Electrical Engineering Department,

Fourth Year - Communications & Electronics.

EE 466 ANTENNA

Lab Assignment-2 (GUI)

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➢ Contents

1. Interface design & Code — Page 4

   1.1. Select — Page 4

   1.2. Sketch — Page 5

   1.3. Reset — Page 10

   1.4. Special Cases — Page 11

2. Examples — Page 13

   2.1. Part 1: linear antenna (dipole of general length) — Page 13

   2.2. Part 2: Uniform linear antenna array (ULA) — Page 15

   2.3. Part 3: Nonuniformly-Fed linear antenna array — Page 16

      A. Binomial Arrays — Page 16

      B. Dolph-Tschebysceff Arrays — Page 17

   2.4. Special Case for dipole antenna — Page 19

      A. Infinite small dipole — Page 19

      B. Short dipole — Page 19

      C. $\lambda/2$ dipole — Page 20

➢ List of Figures

Figure 1: Interface design - linear antenna (dipole of general length).	Page 4
Figure 2: Select.	Page 4
Figure 3: Interface design - Uniform linear antenna array (ULA).	Page 5
Figure 4: Interface design - Nonuniformly-Fed linear antenna array (Binomial Arrays).	Page 5
Figure 5: Interface design - Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).	Page 6
Figure 6: Code – Select.	Page 6
Figure 7: Sketch Button.	Page 7
Figure 8: Code - Sketch.	Page 7 : Page 10
Figure 9: Reset.	Page 10
Figure 10: Code - Reset.	Page 10
Figure 11: Special Cases.	Page 11
Figure 12: Code - Special Cases.	Page 11 : Page 12
Figure 13: Example 1 - Part 1: linear antenna (dipole of general length).	Page 13
Figure 14: Example 2 (Errors) - Part 1: linear antenna (dipole of general length).	Page 14
Figure 15: Example 1 - Part 2: Uniform linear antenna array (ULA).	Page 15

Figure 16: Example 2 (Errors) - Part 2: Uniform linear antenna array (ULA).	Page 16
Figure 17: Example 1 - Part 3: Nonuniformly-Fed linear antenna array (Binomial Arrays).	Page 16
Figure 18: Example 2 (Errors) - Part 3: Nonuniformly-Fed linear antenna array (Binomial Arrays).	Page 17
Figure 19: Example 1 - Part 3: Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).	Page 17
Figure 20: Example 2 (Errors) - Part 3: Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).	Page 18
Figure 21: Infinite small dipole.	Page 19
Figure 22: Short dipole.	Page 19
Figure 23: $\lambda/2$ dipole.	Page 20

https://github.com/MahmoudFierro98/Antenna_Lab/

1. Interface design & Code

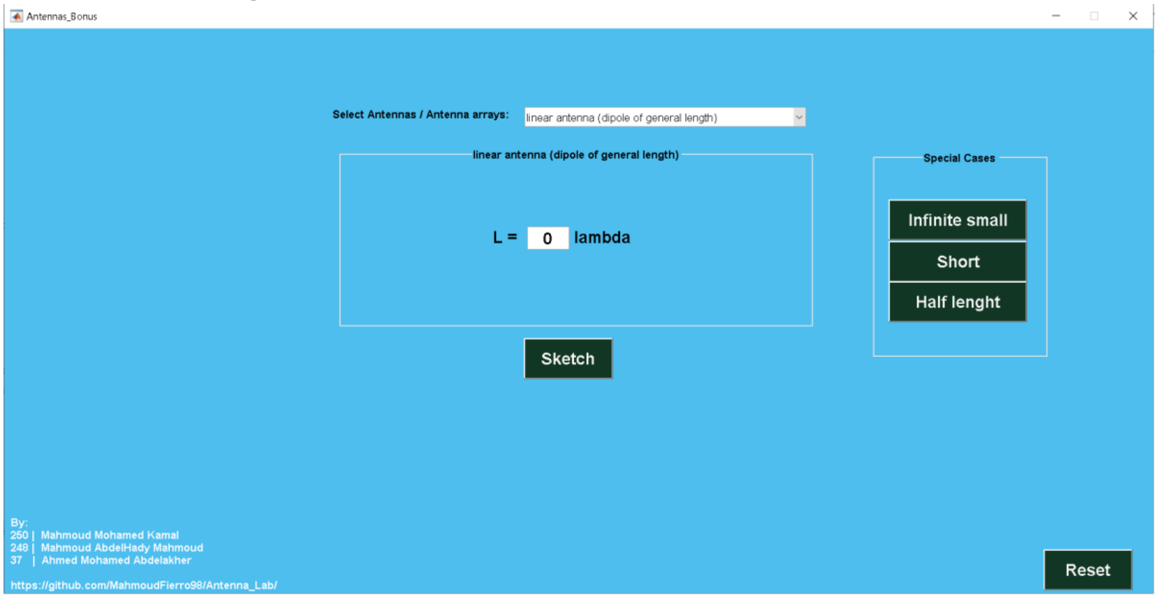

Figure 1: Interface design - linear antenna (dipole of general length).

1.1. Select

To choose any type of antennas you want.

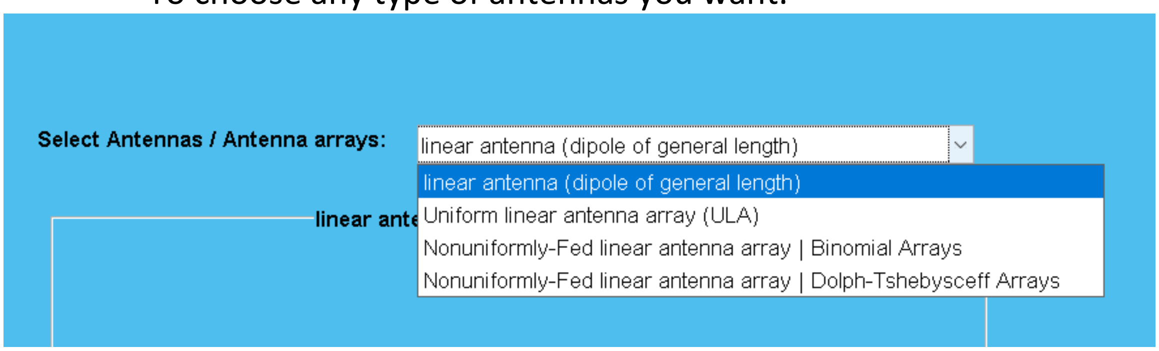

Figure 2: Select.

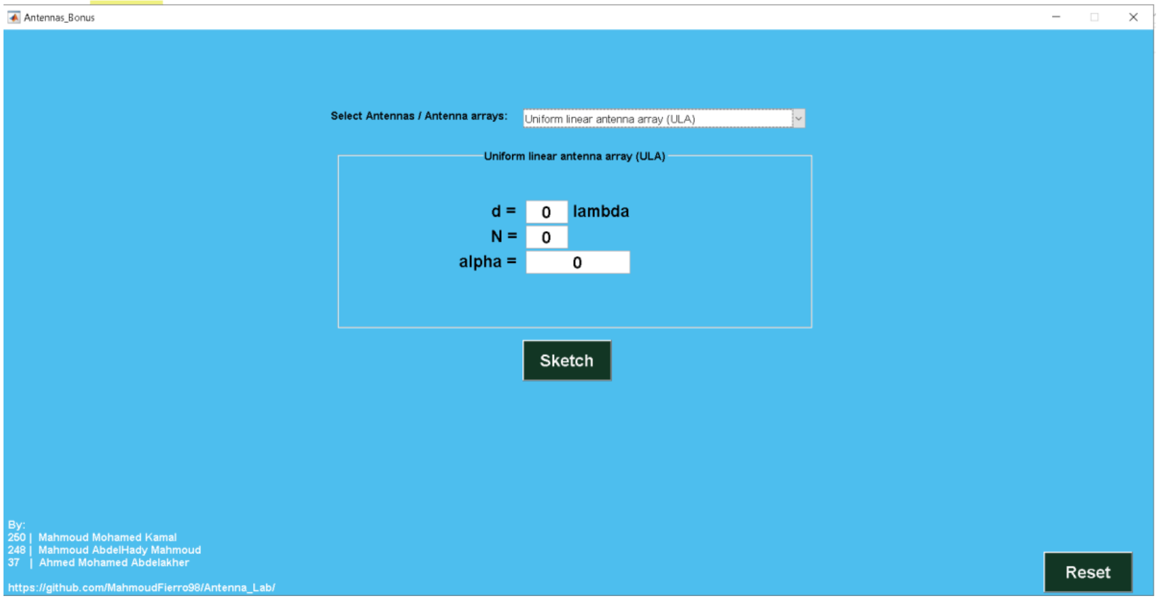

Figure 3: Interface design - Uniform linear antenna array (ULA).

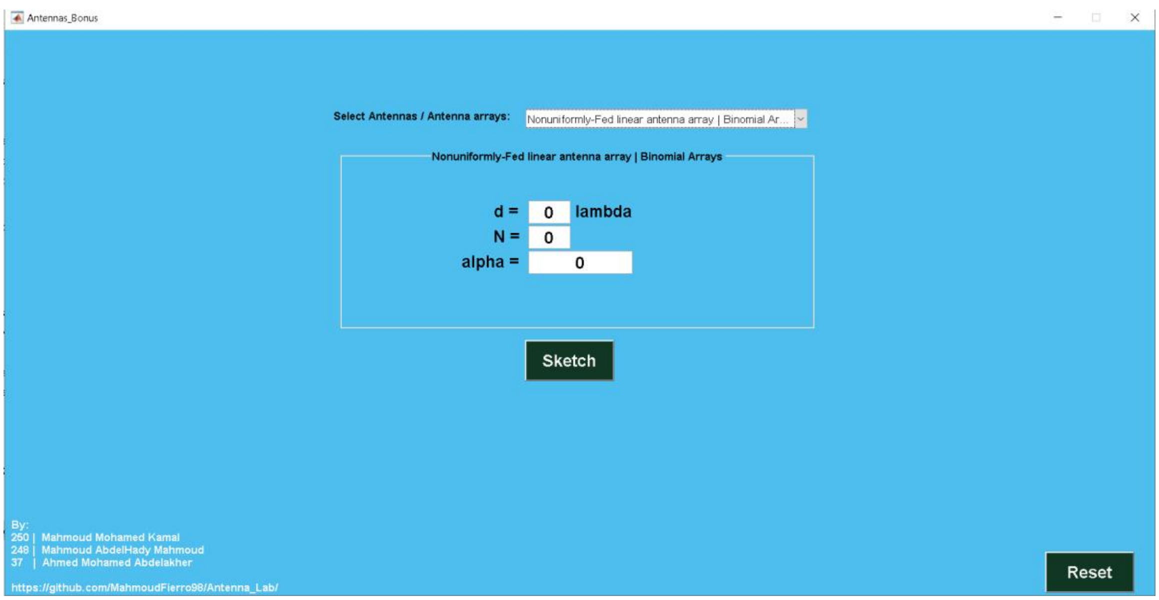

Figure 4: Interface design - Nonuniformly-Fed linear antenna array (Binomial Arrays).

