PARAMETER EXTRACTION OF DIELECTRIC CONSTANT

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Parameter Extraction of Dielectric Constant

Generally, parameter extraction is defined as the problem of finding a set of parameter values for a device model such that its response matches a set of measurements on a corresponding device under test.

Example Overview

This example demonstrates a parameter extraction process using Empipe3D.

A set of "measurements" is prepared by running HP HFSS to obtain the reflection coefficient S_{11} in a waveguide, a section of which is filled with a dielectric block. See Fig. 1. We assign a value to the dielectric constant $\varepsilon_r = 2.2$. The S_{11} response is measured in the frequency range 7 GHz to 11 GHz with a step of 0.1 GHz.

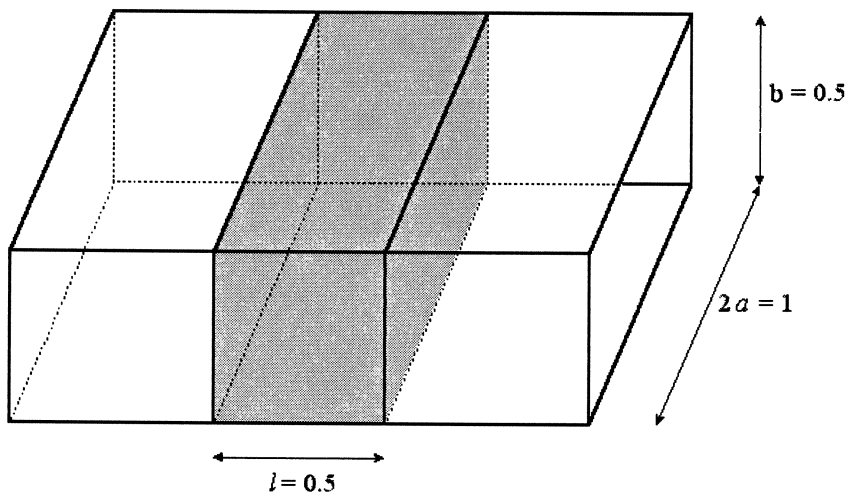

Fig. 1. The dielectric-filled waveguide section and its dimensions in inches.

The S_{11} response of the above structure obtained from the HP HFSS postprocessor output is shown in Fig. 2.

