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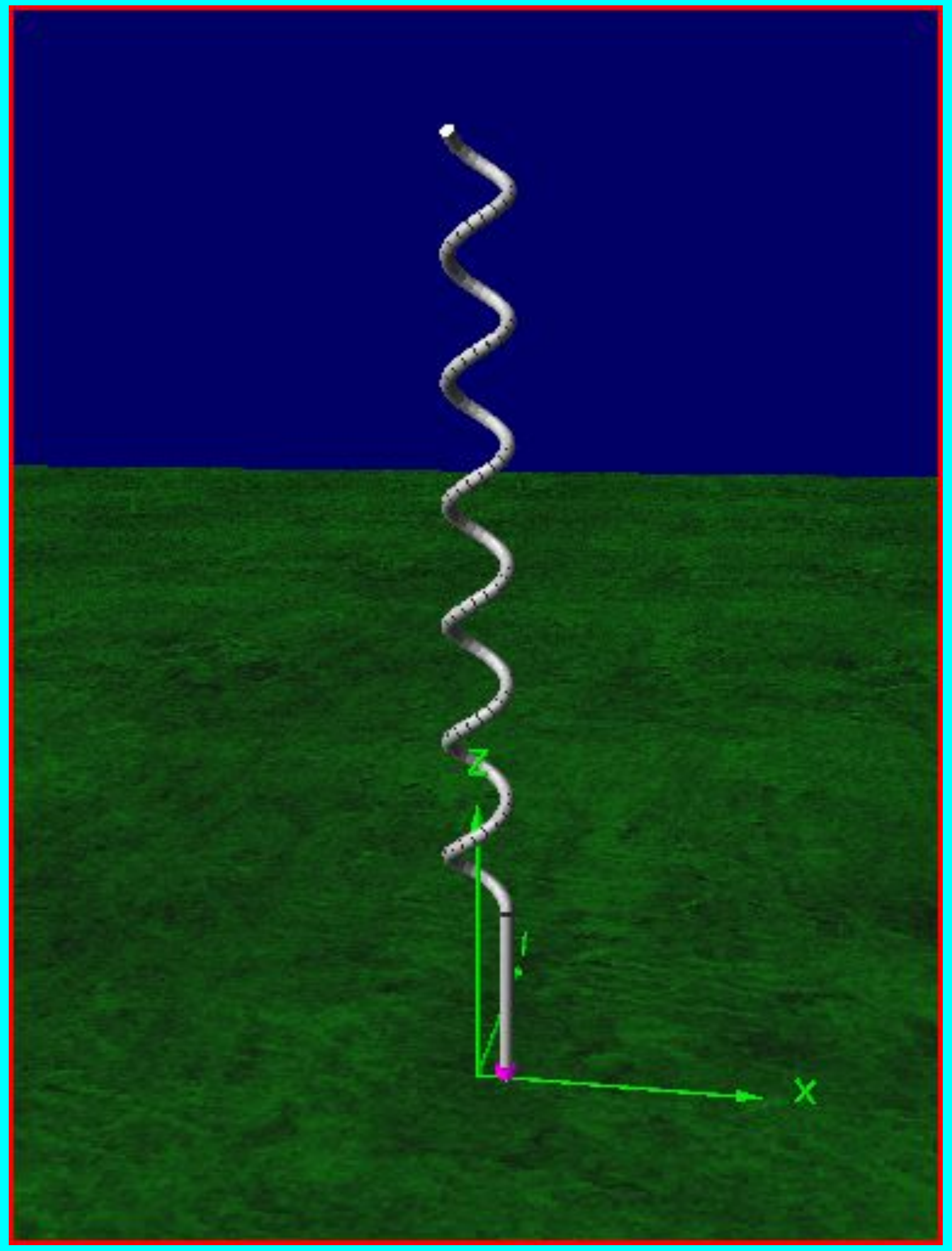
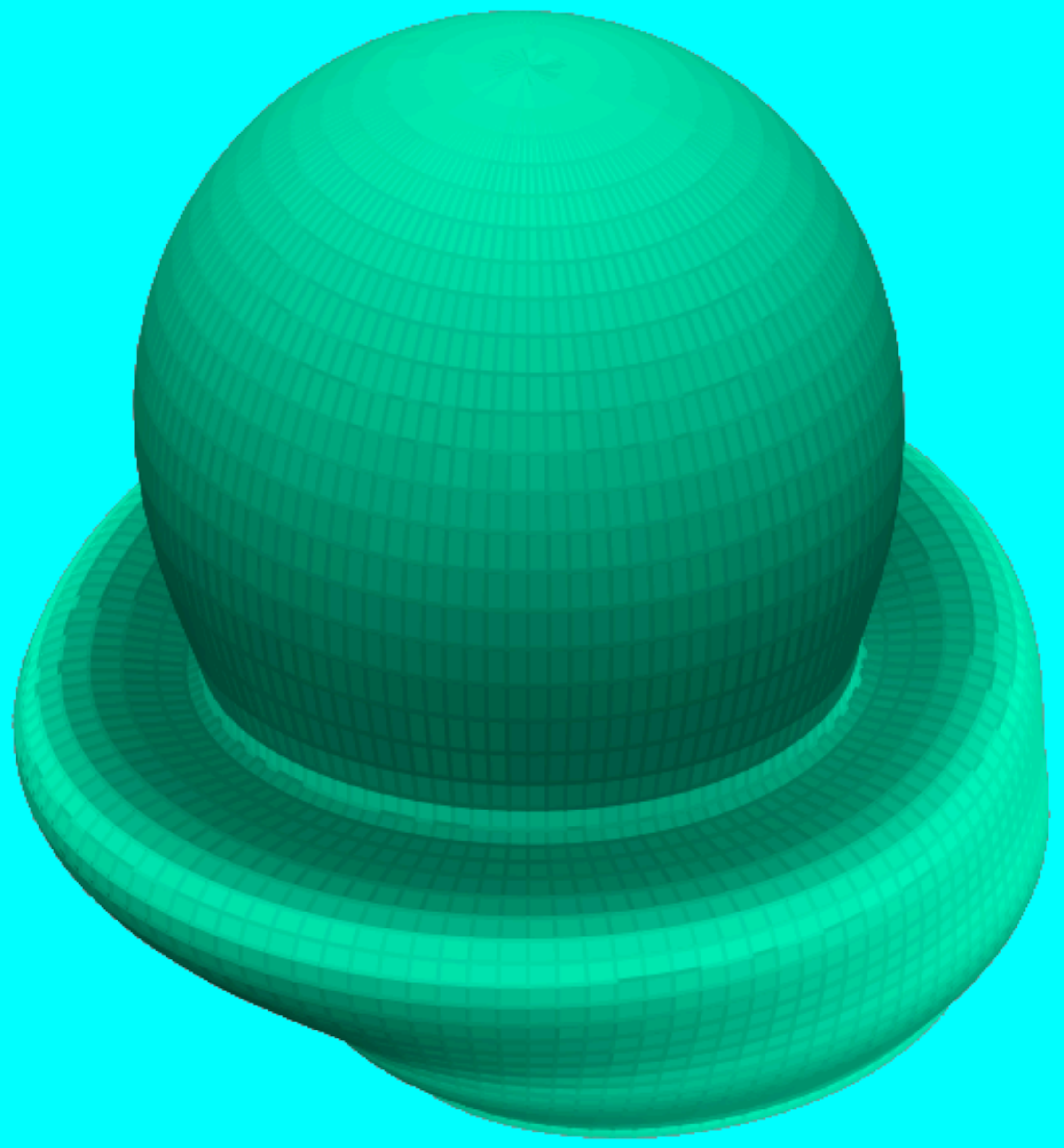
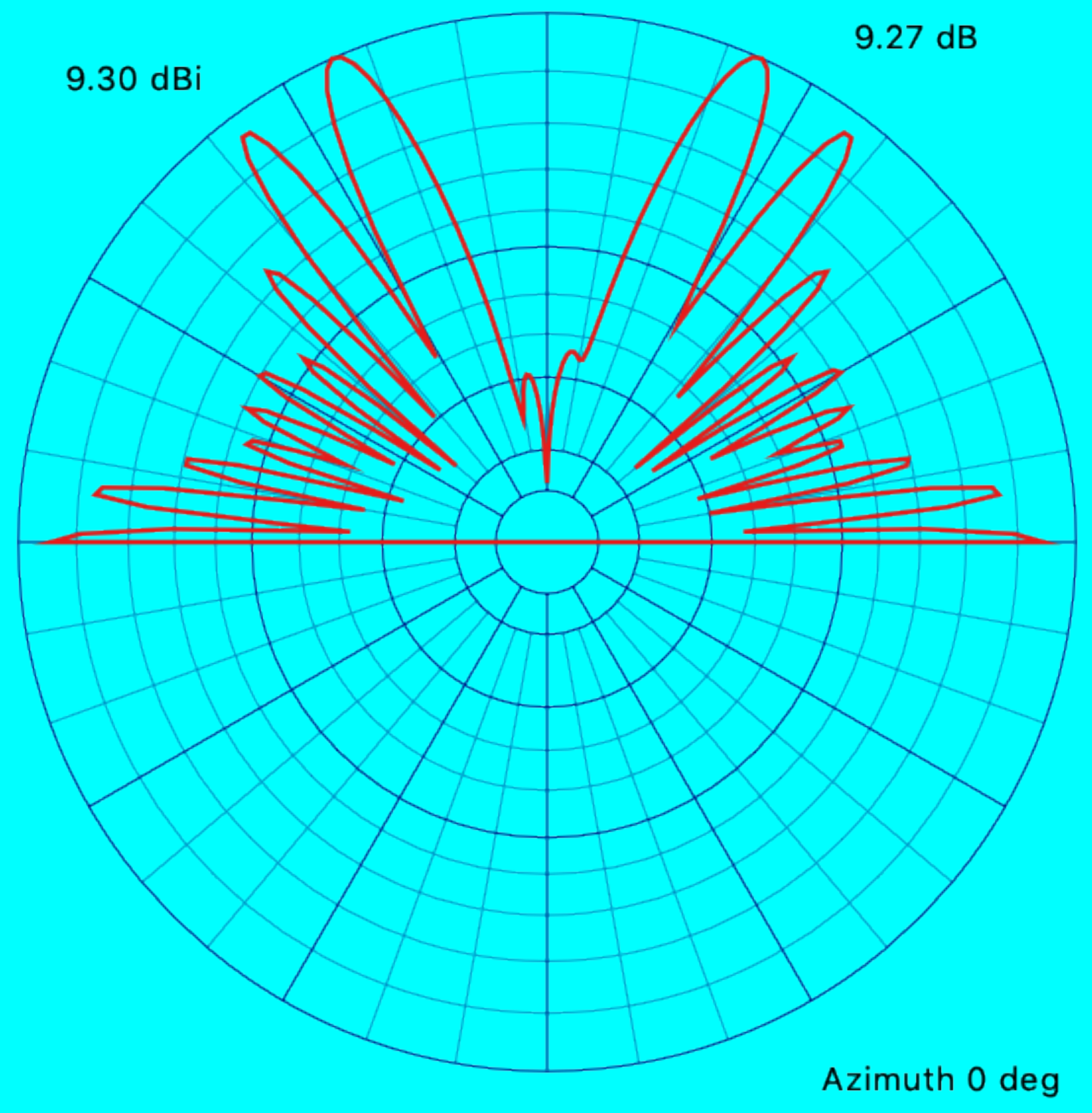
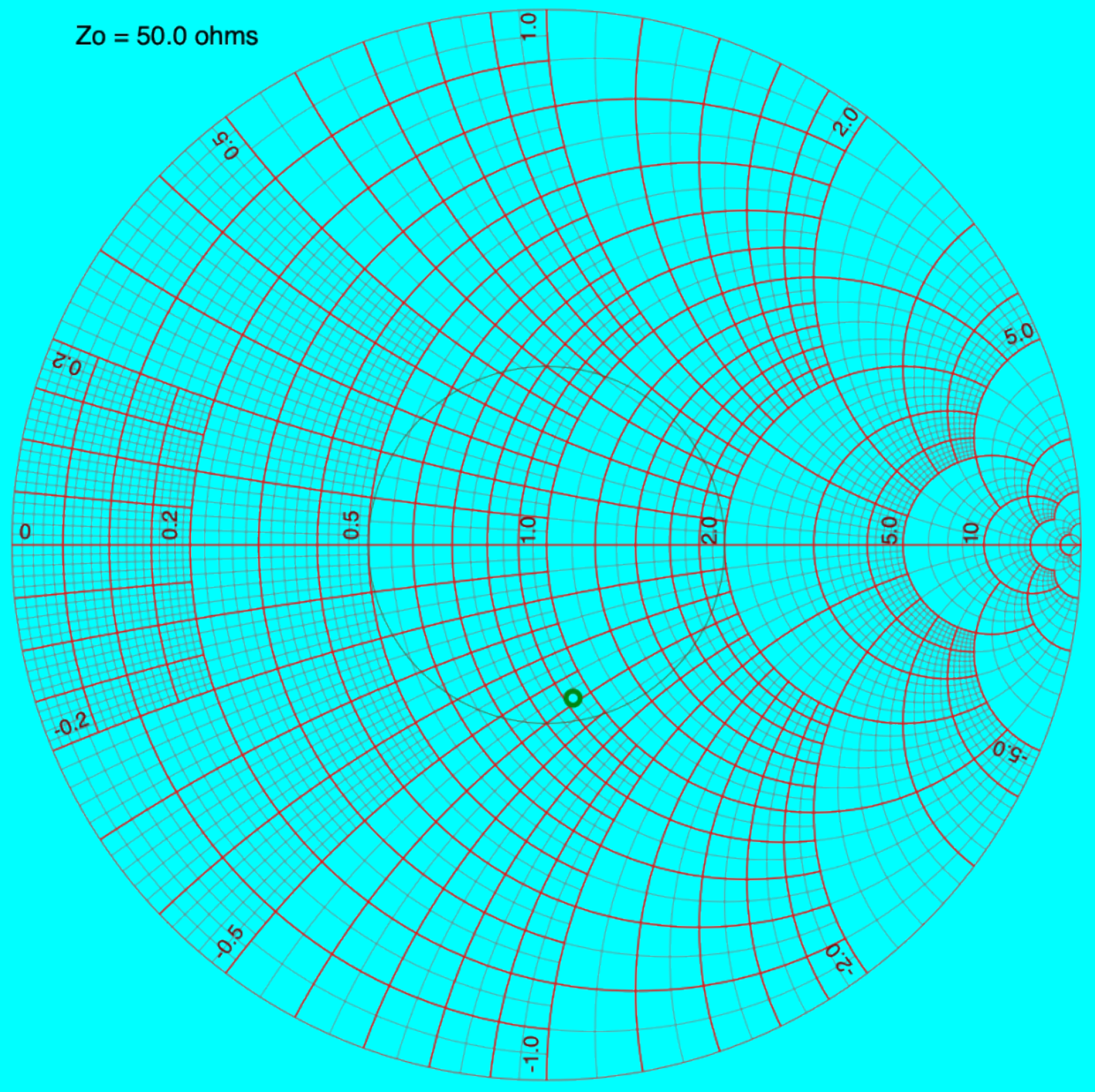
LORA / LORAWAN TUTORIAL 38

NEC Antenna Modelling Software, 4NEC2



v1.1.0

INTRO

- In this tutorial I will explain what a NEC antenna modelling software is and how to use the 4NEC2 antenna modelling software.

WHAT IS THE PURPOSE OF ANT. MODELLING S/W

- On Internet and YouTube you can find tutorials how to build certain antennas.
- But often I wonder what is the performance of these antennas?
  What if I use a slightly different wire diameter or slightly change the length of a particular wire? Will these changes impact the antenna performance significantly of not at all?
- Using an antenna modelling software can help you to answer these questions without having to build the actual antenna right away.
- NEC (Numerical Electromagnetics Code) is a popular antenna modelling system for wire and surface antennas and simulates the electromagnetic response of antennas and metal structures.

WHAT IS THE PURPOSE OF ANT. MODELLING S/W

- The accuracy of the calculation depends on how well you model the antenna and the information you provide with regard to the ground and wire conductivity.

- But be aware, in the real world using the actual antenna, the result will be slightly different compared to the simulation. This is caused by reflections, weather conditions, where the antenna is mounted etc.

WHAT IS THE PURPOSE OF ANT. MODELLING S/W

- For the LoRa/LoRaWAN tutorials I have build several simple antennas, which I will demonstrate in upcoming tutorials, and I have model these antennas. To my surprise most of these antennas behaves as predicted by the antenna modelling software.

- If you are planning to build your own antenna I highly recommend that you first model your antenna before actually building it. It will safe you time, money and frustration.

- For example I used a steel coat hanger with a 3 mm wire diameter to build an antenna. I spend 2 hours to remove the plastic coating and cutting the antenna elements to their correct lengths.

- When I finished building the antenna I used the N1201SA antenna analyser to check the VSWR.

WHAT IS THE PURPOSE OF ANT. MODELLING S/W

- The result was not great, my antenna has a VSWR of 3.
- I decided to use an antenna modelling software to check what I have done wrong.
- By changing certain antenna parameters in the model I concluded that I used the wrong wire diameter. Instead of 3 mm I should have used a wire diameter of 1.8 mm to get a VSWR less than 2.
- The antenna modelling software also provides the horizontal and vertical antenna radiation patterns. These radiation patterns are just as important as the VSWR.
- What if the main lobe is pointing upwards instead of sideways. If your sensors and gateways are located on a flat area than this antenna will not perform great.

NEC ANTENNA MODELLING SOFTWARE

- Here are a few NEC antenna modelling software:

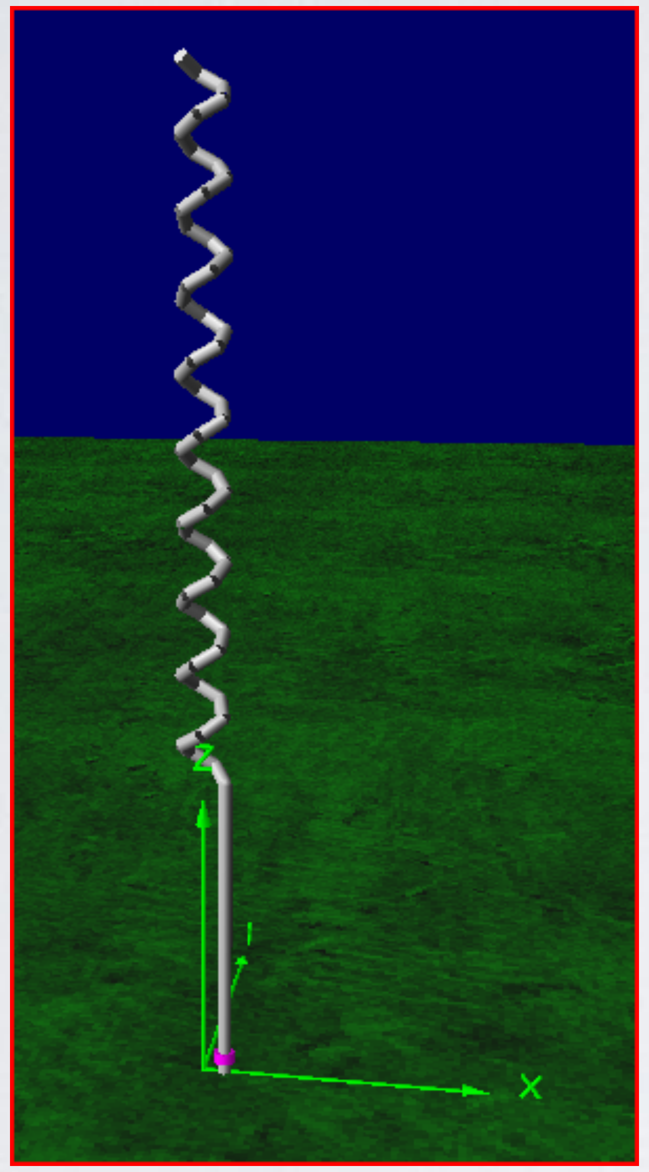
  - **EZNEC** - Available for Windows. It has a free and a paid version. The free version has a 20 segments limit.
    http://www.eznec.com

  - **4NEC2** - Available for Windows and its free. This tool has many options.
    https://www.qsl.net/4nec2/

  - **cocoaNEC** - Available for MAC OSX and its free. This tool has limited options.
    http://www.w7ay.net/site/Applications/cocoaNEC/

NEC ANTENNA MODELLING SOFTWARE

- I have used cocoaNEC but I encountered problems when trying to model a normal mode helical antenna.



Normal mode helical antenna modelled with the 4NEC2 program.

- So I ended up using 4NEC2 which I highly recommend. Unfortunately it is only available for Windows.

NEC

- The previous mentioned 3 antenna modelling software uses the NEC-2 (Numerical Electromagnetics Code) engine which does all the calculations.

- NEC was developed by the Lawrence Livermore National Laboratory in the 1970s and is an antenna modelling system for wire and surface antennas.

- More information about NEC-2: https://www.nec2.org

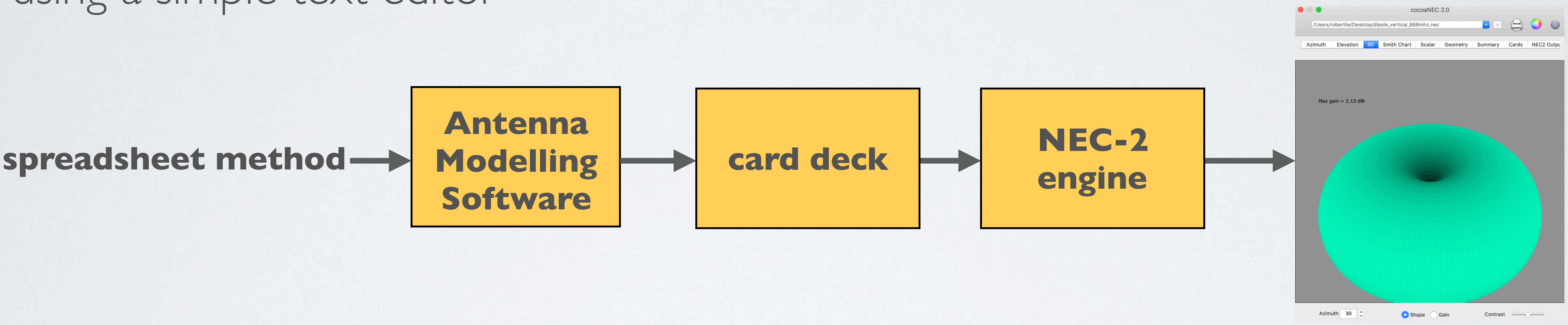
- The NEC2 documentation is composed of three sections:
  Part I: NEC Program Description - Theory, https://www.nec2.org/other/nec2prt1.pdf
  Part II: NEC Program Description - Code, http://www.radio-bip.qc.ca/NEC2/nec2prt2.pdf
  Part III: NEC User's Guide, https://www.nec2.org/other/nec2prt3.pdf
  Part III is the documentation you need.

