CAPABILITIES OF VIRAF

Riccardo Cioni*, Mauro Bandinelli*, Lorenzo Benvenuti*, Eugenio Chiavaccini* and Giovanni Galgani*

Introduction

Basing on its past experience in the field of RCS and antenna siting optimization, IDS developed the VIRAF (VIRtual Aircraft Framework), aimed at assisting the user in RCS prediction for stealth design and antenna siting aboard aircrafts, helicopters and missiles.

The system embeds CAD and mesh generation routines especially designed for aircraft applications. Full wave (MOM, FDTD) as well as asymptotic prediction codes (PO, PTD, ITD) are included into the system, in order to manage the entire frequency spectrum.

A parallel out of core MoM solution, that will evolve towards a MLFMM in the near future, allows to manage problems of several wavelengths and allow a smooth transition between full wave and asymptotic methods. An FDTD solution including frequency dispersive materials allows to manage meta-materials, chiral materials and plasmas layers other than standard dielectrics. Novel ITD formulations allow to efficiently manage diffraction from dielectric and RAM materials in the high frequency limit, with a high confidence level.

Antenna siting can be performed for radio navigation aids, radar systems and TLC. For very high demanding designs, VIRAF can be interfaced with ADF, (Antenna design Framework) an IDS developed system aimed at custom antenna design.

The system relies on a client server architecture that makes the system number crunching capabilities tailored to the user's need and prone to be improved depending on user's needs.

General Description of VIRAF

VIRAF is a system that assist the user through all the main steps of the electromagnetic design process of new generation aerial platforms. As such, it is mainly composed of the following sections

- A CAD for geometrical modeling and electromagnetic mesh generation
- An EMC EMI section for the simulation of the equipment installation process aboard an aircraft.
- A RADAR signature section for the evaluation of RCS and radar images
- An IR signature section for the evaluation of infrared signature
- A data base for data storage of all the results and data for a given design
- Utilities for definition of material properties, data base management and for the management of computational processes.

Data for a given project can be stored, retrieved and reused or shared on new projects. This feature greatly improves the efficiency of the design workflow due to the fact that the run of computational processes is directly managed by the system, without or with low intervention of the user, the system is highly scalable in terms of computational power and easily upgradeable as a function of new highly demanding projects.

Every electromagnetic simulation section shares the same CAD geometrical model, in order to allow for concurrent design, and in most of cases also electromagnetic (mesh) models are also shared. Moreover, every section has its own diagnostic routines for a better interpretation of results and dedicated post processors.

CAD and Mesh Generation Section

Whatever the e.m. problem to solve, simulations must be based on a reliable CAD model. For this reason, a commercial CAD is integrated into the system. This allows to use the same geometrical model used in aeroelastic, mechanical as well as aerodynamic analyses or to define a new one. The CAD layout is further processed to provide the appropriate mesh. For MOM and PO the mesh

* IDS Ingegneria Dei Sistemi SPA, Via Livornese 1019 56010, San Piero a Grado, Pisa, Italy

is triangular based whereas FDTD requires a Cartesian homogeneous grid.

For the reasons above, VIRAF encloses a PO/PTD and MOM mesh generation routines explicitly developed at IDS, implementing a number of tools able to improve the quality of the mesh both with local (on selected triangles) and global (Lapacian and Delaunay smoothing) refinements. A recently developed mesher for FDTD allows to generate the Cartesian 3D grid in a semi automatic way, starting from the CAD model .

EMC/EMI Section Description

The EMC/Antenna Siting Analysis Section aims to assist the user in the analysis and design of the avionic radiating sub-systems (antennas plus electronics) aboard the airframe, verifying and optimizing the installation layout.

For a given airborne antenna operating in the frequency range from HF up to radar bands the framework VIRAF can predict its performance in terms of Directivity Gain (to be compared with Civil (e.g. ICAO) and Military Standards (e.g. MIL-STD)) in order to identify possible problems due to bad siting. Also near field (E and H), antenna impedance (Scattering Matrix-parameters), inter antenna coupling and aircraft induced currents are available. In Fig.1 a VOR radiation pattern and its relevant induced currents are depicted:

Antenna performance are evaluated also at "service level" if required (e.g. IFF service is usually compound by two antennas and it is of major interest to synthesize the overall system capabilities, more than the single antennas' ones).

A better insight (more useful both at design and aircraft certification level) can be obtained by using *Operative post processing* functions to obtain operative parameters such as link budgeting assessment and EMI compatibility. Also dynamic effects as the rotor blade modulation on navigation receivers can be evaluated; bitmaps in Fig. 2 shows how this phenomenon affects a VOR subsystem performances in terms of unwanted received signal modulation and bearing error.

