Radar Cross Section Analysis for an Ogive Target

(Around Radome or a Missile)

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***Abstract*—Radar cross section and its reduction is an area, which has a lot of room for research and over the past few decades, this particular area has gained significant importance in military and defense applications. Radar cross section is dependent on a number of parameters including shape, orientation, operating frequency, aspect angle, permittivity, permeability, transmitted power and related aspects. The research presented in this paper investigates the radar cross section of an ogive shape structures, which is related to missiles and aircrafts. Simulations for radar cross section are performed for different aspect angles and frequencies. The results show that radar cross section is highly dependent on the aspect angles and hence, significant counter measures can be achieved by using ogive and alike structures.**

***Keywords*—radar cross section; ogive; fuselage; scattering; angle; frequency**

I. INTRODUCTION

Radar cross section is a measure of how big the target appears to the radar and thus it tells the detectability of the target to the radar. It determines the ability to reflect radar signals in the direction of the radar receiver. The prediction of the RCS of bodies both simple and complex is a different electromagnetic problem that has challenged scientists and engineers since the development of the radar [1].

The point to notice is that not all of the radiated energy falls on the target. RCS is the product of three factors namely; the projected cross section, reflectivity and the directivity.

Reflectivity is the percent of intercepted power scattered by the target, whereas the directivity represents the ratio of the power scattered back in the radars direction to the power that would have been backscattered, had the scattering been uniform in all directions isotropically [2].

The amount of reflected power from the target located at range R from the radar is given by

$$P_r = \sigma P_{iD} \qquad (1)$$

Where P_{iD} is the power density of a wave incident on a target

RCS (σ) is defined as

$$\sigma = 4\pi R^2 \lim_{R\to\infty}\left(\frac{P_{rD}}{P_{iD}}\right) \qquad (2)$$

Where P_{rD} is the power density of the scattered waves at the receiving antenna. The RCS defined by this equation is known as backscattered RCS of the target. The backscattered RCS is measured from all waves that are scattered in the direction of the radar. These waves should have same polarization as that of the receiving antenna. It is a subset of the total scattered RCS, which obviously is greater than the target RCS. RCS is a function of θ and Φ .

RCS prediction requires solving either differential or integral equations, which can get complex for various objects. Some of the most commonly used methods are Geometrical Optics, Physical Optics and method of moments. This research is focused on Physical optics for simulations using POFACETS GUI [3]. The term scattering cross section refers to the spatial distribution of energy or fields around a target, usually at distances significantly greater than any target dimension [1].

An ogive is a pointed curved surface used to form a streamlined nose of a bullet, shell, missile or an aircraft. It is considered as a low RCS shape and we'll be using it as a model for our simulations. There has been a considerable interest in super maneuverability where previously unattained regions of the maneuver envelope for a fighter aircraft are attempted [4-5].

Generally aircrafts have complex ogives, that is why there was a need of looking into ogive and alike structures. Here simulation results have been provided using ogive shape to find out the behavior of these shapes under differenct angles and frequencies. A good low RCS aircraft design should exploit shaping to the greatest possible extent [2].

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II. RADAR CROSS SECTION FOR OGIVE SHAPES

Ogive shape can also be approximated for a radome of the radar. Radome is a protective housing for an antenna to protect the antenna from adverse environments in ground-based, shipboard, airborne and aerospace applications while having insignificant effect on the electrical performance of the enclosed antenna. For airborne radomes the exterior shape has to be streamlined with respect to aerodynamic forces, be camouflaged or architecturally acceptable in appearance. Radome always changes the electrical performance of the antenna because of wave reflections and refractions at interfaces between materials media and because of losses in the radome materials [6]. Similarly, for the missile section which generally has geometry similar to that of a hypothetical missile, it was expected that the diagrams would adjust more adequately to those of the hypothetical missile [7].

Simple shapes' RCS are known according to the ratio between their dimensions and the wavelength. Every more complex shape can be considered as the sum of simple shapes, nevertheless the complex shape's RCS will not be the sum of each simple shape's RCS: in fact, because of the coherence or no coherence between the different RCS, they can be added as well as subtracted [8].

