International Journal of Pure and Applied Mathematics
Volume 119 No. 16 2018, 469-477
ISSN: 1314-3395 (on-line version)
url: http://www.acadpubl.eu/hub/
Special Issue
http://www.acadpubl.eu/hub/

ANALYSIS OF RADAR CROSS SECTION AND DETECTION

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Abstract: This paper reviewed on Radar Cross Section (RCS) of Space vehicle, fighter aircraft and naval ship. As RCS is one of the most important factors for defense and military applications. RCS depends on various parameters including shape, orientation, Radar absorbent material, operating frequency and aspect angle. Hereby analyzing the RCS of various paper that have been surveyed, which also includes a space vehicle (complex objects) by comparing each and every individual shapes, by performing the simulation through specific computer tools. Thus the RCS plays a vital role by comparing the analysis results for various fields such as fighter aircraft, naval ship and space vehicle and provided to give a measure of the RCS accuracy by the use of these techniques.

Keywords: Radar Cross Section, Analysis, Detection, Fighter Aircraft, Naval Ship, Space Vehicle, Computer Simulation

1. Introduction

The radar cross section is a fundamental concept that the rest of this proposed work is based on. RCS is the measure of a target's ability to reflect radar signals in the direction of the radar receiver, which is given by the following equation.

$$RCS = \lim_{r\to\infty} 4\pi r^2 \frac{|E_s|^2}{|E_i|^2} \quad \text{Unit: dBsm}$$

where, Ei is the incident electric field vector, Es is the scattered electric field vector, variable r is the distance (or range) from the receiver to the target. The limit of r in is set to infinity so that the RCS is independent of range at which the receiver is from the target. RCS is determined by factors namely, size, material and surface of the target.

Factors Determining RCS:

Size- As per the concept, stronger its reflection, will obtain greater RCS, but one of the band may not even detect the size of the object.

Material- Materials such as metals will tends to produce a strong reflective radar signals. Some devices are designed for the radar active such as radar antenna, will increase the RCS.

Radar absorbent paint- The planes and specifically SR-71 black bird were painted with a special “iron ball paint”, consist of small metallic-coated balls. The produced radar energy is converted to heat than being reflected.

Shape, directivity and orientation- If any ray incident along the normal direction will reflect back in the same path, thereby produce a strong reflected signal. The plane will have a stronger signal from the side rather than the front side, so the orientation will play a vital role between the Radar station and the target.

Smooth surfaces- Apart from the surface the indentations that act as corner reflectors which would increase RCS from many orientations.

2. Literature Review

Prediction of radar cross section measurements for different individual shapes, has been surveyed in this paper and they have developed the coding to get the simulated graphs for various objects. This paper has described the radar absorbing material parameters, also includes the absorbent material, shape, size, incident and reflected angle, also distance between the radar transmitter and target and radar cross section measurements, by using very simple objects (targets). Simple objects like rectangular and triangular flat plate, ellipsoid, truncated cone and sphere were measuring the backscattered radiation target [1].

Radar Cross Section of simple objects as similar to [1]. But with the far analysis given in this paper is based on far field monocratic RCS measurements in the optical region and carried out using Physical Optics (PO) method for determining RCS, but also the cascaded objects with backscatter has been computed narrowly in the Computer Simulation. [2].

The analyzes of RCS as similar to[1] and [2] but considering only 2 shapes – sphere and flat plate in the subsistence of an infinite perfect conducting plane. Simulations performed in the software eST Microwave Studio®, and it shows how the presence of a conducting plane differs the original RCS of the individual shapes (targets) at free space as they penetrate the conducting plane. The normalized RCS has a typical behavior and can be designed by simple equations for each target as a function of its relative height to the conductive ground plane [3].

Analyzing the RCS and detection system of naval ships, the simulation tool used here is SYSCOS specifically for large target scattering system targets scattering analysis named SYSCOS. The system is conceptually based on the PO, GO, and PTD, also includes direct center scattering analysis [9] which gives relatively simple way to discriminate problem definition in various stages, while comparing with conventional image-based approaches [8].

