An Introduction to Sonnet

Dr. José Ernesto Rayas-Sánchez

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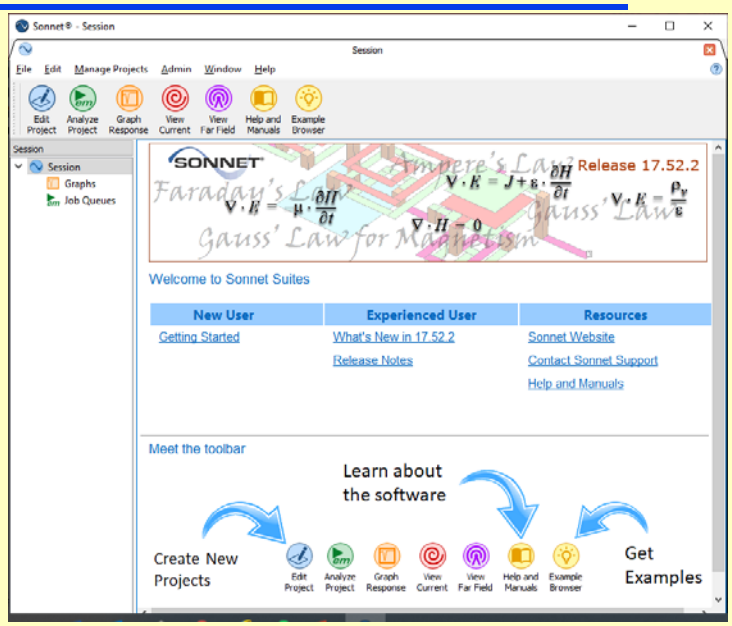
Sonnet EM Simulator

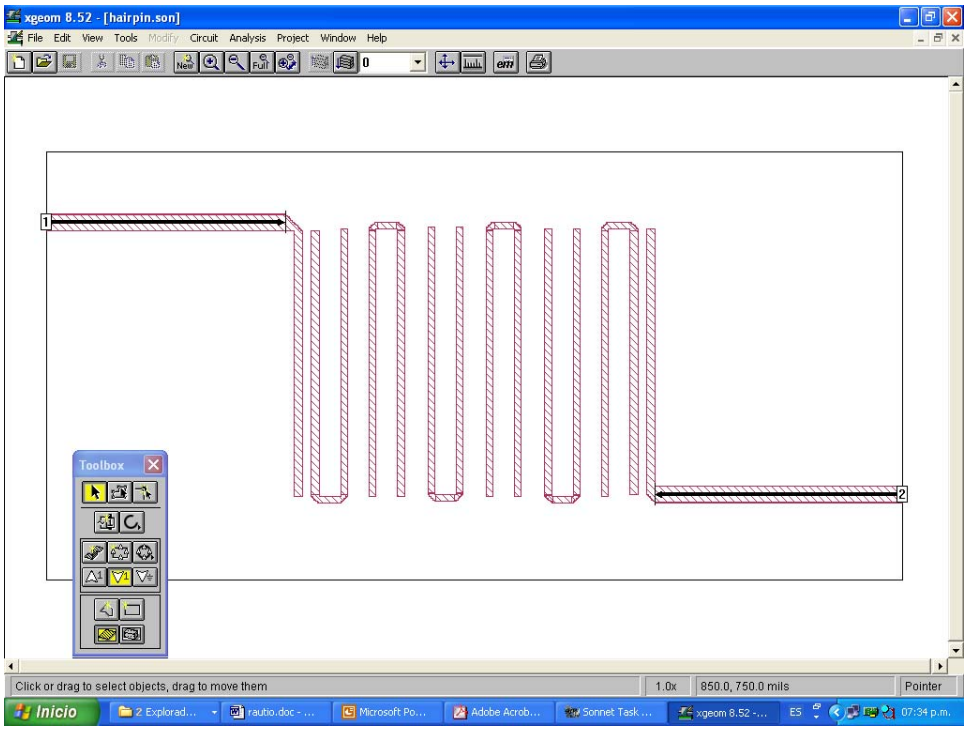
- A 3-D planar EM analysis software
- Based on the Method of Moments
- Intended for frequency-domain analysis of planar circuits (microstrip, stripline, PCBs, and integrated circuits)
- Not intended for completely arbitrary 3-D problems
- Development started in 1983 by Dr. James C. Rautio
- Commercial introduction in 1989

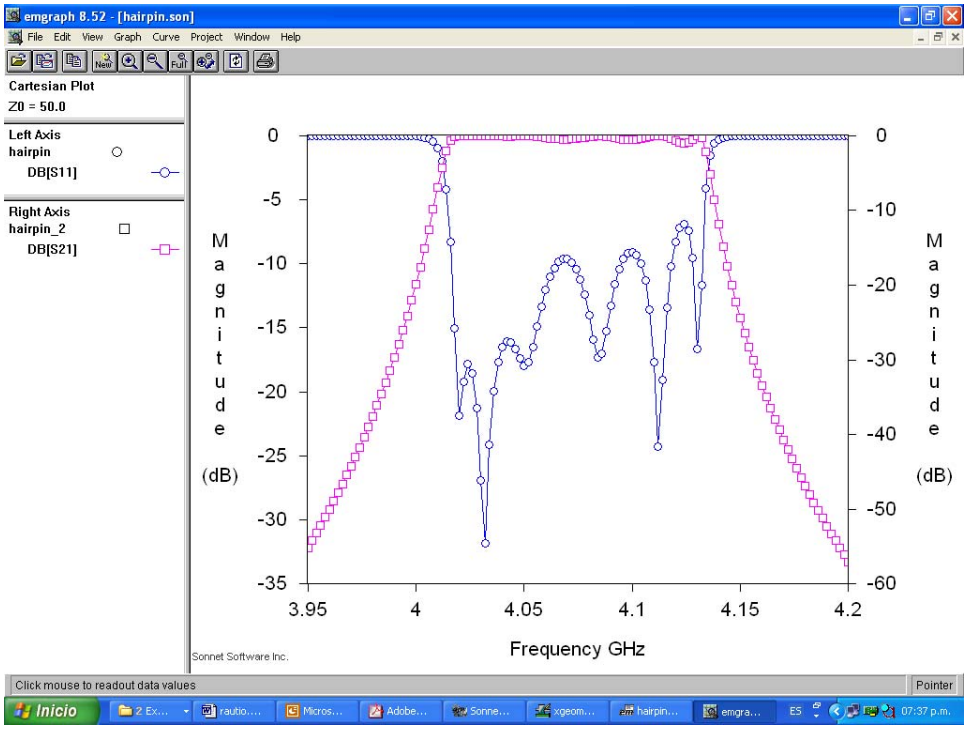
https://www.sonnetsoftware.com/

Sonnet's User-Interface

(v17.52.2)







Basic Sonnet Tools

- 'xgeom', for drawing the circuit to be analyzed
- 'em' to perform the EM analysis (main engine)
- 'emgraph' to plot the results (S-parameters, etc.)
- 'emvu' to view and animate current distributions (for a given exciting frequency)
- 'patvu' to compute the far-field radiation pattern of radiating structures (such as patch antennas)

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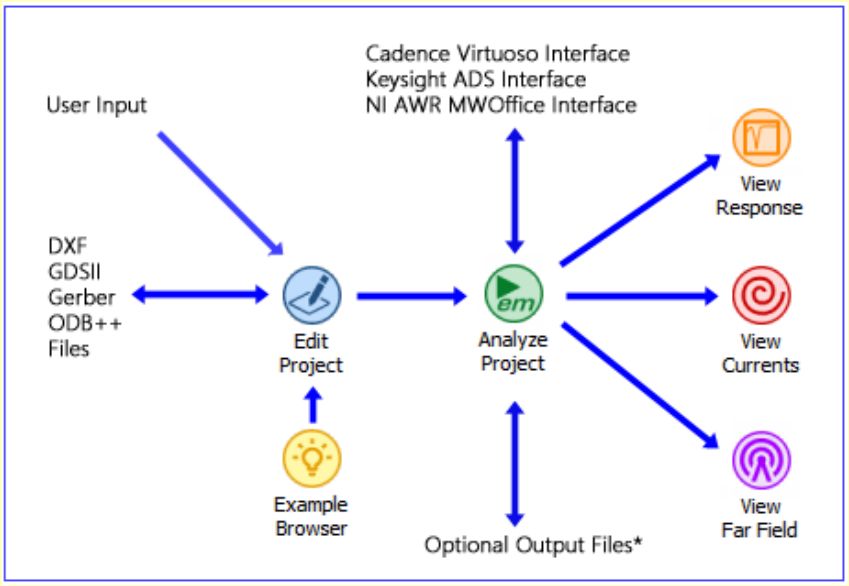
Sonnet's Design Suite: Open Environment



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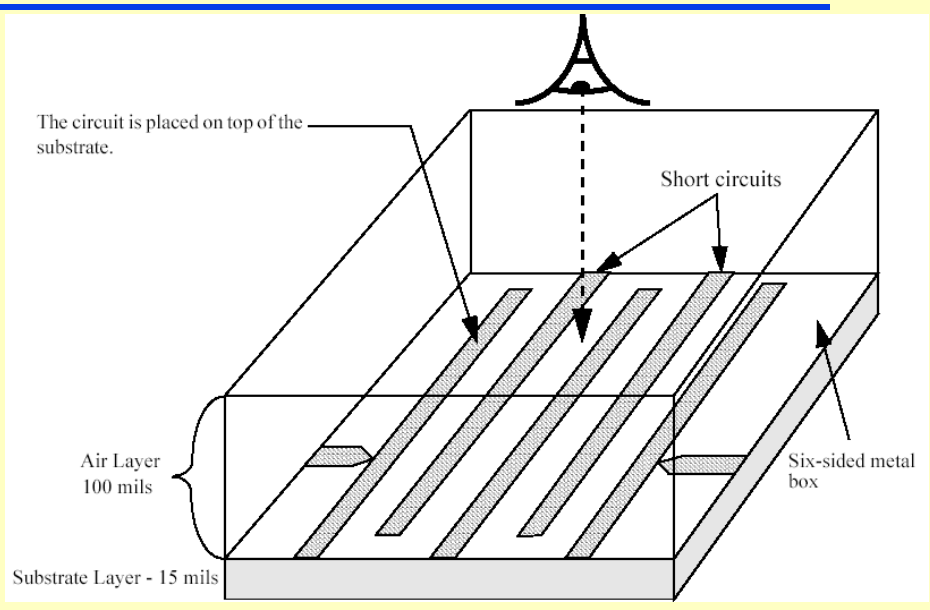
The Project Editor – Example 1



