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Radar Cross Section Estimation for a Complex Shaped Objects Using SPSG and PO Methods

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Abstract: Radar plays a crucial role in the present war scenario and defence applications. RCS is an important parameter that defines the target cross sectional area. The higher the RCS value, the greater the target detection capability of the Radar. RCS estimation mainly depends on the dimension, structure, inclination of the object towards the Radar, and also the material of which the object is made. Among these, the dimension, structure, and inclination of the object are considered to be the most significant features in RCS estimation process. RCS determination is an important task for identifying or classifying the objects as either friend or foe. Accurate estimation of Radar Cross Section (RCS) at high frequencies and reduction of radar perceivability at different frequencies is a challenging task. An efficient algorithm is required that can run on a standard PC which provides RCS predictions within a short time. In this paper, Spherical Polar Scattering Geometry (SPSG) and Physical Optics (PO) based algorithms are proposed to estimate RCS of complex structured objects.

Keywords- Radar Cross Section (RCS): Spherical Polar Scattering Geometry (SPSG): Physical Optics (PO): Frequency: Dimension: Wavelength.

INTRODUCTION

The Radar Cross Section of an object accepts a fundamental part in disclosure by radar. Redesign or decreasing of RCS of object which is being recognized by radar needs control dependent upon the applications. A thorough perception of the electromagnetic scattering characteristics of an object is essential for productive execution of needed control of its RCS. In military applications, decrease the RCS of air targets like rockets, flying machines, and spy satellites. Correspondingly, ground vehicles and rocket launchers ought to be arranged with the objective that they have least RCS. For testing of radars and searchers, counterfeit targets are required. These fake targets are to be expected for required RCS and sometimes, redesign the RCS to meet the range and testing conditions. [1-5].

A.RCS CONTROL

RCS Increase and Decrease: A few applications require improvement of the RCS. Getting ready planes require persevering after and along these lines for dependable following their RCS is extended. Fabricated airborne objects are used for rocket execution evaluation and these targets are followed by radars. The RCS of these airborne targets is improved. Customary practice is to use Luneburg focal points, corner reflectors and moreover transponders with enhancers. It depends on the application. Few applications require reduction of RCS [6-9]. Shaping and radar absorbing materials are the two essentially

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utilized RCS diminishment strategies on maritime ships.

B.RCS EVALUATION

The performance of the objects is evaluated using RCS prediction methodologies and RCS full scale measurements. Standard spheres that undergo calibration test with the dimensions 3”, 7” and 11” radius the RCS obtained are -17.44 dBsm, -10 dBsm and 6.10 dBsm considered for comparison. From Fig.1 it is observed that RCS can be evaluated using techniques like full scale measurements, scaled model measurements, RCS theoretical prediction software tools [10-15].

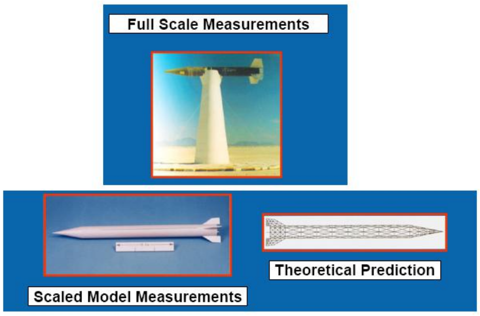

Fig.1 Techniques to RCS analysis and evaluation

RCS Simulation of Sphere:

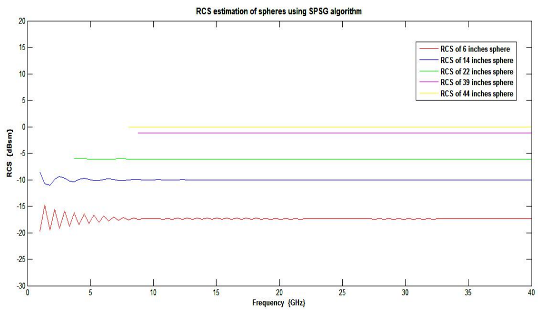

Fig.2 RCS (dBsm) vs. frequency (GHz) for diameters of sphere

From Fig. 2 it is observed that the spheres with standard diameters are considered for RCS estimation with respect to frequency varying in the range of 1 to 40 GHz using SPSG algorithm. Standard spheres with diameters of 6", 14", 22", 39" and 44" are considered for estimation using SPSG.

