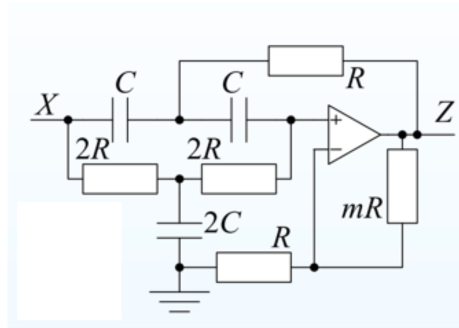
1. In the lab we analyzed filtering 60 Hz power-line noise from ECG signal using a digital (signal processing) filter. Now let's try to an analog (circuit) filter approach to remove the 60 Hz line-noise. Following is an active twin-T notch filter with transfer function:

$$H(\omega) = \frac{Z(\omega)}{X(\omega)} = \frac{(1+m)\left((2j\omega RC)^2+1\right)}{(2j\omega RC)^2+4(1-m)j\omega RC+1}$$



Here `m` is the ratio of the two feedback resistance which determines the gain and quality for the filter. The drop frequency of this twin-T notch filter is $f_{drop}=1/4\pi RC$. For designing a 60 Hz drop filter, let's use `R=10 kΩ` and `C=133 nF`.

(a) For `m={0.8, 0.9}` plot the magnitude and phase response of `H(ω)` with a range of f`=ω/2`π`=[0, 200 Hz]`.

(b) Consider the ECG signal used during the class (`ecg_signal.mat`) as the input (`x(t)=ecg`) of a 60 Hz twin-T notch filter with `m=0.9`. Using the functions `fft()` and `ifft()`, determine the `X(ω)`, `Z(ω)`, and `z(t)`[`z(t)` is the output signal from the twin-T notch filter]. Plot `x(t)`, `X(f)`, `Z(f)`, and `z(t)` in a 4x1 subplot for the range of $-250 \le f \le 250$ and $0 \le t \le 2.5$.

[Please pay attention to the proper use of `fftshift()` and `ifftshift()` while solving this problem.]

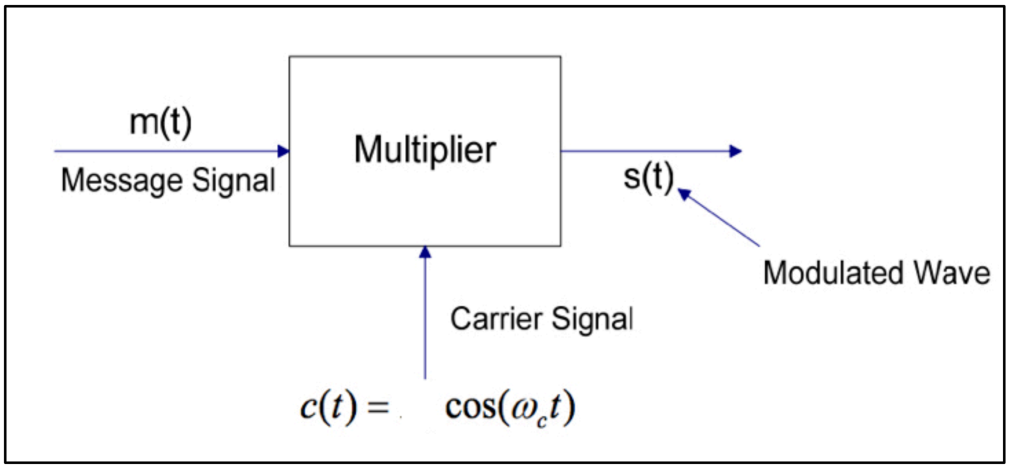
2. Calculate the energy of time domain signal `x(t)` and `z(t)` for the range of $0 \le t \le 2.5$. Also calculate the energy of these signals in frequency domain using Parseval's theorem. Plot `Energy(X)` and `Energy(Z)` as a function of frequency `f` in a 2x1 subplot (Energy vs frequency plot is know as energy spectrum of a signal).

2. Let's say you are using a Double-Sideband Suppressed Carrier Modulation (DSB-SC) scheme to transmit a message `m=[6 0 4 -6 2]` to your friend at San Jose over a communication channel that has good transmission characteristics in the frequency range of 400 kHz to 600 kHz. You decided to modulate your message with carrier signal $c(t)=\cos(1000\times10^3\pi t)$ and encode your message `m(t)` at `1/10` of the carrier frequency (i.e. `50 kHz`). Your friend received the signal you transmitted and demodulated it by multiplying with a local oscillator signal $lo(t)=\cos(1000\times10^3\pi t+\pi/3)$ and then passing the signal through a low-pass filter with transfer function `H(f)` where:

$$H(f) = \begin{cases} 2, & |f| < 500 \times 10^3\ Hz \\ 0, & elsewhere \end{cases}$$

In a 4x1 subplot show the time domain signal transmitted `s(t)`, frequency domain magnitude of the transmitted signal |S(f)|, time domain <u>demodulated and low-pass filtered</u> output signal `vo(t)` and corresponding frequency domain spectrum `|Vo(f)|`.

Your modulation scheme:



Demodulation scheme of your friend: