International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 4, October 2014

Research Paper

DESIGN OPTIMIZATION OF ARMY RADAR FRAME (ARF) FOR THERMAL AND STRUCTURAL CONDITIONS

Bikesh Kumar[1]* and Damodar Reddy[1]

*Corresponding Author: Bikesh Kumar, bkumar307@gmail.com

Sensitive electronic equipment operating in harsh environment depend upon the vibration protection of the equipment. General methodology that is followed is to optimize the design for vibration for random loads by using damping and stiffness of mounts and is mostly stressed on optimizing the dynamic response of internal components. But the vibration protection of the equipment depends and on the dynamic response of the external structure which is very often neglected.In this project total emphasis is laid on to make a optimal design and improve the design stiffness of the external structure. In the present paper an Army Radar frame has been designed and optimized for vibration control and temperatures using Ansys. Army Radar Frame (ARF) is a structural frame used to mount the communication antennas and the supporting electronic equipment for the system.

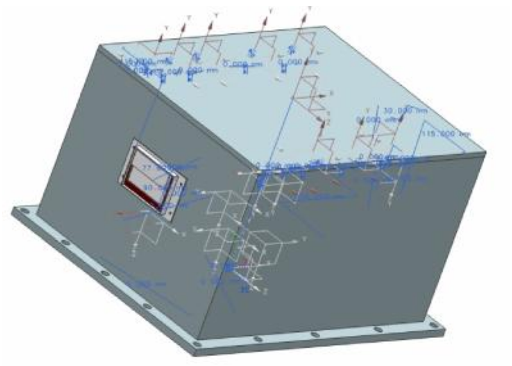
Keywords: Army RADAR frame, Vibration control, ANSYS, FEA, PSD

INTRODUCTION

3D Modeling of Army Radar Frame Assembly

The Army Radar frame assembly is a structural frame used to mount the communication antennas and the supporting electronic equipment for the system. The ARF mounted with the antennas and the supporting electronic components is fit on to the communication towers located on the army vehicle. The function of the frame is to house the

Figure 1: Shows Army Radar Frame Assembly Structure



[1] M.Tech Student, Department of Mechanical Engineering, Malla Reddy College of Engineering & Technology, Hyderabad, India.

[2] Associate Professor, Department of Mechanical Engineering, Malla Reddy College of Engineering & Technology, Hyderabad, India.

communication antennas and the supporting electronic equipment. The 3D model of the Radar Frame assembly is created using UNIGRAPHICS NX software from the 2d drawings.

FINITE ELEMENT ANALYSIS OF ARMY RADAR FRAME ASSEMBLY

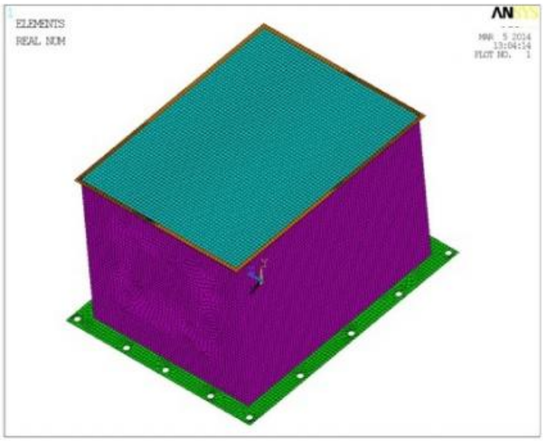
Finite Element Modeling

3D model of the Army Radar frame assembly was developed in UNIGRAPHICS from the 2d drawings. The model was then converted into a parasolid to import into ANSYS. A Finite Element model was developed with shell and mass elements. The elements that are used for idealizing the ARF Assembly were described below. A detailed Finite Element model was built with shell and mass elements to idealize all the components of the Army radar frame assembly. Modal analysis was carried in the frequency range of 0-300 Hz to capture the natural frequencies and their mass participations. A Response Spectrum Analysis (RSA) was simulated in the same range to evaluate combined response of the system under given slope in X, Y and Z direction. A PSD analysis was performed on the Army Radar frame in the range of 0 -1000 Hz in X, Y and Z directions to simulate its behavior due to random excitations.

