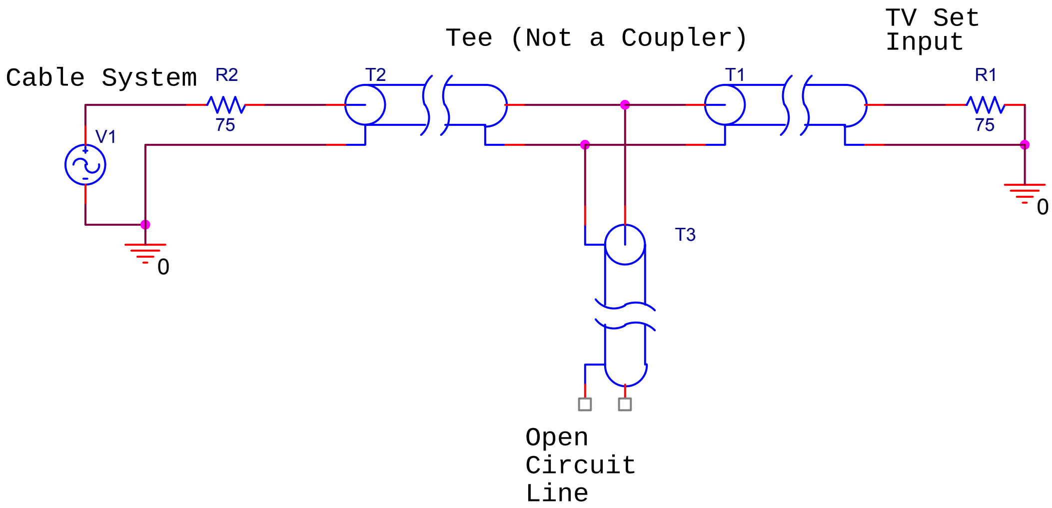
Analysis Using Matlab



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 nothing connected to it (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 TV set (T1 above). Assuming that the cable is properly matched to the TV, the input impedance of the cable connected to the TV (T1) 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 of any cable (Z_{in}) is a function of the electrical length of the cable (through the terms like tanβd where d is the length), the Z_{in} of the open-circuited cable (T3) 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 an open circuit or just use a very large value for Z_L. To be as general as possible, choose the latter approach. Then $Z_{in} = Z_o \dfrac{Z_L + jZ_o \tan\beta d}{Z_o + jZ_L \tan\beta d} \approx -jZ_o \cot\beta d$. *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 and which is as large an impedance mismatch as can be obtained.*

The input impedance of an open circuited cable is

$Z_{in} = Z_o \dfrac{Z_L + jZ_o \tan\beta d}{Z_o + jZ_L \tan\beta d} \approx -jZ_o \cot\beta d$ *while the input impedance of a matched cable is* $Z_{in} = Z_o$. *Ideally, at the location of the Tee, these two impedances will add in parallel. Since this is a parallel combination, it is easier to add them as admittances. $Y_{in}=1/Z_{in}$ and $Y_{in}=1/Z_o$, respectively.*

