UNIVERSITY OF UTAH
ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

ECE 5320 LABORATORY #2 Autumn 2006

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. A monopole antenna is a common load that is found on the inputs and outputs of communication systems. The load impedance of an antenna of length $\lambda/4$ for a given frequency is 36 + 21.3*j ohms. By shortening the antenna slightly the antenna gains a broader bandwidth and becomes real for a load of 34 ohms. The trade-off is that antenna gain is sacrifaiced for better bandwidth.

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 S11 and S21 of the following microwave circuit for the frequency band 1-8 GHz using lumped elements in ADS.

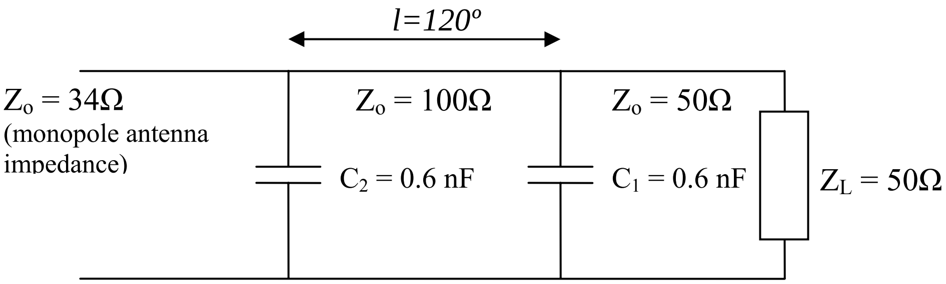

Fig. 1. A one-section bandpass filter.

The line length is given at the center-band frequency of 5.5 GHz. Take $\Delta f = 0.1$ GHz and plot S11 and S21 vs. frequency. When simulating make sure the terminations match the characteristic impendence (ie.. 34 Ohms for Port1 and 50 Ohms for Port2)

2. Alter the line length (*l*) from 120° to get S11 = 0 at the centerband frequency of 5.5 GHz. For this optimally designed line length (*l*), calculate and plot S11 and S21 over the frequency band 1-8 GHz. Determine the band for which SWR ≤ 1.5(ie.. $S_{11} \le$ 0.2).

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 SWR ≤ 1.5.

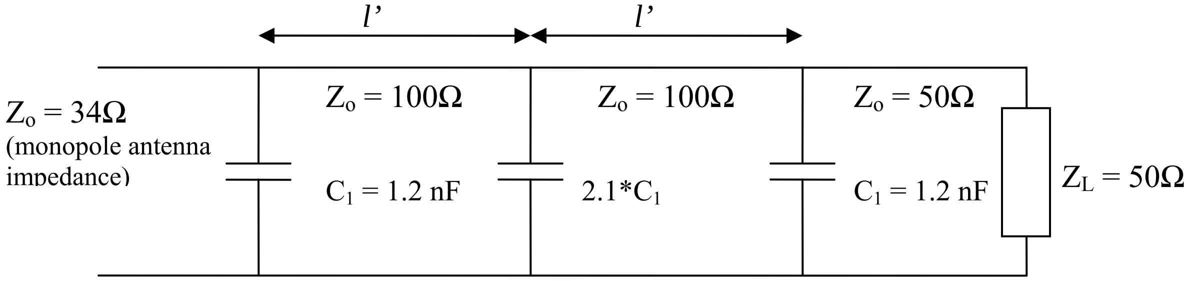

Fig. 2. A two-section filter.

4. Repeat Step 3 using one-sided open-circuited stubs (as shown in Fig. 3) in lieu of the lumped capacitances C1 and 2.1*C1. With the HP ADS software, include and also neglect the end capacitances for the open-circuited stubs. Use Z_o=100 Ω as the characteristic impedance for the shunt stubs.

   Compare the two sets of results for S11 and S21 (with and without end capacitances) with those obtained in Step 3 using the lumped elements C1 and 2.1*C1. Explain the differences, if any.

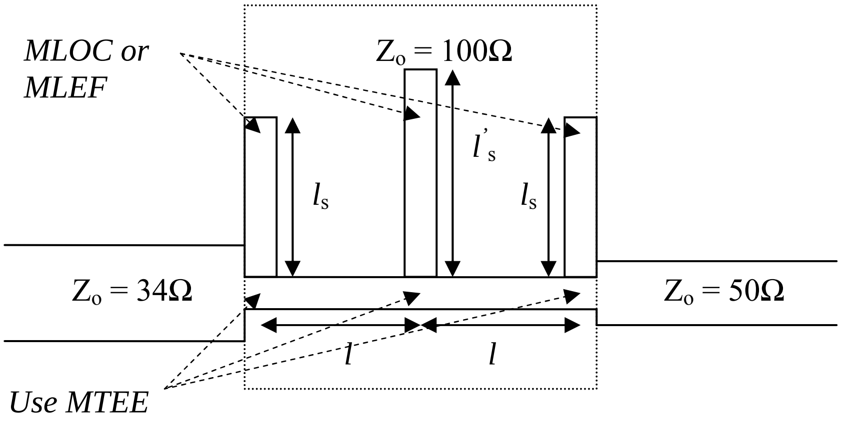

Fig. 3 - Circuit realized with three one-sided open-circuited shunt stubs instead of lumped capacitors.

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 S11 and S21 with those obtained in Step 4. Explain the differences if any.

6. The previous designs assumed that the device used to measure the S11, S21 properties could be perfectly matched at each port for testing. Now save copies of the designs for parts 4 and 5.
7. Re-simulate the responses of each system using only 50 Ohm terminations, this will simulate the condition that will exist when comparisons are made to measurements later on. Make sure to take in to account a length of MLIN used for the 34 Ohm line. This length of line will be used to connect a monopole antenna. What type of effect did the mismatch have on the response.

Experimental Part

1. Choose either of the designs of the two-section filters developed in Steps 4 or 5 for fabrication and experimental testing. The purpose of this circuit will be to provide a match for a monopole antenna and low-pass filtering to remove higher frequency noise. What aspects of the chosen circuits response determined your choice.
2. Have the TA help you convert the file to a format for fabrication. The file will be taken and fabricated for test at the beginning of the next weeks lab.

(You will need to continue from this point after fabrication)

3. When your two-section filter circuit is ready, measure S11 and S21 up to 8 GHz and see if you achieved a match at 5.5 GHz and whether the circuit acts as a notch filter at another frequency.
4. Solder a vertical monopole wire antenna of length $\lambda_o/4$ at 5.5 GHz to the open end of Circuit with the 34 Ohm line. Measure S11 as a function of frequency for the frequency bands of 5.4 to 5.6 GHz. By clipping off the top end of the vertical wire, determine the S11 to see if a wider bandwidth is obtained for S11 < 0.2(VSWR < 1.5).

Lab report items

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 characteristic 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 calcuations 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 S11 for the completed circuit with the tuned monopole attached and indicate the bandwidth and center frequency of the circuit.
- Provide an overview about how the response of this circuit would fit in with the operation of an FSK receiver with data at the frequencies of 5.4 and 5.6 Ghz.