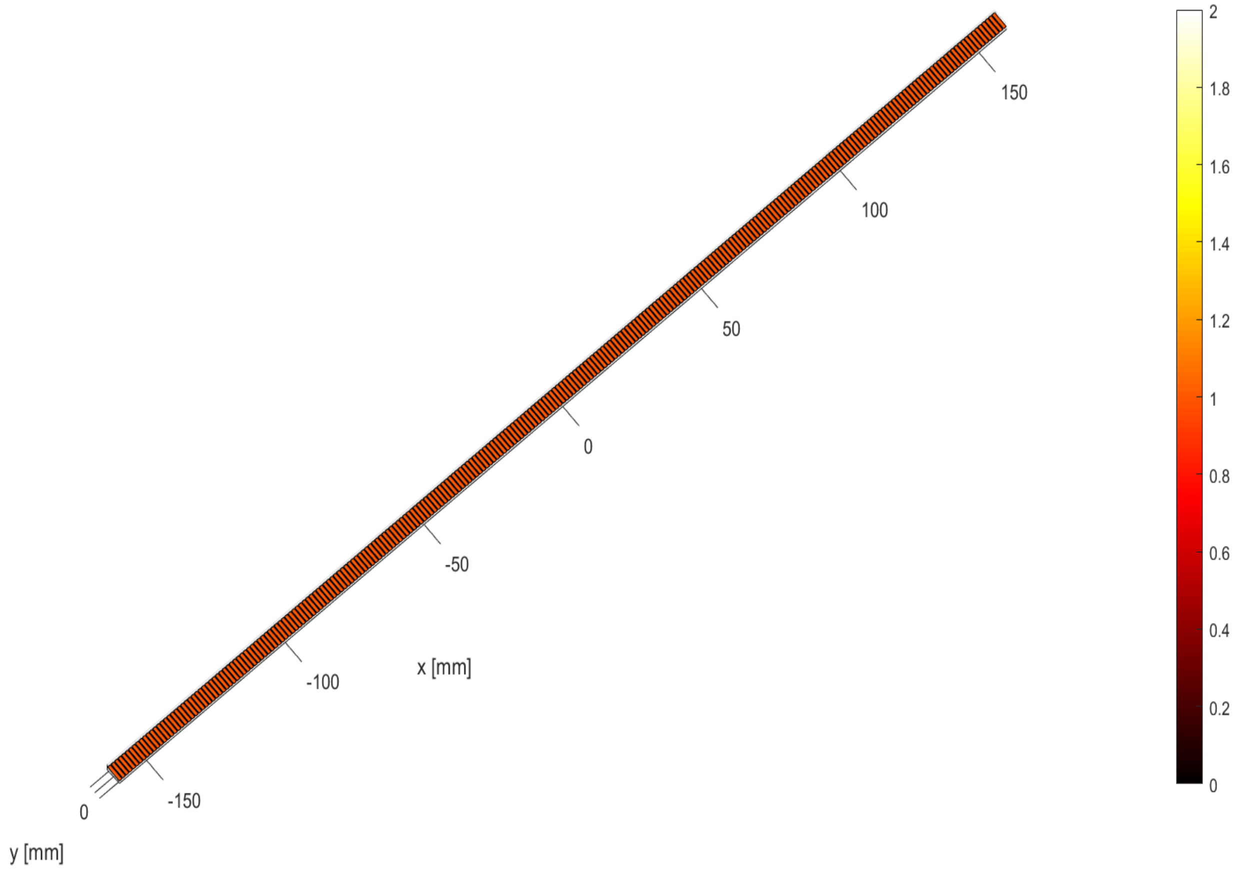
Results of the Field II Simulation

1.

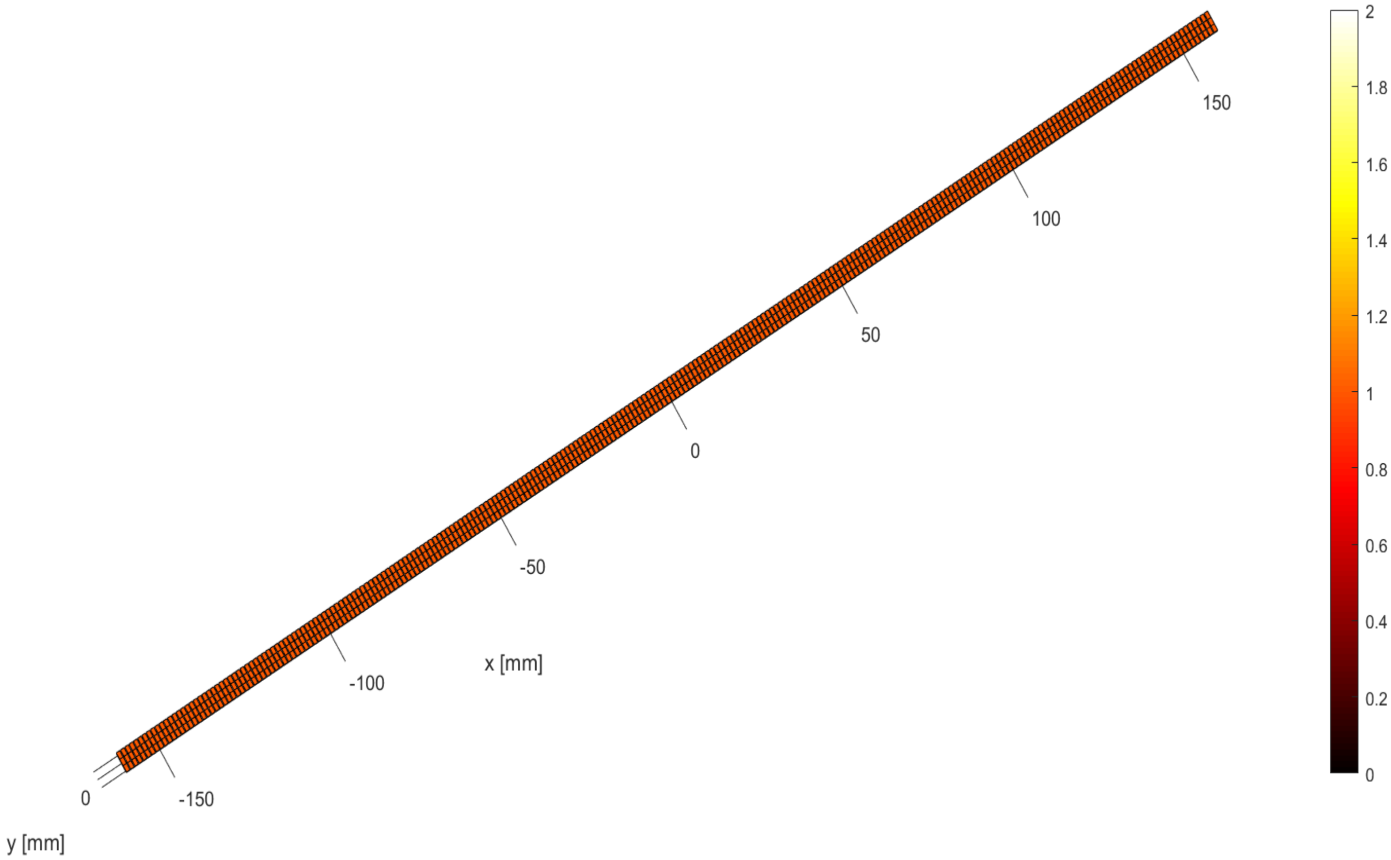
I used a linear array transducer. The center frequency that was used is 2.5 MHz. Sampling Frequency of 100MHz. The Array Transducer consists of 256 elements. The speed of the sound that I used is 1540 meters per second. The phantom with a cyst is analogous to a cyst in a tissue. The speed of acoustic waves in tissue is very near to the speed of acoustic waves in water. So, I chose 1540 meters per second.

2.

The geometry of the aperture of the linear array transducer.

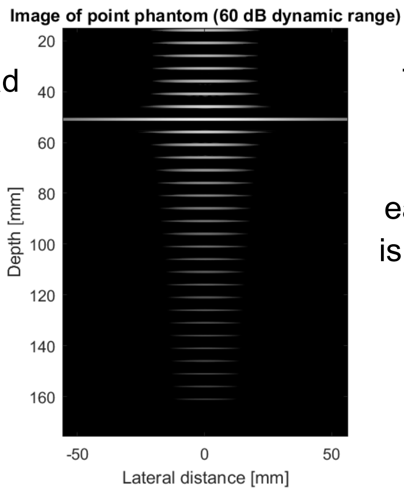


I also tried using sub apertures. By the sub apertures I mean dividing a physical element into multiple elements. This geometry gives a clearer picture and better accuracy than that given by a single array aperture. Also, sub apertures provides An advantage of multiplexing the signals received. I feel that this gives more lateral resolution of scatterers.

