Study of the F-5 jetfigheter Radar Cross Section reduction by Using Radar Absorbing Material

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Abstract—The article presents a preliminary study of the Radar Cross Section (RCS) reduction on the modified aircraft F-5. First, it was studied the RCS of the aircraft from computational simulations based on prior knowledge of vulnerable areas of this aircraft to radar threats. Subsequently, were evaluated the possible applications of Radar Absorbing Materials (RAM) on the surface of the aircraft, in order to reduce the RCS. The Material used in the simulations was the RAM FC70-05-31, developed in the Division of Materials, which has good attenuation in the range of 10 to 12 GHz. The study of this reduction was accomplished by applying RAM in four different scenarios. In this work, studies were performed at frequencies of 10 and 11 GHz. At 10 GHz frequency, where the RAM is less sensitive, it was only analyzed for the scenario 1; whereas with 11 GHz frequency, where the material is more sensitive, it was analyzed 4 different scenarios. The RCS simulations of the F-5 and its RCS reduction by RAM application were carried out with the support of the software "Computer Simulation Technology" (CST) 2012 version. Such technology makes it possible to simulate the application with an absorber material layer on the surface of the aircraft. For the study of the RCS reduction on the F-5, it was first necessary to develop a detailed 3D model of the F-5. The model was developed with the support of the software "Computer Aided Three-Dimensional Interactive Application" (CATIA), in current study. It was concluded that it is impossible to make much progress attempting to retrofit stealth onto a conventional aircraft because if the shape is wrong, no amount of absorbing material treatments will reduce the RCS.

Keywords— radar cross section;radar absorber material; computational simulation, radar cross section reduction***.***

1. Introduction

The goal to reduce the RCS of a military aircraft is directly related to the distance at which it can be detected by hostile radar. The radar equation given below provides a quantitative way to analyze the impact of a target's RCS reduction in its sensing distance for monostatic radar [1]:

$$R_{max} = [(P_t G^2 \lambda^2 \sigma) / (4\pi)^3 P_{min} L)]^{1/4}, \quad (1)$$

where: R_{max} is the maximum range of the radar detection, P_t is the radar antenna's transmission power, D_t is the antenna's directivity, P_{min} is the minimum power detected by the radar, $G = G_r = G_t$ is the radar gain, G are the losses associated with the radar electronics and the environment, and σ is the RCS [2, 3].

Analyzing (1) reveals that among the variables of the radar equation, the only one of possible control by the target aircraft is its RCS, since all others are inherent to the hostile radar system or the environment. Therefore, from the viewpoint of the aircraft, the radar parameters and environment can be considered as a constant of the detection system. An examination of (1) shows that the RCS of a target should be decreased by sixteen times so that the maximum detection distance R falls by its half.

2. Methodology

The computational resources used in this project were the CATIA V5 software to develop 3-D models of the aircraft which shall have the reduction of its RCS studied. To study the electromagnetic scattering we used the package A-Solver of the software Computer Simulation Technology - CST 2012 version [7]. To study the RCS reduction we insert the RAM – FC 70-05-31 [1, 2, 7, 8] on the library of the CST, which was simulated its application in parts of the surface of the aircraft, called scenarios 1, 2, 3 and 4.

In order to facilitate the simulations of the RCS on the F-5 and modify the aircraft, because it is still in operation, some of its characteristics were modified [3, 4, 5]. The simplifications were to set a metallic canopy, removal of external antennas, withdrawal of navigation and training lights, as well as the removal of the "probe" for refueling during flight and weapons. The Figure 1 shows in detail the three-dimensional model split to enable the necessary RAM application according to scenarios 1, 2, 3 and 4 [6].

In scenario 1 it is presented the aircraft almost completely covered. It was just not applied RAM on the canopy as it would compromise the pilot's vision and on the Radome's surface because it could attenuate the signal emitted and received by its own radar. In scenario 2, in addition to the surfaces uncovered in scenario 1, also were not coated the turbine palettes and the exhaust. In scenario 3, in addition to the parts not covered in scenario 2, the air inlet of the aircraft was not coated, and in scenario 4, only the horizontal and vertical stabilizers were coated, in addition to the uncoated parts in scenario 3, the wings, and parts of the fuselage and rear of the aircraft.

