Random Spectral Analysis of Integrated Avionics Module

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ABSTRACT

In actual operating conditions, each product like machine structures and its component is subjected to vibrations. The vibrations created because of incidence of dynamic forces following up on the machine, inner forces inside of the framework and natural conditions the unfriendly of the vibrations will run from immaterial to destructive depending on the seriousness of the unsettling influences and therefore the affectability of the instrumentation. OBC, MIU and Relay boxes are a little of the essential electronic subsystems in Missile frameworks. These units are set in numerous areas of the rocket/missile. Therefore as to diminish the load, to have simple combination and reduce the cabling it is needed to affix the same electronic packages and to create a solitary unit. This unit comprises of various PCBs of the individual packages in a chassis. This IAM has to meet all requirements for the various component situations in line with the particulars. For that purpose Finite element Model of the IAM unit has been created and modular investigations, random response examination have been done. This paper present investigation of spectrum examinations and assesses the response at important location inside the IAM and important changes are to be recommended for the quantity of inhabitants in components and mounting of the PCBs to possess least vibration response to qualify it for the dynamic environment. 3D modeling software package, SOLID WORKS 2008 was used for designing and analysis software package, FEMAP 10.2 with NASTRAN convergent thinker was used for arbitrary ghostlike investigation.

1. Introduction

The unit IAM contains of numerous individual electronic sub frameworks typically placed or set at various location in missile framework. OBC, MIU and Relay boxes are some imperative electronic subsystems in Missile frameworks. This unit comprises of various PCBs of the individual bundles or package in a frame. These units are place in various segments of the missile. Therefore to decrease the weight, to have easy integration and diminish the cabling it is required to consolidate the aforementioned electronic packages and to create a solitary unit. This IAM has to qualify for the distinctive dynamic situations consistent with the specification. This Unit is utilized as a part of each and every missile system for the purpose of communication.

Generally, the failure of individual hardware, inbuilt components of airborne vehicles and other equipment are due to vibrations. an outline of strategies to detect, locate and characterize damage in auxiliary and mechanical systems[1] by examining changes in measured vibration response have been provided. The modular parameters behind this innovation are mass, damping and solidness of the
structure. In this manner, changes within the physical properties e.g. mass, damping and solidness of the structure causes detectable changes in the modular properties.

The by and large acknowledged strategies for vibration control of mechanical gear [2] incorporate force reduction, mass expansion, tuning, disengagement and damping. There are numerous wellsprings of mechanical vibrations in mechanics and gadgets yet their location and distinguishing proof is extremely difficult. The reasons and strategy to control the vibration [3] which aggravates ordinary machines operation are distinctive. Some of them turn out from the realization of the technological procedure and other from poor quality work of components, their unusual gathering, wear and tear of parts, and so on next to that a few reasons turn out from the external influence related to environment.

Vibration damping [4] gadget includes at least one unbending housing part steadily arranged in a vibrating part, and a majority of autonomous mass individuals arranged non-adhesively. All mounting frameworks accomplished by two fundamental properties [5]: 1) constrained movement, and 2) provide vibration isolation and noise reduction.

Thus, to give the primary essential capacity, the mounting framework must be stiff to minimize relative movements. With a specific end goal to minimize transmitted vibration, the mounting framework must be progressively delicate. This fundamental issue, alongside the requirement for more service lives and diminished expenses, is the explanation behind new innovation improvements.

2. Methodology and 3D MODELLING OF IAM
   - Development of 3D model of IAM.
   - Perform Modal analysis to find natural frequencies on the base line model of the NRF and optimization of model (if required) by considering iterative method to shift natural frequency within the range.
   - Performance of random analysis on optimize model.

The 3D model of the Integrated Avionics Module is created using UNIGRAPHICS NX. The electronic accessories like RIC, MIU, OBC, and other component are considered for IAM modeling. Figure 1 illustrates the exploded view of IAM with location of RIC, MIU, and OBC etc. Figure 1 shows the solid model of IAM enclosure.

