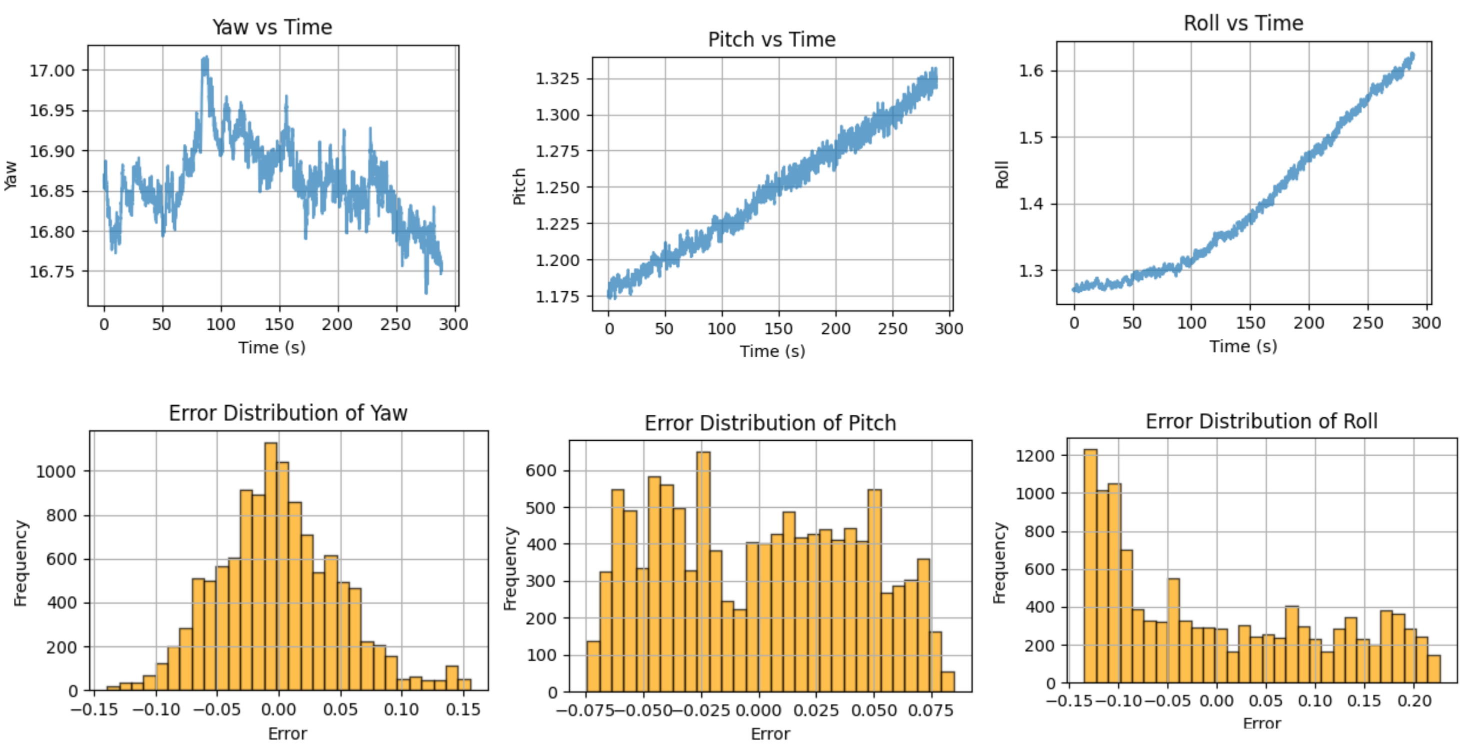
Vector Nav VN-100 IMU Data Analyzation

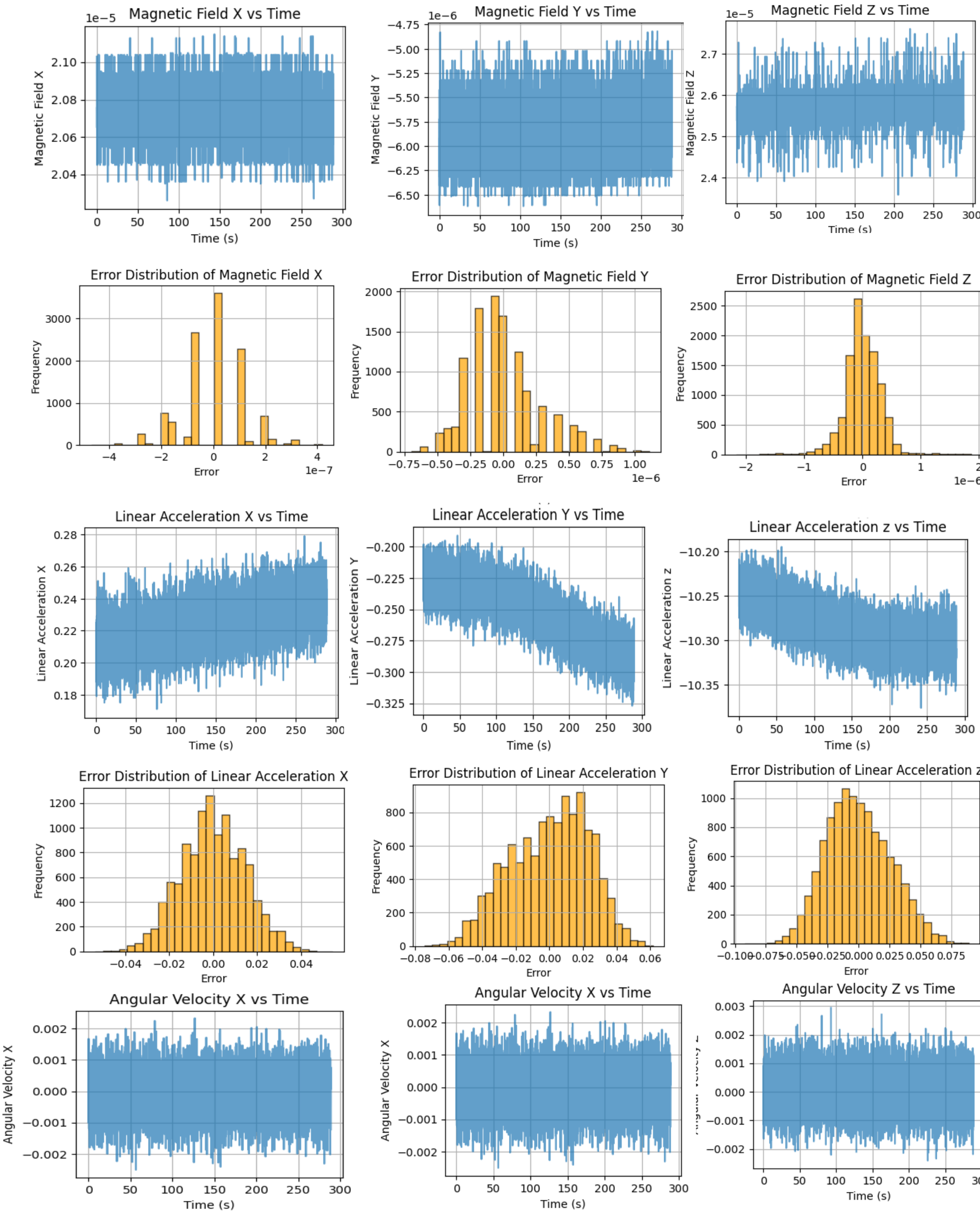
Data Collection and Setup

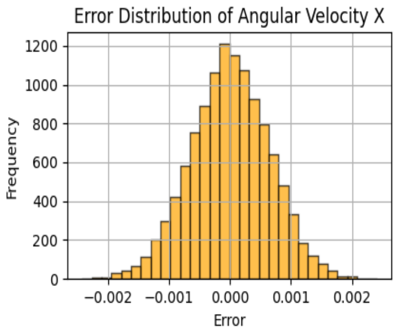
A time series dataset was collected using a VectorNav VN-100 Inertial Measurement Unit (IMU) for two duration of 15 minutes and 5 hours. The data collection was performed with the IMU in a stationary position in a basement of my apartment chosen to minimize external disturbances. Care was taken to position the IMU away from computers, moving objects, and other potential sources of interference to ensure the highest quality of data.

