Empipe™ Version 1.0 Technical Brief

INTRODUCTION

Empipe™ is a smart software interface, smoothly connecting **OSA90/hope**™ of Optimization Systems Associates Inc. of Dundas, Ontario, Canada, and ***em***™ of Sonnet Software, Inc. of Liverpool, New York.

The general CAD software system **hope** offers simulation, modelling, statistical analysis, and nominal and yield optimization (design centering) for linear and nonlinear analog circuits. It has an open architecture allowing you to integrate external programs into its design optimization framework. Refer to the **OSA90/hope Technical Brief** for complete details.

The efficient full-wave EM simulator ***em*** is for predominantly planar circuits. With full accuracy up to millimeter-wave frequencies, ***em*** simulates arbitrary geometries accounting for dispersion, coupling, surface waves, radiation, metallization and dielectric losses, etc. It is recommended whenever high simulation accuracy is needed in the design process.

By interfacing ***em*** with **hope**, **Empipe** provides RF and microwave designers with an exciting new dimension in facing the challenges of integrated circuit modeling and optimization. Direct optimization-driven field simulations are now possible by **hope**'s powerful optimizers.

COMMUNICATION BETWEEN OSA90/hope AND *em*

Empipe exploits the **Datapipe**™ technology of **hope**. This technology, realized through UNIX interprocess pipes, facilitates high-speed data communication between **hope** and ***em***.

PARAMETER CONVERSION

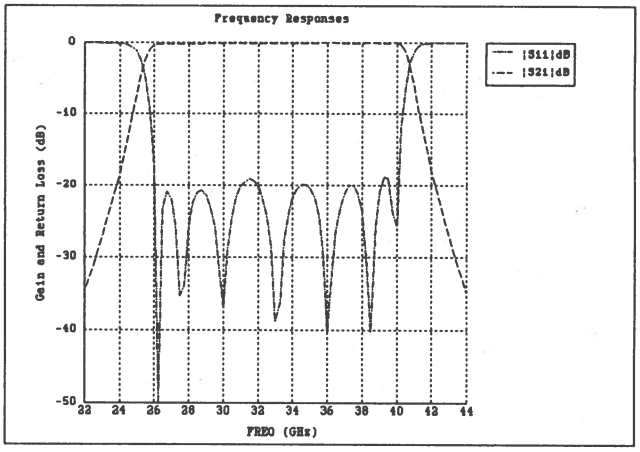
Empipe reads the values of geometrical parameters from **hope** and converts them to a format suitable for ***em***. Discretization requirements of ***em*** are internally handled by the **Empipe** interpolation and sophisticated data management system. This is particularly useful in optimization where dimensions, not the coordinate values are designable parameters.

OPTIMIZABLE COMPONENT LIBRARY

Empipe provides a complete library of microstrip components for ***em*** simulation. The library includes common components, such as microstrip line, step, cross; special microstrip structures, such as double stub, double-folded stub, interdigital capacitor; and multilayer components, such as overlayed double patch capacitor. These components, individually simulated by ***em***, are directly incorporated into the overall circuit, simulated and optimized by **hope**.

EXAMPLE

A 26-40 GHz microstrip interdigital capacitor filter was optimized by **hope** using **Empipe** library components. After minimax, or equal-ripple, optimization and rounding the optimization variables to 0.1mil resolution, the resulting filter gain and return loss are shown in the accompanying diagram.



AVAILABILITY

Empipe is available on Hewlett-Packard, Apollo and Sun workstations. For further information contact

Optimization Systems Associates Inc.
P.O. Box 8083, Dundas, Ontario
Canada L9H 5E7

Tel 416 628 8228 Fax 416 628 8225

OSA90/hope, hope, Datapipe and Empipe are trademarks of Optimization Systems Associates Inc. UNIX and em are trademarks of respective organizations.

Empipe™ Version 1.1 Technical Brief

INTRODUCTION

Empipe™ is a smart software interface, smoothly connecting **OSA90/hope**™ of Optimization Systems Associates Inc. of Dundas, Ontario, Canada, and ***em***™ of Sonnet Software, Inc. of Liverpool, New York.