The total RCS contains scattering field, which can be achieved by direct simulation of the antenna and the fuselage modeled together [9-12]. The radiation pattern of an antenna is generally the basic requirement since it determines the spatial distribution of the radiated energy [13].

RCS of a target is directly proportional to the size of the target. RCS measurements in the frequency region, where the target extent and wavelength are comparable, are referred to as Rayleigh region. Whereas the RCS measurement in frequency region, where the target extent is much larger than the operating wavelength, is known as the optical region [14].

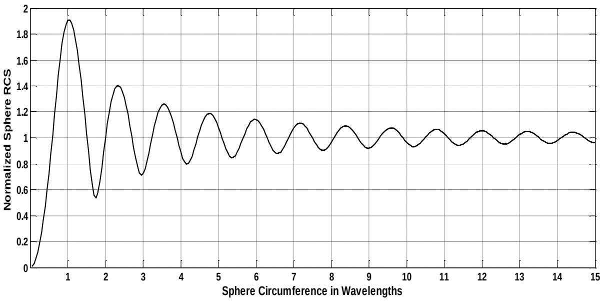

Fig. 1. *Normalized Radar Cross Section for a sphere*

Here, we first see the RCS of a perfectly conducting sphere and then we will move our discussion to the ogive structure. Fig.1 shows the normalized sphere radar cross section for a perfectly conducting sphere. Waves scattered from a perfectly conducting sphere have the same polarization with the incident waves. The normalized backscattered RCS for a perfectly conducting sphere is given as [14]

$$\frac{\sigma}{\pi r^2} = \left(\frac{j}{kr}\right)\sum_{n=1}^{\infty}(-1)^n(2n+1)\left[\left(\frac{krJ_{n-1}(kr)-nJ_n(kr)}{krH^{(1)}_{n-1}(kr)-nH^{(1)}_n(kr)}\right)\right]-\left(\frac{J_n(kr)}{H^{(1)}_n(kr)}\right) \tag{3}$$

Where r is the radius of the sphere, $k = 2\pi/\lambda$, λ is the wavelength , J_n is the spherical Bessel of the first kind of order n , and $H_n^{(1)}$ is the Hanel function of order n.

Fig.2 shows the radar cross section for various values of aspect angles for a plate radius of 4m and operating frequency of 2 GHz whereas Fig.3 shows the corresponding RCS for a frequency of 8 GHz.

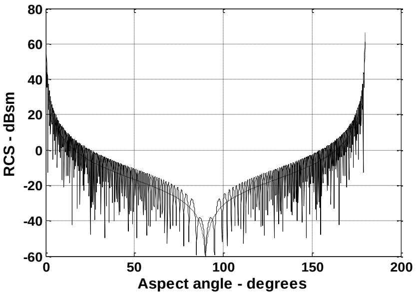

Fig. 2. *RCS vs. Aspect angle for 2GHz*

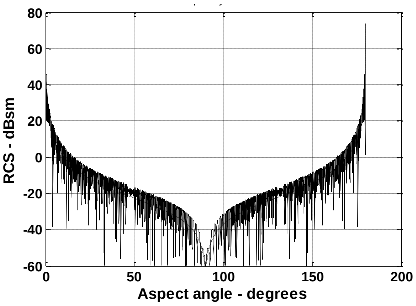

Fig. 3. *RCS vs. Aspect angle for 8 GHz*

These figures showed the behavior for a sphere, A flat plate that is perpendicular to the radar line-of-sight reflects directly back at the radar. A tilted plate reflects away from the radar. A corner reflects directly back to the radar somewhat like a flat plate [1]. Now we are going to analyze the RCS of more complex structures i.e. ogives. An ogive is a well known example of a low radar cross section conducting body.

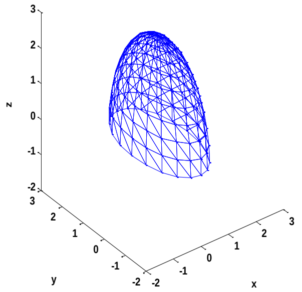

Fig. 4. *3-D view of an Ogive*

We have used [3] for simulating a perfect electric conductor, ogive shape for evaluating the RCS for various values of aspect angles and frequency, where relative permittivity is set to 3.7 and loss tangent is set to 0.0046. Fig.5 shows the plot of RCS vs. angle for an operating frequency of 0.3 GHz whereas fig.6 shows the corresponding plots for 2 GHz.