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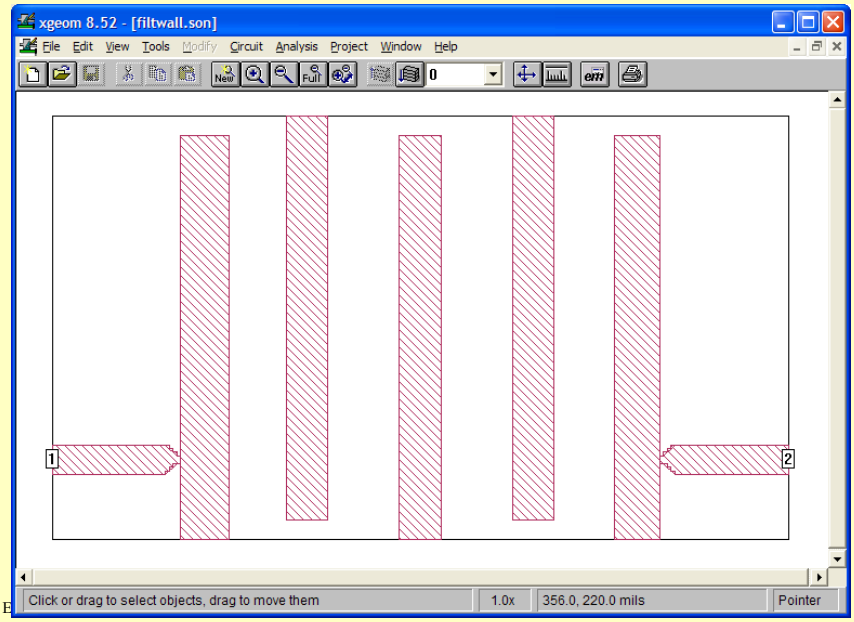
The Project Editor – Example 1 (cont.)



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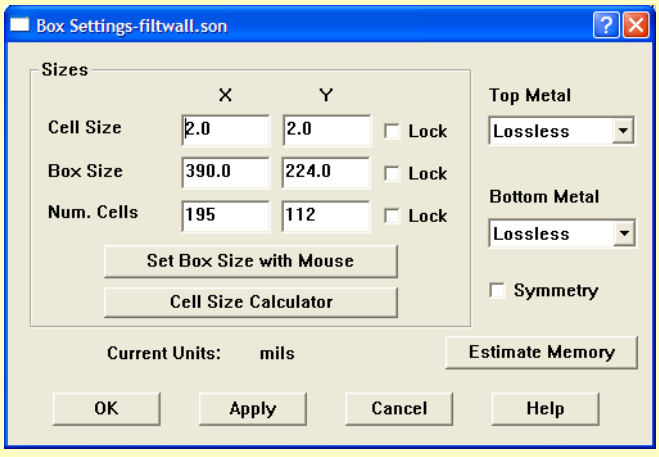
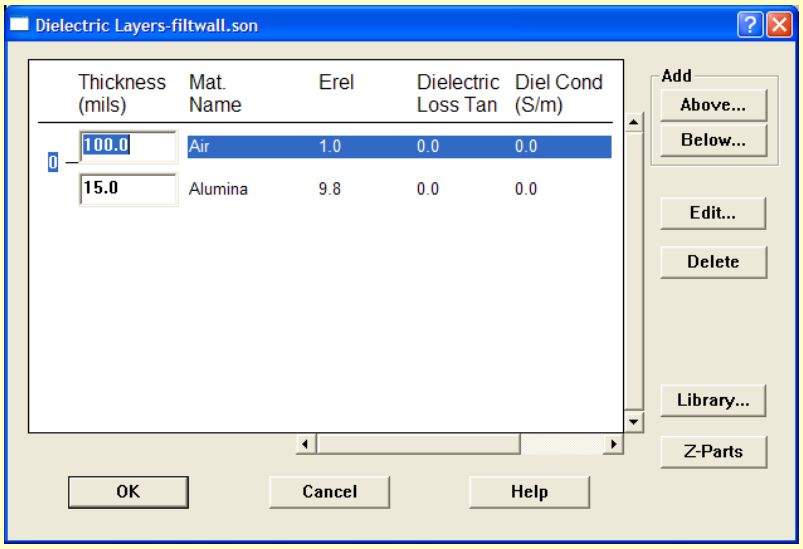
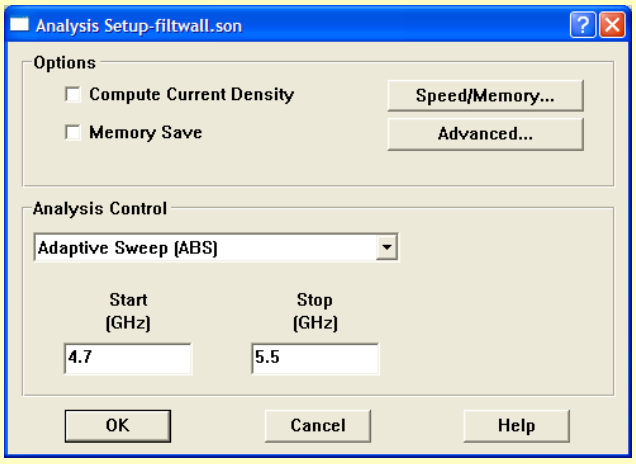


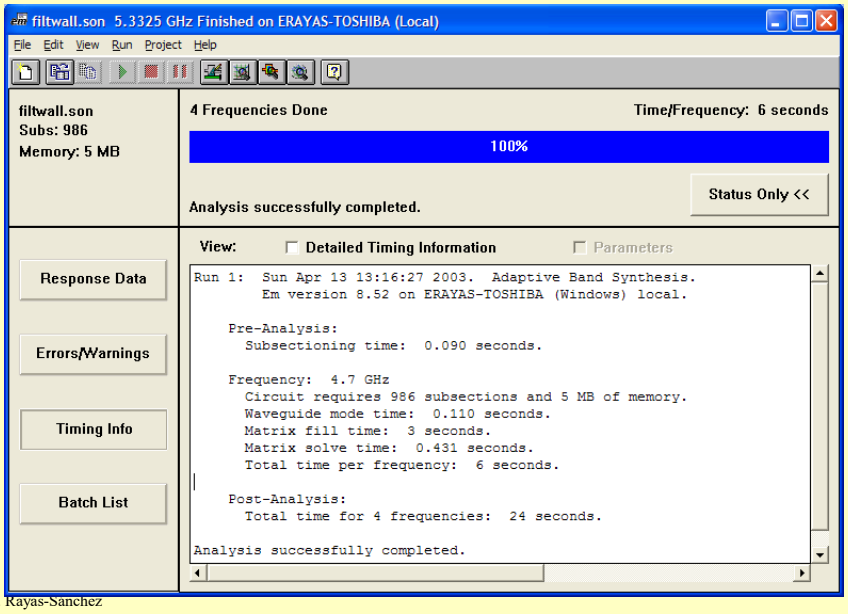
The Project Editor – Example 1 (cont.)



