FINITE ELEMENT MODELLING OF ANTENNAE RADIATION PATTERNS

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Abstract

Helicopters are relatively small compared to transport aircraft and over–equipped with radio–communications and radio–navigations equipment. A good positioning of related antennae is critical to achieve good performance in this very constrained context. Computer based models can help to achieve optimized antennae location at low cost over short development cycles.

EUROCOPTER has been using the ASERIS–BE finite element software, developed at Aerospatiale, to study antennae radiation patterns. Successful computations, with respects to flight test results, were obtained on various helicopters in the HF, VHF and UHF ranges.

This paper introduces briefly the Boundary Element method (also known as the Method of Moments) used by ASERIS–BE. Some HF, VHF and UHF radiation patterns computations are presented and compared to flight tests. An application of the same method to define the High Intensity Radiated Fields (HIRF) environment for helicopters in the HF band is also presented. Finally, Electromagnetic Compatibility (EMC) applications and research topics, including parallel computing are discussed.

1. Introduction

Helicopters use many radio equipments for communication and navigation purpose. Suitable external space is scarce and competition is fierce between radio and other types of equipments. Customization and addition of optional equipments such as hoist, search light, FLIRs, may modify the radiation patterns of the antennae and thus the performances of radio equipments.

The evaluation of these demanding and sometimes contradictory requirements are achieved through flight tests and engineering experience. Today, however, as computer power keeps increasing, simulation can help and brings answer in the short industrial cycle associated to customizing existing products. Simulation may complements flight tests on two different ways:
– by predicting the effect of a modification on an already qualified installation;
– by pointing out what to look at when a flight test program for a new or difficult case is defined.

We shall successively present the simulation method, comparisons between flight test and computations and derived applications to HIRF (High Intensity Radiated Fields), EMC (Electromagnetic Compatibility) and research topics.

2. Finite Elements and ASERIS–BE code

Most of the computing methods for electromagnetism fall in one of the categories listed below:
- the finite difference method;
- the finite element method;
- the Physical Theory of Diffraction;
- the Geometrical Theory of Diffraction.

The first two methods are exact in the sense that they solve Maxwell's equations whereas the latter are valid for higher frequencies. Practically, one may use the exact (but computer power demanding) methods when the available computing power is sufficient (the amount of memory and computing time needed rise sharply with the frequency) and turn to the latter methods for "optical frequencies". For helicopters, most of the equipment use frequencies either below 400 MHz (upper limit of UHF communications) or above 1GHz. There is thus a natural boundary for exact methods and high frequency approximations.

From now on, we shall only discuss frequencies lower than 400 MHz and the finite element method.

We use ASERIS–BE, a software developed and distributed by Aerospatiale Space and Defence branch and Joint Research Center [1]. ASERIS–BE is based on the integral equations of Stratton–Chu [2]. From an user point of view, the meshes are surfacic for the fuselage, either lineic or surfacic for the antennae, and once the unknowns are computed (the unknowns are the surfacic currents discontinuities), any electromagnetic data of interest can be expanded. These data are far–fields (for antennae radiation patterns), near–fields, induced currents on the fuselage or wires.

Depending on the type of application and frequency range, antennae are modelized either by their exact geometry or by an electromagnetic equivalent. In the first category we find HF antennae, VOR. On the other hand, VHF and UHF communication antennae (including homing application), either passive whip or active blade, are adequately modelized by a quarter wavelength monopole. In fact these communication antennae are designed to be isotropic and matched. Monopoles are isotropic and the formalism of the ASERIS–BE code insures the matching of the antenna with its generator.

Figures 1 and 2 below show typical meshes of the Super Puma. Note that for HF radiation pattern, holes in the metallic skin are not taken into account while they are essential in EMC problems. It may be useful, for some applications, to describe precisely the dielectric properties of non conductive materials (fiberglass, plastics) or less than perfect conductors (carbon composites). In most antenna applications however, a very useful approximation is to consider only two type of materials: perfect conductors and perfect dielectrics.

