FERMAT: A HIGH FREQUENCY EM SCATTERING CODE FROM COMPLEX SCENES INCLUDING OBJECTS AND ENVIRONMENT

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ABSTRACT

In this paper, a fast high frequency analysis method of complex 3D targets and environment is achieved by coupling electromagnetic asymptotic formulations and Shooting and Bouncing Ray (SBR) approach. Different applications of the tools from EM fields evaluation are then presented.

1 INTRODUCTION

Coupling of electromagnetic asymptotic and Shooting and Bouncing Rays (SBR) techniques have been developed with growing applications in scattering field computation. Recent papers describe the potentiality of this method in Radar Cross Section (RCS) analysis, time domain, range profiles signatures and Synthetic Aperture Radar (SAR) images of complex realistic 3D targets such as aircraft or ground vehicles. More recently, inter-system EM interference on high level integration platforms (ship types) and EM environment produced by various RF equipment (airport type) which may affect significantly functional system performance, require the prediction and evaluation of surrounding EM field.

ONERA and OKTAL SE are cooperating on the development of the FERMAT numerical simulation tool with the ambition to calculate scattered electromagnetic fields at high frequency (the size of the objects is supposed large compared to the wavelength), in a modelled complex environment including ground and buildings with their physical properties.

This paper reminds about the assessment of coupling SBR and EM asymptotic formulations. Then, it presents different applications of the tool using the results of our investigation in the possibility of field evaluation both in near and far field zones from various interactions. A visualisation display is proposed in a general bistatic multi-receiver formulations of the scattered fields.

2 SIMULATION TOOL COMPONENTS

In addition to electromagnetic part wave interaction formulations, the numerical simulation associates several components.

2.1 Geometrical realistic database

Virtual 3D geometrical data bases are composed of complex objects, numerical model of terrain which could be woodlands vegetation, isolated trees, crop fields or specific buildings and interesting scenes. They are described by thousands of polygons. As examples, on figures 1 and 2 are respectively represented a 150 000 facet aircraft and a 500 000 facet landscape. Specific features and textures related to infrared, optics and electromagnetic are provided for each polygon of the scene database and for each polygon of the targets.

For radar analysis, two classes of materials have been defined: the metallic materials and the environmental clutter with. Each category of clutter is characterised by its backscattering coefficient average σ_0, which depends on the incidence angle and polarisation components (HH, VV, VH, and HV). Metallic materials follow the Fresnel reflection coefficients $R_\perp$ (-1) and $R_{//}$ (+ 1).

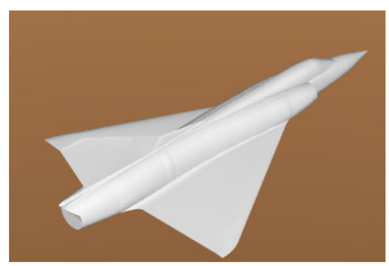

Figure 1 : Model of aircraft

Figure 2: Terrain database

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2.2 Shooting and bouncing rays technique

In SBR technique [1], a set of rays representing the incident plane wave is shot towards the object. The main part of the computation time stands in the geometrical intersection calculations between rays and surfaces. Improvement is achieved in terms of memory cost and computation time by introducing dynamic calculations of the intersections. From an emitting point, the scene is included in a cone in which only few "rough" elementary tubes of four rays are launched. Every tube will be divided into four other tubes as far as their intersection with the target constitutes a planar surface. Shooting ray number is reduced thanks to this planar or homogeneous criterion of intercepted surfaces whereas, in literature, regular dense grid of geometrical optics rays (10 rays per wavelength) is generally shot (figure 3).