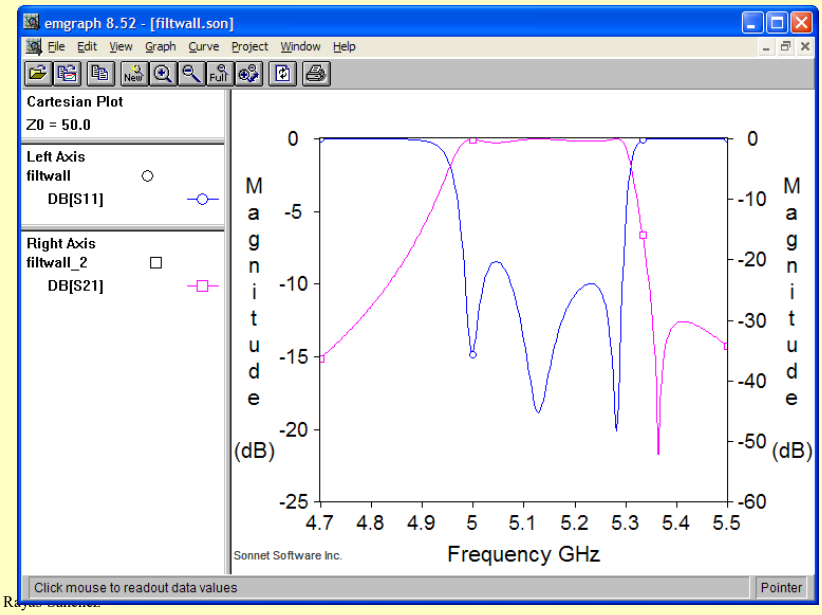
Setting-up the Analysis – Example 1



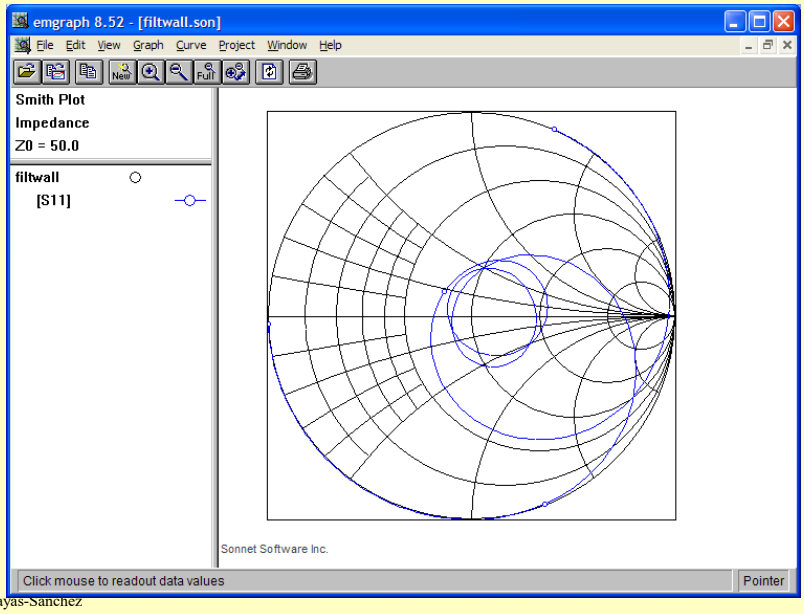
Running the Simulation – Example 1



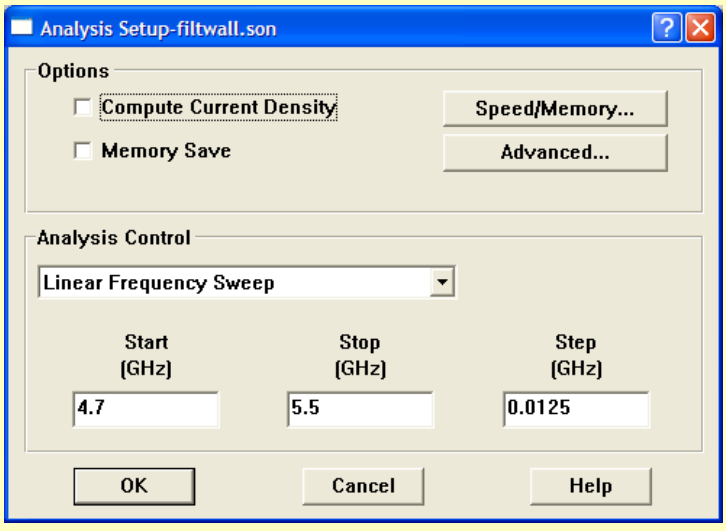
Showing Results – Example 1



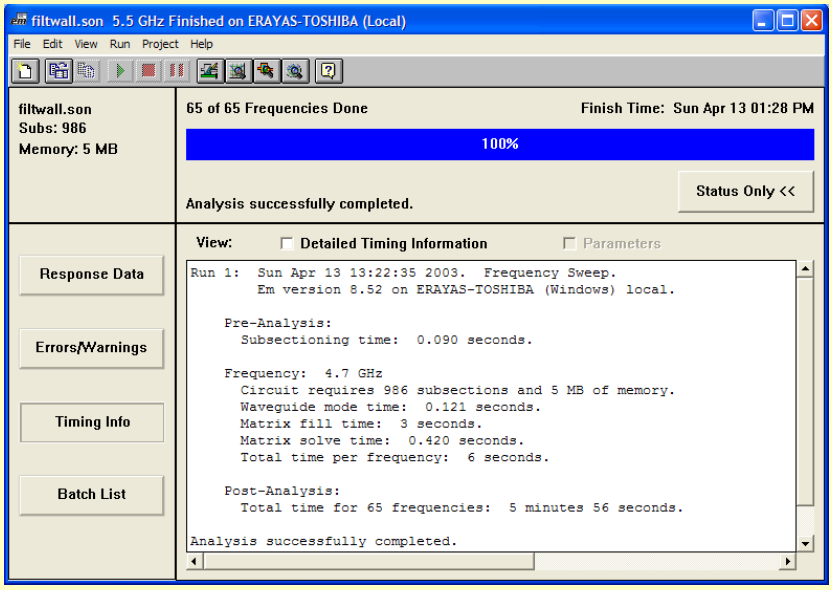
Showing Results – Example 1 (cont.)



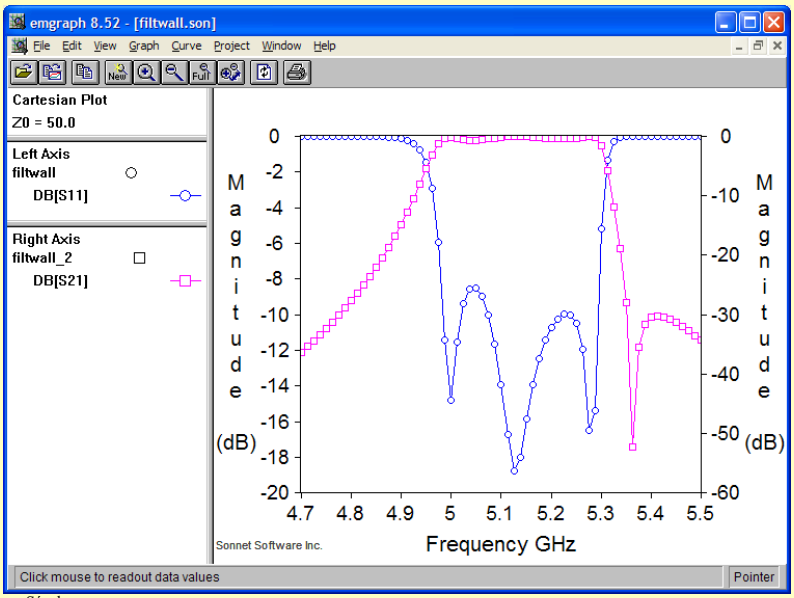
Setting-up the Analysis – Example 1 (cont.)



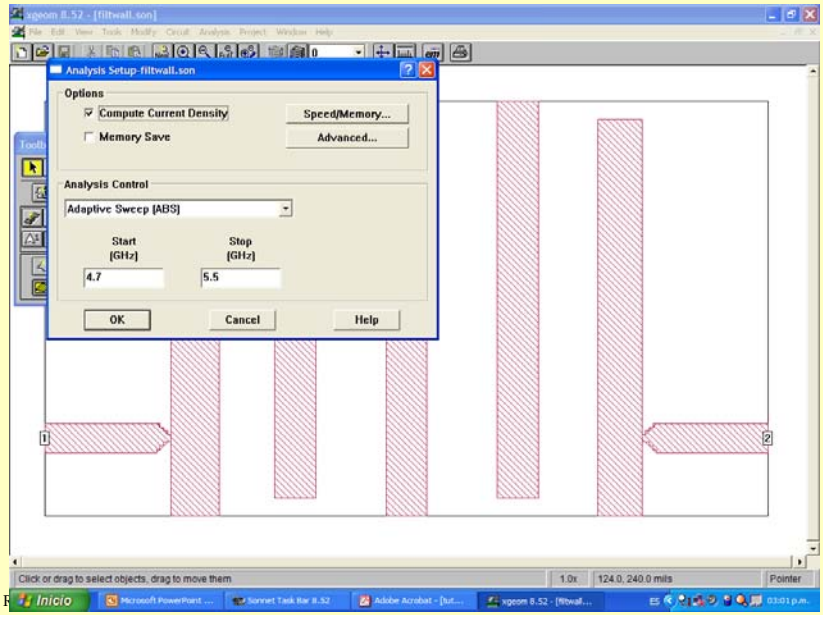
Running the Simulator – Example 1 (cont.)



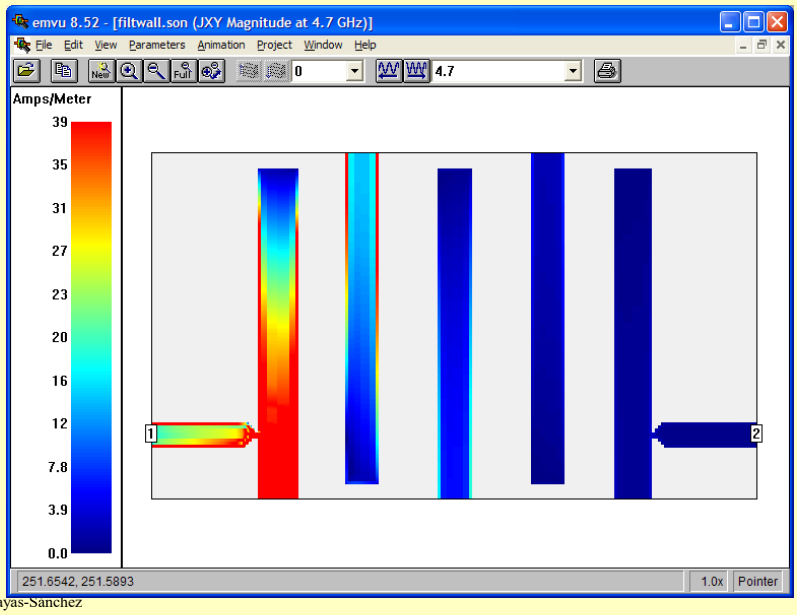
Showing Results – Example 1 (cont.)



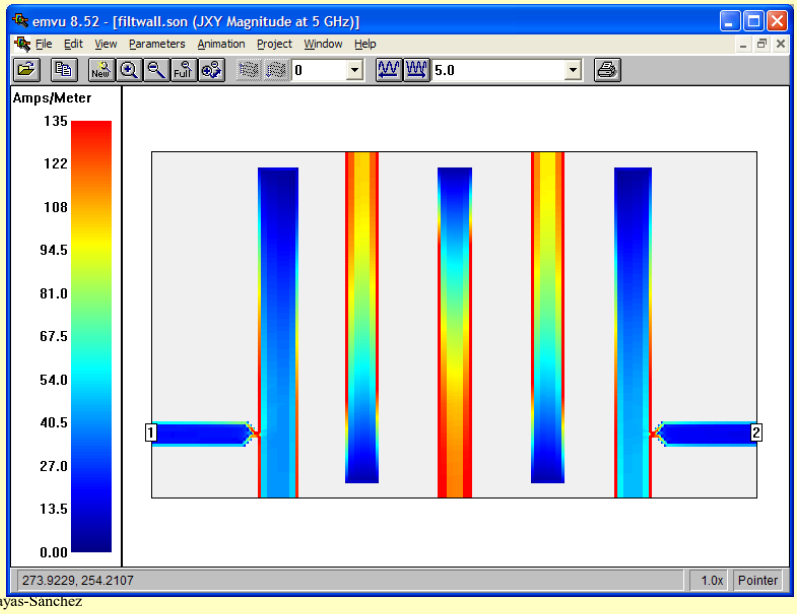
Current Density Viewer – Example 1 (cont.)



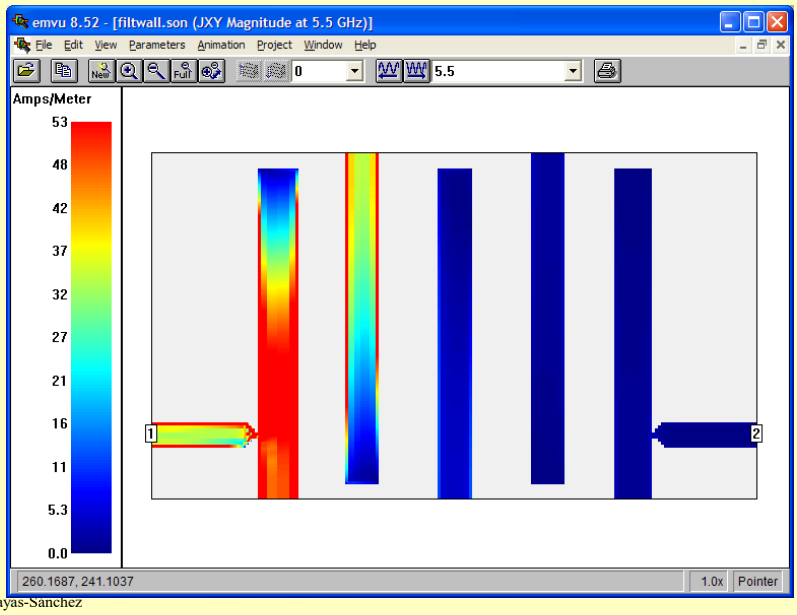
Current Density Viewer – Example 1 (cont.)



