Radar Cross Section Measurements (8-12 GHz) of Magnetic and Dielectric Microwave Absorbing Thin Sheets

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The aim of this work is to present radar cross section (RCS) measurements of a panel constituted of a flat aluminum plate with and without radar absorbing materials (RAM) type thin rubber sheets, in the range of 8 – 12 GHz. Two different loads were evaluated in the RAM formulation: 1. Magnetic (ferrites - MnZn, NiZn and MgZn based), and 2. Dielectric (conducting polymers - polyaniline based). The measurements were carried out in the anechoic chamber at Centro Técnico Aeroespacial (CTA)-Ministério da Defesa facilities of São José dos Campos-SP, Brazil, and the RAM manufacturing in the Divisão de Materiais/IAE/CTA. The RCS measurements, in square meters, were estimated using theoretical values from reflectors with controlled dimensions. The RCS results showed a RCS reduction of 55-95% and of 40-80%, when the magnetic and the dielectric panels were impinged at normal incidence, respectively.

Key words:Radar cross section, radar absorbing material, RAM, magnetic absorber, dielectric absorber, ferrites, conducting polymers, polyaniline.

I Introduction

Radar absorbing materials can be classified in two broad categories, either dielectric or magnetic absorbers [1-7]. Dielectric absorbers depend on the ohmic loss of energy that can be achieved by loading lossy fillers like carbon, graphite, conducting polymers or metal particles/powder into a polymeric matrix. Among the dielectric properties can be cited the dielectric constant and the loss tangent ($\tan\delta$). Magnetic absorbers depend on the magnetic hysteresis effect, which is obtained when particles like ferrites are filled into a polymeric matrix [4,5].

The RCS can technically be defined as the area of a fictitious perfect reflector of electromagnetic waves that would reflect the same amount of energy back to the transmitting/receiving radar antenna, as would the actual target [5]. Table 1 gives some radar cross section values (m^2) from several targets [5].

Table I. Typical radar cross section values [5].

Target	RCS (m^2)
Large commercial airplane	100
Large fighters	5-6
Small fighters	2-3
Man	1
Small bird	0,01
Bug	0,00001
F-117 fighter	0,1
B-2 bomber	0,01

The RCS method requires a double face panel, where one side is used as reflector material (reference) and the other is coated with RAM. The panel is fixed on a rotating support, which is positioned in front of the receiving and transmitting horns. The advantage of this methodology is that it allows the evaluation of the reference and RAM, by rotating the device from 0 to 360^o, evaluating both sides of the panel, one after the other. Fig.1 shows a simplified scheme of the device used in RCS method [7]. With this method is not necessary to make two separate measurements, because the RCS diagram of the RAM is made by rotating the device from 0 to 180^o and the reference (metal plate-reflector) is made from 180to 360^o. Thus, it is a self-calibrating measurement, once the perpendicularity of the arrange is guaranteed [7,8].

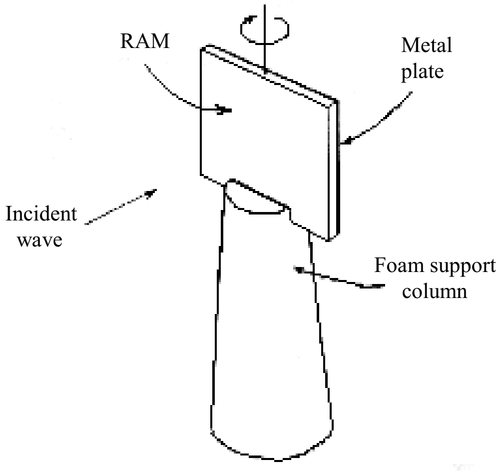

Figure 1. Device scheme used for the RCS method [7,8].

To calculate the RCS, it must be considered the power that is transferred back from a target, in a free space condition, to the transmitting/receiving radar antenna, being this antenna the same one used to launch the radiation. The radar cross section (σ) of the target is a transfer function which relates incident power density and reflected power density. The effect of lower RCS values on reducing the range of vehicle detection is illustrated by (1). The final term of the equation indicates the fourth power relationship between radar cross section and range (distance between the target and the receiving/transmitting antenna) [6].

$$P_r = P_t \frac{G^2 \lambda^2}{(4\pi)^4} \frac{\sigma}{R^4} \tag{1}$$

In above expression, P_r = Received energy (W), P_t = Transmitted energy (W), G = Antenna gain (dBi), λ = Wavelength (m), σ = Radar cross section (m^2), R = Range (m)

II Experimental

The equipment utilized in RCS measurement comprises: 1) anechoic chamber, matched at 2-18 GHz, 2) sweep model HP 83630B (Hewlett Packard), 3) spectrum analyzer model HP8593E, 4) PC computer with GPIB interface, 5) adaptators and low lose coaxial cables from *Huber-Suhner Company*, model Sucoform SM-141-PE (50Ω), 6) antennas 8-12 GHz, 7) aluminum plates as reference material (2 mm x 20 cm x 17cm).

