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MECH 875 - Mechanical Vibrations

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**Vibration Measurements on Steering Wheel Maneuvering**

**Abstract**

The objective of this report is to offer a cost-effective solution for measuring steering wheel angles with noise due to vibrations in a vehicle. Traditionally, on car-crash testing there is not recordings of the steering wheel angles due to sensors getting damaged. A solution proposed to this problem is to use a wireless measurement device that broadcasts steering wheel data during vehicle testing. The resulting data is then filtered and analyzed to separate the noise measurements due to vibrations and the steering wheel data. From the results, the effectiveness of this method is evaluated, and future car-crash applications are discussed.

**Introduction**

When measuring accelerations or angular rates in vehicles, vibrations from the road contribute noise to the measurements. During car-crash testing, vibrations due to impact become an obstruction to interpret data and often require heavy duty measurement devices. Furthermore, these devices need to be attached to a section that has the least damage to avoid malfunctions. For this reason, obtaining steering wheel angles becomes a task almost impossible during car-crash analysis. In this project, a disposable sensor is used to investigate the effectiveness on recording steering wheel angles during vehicle maneuvering. The outcome of the project would be to determine feasibility of this sensor in car-crash testing analysis. This will be determined by identifying steering wheel angles during cornering.

The first section offers a Background Study on the subject. Secondly, an instrumentation section offers details of the specifications in the sensor along with the experimental setup. Third is the results and analysis that are found from the experiment. This analysis includes signal processing and response characterization of the system. Finally, a summary of conclusions and recommendations is offered for future research.

**Background**

Signal Processing is used to filter out noise or unwanted information that sensors record. This noise can be present due to the electric components within it, and from exterior sources as well. These exterior sources can include many parameters depending on what is being measured. On the case for this experiment, the noise source will come primarily from road vibrations. For this reason, it is necessary to find a way to distinguish in between noise data and relevant sensor measurements. To illustrate this concept, a sample time domain signal is shown in Figure 1. This graph shows a “clean” sine signal that has no disturbances to it.

