NEC
Numerical Electromagnetics Code

Numerical Analysis of the Electromagnetic Properties of Antenna Structures

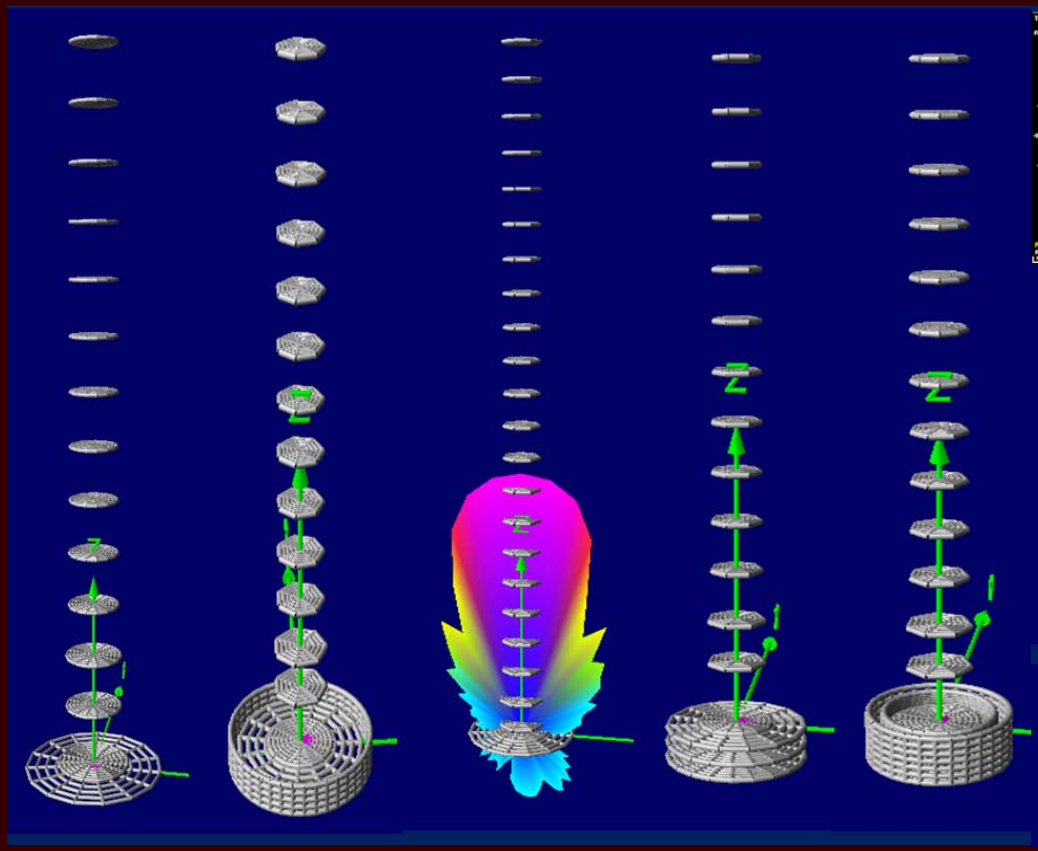
Analytical Modeling

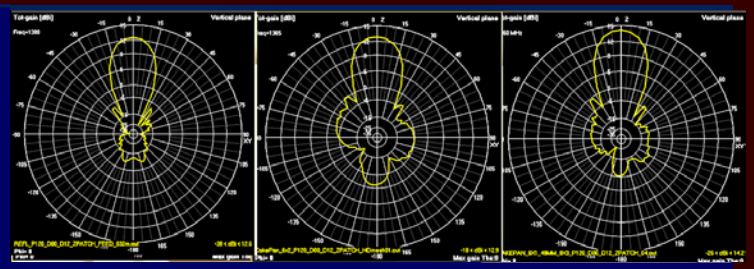
NEC
Numerical Electromagnetics Code
Overview

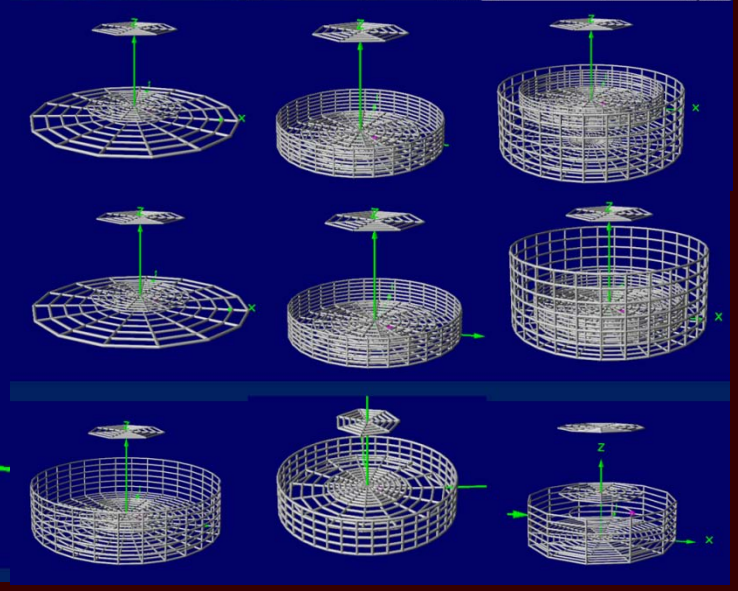
The NEC **Numerical Electromagnetics Code**
is an antenna modeling program for wire and surface antennas.

It was originally written in FORTRAN
during the 1970s by Lawrence Livermore National Laboratory.

NEC
Numerical Electromagnetics Code Overview







Antenna Modeling via Arie Voors' 4NEC2

An Overview of Numerical Electromagnetics Code Antenna Modeling

Many variations of the antennas were modeled to compare performance parameters.

The intent of the next few slides is to show what can be done with NEC Modeling highlighting some basic concepts

I recommend you gain experience in NEC Modeling :

https://www.qsl.net/4nec2/

You can't *guess* and expect optimal results
Learn to *use* a nanoVNA analyzer !

Numerical Electromagnetics Code

Antenna Modeling via Arie Voors' 4NEC2

The **Numerical Electromagnetics Code** is an antenna modeling program for wire and surface antennas. It was originally written in FORTRAN during the 1970s by Lawrence Livermore National Laboratory.

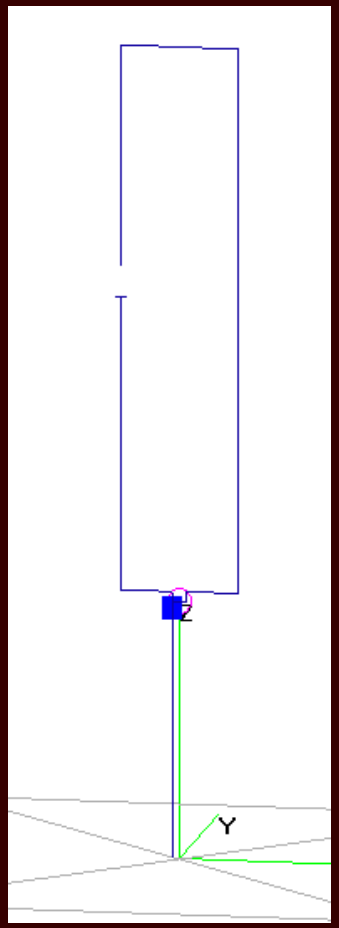
The NEC-2 Engine used by the **4NEC2** software is the original **(now public domain)** Lawrence Livermore Code.

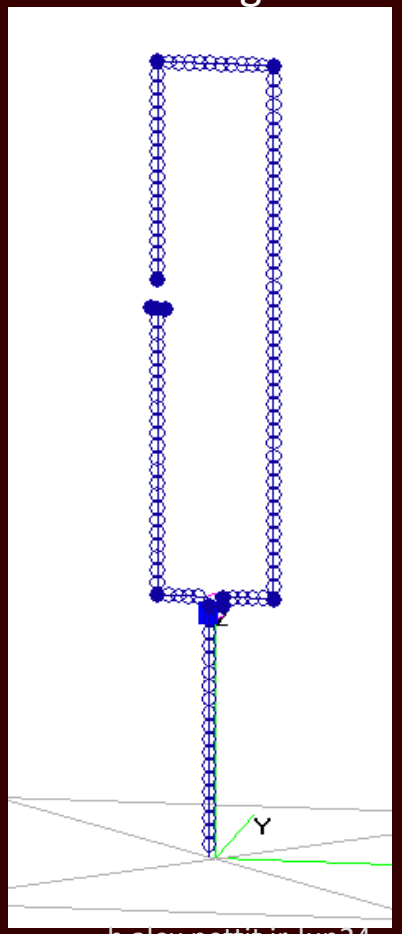
It performs an analysis of an antenna by Finite Element Analysis Techniques which divides wires into a number of small elements and computes their currents and resultant electric and magnetic fields

Numerical Electromagnetics Code

Antenna Modeling via Arie Voors' 4NEC2

NEC Modeling
performs an antenna analysis by
Finite Element Analysis techniques
which divides wires into a number of
small elements and computes their currents
and resultant electric and magnetic fields





Numerical Electromagnetics Code

Antenna Modeling via Arie Voors' 4NEC2

NEC Modeling
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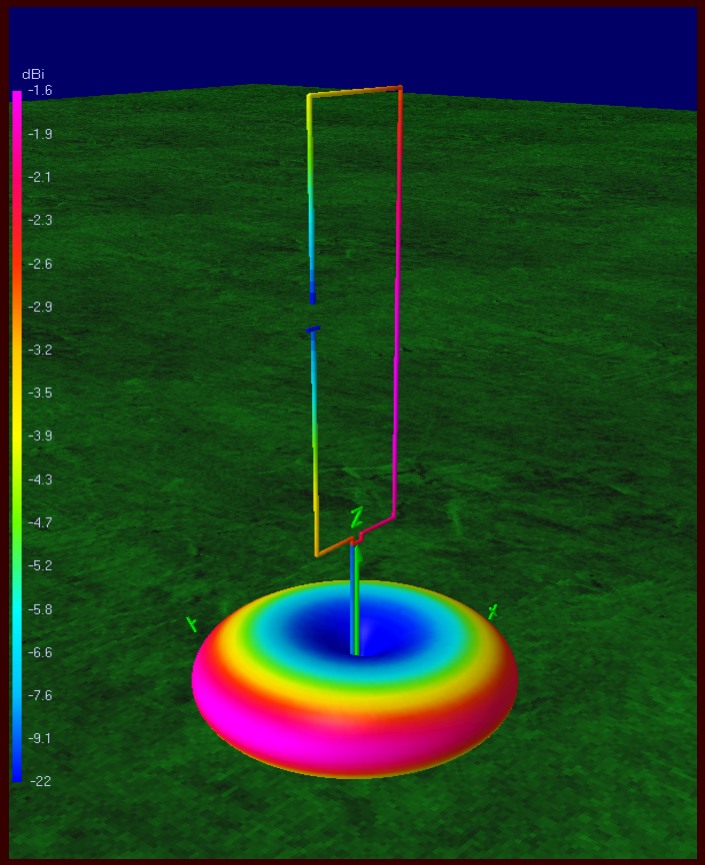
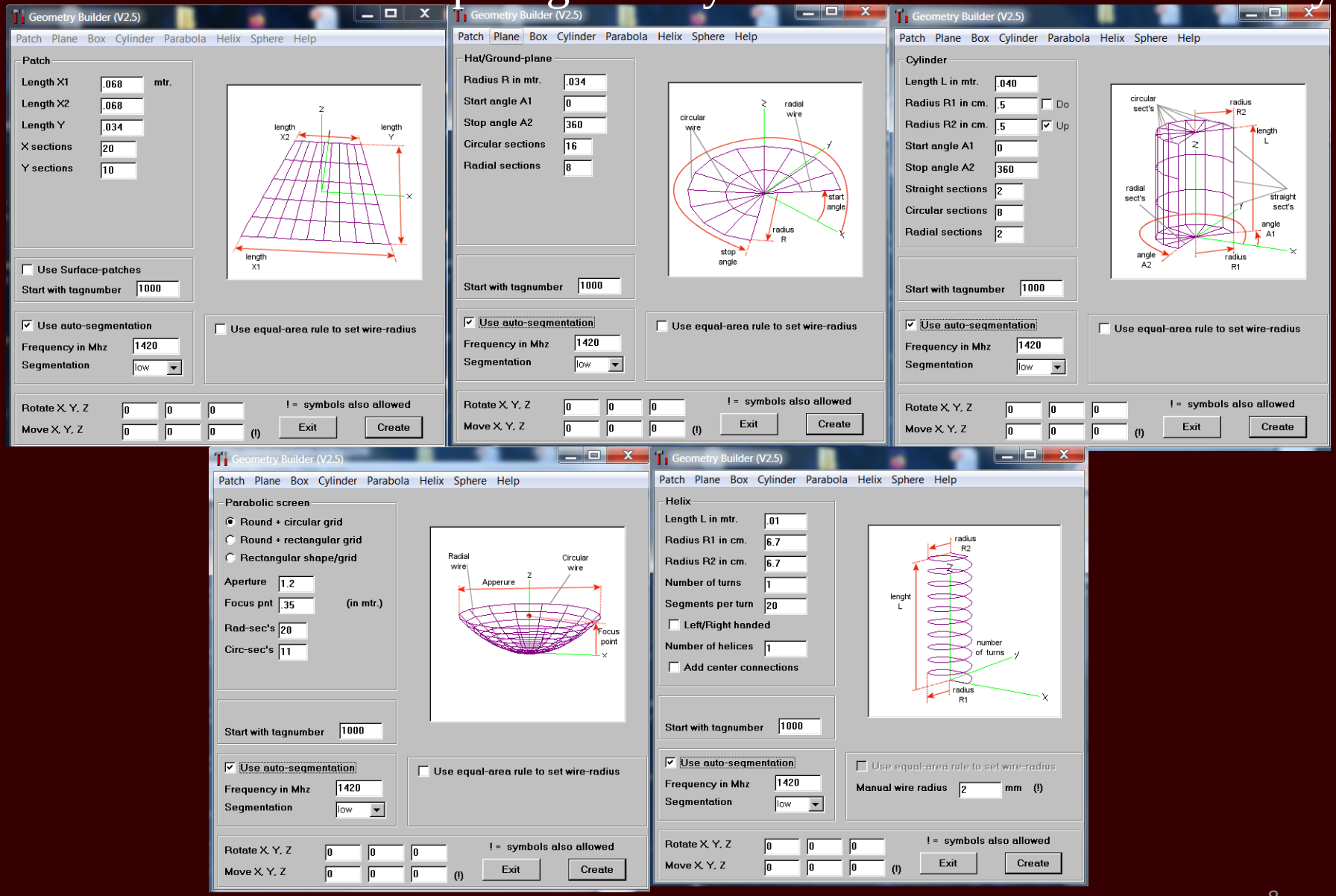