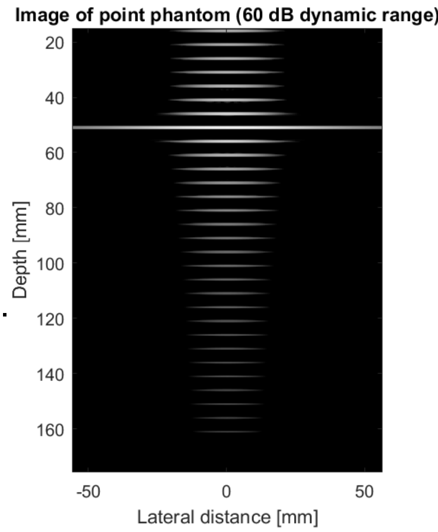


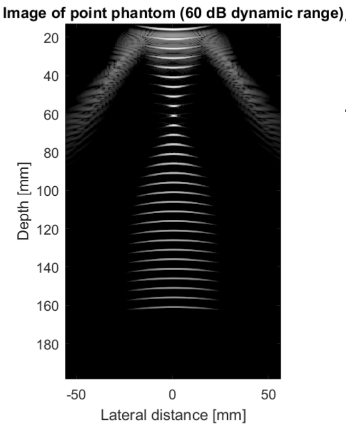
The geometry of the linear array transducers with sub apertures.

nactive=75
The point spread
Function of the
Point phantom
Is imaged with
74 active
Elements
Out of 256
Transducer
Elements.
30 points were
Used in the point
phantom.Here, a
Single aperture
Of elements is used



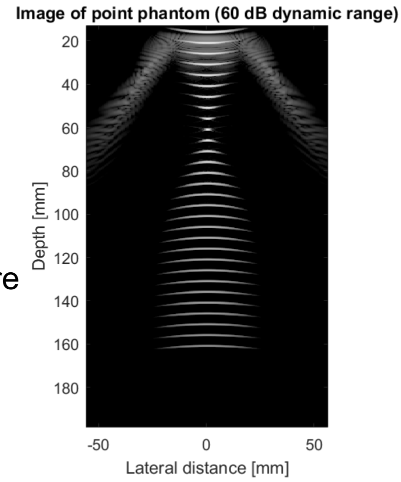
The aperture scan
corresponding to
sub apertures.
each physical element
is divided into 3 elements.





The aperture scan corresponding to single aperture when there is wave focusing.

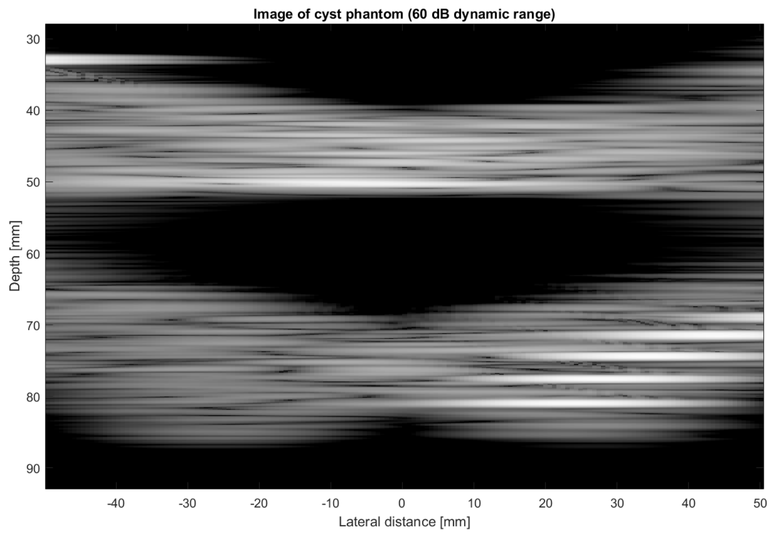
The aperture scan Corresponding to Sub-apertures when there Is wave focusing.



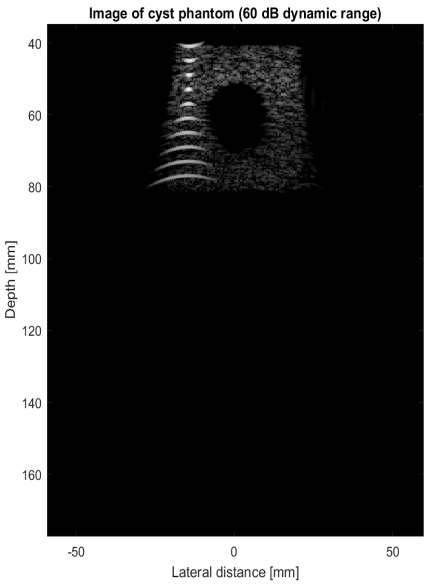
3.

I tried simulating with both plane waves and wave focusing. Focusing the beam gave a clearer picture than the image obtained due to plane waves.

A. Image Formed Without Focusing Plane waves



B. Image obtained When the beam is focused.

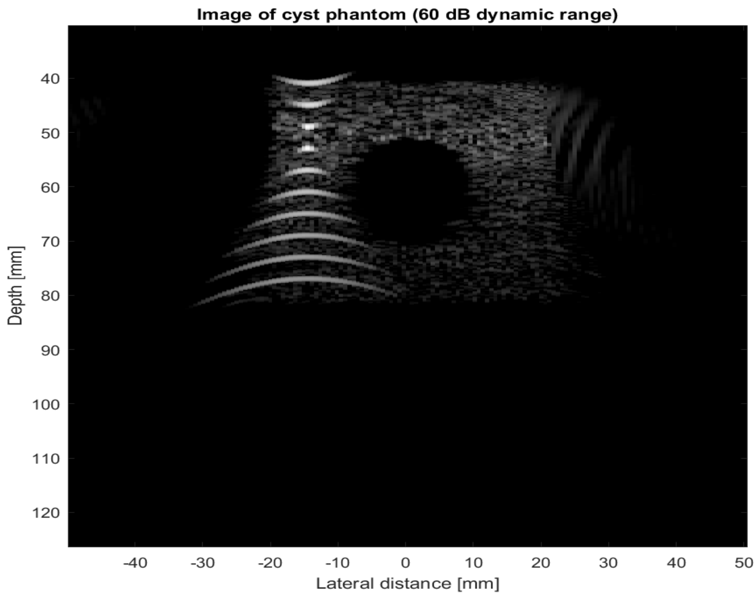


So, I wanted to use a focused beam for scanning the phantom as it is clear from the above two figures.
Here the number of active elements is 94. Width of each physical element is equal to the wavelength of the acoustic wave. The height of each physical element is 5mm. The distance or the gap between two successive physical elements in the transducer is one fourth of the wavelength. Sinusoidal wave of two wavelengths(two cycles) is used as a pulse and to excite the transducer elements. The beam is then scattered and then received by elements of the transducer. The number of A-lines is known. So, from the RF signals the image is constructed.

4.

