Fields and Waves I

ECSE-2100 **Spring 2007**

Project 1 (*Due: February 7, 14 & 21)*

RF Notch Filter

Trap for Unwanted Frequencies

For this project, students can work in groups of two to four. Hand in one report for each group.

Grading

1. Design (10 pts)	_____
2. **Analysis of Design** (8 pts)	_____
3. Frequency Response for Design (15 pts)	_____
4. Performance of Design (10 pts)	_____
5. Discussion (5 pts)	_____
Task Breakdown (2 pts)	_____
Total	_____

Group Members:

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

Note: The lossless version of tasks 1, 2 and 3 should be checked off by 7 February. Design testing should begin on 7 February and be completed by 14 February. The final report is due on 21 February.

Tasks 1-3, Lossless Version Checked: _____ (TA or Instructor).
This preliminary check off confirms that this group is proceeding correctly with their project.

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Rensselaer Polytechnic Institute

Revised: 2/2/2007
Troy, New York, USA

Television

Some background information and general TV history resources:

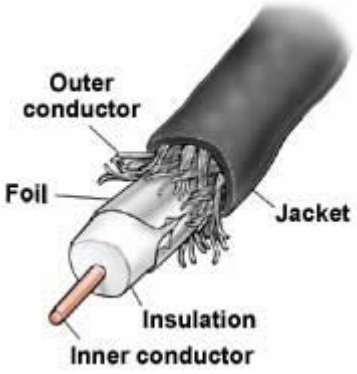
1. List of significant historical events in TV history: http://en.wikipedia.org/wiki/List_of_%27years_in_television%27
2. Alan B. Dumont, RPI grad who built the first practical TV: http://en.wikipedia.org/wiki/Allen_B._DuMont (check out the link to Rensselaer on this page for some very interesting info)
3. Television History, the first 75 years: http://www.tvhistory.tv/
4. The history of TV: http://inventors.about.com/library/inventors/bltelevision.htm
5. Radio and television history sites: http://www.rtvf.unt.edu/links/histsites.htm
6. Media History: http://www.mediahistory.umn.edu/teevee.html

Television channel frequencies:

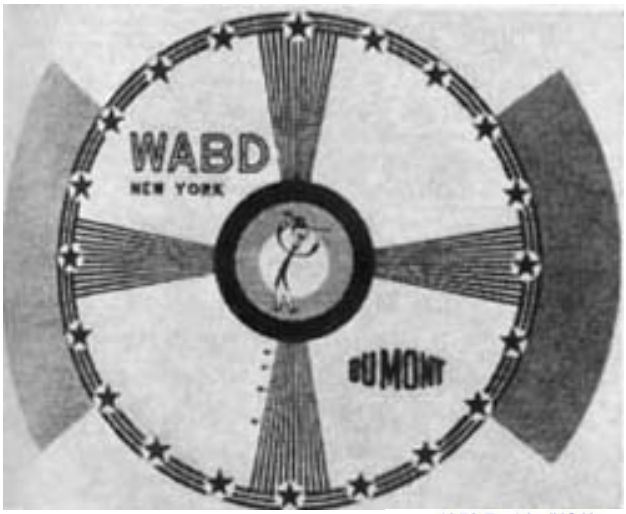
1. http://www.arrl.org/tis/info/catv-ch.html
2. http://www.atxnetworks.com/qrf/catvfrq1.htm
3. http://www.tvtower.com/Commercial%20Television%20Frequencies.html
4. http://www.w4zt.com/freqs/catv.html
5. http://www.turnkey.net/CATV%20frequencies.htm
6. http://www.chem.hawaii.edu/uham/catvfreq.html

Coaxial Cable Information

1. http://www.ocarc.ca/coax.htm
2. http://www.rfcafe.com/references/electrical/coax_chart.htm
3. http://www.phptr.com/articles/article.asp?p=169518&seqNum=2&rl=1
4. http://en.wikipedia.org/wiki/Coaxial_cable
5. http://www.pfm.howard.edu/infosys/choosing_correct_cable.pdf
6. http://www.signalengineering.com/ultimate/coax_basics.html
7. http://www.educypedia.be/electronics/cablingrf.htm
8. http://www.zianet.com/ebear/coaxlist.html
9. http://www.epanorama.net/documents/wiring/coaxcable.html
10. http://www.timesmicrowave.com/cgi-bin/calculate.pl