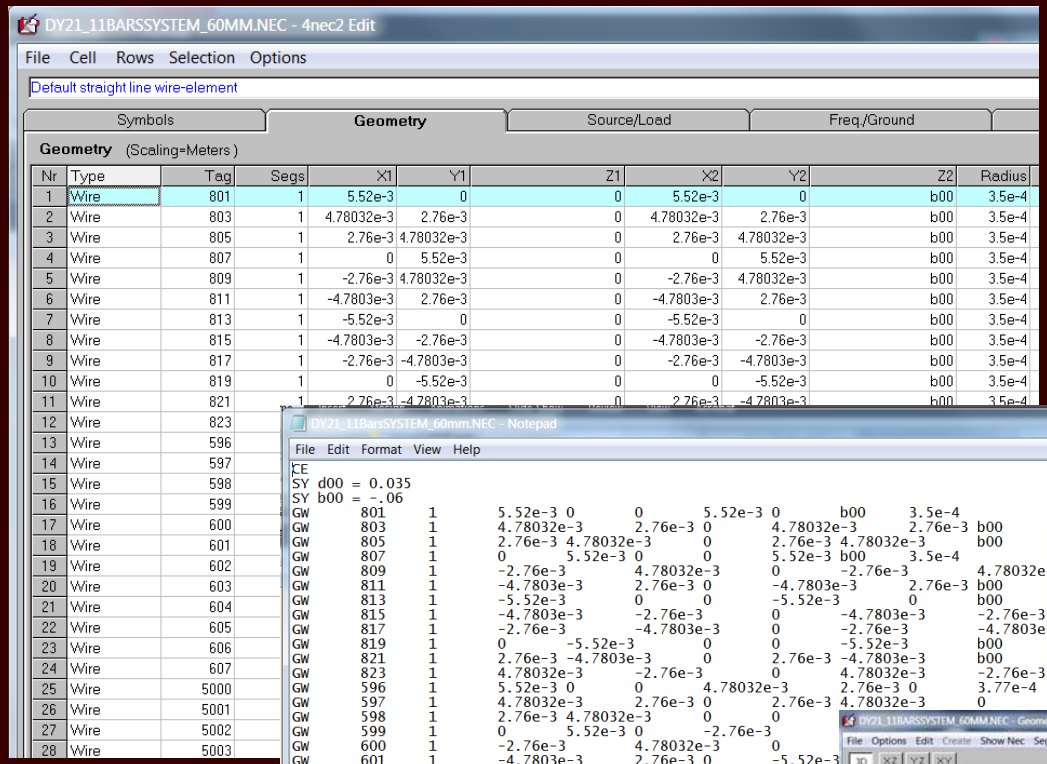
Complex Structure Geometry Builder

complex geometry can be created from this library

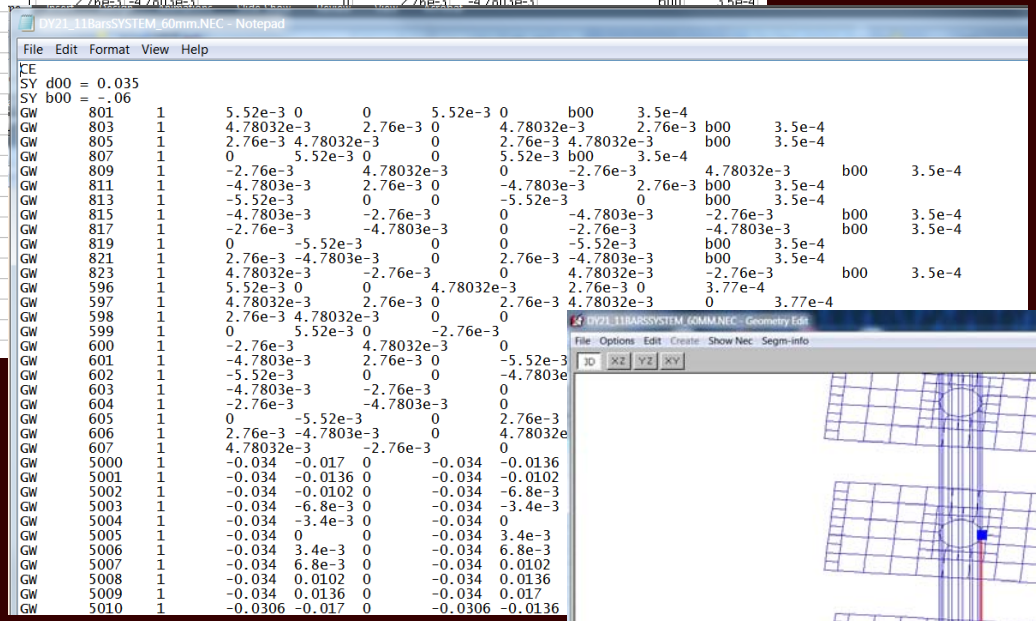


Numerical Electromagnetics Code

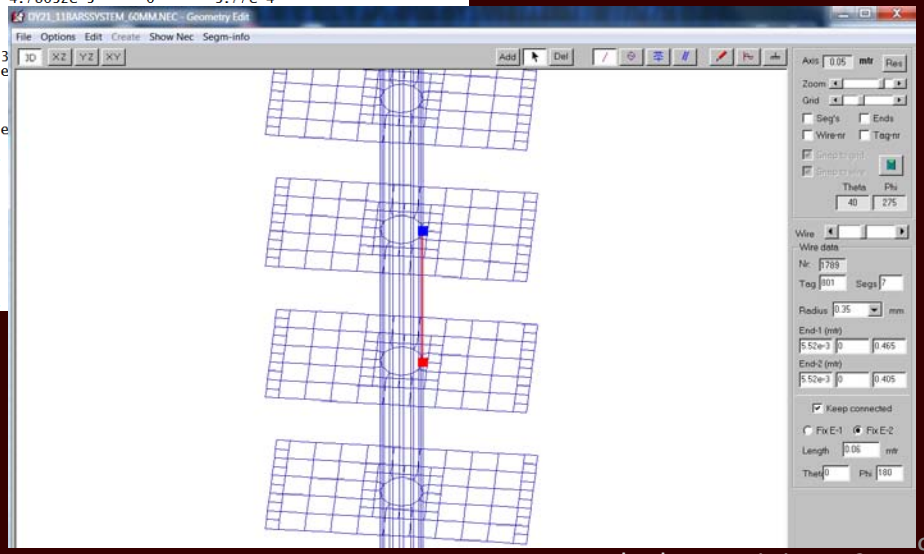
Geometry Entry / Modification Editors



Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius
1	Wire	801	1	5.52e-3	0	0	5.52e-3	0	b00	3.5e-4
2	Wire	803	1	4.78032e-3	2.76e-3	0	4.78032e-3	2.76e-3	b00	3.5e-4
3	Wire	805	1	2.76e-3	4.78032e-3	0	2.76e-3	4.78032e-3	b00	3.5e-4
4	Wire	807	1	0	5.52e-3	0	0	5.52e-3	b00	3.5e-4
5	Wire	809	1	-2.76e-3	4.78032e-3	0	-2.76e-3	4.78032e-3	b00	3.5e-4
6	Wire	811	1	-4.7803e-3	2.76e-3	0	-4.7803e-3	2.76e-3	b00	3.5e-4
7	Wire	813	1	-5.52e-3	0	0	-5.52e-3	0	b00	3.5e-4
8	Wire	815	1	-4.7803e-3	-2.76e-3	0	-4.7803e-3	-2.76e-3	b00	3.5e-4
9	Wire	817	1	-2.76e-3	-4.7803e-3	0	-2.76e-3	-4.7803e-3	b00	3.5e-4
10	Wire	819	1	0	-5.52e-3	0	0	-5.52e-3	b00	3.5e-4
11	Wire	821	1	2.76e-3	-4.7803e-3	0	2.76e-3	-4.7803e-3	b00	3.5e-4
12	Wire	823								
13	Wire	596								
14	Wire	597								
15	Wire	598								
16	Wire	599								
17	Wire	600								
18	Wire	601								
19	Wire	602								
20	Wire	603								
21	Wire	604								
22	Wire	605								
23	Wire	606								
24	Wire	607								
25	Wire	5000								
26	Wire	5001								
27	Wire	5002								
28	Wire	5003								

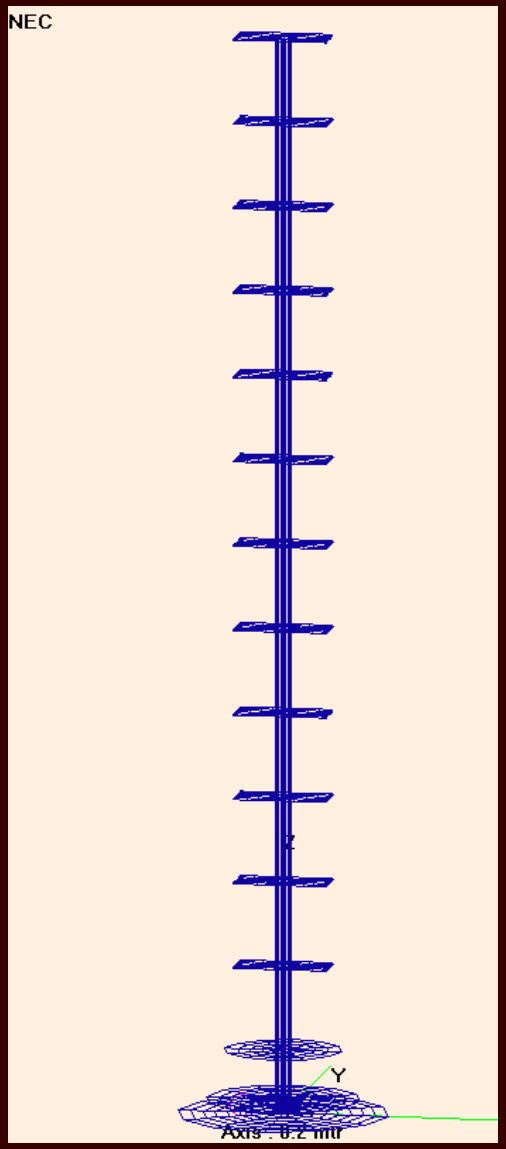



```
CE
SY d00 = 0.035
SY b00 = -.06
GW      801     1       5.52e-3 0       0       5.52e-3 0       b00     3.5e-4
GW      803     1       4.78032e-3      2.76e-3 0       4.78032e-3      2.76e-3 b00     3.5e-4
GW      805     1       2.76e-3 4.78032e-3      0       2.76e-3 4.78032e-3      b00     3.5e-4
GW      807     1       0       5.52e-3 0       0       5.52e-3 b00     3.5e-4
GW      809     1       -2.76e-3        4.78032e-3      0       -2.76e-3        4.78032e-3      b00     3.5e-4
GW      811     1       -4.7803e-3      2.76e-3 0       -4.7803e-3      2.76e-3 b00     3.5e-4
GW      813     1       -5.52e-3        0       0       -5.52e-3        0       b00     3.5e-4
GW      815     1       -4.7803e-3      -2.76e-3        0       -4.7803e-3      -2.76e-3        b00     3.5e-4
GW      817     1       -2.76e-3        -4.7803e-3      0       -2.76e-3        -4.7803e-3      b00     3.5e-4
GW      819     1       0       -5.52e-3        0       0       -5.52e-3        b00     3.5e-4
GW      821     1       2.76e-3 -4.7803e-3      0       2.76e-3 -4.7803e-3      b00     3.5e-4
GW      823     1       4.78032e-3      -2.76e-3        0       4.78032e-3      -2.76e-3        b00     3.5e-4
GW      596     1       5.52e-3 0       0       4.78032e-3      2.76e-3 0       3.77e-4
GW      597     1       4.78032e-3      2.76e-3 0       2.76e-3 4.78032e-3      0       3.77e-4
GW      598     1       2.76e-3 4.78032e-3      0       0
GW      599     1       0       5.52e-3 0       -2.76e-3
GW      600     1       -2.76e-3        4.78032e-3      0
GW      601     1       -4.7803e-3      2.76e-3 0       -5.52e-3
GW      602     1       -5.52e-3        0       0       -4.7803e
GW      603     1       -4.7803e-3      -2.76e-3        0
GW      604     1       -2.76e-3        -4.7803e-3      0
GW      605     1       0       -5.52e-3        0       2.76e-3
GW      606     1       2.76e-3 -4.7803e-3      0       4.78032e
GW      607     1       4.78032e-3      -2.76e-3        0
GW      5000    1       -0.034  -0.017  0       -0.034  -0.0136
GW      5001    1       -0.034  -0.0136 0       -0.034  -0.0102
GW      5002    1       -0.034  -0.0102 0       -0.034  -6.8e-3
GW      5003    1       -0.034  -6.8e-3 0       -0.034  -3.4e-3
GW      5004    1       -0.034  -3.4e-3 0       -0.034  0
GW      5005    1       -0.034  0       0       -0.034  3.4e-3
GW      5006    1       -0.034  3.4e-3  0       -0.034  6.8e-3
GW      5007    1       -0.034  6.8e-3  0       -0.034  0.0102
GW      5008    1       -0.034  0.0102  0       -0.034  0.0136
GW      5009    1       -0.034  0.0136  0       -0.034  0.017
GW      5010    1       -0.0306 -0.017  0       -0.0306 -0.0136
```



Simple geometry can be defined in tables
Complex can be combined and modified
via
NEC Text Editor
MS Notepad Editor
NEC 3D view Editor

Geometry Entry / Modification Editors



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NEC Text Editor
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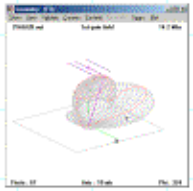
NEC 3D view Editor

Numerical Electromagnetics Code

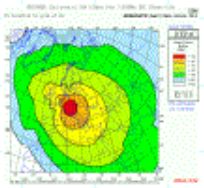
Screenshots of 4NEC2 Analysis Capability