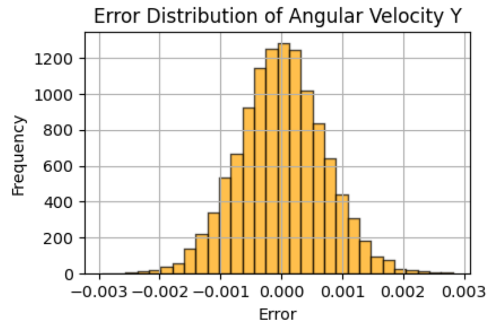
15 Mintues Stationary Data Analysis

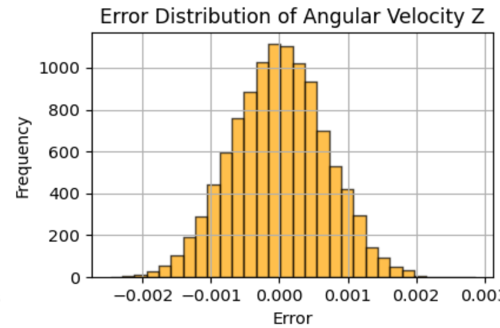
Time Series Plots And Error Distribution




Magnetic Field X vs Time
Magnetic Field X
Time (s)
Magnetic Field Y vs Time
Magnetic Field Y
Time (s)
Magnetic Field Z vs Time
Magnetic Field Z
Time (s)
Error Distribution of Magnetic Field X
Frequency
Error
Error Distribution of Magnetic Field Y
Frequency
Error
Error Distribution of Magnetic Field Z
Frequency
Error
Linear Acceleration X vs Time
Linear Acceleration X
Time (s)
Linear Acceleration Y vs Time
Linear Acceleration Y
Time (s)
Linear Acceleration z vs Time
Linear Acceleration z
Time (s)
Error Distribution of Linear Acceleration X
Frequency
Error
Error Distribution of Linear Acceleration Y
Frequency
Error
Error Distribution of Linear Acceleration z
Frequency
Error
Angular Velocity X vs Time
Angular Velocity X
Time (s)
Angular Velocity X vs Time
Angular Velocity X
Time (s)
Angular Velocity Z vs Time
Time (s)







Noise Characteristics Analysis

The mean and standard deviation were calculated for each measurement:

Parameter	Mean	Standard Deviation
Yaw	16.8615	0.0494
Pitch	1.2474	0.0424
Roll	1.4011	0.111
Magnetic Field X	0.2073	0.0012
Magnetic Field Y	-0.0593	0.0028
Magnetic Field Z	0.2575	0.0031
Linear Acceleration X	0.2247	0.0147
Linear Acceleration Y	-0.2525	0.0234
Linear Acceleration Z	-10.284	0.0259
Angular Velocity X	-0.0001	0.0006
Angular Velocity Y	0	0.0007
Angular Velocity Z	0.0001	0.0007

Error Distribution Analysis

The noise characteristics of the IMU measurements appear to follow a Gaussian (normal) distribution. This is evidenced by:

1. The symmetrical fluctuations around the mean values in the time series plots.
2. The relatively small standard deviations compared to the mean values, indicating that most of the data points cluster around the mean.
3. The consistent, random-looking variations in the measurements, which is typical of white Gaussian noise in sensor readings.

Observations

1. **Orientation**: The yaw readings indicate a consistent orientation, with minimal fluctuations, suggesting stable positioning. The pitch angle reflects a slight tilt, stable over time with minor

variations. The roll measurement shows some instability, indicated by a higher standard deviation compared to yaw and pitch, suggesting potential sensitivity to slight disturbances.

2. **Linear Acceleration**:The Z-axis acceleration closely approximates Earth's gravity (-9.81 m/s^2), with the slight difference likely due to minor misalignment or calibration offset. X and Y accelerations are close to zero but show some offset, possibly due to a slight tilt in the IMU's placement or might be due to taping.

3. **Angular Velocity**: All axes show mean values very close to zero, consistent with a stationary setup. The small standard deviations indicate high stability in these measurements.

4. **Magnetic Field**:The magnetometer readings show very stable values with extremely low standard deviations, indicating minimal external magnetic interference during the data collection.

Overall, the data indicates stable readings from the IMU sensors when stationary, with minor fluctuations across yaw, pitch, and roll angles. The magnetic field and linear acceleration readings also suggest reliable performance, although the roll measurement shows slightly more instability than the other angles.