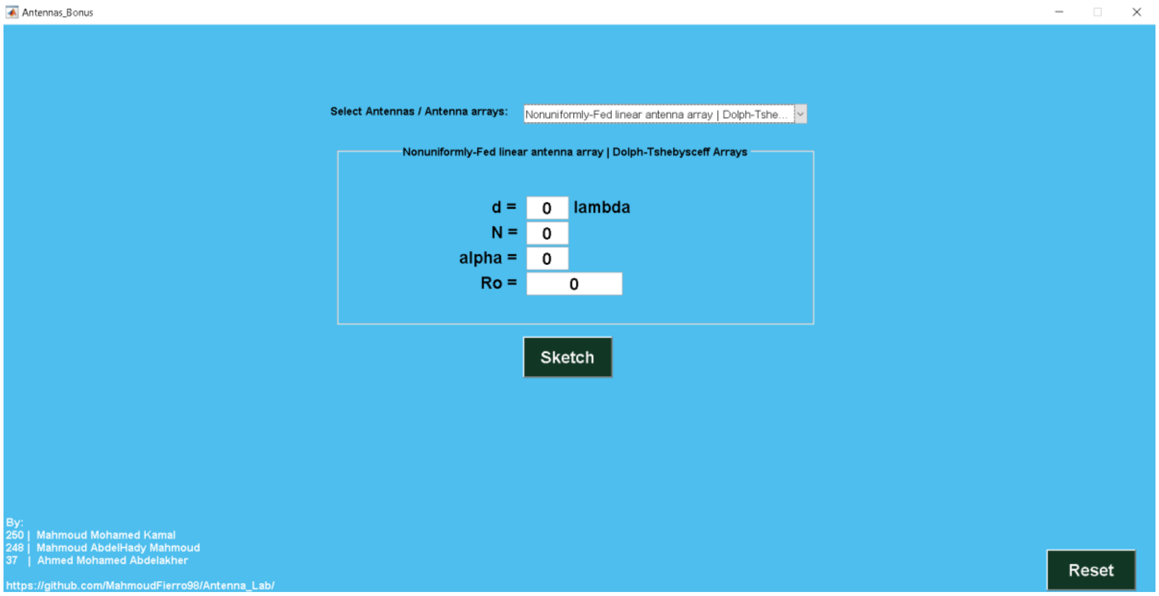

Figure 5: Interface design - Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).

```
% --- Executes on selection change in select.
function select_Callback(hObject, eventdata, handles)
select = get(handles.select,'Value');
set(handles.part1,        'Visible','off');
set(handles.part2,        'Visible','off');
set(handles.part3a,       'Visible','off');
set(handles.part3b,       'Visible','off');
set(handles.special_case, 'Visible','off');
set(handles.s1p,          'Visible','off');
set(handles.s2p,          'Visible','off');
set(handles.s3p,          'Visible','off');
set(handles.str,          'Visible','off');
set(handles.l_1,     'String','0');
set(handles.d_2,     'String','0');
set(handles.N_2,     'String','0');
set(handles.alpha_2, 'String','0');
set(handles.d_3a,    'String','0');
set(handles.N_3a,    'String','0');
set(handles.alpha_3a,'String','0');
set(handles.d_3b,    'String','0');
set(handles.N_3b,    'String','0');
set(handles.alpha_3b,'String','0');
set(handles.Ro_3b,   'String','0');
switch select
    case 1
        set(handles.part1,        'Visible', 'on');
        set(handles.special_case, 'Visible', 'on');
    case 2
        set(handles.part2, 'Visible', 'on');
    case 3
        set(handles.part3a,'Visible', 'on');
    case 4
        set(handles.part3b,'Visible', 'on');
end
```

Figure 6: Code – Select.

1.2. Sketch

Figure 7: Sketch Button.

```
% --- Executes on button press in sketch_buttom.
function sketch_buttom_Callback(hObject, eventdata, handles)
Lambda = 1;
B      = (2*pi)/Lambda;
select = get(handles.select,'Value');
set(handles.special_case, 'Visible','off');
set(handles.s1p,          'Visible','off');
set(handles.s2p,          'Visible','off');
set(handles.s3p,          'Visible','off');
set(handles.str,          'Visible','off');
figure(1);
figure(2);
figure(3);
switch select
    case 1
        set(handles.special_case, 'Visible','on');
        l_1   = get(handles.l_1,'String');
        Theta = linspace(-pi,pi,350);
        Phi   = linspace(-2*pi,2*pi,350);
        L     = str2num(l_1) * Lambda;
        En    = abs((cos(((B*L)/2).*cos(Theta)) - cos((B*L)/2)) ./ sin(Theta));
        if (L < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (L >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        else
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','g');
            set(handles.str, 'String','Done');
            figure(1);
            polar(Theta,En);
            view([90 90]);
            title('linear antenna (dipole of general length) - The 2D pattern of the dipole');
            Phi_3D   = meshgrid(Phi);
            Theta_3D = meshgrid(Theta);
            En_3D    = meshgrid(En);
            X        = En_3D.*sin(Theta_3D).*cos(Phi_3D');
            Y        = En_3D.*sin(Theta_3D).*sin(Phi_3D');
            Z        = En_3D.*cos(Theta_3D);
            figure(2);
            surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
            axis vis3d;
            axis equal;
            lighting gouraud;
            title('linear antenna (dipole of general length) - The 3D pattern of the dipole');
            close(figure(3));
        end
    case 2
        d_2       = get(handles.d_2,     'String');
        N_2       = get(handles.N_2,     'String');
        alpha_2   = get(handles.alpha_2, 'String');
        d         = str2num(d_2) * Lambda;
        N         = str2num(N_2);
        alpha     = str2num(alpha_2);
        Gamma     = linspace(-pi,pi,6000);
        Phi       = linspace(-pi,pi,6000);
        ebsi      = B*d*cos(Gamma) + alpha;
        AF        = abs(sin((N*ebsi)/2) ./ (N * sin(ebsi/2)));
        if (d < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (d >= 0)');
            close(figure(1));
```

```
            close(figure(2));
            close(figure(3));
        elseif (N < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (N >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        else
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','g');
            set(handles.str, 'String','Done');
            figure(1);
            plot(ebsi,AF);
            title('Uniform linear antenna array (ULA) - array factor vs ebsi');
            xlabel('ebsi','fontsize',10);
            ylabel('AF','fontsize',10);
            figure(2);
            polar(Gamma,AF);
            view([90 90]);
            title('Uniform linear antenna array (ULA) - The 2D pattern of the array');
            Phi_3D   = meshgrid(Phi);
            Gamma_3D = meshgrid(Gamma);
            AF_3D    = meshgrid(AF);
            X        = AF_3D.*sin(Gamma_3D).*cos(Phi_3D');
            Y        = AF_3D.*sin(Gamma_3D).*sin(Phi_3D');
            Z        = AF_3D.*cos(Gamma_3D);
            figure(3);
            surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
            lighting gouraud;
            title('Uniform linear antenna array (ULA) - The 3D pattern of the array');
        end
    case 3
        d_3a     = get(handles.d_3a,     'String');
        N_3a     = get(handles.N_3a,     'String');
        alpha_3a = get(handles.alpha_3a, 'String');
        d        = str2num(d_3a) * Lambda;
        N        = str2num(N_3a);
        alpha    = str2num(alpha_3a);
        Theta    = linspace(-pi,pi,6000);
        Phi      = linspace(-pi,pi,6000);
        u        = (B*d*cos(Theta) + alpha)/2;
        AF       = abs(cos(u).^(N-1));
        if (d < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (d >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        elseif (N < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (N >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        else
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','g');
            set(handles.str, 'String','Done');
            figure(1);
            plot(u,AF);
            title('Nonuniformly-Fed linear antenna array | Binomial Arrays - array factor vs u');
            xlabel('u','fontsize',10);
```

```
            ylabel('AF','fontsize',10);
            figure(2);
            polar(Theta,AF);
            view([90 90]);
            title('Nonuniformly-Fed linear antenna array | Binomial Arrays - The 2D pattern of the array');
            Phi_3D   = meshgrid(Phi);
            Theta_3D = meshgrid(Theta);
            AF_3D    = meshgrid(AF);
            X        = AF_3D.*sin(Theta_3D).*cos(Phi_3D');
            Y        = AF_3D.*sin(Theta_3D).*sin(Phi_3D');
            Z        = AF_3D.*cos(Theta_3D);
            figure(3);
            surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
            axis vis3d;
            axis equal;
            lighting gouraud;
            title('Nonuniformly-Fed linear antenna array | Binomial Arrays - The 3D pattern of the array');
        end
    case 4
        d_3b     = get(handles.d_3b,     'String');
        N_3b     = get(handles.N_3b,     'String');
        alpha_3b = get(handles.alpha_3b, 'String');
        Ro_3b    = get(handles.Ro_3b,    'String');
        d        = str2num(d_3b) * Lambda;
        N        = str2num(N_3b);
        alpha    = str2num(alpha_3b);
        Ro       = str2num(Ro_3b);
        M        = N - 1;
        Zo       = cosh((1/M)*acosh(Ro));
        Z        = linspace(-Zo,Zo,6000);
        u_up     = acos(Z./Zo);
        u_down   = -u_up;
        u        = [u_down ; u_up];
        Theta1   = acos(((2.*u_down)-alpha)/(B*d));
        Theta2   = -Theta1;
        Phi      = linspace(-pi,pi,6000);
        AF       = abs(cosh(M.*acosh(Z)));
        if (d < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (d >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        elseif (N < 0)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: (N >= 0)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        elseif (Ro <= 1)
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','r');
            set(handles.str, 'String', 'Error :: always (Ro > 1)');
            close(figure(1));
            close(figure(2));
            close(figure(3));
        else
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','g');
            set(handles.str, 'String','Done');
            figure(1);
            plot(Z,AF);
            title('Nonuniformly-Fed linear antenna array | Dolph-Tshebysceff Arrays - array factor vs Z');
            xlabel('Z','fontsize',10);
```

```
            close(figure(1));
            close(figure(2));
            close(figure(3));
        else
            set(handles.str, 'Visible','on');
            set(handles.str, 'ForegroundColor','g');
            set(handles.str, 'String','Done');
            figure(1);
            plot(Z,AF);
            title('Nonuniformly-Fed linear antenna array | Dolph-Tshebysceff Arrays - array factor vs Z');
            xlabel('Z','fontsize',10);
            ylabel('AF','fontsize',10);
            figure(2);
            polar(Theta1,AF,'-b');
            hold on;
            polar(Theta2,AF,'-b');
            view([90 90]);
            title('Nonuniformly-Fed linear antenna array | Dolph-Tshebysceff Arrays - The 2D pattern of the array');
            Phi_3D   = meshgrid(Phi);
            Theta_3D = meshgrid(Theta1);
            AF_3D    = meshgrid(AF);
            X        = AF_3D.*sin(Theta_3D).*cos(Phi_3D');
            Y        = AF_3D.*sin(Theta_3D).*sin(Phi_3D');
            Z_       = AF_3D.*cos(Theta_3D);
            figure(3);
            surf(X,Y,Z_,'EdgeColor','interp','FaceAlpha',0.1);
            axis vis3d;
            axis equal;
            lighting gouraud;
            title('Nonuniformly-Fed linear antenna array | Dolph-Tshebysceff Arrays - The 3D pattern of the array');
        end
    end
```

Figure 8: Code - Sketch.

1.3. Reset

To reboot program and close all figures.

