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Prediction of Radar Cross Section of Target Using Backscattered Phenomenon

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Abstract- Prediction of radar cross section measurements for different target shapes has been studied in this paper and we are developing the mat lab coding to simulate the output graphs for different objects. This paper has describe the radar absorbing material characterization and radar cross section measurements, by using very simple objects (or) targets.

Simple targets like sphere, rectangular flat plate, triangular flat plate, ellipsoid, truncated cone, cylinder and circular flat plate were measuring the backscattered radiation target. Typical radar cross sections were obtained in different aspect angles, like'θ' by reflecting the object from target to radar and detecting in shapes like frequency,'φ' and also detect the size, shape ,material, incident angle, reflected angle and distance between the radar transmitter and target.

Keywords-*component; Radar cross section; Radar shapes, Radar measurements*

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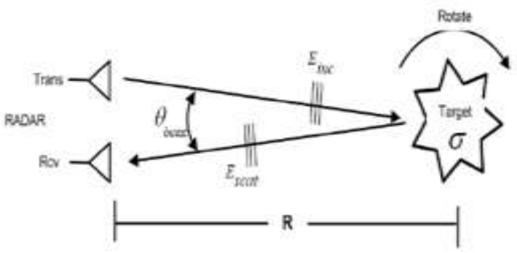
1. INTRODUCTION

(RCS) is a measure of how detectable an object is with radar. A larger RCS indicates that an object is more easily detected. When radar waves are beamed at a target, only a certain amount is reflected back



Radar Cross Section diagramwhile important in detecting targets, strength of emitter and distance are not factors that affect the calculation of a RCS because the RCS is (approximately) only a property of the target. The amount of incident power interrupted by the target and reradiated in the direction of radar is known as radar cross section.

$$\sigma = \lim_{R\to\infty} 4\pi R^2 \left|\frac{E_r}{E_i}\right|^2 (1)$$

Backscattered Phenomenon:

The best known example of a radar target of known scattering properties is a conducting sphere whose backscatter cross section in the optical regime is given by the formula is $\sigma_{sphere} = \pi r^2, r \gg \lambda (2)$

where r is the radius of the sphere and λ is the wavelength of the radiation [2].

Simple Objects:

Ellipsoid:

An ellipsoid is a three-dimensional figure. Each of three perpendicular axis, whose plane selection are normal to one axis are circles and all the other plane sections are ellipse.

Rectangular Flat Plate:

A 4-sided flat shape. Where all interior angles are right angle (90).And also opposite sides of parallel and of equal length.

Sphere:

A 3-dimensional object shaped like a ball. Every point on the surface is the same distance from the center.

Triangular Flat Plate:

It is a 3-sided flat plate and having three corners. All sides of triangle are equal length. It is having three vertices

Truncated Cone:

It is also known as frustum. A frustum is a portion of solid (normally a cone) that lies between two parallel planes cutting in it.

Cylinder:

Acylinder whose radius of cross sectionis ellipse is called an elliptical cylinder. A Cylinder whose radius of cross section is circular is called a circular cylinder. Here we are considering the length between the two circular cylinder and elliptical cylinder.

Circular Flat Plate:

It is a 3 sided flat plat. Every point on the surface is same distance from the center. It is having a three co- ordinary, z. we are taking at an angleθ.

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2. Factors That Effect on Radar Cross Section

Size:
As a rule, the larger an object, the stronger it's RADAR reflection and thus the greater it's RCS. Also, RADAR of one band may not even detect certain size objects. For example. 10 cm (S-band RADAR) can detect rain drops but not clouds whose droplets are too small.

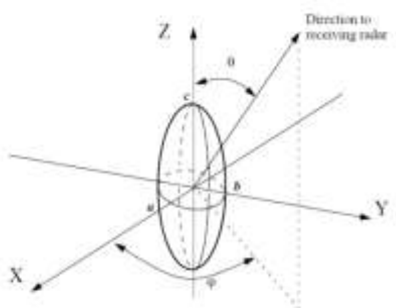
RCS of an Antenna:For the case of an antenna the total RCS can be divided into two separate components as Structural Mode RCS and Antenna Mode RCS. The two components of the RCS relate to the two scattering phenomena that takes place at the antenna. When an electromagnetic signal falls on an antenna surface, some part of the electromagnetic energy is scattered back to the space. This is called structural mode scattering. The remaining part of the energy is absorbed due to the antenna effect. Some part of the absorbed energy is again scattered back into the space due to the impedance mismatches, called antenna mode scattering.

