RCS PREDICTION OF ARBITRARY SHAPEDOBJECTSUSING HYBRID ITERATIVE METHOD

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ABSTRACT

Hybrid Iterative Method has been established to obtain the induced surface currents on a three dimensional complex target. Software has been developed for the same. It is hoped that with this information one can calculate the scattered field due to three dimensional complex targets (12) and hence that Radar Cross Section (RCS) for the same can be estimated theoretically.
KEYWORDS:- Hybrid, complex, scattered field, RCS

1.INTRODUCTION

Modern military aero planes require low radar cross section (RCS) to minimize enemy detection. Significant progress in this area has been made in recent years. Therefore, interest has developed in estimating the RCS of jet aircrafts. According to a published report [1], the RCS of a B-1A bomber is two orders of magnitude less than that of a B-52. This is mainly achieved by shaping the body of the aero plane and by using radar absorbing material. Among the remaining contributors to the total RCS of the aero plane the jet intake stands out. There has been a long history of study on the RCS of a jet intake [2]-[6] of arbitrary shape. In order to deal with such targets a significant study has been made on the RCS of complex target [7]. There are various methods for estimating the RCS of a complex target namely the method based on Geometrical Optics and Physical Optics, Keller's GeometricalTheory of Diffraction (GTD), the method of Equivalent Current (MEC) formulated by Michaeli and others [8], Physical Theory of Diffraction method (PTD) postulated by Ufimtsev [9]. Incremental Length Diffraction Coefficient (ILDS) method by Mitzner etc. Generally to calculate the RCS of an arbitrary shaped targets one has to solve the Magnetic Field Integral Equation (MFIE). There are several methods to solve MFIE. One such method is Method of Moments (MOM). MOM was not preferred in case of large sized bodies due to abnormally large size of matrices, to be solved. A new technique 'HYBRID ITRATIVE METHOD' has been used to calculate the induced currents on the surface of the scatterer. HIM is an iteration method and has been suggested by P.Krishnamurthy et.al. [10]. HIM speed up the algorithm as well as extends the range of problems that can be solved by iterative scheme. In iterative method, the surface of the scatterer is divided into lit and shadow regions. Physical Optics approximation is an appropriate method to compute surface current on the illuminated region of the scatterer. This current is taken as initial approximation correction current for shadow side region computing the higher order currents by iteration. In this paper an attempt is made to extend this method to more complex three dimensional targets, whereas P. Krishnamurthy et.al. [10] have applied HIM to a cylinder and a circle.

2.FORMULATION OF THE PROBLEM
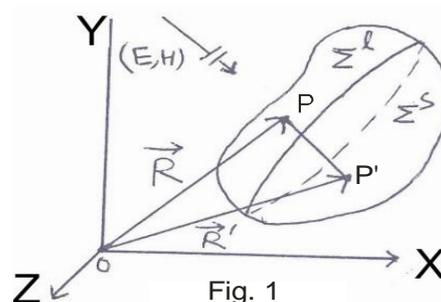
Fig. 1

Let us consider a perfectly conducting body of arbitrary shape in three dimensional space(Fig. 1). The body is illuminated by a plane wave. The induced surface current density $\vec{J}(\vec{R})$ at observation point P (Fig.1) can be computed

$$\vec{J}(\vec{R}) = 2\left[\hat{n} \times \vec{H}^{i}(\vec{R})\right] + \frac{1}{2}\left[\hat{n} \times \int_{\Sigma} \vec{J}(\vec{R}') \times \overline{\nabla}G(r)dS\right] \qquad .(1)$$

By MFIE as given by Maue (11)

Where,

$\vec{H}^{i}(\vec{R})$ - incident Magnetic Field vector at P

$\hat{n}$ - Outward drawn normal to the surface at P

$G(r)$ - Free space Green function

Now let us define the operator L such that

$$L(\vec{J}) = \int_{\Sigma} \vec{J}(\vec{R}') \times \overline{\nabla}'G(r)ds' \qquad (2)$$

So equation (1) can be written as

$$\vec{J}(\vec{R}) = 2\left[\hat{n} \times \vec{H}^{i}(\vec{R})\right] + \frac{1}{2}\hat{n} \times L(\vec{J}) \qquad (3)$$

Here, the surface of the body is denoted by Σ, $\vec{R}$ and $\vec{R}'$ are the observation and source position vectors respectively on Σ

And,

$$r = \vec{R} - \vec{R}' \qquad (4)$$

The prime on the gradient operator in equation (1) and (2) indicates that the differentiation is performed on the source coordinates G(r) is the free space Green's function given by

$$G(r) = e^{jkr}/4\pi r \qquad (5)$$

Where, k- Free space propagation constant

To solve MFIE for the induced surface current density $\vec{J}(\vec{R})$, the total surface is divided into lit (Σ^{l}) and shadow (Σ^{s}) regions. The dividing line between the two regions is called the Geometrical optics shadow boundary (Fig 1) and defined as the locus of the points satisfying $\hat{u}.\hat{n} = 0$ where $\hat{u}$ is the unit vector in the direction of propagation of the incident field. To start the iteration scheme we assume that first shadow side current is zero and the total induced surface current is due to the surface current on illuminated (lit) region. This is the Physical Optics current and given by

