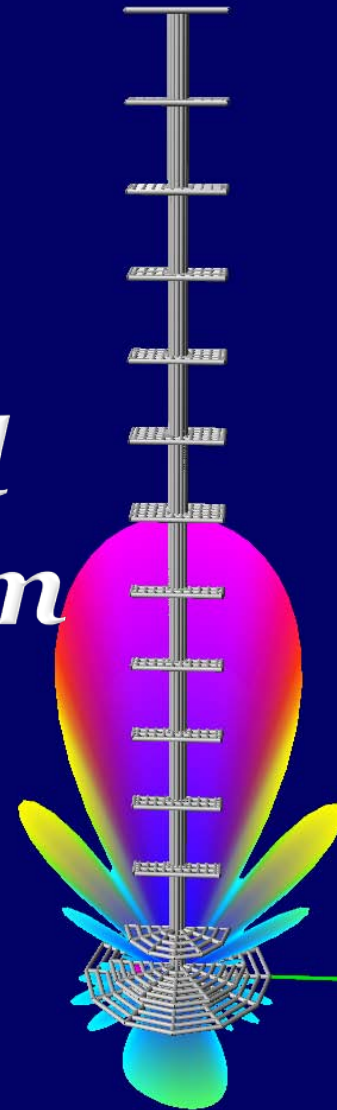
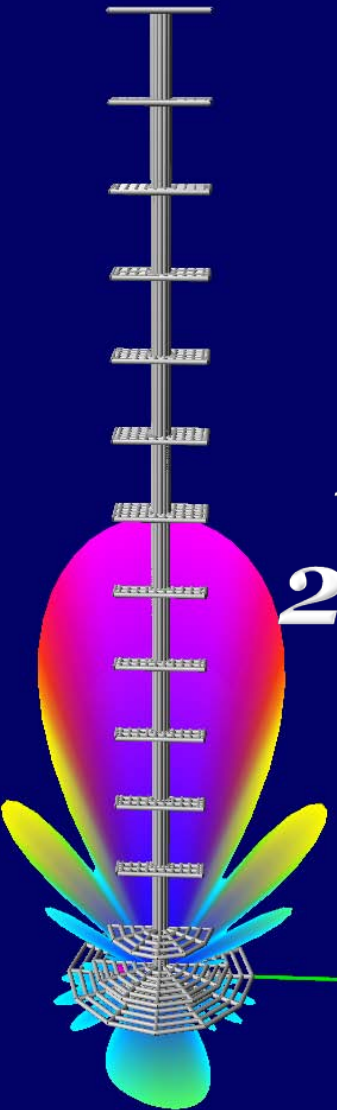


21cm Circular_Patch_Feed

Plate_Director Yagi Antenna

*Development
of an
Efficient Low_Noise
Portable Economical
21cm Neutral Hydrogen
Radio Telescope
Antenna*



b alex pettit jr June 24

Background

The development of this Circular Patch Feed (disk / plate) Yagi Antenna is based on the Design by **Dr Matjaz Vidmar**

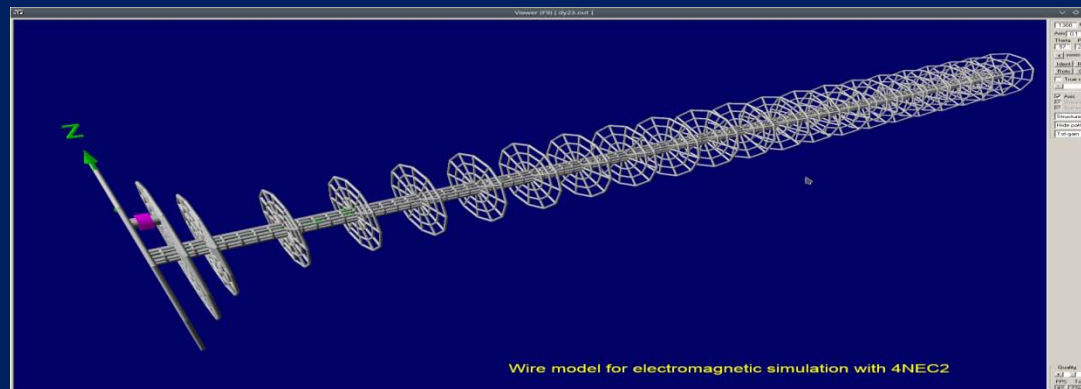
Matjaz Vidmar S53MV

<https://lea.hamradio.si/~s53mv/cigar/design.html>

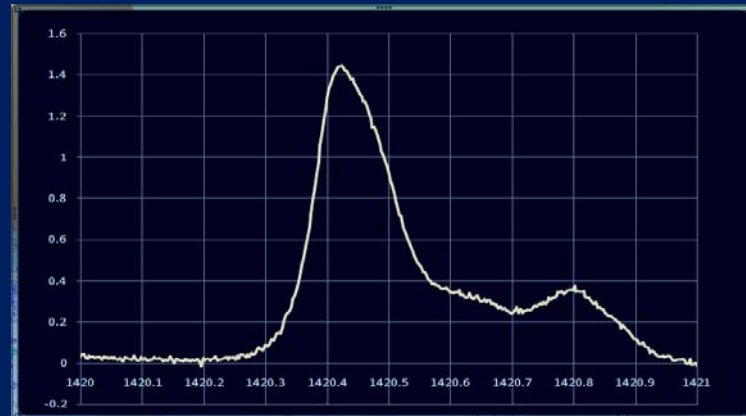
<https://s53mv.s56g.net/>



I would like to thank Dr Vidmar for his many emails of assistance and for his NEC antenna model.



Project Goal



The initial structures fabricated were Circular Patch Feed Disk Director Yagis .

Their performance results were unexpectedly impressive.

An investigation into manufacturing components for a low cost “*scope_in_a_box*” variant was begun. The Goal : a **‘\$50 Antenna’**

The Problem : A large number of elements is required, but a low cost source for the aluminum disks was never identified.

Quotes for fabrication via Water_Jet, Laser_Cutting, and Stamping were obtained, but in all cases, the cost was \$4-6 each for the Directors alone.

This was beyond the intended budget .

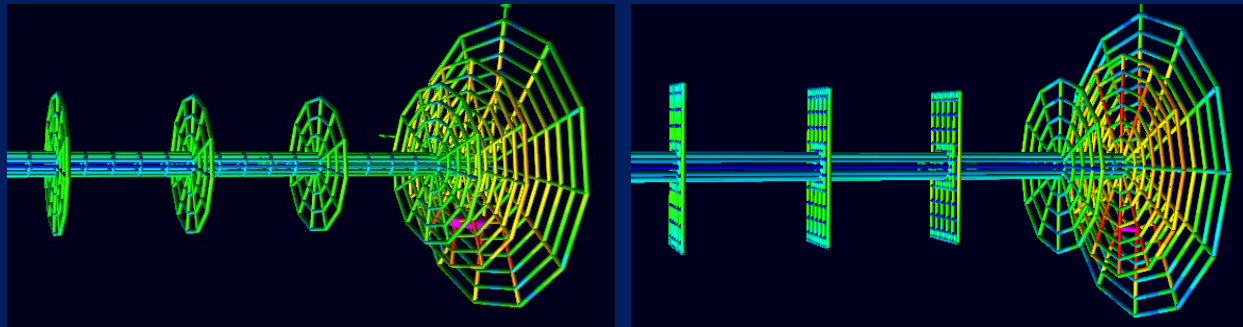
Manual fabrication via band saw, drill press, and lathe machining operations was slow and tedious and required several hours of labor.

Fine for a few prototypes, but not for even a small production lot :

Thus, the idea was put on hold for several months.

Development

In examining the electrical current patterns on the circular elements via the NEC (numerical electromagnetics code) models, it seemed possible to replace the circular director elements with rectangular plates.



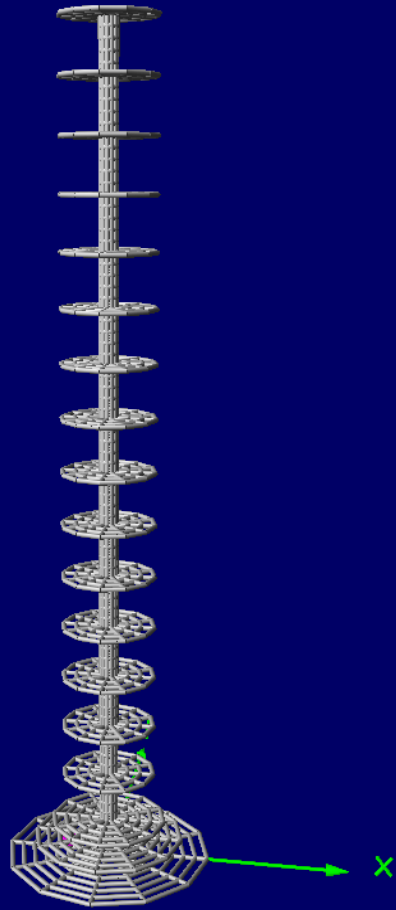
The analytical models and subsequent fabricated antennas validated this assumption.

What was Not anticipated :

The circular disk directors could be replaced with rectangular plates with
Virtually No Loss in Performance

Rectangular Plate Directors offered much simpler and lower cost fabrication.
Result : the effort resumed.

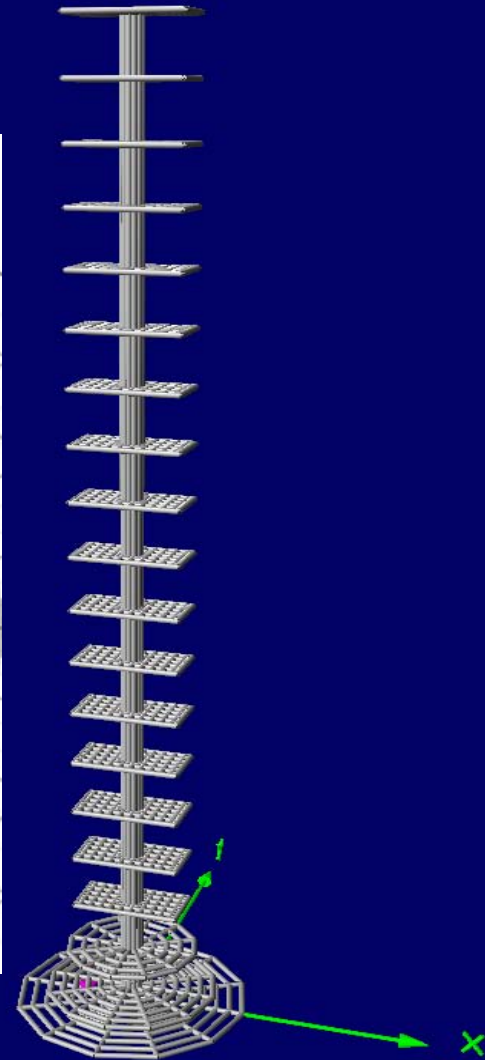
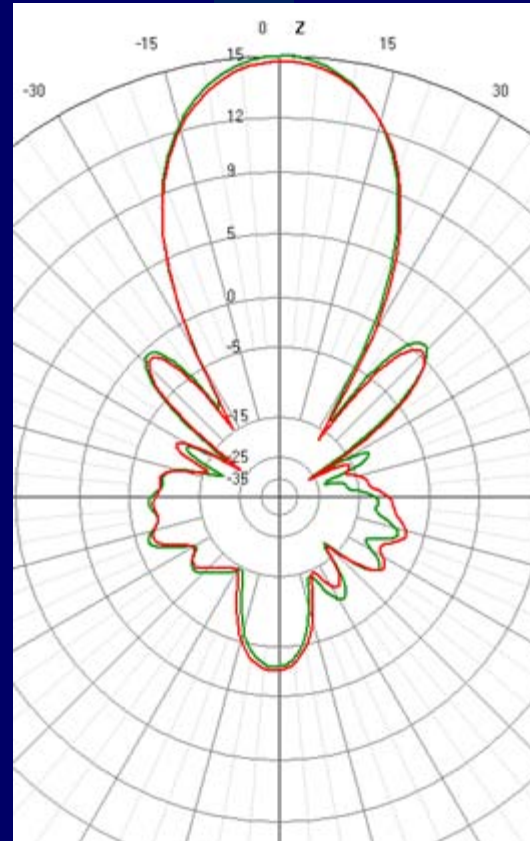
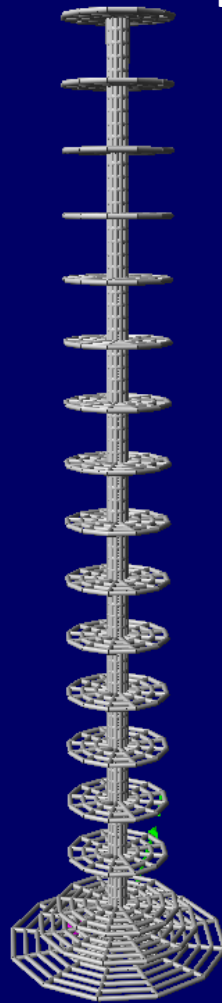
21cm Circular_Patch_Feed Disk Yagi Antenna



Patch Feed Yagi with Circular Disk Directors
works well, but difficult to fabricate disks

21cm Circular_Patch_Feed Disk vs Plate Yagi Antenna

Theoretical NEC Model Analysis

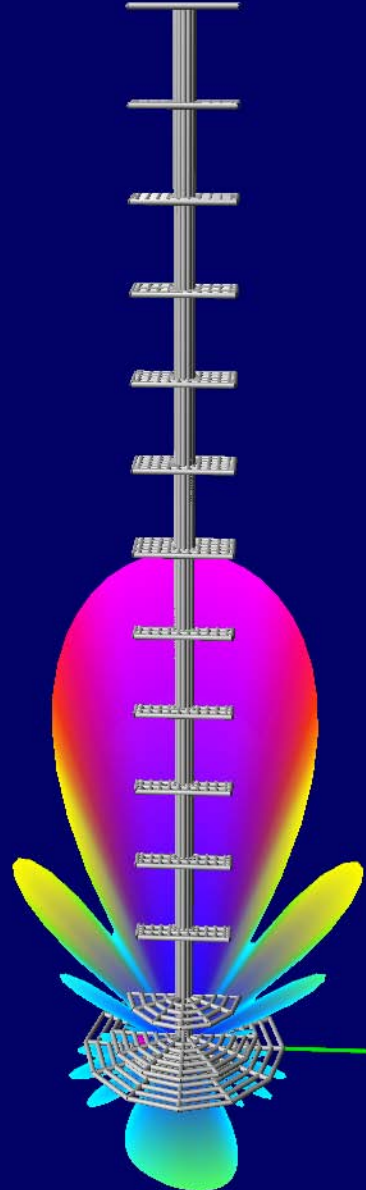
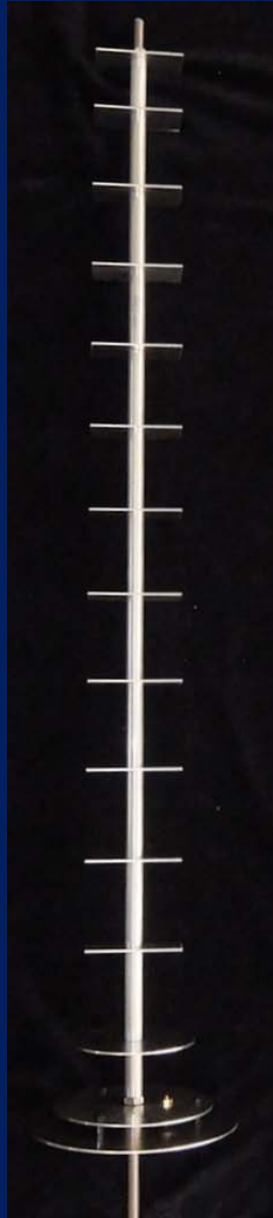


