Final Project

ECE 391 Transmission Lines

Spring 2025

Due 6/13/25 50 points, 20% of course total (+9.5% bonus).

- ➔ Your report must be submitted to Canvas by 5 pm on Friday June 13, 2025. Reports will not be accepted after this deadline.

- ➔ **Generative AI Policy**:
    - Using generative AI tools (e.g., ChatGPT, Copilot, Grok, etc.) to *solve* any part of the design tasks is considered academic misconduct, as defined by Section 4.2 in OSU's Code of Student Conduct, and is **strictly prohibited**.
    - Any suspicion of AI use in *solving* the design tasks will result in the report being rejected and left ungraded until the author verbally explains and justifies their design choices to the course instructor or TAs.
    - Using AI tools to *write* the report is also prohibited. Any suspicion of AI being used to *write* the report will result in the written sections of concern being rejected.
    - AI tools may be used *exclusively* to **confirm** correct grammar and structure. 'Corrected' text that is generated by AI will be rejected and awarded zero points.

- ➔ Check your schematics carefully for correct units (e.g., a mm is not the same thing as a mil).

- ➔ Report organization:
    - **Format**: 5-point deduction for bad formatting.
        - Type-written text using a professional font (e.g., Arial, Calibri, Times New Roman) at 10 - 12 pt.
        - Figures and graphs must be numbered and have a caption below them that clearly explains the figure or graph.
        - Smith charts with your solutions must be included in the report, either as a figure or as an independent page within the report.
    - **First (cover) page**: Report title, your first and last name, course name and the date.
    - **Second page**: Executive summary: (200 – 300 words) include a brief description of the project, the goals/objectives of the project, and your observations/conclusions (or just what you learned). This summary is worth 10 points alone. It should therefore be well-written, as the quality of the description, clarity of the goals/objections, and

thoughtfulness of the observations/conclusions will be considered in the grading. The word count in this section should be no less than 200 and no more than 300, which would correspond to approximately half a page.

- **Remaining pages**: Separate each design task specified below into a separate section. In each section, include the task description in your own words at the beginning. Group all work, graphs and figures for each task within the corresponding section.

➔ Design parameters and ADS instructions:

- Refer to the file "Project Assignments SP25" on Canvas under the Final Project Module. Here you will find the frequency, load inductance and load resistance that you will design matching networks for, along with the substrate thickness and dielectric constant you need to use when designing microstrip lines for the matching networks.
- Other parameters to use for your microstrip line substrates: Use a metal thickness of T=17 microns and conductivity of 4.1e7 S/m. Additional MSUB parameters: Mur=1, Hu=3.9e34 mil, TanD=0, Rough=0 mil.
- For microstrip networks, include a section of microstrip line at the feed (connected directly to Term/TermG) with the same characteristic impedance as the Term/TermG component.
- Refer to ADS Help to learn more about each component and the papers they cite or equations they are implementing, if necessary.

Design Task 1 – 2-Element Lumped Element Matching Network (10 points)

Design a 2-element lumped element matching network to match a series R-L load to 50 Ω, using the values for the resistance and inductance from the Project Assignments file.

1. Calculate the element values for the matching network. Show the equations in your report; you can either type them in or snip a figure from the lecture slides. Specify the element values in nH or pF.

2. Demonstrate the matching network solution on a Smith chart. Include the Smith chart in your report.

3. Implement the matching circuit in ADS. Show the schematic in your report.

4. Use ADS to plot the magnitude of the reflection coefficient (or S(1,1)) from **0.5-14** GHz.

5. Determine the % bandwidth over which the reflection coefficient magnitude is <0.25. This is found by determining the lower and upper frequencies where the reflection coefficient equals 0.25 and dividing the difference between those two frequencies by the average of those two frequencies.

6. For this task, you either used a shunt-series design (with the element closest to the load in shunt) or a series-shunt design (with the element closest to the load in series). Using a second Smith chart that you include in the report, show why the design you did not choose **would or would not** work.

Design Task 2 – T-Line / Quarter-Wave Distributed Matching Network (10 points + bonus 5% of course total)

Design a distributed-lumped element matching network to match a series R-L load to 50 Ω, using the values for the resistance and inductance from the Project Assignments file. The matching network should have a section of 50 Ω transmission line near the load that converts Im(Z_L) to 0 Ω, followed by a quarter-wave transformer that completes the matching to 50 Ω. Another 50 Ω section of microstrip should separate the transformer and the source component when using microstrip lines (parts 6 – 9).

1. Plot the normalized load on a Smith chart. Rotate toward the generator on the Smith chart until the imaginary part of the impedance is 0. On the Smith chart, indicate the distance moved toward the generator in wavelengths and the new un-normalized value of impedance at that distance from the load.

2. Given the real impedance that was achieved after rotating toward the generator, determine the impedance of the quarter-wave transformer needed to complete the match to 50 Ω.

