

ECE 3317

Fall 2023

Project

Date of last update: Oct. 31, 2023

Due Date

This project is due at 11:59 p.m. on Monday, Dec. 4. (This is after the last day of class.) Please submit it by sliding it under the instructor's door (no electronic submissions).

Academic Honesty Policy

You are expected to work on this project entirely by yourself. Do not discuss the project with anyone other than the instructor. To do so will be considered a violation of the UH Academic Honesty Policy.

Corrections

If there are any corrections or updates to the project, they will be posted on the class Canvas site. The class Canvas site will always have the latest version of the project. Please periodically check the "date of last update" on the top of the first page to make sure that your version of the project is the latest.

Project Description

A microstrip line of width w (the "feed line") having a characteristic impedance of $Z_0 = 50 \text{ } [\Omega]$ is connected to a device as shown below in Fig. 1. The device has a complex input impedance (which is the load impedance Z_L seen by the feed line of) that is given by $Z_L = 75 + j25 \text{ } [\Omega]$. This load impedance is constant and does not change with frequency. The (nonmagnetic) substrate has a relative permittivity of $\epsilon_r = 2.33$ and a thickness h of 1.524 [mm]. (This thickness is 60 mils, or 60 thousandths of an inch). Assume that the substrate and both of the

lines (main line and stub line) are lossless. The guided wavelength on the main line of width w having a characteristic impedance of $Z_0 = 50 \text{ } [\Omega]$ is given by

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_r^{eff}}}, \quad (1)$$

where ϵ_r^{eff} is the effective relative permittivity on the feed line. This effective relative permittivity is assumed to be a constant (independent of frequency) and is found (using TXLINE) at the design frequency $f_0 = 5.0 \text{ } [\text{GHz}]$. A short-circuited microstrip stub line of length l_s is attached to the feed line at a distance d from the device (the short circuit is realized by using a vertical via pin that connects the end of the stub line to the ground plane). The stub line also has a characteristic impedance of $Z_0 = 50 \text{ } [\Omega]$. The stub position d and length l_s are designed to give a match on the main feed line at $5.0 \text{ } [\text{GHz}]$. That is, we are using the method called “single-stub matching”. Note that the system will be matched only at the design frequency of $5.0 \text{ } [\text{GHz}]$. The purpose of this project is to study the bandwidth of the impedance match.

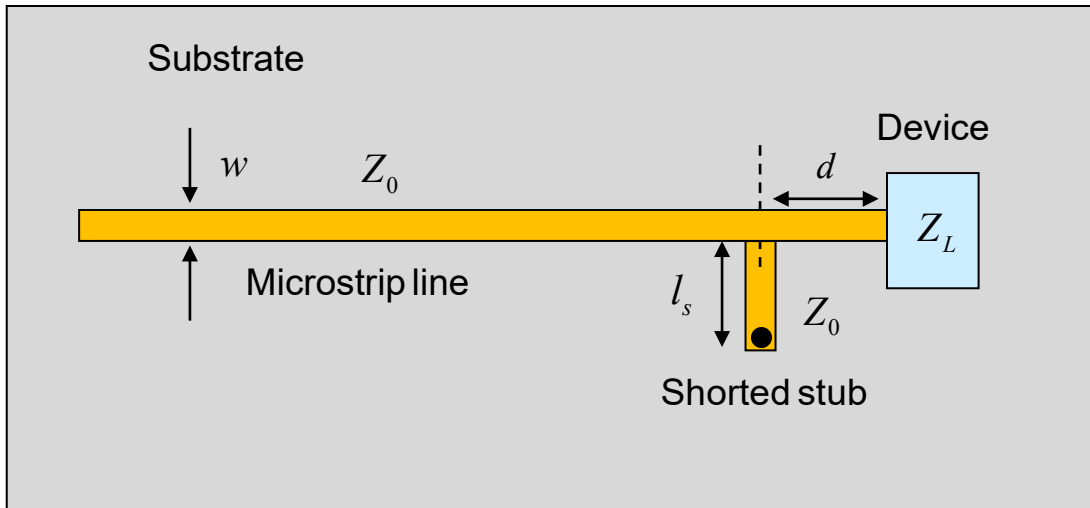


Figure 1. Layout for the design (top view).

