

Sistema de filtragem

```
clearvars
```

Recolha de dados

```
filename = "domingues2_perna.csv";
data_table = readtable(filename, "VariableNamingRule", "preserve");
data_set_z = table2array(data_table(:, "z_accel"));
data_time = table2array(data_table(:, "Hours:Minutes:Seconds.Milliseconds"));
data_time = seconds(data_time); data_time = data_time - data_time(1);

% bitalino_Fs = 100;
% data_table = readtable("domingues_coxis_03.txt");
% data_set_z = table2array(data_table(:, "Var6"));
% data_time = linspace(0,length(data_set_z)/bitalino_Fs,length(data_set_z))';
```

Frequênciа

```
L = length(data_time);

Fs = mean(1./diff(data_time));
disp("Sampling rate: " + Fs + "Hz")
```

```
Sampling rate: 61.5266Hz
```

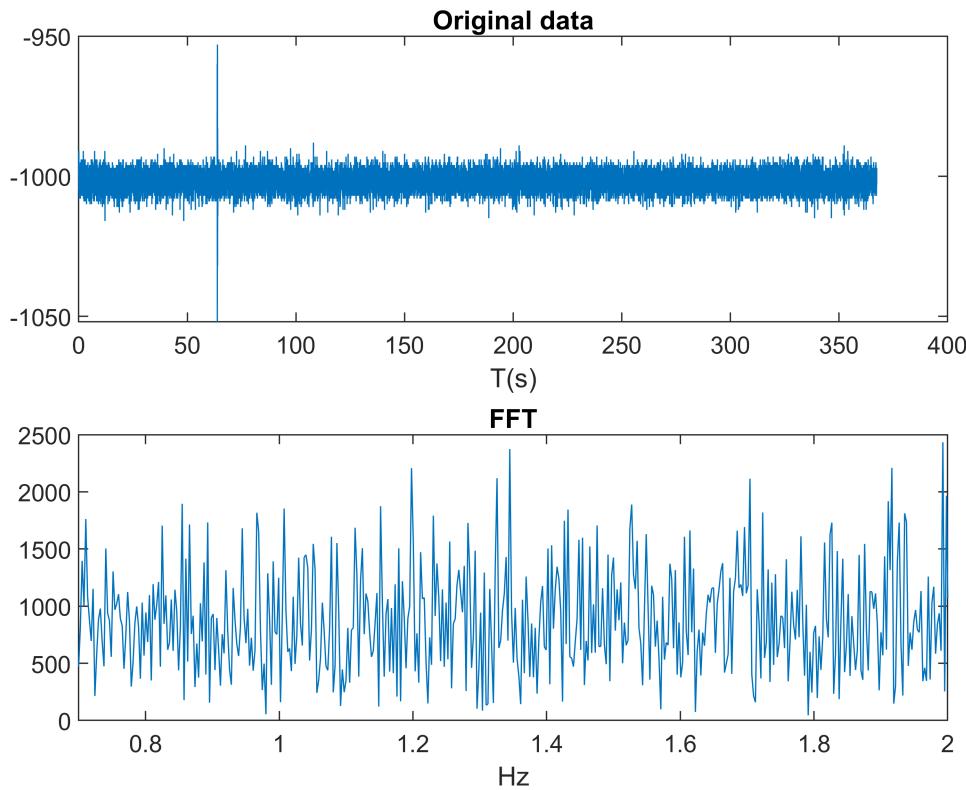
```
f = Fs*(0:(L/2))/L;
```

Z_DATA

```
fft_z = fft(data_set_z - mean(data_set_z));
```

Plots

```
figure,
subplot(211), plot(data_time, data_set_z)
title("Original data"), xlabel("T(s)")
subplot(212), plot(f, abs(fft_z(1:numel(f)))*2)
title("FFT"), xlim([0.7, 2]), xlabel("Hz")
```



Remove outliers

```
% Fill outliers
[outliers,outlierIndices,thresholdLow,thresholdHigh,center] = ...
    filloutliers(data_set_z,"linear","movmedian",60,"SamplePoints",data_time);

% Display results
clf
plot(data_time,data_set_z,"Color",[77 190 238]/255, ...
    "DisplayName","Input data")
hold on
plot(data_time,outliers,"Color",[0 114 189]/255,"LineWidth",1.5, ...
    "DisplayName","Cleaned data")

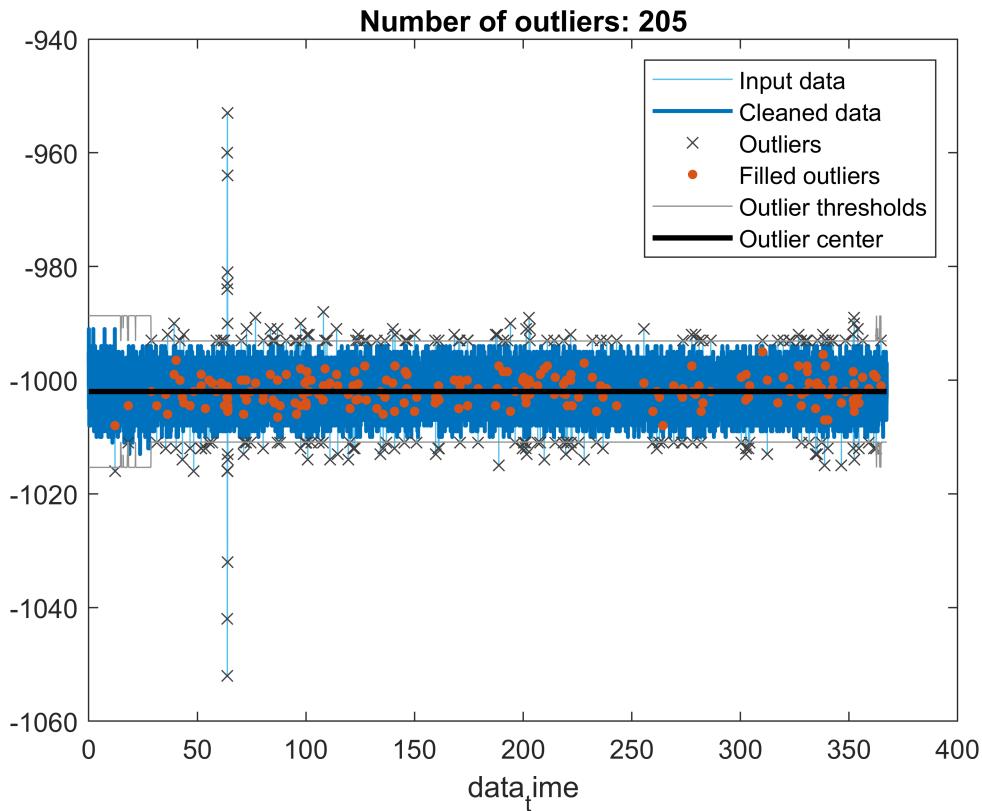
% Plot outliers
plot(data_time(outlierIndices),data_set_z(outlierIndices),"x",...
    "Color",[64 64 64]/255,"DisplayName","Outliers")
title("Number of outliers: " + nnz(outlierIndices))

% Plot filled outliers
plot(data_time(outlierIndices),outliers(outlierIndices),".", "MarkerSize",12, ...
    "Color",[217 83 25]/255,"DisplayName","Filled outliers")

% Plot outlier thresholds
plot([data_time(:); missing; data_time(:)],...
    [thresholdHigh(:); missing; thresholdLow(:)],"Color",[145 145 145]/255, ...
    "DisplayName","Outlier thresholds")
```

```
% Plot outlier center
plot(data_time,center,"k","LineWidth",2,"DisplayName","Outlier center")

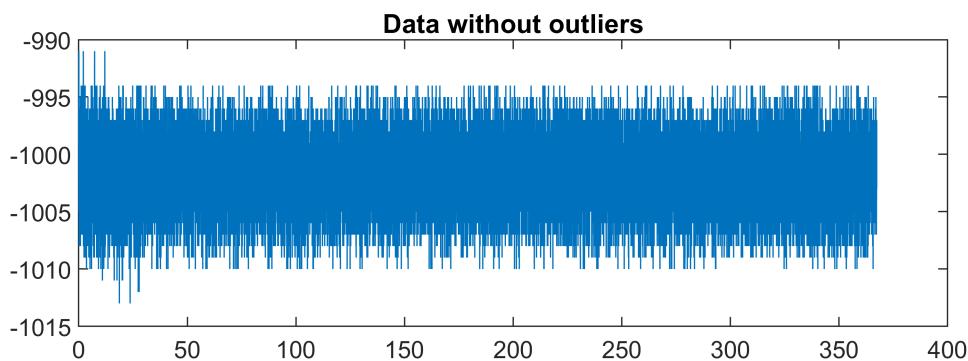
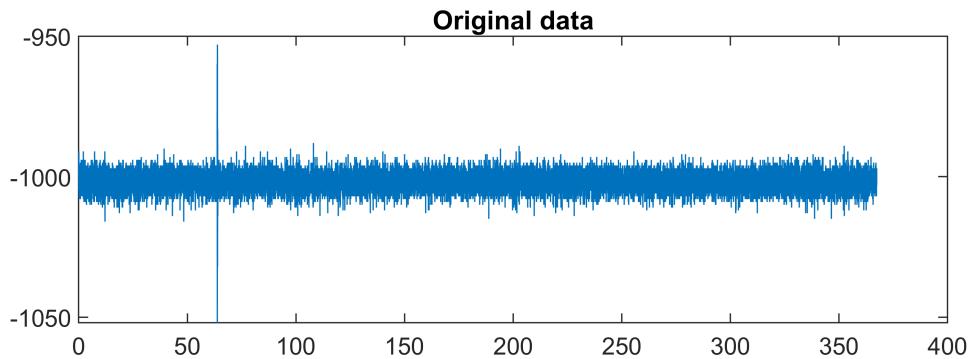
hold off
legend
xlabel("data_time")
```



