ECE 3317
Fall 2025

Project

Date of last update: Oct. 21, 2025

Due Date

This project is due at 5:00 pm on Monday, Dec. 8. (This is after the last day of class.) Please submit it by sliding it under the instructor's door.

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" at the top of the first page to make sure that your version of the project is the latest one.

Project Description

A microstrip line of width w_{M} (the "main line") having a characteristic impedance of $Z_0 = 50\ [\Omega]$ is connected (on the left) to a quarter-wave transformer line as shown in Fig. 1 below. (The quarter-wave transformer is 1/4 of a guided wavelength long, with the guided wavelength λ_g^{T} being that on the transformer line of width w_{T}.) At the output (right side) of the transformer is another 50 [Ω] line of width w_{M} and length d that connects to a device. The device has a complex input impedance (which is the load impedance Z_L seen by the line of length *d*) that is given by

$$Z_L = 37.5 - j25\,[\Omega].$$

The substrate has a relative permittivity of $\varepsilon_r = 2.35$ and a thickness *h* of 1.524 [mm]. (This thickness is 60 mils, or 60 thousandths of an inch). Assume that the substrate and all the lines are lossless. The thickness *t* of the metal lines 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 guided wavelength on the main line of width w_{M} having a characteristic impedance of $Z_0 = 50\,[\Omega]$ is given by

$$\lambda_g^{\mathrm{M}} = \frac{\lambda_0}{\sqrt{\varepsilon_r^{\mathrm{eff,M}}}}, \tag{1}$$

where $\varepsilon_r^{\mathrm{eff,M}}$ is the effective relative permittivity on the main line. Similarly, the guided wavelength on the transformer line of width w_{T} is given by

$$\lambda_g^{\mathrm{T}} = \frac{\lambda_0}{\sqrt{\varepsilon_r^{\mathrm{eff,T}}}}, \tag{2}$$

where $\varepsilon_r^{\mathrm{eff,T}}$ is the effective relative permittivity on the transformer line. Both of these effective relative permittivities are assumed to be constants (independent of frequency), and are calculated at the design frequency f_0 = 3.0[GHz].

Note: In Fig. 1 the transformer is shown as having a width that is wider than the main line. This may or may not be the case for your design.

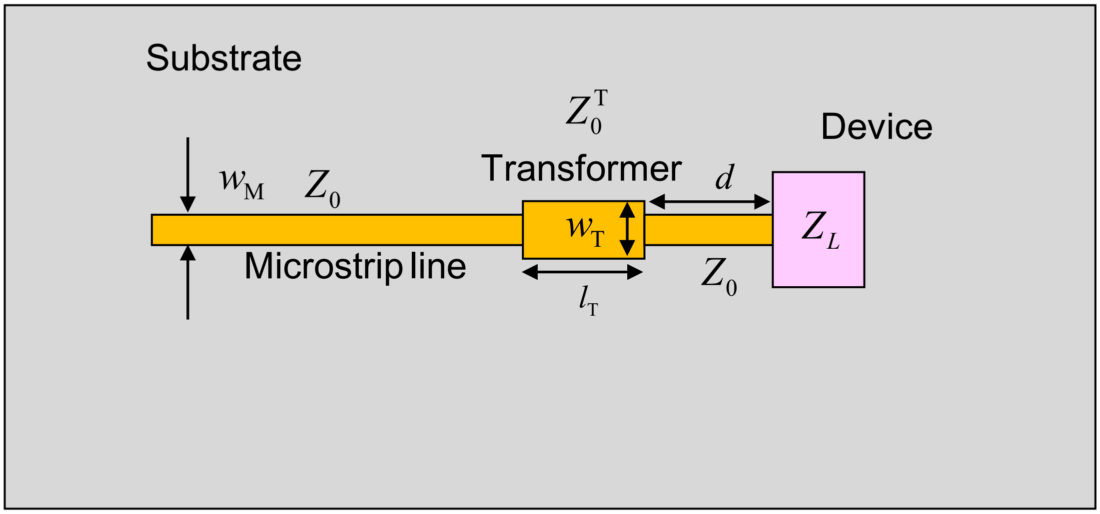


Figure 1. Layout for the design (top view).

Tasks

Part I: Design of the System

Note: The system is designed at $f_0 = 3.0\,[\mathrm{GHz}]$.

1) Calculate the width of the line w_{M} (in mm) to give Z_0 of 50 [Ω] at f_0. Use TXLINE to do this. It is also recommended that you also use the approximate formula for Z_0 given below in the section called "Microstrip Design Formulas" to find the value of w_{M}, as a sanity check.

2) Calculate the values of $\varepsilon_r^{\mathrm{eff,M}}$ and λ_g^{M} for the main line of width w_{M} from TXLINE at the frequency f_0. It is recommended that you also use the approximate formula for $\varepsilon_r^{\mathrm{eff}}$ given below in the section called "Microstrip Design Formulas" to find these two values, as a sanity check.

3) Find the length d (in mm). This extension line of length d converts the complex device impedance at the frequency f_0 into a real impedance. Use the shortest possible value of d

in your design. You will need the value of λ_g^{M} at the frequency f_0 for this calculation (which you found from step (2)). Use the Smith chart for the calculation of *d*.

4) Find the (real) input impedance seen by the transformer looking into the extension line to the right of it), at the frequency f_0. Use the Smith chart for this calculation.