The setup is shown in Figure 2. The transmitted output of a microwave generator is directed toward a target. Energy reflected from the target to the receiving antenna is detected by microwave receiver with PC computer with GPIB interface.

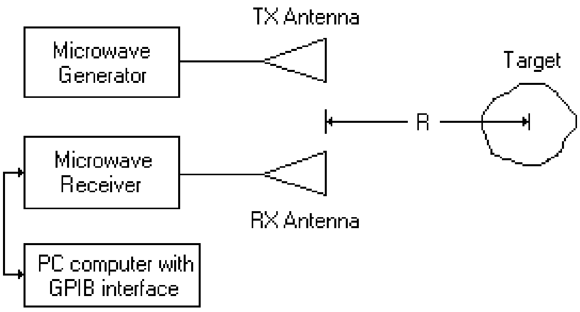

Figure 2. RCS measurement setup.

The RAM sheets, with dimensions equal to 4 mm x 20 cm x 17 cm, manufactured at Divisão de Materiais/IAE/ Centro Técnico Aeroespacial, are constituted as follows [9-13]:

1. Magnetic: MnZn, NiZn, MgZn ferrites and iron carbonyl in an elastomeric matrix (urethane or silicone rubber), in the form of thin flexible sheets. The loads were filled in the matrix with ratio weight of 20% MnZn, 10%NiZn, 5% MgZn and 5% iron carbonyl. Physico-chemical characteristics of the fillers and the polyurethane and silicone resins as well as the sheet preparation procedures were previously described [1, 9-12, 14-16].

2. Dielectric: conducting polymer - based on polyaniline (PAni), in a elastomeric matrix (EPDM – etilene-propilene-diene terpolymer), in form of thin flexible sheets. Blends of EPDM/doped PAni were prepared in an internal mixer coupled to a torque Rheometer (Haake Rheocord 90) in a ratio 70/30 w/w. This procedure was previously described [13,17-19].

III Results and Discussion

Figure 3 shows the RCS diagram of the reference aluminum plate, obtained at 8 GHz, with a rotation of 180^o. It is observed a peak at 0^o corresponding to values of -49,1 dBm, due to the normal incidence of the electromagnetic waves on the reference plate. The position of the plate is a critical parameter for the success of the measurements. Changes of $\pm$ 8^o, for example, can alter the signal intensity for nearly –57 dBm. This abrupt dropping of the signal for angles different from 0^o is due to the flat geometry of the target, scattering the electromagnetic wave impinged on it in away from the receiving antenna.

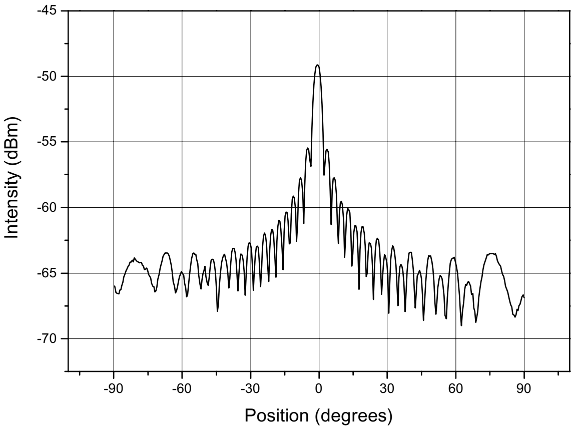

Figure 3. RCS diagram (dBm) for an aluminum plate (20 cm x 17 cm) at 8 GHz.

The RCS values of targets with different geometries can be calculated using theoretical considerations. A perfect flat rectangular reflector can have its theoretical RCS value calculated as a function of the incident radiation frequency, according to (2):

$$\sigma = \frac{4\pi a^2 b^2}{\lambda^2} \qquad (2)$$

where σ is the radar cross section (m^2), a is the height (in meters), b is the width (in meters) and λ the wavelength (in meters) [8].

Table II shows the calculated RCS values of an aluminum flat plate reflector (20 cm x 17 cm) as function of frequency.

Table II. Calculated RCS values for aluminum flat plate (20cm x 17 cm) as a function of frequency.