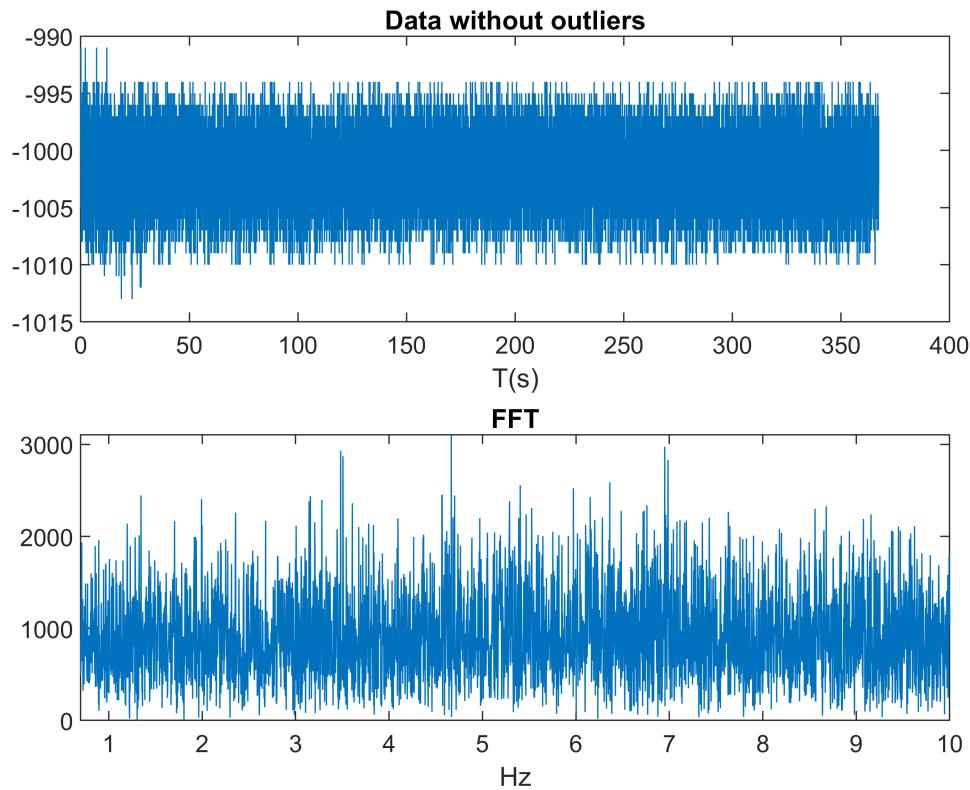
```
clear outlierIndices thresholdLow thresholdHigh center
```

Plots

```
figure,
subplot(211),plot(data_time, data_set_z)
title("Original data")
subplot(212),plot(data_time, outliers)
title("Data without outliers")
```



```
fft_outliers = fft(outliers - mean(outliers));  
  
% Smooth input data  
smoothedData = smoothdata(fft_outliers, "movmean", 5);  
  
figure,  
subplot(211), plot(data_time, outliers)  
title("Data without outliers"), xlabel("T(s)")  
subplot(212), plot(f, abs(fft_outliers(1:numel(f)))*2)  
title("FFT"), xlim([0.7, 10]), xlabel("Hz")
```

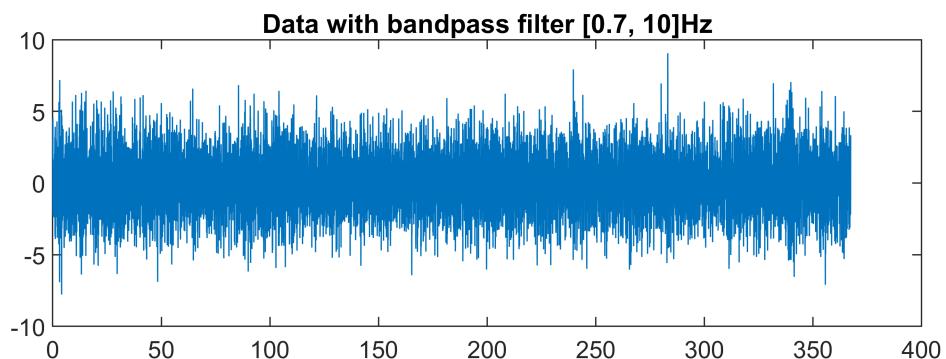
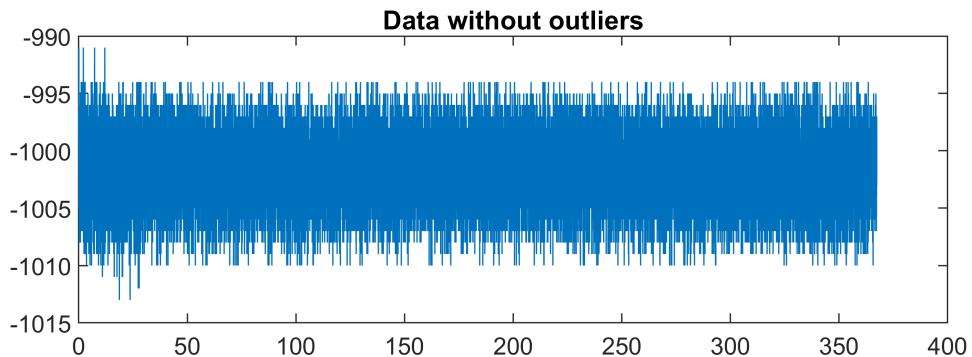


Bandpass filter [0.7 - 10]Hz

```
% Hd = butter_ecg(Fs);
% filtered = filter(Hd,outliers);
filtered = filter_bpm(outliers);
```

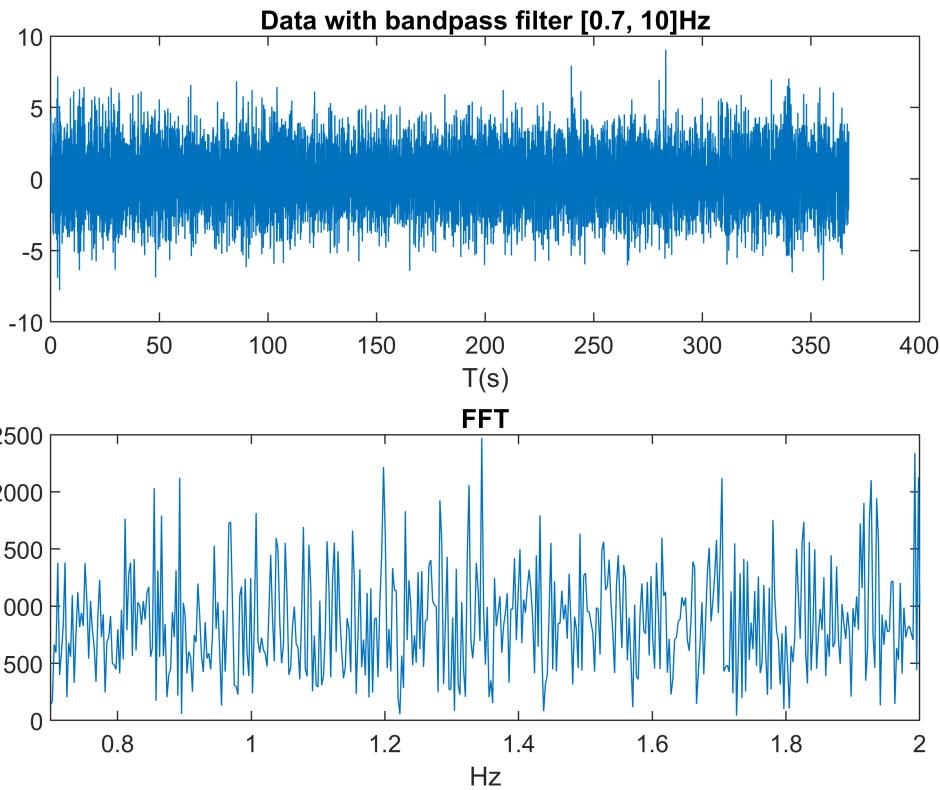
Plots

```
figure,
subplot(211),plot(data_time, outliers)
title("Data without outliers")
subplot(212),plot(data_time, filtered)
title("Data with bandpass filter [0.7, 10]Hz")
```



```
fft_filtered = fft(filtered);

figure,
subplot(211),plot(data_time, filtered)
title("Data with bandpass filter [0.7, 10]Hz"), xlabel("T(s)")
subplot(212),plot(f, abs(fft_filtered(1:numel(f)))*2)
title("FFT"), xlim([0.7, 2]), xlabel("Hz")
```



```
[~, I] = max(abs(fft_filtered(1:numel(f)))*2);
disp("Estimated frequency: " + f(I) + "Hz")
```