5 Hours Data Analysis

Allan Deviation Analysis

The Allan deviation plots provide insights into the noise characteristics of the IMU sensors. These plots help identify different types of noise present in the data:

Key Noise Characteristics

1. **Noise Density (D):** Represents the white noise level in the sensor output.
2. **Angle Random Walk (N):** Indicates random fluctuations in angle measurements over time.
3. **Rate Random Walk (K):** Describes random fluctuations in rate measurements.
4. **Bias Instability (B):** Represents the long-term stability of the sensor bias.

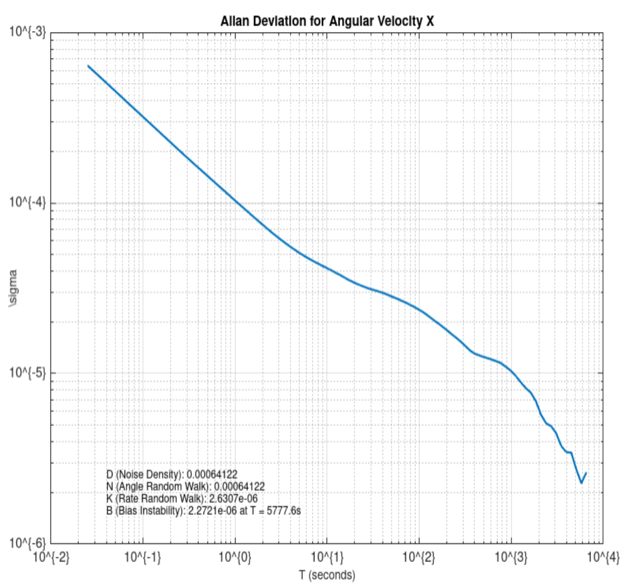