RADAR Absorption Point: The SR-71 Blackbird and other planes were painted with a special "iron ball paint". This consisted of small metallic-coated balls. RADAR energy is converted to heat rather than being reflected.

Material:
Materials such as metal are strongly radar reflective and tend to produce strong signals. Wood and cloth (such as portions of planes and balloons used to be commonly made) or plastic and fiber glass are less reflective or indeed transparent to RADAR making them suitable for ran domes. Even a very thin layer of metal can make an object strongly radar reflective. Also, some devices are designed to be RADAR active, such as RADAR antennae and this will increase RCS

3. Description of Simple Targets

Ellipsoid:



Ellipsoid figure centered at (0, 0, 0)

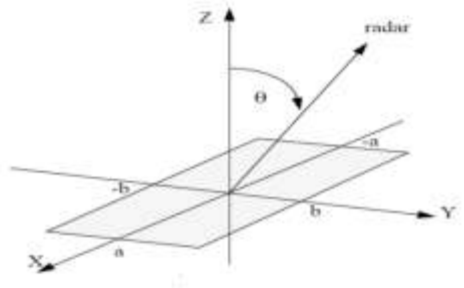
$$\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2 = 1 \quad (3)$$

Ellipsoid backscattered RCS formula is $\sigma = \pi c^2$ (4)

Rectangular Flat Plate: Consider a perfectly conducting rectangular flat plate in the x-y plan as shown in Fig. The two sides of the plate are denoted by 2a and 2b. For a linearly incident wave in the x-z plane, the horizontal and vertical backscattered RCS respectively given by

$$\sigma_V = \frac{b^2}{\pi}\left|\sigma_{1V} - \sigma_{2V}\left[\frac{1}{\cos\theta} + \frac{\sigma_{2V}}{4}(\sigma_{3V} + \sigma_{4V})\right]\sigma_{5V}^{-1}\right|^2 \quad (5)$$

$$\sigma_H = \frac{b^2}{\pi}\left|\sigma_{1H} - \sigma_{2H}\left[\frac{1}{\cos\theta} - \frac{\sigma_{2H}}{4}(\sigma_{3H} + \sigma_{4H})\right]\sigma_{5H}^{-1}\right|^2 (6)$$



The horizontal and vertical backscattered RCS is reduced to

$$\sigma_H \to 0 (7)$$

$$\sigma_V = \frac{ab^2}{\lambda}\left\{\left(1 + \frac{\pi}{2(2a/\lambda)^2}\right) + \left(1 - \frac{\pi}{2(2a/\lambda)^2}\right)\cos(2ka - \right.$$
$3\pi 5$(8)

The back scattered RCS for a perfectly conducting thin rectangular plate for incident wave at any θ, ϕ can be approximated by

$$\sigma = \frac{4\pi a^2 b^2}{\lambda^2}\left(\frac{\sin(ak\sin\theta\cos\varphi}{ak\sin\theta\cos\varphi}\frac{\sin(bk\sin\theta\cos\varphi}{bk\sin\theta\sin\varphi}\right)^2(\cos\theta)^2 (9)$$

Sphere: In this section, it is assumed the radar is always illuminating an object from the positive z direction. Due to symmetry waves scattered from a perfectly conducting sphere are cross-signal (have the same signal) with the incident waves. This means that the backscattered waves are practically zero. For example, if the incident waves were left circularly signal (LCS), then the backscattered wave will also be LCS. However, because of the opposite direction of propagation of the backscattered waves, they are considering to be Right circularly signal (RCS) by the receiving antenna. Therefore, the perfect signal (PS), backscattered wave from a sphere are LCS in z axis, the opposite signal (OS), backscattered wave from a sphere is negligible.

