Quasi-static Analysis of Shielded Microstrip Lines

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Abstract: Microstrip lines are the most commonly used transmission lines at high frequencies.
In this paper, we will illustrate how to model the capacitance of microstrip lines using COMSOL. The goal is to use COMSOL to determine the capacitance per unit length of shielded microstrip lines. We compared the results with those obtained by variational methods and found them to be very close.

Keywords: Shielded microstrip lines, Capacitance, Modeling.

1. Introduction

Microstrip lines are the most commonly used in all planar circuits despite of the frequencies ranges of the applied signals. Microstrip lines are the most commonly used transmission lines at high frequencies. Quasi-static analysis of Microstrip lines involves evaluating them as parallel plates transmission lines, supporting a pure "TEM" mode.

Since there is no exact solution for the capacitance, microstrip lines have been analyzed using different techniques such as moment method, variational method, finite difference method, finite element method, and PSpice [1-6]. These methods evaluate, in different manners, the capacitance per unit length of the microstrip line, from which the characteristic impedance can be obtained. In this paper, we use COMOSL, a finite element package, to model a shielded microstrip line.

2. Results and Discussions of the Model

The shielded microstrip line consists of a conducting strip which is surrounded by a homogeneous, isotropic dielectric medium with permittivity ε_r as shown in Fig 1, where

ε_r = relative permittivity or dielectric constant

μ_r = relative permeability

w = width of the conductor
h = height of the substrate
t = conductor's thickness
d = width of the dielectric material

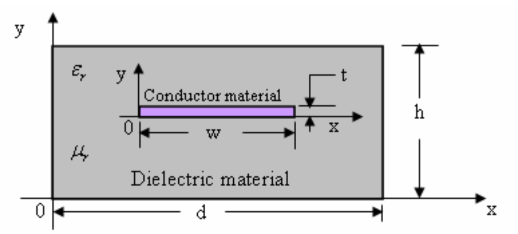

Figure 1. Cross-section of the shielded microstrip line.

We used the variational method [7] to compare our results from COMSOL.

The capacitance per unit length C is

$$C = \frac{Q}{V_0}. \tag{1}$$

Where Q is charge on one conductor in Columbs /meter.
V_0 is potential difference in volts.

The characteristic impedance and the capacitance [8] are related ad derived as

$$Z_0 = \frac{1}{c\sqrt{CC_0}} \quad . \tag{2}$$

Where Z_0 is characteristic impedance.

$c = 3\times10^8 m/s$ (speed of light in vacuum)

C_0 is the capacitance per unit length of the line when all of the dielectric are air ε_r =1.

C is the capacitance per unit length

The transmission line medium is homogenous, that is,

$$\varepsilon_r = \frac{C}{C_0} \tag{3}$$

If we solve for C in (3) and substitute into (2),

$$C = \frac{\sqrt{\varepsilon_r}}{cZ_0} \tag{4}$$

We used the following values for computation using COMSOL.

Dielectric material:

d = 12 mm, h = 1mm, ε_r =1, μ_r =1, σ = 0 S/m.

Conductor material:

w = 1 mm, t = 0.001mm, ε_r =1, μ_r =1, σ = 5.8 x 10^7 S/m (copper).

Based on the dimensions of the microstrip line given above the characteristic impedance obtained from variational method is Z_0 = 65.16 and the corresponding capacitance per unit length is $C = 51.16 pF/m$.

The shielded microstrip line is modeled in two different ways using COMSOL [9].

Method 1, which is called AC/DC method, is based on making a static analysis to get the capacitance directly for the simulation as a variable.

Figure 2 shows the geometry of the shielded microstrip line model used in COMSOL based on the data provided above. We assume that the thickness of the conductor is very small (theoretically zero). In most papers thickness of the conductor is assumed to be zero.

Figure 3 shows the Physical setting for subdomain and boundary conditions used in COMSOL.

The values of the relative permittivity ε_r and relative permeability μ_r are set according to the values given above.

