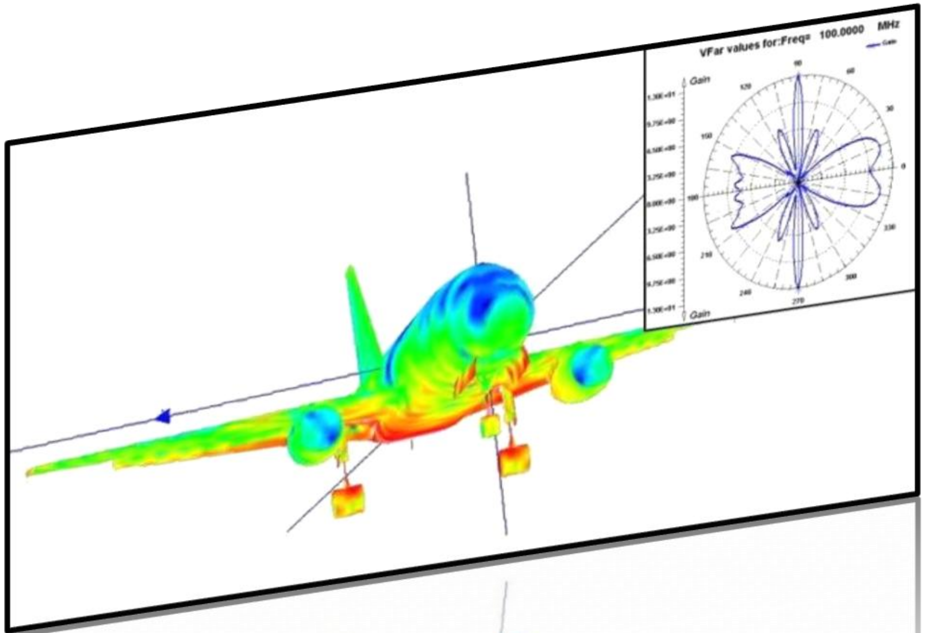

NEC

Numerical Electromagnetic Code

THE UNIVERSITY OF UTAH

Eric J. Lundquist

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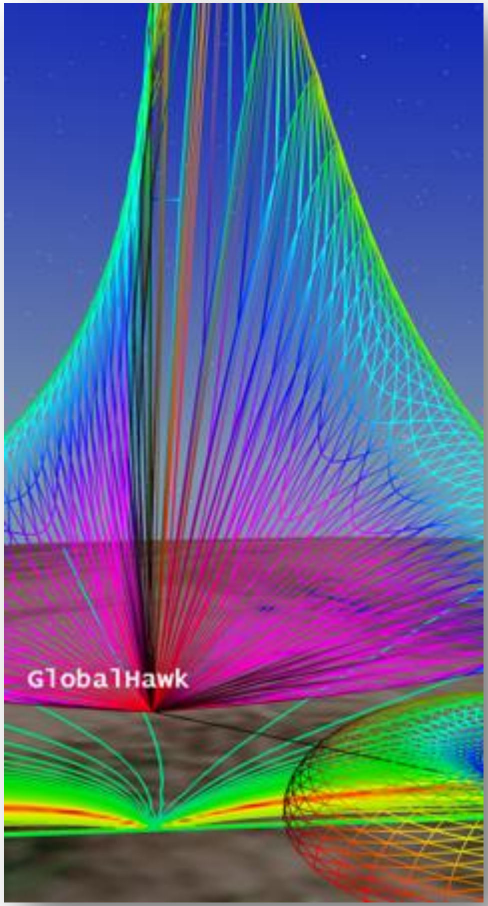
Objective Statement

- Develop understanding of NEC
- Apply NEC to current applications
- Successfully use NEC to design and simulate antenna systems
- Compare and contrast NEC results to analytical solutions
- Interpret NEC results for practical application

NEC Overview

Advantages

- Algorithm for antenna modeling
- Publicly available
- No theoretical limit
- Wide application
  - Very large arrays
  - Detailed modeling of very small antenna systems

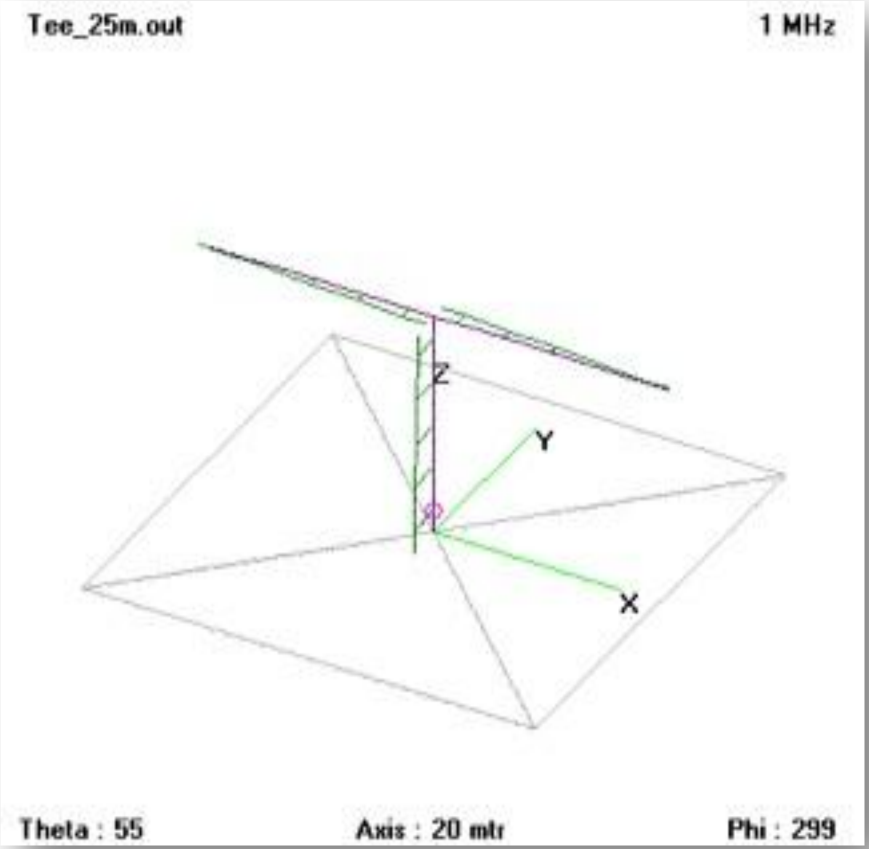


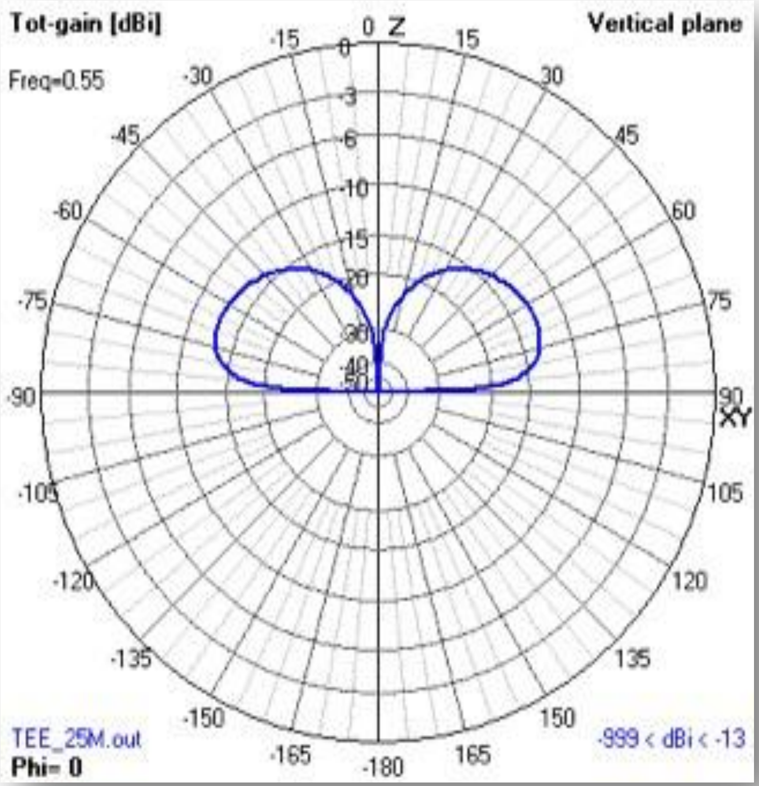
Disadvantages

- Computing time increases as number of wire segments N is increased
- Decreasing the number of wire segments N below guideline may cause computed feed-point impedance to be incorrect
- Guideline = More than 10 segments per λ/2

