ECE 6340

# Fall 2015

### Project

## Dec. 10, 2015

## INSTRUCTIONS

This project is due on Wednesday, Dec. 16, at 5:00 p.m. (please submit it by slipping it under the instructor’s door). Please work individually on the project, and do not discuss it with anyone other than the instructor.

##### PROBLEM DESCRIPTION

The purpose of this project is to examine how a pulse propagates down a rectangular waveguide from a practical source. The pulse signal is launched by a coaxial probe inside the waveguide.

A vertical probe is inside of an infinite air-filled rectangular waveguide (see the figure at the end). The probe is centered inside the waveguide at *x* = *a*/2 and runs from *y* = 0 to *y* = *b*. The probe may be assumed to have a *y*-directed current *ip*(*t*) that does not vary with the vertical position *y*. The waveguide is a standard X-band waveguide having dimensions



The waveguide is made of copper. The conductivity of the copper is taken as

.

The probe is assumed to have zero radius for simplicity. The probe current is taken as

 (1)

where *T* = 1.0×10-10 [s].

## FORMULATION AND CALCULATION

Derive a formula for the electric field *Ey* (*x*,*z*,*t*) for *z* > 0 inside the waveguide. Do this by first deriving the field *Ey* (*x*,*z*,*ω*) as a function of frequency if the probe current is *I*0 in the phasor domain at a frequency of *ω* = 2*π f* (*I*0 is an arbitrary but fixed complex number that does not depend on time.) Then combine this phasor-domain solution with the Fourier transform method to obtain the electric field in the time domain.

Your result should be in the following form:

, (2)

where

 (3)

and the transfer function is given by

 (4)

with

 (5)

## (6)

 (7)

The formula for the conductor attenuation of the TE*m*0 mode of a rectangular waveguide is

, (8)

## where

. (9)

When we are below the cutoff frequency of a given mode, we ignore the conductor attenuation. that is, the conductor attenuation in Eq. (7) is only added when we are above cutoff.

The square root in Eq. (7) is chosen to make sure that this term is a positive real wavenumber or a negative imaginary number. This can be ensured by choosing the wavenumber of the lossless guide as

## . (10)

Note that

. (11)

Note that the transform of the probe current in Eq. (3) can be obtained in closed form, and you should do this as part of your derivation.

Although the above results give the exact field in the waveguide at any *z* and any time *t*, numerical results may be difficult to obtain due to the large number of waveguide modes required. To simplify the problem for calculation purposes, we can take only the TE10 waveguide mode, so that we use a transfer function given by

. (12)

This corresponds practically to putting a filter in the waveguide to filter out all of the waveguide modes except the TE10 mode.

## RESULTS

1. Plot the field *Ey* (*x*,*z*,*t*) vs. *t* at *x* = *a*/2, for the following distances:

*z* = 0.01 m, 0.1 m, 1 m, 10 m, 100 m.

1. Repeat the above results assuming that the waveguide is lossless (*αc* = 0 for all of the modes).

In all of the results, assume only the TE10 mode, so that the transfer function is taken as that of Eq. (12).

**VALIDATION**

If you set

, (13)

where *A* is some positive constant, then your output waveform *Ey* (*x*,*z*,*t*) should be the same as your input probe current waveform *ip*(*t*), except that it is scaled by a factor of *A* and delayed in time by *z*/*c*. It is strongly recommended that you do this validation first, to make sure that your numerical inverse Fourier transform integration is working properly, before you obtain results for the actual waveguide.

## FORMAT GUIDELINES

## The project should 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)
* Appendices (optional)

## The Results section should provide the results that are required, and also provide a discussion of the results. Feel free to include any additional results that you wish.

## A very 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. Another important part of your grade will depend on the discussion and your interpretation of the results, as well as a discussion of the numerical aspects of the project.

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.

## The project should be done on a word processor, with the equations also done in the word processor. You may use any word processor that you wish. However, it is recommended that you write the report using Microsoft Word along with MathType to do the equations. (This is how this project document was written.) For a free 30-day trial version of MathType, please visit www.mathtype.com.

## 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 transform of the probe current as a function of *ω* to help you with this. Breaking up the numerical integration in into several subregions might also prove to be helpful.

## You may also wish to explore how many terms of the series you need to keep to get convergence. Note that as the distance *z* increases, the higher-order modes will decay faster when they are below cutoff. Therefore, the smaller *z* is, the more terms of the series you should expect to need.

## GEOMETRY

END VIEW



Probe



TOP VIEW



Probe