The general CAD software system **hope** offers simulation, modeling, statistical analysis, and nominal and yield optimization (design centering) for linear and nonlinear analog circuits. It has an open architecture allowing you to integrate external programs into its design optimization framework. Refer to the **OSA90/hope**™ **Technical Brief** for complete details.

The efficient full-wave EM simulator ***em*** is for predominantly planar circuits. With full accuracy up to millimeter-wave frequencies, ***em*** simulates arbitrary geometries accounting for dispersion, coupling, surface waves, radiation, metallization and dielectric losses, etc. It is recommended whenever high simulation accuracy is needed in the design process.

By interfacing ***em*** with **hope**, **Empipe** provides RF and microwave designers with an exciting new dimension in facing the challenges of integrated circuit modeling and optimization. Direct optimization-driven field simulations are now possible by **hope**'s powerful optimizers.

COMMUNICATION BETWEEN OSA90/hope AND *em*

Empipe exploits the **Datapipe**™ technology of **hope**. This technology, realized through UNIX interprocess pipes, facilitates high-speed data communication between **hope** and ***em***.

AUTOMATIC PARAMETER CONVERSION

Empipe reads the values of geometrical parameters from **hope** and converts them to a format suitable for ***em***. Discretization requirements of ***em*** are internally handled by the **Empipe** interpolator.

OPTIMIZABLE COMPONENT LIBRARY

Empipe provides a comprehensive library of ***em***-ready microstrip components. The library includes both simple components, such as microstrip line, step, cross and tee, and more sophisticated structures, such as folded double stub, interdigital capacitor and overlay double patch capacitor. These components are fully parameterized and indistinguishable in syntax from the other built-in library elements (equivalent circuit models) in **hope**. The components, individually simulated by ***em***, are directly incorporated into the overall circuit, simulated and optimized by **hope**. The ***em*** simulation results are also available for graphical display and postprocessing.

The **Empipe** Version 1.1 optimizable component library contains the following microstrip elements:

- asymmetrical gap
- bend
- mitered microstrip bend
- cross junction
- interdigital capacitor (two models)
- double patch capacitor
- double stub (two models)
- folded double stub (two models)
- symmetrical gap
- microstrip line
- overlay double patch capacitor (four models)
- open stub
- rectangular structure
- spiral inductor
- step junction
- T-junction

SIMULATION OF ARBITRARY STRUCTURES

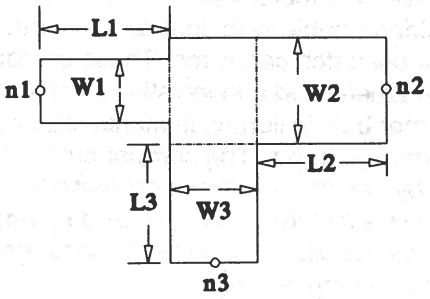
In addition to the built-in library of parameterized elements, **Empipe** also allows you to pass a "geo" file describing an arbitrary structure to ***em*** for simulation. The simulation results are automatically retrieved by **Empipe** and incorporated as part of the overall circuit definition.

INTELLIGENT DATABASE MANAGEMENT

An intelligent database management system is built into **Empipe**. By keeping track of the EM simulation history, it ensures that once a component is simulated by ***em***, the simulation will never have to be duplicated at the same point(s). This mechanism is particularly valuable in realizing computational savings in optimization and statistical analysis.

Empipe SYNTAX

Empipe syntax is exemplified by the ***em***-ready microstrip T-junction component EM_TEE.



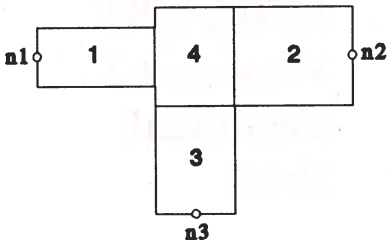
Keywords

INDEX	database index
W1	line width at node n1 (symmetrical)
W2	line width at node n2 (symmetrical)
W3	line width at node n3
L1	line length at node n1
L2	line length at node n2
L3	line length at node n3
H	substrate thickness
H2	shielding height
EPSR	substrate dielectric constant
UR	substrate relative permeability
TAND	dielectric loss tangent
MTAND	magnetic loss tangent
T	conducting metal strip thickness
RHO	conducting metal strip resistivity
SR	surface reactance in Ω/square
XCELL	cell size along the X-axis
YCELL	cell size along the Y-axis
FMIN	lower limit of the frequency range
FMAX	upper limit of the frequency range
FSTEP	increments in the frequency range

