Structural Dynamic Analysis of FM Transmitter against specific Random Vibration

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ABSTRACT

One of the most important components of modern aviation is the avionic system, control, guidance, and communication system. One common aim in military applications is to design and manufacture systems that possess a useful life of at least 20 years with high reliability. Various materials and interfaces are used in electronic systems, making the systems very complex. Moreover, electronic systems are subjected to various environmental conditions during storage, handling, transportation, and operation. As a result, there are a variety of failure modes. According to a study on the hardware failure rates of military aircraft electronic systems in the US, 40% of failures occur in electrical connectors, 30% in cables and harnesses, 20% in electronic components, and 10% are caused by other factors. In this thesis, a dynamic analysis of the Frequency Modular Transmitter package that consists of an electronic box, printed circuit boards, and electronic components are presented. Detailed vibration analysis of an electronic assembly is performed by finite element methods using ANSYS. FM Transmitter package is subjected to the random vibration spectrum from 20Hz to 2000Hz frequency range. Mode shapes and Natural Frequencies are obtained by giving the fixed support boundary conditions near the four bolts. And also, Response Power Spectral Density curve has been drawn to find the maximum vibration response at which the structure is experiencing vibration excitation in the respective directions of X, Y, and Z.

Keywords- FM Transmitter, Structural Dynamic Analysis, Finite Element Modal Analysis, Random Vibration Analysis

INTRODUCTION

In vibrations, the maximum displacement is the amplitude. A sudden change in the direction or magnitude of a velocity vector or the sudden application of force causes a shock, which disturbs the balance in a system. A simple airframe structure, such as those found on airplanes and missiles, does not transmit shock easily. The natural airframe frequencies contribute to transient vibrations caused by impact forces. Random vibration more closely represents the environment in which the equipment will operate included in this are planes, missiles, automobiles, etc. In order to ensure the safety of the system during its launch and landing, a redundant system is employed on the missile. This additional system consists of a motor that is powered by an electronic control unit, such as a transmitter mounted inside the missile. If these transmitters are exposed to vibrations, then this may cause them to fail. Therefore, vibration analysis should be investigated to prevent component failures in the future. In modern electronic equipments, which is used widely in military applications, must be able to survive in harsh environmental conditions for the life cycle of 20 years and more. The Frequency Modular Transmitter on which it is subjected to dynamic loads that is, loads whose magnitude as well as direction of action and/or position vary with time. In this, the analysis of stresses and deflections developed in a FM Transmitter undergoing dynamic loads is the fundamental objective. A modal analysis has to be completed on the system to provide the dynamic characteristics of the system. The natural frequencies and mode shapes are combined appropriately to give the structural response of the system. Random Vibration Analysis (RVA) is done to calculate the system's structural response to spectrum of random excitations and non-deterministic loads. RVA is conducted in the frequency domain and is usually performed over a large range of frequencies from 20 to 20,000Hz. the loads are applied in the X, Y, and Z directions separately. The loads are described by power spectral density (PSD) functions. The PSD functions are a measure of a vibration's intensity in the frequency domain.

LITERATURE SURVEY

Ren Guoquan1 et al [1] published a paper on Modal analysis of printed circuit board based on finite element method. In this paper, the vibration characteristics of PCB have been studied by performing the finite element model in ANSYS of the PCB for the theory of modal analysis. The modal parameter identification technology is used to experiment with modal analysis. The theoretical and experimental results are basically consistent. Under the premise of the correct model, a quantitative analysis of the impact of a PCB thickness on its natural frequency is made in ANSYS. The results show that the natural frequency of the PCB increases with the increase of the thickness, and the higher-order leads to faster growth, which will provide a reference for the PCB design.

Banu Aytekint et al [2] published a paper on Vibration analysis of a simply supported PCB with a component- An analytical approach. In this paper, the dynamic analysis of aprinted circuit board (PCB) a component on it under a vibratory loading has been performed. The main objective is to study and develop an analytical model for common PCB configurations and electronic components on them. In order to find the dynamics of the assembly under vibratory loading, and to study the effects of component location. In this paper an analytical model simply supported PCB with a component is presented. The validity of the two degrees of freedom analytical model is demonstrated by comparing numerical results for random vibration input with those of a finite element model.