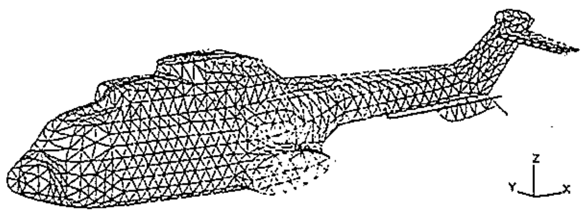

fig. 1 Super Puma mesh for HF application

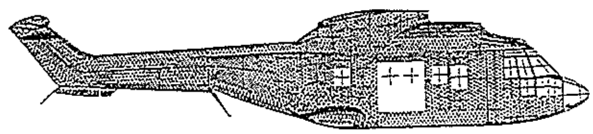

figure 2: Super Puma mesh for EMC application

3. Antennae radiation pattern: a comparison between computations and flight tests

The range, in various directions depends on the power of the radio equipment, the fraction of that power transmitted to the antenna, the altitude of both transmitter and receiver, and the radiation pattern. Flight tests and ground tests yield all these data.

Concerning finite element computation, its significant output is its ability to take into account the multiple interactions between the antenna and the structure of the helicopter and the results can be presented in the same manner as flight test radiation patterns: an antenna gain diagram with a normalization of 0 dB for the maximum.

The radiation pattern of an antenna is a three dimensional set of data. It is quite easy, and illuminating in some cases, to produce a 3D global picture of the gain for a computer but much less so for flight tests. Therefore, all the following comparisons take place in the horizontal plane and concern the vertical polarization. This is quite representative of air to ground communication at large distances and small altitude.

Figures 3 to 7 show a comparison between flight tests (dotted line) and computation (continuous line) in the UHF band for an Ecureuil. Frequencies have been rounded to the closest decade. Although these diagrams are quite lively, as can be expected in the UHF band, the agreement is quite good especially for the detection of peaks of lower gain.

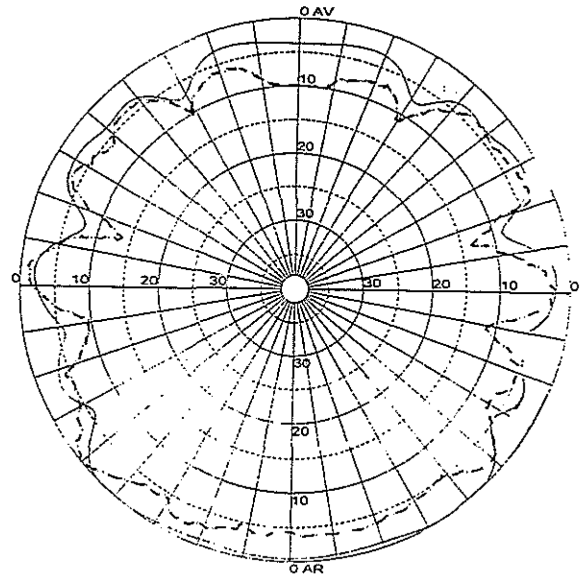

figure 3: comparison at 230 MHz
flight test dotted line
computation continuous line

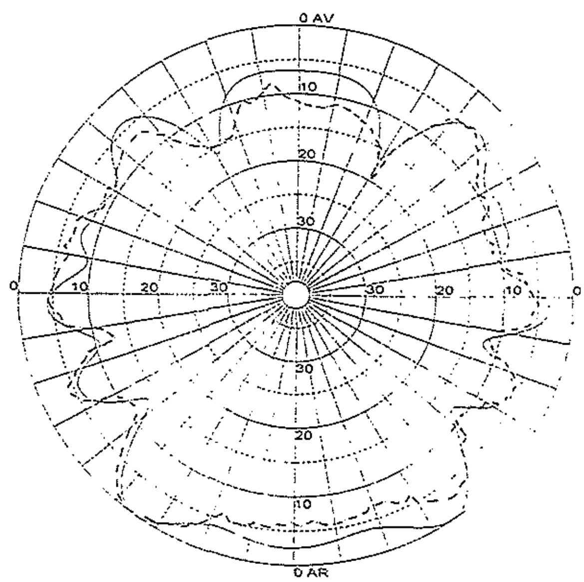

figure 4: comparison at 240 MHz
flight test dotted line
computation continuous line