Figure 9: Reset.

```
% --- Executes on button press in reset_button.
function reset_button_Callback(hObject, eventdata, handles)
set(handles.select,            'Value',1);
set(handles.part1,             'Visible','on');
set(handles.part2,             'Visible','off');
set(handles.part3a,            'Visible','off');
set(handles.part3b,            'Visible','off');
set(handles.special_case,      'Visible','on');
set(handles.s1p,               'Visible','off');
set(handles.s2p,               'Visible','off');
set(handles.s3p,               'Visible','off');
set(handles.str,               'Visible','off');
set(handles.l_1,        'String','0');
set(handles.d_2,        'String','0');
set(handles.N_2,        'String','0');
set(handles.alpha_2,    'String','0');
set(handles.d_3a,       'String','0');
set(handles.N_3a,       'String','0');
set(handles.alpha_3a,   'String','0');
set(handles.d_3b,       'String','0');
set(handles.N_3b,       'String','0');
set(handles.alpha_3b,   'String','0');
set(handles.Ro_3b,      'String','0');
close(figure(1));
close(figure(2));
close(figure(3));
```

Figure 10: Code - Reset.

1.4. Special Cases

Show only if you select linear antenna (dipole of general length).

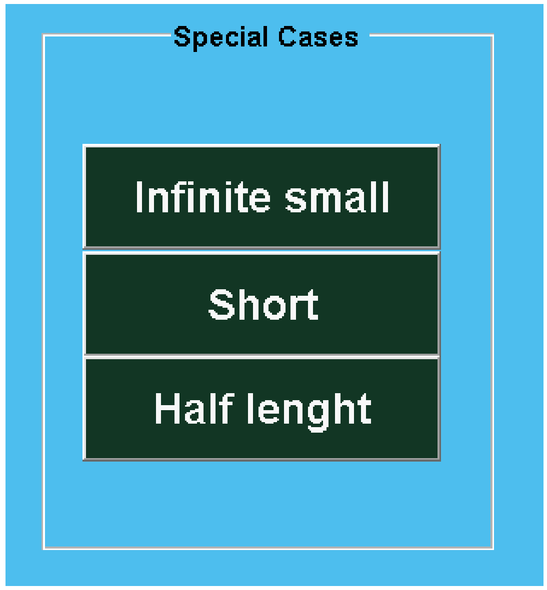

Figure 11: Special Cases.

```
% --- Executes on button press in s1.
function s1_Callback(hObject, eventdata, handles)
Lambda = 1;
B       = (2*pi)/Lambda;
set(handles.s1p,'Visible','on');
set(handles.s2p,'Visible','off');
set(handles.s3p,'Visible','off');
set(handles.str,'Visible','off');
Theta = linspace(-pi,pi,350);
Phi   = linspace(-2*pi,2*pi,350);
L     = (1/50) * Lambda;
En    = abs(sin(Theta));
set(handles.str, 'Visible','on');
set(handles.str, 'ForegroundColor','g');
set(handles.str, 'String','Done');
figure(1);
polar(Theta,En);
view([90 90]);
title('Infinte small dipole - The 2D pattern of the dipole');
Phi_3D   = meshgrid(Phi);
Theta_3D = meshgrid(Theta);
En_3D    = meshgrid(En);
X        = En_3D.*sin(Theta_3D).*cos(Phi_3D');
Y        = En_3D.*sin(Theta_3D).*sin(Phi_3D');
Z        = En_3D.*cos(Theta_3D);
figure(2);
surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
axis vis3d;
axis equal;
lighting gouraud;
title('Infinte small dipole - The 3D pattern of the dipole');
close(figure(3));
```

```
% --- Executes on button press in s2.
function s2_Callback(hObject, eventdata, handles)
Lambda = 1;
B       = (2*pi)/Lambda;
set(handles.s2p,'Visible','on');
set(handles.s1p,'Visible','off');
set(handles.s3p,'Visible','off');
set(handles.str,'Visible','off');
Theta = linspace(-pi,pi,350);
Phi   = linspace(-2*pi,2*pi,350);
L     = (1/10)  * Lambda;
En    = abs(sin(Theta));
set(handles.str, 'Visible','on');
set(handles.str, 'ForegroundColor','g');
set(handles.str, 'String','Done');
figure(1);
polar(Theta,En);
view([90 90]);
title('Short dipole - The 2D pattern of the dipole');
Phi_3D    = meshgrid(Phi);
Theta_3D  = meshgrid(Theta);
En_3D     = meshgrid(En);
X         = En_3D.*sin(Theta_3D).*cos(Phi_3D');
Y         = En_3D.*sin(Theta_3D).*sin(Phi_3D');
Z         = En_3D.*cos(Theta_3D);
figure(2);
surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
axis vis3d;
axis equal;
lighting gouraud;
title('Short dipole - The 3D pattern of the dipole');
close(figure(3));

% --- Executes on button press in s3.
function s3_Callback(hObject, eventdata, handles)
Lambda = 1;
B       = (2*pi)/Lambda;
set(handles.s3p,'Visible','on');
set(handles.s1p,'Visible','off');
set(handles.s2p,'Visible','off');
set(handles.str,'Visible','off');
Theta = linspace(-pi,pi,350);
Phi   = linspace(-2*pi,2*pi,350);
L     = (1/2)  * Lambda;
En    = abs((cos(((B*L)/2).*cos(Theta)) - cos((B*L)/2)) ./ sin(Theta));
set(handles.str, 'Visible','on');
set(handles.str, 'ForegroundColor','g');
set(handles.str, 'String','Done');
figure(1);
polar(Theta,En);
view([90 90]);
title('lambda/2 dipole - The 2D pattern of the dipole');
Phi_3D    = meshgrid(Phi);
Theta_3D  = meshgrid(Theta);
En_3D     = meshgrid(En);
X         = En_3D.*sin(Theta_3D).*cos(Phi_3D');
Y         = En_3D.*sin(Theta_3D).*sin(Phi_3D');
Z         = En_3D.*cos(Theta_3D);
figure(2);
surf(X,Y,Z,'EdgeColor','interp','FaceAlpha',0.1);
axis vis3d;
axis equal;
lighting gouraud;
title('lambda/2 dipole - The 3D pattern of the dipole');
close(figure(3));
```

Figure 12: Code - Special Cases.

2. Examples

2.1. Part 1: linear antenna (dipole of general length)

Example 1: $l = 2\lambda$

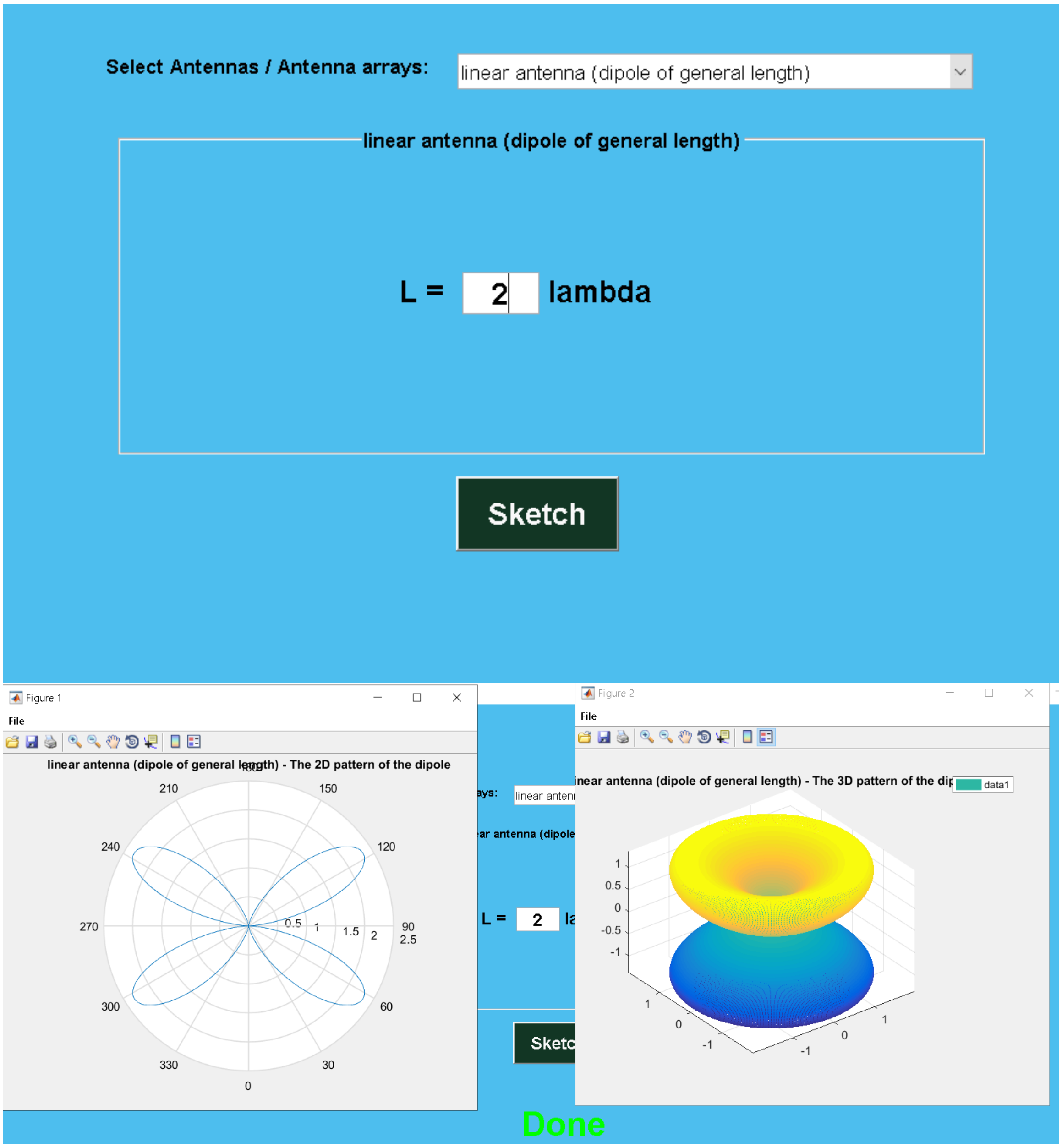

Figure 13: Example 1 - Part 1: linear antenna (dipole of general length).