Patch Feed Yagi with Circular Disk and Rectangular Plate Directors

The model showed identical performance using rectangular plates

21cm Circular_Patch_Feed Plate Yagi Antenna

NEC Model



Disk
Yagi



0.75m Disk vs Plate Yagi Actual Field Test Data

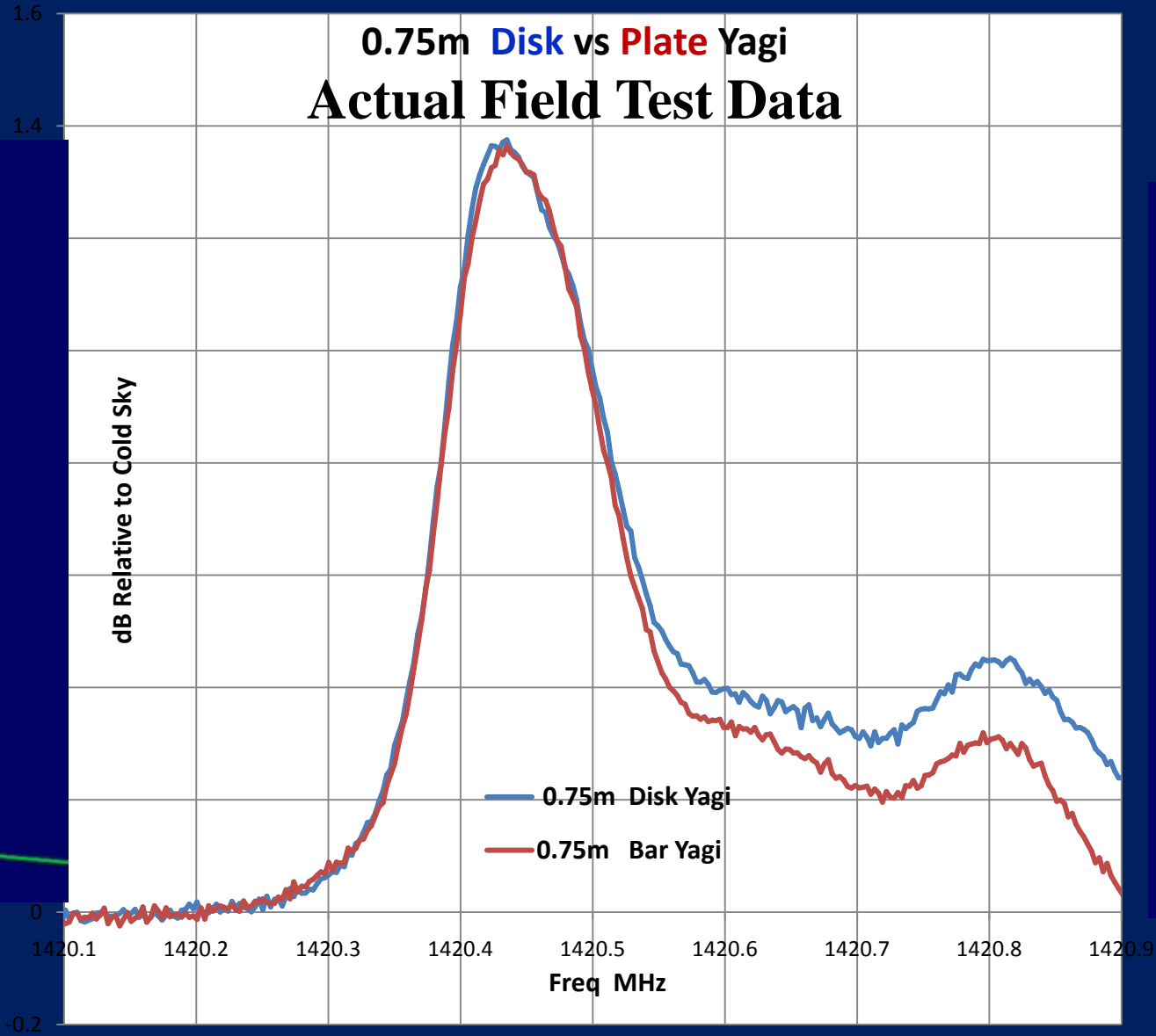
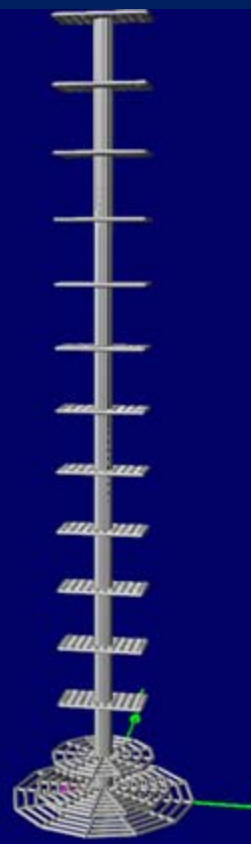


Plate
Yagi



Patch Feed Yagi with **Circular Disk** and **Rectangular Plate** Directors
Field Tests verified "identical" performance between the two designs

Analytical Modeling

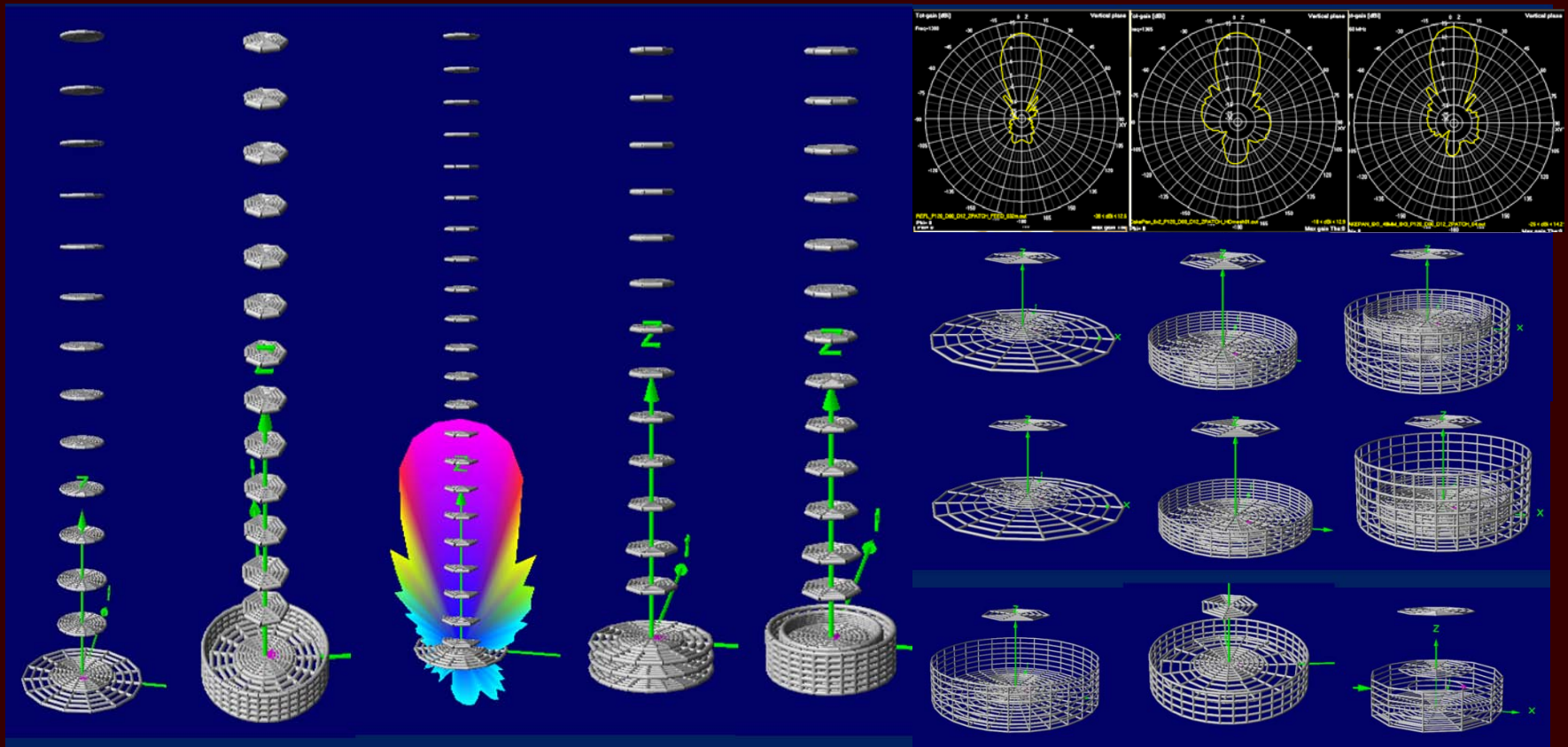
NEC

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.

During the development of the Final Design
132 NEC Model variations were evaluated
to optimize the final configuration





Version: 5.8.1
Nov 2015
Windows -7 (64 bit) running on Intel Pentium
Physical memory : 24396 Mb, allocated : 8135 Mb
Virtual memory : 2045 Mb, allocated : 70 Mb
ons/Remarks
Help-file (F1)

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 !**



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.

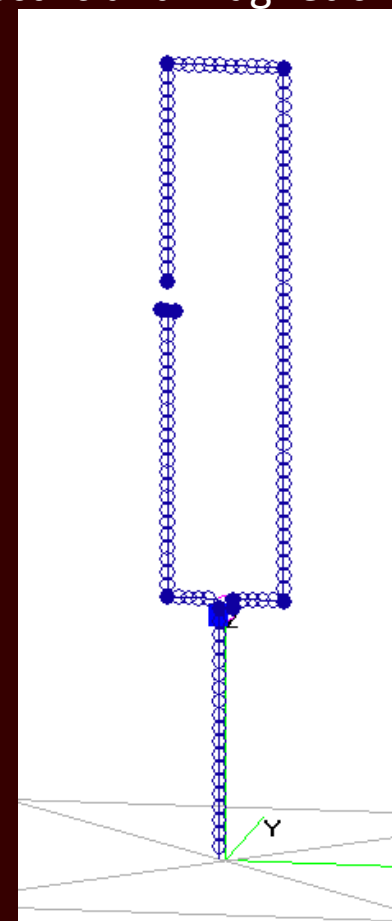
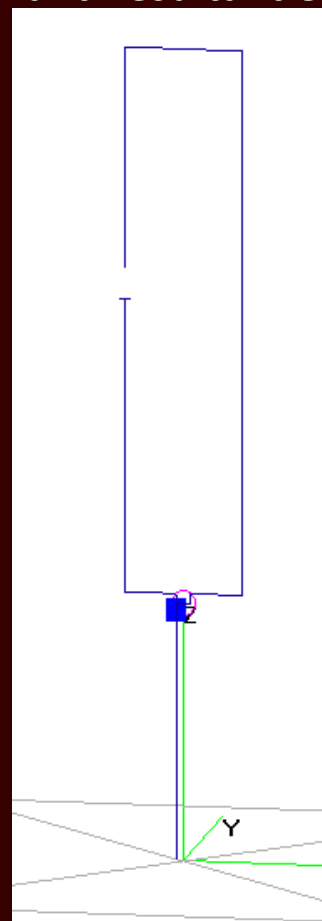
The NEC-2 Engine used by the **4NEC2** software is the original **(now public domain)** Lawrence Livermore Code.

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

Version: 5.8.0 - Windows -7 (64 bit) running on Intel Pentium
Nov 2015 Physical memory : 24396 Mb, allocated : 8135 Mb
Virtual memory : 2045 Mb, allocated : 70 Mb
ons/Remarks
Help-file (F1)

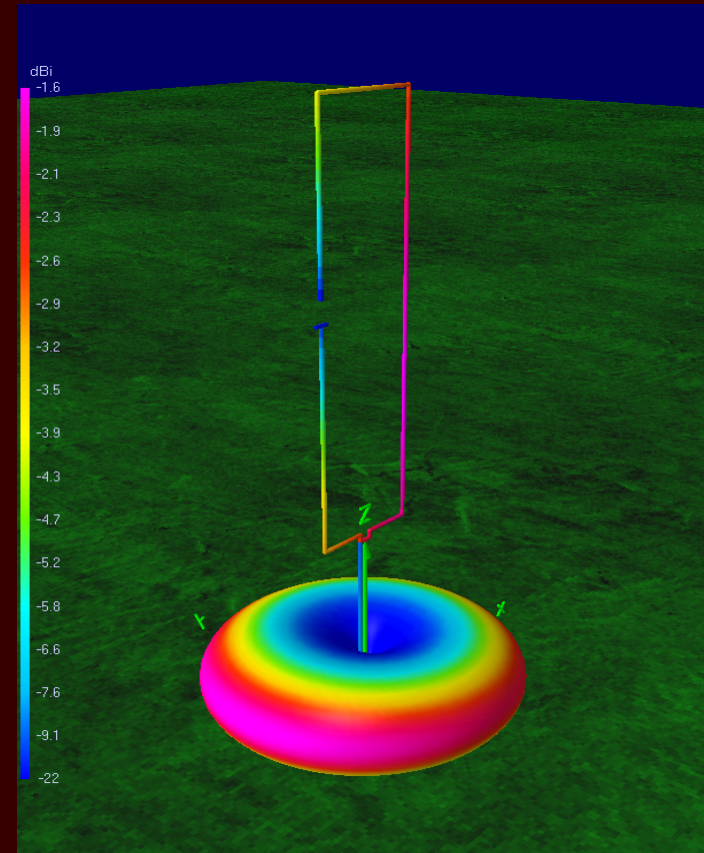


NEC Modeling performs an antenna analysis by Finite Element Analysis techniques which divides wires into a number of small elements and computes their currents and resultant electric and magnetic fields





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



complex geometry can be created from this library

The image displays five windows of the Geometry Builder (V2.5) software, each showing a different geometric primitive and its configuration parameters. Each window includes a 3D visualization of the object and a set of controls for its properties.

- Patch:** Shows a trapezoidal grid. Parameters include Length X1 (0.068 mtr), Length X2 (0.068), Length Y (0.034), X sections (20), and Y sections (10). It has checkboxes for "Use Surface-patches" and "Use auto-segmentation".
- Hat/Ground-plane:** Shows a circular grid. Parameters include Radius R (0.034 mtr), Start angle A1 (0), Stop angle A2 (360), Circular sections (16), and Radial sections (8). It has checkboxes for "Use auto-segmentation" and "Use equal-area rule to set wire-radius".
- Cylinder:** Shows a cylindrical grid. Parameters include Length L (0.040 mtr), Radius R1 (5 cm), Radius R2 (5 cm), Start angle A1 (0), Stop angle A2 (360), Straight sections (2), Circular sections (8), and Radial sections (2). It has checkboxes for "Use auto-segmentation" and "Use equal-area rule to set wire-radius".
- Parabolic screen:** Shows a parabolic grid. Parameters include Aperture (1.2), Focus point (0.35 mtr), Rad-sec's (20), and Circ-sec's (11). It has checkboxes for "Use auto-segmentation" and "Use equal-area rule to set wire-radius".
- Helix:** Shows a helical structure. Parameters include Length L (0.01 mtr), Radius R1 (6.7 cm), Radius R2 (6.7 cm), Number of turns (1), Segments per turn (20), and Manual wire radius (2 mm). It has checkboxes for "Use auto-segmentation" and "Use equal-area rule to set wire-radius".

DY21_11BARSSYSTEM_60MM.NEC - 4nec2 Edit

File Cell Rows Selection Options

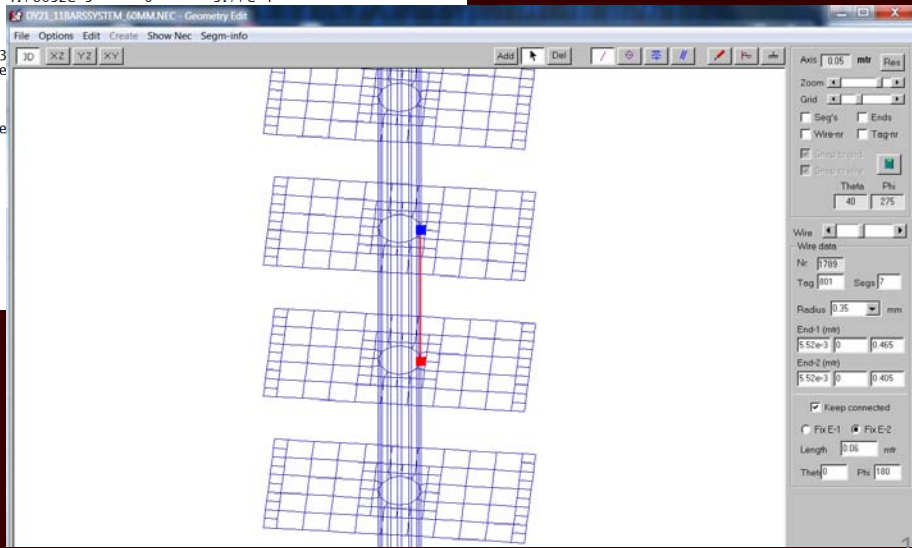
Default straight line wire-element

Symbols		Geometry				Source/Load		Freq./Ground		
Geometry (Scaling=Meters)										
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	1	0	5.52e-3	0	0	5.52e-3	b00	3.5e-4
13	Wire	596	1	5.52e-3	0	0	5.52e-3	0	b00	3.5e-4
14	Wire	597	1	4.78032e-3	2.76e-3	0	4.78032e-3	2.76e-3	b00	3.5e-4
15	Wire	598	1	2.76e-3	4.78032e-3	0	2.76e-3	4.78032e-3	b00	3.5e-4
16	Wire	599	1	0	5.52e-3	0	0	5.52e-3	b00	3.5e-4
17	Wire	600	1	-2.76e-3	4.78032e-3	0	-2.76e-3	4.78032e-3	b00	3.5e-4
18	Wire	601	1	-4.7803e-3	2.76e-3	0	-4.7803e-3	2.76e-3	b00	3.5e-4
19	Wire	602	1	-5.52e-3	0	0	-5.52e-3	0	b00	3.5e-4
20	Wire	603	1	-4.7803e-3	-2.76e-3	0	-4.7803e-3	-2.76e-3	b00	3.5e-4
21	Wire	604	1	-2.76e-3	-4.7803e-3	0	-2.76e-3	-4.7803e-3	b00	3.5e-4
22	Wire	605	1	0	-5.52e-3	0	0	-5.52e-3	b00	3.5e-4
23	Wire	606	1	2.76e-3	-4.7803e-3	0	2.76e-3	-4.7803e-3	b00	3.5e-4
24	Wire	607	1	4.78032e-3	-2.76e-3	0	4.78032e-3	-2.76e-3	b00	3.5e-4
25	Wire	5000	1	5.52e-3	0	0	4.78032e-3	2.76e-3	0	3.77e-4
26	Wire	5001	1	4.78032e-3	2.76e-3	0	2.76e-3	4.78032e-3	0	3.77e-4
27	Wire	5002	1	2.76e-3	4.78032e-3	0	0	0	0	0
28	Wire	5003	1	0	5.52e-3	0	-2.76e-3	0	0	0
	Wire	600	1	-2.76e-3	4.78032e-3	0	0	0	0	0
	Wire	601	1	-4.7803e-3	2.76e-3	0	-5.52e-3	0	-4.7803e-3	0
	Wire	602	1	-5.52e-3	0	0	0	-4.7803e-3	0	0
	Wire	603	1	-4.7803e-3	-2.76e-3	0	-2.76e-3	0	0	0
	Wire	604	1	-2.76e-3	-4.7803e-3	0	-4.7803e-3	0	0	0
	Wire	605	1	0	-5.52e-3	0	0	2.76e-3	0	0
	Wire	606	1	2.76e-3	-4.7803e-3	0	0	4.78032e-3	0	0
	Wire	607	1	4.78032e-3	-2.76e-3	0	0	0	0	0
	Wire	5000	1	-0.034	-0.017	0	-0.034	-0.0136	0	0
	Wire	5001	1	-0.034	-0.0136	0	-0.034	-0.0102	0	0
	Wire	5002	1	-0.034	-0.0102	0	-0.034	-6.8e-3	0	0
	Wire	5003	1	-0.034	-6.8e-3	0	-0.034	-3.4e-3	0	0
	Wire	5004	1	-0.034	-3.4e-3	0	-0.034	0	0	0
	Wire	5005	1	-0.034	0	0	-0.034	3.4e-3	0	0
	Wire	5006	1	-0.034	3.4e-3	0	-0.034	6.8e-3	0	0
	Wire	5007	1	-0.034	6.8e-3	0	-0.034	0.0102	0	0
	Wire	5008	1	-0.034	0.0102	0	-0.034	0.0136	0	0
	Wire	5009	1	-0.034	0.0136	0	-0.034	0.017	0	0
	Wire	5010	1	-0.0306	-0.017	0	-0.0306	-0.0136	0	0