NEC

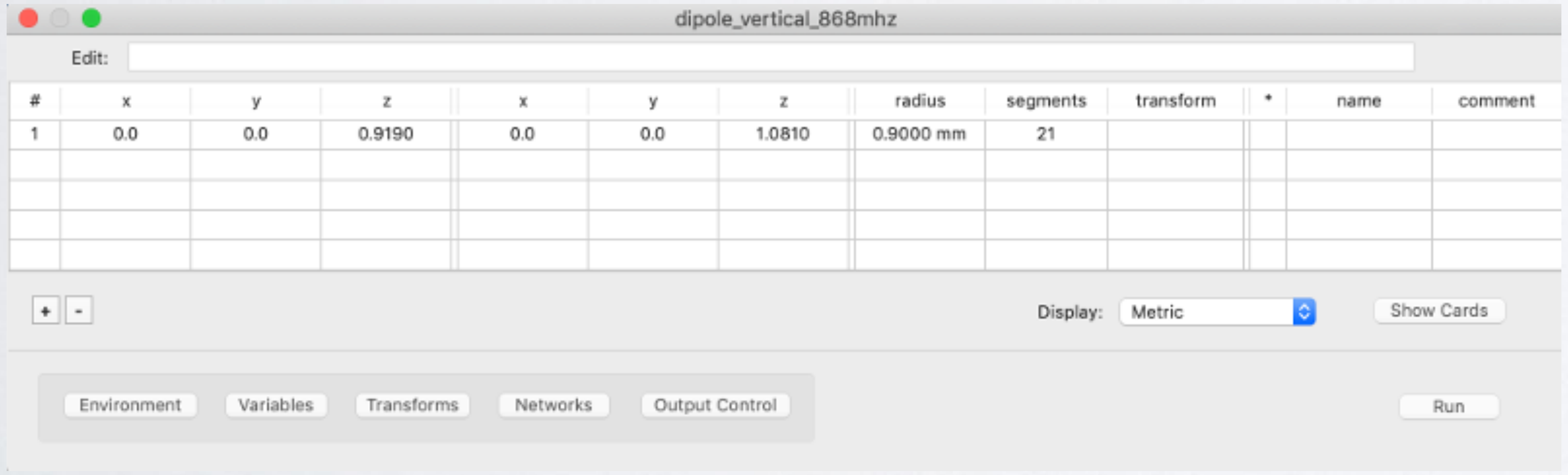
- NEC2 quick reference: https://www.mobilefish.com/download/lora/nec2_quick_reference.pdf

HOW IT WORKS

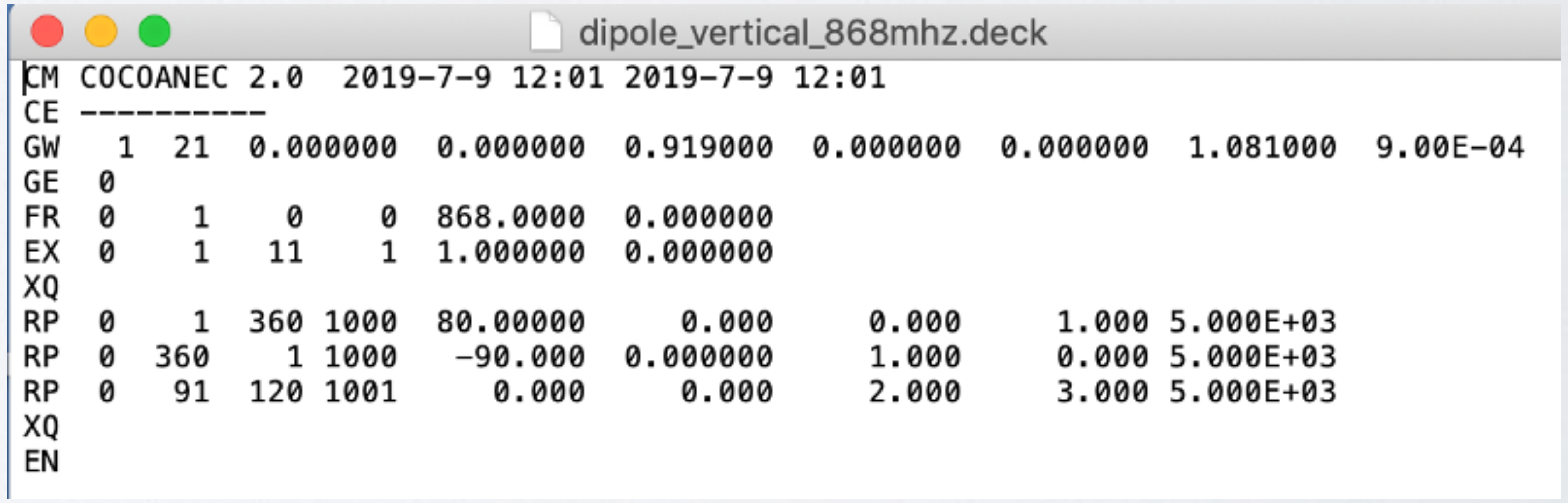
- In general, most antenna modelling software provides 2 input methods:
  - using a spreadsheet style editor
  - using a simple text editor



Spreadsheet style editor



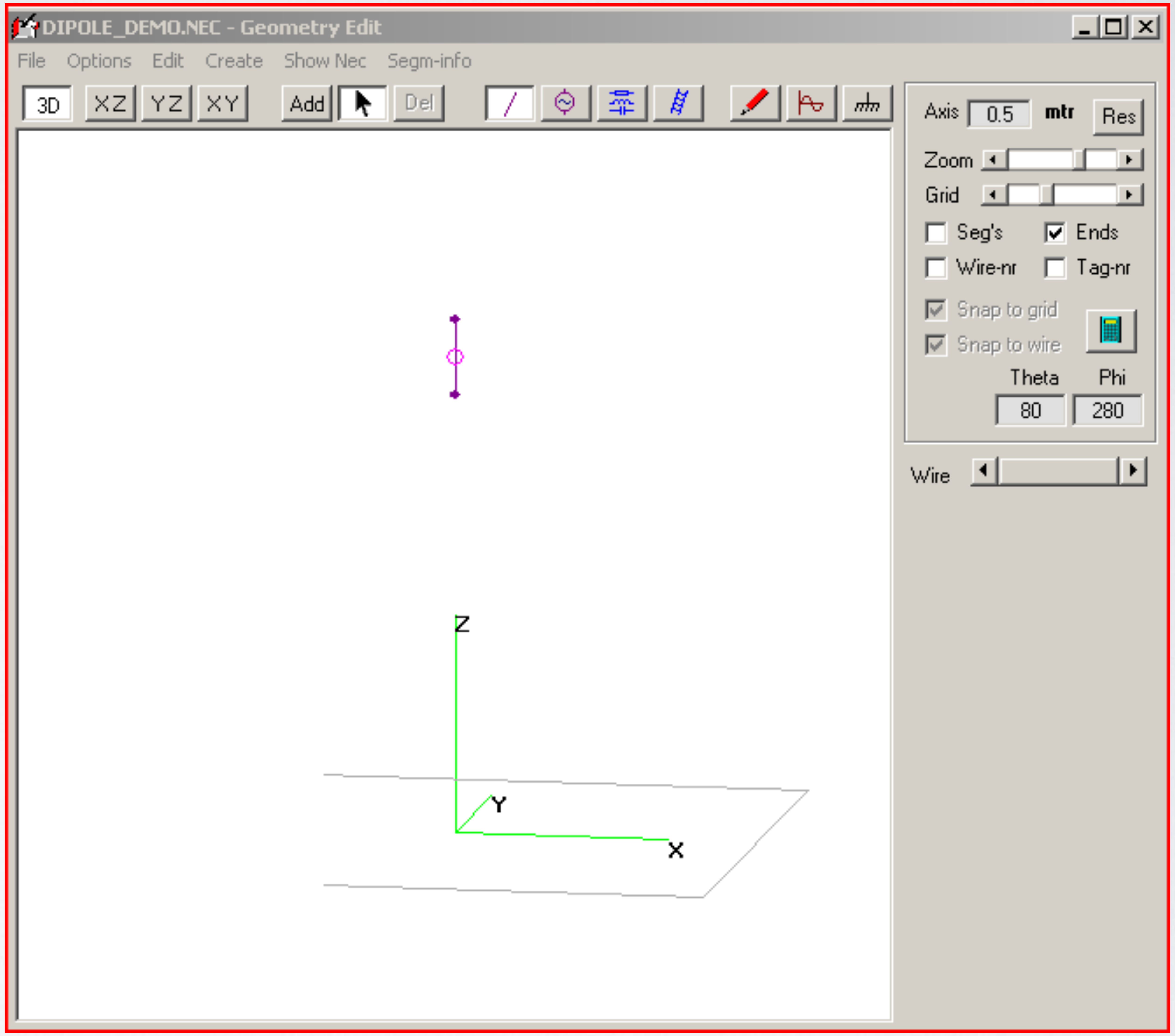
Text editor with card deck


dipole_vertical_868mhz.deck

```
CM COCOANEC 2.0  2019-7-9 12:01 2019-7-9 12:01
CE ----------
GW   1  21  0.000000  0.000000  0.919000  0.000000  0.000000  1.081000  9.00E-04
GE  0
FR  0    1    0    0  868.0000  0.000000
EX  0    1   11    1  1.000000  0.000000
XQ
RP  0    1  360 1000  80.00000     0.000     0.000     1.000 5.000E+03
RP  0  360    1 1000   -90.000  0.000000     1.000     0.000 5.000E+03
RP  0   91  120 1001     0.000     0.000     2.000     3.000 5.000E+03
XQ
EN
```

HOW IT WORKS

- There are antenna modelling software available (e.g. 4NEC2) where you can model the antenna by drawing it, using a Graphical User Interface (GUI).



4NEC2 ANTENNA MODELLING DEMONSTRATION

INSTALL 4NEC2

- Goto https://www.qsl.net/4nec2/ and download 4nec2 (setup.exe)
  The downloaded 4nec2.zip file contains file Setup_4nec2.exe (v 5.8.16)
  Unzip this file.

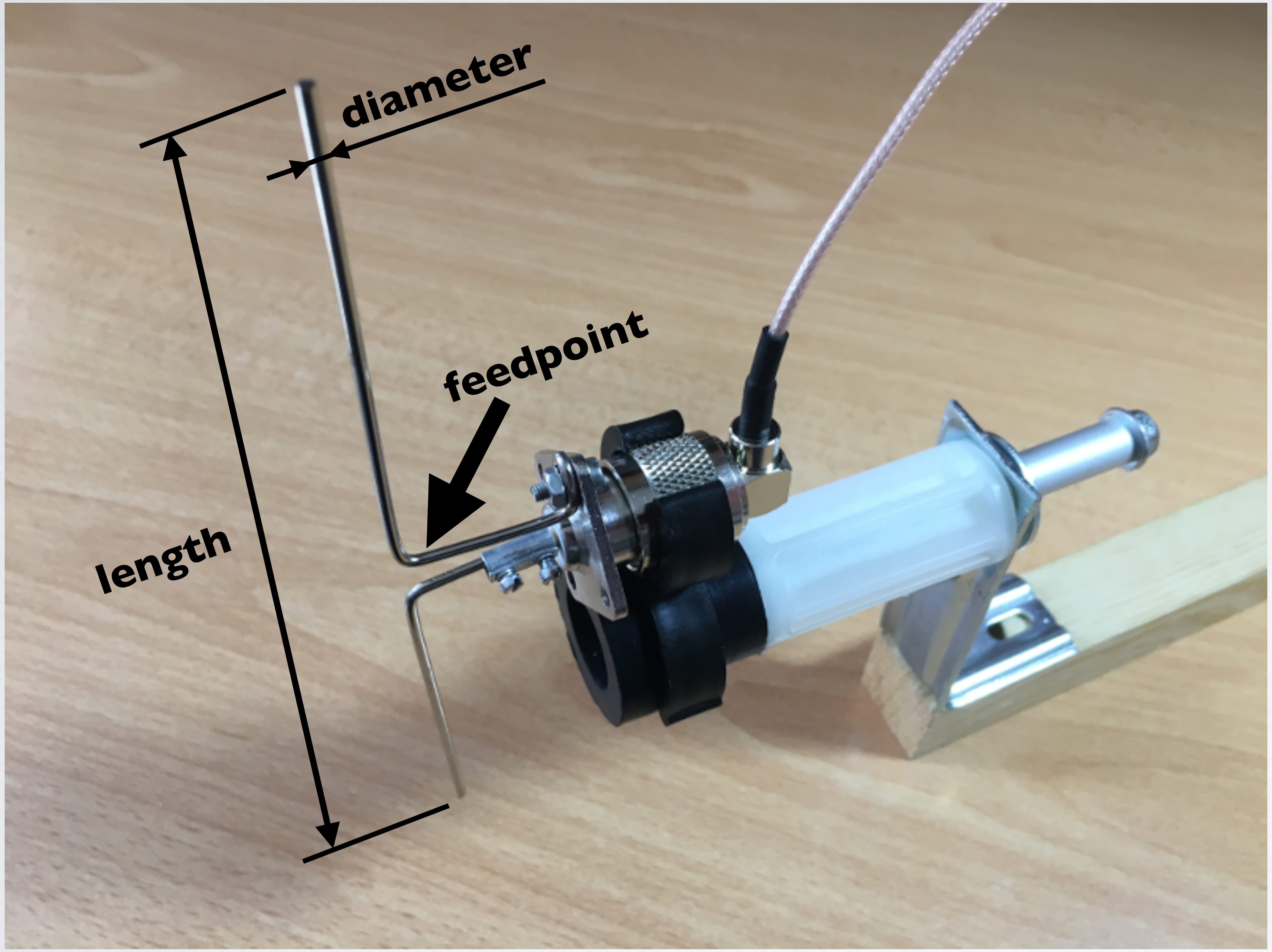
- Install 4NEC2 by double clicking file Setup_4nec2.exe.
  4NEC2 can be installed on any directory.
  For example: c:\tools\4nec2

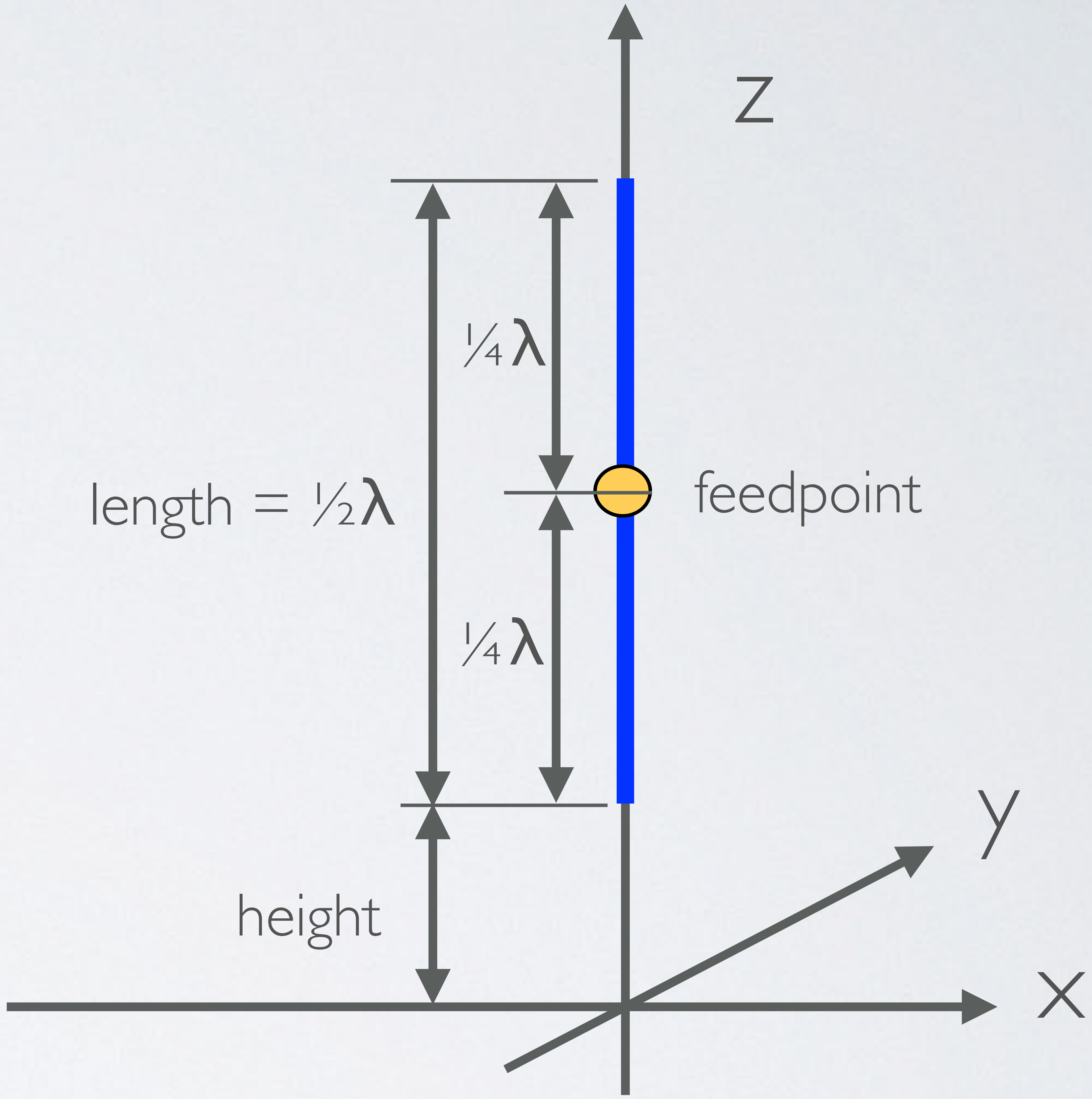
- The folder c:\tools\4nec2 contains:
  - The getting started guide: **_GetStarted.txt**
  - The complete NEC-2 Manual, Part III: User's guide: **Nec2.doc**
  - The NEC2 Short reference card: **Cards.rtf**

INSTALL 4NEC2

- The complete 4NEC2 help in document format **4nec2/exe/4nec2.rtf**
- Many antenna model examples: **4nec2/models**

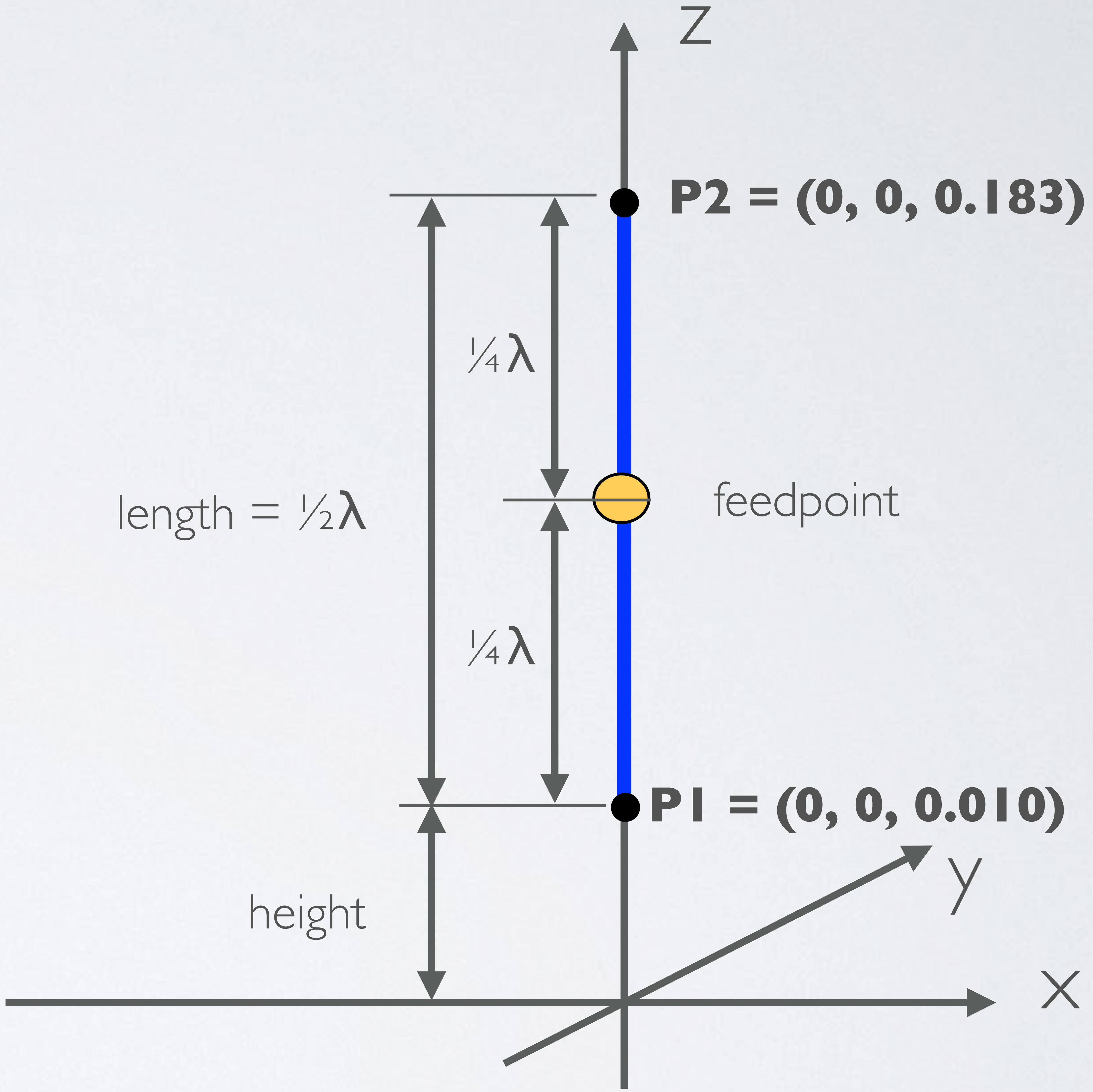
½ WAVELENGTH DIPOLE ANTENNA





½ WAVELENGTH DIPOLE ANTENNA

- ½λ dipole antenna (vertical polarised).
- Antenna parameters:
  f = 868 MHz
  λ = 0.34538 m, ½λ = 0.17269 m
  wire material = stainless steel
  length = 0.173m
  wire diameter = 1.8 mm
  wire radius = 0.9 mm = 0.0009 m
  height = 0.010 m (1 cm above ground)



Coordinates in meters

PROCEDURE TO USE 4NEC2

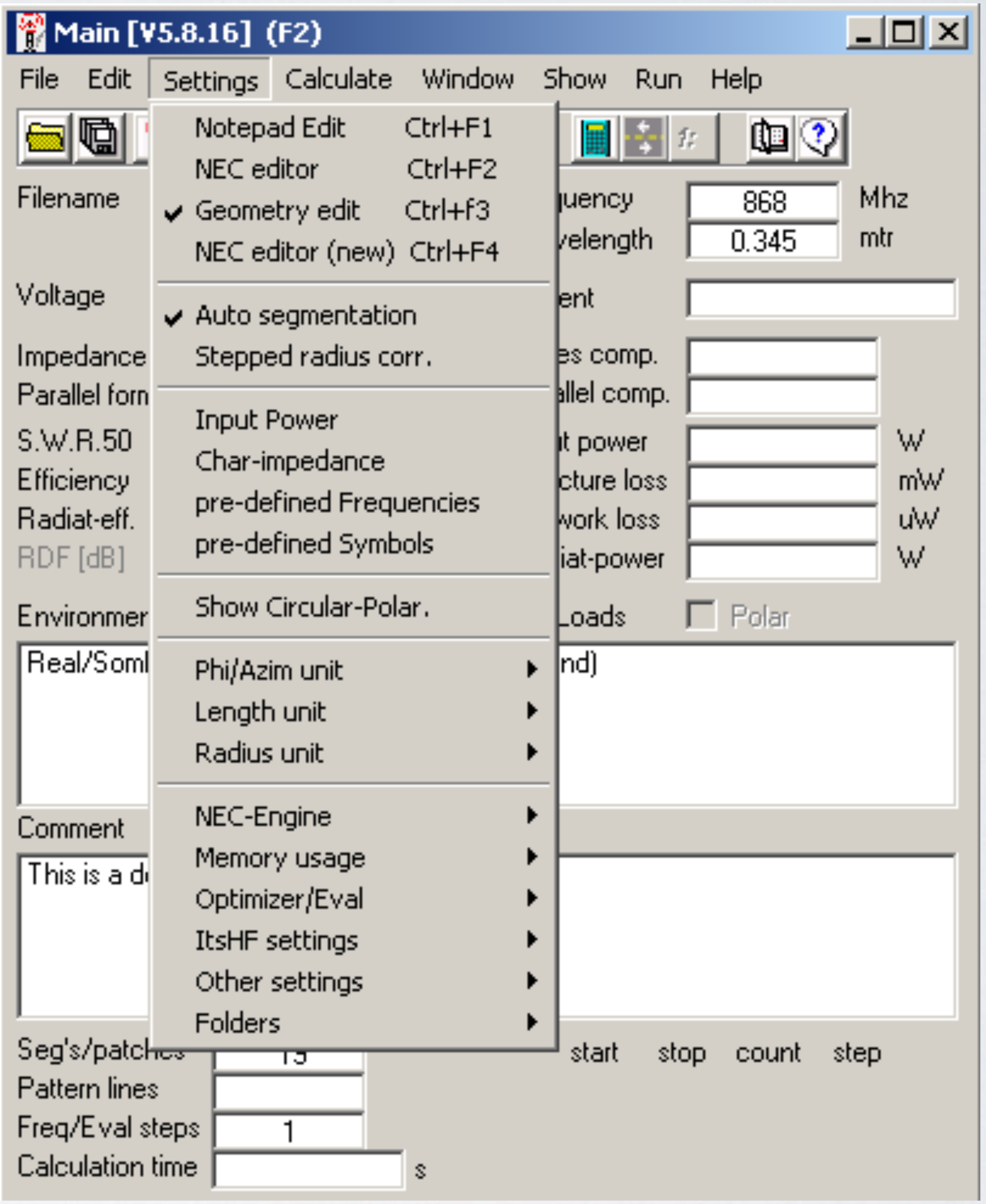
- Start the 4NEC2 program.

- Close all windows except the Main window.

