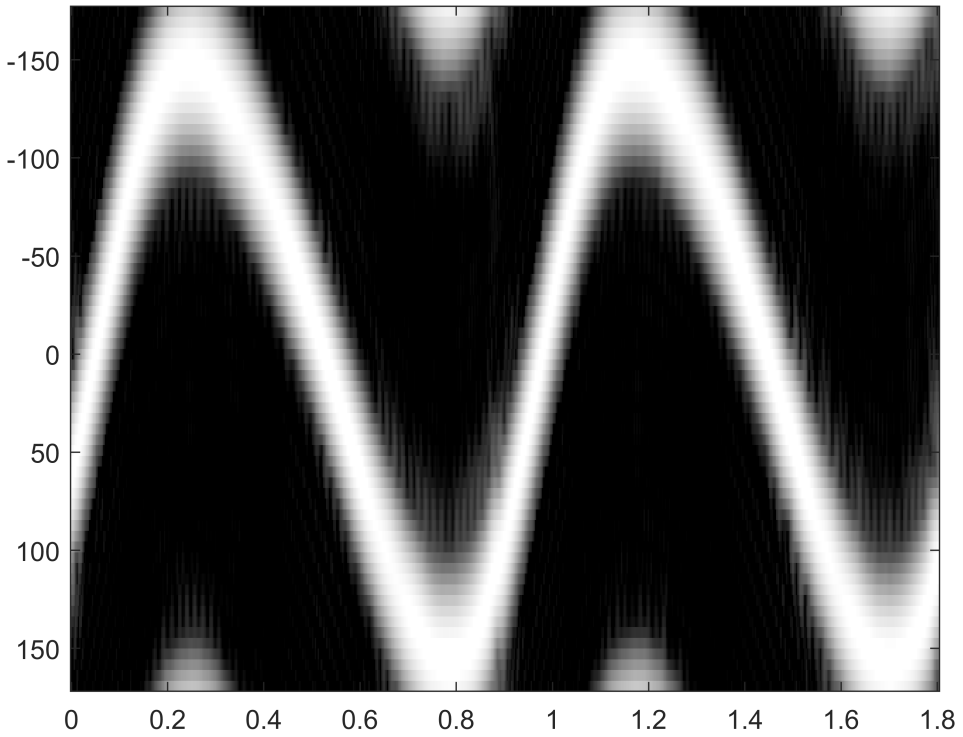
Part 3

```
slowmotion = load("slowmotion.mat");
```

```
IQ = slowmotion.iq;
s = slowmotion.s;
sm_framerate = s.Framerate_fps;
sm_depthIncrease_iq = s.iq.DepthIncrementIQ_m;
sm_startDepth_iq = s.iq.StartDepthIQ_m;
sm_num_beams_iq = s.iq.BeamsIQ;
sm_samples_iq = s.iq.SamplesIQ;
sm_frames_iq = s.iq.FramesIQ;
tissue = slowmotion.tissue;
sm_gain_iq = s.iq.feflowgain_dB;
sm_dyn_iq = s.iq.DynRange_dB;
sm_frsig = s.iq.frsIQ_Hz;
```

```
middle_beam = squeeze(IQ(:,4,:));
timeaxis=[1:s.iq.FramesIQ]/s.Framerate_fps;
depthaxis=[1:s.iq.SamplesIQ]*s.iq.DepthIncrementIQ_m*100;
%since y axis is the samples and x axis is the frames
y_axis = sm_startDepth_iq:sm_depthIncrease_iq:(sm_samples_iq-1)*sm_depthIncrease_iq + sm_startD
x_axis = 0:1/sm_framerate:(sm_frames_iq-1)*1/sm_framerate;
Nfft = 64;
crop = 16;
dyn = 40;
gain = -90;
depthindex = round(size(IQ,1)/2)-10:round(size(IQ,1)/2)+10;
P = zeros(Nfft, sm_frames_iq-crop+1);
for n=1:sm_frames_iq-crop+1
    iqsegm = middle_beam(depthindex,n+[0:crop-1])';
    iqsegm = iqsegm.*(hamming(crop)*ones(1,length(depthindex)));
    P(:,n) = mean(abs(fftshift(fft(iqsegm,Nfft))).^2,2);
end
