Electromagnetic field evaluation by means of standard algorithms and cartographic data: broadcast case into the urban environment

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Abstract

Characteristics of available data and choice of algorithms are the main parts of evaluation activities that use software simulation to resolve any one territorial intervention and to survey environmental impact. Our paper investigates how urban data in a standard format and for very wide purposes (Cartesia applications), together with algorithms of electromagnetic field calculations, can be involved in these activities. The algorithms are the same as those certified by the international regulator, the ITU (International Telecommunication Union) that includes two consultative bodies for telephony (CCITT - Comité Consultatif International de Téléphonie et de Télégraphie) and radio-communications (CCIR - Comité Consultatif International de Radiocommunications), but they are adapted to specific problems.

In the last few years, the large development of wireless communications has accelerated electromagnetic propagation studies that should solve urban area aspects. In effect, the broadcast problem involves, with conflicting requirements, people health management, energy distribution and availability of point-area communication channels. Consequently, the legislator has imposed rules on the limits of electromagnetic field values and protocols of evaluation criteria for maximum exposure to radiation.

Our paper aims to put in evidence some technical aspects included into the evaluation of effects originating from telecommunication plant implementation or modification.

Our paper describes the inclusion method of building data and special algorithms that implement the rules and recommendations of the ITU. Finally, results of some case studies are shown.
1 Introduction

In order to show the more relevant aspects of this complex problem, we will investigate in the present paper only realistic solutions for a broadcast service, which is massive and extendable to all people. However, there are inquiries in our bibliography [1–9] that are more technical.

From this point of view, the more fundamental components for a good solution are the following: generalized urban data availability, algorithms of sources modelling together with algorithms of electromagnetic field forecasting that are available as freeware and accepted by everyone.

More advanced and sophisticated forecast methods, in the field of the frequencies of interest, need to add the following elements:

- urban data resolution of the order of a centimetre;
- detailed knowledge of all materials that compose the environment, together with their electrical and magnetic properties;
- precise location, property, geometry and mechanical structure of each primary source (antenna);
- an evaluation method that includes cars (automotive aspects). In effect, they can modify the results of forecast analysis because their materials have a great influence on electromagnetic propagation.

Availability of the last data with their specific properties is limited to small/very small areas by means of a special and single detection campaign. It is implemented to resolve specific problems, but cost and duration of the measurements are prohibitive for its application in the most widespread investigations. Foundation of a generalized service on the territory is not possible evidently.

In order to provide a pre-evaluation service for citizens and for organizations involved in installation and system communication management, we have estimated how data, collected for different analyses and available for most towns, can be elaborated and used to solve electromagnetic propagation forecasting.

2 Formulation of problem

In general, these data, even if detailed, do not have all the characteristics that are indispensable to apply analytical models, which are most complete and sophisticated, rigorously. For example, the ray-tracing method, used in the case of a simple radiator, when the main source can be separated from its support.

Our prediction method includes simulation algorithms proposed and approved from the ITU to evaluate, in a deterministic mode and in each point of the territory, the electromagnetic field generated from a single source of radio-communication. Buildings act as obstacles that modify the altitude of terrain.

In synthesis, the main equations and procedures, which we adopted in our method, are the following [10–15]:

- Free-space loss (basic transmission loss formula, Friis transmission formula).
• Evaluation of Fresnel ellipsoid (3D) and Fresnel zones (2D-3D).
• Effective Earth radius.
• Diffraction: approximation of single knife-edge obstacle.
• Diffraction: multiple isolated obstacles (primary obstacles), Epstein-Petterson, Deygout methods.
• Diffraction: reduced equations for double and triple isolated obstacles
• Smooth Earth effects

Obviously, some information for very short distances is in this case lost, how phase and modulation data produced by means of multi-paths. In any case, the precise evaluations of these characteristics are not compatible with the property of the available data.

Furthermore, this information is of reduced or insignificant use in many situations, certainly in the case of polluting field and, under particular hypothesis, of useful field evaluation.

Regarding the source models, we assume normally no punctual sources, but complete radiation and power characteristics of each commercial element that forms the antenna systems. Then we determine the vectorial sum of fields generated from coherent sources and the rms value of incoherent contributions of the polluting field. That is to say, we calculate the transversal component of each coherent field for the respective service field.

3 Cartesia’s data

A first evaluation of our method uses land data from the Cartesia society. These include and describe Rome city in full. They have been implemented, over a long period (many years), for general use in the town-planning management.

Figure 1: Vectorial data from the Cartesia society. In the sub-window are shown the format and value of data fields. By means of some data, it can elaborate a 3D visualisation.
They have been produced in different formats. The shape format includes for each entity: ground and eave elevations, middle line of streets ...

The extension of the area granted for our test is 100 hectares, including Termini station and neighbouring zones.

Figure 1 shows a top view of these data together with typical values associated to a particular entity (selected in the square) by means of the shape format.

