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Simulation of Bistatic Scattering Characteristics for Multilayered Dielectric Targets

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Introduction

The method of shooting and bouncing rays (SBR) is widely used in high frequency electromagnetic computation for complex targets. In order to study the bistatic scattering characteristics of dielectric-coated targets, a modified shooting and bouncing is proposed based on the combination of SBR and transmission line equivalent model in this paper.

Bistatic EM Calculation Based on SBR

A. Ray Tracing

Ray tracing in this paper is done by means of the open source code POV-Ray. Firstly, the three dimensional geometric model for target whose EM scattering field to be calculated is imported. Then the location of light and camera which are considered as transmitting antenna and receiving antenna in radar system should be set in terms of EM calculation geometry. Finally, every ray tube from launched plane is traced by geometrical optics until it returns back to the receiving plane.

B. Field Tracking

The incident EM wave is assumed to be plane wave when calculating radar cross section (RCS) by SBR. As it is irradiated to the objects, the reflected direction as well as electric field can be solved according to the geometric optics which is based on ray-based coordinate system shown in Fig.1

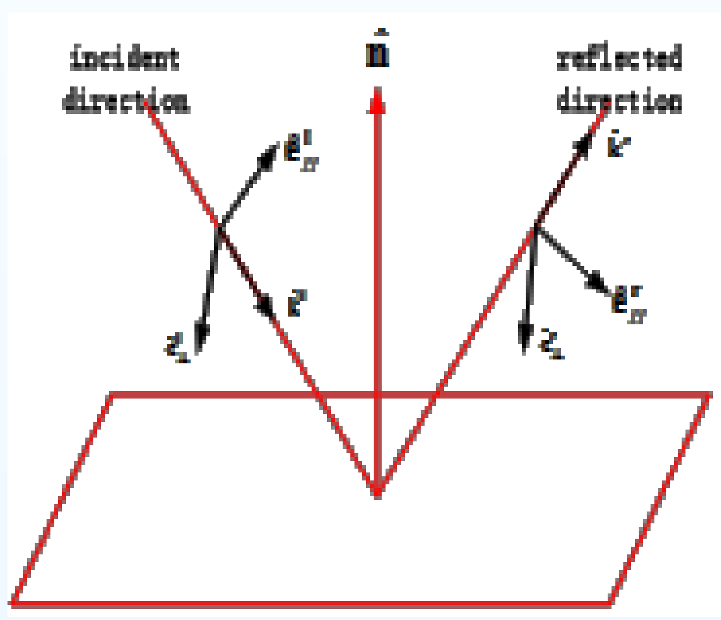


Fig.1 Ray–based coordination system

While the uniform plane wave propagates in space, there is no effect on its amplitude and propagation direction except for a delayed phase. Fig. 2 illustrates the phase calculation geometry where P is phase reference center.

Assuming that a ray starts from transmitting plane at the plane e1, and incidents the point P1 on the target, then reflects to the point P2, finally it returns back to the point in receiving plane.

