Antenna Modelling Software

- What
- How
- Programs
  - NEC based
  - Others
- Program extensions

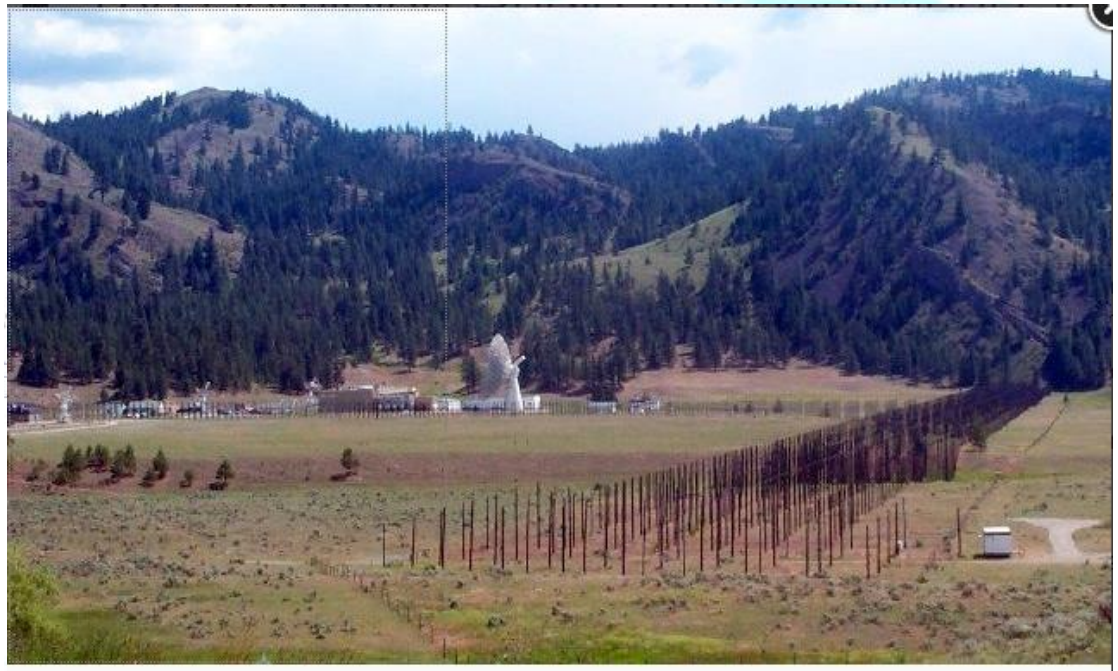
Antenna Modelling

- Mathematical
  - Chain Home Radar Antennas (WW2)
  - Derived from Maxwell's Equations
  - Proven on large antenna ranges
- Scale Models
  - $Model_{frequency} = \frac{Full_{size}}{model_{size}} * Full_{size_{frequency}}$
  - $Model_{conductivity} = \frac{full_{size}}{Model_{size}} * full_{size_{conductivity}}$
- Computer Models
  - NEC (Numerical Electro-magnetic Code) US Navy

Mathematical Modelling

- Original DRAO
  (Dominion Radio Astrophysical Observatory)
  Antennas

The main goal of the T-shaped radio telescope at Penticton was to produce a map of radio sources in our galaxy.



The 1,700 cedar posts of the 1.3-kilometre radio telescope.
Source: National Research Council of Canada/Herzberg Institute of Astrophysics/Dominion Radio Astrophysical Observatory

Scale models

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A 10:1 model
Eg 300 MHz antenna (1m) on a 30m aircraft
Is mainly for initial pattern measurements.
For impedances the model scale must be reduced to 4:1 or 2:1.

Computational Modelling

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Codes are based on a full-wave formulation of the Maxwell's equations and associated boundary conditions. Some other codes are based on an asymptotic solution of the Maxwell's equations.

- **Finite-Difference Time-Domain method (NEWS, X-NEWS)**
- **Finite Element Method (FEM, X-FEM)**
- **High Frequency Structure Simulator (HFSS)**
- **WirePlate (WIPL)**
- **FEKO "FEldberechnung für Körper mit beliebiger Oberfläche"**
- **Numerical Electromagnetic Code (NEC)**
- **Electromagnetic Surface Patch (ESP)**
- **NEWAIR (Geometric theory of diffraction, GTD based)**

Computational Modelling

- Most codes are based on the Method of Moments (MoM) integral formulation of Maxwell's equations
  - Most Amateur programs break the model into a number of current driven elements and then combine the effect of the fields EG NEC
  - There are limits to “free” versions
    - Wires cannot meet in the middle of a segment
    - Wire intersection angle limit
    - Wires must be the same diameter (tapers can be “fudged”)
    - Wires in close proximity must have their segments matched
    - Other limits

NEC

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- Developed by Lawrence Livermore Laboratory in 1981 for the US Navy based on the AMP program contracted in 1970
- Antenna is divided into short segments with linear variation of current and voltage.
- Developed in a number of stages
  - NEC2 models in free space or over finitely conducting ground. Free (with a command line interface) so used in most NEC programs.
  - NEC4.2 smaller structures, accurate stepped radius and junctions, improved ground modelling (buried conductors). Requires $US500 license.

EZNEC

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- **Available in a number of variations**
- **https://www.eznec.com/**
  - **Demo 20 segments (ARRL version 500) Free**
  - **EZNEC 500 segments $US99**
  - **EZNEC+ 2000 segments $US149**
  - **EZNECpro 20,000 segments $US525**
  - **EZNECpro/4 $US675 (NEC4 engine)**
    - License must be approved $US500 for non-commercial use.

AutoEz

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- An “add-on” for EZNEC allowing you to “parameterize” the program by using variables to control aspects of the module.
  - Excel taken to the limit!
  - Simplified data input
  - Improved results presentation
  - Free demo (30 segments or EZNEC limit)
  - Full version $US79

4NEC2

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- Free
- Two programs
  - 4NEC2 (basic NEC 2 engine but supports NEC4)
  - 4NEC2X (Extended) 3D presentation
- Includes and optimizer and sweeper
- Improved input and output compared to EZNEC

MiniNEC

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- $US29
- http://www.blackcatsystems.com/software/mininec-antenna-analysis-modeling-software.html
- This is an improved version of that released by NTIS based on the NEC2 engine.
- This is a 1991 review of MiniNEC by Roy Lewallen (the author of EZNEC)
    - https://www.arrl.org/files/file/Technology/tis/info/pdf/9102018.pdf

MMANA-GAL

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- **Free in basic form**
  - 8192 Segments
  - Similar to EZNEC
- **Pro version available for €139**
  - 45,000 segments
  - Improved graphics

ASAP

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- Free (NEC2 based)
- http://raylcross.net/asap/
- Basic interface to NEC2

So What to use?

Program	Cost	Limit	Note
EZNEC	$US99	Free versions too restrictive	Most common
AutoEZ	$US79	optimizer, Same segments as associated EZNEC	Requires EZNEC Improves in/out
4NEC2	Free	Same as NEC engine	Roughly ~= EZNEC+AutoEZ
NEC	Free	2000 segments	No user interfaces
NEC4-2	$US500	20,000 segments	Use with 4NEC2
MININEC	$US29	2000 segments?	Also free basic
MMANA-GAL	free	8192 segments	Pro €139
ASAP	Free	2000 segments?	Basic interface

There are many more programs available

An Example

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- 40m vertical with two raised radials
  - Vary base between -0 to 20 ft
    - Special cases, buried radials, slanted radials
  - Design antenna (resonance, matching)
  - Determine efficiency
    - Set all losses =0 and compare to measured with losses
- Compare input and output of programs
- Show issues

An Example

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- Compare
  - EzNEC
    - MMNA-GAL similar
  - AutoEZ
  - 4NEC2
  - NEC
    - Original command line interface
    - Inspired the “enhancements”
    - More basic “enhanced” programs
      - MiniNEC, ASAP

Modelling Steps

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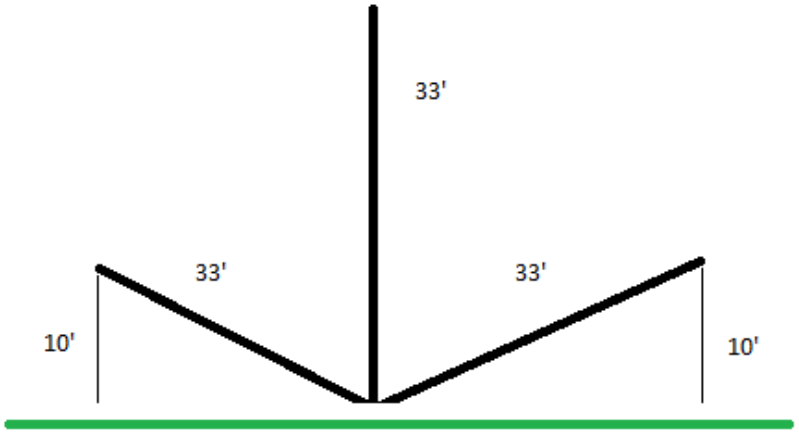
1. Sketch the antenna (same for all)
   - 4NEC2 has a graphical input
2. Input Model
   - Wires, segments, Sources and loads
3. Check for problems
4. Run
5. Output results

- Notes:
  - dimensions 33' chosen to demonstrate optimization
  - Slant to demonstrate model input options

Sketch

Horizontal Radials
h= -0.5’,0’,1’,10’,20’

Slanted Radial
(special case 0 to 10’)



Input Model (EZNEC)

Wires

Wire Create Edit Other

Coord Entry Mode | Preserve Connections | Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	0	0	10	W2E2	0	0	43		#14	20
2	-33	0	10		0	0	10	W3E2	#14	1
3	33	0	10		0	0	10	W1E1	#14	20

EZNEC+ v. 6.0

File Edit Options Outputs Setups View Utilities Help

Open | Save As | Ant Notes | Currents | Src Dat | Load Dat | FF Tab | NF Tab | SWR | View Ant | NEC-2D | FF Plot

