Demo: Computing and Displaying Antenna Patterns

In this demo, we will illustrate some basic MATLAB tools for computing and displaying antenna patterns. Specifically, you will learn to:

- Perform basic manipulations in spherical coordinates
- Define simple antennas using MATLAB's antenna toolbox
- Plot antenna patterns in 2D and 3D
- Use the antenna patterns and free-space path loss functions to compute the path loss along a trajectory

Contents

Spherical coordiantes.

We first demonstrate how to perform basic manipulations in spherical coordinates.

For example, the code below generates four random points in 3D and converts them to spherical coordinates

```
% Generate random data
X = randn(3,4);

% Compute spherical coordinates of a matrix of points
% Note these are in radians!
[az, el, rad] = cart2sph(X(1,:), X(2,:), X(3,:));

% We can then convert back
[x,y,z] = sph2cart(az,el,rad);
Xhat = [x; y; z];
```

Simulation constants

For the remainder of the demo, we will use the following simulation constants

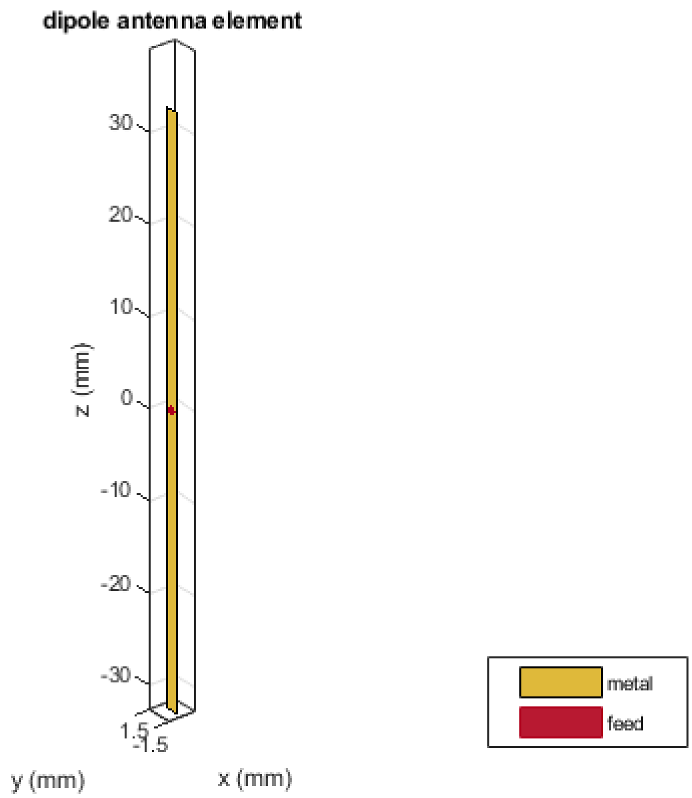
Note: In MATLAB, all values are in metric units m, s, Hz, etc. Not GHz or MHz.

```
fc = 2.3e9;     % Carrier frequency
vp = physconst('lightspeed');  % speed of light
lambda = vp/fc;   % wavelength
```

Dipole antenna

For a first antenna, we construct a simple dipole.