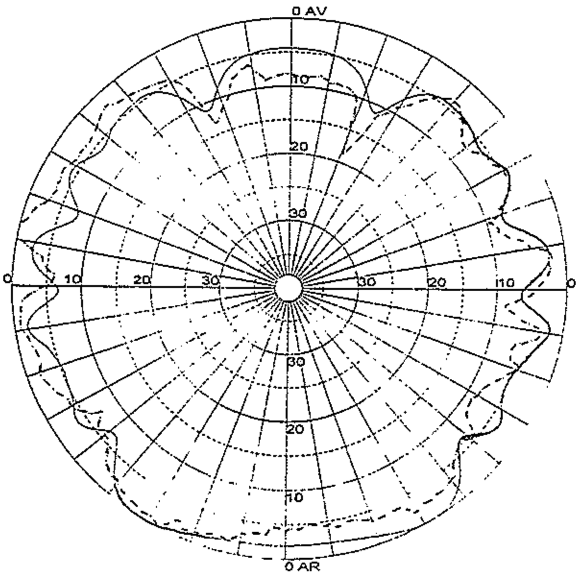

figure 5: comparison at 280 MHz
flight test dotted line
computation continuous line

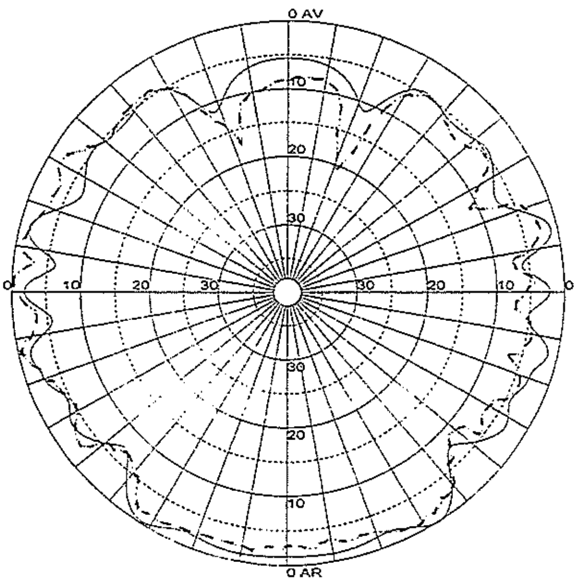

figure 6: comparison at 330 MHz
flight test dotted line
computation continuous line

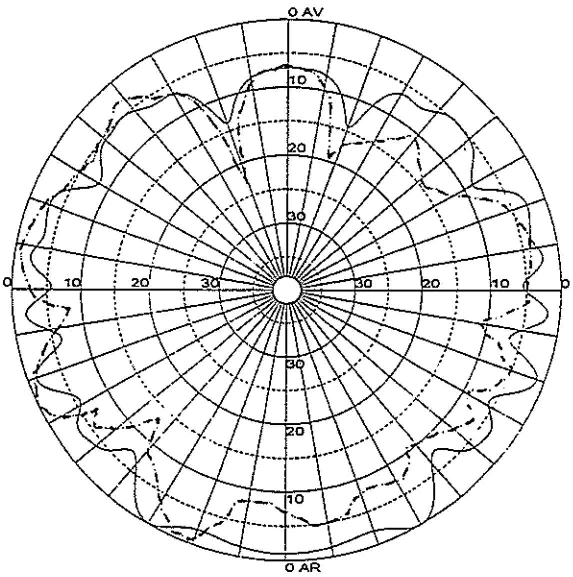

figure 7: comparison at 360 MHz
flight test dotted line
computation continuous line

Figures 8 to 13 are another set of comparisons, in the tactical VHF–FM range, on the Super Puma. Flight tests (dotted line) and computation (continuous line) are in very good agreement in these relatively round diagrams. Some masks or interferences reduce the gain marginally and these oscillations are correctly predicted by the computations. The agreement obtained on such little variation of the gain is also to be credited to the precision of flight tests results.

