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Research Paper

DESIGN AND OPTIMIZATION OF AN ANTENNA FRAME FOR THEMAL AND STRUCTURAL CONDITIONS

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As the power densities of power converters continue to grow, thermal issues are becoming extremely important and vital for the product quality. Excessive temperatures of the critical components, such as Low Band Homodynes (LBH) and High Band Homodynes (HBH), are the dominant cause of equipment failures. Power systems for heavy electronic equipment are usually housed in completely sealed enclosures due to safety reasons. Since the cooling of these systems primarily relies on natural convection, the effective management of the heat removal from a sealed enclosure poses a major thermal-design challenge. In fact, thermal design through thermal modeling and simulation is becoming an integral part of the design process because it is usually less time consuming and less expensive compared to the experimental cut-and-try approach. In the present paper a Antenna Frame's (AF) antenna mounting frame has been designed and optimized for vibration control and temperatures. Antenna Frame (AF) is a structural frame used to mount the communication antennas and the supporting electronic equipment for the system. The AF 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 communication antennas and the supporting electronic equipment.3D modeling software (UNIGRAPHICS NX) was used for designing and analysis software (ANSYS) was used for structural and thermal analysis.

Keywords: Antenna frame, Thermal analysis, Structural analysis, NX-CAD

INTRODUCTION

Vibration protection of sensitive electronic equipment operating in harsh environments often relies on design stiffness. The traditional optimal design for vibration isolation from random vibration is based on a trade-off choice of damping and stiffness properties of mounts, and is focused primarily on optimizing the dynamic response of the internal electronic equipment, subject to limitations imposed on their rattle space. However, the reliability of the electronic equipment depends primarily on the vibration responses of the external structure that are often lightly damped and extremely responsive over a wide

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frequency range. The traditional approach, hence, completely ignores the presence of such components. Consequently, the traditionally designed vibration components are often insufficient for maintaining a fail-safe vibration environment for electronic equipment. The new design approach focuses basically on dynamic properties and responses of the critical external structure of an electronic device. The optimally chosen vibration resistant design allow the vibration experienced by the above external structure to be minimized, subject to restraints imposed on the peak deflections of the electronic structure.

HOMODYNE

A direct-conversion receiver (DCR), also known as homodyne, synchrodyne, or zero-IF receiver, is a radio receiver design that demodulates the incoming radio signal using synchronous detection driven by a local oscillator whose frequency is identical to, or very close to the carrier frequency of the intended signal. This is in contrast to the standard super heterodyne receiver where this is accomplished only after an initial conversion to an intermediate frequency.

ANTENNA FRAME

Broadband refers to a communication bandwidth of at least 256 Kbps. Each channel is 6 MHz wide and it uses an extensive range of frequencies to effortlessly relay and receive data between networks. In telecommunications, a broad band signaling method is one that handles a wide band of frequencies. Broadband is a relative term, understood according to its context. The wider (or broader) the bandwidth of a channel, the greater the information-carrying capacity, given the same channel quality.

A television antenna may be described as “broadband” because it is capable of receiving a wide range of channels; while a single-frequency or Lo-VHF antenna is “narrowband” since it receives only 1 to 5 channels. The US federal standard FS-1037C defines “broadband” just as a synonym for wideband.

In data communications a 56k modem will transmit a data rate of 56 kilobits per second (kbit/s) over a 4 kilohertz wide telephone line (narrowband or voice band). The various forms of digital subscriber line (DSL) services are broadband in the sense that digital information is sent over a high-bandwidth channel. This channel is at higher frequency than the baseband voice channel, so it can support plain old telephone service on a single pair of wires at the same time.

However when that same line is converted to a non-loaded twisted-pair wire (no telephone filters), it becomes hundreds of kilohertz wide (broadband) and can carry up to 60 megabits per second using very-high-bitrate digital subscriber line (VDSL or VHDSL) techniques.

In the late 1980s, the Broadband Integrated Services Digital Network (B-ISDN) used the term to refer to a broad range of bit rates, independent of physical modulation details.

Figure 1: Different Antenna Mounting Frame Assembly Structure Used for Army Application

PROBLEM DEFINITION

The objective of my project is to:

- Perform Modal analysis to find natural frequencies on the base line model of the AF
- Optimize the baseline model (iterative method) to shift the natural frequencies above the operating frequency of AF by changing design stiffness and by restricting the weight below 150 kgs.
- Perform Response spectrum analysis (RSA) on the optimized model to find the effect of all the frequencies present below the operating frequency range of AF in X, Y and Z direction.
- Perform PSD analysis on the optimized model in the frequency range of 0-1000Hz in X, Y and Z directions.
- Perform thermal analysis on the baseline model to find the temperature distribution with radiation.
- Perform thermal analysis on the optimized model to find the temperature distribution with radiation.

