Rendering of Antenna 3D Beam Pattern Geometry using 4NEC2 Output File

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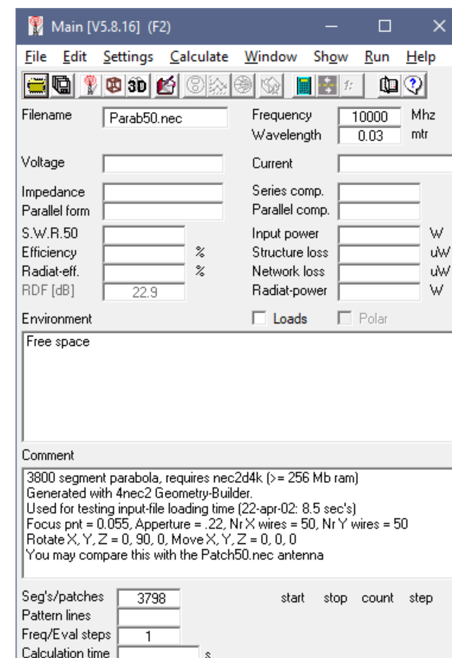
Introduction : 4NEC2 Program

- NEC2 is ..
  - Common program to analyze antenna beam pattern.
  - Programed in FORTRAN, therefore it is not familiar and difficult to use.
- 4NEC2
  - Arie Voors encapsulates NEC2 code with windows-based GUI and provides good environment to use NEC2 code.
  - 4NEC2 program is easy to use.



Introduction : 4NEC2 Output File

- Input/output files are ascii text files and easy to read.
- 4NEC2 is good for a beginner of Antenna beam pattern to understand.

3YAGI20.out - Notepad

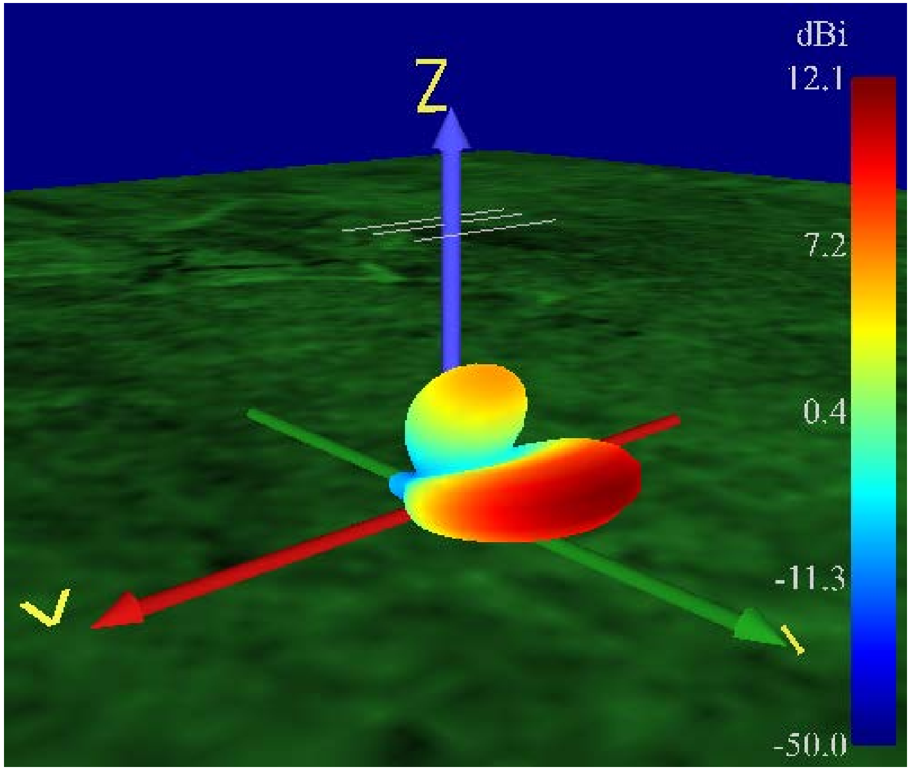
File Edit Format View Help

```
             **********************************************

              NUMERICAL ELECTROMAGNETICS CODE (NEC-2D)

             **********************************************


                    - - - - COMMENTS - - - -

          3el Yagi for 20 meters @ 50 feet.


             - - - STRUCTURE SPECIFICATION - - -

                 COORDINATES MUST BE INPUT IN
                 METERS OR BE SCALED TO METERS
                 BEFORE STRUCTURE INPUT IS ENDED


 WIRE                                                                      NO. OF    FIRST  LAST     TAG
 NO.        X1         Y1         Z1          X2         Y2         Z2      RADIUS   SEG.     SEG.   SEG.     NO.
    1   -4.83200    2.74320   15.24000     4.83200    2.74320   15.24000    0.00500     19        1     19       1
    2   -5.12020    0.00000   15.24000     5.12020    0.00000   15.24000    0.00500     19       20     38       2
    3   -5.52400   -1.82280   15.24000     5.52400   -1.82280   15.24000    0.00500     19       39     57       3

  TOTAL SEGMENTS USED=   57     NO. SEG. IN A SYMMETRIC CELL=   57     SYMMETRY FLAG=  0


       - MULTIPLE WIRE JUNCTIONS -
JUNCTION    SEGMENTS  (- FOR END 1, + FOR END 2)
 NONE


             - - - - SEGMENTATION DATA - - - -

                    COORDINATES IN METERS

          I+ AND I- INDICATE THE SEGMENTS BEFORE AND AFTER I


 SEG.   COORDINATES OF SEG. CENTER     SEG.     ORIENTATION ANGLES     WIRE    CONNECTION DATA   TAG
 NO.        X          Y          Z     LENGTH     ALPHA      BETA    RADIUS    I-    I    I+     NO.
    1  -4.57768    2.74320  15.24000  0.50863   0.00000   0.00000   0.00500    0    1    2      1
```

```
   44    3  -0.1102  -0.0863   0.7218  0.02754  -5.2758E-03  6.1832E-03  8.1281E-03  130.472
   45    3  -0.0826  -0.0863   0.7218  0.02754  -5.9352E-03  6.8522E-03  9.0653E-03  130.898
   46    3  -0.0551  -0.0863   0.7218  0.02754  -6.4254E-03  7.3417E-03  9.7564E-03  131.192
   47    3  -0.0275  -0.0863   0.7218  0.02754  -6.7272E-03  7.6399E-03  1.0180E-02  131.365
   48    3   0.0000  -0.0863   0.7218  0.02754  -6.8291E-03  7.7400E-03  1.0322E-02  131.422
   49    3   0.0275  -0.0863   0.7218  0.02754  -6.7272E-03  7.6399E-03  1.0180E-02  131.365
   50    3   0.0551  -0.0863   0.7218  0.02754  -6.4254E-03  7.3417E-03  9.7564E-03  131.192
   51    3   0.0826  -0.0863   0.7218  0.02754  -5.9352E-03  6.8522E-03  9.0653E-03  130.898
   52    3   0.1102  -0.0863   0.7218  0.02754  -5.2758E-03  6.1832E-03  8.1281E-03  130.472
   53    3   0.1377  -0.0863   0.7218  0.02754  -4.4738E-03  5.3516E-03  6.9752E-03  129.895
   54    3   0.1652  -0.0863   0.7218  0.02754  -3.5629E-03  4.3777E-03  5.6443E-03  129.141
   55    3   0.1928  -0.0863   0.7218  0.02754  -2.5831E-03  3.2834E-03  4.1777E-03  128.192
   56    3   0.2203  -0.0863   0.7218  0.02754  -1.5758E-03  2.0873E-03  2.6153E-03  127.051
   57    3   0.2479  -0.0863   0.7218  0.02754  -5.5406E-04  7.6849E-04  9.4740E-04  125.791


                        - - - POWER BUDGET - - -

                          INPUT POWER   = 1.5581E-02 WATTS
                          RADIATED POWER= 1.5385E-02 WATTS
                          STRUCTURE LOSS= 1.9564E-04 WATTS
                          NETWORK LOSS  = 0.0000E+00 WATTS
                          EFFICIENCY    =  98.74 PERCENT


                              - - - RADIATION PATTERNS - - -

 - - ANGLES - -         - POWER GAINS -       - - - POLARIZATION - - -    - - - E(THETA) - - -      - - - E(PHI) -
 THETA     PHI         VERT.   HOR.   TOTAL      AXIAL     TILT   SENSE     MAGNITUDE    PHASE       MAGNITUDE    PH
DEGREES  DEGREES        DB      DB      DB       RATIO     DEG.              VOLTS/M    DEGREES       VOLTS/M     DEG
 -90.00     0.00     -999.99 -999.99 -999.99    0.00000    0.00             7.81629E-12    58.16    0.00000E+00
 -85.00     0.00      -20.11 -999.99  -20.11    0.00000    0.00  LINEAR     9.54471E-02  -110.33    0.00000E+00
 -80.00     0.00      -16.14 -999.99  -16.14    0.00000    0.00  LINEAR     1.50772E-01   -85.37    0.00000E+00
 -75.00     0.00      -12.75 -999.99  -12.75    0.00000    0.00  LINEAR     2.22605E-01   -57.59    0.00000E+00
 -70.00     0.00       -9.69 -999.99   -9.69    0.00000    0.00  LINEAR     3.16807E-01   -37.94    0.00000E+00
 -65.00     0.00       -7.82 -999.99   -7.82    0.00000    0.00  LINEAR     3.92982E-01   -24.32    0.00000E+00
 -60.00     0.00       -7.36 -999.99   -7.36    0.00000    0.00  LINEAR     4.14282E-01   -11.87    0.00000E+00
 -55.00     0.00       -8.31 -999.99   -8.31    0.00000    0.00  LINEAR     3.71118E-01     4.73    0.00000E+00
 -50.00     0.00      -10.04 -999.99  -10.04    0.00000    0.00  LINEAR     3.04320E-01    34.83    0.00000E+00
 -45.00     0.00       -9.24 -999.99   -9.24    0.00000    0.00  LINEAR     3.33756E-01    79.44    0.00000E+00
 -40.00     0.00       -5.62 -999.99   -5.62    0.00000    0.00  LINEAR     5.05995E-01   109.56    0.00000E+00
 -35.00     0.00       -2.40 -999.99   -2.40    0.00000    0.00  LINEAR     7.33400E-01   124.22    0.00000E+00
 -30.00     0.00       -0.09 -999.99   -0.09    0.00000    0.00  LINEAR     9.56710E-01   132.17    0.00000E+00
 -25.00     0.00        1.50 -999.99    1.50    0.00000    0.00  LINEAR     1.14882E+00   137.06    0.00000E+00
 -20.00     0.00        2.57 -999.99    2.57    0.00000    0.00  LINEAR     1.29914E+00   140.31    0.00000E+00
 -15.00     0.00        3.26 -999.99    3.26    0.00000    0.00  LINEAR     1.40701E+00   142.53    0.00000E+00
 -10.00     0.00        3.68 -999.99    3.68    0.00000    0.00  LINEAR     1.47713E+00   143.99    0.00000E+00
  -5.00     0.00        3.91 -999.99    3.91    0.00000    0.00  LINEAR     1.51583E+00   144.84    0.00000E+00
   0.00     0.00        3.98 -999.99    3.98    0.00000    0.00  LINEAR     1.52811E+00   145.11    0.00000E+00
```

Introduction : Generated X3D Files

- X3D files are generated using our program from output file.
  - Commonly familiar 3D scene
  - We can control composition and color as we want.
  - We are now searching a way to give more information, intuitively.