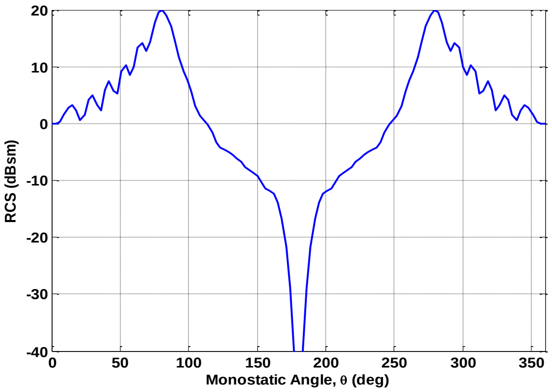

Fig. 5. *RCS vs. Angle for 0.3 GHz frequency*

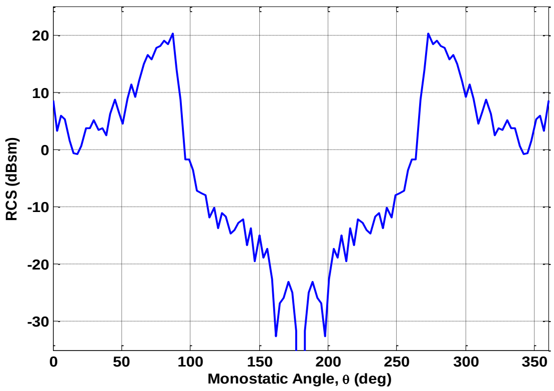

Fig. 6. *RCS vs. Angke for 2 GHz frequency*

It is quite evident from the figures that raise in frequency results in wide spread around the depression and its peak is observed at 180 degrees and it corresponds to open space or centre point of the ogive. It shows that for a typical ground based radar, lower operating frequency would result in a wider range for more visibility of the target.

Fig.7 to fig.12 represents the plots of radar cross section versus the frequency for different values of elevation theta angles and the azimuth phi angles. Change of the azimuth angle will not cause much change in RCS due to the shape of ogive as it is almost same all around (see fig.9) , however for change of the elevation angle there is considerable change in the resultant radar cross section.