Example

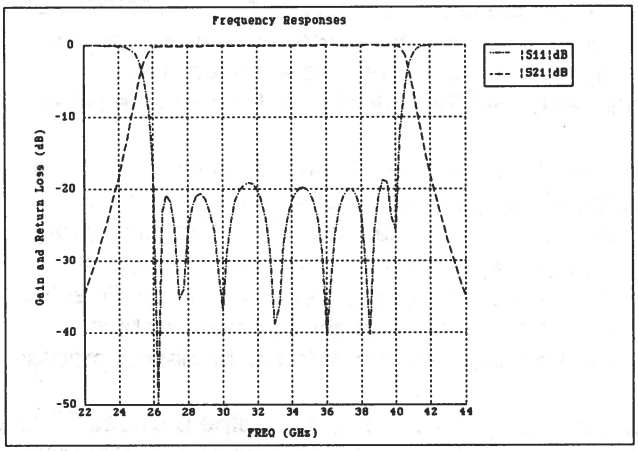
```
EM_TEE  1 2 3 0    INDEX=1    W1=2mil
        W2=4mil    W3=3mil    L1=8mil
        L2=4mil    L3=0       H=5mil
        H2=120mil  EPSR=1.9   T=3um
        TAND=0.001
        XCELL=1mil  YCELL=1mil
        FMIN=1GHZ   FMAX=10GHZ
        FSTEP=1GHZ;
```

Polygon Groups



EXAMPLE

A 26-40 GHz microstrip interdigital capacitor filter was optimized by **hope** using **Empipe** library components. After minimax, or equal-ripple, optimization and rounding the optimization variables to 0.1mil resolution, the resulting filter gain and return loss are shown in the accompanying diagram.



AVAILABILITY

Empipe is available on Hewlett-Packard and Sun workstations. For further information contact

Optimization Systems Associates Inc.
P.O. Box 8083, Dundas, Ontario
Canada L9H 5E7

Before Oct. 4/93 Tel 416 628 8228 Fax 416 628 8225
After Oct. 4/93 Tel 905 628 8228 Fax 905 628 8225

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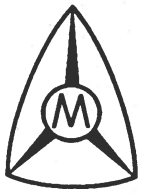


Empipe™ Version 2.0 Technical Brief

INTRODUCTION

Empipe™ is a smart software interface connecting **OSA90/hope™** of Optimization Systems Associates Inc. of Dundas, Ontario, Canada, and ***em***™ of Sonnet Software, Inc. of Liverpool, New York.

Empipe provides RF and microwave designers with the exciting new dimension of direct EM optimization, even for structures with arbitrary geometries!

OSA90/hope is a general CAD software system for simulation, modeling, statistical analysis, and nominal and yield optimization (design centering) for linear and nonlinear analog circuits. Its open architecture allows external programs to be integrated into a design optimization framework. See the **OSA90/hope Technical Brief** for complete details.

em is an efficient full-wave EM simulator for predominantly planar circuits. With full accuracy up to millimeter-wave frequencies, ***em*** simulates arbitrary geometries accounting for dispersion, coupling, surface waves, radiation, metallization and dielectric losses, etc. It is recommended whenever high simulation accuracy is needed in the design process.

INTERFACE BETWEEN OSA90/hope AND *em*

Empipe incorporates our exclusive **Datapipe™** technology to facilitate high-speed data communications between **OSA90/hope** and ***em***, even across networks.

Empipe reads the geometrical parameter values from **OSA90/hope** and then converts them to the format required by ***em***. In **OSA90/hope**'s user-friendly environment you can define optimizable variables, statistical tolerances, and interdependent parameters linked by mathematical expressions.

Discretization of the geometrical parameters for on-grid ***em*** simulation is automatically handled by **Empipe**. For off-grid points, user-selectable linear or quadratic interpolation is employed. The computational savings realized by the interpolation are particularly valuable for EM-based statistical analysis and yield optimization. An intelligent database system is built into **Empipe** to ensure efficient retrieval of ***em*** analysis results.