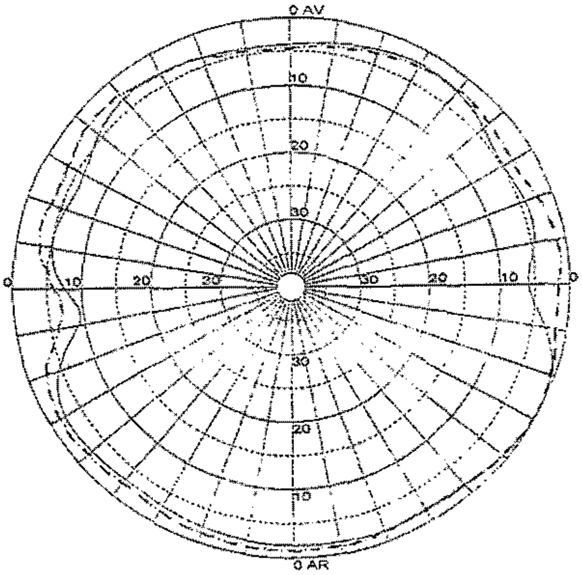

figure 8: comparison at 35 MHz
flight test dotted line
computation continuous line

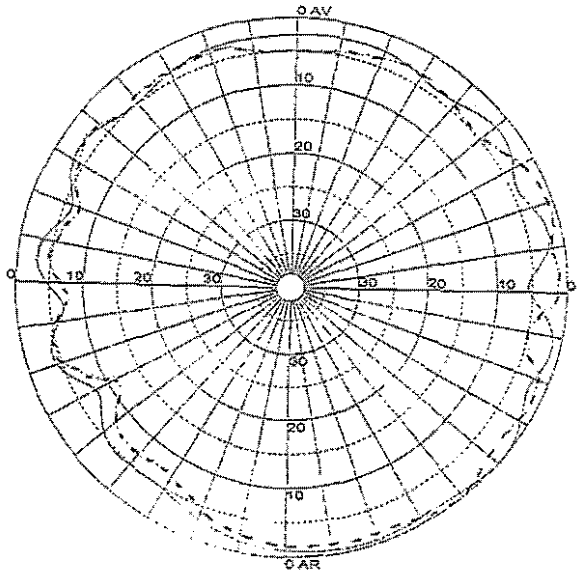

figure 10: comparison at 55 MHz
flight test dotted line
computation continuous line

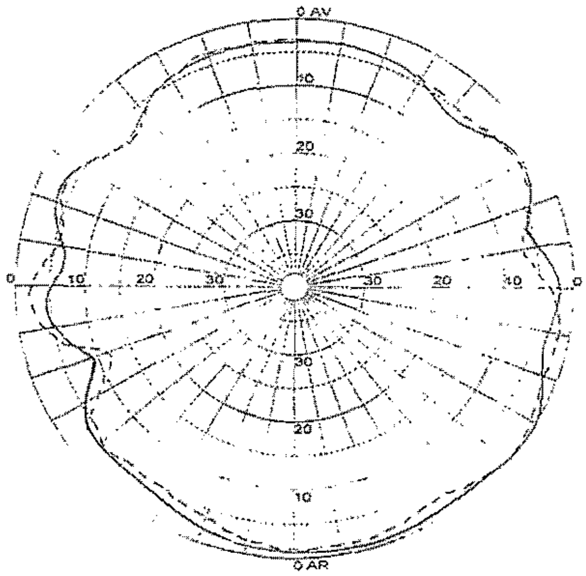

figure 9: comparison at 45 MHz
flight test dotted line
computation continuous line

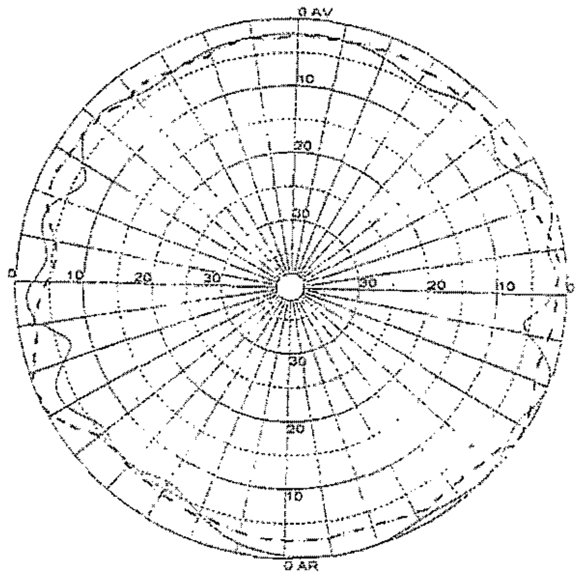

figure 11: comparison at 65 MHz
flight test dotted line
computation continuous line