- Main menu select:
  Settings | Length unit | select your unit, for example: Meters
  Settings | Radius unit | select your unit, for example: Millimeters

- Enable Geometry edit

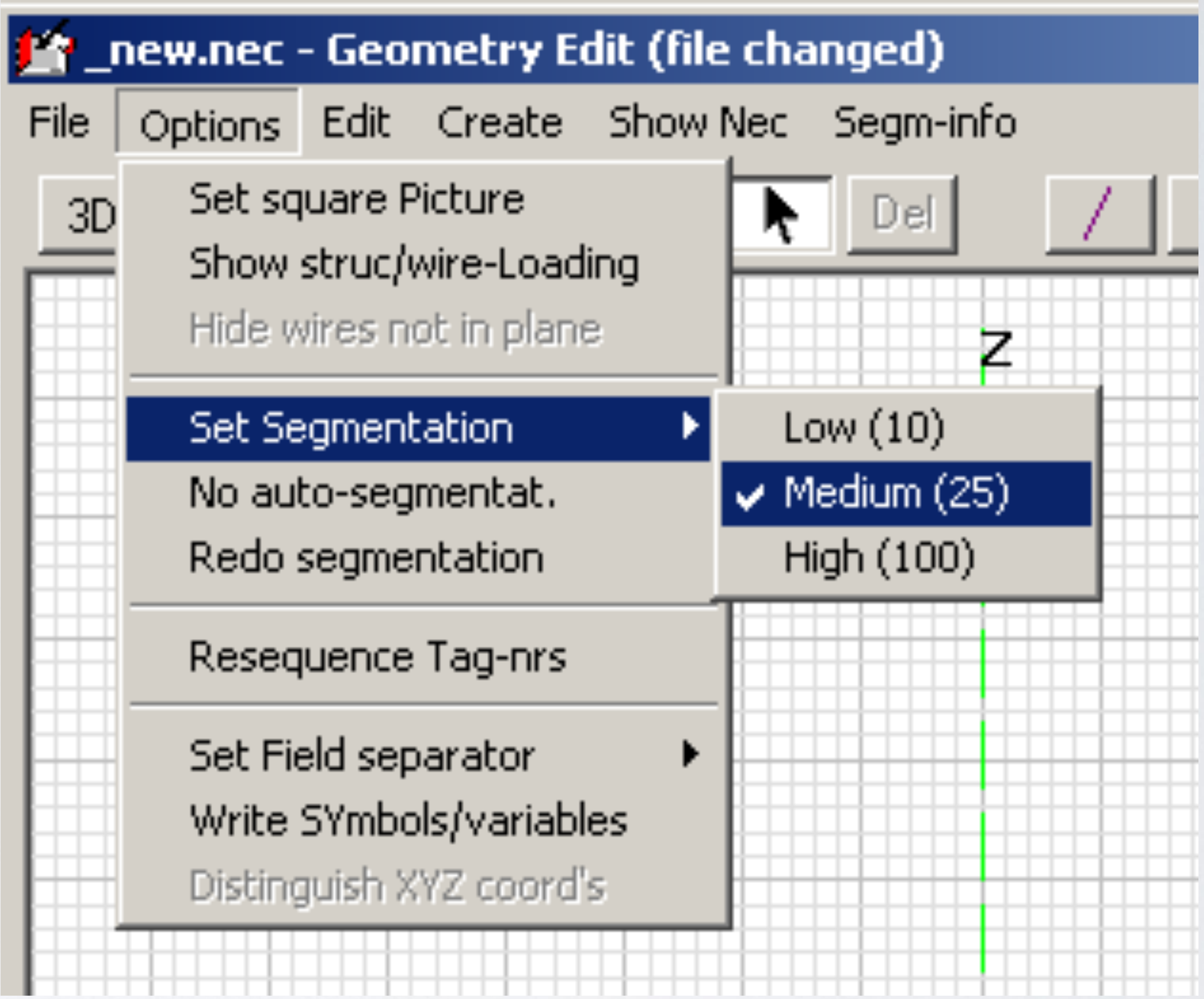
- Enable Auto segmentation



PROCEDURE TO USE 4NEC2

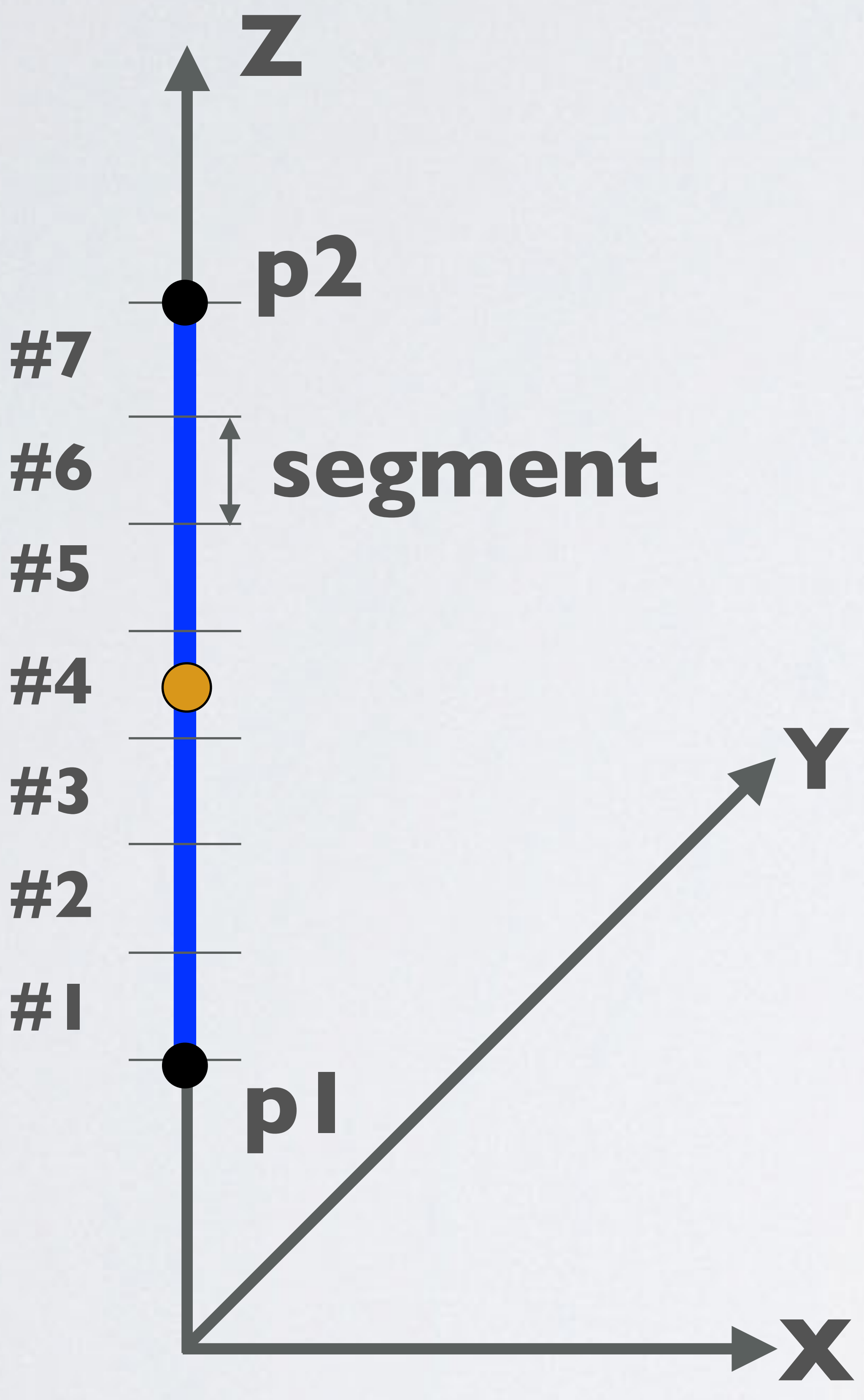
- Open Geometry Editor (CTRL + F3)
  CTRL + F1: Notepad
  CTRL + F2: NEC editor
  CTRL + F3: Geometry edit (GUI editor)
  CTRL + F4: NEC editor (new)

- Geometry Editor:
  Options | Set Segmentation | Medium (25)



NUMBER OF SEGMENTS

- An antenna consists of wires and each wire is subdivided into segments.

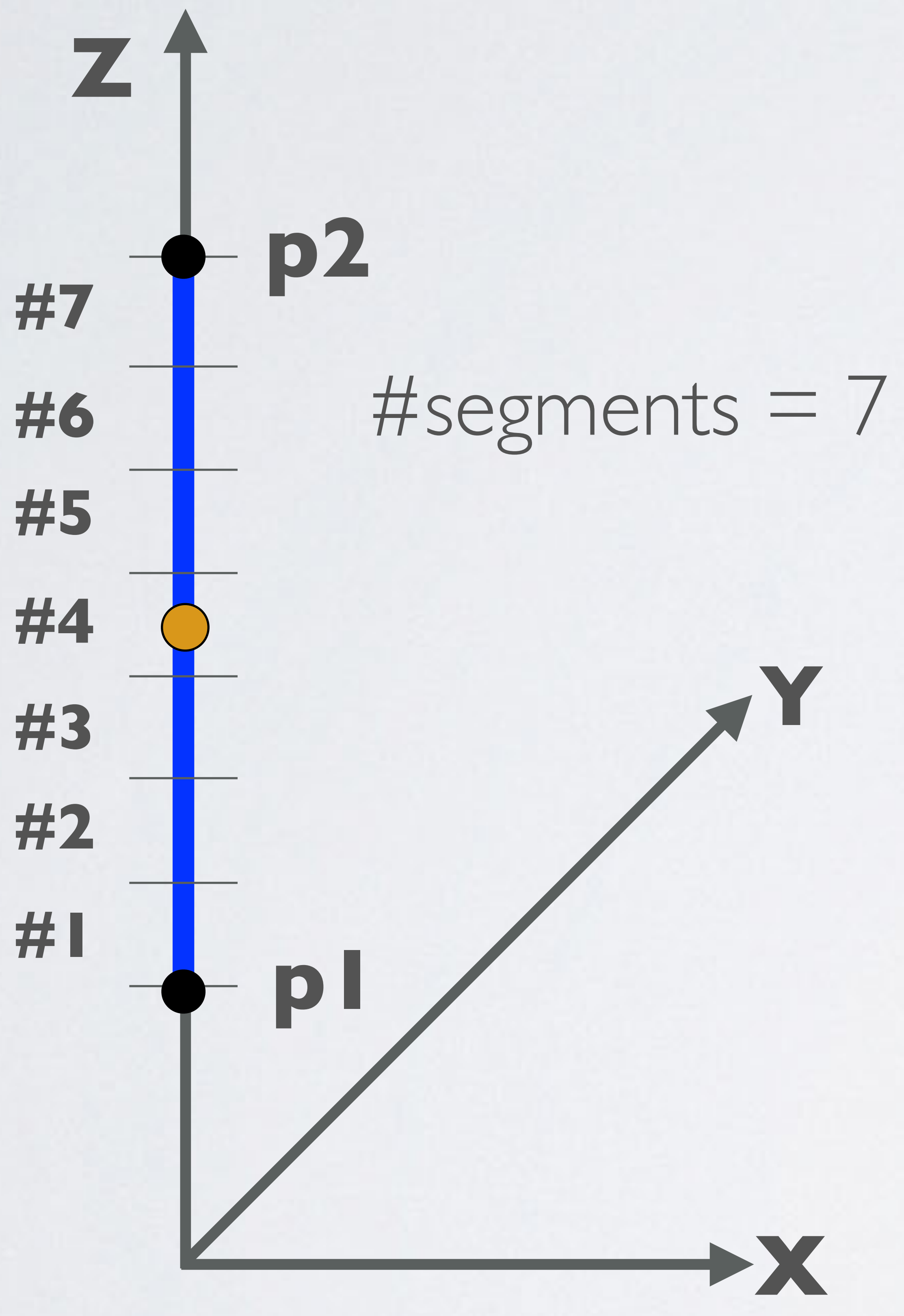


½λ dipole antenna

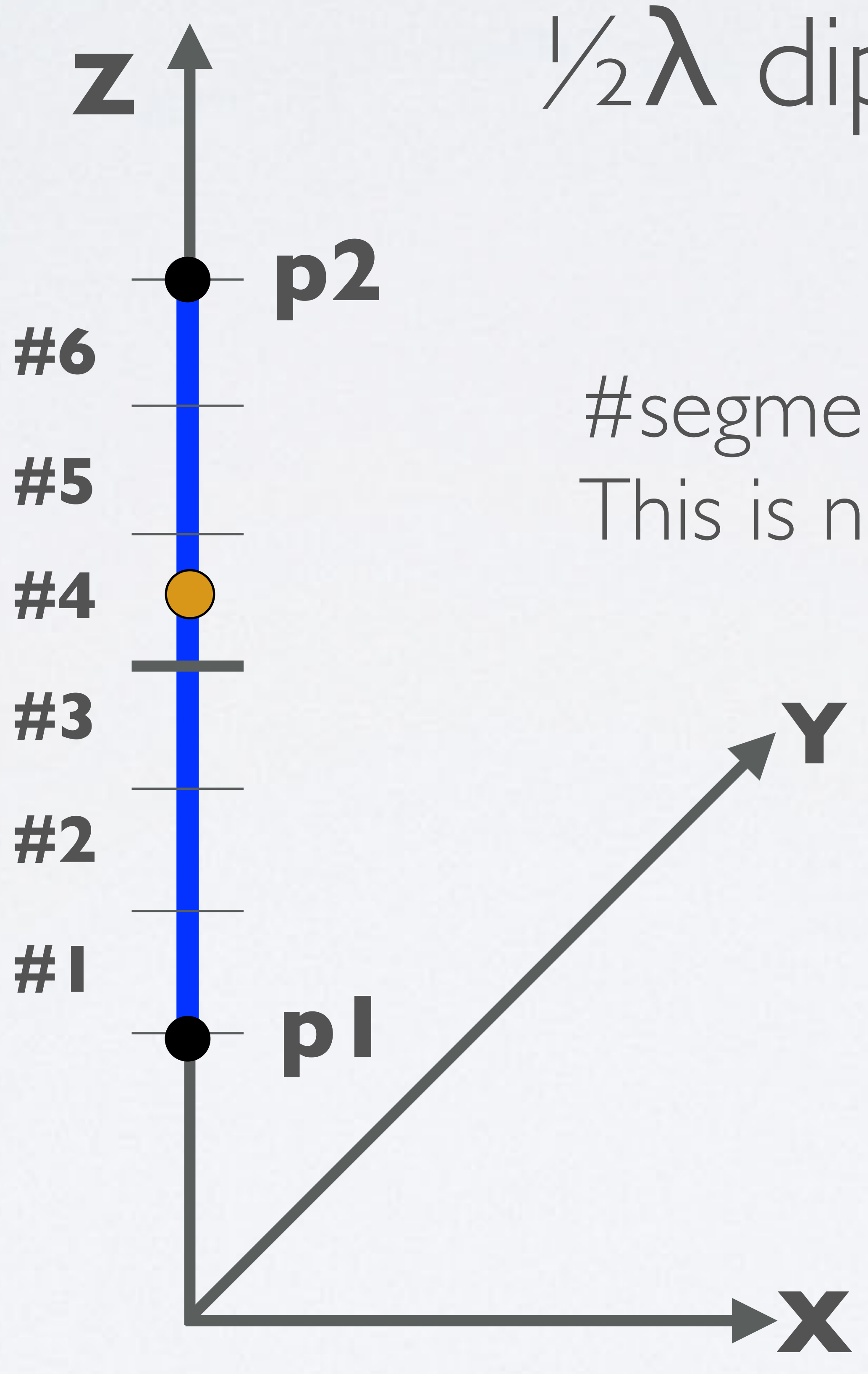
- Draw a wire between 2 points: p1= (x_1,y_1,z_1) and p2 = (x_2,y_2,z_2).
- Divide the wire into segments. No of segments = 7
- In this example the feedpoint is located at segment #4.

NUMBER OF SEGMENTS

- If the feedpoint is located in the middle of a wire the number of segments must be an odd number.



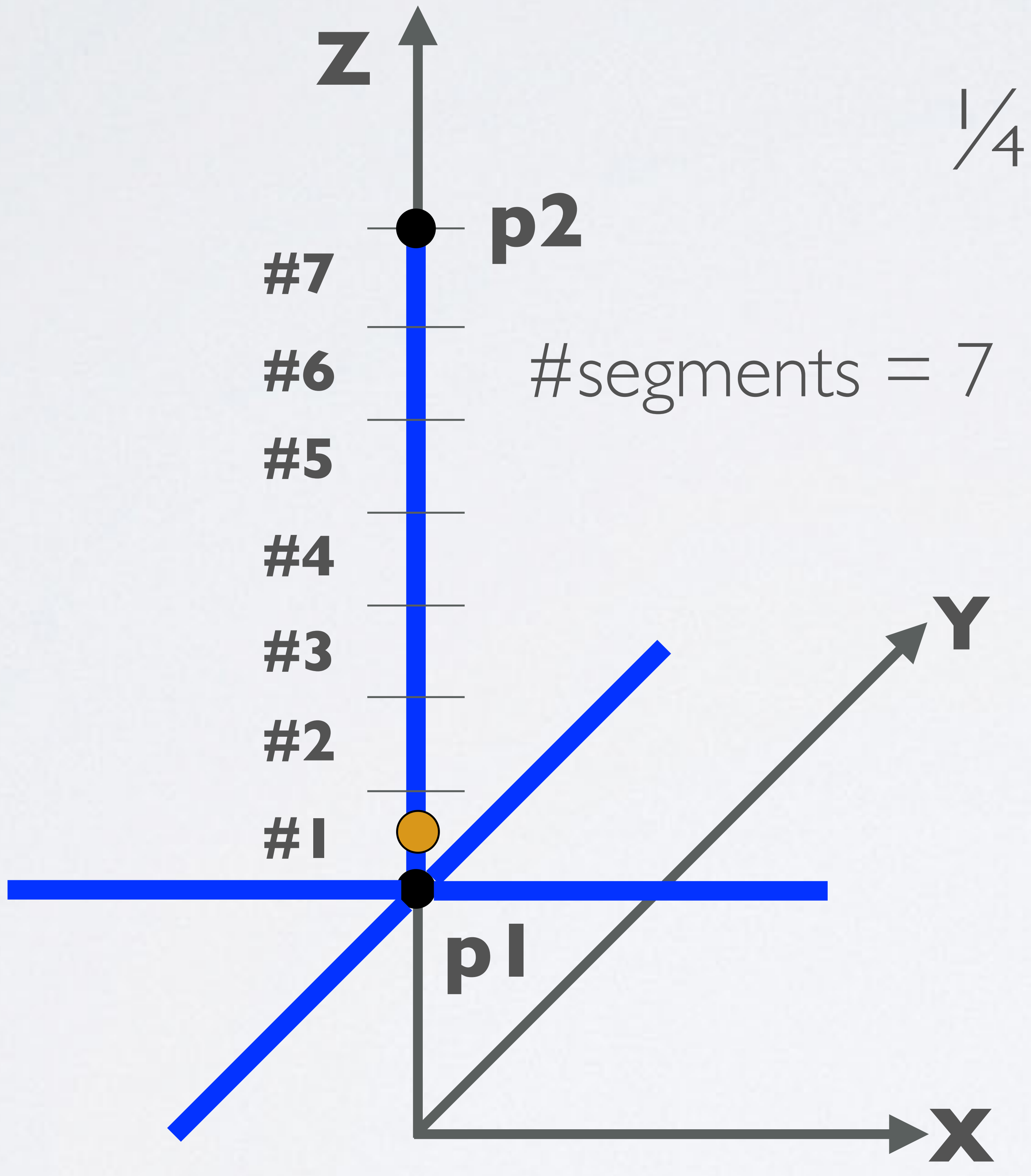
½λ dipole antenna



#segments = 6
This is not good. Feedpoint is off center.

NUMBER OF SEGMENTS

- If the feedpoint is located at the end of a wire the number of segments can be an odd or an even number, it does not matter.



¼λ ground plane antenna

NUMBER OF SEGMENTS

- You can let the 4NEC2 program to automatically calculate the number of segments.
- But you can do it yourself, but it is not recommended.
  There are certain rules you must follow.
- If the number of segments is too low the calculations are not accurate.
  If it is too high the calculations takes a lot of time.

NUMBER OF SEGMENTS

- The length of each segment must be between 5% and 10% of the wavelength.
- If the ratio of segment length to wire radius is greater than 8 the NEC engine simulates the current flow in the wire as a very thin current thread.
  The NEC engine uses the default "Thin Wire Kernel'' (Do not use EK card)
- If the ratio is between 2 and 8 the NEC engine should simulate the current to be evenly distributed on the circumference of the wire for a more accurate result.
  In this situation you should use the EK card (Extended Thin Wire Kernel).
- Never make the ratio go below 2.

NUMBER OF SEGMENTS

- Rules:

Rule 1: Segment length must lie between $5\%\lambda$ and $10\%\lambda$
Rule 2: Ratio = Segment length / wire radius
If the Ratio is between 2-8 use the EK card
If the Ratio > 8 do not use the EK card

NUMBER OF SEGMENTS

- Example:
  frequency = 868 MHz, thus λ=345.38 mm
  Wire length = 175 mm
  Wire diameter = 1.8 mm
  Question: Can the wire be divided in 8 segments and should EK card be used or not?

- Answer:
  5%λ = 0.05 x 345.38 = 17.269 mm
  10%λ = 0.10 x 345.38 = 34.538 mm
  Segment length = Wire length / number of segments = 175 / 8 = 21.87 mm

NUMBER OF SEGMENTS

- The segment length=21.87 mm and lies between 17.269 mm and 34.538 mm
  The number of segments=8 is correctly chosen.

- Ratio = Segment length / wire radius
  Wire diameter = 1.8 mm
  Ratio = 21.87 / 0.9 = 24.3
  The ratio is greater than 8, which means do not use the EK card.

EK CARD

- Use the EK card to specify the use of the extended thin-wire kernel.
  EK stands for Extended Kernel.
  For example:

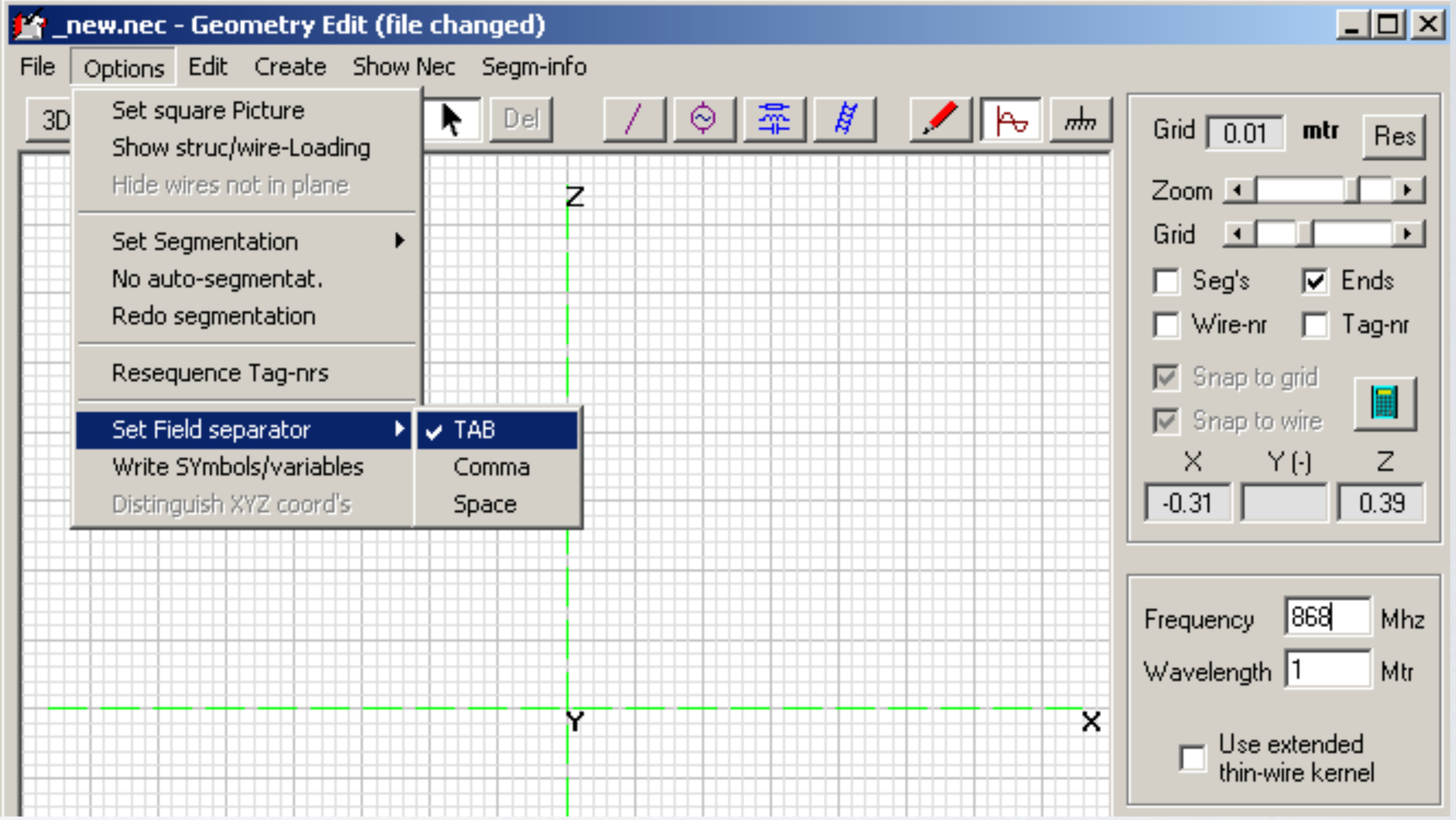
```
EK   0
```

0 or blank = Use the extended thin-wire kernel (Ratio 2-8).
-1 or no EK card = Use the standard thin-wire kernel (Ratio > 8).