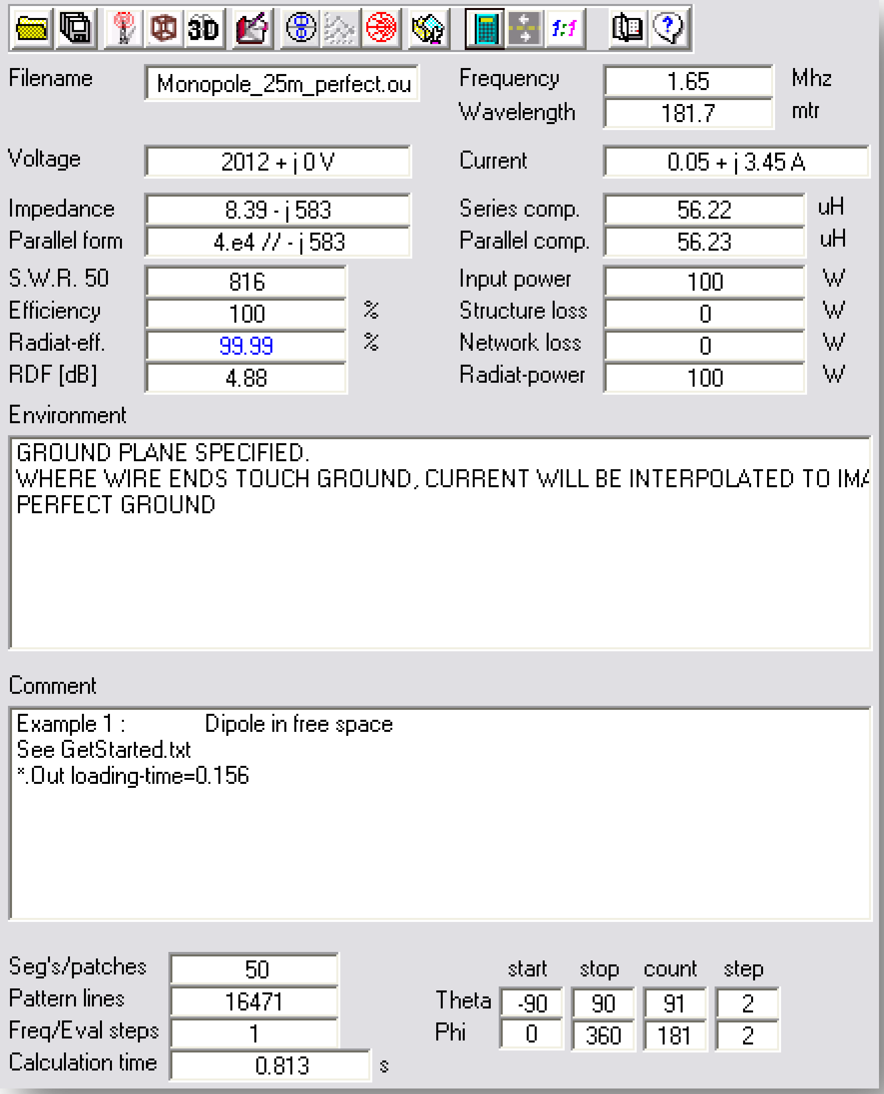
N>10
per λ/2

Tee Antenna Example





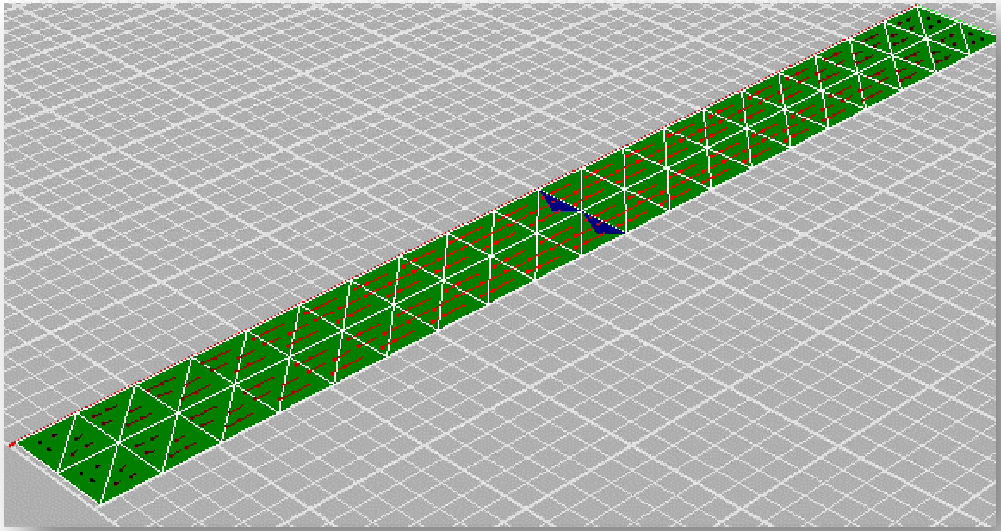
User Interface



How NEC Works

Method of Moments

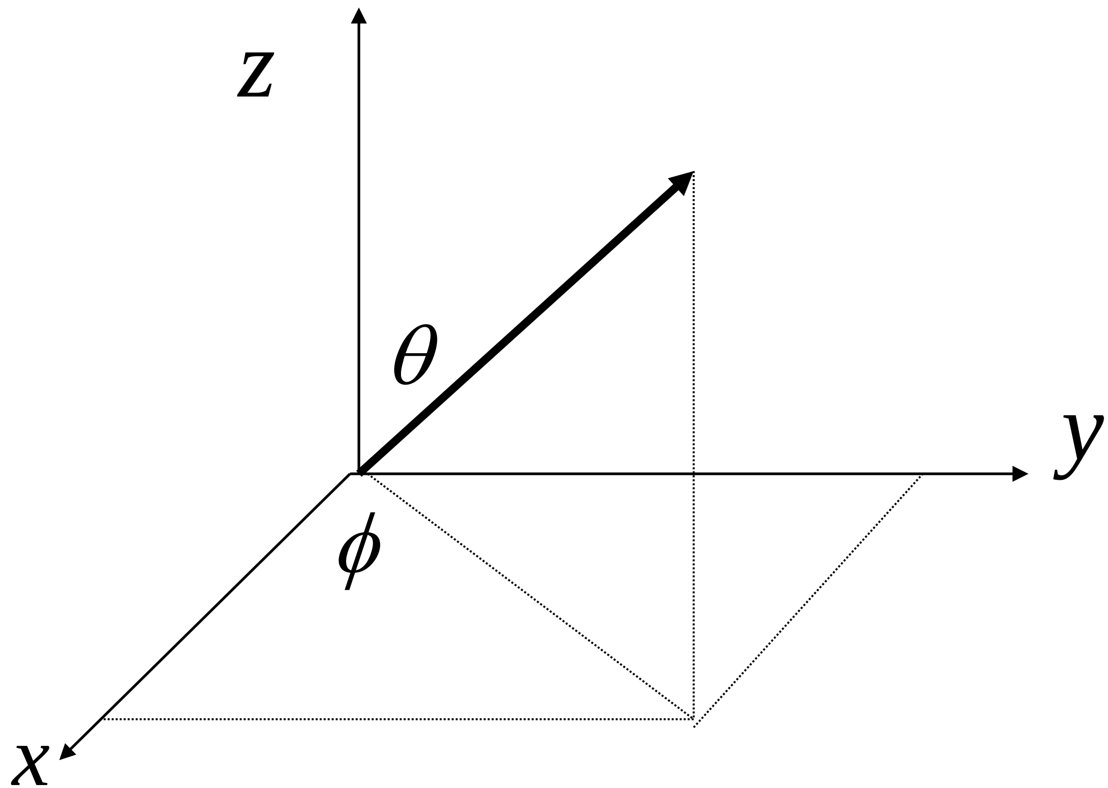
- Model constructed of thin, perfectly conducting wires
  - Plane = 2D intersecting grid of wires
  - Volume = 3D intersecting grid of wires
  - Loss = Lumped impedance resistance in each segment
- Add source (voltage or current) to a conducting segment
- Calculations in free space or ground plane vicinity
- Abbreviated MoM



Method of Moments Calculations

- Impedance matrix *Z* is built
- Linear system *V=ZI* solved
  - Currents *I* later used to recover the surface current distribution
  - Source impedance of defined sources also calculated
- From this first step, the three following procedures may be solved independently:
  - Exact surface current distribution
  - Near fields (E and M)
    - Also wave impedance (*Z=E/H*) provided in this process
  - Far fields (E and M)
    - Gain, directivity, and other parameters also provided in this process

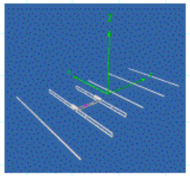
NEC Coordinate System



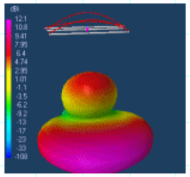
The *x*-*y* plane (*z* = 0) is where the ground plane is located, if used.

Using 4NEC2 – A Tutorial

Download 4NEC2



4nec2



NEC based antenna modeler and optimizer

by Arie Voors

4nec2 is a completely free Nec2, Nec4 and windows based tool for creating, viewing, optimizing and checking 2D and 3D style antenna geometry structures and generate, display and/or compare near/far-field radiation patterns for both the starting and experienced antenna modeler.

When running frequency sweeps, linear or logarithmic style SWR, Gain, F/B-ratio and impedance line-charts are produced. With the included Optimizer and Sweeper one is able to optimize antenna- and/or other environment-variables for Gain, resonance, SWR, efficiency and/or F/B, F/R-ratio. With the sweeper one is able to graphically display the effect of changing one or more of these variables for a specified range of values/frequencies.

For the starting modeler a graphically based 3D geometry-editor is included which requires no additional NEC knowledge while still enabling you to create and visualize and compare current-distribution, far/near-field patterns and Gain/SWR charts. More experienced modelers can use the gradient style and/or the genetic algorithm based optimizers to improve their designs.

To list some of its features or see some screenshots, click the appropriate links below on the left. To download and try the software click upmost two links below on the right (setup.exe) or the third link for a single zip containing all separate files.

NOTE: When experiencing problems running 4nec2, please consult the 'List known bugs' page on this website for latest news.

Information

List features
View screenshots
Show release notes
List known bugs
FAQ

4NEC2 Tutorials

Links and other stuff

Downloads

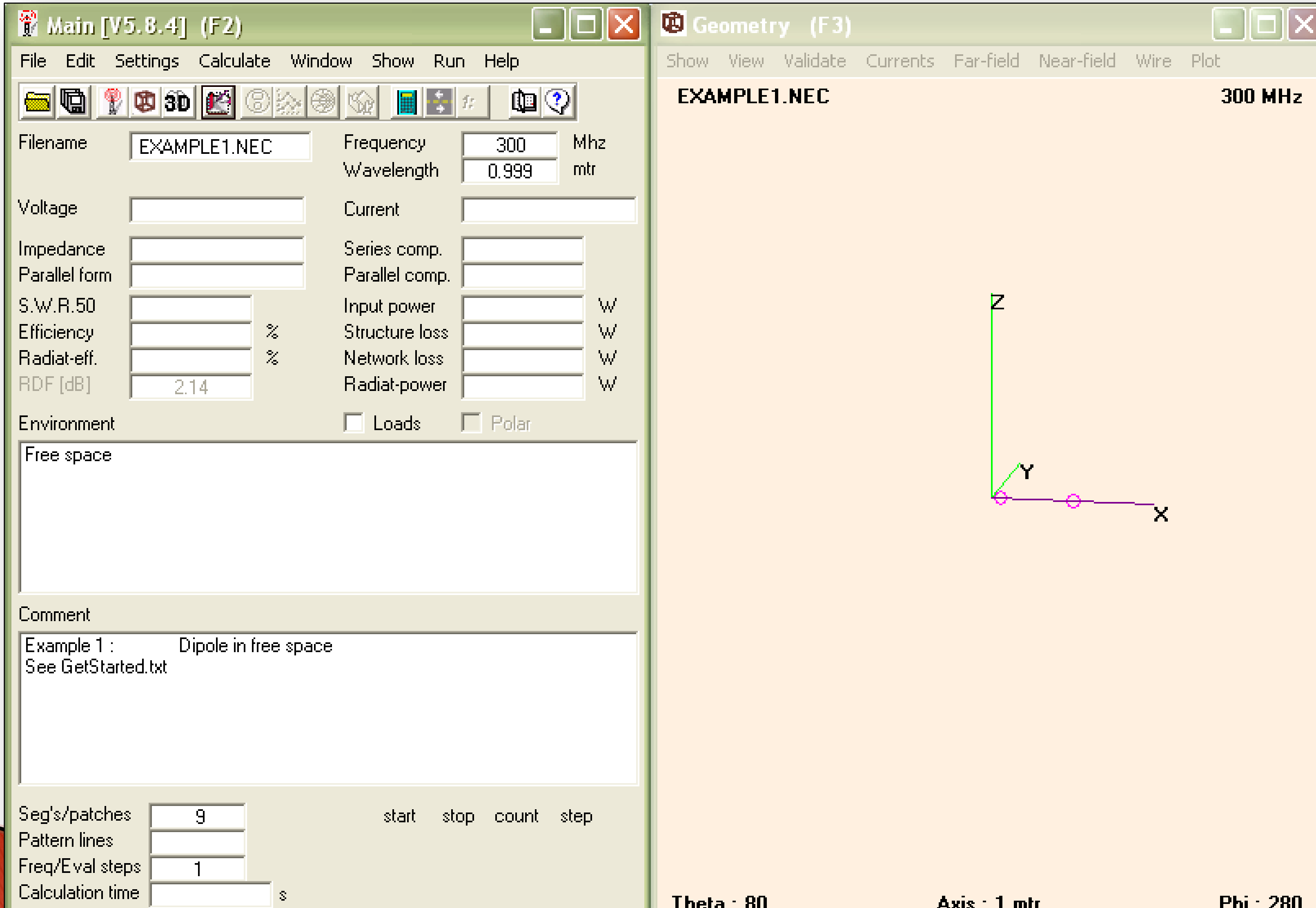
* Latest 4nec2 version (5.8.4)
* 4nec2 files as a ZIP (no install) (5.8.4)