40 m vert 2 raised radials

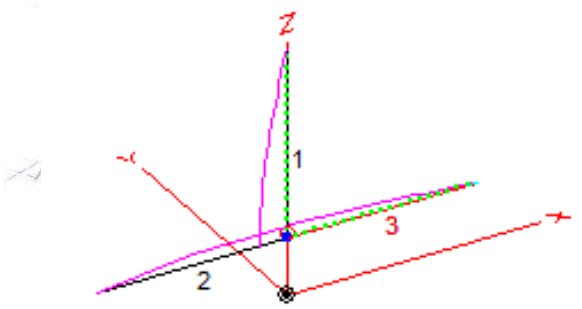
File	40m vert 2 raised radials.EZ
Frequency	7.15 MHz
Wavelength	137.562 ft
Wires	3 Wires, 41 segments
Sources	1 Source
Loads	0 Loads
Trans Lines	0 Transmission Lines
Transformers	0 Transformers
L Networks	0 L Networks
Ground Type	Real/High Accuracy
Ground Descrip	1 Medium (0.005, 13)
Wire Loss	Copper
Units	Feet
Plot Type	3D
Step Size	5 Deg.
Ref Level	0 dBi
Alt SWR Z0	75 ohms
Desc Options	

Sources

Source Edit

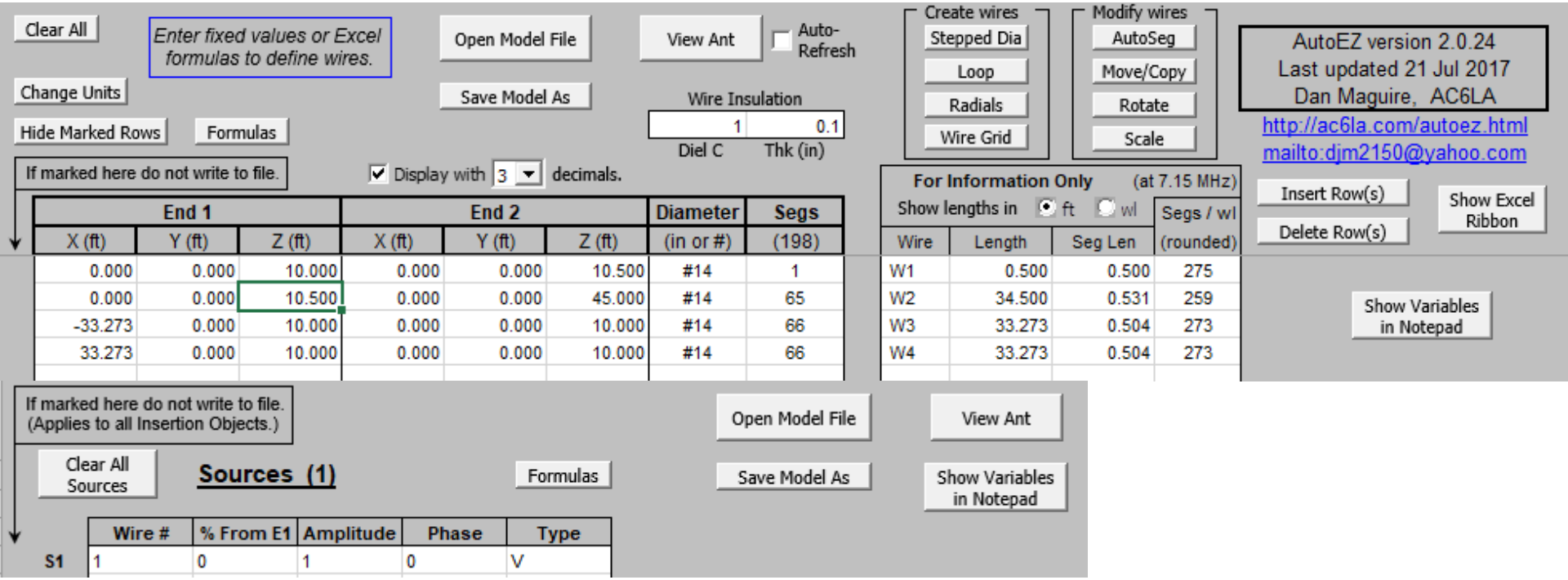
Sources

No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	1	0	2.5	1	1	0	V



Input Model (AutoEZ)

- Uses Excel tables and variables can be used



Input Model (AutoEZ)

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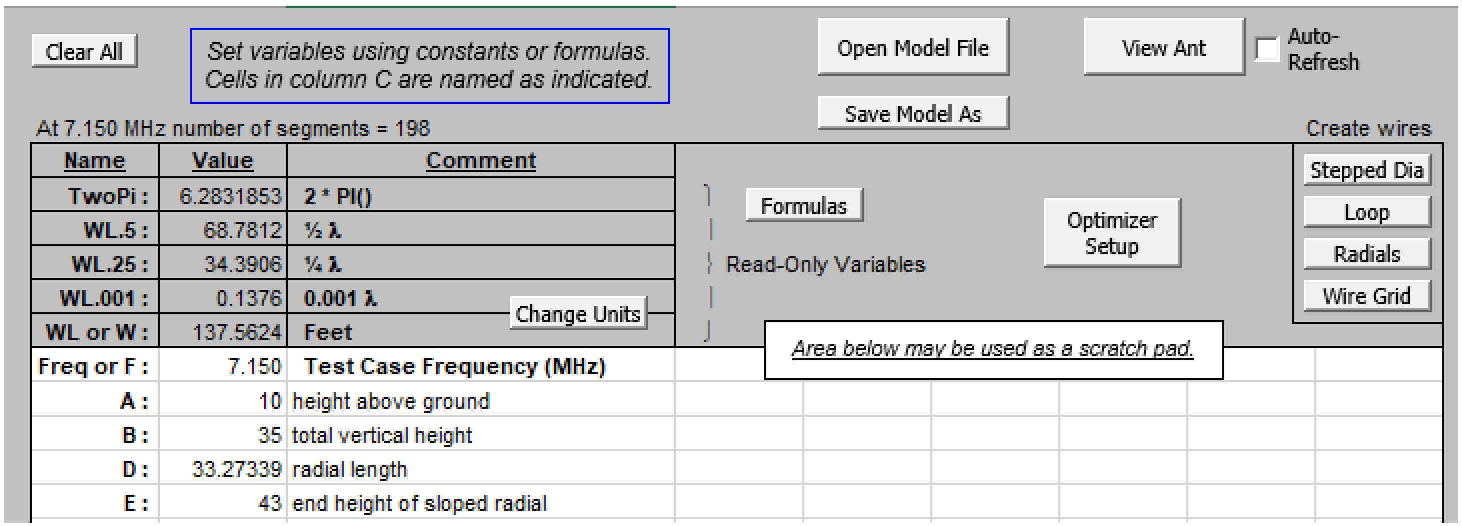
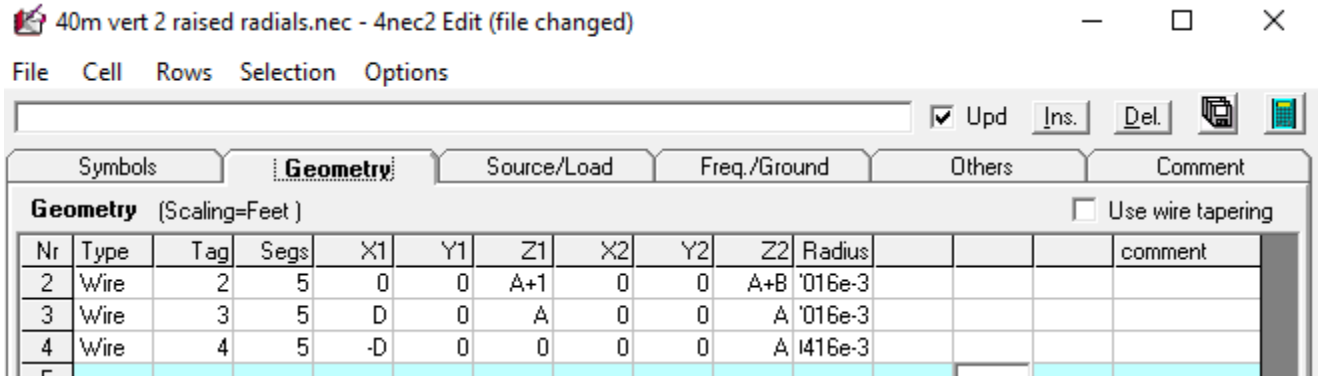
- Variables can be used



Input Model (4NEC2)

- Several editors including a rudimentary graphics editor. Can use Variables and formulae. Inputs EZNEC files.