In paper [10] is as similar to [8] but in the aspect on different filed that is fighter aircraft by means of radar absorbent material as an important parameter where the material is more sensitive the simulation is carried out in software namely "Computer Aided Three-Dimensional Interactive Application". If the shape is wrong, no amount of absorbing material treatments will reduce the RCS [10].

3. Concepts and Methodology

In [8], the radar cross section (RCS) reduction of a naval ship plays a vital role in the design issues when considering the reduction techniques such as shaping shielding and the absorbent material which provides the effectiveness of RCS and in a Conventional image-based approaches such as range-profile and synthetic aperture radar requiring another data discriminate the problem areas using scattering center analysis.

This method directly results the RCS value of level coloring procedure for each subsurface due to single and multiple reflections that have been summed and displayed.

A software system used here is SYSCOS mainly composed of three parts; preprocessor, main solver, and postprocessor. The main solver broadly classified into two: The SYSCOS solver is used for analyzing the specular reflections on the target surface, while the SYSCOS DIFF solver for the diffraction of the target edge. The objective to achieve the target model and calculation such as frequency, range of incident angle (azimuth and elevation), maximum number of reflection (order) and polarization.

In [9], the main intention is to reduce the RCS in fighter aircrafts which is directly related to the distance that can be detected by hostile radars. The given below given radar equation (Eq.1) provides an impact on RCS reduction of a target in monocratic radars.

$$R\text{max}=[(P\text{t}G2\lambda2\sigma)/\ (4\pi)3\ P\text{min}L)]1/4 \qquad \text{eqn. (1)}$$

where, Rmax is the maximum range, Pt is transmission power, Pmin is the minimum power detected, G is the radar gain, L is the loss related to the radar electronics and the environment, and σ is the RCS.

Here the computational software used in the study was CATIA V5 to develop the 3D models of aircraft which also includes the reduction if it RCS and electromagnetic scattering in the simulation tool namely A-solver CST-2012 version.

As [8] and [10] are with respect to aircraft in the air and the naval ship in the sea respectively, we have designed and included the space vehicle in this survey paper of RCS which resembles as like as the cone shape of a Re-entry vehicle by combining the individual shapes such as hemisphere, truncated cone and circular plate to form a complex object by referring to the paper [1], in order to analysis the RCS and detection with respect to the radar absorbent paint, aspect angle i.e.; viewing angle and frequency.

The software used here is the ANSOFT version of HFSS tool (High Frequency Structural Simulator). This is a full wave 3D electromagnetic field Simulator which uses a finite element method. It provides a high graphical user interface and this simulator is a user friendly environment which provides flexibility, compatibility and accuracy for any type of complex problem definition. If there were no margin on size of matrix, number of digits during computation, there would be no margin to the accuracy of FEM.

Problem Definition for the considered complex object

The parameters and the dimensions that are designed for the complex object are:

1. The radius of the Sphere is matched with the small-end of the cone i.e.; m=r1=0.5 meter
2. The radius of the large-end of the cone is matched with the radius of the circular plate i.e.; r2=n=3 meter.
3. The height of the cone is h=5 meter.
4. The frequency for a vehicle is 1 GHz.
5. The half cone angle of the truncated cone is theta in degree.
6. The viewing angle of the complete complex object is from 0 to 180 degrees

   (i) The viewing of Sphere is from 0 to 40 degree.

   (ii) The viewing of truncated cone is from 41 to 90 degree.

   (iii) The viewing of Circular plate is from 91 to 180 degree.

4. Results

Analysis of RCS and Detection of various software used in these papers:

In [8], the RCS values of the modeled ship designed for 5 set of radar frequencies i.e.; 4, 8, 10, 12 and 18 *GHz* with the elevation of 4 *degree*. This gives the observation of several high peaks of RCS value. Particularly, a high and narrow peak occurs around 24 *degree* due to multiple reflections between the side surfaces and the onboard equipment of the naval ship, whose scattering center analysis result in case of 12 *GHz* radar frequency.

To reduce the high and narrow peak, a multilayered RAM is virtually attached on the corresponding surfaces. Thereby one can know The RCS levels of the ship before and after the RAM attachment which will gradually remarkably reduced around 24 degree of the azimuth angle are as shown in this fig1.

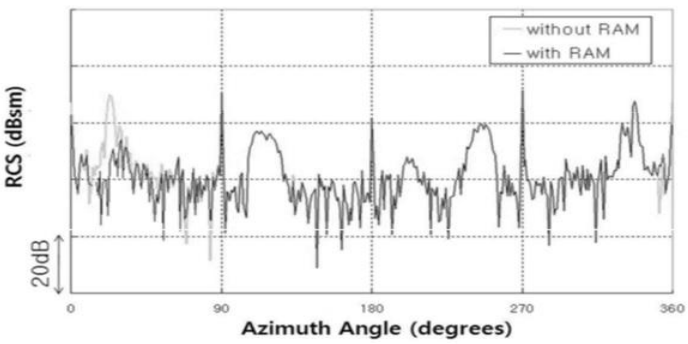

Figure 1. RCS levels of the objective naval ship before and after RAM attachment

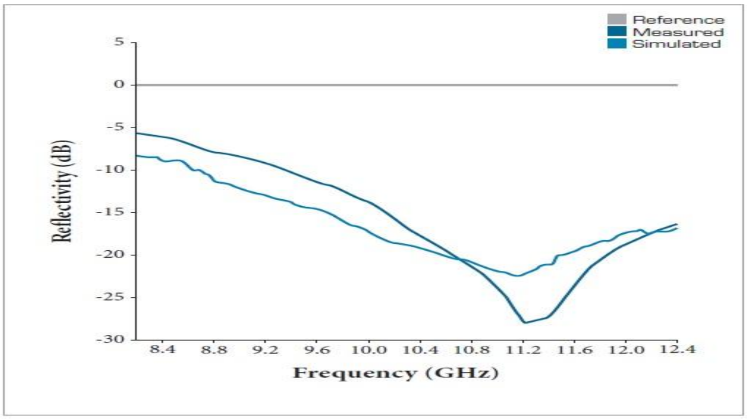

Figure 2. The reflectivity curve of the RAM used for RCS reduction

Therefore the above fig concludes that the RCS analysis and reduction design process of large and complex targets such as naval ships. Also, gives the better performance in numerical validation tests for both various simple targets and real complex targets in proving the accuracy of this system and is applicable to real targets.

Thereby the reduction of RCS in the fighter aircraft is performed with the 11.1GHZ is managed by RAM with the increments of 1° ranging from 0 to 360 degree of aspect angle thus the simulation gives the same performance for the other set of frequency because the RAM is more sensitive. The below fig2. Shows the reflective curve of the RCS after the attachment of RAM. Fig3.shows the Comparison between the RCS of fighter aircraft at 11.1 GHz, partially coated and uncoated with RAM. Table:1 gives the numerical analysis of RCS partially coated and uncoated with RAM.

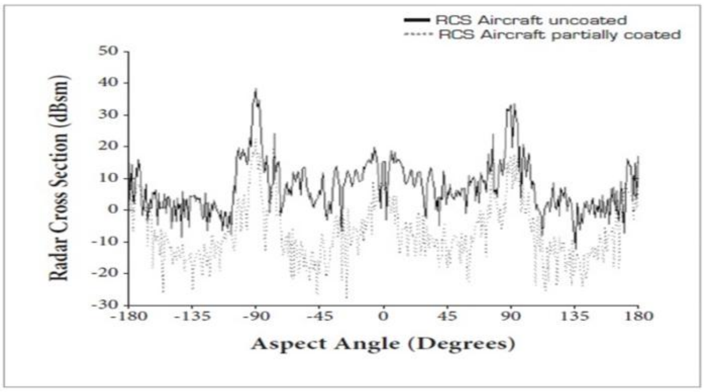

Figure 3. Comparison between the RCS of fighter aircraft at 11.1 GHz, partially coated and uncoated with RAM

Table 1. Comparison between the RCS of fighter aircraft at 11.1 GHz, partially coated and uncoated with RAM

