May 10, 2016

ECE 6341

Spring 2016

PROJECT

Note: Please check the date at the top of this page to make sure that your version of the project is the latest one. The latest one will always be the one that is posted on the class Blackboard site.

A microstrip line is shown in Fig. 1 below. The line is located at the interface, $z = 0$. Assume that the surface current density on the line has the form

$$J_{sx}(x, y) = B(y)\, e^{-jk_{x0}x} \tag{1}$$

where

$$B(y) = \frac{I_0 / \pi}{\sqrt{\left(\frac{w}{2}\right)^2 - y^2}} \quad . \tag{2}$$

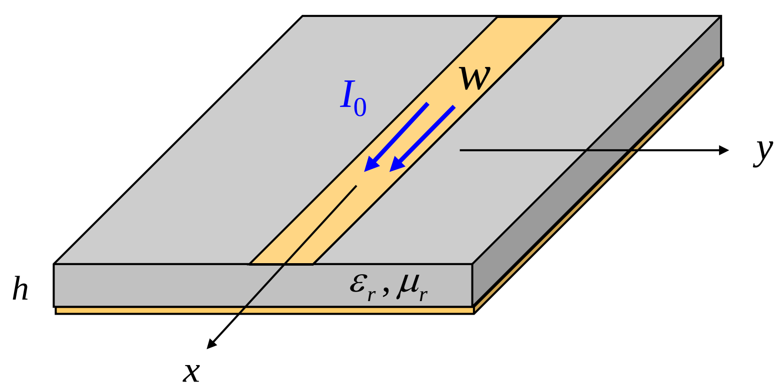

Fig. 1. Geometry of a microstrip line.

Task 1

Your first task is to implement the solution of the transcendental equation for the unknown wavenumber k_{x0} using the spectral-domain method. You may use any software or programming language that you prefer (Mathcad, Matlab, Mathematica, Fortran, etc.). The final transcendental equation is:

$$\int_0^\infty J_0^2\left(\frac{k_y w}{2}\right)\frac{1}{k_t^2}\left[k_{x0}^2 V_i^{TM}(0,0)+k_y^2 V_i^{TE}(0,0)\right]dk_y=0, \tag{3}$$

where

$$V_i^{TM}(0,0)=\frac{1}{D_m(k_t)} \tag{4}$$

$$V_i^{TE}(0,0)=\frac{1}{D_e(k_t)} \tag{5}$$

and

$$D_m(k_t)=Y_0^{TM}-jY_1^{TM}\cot(k_{z1}h)$$

$$D_e(k_t)=Y_0^{TE}-jY_1^{TE}\cot(k_{z1}h).$$

with

$$Y_0^{TM}=\frac{\omega\varepsilon_0}{k_{z0}},\ Y_1^{TM}=\frac{\omega\varepsilon_0\varepsilon_r}{k_{z1}},\ k_{z0}=\left(k_0^2-k_t^2\right)^{1/2},\ k_{z1}=\left(k_1^2-k_t^2\right)^{1/2},\ \ k_t=\left(k_{x0}^2+k_y^2\right)^{1/2}.$$

Task 2

Your second task is to implement the following formula for the characteristic impedance Z_0 using the voltage-current method. The final formula is:

$$Z_0=-\frac{1}{\pi}\left(\frac{k_{x0}}{\omega\varepsilon_0\varepsilon_r}\right)\int_0^\infty J_0\left(\frac{k_y w}{2}\right)F(k_t)\,dk_y, \tag{6}$$

where

$$F\left(k_t\right)=\frac{1}{D_m\left(k_t\right)}\left(jY_1^{TM}\right)\left(\frac{1}{k_{z1}}\right) \tag{7}$$

with

$$D_m\left(k_t\right)=Y_0^{TM}-jY_1^{TM}\cot\left(k_{z1}h\right)$$

and

$$Y_0^{TM}=\frac{\omega\varepsilon_0}{k_{z0}},\ Y_1^{TM}=\frac{\omega\varepsilon_0\varepsilon_r}{k_{z1}},\ k_{z0}=\left(k_0^2-k_t^2\right)^{1/2},\ k_{z1}=\left(k_1^2-k_t^2\right)^{1/2},\ \ k_t=\left(k_{x0}^2+k_y^2\right)^{1/2}.$$

