Introduction

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- Class: ESE 351

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- : https://www.mathworks.com/help/

- : Reference links: : https://www.engineersgarage.com/audio-filters-designing-an-audio-equalizer-7-8/ : https://en.wikipedia.org/wiki/Center_frequency : http://learningaboutelectronics.com/Articles/Center-frequency-calculator.php#answer : https://www.mathworks.com/help/signal/ref/lowpass.html#d124e104385 *

Inputs

Input sounds to use

```
[giant,fg] = audioread('Giant Steps Bass Cut.wav');
[BlueinGreen,fb] = audioread('Blue in Green with Siren.wav');
[SpaceStation,fsp] = audioread('Space Station - Treble Cut.wav');

% Use Inputs from Homework 1 for Lowpass and Highpass DT Circuits:
R = 1000;       % Ohms
C = 5 * 10^-6 ;  % Farads
tau = R * C;        % seconds
t_end = 50*tau;
fsound = 44100;         % sample frequency = 44.1 kHz
delta_t = 1/fsound;     % sampling period = 1/sample frequency

band1 = [20 200]; % 20hz to 200hz
band2 = [200 500]; % 200hz to 500hz
band3 = [900 1000]; % 900hz to 1khz
band4 = [2000 5000]; % 2khz to 5khz
band5 = [10000 20000]; % 10Khz to 20khz

% Center frequencies sqrt(f1*f2)
```

```matlab
%{
center_low = sqrt(20*200); %low
%mid
center2 = sqrt(200*500);
center3 = sqrt(900*1000);
center4 = sqrt(2000*5000);
center_high = sqrt (10000*20000); %High
%new r and c
% new tau
%}
```
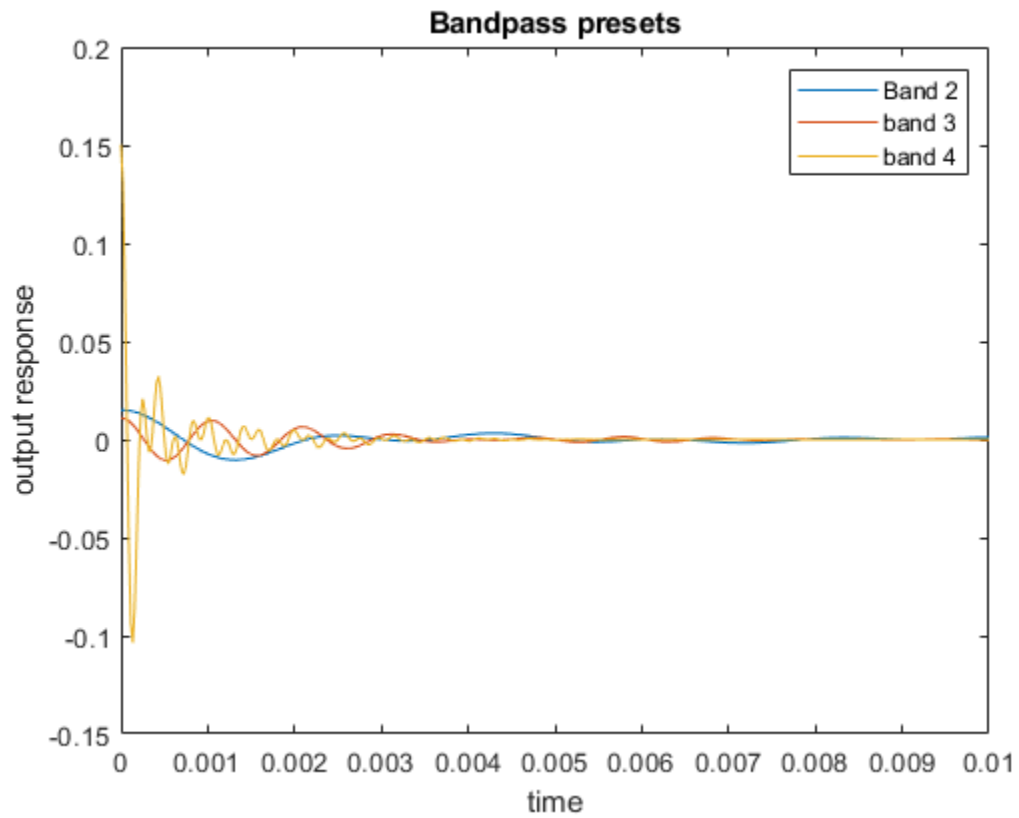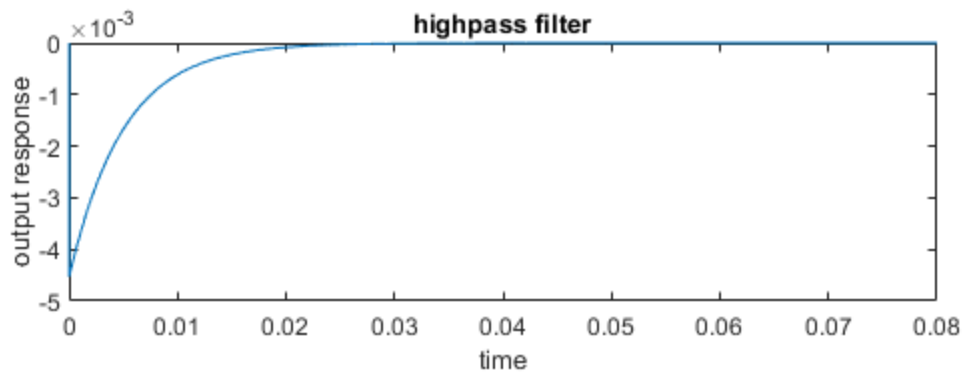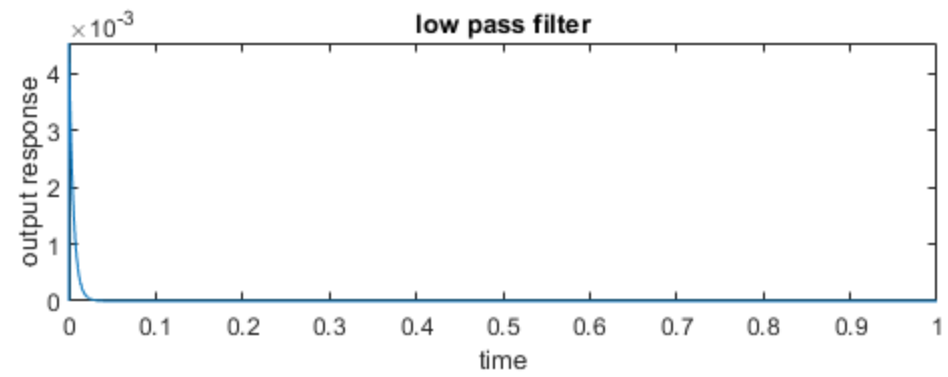
PRESETS

```matlab
gain = [1,-1,0,7,0]; %Preset gain
x = [1 zeros(1,fsound)];
b_low = [0 delta_t/tau]; a_low = [1 delta_t/tau-1];
b_high = [1 -1]; a_high = [1 delta_t/tau-1];
%LOW PASS
Band1 = filter([0 delta_t/tau],[1 delta_t/tau-1],x); %lowpass
Band5 = filter([1 -1],[1 delta_t/tau-1],x); %highpass
t1 = 0:delta_t:length(fsound);
figure;
subplot(2,1,1);
plot(t1,Band1);
title('low pass filter');
xlabel('time');
ylabel('output response');
subplot(2,1,2);
plot(t1,Band5);
title('highpass filter');
xlabel('time');
ylabel('output response');
xlim([0 0.08]);
ylim([-0.005 0]);
sgtitle('Lowpass and Highpass Presets');
%UNITY
unity = x; %flat frequency response is the same as the original
%BANDPASS
[Band2,filt2] = bandpass(x,band2,fsound);
[Band3,filt3] = bandpass(x,band3,fsound);
[Band4,filt4] = bandpass(x,band4,fsound);
figure;
plot(t1,Band2);
xlim([0 0.01]);
hold on
plot(t1,Band3);
xlim([0 0.01]);
plot(t1,Band4);
xlim([0 0.01]);