The geometrical structure of these data is vectorial: curves are sequences of following straight lines. The visualisation of the same figure is 2D, but the information, included in the shape format, allows the generation of a more realistic 3D representation.

Figure 2: Data from the Cartesia society after 3D elaboration.

4 Topographic data reorganization

At first, vectorial data are not in 3D. It is necessary to convert these bi-dimensional objects into three-dimensional structures and to join the terrain elevation eventually. We have developed a dedicated software program that executes this transformation and superimposes for each element its texture, in the equipment by the same Cartesia society.

Figure 2 shows the previous 2D data of figure 1 after 3D transformation. The perspective image visualises Termini station observed from a south-north direction.

The same figure puts in evidence how each building can include more elements (primary closed curves) that define the complete structure. In particular, we distinguish between court and a second top roof by the clockwise or counterclockwise sequence of the straight-lines.
The same software program creates a DTM (Digital Thematic Map) including buildings. We fixed the resolution of the DTM grid to 20 cm. This value has been estimated considering the deterioration of elaborated data when applications of interest are simulated.

Figure 3: An example of 3D visualisation. The DTM is a regular grid with a step of 20 cm. The limit of the visualised zone depends on the maximum number of display pixels.

Figure 4: The previous DTM of figure 3. The smaller resolution (1 m) allows the management of a larger zone. In the original figure, colours define different altitudes. Finally, we used terrain steps to put in evidence the inclusion in the DTM of ground elevation variations.
Figures 3 and 4 show some aspects of this reorganisation:
- Buildings and other structures contribute to modify the original ground elevation.
- Vertical walls of buildings are modified (represented) by oblique plans. Their inclination depends on the grid resolution.
- Original distinction between different structures or buildings is lost.
- Physical properties of elements can be included in a superimposed data layer, with a different resolution grid eventually.

5 Field source model

We design antenna systems, which are also more complicated, combining and assembling commercial units. The reason that we need to design directly by using COTS (Commercial Off The Shelf) components resides in the cost reduction and project achievability. In practice, commercial unities are panels and dipoles.

The software program must assemble these, using for each its frequency, phase, power source, radiation diagrams and belongings of coherent groups.

Likewise, sources of magnetic field can be described eventually using geometrical data, structural shapes and load characteristics of electrical system lines.

Figure 5 shows radiation diagrams of a simple radiator. In particular, the software program allows one to generate a radiation diagram from listed data, i.e. antenna gain for angle of interest at specific vertical and horizontal plans, or to synthesize the same diagram by a single point source.

Normally, COTS antenna components are described from the radiation diagram by a list or graphic format, so the first method of program design is more frequently used.

Figure 5: Model of simple radiator. This is the commercial base-element to the build antenna system.
6 Obtainable results

Under previously defined conditions, our procedure simulates, without complexity, by employing methods that are official and recognized (ITU) and by using public data, the effect produced by realistic sources of electromagnetic field inside the urban environment.

Figure 6 visualizes a typical situation of an electromagnetic forecast. An antenna, with a particular radiation diagram, has been placed on a building roof. In order to put in evidence the effect of obstacles (i.e., the other buildings), the antenna in that figure is an isotropic radiator. Without obstacles, electromagnetic field level depends only on distance. Obstacles generate diffraction effects, in particular horizontal diffraction from the edge of the roof, and shadow zones. By connecting the single field level with one different grey degree, the effect of buildings is clear. Furthermore, different investigations can be undertaken, evaluating electric field at a specific point, or along a generic path (e.g. road measurements forecast), or many statistical calculations of the same electric field level in a specified area.

Boundaries input are a friendly tool of the visualization program, so that area can be chosen to correlate with many different data (people, social destination of buildings, etc.) in a specific and delimited zone of interest.

![Figure 6: The calculated electric field can be superimposed on the zone of interest. Electric field can be evaluated at specific points, or along the generic paths, or in a specified area from the point of view of the service or of the pollution.](image)

Our method can forecast the value of a polluting field together with the level of service field. It is a powerful application that resolves many questions in the field of design and warrants making changes in existing plants or in new installations.
7 Developments and improvements

It must be emphasized that the described procedure uses data and algorithms achieved for different aims, not specifics, to evaluate pollution risk generated from scattered electromagnetic fields.

A measurement campaign could obtain a very useful accurate calibration, and could detect employment limits of the method eventually. That systematic campaign should compare measurements of field generated by existing systems with the forecasted field by means of this method.

References

[3] Ottavi, C.M., Ferrara, V. & Guerriero, M., "Prediction method that extends the point to point procedures to large areas in the evaluation of broadcasting services and interference levels in band IV, V and VI", ALTA FREQUENZA, LVIII C(2), pp. 217-223, 1989
[9] Ferrara, V. & Ottavi, C.M., Previsione di propagazione elettromagnetica nelle città mediante ray tracing 3-D insieme a UTD e uso di dati GIS