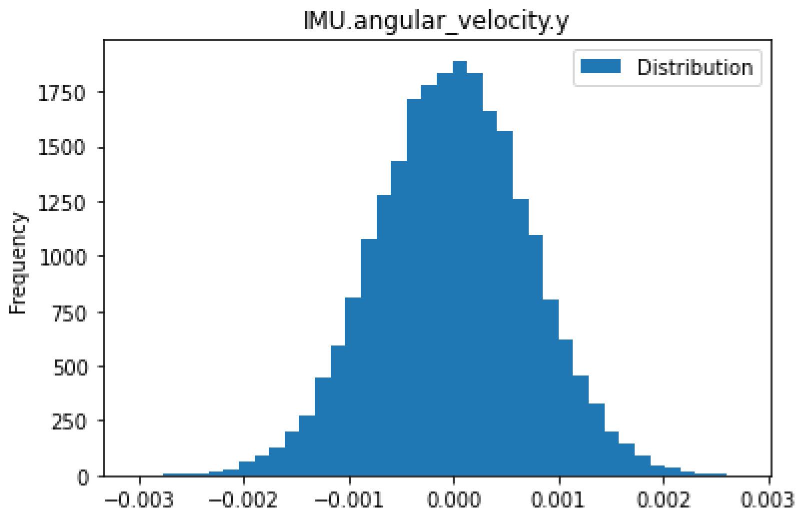

Fig-9 Time series plot of Pitch angle

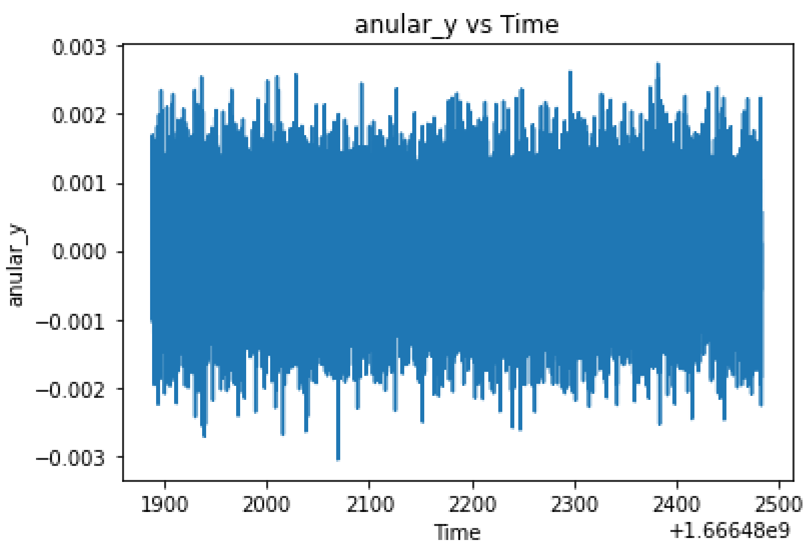

Fig-10 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of angular-velocty in y direction is 0.0007240649661680996 and the Mean of angular-velocity in y direction is -8.092631490505798e^-06

Distribution followed: Gaussian/ Normal Distribution

Angular velocity in z:

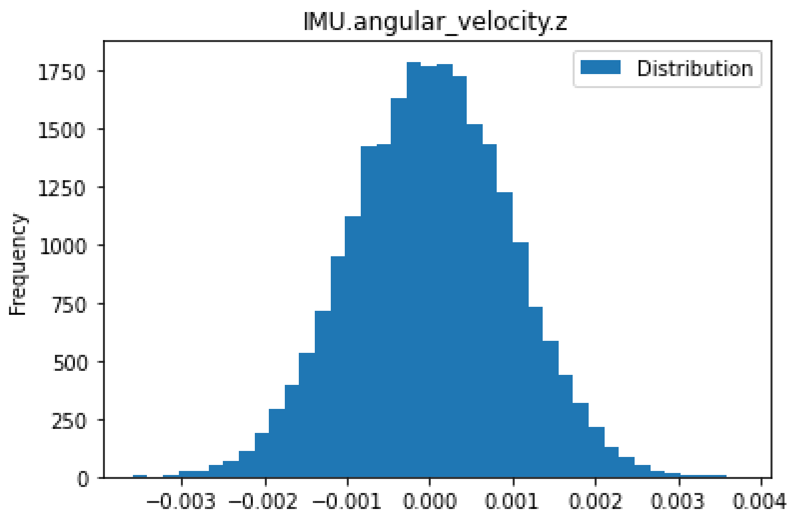

Fig-11 Time series plot of Pitch angle

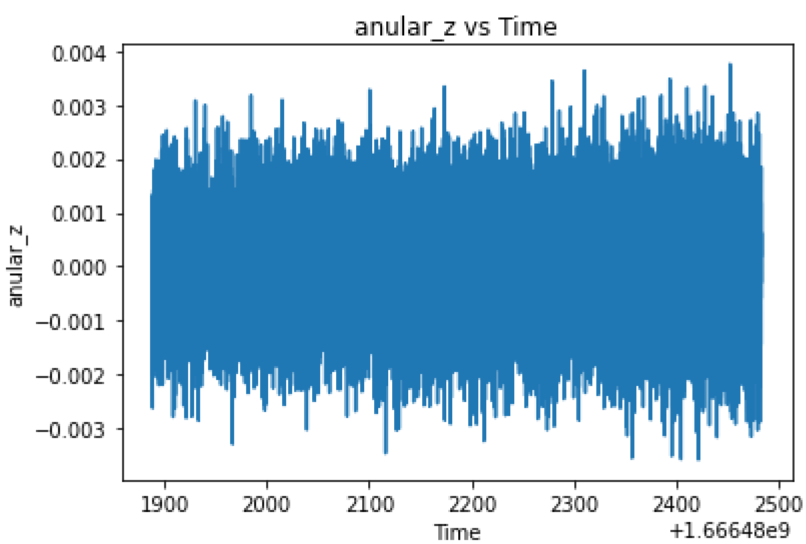

Fig-12 Time series plot of Pitch angle

Noise characteristics:

The Standard Deviation of angular-velocty in z direction is 0.0009574947402912831 and the

Mean of angular-velocity in z-direction is 2.2197823895143672e-05

Distribution followed: Gaussian/ Normal Distribution

Linear acceleration in x,y,z directions:

Linear-acceleration in x:

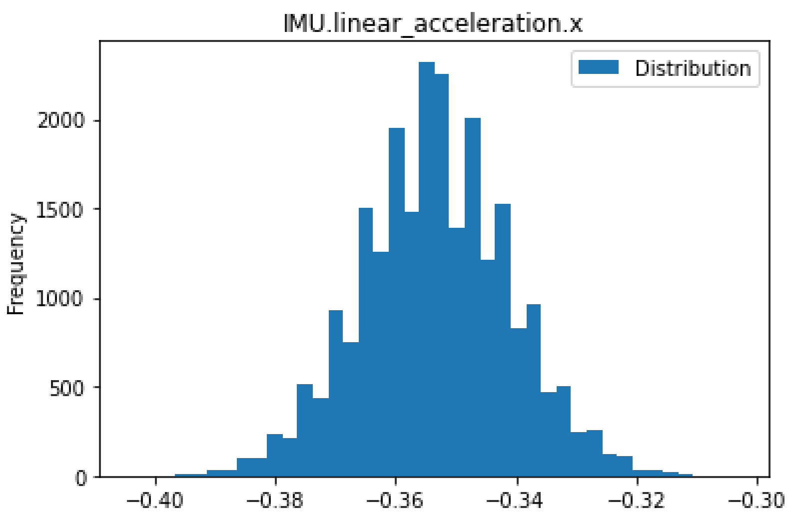

Fig-13 Time series plot of Pitch angle

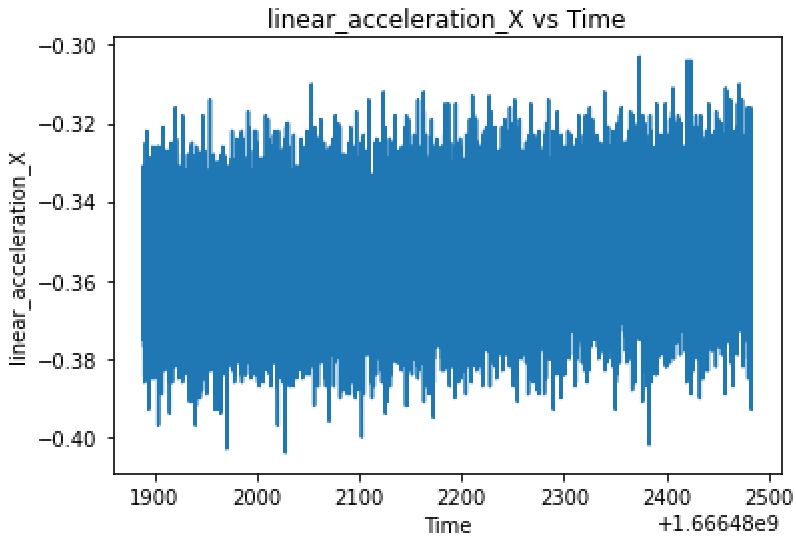

Fig-14 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of linear-acceleration in x direction is 0.012417263968218432 and the Mean of linear-acceleration in x direction is -0.353317887749958

Distribution Followed: Gaussian/ Normal Distribution

Linear-acceleration in y:

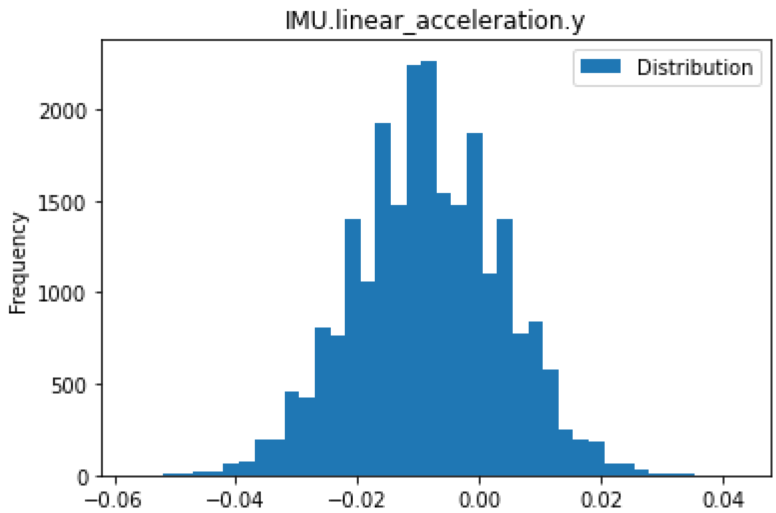

Fig-15 Time series plot of Pitch angle

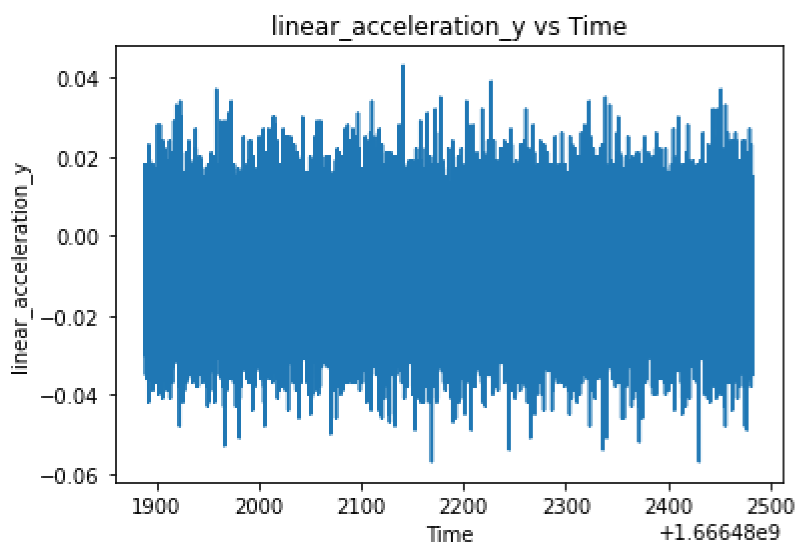

Fig-16 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of linear-acceleration in y direction is 0.012208645769531859 and the Mean of linear-acceleration in y direction is -0.008529910939337927

Distribution Followed: Gaussian/ Normal Distribution

Linear-acceleration in z:

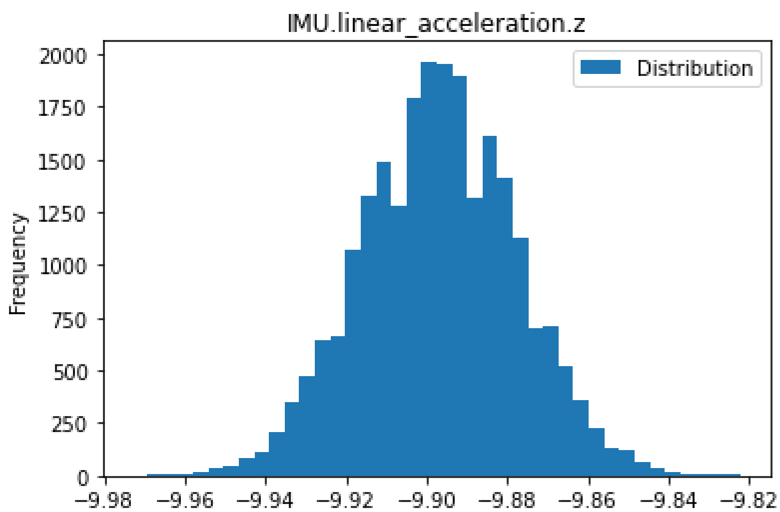

Fig-17 Time series plot of Pitch angle

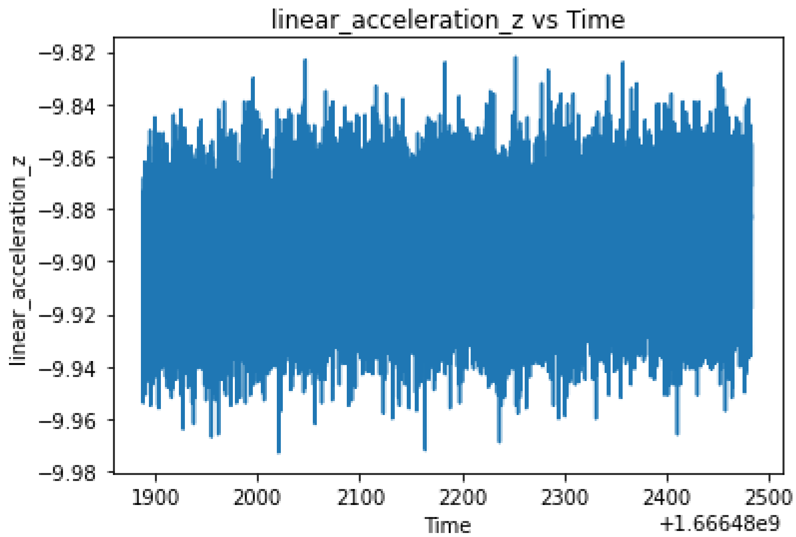

Fig-18 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of linear-acceleration in z direction is 0.019255546163588107 and the Mean of linear-acceleration in z direction is -9.896857040833474

