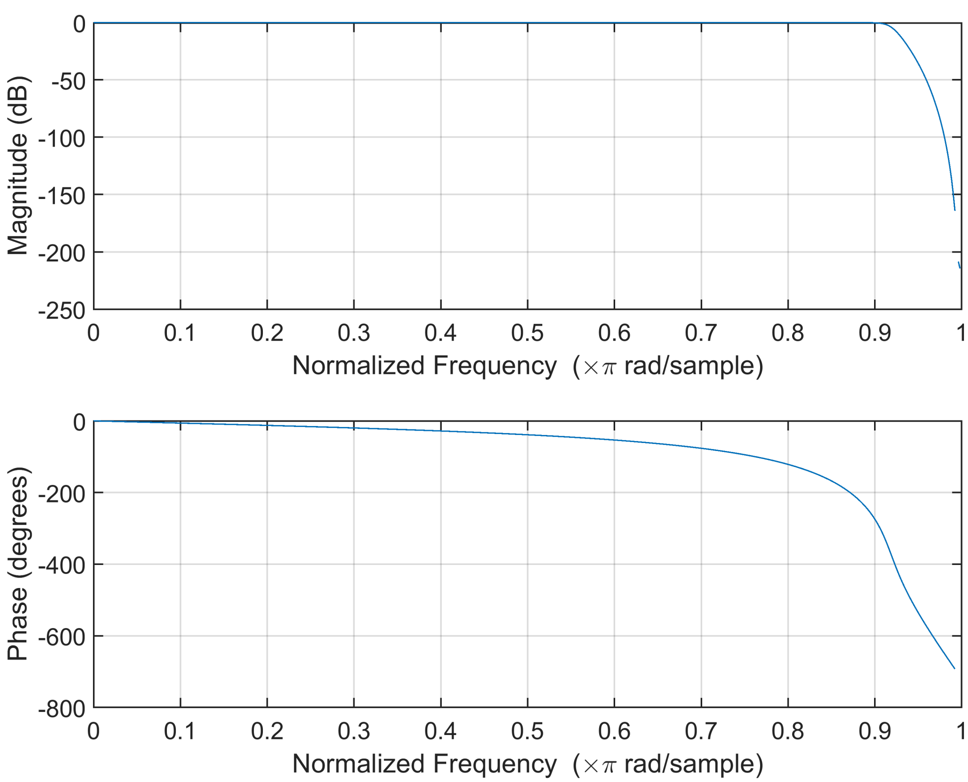
Butterworth Filter Design

I- Lowpass Butterworth Transfer Function

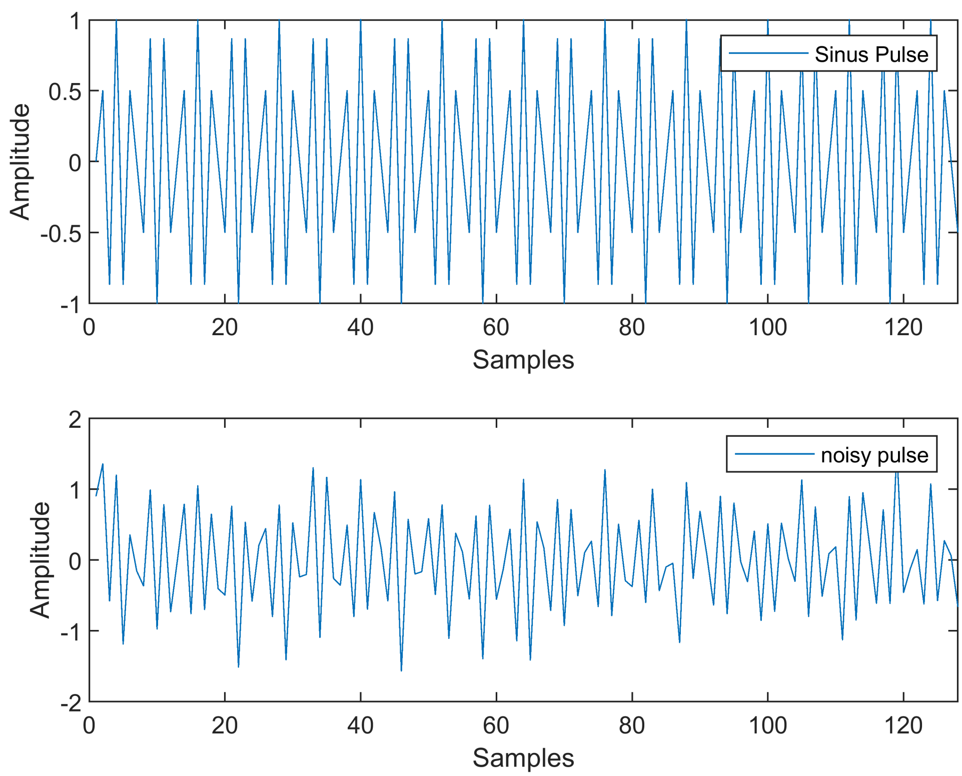
Design a 8th-order lowpass Butterworth filter with a cutoff frequency of 21 KHz, which, for data sampled at 48 KHz, corresponds to rad/sample. Plot its magnitude and phase responses. Use it to filter a 128-sample of sinusPulse.

```
clear
fc = 22000;          % Cutoff Frequency
fs = 48000;          % Sampling Frequency

[b,a] = butter(8,fc/(fs/2),'low');  % Butterworth 8th-order filter
freqz(b,a)
```




```
load input_t.mat sinusPulse
dataIn = awgn(sinusPulse,12);           % SNR = 12dB : Add noise into sinusPulse
dataOut = filter(b,a,dataIn);           % Filter the dataIn using butterworth
                                        % filter parameters (a,b)
```

