Implementation and Verification of Simulation Methods to Determine Radar Cross Section of Simple Targets

Group Captain Md. Afzal Hossain

Department of Computer Science and Engineering
Military Institute of Science and Technology(MIST)
Dhaka, Bangladesh
Email: head@cse.mist.ac.bd

Zamil Uddin Faysal[1], Md Shamaun Sobhan[2] and Fatema Oshin Ara[3]
Department of Aeronautical Engineering
Military Institute of Science and Technology(MIST)
Dhaka, Bangladesh
Email: [1]zamilfaisal@gmail.com, [2]shamaunshohan@gmail.com, [3]fatemaoshin@gmail.com

***Abstract* – This paper analyses the method of measuring Radar Cross Section(RCS) of different target geometries through computer simulation as well as theoretical calculations. The measurements have been done in the frequency range of 7-10 GHz at varying aspect angles of the targets. The simulated and theoretically obtained results showed profound agreement with each other. The used simulation methodology can be implemented for carrying out further research on radar cross section reduction mechanisms at minimum expenses.**

Keywords – Radar Cross Section, Simulation methods, Comparison

I. INTRODUCTION

The aim of radar cross section (RCS) measurements is to determine the equivalent effective area of the target when it is impinged by a radar wave. To determine the type of any target the measurement of RCS is very important.

RCS is the ability of target to reflect the radar signal's in the direction of the radar. RCS is a characteristic of the particular target and is a measure of its size as seen by the radar. RCS is also a function of frequency, polarization, target configuration and orientation with respect to the incident field. The radar range equation is the basis for the design and operation of dynamic RCS test ranges. The influence of RCS on the received power by the radar is shown by the radar range equation. The radar equation for free space propagation is given by-

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R^4} \tag{1}$$

Where, the transmitted and received power is denoted by $\boldsymbol{P_t}$ and $\boldsymbol{P_r}$, the transmitting and receiving antenna gain is denoted by $\boldsymbol{G_t}$ and $\boldsymbol{G_r}$, $\boldsymbol{\lambda}$ is the operating wavelength, $\boldsymbol{R}$ is the radar range and $\boldsymbol{\sigma}$ is the radar cross section of the target. The power reflected or scattered by a target is the product of its effective area and the incident power density. Generally the 'area' is called scattering cross section of the target. It is called 'backscattering cross section' or the 'Radar Cross Section' for directions back towards the radar. The scattering cross section is not a constant. It is an angular dependent property of the target. The far field RCS does not vary with changes in range. RCS has no general relationship with the physical area of the object although RCS is defined in terms of area [1].

The RCS is a measure of the power that returns to source or reflects in a given direction. To define more precisely, RCS is a measure of reflective strength of a target 4π times the ratio of the power per unit solid angle scattered in a specified direction to the power per unit area in a plane wave incident on a scatterer from a specified direction [2].

$$\sigma = \lim_{R\to\infty} 4\pi R^2 \frac{|\mathbf{E}^{scat}|^2}{|\mathbf{E}^{inc}|^2} \tag{2}$$

Where, $\mathbf{E}^{scat}$ is the scattered electric field and $\mathbf{E}^{inc}$ is the field incident at the target. RCS is displayed in logarithmic form for convenience due to large variation in RCS pattern from one aspect angle to another [1].

$$RCS(dBsm) = 10\log_{10}\sigma \tag{3}$$

RCS of a target will have a wide variation, if the illuminating electromagnetic wave has got a wide range of frequencies. The variation of RCS with frequency is classified into Rayleigh region, Mie region and Optical region depending on the size of the object [4].

