Antenna modeling

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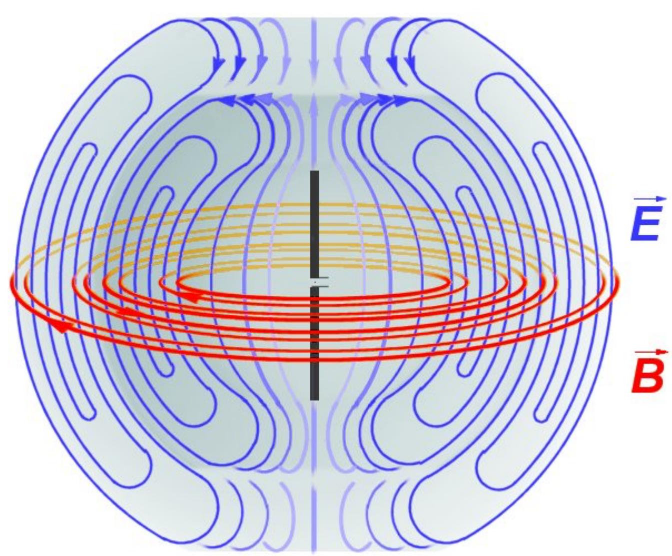
What does an antenna do?

Transition from feedline to space

- Transmitter → Feedline current → Accelerating charges → EM radiation
- EM wave → Accelerating charges → Feedline current → Receiver



http://i.stack.imgur.com/h5ijc.jpg

Antenna modeling

How will an antenna design perform?

- Radiation pattern (where the waves go, azimuth & elevation)
- Impedance (antenna as a load)
- SWR (how much of my power actually radiates)
- EM field intensity

"What if" analyses: How do changes in antenna design affect performance?

EM theory enables all of these to be calculated from the current flowing in the antenna. The hard part is calculating the current.

Computing antenna currents

EM theory (Maxwell, et al) gives equations for current on a thin straight wire in empty space.

EM theory gives principles for calculating current on an arbitrary conductor, in the vicinity of other conductors and dielectrics (ground, trees vehicles, buildings), but no formulas.

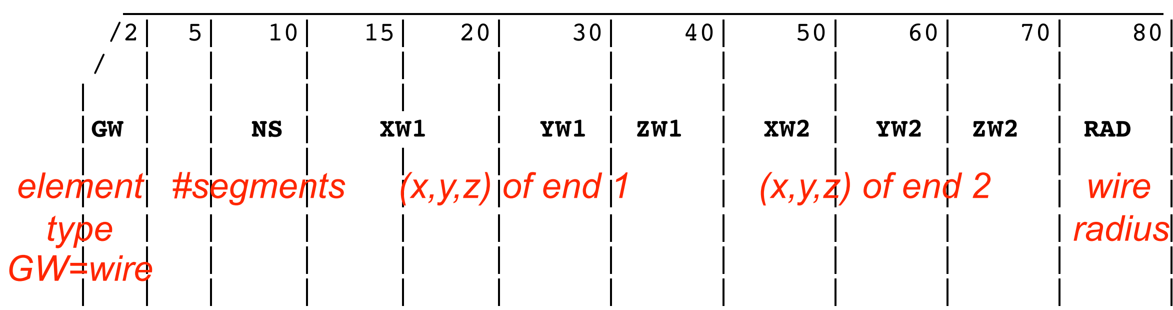
Wikipedia

Computational methods, based on EM theory, calculate antenna currents from the sources and the antenna geometry.

Numerical Electromagnetics Code (NEC)

NEC-2: Lawrence Livermore Laboratory, 1981 *http://nec2.org*

Antenna is modeled as thin straight wires, divided into segments, coded on punch cards. Other cards describe sources and control the simulation



Numerical Electromagnetics Code (NEC)

NEC-2: Widely available, two major limitations

- Can't do tapered elements
- Can't do wires on or under the ground

but these have workarounds that extend NEC's capability to Yagis, verticals, and Beverage antennas.

NEC-4: Newer, more accurate, more expensive

Contemporary versions of NEC-2, for hams

EZNEC, by W7EL (Windows, free & paid) *www.eznec.com*
4NEC2, by Arie Voors (Windows, free) *www.qsl.net/4nec2*
MNOTA-GAL, by JE3HHT, DL2KQ, DL1PBD (Windows, free) *gal-ana.de/basicmm/en/*
CocoaNEC, by W7AY (MacOS, free) *www.w7ay.net*

Improvements:

- Better user interface: cards replaced by spreadsheet & menu options.
- Graphical outputs
- CocoaNEC also has a C-like programming language.
- CocoaNEC and 4NEC2 have optimization capabilities.

Where to read about using NEC-2 (mostly EZNEC)

ARRL Antenna Handbook, Chapter 8

Steve Nichols G0KYA, "An Introduction to Antenna Modeling"
http://www.arrl.org/shop/An-Introduction-to-Antenna-Modeling/

Four articles by L.B. Cebik in QST, Nov 2000 – Feb 2001
http://wireless.ictp.it/school_2005/download/nec2/nec_part1.pdf … nec_part4.pdf

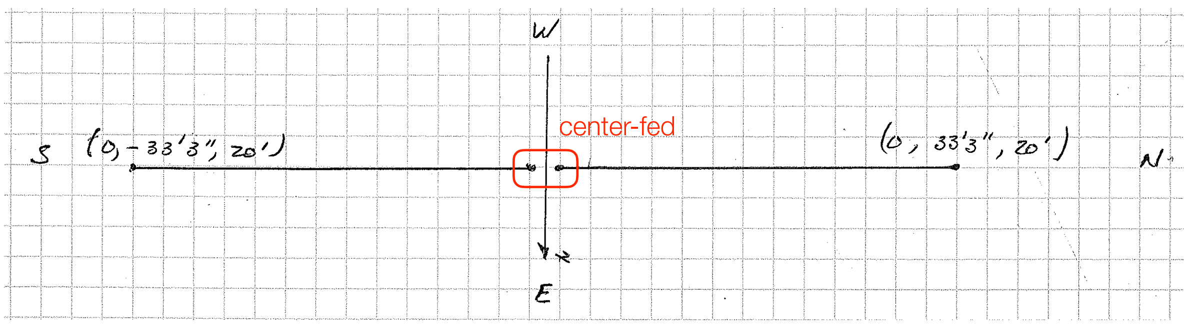
Greg Ordy W8WWV, "How to Start Modeling Antennas Using EZNEC"
http://www.arrl.org/files/file/Antenna Modeling for Beginners Supplemental Files/EZNEC Modeling Tutorial by W8WWV.pdf