Tasks

Part I: Design of the System

Note: The system is designed at $f_0 = 5.0$ [GHz].

- 1) Calculate the width of the feed line (and stub line) w (in mm) to give Z_0 of 50 [Ω] at f_0 . (The main line and the stub line have the same Z_0 (50 [Ω]), and hence they have the same width w .) Use TXLINE to do this. It is also recommended that you use the approximate formula for Z_0 given below in the section called “Microstrip Design Formulas” to also find the value of w , as a sanity check (but please use the value from TXLINE in your design).
- 2) Calculate the values of ϵ_r^{eff} and λ_g for the main feed line (and stub line) of width w from TXLINE at the frequency f_0 . It is recommended that you also use the approximate formula for ϵ_r^{eff} given below in the section called “Microstrip Design Formulas” to find these two values, as a sanity check (but please use the values from TXLINE in your design).
- 3) Find the lengths d and l_s (in mm). You will need the value of λ_g at the frequency f_0 for this calculation (which you found from step (2)). Use the Smith chart for the calculation of these two lengths, and include your Smith chart showing your work in an appendix.

Make a final table that summarizes all of your final dimensions (w, d, l_s) (in mm) from your calculations above, based on TXLINE.

Part II: SWR and Bandwidth

- 1) Make of plot of the SWR on the main feeding line to the left of the stub line vs. frequency, from 3.0 [GHz] to 7.0 [GHz]. On the vertical scale, choose an SWR range from 1.0 to 3.0. (Use MATLAB or any other package that you prefer to make your plot.)

- 2) Determine numerically what the percent bandwidth of the system is. The percent bandwidth is defined as

$$\text{BW}\% \equiv \left(\frac{f_2 - f_1}{f_0} \right) 100,$$

where f_1 and f_2 are the lower and upper frequencies for which $\text{SWR} = 2.0$, and f_0 is the design frequency (5.0 GHz). (Please see a qualitative sketch below in Fig. 2.) Note that an SWR of 2.0 corresponds to $|\Gamma_L| = 1/3$. (The magnitude of the reflection coefficient can also be expressed as -9.54 dB, which is why engineers often use -10 dB to define bandwidth.)

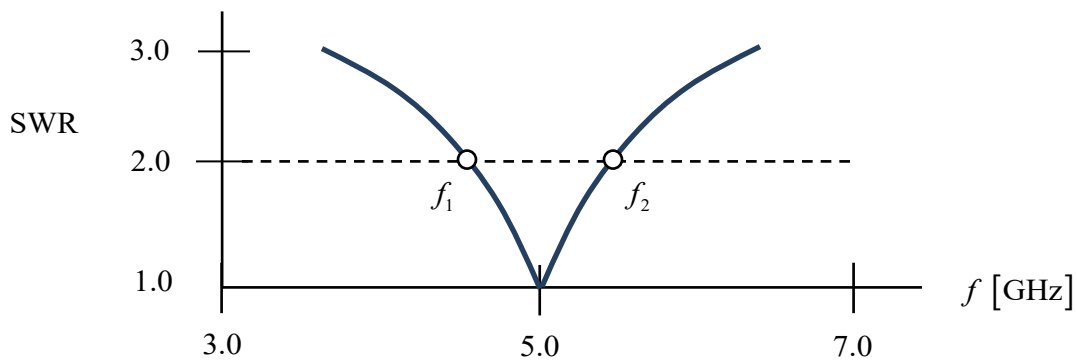


Figure 2. A qualitative sketch of what the SWR plot should look like.

Calculation Method:

At an arbitrary frequency f , your program should calculate the input impedance seen by the feed line at a point that is just to the left of the stub line. Your program should then calculate the reflection coefficient seen by the main feed line looking into system at a point that is just to the left of the stub line. From this, the SWR on the main feed line (to the left of the stub) is then calculated at the frequency f .

