UNIVERSITY OF UTAH
ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

ECE 5320/632 LABORATORY #2

Room 2275 MEB

LOAD MATCHING BY SHUNT CAPACITIVE ELEMENTS

Introduction

Load matching is a very important subject in microwave engineering because reflected power is usually wasted power. Complicated and extended microwave circuits should be matched component-by-component to get the best results over some desired operating bandwidth. If there are several mismatched components in a circuit, the overall signals will exhibit rapid variations with frequency and there is no effective way to further reduce the SWR by overall matching. Matching needs to be done between every pair of components, if possible.

Goal

To learn how to use an added matching element to cancel reflections at one frequency, and to explore the resulting bandwidth of the match.

Design

1. Calculate S_{11} and S_{21} of the following microwave circuit for the frequency band 1.0-8.0 GHz.

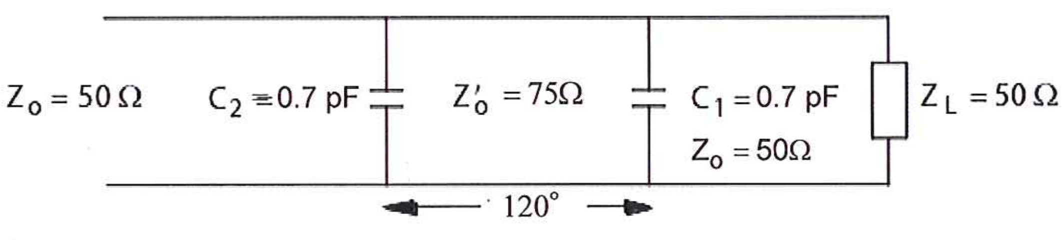

Fig. 1. A one-section band-pass filter.

The line length $\ell = 120^\circ$ is given at the center band frequency of 4.0 GHz. Take Δf = 20 MHz and plot S_{11} and S_{21} vs. frequency.

2. Alter the line length from 120° to get $S_{11} = 0$ at the center band frequency of 4.0 GHz. Use the method of load optimization from the Lab 2 supplement. For this optimally-designed line length, calculate the plot S_{11} and S_{21} over the frequency band 1.0-8.0 GHz. Determine the band for which $\text{SWR} \le 1.5\ (S_{11} \le 0.2 \text{ or } -14 \text{ dB})$.

3. Repeat Step 2 using three capacitances instead of two i.e. a two-section factor filter instead of a single-section filter. The circuit layout for this two-section filter is given in Fig. 2. Determine the band for which $\text{SWR} \le 1.5\ (S_{11} \le 0.2 \text{ or } -14 \text{ dB})$.

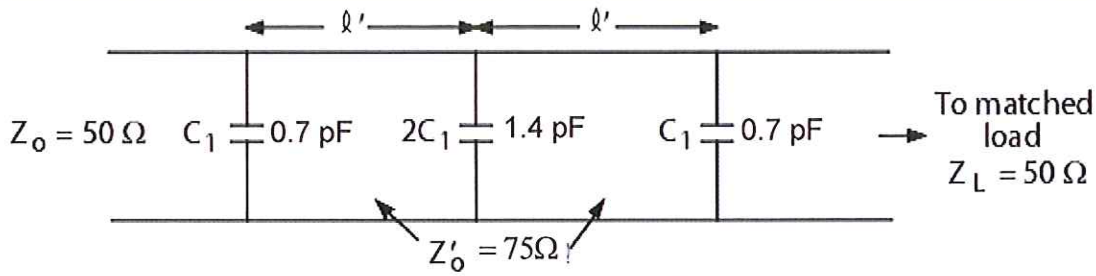

Fig. 2. A two-section filter.

4. Repeat Step 3 using one-sided open-circuited stubs (as shown in Fig. 3) in lieu of the lumped capacitances C_1 and $2C_1$. With the HP ADS software, include as well as neglect the end capacitances for the open-circuited stubs. Use $Z_0' = 100\ \Omega$ as the characteristic impedance for the shunt stubs.

   Compare the two sets of results for S_{11} and S_{21} (with and without end capacitances) with those obtained in Step 3 using the lumped elements C_1 and $2C_1$. Explain the differences, if any.