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

Cable TV frequencies run from about 50MHz to 650MHz, according to the reference above. The following Matlab m-file was written to analyze the blocker design. In this program, the frequency f is specified as a vector covering the entire range of CATV frequencies. Then Z_o and Z_L (called Zl in the program) are given and β is determined for each frequency from the propagation velocity v. Next, the input impedance of the open circuit line is determined at each of the frequencies. So far we have three vectors of equal length – f, β, and Z_{in}. Next, the parallel combination of the two impedances is determined. This combination (Ztotal) is now the load seen by the original CATV cable. The reflection coefficient on the original cable is then determined from $\Gamma = \frac{Ztotal - Zo}{Ztotal + Zo}$*, where we have used Ref instead of Γ due to Matlab limitations. The transmission coefficient is then determined from $\tau = 1+\Gamma$ or Trans = 1+Ref in Matlab. The transmission coefficient tells us what transmits past the Tee into the TV set. We then plot the real and imaginary parts of each of these terms along with their magnitude. It is the magnitude that is of the most interest. The output plots from this program for d=.25m are shown after the program listing.*

```
% Program for modeling a CATV channel blocker
% K. A. Connor 10 November 1999

f=[5:.01:65]*1e7;
Zo=75; d=.224; beta=2*pi*f/2e8;Zl=1e8;

% Input impedance of the open circuit line