Estimated frequency: 4.6662Hz

```
disp("Estimated BPM: " + f(I)*60)
```

Estimated BPM: 279.9732

Segmentation and Windowing

Segmentation

```
samples_15s = round(Fs*15);
samples_60s = samples_15s * 4;
[segmented, time_array] = segment_data(filtered,data_time,samples_60s,samples_15s);

f_segment = Fs*(0:(samples_60s/2))/samples_60s;

n = size(segmented,2)

n = 20
```

Windowing

```
windowed = hamming(samples_60s,"symmetric") .* segmented;
```

BPM

```
fft_windows = fft(windowed);
```

```

index_7 = find(f_segment>.7,1)

index_7 = 44

index_100 = find(f_segment<2,1,"last")

index_100 = 121

bpms = zeros(1,n);
figure
for count = 1:n
    figure
    fft_cut = fft_windows(1: numel(f_segment),count);
    [M, I] = max(abs(fft_cut(index_7:index_100))*2);
    bpms(count) = f_segment(I+index_7-1)*60;

    subplot(211)
    plot(time_array(:,count),windowed(:,count))
    title("Estimated BPM: "+bpms(count))
    conf = confidence(fft_windows(1: numel(f_segment),count),f_segment,0.7,2);
    xlabel(conf)

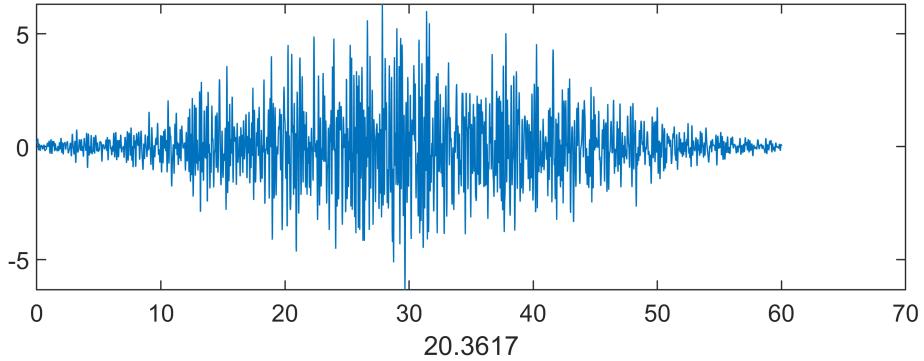
    subplot(212)

    if conf > 25
        plot(f_segment, abs(fft_cut)*2)
    else
        plot(f_segment, abs(fft_cut)*2, "r")
    end
    xlim([0.7, 2])
    title("confidence = " + conf)
    xlabel("f (Hz)'), ylabel("U.A.")

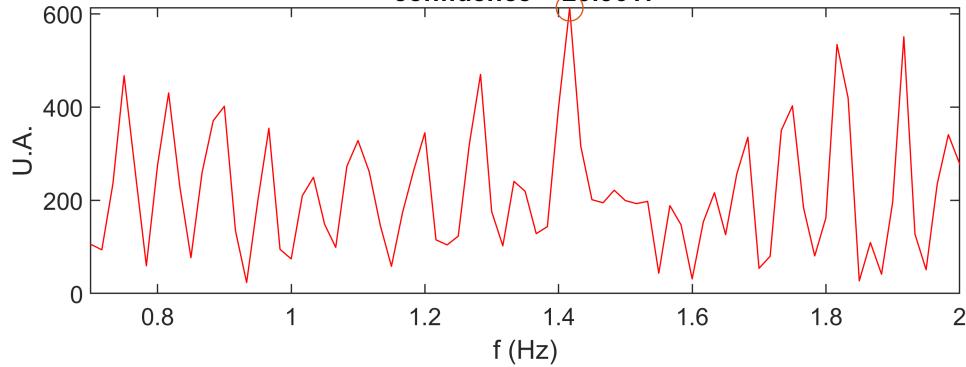
    hold on
    plot(f_segment(I+index_7-1), M, 'o', 'MarkerSize', 10)
end