title('Bandpass presets');
xlabel('time');
ylabel('output response');
legend('Band 2','band 3','band 4');
```
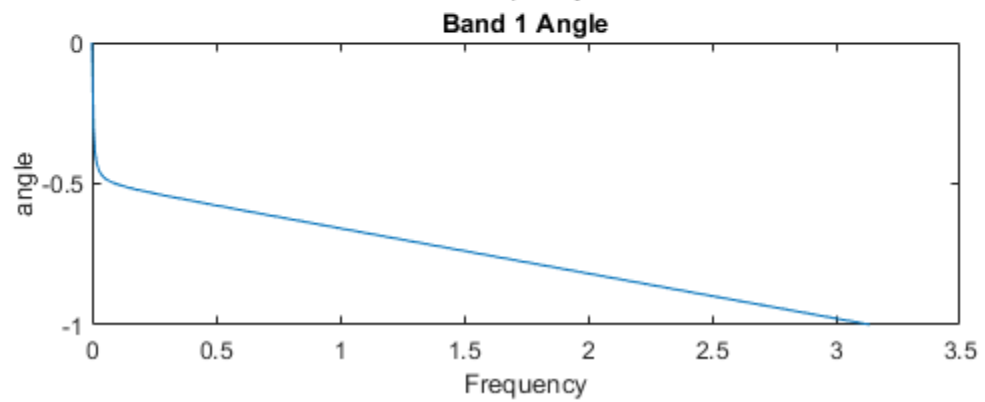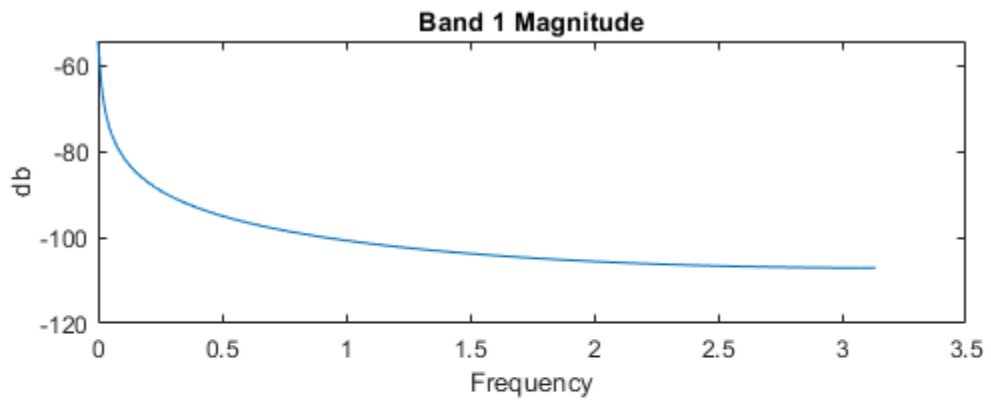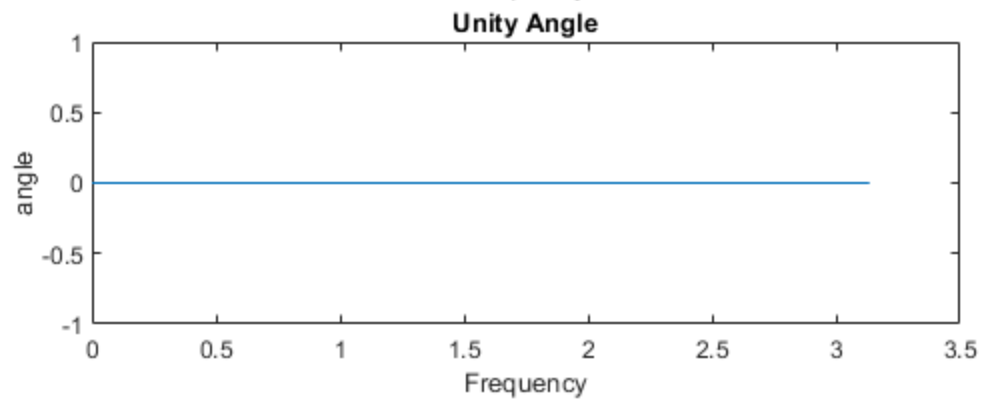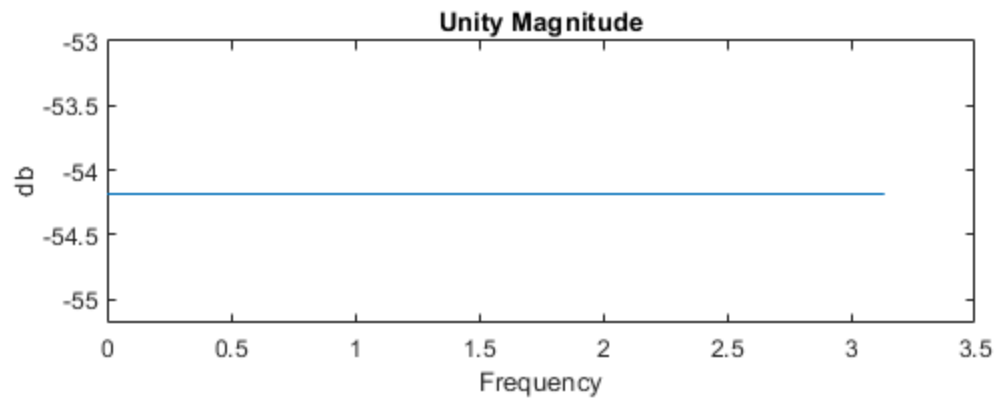
```matlab
%combined filters
Mixer =
 gain(1)*Band5+gain(2)*Band2+gain(3)*Band3+gain(4)*Band4+gain(5)*Band1;

%FREQUENCY RESPONSE OF PRESETS
t = (0:1:length(Band1)-1)';
h_low = tf(b_low,a_low);
h_high = tf(b_high,a_high);
% freq1 = lsim(h_low,input_g,t);
% freq5 = lsim(h_high,input_g,t);
[u1,frequ] = freqz(x,512);
[h1,freq1] = freqz(Band1,512);
[h2,freq2] = freqz(filt2,512);
[h3,freq3] = freqz(filt3,512);
[h4,freq4] = freqz(filt4,512);
[h5,freq5] = freqz(Band5,512);
%unity
figure;
subplot(2,1,1);
plot(frequ, mag2db(abs(u1)));
title('Unity Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(frequ, angle(u1)/pi);
title('Unity Angle');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 1 converting magnitude to decibels
figure;
subplot(2,1,1);
plot(freq1, mag2db(abs(h1)));
title('Band 1 Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq1, angle(h1)/pi);
title('Band 1 Angle');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 2
figure;
subplot(2,1,1);
plot(freq2, mag2db(abs(h2)));
title('Band 2 Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq2, angle(h2)/pi);
title('Band 2 Angle');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 3
figure;
```
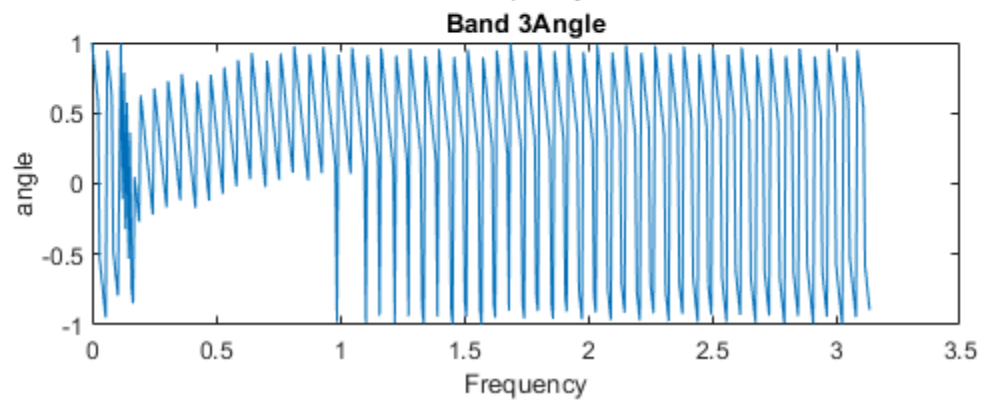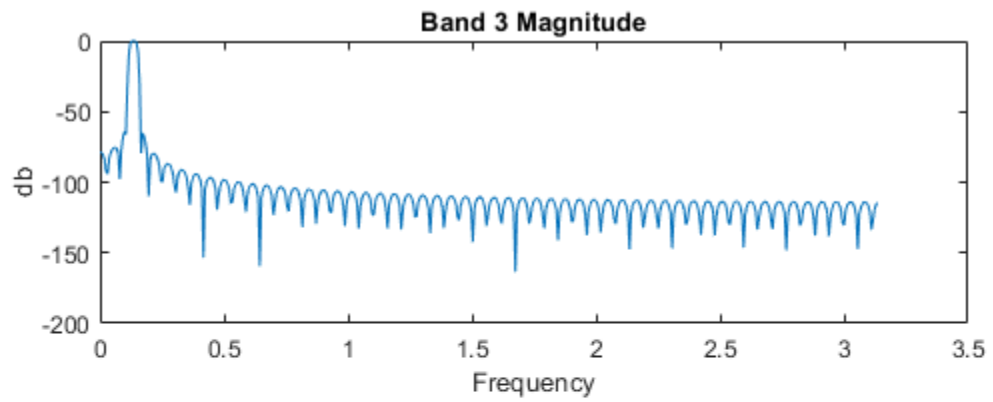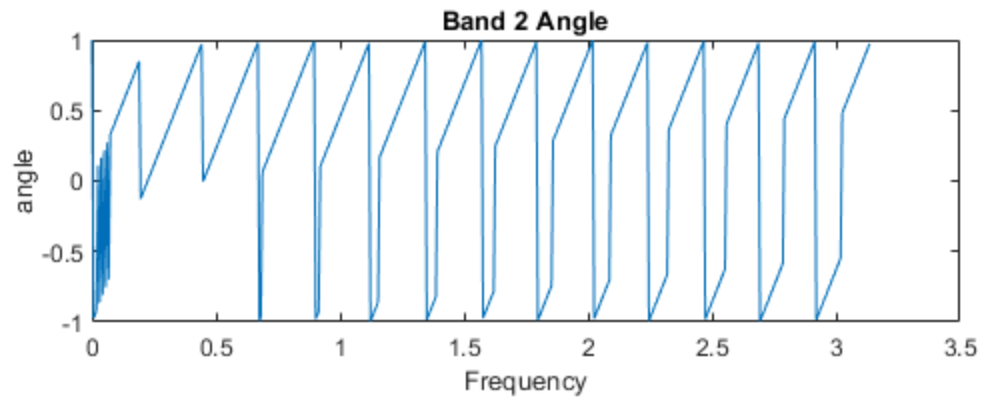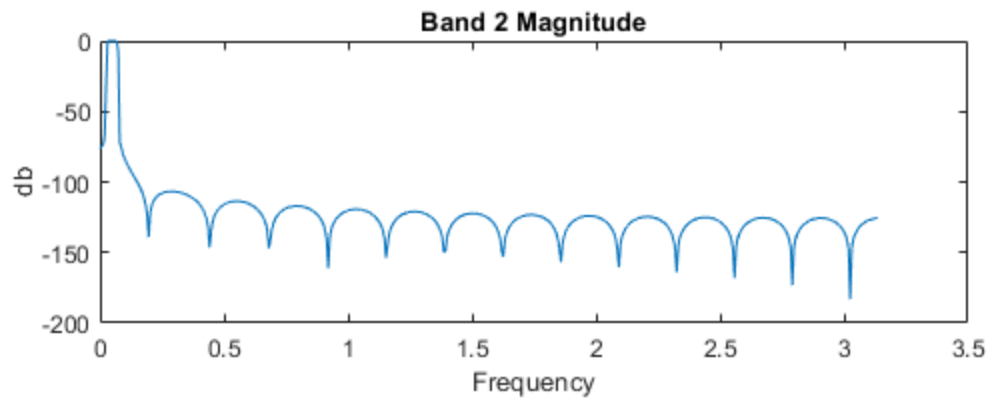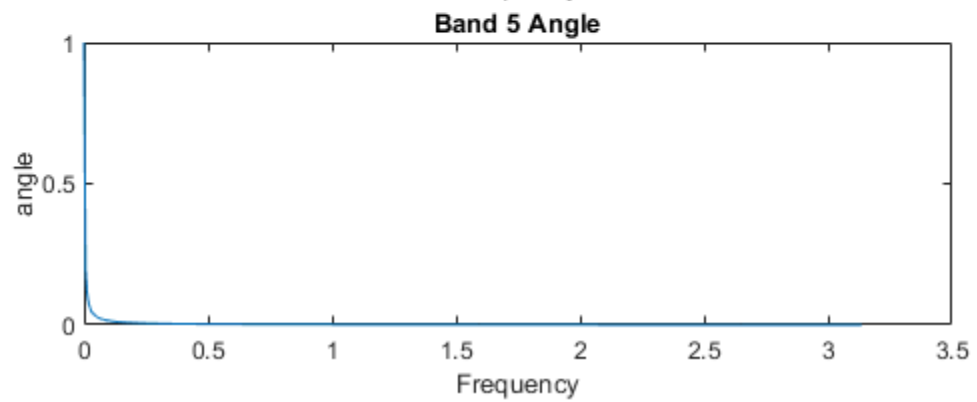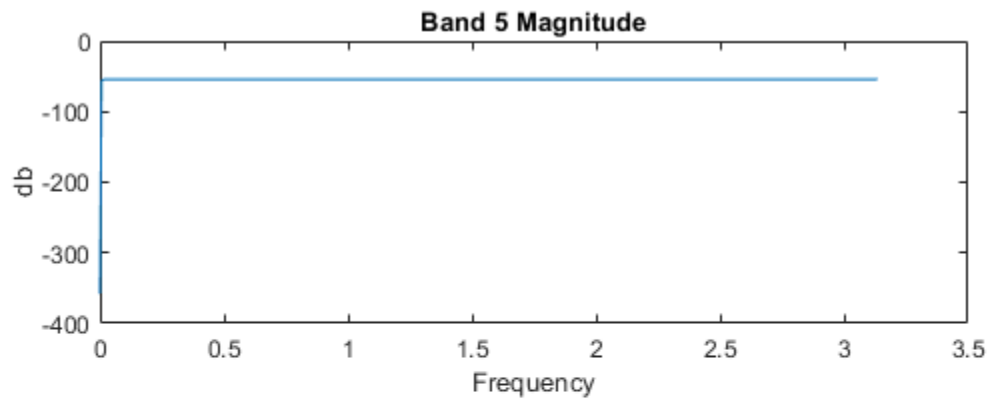
```matlab
subplot(2,1,1);
plot(freq3, mag2db(abs(h3)));
title('Band 3 Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq3, angle(h3)/pi);
title('Band 3Angle');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 4
figure;
subplot(2,1,1);
plot(freq4, mag2db(abs(h4)));
title('Band 4 Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq4, angle(h4)/pi);
title('Band 4 Angle');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 5
figure;
subplot(2,1,1);
plot(freq5, mag2db(abs(h5)));
title('Band 5 Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq5, angle(h5)/pi);
title('Band 5 Angle');
xlabel('Frequency');
ylabel('angle');
```
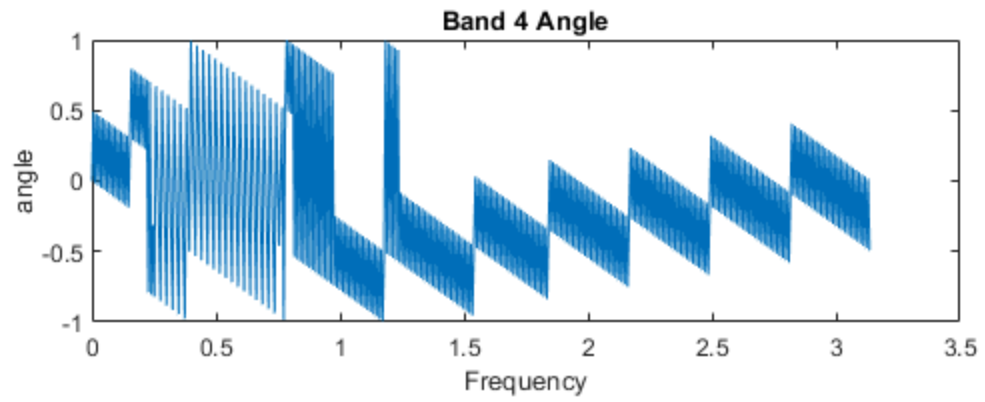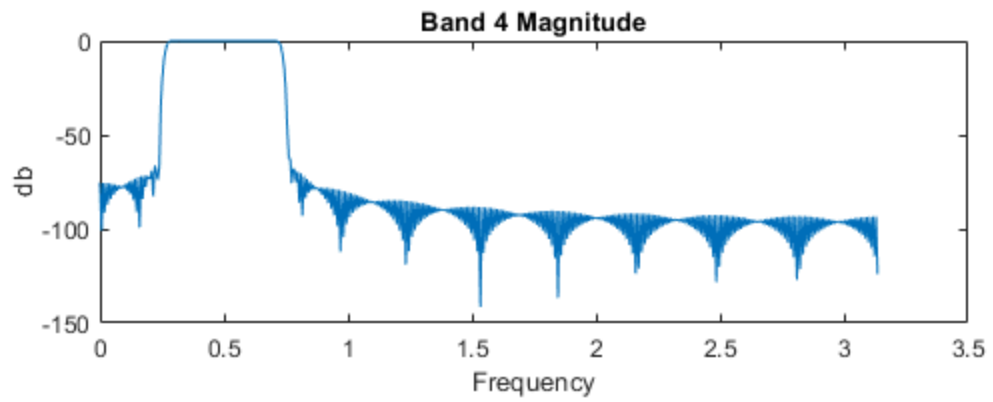
Lowpass and Highpass Presets