freqAxis = (([0:Nfft-1]/Nfft)-0.5)*sm_framerate;
figure(), imagesc(x_axis,freqAxis,10*log10(P));
colormap(gray(255));
caxis([-dyn 0]-gain)
```



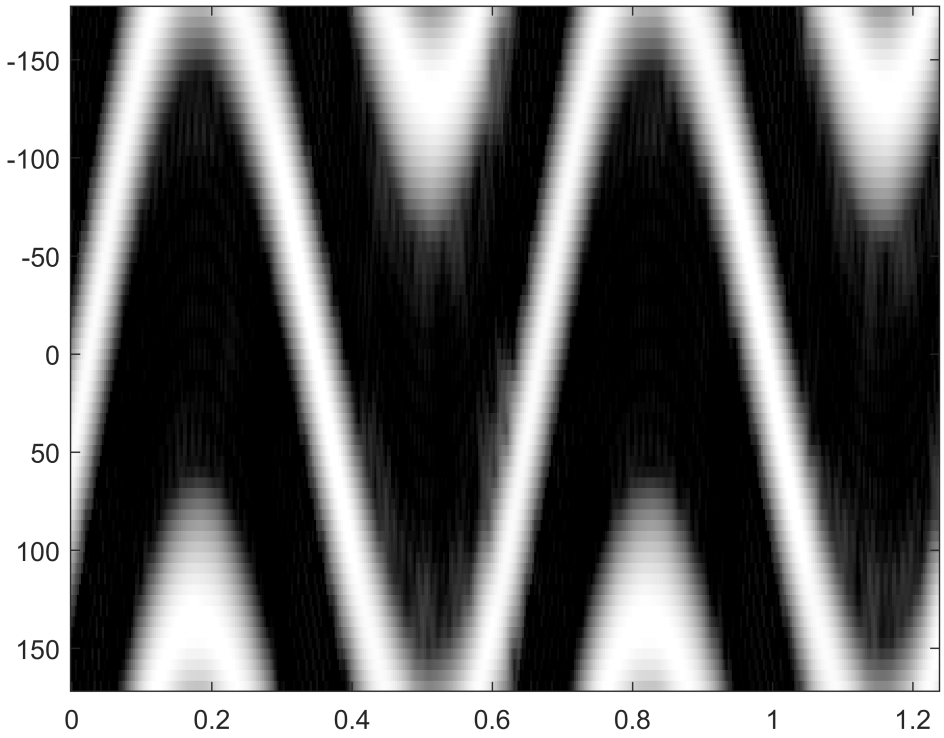
Part 4

```
fastmotion = load("fastmotion.mat");
```

```
IQ_fm = fastmotion.iq;
f = fastmotion.s;
fm_framerate = f.Framerate_fps;
fm_depthIncrease_iq = f.iq.DepthIncrementIQ_m;
fm_startDepth_iq = f.iq.StartDepthIQ_m;
fm_num_beams_iq = f.iq.BeamsIQ;
fm_samples_iq = f.iq.SamplesIQ;
fm_frames_iq = f.iq.FramesIQ;
fm_tissue = fastmotion.tissue;
fm_gain_iq = f.iq.feflowgain_dB;
fm_dyn_iq = f.iq.DynRange_dB;
fm_frsig = f.iq.frsIQ_Hz;

middle_beam_fm = squeeze(IQ_fm(:,4,:));
%since y axis is the samples and x axis is the frames
y_axis_fm = fm_startDepth_iq:fm_depthIncrease_iq:(fm_samples_iq-1)*fm_depthIncrease_iq + fm_sta
x_axis_fm = 0:1/fm_framerate:(fm_frames_iq-1)*1/fm_framerate;
timeaxis=[1:fm_frames_iq]/fm_framerate;
Nfft_fm = 64;
crop_fm = 16;
dyn_fm = 40;
```

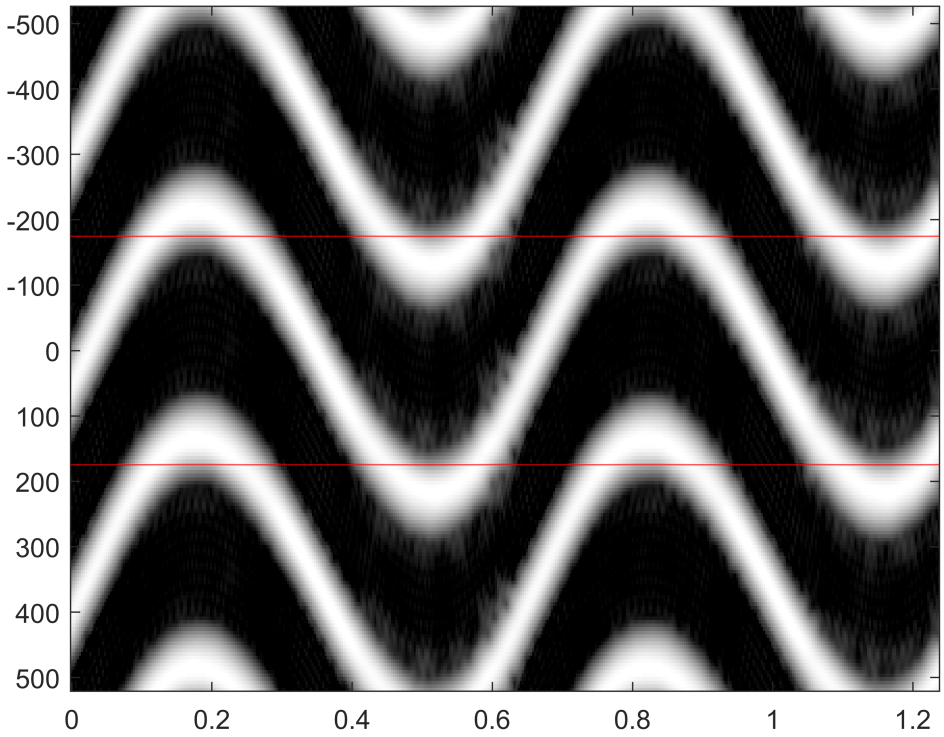
```
gain_fm = -90;
depthindex_fm = round(size(IQ_fm,1)/2)-10:round(size(IQ_fm,1)/2)+10;
P_fm = zeros(Nfft_fm, fm_frames_iq-crop_fm+1);
for n_fm=1:fm_frames_iq-crop+1
