Lab_3 Report

EECE 5554 Robotics Sensing and Navigation – Professor Singh

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1. Short description on driver and imu

In Lab_3, I receive the vectornav vn-100 imu for measuring the IMU data. The IMU will publish the yaw, pitch, roll and magnetic, acceleration and angular rates. We collect the data in $VNYMR format through the driver, converting the yaw, pitch and roll into quaternions. When finished collecting the individual rosbag data, we collected the stationary data in groups for 5 hours in the basement(just in the classroom). Then I write a Matlab file to do transfer the quaternions back to yaw, pitch and roll, then do the data analysis. For the stationary data that is collected in group, it is using the allan variance method. The data analysis is below.

7.2.3 Yaw, Pitch, Roll, Magnetic, Acceleration, and Angular Rates

Yaw, Pitch, Roll, Magnetic, Acceleration, and Angular Rates

Register ID :	27 **Async Header :** YMR **Access :** Read Only
Comment :	Attitude solution, magnetic, acceleration, and compensated angular rates.
Size (Bytes):	48
Example Response:	$VNRRG,27,+006.380,+000.023,-001.953,+1.0640,-0.2531,+3.0614,+00.005,+00.344,-09.758,-0.001222,-0.000450,-0.001218*4F

Offset	Name	Format	Unit	Description
0	Yaw	float	deg	Calculated attitude heading angle in degrees.
4	Pitch	float	deg	Calculated attitude pitch angle in degrees.
8	Roll	float	deg	Calculated attitude roll angle in degrees.
12	MagX	float	Gauss	Compensated magnetometer measurement in x-axis.
16	MagY	float	Gauss	Compensated magnetometer measurement in y-axis.
20	MagZ	float	Gauss	Compensated magnetometer measurement in z-axis.
24	AccelX	float	m/s^2	Compensated accelerometer measurement in x-axis.
28	AccelY	float	m/s^2	Compensated accelerometer measurement in y-axis.
32	AccelZ	float	m/s^2	Compensated accelerometer measurement in z-axis.
36	GyroX	float	rad/s	Compensated angular rate in x-axis.
40	GyroY	float	rad/s	Compensated angular rate in y-axis.
44	GyroZ	float	rad/s	Compensated angular rate in z-axis.

You can configure the device to output this register at a fixed rate using the Async Data Output Type Register in the System subsystem. Once configured the data in this register will be sent out with the $VNYMR header.