Steve Stearns K6OIK, "Antenna Modeling for Radio Amateurs"
http://www.fars.k6ya.org/docs/K6OIK,_Antenna_Modeling_for_Radio_Amateurs,_ARRL_Pacificon,_Oct_2017.pdf

NEC-2 Manual, Part III: User's Guide, *http://www.nec2.org*

Simple example: 40m dipole

Good to sketch it out first, get (x,y,z) coordinates of endpoints of wires.



Simple example: 40m dipole

Transfer antenna elements to spreadsheet (CocoaNEC)

Rule of thumb: ≥10 segments per half-wavelength (should be odd)

Dipole40m-flattop

Edit:

#	x	y	z	x	y	z	radius	segments	transform	*
1	0 ft	-33' 3.0"	20 ft	0 ft	33' 3.0"	20 ft	0.032 in	22		

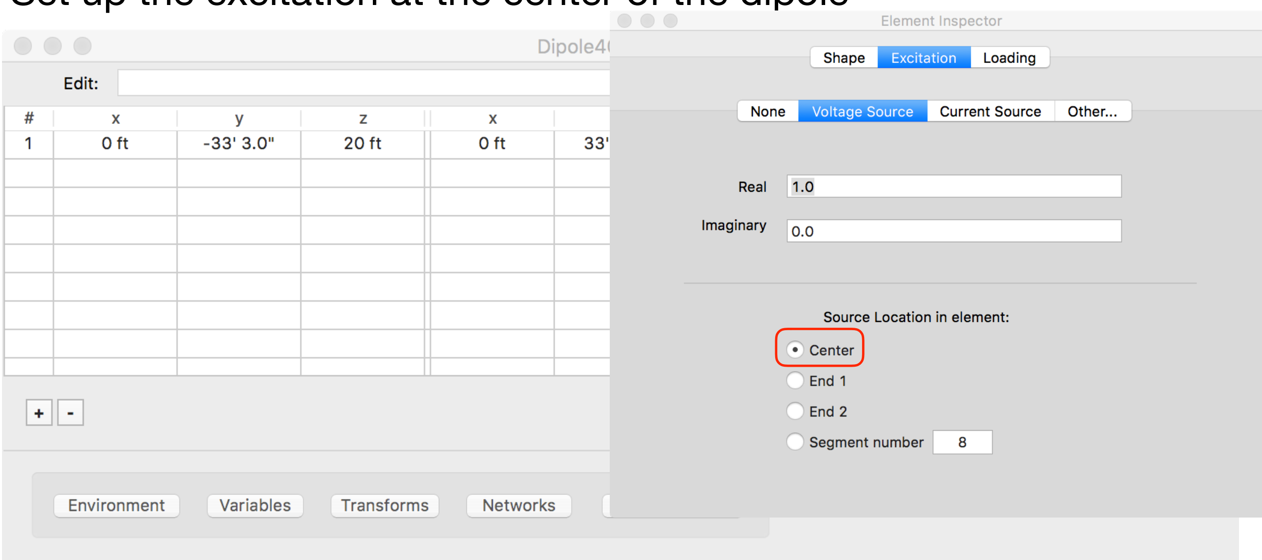
In the model, dipole is one long wire, not two (software inserts the source).
For an inverted-VEE or sagging dipole, use two wires and a third, short wire in the center for the feedpoint.