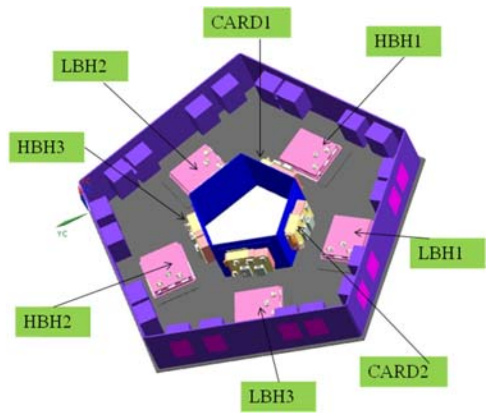
3D MODELING OF ANTENNA FRAME ANTENNA FRAME ASSEMBLY

The antenna frame assembly is a structural frame used to mount the communication antennas and the supporting electronic equipment for the system. The 3D model of the Antenna Frame assembly is created using UNIGRAPHICS NX software from the 2d drawings. UNIGRAPHICS NX is the world's leading 3D product development solution. This software enables designers and engineers to bring better products to the market faster.

MATERIAL PROPERTIES

All the components of the AF Assembly are made using Aluminium HE 30 material. All the components of the AF Assembly are assigned as per the below material properties. The total weight of the base line model of the AF Assembly for Finite Element simulation is 136 Kgs.

Figure 2: AF Antenna Frame assembly structure with HBH and LBH and CARD



METHODOLOGY

Finite element analysis was carried in the following steps:

- Create 3D model of the base line model of the AF using UNIGRAPHICS NX and save as parasolid.

Table 1: Material Properties

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

- Import parasolid into Ansys to perform the structural analysis.
- Perform Modal analysis to find natural frequencies on the base line model of the AF in the frequency range of 0 – 200Hz
- Optimize the baseline model (iterative method) to shift the natural frequencies above the operating frequency of AF by changing design stiffness and by restricting the weight below 150 kgs.
- Perform Response spectrum analysis (RSA) on the optimized model to find the effect of all the frequencies present below the operating frequency range of AF in X, Y and Z direction.
- Perform PSD analysis on the optimized model in the frequency range of 0-1000Hz in X, Y and Z directions.
- Perform thermal analysis on the baseline model to find the temperature distribution with radiation.
- Perform thermal analysis on the optimized model to find the temperature distribution radiation.

FINITE ELEMENT ANALYSIS OF AFASSEMBLY

Modal Analysis of the Base Line Model

Perform thermal analysis on the optimized model to find the temperature distribution with radiation. 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.

Total weight of the Base Line Model is 136Kgs.

Mode Shapes: 17 Natural frequencies observed in the frequency range of 0-200Hz.out of 17 frequencies 13 natural frequencies are observed to be critical frequencies. Some of the mode shapes of the critical frequencies are plotted below.

From the above modal analysis it is observed that there exist 3 critical natural frequencies in the operation frequency range of 0-200Hz.The three critical frequencies observed are frequency 1@127.8Hz,frequency 12 @ 187.19Hz and frequency 13 @187.41Hz.These frequencies are

Figure 3: Boundary Conditions of the AF Assembly

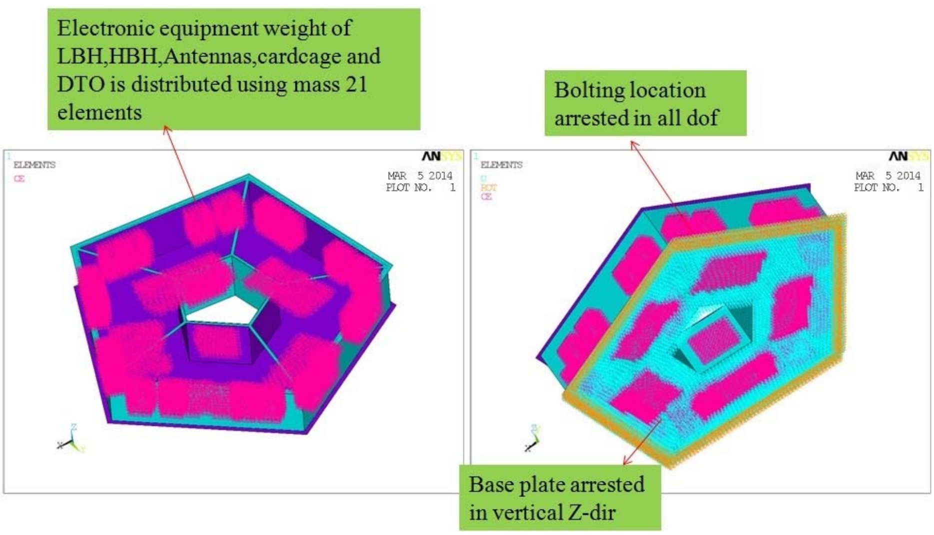


Table 2: Weight Distribution of the Electronic Equipment

weights of the electronic equipment			
Component	**No. of components**	**Unit weight(Kgs)**	**Total weight(Kgs)**
LBH	3	4	12
HBH	2	5	10
Card Cage	2	2.5	5
Antenna	16	1.8	28.8
DTO	1	1.5	1.5
Total		57.3	

Table 3: Frequencies and Mass Participation

		Participation Factor			Effective Mass		
Mode	**Frequency**	**X-dir**	**Y-dir**	**Z-dir**	**X-dir**	**Y-dir**	**Z-dir**
1	127.872	3.24E-03	-6.40E-03	0.13869	1.05E-05	4.10E-05	1.92E-02
2	131.858	-6.09E-02	-5.16E-03	5.94E-03	3.71E-03	2.66E-05	3.53E-05
3	132.432	-5.13E-03	6.11E-02	1.56E-02	2.63E-05	3.74E-03	2.45E-04
4	145.621	-1.50E-03	2.64E-03	1.32E-03	2.24E-06	6.95E-06	1.74E-06
5	145.729	6.33E-04	2.10E-03	1.88E-03	4.01E-07	4.40E-06	3.54E-06
6	166.091	6.78E-04	6.37E-04	-1.73E-04	4.59E-07	4.06E-07	3.00E-08
7	166.153	-9.59E-05	1.55E-04	2.26E-05	9.19E-09	2.39E-08	5.09E-10
8	176.26	3.65E-03	6.31E-02	7.33E-05	1.33E-05	3.98E-03	5.37E-09
9	176.28	-6.19E-02	4.03E-03	-5.40E-04	3.83E-03	1.62E-05	2.92E-07
10	178.022	2.19E-03	-6.50E-04	-1.01E-02	4.81E-06	4.22E-07	1.01E-04
11	187.046	-4.70E-02	5.06E-02	4.99E-02	2.21E-03	2.56E-03	2.49E-03
12	187.195	0.13288	3.75E-02	1.41E-02	1.77E-02	1.41E-03	1.98E-04
13	187.415	-1.99E-02	0.12551	-2.40E-02	3.94E-04	1.58E-02	5.76E-04
14	188.769	-6.38E-03	1.19E-02	-6.31E-04	4.07E-05	1.43E-04	3.99E-07
15	189.063	1.35E-03	-1.75E-02	5.84E-03	1.82E-06	3.08E-04	3.41E-05
16	198.76	-9.73E-05	-1.88E-03	2.62E-04	9.47E-09	3.52E-06	6.87E-08
17	198.906	-1.31E-03	1.22E-04	-5.31E-04	1.71E-06	1.49E-08	2.82E-07

Figure 4: Shows the 1st Mode Shape @127Hz for the Baseline Model

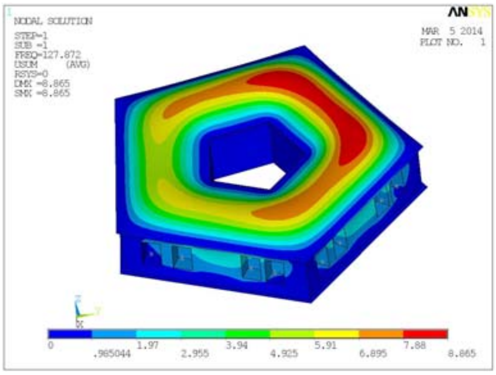


Figure 5: Shows the 12th Mode Shape @187.2Hz for the Baseline Model

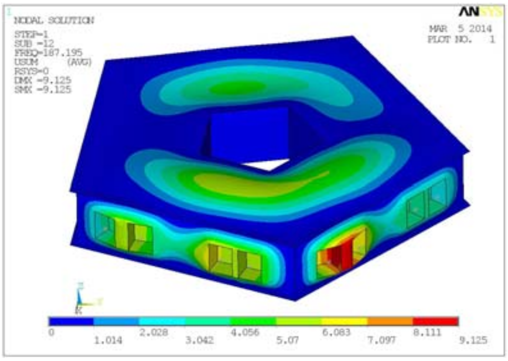
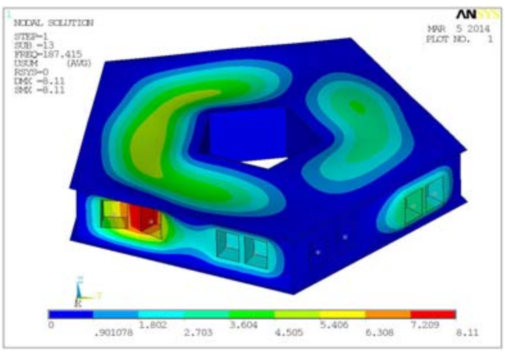