![Figure 1: Detailed View of IAM with its parts](image1)

![Figure 2: Solid model of IAM](image2)

2.1. Modal Analysis
Modular examination is being performed for comprehension auxiliary attributes, working conditions and performance criteria and empowers planning for optimal behavior or tackling basic criteria issues in existing outlines. This Modular Analysis used to decide a structure's vibration attributes as under:

- Natural frequencies
- Mode shapes
- Mode participation factors

Normally, modal analysis computes the natural frequencies as well as mode shapes of a structure. Typically, modular examination figures the regular frequencies and additional mode states of a structure. Typical modes examination settles for the undamped free vibrations as takes general equation of motion equation 1 and 2.

\[
[M][\ddot{u}] + [C][\dot{u}] + [K][u] = \{F(t)\} 
\]  

(1)

Assume free vibrations and ignore damping:

\[
[M][\ddot{u}] + [K][u] = \{0\} 
\]  

(2)

Each and every mode shape is similar to a static dislodged shape in which there are displacements and pivots for every lattice point.

2.2. Input of Modal Analysis

A parametric value of chassis and PCB’s are given in table 1.

| Material          | Aluminum          |
|-------------------|-------------------|
| Young’s Modulus (E) | 70Gpa             |
| Density (ρ)       | 2700kg/m³         |
| Frequency Range   | 20-2000 Hz        |
| Solving Method    | Lancoz method     |
| Poisson Ratio     | 0.29              |

| Material          | Epoxy Glass (FR4) |
|-------------------|-------------------|
| Young’s Modulus (E) |                  |
| E<sub>x</sub>     | 19.42             |
| E<sub>y</sub>     | 19.42             |
| E<sub>z</sub>     | 3.42              |
| G<sub>xy</sub>    | 6.8               |
| G<sub>yz</sub>    | 1.44              |
| G<sub>zx</sub>    | 1.44              |
| Density (ρ)       | 1814 kg/m³       |
| Frequency Range   | 20-2000 Hz        |
| Solving Method    | Lancoz method     |
| Poisson Ratio     | μ<sub>xy</sub> 0.25 |
|                   | μ<sub>yz</sub> 0.16 |
|                   | μ<sub>zx</sub> 0.16 |

IAM model are meshed in FEMAP and boundary conditions applied to the model. The lugs are constrained in solid modal and also in FE model constraining at nodes i.e. same locations as in solid model. The chassis and PCB’s are created with plate elements and fins are created with beam elements in FEMAP.
The FE Model of IAM is shown in fig 3 and total number of nodes and element is found as 7852 and 8496 respectively whose element size is 0.01m which is Hexahedral in shape.

![Figure 3: FE Model of PSB's with Plate](image1)

![Figure 4: FE Model of IAM Assembly with fixed Nodes Set](image2)

The modal analysis has been performed in FEMAP package with NX-NASTRAN as solver and the total 60 number of modes is found with lowest and highest frequency of 191.63 Hz and 1994.18 Hz respectively within the input frequency range of 20 Hz to 2000Hz. Typically, the mode shape of IAM assembly of first 2 modes has been shown in fig. 5 and fig. 6.

![Figure 5: Mode 1: Frequency 191.63 Hz](image3)

![Figure 6: Mode 2: Frequency 214.10 Hz](image4)

2.3. RANDOM RESPONSE ANALYSIS
Random vibration analysis takes at random accelerations or forces over a range of frequencies. And is a type of spectrum analysis. The response spectrum is being plotted between response spectral value (g^2/Hz) verses frequency (Hz) that captures the intensity and frequency content of time-history loads. Random vibration analysis is probabilistic in nature because both input and output quantities represent only the probability that they take on certain values.

The boundary condition as well as location of nodes in each and every part of the IAM unit is illustrated in figure number 7. Also, the excitation of the unit is provided individually in the three axis directions and the corresponding results are analyzed.

