AutoEZ: A Revolution in the Evolution of Antenna Modeling

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Contents

The Current State of EZNEC/NEC-Based Antenna Modeling

- Current up to May, 2024 (things change!).
- See my 2011 Contest University presentation for NEC history and an introduction to antenna modeling.
  - Numerical Electromagnetics Code (NEC). ~1980.
  - The Wikipedia page for NEC is a good overview.
  - Deck of cards and line printer output!
- For <u>many years</u>, the first question usually asked was whether you use NEC-2 or NEC-4 as your modeling engine.
  - NEC-2: free (public domain), with some serious known limitations but clever workarounds in EZNEC (and others).
  - NEC-4: $400 license fee, with many improvements and far fewer limitations. (LLNL (Lawrence Livermore))
  - To use NEC-4 with EZNEC the Pro/4 version was needed ($600). Total investment (well worth it): $1000.

The Current State of EZNEC/NEC-Based Antenna Modeling (2)

- There have been several significant events in the NEC and EZNEC world over the last few years.
- NEC-4.2 was released.
- NEC-5.0 was released.
  - NEC-5.0 is based upon a different electric field solution method (it's not just tweaks to NEC-4.2, it is a separate product).
- Sadly, Gerald Burke, long time NEC developer at Lawrence Livermore National Labs (LLNL), died in 2021.
  - There will be no NEC-6 (my opinion).
- Around 2 years ago, around the release of EZNEC 7.0, EZNEC creator Roy Lewallen, W7EL, moved towards retirement.
- Gee, death and retirement… Is that a problem going forward?

The Current State of EZNECNEC-Based Antenna Modeling (3)

- Not really!
- Some bug fixes and improvements have been made to NEC-5.0 by Roy, W7EL and Dan, AC6LA. It is not dead.
  - LLNL claims to be looking for folks interested in support/enhancement of NEC-5.0.
- EZNEC Pro+ v 7.0 became **free**!
- The license fees for NEC-4.2 and NEC-5.0 were reduced to $110 (from $400). Still licensed through LLNL.
- This means that the pinnacle of NEC modeling software with EZNEC now costs $110 or $220 for both NEC-4.2 and NEC-5.0 engines (was once $1000).
- W7EL does not generally respond to support requests but has been known to fix bugs and lurks in the background.

The Current State of EZNEC/NEC-Based Antenna Modeling (4)

- NEC and EZNEC could each be their own topics, but that's not this presentation!
- Moving models from NEC-4 to NEC-5 can require some tweaks for best results.
  - e.g. Source placement and # of segments.
- If in the past you shied away from modeling due to cost, performance, or model size, those days are gone, and have been for a few years.
  - Modern PCs are so much faster and contain much more memory than the typical PC of 20+ years ago.
  - What used to be a slog is now a breeze.
- Additional current EZNEC information is included at the end of this presentation.
- Now back to AutoEZ.

What is AutoEZ?

- A software *front end* for EZNEC (v. 5, 6, 7) created by Dan Maguire, AC6LA (Automated Use of EZNEC).
  - Dan is out in *6 land* and it's hard to get him back here, so I am tackling this most worthwhile topic in his stead.
  - Runs on a PC under Windows.
- AutoEZ is an extension of Microsoft Excel (Visual Basic extensions in the form of macros).
  - Brings the power of **Excel** to antenna modeling.
- EZNEC is automatically executed under AutoEZ.
  - EZNEC is still visible and can be manually controlled although care needs to be taken to not *bump elbows*.
  - EZNEC is a *front end* for NEC, versions 2, 4, 4.2, and 5.

What is AutoEZ? (2)

- The AutoEZ tool chain:
  - AutoEZ (Excel) -> EZNEC ~> NEC
  - AutoEZ is a front end for EZNEC which is a front end for NEC.
- Gee, this sounds like a lot of parts!
- Some degree of knowledge is needed about four related and overlapping yet different programs.
- Is this a steep learning curve?

What is AutoEZ? (3)

- Yes!
- But the rewards and results are more than worth the effort.
- The ability to quickly and efficiently design, analyze, and optimize antennas based upon NEC has never been greater (this is the *revolution*, not *evolution*).
- AutoEZ is a powerful tool for learning about antennas through the *what-if* process (lots of permutations).
- Like all CAD (computer aided design) tools the capabilities of the user are greatly amplified, but, the tools must be learned to the appropriate level.
- If you are an EZNEC user with some experience with Excel, there should be very little angst using AutoEZ.

What is AutoEZ? (4)

- An AutoEZ license is $79 (USD) via PayPal.
  - All single licensee owned PCs, free updates.
  - Demo version available with 30 segment limit.
  - Money back guarantee if not satisfied.
- Must be genuine Microsoft Excel, not generally compatible (and free) alternatives such as OpenOffice or LibreOffice.
  - Excel version 97 or greater.
  - *Used* Microsoft licenses are available.
- Detailed purchase/requirements info can be found at https://ac6la.com/aepurchase.html

AutoEZ Key Features

- Model with Variables.
- Model with Formulas (we are in Excel!).
- Automate long runs of permuted models that otherwise would be tedious to run and analyze.
- Optimize Models (weighted objectives: gain, etc).
- Accepts models from many different tools.
  - EZNEC, AO, YO, YW, NEC/Wires, MMANA-GAL, 4nec2
  - YM, YS (mechanical descriptions of Yagis)
- There are many other AutoEZ features that our limited time today prohibits exploring (see References) .
  - Features to help create models and to analyze results.

Model With Variables/Formulas

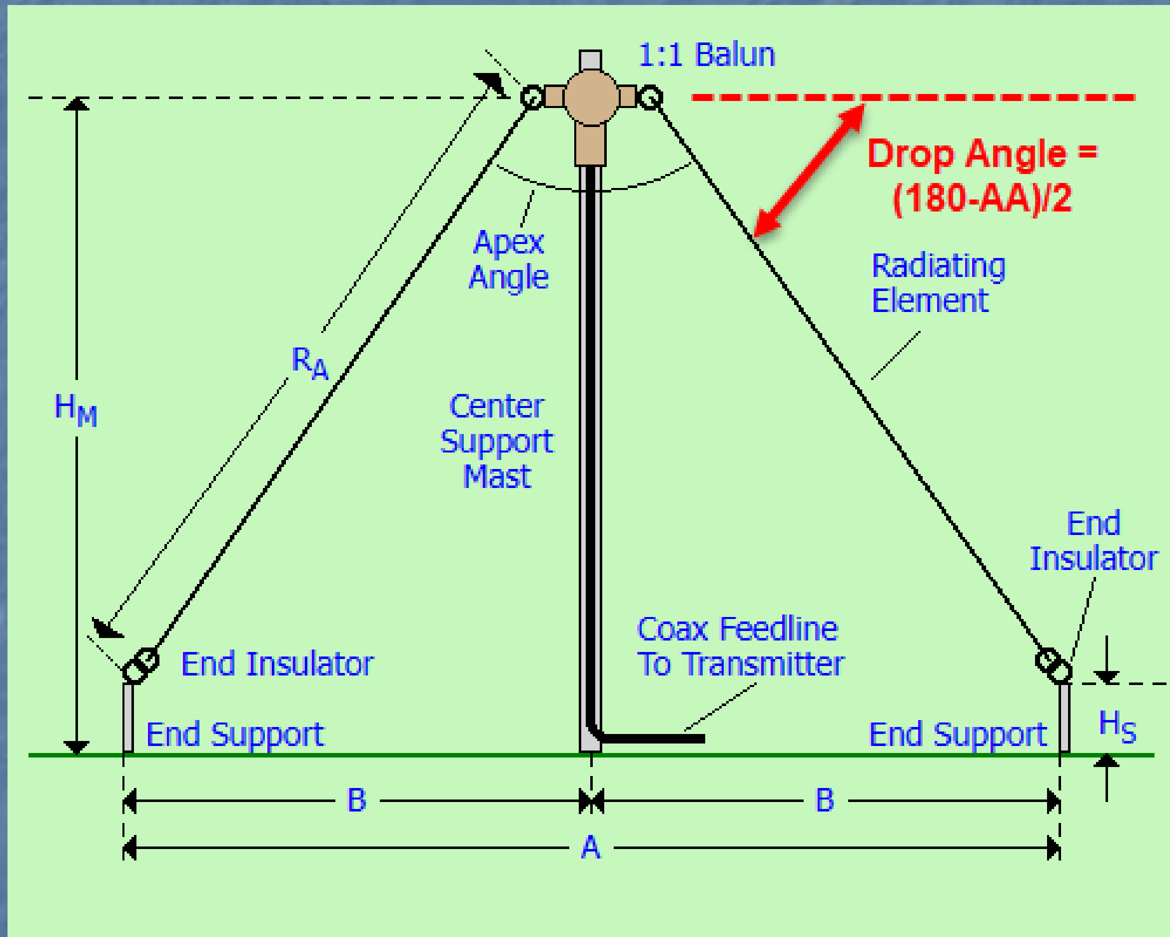
- An EZNEC model is built from numbers/choices inserted into tables (~8). Tables include:
  - Wires, Sources, Loads, Transmission Lines, etc.
- EZNEC evolved to include many powerful commands to create and *edit* the numbers, especially for Wires, which are defined by two X,Y,Z endpoints in space.
  - Manipulating all of the Wire numbers probably turns off more people to modeling than anything else.
  - In *days gone by* it was common to work with a pad of paper and a calculator to figure out Wire endpoints.

Model With Variables/Formulas (2)

- Let’s look at an Inverted Vee example.
- As an antenna, why pick the Inverted Vee over a dipole?
  - One high center support versus two or three.
  - Resonant feed point impedance closer to 50 Ohms and not 72 Ohms (lower SWR in a 50 Ohm system).
  - Closer to an omnidirectional azimuth pattern for equal coverage in all directions (not the dipole *barbell*).
  - When low to the ground more of an NVIS antenna.
    - AKA *cloud warmer.*

Model With Variables/Formulas (3)

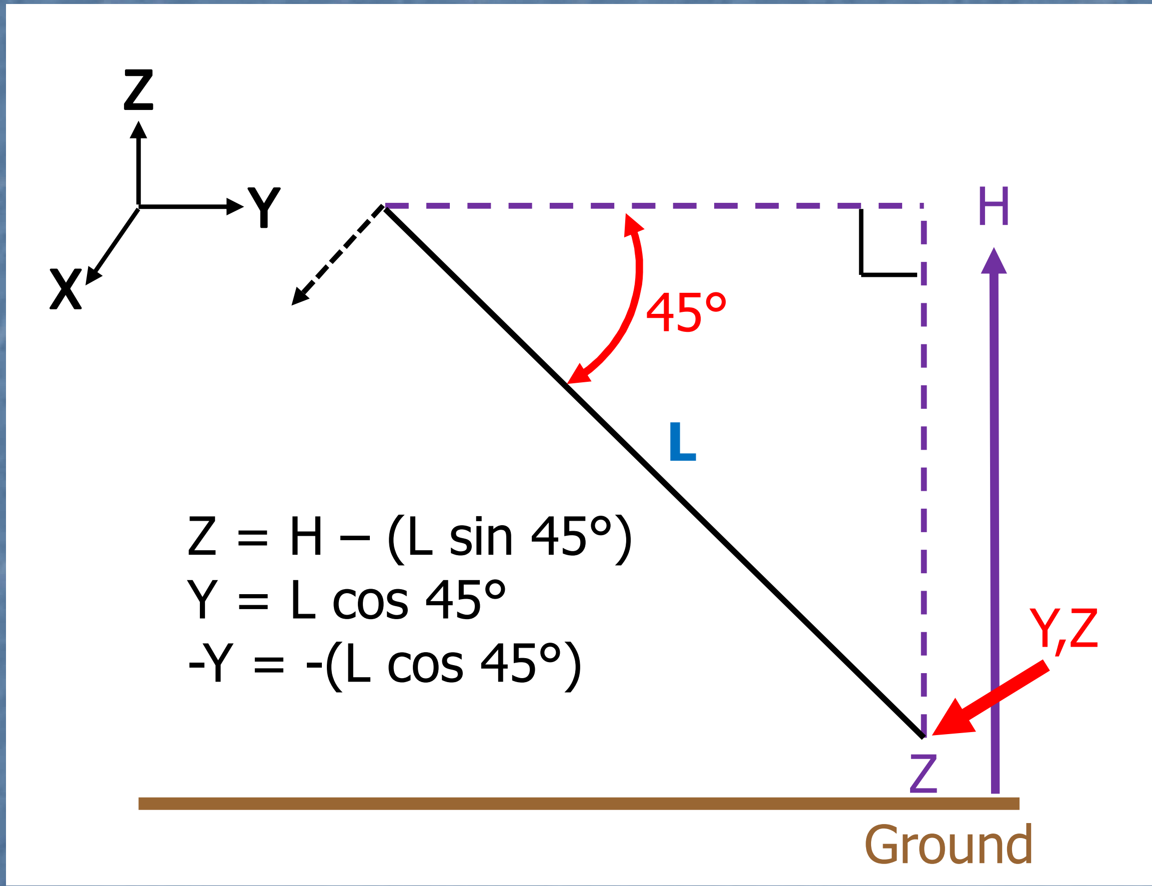
- Diagram taken from K7MEM.
- Apex Height
- Apex Angle
- Drop Angle
- Half Length (Ra)
- 80m: 3.525 MHz
- #12 bare copper wire



K7MEM.com/Ant_Inverted-V.html

Model With Variables/Formulas (4)

- Let's start with an apex angle of 90 degrees.
- Drop angle is 45 degrees.
- Vee center at 0,0,H.
- Let's pick H = 50'.
- What are the end points?
- One side mirrors the other |-Y| = |Y|.
- Some amount of high school trigonometry is often needed to compute end points.