Unity Magnitude

Unity Angle

Band 1 Magnitude

Band 1 Angle

Band 2 Magnitude

Band 2 Angle

Band 3 Magnitude

Band 3Angle

Band 4 Magnitude

Band 4 Angle

Band 5 Magnitude

Band 5 Angle

APPLYING PRESETS FILTERS TO GIANT ON STEPS

```
input_g = giant;
input_g = input_g(:,1);
gain = [1,5,10,0,11]; %Preset gain
Band1 = filter([0 delta_t/tau],[1 delta_t/tau-1],input_g); %lowpass
Band5 = filter([1 -1],[1 delta_t/tau-1],input_g); %highpass
[Band2,filt2_g] = bandpass(input_g,band2,fsound);
[Band3,filt3_g] = bandpass(input_g,band3,fsound);
[Band4,filt4_g] = bandpass(input_g,band4,fsound);
%combined filters
Mixer_giant =
 gain(1)*Band1+gain(2)*Band2+gain(3)*Band3+gain(4)*Band4+gain(5)*Band5;
filename = 'GiantSteps_filtered.wav';
audiowrite(filename,Mixer_giant,fsound);
% current observations: band1 is a bass booster
% band2 is a like a soft bass, band3 is meh,band4 is  treble
 boost,band5 is
% a volume boost...upon further observation, it seems as though band3
 is
% what filters out the piano sound

Warning: Data clipped when writing file.
```

APLYING PRESETS TO SPACE STATION

```
input_s = SpaceStation;
input_s= input_s(:,1);
gain = [1,5,10,0,11]; %Preset gain
Band1 = filter([0 delta_t/tau],[1 delta_t/tau-1],input_s); %lowpass
Band5 = filter([1 -1],[1 delta_t/tau-1],input_s); %highpass
[Band2,filt2_s] = bandpass(input_s,band2,fsound);
[Band3,filt3_s] = bandpass(input_s,band3,fsound);
[Band4,filt4_s] = bandpass(input_s,band4,fsound);
%combined filters
Mixer_space =
 gain(1)*Band1+gain(2)*Band2+gain(3)*Band3+gain(4)*Band4+gain(5)*Band5;
filename = 'SpaceStation_filtered.wav';
audiowrite(filename,Mixer_space,fsound);
% After filter sounds exteremely horrible

Warning: Data clipped when writing file.

%FREQUENCY RESPONSE OF ORIGINAL SYSTEM
g_res = fft(input_s);
g_res = g_res(1:length(g_res)/2);
f = [0:length(g_res)-1].*fg./length(g_res);
figure;
subplot(2,1,1);
plot(f,abs(g_res)); %Magnitude
```
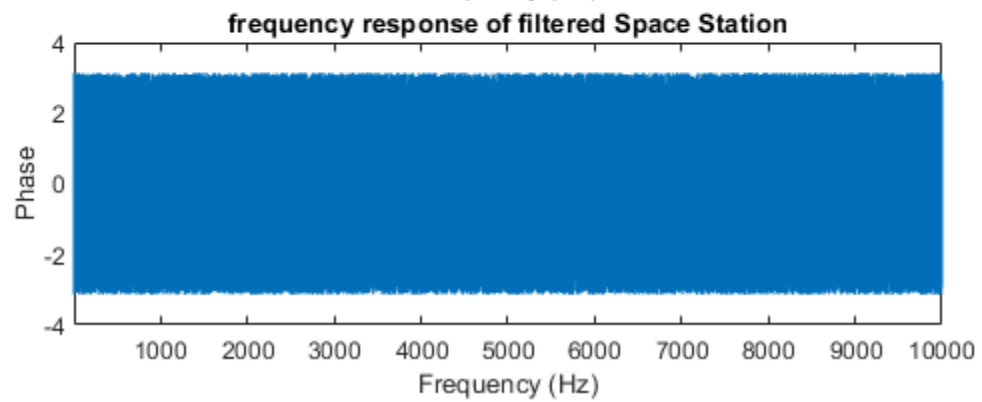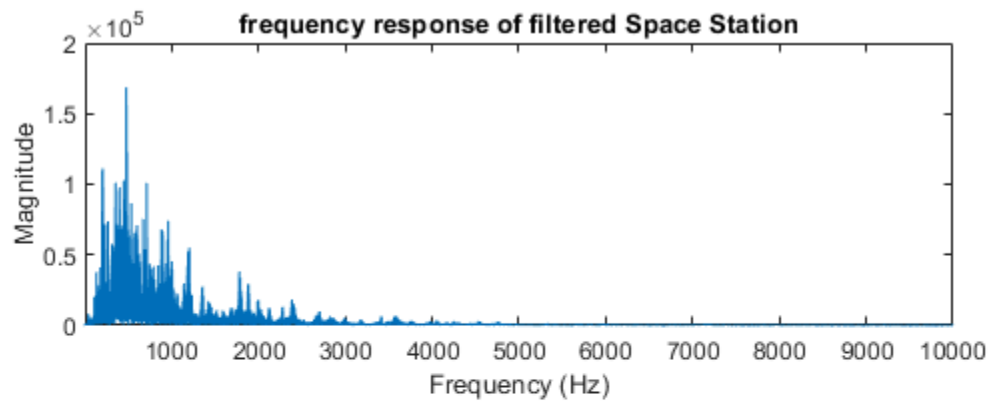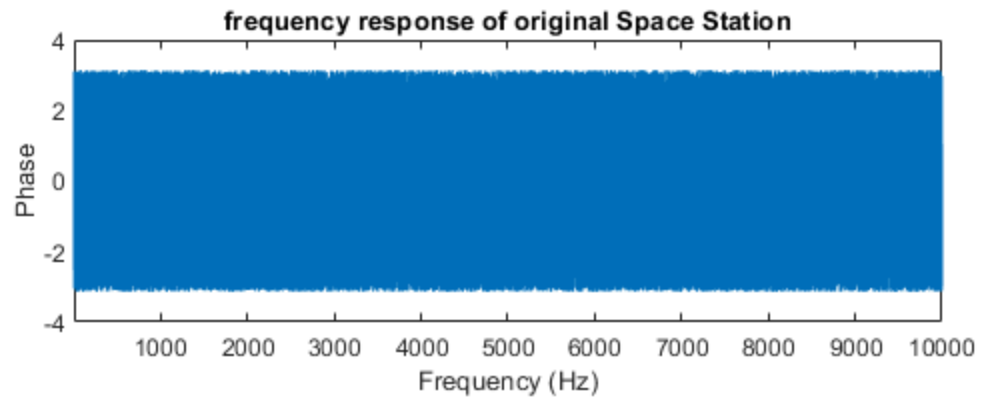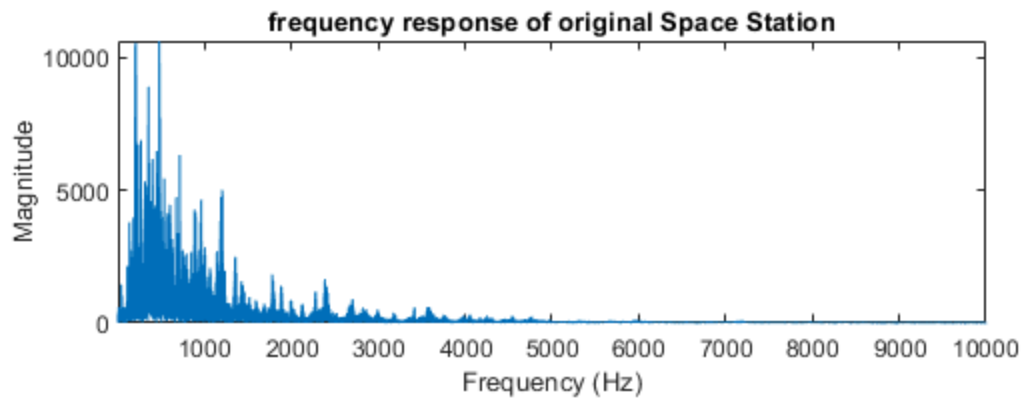
```matlab
title('frequency response of original Space Station');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res));%phase
title('frequency response of original Space Station');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

%FREQUENCY RESPONSE OF MIXED SYSTEM
g_res2 = fft(Mixer_space);
g_res2 = g_res2(1:length(g_res2)/2);
f = [0:length(g_res2)-1].*fg./length(g_res2);
figure;
subplot(2,1,1);
plot(f,abs(g_res2)); %Magnitude
title('frequency response of filtered Space Station');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res2));%phase
title('frequency response of filtered Space Station');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

Warning: Integer operands are required for colon operator when used as
 index.
Warning: Integer operands are required for colon operator when used as
 index.
```

