# Study of the Vibration Environment Observed during Road Transportation of the Satellite

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*Abstract*— Mechanical vibration and shock cause detrimental effects on the sophisticated space related hardware's i.e. electronic packages, antenna, payloads, to avoid these unwanted vibration and shock inputs during the transportation of payloads between one facility to another or transportation of fully assembled payloads from one centre to another centre. That's why it is required to measure vibration to study & understand the vibration forces acting on payload, currently there are just few methods to measure it with limited settings, we are choosing this project "STUDY OF THE VIBRATION ENVIRONMENT OBSERVED DURING ROAD TRANSPORTATION OF THE SATELLITE" by creating a methodology in LABVIEW system developing software which will help to acquire the vibration & shock data in time & frequency domain with custom features to understand the "g" forces acting on the payload.

***Keywords:*** Road Transportation, Satellite

## I. INTRODUCTION

### *A. Vibration*

When body particles are displaced by the application of external force, the internal force in the form of elastic energy are present in the body, tries to bring the body to its original position, at equilibrium position, the whole elastic energy is converted into kinetic energy and the body continues to move in the opposite direction of it, The whole of kinetic energy is again converted into elastic or strain energy due to which the body again returns to its equilibrium position.

### *B. Vibration Occurs During Transportation*

Oscillations are usually classified in many ways and in the case of transportation one needs to define whether one is referring to a fixed or variable frequency vibration, whether it is a single or multiple frequencies, or whether it is periodic or random since the body that experiences the vibrations is subjected to oscillations across the entirely or part of the body. As a result, these oscillations experienced by a body into vibration forces; the vibration response of something that is not predictable is known as random vibration and it is measured in the form of power spectral density or PSD.

### *C. Power Spectrum Density*

Given that random vibrations are neither predictable nor do they maintain a constant cadence, they can be characterized by the amount of energy that they add for each frequency in addition, those vibrations are particular to a specific transport – it is like the vibration DNA of that transport. Therefore, since they are transport-specific, they are unrelated to the material being transported. For this reason, they are defined as a density so that they are applicable regardless of the amount of material being transported.

### *D. Methods to Measure the Vibration*

#### *1) Shock Detector*

A shock detector is a device which indicates whether an impact has occurred. Shock detectors can be used on shipments of fragile valuable items to indicate whether a potentially damaging drop or impact may have occurred. It changes the color after Critical shock value observed by detector. Values are in "g" acceleration form.


Fig. 1: Shock detector sticker of 50g


Fig. 2: It turns into red at 50g

#### *2) Data Logger*

A data logger is an electronic device that records data over time or in relation to location either with a built in instrument or sensor via external instruments and sensors. They are based on digital processor and called digital data logger. They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Some data loggers interface with a personal computer, and use software to activate the data logger and view and analyse the collected data, while others have a local interface device i.e. keyboard, lcd can be used as a stand-alone device.


Fig. 3: Data recorder

*3) Modes of Transportation*

There are four main modes of transportation which involves road, rail, marine, air transportation. Each mode has its advantages and disadvantages for its role in the supply chain. A primary responsibility of logistics managers worldwide is calculating what the best mode is for a specific shipment. Each factor comes into play – volume, speed, distance, and cost.

Road profile has standard known as ISO 8608 road standard, where road profile is depends on vertical axis fluctuation. Where data of profile can be measured in three different types; first method is known as direct method where one profilometer is placed behind the vehicle and it retrieves the data according to the road profile, second method is indirect method where camera or depth sensors are used to measure road profile, last method where data is retrieved from suspension deflection of the vehicle and road profile is categorised in different class depends on the wavelength and the waviness of the road profile.

## II. TECHNOLOGY & LITERATURE REVIEW

*1) Review Related To Study of Vibration Analysis on Road Transportation*

S.Paul singh, G burgwss, J.singh[1] they have done the analysis on the vibration forces that occur during transportation, the study was done using two types of truck: small local trucks for local distribution areas and larger tractor-trailers for cross-country transportation in brazil over 1200 km. this paper also provides the comparison between vibration data of local trucks & heavy trailer.

Jongmin park, sangil choi and mo jung[2] this paper provides a compared study between domestic transport vibration levels with those presented by the international standards (ASTM:USA, ISTA:Chicago), three representative trucks and transport test routes of domestic freight transport were selected to develop a simulation protocol for a truck transport environment in korea, also data has compared between leaf spring and air ride suspension system.