Example 2: $Errors$
$if\ l < 0$

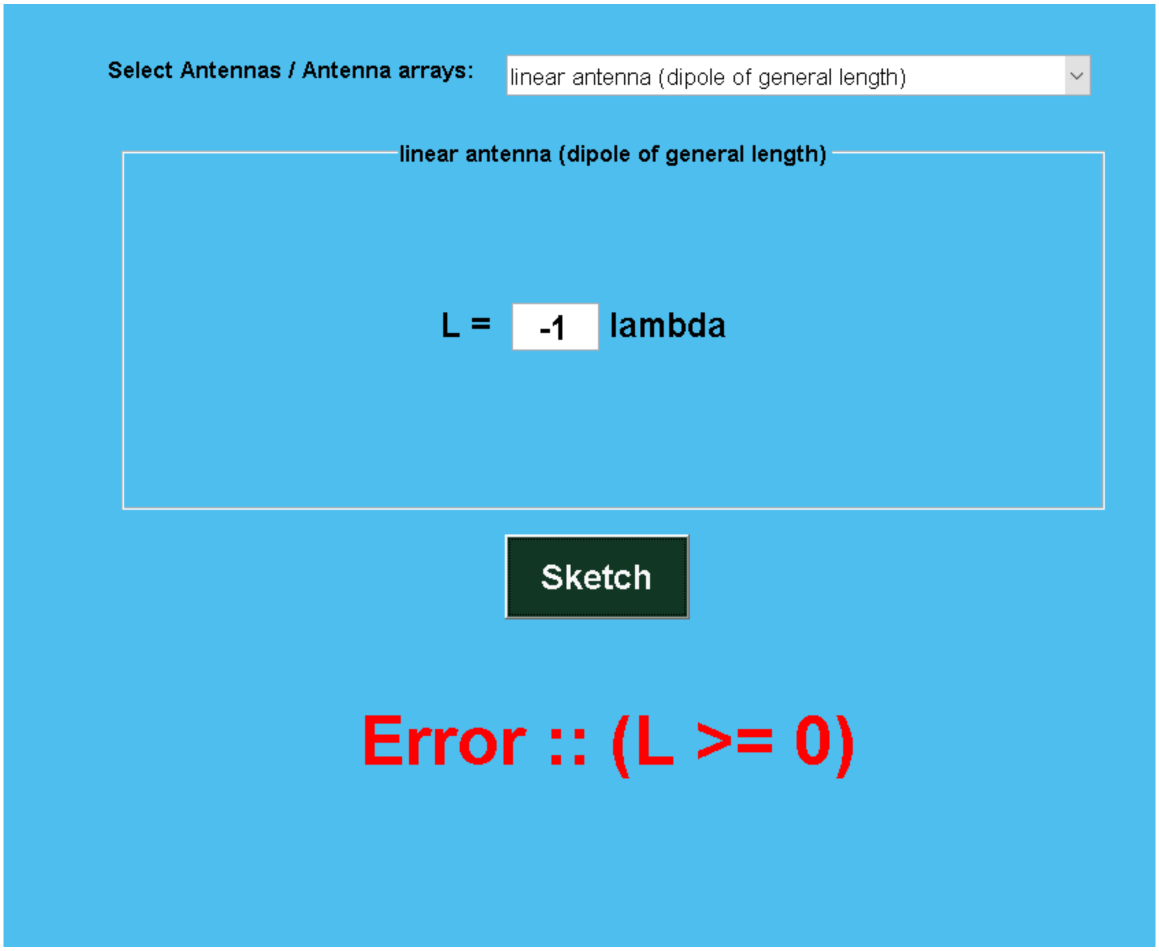

Figure 14: Example 2 (Errors) - Part 1: linear antenna (dipole of general length).

2.2. Part 2: Uniform linear antenna array (ULA)

Example 1: $d = \frac{4\lambda}{7}, \mathrm{N} = 7, \alpha = \frac{-4\pi}{7}$

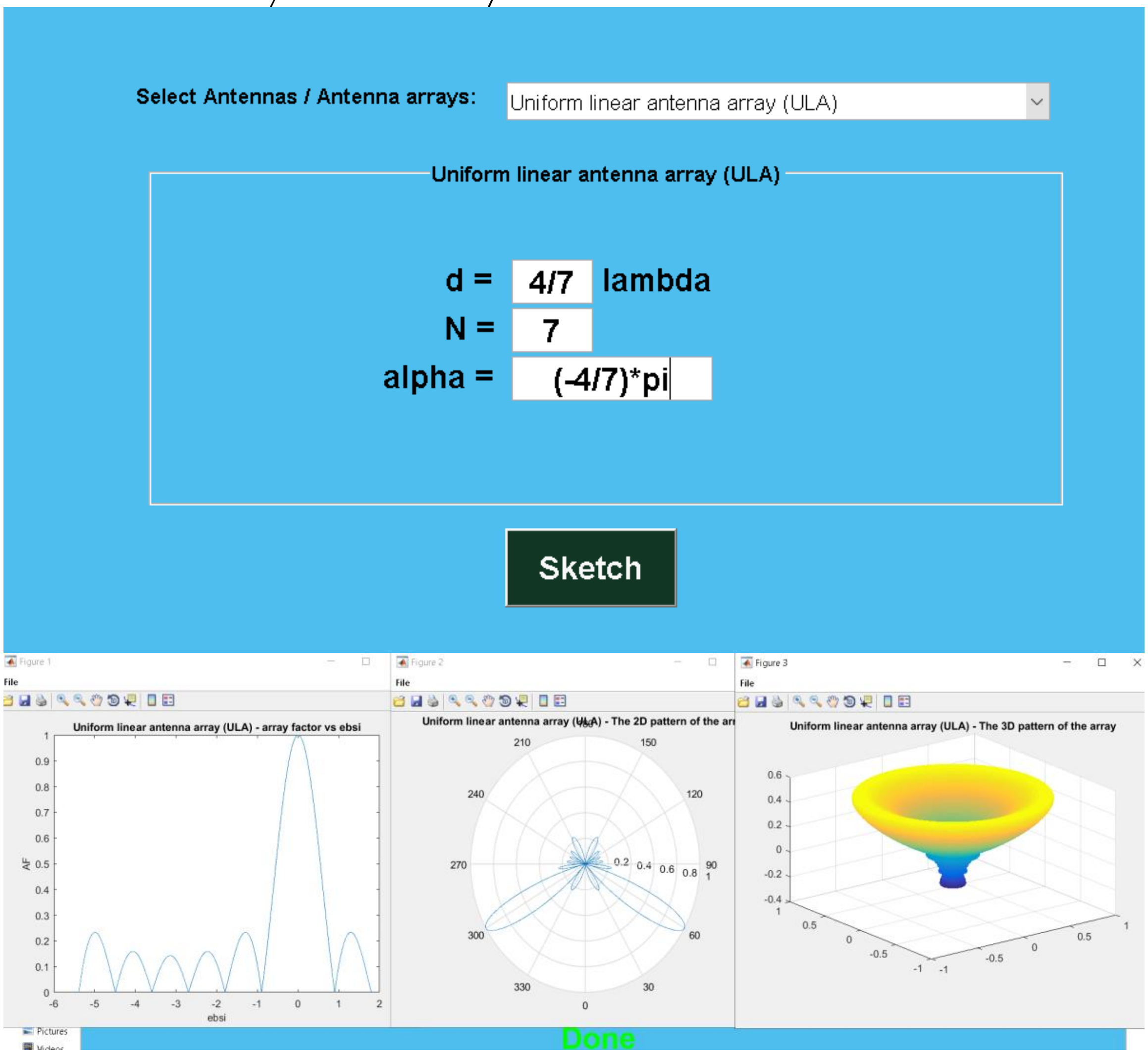

Figure 15: Example 1 - Part 2: Uniform linear antenna array (ULA).

Example 3: $Errors$
$if\ d < 0\ or\ N < 0.$

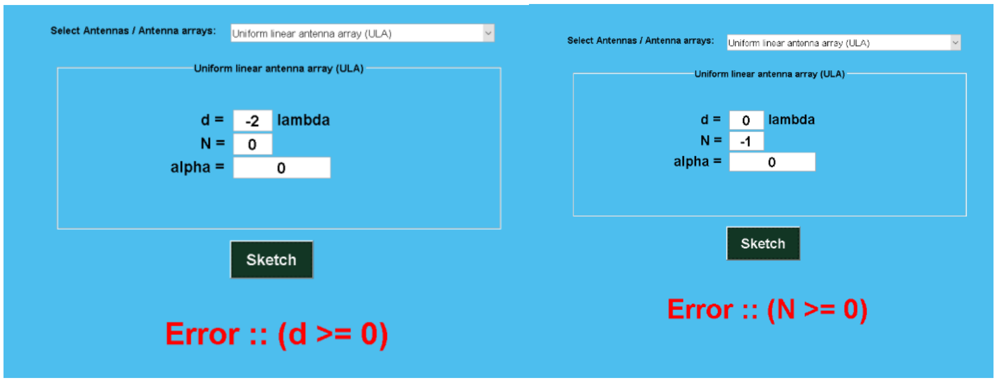

Figure 16: Example 2 (Errors) - Part 2: Uniform linear antenna array (ULA).

2.3. Part 3: Nonuniformly-Fed linear antenna array

A. Binomial Arrays

Example 1: $d = \frac{3\lambda}{4}, \mathrm{N} = 8, \alpha = 0$

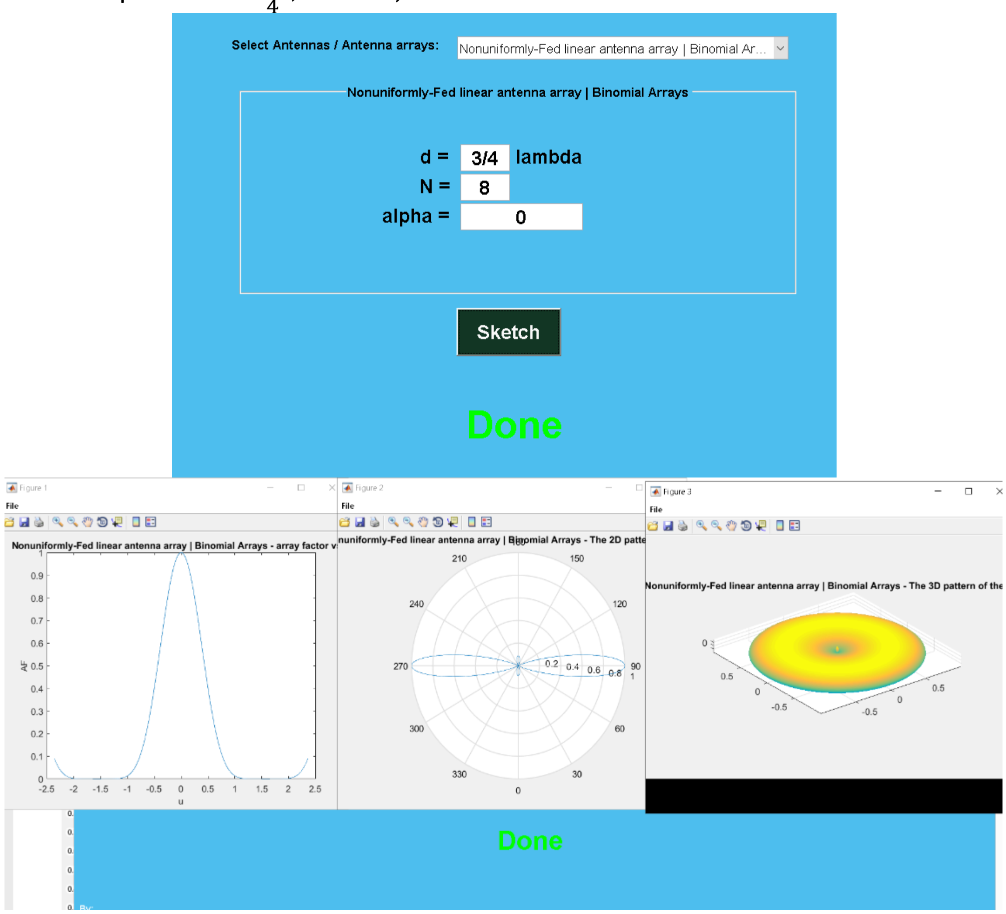

Figure 17: Example 1 - Part 3: Nonuniformly-Fed linear antenna array (Binomial Arrays).