frequency response of original Space Station

frequency response of original Space Station

frequency response of filtered Space Station

frequency response of filtered Space Station

APPLYING NEW GAIN TO EQUALIZER AND NEW SOUND

```matlab
input_green = BlueinGreen;
input_green = input_green(:,1);
gain_new = [0,8,0,0,0];
Band1 = filter([0 delta_t/tau],[1 delta_t/
tau-1],input_green); %lowpass
Band5 = filter([1 -1],[1 delta_t/tau-1],input_green); %highpass
[Band2,filt2_g] = bandpass(input_green,band2,fsound);
[Band3,filt3_g] = bandpass(input_green,band3,fsound);
[Band4,filt4_g] = bandpass(input_green,band4,fsound);
Mixer_blue =
 gain_new(1)*Band1+gain_new(2)*Band2+gain_new(3)*Band3+gain_new(4)*Band4+gain_new(
filename = 'BlueinGreen_filtered.wav';
audiowrite(filename,Mixer_blue,fsound);
%gain [0,8,0,0,0];
%siren was removed at that gain take out the treble and the bass and
 leave
%some lower bandpass filter in. this region of filter is low enough to
%support the piano playing and low enough to filter out the high pitch
 siren.

Warning: Data clipped when writing file.

%FREQUENCY RESPONSE OF ORIGINAL SYSTEM
g_res = fft(input_s);
g_res = g_res(1:length(g_res)/2);
f = [0:length(g_res)-1].*fg./length(g_res);
figure;
subplot(2,1,1);
plot(f,abs(g_res)); %Magnitude
title('frequency response of original BlueinGreen');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res));%phase
title('frequency response of original BlueinGreen');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

%FREQUENCY RESPONSE OF MIXED SYSTEM
g_res2 = fft(Mixer_space);
g_res2 = g_res2(1:length(g_res2)/2);
f = [0:length(g_res2)-1].*fg./length(g_res2);
figure;
subplot(2,1,1);
plot(f,abs(g_res2)); %Magnitude
title('frequency response of filtered BlueinGreen');
xlabel('Frequency (Hz)');
```
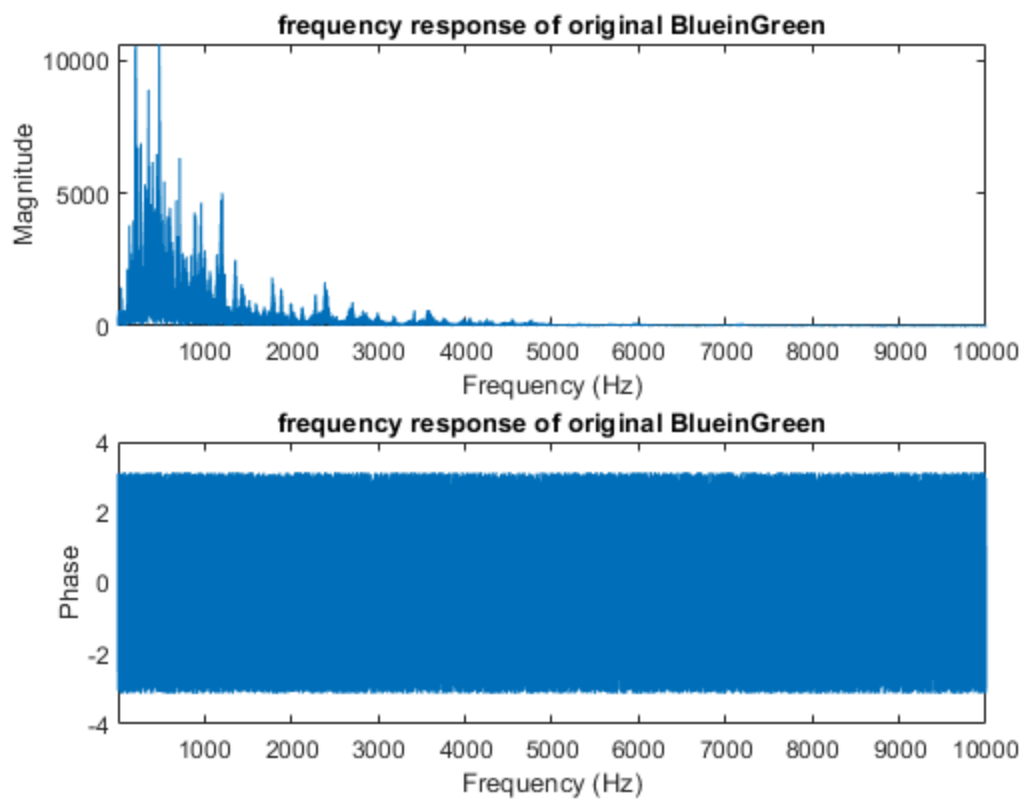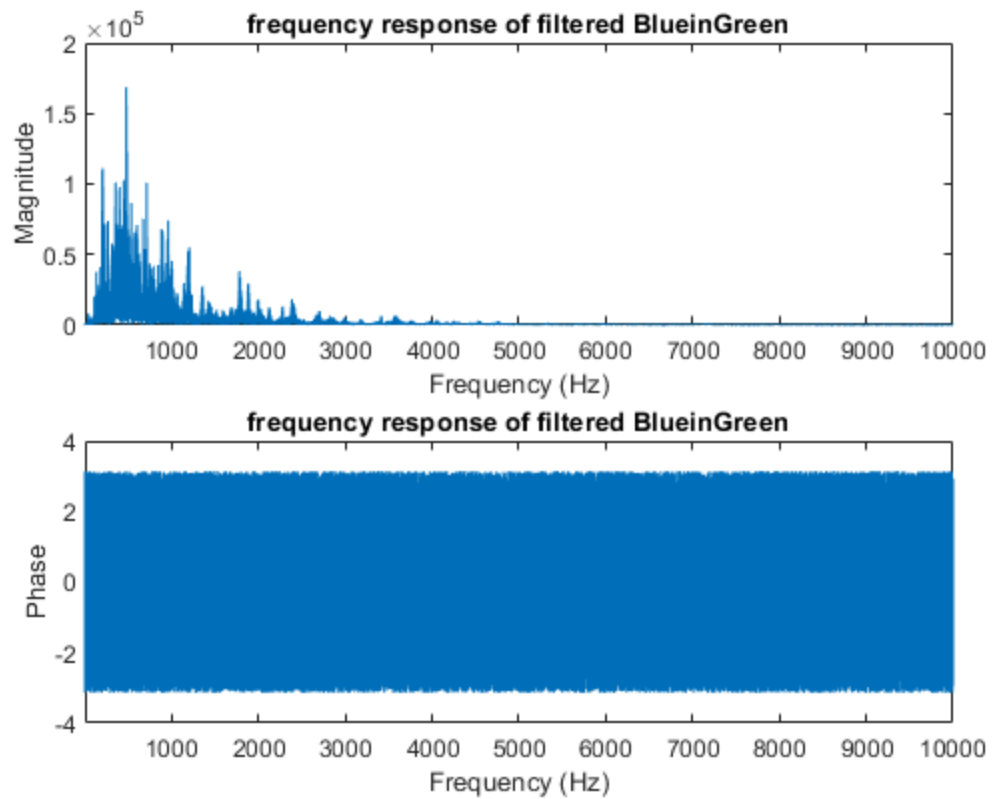
```
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res2));%phase
title('frequency response of filtered BlueinGreen');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

Warning: Integer operands are required for colon operator when used as
 index.
Warning: Integer operands are required for colon operator when used as
 index.
```
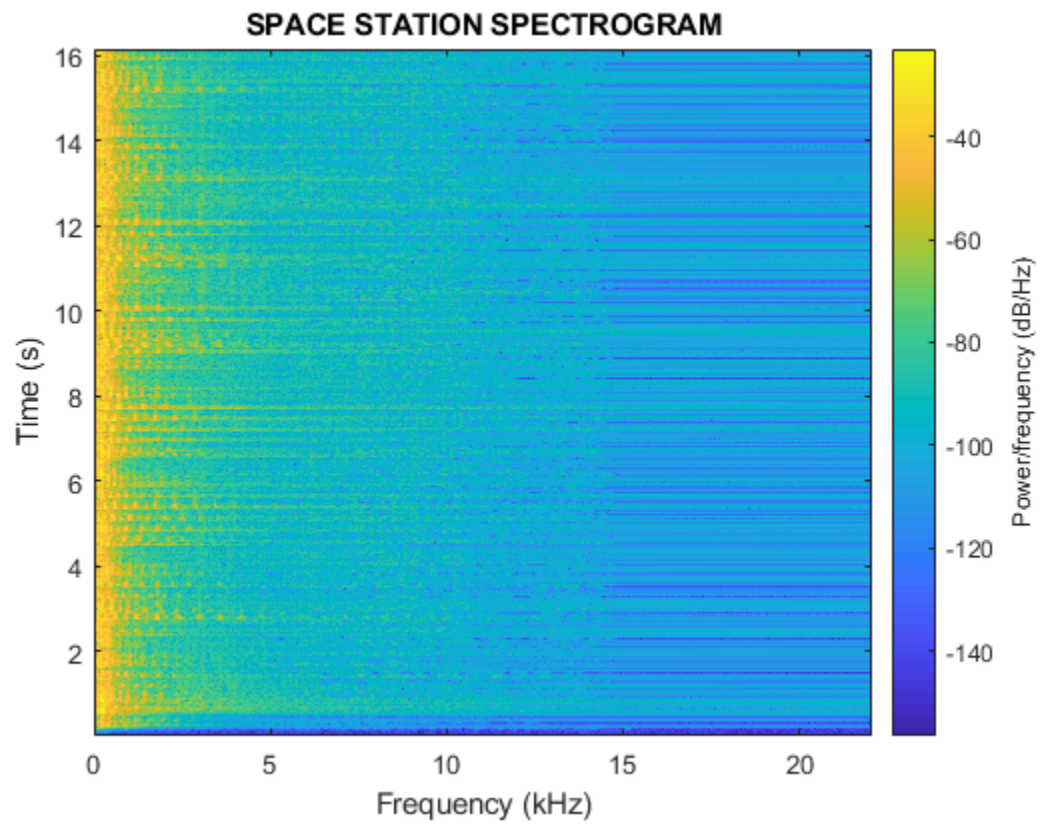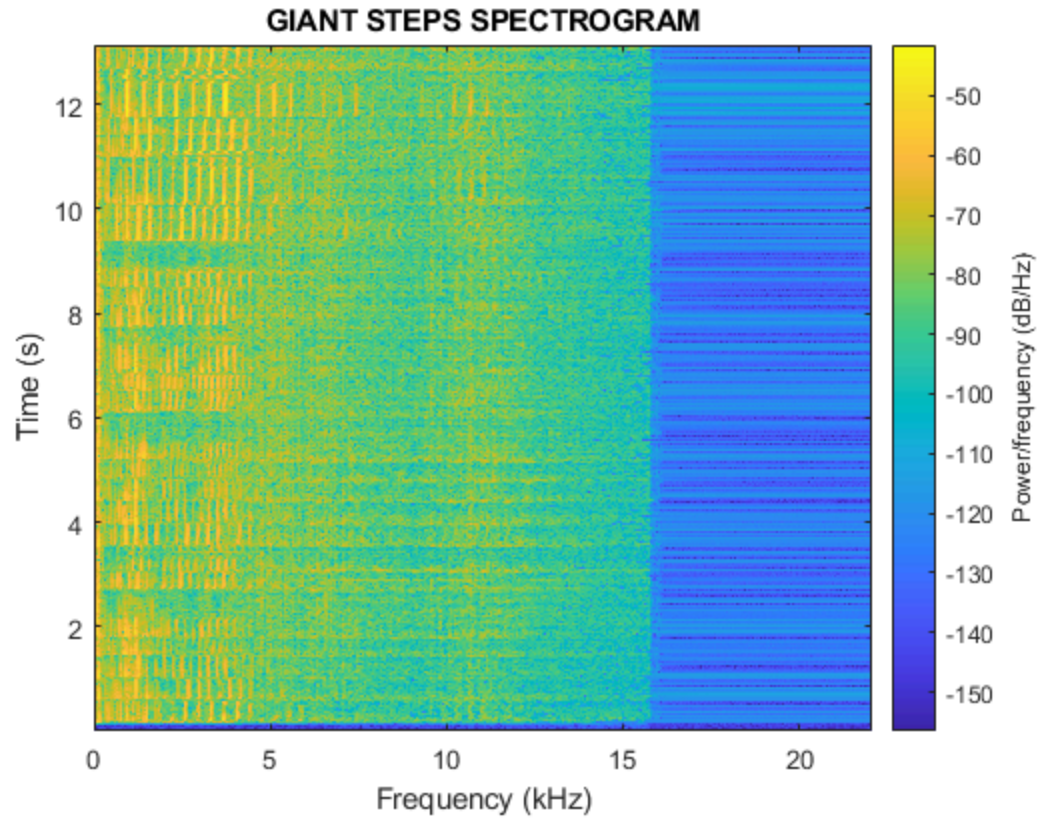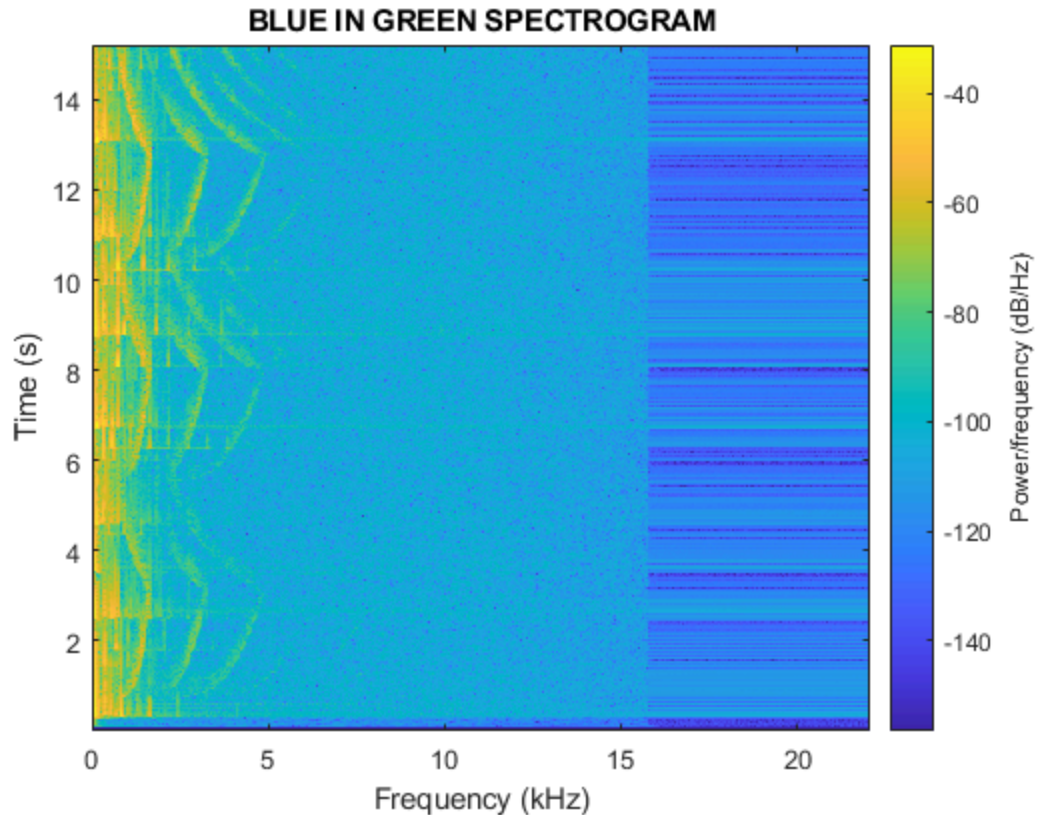
SPECTROGRAM ON SOUNDS

```
figure;
spectrogram(input_g,1024,200,1024,fsound);
title('GIANT STEPS SPECTROGRAM');
figure;
spectrogram(input_s,1024,200,1024,fsound);
title('SPACE STATION SPECTROGRAM');
figure;
spectrogram(input_green,1024,200,1024,fsound);
title('BLUE IN GREEN SPECTROGRAM');
```