Input Model (NEC)

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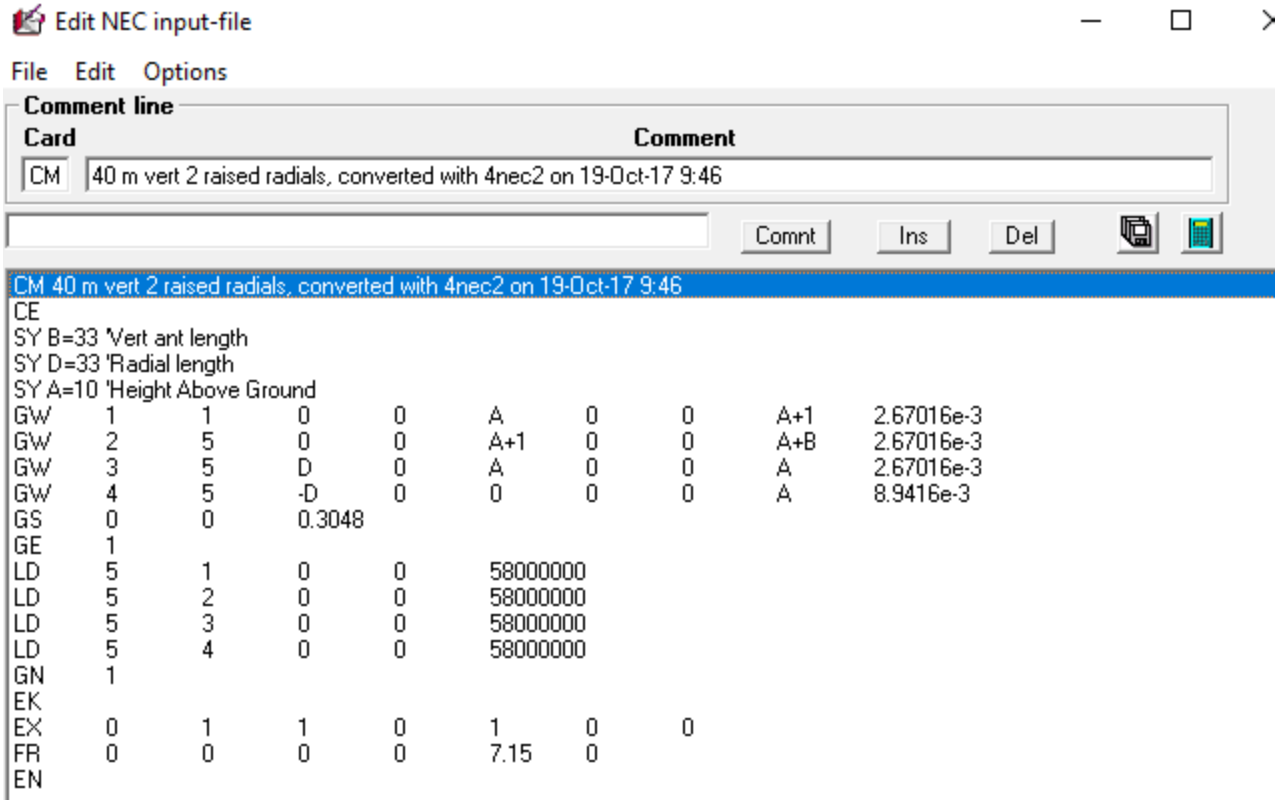
- **Pure text file**



Check for problems EZNEC

- EZNEC runs a rules check before giving SWR or field data. Yellow is a warning, Red is an rule violation.
  - Fix Source 1 by adding a short wire
  - Fix wire 2 by adding more segments (auto-segment)

Check for problems AutoEz

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- Uses EZNEC to check

Check for problems 4NEC2

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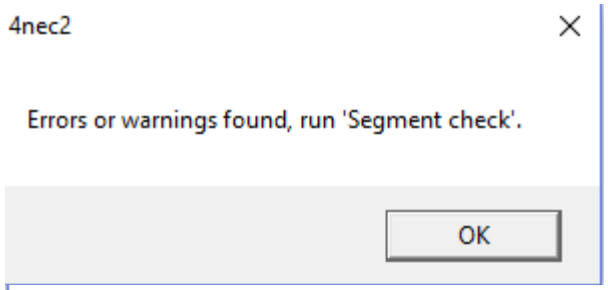
- Warnings can be cryptic and assume that you know the NEC input file rules



File Edit Format View Help

```
40m vert 2 raised radials.nec wavelength=41.93 mtr.

Error: Wire 1, seg 1 (tag 1), seg-len (6) differs more than 5 * seg-len (36) for wire 3
Error: Wire 1, seg 1 (tag 1), seg-len (6) differs more than 5 * seg-len (43.33) for wire 2
Error: Wire 2, seg 2 (tag 2), seg-len (43.33) differs more than 5 * seg-len (6) for wire 1
Error: Wire 4, seg 32 (tag 4), seg-len (37.62) differs more than 5 * seg-len (6) for wire 1
```

Check for problems NEC

- - - • - • - - - • - - • • • - • - - • • • • - - • • • • - •

- Limited rules checking
- Limited Help

Run EZNEC

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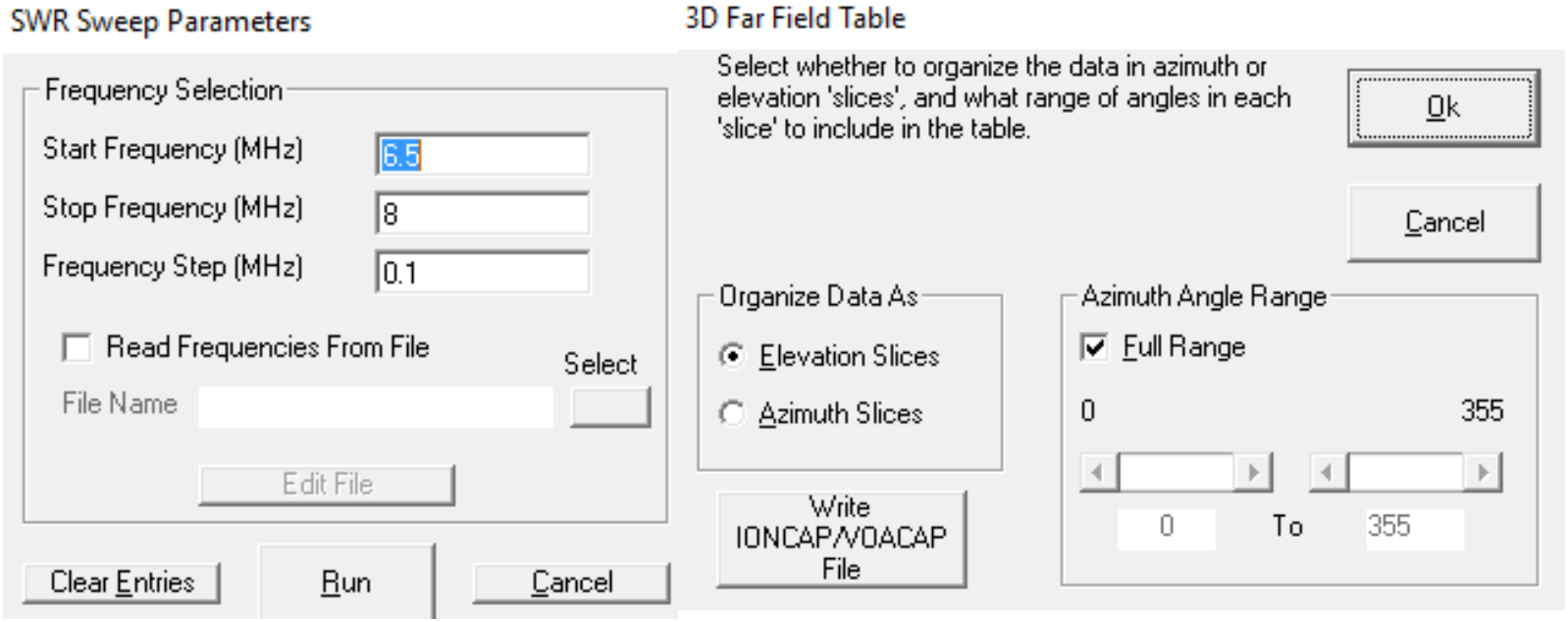
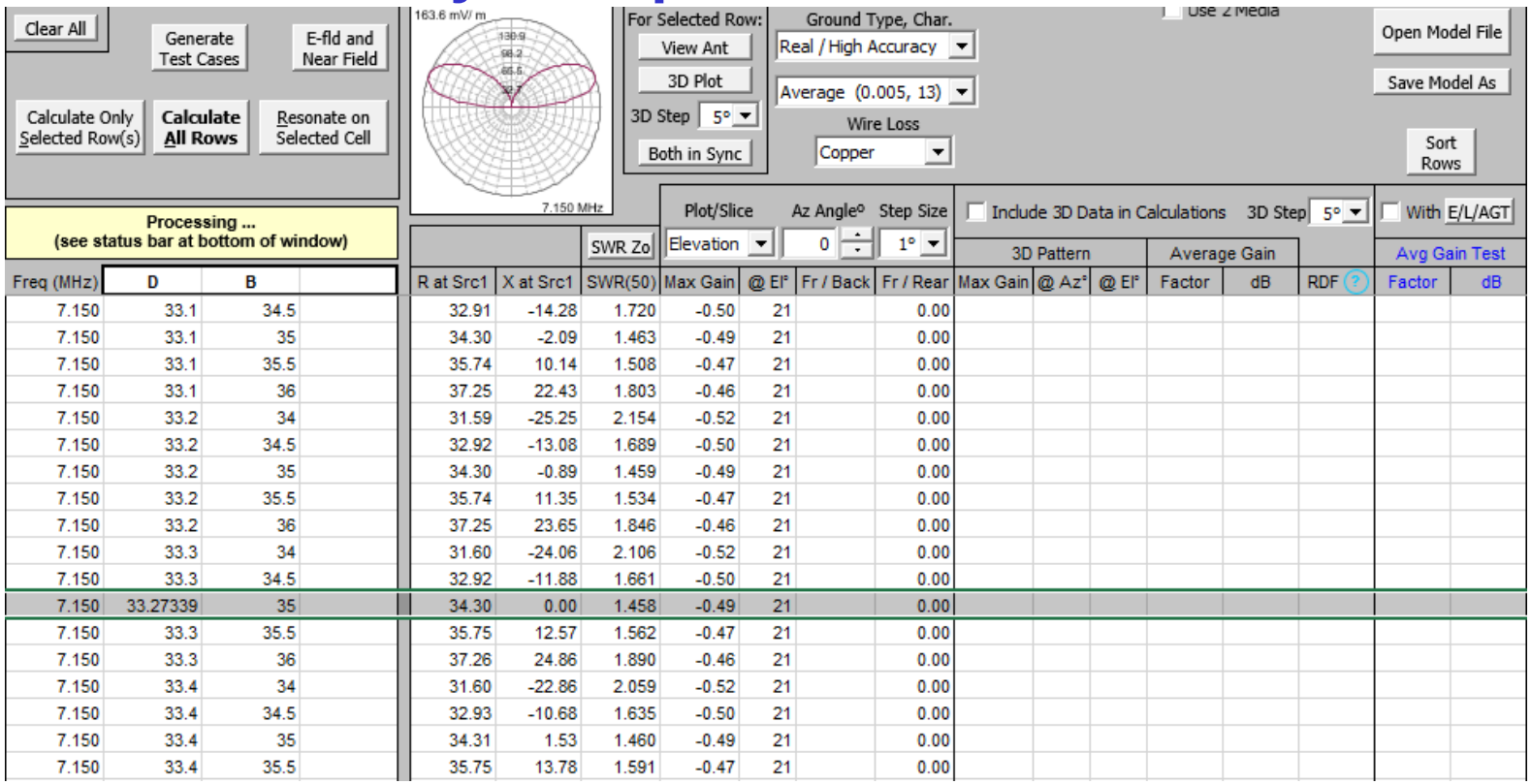
- You can select various outputs e.g. SWR, FF plot

