

Project 1 (Due: 28 February)
RF Notch Filter
Trap for Unwanted Frequencies

For this project, students can work in groups of two to four. No reports will be accepted from single students. Include this page on the front of your report.

Grading

Design 1 (5 pts) _____

Design 2 (5 pts) _____

Analysis of for 10 MHz (5 pts) _____

Analysis of TV channel (5 pts) _____

Frequency Response for Design 1 (10 pts) _____

Frequency Response for Design 2 (10 pts) _____

Performance of Best Design (10 pts) _____

Task Breakdown (0 pts, but required) _____

Extra Credit (0 - 15 pts) _____

Total _____

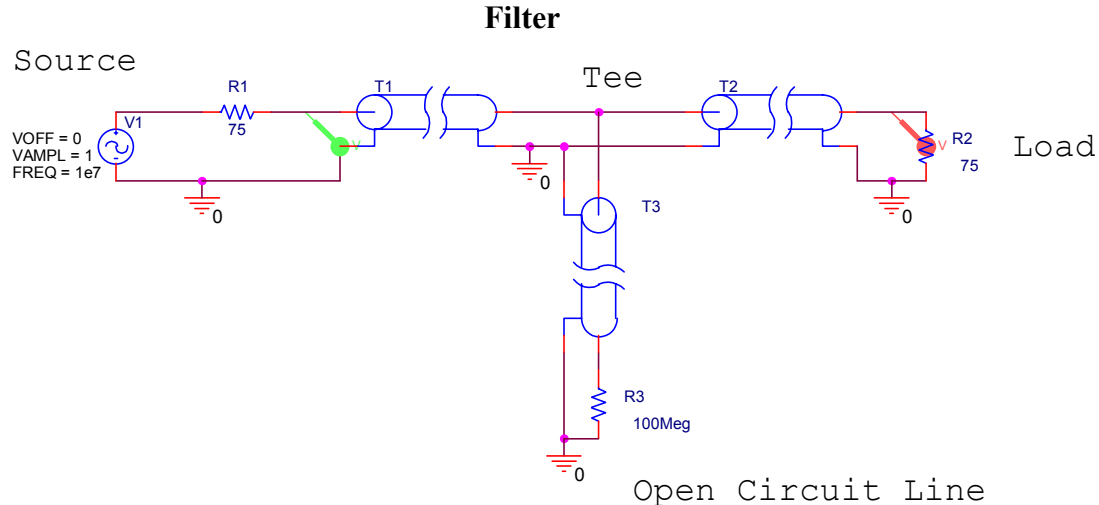
Group Members:

1. _____

2. _____

3. _____

4. _____



Introduction

The purpose of this project is to build a simple device that blocks the signal from a particular frequency while passing a signal at a second frequency. No active or lumped circuit elements will be used for this purpose. Rather, this will be accomplished by adding a stub terminated with a short or open circuit.

The basic principle of this signal blocker is relatively simple. The input cable (T1 in the figure above) is interrupted with a Tee coupler to which is connected a short piece of cable (T3 above) with no load (open 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 load (T2 above). Assuming that the cable is properly matched to the load, 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 load is 75 ohms (as in a TV system). 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 open-circuited cable will change with frequency. If the length of this cable is properly selected, the signal from one frequency will be reflected from the Tee since the effective load for T1 will be a short circuit. The signals from other frequencies will not be reflected since the input impedance of the stub is not zero at these frequencies. 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 and that we are using a short circuit load instead of the open circuit load in this project. Also, assume that it is insulated with polyethylene $\epsilon_r = 2.26$. Then the velocity of propagation on the line is $v = 2 \times 10^8$ m/s (your cable will have a different velocity). 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

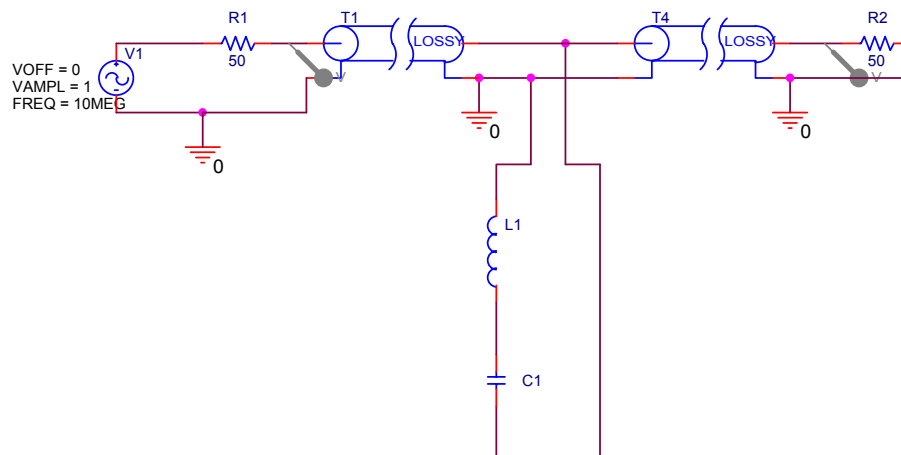
$$Z_{in} = Z_o \frac{Z_L + jZ_o \tan \beta d}{Z_o + jZ_L \tan \beta d} \approx jZ_o \tan \beta d, \text{ where we have assumed that the transmission line}$$

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, which is as large an impedance mismatch as can be obtained, the magnitude of the reflection coefficient is one. The input signal 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 load.

Why would we want to do this? First, assume that the system of interest is the cable TV system in your residence. Let us assume that you would like to block one of the channels coming in for some reason, maybe you are annoyed with your roommate watching the Weather Channel all the time. You can select the parameters of the open circuited stub (as such short cables are called) to short out the signal at the frequency of the unwanted channel. If you do this correctly, you will leave the other channels unaffected. Information on the frequencies of cable TV channels can be found on our Supplementary Materials Webpage. A second example of getting rid of unwanted frequencies, assume that you are doing some kind of an RF (Radio Frequency) experiment involving a low power signal at 144MHz. For example, moon bounce experiments are done at this frequency. Unfortunately, the signal is very small coming back from the moon and there is a lot of power in the FM broadcast band near 100MHz. This FM station power, if detected by your receiver can saturate the front-end amplifier so it is not able to amplify the signal you sent to the moon. To avoid this problem, you can filter out or block the FM signals before they get to your amplifier so it is able to respond to the signal at 144MHz. There is a short description of this situation at <http://www.qsl.net/ea6vq/qrmfm.html>. (QRM is signal interference.) There is also an extensive description of eliminating AM band frequencies at <http://www.dxing.com/tnotes/tnote06.pdf>. Third, you may be operating some kind of wireless system where there is a lot of noise generated (by a motor or some other system) at several harmonics of 6kHz. Again, to block out the noise, you can use some kind of filter.