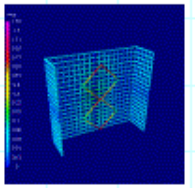

Main window

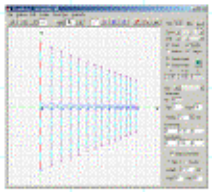

Overview

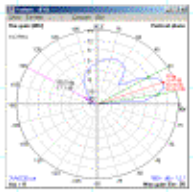

Nec editor

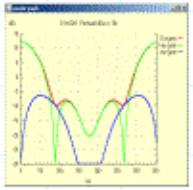

Impedance matching

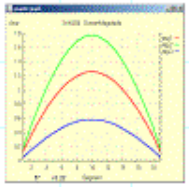

Area Coverage

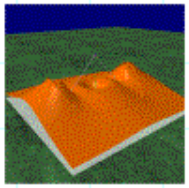

Current distribution

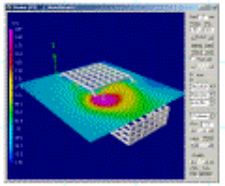

Geometry edit

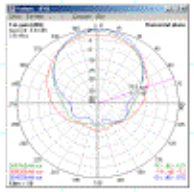

Far-field pattern

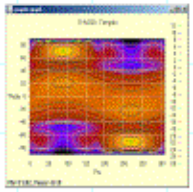

Linear far-field plot

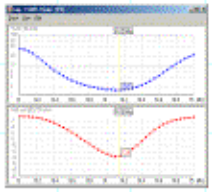

Current distibution


3D Near-field pattern

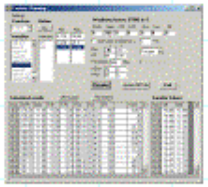

Field inside car

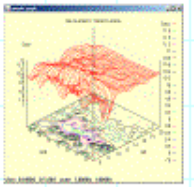

Compare patterns

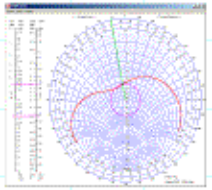

FF surface plot

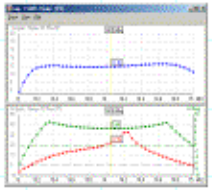

SWR for freq-sweep

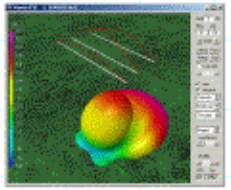

Helix model


Optimizer window

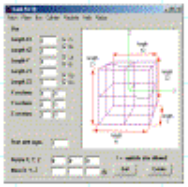

Search space

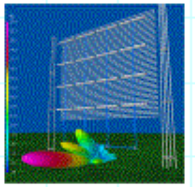

Smith chart


Gain, F/B and F/R ratio


3D viewer

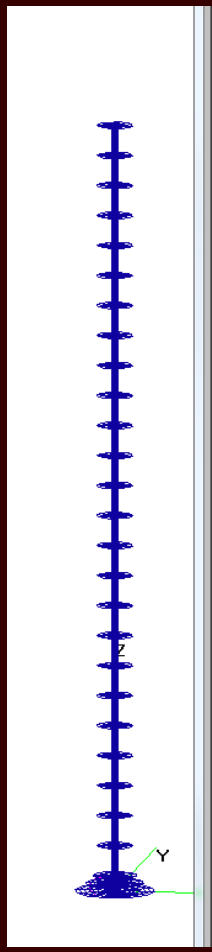

Ship model


Geomtry builder


HRS441 antenna

NEC
Numerical Electromagnetics Code

WIRE LIST geometric description of the antenna



Nr	Type	Tag	Segs	X1	Y1	Z1	X2	Y2	Z2	Radius
44	Wire	143	2	-.032043	-.0185	0	-.0185	-.032043	0	.001068
45	Wire	144	2	-.0185	-.032043	0	0	-.037	0	.001068
46	Wire	145	2	0	-.037	0	.0185	-.032043	0	.001068
47	Wire	146	2	.0185	-.032043	0	.032043	-.0185	0	.001068
48	Wire	147	2	.032043	-.0185	0	.037	0	0	.001068
49	Wire	148	1	.026667	0	0	.023094	.013333	0	.000941
50	Wire	149	1	.023094	.013333	0	.013333	.023094	0	.000941
51	Wire	150	1	.013333	.023094	0	0	.026667	0	.000941
52	Wire	151	1	0	.026667	0	-.013333	.023094	0	.000941
53	Wire	152	1	-.013333	.023094	0	-.023094	.013333	0	.000941
54	Wire	153	1	-.023094	.013333	0	-.026667	0	0	.000941
55	Wire	154	1	-.026667	0	0	-.023094	-.013333	0	.000941
56	Wire	155	1	-.023094	-.013333	0	-.013333	-.023094	0	.000941
57	Wire	156	1	-.013333	-.023094	0	0	-.026667	0	.000941
58	Wire	157	1	0	-.026667	0	.013333	-.023094	0	.000941
59	Wire	158	1	.013333	-.023094	0	.023094	-.013333	0	.000941
60	Wire	159	1	.023094	-.013333	0	.026667	0	0	.000941
61	Wire	160	1	.016333	0	0	.014145	.008167	0	.00074
62	Wire	161	1	.014145	.008167	0	.008167	.014145	0	.00074
63	Wire	162	1	.008167	.014145	0	0	.016333	0	.00074
64	Wire	163	1	0	.016333	0	-.008167	.014145	0	.00074
65	Wire	164	1	-.008167	.014145	0	-.014145	.008167	0	.00074
66	Wire	165	1	-.014145	.008167	0	-.016333	0	0	.00074
67	Wire	166	1	-.016333	0	0	-.014145	-.008167	0	.00074
68	Wire	167	1	-.014145	-.008167	0	-.008167	-.014145	0	.00074
69	Wire	168	1	-.008167	-.014145	0	0	-.016333	0	.00074
70	Wire	169	1	0	-.016333	0	.008167	-.014145	0	.00074
71	Wire	170	1	.008167	-.014145	0	.014145	-.008167	0	.00074
72	Wire	171	1	.014145	-.008167	0	.016333	0	0	.00074
73	Wire	172	1	.006	0	0	.005196	.003	0	.00038
74	Wire	173	1	.005196	.003	0	.003	.005196	0	.00038
75	Wire	174	1	.003	.005196	0	0	.006	0	.00038
76	Wire	175	1	0	.006	0	-.003	.005196	0	.00038
77	Wire	176	1	-.003	.005196	0	-.005196	.003	0	.00038
78	Wire	177	1	-.005196	.003	0	-.006	0	0	.00038
79	Wire	178	1	-.006	0	0	-.005196	-.003	0	.00038
80	Wire	179	1	-.005196	-.003	0	-.003	-.005196	0	.00038
81	Wire	180	1	-.003	-.005196	0	0	-.006	0	.00038
82	Wire	181	1	0	-.006	0	.003	-.005196	0	.00038
83	Wire	182	1	.003	-.005196	0	.005196	-.003	0	.00038

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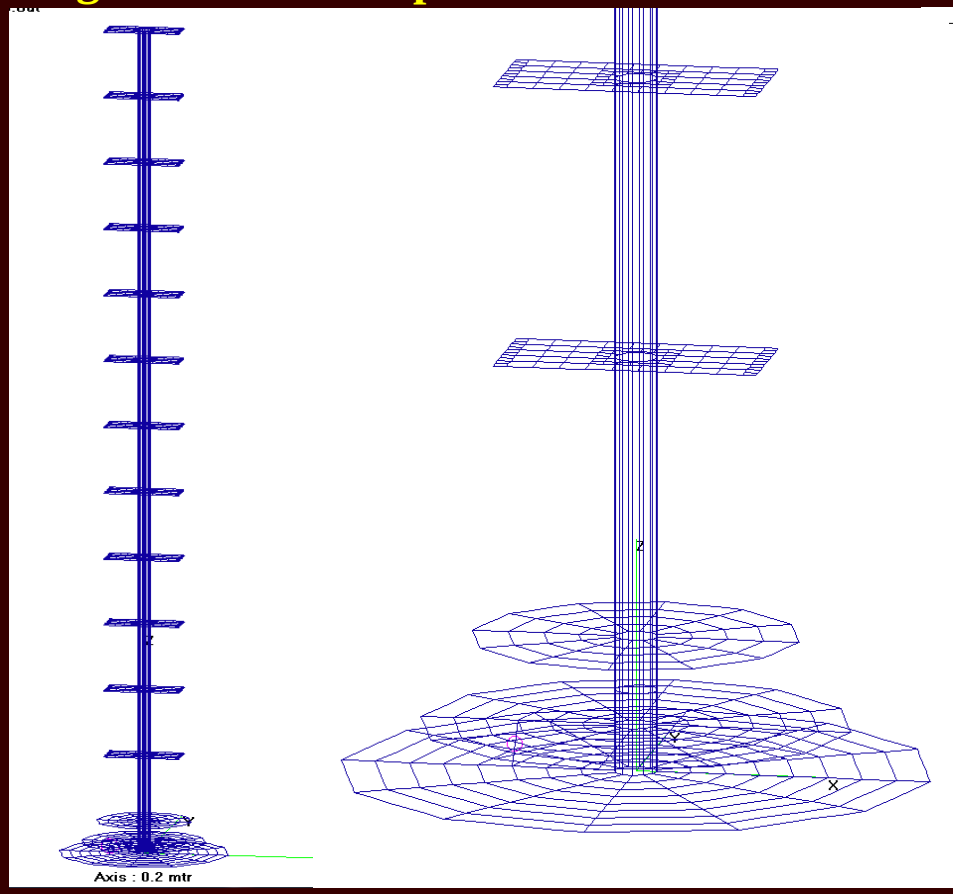
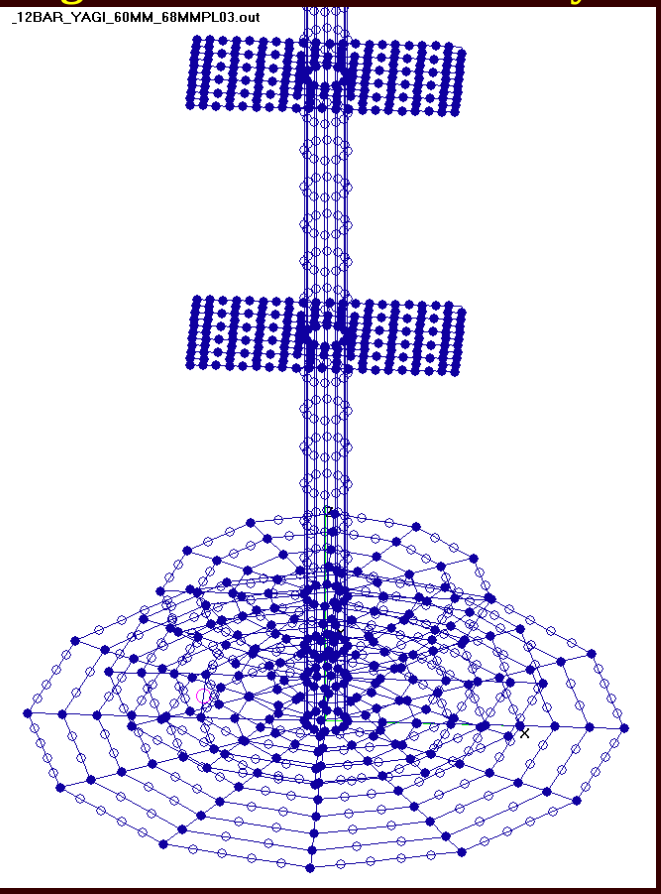
ANTENNA GEOMETRY

geometric description of the antenna



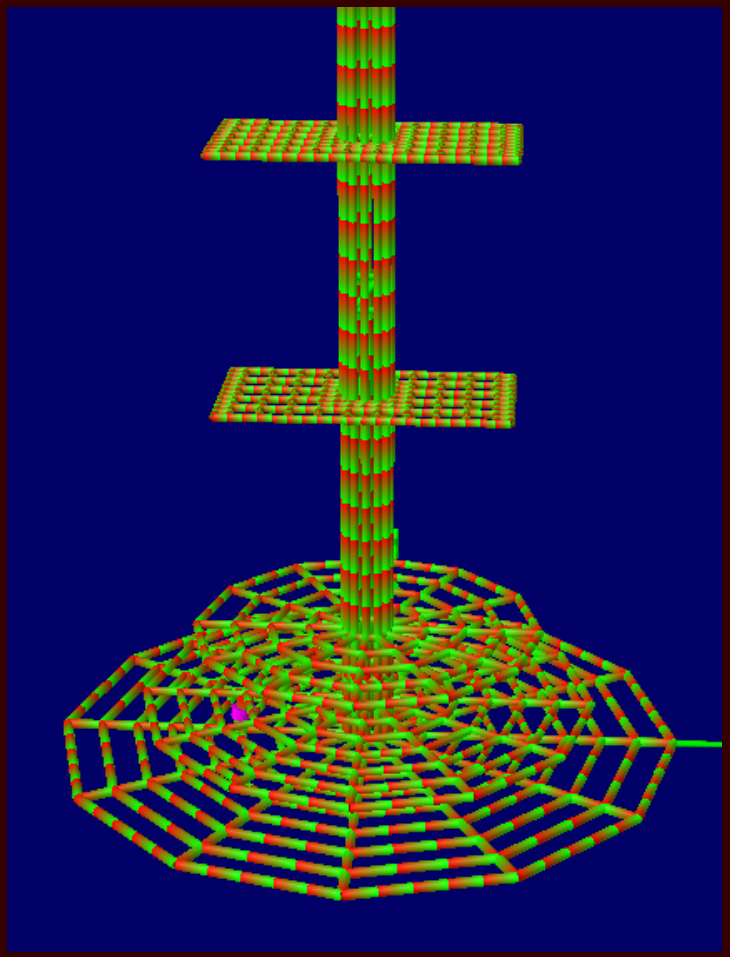
segmentation used for analysis



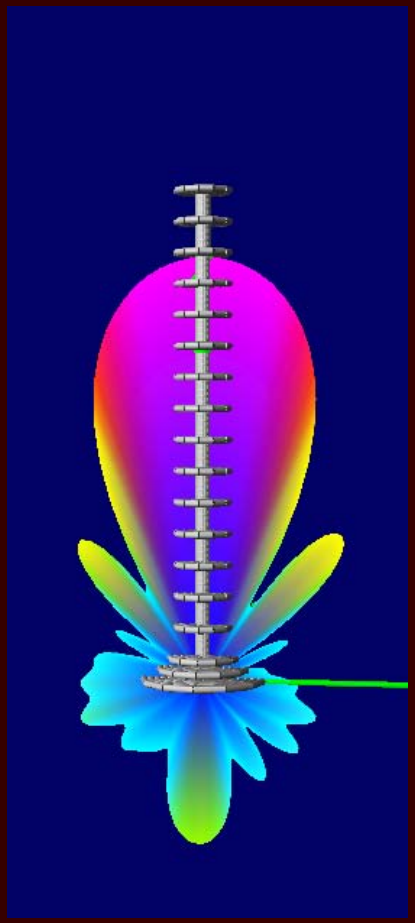
NEC

Numerical Electromagnetics Code

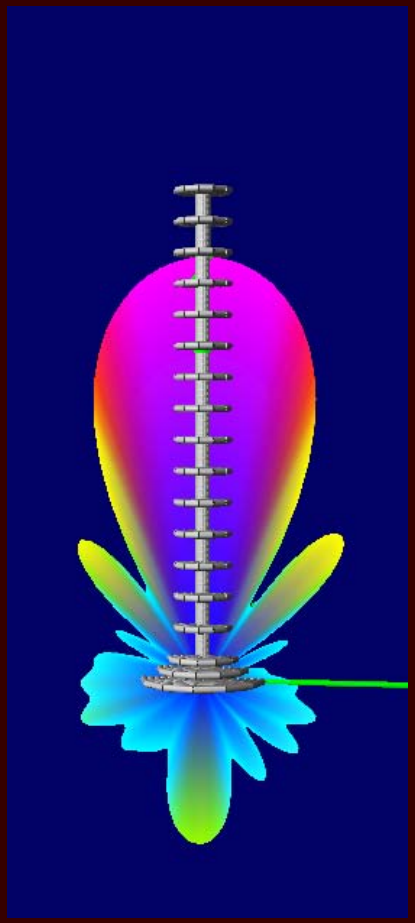
SEGMENTATON : each of these small elements are analyzed



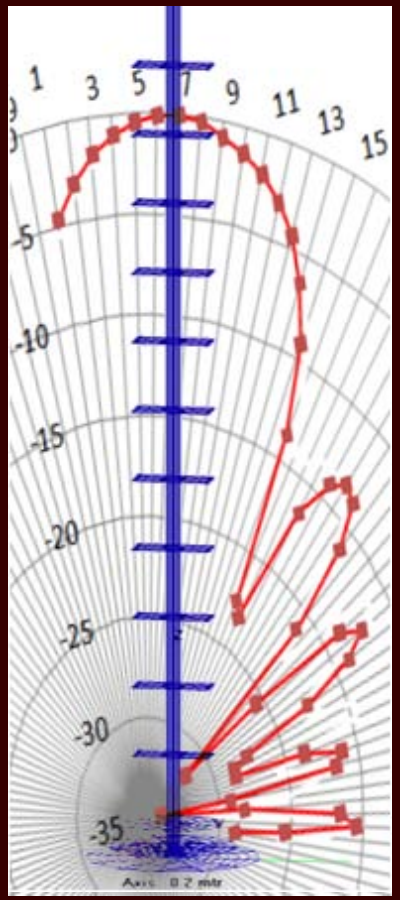
NEC
Numerical Electromagnetics Code
Analytical Models



A Typical
Analytical Model
is just an
Interesting
Academic
Exercise



NEC
Numerical Electromagnetics Code
Model Validation



But : When

Validated by Testing

an

Analytical Model

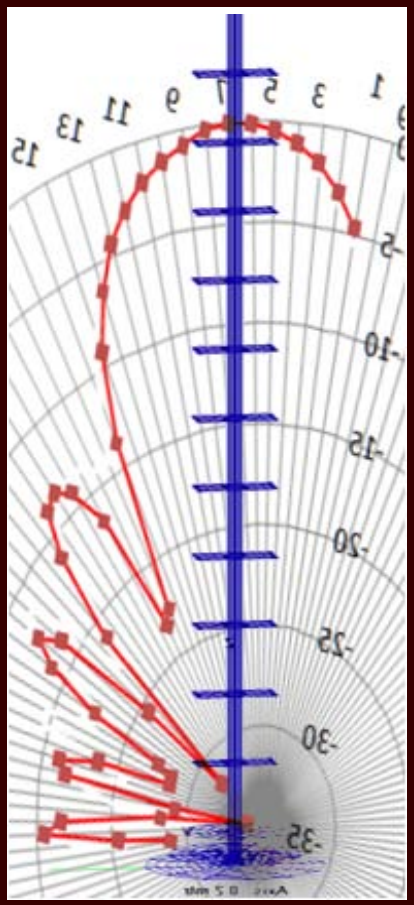
Becomes the Basis

for useful

Predictions of Performance

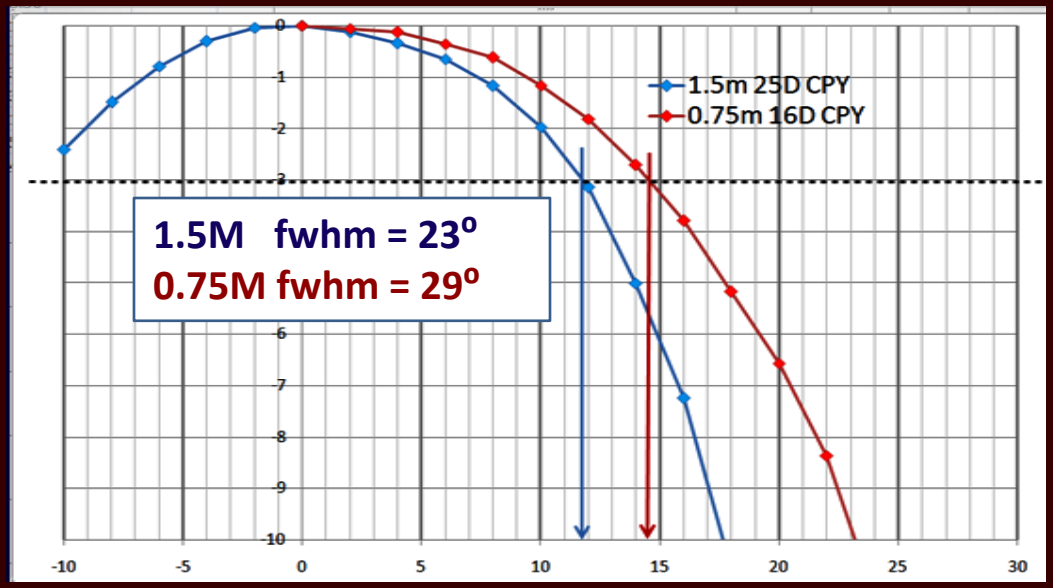
of

Changes / Modifications



Modeling vs Testing
Antenna Beam Width Characterization

1.5m 25 Director *0.75m 17 Director*

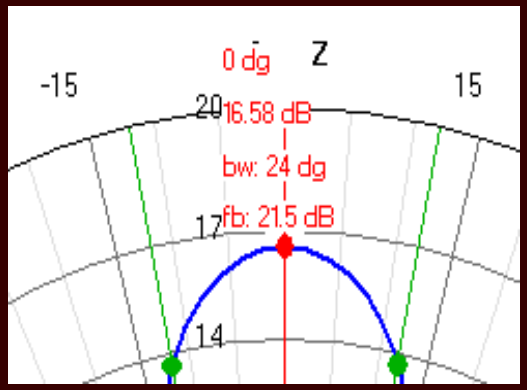


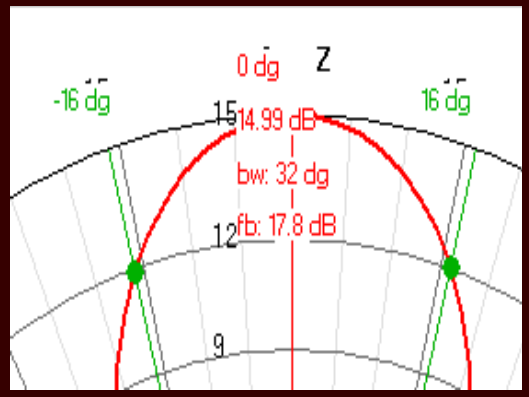
Field Test Beam Width

25D 1.5M fwhm = 23°

17D 0.75M fwhm = 29°

1.5m 25 Director *0.75m 17 Director*





NEC Models

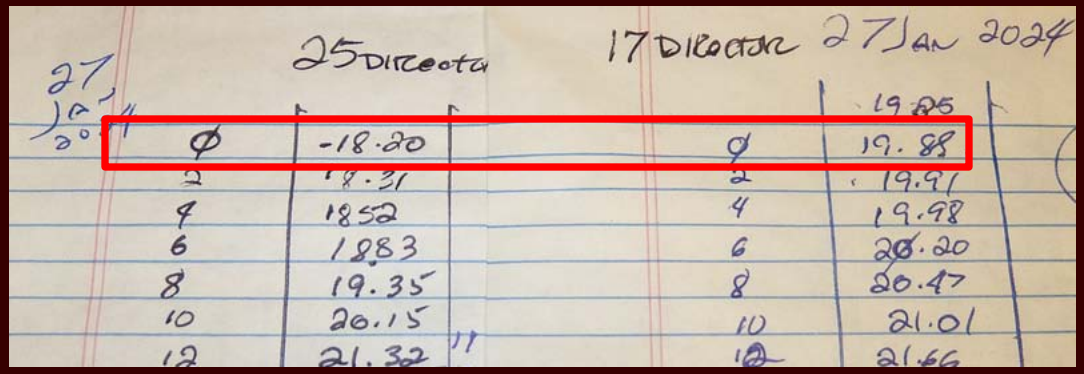
25D 1.5M fwhm = 24°

17D 0.75M fwhm = 32°

Modeling vs Testing
Antenna (relative) Gain Characterization

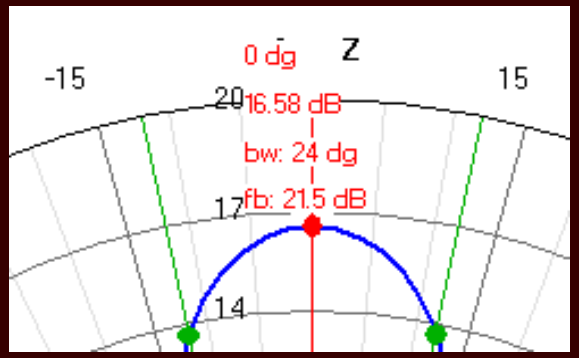
Field Test Data

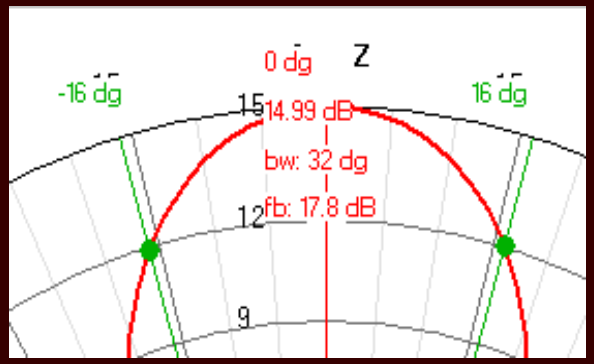
1.5m 25 Director vs 0.75m 17 Director



NEC Model Data

1.5m 25 Director vs 0.75m 17 Director





Field Test Data

25D max dB = -18.20
17D max dB = -19.85
difference = **1.65 dB**

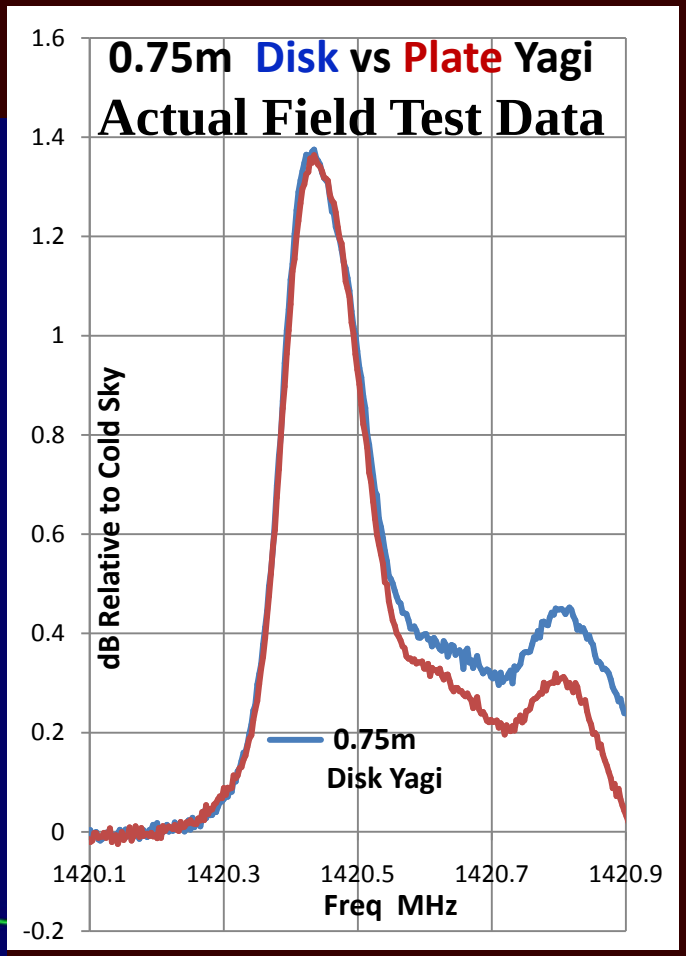
NEC Model Data

25D max dBi = 16.58
17D max dBi = 14.99
difference = **1.59 dB**

21cm Circular_Patch_Feed Disk vs Plate Yagi Antenna

Field Tests VS Theoretical NEC Model Analysis

Disk Yagi



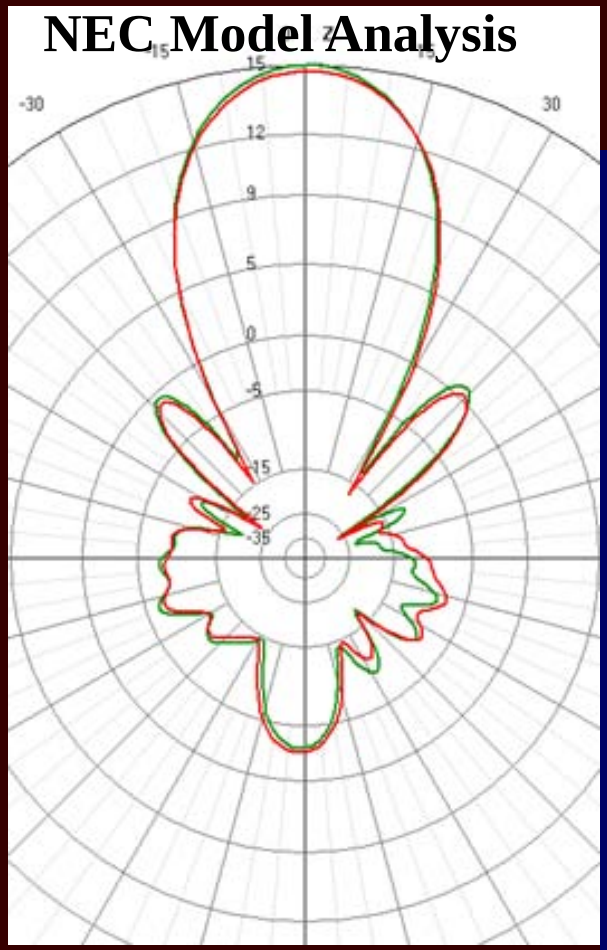
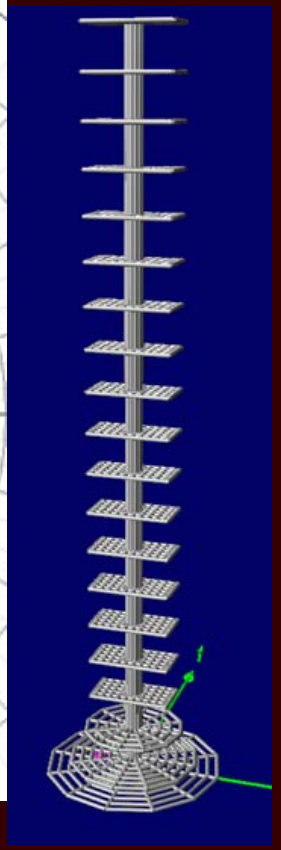


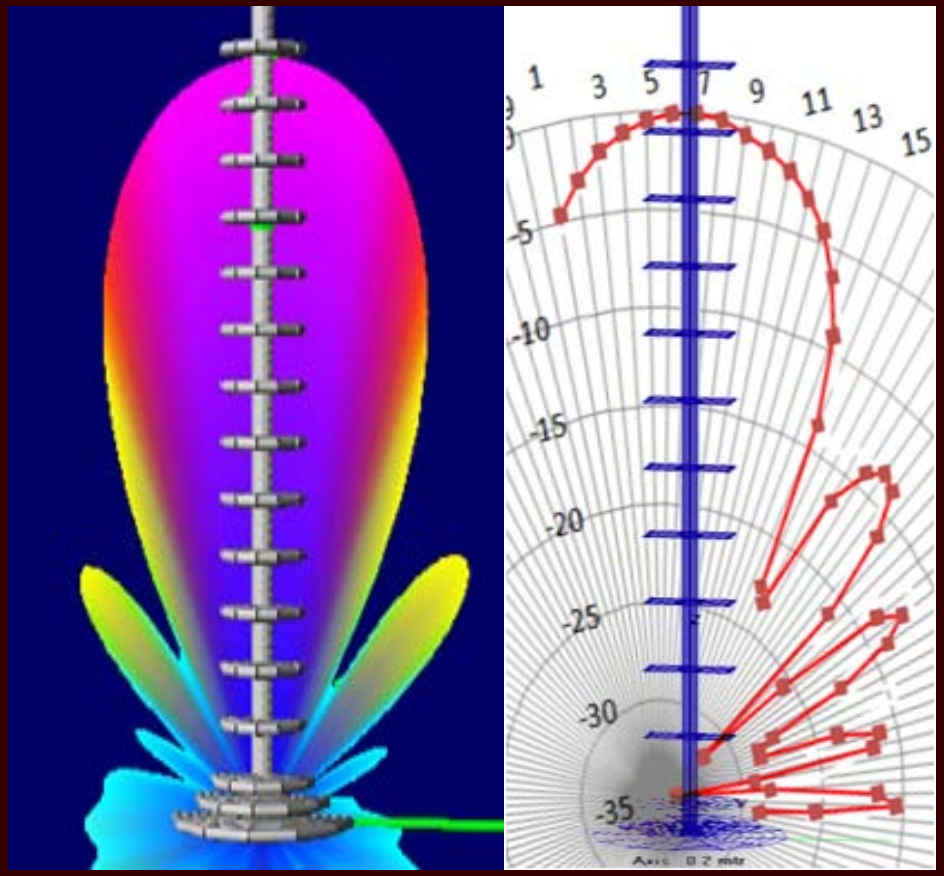
Plate Yagi



Patch Feed Yagi with Circular Disk and Rectangular Plate Directors

The model showed identical performance using rectangular plates

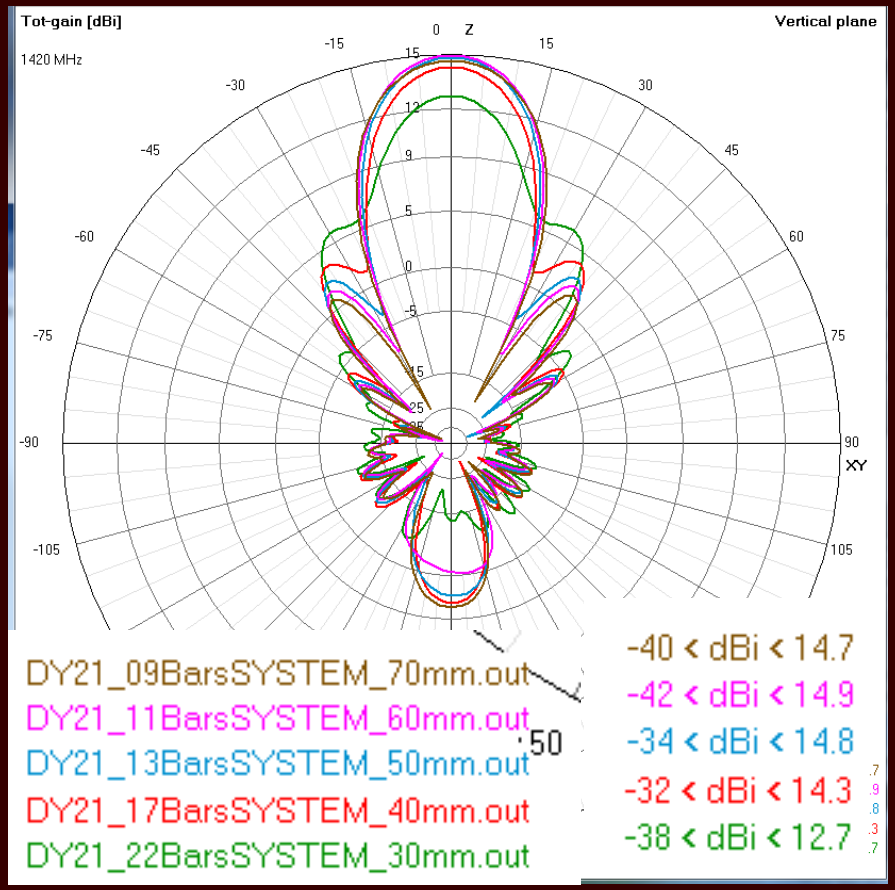
NEC Modeling + Field Testing Validates the Design



NEC Validated Model =

Predictions of Performance of Changes / Modifications

Beam Pattern vs Director Spacing Study

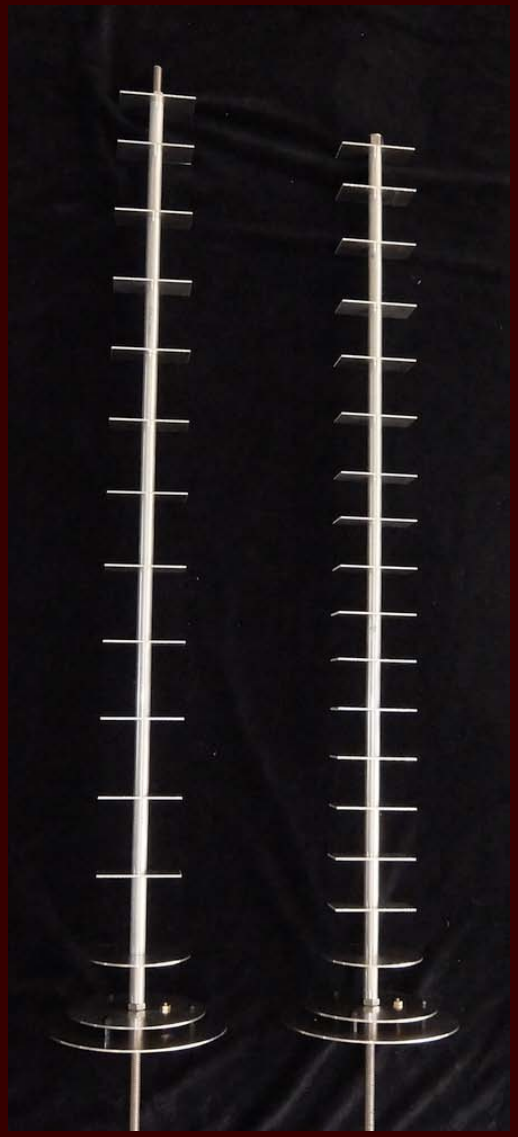


an NEC Study was performed to optimize the Front/Back Gain

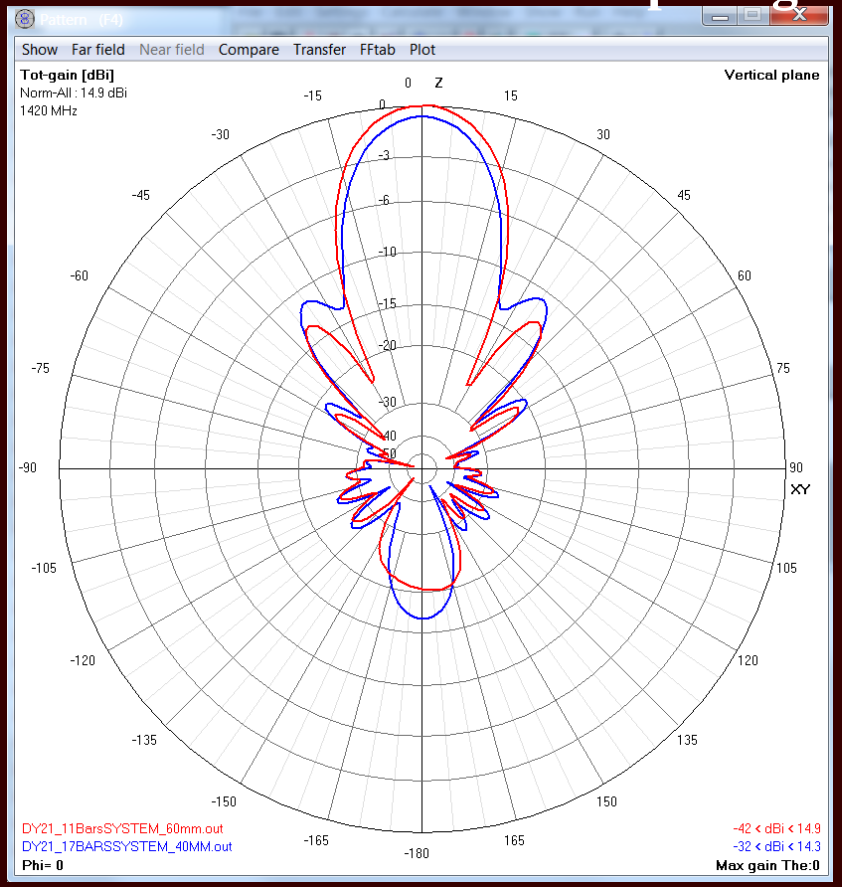
60mm Director Spacing was selected

NEC Validated Model =

Predictions of Performance of Changes / Modifications



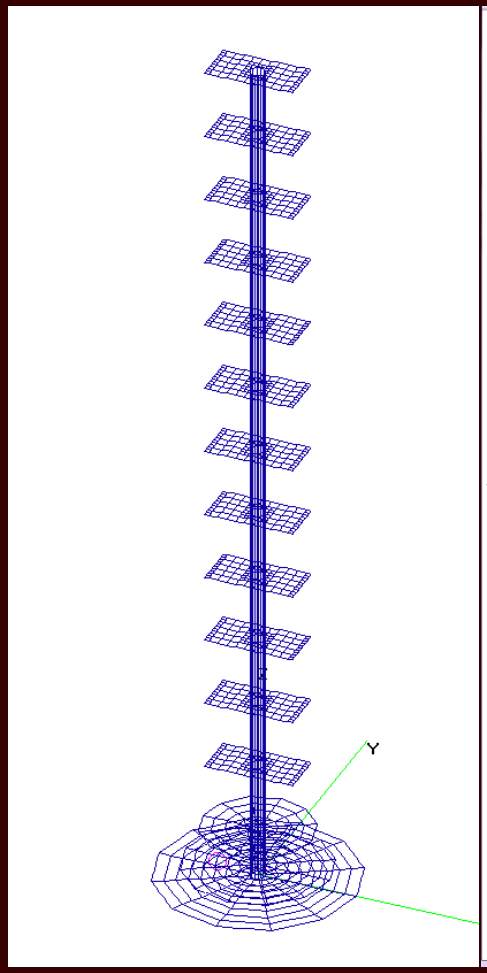
40mm vs 60mm Plate Director Spacing Study

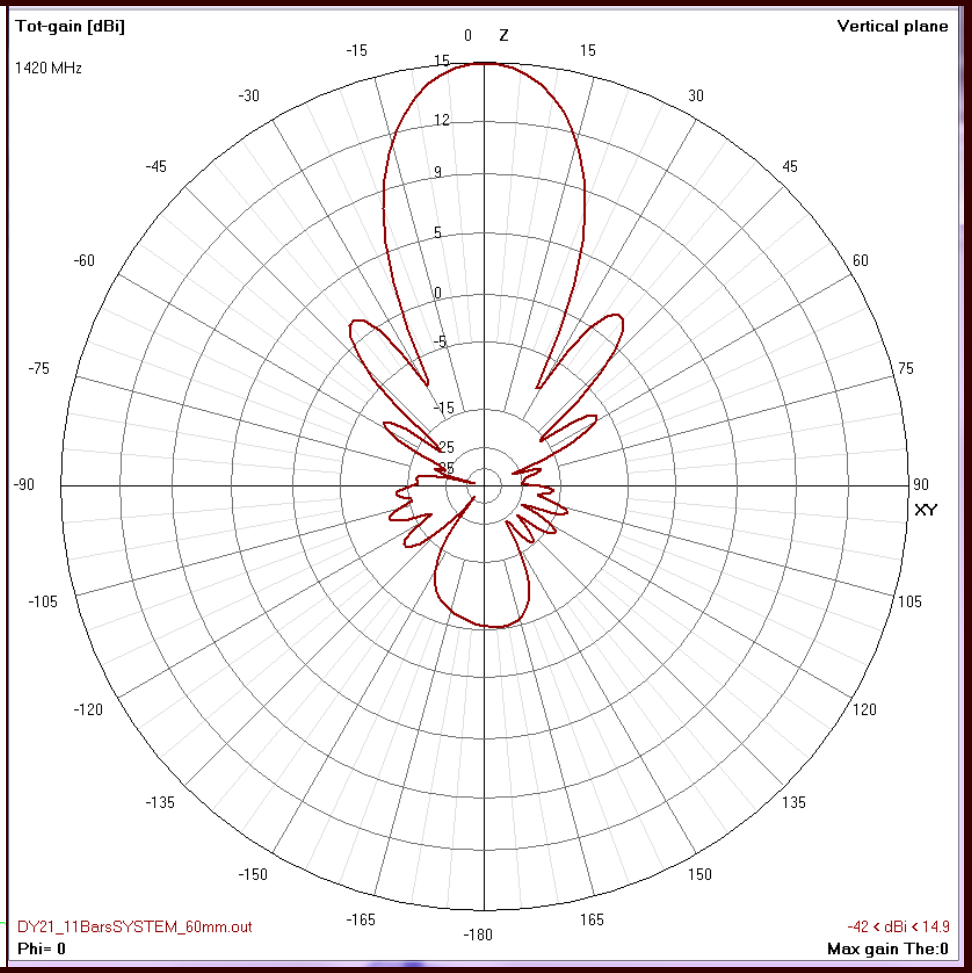


40mm and 60mm Director Spaced Antennas were modeled, fabricated, and tested to verify NEC model results