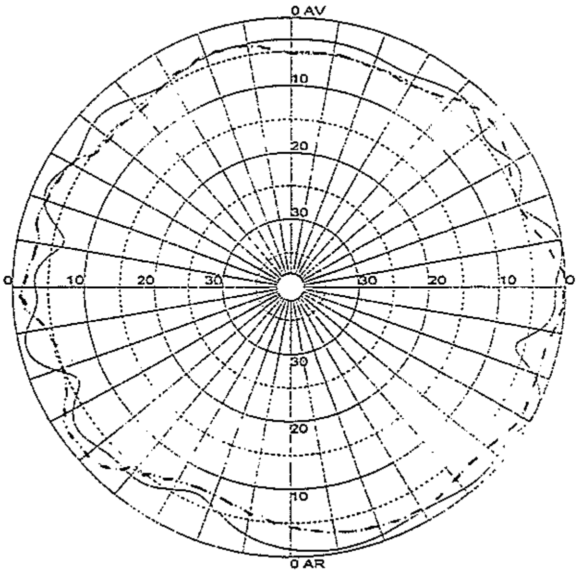

figure 12: comparison at 75 MHz
flight test dotted line
computation continuous line

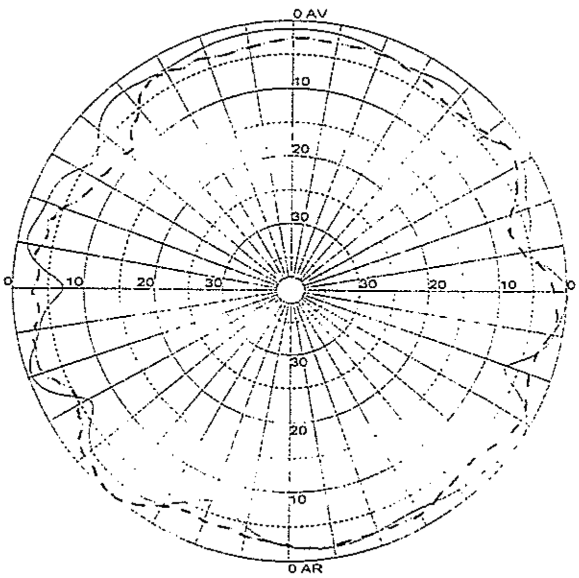

figure 13: comparison at 85 MHz
flight test dotted line
computation continuous line

In order to illustrate the usefulness of 3D plots, we show on figure 14 the total gain (horizontal and vertical polarization combined) of a Super Puma HF installation at 2 MHz. This plot shows at first glance that the diagram is indeed that of a dipole in free–space and also the inclination of that dipole. Depending on the inclination of the equivalent dipole, the HF transmission will be optimized for surface wave or ionospheric reflection.

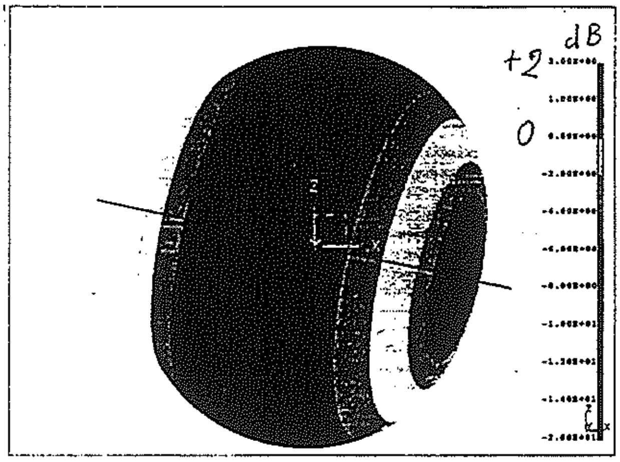

figure 14: 3D High Frequency (2 MHz) plot
A perfect dipole !

4. An application to helicopter electromagnetic environment (HIRF environment)

The process of defining the HIRF (High Intensity Radiated Fields) environment for aircrafts will not be explained in its entirety here. Let us just say that it is based on a list of the most powerful emitters in every frequency band. For each driver emitter in its frequency band, the near field generated is computed with the relevant hypothesis (IFR widebody jet, VFR helicopter). In the case of large emitters at small distances (VFR helicopters are concerned) the easy–to–use far field formula is not valid and yields a grossly exaggerated environment.