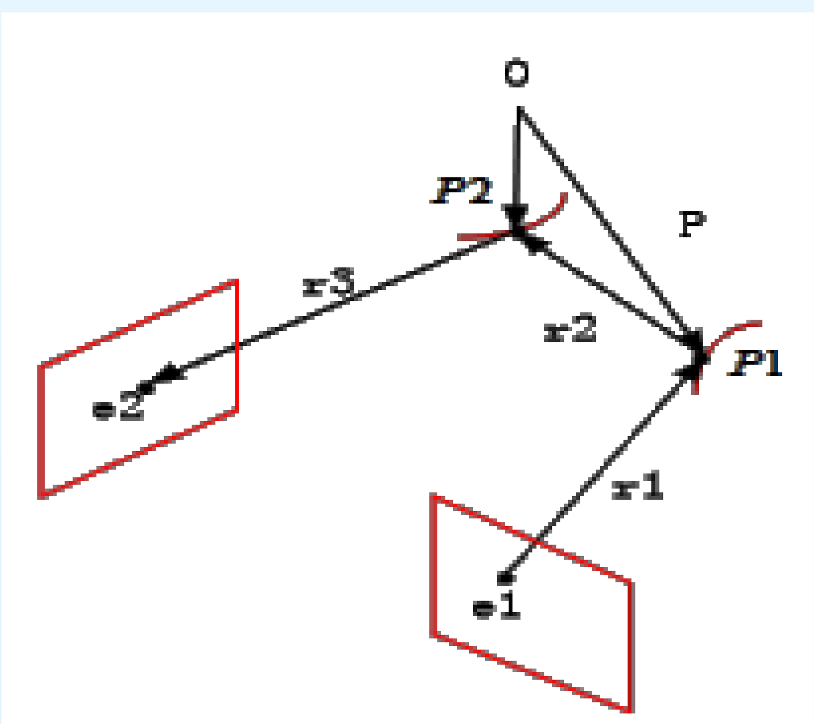


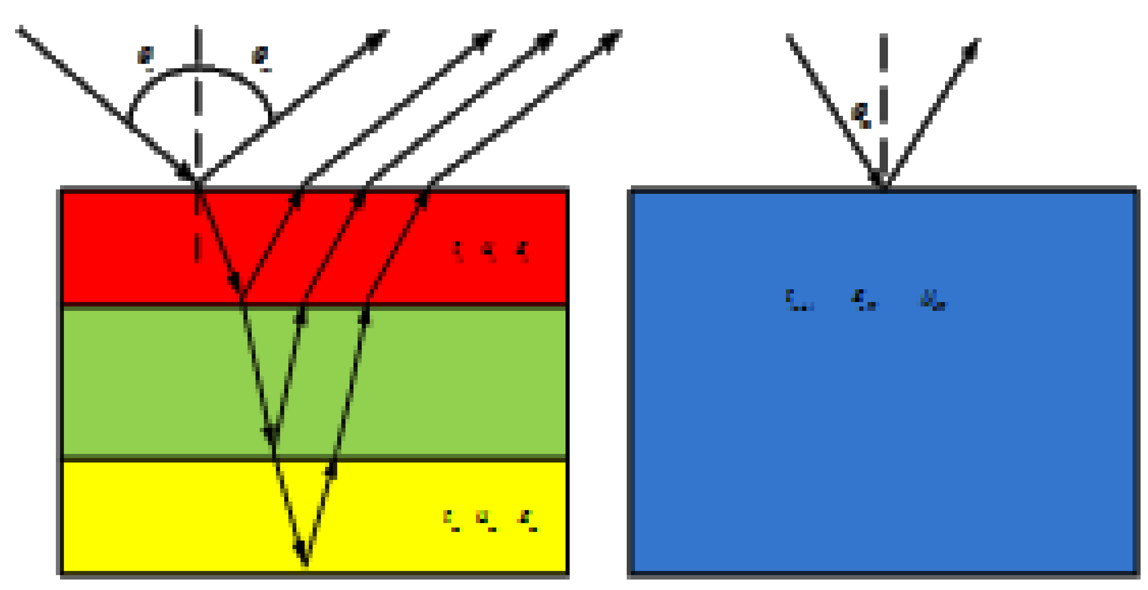
Fig.2 Phase calculation geometry

C. EM Field Calculation Using Physical Optics

PO technique adopts the EM current on the surface instead of the scatter, and integrates the induction field of the current to obtain the total scattered field.

Transmission Line Equivalent Model

As seen in Fig. 3(a), when a target consists of multilayered dielectric materials, ray tracing is extremely complicated. In this figure, for the mth layer, t_m is the thickness, ε_m is the relative permittivity, μ_m is the relative permeability, β_m^{TL} is equivalent propagation constant, and Z_m^{TL} is equivalent wave impedance. While an incident wave hits N-layer dielectric plates, it then splits to create reflected and refracted rays, and the divided rays continue to propagate and spilt. As layers increase, the number of rays grows exponentially.



(a) N-layer dielectric plate (b) Equivalent single layer model

Fig.3 N-layer dielectric plate and equivalent single layer model

To alleviate the tough demands of storage and computational efficiency, we introduce the transmission line equivalent model which makes multilayered dielectric equivalent to a single layer . This model greatly simplifies the process of ray tracing and calculation of reflection coefficient.

Equivalent model shown in Fig. 3(b), t_{total} is the total thickness of N-layer dielectric, ε_{eff} is the equivalent relative permittivity, and μ_{eff} is equivalent relative permeability

Computational Examples

In this part, two computational examples using the modified SBR are presented.

A. Bistatic RCS Calculation of Trihedral Corner Reflector Coated by Dielectric

The first example is the bistatic RCS calculation of the dielectric coated trihedral corner reflector shown in Fig. 4. The length of the right-angle side is 0.2m.