Fig. 1. 3D Perspective model of the aircraft F-5 generated developed with the software CATIA.

The Figs. 2, 3, 4 and 5 illustrate respectively the scenarios 1, 2, 3 and 4, where the F-5 is partially coated with RAM, noticing that the coated surfaces are yellow and the uncoated surfaces are grey.

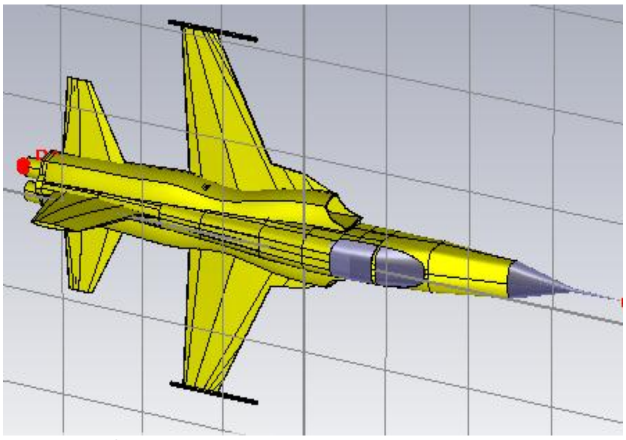

Fig. 2. Aircraft F-5 partially coated with RAM, according to scenario 1.

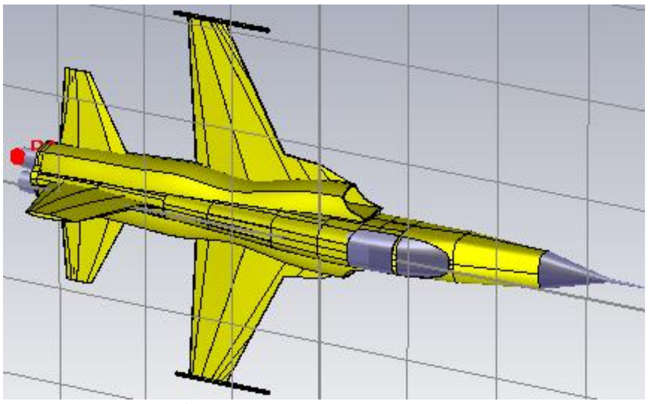

Fig. 3. Aircraft F-5 partially coated with RAM, scenario 2.

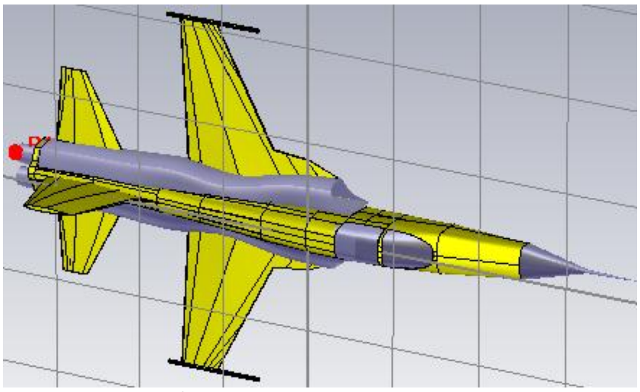

Fig. 4. Aircraft F-5 partially coated with RAM, scenario 3.

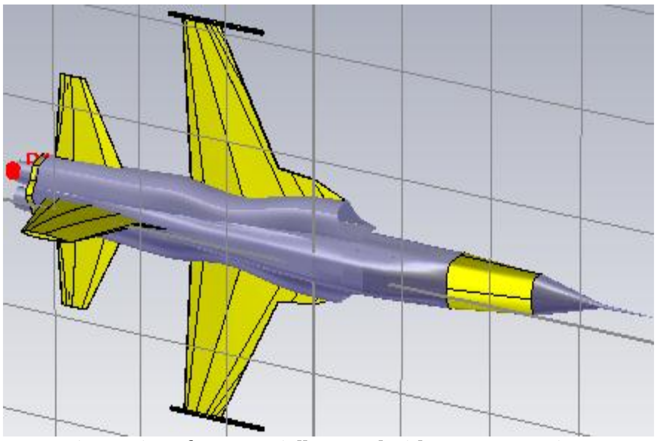

Fig. 5. Aircraft F-5 partially coated with RAM, scenario 4.

