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Choosing a Grid for Empower Simulation

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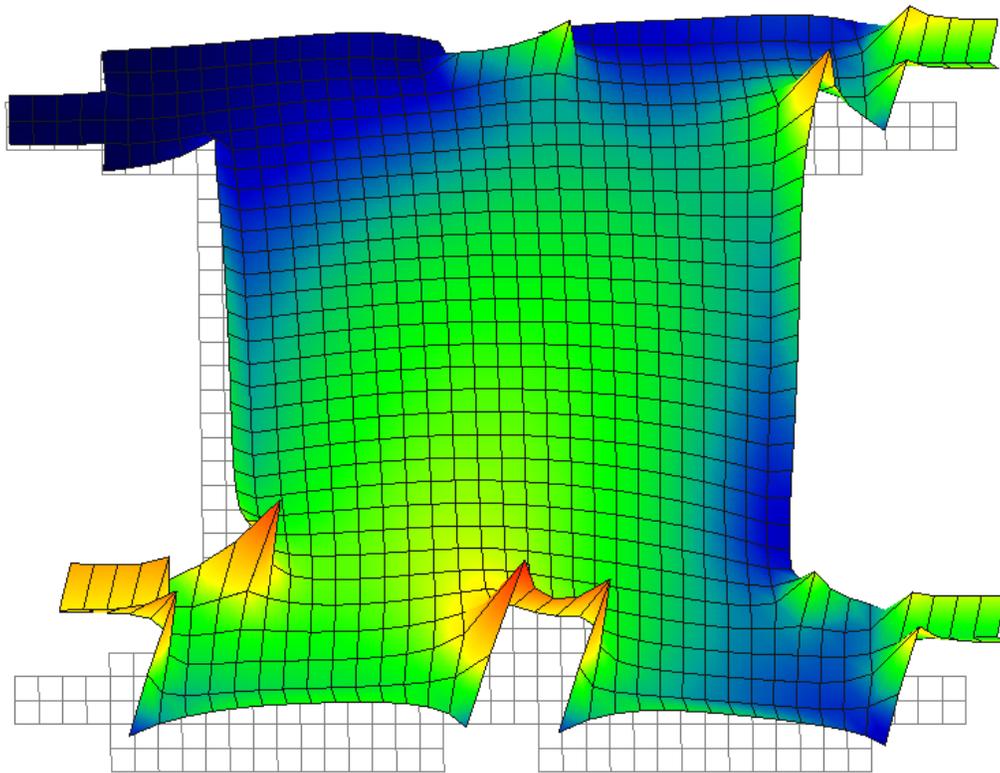
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Eagleware PN 11

**Choosing a Grid for
EMPOWER Simulation**

Product Note



Techniques for ensuring successful electromagnetic simulation with EMPOWER

Choosing a Grid for EMPOWER Simulation

EMPOWER, Eagleware's 3D planar electromagnetic simulator, divides the simulation box (see Figure 1) into many small rectangles to facilitate solution of the layout. This application note describes how to choose the size and shape of this grid, and how this choice can affect simulation time and accuracy.

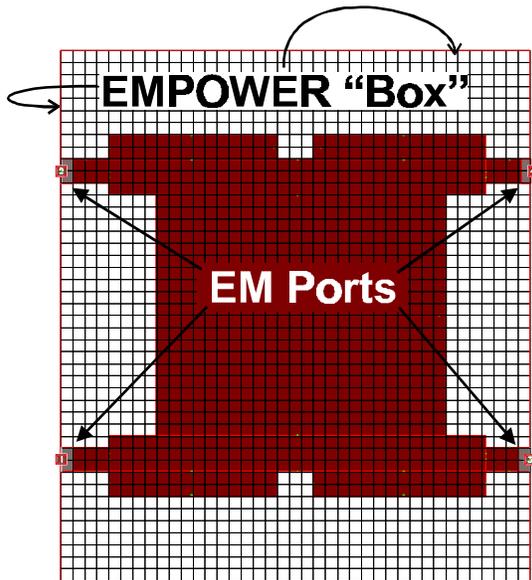


Figure 1: Components of a four port coupler configured for simulation.

What is the EMPOWER Grid?

All electromagnetic (EM) simulators solve complex EM problems in much the same way: A matrix of equations, or system of equations, is constructed and then solved to find current densities, voltages, or EM fields within the structure. EMPOWER uses the Method of Lines (MOL), which solves to find currents within the metal pattern(s) of a layout. The EMPOWER grid is defined in the LAYOUT properties dialog, shown in Figure 2.