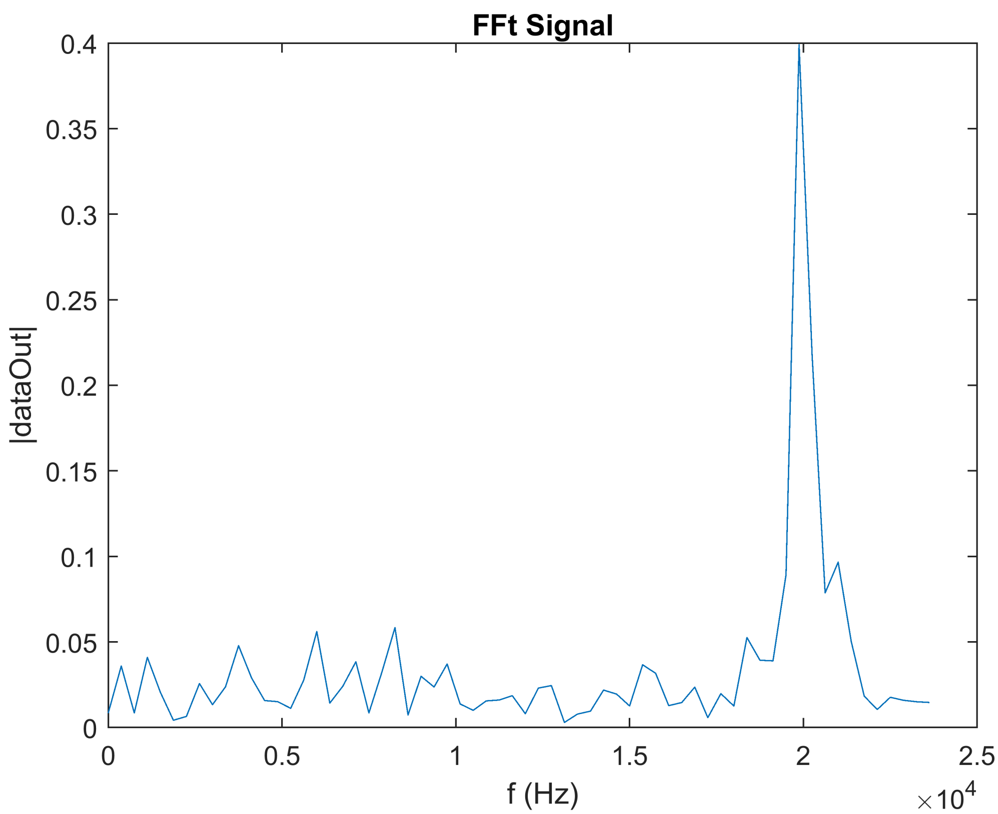
```
figure
%% Sinus Pulse
subplot(2,1,1)
plot(real(sinusPulse))
xlim([0 length(sinusPulse)])
legend('Sinus Pulse')
xlabel('Samples')
ylabel('Amplitude')

%% Noisy Sinus Pulse

subplot(2,1,2)
plot(real(dataIn))
legend('noisy pulse')
xlabel('Samples')
ylabel('Amplitude')
xlim([0 length(sinusPulse)])
```




```
figure
y_fft = abs(fft(dataOut));                  % Fast Fourier Transform
P2 = abs(y_fft/length(sinusPulse));         % Calculate the Modulus or just the real values
                                            % because the fft produce
                                            % complex values
P1 = P2(1:round(length(sinusPulse)/2));     % Single Side
```

Define the frequency domain `f` and plot the single-sided amplitude spectrum `P1`.

```
f = fs*(0:(length(sinusPulse)/2)-1)/length(sinusPulse);          % Frequency Vector
plot(f,P1)
title('FFt Signal')
xlabel('f (Hz)')
ylabel('|dataOut|')
```



References :

- https://www.mathworks.com/help/signal/ref/butter.html
- https://en.wikipedia.org/wiki/Butterworth_filter