# STRUCTURAL STABILITY ANALYSIS OF RADOME WITH LIQUID TUNED FSS

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## ABSTRACT

A special purpose radar absorption structure (RAS) has been developed using fiber-reinforced composites with excellent mechanical and electrical properties. The RAS is an element made up of complex structure and materials used in stealth technology. Frequency Selective Surface (FSS) is one of the most representative form of RAS. In this study, we investigated the possibility of active FSS with microchannel structure which can be activated on military aircraft radome. The micro channel is arranged in parallel inside of the radome and can regulate the flow of liquid inside to change the state of the FSS. The micro channel inside the radome and the stacking sequence and fiber orientation of the composite reinforcing the surface of the will affect the structural stability of the radome. We analyzed the structural stability of the radome by using the finite element analysis to simulate the inertia force during highly maneuverable flight situation. In addition, the designed FSS has confirmed that it is "transparent" electronically in the target X-band frequency area.

## 1 INTRODUCTION

Fiber-reinforced plastics have good mechanical and electrical properties and are used in many applications. One of the areas where composites are performing well is military stealth technology. Stealth technology is essential to take advantage of the radar-dominated modern warfare. Radar cross section (RCS) is an indicator of how well objects are detected on the radar. The smaller this value is, the less it is detected. Radar absorbing materials (RAM) and Radar absorbing structures (RAS) are usually used to reduce RCS. In this study, we discussed FSS, which is a representative method of RCS.

Due to the irregularity of the ground surface, radar is often used to detect airborne objects in the sky. Therefore, the stealth performance of an airplane is essential for survival. Military airplanes have a special reflective form of radar to enhance stealth performance. However, allied fighters must use their own radar to detect enemy fighters. The front and back sentences take the form of paradox. And a frequency selective surface (FSS) makes it possible. The FSS acts as a bandpass filter for radio waves. It transmits radio waves only in the specific band we want and reflects the remainder. This allows you to avoid enemy radar while using friendly radar.

Most of the existing FSSs are passive type. It is built into the radome that protects the fighter's radar, and the specific frequency range is always open If information about the frequency band is leaked, an electrical attack can come through the opened radio window. There has been a problem with this, and the need for the development of an active FSS that opens and closes the radio window has been raised. In this study, we implemented active FSS using micro channel structure. Existing FSSs using liquids have used metal slug, mercury, or liquid crystals. However, this study showed that even water can function as an active FSS.

The micro channel structure of the radome causes internal stress concentration and degrades the structural stability. Military airplanes are more likely to be exposed to highly maneuverable flight situation during their mission. Inertia force applies a large load to the structure. If the structure is not

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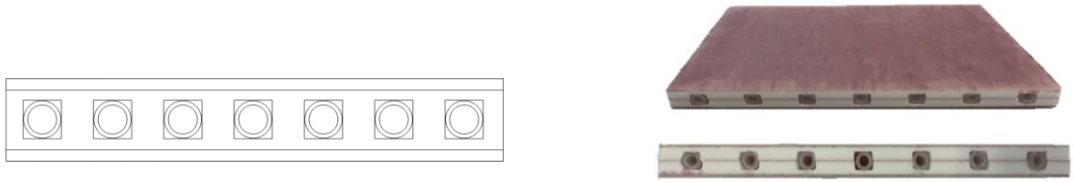
sufficiently stable, it can lead to failure of the structure. In this study, structural stability of a radome scale model with a micro channel structure was investigated using finite element analysis.

## 2 METHOD

Small FSS specimens are designed to check mechanical and electrical properties. The FSS is designed to be 10 GHz, the frequency of the X-band region, which is the most widely used for fighter radar. We also created a model for computer simulation verification. The electrical properties of the specimens were tested and the both mechanical and electrical properties of the model were verified.

The dimensions of the FSS were designed with reference to the reduced radome model. The FSS is made up with E-glass/epoxy composite laminate, silicon tube and aerospace foam (Rohacell, HF-71). Design shape and fabricated FSS specimen can be seen in Figure 1 and its design parameters are shown in Table 1. In the process of fabricating the FSS, a square hole is formed at regular intervals in the aerospace foam, and the silicon tubes are planted there. Next, a glass-epoxy composite reinforcing structure is bonded to the front and back of the foam. To confirm the effect of curved surface shape of FSS on performance, we also fabricated FSS with single curvature (R = 543mm). All parts were assembled using EA9309.NA adhesive.

Propagation analysis of the designed FSS was performed through CST Microwave-studio. All the various states of the FSS have been tested. To verify the results of the simulation, the actual propagation characteristics of the specimen were performed using the free space measurement method.



(a) (b)

Figure 1: FSS design: (a) Shape of FSS; (b) Fabricated FSS

Finite element analysis was performed to understand the structural stability of the radome in the high maneuverability flight situation. The radome model is made in tangent ogive form. The micro channel is composed of aerospace foam and E-glass/epoxy composite is used to strengthen the front and back surfaces. The stacking sequence of the composite material was [0/90/0] s and was made with a total of 6ply. The gravitational acceleration of 7.5G was applied to both the axial direction and the horizontal direction by simulating the inertial force generated during sharp turn. There are two types of radome's failure determinations. First, we should check the Von-Mises stress distribution inside the foam that makes up the radome. Second, identify the Tsai-Wu index of the composite laminate on the surface of the radome. If both failure criteria are not satisfied at the same time, it is structurally stable.