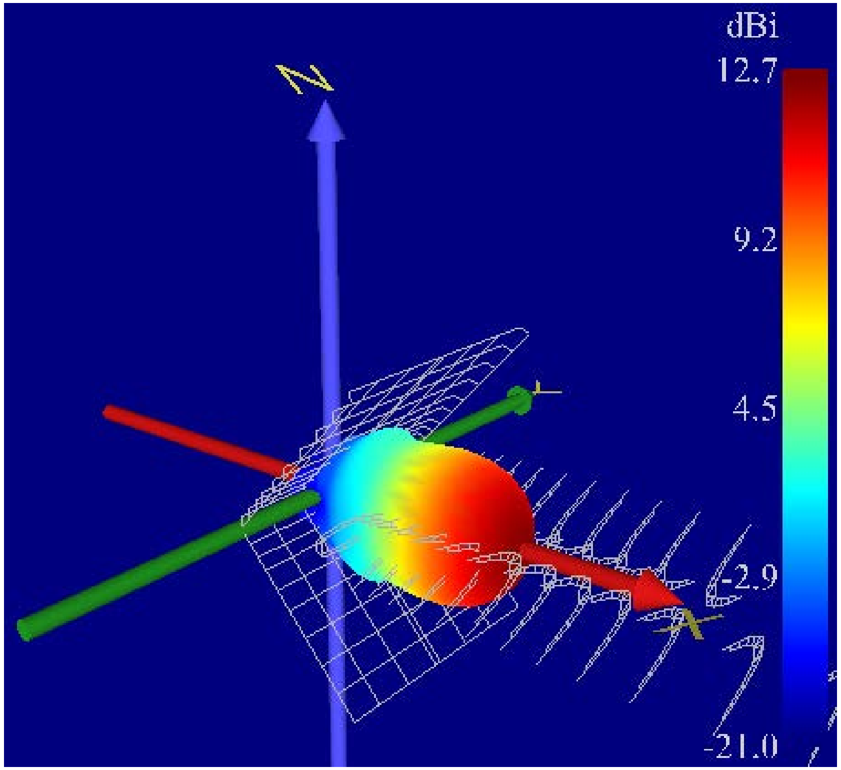
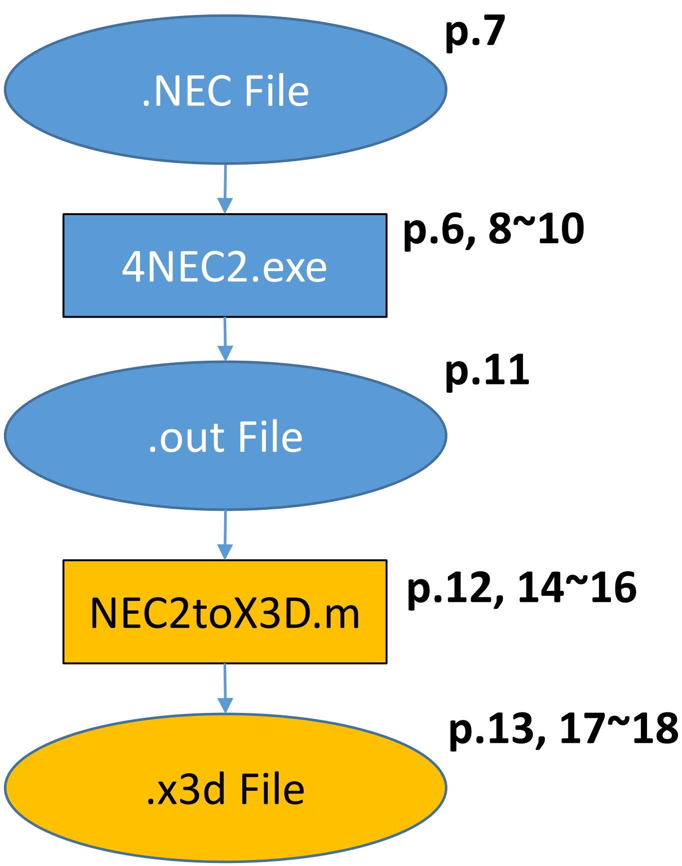


Table of Contents : Conversion Procedure to Generate X3D File

- In this presentation
  - The conversion procedure to generate X3D file from 4NEC2 output file.
  - The 4NEC2 output format and NEC2toX3D.m code are introduced briefly.



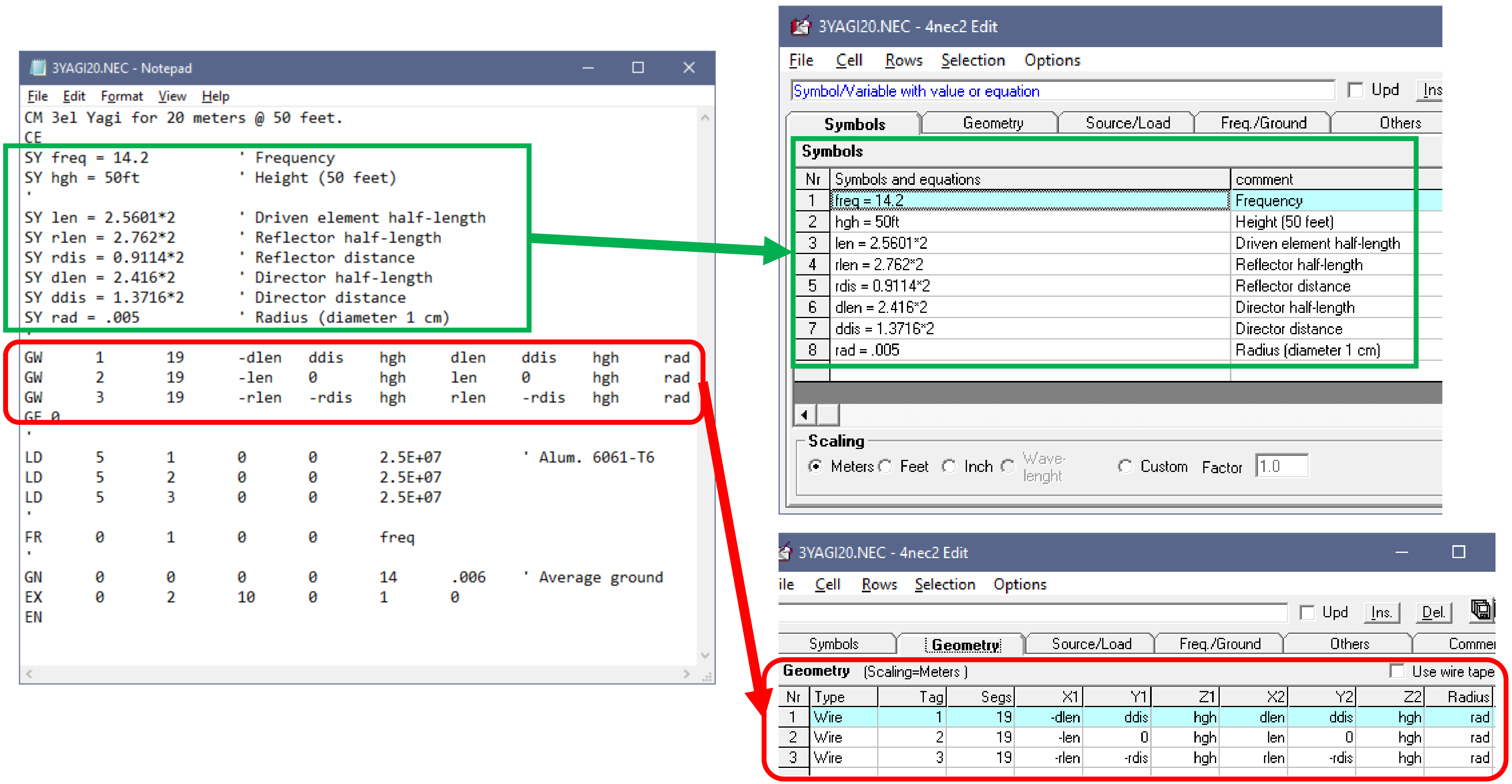
4NEC2 Program

- NEC-2 based antenna modeler and optimizer
  - (NEC-2 Fortran Code) + (GUI), By Arie Voors
  - You can get this program free. (ver 5.8.16)
  - http://www.qsl.net/4nec2/

- NEC (Numerical Electromagnetics Code)
  - Popular antenna modeling system for wire and surface antennas
  - It was originally written in FORTRAN in the 1970s by Gerald Burke and Andrew Poggio of the Lawrence Livermore National Laboratory
  - By far the most common version is **NEC-2**, the last to be released in fully public form
  - https://en.wikipedia.org/wiki/Numerical_Electromagnetics_Code

