Focus on CAD

Concurrent EM simulation is current goal

Suppliers of circuit simulation software have for some time been claiming integration of electromagnetic simulators into their CAD packages. However, the goal now is to achieve full integration, whereby the circuit elements undergo EM optimization in real time during the circuit design process, rather than the transfer of a set of S-parameters from the EM simulator for use in the circuit simulator. The progress towards this aim will form the subject of a one-day Workshop to take place at the IEEE MTT-S International Microwave Symposium in Orlando, on 15 May 1995. Participants include Optimization Systems Associates (OSA) of Canada, which is jointly chairing the session along with Università degli studi di Perugia, and Jansen Microwave of Aachen, Germany. Among companies not participating in the MTT-S Workshop, HP-Eesof also reports moves in the direction of concurrent EM simulation.

Two new EM packages have also been launched recently, a full 3D simulator from MacNeal-Schwendler, and a "budget" planar 3D simulator from Number One Systems, and Compact has introduced an upgrade to its EM simulator. Microwave Explorer 3.0 has added a second simulation engine, for open environments, to its original packaged environment engine.

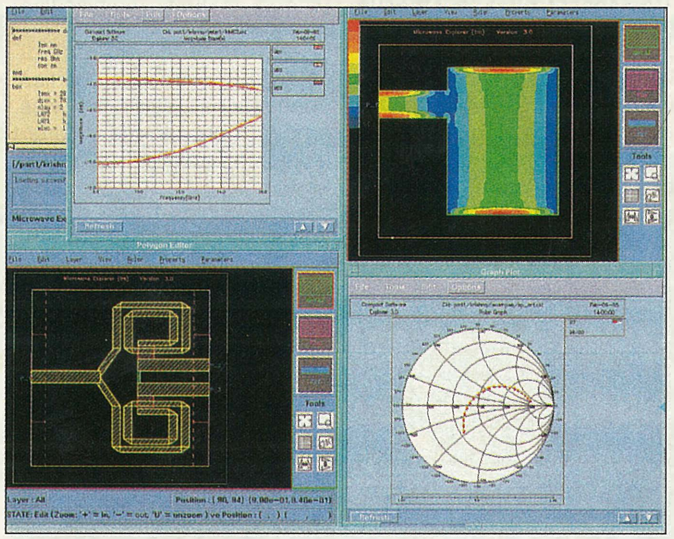


Figure 1 shows a simulation session in Compact Microwave Explorer 3.0, which allows viewing and editing of different sets of circuit data while simulations are processed as background tasks.

Review

OSA will present information on integrated electromagnetic analysis both in the specialist Workshop and in the main Symposium at MTT-S. Interestingly, its Symposium paper will use as an example the 7GHz doubler circuit which was the subject of our CAD Review in the May 1994 issue of Microwave Engineering Europe (pp 43-53).

OSA uses a technique it calls "Geometry Capture" to parameterize a planar microstrip structure during harmonic balance optimization. The technique provides automatic translation of the values of user-defined design parameters into absolute co-ordinates, which are then ready for transfer into the EM simulator. Initially a set of geometries is defined by the user, using a graphical layout tool (OSA uses Xgeom from Sonnet Software). This geometry set follows the evolution of the physical structure (for example changing the length and width of a tuning stub) as the electrical design parameters change.

Optimization

The parameterization is performed for all the defined perturbations before the electromagnetic simulator is activated. Interpolation and modelling techniques are also used to reconcile the discrete nature of the numerical EM solvers with the continuous variables and gradients required by the optimizers. In this way the EM simulation becomes part of the optimization loop. In the case of OSA/hope, the EM simulation is carried out in Sonnet Software's simulator, Em, which is connected via Empipe (described in the CAD focus in the May 1994 issue of Microwave Engineering Europe).

According to OSA, the full benefit of integral EM analysis may not be fully achieved unless it is driven by optimization routines to adjust the design parameters, and is performed on the complete structure rather than on individual components in order to model any coupling or interaction between them. In the 7GHz coupler example, significant couplings were identified between the distributed microstrip elements in the design, such as the coupling between the radial stubs and the bias pads. The additional optimization allowed the target design specification of 3dB minimum conversion gain to be met, which was not achieved by the unoptimized design.

