IDRA/GID 3D asymptotic code for the modelling of the antenna pattern in the vicinity of large structures

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SUMMARY: A 3D electromagnetic code using the asymptotic technique of rays has been developed to analyse radiation pattern of high-frequency antennas located in the vicinity of large perfectly conducting structures. This code called IDRA is actually hybridised with GID. Any parts of the structure and different levels of complexity in the electromagnetic solution can be independently selected. Here, a ray tracing technique is used to find the rays that interact from the source to the structure. Interactions taken into account are: single and double reflections with plane, convex and concave surfaces; single and double diffractions with edges; vertices diffractions; creeping waves; double interactions such as: reflection/diffraction, reflection/creeping waves, diffraction/creeping waves. The coefficients of the Uniform Theory of Diffraction are then used. The post-processing of data consists in the calculation and the visualization of both the modified pattern of the source and the rays visualization, sorted by energy.

KEYWORDS: Uniform Theory of Diffraction, electromagnetic simulation, antenna design, asymptotic technique, rays tracing, creeping waves.

INTRODUCTION

The problem of radiation pattern from sources in the presence of perfectly conducting objects is of great interest in the design of transmitting or receiving antennas on structures. The optimal antenna location on vehicles (car, aircraft, missile, ship), for instance, is particularly hard to find because of the lot of costly tests which must be managed. A reliable and fast electromagnetic code, able to model antenna/structure couplings, is the only way for engineers. Nevertheless, whenever the electromagnetic wave-length is short compared with dimensions of the structure, common numerical techniques such as Method of Moments (MoM), finite-elements method (FEM) or finite differences in time domain (DFDT) are known to be no more available, due to the great computering resources needed: large RAM memory and code parallelization to decrease the calculation time are necessary. The Uniform Theory of Diffraction (UTD) [1] is an alternative technique which can solve these complex problems. A 3D software called IDRA has been developed. The skill of GID to design arbitrary shaped bodies with NURBS has been hybridised with a UTD fortran code powered by openNURBS Toolkit. Interactions such as reflections, diffractions by corners and edges, creeping waves and all the combinations of these are treated.

IDRA: A GID PROBLEM-TYPE FOR HIGH-FREQUENCY MODELLING

The IDRA/GID hybridization exploits both the friendly and powerful Graphical User Interface properties of GID to design directly the geometry and the GID's import features that allow to use most of common CAD formats (IGES, VDA,…).

The UTD asymptotic method is based upon the assumption that fields propagate along rays. In the current version, IDRA searches the following rays (Fig. 1):

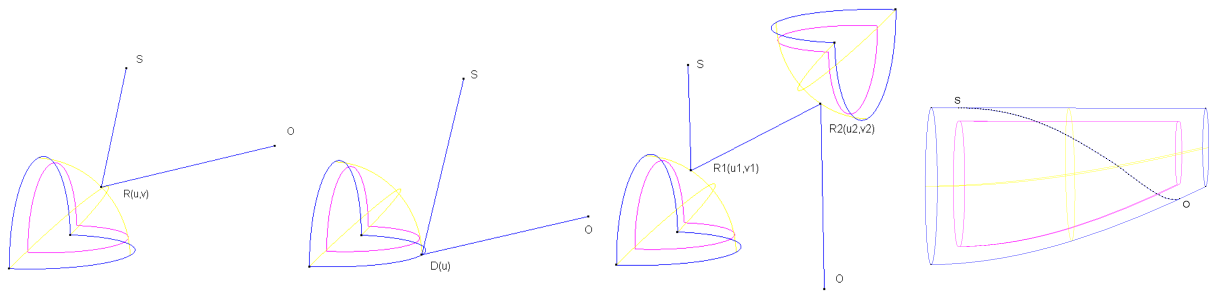
- Incident;
- Reflection on plane, concave and convex surfaces;
- Diffraction by straight and curved wedges;
- Diffraction by corners;
- Creeping waves on arbitrary shaped surfaces;
- Reflection – Reflection;
- Reflection – Diffraction;
- Reflection – Creeping waves.

Wedge caustics, which are one of the UTD theoretical limits, are treated separately, using the equivalent currents technique.