BUILT-IN COMPONENT LIBRARY

Empipe provides a built-in library of parameterized microstrip components. These components are ***em***-ready and optimizable. The library includes

- asymmetrical gap
- bend
- mitered microstrip bend
- cross junction
- interdigital capacitor (two models)
- double patch capacitor
- double stub (two models)
- folded double stub (two models)
- symmetrical gap
- microstrip line
- overlay double patch capacitor (four models)
- open stub
- rectangular structure
- spiral inductor
- step junction
- T-junction

OPTIMIZATION OF ARBITRARY STRUCTURES

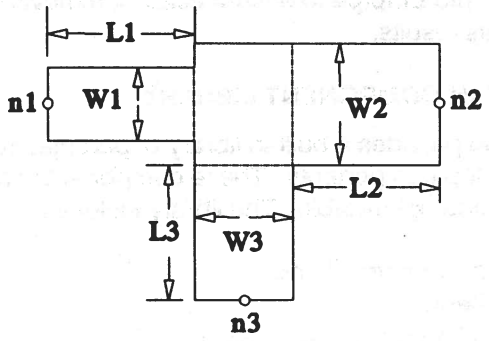
In addition to the built-in library components, **Empipe** Version 2.0 supports user-defined EM-optimizable arbitrary structures. Using our unique Pattern Sensor technology, user-defined optimizable **Empipe** components can be created, with user-definable parameter names, from "geo" files describing an arbitrary structures. Any structures that you can simulate using ***em*** you can now optimize using **Empipe**!

EM AND CIRCUIT MODELS

The ***em*** simulation results are directly incorporated into the overall circuit defined in **OSA90/hope**. You can seamlessly integrate any number of ***em***-simulated structures with elements represented by conventional empirical models in the same circuit for linear and nonlinear simulation and optimization. This also allows you to decompose a large structure into several substructures, individually simulated by ***em*** and then connected via circuit theory, for a less accurate but faster analysis.

Empipe SYNTAX

The syntax is illustrated by the built-in **Empipe** component EM_TEE (microstrip T-junction).