And get tabular data for use in other programs



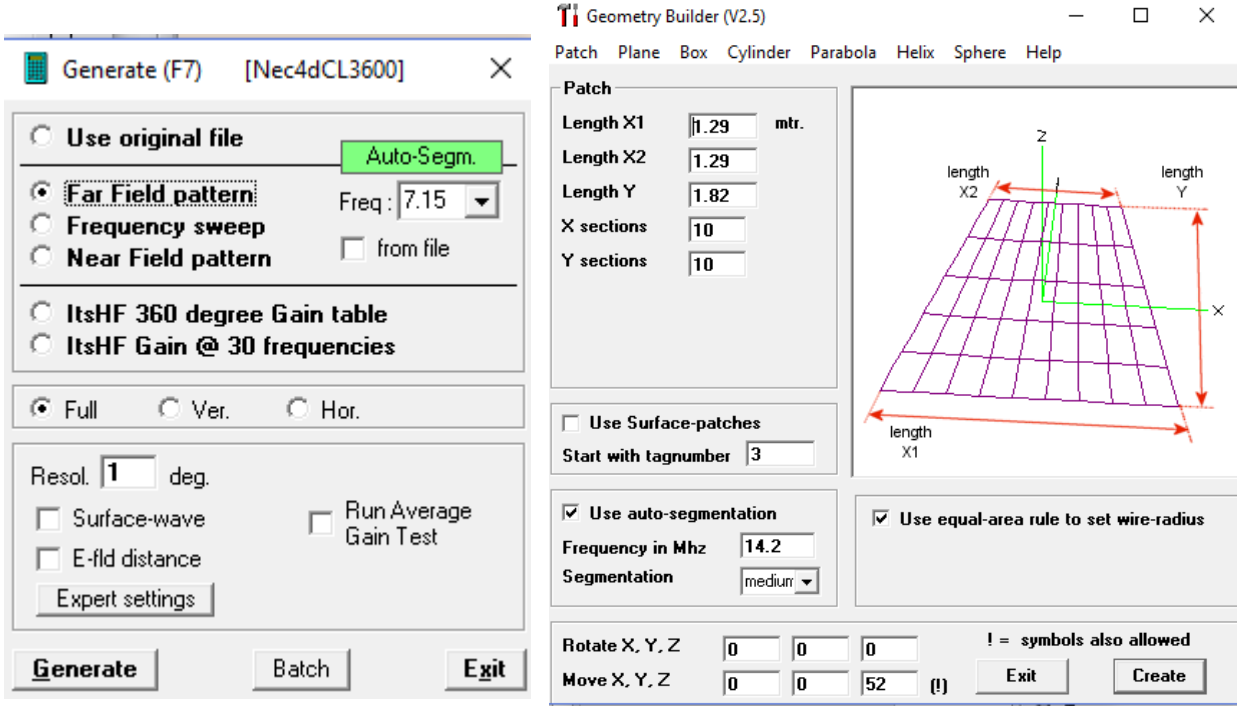
Run AutoEZ

- Note can vary multiple variables



Run 4NEC2

- A bit confusing as a variety of external programs are called.