MATERIAL PROPERTIES

All the components of the Army Radar Frame Assembly are made using Aluminium HE 30 material. All the components of the Army Radar Frame Assembly are assigned as per the below material properties. The total weight of the base line model of the Army Radar Frame Assembly for Finite Element simulation is 32 Kgs.

Figure 2: Shows the Finite Element Model of the Army Radar Frame (ARF) Assembly



METHODOLOGY

A detailed Finite Element model was built with shell and mass elements to idealize all the components of the Army Radar Frame assembly. Modal analysis was carried to capture the natural frequencies and their mass participations.

A Response Spectrum Analysis (RSA) was simulated to evaluate response of the system under given conditions along horizontal X, Y and vertical Z direction and the square root of the sum of the squares (SRSS) method was used to combine the total response in each

Table 1: Material Properties

Material Properties				
Material	**Young's Modulus (N/mm^2)**	**Poisson's Ratio**	**Density (kg/mm^3)**	**Yield Stress (N/mm^2)**
Aluminium (HE 30)	7.0E+04	0.3	2700	160

direction. The stresses in the structural members were calculated and compared against the allowable stresses of the material. A PSD analysis was performed on the Army Radar frame Assembly in the range of 0-1000 Hz in X, Y and Z directions to simulate its behavior due to random excitations.

Finite element analysis was carried in the following steps:

- Create 3D model of the base line model of the ARF using UNIGRAPHICS NX and save as parasolid.
- Import parasolid into Ansys to perform the structural analysis.
- Perform Modal analysis to find natural frequencies on the base line model of the ARF.
- Optimize the baseline model (iterative method) to shift the natural frequencies above the operating frequency of ARF by changing design stiffness and by restricting the weight below 35 kgs.
- Perform Power Spectral Density analysis (PSD) on the optimized model to find the effect of all the frequencies present below the operating frequency range of ARF in X, Y and Z direction.
- Perform thermal analysis on the baseline model to find the temperature distribution.
- Perform thermal analysis on the optimized model to find the temperature distribution.

MODAL ANALYSIS OF THE BASE LINE MODEL

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a seismic analysis.

Mode Shapes: 11 Natural frequencies observed in the frequency range of 0-300 Hz out of 11 frequencies 2 natural frequencies at

Table 2: Frequencies and Mass Participation

Mode	Frequency	Participation Factor			Effective Mass (Tonnes)		
		X-dir	Y-dir	Z-dir	X-dir	Y-dir	Z-dir
1	126.655	9.11E-03	2.01E-02	–2.54E-03	8.29E-05	4.03E-04	6.45E-06
2	138.756	1.69E-03	4.90E-02	2.58E-03	2.87E-06	2.40E-03	6.65E-06
3	144.342	8.42E-02	–8.98E-03	–2.27E-03	7.08E-03	8.06E-05	5.16E-06
4	153.107	4.04E-02	1.88E-02	–2.47E-04	1.63E-03	3.54E-04	6.11E-08
5	175.97	4.23E-03	4.79E-02	2.09E-02	1.79E-05	2.30E-03	4.36E-04
6	186.385	–1.94E-03	5.65E-02	–3.47E-02	3.76E-06	3.20E-03	1.21E-03
7	200.286	5.22E-03	–4.45E-04	–3.05E-02	2.72E-05	1.98E-07	9.33E-04
8	205.864	1.58E-03	–2.18E-03	0.13287	2.49E-06	4.75E-06	1.77E-02
9	230.055	–1.30E-02	1.47E-03	–1.43E-03	1.68E-04	2.16E-06	2.05E-06
10	239.016	–3.75E-04	1.24E-02	2.74E-03	1.41E-07	1.54E-04	7.51E-06
11	243.33	1.16E-03	3.02E-02	4.54E-03	1.36E-06	9.10E-04	2.06E-05

144 Hz and 205 Hz are observed to be critical frequencies. They are critical because the frequency at 144 Hz is having a mass participation of 7Kgs in X-direction which is 22% of the total weight and the frequency at 205 Hz is having 17.6 kgs in Z-direction which is 55% of the total weight of the assembly. The mode shapes of critical frequencies are plotted below.