Figure 6: Shows the 13th Mode Shape @187.4Hz for the Baseline Model



critical because the frequency 1 @ 127.8 Hz has 14% of mass participation in Z-dir, the frequency 12 @ 187.19Hz has 13% of mass participation in X-dir and frequency 13 @187.41Hz has a mass participation of 12% in Y-dir. Any frequency with more than 5% of the mass participation factor is considered as critical.

So, it is necessary to shift these natural frequencies above the operating range of 0-200Hz to protect the AF assembly structure from vibrations.

Response Spectrum analysis is carried out to check the combine response of all the 17 modes in the operating range on the structure for a base excitation of 0.4mm displacement. The results are documented below.

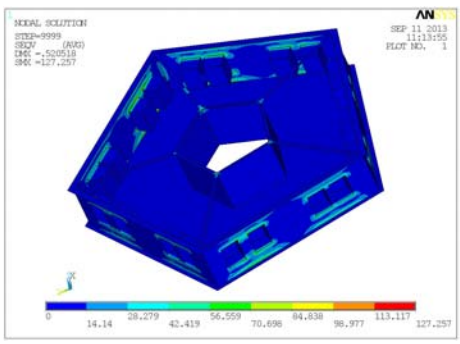
RESPONSE SPECTRUM ANALYSIS (RSA) ON THE BASELINE MODEL

Response spectrum analysis was done on the baseline model of AF assembly in the frequency range of 0-200 Hz. in X, Y and Z directions. The constant displacement of 0.4 mm is applied on the bolting nodes and the square root of the sum of the squares (SRSS) method was used to combine the total response in each direction. Maximum VonMises stress of 127N/mm2 is observed on the side antenna plate

Results of RSA-X dir

Maximum Total deformation of 0 .5mm is observed on the side antenna plate.

Figure 7: Shows the VonMises Stress of the Baseline AF for RSA in X-dir

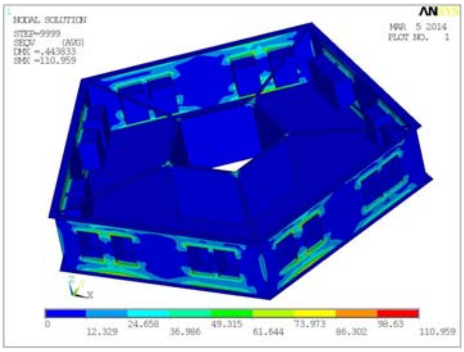


Results of RSA-Y dir

Maximum Total deformation of 0 .44mm is observed on the side antenna plate.

Maximum VonMises stress of 111N/mm2 is observed on the side antenna plate.

Figure 8: Shows the VonMises Stress of the Baseline AF for RSA in Ydir

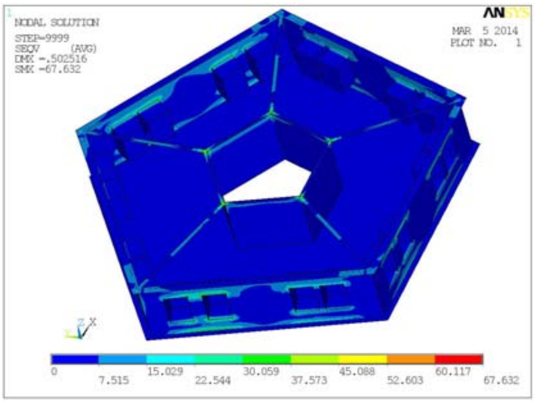


Results of RSA-Z dir

Maximum Total deformation of 0 .5mm is observed on the top cover plate

Maximum VonMises stress of 67N/mm2 is observed on the top rib

Figure 9: Shows the VonMises Stress of the Baseline AF for RSA in Z-dir



The yield strength of the aluminum material used for the AF antenna mounting structure is 160N/mm^2.From the above results the stresses in X-dir is 127N/mm^2.The factor of safety is very less. So, it is recommended that the AF antenna mounting structure assembly should be modified to sustain the random vibrations.