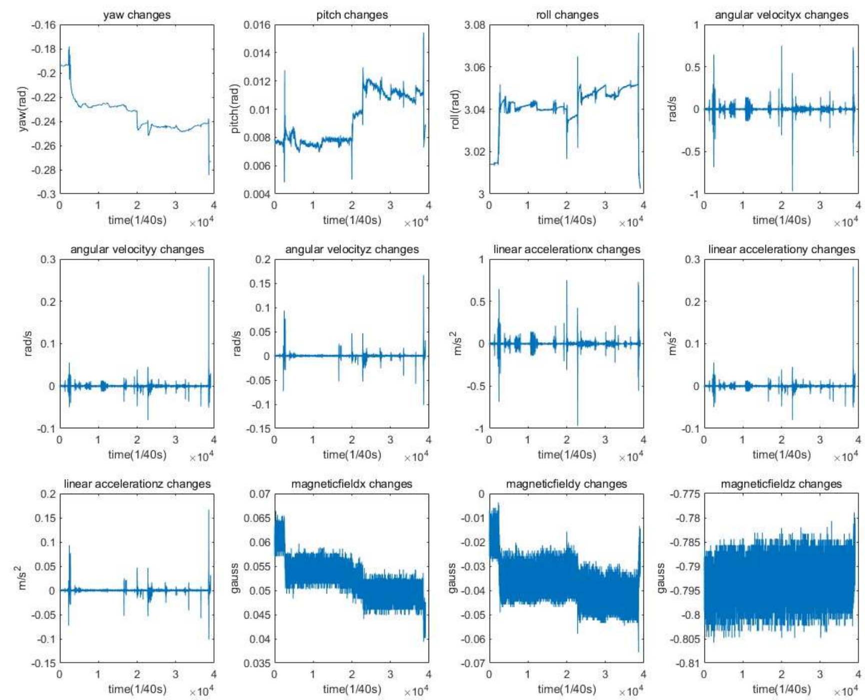
2. Data analysis

1.individual data

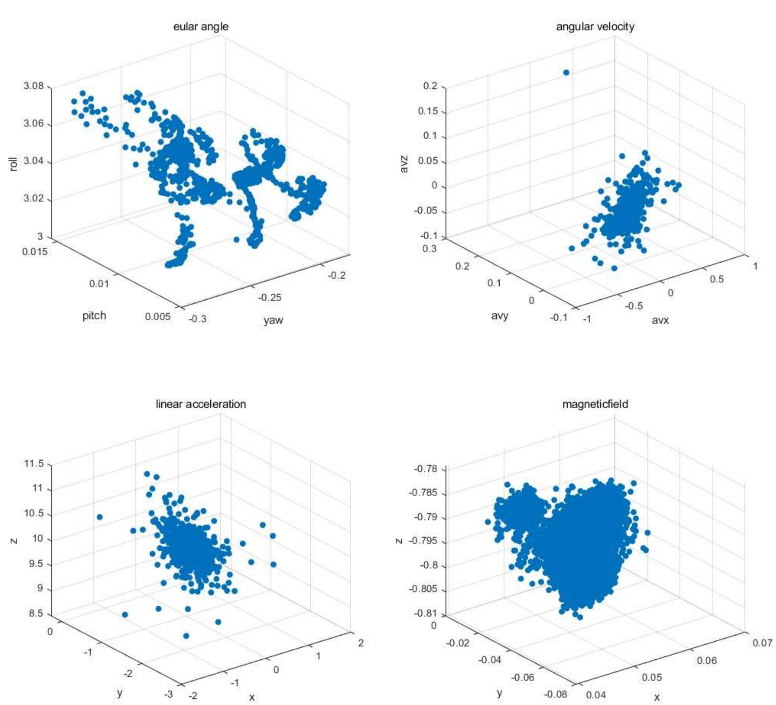
The data of the imu sensor output varies in time is plotted below. It shows that the 12 different outputs varies with the time(the frequency is 40Hz).

Description of the chart:

For yaw, pitch and roll, it is stable but changed for some time, it is because I put it on the bed and I sit on the other side of the bed for some time, so maybe that will be some changes in the chart. The same thing happens to the accel, gyro. One parameter change, other parameters also change at once. All in all, the stationary data is stable in total, although it changes sometimes, because it is very sensitive.



Here is the plot of the vectornav output in 3D:



3. Allan Variance with group data.
   Questions:
   1. what types of error sources and noises:
      There will be some random noises in the environment, the temperature also affect the output. The vibration is also another error source, but we can measure that in basement, to make the vibration of building smaller.
   2. where to collect the data
      The basement of Snell library, our classroom, on Saturday.
   3. how do we model that
      according to the matlab website offered in Lab3 instruction:

      The gyroscope measurement is modeled as:

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

      For each sample, calculate the output angle theta:

      $$\theta(t) = \int^t \Omega(t')dt'$$

      Next, calculate the Allan variance:

      $$\sigma^2(\tau) = \frac{1}{2\tau^2} < (\theta_{k+2m} - 2\theta_{k+m} + \theta_k)^2 >$$