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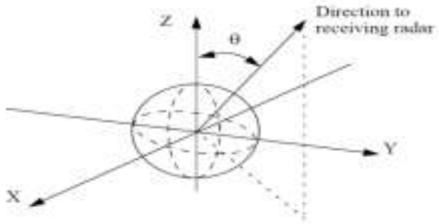


The normalized exact backscattered RCS for a perfectly conducting sphere is a MIE series is given by

$$\frac{\sigma}{\pi r^2} = \left(\frac{j}{kr}\right)\sum_{n=1}^{\infty}(-1^n)(2n+\ 1)\left[\left(\frac{kr\,J_{n-1}-nJ_n(kr)}{kr\,H_{n-1}^{(1)}(kr)-n\,H_n^{(1)}(kr)}\right)-\right.$$
$$Jn(kr)Hn1(kr)(10)$$

Mie is nothing but a scientist name. Where r is the radius of the sphere, k= 2π/λ, λ is the wavelength. *Jn be* the Bessel function of first order n. HN is the hankle function of n. and is given by

$$H_n^{(1)}(kr) = J_n(kr) + jY_n(kr)(11)$$

Two regions are identified here they are Rayleigh, optical region. First is optical region (corresponding to smaller region). In this case,

$\sigma = \pi r^2 r >> \lambda (12)$

Second is Rayleigh region (corresponding to larger region). In this case,

$\sigma = 9\pi r^2 (kr)^4 r \ll \lambda (13)$

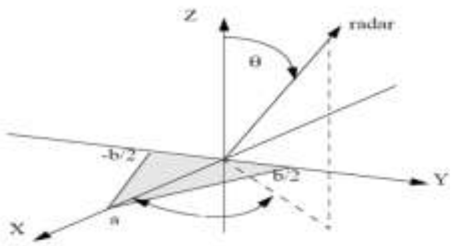
The region between Optical and Rayleigh region is oscillatory in nature are called Mie region.

Triangular Flat Plate

Consider the triangular flat plates defined by the isosceles triangle are oriented.

The back scattered RCS can be approximate for small aspect.

$$\sigma = \frac{4\pi A^2}{\lambda^2}(\cos\theta)^2\sigma_0 \quad (14)$$



Triangular flat plate backscattered RCS formula is

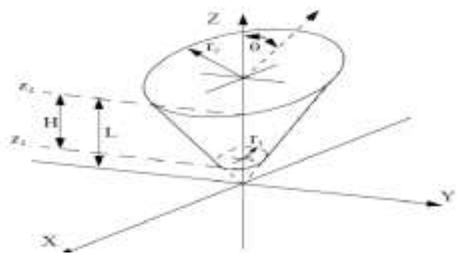
$$\sigma = \frac{4\pi A^2}{\lambda^2}(\cos\theta)^2\left[\frac{(\sin(\beta/2))^4}{(\beta/2)^4}\right] \quad (15)$$

Truncated cone

The half cone angle α is given by

$$\tan\alpha = \frac{(r_2-r_1)}{H} = \frac{r_2}{l} \quad (16)$$

Where Z is equal to Z1 or Z2 depending on whether the RCS contribution is from small or larger of the cone. Again using trigonometric identities can be reduces to



$$\sigma = \frac{\lambda z\tan\alpha}{8\pi\sin\theta}(\tan(\theta-\alpha))^2 \quad (17)$$

When the radar illuminates the frustum starting from the smaller end (i.e., the radar is in negative Z direction should modified to $\sigma = \frac{\lambda z\tan\alpha}{8\pi\sin\theta}(\tan(\theta+\alpha))^2$ (18)

Indicator: Indicator '0' is when viewing from smaller end.

Indicator'1' is when viewing from larger end.

Cylinder

Two cases are presented: first, the general case of an elliptical cross section cylinder; second, the case of a circular cross section cylinder. The normal and non-normal incidence backscattered RCS due to linearly incident wave from an elliptical cylinder with minor and major radii being r1 and r2 are respectively given below

$$\sigma_{\theta_n} = \frac{2\pi H^2 r_2^2 r_1^2}{\lambda[r_1^2(\cos\varphi)^2 + r_2^2(\sin\varphi)^2]^{1.5}} \quad (19)$$

$$\sigma = \frac{\lambda r_2^2 r_1^2 \sin\theta}{8\pi(\cos\theta)^2[r_1^2(\cos\varphi)^2 + r_1^2(\sin\varphi)^2]^{1.5}} \quad (20)$$