For each point source and observation direction and for all geometrical NURBS elements, IDRA:

- Searches the simple geometrical elements (plane surfaces and straight edges) of the structure and applies the Descartes-Snell laws for the reflection and the Keller cone principle for the diffraction;
- Searches, for the other NURBS elements, the interaction point on the element by minimization of the ray length, following the generalized Fermat principle (Fig. 1abc);
- Searches the geodesic surface path between the attachment and detachment points of the creeping waves (Fig. 1d);
- Checks if the incident and the scattered rays are not intercepted by the other elements;
- Computes the far field, derived from the scattering UTD coefficients [1].

The rays tracing is the most CPU time costing part of IDRA.



(a) (b) (c) (d)

Fig. 1: Rays searching for arbitrary shaped NURBS elements: single reflection (a); single diffraction (b); double-reflection (c); creeping waves along geodesics (d).

IDRA is integrated in GID as 2 typical "problem type":

- the IDRA/PREPROCESSING allows the electromagnetic problem to be defined. The results of computation (pattern, rays energy by direction and electromagnetic contribution for each geometrical element) are then available in ASCII files;
- the IDRA/POSTPROCESSING allows the user to manipulate results of computation. To make interpretation easier, radiation pattern and rays can be directly visualized together with the geometry.

IDRA/PREPROCESSING

The PREPROCESSING sequence of IDRA allows the user to define the problem parameters: the source, the structures, the electromagnetic contributions, and the IDRA outputs (Fig. 2). IDRA gives several degrees of freedom for the user. One consists in selecting independently all or parts of the structure, liable to interact with the source. The degree of complexity of the problem is also chosen by selecting all or some electromagnetic contributions. Both these options control the time of calculation, allow to increase progressively the problem complexity and finally give a physical approach of the problem by decomposition.

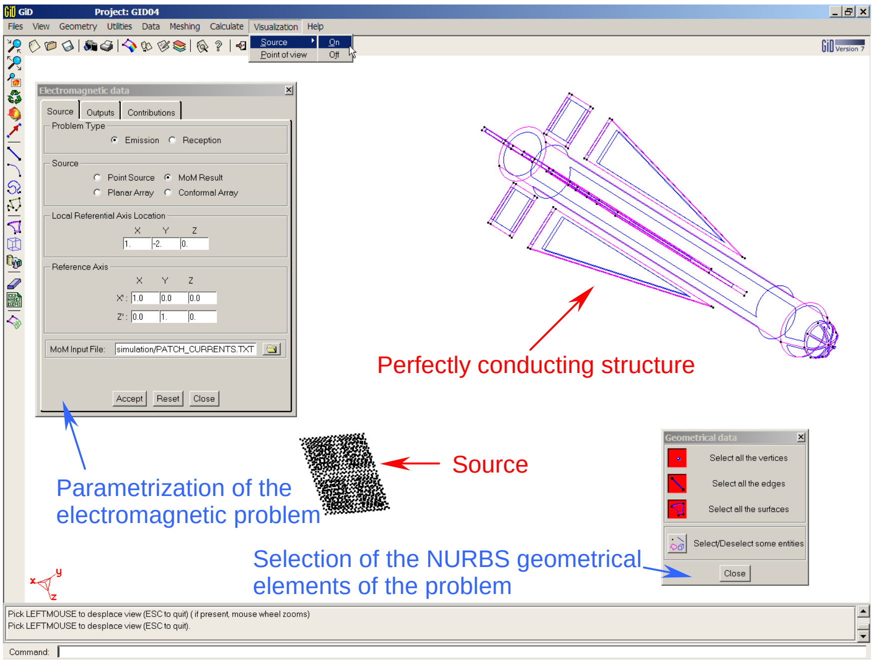


Fig. 2: View of IDRA/GID software for the modelling of radiation pattern from a high-frequency patch antenna located in the vicinity of a perfectly conducting structure.

IDRA can handle 2 kinds of sources: antennas which are characterized by their far-field (modelled by a MoM method, for instance, or measured) and dipoles (related to wire antennas linear current or triangular surfaces constituting a current distribution obtained by MoM code). The antenna location and orientation are fixed in a special frame (Fig. 3) and can be checked visually, using a special tool that displays the location antenna phase center or the dipoles that compose the antenna (see Fig. 2 : a patch antenna composed by 1044 dipoles, the current of which are deduced from a MoM calculation).