M.D. Prashanth [3] published a paper on Vibrational analysis of a printed circuit board: Effect of a boundary condition. In this paper, An electronic package consisting of printed circuit boards assembly inserted in mechanical housing. When the spacecraft experiences various types of loads during its launch such as vibration, acoustic, and shock loads the Prediction of response for printed circuit boards due to vibration loads is important for the mechanical design and reliability of electronic packages. For accurate prediction of response due to vibration loads,
the modeling and analysis of printed circuit boards is required at which the response of PCB is highly dependent on the mounting configuration of PCB. To reduce the PCB response, anti-vibration mounts or stiffeners are used. Vibration analysis of printed circuit boards is carried out using the finite element method. The main objective of this paper is to determine the dynamic characteristics of a printed circuit board. Modeling and analysis of PCB is tobe carried out to study the effect of boundary conditions onthe vibration response. The modeling of stiffeners or ribs are also be considered in detail. The analysis results is validated using vibration tests of PCB.

Somashekar V.N et al [4] published a paper on Vibration Response Prediction of the Printed Circuit Boards using Experimentally Validated Finite Element Model. In this paper, The electronic package consists of printed circuit boards are placed in mechanical housings which are stacked together. An electronic package design for vibration loads is verified by conducting tests on actual hardware. In this paper, the dynamic characteristics of the PCB is determined accurately using a basic FEA tool andto avoid the costly testing methods which require hardware.Here using vibration tests on PCB, the normal modes & frequency response functions (FRF) of PCB are determined and validated. The validated model is used to predict vibration response for random vibration input. In this paperit is shown that how the responses are accurately predicted for random vibration input for a design parameter variation of PCB and the results are also validated using a vibration
test on PCB.

Venkat et al [5] published a paper on Vibration Analysis ofPrinted Circuit Board Plates with Varying Boundary Conditions. In this paper, more than 6 layers of Printed Circuit Board (PCB) is used in military applications, with pre-preg and copper composition. As the multiple layers of PCBs E value will vary from one design to another due to its dependance on composition of the layers. These PCB plates are subjected to vibration loads, the E value obtained
was used in the FEM analysis (using ANSYS 16) to solve the vibration response of the PCB. This study also

includes analytical calculation and experimental estimation of the natural frequency for different boundary conditions of the PCB plate. The natural frequency estimation through analytical and experimental methods show good correlation thus validating the estimation procedure of E of the PCB as well. This work gives us a robust method for estimating Young's modulus of Multi-layer PCB which finds application in a variety of military electronics.

Ogbuanya T.C et al [6] published a paper on The Design and Construction of a Frequency Modulated (FM) Transmitter with Output Capacity of 10 Watts and Range above 4km. In this paper, FM Transmitter is designed and constructed in cheap price, simple maintenance, efficient which operates ona low power supply. 10-watt FM Transmitter is designed and constructed within a range of 4km in free air. Research and development (R&D) were used for the study, the necessary tools and materials were acquired. Design procedure involving the modification of an output of a transmitter was adopted. Based on the procedures used and the tests that carried out, the specific findings included are appreciable range with the stable frequency of transmission obtained on a power source devised from a 12v lead-acid battery. Various instructional applications and mass production strategies were outlined. The completion of this study has found that practical frequency modulated FM transmitters requiring low power can be designed and constructed in the appreciable range of FM transmitter on the low power supply has been achieved in this works, further studies in areas of signal coupling technique need to be carried to improve the range of transmission.

Liangjun Xu et al [7] published a paper on Research on a dynamic model of printed circuit board based on finite element method. In this method, the reliability of the electronic components installed on the surface is related to the vibration characteristics of printed circuit boards. In this paper, the material properties of the printed circuit board are analyzed by establishing the dynamic model of the anisotropic printed circuit board. The influence of boundary conditions and lumped mass on the vibration characteristics of the printed circuit boards are analyzed.