Numerical Electromagnetics Code

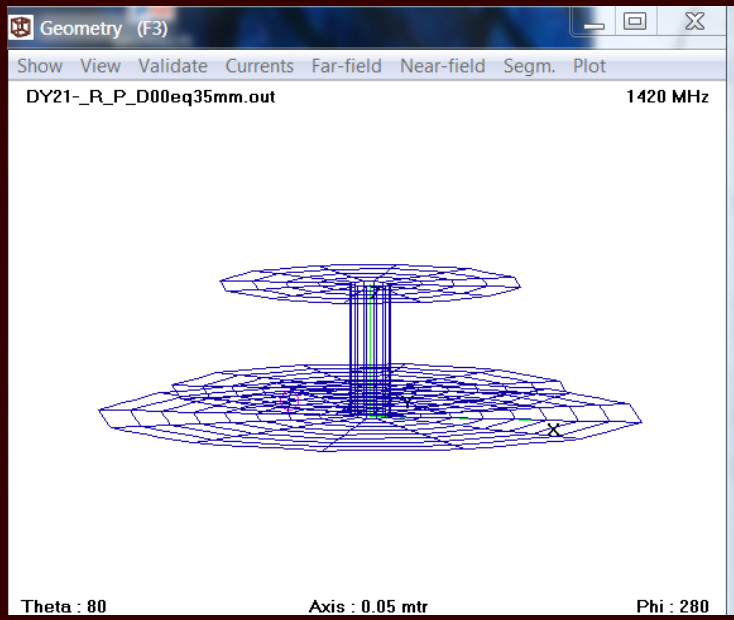
Beam Pattern / Gain Analysis

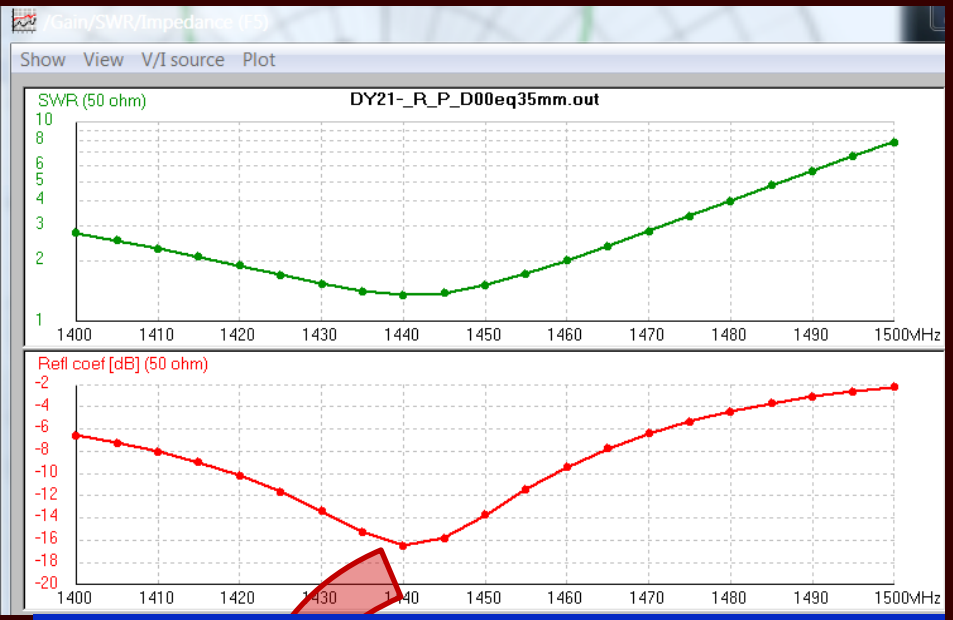




60mm Director Element Spaced Antenna Selected

MODEL VALIDATION nec Model Data vs VNA Analysis





Virtually IDENTICAL Results

Field Tests

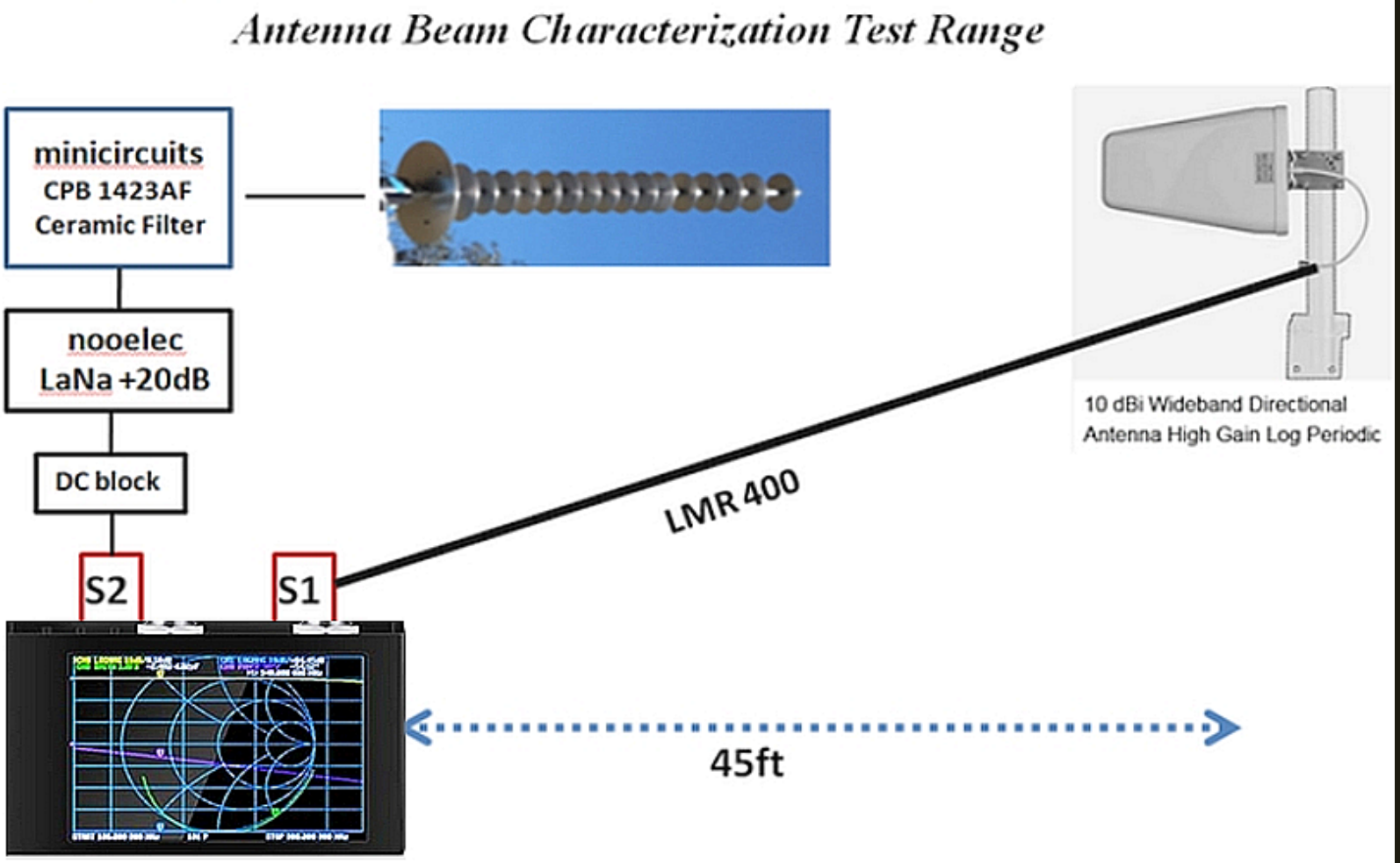
A series of tests was performed to physically

1) measure the beam-width of the antenna by incrementally rotating the antenna through a remote RF source and recording the Rx signal level

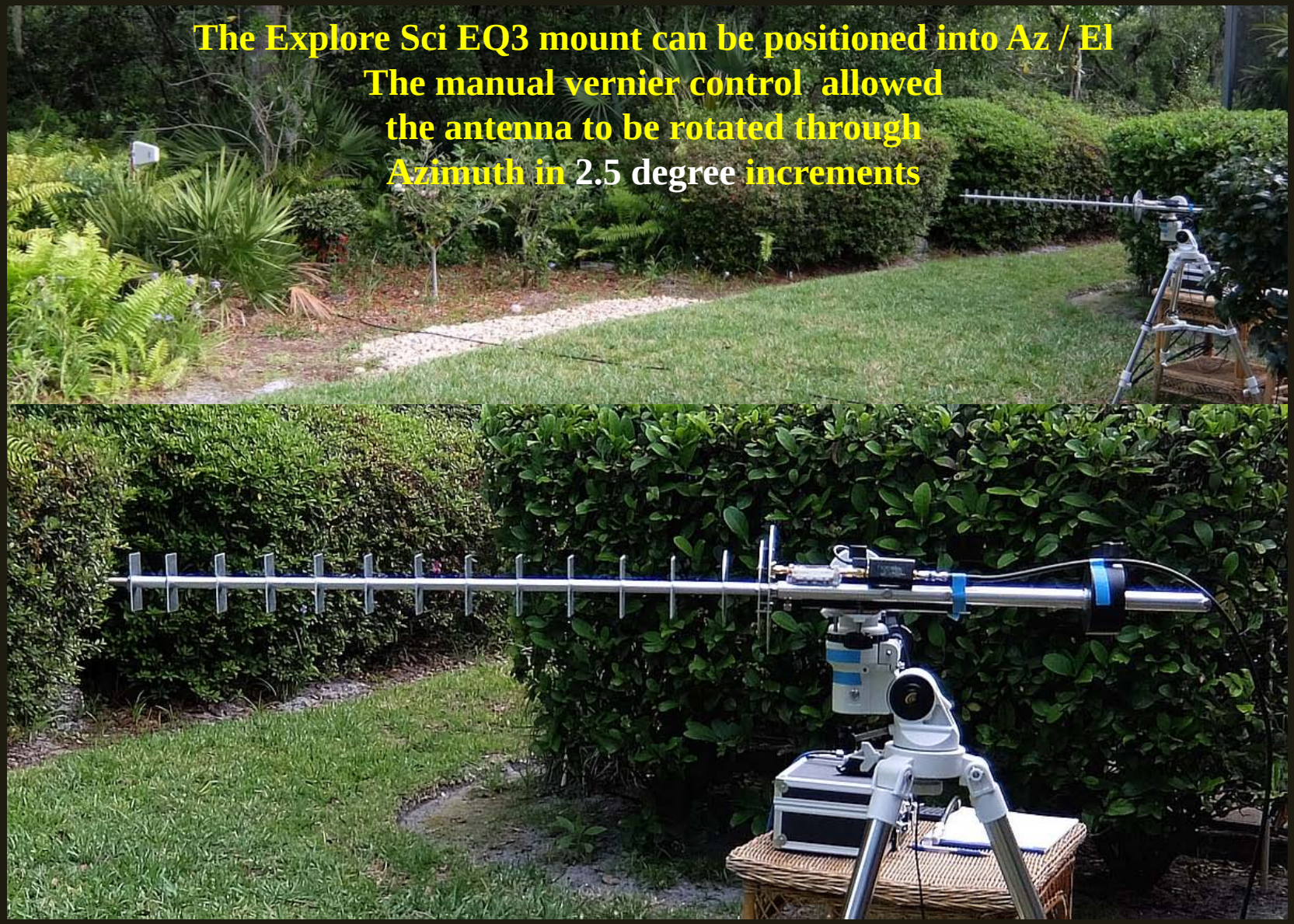
2) characterize the antenna's relative S/N by measuring the Hydrogen Spectra Peak at a reference point (declination + 40 dg right_assension 20:30 hrs) vs background 'Cold_Sky' signal level

Antenna Beam Pattern Characterization Tests

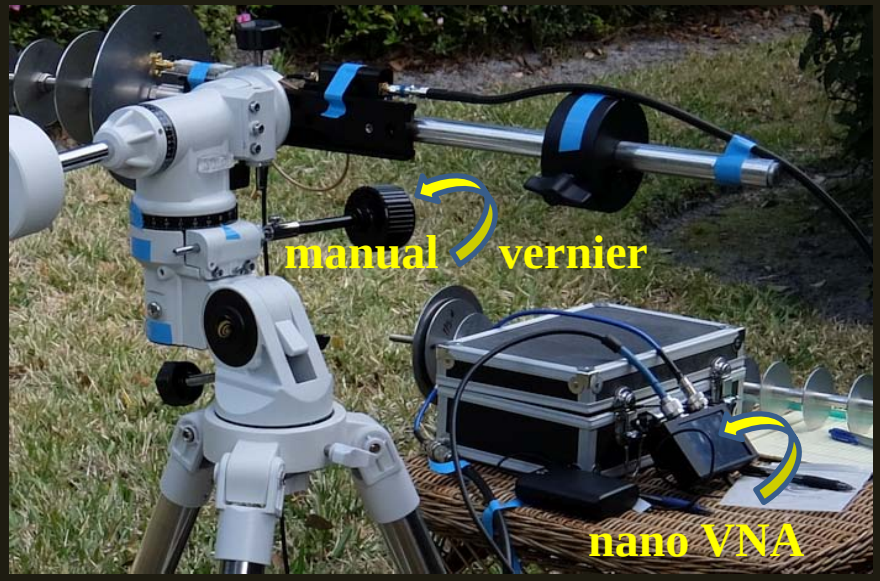
Test setup : using a nanoVNA

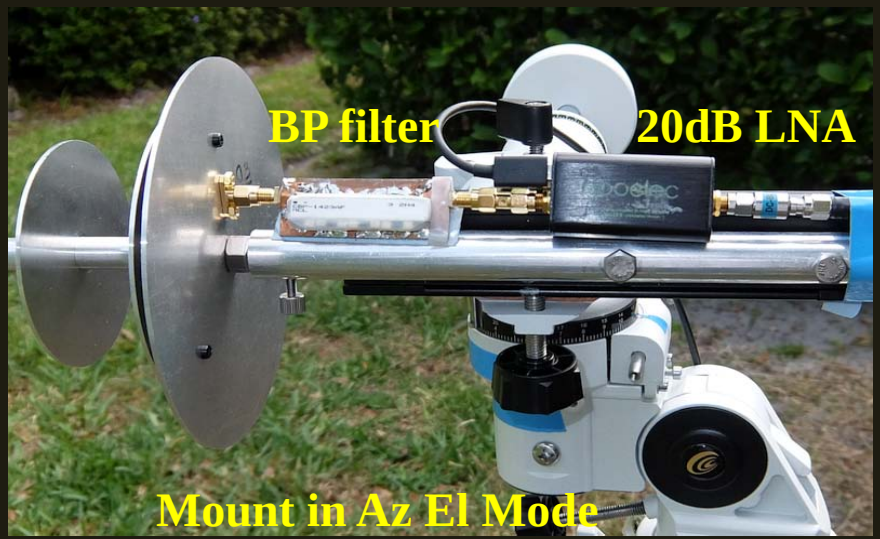


A Test Range was designed based on a nanoVNA to characterize the antenna's BEAM PATTERN

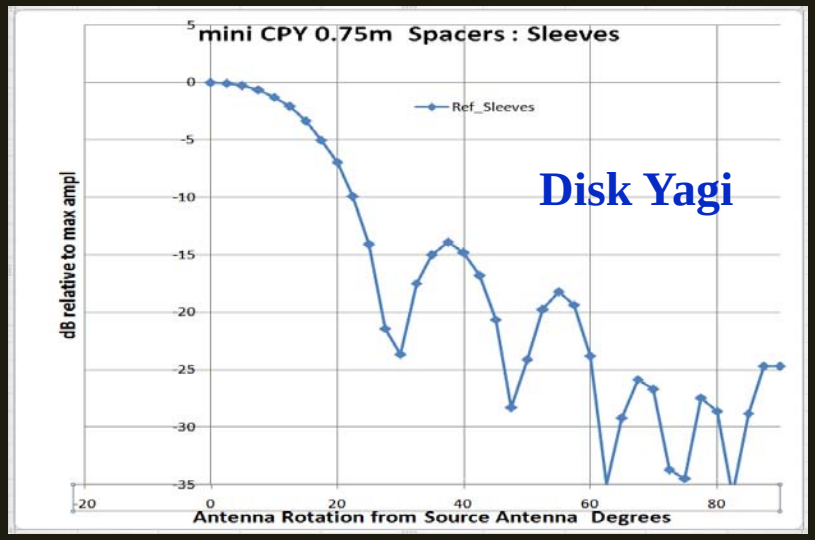

The Explore Sci EQ3 mount can be positioned into Az / El
The manual vernier control allowed
the antenna to be rotated through
Azimuth in 2.5 degree increments

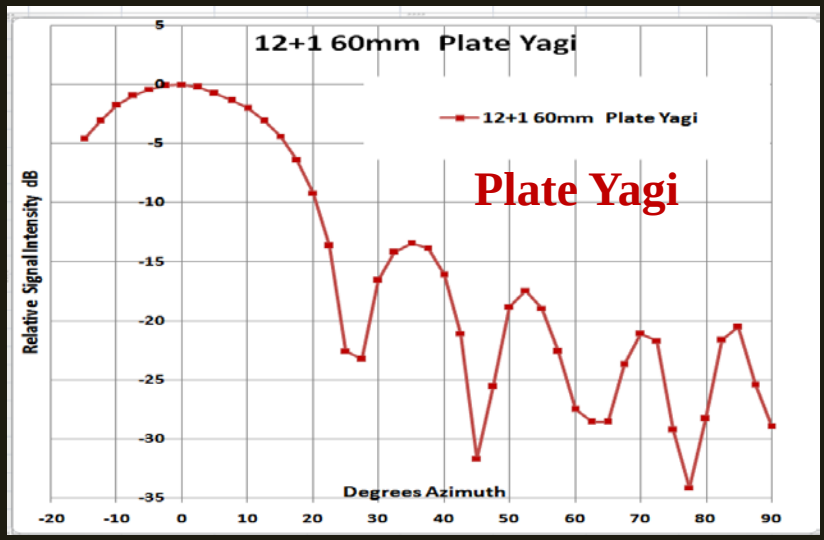
Circ Patch Feed Plate Yagi **Beam Pattern Field Testing Setup**

