Implementation of the Equivalent Currents Method in the IPO method

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1. INTRODUCTION

The Iterative Physical Optics (IPO) method has been developed in 1995 [1] to compute the Radar Cross Section (RCS) of open-ended cavities. This method consists in an iterative resolution of the Magnetic Field Integral Equation (MFIE). Then this method has been extended to targets that are not cavities [2] with good accuracy. In this paper, we present an evolution of the IPO method to compute RCS of targets, taking into account edges' diffractions in the resolution of the MFIE. The Equivalent Currents Method [3-4] is used to compute the diffracted fields.

2. PRINCIPLE

The IPO method applied to target that are not cavities is decomposed in three steps which are for Perfectly Electrical Conducting (PEC) targets:

1. Computation of the magnetic field induced on the target's surface
2. Iterative computation of the electric current on the surface
3. Computation of the EM field scattered by the electric current to the observation point

In some cases, there are edges on the target, and the diffracted fields can influence significantly the RCS. It is interesting in these cases to take into account edges' diffractions in the IPO algorithm to increase the accuracy of RCS prediction. We have developed an evolution of the IPO in which the diffracted EM fields are computed. The ECM [3-4] has been chosen to compute the diffracted EM fields. The new algorithm of the modified IPO method is still decomposed in three steps:

1. Computation of the magnetic field induced on the target surface and computation of the first order diffracted fields to observation point
2. Iterative computation of electric current on the surface taking into account edges' diffractions.
3. Computation of the EM scattered to the observation point by the electric current on the surface taking into account edges' diffractions.

3. FORMULATION

An $e^{-j\omega t}$ dependence is assumed and suppressed. Equations are presented for Perfectly Electrical Conducting (PEC) targets.

Step 1:

In this step, we compute the magnetic field induced on the target's surface (Figure 1) and we compute the first order EM fields diffracted to the observation point R.

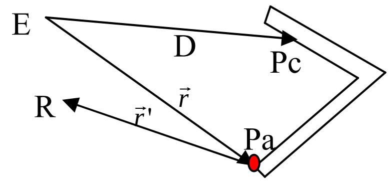


Figure 1

- *Computation of the magnetic field induced on the target surface*

The magnetic field induced on a point Pc of the surface is:

$$\vec{H}_{ind}(P_c) = H_i * Ge * \frac{e^{jkD}}{D}\hat{h}_i = \frac{E_i}{Z_0} * Ge * \frac{e^{jkD}}{D}\hat{h}_i \qquad (1)$$

where: D is the distance between the Transmitter and a point Pc
Ge is the transmitter gain
In the following Ge and Ei are assumed to be equal to 1, thus $H_i = \frac{1}{Z_0}$.

- *Computation of the first order EM fields diffracted to the observation point*

The incident EM field diffracted to observation point R is computed using the ECM [3-4]. It can be expressed (notations used are indicated on the Figure 2) as:

$$\vec{E}_{diff}(R) = 2\int_C \vec{C}_{diff}\, G(\vec{r}, \vec{r}\,')\,dt \qquad (2)$$

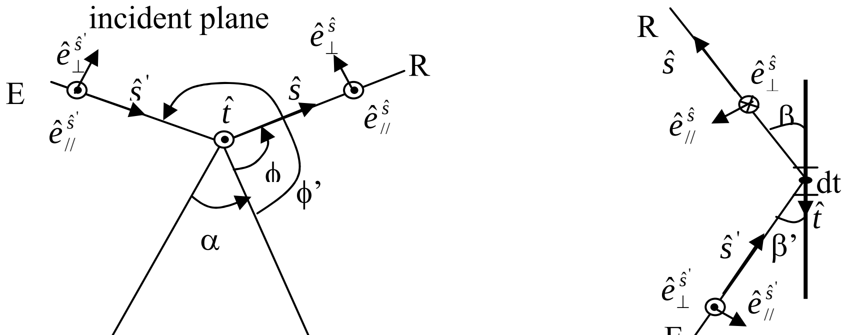
where:
$$\vec{C}_{diff} = \begin{bmatrix} \cos\gamma (D_\perp - D'_\perp)\hat{e}_\perp^{\hat{s}} \\ -\dfrac{\sin\gamma \sin\beta (D_{//} - D'_{//})}{\sin\beta'}\hat{e}_{//}^{\hat{s}} \\ -\dfrac{\cos\gamma \sin\beta (D_X - D'_X)}{\sin\beta'}\hat{e}_{//}^{\hat{s}} \end{bmatrix} \qquad (3)$$

$D_{//}, D_\perp, D_X$ are diffraction coefficients

$D'_{//}, D'_\perp, D'_X$ are the Physical Optics coefficients

$\hat{e}_\perp^{\hat{s}} = \dfrac{\hat{t} \wedge \hat{s}}{|\hat{t} \wedge \hat{s}|}$ et $\hat{e}_{//}^{\hat{s}} = \hat{s} \wedge \hat{e}_\perp^{\hat{s}}$

γ is the angle between the incident electric field and the normal to incident plane



Normal edge plane   Parallel edge plane

Figure 2

Step 2:

In this step, we solve iteratively the MFIE to compute the electric current on the surface.