```

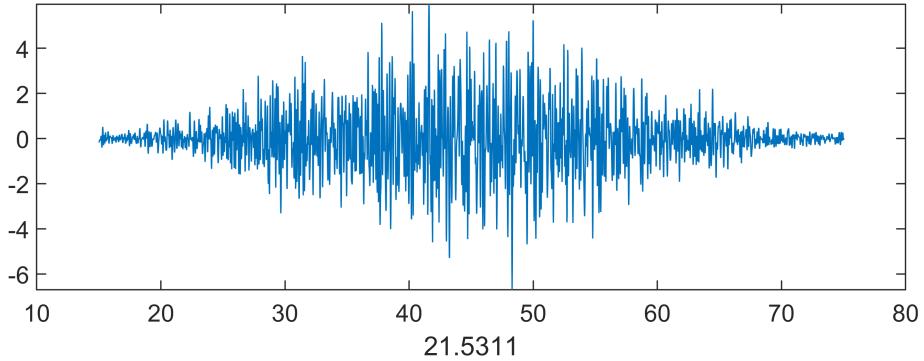
Estimated BPM: 84.9907



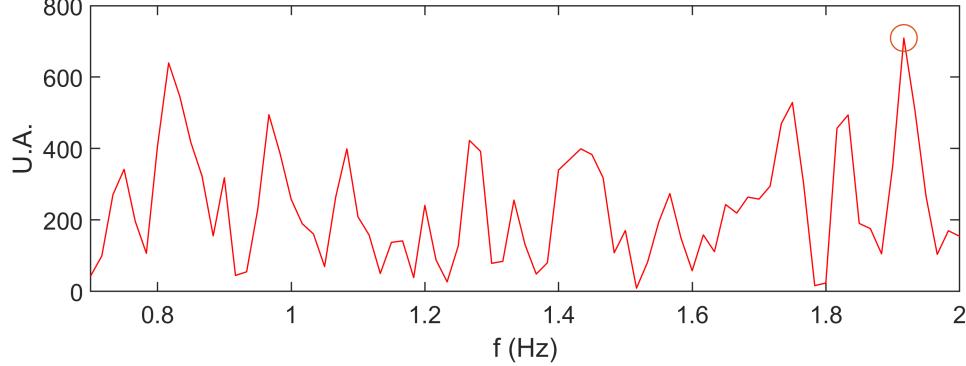
confidence = 20.3617



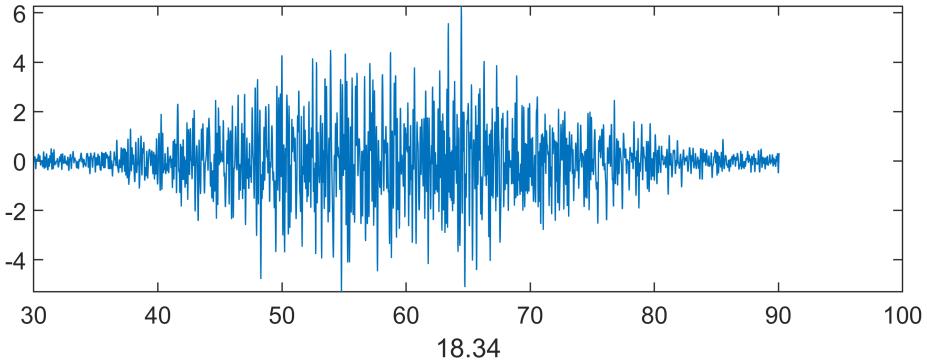
Estimated BPM: 114.9874



confidence = 21.5311

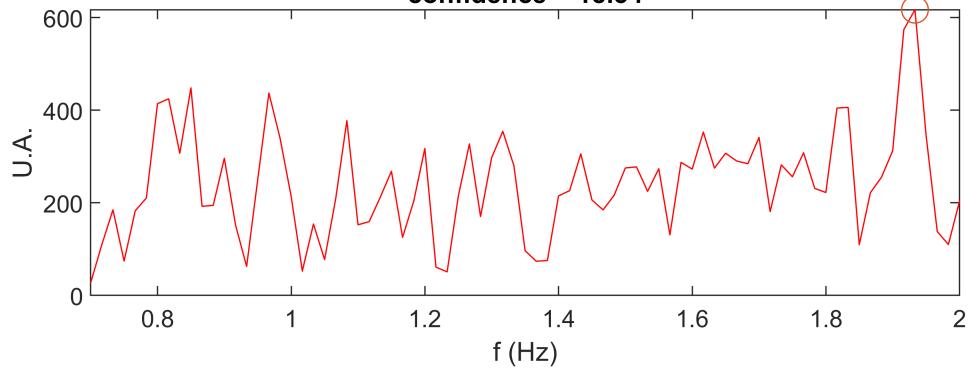


Estimated BPM: 115.9873

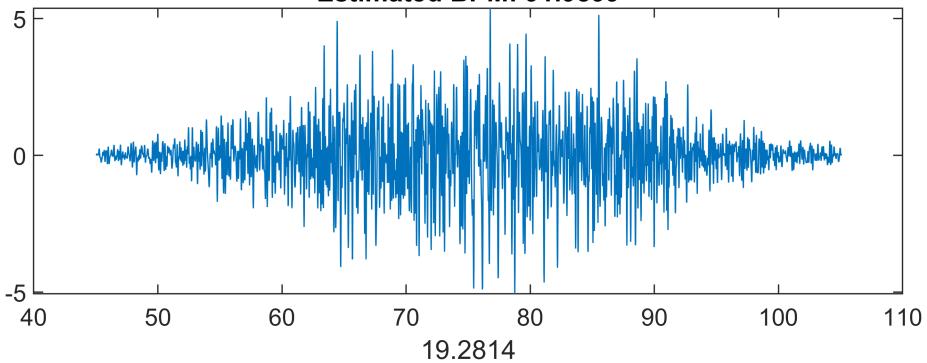


18.34

confidence = 18.34

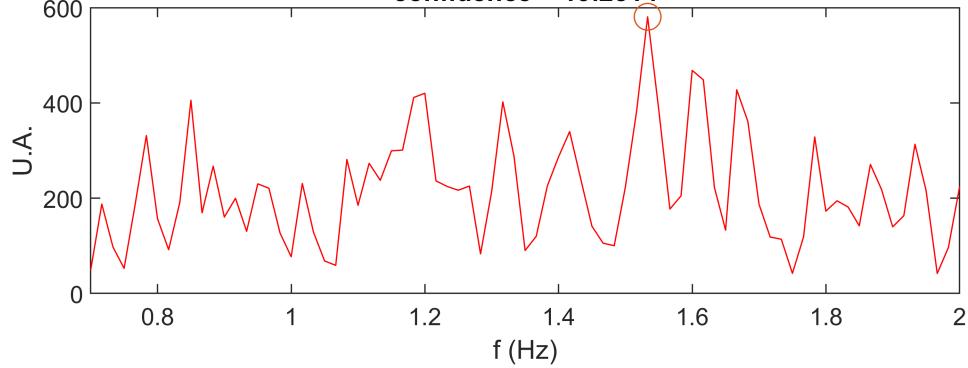


Estimated BPM: 91.9899

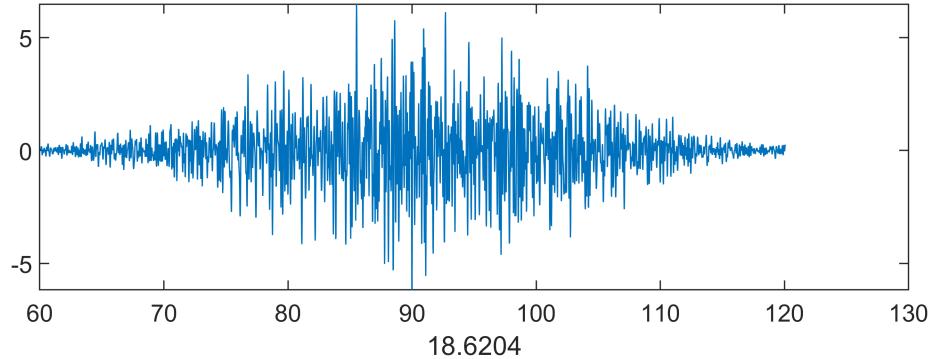


19.2814