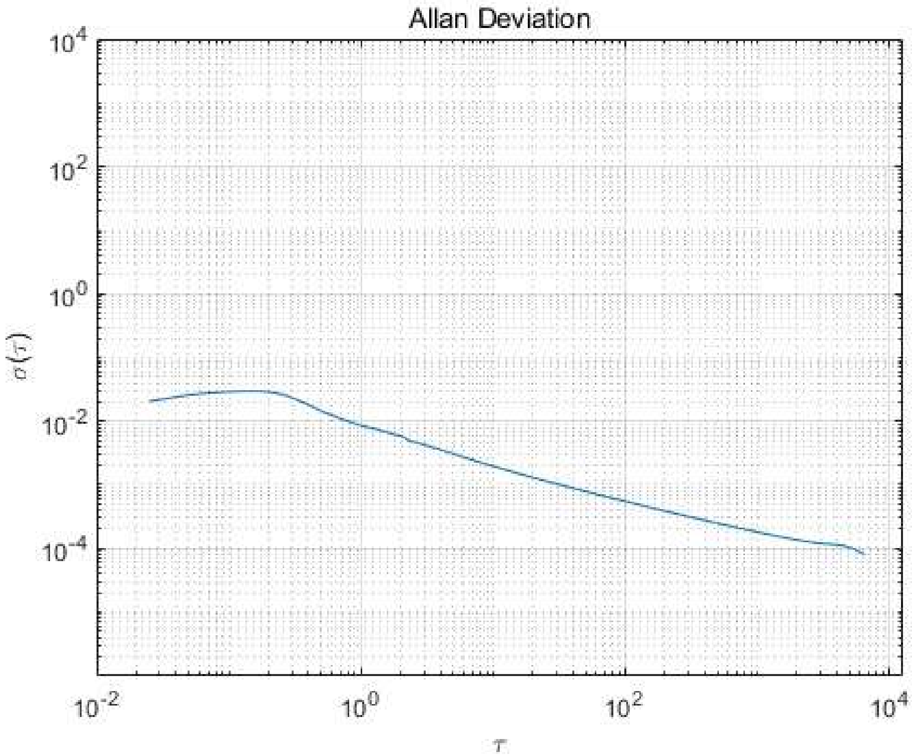
      where $\tau = m\tau_0$ and $<>$ is the ensemble average.

      The ensemble average can be expanded to:

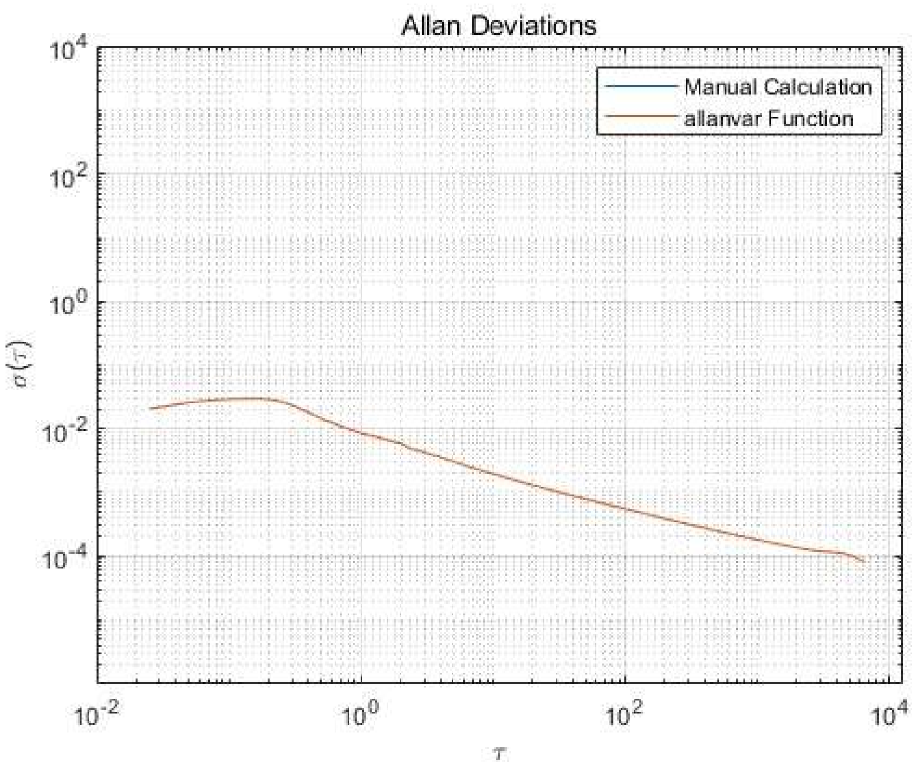
      $$\sigma^2(\tau) = \frac{1}{2\tau^2(L-2m)} \sum_{k=1}^{L-2m} (\theta_{k+2m} - 2\theta_{k+m} + \theta_k)^2$$

      Finally, the Allan deviation is used to determine the gyroscope noise parameters. $\sigma(t) = \sqrt{\sigma^2(t)}$

      We take gyro of Z axis as example:



The Allan variance can also be calculated using the allanvar function.