Figure 3: Shows the 3rd Mode Shape @144 Hz

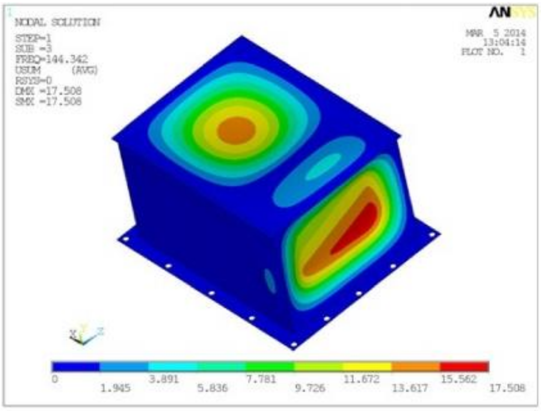
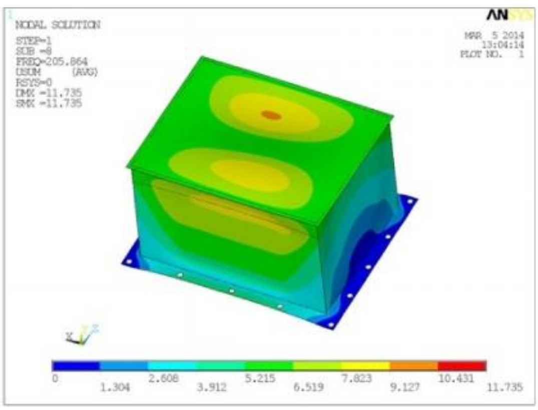


Figure 4: Shows the 8th Mode Shape @205 Hz

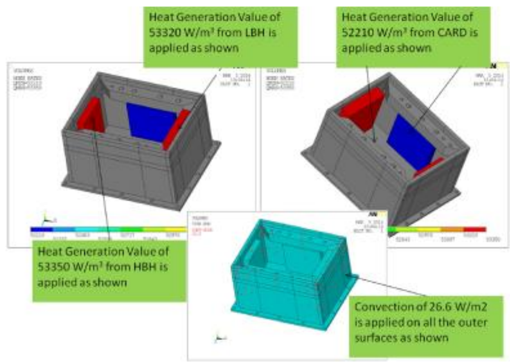


From the above modal analysis it is observed that there exists 2 critical natural frequencies in the operation frequency range of 0-300 Hz.It is necessary to shift these natural frequencies above the operating range of 0-300 Hz to protect the (ARF) Army Radar Frame assembly structure from vibrations.

THERMAL ANALYSIS OF THE BASE LINE MODEL

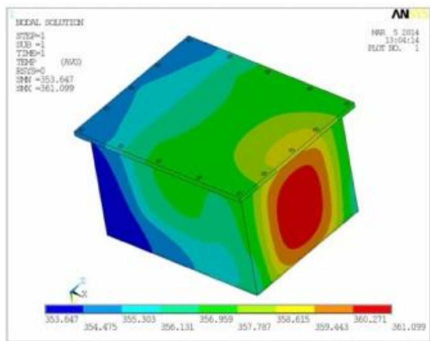
Thermal analysis is performed on the Base line model of Army Radar Frame (ARF) assembly structure to find the temperature distribution due to the power dissipation of electronic components. Thermal analysis is done for the ambient temperature of 55 °C with and without radiation effect. Solid 70 Element is used to capture the thermal conductivity from the homodynes to the bottom plate.

Figure 5: Shows the Thermal Boundary Conditions Applied for Thermal Analysis



Results Without Radiation

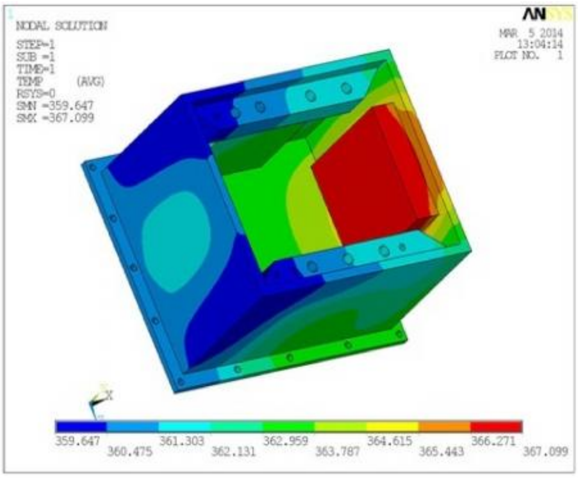
Figure 6: Shows the Temperature Distribution on the ARF Assembly



Results with Radiation

Thermal analysis is performed on the Base line model of ARF Army Radar Frame assembly structure to find the temperature distribution due to the power dissipation of electronic components and also due to radiation effect.

