REAL-TIME RADAR CROSS SECTION OF COMPLEX TARGETS BY PHYSICAL OPTICS GRAPHICAL PROCESSING

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Abstract

Radar cross section (RCS) of complex targets can be obtained in real time using the hardware capabilities of a high performance graphic workstation. Target geometry is modelled by a computer-aided design package. RCS is computed under physical optics high-frequency approximation.

Introduction

The computation of RCS of large and complex targets usually involves different scattering mechanisms, such as specular reflection, diffraction at wedges, multiple scattering, shadowing effects, returns from discontinuities, creeping waves, etc. Classical techniques for numerical computing of RCS taking into account all these effects give very accurate results, but on the other hand, they require very long CPU run time on powerful computers.

The objective of this paper is to show that RCS computation in real time is possible with a high-performance graphic workstation. Physical optics surface integral is computed using the hardware capabilities of a graphics accelerator.

Although diffraction at wedges, multiple scattering and second-order effects are not taken into account, it has been found that RCS of complex targets at high frequency is predicted with reasonable accuracy by physical optics approximation.

Target modelling

A computer aided design package for geometric modelling of solids [1] has been used for modelling target geometry. The target is described as a collection of parametric surfaces, defined with two-dimensional NURBS (non-uniform rational B-splines). Intersections between surface patches are defined by NURB trimming curves on the parametric space of the intersected surfaces.

RCS analysis packages usually describe the target in terms of facets and wedges [2]. The faceting approach has a potential limitation when a large number of facets might be required, which may exceed declared array sizes or which can lead to longer CPU run times. Parametric surface modelling of the target impose weaker storage memory requirements that the faceting approach, and the modelled surface adjusts more accurately to the real target surface.

Physical Optics

The scattered fields from an arbitrary object are described by the well-known Sttraton-Chu integral equations [3]. Physical optics is based on the tangent plane approximation [4]: if the radius of curvature of a conducting surface is greater than the wavelength, the tangential component of the magnetic field over the surface can be approximated by twice the incident one over the illuminated area, and zero over shaded regions. The integrals, therefore, extend only over the illuminated portion of the surface.

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The resulting integral approximation for monostatic RCS is:

$$\sigma = \frac{4\pi}{\lambda^2} \left[\int_S \cos\theta \quad e^{-2jKz} ds \right]^2$$

where θ is the angle between the outward surface normal and the direction of observation and z the distance to the integration surface patch ds projected on the direction of observation.

Due to its great simplicity, physical optics approximation is widely used to compute monostatic RCS, regardless it has serious defects [4]:

- It obtains only reflection from surfaces, but not diffraction at wedges.
- It fails for wide non-specular angles.
- It has no dependance on polarization.
- It yields false shadow boundary contributions, due to the artificial boundary between illuminated and shadow regions, which can be overcome by stationary phase evaluation of the integral.

Hardware Graphic Processing of RCS

The main difficulty to compute the physical optics surface integral by classical numerical techniques is the detection of shadow regions. This difficulty can be easily overcome using the hidden surface removal capabilities of a graphic workstation, which can be performed by hardware if a graphics accelerator is present. Hidden surfaces are removed comparing the distance from the observer to each pixel to be drawn with the distance of the previously drawn pixel in the same display location, stored in a portion of RAM called "z-buffer" [5].

A photorealistic drawing of the target is made from a view-point coincident with radar position, so that shadowed regions are not displayed. A directional light source is defined on the same direction as the incident wave-front. If the target surface is modelled to have only diffuse light reflection, it results that the brightness of each pixel on the drawing is equal to $\cos\theta$, where θ is the angle between the outward surface normal and the direction of observation.

Therefore, the physical optics surface integral can be evaluated as the coherent addition of the brightness of all the pixels on the display. The phase of each pixel contribution can be easily obtained from the distance to the observer stored in z-buffer.

Graphic processing has the following advantages over classical numerical techniques:

- Evaluation of surface integral independent of target complexity.
- Automatic shadowed region removal.
- CPU time independent of target complexity.
- Real-time computation if hardware graphics accelerator is used.
- Very low RAM requirements, independent of target complexity.
- Target can be modelled by parametric NURB surfaces, requiring less mass storage memory that the faceting approach, and adjusting more accurately to the real target surface.

CPU run time

On a high performance graphic workstation with hardware graphics accelerator, the CPU run time is about 30 microseconds/pixel/angle. Classical numerical techniques require much longer CPU run time: RECOTA package, developed by

Boeing Aerospace [2], takes about 11 milliseconds/facet/angle for each polarization on a VAX 11/785, including diffraction at wedges, multiple scattering and second-order effects.