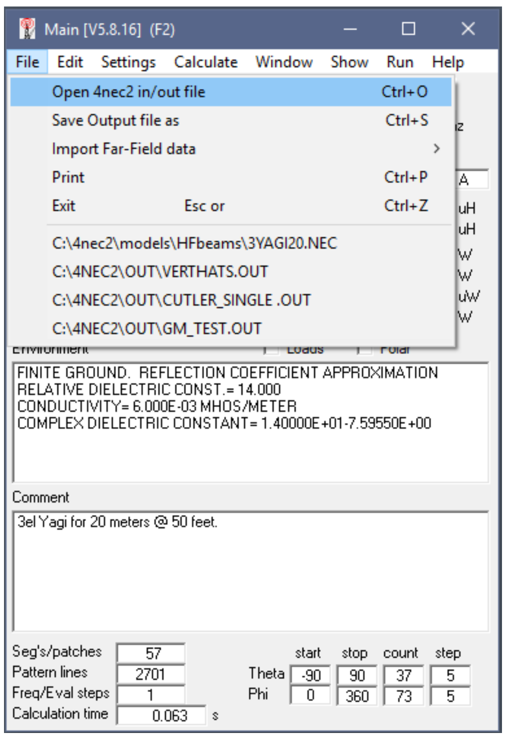
Input of 4NEC2

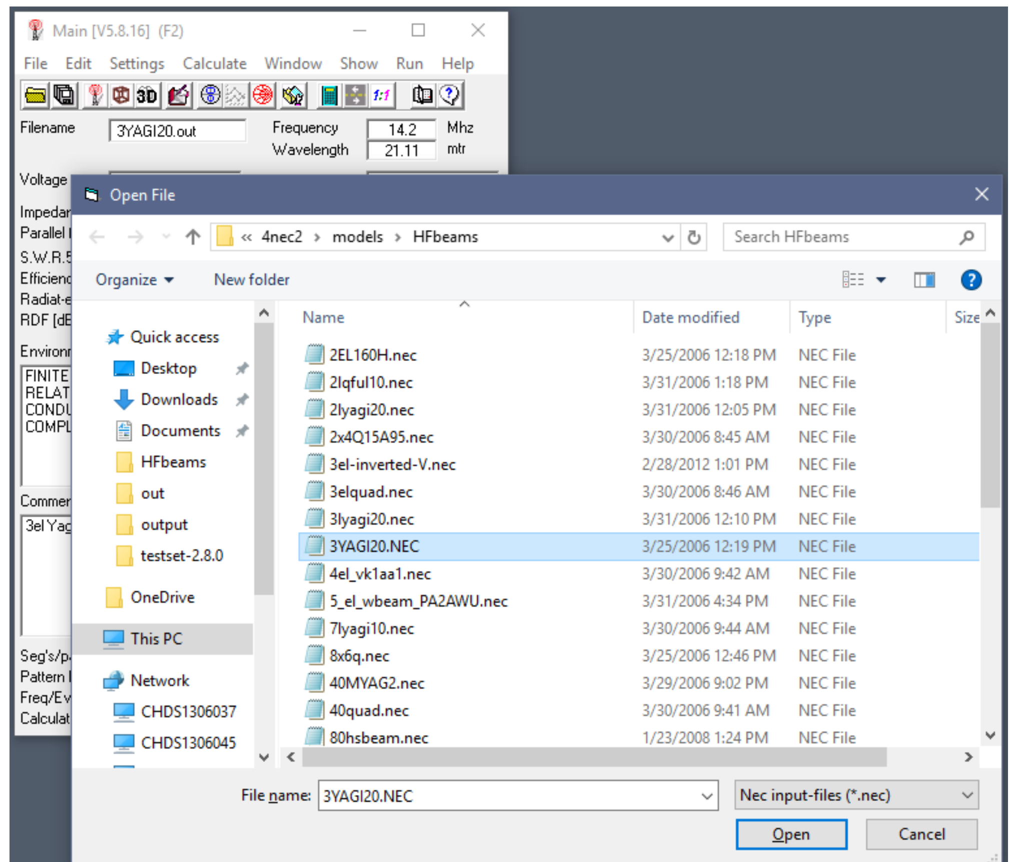
- .NEC file has Geometry information of Antenna



Run 4NEC2.exe (1/3)

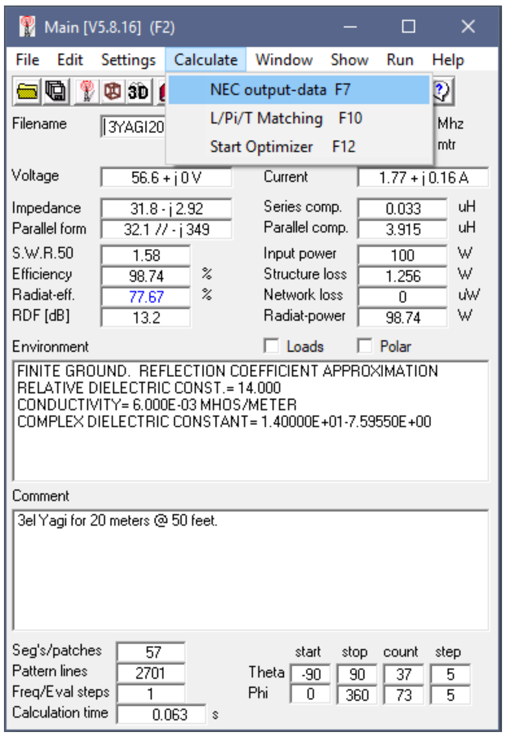
- Menu → File → Open 4nec2 in/out files → Open
  - .nec samples are in folder of 4nec2/models/

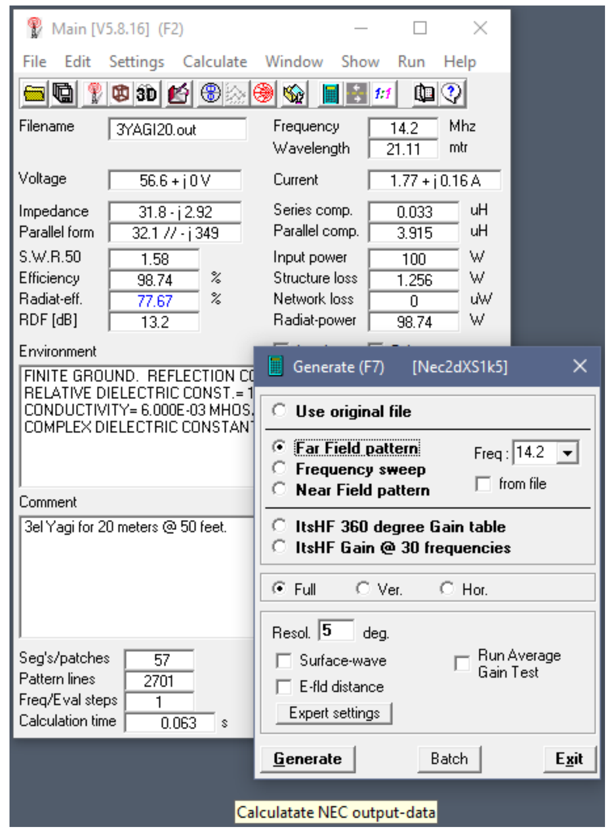




Run 4NEC2.exe (2/3)

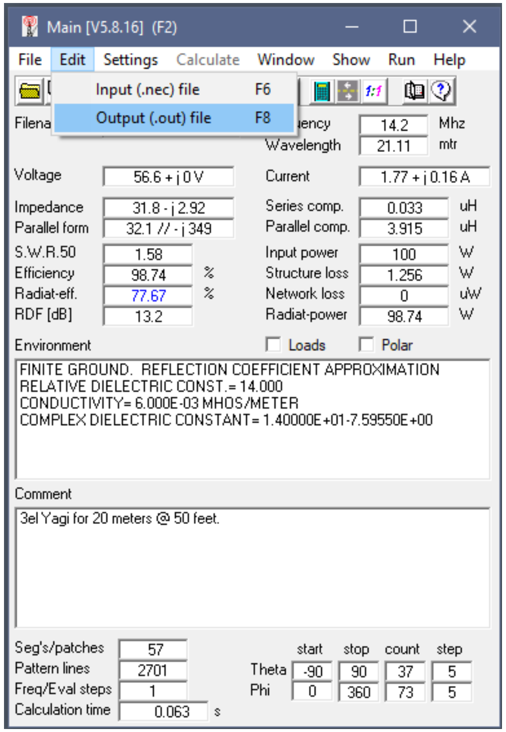
- Menu → Calculate → NEC output-data
→ Far-Field pattern → Generate

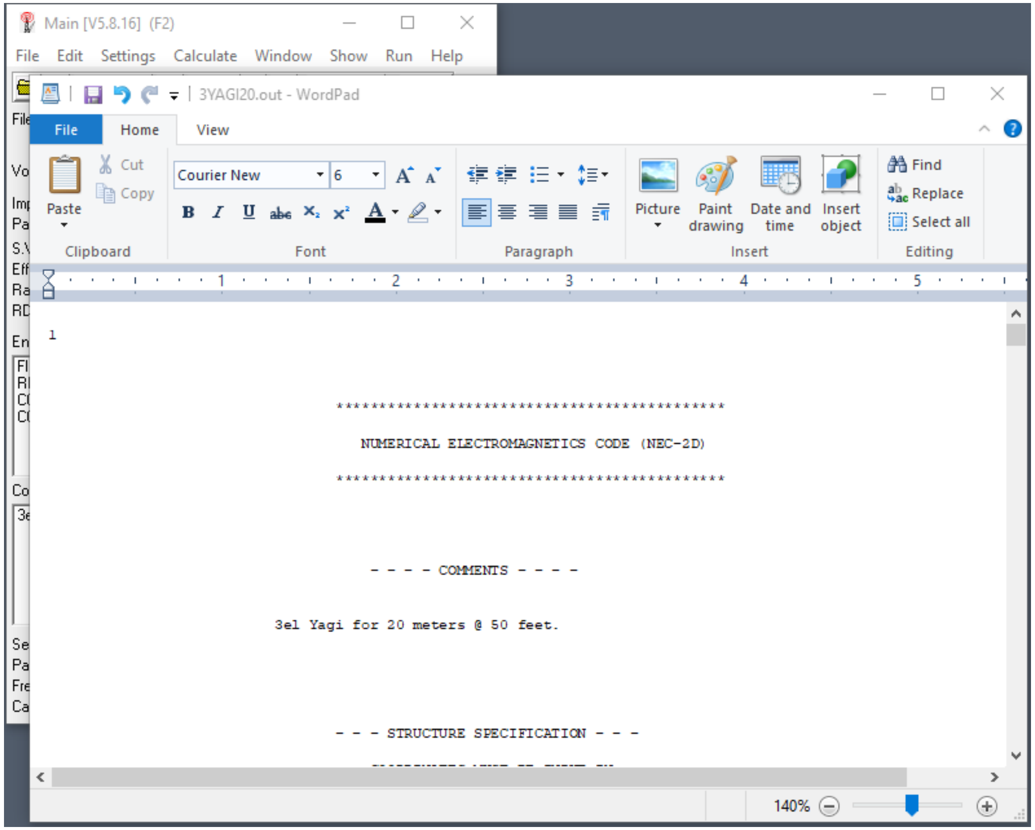




Run 4NEC2.exe (3/3)

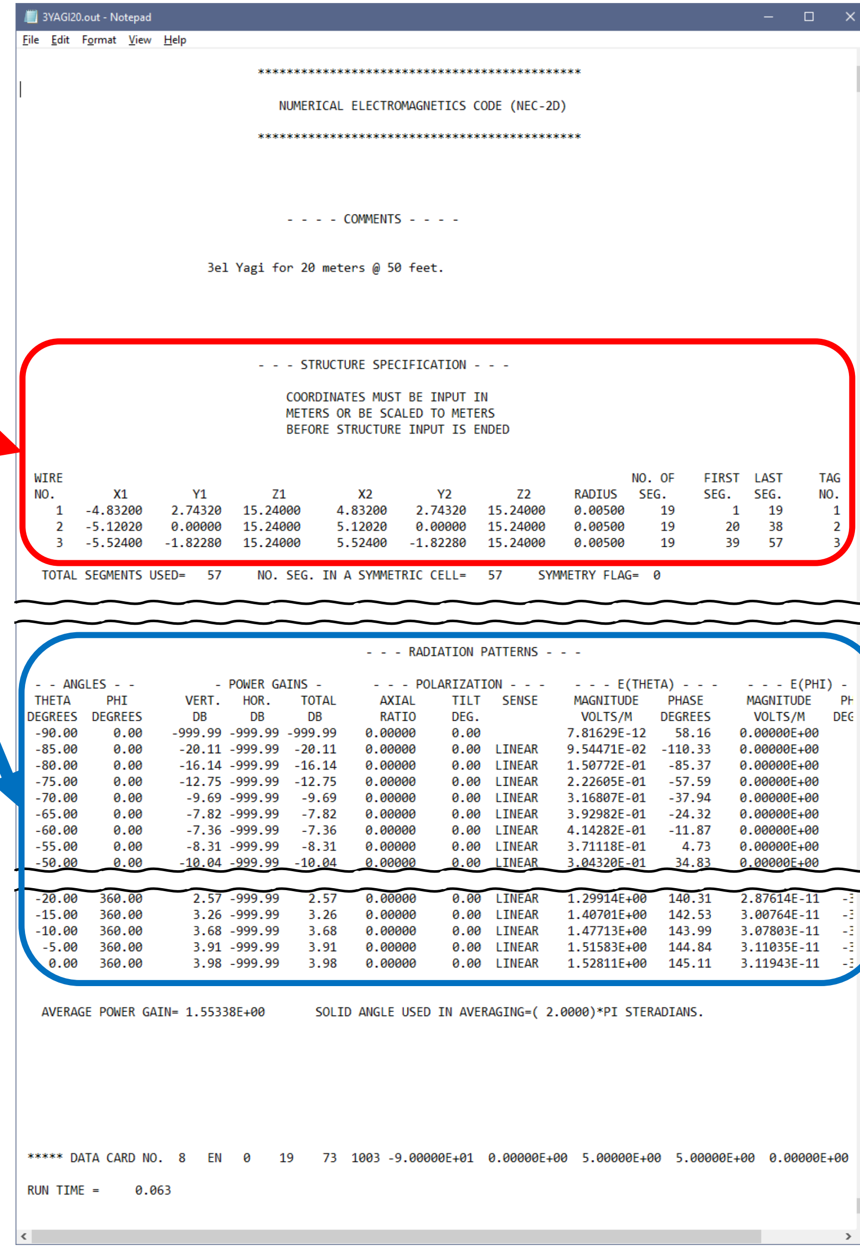
- Menu → Edit → Output (.out) file
  - .out results are in folder of 4nec2/out/





