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HIGH FREQUENCY RADAR CROSS SECTION OF COMPLEX OBJECTS IN REAL TIME

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Introduction

Classical techniques for numerical computation of RCS of large and complex targets require very long CPU run time on powerful computers [2]. The objective of this paper is to show that real-time RCS computation is possible with a high-performance graphic workstation. Physical Optics (PO) and Physical Theory of Diffraction (PTD) approximations [4] are computed using the hardware capabilities of a graphics accelerator.

Real-time computation is achieved through graphical processing of an image of the target present at the workstation screen. First-order reflections are obtained by rendering of the target with a local illumination algorithm, and multiple scattering with a global illumination one.

A computer aided design package for geometric modeling of solids [1] has been used for modeling target geometry. The target is described as a collection of parametric surfaces, defined with two-dimensional NURBS (non-uniform rational B-splines). Parametric surface modeling of the target impose weaker storage memory and CPU time requirements that the faceting approach, and the modelled surface adjusts more accurately to the real target surface [3],[5].

Hardware Graphic Processing in Real Time

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 reflection of ligth, it results that the brightness of each pixel on the drawing is proportional to its PO contribution to the total RCS [3],[5]. 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 a portion of RAM called "z-buffer" [3],[5].

In order to compute high-frequency edge diffraction, target edges are detected and angles with incidence direction are computed through graphical processing of the target image. The line integral of method of equivalent currents (MEC) [4] is evaluated by coherent addition of PTD coefficients for each pixel in target edges.

Graphic processing has the following advantages over classical numerical techniques [3],[5]:

- Evaluation of surface and line integrals independent of target complexity.
- CPU time and RAM requirements independent of target complexity.
- Real-time computation if hardware graphics accelerator is used.
- 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.

On a HP-370 Turbo SRX high performance graphic workstation with hardware graphics accelerator, the CPU run time is about 30 microseconds/pixel/angle for PO and 300 microseconds/pixel/angle for PO+PTD for both polarizations, while RECOTA package, developed by Boeing Aerospace [2], takes about 22 milliseconds/facet/angle on a VAX 11/785, including multiple scattering and second-order effects.

Multiple scattering

Multiple scattering contribution to RCS has been computed by global illumination radiosity method, which models the interaction of light between perfectly diffuse surfaces, with a reduced computational effort [6]. The well-known technique of ray-tracing has not been used because of its prohibitive computational cost.

Due to the incoherent nature of the radiosity method, based on an energy equilibrium basis [6], RCS with multiple scattering must be obtained as the incoherent addition of first order physical optics contribution plus multiple scattering radiosity contribution [5]. The later is computed by incoherent summation of the increment of brightness of each pixel due to global illumination rendering of the target [5].

The results obtained by radiosity graphical processing require a CPU time of about 10 to 50 times greater than first order physical optics graphical processing. Although this is not a real time algorithm, it is still much faster than classical multiple scattering methods, so we can consider it a quasi-real time algorithm.

Results

In fig. 1 the results obtained with PO for a Boeing 727 aircraft are compared with full-scale measurements for horizontal polarization. The agreement is very good. The graphical processing RCS has been obtained in real time (3 seconds/angle), while classical numerical techniques require several hours due to the large size of the target (128 λ).

The RCS of a 5 λ x 5 λ rectangular plate has been computed by graphical processing with PO + MEC-PTD approximations. Fig. 2 compares the results with measurements and theoric GTD formulation.

Fig. 3 shows the results of problem no. 2 of JINA'90 workshop [7]: a 4 λ triangular cylinder. Results obtained with graphical processing are compared with a method of moments solution presented at the workshop. Note that MEC-PTD improves PO solution where edge diffraction is significant.

The RCS computed by radiosity method for a dihedral is compared with experimental measurements and theoric PTD with multiple scattering formulation in fig. 4. The agreement is excellent.

Finally, fig. 5 compares the radiosity results for a complex object with first order physical optics and experimental measures. Note that first order RCS is lightly smaller than the measured one at angles between 50° and 70°, in which a double reflexion occurs between the fuselage and the leading edge of the wing. Note also that due to the incoherent nature of radiosity method, it can not predict phase cancellations on reflected fields, so that RCS nulls disappear.

Conclusions

- First order PO approximation predicts with reasonable accuracy RCS of real radar targets.
- Real-time results are possible with hardware graphical processing.
- MEC with PTD coefficients improves PO results for both polarizations when edge diffraction is dominant.
- Although multiple reflection effects are of secondary importance when RCS of real targets is computed, they can be included if a global illumination method is used for graphical processing. Due to the incoherent nature of radiosity algorithm, it can not predict phase cancellations on reflected fields, so that RCS prediction is always in excess of the measured one.

