

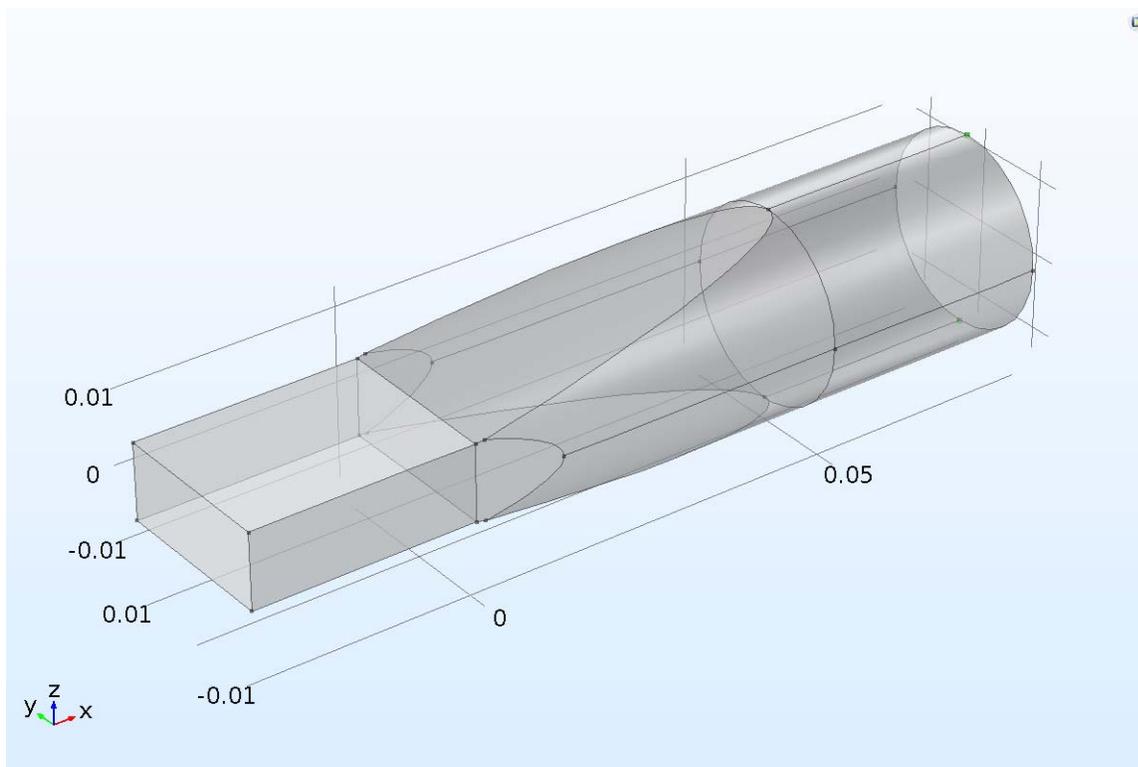
About waveguide ports I

Input and output waveguide ports- an example

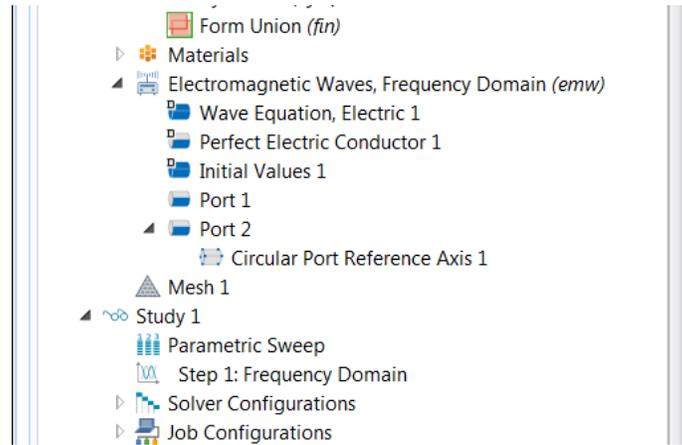
This is the first of a series about using waveguide ports in Comsol. There are, of course, useful examples and documentation available with your installation. However some aspects of the application of the port boundary condition may still be unclear to new users.