Model With Variables/Formulas (5)

- In EZNEC, the Wires table is:

Wires

Wire Create Edit Other

☐ Coord Entry Mode ☐ Preserve Connections ☑ Show Wire Insulation ☐ Show Loss

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	50	W2E1	0	47.3337	2.66627		#12	31
2	0	0	50	W1E1	0	-47.3337	2.66627		#12	31
*										

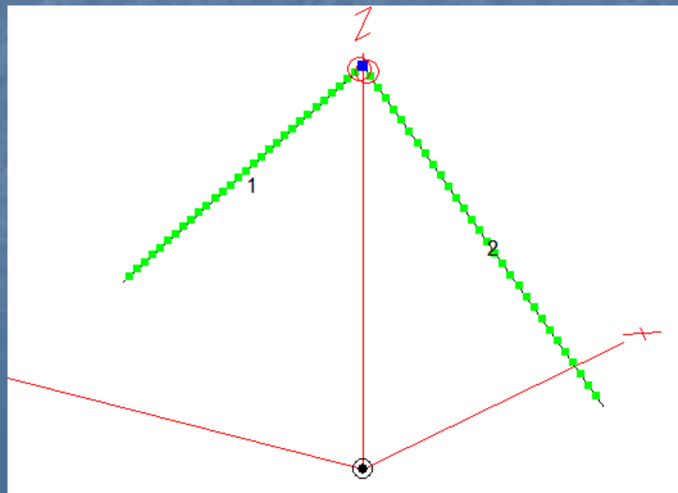
- The Sources table is:

Sources

Source Edit Other

Sources

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



Model With Variables/Formulas (6)

- Where did the length of the Wires (L) come from?
- I started with a flat dipole of the approximate length and *fiddled* with the ends until I came close enough to resonance (X (reactance) = 0) at 3.525 MHz.
- I used two EZNEC commands to rotate the two ends down by 45 degrees (drop angle).
- Since this change shifted the resonant frequency a little bit, I again *fiddled* with the length to reestablish resonance.
- I did not need, therefore, to work out the coordinates with pencil and paper like in the old days.
  - Took a few minutes and I didn’t break a sweat.
- The result is an EZNEC inverted vee model as desired.

Model With Variables/Formulas (7)

- AutoEZ presents nearly the identical tables as EZNEC, but now the spreadsheet cells can contain variables and formulas as well as numbers.
  - The tables have two modes: resulting numbers and input formulas that when evaluated lead to the numbers.
- AutoEZ can read and write EZNEC format files as well as its own format (.weq). I read in my EZNEC model as a convenient starting point.
- Here's what the AutoEZ model looks like with variables and formulas.

Model With Variables/Formulas (8)

- The variables are the height, drop angle, and length (in feet).
- The variables are specified on the Variables Excel sheet.
- The initial length was taken from AutoEZ after loading the model from EZNEC.

Helpful values provided by AutoEZ

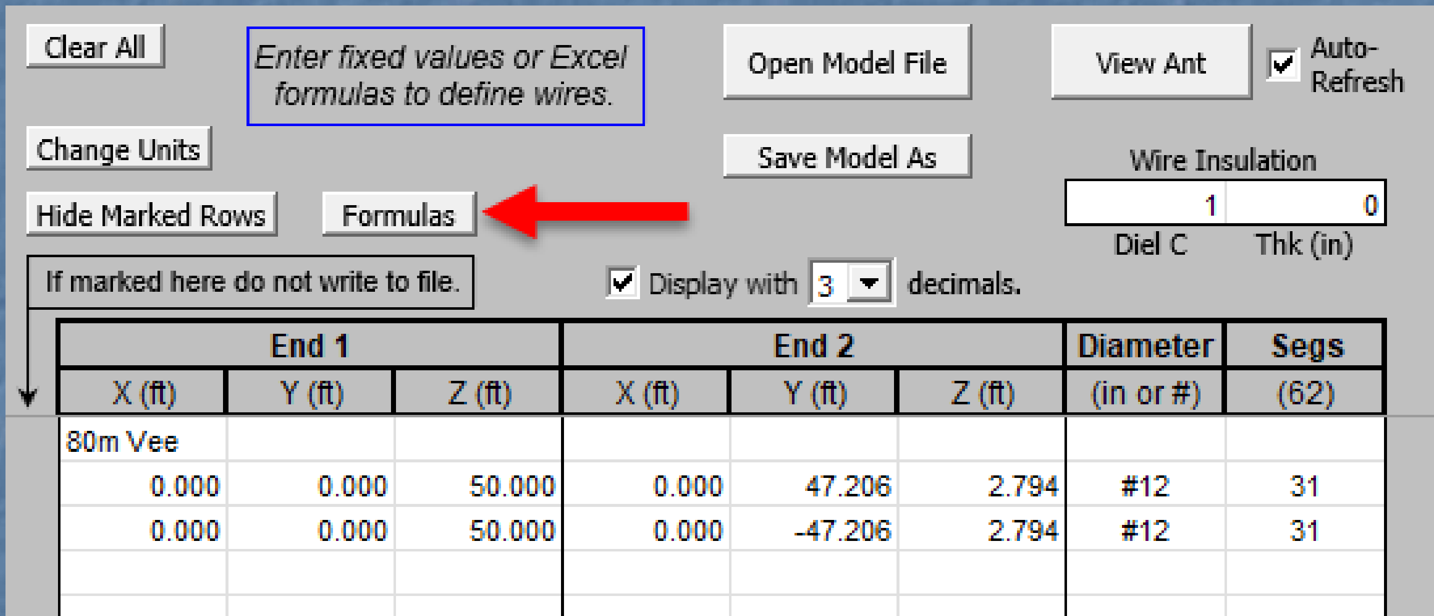
At 3.525 MHz number of segments = 62

Name	Value	Comment
TwoPi :	6.2831853	2 * PI()
WL.5 :	139.5136	½ λ
WL.25 :	69.7568	¼ λ
WL.001 :	0.2790	0.001 λ
WL or W :	279.0273	Feet
Freq or F :	3.525	Test Case Frequency (MHz)
A :	50	apex height in feet
B :	45	drop angle in degrees
D :	66.76	length of each side in feet
E :		
G :		

Change Units

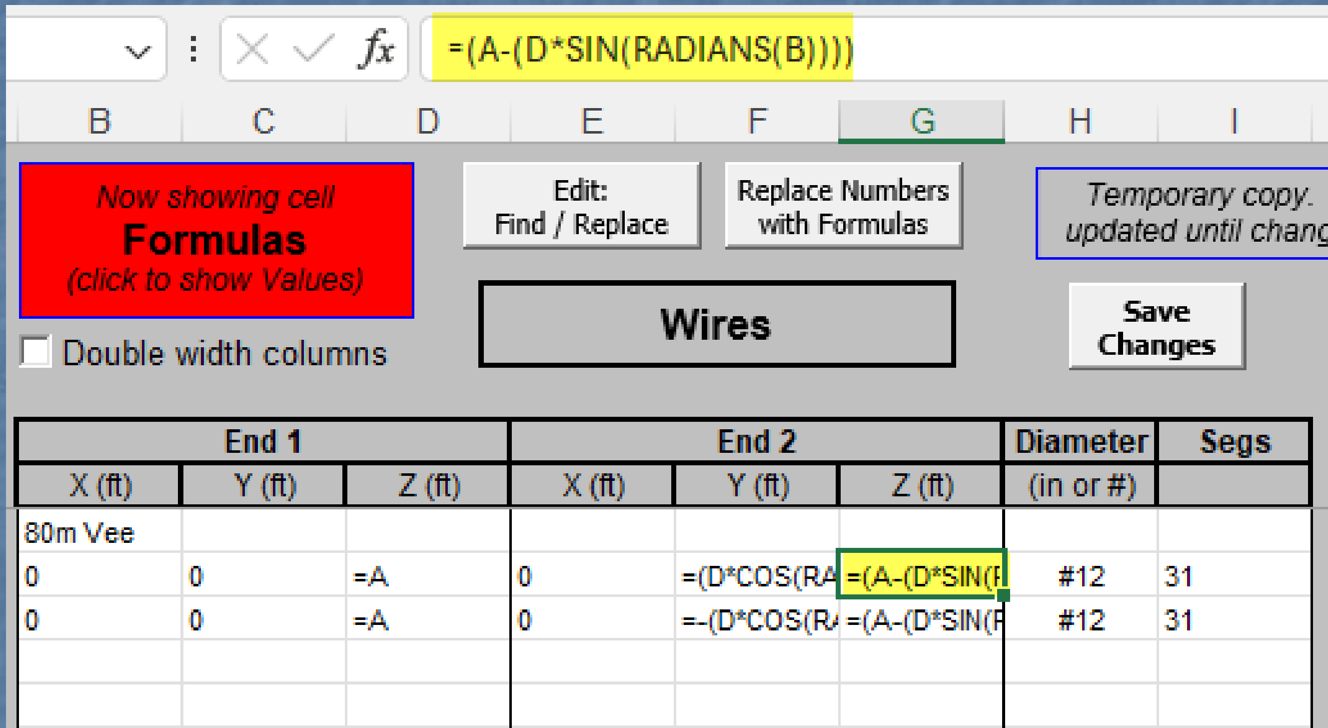
Model With Variables/Formulas (9)

- The AutoEZ Wires sheet is similar to the EZNEC Wires window.



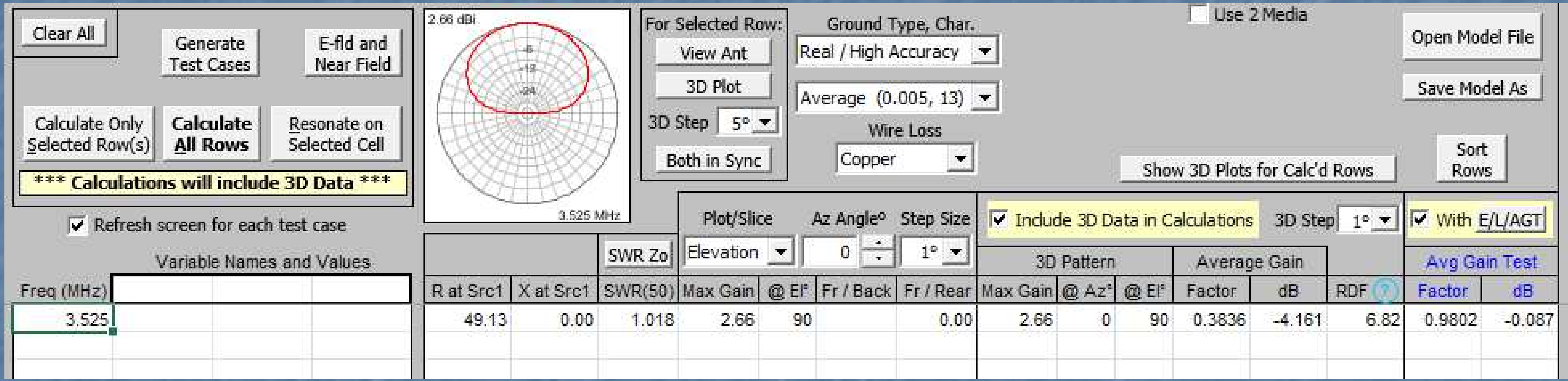
- What's the big deal? Looks like EZNEC.
- Note the Formulas button – clicking leads to:

Model With Variables/Formulas (10)



- Variables A, B, and D and the previous formulas are used to set the Y and Z coordinate values. Excel syntax.
- We now have a parameterized model.
- Switch to the Calculate sheet and ***Calculate All Rows***.