3. Implement the matching circuit in ADS. Use ideal (lossless) t-lines (not microstrip) for the matching circuit. Show the schematic in your report.

4. Use ADS to plot the magnitude of the reflection coefficient (or S(1,1)) from **0.5-14** GHz.

5. Determine the % bandwidth over which the reflection coefficient magnitude is <0.25. This is found by determining the lower and upper frequencies where the reflection coefficient equals 0.25 and dividing the difference between those two frequencies by the average of those two frequencies. (Note: for some designs, the lower and/or upper frequencies may be outside the 0.5-14 GHz range. If that is the case for your design, just state that.)

6. (1.0% bonus) Implement the matching network using microstrip lines (MLIN) and determine the bandwidth, as was done in the previous part for ideal t-lines (TLIN).

7. (0.5% bonus) At each step in width, include the ADS 'MSTEP' component with the correct values. Briefly explain what this component does. Compare the results obtained with and without the step component and explain any differences observed in bandwidth, cutoff and resonant frequencies, reflection coefficient, etc.

8. (2.5% bonus) Replace the single-section quarter-wave transformer with a 3-section binomial one (as in HW8) that would match the assigned load to 50 Ω. Compare the results obtained with this configuration to those of the single-section transformer and explain the differences.

9. (1% bonus) Include 'MSTEP' components (there should be four) in the binomial matching network and compare the results obtained with the step components to those without.

Design Task 3 – Shunt Stub Distributed Matching Network (10 points + bonus 4.5% of course total)

Design a shunt stub matching network to match a series R-L load to 50 Ω, using the values for the resistance and inductance from the Project Assignments file.

1. Show the design for the matching network on a Smith chart. Use 50 Ω transmission lines in your design. On the Smith Chart, clearly show the distance between the load and the stub, and the length and type of stub (open circuit or short circuit). Show all lengths in terms of wavelengths.

2. Use Linecalc to design the microstrip lines needed to implement your matching circuit in microstrip. Use the substrate thickness and dielectric constant shown for you in the Project Assignments file. Show an image of your Linecalc results that gives the correct width for the 50 Ω line. In your report, give the 50 Ω line width and the physical line lengths (in mm) that you need to achieve the electrical lengths of the two t-lines (straight section and stub) from part 1.

3. Implement the matching circuit in ADS. Show the schematic in your report.

4. Use ADS to plot the magnitude of the reflection coefficient (or S(1,1)) from **0.5-14** GHz.

5. Determine the % bandwidth over which the reflection coefficient magnitude is <0.25. This is found by determining the lower and upper frequencies where the reflection coefficient equals 0.25 and dividing the difference between those two frequencies by the average of those two frequencies. (Note: for some designs, the lower and/or upper frequencies may be outside the 0.5-14 GHz range. If that is the case for your design, just state that.)

6. (1.5% bonus) Include the 'MTEE_ADS' component at the stub junction. Briefly explain the purpose of including this component and compare the results without the Tee component to those with while explaining any differences.

7. (3% bonus) Terminate the regular (rectangular) stub used in the previous parts with an open-circuited radial stub component 'MRSTUB'. Radial stubs are many used to achieve RF shorts where vias are not possible. Therefore, set the radius of this stub to 90° (in electrical length). Adjust the angle (and radius) until you obtain similar results to those of the rectangular stub. Explain (in your own words!) the issues that may arise from open-circuited stubs.

Design Task 4 – T-Line / Lumped Element Matching Network (10 points)

Design a lumped/distributed matching network to match a series R-L load to 50 Ω, using the values for the resistance and inductance from the Project Assignments file. The matching network should have a section of 50 Ω transmission line near the load that converts Re(Z_L) to 50 Ω, followed by a series lumped element that completes the matching to 50 Ω by canceling the imaginary part of the converted impedance.

1. Plot the normalized load on a Smith chart. Rotate toward the generator on the Smith chart until the real part of the impedance is 1. On the Smith chart, indicate the distance moved toward the generator in wavelengths and the new un-normalized value of impedance at that distance from the load.

2. Given the imaginary impedance that was achieved after rotating toward the generator, determine the series lumped element (inductor or capacitor) needed to cancel the imaginary part. Give the value in nH or pF.

3. Implement the matching circuit in ADS. Use ideal (lossless) t-lines (not microstrip) for the matching circuit. Show the schematic in your report.

4. Use ADS to plot the magnitude of the reflection coefficient (or S(1,1)) from **0.5-14** GHz.

5. Determine the % bandwidth over which the reflection coefficient magnitude is <0.25. This is found by determining the lower and upper frequencies where the reflection coefficient equals 0.25 and dividing the difference between those two frequencies by the average of those two frequencies. (Note: for some designs, the lower and/or upper frequencies may be outside the 0.5-14 GHz range. If that is the case for your design, just state that.)