Task 3

Your third task is to derive the following formula for the vertical electric field E_z at the surface of the ground plane (z = -h), for a given value of x and y:

$$E_z\left(x,y,-h\right)=I_0\frac{1}{\pi}\left(\frac{k_{x0}}{\omega\varepsilon_0\varepsilon_r}\right)e^{-jk_{x0}x}\int_0^\infty J_0\left(\frac{k_y w}{2}\right)I_i^{TM}\left(-h\right)e^{-jk_y y}dk_y\,, \tag{8}$$

where

$$I_i^{TM}\left(-h\right)=-\left(\frac{1/D_m\left(k_t\right)}{jZ_1^{TM}\sin\left(k_{z1}h\right)}\right) \tag{9}$$

and

$$D_m\left(k_t\right)=Y_0^{TM}-jY_1^{TM}\cot\left(k_{z1}h\right).$$

Then implement this formula, assuming that I_0 = 1 Amp.

PARAMETERS

Assume the following parameters:

$\varepsilon_r=2.35$

$h=1.524$ mm (60 mils)

$w=2$ mm

RESULTS

1) Find the normalized wavenumber k_{x0} / k_0 using the spectral-domain method for the following frequencies: 1.0 GHz, 5 GHz, 10 GHz, 20 GHz, and 40 GHz. Compare with the results from TXLINE by making a table.

2) Make a table showing the characteristic impedance Z_0 at the same five frequencies as in Part 1 above, calculated using three different methods:

- The voltage-current method described above
- The quasi-TEM method
- Using TXLINE

3) Make a table showing the field E_z on the ground plane (z = - h) at x = 0 for the following values of y: $y = 0$, $y = w/2$, $y = h$, $y = 2h$, $y = 5h$, $y = 10h$. Assume a frequency of 10 GHz.

Make sure that all of your results are accurate to at least four significant figures if possible. (Make sure that your integration in the k_y plane is at least that accurate, and also make sure that when you search for the root of the transcendental equation to find k_{x0} that you find the root to at least this number of significant figures.)

NUMERICAL HINTS

When you perform the integration in k_y, make sure that you check for convergence, with respect to both the limit of integration and the sample density.

You may wish to break up the integration in k_y (from zero to infinity) into several regions; for example $(0, k_0) + (k_0, 10k_0) + (10k_0, 100k_0) + (100k_0, 500k_0)$. This could help with the convergence, since the integrand may oscillate faster for smaller values of k_y., requiring a higher sample density.

GRADING

The project will be graded mainly on the accuracy of the results, but also on the quality of the data presentation in the report, the neatness, and the quality of discussion and interpretation of results. The report must be done using a word processor.

The report should contain the following sections:

- A cover page containing the project title, name of class (ECE 6341), your instructor's name, your name, and any other information that you want to include.
- An Abstract. This should be no more than about one paragraph long, in which a very concise summary of the entire report is given.
- An Introduction. This should be limited to no more than one half of a page. Explain what the purpose of the project is, and what the main objectives are. Give some background and motivation (but do not copy directly from what is already written here in the project description!).
- A Formulation section, giving the derivation of the field on the ground plane.
- A Results section. Note that your grade depends mainly on the accuracy of your results, but also in part on your making some good observations concerning the results.
- A Conclusion section. This should be limited to about one-half page in length. Summarize the main conclusions that you reached while doing this project.
- A References section. Put here any references that you cited in your report.

The project should use a 1.5 line spacing and a Time Roman 12-point font (the same format as this project description is written is). Ideally, MathType (or Equation Editor in Word) should be used for the equations.

The project will be graded mainly on the accuracy of the results and the quality of the discussion — not on length. Do not try to add more length than is necessary. Make sure that you have enough discussion to adequately make meaningful interpretations and conclusions, both in the Results and Conclusions sections.

It is expected that your report will be written using adequate grammar and writing style, and this will also be a part of the grading. This should be the type of report that you would feel comfortable turning into your supervisor if you were doing this as a job assignment. Write accordingly.