Output of 4NEC2

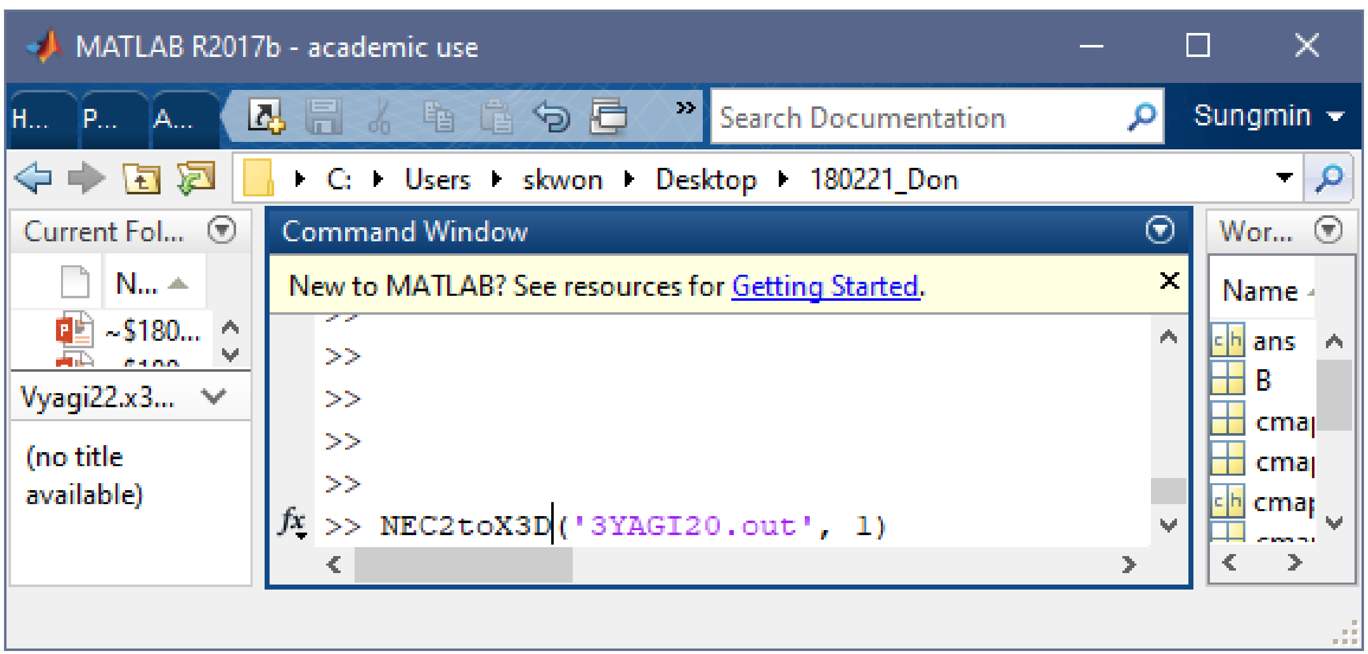
- .out file has
  - Geometry information of the antenna
  - Radiation patterns of the antenna
    - **Power gains** (vertical/horizontal/total)
    - **Electric field magnitude** (theta/phi)
- .out files are
  - Located at folder of 4nec2/out/



```
3YAGI20.out - Notepad
File  Edit  Format  View  Help

          **********************************************
               NUMERICAL ELECTROMAGNETICS CODE (NEC-2D)
          **********************************************

                      - - - - COMMENTS - - - -

              3el Yagi for 20 meters @ 50 feet.

                - - - STRUCTURE SPECIFICATION - - -

                  COORDINATES MUST BE INPUT IN
                  METERS OR BE SCALED TO METERS
                  BEFORE STRUCTURE INPUT IS ENDED

WIRE                                                                         NO. OF    FIRST  LAST     TAG
NO.     X1        Y1        Z1          X2        Y2        Z2      RADIUS    SEG.     SEG.   SEG.     NO.
  1   -4.83200   2.74320  15.24000    4.83200   2.74320  15.24000   0.00500    19        1     19       1
  2   -5.12020   0.00000  15.24000    5.12020   0.00000  15.24000   0.00500    19       20     38       2
  3   -5.52400  -1.82280  15.24000    5.52400  -1.82280  15.24000   0.00500    19       39     57       3
 TOTAL SEGMENTS USED=   57      NO. SEG. IN A SYMMETRIC CELL=   57      SYMMETRY FLAG=  0

                - - - RADIATION PATTERNS - - -

 - - ANGLES - -         - POWER GAINS -      - - - POLARIZATION - - -    - - - E(THETA) - - -     - - - E(PHI) -
 THETA    PHI       VERT.   HOR.   TOTAL     AXIAL    TILT  SENSE       MAGNITUDE    PHASE       MAGNITUDE    PH
DEGREES  DEGREES     DB      DB      DB      RATIO    DEG.               VOLTS/M    DEGREES       VOLTS/M     DEG
 -90.00    0.00   -999.99 -999.99 -999.99   0.00000   0.00             7.81629E-12   58.16     0.00000E+00
 -85.00    0.00    -20.11 -999.99  -20.11   0.00000   0.00  LINEAR     9.54471E-02 -110.33     0.00000E+00
 -80.00    0.00    -16.14 -999.99  -16.14   0.00000   0.00  LINEAR     1.50772E-01  -85.37     0.00000E+00
 -75.00    0.00    -12.75 -999.99  -12.75   0.00000   0.00  LINEAR     2.22605E-01  -57.59     0.00000E+00
 -70.00    0.00     -9.69 -999.99   -9.69   0.00000   0.00  LINEAR     3.16807E-01  -37.94     0.00000E+00
 -65.00    0.00     -7.82 -999.99   -7.82   0.00000   0.00  LINEAR     3.92982E-01  -24.32     0.00000E+00
 -60.00    0.00     -7.36 -999.99   -7.36   0.00000   0.00  LINEAR     4.14282E-01  -11.87     0.00000E+00
 -55.00    0.00     -8.31 -999.99   -8.31   0.00000   0.00  LINEAR     3.71118E-01    4.73     0.00000E+00
 -50.00    0.00    -10.04 -999.99  -10.04   0.00000   0.00  LINEAR     3.04320E-01   34.83     0.00000E+00
 -20.00  360.00      2.57 -999.99    2.57   0.00000   0.00  LINEAR     1.29914E+00  140.31     2.87614E-11   -:
 -15.00  360.00      3.26 -999.99    3.26   0.00000   0.00  LINEAR     1.40701E+00  142.53     3.00764E-11   -:
 -10.00  360.00      3.68 -999.99    3.68   0.00000   0.00  LINEAR     1.47713E+00  143.99     3.07803E-11   -:
  -5.00  360.00      3.91 -999.99    3.91   0.00000   0.00  LINEAR     1.51583E+00  144.84     3.11035E-11   -:
   0.00  360.00      3.98 -999.99    3.98   0.00000   0.00  LINEAR     1.52811E+00  145.11     3.11943E-11   -:

  AVERAGE POWER GAIN= 1.55338E+00      SOLID ANGLE USED IN AVERAGING=( 2.0000)*PI STERADIANS.

***** DATA CARD NO.  8   EN   0    19    73  1003 -9.00000E+01  0.00000E+00  5.00000E+00  5.00000E+00  0.00000E+00

RUN TIME =     0.063
```

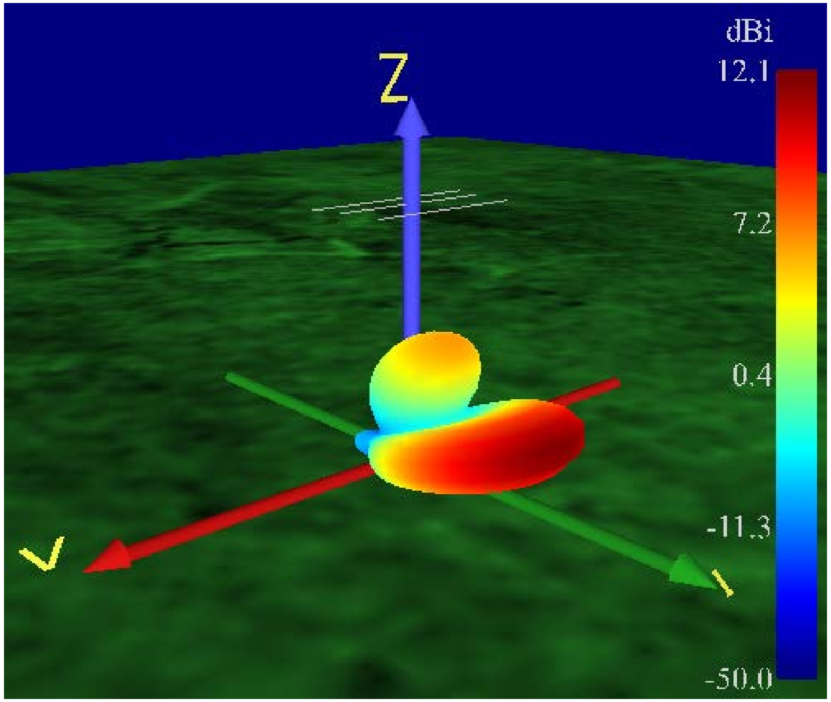
Run NEC2toX3D.m

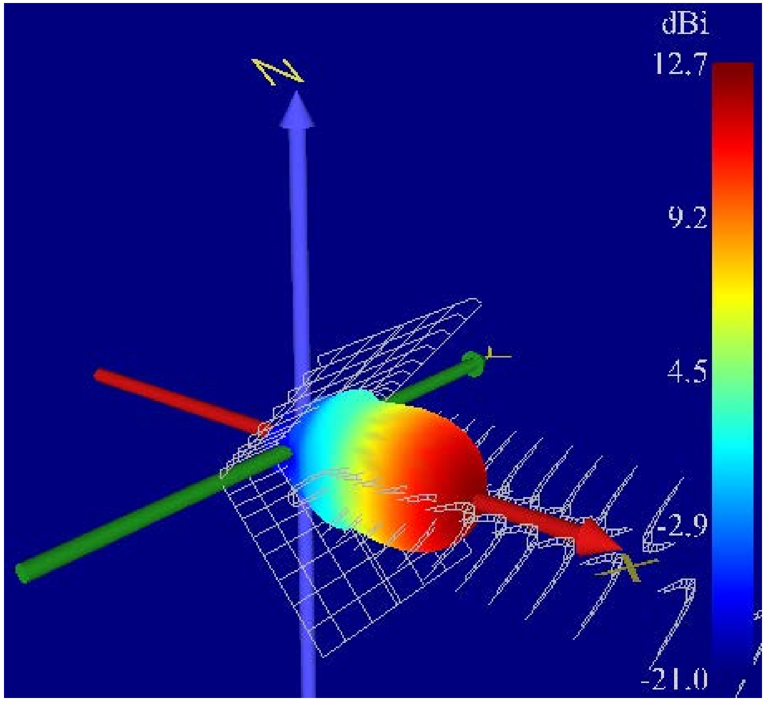
- Launch MATLAB → NEC2toX3D(filename, scale)
  - filename : Output file name of 4NEC2
  - scale : scale of antenna geometry
- .x3d file is generated at same folder.