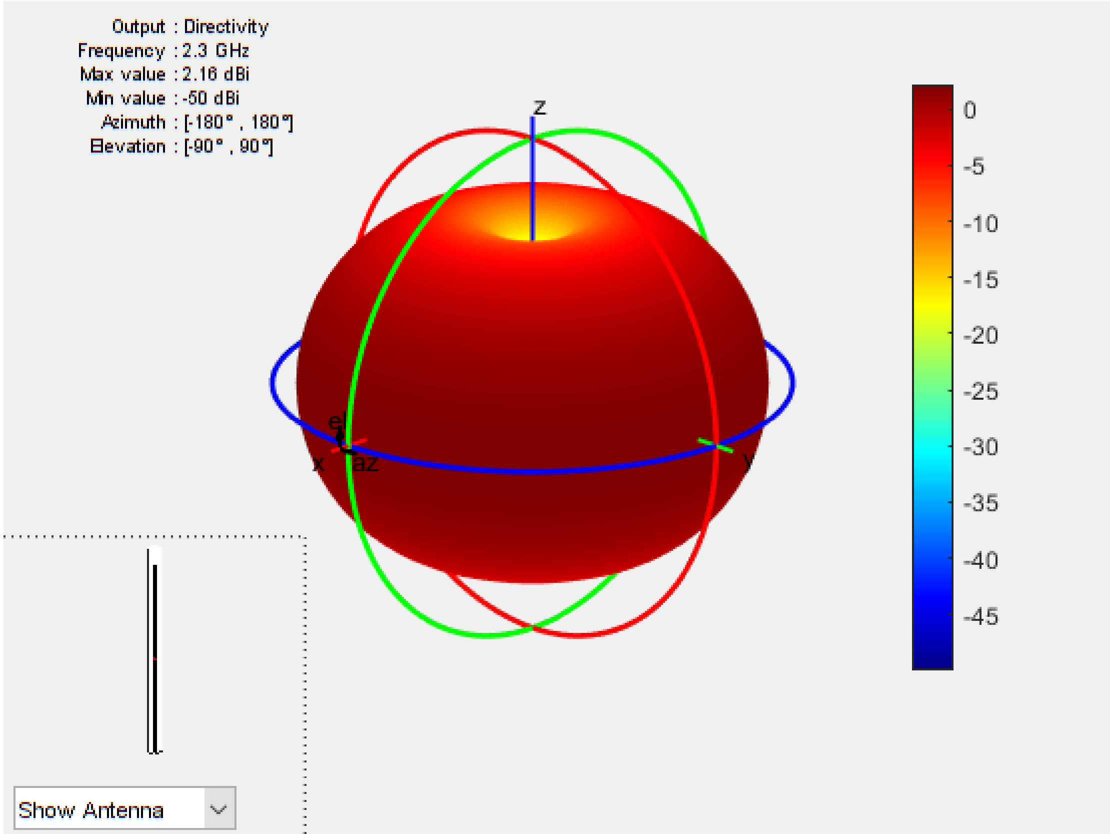
```
% Construct the antenna object
ant = dipole(...
    'Length', lambda/2,...
    'Width', 0.01*lambda );

% Display the antenna
ant.show();
```



Displaying the pattern

We can display the antenna pattern with the following command.

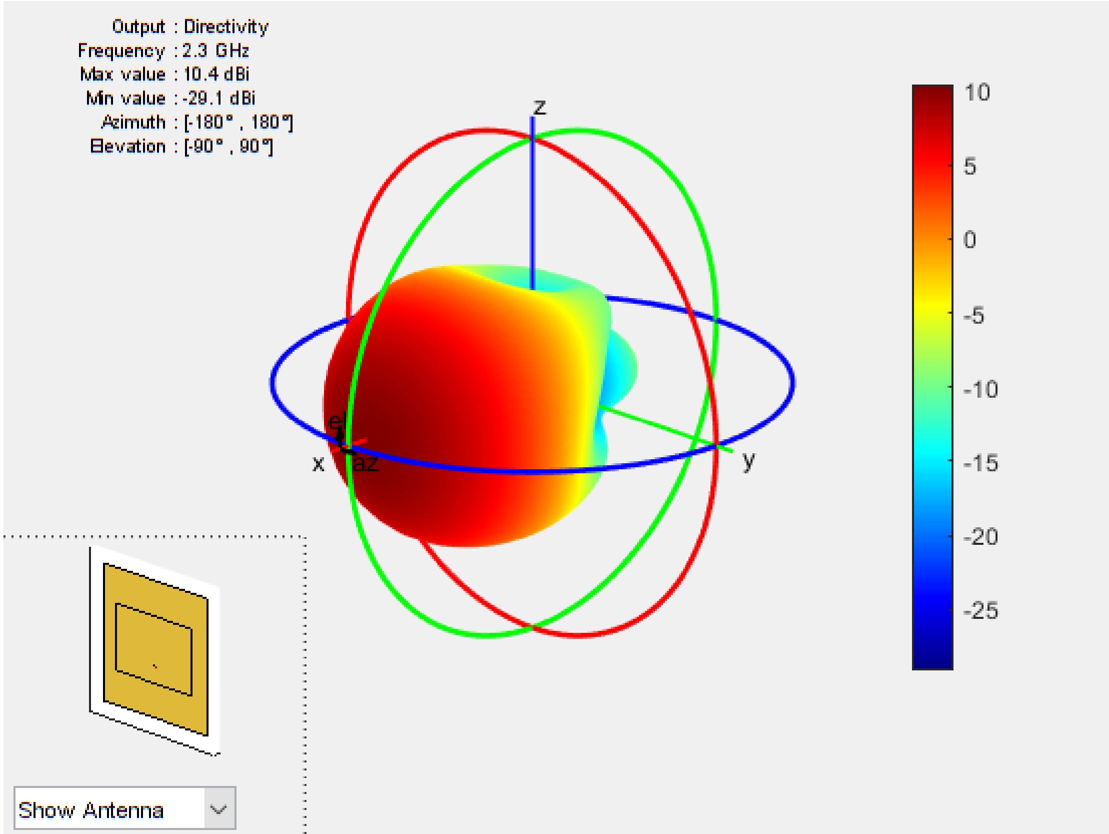
```
ant.pattern(fc)
```



Patch Element

We now consider a more complex antenna. The antenna toolbox can analyze a number of antennas in use. However, once the antenna is more complex, you will start to notice that the analysis becomes very slow.

