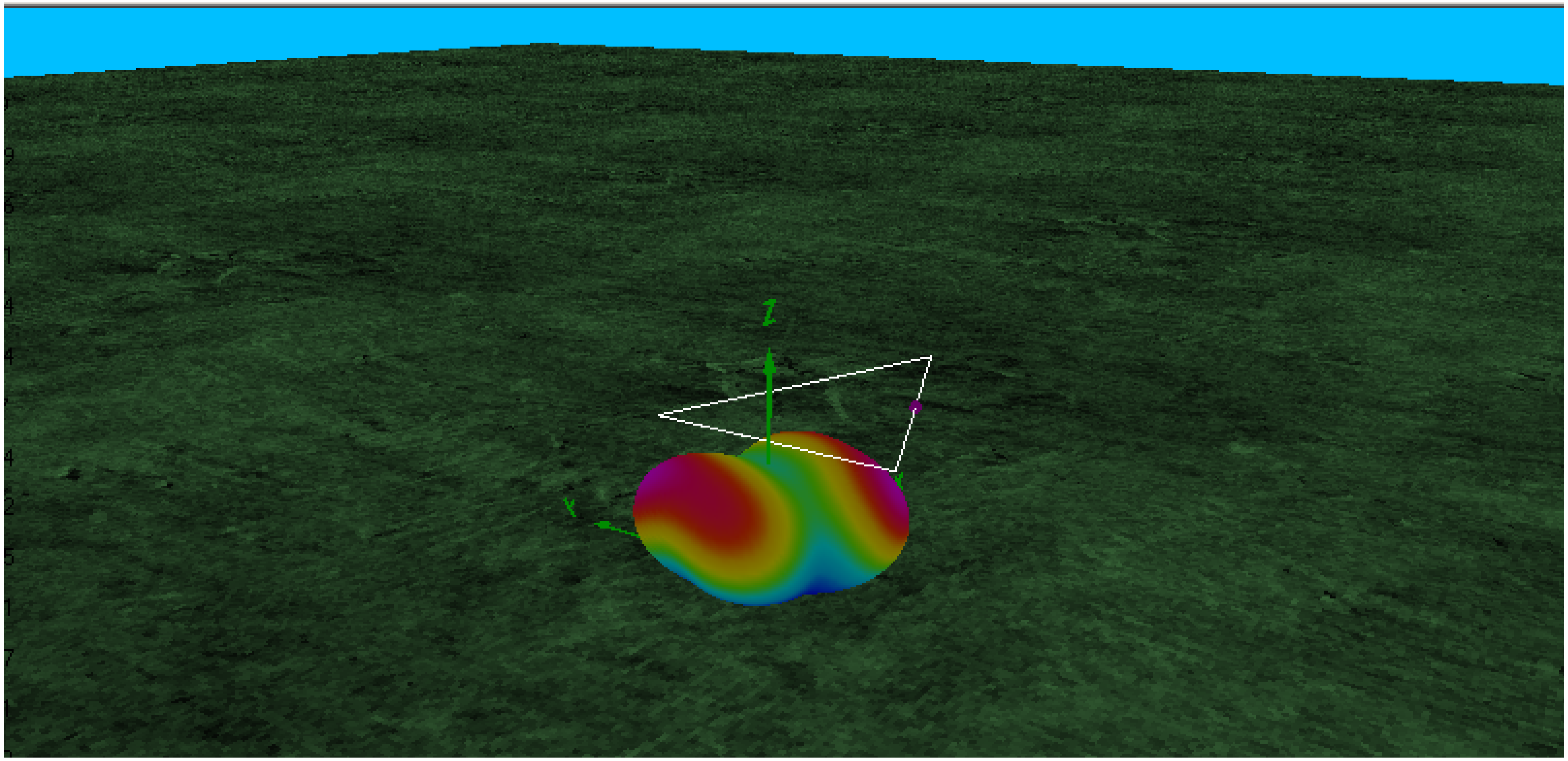
1 Antenna Simulation with 4nec2 by Arie Voors PA2B

Mike Masterson WN2A http://www.qsl.net/wn2a 11 October 2025



A 40 meter Delta Loop Antenna at 40 ft. elevation, Average Ground

2 Here in **FN24LQ,** the 20 and 30 Meter CW Bands are Wide Open in Late August!

But the guys back in Jersey want me to do a talk on Antenna Simulations…….

Oh Well...

3 **What is an Antenna?** It is a Transducer that converts Electrical signals into electromagnetic waves.

When it comes to Antennas, no design does it all. Just various designs to solve various needs. You choose based on your needs.

All *Functional* Antennas interact with their environment. Grounds, nearby objects affect VSWR, Patterns- and more.

Why Do Antenna Simulations??

To better predict what we may expect from the antenna before building it. It is *much* easier to do than perform *accurate* antenna range tests.

To better understand Antenna <> Environment Interactions.

Hams need antennas, no matter what band or mode you operate!

There is an old amateur radio saying:

"a dime in the antenna is worth a dollar in the transmitter any day"

What is 4nec2 ?

4Nec2 is an antenna modeling program that uses the NEC (Numerical Electromagnetics Code).

The NEC was created at Lawrence Livermore National Laboratory.

Arie Voors, PA2B created 4nec2 as the GUI or “Wrapper” to allow the *maximum* use of the NEC in an easy-to-use environment. This effort took nearly 20 years.

What can 4nec2 do?

After entering Antenna Geometry, the program:

calculates the Antenna Patterns
calculates VSWR, Return Loss, displays Smith Chart
calculates Radiation Efficiency, Average Gain Test, more

5 **4nec2 can take into account:**

Wire "Copper" Losses
Wire Insulation
Traps, Loads, Transmission Lines, Two-Port Networks
Single and Multiple Feed Points (multi-bay arrays, etc)
(each source or generator has *two* terminals)
Height above Ground
Ground Losses for various ground types
and lots more…

4nec2 can *Optimize* Antennas !

4nec2 interfaces with VOACAP propagation models to show coverage.

6 **How does 4nec2 do this??**

Basically by breaking the antenna wires into smaller "segments" like little dipoles...

Then the current in each segment is calculated..

Then the Electromagnetic Field is summed up from all these segments...

This generates the antenna patterns.

The math technique is "The Method of Moments"

The Price Is Right! Download free at https://www.qsl.net/4nec2/

Many YouTube Videos and Third-Party Documents available.

This program is a Windows executable,

Runs great on Linux with Wine.

Or on Mac with Parallels, etc

7 Our Focus is on *Simulation* of basic antennas, mainly 40 meters, multiband and 2 meters. We will look at antennas that are basic, easy-to-build antennas. It is not intended to compare one antenna against another, but this helps understand antenna simulations. Also the matter of *feedlines* will come up in the discussion, as these are part of any *antenna system*.

There is *No Way* we can cover all the capabilities of 4nec2!
This program has virtually all of the capabilities one would need for antenna simulation.
These are *simulations*, not real, measured data but the NEC model used here has been the industry standard.
There are many YouTube videos, PDF's etc available for 4nec2.

We will start with some "prepared" basic designs, and depending upon available time, we can modify and simulate these antennas "live" as we go. This will require several sessions.

So, what do we need to do??

The Basic Steps needed for each antenna simulation:

Entering the antenna model into the Editor
NEC Editor (new) or the Geometry Editor

Set up and Run the Simulation

Display Impedance, VSWR , Radiation Efficiency, AGT

Display Geometry and Patterns

Interpret The Results!

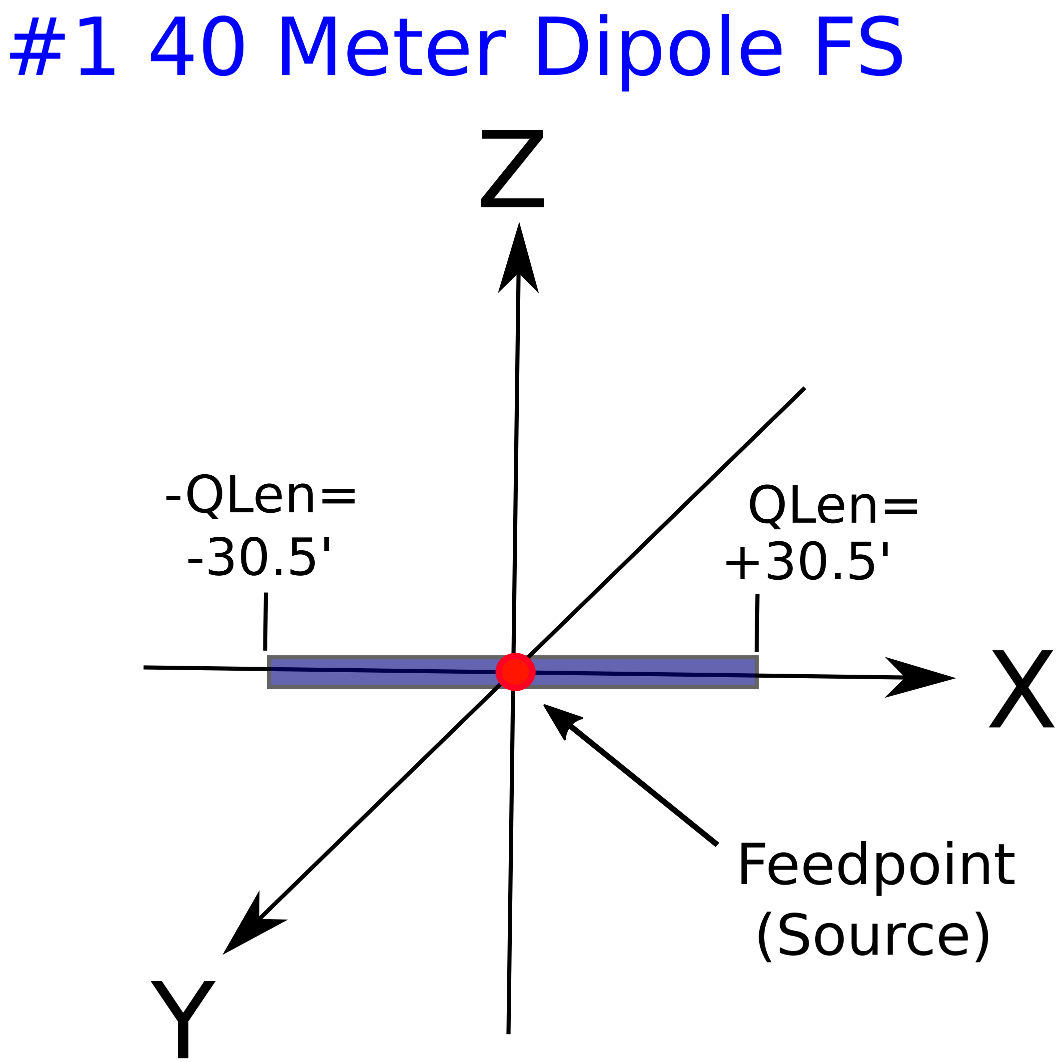
So, Let's do some Antenna Modeling!

	Example Antennas:	Filenames:
1	40 Meter Dipole, Free Space	*#1_40M_Dipole_FS.nec*
	40 Meter Dipole, Free Space, Ins	*#1_40M_Dipole_FS_Ins.nec*
2	40 Meter Dipole Horiz. above Ground	*#2_40M_Dipole_Horiz.nec*
	40 Meter Dipole Horiz, Ins. above Ground	*#2_40M_Dipole_Horiz_Ins.nec*
3	40 Meter Dipole Vertical above Ground	*#3_40M_Dipole_Vertical.nec*
4	40 Meter Ground Plane above Ground	*#4_40M_Ground_Plane.nec*
5	AK2F Delta “Loop Skywalker”	*#5_AK2F_Loop_1.nec*
6	Cage Antenna, two conductor	*#6_Cage_Antenna_2.nec*
7	Cage Antenna, four conductor	*#7_Cage_Antenna_4.nec*
8	N2XP End-Fed	*#8_N2XP_EFHW.nec*
9	2 Meter 2-Bay Folded Dipoles	*#9_2M_Folded_Dipole_2.nec*

Some, but not all of the above models have been built and used to some extent, but none rigorously tested. These are 4nec2 simulations only.

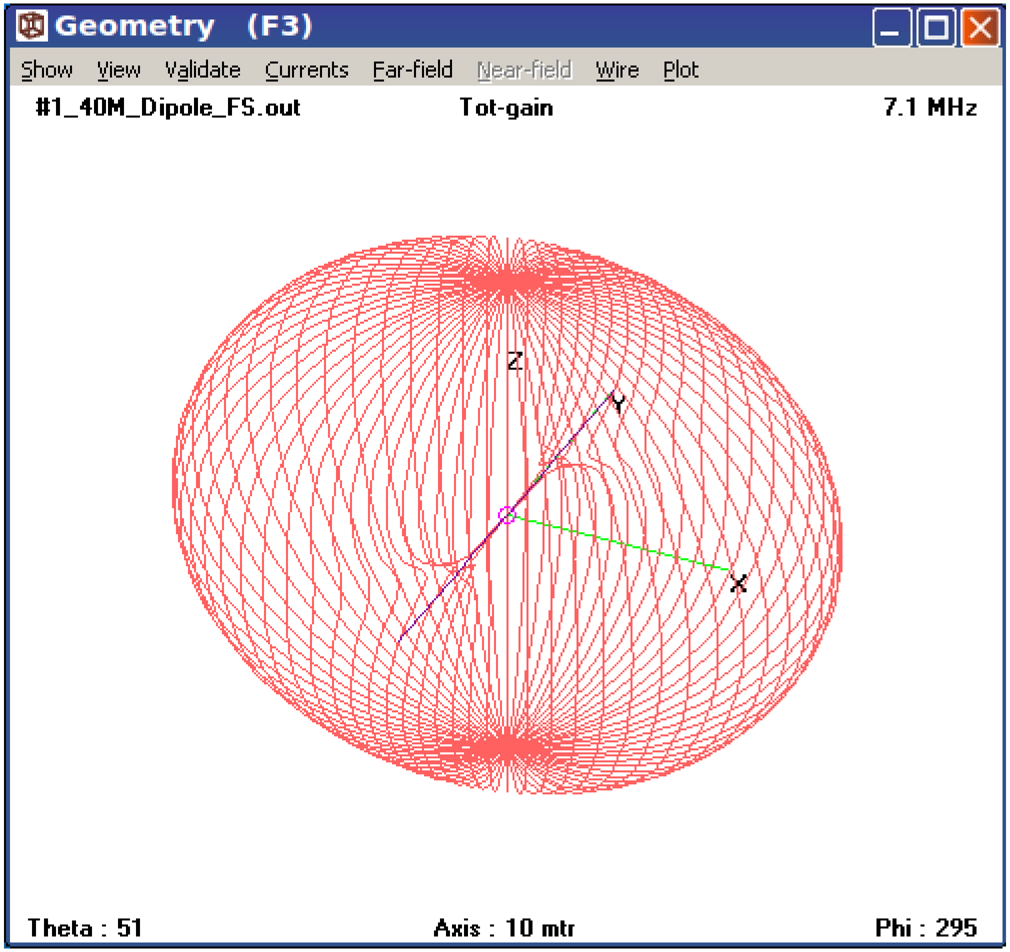
10 **#1 Dipole in Free Space (FS) (40 Meters)**

File Name: ***#1_40M_Dipole_FS.nec*** Wire:0.080” Ideal Conductor. Zc=50 Ω



11 *#1 Dipole in Free Space FS 40 Meters (continued)*

A simple loss-less dipole, no ground effect, no losses (yet). This is the most basic antenna configuration, but very efficient, as we will see.



BASIC STEPS:

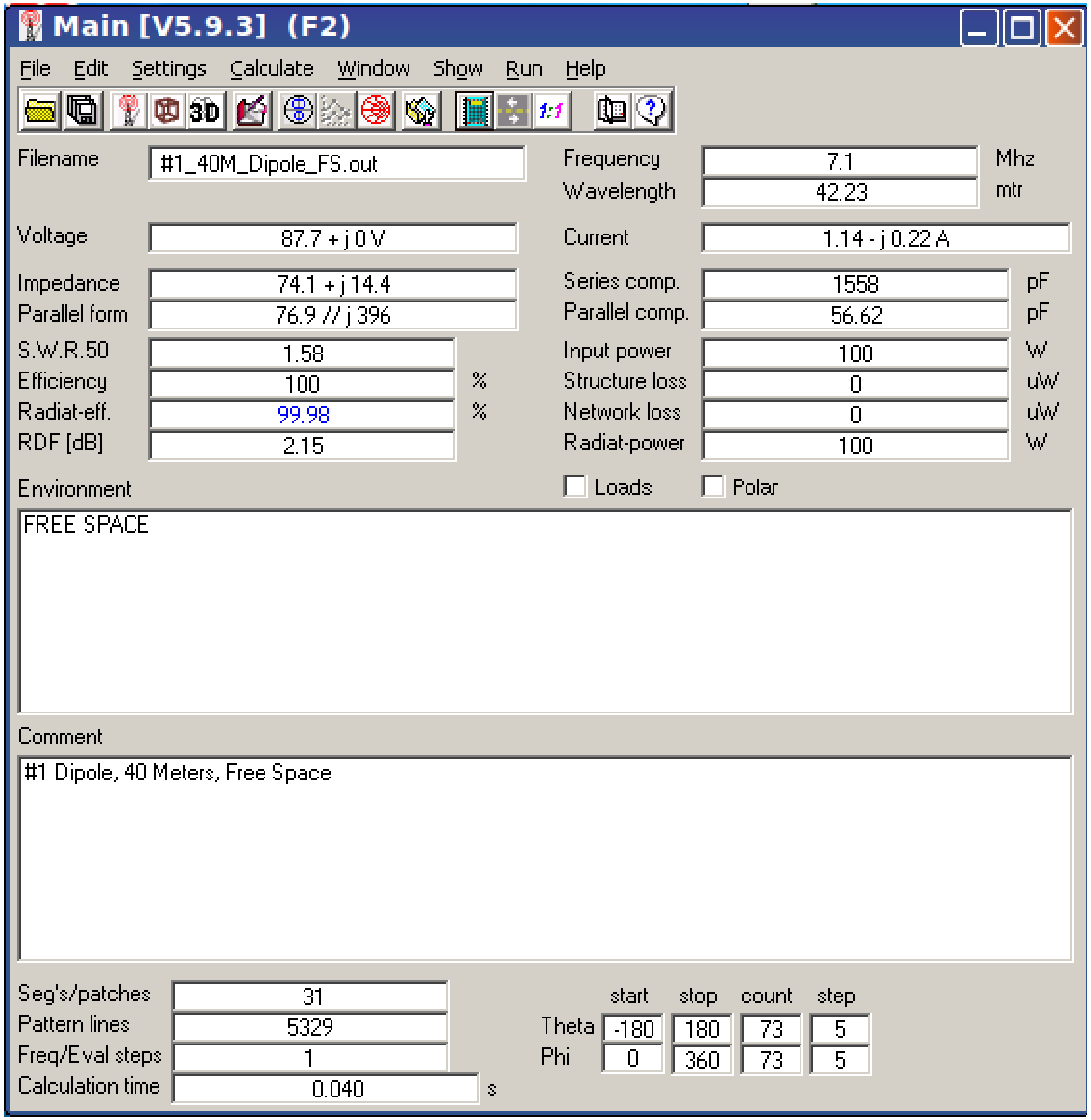
1) Main Window (F2):

This is the window that opens when you first launch 4nec2.

It displays some of the simulation data, if available.

You set the driving point impedance here (50Ω, 300Ω, 450Ω etc)

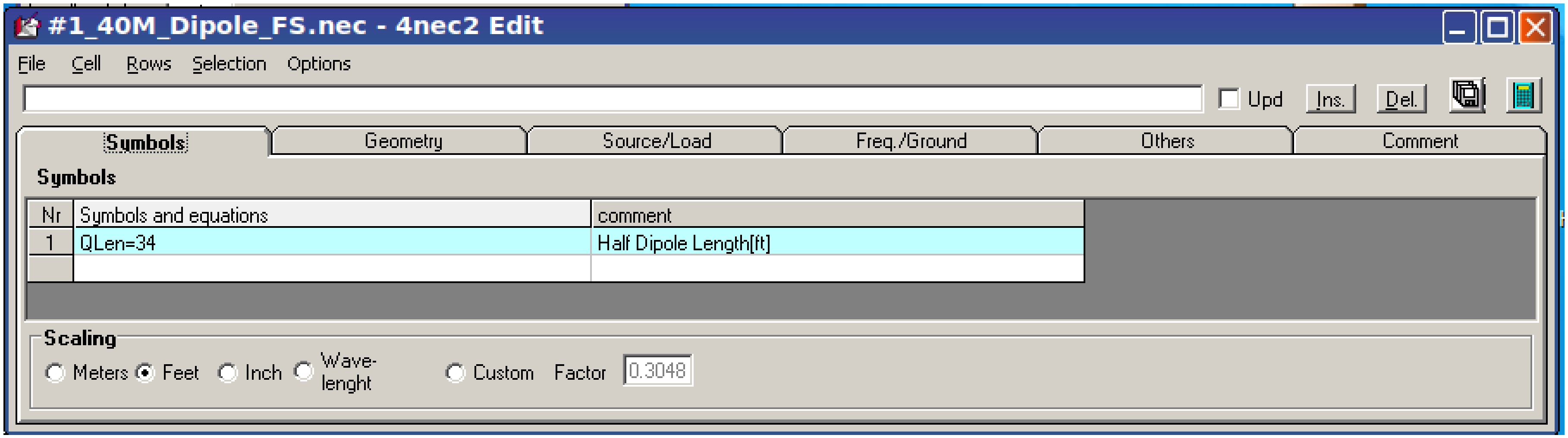
Main window allows you to generate simulations by clicking the icons on top.



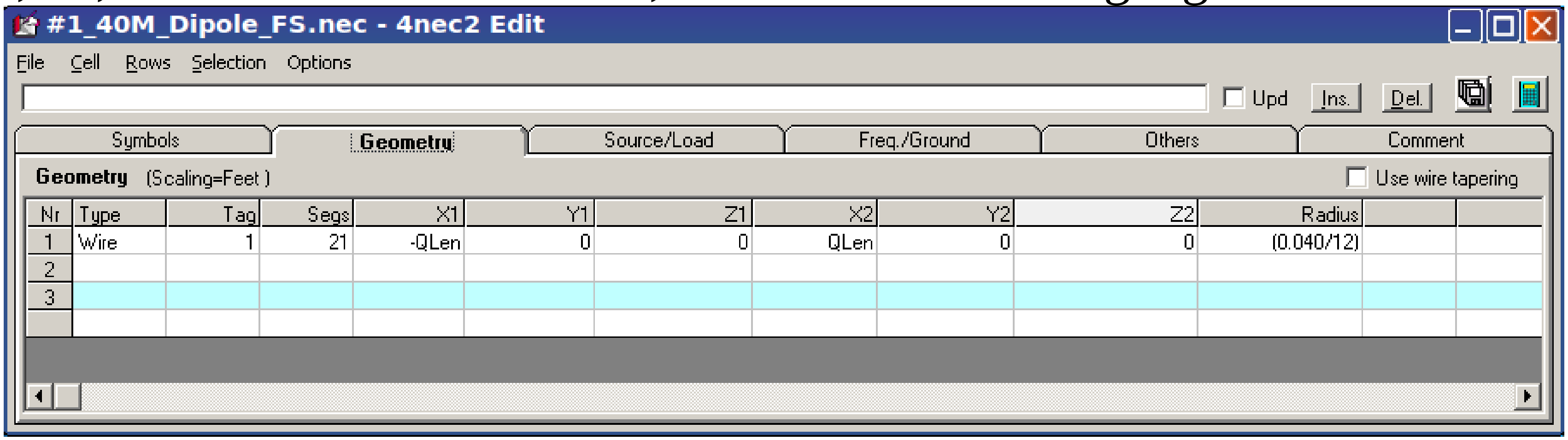
13 **2) Edit Window (F6).**

This is where the most of your model data goes, and where your antenna is defined in its environment. There are several Edit Window choices, that can be selected from the Main Window>>Settings.