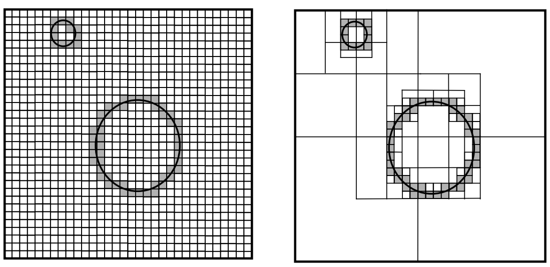

Figure 3 : Regular and adaptive grid (down to $\lambda/10$)

2.2 Specific tools

Generation and management scenarios tools have been developed in order to position emitting sources and to calculate the radiated and scattered electromagnetic fields at the interesting areas. Convivial output presentation tools are carried out to help users in bulky results analysis.

3 COMPUTATION STRATEGY

The asymptotic electromagnetic models developed and exploited in FERMAT rely on a methodology treating in a unified way and whatever the distances with the obstacles, the electromagnetic calculations of EM fields.

3.1 Plane wave and target interaction

High frequency asymptotic and shooting rays techniques were coupled in order to predict the scattering field from complex targets [2]. To evaluate the multiple interactions, each ray is followed from one part of the target to another one. For large targets (according to the wavelength), the RCS of complex targets can be predicted using the high frequency asymptotic approximations. For facetted targets, two principal methods are applied: Physical Optics (PO) for surface scattering [2, 3, 5] and Geometrical Optics (GO) coupled with previous method to take into account multiple interactions. Contributions from all rays are summed up at observation points to calculate the final scattered field, eventually leading to the RCS of the target for far-field observation. The previous models are completed by edges diffraction [3, 6] using Equivalent Current Method (ECM) or/and Uniform Theory of diffraction (UTD). The coupling between such methods and GO takes into account throughout the multiple bounces, the reflection(s)-diffraction coupling.

For near field evaluation, an efficient computation strategy has been carried out, according to the distance to the obstacles disturbing the electromagnetic field. It is based on a judicious adaptive subdivision of the radiating surfaces or obstacles incorporated in the scene [7].

3.2 Plane wave and environment interaction

Backscattering coefficient average σ_0 characterises each category of clutter. Tabulated values depend on the incidence angle and polarisation components (HH, VV, VH, and HV). Moreover, real simulation values for σ are obtained by including statistical fluctuations such as Rayleigh for speckle effects. Data on backscattering coefficients are extracted from (sparse) measurement campaigns published in literatures and F.T. Ulaby and M.C. Dobson's works [4]. An important synthesis task was performed in order to take into account frequency bands diversity and polarisation information. Prospective work is ongoing in order to include general behaviour for bistatic scattering.

4 VALIDATIONS AND APPLICATIONS

The validation essentially consists in comparing the electromagnetic models used either with methods of reference or with measurements on simple objects known as canonical. These comparisons are performed during specific workshop sessions on objects with simple geometry, with the possibility to test various electromagnetic interactions. As an example, calculations at very high frequencies were carried out on a non conventional trihedral with one tilted face and various dielectric materials, on which exhaustive measurements have been conducted (figure 4). Very good agreement between calculations and measurements is established.

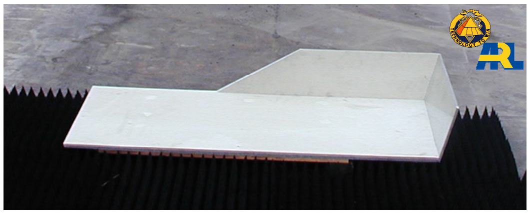

Figure 4: Test case of modified trihedron

Principal applications show the unifying feature of the computation strategy, one can quote:

- Evaluation of complex targets RCS in centimetre and millimetre wavelength.
- Simulations of radar behaviour, in centimetre or millimetre wavelength, in pre-set scenarios with specific targets and natural environment. Compared with tools based on rays tracing, the SBR technique offers quite higher performance.
- Calculation of antenna patterns in presence of surrounding structures: antenna diagram on carrier, calculations of radiated fields around transmitting antennas to define safety zones in urban telecommunications applications.
- The calculation of radiated electromagnetic fields, for applications in external inter-system electromagnetic coupling. In this application, EM fields emitted by a transmitter are calculated on surfaces of coupling (or interface) with a likely disturbed element, by taking into account all the environment.