Example 3: $Errors$
$if\ d < 0\ or\ N < 0.$

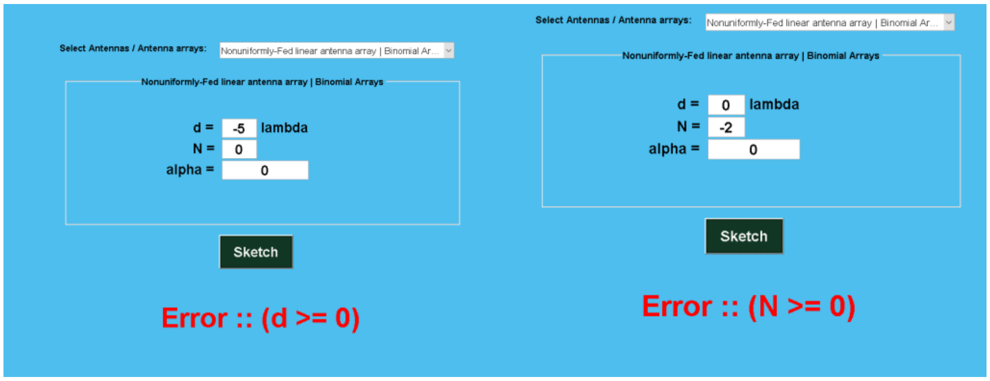

Figure 18: Example 2 (Errors) - Part 3: Nonuniformly-Fed linear antenna array (Binomial Arrays).

B. Dolph-Tschebysceff Arrays

Example 1: $d = \frac{\lambda}{2}, \mathrm{N} = 6, \alpha = -\pi, R_0 = 10.$

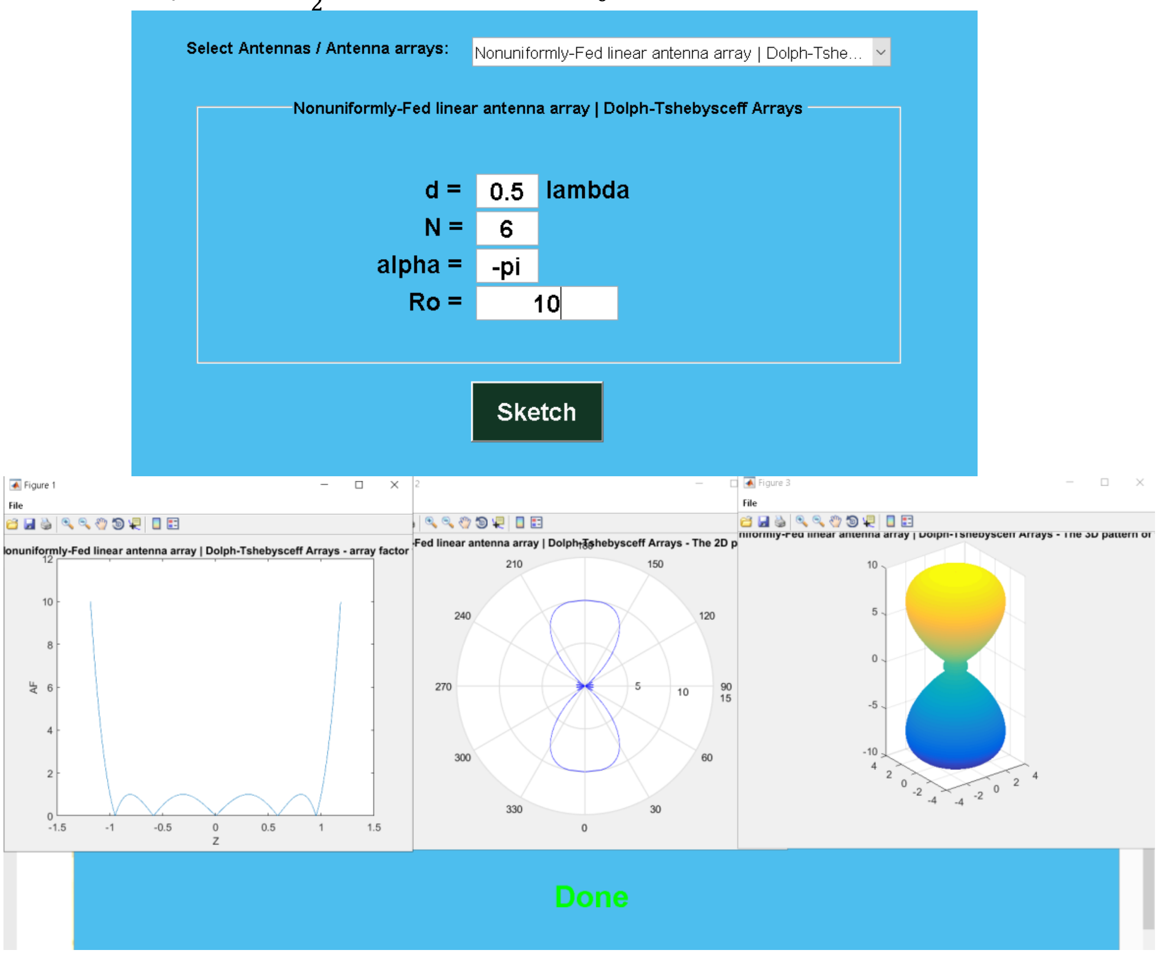

Figure 19: Example 1 - Part 3: Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).

Example 3: $Errors$

$if\ d < 0\ or\ N < 0$, we will ask you again.

$Always\ R_0 > 1.$

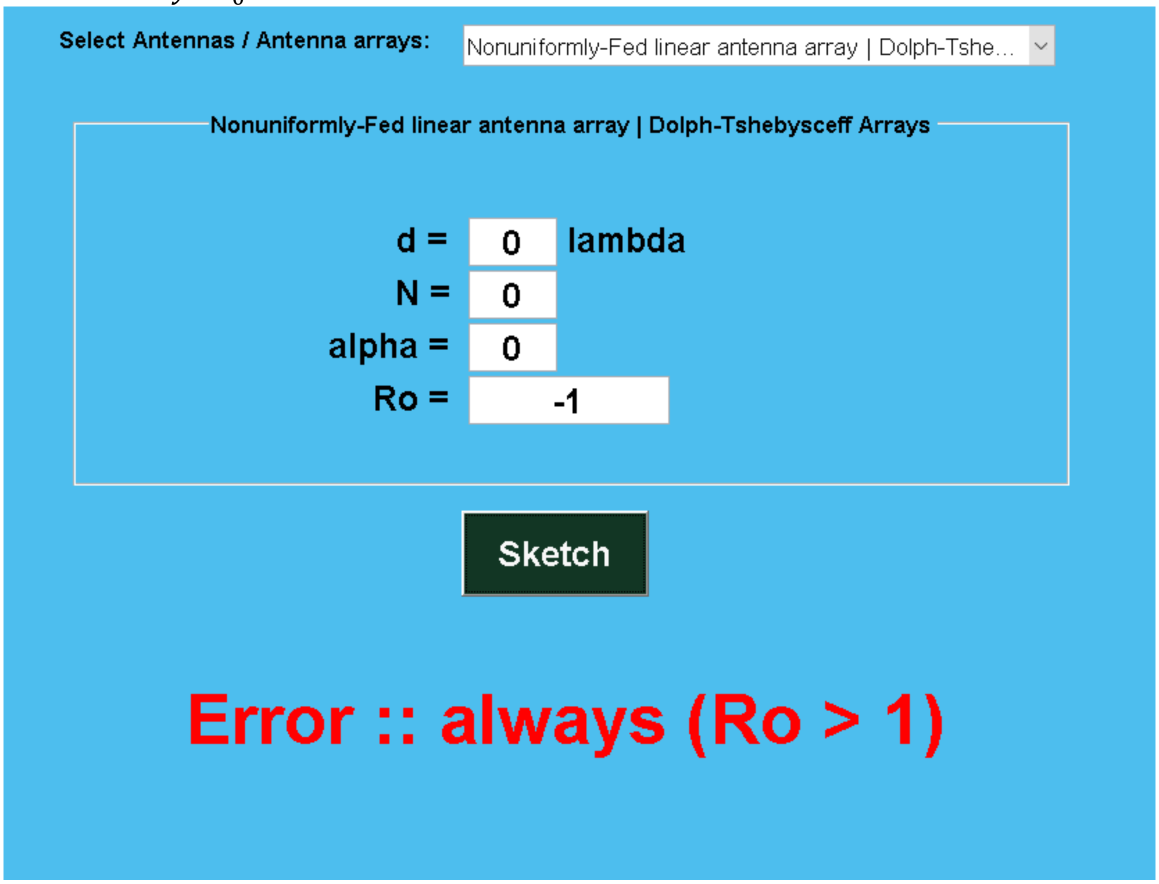

Figure 20: Example 2 (Errors) - Part 3: Nonuniformly-Fed linear antenna array (Dolph-Tschebysceff Arrays).

2.4. Special Case for dipole antenna

A. Infinite small dipole

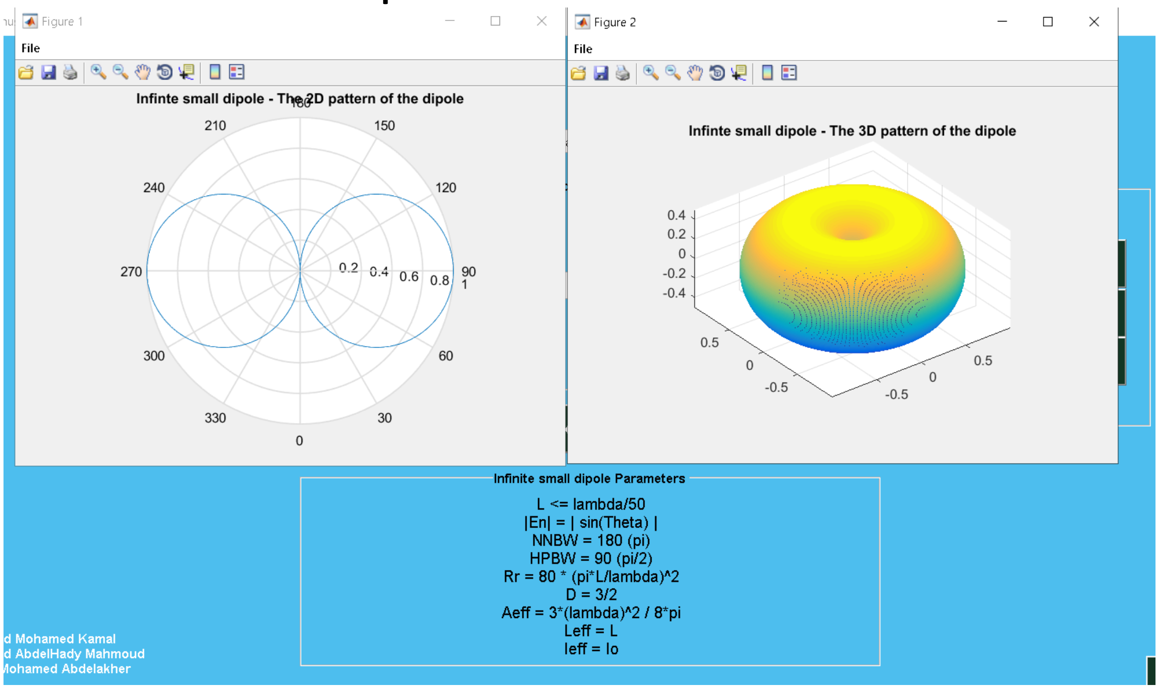

Figure 21: Infinite small dipole.

