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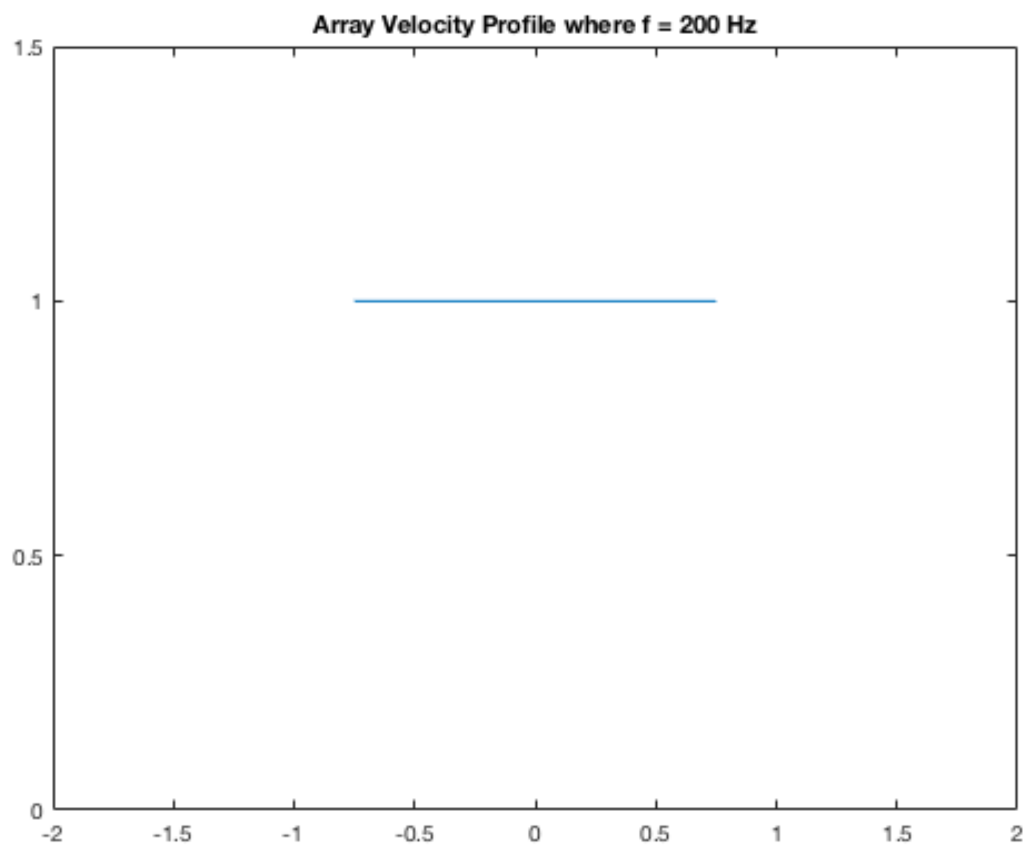
Project 1 – ECE 502

1. Fifteen 100 mm drivers are used to construct a 1.5m, one-dimensional horizontally placed loudspeaker array. Each driver exhibits uniform volume velocity. For frequencies f = {200, 700, 1500} Hz, you are required to compute and display the following:
    a. The loudspeaker elements touch each other leaving no gap between them.
        i. The array velocity profile

```
% Part i - The array velocity profile %
arrayLength = 1.5; %in meters
resolution = 0.01;
xarr = -arrayLength/2:resolution:arrayLength/2;
velocityProfile = ones(1,length(xarr));
plot(xarr,velocityProfile);
title('Array Velocity Profile where f = 200 Hz')
ylim([0 1.5]);
xlim([-2 2]);
```



ii. The array radiation function (beam pattern) as function of the azimuth angle (polar plot)

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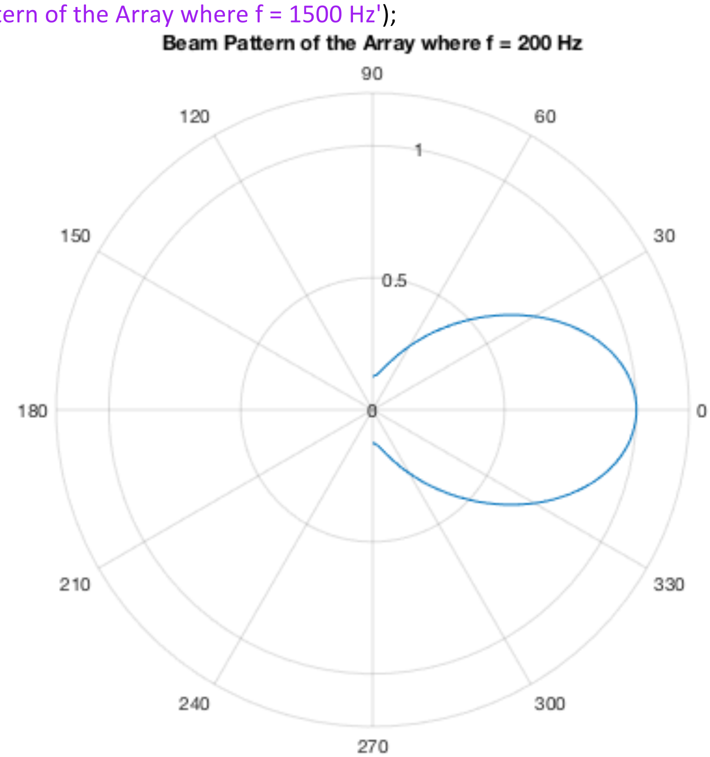
% Part ii - The array radiation function (beam pattern) as the function of
% the azimuth angle (polar plot)
c = 341;
w = 2*pi*f3;
k = w/c;

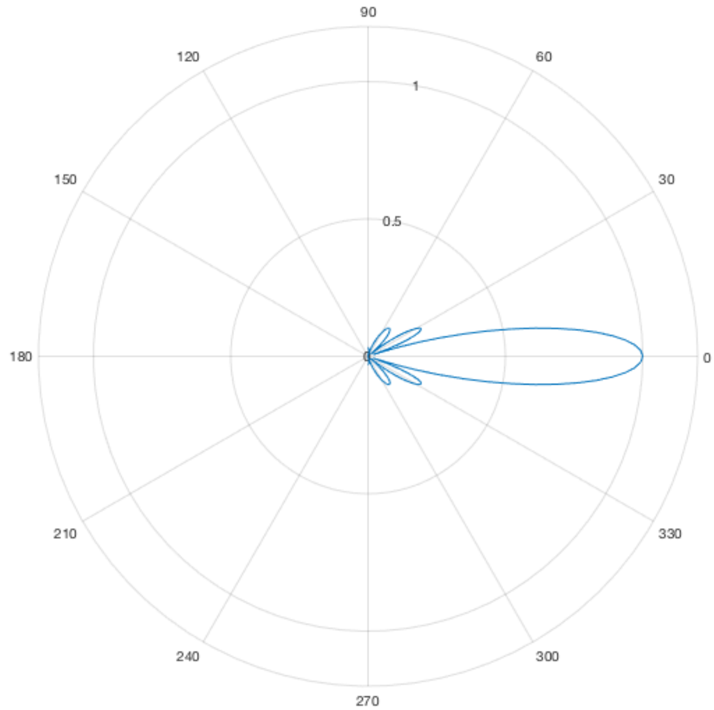
dtheta = length(velocityProfile);
theta = linspace(-pi/2, pi/2, dtheta);
R = zeros(1, length(theta));

l = linspace(-arrayLength/2, arrayLength/2, length(velocityProfile));
for i = 1:length(theta)
   newTheta = theta(i);
  for z = 1:length(velocityProfile)
     R(i) = R(i) + 1/length(l) .* real(exp(j*k*l(z)*sin(newTheta)));
  end
  R(i) = abs(R(i));
end