+ - Display: English - mixed Show Cards

Environment Variables Transforms Networks Output Control Run

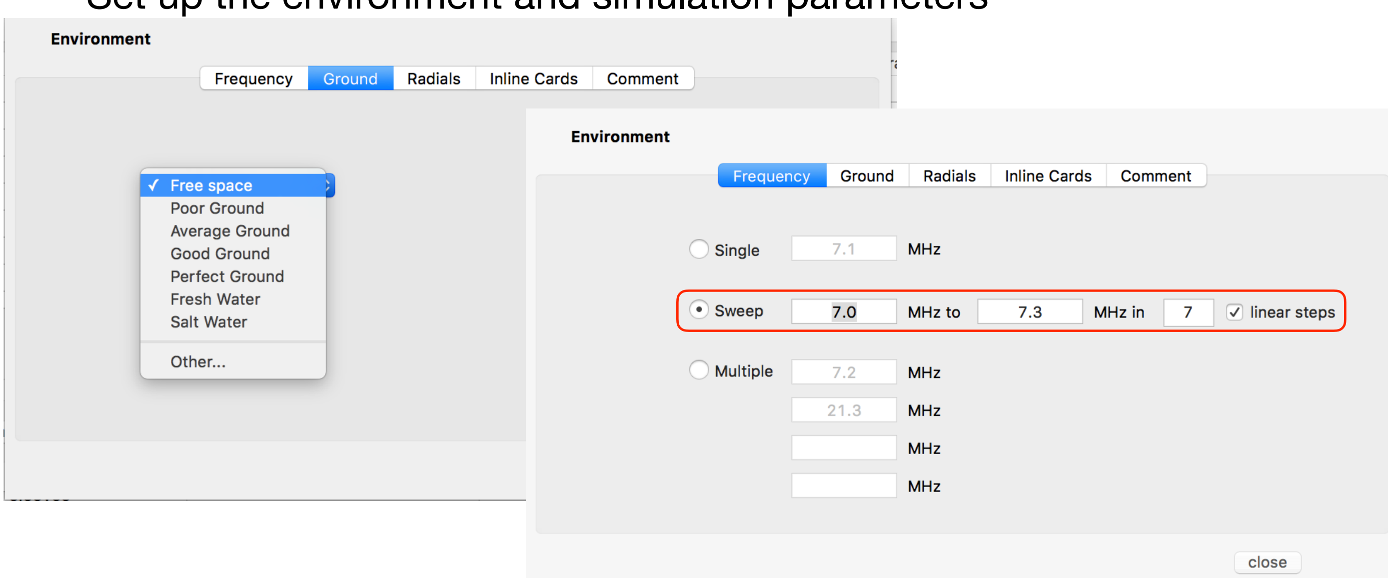
Simple example: 40m dipole in space

Set up the excitation at the center of the dipole



Simple example: 40m dipole in space

Set up the environment and simulation parameters



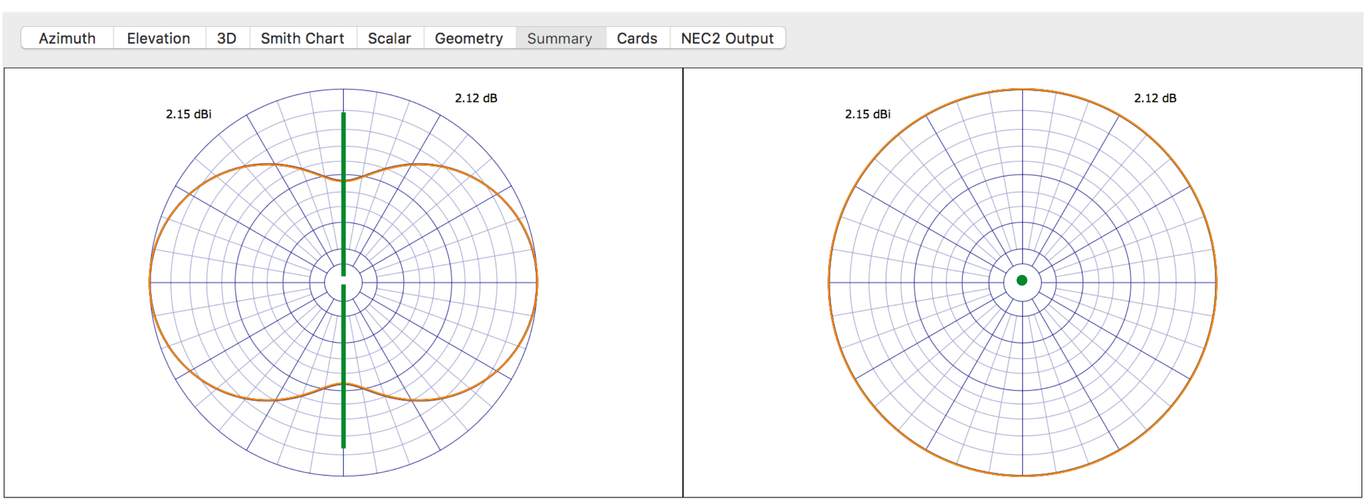
Simple example: 40m dipole in space

This is the card deck that results (“assembly language”)

```
CM COCOANEC 2.0  2018-05-12 07:40 2018-05-12 07:40   comments
CE ----------
GW  1   23  0.000000  -10.1346  6.096000  0.000000  10.13460  6.096000  8.14E-04   wire
GE  1  end geometry (ground plane present)
FR  0    1    0    0  7.000000  0.000000   frequency (7 MHz)
GN  1    0    0  ground (free space)
EX  0    1    8    1  1.000000  0.000000   excitation (voltage source)
XQ  execute
RP  0    1  360 1000  70.00000     0.000     0.000     1.000 5.000E+03   radiation pattern
RP  0  360    1 1000   -90.000  0.000000     1.000     0.000 5.000E+03   request
RP  0   91  120 1001     0.000     0.000     2.000     3.000 5.000E+03
XQ
FR  0    1    0    0  7.050000  0.000000   frequency (7.05 MHz)
GN  1    0    0
EX  0    1    8    1  1.000000  0.000000
```

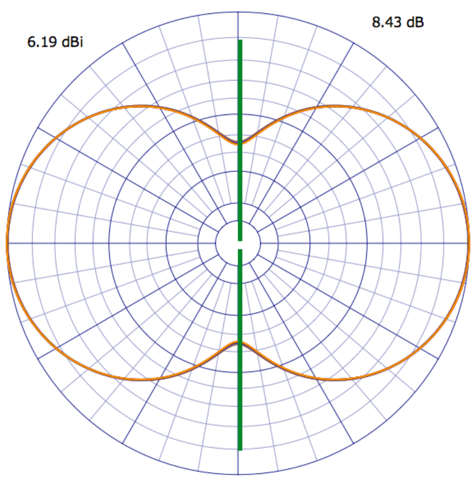
(etc)

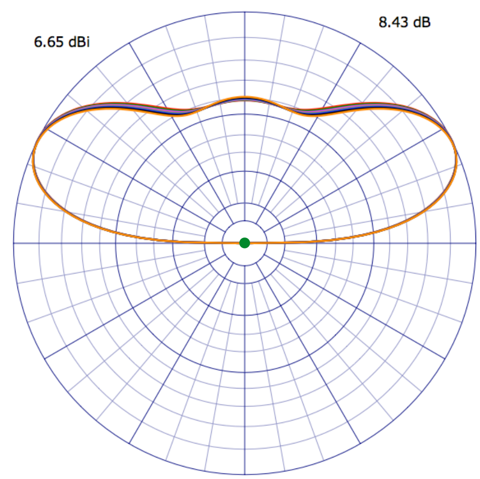
Radiation pattern. Free space.