PROCEDURE TO USE 4NEC2

- Geometry Editor select:
  Options | No-auto-segmentation DO NOT SELECT
  Options | Set Field separator | TAB
  Options | Write Symbols / variables DO NOT SELECT
  File | New
  File | Save As | dipole_demo.nec

- Set display frequency: 868 MHz (Press Enter)
  Save file and open dipole_demo.nec



CE CARD

- Use the CE card to specify the end of the comment section.
  CE stands for Comment End.
  For example:

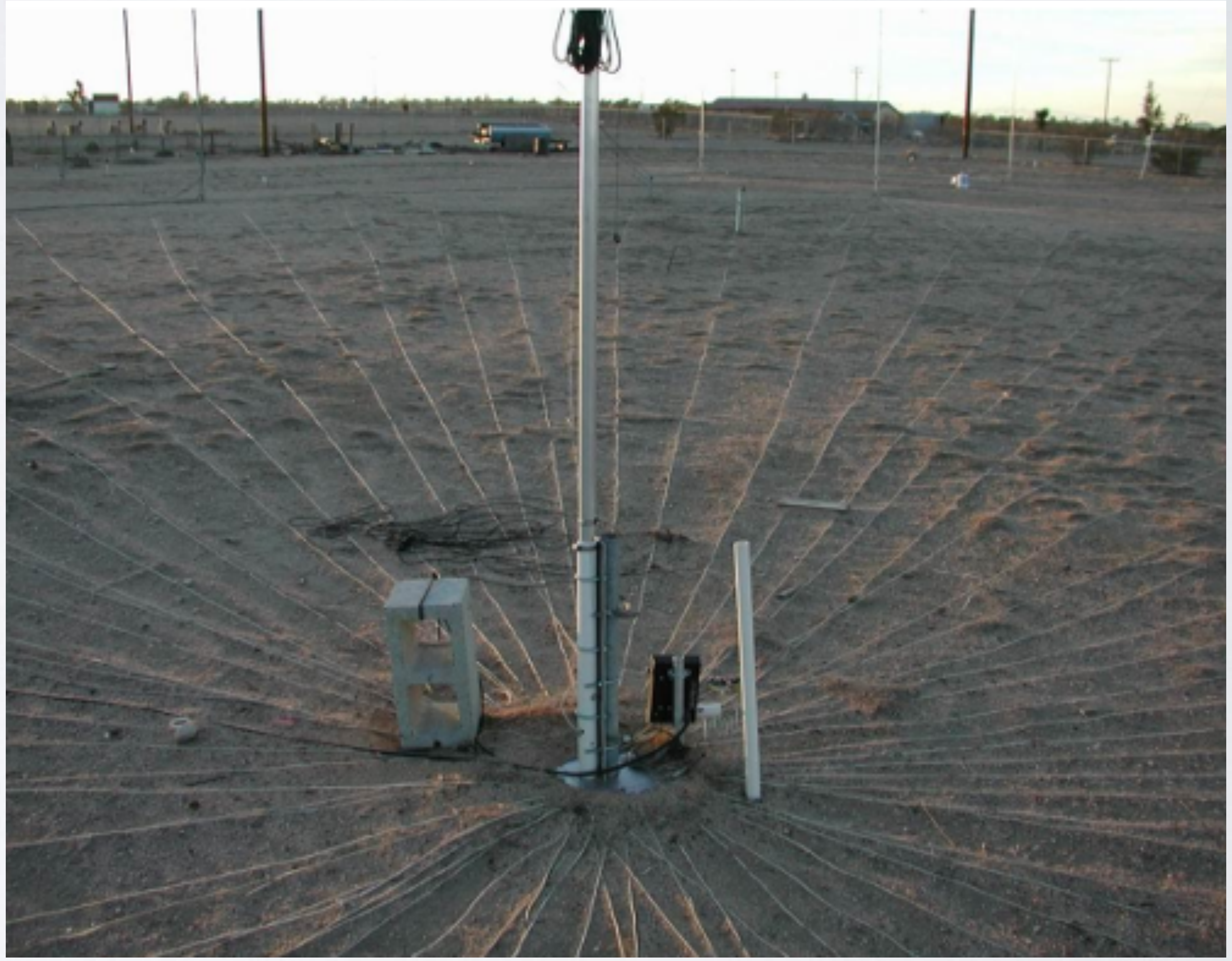
  CE

GE CARD

- Use the GE card to specify the end of the geometry input.
  GE stands for Geometry End.
  For example:

GE 0

0 = No ground.
1 = Ground plane present,
wire-ends for Z=0 are 'connected' to ground.
In LoRa systems this is not used.
-1 = Ground present, wire-ends are not 'connected'
to ground (GN card required)

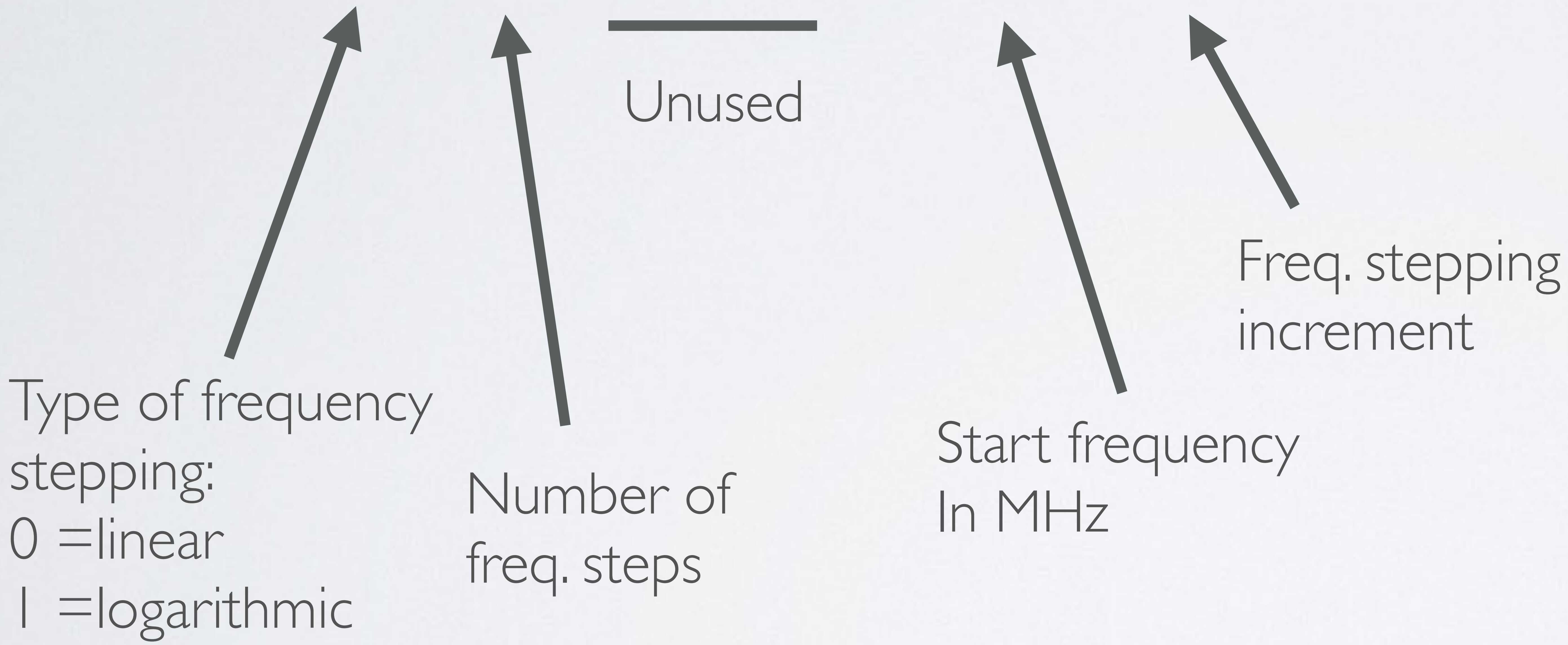


Source: https://qrznow.com/vertical-antennas-tips-and-tricks-on-this-weeks-qa-wednesday-dxe/

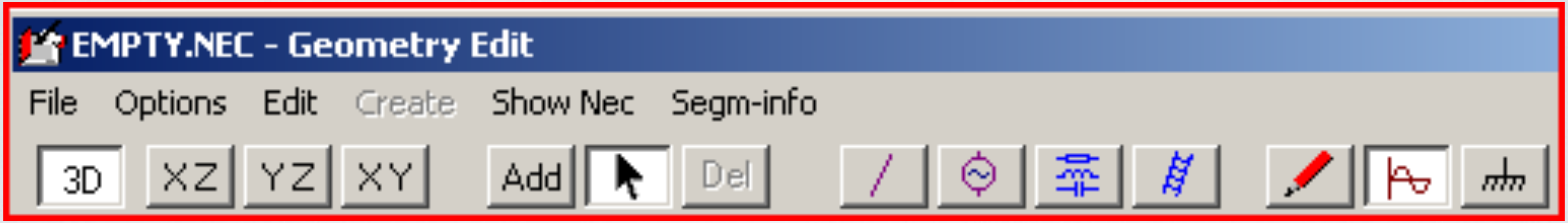
FR CARD

- Use the NEC FR card to specify the design frequency.
  FR stands for Frequency.
  For example:

```
FR  0  1  0  0  868  0
```



PROCEDURE TO USE 4NEC2



3D view
XZ plane
YZ plane
XY plane

Add new object
Select object
Delete object

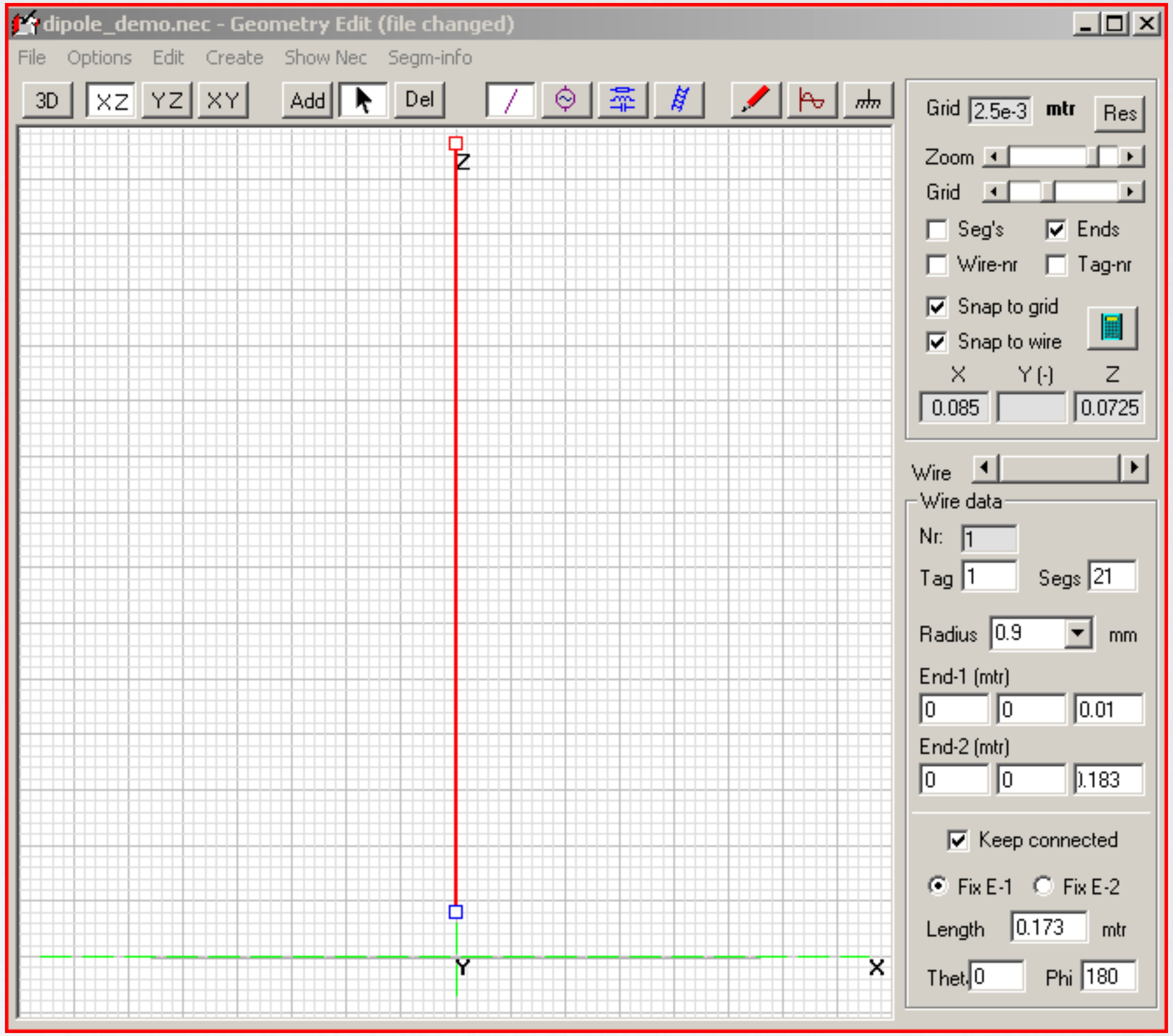
Wire geometry
V/I sources
RLC loading
Transmission lines

Comment/Wire data
Frequency
Ground parameters

PROCEDURE TO USE 4NEC2

- Model the antenna, first select XZ plane.

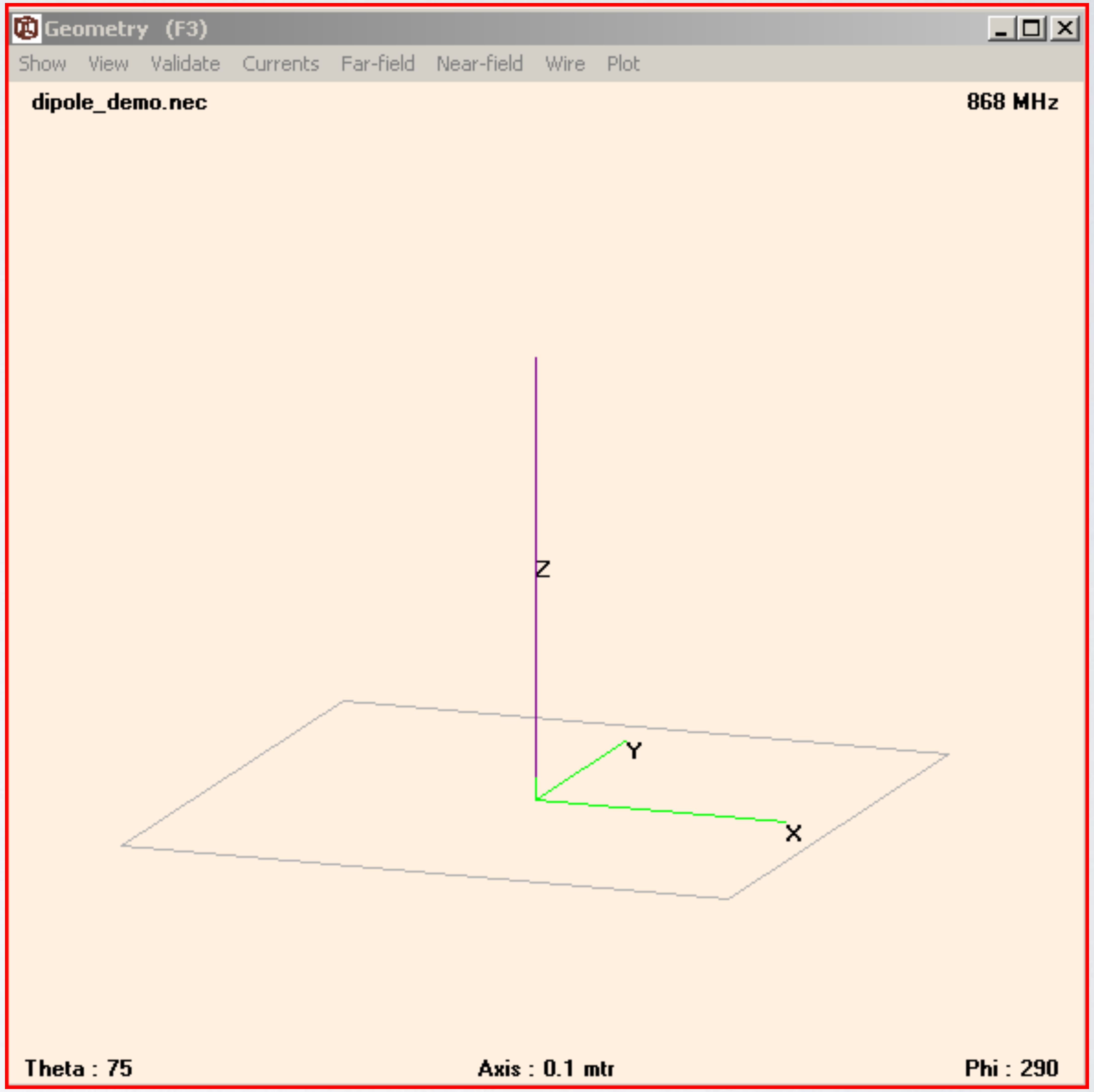
- Draw a vertical line on the z-axis.
  Radius = 0.9 mm
  End-1 = 0, 0, 0.010 m
  End-2 = 0, 0, 0.183 m
  The wire is automatically divided into 21 segments.



PROCEDURE TO USE 4NEC2

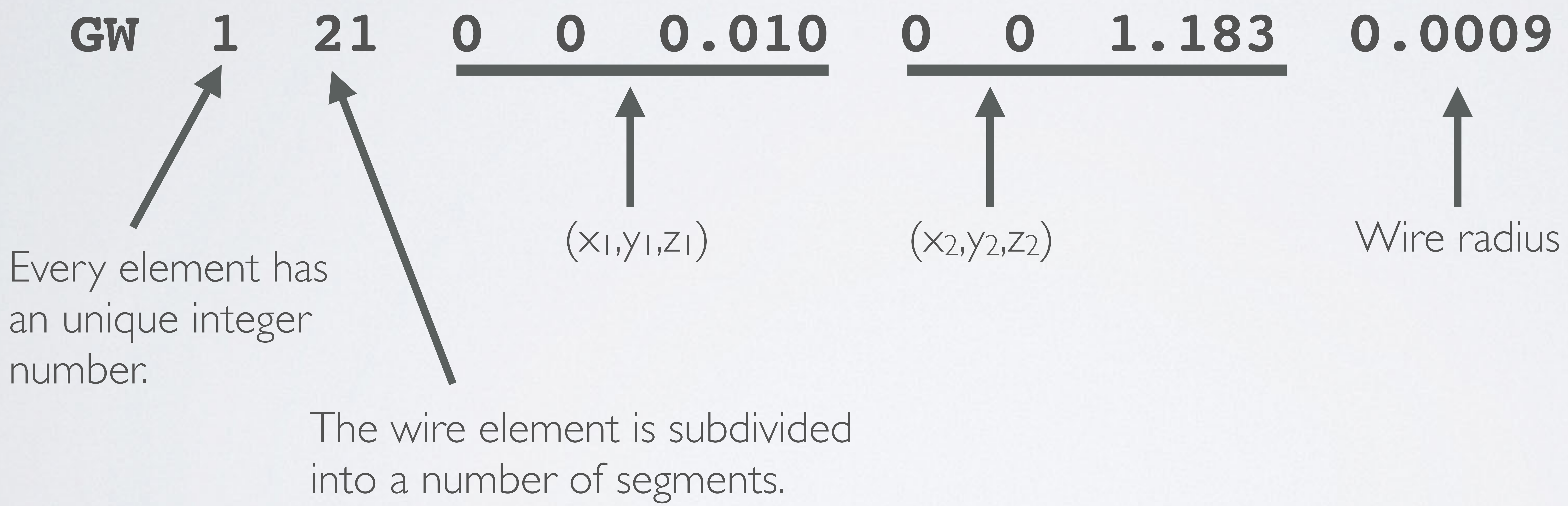
- Open Geometry window (F3).
  Show segments: Show | Segments
  Visually check the model.
  Validate | Run geometry check.
  Validate | Run segment checks.
  Save file and open dipole_demo.nec

Keys	Description
↑ ↓	Rotate up/down
← →	Rotate left/right
Page Down	Zoom out
Page Up	Zoom in
CTRL + ← →	Move left/right
CTRL + ↑ ↓	Move up/down
Home	Reset



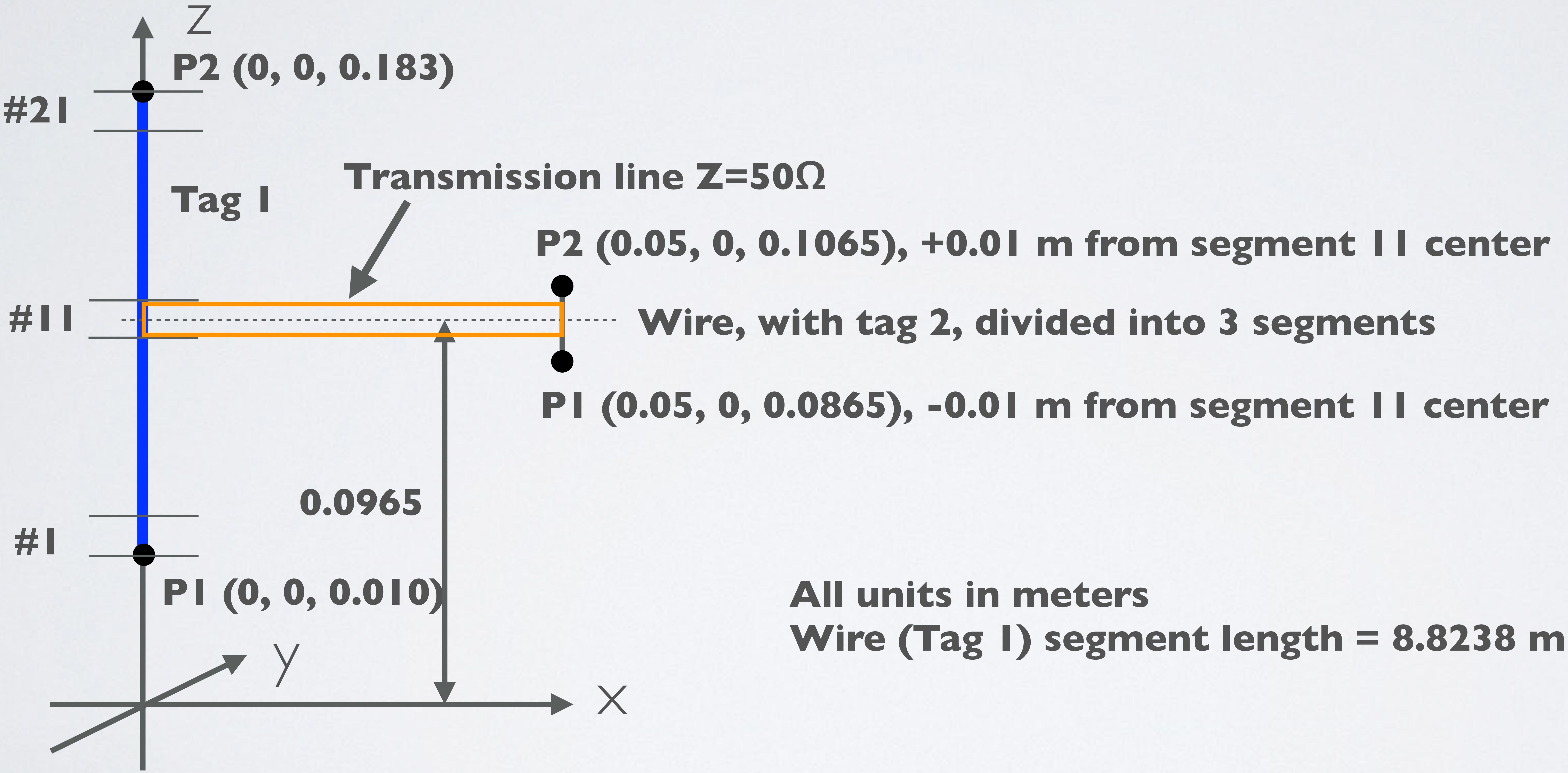
GW CARD

- Use the NEC GW card to specify the wire dimensions.
  GW stands for Geometry Wire.
  For example:



PROCEDURE TO USE 4NEC2

- Add feed / transmission line (optional).
  Save file and open dipole_demo.nec



All units in meters
Wire (Tag 1) segment length = 8.8238 mm

TL CARD

- Use the NEC TL card to specify the transmission line.
  TL stands for Transmission Line.
  For example:

```
TL  2  2  1  11  50  0.5
```

- 2 — Tag number of wire 1
- 2 — Segment number of wire 1
- 1 — Tag number of wire 2
- 11 — Segment number of wire 2
- 50 — Impedance in Ohms
- 0.5 — The length of the transmission line in meters

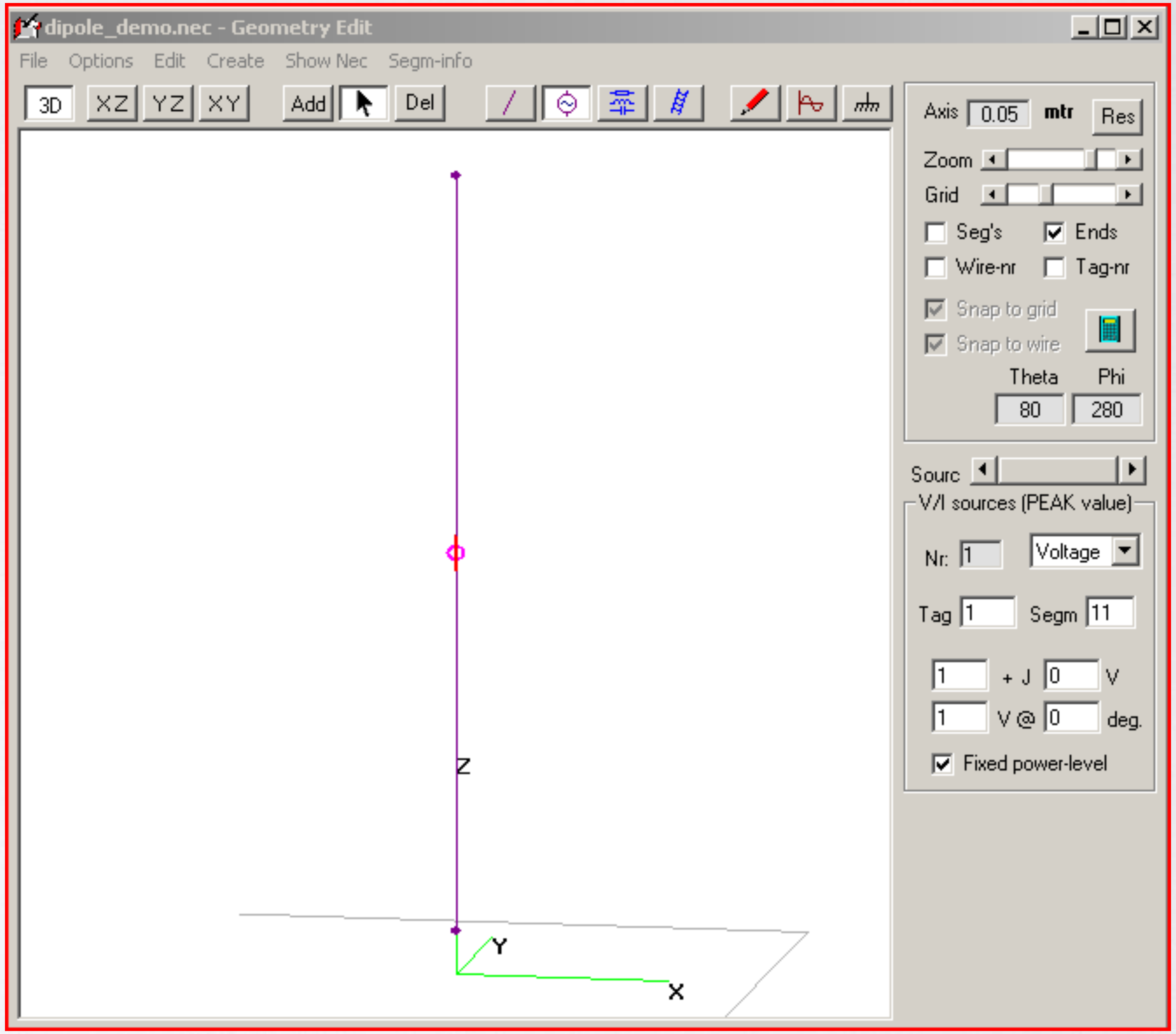
PROCEDURE TO USE 4NEC2

- In all my antenna models, I never model the transmission line.
  For demonstration purpose I have shown how this is done in case you need it.
  Delete the transmission line and wire tag 2.