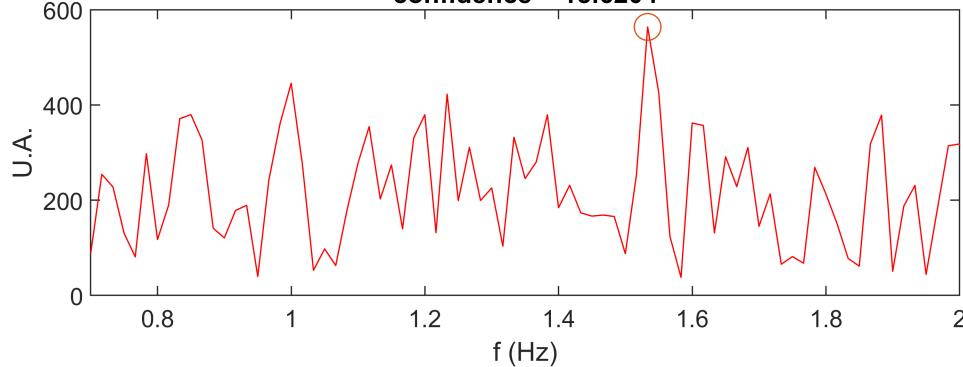
confidence = 19.2814



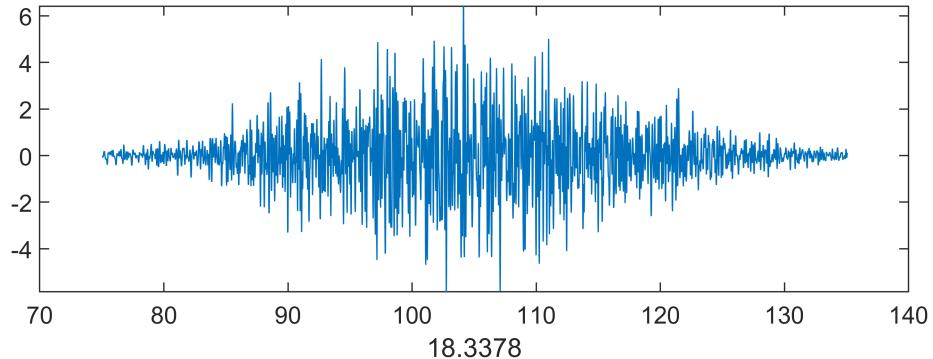
Estimated BPM: 91.9899



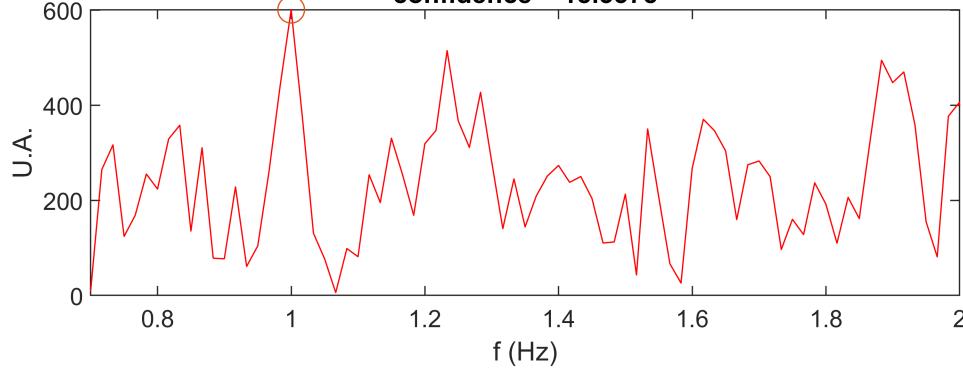
confidence = 18.6204

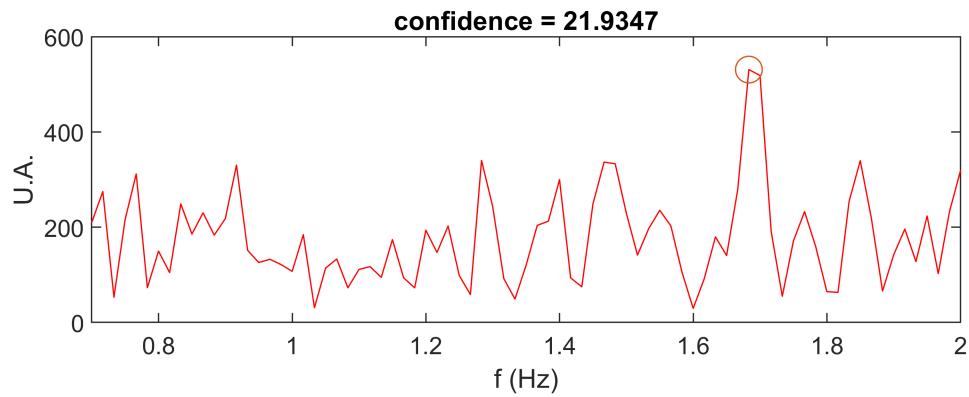
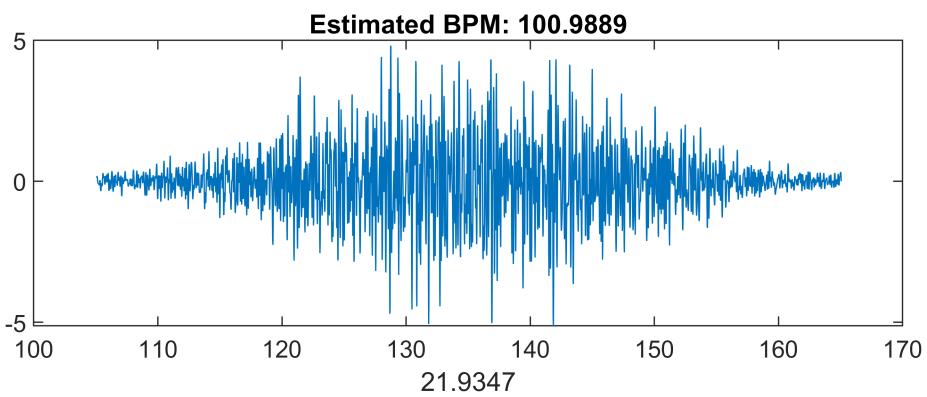
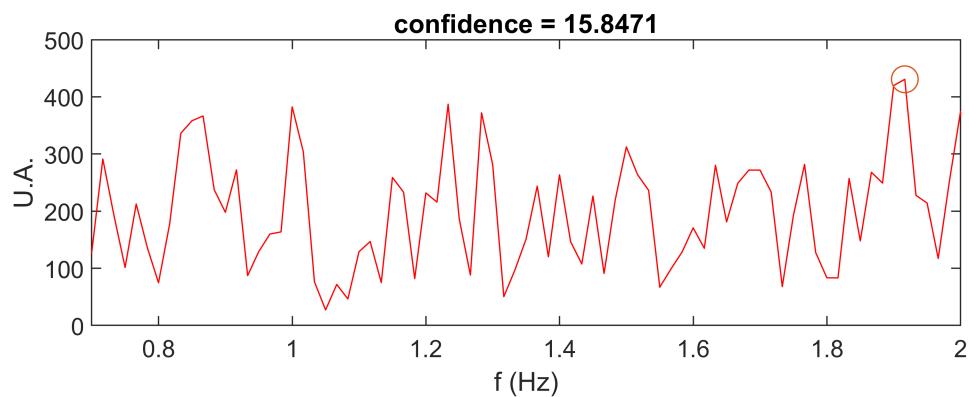
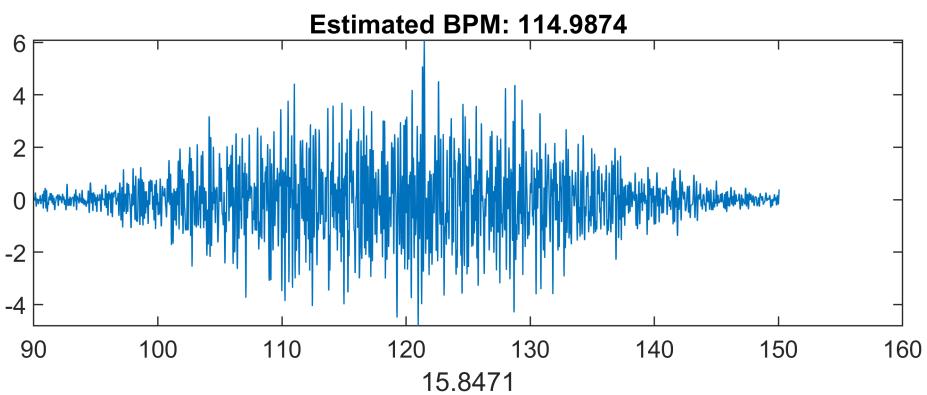


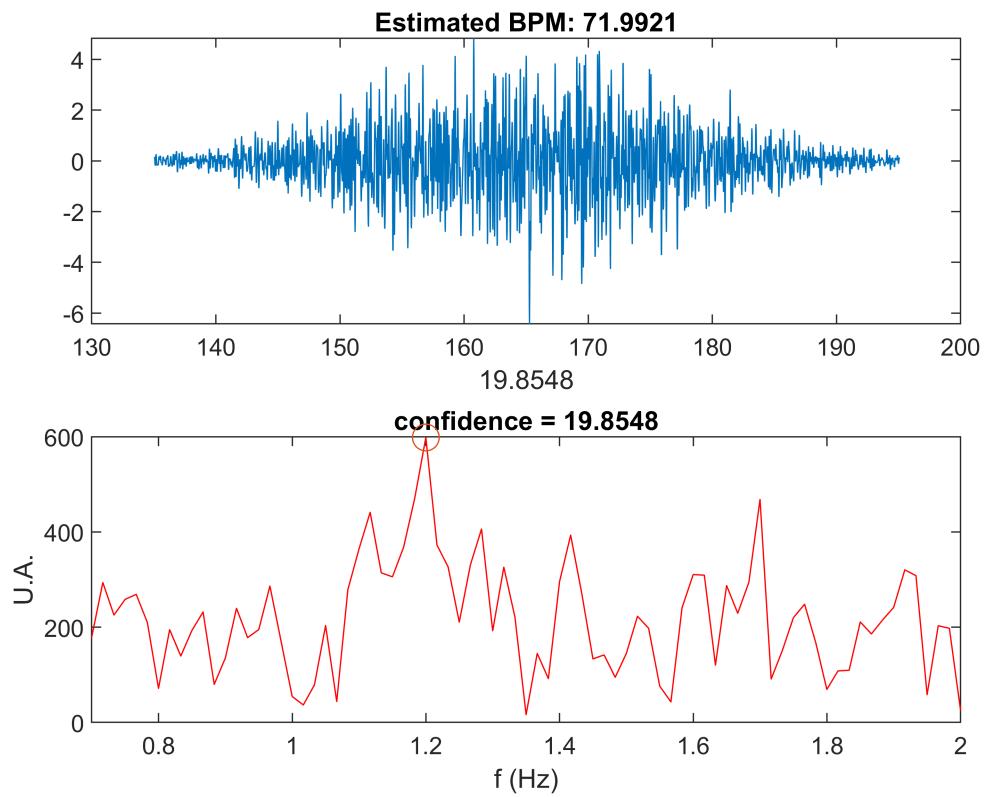
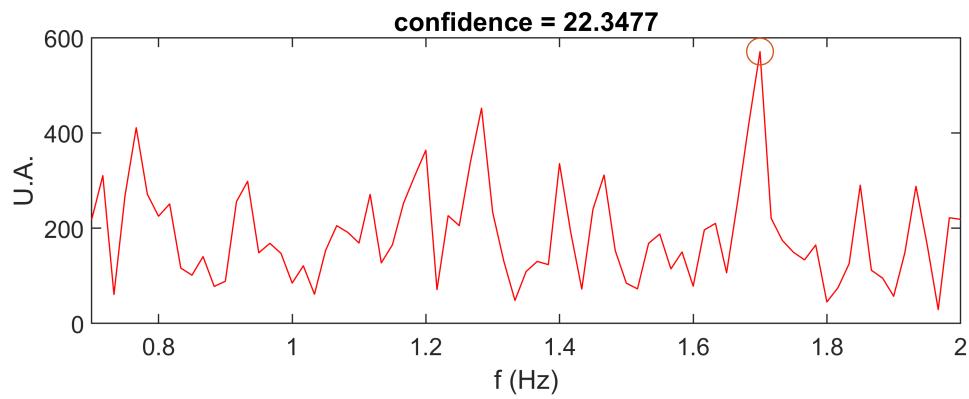
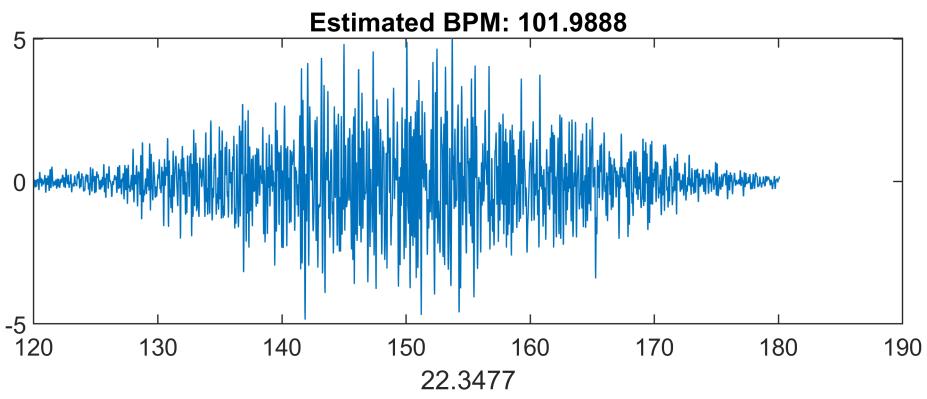
Estimated BPM: 59.9934



