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2.3 Lab-HW: Removing Interference from a Speech Signal

```
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% Project for ECE-6720

clear;clc;

playBadAudio = false;
playNewAudio = false;
saveAudioFiles = false;
savePlots = false;
```

Part A

```
% Load in the speechbad file
% it contains on signal, xxbad, which is the sum of the speech signal and
% the very large amplitude sinusiods at 1555 Hz and 2222 Hz.

load("speechbad.mat");

% Interference frequencies are in f_interference vector.

% Sampling rate is 8000 Hz. This is the fs variable.
% The good speech signal is scaled so the max value is one
A_speech = 1;

% Make a spectrogram (in dB).
spectrumData = fft(xxbad);
n = length(xxbad); % number of samples
f = (0:n-1)*(fs/n); % frequency range
signalLength = (length(xxbad)-1)/fs;
badSignalSpectrum = db(abs(spectrumData), "power");
```

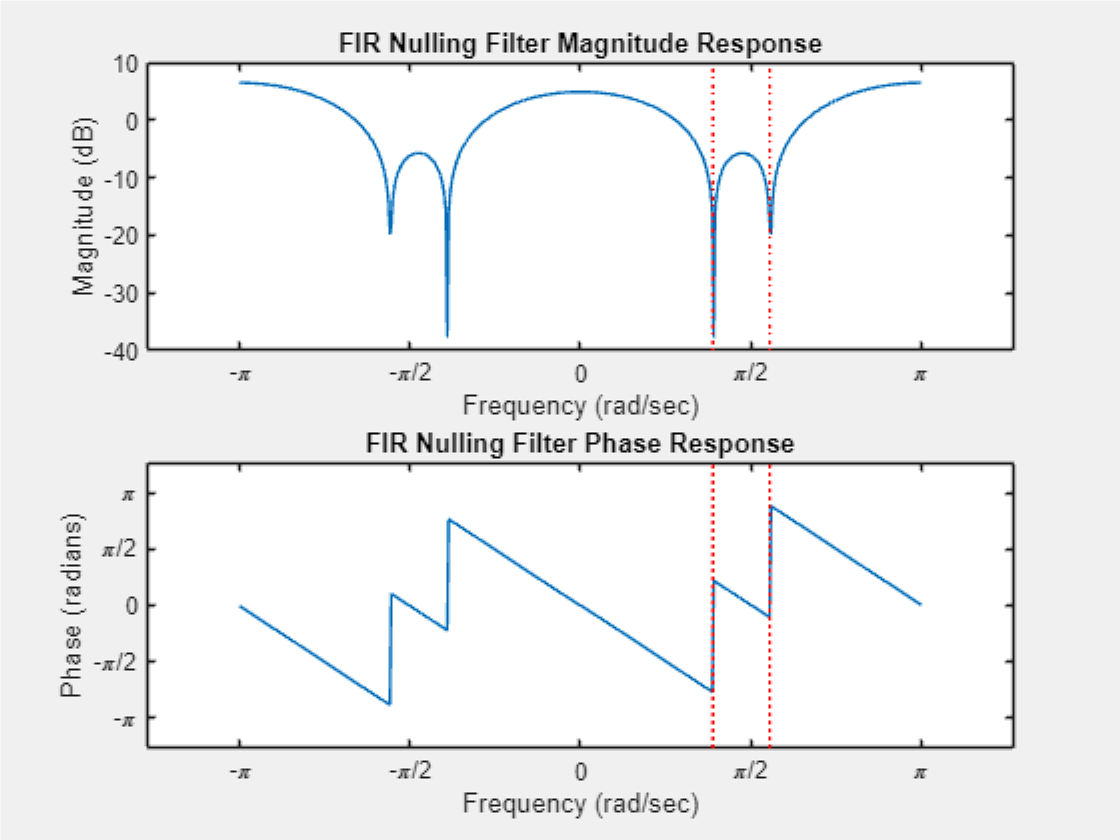
Part B

Create a cascaded set of two second-order nulling filters for the two frequencies.

```
% For filter a, it nulls the 2222 Hz signal
a = zeros([1 3]);
a(1) = 1;
a(2) = -2 * cos((2222/8000)*(2*pi));
```

```
a(3) = 1;


% For filter a, it nulls the 1555 Hz signal
b = zeros([1 3]);
b(1) = 1;
b(2) = -2 * cos((1555/8000)*(2*pi));
b(3) = 1;

% Normalize Filters
% a = a/sum(a);
% b=b/sum(b);

% Convolve the two second-order filters to get a single fourth-order
% filter.
c = conv(a, b);

% Normalize the filter.
% c = c/sum(c);

responseResolution = 500;
frequencyRange = linspace(0, 2*pi, responseResolution);
frequencyRangeHz = linspace(0, fs, responseResolution);
spectralResponse = zeros(size(frequencyRange));

for k = 1:responseResolution
    total = 0;
    for n = 1:length(c)
        total = total + exp(-1*1i*frequencyRange(k)*(n-1)) * c(n);
    end
    spectralResponse(k) = total;
end

% Get the magnitude and phase response of the spectral response
magnitudeResponse = abs(spectralResponse);
phaseResponse = angle(spectralResponse);

% Convert the values into the ones that need to be plotted.