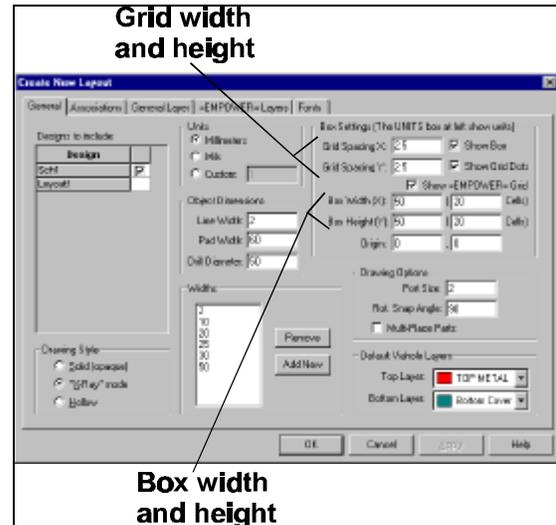


Figure 2: Grid settings are specified in the LAYOUT properties dialog.

Note: To view the EMPOWER grid, the "Show EMPOWER Grid" box shown in Figure 2 must be checked.

Figure 3 shows a single microstrip line with a superimposed grid. The grid is used to form cells in the matrix which EMPOWER must solve. The zoomed grid cell in Figure 3 shows four currents that are added to the matrix. This means that for each cell in the layout, the matrix will have four unknown variables to include in the matrix. The amount of memory required to simulate a particular layout will vary greatly with the grid because some cells have shared walls with common current definitions, which can reduce the number of equations to solve.

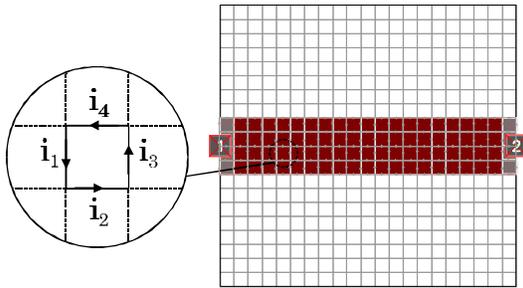


Figure 3: Each cell contributes currents to the matrix to be solved.

Gridding rules to remember:

- In the default mode¹ only metal cells add entries to the EMPOWER matrix;
- The amount of memory required to complete a simulation is directly proportional to the number of cells in the layout;
- The amount of time required to complete a simulation is also a function of the matrix size.

Discretization

As mentioned before, EMPOWER builds a matrix from the layout grid. When adding current values from a grid cell, EMPOWER assumes one of two things:

1. The cell is full of metal or
2. The cell is empty (no metal).

¹ EMPOWER has two modes of calculation: 1) current mode (default), where currents within the metal structure are solved. This is typically used on layouts where more open air or substrate exists than metal (e.g. microstrip and stripline), and 2) voltage mode, where voltages between metal traces are solved. This is typically used on layouts where more metal exists than open air or substrate (e.g. coplanar waveguide and slotline). Voltage mode is enable on a metal layer by selecting the "Slot-Type" checkbox in the EMPOWER Layers property page of the LAYOUT properties dialog.

These are the only two options for adding entries to the matrix, so layouts which do not exactly fit the grid fall victim to a process known as discretization.

EMPOWER uses a simple rule to determine whether a cell is full or empty: If a cell is half filled with metal (or more), it is assumed to be full. If the fill amount is less than half, the cell is assumed to be empty. Table 1 shows cells with partial metal filled percentages. The "Filled" column shows cells that would be simulated as being full of metal. The "Not Filled" column shows cells that would be simulated as empty, or without any metal.

Filled		Not Filled	
			
			

Table 1: Discretization effects on cells with various fill percentages.

Discretization affects the shape of a layout. Figure 4 shows a curved microstrip line on a coarse grid and the resulting structure after discretization. Since the straight portions of the line lie exactly within the grid, these sections will be simulated as intended. However, the curved areas do not exactly fill the cells, so discretization changes the shape of the line. In some layouts, the discretization effects may not be an issue. However, in many layouts, such as Figure 4, several discontinuities are introduced by this process. The resulting simulation in this case may not be representative of the original structure.

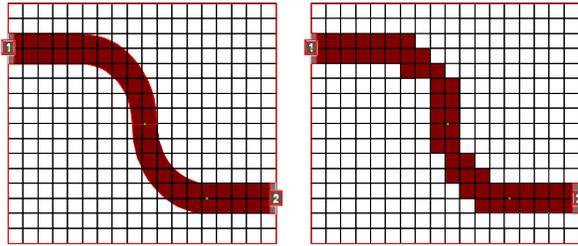


Figure 4: Curved microstrip line with a 4 mm square grid (left) and discretized, actual simulated layout (right).

Figure 5 shows the same curved microstrip line using a grid with half the dimensions of the previous layout.