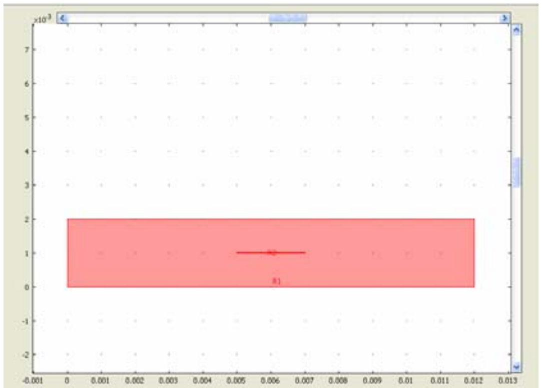

Figure 2. Geometry of the shielded microstrip line model used in COMSOL

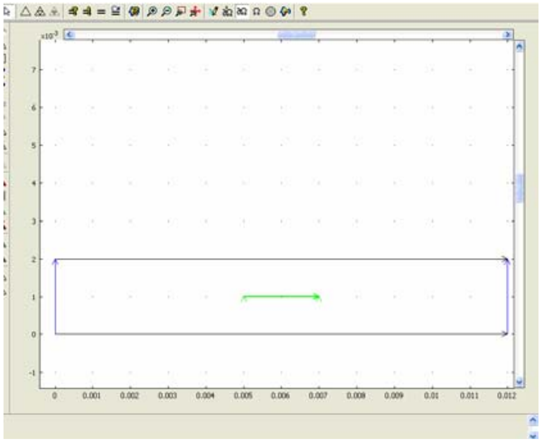

Figure 3. Physical setting for subdomain and boundary conditions used in COMSOL

The software COMSOL is used to generate the mesh for the model as in Fig 4. The mesh consists of 2761 elements.

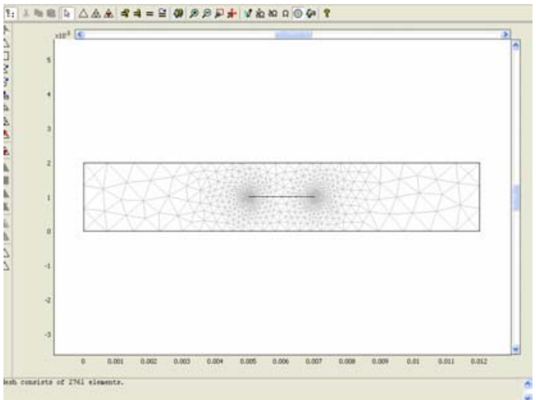

Figure 4. Meshing for the model used in COMSOL (the mesh consists of 2761 elements)

When the model is solved using COMSOL the result is shown in Fig. 5.

The figure shows the potential distribution within the shielded microstrip line.

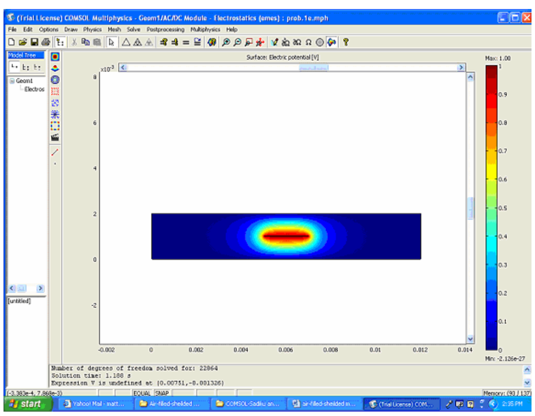

Figure 5. Solution of the generated mesh for the model used in COMSOL.

The potential distribution along line y = h/2 is shown in Fig. 6.

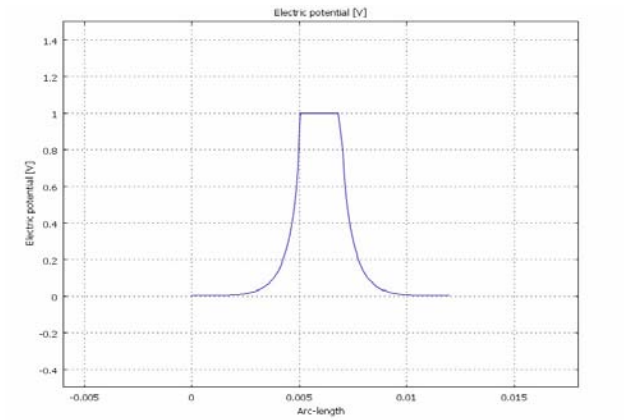

Figure 6. The potential distribution along line y = h/2 for figure 5.

Figure 7 shows the calculation of the capacitance per unit length of the microstrip line. As shown in the figure, the value is C = 5. 11105 X 10^{-11} F/m. This is confirmed by the results from the variational method.

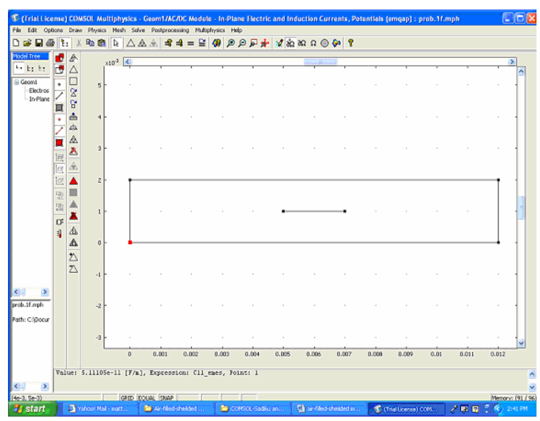

Figure 7. Calculated value of capacitance of microstrip line.