magnitudePlotResponseDB = fftshift(db(magnitudeResponse, "power"));
phaseResponsePlot = fftshift(angle(spectralResponse));
frequencyRangePlot = linspace(-pi, pi, responseResolution);

% Plot the magnitude response
filterSpectralResponseFig = figure(1);
hold on;
subplot(2,1,1);
plot(frequencyRangePlot, magnitudePlotResponseDB); % Magnitude in dB
% Plot a vertical line
for i = 1:length(f_interference)
    xline = f_interference(i);
    xline_radians_s = xline/fs*2*(pi);
    ymin = min(magnitudePlotResponseDB);
    line([xline_radians_s xline_radians_s],
 ylim, 'LineStyle', ':', 'Color', 'r');
```

```
    % text(xline_radians_s, max(ylim), sprintf('%g Hz', xline),
 'HorizontalAlignment', 'right', 'Rotation', 90, 'Color', 'k');
    % text(xline_radians_s, ymin, sprintf('%g Hz', xline),
 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'center');
end
xlabel('Frequency (rad/sec)');
ylabel('Magnitude (dB)');
title('FIR Nulling Filter Magnitude Response');
set(gca,'XTick',-pi:pi/2:pi)
set(gca,'XTickLabel',{'-\pi','-\pi/2','0','\pi/2','\pi'})

% Plot the phase response
subplot(2,1,2);
plot(frequencyRangePlot, phaseResponsePlot); % Phase in degrees
xlabel('Frequency (rad/sec)');
ylabel('Phase (radians)');
title('FIR Nulling Filter Phase Response');
set(gca,'XTick',-pi:pi/2:pi)
set(gca,'XTickLabel',{'-\pi','-\pi/2','0','\pi/2','\pi'})
set(gca,'YTick',-pi:pi/2:pi)
set(gca,'YTickLabel',{'-\pi','-\pi/2','0','\pi/2','\pi'})
for i = 1:length(f_interference)
    xline = f_interference(i);
    xline_radians_s = xline/fs*2*(pi);
    ymin = min(phaseResponsePlot);
    line([xline_radians_s xline_radians_s],
 ylim, 'LineStyle', ':', 'Color', 'r');
    % text(xline_radians_s, max(ylim), sprintf('%g Hz', xline),
 'HorizontalAlignment', 'right', 'Rotation', 90, 'Color', 'k');
    % text(xline_radians_s, ymin, sprintf('%g Hz', xline),
 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'center');
end
hold off;

% Filter the audio signal.
filteredSignal = filter(c, length(xxbad)/fs, xxbad);
```