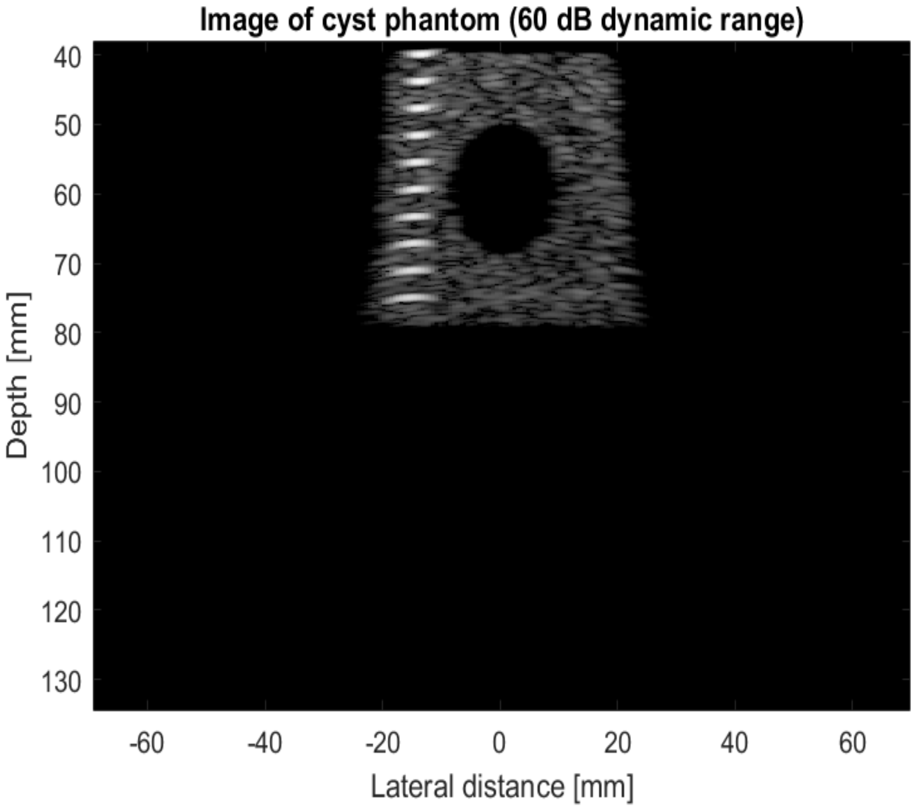
I generated a phantom with a cyst. Then scatters are introduced into the phantom. There are no scatterers inside the cyst. The amplitudes of the point scatterers were increased to 100.

A. The number of active Elements used in this case was 94. The focus is at 50 mm along The depth axis. The number of Subelements (mathematical elements) in a single physical Element is 5.

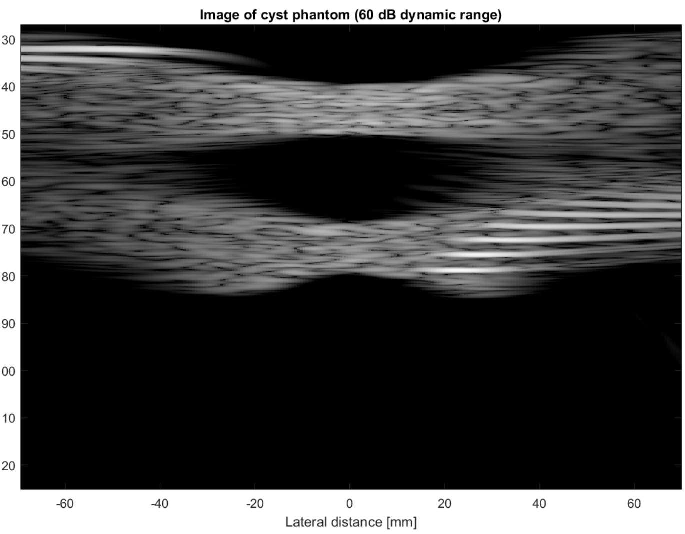


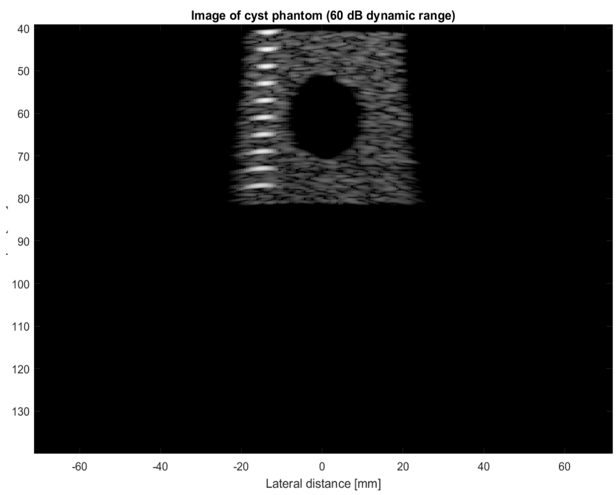
B. Here, I changed the speed of sound to 1500,
there is not much difference between the image obtained when speed is 1540m/s and the image obtained when the speed is 1500 m/s.

The resolution is varying.



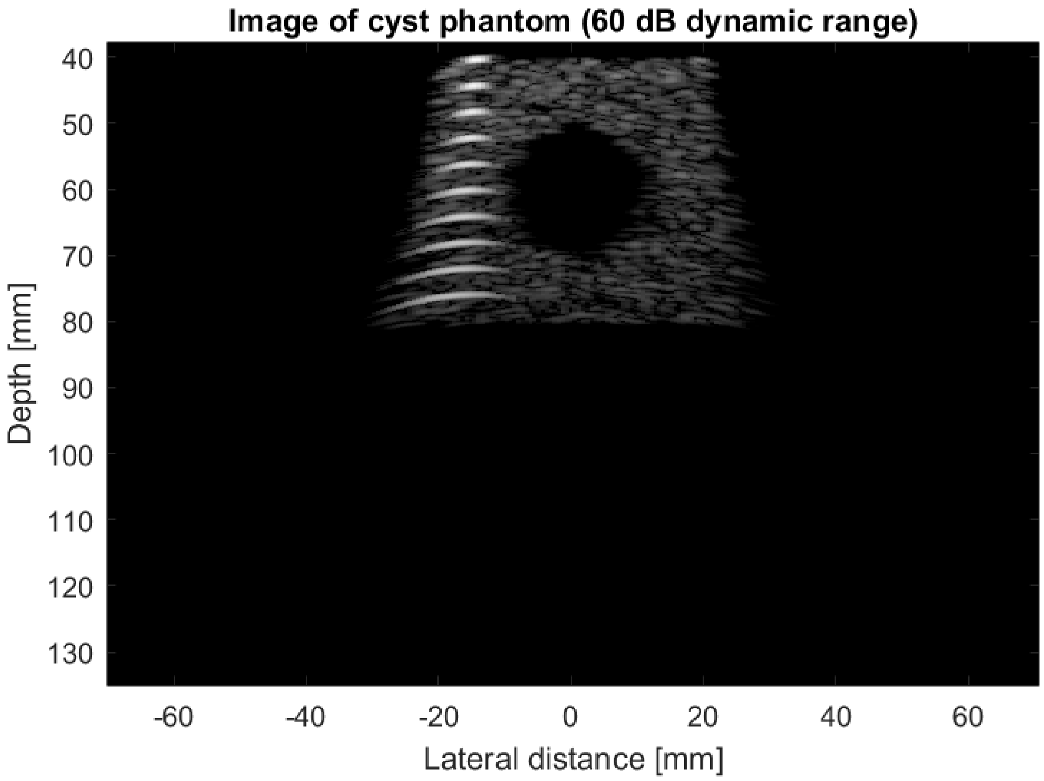
C. The figure below is that of a plane wave unfocussed.The speed Of sound is 1500 m/s in this case.





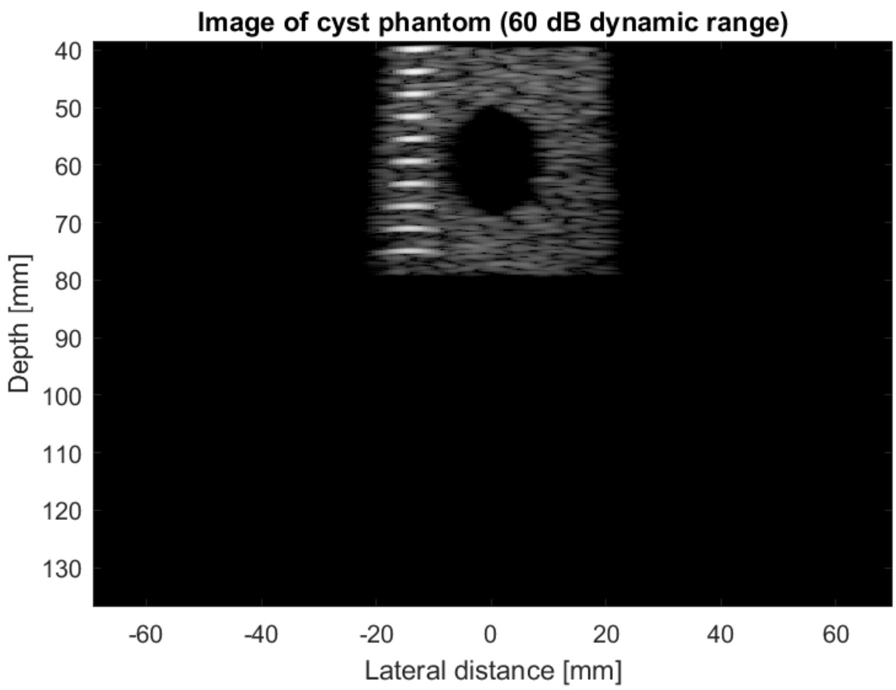
D. In The figure on the bottom right of the previous page , the focus Is at 60cm along the depth and the center of the cyst is Also at the same distance.Th cyst is clear compared to that of figure A where the focus occurs before the center of the cyst.