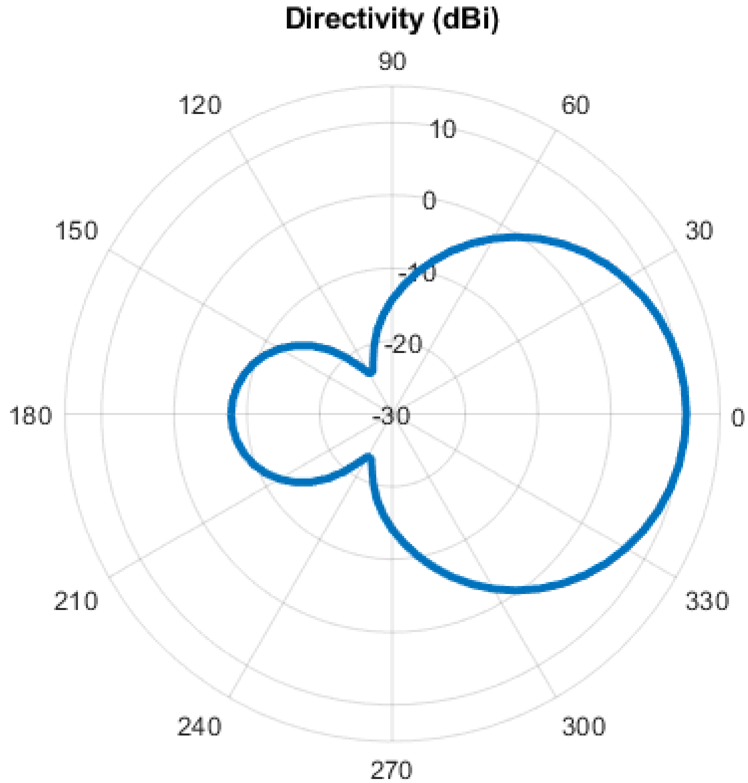
```
len = 0.49*lambda;
groundPlaneLen = lambda;
ant2 = patchMicrostrip(...
    'Length', len, 'Width', 1.5*len, ...
    'GroundPlaneLength', groundPlaneLen, ...
    'GroundPlaneWidth', groundPlaneLen, ...
    'Height', 0.01*lambda, ...
    'FeedOffset', [0.25*len 0]);

% Tilt the element so that the maximum energy is in the x-axis
ant2.Tilt = 90;
ant2.TiltAxis = [0 1 0];

% Display the antenna pattern after rotation.
% This may take a few minutes.  So be patient
ant2.pattern(fc, 'Type', 'Directivity');

% You can also save the pattern
[dir,az,el] = ant2.pattern(fc, 'Type', 'Directivity');
```



Plotting a cross-section

Once the antenna pattern is stored in an array, you can plot cross sections as follows. Suppose we want to plot the cross-section at an elevation angle of 0