Integral solvers

Jansen Microwave has introduced two independent EM solvers which operate as an integral part of its LINMIC+/N linear and nonlinear CAD package for MICs and MMICs. LINMIC+/N was described in the CAD focus in the May 1994 issue of Microwave Engineering Europe.

SFPMIC+ allows full-wave electromagnetic analysis of irregular conductor geometries in single dielectric and multidielectric substrates of up to 6 layers, using a spectral operator expansion (SOE) technique. This is used in conjunction with variable grid discretization, to keep analysis times per frequency to a minimum. The effects of surface waves and package parasitics are included. Structures with up to 4 ports can be analysed, and the results data can be output as S-parameters and as irregular shape layout information for direct use in LINMIC+. Immediate visualization is possible in all the standard output formats of LINMIC+.

The second solver, UNISIM, provides electromagnetic analysis in circuits of an irregular strip type and in coplanar waveguide (CPW). It offers all the features of SPFMIC+ described above, but uses regular grid discretization and a direct or optional iterative solver to permit handling of a higher number of unknowns (up to 50,000). Visualization of current distributions for strip type conductor configurations, and of slot electric field for CPW structures, is available.

Dedicated

On the subject of electromagnetic optimization, a HP-Eesof spokesman said that its circuit simulators have for some time incorporated dedicated solvers for modelling the electromagnetic characteristics of certain components, including multiple coupled lines, during circuit optimization, although there is no capability at present to include Momentum in this loop.

The use of Momentum as an independent simulator is recommended where the layout of the circuit is such that significant coupling between components would occur, and for simulation and development of new planar elements not already part of the component library or outside the frequency range covered by the library.

Dual engine

Microwave Explorer 3.0 from Compact started shipping in February of this year: Version 2.0 was reviewed in the May 1994 issue of Microwave Engineering Europe. Explorer is now able to perform full-wave 2.5D electromagnetic analysis on structures in open environments, such as patch antennas, in addition to its existing packaged environment capability. It achieves this by means of a second analysis engine rather than by modifications to the first, as the requirements for efficient analysis in the two environments are quite different. The two engines have been tested to ensure that they produce the same results in situations where the two sets of conditions converge, such as at low frequencies.

Periodic

Both the engines are based on a periodic structure approach. The open environment engine models electromagnetic effects such as surface wave losses and parasitic radiation, which allows optimization of both the size and shape of microstrip antennas. It is also helpful in predicting the parasitic radiation and coupling effects between circuit elements such as filters, phase bridges and meander lines.

The closed environment engine predicts the effects of side walls and package resonances, and allows the use of lossy materials as top and bottom package covers to minimize resonances. A "box mode pre-processor" offers a rapid initial analysis of the package to identify any resonances which may cause problems, prior to a full simulation.

Geometry

Both the simulation engines perform analysis of arbitrarily shaped 2.5D structures: 2.5D geometry is defined as a planar layered substrate with arbitrarily shaped metallization on the surfaces of the various layers. The additional half dimension is formed by vertical connections, such as vias, running between the different layers. In Explorer 3.0 there is no limit on the substrate parameters such as thickness, dielectric constant, loss tangent, bulk resistivity or permeability, nor on the frequency range over which analysis can take place. The number of layers and ports is also unlimited, subject only to the computational capability of the hardware. A de-embedding procedure is available to remove the port discontinuities or to redefine the reference plane for S-parameter calculations.

Other features new to Version 3.0 include import and viewing capability for GDS II files. Input of non-Manhattan geometry, that is the entry of polygons on a grid with an angle other than 90°, is permitted by the new version of the Polygon Editor. Output in the format of a Smith Chart is now available for S-parameter data.

Field visualization

MacNeal-Schwendler (MSC), whose MSC/EMAS simulator already provides open boundary analysis of electromagnetic fields, has now launched MicroWaveLab, a full 3D simulator which provides a similar function in a packaged or semi-open environment.