Distribution: Gaussian/ Normal Distribution

Magnetic field in x,y,z directions:

Magnetic field in x:

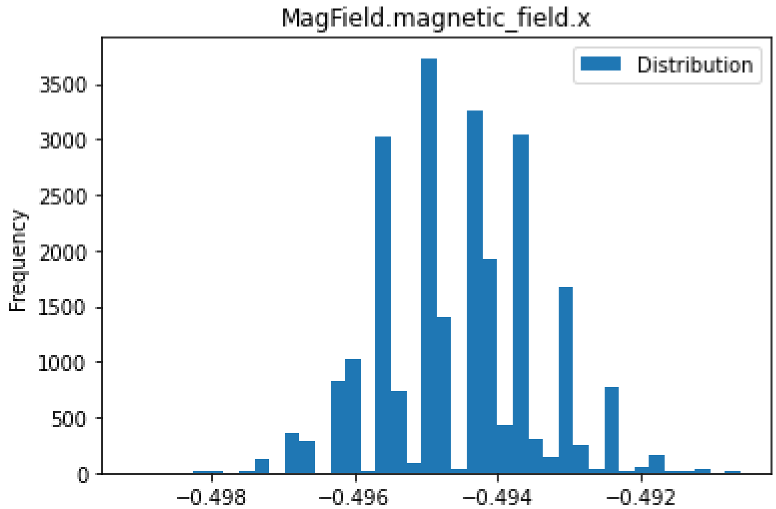

Fig-19 Time series plot of Pitch angle

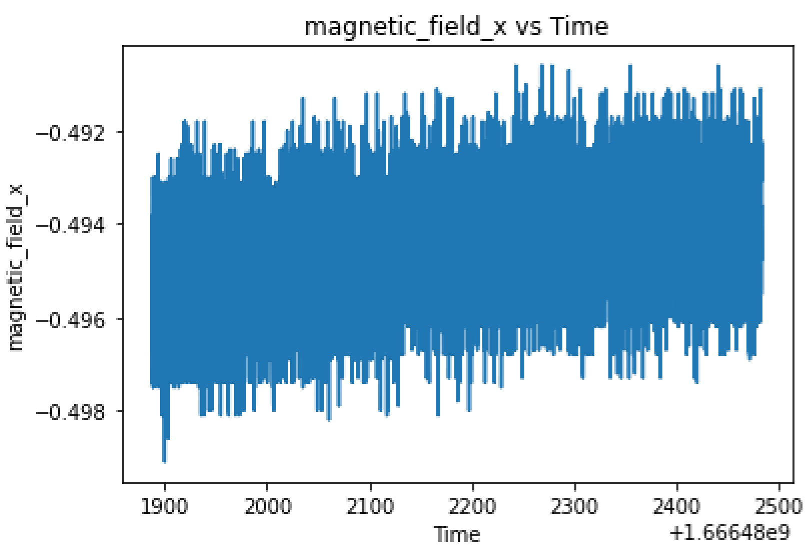

Fig-20 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of Magnetic Field in x direction is 0.0010824990019400148 and the mean of Magnetic Field in x direction is -0.4945403923710301

Distribution: Gaussian/ Normal Distribution

Magnetic field in y:

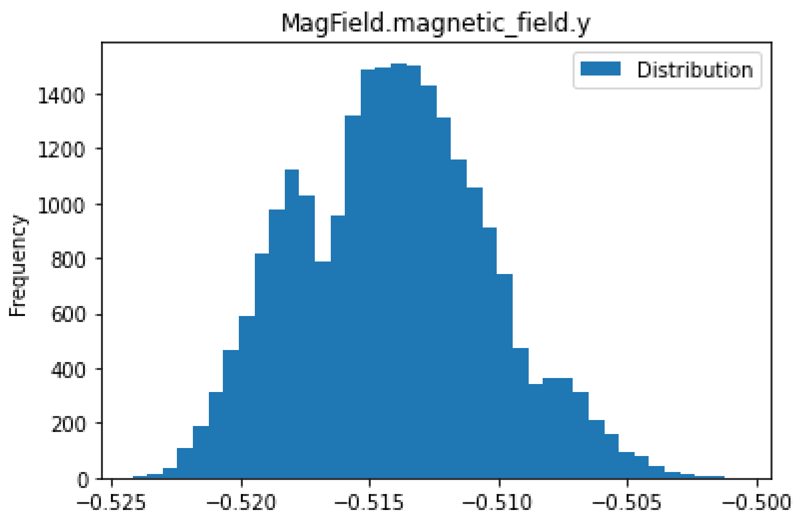

Fig-21 Time series plot of Pitch angle

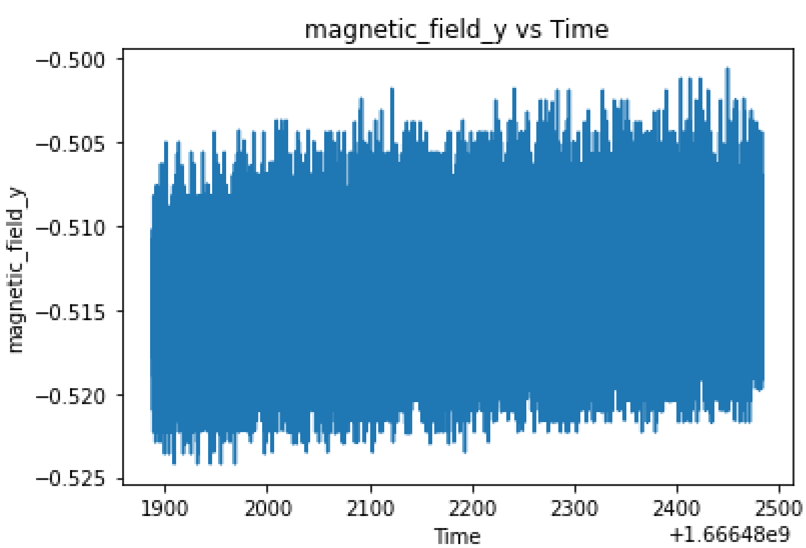

Fig-22 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of Magnetic Field in y direction is 0.003729973294799789 and the Mean of Magnetic Field in y direction is -0.514095135271383

Distribution Followed: Gaussian/ Normal Distribution

Magnetic field in z:

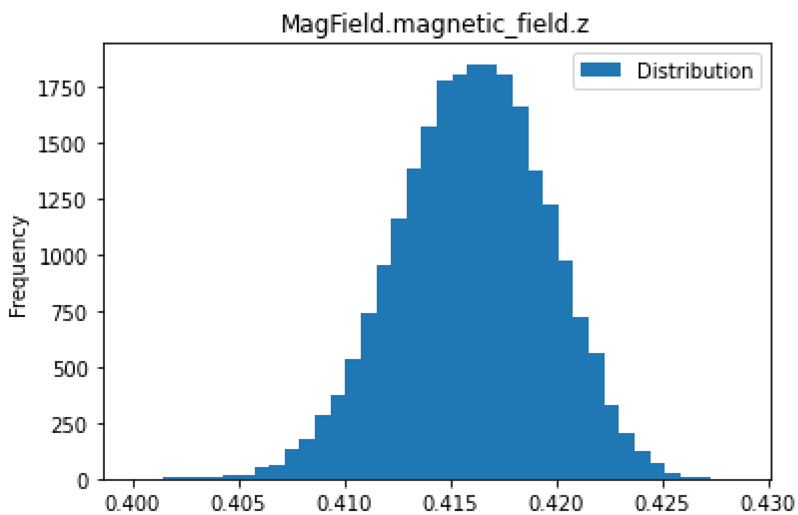

Fig-23 Time series plot of Pitch angle

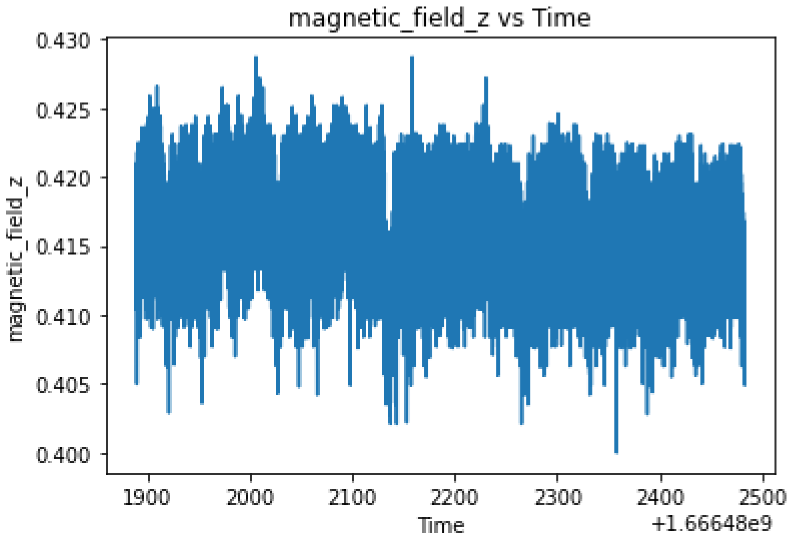

Fig-24 Time series plot of Pitch angle

Noise Characteristics:

The Standard Deviation of Magnetic Field in z direction is 0.0034346844073761137 and the Mean of Magnetic Field in z direction is 0.41597252982691985

Distribution Followed: considering the central limit theorem which states that as independent random variables are summed, the result tends to approach a Gaussian distribution, even if the variables themselves are non-Gaussianas so our data shown in all the above frequency distribution graphs fit in the Normal/ Gaussian distribution. As the errors are combined, the result would fit in a normal distribution data.

kind of errors and sources of noise present:

Despite the fact that the IMU was stationary when the data is collected, its evident that it has errors, noise in it and there are various possible errors for it, such as Quantization Noise, Angle /

Velocity Random Walk Noise, Correlated Noise, Bias Instability Noise, Rate / Acceleration Random Walk Noise.

One of the most predominant errors assumed to be a reason in our case is the random walk (sensor noise) because the data was collected for 5 hours. So if a small error is existing in the sensor data while it gets integrated to the whole time period it would become larger and would affect the static alignment.

The white noise associated with the angle random walk contributes the most to the overall drift of the system. Which would be analyzed in the gyro and accelerometer simulations.

There are multiple other types of noises like brownian noise,pink noise etc. which are related to rate random walk, bias instability respectively.

Out of various noise parameters with allan variance we will be looking at N(Angle random walk), K(rate random walk), B (Bias instability) and comparing the same with the IMU soecifications in the VN-100 data sheet.

Allan Deviation with Noise parameters - Gyroscope:

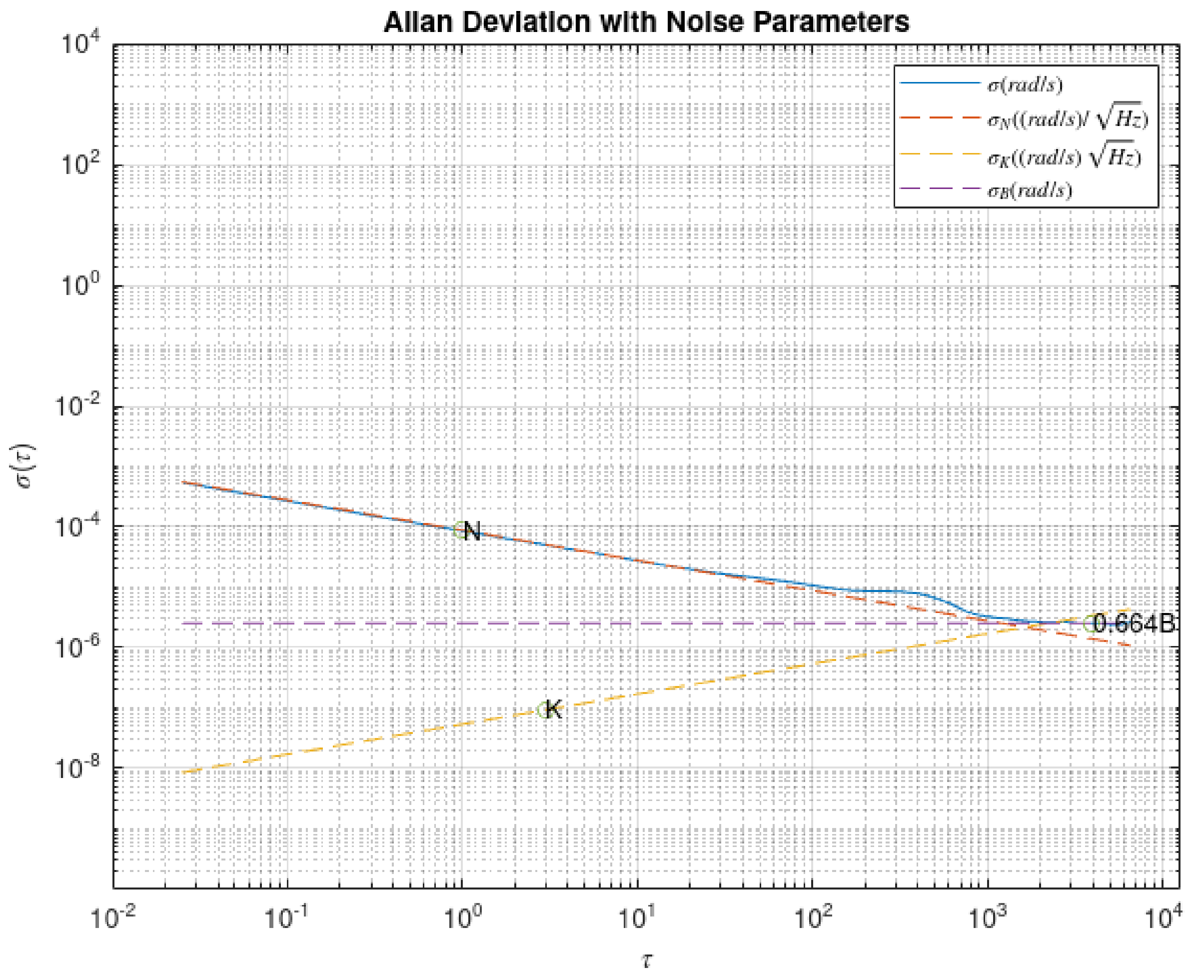

Fig-25 Time series plot of Pitch angle

The above graph presents the N,K,B noise parameters in the gyroscope data using the Allan Variance, where each parameter is normalized over the three axes.