Current Density Viewer – Example 1 (cont.)



Current Density Viewer – Example 1 (cont.)



The Substrate, Subsectioning, and Cell Size

- Sonnet encloses the circuit in a metal box
- The substrate covers the bottom area of the box
- Cell Size, Box Size and Number of Cells in each direction (*x* or *y*) are related as

  Cell Size × Number of Cells = Box Size
- The EM analysis starts by automatically subdividing the circuit into small rectangular subsections
- Sonnet uses variable size subsections (small subsections are used where needed)
- A Cell is the building block for all subsections, and each subsection is built from one or more cells
- To reduce memory requirements use a cell size as large as possible

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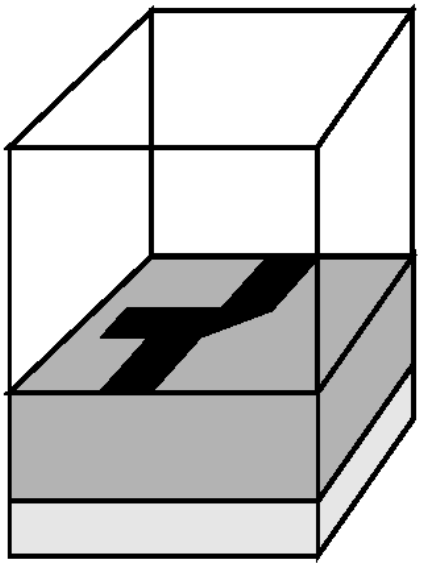
The Box and the Substrate



Em analyzes planar structures inside a shielding box. Port connections are usually made at the box sidewalls. Vias and dielectric bricks (not shown) may also be included.

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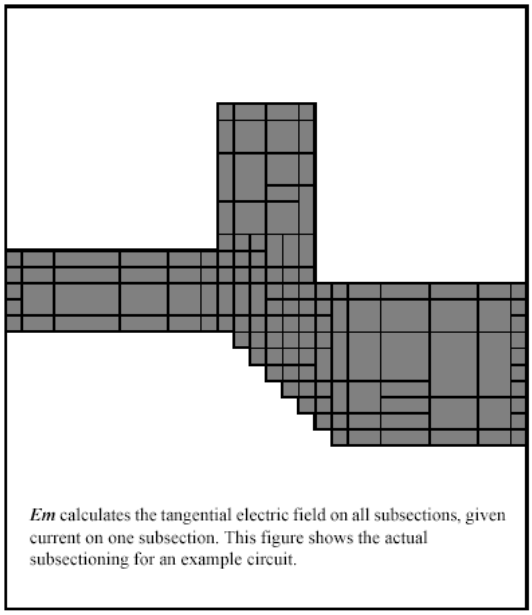
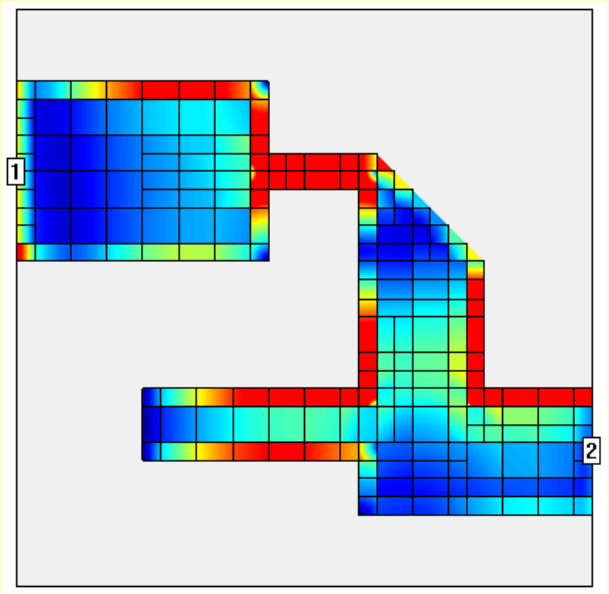
Subsectioning



Em calculates the tangential electric field on all subsections, given current on one subsection. This figure shows the actual subsectioning for an example circuit.

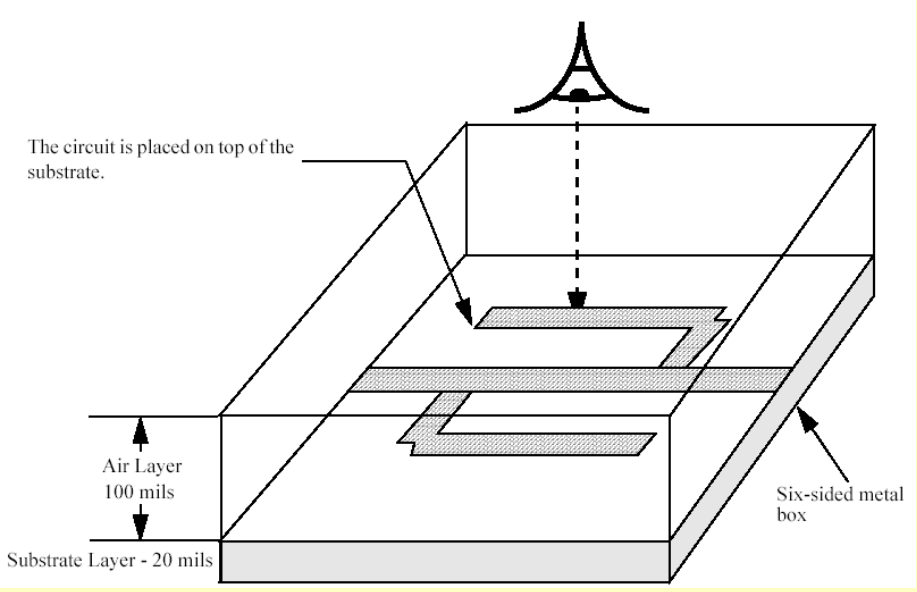
Subsectioning (cont.)



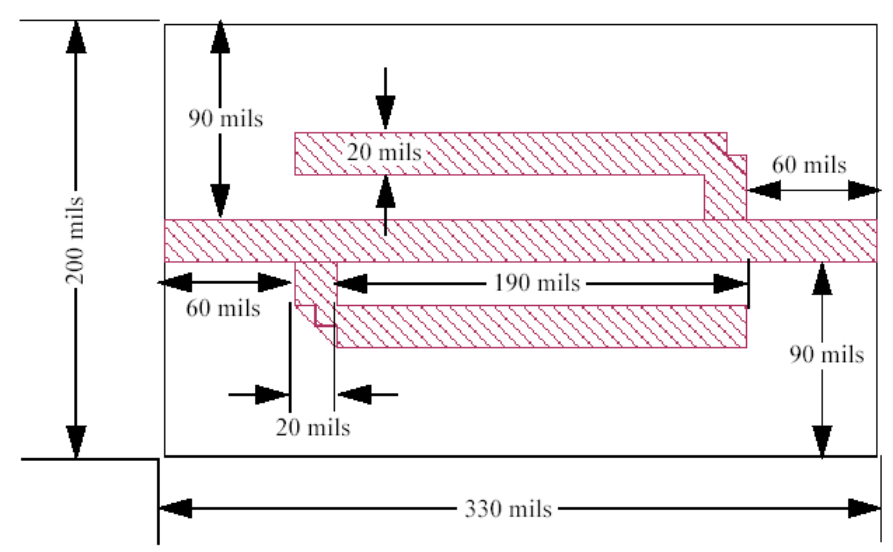
Metalization Levels and Dielectric Layers

- Sonnet Professional can handle any number of metalization levels
- Metalization is refered to as “levels” and dielectric as “layers”
- Each metalization level is sandwiched between two dielectric layers

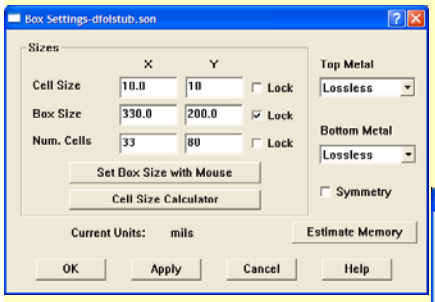
Example 2: A Double Folded Stub Filter

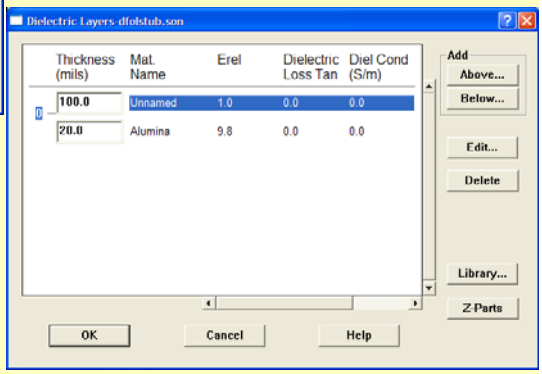


Example 2: A Double Folded Stub Filter (cont.)

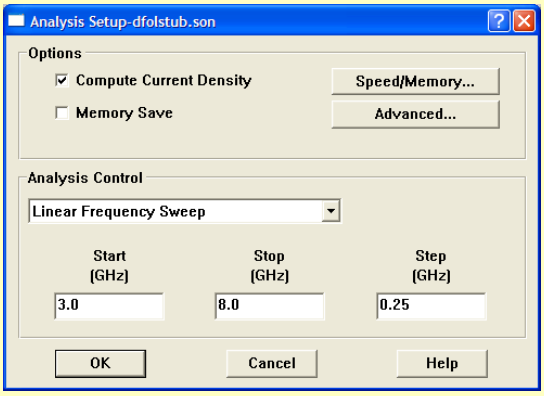


Setting up the Structure – Example 2





Setting up the Analysis – Example 2



$$\lambda_{\min} = \frac{c}{f_{\max}\sqrt{\varepsilon_e}}$$

$$\lambda_{\min} \approx \frac{300\text{Mm/s}}{8\text{GHz}\sqrt{9.8}}$$

$\lambda_{\min}$ = 11.98 mm = 471.61 mil

$\lambda_{\min}$ / 20 = 23.58 mil Cell size < 23.58 mil

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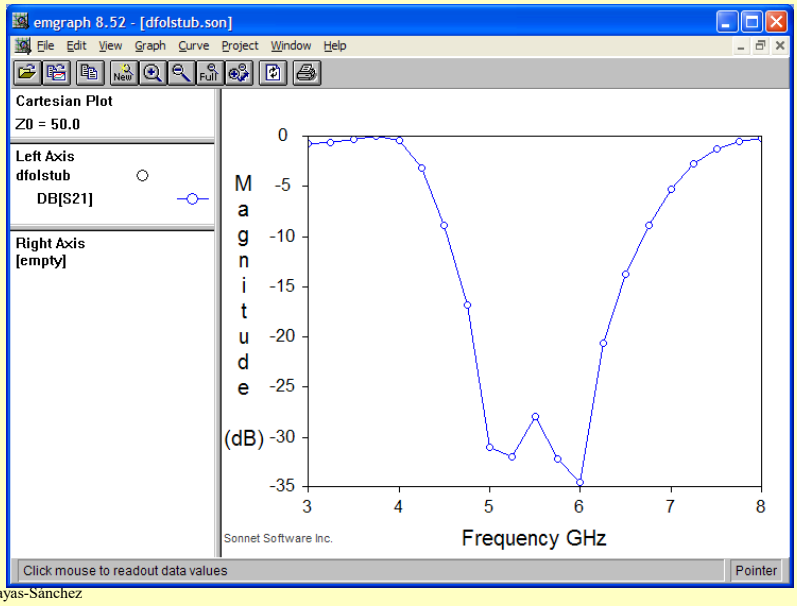
Results – Example 2