Frequency (GHz)	RCS (m^2)
8,0	10,3
9,0	13,0
10,0	16,1
11,0	19,5
12,0	23,2

The peak of –49,1 dBm at 8 GHz observed in Figure 3 was correlated with the calculated RCS value of 10,3 m^2(Table II). Using this correlation and (3) it was plotted the diagram presented in Figure 4. Attenuation,

$$dB = 10 \cdot log\frac{P_1}{P_2} \qquad (3)$$

In (3), P_1 is the read back energy and P_2 is the incident energy.

Figure 4 shows the RCS values of the reference aluminum plate, in square meters, at 8 GHz, as a function of the rotation angle in the range of - 90 to + 90^o. The curve profile is typical of an aluminum flat plate, showing the decrease of RCS values far from 0^o.

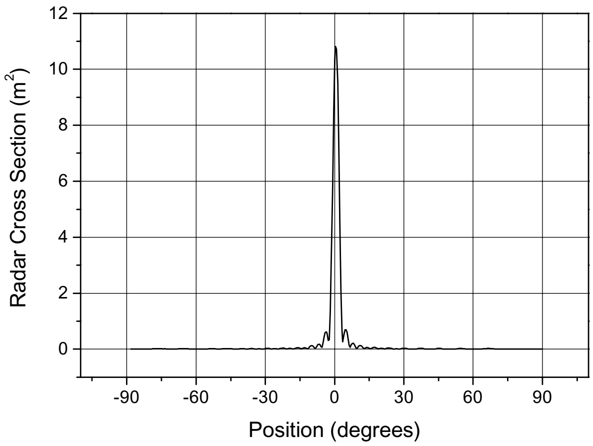

Figure 4. RCS diagram (m^2) for an aluminum plate (20 cm x 17 cm) at 8 GHz.

Afterwards, RCS measurements were carried out with the panel having one side coated by RAM elastomeric sheet filled with magnetic material, at 8, 9, 10, 11 and 12 GHz Figure 5 shows the RCS diagram expressed in dB and Figure 6 the RCS diagram expressed in square meters, both obtained at 8 GHz. In the range of 0 to -180^o is observed a peak at –90^o(-49,1 dBm), corresponding to the normal incidence of the radiation on panel reference side. In the range of 0 to +180^o the highest attenuation of –59,3 dBm occurs at 90^o corresponding to the normal incidence of the radiation on the RAM coated side. The difference between these two peaks is equal to an attenuation of 10,2 dB, at 8 GHz, corresponding to a RCS reduction of 10,3 m^2 (reference side) to 0,98 m^2 (RAM coated side) (Figure 6). According to the literature, this value corresponds to an attenuation of the incident electromagnetic radiation of 90,4 % [6].

The attenuation obtained at the frequency of 8 GHz, presented in figure 5 and 6, was also calculated for the frequencies of 9, 10, 11 e 12 GHz, at the incidence angle of 90^o. The data are presented in Figure 7 in dB and Figure 8 in m^2. However, it is observed that the RCS values, in m^2, increase with frequency, due to the dependence of this measurement on the wavelength of the incident radiation, according to (1). The calculated RCS in $m^2$to the coated side is nearly constant in the range of 8 to 11 GHz and slight larger to 12 GHz (Figure 8).

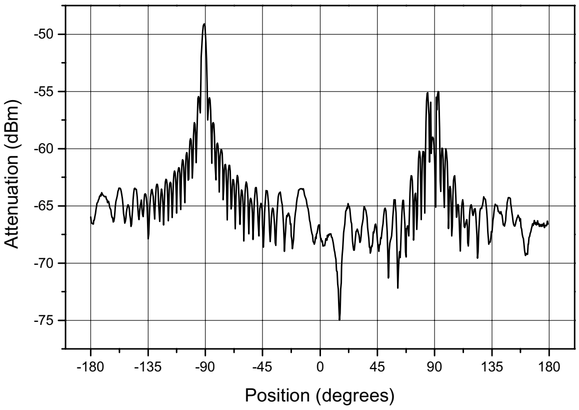

Figure 5. RCS measurements (in dBm) for the panel (20 cm x 17 cm) at 8 GHz. Reference side (-180^o to 0^o) and RAM (magnetic component) side (0^0 to +180^o).