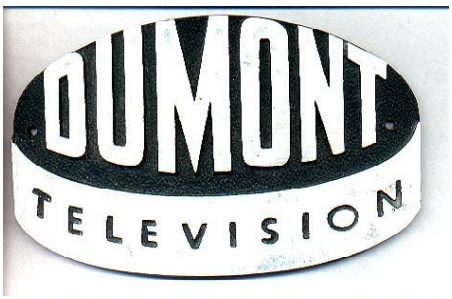


1939 Du Mont Model 183 - 14" Screen



1953 Sharp - TV3-14T
First Japanese TV

© 2003 TVhistory.TV



1952 Zenith (USA)
21" Model K2230R

TVhistory.TV

Photo is from Sams Photofact ® 187, dated Dec. 1952
Reprinted with permission of Sams Technical Publishing

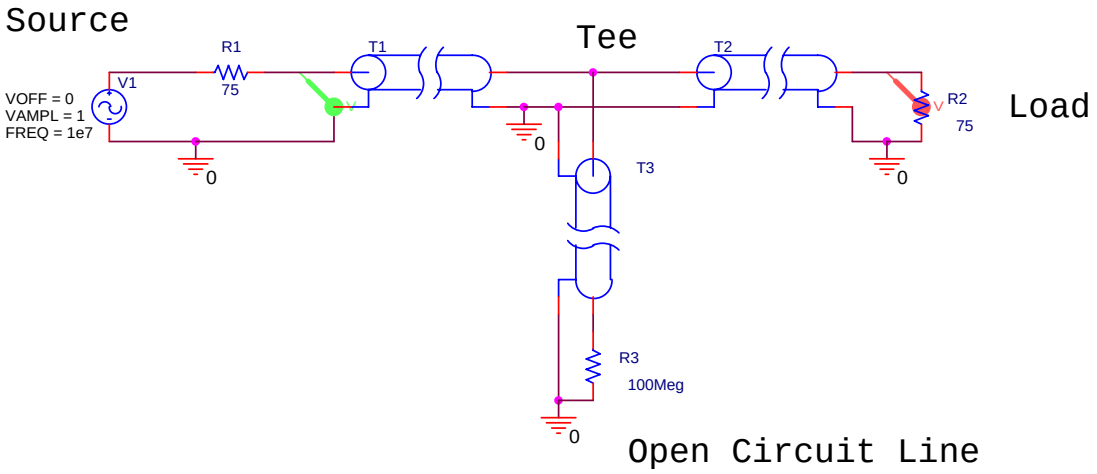
1952 RCA -- 17" Model 7T122 (USA)

© 2004 TVhistory.TV

1950 Du Mont (USA)
19" RA-109-A2 "Hanover"

© 2003 TVhistory.TV

Filter



Introduction

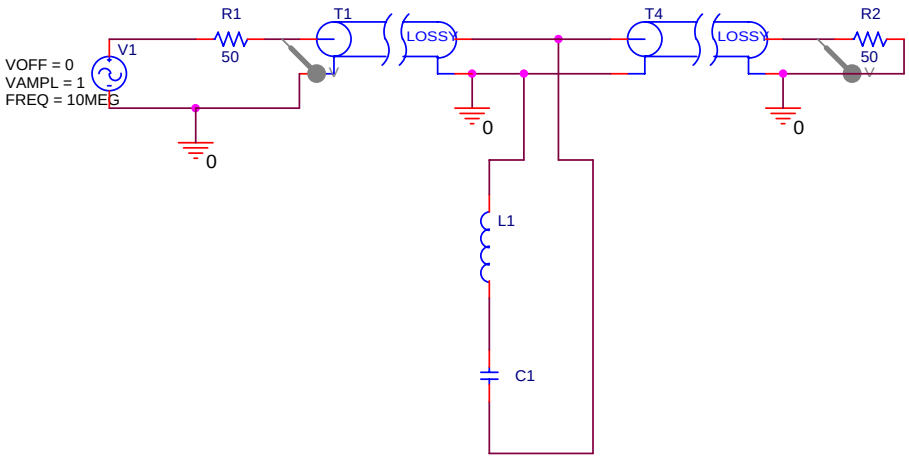
The purpose of this project is to build a simple device that blocks the signal from a particular frequency while passing a signal at a second frequency. No active or lumped circuit elements will be used for this purpose. Rather, this will be accomplished by adding a stub-type tuner to the cable that brings the signal to the load. A picture of a standard triple-stub tuner (it has three shorted stubs with the ability to adjust the length of the stub) is shown in the following picture.