The Fig. 6 shows the comparison between the reflectivity measured e simulated with CTS software to RAM FC 70-05-31 used in the study of the RCS reduction.

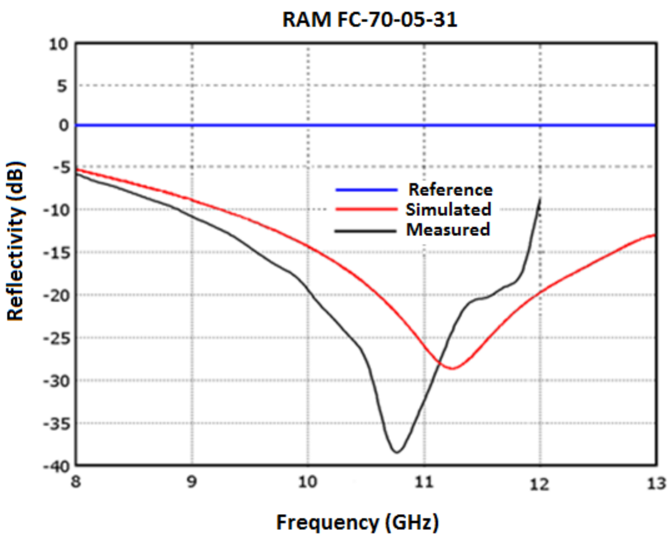

Fig. 6. The reflectivity curve of the RAM FC 70-05-31 used in the study of RCS reduction.

III. Results

The preliminary study of RCS reduction on the F-5 aircraft by managed application of RAM was performed at frequencies of 10 and 11 GHz and with aspect angles ranging from 0 ° to 360 ° with increments of 1 °.

A. RCS reduction of the F-5 at 10 GHz

Fig. 7 shows the comparison between the RCS of the F-5 modified at the frequency of 10 GHz, partially coated and uncoated with RAM shown in Fig. 2 (scenario 1).

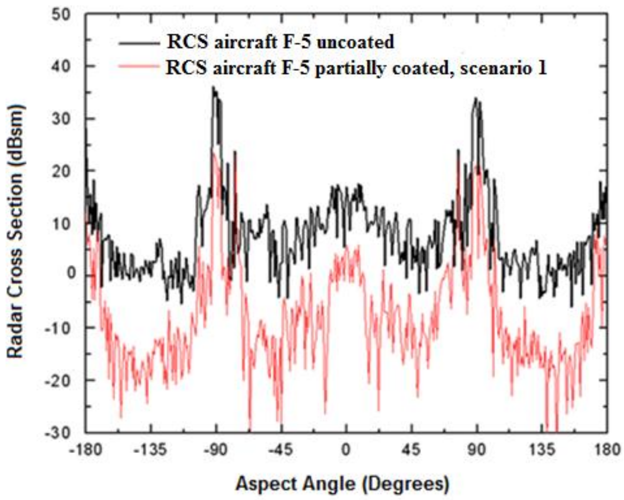

Fig. 7. Comparison between the RCS of the F-5 modified at 10 GHz, partially coated and uncoated with RAM (scenario 1).

The peaks between -180 ° and 180 ° correspond to the RCS on the rear of the aircraft. The following peaks between -90 ° and 90 ° correspond to the RCS on the lateral. Lastly, the peaks between -10 ° and 10 ° correspond to the frontal RCS. In the other angles the RCS is a composition of parts. Table I shows a comparison between the peak values and the RCS average in the range of 10 GHz with intervals of 10 degrees to the frontal RCS, lateral, and rear of the F-5.

TABLE I. **COMPARISON BETWEEN THE RCS OF F-5 AT 10 GHZ FREQUENCY, UNCOATED AND PARTIALLY COATED WITH RAM FC70-05-31**

RCS		**RCS F-5 to Scenario 1 (dBsm)**	
Peak		Uncoated	Partially coated with RAM (absorption 14 dB)
Frontal	0º	14,1	5,91
Lateral	90º	37,4	18,7
Rear	180º	14,4	12,0

At the frequency of 10 GHz, only scenario 1 was analyzed. The other four scenarios are analyzed at a frequency of 11 GHz, where the material is more sensitive. Analyzing Fig. 6, it is found that the material has absorption of approximately 14 dB at a frequency of 10 GHz; whereas at the frequency of 11 GHz the absorption is around 26 dB.