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Example

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EM_TEE  1 2 3 0    INDEX=1    W1=2mil
        W2=4mil    W3=3mil    L1=8mil
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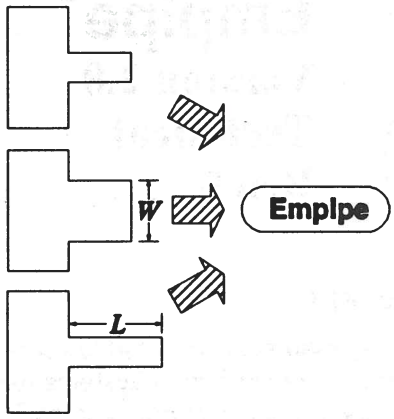
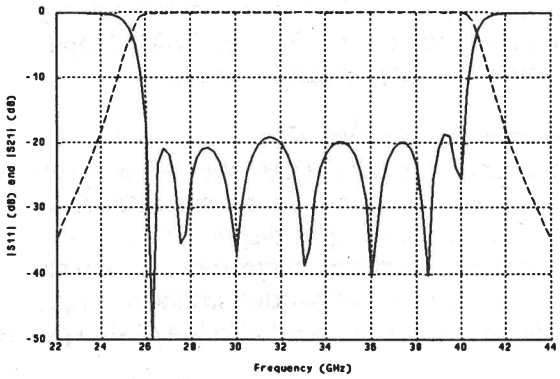
        H2=120mil  EPSR=1.9   T=3um
        TAND=0.001
        XCELL=1mil   YCELL=1mil
        FMIN=1GHZ    FMAX=10GHZ
        FSTEP=1GHZ;
```

ARBITRARY GEOMETRY



DESIGN EXAMPLE

A 26-40 GHz microstrip interdigital capacitor filter was optimized by **OSA90/hope** with **Empipe** and ***em***. After minimax, or equal-ripple, optimization and rounding the optimization variables to 0.1mil resolution, the resulting filter gain and return loss are shown in the accompanying diagram.



AVAILABILITY

Empipe is available on Hewlett-Packard and Sun workstations. For further information contact

Optimization Systems Associates Inc.
P.O. Box 8083, Dundas, Ontario
Canada L9H 5E7

Tel 905 628 8228 Fax 905 628 8225

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Empipe™ Version 3.1 Technical Brief

INTRODUCTION

Empipe™ is a direct electromagnetic optimization software system driving the field solver ***em***™ of Sonnet Software, Inc., harnessing the optimization engine **OSA90**™ of Optimization Systems Associates Inc.

em is an efficient full-wave EM field solver for predominantly planar circuits. With full accuracy up to millimeter-wave frequencies, ***em*** simulates arbitrary geometries accounting for dispersion, coupling, surface waves, radiation, metallization and dielectric losses, etc. It is recommended whenever high simulation accuracy is needed in the design process.

OSA90 features powerful and robust gradient-based optimizers: ℓ_1, ℓ_2, Huber, minimax, quasi-Newton, conjugate gradient, as well as non-gradient simplex and random optimizers.

Empipe offers the exclusive Geometry Capture™ tool for parametric design encapsulation of arbitrary structures. The user's graphical inputs to ***xgeom***™ (Sonnet Software, Inc.) are processed to automatically define optimizable variables. The captured structures are as easy to use as conventional circuit elements. The EM analyses are automatically and efficiently managed by **Empipe** using our exclusive Datapipe™ technology, even across networks.

INTERPOLATION AND DATABASE