Method 2 is called time-harmonic analysis. We get the capacitance (C) from the admittance (Y) by dividing the imaginary part (Im) with the angular frequency (ω), that is, $C = \dfrac{\mathrm{Im}(Y)}{\omega}$.

The model used for this method is shown in Figure 8 and the correspondent mesh is shown in Figure 9.

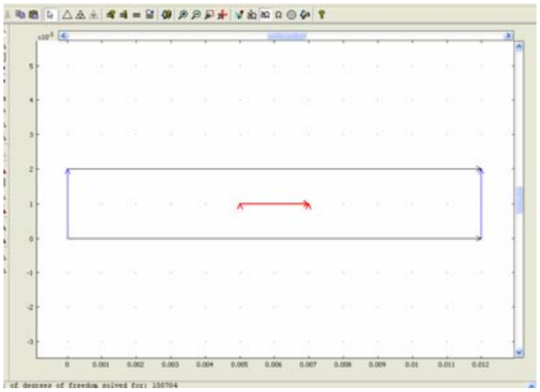

Figure 8. Geometry of the time-harmonic subdomain and boundary conditions for the Model used in COMSOL.

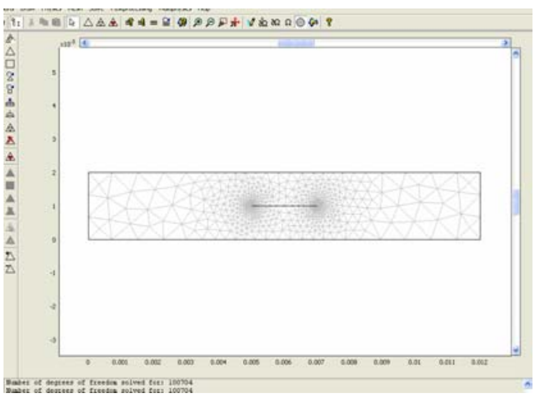

Figure 9. Mesh for the time-harmonic analysis of the Model used in COMSOL (2761 elements).

Figure 10 shows the calculation of the capacitance per unit length of the microstrip line. As shown in the figure, the value is C = 5. 11117 X 10^{-11} F/m. This too is confirmed by the results from the variational method.

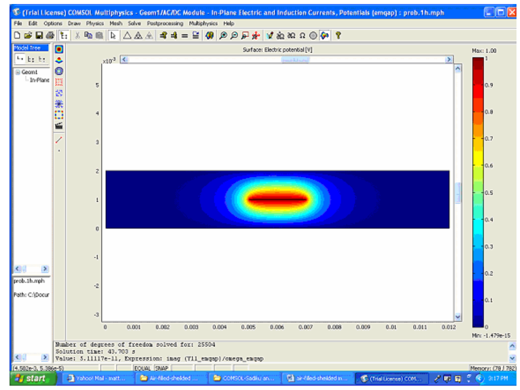

Figure 10. Calculation of the capacitance in the time-harmonic analysis for the Model used in COMSOL.

The potential distribution along line y = h/2 is shown in figure 10 for figure 9.

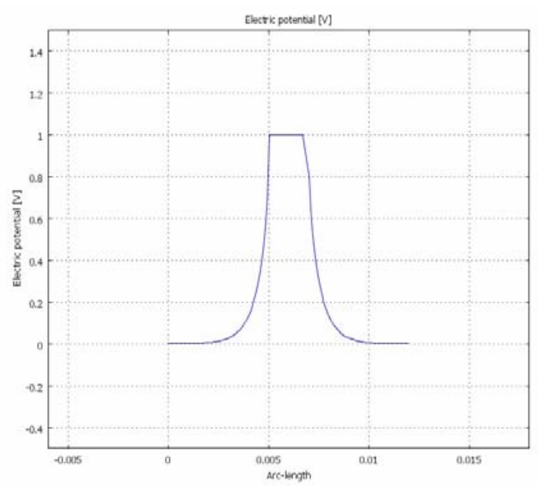

Figure 10. The potential distribution along line y = h/2 for figure 9.

3. Conclusions

The capacitance of shielded micropstrip line has been calculated using COMSOL in two ways. The results of the COMSOL model are compared with that obtained by variational method and found to be very close.

4. References

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