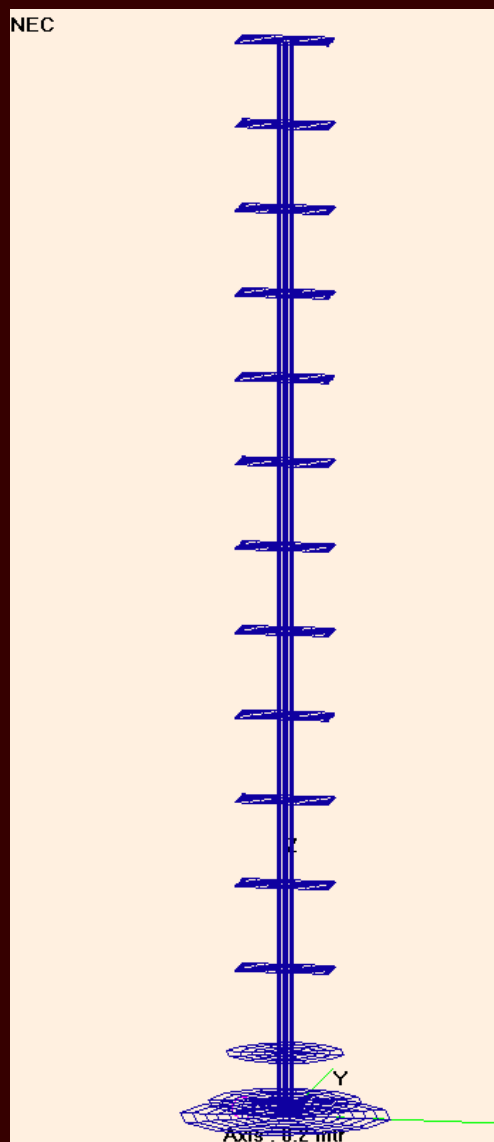
DY21_11BARSSYSTEM_60mm.NEC - Notepad

```

File Edit Format View Help
!C
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 0 0 0
GW 599 1 0 5.52e-3 0 -2.76e-3 0 0 0
GW 600 1 -2.76e-3 4.78032e-3 0 0 0 0 0
GW 601 1 -4.7803e-3 2.76e-3 0 -5.52e-3 0 -4.7803e-3 0
GW 602 1 -5.52e-3 0 0 0 -4.7803e-3 0 0
GW 603 1 -4.7803e-3 -2.76e-3 0 -2.76e-3 0 0
GW 604 1 -2.76e-3 -4.7803e-3 0 -4.7803e-3 0 0
GW 605 1 0 -5.52e-3 0 0 2.76e-3 0 0
GW 606 1 2.76e-3 -4.7803e-3 0 0 4.78032e-3 0 0
GW 607 1 4.78032e-3 -2.76e-3 0 0 0 0 0
GW 5000 1 -0.034 -0.017 0 -0.034 -0.0136 0 0
GW 5001 1 -0.034 -0.0136 0 -0.034 -0.0102 0 0
GW 5002 1 -0.034 -0.0102 0 -0.034 -6.8e-3 0 0
GW 5003 1 -0.034 -6.8e-3 0 -0.034 -3.4e-3 0 0
GW 5004 1 -0.034 -3.4e-3 0 -0.034 0 0 0
GW 5005 1 -0.034 0 0 -0.034 3.4e-3 0 0
GW 5006 1 -0.034 3.4e-3 0 -0.034 6.8e-3 0 0
GW 5007 1 -0.034 6.8e-3 0 -0.034 0.0102 0 0
GW 5008 1 -0.034 0.0102 0 -0.034 0.0136 0 0
GW 5009 1 -0.034 0.0136 0 -0.034 0.017 0 0
GW 5010 1 -0.0306 -0.017 0 -0.0306 -0.0136 0 0
    
```



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



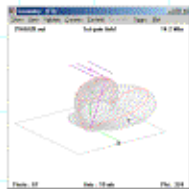
Simple geometry can be
defined in tables
Complex can be combined
and modified
via
NEC Text Editor
MS Notepad Editor
NEC 3D view Editor

Numerical Electromagnetics Code

Screenshots of 4NEC2 Analysis Capability



Main window



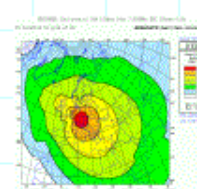
Overview



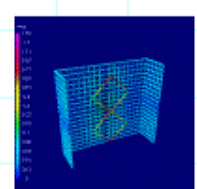
Nec editor



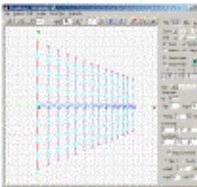
Impedance matching



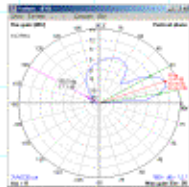
Area Coverage



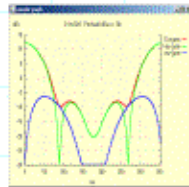
Current distribution



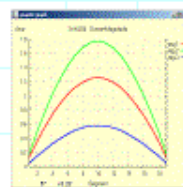
Geometry edit



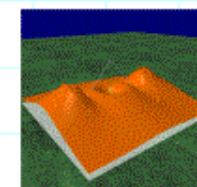
Far-field pattern



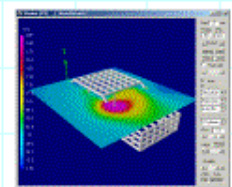
Linear far-field plot



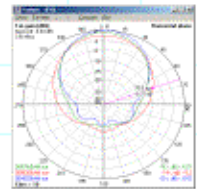
Current distibution



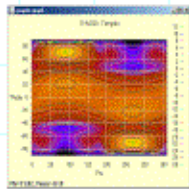
3D Near-field pattern



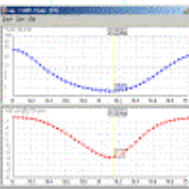
Field inside car



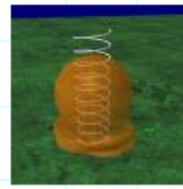
Compare patterns



FF surface plot



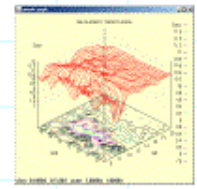
SWR for freq-sweep



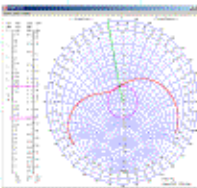
Helix model



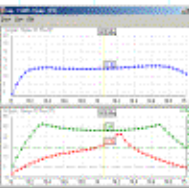
Optimizer window



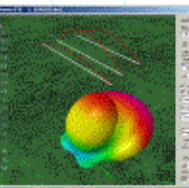
Search space



Smith chart



Gain, F/B and F/R ratio



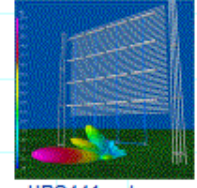
3D viewer



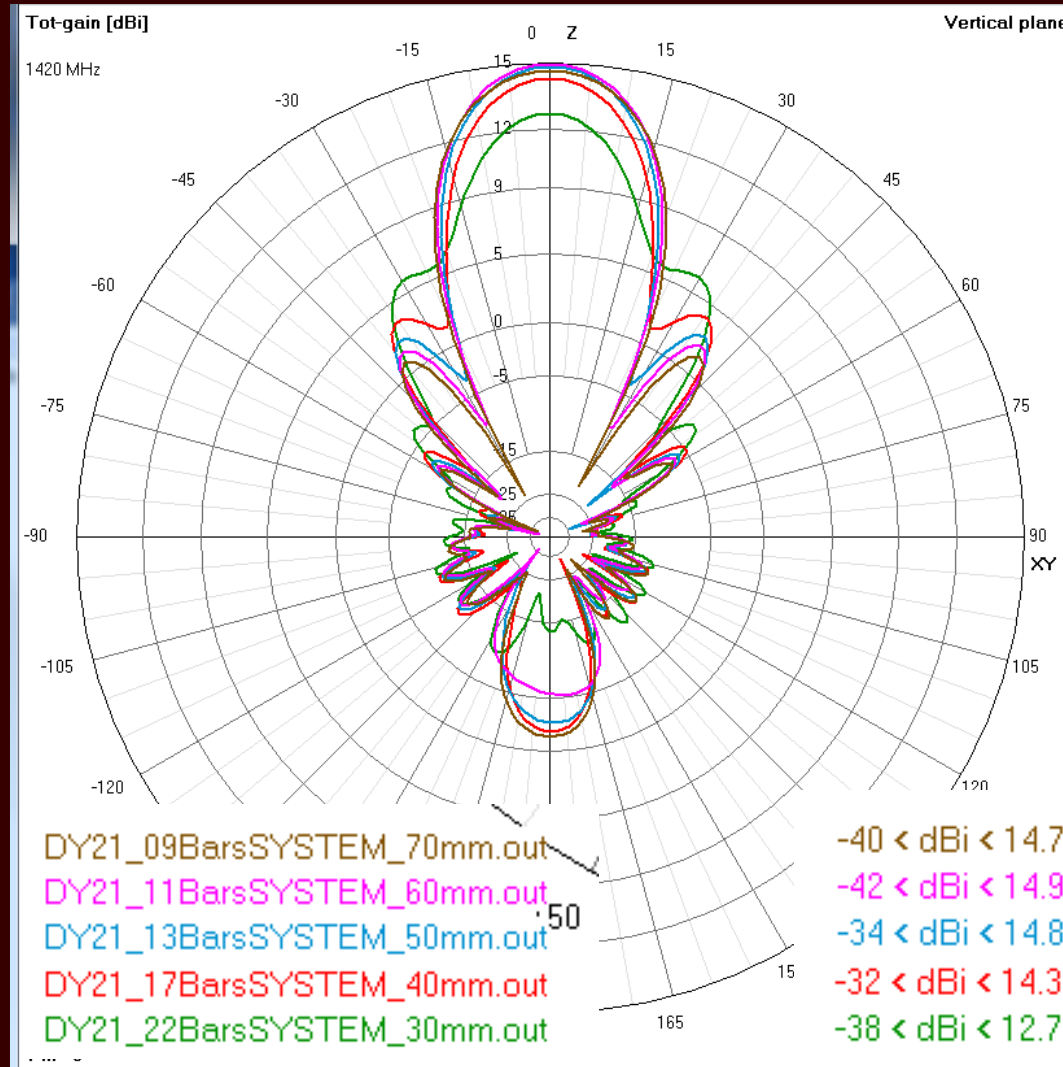
Ship model



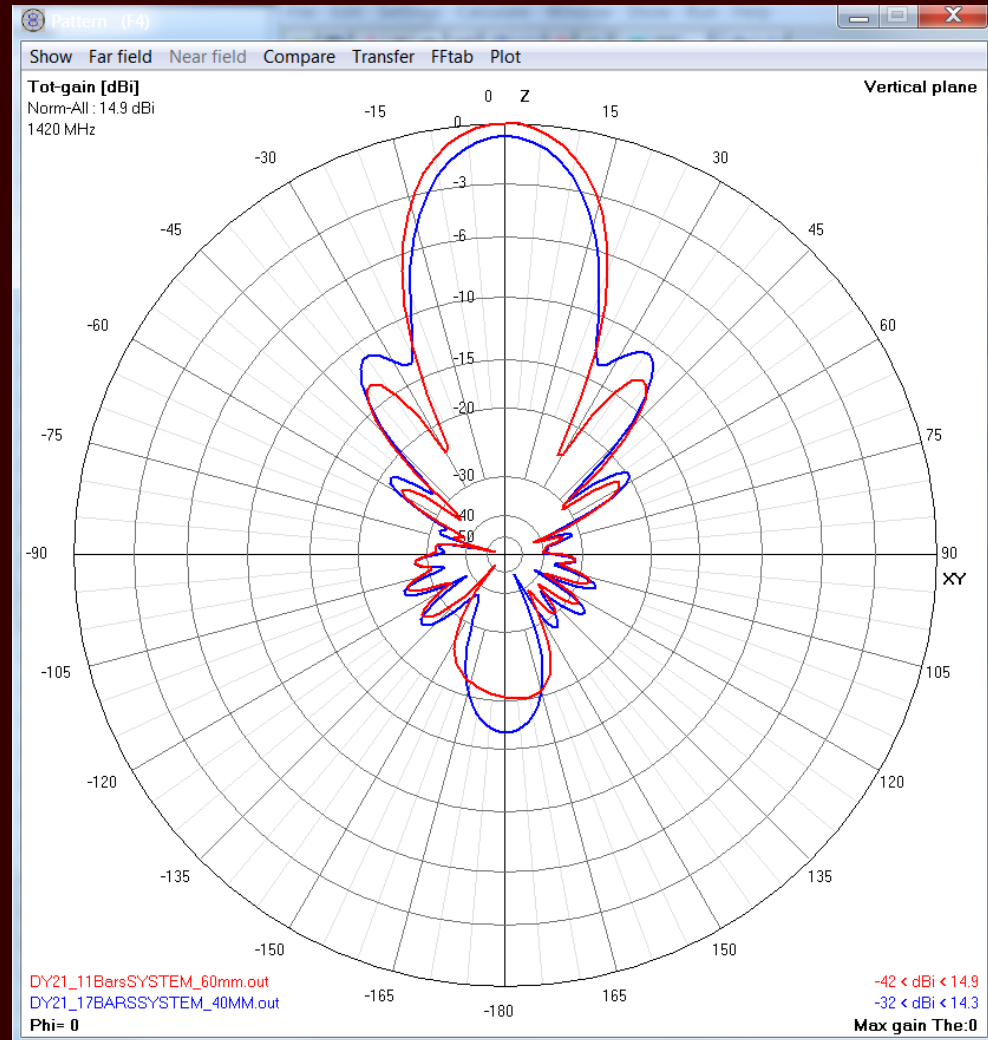
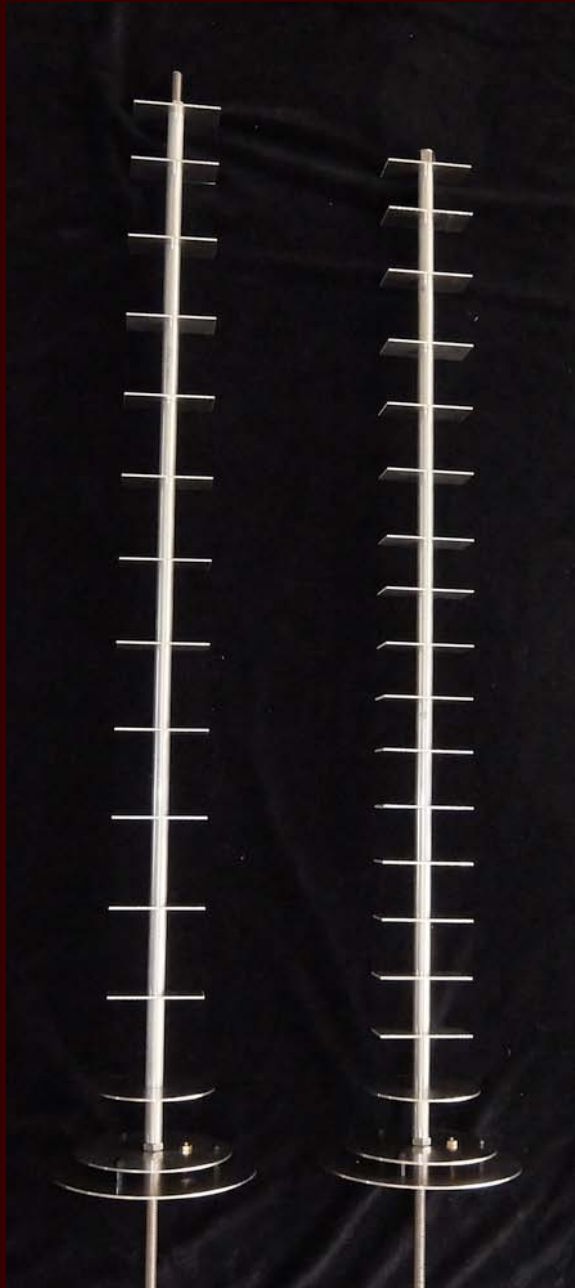
Geomtry builder