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

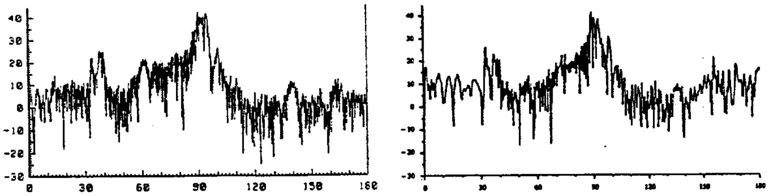
[3] "*Real-Time RCS of Complex Targets by Physical Optics Graphical Processing*", J.M.Rius, M.Ferrando, Proc. of IEEE AP-S 1990, Dallas, pp. 1280-1283

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

[5] "*Fast Algorithms for RCS Computation of Complex Objects*", J.M.Rius, M.Vall-llossera, M.Ferrando, Proc. of JINA'90, Nice, pp. 88-91

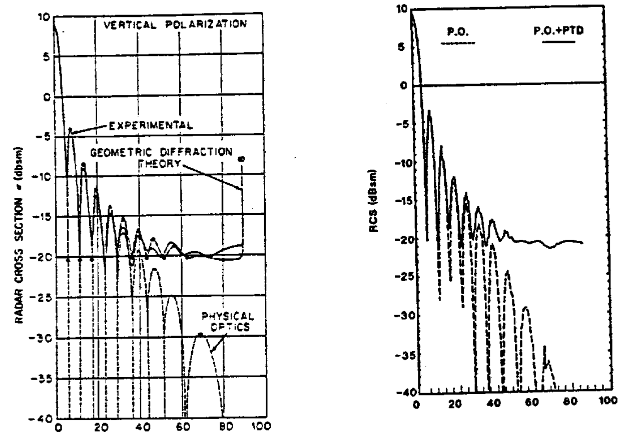
[6] "*Modeling the Interaction of Light Between Diffuse Surfaces*", C.M. Goral, K.E. Torrance, D.P. Greenberg, B. Battaile, ACM Computer Graphics, Proceedings of SIGGRAPH 1984

[7] "*RCS of perfectly conducting or coated bodies*", Workshop JINA'90, Nice, 16th November 1990



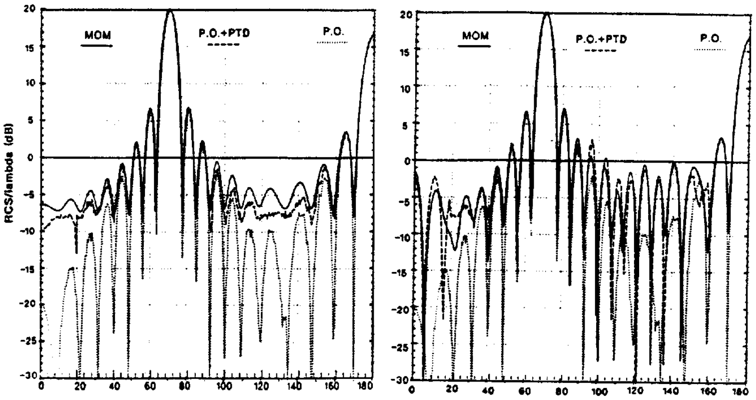
a) Physical optics graphical processing b) Measured RCS for horizontal polarization

Fig. 1: RCS of Boeing 727-100C at 0.94 GHz



a) Experimental and theoric GTD formulation b) Graphical Processing PO + MEC-PTD

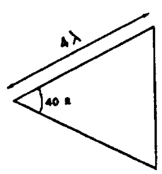
Fig. 2: RCS of flat rectangular plate 5 λ x 5 λ



a) TM polarization

b) TE polarization

Fig. 3: RCS of triangular cylinder (4λ) [7]



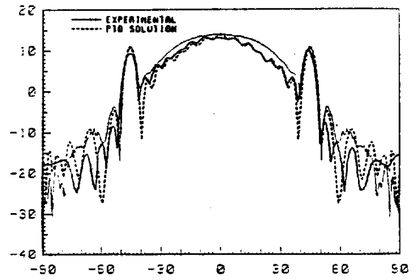


Fig. 4:

RCS of 90° dihedral,
5.6 λ x 5.6 λ plates at 9.4 GHz
Thin line: Radiosity graphical processing
Thick line: Experimental measurement
Dot line: PTD with multiple reflections

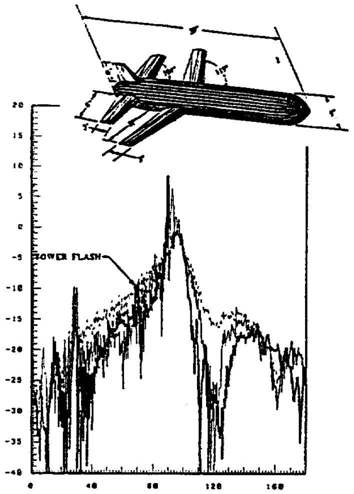


Fig. 5:

RCS of missile of 1 m. length at 12 GHz
Dot line: Radiosity graphical processing
Thin line: P.O. graphical processing
Thick line: Experimental measurement