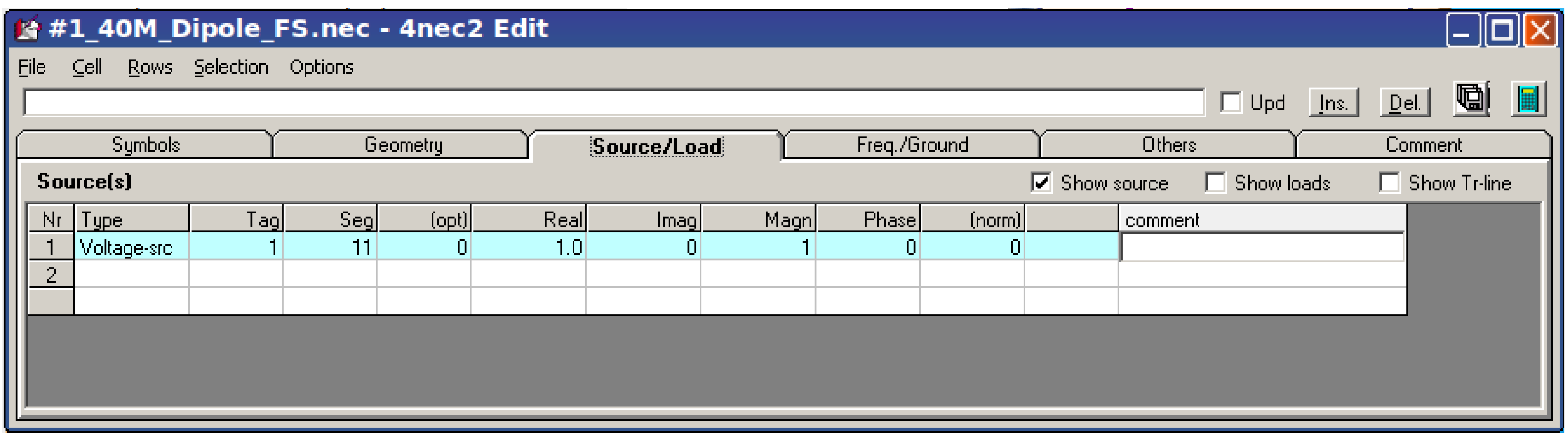
NEC Editor (new). This is the one that I use because all the details can be entered here. This is a powerful tool for creating antenna models. The different tabs (Symbols, Geometry, etc) contain all your model data. As you enter data, you can better visualize what you are doing when after you save the Edit window (floppy icon), then click on the Geometry Window (F3). This Symbols Tab is where we define *variables*, which can be used in multiple places in a model, saving time and effort. Items like wire sizes ,etc.



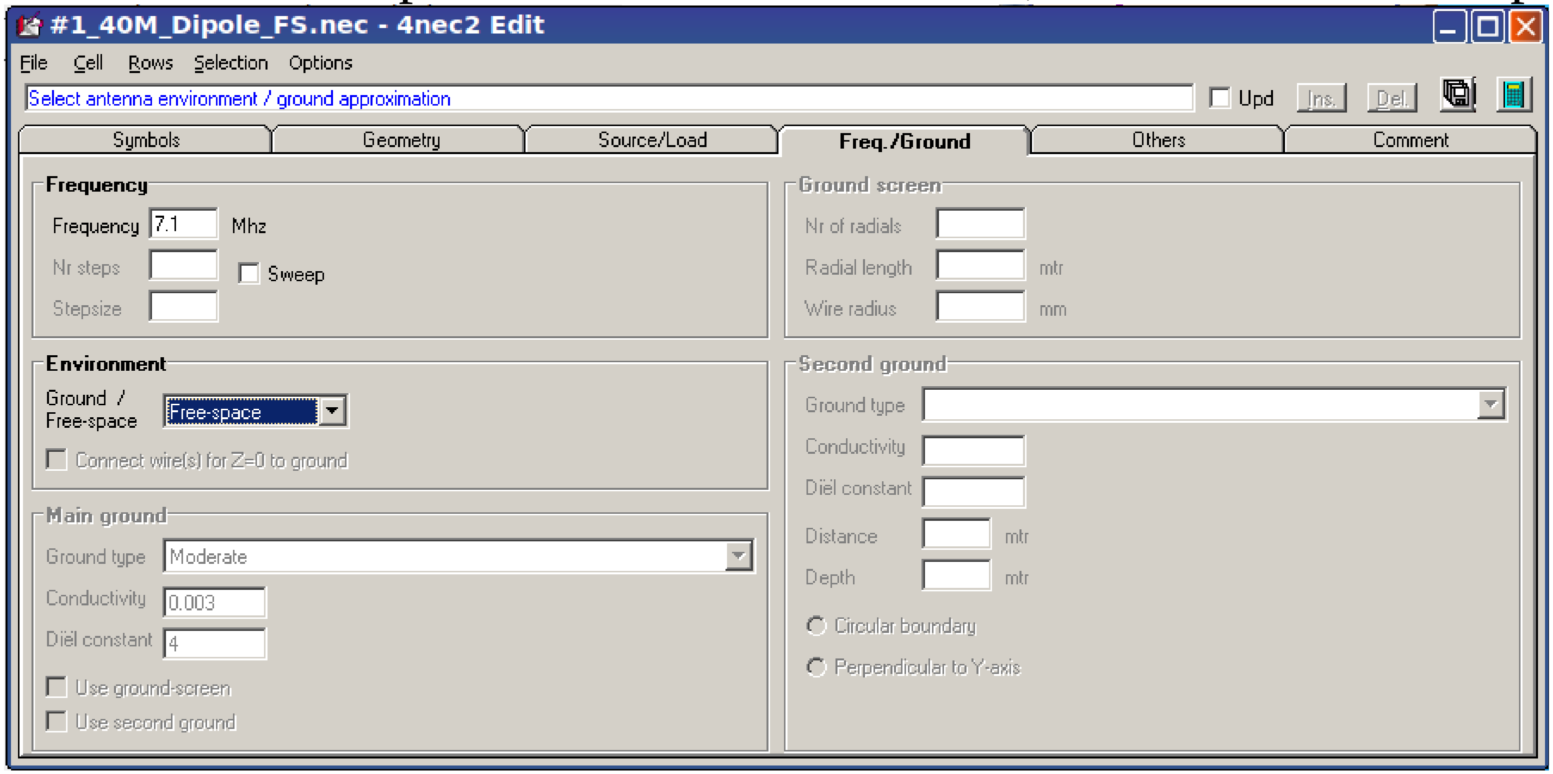
14 Next, the Geometry Tab, where you enter Wire info. Define a Tag number, Enter number of segments for this wire, dimensions in X1,Y1,Z1 and X2,Y2,Z2 Cartesian coordinates, and the wire radius/gauge.



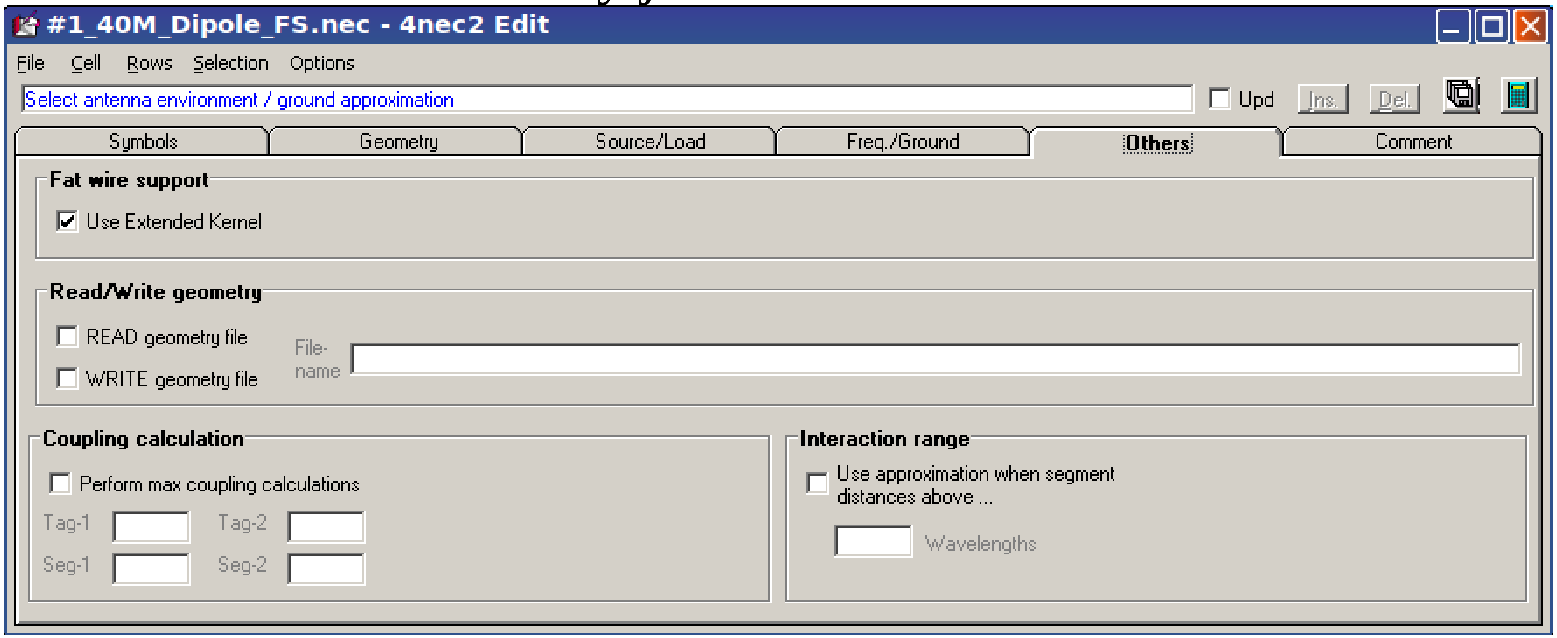
The Source/Load Tab is where we define the feedpoint(s). This is done by entering which tab and the segment that the feedpoint is located at.



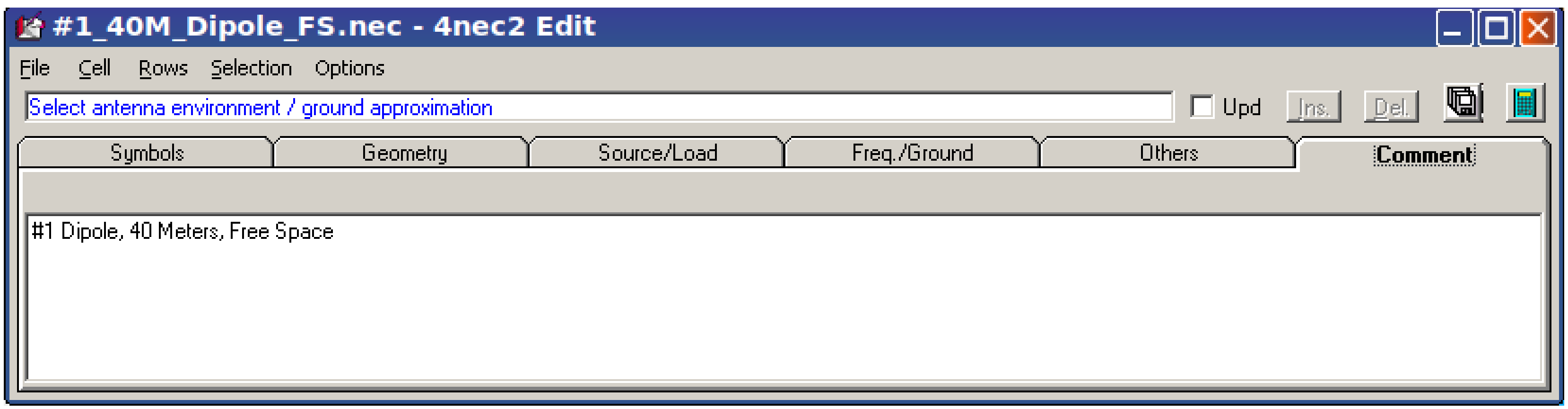
15 The Freq/Ground Tab is where the default frequency is entered and what ground conditions are present in the environment, unless it is in free-space.



16 The “Others” tab is normally just set to allow use of the Extended Kernel.

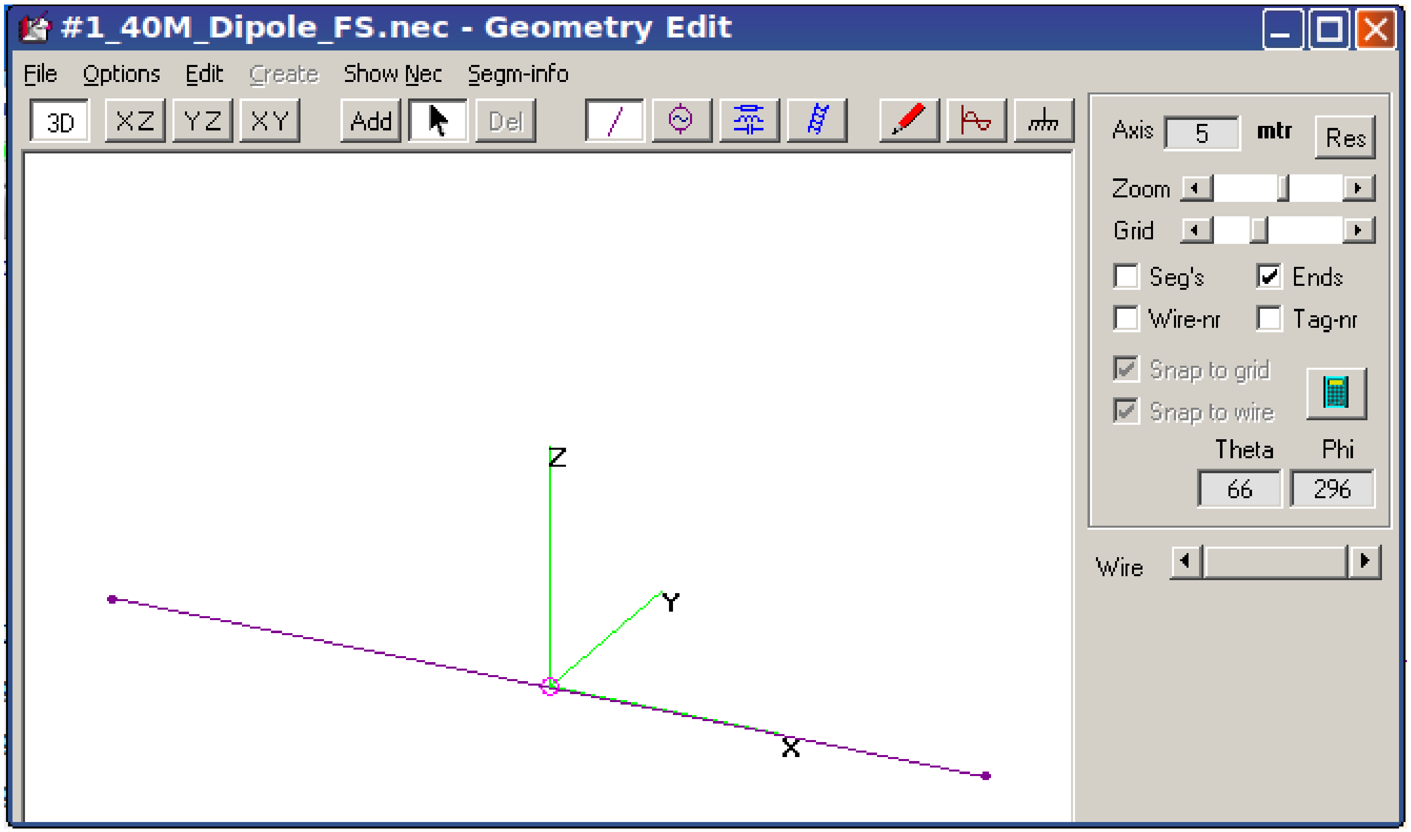


Last on the Edit Window is “Comment”



17 Alternately, the **Geometry Edit**. This may be better to help visualize the antenna you are creating if you elect to use it instead of the previous editor, **NEC Editor (new)** The Geometry Edit may be initially simpler, but as more wires (elements) are added, it can get crowded and more difficult to read.

At this point, after your data is entered you can press the "Calculator Icon" found on either Editor or (my preference) the Main Window.



Hints and Kinks:

1) Starting at the Main Menu, it is best to check your various settings!

   Settings>>Char-Impedance. Your old values you used previously may be still in there. Verify if you want 50Ω, 300Ω, 450Ω or whatever.

   Settings>>NEC Editor (new) *or* Settings>>Geometry edit select the editor you want to use.

   Settings>>Auto Segmentation. Checking this makes the program assign a number of segments per halfwave. You may want more or less, or as I do instead, define the number of segments in the editor.

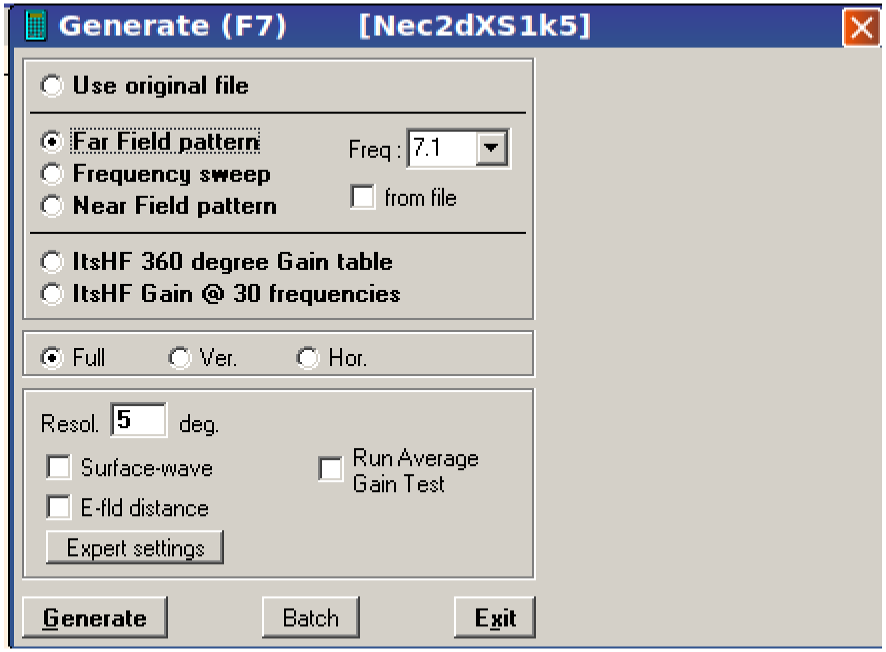
   There are other settings that should be verified.

2) Be careful entering data into the editor, especially the Geometry Tab. Sometimes extraneous entries may appear, resulting in an error or unexpected results. Did you click the mouse in a row or column where it should not have been, or add a wire with no coordinates?

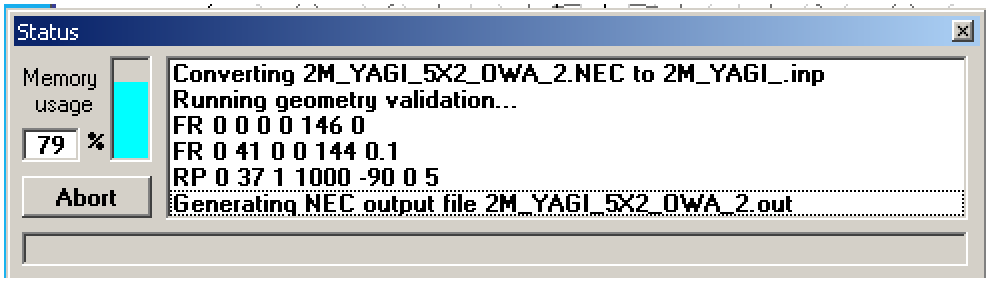
3) After you define the antenna in whichever Editor you use, I recommend saving the editor data by clicking the “Floppy” icon, then *close* the Edit Window. You should do this before running the simulation.

4) Antenna Gain: dBi (isotropic) = dBd (dipole) +2.14. This is in free space conditions, not over ground. 4nec2 uses dBi, so keep this in mind.

19 After you click on the “Calculator Icon” this window pops up:



And after adjusting the simulation settings, Freq, etc you can click on “Generate” which starts simulation. A “Status” window briefly pops up.

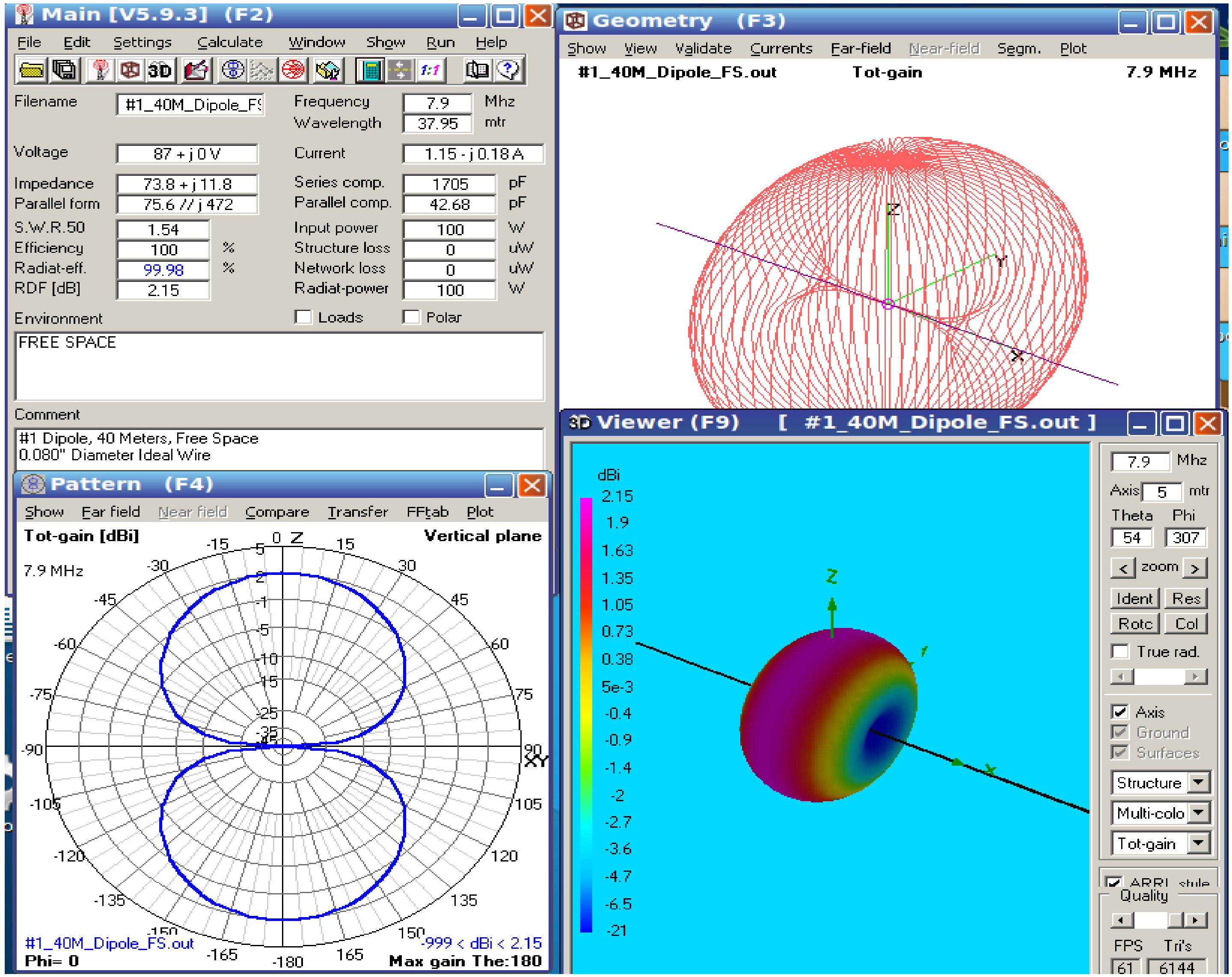


20 And some Results of *#1_40M_Dipole_FS.nec* can now be viewed:

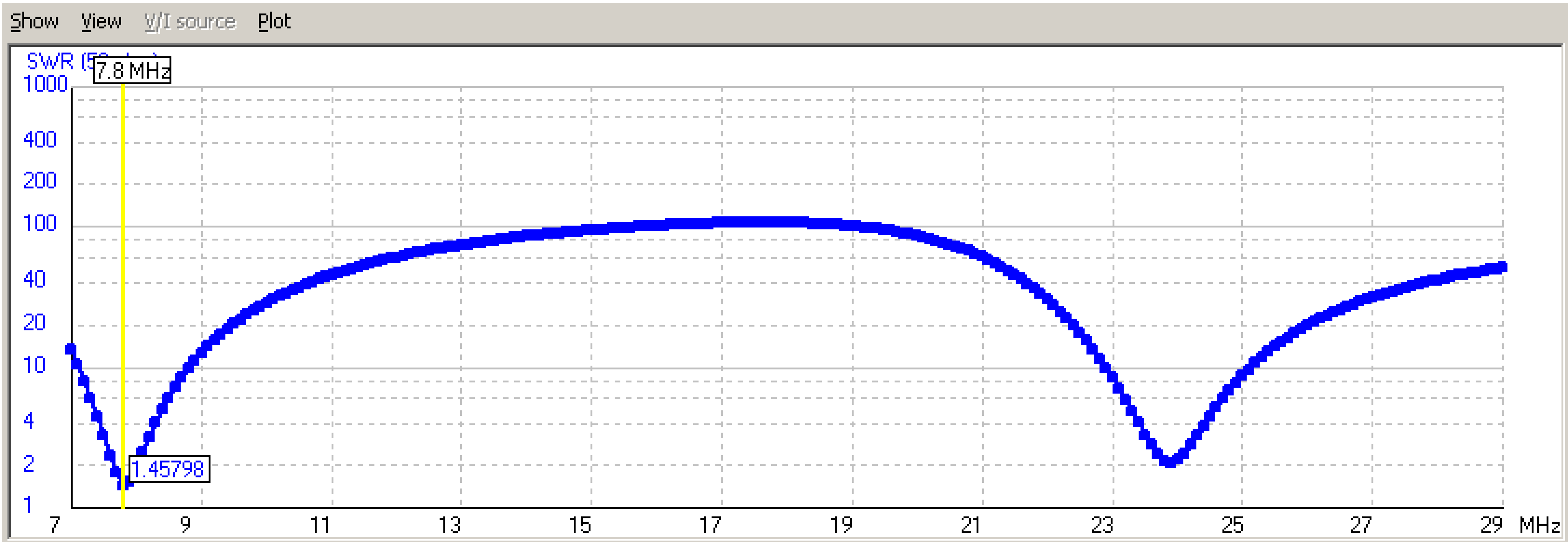
SWR 1.58:1 in 50Ω system. Radiation efficiency >99.9%, +2.15dB gain over isotropic or dBi.

