Study of the Electromagnetic scattering by a metallic object of arbitrary shape

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Abstract

In this paper, the Wave Concept Iterative Procedure WCIP is presented [1-2].

The formulation is developed to analyse scattering metallic objects of arbitrary shape. We test it in the case of scattering by an infinite metallic cylinder with a square section. We observe a good agreement between the results derived from WCIP and Multi Resolution Time Domain MRTD [3].

Index terms

Electromagnetic Scattering, Radar Cross Section and Wave Concept Iterative Process WCIP

1. Introduction

The scattering problems of electromagnetic waves, by conducting objects of arbitrary shape placed in free space, is of great scientific interest, in many application, namely, antennas design, remote control,…

In this paper, we develop the formulation of the Wave Concept Iterative Process WCIP in order to resolve the electromagnetic scattering problems by arbitrary metallic shapes. Knowing that mathematically all object can be divided in small scattering surfaces. These surfaces can be placed on a fictitious circular cylinder. So we can resolve the electromagnetic problems in the cylindrical coordinate system. In order to validate the method and the previous mathematic hypothesis we calculate the radar cross section for a square perfect electric conductor object.

2. Theory

2.1 The Waves Concept

Let S be an arbitrary closed surface we study scattering of electromagnetic wave in a point of the surface S by the Wave Concept Iterative Process (WCIP) and let $\vec{n}$ denote the normal vector to this surface definite in each point as presented in Fig. 1.
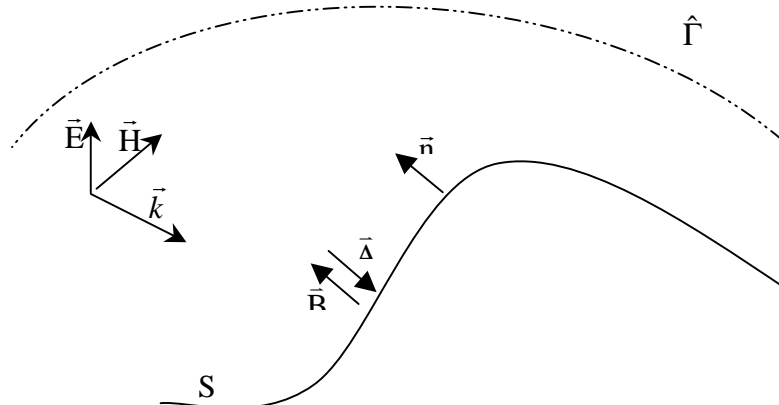

Figure 1: Definition of the Scattering surface and related vectors

The Wave Concept Iterative Process is based on the definition of two waves, $\vec{A}$ and $\vec{B}$, related with the tangential electric and magnetic field $\vec{E}$ and $\vec{H}$. In place of magnetic field $\vec{H}$ the current $\vec{J}$ deduced from $\vec{H}$, is used:

$$\vec{J} = \vec{H} \wedge \vec{n} \qquad [1]$$

The Incident $\vec{A}$ and reflected $\vec{B}$ waves are defined by a liner combination of electric field and current [1-2-4]

$$\vec{A} = \frac{1}{2\sqrt{Z_0}} (\vec{E} + Z_0 \vec{J}) \qquad [2a]$$

$$\vec{B} = \frac{1}{2\sqrt{Z_0}} (\vec{E} - Z_0 \vec{J}) \qquad [2b]$$

Z_o is arbitrary impedance. In the following we shall consider the free space impedance as Z_o

$$Z_o = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 120\pi\Omega \qquad [3]$$

2.3 The Wave formulation

The Wave Concept Iterative Process based on the expression of boundary and closing condition, in the case of the scattering by an obstacle, the relation ship between $\vec{A}$ and $\vec{B}$ is expressed as **:**

$$B = \hat{\Gamma} A \qquad [4]$$

$$A = RB \qquad [5]$$

Where $\hat{\Gamma}$ designates the scattering operator associated to the geometry of the target [5] and R is a reflected coefficient defined on the surface;

$$\hat{\Gamma} = \sum_n |f_n\rangle \frac{Z_n - Z_o}{Z_n + Z_o} \langle f_n| \qquad [6]$$

$\{|f_n\rangle\}_{n \in IN}$ is a complete modal base

Z_n the impedance of the nth target mode [5] and Z_0 the parameter introduce in equation [3].

3. Problem Statement

The structure is meshed in to elementary cells Fig.2. In this case the Cartesian coordinate system became inefficient that is way we use cylindrical coordinate formulation. To pass to cylindrical coordinate we have to find common normal at all cells.

The study of electromagnetic interaction between two cells is equivalent to the modelling of the wave scattering on one or more coaxial fictitious cylinders, which have a common axis (Oz). This common centre is constructed geometrically by the intersection between the rights bisectors of the two cells [6-7].

