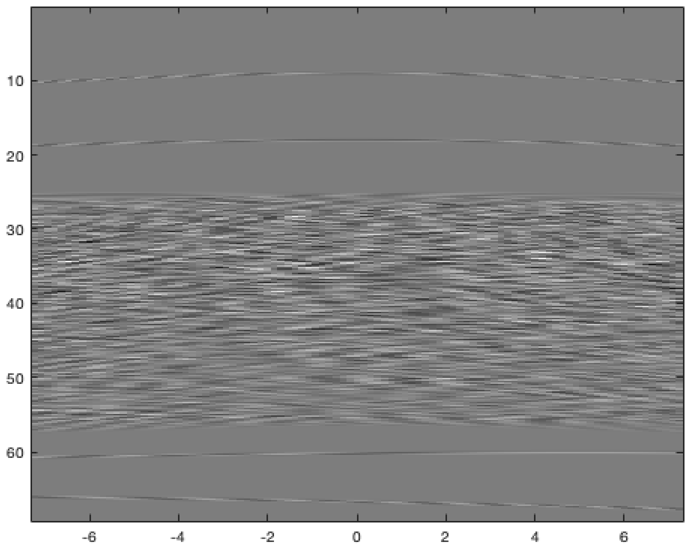
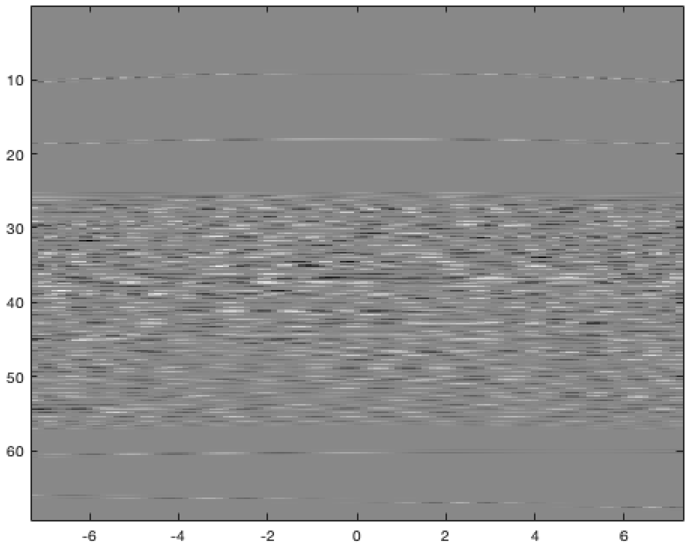
```
%       template_beamform.m
%       Ultrasound beamforming project template
%
%       This script requires the variables
%       Data [ntime, nelem]     RF signals from each array element
%       f0                      Transducer center frequency (MHz)
%       fs                      sampling frequency (MHz)
%       c                       speed of sound (mm/usec)
%       dx                      transducer element spacing (mm)
%
% Get needed variables
%
clear all clc
load data23;
f0 = 5;         % MHz
fs = 20;        % MHz
c = 1.54;       % mm/us
%
% Output Array Parameters
%
% Determine the array spacing dx in mm
dx = c/f0/2;
deltat=1/fs;
[ntime, nelem] = size(Data);            % # time samples, # array elements
disp(sprintf('f0=%g MHz, deltat=%g usec, dx=%g mm', f0, deltat, dx))
disp(sprintf('# of Time Samples=%g,  # of Array Elements=%g',ntime,nelem))

%

% --> QUESTION a. <--
% Make a "wavefield" plot of the raw Data
% Comment this out while you debug other parts of your program
%
x_n=linspace(-(nelem-1)*dx/2,(nelem-1)*dx/2,nelem);
t = linspace(1,ntime,ntime )*deltat;
r = c*t/2;
figure(1)
showimage3(Data, 1,-1,x_n,r)  % plotting the transpose here...time along x, tranducer x along y.
disp 'hit key', pause

%
% --> QUESTION b. <--
% Compute the number of total beams and beam spacing
% I used variables called
%       nbeam = number of beams
%       sin_theta = vector of beam positions
%
nbeam = round(2*sqrt(2)*(nelem-1)*dx*f0/c);
disp(sprintf('nbeam = %g', nbeam));
sin_theta = sin (linspace(-pi/4,pi/4,nbeam));

% --> QUESTION f. <--
databb = zeros(ntime,nelem);    % Phase-Shifted Baseband data

% code here to demodulate and write into databb
for ie = 1:nelem
    for it=1:ntime
        databb(it,ie) = fft(Data(it,ie)*exp(2i*pi*f0*t(it)));
        if databb(it,ie) < 5
            databb(it,ie) = ifft(databb(it,ie));
        end

    end
end
% Plot and Show data

figure(2)
showimage3(real(databb), 1,-1,x_n,r)
disp(sprintf('real part'))
disp 'hit key', pause

figure(3)
showimage3(imag(databb), 1,-1,x_n,r)
disp(sprintf('imag part'))
disp 'hit key', pause
%plot...
figure(4)
showimage3(abs(databb), 1,-1,x_n,r)
```