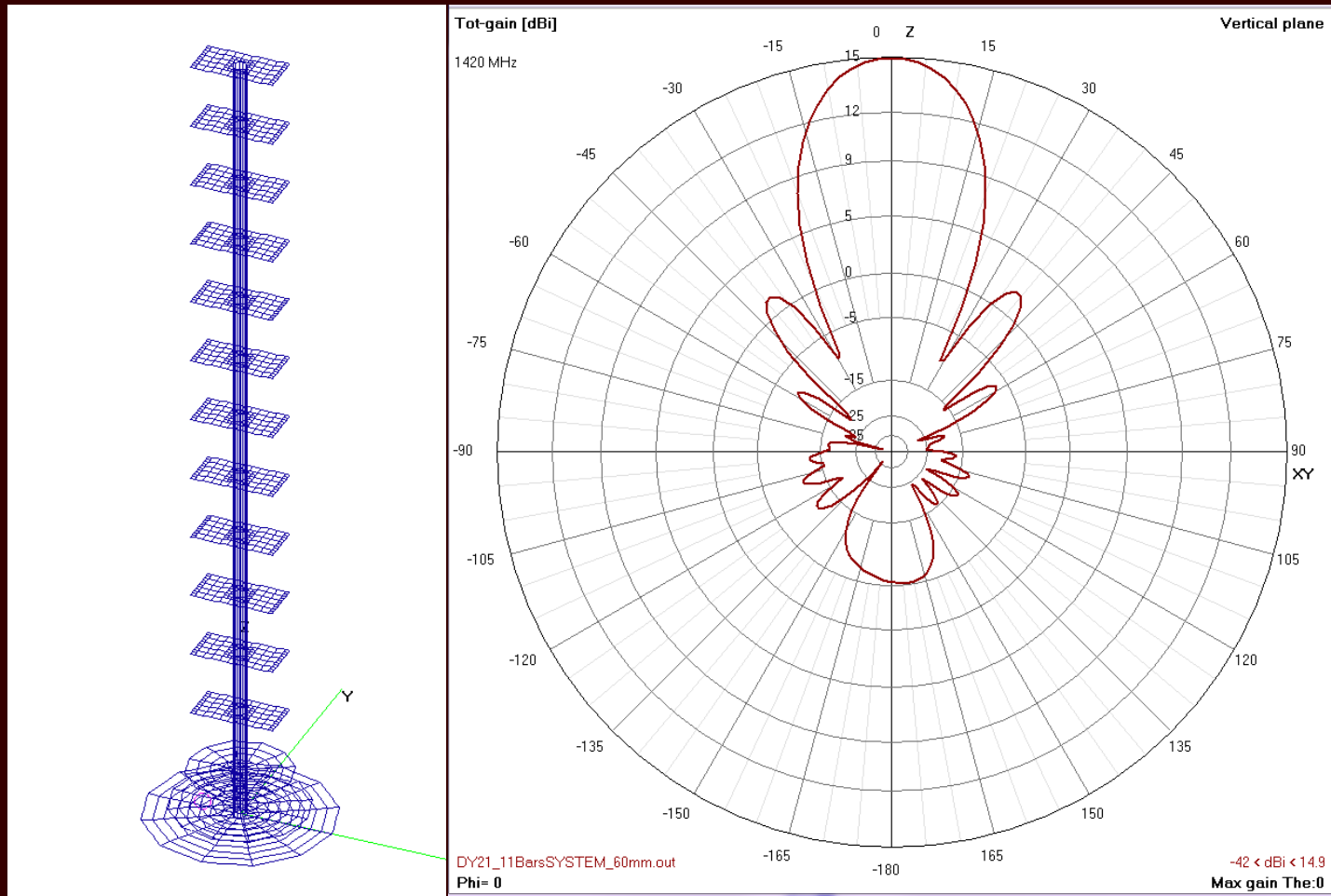
HRS441 antenna



an NEC Study was performed to optimize the Front/Back Gain
60mm Director Spacing was selected



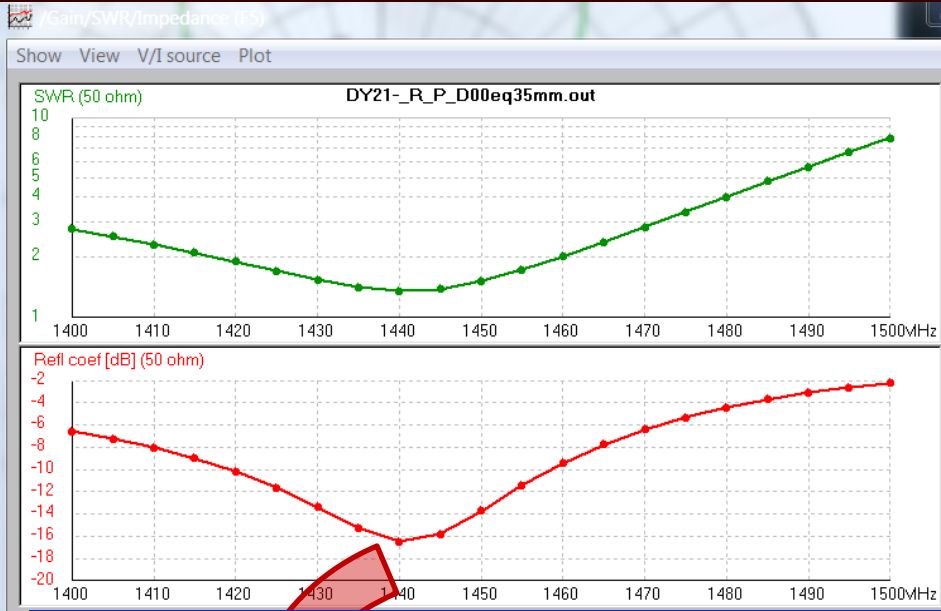
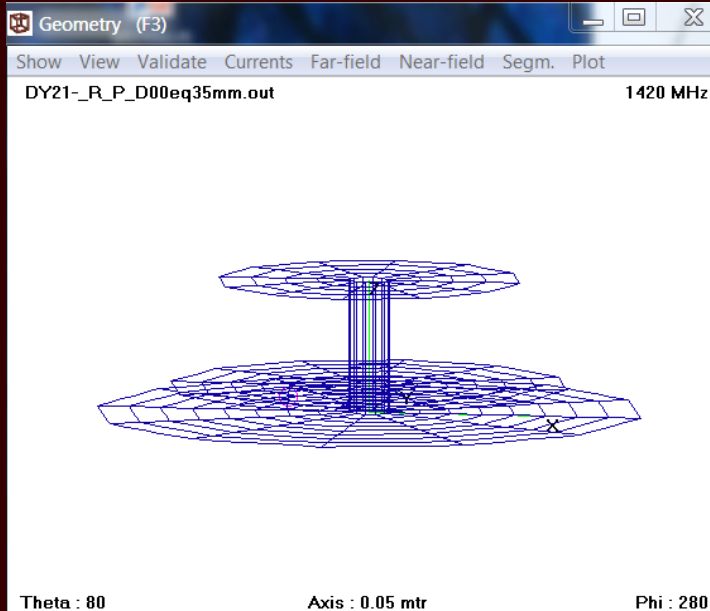
40mm and 60mm Director Spaced Antennas were modeled, fabricated, and tested to verify NEC model results



60mm Director Element Spaced Antenna Selected

Numerical Electromagnetics Code

Model Data vs VNA Analysis



Virtually IDENTICAL Results

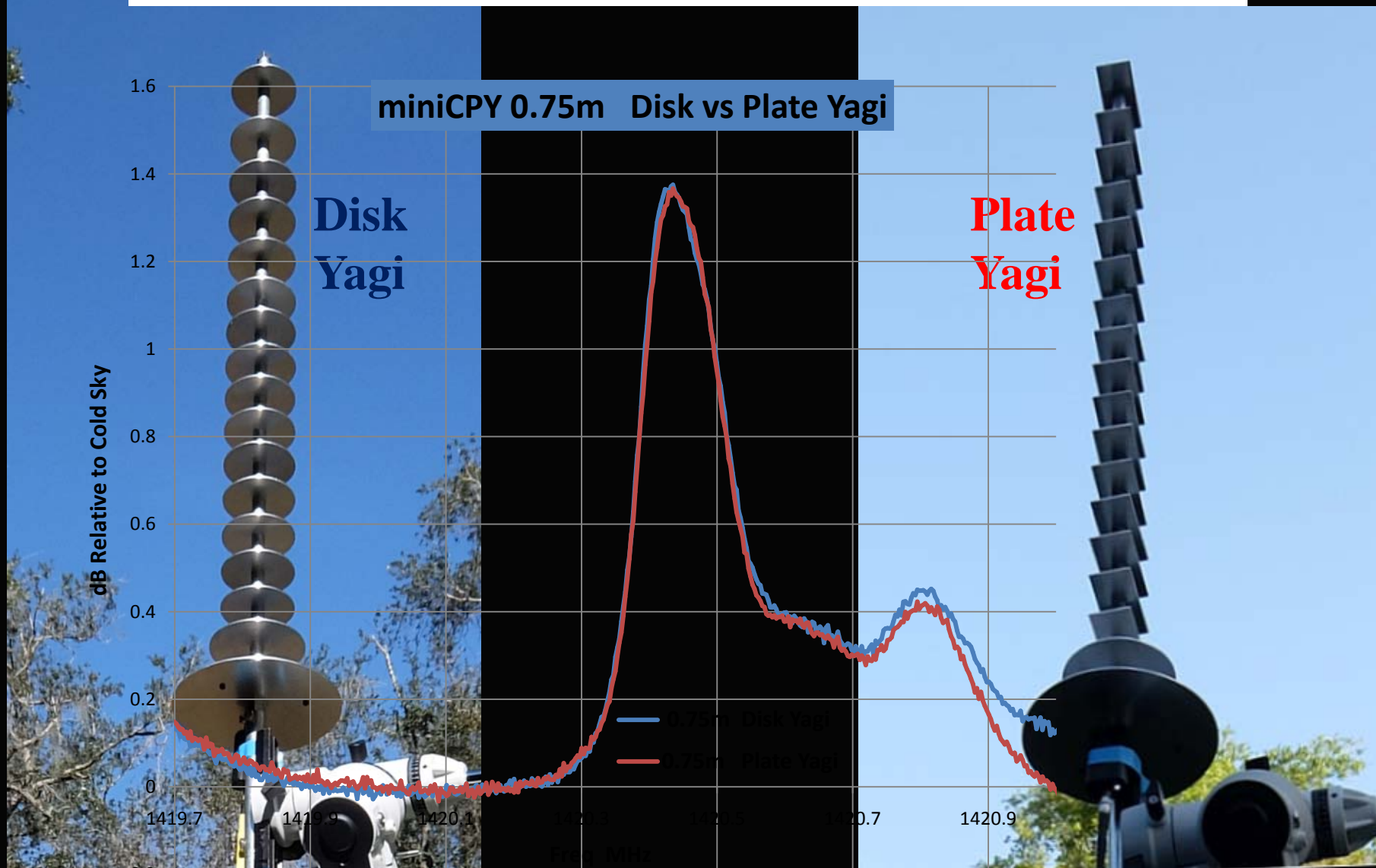


Field Tests

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**

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

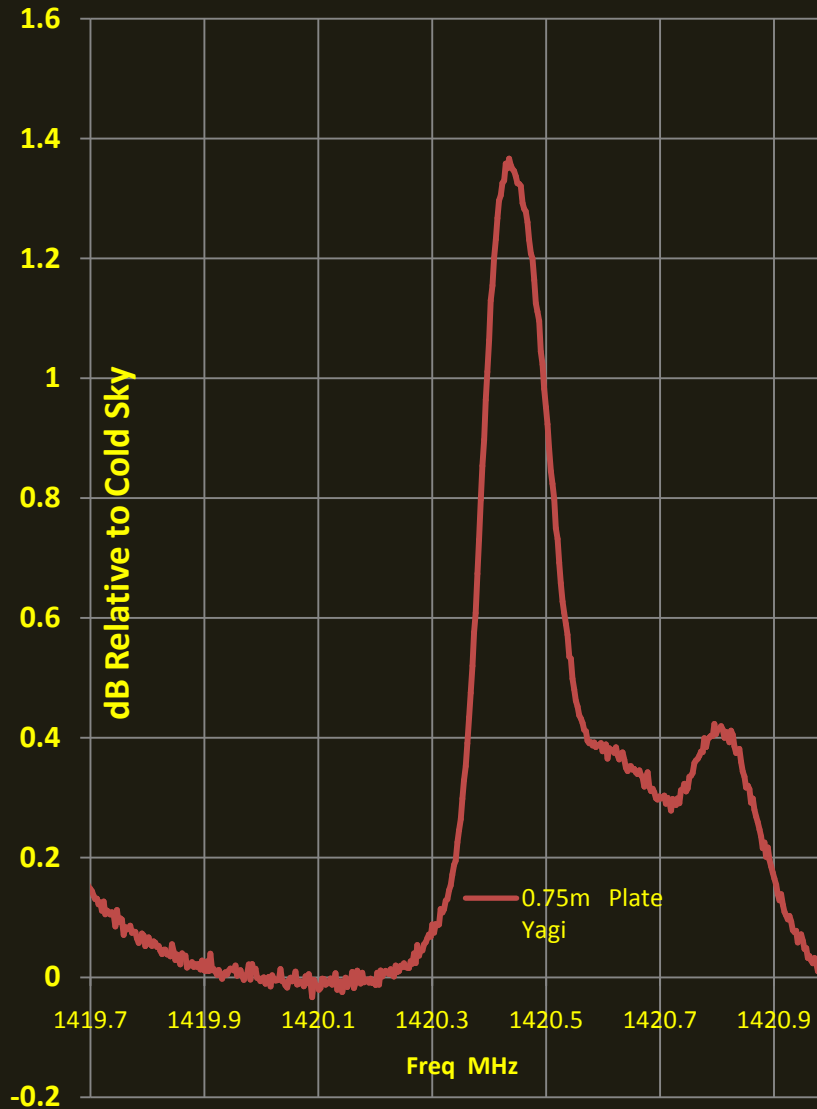
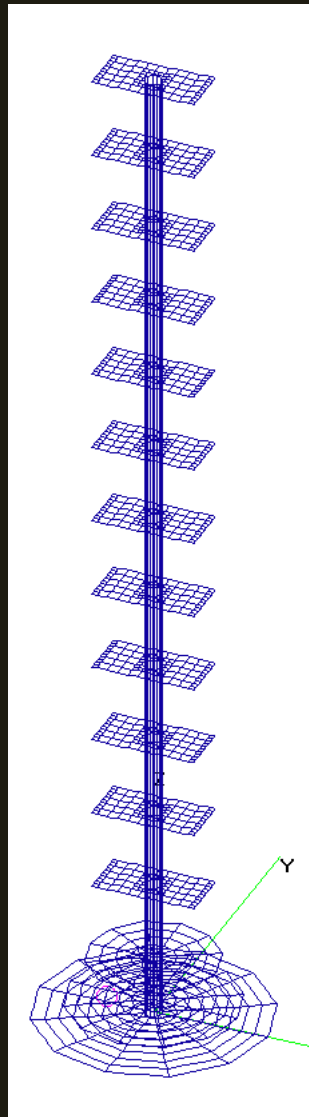
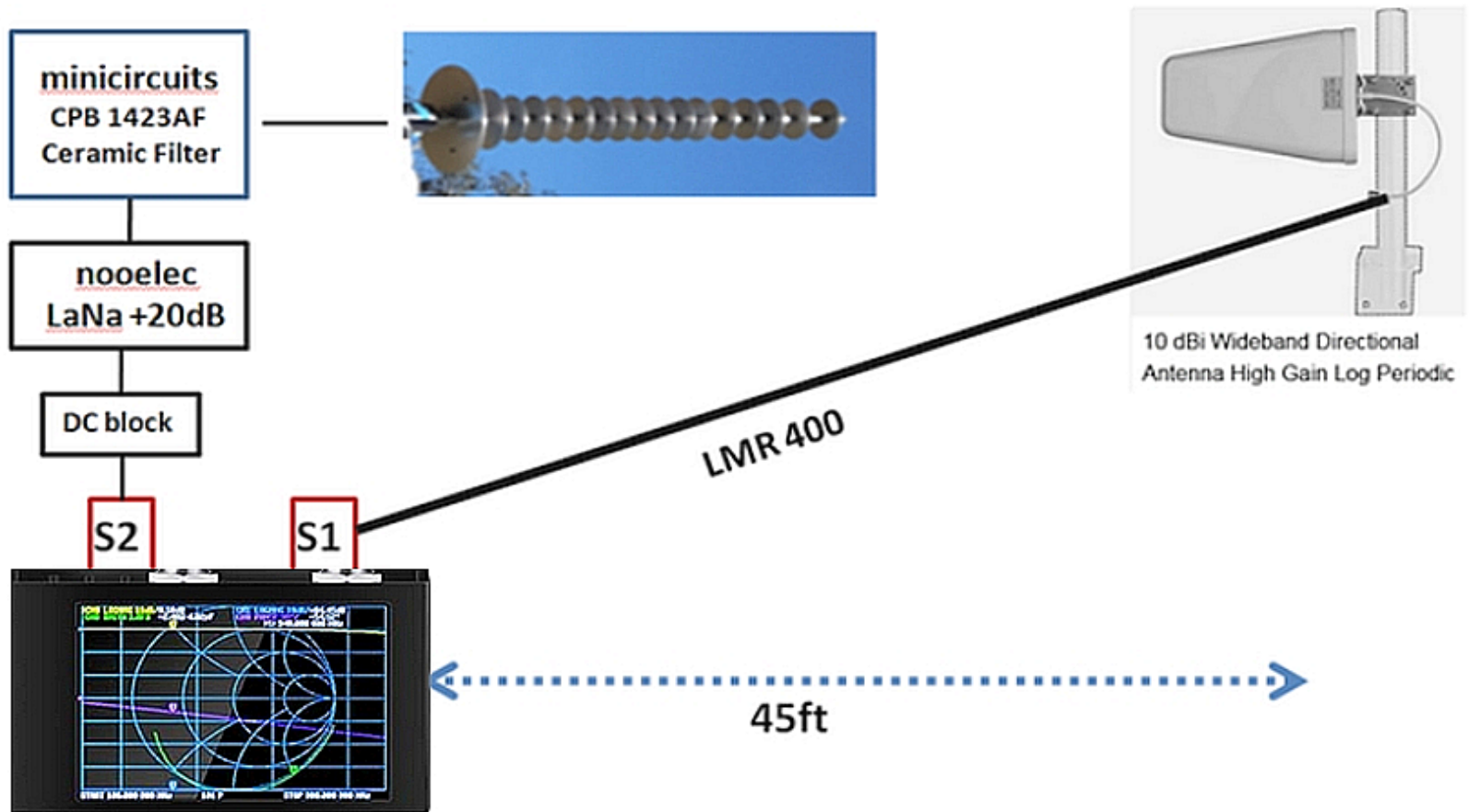