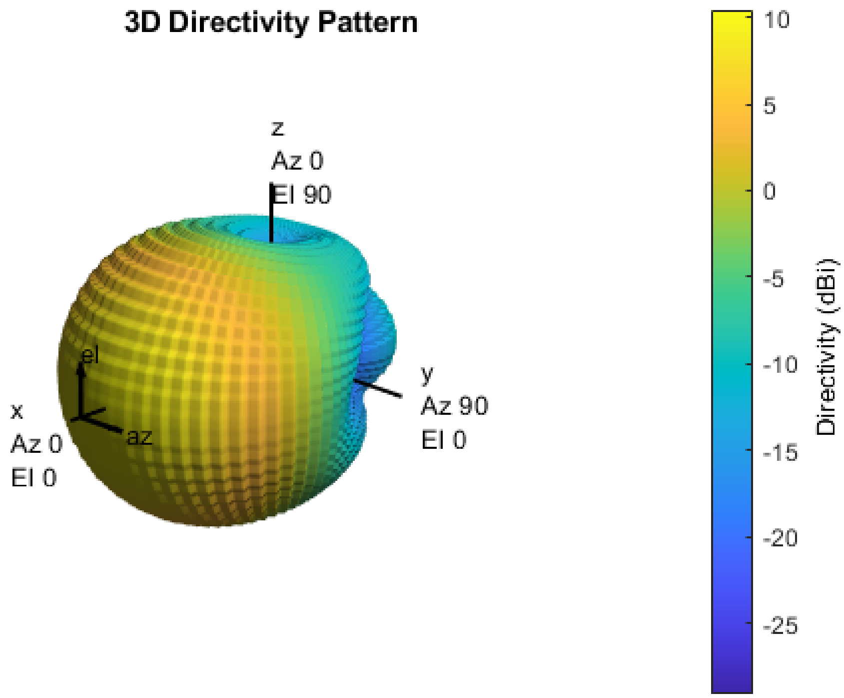
```
% Elevation angle to plot
elPlot = 0;

% Find the index closest to the desired angle
[~, iel] = min(abs(el - elPlot));

% Plot using the polar plot.
% Note the conversion to radians.  You also have to use the |rlim|
% command to set the limits.
polarplot(deg2rad(az), dir(iel,:),'LineWidth', 3);
rlim([-30, 15]);
title('Directivity (dBi)');
```



Creating a custom antenna pattern

While MATLAB has many common antennas, you will often need to load antenna data from a manufacturer or other source. Also, even when using MATLAB's antenna elements, it is often useful to compute the pattern once and store it. For this purpose, you can create a custom antenna element. Here, we will create a custom antenna element with directivity pattern we just computed from the microstrip element.

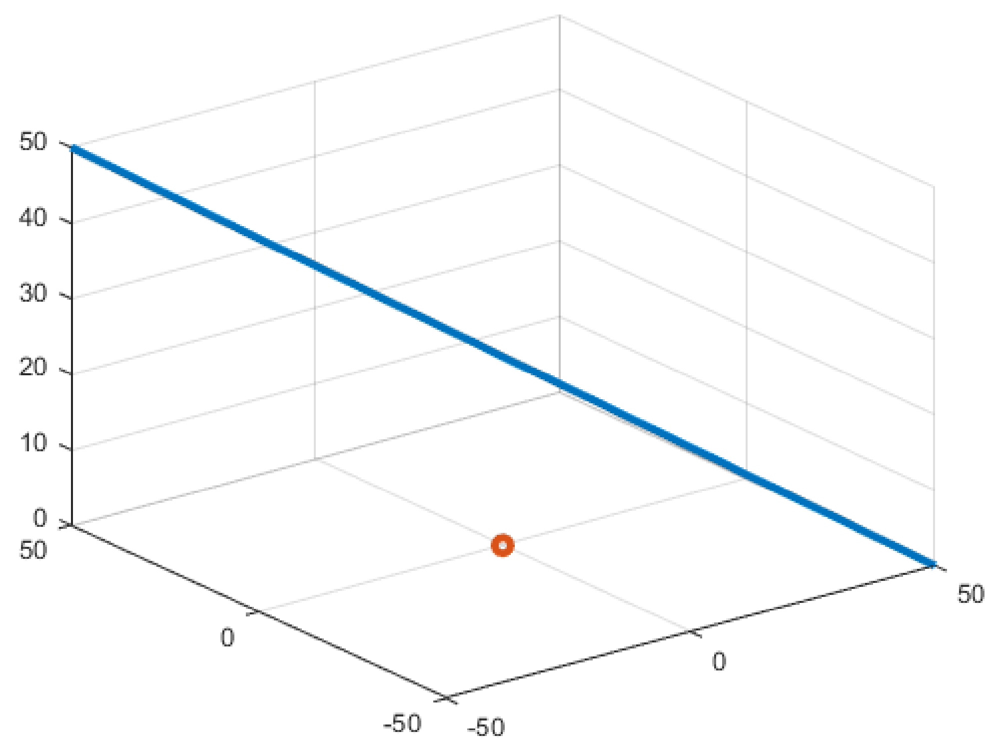
```
phasePattern = zeros(size(dir));
ant3 = phased.CustomAntennaElement(...
    'AzimuthAngles', az, 'ElevationAngles', el, ...
    'MagnitudePattern', dir, ...
    'PhasePattern', phasePattern);

% Plot the antenna pattern.
% Note the format is slightly different since we are using
% the pattern routine from the phased array toolbox
ant3.pattern(fc);
```