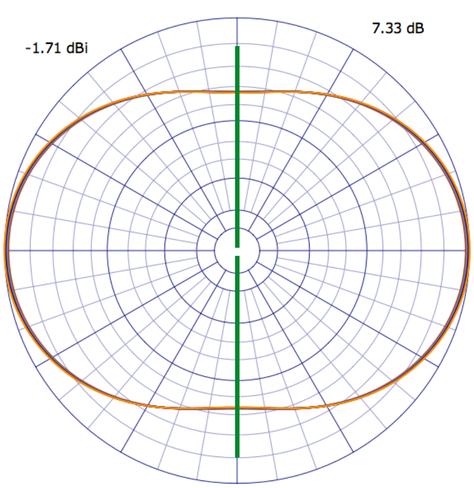
In free space, antenna height (z) is effectively ignored.

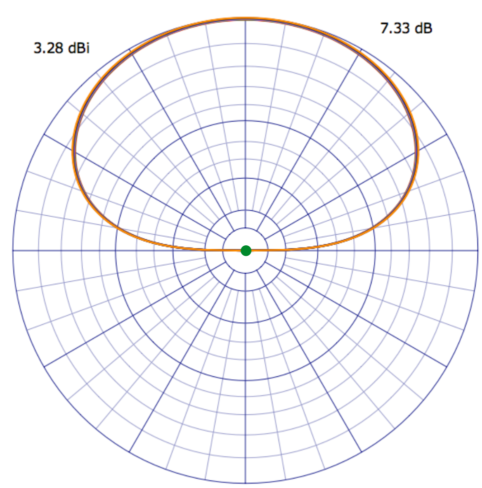
Behavior over poor ground. Height 66.5 feet.



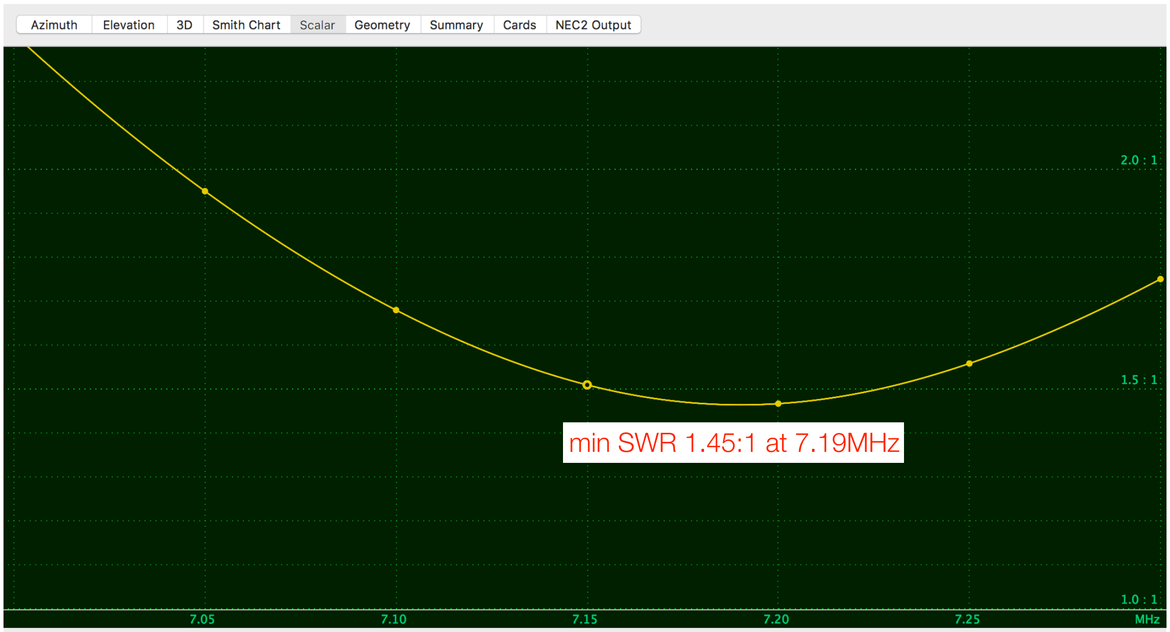


Behavior over poor ground. Height 20 feet.



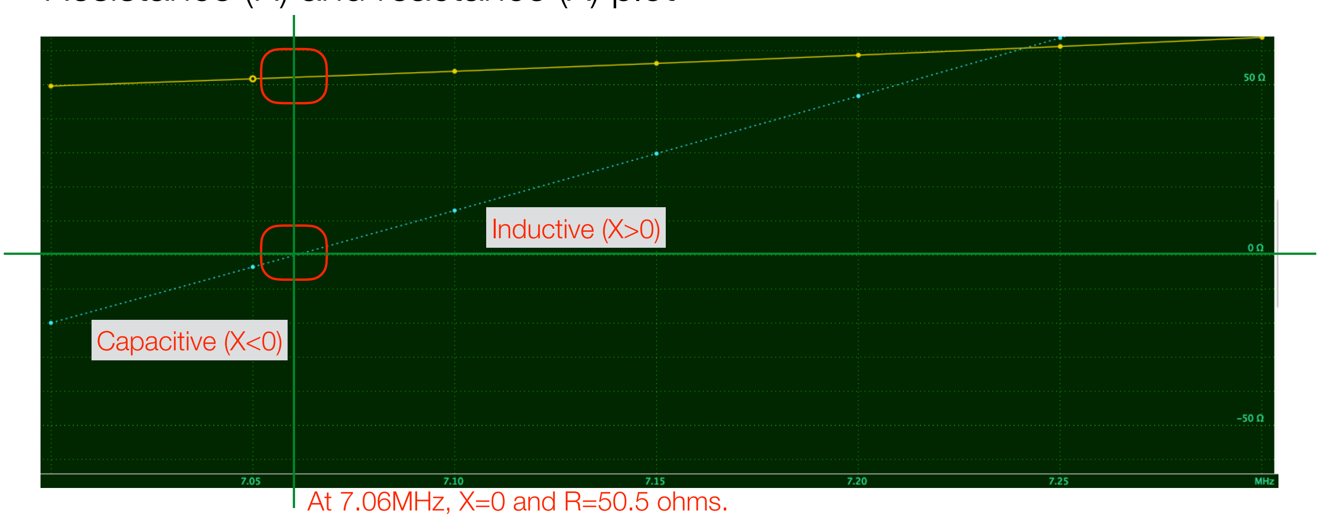


SWR vs frequency. Free space.