Typical Dipole in Free-Space (FS) Pattern.

Ideal Free Space conditions with ideal (perfect) wire.

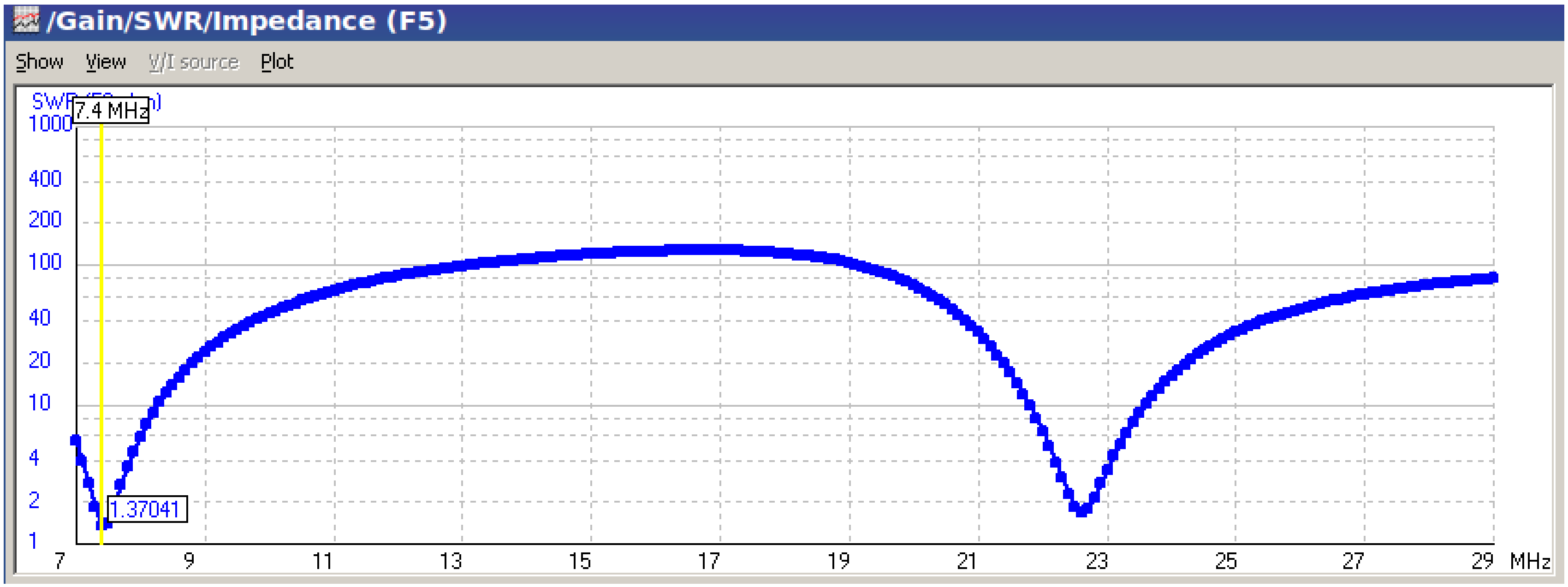


21 On the Generate Window (F7), if we opt for a frequency sweep of 7 to 30 MHZ we can get Line charts (F5), with VSWR data:



You see our dipole *#1_40M_Dipole_FS.nec* resonates at 7.8 MHz.

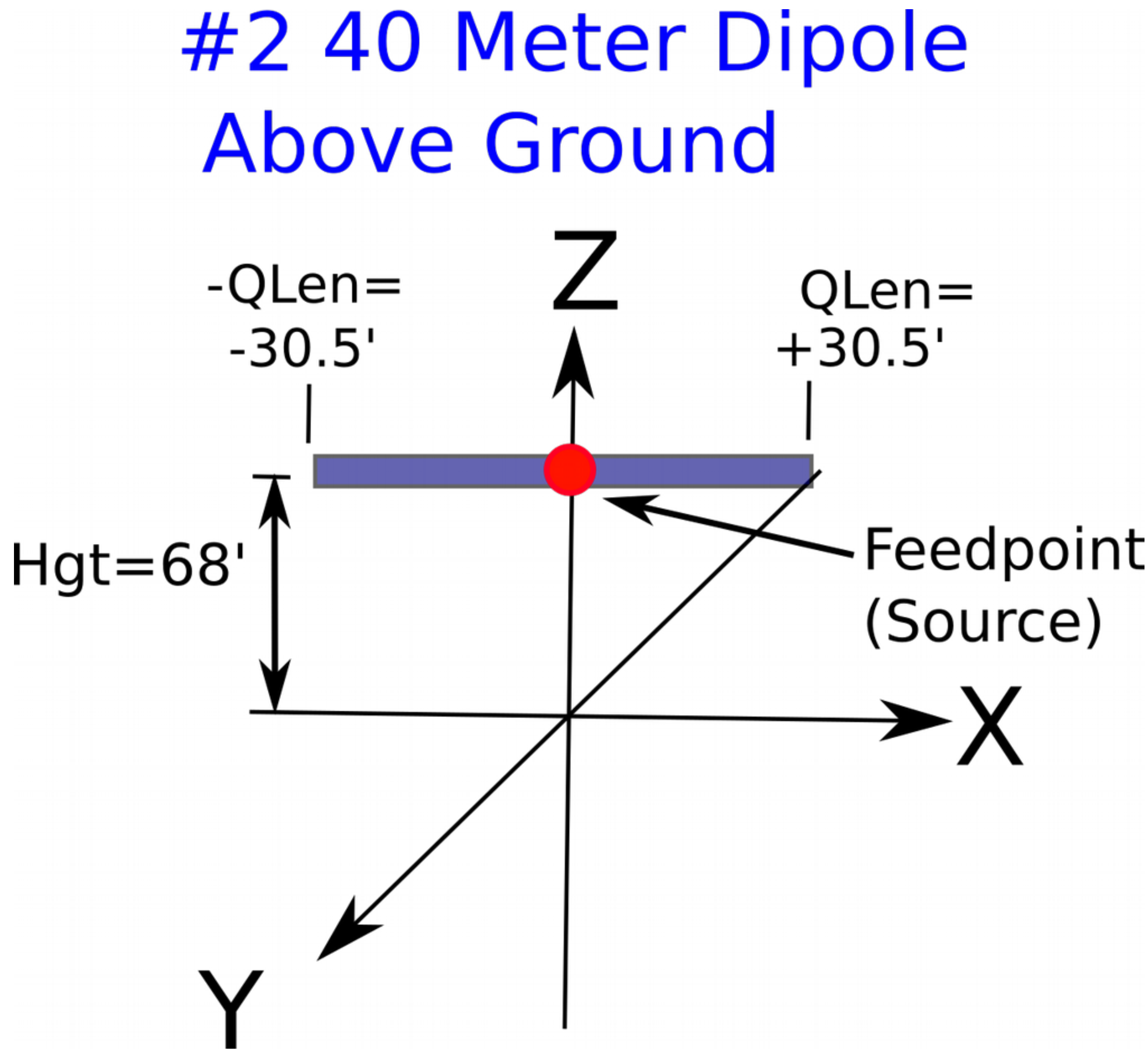
22 Let’s take our *#1_40M_Dipole_FS.nec*, change the file name to *#1_40M_Dipole_FS_Ins.nec*, modify it by including an PVC jacket on the wires. We will put 0.032” PVC(soft) on it. The resonate frequency drops from~7.8 to ~7.4 MHz for an approx 5.1 % drop in the frequency. Dielectric loading of the wire. These *free space* dipoles show >99.9% efficiency.



Problem is, these are *ideal* antennas. But for the remainder of this paper let’s model above Real Ground, with copper (unless otherwise noted). This is like what we actually have as amateurs.

23 **#2 Horizontal Dipole above ground**

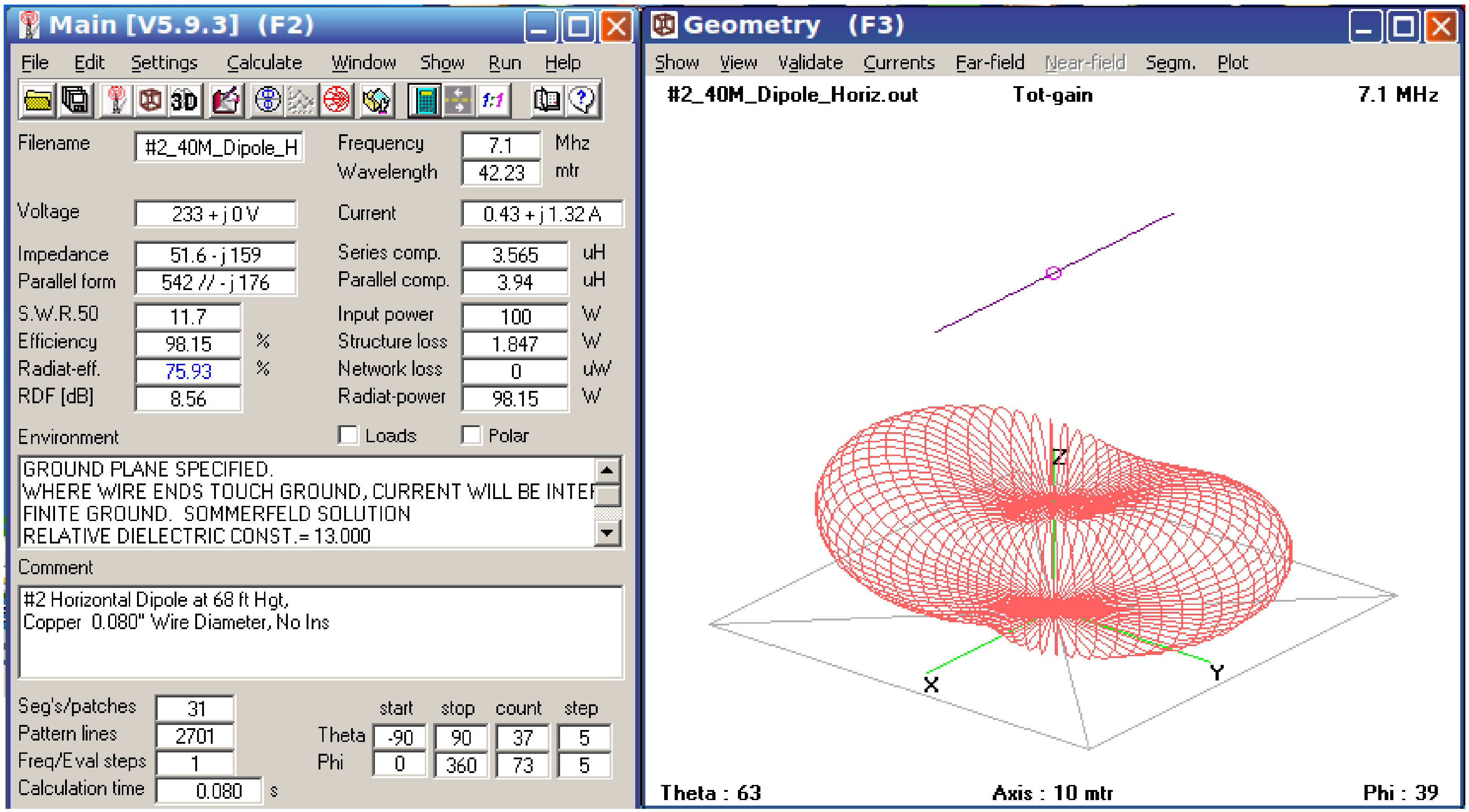
#2_40M_Dipole_Horiz.nec Zc=50Ω



#2 Horizontal Dipole above ground (continued)

Model: 68 ft above Real, Average ground, 0.080”dia copper wire.

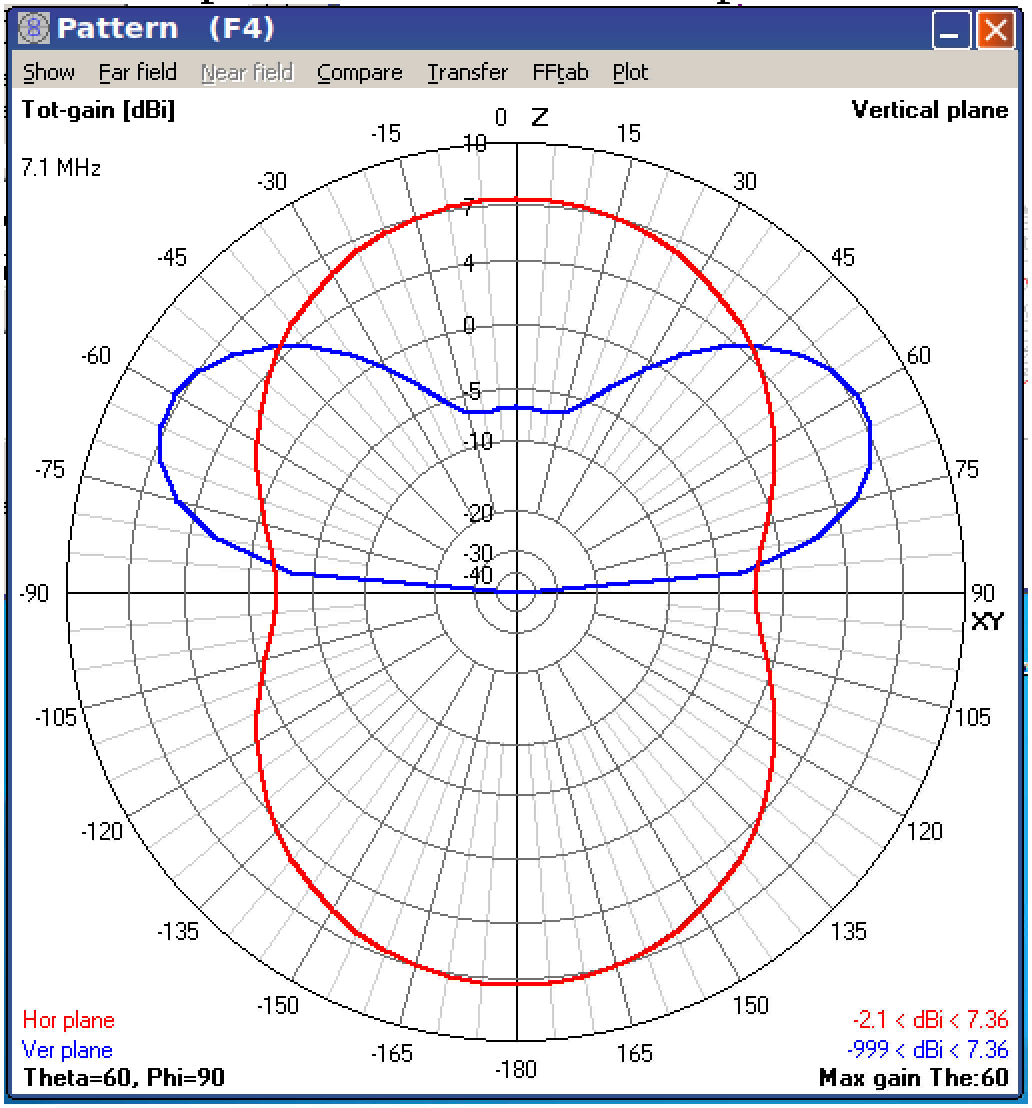
Note: Height is λ/2, Radiation efficiency still good at ~75%. Less height λ/4 reduces the efficiency only slightly, but the radiation angle goes up.



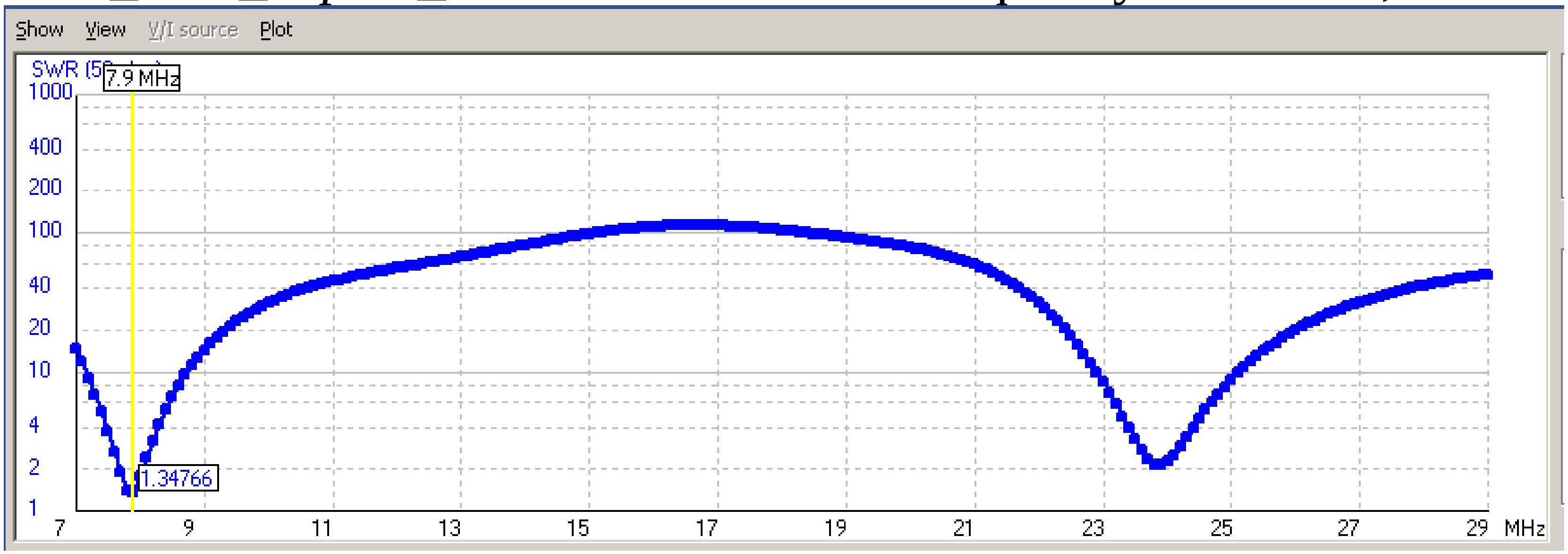
25 #2 Horizontal Dipole above ground (continued) The Antenna Pattern looks as expected. Horizontal plane in red. Vertical plane in blue.

Gain is ~7.36dBi at 30 degrees above horizon.

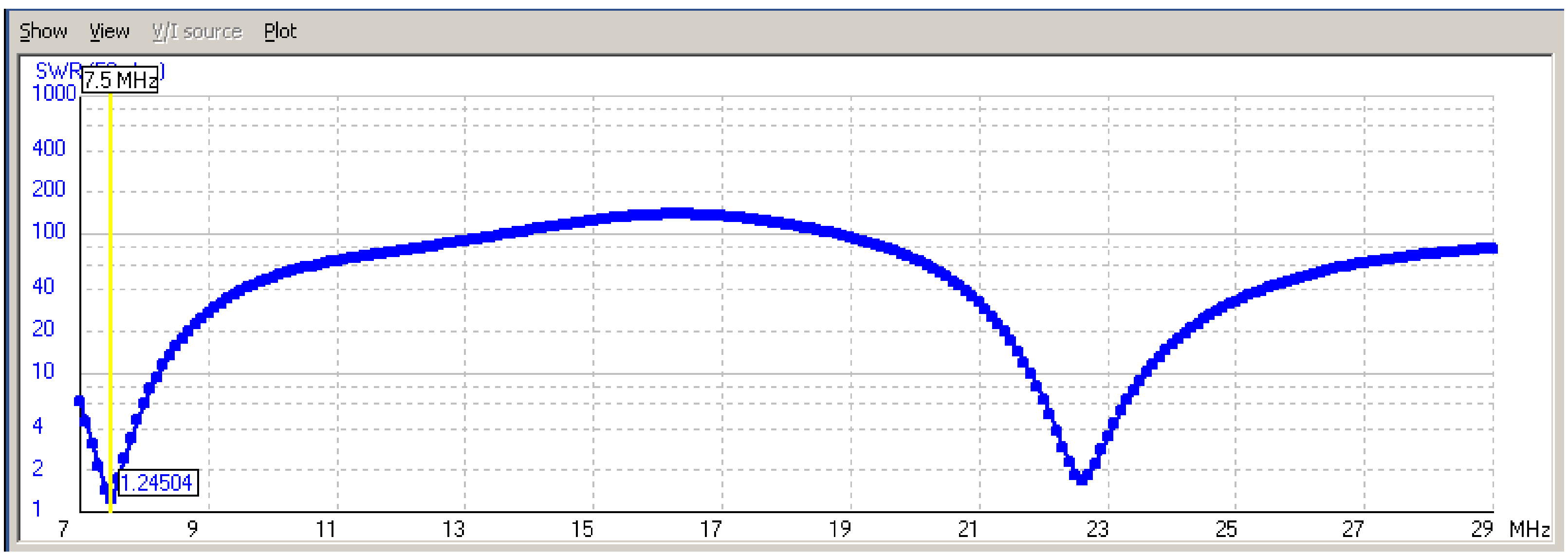
This is the usual that we will see at λ/2 at 7 MHz, approx 68 ft.