I consider here a transition between a rectangular and a cylindrical waveguide. This is similar but not identical to the *waveguide adapter* example shipped with the RF module. Note that the output port is circular rather than elliptical in the example.

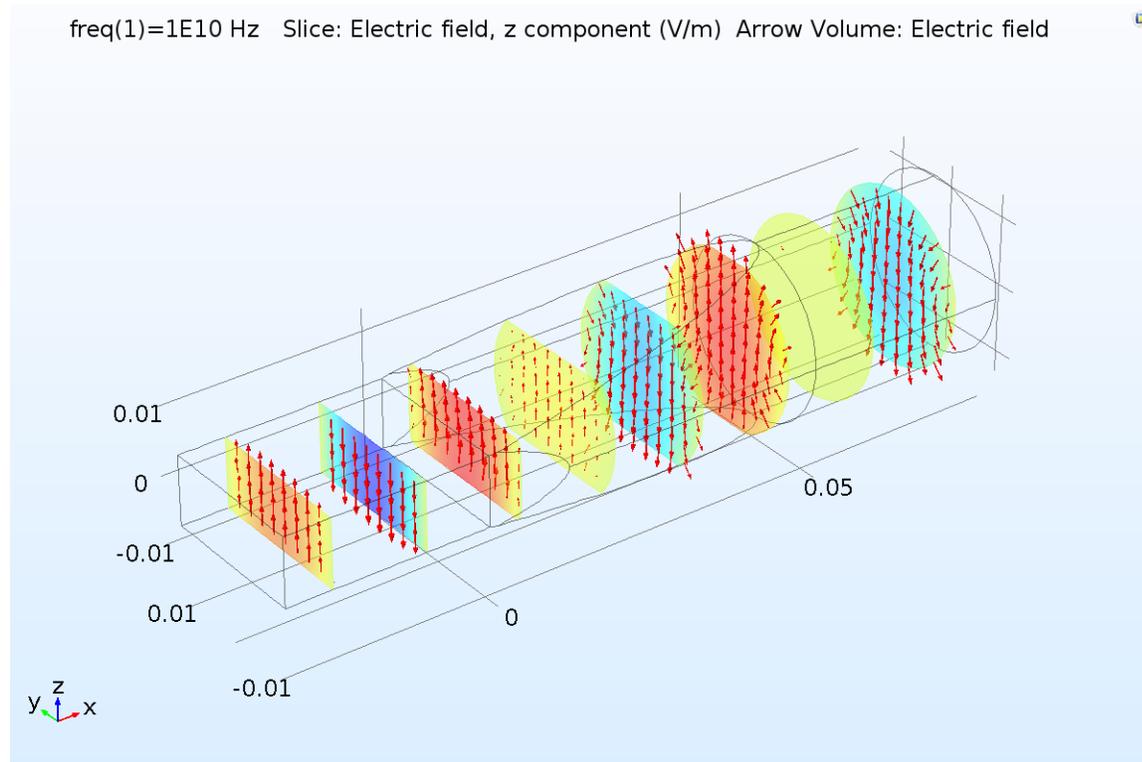
The figure below shows the geometry. The input port is a standard X-band waveguide (0.4" x 0.9") and the the output is a 2.54 cm diameter circular guide.