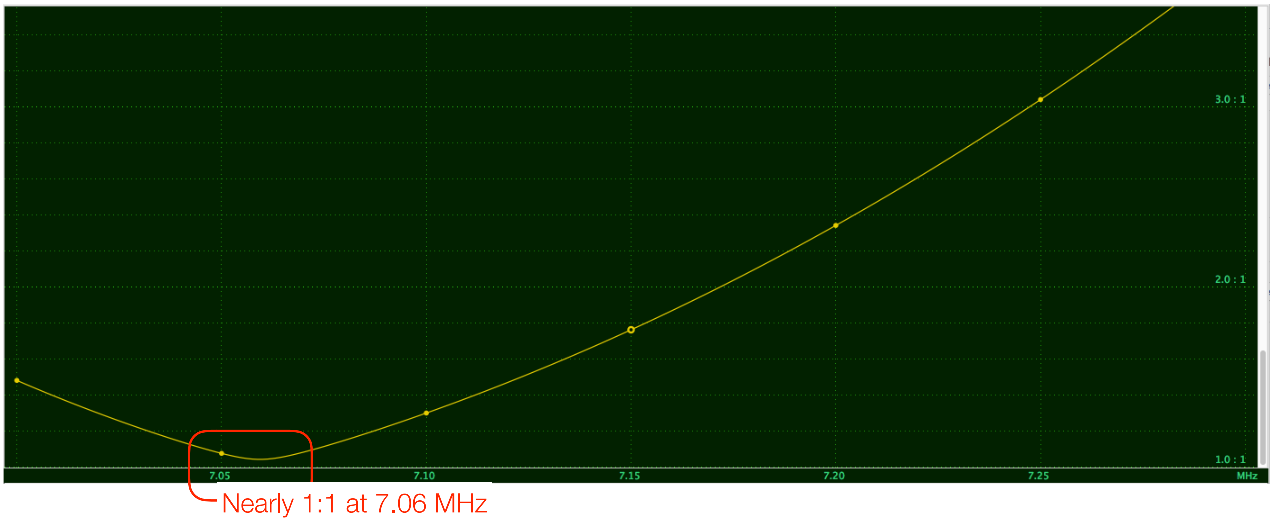
Behavior over perfect ground. Height 20 feet.

Resistance (R) and reactance (X) plot



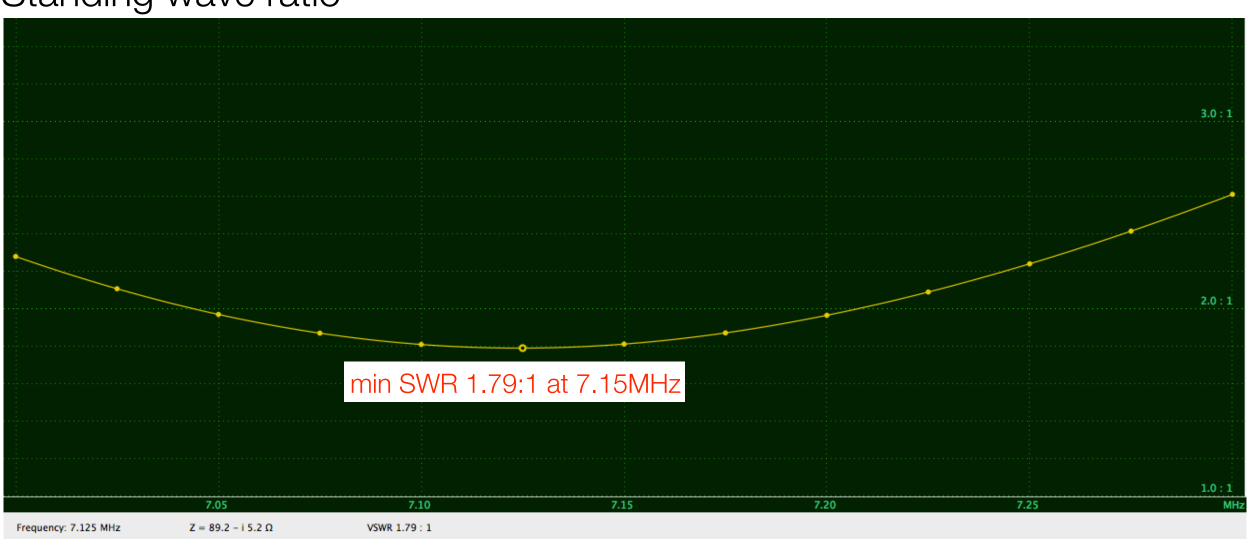
Behavior over perfect ground. Height 20 feet.

Standing wave ratio



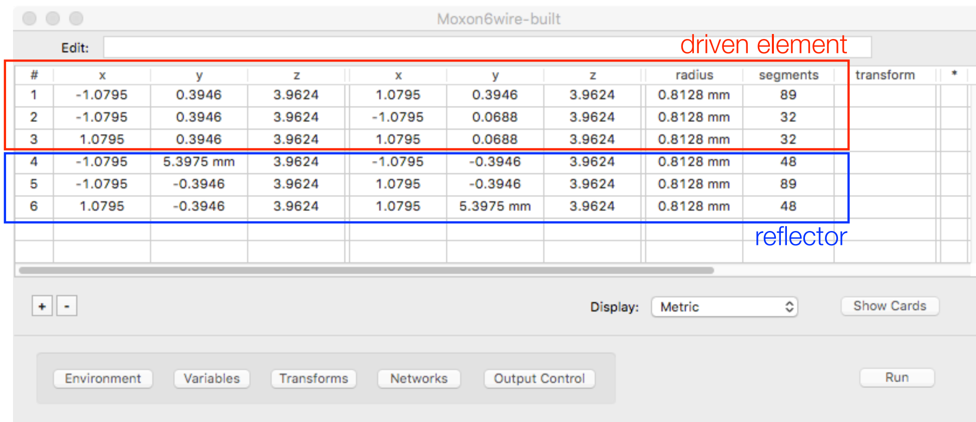
Behavior over poor ground. Height 20 feet.