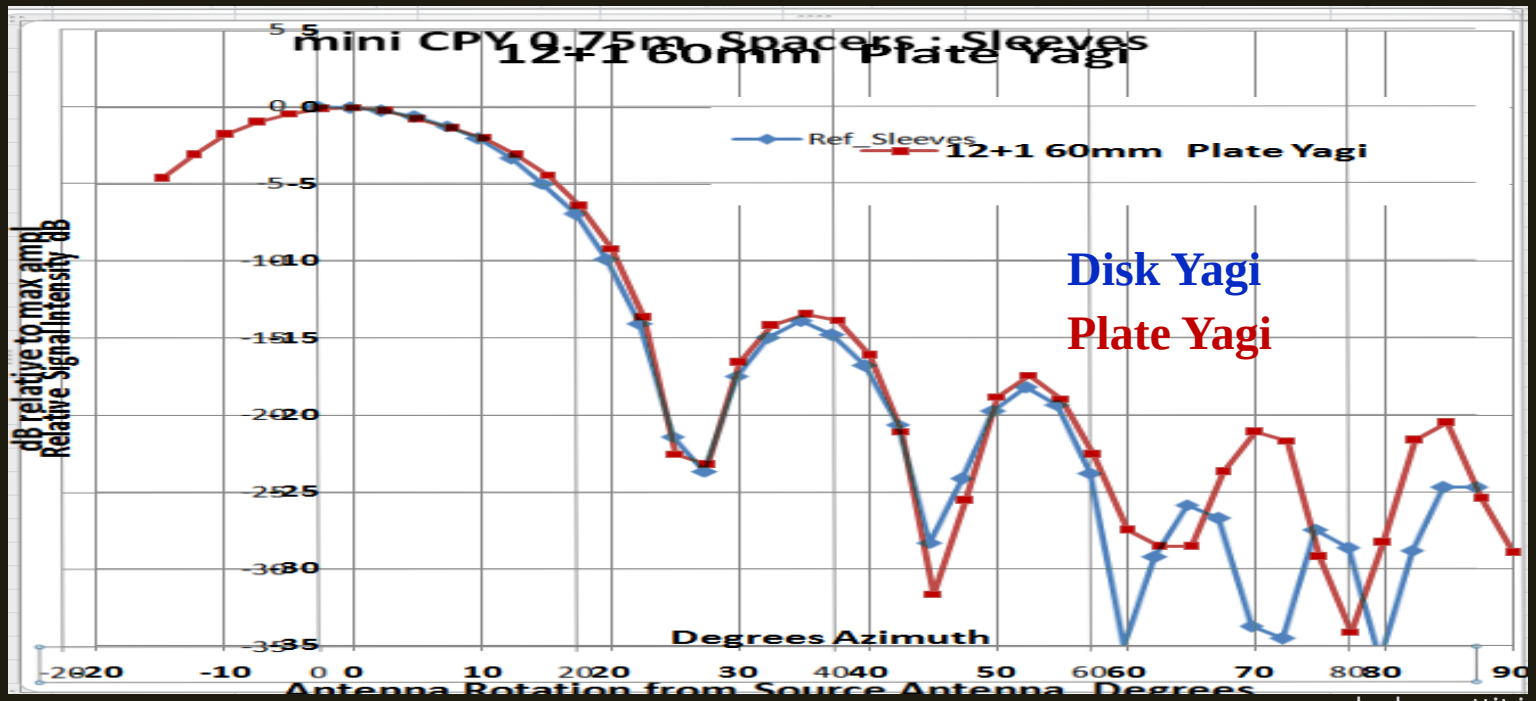




Antenna Beam Pattern Field Characterization Tests

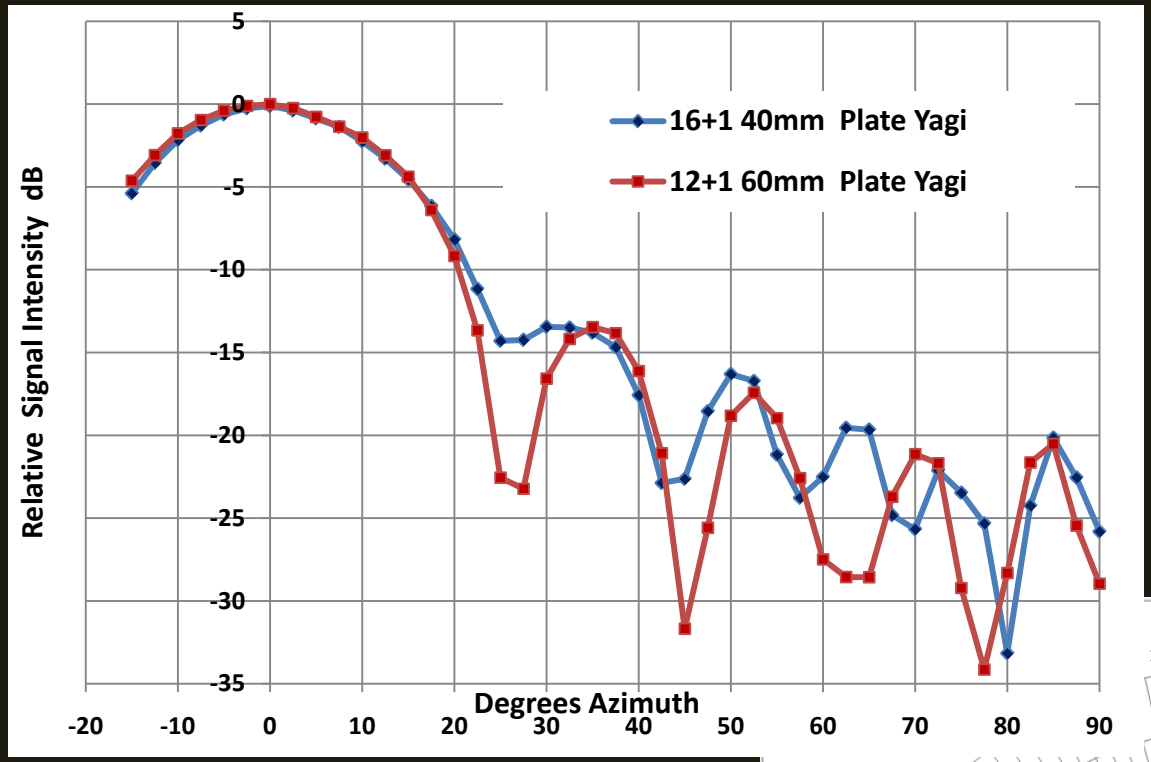


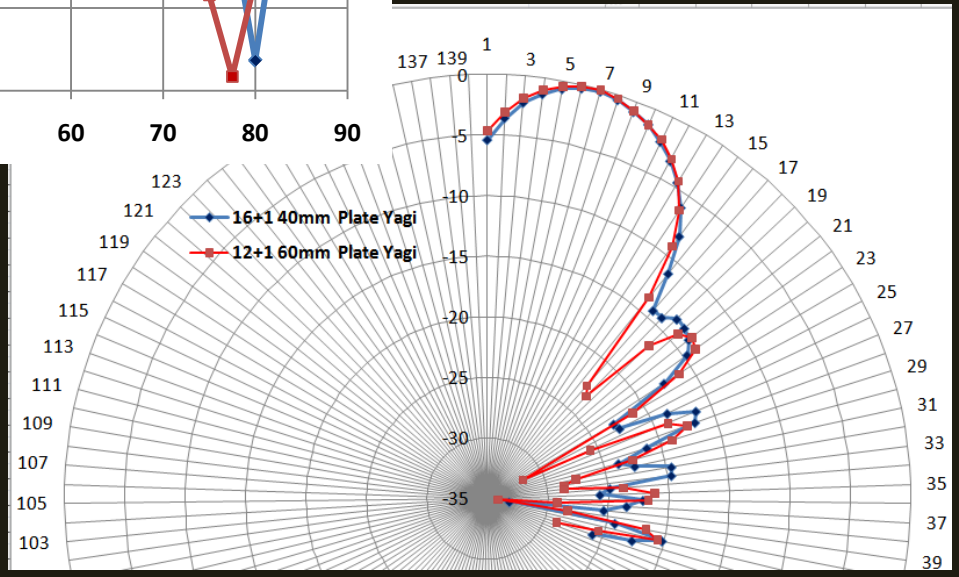




Circ Patch Feed Plate Yagi **Beam Pattern Field Test Data Results**

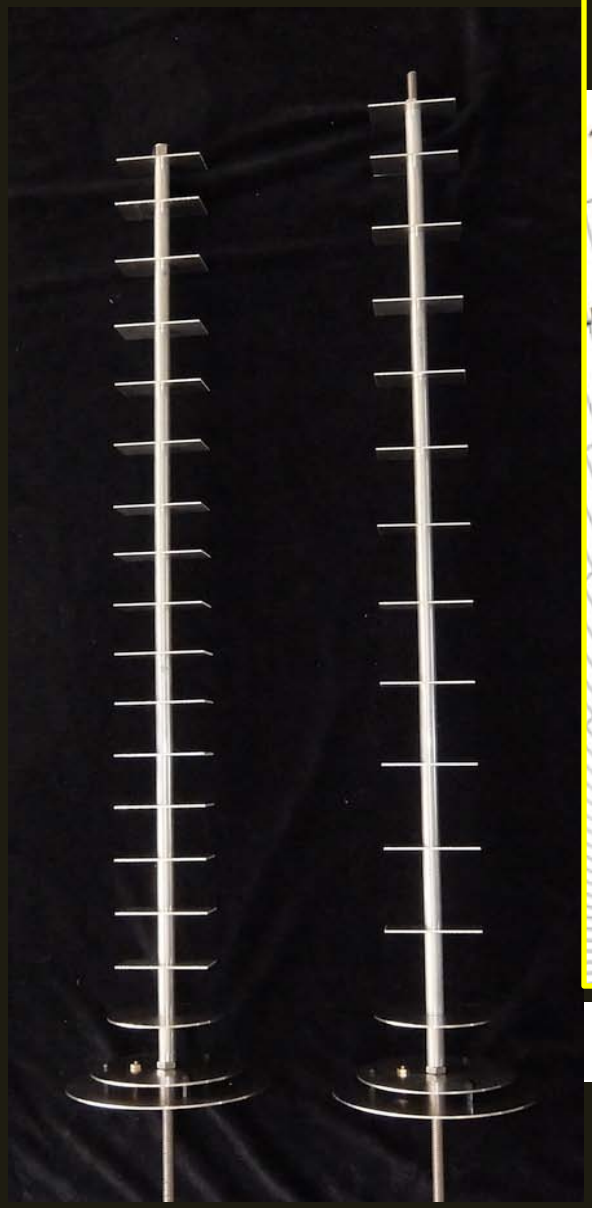
0.75m long Yagi w/ 40mm vs 60mm Director Spacing Comparison

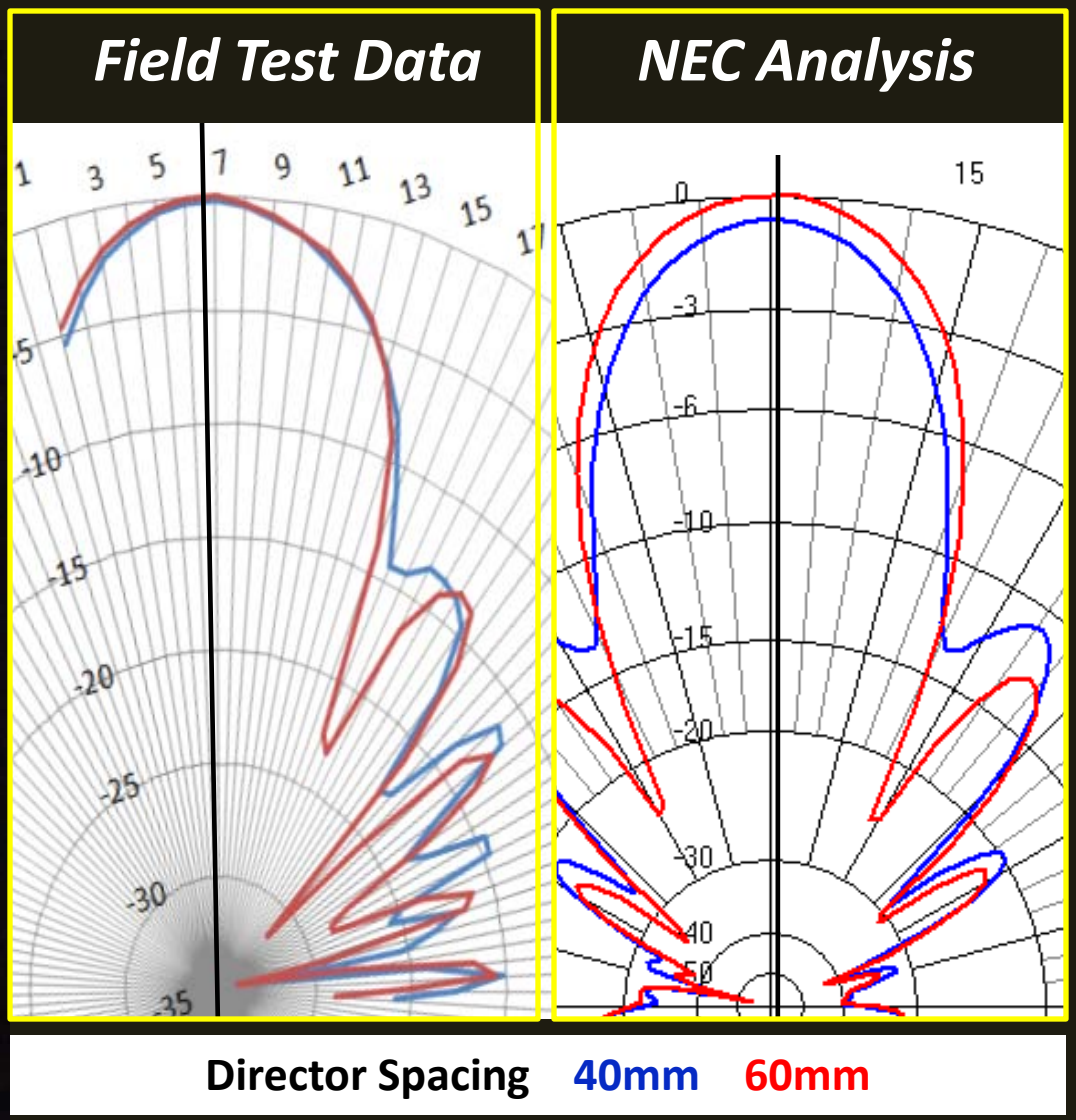




Cir Patch Feed Plate Yagi 0.75m long

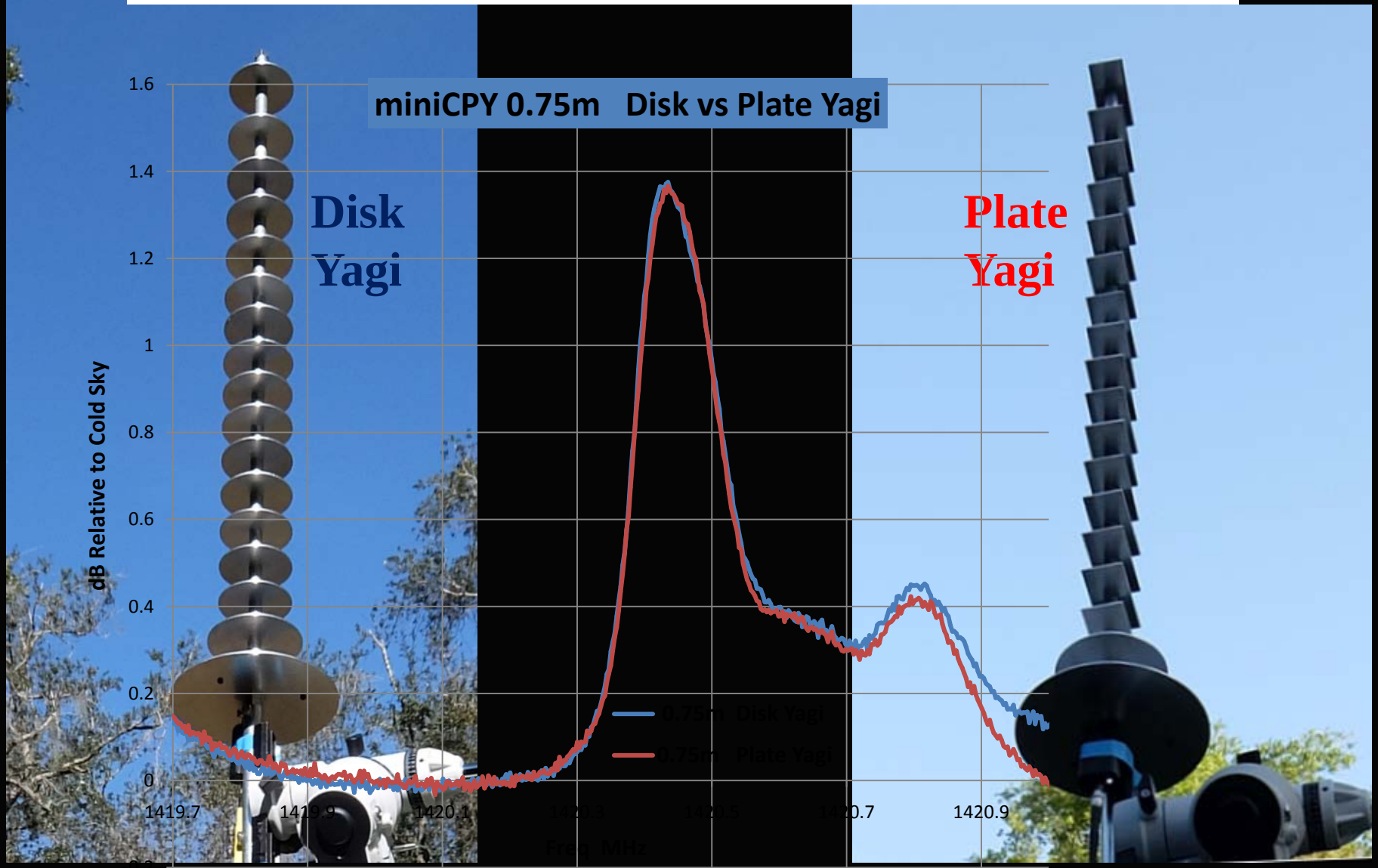
Beam Pattern Field Testing vs Numerical Electromagnetics Code