METHODOLOGY

This thesis firstly aimed to understand the dynamic behaviour of an FM Transmitter package assembly mounted in the airframe with the help of four bolts. The package consists of Modulator PCB, Modulator PCB-I, Power supply PCB, Power amplifier PCB and Filter PCB this assembly is under vibratory loading that is random in nature. Based on the experimental data, FM Transmitter is designed in SOLIDWORKS 3D model software and finite element analysis done in ANSYS software. It is important to understand the dynamic characteristics of packaging configuration using modal analysis to prevent the components from failure. Using Modal analysis, the naturalfrequencies and the mode shapes are determined at which the structure will resonate in the absence of external excitations. The graph between the frequency vs amplitude which is the Power spectrum density curve has shown the response of the package to the spectrum of random excitations. Random Vibration analysis is conducted in a frequency domain and is performed under 20-2000Hz of large range frequencies which is generally used n missile applications

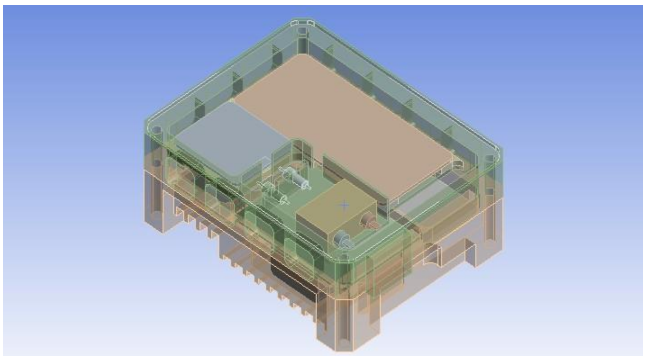
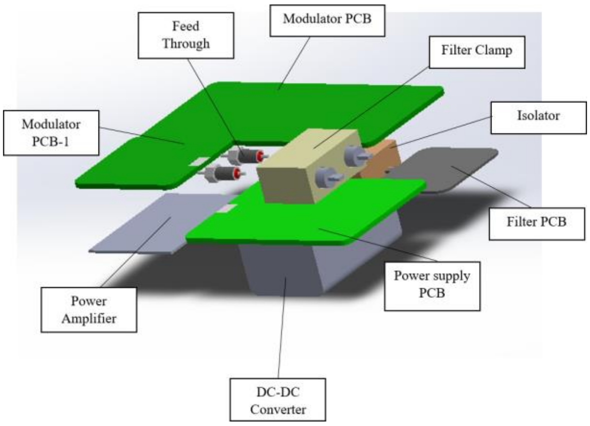


Fig 1. Frequency Modular Transmitter package

FM Transmitter package is enclosed in a top deck and bottom deck sub-assembly which consists of five printed circuit boards (PCBs) namely Modulator PCB, Modulator PCB-I, Power supply PCB, Power amplifier PCB and

FilterPCB. It also has feed through, isolator, filters, and filter clamp as shown in the figure. Top deck and button deck were attached with four bolts This FM Transmitter package is mounted in the airframe with the help of



four bolts. Solidelement SOLID92 of ANSYS® was used for modelling thepackaging components.

Fig 2. FM Transmitter package consisting of various PCBs

Aluminium material properties are considered for the chassis and FR-4 material properties are considered for the PCBs. The properties of the FM Transmitter package and PCBs used in the FEA model are shown in the table.

S.No	Components	Material Used	Young's Modulus (Mpa)	Poisson's Ratio	Density (kg/m^3)
1.	PCBs	FR-4	1.11E+10	0.28	1900
2.	Chassis	Aluminum Alloy	7.0E+10	0.3	2780