Final Output X3D file

- X3D Scene has
  - Antenna Shape Geometry
  - Antenna 3D Beam Pattern (Antenna Total Gain) Geometry
  - Color Map Index





Excerpts from NEC2toX3D.m (1/3)

- Part 1 - Antenna Shape Geometry
  - Line 5~29 : Read from 4NEC2 output file
  - Line 183~204 : Write down as LineSet using X3D grammar

```
4
5   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Extract Antenna Geometry Array [ x1 y1 z1 x2
6   %%%%
7   %%%%
8   % Jump file pointer to Antenna Geometric Array
9   % Find word '  WIRE'
10  % and Get next of next line
11  tline = '      ';
12  while ~(  (tline(3)=='W') && (tline(4)=='I') && (tline(5)=='R') && (tline(6)=='E'))
13      tline = fgetl(fid);
14      if (max(size(tline)) < 6)   tline = '      ';   end
15  end
16  tline = fgetl(fid);
17  tline = fgetl(fid);
18  %disp(tline);
19  % Extract Antenna Geometry Array [ x1 y1 z1 x2 y2 z2 : ..... ]
20  numberOfWire = 0;
21  while (max(size(tline)) > 100)
22      numberOfWire = numberOfWire + 1;
23      antennaWireTemp(numberOfWire,:) = sscanf(tline,'%f',[1 12]);
24      tline = fgetl(fid);
25  end
26  numberOfWire
27  antennaWire = antennaWireTemp(1:numberOfWire, 2:7);
28  %antennaWire
29  clear antennaWireTemp
30
```

```
182
183 %%%%  Write Down Antenna Shape
184 [nElement temp] = size(antennaWire);
185
186 fprintf(pf_X3D,'\n    <!-- Antenna Geometry Part -->  \n');
187 fprintf(pf_X3D,'    <Transform scale=''%d %d %d''>  \n',scale_antenna, scale_antenna
188 fprintf(pf_X3D,'      <Shape>  \n');
189 fprintf(pf_X3D,'        <Appearance>  \n');
190 fprintf(pf_X3D,'          <Material emissiveColor=''0.7 0.7 0.7''/> \n');
191 fprintf(pf_X3D,'        </Appearance>  \n');
192 fprintf(pf_X3D,'        <LineSet vertexCount=''');
193    for i = 1:nElement
194        fprintf(pf_X3D,'2 ');
195    end
196 fprintf(pf_X3D,'''>\n');
197 fprintf(pf_X3D,'          <Coordinate point=''');
198    for i = 1:nElement
199        fprintf(pf_X3D,'%f %f %f %f %f %f ',antennaWire(i,1),antennaWire(i,2),antenna
200    end
201 fprintf(pf_X3D,'''/>\n');
202 fprintf(pf_X3D,'        </LineSet>\n');
203 fprintf(pf_X3D,'      </Shape>\n');
204 fprintf(pf_X3D,'    </Transform>  \n');
205
```

Excerpts from NEC2toX3D.m (2/3)

- Part 2 - Antenna 3D Beam Pattern Geometry
  - Line 33~57 : Read from 4NEC2 output file
  - Line 206~210, 318~360 :
    Write down as
    IndexedFaceSet
    using X3D grammar

```matlab
33      %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Extract Antenna Pattern Array [ THETA PHI TOT.
34      %%%%
35      %%%%
36      % Jump file pointer to Antenna Pattern Array
37      % Find word ' DEG'
38      % and Get next line
39      tline = '    ';
40      while ~(  (tline(2)=='D') && (tline(3)=='E') && (tline(4)=='G'))
41          tline = fgetl(fid);
42          if (max(size(tline)) < 4)   tline = '    ';   end
43      end
44      tline = fgetl(fid);
45      %disp(tline);
46      % Extract Antenna Pattern Array [ THETA PHI TOTALDB: ..... ]
47      numberOfPattern = 0;
48      while (max(size(tline)) > 2)
49          numberOfPattern = numberOfPattern + 1;
50          antennaPatternTemp(numberOfPattern,:) = sscanf(tline,'%f',[1 5]);
51          tline = fgetl(fid);
52      end
53      antennaPattern = antennaPatternTemp(1:numberOfPattern, 1:2);
54      antennaPattern(1:numberOfPattern,3) = antennaPatternTemp(1:numberOfPattern, 5);
55      numberOfPattern
56      %antennaPattern
57      clear antennaPatternTemp
```

```matlab
318     function HandleSurface(obj_handle)
319     global pf_X3D;
320     info.coord      = 'surfCoord';
321     info.coordIndex = 'surfCoordIndex';
322     info.color      = 'surfColor';
323     info.colorIndex = 'surfColorIndex';
324
325     obj = get(obj_handle);
326     handle_str = sprintf('%s%g',deblank(obj.Type),double(obj_handle));
327     handle_str = abs(handle_str);
328     h = find(handle_str == '.');
329     handle_str(h) = []; %#ok
330     handle_str = char(handle_str);
331
332     if(strcmp(obj.Visible,'on'))
333         % Handle FaceColor mode
334         if ~strcmp(obj.FaceColor,'none')
335             fprintf(pf_X3D,'      <Shape>\n');
336             fprintf(pf_X3D,'        <IndexedFaceSet ');
337             if ~ischar(obj.FaceColor)
338                 i = 0;
339             else
340                 switch obj.FaceColor
341                     case 'flat'
342                         colorIndex(obj,info.colorIndex,'flat');
343                     case 'interp'
344                         colorIndex(obj,info.colorIndex,'interp');
345                     case 'texturemap'
346                     otherwise
347                         error('Unknown FaceColor type in Handle Patch');
348                 end
349             end
350             coordIndex(obj,info.coordIndex);
351             sendStr(24,'solid=''false''> \n');
352
353             coord(obj,info.coord);
354
355             facecolor(obj,info.color,obj.FaceColor);
356
357             fprintf(pf_X3D,'        </IndexedFaceSet>\n');
358             fprintf(pf_X3D,'      </Shape>\n');
359         end
360     end
```

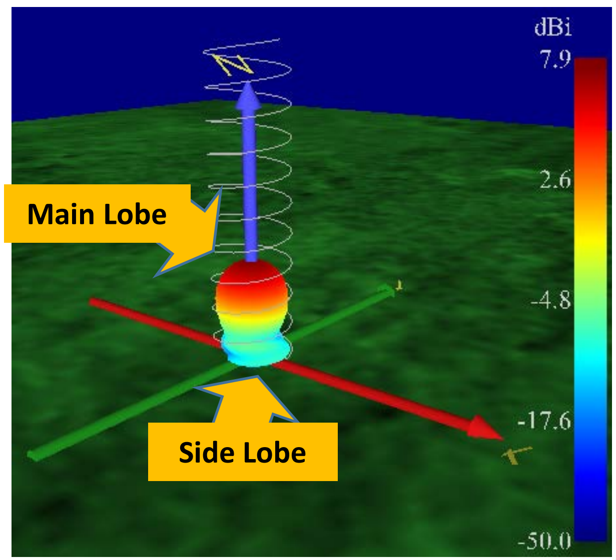
Excerpts from NEC2toX3D.m (3/3)

- Part 3 - Color Map Index
  - Line 218~292 : Write down using HUD Prototype

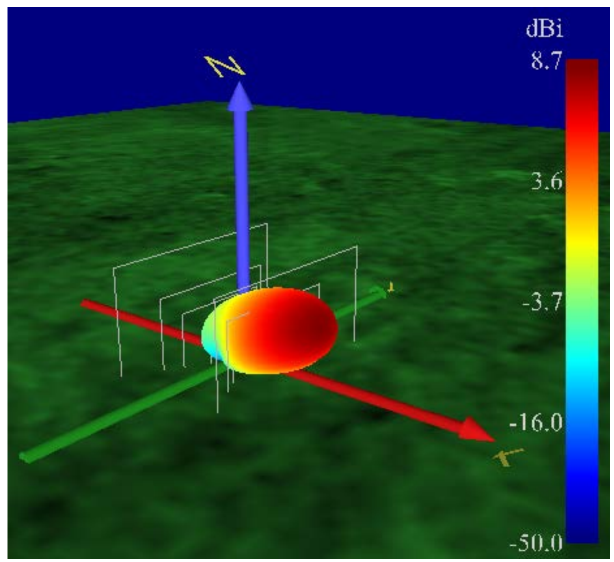
```
218      %%%% Colormap
219 –    fprintf(pf_X3D,'\n    <!-- HUD : Colormap Part -->  \n');
220 –    fprintf(pf_X3D,'    <!-- Simple Heads-Up Display (HUD) Prototype\n \n Manages the display of a HUD an
221 –    fprintf(pf_X3D,'    <ExternProtoDeclare appinfo=''Heads-up display (HUD) keeps child geometry aligned
222 –    fprintf(pf_X3D,'      <field accessType=''inputOutput'' appinfo=''offset position for HUD relative to
223 –    fprintf(pf_X3D,'      <field accessType=''inputOutput'' appinfo=''X3D content positioned at HUD offse
224 –    fprintf(pf_X3D,'      <field accessType=''outputOnly'' appinfo=''HUD position update (in world coordi
225 –    fprintf(pf_X3D,'      <field accessType=''outputOnly'' appinfo=''HUD orientation update relative to o
226 –    fprintf(pf_X3D,'    </ExternProtoDeclare>  \n');
227 –    fprintf(pf_X3D,'    <ProtoInstance DEF=''HeadsUpDisplayInstance'' name=''HeadsUpDisplay''>  \n');
228 –    fprintf(pf_X3D,'      <!-- example: upper left-hand corner of screen (x=-2, y=1) and set back z=-5 fr
229 –    fprintf(pf_X3D,'      <fieldValue name=''screenOffset'' value=''0 0 -5''/>  \n');
230 –    fprintf(pf_X3D,'      <fieldValue name=''children''>  \n');
231 –    fprintf(pf_X3D,'        <Transform translation=''1.9 0 0''>  \n');
232 –    fprintf(pf_X3D,'          <Shape>  \n');
233 –    fprintf(pf_X3D,'            <Box size=''0.2 3 0.01'' solid=''false''/>  \n');
234 –    fprintf(pf_X3D,'            <Appearance>  \n');
235 –    fprintf(pf_X3D,'              <PixelTexture image=''1 33 3 0x000081 0x0000A1 0x0000C1 0x0000E1 0x0002
236 –    fprintf(pf_X3D,'            </Appearance>  \n');
237 –    fprintf(pf_X3D,'          </Shape>  \n');
238 –    fprintf(pf_X3D,'        </Transform>  \n');
239 –    fprintf(pf_X3D,'        <Transform translation=''1.78 0 0''>  \n');
240 –    fprintf(pf_X3D,'          <Transform translation=''0 1.7 0''>  \n');
241 –    fprintf(pf_X3D,'            <Shape>  \n');
242 –    fprintf(pf_X3D,'              <Text string=''"dBi"''>  \n');
243 –    fprintf(pf_X3D,'                <FontStyle DEF=''colormapTickFont'' justify=''"END" "MIDDLE"'' size='
244 –    fprintf(pf_X3D,'              </Text>  \n');
```