Figure 7: Shows the Temperature Distribution on the Side Plate of Army Radar Frame Due to Radiation



From the above thermal analysis it is concluded that

1. Maximum temperature observed without radiation is 88 °C.
2. Maximum temperature observed with radiation is 94 °C.

The threshold temperature of homodynes is 80 °C with radiation. But as per the thermal analysis the max temperature observed is 94 °C. So modifications are required for the ARF Army Radar Frame assembly for more heat transfer.

Following are the different alternatives which can be mounted to the homodynes for more heat transfer.

1. Heat sinks can be mounted for the homodynes, however the weight of the structure will increase.
2. Each heat sink measures ~ 2.5 Kg.
3. Different heat sinks optimizing the weight and conducting the heat are given below.

From the above Modal and thermal analysis it is observed that it is necessary to modify the Army Radar Frame (ARF) assembly for the electronic equipment to function in the harsh environment and the following design changes are proposed.

Table 3: Changes Made on the Baseline Model

S. No.	Entity	Changes Made
1.	Bottom Plate	Base thickness is increase from 4 mm to 6 mm
2.	Side Plates	Additional 3 mm thick platform for homodyne resting
		Additional 6 mm thick pin fins added for conduction and convection
3.	Top Plate	Ribs of 8 mm added to add strength

Figure 8: Shows the Changes Made on the Army Radar Frame Assembly

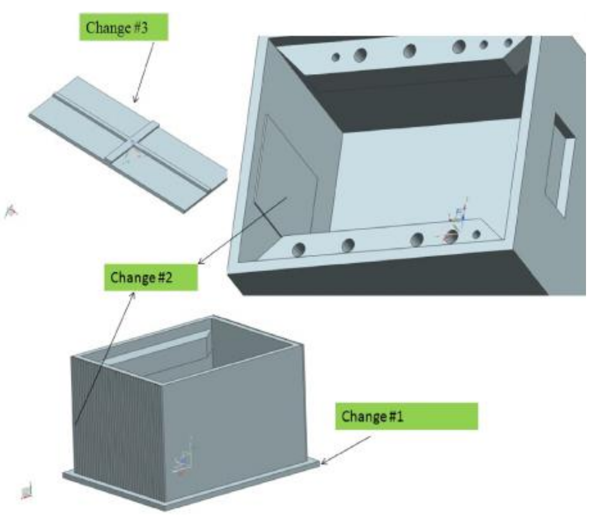


Table 4: Frequencies and Mass Participation

Mode	Frequency	Participation Factor			Effective Mass		
		X-dir	Y-dir	Z-dir	X-dir	Y-dir	Z-dir
1	207.453	–2.32E-04	4.17E-02	5.79E-06	5.40E-08	1.74E-03	3.35E-11
2	240.983	–4.29E-07	–9.57E-05	8.98E-03	1.84E-13	9.15E-09	8.07E-05
3	241.069	8.66E-05	–9.74E-05	7.65E-03	7.50E-09	9.48E-09	5.85E-05
4	299.061	2.80E-04	3.05E-04	–7.73E-02	7.83E-08	9.33E-08	5.97E-03

Modal Analysis on the Modified Model

Modal analysis is carried out on the modified model. The mode numbers and participation factors are shown in the below table.

Power Spectrum Density (PSD) Analysis

PSD Analysis Along X-Direction

PSD analysis is carried out on modified model with base excitation in X, Y and Z direction from 0-1000 Hz.

