Preparation Assignment for Project 2

Due at the start of class.

Reading Assignment

See the handouts for each lesson for the reading assignment.

27 March Lesson 4.4

Write out in phasor form the voltage and current on the 75 ohm transmission line you analyzed in Homework 6 for each of the three loads: 75 ohms, open circuit and 300 ohms. Be specific – use real numbers for all of the parameters.

29 March Lessons 4.5 and 4.6

a. Write out the voltage and current on the 50 ohm transmission line (in phasor form) with a 93 ohm load analyzed in question b5 of problem 1 in lesson 4.4.

b. For a lossless line with a purely resistive load, when will $Z_{in} = Z_L$? That is, when will the input impedance equal the load impedance?

c. Write out the general expression for the characteristic impedance of a general lossy line. Under what conditions does this expression reduce to that of a lossless line?

d. What is the VSWR when a transmission line is properly matched?

31 March Lesson 4.2

a. What parameters are essentially the same for low-loss lines? What is new?

b. Write out the voltage and current on the 50 ohm line with a 93 ohm load (in phasor form) using the low-loss line parameters developed in problem 1 of lesson 4.5.

c. What is a lattice diagram? (This also goes by other names such as reflection diagram, bounce diagram, etc.)

d. Try out the Java applet listed with today's lesson. Consider the case where the source resistance is 50 ohms, the cable impedance is 50 ohms and the load is 25 ohms. Also, try the applet at http://users.ece.gatech.edu/%7Ewrscott/applet_bounce/Reflect1.html by setting up the same kind of problem. Print out a plot produced by one of the applets showing the voltage at some location on the line. Identify the location.

3, 7 April (5 April is a holiday)

Open Shop for Project 2

Project 1 (*Due: 10 April)*

Cable TV Station Blocker

For this project, students can work in groups of two to four. No reports will be accepted from single students.

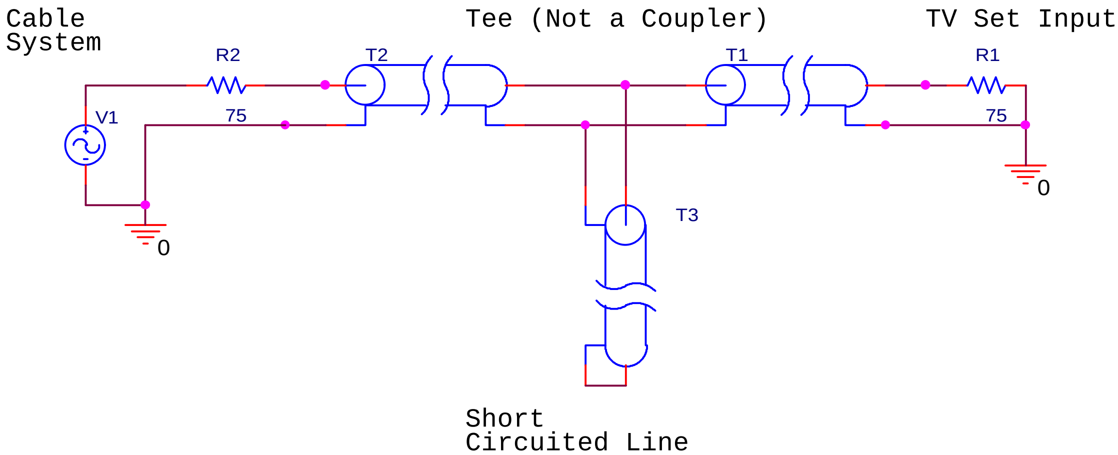
Grading

Analysis (15 pts)	_________
Testing Your Model (10 pts)	_________
Testing Your Design (15 pts)	_________
Discussion (5 pts)	_________
Quality of Performance (5pts)	_________
Extra Credit (0 – 10 pts)	_________
Total	_________

Group Members:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Cable TV Blocker



Introduction

The purpose of this project is to build a simple device that blocks the signal from a particular cable TV channel while leaving the other channels with sufficient signal to be viewable. No active or lumped circuit elements will be used for this purpose. Rather, this will be accomplished by adding a stub-type tuner to the cable that brings the signal to the TV. Appendix C of Paul, Whites and Nasar has a discussion of stub tuners. Usually such devices are used to match a load to a cable rather than what we are doing here – unmatching a load from a cable.

The basic principle of this signal blocker is relatively simple. The CATV cable (T2 in the figure above) is interrupted with a Tee coupler to which is connected a short piece of cable (T3 above) with a shorted load (short circuited line). The input impedance of this extra piece of cable adds in parallel to the input impedance of the cable that runs from the Tee to the TV set (T1 above). Assuming that the cable is properly matched to the TV, the input impedance of this cable will be equal to the characteristic impedance of the cable. In this case, the impedance of the cable and the TV is 75 ohms. Since the input impedance Z_{in} is a function of the electrical length of the cable (through the terms like $\tan\beta d$ where d is the length), the Z_{in} of the short-circuited cable will change with frequency. If the length of this cable is properly selected, the signal from one CATV channel will be reflected from the Tee while the signals from other channels will not be reflected. A crude explanation of how this can work can be made by looking just at two frequencies where Z_{in} is either very small or very large.