    iqsegm_fm = middle_beam_fm(depthindex_fm,n_fm+[0:crop_fm-1])';
    iqsegm_fm = iqsegm_fm.*(hamming(crop_fm)*ones(1,length(depthindex_fm)));
    P_fm(:,n_fm) = mean(abs(fftshift(fft(iqsegm_fm,Nfft_fm))).^2,2);
end
freqAxis_fm = (([0:Nfft_fm-1]/Nfft_fm)-0.5)*fm_framerate;
figure(), imagesc(x_axis_fm,freqAxis_fm,10*log10(P_fm));
colormap(gray(255));
caxis([-dyn_fm 0]-gain_fm)
```




```
P_fm_extend = [P_fm;P_fm;P_fm];
```

```
v_nyq_p = (f.Framerate_fps)/(2);
v_nyq_n = (-f.Framerate_fps)/(2);
```

```
frequencyaxis=([0:Nfft_fm-1]/Nfft_fm)-0.5;
frequencyaxis=[frequencyaxis-1, frequencyaxis, frequencyaxis+1]*fm_framerate;
figure(), imagesc(x_axis_fm,frequencyaxis,10*log10(P_fm_extend));
hold on
yline(v_nyq_p,'r');
yline(v_nyq_n,'r');
colormap(gray(255));
caxis([-dyn_fm 0]-gain_fm);
```



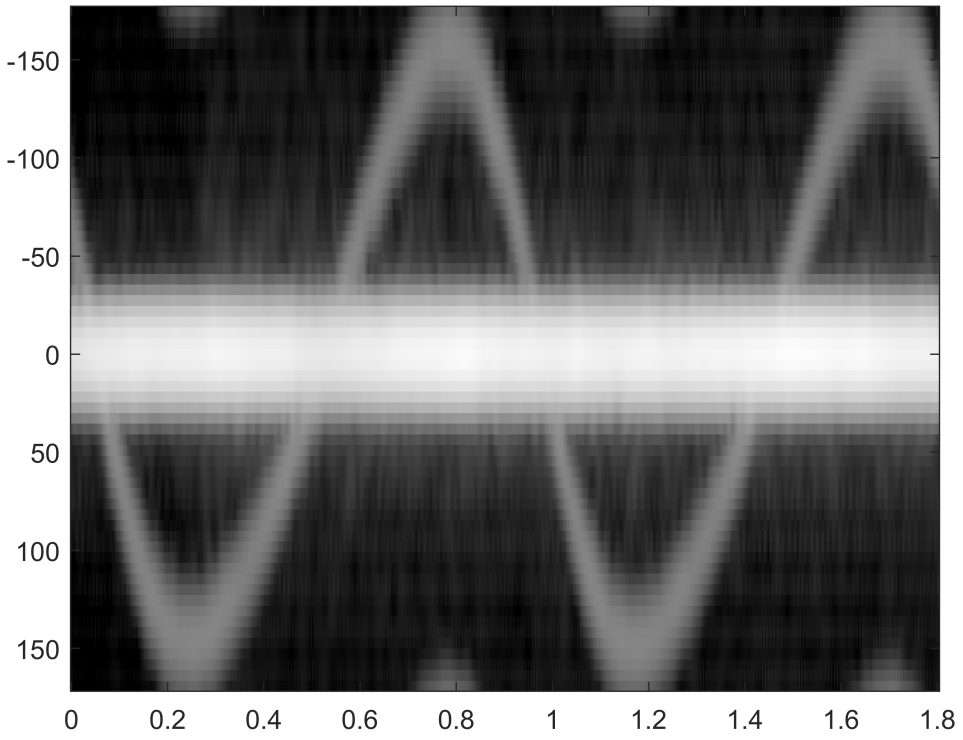
Part 5

```
slowmotion_clutter = load("slowmotion_clutter.mat");
```

```
IQ_c = slowmotion_clutter.iq;
s_c = slowmotion_clutter.s;
smc_framerate = s_c.Framerate_fps;
smc_depthIncrease_iq = s_c.iq.DepthIncrementIQ_m;
smc_startDepth_iq = s_c.iq.StartDepthIQ_m;
smc_num_beams_iq = s_c.iq.BeamsIQ;
smc_samples_iq = s_c.iq.SamplesIQ;
smc_frames_iq = s_c.iq.FramesIQ;