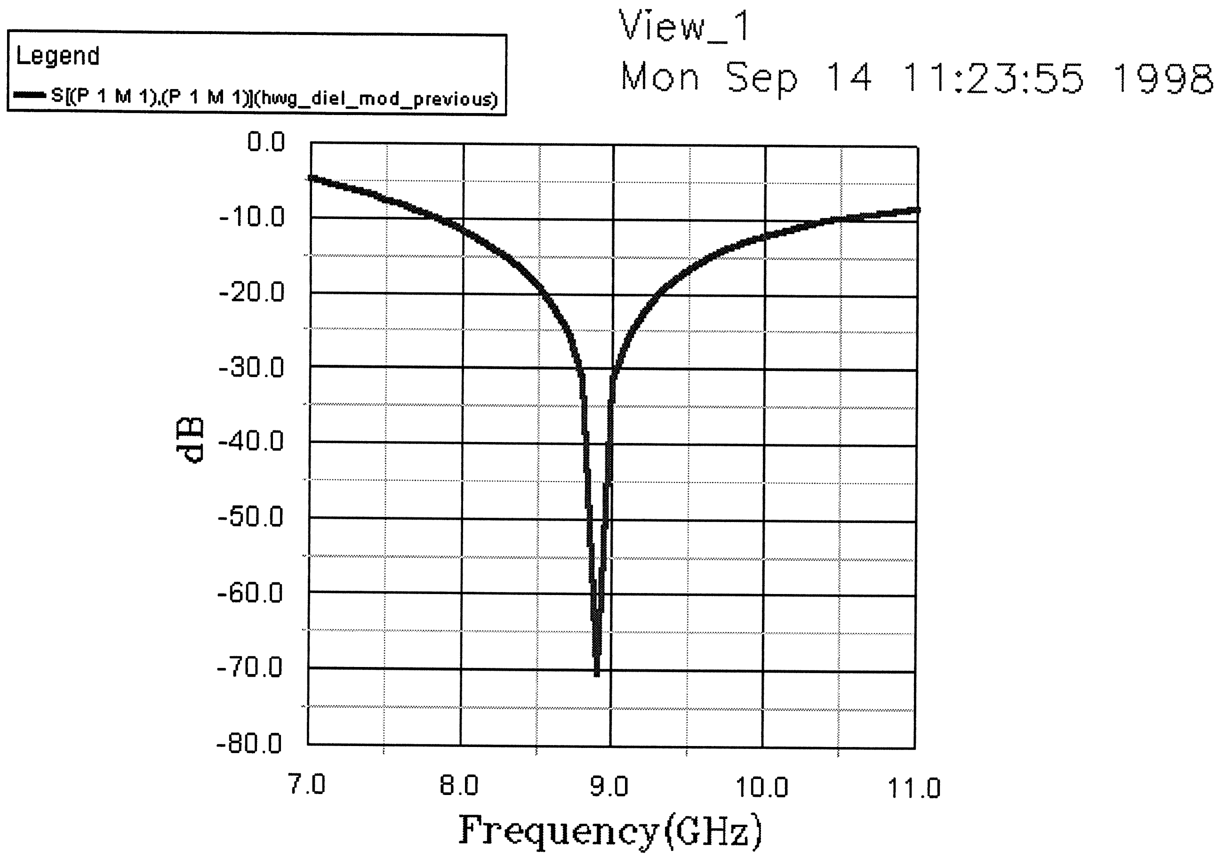

Fig. 2. Magnitude of the reflection coefficient $|S_{11}|$.

The S_{11} response versus frequency is exported to a Touchstone format (real and imaginary parts). This data is used as "measurement" data by inserting it into the netlist file, as shown in the Appendix.

Parameter Extraction Using Empipe3D

The parameter extraction problem we solve here is intrinsically an optimization problem. The general procedure for setting up the project is the same as in the case of any other optimization example. Nominal and perturbed HP HFSS projects have to be created in order to allow Empipe3D to determine correctly the optimization variables. We do not assign upper and/or lower optimization goals as one does in a design problem. Here we require that the relevant response of the device matches as closely as possible the "measurement" data.

The present example has been formulated on the assumption that "measurement" data is available for the S_{11} response of the waveguide structure shown in Fig. 1. The dielectric constant is assumed unknown: its value has to be found with reasonable accuracy. There is only one parameter to be optimized in this example: the dielectric constant ε_r of the dielectric-filled waveguide section.

Nominal and Perturbed Projects

Two projects were created for this example. The nominal and perturbed projects have identical geometry, but different dielectric constant. This is seen in the Empipe3D Geometry Capture form editor window in Fig. 3.

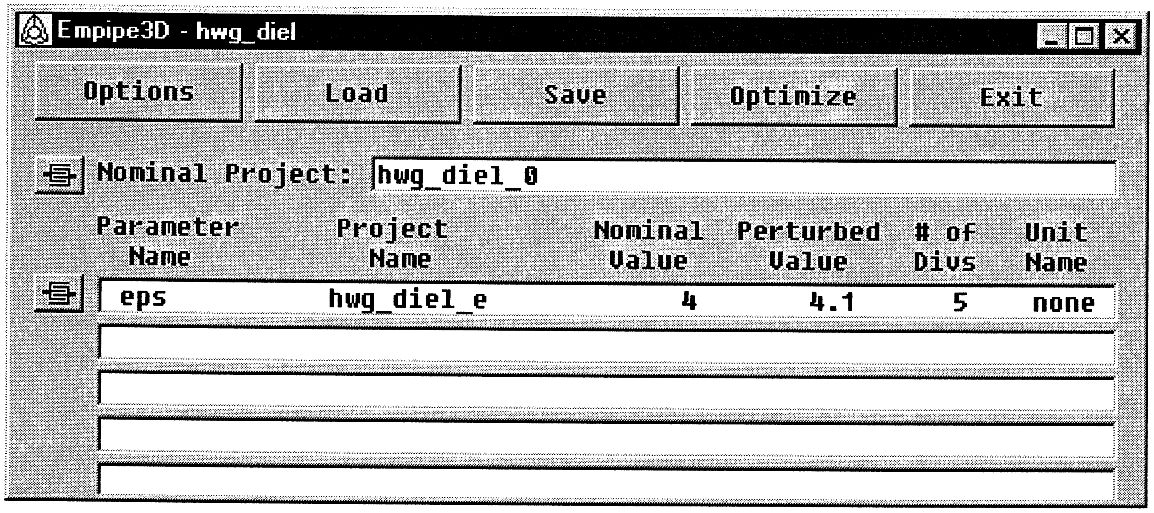

Fig. 3. Empipe3D Geometry Capture form editor showing the nominal and perturbed dielectric constant.