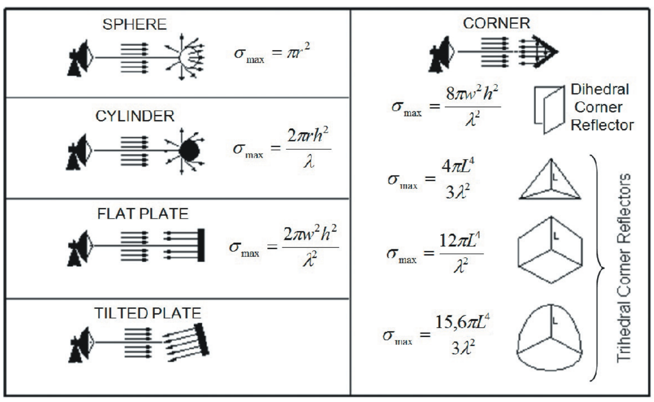

Figure 1. Backscattering from simple shapes (targets) and RCS equations for each target.[3]

RCS of a target may have a huge value of a target from one angle and at the same time has a small value from another angle. Absorbing radar waves, reflecting radar waves that cancel themselves and reflecting radar waves away from its origin are some ways to reduce the RCS of any target [5].

II. SIMULATION

Simulation software used for the study was CST Studio Suite. Software is one of the most reliable in the field of RCS simulation. In particular the microwave studio of this software was in effect. Simulations were carried out at the frequency range of 7-10 GHz.

The solver chosen for generating solutions was asymptotic solver with medium accuracy. Asymptotic solvers are developed to approximate electromagnetic propagation using the optical properties of very high frequency EM waves for electrically large problems. Asymptotic method is based on the Shooting Bouncing Ray(SBR) method [6]. This is capable of tackling simulations with an electric size of many thousands of wavelengths as in case of radar cross section analysis.

The SRB method combines the method of Geometric Optics (GO) and Physical Optics (PO).In Geometric Optics, electromagnetic propagation is first represented with the reflection, refraction, and divergence of optical rays. Then the electromagnetic properties of magnitude, direction, and phase are added on top of the ray traces to imitate the properties of waves. In Physical Optics, incident electromagnetic waves are converted into equivalent surface currents on the scattering surfaces of the structure under study. The current is then integrated and re-radiated as electromagnetic waves towards the observation points everywhere in the computational domain.

SBR begins the computation by launching numerous rays from the sources like antennas or regions of plane waves. Each ray then propagates through the computational domain and bounces between the target surfaces under study using the GO method. Next, the electromagnetic fields at each hit point are converted into surface currents using the PO methods and re-radiated towards all observation points. Finally, the fields at each observation point are summed up to represent the final electromagnetic field computed at the corresponding location of the computational domain [7].

Due to lack of physical memory of the computing machine highly accurate solver could not be selected. The modelled corner reflector was of 30 cm faces. Metallic cylinder was of radius 20 cm and length 52 cm. Simulated flat plate is of length 62 cm and width 40 cm.

III. RESULTS AND DISCUSSIONS

Corner Reflector

Tetrahedral corner reflector of three faces each of length 30 cm and was characterized at 7-10 GHz. Table I reports the simulated and calculated RCS values for this particular corner reflector. The resulting variation between the simulated and calculated value is attributed to the unavailability of physical memory of the computing machine to generate highly accurate solution.

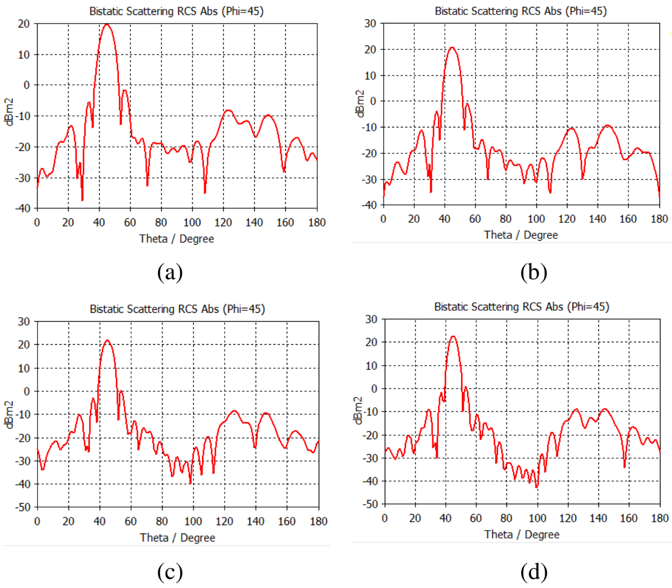

Figure 2. Simulated RCS graph of a Corner Reflector at (a) 7GHz (b) 8GHz (c) 9GHz (d) 10GHz