Results

In order to validate the graphic processing of the surface integral, the results obtained for simple objects are compared with analytic evaluation of physical optics integral. Fig. 1 shows RCS of an ellipsoid of semiaxis 3, 2 and 1 meters, compared with the theoretical expression $\sigma = \pi \rho_1 \rho_2$, where ρ_1 and ρ_2 are the principal radius of curvature at the specular reflexion point. The agreement is very good.

Fig. 2 shows normalized RCS (σ/λ^2) for a circular right cylinder of radius 1.14 λ and height 7.91 λ, at a frequency of 10 GHz. Analytic physical optics results are 23.2 dB for the circular cap (0°), and 26.5 dB for the cylindric surface (90°). According to aperture antenna theory, first RCS nulls must be located at 15.3° for the circular cap, and 90° - 3.6° for the cylindric surface. The agreement with graphical processing results is excellent.

A generic missile model has been used to validate the physical optics results for complex radar targets at high frequency. Fig. 3 shows the graphic processing results, as well as RECOTA predictions and measured RCS [2]. Although wedge diffraction and multiple reflexions are not computed by graphic processing, main RCS contributions are correctly detected at 10° (-20 dBsm), 30° (-11 dBsm), 90° (8 dBsm), and 140° (-16 dBsm). RCS null at 120° is also detected. Note that some of these values are predicted more accurately by real-time physical optics graphic processing than by RECOTA.

References

[1] "IDEAS Geomod user's guide", Structural Dynamics Research Corp. (SDRC), Milford, OH 45150.

[2] "Radar Cross Section of Complex Targets", Nazih N. Youssef, IEEE Proc., vol. 77, no. 5, may 1989, pp. 722-734

[3] "Electromagnetic Theory", J.A. Stratton, McGraw-Hill, New York, 1941

[4] "Radar Cross Section", E.F. Knot et al., Artech House, Inc. 1985

[5] "Computer Graphics for Engineers", B.R. Dewey, Harper & Row Inc., 1988

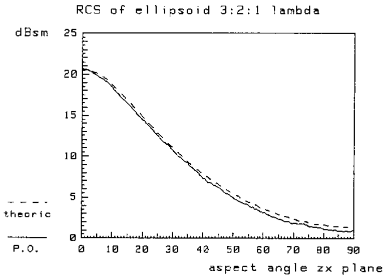

Fig. 1

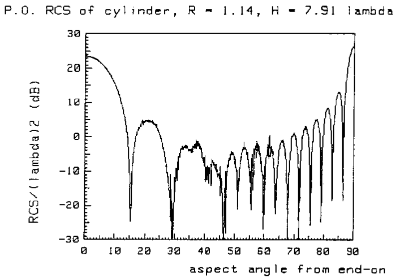

Fig. 2

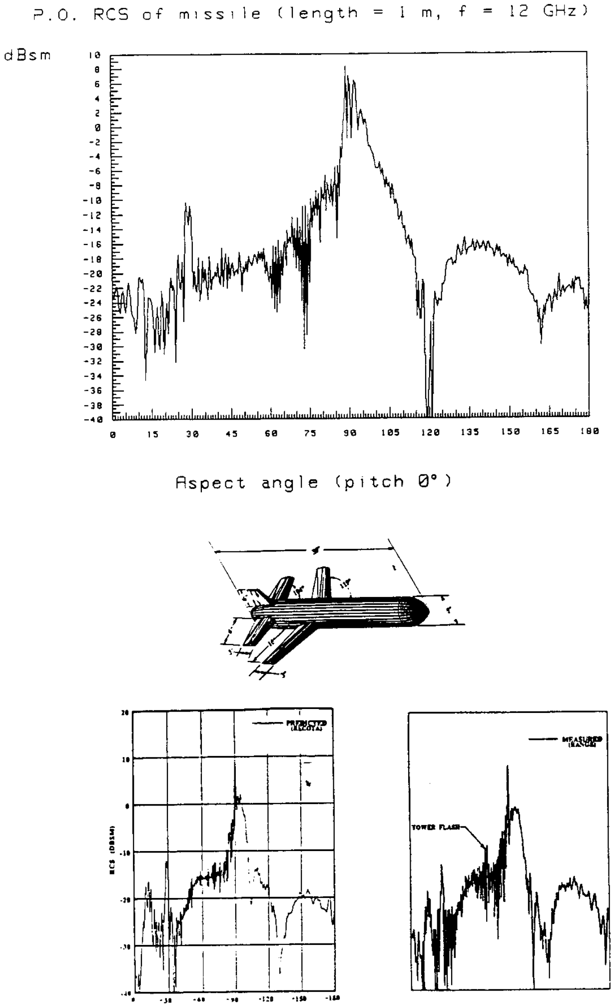

Fig. 3: Predictions and measured RCS for generic missile. Frequency 12 GHz, pitch 0°, vertical polarization.