GIANT STEPS SPECTROGRAM

SPACE STATION SPECTROGRAM

BLUE IN GREEN SPECTROGRAM

FREQUENCY RESPONSE OF EACH BAND FROM GIANT MIXER

```
t = (0:1:length(Band1)-1)';
h_low = tf(b_low,a_low);
h_high = tf(b_high,a_high);

[u1,frequ] = freqz(input_g,512,fsound);
[h1,freq1] = freqz(Band1,512,fsound);
[h2,freq2] = freqz(filt2_g,512,fsound);
[h3,freq3] = freqz(filt3_g,512,fsound);
[h4,freq4] = freqz(filt4_g,512,fsound);
[h5,freq5] = freqz(Band5,512);

% Mag and Phase Band 1 converting magnitude to decibels
%unity frequency response
figure;
subplot(2,1,1);
plot(frequ, mag2db(abs(u1)));
title('Unity Magnitude');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(frequ, angle(u1)/pi);
```

```matlab
title('Unity Angle');
xlabel('Frequency');

figure;
subplot(2,1,1);
plot(freq1, mag2db(abs(h1)));
title('Band 1 Magnitude on Giant steps');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq1, angle(h1)/pi);
title('Band 1 Angle on Giant steps');
xlabel('Frequency');
ylabel('angle');
% Mag and Phase Band 2
hold on
figure;
subplot(2,1,1);
plot(freq2, mag2db(abs(h2)));
title('Band 2 Magnitude on Giant steps');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq2, angle(h2)/pi);
title('Band 2 Angle on Giant steps');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 3
figure;
subplot(2,1,1);
plot(freq3, mag2db(abs(h3)));
title('Band 3 Magnitude on Giant steps');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq3, angle(h3)/pi);
title('Band 3 Angle on Giant steps');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 4
figure;
subplot(2,1,1);
plot(freq4, mag2db(abs(h4)));
title('Band 4 Magnitude on Giant steps');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq4, angle(h4)/pi);
title('Band 4 Angle on Giant steps');
xlabel('Frequency');
ylabel('angle');
%Mag and Phase Band 5
figure;
subplot(2,1,1);
```

```matlab
plot(freq5, mag2db(abs(h5)));
title('Band 5 Magnitude on Giant steps');
xlabel('Frequency');
ylabel('db');
subplot(2,1,2);
plot(freq5, angle(h5)/pi);
title('Band 5 Angle on Giant steps');
xlabel('Frequency');
ylabel('angle');
```