Standing wave ratio

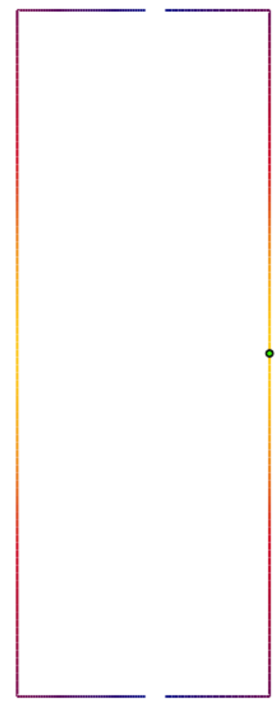


Another example: 6m wire Moxon

Input antenna elements into spreadsheet

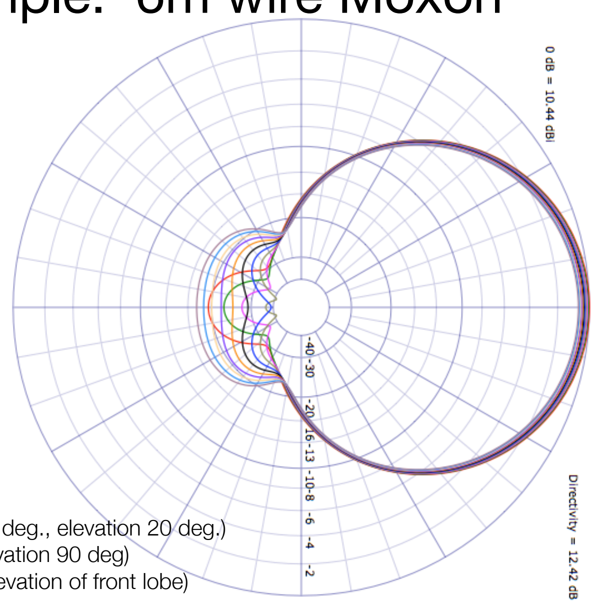


#	x	y	z	x	y	z	radius	segments	transform
1	-1.0795	0.3946	3.9624	1.0795	0.3946	3.9624	0.8128 mm	89	
2	-1.0795	0.3946	3.9624	-1.0795	0.0688	3.9624	0.8128 mm	32	
3	1.0795	0.3946	3.9624	1.0795	0.0688	3.9624	0.8128 mm	32	
4	-1.0795	5.3975 mm	3.9624	-1.0795	-0.3946	3.9624	0.8128 mm	48	
5	-1.0795	-0.3946	3.9624	1.0795	-0.3946	3.9624	0.8128 mm	89	
6	1.0795	-0.3946	3.9624	1.0795	5.3975 mm	3.9624	0.8128 mm	48	

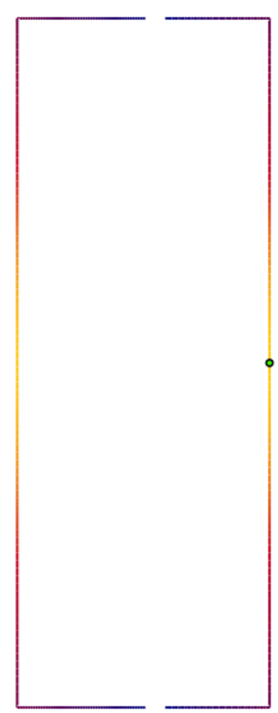


Another example: 6m wire Moxon

Radiation pattern



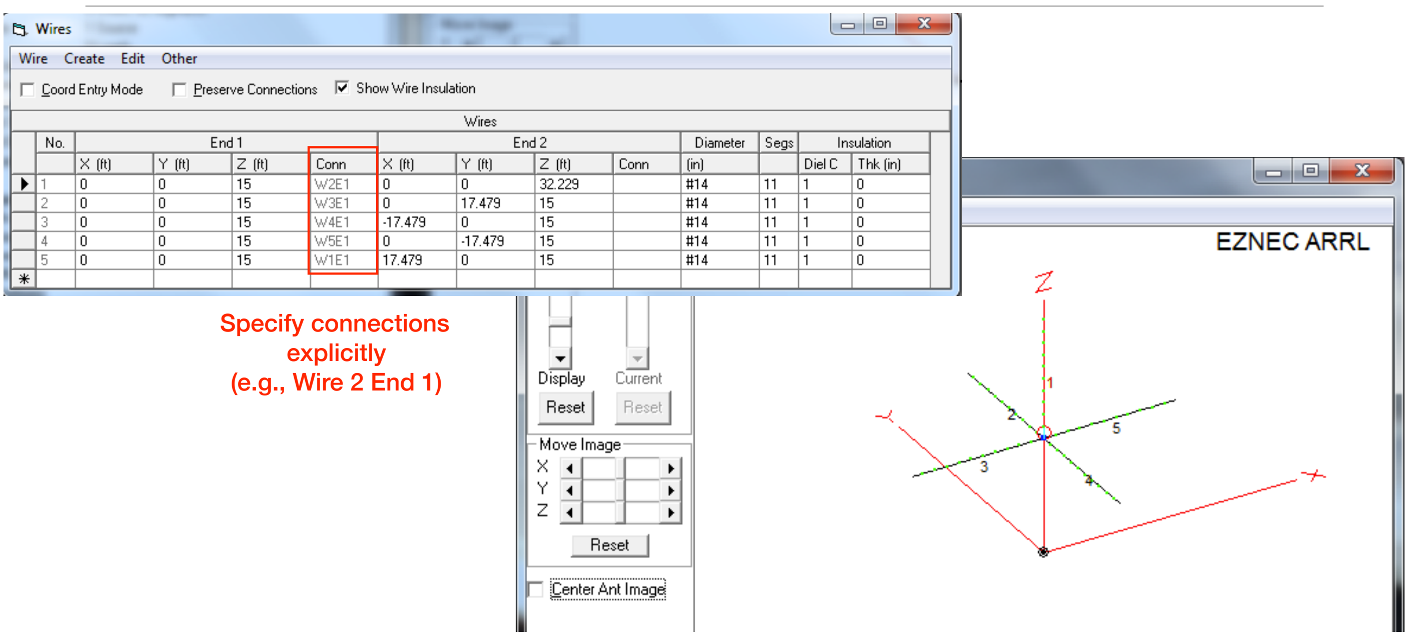
Directivity: 12.42 dB
Max gain: 10.44 dBi (azimuth 89 deg., elevation 20 deg.)
Front-to-back ratio: 9.12 dB (elevation 90 deg)
Front-to-back ratio: 17.39 dB (elevation of front lobe)
Front-to-rear ratio: 7.49 dB
Average Gain: 0.6388 (1.946 dB)