tissue_c = slowmotion_clutter.tissue;
smc_gain_iq = s_c.iq.feflowgain_dB;
smc_dyn_iq = s_c.iq.DynRange_dB;
smc_frsig = s_c.iq.frsIQ_Hz;
```

```
middle_beam_c = squeeze(IQ_c(:,4,:));
timeaxis=[1:s_c.iq.FramesIQ]/s_c.Framerate_fps;
depthaxis=[1:s_c.iq.SamplesIQ]*s_c.iq.DepthIncrementIQ_m*100;
%since y axis is the samples and x axis is the frames
y_axis_c = smc_startDepth_iq:smc_depthIncrease_iq:(smc_samples_iq-1)*smc_depthIncrease_iq + smc
x_axis_c = 0:1/smc_framerate:(smc_frames_iq-1)*1/smc_framerate;
```

```
Nfft_c = 64;
crop_c = 16;
dyn_c = 40;
gain_c = -90;
depthindex_c = round(size(IQ_c,1)/2)-10:round(size(IQ_c,1)/2)+10;
P_c = zeros(Nfft_c, smc_frames_iq-crop_c+1);
for n_c=1:smc_frames_iq-crop_c+1
    iqsegm_c = middle_beam_c(depthindex_c,n_c+[0:crop_c-1])';
    iqsegm_c = iqsegm_c.*(hamming(crop_c)*ones(1,length(depthindex_c)));
    P_c(:,n_c) = mean(abs(fftshift(fft(iqsegm_c,Nfft_c))).^2,2);
end
freqAxis_c = (([0:Nfft_c-1]/Nfft_c)-0.5)*smc_framerate;
figure(), imagesc(x_axis_c,freqAxis_c,10*log10(P_c));
colormap(gray(255));
caxis([-dyn_c 0]-gain_c)
```



Basic filter

```
N = 2;
%b=ones(1,N); %=boxcar(N). May also use hamming(N), hanning(N), ....