This cylinder composed of metallic parts defined on the square and an isolator parts (dielectric parts). In order to calculate the scattering electromagnetic waves by the metallic parts we are going to define the cylindrical basis function $(f_n)_{n \in IN}$ and the impedance of the nth mode (Z_n) [5]. These parameters depend on the radium of the cylinder and the position of the metallic pixels. So the incident waves (A) on the metallic pixels are reflected. The created waves (B) is reflected by the free space and generate the next incident waves via a reflection operator $(\hat{\Gamma})$.
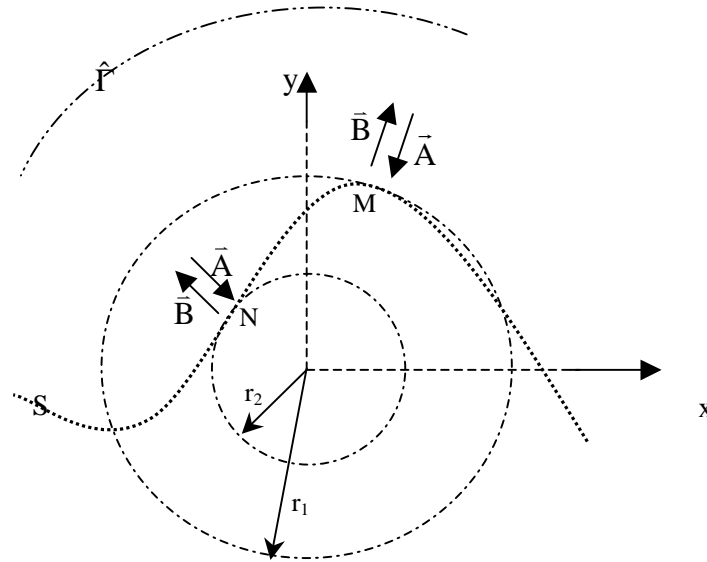
Figure 2: meshed surface and coordinate transformation

$r_{1/2}$ are the radius of the fictitious cylinders.

The geometry analysed by the Wave Concept Iterative Process Method is a square shown in Fig.3. Which dimensions of a=2λ and the frequency is *f*=1GHz; this geometrical parameters are chosen to be the same as in reference [3].
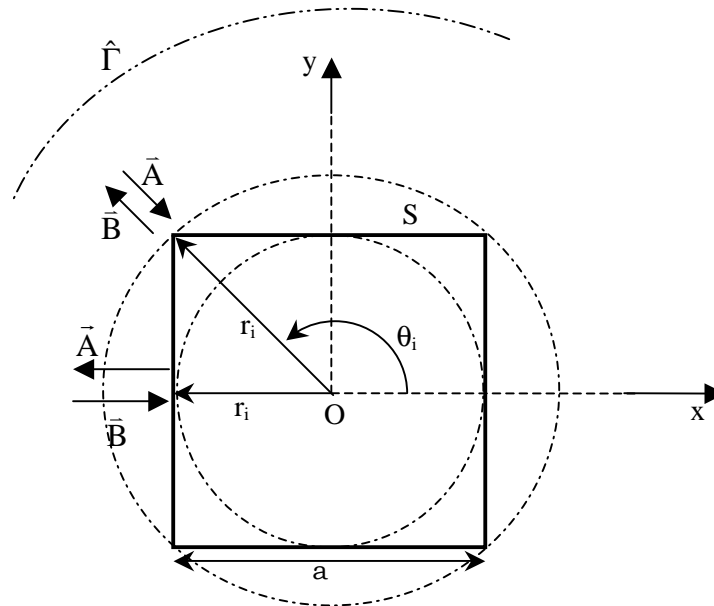

Figure3: conducting square section

4. Numeric Result and Discussion

Corresponding to the above structure, we implemented on Matlab all the calculation up to the radar cross section (RCS) calculation. So, we evaluate the scattering operator of the square geometry using the following described transformation. Then we calculate the surface currant density using the iterative process. Finally, we found the radar cross section. We have compared the results given by WCIP with Multi Resolution Time Domain MRTD, as showing in the following figure.
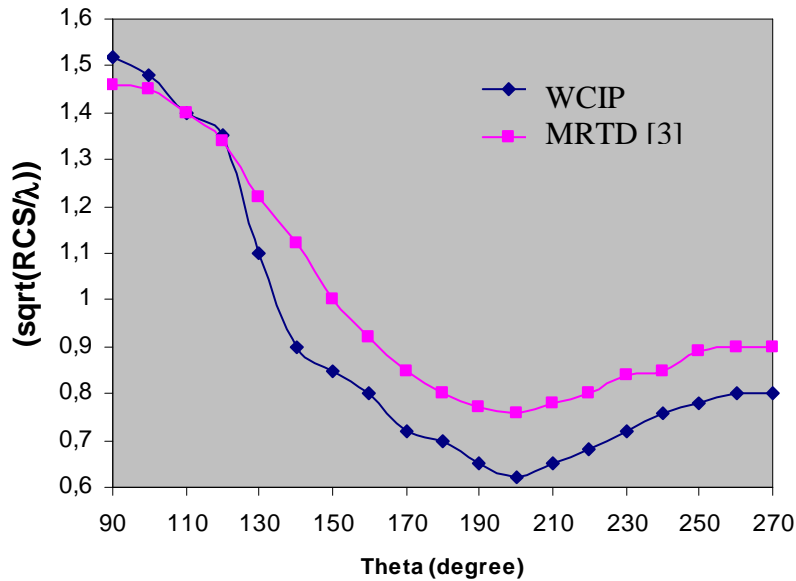
Figure 4 : the normalised RCS of a square geometry, a=2λ , *f*=1GHz;

As expected the results given by the WCIP are in good agreement with previously published results [3]. This allows us to engage in another step for this research.

5. Conclusion

The electromagnetic scattering by a conducting square geometry has been investigated. In order to prove the efficiency of the geometry transformation and the presented iterative method, the Radar Cross Section of the previous structure is calculated. The numerical results agree with the published results. On going research is to generalize the technique that allows us to study the scattering from composite surfaces that can include one or more large arbitrary shaped obstacles as well as the scattering from targets on ocean like rough surfaces

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