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 short-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.

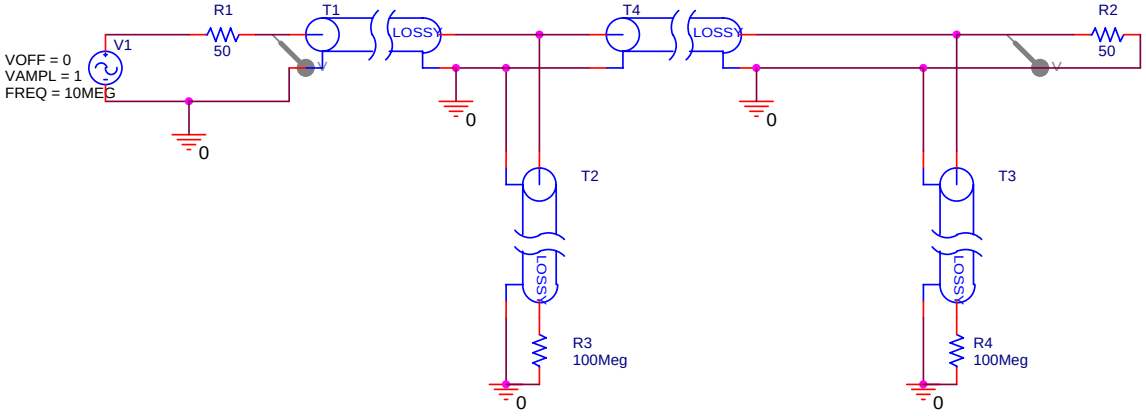
For example, assume that the extra piece of cable has a length = d. Also, assume that it is insulated with polyethylene $\varepsilon_r = 2.26$. Then the velocity of propagation on the line is v = 2×10^8m/s. In the simulation of this line, one can either reduce the expression for Z_{in} for an open circuit 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 $Z_{in} = Z_o \dfrac{Z_L + jZ_o \tan \beta d}{Z_o + jZ_L \tan \beta d} \approx -jZ_o \cot \beta d$, where we have assumed that the transmission line is ideal and therefore lossless. When this is very large ($\cot\beta d \to \infty$), adding it in parallel to the cable will have no effect. When this is very small ($\cot\beta d \to 0$), 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 will see a short-circuit load at the frequency where $\cot\beta d \to 0$ and the signal at that frequency will be reflected from the Tee and not make it to the load.

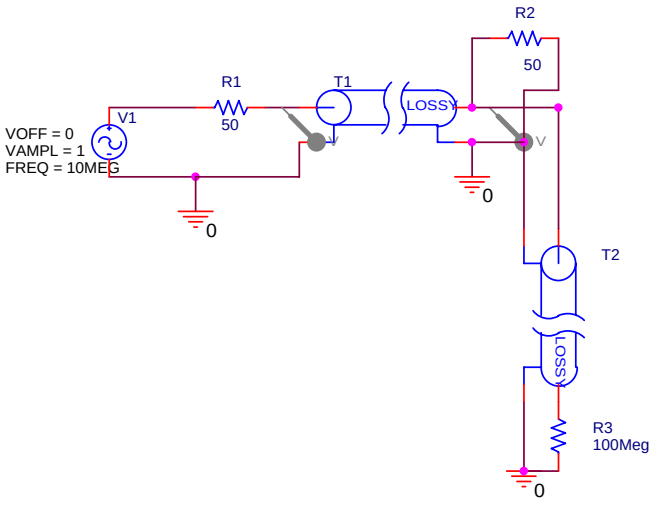
Why would we want to do this? First, assume that the system of interest is the cable TV system in your residence. Let us assume that you would like to block one of the channels coming in for some reason. You can select the parameters of the open circuited stub (as such short cables are called) to short 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 Supplementary Materials Webpage and using the links on the first page of this document. 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.