MicroWaveLab, which like MSC/EMAS employs finite element analysis, calculates S-parameters, input impedance and propagation parameters as well as network parameters in various formats. Input can be via an internal solids modelling tool, or imported from external modelling programs such as ACIS, IGES or DXF. The integral 3D meshing routine is fully automatic, with user-controllable mesh refinement. Output can be produced in the form of X-Y graphs, Smith Charts, polar plots and graphical field visualizations. Typical applications are passive microstrip and waveguide com-

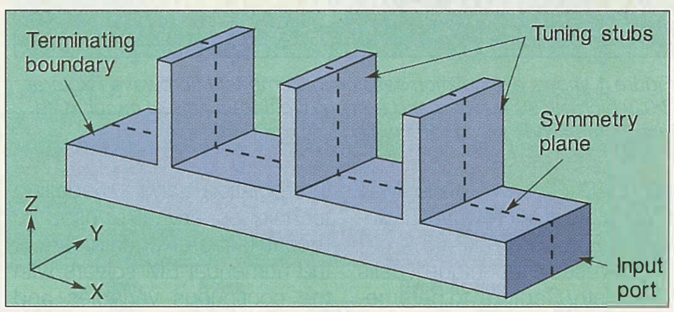
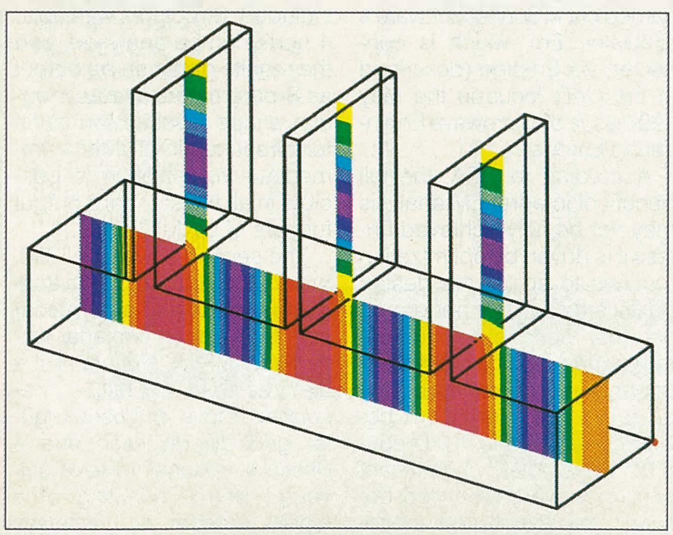
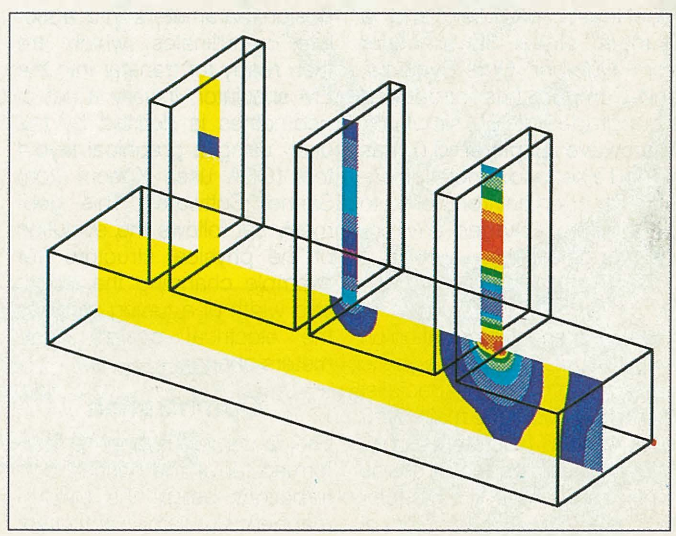
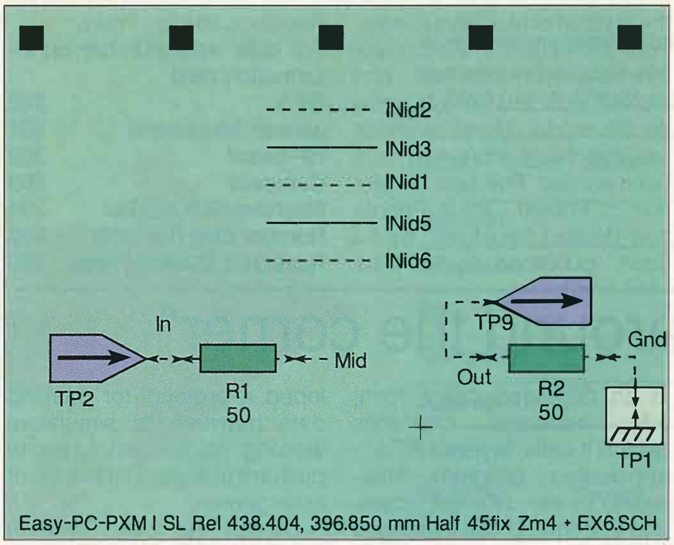