PROCEDURE TO USE 4NEC2

- Add Voltage / Current source

- Select: Voltage
  Select Tag: 1, Segment: 11
  Voltage value: 1 + J 0V
  Enable: Fixed power-level
  Save file and open dipole_demo.nec



EX CARD

- Use the NEC EX card to specify the Voltage or Current source.
  EX stands for Excitation.
  For example:

```
EX   0   1   11   0   1   0
```

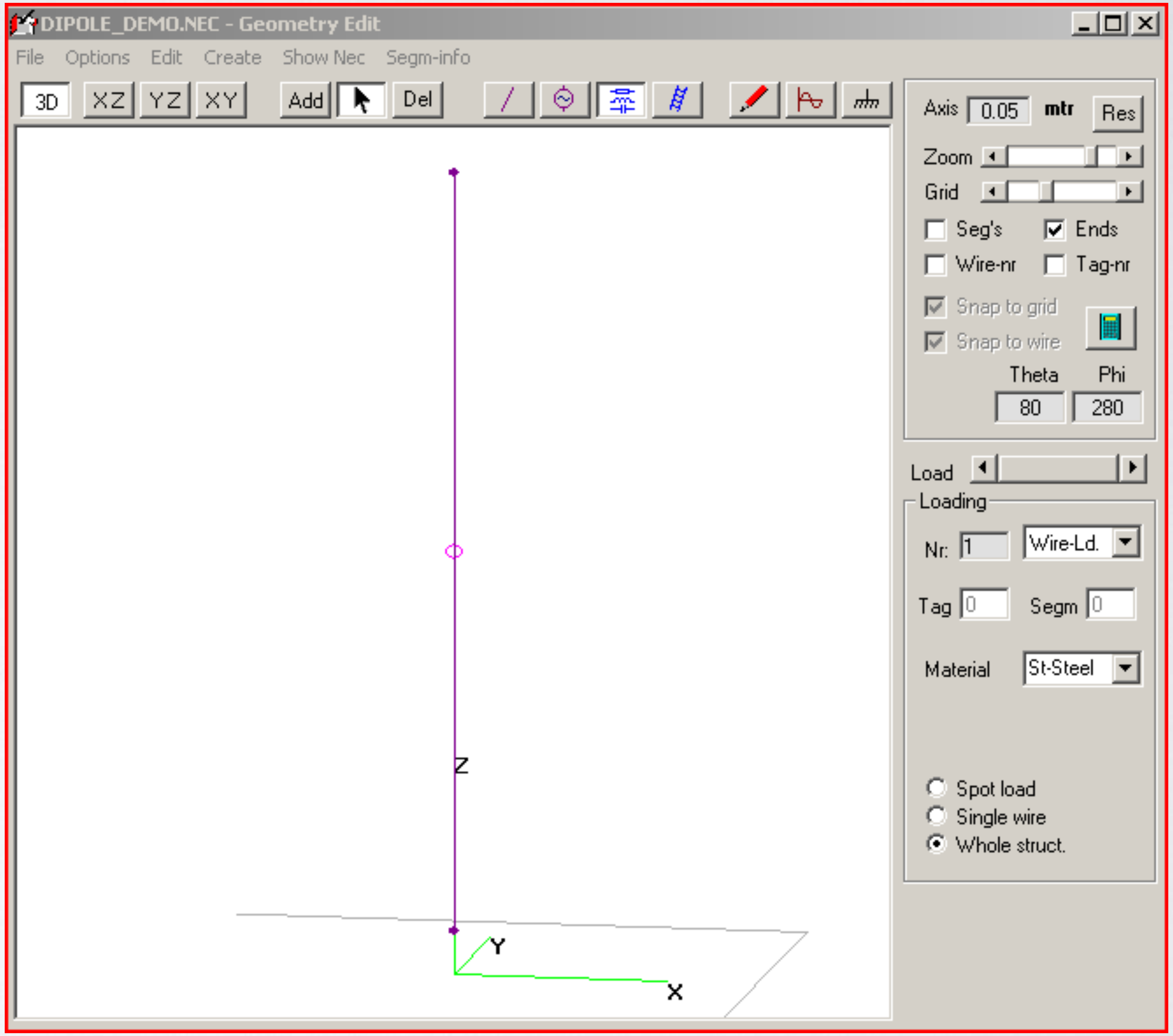
- 0: 0 = Voltage source, 6 = Current Source
- 1: Tag number, referring to a specific element.
- 11: Segment number
- 0: Unused
- 1: Real Volts or Amps
- 0: Imaginary Volts or Amps

I am always using:
Voltage source = 1+j0 volt
(1V @ 0 deg)

PROCEDURE TO USE 4NEC2

- Add wire conductivity.

- Drag mouse over the wire.
  Select: Wire-Ld
  Select G (S/m): St. Steel
  Select: Whole struct.
  Save file and open dipole_demo.nec



LD CARD

- By default a perfect wire is used with zero loss.
  Use the NEC LD card to specify the wire conductivity.
  LD stands for Loading.
  For example:

```
LD  5  0  0  0  1390000  0
```

Use loading type 5 to specify the wire conductivity

Tag number, referring to a specific element.
If Tag number = 0 all elements have the same material conductivity.

When both numbers are zero all segments of the wire element will have the wire conductivity

Electrical conductance in mho/meter

Unused

ELECTRICAL CONDUCTANCE

- The SI unit for electrical conductance is Siemens per meter (S/m). The archaic term for this unit is the mho (ohm spelled backwards).

- One mho is equal to one Siemens.

ELECTRICAL CONDUCTANCE

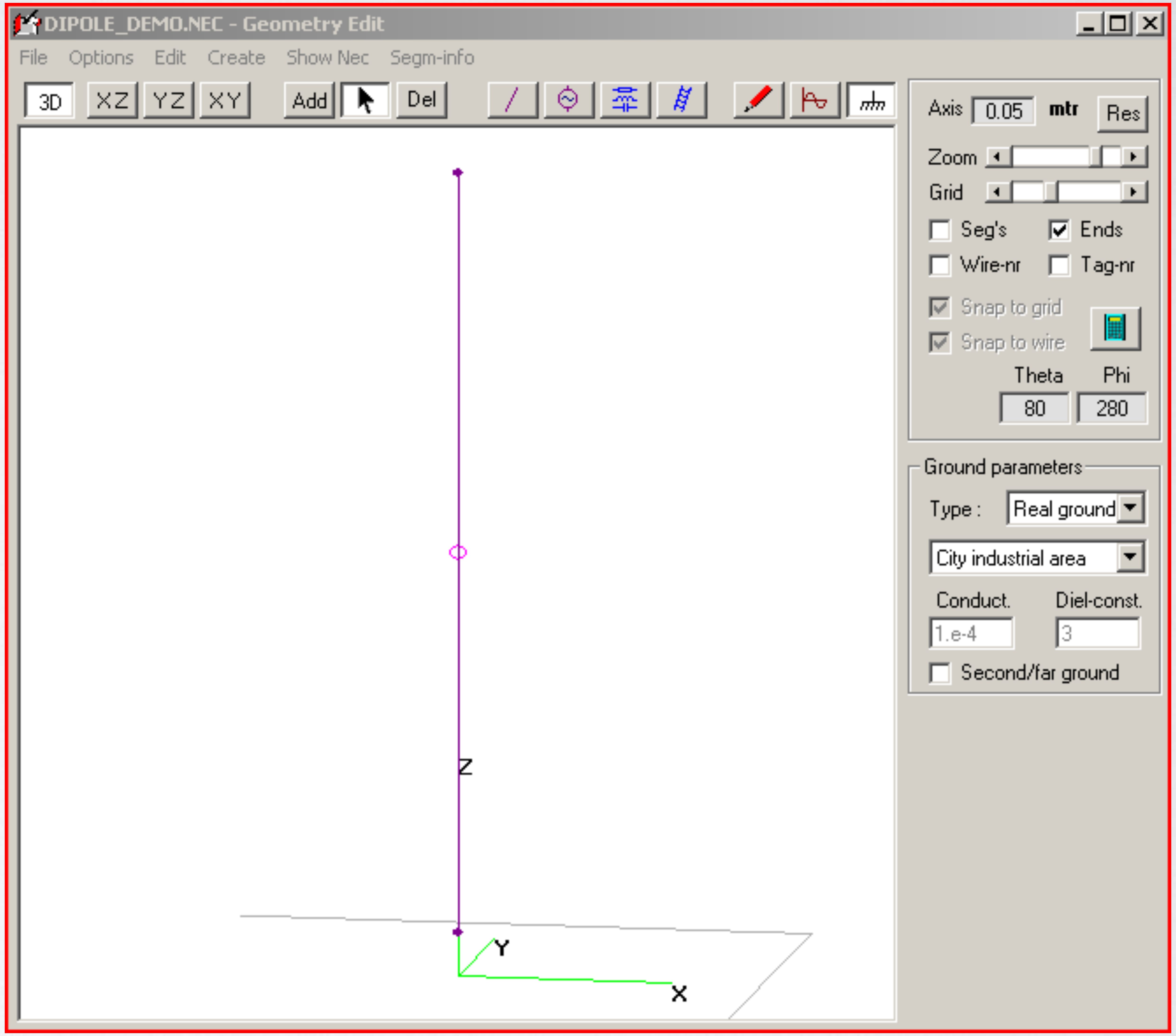
Material	Electrical Conductance (mho/m or S/m)
Perfect	9.9×10^{99}
Silver	6.29×10^{7}
Copper	5.8×10^{7}
Aluminium	3.77×10^{7}
Alu-T832	3.08×10^{7}
Alu-T6	2.49×10^{7}
Brass	1.56×10^{7}
P-bronze	90900000
Stainless steel	1.39×10^{6}
Insulator	0.00001

Source: 4NEC2 program

PROCEDURE TO USE 4NEC2

- Specify ground parameters

- Select Type: Real ground
  Select: City industrial area
  Save file and open dipole_demo.nec



PROCEDURE TO USE 4NEC2

- You can choose between 5 ground types.
  All ground types extends indefinitely to the horizon.

- **Free space** (**GN -1**)
  There is an absence of any surface beneath the antenna.
  There is no ground influence.
  The antenna radiates in all directions without reflections.
  Use this option to compare antennas of similar types.

- **Fast ground** (**GN 0** 0 0 0 3 0.0001)
  Can model a ground screen (number of radials etc) at Z=0.
  Vertical and horizontal wires should not touch ground.
  Horizontal wires should be at least $\lambda/10$ above ground.

PROCEDURE TO USE 4NEC2

- **Perf ground** (**GN 1**)
  The ground has perfect conductivity. No losses!
  The ground acts like a mirror and creates an image antenna identical to the original.

  Horizontal wires should not touch ground and should be above ground by a certain factor:
  $(h^2 + r^2)^{1/2} > 10^{-6}\,\lambda$
  h = wire height
  r = wire radius
  λ = wavelength

  Vertical wires may touch the ground.

PROCEDURE TO USE 4NEC2

- **Real ground** (**GN 2** 0 0 0 3 0.0001) **aka Sommerfeld-Norton**
  Use this ground type for the highest accuracy of results for antenna models above ground.

  Vertical and horizontal wires should not touch ground.
  Horizontal wires should be at least λ/200 above ground.

  Specify the ground conductivity near the antenna.
  You can also specify a second ground type that extends a specified radius.

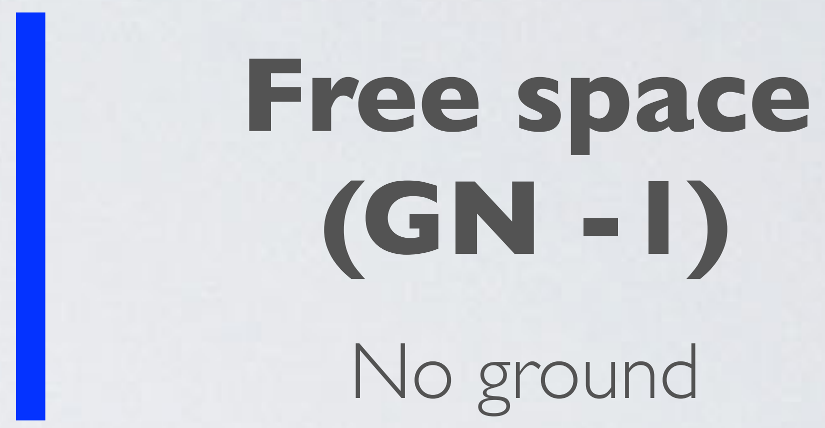
PROCEDURE TO USE 4NEC2

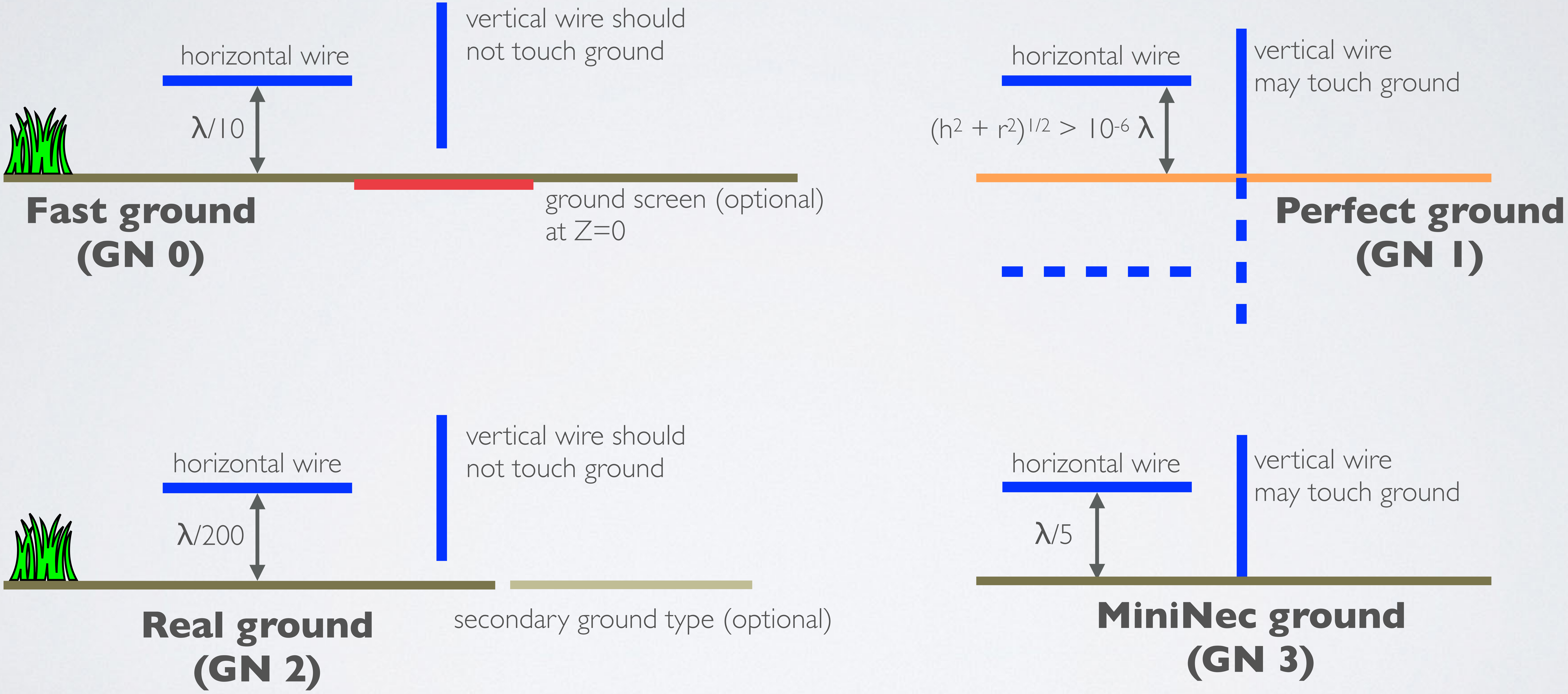
- **MiniNec ground** (**GN 3** 0 0 0 3 0.0001)
  When wires are connected to a real ground or fast ground (Z=0) the reported antenna impedance is usually unpredictable. To avoid this, use a real ground with an elevated radial system or, when using verticals, use the MiniNec ground type.

  Vertical wires may touch ground.
  Horizontal wires should be at least λ/5 above ground.

PROCEDURE TO USE 4NEC2

Ground type overview:





GN CARD

- Use the NEC GN card to specify the ground parameters.
  GN stands for Ground.
  For example:

```
GN  2  0  0  0  3  0.0001
```

Unused

Number of radial wires in the ground
0 = No ground screen

Conductivity in mhos/meter of the ground.
Leave blank in the case of a perfect ground.

Dielectric constant of the ground.
Leave blank in case of a perfect ground.

Ground type:
-1 = free space
0 = fast ground. Can specify ground screen.
1 = perfect ground (= perfect conductivity)
2 = real ground (Sommerfeld-Norton). Can specify second/far ground type.
3 = MiniNec ground

GN CARD

- Free space: **GN -1**
  Perfect ground: **GN 1**

GROUND DIEL-CONST & CONDUCTIVITY

Ground	Diel-const	Conduct. mhos/meter
Poor	5	0.001
Moderate	4	0.003
Average	13	0.005
Good	17	0.015
Dry, sandy, costal	10	0.001
Pastoral hills, rich soil	17	0.007
Medium hills and forest	13	0.004
Mountainous hills < 1000 m	5	0.002
Rocky, steep hills	13	0.002
Fertile land	10	0.002

Source: 4NEC2 program (For ground type = 0, 2 and 3)

GROUND TYPE

Ground	Diel-const	Conduct. mhos/meter
Rich agriculture land, low hills	15	0.001
Marshy land, densily wooded	12	0.0075
Marshy, forested, flat	12	0.008
Highly moist ground	30	0.005
City industrial area	3	0.0001
City industrial average att.	5	0.001
City industrial maximum att.	3	0.0004
Fresh water	80	0.001
Fresh water 10° / 100 MHz	84	0.001
Fresh water 20° / 100 MHz	80	0.005

Source: 4NEC2 program (For ground type = 0, 2 and 3)

GROUND TYPE

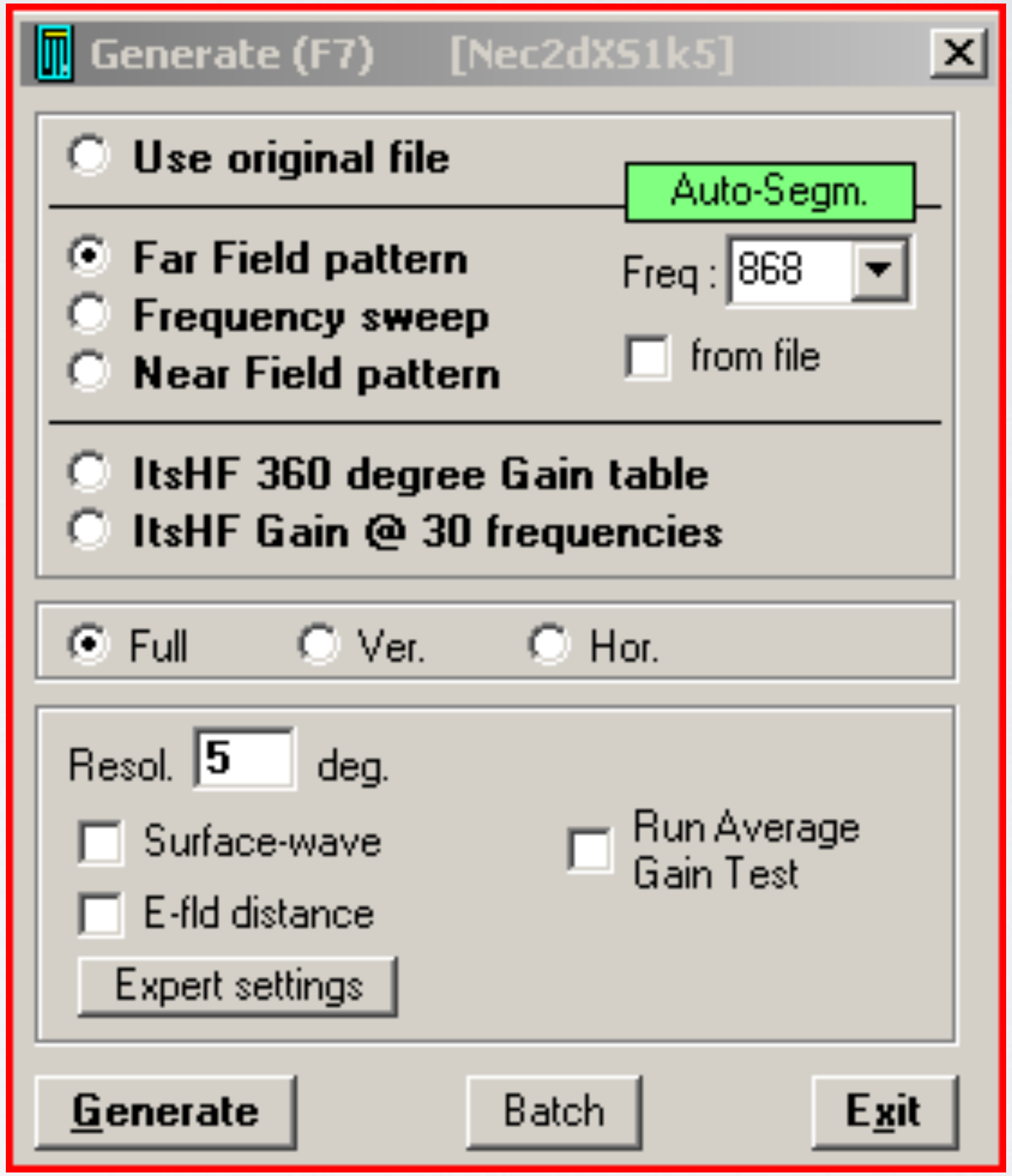
Ground	Diel-const	Conduct. mhos/meter
Sea water	81	5
Sea water 10°, up to 1 GHz	80	4
Sea water 20°, up to 1 GHz	73	4
Sea ice	4	0.001
Polar ice	3	0.0003
Polar ice cap	1	0.0001
Artic land	3	0.0005

Source: 4NEC2 program (For ground type = 0, 2 and 3)

PROCEDURE TO USE 4NEC2

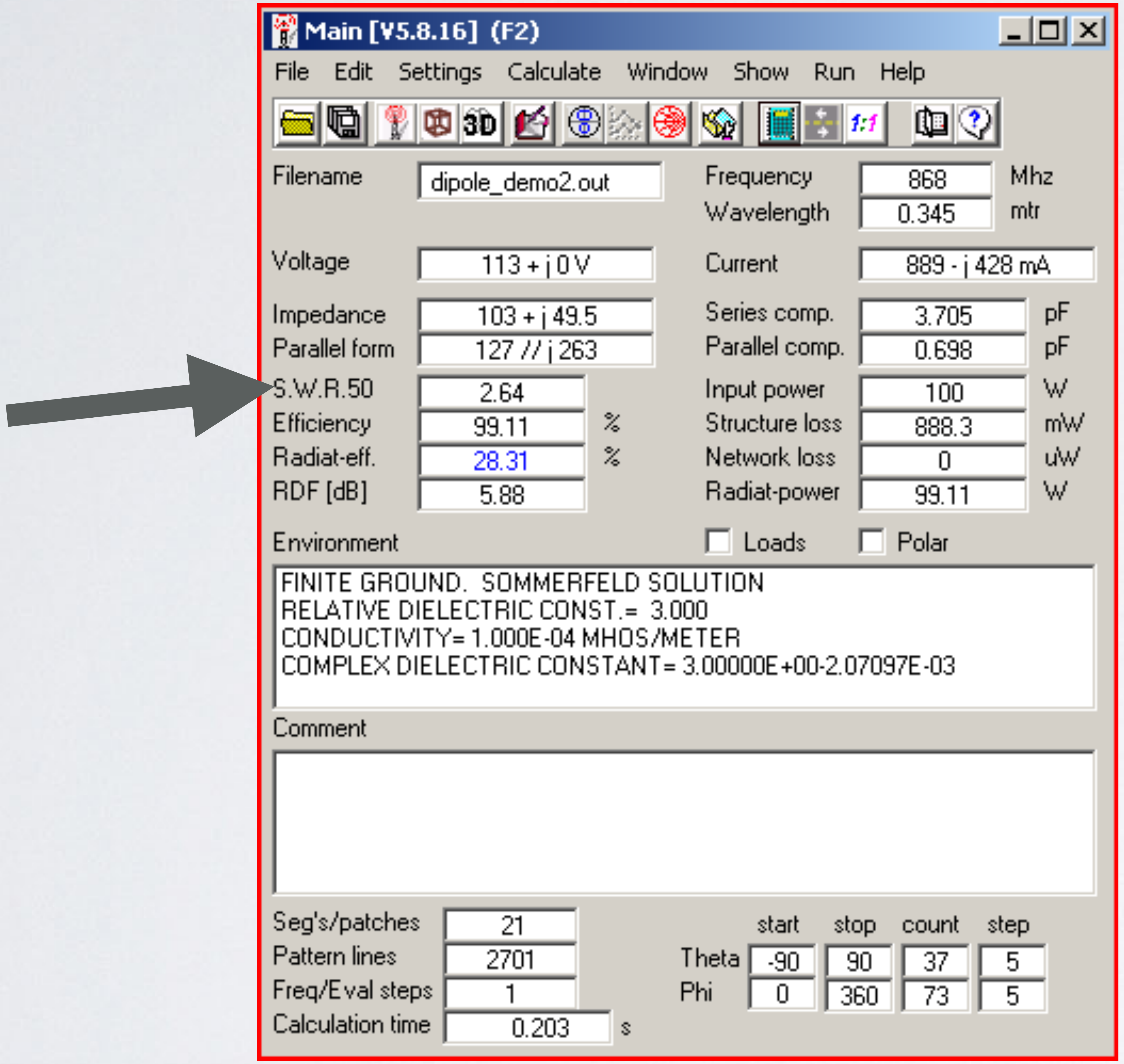
- Press the Calculate button to run the NEC engine.