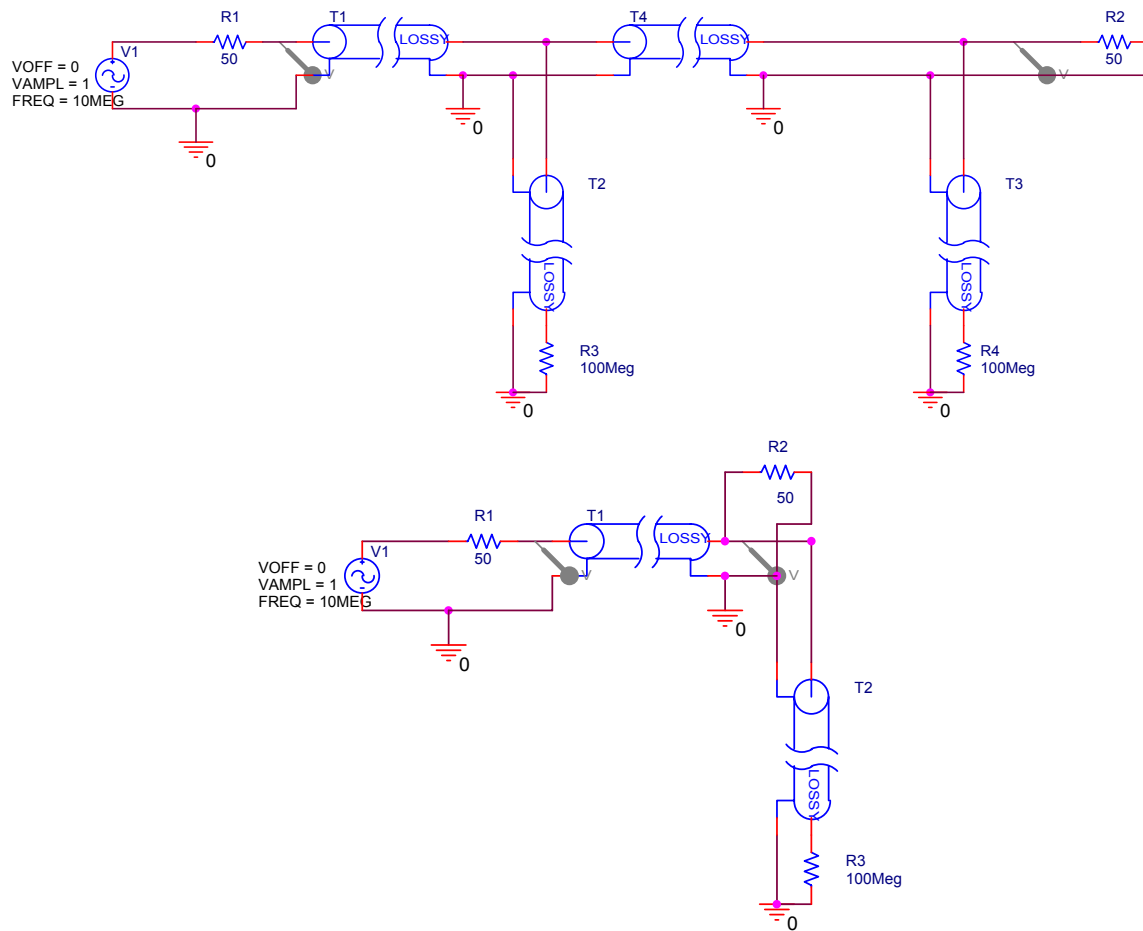
The simple, single open stub configuration shown above is probably the simplest way to build such a filter. You could also do it with discrete components, as shown in the following figure. Several schemes for discrete component filters can be found in the dxing.com link in the previous paragraph.

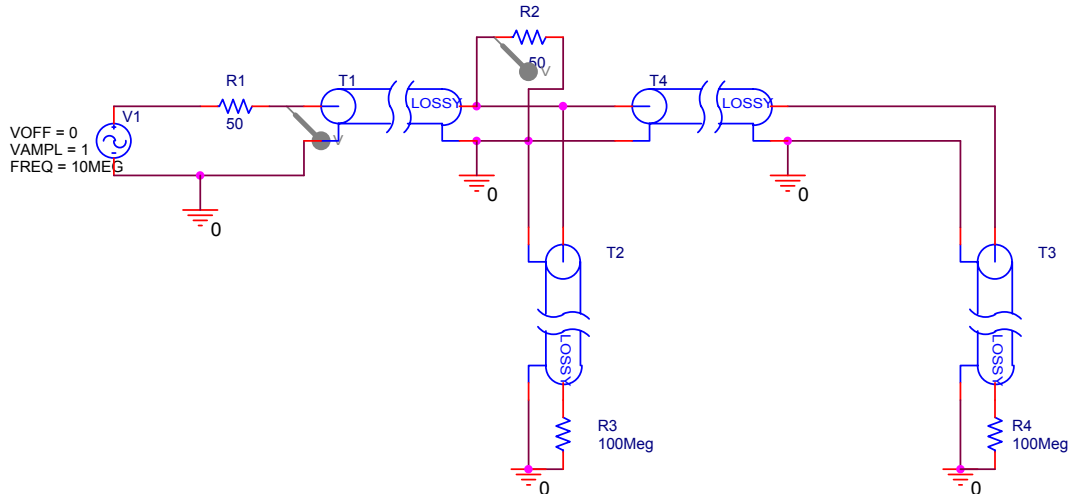


At the resonant frequency of the LC combination, there will be a short across the line and the input signal will not reach the load. Both of these can work, but there are other

options that generally work better, including the more elaborate discrete component filters in the dxing.com link.