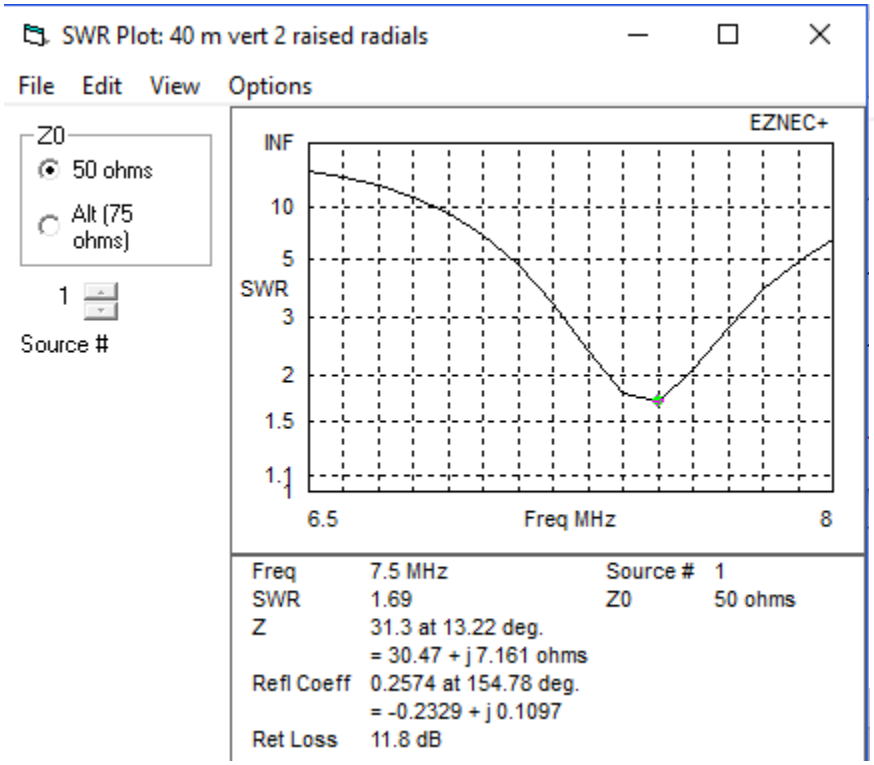


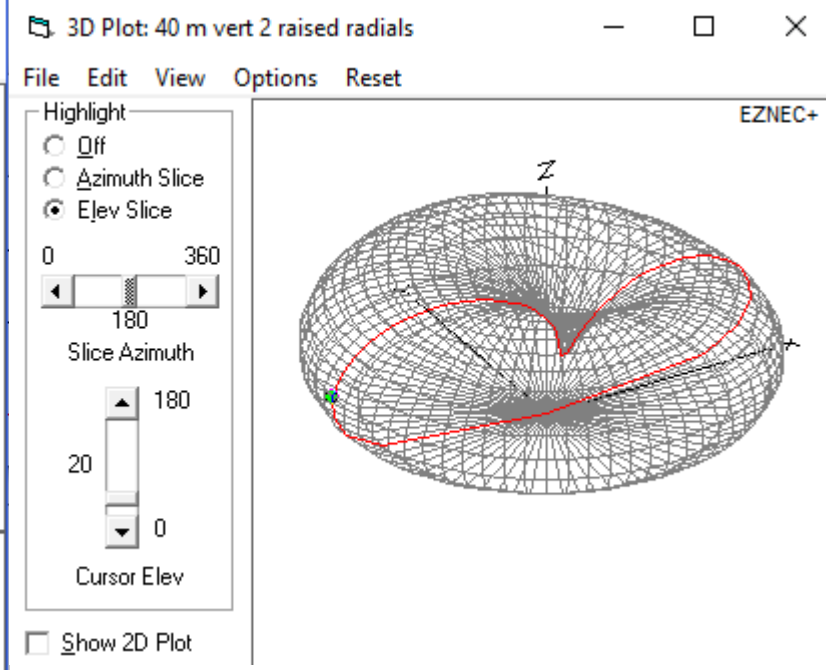
Run NEC

- Pure command line operation.
- Limited graphics engine

Output results EZNEC

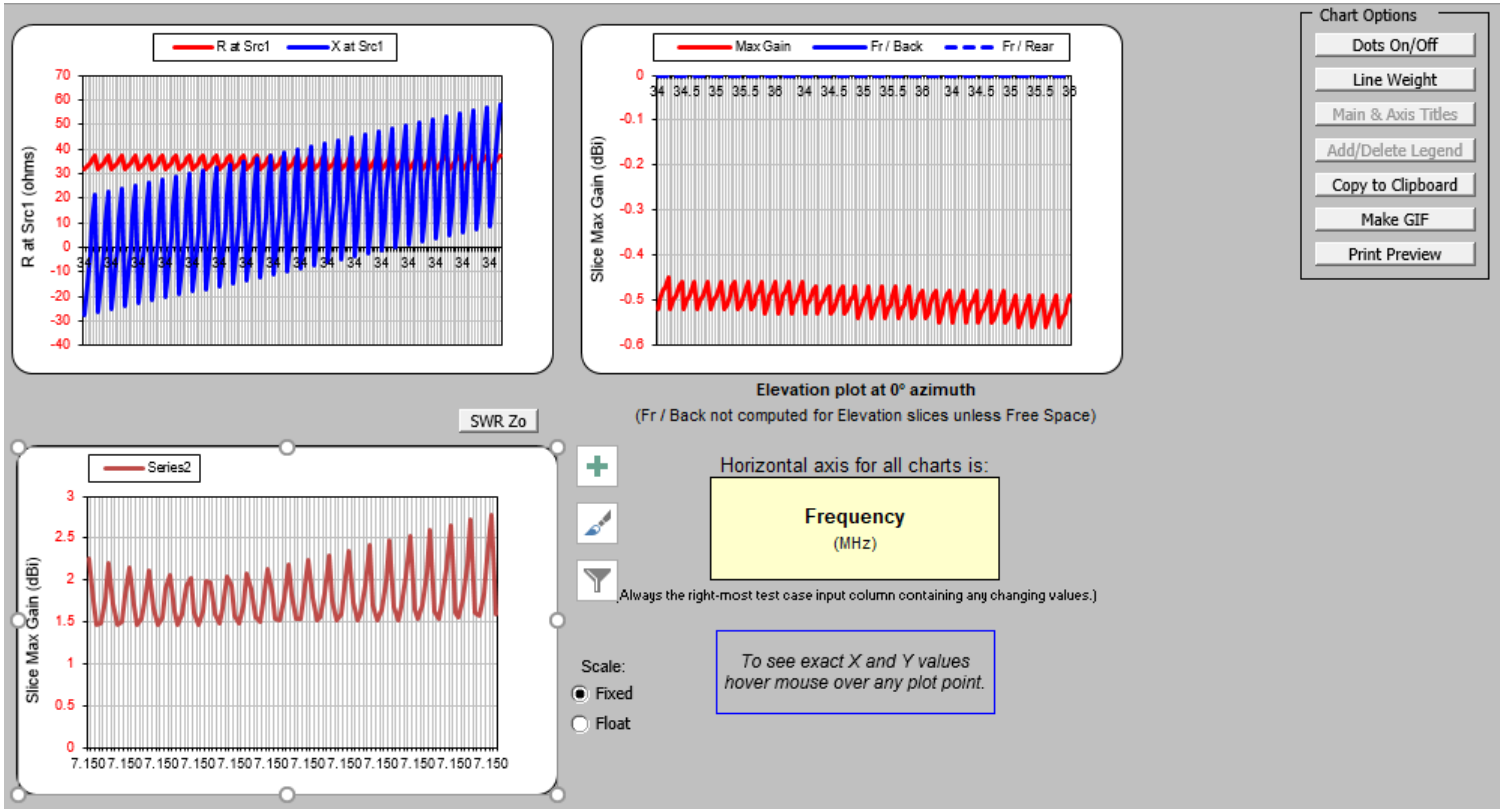
- Can also get tabular data





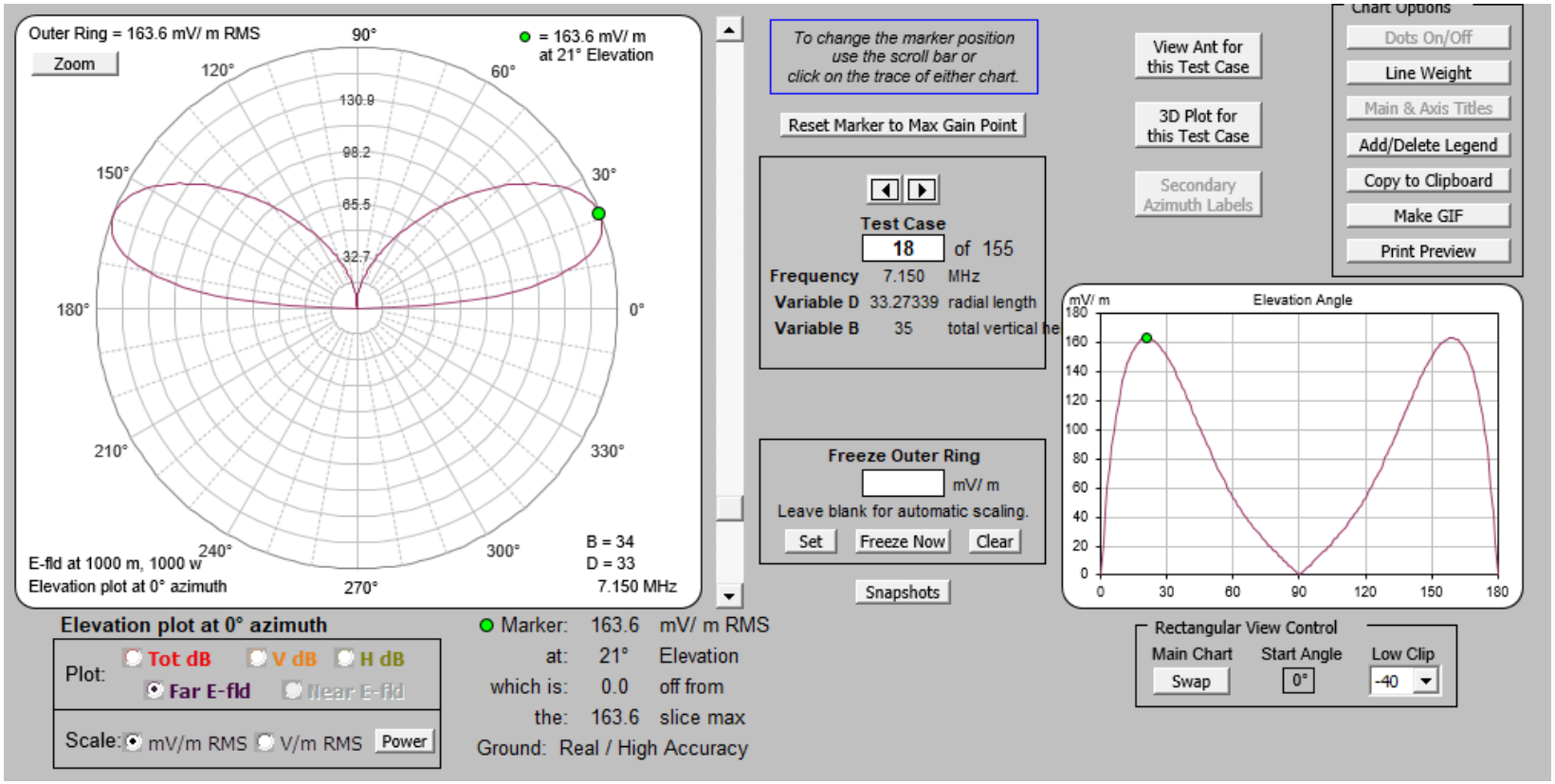
Output results AutoEZ

- Effect of varying multiple variables can be shown



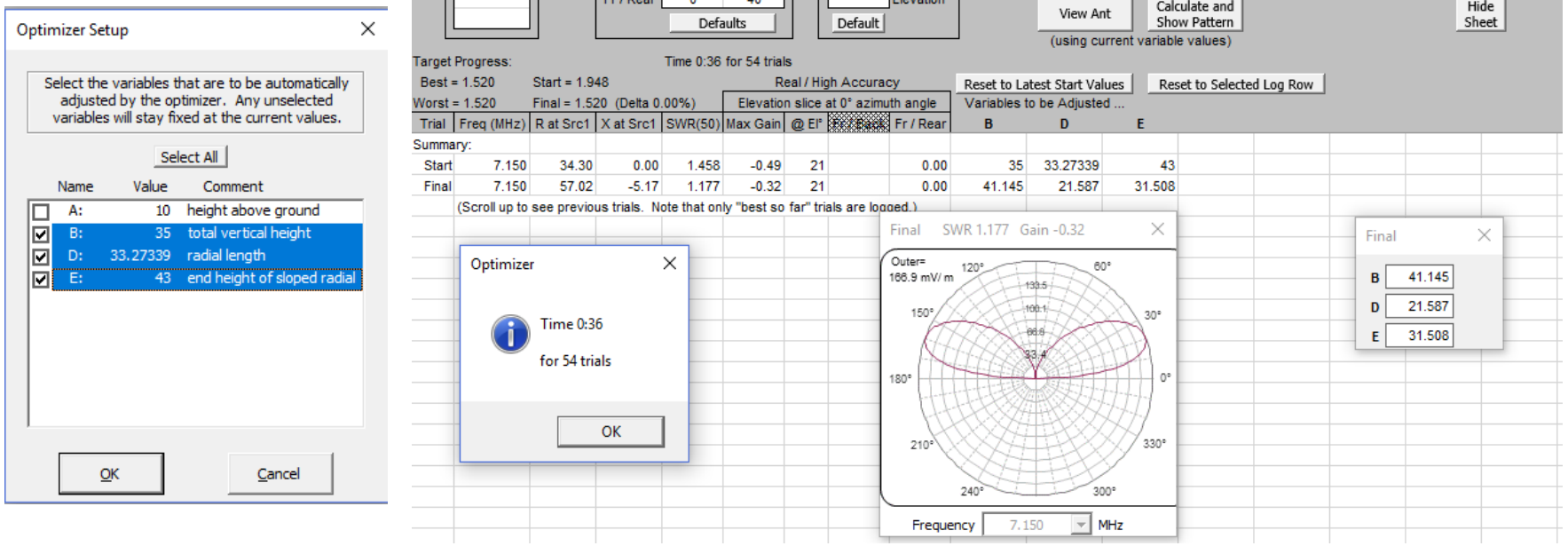
Output results AutoEZ

- A number of additional outputs are available



Output results AutoEZ

- There is an optimizer



Output results 4NEC2

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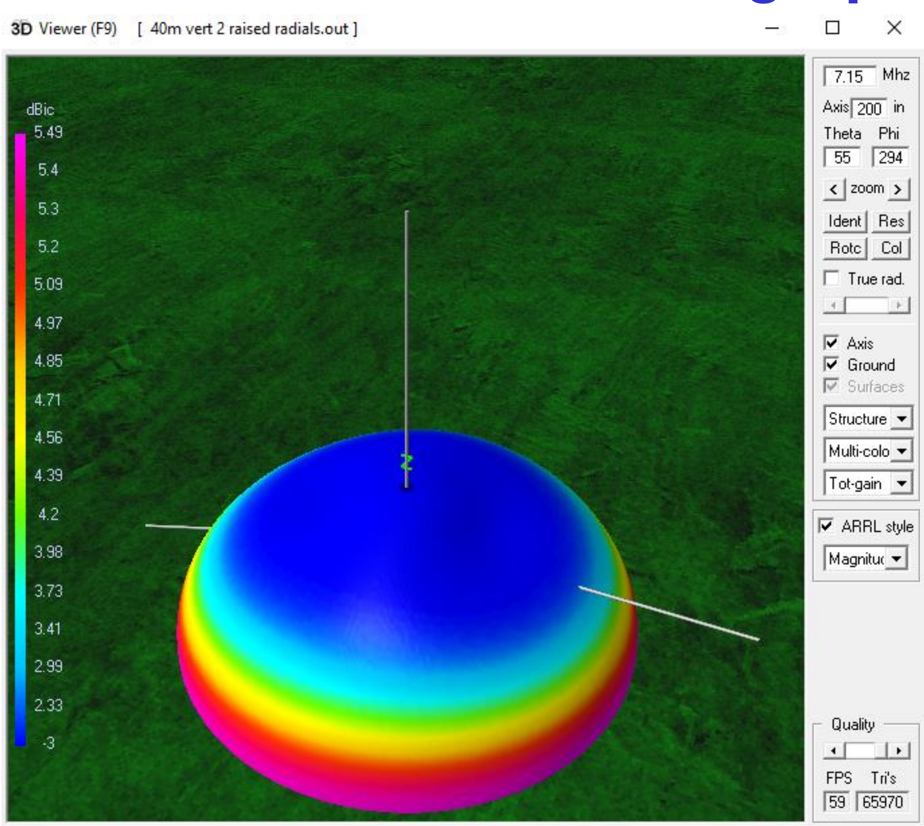
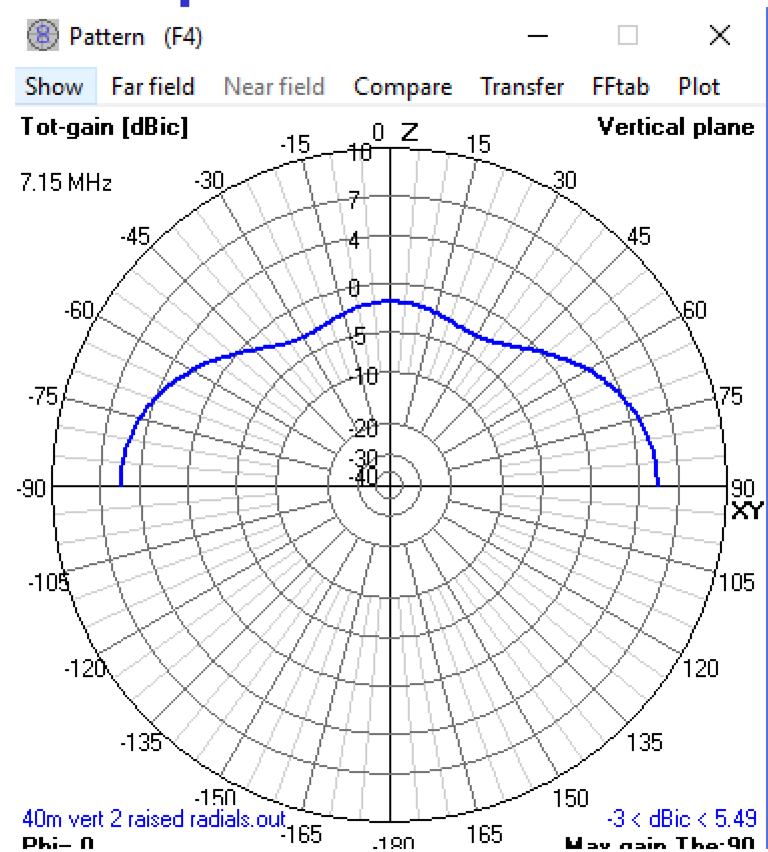
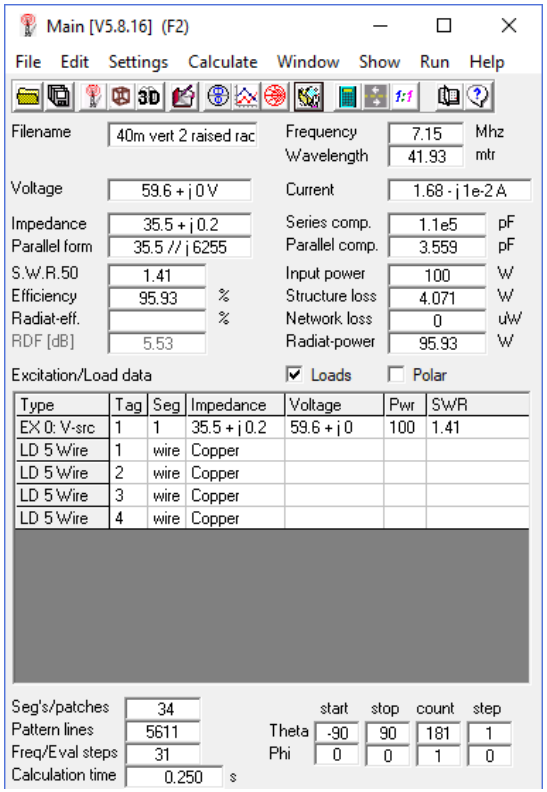
- There are tabular and graphics outputs

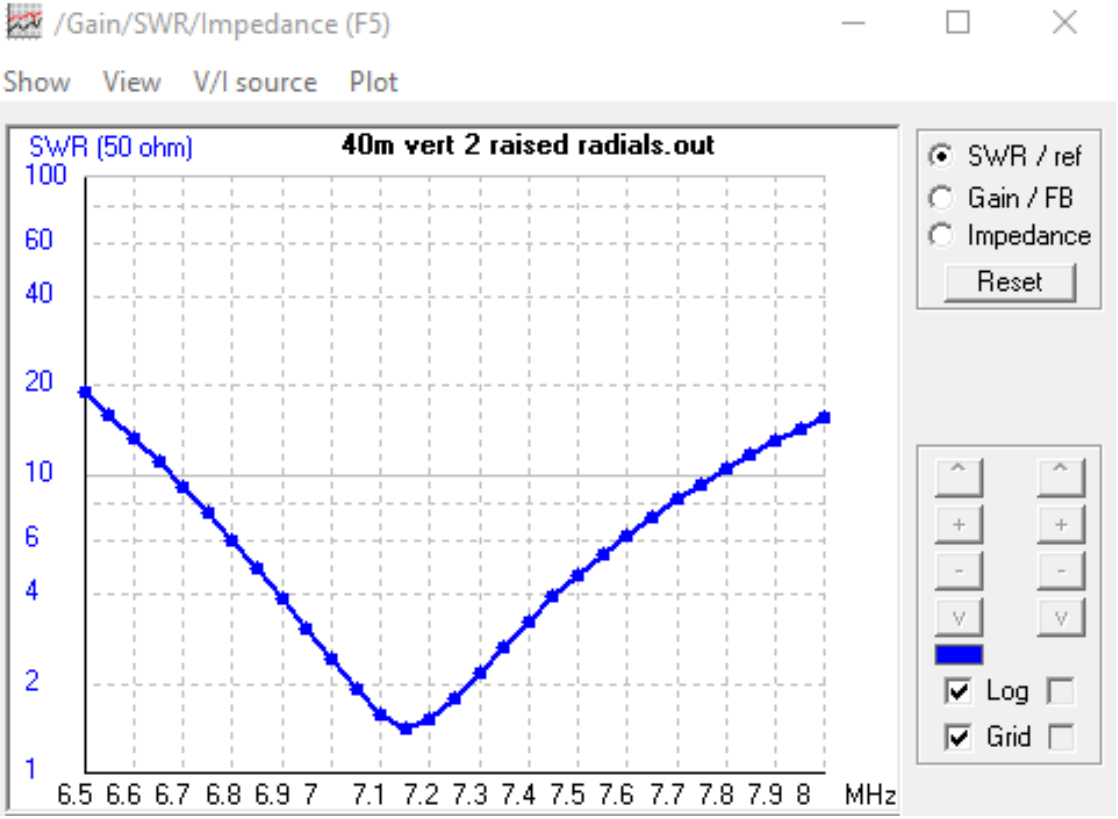