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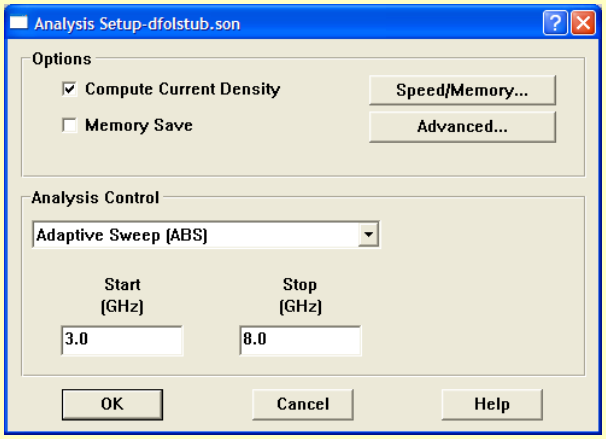
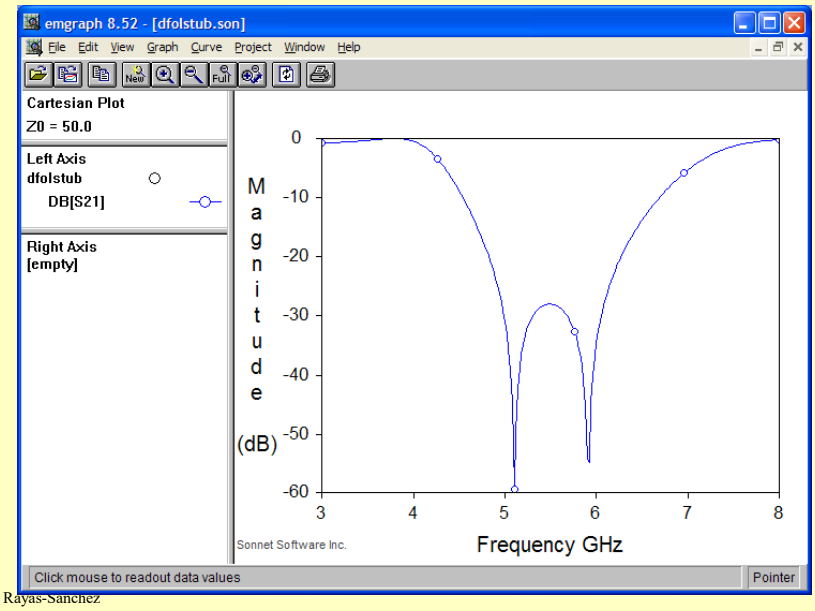
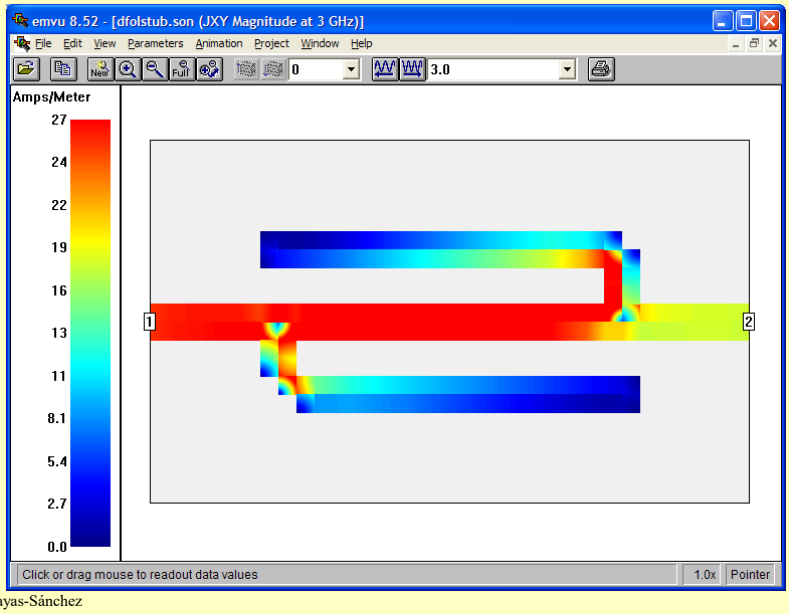
Using Adaptive Frequency Sweep – Example 2



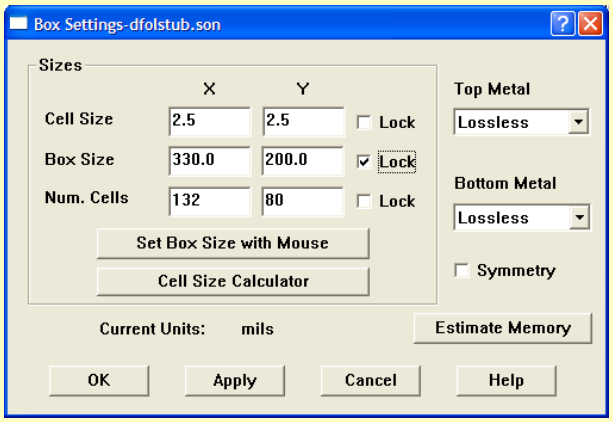
Results – Example 2



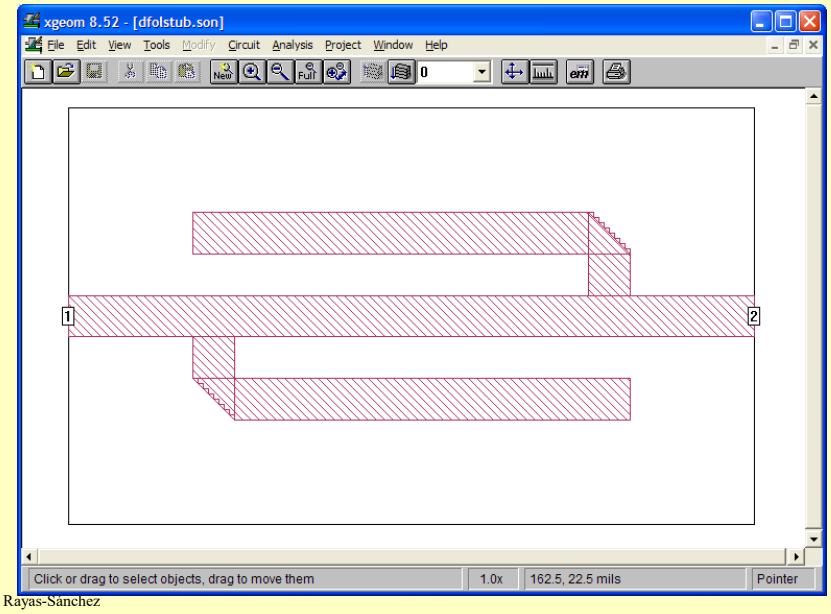
Results – Example 2



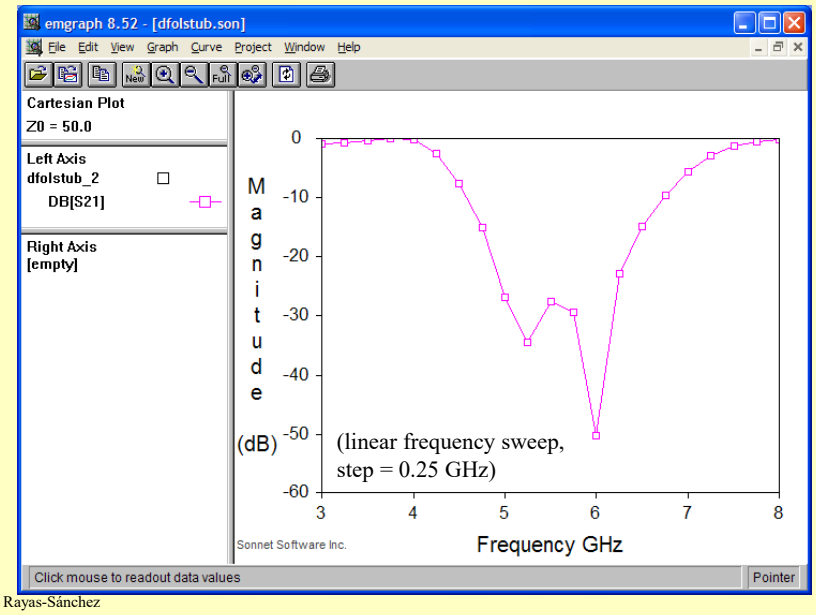
Increasing Resolution – Example 2



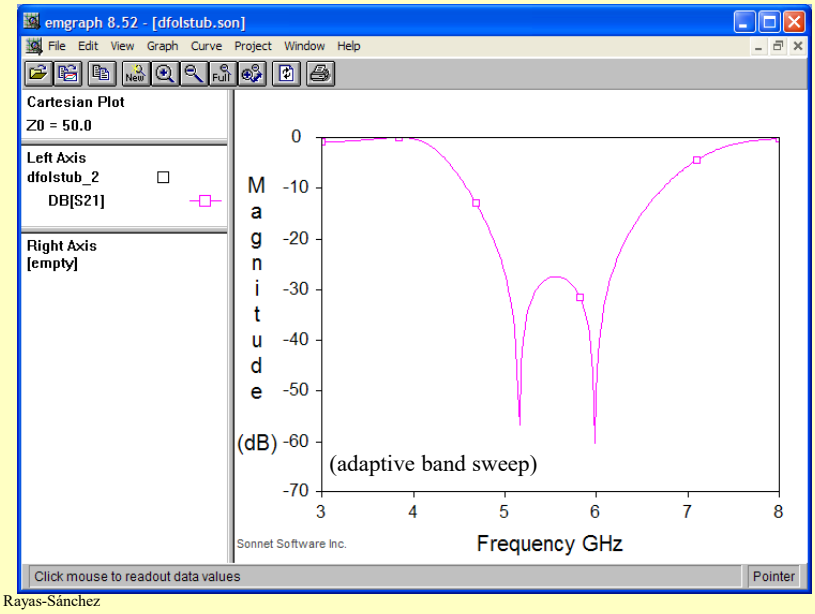
Increasing Resolution – Example 2 (cont.)



