Application of GID to microwave printed circuits and antennas design

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Abstract *– In this paper, we present the application of GID to the design of multilayered planar printed circuits and antennas for microwave applications. In this context GID is used as main preprocessing tool, i.e. to build the geometry, to assign condition to some elements, to mesh the geometry and to generate the input for the analysis tools. To tailor GID to the special requirements of the printed circuit world, a new problem type has been developed that make the design of printed circuits more user-friendly and closer to the existing commercial tools dedicated to this task. This new environment has also been integrated inside the framework MADS (Multipurpose Antenna Design Simulator). All the developments have been realised in the frame of an European EU-ESPRIT project.*

INTRODUCTION

While microwave printed circuits are difficult to analyse, their geometrical structure is relatively simple. Microwave printed circuits are made by one, or more, dielectric layers (often called "substrates"). These substrates have basically the same structure of the standard boards used in electronic applications: a large, but thin dielectric slab with one or both faces covered by a thin film of copper where the circuit will be printed out. This explains why a lot of sophisticated methods for numerical analysis have been developed in the past and new ones are still under development, but also why there are so few developments concerning the pre-processing, design and meshing. The situation is very far from what happens for example in the mechanical field where a lot of commercial general-purpose tools, like GID, were developed to help the engineers to design and mesh the structures in a very efficient way. In fact standard CAD environments are often too heavy and not well suited for microwave printed circuits design and the present situation is that the few existing commercial microwave CAD softwares have developed their own dedicated GUIs and meshers, while at research level people still continue to use home made user interfaces and semi-automatic meshing.

This happens because the design of microwave circuits presents some particularities that it is worth to explain. While at low frequency the substrate acts only as hard support for the printed strips and for the electronic components, when the frequency increase the circuit performances are strongly affected by the substrate characteristics. In particular the response is affected by the electric permittivity, the magnetic permeability and the substrate thickness, but the effects due to the transversal size of the substrate are negligible, at least in typical applications.

From the previous observations, some methods of numerical analysis have been developed (essentially equivalent to Boundary Element Methods), which consider the substrates as infinite and take into account their effect analytically. In particular the method used in our application is based on a surface integral equation formulation of the electromagnetic problem [1, 2]. This equation contains special Green's Functions that take into account all the effects due to the presence of the substrates [3] and the only unknown is the current density J in the metallic strips. The Method of Moments (MoM) is applied to this equation, and in particular to the unknown current density, to obtain a system of equation that will be solved numerically. This means that with respect to methods almost purely numerical, like finite differences, where the entire 3D space must be discretised, in this case only the copper strips (that can be considered practically 2D) must be meshed. On the other side the dimensions of the strips affect barely the performance of the circuit and their design must be realised with an extreme precision. Moreover, the shapes of the circuits can look sometimes complicate, but most of the time a big circuit can be reduced to a series of basic shapes connected between them. Such shapes can be described very easily and effectively through a parametric representation.

All what said until now shows clearly how the design of printed circuits can be a quite easy task whenever a dedicated drawing program is available, but that at the same time the requirements are often hard to be satisfied by standard CAD environments. To make an example, a 2D drawing tool can be enough to design the strips of the circuit and, in the case of more dielectric layers, the capability to manage more design layers (sheets), option that is almost ever included in the modern drawing tools and satisfies completely the requirements. But at the same time the designer must be able to describe the vertical structure of the circuit, assign its characteristic to each dielectric material and associate each metallization level to a specific dielectric. Such a description requires either a full 3D representation, which is complete but onerous, or a schematic representation of the vertical structure of the circuit and just a link between the vertical structure and the design level.

This second option is what we realised inside GID and what will be described in the following of this paper. In the first part of the next section we will describe the part of the problem type dedicated to the creation of the vertical structure. In the second part we will show how insert circuits elements at the right level through a parametric description and in the last part we will describe briefly the generation of the input files for the electromagnetic analysis and the integration of GID inside MADS [4, 5].

A PROBLEM TYPE FOR MICROWAVE PRINTED CIRCUITS

A new problem type has been developed to answer to the main requirements of the printed circuit design. All the special features developed are contained both in a toolbar and in a menu (see Fig. 1).