Boundary Conditions:

Functional vibration levels: PSD

Table 5: Shows the Spectral Values vs Frequency for PSD Analysis

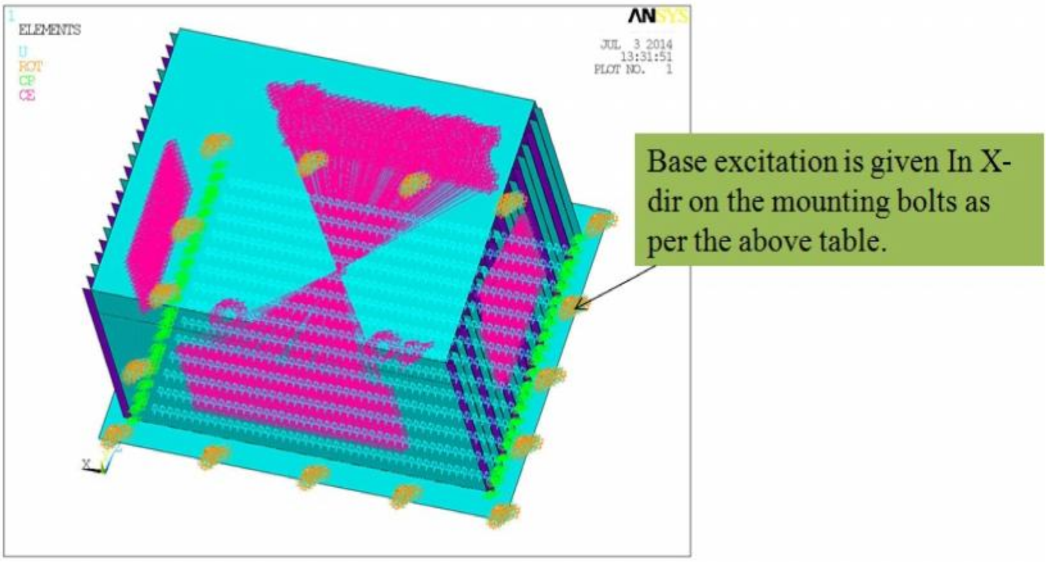
Random	g^2/Hz
20	0.003
50	0.02
450	0.02
1000	0.001

Results: Total Deflection:

The maximum 1 sigma deflection observed is 0.012 mm.

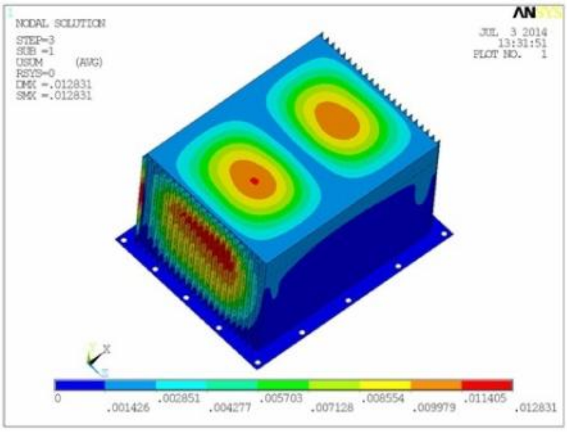
The maximum 3 sigma deflection observed is 0.036 mm.

Figure 9: Shows the Boundary Condition Applied for PSD in X-Dir



This implies that only 0.3% of the time the Army Radar Frame deflection reaches 0.036 mm.

Figure 10: Shows the Total Deflection of the Army Radar Frame for PSD in X-Dir



VonMises Stress

The maximum 1 sigma Stress observed is 3.6 N/mm^2.

The maximum 3 sigma Stress observed is 10.8 N/mm^2.

This implies that only 0.3% of the time the ARF deflection reaches 10.8 N/mm^2.

Figure 11: Shows the VonMises Stress of the Army Radar Frame for PSD in X-Dir

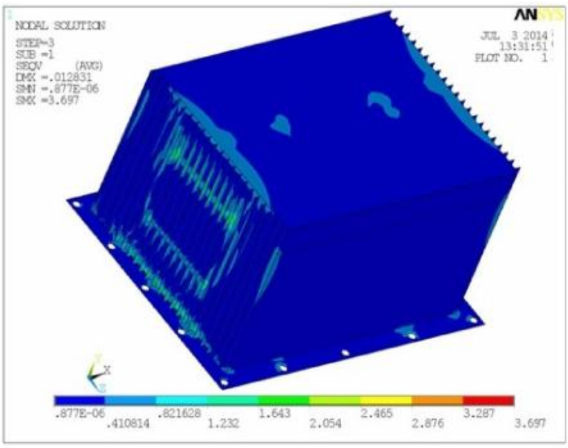
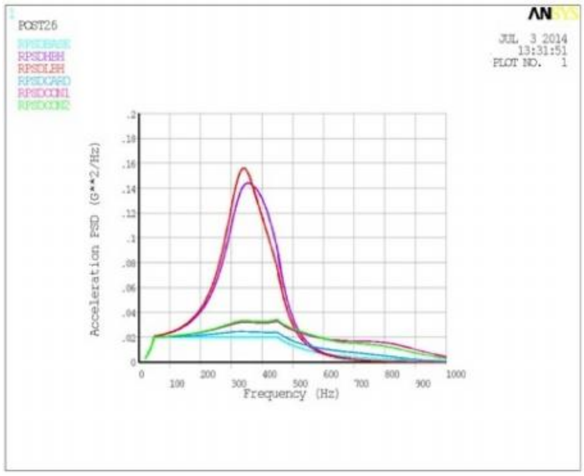