Fig -Allan Deviation - Angular Velocity X-axis

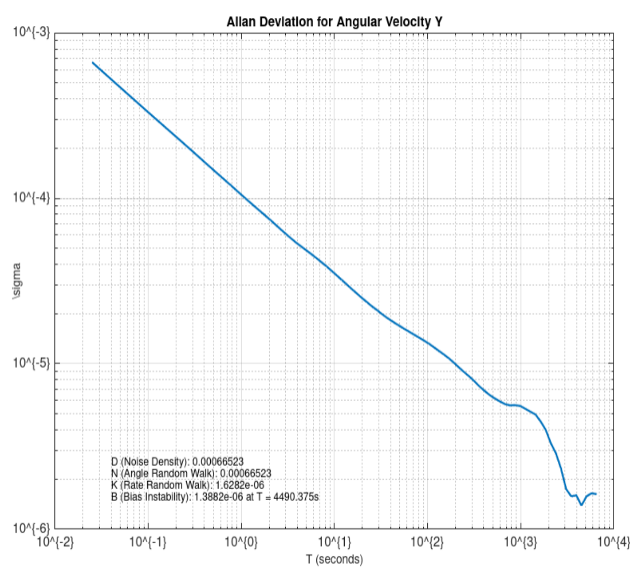


Fig -Allan Deviation - Angular Velocity Y-axis

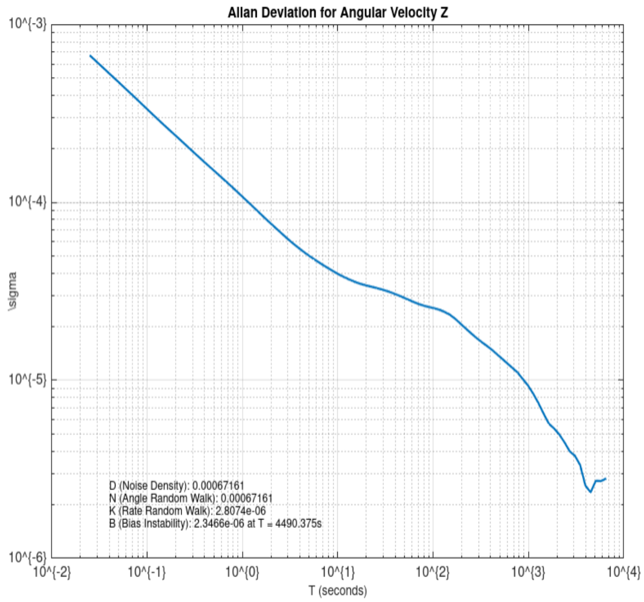


Fig -Allan Deviation - Angular Velocity Z-axis

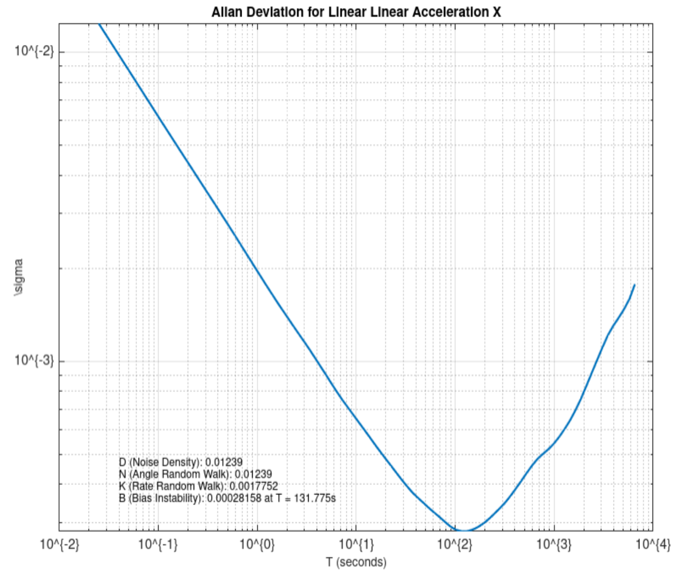


Fig -Allan Deviation - Linear Acceleration X-axis

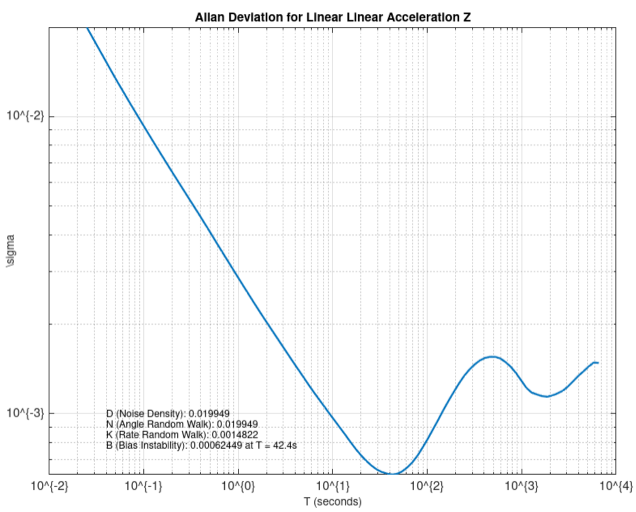


Fig -Allan Deviation - Linear Acceleration Y-axis

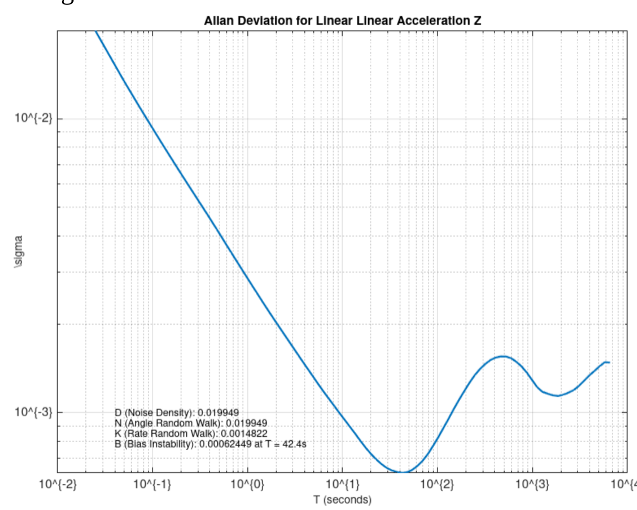


Fig -Allan Deviation - Linear Acceleration Z-axis

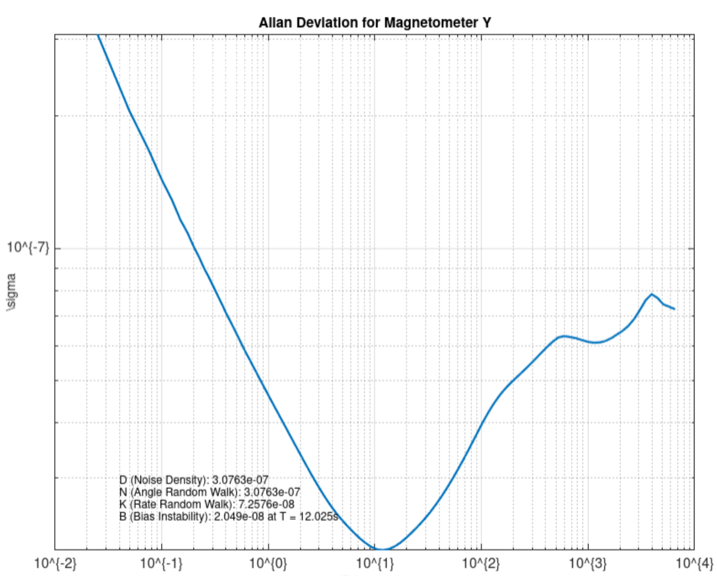


Fig -Allan Deviation – Magnetometer X-axis

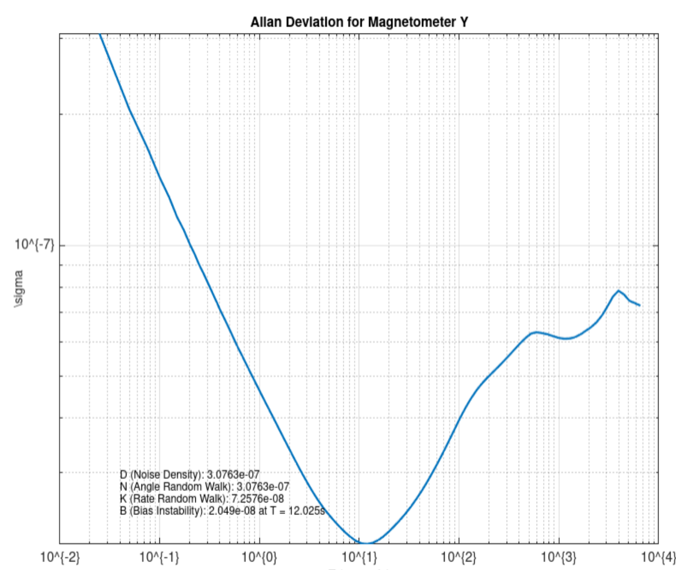