Zin=Zo.*(Zl+j.*Zo.*tan(beta.*d))./(Zo+j.*Zl.*tan(beta.*d));

% Combination of Zin and Zo

Ztotal=1./(1./Zin+1./Zo);

% Reflection Coefficient

Ref=(Ztotal-Zo)./(Ztotal+Zo);

% Transmission Coefficient

Trans=1+Ref;

%Plotting Results

plot(f,real(Zin),f,imag(Zin),f,abs(Zin));
title('Input Impedance of Open Line');xlabel('Frequency');grid;figure;

plot(f,real(Ref),f,imag(Ref),f,abs(Ref));
title('Reflection Coefficient');xlabel('Frequency');grid;figure;

plot(f,real(Trans),f,imag(Trans),f,abs(Trans));
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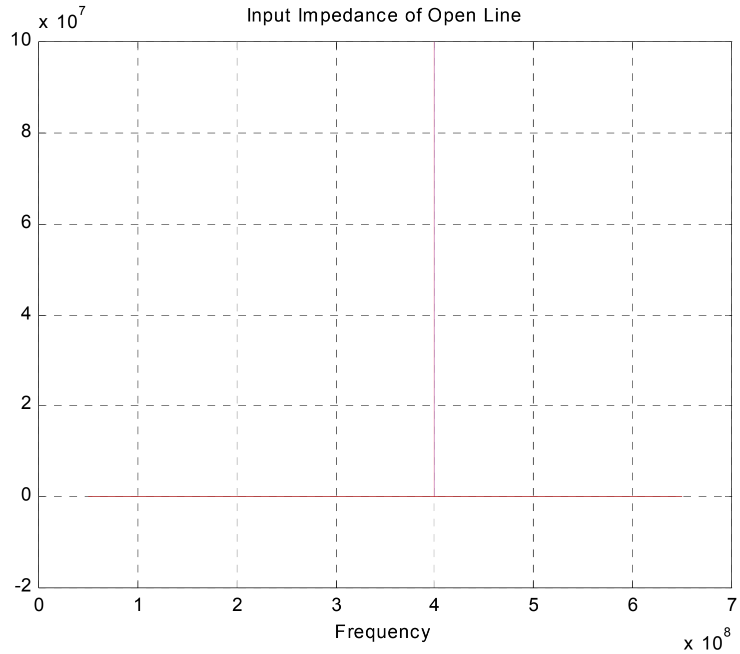
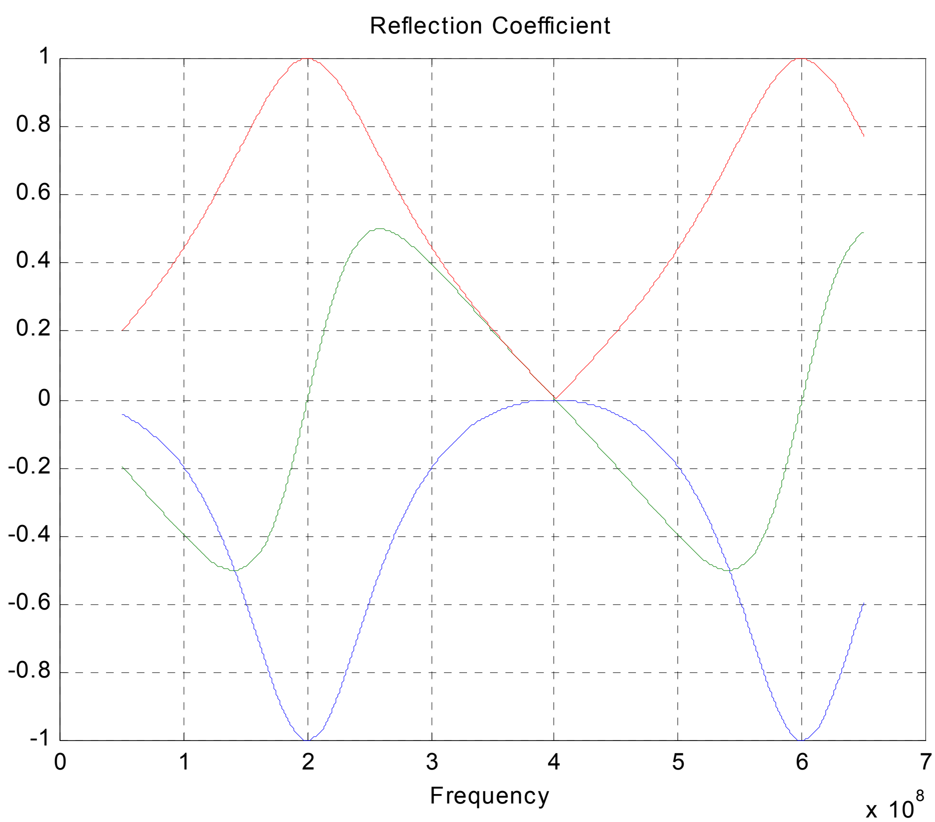
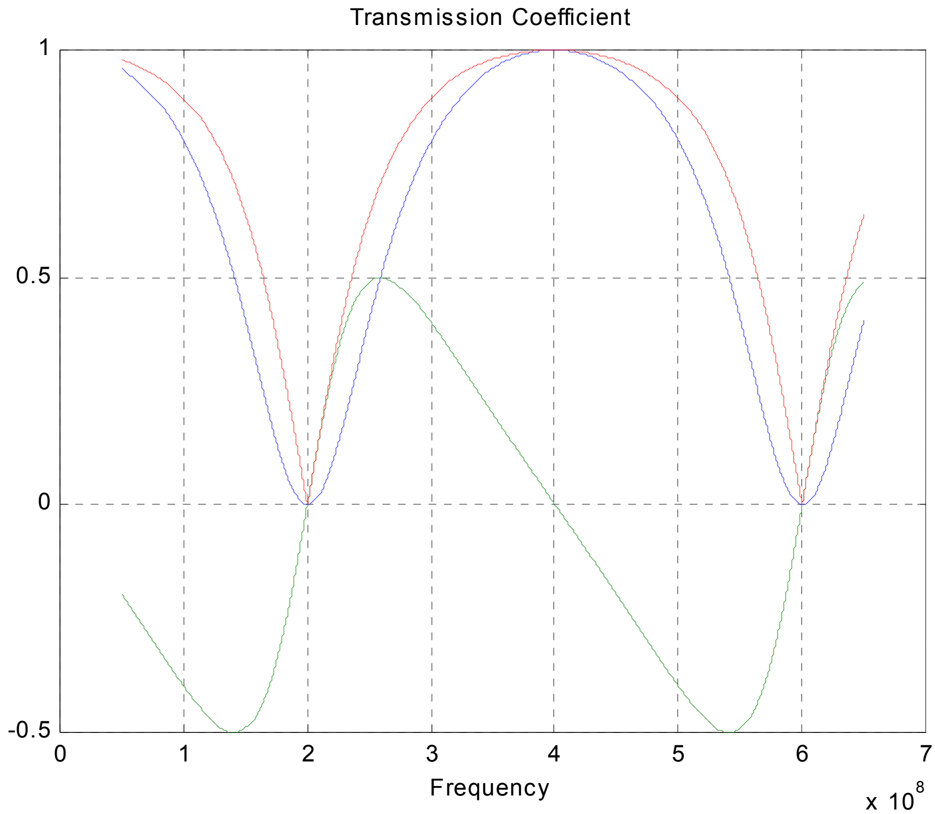
```
title('Transmission Coefficient');xlabel('Frequency');grid;
```

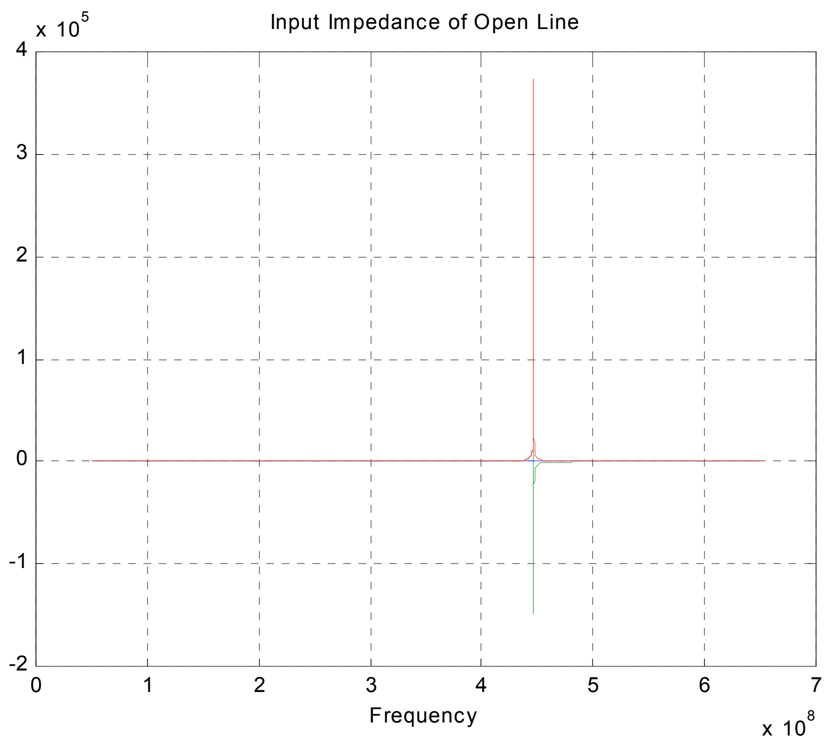