Considered Fs ad T0:

Fs=40 hz, T0= 0.025sec

Allan Deviation with Noise parameters - Accelerometer:

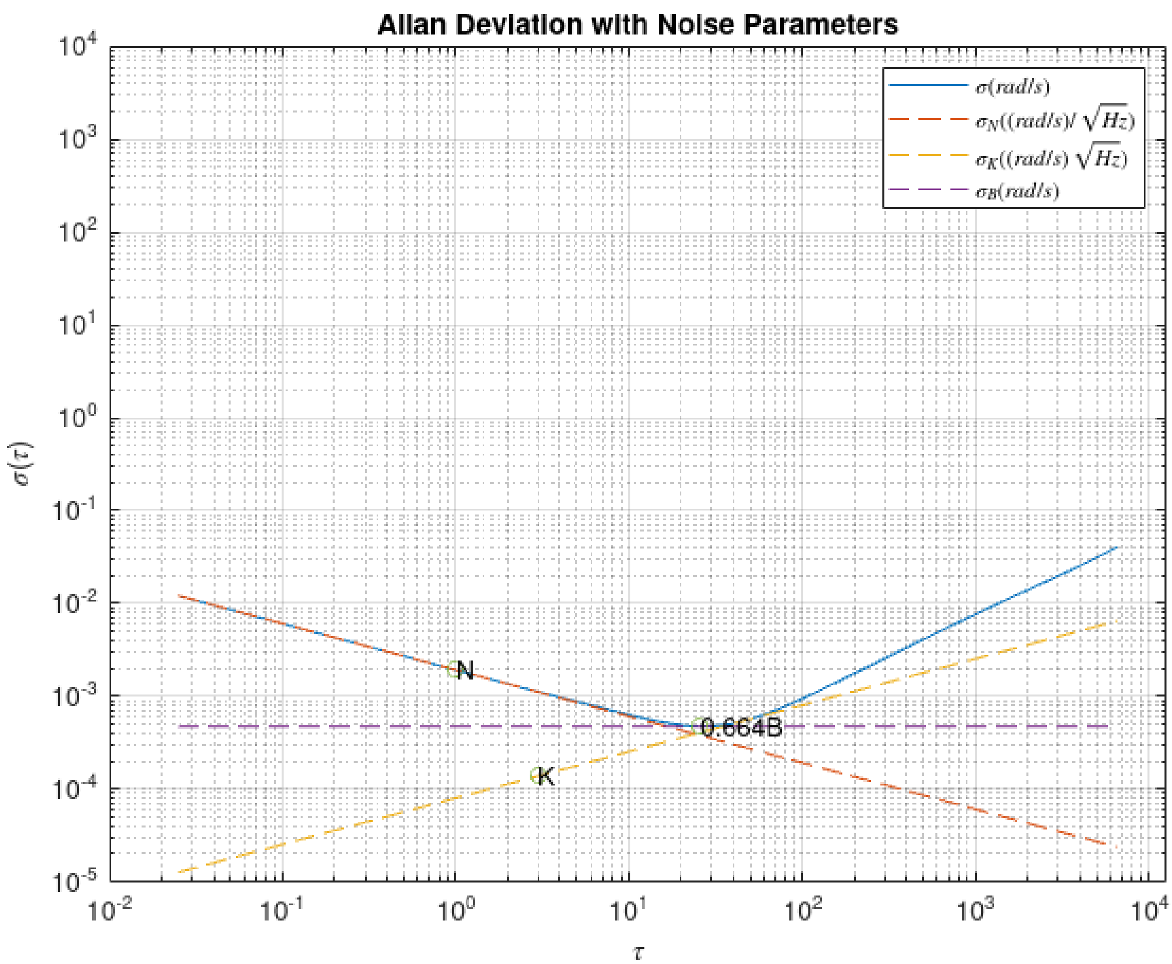

Fig-26 Time series plot of Pitch angle

The above graph presents the N,K,B noise parameters in the Accelerometer data using the Allan Variance, where each parameter is normalized over the three axes.

Considered Fs ad T0:

Fs=40 hz, T0= 0.025sec

Allan Deviation of HW and Simulation - Gyroscope axis_x:

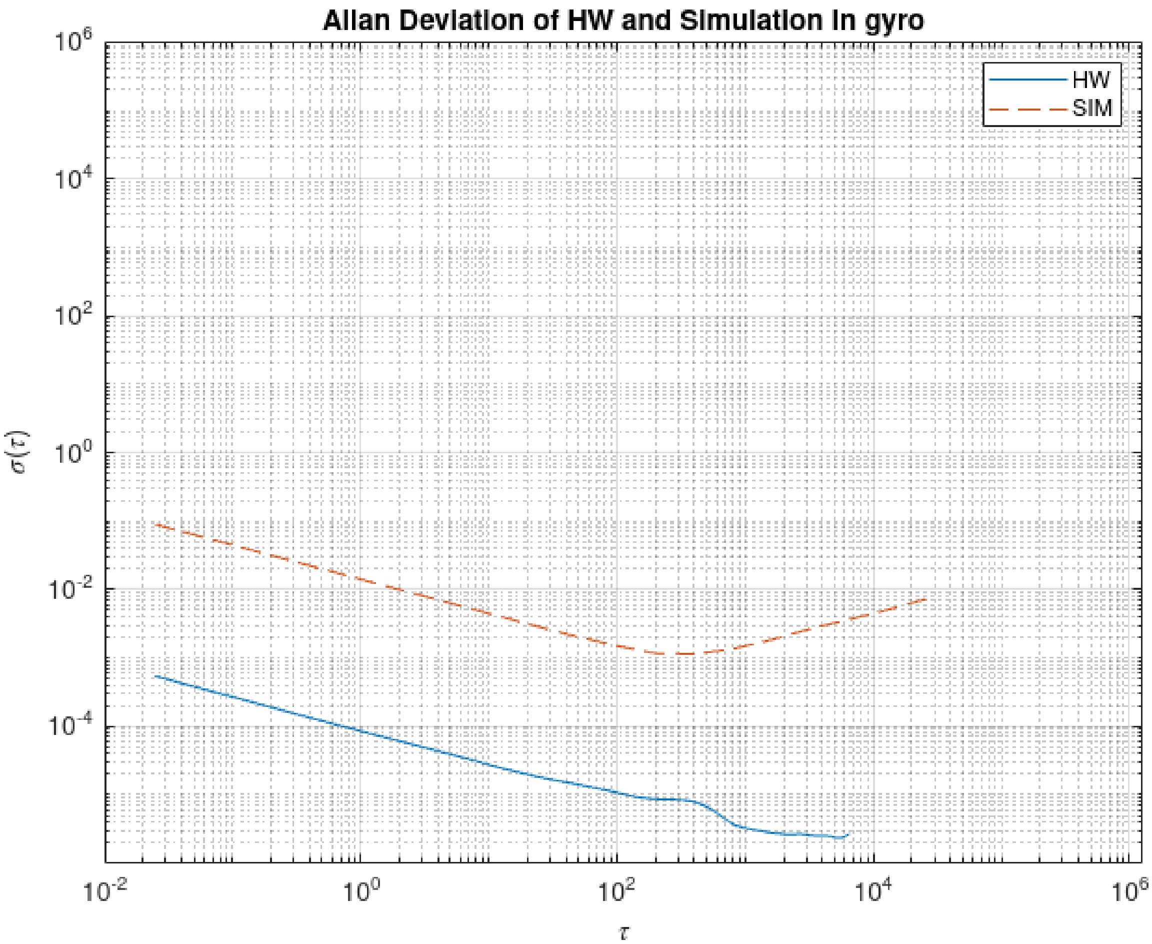

Fig-27 Time series plot of Pitch angle

The graph shows the allan variance of the angular velocity in x direction where the