In this project, three transmission line circuits are possible, as shown in the following circuits. Note the circuits all have 50 $[\Omega]$ components. Cable systems are 75 $[\Omega]$. Make sure you implement the correct circuit parameters in your models. In all the circuits, R2 corresponds to the load. In the implementation, R2 would be your cable box. The length of T1 is not that important. However, since you are using lossy lines, the voltage that “arrives” at the end of T1 will be affected by the length. The length of T4 is $\lambda/4$ at the frequency you wish to block. In your calculation, you should discuss why this length is chosen for T4.





The first option is a double stub circuit. The second is a single stub circuit. The third moves the single and double stubs directly across the load instead of between the load and the source.

The set of pictures was generated using the student version of PSpice. Using this program is one of the options you will have for this project. Note that there are two kinds of transmission lines shown. One is ideal and the other is lossy. Both are useful. Also, the source frequency in these figures is 10MHz. If you choose to do the experiment in the studio classroom (discourage), then you will use this frequency. If you do the experiment on cable TV, then your frequency will be the channel you are trying to block.

A real Stub Tuner: A picture of a triple-stub tuner (it has three shorted stubs with the ability to adjust the length of the stub) is shown in the following picture. This device can be used to connect two devices that have difference impedance values such that the reflection coefficient is zero. While it is possible to use a short or open circuit stub to prevent reflections (the opposite of this project's goal), it is much more practical to use the tuner. The knobs raise and lower screws inside the connector. There really isn't a simple way to determine the impedance of the tuner. Numerical computing programs are used to analyze these devices. "Tuning" the stub tuner is actually somewhat of an art form. While there are some guidelines, you can simply adjust the tuner until the reflection coefficient is zero.



Look to the Past: Those of you who know how this project was specified in the past, you will note that we have previously used either a short-circuited or 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. This is not necessarily a serious problem, so this time we will use an open stub. Those of you who have heard nothing about this project should look over the 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 that includes a lot of the important analysis steps for the channel blocker. This latter document should be read thoroughly.

Analysis Option 1: In the project from Fall '99, the channel blocker circuit was modeled using Matlab. You can use the program listing provided in the comments as a guide. The comments also include sample plots. Also, see the Matlab analysis document that you can link to from the project page.

Analysis Option 2: The traditional way to analyze stub filters is to use a Smith Chart. This is discussed in the textbook and at the following sites on the web.

Smith Chart References:

http://weewave.mer.utexas.edu/DPN_files/courses/363M/tuner_exmpl/dbl_tnr.html

<http://www.ee.surrey.ac.uk/Personal/D.Jefferies/stubs.html>

<http://www.acusd.edu/~ekim/e171f00/lab3.pdf>

<http://people.deas.harvard.edu/~jones/es151/pages/gallery/gallery.html>

http://www.eecs.umich.edu/emag/labmanual/EECS230_LE5.pdf

Analysis Option 3: Since transmission lines can be modeled using PSpice.

In this project, you are to consider the various configurations for the blocker or filter and decide which works the best. You can use any of the three analysis options. The output from your analysis should show how well the filter would work. This requires that the loss in the lines be included (which it is not in the Fall '99 Matlab file).

You must design two systems. One should block some cable TV channel, your choice, and leave most other channels unaffected. The other should block 10MHz while allowing 14.4MHz to pass more-or-less unaffected.

Additionally, you need to model two of the three circuits, your choice, for both the TV channel blocker and the 10 MHz blocker.

Once the analysis has been done, you must either build a channel blocker for a TV channel (two F-type Tee connectors will be provided, but you will have to obtain your

own cable) or do the experiment in the studio showing that the 10MHz signal is blocked while the 14.4MHz signal is not. If you choose to build the TV channel blocker, you should test it yourself and record the results (e.g. channels blocked and channels unaffected). You will hand in the channel blocker and the grader will test it on a cable system. (My TV has very good signal processing, your blocker must be well designed.) If you do the experiment in the studio, you must record the input and output voltages at 8MHz, 9MHz ... 15MHz (1MHz increments).