Mode	Frequency (Hz)
1	1226.8
2	1673
3	2357.9
4	3073.2
5	4744

Table 1. FM Transmitter package material parameters

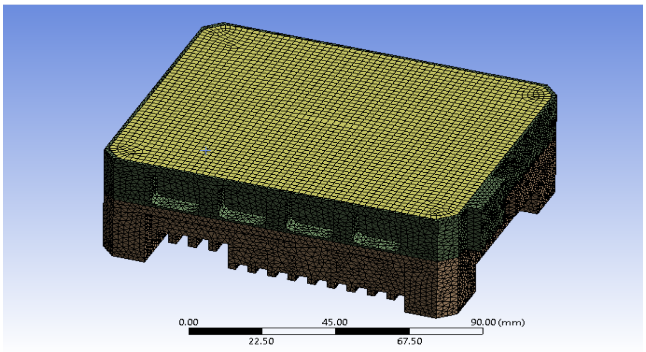


Fig 3. Mesh of the FM Transmitter

Boundary Conditions are given at the bottom deck sub assembly by giving the fixed support at the bottom with thehelp of four bolts which is to be mounted in the air frame.

Frequency(Hz)	PSD (g^2/Hz)
20	0.0125
40	0.5
1000	0.5
1600	0.05
2000	0.05

Table 2 PSD G Acceleration tabular input

RESULTS AND DISCUSSIONS

In this research, based on the modal analysis, the structural vibration characteristics of an FM Transmitter package are determined to find the areas of weakness in an assembly. Specifically, for missiles the frequency range varies from

20 to 2000Hz. By including the Modal section in our analysis sequence, and setting the ANSYS software to find 6 maximum nodes for our geometry, it creates mode shape results for 6 nodes. By evaluating the results, we finally getfrequency, total deformation, and displacement corresponding to those 6 nodes.

Table 3. Modes with respect to its Frequencies

Random Vibration Analysis of FM Transmitter inX-Direction

Directional Deformation in X-axis

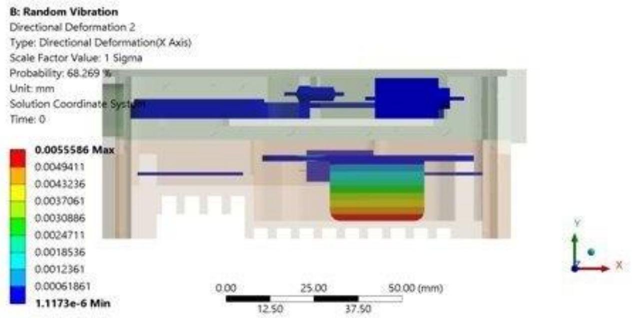


Fig 4. Directional Deformation of FM Transmitter inX-axis

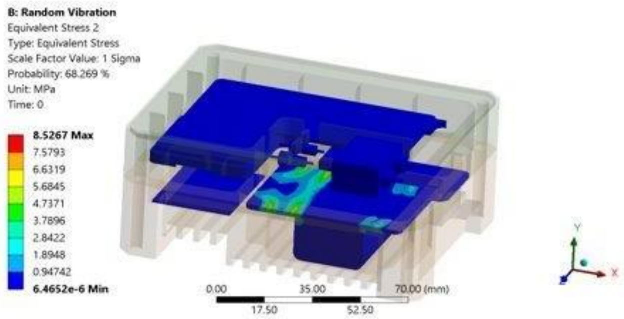
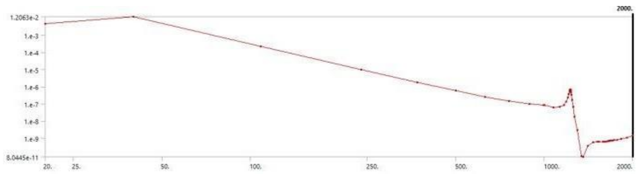


Fig 5. .Equivalent stress in X- direction



Graph 1. Directional Deformation in Y-axis Random Vibration Analysis of FM Transmitter inY-Direction