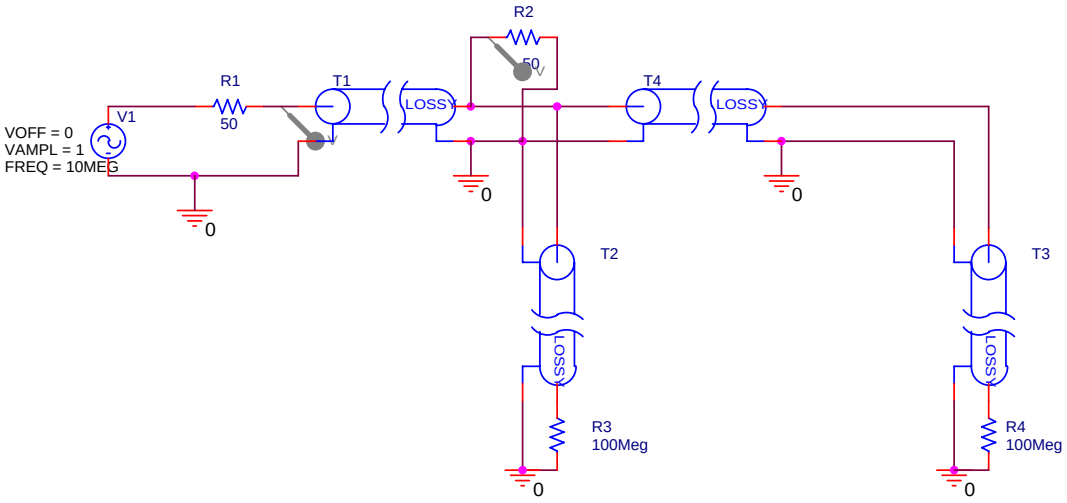
The simple, single open stub configuration shown above is probably the simplest way to build such a filter. You could also do it with discrete components, as shown in the following figure. Several schemes for discrete component filters can be found in the dxing.com link in the previous paragraph.



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. Several options follow.

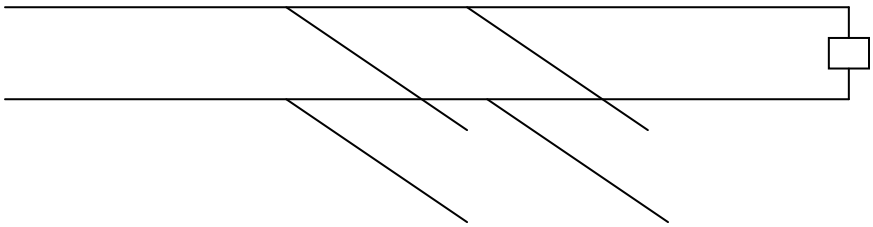




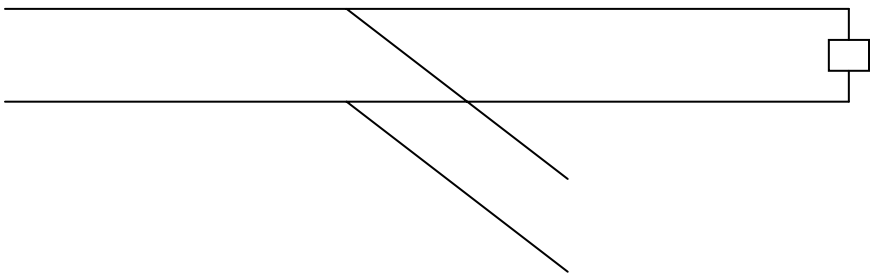


The first option is a double stub circuit. The second and third move the single and double stubs directly across the load instead of between the load and the source.
These options can also be shown generically.