Figure 2(a) (above) shows 13.5GHz three-stub waveguide bandstop filter analyzed by MicroWaveLab from MSC, and 2(b) (below left) and (c) (below right) show contour plots of real part of electric field at 11GHz and 13.5GHz respectively.







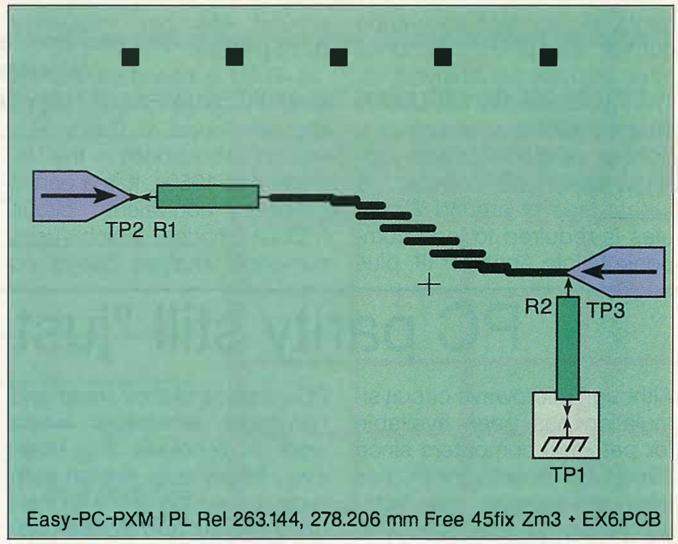
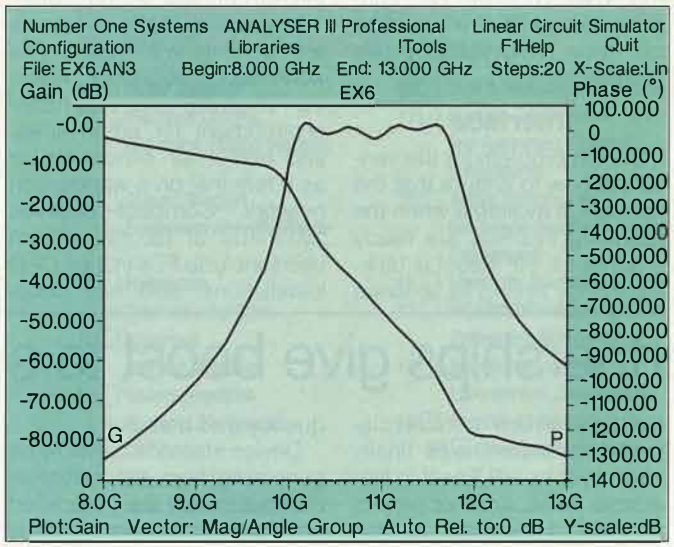


Figure 3 shows the input schematic (above left) and layout (above right), for 11GHz bandpass filter modelled by LAYAN, from Number One Systems. The output circuit response after simulation by Analyser III is shown below.



ponents such as connectors, adapters, transitions, filters and resonators.