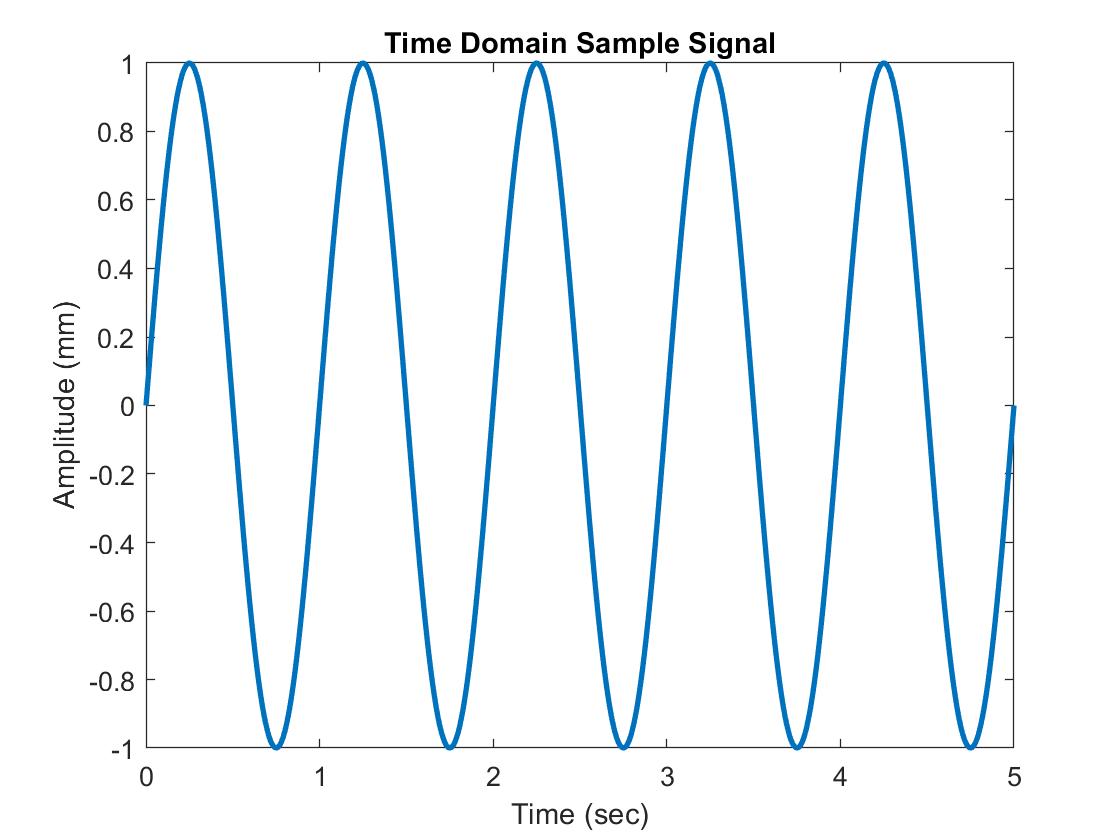


Figure 1.- Time Domain Sample Signal

The next step is to perform a Fast Fourier Transform (FFT) to convert the time domain signal into a frequency domain one which is illustrated in Figure 2. This Figure shows only one peak which denotes the frequency content of the time domain signal. This is expected because the time signal has no other disturbances on it.