(4)Nec2 support files

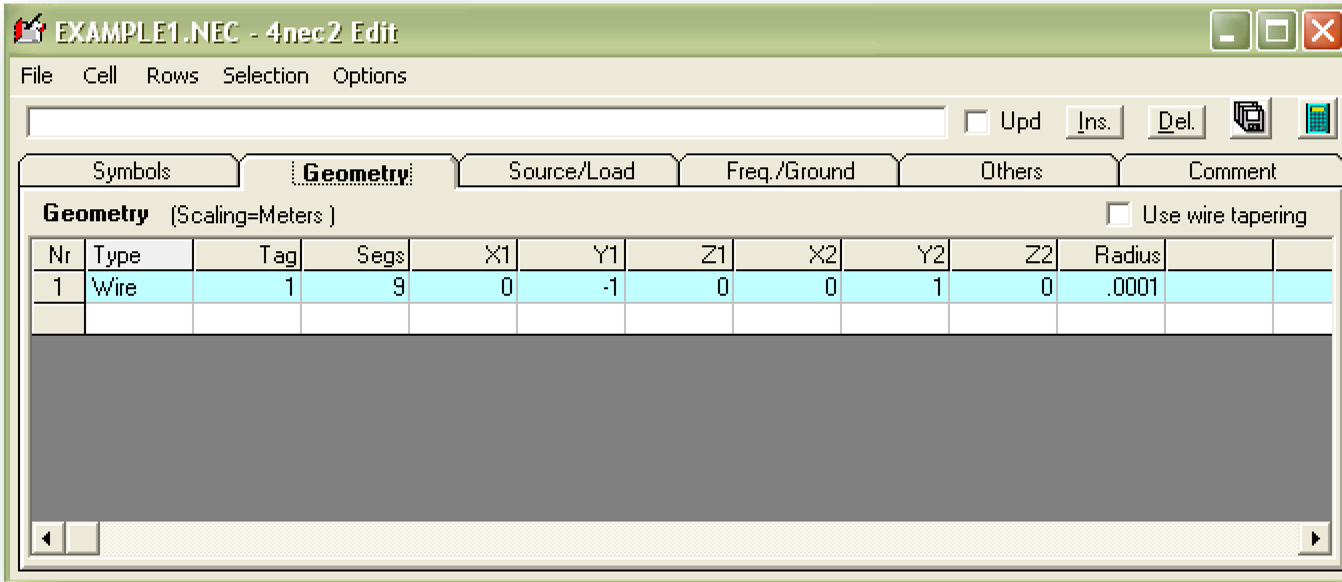
Gnuplot 2D/3D plotting
ItsHF propagation prediction

HAM-magazine article in Dutch

Main Interface and Geometry Window

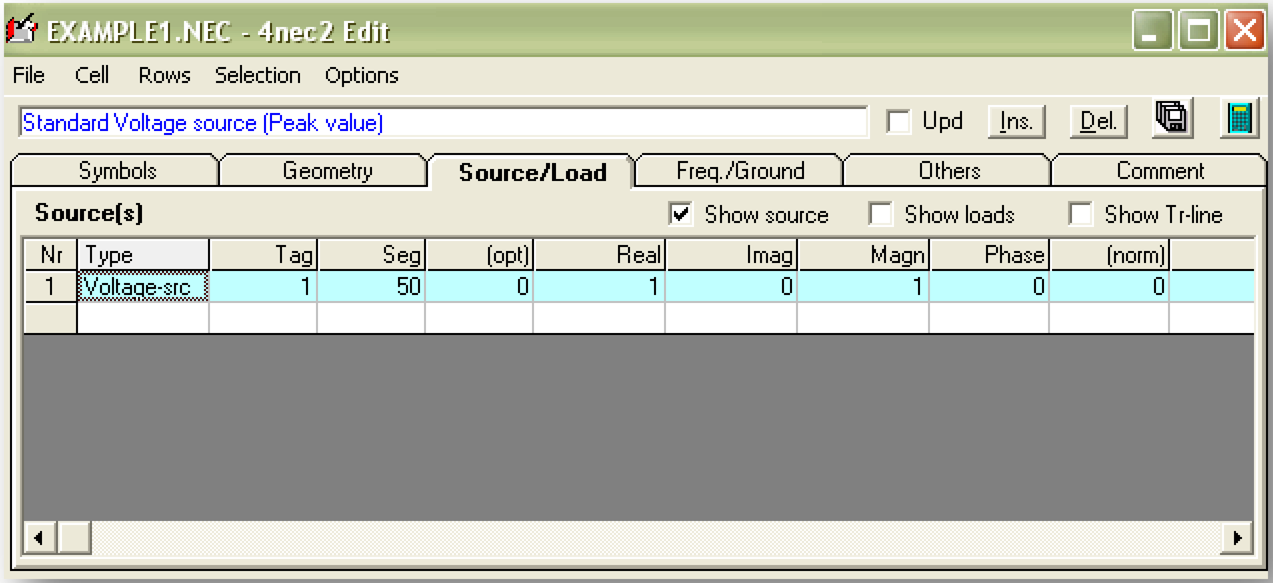


NEC Editor – Geometry



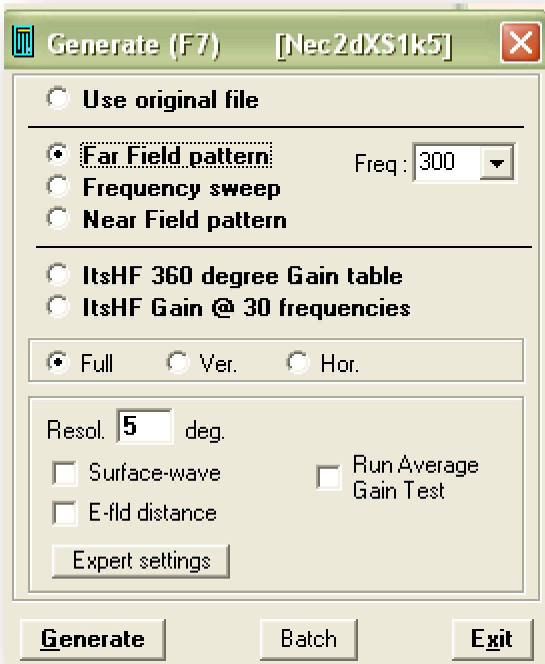
- Ctrl+F4
- Wire dimensions
- Voltage sources
- Wire segments