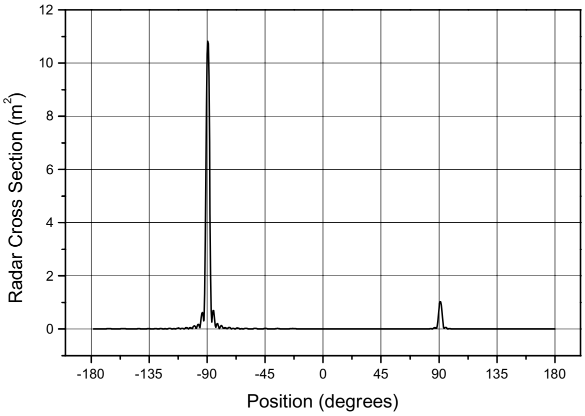

Figure 6. RCS measurements (in m^2) for the panel (20 cm x 17 cm) at 8 GHz. Reference side (-180^o to 0^o) and RAM (magnetic component) side (0^0 to +180^o).

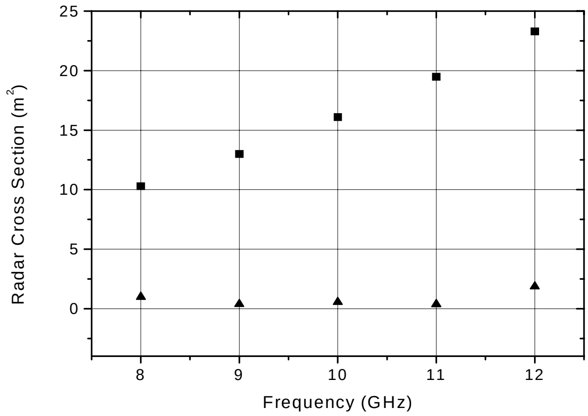

Figure 8. Attenuation values (m^2) as a function of frequency of RAM loaded with the magnetic fillers. ■ - reference, ▲ - coated panel.

An imported magnetic material (liquid microwave absorbing ferroflow type C, based on urethane matrix, from Microwave Filter Company Inc, East Syracure, NY) with thickness of (4.0 ± 0.1 mm) was characterized adopting the same way previously described. Figures 9 and 10 show the RCS results for the imported sample. It was observed smaller RCS values (nearly -4,7 dB, corresponding to an attenuation of 66%) than that ones determined for the prepared RAM (nearly -15 dB and 97% of attenuation). This result suggests that this imported RAM is less effective to attenuate the incident radiation than those manufactured at Divisão de Materiais/IAE/CTA, Brazil.

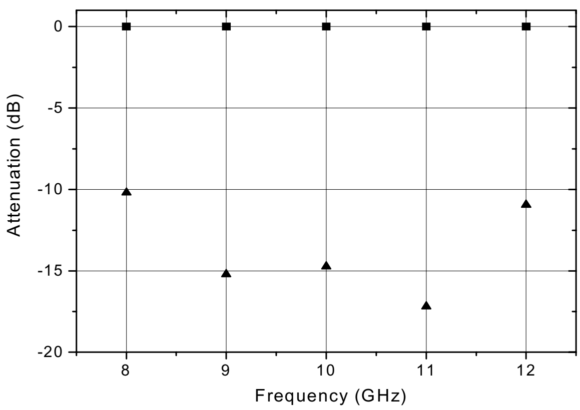

Figure 7. Attenuation values (dB) as a function of frequency for RAM loaded with magnetic fillers. ■ - reference, ▲ - coated panel.

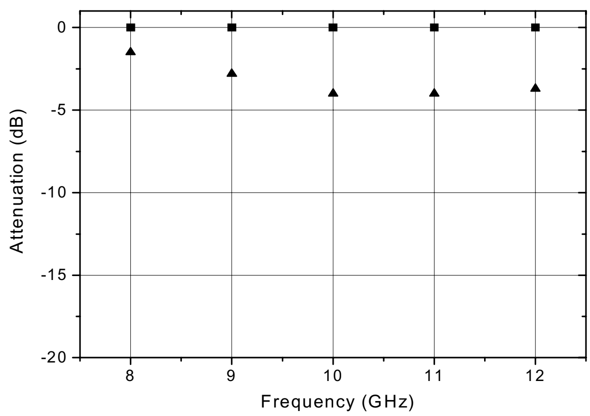

Figure 9. Attenuation values (dB) as a function of frequency of RAM loaded with magnetic fillers.