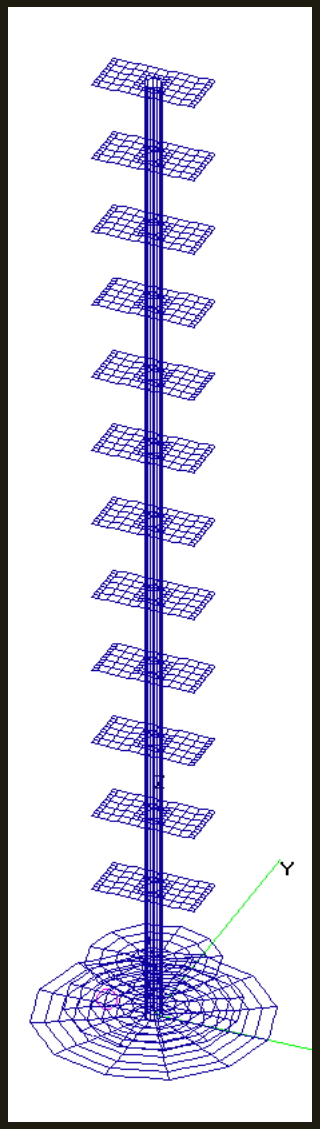
Director Spacing 40mm 60mm

0.75m Disk and Plate Yagi H-Line Data Milky Way Cygnus Region



The more easily fabricated Plate Director Antenna had Identical Performance to the Disk Director Antenna

0.75m Plate Yagi H-Line Data Milky Way Cygnus Region



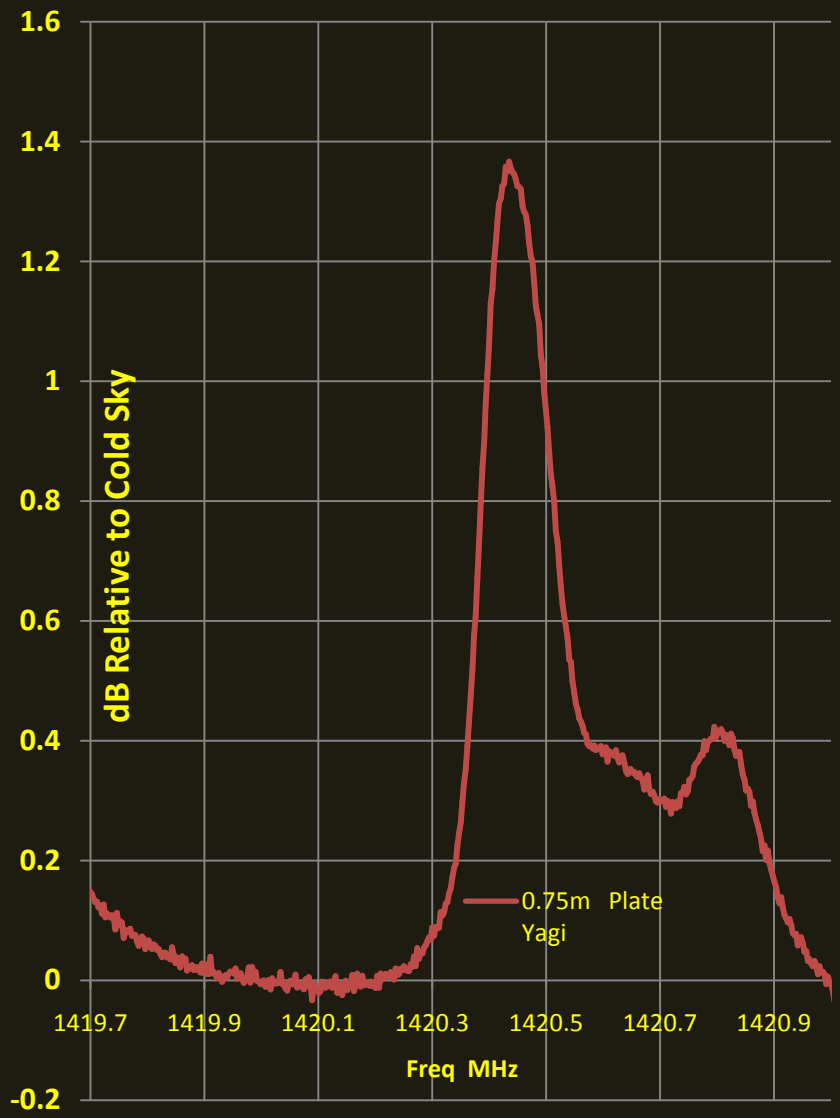


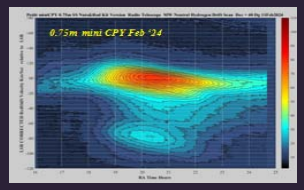
Plate Director Antenna NEC model and Fabricated Antenna

Results

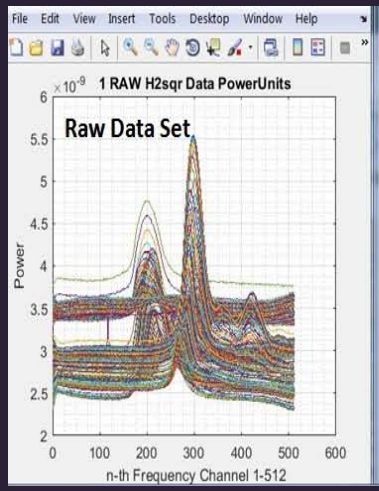
Data was acquired using AirSpy SDR# Studio and D.Kaminski IF_Average

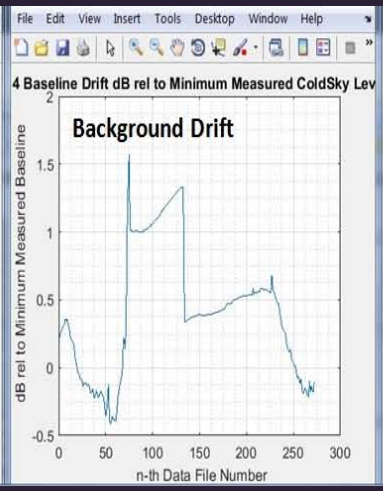
Each Spectra was a 5 minute average of data = a sky drift of 1.25 dg

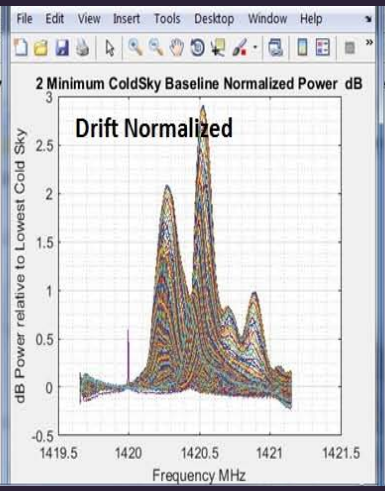
MS Excel was used to evaluate a few spectra.
Custom Matlab scripts created the contour plots

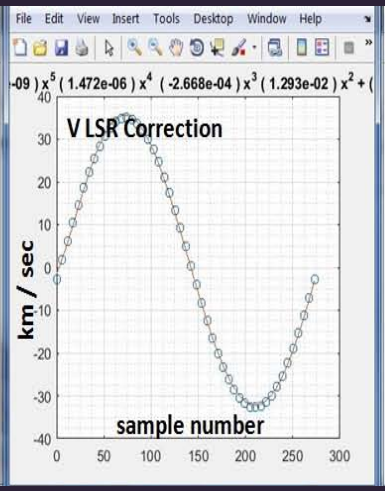


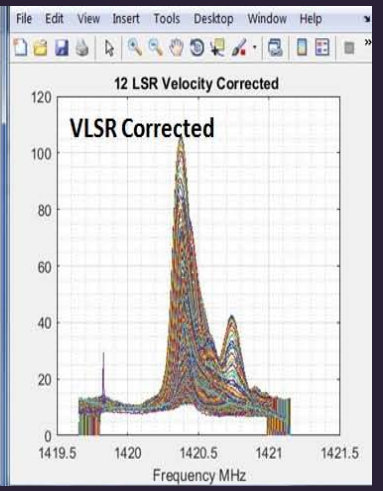
Matlab pre-processing removed drift from electrical / environmental changes and corrected for Earth's Rotational and Orbital Velocity (VLSR correction)



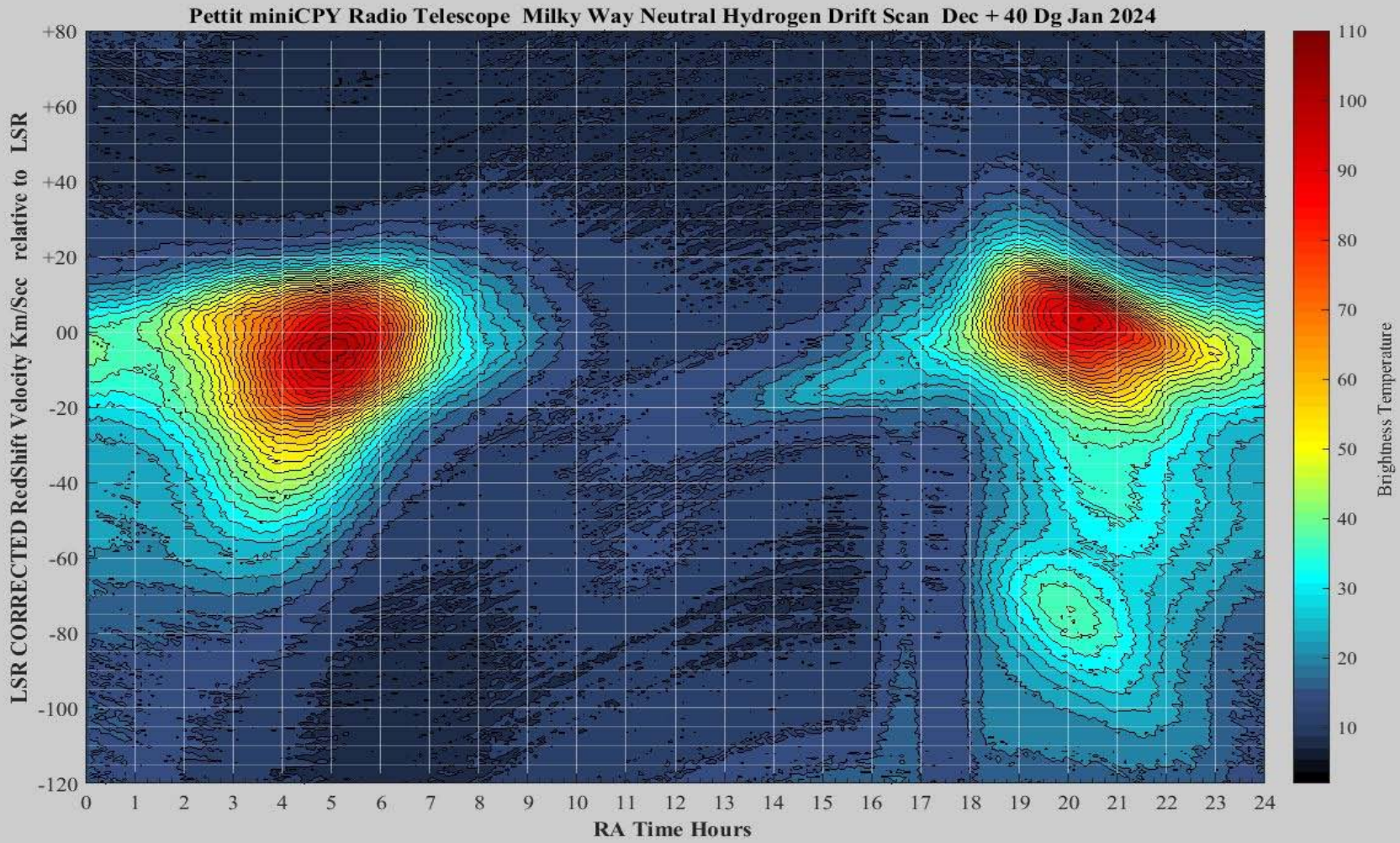




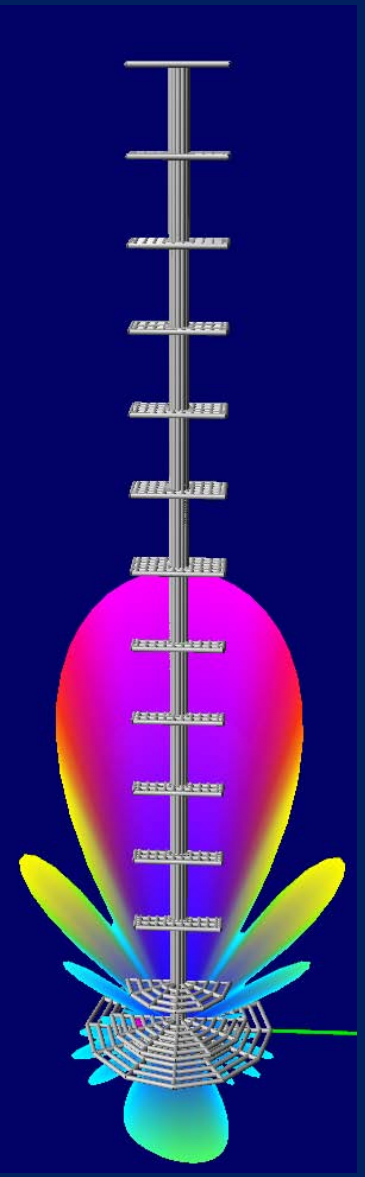




Declination +40dg
24 hour drift scan Contour Plot



21cm Circular_Patch_Feed Plate_Director Yagi Antenna



The End