B. RCS reduction of the F-5 at 11 GHz

The Fig. 8 shows a comparison between the RCS of the F-5 modified at a frequency of 11 GHz, partially coated and uncoated with RAM, shown in Fig. 2 (scenario 1).

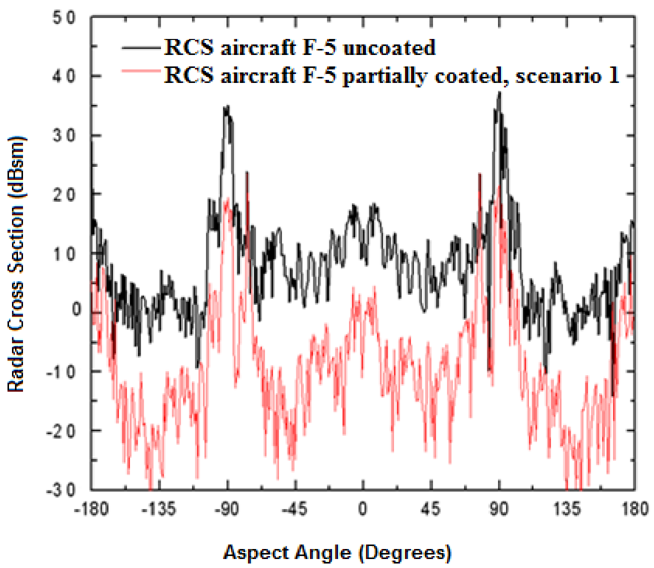

Fig. 8. Comparison between the RCS of the F-5 modified at 11 GHz, partially coated and uncoated with RAM. (scenario 1).

The Fig. 9 shows a comparison between the RCS of the F-5 modified at a frequency of 11 GHz, partially coated and uncoated with RAM, shown in Fig. 3 (scenario 2).

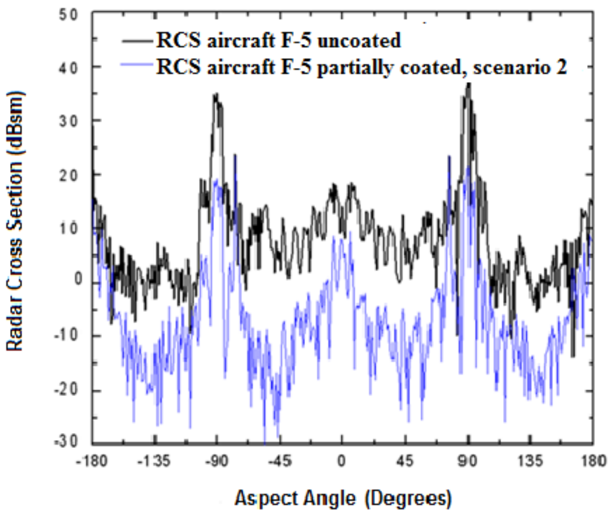

Fig. 9. Comparison between the RCS of the F-5 modified at 11 GHz, partially coated and uncoated with RAM. (scenario 2).

The Fig. 10 shows a comparison between the RCS of the F-5 modified at a frequency of 11 GHz, partially coated and uncoated with RAM, shown in Fig. 4 (scenario 3).

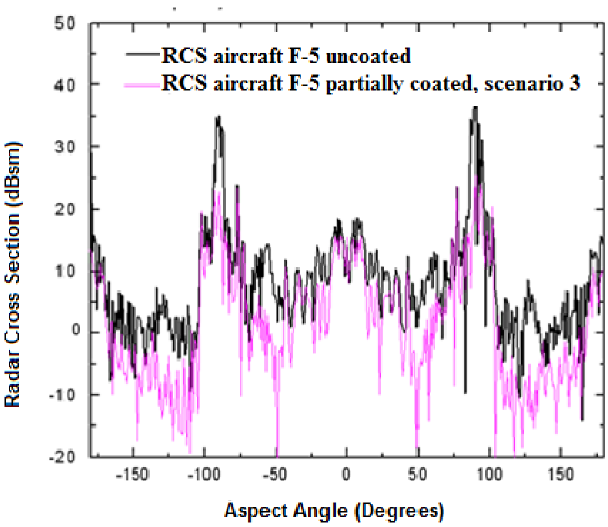

Fig. 10. Comparison between the RCS of the F-5 modified at 11 GHz, partially coated and uncoated with RAM. (scenario 3).