E. The image below is when the speed of sound is 1520. The focus is at 40 mm which occurs before the center of the cyst.

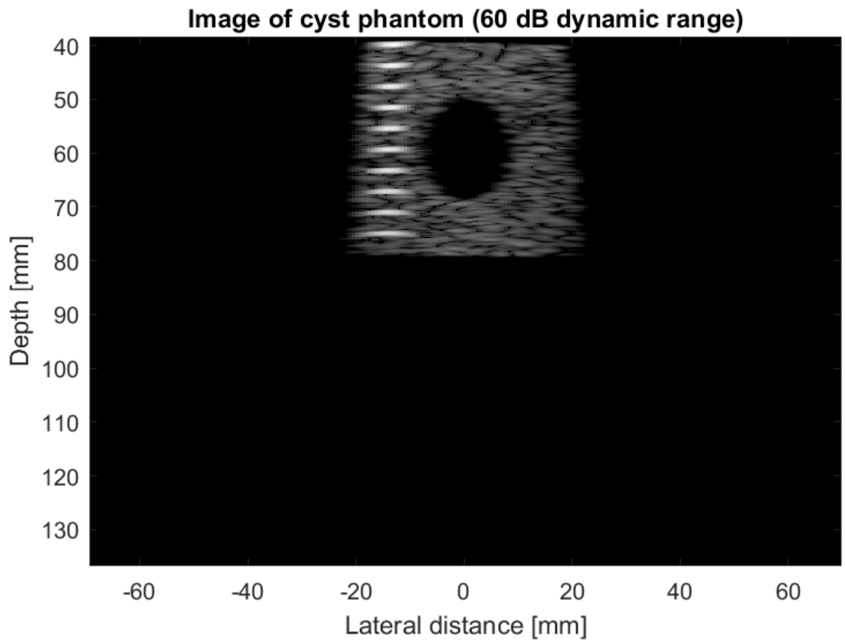


F.

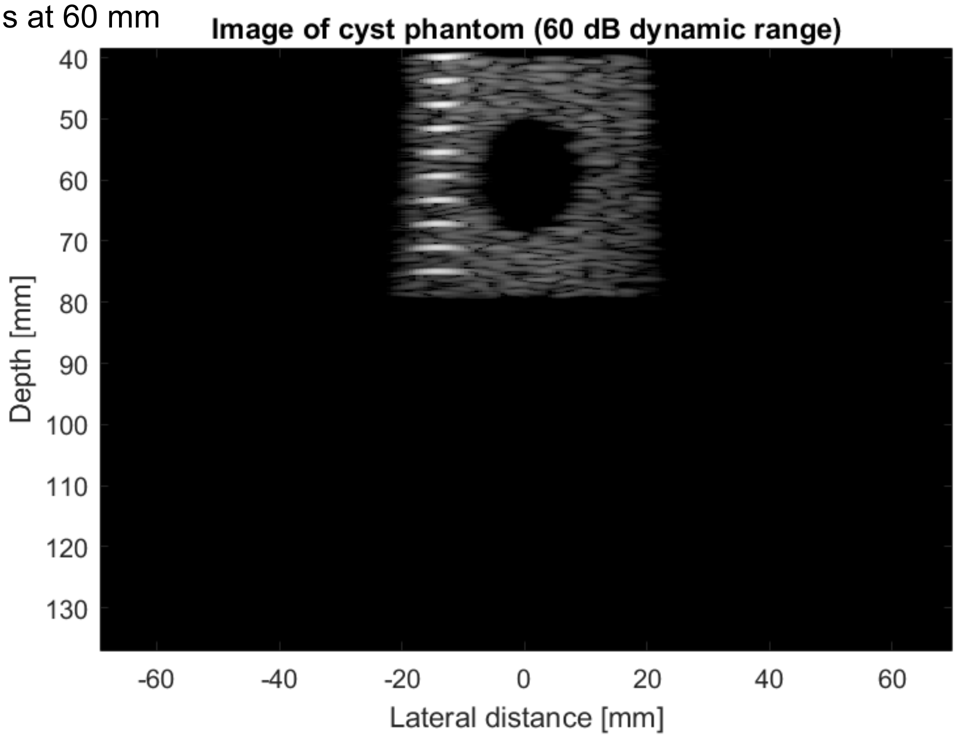
The transmit focus is
At 60 mm along the depth
Axis and receive focus
Is at 80 mm along the depth
axis.



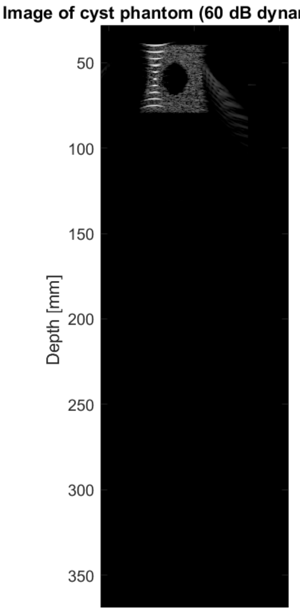
G. The focus during transmit is at 60 mm along the depth axis and the focus during receive is at 100mm along the depth axis.

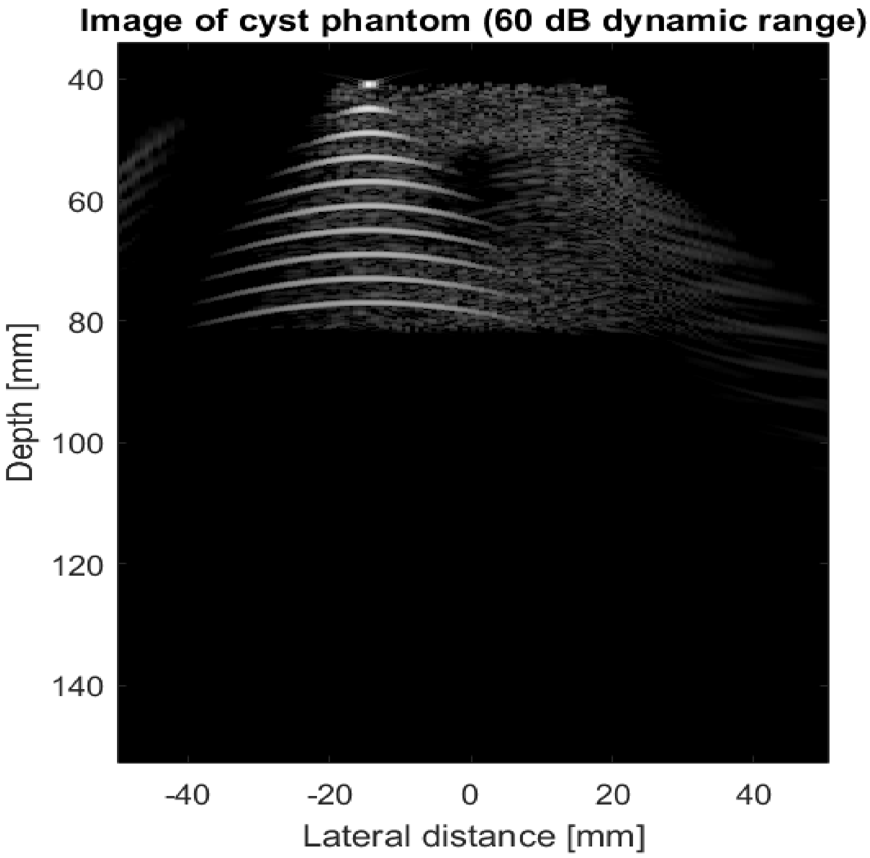


H.The focus during transmit is at 60 mm along the depth axis and the focus during receive is at 120mm along the depth axis.