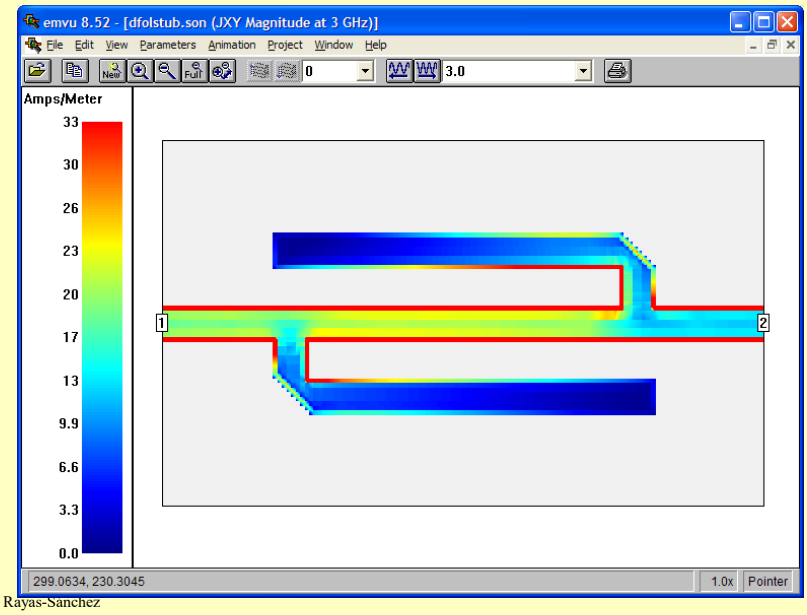
Increasing Resolution – Example 2 (cont.)



Increasing Resolution – Example 2 (cont.)



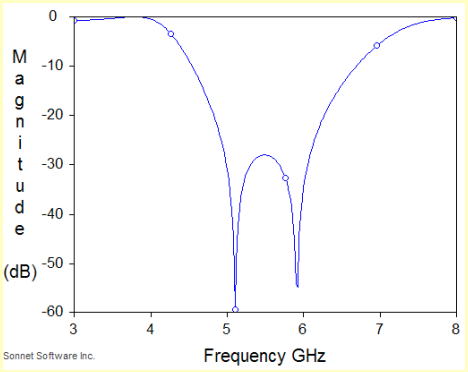
Increasing Resolution – Example 2 (cont.)



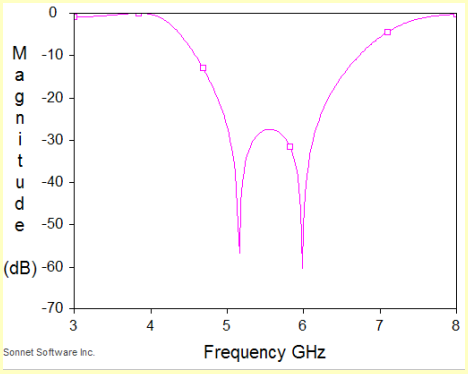
Increasing Resolution – Example 2 (cont.)

Grid size (resolution) should be defined in terms of λ_{min}

Cell size = 10 mil



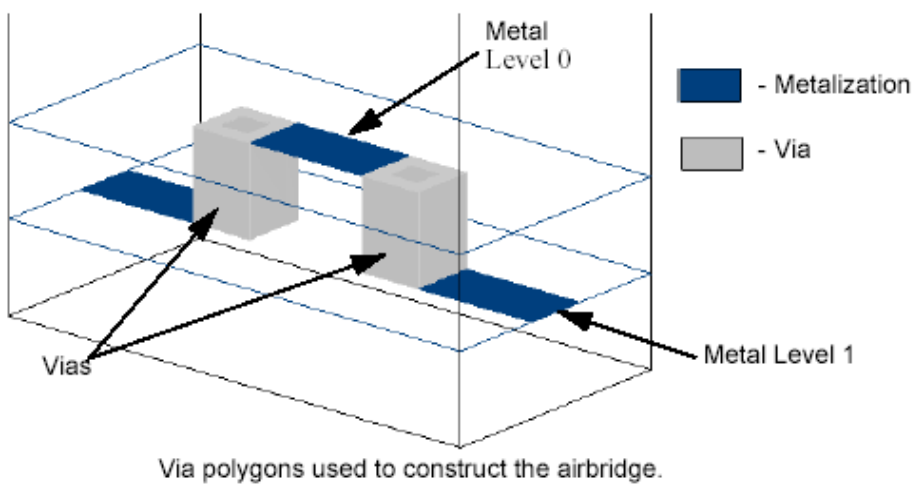
Cell size = 2.5 mil



Vias

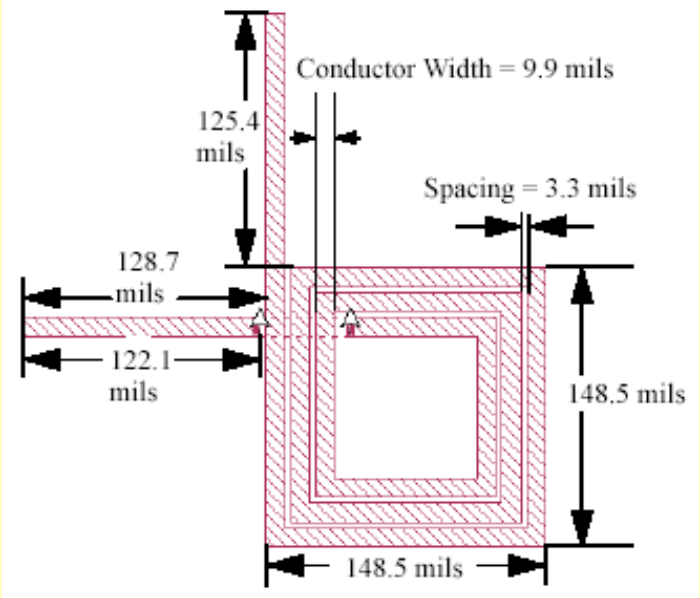
- A special kind of subsection which allows current to flow in the z-direction between metals
- "Ground via" connect metal on the surface of the substrate to the ground plane beneath the substrate
- "Level-to-level via" connect metalization between any two adjacent levels

Vias (cont.)

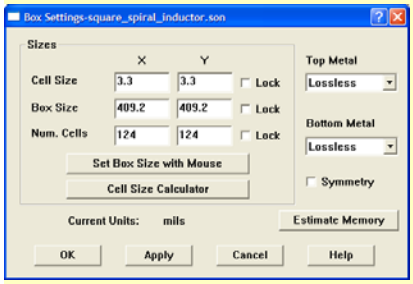


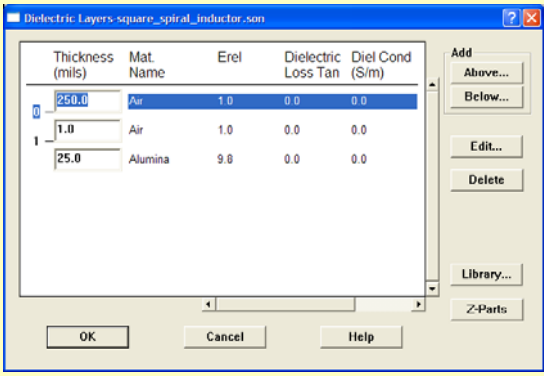
Via polygons used to construct the airbridge.

Example 3: Square Spiral Inductor



Setting Up the Structure – Example 3





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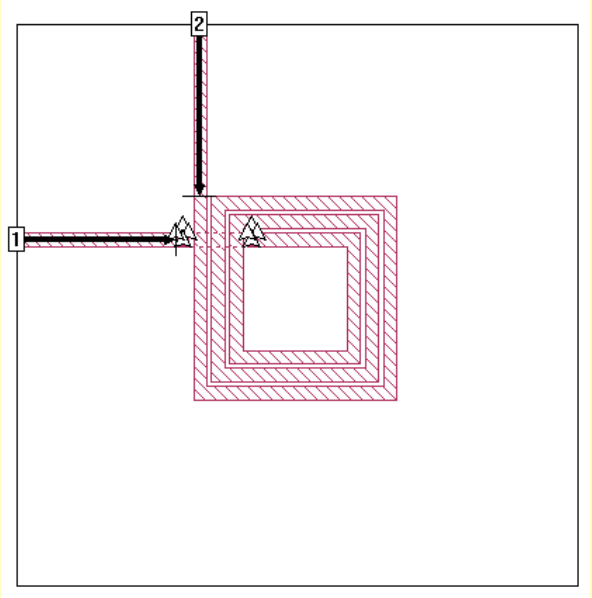
Square Spiral Inductor – Example 3