- Select: Far-Field pattern
  Select: Full
  Resolution: 5 deg
  Press: Generate



PROCEDURE TO USE 4NEC2

- In the Main window, you can see the calculated SWR.

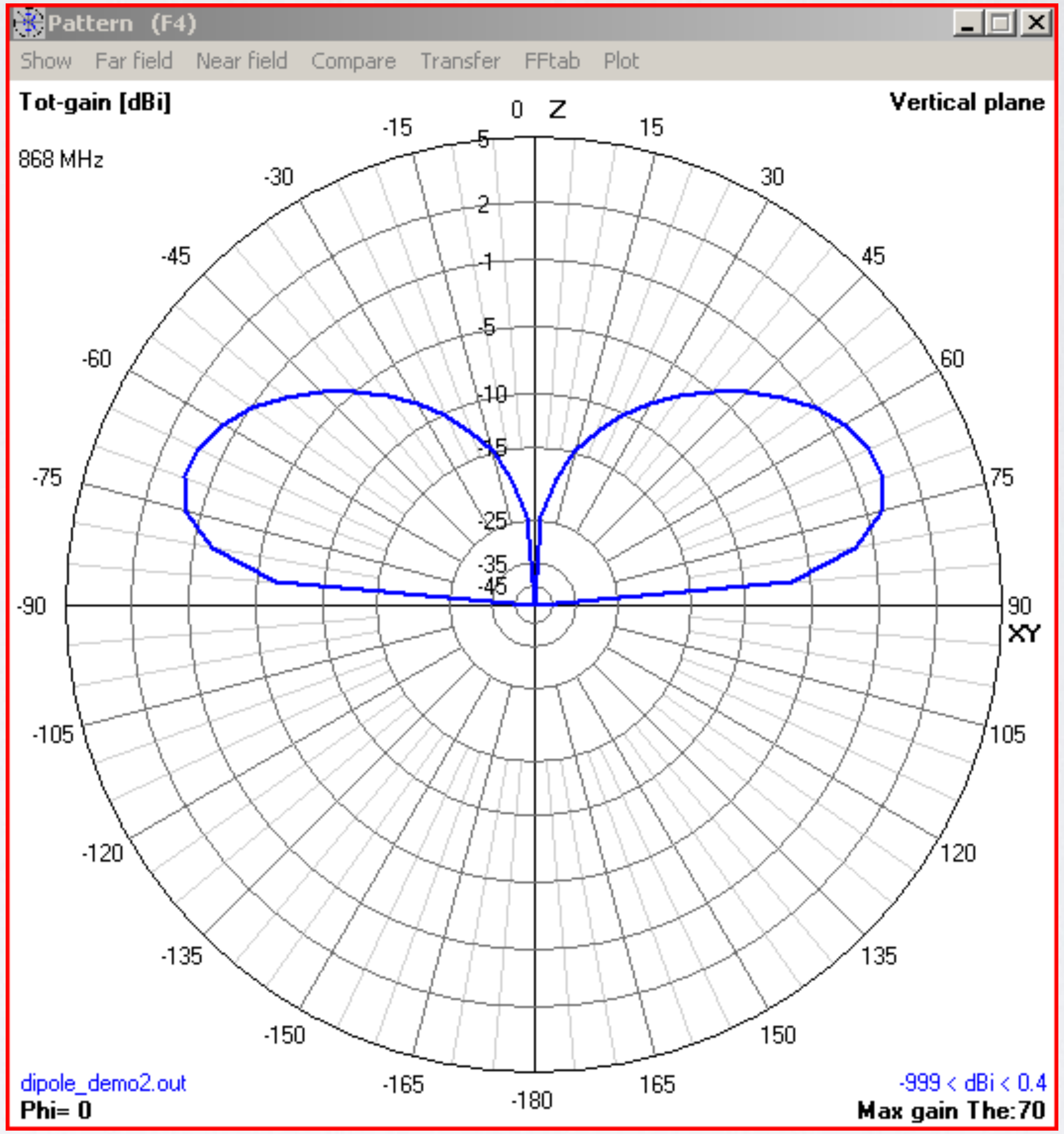


PROCEDURE TO USE 4NEC2

- In the Pattern window (F4) you can see the the vertical and horizontal radiation pattern. Use Spacebar to switch from Vertical plane to Horizontal plane.

- Click on blue line to show the gain at certain angles.

- Drag mouse to show the gain at certain angles.



AZIMUTH & ELEVATION

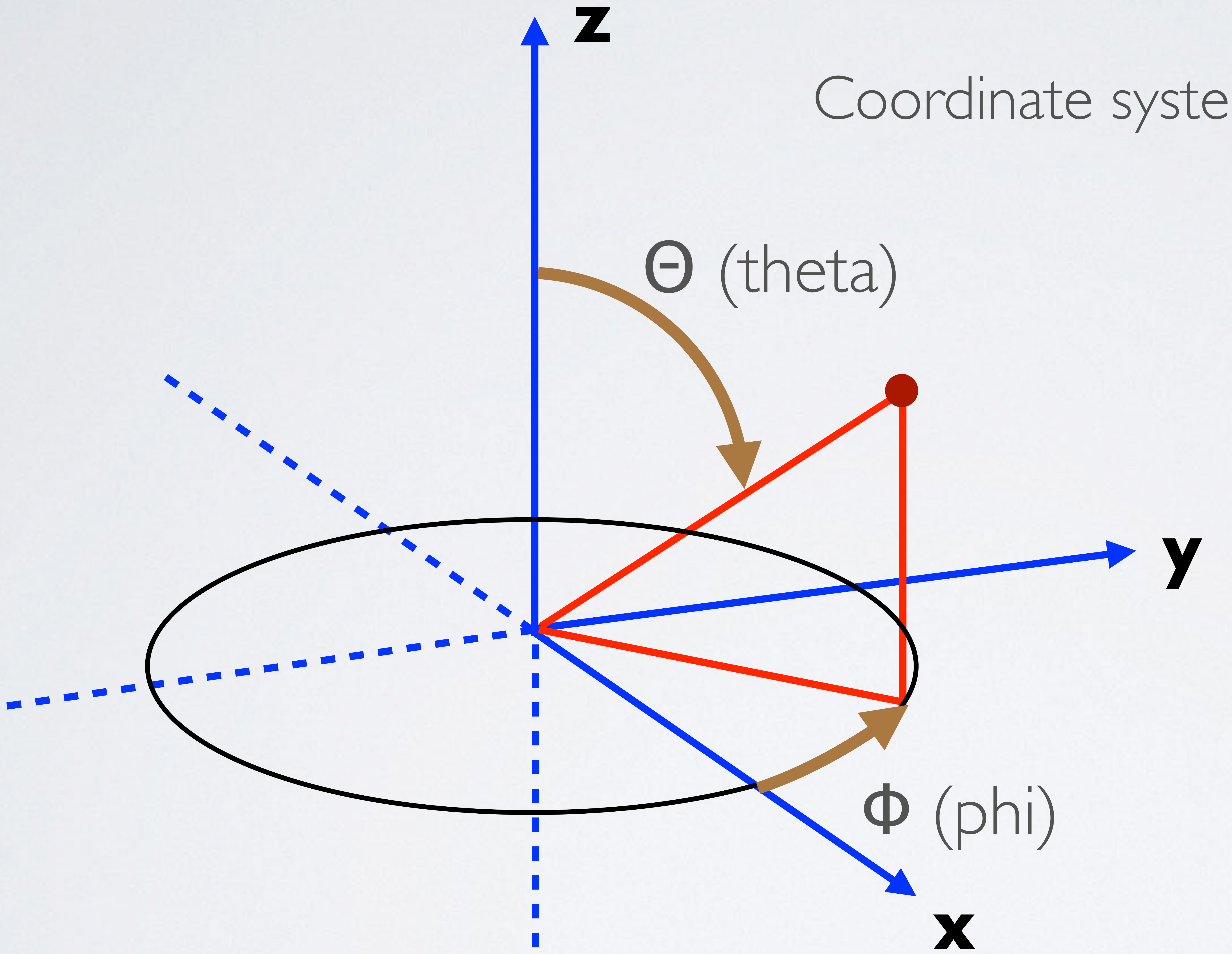
- Azimuth (or horizontal plane) is the angle measured counterclockwise of the x-axis.
  The azimuth angle symbol is Φ (phi).
  Theta runs [0, 360) degrees.

- Elevation (or vertical plane) is the angle measured of the z-axis.
  The elevation angle symbol is Θ (theta).
  Phi runs [0, 180) degrees.

- The above is based on the 4NEC2 antenna modelling software and can differ with other software systems.