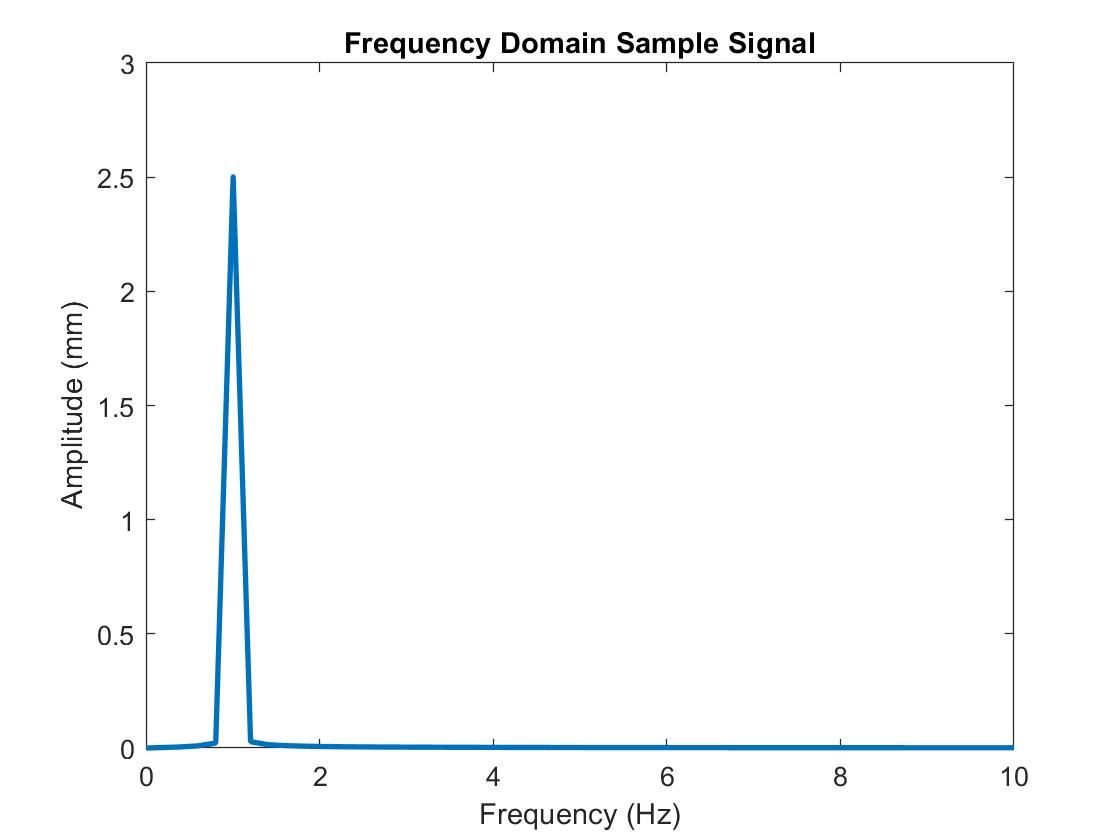


Figure 2.- Frequency Domain Sample Signal

When a time signal has noise, it can be denoted to be the superposition of many sine waves together that at first glance do not seem meaningful to interpret data. In this case, an FFT would show all the frequency content of each individual wave that composes the noisy signal. Through this, it will be possible to remove all unnecessary data and obtain only relevant information about the time signal. An example is shown in Figure 3 that illustrates the same time signal with noisy along with its frequency content.

