Composite Scattering from Electric-Large Target over Randomly Rough Surface Using Fast Computation of BART

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Abstract

Calculation of radar cross section (RCS) and scattering analysis for electric-large targets located in natural environment have been under study for many years. Complexities due to large target size and multi-interactions between isolated target and surrounding random media, e.g. rough surface, make model simulation much more difficult. Instead of purely numerical computation, high frequency approximation has been well applied with good accuracy and convincing physical insight, which may be listed as the geometrical optics (GO), physical optics (PO), geometrical theory of diffraction (GTD), physical theory of diffraction (PTD), and ray tracing, etc.

To carry out RCS calculation under high frequency approximation, one approach is to decompose the target into a group of components with primitive geometries and calculate scattering from all components, separately. For example, the RECOTA code for RCS calculation was developed to make the target meshed to facets, and PO/PTD scattering/diffraction of facets/edges were taken into account, as well as GO-PO double scattering between every two directly facing facets. The software XPatch is a commercialized mature tool for RCS and imaging signature calculation, where multiple scatterings from concave structures is also taken into account, using the shooting and bouncing rays (SBR) method. Moreover, the GRECO is a real time tool for computation of target single scattering, which takes advantage of hardware accelerating technique of 3D graphic visualization. Recently, some efforts are paid to hybrid approaches of numerical and high frequency methods.

Regarding the coexistence of target and rough surface, it becomes of great interest to understand and simulate their composite scattering and mutual interactions, e.g. a ship over sea surface, or a vehicle on land surface. As a more complicated model, the RCS calculation of a 3D target over randomly rough surface has been remained for further study.

In this paper, the bidirectional analytic ray tracing (BART) method is developed to effectively calculate composite scattering of a 3D electric-large target over randomly rough surface. The basic idea is to launch ray tubes both from the source and observation, trace among the facets, and record the illumination areas of rays shooting on facets and edges, as

shown in Fig. 1. The forward and backward rays illuminate a common area of the facet, and all differential elements of this common area contribute in the same way to the $(m\mathrm{GO} + 1\mathrm{PO} + n\mathrm{GO})$ -order scattering.

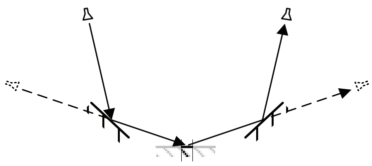


Fig. 1 Bidirectional ray tracing.

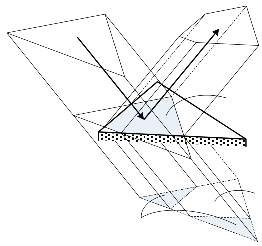


Fig. 2 Ray tracing and shadowing polygon calculation.

For each pair of forward and backward rays illuminating the same facet/edge, a scattering path from source to observation is constructed by linking the forward and backward rays, and corresponding scattering contribution is added up to the total scattering. Comparing to the conventional unidirectional tracing, more scattering mechanisms can be taken into account in bidirectional tracing.

In addition, analytic tracing of polygon ray tubes is implemented to precisely calculate their illumination, reflection and shadowing based on geometric computation, such as polygon union, intersection and difference. An analytic tracing technique is employed. Ray tubes are described as polygonal cylinders as shown in Fig. 2. Shadowing is accurately determined by geometric calculations of polygons. Since all tracing and shadowing are analytically treated, the restriction of small electric-size of target facets is released, and the facet meshing is uniquely determined by the target geometry and becomes irrelevant to its electric-size.

Rough facets are similarly introduced to model rough surface. Instead of reflection and diffused scattering of flat facets, coherent scattering and incoherent scattering from rough facets are considered. Analytic rough surface model such as the integral equation method (IEM) is employed. Based on the surface geometry and its conjuncture with the target, rough surface is first meshed into electric-large patches, i.e. rough facets, and inter-correlations among different rough facets are ignored. During ray tracing, rough facets are processed in the same way as flat facets except its scattering calculation. Rough surface scattering includes two parts: coherent and incoherent. For a large rough surface, the coherent scattering part concentrates on the specular direction, and incoherent scattering diffusely spreads over all directions. They are somehow similar to the GO and PO scattering of flat surfaces, respectively.