The program analyzes the distribution of electric and magnetic fields and produces S-parameter data, as well as also providing information on current distributions, port impedances, energy densities and power losses. Propagation constants for different modes are available, which assist in the analysis of waveguide and coaxial components. The graphical representation of the electromagnetic fields includes phase and magnitude information, and can be performed in a volume or on cut surfaces.

The material library includes media with inhomogeneous characteristics, and lossy media, both isotropic and anisotropic. Absorbing open boundaries are provided for open-ended structures, which also allow antennas to be analyzed. MicroWaveLab is available for UNIX-based workstations (HP, IBM, Sun, Solaris, SGI and DEC) and for Cray and Convex multiprocessing supercomputers.

Filter

An example of a typical component analyzed by MicroWaveLab is shown in figure 2(a). The three-stub waveguide filter has a narrow stopband centred at 13.5GHz, and its analysis utilizes the edge element formulation feature of the program, which allows more accurate prediction of field behaviour in the vicinity of corners, edges and sharp points. The resulting contour plot for the real part of the electric field at the bandpass frequency of 11GHz, along a cross-section of the waveguide, is shown in figure 2(b), while figure 2(c) shows the corresponding plot at the bandstop frequency of 13.5GHz.

Economy

EM simulation and its necessary hardware is often considered a major financial investment which cannot always be justified for a smaller microwave and RF design business. A new "budget" package from the UK software house Number One Systems seeks to fill this need, and works in a PC DOS environment instead of requiring the customary UNIX workstation.

Produced with economy in mind, LAYAN works with the Number One Systems' existing products, Easy-PC Professional XM and Analyser III Professional (which are both required with it) to give a 3D planar electromagnetic simulation of printed circuits up to around 10GHz. It takes as its input a board layout generated in Easy-PC Professional XM from an input schematic, and operates by splitting the transmission line into sub-sections according to the frequency range of interest. It then computes the parasitics and modifies the netlist of the schematic before feeding it back into Analyser III Professional for simulation.

Coupling radius

DC resistance and skin effect are taken into account, as are the dielectric constant and loss tangent of the board material. Resistance calculations allow for the conductivity and thickness of both surface metallization and via metals. A coupling radius is input as one of the simulation parameters: LAYAN will ignore capacitive and inductive effects outside this radius. The magnitude of the coupling radius defines the accuracy of the simulation by adjusting the complexity of the equivalent circuit. The use of a large coupling radius, as might be expected, increases processing time in both parasitic extraction and subsequent circuit simulation.

Filter

The design of a microstrip parallel-coupled bandpass filter with 1.5GHz bandwidth at 11GHz forms an example given in the software manual. figures 3(a) and 3(b) show respectively the schematic and the layout of the filter. The 50Ω resistors are currently required by Analyser III to define a 50Ω system for simulation to take place in: it is intended to provide this automatically in future versions.

LAYAN split the track into sections not exceeding $\lambda/20$ length, resulting in an equivalent circuit over 4,000 components. Figure 3(c) shows the output frequency response after analysis by Analyser III. The time quoted for the LAYAN analysis of this structure on a 50MHz 486DX PC was approximately 2.5 minutes. A further time of around 7 minutes is required to load components into Analyser III, plus around 45s per frequency point plotted.

LAYAN is based on a UNIX program called FACET, originally developed at Philips Research Laboratories in the UK in the mid 1980s. It is a partial element equivalent circuit (PEEC) model, which uses numerical analysis based on the Method of Moments to compute the values of the capacitors, resistors and self- and mutual inductors which make up the model. These methods are described more fully in a book entitled "Practical Simulation of Printed Circuit Boards and Related Structures" by KJ Scott, published in 1994 by Research Studies Press.

For data write number on information card

OSA	**260**
Jansen Microwave	**261**
HP-Eesof	**262**
Compact	**263**
MacNeal-Schwendler	**264**
Number One Systems	**265**
Research Studies Press	**266**

PC parity still "just around the corner"

Although microwave circuit simulation has been available for personal computers since 1984, until recently the PC has been considered the "lightweight" option, with more complex simulations still being performed in a workstation UNIX environment. Now that the 100MHz Pentium offers instruction rates approaching that of a basic workstation, it may be timely to consider where the two platforms now stand in relation to each other.