Output Plots

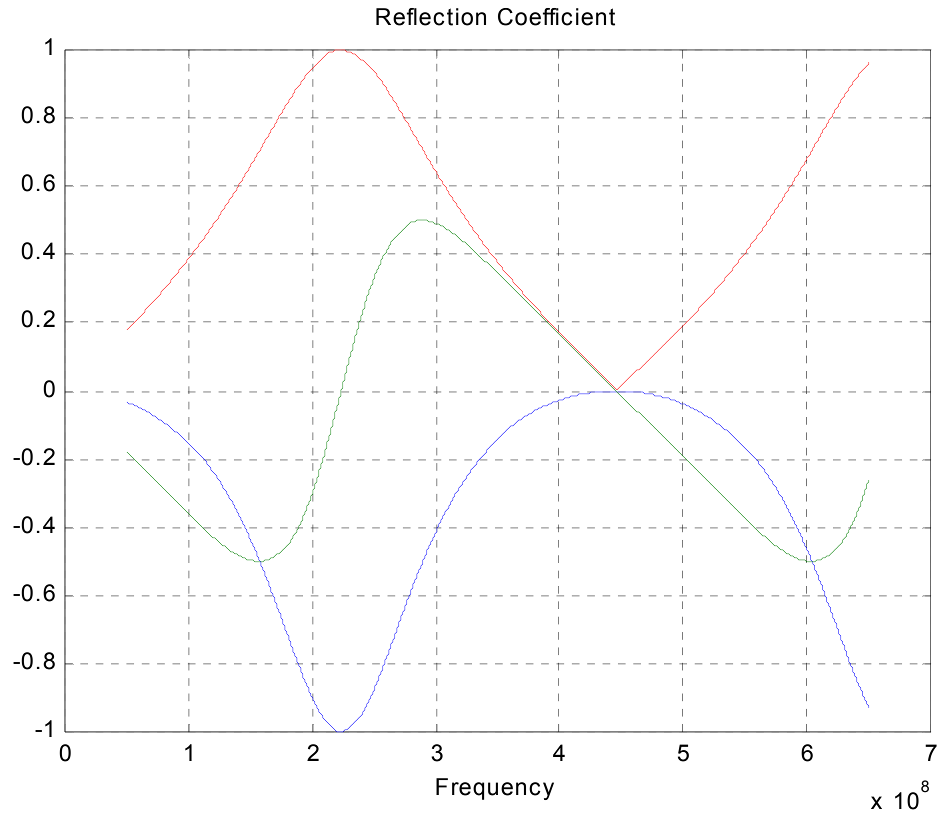


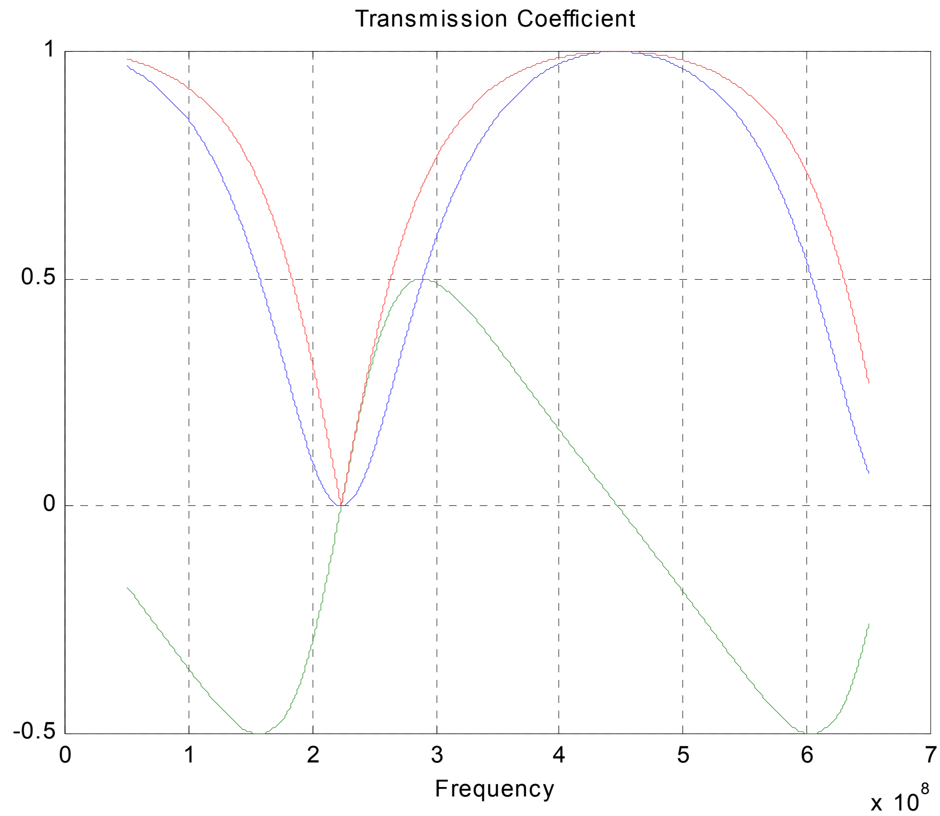




Note that, for this choice of length, the blocked frequencies are at 200MHz and 600MHz.

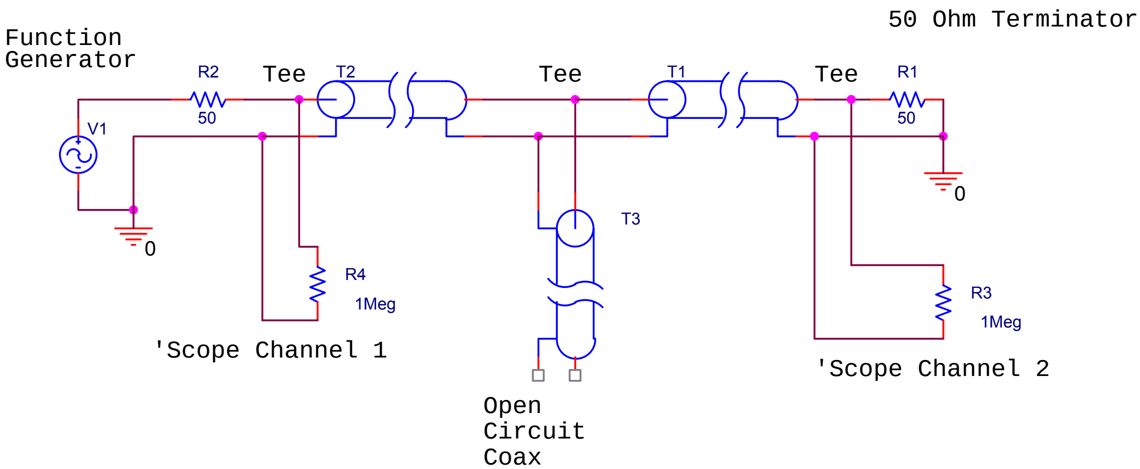






which blocks the particular frequency of 223.2MHz.

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 three pieces of coax from the cable box. Connect to Tees as shown. Measure the length of the open circuit cable. If it is not at least 4 meters long, add another piece of cable using a Tee to increase the total length. Measure the length of this cable combination. Input this length into the equations used to model the blocker, using 50 ohms for Z_o. The modified code and the results of such analysis follow.