TABLE I. RCS values of a corner reflector in function of frequency

Frequency(GHz)	Simulated RCS(dBm^2)	Calculated RCS(dBm^2)
10	22.8	22.65
9	21.9	22.19
8	20.8	21.68
7	19.7	21.1

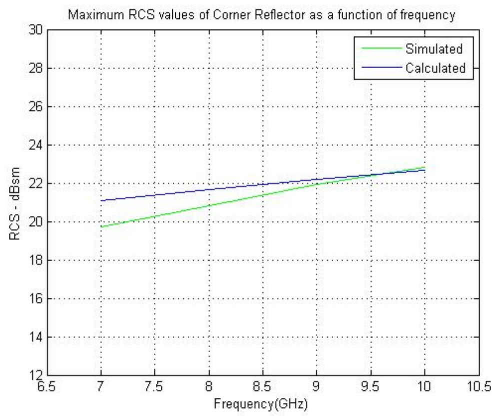

Figure 3. Graph comparing the maximum simulated and calculated RCS values of a corner reflector in the range of 7-10 GHz.

Flat Plate

Simulated flat plate was of length 62 cm and width 40 cm. Figure 4 illustrates the RCS patterns of this particular flat plate at frequencies of 7-10 GHz for varying aspect angles. For 9 GHz operational frequency the peak value is observed at aspect angle of 90 degree and the simulated value is 45.5 dBm^2.

The RCS of a flat plate can be interpreted theoretically from the formula shown in figure 1. A comparison of theoretical and the simulated values are shown in table II. Calculated and simulated values show good agreement with each other verifying the accuracy of simulation model.

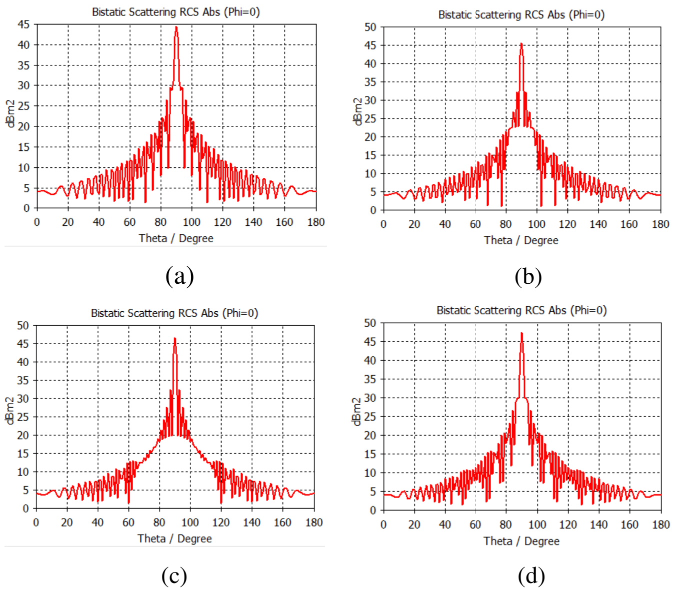

Figure 4.Simulated RCS graph of a Flat Plate at (a) 7GHz (b) 8 GHz (c) 9GHz (d) 10GHz

TABLE II. RCS values of a flat plate in function of frequency

Frequency(GHz)	**Simulated RCS(dBm^2)**	**Calculated RCS(dBm^2)**
10	47.5	46.32
9	46.6	45.41
8	45.5	44.39
7	44.4	43.23

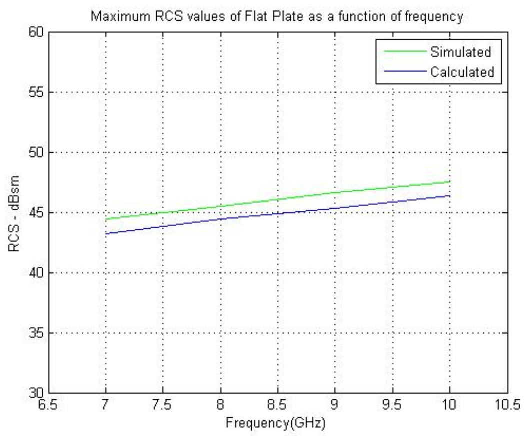

Figure 5. Graph comparing the maximum simulated and calculated RCS values of a Flat Plate in the range of 7-10 GHz

Metallic Cylinder

Figure 6 represents the RCS patterns of a metallic cylinder of radius 20 cm and length 52 cm at frequencies of 7-10 GHz.