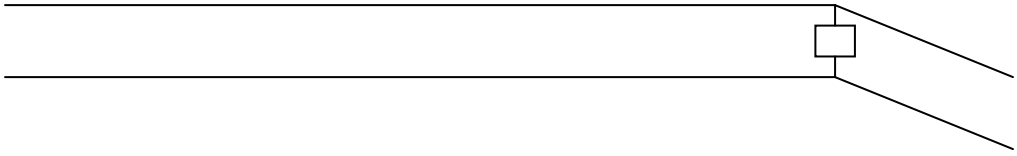
Double Open Stub Tuning



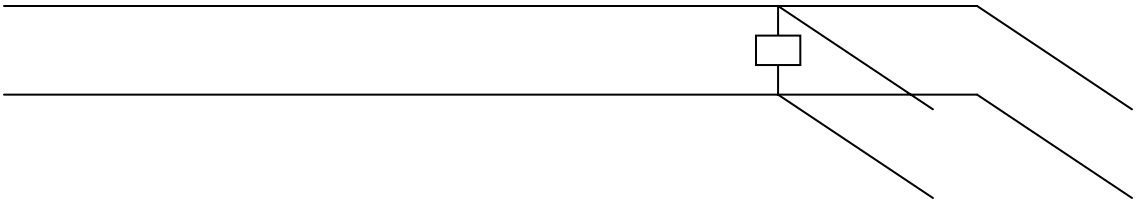
Single Open Stub Tuning



Single Open Stub Filter at Load



Double Open Stub Filter at Load



The first 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. We will use this frequency to address an experiment you can do in the studio classroom. We will use something around 100MHz for blocking a cable TV signal.

Look to the Past: Those of you who know how this project was specified in the past 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 which 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 text book 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://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, you can do your analysis by downloading the student version of this excellent program. Please also see the PSpice analysis document linked to on the projects page. Your final analysis must be done with the lossy transmission line model.

Overall Goals:

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 will 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 a TV channel below 150MHz and one should block a channel above 300MHz. Your lossy transmission line model must be correct at the frequency of interest for both cases. For the Matlab analysis option, your model should hold at all reasonable frequencies. For the PSpice option, there is no way to easily incorporate a frequency dependent resistance per unit length. Thus, you should do a complete frequency scan (covering the entire range of channel frequencies) for each of the two cases. This will help you to identify the range of validity of your two models. For each of the two cases, you should analyze two possible designs and compare their performance.

Once the analysis has been done, you must build a channel blocker for the two TV channels (two F-type Tee connectors will be provided for each group and, we hope, some cable and connectors). You must test your final designs (for the two channels) and record the results (e.g. channels blocked and channels unaffected). Then, you must demonstrate its efficacy to a TA using the cable feed in the studio to the TV display and the spectrum analyzer.

Specific Tasks:

1. Specify two filter schemes. Draw each configuration. Be sufficiently complete so that you can analyze your design. You should include all information on the parameters of the cables, lumped elements, etc. you are using and justify the accuracy of your numbers. Fully document the sources of your information. (10 pts)

2. Using one of the three analysis options, qualitatively analyze the filter schemes (show your work). For example, if you are using an open stub configuration, show your hand calculations for its length and predict the frequencies it will block. Check these frequencies against the list of CATV stations on campus to identify which signals will be affected. You should also set up and explain the more detailed analysis (using one of the three options) you will do for your designs at each frequency. *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. The results (plots) for your analysis are asked for in the next section.*
    a. Blocking a lower frequency cable TV station (your choice) while leaving as many other channels as possible unaffected.
        i. **Design 1** (4 pts)
        ii. **Design 2** (4 pts)
    b. Blocking a higher frequency cable TV station (your choice) while leaving as many other channels as possible unaffected.
        i. **Design 1** (4 pts)
        ii. **Design 2** (4 pts)

3. For all three types of analysis, do it first for lossless lines. Then it must be repeated for lossy lines. *Note that you are to do only one of these options. You must also clearly annotate your plots so it is completely clear what information they contain.*
    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. (15 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 all cable TV frequencies for the TV channel blocker. (15 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. (15 pts).

4. Build and test the TV channel blocker which must be turned in with your report and tested in class jointly with one of the course instructors. Testing should include connecting your blocker to the spectrum analyzer and recording changes in the observed spectrum. A simple way to do this is to photograph the display of the spectrum analyzer. However, a simple sketch is also fine. You should also connect your blocker to the cable line that feeds the VCR and observe changes in the display projected on the screens at the front of the room. Describe the changes you see.
    a. **Low Frequency Preferred Design** (5 pts)
    b. **High Frequency Preferred Design** (5 pts)

5. Discuss your results. What worked as expected? What did not? How close are the predictions of your model to the actual experimental results you obtained? (5 pts)

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. In your 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. (2 pts)

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.

It is likely that this project description will be updated. Please check class announcements and your email on a regular basis.