Figure 12: Shows PSD-X Response on ARF Electronic Modules in Linear Scale



From the above graphs it is seen that:

- Maximum PSD response on the HBH is 0.15 g^2/Hz at a frequency of 346 Hz.
- Maximum PSD response on the LBH is 0.16 g^2/Hz at a frequency of 346 Hz.
- Maximum PSD response on the CARD is 0.025 g^2/Hz at a frequency of 346 Hz.
- Maximum PSD response on the CONNECTOR is 0.034 g^2/Hz at a frequency of 460 Hz.

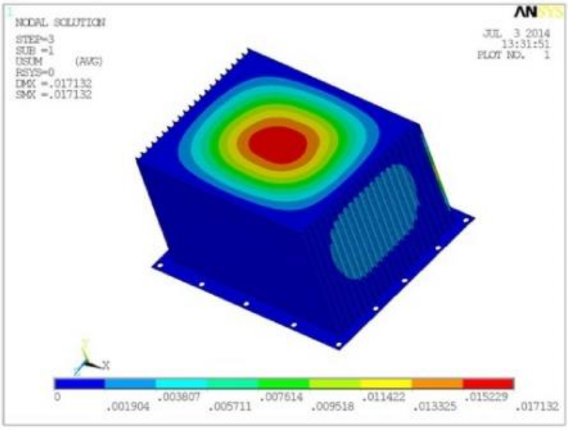
The Yield strength of the material Aluminium (HE 30) is 160 N/mm^2. From the above analysis the maximum 3 sigma stress observed is 10.8 N/mm^2. From the above results and it can be concluded the Army Radar Frame assembly is safe for the random vibrations in X-direction.

Results of PSD in Y-Dir: Total Deflection

The maximum 1 sigma deflection observed is 0.017 mm.

The maximum 3 sigma deflection observed is 0.051 mm.

Figure 13: Shows the Total Deflection of the Army Radar Frame for PSD in Y-Dir



This implies that only 0.3% of the time the Army Radar Frame deflection reaches 0.051 mm.

VonMises Stress

The maximum 1 sigma Stress observed is 1.2 N/mm^2.

The maximum 3 sigma Stress observed is 3.6 N/mm^2.

This implies that only 0.3% of the time the ARF reaches 3.6 N/mm^2.

Figure 14: Shows the VonMises Stress of the Army Radar Frame for PSD in Y-Dir

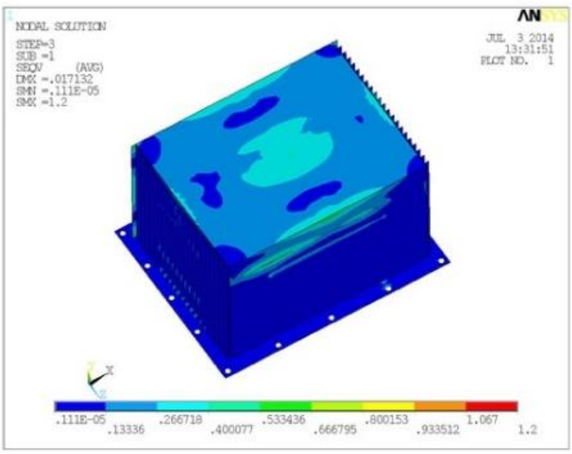
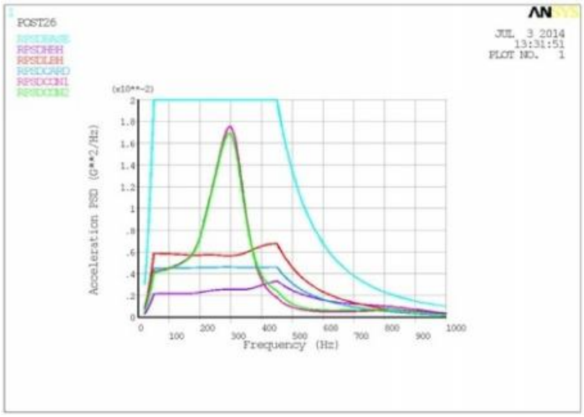