B. Short dipole

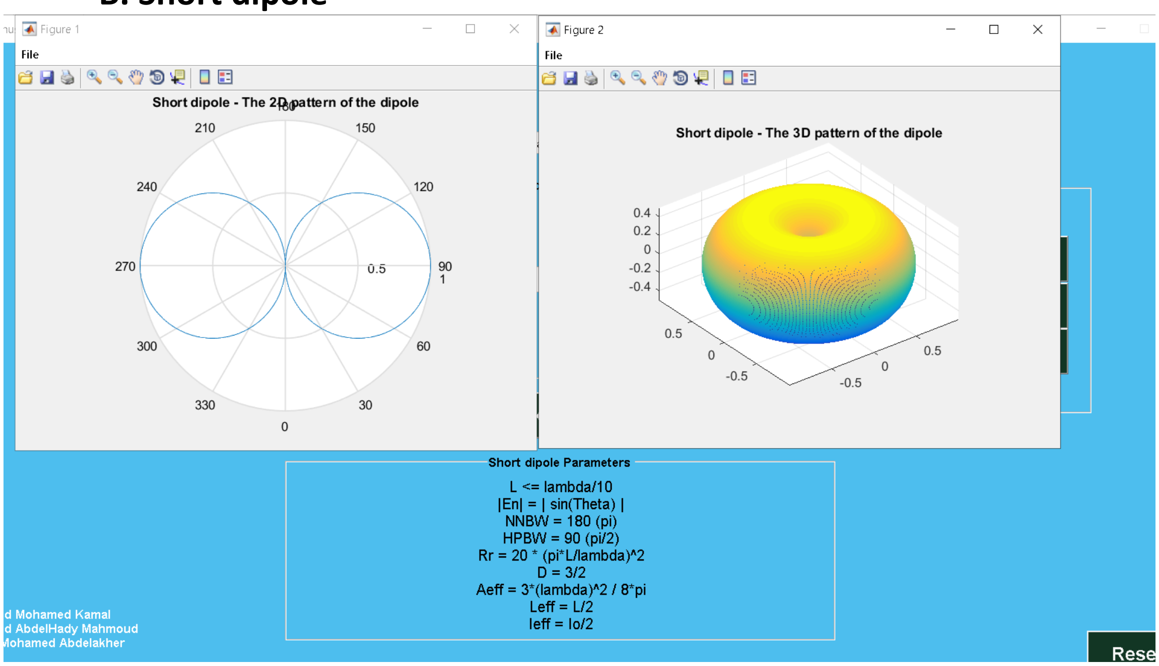

Figure 22: Short dipole.

C. $\lambda/2$ dipole

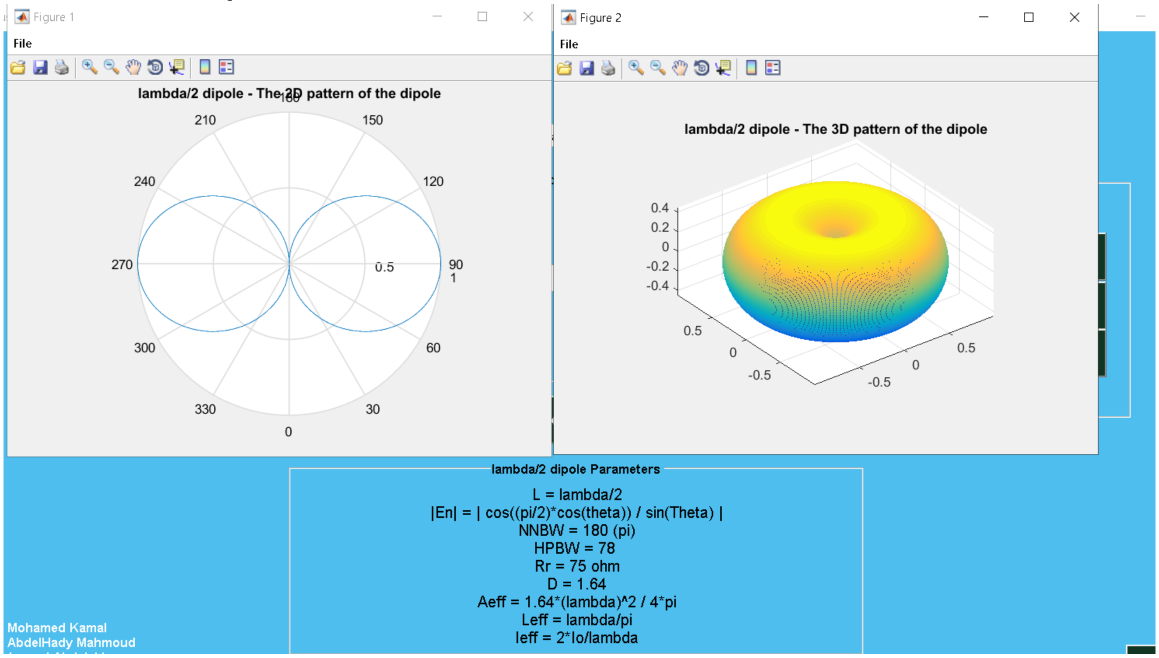

Figure 23: $\lambda/2$ dipole.

Electrical Engineering Department,

Fourth Year - Communications & Electronics.

EE 466 ANTENNA

Patch Antenna

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Ahmed Mohamed Abdelakher	1	37

➢ Contents

1. Introduction to Patch Antenna	**Page 2**
2. Matlab	**Page 6**
3. Copy of Code	**Page 9**

➢ List of Figures

Figure 1: Single Patch Antenna with 3D Radiation Pattern, Azimuth Plane Pattern and Elevation Plane Pattern.	Page 2
Figure 2: A 4x4 Patch Array Antenna with 3D Radiation Pattern, Azimuth Plane Pattern and Elevation Plane Pattern.	Page 3
Figure 3: Azimuth Plane Patterns of the 4 x 4 Patch Array in Polar and Rectangular Coordinates.	Page 4
Figure 4: Elevation Plane Patterns of the 4 x 4 Patch Array in Polar and Rectangular Coordinates.	Page 4
Figure 5: Code.	Page 6
Figure 6: Create and view a microstrip patch with specified parameters.	Page 7
Figure 7: Plot the radiation pattern of the antenna at a frequency of 1.67 GHz.	Page 7
Figure 8: Calculate and plot the impedance of the antenna over the specified frequency range.	Page 8
Figure 9: Patch 1X4 Antenna Array.	Page 8
Figure 10: Create a microstrip patch antenna using 'FR4' as the dielectric substrate.	Page 8

https://github.com/MahmoudFierro98/Antenna_Lab/

1. Introduction to Patch Antenna

Directional antennas are used for coverage as well as point-to-point links. They can be patch antennas, dishes, horns or a whole host of other varieties. They all accomplish the same goal: radiating their energy out in a particular direction.
Patch Antennas
A patch antenna, in its simplest form, is just a single rectangular (or circular) conductive plate that is spaced above a ground plane. Patch antennas are attractive due to their low profile and ease of fabrication.
The radiation pattern of a single patch is characterized by a single main lobe of moderate beamwidth. Frequently, the beamwidths in the azimuth and elevation planes are similar, resulting in a fairly circular beam, although this is by no means universal. The beamwidths can be manipulated to produce an antenna with higher or lower gain, depending on the requirements. An antenna built with a single patch will have a maximum gain of about 9 dBi or a bit less.
The patch antenna in Figure 1 shows how simple these antennas can be. This is a simple rectangular patch built over a rectangular ground plane. The radiation patterns exhibit typical patch antenna characteristics. There is a single main lobe with a fairly wide beamwidth with shallow nulls pointing up and down from the antenna. Other than that, there aren't many features to the pattern. The one shown in Figure 1 is designed to have higher gain rather than symmetrical plane patterns. The gain is about 8.8 dBi with an azimuth plane beamwidth of 70 degrees and an elevation plane beamwidth of 57 degrees. These are not uncommon beamwidths for single patch antennas.

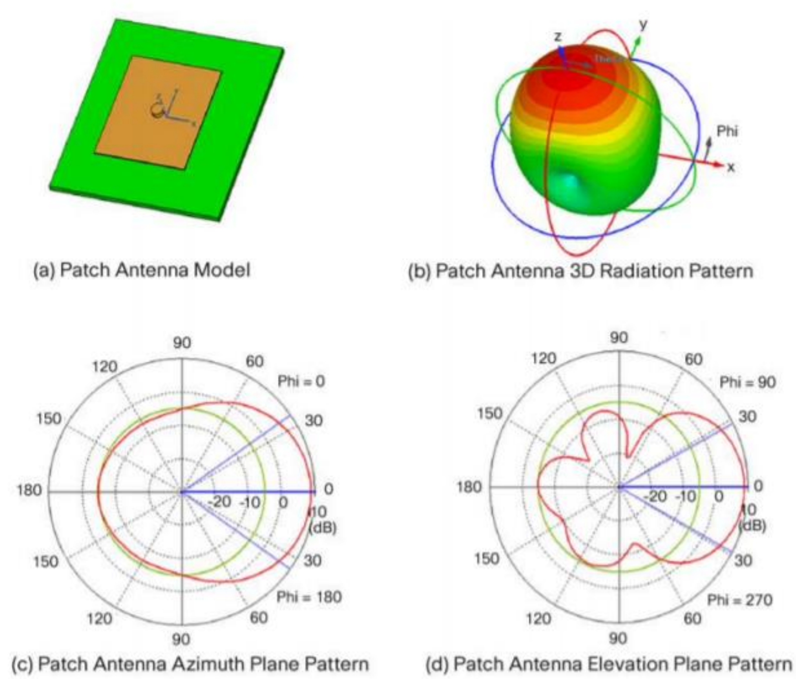

Figure 1: Single Patch Antenna with 3D Radiation Pattern, Azimuth Plane Pattern and Elevation Plane Pattern.

The azimuth and elevation plane patterns are derived by simply slicing through the 3D radiation pattern. In this case, the azimuth plane pattern is obtained by slicing through the x-z plane, and the elevation plane pattern is formed by slicing through the y-z plane. Note that there is one main lobe that is radiated out from the front of the antenna. There are three back lobes in the elevation plane (in this case), the strongest of which happens to be 180 degrees behind the peak of the main lobe, establishing the front-to-back ratio at about 14 dB. That is, the gain of the antenna 180 degrees behind the peak is 14 dB lower than the peak gain.

Again, it doesn't matter if these patterns are shown pointing up, down, to the left or to the right. That is usually an artifact of the measurement system. A patch antenna radiates its energy out from the front of the antenna. That will establish the true direction of the patterns.

Patch Array Antennas

A patch array antenna is, in general, some arrangement of multiple patch antennas that are all driven by the same source. Frequently, this arrangement consists of patches arranged in orderly rows and columns (a rectangular array) as shown in Figure 2. The reason for these types of arrangements is higher gain. Higher gain commonly implies a narrower beamwidth and that is, indeed, the case with patch arrays. The array shown here has a gain of about 18 dBi with an azimuth and elevation plane beamwidth of about 20 degrees. Notice that the back lobes are very small and that the front-to-back ratio is about 30 dB. The first sidelobes are down from the peak about 14 dB.