According to both Compact and HP-Eesof, the main limiting factor is the suitability of the available operating systems (OS). Both vendors offer PC versions of their linear and non-linear simulators which work in Windows 3.1. However, heavy duty design software, especially that with integrated layout and electromagnetic simulation, needs a capable 32-bit operating system, and while Windows NT, Windows 95 and OS/2 all promise this, they have yet to prove themselves.

Interface

The main problem for the vendors is how to ensure that the software is available when the operating systems are ready to accept it. HP-Eesof is tackling this by writing its software in an OS-independent form, with separate interfaces (which it calls "layered APIs" - application program interfaces) to the different operating systems. These interfaces ensure that the application requirements are translated into the appropriate system calls.

In practice many designers are working with mixed PC/workstation installations, where the PC can be used in its native environment for some linear and non-linear simulation, or as a terminal on a workstation network. Compact believes two-thirds of its mainstream users include PCs in their CAD installations, and has developed a protocol for passing data between its simulators working on the two types of platform to support this type of arrangement.

Overall the conclusion is that for linear simulation there is little difference between the two platforms, and the PC is quite adequate for non-linear simulation, but still has some way to go in terms of a suitable operating system before parity can be achieved with workstations on full-featured integrated CAD suites.

For data write number on information card

HP-Eesof	**267**
Compact	**268**

Academic partnerships give boost to software R&D

The growing synergy between industrial and academic research is scarcely anywhere more apparent than in the field of CAD software. Software is by its nature an academically demanding subject, and in several instances directors of CAD software houses also hold posts in academic institutions. Others find that providing financial support to academic projects can yield cost benefits over in-house development.

Joint research

HP-Eesof, for example, is supporting research activities in several Universities across Europe: while not all of these will result in a commercial product, some notable results have been achieved. In particular, HP-Eesof's electromagnetic simulator, Momentum, resulted from a joint effort between HP and the Department of Information Technology at the University of Ghent in Belgium. The spin-off company, Alphabit, which commercialized Momentum, was finally taken over by HP-Eesof in November 1994. Another project at Delft University in the Netherlands, jointly supported by Philips, produced Philips' BJT model "MEXTRAM", which is now part of the HP-Eesof harmonic balance simulator.

Physics-based

Industrial sponsorship is providing funding for extended work on the physics-based device models being developed at the University of Leeds in the UK. The MESFET model was originally reported in the May 1992 issue of Microwave Engineering Europe. This has now been re-written into ANSI C to run under a UNIX operating system, and is achieving typical simulation times on a HP710 workstation of approximately 1 second for a 250-point DC I-V characteristic, and less than 0.5s for S-parameters at a single frequency and bias point.

Device statistics can now be generated from the statistical distribution of the modelled physical parameters. A large signal model has also been generated from simulated S-parameters, which works over a "simulation plane" in a similar manner to the HP-Eesof Root Model. The resulting model can then be used in commercial harmonic balance simulators.

A further enhancement is the application of a Design of Experiments methodology, similar to that described for HP-Eesof Momentum in the May 1994 CAD focus in Microwave Engineering Europe. This approach helps to demonstrate the parameters having the most significant effect on device or circuit performance, and assists in making the design more process-tolerant.

PHEMT and HBT

Following on from the MESFET model, similar physics-based models have now been developed, and are still under improvement, for PHEMTs and HBTs.

The HEMT model is currently being used to characterize and model devices used in the GEC-Marconi Materials Technology F40 and F40X foundry processes, and to assist in the design of a 40GHz high power amplifier.

Work is now progressing on a reverse modelling technique based on these physical models, which will allow the estimation of physical parameters from electrical performance, rather than vice versa.

A further, EPSRC-funded, project at Leeds seeks to apply all the features of the models described above to a PHEMT model for use in the design of millimetre-wave ICs at 94GHz.

For data write number on information card

HP-Eesof	**269**
University of Leeds	**270**