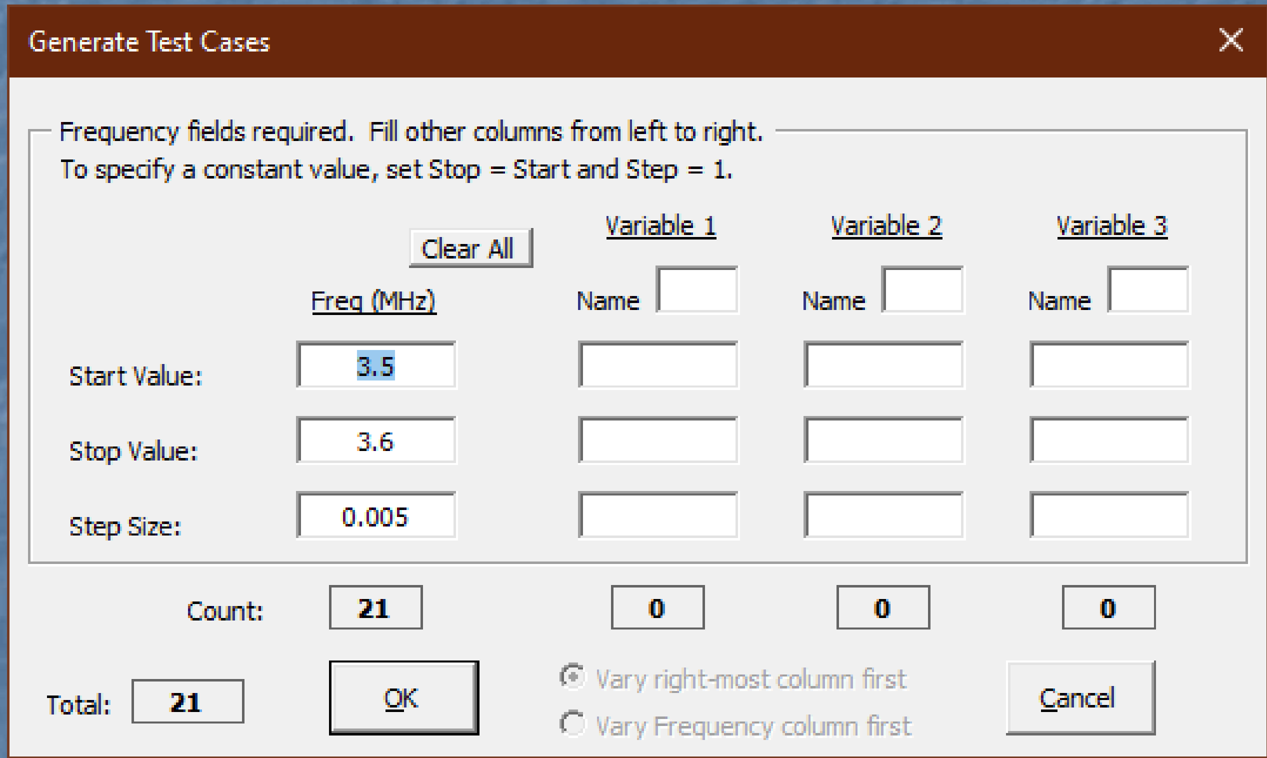
Model With Variables/Formulas (11)



- A few points to highlight:
  - Freq, R, X, SWR, slice max gain, pattern at slice, optional 3D results (RDF, AKA Directivity), optional *Average Gain Test*.
- Yes, this is a *cloud warmer!*
- This is all available in EZNEC, so what's the big deal?
- Now, we can *Generate Test Cases*….

Model With Variables/Formulas (12)

- A frequency span and up to 3 variables can be stepped through a range of values to investigate a design space.
- Let's start with 3.5 to 3.6 MHz with 5 KHz steps (21 total steps).



Model With Variables/Formulas (13)

- EZNEC is run at the 21 frequency points and all of the data is collected for analysis in AutoEZ.
- EZNEC does sweep SWR, but that's it.
- Every line comes from a run of EZNEC.
- Move to the Pattern sheet.

☑ Refresh screen for each test case

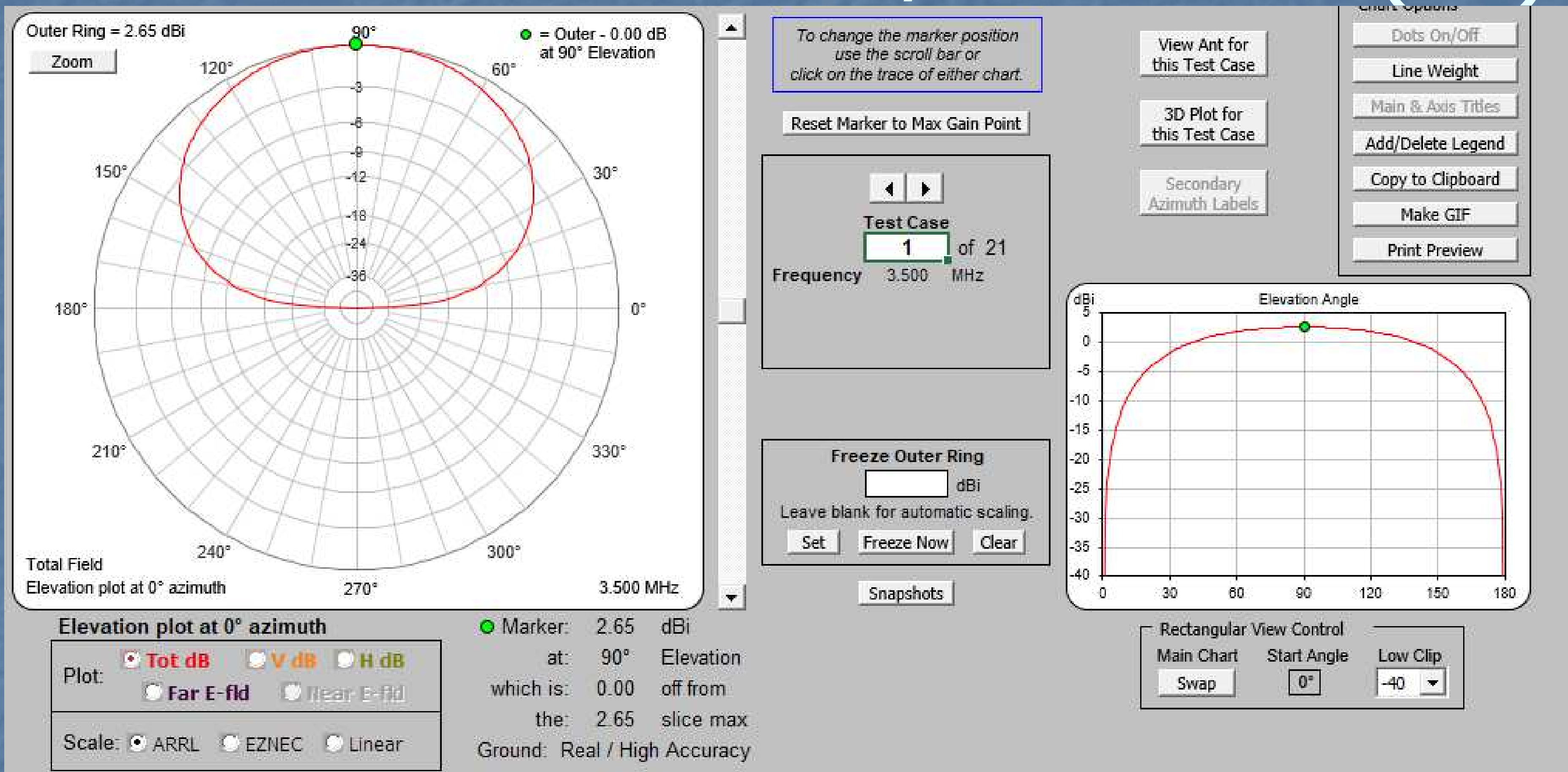
3.500 MHz

SWR Zo

Plot/Slice	Az Angle°	Step Size
Elevation	0	1°

Freq (MHz)	Variable Names and Values			R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr / Back	Fr / Rear
3.500				47.82	-12.64	1.299	2.65	90		0.00
3.505				48.02	-10.16	1.235	2.66	90		0.00
3.510				48.22	-7.69	1.174	2.67	90		0.00
3.515				48.42	-5.22	1.117	2.67	90		0.00
3.520				48.62	-2.74	1.064	2.68	90		0.00
3.525				49.13	0.00	1.018	2.66	90		0.00
3.530				49.34	2.47	1.053	2.67	90		0.00
3.535				49.54	4.95	1.105	2.68	90		0.00
3.540				49.75	7.43	1.160	2.68	90		0.00
3.545				49.95	9.90	1.219	2.69	90		0.00
3.550				50.16	12.38	1.280	2.70	90		0.00
3.555				50.37	14.85	1.343	2.71	90		0.00
3.560				50.58	17.33	1.409	2.71	90		0.00
3.565				50.79	19.81	1.478	2.72	90		0.00
3.570				51.32	22.55	1.556	2.70	90		0.00
3.575				51.54	25.03	1.631	2.71	90		0.00
3.580				51.75	27.51	1.708	2.71	90		0.00
3.585				51.97	29.99	1.788	2.72	90		0.00
3.590				52.18	32.47	1.872	2.73	90		0.00
3.595				52.40	34.95	1.957	2.74	90		0.00
3.600				52.62	37.43	2.046	2.74	90		0.00

Model With Variables/Formulas (14)

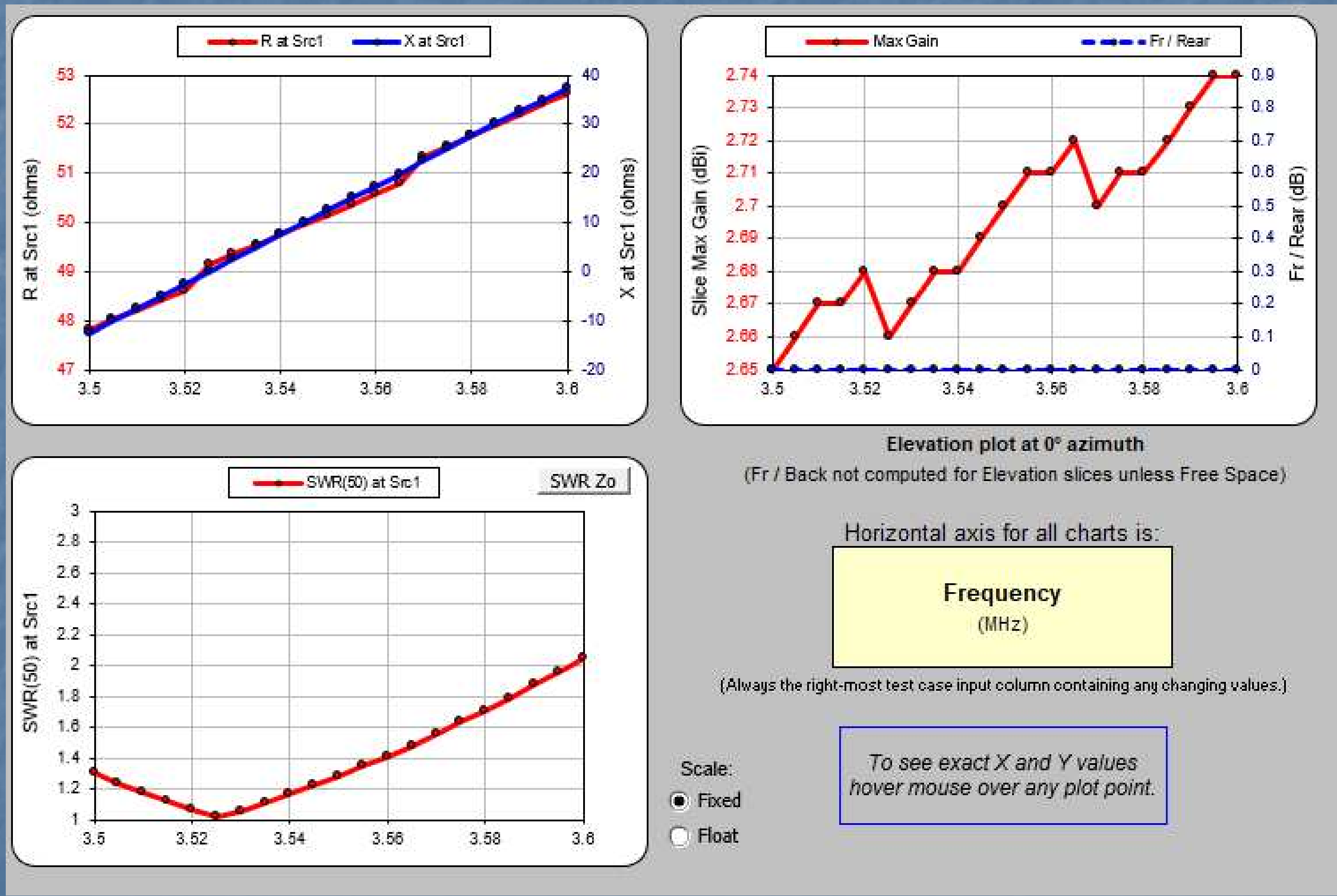


- Pattern slice analysis, including the ability to create labeled plots for the Clipboard and GIFs.

Model With Variables/Formulas (15)

This is the Triple sheet. R, X, SWR, and slice max gain as well as F/B and F/R.

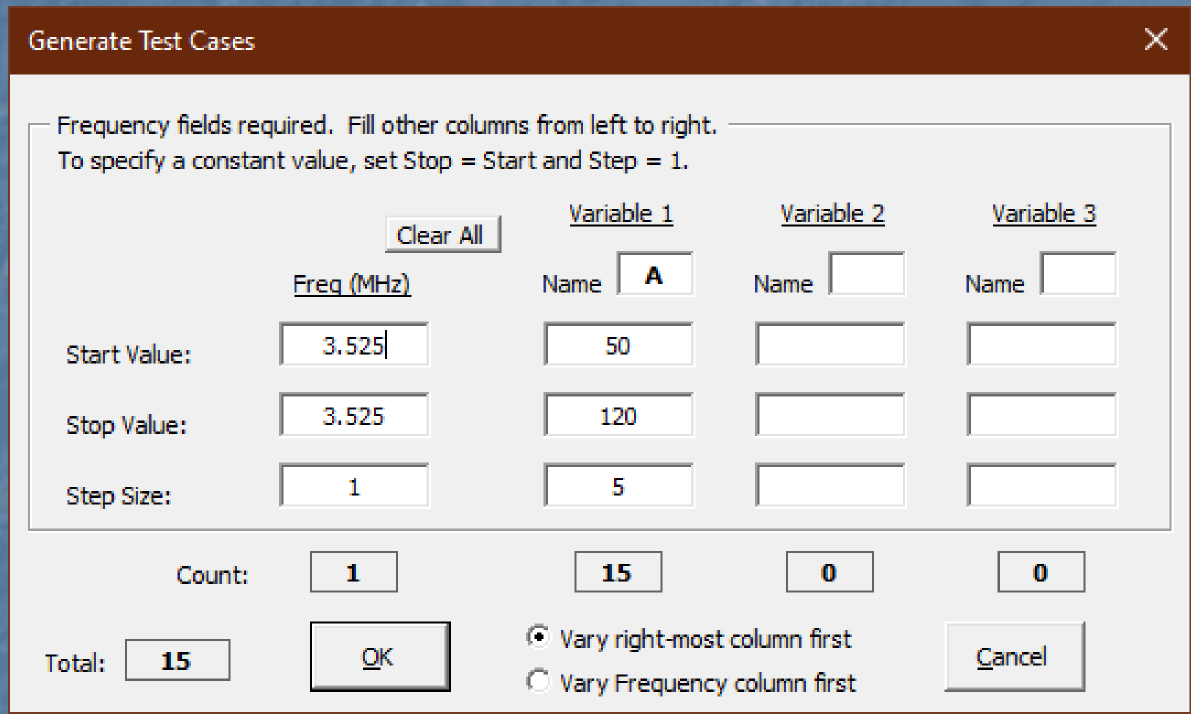
There is also a Smith Chart sheet (not shown).



It's easy to label and save the graphs.

Model With Variables/Formulas (16)

- Rather than vary the frequency, hold it constant at the target of 3.525 MHz and vary the apex height from 50 to 120 feet in steps of 5 feet.
- A is the name of the apex height variable.



Model With Variables/Formulas (17)

☑ Refresh screen for each test case

3.525 MHz

Plot/Slice: Elevation | Az Angle°: 0 | Step Size: 1°

SWR Zo

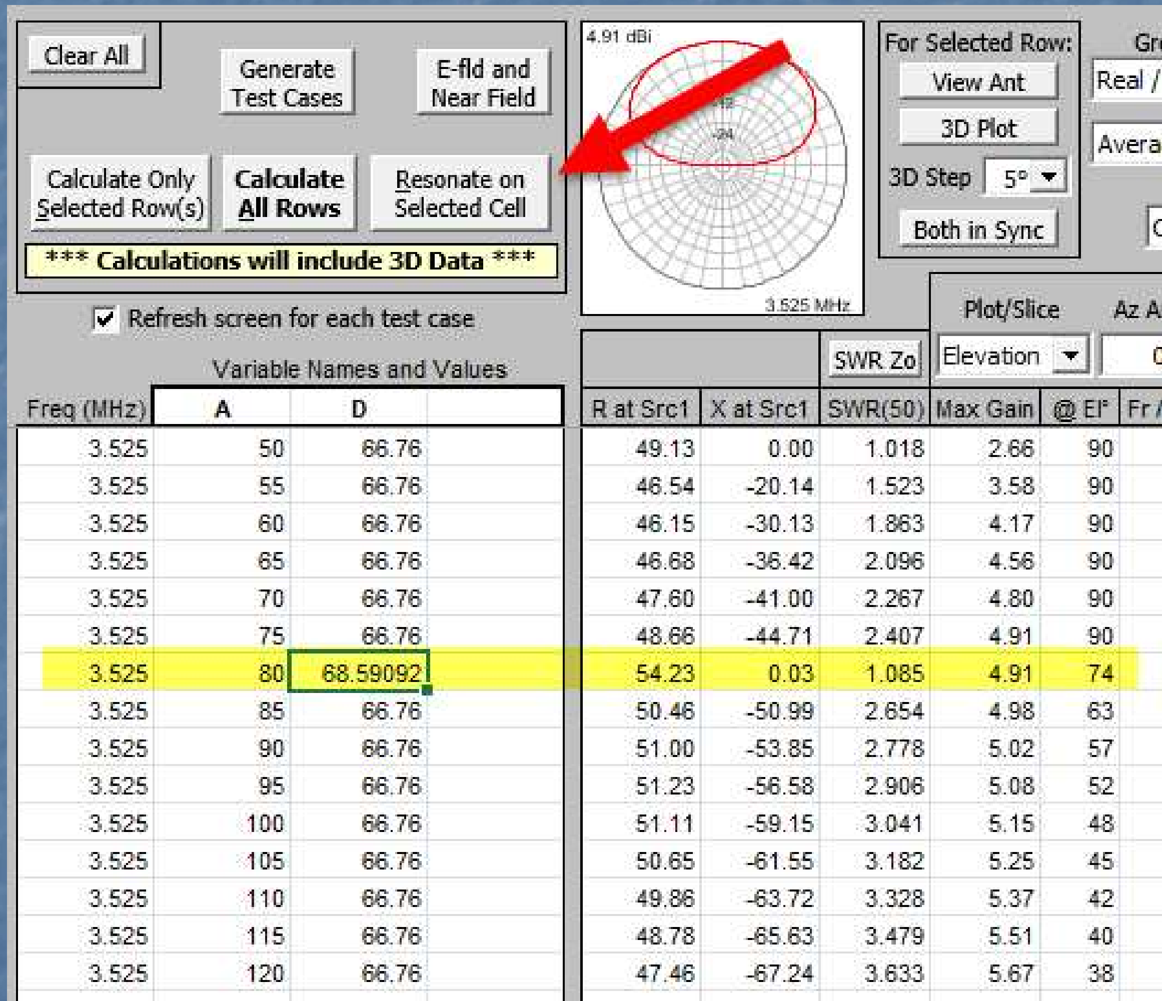
Variable Names and Values

Freq (MHz)	A	R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr / Back	Fr / Rear
3.525	50	49.13	0.00	1.018	2.66	90		0.00
3.525	55	46.54	-20.14	1.523	3.58	90		0.00
3.525	60	46.15	-30.13	1.863	4.17	90		0.00
3.525	65	46.68	-36.42	2.096	4.56	90		0.00
3.525	70	47.60	-41.00	2.267	4.80	90		0.00
3.525	75	48.66	-44.71	2.407	4.91	90		0.00
3.525	80	49.65	-47.97	2.532	4.94	72		0.00
3.525	85	50.46	-50.99	2.654	4.98	63		0.00
3.525	90	51.00	-53.85	2.778	5.02	57		0.00
3.525	95	51.23	-56.58	2.906	5.08	52		0.00
3.525	100	51.11	-59.15	3.041	5.15	48		0.00
3.525	105	50.65	-61.55	3.182	5.25	45		0.00
3.525	110	49.86	-63.72	3.328	5.37	42		0.00
3.525	115	48.78	-65.63	3.479	5.51	40		0.00
3.525	120	47.46	-67.24	3.633	5.67	38		0.00

- Note the reduction in take-off angle as the vee moves higher.
- The feed point impedance changes as the height changes.
- What if I was thinking of putting the apex at 80'?
  - How would the length change to bring the vee into resonance?

Model With Variables/Formulas (18)

- By selecting the D variable cell at 80' and clicking *Resonate on Selected Cell* AutoEZ will vary the value of D on that row until the reactance is driven to 0 Ohms.
- For the 45 degree drop angle with an 80' apex at 3.525 MHz each side of the vee is 68.59' long.
- SWR is 1.085.
- AutoEZ did the *fiddling*.



Freq (MHz)	A	D	R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr /
3.525	50	66.76	49.13	0.00	1.018	2.66	90	
3.525	55	66.76	46.54	-20.14	1.523	3.58	90	
3.525	60	66.76	46.15	-30.13	1.863	4.17	90	
3.525	65	66.76	46.68	-36.42	2.096	4.56	90	
3.525	70	66.76	47.60	-41.00	2.267	4.80	90	
3.525	75	66.76	48.66	-44.71	2.407	4.91	90	
3.525	80	68.59092	54.23	0.03	1.085	4.91	74	
3.525	85	66.76	50.46	-50.99	2.654	4.98	63	
3.525	90	66.76	51.00	-53.85	2.778	5.02	57	
3.525	95	66.76	51.23	-56.58	2.906	5.08	52	
3.525	100	66.76	51.11	-59.15	3.041	5.15	48	
3.525	105	66.76	50.65	-61.55	3.182	5.25	45	
3.525	110	66.76	49.86	-63.72	3.328	5.37	42	
3.525	115	66.76	48.78	-65.63	3.479	5.51	40	
3.525	120	66.76	47.46	-67.24	3.633	5.67	38	

Model With Variables/Formulas (19)

- In fact, I could select the whole D column and AutoEZ would run EZNEC to bring all lengths into resonance.
- This was done with one click.

☑ Refresh screen for each test case

Variable Names and Values

SWR Zo | Plot/Slice: Elevation | Az An: 0

Freq (MHz)	A	D		R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr /
3.525	50	66.76		49.13	0.00	1.018	2.66	90	
3.525	55	67.46792		48.40	0.00	1.033	3.52	90	
3.525	60	67.85618		48.87	0.01	1.023	4.11	90	
3.525	65	68.11028		49.97	0.01	1.001	4.51	90	
3.525	70	68.29869		51.36	0.02	1.027	4.75	90	
3.525	75	68.45348		52.83	0.02	1.057	4.87	90	
3.525	80	68.59092		54.23	0.03	1.085	4.91	74	
3.525	85	68.71921		55.43	0.03	1.109	4.95	64	
3.525	90	68.84179		56.34	0.04	1.127	4.99	57	
3.525	95	68.95969		56.91	0.05	1.138	5.05	53	
3.525	100	69.07231		57.09	0.06	1.142	5.12	49	
3.525	105	69.17818		56.87	0.06	1.137	5.22	46	
3.525	110	69.27535		56.26	0.07	1.125	5.34	43	
3.525	115	69.36147		55.28	0.07	1.106	5.48	40	
3.525	120	69.43523		53.98	0.07	1.080	5.64	38	

Model With Variables/Formulas (20)

- Let’s say I wanted to explore the 80’ apex and vary the drop angle from 10 to 60 degrees?
- Fix the height and length, vary the drop angle (variable B).

Variables

Freq or F :	3.525	**Test Case Frequency (MHz)**
A :	80	apex height in feet
B :	45	drop angle in degrees
D :	68.6	length of each side in feet
E :		

Generate

Clear All

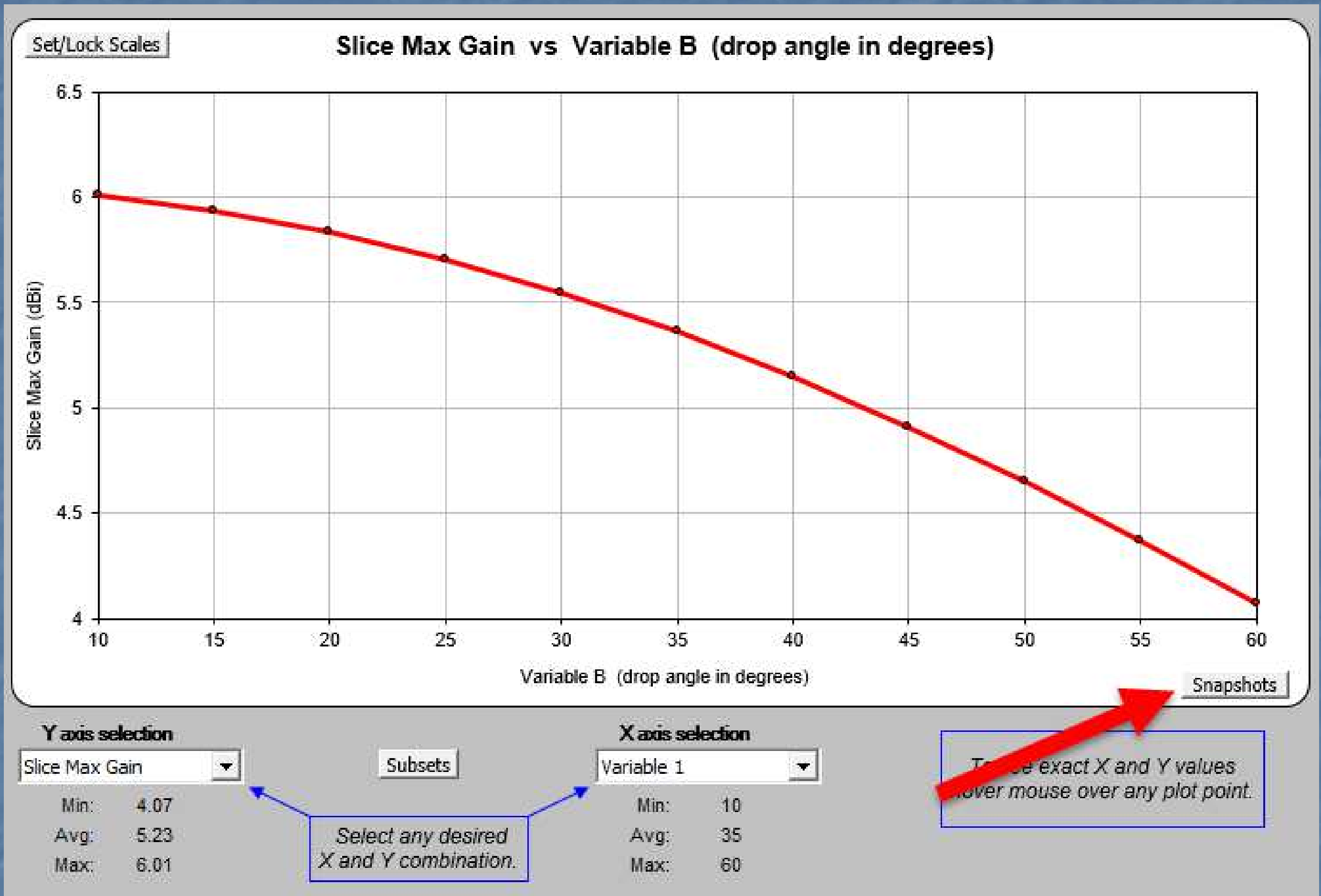
	Freq (MHz)	Variable 1
Name		B
Start Value:	3.525	10
Stop Value:	3.525	60
Step Size:	1	5

Results

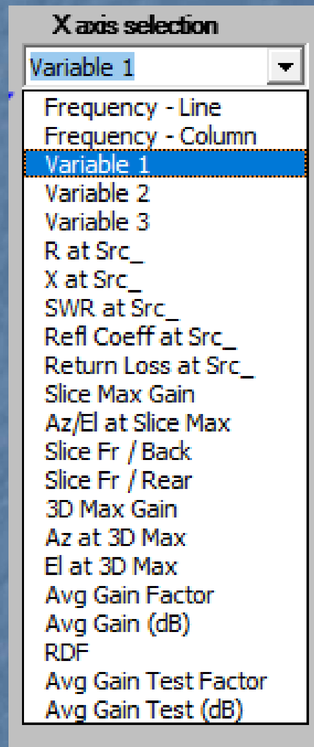
SWR Zo | Elevation | 0

	Variable Names and Values								
Freq (MHz)	B			R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr / B
3.525	10			92.45	27.70	2.074	6.01	56	
3.525	15			89.71	27.25	2.023	5.93	58	
3.525	20			85.90	25.82	1.940	5.83	60	
3.525	25			81.09	23.30	1.824	5.70	62	
3.525	30			75.40	19.58	1.676	5.54	65	
3.525	35			68.95	14.57	1.498	5.36	67	
3.525	40			61.85	8.17	1.294	5.15	70	
3.525	45			54.25	0.27	1.085	4.91	74	
3.525	50			46.33	-9.24	1.229	4.65	78	
3.525	55			38.26	-20.44	1.703	4.37	90	
3.525	60			30.28	-33.39	2.610	4.07	90	

Model With Variables/Formulas (21)

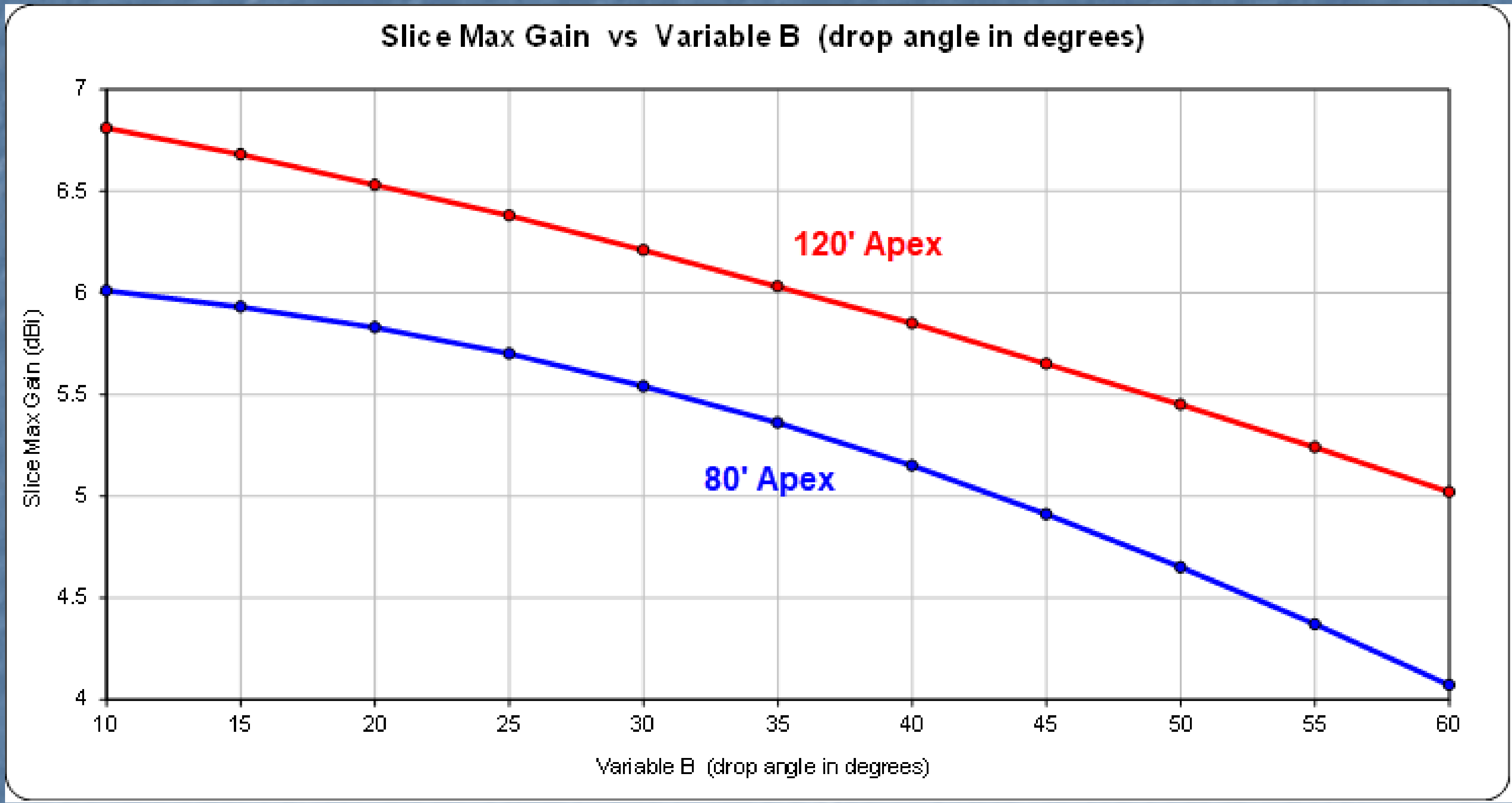


X and Y axis choices



- The graph on the Custom (graph) sheet can be used to plot the max gain as a function of the drop angle.
- This is at the 80′ apex.
- The Snapshots button saves and compares different data sets.

Model With Variables/Formulas (22)



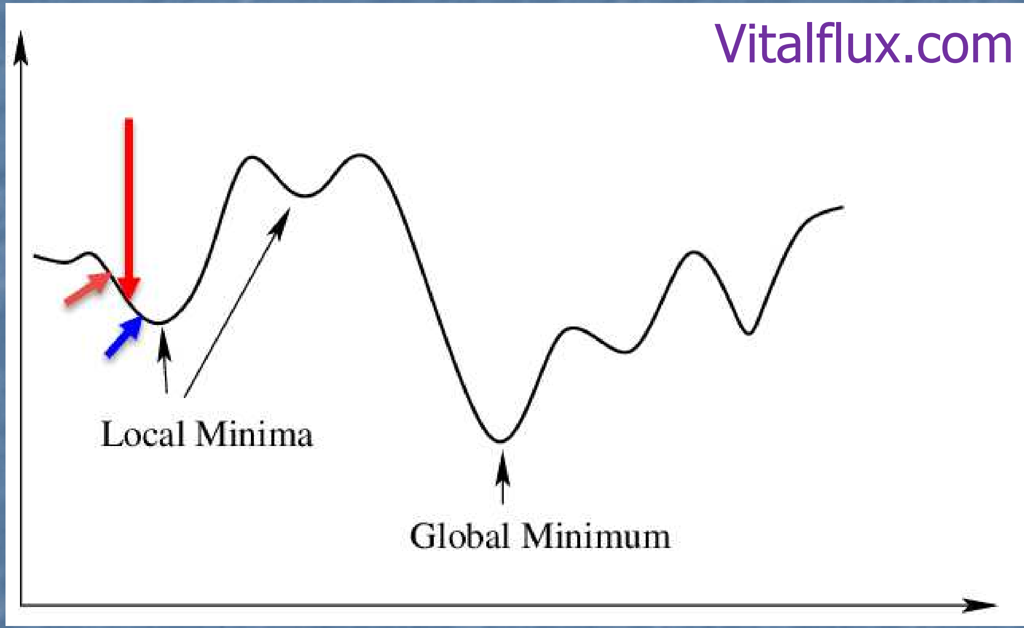
- Comparison of 80’ apex to 120’ apex as a function of drop angle using a Snapshot.

Optimize Models

- Often more of an art than science.
  - Which makes it rewarding and fun and highly creative.
- Optimize means to optimize *something*.
  - An initial design (starting point) is needed (not a blank piece of paper). It's not hard, however, to make a reasonable guess.
  - Optimize can mean maximum or minimum (e.g gain / SWR).
- The Nelder-Mead simplex algorithm is used in AutoEZ.
  - Details on https://ac6la.com/aeoptimize.html
  - Additional information on the N-M Wikipedia page.
- One of the pitfalls in optimization is getting *trapped in a local minimum*. Find a solution that looks good but is not the best one.
- Exhaustive search optimization (*brute force*) can find the optimum solution, but usually is too costly (most design spaces have several variables and are insanely large).

Optimize Models (2)

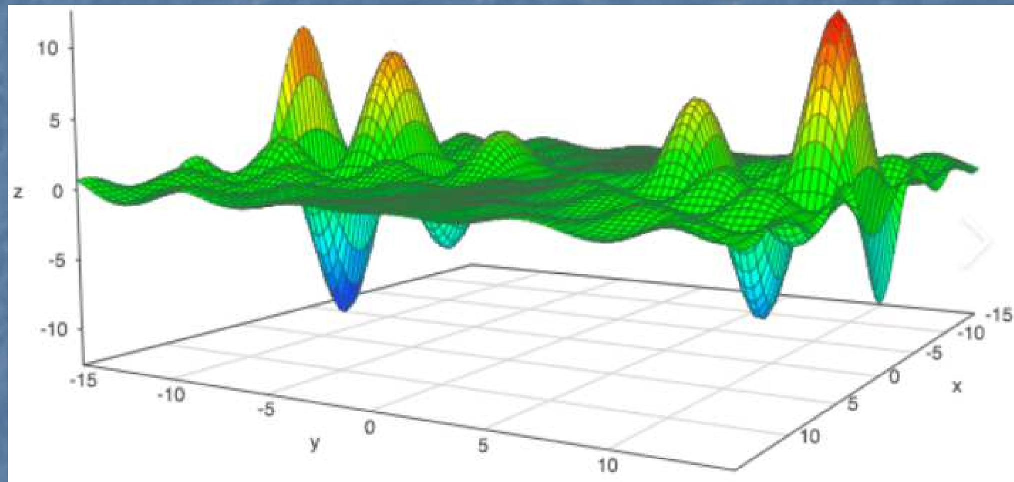
- Consider a one-dimensional function:
- The goal is to find the global minimum (or maximum).
  - Can't solve with calculus!
- A brute force method would evaluate every point along the X-axis and find the minimum.
- This can take a lot of time/cost, especially if many dimensions.



- A less costly method might make a guess at the red arrow and then evaluate the points to the left and right and decide to move to the blue arrow as the next center point since it is lower.
- Once the process starts to go higher, it could stop, declaring victory.
- Unfortunately, it has found a local minima, not the global minimum.

Optimize Models (3)

- Even with only two-dimensions the terrain can get very complex.
- 3 axes, 2 dimensions.



- A 5 element Yagi might have 9 dimensions.
  - The lengths of the 5 elements (dipoles).
  - The positions on the boom for 3-4 elements.
  - What if the goal is to maximize gain, reach a *good enough* SWR and *good enough* Front/Back ratio?
  - This is not a simple problem, and the design space is huge.

Optimize Models (4)

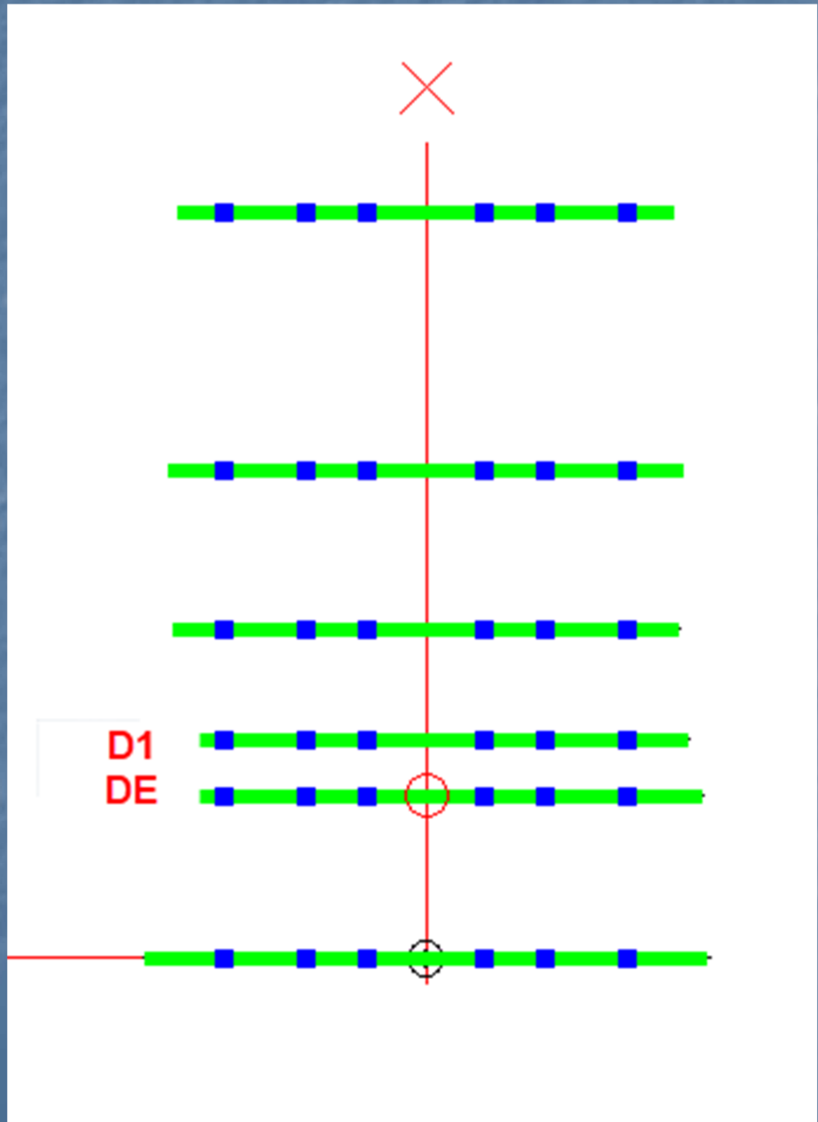
- There are hundred of optimization algorithms.
  - Often, they are designed to exploit some known bit of information about the problem so that they have the best chance of avoiding getting trapped in a local minima and being fast.
  - Solving the problem is always easier when you understand the problem.
  - Dan, AC6LA, spent time testing different algorithms before settling on Nelder-Mead, which is well suited for problems with many dimensions.
  - Over the last 10+ years I have used the AutoEZ optimizer with around 20 Yagi designs, mostly OWA.

