Fast Computer Tool for the Analysis of Propagation in Urban Cells

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Abstract

FASPRO is an accurate and extremely efficient tool to perform deterministic analyses of propagation in urban picocells and microcells. A fully 3D propagation model is considered. The topographical input data are based on a 3D plane-facets model of the urban environment which is given in terms of DXF files. FASPRO is able to read DXF files from AUTOCAD, Microsystem, CADDs and other CAGD and topographical tools. In addition, FASPRO has its own facility which allows it to create new urban scenes. FASPRO visualizes the geometry on the screen as a 2D map of the urban scene or a 3D isoparametric view. The electromagnetic analysis is performed using UTD techniques. First order coupling mechanisms (direct, reflected and edge-diffracted rays), second order coupling mechanisms (double reflected, diffracted-reflected, diffracted-reflected, double diffracted, etc.) and third order mechanisms (e.g. reflected-diffracted-reflected, etc.) are included. It must be noted that, thanks to the incorporation of diffraction in all the edges of the 3D model, coverage in areas in the deep shadow of the transmitter antenna can be predicted well. A new ray-tracing algorithm is used to speed-up the computations. This ray-tracing algorithm is based on a modification of the Z-Buffer and the "Bounding Volumes" schemes, in which the elements are arranged in an angular map (AZB, Angular Z-Buffer).

Key words: efficient ray-tracer, UTD/GTD urban propagation tool

Introduction

A computer tool, FASPRO, for the analysis of propagation in urban picocells is presented. FASPRO performs fully 3-Dimensional Analyses using UTD (Uniform Theory of Diffraction). The tool makes an extensive use of dialogue windows, graphic interfaces and can be integrated with the most employed tools for Computer Aided Geometrical Design (CAGD) and with the tools for the analysis and planning of mobile communication systems. FASPRO visualizes the geometry on the screen as a 2D map of the urban scene and also as 3D isoparametric views (Fig 1-2). The user can see a 3D view choosing the point of view.

The urban geometry is represented by plane facets. The scene is arranged as a set of entities, each one of them corresponding to a building. Each building is represented by its foundation, its height and the electrical constants \( \varepsilon \) and \( \sigma \) of its walls.

A new ray-tracing algorithm is used to speed-up the computations. This ray-tracing algorithm is based on a modification of the Z-Buffer and the "Bounding Volumes" schemes, [1], in which the elements are arranged in an angular map (AZB, Angular Z-Buffer). This algorithm is summarized in [2]-[3].

FASPRO provides a friendly way to visualize the propagation results. But the code also writes in output files the field levels and other data it obtains in each execution. The user can access these files if he prefers to employ other visualization tools or perform any other post-processing.
Electromagnetic Treatment

The electromagnetic analysis is performed using UTD techniques. First order coupling mechanisms (direct, reflected and edge-diffracted rays), second order coupling mechanisms (double reflected, diffracted-reflected, diffracted-reflected, double diffracted, etc.) and third order mechanisms (e.g. reflected-diffracted-reflected, etc.) are included. The total field in the observation point is obtained as the coherent adding of the fields of all the coupling mechanisms.

The transmitter antenna can be defined by a set of electric and magnetic dipoles or by its radiation pattern.

All the reflections are computed applying Image Theory taking advantage of the fact that all the facets are flat. The antenna image is placed and orientated assuming that all the facets are perfect conductors. The material constant is considered by multiplying the reflected field by the Fresnel coefficients, taking into account the incident angle and the surface roughness. The reflection of the ground surface can be treated either by one (or several) plane facets or by considering the image of the entire urban scene.

The diffraction coefficient is computed using UTD. This coefficient has two terms: one that takes into account the boundary between the lit and the shadowed regions for the direct ray, and the other term that makes the transition boundary of the reflection to be continuous. Both terms are computed considering the facets perfect conducting. The term associated with the reflection boundary is multiplied by the Fresnel reflection coefficient of the wedge walls taking into account the incident angle in the lit wall of the wedge. It must be noted that, thanks to the incorporation of diffraction in all the edges of the 3D model, coverage in areas in the deep shadow.
of the transmitter antenna can be predicted well. The coverage by diffraction in the horizontal top edges of the highest buildings is quite important because this mechanism can cover a very large area of the cell.

The diffraction-reflection is evaluated applying Image Theory, considering the appropriate rotation of the image-edge.

**Geometrical Treatment**

The geometrical model of the scene is defined by a DXF file. This file contains information to characterize each building completely: the vertices of a polygon defining the building foundation and its height. The geometrical data should be completed with the material data of each facet. The user has two ways to define the electrical constants (ε and σ and roughness parameter): a) by introducing explicitly their numerical values; b) by a code number that associates the facet material to one of a table.

FASPRO has associated a code called EDIF which allows us to create, read, modify and export the geometry and morphology of any urban scene. EDIF and FASPRO can work with three different kinds of files to define an urban scene called NAME:

- NAME.DXF
- NAME.OUT
- NAME.DAT

NAME.DXF is a file with a DXF format which can be generated by many CAD tools, for instance AUTOCAD, MICROSTATION, etc. NAME.OUT is a file with a FASPRO proprietary format which represents the geometrical and morphological data of the scene in a simplified but complete way. NAME.DAT is also a FASPRO proprietary format that includes geometrical, morphological and electrical data (e.g. antenna positions, fields levels, etc) of the scene. NAME.DAT is generated after an execution by FASPRO.