The accuracy and performance of BART are validated and evaluated by comparing with exact computational electromagnetic methods in small electric-scale. Fig. 3 shows an example.

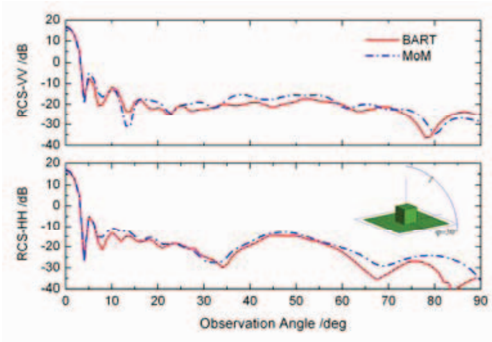
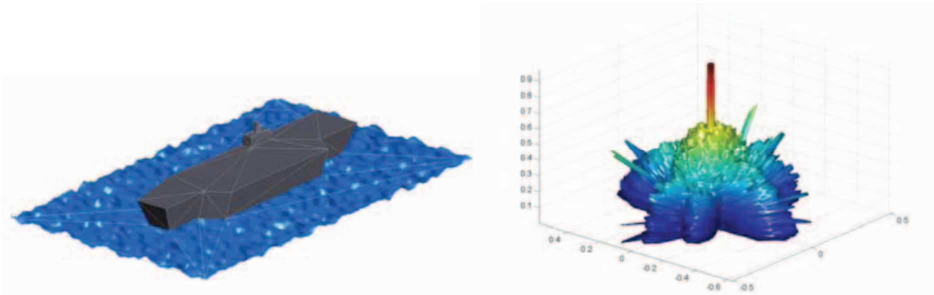
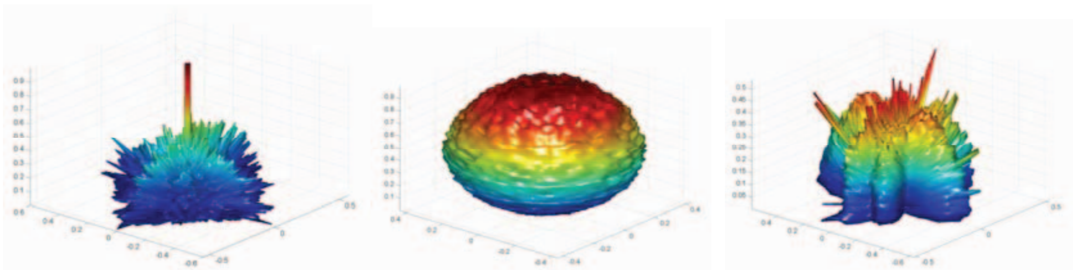


Fig. 3 Comparison of BART and MoM for RCS of a cube on plane for code validation.

Finally, numerical examples of angularly composite scattering (mono-static and bistatic) from a three-dimensional electric-large, e.g. a ship like, target over randomly rough surface are presented and discussed. Fig. 4 shows an example of composite scattering from an electric-large ship over randomly rough sea surface.



(a) Model (b) Total RCS



(c) RCS contributed by the ship-target (d) RCS contributed by rough surface (e) RCS contributed by interaction

Fig. 4 Angular pattern of monostatic RCS contributed by different parts of scattering.

References

[1] F. Xu and Y.Q. Jin, "Bidirectional Analytic Ray Tracing for Fast Computation of Composite Scattering from An Electric-Large Target over Randomly Rough Surface", *IEEE Transactions on Antennas and Propagation*, 2009, 57(5): 1495-1505.