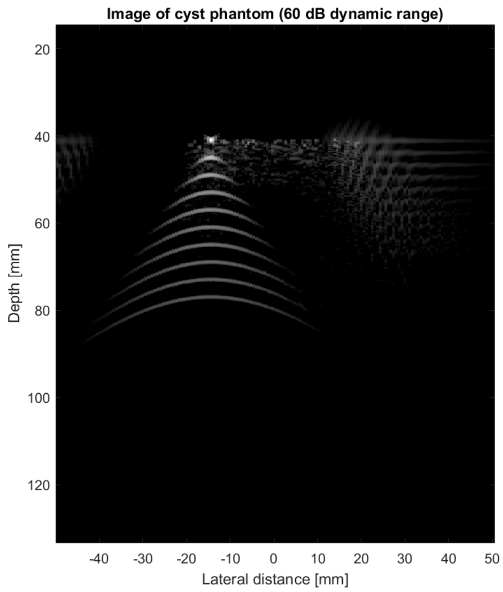


I. In the image below, the focus during Transmit is at 60mm Along the depth Axis and the Focus during Receive is at 40 mm along The depth axis.





J. The focus during transmit is at 40mm During the receive it is at 35 mm along the Depth axis.



K. In the above image, the acoustic wave
Excitation is not apodised while transmit.
I felt that it is better to apodise both
During transmit and receive.

SIMULATION OF A CYST PHANTOM

FIELD II SIMULATOR

BM5170 Ultrasound in Medicine
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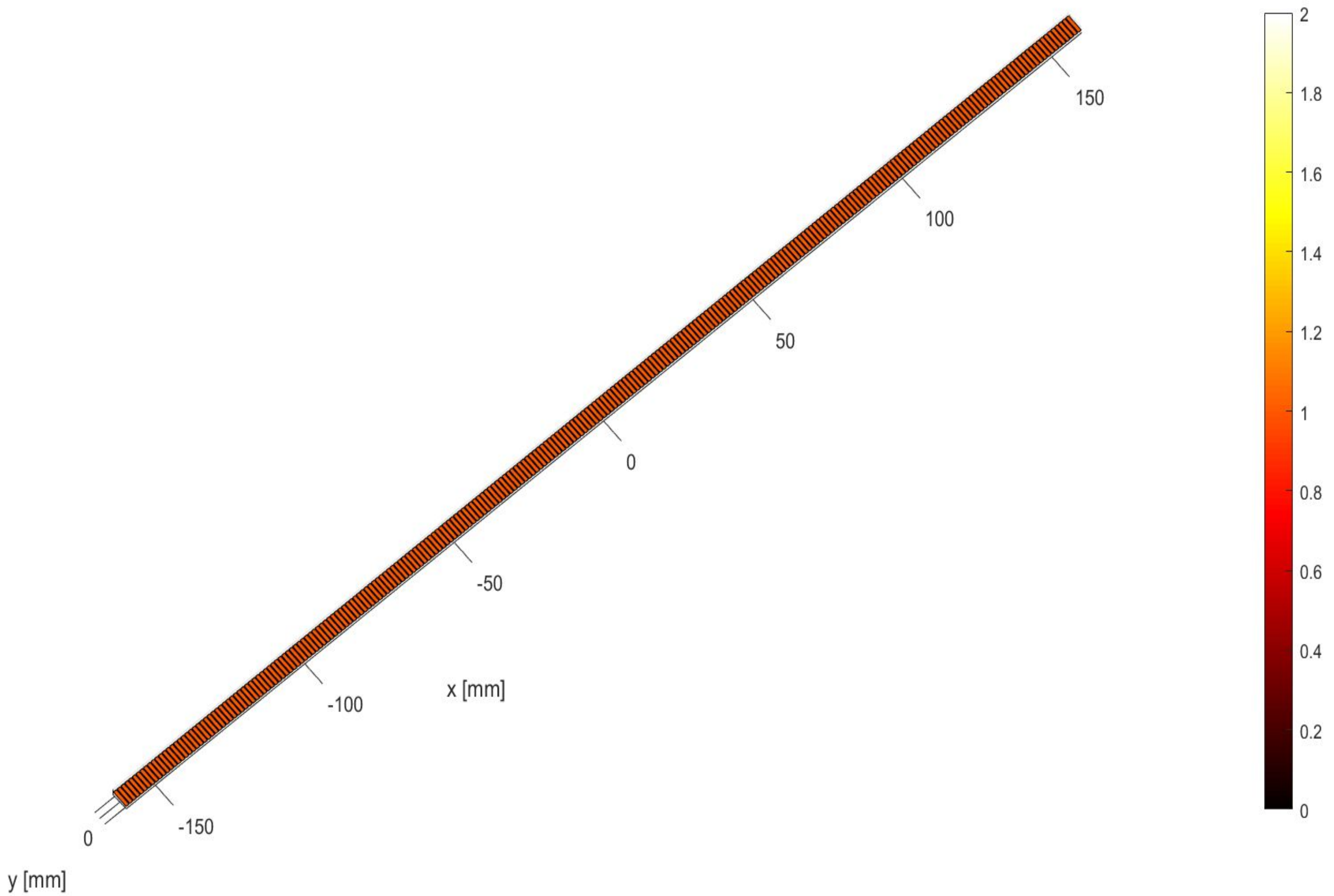
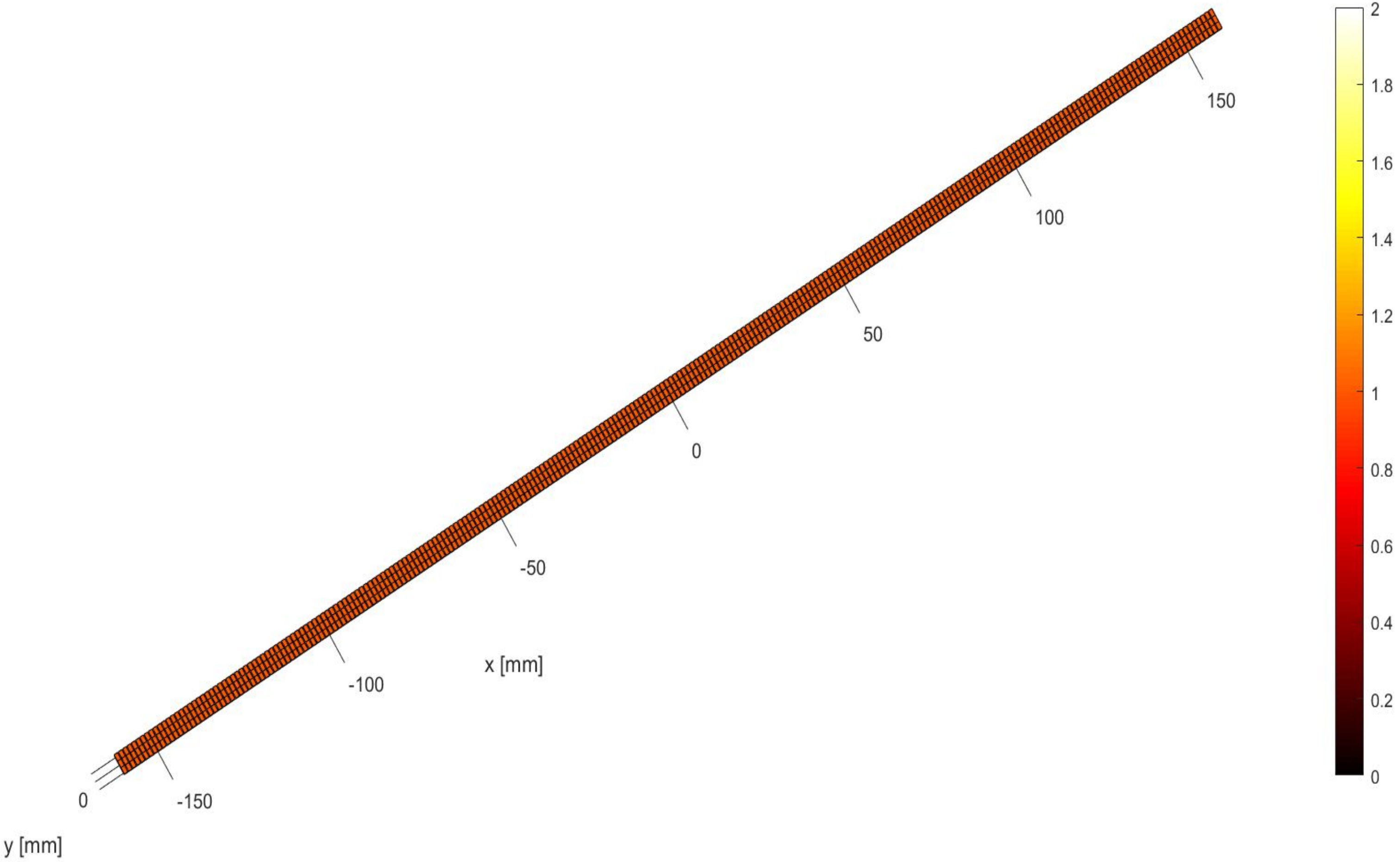
BM20BTECH11004