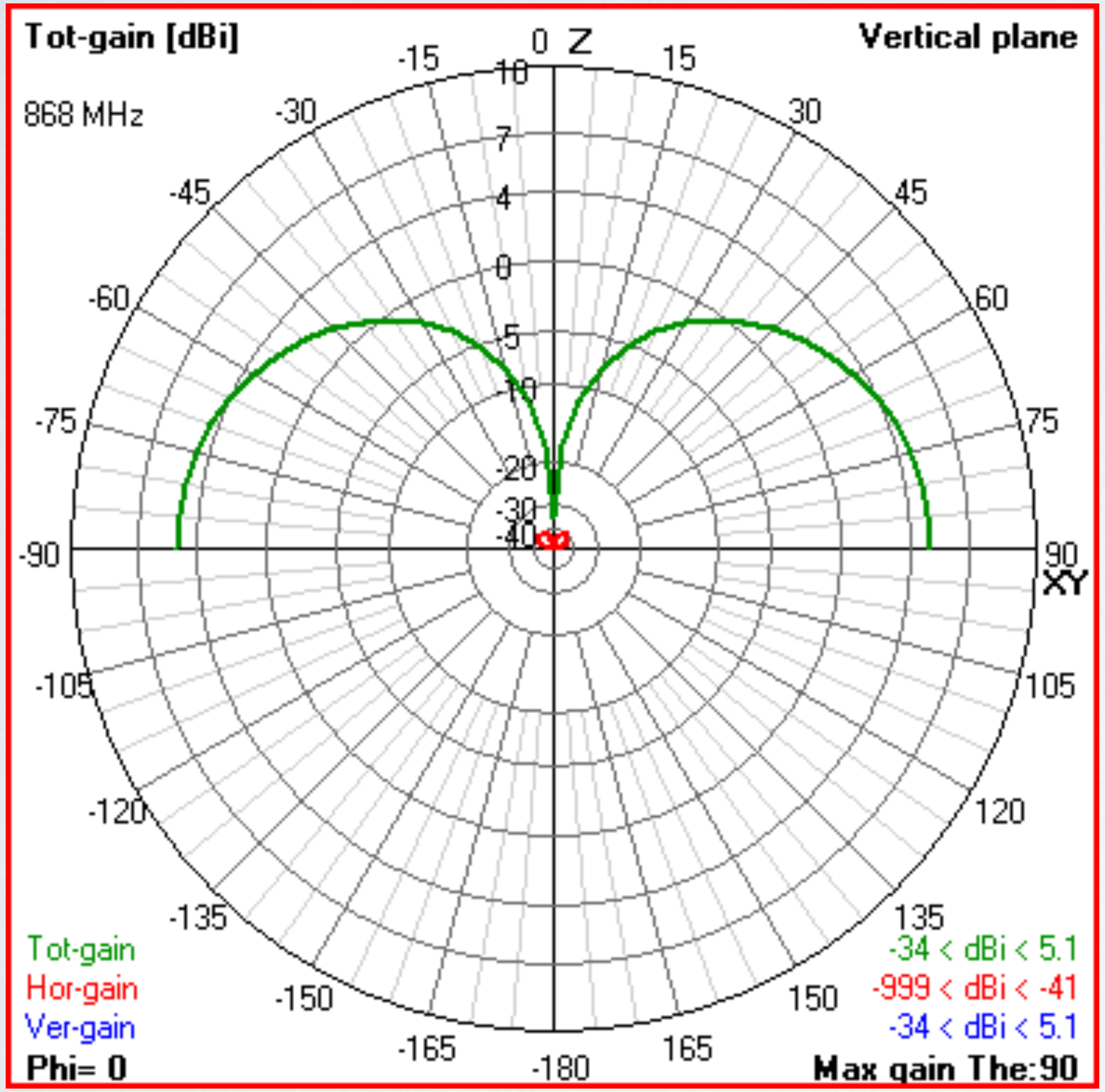
AZIMUTH & ELEVATION

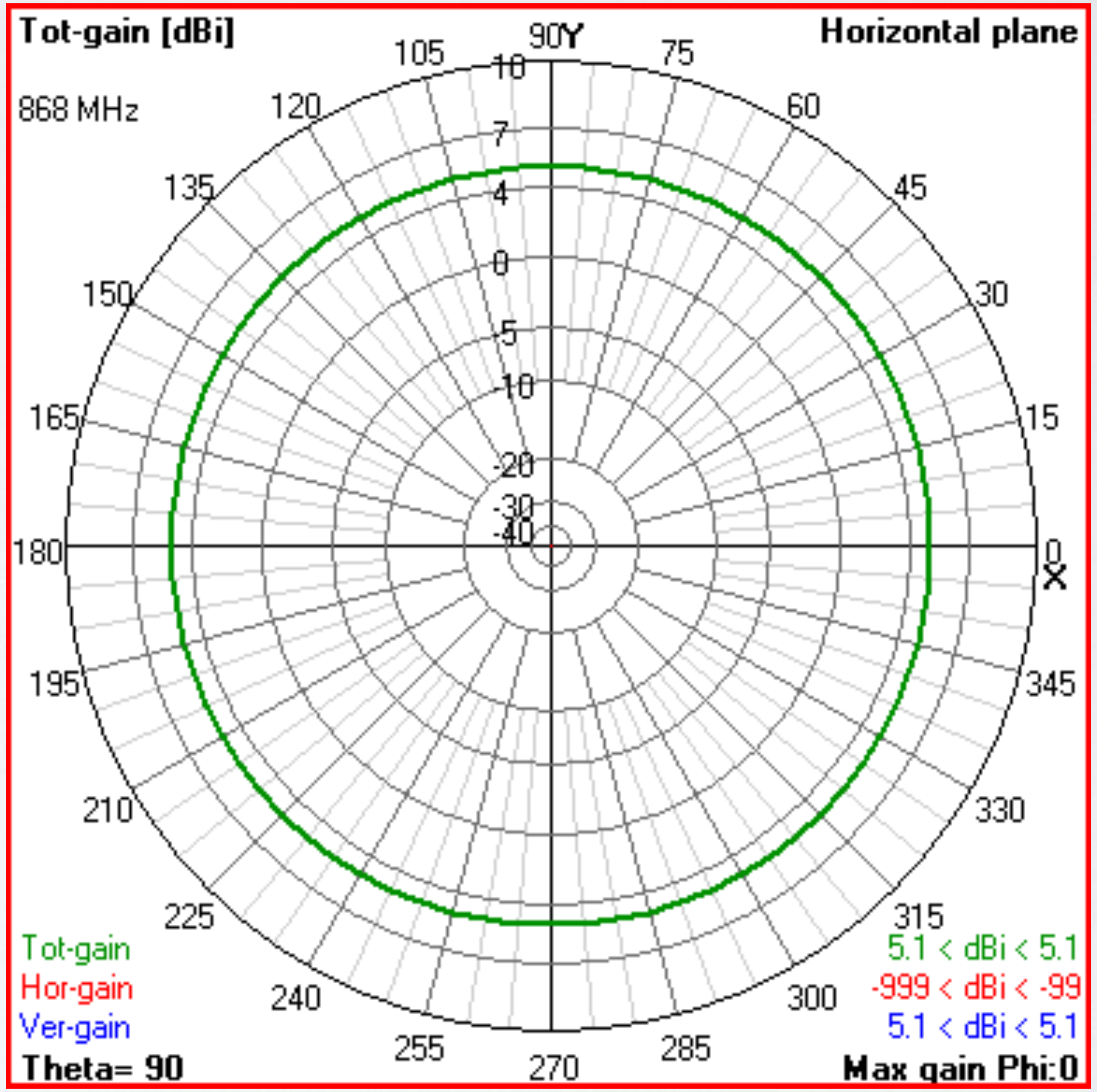
Coordinate system used by 4NEC2



AZIMUTH & ELEVATION

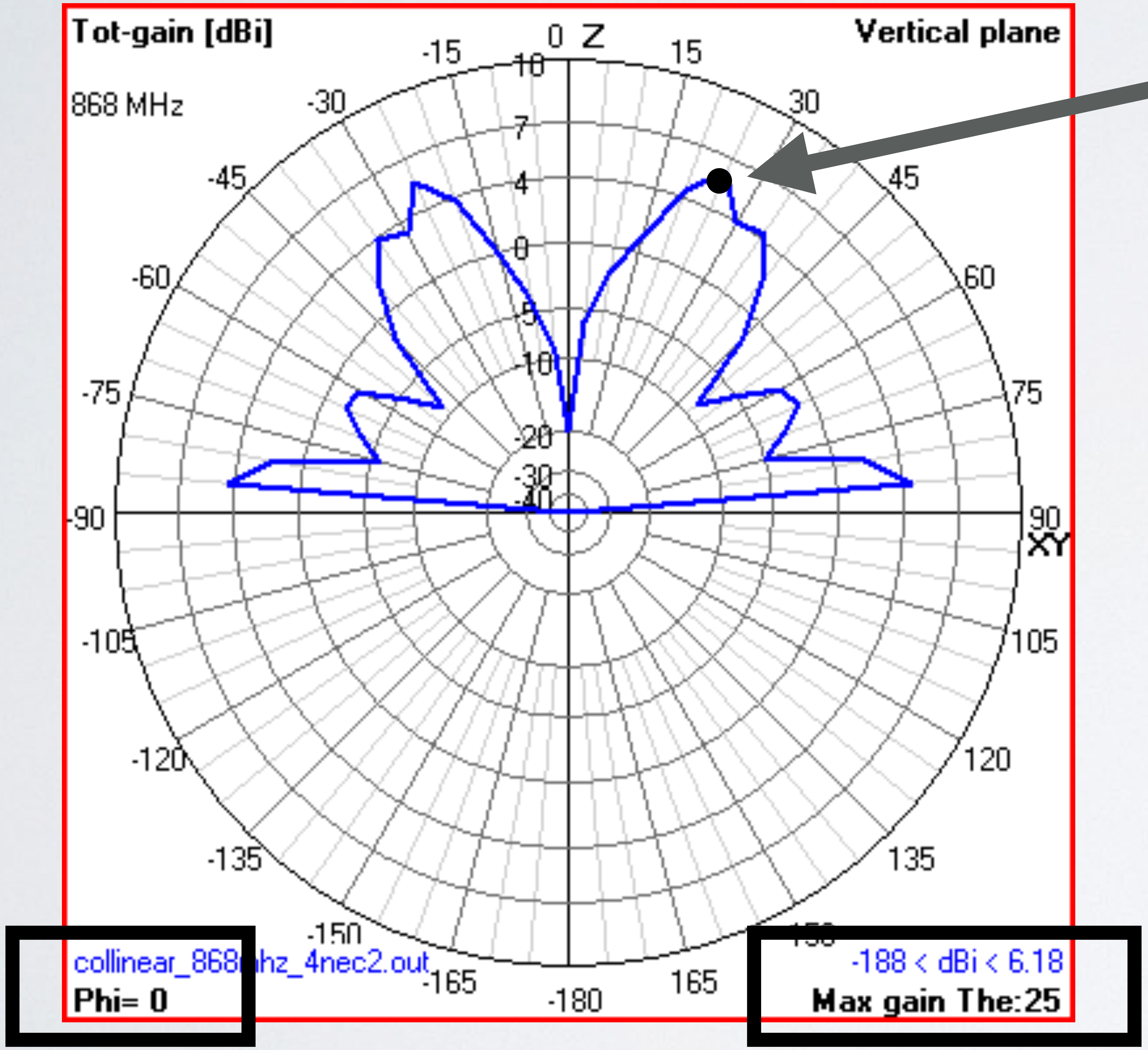
- 4NEC2 example





AZIMUTH & ELEVATION

- 4NEC2 example

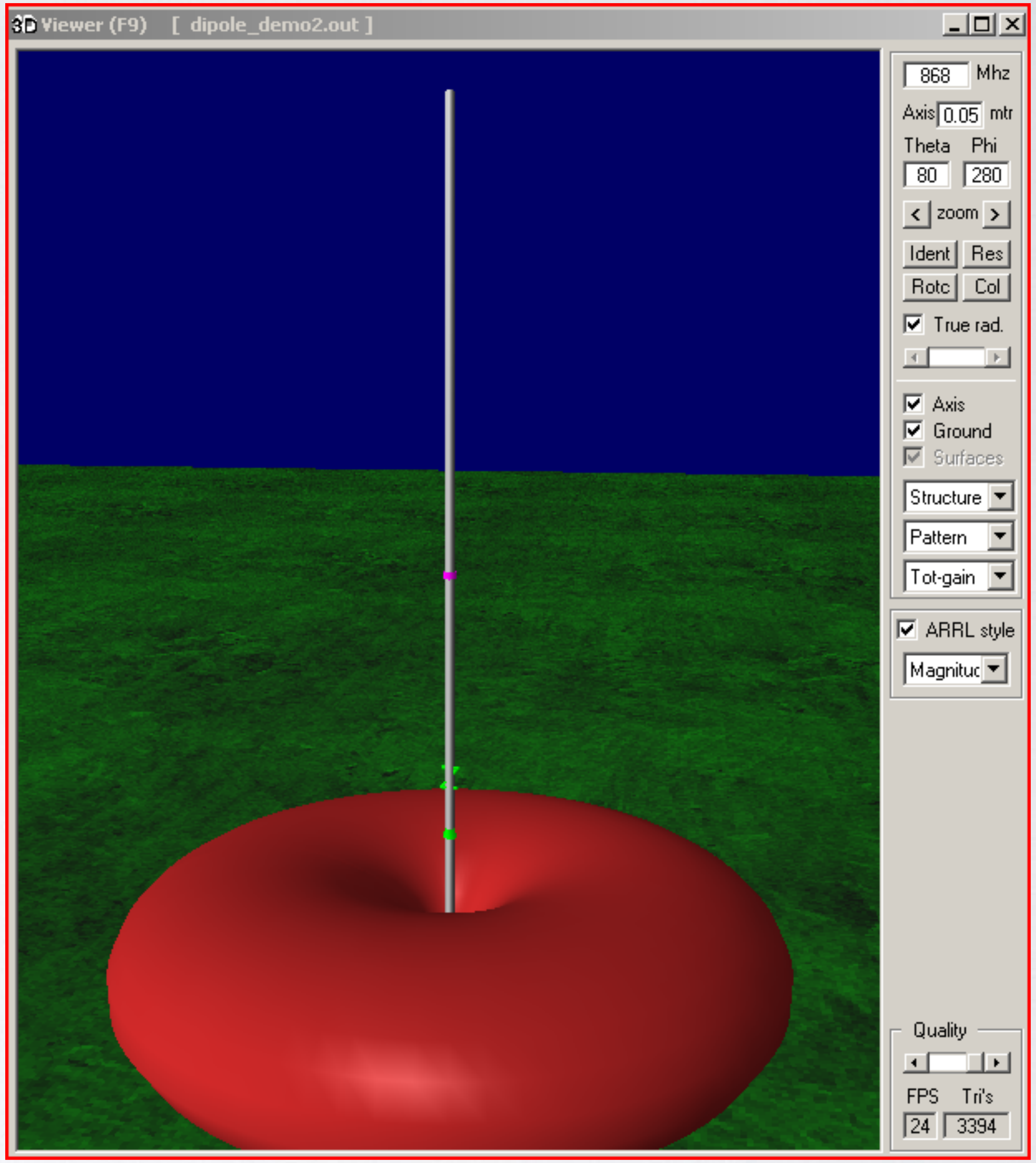


The maximum gain is 6.18 dBi at azimuth Φ (phi) = 0°
elevation Θ (theta) = 25°

PROCEDURE TO USE 4NEC2

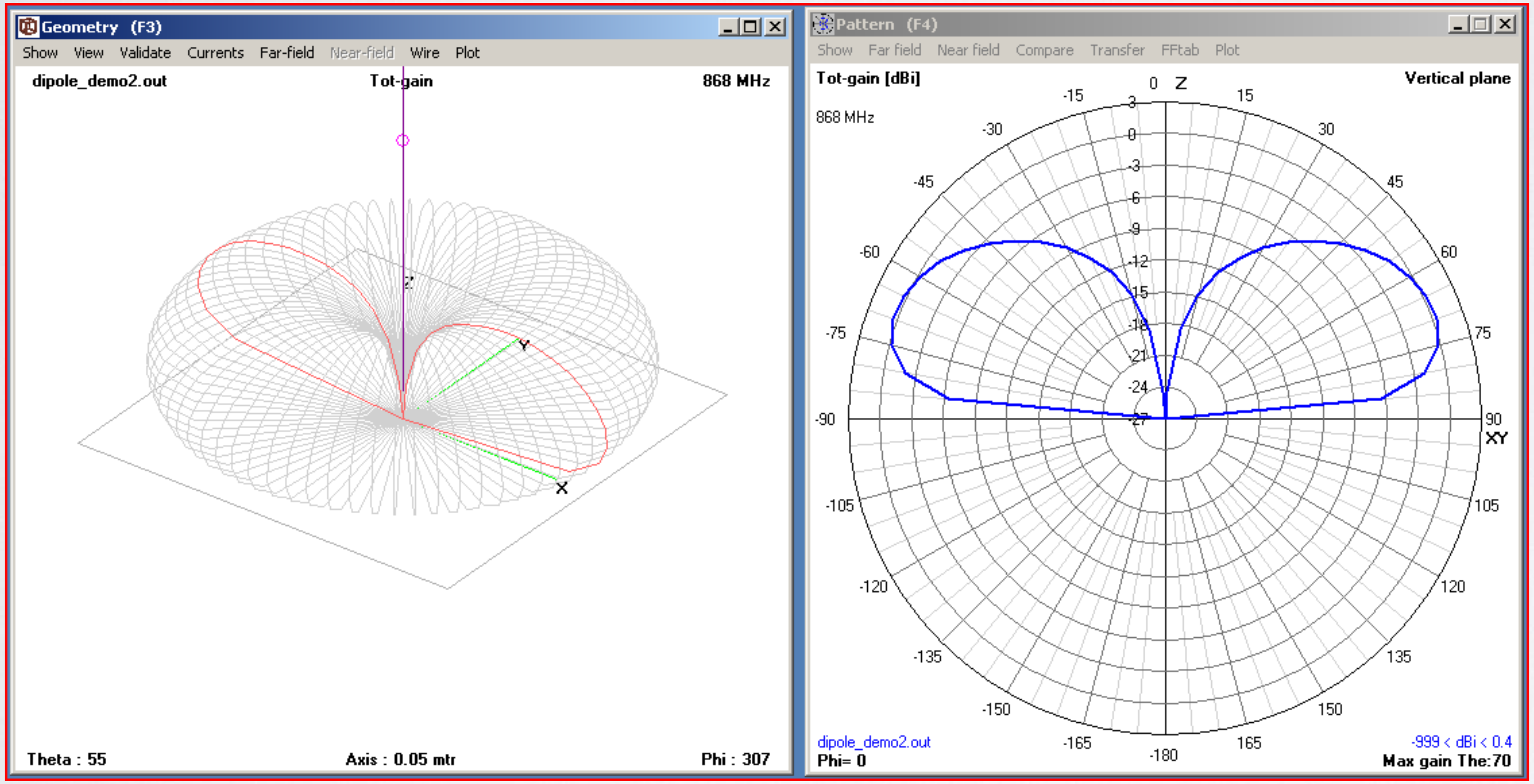
- On main menu
  Press 3D button

- Select: Structure
  Select: Pattern
  Select: Tot-Gain



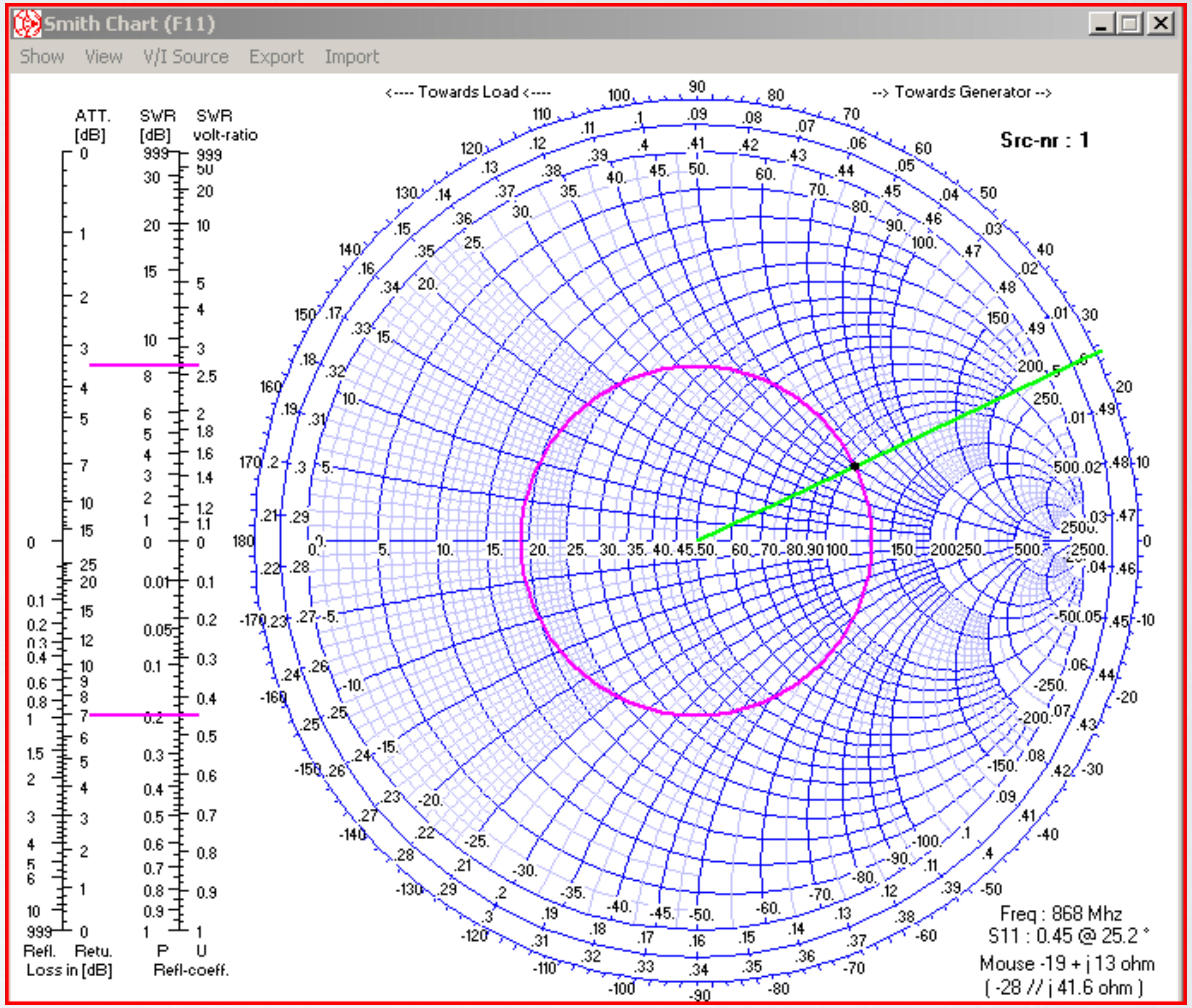
PROCEDURE TO USE 4NEC2

- Open Geometry window (F3) and select Show | Near / Far field
  Open Pattern window (F4) and display Vertical plane.



PROCEDURE TO USE 4NEC2

- On main menu
  Press Smith Chart button



PROCEDURE TO USE 4NEC2

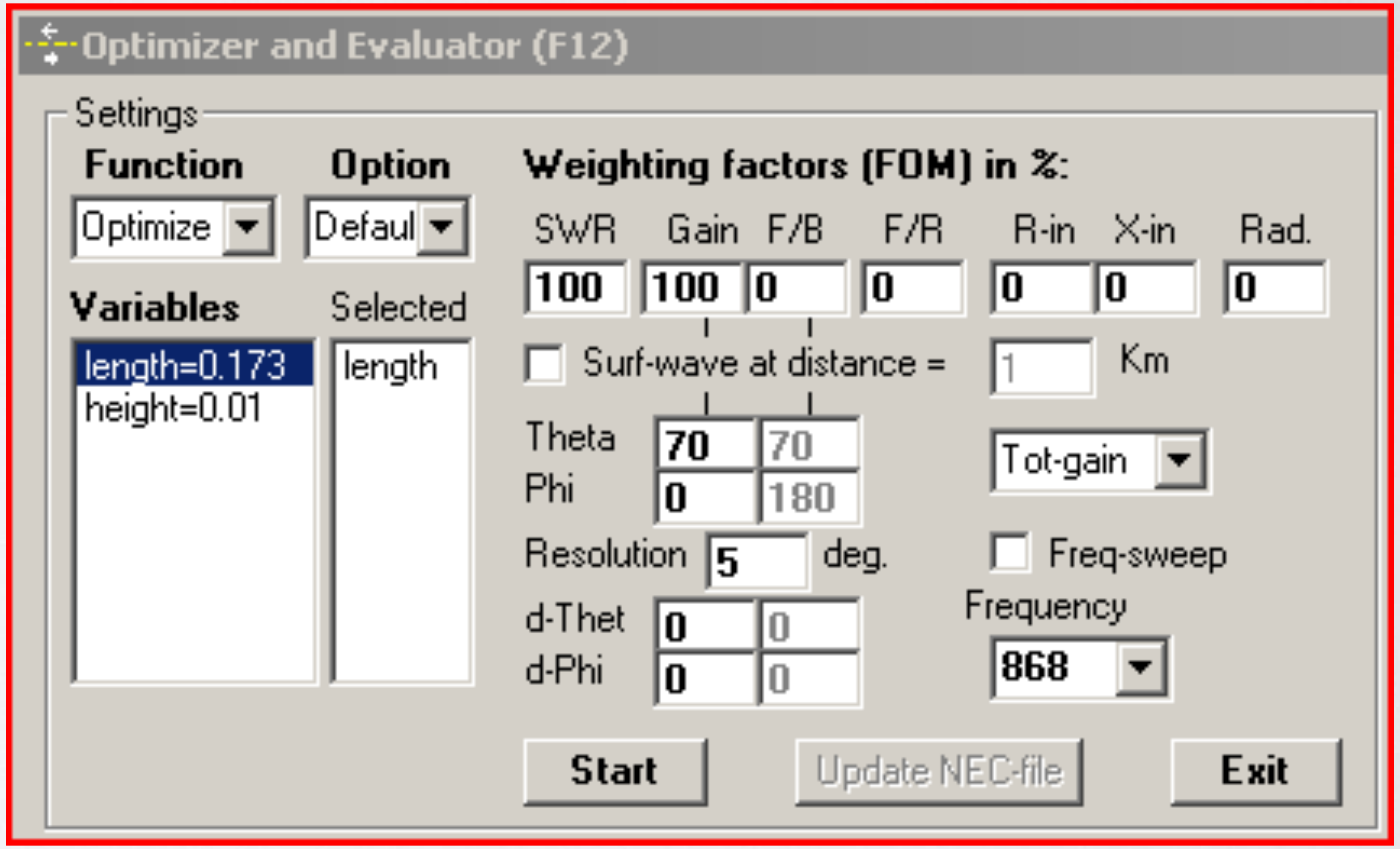
- The VSWR = 2.64. This is too high!
  I will now optimise the antenna.

- Modify file dipole_demo.nec and open the file in the Geometry Edit window.

```
CM This is a demonstration
SY length=0.173
SY height=0.01
CE
GW  1 21  0 0 height  0 0 height+length 9.e-4
GE  0
LD  5 0 0 0 1390000 0
EX  0 1 11  0 1 0
GN  2 0 0 0 3 0.0001
FR  0 1 0 0 868 0
```

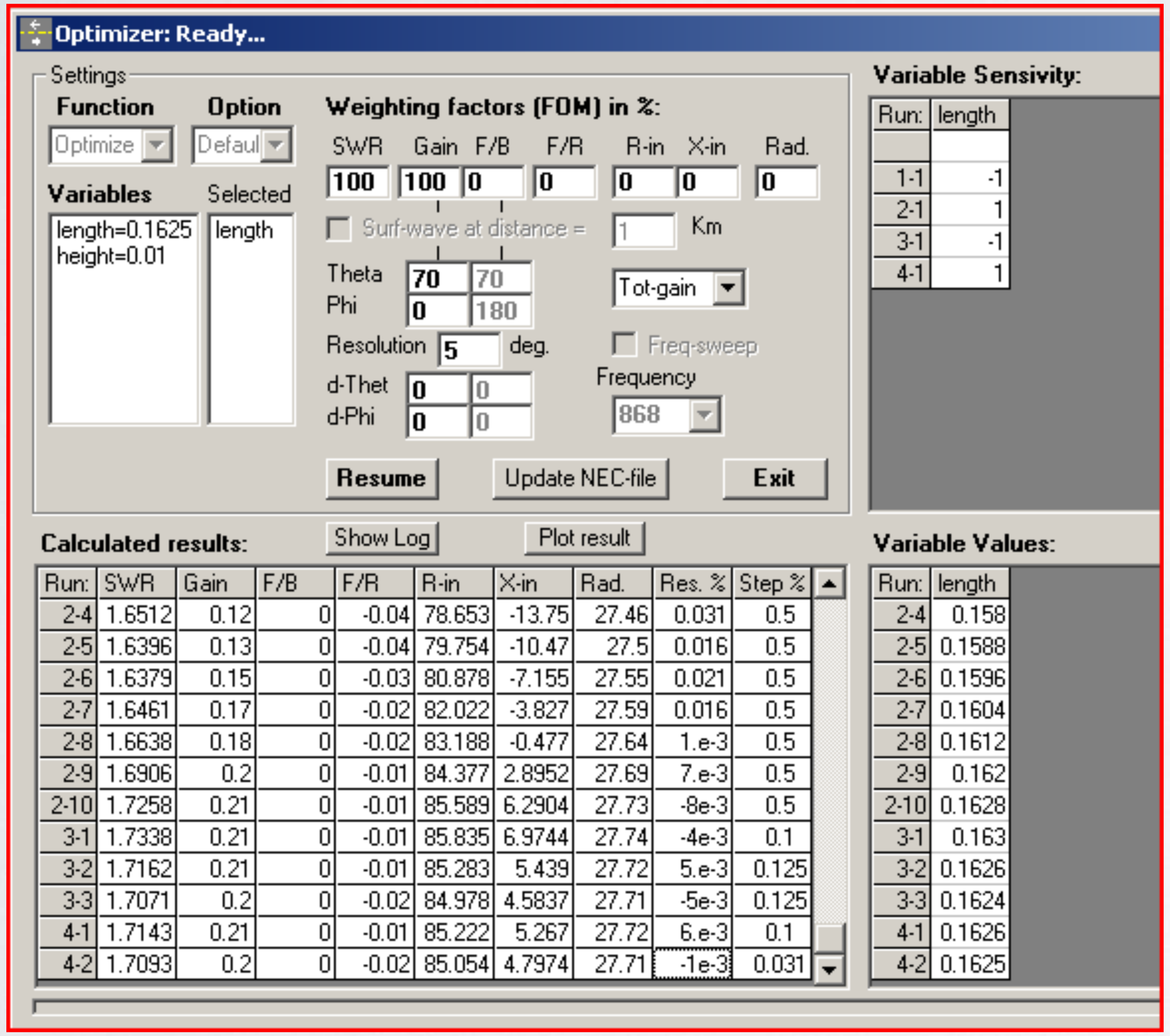
PROCEDURE TO USE 4NEC2

- Press the Calculate button.
- Close all windows except Main window.
  Select menu: Calculate | Start optimiser
  Note: To use the optimiser, the model requires at least one variable (aka symbol SY) to optimise.
- Select Function: Optimize
  Select: length
  Select: SWR = 100%
  Select Gain = 100%
  Press Start button



PROCEDURE TO USE 4NEC2

- If length = 0.1625 m, the VSWR = 1.7093.

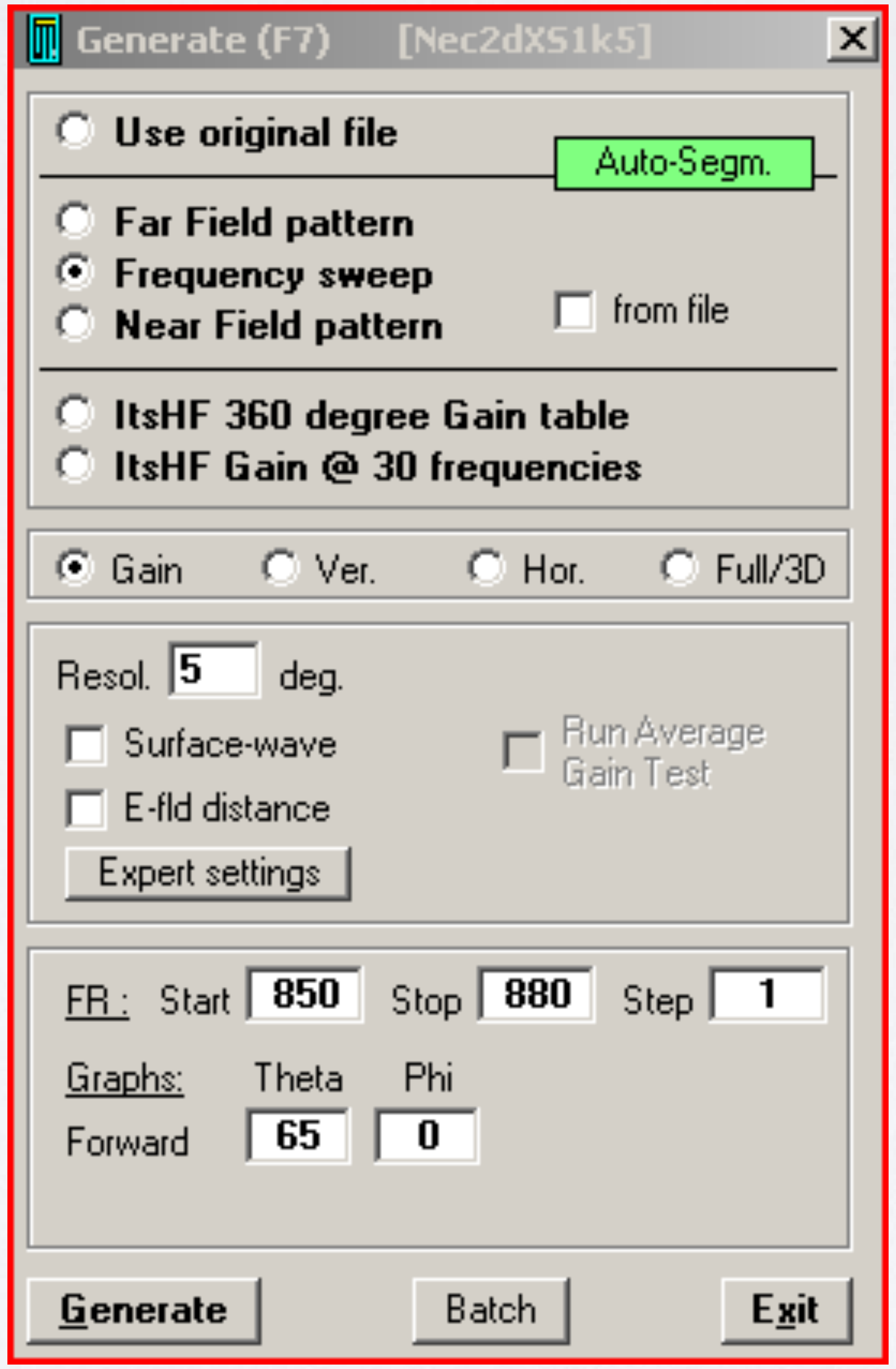


- Press buttons: Update NEC-file and Exit

PROCEDURE TO USE 4NEC2

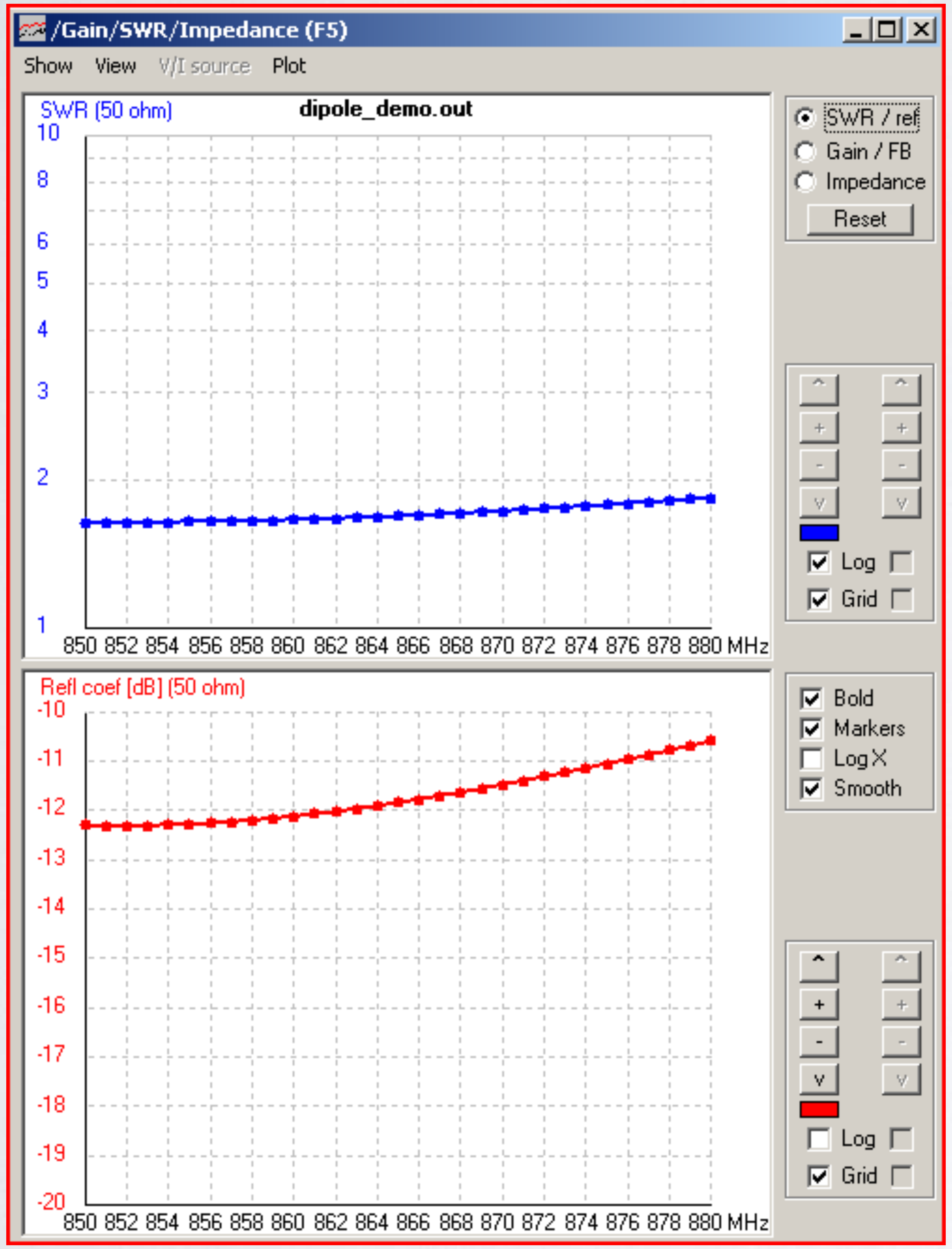
- Press the Calculate button.