#2_40M_Dipole_Horiz.nec Resonate Frequency ~7.9 MHz, bare wire:

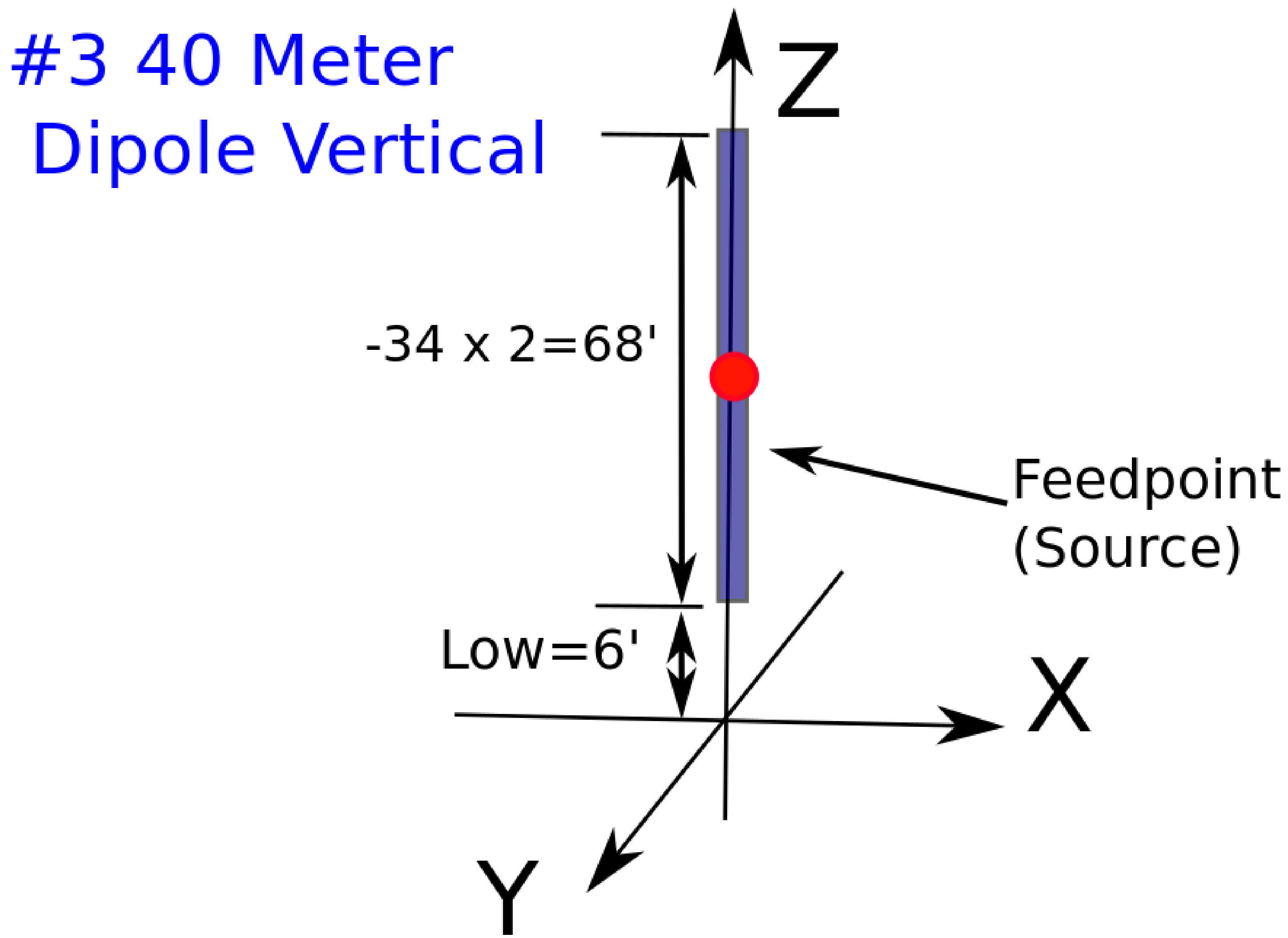


#2_40M_Dipole_Horiz_Ins.. Let's apply a 0.032" thick PVC (soft) jacket. A drop from 7.9MHz to 7.4MHz, about 5.1%



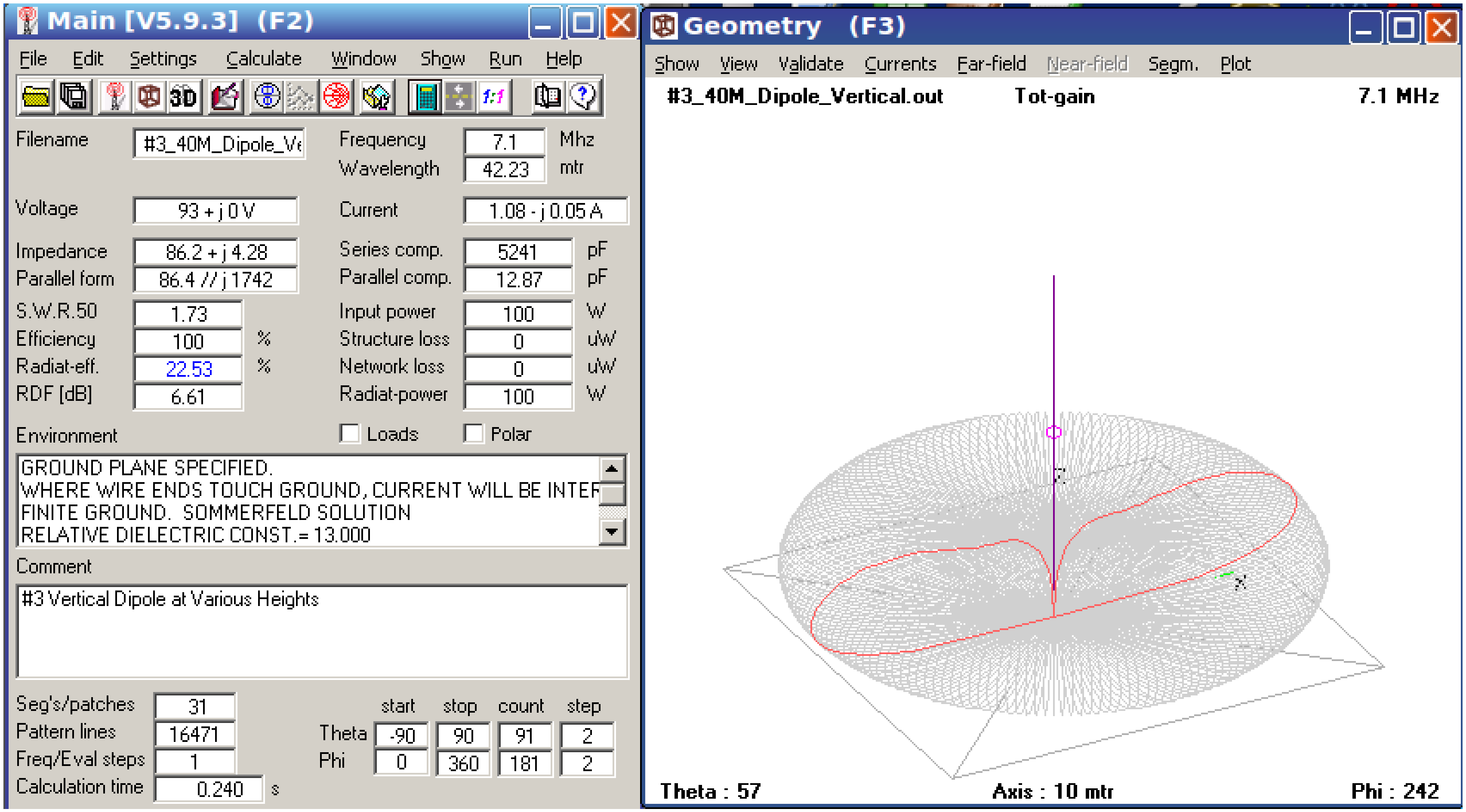
27 **#3 40 Meter Dipole Vertical above Ground**

#3_40M_Dipole_Vertical.nec Wire: AWG#12 Copper. Zc=50

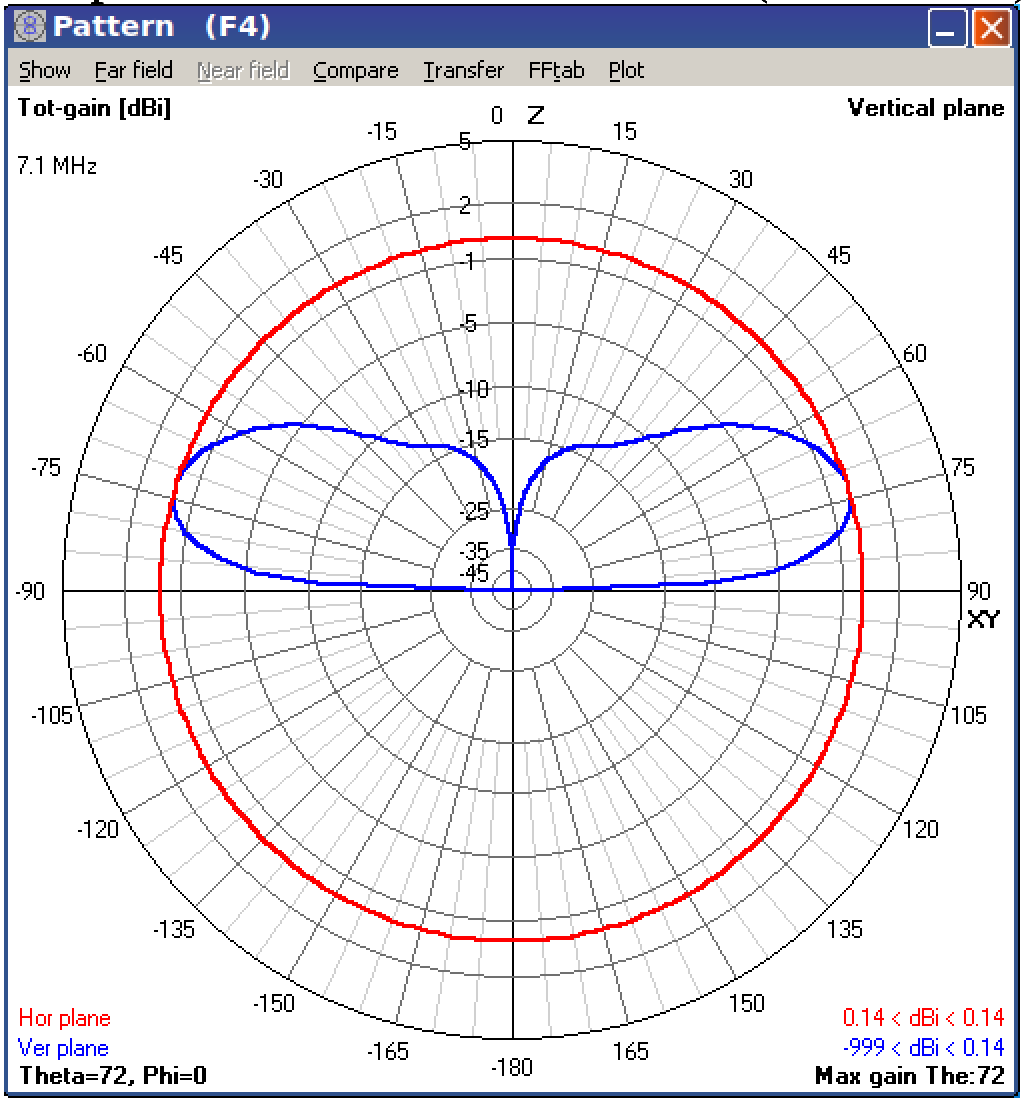


#3 40 Meter Dipole Vertical above Ground (Continued)

This antenna has the property of low radiation angle, but due to ground losses, the radiation efficiency is only ~22%. Still, gain is +0.14dBi at 15° above horizon, omnidirectional.

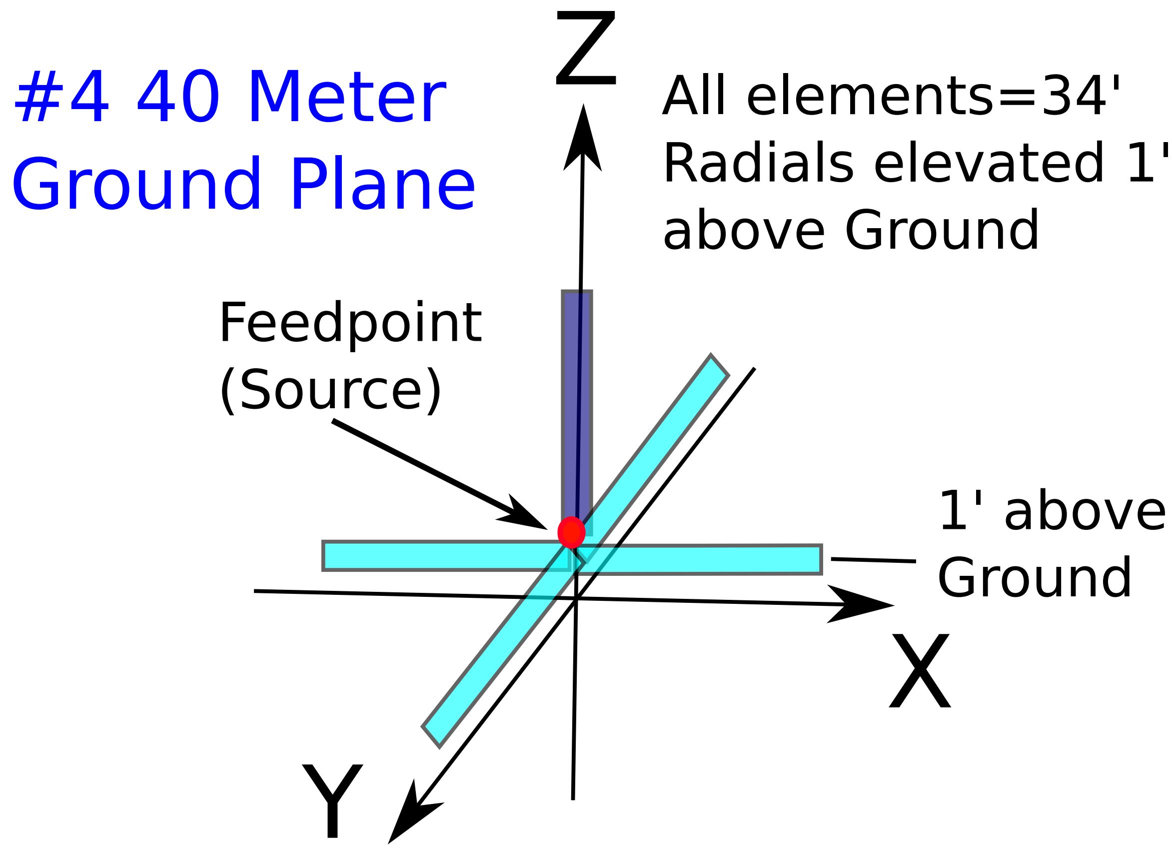


#3 40 Meter Dipole Vertical above Ground (Continued)

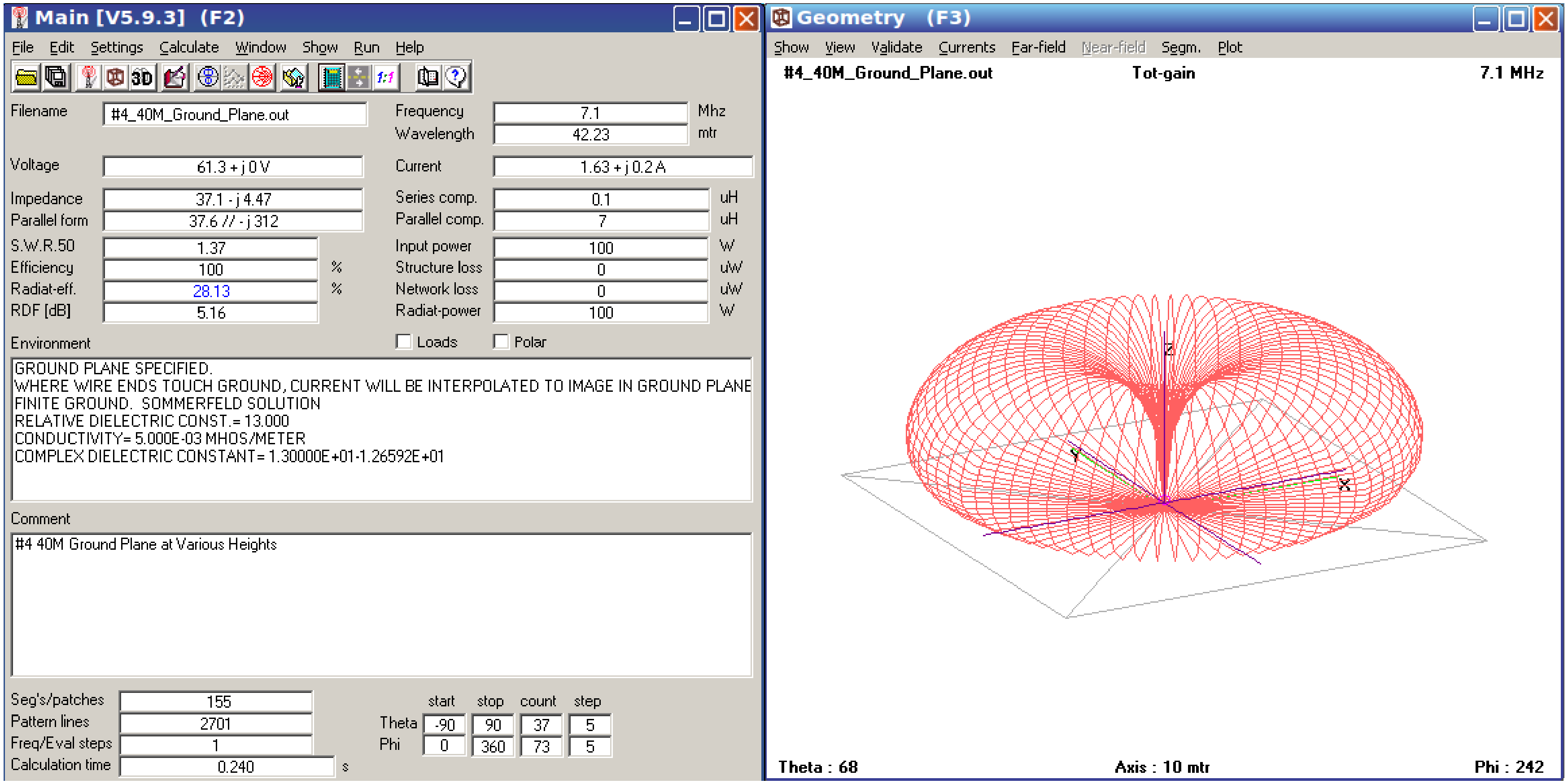


30 **#4 40 Meter Ground Plane above ground** *#4_40M_Ground_Plane.nec*

Wire: Driven Element :AWG#8 Radials: AWG#12. Zc=50Ω

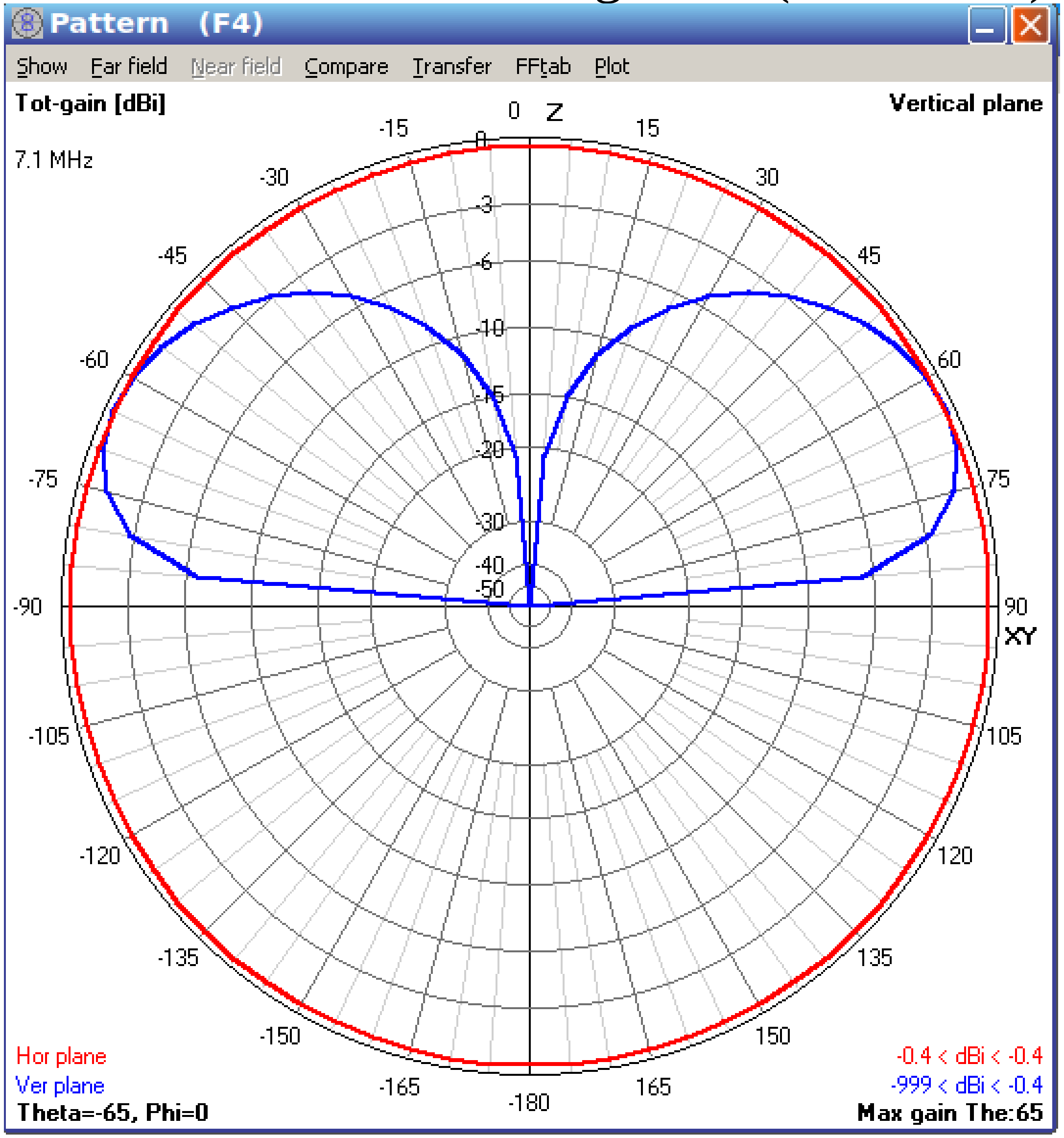


#4 40 Meter Ground Plane above ground (Continued)



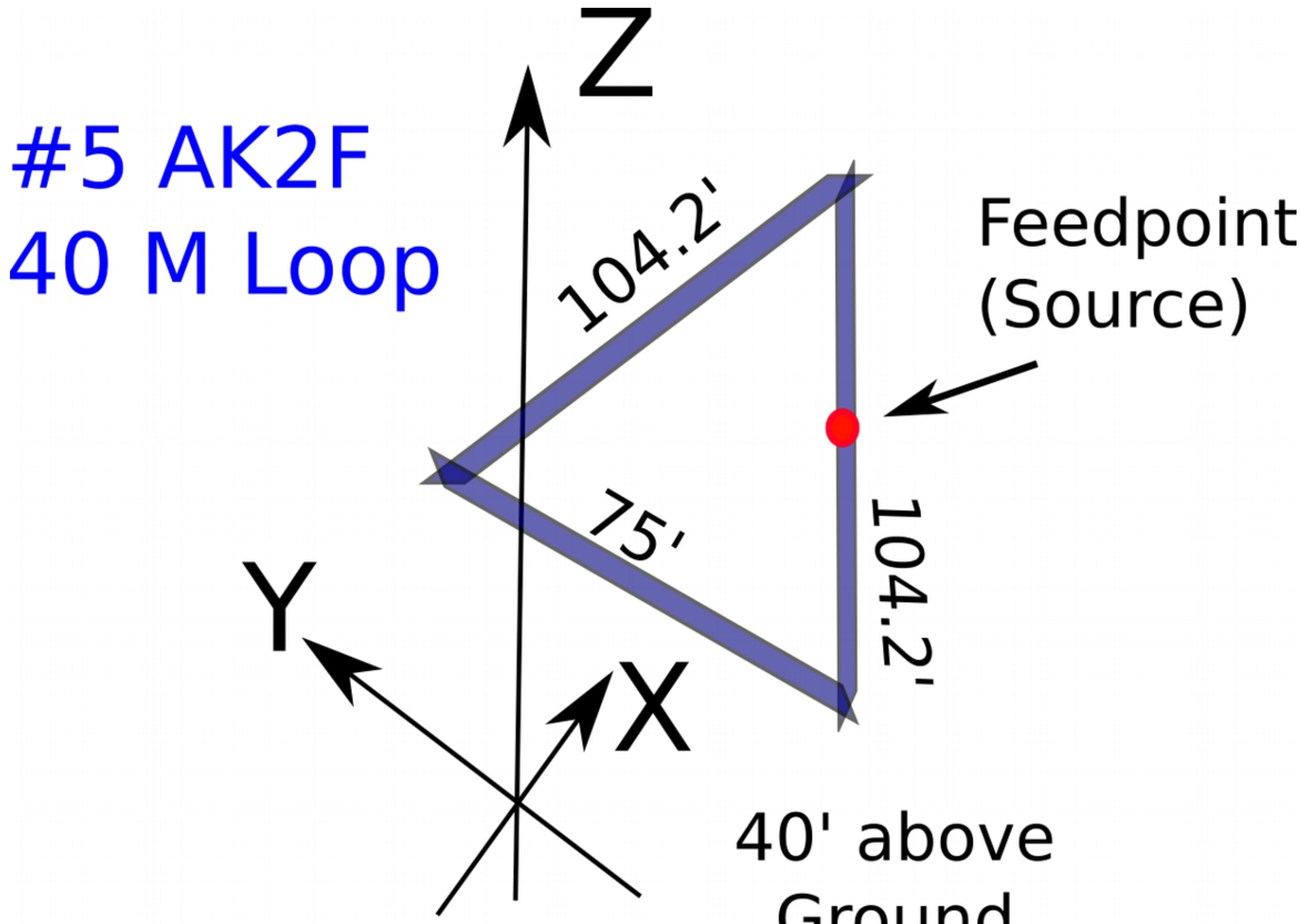
This ground plane has slightly better radiation efficiency at ~28%, lowish radiation angle. Omnidirectional Gain is low ~ -0.4dBi at 30° above horizon. Better ground conditions such as salt water improves gain and efficiency.