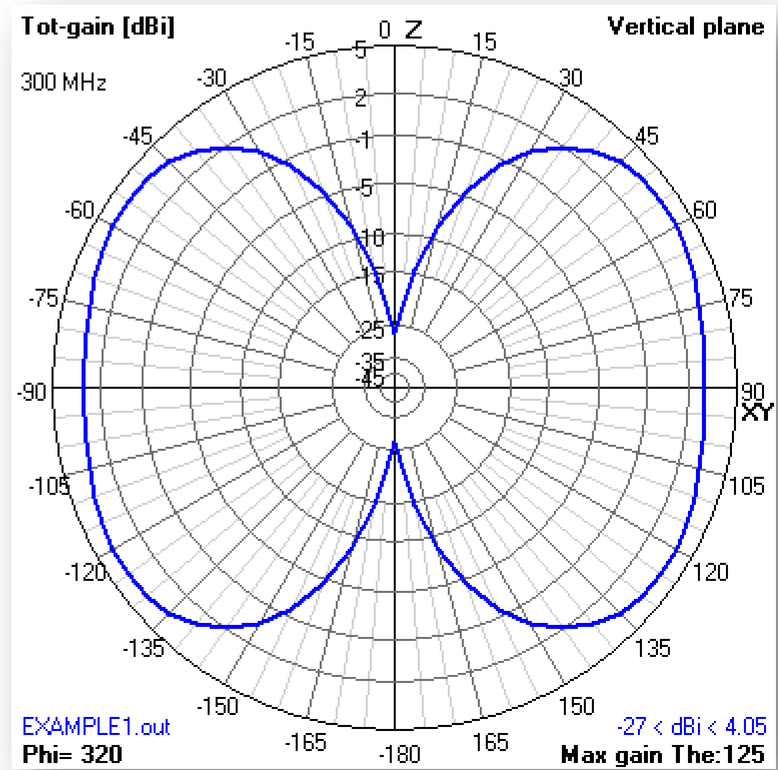
NEC Editor – Source/Load



- Ctrl+F4
- Wire dimensions
- Voltage sources
- Wire segments

Generate Radiation Pattern





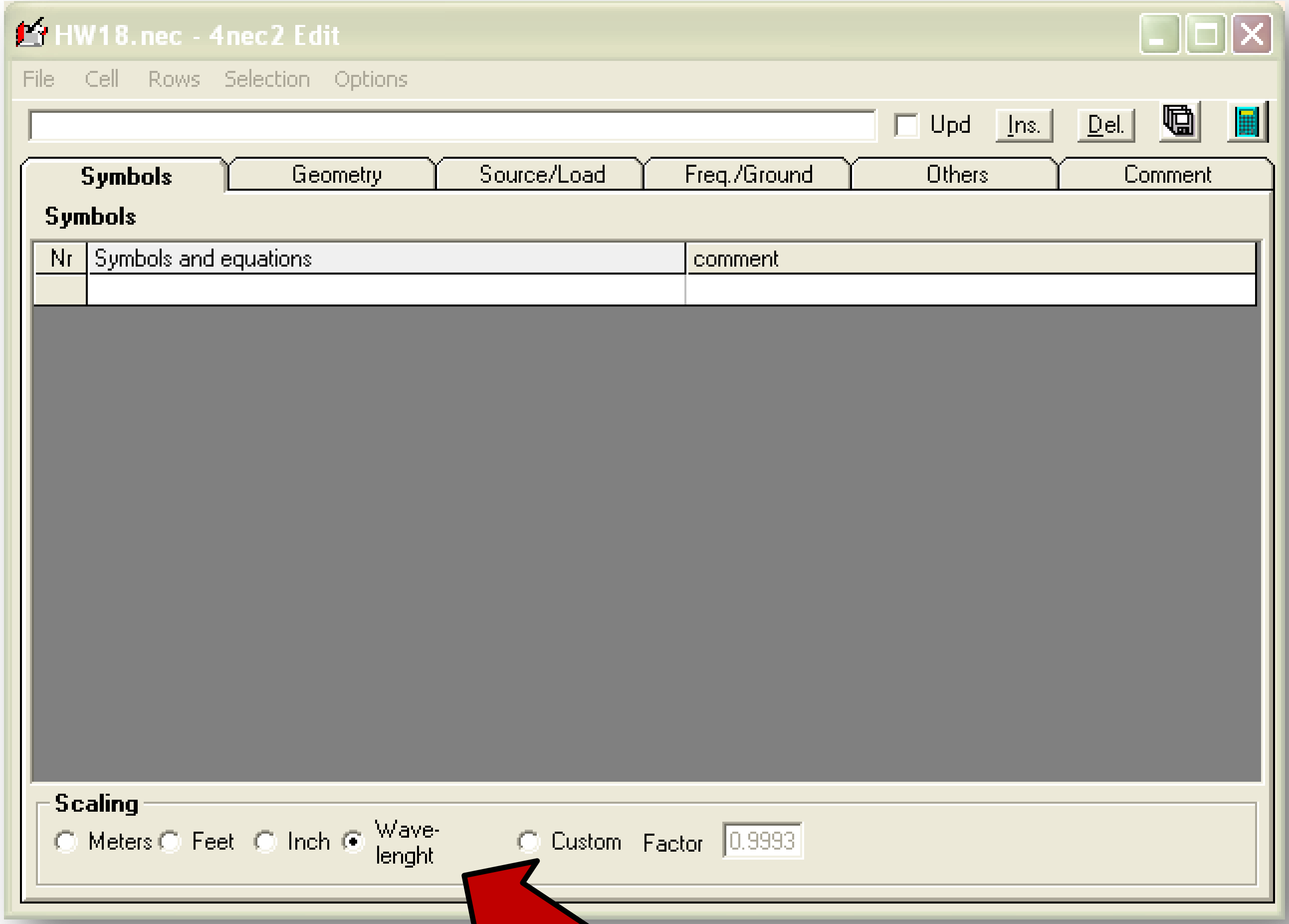
Practical Application:
The Parallel and Colinear Dipole Problem

Dipole Application

- Side-by-side parallel dipole antennas
  - L = 0.4781 λ (nominal half-wave dipoles)
  - Inter-element distance d/ λ = 0.40
  - Progressive phase difference a = -144°

- Colinear dipole antennas
  - L = 0.4781 λ
  - End-to-end separation s = 0.40 λ
  - All antennas fed in phase a = -144°

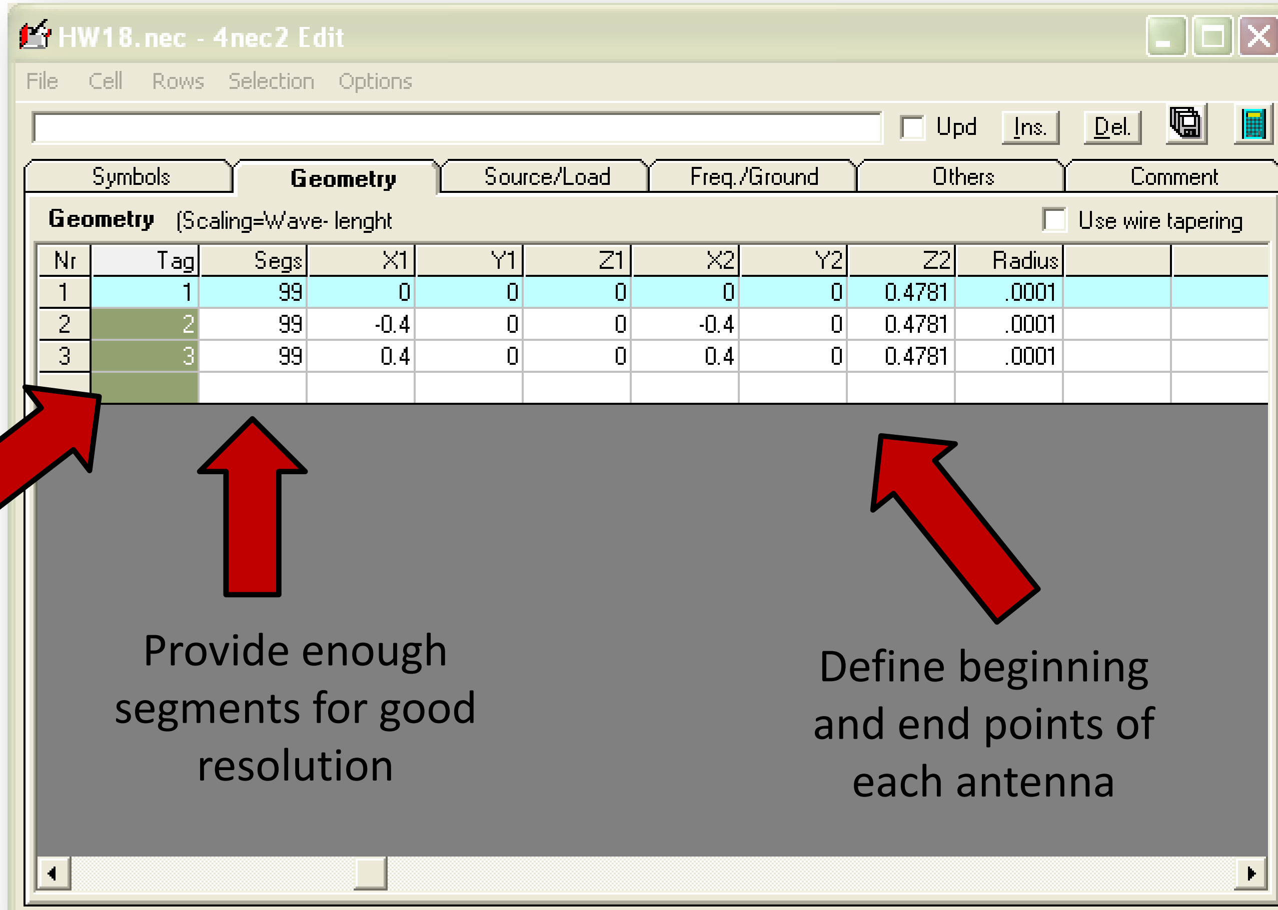
Open Geometry Editor



Define dimensions in terms of wavelengths

Program Antenna Dimensions

Assign a tag to each antenna

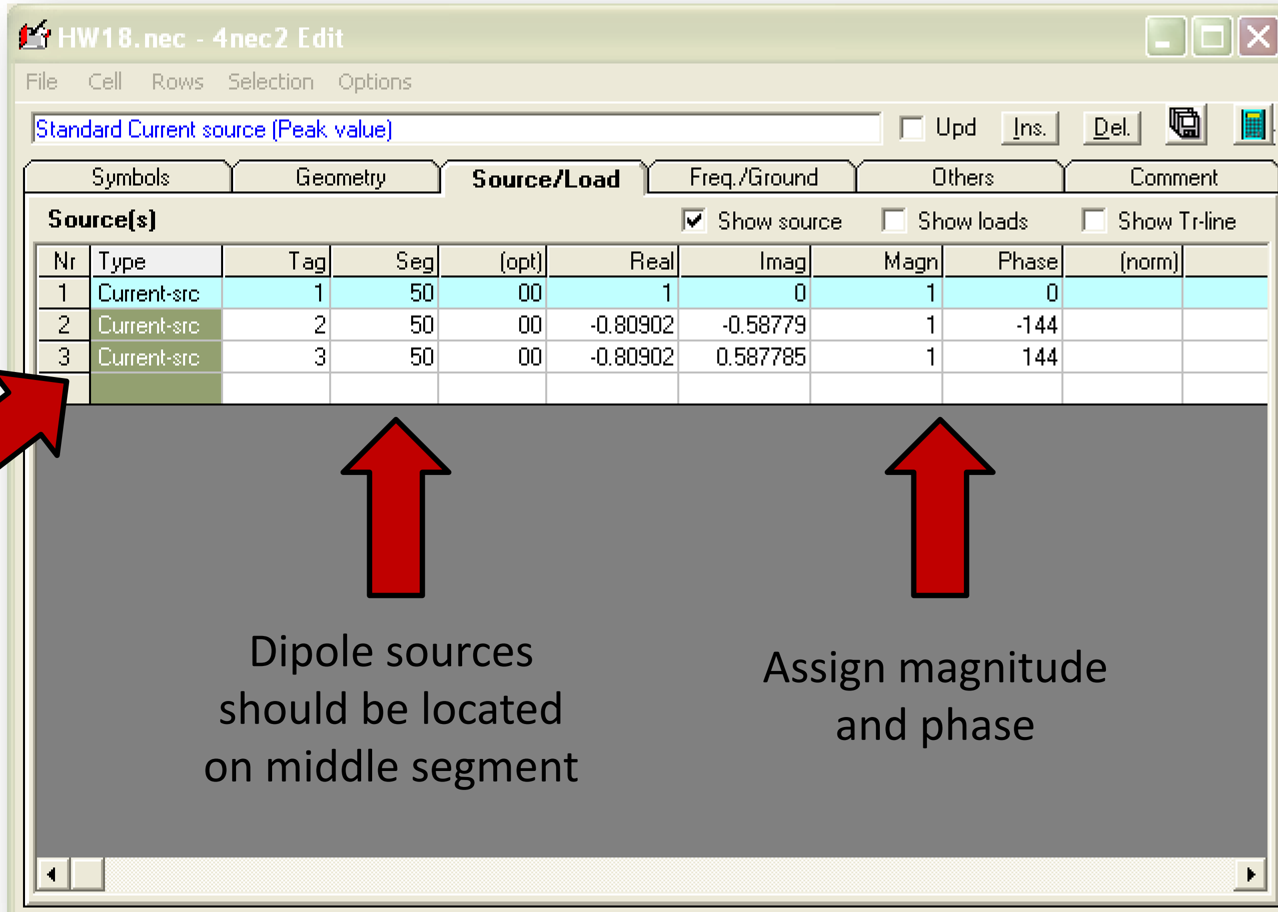


Nr	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius
1	1	99	0	0	0	0	0	0.4781	.0001
2	2	99	-0.4	0	0	-0.4	0	0.4781	.0001
3	3	99	0.4	0	0	0.4	0	0.4781	.0001