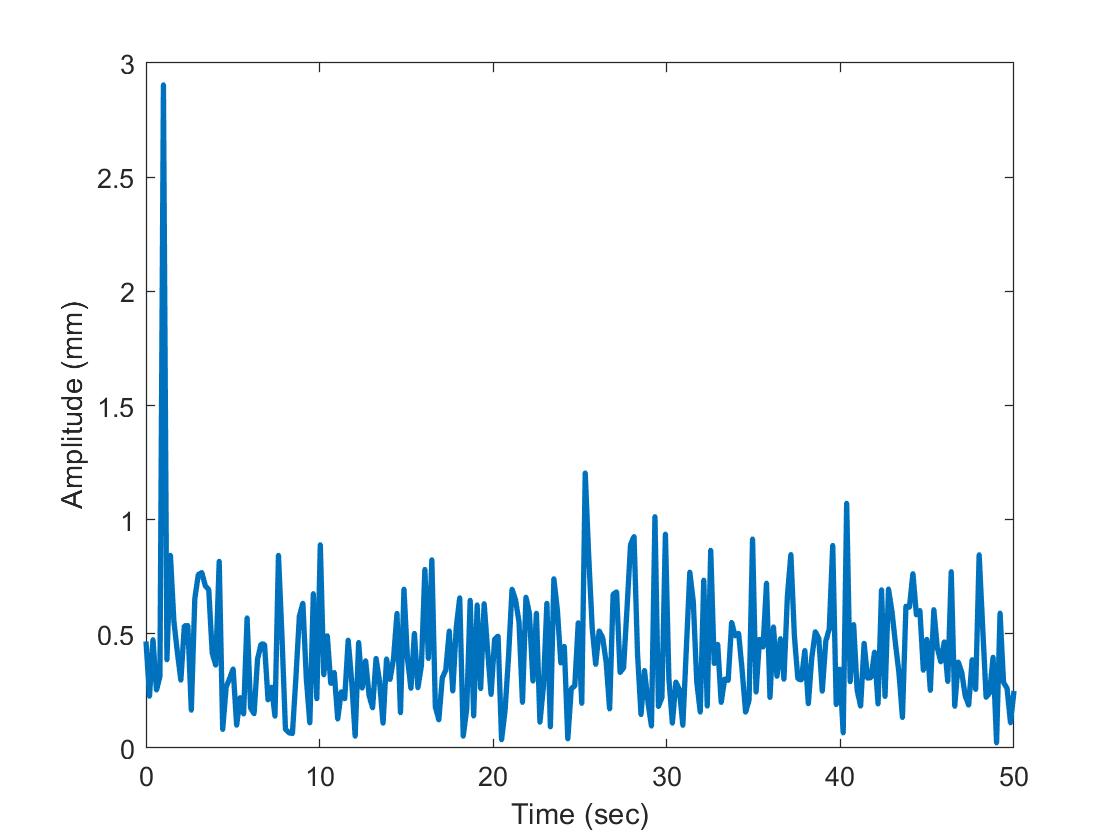
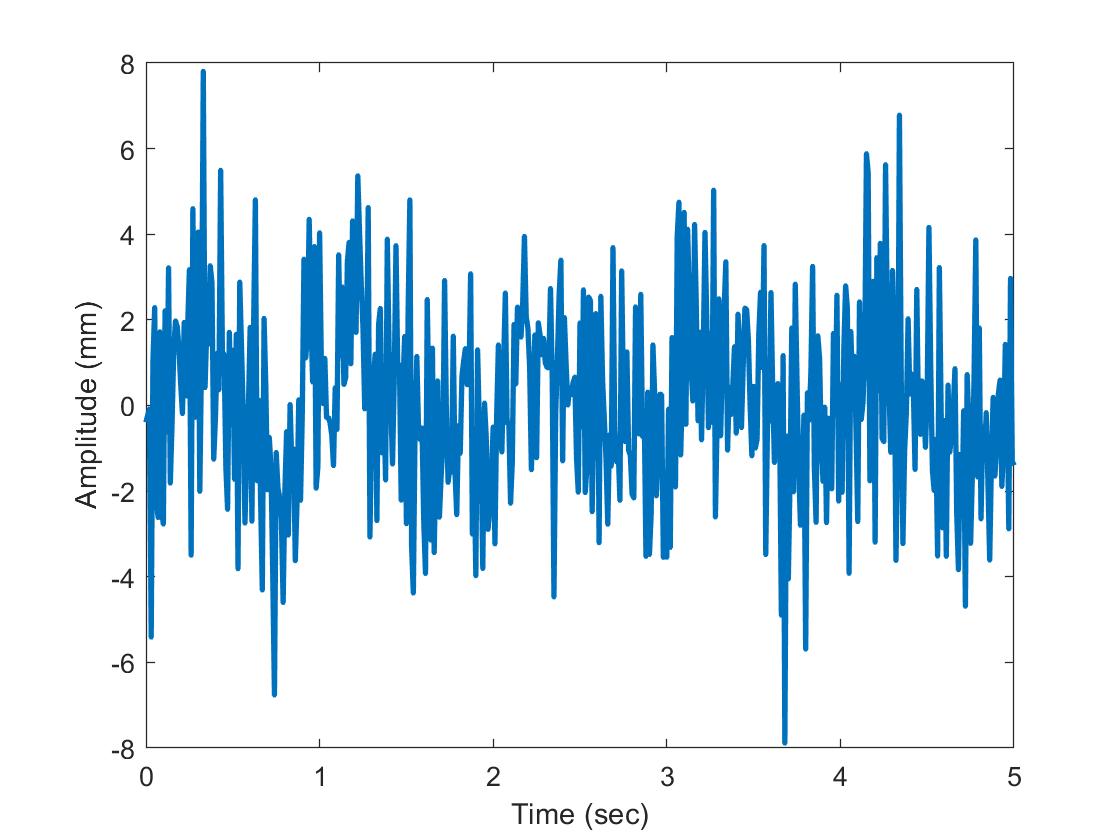


Figure 3.- Noisy Time Domain Sample Signal (left) and Noisy Frequency Sample Signal (right)

In Figure 3 it is noticeable that the frequency content still shows the same peak as the clean frequency signal. This provides us with frequency information that it is easier to find than what the time signal shows. The same procedure will be used to analyze the steering wheel behavior of a vehicle under road vibrations.

**Instrumentation and Testing Setup**

To measure the steering wheel angles, a Witmotion BWT61CL Sensor is used. This sensor contains a JY61 Gyroscope, a 150mAh lithium battery, and Bluetooth Transmitter. The sensor specifications are summarized on Table 1, and a sample image of the sensor is presented on Figure 1.