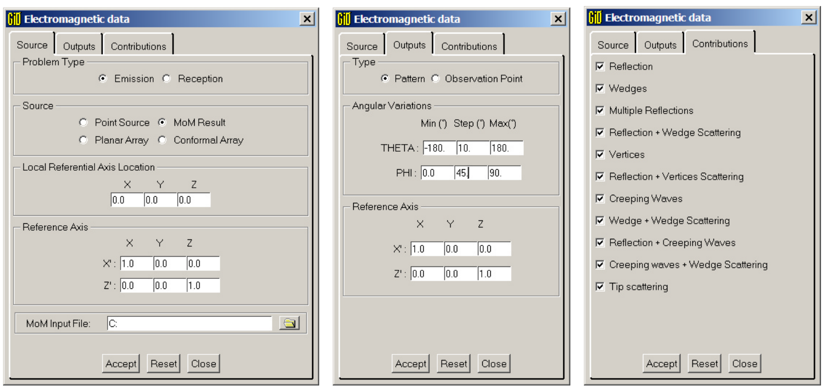


Fig. 3: Notebook frame for the parametric insertion of electromagnetic data.

The typical IDRA outputs are azimuthal radiation patterns calculated for site planes or electrical far-field values at fixed observation points. This last is particularly useful for the evaluation of the mutual coupling between antennas. In this case, each source is modelled independently from IDRA. The antennas are then successively computed by IDRA as transmitting antenna in the presence of the structure, and fields are calculated at the point of location of the second antenna that is supposed to be passive. The knowledge of the antenna impedances follows to the currents and then to the coupling matrix. The two realistic radiation patterns can so be calculated [2].

IDRA/POSTPROCESSING

Radiation patterns can be displayed together with the geometry in the POSTPROCESSING sequence of IDRA, showing so a realistic view of the structure influence (Fig. 5). A decomposition by electromagnetic contributions and geometrical contributors is also possible. Furthermore, rays paths can be displayed as a function of both the direction and the range of energy around the maximum field value in that condition. These post-processes give a good physical interpretation to the engineer.

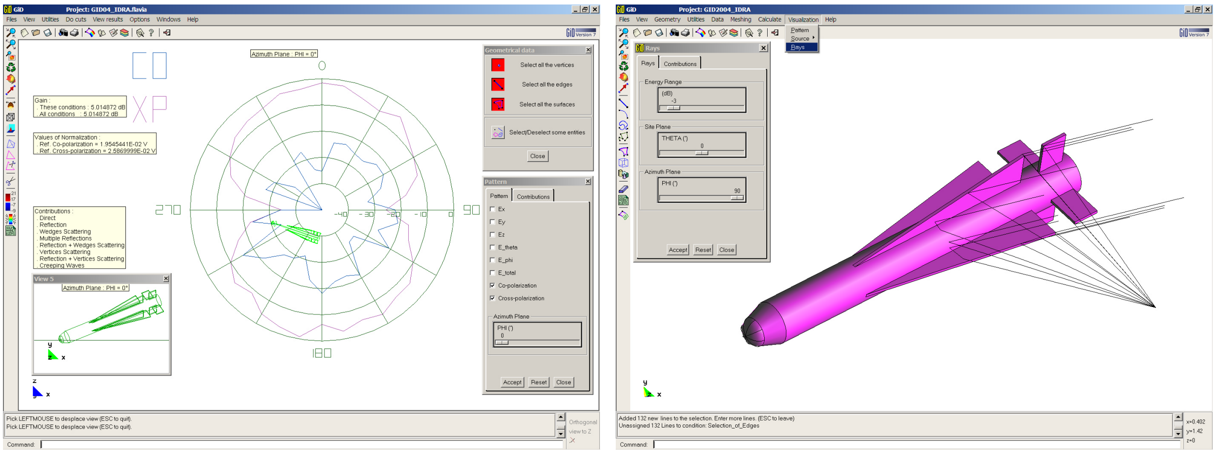


Fig. 5: IDRA/POSTPROCESSING: visualization of the radiation pattern from a 1GHz dipole located at 1m far from the structure (left). The rays coming from the source and that interact with the structure are visible in a particular direction (defined by the azimuthal and site angles) and in a particular range of energy around the maximum in that direction (right).

PERSPECTIVES

Future versions of IDRA will certainly consist in hybridizing the present UTD code with our MoM code ICARE. The software will be then able to model most of the actual high-frequency electromagnetic problems: sophisticated antennas, conformal antennas or coupling between antennas on surface, taken into account both the diffracted fields and the surface creeping waves... Be that as it may, GID as demonstrated here its reliable quality for the use of electromagnetic codes.

REFERENCES

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