- Select: Frequency sweep
  Select: Gain
  Select Resolution: 5 deg.
  Frequency start: 850 Mhz
  Frequency stop: 880 MHz
  Step: 1
  Press Generate button



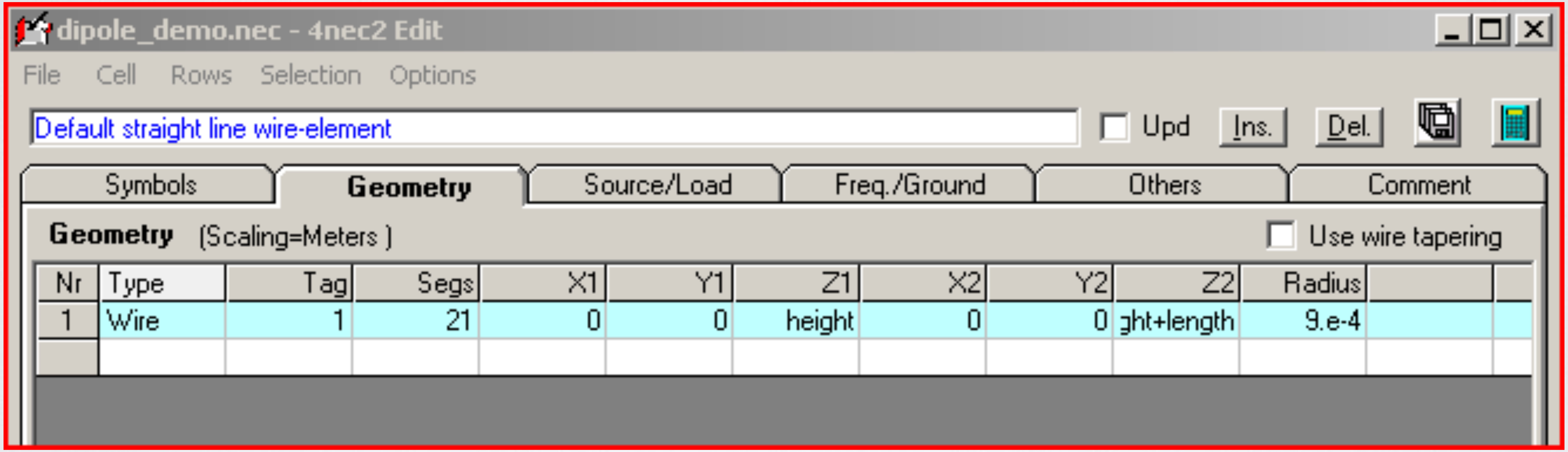
PROCEDURE TO USE 4NEC2

- The generated plots.



PROCEDURE TO USE 4NEC2

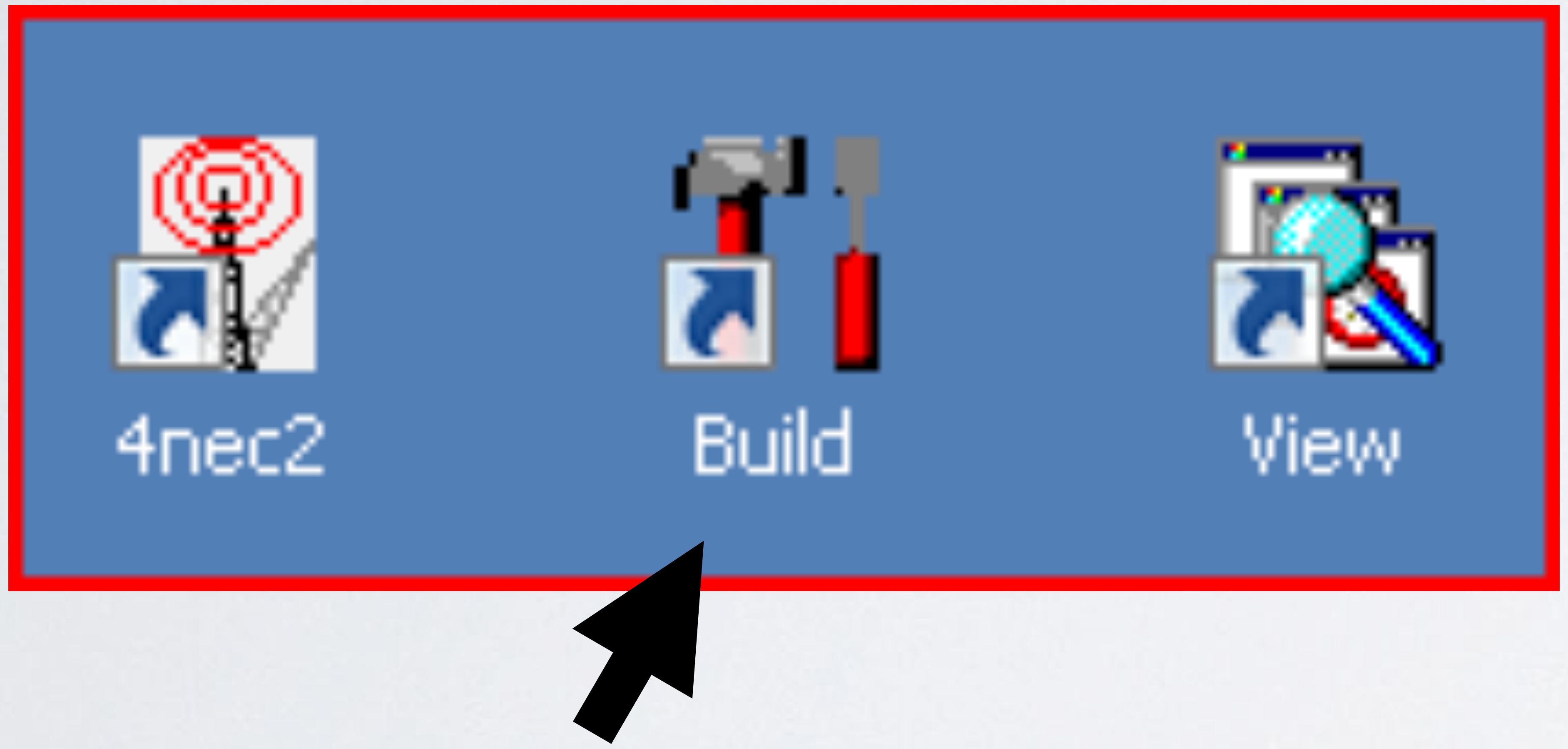
- Another way to model an antenna is to use the NEC editor (new) (CTRL+F4).
  Press the tabs: Symbols, Geometry, Source/Load, Freq./Ground/Others and Comment

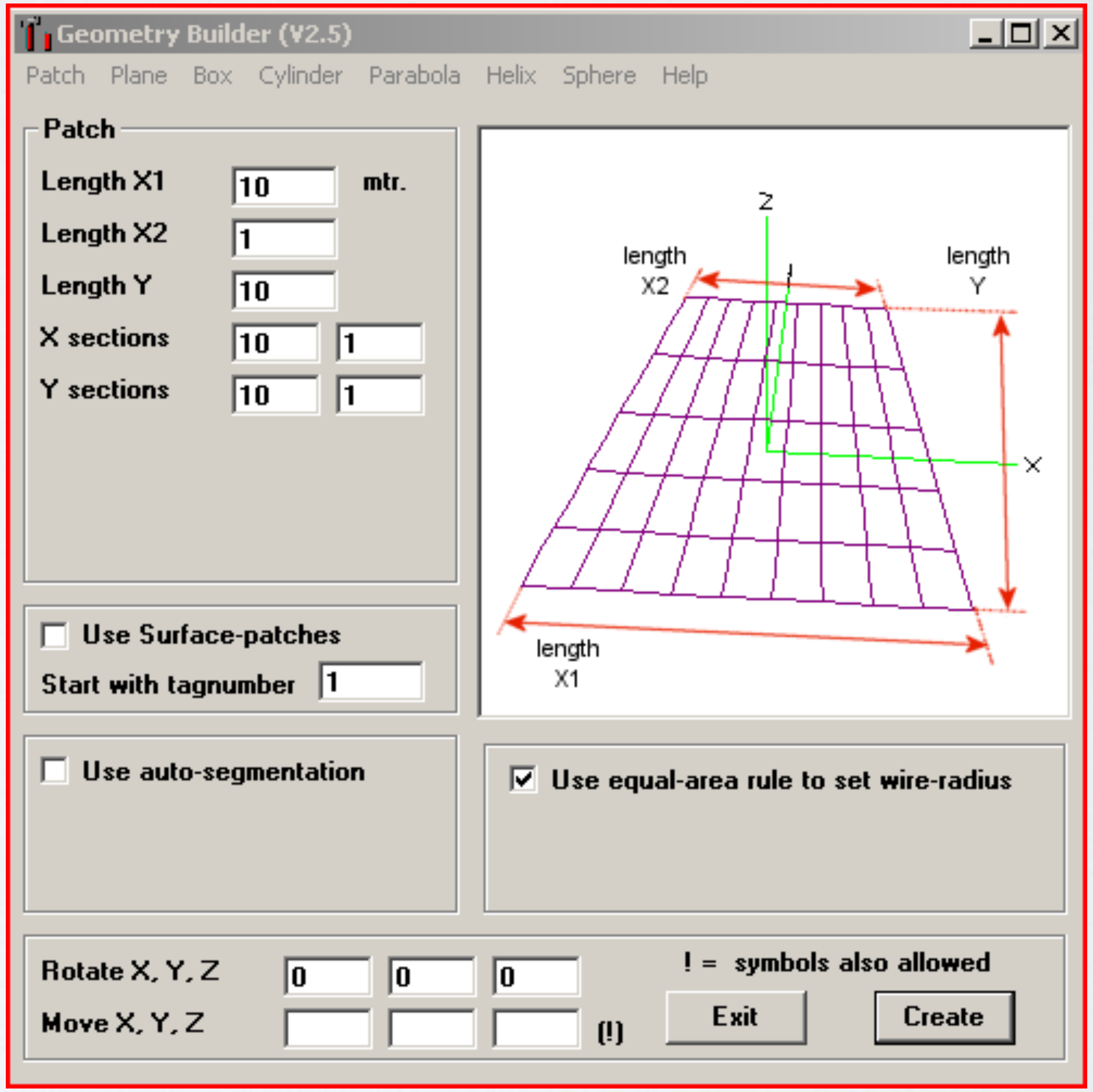


- I will not demonstrate how to use this editor.
  Try it yourself.

PROCEDURE TO USE 4NEC2

- For complex geometries (Patch, Plane, Box, Cylinder, Parabola, Helix and Sphere) try the installed Geometry Builder tool.





- I will not demonstrate how to use this tool.
  Try it yourself.

4NEC2 REMARKS

- 4NEC2 software allows inline comments (single quotes) and SYmbol (SY) cards but these are 4NEC2 specific and is NOT part of the NEC2 specification. Other software such as cocoaNEC will not run when they encounter SY cards.

- This card deck can not be run in cocoaNEC because it uses SY cards and inline commands:
https://www.mobilefish.com/download/lora/collinear_868mhz_4nec2.nec.txt

- You can use arithmetic operators, trigonometric functions, mathematical functions and predefined identifiers in the Symbol cards.

4NEC2 REMARKS

- **Arithmetic operators:**
  + - plus. Example: SY a=2+3, result is 5
  - - minus. Example: SY a=2-3, result is -1
  / - division. Example: SY a=6/3, result is 2
  ***** - multiplication. Example: SY a=2*3, result is 6
  ^ - power of . Example: SY a=2^3, result is 8

4NEC2 REMARKS

- **Trigonometric functions:**
  sin(Θ) - sine of an angle in degrees.
  Example: SY a=sin(30°), result is 0.5
  cos(Θ) - cosine of an angle in degrees.
  Example: SY a=cos(60°), result is 0.5
  tan(Θ) - tangent of an angle in radians.
  Example: SY a=tan(45°), result is 1
  atn(y/x) - arc tangent of a value, result in degrees.
  Example: SY a=atn(1), result is 45°

4NEC2 REMARKS

- **Mathematical functions:**
  sqr(x) - square root of x. Example: SY a=sqr(4), result is 2
  exp(x) - exponent of x (e^x). Example: SY a=e(2), result is 7.38906
  log10(x) - log base 10 of x. Example: SY a=log10(2), result is 0.30103
  log(x) - natural log of x (ln x). Example: SY a=log(2), result is 0.69315
  abs(x) - the absolute value of an int. Example: SY a=abs(-2), result is 2
  sgn(x) - sign value of x. Example: SY a=sgn(-2), result is -1
  If x <0, result = -1
  If x = 0, result = 0
  If x >0, result = 1

4NEC2 REMARKS

int(x) - remove the fractional part of x and return the resulting integer value. If x is negative, it returns the first negative integer less than or equal to x. Example: SY a=int(-2.4), result is -3

fix(x) - remove the fractional part of x and return the resulting integer value. If x is negative, it returns the first negative integer greater than or equal to x. Example: SY a=fix(-2.4), result is -2

4NEC2 REMARKS

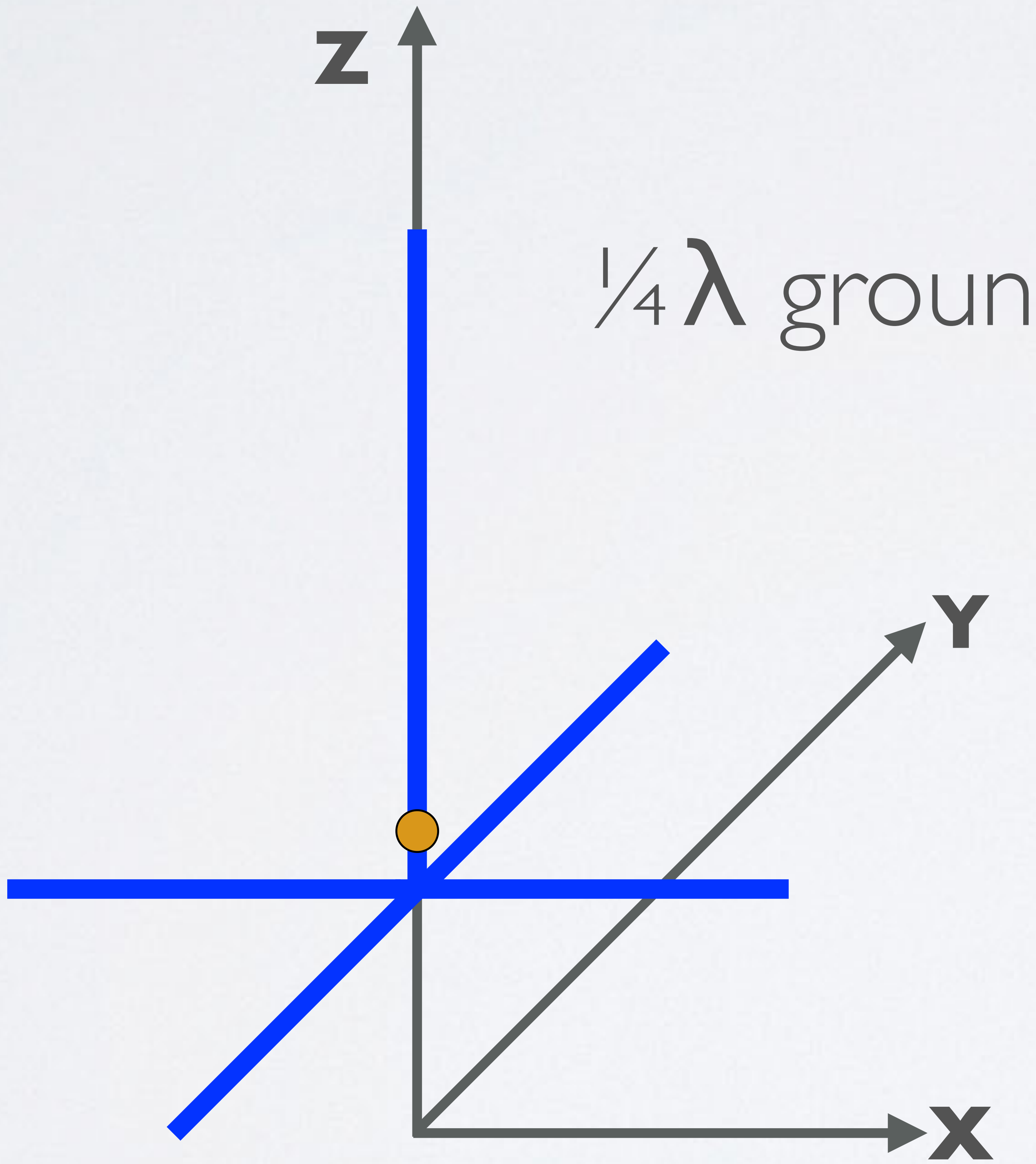
- **Predefined identifiers:**
  cm - centimeter. Example: SY a=100cm, same as 1 m.
  mm - millimeter. Example: SY a=1000mm, same as 1 m.
  in - inch. Example: SY a=100in, same as 2.54 m.
  ft - feet. Example: SY a=10ft, same as 3.048 m.
  pF - pico Farad. Example: SY a=1pF, same as 1.0E-12 F
  nF - nano Farad. Example: SY a=1nF, same as 1.0E-9 F
  uF - micro Farad. Example: SY a=1uF, same as 1.0E-6 F
  nH - nano Henry. Example: SY a=1nH, same as 1.0E-9 H
  uH - micro Henry. Example: SY a=1uH, same as 1.0E-6 H
  pi - PI constant 3.14159. Example: SY a=pi

4NEC2 REMARKS

- **AWG wire radius identifiers**
  #0 - #20 - American Wire Gauges. Example: SY a=#20, same as 0.000406 m
  https://www.mobilefish.com/download/lora/awg2metric.pdf
  You can only use #0 - #20

4NEC2 REMARKS

- Do not cross wires.
- Do not model elements below the ground (z=0).



¼λ ground plane antenna

The antenna model consists of 5 wires and not 3 wires.

SOME INFORMATION ABOUT COCOANEC

- cocoaNEC has several limitations which other antenna modelling software does not have. For example: You can not model helixes in the spreadsheet, and helixes are not displayed in the 3D model.

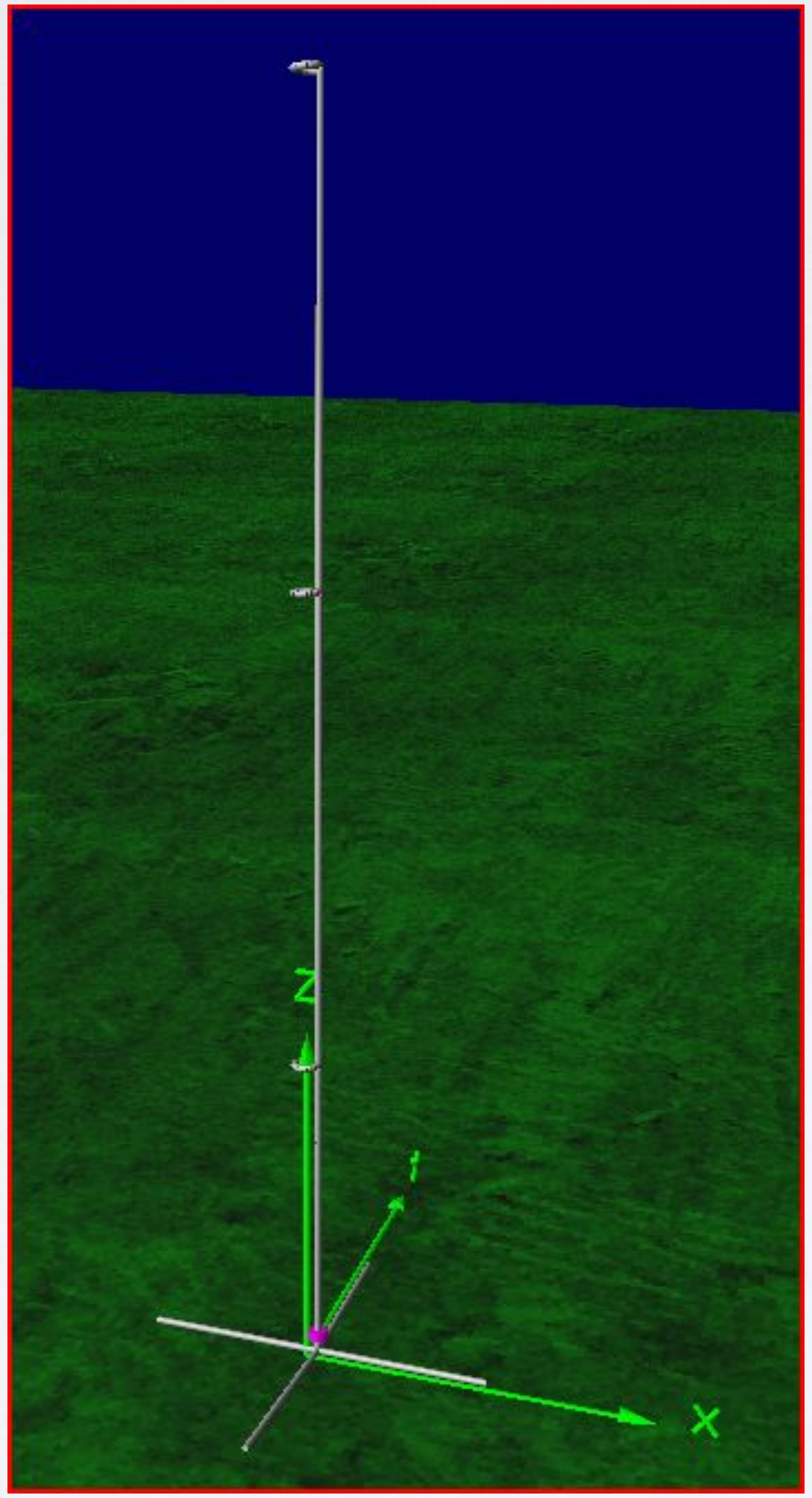
- It is important to see all your antenna elements in 3D to verify if your antenna is correctly modelled.

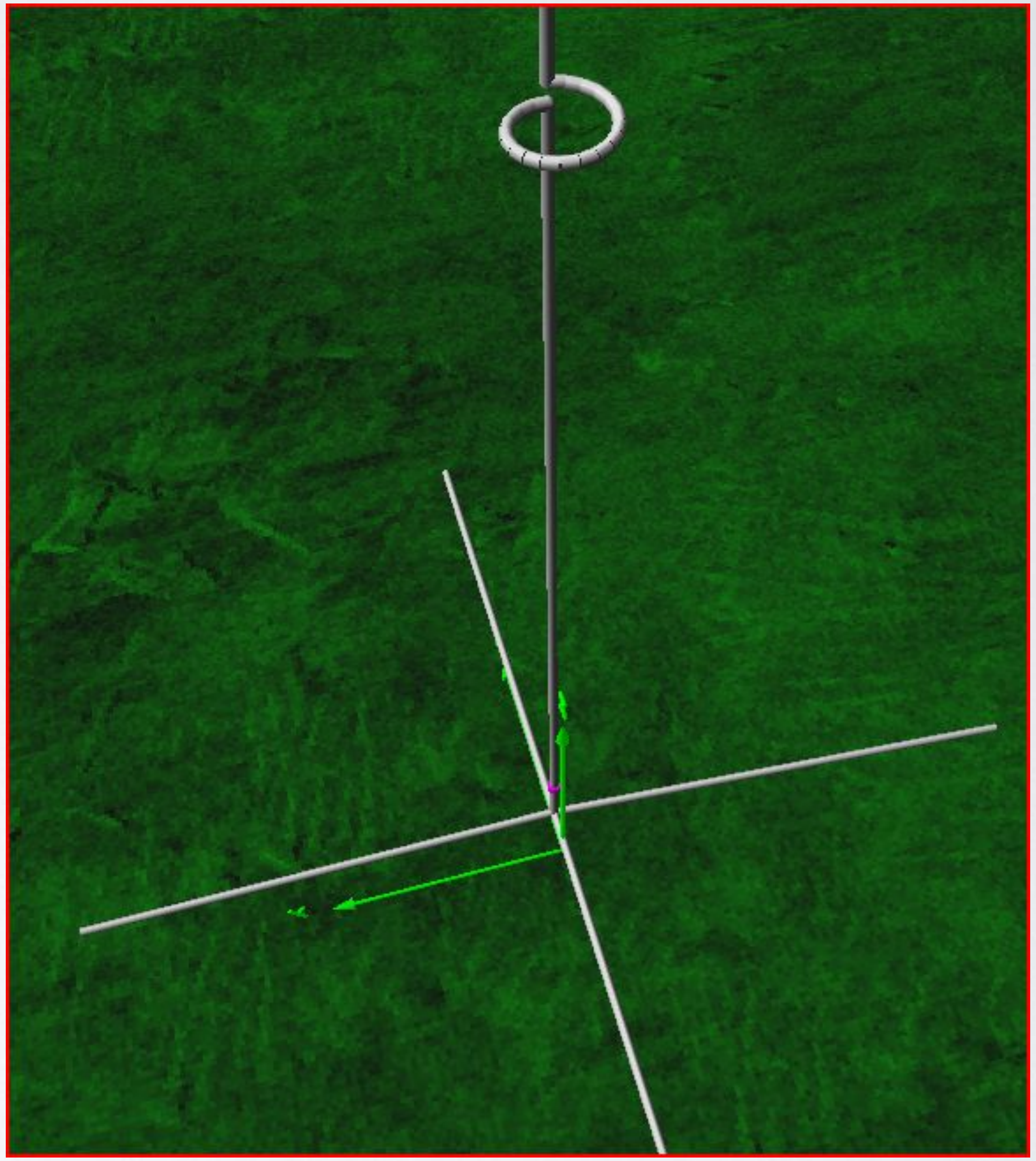
- In cocoaNEC and 4NEC2 wire radius can be entered in American Wire Gauge format.
  For example: **#12**

COCOANEC

cocoaNEC

4NEC2





MORE INFORMATION

- More information about 4NEC2:
  https://www.qsl.net/4nec2/