Jagjit singh, S.paul singh and eric joneson[3] the purpose of this paper was to determine the levels of vibration as a function trailer suspension at normal operating speeds in commercially used truck equipment, over 16000km of road surfaces in north America, it provides the comparison between leaf spring and air ride suspension system where result was 1 to 3 Hz for an air ride suspension system & 3 to 4 Hz for a leaf spring system.

Vanee chonhenchob, sher paul singh, jay jagjit, sukasem sittipod, dathpan swasdee[4] in this paper vibration analsyis has been done under 4 trucks transporting across the Bangkok on different highways. It also shows the PSD plot graph analysis.

S.P.singh, A.P.S.sandhu, J.singh, E.joneson[5] This paper provides a brief overview of the road and rail transportation environment in india, it also provides the results of a 2 year study that analysed truck and rail transport vibration for the major freight distribution routes between new delhi, bangalore, Mumbai, Chennai, Hyderabad and Kolkata.

Dariusz grzesica[6] The data include vibrations from three directions: longitudinal, transverse and vertical. Based on collected data the quantitative analysis of vibrations was conducted. The peak acceleration as well as the acceleration level was identified. The growth rate acceleration affecting the smoothness of driving and the impact of the vehicle on the stony surface were calculated. The study shows that the greatest impact on transporting cargo have vertical vibrations.

*B. Conclusion*

- Common result was the accelerations increased with lighter loads, bad road conditions and higher speeds.
- The data from study can be used to program vibration tables to reproduce these vibration conditions for packages testing.
- The vertical vibration levels measured in shipments were the highest, followed by lateral & longitudinal levels.
- The travel speed increased, the truck vibration level increased, although the increase rate of the air-ride truck was more significant than leaf-spring truck.
- Data compared between ASTM & ISTA, shows that the measured vertical vibration levels are more severe than levels used for existing test methods.
- All analysis has been under vibration data logger device of different companies.

*C. Objective*

- Analysis on the vibration forces that occur during road transportation.
- Data is used to program vibration tables to reproduce vibration simulation for packages testing.
- Comparing the g force data between different types of suspension system.
- Retrieve the g forces by mounting a data logger to the structure.

## III. METHODOLOGY & IMPLEMENTATION

This project is carried out in three phases for our convenience: shocklog data retrieving, sinewave test, Labview data acquisition.

*A. Phase 1 Shocklog Data Retrieving*

ShockLog is a data logger device which continually monitor and report in real time the shock, vibration, and environmental conditions experienced by structures and equipment during transit, storage, and operation. It records the direction, amplitude, and duration of impact force.

Optional sensors record changes in temperature, humidity, atmospheric pressure, tilt and roll.

We have done the random vibration test on single degree of freedom system where shocklog is mounted on SDOF system to acquire the vibration data observed by SDOF system.


Fig. 4: Single degree of freedom system

SDOF system has 4 springs, Each spring has stiffness of 15N/mm with mass of 40 kg

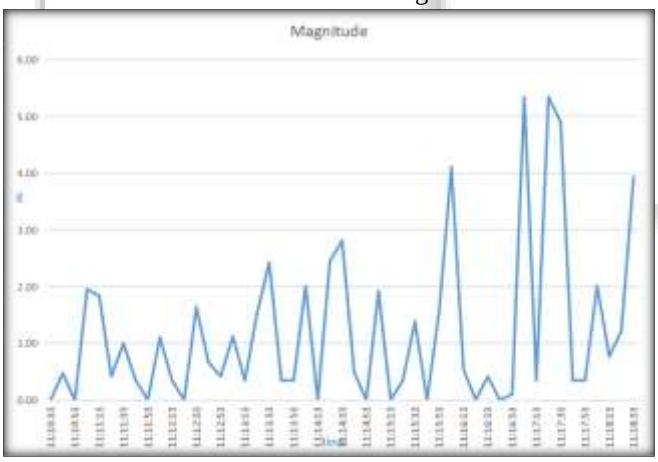



Fig. 5: This a data retrieved graph of acceleration g vs time

Magnitude is √(max peak @ (x axis)$^2$ + max peak @ (y axis)$^2$ + max peak (z axis)$^2$). This graph represents the magnitude of vibration with respect to time, it is monitored between 11:10:33 to 11:18:33 where it goes to the maximum "g" value of "5" at the 11:16:53 & 11:17:23.