#4 40 Meter Ground Plane above ground (Continued)

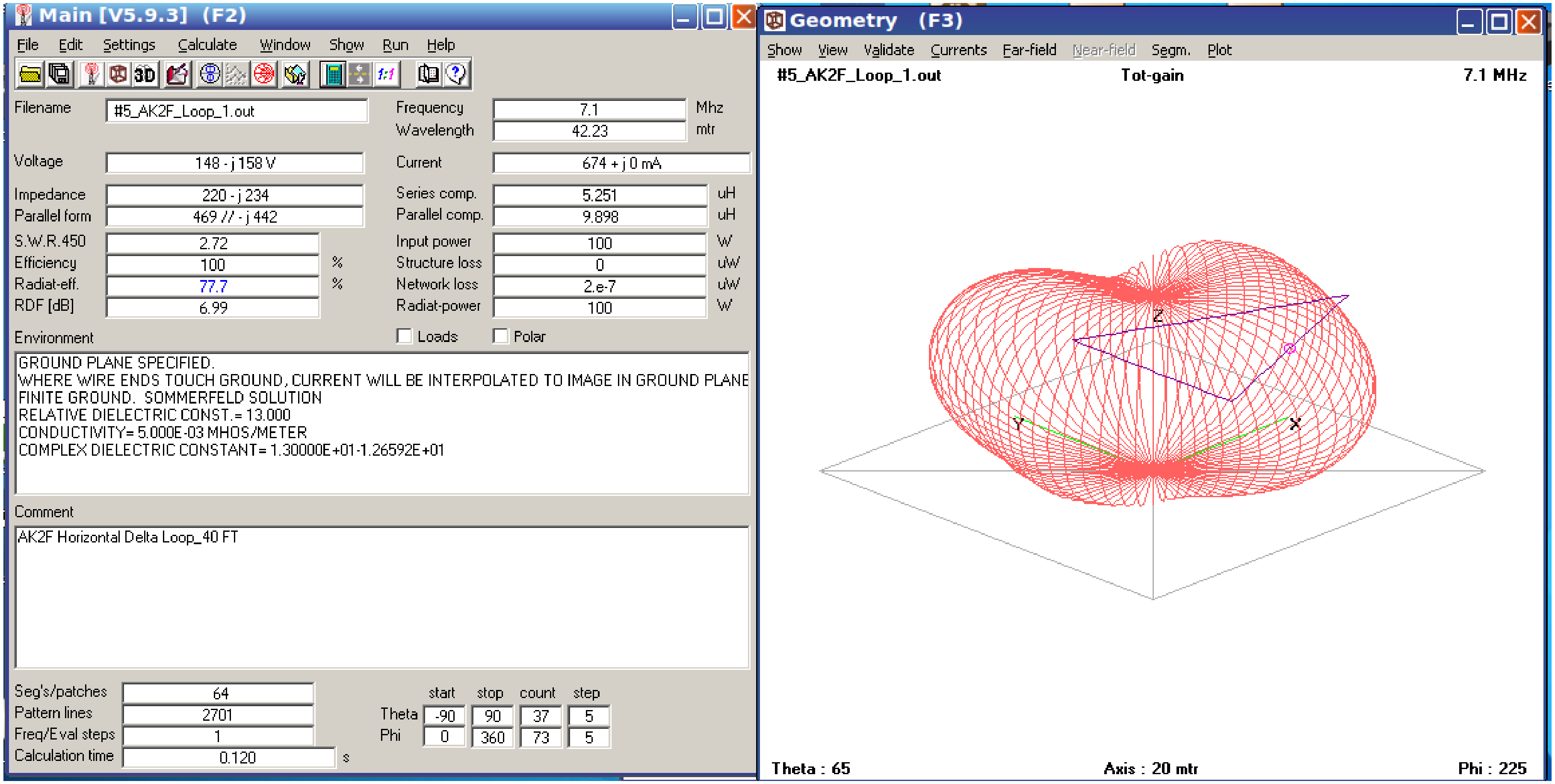


33 **#5 AK2F Delta "Loop Skywalker"** *#5_AK2F_Loop_1.nec*

Wire: AWG#18 Copper. Zc=450Ω

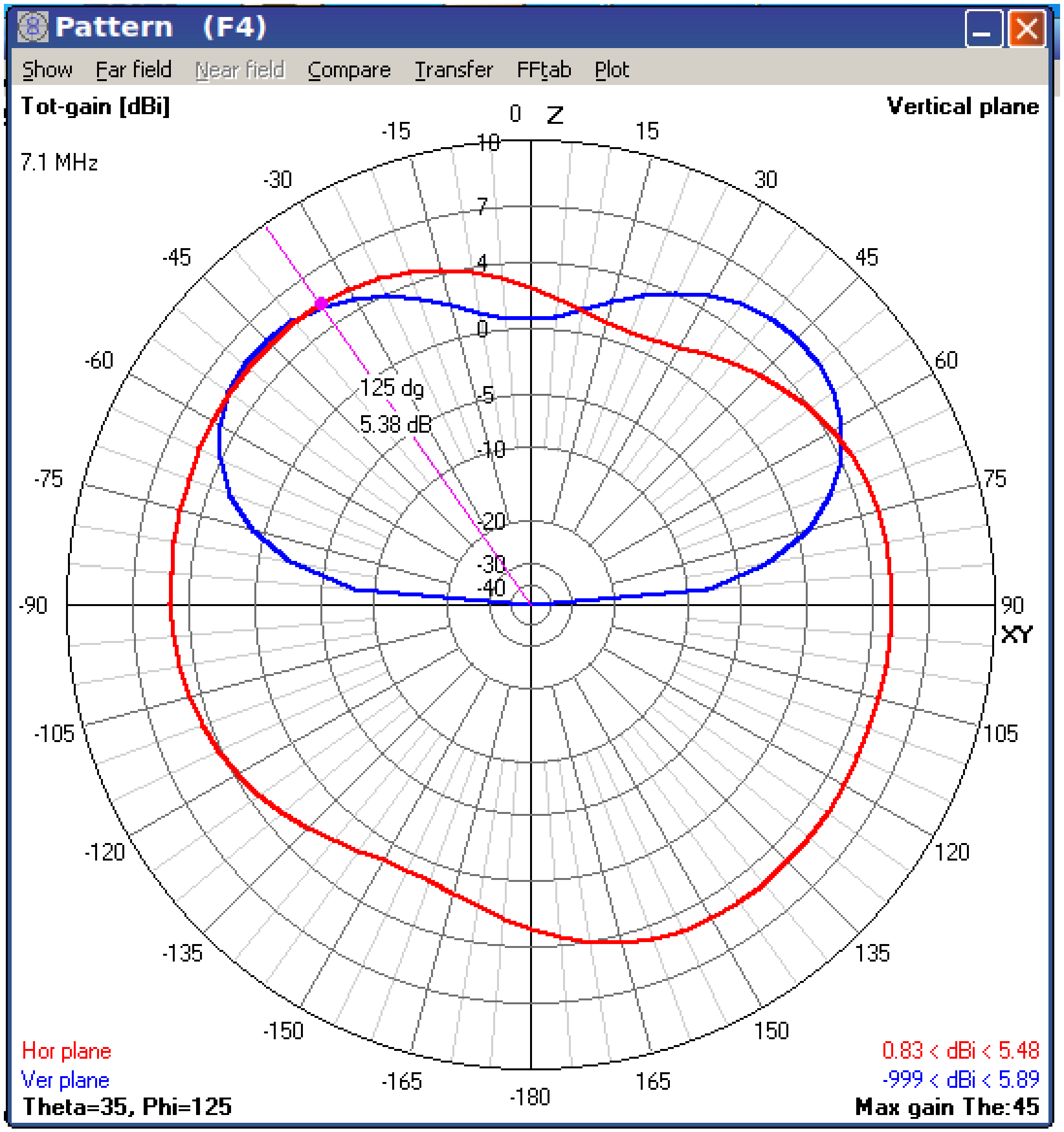


#5 AK2F Delta "Loop Skywalker"(Continued)



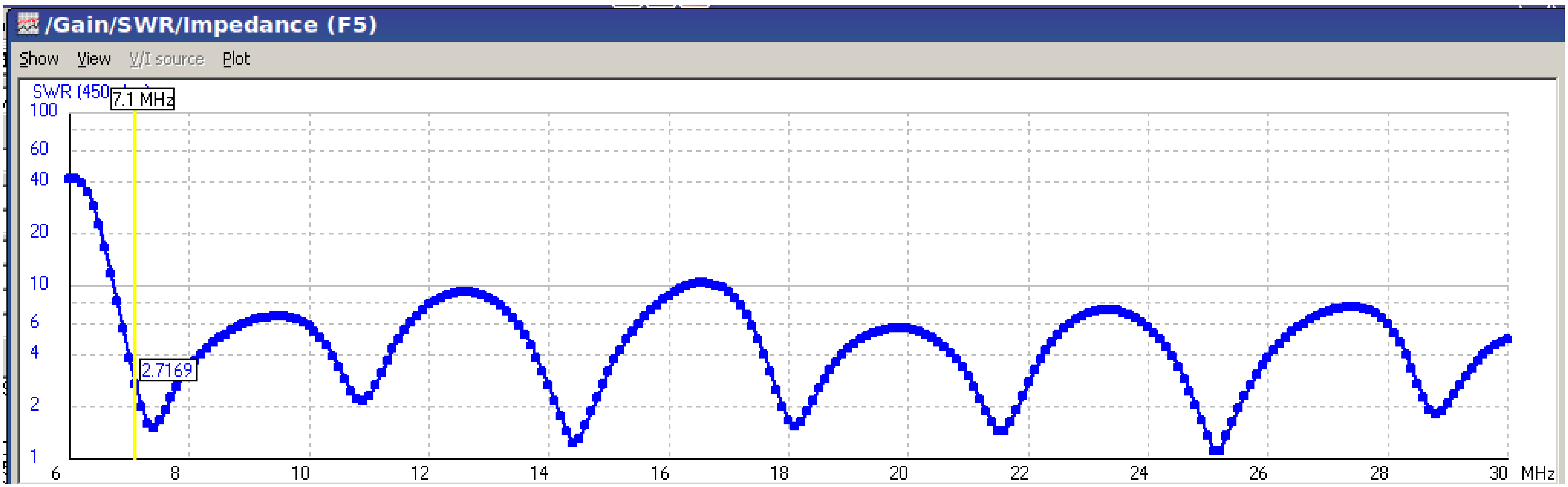
This delta loop shown here at 40' height has radiation efficiency~77.7%, gain +4.95dBi at 30° above horizon. Raise it to just 50' and radiation efficiency goes up to 80%, gain up to +6.19dBi. Got Three Tall Trees?

#5 AK2F Delta "Loop Skywalker"(Continued)



#5 AK2F Delta "Loop Skywalker"(Continued)

Tired of 40 meters? This is a good Multiband Antenna. This is shown at 40' height. Not many simple antennas can do this. From this simulation, it appears some effective matching can be had when fed with 450Ω Ladder Line and a tuner at the shack. This is only a simulation---your results may vary .



#5 AK2F Delta "Loop Skywalker"(Continued)

What to expect in terms of Line Loss driving this antenna??

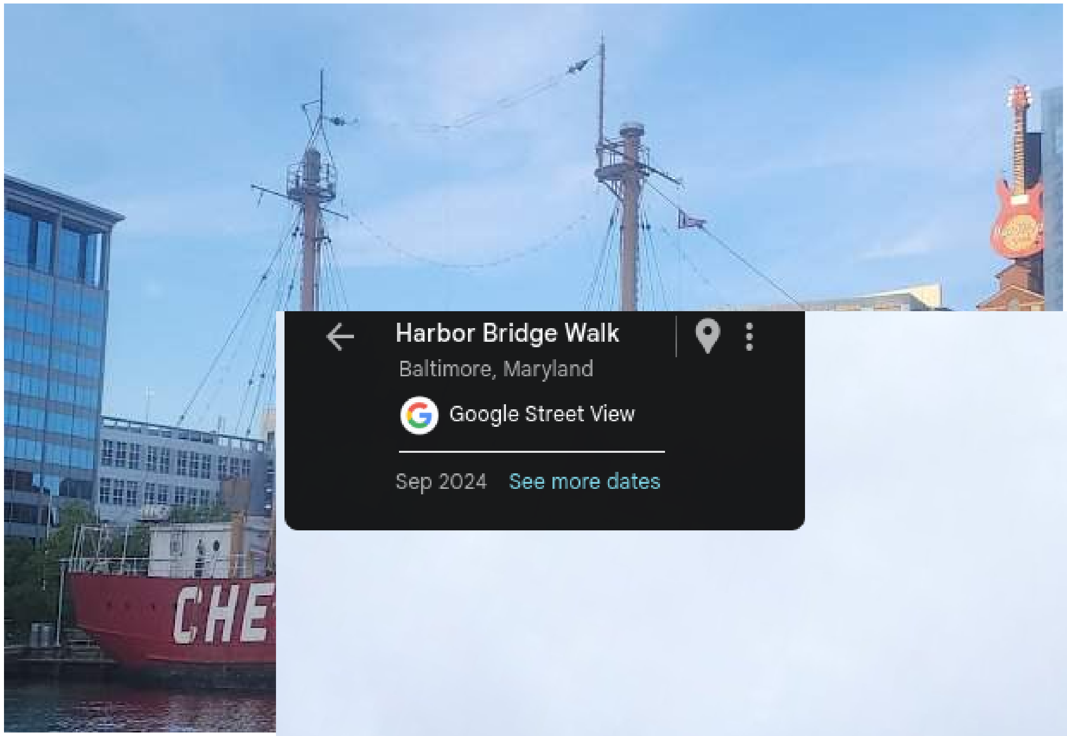
Calculated Values:

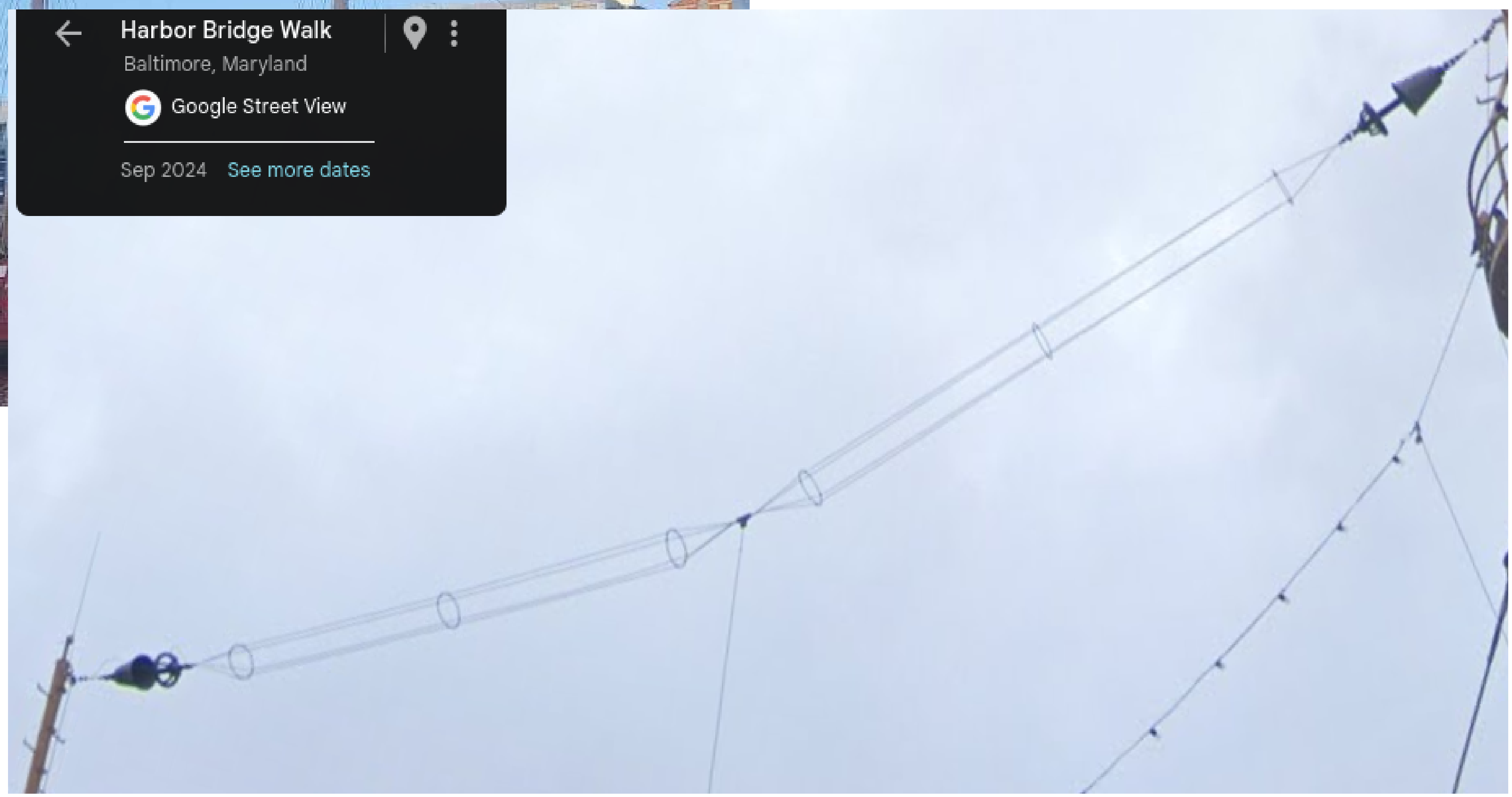
Freq [MHz]	Loss in [dB/100 ft] 450 Ω Matched*	VSWR	Total Loss with VSWR* [dB]
7.1	0.141	2.7:1	0.212
10.1	0.17	5.46:1	0.466
14.1	0.203	2.17:1	0.264
18.1	0.233	1.54:1	0.255
21.2	0.254	2.23:1	0.336
24.9	0.277	1.67:1	0.313
28.5	0.297	2.73:1	0.446

** Wireman #551 (AWG#18) 100 ft 450 Ω Ladder Line matched in the Shack with a Balanced Tuner. From KV5R Website's data and calculator.*

https://kv5r.com/ham-radio/coax-loss-calculator/

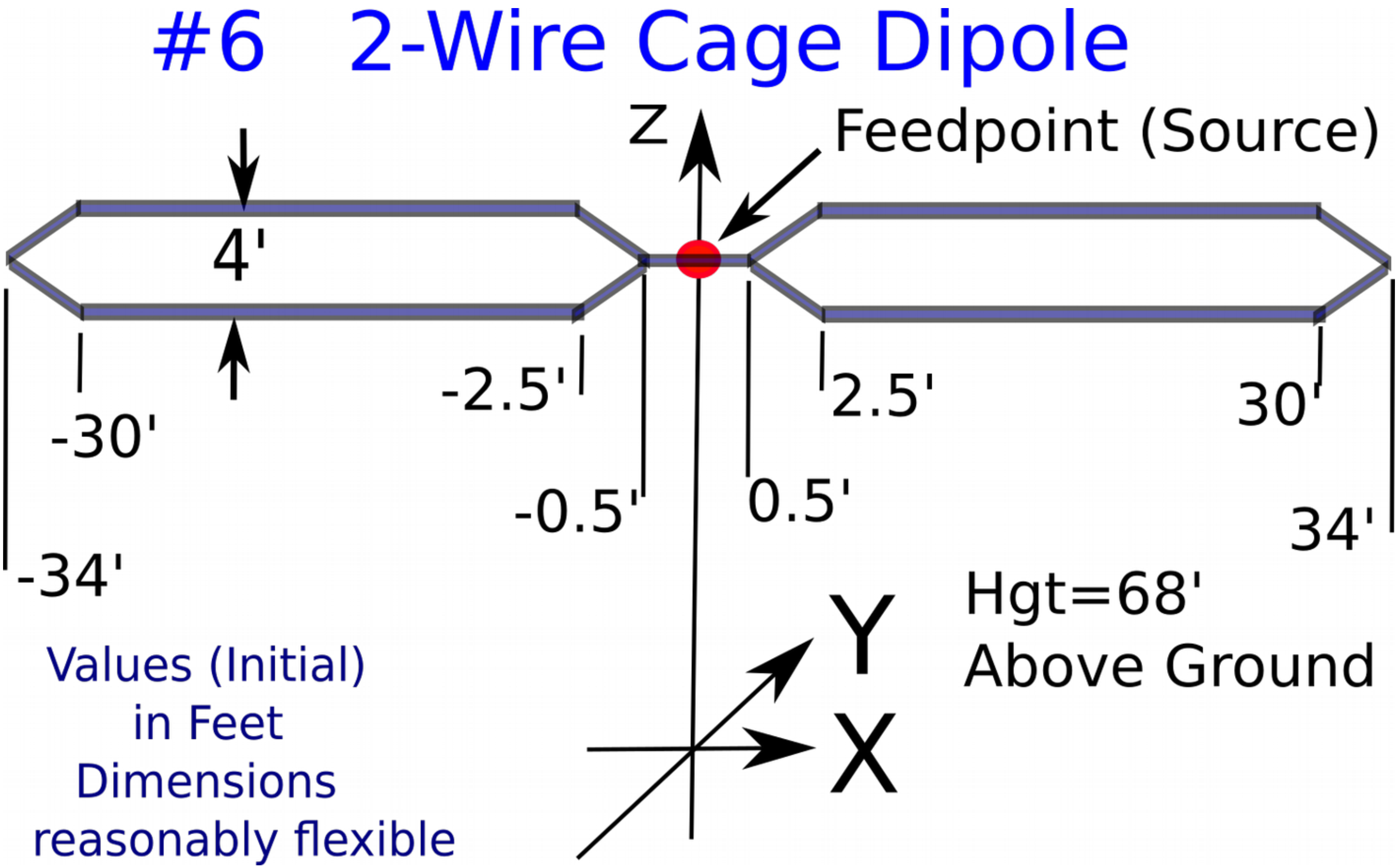
#6 & #7 Cage Antennas (a.k.a. Bowtie, Biconical,Fan, Fat Dipole, etc)
My inspiration for this antenna came from the USCG Chesapeake in Baltimore Harbor, but others exist. Some are *well-known/notorious/huge!*





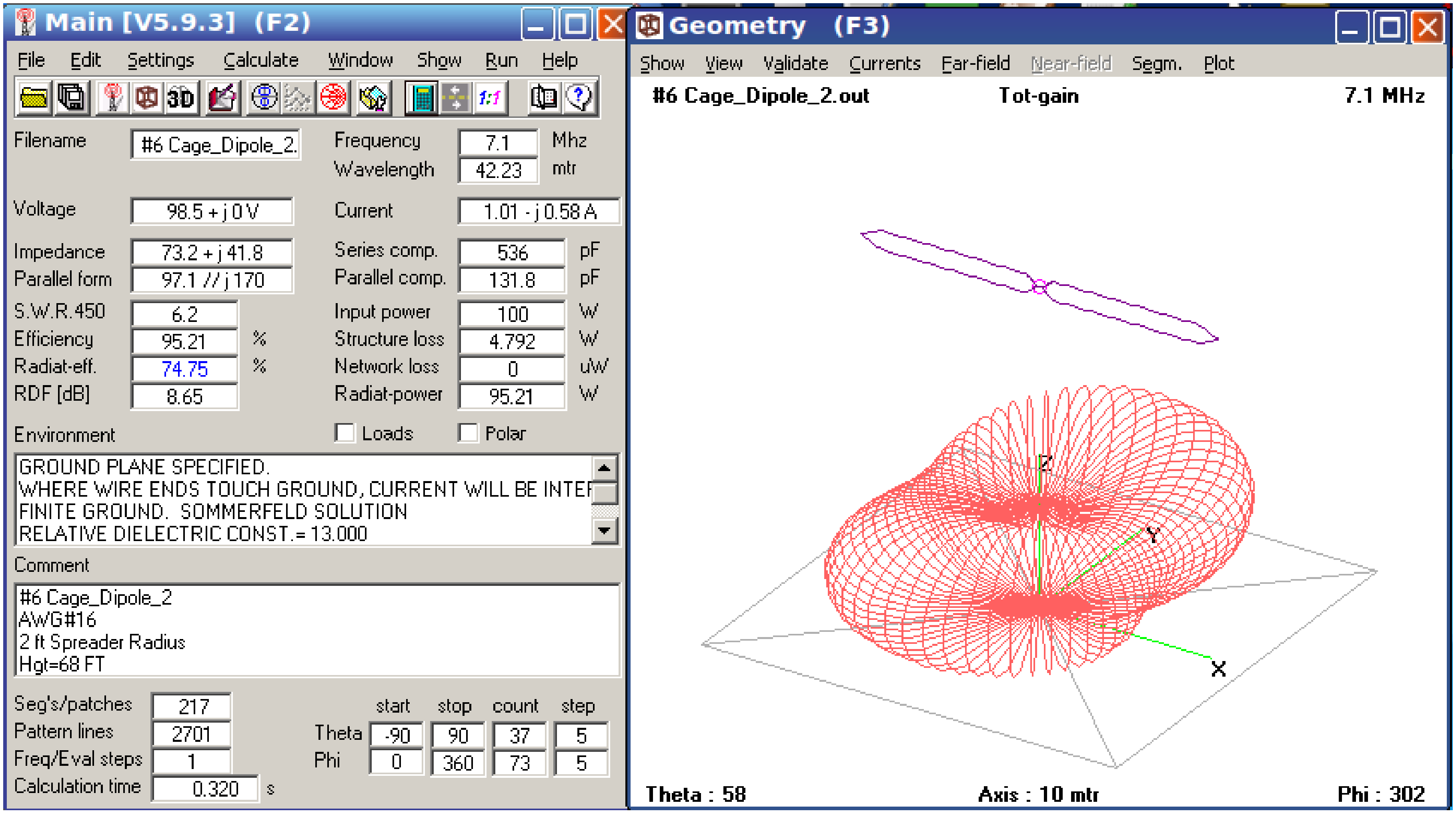
39 **#6 Cage Antenna Two Conductor** ***#6_Cage_Antenna_2.nec***

Wire: AWG#16 Copper. Zc=300 or 450Ω (Results shown for both)



#6 Cage Antenna Two Conductor *#6_Cage_Antenna_2.nec*

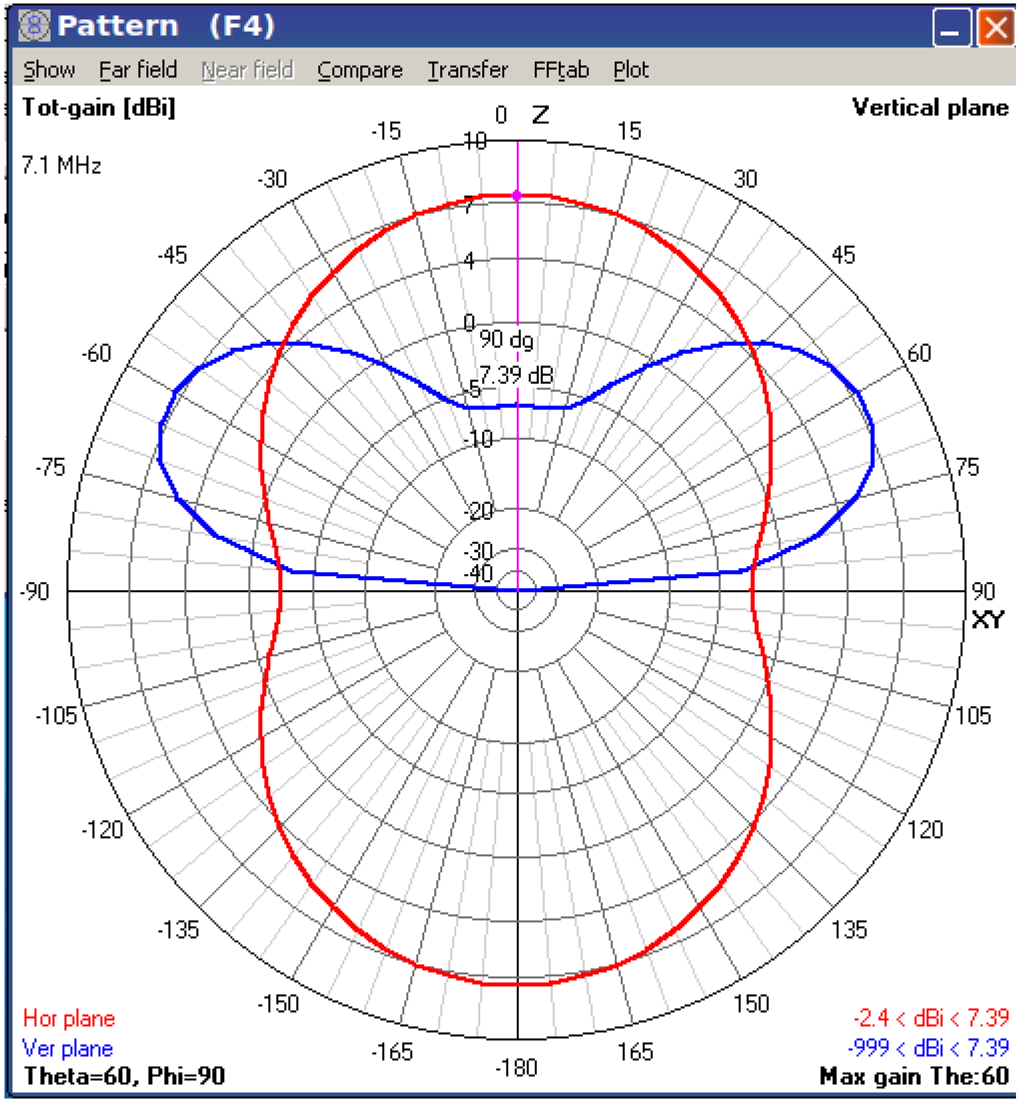
We set the source impedance to 450Ω, and use it with ladder line that can be tuned with a balanced antenna tuner at the shack.