Table 4: The Summary of the Results of RSA X,Y and Z Directions are Given in the below

S.I No.	Summary of the Results from RSA analysis			
1	Item	RSA X-dir	RSA Y-dir	RSA Z-dir
2	Displacement (mm)	0.5	0.44	0.5
3	VonMises Stress (N/mm2)	127	111	67

THERMAL ANALYSIS OF THE BASE LINE MODEL

Boundary Conditions

Results with Radiation

Thermal analysis is performed on the Base line model of AF assembly structure to find the

Table 5: Heat Generation Values of HBH and LBH

Heat Generation	Values
LBH	42000 W/m^3
HBH	45000 W/m^3
CARD	38000 W/m^3

Table 6: Material Properties used for Thermal Analysis with Radiation are Shown in the Below

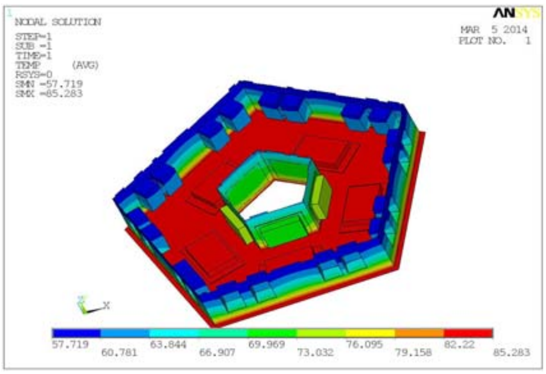
Material Properties for thermal analysis with radiation	
Density of Aluminum	2700 Kg/ m^3
Thermal Conductivity of Aluminum	235 W/m k
Emissivity of Aluminum (commercial)	0.09
Solar Energy observed by body	750 W/m^2
Stefan Boltzmann Constant	5.67E-8 W/m^2 K4

temperature distribution due to the power dissipation of LBH, HBH, and CARD and also due radiation effect.

Thermal Analysis of the Original Model of AF Result

AF Maximum temperature obtained with radiation on the AF is 85 degrees. But the threshold temperature of the homodynes is only 80 degrees. So it is recommended to change the design to operate for the given thermal conditions.

Figure 10: shows Nodal Temperature of the



From the above modal analysis results it is observed that the critical frequencies are shifted above the operating frequency zone of 0 – 200Hz.The AF is analyzed for random vibrations to check the response of the structure for the base excitation. Response Spectrum analysis is carried out to check the combine response of all the 5 modes in the operating range on the structure for a base excitation of 0.4mm displacement.

Table 7: Changes on Baseline

Changes Made on the Baseline Model		
S.No	Entity	Changes Made
1	Bottom Plate	1.Base thickness is increase from 2mm to 3mm. 2.Additional 3mm thick platform for homodyne resting 3.Additional 3mm thick pin fins added for conduction
2	Side Plates	Ribs added and decreased thickness from 10mm to 8mm
3	Antennas	Antenna cover plates thickness increased from 3 mm to 4 mm
4	Card Cage	Card cage removed and a processor of weight 1.5 kg added
5	Top Plate	Ribs of 6mm added

RESPONSE SPECTRUM ANALYSIS (RSA) ON THE MODIFIED MODEL

Response spectrum analysis was done on the modified model of AF assembly in the frequency range of 0-200 Hz. in X, Y and Z directions. The constant displacement of 0.4 mm is applied on the bolting nodes and the square root of the sum of the squares (SRSS) method was used to combine the total response in each direction.

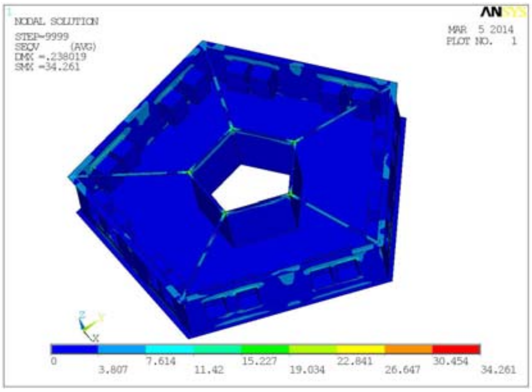
Table 3: Frequencies and Mass Participation

