



Pre-Project 1: CATV Channel Blocker (aka Band Block or Notch Filter)

For Projects, students are to work in groups of 2-4.

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 your design and, most importantly, one can be responsible for coordinating all the tasks and making sure that everyone is on schedule. In your final project report, you must clearly describe how you divided up the work and who did what. It is not acceptable to say that everyone did everything. A particular member of your group must be responsible for each task.

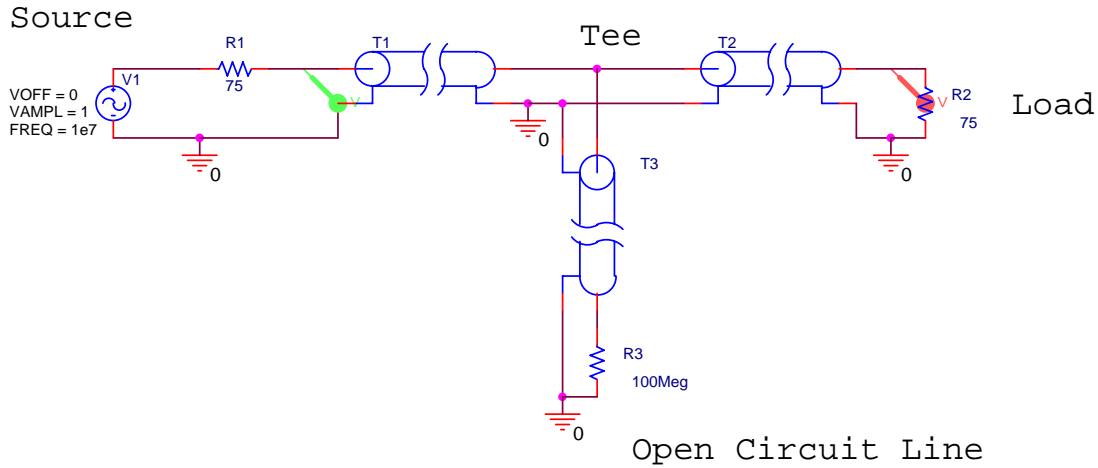
Suggestions: One thing that we all learn when working on projects is that everything will go better if one begins writing the report on day one. In this way, it is easy to see what yet needs to be done. Lay out the structure of the report and identify the person responsible for each section. Then the report writer will know who to bug to get things done on time. Also, the report writer needs to be sure that the report makes overall sense and does not appear to be a cut and paste job with no continuity. Be sure that you clearly identify the source of any significant information you have used. For example, you will obviously need the parameters for cables. What specification information did you use? If you used formulas from the book, lecture slides, class notes, other texts, etc. clearly indicate page numbers, etc. If you received help from anyone else (which is perfectly OK), make sure that you give them credit. You should not outsource your report, but you can really get help from anyone. *Finally, do not include plots generated from Matlab, PSpice, etc. without including a discussion of the information contained in the plot.* The easiest way to do this is to clearly label the plots with arrows and text boxes. The reader of your report should know exactly why the plot is included in your report and what it tells us.

Group Members:

1. _____
2. _____
3. _____
4. _____



Project 1 involves designing and building a simple CATV channel blocker. In the first session on 23 September, you will investigate the performance of some sample open-circuit stubs as blockers. You do not need to build anything at this point, but some simple analysis is necessary.



Introduction

The purpose of this project is to build a simple device that blocks the signal at 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-type tuner to the cable that brings the signal to the load. A PSpice realization of this idea is shown above.

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 T2 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 while the signals from other frequencies 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 T3 has a length = d . 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. In the simulation of this line, one can either reduce the expression for Z_{in} for an open circuit load or just use a very large 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 $Z_{in} = Z_o \frac{Z_L + jZ_o \tan \beta d}{Z_o + jZ_L \tan \beta d} \approx -jZ_o \cot \beta d$, where we have assumed that the

transmission line is ideal and therefore lossless. When this is very large ($\cot \beta d \rightarrow \infty$), adding it in parallel to the cable will have no effect. When this is very small ($\cot \beta d \rightarrow 0$), 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 input signal from T1 will see a short-circuit load at the frequency where $\cot \beta d \rightarrow 0$ 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. 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 largely unaffected. Information on the frequencies of cable TV channels can be found on our Projects Webpage. Second, 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 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.



Tasks for the Pre Project:

To be completed before class on Wednesday (checked at the beginning of class and turned in by 6pm):

Set up the cable configuration shown above for PSpice simulation. All cables are to have a $Z_o = 75 \text{ Ohms}$. Also, assume a velocity factor of 67%, which is a typical value but may not be correct for the actual cables you will use in your project. The goal here is to set up the analysis so you will be able to easily use it once you have actual data. For cable T1, choose a long delay time to represent a few hundred meters and for cable T2, choose a delay time that corresponds to a length of 1 meter. The delay time for T3 is at the heart of the design for this project. Analyze your configuration using the AC Sweep option covering the entire frequency range for Cable TV. You will have to use the resources on the *Projects* page to determine this range.