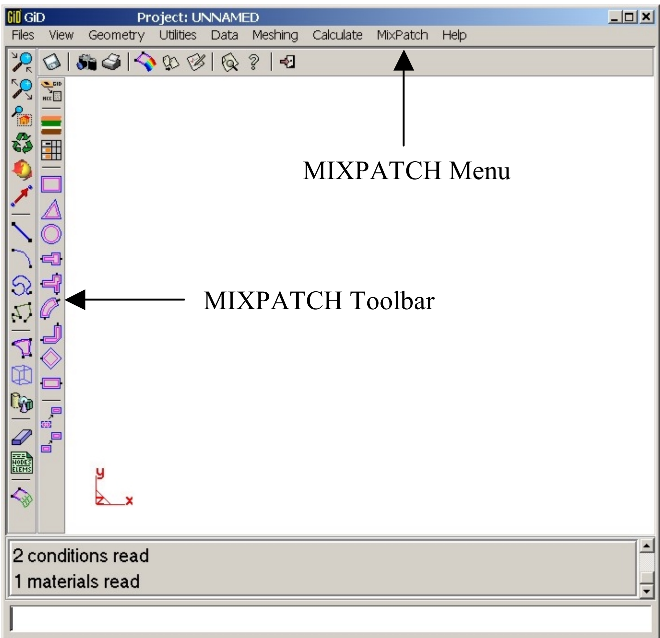
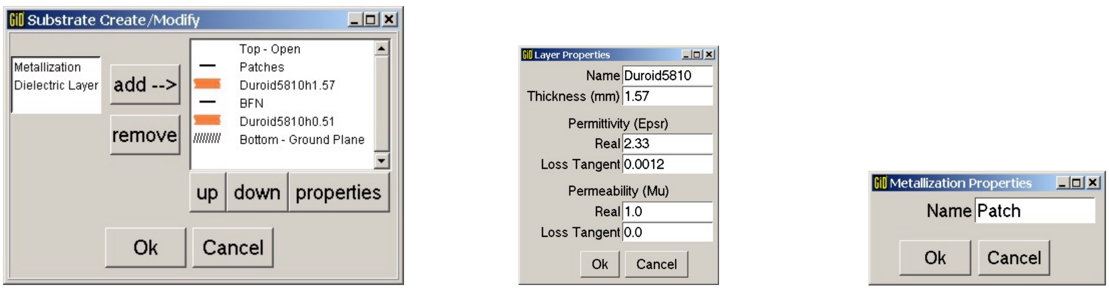


Fig. 1 – GID-MIXPACTH environment

The Toolbar contains four main classes of tools: Exportation of geometry and mesh for the Electromagnetic analysis, Design and management of the antenna substrate, Insertion of printed circuit components and two shortcuts for MOVE-SURFACES and COPY-SURFACES functions.

The first step in the design of a printed circuit is the definition of the dielectric layers where the circuit will be printed out. A special frame, shown in Fig. 2-a, and several procedures have been developed to give to the user an effective way to build this structure.



(a) (b) (c)

Fig. 2 – Frame for the design of the circuit substrate

The list on the left contains the type of materials that can be added to the antenna substrate. In the current situation only metallizations and dielectric layers can be added to the circuit substrate, but other types, like slots and via holes, could be easily added in a further version. The list on the right of the frame shows the substrate structure of the circuit as has been built by the user. The user can use the buttons in the frame to add/delete, move up/down an element of the list and assign some properties to it (see Figures 2-b and 2-c).

Once the substrate setup finished and the “OK” button in Fig. 2-a pressed, a number of GID layers, equivalent to the number of metallizations present in the substrate structure, will be automatically created. Then the “Substrate” frame, shown in Fig. 3, will pop up. This frame shows a schematic view of the vertical section of the antenna substrate and allows the management of the layers during the drawing phase. The same actions can be done also in the original “layers frame” from GID, but this schematic view helps more the user during the design phase.

The second step is the drawing of the circuit. The circuit geometry can be drawn using both the standard GID tools and the predefined elements in the dedicated toolbar.

The predefined elements are at the moment: rectangle, triangle, circle, line-step, tee-junction, curve, chamfered bend, corner-fed patch and line, but other typical shapes could be easily added in the future. Fig. 4 shows the frame used for the parametric insertion of a microstrip line (which is basically a rectangle, but where the reference point for insertion can be the middle of an edge). The user can set the dimension of the line just inserting length and width in the appropriate fields and he can eventually also impose a rotation and an offset with respect to the point where the element will be inserted. This point can be inserted manually or picked up in the screen with the mouse.

Fig. 3 – Frame for the management of the layer in the drawing phase

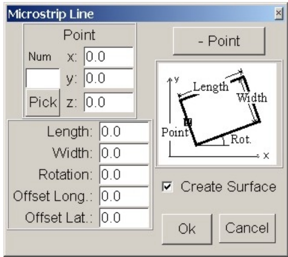
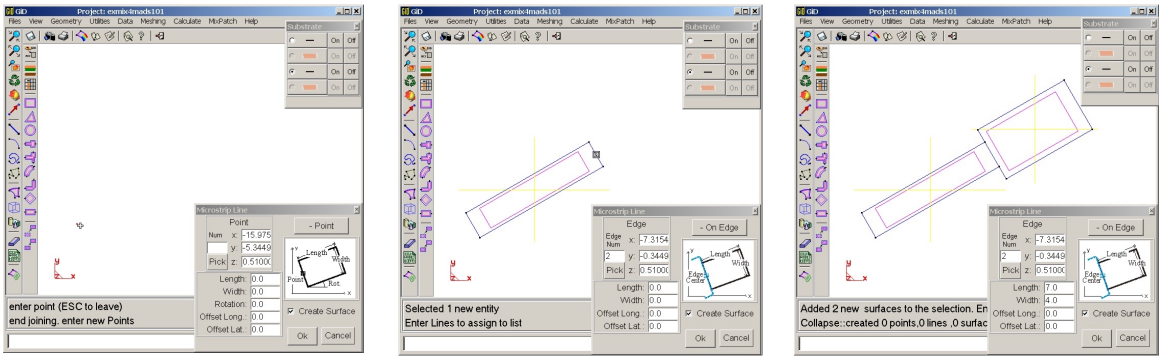