5) Calculate the value of the transformer impedance Z_0^{T} that will transform the (real) impedance found from step (4) into 50 [Ω], so that the main feed line to the left of the transformer sees a perfect match at the frequency f_0.

6) Calculate the width w_{T} of the quarter-wave transformer (in mm), at the frequency f_0 using TXLINE, to give the value of Z_0^{T} from step (5). It is recommended that you also use the approximate formula for the characteristic impedance given below in the section called "Microstrip Design Formulas" to find w_{T}, as a sanity check.

7) Calculate the value of $\varepsilon_r^{\mathrm{eff,T}}$ and λ_g^{T} for the transformer line of width w_T from TXLINE at the frequency f_0. It is recommended that you also use the approximate formula for $\varepsilon_r^{\mathrm{eff}}$ given below in the section called "Microstrip Design Formulas" to find these two values, as a sanity check.

8) Find the length of the transformer l_{T} (in mm). You will need the value of λ_g^{T} at the frequency f_0 for this calculation (which you found from step (7)).

Make a final table that summarizes all your final dimensions (w, d, w_T, l_T) from your calculations above, based on TXLINE.

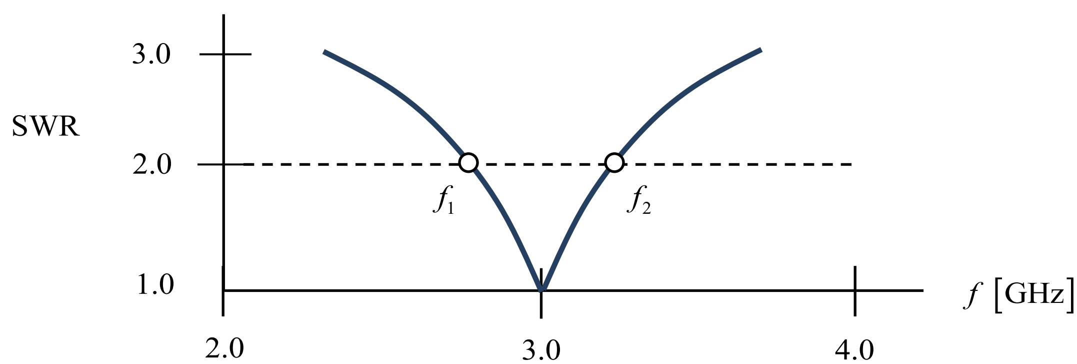
Part II: SWR and Bandwidth

1) Make of plot of the SWR on the main feeding line to the left of the transformer vs. frequency, from 1.0 [GHz] to 5.0 [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

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

where f_1 and f_2 are the lower and upper frequencies for which $\mathrm{SWR} = 2.0$, and f_0 is the design frequency. Please see the qualitative sketch below. (This is not an accurate plot, just a sketch that illustrates the frequencies f_1 and f_2.)



Calculation Method

At an arbitrary frequency *f*, your program should first calculate the input impedance seen at the left end of the extension line of length *d*. This is the load impedance seen by the transformer line. Then your program should calculate the input impedance at the left end of the transformer line. This is the load impedance seen by the main feed line. Your program should then calculate the reflection coefficient seen by the main feed line looking into the transformer at the arbitrary frequency *f*, and from this, the SWR on the main line at the arbitrary frequency *f*.

For the above calculations, remember that we have a formula from the class notes (the "tangent" formula) that tells us what the input impedance is at the beginning (left end) of any transmission line, if we know what the load impedance is on the right end of the line.

When you do the calculation of the input impedance at an arbitrary frequency f to get the SWR and make the plot, please assume that the effective relative permittivity of the main line and the transformer line are both constants, independent of frequency, and use the values that you obtained at f_0. Similarly, assume that the characteristic impedances of the main line and the transformer line are fixed, and do not depend on frequency. (The input impedance seen by the transformer will depend on frequency, and the input impedance seen by the main feed line will also depend on frequency.)

As a sanity check, at the frequency f_0 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. 2 below) from the substrate parameters and the line width w (which can represent ether the width of the main line w_{M} or the width of the transformer line w_{T}).

Please use TXLINE for all your dimensions and values in your final design. However, the CAD formulas below might be useful to you as a sanity check.

$$Z_0 = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_r^{\mathrm{eff}}}} \ln\left(\dfrac{8h}{w} + \dfrac{w}{4h}\right); & \text{for } \dfrac{w}{h} \le 1 \\[2ex] \dfrac{120\pi}{\sqrt{\varepsilon_r^{\mathrm{eff}}}\left(\dfrac{w}{h} + 1.393 + 0.667\ln\left(\dfrac{w}{h} + 1.444\right)\right)}; & \text{for } \dfrac{w}{h} \ge 1 \end{cases}$$

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

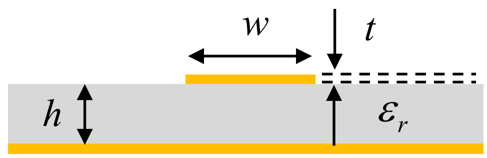


Figure 2. Geometry of a microstrip line (end view).

Important Notes

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 $1.0\times10^{+10}$ [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

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

It is strongly recommended that you use MathType for all of your equations, to make them look professional. (MathType was used to make the equations 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 (after the cover page). 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.