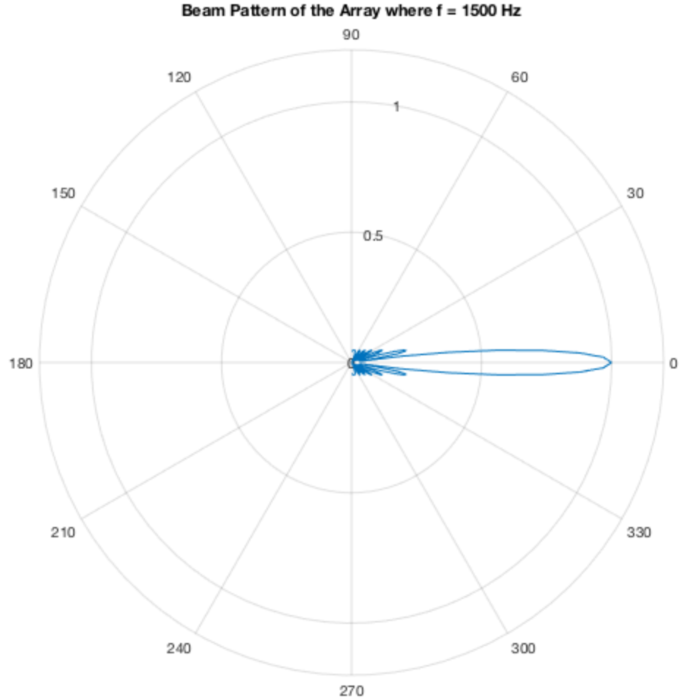
polarplot(theta,R);
title('Beam Pattern of the Array where f = 1500 Hz');
```



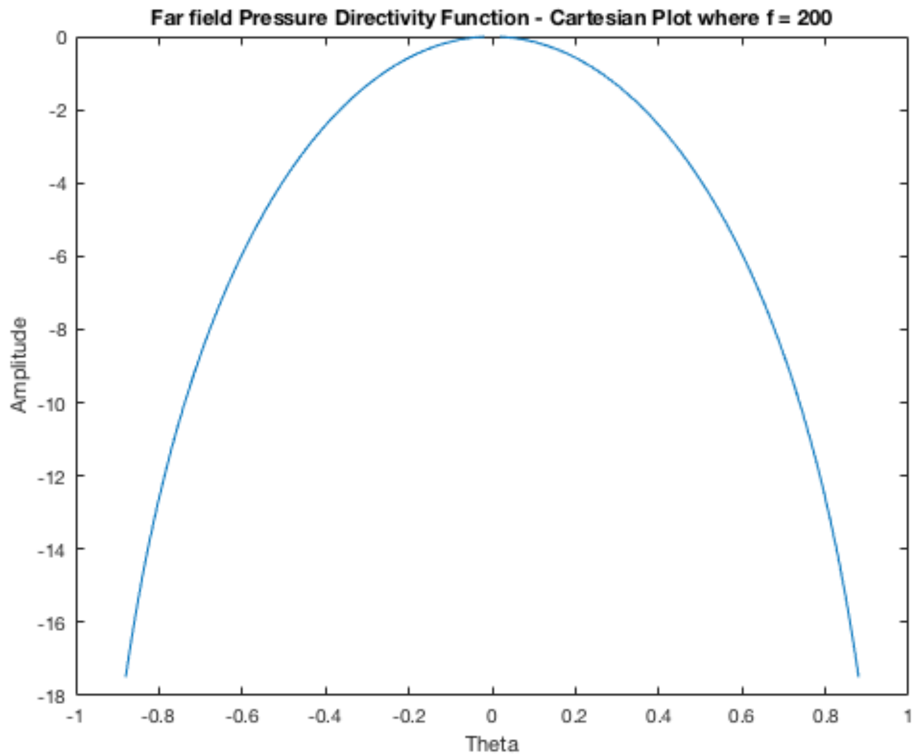
**Beam Pattern of the Array where f = 700 Hz**

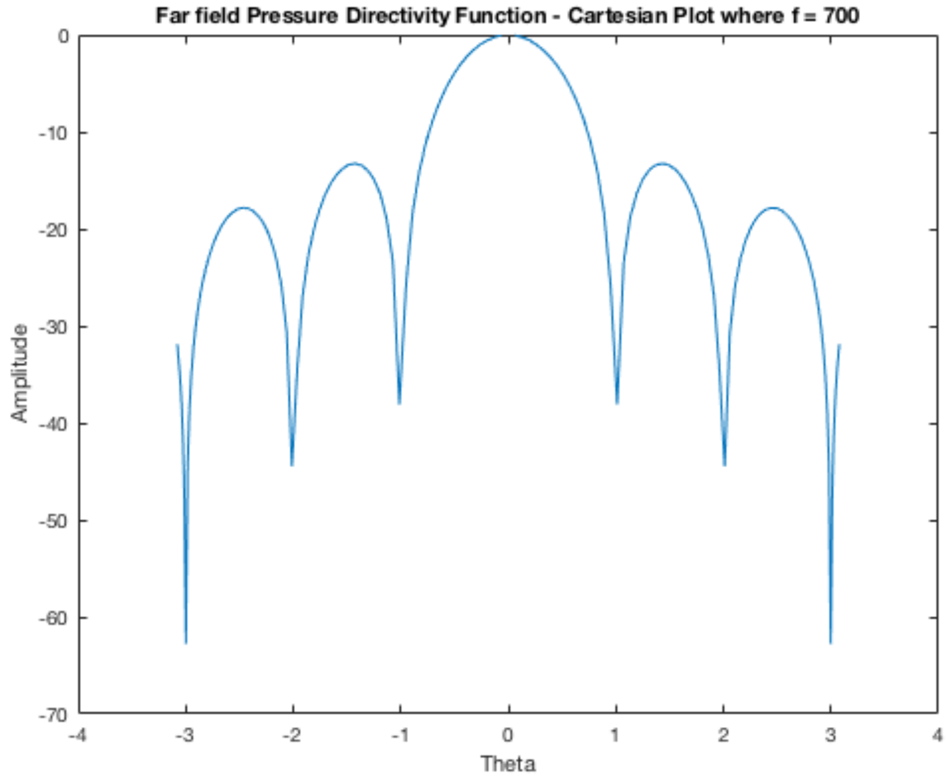


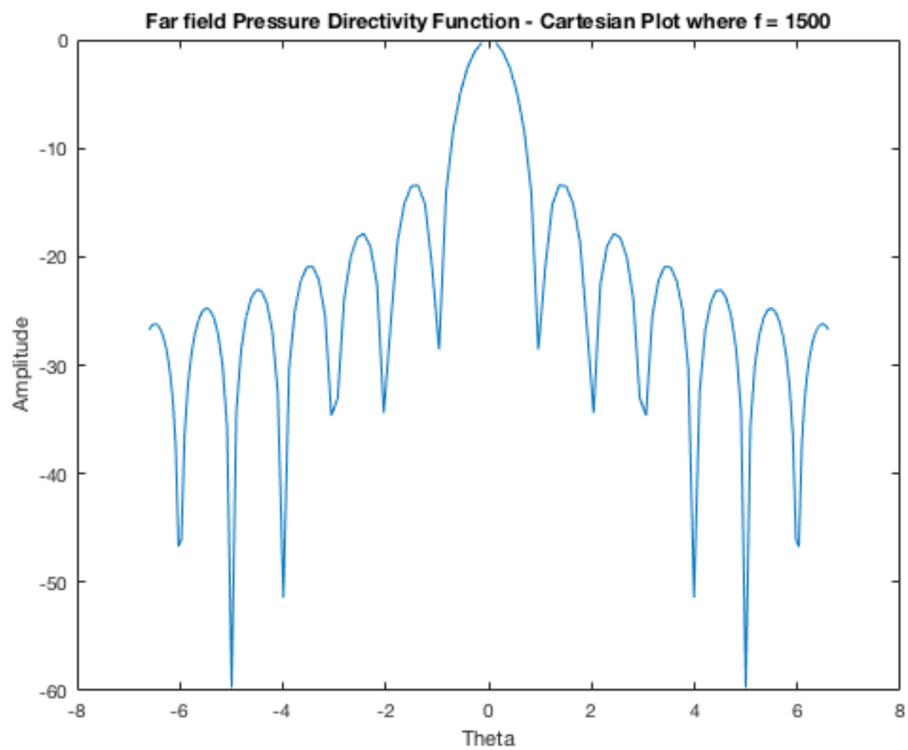

**Beam Pattern of the Array where f = 1500 Hz**



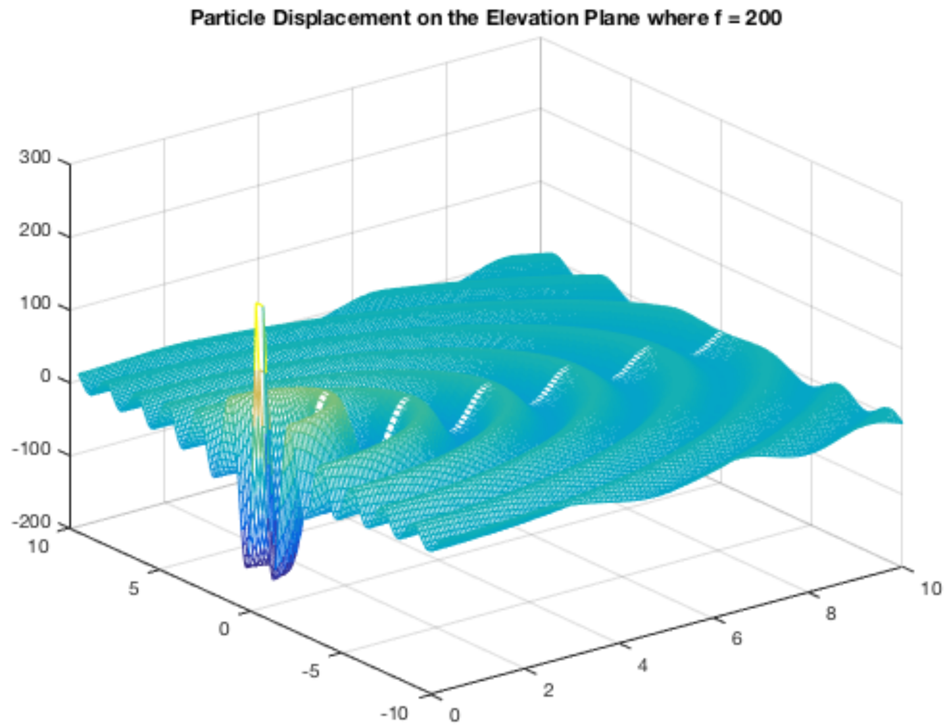
iii. The far field pressure directivity function (Cartesian plot)