150
100
50
0
-50
-100
-150
x [mm]
0
y [mm]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0



x [mm]
y [mm]
-150
-100
-50
0
50
100
150
0
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

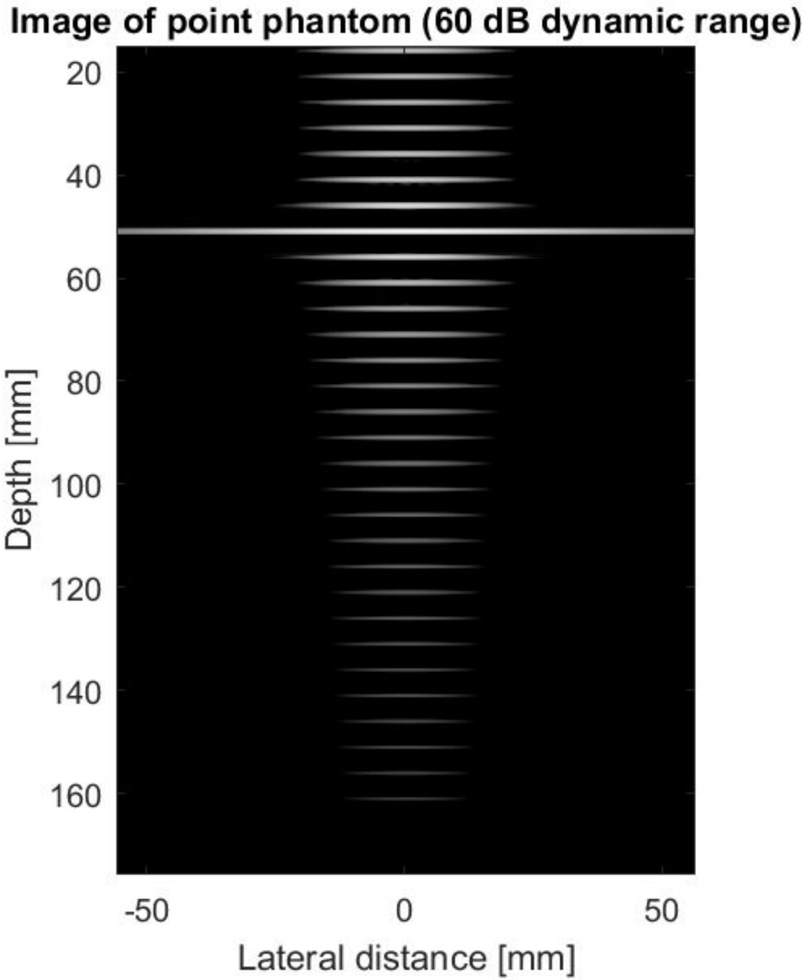
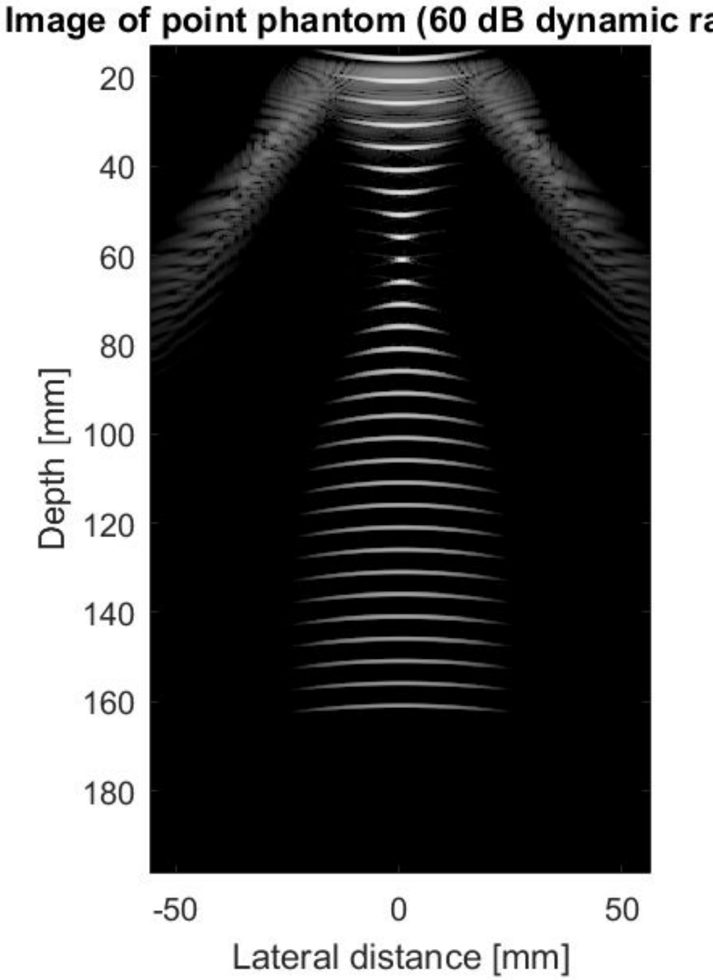
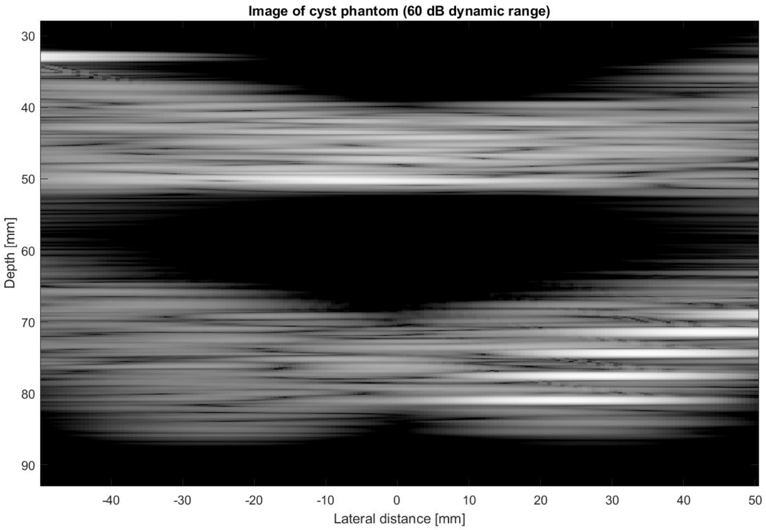


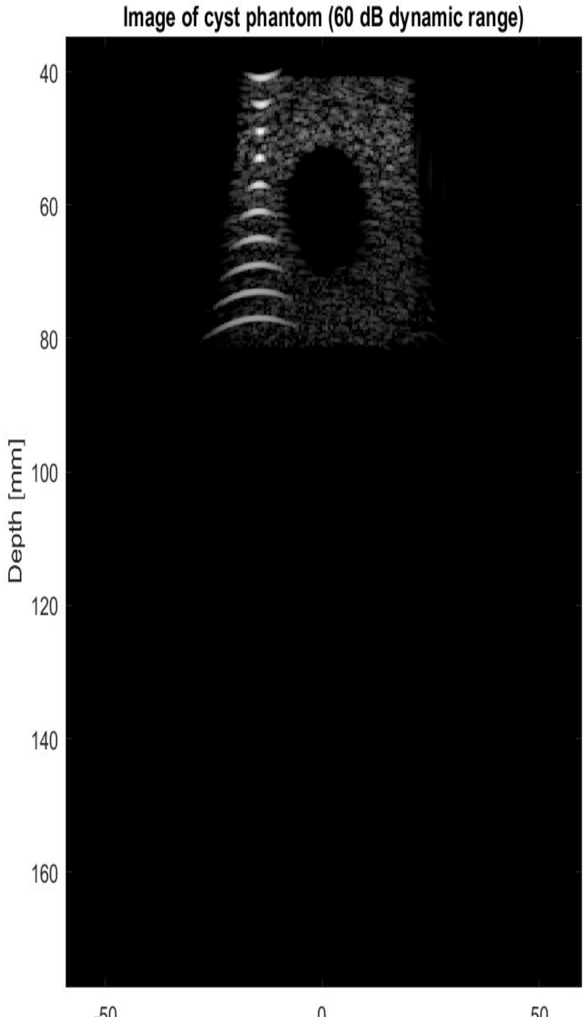
Image of point phantom (60 dB dynamic range)
Depth [mm]
20
40
60
80
100
120
140
160
-50
0
50
Lateral distance [mm]