Provide enough segments for good resolution

Define beginning and end points of each antenna

Program Source Parameters



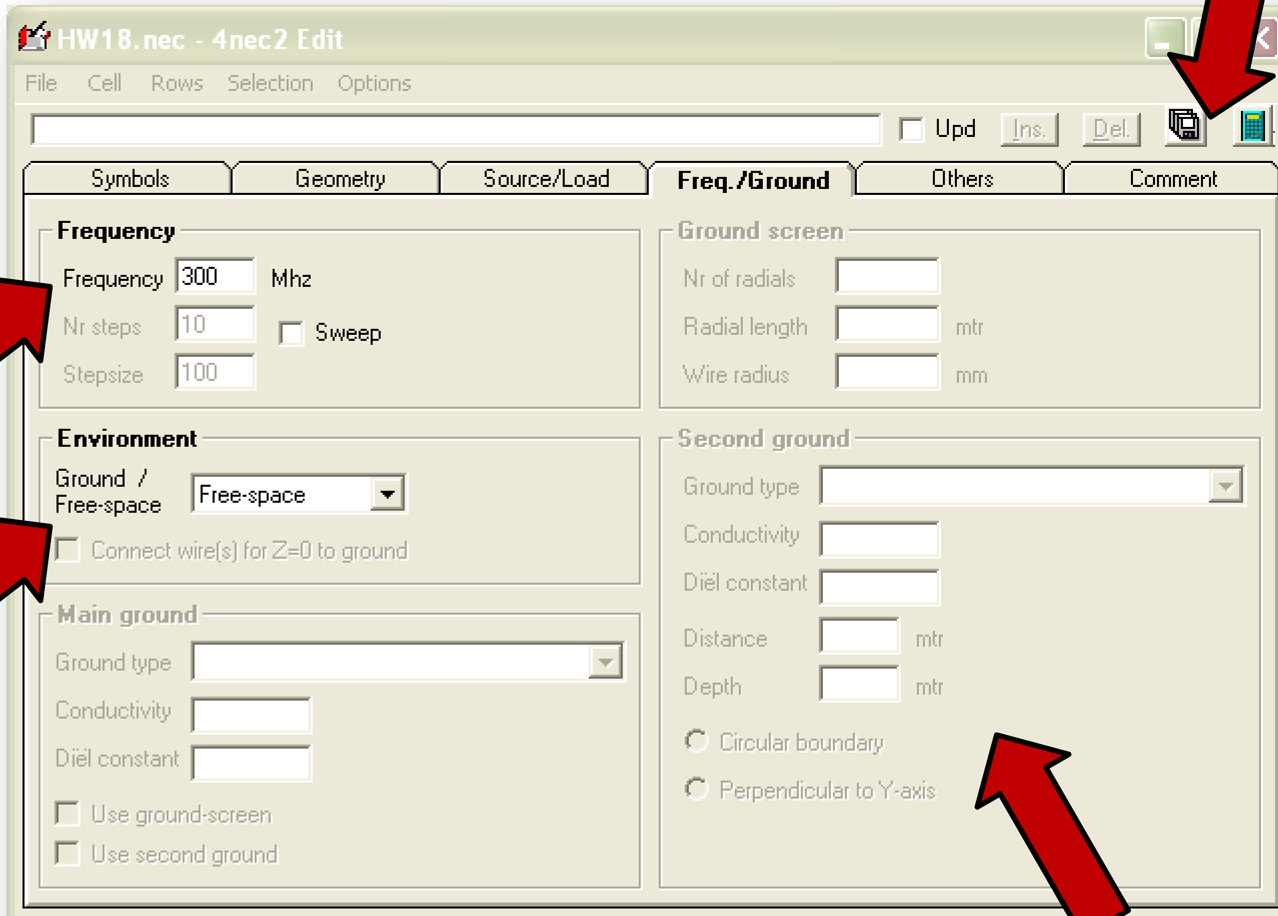
Select source type

Dipole sources should be located on middle segment

Assign magnitude and phase

Program Simulation Frequency

Save and run simulation



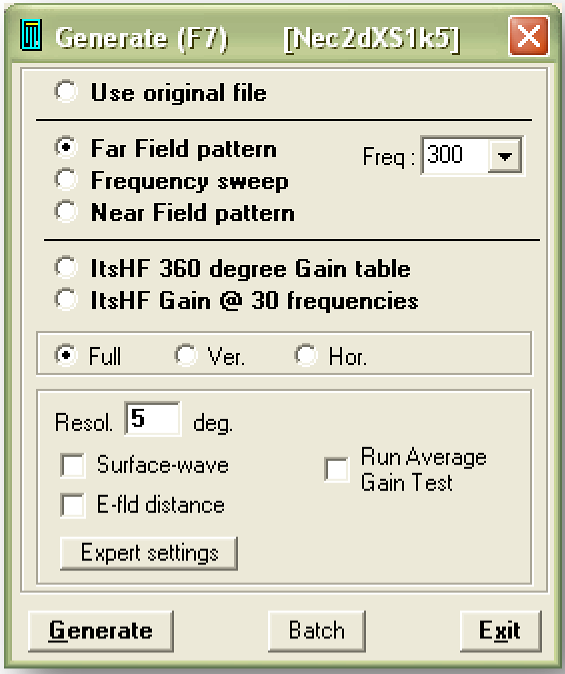
Specify frequency

Choose ground or free-space

Now we are simulating in free-space, but ground environment can also be used

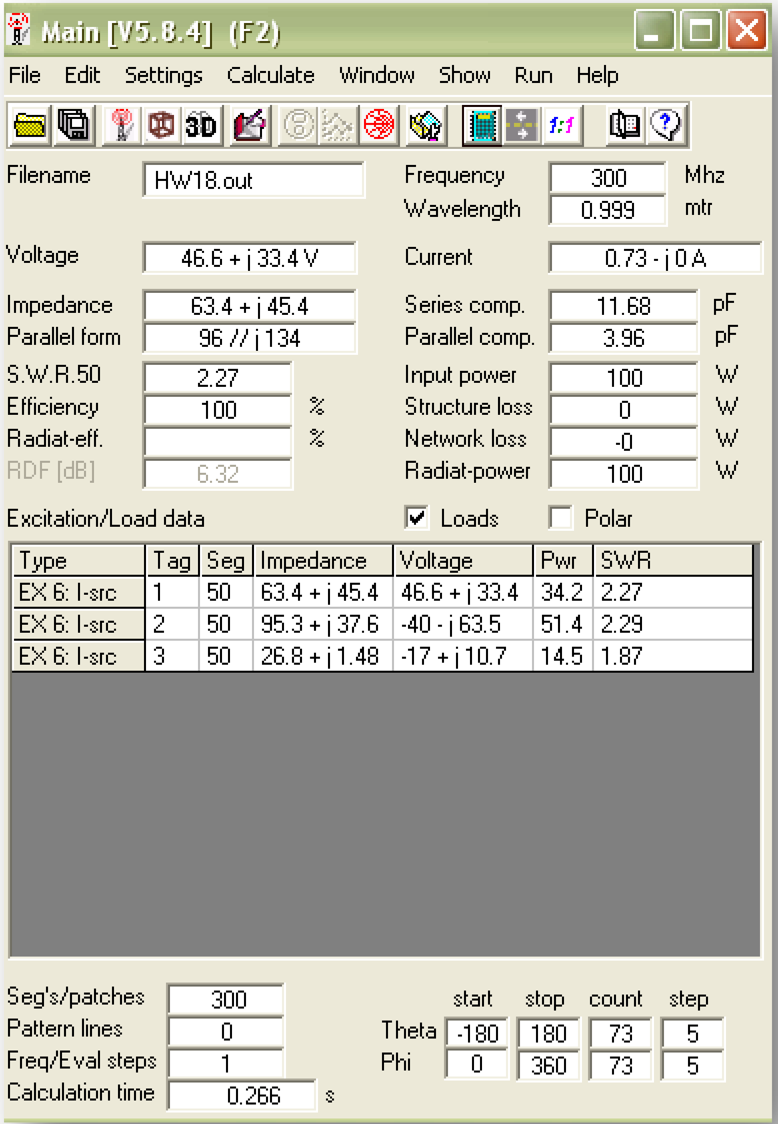
Generate Results

- Full, Vertical, or Horizontal Plane
- Select Full for 3D
- Frequency sweep and near field also possible



Parameters

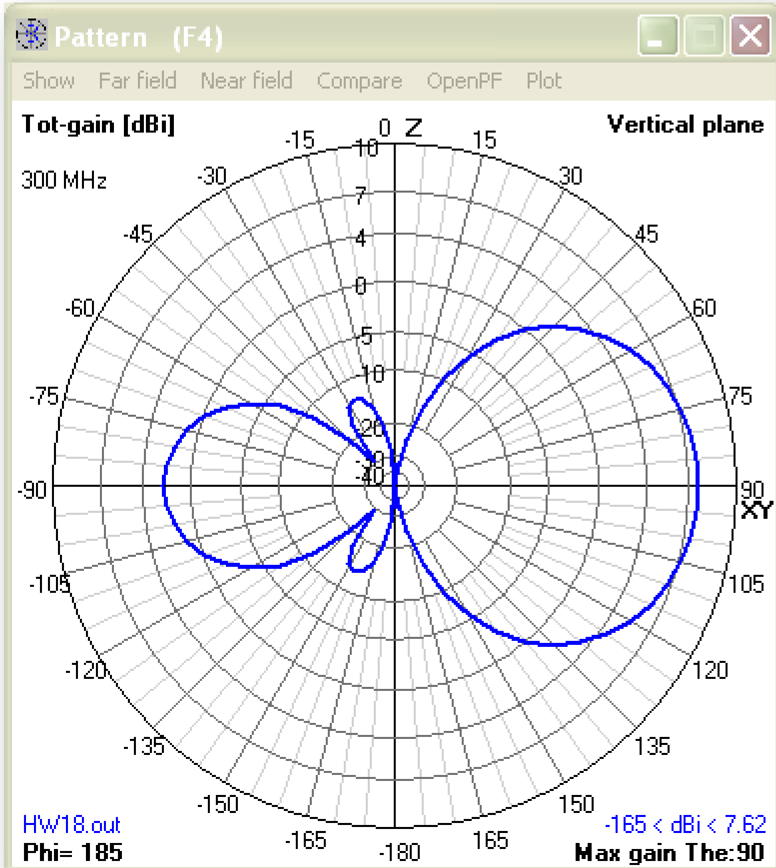
Select “Loads” to see input impedance at each source segment