RCS of Sphere model with different dimensions of radius are considered for different frequencies ranging from 1 GHz to 38 GHz shown in Fig.3.

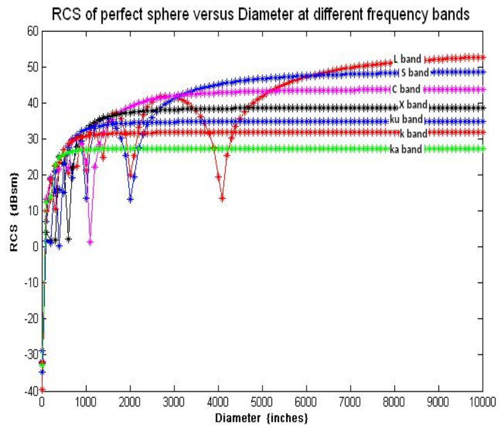

Fig.3 RCS of Sphere with different dimensions

RCS Simulation of Sphere without Dent (simple object):

Perfect sphere when manufactured and when it’s RCS is measured it may slightly differ due to manufacture fault. Here, RCS analysis has been carried out for sphere without dent [2] using SPSG based algorithm. Equation (1) is radar cross section (σ) of metal sphere with sphere radius (a) using Kerr relation as [1-7],

$$\frac{\sigma}{\pi a^2} = \frac{1}{\rho^2}\left|\sum_{n=1}^{\infty}(-1)^n(2n+1)(a_n^s - b_n^s)\right|^2 \quad (1)$$

A solid perfectly conducting sphere with radius ‘r’ is shown in the Fig. 4 has been considered for RCS analysis sphere radius 7 inches. Fig. 5 shows polar plot for RCS of sphere without dent. It is observed that RCS of sphere remains constant around -10 dBsm over entire aspect range of 0º to 360º.

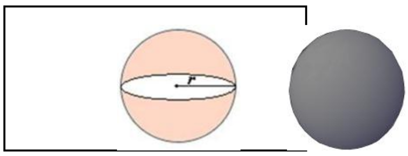

Fig.4 Sphere without dent

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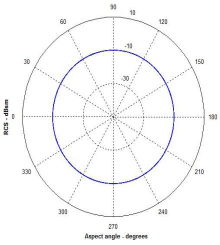

Fig.5 Polar plot for RCS of Sphere without dent

RCS Simulation of Sphere with Dent (Complex Object):

No sphere is perfect sphere when manufactured and when it's RCS is measured it may slightly differ due to manufacture fault. Here, error analysis has been carried out for RCS of sphere with dent [2]. RCS analysis is carried out for a sphere with hemispherical dent using modified SPSG. A solid perfectly conducting sphere with radius 'r' with a hemispherical dent radius 'p' is shown in Fig. 6 has been considered for RCS analysis with sphere radius 7 inches and dent radius 1 inch. Taking dent location on sphere at 60º in azimuthal considering elevation fixed [16].

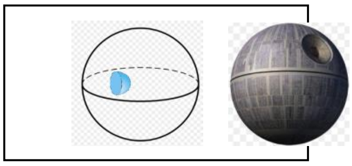

Fig.6 Sphere with dent

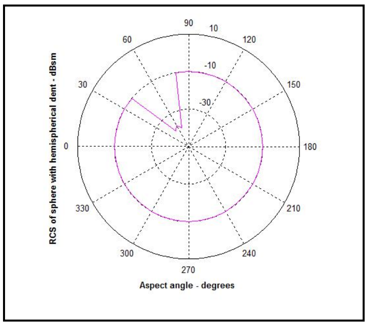

Fig.7 Polar plot for RCS of Sphere with dent

It is noted from Fig. 7 that dent RCS is around -38 decibels in square meter or dBsm at 60º whereas RCS of sphere is around -10 dBsm in remaining aspects of 0º to 360º.

TABLE I. ERROR ANALYSIS FOR RCS OF SPHERE WITH AND WITHOUT DENT

Sphere RCS	***Dent RCS***
-10 dBsm	-38

Sphere RCS	***Dent RCS***
	dBsm

RCS values of sphere values with and without dent are given in TABLE I.