For example, assume that the extra piece of cable has a length = d. Also, assume that it is insulated with polyethylene $\varepsilon_r = 2.26$. Then the velocity of propagation on the line is v = 2 x 10^8m/s. In the simulation of this line, one can either reduce the expression for Z_{in} for a short circuit or just use a very small value for Z_L. To be as general as possible, we should choose the latter approach, because there will always be some loss in a real transmission line. Then $Z_{in} = Z_o \dfrac{Z_L + jZ_o \tan bd}{Z_o + jZ_L \tan bd} \approx jZ_o \tan bd$, where we have assumed that the transmission line is ideal and therefore lossless. When this is very large ($\tan\beta d \rightarrow \infty$), adding it in parallel to the cable will have no effect. When this is very small ($\tan\beta d \rightarrow 0$), adding it in parallel to the cable will look like a short circuit and which is as large an impedance mismatch as can be obtained. The signal on the CATV cable will see a short-circuit load at the frequency where $\tan\beta d \rightarrow 0$ and the signal at that frequency will be reflected from the Tee and not make it to the TV.

Look to the Past: Those of you who know how this project was specified in the past will note that we previously used an open-circuited line. The open-circuited line is easier to implement, since one only needs to cut a wire and leave it unconnected. However, even a small amount of open wire at the end of the line will act like an antenna. Thus, it is much better to short the end of the line and leave no signal wire exposed. Those of you who have heard nothing about this project should look over last semester's (Fall '99) project write up, which can be found at the bottom of the course Project page. There is also a set of comments on this project which includes a lot of the important analysis steps for the channel blocker. This latter document should be read thoroughly, but keep in mind that the blocker considered uses an open-circuit line.

The simplest implementation of the blocker is made using the following parts. First, a CATV splitter is purchased. Such a device is used to connect two TV sets to one cable line. This reduces the power to each set, of course, but the source and the TV sets are all properly matched. The splitter uses a transformer and/or discrete components to make the impedance looking into any of its three connections equal to 75ohms. This is not the device we need. Rather we need a Tee. Remove the cover of the splitter and then remove all of the discrete components. Connect the input and the two outputs directly together to form the same kind of Tee we use in the studio with the 50ohm cables. Next, purchase two short CATV cables with connectors on each end. Disconnect the TV set from its cable. Insert the Tee we made with the splitter. Connect one of the new short cables to one of the outputs of the Tee. Connect the other end of this cable to the TV set. The picture should look as good as before. Then connect the second new cable to the other output of our Tee. Depending on the length of this second cable, the station being watched will look the same or have a much weaker signal. The length of this second cable can be shortened to block a particular channel, once we have analyzed the system and determined the correct length. Some kind of a shorted connector will have to be placed at the end of the extra cable. This can be done by exposing some length of both the center conductor and the shield and then pushing them together. Be sure to check that a good solid connection is made. There are many other ways of doing this, but this method works reasonably well.

Problems – Real cables have some loss. Thus, their ability to block a channel might not be as good as our lossless line analysis might suggest. Also, the Tee may very likely be adding some additional capacitance to the location where the three cables come together. It is also difficult to determine the effective length of the cables when we have to account for the connectors. Therefore, it is usually best to field fit the cable length, by cutting it a bit long, testing it, and then cutting again and again until the desired channel is blocked.

Analysis: (15 pts)

1. Write out the equations that describe how this channel blocker works.
2. Select a channel to block.
3. Select a length for the short-circuited cable that will block your desired channel.
4. Determine the voltage and power transfer function for the complete system.
5. Use Maple, Matlab or something equivalent to solve the equations for the entire range of frequencies of the CATV channels received in the Albany-Schenectady-Troy area. Plot your results.

Information on the Standard Cable-TV Frequencies can be found at http://www.info2000.net/~aloomis/catv.html

Testing Your Model: (10 pts) To test your model and assess your choice of cable length, you must identify all channels that will be blocked by your choice of cable length. You should select a cable length that blocks as few channels as possible. The following will be filled out by a TA or instructor.

CATV Channels Blocked ____

Length ______________ **Witnessed** ___________

Testing Your Design: Show that your design works with experimental data from your hardware. To demonstrate your design you must either build a CATV channel blocker (which will be tested by a member of the course staff) or use your model on an equivalent experiment that can be done in the studio. Since the function generator is limited to 15MHz, use a range of frequencies that is equivalent to the CATV frequencies you analyzed (500kHz to 13MHz). The latter choice is simpler to do since you do not need to build anything. To build the former, you will have to provide your own Tee, which can be made from a coupler by removing the lumped circuit elements and by wiring together the three connectors, as discussed above. Please be sure that you test your blocker yourself, since they never work for the desired channel without some final adjustments of length, due to the non-ideal nature of the components used.