The ground plane is treated as another flat facet in the code version FASPRO V4.5, which computes any reflection on the ground in the same way as it is computed the reflection in the rest of the facets. The version V 5.5 of FASPRO considers the reflection on the ground using the antenna and its image on the ground as simultaneous sources in a scenario defined by the buildings of the original geometry and the mirror images of these buildings relative to the ground. The images of the buildings are defined by the mirror images of their facets. In this scenario the ground has been removed.

Many times the DXF file as it is given by a topographical data provider gives maps with too many details. These maps need to be cleared in order to run an electromagnetic simulator properly. FASPRO allows the user to “clear” the map. The clearing facility of EDIF allows the user to investigate the impact of each building because the user can delete any one of the scene.

**INPUT DATA**

FASPRO reads three input files: one file defining the urban scene (previously mentioned), another one defining the transmitting antenna and the third one specifying the remaining parameters.

The second kind of input data of FASPRO contains information about the transmitter antenna. This can be defined: a) by a set of electric and magnetic dipoles (option DIP of FASPRO) or by means of its radiation pattern (option ANT of FASPRO).

The third set of input data required is an electrical data file that can be easily generated using the graphic user interface of FASPRO. Figure 3 shows the main screen of FASPRO to help with the input of the electrical parameters.
The boxes of this screens are as follows:

*Field effects boxes:* to indicate the ray-mechanisms to be considered (direct-ray, reflected-ray, diffracted-ray; etc.).

*Antenna Type Box:* by ANT, it is indicated that an antenna defined by its radiation pattern must be considered. In the box *Radiation Pattern File* the name of the file which contains the radiation pattern of the antenna is defined. The pattern should be given in dB and must be normalized to zero (its maximum must be zero. In the box *Radiation Pattern* the type of radiation pattern is defined: with symmetry of revolution; defined by the E and H-planes; generic pattern; etc. By *RV2* a radiation pattern defined by the E and H-planes is indicated.

*Antenna Height:* Height of the transmitter antenna relative to the ground.

*Transm Power:* Total power emitted by the transmitter.

*Mean Points:* Number of points considered around each point to compute the average value of the field. When as in the figure the 0 is given, no average is computed

*Number of Points/path:* Number of points along the path when the option of computing the field level along a line has been chosen.

*Observer Height:* Height of the observer antenna relative to the ground.

*Maximum ADF Level:* Field Level considered to compute the Average Duration of Fadings

The rest of the input parameters are introduced with the help of other FASPRO screens. Most of these data can be introduced either by using the keyboard or the mouse. These parameters are:

- The location of the transmitter antenna and its axis. Figure 4 shows an example of antenna allocation and orientation.

- The option for the distribution of the observation points. These can be distributed along a line or in the nodes of a mesh. Both options can be defined graphically with the help of the zoom facility.

- The field components (E_x, E_y, E_z or E_total) to be pictured or saved in the output files.

- The option to compute some statistical parameter such as: the PDF (Probability Distribution Function), CPD (Cumulative Probability Distribution), ADF, LCR (level Crossing Rate) etc.
Output Data

The main output of FASPRO is a file with the fields levels in each one of the points of the "mesh" or of the "line" previously selected. This file contains the fields due to each ray mechanism selected and the total field. The units to represents results can be chosen among dBm, dB\(\mu\) and dBV/m.

The user can also visualize, by means of a color code, the field level in the urban scene if he has selected the option "mesh" or the curve of the field intensity if he has selected the option "line". He has also the option to save both pictures as bitmap images.

FASPRO also has the possibility of presenting the PDF, CPD, ADF and LCR for each point if the user has selected the statistic study.

FASPRO can export the "cleared" DXF file which has been obtained using the geometrical processing facility of the code. This file also includes the antenna position and the material composition of the buildings.

Language and Computer on Which Code Runs

The kernel of FASPRO is written in FORTRAN. The graphics and the user's interface has been developed using the FORTRAN Powerstation of Microsoft. The code runs in any platform with Windows 95 or Windows NT. A minimum of 16 MB of RAM is required (32 MB or more recommended). The kernel can be easily fitted to run in any machine.

Validation / Status

FASPRO has been successfully validated by comparing predictions and measurements in Madrid, Tokyo and Manhattan streets. Figure 5 shows a comparison between FASPRO predictions and measurements taken from [4].

FASPRO is operative and commercially available. A DEMO version is also available.

Figure 5. Comparison between measured and computed values

Representative Results

Figs 6. shows the total fields in 1000 points along a line considering simple and double effects coupling mechanisms. The cell, the line and the antenna allocation and orientation are indicated in Fig 4. The antenna is 7m in height and the frequency is 922 MHz. We have considered a
local mean by averaging the fields values of the closest 11 points. The CPU time to obtain these results was about 60 seconds using a Pentium (133 MHz, 64 MB of RAM).

![Figure 6. Field level along a line.](image_url)

Figure 6. Field level along a line.

Figure 7 presents a quite demanding analysis case. Now we have the coverage of the field for the cell of fig 4. The observations points are defined using a mesh of 100x100 points. Simple and double effects coupling mechanisms, except double-diffraction have been considered. It can be noted that simple and double effects with diffraction provide great field coverage thanks to the downwardly directed diffraction that appears in the upper edges of the higher buildings of the scene. This can indicate that in an urban environment with high skyscrapers the field coverage by diffraction can be greater than high order reflection, therefore a 3D analysis becomes necessary for analysis and design purposes. The CPU-time has been about 1 minutes for simple effects and about 5 minutes for the double effects considered using the PC outlined above.

![Figure 7. Field coverage for a large microcell.](image_url)

Figure 7. Field coverage for a large microcell.

References