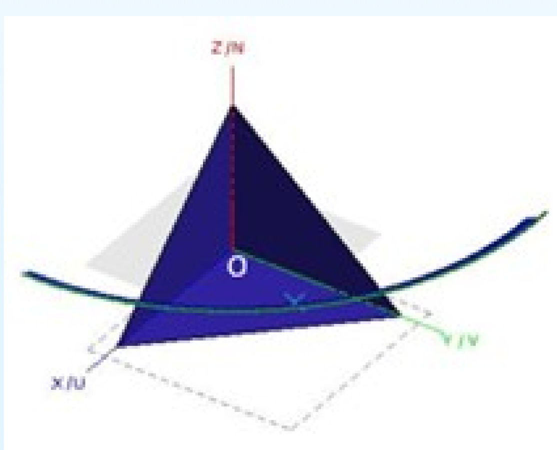
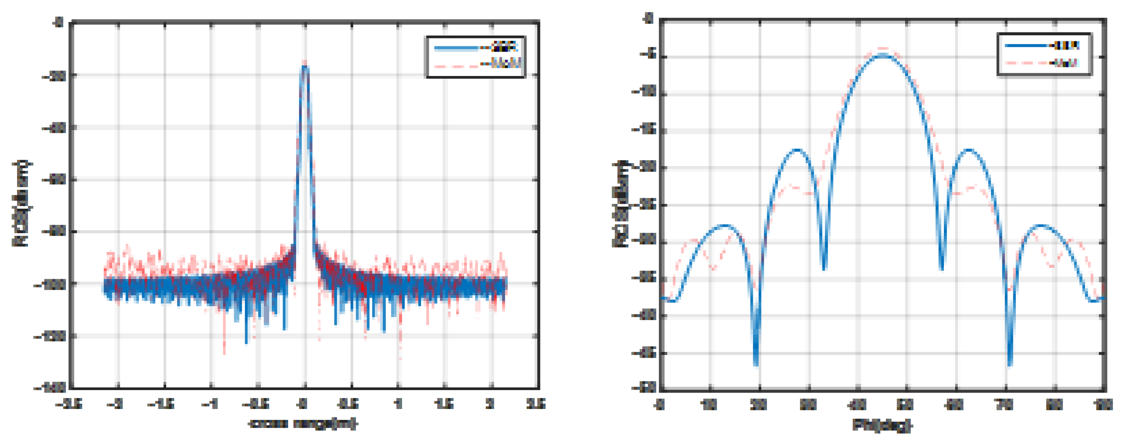


Fig.4 Trihedral corner reflector coated by dielectric



(a) RCS magnitude (b) High resolution cross range profile(HRCRP)

Fig.5 RCS and HRCRP of trihedral corner reflector

B. Monostatic and Bistatic Images of Slicy

The second example demonstrates 2-D radar image of target coated by multilayered dielectric using modified SBR is feasible. In the following example, the Slicy model shown in Fig.6 is studied. This model is composed of cubes, cylinders and corner reflection. And the length of this model is about 3m, the width and height are 2.7m and 1.8m, respectively.