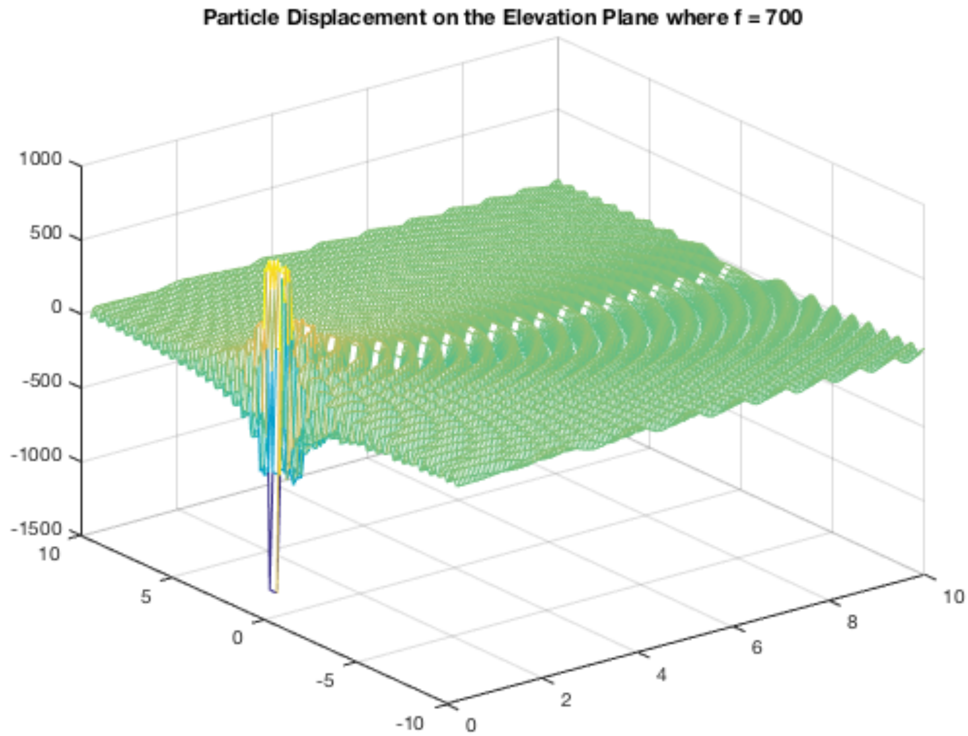


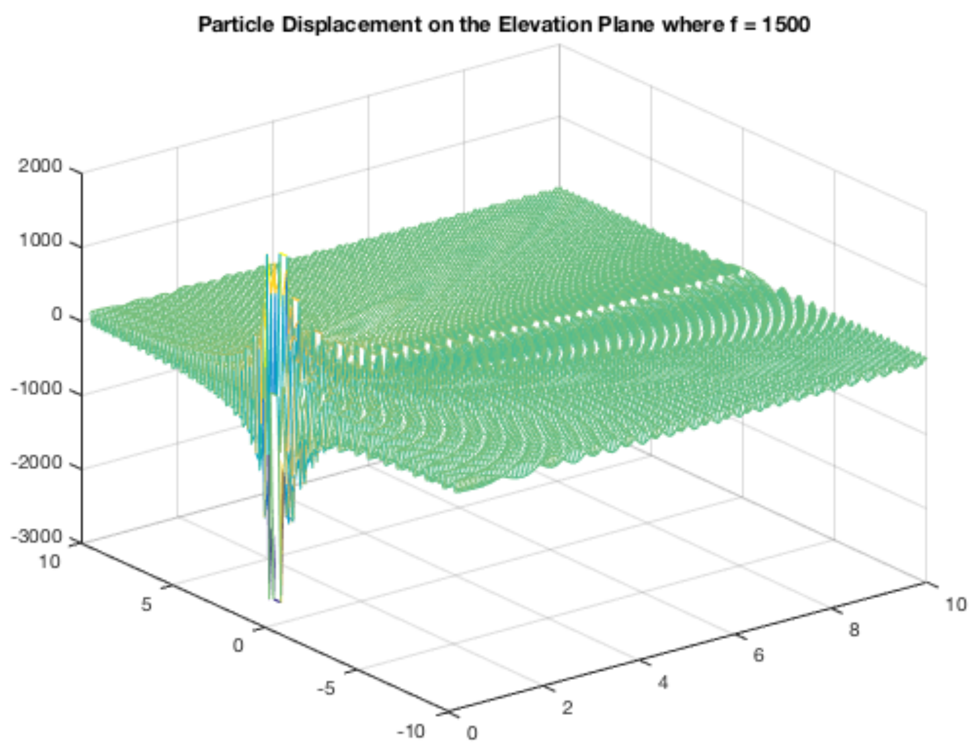

Far field Pressure Directivity Function - Cartesian Plot where f = 700
Amplitude
Theta
0
-10
-20
-30
-40
-50
-60
-70
-4
-3
-2
-1
0
1
2
3
4


Far field Pressure Directivity Function - Cartesian Plot where f = 1500
Amplitude
Theta
0
-10
-20
-30
-40
-50
-60
-8
-6
-4
-2
0
2
4
6
8

iv. The particle displacement on the elevation plane






2. 2D Speaker array