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=8.7485e^-05 rad/s /sqrt(Hz)

K=9.2686 e^-08 (rad/s) *sqrt(Hz)

B=3.7774e^-06 rad/s

Allan Deviation of HW and Simulation - Gyroscope axis_y:

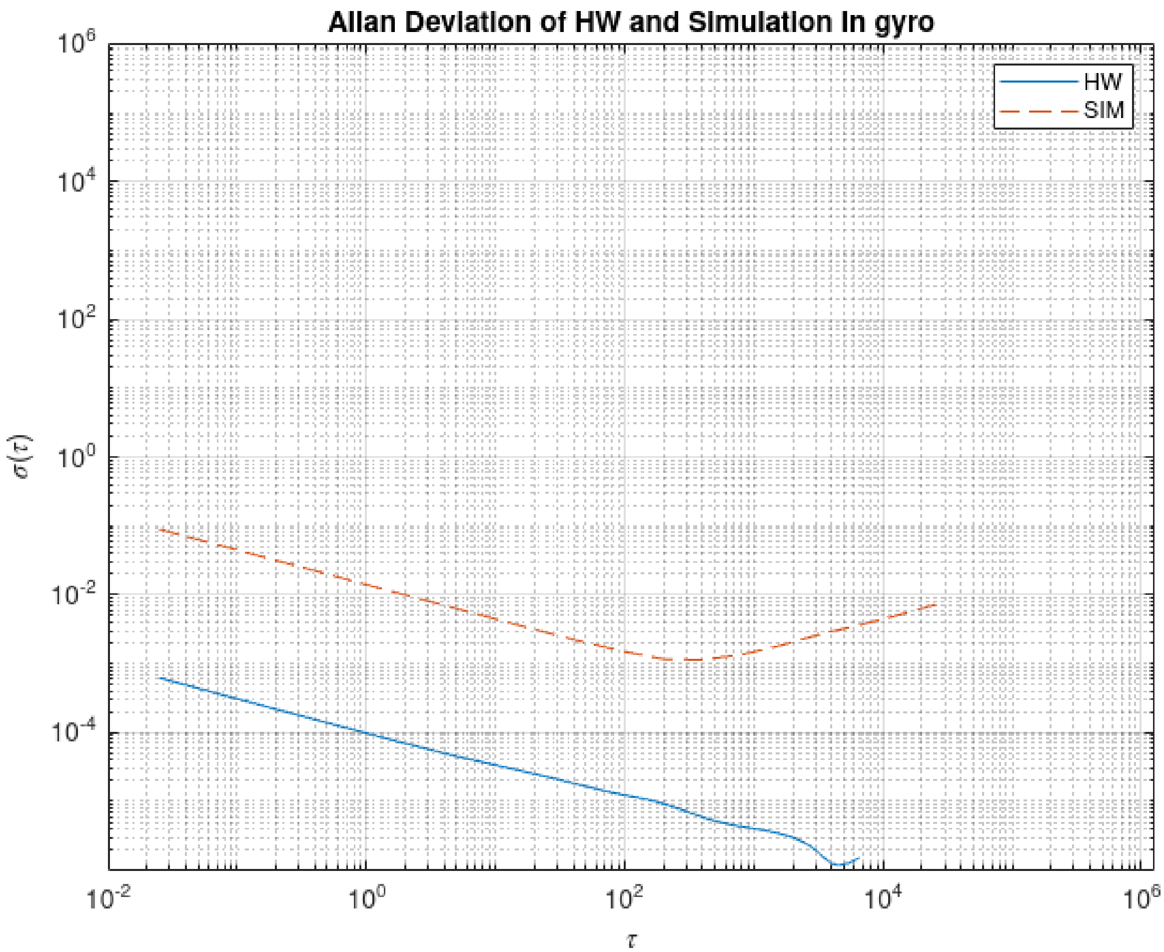

Fig-28 Time series plot of Pitch angle

The graph shows the allan variance of the angular velocity in y direction where the

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=9.7506e^-05 rad/s /sqrt(Hz)

K=3.0066 e^-08 (rad/s)*sqrt(Hz)

B=6.0784e^-06 rad/s

Allan Deviation of HW and Simulation - Gyroscope axis_z:

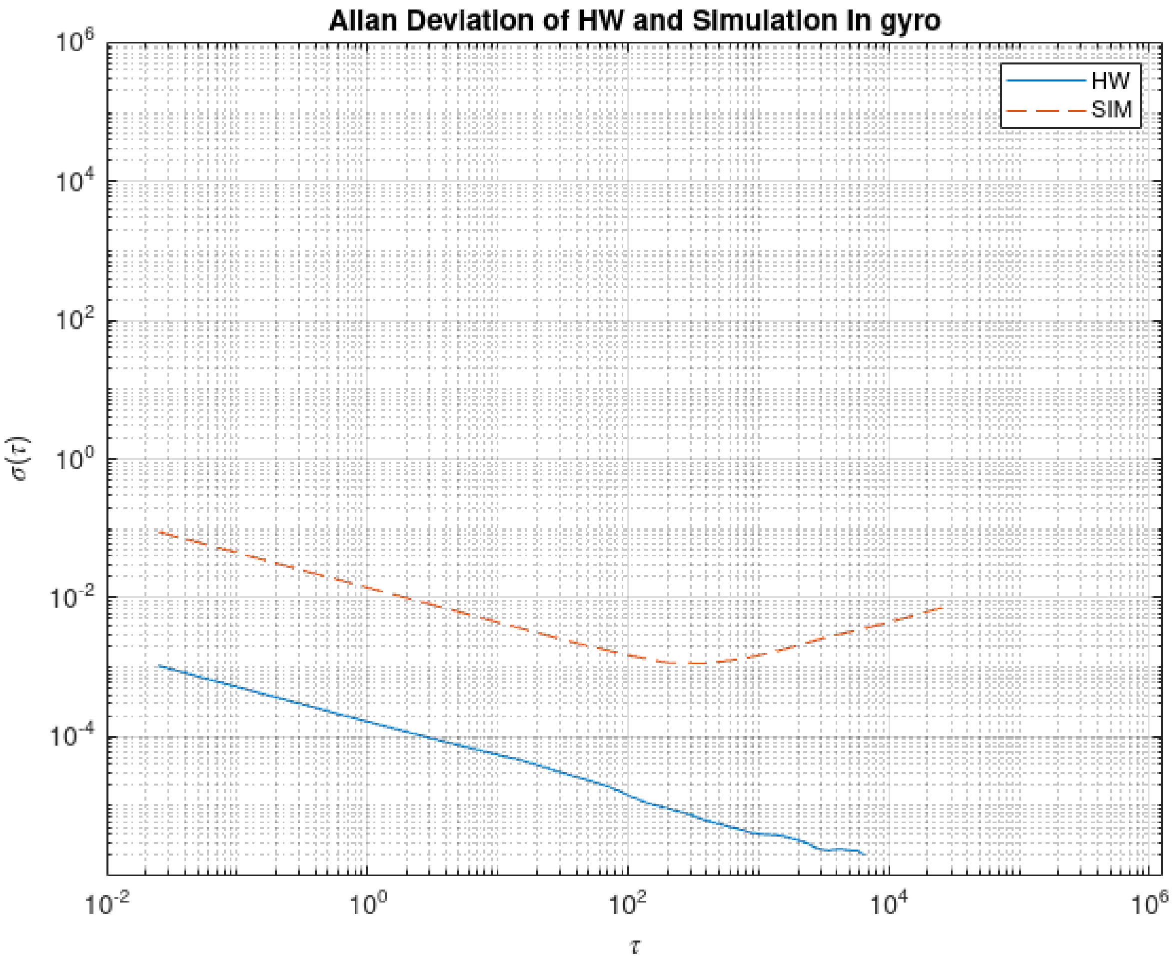

Fig-29 Time series plot of Pitch angle

The graph shows the allan variance of the angular velocity in z direction where the

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=1.6485e^-05 rad/s /sqrt(Hz)

K=6.7161 e^-08 (rad/s) * sqrt(Hz)

B=3.5955e^-06 rad/s

In order to compare the measured values with the standard values in the datasheet, we shall be considering the N at T(tau)=1 and compare it.

In the case of gyroscope the units of N will be m/s^2 / sqrt(Hz).

Calculating the Average "N" i.e N avg =6.7158e^-05 rad/s /sqrt(Hz) and the N std= 0.0035 deg/s /sqrt(Hz) = 6.1e^-05 rad/s /sqrt(Hz) as per the datasheet of VN-100.

So the measured value is very near to the standard value in the VN-100 data sheet.

Allan Deviation of HW and Simulation - Accelerometer axis_x:

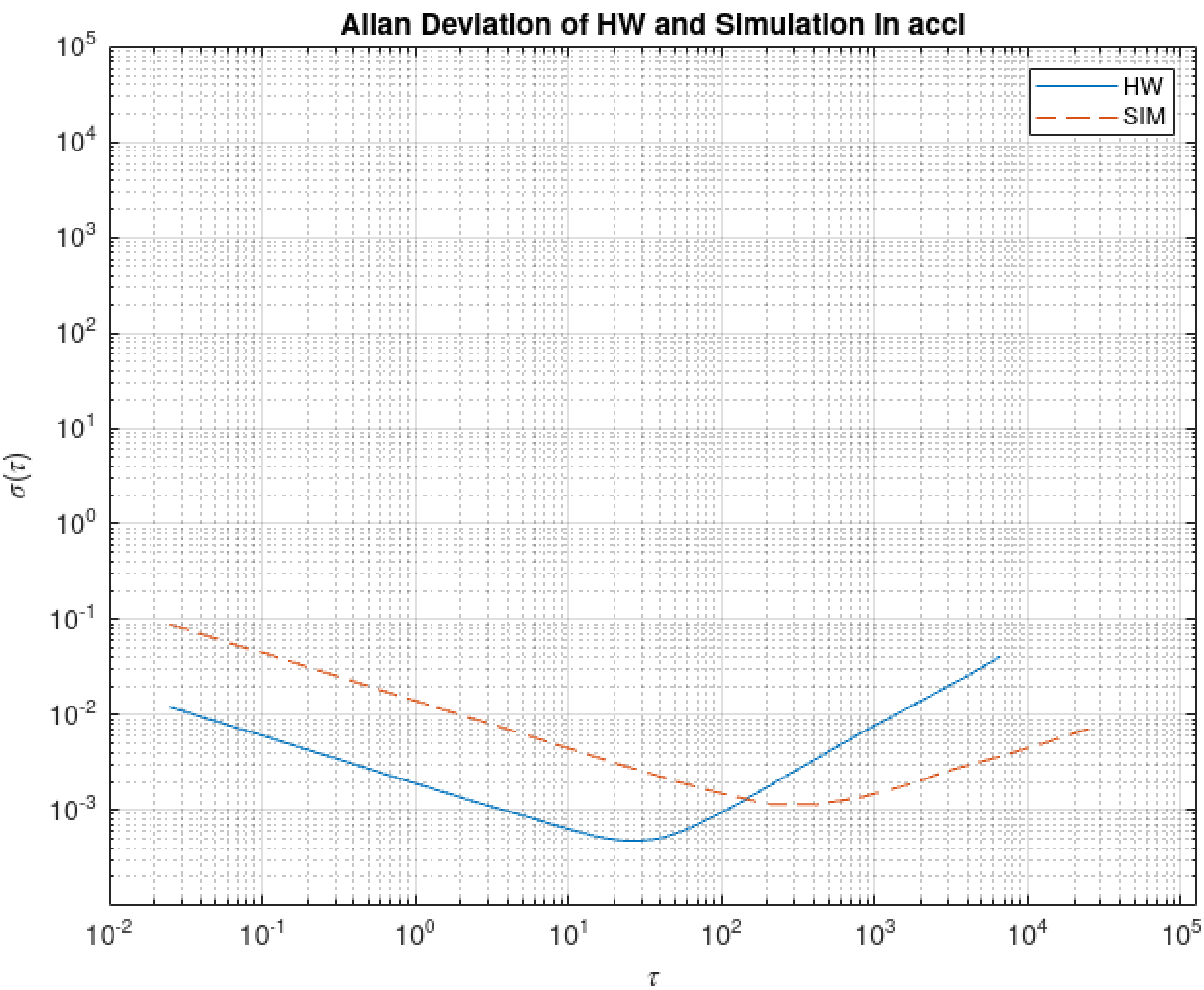

Fig-30 Time series plot of Pitch angle

The graph shows the allan variance of the Linear acceleration in x direction where

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=0.0019 m/s^2 / sqrt(Hz)

K=1.3845 e^-05 (m/s^2) * sqrt(Hz)

B=7.1508e^-04 m/s

Allan Deviation of HW and Simulation - Accelerometer axis_y:

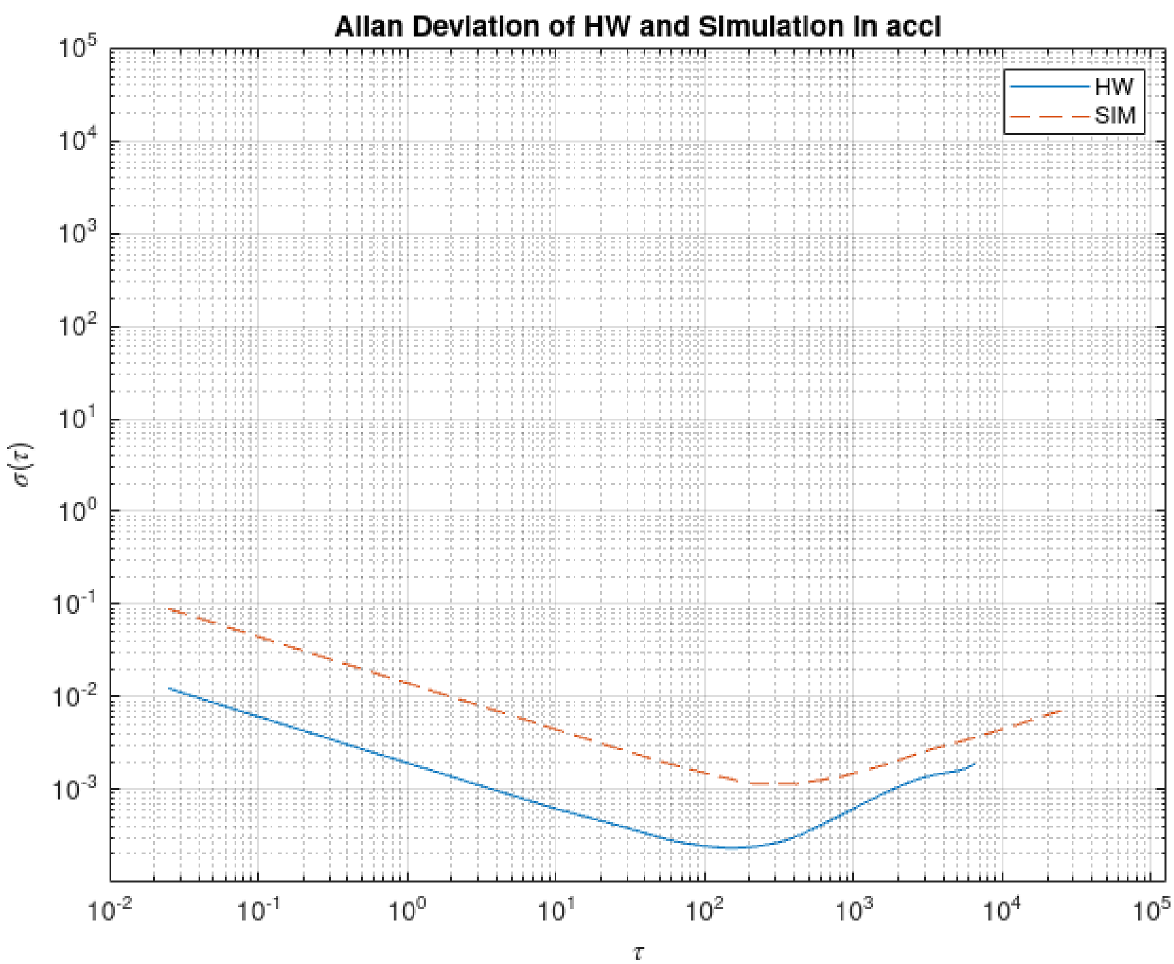

Fig-31 Time series plot of Pitch angle

The graph shows the allan variance of the Linear acceleration in y direction where

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=0.0019 m/s^2 / sqrt(Hz)

K=3.8687 e^-05 m/s^2 * sqrt(Hz)

B=3.5022e^-04 m/s

Allan Deviation of HW and Simulation - Accelerometer axis_z:

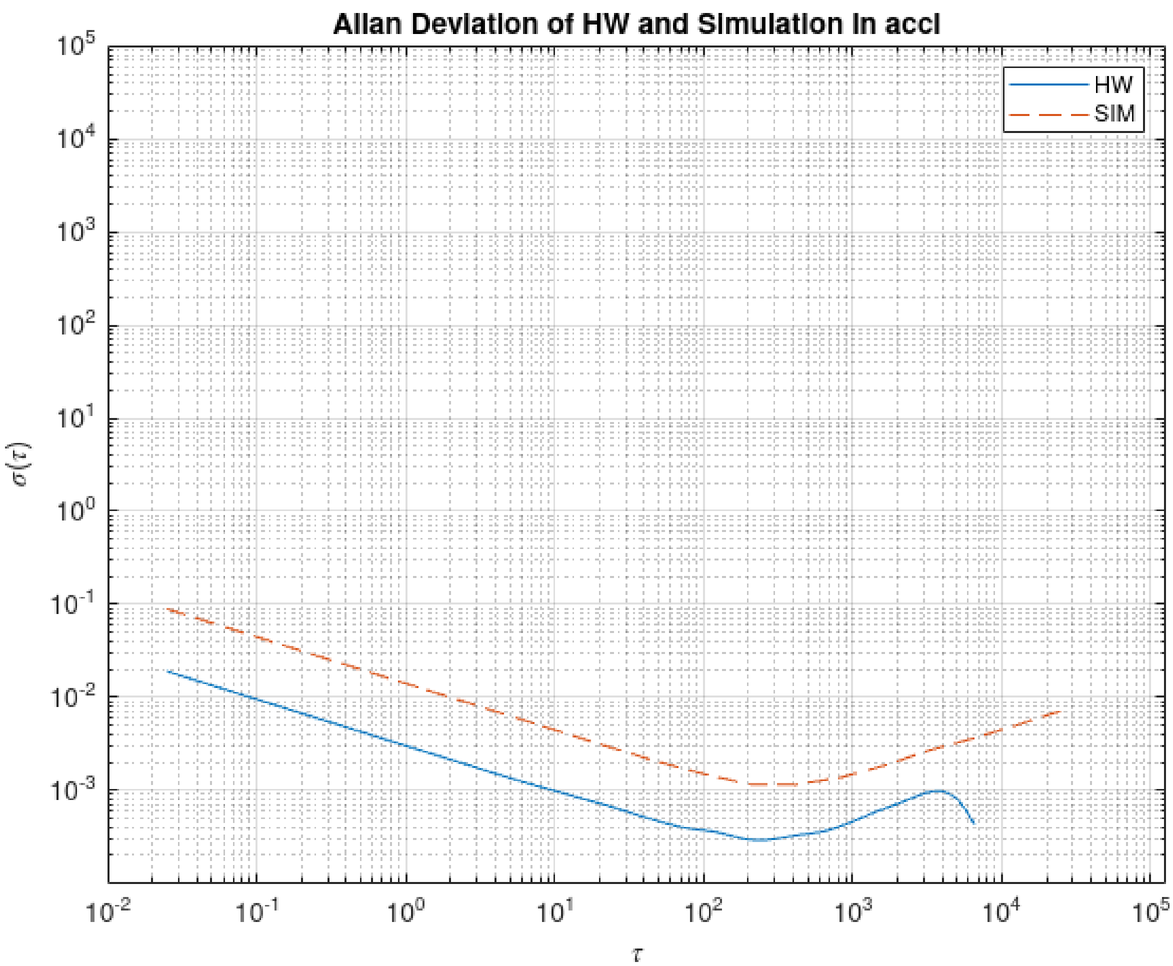

Fig-32 Allan deviation of HW and Simulation in acceleration

The graph shows the allan variance of the Linear acceleration in z direction where

Fs=40 hz, T0= 0.025sec and the calculated noise parameters are:

N=0.0030 m/s^2 / sqrt(Hz)

K=2.4478 e^-05 m/s^2 * sqrt(Hz)

B=0.0015e^-04 m/s

In order to compare the measured values with the standard values in the datasheet, we shall be considering the N at T(tau)=1 and compare it.

In the case of an accelerometer the units of N will be m/s^2 / sqrt(Hz).

N avg= 2.26e^-3 m/s^2 / sqrt(Hz)

N-std=0.14 mg/sqrt(Hz) = 1.37e-3 m/s^2 /sqrt(Hz),

Calculating the Average "N" i.e N avg = 2.26e^-3 m/s^2 / sqrt(Hz) and the N-std=0.14 mg/sqrt(Hz) = 1.37e-3 m/s^2 /sqrt(Hz)

So the measured value is very near to the standard value in the VN-100 data sheet.