Band 1 Magnitude on Giant steps

Band 1 Angle on Giant steps

Band 2 Magnitude on Giant steps

Band 2 Angle on Giant steps

Band 3 Magnitude on Giant steps

Band 3 Angle on Giant steps

Band 4 Magnitude on Giant steps

Band 4 Angle on Giant steps

Band 5 Magnitude on Giant steps

Band 5 Angle on Giant steps
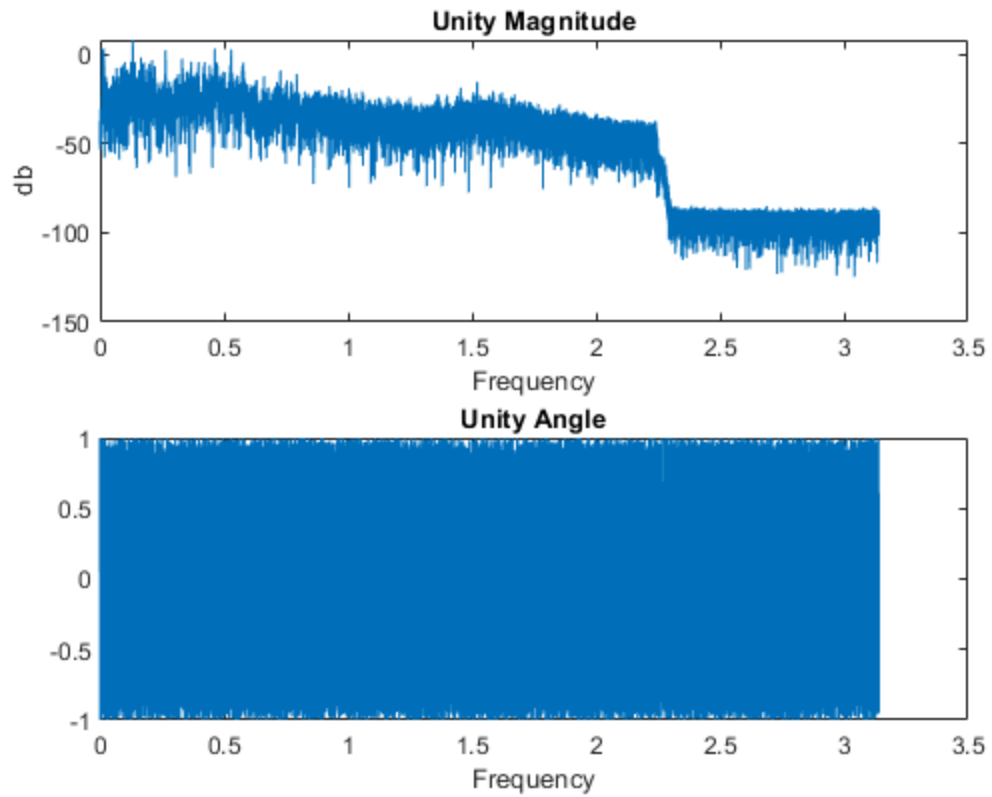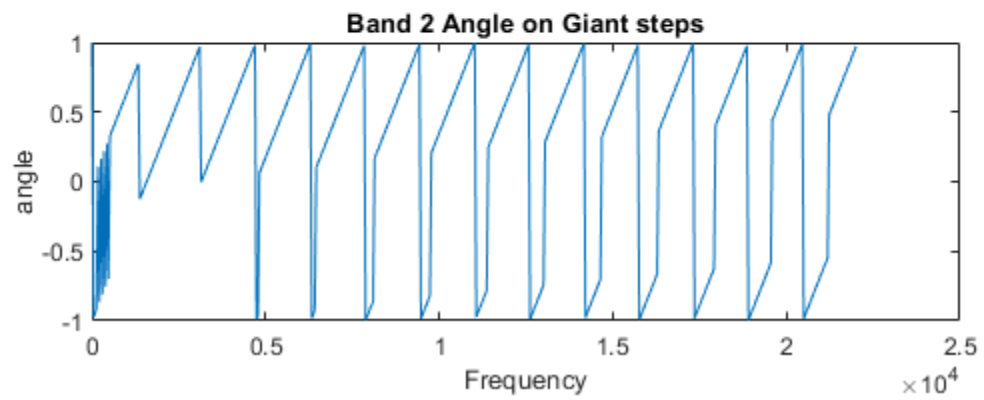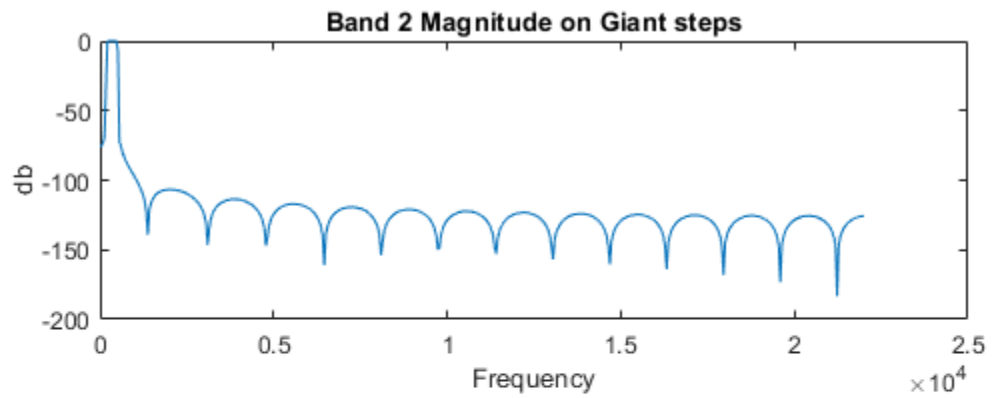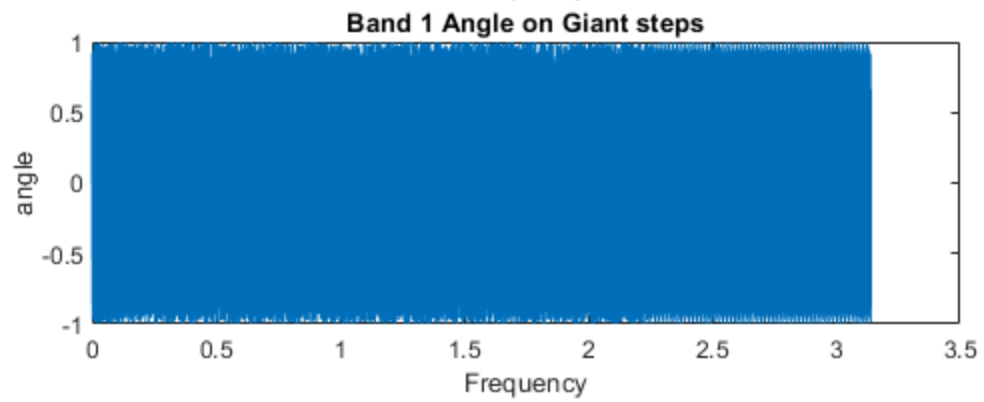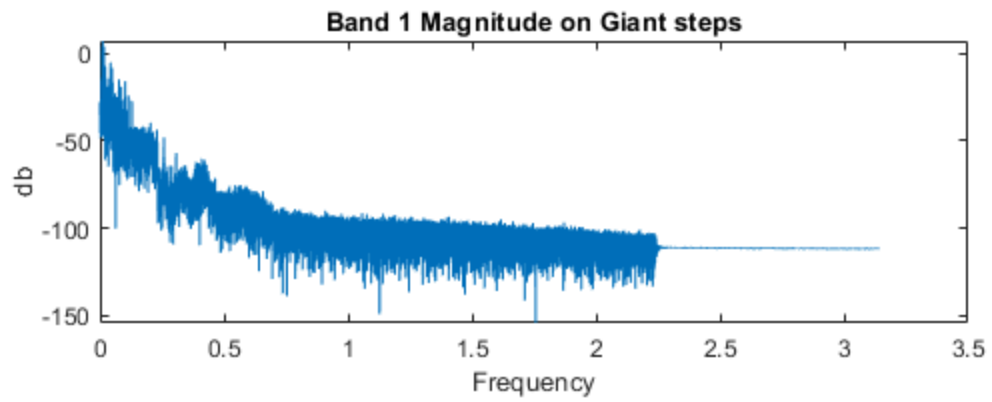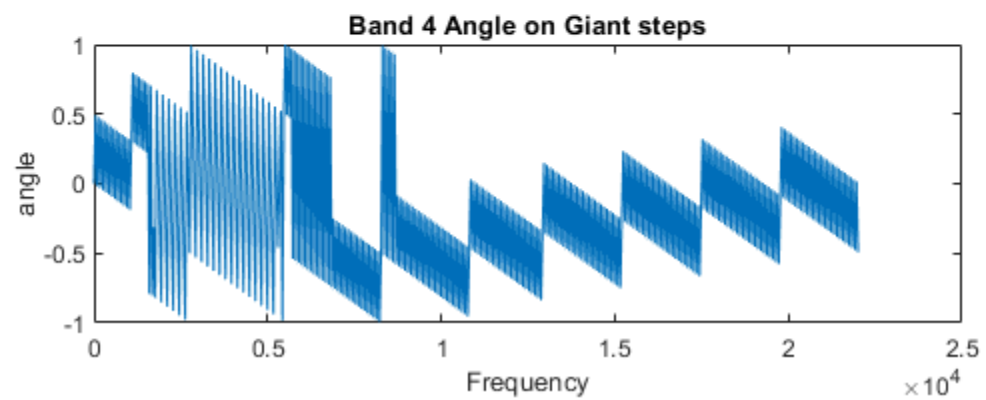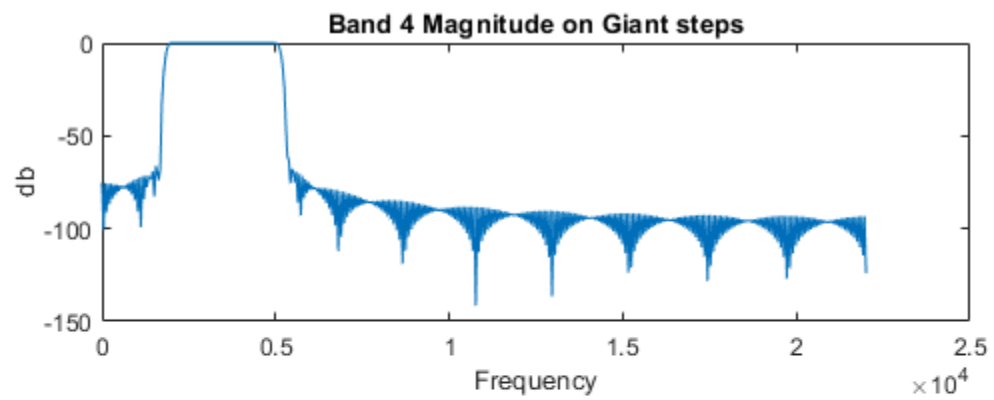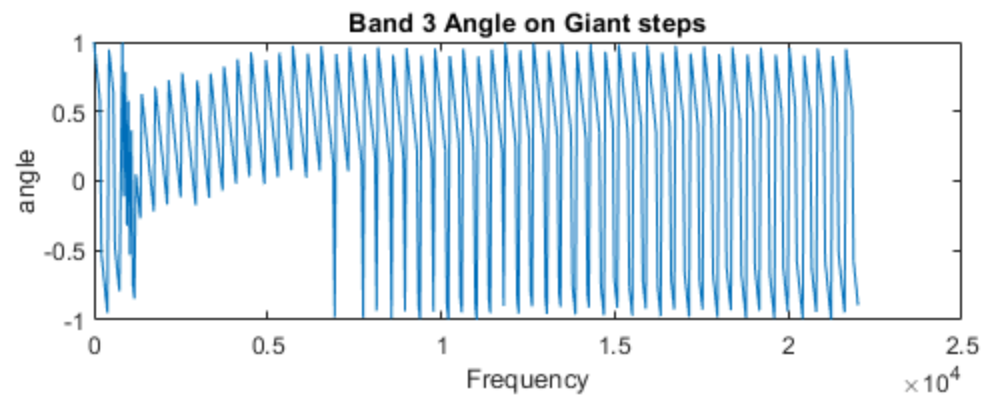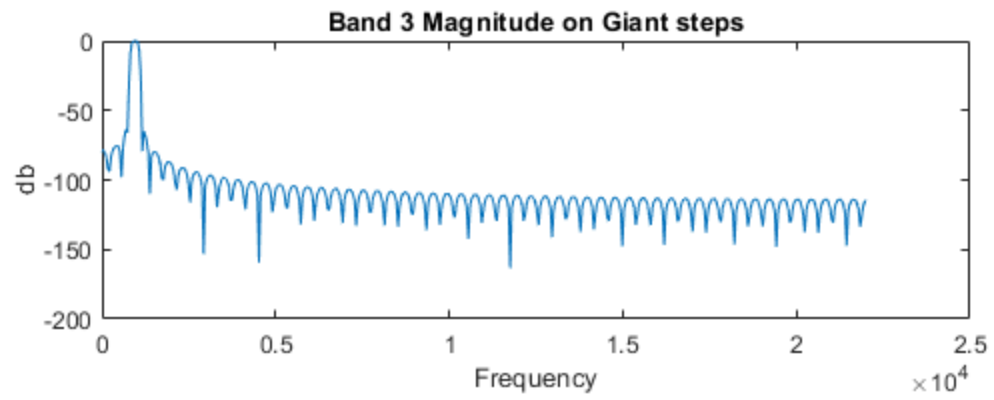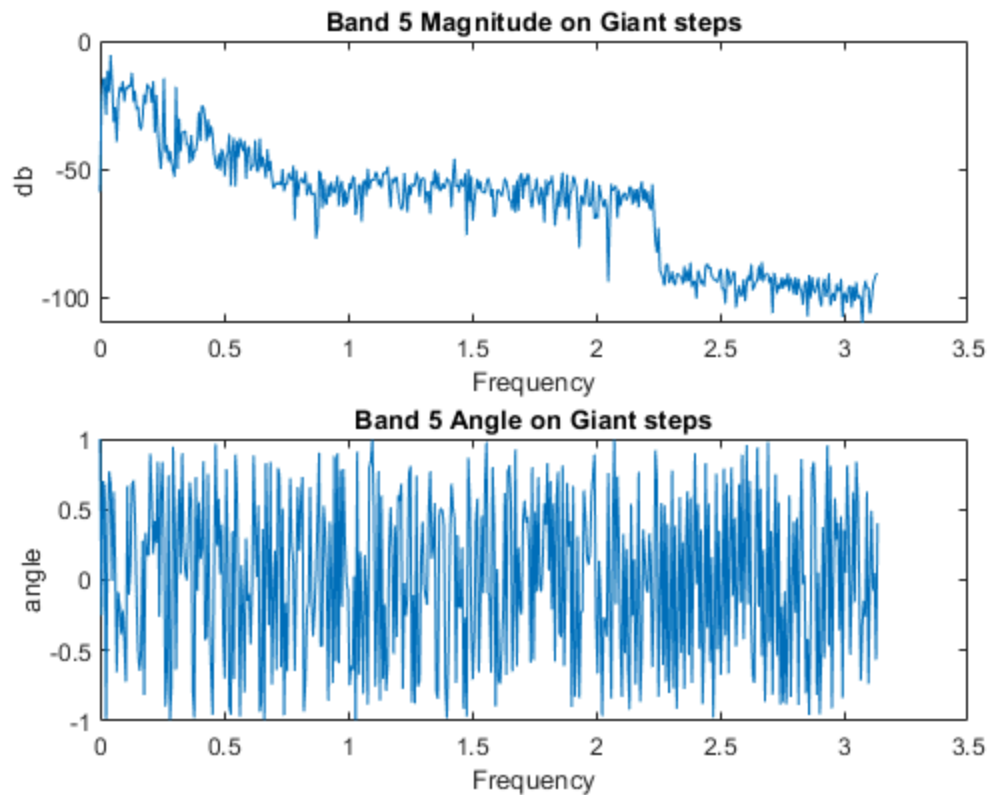
```
%FREQUENCY RESPONSE OF ORIGINAL SYSTEM
g_res = fft(input_g);
g_res = g_res(1:length(g_res)/2);
f = [0:length(g_res)-1].*fg./length(g_res);
figure;
subplot(2,1,1);
plot(f,abs(g_res)); %Magnitude
title('frequency response of original Giant Steps');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res));%phase
title('frequency response of original Giant Steps');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

%FREQUENCY RESPONSE OF MIXED SYSTEM
g_res = fft(Mixer_giant);
g_res = g_res(1:length(g_res)/2);
f = [0:length(g_res)-1].*fg./length(g_res);
figure;
subplot(2,1,1);
plot(f,abs(g_res)); %Magnitude
title('frequency response of filtered Giant Steps');
```

```matlab
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res));%phase
title('frequency response of filtered Giant Steps');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);
```