		Participation Factor			Effective Mass		
Mode	Frequency	X-dir	Y-dir	Z-dir	X-dir	Y-dir	Z-dir
1	163.633	1.66 E-03	-2.49 E-03	0.15554	2.75 E-06	6.20 E-06	2.42 E-02
2	167.45	-2.07 E-02	1.69 E-02	1.49 E-02	4.28 E-04	2.85 E-04	2.22 E-04
3	168.487	1.69 E-02	2.01 E-02	7.74 E-03	2.85 E-04	4.04 E-04	5.9 E-05
4	182.471	-5.55 E-04	8.09 E-04	-5.30 E-03	3.08 E-07	6.54 E-07	2.81 E-05
5	183.2	2.59 E-05	-7.12 E-04	-2.31 E-03	6.72 E-10	5.08 E-07	5.35 E-06

Results of RSA in X-dir

Maximum VonMises stress of 34.2N/mm2 is observed on the top cover plate

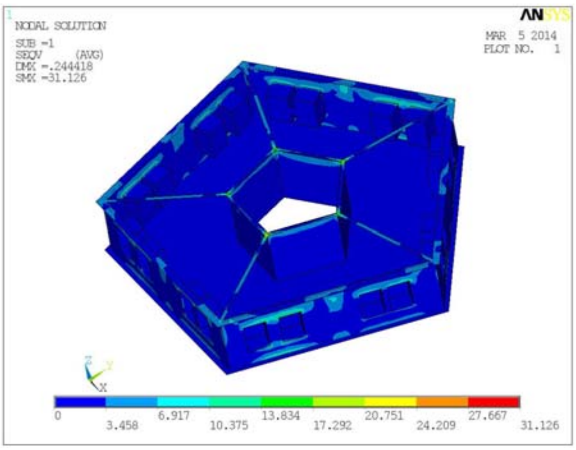
Figure 11: Shows the VonMises Stress of the Modified AF for RSA in X-dir



Results of RSA in Y-dir

Maximum VonMises stress of 31N/mm^2 is observed on the side plate

Figure 12: Shows the VonMises Stress of the Modified AF for RSA in Y-dir



Results of RSA in Z-dir

Maximum VonMises stress of 66N/mm2 is observed on the top cover plate

The summary of the results of RSA X, Y and Z directions for modified model are given in the below Table 9.

Figure 13: Shows the VonMises Stress of the Modified AF for RSA in Z-dir

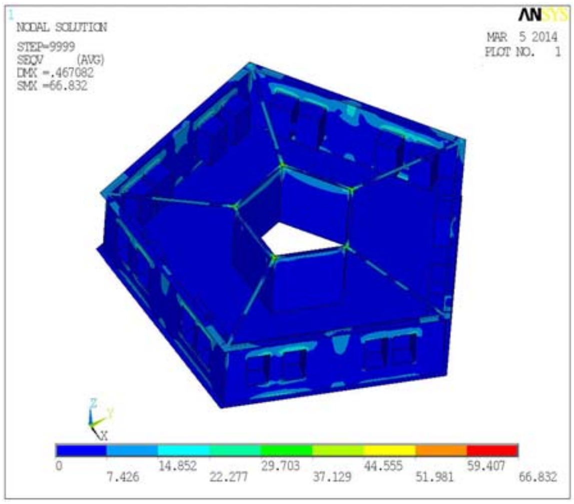


Table 9: Summary of the Results Modified from RSA Analysis

S.No.	Item	RSA X-dir	RSA Y-dir	RSA Z-dir
2	Displacement (mm)	0.23	0.24	0.46
3	VonMises Stress (N/mm^2)	34.2	31	66

POWER SPECTRUM DENSITY (PSD) ANALYSIS

PSD Analysis Along X- direction

PSD analysis is carried out on modified model of AF model with base excitation in X direction from 0-1000Hz to observe the structure behavior due to random vibrations.

VonMises Stress

The maximum 1 sigma Stress observed is 26.3N/mm^2.

The maximum 3 sigma Stress observed is 78.9 N/mm^2.

This implies that only 0.3% of the time the AF stress reaches 52.35 N/mm^2.