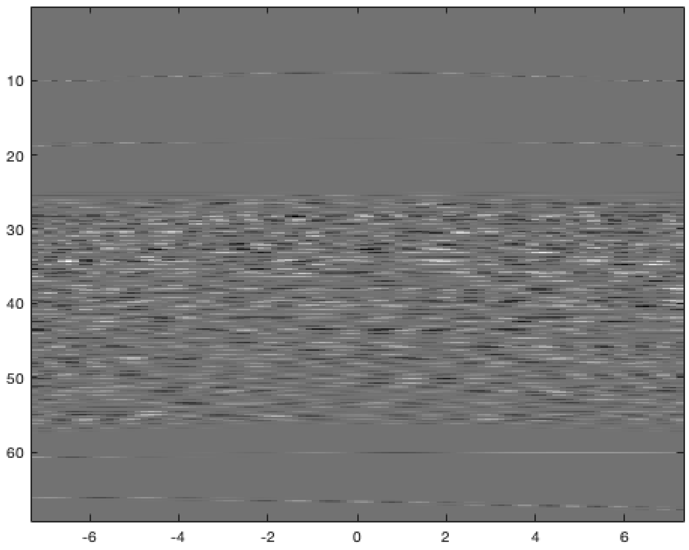
```
disp(sprintf('databb'))
disp 'hit key', pause

%
% Create room for answers and precompute information
%       This section merely makes matlab allocate memory before doing
%       any other processing. It is not a necessary section, but will
%       make Matlab run a little faster since it doesn't have to reallocate
%       space every time you add another beam
%
rsdata = zeros(ntime,nbeam);% r-sin(theta) data buffer
rsdata_i = zeros(ntime,nbeam);
rsdata_j = zeros(ntime,nbeam);
rsdata_k = zeros(round(ntime/3),nbeam);
bbshift = zeros(ntime,nelem);   % Phase-Shifted Baseband data
theta_1=linspace(-pi/4,pi/4,nbeam);
x_n=linspace(-(nelem-1)*dx/2,(nelem-1)*dx/2,nelem);
tau=zeros(ntime,nelem,nbeam);
t=linspace(0,ntime/fs,ntime);
mt=zeros(ntime,nelem,nbeam);
phase=zeros(ntime,nelem,nbeam);
%
% Repeat for every beam
%
for ib=1:nbeam
        %disp(sprintf('Beam %d of %d', ib, nbeam))

% --> QUESTION c, d, g, h <--
% For the current beam, compute time delays (or delayed samples)
% and phase rotations (if needed) for each channel (i.e. transducer
% element) as a function of range, as well as gain corrections.
    for ie=1:nelem
        for it=1:ntime
%--> QUESTION c <--
            tau(it,ie,ib) = -x_n(ie)*sin(theta_1(ib))/c + (x_n(ie)*cos(theta_1(ib)))^2/2/c/r(it);
            mt(it,ie,ib)=floor(tau(it,ie,ib)*fs);
%--> QUESTION g <--
            phase(it,ie,ib)= -2*pi*f0*tau(it,ie,ib);
            if (td <= 1800) && (td > 0)
%--> QUESTION d <--
                bbshift(it,ie) = Data(it + mt(it,ie,ib),ie);
%--> QUESTION e <--
                rsdata(it,ib) = rsdata(it,ib) + Data(it + mt(it,ie,ib),ie)/nelem;
%--> QUESTION i <--
                rsdata_i(it,ib) = rsdata_i(it,ib) + databb(it + mt(it,ie,ib),ie)*exp(1i*phase(it,ie,ib))/nelem;
%--> QUESTION j <--
                if mod(ie,2) == 1
                    rsdata_j(it,ib) = rsdata_j(it,ib) + databb(it + mt(it,ie,ib),ie)*exp(1i*phase(it,ie,ib))/round(nelem/2);
                end
%--> QUESTION k <--
                if mod(it,3) == 0
                    rsdata_k(round(it/3),ib) = rsdata_k(round(it/3),ib) + databb(it + mt(it,ie,ib),ie)*exp(1i*phase(it,ie,ib))/nelem;
                end
            end
        end
    end
end

figure(5)
subplot(3,1,1)
plot(t/ntime,Data(:,12)*dx-(nelem-1)*dx/2)
xlabel("s")
ylabel("mm")
hold on
plot(t/ntime,bbshift(:,12)*dx-(nelem-1)*dx/2)
legend("before shifted","after shifted")
title("element=12")
xlabel("s")
ylabel("mm")

subplot(3,1,2)
plot(t/ntime,Data(:,30)*dx-(nelem-1)*dx/2)
title("element=30")
xlabel("s")
ylabel("mm")
hold on
plot(t/ntime,bbshift(:,30)*dx-(nelem-1)*dx/2)
legend("before shifted","after shifted")
title("element=30")
xlabel("s")
```

