Parametric Models of Creeping Wave Scattering Center in Resonance Range

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***Abstract*—Based on the Specificity of the scattering mechanism of the radar target in the resonance range, we studied the scattering characteristics of targets in resonance range and the parametric models of the scattering centers of the creeping wave . we also gave an example to illustrate that the scattering mechanism of the target in the resonance range are complicated. Furthermore, we deduced and fitted the formulas of the cylinder's surface diffraction field produced by creeping wave, and then we obtaind the GTD and UTD creeping wave parametric models of the cylinder.**

Keywords—resonance region; creeping wave; parametric scattering center models

I. INTRODUCTION

The research of radar cross section (RCS) has always been a hot issue in the field of electromagnetics. Generally speaking, the current research are focusing on the calculation and analysis of high-frequency electromagnetic scattering characteristics. Few studies involving RCS at the low and medium frequency. With the electromagnetics engineering applications are widely used, the accurate prediction of the targets' scattering characteristics at low and medium frequency has become more and more important. The scattering mechanism in the resonance range follow unique laws and characteristics. Compared with the optical scattering range, the scattering echo in the resonance range contains a large number of low-frequency components, and the interaction between scattering centers are intensely. A single scattering center often contains a variety of scattering mechanism components; At the same time, due to the fact that modern radar targets are mostly low-scattering targets, the mirror reflection and edge diffraction has been greatly attenuated. In a certain posture, the contribution of the creeping wave will be greater than the scattering of the surfaces and the edges.

II. COMPLEX TARGETS SCSTTERING CHARACTERISTICS IN RESONANT REGION

Take the F-22 fighter as an example to further explain the laws and characteristics of the scattering mechanism in the resonance range. The geometric model shown in Fig. 1, which contains a large number of edge and surface structures, A preliminary deduction is that in some posture, the secondary scattering mechanism contributes more to the target RCS. In addition, we caculate the RCS of the fighter in optical range as a comparative verification.

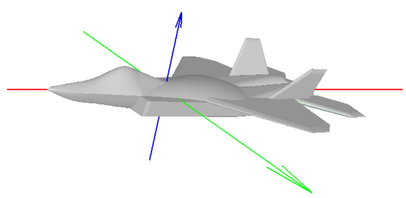

Fig.1. geometric model of F-22

We caculated the RCS of the fighter at the posture of $\theta = 90°, \phi = 0° \sim 360°$,the calculation results are shown in Figure 2 and Figure 3.

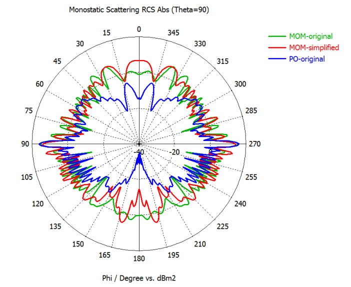

Fig.2. Comparison of MOM and PO results at 400MHz

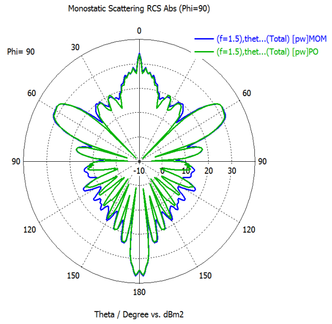

Fig.3. Comparison of MOM and PO results at 1.5GHz

From the calculation results, we can conclude that the PO algorithm is basically consistent with the MOM algorithm in the range of plus or minus 45 degrees in the lateral direction at 400 MHz, but there are still some inaccuracy in the forward and backward direction. It shows that even if at the low frequency(400MHz),the PO algorithm can still be used to calculate the approximate scattering mechanism in the lateral direction. However, the influence of edge diffraction and creeping wave should also be considered in the forward and backward directions. As a comparison, it can be seen that PO and MOM are completely consistent at 1.5 GHz frequency. Next we focus on the creeping wave scattering characteristics of the two-dimensional airfoil shown in Figure 4.

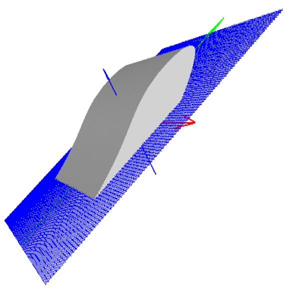

Fig.4. geometric model of 2-D airfoil

We caculate the RCS of the airfoil in the posture of $\theta = 0° \sim 360°, \phi = 90°$,the horizontal and vertical polarizations are considered separately, and respectively, each type of polarization includes a creeping wave contribution and no creeping wave contribution. The calculation results are shown in Figure 5 and Figure 6.