```
%% Question 2 %%
```

```
% A two-dimensional rectangular loudspeaker array, consisting of
densely-placed ideal
% elements, has dimensions 1.5 m in the x-direction and 1 m in the z
direction and it is
% vertically-placed.

clear all
close all
clc

%% PART A For frequencies f = {300, 1000, 3000} Hz, plot the far field
pressure pattern as:
f = 000;
c = 341; % speed of sound in m/s
rho = 1.225; % density of air
lambda = c/f; % wavelength
w = 2*pi*f; % omega
k = w/c;
X_Dim = 1.5; % meters
Z_Dim = 1; % meters

%% Part i Projected on the azimuth plane (polar plot) %%

% velocity profile
resolution = 0.01;
azimuth_arr = -X_Dim/2:resolution:X_Dim/2;
velocityProfileX = ones(1, length(azimuth_arr));

dthetaX = length(velocityProfileX);
thetaX = linspace(-pi/2, pi/2, dthetaX);
Rx = zeros(1, length(thetaX));

lx = linspace(-X_Dim/2, X_Dim/2, length(velocityProfileX));
for i = 1:length(thetaX)
    newThetaX = thetaX(i);
   for z = 1:length(velocityProfileX)
        Rx(i) = Rx(i) + 1/length(lx) .*
real(exp(1i*k*lx(z)*sin(newThetaX)));
   end
   Rx(i) = abs(Rx(i));
end

figure(1);
polarplot(thetaX,Rx);
title(['Beam Pattern Projected onto Azimuth where f = ', num2str(f), '
Hz']);

%% Part ii Projected on the elevation plane (polar plot) %%
elevation_arr = -Z_Dim/2:resolution:Z_Dim/2;
% velocityProfileY = ones(1, length(elevation_arr));

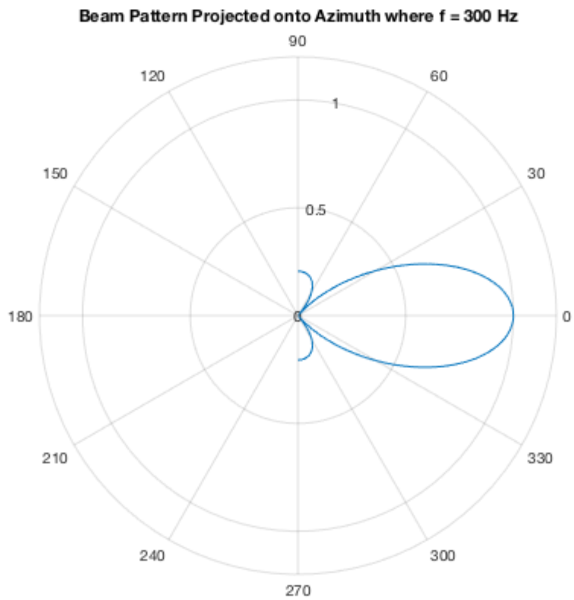
dthetaY = length(velocityProfileX);
thetaY = linspace(-pi/2, pi/2, dthetaY);
Ry = zeros(1, length(thetaY));

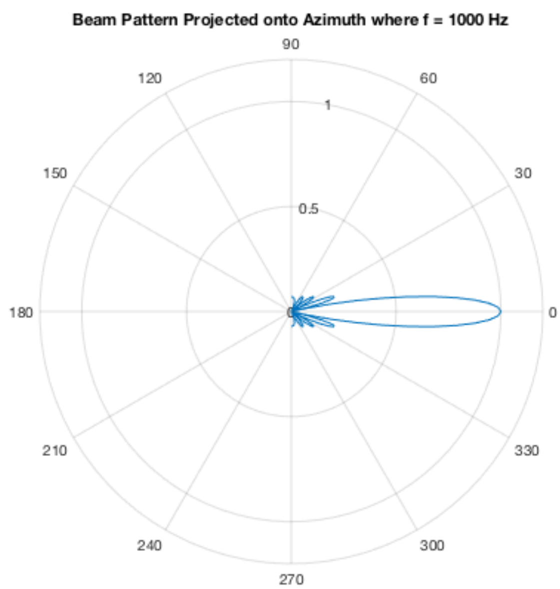
ly = linspace(-Z_Dim/2, Z_Dim/2, length(velocityProfileX));
```

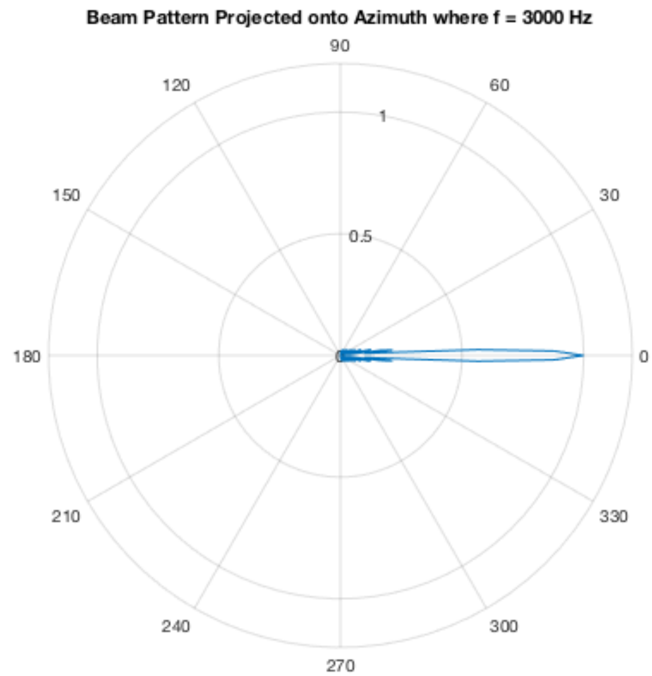
```
for i = 1:length(thetaY)
    newThetaY = thetaY(i);
   for z = 1:length(velocityProfileX)
       Ry(i) = Ry(i) + 1/length(ly) .*
real(exp(1i*k*ly(z)*sin(newThetaY)));
   end
   Ry(i) = abs(Ry(i));
end