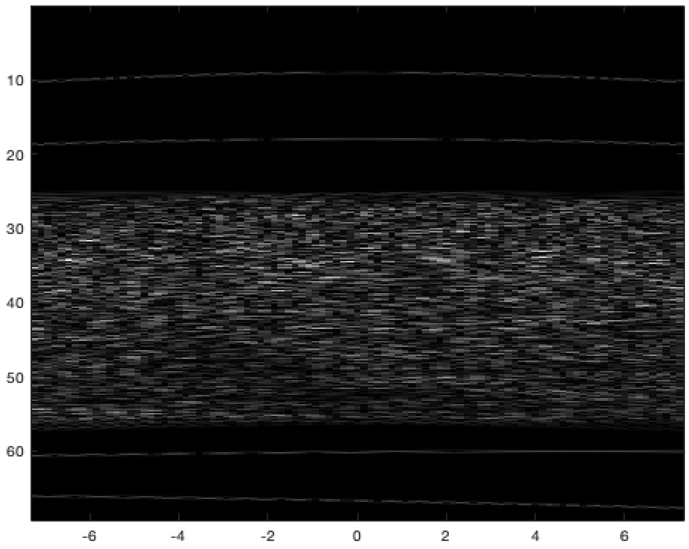
```
ylabel("mm")

subplot(3,1,3)
plot(t/ntime,Data(:,47)*dx-(nelem-1)*dx/2)
title("element=47")
xlabel("s")
ylabel("mm")
hold on
plot(t/ntime,bbshift(:,47)*dx-(nelem-1)*dx/2)
legend("before shifted","after shifted")
title("element=47")
xlabel("s")
ylabel("mm")


figure(6)
showimage3(abs(rsdata), 1, 40,theta_1,r)
disp(sprintf('rsdata'))
disp 'hit key', pause

figure(7)
showimage3(abs(rsdata_i), 1, 40,theta_1,r)
disp(sprintf('rsdata_i'))
disp 'hit key', pause

figure(8)
showimage3(abs(rsdata_j), 1, 40,theta_1,r)
disp(sprintf('rsdata_j'))
disp 'hit key', pause

figure(9)
showimage3(abs(rsdata_k), 1, 40,theta_1,3*r)
disp(sprintf('rsdata_k'))
disp 'hit key', pause
```