Fig Allan Deviation – Magnetometer Y-axis

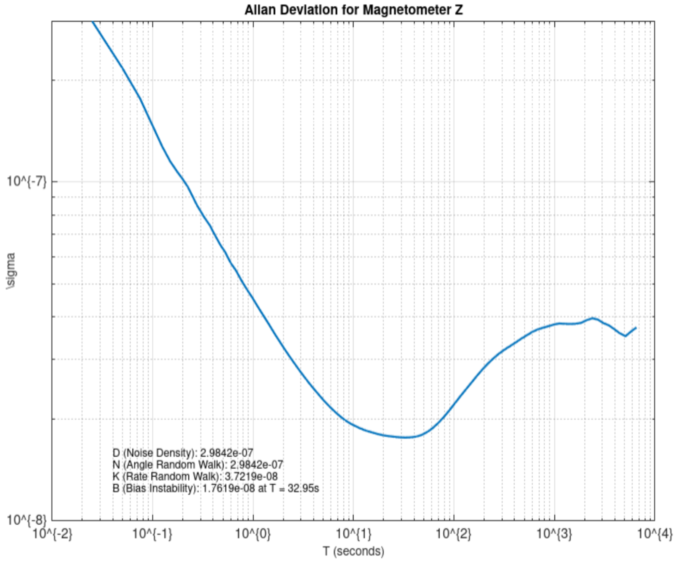


Fig -Allan Deviation – Magnetometer Z-axis

	Angle Random Walk (N)	Rate Random Walk (K)	Bias Instability (B)
Linear Acceleration - X	0.01239	0.0017752	0.00028158
Linear Acceleration - Y	0.012379	0.0051888	0.00037282
Linear Acceleration - Z	0.019949	0.0014822	0.000624499
Angular Velocity – X	0.00064122	2.63E-06	2.27E-06
Angular Velocity - Y	0.00066523	1.63E-06	1.39E-06
Angular Velocity – Z	0.00067161	2.81E-06	2.35E-06
Magnetic Field - X	1.25E-07	1.81E-08	1.03E-08
Magnetic Field – Y	3.08E-07	7.26E-08	2.05E-08
Magnetic Field – Z	2.98E-07	3.72E-08	1.76E-08