b = hamming(N);
b=b/sum(b); %Normalization of filter coefficients
iq_lp=filter(b,1,middle_beam_c,[],2)
```

```
iq_lp = 142×631 complex
10^3 ×
```

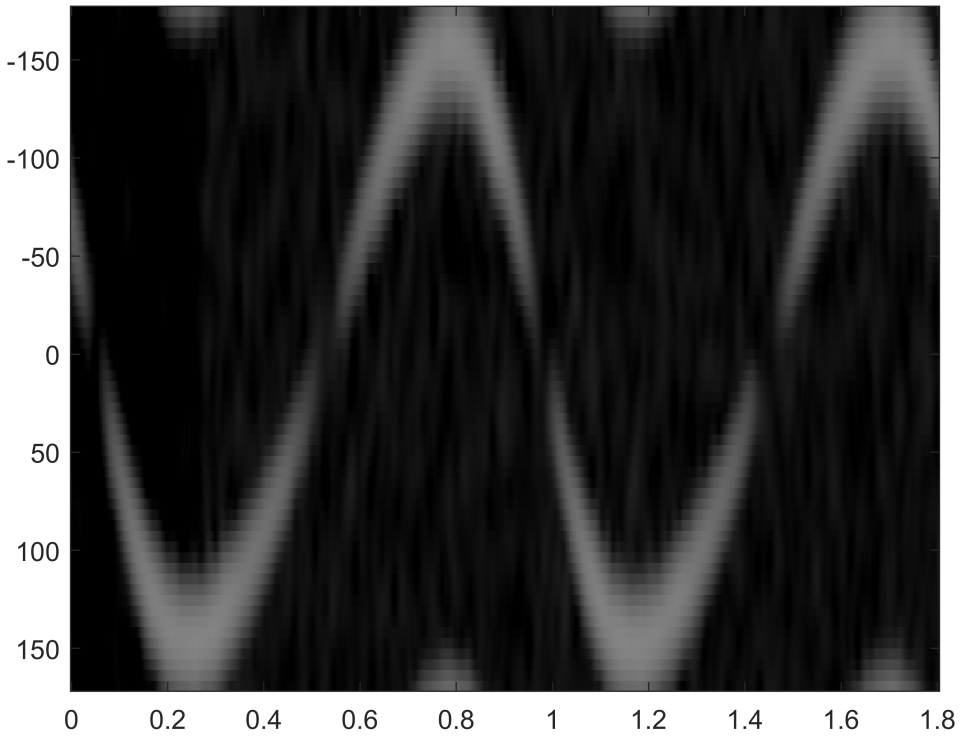
```
  -1.6820 - 0.3150i  -3.3570 - 0.5415i  -3.3775 - 0.4725i  -3.3420 - 0.4870i ···
  -0.0040 - 0.0195i   0.0265 - 0.0765i   0.0710 - 0.1185i   0.1570 - 0.0890i
  -0.7300 + 1.0575i  -1.5460 + 2.1950i  -1.6805 + 2.2165i  -1.7495 + 2.3225i
   0.4935 + 0.0820i   0.9415 + 0.1375i   0.9230 + 0.1985i   0.9690 + 0.3320i
   0.6355 + 0.7090i   1.3745 + 1.3105i   1.4730 + 1.2660i   1.4565 + 1.2080i
  -1.1980 - 2.4225i  -2.4010 - 4.7660i  -2.3190 - 4.7740i  -2.1970 - 4.7120i
  -0.1790 - 0.9655i  -0.3275 - 1.8560i  -0.4100 - 1.9160i  -0.4350 - 2.0760i
  -0.9290 - 0.1535i  -1.9595 - 0.2580i  -2.0280 - 0.3070i  -2.0170 - 0.4615i
   0.1320 + 1.0930i   0.3160 + 2.2400i   0.3025 + 2.3145i   0.2245 + 2.3870i
  -1.6555 - 1.1545i  -3.4660 - 2.3405i  -3.7270 - 2.4140i  -3.7455 - 2.4470i
     ⋮
```

```
filtered_middle_beam_c = middle_beam_c-iq_lp
```

```
filtered_middle_beam_c = 142×631 complex
10^3 ×
  -1.6820 - 0.3150i   0.0070 + 0.0885i  -0.0275 - 0.0195i   0.0630 + 0.0050i ···
  -0.0040 - 0.0195i   0.0345 - 0.0375i   0.0100 - 0.0045i   0.0760 + 0.0340i
  -0.7300 + 1.0575i  -0.0860 + 0.0800i  -0.0485 - 0.0585i  -0.0205 + 0.1645i
   0.4935 + 0.0820i  -0.0455 - 0.0265i   0.0270 + 0.0875i   0.0190 + 0.0460i
   0.6355 + 0.7090i   0.1035 - 0.1075i  -0.0050 + 0.0630i  -0.0115 - 0.1210i
  -1.1980 - 2.4225i  -0.0050 + 0.0790i   0.0870 - 0.0870i   0.0350 + 0.1490i
  -0.1790 - 0.9655i   0.0305 + 0.0750i  -0.1130 - 0.1350i   0.0880 - 0.0250i