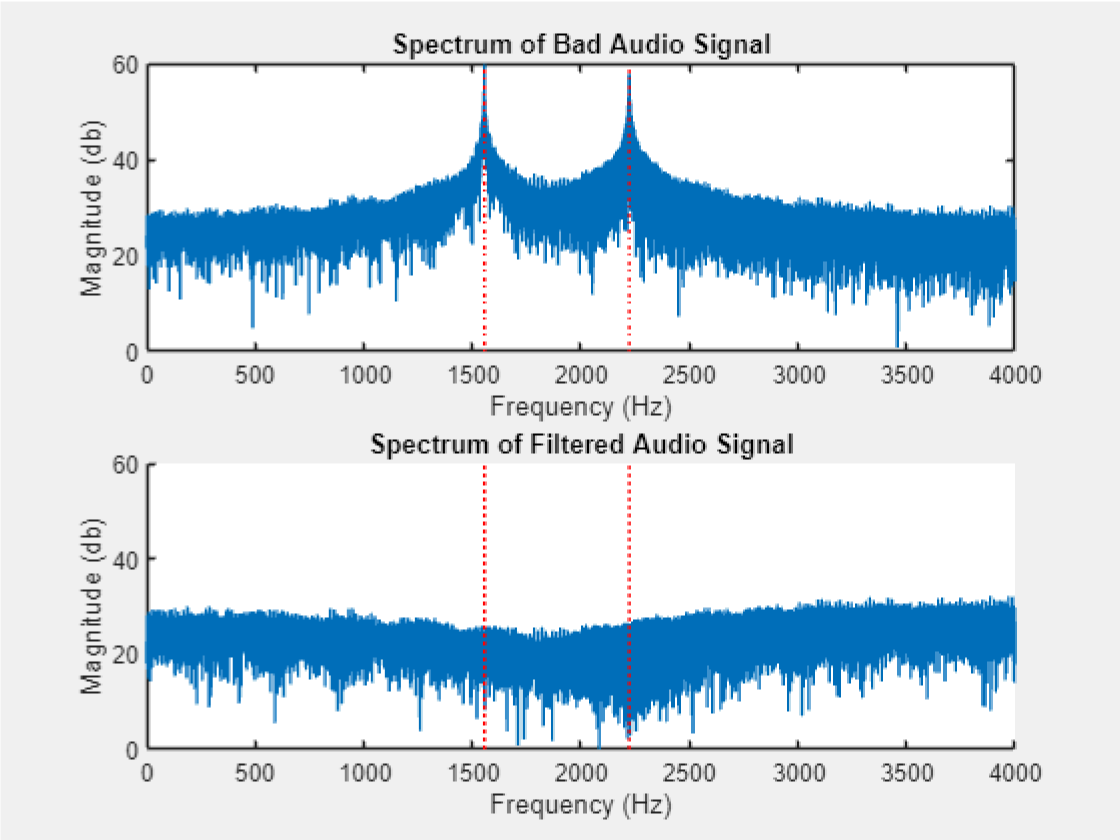
Part C

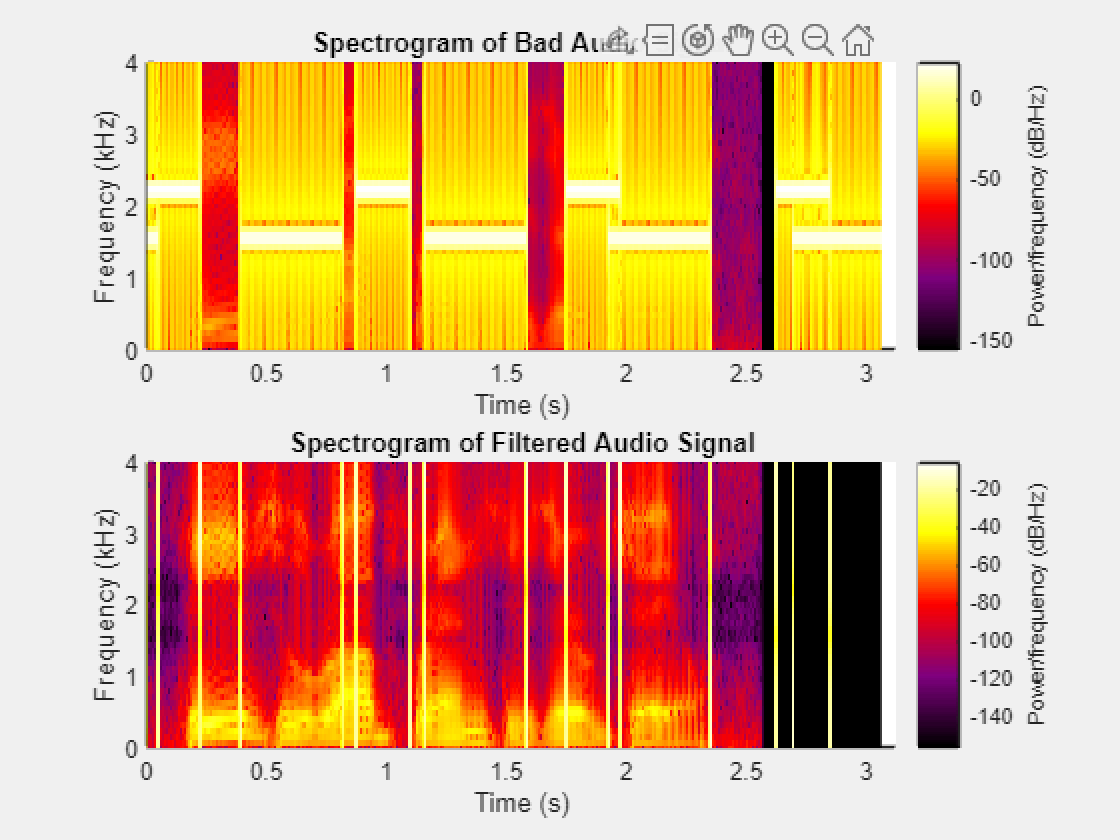
Make a spectrogram (in dB).

```
spectrumData = fft(filteredSignal);
n = length(filteredSignal); % number of samples
f = (0:n-1)*(fs/n); % frequency range
signalLength = (length(filteredSignal)-1)/fs;
goodSignalSpectrum = db(abs(spectrumData), "power");


figure_Spectrum = figure(2);

hold on;
subplot(2,1,1);
plot(f,badSignalSpectrum);
xlabel('Frequency (Hz)');
ylabel('Magnitude (db)');
title('Spectrum of Bad Audio Signal');
ylim([0 60]);
xlim([0 fs/2]); % Plot up to the nyquist frequency.
for i = 1:length(f_interference)
    xline = f_interference(i);
    ymin = min(ylim);
    line([xline xline], ylim, 'LineStyle', ':', 'Color', 'r');
```

```
    % text(xline_radians_s, max(ylim), sprintf('%g Hz', xline),
 'HorizontalAlignment', 'right', 'Rotation', 90, 'Color', 'k');
    % text(xline_radians_s, ymin, sprintf('%g Hz', xline),
 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'center');
end
hold off;

subplot(2,1,2);
hold on;
plot(f,goodSignalSpectrum);
xlabel('Frequency (Hz)');
ylabel('Magnitude (db)');
title('Spectrum of Filtered Audio Signal');
ylim([0 60]);
xlim([0 fs/2]); % Plot up to the nyquist frequency.
for i = 1:length(f_interference)
    xline = f_interference(i);
    ymin = min(ylim);
    line([xline xline], ylim, 'LineStyle', ':', 'Color', 'r');
    % text(xline_radians_s, max(ylim), sprintf('%g Hz', xline),
 'HorizontalAlignment', 'right', 'Rotation', 90, 'Color', 'k');
    % text(xline_radians_s, ymin, sprintf('%g Hz', xline),
 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'center');
end
hold off;

% Spectrogram Plots