Optimization Variable and Specifications

The Empipe3D Select Variables window displays the single optimization parameter and its initial value of 4, which corresponds to the value in the nominal project (Fig. 4).

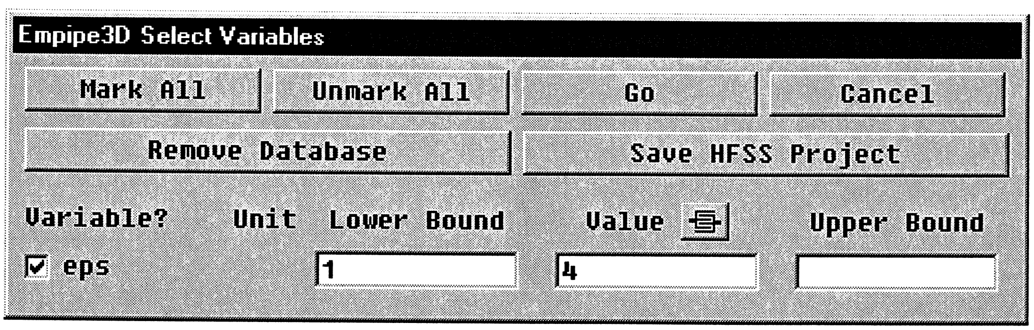

Fig. 4. The Empipe3D Select Variables window.

There is no need to fill in the optimization specifications in the Empipe3D Specifications window because the relevant setup will be created directly in the Empipe3D netlist file.

The default netlist file, which is automatically generated by Empipe3D, is shown in Fig. 5.