Output results 4NEC2

- There are tabular and graphics outputs





Output results 4NEC2

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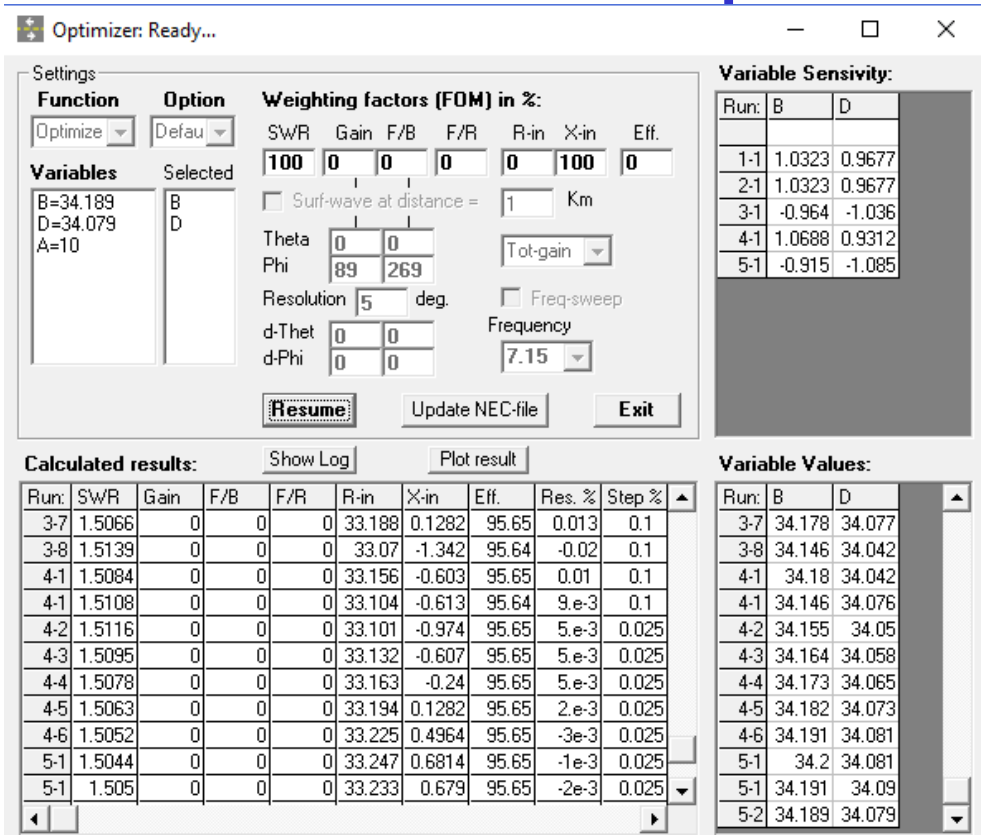
- There is a multivariable optimizer



Output results NEC

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- Mainly tabular
- Limited Graphics

Comments

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- NEC is an old mainly text based program which has resulted in many “improvements”
- EZNEC is most familiar to Amateurs and AutoEZ adds useful features.
- 4NEC2 has all of the features of EZNEC+ AutoEZ and can use EZNEC files but the work flow is not easy to follow. The 3D graphics are nice and a graphics editor may help some people.
- ALL programs require an understanding of the limitations of NEC especially NEC2.