The same finite element method used for helicopter mounted antennae can be used to predict far field and near field. Far field results, if equal to measurements or antenna vendor's data validate the modelization of the antenna and give credit to near field results that are obtained with the same current distribution.

The HF emitter in Issoudun, France, is one of Europe most powerful HF emitter. A very similar emitter also exists in Great–Britain. It is a mast mounted antenna with a number of giant dipoles that varies from 4 to 24 depending on the frequency.

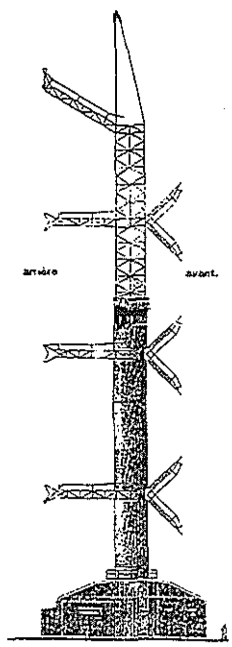

figure 15: side view of Issoudun emitter. Note the size of the human being, on the right.

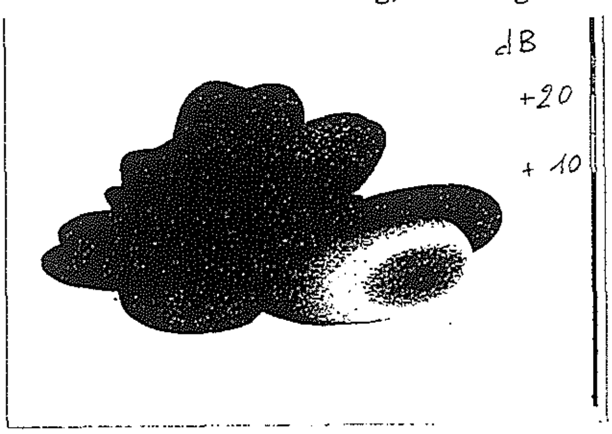

figure 16: Radiation pattern at 8.5 MHz 16 active dipoles are modelized.

The radiation pattern is highly anisotropic with a maximum computed gain of 21 dB. This is confirmed by vendor's data within a 0.3 dB margin. If we consider a typical distance of 100 feet between the emitter and the helicopter we find a worst case near field of 350 V/m whereas far field formula gave over 1000 V/m.

5. EMC applications and research topics

Electromagnetic Compatibility (EMC) has become a major safety and certification issue. From full system functional testing down to equipment immunity or even printed circuit board compatibility there is a whole world for finite element modelling. At aircraft level, at least one target is a candidate for modelling: transfer functions.

Some transfer functions (a function of frequency) are the ratio of an incoming plane wave and induced currents in the aircraft. Presently, they are mostly determined by full aircraft testing. This is expensive and quite late in the certification process. Thus it is worth trying to modelize transfer functions. This problem is more difficult than antenna radiation pattern since not only the external skin but also details of the inside structure are to be taken into account. The greatest challenge is to modelize enough relevant details without being overwhelmed by complexity. This problem is not specific to the helicopter industry and an European Union backed project has been launched in 1996 to tackle that problem. This project, EMCP2 [3] (Electromagnetic Compatibility using Parameterisation and Parallelisation) includes the development of a new software technology (parameterisation) to get several frequencies results in one computation. This miracle, by finite element or method of moment standard, is obtained by computing not only the interaction matrix between the elements but also its frequency derivatives up to a high order. This automatic derivation tool is computer intensive and memory hungry so the project will use parallel computing. At this state of the project, most of the software development is done and it remains to be seen if its exciting promises are fulfilled.

Let us note that the frequency derivation tool of the EMCP2 project would allow quick and cheap computation of radiation patterns with a small frequency step.

6. Conclusion

We have shown that finite element modelling is a versatile tool for a variety of electromagnetic problems. At the present time, the prediction of antennae radiation pattern is mature and complements flight tests nicely. HIRF/ EMC applications are promising. As Computer Aided Design becomes more integrated and available to engineering and as computing cost decreases, modelling of complex 3D objects becomes an everyday tool for the engineer with effective cycles of the order of a week.

References

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Book
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Internet web page
[3] http://mip.ups–tlse.fr/emcp2