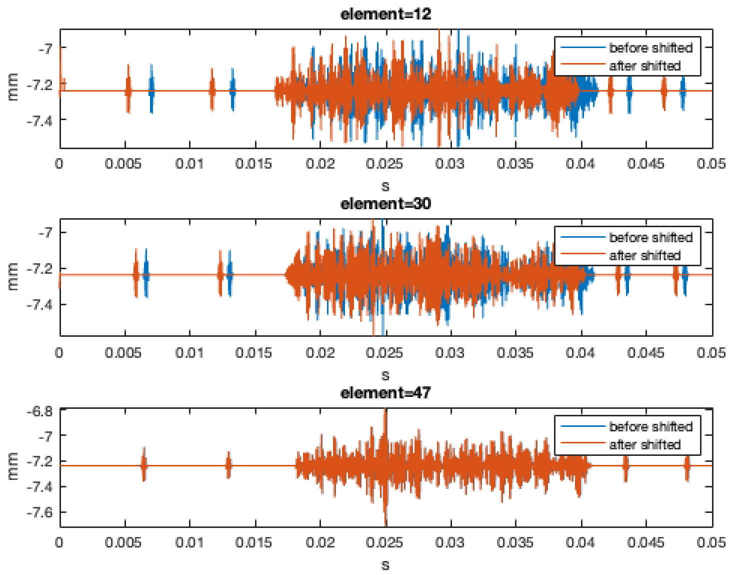
```
f0=5 MHz, deltat=0.05 usec, dx=0.154 mm
# of Time Samples=1800,  # of Array Elements=95
hit key
nbeam = 133
real part
hit key
imag part
hit key
databb
hit key
rsdata
hit key
rsdata_i
hit key
rsdata_j
hit key
rsdata_k
```