The Fig. 11 shows a comparison between the RCS of the F-5 modified at a frequency of 11 GHz, partially coated and uncoated with RAM, shown in Fig. 5 (scenario 4).

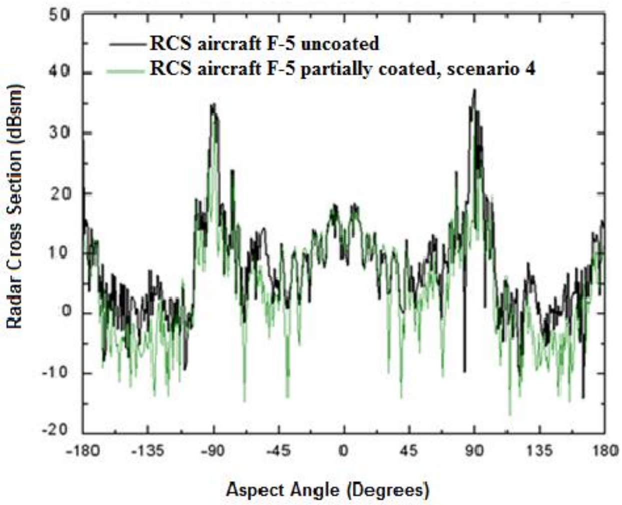

Fig. 11. Comparison between the RCS of the F-5 modified at 11 GHz, partially coated and uncoated with RAM. (scenario 4).

The Table II shows a comparison between the peak values of the RCS at 11 GHz and the RCS in the frontal, lateral, and rear of the F-5.

TABLE II. **Comparison between the RCS of the F-5 at 11 GHz frequency, uncoated and partially coated with RAM FC70-05-31**

RCS of the F-5 covered and uncovered						
Incidence		Uncoated	Coated with RAM (absorption 26 dB)			
			Scenarios			
			1	2	3	4
Frontal	0º	14,1	-5,42	7,7	14,4	15,4
Lateral	90º	37,4	21,5	21,4	34,7	25,4
Rear	180º	14,4	5,42	15,5	14,1	13,5

The Table III shows a comparison between the average values of the RCS at 11 GHz, with intervals of 10 ° to the RCS in the frontal, lateral, and rear of the F-5.

TABLE III. **Comparison between the F-5 RCS average at 11 GHz frequency, uncoated and partially coated with RAM FC70-05-31**

RCS of the F-5 covered and uncovered						
Incidence		Uncoated	Coated with RAM (absorption 26 dB)			
			Scenarios			
			1	2	3	4
Frontal	-5º a 5º	13,5	-1,12	2,58	14,0	13,1
Lateral	85º a 95º	27,7	9,79	8,33	18,1	17,4
Rear	175 a -175	13,4	0,13	5,76	8,8	8,9

IV. Conclusions

For an application on scenario 1, where the RAM FC 70-05-31 is less sensitive absorbing around 14 dB at 10 GHz, resulted in a reduction of 10 dB for frontal RCS, and around 15 dB to the lateral and rear RCS. For the same scenario 1, at the frequency of 11 GHz, where the material has an absorption around 26 dB, it was showed a reduction of the RCS around 20 dB to the front, 16 dB to the lateral and 10 dB for the rear. For scenario 2, whose differences are only changing the exhaust turbine and RAM for metal, the attenuation was approximately 7 dB for the RCS in the front, and it remained unchanged for the side and rear. For scenarios 3 and 4, the application of RAM proved to be inefficient for RCS reduction. In conclusion, the fundamental reason that it is impossible to make much progress attempting to retrofit stealth onto a conventional aircraft is because if the shape is wrong, no amount of material treatments will reduce the RCS. Consideration must be given to any part of an aircraft that a radar wave can reach to develop a low observable aircraft. In other hand, the first critical factor to consider in the design process is the shape of the aircraft. This element has to be designed into the aircraft from the beginning.

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