Special Case
"Gull Wing" Radials

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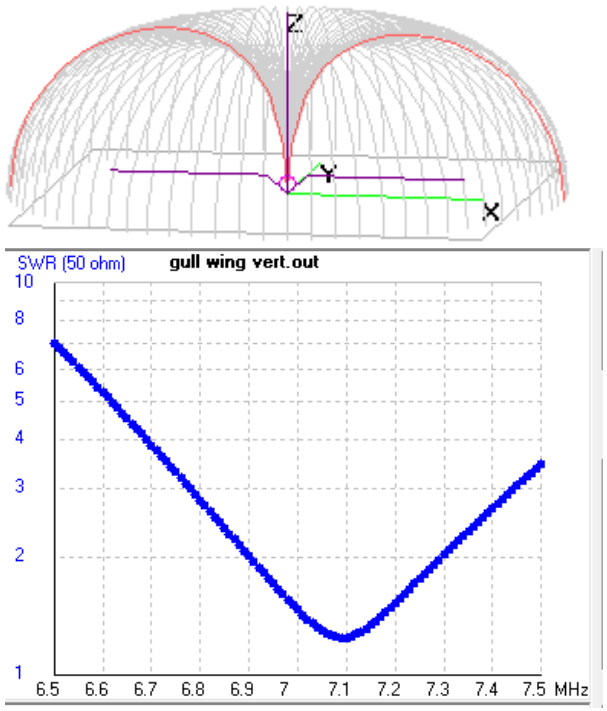
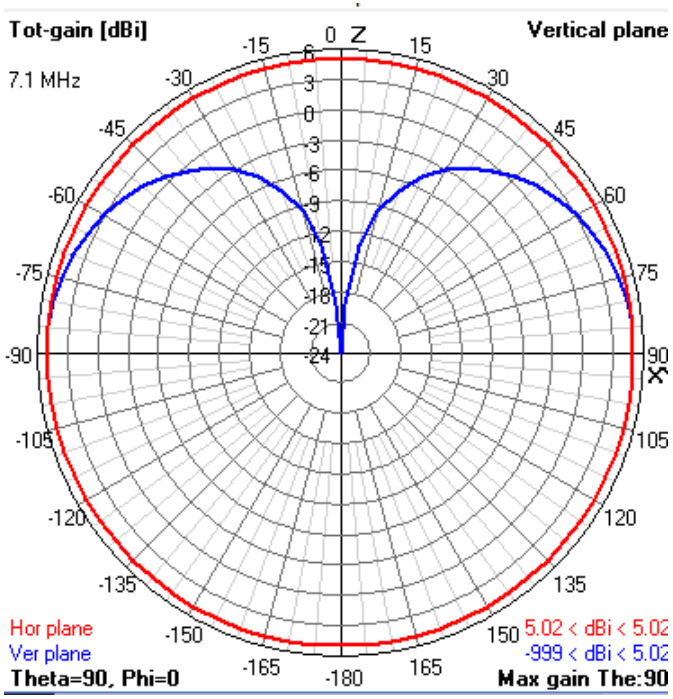
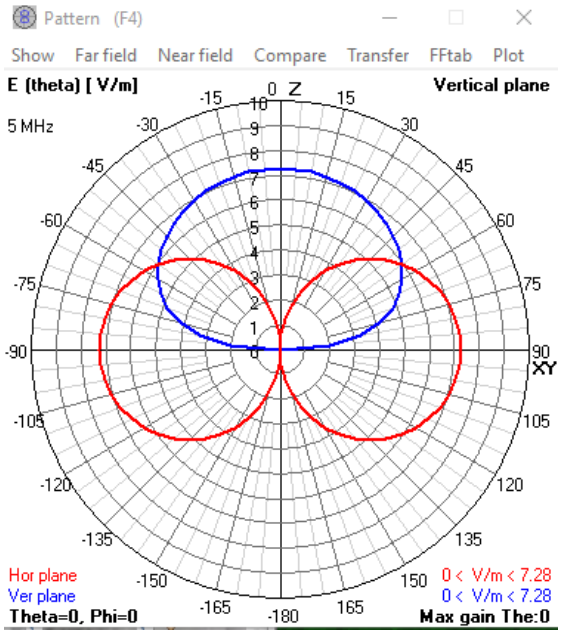
- NEC2 has problems with wires that intersect at an acute angle. NEC4 can handle this.

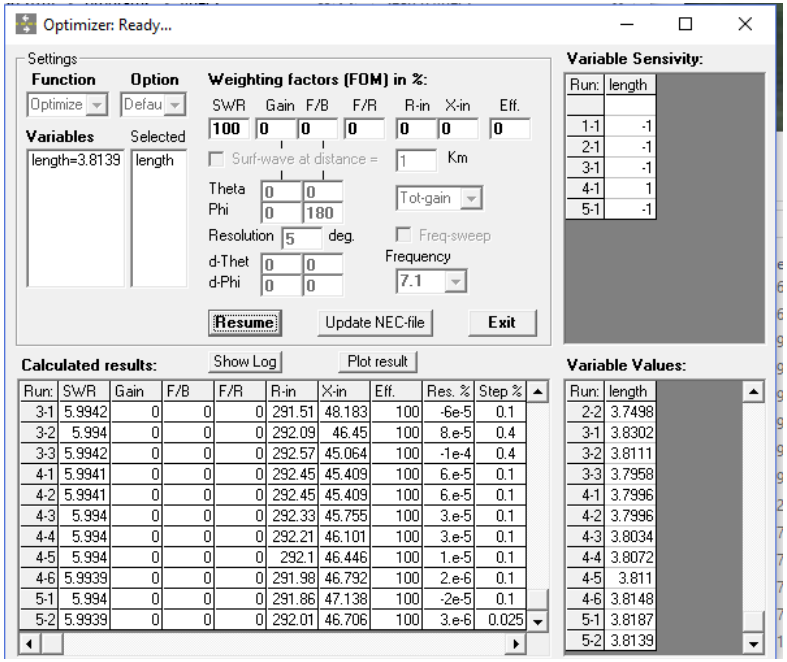




Special Case Buried Wires

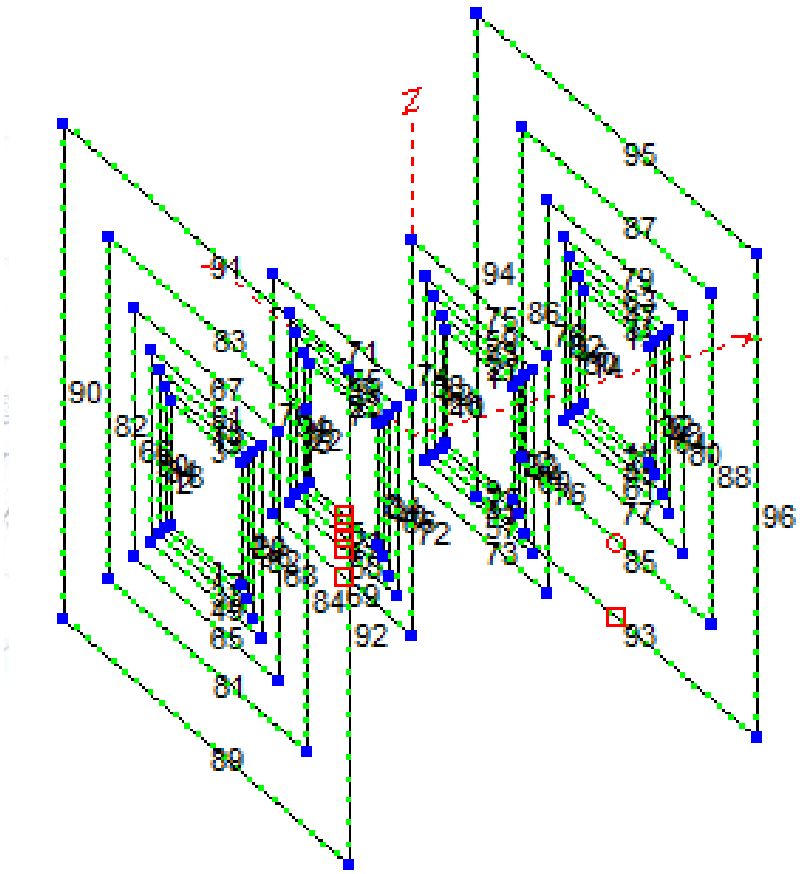
- NEC 2 will not calculate wires in the ground but using the NEC 4 engine the length of a buried dipole can be modelled and optimised.