  -0.9290 - 0.1535i  -0.1015 + 0.0490i   0.0330 - 0.0980i  -0.0220 - 0.0565i
   0.1320 + 1.0930i   0.0520 + 0.0540i  -0.0655 + 0.0205i  -0.0125 + 0.0520i
  -1.6555 - 1.1545i  -0.1550 - 0.0315i  -0.1060 - 0.0420i   0.0875 + 0.0090i
     ⋮
```

```
P_c_f = zeros(Nfft_c, smc_frames_iq-crop_c+1);
for n_c=1:smc_frames_iq-crop_c+1
    iqsegm_c = filtered_middle_beam_c(depthindex_c,n_c+[0:crop_c-1])';
    iqsegm_c = iqsegm_c.*(hamming(crop_c)*ones(1,length(depthindex_c)));
    P_c_f(:,n_c) = mean(abs(fftshift(fft(iqsegm_c,Nfft_c))).^2,2);
end

freqAxis_c = (([0:Nfft_c-1]/Nfft_c)-0.5)*smc_framerate;
figure(), imagesc(x_axis_c,freqAxis_c,10*log10(abs(P_c_f)));
colormap(gray(255));
caxis([-dyn_c 0]-gain_c)
```




```
N = 2;
b=ones(1,N); %=boxcar(N). May also use hamming(N), hanning(N), ....
%b = hamming(N);
b=b/sum(b); %Normalization of filter coefficients
iq_lp=filter(b,1,middle_beam_c,[],2)
```

```
iq_lp = 142×631 complex
10^3 ×
  -1.6820 - 0.3150i  -3.3570 - 0.5415i  -3.3775 - 0.4725i  -3.3420 - 0.4870i ···
  -0.0040 - 0.0195i   0.0265 - 0.0765i   0.0710 - 0.1185i   0.1570 - 0.0890i
  -0.7300 + 1.0575i  -1.5460 + 2.1950i  -1.6805 + 2.2165i  -1.7495 + 2.3225i
   0.4935 + 0.0820i   0.9415 + 0.1375i   0.9230 + 0.1985i   0.9690 + 0.3320i
   0.6355 + 0.7090i   1.3745 + 1.3105i   1.4730 + 1.2660i   1.4565 + 1.2080i
  -1.1980 - 2.4225i  -2.4010 - 4.7660i  -2.3190 - 4.7740i  -2.1970 - 4.7120i
  -0.1790 - 0.9655i  -0.3275 - 1.8560i  -0.4100 - 1.9160i  -0.4350 - 2.0760i
  -0.9290 - 0.1535i  -1.9595 - 0.2580i  -2.0280 - 0.3070i  -2.0170 - 0.4615i