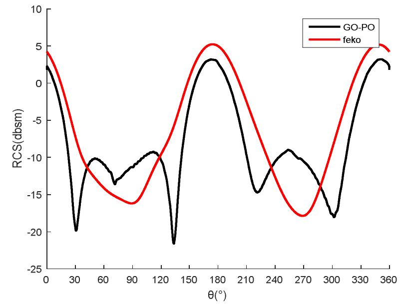

Fig.5. vertical polarization

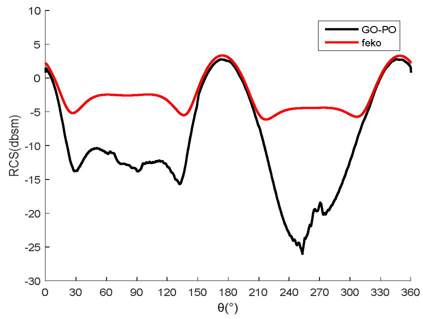

Fig.6. horizontal polarization

It can be seen that, at 400 MHz, the effect of creeping wave can not be ignored on the current angle range. The differences are mainly concentrated around 90° and 270°. Furthermore, The contribution of vertical polarization (the incident electric field is perpendicular to the chord plane) to the shadow region is relatively larger than horizontal polarization, especially when the incidence frequency is relatively low, the contribution is greater. Therefore, the calculation of the low-scattering target's RCS must take into account the contribution of creeping waves of the airfoil.

III. Creeping Wave Parametric Models of the Cylinder

Electromagnetic parametric models is mainly used in radar target identification. From the characteristics of the far-field generated by the target, extracted the information for target identification. The acquired information will be processed by the computer and compared with the characteristics of the known targets so that the purpose of automatically identify the target can be achieved.

In this problem, the expression of the field in the shadow area is

$$E^{d}(p)=E^{i}(Q_1)\cdot[\hat{n}_1\hat{n}_2F+\hat{b}_1\hat{b}_2G]\sqrt{\frac{\rho_c}{s(\rho_c+s)}}e^{-jks} \tag{1}$$

Now we consider soft boundary conditions. We use the way of function fitting to fit the curve of the variation of diffraction field with the creeping distance and the frequency of the incident wave .Then finally obtain the form of the parametric model of the GTD diffraction field in the shadow zone. The form is

$$S(f,t,\rho_g)=A\cdot(\frac{f}{f_c})^{\alpha}\cdot\exp(-2\pi f\gamma_n\cdot\rho_g\cdot t) \tag{2}$$

In the following, we use an infinitely long cylinder with incidence of plane wave as an example, to obtain the specific value of the parameter in the parametric model. It is assumed that the unit intensity electric polarization plane wave perpendicularly incident on an infinitely long cylinder with perfect conductivity. The following Fig. 7 and Fig. 8 respectively show the fitting results of the amplitude of diffaction field with frequency and creeping distance.

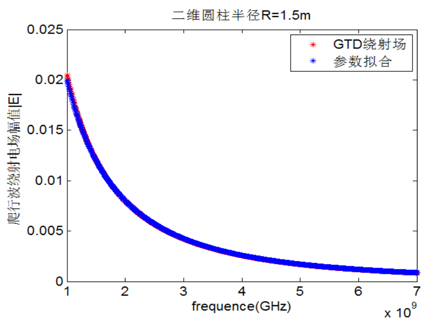

Fig.7. variation with frequence

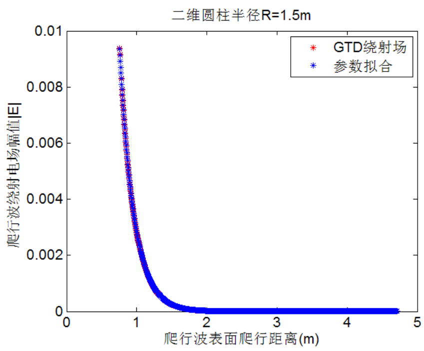

Fig.8. variation with creeping distance

Ultimately,the GTD parametric model of the surface diffracted field generated by the creeping waves can be derived as

$$S=(f,t,\rho_g)=0.633\cdot\rho_g^{\frac{1}{3}}\cdot k^{-\frac{1}{6}}\cdot e^{-1.6\cdot\rho_g^{\frac{-2}{3}}\cdot k^{\frac{1}{3}}\cdot t} \tag{3}$$

Furthermore, the UTD parameterized model of the surface diffracted field amplitude produced by creeping waves can be obtained by a similar method.

$$S(f,t,a,\theta)=0.633\cdot(\cos\theta)^{-\frac{2}{3}}\cdot a^{\frac{1}{3}}\cdot k^{-\frac{1}{6}}\cdot e^{-1.6\cdot a^{-\frac{2}{3}}\cdot k^{\frac{1}{3}}\cdot(\cos\theta)^{\frac{4}{3}}\cdot t} \tag{4}$$

IV. CONCLUSION

This paper discusses the scattering characteristics of the target in the resonance range and analysed the importance of back-scattering of the creeping waves of the airfoil. More importantly, we analysed the formula of the surface ray field of the cylinder, and deduced the expression of the parametric model of the field, and obtained the specific values of the main parameters in the parametric model via fitting the curve of the amplitude of the field with the frequency and the creeping distance, prepared for further deepening on the creeping wave parametric model.

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