A Novel Ultra Wide Band Radar Absorber Based on Hexagonal Resistive Patch FSS

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***Abstract*—Design and development of a novel Ultra Wide Band (UWB) panel Radar Absorbing Material (RAM) with Radar Cross Section Reduction (RCSR) of 10 dB (minimum) from 1.7 GHz. to 25 GHz. using hexagonal resistive patch Frequency Selective Surface (FSS) is presented in this paper. The four layers RAM is analyzed using transmission line model (TLM) and full-wave analysis of the design is carried out using HFSS v15 simulation software. The resistive FSS layers are designed as electrically very thin PCBs using 0.2 mm thick FR4 substrate. The prototype RAM is developed as a panel of size (280 mm x 280 mm). The thickness of panel RAM is** 16.8 mm**. and the weight is** 190 gm**. Monostatic RCS measurements are carried out on RAM in microwave anechoic chamber. Experimental and simulation results agree very well.**

***Keywords*—FSS, Jauman absorber, RAM,RCS,RCSR.**

I. Introduction

Broad band Radar Absorbing Materials (RAMs) with weight and thickness constraints are crucial for radar cross section reduction (RCSR) of air-vehicle surfaces. But wide RCSR bandwidths and low thickness are conflicting requirements. Wide band Jaumann radar absorbers with novel chip resistor spacecloths is described in [1] and resistive fractal FSS based 3 to 12 GHz. RAM is described in [2]. Circuit analog wide band RAM based on *low pass* resistive FSS is reported in [3].

In this paper, a novel UWB panel RAM is presented with an RCSR of 10 dB (minimum) from 1.7 GHz. to 25 GHz. The design is analyzed using transmission line equivalent circuit model and optimized in HFSS v15 simulation software. The four resistive FSS layers are designed as PCBS and fabricated using accurate photolithographic technology, thus translating the design to accurate and reliable hardware. The UWB panel RAM construction is highly weight efficient with thickness constraints. The panel RAM is tested for its RCSR in microwave anechoic chamber to verify the design.

II. EM Design and Simulation of UWB Panel RAM

For a non-magnetic dielectric RAM, which is broadband, minimum thickness constraint is given by Rozanov [4] as

$$\lambda_{max} \, \Gamma_0 \leq 172 \, d \ldots\ldots (1)$$

λ_{max} is the wavelength at the lowest frequency, Γ_0 is the reflection coefficient in dB and d is the total thickness of RAM. Accordingly, the least thickness of a -10 dB UWB RAM such as proposed in this paper cannot be less than 1/17 of the largest operating wavelength which is calculated to be 10.4 mm. The total thickness of RAM proposed in this paper is 16.8 mm and hence does not violate the fundamental design rules given in [4].

The dielectric profile of RAM is given in Fig. 1. The four resistive FSS layers are each backed by RF transparent dielectric spacers, finally backed by the conducting plane, which needs to be shielded. The transmission line equivalent circuit model of RAM is shown in Fig. 2(a). Each resistive FSS layer is modeled as a series RC circuit, in shunt with the short circuited transmission line. The dielectric spacers are each modeled as transmission lines of lengths d1, d2, d3 and d4. Two degrees of freedom of the FSS geometry namely the length of the side of regular hexagon patch and the pitch simplify the design of RAM for realizing the desired UWB RCSR performance. The design details of RAM are given in Table 1.

Fig. 1. Dielectric profile of UWB panel RAM.

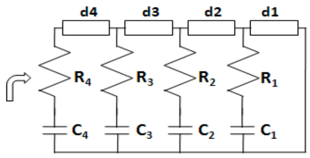

Fig.2 (a). Transmission line model of four layers RAM.

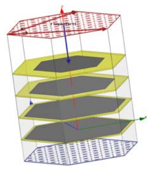

Fig.2 (b). Unit cell geometry model of four layers RAM in HFSS.

The unit cell geometry model of RAM in HFSS is shown in Fig. 2(b). Layer 1 is the FSS next to the conducting backplane.