*B. Phase 2 Sinewave Test*

We made one prototype here which represents the system generated sine waves with different variable amplitude to configure our program is retrieving data correctly.

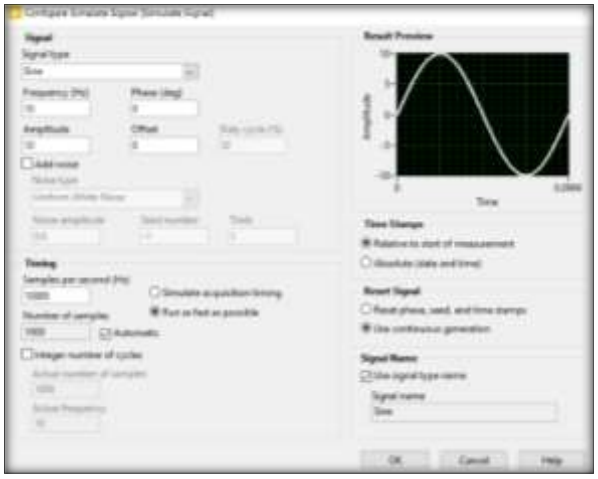


Fig. 6: Sine wave data setup

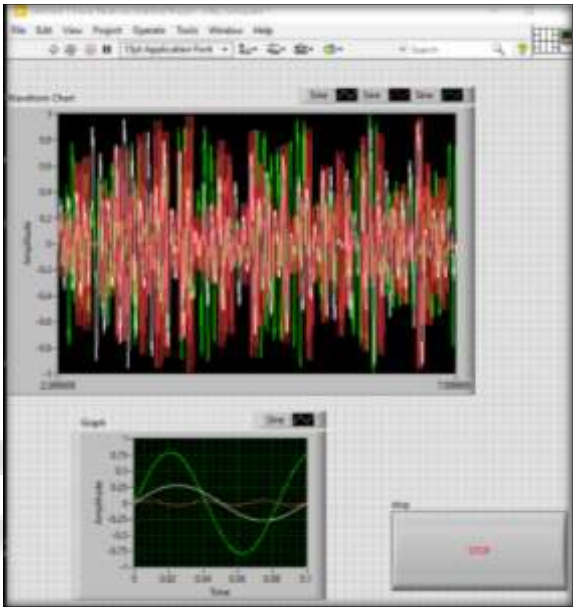


Fig. 7: Image off live display & event graph

As shown in image it represents the three directional graph x, y, z respected to white, red, green.

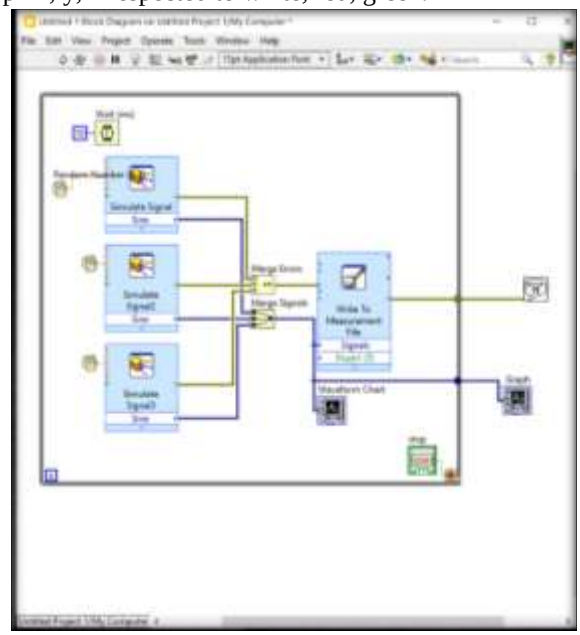
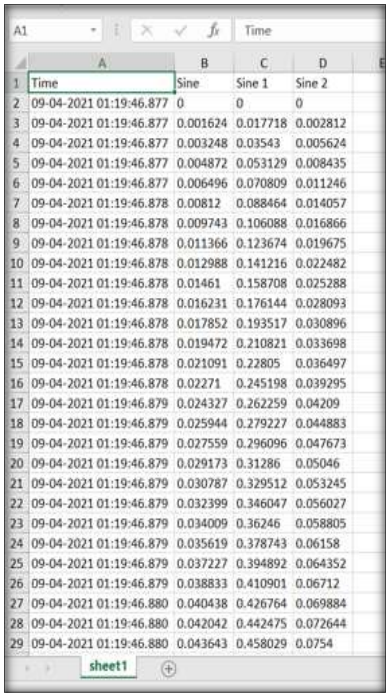