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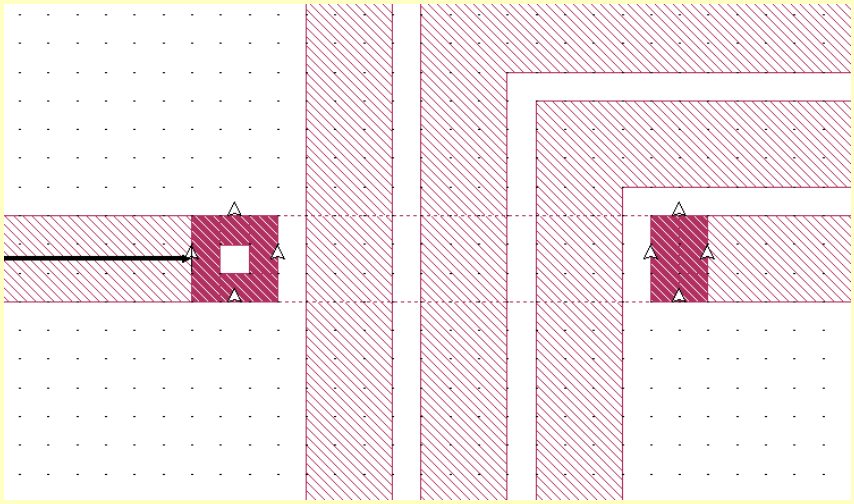
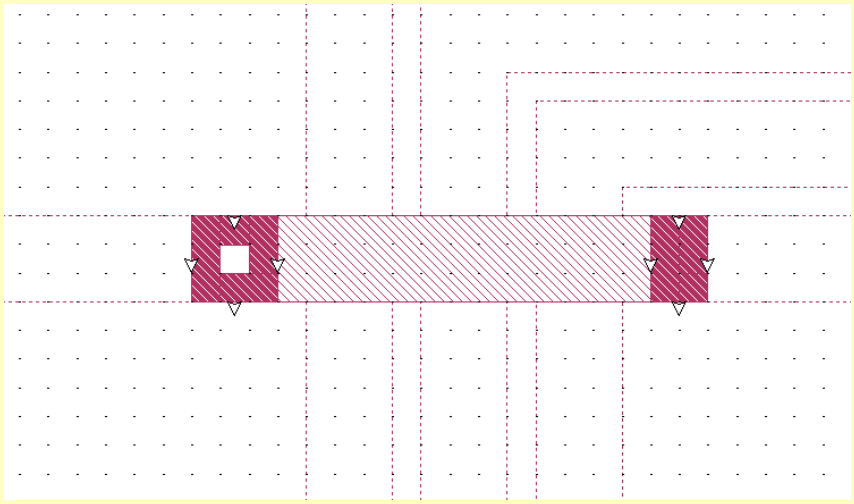
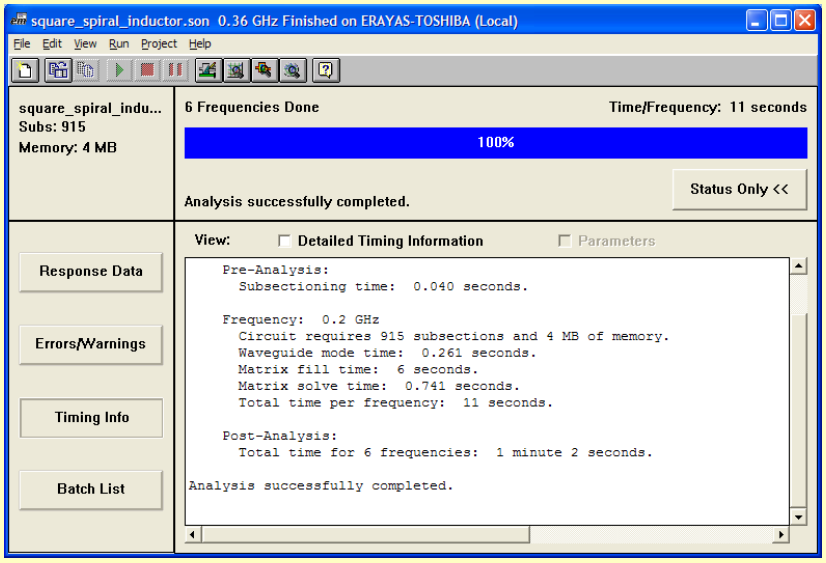
Vias (Lower Level) – Example 3



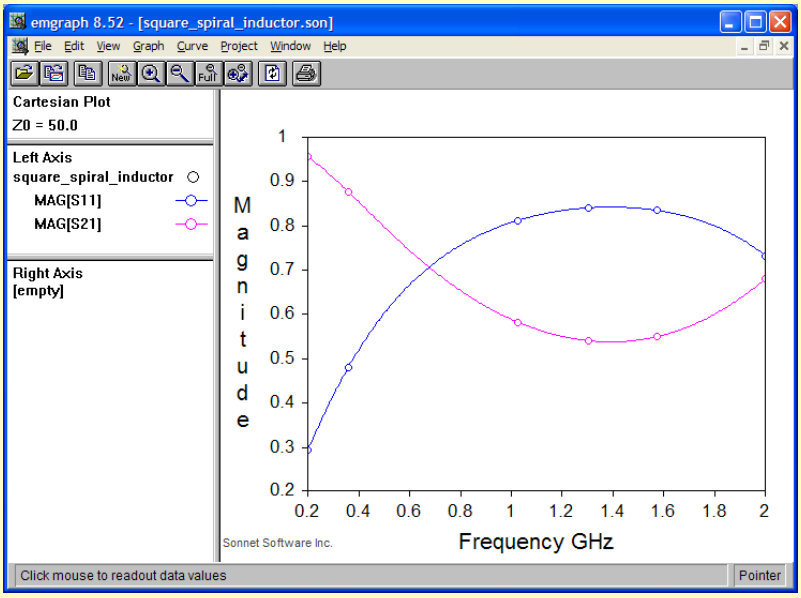
Vias (Upper Level) – Example 3



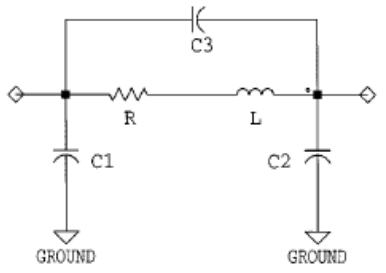
Simulation Time – Example 3

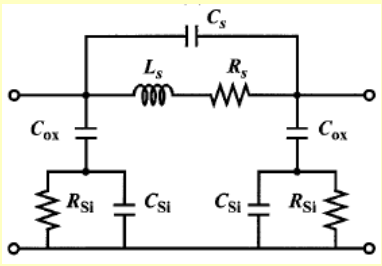


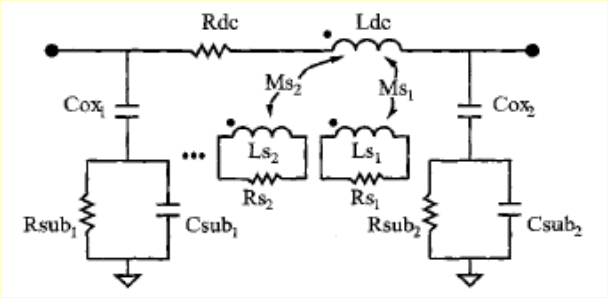
Results – Example 3



Lumped Circuit Models for Spiral Inductors







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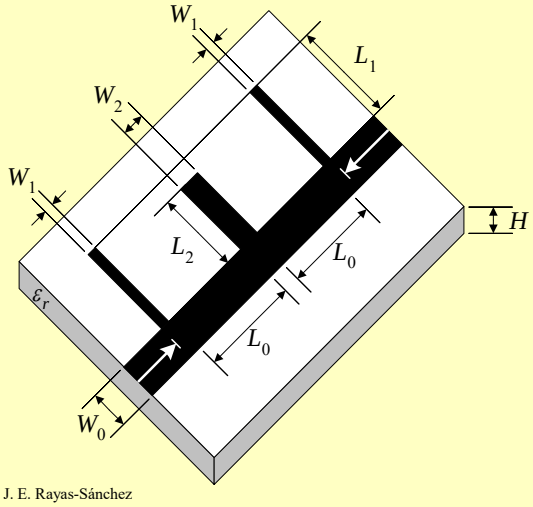
Example 4

Bandstop Microstrip Filter with Quarter-Wave Open Stubs



$H = 25$ mil
$\varepsilon_r = 9.4$ (alumina)
$W_0 = 25$ mil
$W_1 = 9$ mil
$W_2 = 19$ mil
$L_0 = 95$ mil
$L_1 = 115$ mil
$L_2 = 114$ mil

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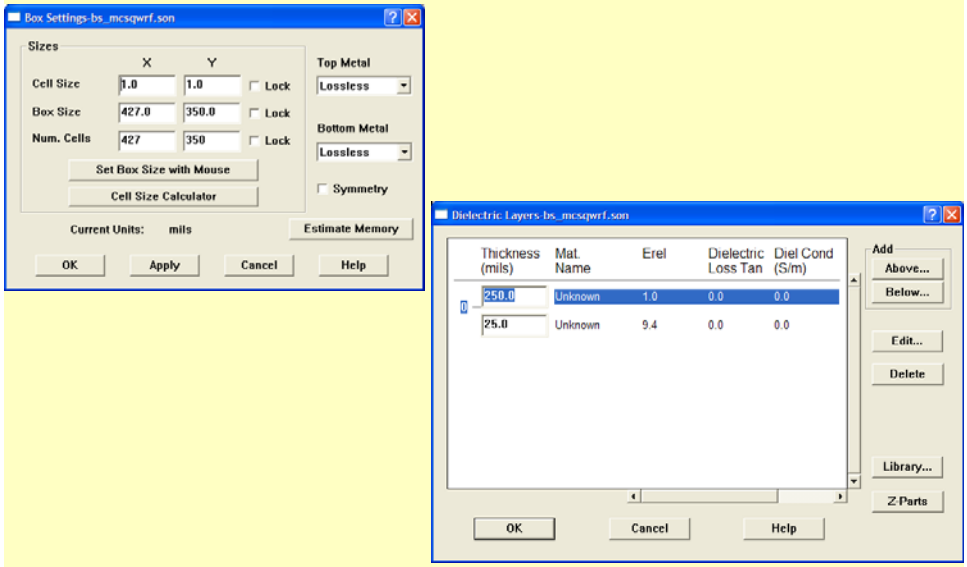
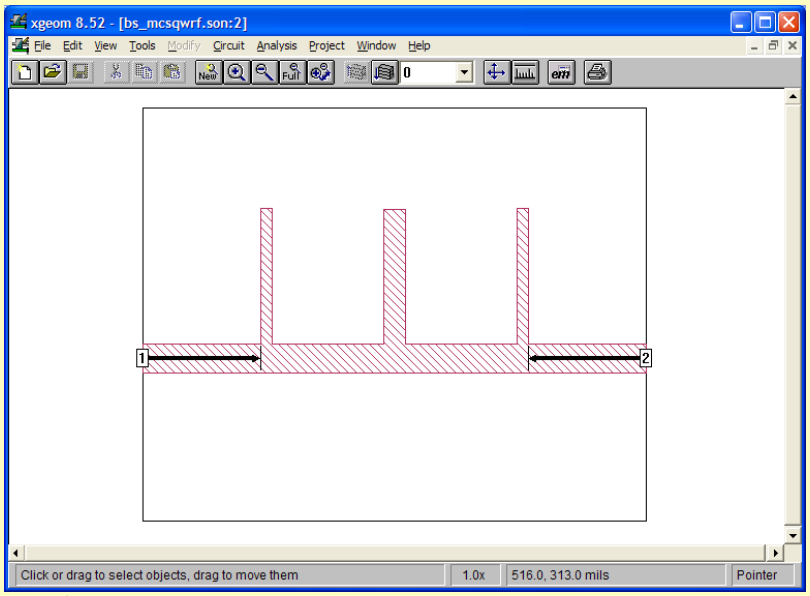
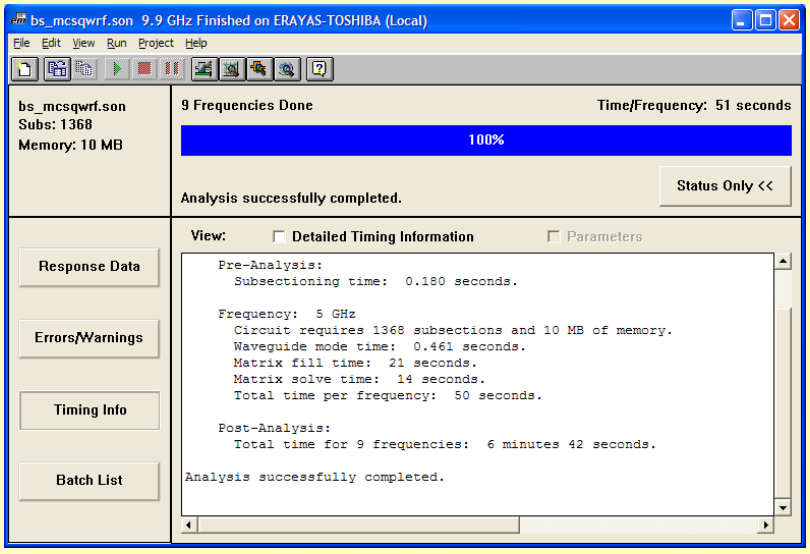
Setting-up Structure – Example 4