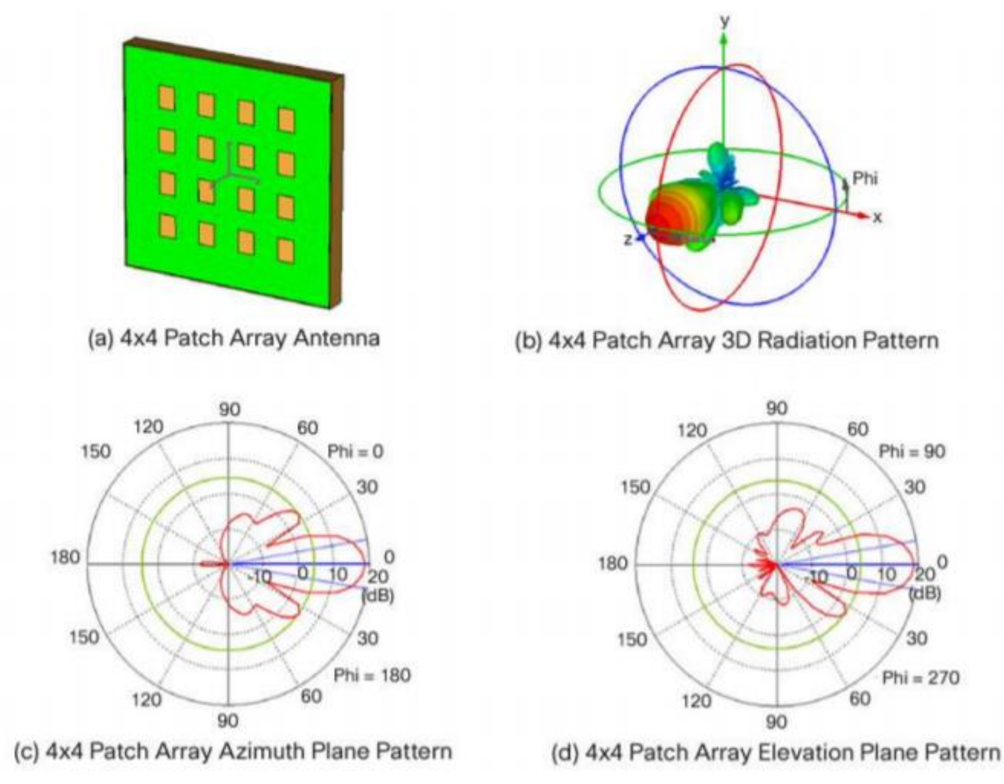

Figure 2: A 4x4 Patch Array Antenna with 3D Radiation Pattern, Azimuth Plane Pattern and Elevation Plane Pattern.

Antenna patterns are frequently shown normalized to the peak gain. The peak gain (in dBi) is simply subtracted from the gain at all the points on the curve and the pattern is plotted with the new values. These patterns are expressed in dB with 0 dB corresponding to the peak gain. A normalized pattern is especially useful when the sidelobe levels and the depth of the nulls are of interest since it's easier to read their respective levels. The patterns of the patch array shown here have enough lobes and features that a look at their normalized patterns in rectangular coordinates might be interesting. Figure 3 shows the azimuth plane in both polar and Cartesian (rectangular) coordinates. Figure 4 shows the elevation plane in both coordinate systems.
The side lobe levels are easily readable from the rectangular plots. In the azimuth plane, the side lobes are down about 14 dB from the peak. The first side lobe levels are more than 14 dB down in the elevation plane. Note that the back lobe is 30 dB down from the peak. That means the front-toback ratio is 30 dB. Of course, if the patterns are given in normalized form, the peak gain must be given to determine absolute levels of any of the pattern parameters. The side lobes are labeled in all the plots. Notice that the lower side lobes are to the left of the main beam in the Cartesian plots. These plots show the main beam at 0 degrees, so below the main beam would imply negative angle and above the main beam would imply positive angle.

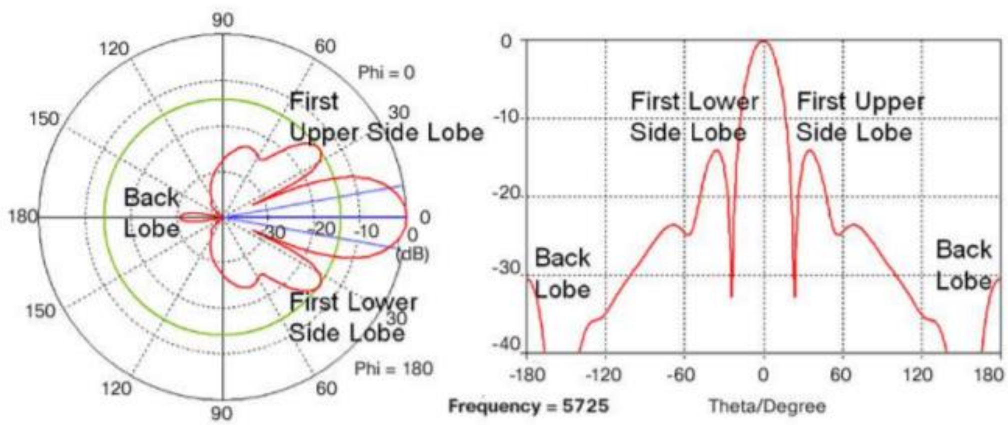

Figure 3: Azimuth Plane Patterns of the 4 x 4 Patch Array in Polar and Rectangular Coordinates.

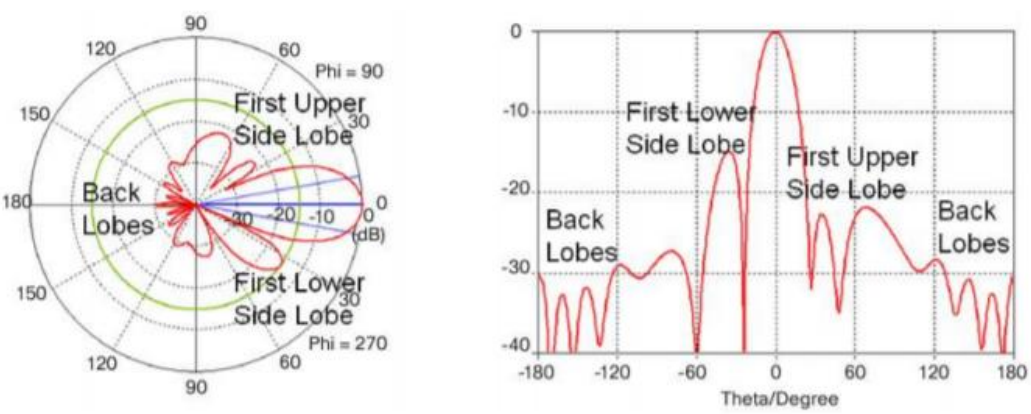

Figure 4: Elevation Plane Patterns of the 4 x 4 Patch Array in Polar and Rectangular Coordinates.

Microstrip antenna

In telecommunication, a microstrip antenna (also known as a printed antenna) usually means an antenna fabricated using photolithographic techniques on a printed circuit board (PCB). It is a kind of internal antenna. They are mostly used at microwave frequencies. An individual microstrip antenna consists of a patch of metal foil of various shapes (a patch antenna) on the surface of a PCB (printed circuit board), with a metal foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array. The antenna is usually connected to the transmitter or receiver through foil microstrip transmission lines. The radio frequency current is applied (or in receiving antennas the received signal is produced) between the antenna and ground plane. Microstrip antennas have become very popular in recent decades due to their thin planar profile which can be incorporated into the surfaces of consumer products, aircraft and missiles; their ease of fabrication using printed circuit techniques; the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas.

The most common type of microstrip antenna is commonly known as patch antenna. Antennas using patches as constitutive elements in an array are also possible. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

2. Matlab

Patch_Antenna.m

```matlab
%%
% Alexandria University - Faculty of Engineering
% Electrical and Electronic Engineering Department - Fourth Year - Communications & Electronics
%
% Course: Antenna Lab
% Patch Antenna
%
% Name    : Mahmoud Mohamed Kamal Ismail - Mahmoud AbdElHady Mahmoud - Ahmed Mohamed Abdelakher
% Section : 7                            - 7                        - 1
% Seat No.: 250                          - 248                      - 37

%%
clear;
close all;
clc;

%% Create and view a microstrip patch with specified parameters.
pm = patchMicrostrip('Length',75e-3, 'Width',37e-3,                ...
        'GroundPlaneLength',120e-3, 'GroundPlaneWidth',120e-3);
pm.Height = 0.01;
pm
figure(1);
show(pm);

%% Plot the radiation pattern of the antenna at a frequency of 1.67 GHz.
figure(2);
pattern(pm,1.67e9);

%% Calculate and plot the impedance of the antenna over the specified frequency range.
figure(3);
impedance(pm,linspace(0.5e9,2e9,50));

%% Patch Antenna Array
a = linearArray;
a.Element        = pm;
a.ElementSpacing = 0.1;
a.NumElements    = 4;
figure(4);
layout(a);
figure(5);
pattern(a,1.67e9);

%% Create a microstrip patch antenna using 'FR4' as the dielectric substrate.
d  = dielectric('FR4');
pm = patchMicrostrip('Length',75e-3,'Width',37e-3,      ...
        'GroundPlaneLength',120e-3,'GroundPlaneWidth',120e-3, ...
        'Substrate',d)
figure(6);
show(pm);
```

Figure 5: Code.

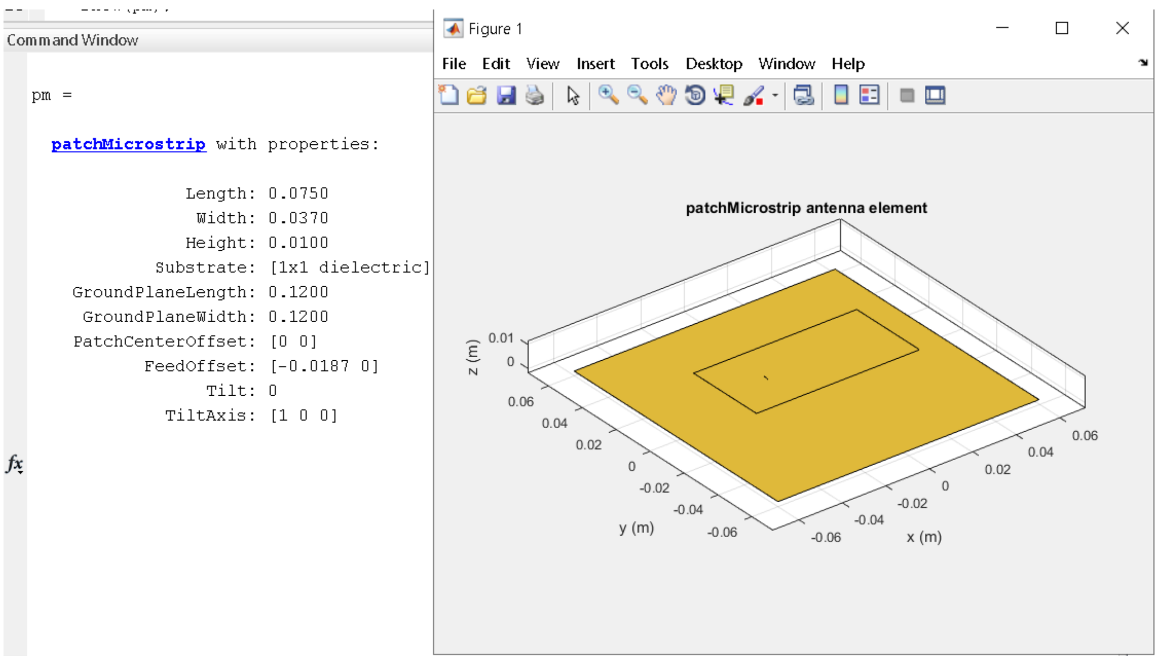

Figure 6: Create and view a microstrip patch with specified parameters.