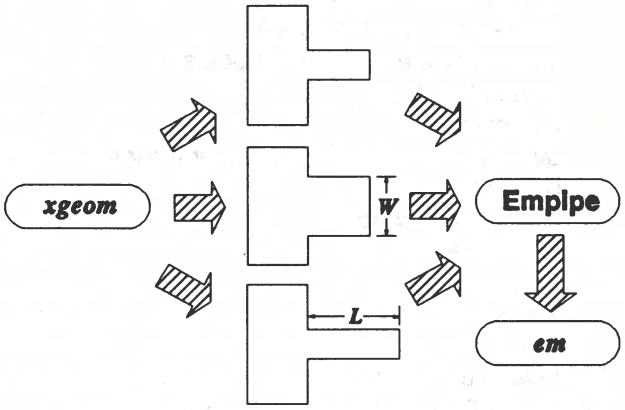
Advanced interpolation and database techniques are built-in to achieve unrivalled efficiency and accuracy.

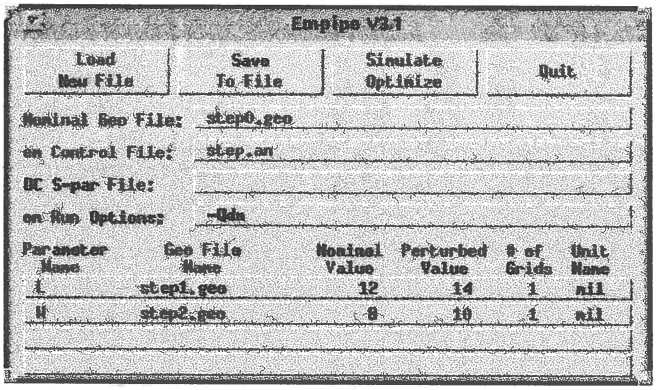
Discretization of the geometrical parameters for on-grid ***em*** simulation is automatically handled by **Empipe**. For off-grid points, user-selectable linear or quadratic interpolation is employed.

An intelligent database system is built into **Empipe** to avoid duplicate ***em*** simulation and ensure efficient retrieval of the ***em*** analysis results.

GEOMETRY CAPTURE™

Geometry Capture is an exclusive feature of **Empipe** for user-defined EM-optimizable arbitrary structures. Designable parameters and optimization variables are automatically captured from a set of "geo" files created using ***xgeom***. In addition to geometrical dimensions, substrate and metallization parameters can also be optimized. Any structures that you can simulate using ***em*** you can now optimize using **Empipe**!





GRAPHICAL USER INTERFACE

Empipe offers a rich set of graphical display options from **OSA90**, including response function(s) versus frequency or an arbitrary variable, parametric plot of two responses, Smith chart, polar plot, contours and even 3D visualization. *S*, *Y* and *Z* parameters, two-port insertion loss and group delay are automatically derived from the ***em*** output. User-defined responses can be created using algebraic expressions and mathematical functions. All built-in and user-defined responses can be optimized and the specifications can be entered directly on the graphical display of the response of interest. Graphical plots can be saved to HPGL or PostScript files.

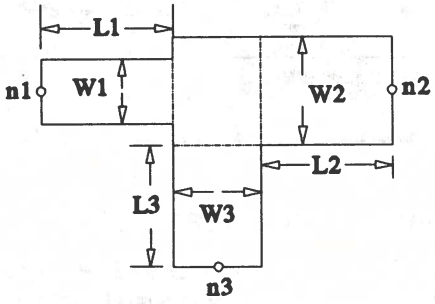
BUILT-IN COMPONENT LIBRARY

For convenience of use, **Empipe** provides a library of predefined optimization-ready microstrip components. The library includes

- asymmetrical gap
- bend
- mitered microstrip bend
- cross junction
- interdigital capacitor (two models)
- double patch capacitor
- double stub (two models)
- folded double stub (two models)
- symmetrical gap
- microstrip line
- overlay double patch capacitor (four models)
- open stub
- rectangular structure
- spiral inductor
- step junction
- T-junction

For example, the library component EM_TEE defines a microstrip T-junction with the following syntax:

```
EM_TEE  1 2 3 0    INDEX=1    W1=2mil
        W2=4mil    W3=3mil    L1=8mil
        L2=4mil    L3=0       H=5mil
        H2=120mil  EPSR=1.9   T=3um
        XCELL=1mil   YCELL=1mil
        FMIN=1GHZ    FMAX=10GHZ
        FSTEP=1GHZ   TAND=0.001;
```



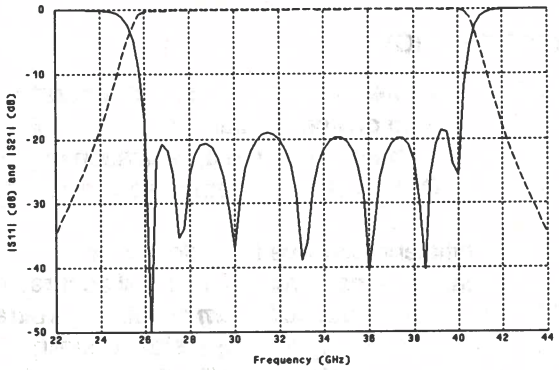
EM AND CIRCUIT MODELS

Using **Empipe**, you can decompose a large structure into several substructures, individually simulated by *em* and then connected via circuit theory. With optional circuit features available from **OSA90/hope™**, you can seamlessly integrate *em* analysis results with circuit library elements, not only in linear small-signal analysis, but also in nonlinear large-signal harmonic balance simulation and optimization. **OSA90/hope** offers a comprehensive library of nonlinear devices.

Space Mapping™ is a fundamental new theory exclusive to **OSA90/hope** for extremely fast EM optimization exploiting "coarse" or empirical models. The optimal solution is then mapped to the fine EM model space using very few EM simulations.

DESIGN EXAMPLE

A 26-40 GHz microstrip interdigital capacitor filter was optimized using **Empipe** and *em*. The responses at the minimax solution are shown in the following figure.



OTHER PRODUCTS FROM OSA

OSA90/hope™ is a general CAD software system for simulation, modeling, statistical analysis, nominal and yield optimization of linear and nonlinear circuits.

HarPE™ is the world's best commercial software system for device parameter extraction, simulation, optimization and statistical modeling.

PLATFORMS AND SUPPORT

Empipe runs under X-Windows on Hewlett-Packard, Sun and DEC workstations. **Empipe** comes with a 90 day limited warranty. A software support option which includes software upgrades is also available.

You can rely on professional and timely support from our technical experts, including authors of the program. For further information contact

Optimization Systems Associates Inc.
P.O. Box 8083, Dundas, Ontario
Canada L9H 5E7

Tel 905 628 8228
Fax 905 628 8225

Empipe, OSA90, OSA90/hope, Geometry Capture, Datapipe and Space Mapping are trademarks of Optimization Systems Associates Inc.
em, *xgeom*, X-Windows, Sun Workstation and PostScript are trademarks of respective organizations.

Empipe™ Version 4.0 Technical Brief

INTRODUCTION

Empipe™ is a direct electromagnetic optimization software system driving the field solver ***em***™ of Sonnet Software, Inc., harnessing the optimization engine **OSA90**™ of Optimization Systems Associates Inc.

em is an efficient full-wave EM field solver for predominantly planar circuits. With full accuracy up to millimeter-wave frequencies, ***em*** simulates arbitrary geometries accounting for dispersion, coupling, surface waves, radiation, metallization and dielectric losses, etc. It is recommended whenever high simulation accuracy is needed in the design process.

OSA90 features powerful and robust gradient-based optimizers: ℓ_1, ℓ_2, Huber, minimax, quasi-Newton, conjugate gradient, as well as non-gradient simplex, random and simulated annealing optimizers.

Empipe offers OSA's exclusive Geometry Capture™ tool for parametric design encapsulation of arbitrary structures. The user's graphical inputs to ***xgeom***™ (Sonnet Software, Inc.) are processed to automatically define optimizable variables. The captured structures are as easy to use as conventional circuit elements. The EM analyses are automatically and efficiently managed by **Empipe** using our exclusive Datapipe™ technology, even across networks.

INTERPOLATION AND DATABASE

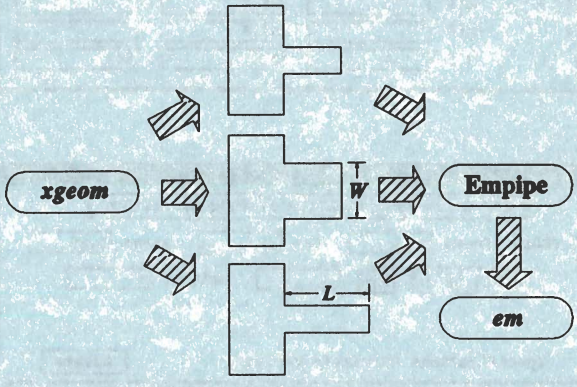
Advanced interpolation and database techniques are built in to achieve unrivalled efficiency and accuracy.

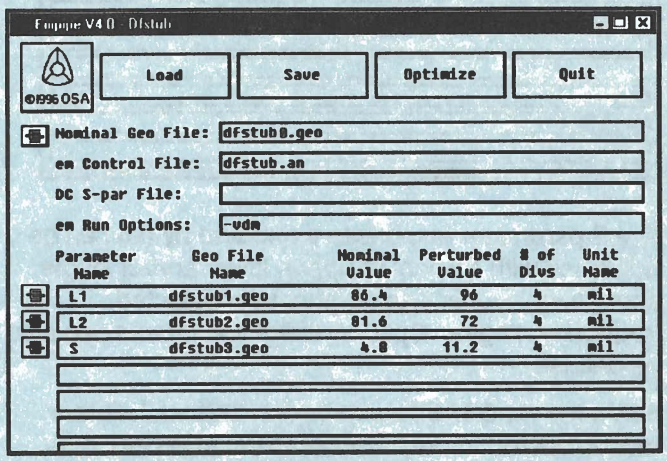
Discretization of the geometrical parameters for on-grid ***em*** simulation is automatically handled by **Empipe**. For off-grid points, user-selectable linear or quadratic interpolation is employed. Also selectable by the user are the parameters to be interpolated: *S*, *Y* or *Z*, in either rectangular or polar form.