Figure 14: Shows the VonMises Stress of the AF for PSD in X-dir

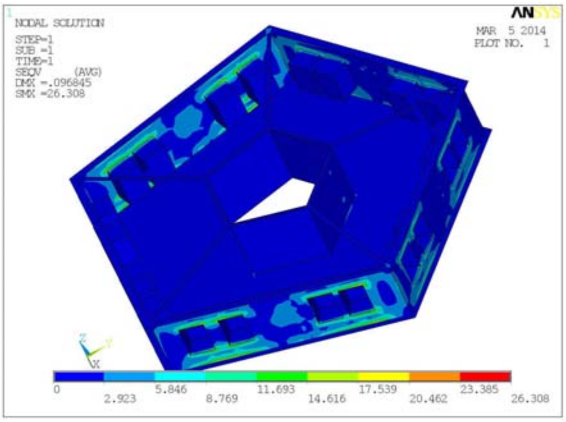
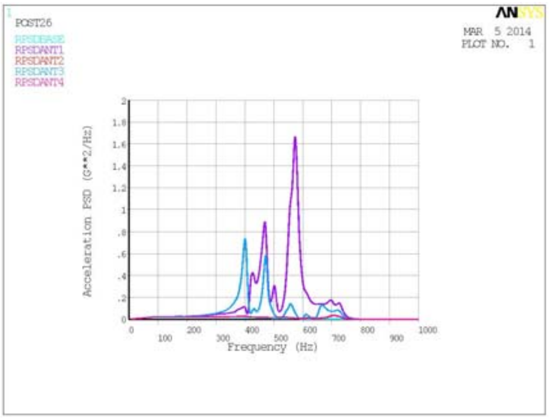


Figure 15: Shows PSD-X Response on AF Antennas in Linear and Logarithmic Scale



PSD Analysis Along Y- direction

VonMises Stress

The maximum 1 sigma Stress observed is 27.3N/ mm^2.

The maximum 3 sigma Stress observed is 81.9 N/mm^2.

This implies that only 0.3% of the time the AF stress reaches 81.9 N/mm^2.

PSD Analysis along Z-direction

VonMises Stress

The maximum 1 sigma Stress observed is 23.9N/ mm^2.

Figure 16: shows the VonMises Stress of the AF for PSD in Y-dir

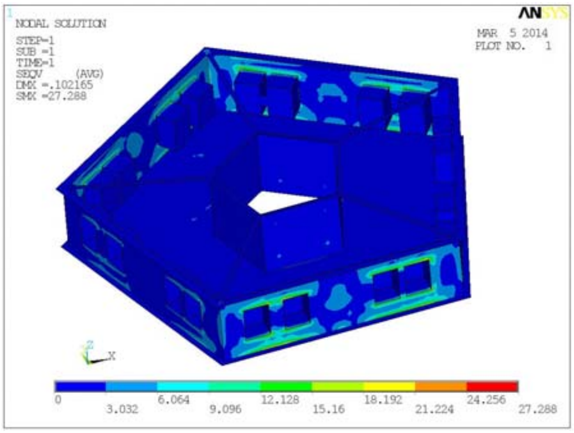
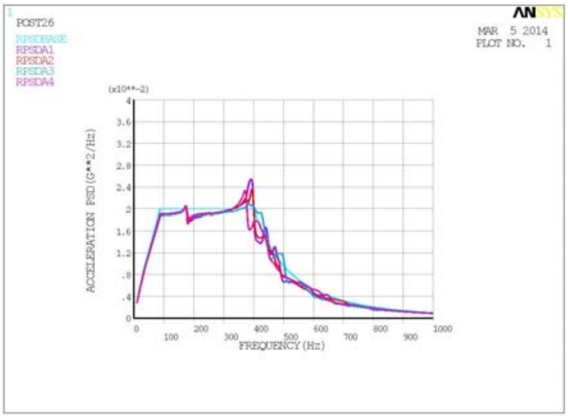


Figure 17: shows PSD-Y Response on AF Antennas in Linear and Logarithmic Scale



The maximum 3 sigma Stress observed is 71.7 N/mm^2.

This implies that only 0.3% of the time the AF stress reaches 71.7 N/mm^2.

THERMAL ANALYSIS OF THE MODIFIED MODEL

Results with Radiation

Thermal analysis is performed on the Modified model of AF assembly structure to find the temperature distribution due to the power dissipation of LBH, HBH, CARD and also due radiation effect.