Incidence		Avg RCS in m^2				
		Uncoated	Scenarios coated with RAM			
			1	2	3	4
Frontal	$-5^0 \, to \, 5^0$	10.47	0.77	3.55	12.02	12.30
Lateral	$85^0 \, to \, 95^0$	426.58	9.33	12.59	139.81	56.23
Rear	$-175^0 \, to \, 175^0$	11.22	1.04	1.88	2.00	2.47

Finally, Using the MATLAB programming, prediction of radar cross section of some simple shapes of targets like Sphere, Truncated cone and Circular plate obtained were characterized by measuring the backscattered radiation patterns in different aspect angles. The RCS models have been developed for complex objects by combining the individual shapes which was first developed in MATLAB and after successful verification, designed and verified in a real time simulation environment for the better accuracy and RCS detection

Fig:4 represents the MATLAB plot for different values of RCS in dBsm of a Re-entry vehicle obtained by varying aspect angle from 0 to 180 degree. Fig:5 represents the HFSS plot for different values of RCS in dBsm of a Space vehicle obtained by varying aspect angle from 0 to 180 degree.

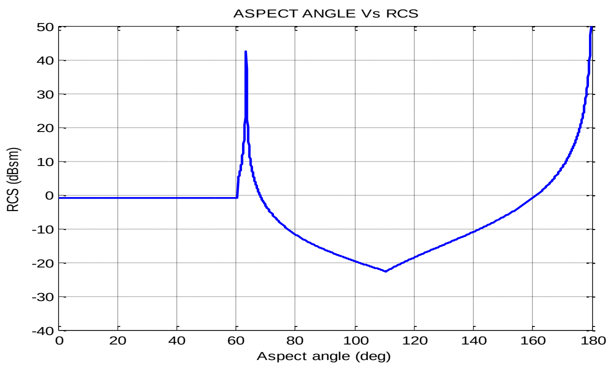

Figure 4. Plot of Normalized RCS in MATLAB

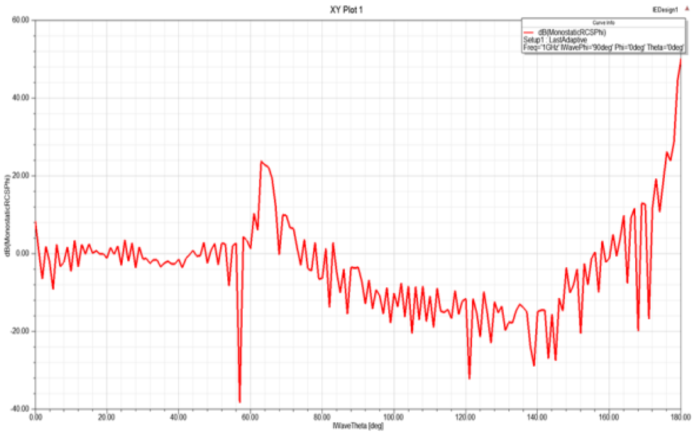

Figure 5. Plot of normalized RCS in HFSS

5. Conclusion & Future Scope

In this work, Radar cross-section (RCS) is an important study parameter for defense and military applications. The RCS parameter regulates the detection range and its effectiveness has been studied and understood for various fields that have been considered by finding the RCS using different parameters from which a viewer views the target object by using various simulation tool thereby RCS gives the great impact for any type of problem definition in detecting the various targets. RCS tends to be highly oscillatory when the scattering spacing is more and vice versa.

RCS can be contoured by simple equations for any type of targets as a function of its relative height to the ground plane. Even after a plenty of study and research in the vast field of radars are in high demand for both civilian and military contexts(surveillance, tracking, and imaging applications).

Therefore, in further process, the target detection by means of imaging will achieve more effectiveness in perfect analyzing the Cross Section than from the radiation pattern. Thus the motivation of this proposed work can be implemented in Modern Military Vehicles, Fighter Aircrafts and Ships to avoid detection by hostile radars. The enhancement of radar cross section estimation has the great challenges in various applications.

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