A Complicated Case VE7SCC Quad

- 2 el on 30 and 40m
- 4 el on 20, 17, 15, 12, 10
- Models interaction of elements which is complicated.
- Can add coax matching sections
- Can model antenna switching
- Easy to generate model



A Complicated Case
VE7SCC Quad

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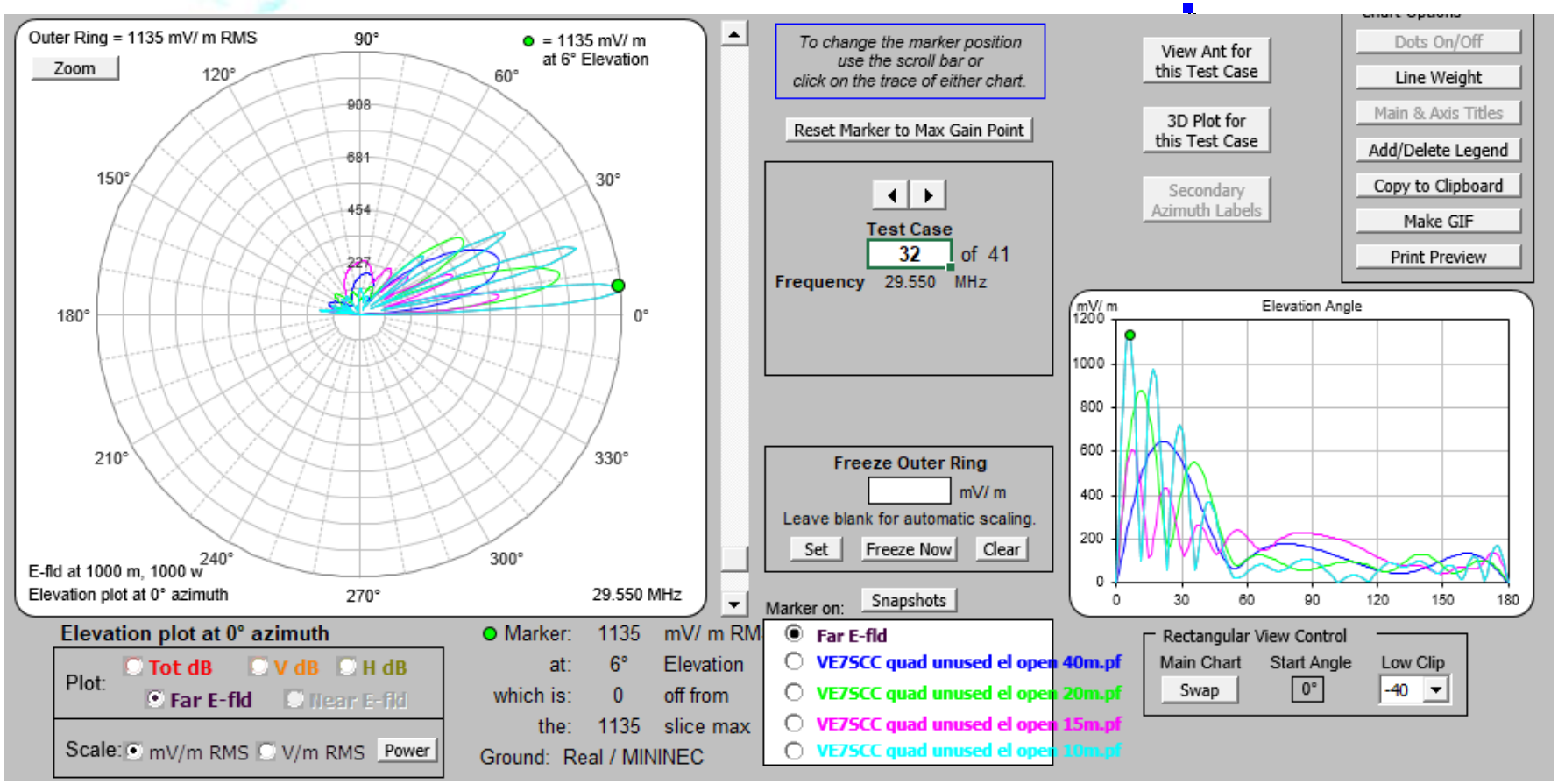
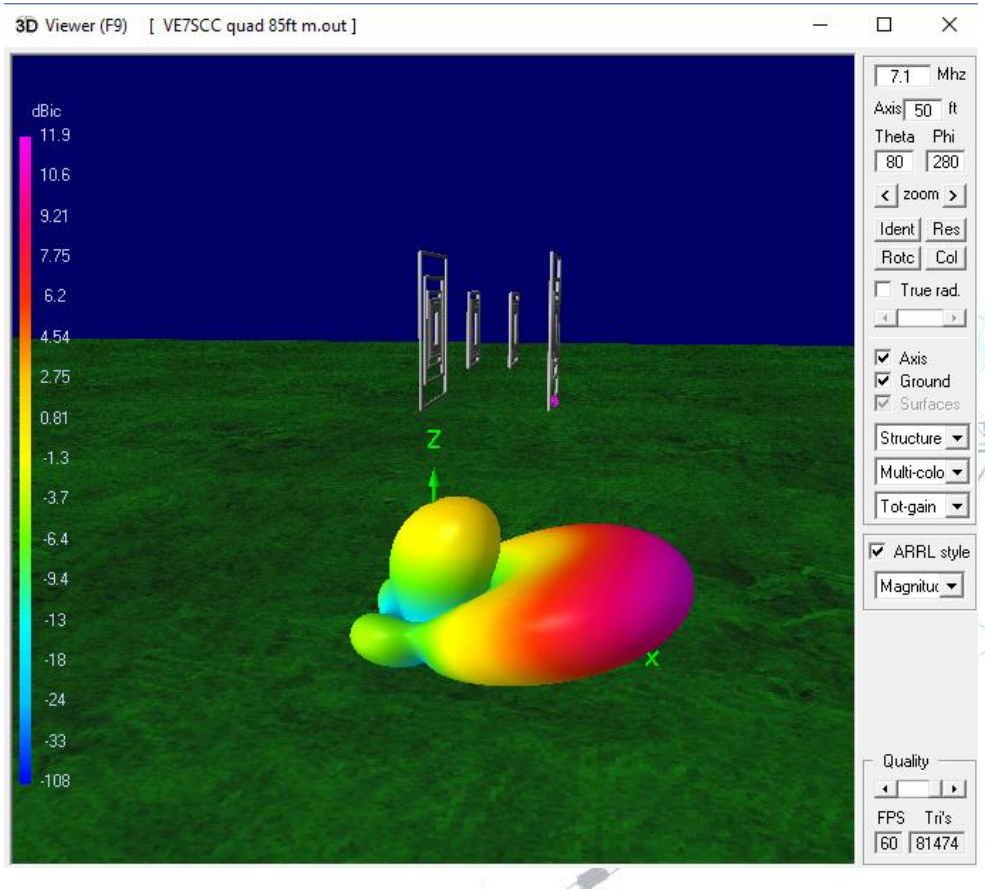
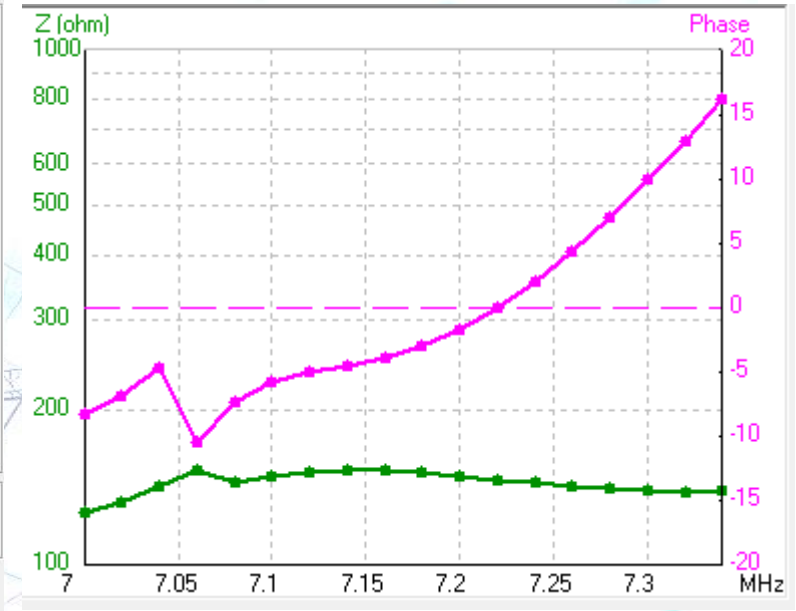


A Complicated Case
VE7SCC Quad





Sinclair 440 Beam

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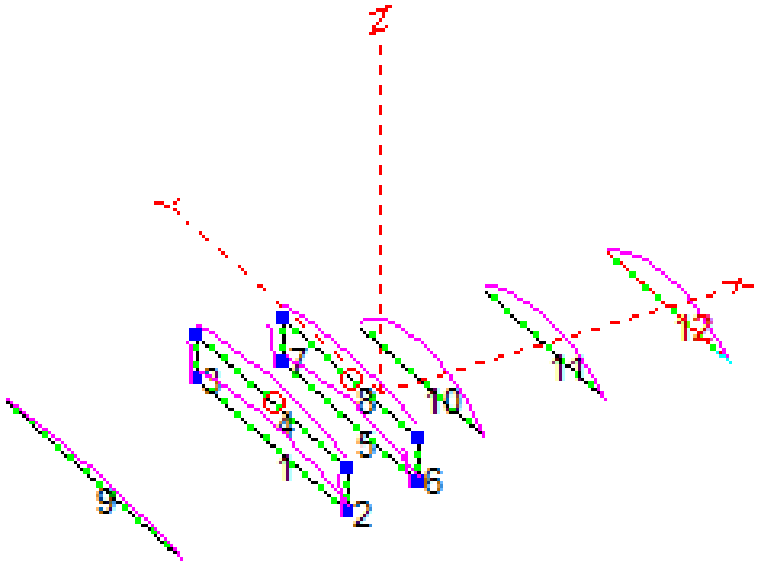
- John White showed this as part of his Yagi presentation
- NEC 4 should be used to model the cross-overs which are too close for NEC2 but NEC2 works by using the equivalent 2 sources.



A NEC4 Case
Sinclair 440 Beam

- The matching appears to be dependant upon the interaction of the folded dipoles as otherwise 1/4λ 125ohm coax would be required. This curve was confirmed with an AIM600 but with better SWR.