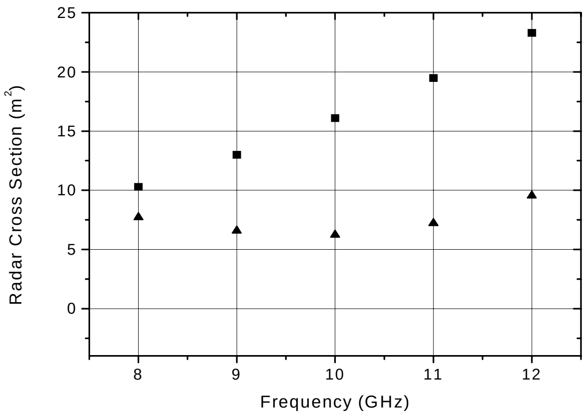

Figure 10. Attenuation values (m^2) as a function of frequency of RAM loaded with magnetic fillers. ■ - reference, ▲ - painted panel.

The RCS measurements done to the RAM loaded with magnetic fillers was also done for the RAM filled with the polyaniline, at 8, 9, 10, 11 and 12 GHz, at the incidence angle of 90^o. The data are presented in Figure 11 (in dB) and Figure 12 (in m^2). It is observed that the RCS values of the reference increase with the frequency (Figure 12), due to the dependence of this measurement on the wavelength of the incident radiation, according to (1). Figure 12 show that the RCS values of RAM filled with polyaniline are larger than those obtained for the panel coated with magnetic RAM for frequency values higher than 8 GHz. This result suggests that the studied RAM sheets loaded with the magnetic filler are more effective to attenuate the incident radiation than those filled with conducting polymer.

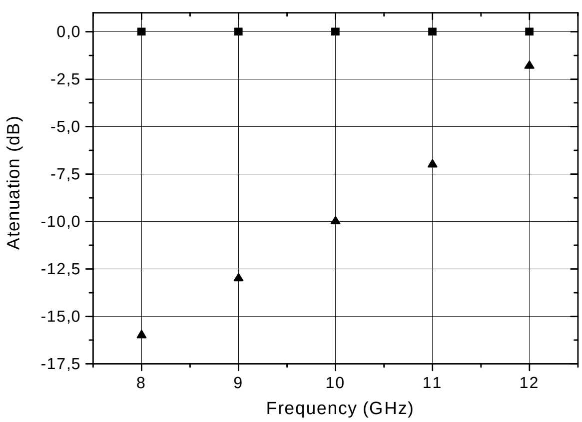

Figure 11. Attenuation values (dB) as a function of frequency of RAM with dielectric component. ■ - reference, ▲ - PAni loaded panel.

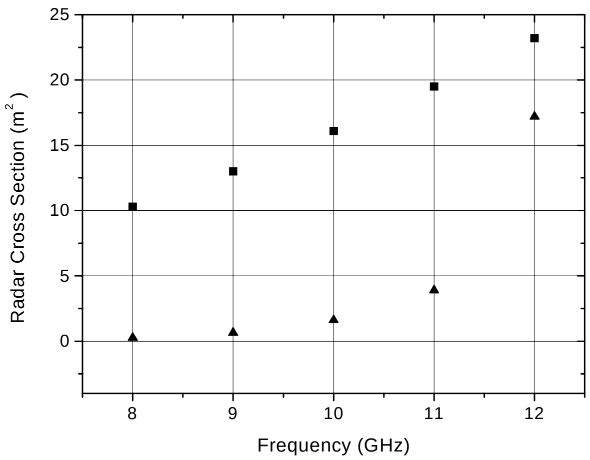

Figure 12. Attenuation values (m^2) as a function of frequency of RAM with dielectric component. ■ - reference, ▲ - PAni loaded panel.

Considering that the PAni loaded RAM is nearly five times lighter than the magnetic RAM, the use of the microwave absorbing sheet loaded with PAni can be advantageous in the range of 8-10 GHz. It is interesting to say that the RCS of a conducting rubber sheet based on conducting polymer is unpublished and no datum is available in the literature to compare with the processed RAM in this study.

IV Conclusions

The RAM thin sheets processed at the Divisão de Materiais/IAE/CTA were sucessfully evaluated by RCS method, using a flat aluminum panel as reference, in the range of 8 to 12 GHz. The measurements showed that the RCS increases with frequency for a panel coated with RAM based on conducting polymers. The obtained RCS values in m^2 are nearly constant and close to 1 m^2 for the panel coated with the magnetic RAM. The results showed a RCS reduction of 55-98% and of 40-95%, when the magnetic and the dielectric panels, were impinged at normal incidence, respectively. The magnetic sheets showed more effective to attenuate the incident radiation that the RAM loaded with conducting polymer in the frequence range of 8-12 GHz. However, considering that PAni loaded RAM is nearly five times lighter than the magnetic one, its application in aeronautical field is very promising.

Acknowledgements

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