Depth [mm]
20
40
60
80
100
120
140
160
180
-50
0
50
Lateral distance [mm]




```
% Generate aperture for emission
emit_aperture = xdc_linear_array (N_elements, dim_x, dim_y, w_x, 1, 3, focus);
```



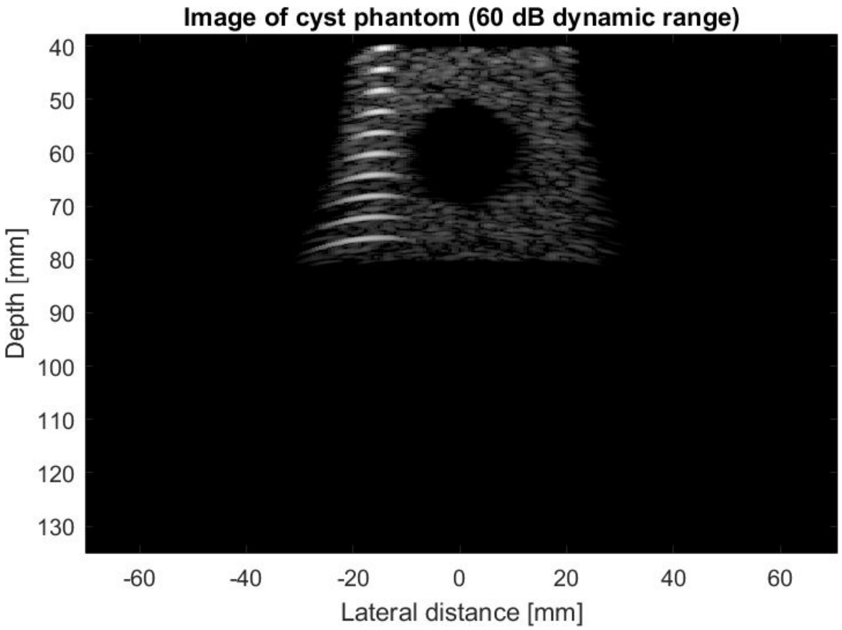


Image of cyst phantom (60 dB dynamic range)
40
50
60
70
80
90
100
110
120
130
Depth [mm]
-60
-40
-20
0
20
40
60
Lateral distance [mm]

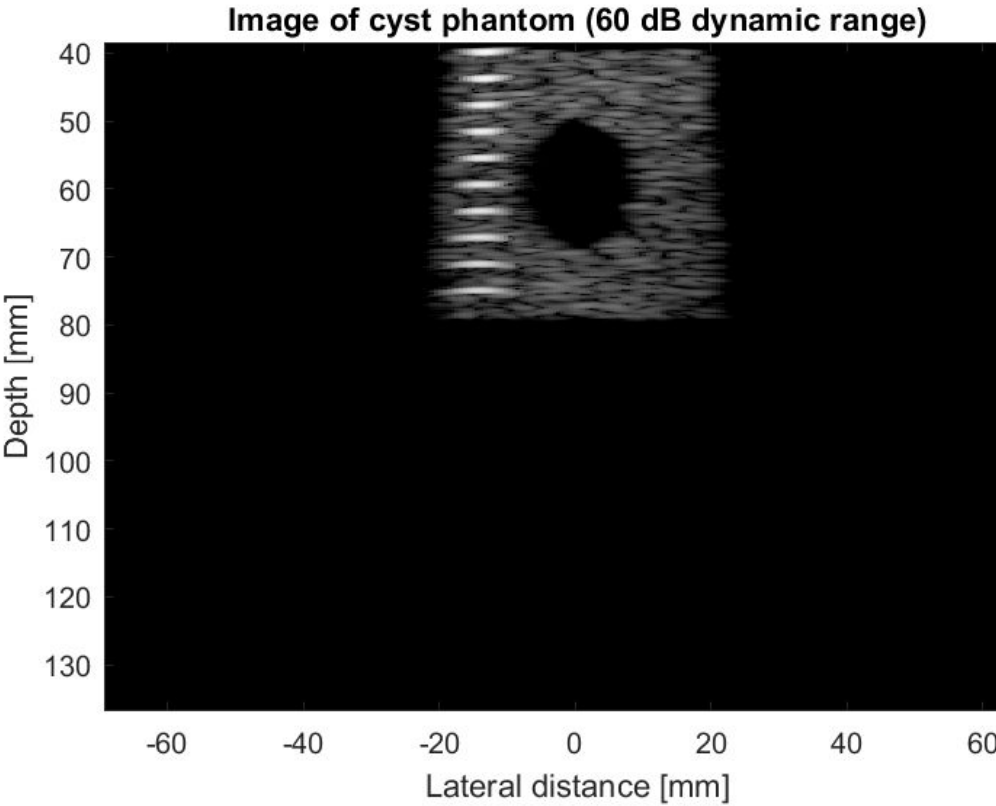
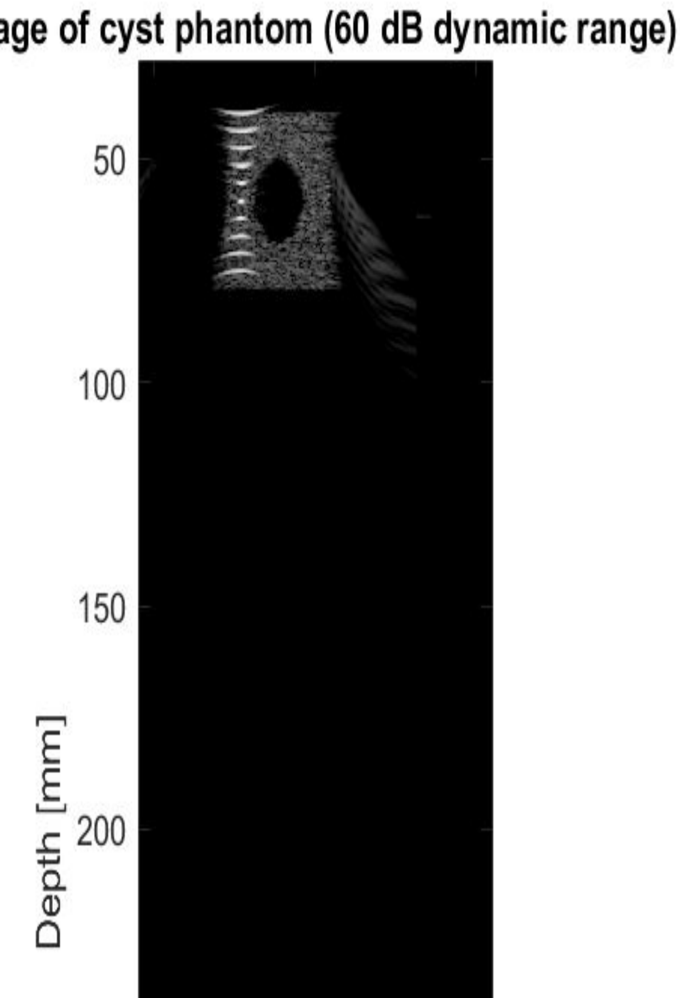


Image of cyst phantom (60 dB dynamic range)
40
50
60
70
80
90
100
110
120
130
Depth [mm]
-60
-40
-20
0
20
40
Lateral distance [mm]


age of cyst phantom (60 dB dynamic range)
50
100
150
200
Depth [mm]

