ECE 6340

# Fall 2013

### Project

Updated: Oct. 9, 2013

## INSTRUCTIONS

This project is due on Monday, Dec. 9, 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

The purpose of this project is to compare the pulse propagation on two common types of transmission lines that are used with printed circuit boards, namely microstrip line and stripline. The two type of transmission lines are shown below. The stripline structure is perfectly TEM in the absence of losses, while the microstrip line has significant dispersion due to the combination of the substrate below the line and air above the line.

The stripline is designed to have a characteristic impedance *Z*0 of 50 [Ω] in the absence of losses. The microstrip line has a characteristic impedance *Z*0(*f*) that is frequency dependent, but the line is designed so that the characteristic impedance of the lossless line is 50 [Ω] at low frequency, i.e., *Z*0(0) = 50 [Ω]. A signal generator is attached at *z* = 0 with the polarity shown in the figure below. The signal generator applies a voltage pulse that is described by

  (1)

where *T* = 1.0×10-10 [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 use in order to calculate the inverse Fourier transform integral (the integral in *ω*). Your results should be in the following form:

 (2)

with

. (3)

## RESULTS

## A) Frequency-Domain

1. Plot the effective relative permittivity of the microstrip line versus frequency, from 0 to 100 GHz. (The effective relative permittivity of the stripline is simply the actual permittivity of the substrate.)
2. Plot the phase and group velocity of each line versus frequency, from 0 to 100 GHz. (The group velocity may be determined by taking a numerical derivative.)
3. Plot the conductor attenuation *αc*, the dielectric attenuation *αd*, and the total attenuation *α* (where *α* = *αc* + *αd*) versus frequency for each line, from 0 to 100 GHz.

## B) Time-Domain

1. Plot the transmission-line voltage *v*(*z*,*t*) versus *z* for the following times: *t* = 0.125 [ns], 0.25 [ns], 0.5 [ns], 1.0 [ns], 2.0 [ns]. You are making a series of “snapshots” of the voltage wave as it travels down the line. Do this for each transmission line and compare.
2. Repeat the above results assuming that the lines are lossless (*α* = 0). That is, there is no conductor loss and no dielectric loss on either line.

## 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.

## GEOMETRY

+

-

*w*

*x*

*z*

TOP VIEW

*w*

*h*

*t*

*x*

*y*

*w*

END VIEW: Microstrip

**PARAMETERS OF MICROSTRIP LINE:**

*w*

*t*

*x*

*y*

*w*

*b*

*b*/2

*b*/2

END VIEW: Stripline

*εr* = 2.33 (Rogers Duroid 5870)

tan *δ* = 0.0012 (loss tangent of substrate)

*h* = 1.575 [mm] (62 mils)

*w* = 4.66 [mm] (this should correspond to *Z*0 = 50 [Ω] at low frequency)

*t* = 0.017 [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)

**PARAMETERS OF STRIPLINE:**

*εr* = 2.33 (Rogers Duroid 5870)

tan *δ* = 0.0012 (loss tangent of substrate)

*b* = 1.575 [mm] (62 mils)

*w* = 1.20 [mm] (this should correspond to *Z*0 = 50 [Ω])

*t* = 0.017 [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 tables denotes  (the real part of the complex effective permittivity). Hence, .

#### **APPROXIMATE CAD FORMULAS**

Note: In these formulas, *εr* is the real part of the complex effective permittivity. That is,  denotes *ε*′*rc*. The characteristic impedances are in ohms and the attenuation constants are in nepers/meter. A nonmagnetic substrate is assumed. It is assumed that the strip and ground plane(s) are made of the same metal, and *Rs* denotes the surface resistance of the metal. The surface resistance of the metal is given by

,

where *σ* is the conductivity of the metal and *δ* is the skin depth of the metal, given (in meters) by

.

**A) Microstrip Formulas**

#### **Phase Constant**

,

where the frequency-dependent “effective relative permittivity” is



where low-frequency value is given by

**

and

.

The effective width is given by

.

## Characteristic Impedance (low frequency)





## Conductor Loss

:



:



:

,

where *e* = 2.71828.

#### **Dielectric Loss**



,

where the “filling factor” *q* is given by

.

**B) Stripline Formulas**

#### **Phase Constant**



## Characteristic Impedance



where



where



## Conductor Loss



,

where



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#### **Dielectric Loss**



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## REFERENCES

E. Yamashita , K. Atsuki and T. Ueda  “An approximate dispersion formula of microstrip lines for computer-aided design of microwave integrated circuits,”  *IEEE Trans. Microwave Theory Tech*.,  vol. MTT-27,  pp.1036 -1038, Dec. 1979.

R. A. Pucel, D. J. Masse, and C. P. Hartwig, “Losses in Microstrip,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-16, 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*, Vol. MTT-16, p. 1064, Dec. 1968.

David M. Pozar, *Microwave Engineering*, 4th edition, Wiley, 2011.