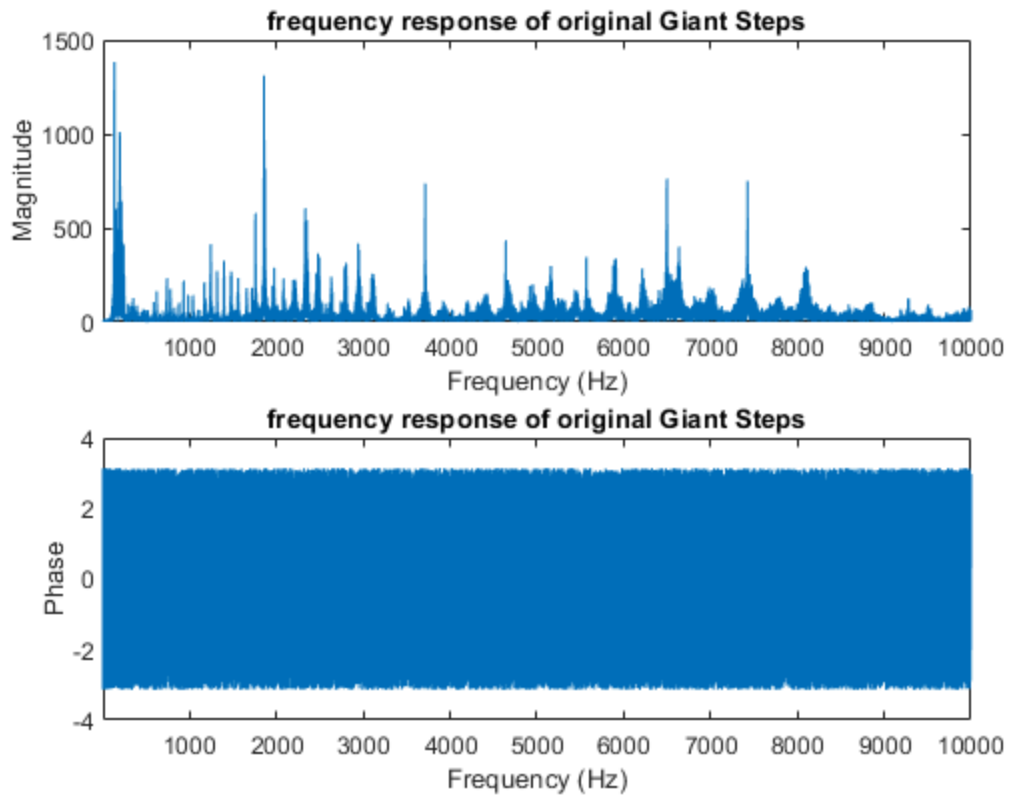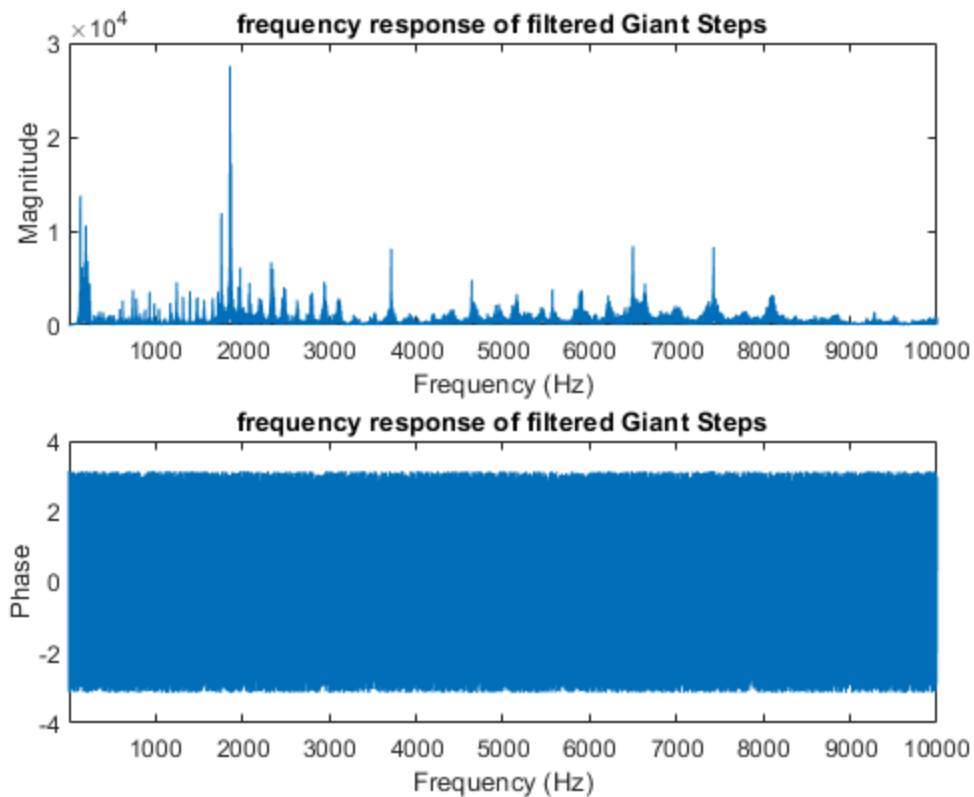
SOUND CHOICE FILTER: CHELSEA FOOT-BALL CLUB ANTHEM

```
fg = 44100;
samples = [1,20*fg];
[chelsea,fg] = audioread('Chelsea.mp3',samples);
gain_c = [0.5,0.1,1,0.1,0.5];
Band1 = filter([0 delta_t/tau],[1 delta_t/tau-1],chelsea); %lowpass
Band5 = filter([1 -1],[1 delta_t/tau-1],chelsea); %highpass
[Band2,filt2_c] = bandpass(chelsea,band2,fsound);
[Band3,filt3_c] = bandpass(chelsea,band3,fsound);
[Band4,filt4_c] = bandpass(chelsea,band4,fsound);
Mixer_chelsea =
 gain_c(1)*Band1+gain_c(2)*Band2+gain_c(3)*Band3+gain_c(4)*Band4+gain_c(5)*Band5;
filename = 'Chelsea_filtered.wav';
audiowrite(filename,Mixer_chelsea,fsound);

%FREQUENCY RESPONSE OF ORIGINAL SYSTEM
g_res = fft(chelsea);
g_res = g_res(1:length(g_res)/2);
f = [0:length(g_res)-1].*fg./length(g_res);
figure;
subplot(2,1,1);
plot(f,abs(g_res)); %Magnitude
title('frequency response of original Chelsea');
```

```matlab
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res));%phase
title('frequency response of original Chelsea');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

%FREQUENCY RESPONSE OF MIXED SYSTEM
g_res2 = fft(chelsea);
g_res2 = g_res2(1:length(g_res2)/2);
f = [0:length(g_res2)-1].*fg./length(g_res2);
figure;
subplot(2,1,1);
plot(f,abs(g_res2)); %Magnitude
title('frequency response of filtered Chelsea');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(g_res2));%phase
title('frequency response of filtered Chelsea');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);
```
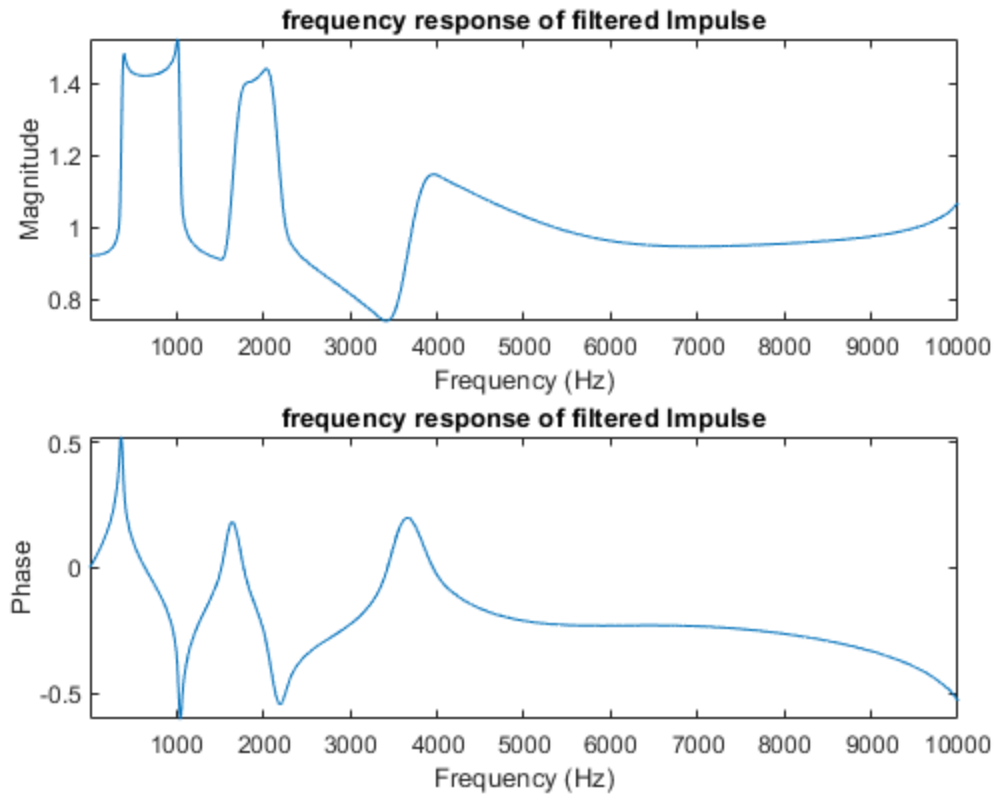
frequency response of original Chelsea