   0.1320 + 1.0930i   0.3160 + 2.2400i   0.3025 + 2.3145i   0.2245 + 2.3870i
  -1.6555 - 1.1545i  -3.4660 - 2.3405i  -3.7270 - 2.4140i  -3.7455 - 2.4470i
      ⋮
```

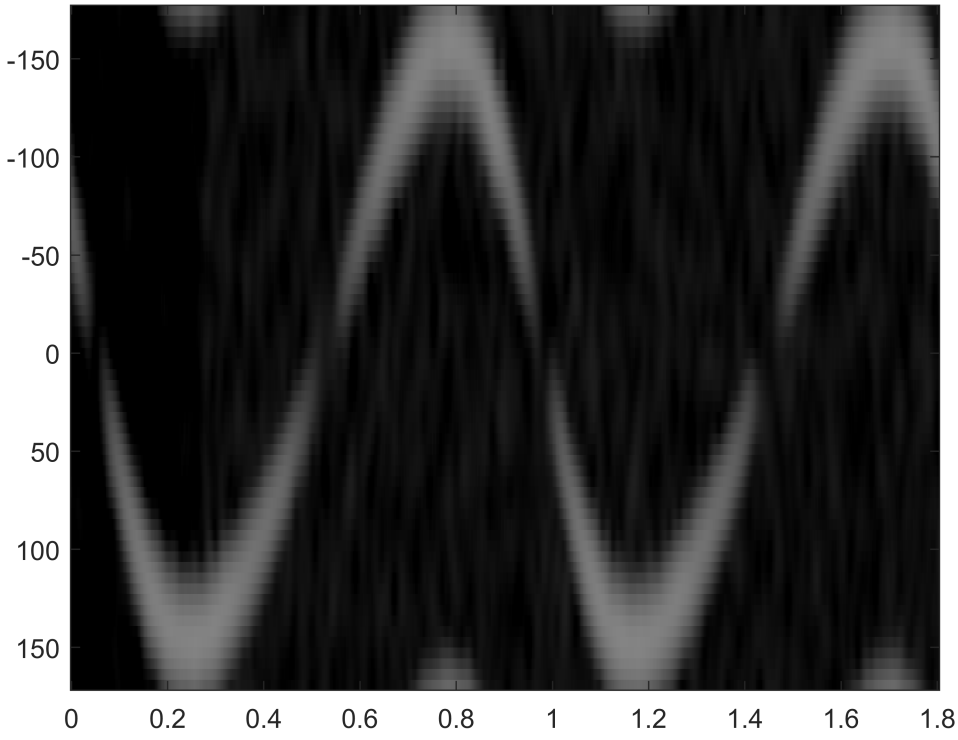
```
filtered_middle_beam_c = middle_beam_c-iq_lp
```

```
filtered_middle_beam_c = 142×631 complex
10^3 ×
  -1.6820 - 0.3150i   0.0070 + 0.0885i  -0.0275 - 0.0195i   0.0630 + 0.0050i ···
  -0.0040 - 0.0195i   0.0345 - 0.0375i   0.0100 - 0.0045i   0.0760 + 0.0340i
  -0.7300 + 1.0575i  -0.0860 + 0.0800i  -0.0485 - 0.0585i  -0.0205 + 0.1645i
   0.4935 + 0.0820i  -0.0455 - 0.0265i   0.0270 + 0.0875i   0.0190 + 0.0460i
   0.6355 + 0.7090i   0.1035 - 0.1075i  -0.0050 + 0.0630i  -0.0115 - 0.1210i
```

```
  -1.1980 - 2.4225i  -0.0050 + 0.0790i   0.0870 - 0.0870i   0.0350 + 0.1490i
  -0.1790 - 0.9655i   0.0305 + 0.0750i  -0.1130 - 0.1350i   0.0880 - 0.0250i
  -0.9290 - 0.1535i  -0.1015 + 0.0490i   0.0330 - 0.0980i  -0.0220 - 0.0565i
   0.1320 + 1.0930i   0.0520 + 0.0540i  -0.0655 + 0.0205i  -0.0125 + 0.0520i
  -1.6555 - 1.1545i  -0.1550 - 0.0315i  -0.1060 - 0.0420i   0.0875 + 0.0090i
      ⋮
      ⋮
```

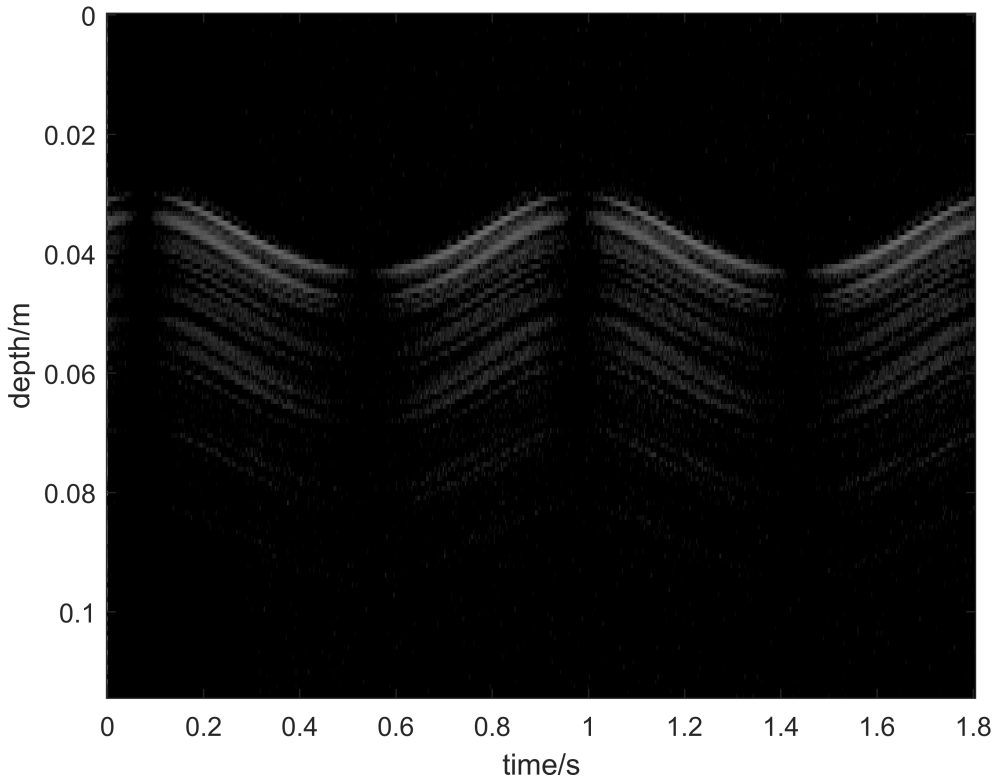
```
P_c_f = zeros(Nfft_c, smc_frames_iq-crop_c+1);
for n_c=1:smc_frames_iq-crop_c+1
    iqsegm_c = filtered_middle_beam_c(depthindex_c,n_c+[0:crop_c-1])';
    iqsegm_c = iqsegm_c.*(hamming(crop_c)*ones(1,length(depthindex_c)));
    P_c_f(:,n_c) = mean(abs(fftshift(fft(iqsegm_c,Nfft_c))).^2,2);
end

freqAxis_c = (([0:Nfft_c-1]/Nfft_c)-0.5)*smc_framerate;
figure(), imagesc(x_axis_c,freqAxis_c,10*log10(abs(P_c_f)));
colormap(gray(255));
caxis([-dyn_c 0]-gain_c)