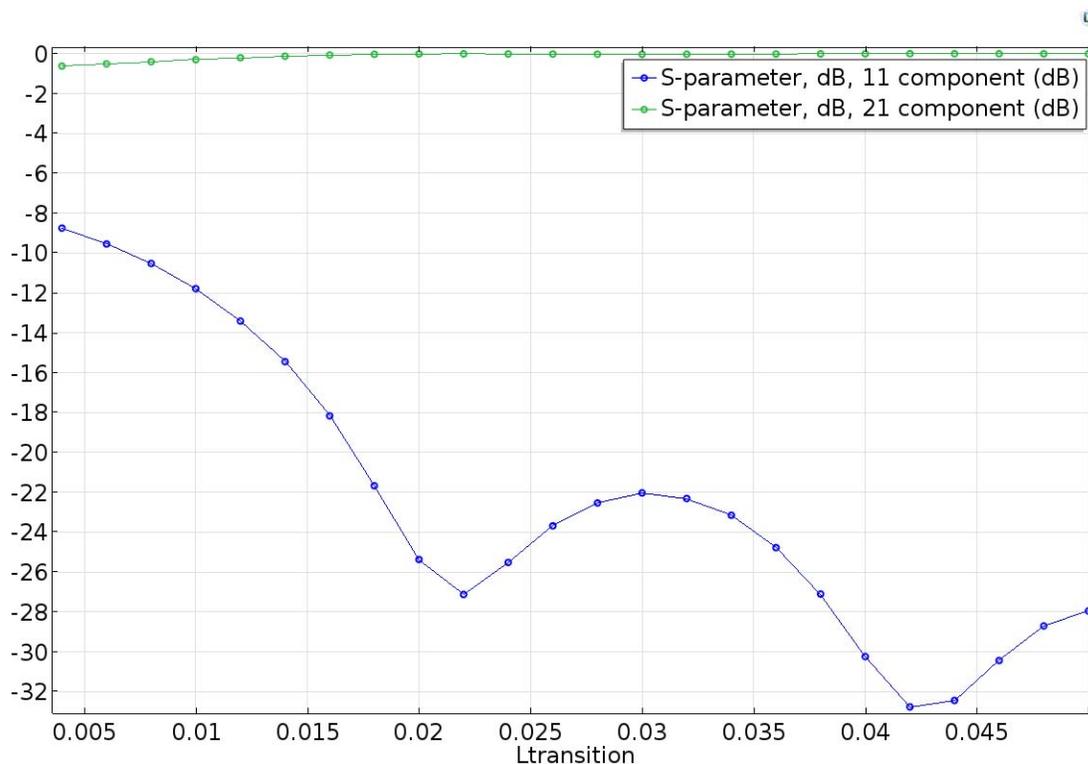
We can use rectangular and circular analytic port conditions at the input and output ports, respectively. The lowest (and the Comsol default) TE waveguide mode at the input is TE₁₀. The lowest circular waveguide mode is TE₁₁, again selected by default. BUT- this mode can have its electric field vector in any direction in the plane of the port! In order to choose the electric field direction, it is necessary to right-click the Port 2 node, and then select Points > Circular port reference axis. THEN two points can be chosen to define the electric field vector direction. I have chosen points defining a z direction (barely visible as green points in the figure above). The snapshot below shows the node for the circular port.



The figure below shows the result of a calculation at 10 GHz. Here arrows represent the electric field (all components) and slice color represents the z component of the electric field. We can see the gradual evolution from the TE₁₀ rectangular mode to the TE₁₁ circular mode in the tapered section.



We can calculate the dependence of the S parameters on the length of this tapered transition region. The result of this calculation is shown below. As we might expect, the transmitted wave increases and the reflected wave generally decreases with increasing transition length. Superimposed on this trend we see a periodic variation in S₂₁ due to reflections within the transition taper.



Let us now turn to the choice of mode at the output port. At first sight it is not clear what this choice does. (Obviously the mode choice at the input determines which mode gets launched). To understand what is going on at the output port we should refer to the equation