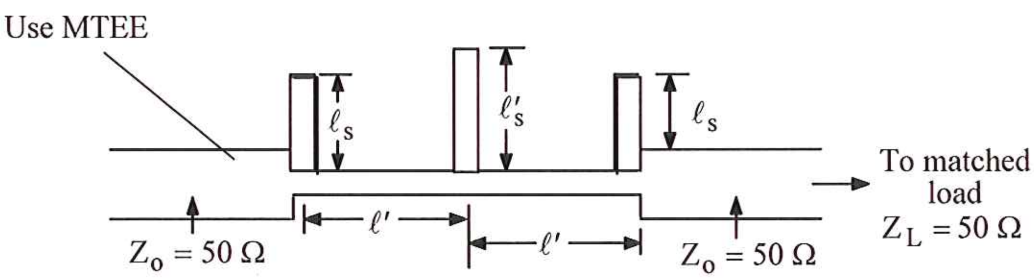

Fig. 3. Circuit of Fig. 3 realized with three one-sided open-circuited shunt stubs instead of lumped capacitors.

5. Redesign the circuit of Fig. 3 using **balanced two-sided stubs** instead of single-sided stubs. For this circuit, calculate and compare the results for S_{11} and S_{21} with those obtained in Step 4. Explain the differences if any.

6. For a second experiment, design a $Z_o = 50\Omega$ microstrip line of length 1.5 inches to connect to the test fixture at one end and left open-ended at the other end. We will use this microstripline to measure the impedance of a monopole wire antenna of length $\lambda_o/4$ at 2500 MHz, where λ_o is the wavelength in air.

Experimental Part

1. Choose either of the designs of the two-element filter developed in Steps 4 or 5 for experimental testing. Generate the circuit as an ADS "layout" using the information at the end of the Lab 2 Supplement. Your circuit must be a total of 2500 mils (2.5 in) in length.

2. Export the gerber files necessary to fabricate the circuits and email them to your TA. These files will be used to mill a circuit board to be measured in the test fixture.

(Stop here until you receive your fabricated circuits but read through the rest of the lab)

3. When your two-element filter circuit is ready, measure and capture S_{11} and S_{21} up to 8 GHz and see if you achieved a match at 4 GHz. Change the stop frequency on the NA to 10 GHz. Determine if the circuit acts as a notch filter at another frequency. Changing the stop frequency will invalidate the calibration but give you an approximate response at the high frequencies. After noting the higher response, set the stop frequency back to 8 GHz and turn "correction" on under the "cal" menu. This reinstates your calibration.

4. Solder a vertical monopole wire antenna of length $\lambda_o/4$ at 2500 MHz to the open end of Circuit 2. Measure S_{11} as a function of frequency for the frequency band 2300 to 2700 MHz. By clipping off the top end of the vertical wire first 2 and then 4 mm. determine the S_{11} to see if a wider bandwidth is obtained for $\text{VSWR} < 1.5\left(S_{11} < 0.2 \text{ or } -14\text{dB}\right)$.

Write-Up

The write-up, in this case, will be similar to that of Lab 1. Hole-punch your report and put it in a three-ring binder. After it is organized and documented so that it reads like a report, staple it together in the upper left-hand corner and turn it in for grading. Use a large three-ring binder to store both your lab reports and your homework sets for future reference and possibly for future grade adjustments due to the differences in TA grading.

The following item should be included as part of your lab report.

- Circuit schematic, plots of S-parameters and VSWR observations for part 1. What can be said about the quality of the match between the incoming and outgoing lines?
- Circuit schematic, plots of S-parameters and VSWR observation for Part 2. Give the line length in degrees that met the desired criteria. Indicate what characteristics of the response are band-pass in nature. What does VSWR show about the quality of the circuits match in this case?
- Circuit schematic, plots of S-parameters and VSWR observation for Part 3. Was there any improvement in the qualities of the circuit responses and how was it quantified?
- Provide the equations, methods and calculations used to convert from lumped elements to open-circuited stubs and the inductive sections.
- Provide the circuit schematics and S-parameter plots and observation about the design for both Part 4 and Part 5.
- Indicate what circuit was chosen for fabrication and why?
- Provide measurements of the response of the circuit and compare with the simulations for the mismatched conditions.

- Provide measurements of the S_{11} for the completed circuit with the tuned monopole attached and indicate the bandwidth and center frequency of the circuit.