For a circular cylinder of a radius r, then due to roll symmetry, the Equations can be reduced to

$$\sigma_{\theta_n} = \frac{2\pi H^2 r}{\lambda} \quad (21)$$

$$\sigma = \frac{\lambda r\sin\theta}{8\pi(\cos\theta)^2} \quad (22)$$

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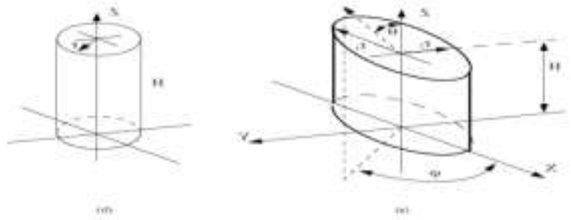
It shows the back scattered RCS of an elliptical cylinder and shows the back scattered RCS of an elliptical cylinder and circular cylinder.

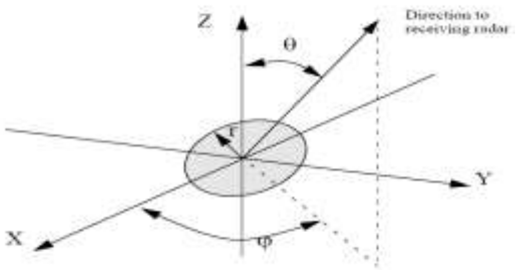


Elliptical Cylinder; Circular Cylinder `

` Cylinder type: 'Circular,' i.e., r1=r2.

'Elliptic,' i.e., r1 ≠ r2.

Circular Flat Plate:



It shows a circular flat plate of radius r,

Centered at the origin. Due to circular symmetry, the circular backscattered RCS of a circular flat plate has no dependency on φ. The RCS is only aspect angle (θ) dependent. For normal incidence (i.e., zero aspect angle (θ) the backscattered RCS of circular flat plate is

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$$\sigma = \frac{4\pi^3 r^4}{\lambda^2}\theta = 0^0 \text{ (23)}$$

For non-normal incidence, two

Approximations for the circular flat plate backscattered RCS for an linearly incident wave are

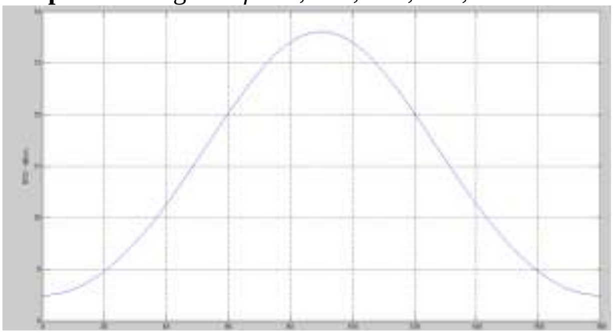
$$\sigma = \frac{\lambda r}{8\pi \sin\theta((\tan\theta))^2} \text{ (24)}$$

$$\sigma = \pi k^2 r^4 \left(\frac{2J_1(2kr\sin\theta)}{2kr\sin\theta}\right)^2 (\cos\theta)^2 \text{(25)}$$

4. Simulation Results

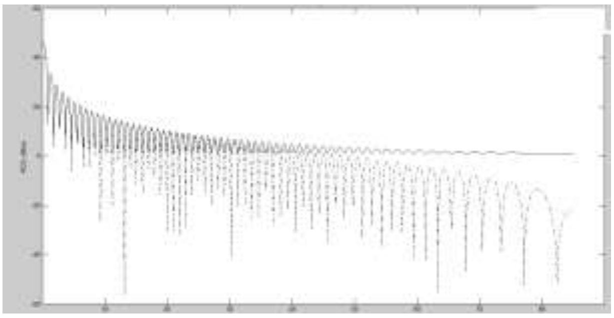
Ellipsoid:

Graph1: Here given φ=30, a=2, b=3, c=4;



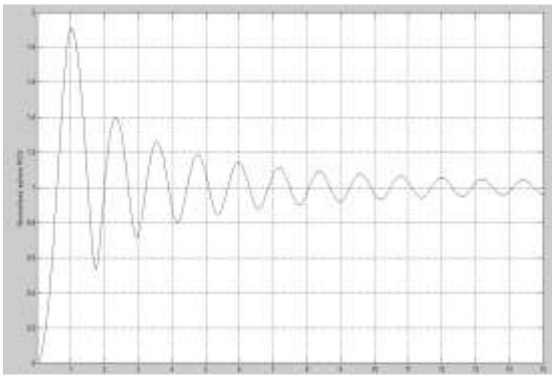
Rectangle Flat Plate:

Graph2: Here a=1, b=2, frequency=30;

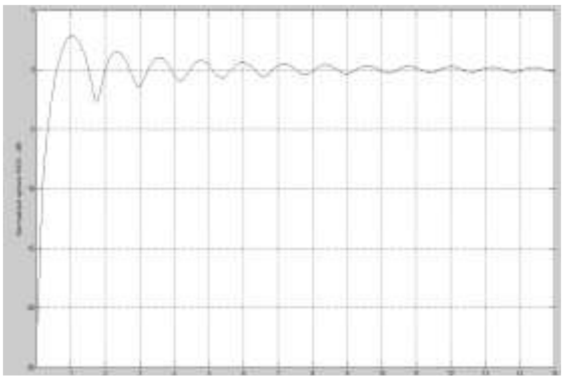


Sphere:

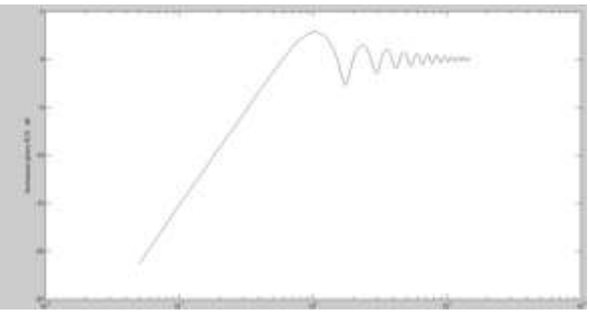
Graph3: Sphere in RCS



Graph4: RCS sphere in db

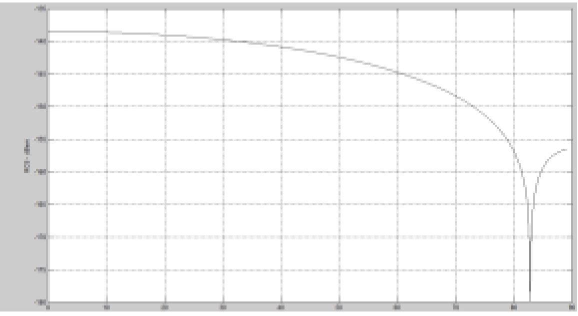


Graph 5: Normalized sphere RCS in db



Triangular Flat Plate:

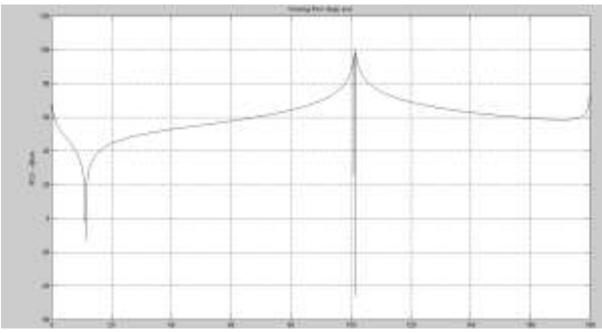
Graph 6: Here we are given a-1, b=2, φ=5, freq=30



Truncated Cone:

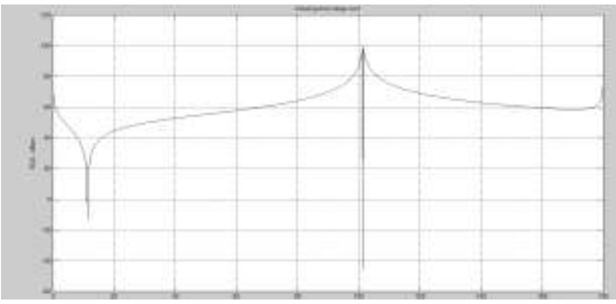
Graph 7: Here given r1=1, r2=2, h=5, freq=30, indicator.