RCS value is depicted in the figure as a function of aspect angles. For 10 GHz frequency of operation maximum value of RCS is 20.2 dBm^2 obtained at an aspect angle of 87 degree. The diagram clearly signifies the variation of RCS values of a cylinder with changes in its orientation.

The simulated value is compared with a theoretically calculated value as obtained from figure 1 to verify the accuracy of methodology of simulation. Following table III shows a comparative study of calculated and simulated RCS value. Limited variation is observed between the values of concern.

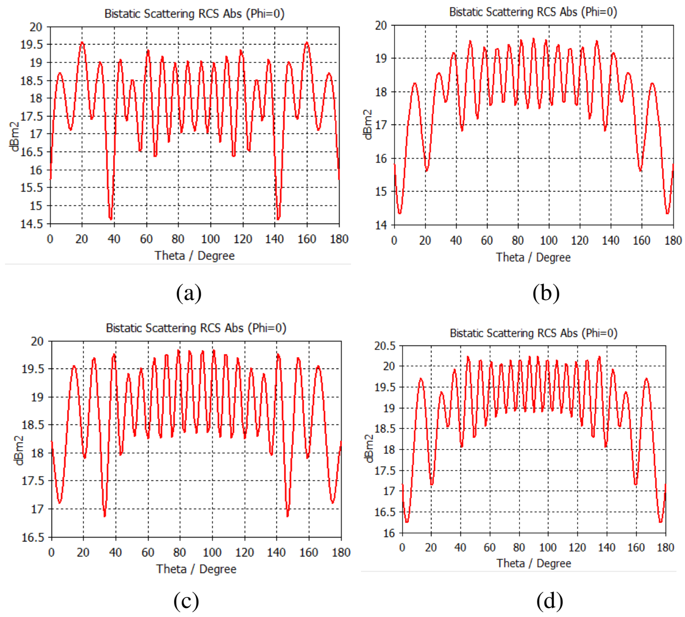

Figure 6. Simulated RCS graph of Metallic Cylinder at (a) 7GHz (b) 8GHz (c) 9GHz (d) 10 GHz

TABLE III. RCS values of a metallic cylinder in function of frequency

Frequency(GHz)	**Simulated RCS(dBm^2)**	**Calculated RCS(dBm^2)**
10	20.2	20.54
9	19.8	20.08
8	19.6	19.57
7	19.6	19.0

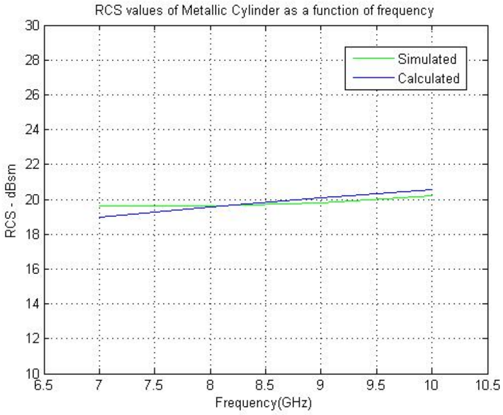

Figure 7. Graph comparing the maximum simulated and calculated RCS values of a Metallic Cylinder in the range of 7-10 GHz

IV. CONCLUSION

The paper presented a simulation methodology to determine the RCS values of simple targets of corner reflector, cylinder and flat plate. The RCS patterns of these targets as function of aspect angles at various frequencies showed the degree of dependency of RCS on operational frequency and orientation of the concerned target. The simulated RCS values showed good agreement with theoretically calculated RCS values verifying the accuracy of simulations modelled.

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