RCS simulation of plasma generation around the sphere:

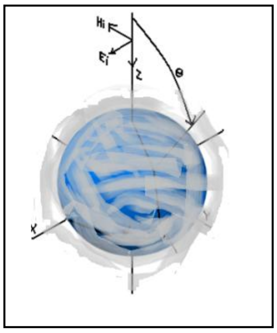

Fig.8 Plasma sphere

Plasma generated around the sphere is shown in Fig.8. Plasma stealth is known as active stealth technology and the electromagnetic waves will be scattered, refracted or absorbed when it strikes the plasma or ionized gas [10-16]. Standard spheres that undergo calibration tests with the dimension 7" Radius with RCS value of 0.1 m^2 or -10.0 dBsm is considered for comparison with the results simulated for RCS of plasma sphere and RCS of metal sphere. Plasma based SPSG is developed to simulate plasma RCS. Equation (2) is radar cross section of plasma sphere and equation (3) is propagation constant (k), substituting $n=n_1+jn_2$, as stated by Mie's theory, RCS of the plasma sphere is given by σ as [1]-[12],

$$\sigma = \frac{\pi}{k^2}\left\{\left[\sum_{l=i}^{\infty}(-1)^l(2l+1)(a_{lr}-b_{lr})\right]^2+\left[\sum_{l=1}^{\infty}(-1)^l(2l-1)(a_{li}-b_{li})\right]^2\right\}$$

(2)

$$k=\omega\sqrt{\mu_0\varepsilon_0\left(1-\frac{\omega_p^2}{\omega^2}\right)}$$

(3)

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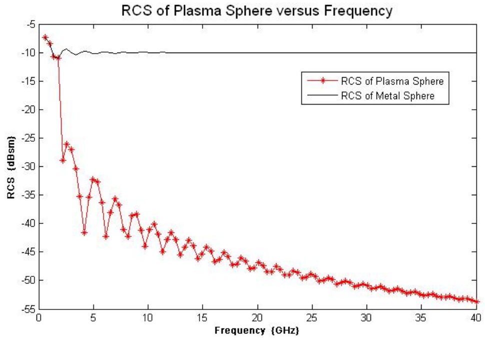

Fig.9 RCS of sphere covered with plasma

It is noted from Fig.9 that RCS of plasma generated around sphere and metal sphere. When transmitting wave frequency is less than plasma frequency (2.5 GHz) the waves will be reflected and if transmitting frequency is greater than the plasma frequency, the waves will absorbed by plasma. It shows that plasma covers on the objects are used for RCS decrease for few applications (like stealth).

TABLE II ERROR ANALYSIS FOR RCS OF SPHERE

S.No	***Sphere Diameterin inches***	***Radar Observation(P)***	***SPSG (Q)***	***Error (P)-(Q)***
1	6"	-17.44	-17.45	0.01
2	14"	-10	-9.99	0.01
3	22"	-6.10	-6.12	0.02
4	39"	-1.05	-1.06	0.01
5	44"	-0.1	-0.09	0.01

RCS values of sphere using SPSG and Radar observation are shown in Table II. It is observed that the error between radar observation and proposed algorithm is random in nature. It is also observed that the proposed SPSG algorithm is found to be nearer with the practical observed values of the radar. Measurement values for sphere without dent is available whereas, sphere with dent is not available in open literature.

C.RESULTS AND DISCUSSION

There is a change in RCS with respect to dimension and frequency for target models sphere shown in Fig. 2. As size of a target increases, obviously RCS increases and as frequency increases, RCS also increases. RCS variation is observed for different dimensions of Sphere for different frequency bands shown in Fig.3. RCS of sphere with and without dents are shown in Fig.5 and Fig.7. RCS of plasma sphere is shown in Fig.9.

D.CONCLUSION

It is concluded that radar cross section was computed for curved shaped object sphere. The backscattered RCS for these objects were estimated using RCS prediction methodology called Physical Optics. The far field monostatic RCS for these objects has been computed at various dimensions and at some specified Radar frequencies ranging from 1 GHz to 38 GHz. In this plots are obtained for RCS verses frequency for various dimensions for the given objects and the plots are also obtained for various frequencies for RCS verses aspect angle for the given objects. RCS enhancement is seen with respect to size and frequency. Using SPSG, RCS versus frequency plots are obtained for different diameters of sphere which are highly impractical with radar measurements and also with RCS prediction software tools. The proposed algorithms are easy to use with mathematical modeling for RCS estimation of objects in the absence of radar measurements due to system complexity and cost effective with hardware and software.

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