ECE 6340

# Fall 2012

### Project

## INSTRUCTIONS

This project is due on Monday, Dec. 10, at 5:00 p.m. (please slip it under the instructor’s door). Please work individually on the project, and do not discuss it with anyone other than the instructor. To do otherwise will be considered a violation of the UH Academic Honesty Policy.

##### PROBLEM DESCRIPTION

A microstrip line is shown below. The line has a characteristic impedance *Z*0(*f*) that is frequency dependent, but the line is designed so that the characteristic impedance is 50 [Ω] at low frequency, i.e., *Z*0(0) = 50 [Ω]. The line has a length *L* = 10 [cm] and is connected to a load *ZL* = 50 [Ω] at *z* = *L* as shown. A signal generator is attached at *z* = 0 with the polarity shown. The signal generator applies a voltage pulse that is described by



where *T* = 2.0×10-11 [s].

## FORMULATION AND CALCULATION

Formulate the transmission line voltage *v*(*z*, *t*). Do this by first solving for the Fourier transform of the voltage at any point *z* on the line. Give enough details to make the derivation complete. However, you do not need to re-derive anything in your write-up that is already derived in the class notes. Then implement the calculation of the voltage using any software package that you prefer to do the inverse Fourier transform integral (the integral in *ω*). Your results should be in the following form:

 (1)

with

, (2)

where *T*(*z*,*ω*) is a transfer function that gives the frequency-domain (i.e., phasor domain) voltage response at *z* due to a unit-amplitude input voltage at *z* = 0. You should derive an expression for the transfer function *T*(*z*,*ω*) for the line having a characteristic impedance *Z*0 that is terminated with a load impedance *ZL*. (The derivation should be similar to that of Prob. 3 on HW 4.)

## RESULTS

## A) Frequency-Domain

1. Plot the characteristic impedance of the line versus frequency from 0 to 100 GHz.
2. Plot the effective relative permittivity versus frequency from 0 to 100 GHz.
3. Plot the conductor attenuation *αc*, the dielectric attenuation *αd*, and the total attenuation *α* (where *α* = *αc* + *αd*) versus frequency from 0 to 100 GHz.

## B) Time-Domain

1. Plot the transmission-line voltage *v*(*z*,*t*) versus *z* for the following times: *t* = 0.1 [ns], 0.2 [ns], 0.3 [ns], 0.4 [ns], 0.5 [ns], 0.6 [ns], 0.7 [ns], 0.8 [ns], 0.9 [ns], 1.0 [ns]. You are making a series of “snapshots” of the voltage wave as it travels down the line, hits the load, and reflects back.
2. Plot the transmission-line voltage *v*(*z*,*t*) vs. *t* at *z* = *L*. This will show what an oscilloscope will read if it is connected to the load.
3. Repeat the above results in parts (1) and (2) assuming that the line is an ideal lossless TEM transmission line. This means that it is lossless (*α* = 0) and that there is no dispersion, so that the effective permittivity does not vary with frequency, and is the value at zero frequency. Also, assume that the characteristic impedance does not vary with frequency, and remains 50 [Ω] at all frequencies.

## FORMAT GUIDELINES

## The project should be done on a word processor and have the following sections:

* Title page
* A brief Abstract
* An Introduction section
* An Analysis section
* A Results section
* A Conclusion section
* A Reference section (if any references are cited)

## The Results section should provide the results that are required, and also provide a thorough discussion of the results.

## A significant part of your grade will depend on the accuracy of your results, so you are encouraged to do as much numerical checking as possible to have confidence in your results.

## A significant part of your grade will also depend on the thoroughness of your discussion and your interpretation of the results.

You will also be graded on the neatness and quality of your write-up, and the quality of your results. Please use good scales and labeling when you plot your results so that the plots are easy to read and look nice.

## NUMERICAL ISSUES

## Numerical experimentation will probably be required to make sure that you have a sufficient limit of integration in for the inverse Fourier transform integral, and that you have a sufficient sample density when you compute the integral (assuming that you program the integration yourself). You may wish to plot the function to help you with this.

## MICROSTRIP GEOMETRY

+

-



*w*

*x*

TOP VIEW

*z*



*L*

*w*

*h*



END VIEW

*t*

*x*

*y*

*w*

**PARAMETERS OF MICROSTRIP LINE:**



 (loss tangent of substrate)

*h* = 1.524 [mm] (60 mils)

*w* = 4.85 [mm] (this should correspond to *Z*0 = 50 [Ω] at low frequency)

*t* = 0.018 [mm] (corresponding to 0.5 oz copper /ft2 for the copper cladding)

*σ* = 3.0 × 107 [S/m] (for typical copper conductors, allowing for surface roughness)

Note:  is the above table denotes  (the real part of the complex effective permittivity). Hence, .

#### **APPROXIMATE DESIGN FORMULAS**

Note: In these formulas, *εr* is the real part of the complex effective permittivity. That is,  denotes .

#### **Phase Constant**



where the “effective relative permittivity” is



 



## Characteristic Impedance



where

 

 

## Conductor Loss

Note: in these formulas,  means .

:



:



:



where



 (This is the skin depth, assuming the metal is nonmagnetic).

#### **Dielectric Loss**





where the “filling factor” *q* is

.

## REFERENCES

L. G. Maloratsky, Passive RF and Microwave Integrated Circuits, Elsevier, 2004.

I. Bahl and P. Bhartia, Microwave Solid State Circuit Design, Wiley, 2003.

R.A. Pucel, D. J. Masse,and C. P. Hartwig, “Losses in Microstrip,” *IEEE Trans. Microwave Theory and Techniques*, pp. 342-350, June 1968.

R.A. Pucel, D. J. Masse,and C. P. Hartwig, “Corrections to ‘Losses in Microstrip’,” *IEEE Trans. Microwave Theory and Techniques*, Dec. 1968, p. 1064.