To obtain the noise parameters for the gyroscope, use the following relationship between the Allan variance and the two-sided power spectral density (PSD) of the noise parameters in the original data set Ω. The relationship is:

$$\sigma^2(\tau) = 4\int_0^\infty S_\Omega(f)\frac{sin^4(\pi f\tau)}{(\pi f\tau)^2}df$$

From the above equation, the Allan variance is proportional to the total noise power of the gyroscope when passed through a filter with a transfer function of $sin^4(x)/(x)^2$. This transfer function arises from the operations done to create and operate on the clusters.

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

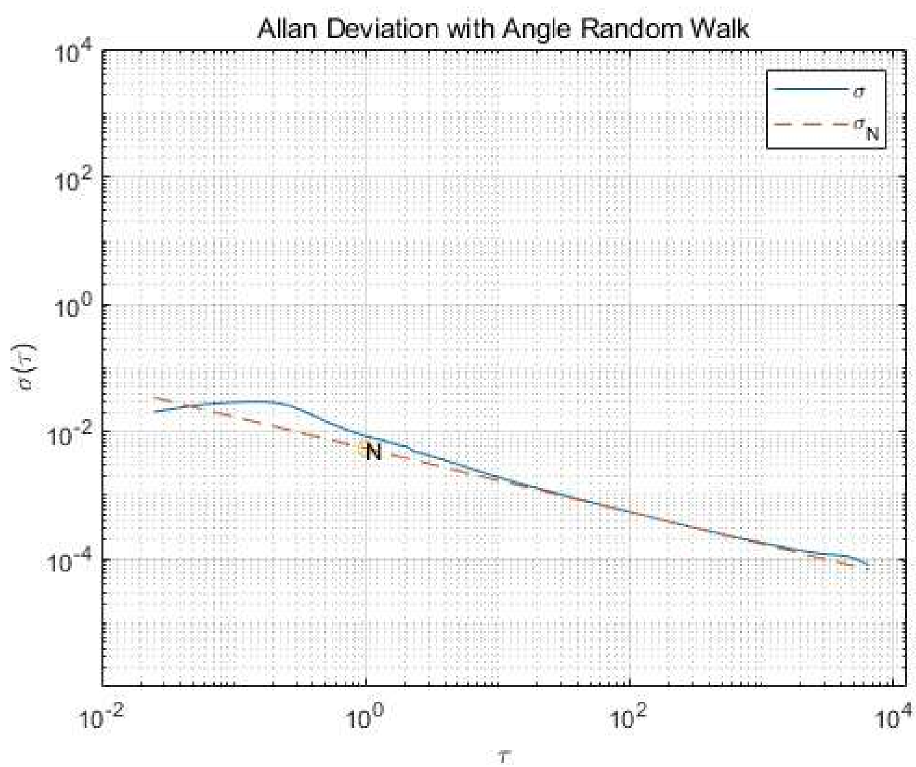
$$S_\Omega(f) = N^2$$

where

N = angle random walk coefficient

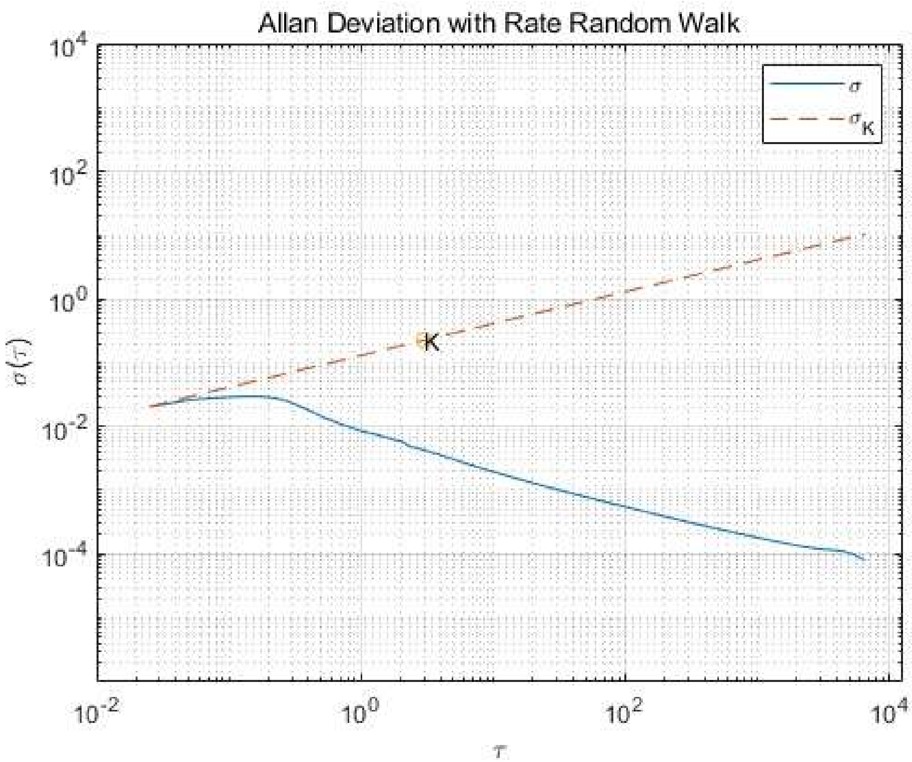
Substituting into the original PSD equation and performing integration yields:

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



The rate random walk is characterized by the red noise (Brownian noise) spectrum of the gyroscope output. The PSD is represented by:

> $$S_{\Omega}(f) = (\frac{K}{2\pi})^2 \frac{1}{f^2}$$
>
> where
>
> K = rate random walk coefficient
>
> Substituting into the original PSD equation and performing integration yields:
>
> $$\sigma^2(\tau) = \frac{K^2 \tau}{3}$$



Bias Instability

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

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

where

B = bias instability coefficient

f_0 = cut-off frequency

Substituting into the original PSD equation and performing integration yields:

$$\sigma^2(\tau) = \frac{2B^2}{\pi}[\ln 2 + - \frac{sin^3x}{2x^2}(sinx + 4xcosx) + Ci(2x) - Ci(4x)]$$

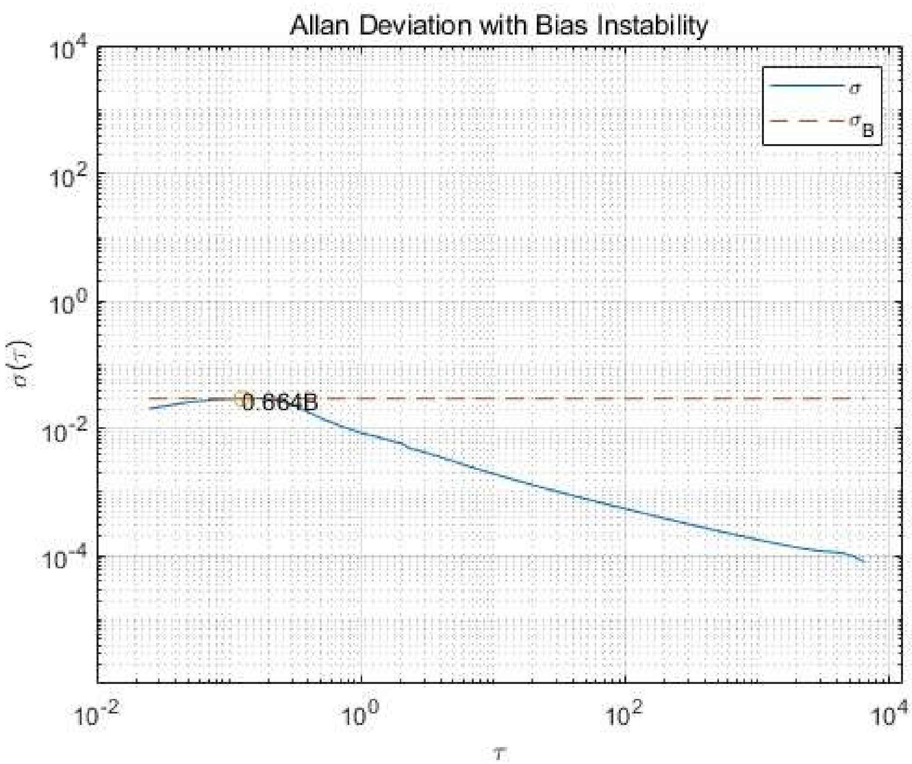
where

$x = \pi f_0 \tau$

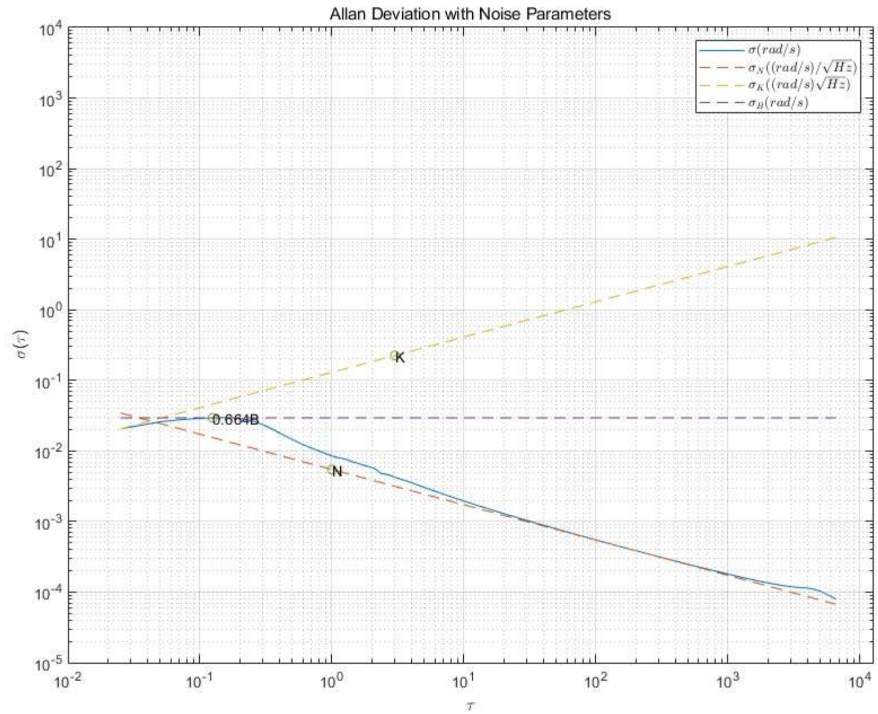
Ci = cosine-integral function

When τ is much longer than the inverse of the cutoff frequency, the PSD equation is:

$$\sigma^2(\tau) = \frac{2B^2}{\pi}\ln 2$$



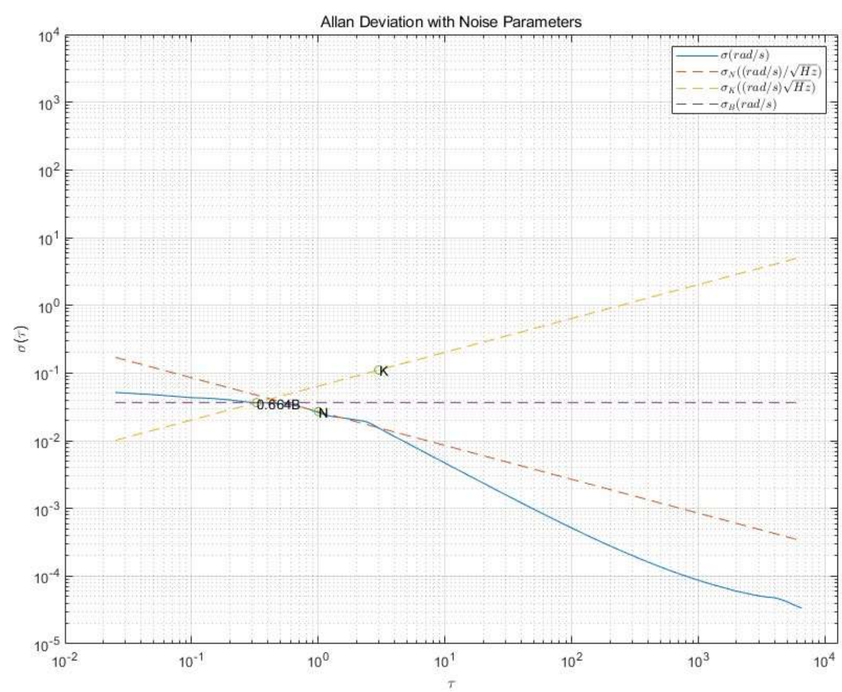
So final outcome is :