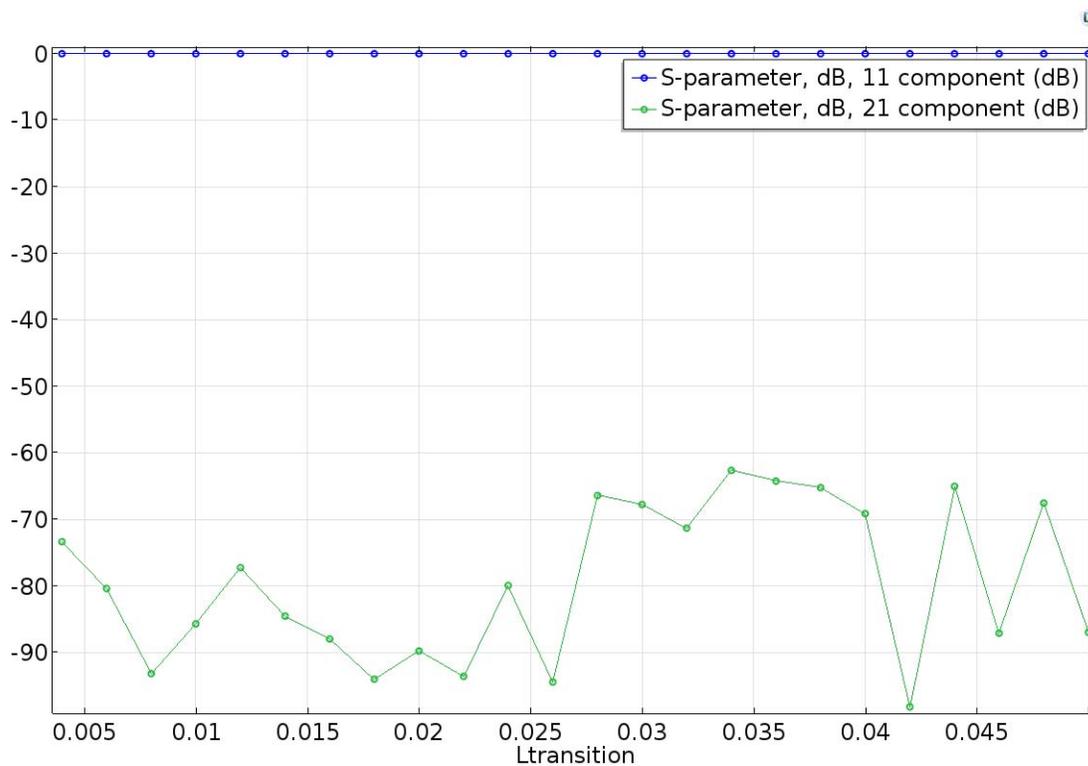
Show equation assuming:

Study 1, Frequency Domain

$$S = \frac{\int_{\partial\Omega} \mathbf{E} \cdot \mathbf{E}_2}{\int_{\partial\Omega} \mathbf{E}_2 \cdot \mathbf{E}_2}$$

Here \mathbf{E}_2 is the electric field corresponding to the mode selected and \mathbf{E} is the electric field solution. When solving, Comsol determines the electric field everywhere in the domain, satisfying the electric field wave equation and the boundary conditions. At the input and output ports Comsol also determines the scattering parameters. The scattering parameters are complex numbers that match the solution electric field to the electric field of the port modes.

So what happens if we pick the *wrong* mode at the output? An easy way to do this is to pick the wrong reference axis for the circular mode (that is, choose points defining a vector in the y direction). The values for S_{11} and S_{21} tell the story. Now S_{21} is very small (indicating no wave emerging from the output port) and S_{11} is almost zero dB (indicating that all of the incident wave is reflected). This happens because the mode we chose for the output port has an electric field polarized in the y direction, and the exciting field has an electric field polarized in the z direction. (In mathematical terms the two polarizations are *orthogonal*). Comsol finds a solution with $S_{21} \approx -\infty$ dB and zero electric field at the output port plane. We have calculated the solution for a short circuit output port!



When to use a port condition (and when not to)

Using a port boundary condition will give a correct result provided the following conditions are satisfied:

1. Only a single waveguide mode is present at the port.
2. The correct waveguide mode is assigned at each port.

Often these conditions are easily satisfied because many waveguide components are designed to have only a single propagating mode. However it is useful to provide an example where this is not the case.

Suppose there is an obstacle in a waveguide. That obstacle in general will cause some degree of mode conversion. If the converted modes are above cutoff they will propagate toward the ports, and the resulting solution cannot be completely correct. If these converted modes are small in amplitude the result may be "good enough;" if the modes are significant the result will be inaccurate.