Frustum at larger end



Graph8: Here we are given r1=1, r2=2, h=5, freq=30, indicator=0;

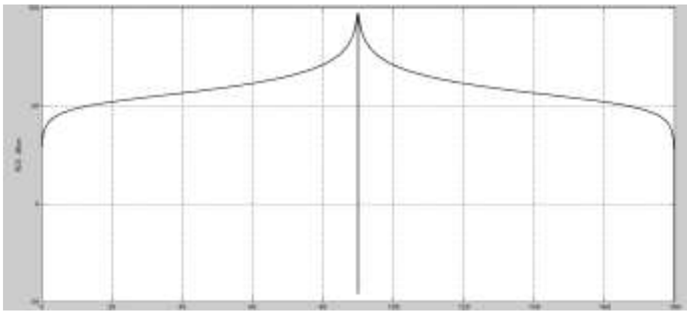
Frustum at smaller end



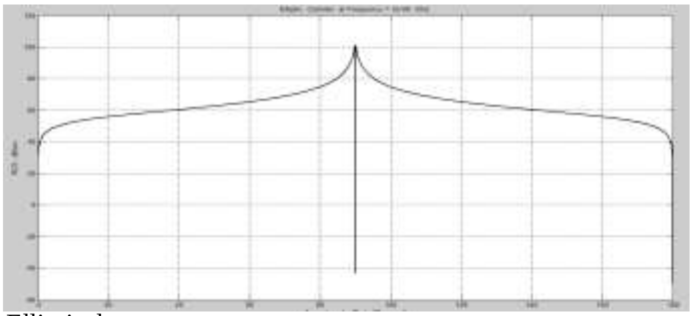
Cylinder:

Graph 9: Here we are given r1=1, r2=2, freq=30, φ=20, h=5;

Circular type



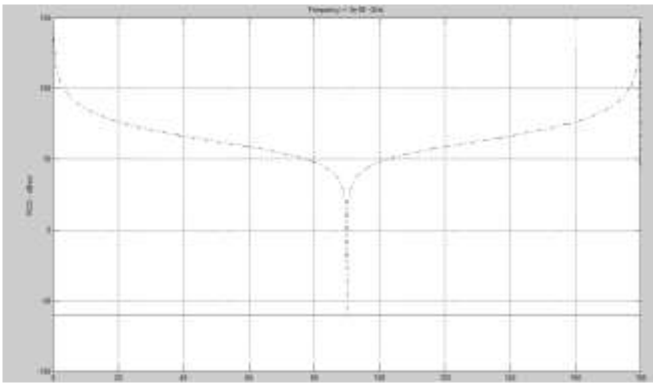
Graph 10: Here we are given r1=1, r2=2, h=5, freq=30, φ=20;



Elliptical type

Circular Flat Plate:

Graph 11: Here we are given r=5, freq=30;



5. Conclusion

Using the MATLAB programming, prediction of radar cross section of some simple shapes of targets like sphere, ellipsoid, circular flat plates, truncated cone (frustum), cylinder, rectangular flat plate, triangular flat plate (isosceles) and complex targets are obtained, Were characterized by measuring the backscattered radiation patterns in different aspect angles The RCSvariation as a function of frequency is obtained for two scatters and are presented. When the scattering spacing is more, RCS is highly oscillatory, while RCS is less oscillatory for lower scattering spacing. The backscattered RCS as a function of sphere circumference in wavelength is obtained these variations are obtained in the three regions namely RAYLEIGH, MIE, and OPTICAL REGIONS. In optical region, RCS oscillates as a function of frequency. For this purpose, spheres are flown attached to balloons. In order to obtain Doppler shift, spheres of known RCS are dropped out of an airplane and towed behind the airplane whose velocity is known to the radar.

6. FutureScope

Target cross sections of complex or extended targets such as aircrafts, ships and missiles are complicated and difficult to obtain. In such cases, the best radar RCS estimates are those obtained experimentally. However, experimentally RCS measurements may not always be possible. In such cases, estimates of the target physical shape and dimensions are used to compute RCS estimate using computer simulations. Since a target cross section is very sensitive to aspect angle, unless the target is stationary, change (fluctuate) over a period of time. Swirling has calculated the detection probability densities for different types of target fluctuations widely known as swirling-I through swirling-IV. Targets that do not have any fluctuations are normally referred to as swerling-0 or swirling-V targets.

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