Plate Director Antenna NEC model and Fabricated Antenna

Antenna Beam Pattern Characterization Tests

Test setup : using a nanoVNA

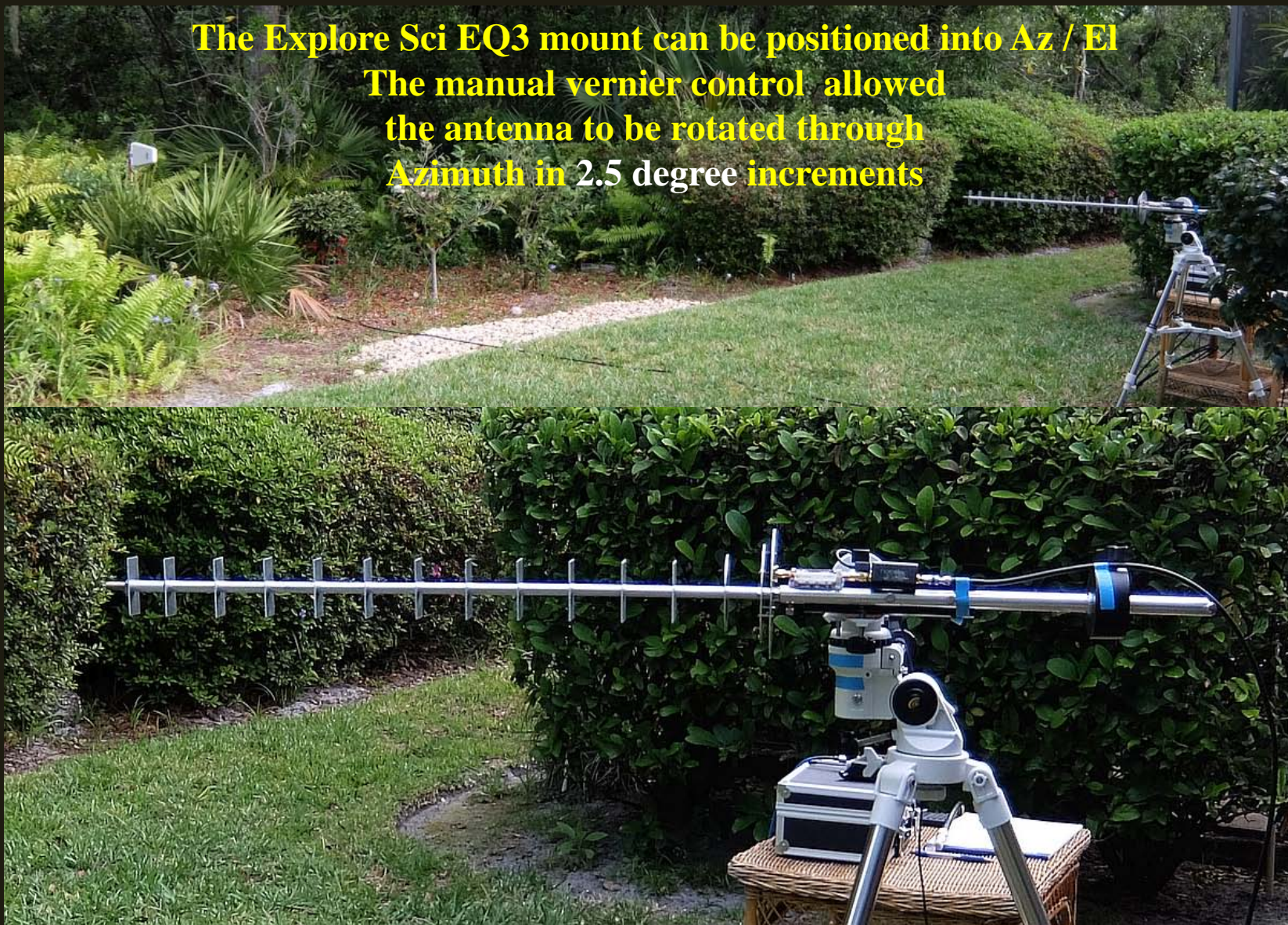
Antenna Beam Characterization Test Range



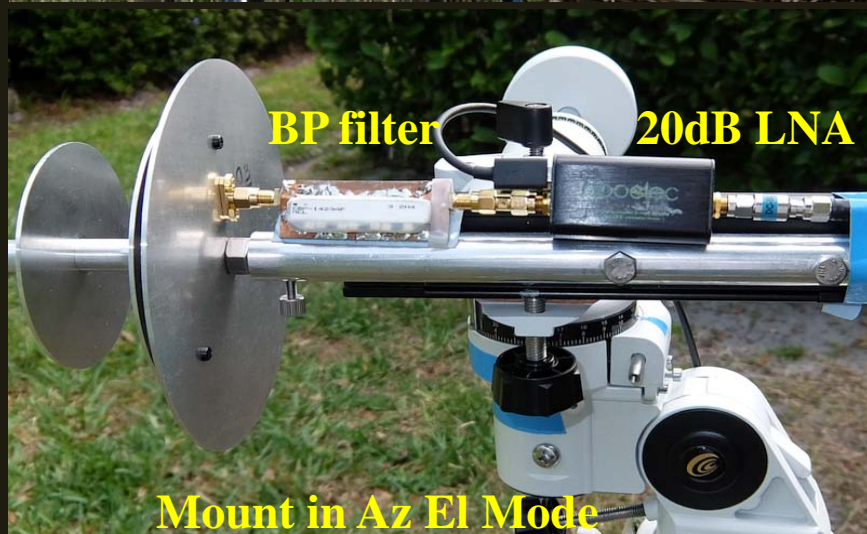
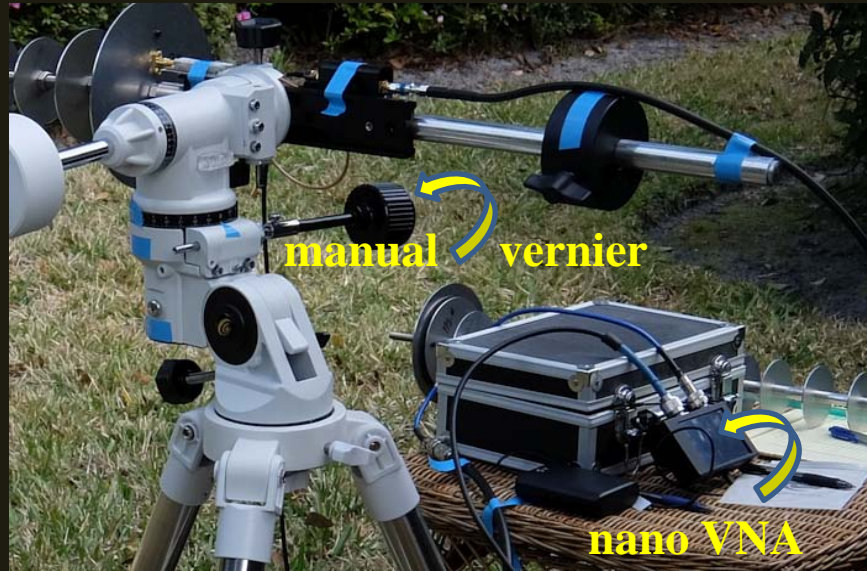
A Test Range was designed based on a nanoVNA to characterize the antenna's BEAM PATTERN

Circ Patch Feed Plate Yagi Beam Pattern Field Testing Setup

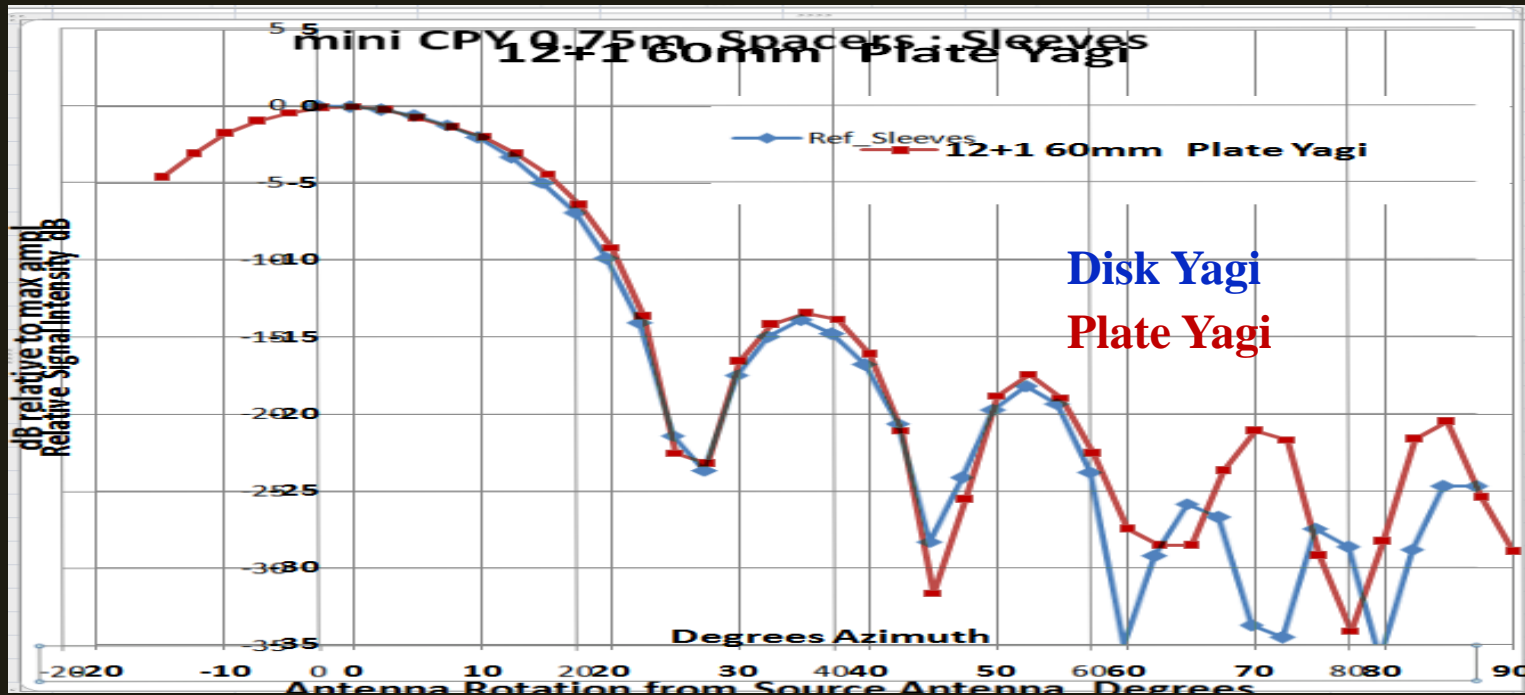
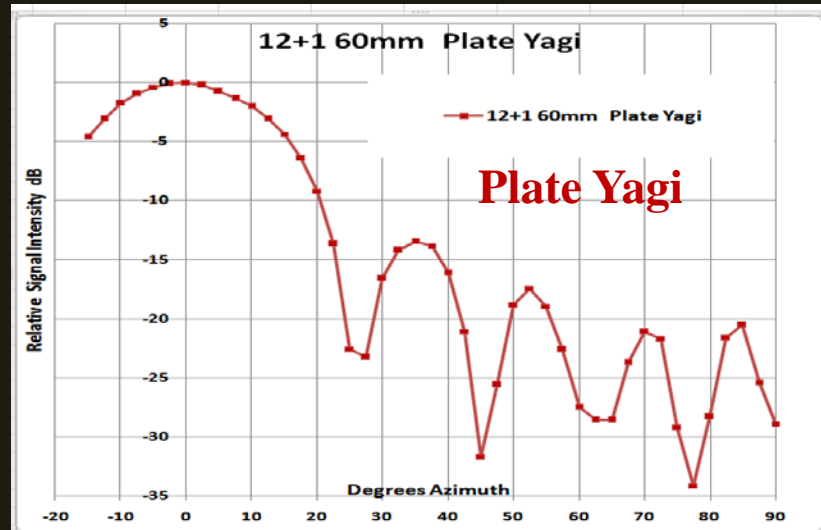
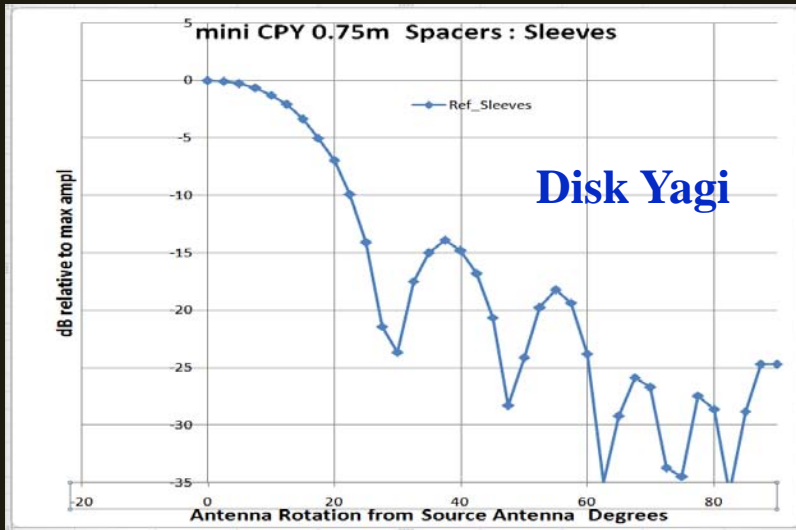
**The Explore Sci EQ3 mount can be positioned into Az / El
The manual vernier control allowed
the antenna to be rotated through
Azimuth in 2.5 degree increments**



Circ Patch Feed Plate Yagi Beam Pattern Field Testing Setup

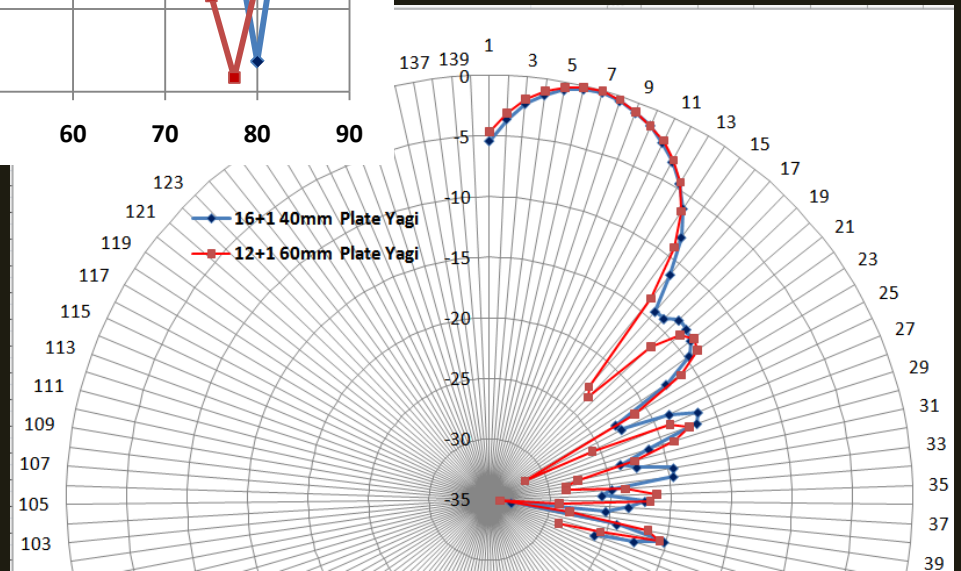
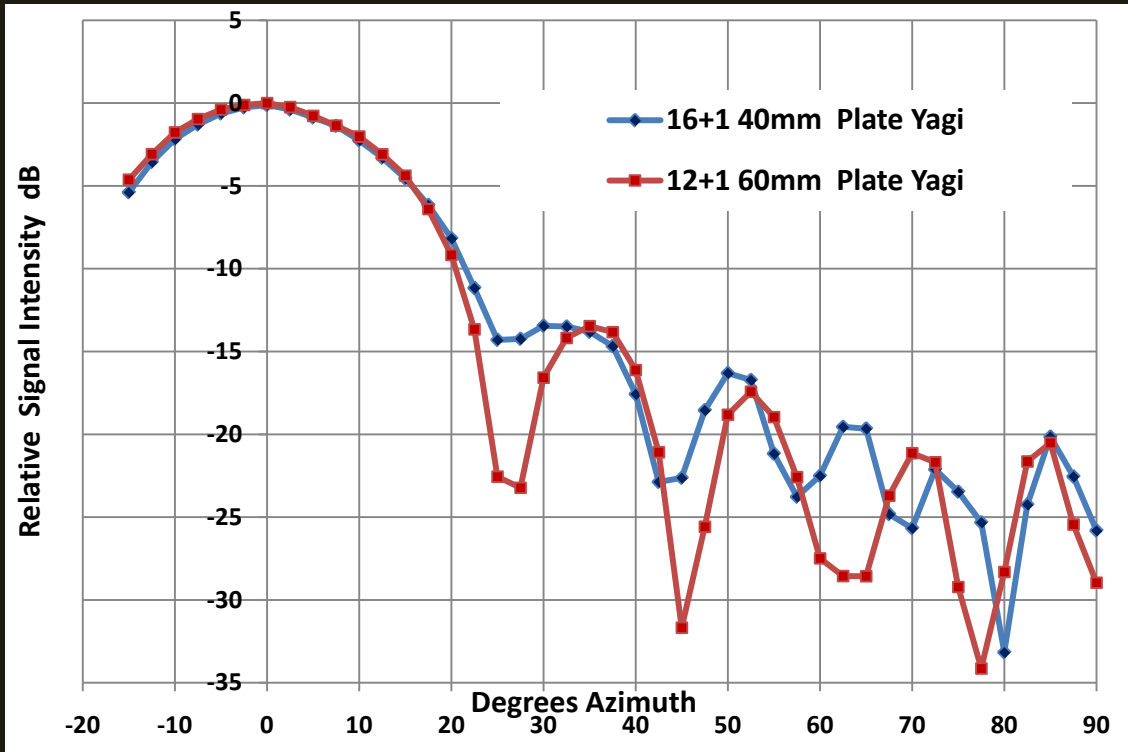