Fig. 8: Block diagram of prototype



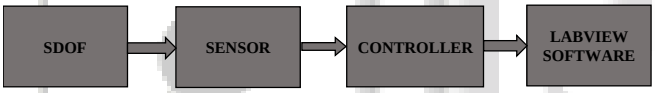
| | A | B | C | D |
|---|---|---|---|---|
| 1 | Time | Sine | Sine 1 | Sine 2 |
| 2 | 09-04-2021 01:19:46.877 | 0 | 0 | 0 |
| 3 | 09-04-2021 01:19:46.877 | 0.001624 | 0.017718 | 0.002812 |
| 4 | 09-04-2021 01:19:46.877 | 0.003248 | 0.03543 | 0.005624 |
| 5 | 09-04-2021 01:19:46.877 | 0.004872 | 0.053129 | 0.008435 |
| 6 | 09-04-2021 01:19:46.877 | 0.006496 | 0.070809 | 0.011246 |
| 7 | 09-04-2021 01:19:46.878 | 0.00812 | 0.088464 | 0.014057 |
| 8 | 09-04-2021 01:19:46.878 | 0.009743 | 0.106088 | 0.016866 |
| 9 | 09-04-2021 01:19:46.878 | 0.011366 | 0.123674 | 0.019675 |
| 10 | 09-04-2021 01:19:46.878 | 0.012988 | 0.141216 | 0.022482 |
| 11 | 09-04-2021 01:19:46.878 | 0.01461 | 0.158708 | 0.025288 |
| 12 | 09-04-2021 01:19:46.878 | 0.016231 | 0.176144 | 0.028093 |
| 13 | 09-04-2021 01:19:46.878 | 0.017852 | 0.193517 | 0.030896 |
| 14 | 09-04-2021 01:19:46.878 | 0.019472 | 0.210821 | 0.033698 |
| 15 | 09-04-2021 01:19:46.878 | 0.021091 | 0.22805 | 0.036497 |
| 16 | 09-04-2021 01:19:46.878 | 0.02271 | 0.245198 | 0.039295 |
| 17 | 09-04-2021 01:19:46.879 | 0.024327 | 0.262259 | 0.04209 |
| 18 | 09-04-2021 01:19:46.879 | 0.025944 | 0.279227 | 0.044883 |
| 19 | 09-04-2021 01:19:46.879 | 0.027559 | 0.296096 | 0.047673 |
| 20 | 09-04-2021 01:19:46.879 | 0.029173 | 0.31286 | 0.05046 |
| 21 | 09-04-2021 01:19:46.879 | 0.030787 | 0.329512 | 0.053245 |
| 22 | 09-04-2021 01:19:46.879 | 0.032399 | 0.346047 | 0.056027 |
| 23 | 09-04-2021 01:19:46.879 | 0.034009 | 0.36246 | 0.058805 |
| 24 | 09-04-2021 01:19:46.879 | 0.035619 | 0.378743 | 0.06158 |
| 25 | 09-04-2021 01:19:46.879 | 0.037227 | 0.394892 | 0.064352 |
| 26 | 09-04-2021 01:19:46.879 | 0.038833 | 0.410901 | 0.06712 |
| 27 | 09-04-2021 01:19:46.880 | 0.040438 | 0.426764 | 0.069884 |
| 28 | 09-04-2021 01:19:46.880 | 0.042042 | 0.442475 | 0.072644 |
| 29 | 09-04-2021 01:19:46.880 | 0.043643 | 0.458029 | 0.0754 |

Fig. 9: Excel sheet

Data is written and stored in excel form with respect to time and 3 directions.

*1) Phase 3 Labview Data Acquisition*

In the final phase we have done the vibration test on SDOF system with the help of our data acquisition methodology in labview software.




Block diagram of project


Fig. 10: Accelerometer

SDOF system used as shown in phase 1 and where accelerometer sensor is mounted on this system which is a piezoelectric based accelerometer and it has more sensitivity than the other types of accelerometer is used with the range of 50g & 100mv/g capacity.