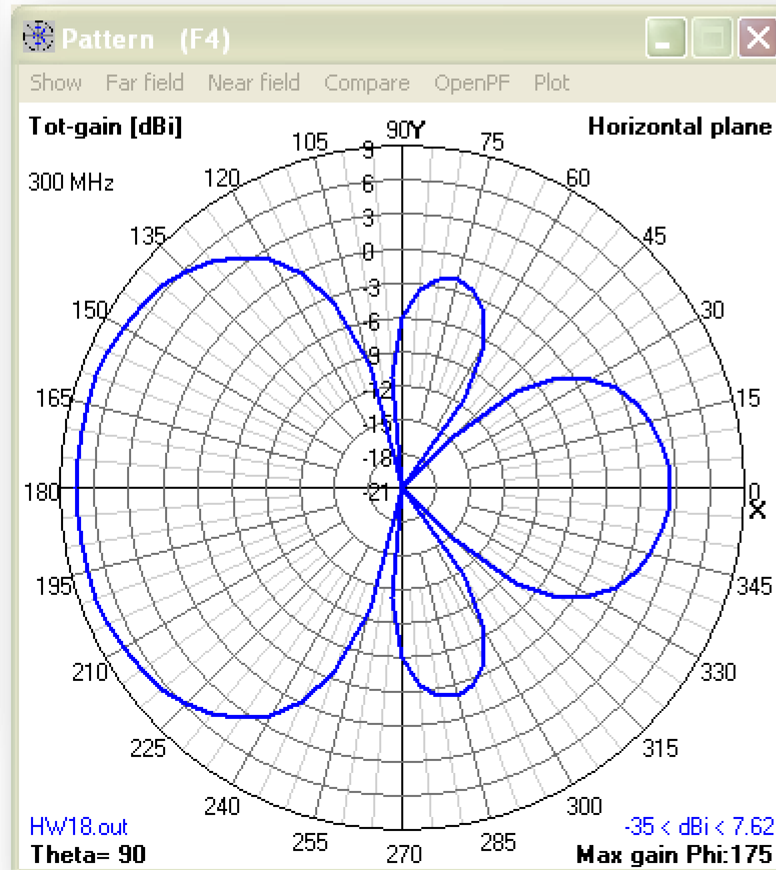


Input Impedance

- In simulation, source impedance *will* vary depending on parameters such as wire radius, frequency, etc.
- Be sure to use parameters assigned to homework problems in order to obtain correct results

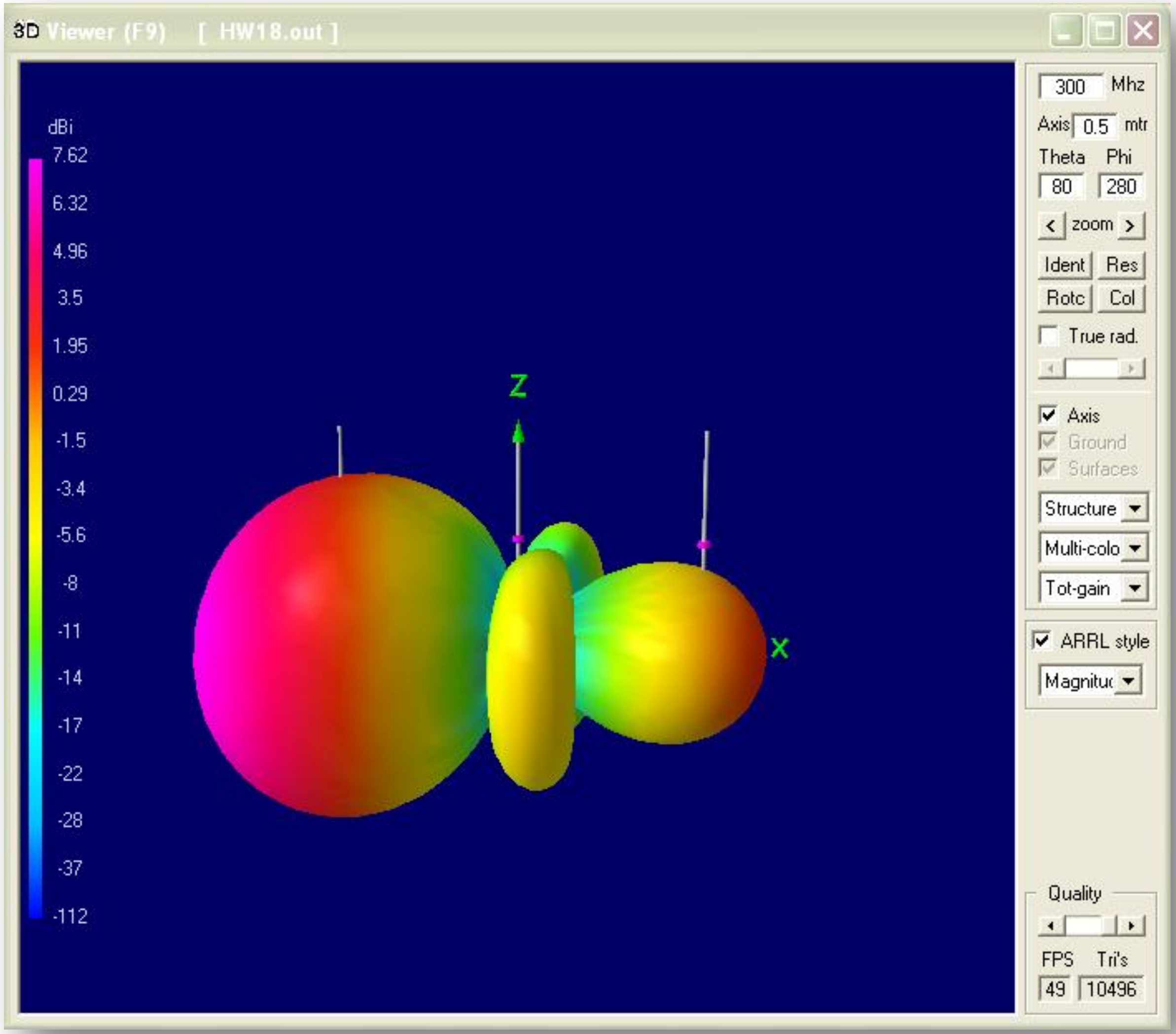
Radiation Patterns





3D Viewer

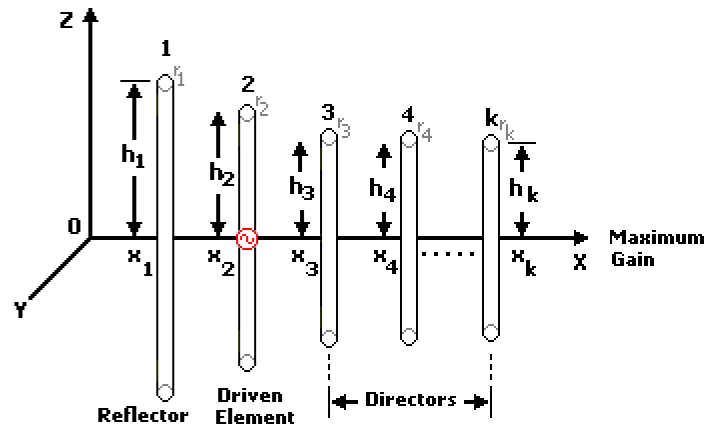
- Run far field simulation
- Hit F9 for 3D



Practical Application:
The Yagi-Uda Antenna Problem

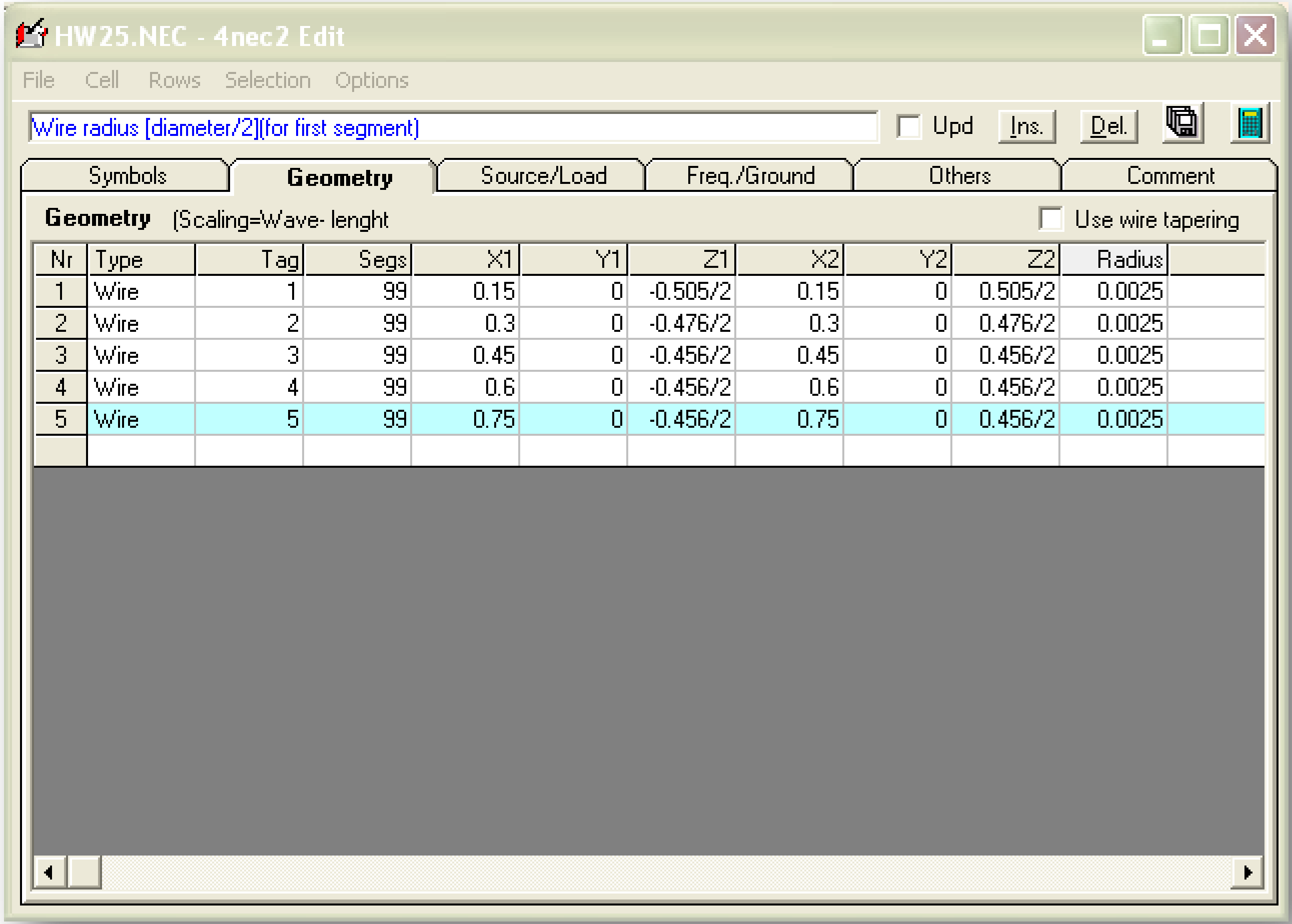
Yagi-Uda Application

- Five-element Yagi-Uda antenna design
  - Spacing = 0.15λ
  - Reflector length = 0.505 λ
  - Driver length = 0.476 λ
  - Three directors of length = 0.456 λ
- Verify: Are these correct?
  - Gain = 10.0 dB
  - Front-to-back ratio = 13.1 dB
  - Input impedance = 9.6 + j13.0 ohms
  - For H-plane (θ = 90° xy plane)
    - Half-power beam width HPBW = 76°
    - Side-lobe level SLL = -8.9 dB