Antenna Beam Pattern Field Characterization Tests



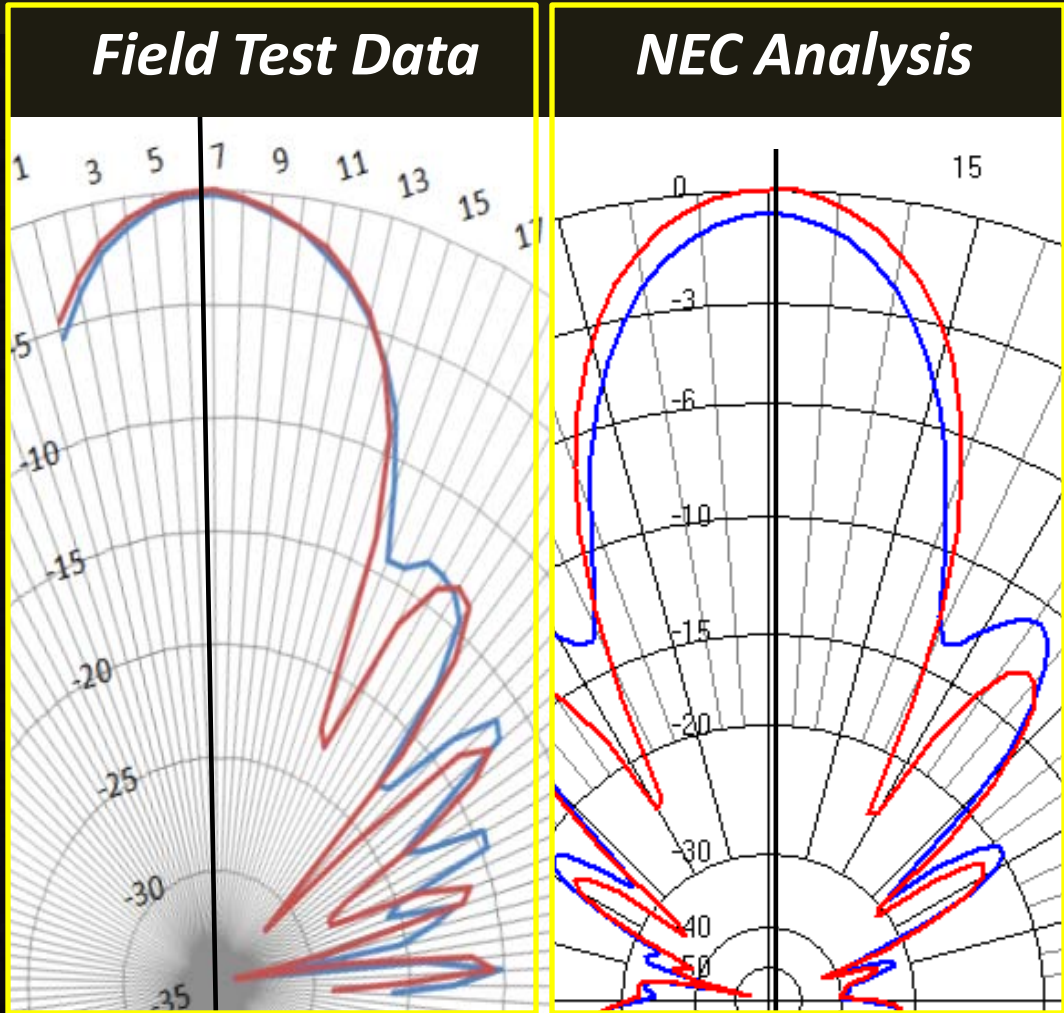
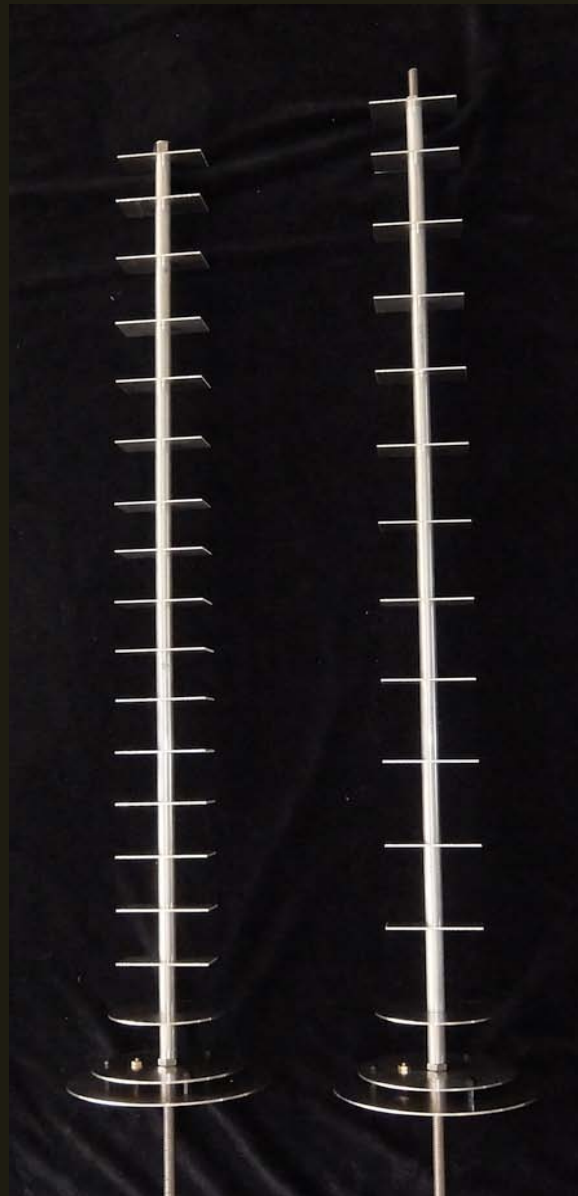
Circ Patch Feed Plate Yagi Beam Pattern Field Test Data Results

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**

Performance

0.75m Cir Patch Feed Plate Yagi Antenna Final Design

Performance Specifications :

Fwd Gain : +14.9 dB

Front-Back Ratio : +56.9 dB

½ Power Beam_width : 28 °

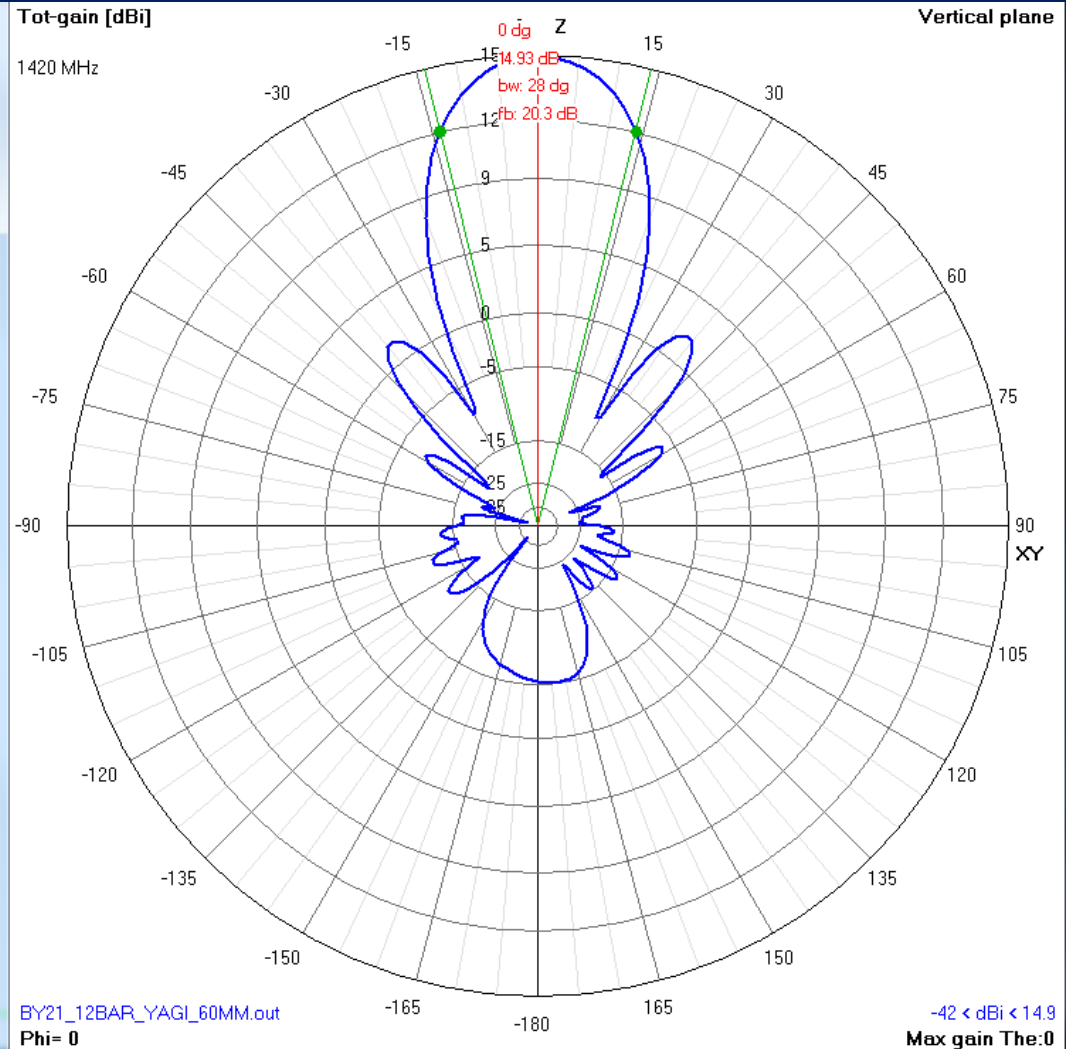
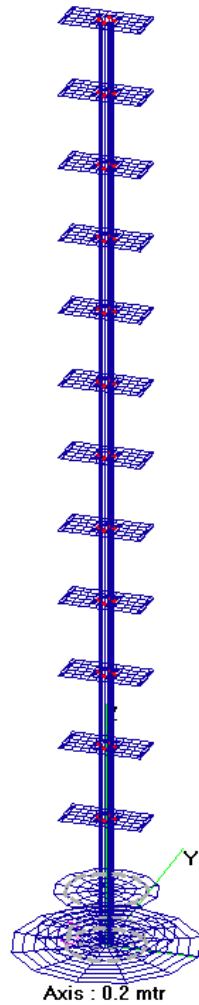
Max Signal to Cold Sky

@ Declination + 40 ° RA 20:30 Hrs Cygnus :

+1.35 dB (using noelec SAWbird H1 LNA)

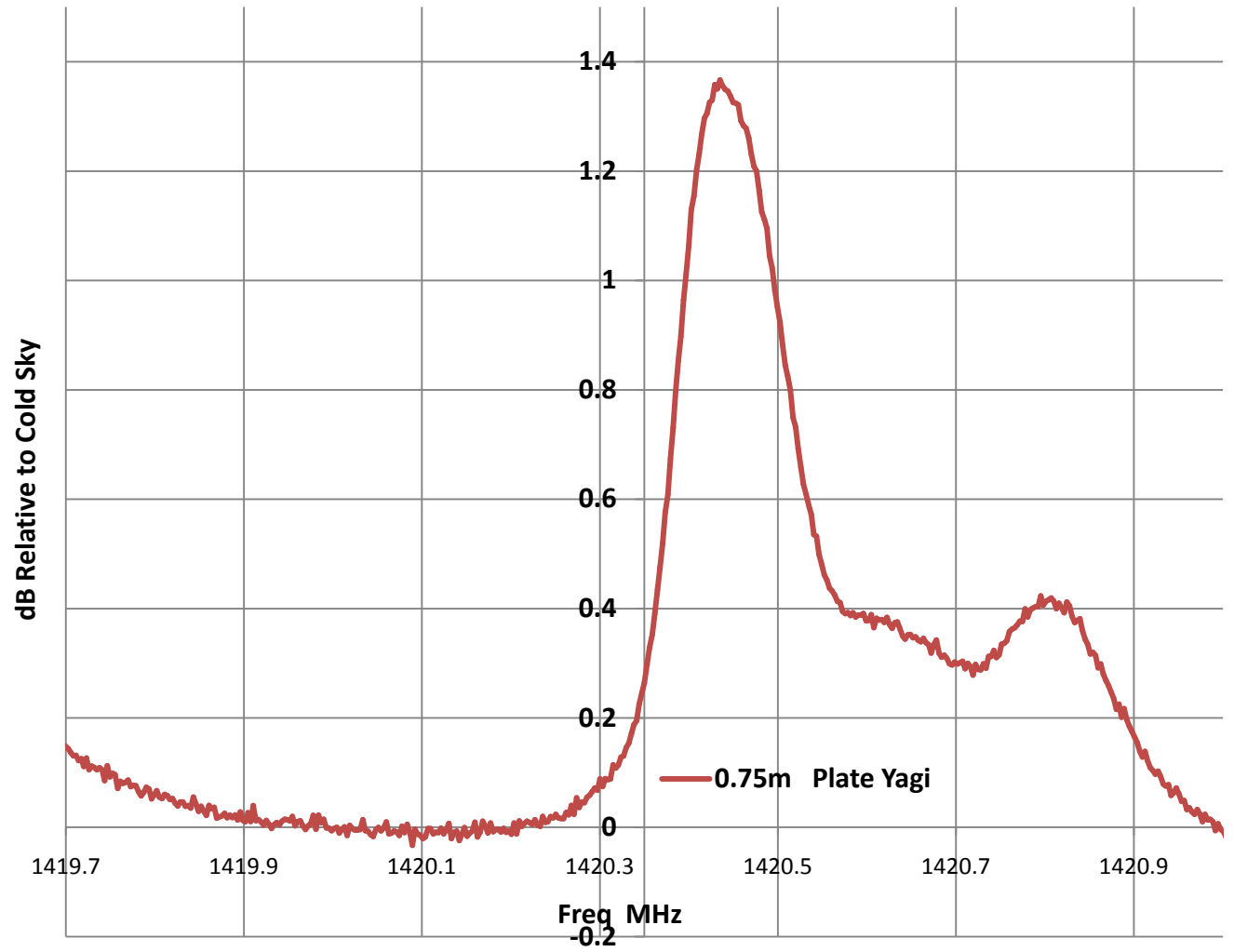
Performance Specifications :

Fwd Gain : +14.9 dB Front-Back Ratio: 56.9 dB ½ Power Beam_width : 28 °



Performance Specifications :