```
% K. A. Connor 10 November 1999

f=[1.5:.01:15]*1e6;
Zo=50% Program for modeling a CATV channel blocker
; d=5; beta=2*pi*f/2e8;Zl=1e8;

% Input impedance of the open circuit line

Zin=Zo.*(Zl+j.*Zo.*tan(beta.*d))./(Zo+j.*Zl.*tan(beta.*d));

% Combination of Zin and Zo

Ztotal=1./(1./Zin+1./Zo);

% Reflection Coefficient

Ref=(Ztotal-Zo)./(Ztotal+Zo);

% Transmission Coefficient

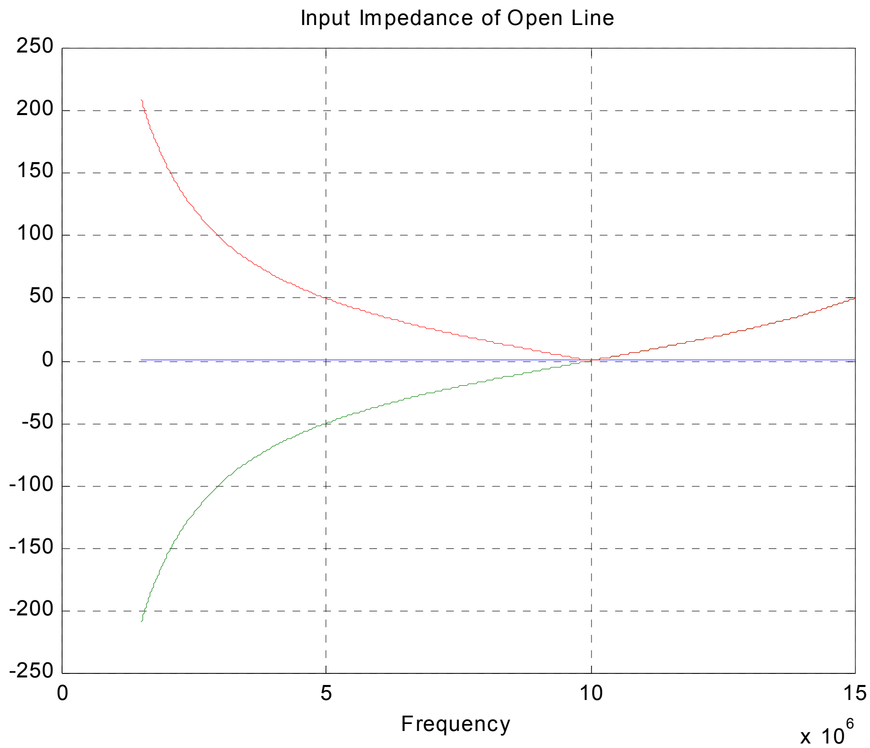
Trans=1+Ref;