Table 1. Witmotion BWT61CL Sensor Specifications

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Quantity | Parameter | Quantity |
| Voltage | 3.3 V – 5V | Current | < 40mA |
| Accelerated Speed Range | 16g’s | Angular Speed Range | 2000/s |
| Angle Range | 180 | Measurement Stability | 0.05 |
| Output Frequency | 100 Hz | Baud Rate | 115200 pulse/s |
| Transmission Distance | <10 m | Date Interface | Serial TTL Level |

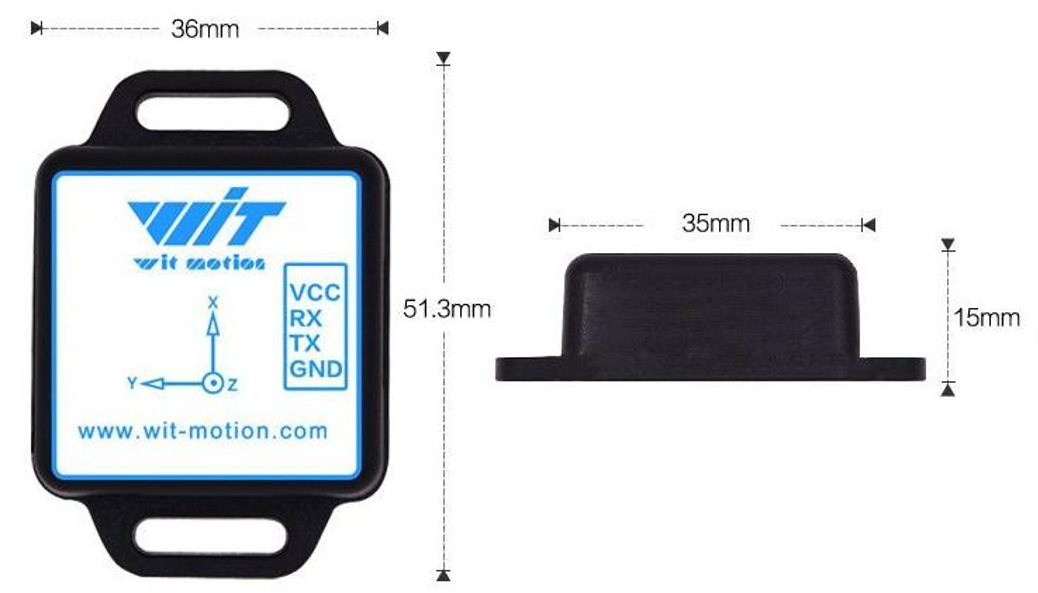


Figure 1 – Witmotion BWT61CL Sample Image with Dimensions

This sensor communicates with an Android device where the information is sent and stored. To perform this experiment, a Nissan Altima 2014 as shown in Figure 2, is used. The sensor is zeroed at the center of the steering wheel, and then attached with high tension bands to allow for higher displacement transmissibility in between the sensor and the steering wheel as shown in Figure 2.



Figure 2 – Test Vehicle and Sensor Positioning in Steering Wheel.

The test took place in 2 different scenarios which consisted of a typical asphalt street and one with a rough dirt terrain and uneven surfaces as shown in Figure 3. Each scenario was repeated twice to provide with repeatability giving a total of four different tests. The driving conditions consisted of first straight up driving followed by a right turning, driving straight up again and perform a left turn before stopping.



Figure 3 – Different Testing Scenarios: Asphalt Road (Left), Dirt Road (Right)

Maybe ==== Test the Longest Range of Connectivity of the Sensor

**Results and Analysis**

The results provided from the experiment are summarized in Figure 3 and some main recordings are shown in Table 2.



Figure 4 –Acceleration Readings for both Flat and Rough Roads





Figure 5 –Steering Readings for both Flat and Rough Roads



**Conclusion**

From the results, it can be concluded….