Max Signal to Cold Sky @ Declination + 40 ° RA 20:30 Hrs Cygnus 1.35 dB



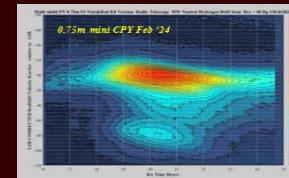
Results

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

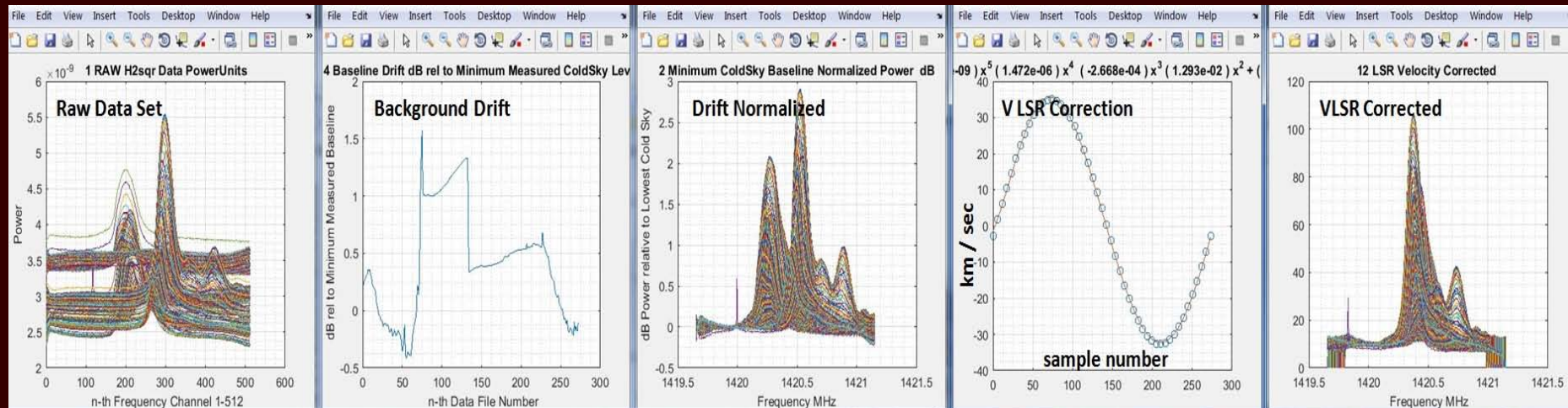
Each Spectra was a 5 minute average of data = a sky drift of 1.25 dg

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)



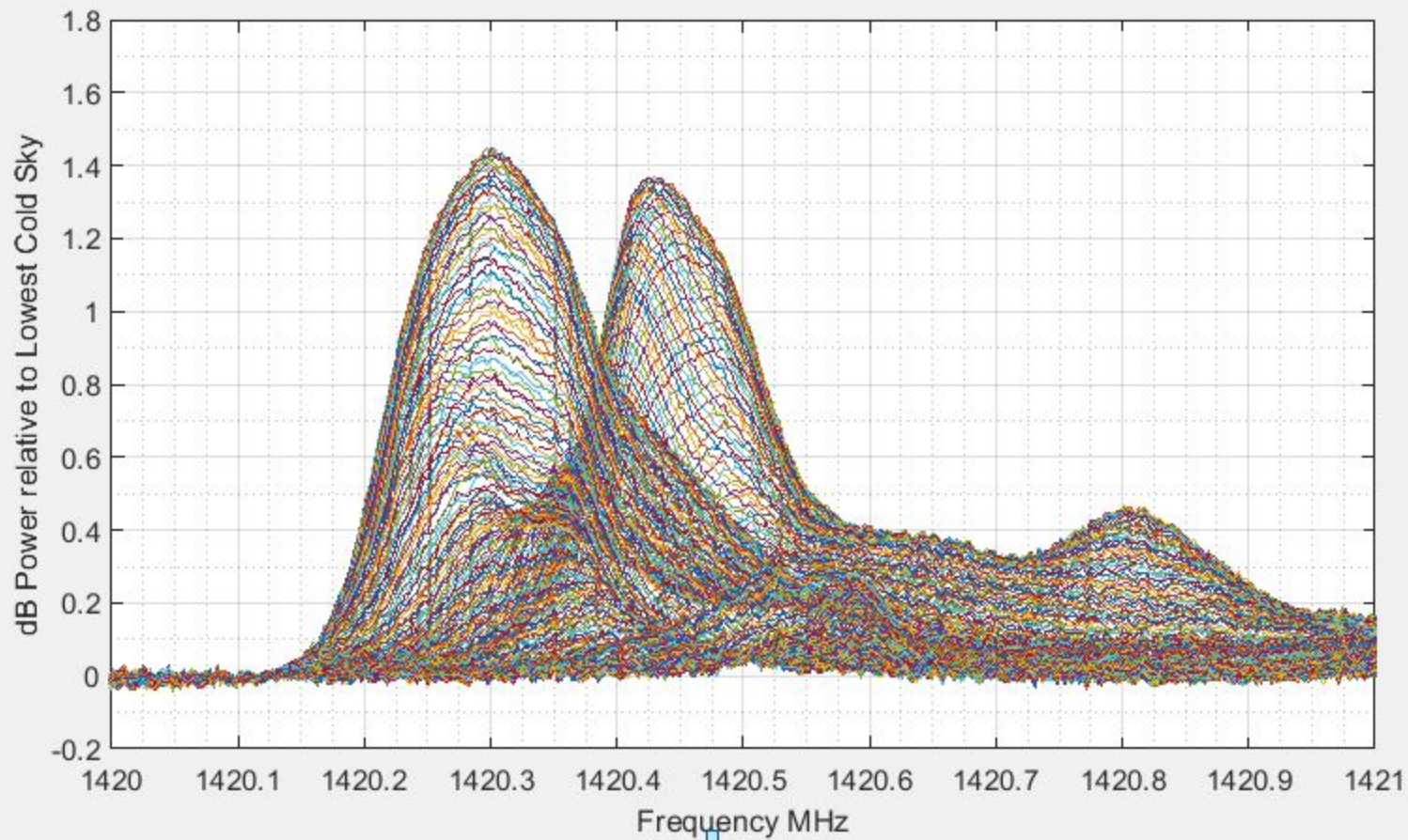
0.75m mini 13 disk CPY

AirSpy SDR# Studio and D.Kaminski IF_Average



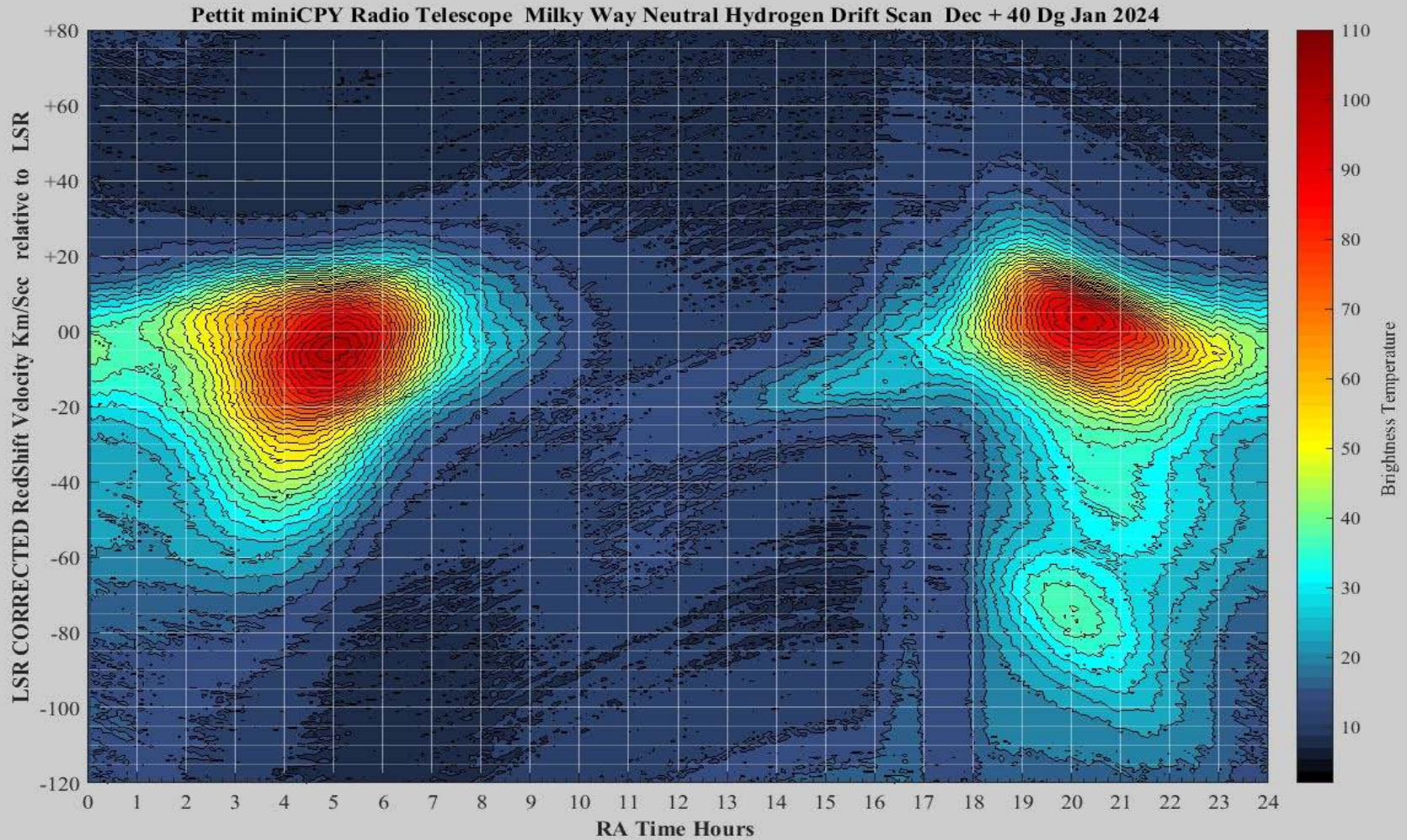
Declination +40dg

24 hour drift scan spectrum set



Declination +40dg

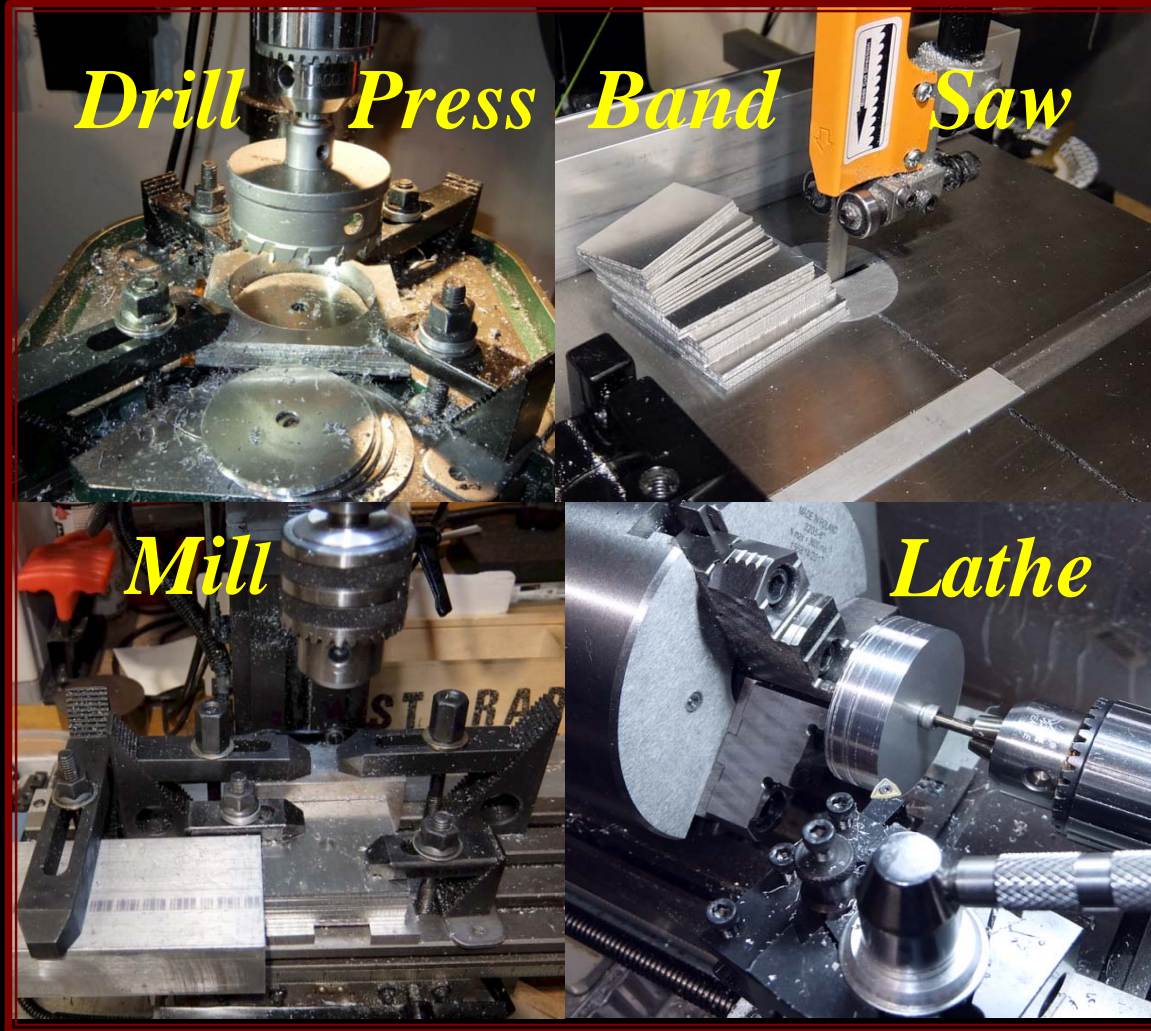
24 hour drift scan Contour Plot



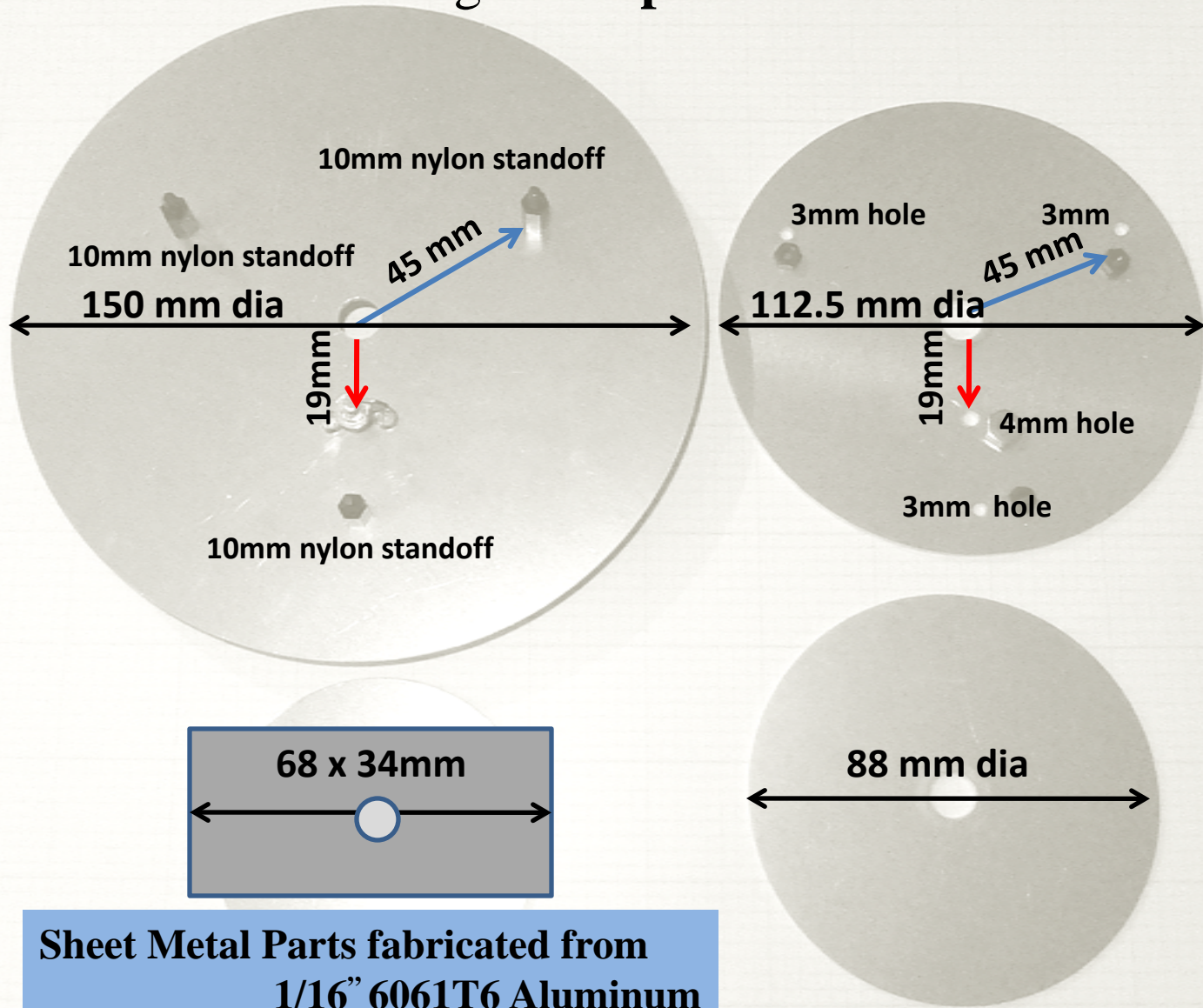
Fabrication

*Fabrication Details of The
21cm Circular_Patch_Feed
Rectangular_Director_Plate
Yagi Antenna
0.75m long 13 Directors*