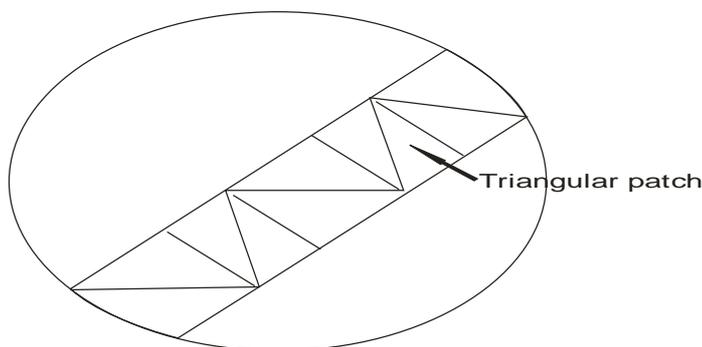$$\vec{J}(\vec{R}) = 2\hat{n} \times \vec{H}^{i}(\vec{R}) \qquad (6)$$

Fig. 2

This Physical Optics current given by equation (6) has been taken as the initial guess for iteration method. Now the value of current given by expression (6) is being put back in equation (2) to calculate correction current. By putting this correction current in equation (1) We get new value of surface induced current $\vec{J}(\vec{R})$. Again the process is repeated and iteration is kept on. After each iteration we get higher order approximation surface current. The iteration lasts when the method gets converged. To calculate induced currents on the surface of the scatterer, it is convenient to divide the scatterer surface into a number of small triangular patches. First we calculate the value of operator $L(\vec{J})$ for each

triangular patch. Since surface current $\vec{J}(\vec{R})$ can be considered as constant over a small triangular patch, one can write $L(\vec{J})$ as:

$$L(\vec{J}) = \vec{J}(\vec{R}) \times \int_{\Delta} \overline{\nabla}' G(r) ds' \qquad (7)$$

Where, $G(r)$ is a scalar quantity after which the operation of del operator becomes a vector. The vector thus obtained over the surface of a triangular patch is called self-patch Vector. The formulation is based on the assumption that both the observation point and source point lie within the same triangle. Computer Programme has been successfully developed for this purpose. After calculating L (J) for a triangular patch, it is necessary to determine the effect of the current fallowing in a triangular patch on the other triangular patches or in other words, we calculate the current in a particular triangular due to current flowing in another adjacent triangle for this purpose we assume that both triangles are in the same x-y plane. A computer programme has been developed for this purpose. Finally we consider a more general case, namely that observation point as well the triangles are there in three dimensional space and we have to calculate the value of the following integral.

$$\int \hat{n} \times \hat{H} \times \overline{\nabla} G \ ds \qquad .(8)$$

Where the integration is to be done over the area of a triangle &

$$G = e^{\textit{Jkr}} / 4\pi r$$

Where r is the distance from any point on the triangle to the observation point. Computer programme for this purpose has been successfully developed. Now with the help of equation (1), (2), (7) & (8) total surface current on surface of scatterer is calculated. if the total magnetic field vector on the surface of a perfectly conducting scatterer is H^T and $\hat{n}$ is a unit vector normal to the scatterer surface. Then for perfectly conducting scatterer the surface current is given by

$$\vec{J}(\vec{R}) = \hat{n} \times \overline{H^T} \qquad (9)$$

The scattered magnetic field H (R) is obtainable from magnetic field integral equation (MFIE) given by

$$\vec{H}^s(\vec{R}) = \frac{1}{4\pi} \int_s \hat{n} \times \vec{H}^T \times \overline{\nabla}' G(r) ds' \qquad (10)$$

Since we know the incident magnetic field vector $\overrightarrow{H}^i$ Therefore, the radar cross section, (6) for perfectly conducting scatterer can be calculated by the following expression

$$\sigma = R \xrightarrow{\text{lim}} \infty \frac{\left|\vec{H}^s\right|^2}{\left|\vec{H}^i\right|^2} \qquad (11)$$

Where $\overrightarrow{H}^s$ and $\overrightarrow{H}^i$ are the scattered and incident magnetic field.

3.RESULTS AND CONCLUSION

The Software has been developed successfully for computing the current on surface of scatterer (complex target). Using this information the scattered field due to three dimensional complextargets under consideration can be obtained. Further since the incident field is already known, hence the RCS can be estimated.

4.ACKNOWLEDGEMENT

AUTHOR

Dr.Neeraj Tyagi received his M.Phil.andPh.D. Degrees from Department of Electronic Sciences, University of Delhi, South Campus in 1989 and 1995 respectively. During 1992-1993 he taught in the same department and during 1994-2012 in DeenDayalUpadhyayaCollege, University of Delhi. He is Deputy Dean,Works,University of Delhi, Delhi

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