Optimize Models (5)

- I was often starting with an existing OWA design – you must start with something. (OWA = Optimized Wideband Array)
  - They were the previous generation Yagi's and the idea was to look to improve them with AutoEZ.
  - In several cases there were updated taper schedules for a higher wind rating – changing taper changes the dimensions.
- Improvements were made, but generally small. ~0.5 dB, flatter SWR, etc.
- Establishes that AutoEZ is in line and competitive with previous optimizers.
  - Did not get stuck in a never-ending loop.
  - Some local minima trapping.
  - Could find preposterous solutions that failed the Average Gain Test.
  - Avoid local minima traps by permuting and retrying - perhaps start in another *valley*.
  - Some designs took around 700 runs of EZNEC and perhaps 20+ minutes. Small price to pay for a solid antenna design.

Optimize Models (6)

- Don’t expect to get everything you want.
  - “There are no *ideal* solutions, only tradeoffs”.
  - Gain, Pattern shape, F/B, F/R, SWR, etc, all come with a price. Whack-a-mole.
- Let’s look at a 6 element 20m OWA Yagi on a 48’ boom.
- OWA: *Coupled resonators* formed by closely-spaced DE and D1 lead to a wide and low SWR response.
- 42 NEC Wires.



Optimize Models (7)

- This is the Variables sheet.
- Working in inches.
  - 1440″ = 120′ high.
- 13 variables, but only 10 are *optimized*.
- Height above ground and the positions of the REF and D4 are fixed (boom is fixed).
- AutoEZ will be adjusting the tip lengths.

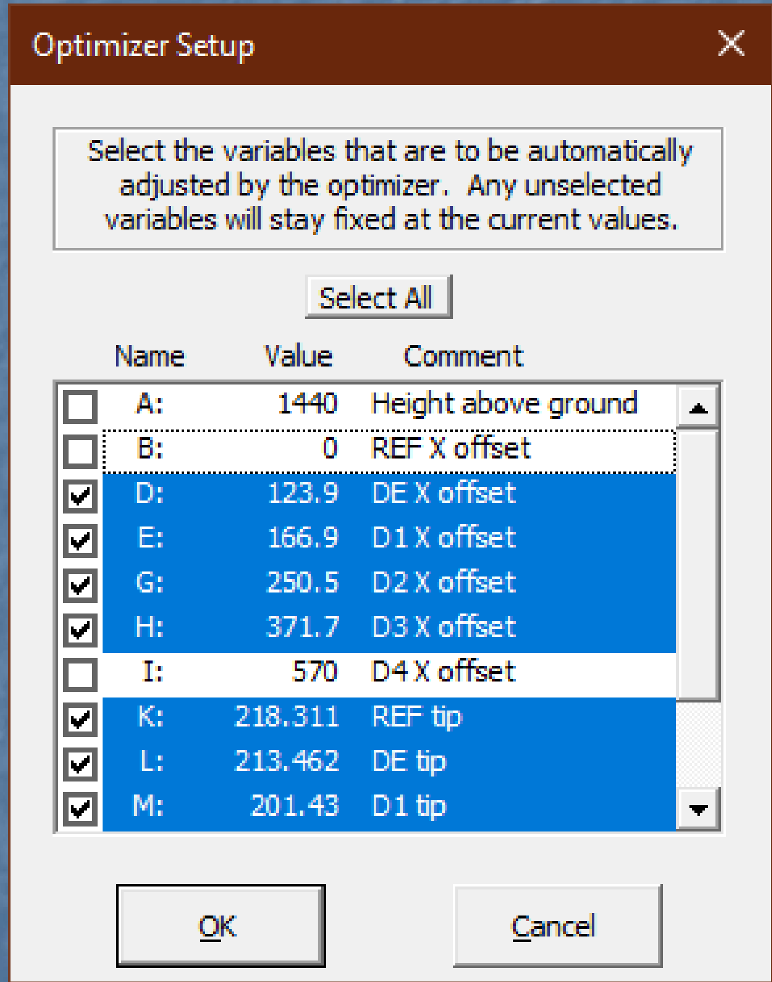
At 14.150 MHz number of segments = 318

Name	Value	Comment
TwoPi :	6.2831853	2 * PI()
WL.5 :	417.0619	½ λ
WL.25 :	208.5310	¼ λ
WL.001 :	0.8341	0.001 λ
WL or W :	834.1239	Inches
Freq or F :	14.150	Test Case Frequency (MHz)
A :	1440	Height above ground
B :	0	REF X offset
D :	123.9	DE X offset
E :	166.9	D1 X offset
G :	250.5	D2 X offset
H :	371.7	D3 X offset
I :	570	D4 X offset
J :		
K :	218.311	REF tip
L :	213.462	DE tip
M :	201.43	D1 tip
N :	194.313	D2 tip
O :	196.765	D3 tip
P :	189.179	D4 tip
Q :		

Change Units

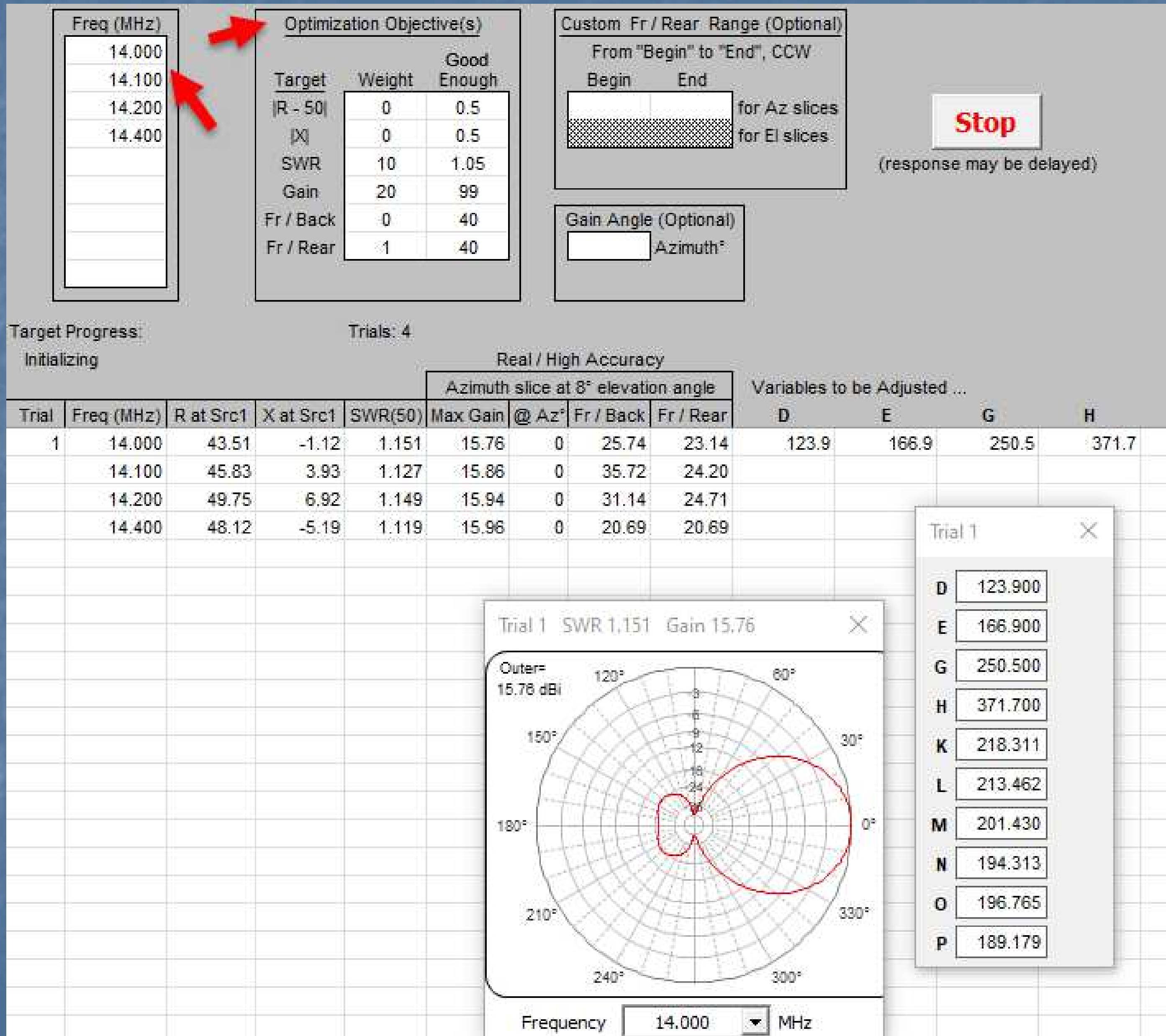
Optimize Models (8)

- Use the Optimizer Setup button to select what Variables should be adjusted.
- Unselected are fixed.
- Move to the Optimize sheet.



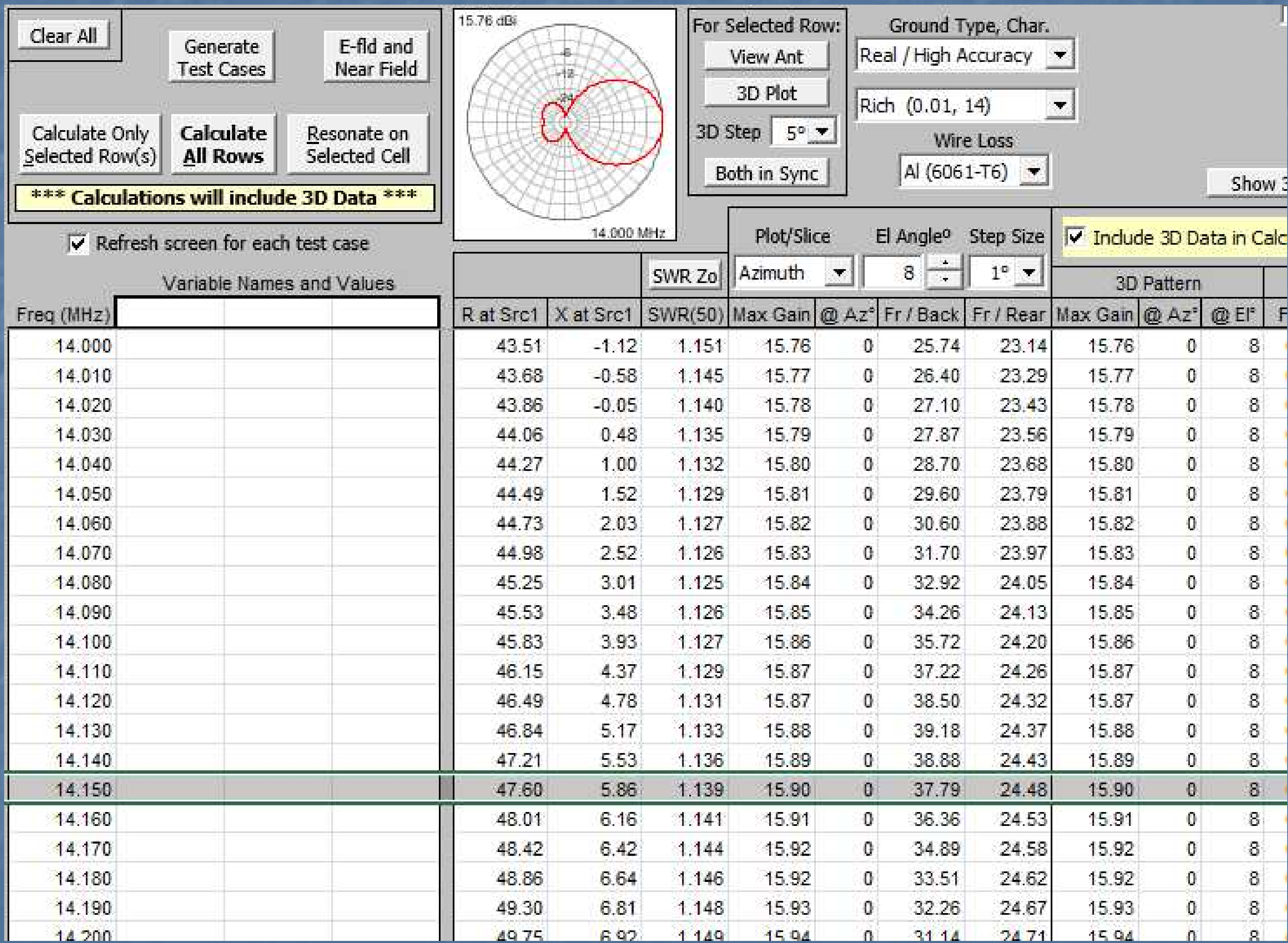
Optimize Models (9)

- The Optimize sheet sets up and runs the optimization.
- OWA is established by setting Frequency targets across the band.
- Targets have weights.
- Progress is updated in the table and pattern.
- It's fun if you are a geek or nerd!
- The weights tend to evolve as you get close to what you want across a set of optimization runs.