What else can be modeled?

- Coaxial cables
- LC matching networks, traps, loading coils
- Radials for vertical antennas

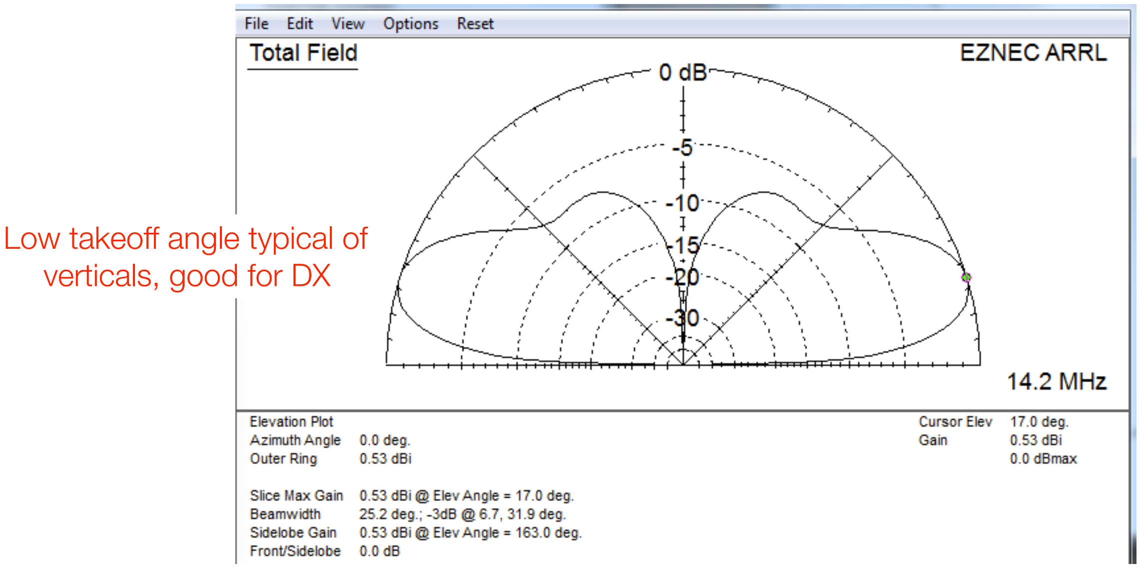
One more example: 20m vertical, using EZNEC



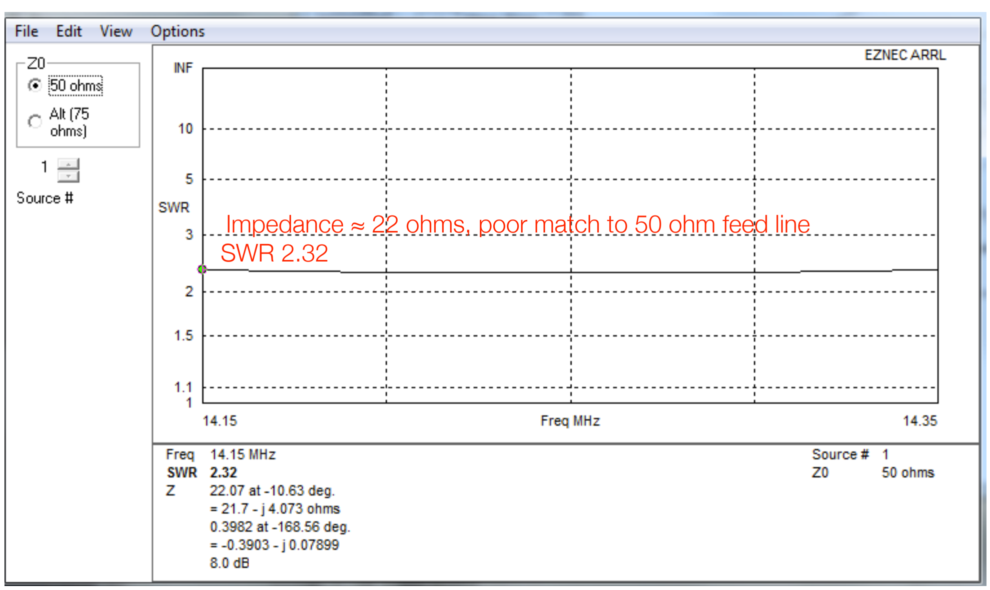
No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs	Insulation Diel C	Insulation Thk (in)
1	0	0	15	W2E1	0	0	32.229		#14	11	1	0
2	0	0	15	W3E1	0	17.479	15		#14	11	1	0
3	0	0	15	W4E1	-17.479	0	15		#14	11	1	0
4	0	0	15	W5E1	0	-17.479	15		#14	11	1	0
5	0	0	15	W1E1	17.479	0	15		#14	11	1	0