figure(2);
polarplot(thetaY,Ry);
title(['Beam Pattern Projected onto Elevation where f = ', num2str(f),
' Hz']);
%% Part iii Projected both on the azimuth and elevation places (3-
dimensional plot) %%
R = Rx' * Ry;
[THETA, PHI] = meshgrid(thetaX, thetaY);
[px,py,pz] = sph2cart(PHI, THETA, R);
figure(3);
surf(px,py,pz);
title(['3D Beam Pattern projected onto azimuth and elevation when f =
', num2str(f),' Hz']);
```

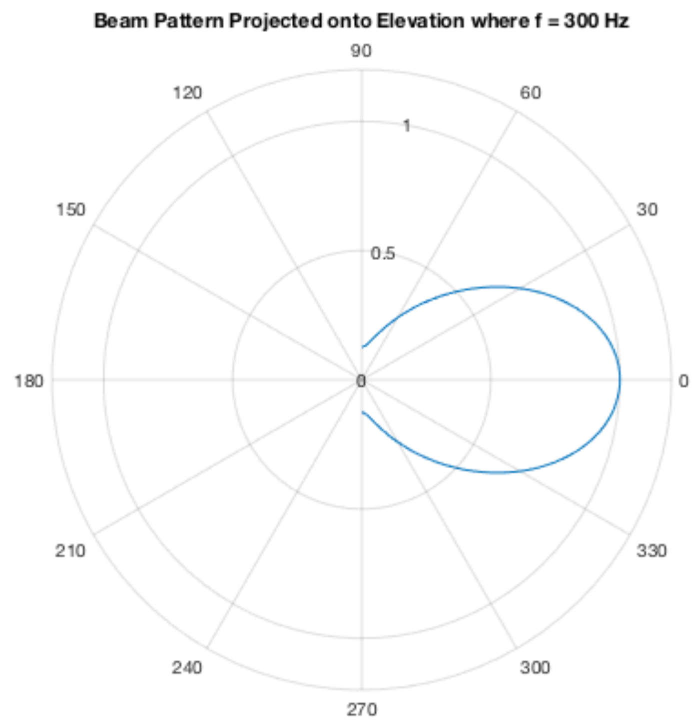
a. Far field pressure without beam steering
    i. Azimth


Beam Pattern Projected onto Azimuth where f = 300 Hz
90
120
60