Directional Deformation in Y-axis

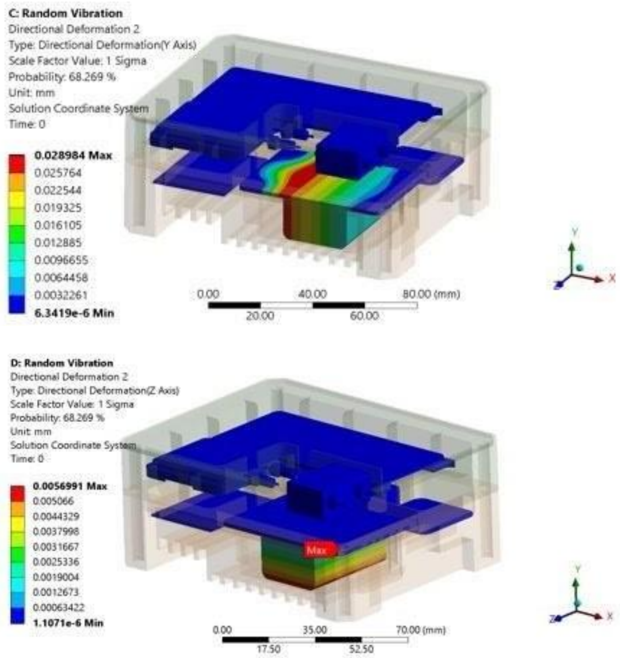


Fig 6. Directional Deformation of FM Transmitter inY-axis

Equivalent stress in Y-direction

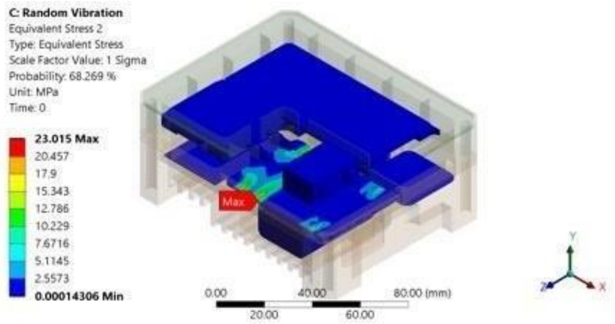
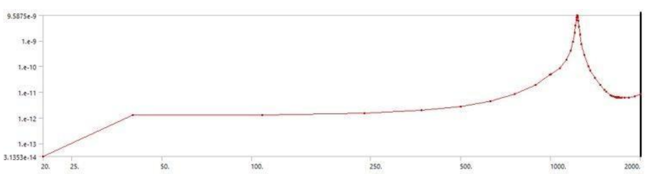


Fig 7. Equivalent stress in Y- direction



Graph 2. Response PSD graph at top deck sub-assembly inY-direction

Random Vibrational Analysis of FM Transmitter in Z -Direction

Directional Deformation of FM Transmitter in Z-axis

Fig 8. Directional Deformation of FM Transmitter in Z-axisEquivalent stress in Z-direction

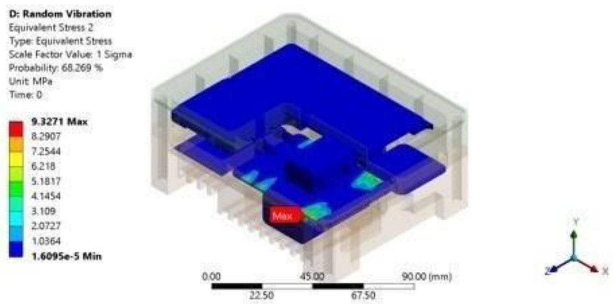
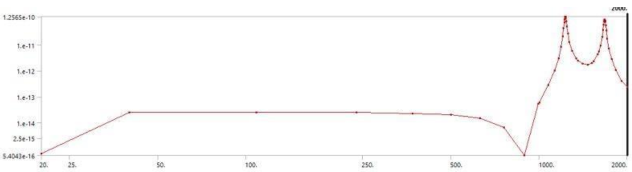


Fig 9. Equivalent stress in Z- direction



Graph 3. Response PSD graph at the Bottom DeckAssembly in Z-direction

CONCLUSION

In this paper, the dynamic characteristics of packaging configuration using modal analysis to prevent the components from failure are obtained. Using Modal analysis, the natural frequencies and the mode shapes are determined at which the structure will resonate in the absence of external excitations. The graph between the frequency vs amplitude which is the Power spectrum density curve has shown the response of the package to the spectrum of random excitations. The maximum deformationand stress is found in Y-direction.

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