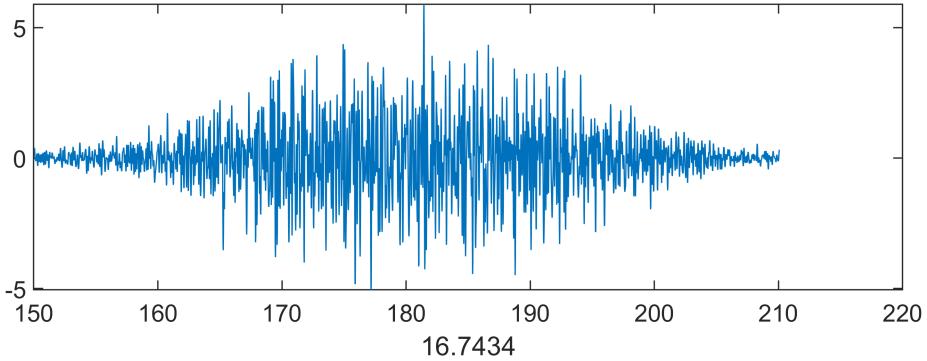
confidence = 18.3378



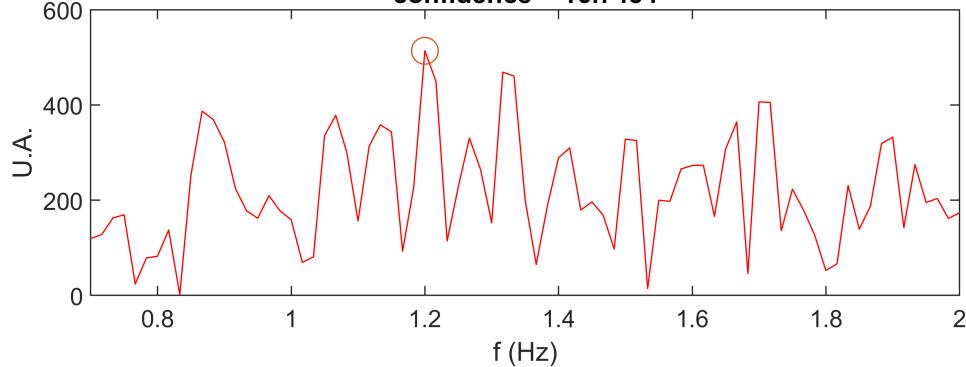




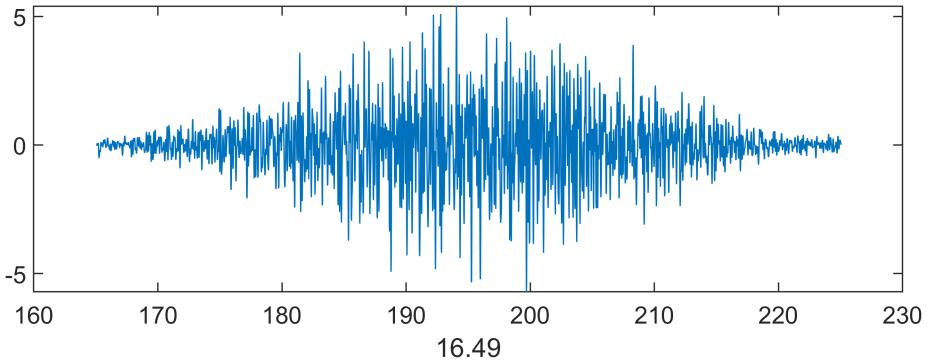
Estimated BPM: 71.9921



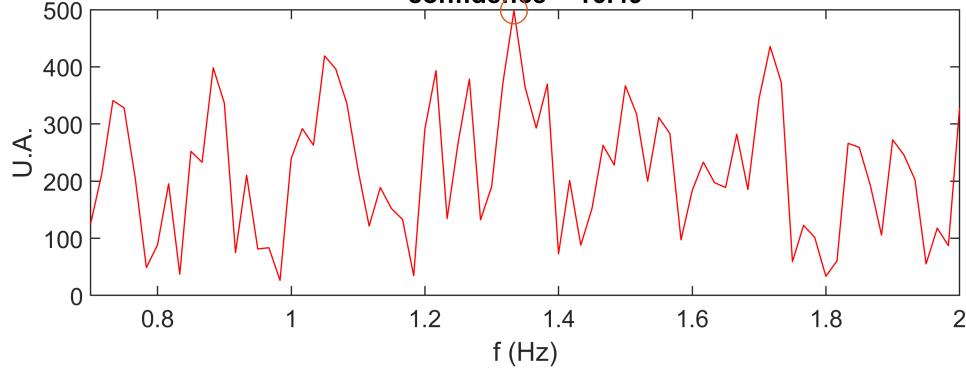
confidence = 16.7434

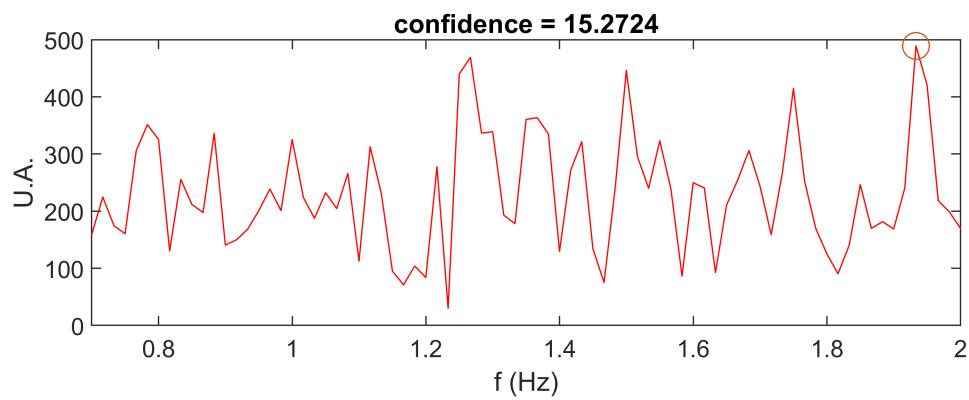