RADAR Signature Section Description

A characterization of radar signature is possible for the whole frequency band of modern radar threats (20 MHz to 40GHz and higher). RADAR signature is possible in terms of:

- RCS (monostatic and bistatic);
- RADAR images (1D, 2D and 3D, monostatic as well as bistatic).

The VIRAF framework encloses both asymptotic as well as full wave solvers. The former enable a fast result evaluation and are based on optics principles. Actually the Physical Optics (PO) code is accessible together with its generalization to the Physical theory of Diffraction (PTD). Moreover the edge transitions between different dielectric materials can be taken into account by means of solutions based on the Incremental theory of Diffraction (ITD). The solver is able to automatically identify and handle multiple bounces and reflections up to the third order. In the case the device under study should suffer higher order reflections, as it happens in the analysis of cavities such as inlets and outlets, a shooting and bouncing ray (SBR) solver may be employed. All these solvers allows the computation of monostatic and bistatic RCS, while keeping fixed the transmitter or the receiver radars only, or setting a fixed angle between them.

As full wave solver VIRAF embeds both a 2D and 3D FDTD and a Moment Method code based in RWG formulation for the Electric Field Integral Equation. At present the FDTD has been tested with 10 million cells, whereas the MoM code is capable to solve up to 70000 unknowns. This allows to analyze an attack aircraft up to 500-600MHz.

The choice between solvers allows significant cross checks between results. Moreover it makes practicable the independent analyses of different portions (when applicable on the basis of a preliminary physical insight) of the same whole structure. Partial results are then post processed and combined to get the final result. This provides computational requirements and time savings and, possibly, a further insight into the RCS mechanism.

The FDTD solver is particularly suited to deal with dielectric materials both with constant and frequency dependent responses. In particular a Drude's model (appropriate for plasma) and a Lorentz's response (with arbitrary number of poles and zeroes) are available. For instance, in in Fig. 3 the interaction between a dipole and a sheet of a frequency dependent magnetic material is illustrated. The real part of the reported Pointing's vector clearly demonstrates the high absorbing behavior of the material.

Moreover, the FDTD solver eases wide band analyses. Thanks to a dedicated time impulse library which includes Gaussian pulses (both *base*- and *pass*-band) and combs for multi-frequency analyses.

Results are then processed in order to extract graphs and curves and to obtain statistical data, such as mean, percentiles and the whole probability density function (pdf) as well. For instance in Fig. 4 the map graph of the RCS of a corner reflector for an RCS augmenter is shown as a function of azimuth and elevation (the augmenter possesses a quad symmetry). The corresponding pdf is also depicted in Fig. 4.

In order to present a more significant example the field scattered from the complex target NASA Almond is illustrated (These results have been presented at the Jina Workshop 2004, Nice, France, 11 Nov 2004). At 1.6GHz, due to the presence of creeping waves and other non specular scattering mechanisms, the MoM method has been employed. In Fig. 5 the mesh (about 30000 triangles) is illustrated and also the $\phi\phi$ (horizontal) polarization RCS is reported. Due to the symmetry only the azimuth range 0-180deg has been analyzed.

IR Signature Section Description

IR Signature Simulation provides a suite of simulation tools for predicting the thermal radiation behavior of a given flying platform (aircraft, helicopter, missile or UAV) in the two IR wavelength bands of interest for self defense purposes:

- Short wave band: $3 \div 5$ μm
- Long wave band: $7 \div 14$ μm

including:

- Volumetric meshing tools for modeling internal compartments and assigning material IR irradiative properties and locating internal power sources.
- Thermal model solution for predicting the thermal equilibrium on the model external surfaces taking into account relative air-speed and internal thermal sources.
- Irradiative Model for predicting the IR emission in the two wavelength bands considering atmospheric propagation.

The relevant aspect of this design environment is the assessment of the platform irradiative performance as a function of elements such as:

- Vehicle Mission in terms of flight conditions and related speed profiles;
- Vehicle definition through its relevant parts obtained by available CAD models for existing aircraft or its conceptual model; for example: characteristics of the fuselage, wings, tails, engine-air inlets, type of engine, power and hypothesis on the exhaust gases.
- Surfaces shape and material characteristics resulting from Low Observables aircraft design.

The IR solver procedure computes the apparent radiation characteristics, then the user may activate a specific post processing tool for:

- Determining the image seen by the specific sensor threat, defined by its essential characteristics (spectral sensitivity, sampling in Y, scanning in X, IFOV, MTF, etc.). The image will be computed in terms of apparent temperature or apparent radiance of the target.
- Determining the radiant intensity of the platform as a function of angle of view (azimuth and elevation and wavelength)
- Determining Target/background apparent contrast.