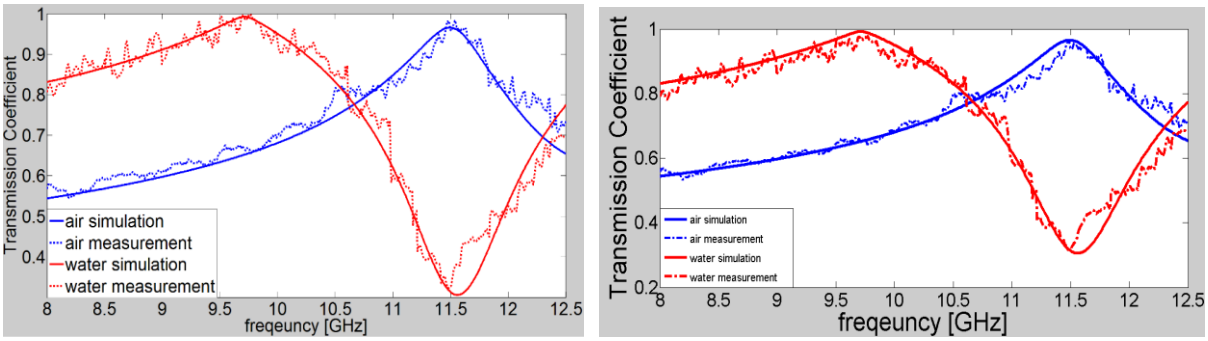
| Design parameter | | Value |
|---|---|---|
| Slab size | [mm] | 100 x 100 |
| Foam thickness | [mm] | 6.4 |
| Foam dielectric constant | – | 1.093 |
| Laminate thickness | [mm] | 0.6 |
| Laminate dielectric constant | – | 4.35 |
| Channel size | [mm] | 4 x 4 |
| Silicon tube thickness | [mm] | 0.5 |
| Silicon tube spacing | [mm] | 10 |
| Silicon tube dielectric constant | – | 11.9 |

Table 1: Design parameters of fabricated FSS.

## 3 RESULTS

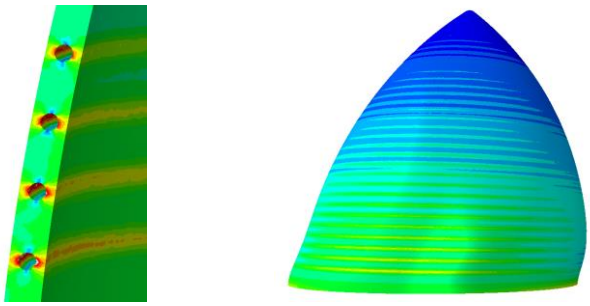
Figure 2 shows the results of the FSS performance test. The red graph shows water in the micro channel and the blue graph shows the opposite. It was confirmed that the performance of FSS measured by free space measurement is almost the same as that obtained by computer simulation. Also, the radio wave transmittance is significantly increased at the 10 GHz designed by the target value. As a result, it was confirmed that micro channel type FSS using water can operate in an active manner.

Structural stability analysis results show that the structure of radome with micro channel FSS is quite safe. The maximum Von-Mises stress in the foam part of the FSS was observed around the micro channel. The maximum Von-Mises stress was lower than the yield stress of the foam. The highest Tsai-Wu index of the total ply of the E-glass/epoxy composite on the FSS surface was much smaller than 1, confirming that the fracture did not occur.



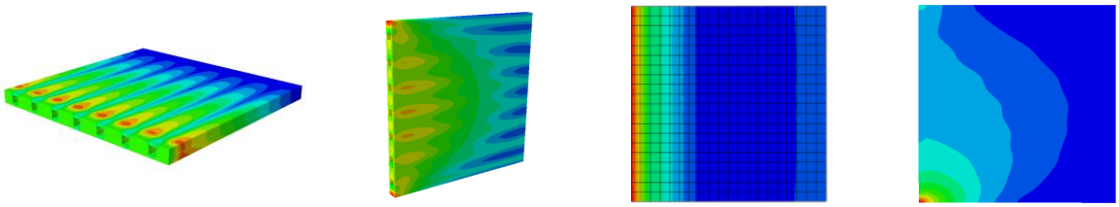

(a) (b)

Figure 2: FSS performance test result: (a) plane; (b) single curvature (R = 543mm)



(a) (b)

Figure 3: Stress distribution tangent ogive: (a) Stress concentration near micro channel; (b) deformation by inertia



(a) (b) (c) (d)

Figure 4: Failure criteria of FSS specimen: (a) Von-Mises horizontal; (b) Von-Mises vertical; (c) Tsai-Wu horizontal; (d) Tsai-Wu vertical;

## ACKNOWLEDGEMENTS

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