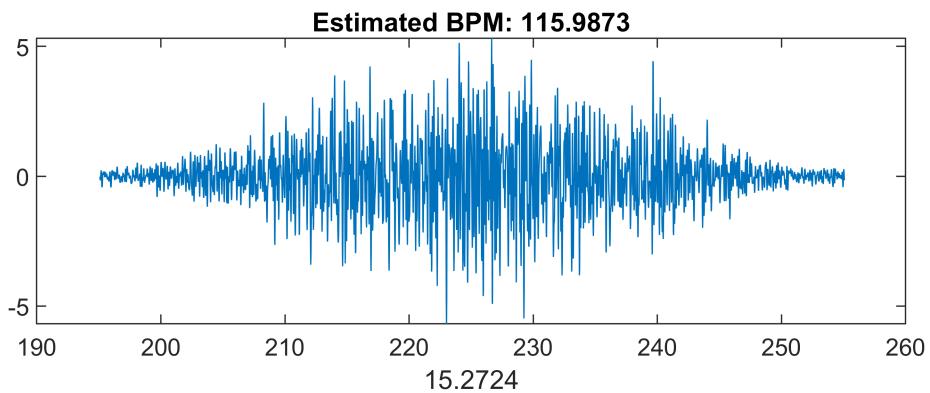
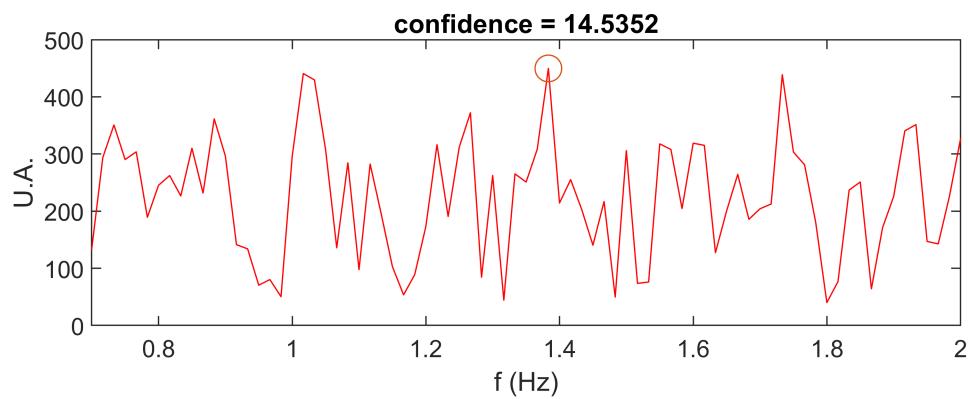
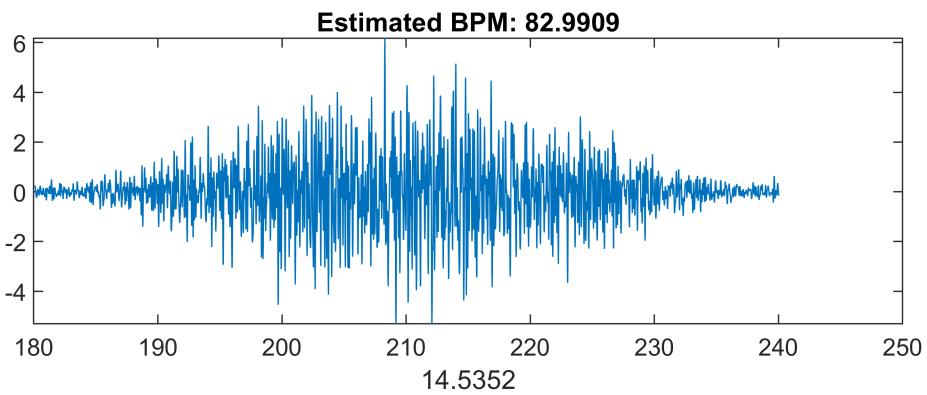


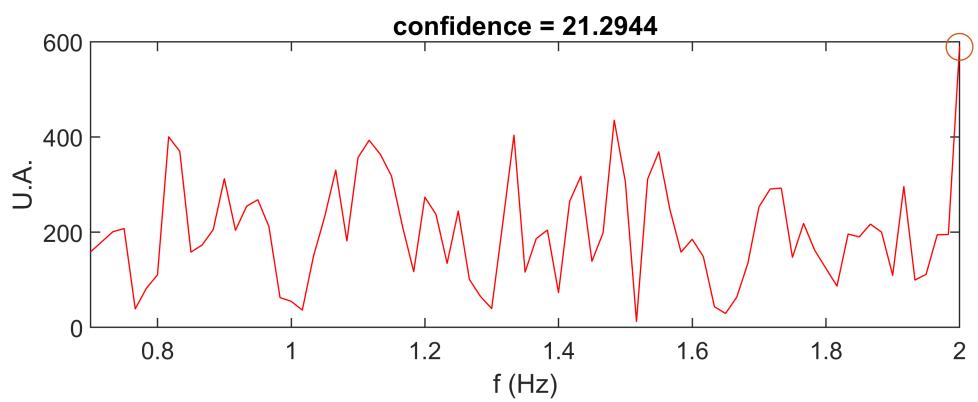
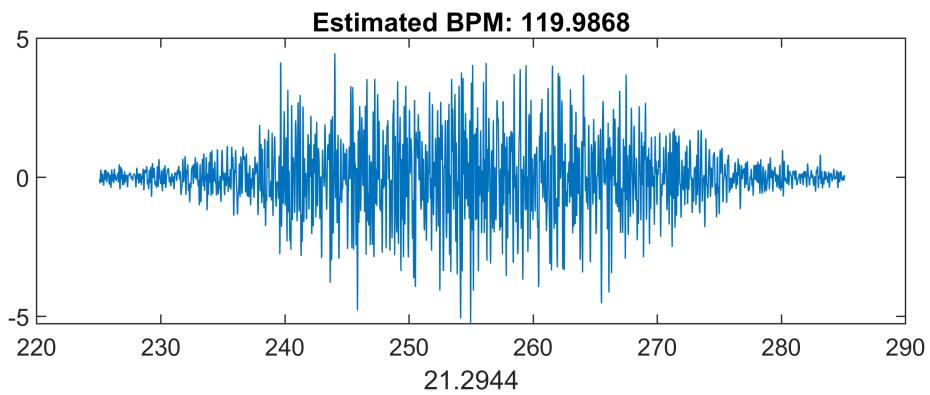
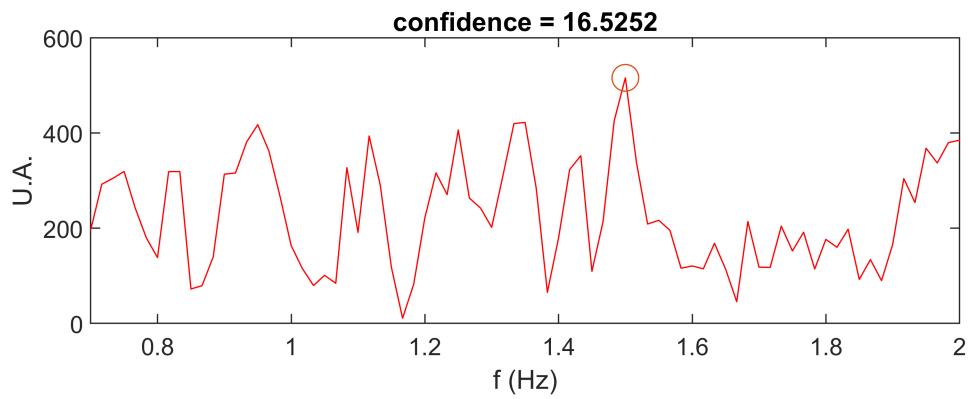
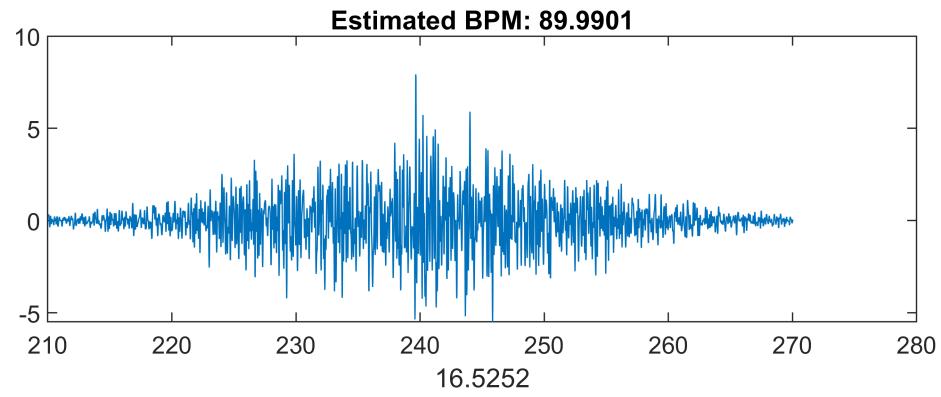
Estimated BPM: 79.9912

