

Design Project #1: Matching Transformers

In this project you will design and test **three** matching networks:

- a) A Quarter-wave transformer
- b) A 4-section Binomial transformer
- c) A 4-section Chebychev transformer

Project Scope

In this design, we will attempt to match a real load of $R_L = 125\Omega$ to a transmission line with a 50Ω characteristic impedance at a frequency of 9 GHz.

The bandwidth of the 4-section transformers is defined by $\Gamma_m = 0.1$.

Assume TEM wave propagation in the transmission lines, and the transmission line dielectric constant is $\epsilon_r = 9.0$.

Project Tasks:

- 1) Design each of the three matching networks, determining both the characteristic impedance and physical length (in cm) of each section.
- 2) Use the design equations in your notes/book to determine the **expected** bandwidth for each design.
- 3) Implement each design on ADS software. Plot the results on :
 - a) a Smith Chart
 - b) a Cartesian plot of $|\Gamma_{in}(\omega)|$ versus frequency (i.e., linear scale).

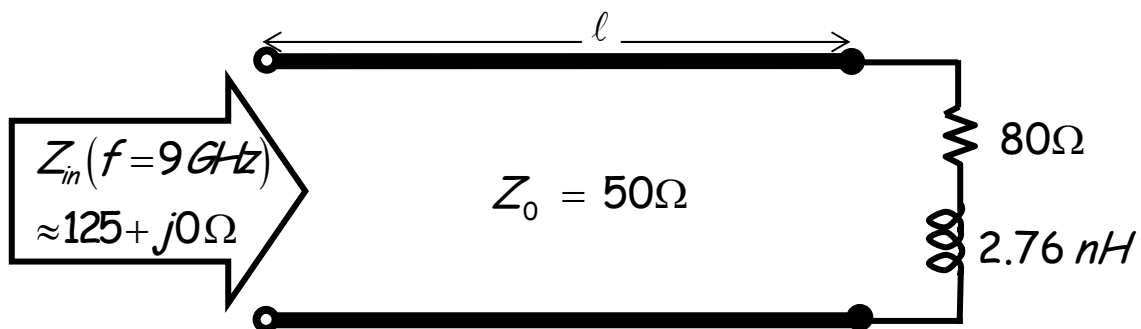
c) a Cartesian plot of $10 \log_{10} |\Gamma_{in}(\omega)|^2$ versus frequency (i.e., dB scale).

Q: Compare the results of each design. In what ways are they different?

4) Use the **markers** on the plots to determine the bandwidth of each design.

Q: You will find that the bandwidths of your design will **not be exactly** the bandwidths predicted by the design equations. **Why** is that? Hint: It is **not** because "ADS has errors"!

5) You will find that at $f = 9 \text{ GHz}$, the following device has an input impedance of approximately $Z_{in} \approx 125 + j0 \Omega$ if the length ℓ is properly determined:



6) Determine the proper value for line length ℓ . Now replace the 125Ω resistor with this 125Ω "load" shown above, and reanalyze (with ADS) each matching transformer design.

7) Compare and contrast the results (Smith Chart and $|\Gamma_{in}(\omega)|^2$ (dB)) with the 125 Ohm resistor results.

Q: How and **why** are the results different? In what ways are they the same? **Why** is this true?

ADS Information

1. You will find attached an ADS Overview (Parts 1 and 2). It will give you a quick tutorial on the general operation of the software. Further assistance can be found in the help file of ADS. Of particular interest is the "Quick Tour", which can be found by selecting *Help -> Topics and Index*.

2. There are several types of analyses that can be performed by ADS. The overview provides examples for "DC" and "Transient" analyses. However, this project will require only the **S-Parameter** analysis (i.e., *Simulations_S-Param*).

3. The only circuit elements you will need for this project are:

a) Port Termination (*Term*) - This device is an element of the *Simulations_S-Param* category. This device is used to define the ports of a multi-port network for S-parameter analysis. Its design parameter is the port impedance (i.e., Z_0). For this project, we will need only one of these devices, connected to the input of the matching network. As such, the simulation will determine only S_{11} (port 1 being the input to the matching network). Note that this means that $S_{11} = \Gamma_{in}$ if the port impedance is $Z_0 = 50\Omega$.

b) Ideal Transmission Line (*TLIN*) - This device is simply a length of ideal transmission line. Its design parameters are characteristic impedance and electrical length (at a specific design frequency). This device is an element of the *TLines-Ideal* category.

c) Resistor (R) - This device is simply an ideal resistor. Its design parameter is simply its resistance in Ohms. It is an element of the *Lumped-Components* category.

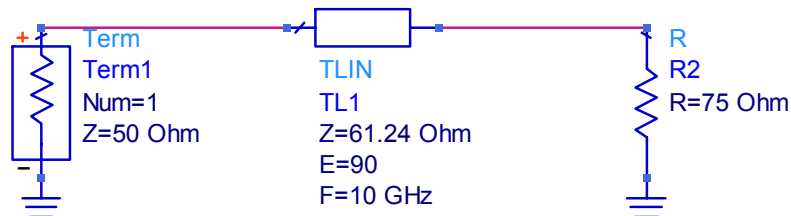
d) Inductor (L) - This device is simply an ideal inductor. Its design parameter is simply its inductance in Henries. It is an element of the *Lumped-Components* category.