Figure 18: Shows the VonMises Stress of the AF for PSD in Z-dir

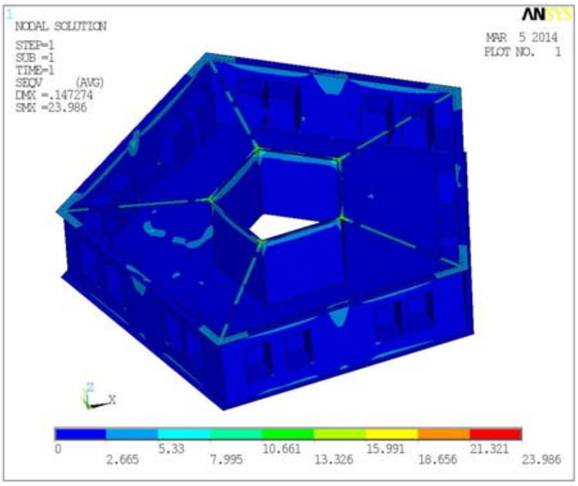


Figure 19: Shows PSD-Z Response on AF Antenna in Linear and Logarithmic Scale

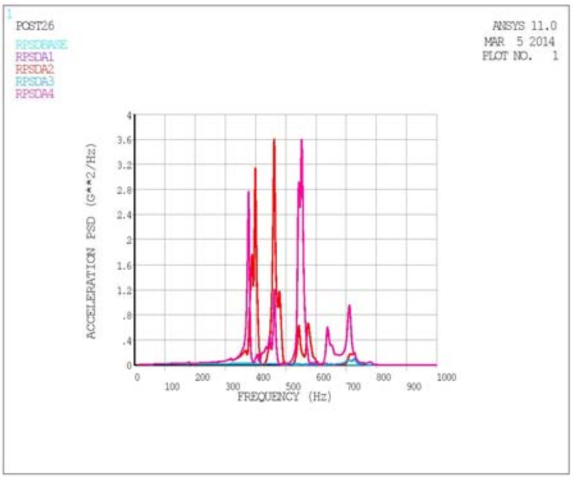
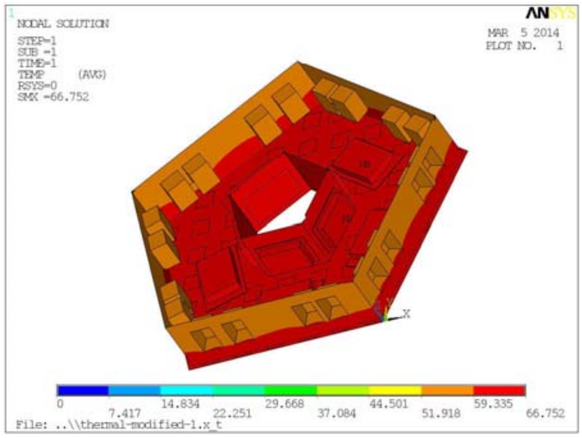


Table 10: Material Properties for Thermal Analysis with Radiation

Material Properties for thermal analysis with radiation	
Density of Aluminum	2700 Kg/ m^3
Thermal Conductivity of Aluminum	235 W/m k
Emissivity of Aluminum (commercial)	0.09
Solar Energy observed by body	750 W/m^2
Stefan Boltzmann Constant	5.67E-8 W/m^2 K4

Figure 20: Shows Nodal Temperature of the modified AF Antenna Mounting Frame



Material Properties used for thermal analysis with radiation are shown in the below table

Thermal Analysis of the AF Modified Model Results

The maximum temperature observed is 66.7 degrees with radiation on the modified AF antenna mounting frame. It can be concluded that the structure is safe for the operating thermal loads.

RESULTS AND DISCUSSION

AF was studied for 3 different cases for baseline and modified model:

- Modal Analysis
- Response Spectrum Analysis
- Power Spectrum Density analysis
- Thermal Analysis

The following observations were made from the modal analysis of the baseline model:

From the modal analysis on the baseline model it is observed that there exists 3 critical natural frequency in the operation frequency range of 0-200Hz.It is necessary to shift these natural frequencies above the operating range of 0-

200Hz to protect the AF assembly structure from vibrations.

The following observations were made from the Thermal analysis of the baseline model:

The threshold temperature of homodynes is 80^0C with radiation. But as per the thermal analysis the max temperature observed is 86^0C.So modifications are required for the AF assembly for more heat transfer.

From the above two analysis it is concluded that the AF requires some changes. These changes are implemented in the modified model and Modal Analysis, Response Spectrum, Power Spectrum Density analysis and Thermal Analysis were carried out to check the frequencies and temperature.

The following observations are made on the Modified AF

It is observed that the critical natural frequency in the operation frequency range of 0-200Hz was shifted to above 200Hz due to the changes implemented.

From the above thermal analysis it is observed that the temperatures are below the threshold temperature of homodynes i, e 80^0C.

Maximum temperature observed is 66^0C

CONCLUSION

In the present paper a AF has been designed and optimized for vibration control and temperatures. Naval Radar Frame (NRF) was studied for 4 different cases for baseline and modified model

- Modal Analysis
- Response Spectrum Analysis
- Power Spectrum Density analysis
- Thermal Analysis

From the above analysis it is concluded that that the critical natural frequencies in the operation frequency range of 0-200Hz were shifted to above 200Hz 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 80^0C.

Therefore it concluded that the modified AF is safe under the given operating conditions.

FUTURE SCOPE

As the AF is mounted on the top of the ship it is subjected to shock loads as well.

So, Shock analysis has to be carried out to check the structure behavior for shock loads in X, Y and Z directions.

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