Interpolating the directivity in the custom pattern

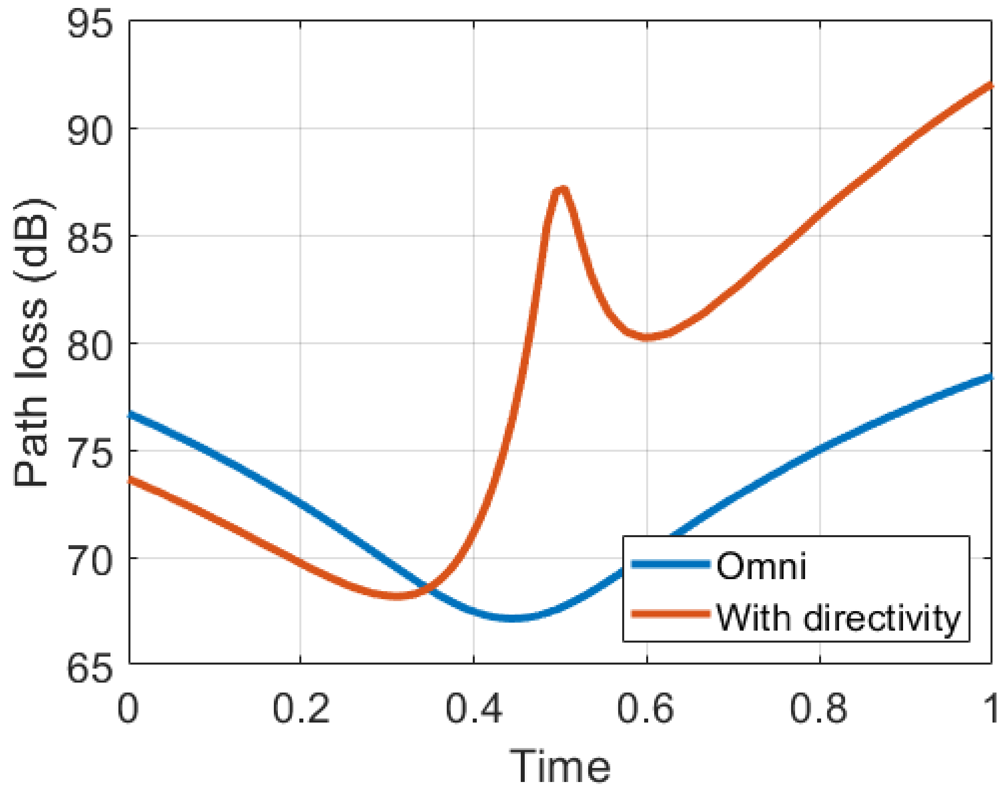
Once we have the antenna pattern, we can interpolate the values of the gain at other directions. To illustrate we will plot the total path loss between a TX at the origin and an object traveling in a linear path along a 3D path. First, we create and plot the path

```
% Define the linear path
npts = 100;
xstart = [50 -50 0]';
xend = [-50 50 50]';
t = linspace(0,1,npts);
X = xstart*(1-t) + xend*t;

% Plot the path in 3D along with the location of the TX at the origin
plot3(X(1,:), X(2,:), X(3,:), 'Linewidth', 3);
hold on;
plot3(0, 0, 0, 'o', 'Linewidth', 3);
grid();
hold off;
```



We compute the angle from the transmitter to the target. Remember to convert to degrees.

```
[azpath, elpath, dist] = cart2sph(X(1,:), X(2,:), X(3,:));
azpath = rad2deg(azpath);
elpath = rad2deg(elpath);

% Compute the free space path loss along the path without
% the antenna gain.  We can use MATLAB's built-in function
plOmni = fspl(dist, lambda);

% Compute the directivity using interpolation of the pattern.
% We can use the ant3.resp method for this purpose, but the
% interpolation is not smooth.  So, we will do this using
% MATLAB's interpolation objects.   First, we create the
% interpolation object.
F = griddedInterpolant({el,az},dir);

% Then, we compute the directivity using the object
dirPath = F(elpath,azpath);

% Compute the total path loss including the directivity
plDir = plOmni - dirPath;

% Plot the path loss over time.  Can you explain the
plot(t, [plOmni; plDir]', 'Linewidth', 3);
grid();
set(gca, 'Fontsize', 16);
legend('Omni', 'With directivity', 'Location', 'SouthEast');
xlabel('Time');
ylabel('Path loss (dB)');
```



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