When you do the calculation of the input impedance (at a point that is just to the left of the stub line) at an arbitrary frequency f to get the SWR and make the plot, assume that the effective relative permittivity of the main line and the stub line are both constants, independent of

frequency, and use the values that you obtained at f_0 . But note that λ_0 is a function of frequency, and therefore so is λ_g . Therefore, distances d and l_s in terms of λ_g are a function of frequency. But the physical distances d and l_s (in mm) do not change, and are the same as what you designed in Part I.

At an arbitrary frequency f , your program will first need to calculate the input impedance looking to the right, at a point that is just to the right of the stub. This input impedance gets added in parallel to the input impedance looking into the stub. This parallel combination is then the effective load impedance for the main feed line at a point just to the left of the stub. This effective load impedance that is seen by the main feed line is what you use to calculate the reflection coefficient seen by the feed line (at a point that is just to the left of the stub line) and the SWR on the feed line (to the left of the stub).

As a sanity check, at a frequency of 5.0 GHz your program should find that the SWR on the main feed line is 1.0 (if you did the design correctly, and your program is working correctly).

Microstrip Design Formulas

The following approximate CAD formulas [1] may be used to determine the characteristic impedance (in Ohms) of a microstrip line (shown in Fig. 3 below) from the substrate parameters and the line width w . Please use TXLINE for the final design of all your dimensions and values. However, the CAD formulas below might be useful to you as a sanity check.

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_r^{eff}}} \ln\left(\frac{8h}{w} + \frac{w}{4h}\right); & \text{for } \frac{w}{h} \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_r^{eff}} \left(\frac{w}{h} + 1.393 + 0.667 \ln\left(\frac{w}{h} + 1.444\right)\right)} & ; \text{ for } \frac{w}{h} \geq 1 \end{cases}$$

$$\epsilon_r^{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12\left(\frac{h}{w}\right)}} \right).$$

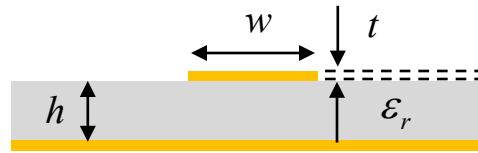


Figure 3. Geometry of a microstrip line (end view).

Note:

The thickness t of the metal lines in TXLINE should be taken to be 17.5 microns (17.5×10^{-6} [m]), which is typical for a printed circuit board (“half-ounce” copper board). (The above approximate CAD formulas ignore the metal thickness.) In TXLINE, set the loss tangent of the substrate to be zero (lossless). Also, set the conductivity of the metal to be 1.0×10^{10} [S/m], which should be large enough to simulate a perfect conductor.

Report Guidelines

Your report should consist of the following sections:

- Cover page
- Academic Honesty Statement
- Abstract
- Introduction
- Results and Discussion (broken down by tasks)
- Conclusions
- References
- Appendix (Smith chart solution)

Your report will be graded on the accuracy of your design and results, the quality of your plot, the quality of your discussion, and the grammar and writing style of your report. The project

(including text and equations) should be done on a word processor (using, e.g., Microsoft Word). The Smith chart solution (in the Appendix) is allowed to be hand drawn, but please use a compass and ruler to make it as accurate and professional looking as possible. It is strongly recommended that you also use MathType to make the equations in your report. (Please see the information in Notes 1 about getting MathType.)

Do not make the report longer than it needs to be; you are not being graded on length. The suggested format of the report (in terms of fonts, margins, etc.) is that used in this project description.

Make sure that if you take any results, equations, figures, etc. from any source other than yourself (including the class notes or this project description), that you give proper credit.

There should be an Academic Honesty statement on p. 2 of your report. This should be a signed statement on a separate page that says “I have worked on this project entirely by myself, and I have not discussed this project with anyone other than the instructor.”

References

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