Fig. 11: Data acquisition entire system

Sensor is connected to its controller and controller is connected with computer where it is configured with the LabVIEW software on the computer. The number of samples are 2000 and sampling rate is established at 10000 Hz per second in labview. We gave excitations & shocks to the ODOF system in vertical direction to acquire the data of g forces observed by system. we calculated theoretically the natural frequency of the one degree of freedom system by knowing of mass and the spring stiffness.

$$f = \frac{1}{2\Pi}\sqrt{\frac{k}{m}}$$

f is frequency K is stiffness and m is mass.

## IV. RESULT

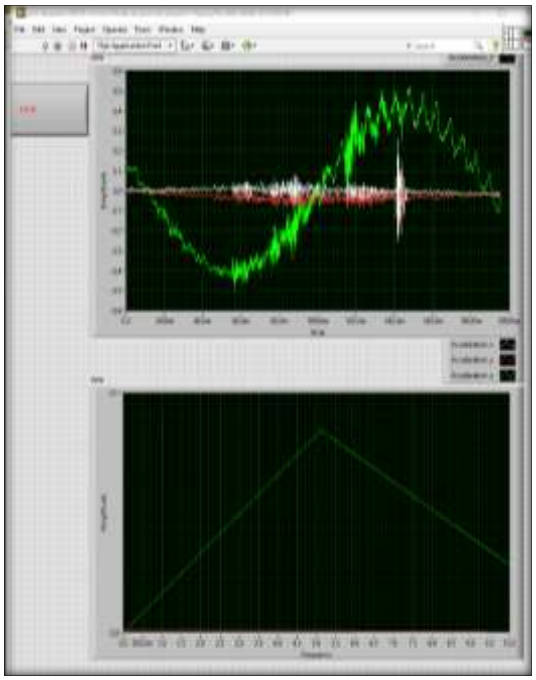


Fig. 12: Graph & PSD resonance

Graph is showing the vibration occurs on the SDOF system where green line is a vertical amplitude and white and red are x and y direction respectively. At the bottom of the graph there is another graph showing triangle formation with highest peak of 5.2 Hz which shows the resonance value of the ODOF system.

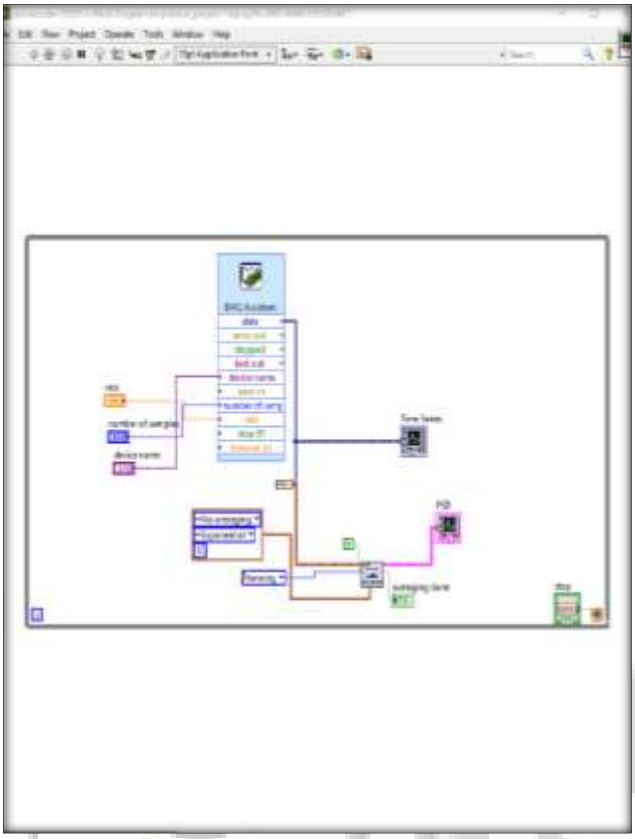


Fig. 13: Block diagram of Data acquisition system

Data is written in the excel form for further operation.

## V. CONCLUSION

- We compared both the Shocklog and LabVIEW data recorder and the result is the same.
- Theoretical and practical both the natural frequency values are same and it is 5.2 Hz.
- It has custom function to change the number of samples and sample rate (Hz).
- It gives a correct and exact g force value in graph.
- As because of one degree of freedom system graph perfectly showing the green line higher amplitude of z axis vertical oscillation than the longitudinal and lateral axis.
- Final result is that system is working perfectly.

## VI. FUTURE WORK

- We will mount a device on satellite container to measure the g forces acting on the satellite.
- We will compare the data between shocklog & our data logger.
- This will help to get to know about all vibration phenomenon acting on shipment and how we can concur it by studying vibration data.

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