An intelligent database system is built into **Empipe** to avoid duplicate ***em*** simulation and ensure efficient retrieval of the ***em*** analysis results.

GEOMETRY CAPTURE™

Geometry Capture is a user-friendly tool for defining EM-optimizable arbitrary structures. In **Empipe**, designable parameters and optimization variables are automatically captured from a set of "geo" files created using ***xgeom***. In addition to geometrical dimensions, substrate and metallization parameters can also be optimized. Any structures that you can simulate using ***em*** you can optimize using **Empipe**!



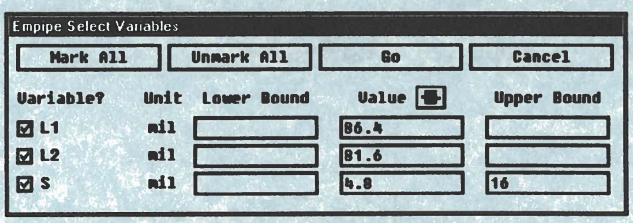


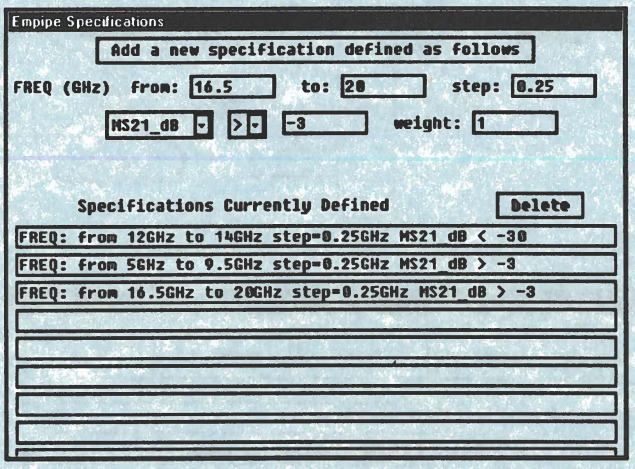
AVAILABLE DISPLAY OPTIONS

Empipe offers a rich set of graphical display options, including response function(s) versus frequency or an arbitrary variable, parametric plot of two responses, Smith chart, polar plot, contours and even 3D visualization. *S*, *Y* and *Z* parameters, two-port insertion loss and group delay are automatically derived from the ***em*** output. You can create user-defined functions and postprocess responses using typical algebraic operations and a rich set of built-in mathematical functions. All built-in and user-defined responses can be optimized.

VARIABLES AND SPECIFICATIONS

Empipe provides a convenient form editor for selecting optimization variables and defining specifications. Upper and lower bounds can be imposed on the variables to limit the parameter values during optimization.





The *S*-parameter responses computed by ***em*** can be optimized with respect to upper, lower and/or single specifications over one or more user-selected frequency ranges. Optional weighting factors can also be defined.

Furthermore, **OSA90**'s expression and math library can be utilized to preprocess the variables, such as relating a number of parameters through equations, and postprocess the *S* parameters to create user-defined responses for display and optimization.

OPTIONAL FEATURES

You can seamlessly integrate ***em*** analysis results into a full fledged circuit simulator not only for linear small-signal analysis, but also for nonlinear large-signal harmonic balance simulation and optimization. These features are available when **Empipe** is combined with **OSA90/hope™**. **OSA90/hope** offers a comprehensive library of linear and nonlinear device models and the flexibility of a general purpose simulation and optimization system. You can decompose a large structure into several substructures, individually simulated by ***em*** and then connected via circuit theory. If couplings between input and output circuits of a FET are of concern you can submit the entire structure for ***em*** simulation and then connect the FET for complete circuit analysis and optimization.

Another significant feature is Space Mapping™, a rapidly developing new theory for engineering design optimization. Exclusive to **OSA90/hope**, it links "coarse" and "fine" models and is particularly useful in bringing design with ***em*** into a practical time frame. Coarse models are used for fast optimization, and the optimal solution is mapped to the fine model space. The results can be astounding!

OTHER PRODUCTS FROM OSA

OSA90/hope™ is a general CAD software system for simulation, modeling, statistical analysis, nominal and yield optimization of linear and nonlinear circuits.

HarPE™ is a well established software system for device parameter extraction, simulation, optimization and statistical modeling.

Our family of electromagnetic optimization products also includes **Empipe3D™** and ***empath™***. **Empipe3D** is designed to drive Ansoft HFSS and HP HFSS. ***empath*** is a concise, streamlined version of **Empipe** and is available directly from Sonnet Software, Inc., as part of its EM CAD suite.

PLATFORMS AND SUPPORT

Empipe runs on PC platforms under Windows 95® and Windows NT®, and on UNIX workstations: Sun, Hewlett-Packard and DEC under X-Windows.

Empipe comes with a 90 day limited warranty. A software support option which includes software upgrades is available. For further information contact

Optimization Systems Associates Inc.
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