Specific Tasks:

1. Specify two filter schemes. Draw each configuration. Be sufficiently complete so that you can analyze your design. This is very simple. Specify the circuits you are modeling.
 - a. **Design 1** (5 pts)
 - b. **Design 2** (5 pts)
2. Using one of the three analysis options, analyze both filter schemes for the two purposes (show your work). *The purpose of this section is to show that you understand how to do the analysis. Thus, you should do some simple calculations and explain your approach, step-by-step. In other words, indicate how you determined the lengths of the cable sections. The results (plots) for your analysis are asked for in the next section.*
 - a. Blocking 10MHz while passing 14.4MHz (as in the studio)
 - i. **Design 1** (2.5 pts)
 - ii. **Design 2** (2.5 pts)
 - b. Blocking a cable TV station (your choice) while leaving as many other channels as possible unaffected.
 - i. **Design 1** (2.5 pts)
 - ii. **Design 2** (2.5 pts)
3. For all three types of analysis, it is a good idea to do it first for lossless lines. Then it must be repeated for lossy lines. You do not have to include the lossless analysis in the report, but it helps to interpret the lossy results. The analysis should only be for the experiment that you choose to implement. You should model both circuit designs for that experiment. *Note that you are to do only one of these options.*
 - a. For the Matlab analysis, you should produce a plot like the transmission coefficient plot on pages 5 and 8 of the project 2 comments (Fall '99) found on the course Project Webpage.
 - i. **Design 1** (10 pts)
 - ii. **Design 2** (10 pts)
 - b. For PSpice, you should produce a plot of the voltage vs. frequency at the load. In both cases, the frequency range should cover 1MHz to 20MHz for the studio experiment or all cable TV frequencies for the TV channel blocker.
 - i. **Design 1** (10 pts)
 - ii. **Design 2** (10 pts)

- c. For the Smith Chart approach, you will have to include all of your Smith Charts. The Smith Chart analysis must be done for at least 5 representative frequencies, including the specific frequencies of interest. *Note – this option probably requires the biggest time investment to learn. You should probably not try it unless you have had a little experience with Smith Charts before or unless you find graphical tools to be particularly useful.*
 - i. **Design 1** (10 pts)
 - ii. **Design 2** (10 pts)
 - d. **Extra Credit (5 pts):** If your analysis is fairly unique (and accurate), you may receive extra credit for this part. You need to choose an approach or include parameters that your peers do not.
4. Either build and test the TV channel blocker or do the experiment in the studio. Final circuit performance will be done by one of the course instructors. You only need to test your preferred design. *You will need to develop and test your design for a velocity of your cable instead of the classroom cable velocity 2×10^8 m/s. This aspect should already have been included in your above model and calculations.*
- a. **Design Performance-Studio** (10 pts) – The studio project will be checked by the instructor who will assess the quality of the channel blocker. Oscilloscope plots must be included with the report.
 - b. **Design Performance-Cable TV** (10 pts) - The transmission line blocking circuit will be handed in with the report and the instructor will check them on a cable system. The blocking frequency and names of the groups should be attached to the circuit.

Task Breakdown: You must formally divide the work up in this project and assign each task to a member of your group. For example, one person can work on the report, one can build or test designs, one can do the analysis of one design and one analyze the other and, most importantly, one can be responsible for coordinating all the tasks and making sure that everyone is on schedule (ie. be a manager). In your project report, you must clearly describe how you divided up the work and who did what. In the event that a group member fails to contribute, I would like to be notified in this section. *There are no points for this, but you will receive a 5 point deduction if it is not included.*

Extra Credit 1 (10pts): Design and implement another method of filtering that is not one of the three stub circuits discussed in this project. Your circuit should block the same channel as your stub circuit. There are many possible circuits and/or components that can achieve this goal. The amount of points received will be dependent on how original I consider your implementation. If you consider a fairly unique approach, you will receive full credit. If your approach is fairly obvious, you will receive partial credit.