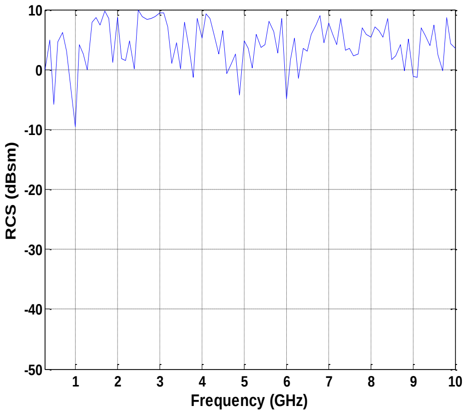

Fig. 7. *RCS vs. frequency when elevation and azimuth angle are set to 0*

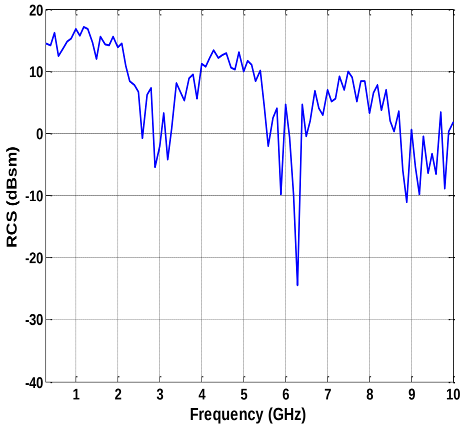

Fig. 8. *RCS vs. frequency when elevation is set to 90 degrees.*

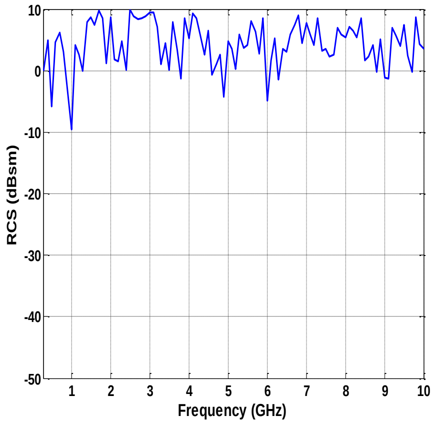

Fig. 9. *RCS vs. frequency when azimuth angle are set to90 degrees*

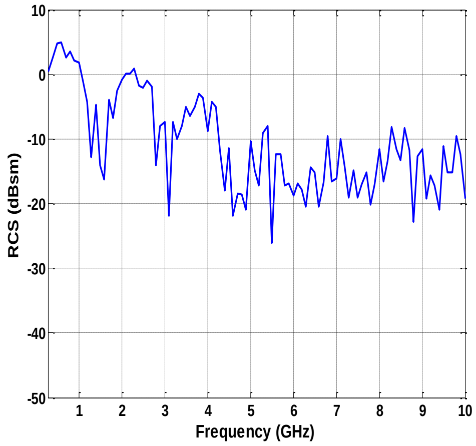

Fig. 10. *RCS vs. frequency when elevation and azimuth angle are set to 90 degrees*

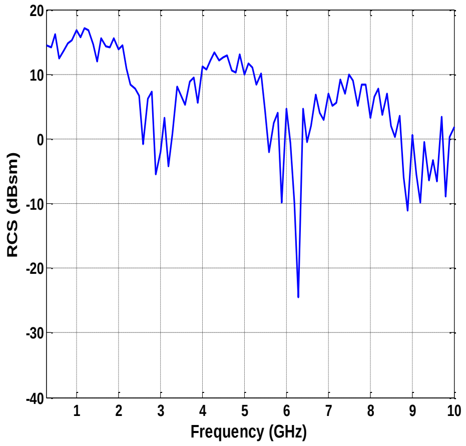

Fig. 11. *RCS vs. frequency when elevation angle is set to 270 degrees*

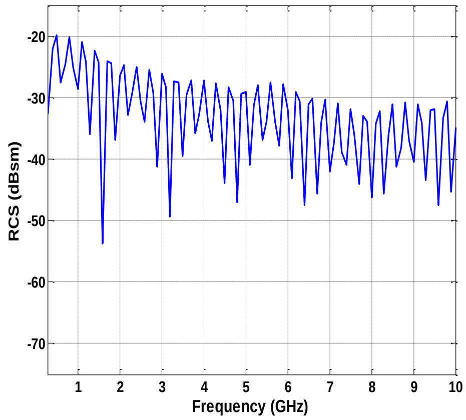

Fig. 12. *RCS vs. frequency when elevation angle is set to 175 degrees*

From these figures, it can be seen that around the ogive structure, the scattering would decrease the radar return and hence lesser RCS would be observed [see fig. 10 and 11]. Now as we get closer to 180 degree i.e. bottom the corresponding RCS would get more and more negative (see fig.12) and at 180 degrees (see fig.13) there would be almost no scattering because of the internal reflections inside the ogive and hence the radar return would get so weak that observed value by the ground based radar will be negligible.

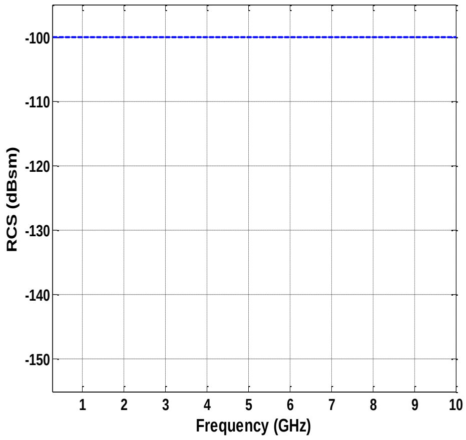

Fig. 13. *RCS vs. frequency when elevation angle is set to 180 degrees*

III. CONCLUSION

This research concludes that an ogive structure, which can be related to a missile or a carefully modified radar radome, can be an ideal structure for an electronic countermeasure system as the depression in the surface can give a very lesser radar cross section and it will be difficult for ground based radar to detect such a target. Although lower operating frequency can be handy for spherical and alike structures, still an ideal ogive can be very difficult to detect as it almost becomes invisible at its depression and also around the ogive it results in a very weak radar return.

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