4. I have made available on the web two files, a design file and a display file. You can open up the design file and then save it under a name of your own choosing. However:

a) Do not leave any spaces in the file name (ADS gets VERY upset when you do this).

b) Save these files to a floppy or to your own disk space. If you save it to a general directory of the computer that you are working on, it may not be there when you return!

5. The design file will open a schematic for a quarter wave transformer that is matched to a 75 Ohm load at 10 GHz:



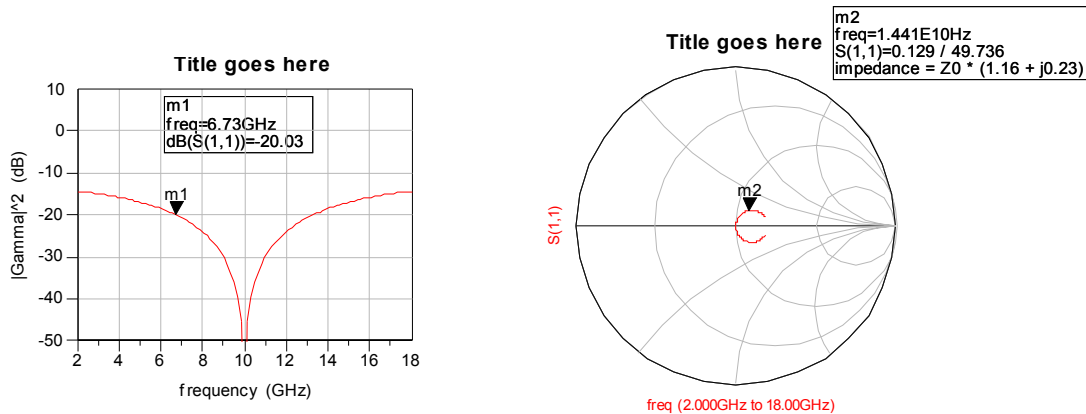
Note ground elements !



S_Param
SP1
Start=2.0 GHz
Stop=18.0 GHz
Step=

Note that this schematic contains all of the required devices except the inductor. You will obviously need to add several more sections of transmission line for your designs. You can simply modify this design, or start from scratch with a new design file.

6. The display file contains formatted Cartesian and Smith Chart plots:



Again, you should save the display file to your own disk space, using a name of your choosing. You may (in fact are encouraged) to modify or add to the display formats in any way. These two files are provided as an aid to you; you may ignore them completely if you wish.

Note that the markers can be moved in ADS by "clicking and dragging" them to a new point on the graph. Likewise, double-clicking on the plots launches a window that allows you to format the graphs in any way you see fit.

Finally, use a vertical log scale that makes sense. Typically, 40 to 60 dB of vertical scale is all that is required (i.e., do **not** give me a 200 dB log scale!).

7. Note that you can copy all graphics from ADS by selecting the graphics and typing "Ctrl-C", and then pasting into a MS document.

Grading and Evaluation

1. Each student team (2 people max.) must work alone on this project—the design and analysis must represent each team's effort and knowledge only. Working with other teams will be considered academic misconduct and **all** students involved will receive a zero grade.
2. However, you may ask your colleagues about how to operate or in any way use ADS.
3. Likewise, you may confer with fellow students about any **general** questions about the theory of wideband, multi-section matching networks. However, these questions must be **general**!
4. You basically should view the project report as a **lab report**. Show how and why the design parameters were determined. "Construct" the circuits in ADS, and then "measure" the circuits in ADS. Provide the results of these "measurements" in report. **Discuss** your results, and include the answers to the questions posed earlier (put particular emphasis on the answers to questions with the word "**why**"!).
5. A report that receives a top grade will exhibit three characteristics:
 - a) **Accurate** - the designs and the analyses are correctly done.
 - b) **Professional** - the results are clearly, completely, and unambiguously presented.
 - c) **Insightful** - the report convinces me that you understand what you have done and why the result appear the way they do. In other words, after reading your report, I want to be impressed with your knowledge and insight.

Therefore, do not confuse the word "**what**" with the word "**why**". Often I ask students to explain **why** something happened, and instead they tell me **what** happened—do **not** do this!

6. I am looking for **quality** over quantity. I do not want this to be a large report requiring lots of writing. Make the points that you want to make in a clear and complete manner, and then **stop** writing!

Assume your audience is a **knowledgeable microwave engineer** (i.e., me!) Thus, you do not need to provide a long (or even short) discussion about what matching networks are, or why they are so great, or what their general characteristics are, or a multiple reflection analysis of them, etc. I assume you know the material that has been presented in class. What I don't know is if you can take that material and: 1) **design** a matching network that works and; 2) explain the behavior of that design when analyzed on ADS.

7. You may **extend** this project beyond what is called for in the project description. If done correctly, this will likely impress me and help me conclude that you are a very motivated, knowledgeable, and professional microwave engineer! Your grade will thus reflect this favorable opinion.

However, this does **not** mean that an extension of the project scope is **required**—you will get full credit with a well-done report that addresses only the project scope described earlier.