Figure 15: Shows PSD-Y Response on ARF Electronic Modules in Linear and Logarithmic Scale



From the above graphs it is seen that

- Maximum PSD response on the HBH is 0.0035 g^2/Hz at a frequency of 430 Hz.
- Maximum PSD response on the LBH is 0.006 g^2/Hz at a frequency of 417 Hz.
- Maximum PSD response on the CARD is 0.005 g^2/Hz at a frequency of 417 Hz.
- Maximum PSD response on the CONNECTOR is 0.016 g^2/Hz at a frequency of 299 Hz.

The Yield strength of the material Aluminium (HE 30) is 160 N/mm^2. From the above analysis the maximum 3 sigma stress observed is 3.6 N/mm^2. From the above results and it can be concluded the Army Radar Frame assembly is safe for the random vibrations in Y-direction.

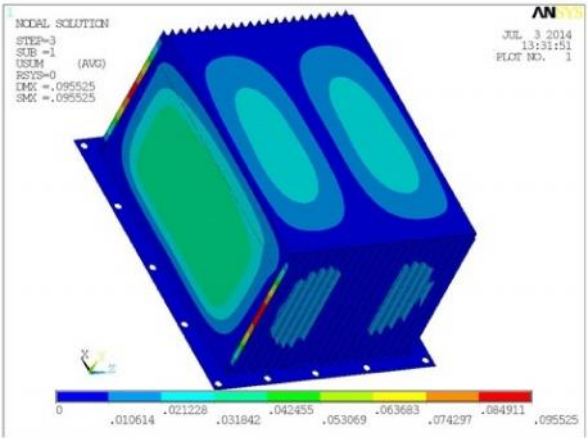
Results: PSD in Z-dir

Total Deflection:

The maximum 1 sigma deflection observed is 0.09 mm.

The maximum 3 sigma deflection observed is 0.27 mm.

Figure 16: Shows the Total Deflection of the Army Radar Frame for PSD in Z-Dir



This implies that only 0.3% of the time the Army Radar Frame deflection reaches 0.27 mm.

VonMises Stress

The maximum 1 sigma Stress observed is 15.7 N/mm^2.

The maximum 3 sigma Stress observed is 47.1 N/mm^2.

This implies that only 0.3% of the time the board deflection reaches 47.1 N/mm^2.

Figure 17: Shows the VonMises Stress of the Army Radar Frame for PSD in Z-Dir

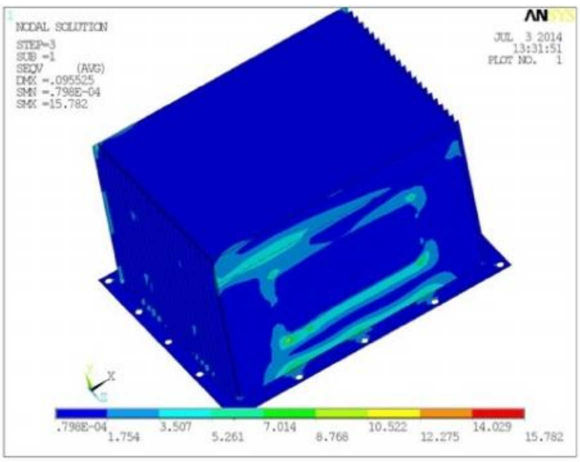
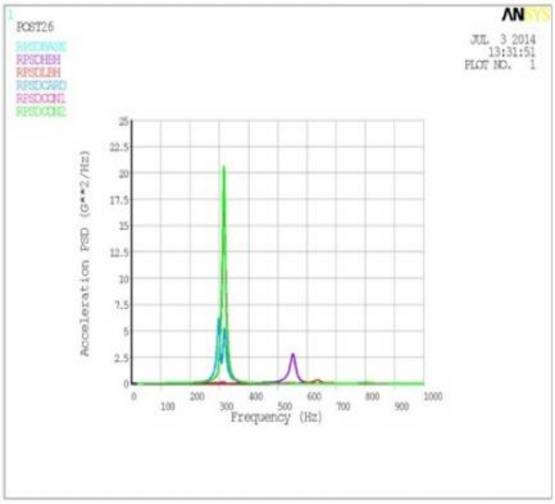