Antenna 3D Beam Patterns (1/2)

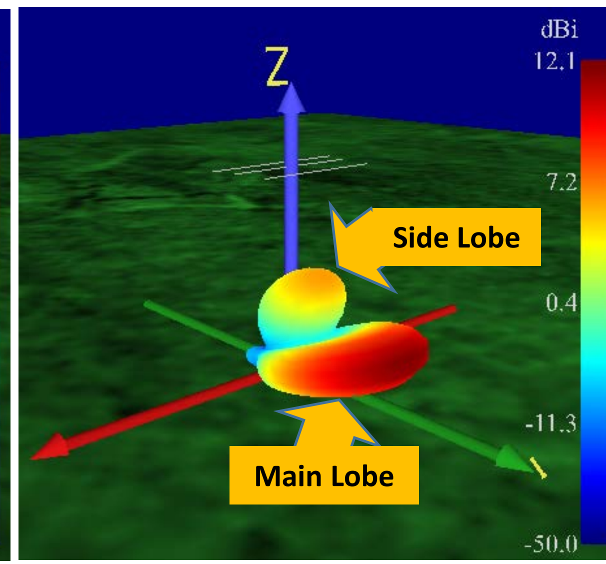
- Case of existence of ground
  - Reflection should be considered in beam pattern.
  - How about existence of sea or water?



<NecHelix.x3d>



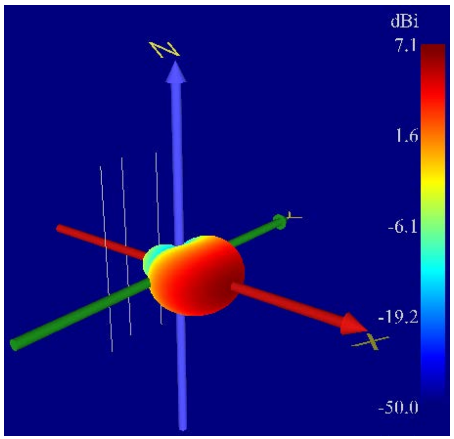
<NecSpiderQuad.x3d>



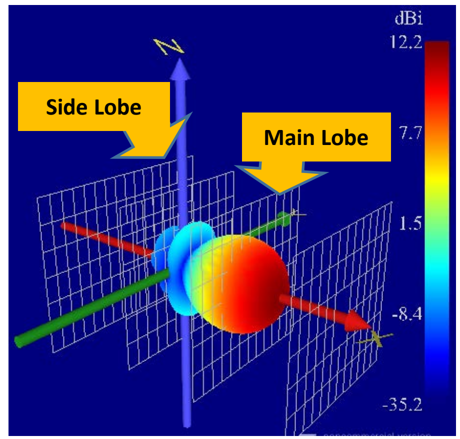
<Nec3ElementYagi20mAt50ft.x3d>

Antenna 3D Beam Pattern (2/2)

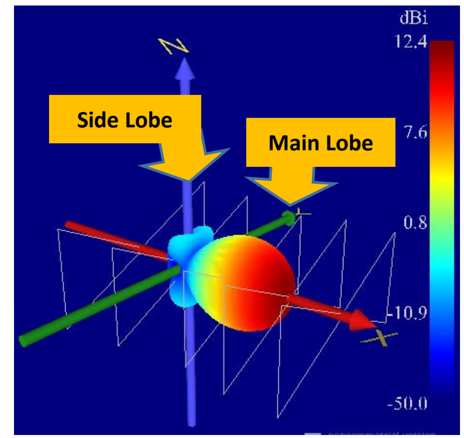
- In the case of free space, maximum magnitude of total antenna gain (in dBi) means the effectiveness of antenna.
- We like this layout, because it is easy to understand which antenna is more effective.



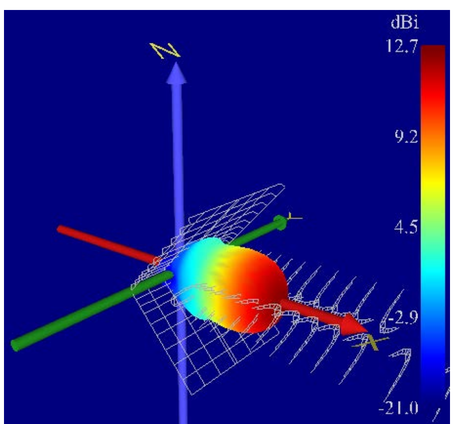
<NecVerticalYagi3Element.x3d>



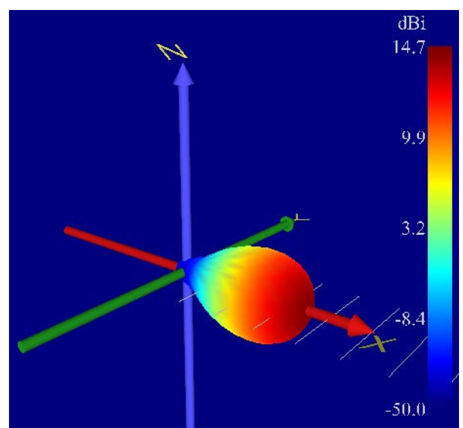
<NecGridYagiWireFence.x3d>



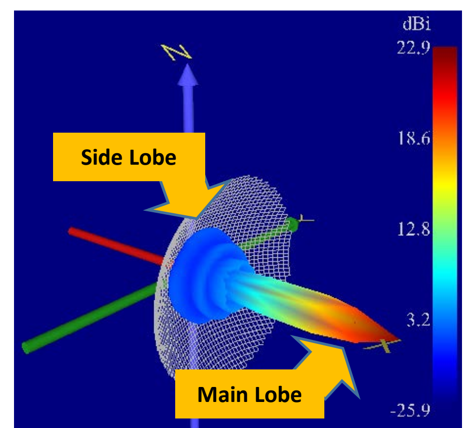
<Nec5ElementTwinDeltaLoop2m.x3d>



<NecBowtieXg91a.x3d>



<NecTvUhf.x3d>



<NecParabola50x50.x3d>

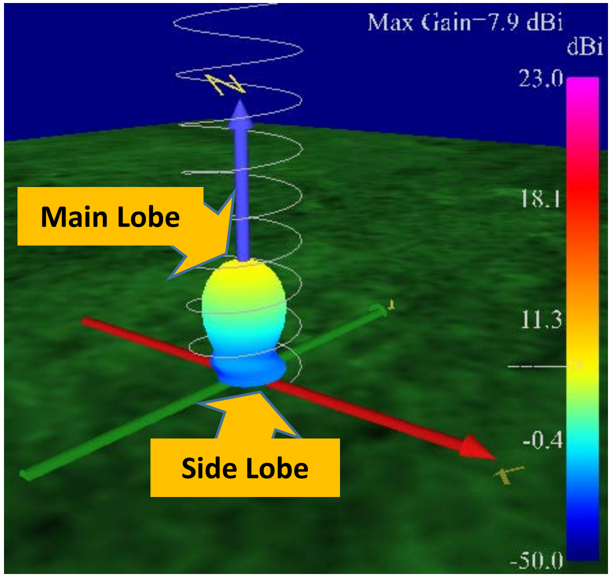
Axis

- For Antenna 3D Beam Pattern
  - Axis : Log scale
  - Unit : dBi (Antenna Gain)

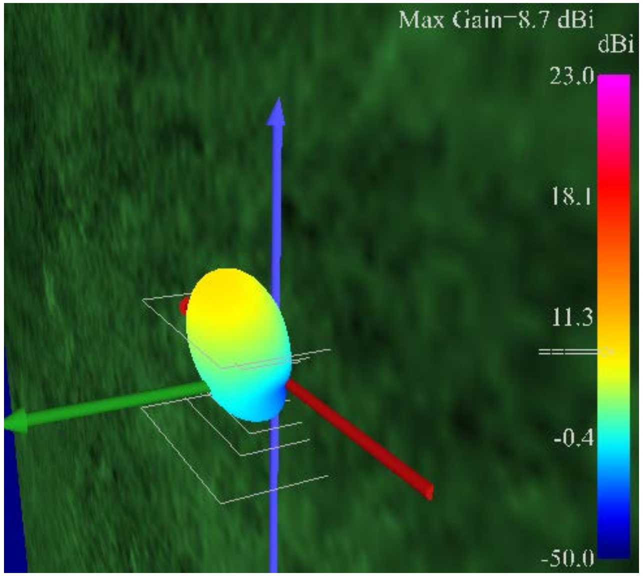
- For Antenna Shape Geometry
  - Axis : Linear
  - Unit : meter (Length)

Suggested visualization (1/2)

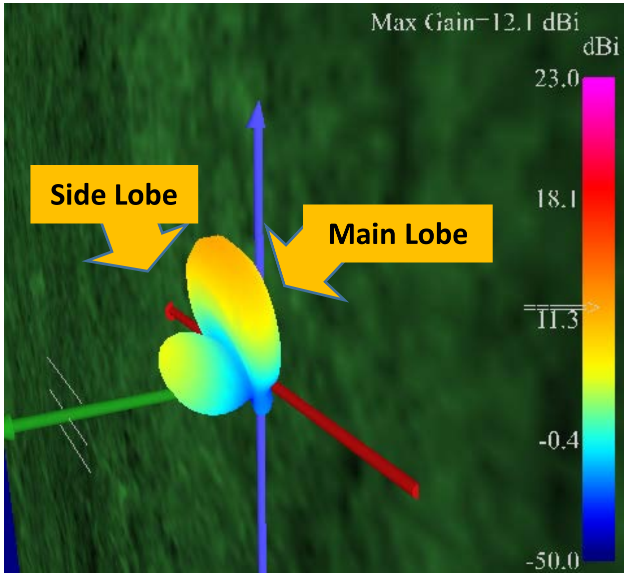
- Beam Propagation : Z axis, logarithmic scales
- Fixed color map : For easy comparison