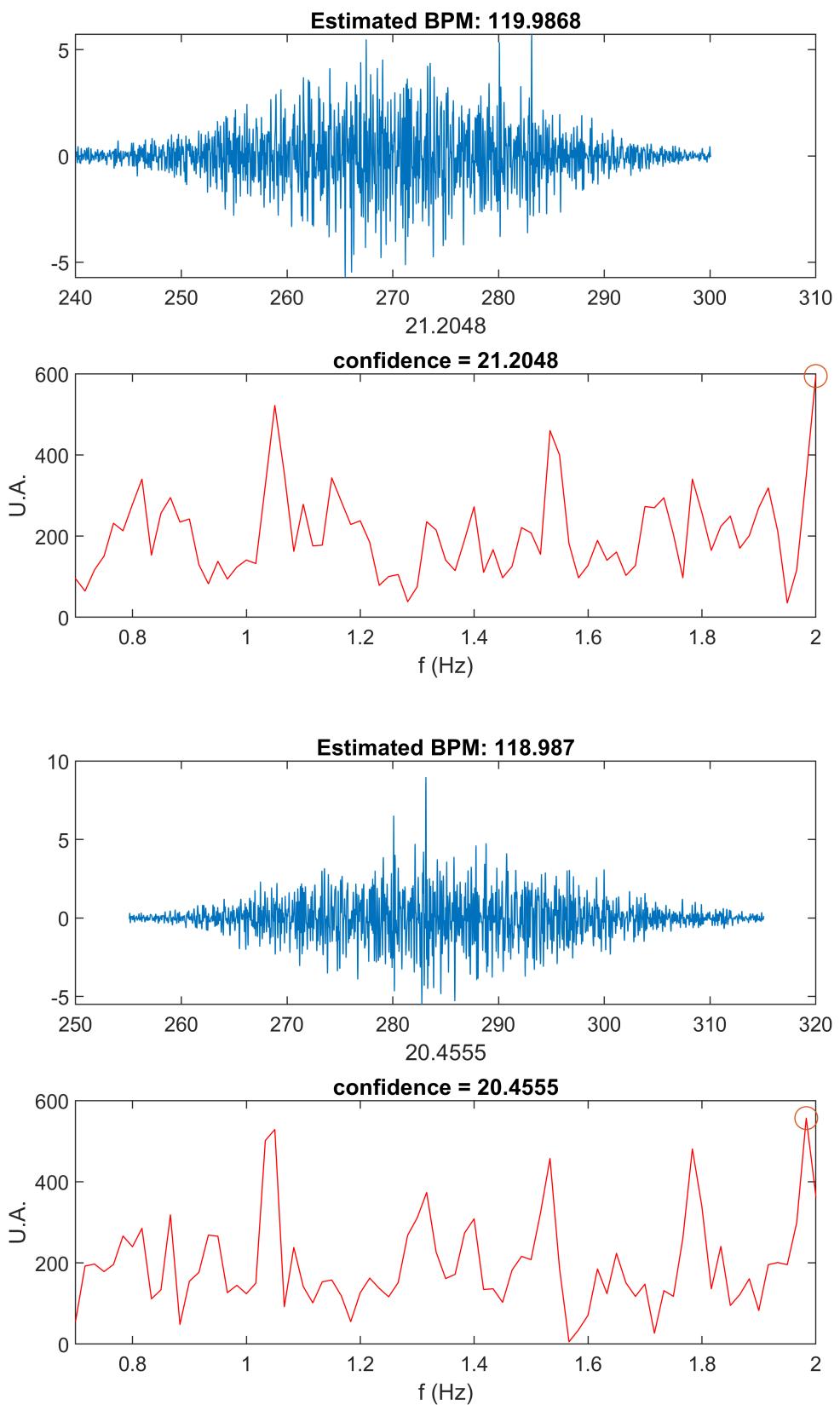


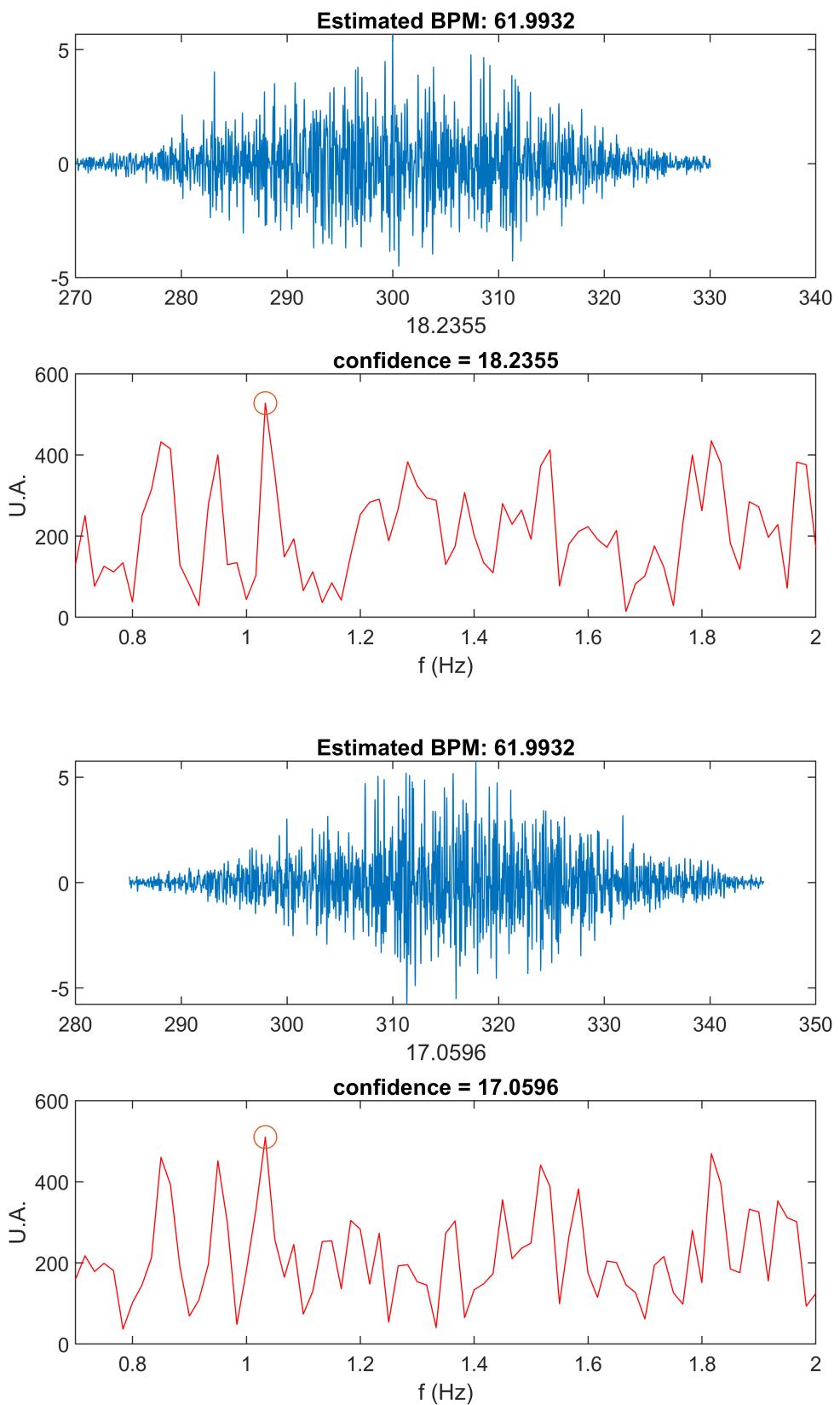
confidence = 16.49











Hilbert Transform

```
ht_data = abs(hilbert(windowed)).^2;
```

Fourier Transform

```
fft_data = fft(ht_data);
```

BPM

```
bpms = zeros(1,n);

index_7 = find(f_segment>.7,1)

index_7 = 44

index_100 = find(f_segment<2,1,"last")

index_100 = 121
```

```
figure
for count = 1:n
    figure
    fft_cut = fft_data(1:numel(f_segment),count);
    [M, I] = max(abs(fft_cut(index_7:index_100))*2);
    bpms(count) = f_segment(I+index_7-1)*60;

    subplot(211)
    plot(time_array(:,count),ht_data(:,count))
    title("Estimated BPM: "+bpms(count))
    xlabel("Tempo (s)", ylabel("U.A."))

    conf = confidence(fft_cut,f_segment,0.7,2);
    subplot(212)
    if conf > 25
        plot(f_segment, abs(fft_cut)*2)
    else
        plot(f_segment, abs(fft_cut)*2, "r")
    end
    xlim([0.7, 2])
    title("confidence = " + conf)
    xlabel("f (Hz)", ylabel("U.A."))

    hold on
    plot(f_segment(I+index_7-1), M, 'o', 'MarkerSize', 10)
    disp("-----")
end
```