1
150
30
0.5
180
0
0
210
330
240
300
270

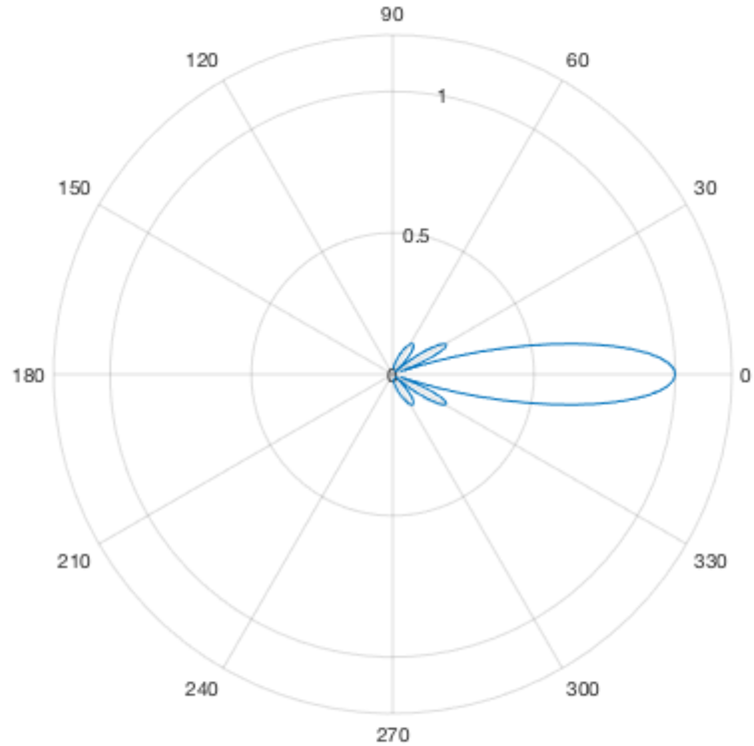

Beam Pattern Projected onto Azimuth where f = 1000 Hz
90
120
60
1
150
30
0.5
180
0
0
210
330
240
300
270



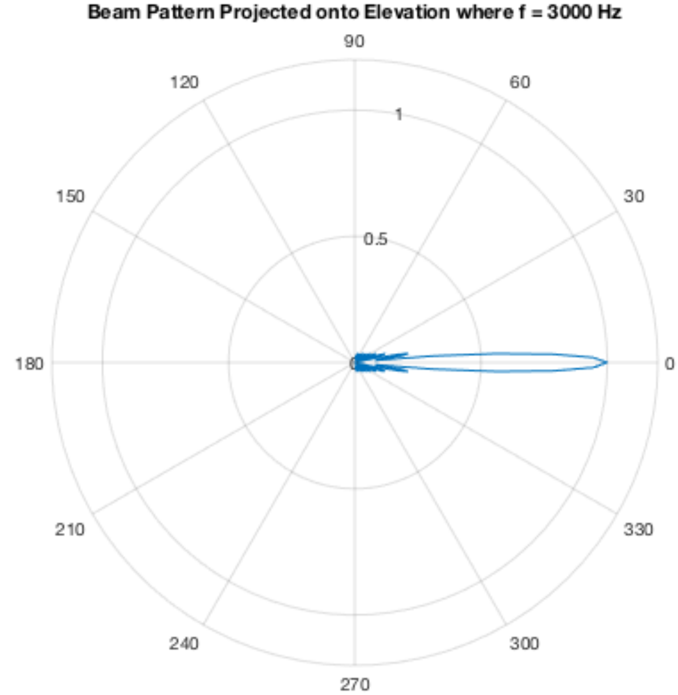

ii. Elevation



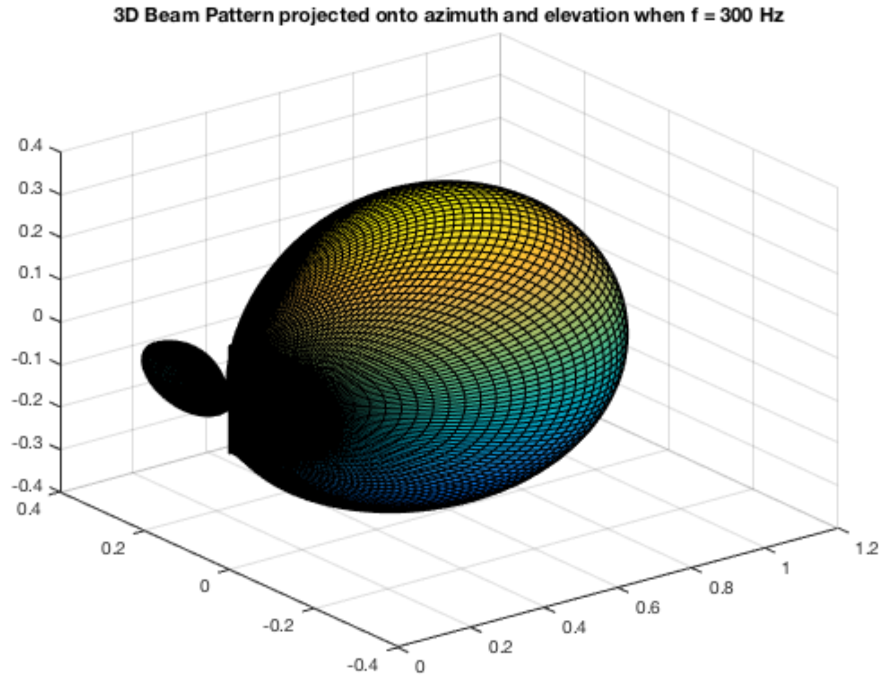
**Beam Pattern Projected onto Elevation where f = 1000 Hz**

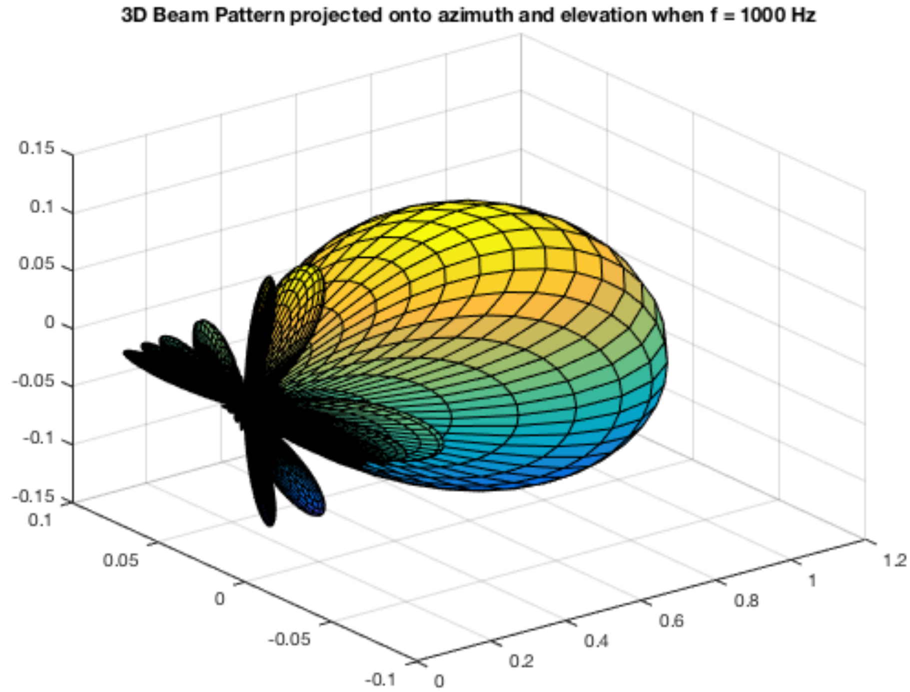


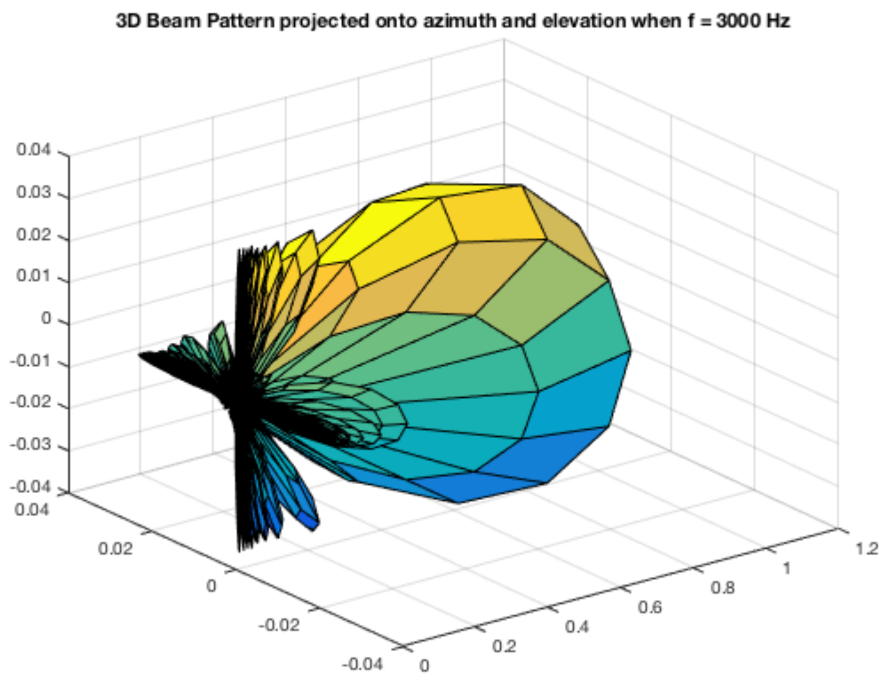

**Beam Pattern Projected onto Elevation where f = 3000 Hz**



iii. Far field pressure projected onto both azimuth and elevation