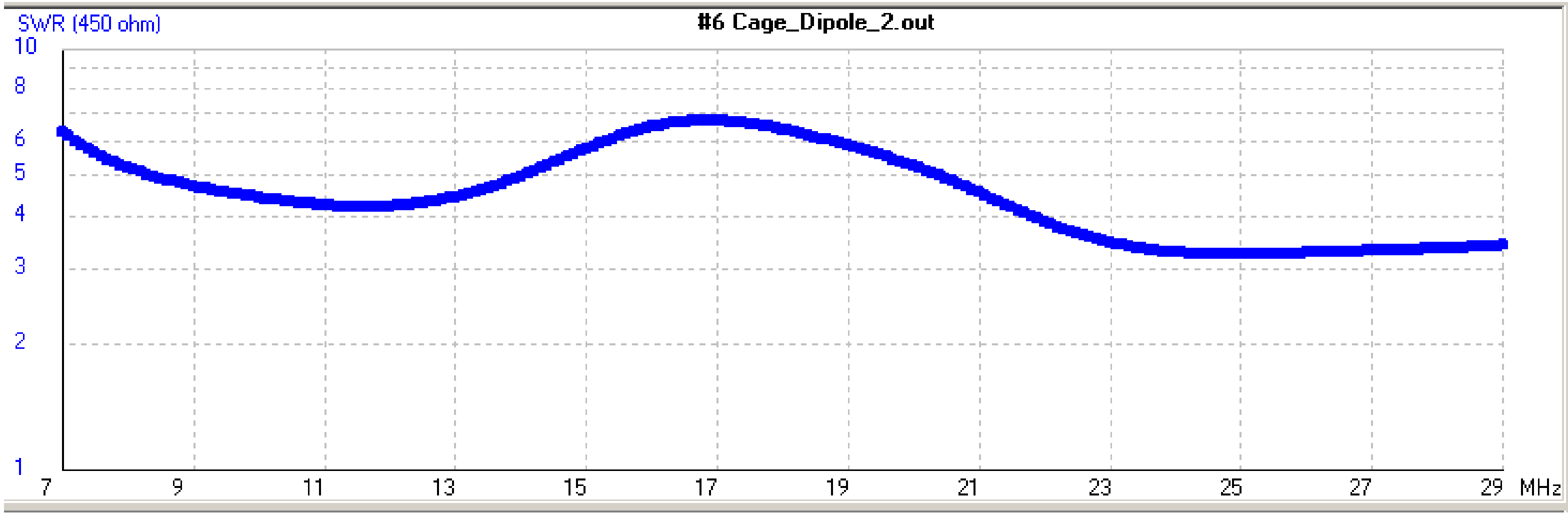
#6 Cage Antenna Two Conductor (Continued).

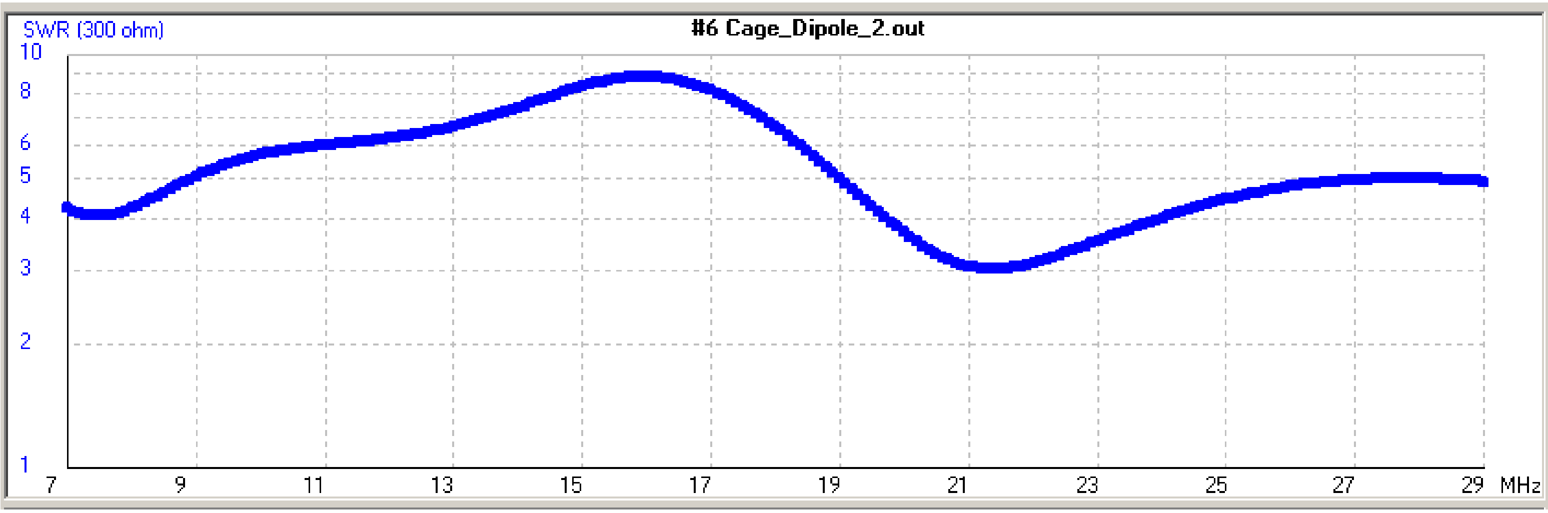
The wire is lighter-weight AWG#16 with 4' spreaders. At 7.1 MHz we have >74% radiation efficiency.

At 50' elevation, the gain is 7.39 dBi at ~30° above horizon.



 #6 Cage Antenna Two Conductor (Continued). *This can be used as a Broadband antenna for 40M-10M (even 6M) inclusive, with a good balanced tuner, especially if good quality ladder line transmission lines are used, to keep loss low. Source Impedance: Top: 450 Ω, Bottom: 300Ω*





#6 Cage Antenna Two Conductor ***#6_Cage_Antenna_2.nec***

Fed with 450Ω or 300Ω, Ladder Line [1]. A Good Balanced Antenna Tuner is recommended, ex: Johnson Matchbox. Simulated & calculated values:

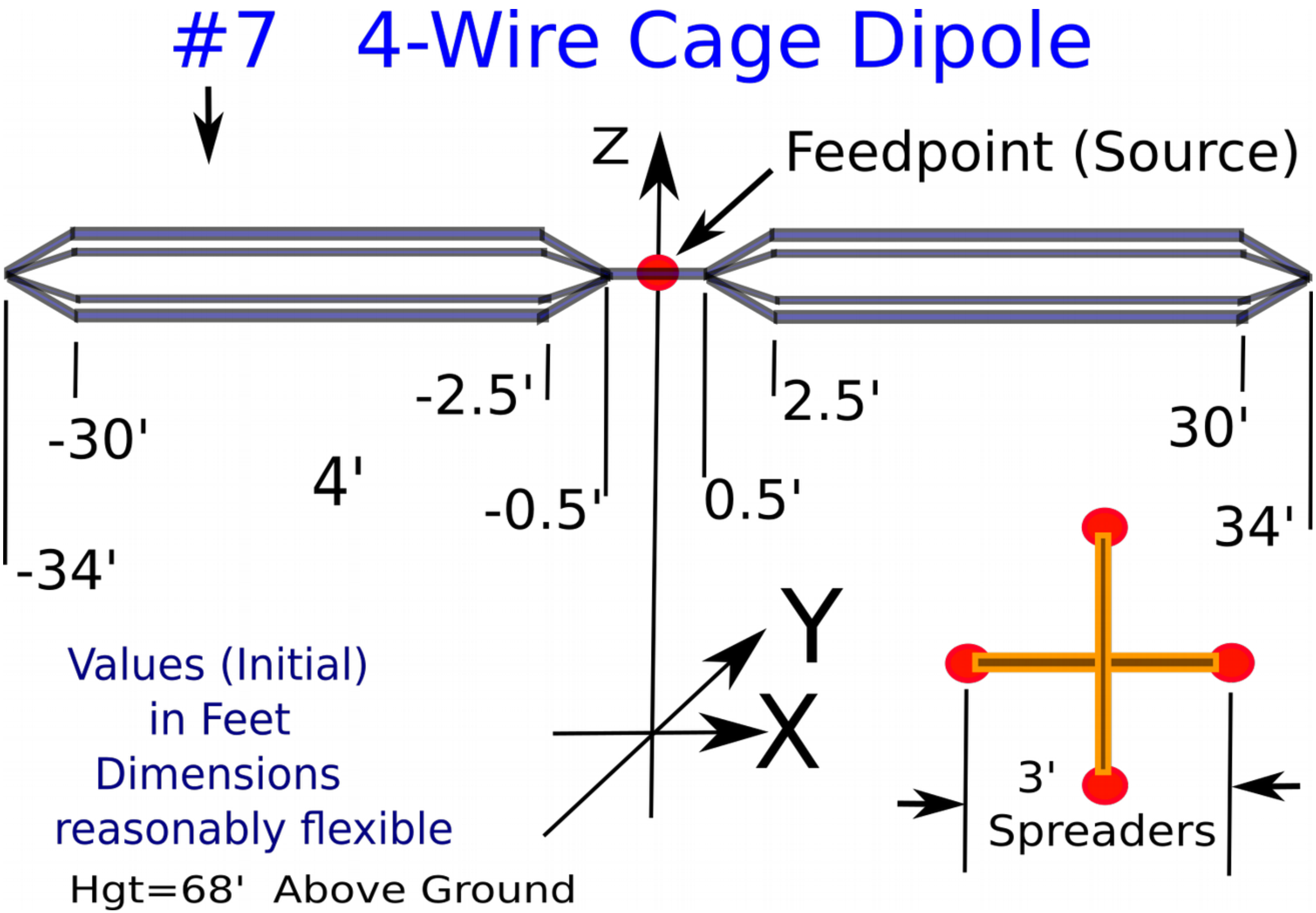
Freq MHz	450Ω Ladder Line [1]			300Ω Ladder Line [1]		
	Matched [dB/100’]	VSWR [2]	Total Loss[dB]	Matched [dB/100’]	VSWR [2]	Total Loss[dB]
7.1	0.141	6.19:1	0.427	0.36	4.18:1	0.74
10.1	0.17	4.40:1	0.239	0.44	5.75:1	1.16
14.1	0.203	5.04:1	0.506	0.52	7.5:1	1.65
18.1	0.233	6.37:1	0.706	0.59	6.5:1	1.63
21.1	0.253	4.47:1	0.546	0.64	3.04:1	0.96
24.9	0.277	3.25:1	0.476	0.68	4.41:1	1.32
28.1	0.297	3.35:1	0.519	0.71	4.99:1	1.56
50.1	0.411	3.75:1	0.773	0.89	3.21:1	1.40

Notes:

1. Data from: 450 Ω Wireman #551 ; 300 Ω DXE-LL300
2. VSWR with this Cage Antenna.

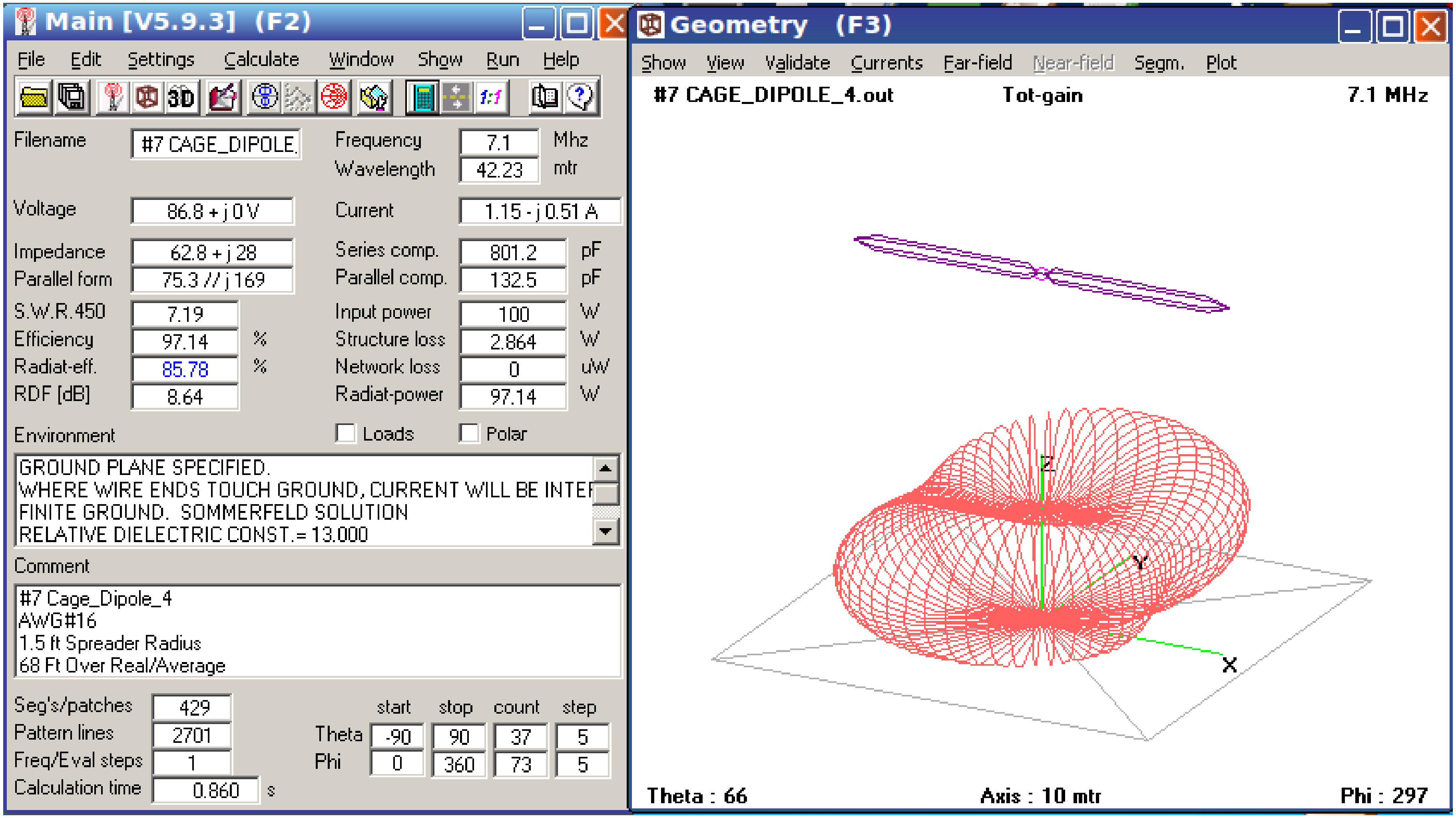
 #7 Cage Antenna Four Conductor ***#7_Cage_Antenna_4.nec***

Wire: AWG#16 Copper. Zc=300 or 450Ω (Results shown for both)



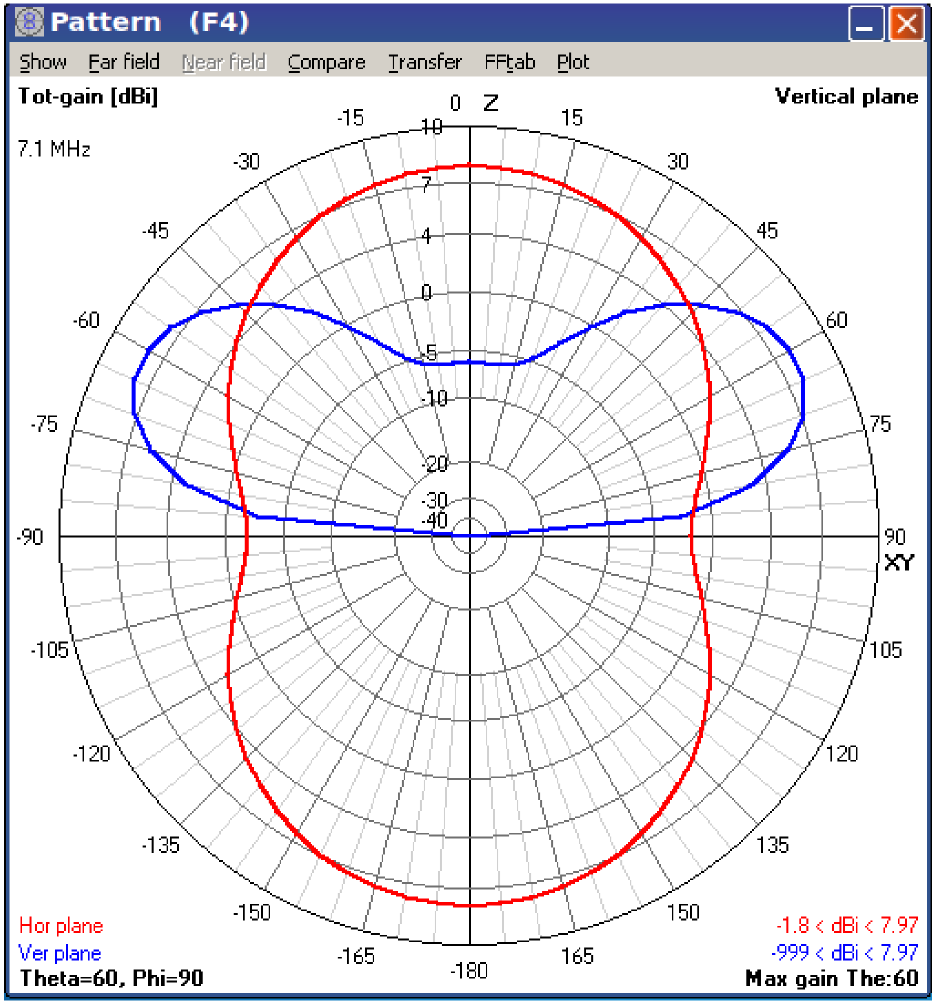
#7 Cage Antenna Four Conductor (Continued).

The wire is also a lighter-weight AWG#16 but with 3' spreaders. At 7.1 MHz we have >85% radiation efficiency. The gain is >7.9 dBi at 30° elevation.

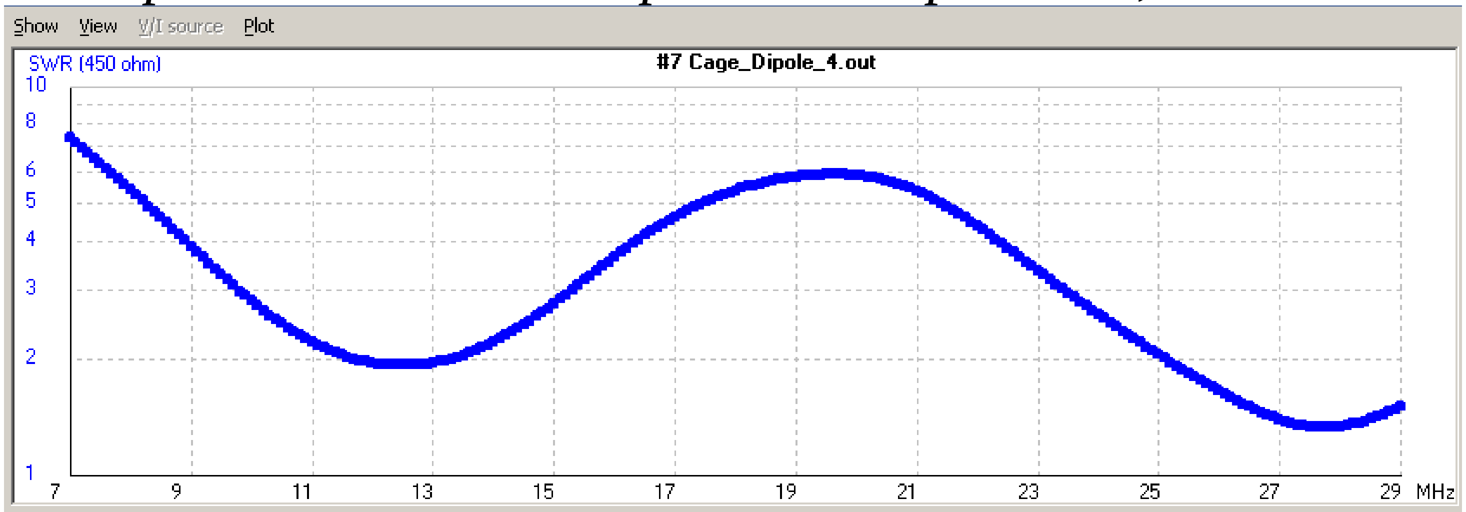


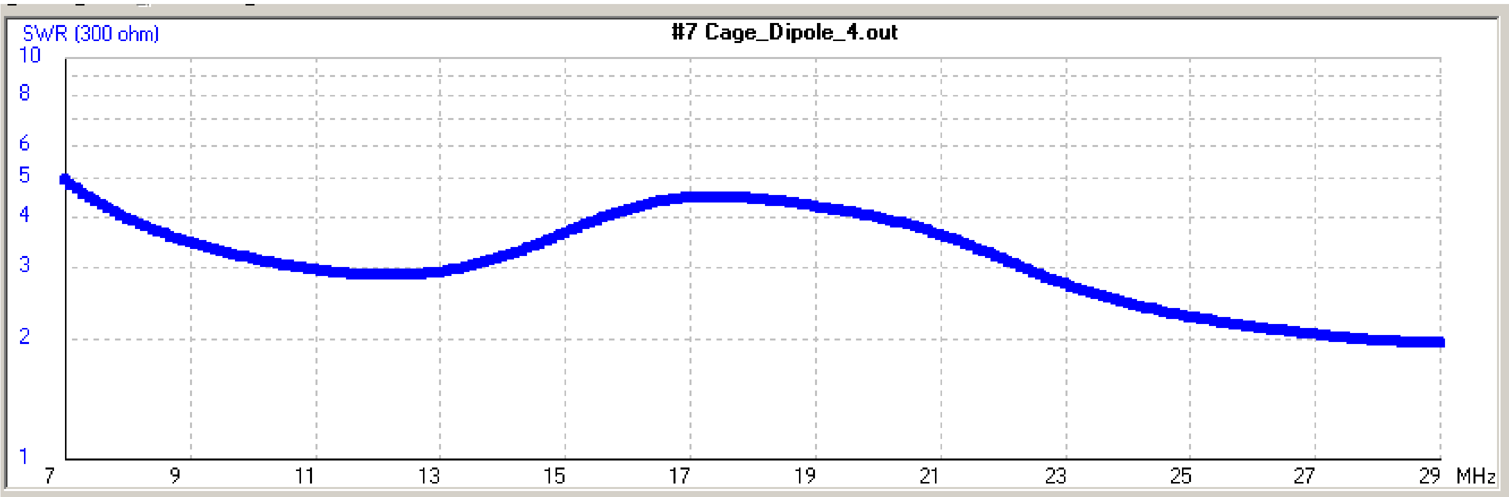
#7 Cage Antenna Four Conductor (Continued).