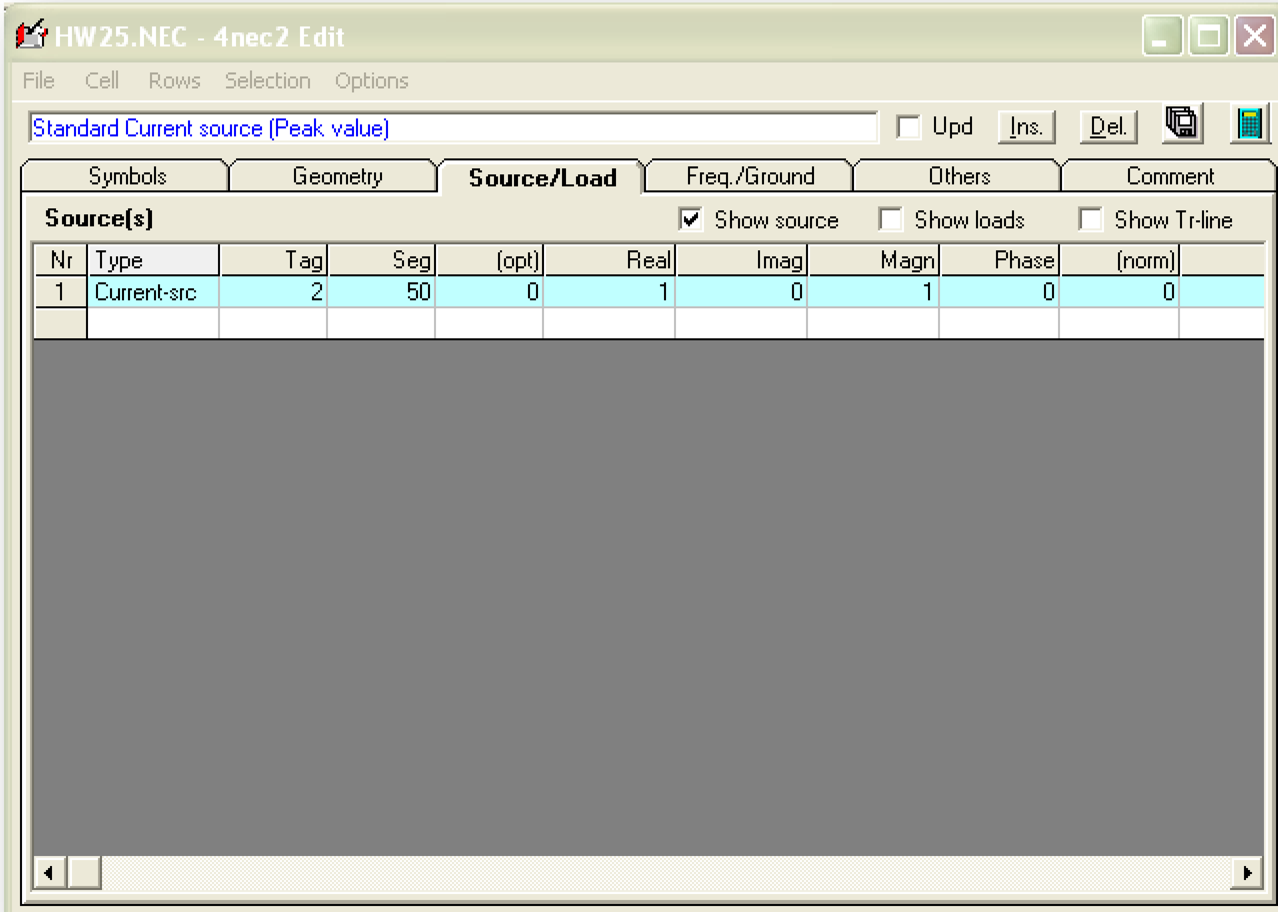
Geometry of a K elements Yagi-Uda

Program Element Dimensions

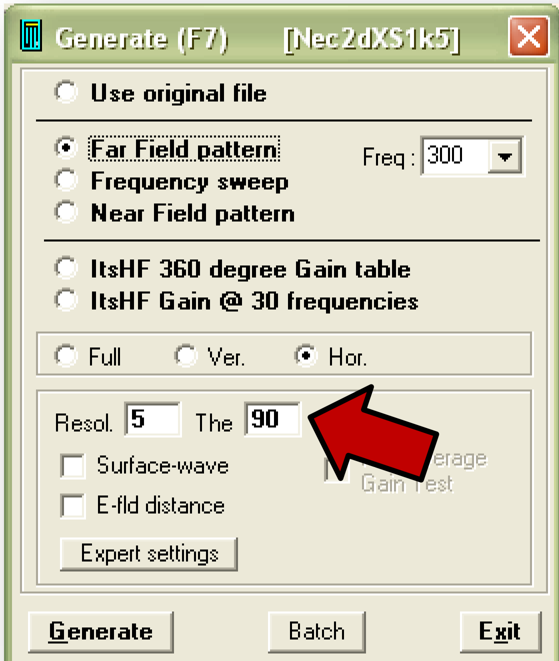


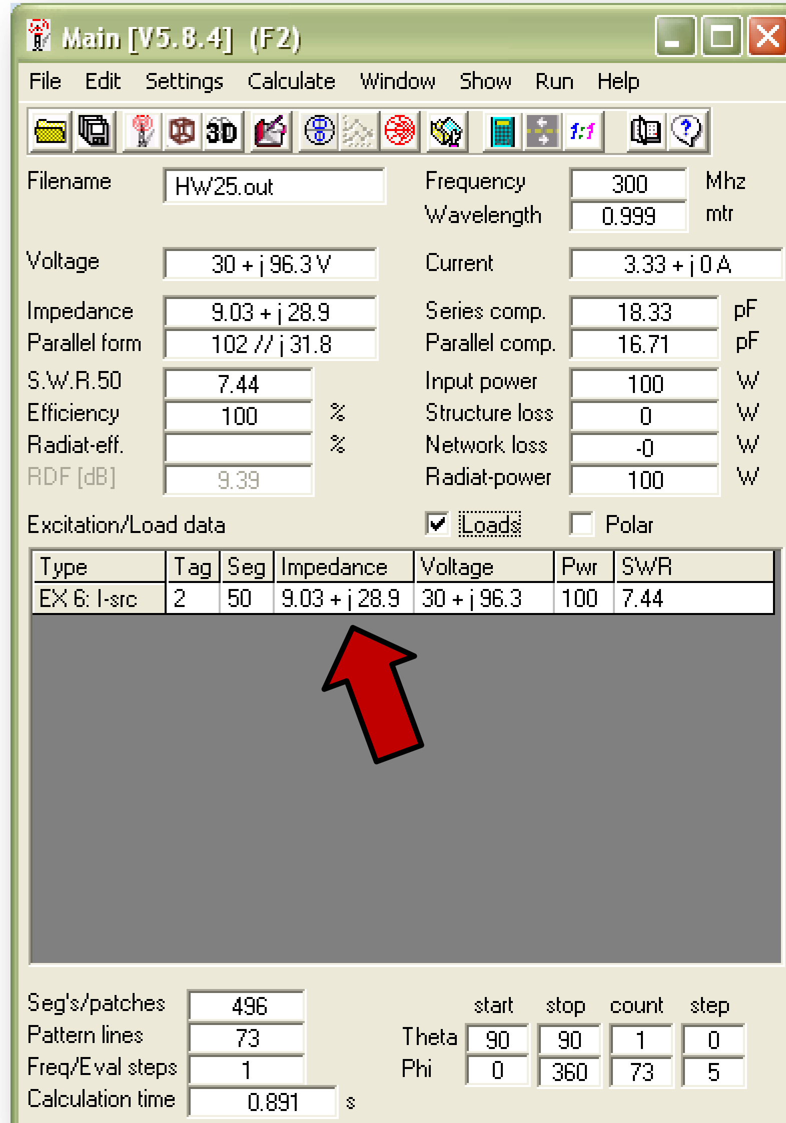
Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius
1	Wire	1	99	0.15	0	-0.505/2	0.15	0	0.505/2	0.0025
2	Wire	2	99	0.3	0	-0.476/2	0.3	0	0.476/2	0.0025
3	Wire	3	99	0.45	0	-0.456/2	0.45	0	0.456/2	0.0025
4	Wire	4	99	0.6	0	-0.456/2	0.6	0	0.456/2	0.0025
5	Wire	5	99	0.75	0	-0.456/2	0.75	0	0.456/2	0.0025