% Create the colormap for the map.
% Define the number of points in the colormap
n = 256;

% Define key colors (black, purple, red, yellow, white)
colors = [0 0 0;       % Black
          0.5 0 0.5;   % Purple
          1 0 0;       % Red
          1 1 0;       % Yellow
          1 1 1];      % White

% Initialize the colormap matrix
customCMap = zeros(n, 3);

% Interpolate the colors
for i = 1:3
    customCMap(:, i) = interp1(linspace(0, 1, size(colors, 1)), colors(:, i),
 linspace(0, 1, n));
end

figure_Spectrogram = figure(3);
subplot(2,1,1);
hold on;
t = 0:1/fs:2-1/fs;
spectrogram(xxbad,100,80,100,fs,'yaxis');
ylim([0 4]);
```

```
xlim([0 3.125]);
title('Spectrogram of Bad Audio Signal');
hold off;
subplot(2,1,2);
hold on;
t = 0:1/fs:2-1/fs;
spectrogram(filteredSignal,100,80,100,fs,'yaxis');
ylim([0 4]);
xlim([0 3.125]);
title('Spectrogram of Filtered Audio Signal');
colormap(figure_Spectrogram, customCMap);
hold off;
```





Data Output

```
% Play the Audio Signals in Matlab
if (playBadAudio)
    sound(xxbad, fs);
end
if (playNewAudio)
    sound(filteredSignal, fs);
end

% Save the audio files
if (saveAudioFiles)
    badAudioFilename = 'AudioSignals/BadAudio.flac';
    filteredAudioFilename = 'AudioSignals/FilteredAudio.flac';
    audiowrite(badAudioFilename, xxbad, fs);
    audiowrite(filteredAudioFilename, filteredSignal, fs);
end

% Save the plots
if (savePlots)
    saveas(figure_Spectrum,'MatlabPlots/AudioSignalSpectrum.png');
    saveas(filterSpectralResponseFig,'MatlabPlots/
FilterSpectralResponse.png');
    saveas(figure_Spectrogram,'MatlabPlots/Spectrogram.png');
end
```

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