```




```
figure();
imagesc(x_axis, y_axis, 20*log10( abs( filtered_middle_beam_c) ) )
dyn_c = 40;
gain_c = -90;
caxis([-dyn_c 0]-gain_c);
ylabel('depth/m');
xlabel('time/s');
axis on;
```

```
colormap(gray(255));
```



Part 6

```
dopplerdata = load("Dopplerdata.mat");
```

```
dd_iq = dopplerdata.iq;
N = 2;
%b=ones(1,N); %=boxcar(N). May also use hamming(N), hanning(N), ....
b = hamming(N);
b=b/sum(b); %Normalization of filter coefficients
iq_lp = filter(b,1,dd_iq,[],2);
iq_hp = dd_iq-iq_lp;
%since y axis is the samples and x axis is the frames
frames_dd = length(dd_iq(1,:));

Nfft_dd = 256;
crop_dd = 16;
segment = 32;
dyn_dd = 30;
gain_dd = -60;
depthindex_dd = round(size(dd_iq,1)/2)-segment:round(size(dd_iq,1)/2)+segment;
P_dd = zeros(Nfft_dd, frames_dd-crop_dd+1);
for n_dd=1:frames_dd-crop+1
    iqsegm_dd = iq_hp(depthindex_dd,n_dd+[0:crop_dd-1])';
    iqsegm_dd = iqsegm_dd.*(hamming(crop_dd)*ones(1,length(depthindex_dd)));
```

```
    P_dd(:,n_dd) = mean(abs(fftshift(fft(iqsegm_dd,Nfft_dd))).^2,2);
end
freqAxis_dd = (([0:Nfft_dd-1]/Nfft_dd)-0.5)*dopplerdata.prf;
frequencyaxis=([0:Nfft_dd-1]/Nfft_dd)-0.5;
frequencyaxis=[frequencyaxis-1, frequencyaxis, frequencyaxis+1]*dopplerdata.prf;

timeaxis_dd = (0:frames_dd-crop_dd)/dopplerdata.prf;
%nyquist limit:
max(freqAxis_dd);
lines = dopplerdata.prf/2;
P_dd_extend = [P_dd;P_dd;P_dd];
figure(), imagesc(timeaxis_dd,frequencyaxis,10*log10(P_dd_extend));
hold on;
xlabel('Time [s]'); ylabel('Doppler shift [Hz]');
set(gca,'YDir','normal')
yline(lines,'r');
yline(-lines,'r');
colormap(gray(255));
caxis([-dyn_dd 0]-gain_dd)
```