Program Source Parameters

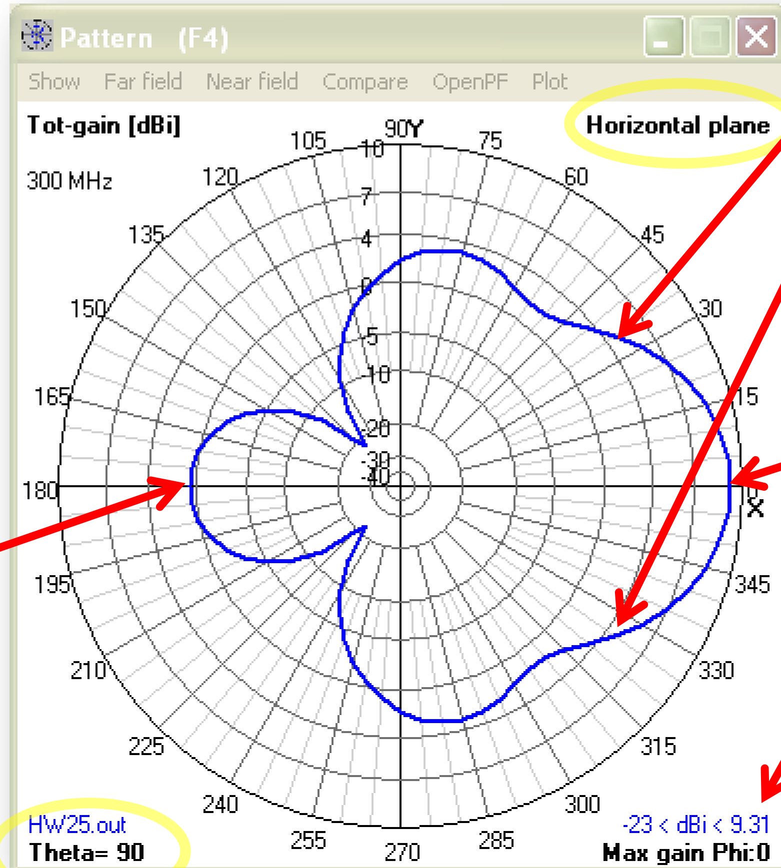


Generate Results





Radiation Patterns

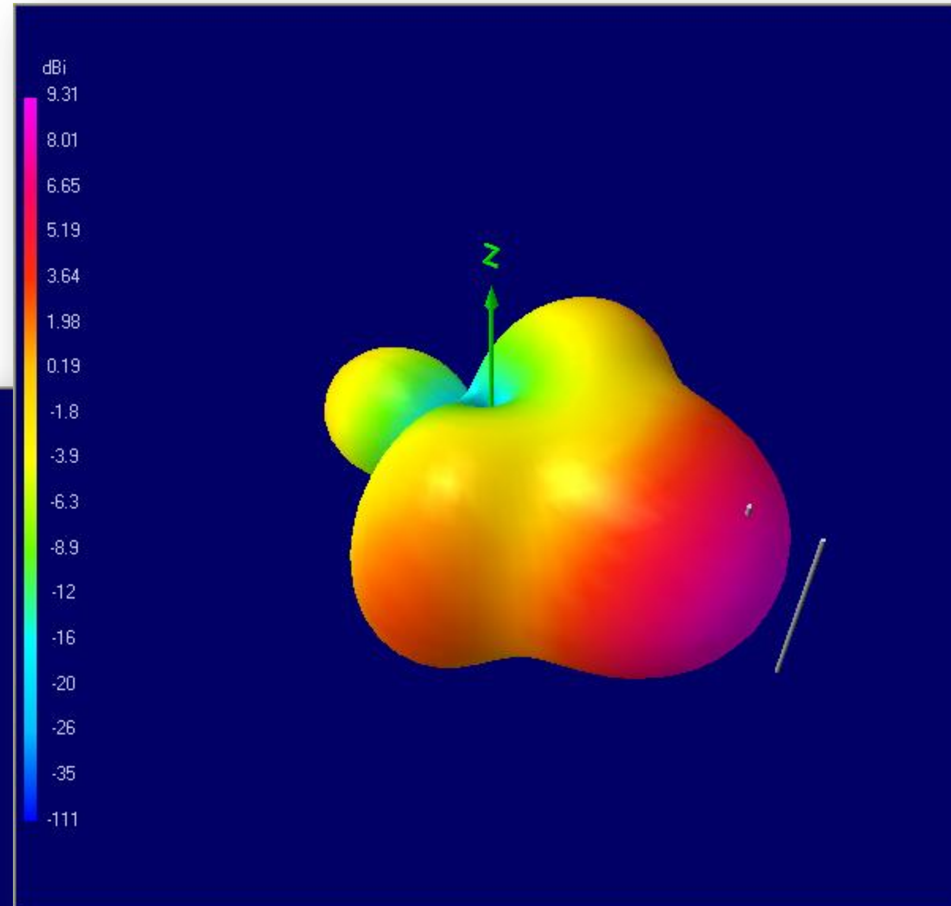


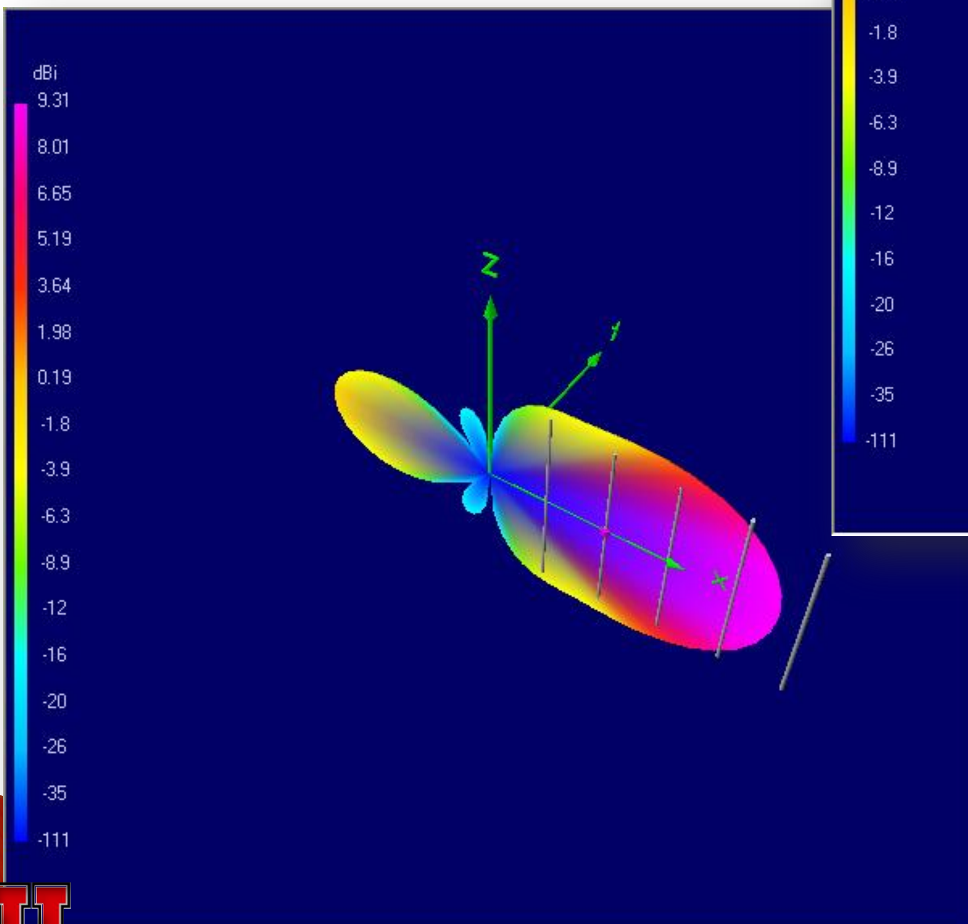
HPBW ≈ 70°

Gain = 9.3 dB

< 1dB
Therefore, SLL ≈ -8.5 dB

3D View


dBi
9.31
8.01
6.65
5.19
3.64
1.98
0.19
-1.8
-3.9
-6.3
-8.9
-12
-16
-20
-26
-35
-111
Z


dBi
9.31
8.01
6.65
5.19
3.64
1.98
0.19
-1.8
-3.9
-6.3
-8.9
-12
-16
-20
-26
-35
-111
Z
y
x

More Practical Application: The Antenna Array Problem

Array Application Problems

- 4-element array stretched along x-axis
  - Ordinary end fire array ($\alpha = -\beta d = -2p \times 0.40 = -144°$)
  - Increased directivity end-fire array
- Inter-element spacing $d/\lambda = 0.40$
- Half-wave dipoles
- Simulate in the xy plane ($\theta = 90°$)
  - Radiation pattern
  - Beam width between first nulls
  - Half-power beam width
  - Directivity
  - Levels of first side lobes in dB below principal lobe

How Would You Solve This Problem?

- Program array dimensions for both cases
- Run simulation for θ = 90° in xy plane
- Obtain data from radiation pattern results
  - Directivity from angle of maximum radiation

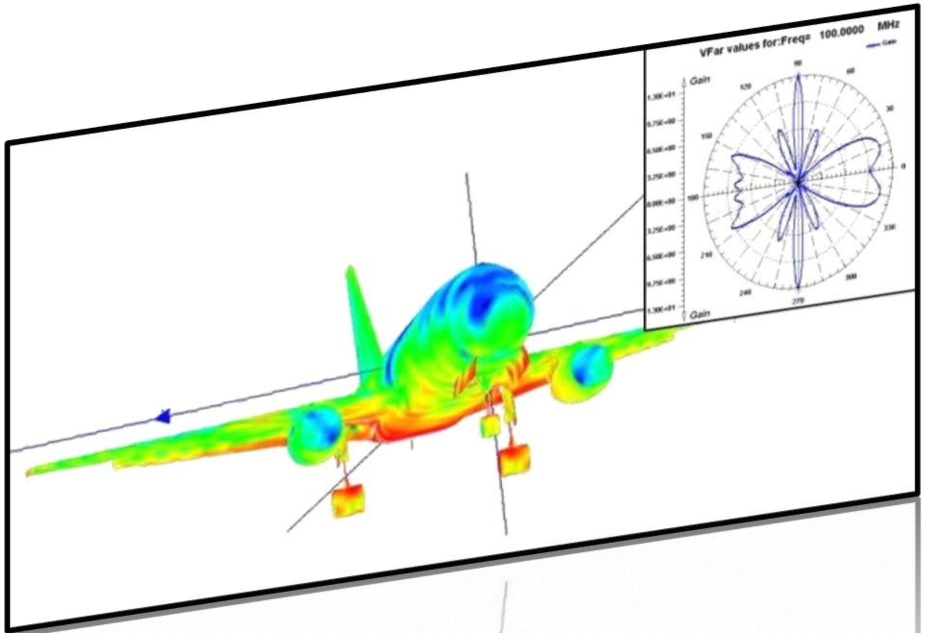
$$D = \max \left(\frac{\text{Radiated power density } (\theta, \phi)}{\text{Total radiated power} / (4\pi)} \right)$$

- Put data in table for comparison
- Refer to this and other tutorials on the website

Evaluations

Objective Statement

- Develop understanding of NEC
- Apply NEC to current applications
- Successfully use NEC to design and simulate antenna systems
- Compare and contrast NEC results to analytical solutions
- Interpret NEC results for practical application



Thank You

Numerical Electromagnetic Code (NEC) Lecture

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