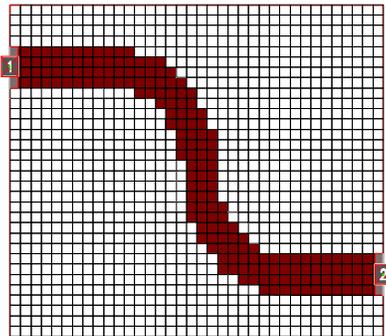


Figure 5: Discretized curved line with 2 mm square grid.

Some structures can suffer enormous discretization errors when the grid size is chosen too large for the structure begin simulated. Figure 6 shows a pair of coupled lines on a large grid. Since there is less than one grid cell in the gap between the lines, and since the cell between the lines is half or more filled, discretization fills in the entire gap with metal. Obviously, the simulated layout will not exhibit the proper behavior of the coupled lines. To avoid this type of problem in cases where there is an intended gap in the layout structure, there should always be at least one empty grid cell in the gap. For the most accurate simulation, at least three cells should be used both across microstrip lines and in gaps, such as the gap between coupled lines. Using a single cell between coupled lines as suggested

above will alleviate filled gap situations (see Figure 6), but will usually be less accurate than three or more cells.

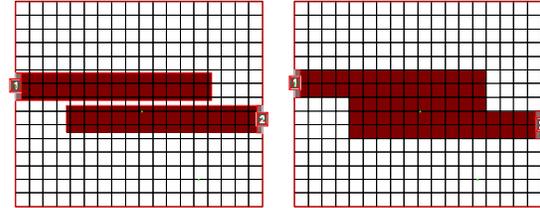


Figure 6: Coupled lines on a coarse grid (left) and the resulting discretized layout (right).

Thinning

EMPOWER employs a built in algorithm called thinning which attempts to combine cells in an intelligent manner to reduce the number of unknown variables (thereby reducing the computation time and memory) without significantly degrading the simulation accuracy. This algorithm usually combines cells in an area of the layout where no discontinuities exist, and where currents are assumed to be more or less constant. In areas of unequal currents, or near discontinuities, cells are not usually combined. Figure 7 shows a single microstrip line and the resulting thinned grid.

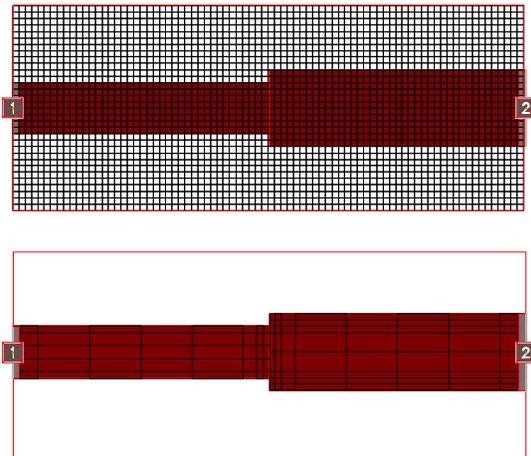


Figure 7: Stepped line (top) and simulated, thinned layout (bottom).

Notice in Figure 7 that the thinned grid contains bigger cells in the region away from the discontinuities (e.g. in the center of each line). The cells nearest the edge of the width step remain as small as the original grid.

The thinned cell sizes are controlled by the user in two ways. First, the original grid size (Figure 7, top) sets the minimum grid cell dimensions. EMPOWER will increase the cell size during thinning, but will never decrease cell size. Second, the maximum grid dimension is set in the EMPOWER setup dialog, shown in Figure 8. This dialog is displayed by double-clicking the EMPOWER simulation in the Workspace window, also shown in Figure 8.

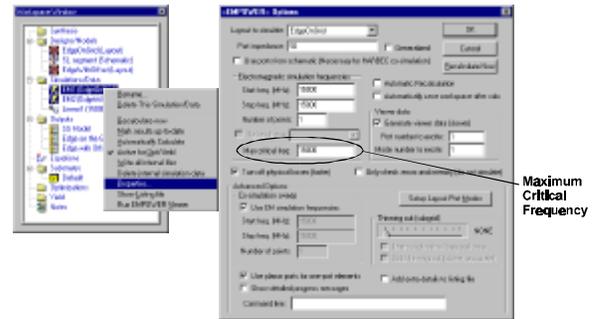


Figure 8: The "Max critical freq" box in the EMPOWER Options dialog controls the maximum cell size created by thinning.

Using the board's effective dielectric constant and the Maximum Critical Frequency (MCF) specified by the user, EMPOWER sets the maximum cell dimension to one-tenth of a wavelength ($\lambda / 10$) at the MCF. This means that the thinning process cannot create cells larger than $\lambda / 10$ at the MCF.

Example: A Tapped Combine Filter

Figure 9 shows the M/FILTER screen for a 2.1 GHz microstrip combine filter. This filter is designed on FR4 ($\epsilon_r=4.8$) with 50 Ω terminations. Figure 10 shows the GENESYS window after optimization. The initial and optimized filter dimensions are shown in Figure 11.