A commercially available resistive sheet of 100 Ω/sq. is used for etching the desired resistive hexagon geometry for all the four layers. The thickness of each Rohacel foam dielectric spacer is 4 mm.

Table 1. Design details of 4 layer UWB RAM.

	patch side length(mm)	Spacing between patches(mm)
Layer1	9.5	0.86
Layer2	9.0	1.72
Layer3	7.6	4.14
Layer4	6.3	6.4

The optimized simulation performance of RAM for normal incidence is given in Fig. 3 for both TE and TM incidence. From the plot it is observed that the RAM performs equally well for both TE and TM modes and hence is suited for circular polarization. Next, the AOI is varied from 0 to 30° and the performance is given in Fig. 4, for TE incidence. It is observed that the UWB RAM can be used for AOI up to 30° without any degradation in performance. For TM incidence, it is observed that the RCSR performance shifts from 1.6 GHz, to 1.7 GHz, still meeting the desired specifications of RCSR of 10 dB from 1.7 GHz.

III. Development of UWB Panel RAM

The four FSS layers of prototype panel RAM are designed as electrically thin PCBs using FR4 substrate of thickness 0.2 mm each, using Visula v2.3 software and are fabricated using a highly accurate PCB fabrication facility and assembled with the Rohacel foam layers. A tin plated copper foil is used as the conducting backplane. A photograph of the assembled UWB panel RAM is shown in Fig. 5 (a).

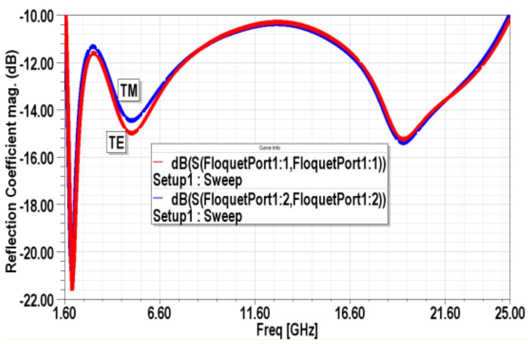

Fig. 3. Optimized simulation performance of RAM for TE and TM incidences, for normal incidence.

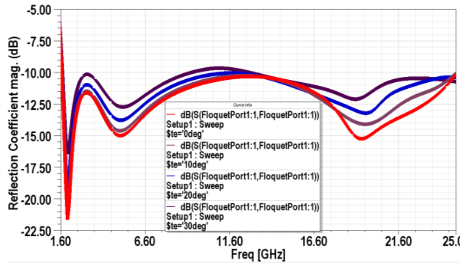

Fig. 4. RAM performance with various AOI from 0 to 30 degrees.

IV. RCS Measurements

Monostatic RCS measurements are carried out on RAM in the microwave anechoic chamber, in C and X bands and are available. It is observed that the measured and simulated results agree closely within 1 dB in C and X bands and are plotted in Fig. 5(b).

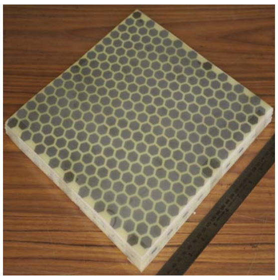

Fig. 5 (a). Photograph of the UWB Panel RAM. Thickness = 16.8 mm.

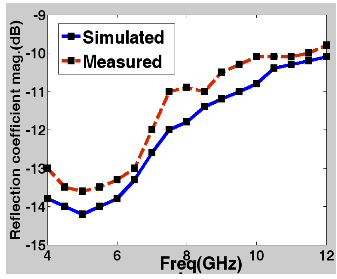

Fig. 5 (b). Comparison of simulation and experimental RCS of UWB panel RAM in C and X bands. Polarization: VP.

V. Conclusion

The novel UWB panel RAM with weight and thickness constraints meets all desired specifications and can be tailored as a radar absorbing structure for aircraft stealth applications.

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