Observations from Allan Deviation Analysis

The Allan deviation analysis conducted on the IMU data over a 5-hour duration provides insights into the stability and performance of various signals measured, including linear acceleration, angular velocity, and magnetic field. The key findings are as follows:

1. Linear Acceleration:

- **X-axis**: The Angle Random Walk (N) is 0.01239, the Rate Random Walk (K) is 0.0017752, and Bias Instability (B) is 0.00028158. This indicates a moderate level of noise and bias stability, suggesting that the linear acceleration in the X direction is relatively stable with minor fluctuations.

- **Y-axis**: Similar to the X-axis, the values are N = 0.012379, K = 0.0051888, and B = 0.00037282. The slightly higher rate random walk suggests that the linear acceleration readings may experience a bit more instability over time compared to the X-axis.

- Z-axis: The readings show higher values for N (0.019949) and B (0.000624499), suggesting that the linear acceleration in the Z direction has more noise and bias instability compared to the other two axes. This could be due to gravitational effects or sensor calibration issues.

2. Angular Velocity:

- **X-axis**: The Angle Random Walk (N) is low (0.00064122), indicating minimal random drift. The Rate Random Walk (K) (2.63E-06) and Bias Instability (B) (2.27E-06) are also very low, suggesting that the angular velocity readings are stable and reliable over the measurement period.

- Y-axis: The N (0.00066523), K (1.63E-06), and B (1.39E-06) values are consistent with the X-axis, indicating that angular velocity measurements in the Y direction are equally stable and consistent.

- **Z-axis**: The readings of N (0.00067161), K (2.81E-06), and B (2.35E-06) indicate stability similar to the X and Y axes, confirming that angular velocity measurements are reliable across all axes.

3. Magnetic Field:

- X-axis: The values for N (1.25E-07), K (1.81E-08), and B (1.03E-08) are quite low, suggesting that the magnetic field readings in the X direction are stable with negligible noise and bias.

- Y-axis: The magnetic field readings in the Y direction show slightly higher noise density (N = 3.08E-07) compared to the X-axis, which may indicate some environmental influence or sensor sensitivity.

- **Z-axis**: The values (N = 2.98E-07, K = 3.72E-08, B = 1.76E-08) suggest similar stability as the other axes, but the slightly higher noise density may indicate variations in the magnetic field readings.

Overall, The Allan deviation data indicates that the IMU sensors performed well during the 5-hour measurement period, showing stable readings and low noise across most measurements. However, linear acceleration in the Z direction exhibited more fluctuations, likely due to gravitational influences or sensor calibration, which requires further investigation. Angular velocity and magnetic field measurements remained stable across all axes, confirming the reliability of the data. Overall, these results align with the VN100 datasheet specifications, validating the expected performance of the sensors under stationary conditions.

Error Sources and Modeling

1. **White Gaussian Noise:** Present in all sensors, modeled as a zero-mean Gaussian distribution affecting short-term measurements.
2. **Bias Instability:** Modeled as a slowly varying random process, impacting long-term accuracy.
3. **Rate Random Walk:** Modeled as an integrated white noise process, affecting rate measurements over time.

Conclusion

The analysis of the 5-hour stationary data using Allan deviation highlights key noise characteristics inherent in IMU sensors. Understanding these helps in modeling and compensating for errors in applications requiring precise motion tracking and navigation. The results align well with the specifications provided by the VN100 datasheet, confirming the expected performance of the sensors under stationary conditions. Comapring with VN100 Datasheet: Overall,results show **lower noise levels** than those typically stated in the VN100 datasheet, especially for angular velocity and acceleration. This suggests that your IMU was operating under optimal conditions, with very stable and clean sensor data during the 5-hour stationary test. However, the small fluctuations in yaw and linear acceleration in the Z direction could be related to environmental factors or calibration issues, but the overall performance aligns well with the expected performance of the VN100.