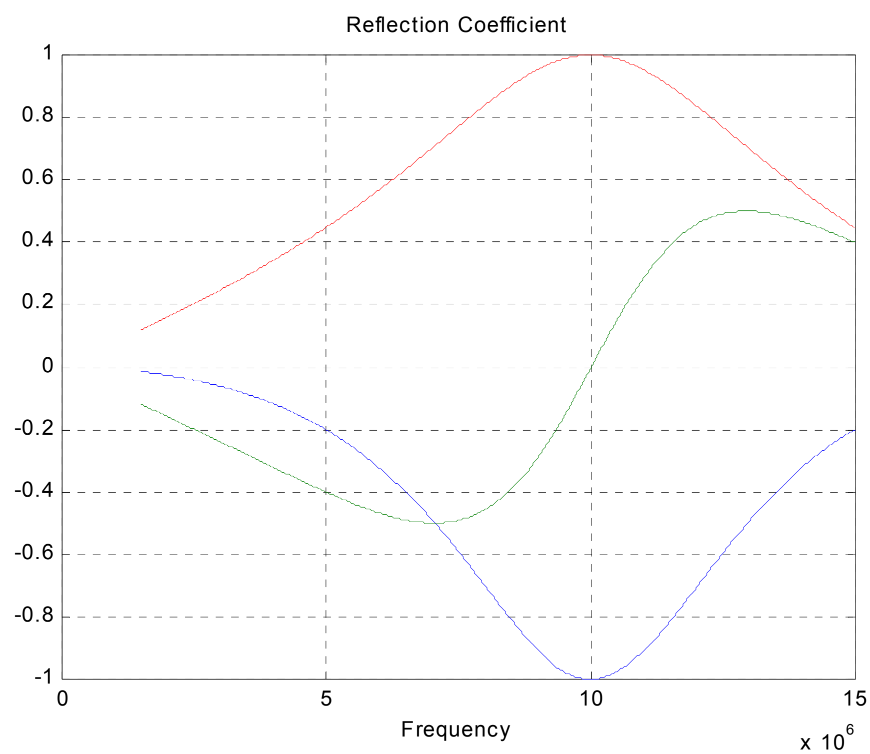
%Plotting Results

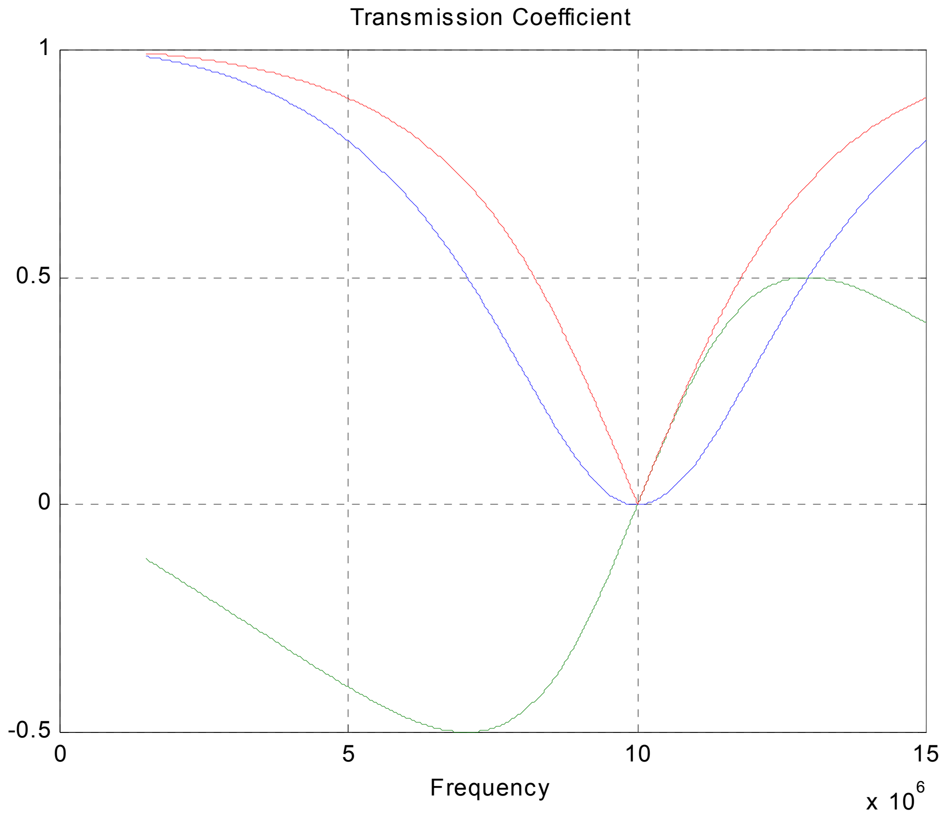
plot(f,real(Zin),f,imag(Zin),f,abs(Zin));
title('Input Impedance of Open Line');xlabel('Frequency');grid;figure;

plot(f,real(Ref),f,imag(Ref),f,abs(Ref));
title('Reflection Coefficient');xlabel('Frequency');grid;figure;
```

```
plot(f,real(Trans),f,imag(Trans),f,abs(Trans));
title('Transmission Coefficient');xlabel('Frequency');grid;
```







Note that this combination of cables (d=5meters) blocks frequencies around 10MHz. Manually change the frequency of the function generator while observing both the input and output to the cables as indicated. A very small output voltage (relative to the input) should be observed around 10MHz, if the experiment is set up correctly.