The gain is ~7.9 dBi at 30° above horizon.



47 #7 Cage Antenna Four Conductor (Continued). *This can be also used as a Broadband antenna for 40M-10M (even 6M) inclusive, with a good balanced tuner, especially if good quality ladder line transmission lines are used, to keep loss low. Source Impedance: Top: 450 Ω, Bottom: 300Ω*





#7 Cage Antenna Four Conductor (Continued)

Fed with 450Ω or 300Ω, Ladder Line [1]. A Good Balanced Antenna Tuner is recommended, ex: Johnson Matchbox. Simulated & calculated values:

Freq MHz	450Ω Ladder Line [1]			300Ω Ladder Line [1]		
	Matched [dB/100’]	VSWR [2]	Total Loss[dB]	Matched [dB/100’]	VSWR [2]	Total Loss[dB]
7.1	0.141	7.18:1	0.49	0.36	4.81:1	0.83
10.1	0.17	2.73:1	0.26	0.44	3.12:1	0.72
14.1	0.203	2.24:1	0.27	0.52	3.22:1	0.95
18.1	0.233	5.46:1	0.62	0.59	4.43:1	1.21
21.1	0.253	5.30:1	0.65	0.64	3.57:1	1.08
24.9	0.277	2.53:1	0.40	0.68	2.27:1	0.83
28.1	0.297	1.34:1	0.31	0.71	1.97:1	0.84
50.1	0.411	4.0:1	0.81	0.89	3.02:1	1.35

Notes:

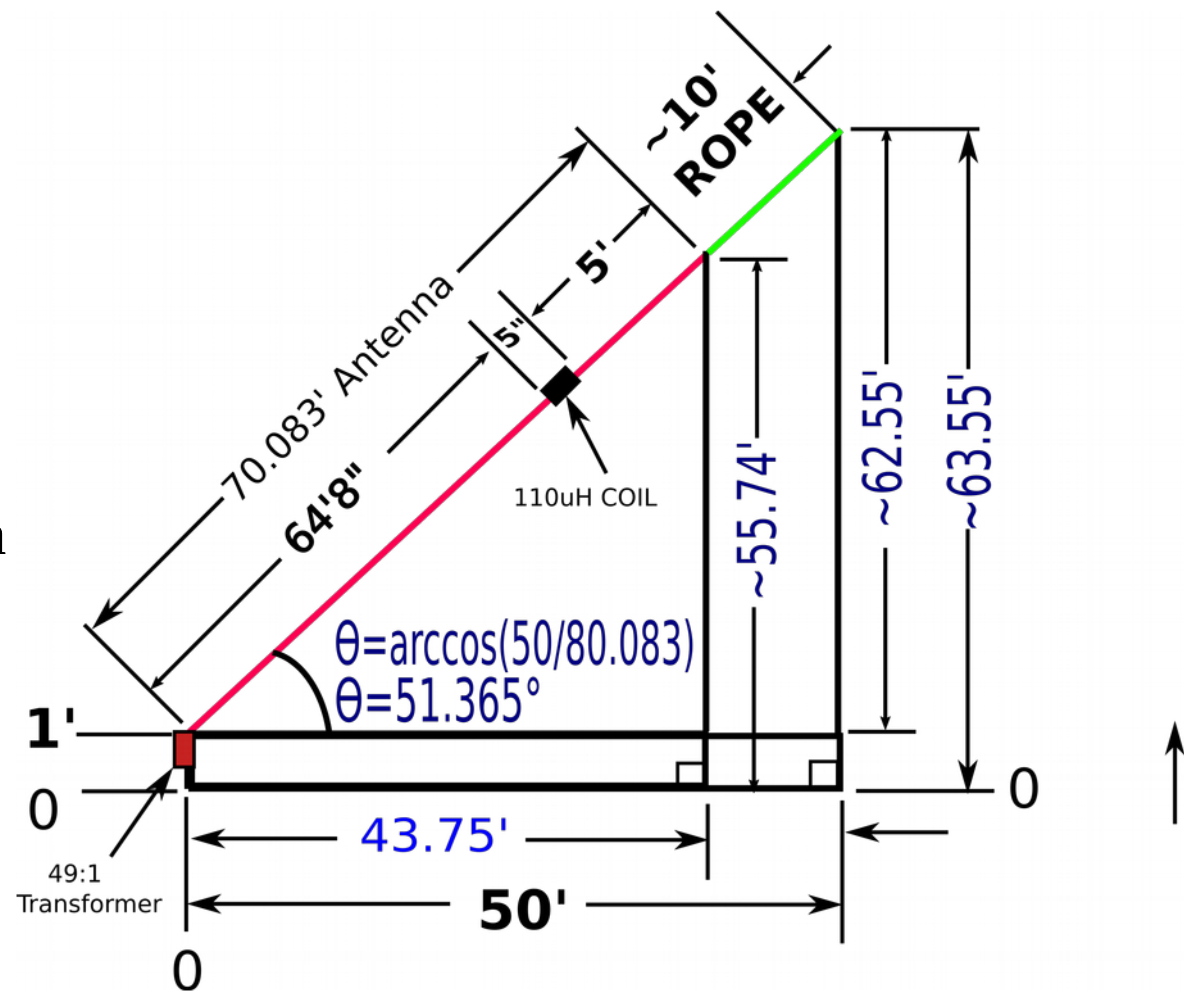
1. Data from: 450 Ω Wireman #551 ; 300 Ω DXE-LL300
2. VSWR with this Cage Antenna.

49 **#8 N2XP End-Fed** ***#8_N2XP_EFHW.nec*** Zc=2450Ω

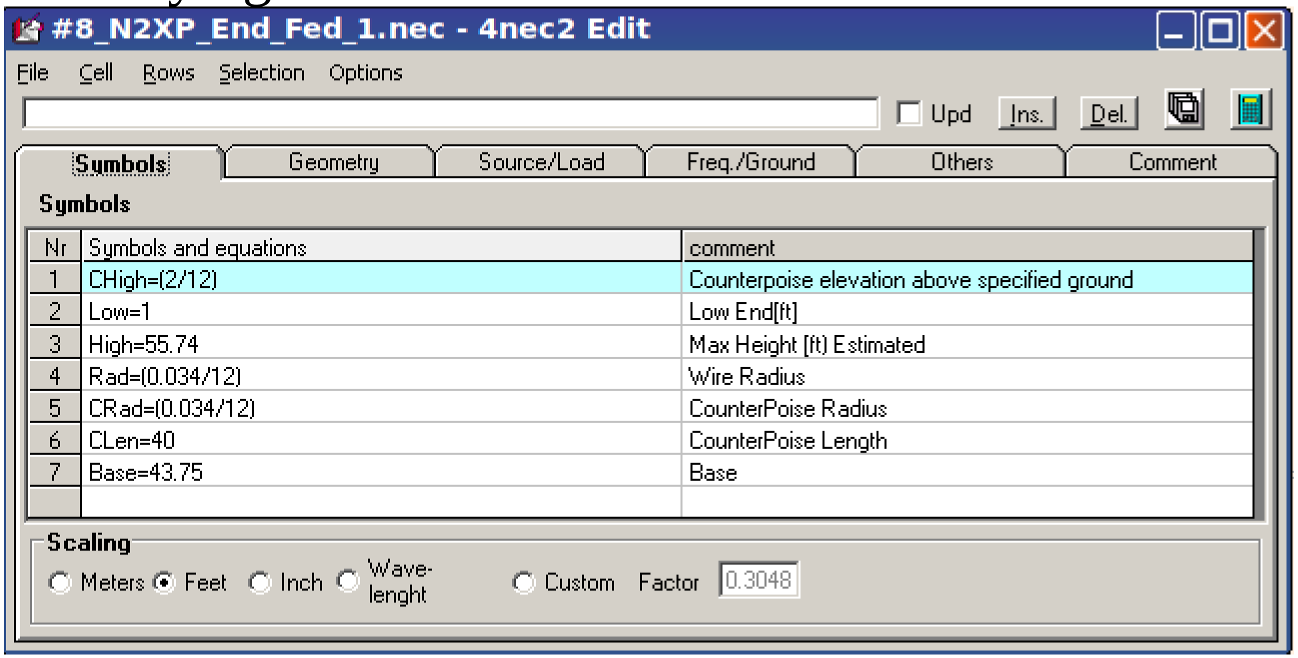
A popular antenna, especially for POTA and FD. Requires only one support. To determine the values to enter into the editor required some geometry: We are given the boldface values.

The antenna wire dimensions, the height of the base (1’) are known accurately. The distance to the tower (50’) is also known. The other dimensions are either unknown or not certain.

So the other dimensions were solved from the given dimensions. We can always modify the dimensions if required.
Wire: 0.068” dia copper.



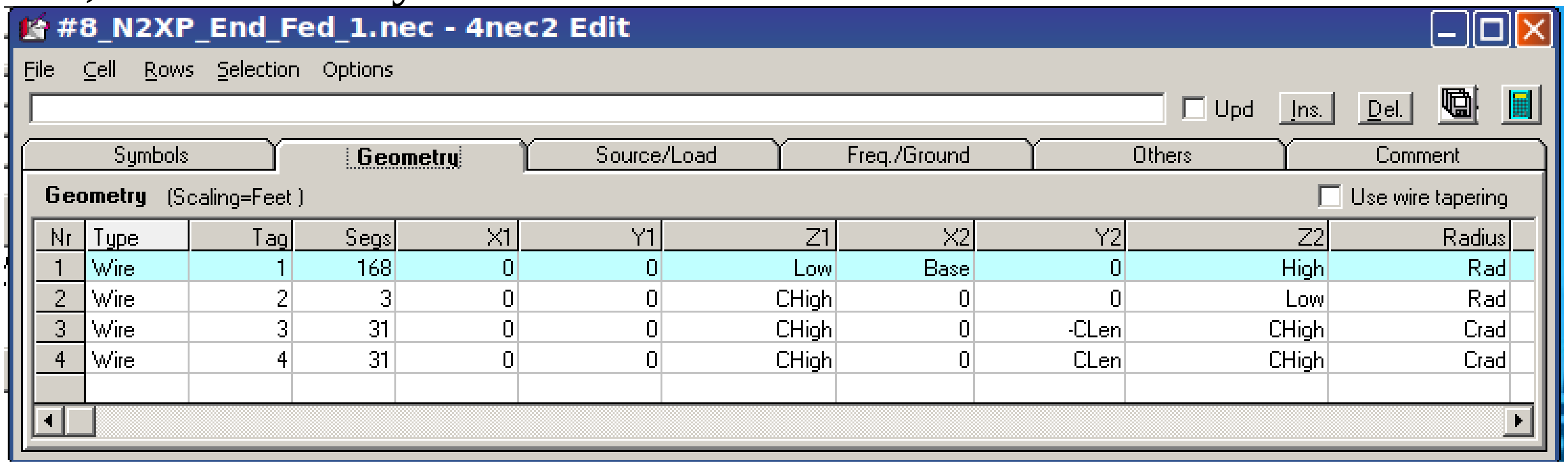
50 We need to input this information into the Editor, starting at the Symbols tab to create some symbols or variables we can use in the Geometry Tab. This makes modifying our model much easier.



There are symbols for the wire lengths, etc.

These are the driven element high point 55.74', low point 1',base length 43.75', counterpoise lengths 40' and counterpoise height (2/12) ft=2". The driven element radius and counterpoise radius 0.034/12= 34mils. It turns out that counterpoise lengths of 40' are not mandatory. Shorter lengths can work just fine. Reduce CLen to 10' and see.

51 Next, the Geometry Tab:



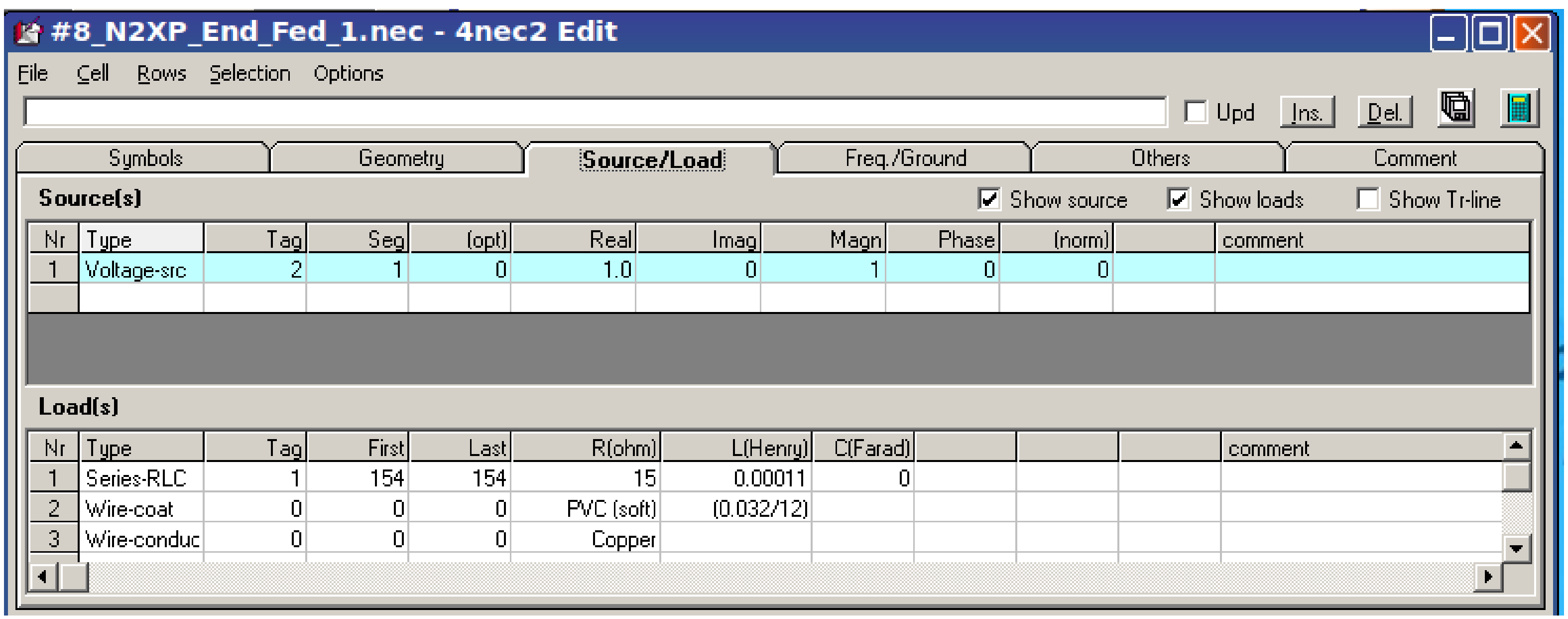
Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius
1	Wire	1	168	0	0	Low	Base	0	High	Rad
2	Wire	2	3	0	0	CHigh	0	0	Low	Rad
3	Wire	3	31	0	0	CHigh	0	-CLen	CHigh	Crad
4	Wire	4	31	0	0	CHigh	0	CLen	CHigh	Crad

Each wire is assigned a “Tag” number, usually same as the Wire Nr, but it doesn’t necessarily have to be,

The entire driven element was given as a lower section of 64’8”, a 110uH coil of 5” length, with an upper section of 5’. This gives us a total of 841 inches, for which we could use 841 segments (Segs), but this is unnecessary and makes computation time very long. Better to assign each segment=5 inches and then we have 168 segments with the load (coil) at segment 154. The line representing the 1’ section is assigned 3 segments, and the two counterpoise wires assigned 31 segments each.

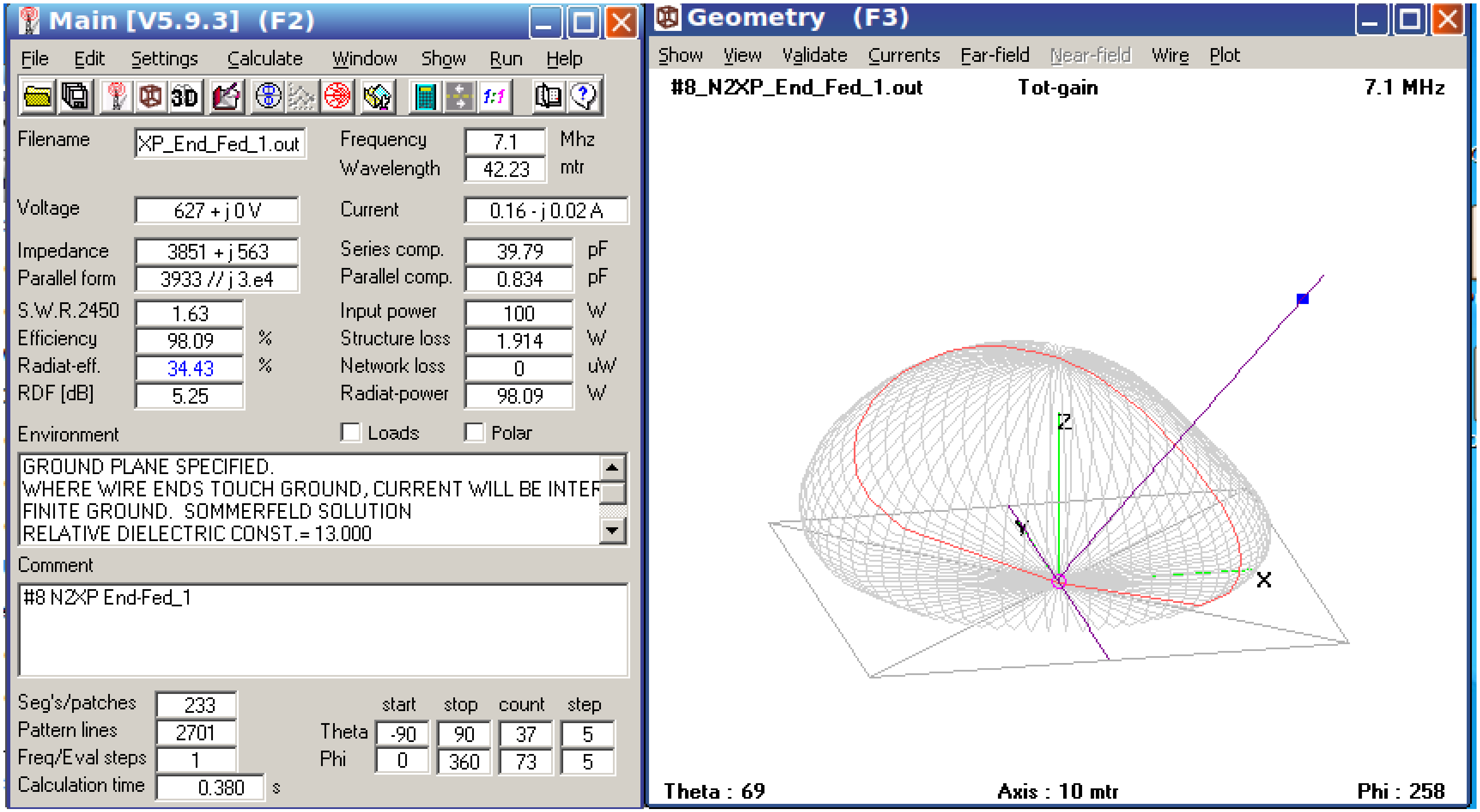
52 And the next tab (but not last one) is the Source/Loads tab where we define where our feedpoint is on Tag #2, Seg#1, and where the 110 uH coil is located up on Tag#1, Seg # 154 on the driven element. The Wires are defined as PVC (soft) 0.032” jacket on copper. You can define the wires as bare or jacketed or a combination of both. The conductor radius is defined in the Symbol and Geometry Tabs.

These can be defined differently for different wires.



The Freq/Ground, Others and Comments contain your choices for what type of ground and the default frequency (7.1 MHz), plus any other notes.

53 This antenna covers the harmonically related bands 80/40/20/15 and 10. With a 49:1 transformer, source impedance is approx 50*49 = 2450Ω.

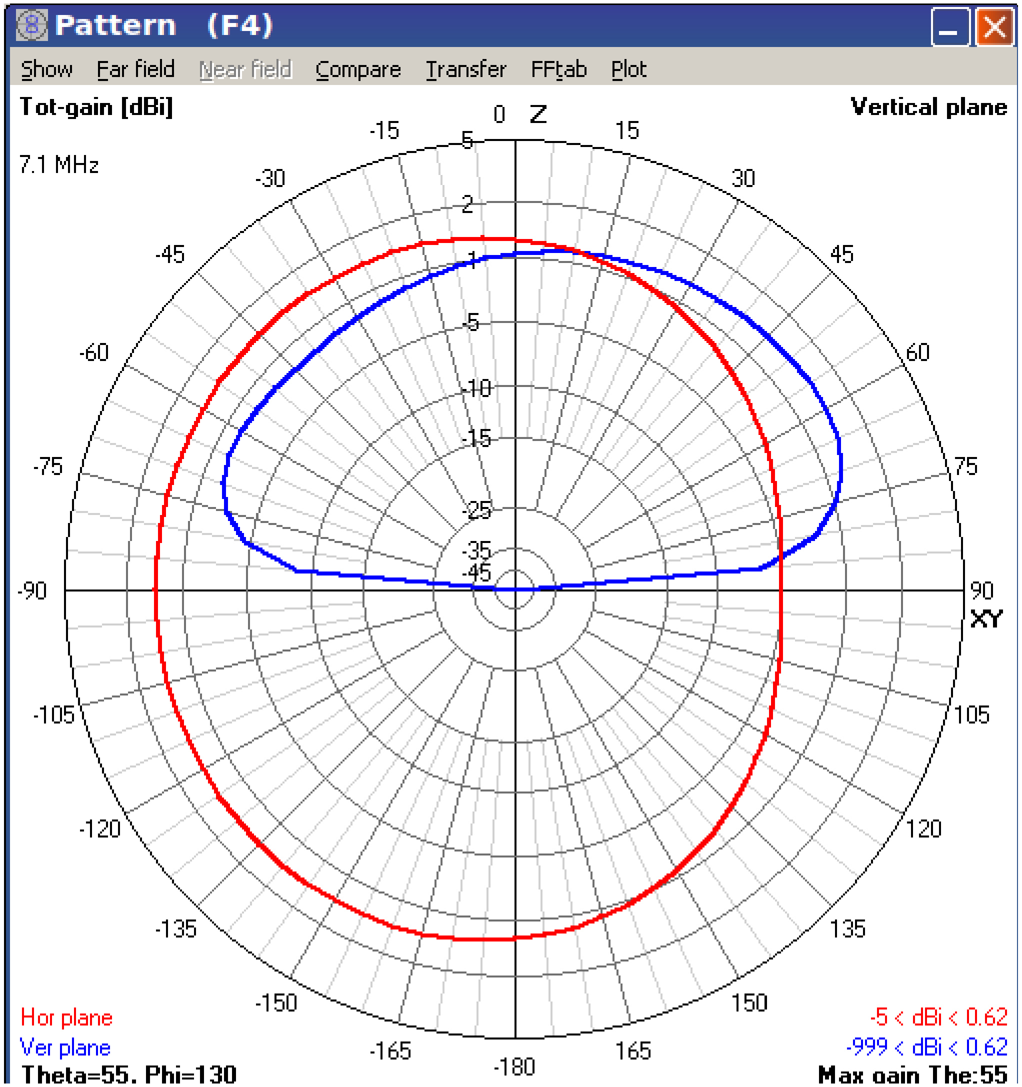


#8 N2XP End-Fed (Continued)

At 40 Meters, in some directions, the previous horizontal dipoles have more gain, but the N2XP End-Fed fills the dipole's notches with nearly omnidirectional gain, where the dipoles have gaps.