<NecHelix.x3d>



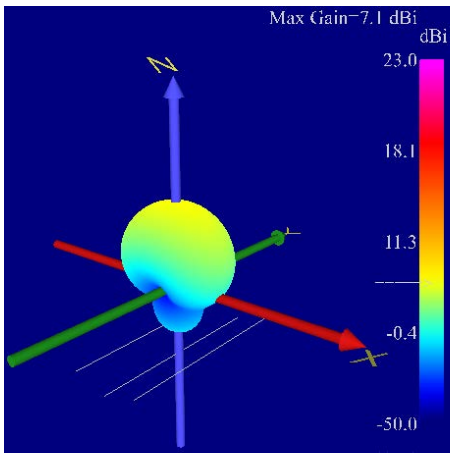
<NecSpiderQuad.x3d>



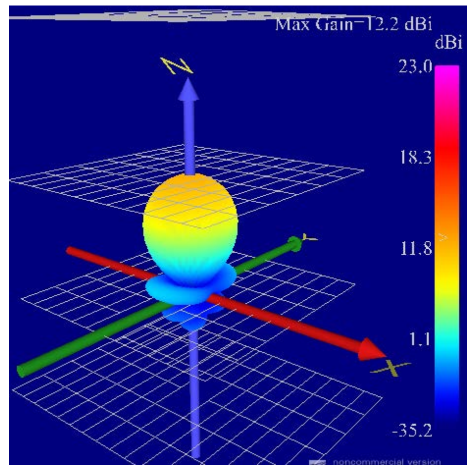
<Nec3ElementYagi20mAt50ft.x3d>

Suggested visualization (2/2)

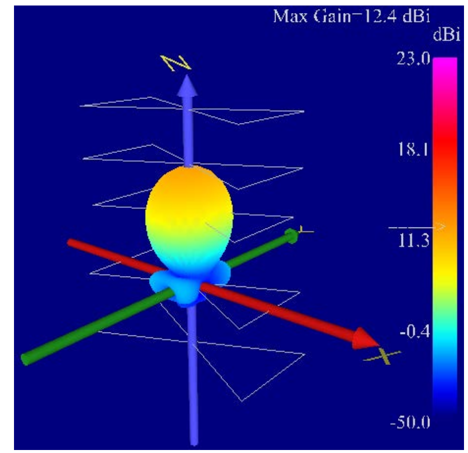
- Beam Propagation : Z axis, logarithmic scales
- Fixed color map : For easy comparison



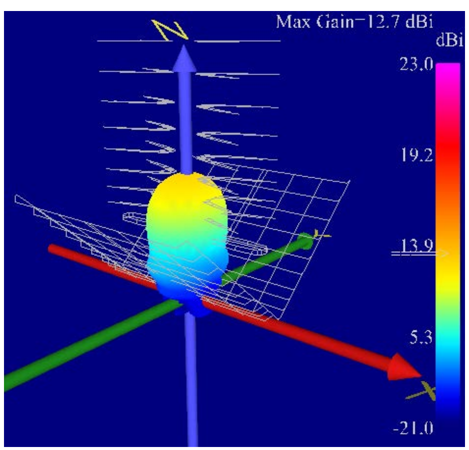
<NecVerticalYagi3Element.x3d>



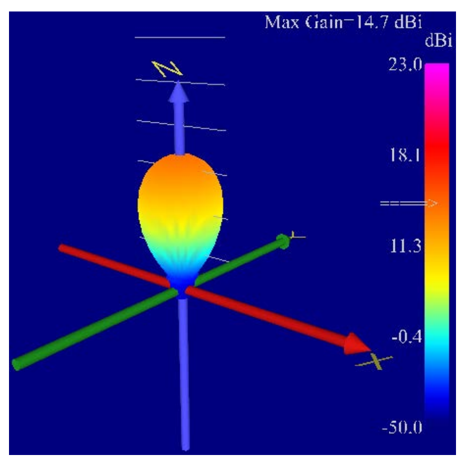
<NecGridYagiWireFence.x3d>



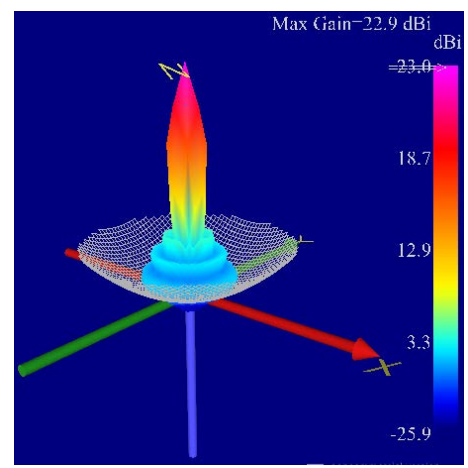
<Nec5ElementTwinDeltaLoop2m.x3d>



<NecBowtieXg91a.x3d>



<NecTvUhf.x3d>



<NecParabola50x50.x3d>

Questions

- Any suggestions and questions are helpful to us.
- Please reply any comments to skwon@nps.edu or Brutzman@nps.edu.

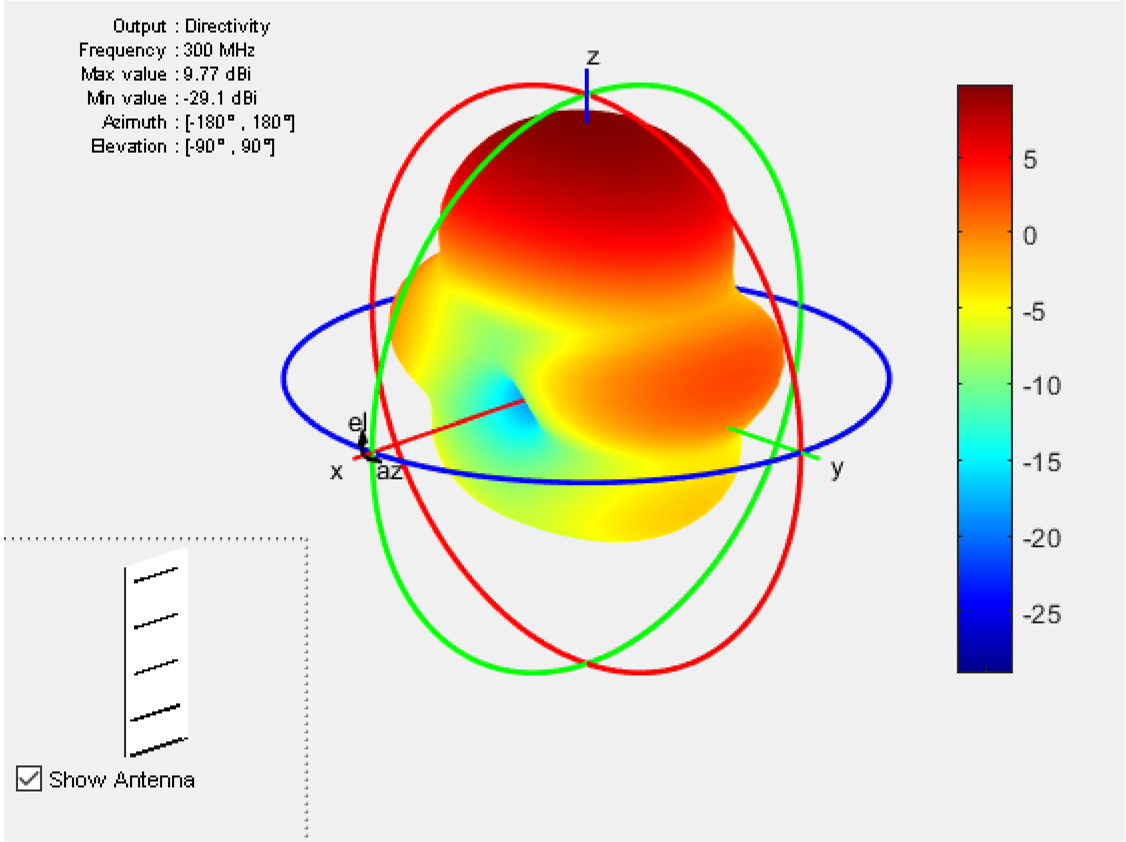
Appendix

- 3D Visualization of Beam Pattern of MATLAB -

FEB 9 2018 – FEB 13 2018

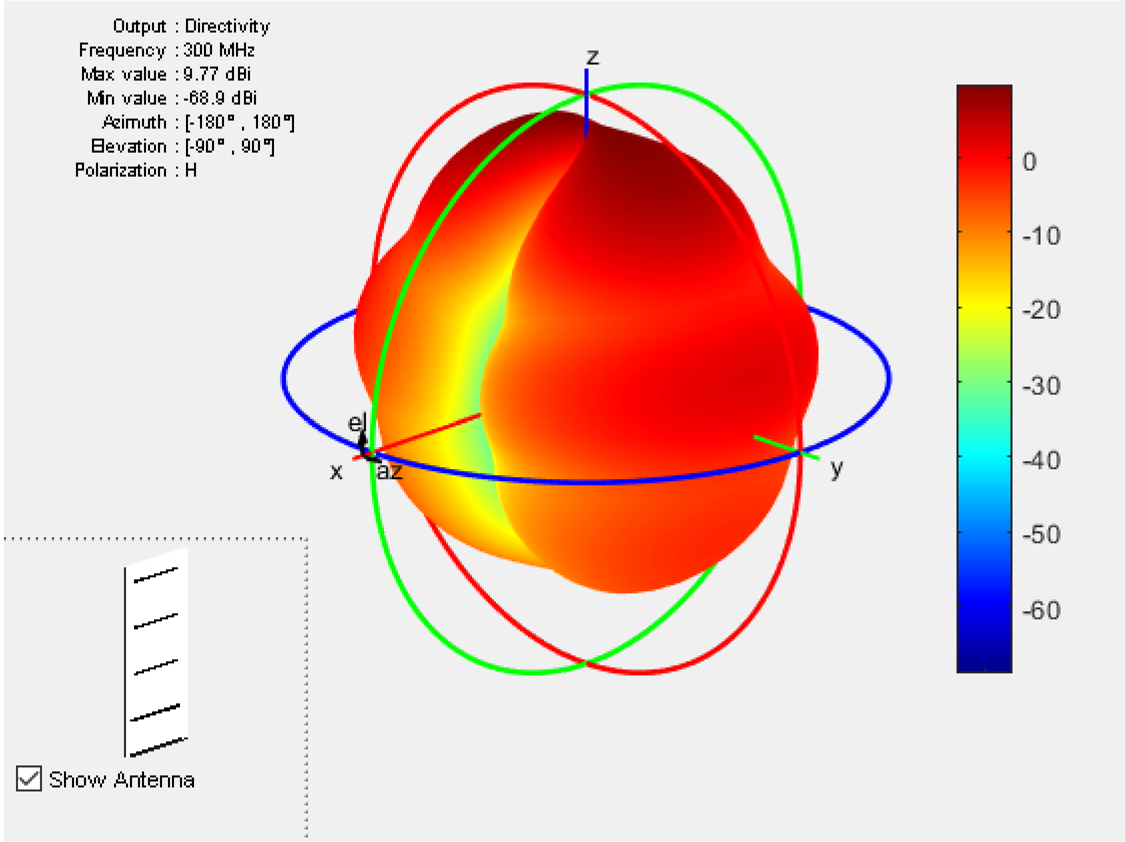
Radiation Pattern

- 3D antenna directivity (in decibels)
  - ant = yagiUda; Freq = 300e6;
  - pattern(ant, freq);