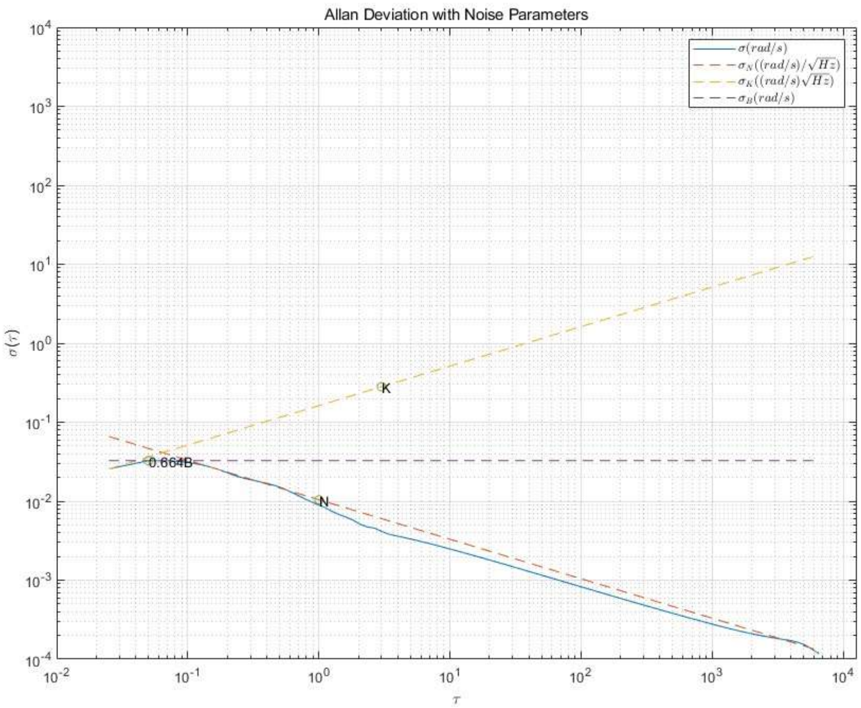
4. connection with VN100

   I analyze the gyro data in x,y,z, and plotted in the series of x,y,z below:

   X:

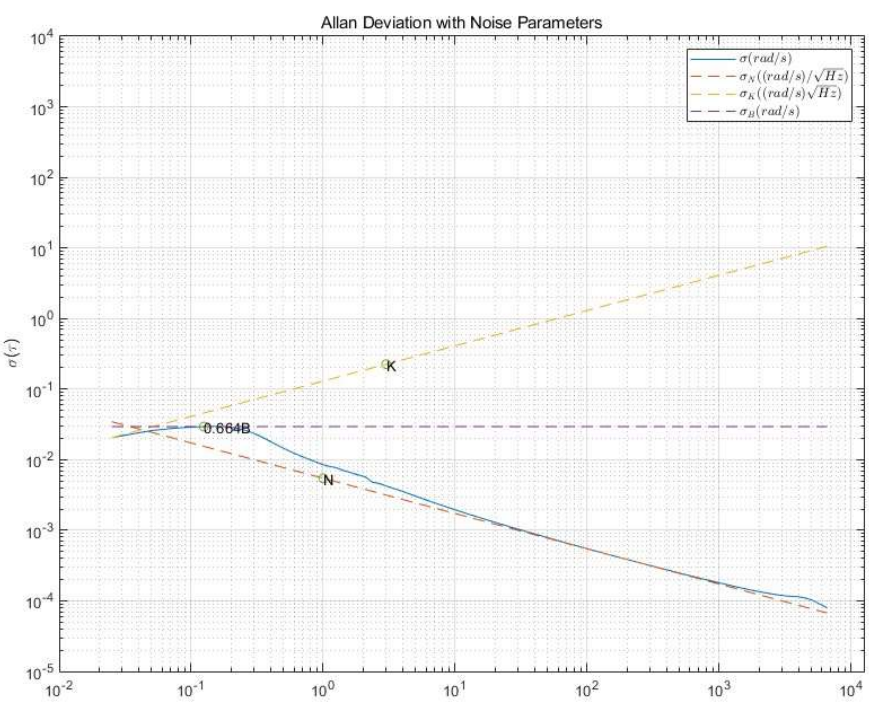


Y:



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

Z:



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

We find the outcome we can find that x,y,z have the same point at 0.644B, we can also find that there exists the random noise and angular random noise, which can be obtain in datasheet of VN-100.