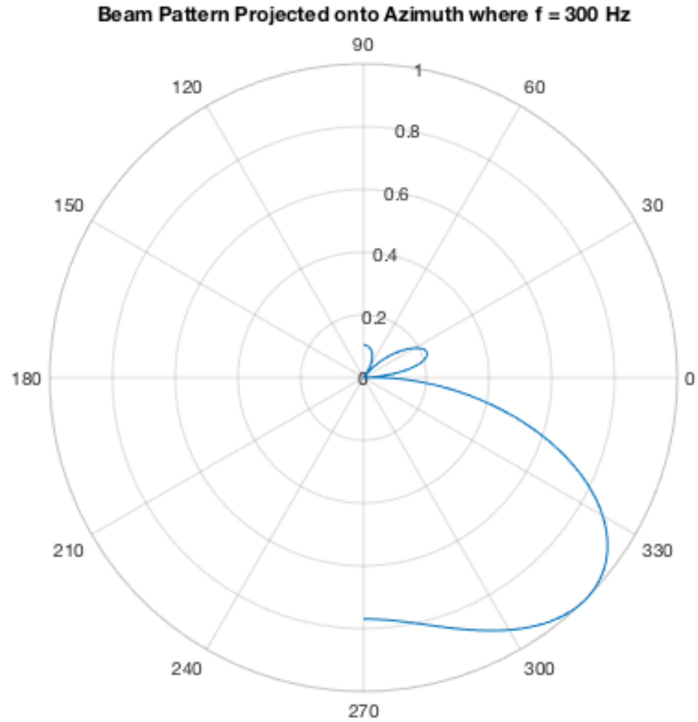




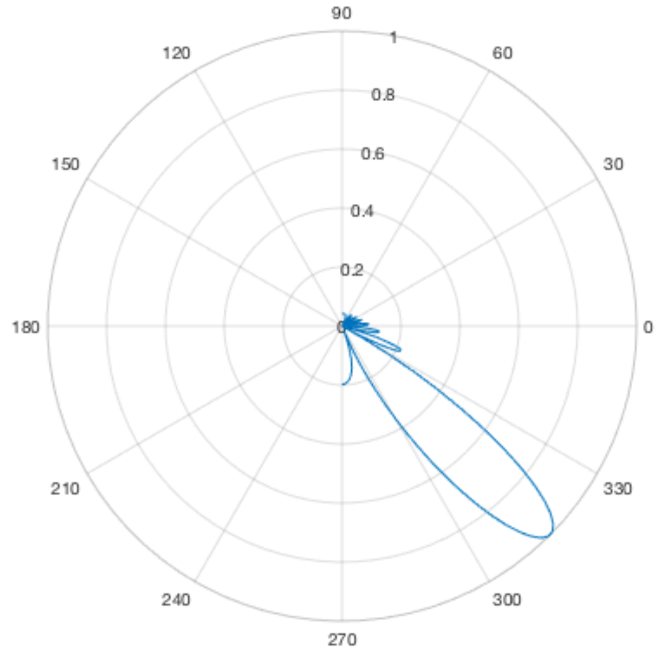




b. With beam steering

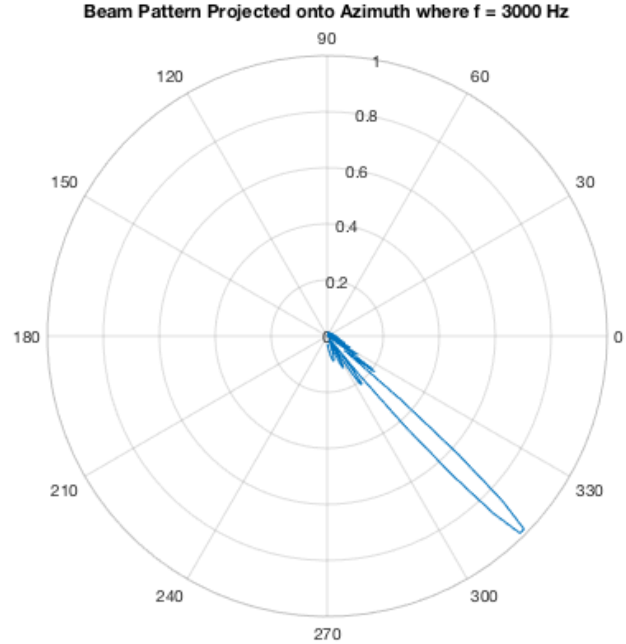
i. Projected onto azimuth



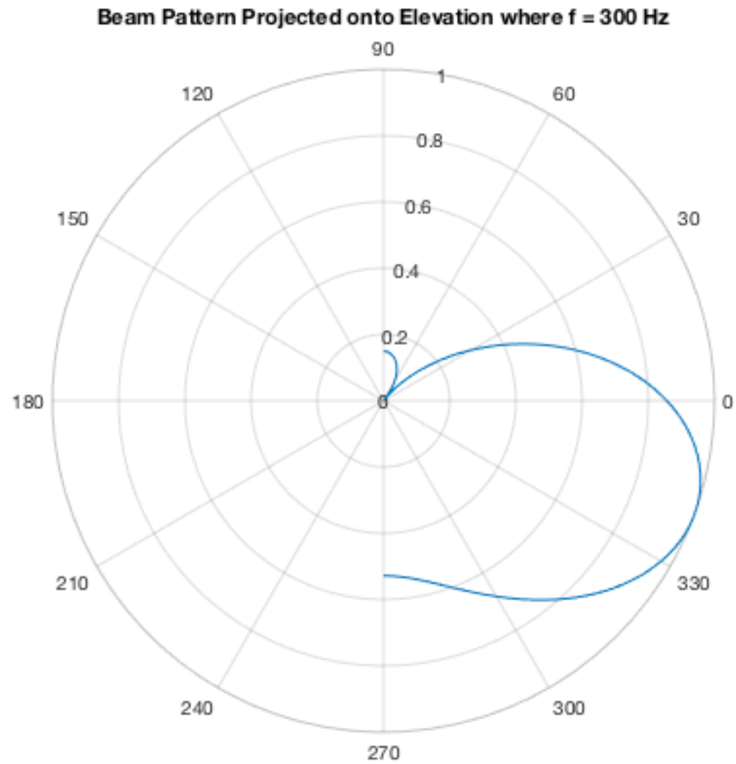
**Beam Pattern Projected onto Azimuth where f = 1000 Hz**

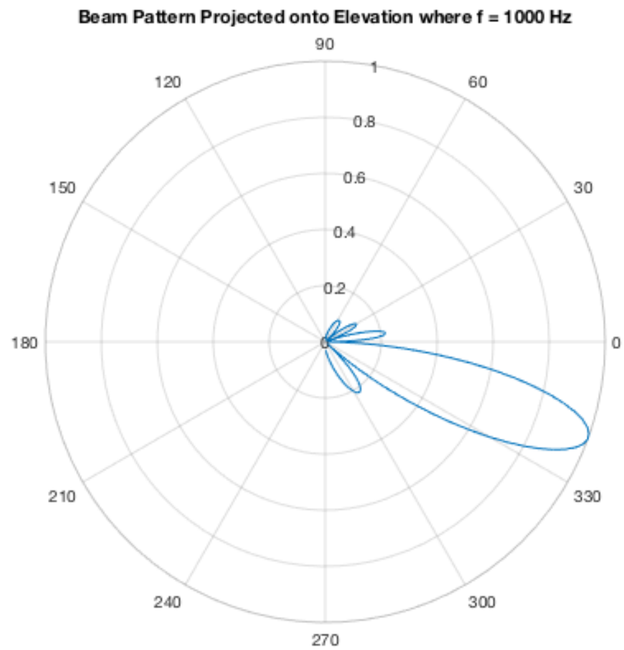


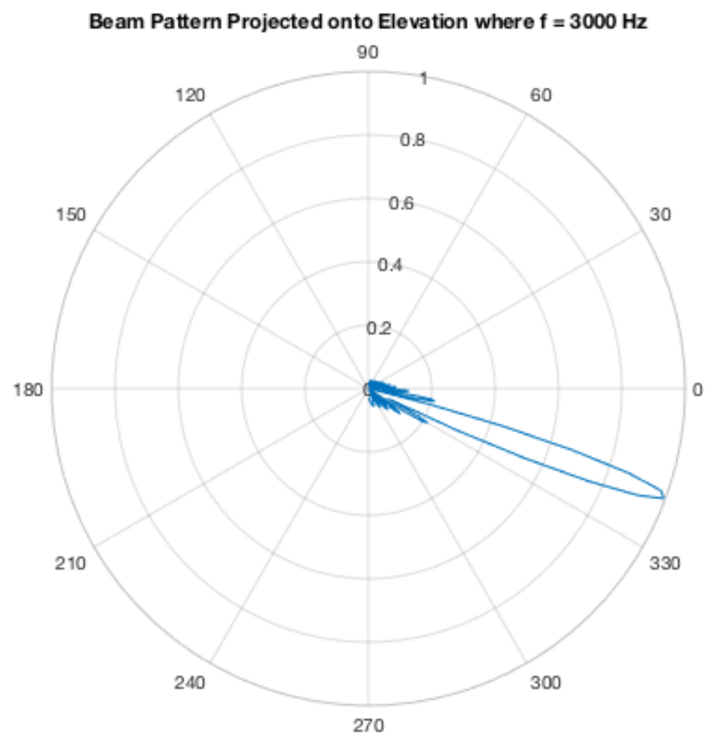

**Beam Pattern Projected onto Azimuth where f = 3000 Hz**



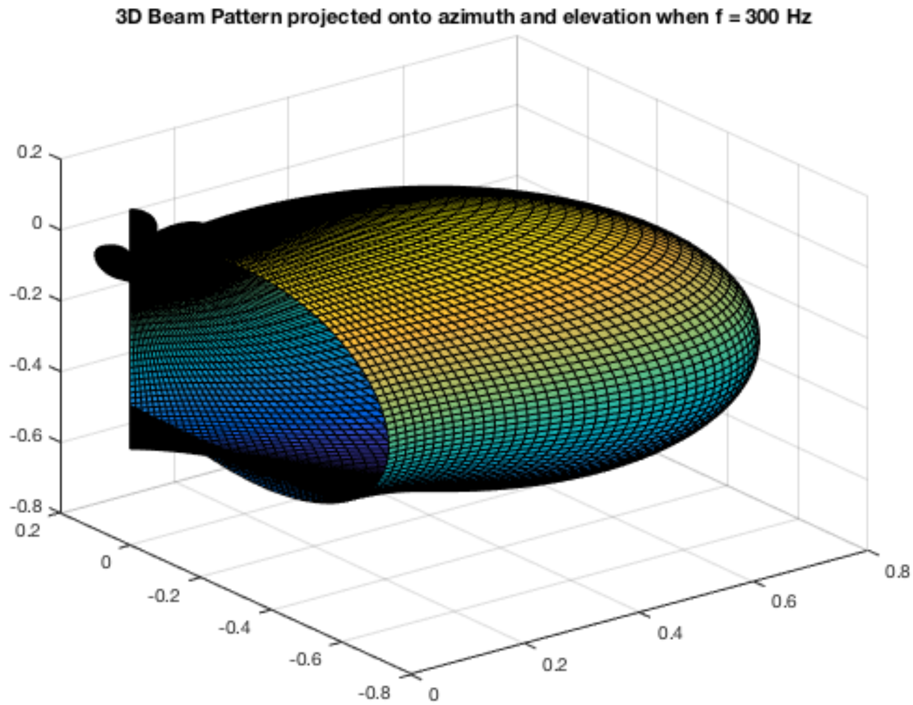
ii. Projected onto elevation

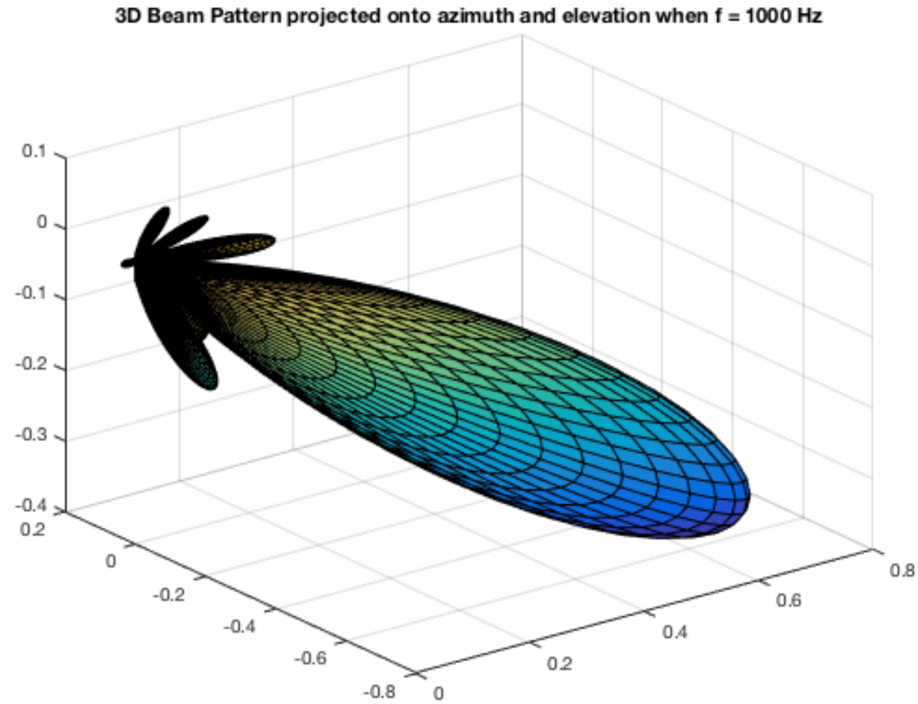


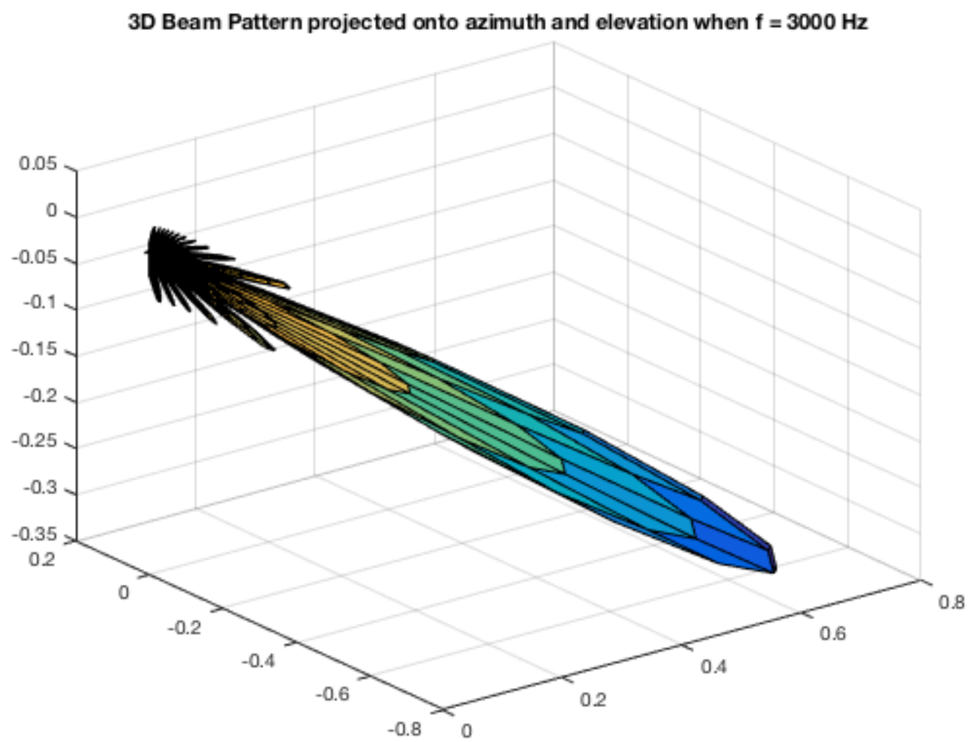

Beam Pattern Projected onto Elevation where f = 1000 Hz
90
120
60
150
30
180
0
210
330
240
300
270
1
0.8
0.6
0.4
0.2
0


Beam Pattern Projected onto Elevation where f = 3000 Hz
90
120
60
150
30
180
0
210
330
240
300
270
1
0.8
0.6
0.4
0.2
0

iii. Projected onto both azimuth and elevation




3D Beam Pattern projected onto azimuth and elevation when f = 1000 Hz
0.1
0
-0.1
-0.2
-0.3
-0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.2
0.4
0.6
0.8


3D Beam Pattern projected onto azimuth and elevation when f = 3000 Hz
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.2
0.4
0.6
0.8