frequency response of original Chelsea

frequency response of filtered Chelsea

frequency response of filtered Chelsea
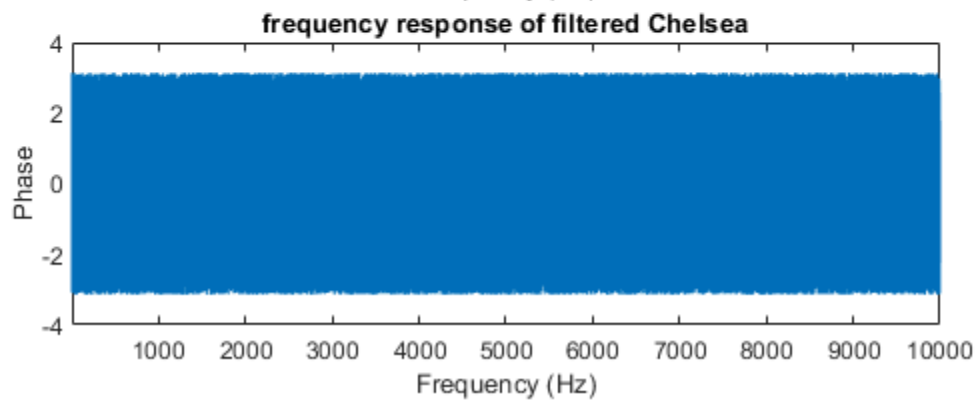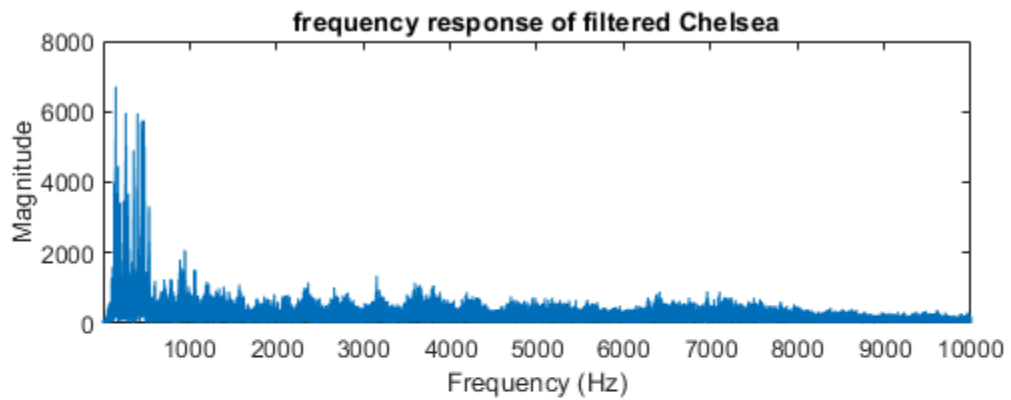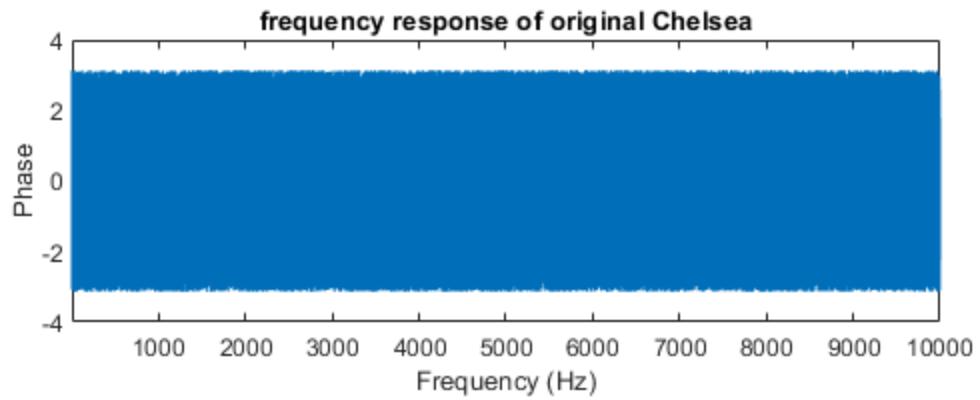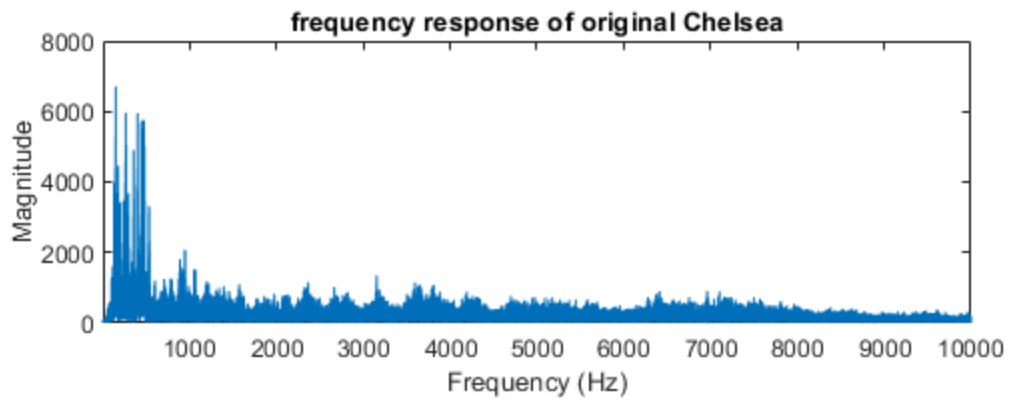
IMPULSE

```matlab
impulse = [1 zeros(1,fsound)];
[Band1_impulse,filt1_impulse] = highpass(impulse,10000,fsound);
imp_B1 = fft(Band1_impulse);
imp_B1 = imp_B1(1:length(imp_B1/2));
%UNITY (BAND PASS FILTER)
[Band2_impulse,filt2_impulse] = bandpass(impulse,band2,fsound);
imp_B2 = fft(Band2_impulse);
imp_B2 = imp_B2(1:length(imp_B2/2));
[Band3_impulse,filt3_impulse] = bandpass(impulse,band3,fsound);
imp_B3 = fft(Band3_impulse);
imp_B3 = imp_B3(1:length(imp_B3/2));
[Band4_impulse,filt4_impulse] = bandpass(impulse,band4,fsound);
imp_B4 = fft(Band4_impulse);
imp_B4 = imp_B4(1:length(imp_B4/2));
%BASS BOOST (LOW PASS FILTER)
[Band5_impulse,filt5_impulse] = lowpass(impulse,200,fsound);
imp_B5 = fft(Band5_impulse);
imp_B5 = imp_B5(1:length(imp_B5/2));
f_band_imp = [0:length(imp_B5)-1].*fsound./length(imp_B5);
%COMBINE BANDS
Mixer_impulse = Band1_impulse+Band2_impulse+Band3_impulse
+Band4_impulse+Band5_impulse;
imp_res = fft(Mixer_impulse);
imp_res = imp_res(1:length(imp_res)/2);
f = [0:length(imp_res)-1].*fg./length(imp_res);
%Impulse response for combined Bands
figure;
subplot(2,1,1);
plot(f,abs(imp_res));
title('frequency response of filtered Impulse');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
xlim([1,10000]);
subplot(2,1,2);
plot(f,angle(imp_res));
title('frequency response of filtered Impulse');
xlabel('Frequency (Hz)');
ylabel('Phase');
xlim([1,10000]);

% Impulse response on each band
figure;
plot(f_band_imp , abs(imp_B1));
hold on
plot(f_band_imp , abs(imp_B2));
plot(f_band_imp , abs(imp_B3));
plot(f_band_imp , abs(imp_B4));
plot(f_band_imp , abs(imp_B5));
title('frequency response of filtered Impulse on each band');
xlabel('Frequency (Hz)');
ylabel('Phase');
```
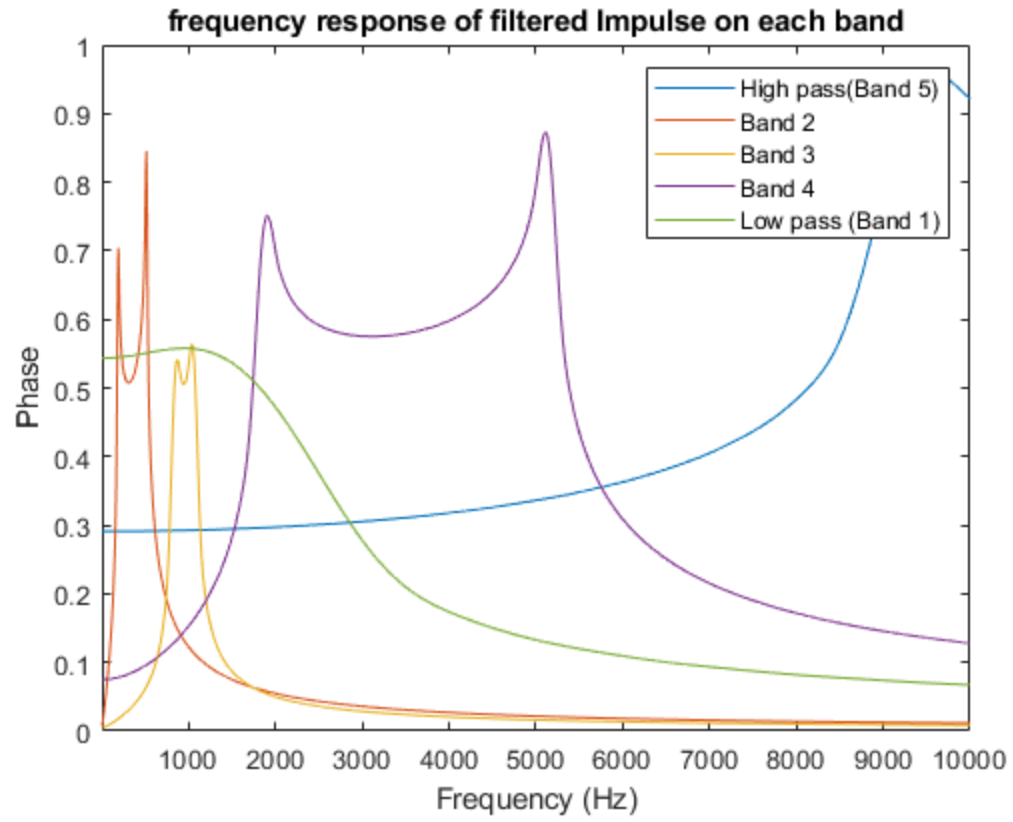
```
xlim([1,10000]);
legend('High pass(Band 5)','Band 2','Band 3','Band 4','Low pass (Band
 1)');
```

*Warning: Integer operands are required for colon operator when used as
 index.*

frequency response of filtered Impulse on each band

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