Fig. 4 – Example of frame for the parametric insertion of new components

To help the user, when the point is picked with the mouse the Z-coordinate of the point is set automatically to the z level of the metallization that is active at that time (see Fig. 5-a).

Another useful feature for printed circuit design is that a new element can be attached directly to the edge of a previous element. In fact the user can choose to add the element on an edge instead that in a point. In this case the user can pick on an existing edge and automatically its number is retrieved and the coordinate of its center are computed and displayed in the corresponding field (see Fig. 5-b). At the same time also the rotation of the element is automatically computed so that the new element is perfectly matched to the previous one (see Fig. 5-c).



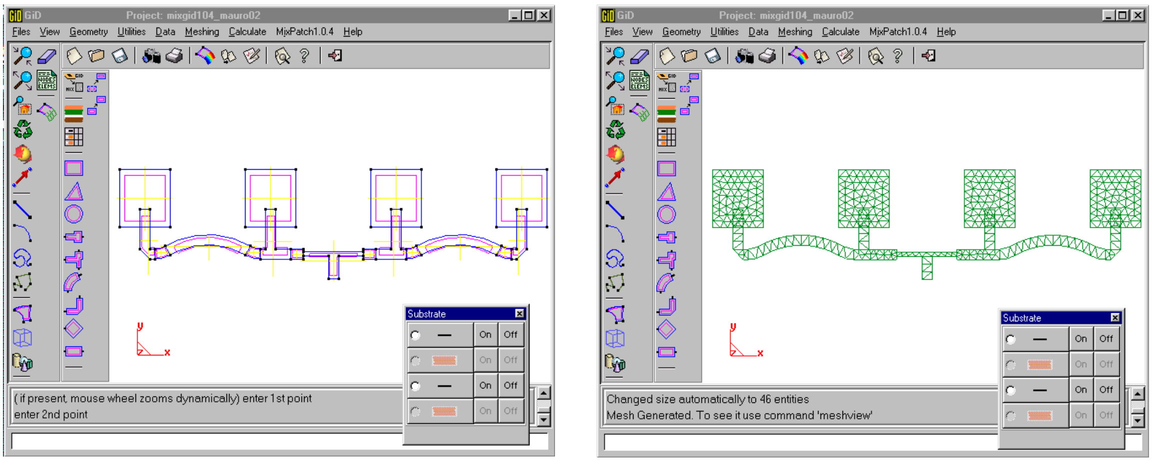
(a) (b) (c)

Fig. 5 – Example of insertion of two cascaded microstrip lines with different section.

After the substrate and the circuit have been designed it remains still to identify the points where to put the generators that will feed the circuit. This has been done using the GID feature to create new conditions that can be applied to any of the geometrical entities. More in details a new condition called “Port” which apply to “lines” has been generated inside the problem type. This condition enables also the insertion of the characteristic of the generator, like the type, the internal impedance and the value of the magnitude and phase.

In Fig. 6 we show an example of geometry and mesh of a printed antenna built on a two layers two metallizations substrate.

GID together with the problem type described above is used in our laboratory as pre-processing for the design of printed circuits and antennas. Moreover the same tool, with some minor changes, has been also integrated inside the system MADS (Multi-purpose Antenna Design Simulator), a framework developed within a European ESPRIT Project. In this case GID is not used as the main user interface, but is just a pre-processing tool inside a bigger system. The MADS environment is in charge of the launch of GID with a new or an existing project and all the file management is also controlled by the MADS system. Thus to avoid possible conflicts the menu item and the main toolbar of GID have been customized in order to remove all the operation requiring the opening of a file browser like “open”, “save as..” etc. and also the possibility to create a new project.



(a) Geometry. (b) Mesh.

Fig. 6 – Example of design. Printed antenna array of 4 electromagnetically coupled patches.

CONCLUSIONS

As explained before, microwave printed circuit design is a delicate task. In this paper we have presented the special features we added to GID in order to tailor it for our purposes. Nevertheless the world of electromagnetic analysis is very wide and each technique can have some special requirements in the pre-processing phase and for this reason we think that, as it happened in the past for mechanical or building engineering, it would be useful to have a CAD environment specially designed for electromagnetic engineering which could help microwave engineers and researchers in their work. In this optic we think that GID could be a good starting point because is a powerful and flexible approach for the treatment of the geometry and of the mesh, and it can be quite easily customised and coupled to a specific method of analysis.

Acknowledgements

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