Optimize Models (10)

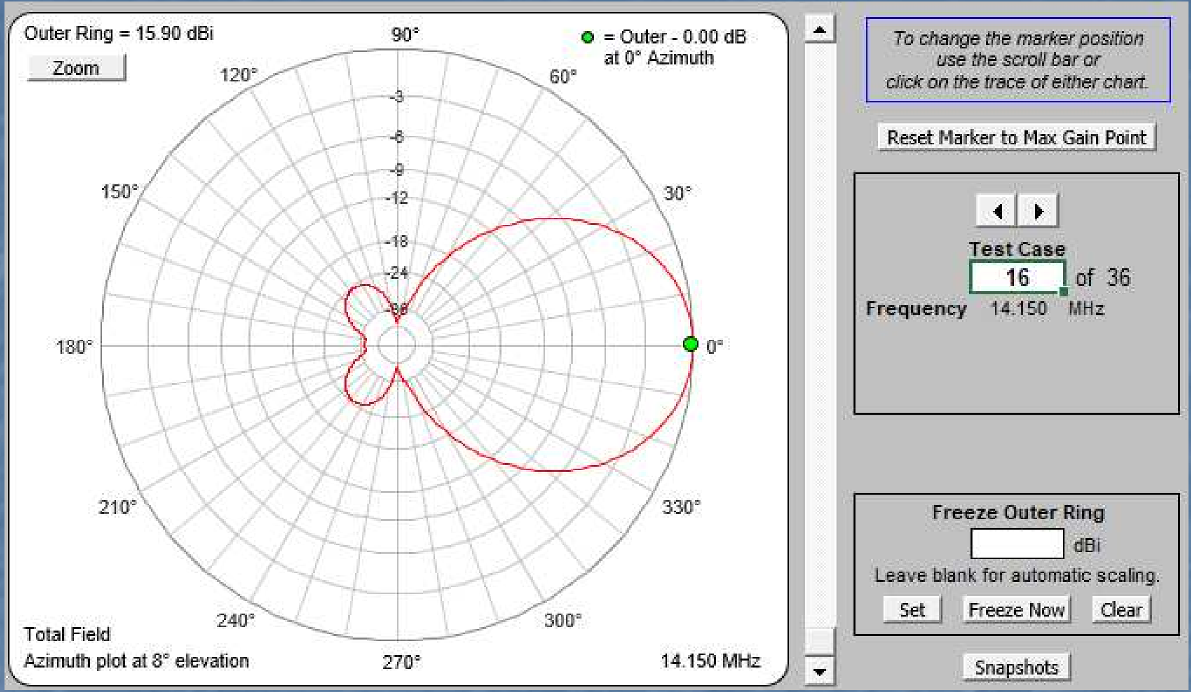
After the optimizer finishes it's time to revisit the Calculate sheet.

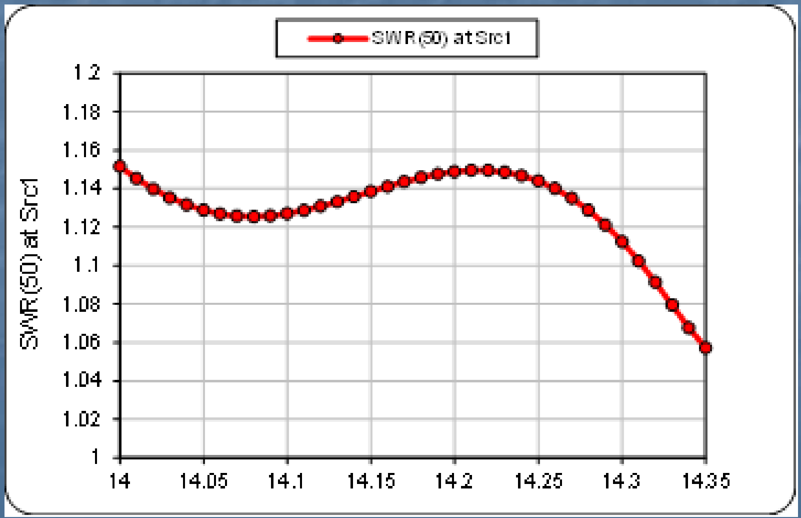


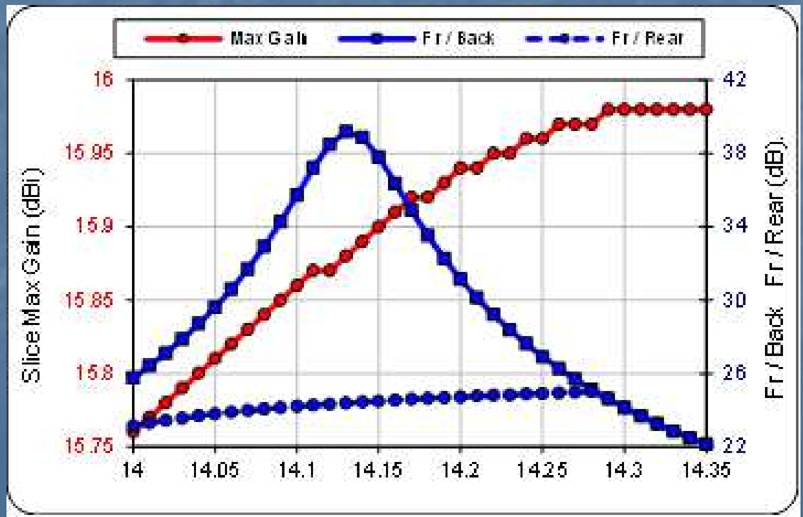
Freq (MHz)	R at Src1	X at Src1	SWR(50)	Max Gain	@ Az°	Fr / Back	Fr / Rear	Max Gain	@ Az°	@ El°
14.000	43.51	-1.12	1.151	15.76	0	25.74	23.14	15.76	0	8
14.010	43.68	-0.58	1.145	15.77	0	26.40	23.29	15.77	0	8
14.020	43.86	-0.05	1.140	15.78	0	27.10	23.43	15.78	0	8
14.030	44.06	0.48	1.135	15.79	0	27.87	23.56	15.79	0	8
14.040	44.27	1.00	1.132	15.80	0	28.70	23.68	15.80	0	8
14.050	44.49	1.52	1.129	15.81	0	29.60	23.79	15.81	0	8
14.060	44.73	2.03	1.127	15.82	0	30.60	23.88	15.82	0	8
14.070	44.98	2.52	1.126	15.83	0	31.70	23.97	15.83	0	8
14.080	45.25	3.01	1.125	15.84	0	32.92	24.05	15.84	0	8
14.090	45.53	3.48	1.126	15.85	0	34.26	24.13	15.85	0	8
14.100	45.83	3.93	1.127	15.86	0	35.72	24.20	15.86	0	8
14.110	46.15	4.37	1.129	15.87	0	37.22	24.26	15.87	0	8
14.120	46.49	4.78	1.131	15.87	0	38.50	24.32	15.87	0	8
14.130	46.84	5.17	1.133	15.88	0	39.18	24.37	15.88	0	8
14.140	47.21	5.53	1.136	15.89	0	38.88	24.43	15.89	0	8
14.150	47.60	5.86	1.139	15.90	0	37.79	24.48	15.90	0	8
14.160	48.01	6.16	1.141	15.91	0	36.36	24.53	15.91	0	8
14.170	48.42	6.42	1.144	15.92	0	34.89	24.58	15.92	0	8
14.180	48.86	6.64	1.146	15.92	0	33.51	24.62	15.92	0	8
14.190	49.30	6.81	1.148	15.93	0	32.26	24.67	15.93	0	8
14.200	49.75	6.92	1.149	15.94	0	31.14	24.71	15.94	0	8

Optimize Models (11)

- All the analysis tools previously presented are available.
- While OWA stretches the SWR bandwidth, gain and F/B curves remain traditional.







Optimize Models (12)

- SWR has increased value with solid state amps.
- Using the AutoEZ optimizer is a good way to make use of an aluminum tubing *boneyard.*
  - Booms and elements from this and that.
- Use software like YM (Yagi Mechanical) to determine taper schedules.
  - Determine wind speed ratings and ice loading limits.
- Fix the locations of the reflector and front director to accommodate the boom length available and turn loose the optimizer to fill in the middle. Make intelligent estimates of # elements/length.
- Congratulations, you are a Yagi designer!

AutoEZ Examples

- The online documentation at ac6la.com is excellent and extensive.
  - https://ac6la.com/aecollectiontoc.html
  - Many examples of popular antennas and topics.
  - Examples include discussions, files, and references.
    - These can be very helpful even if you never model!
  - Most of the examples serve as practical lessons in modeling.
    - Reminds me of the work of L.B. Cebik, W4RNL (SK).
      - See Cebik web site link in the References.

AutoEZ Examples (1)

AutoEZ: Collected Short Examples - Table of Contents

Other Software/Notes by AC6LA

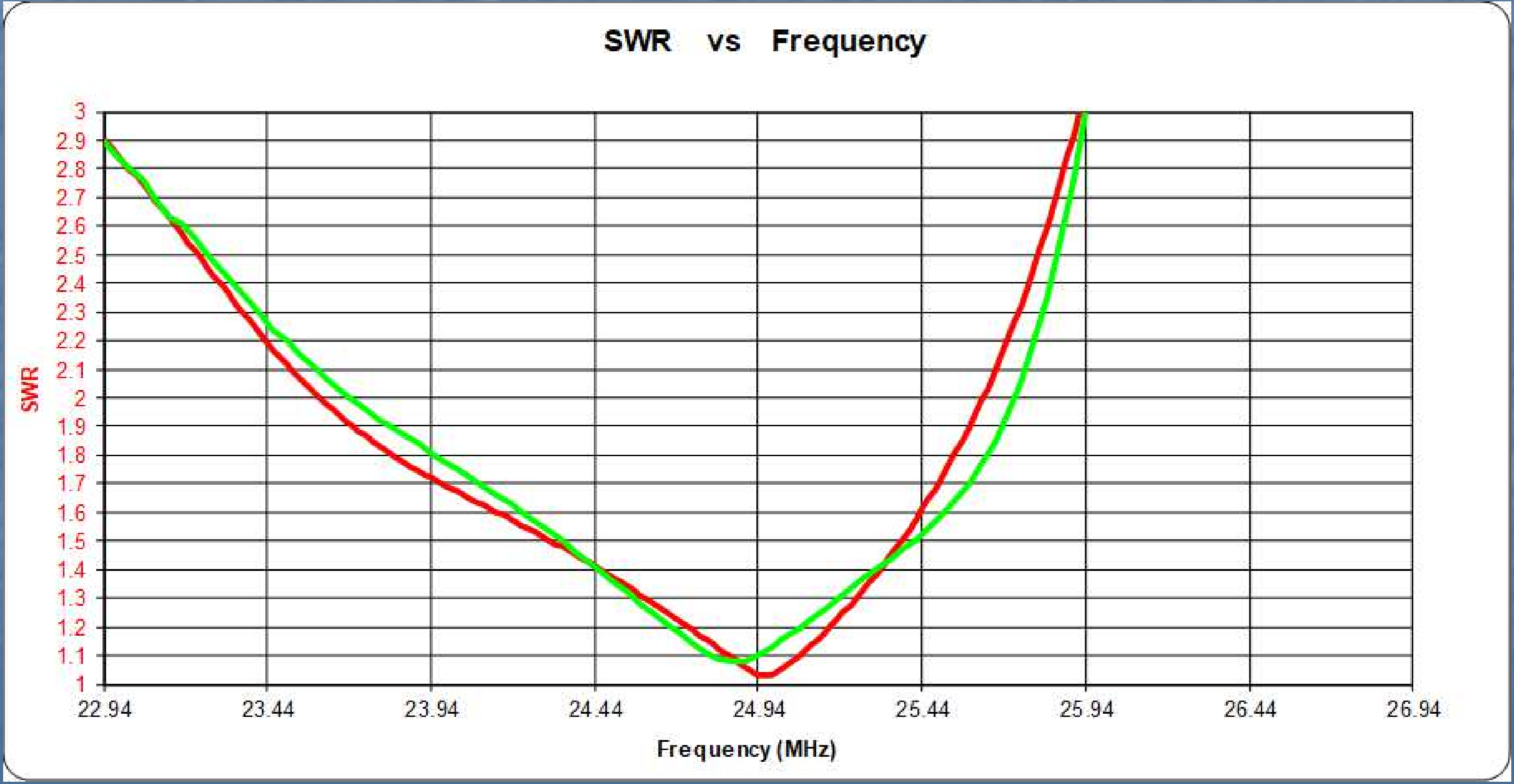
- AutoEZ (this presentation!)
- Zplots (plot impedance data from many sources)
- TLDetails (transmission line analysis)
- XLGTa (antenna gain/temperature ratio > 70 MHz)
- Feed2EL (2 element vertical array)
- MoxGen (Moxon Rectangle generator)
- Additional Loss Due to SWR (note)
- Transmission Line Math (note)
- And a few more….