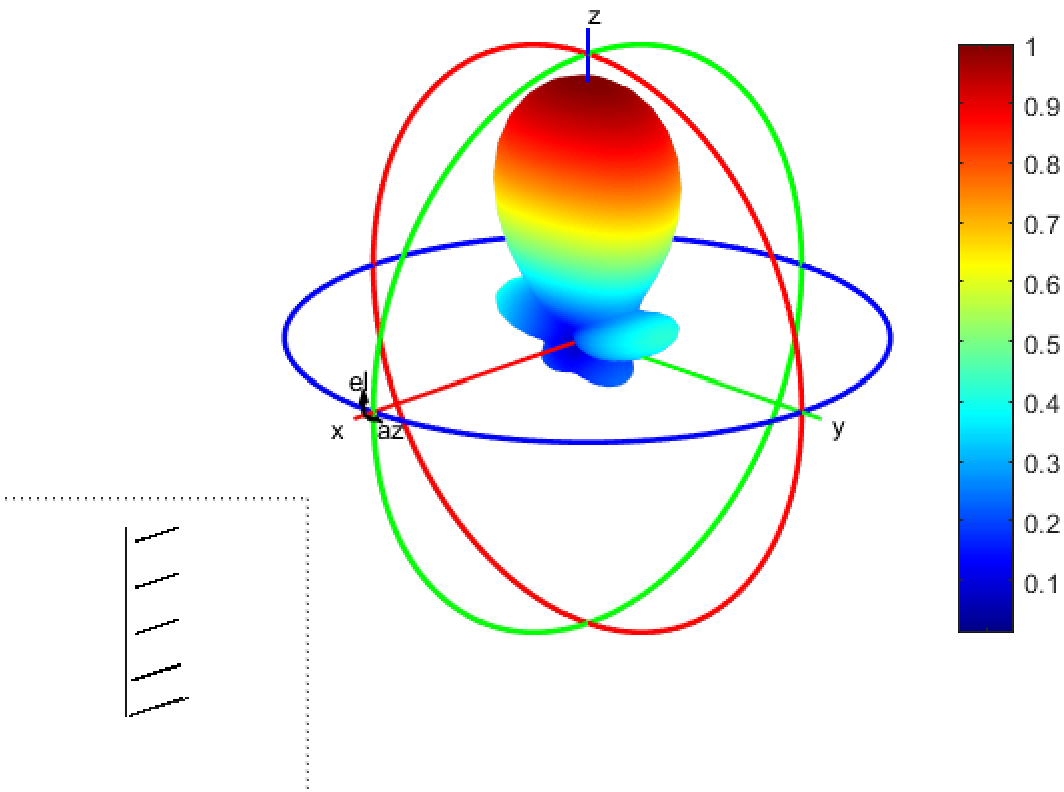
Individual Polarization Components

- Directivity of the azimuthal(H) component of E field
  - Ant = yagiUda; Freq = 300e6;
  - pattern(ant, freq, 'Polarization', 'H');



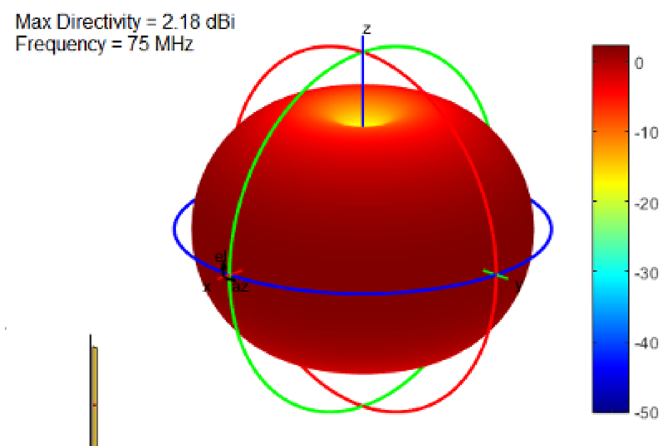
Electric Field and Power

- Normalized magnitude of the E field
  - Ant = yagiUda; Freq = 300e6;
  - pattern(ant, freq, 'Type', 'efield', 'Normalize', true);

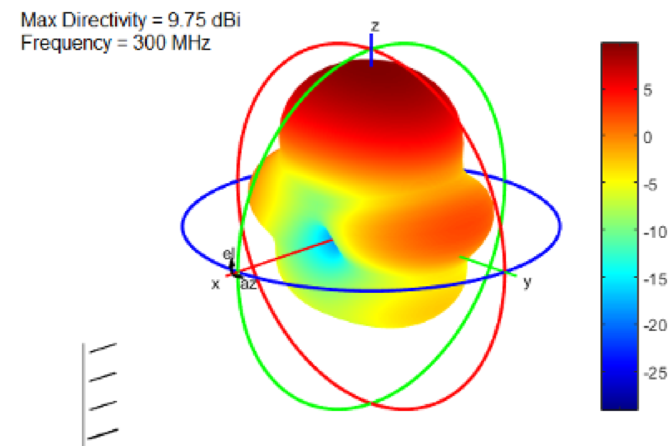


Antenna Radiation Patterns Examples

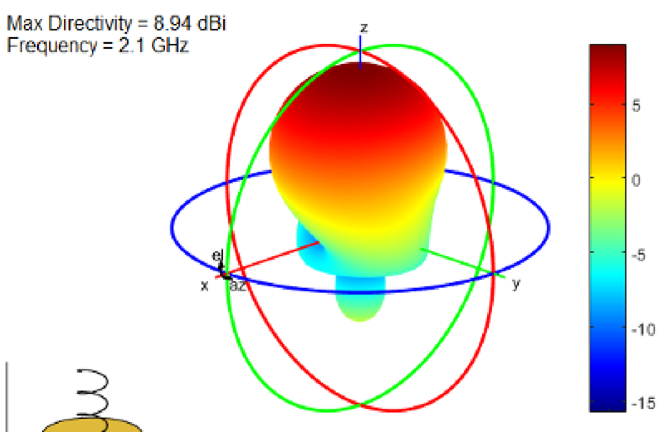
https://www.mathworks.com/help/antenna/gs/_mw_10718407-83ff-44e5-96c5-ff5f768f0e67.html



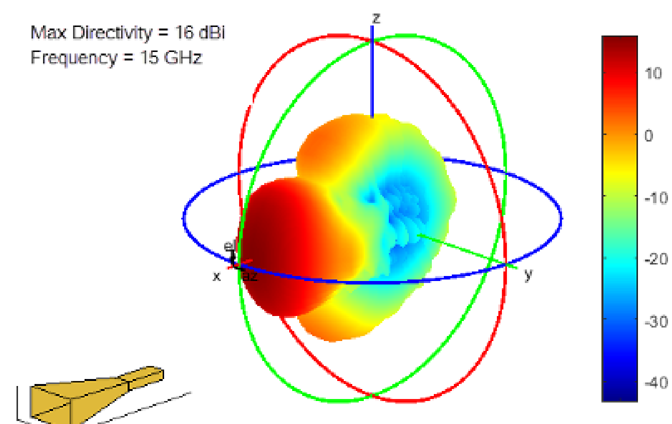
<Dipole>



<YagiUda>



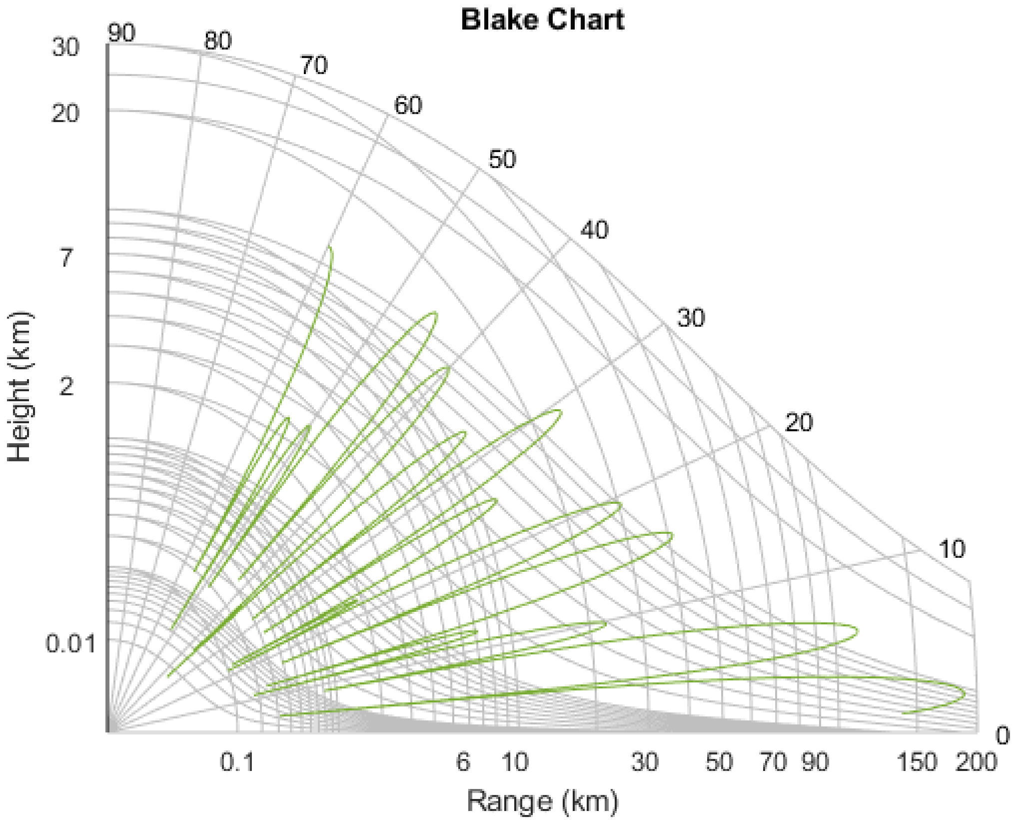
<helix>



<horn>

Blake chart (1/2)

- range-angle-height plot for a narrowband radar antenna
  - the maximum radar range as a function of target elevation



Blake chart (2/2)

CRPL Exponential Reference Atmosphere Model

The `blakechart` function uses the CRPL Exponential Reference Atmosphere to model refraction effects. The index of refraction is a function of height

$$n(h) = 1.0 + (N_s \times 10^{-6}) e^{-R_{exp} h}$$

where N_s is the atmospheric refractivity value (in units of 10^{-6}) at the surface of the earth, R_{exp} is a decay constant, and h is the height above the surface in kilometers. The default value of N_s is 313 and can be modified using the `'SurfaceRefractivity'` Name-Value pair. The default value of R_{exp} is 0.143859 and can be modified using the `'RefractionExponent'` Name-Value pair.

References

[1] Blake, L.V. *Machine Plotting of Radar Vertical-Plane Coverage Diagrams*. Naval Research Laboratory Report 7098, 1970.