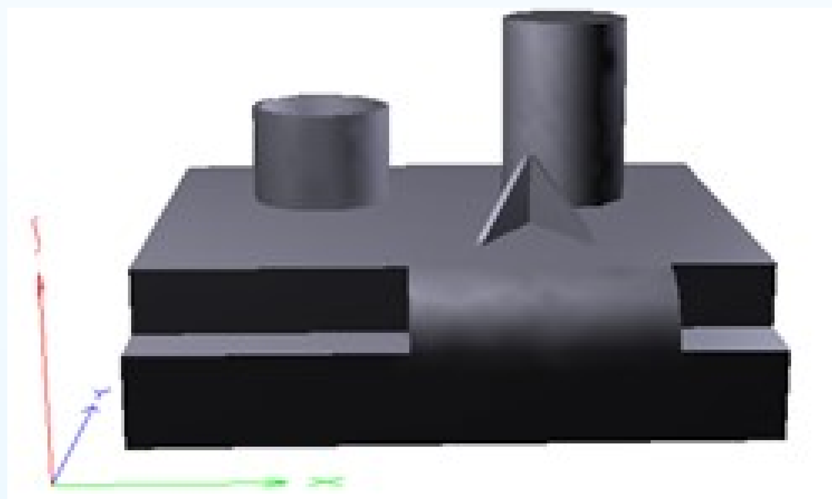
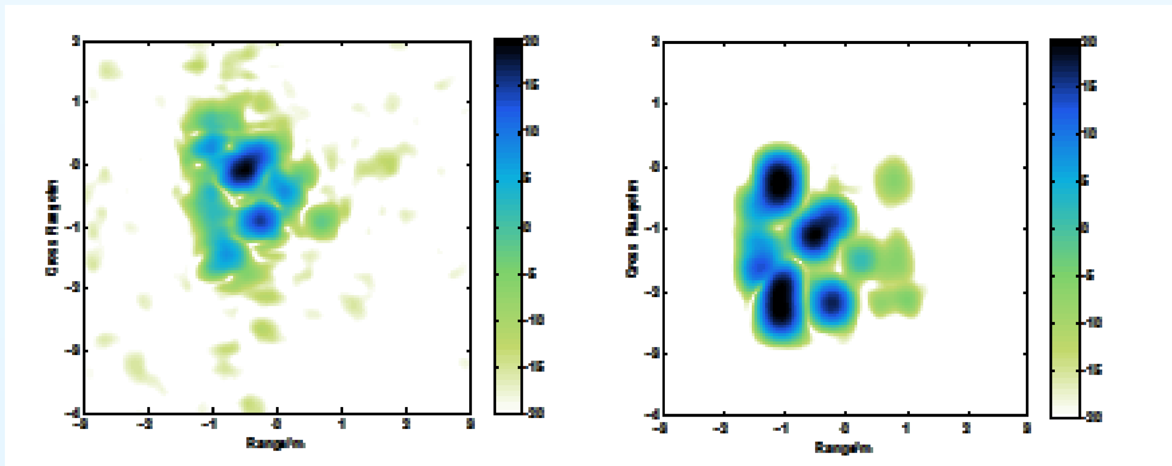
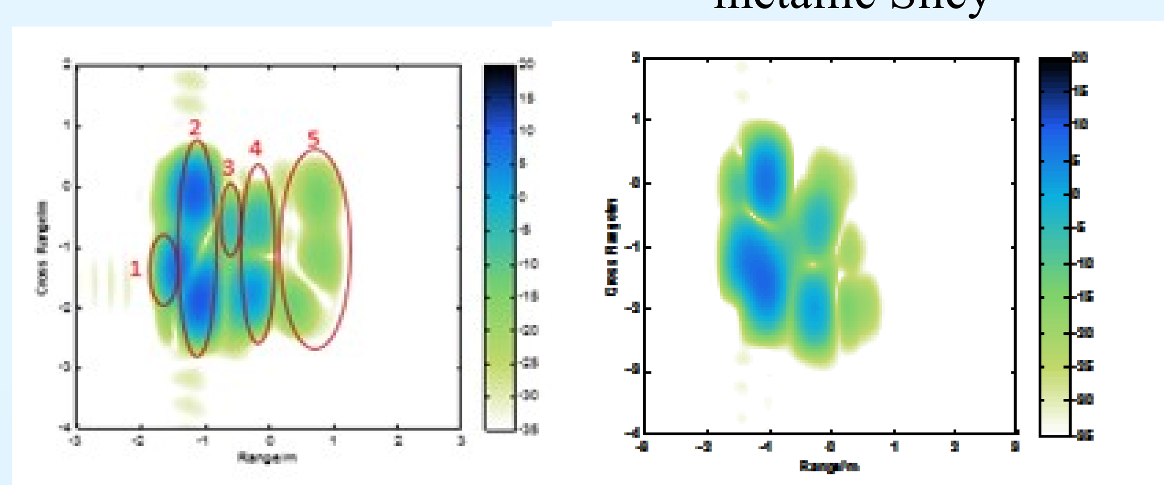


Fig.6 Slicy model



(a) MSTAR SAR image (b) Monostatic image of metallic Slicy



(c) Monostatic image of dielectric Slicy (d) Bistatic image of dielectric Slicy

Fig.7 Radar image of Slicy model

Summary

we propose a technique to compute both monostatic and bistatic wideband scattering characteristic of targets coated with multilayered dielectric materials. Computational results for a single and trihedral reflector and for Slicy are compared with either MoM results or airborne SAR images to validate the EM code. It is seen that with multiple layers to single layer equivalence, the storage as well as computational burden for bistatic SBR is greatly alleviated, with acceptable simulation accuracy.

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