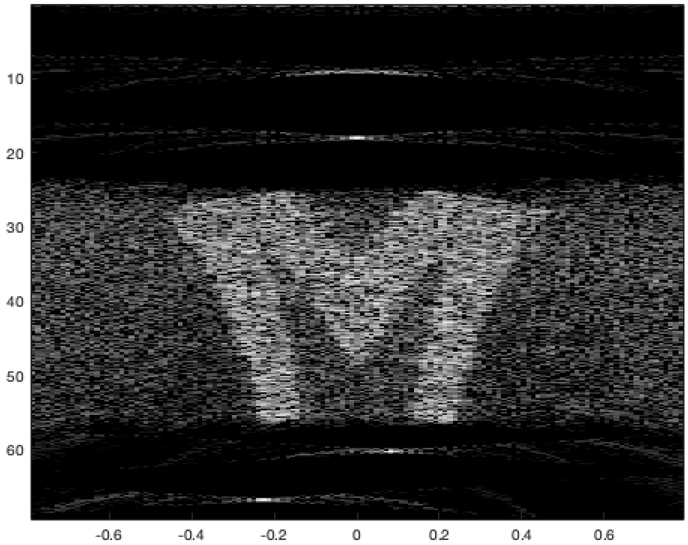

10
20
30
40
50
60
-6
-4
-2
0
2
4
6

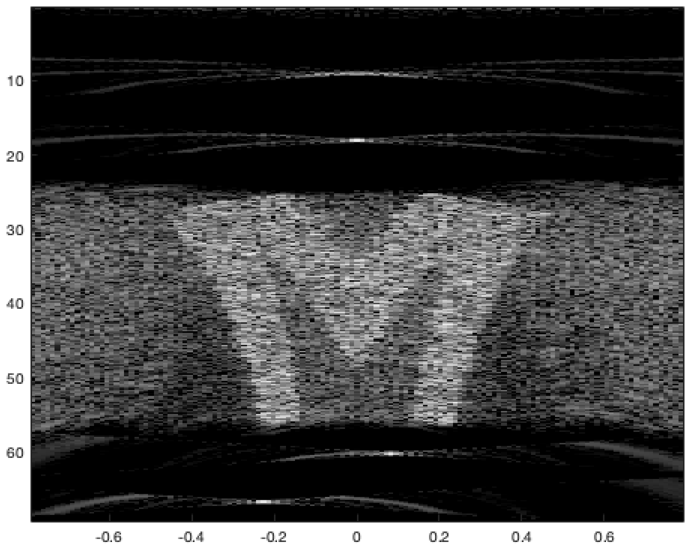

10
20
30
40
50
60
-6
-4
-2
0
2
4
6

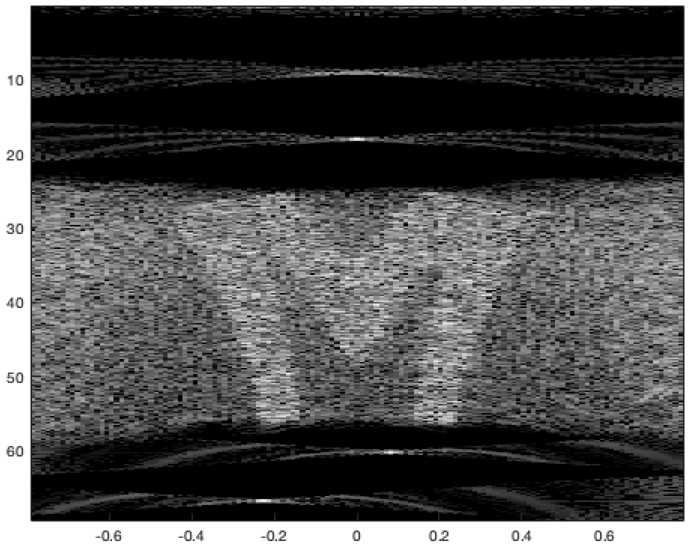

10
20
30
40
50
60
-6
-4
-2
0
2
4
6

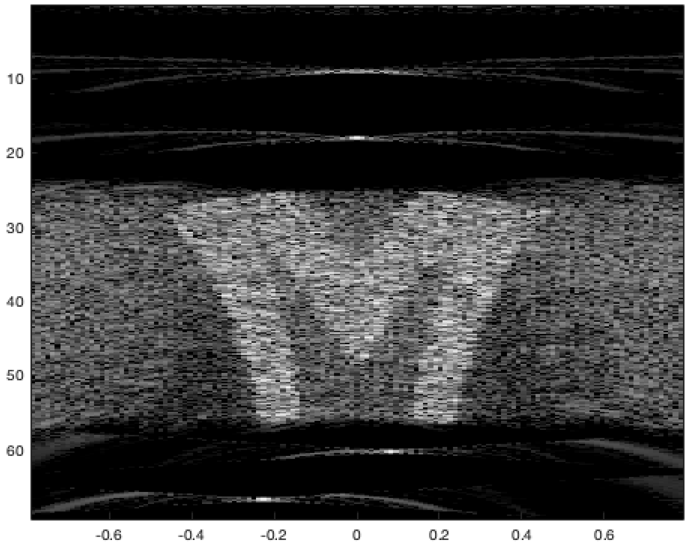

10
20
30
40
50
60
-6
-4
-2
0
2
4
6


element=12
before shifted
after shifted
mm
-7
-7.2
-7.4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
s
element=30
before shifted
after shifted
mm
-7
-7.2
-7.4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
s
element=47
before shifted
after shifted
mm
-6.8
-7
-7.2
-7.4
-7.6
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
s


10
20
30
40
50
60
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


10
20
30
40
50
60
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


10
20
30
40
50
60
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



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