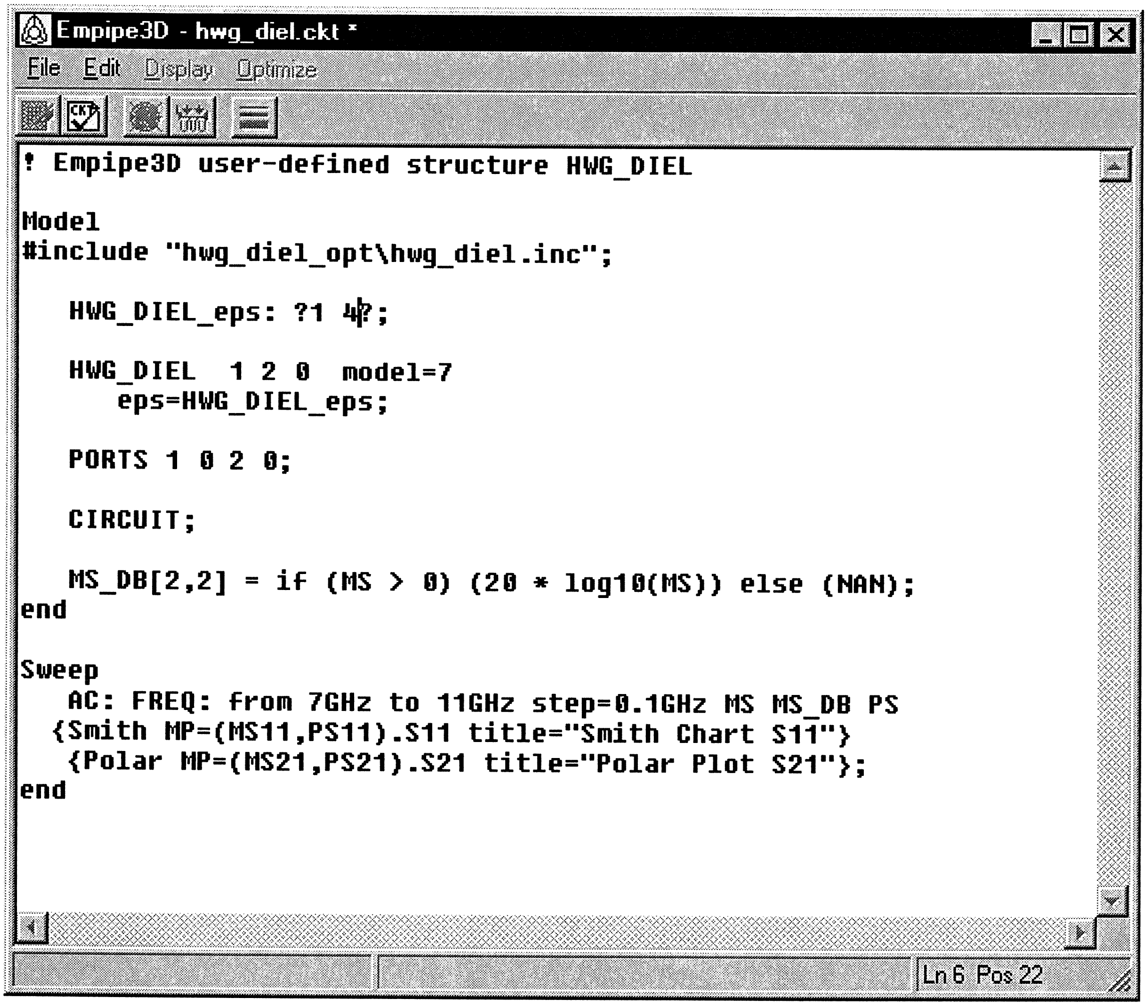

Fig. 5. The default netlist file generated by Empipe3D.

One can see that the Specification Block is missing, because there were no specifications declared in the Empipe3D Specifications window. The default netlist file must be modified in the following manner. The "measurement" data has to be included and assigned to a matrix with proper dimensionality. A Specification Block must be defined stating that the response of the simulated structure must be equal to the measured response. These modifications to the default netlist file can be seen in the Appendix, which shows the modified netlist file *hwg_diel_pe.ckt*. The specifications state that the real and the imaginary parts of S_{11} of the optimized structure must be equated (to the extent possible by optimization) to the real and the imaginary parts of the measured S_{11} at each frequency of the swept frequency band.

Optimization Results

The L2 optimizer was invoked to solve the problem. The accuracy of solution was set to 1e-006 in the L2 Optimization Options dialog box.

After the optimization is completed the expected value of $\varepsilon_r = 2.2$ is obtained. The optimization iterations report (Fig. 6) shows the final value of the objective function. The extracted parameter ε_r is seen in the final Empipe3D Select Variables window, where the optimized values replace the nominal ones (Fig. 7).