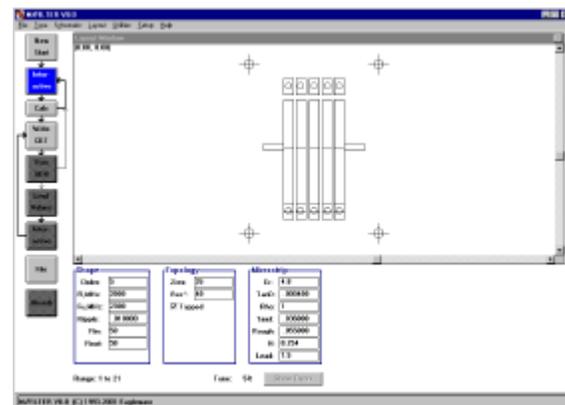


Figure 9: Tapped microstrip combine filter used in the example.

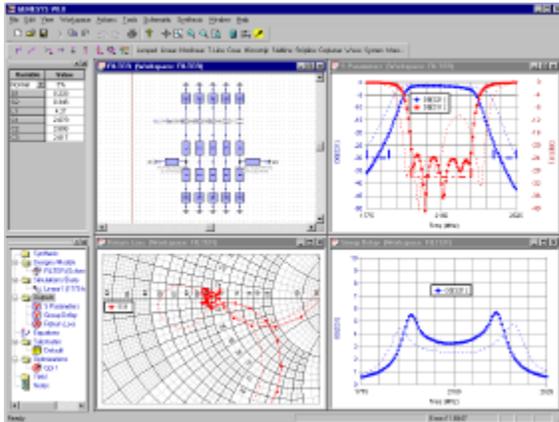
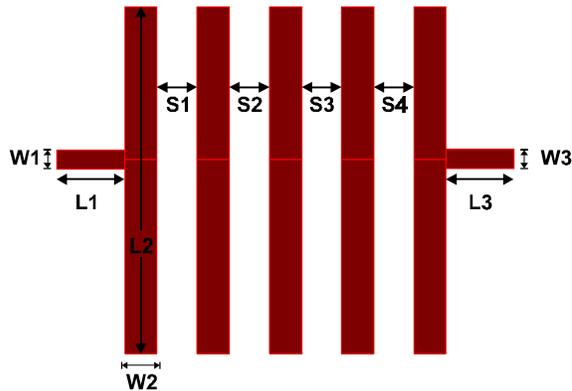


Figure 10: Combine filter workspace after optimization.



Variable	Original (mm)	Optimized (mm)
W1	0.423	0.423
W2	0.716	0.716
W3	0.423	0.423
L1	1.500	1.500
L2	8.018	7.677
L3	1.500	1.500
S1	0.154	0.233
S2	0.243	0.352
S3 (S2)	0.243	0.352
S4 (S1)	0.154	0.233

Figure 11: Original and optimized dimensions for the combine filter. Unchanged dimensions are shown in grey.

To fit on the grid, the grid dimensions must be chosen based on the structure to be simulated. In Figure 11, the optimized dimensions are not even multiples and would be difficult to fit on any grid size. The easiest approach is to round the dimensions to the closest

even size (e.g. 0.1 mm). Table 2 shows the new filter dimensions rounded to the nearest 0.05 mm.

Variable	Rounded Dimensions
W1	0.40
W2	0.70
W3	0.40
L1	1.50
L2	7.70
L3	1.50
S1	0.25
S2	0.35
S3 (S2)	0.35
S4 (S1)	0.25

Table 2: New dimensions for the combine filter, rounded to the nearest 0.05 mm.

Now, the layout is created with a 0.05 mm grid.

Generally, the filter response will change when the dimensions are rounded. If the degradation is severe, it may be necessary to consider a smaller grid size, so that the rounded values remain closer to the optimized dimensions. In some cases, a single dimension can be rounded and taken out of optimization. Then, the remaining values are optimized to recover the response.

Hints for choosing a grid size:

1. When calculating in "current mode," only metal cells add entries to the EMPOWER matrix;
2. The minimum cell size used in simulation is determined by the initial LAYOUT grid;
3. The maximum cell size created by thinning is determined by the "Maximum Critical Frequency";
4. Intentional gaps in metal should contain at least one grid cell to avoid being filled by the thinning process;
5. As a rule of thumb, all microstrip traces should have at least three

- grid cells across to accurately model currents in the line;
6. In general, the time (and memory) required for simulation is directly proportional to the number of cells in the EMPOWER box;
 7. Simulation accuracy is also directly proportional to the number of cells in the box;
 8. Speed and accuracy are inversely related;
 9. The best approach to EMPOWER simulations is to start with a coarse grid (use the rule of thumb given above). Perform a simulation, then decrease the cell size and perform another. When the simulation results do not change from one simulation to another, you have found the correct solution.

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