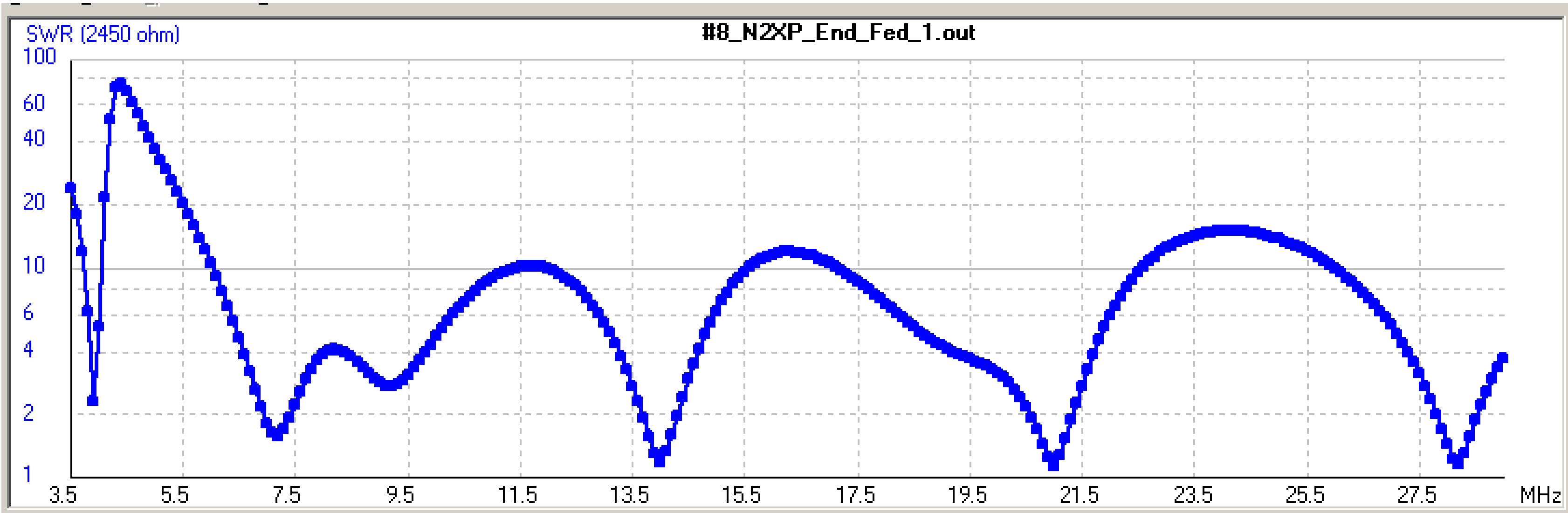
It only requires one elevated support. Your station can be located close to the feedpoint, which is right at the transformer.

Pattern looks nearly omni-directional at these heights, with just less than 1dB gain on 40 Meters.



#8 N2XP End-Fed (Continued)

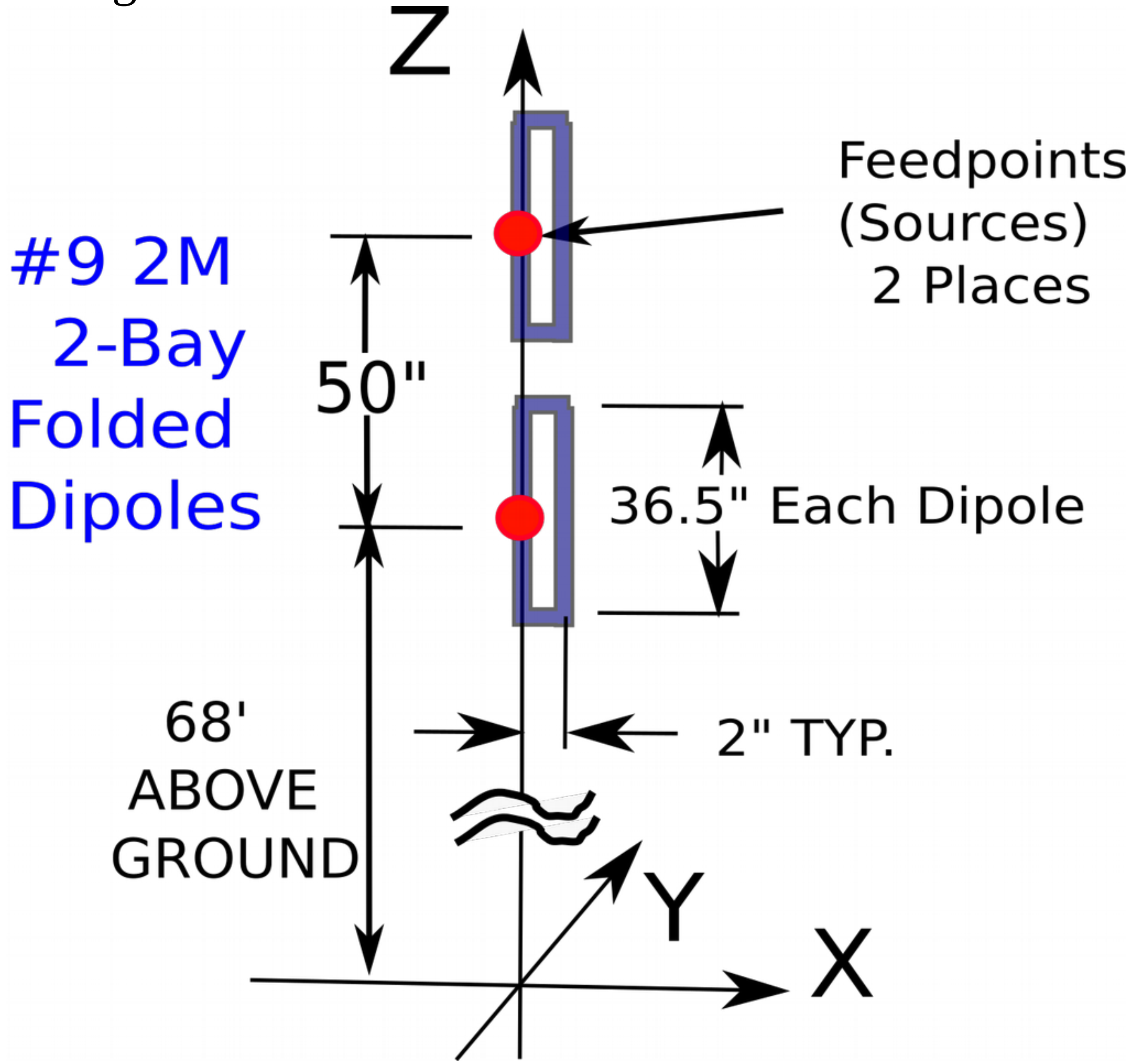
Radiation efficiency at ~35%. This is better than verticals over Real, Avg ground but less efficiency than the horizontal dipoles.



Looks good for the Harmonically-Related 80/40/20/15 and 10 meter bands
Didn't seem too sensitive to how much counterpoise it has, as long as it had something. On the lower bands, the counterpoise helped, especially on 40M. The value of the 110uH loading coil primarily affects the 80 meter tuning.

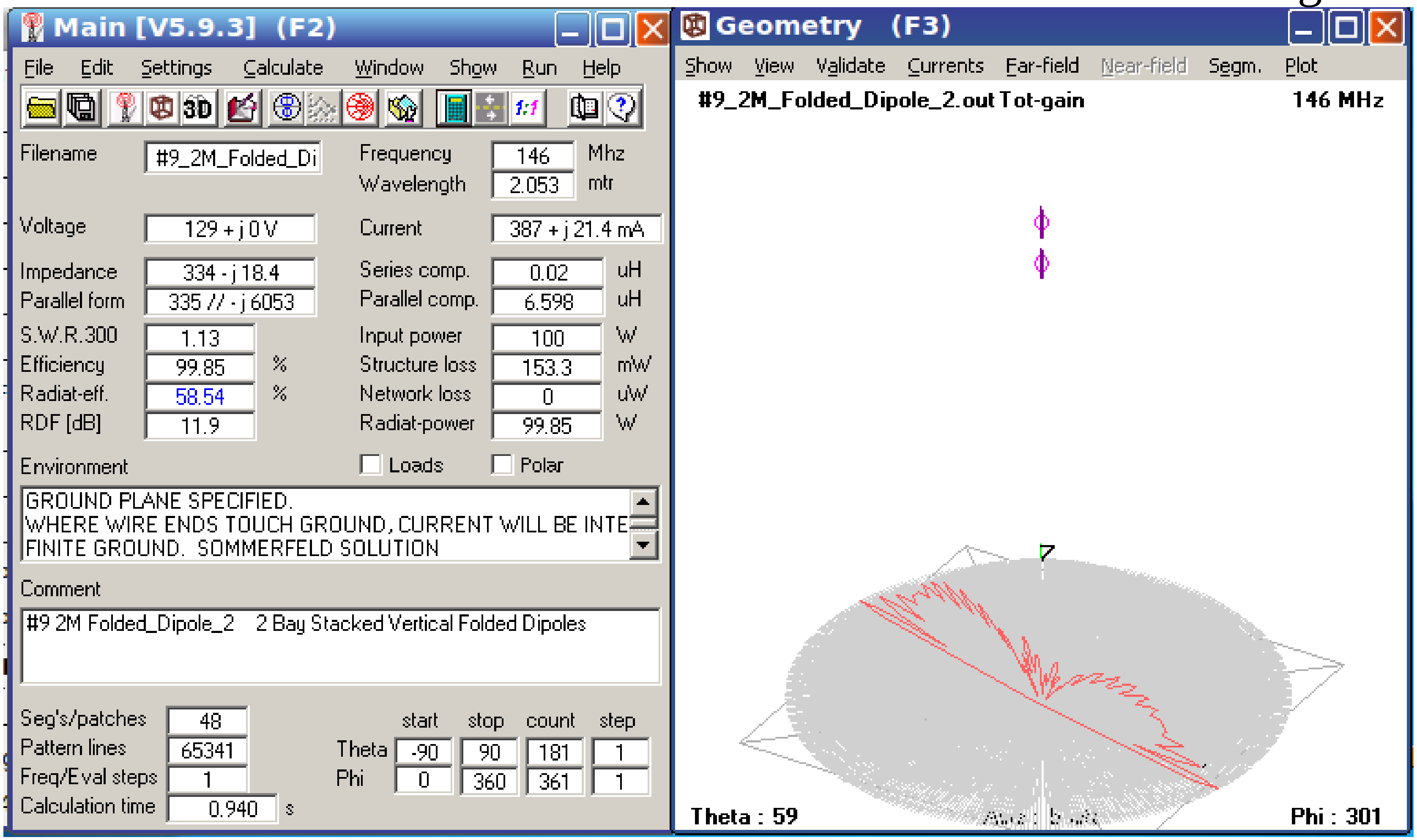
56 **#9 2 Meter 2-Bay Folded Dipoles** *#9_2M_Folded_Dipole_2.nec*

Brass Tubing 0.186”Diameter. Zc=300Ω



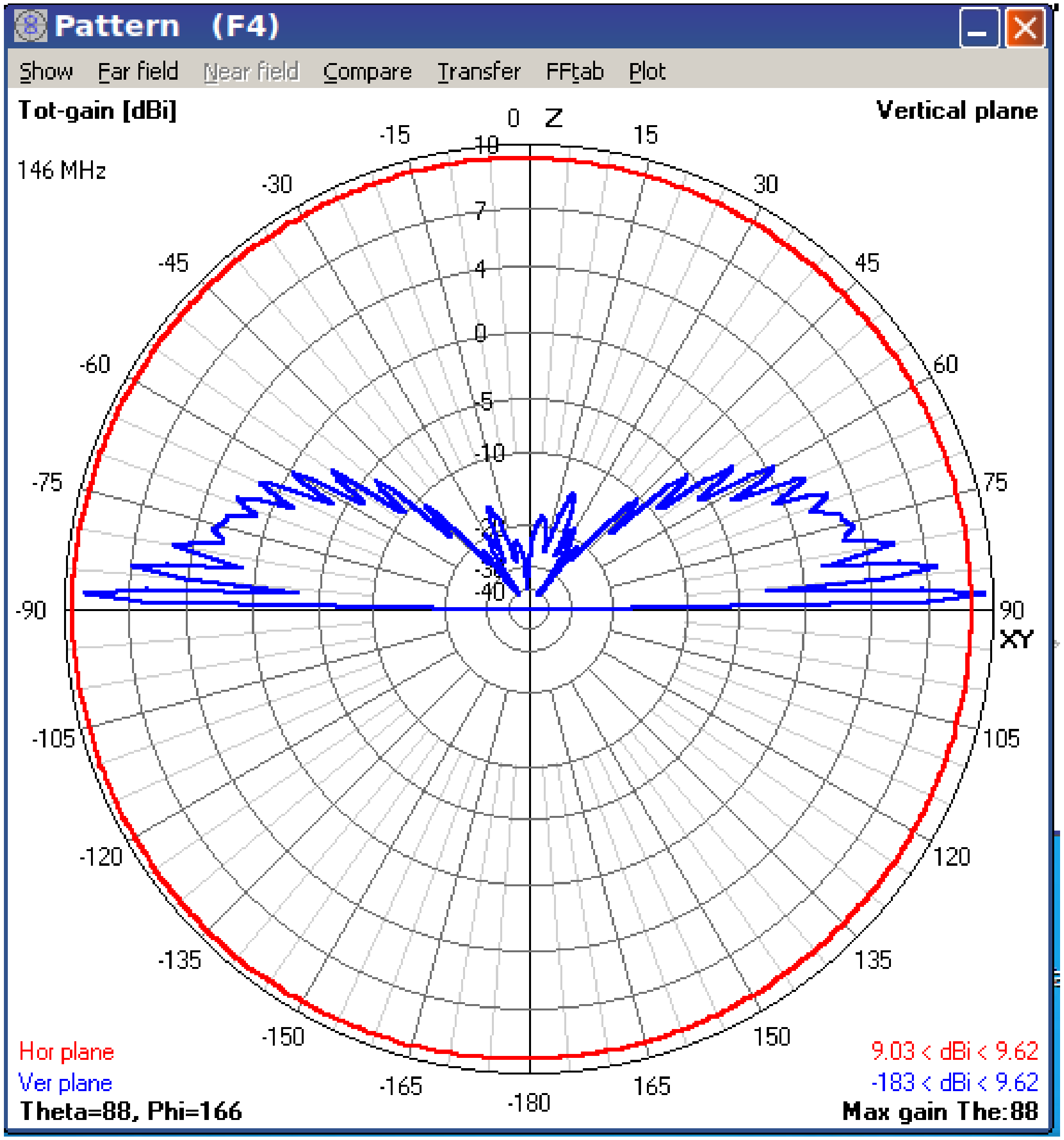
#9 2 Meter 2-Bay Folded Dipoles (Continued)

Inexpensive, non-critical, easy-to-replicate construction with little or no tuning. Good gain ~9.63 dBi omnidirectional. Vertical Polarization, ~58% Radiation Efficiency. Can be supported on same support with other antennas for other VHF/UHF bands. Conductor: 0.186” diameter Brass Tubing



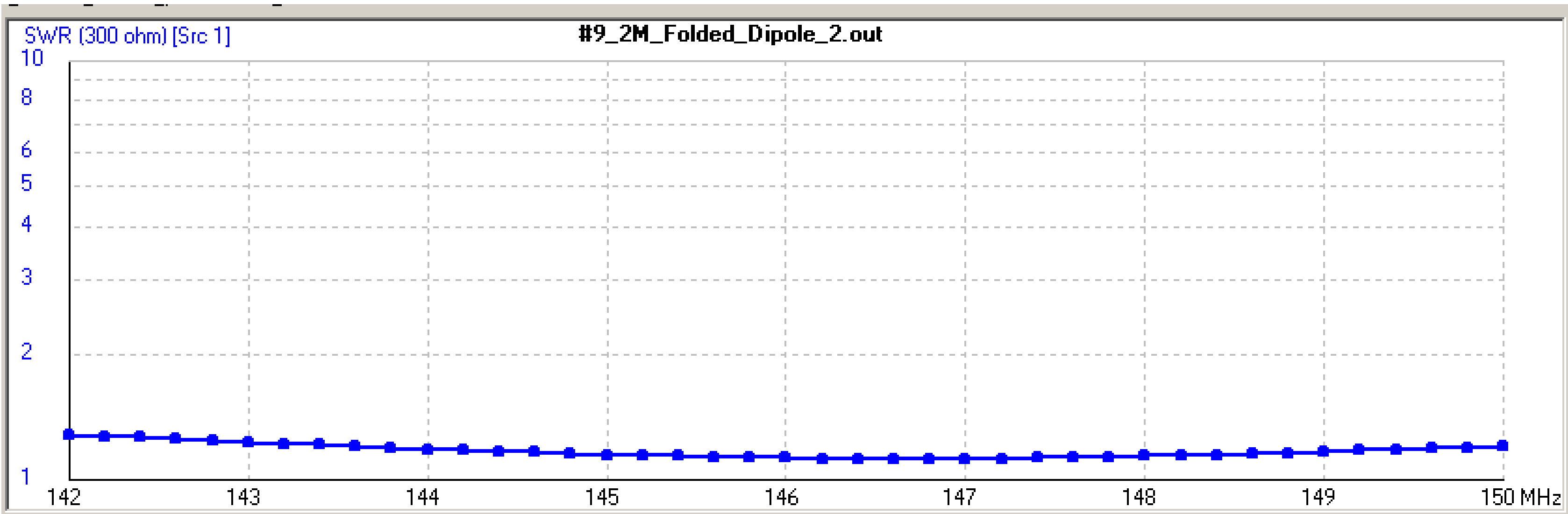
 #9 2 Meter 2-Bay Folded Dipoles (Continued)

Here is the pattern with a low angle of radiation, omnidirectional. The gain of ~9.62 dBi is directed at the horizon. This value is referenced to Isotropic.



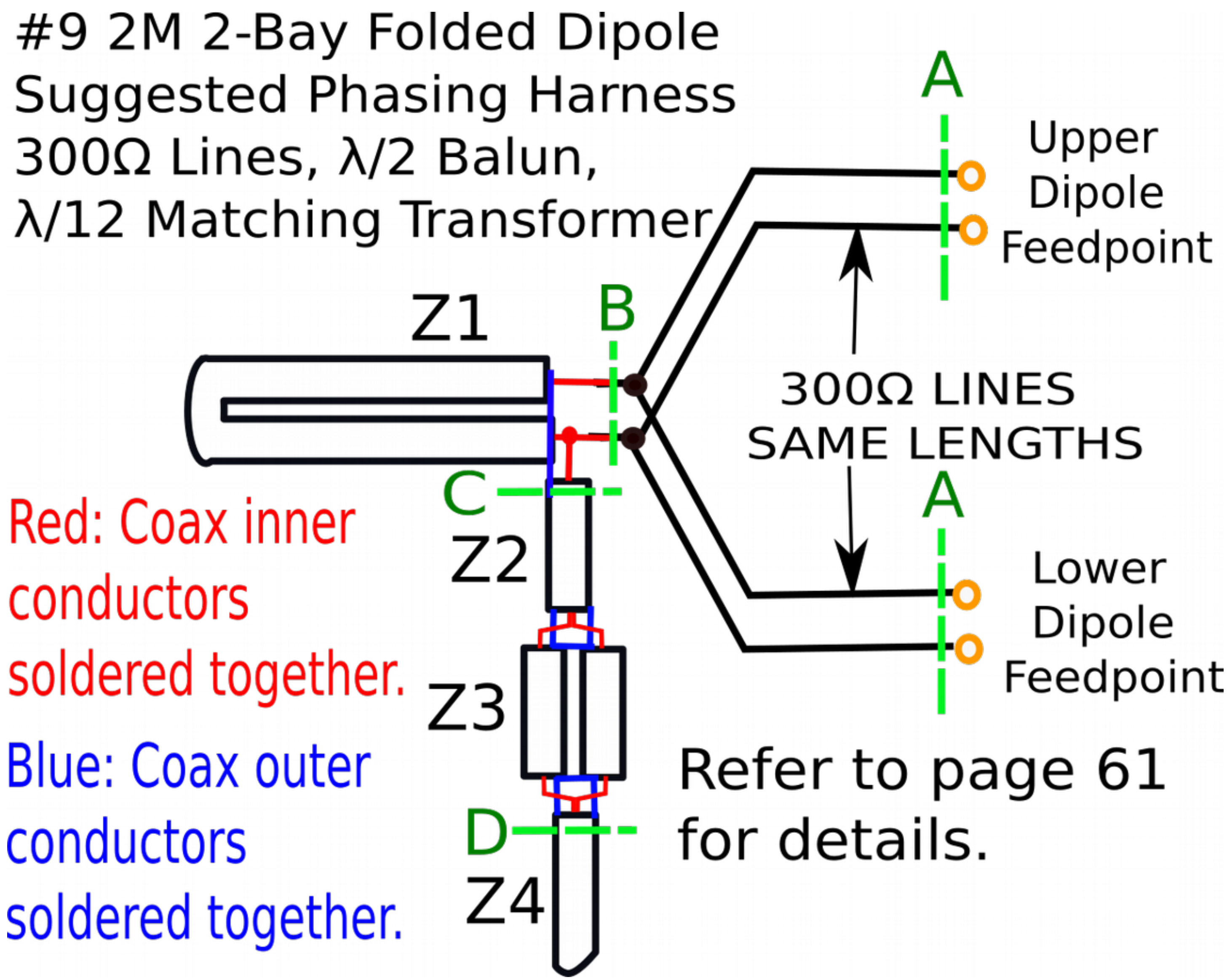
#9 2 Meter 2-Bay Folded Dipoles (Continued)

Very flat, non critical tuning with 300Ω feedlines.



How to feed this thing??

Suggested easy-to-build phasing harness on next page.


#9 2M 2-Bay Folded Dipole
Suggested Phasing Harness
300Ω Lines, λ/2 Balun,
λ/12 Matching Transformer
A
Upper
Dipole
Feedpoint
Z1
B
300Ω LINES
SAME LENGTHS
A
C
Red: Coax inner
conductors
soldered together.
Z2
Lower
Dipole
Feedpoint
Z3
Blue: Coax outer
conductors
soldered together.
Refer to page 61
for details.
D
Z4

#9 2 Meter 2-Bay Folded Dipoles (Continued)

Suggested Phasing Harness Matching Details:

Note: Dashed lines in Green denote reference planes, labeled ‘A’ thru ‘D’.

The folded dipoles present a feed-point impedance of approximately 300 Ω at both feed-points labeled ‘A’. When these feedlines are combined with the proper phase at ‘B’, we see approximately 300Ω /2= 150 Ω. This is presented to the balanced ports of the Z1 4:1 balun, which in turn presents 150Ω /4 or ~ 37.5 Ω. The Bramham λ/12 Transformer made up of Z2 (50 Ω) and Z3 (75Ω /2=37.5 Ω) which matches to ~ 50 Ω for the 50 Ω down-feed Z4. This down-feed Z4 can be any length of low-loss 50Ω coax, like LMR400, etc..

 Suggested Phasing Harness Details:

Z1-Z3 Information:

Z1-Z3 are preferably made from Solid PE Dielectric coax, as its velocity factor is normally close to 0.66. To use a Foam Dielectric Coax, you need to know the velocity factor *from the manufacturer* as it can vary greatly.

Z1: For Solid Dielectric (50 Ω RG-58/U or 75 Ω RG-59/U):
Length [in]= (300/146)*(39.37)*(0.5)*(0.66) =26.69 inches. *Note [1] below*.

Z2: 50 Ω Coax such as RG-58/U *Solid* Dielectric.
Length [in]= (300/146)*(39.37)*(0.125)*(0.66) =6.67 inches. *Note [1] below.*

Z3: 75 Ω Coax such as RG-59/U *Solid* Dielectric, (2) Lengths connected in parallel to provide a 37.5 Ω characteristic impedance. *Note [1] below.*

Z4: 50 Ω Coax, any length, foam or solid. Use your lowest-loss coax for Z4.

Note [1]: If you must use foam dielectric coax, substitute the manufacturer's velocity factor for the constant "0.66" in the above equation(s).

63 To Probe Further: *With Special Thanks to Arie Voors, PA2B*

The 4nec2 website: https://www.qsl.net/4nec2/
The *4nec2.rtf* file packed with the 4nec2.zip download is an excellent reference. After 4nec2.exe is installed, it can be found in /4nec2/exe/ or wherever your OS installs it.

Simulation of Wire Antennas using 4NEC2, Gunthard Kraus
Oberstudienrat, Elektronikschule Tettnang, Germany
https://www.qsl.net/4nec2/Tutorial_4NEC2_english.pdf

The 4nec2 Definitive Guide (A Work-In-Progress)
https://leanpub.com/4nec2definitiveguide/read

K5VR Transmission Line Calculator: Covers both Coax and Parallel Line types.
https://kv5r.com/ham-radio/coax-loss-calculator/

WN2A Website: www.qsl.net/wn2a PDF and .NEC files (T.B.D.)
Ladder-Line: 300 Ω: Wireman #562, DXE-LL300. Not necessarily equivalent
450 Ω: Wireman #551, DXE-LL450. Not necessarily equivalent