Conclusions

VIRAF is currently used at IDS in all the electromagnetic design activities related to antenna siting and RADAR signature evaluation of aircrafts. For this reason the system's maturity is high and the continuous upgrades allow to maintain the system at the cutting edge of prediction technology.

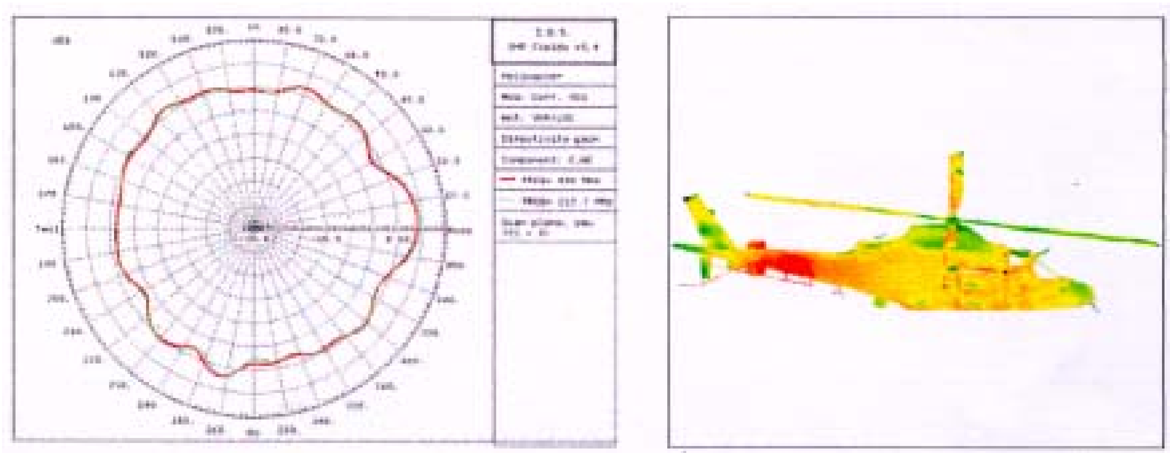

Fig. 1

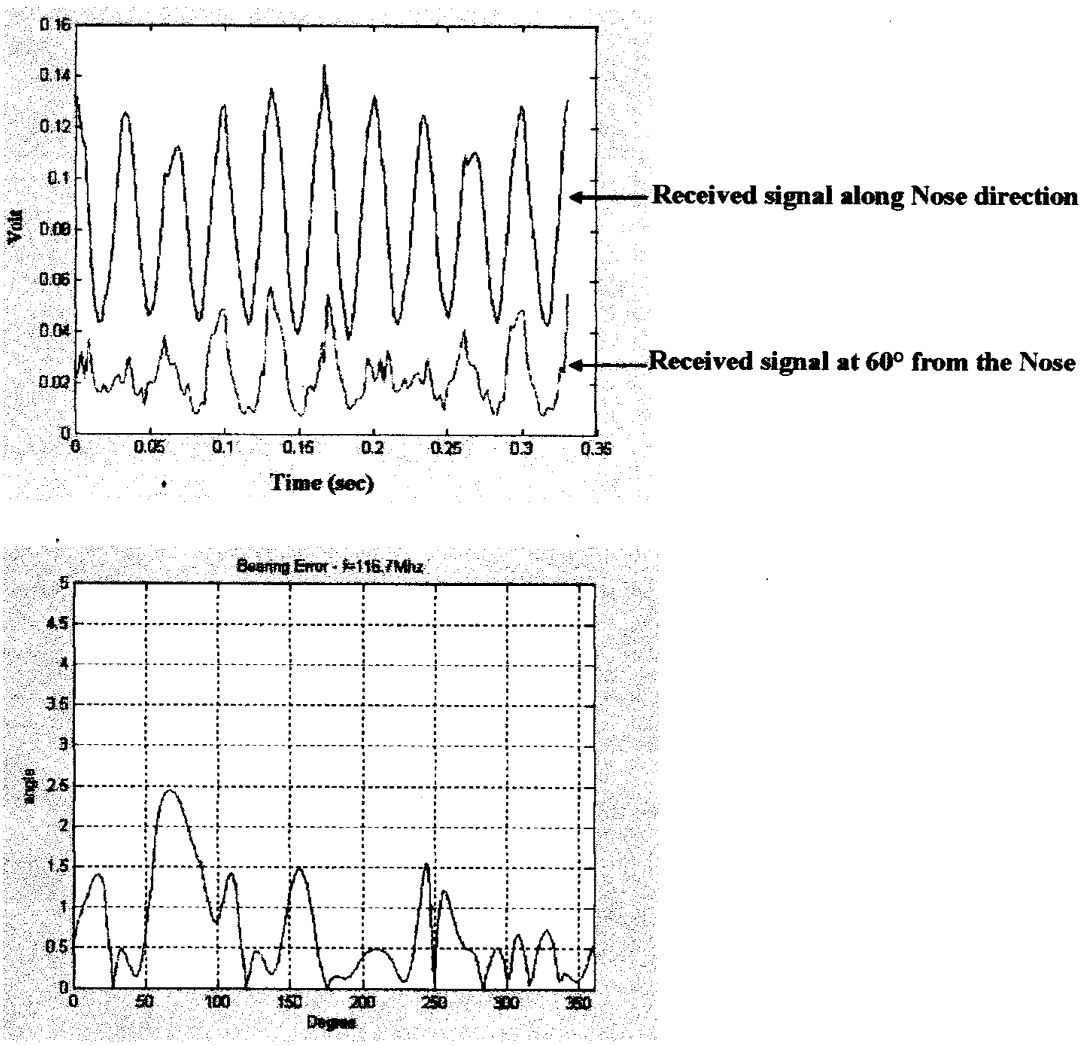
Received signal along Nose direction
Received signal at 60° from the Nose
Volt
Time (sec)
Bearing Error - f=116.7Mhz
angle
Degrees