For the analysis purpose, the input frequency range has been considered between 20-2000 Hz. And also 2% of damping and excitation of 1g (acceleration) has been considered for the analysis. The assembly is meshed with boundary conditions & the excitation of the model is done in X, Y, Z-direction. The response of the unit for the given specification at critical locations chosen in the analysis has been obtained, & the Response at chosen locations is plotted in acceleration PSD format. Typically, the response location of IAM assembly at node 822 and 3033 is plotted and shown in below figure 9 to 13 in all three said direction.

![Figure 7:Response nodes on various PCB’s](image)

![Figure 8:Response at Node 822 in X- direction](image)
Figure 9: Response at Node 3033 in X-direction

Figure 10: Response at Node 822 in Y-direction
Figure 11: Response at Node 3033 in Y-direction

Figure 12: Response at Node 822 in Z-direction
2.4. Results of random analysis of IAM

Random response results are shown in table 3.

| Response Location Nodes | X-Axis 2% Damping | Y-axis 2% Damping | Z-axis 2% Damping |
|-------------------------|------------------|------------------|------------------|
| 3033                    | 52.7566          | 66.9261          | 32.8691          |
| 5535                    | 69.0085          | 75.5685          | 63.340           |
| 4144                    | 44.8318          | 71.2568          | 76.6960          |
| 822                     | 43.4611          | 68.660           | 48.43            |
| 4990                    | 45.52            | 69.045           | 46.5590          |
| 6695                    | 47.8245          | 81.1256          | 68.956           |
| 7947                    | 54.2545          | 75.5846          | 55.9381          |
| 3525                    | 55.7434          | 67.4575          | 61.6581          |
| 5409                    | 46.6292          | 82.500           | 52.32606         |
| 4554                    | 57.6597          | 64.678           | 64.8266          |
| 6592                    | 61.6587          | 73.3254          | 59.571           |

Figure 13: Response at Node 3033 in Z-direction
3. **Result and Discussion:**

The results obtained from analysis are discussed below:

3.1. **Modal Analysis Results**

From the modular analysis, it has been observed that total 60 modes is obtained, having the lowest & highest frequencies are 191.62 Hz and 1994.23 Hz respectively for input frequency ranging from 20-2000 Hz which is under acceptable limit and thus the designed IAM model is safe. On further, random analysis output is obtained as PSD spectrum and the analytical value found as 32.8691grms and 82.500 grms which is lowest & highest RMS in Z-direction and Y-direction at node 3033 and 5409 respectively, for input frequency range of 20-2000 Hz, 2% of damping and excitation of 1g(acceleration).

4. **Conclusion**

For the present analysis the following conclusion has been derived:

1. Random response test was performed on the critical locations within the unit and maximum response level is found to be 82.5 grms which is also in safe limit specified by the manufacturer.

2. Finally, the response values of IAM have been found to be in safe limit specified by manufacturer. Thus, this particular design is safe.

**References**

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**5. NOMENCLATURE**

| SYMBOL | EXPANSION |
|--------|-----------|
| f      | Frequency of the system |
| fn     | Natural frequency |
| fd     | Damped Frequency |
| C      | Damping co-efficient |
| Cc     | Critical Damping co-efficient |
| D      | Magnification factor |
| T      | Transmissibility |
| K      | Stiffness of the spring |
| M      | Mass of the object |
| NE     | Number of elements |
| NN     | Number of nodes |
| ET     | Element Type |
| t      | Time |
| Δf     | Band Width |
| NDB    | Number of Decibels |
| RMS    | Root Mean Square |
| Acronym  | Description                                      |
|----------|--------------------------------------------------|
| PSD-     | Power Spectral Density                           |
| IAM-     | Integrated Avionics Module                       |
| MIU -    | Missile Interface Unit                           |
| OBC-     | On Board Computer                                |
| RIC -    | Relay Interface Car                              |
| FEMAP    | Finite Element Modelling and Post processing     |