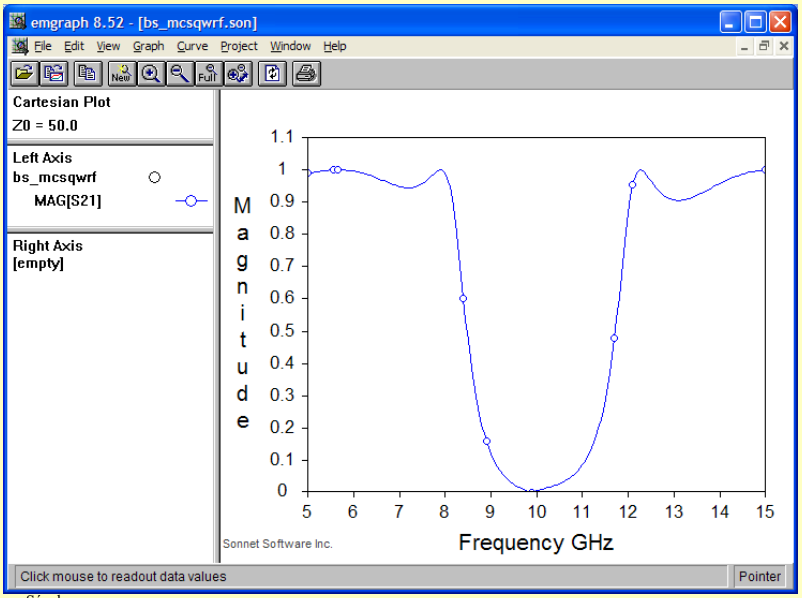
Structure – Example 4



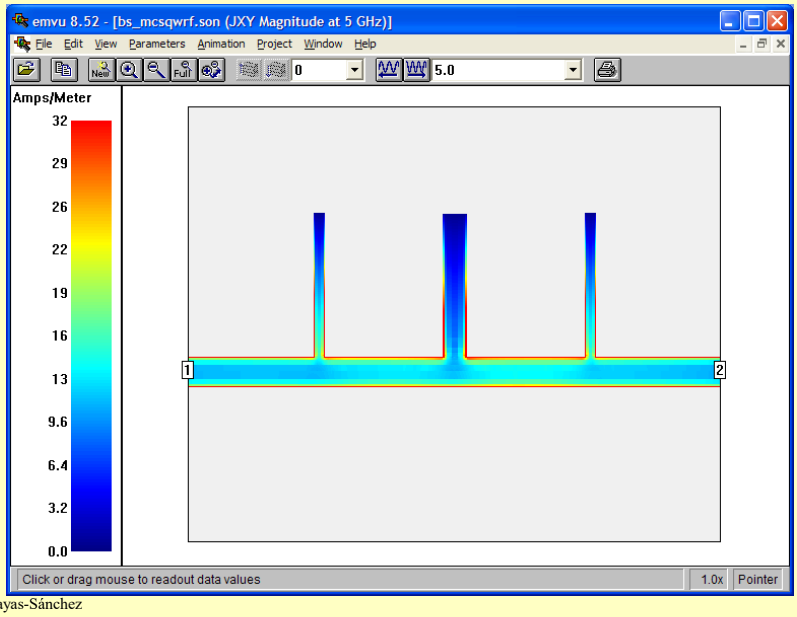
Simulation Time – Example 4



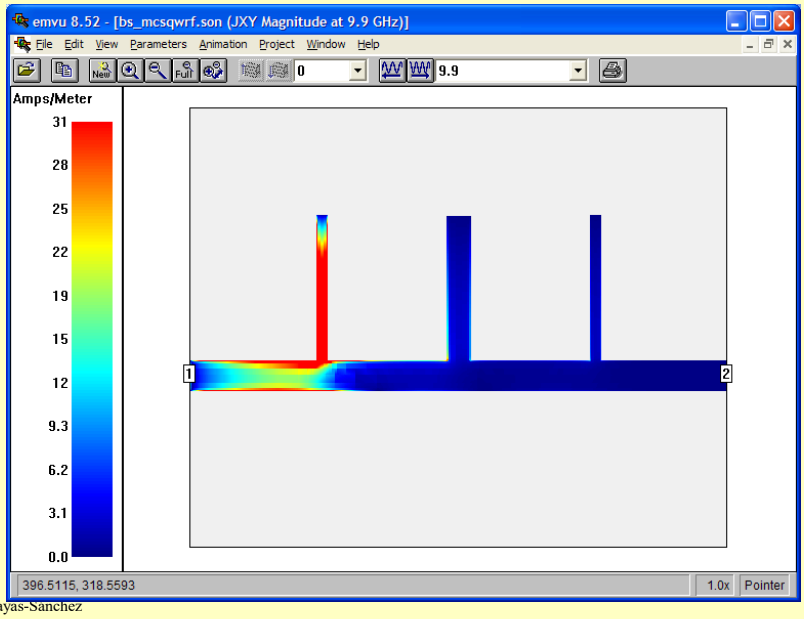
Results – Example 4



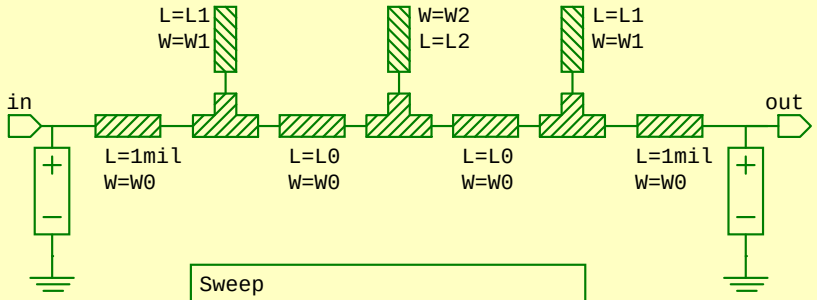
Current Density – Example 4



Current Density – Example 4 (cont.)



APLAC Model – Example 4




```
Declare
iaplacvar
W0 25mil
W1 9mil
W2 19mil
L0 95mil
L1 115mil
L2 114mil
```

```
Sweep
"S-Parameter Analysis"
LOOP 1000 FREQ LIN 5GHz 15GHz
grid

Show Y Mag(S(2,1))
EndSweep
```

```
MSub Alumina_25mil
ER=9.4
H=25mil
```

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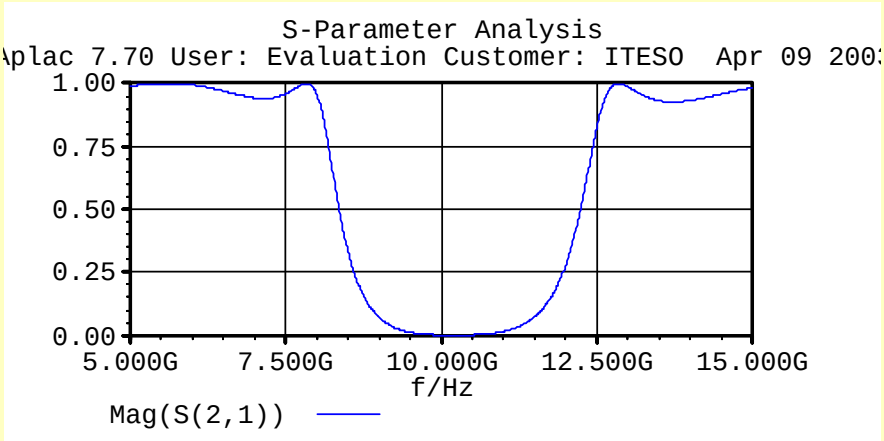
Results using APLAC – Example 4



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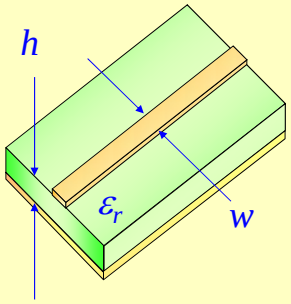
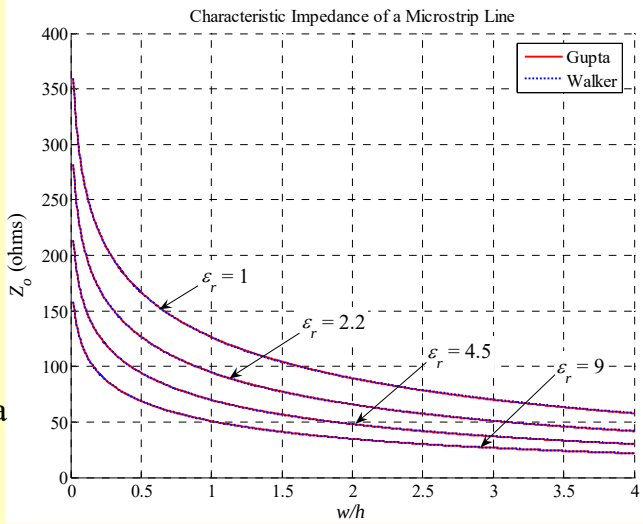
Exercise: A Simple Microstrip Line





- If h = 0.66 mm and ε_r = 9, select w for a 50-Ω line
- Simulate in Sonnet from 0.15-15 GHz (assume L = 10 mm, neglect losses)

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