Specify connections explicitly
(e.g., Wire 2 End 1)

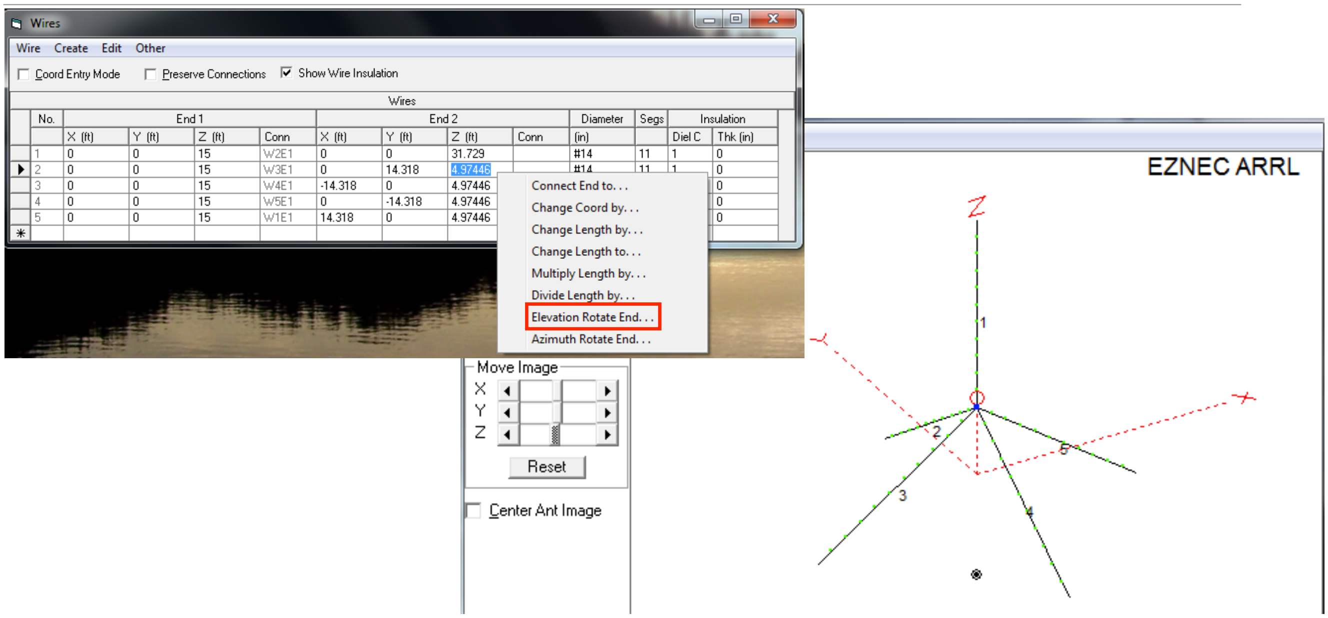
20m vertical, elevation pattern



20m vertical, SWR

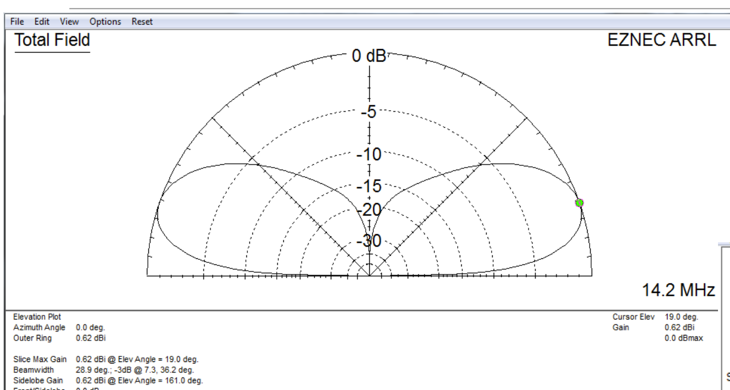


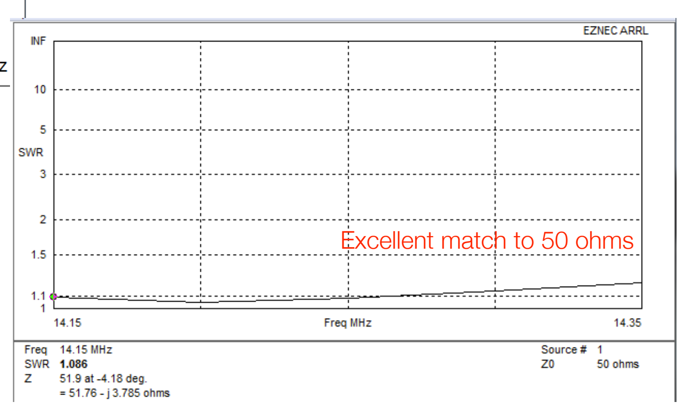
20m vertical, bend radials toward ground



No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs	Insulation Diel C	Insulation Thk (in)
1	0	0	15	W2E1	0	0	31.729		#14	11	1	0
2	0	0	15	W3E1	0	14.318	4.97446		#14	11	1	0
3	0	0	15	W4E1	-14.318	0	4.97446					0
4	0	0	15	W5E1	0	-14.318	4.97446					0
5	0	0	15	W1E1	14.318	0	4.97446					0

20m vertical, bend radials toward ground





Summary

- NEC-2 software is effective for modeling wire-like antennas, including antennas made from tubing, like Yagis.
- Several NEC-based applications are available for Windows and MacOS platforms.
- Can predict radiation patterns, impedance, SWR, and in some cases, optimize designs.
- A variety of print tutorials and references make it easy to get started.