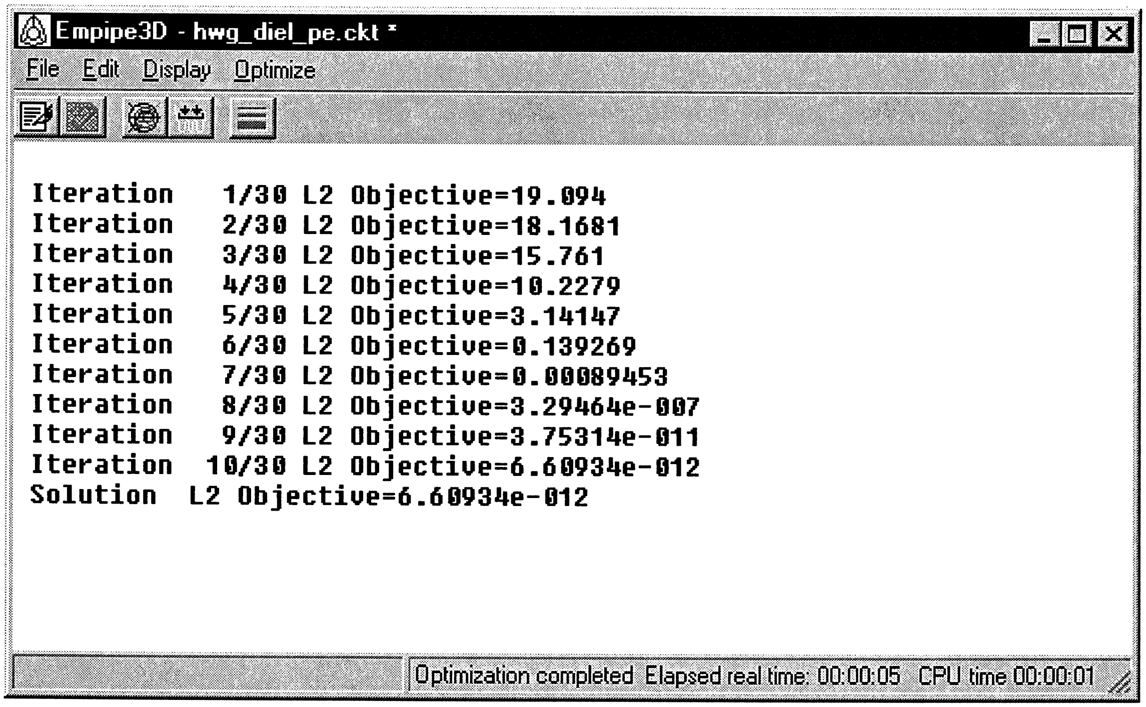

Fig. 6. Empipe3D optimization iterations report.

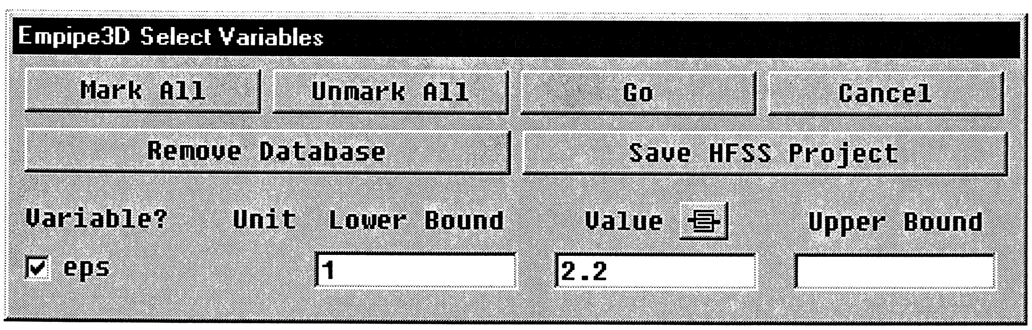

Fig. 7. Empipe3D Select Variables window after the optimization is completed.

Appendix

The modified netlist file

```
! Empipe3D user-defined structure HWG_DIEL

Model
#include "hwg_diel_opt\hwg_diel.inc";

   HWG_DIEL_eps: ?1 4 10?;

   HWG_DIEL  1 2 0  model=7
      eps=HWG_DIEL_eps;

   PORTS 1 0 2 0;

   CIRCUIT;

   F1=7.;
   F2=11.;
   NFS=40.;
   DF=(F2-F1)/NFS;
   J=1+NINT((FREQ-F1)/DF);

   S11_m[41,2] =
      [ 0.478669        0.313324
        0.491330  0.225264
      0.488904    0.142112
      0.473359    0.065859
      0.446791    -0.001917
      0.411381    -0.060043
      0.369346    -0.107748
      0.322883    -0.144645
      0.274123    -0.170721
      0.225074    -0.186305
      0.177578    -0.192038
      0.133264    -0.188836
      0.093519    -0.177837
      0.059453    -0.160358
      0.031891    -0.137831
      0.011361    -0.111757
      -0.001899   -0.083644
      -0.007931   -0.05496
      -0.007030   -0.027084
      0.000281    -0.001272
      0.013292    0.021384
      0.031135    0.039972
      0.052836    0.053778
      0.077346    0.062295
      0.103586    0.065218
      0.130478    0.062442
      0.156983    0.054044
      0.182124    0.040272
      0.205011    0.021517
      0.224859    -0.001702
```

```
        0.240999    -0.028773
        0.252885    -0.058978
        0.260108    -0.0916
        0.262383    -0.125843
        0.259553    -0.160917
        0.251576    -0.196022
        0.238556    -0.230474
        0.220643    -0.263453
        0.198129    -0.294335
        0.171372    -0.322504
        0.140803    -0.347416 ];

   MS_DB[2,2] = if (MS > 0) (20 * log10(MS)) else (NAN);
end

Sweep
   AC: FREQ: from 7GHz to 11GHz step=0.1GHz MS MS_DB PS
  {Smith MP=(MS11,PS11).S11 title="Smith Chart S11"}
   {Polar MP=(MS21,PS21).S21 title="Polar Plot S21"};
end

Spec
   AC: FREQ: from 7GHz to 11GHz step=0.1GHz
   RS11=S11_m[J,1]
   IS11=S11_m[J,2]
end
```