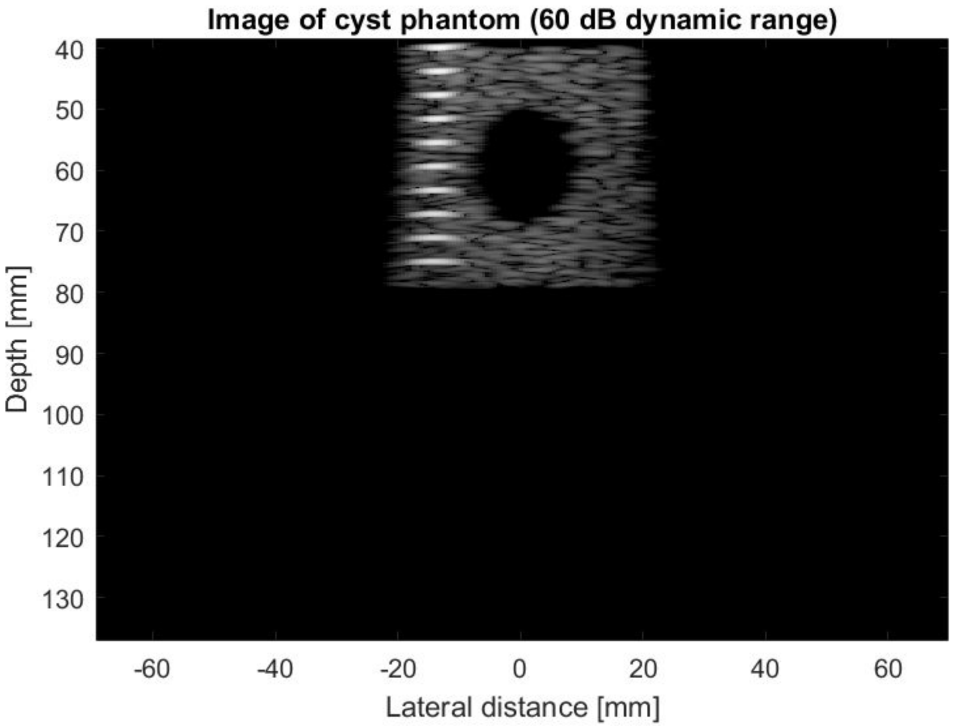


Image of cyst phantom (60 dB dynamic range)
40
50
60
70
80
90
100
110
120
130
Depth [mm]
-60
-40
-20
0
20
40
60
Lateral distance [mm]

Table of Contents


```
fc=2.5e6; % center frequency [Hz] of the transducer
f_sampl=100e6; % Sampling frequency [Hz]
c=1540; % Speed of sound [m/s]
lambda=c/fc; % Wavelength of the acoustic wave [m]

dim_x= lambda; % Width of element[m]
dim_y=5/1000; % Height of element [m]
w_x= dim_x/4; % Kerf gap between two physical elements[m]
focus=[0 0 50]/1000; % Fixed focal point [m]
N_elements=256; % Number of elements in the transducer
N_active=75; % Number of Active elements in the transducer

% Setting the sampling frequency
set_sampling(f_sampl);
% Generate aperture for emission
emit_aperture = xdc_linear_array (N_elements, dim_x, dim_y, w_x, 1, 3, focus);
```

```
Warning:  Remember to set all pulses in apertures for the new sampling
 frequency
```

displaying the geometry of the emit aperture of the transducer

```
data = xdc_get(e_aperture,'rect');
[n,m]=size(data);

colormap(hot(128));
for i=1:m
x=[data(11,i), data(20,i); data(14,i), data(17,i)]*1000;
y=[data(12,i), data(21,i); data(15,i), data(18,i)]*1000;
z=[data(13,i), data(22,i); data(16,i), data(19,i)]*1000;
c= 1;
hold on
surf(x,y,z,c)
end
% Put som axis legends on
Hc = colorbar;
view(3)
xlabel('x [mm]')
ylabel('y [mm]')
zlabel('z [mm]')
grid
```

```
axis('image')
hold off
```

```
Unrecognized
function or
variable
'e_aperture'.

Error in sample_linearimaging (line 18)
data = xdc_get(e_aperture,'rect');
```

Setting the impulse response and excitation of the emit aperture

```
impulse_response=sin(2*pi*fc*(0:1/f_sampl:2/fc));
impulse_response=impulse_response.*hanning(max(size(impulse_response))).';
xdc_impulse (emit_aperture, impulse_response);
excitation=sin(2*pi*fc*(0:1/f_sampl:2/fc));
xdc_excitation (emit_aperture, excitation);

% Generating aperture for reception
receive_aperture = xdc_linear_array (N_elements, dim_x, dim_y, w_x, 1, 3,
 focus);
% Set the impulse response for the receive aperture
xdc_impulse (receive_aperture, impulse_response);

% Loading the computer generated phantom
%[phantom_positions, phantom_amplitudes] = cyst_phantom(10000);
%we can also use the below command for scanning point phantom
%to know how the scan looks like
[phantom_positions, phantom_amplitudes] = point_phantom(30);
% performing linear array imaging

n_lines=N_elements-N_active+1; % Number of A-lines in image

dx=dim_x; % Increment for the image
z_focus=60/1000;

% Pre-allocate some storage
image_data=zeros(1,n_lines);
for i=1:n_lines
    x=(i-1-n_lines/2)*dx;
% Set the focus for this direction
    xdc_center_focus (emit_aperture, [x 0 0]);
    xdc_focus (emit_aperture, 0, [x 0 z_focus]);
    xdc_center_focus (receive_aperture, [x 0 0]);
    xdc_focus (receive_aperture, 0, [x 0 z_focus-20]);
% Set the active elements using the apodization
    apo=[zeros(1, i-1) hamming(N_active)' zeros(1, N_elements-N_active-i+1)];
    xdc_apodization (emit_aperture, 0, apo);
    xdc_apodization (receive_aperture, 0, apo);
% Calculate the received response
    [v, t1]=calc_scat(emit_aperture, receive_aperture, phantom_positions,
 phantom_amplitudes);
    % Store the result
```

```
    image_data(1:max(size(v)),i)=v;
    times(i) = t1;
 end
% Free space for apertures
xdc_free (emit_aperture)
xdc_free (receive_aperture)

% Adjust the data in time and display it as
% a gray scale image
min_sample=min(times)*f_sampl;
for i=1:n_lines
rf_env=abs(hilbert([zeros(round(times(i)*f_sampl-min_sample),1);
 image_data(:,i)]));
env(1:size(rf_env,1),i)=rf_env;
end
% making logarithmic compression to a 60 dB dynamic range
% with proper units on the axis
env_dB=20*log10(env);
env_dB=env_dB-max(max(env_dB));
env_gray=127*(env_dB+60)/60;
depth=((0:size(env,1)-1)+min_sample)/f_sampl*c/2;
x=((1:n_lines)-n_lines/2)*dx;
image(x*1000, depth*1000, env_gray)
xlabel('Lateral distance [mm]')
ylabel('Depth [mm]')
axis('image')
colormap(gray(128))
title('Image of point phantom (60 dB dynamic range)')
```

function for a computer generated phantom with a cyst

```
function [positions, amp] = cyst_phantom (N)
x_size = 40/1000; % Width of phantom [m] (x dim in the image)
y_size = 20/1000; % Transverse width of phantom [m] (thickness dimension of
 the phantom)
z_size = 40/1000; % Height of phantom [m]( depth dimension in the image)
z_start = 40/1000; % Start of phantom surface [m]( phantom starts at this
 depth)

% Creating the general scatterers
x = (rand (N,1)-0.5)*x_size;
y = (rand (N,1)-0.5)*y_size;
z = rand (N,1)*z_size + z_start;

% Generating the amplitudes with a Gaussian distribution
amp=randn(N,1);

% Making the cyst and setting the amplitudes to zero inside.
r=10/1000; % Radius of cyst [m]
xc=0/1000; % Place of cyst [m]
zc=20/1000+z_start;
```

```
inside = ( ((x-xc).^2 + (z-zc).^2) < r^2);
amp = amp .* (1-inside);
% Placing the point scatterers in the phantom
dz=z_size/10;
for i=N-9:N
x(i) = -15/1000;
y(i) = 0;
z(i) = z_start + (i-N+9)*dz;
amp(i) = 100;
end
% Return the variables
positions=[x y z];
end
```

function for generating the point phantom

```
function [positions, amp] = point_phantom(N)

dz=5/1000;        %  Distance between points [m]
z_start=10/1000;  %  Start of point [m]
       %  Number of point targets

%  Create the point scatterers positions

positions = [zeros(1,N); zeros(1,N); (1:N)*dz+z_start]';
amp=ones(N,1);

end
```

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