Range of Frequencies for CATV: _____ to _____

For your plot, only display the voltages at the final load at the end of T2 and at the Tee (the input to T2 and T3). The voltage at the input to T1 will be a big mess, because you are not using a lossy line. The voltages at the input and output to T2 will show a series of zeros (the result of the blocking). Choose the delay for T3 such that the first zero occurs at a frequency of 100MHz. You should now be set up to analyze any cable configuration of this type. Show your plot to a TA and have them sign on the line below confirming that you have completed this analysis.

Teaching Assistant _____

To be completed in class on Wednesday (turned in by 6pm):

There is quite a large collection of open-circuit stubs in JEC 4107. You should perform simple analysis for and test at least two of these stubs. The two stubs must be of significantly different lengths. You may have trouble with one of the stubs, so it is recommended that you consider 3 stubs and choose the two with the best performance. Also, it is a good idea to test each of the three stubs to be sure it is indeed an open circuit. You can do this with the multimeter by measuring the resistance from the input end.

1. Note the number of each stub you are using. If it does not have a number, then you should check with the TA to see that it has length.

The numbers of the three stubs

- i. Stub 1 _____
- ii. Stub 2 _____
- iii. Stub 3 _____

2. To predict the performance of the stubs, it is necessary to measure their length.

The length of the three stubs

- i. Stub 1 _____
- ii. Stub 2 _____



- iii. Stub 3 _____
- 3. Test the three stubs with the spectrum analyzer. Record the frequencies where the minima in signal level are observed. For the short stubs, there will probably be only one frequency in the CATV frequency band. However, for the longer cables there can be several. If you have access to a camera, plan to take a photo of the screen of the spectrum analyzer that shows the minimas for CATV frequencies
 - The frequencies of the minimas for the three stubs
 - i. Stub 1 _____, _____, _____, _____
 - ii. Stub 2 _____, _____, _____, _____
 - iii. Stub 3 _____, _____, _____, _____
- 4. Test the three stubs with the TV signal that can be observed through the VCR and video projector. Indicate the channel numbers where the strongest impact on signal quality is observed. Obviously, you should look up the frequencies of the minimas you observed in part 2 before testing the stubs with the TV signal.
 - The channels with the worst signal for the three stubs
 - i. Stub 1 _____, _____, _____, _____
 - ii. Stub 2 _____, _____, _____, _____
 - iii. Stub 3 _____, _____, _____, _____
- 5. One of the problems in implementing this idea with any old stub is that you may not know the propagation velocity of the cable. All CATV cables are 75 Ohms, but some have a velocity factor of 85%, some 67%, and some near one or the other of these values. The most common value is near one of these two values (82-85%) or (66-70%). Based on the length of the cable and the frequency being blocked, determine which of the two velocity factors holds for your three stubs. This is where doing three stubs comes in handy, because sometimes it is quite difficult to answer this question. For the pre-project, you are only to do the best possible job for each of the three stubs.
 - The velocity factor of the three stubs
 - i. Stub 1 _____
 - ii. Stub 2 _____
 - iii. Stub 3 _____
- 6. Analyze the three stubs using PSpice, setting up the configuration shown on page 2. If you have the velocity and length correct, your analysis should be consistent with your data. Note where you find such consistency and where you do not. Remember that exact agreement is not necessary.



To be completed before class on Thursday (before 4pm):

7. Planning – You are to pick two channels, find the open stub lengths necessary to block those channels and then identify any other channels whose signal is likely to be affected. In the next week, you will be asked to expand on your analysis to include loss and to address a few other practical issues. Next Wednesday, you will build your two designs and test them.
 - a. Identify the two cable channels whose signal will be blocked.
 - b. Look up the frequency of the two channels and then determine the necessary length of the open circuit stub required to block each channel. Justify your choice of stub length from first principles, not from doing a PSpice simulation (that comes next).
 - c. Do a PSpice simulation (AC frequency sweep) for each of the two configurations you have identified. From the PSpice output, identify all campus cable channels that are likely to be affected by your choice of stub. Remember that the blocker is likely to affect 2 or 3 channels whose frequencies are next to one another and that the cable channel numbers do not occur in sequence in frequency. Also, there are some ranges of frequency for which there are no channels (e.g. the FM band) so, while some additional blocking is theoretically possible, there may be no signal to be blocked.
 - d. Email the above information in a word or pdf document to Prof. Connor. Your document should include a figure showing the configuration you have set up in PSpice and the plot from the AC sweep. If you have not already noticed, the plot can be copied to the clipboard with a command found under the Window menu. Ideally, you should submit this on Wednesday, but anytime Thursday before 4pm is also fine. Be sure you list the names of all partners on the document.