- *Iteration 0:*

The initial current on a facet 'v' of the surface is expressed:

$$\vec{J}_0(P_{c_v}) = 2\hat{n}_{c_v} \wedge \vec{H}_{ind}(P_{c_v}) \tag{4}$$

- *Iteration 1:*

The electric current on a facet *'v'* of the surface at the iteration 1 is induced by the initial current on this facet, by the magnetic field radiated by the electric current on the other facets and by the first order EM fields diffracted on this facet *'v'* (Figure 3). The electric current is expressed:

$$\begin{aligned}\vec{J}_1(P_{c_v}) &= \vec{J}_0(P_{c_v}) + 2\hat{n}_{c_v} \wedge \int_{Sc} \vec{J}_0(P_{c_u}) \wedge \vec{\nabla}' G(\vec{r}_{uv}) dS_c \\ &+ 2\hat{n}_{c_v} \wedge \left\{ \frac{2}{Z_0} \int_C \hat{r}' \wedge \vec{C}_{diff}\, G(\vec{r},\vec{r}\,')dt \right\}\end{aligned} \tag{5}$$

- *Iteration N:*

At iteration N (N>1), the electric current on a facet *'v'* of the surface is induced by the initial current on this facet, by the magnetic field radiated by the electric current on the other facets and by the EM field diffracted when edges are excited by the radiation of the surface electric current (Figure 4). The electric current is expressed:

$$\vec{J}_N(P_{c_v}) = \vec{J}_0(P_{c_v}) + 2\hat{n}_{c_v} \wedge \int_{Sc} \vec{J}_{N-1}(P_{c_u}) \wedge \vec{\nabla}' G(\vec{r}_{uv}) dS_c + 2\hat{n}_{c_v} \wedge \sum_{u=1}^{Nc} \frac{2}{Z_0} \int_C \hat{r}' \wedge \vec{E}_{P_u}^{diff} dt \tag{6}$$

where: $$\vec{E}_{P_u}^{diff} = E_{P_u}^{ind}(P_a)\vec{C}_{diff}\, G(\vec{r},\vec{r}\,') \tag{7}$$

$E_{P_u}^{ind}(P_a)$ is the magnitude of the electric field induced on P_a by the radiation of the electric current on P_u. It is expressed:

$$\vec{E}_{P_u}^{ind}(P_a) = -\frac{1}{jkY_0} \vec{\nabla} \wedge \vec{J}_{N-1}(P_u) \wedge \vec{\nabla}' G(\vec{r}) * \Delta S_{P_u} \tag{8}$$

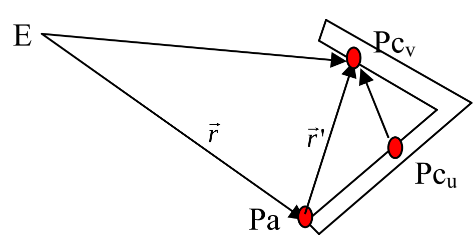


Figure 3

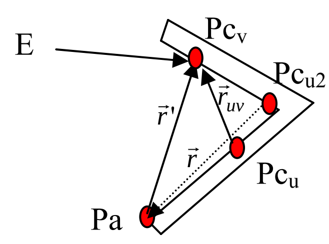


Figure 4

Step 3:

Finally, we compute the electric field scattered at the observation point. It is induced by the first order EM field diffracted $\vec{E}_{diff}(R)$ computed at 'step 1' with equation (2). It is also induced by the radiation of surface electric current and by EM field diffracted when edges are excited by the radiation of surface electric current (Figure 5).

The electric field scattered at the observation point is expressed:

$$\vec{E}_s(R) = \vec{E}_{diff}(R) + \vec{E}_{S_C}(R) + \vec{E}_{S_C}^{diff}(R) \quad (9)$$

Where: $\vec{E}_{diff}(R)$ is the incident field diffracted to R expressed by equation (2)

$\vec{E}_{S_C}(R)$ is the electric field radiated by electric current on the surface and it is expressed:

$$\vec{E}_{S_C}(R) = -\frac{1}{jkY_0}\vec{\nabla} \wedge \int_{S_C} \vec{J}_N(P_C) \wedge \vec{\nabla}' G(\vec{r}_c) dS_C \quad (10)$$

$\vec{E}_{S_C}^{diff}(R)$ is diffracted to R when edges are excited by the radiation of surface electric current. It is expressed:

$$\vec{E}_{S_C}^{diff}(R) = \sum_{u=1}^{Nc} \frac{2}{Z_0} \int_C \left\{ E_{P_u}^{ind}(P_a) \vec{C}_{diff} G(\vec{r}, \vec{r}\,') \right\} dt \quad (11)$$

$E_{P_u}^{ind}(P_a)$ is the magnitude of the electric field induced on P_a by the radiation of the electric current on P_c. It is expressed:

$$\vec{E}_{P_u}^{ind}(P_a) = -\frac{1}{jkY_0}\vec{\nabla} \wedge \vec{J}_N(P_C) \wedge \vec{\nabla}' G(\vec{r}) * \Delta S_{P_C} \quad (12)$$

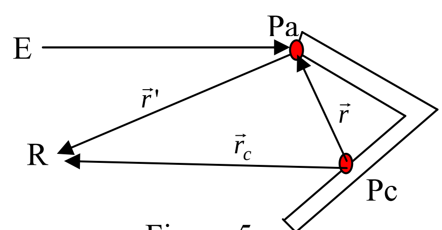


Figure 5

4. CONCLUSION

This communication presents an evolution of the IPO method to compute the RCS of targets taking into account edges' diffractions with the ECM. Comparisons of results obtained with IPO and FEM will be shown during the presentation.
In the future this method could be formulated for the case of open-ended cavities, in which the inner walls of the cavity are excited by the equivalent currents in the aperture. The method will also be formulated for dielectric coated targets using the Leontovitch surface impedance condition.

5. REFERENCES

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