Figure 18: Shows PSD-Z Response on ARF Electronic Modules in Linear and Logarithmic Scale



From the above graphs it is seen that

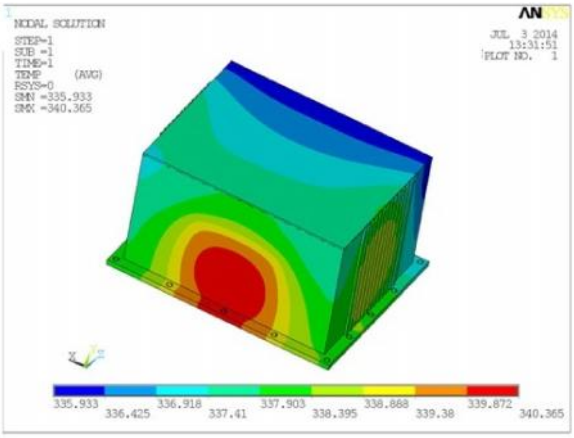
- Maximum PSD response on the HBH is 2.8 g^2/Hz at a frequency of 552 Hz.
- Maximum PSD response on the LBH is 0.32 g^2/Hz at a frequency of 638 Hz.
- Maximum PSD response on the CARD is 6.2 g^2/Hz at a frequency of 299 Hz.
- Maximum PSD response on the CONNECTOR is 21 g^2/Hz at a frequency of 316 Hz.

The Yield strength of the material Aluminium (HE 30) is 160 N/mm^2. From the above analysis the maximum 3 sigma stress observed is 47.1 N/mm^2. From the above results and it can be concluded the Army Radar Frame assembly is safe for the random vibrations in Z-direction.

THERMAL ANALYSIS OF THE MODIFIED MODEL

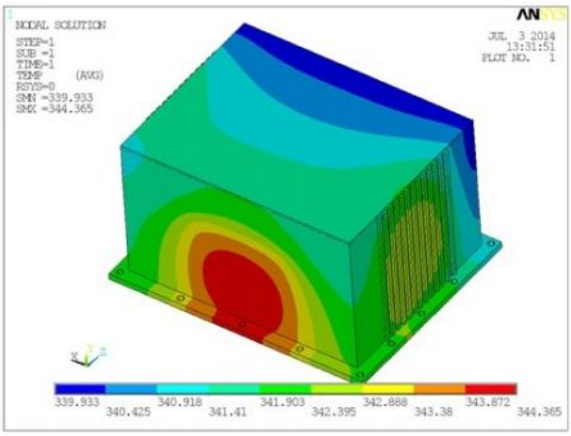
Results Without Radiation

Figure 19: Shows the Temperature Distribution on the Modified ARF Army Radar Frame Assembly



Results with Radiation

Figure 20: Shows the Temperature Distribution on the Side Plate of Modified Army Radar Frame Due to Radiation



From the above thermal analysis it is concluded that

1. Maximum temperature observed without radiation is 67 °C.
2. Maximum temperature observed with radiation is 71 °C.
3. The modified ARF model is safe for the thermal conditions.

CONCLUSION

In the present paper a Army Radar Frame (ARF) has been designed and optimized for vibration control and temperatures.

Army Radar frame (ARF) was studied for 3 different cases for baseline and modified model:

- Modal Analysis.
- Power Spectrum Density Analysis.
- Thermal Analysis with and without radiation.

From the above analysis it is concluded that that the critical natural frequencies in the operation frequency range of 0-300 Hz were shifted to above 300 Hz due to the changes implemented as shown in the report.

From the above thermal analysis it is concluded that the temperatures are below the threshold temperature of homodynes, i.e., 80 °C with radiation.

Therefore it concluded that the modified Army Radar Frame (ARF) is safe under the given operating conditions.

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