Zplots

- Plots data versus frequency which can be computed from the *complex reflection coefficient* obtained from many sources, including models and measured.
  - Accepts the popular *Touchstone®* format (and .csv .data .txt).
  - The nanoVNA PC software can produce this format.
- Comparing antenna model expectations to measured results on a single graph simplifies evaluating the model/measured closeness.
- The complex reflection coefficient (S11 scattering parameter) can be converted into many parameters, including: SWR, Rs, Xs, |Z|, RL, Q, Ls, Cs, etc (can be used with VNAs, not just antennas).
- Zplots is contained in an Excel file.
- Zplots can compare several sweeps on one graph.
- Output can be a rectangular graph, table, or Smith Chart.

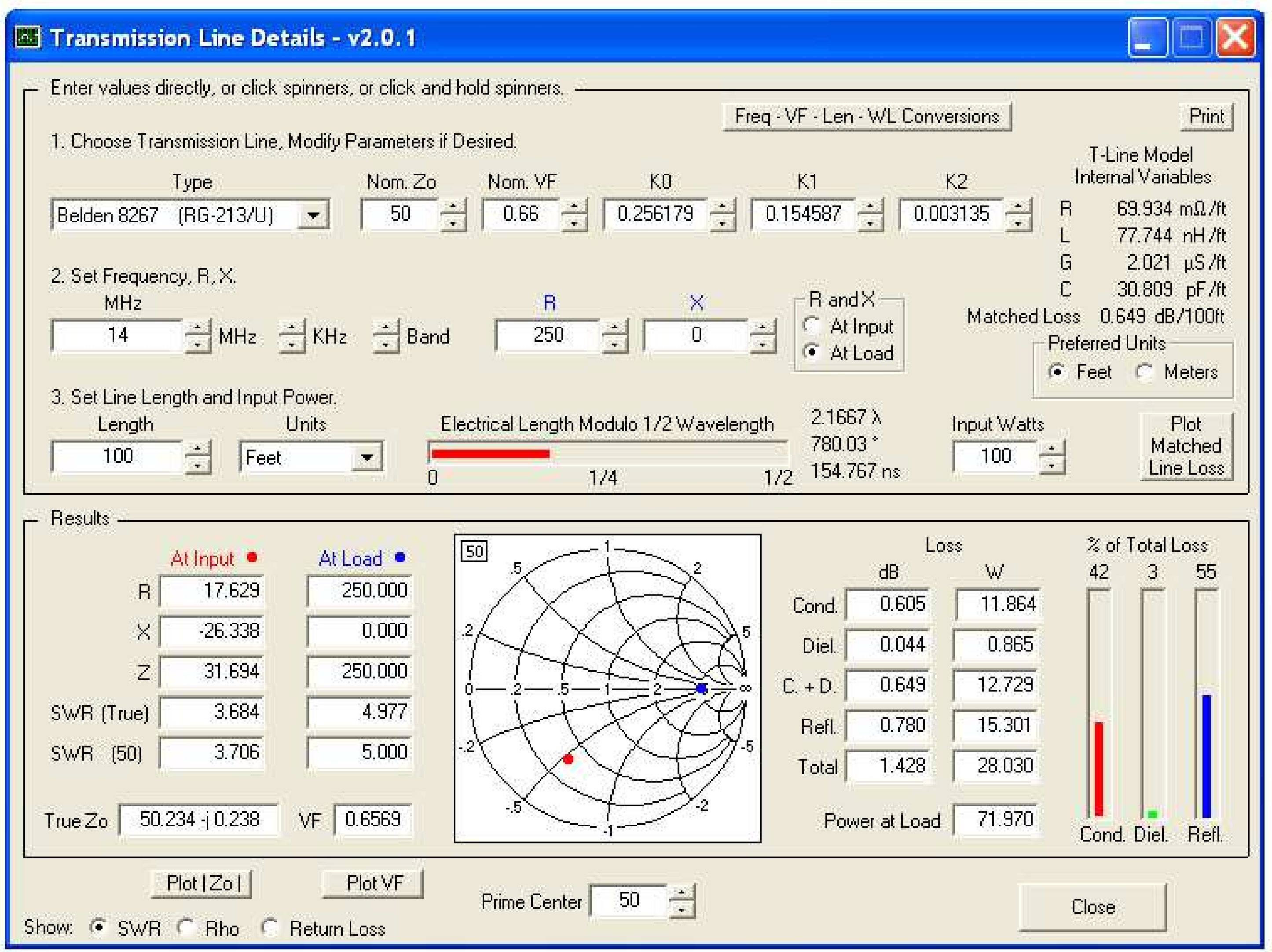
Zplots (2)

- Comparison of 12m Yagi model (red) to measured (green).



TLDetails

- Determine the impedance transformation through a section of TL knowing either the load or input impedance.
- Built-in detailed specifications for approximately 100 different line types (coax, open wire).



Conclusion

- This is a great time to get into antenna modeling!
- Very low cost for the top-of-the-line NEC tools.
  - NEC-4.2/5.0 + EZNEC Pro/2+ v. 7 + AutoEZ < $200.
- Very high functionality and performance.
  - All of these tools created/updated in the last 5 years.
  - AutoEZ is in active development.
  - PCs are screaming fast these days.
  - Lots of examples and models out there.
- NEC-5 appears to be most insensitive to a range of modeling guideline violations. NEC-5 is recommended by Roy, W7EL.

References

- https://ac6la.com (AutoEZ Internet Home)
- djm2150@yahoo.com (Dan’s email)
- ordy@seed-solutions.com (my email)
- Advanced Antenna Modeling by Marcel De Canck, ON5AU (SK): http://www.on5au.be/advanced_modeling_book.html
- Practical Antenna Models vol.1-3 by ON5AU: http://www.on5au.be/practical-antenna-modeling.html
- https://eznec.com/AutoEZ.htm
- https://eznec.com/misc/EZNEC_Printable_Manual/7.0/EZW70_User_Manual.pdf
- https://eznec.com/AutoEZ.htm
- QRZ Antenna Forums: https://forums.qrz.com/index.php?search/129677990/&q=autoez&o=date&c[node]=33&c[user][0]=293912
- Recent site with Cebik work: https://www.antenna2.net/cebik by Lonnie, K1LH.

AutoEZ Feature Summary

- Taken from the page: https://eznec.com/AutoEZ.htm

AutoEZ (Automated use of **EZNEC**) is a separate application that can enhance the power of **EZNEC** by allowing variables to be used in place of or in addition to any numeric value found in any part of an **EZNEC** model, such as wire End 1/End 2 XYZ coordinates, the number of segments in a wire, the magnitude and/or phase of a voltage or current source, the R+jX or RLC values in a load or L network, or any other place where a number might be used. Such variables can then be automatically set to a range of values by doing a "variable" sweep in place of or in addition to a traditional "frequency" sweep. Among the many **AutoEZ** features are:

- For existing **EZNEC** models, semi-automatic replacement of wire XYZ coordinate numeric values with variable names if desired.
- An **optimizer** with the ability to optimize on any combination of SWR, feedpoint R/X, 2D pattern gain, pattern front/back, or pattern front/rear, all at one frequency or over a range of frequencies.
- A **Resonate** button to automatically find the resonant frequency or adjust the dimensions of a model (such as dipole length or loop circumference) to achieve feedpoint resonance.
- **File translation**: In addition to reading **AutoEZ** (.weq) and **EZNEC** (.ez) format model files, **AutoEZ** can read NEC (.nec or .inp), K6STI AO and NEC/Wires (.ant), MMANA-GAL (.maa), DXE Yagi Mechanical (.stm), K7NV Yagi Stress (.ys2), K6STI YO (.yag), and N6BV Yagi for Windows (.yw) format models. Some restrictions apply for other than **AutoEZ** and **EZNEC** formats. Any of these formats can be saved in either **AutoEZ** or **EZNEC** format, hence **AutoEZ** can be used to do "format translations" for many models.

AutoEZ Feature Summary (2)

- Taken from the page: https://eznec.com/AutoEZ.htm

- Functions to create stepped diameter Yagi elements, loops (such as for quad antennas), radials, and wire grids. Variables may be used if desired.
- Functions to Move, Copy, Rotate, or Scale wires with the ability to use a variable to control the operation.
- Automatic temporary removal of all loss from the model (ground loss, wire loss, transmission line loss, etc.) followed by automatic calculation of 3D average gain as one way to judge the accuracy of the calculated results.
- Automatic way to vary the segmentation of the model and then plot the change in feedpoint impedance and 2D pattern metrics as a way to judge if the calculated results have converged.
- Dozens of illustrated examples from simple (show how a dipole feedpoint impedance varies as height above ground changes) to extremely complex (model a 4-square with hybrid coupler feed system as part of the model; model a SteppIR® Yagi with the wire ends "going around the trombone loops" as the frequency is changed). Model files are available for all examples to allow expanding on the scope of the example topic.
- One-screen at-a-glance collection of the most frequently used charts (feedpoint R and X; feedpoint SWR; 2D pattern gain, front/back, front/rear) where the X axis of the charts can be frequency or a sweep of a variable value.

AutoEZ Feature Summary (3)

- Taken from the page: https://eznec.com/AutoEZ.htm

- Automatic creation of High Pass Tee, Low Pass Pi, High Pass L, or Low Pass L impedance matching networks to be included with the model. Matching can be done for a single frequency or at multiple frequencies across a band or bands to see the range of component values required or to simulate an auto-tuner.
- Automatic creation of series section (Regier) or shunt (parallel) stub transmission line matching solutions.
- Built-in list of 100 different transmission lines to allow easy setting of frequency-agile Zo, VF, and loss field values for transmission lines.
- 2D radiation pattern chart in either polar or rectangular format. 2D plots can be for Total/Vert/Horz dBi or Far Field electric field strength or Near Field electric field strength.
- Near Field electric or magnetic field strength 3D chart.
- Custom chart to plot just about anything on the X axis vs just about anything on the Y axis. An Excel trendline can be added to do regression analysis on the charted data.
- Free Demo version available with all the features of the standard program except limited to calculating models with no more than 30 segments.

The **AutoEZ** user interface is very similar to that of **EZNEC** and the communication and data sharing between the **AutoEZ** and **EZNEC** programs is automatic and completely transparent to the user. For more information see the **Quick Start Guide**, various **Detailed Information** sections, and the **Collected Short Examples** all starting at the **AutoEZ** home page.

EZNEC in 2024

- Based upon reading the EZNEC web page:
  - https://eznec.com/ez70faq.htm
- There are now two EZNEC products:
  - Pro/2+ and Pro/4+. Both are free. Both are version 7 in terms of features. This is the latest version.
- The only difference between Pro/2+ and Pro/4+ is that Pro/4+ includes an internal NEC-4.2 engine, which will execute faster than the external 4.2 engine.
- Only previous EZNEC Pro/4 customers qualify for Pro/4+ because W7EL verified your NEC-4 license as part of purchasing Pro/4.
- New customers should download Pro/2+ and then purchase NEC-4.2 or NEC-5 licenses from LLNL as desired. Download engine after purchase.
  - Each is now $110.
  - Pro/2+ will work with external NEC-4.2 and 5 engines.
  - NEC-5 is only available as an external program engine.

EZNEC Calculating Engines

- Differences in calculating engines described on page 180 of the EZNEC 7.0.3 user manual.
- Table prepared by Dan, AC6LA.

Feature Availability vs Engine Choice
for EZNEC Pro/2+ and EZNEC Pro/4+

Feature	Calculating Engine: EZCalcD (NEC-2D)	EZCalc4D (NEC-4D)	External NEC-4.2	External NEC-5
Insulated wires	✓	✓	✓	✓
Buried wires		✓	✓	✓
Unconnected 1-seg wires with insertion objects	✓	✓	✓	
Split sources	✓	✓	✓	
Two ground media	✓	✓	✓	
Two ground media with MININEC ground	✓	✓		
Ground Wave calculation with MININEC ground	✓	✓		✓
Near Field calculation with MININEC ground	✓	✓		✓
Real/High Accuracy (GN2) ground	✓	✓	✓	
Real/Extended Accuracy (GN3) ground		✓	✓	✓

Notes:
1) Features not listed such as lossy transmission lines, L networks, and transformers are available with all engines.
2) The EZCalc4D engine is available only to existing EZNEC Pro/4 users.
3) External NEC-4.2 and/or NEC-5 engines must be purchased from LLNL.

AC6LA

Bio of AC6LA

- I asked Dan for any information about himself that he was willing to share. Here’s what he said:

- I got into ham radio when I was a junior in high school. My Elmer was Mel, W3ZQU, a WWII radio op vet. He owned a TV repair shop (and sold Setchell Carlson TV sets) so obviously I was never at a loss for parts for home brew projects. He also happened to be the father of my high school girlfriend. My Novice call was WN3LVE and he used to tease me mercilessly that I was the only Novice he knew who wanted to upgrade to a 1x4 call, W3LOVE. The girlfriend didn't last. Ham radio did.