5 EXAMPLES OF RESULTS

5.1 RCS calculations

Figure 1 presented a 150 000 facet model of a generic target (here a virtual aircraft). Radar Cross Section (RCS) calculations, at 10 GHz are achieved using the principles previously described. Results (in the plane of the wings) are presented on figure 5.

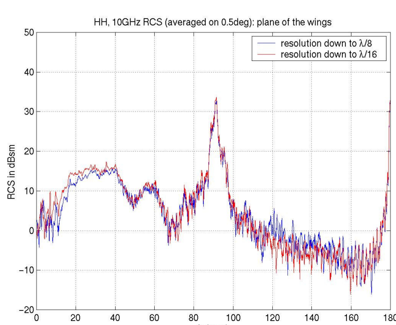

Figure 5: RCS results

5.2 EM fields evaluation around emitting antenna

In this example, calculation of the electromagnetic field is carried out in urban environment, including different interactions with the building, in a volume around the transmitting antenna. The objective is to determine a safety zone, quantified in electric field intensity, around the antenna, according to lawful recommendations (GSM antenna establishment). In the current context of request on the biological effects of EM waves, simulation represents a particularly interesting tool of levels prediction of EM field. In the example on figure 6, the transmitting antennas are composed of dipoles arrays. Calculations are carried out down to very close to the antenna and the obstacles. In this case, specific processing tools lead to iso-density representation of the EM fields.

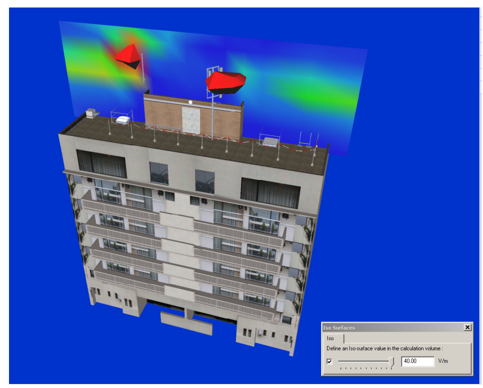

Figure 6: EM field in the vicinity of GSM antennas

5.3 Radar simulation

The multidisciplinary feature of FERMAT is shown through the framework of the "Airport Of the Future" project at ONERA. The global project includes, among other subjects, enhanced vision using millimetre wave radar and infrared sensors imagery principally in poor weather conditions (haze, fog, rain). In order to evaluate the contribution of high resolution sensor system in the airport context, simulations have been conducted on virtual airport (representing the Toulouse Blagnac airport area) database developed by OKTAL SE on figure 7a.

Results, at 500 m from the touch down zone in front of the runway, are transformed from distance – angle to usual visual angle - angle representations are shown for a simulated 94 GHz radar. Images on figure 7b have been calculated on a field of 30º (azimuth) by 10º (elevation) with variable resolutions.

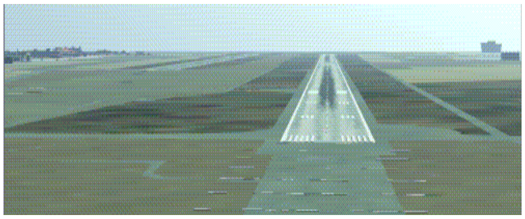

Figure 7a : Toulouse Blagnac airport database

Resolution 0.15° 0.15°

Resolution 0.3° 0.3°

Resolution 0.6° 0.6°

Figure 7b : radar images at 500 m from the touch down zone

4 CONCLUSIONS

From asymptotic electromagnetic models coupled with SBR technique exploited on geometrical and physical 3D databases, tools for various applications of electromagnetic calculations of EM fields have been developed. These tools represent the FERMAT software able to deal with problems of radar, propagation, telecommunications in urban environment, calculation of antenna diagram and EMC constraints in a complex environment.

FERMAT has been extensively validated against canonical and complex objects. Future axes of development concern:

- enrichment of the data banks for materials
- establishment of the low frequencies limits of the method for calculation
- improvement of the way to take into account the surface roughness.

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