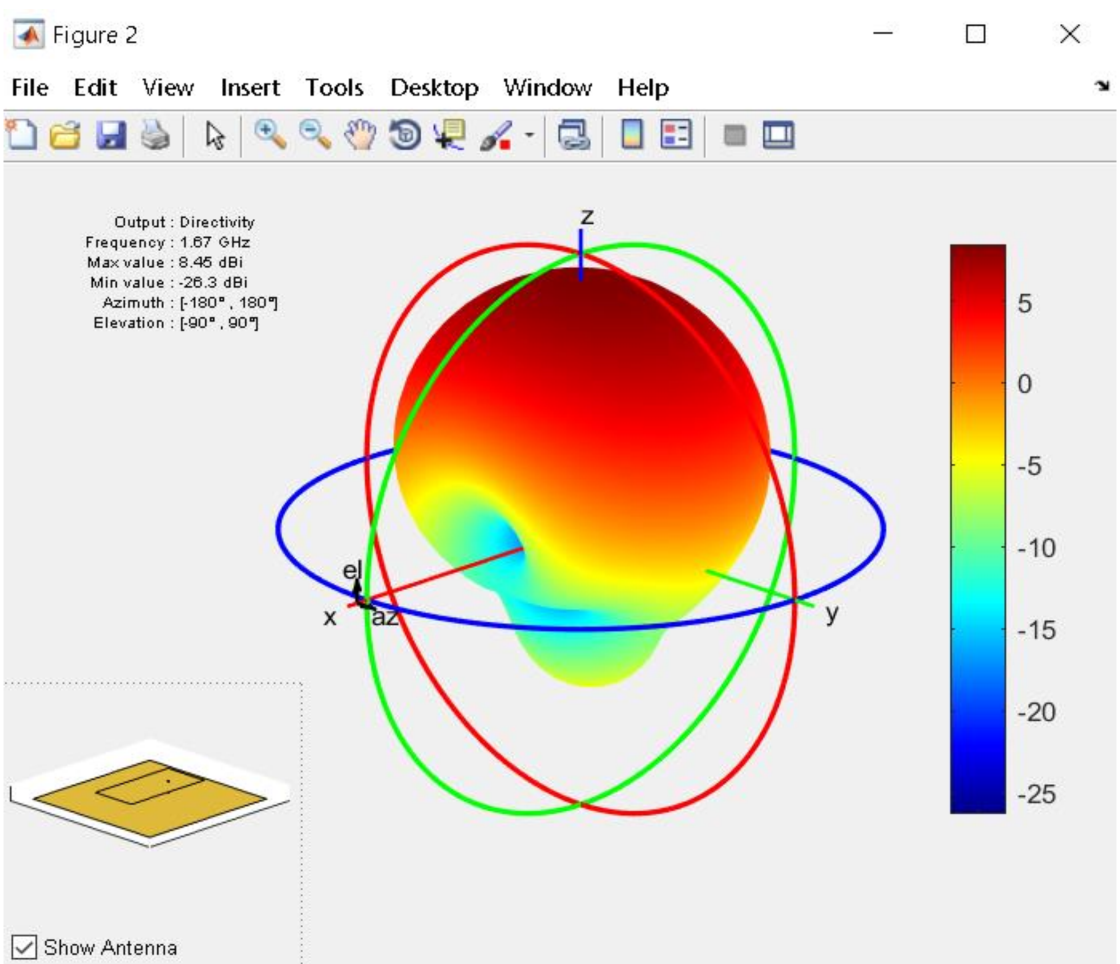

Figure 7: Plot the radiation pattern of the antenna at a frequency of 1.67 GHz.

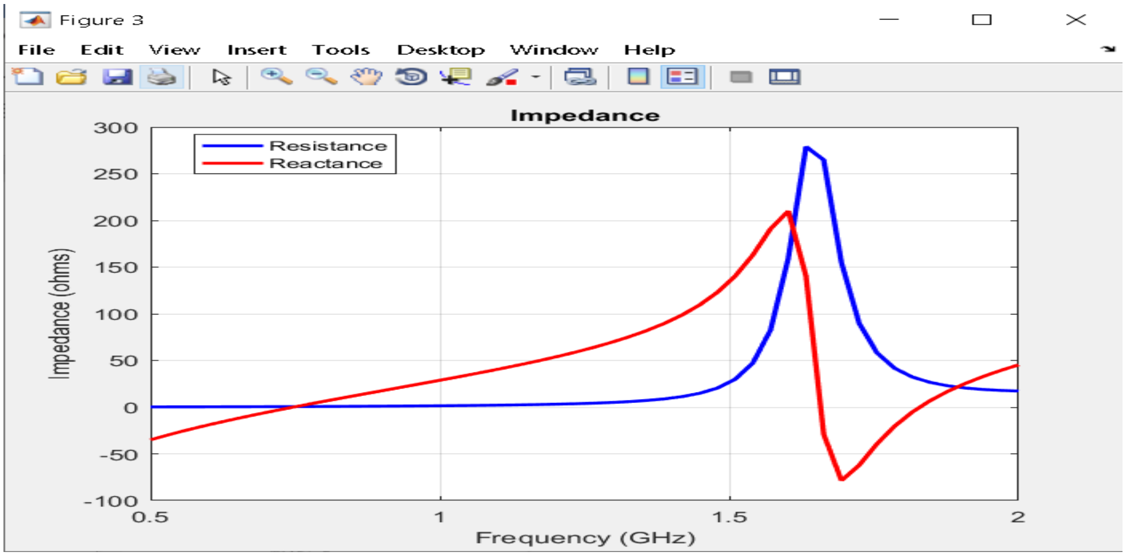

Figure 8: Calculate and plot the impedance of the antenna over the specified frequency range.

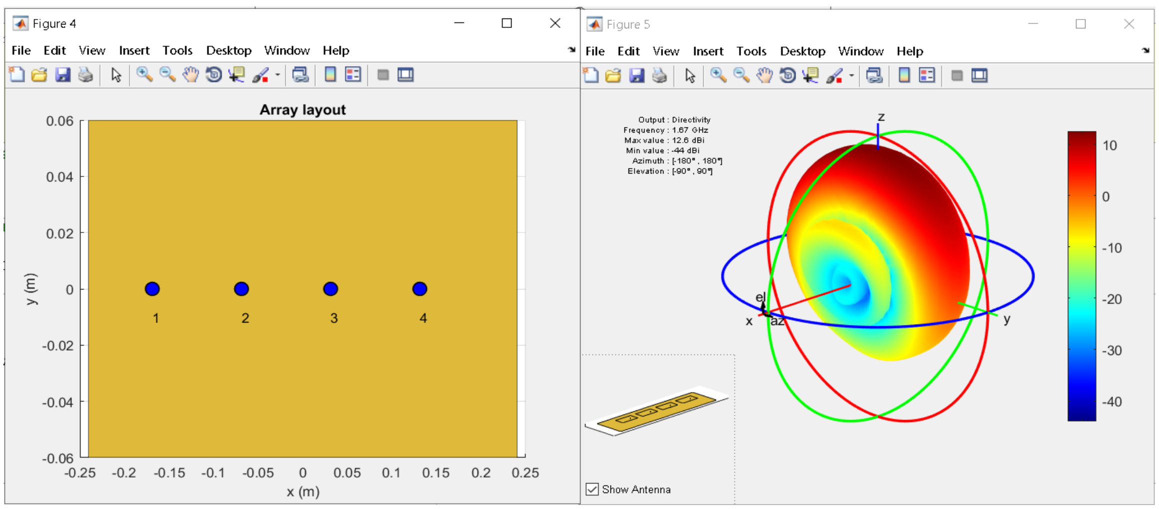

Figure 9: Patch 1X4 Antenna Array.

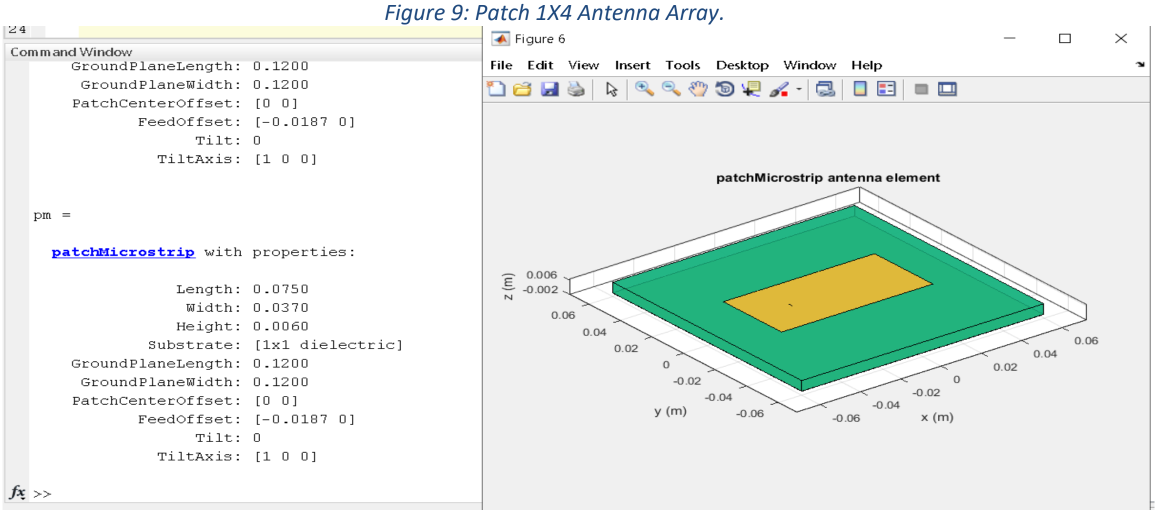

Figure 10: Create a microstrip patch antenna using 'FR4' as the dielectric substrate.

3. Copy of Code

```
%%
% Alexandria University - Faculty of Engineering
% Electrical and Electronic Engineering Department -
Fourth Year - Communications & Electronics
%
% Course: Antenna Lab
% Patch Antenna
%
% Name    : Mahmoud Mohamed Kamal Ismail - Mahmoud
AbdElHady Mahmoud - Ahmed Mohamed Abdelakher
% Section : 7                            - 7
- 1
% Seat No.: 250                          - 248
- 37

%%
clear;
close all;
clc;

%% Create and view a microstrip patch with specified
parameters.
pm = patchMicrostrip('Length',75e-3, 'Width',37e-3,
...
        'GroundPlaneLength',120e-3,
'GroundPlaneWidth',120e-3);
pm.Height = 0.01;
pm
figure(1);
show(pm);

%% Plot the radiation pattern of the antenna at a
frequency of 1.67 GHz.
figure(2);
pattern(pm,1.67e9);

%% Calculate and plot the impedance of the antenna over
the specified frequency range.
figure(3);
impedance(pm,linspace(0.5e9,2e9,50));

%% Patch Antenna Array
a = linearArray;
```

```
a.Element        = pm;
a.ElementSpacing = 0.1;
a.NumElements    = 4;
figure(4);
layout(a);
figure(5);
pattern(a,1.67e9);

%% Create a microstrip patch antenna using 'FR4' as the 
dielectric substrate.
d  = dielectric('FR4');
pm = patchMicrostrip('Length',75e-3,'Width',37e-3, 
...
        'GroundPlaneLength',120e-
3,'GroundPlaneWidth',120e-3, ...
        'Substrate',d)
figure(6);
show(pm);
```

References: https://www.industrialnetworking.com/pdf/Antenna-Patterns.pdf

https://www.antenna-theory.com/antennas/patches/antenna.php

https://en.wikipedia.org/wiki/Microstrip_antenna

https://www.mathworks.com/help/antenna/ref/patchmicrostrip.html