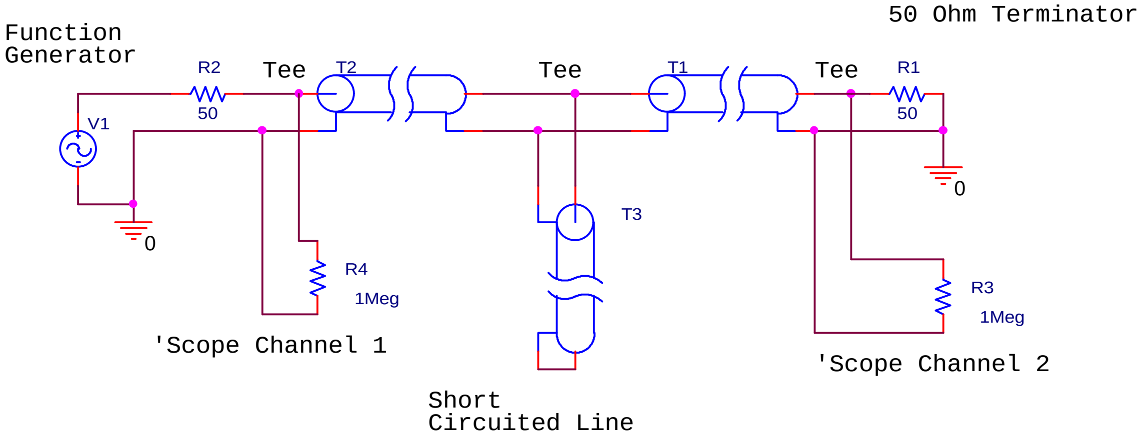
Option 1 – Channel Blocker Test: For this test a working channel blocker must be delivered with the project report. The blocker should have a label that indicates the channels it is designed to block. The following will be filled out by the instructor.

Working Channel Blocker Constructed and Delivered With Report (10 pts) _______

CATV Channels Blocked____

Length ______________ **Witnessed** _______(5 pts)

Option 2 – Equivalent Test in the Studio: The equipment in the studio differs from the CATV test in frequency range (0-15 MHz is possible using the function generator) and cable characteristic impedance (Z_o=50ohms). Set up the configuration shown below using two pieces of coax from the cable box and the artificial (lumped parameter) transmission line. The lumped parameter line is to be used for the short circuited line. Connect the Tees as shown. Remember that each section of the lumped line represents 4 meters of coaxial cable length. Thus, a shorted cable of any length that is a multiple of 4 meters (up to 80 meters) can be created by using a small wire to short across on of the nodes. If you want to use a cable that is not exactly a multiple of 4 meters long, add another piece of cable to the input of the box to increase the total length. Why will it not work to add the cable to the node and then shorting the output to the cable? Input this length into the equations used to model the blocker, using 50 ohms for Z_o. Produce the same plots as you did for the 75 ohm case. You will need these for reference purposes when you do the experiment.



The lumped transmission line is better to use than the full coil of coax for two reasons. First, it is somewhat less lossy. Second, it can be shorted at any node to create a shorter line. This method would not have worked for the open-circuited line, since we cannot disconnect the wires on the lumped line. The lumped line has at least one problem that using a shorted piece of coax does not. The wires in the line are open and thus radiate like antennas. This effect adds to the losses for the line, but since they are smaller than for the coax, it is not significant.

Experiment (10 pts)

1. Describe the method you used to take the data and discuss the features of the data you have obtained. For example, explain the voltage levels observed. You should use HP-Benchlink to make copies of the input and output voltages for a typical blocked frequency and an unblocked frequency.
2. Be sure that you explain why the measurements you have made demonstrate that your model is sufficient to build an actual channel blocker.
3. Have your experimental data signed by a TA or instructor.

The following will be filled out by a TA or instructor.

Function Generator Frequencies Blocked_________________________________

Length ______________ **Witnessed** ______(5 pts)

Discussion: (5 pts) It is highly unlikely that your model and experimental results will agree. Discuss the differences and similarities between the predictions of your model and the results you obtained in practice. You should also discuss your choice of cable length. If you block channels other than the one you have selected, you should discuss why this will not be a problem. For example, maybe no one you know watches the other channel(s).

Quality of Performance: (5 pts) Ideally, the blocker should work for only one channel. Thus, part of your grade will be determined by how well the selected channel is blocked and part will be determined by how little it affects other channels (or frequencies in the studio experiment). Thus, you must be careful to select the cable length to do the best job on the desired frequency and to leave the rest of the channels changed as little as possible. Again, if you make a good case for why you wish to block all of the affected channels, your performance quality can still be considered good.

Extra Credit: (0 to 10 pts)

1. Re do the analysis incorporating the effects of loss in the transmission lines. You will have to use either published data on the cable losses or measure the attenuation. Discuss the similarities and differences between the predictions of the two models.

2. Re do your measurements in the studio using a piece of coaxial cable instead of the lumped transmission line. This will probably require connecting several smaller lines together to get the length you need. Discuss the similarities and differences between the two sets of measurements.