Fig. 2

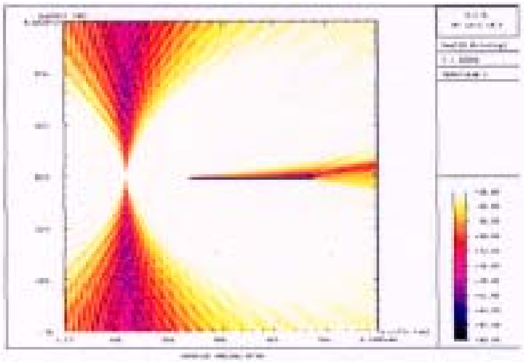

Fig. 3

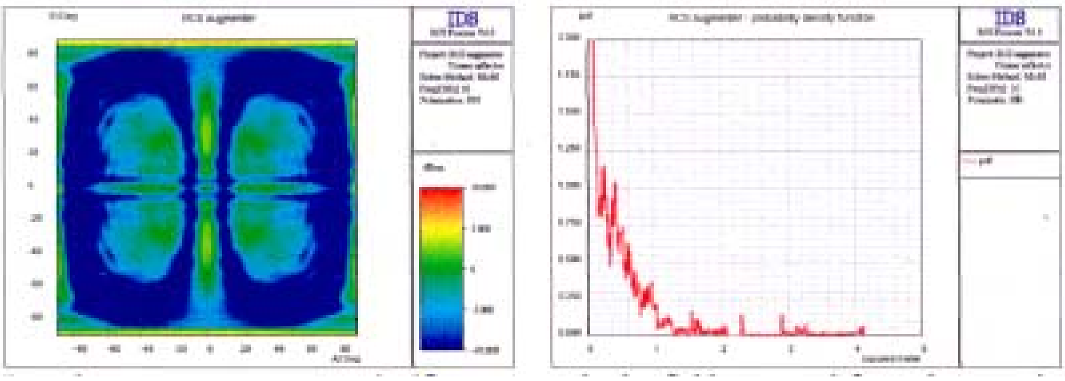

Fig. 4

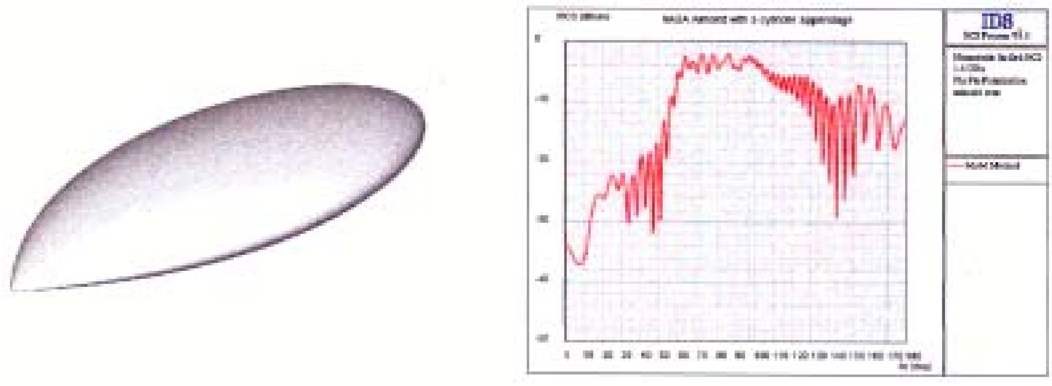

Fig. 5