Fabrication *the processes*



Cir Patch Feed Plate Yagi Component Dimensions

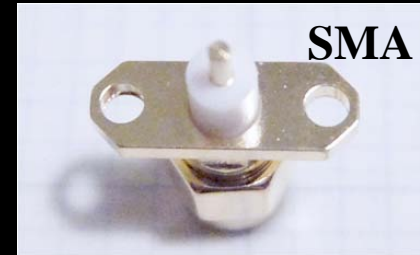


Sheet Metal Parts fabricated from
1/16" 6061T6 Aluminum



Cir Patch Feed Plate Yagi Element Spacer and Feed Components

Sleeving : 0.50" OD / 0.038" ID Aluminum Tube

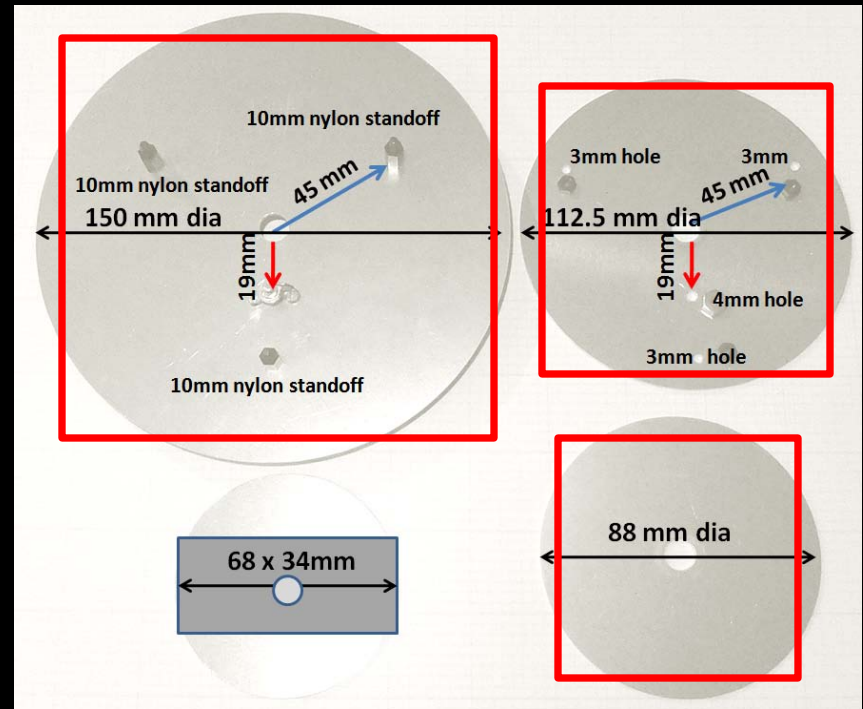
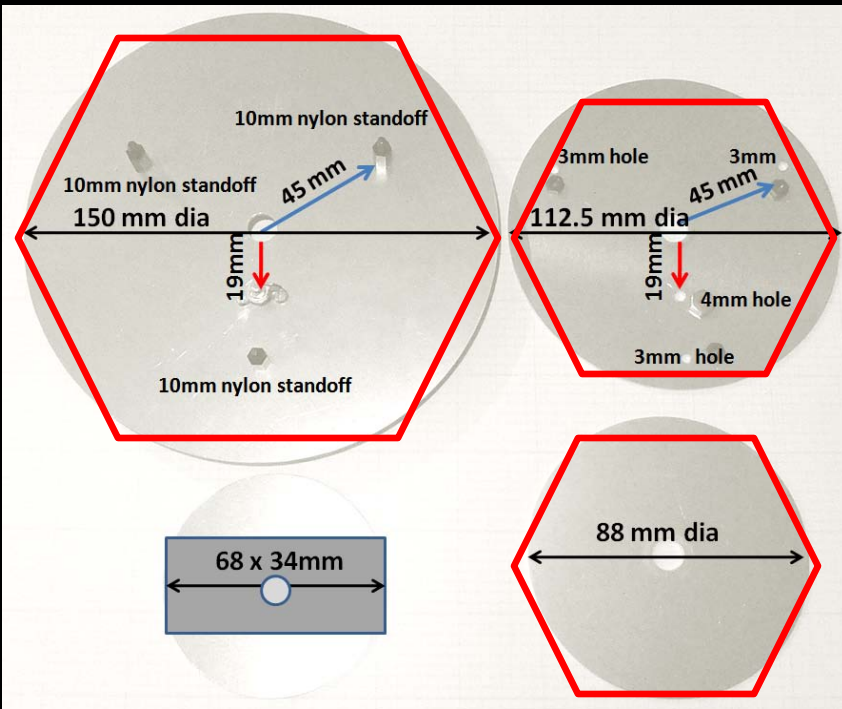


Stainless Steel 3/8"- 16 Thread Threaded Rod 36" Length



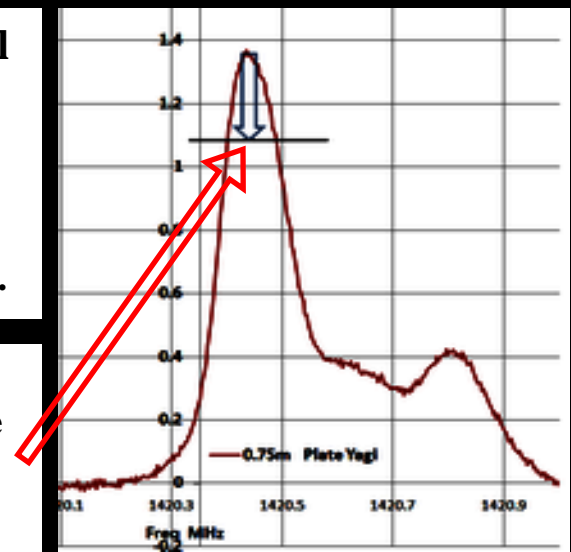
Patch Feed Plate Yagi

Alternate Designs



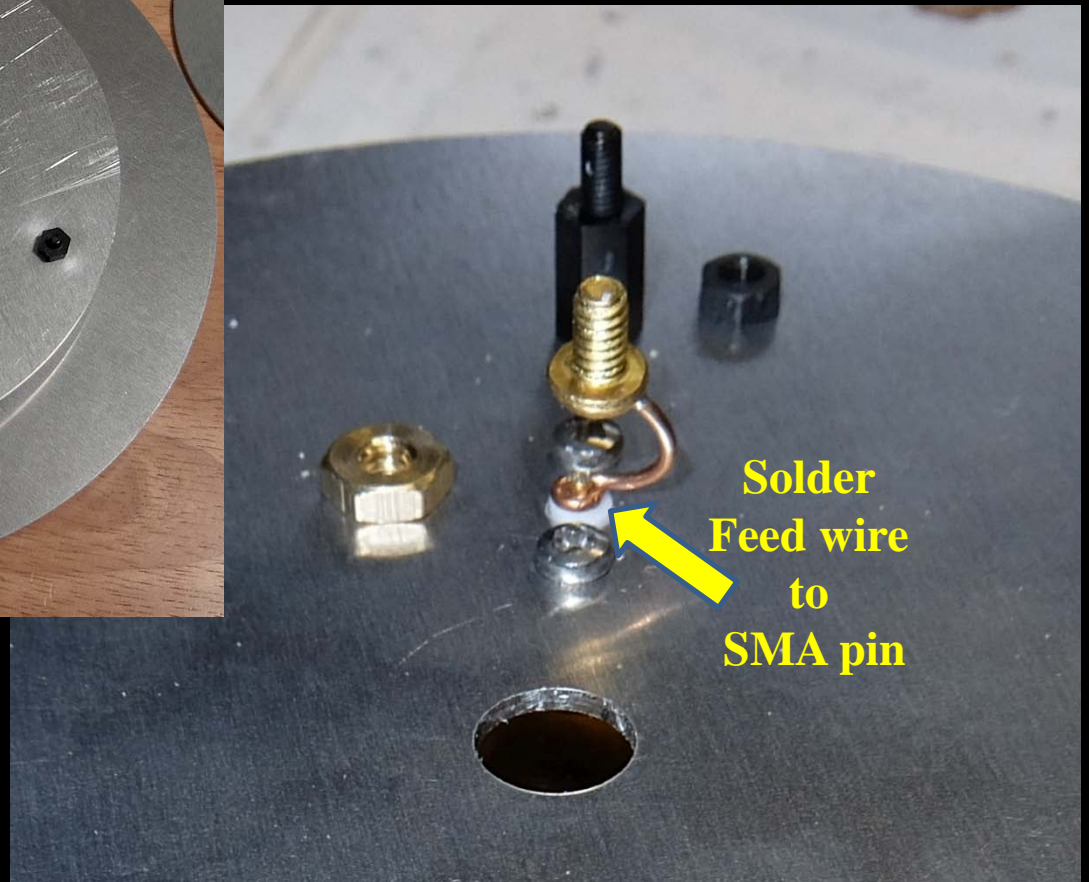
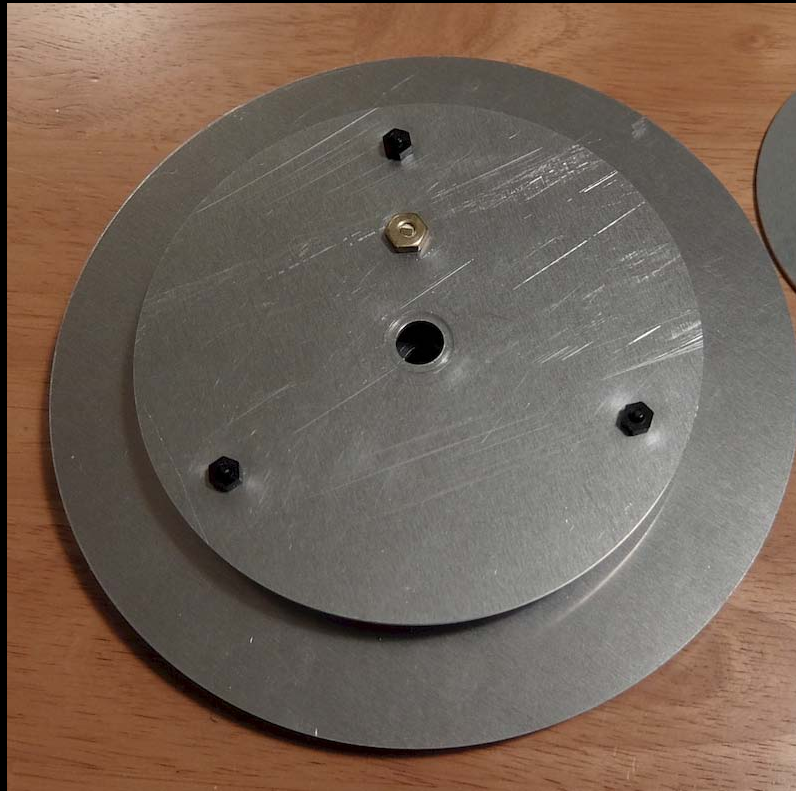
Simplified fabrications of the design should perform equally well
Maintain the same physical area of the Patch Feed ..
For a Square, that would = 100mm x 100mm
I would NOT recommend rectangular shapes for these
3 components as this may increase 290K Ground Noise Reception
(= reduce S/N) by altering the antenna's Back (Reverse) Beam Pattern.

SS Nuts vs Aluminum Spacers
Degrades the Cygnus performance
spec from 1.35 dB to 1.10 dB



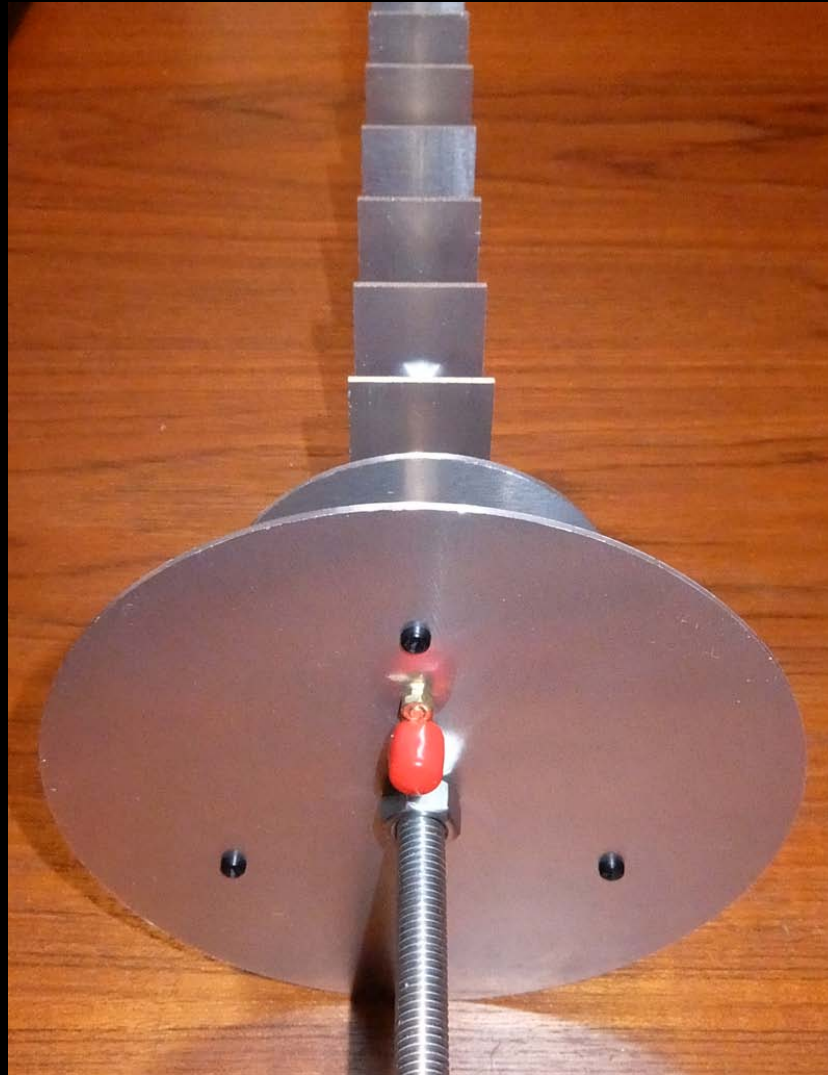
Cir Patch Feed Plate Yagi **Reflector / Feed details**

This pair of components has an F_n of 1380 MHz and can be tuned to 1420 MHz with the addition of the Director Elements

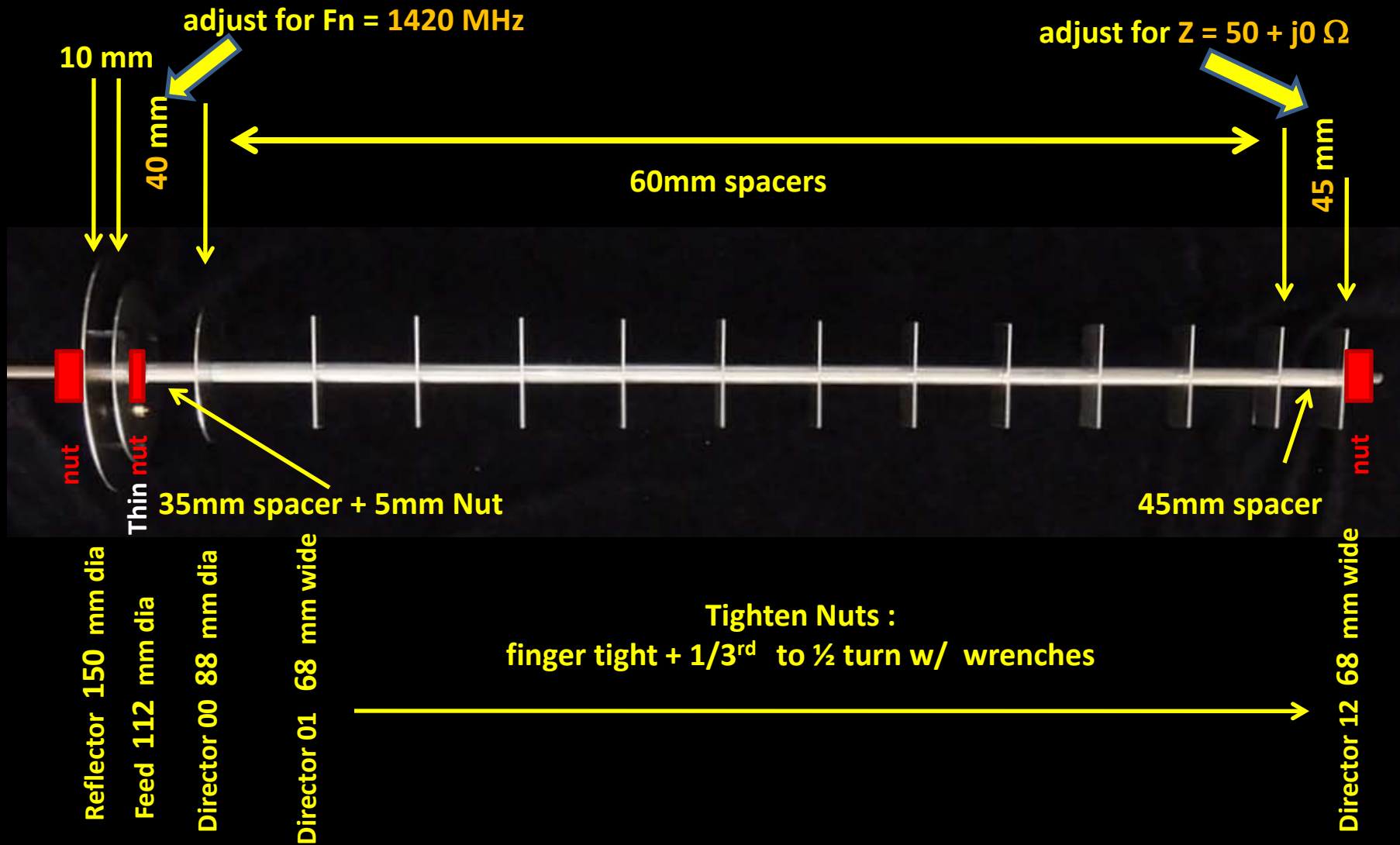


Cir Patch Feed Plate Yagi Reflector / Feed assembly

CORRECT Feed < > Director Orientation

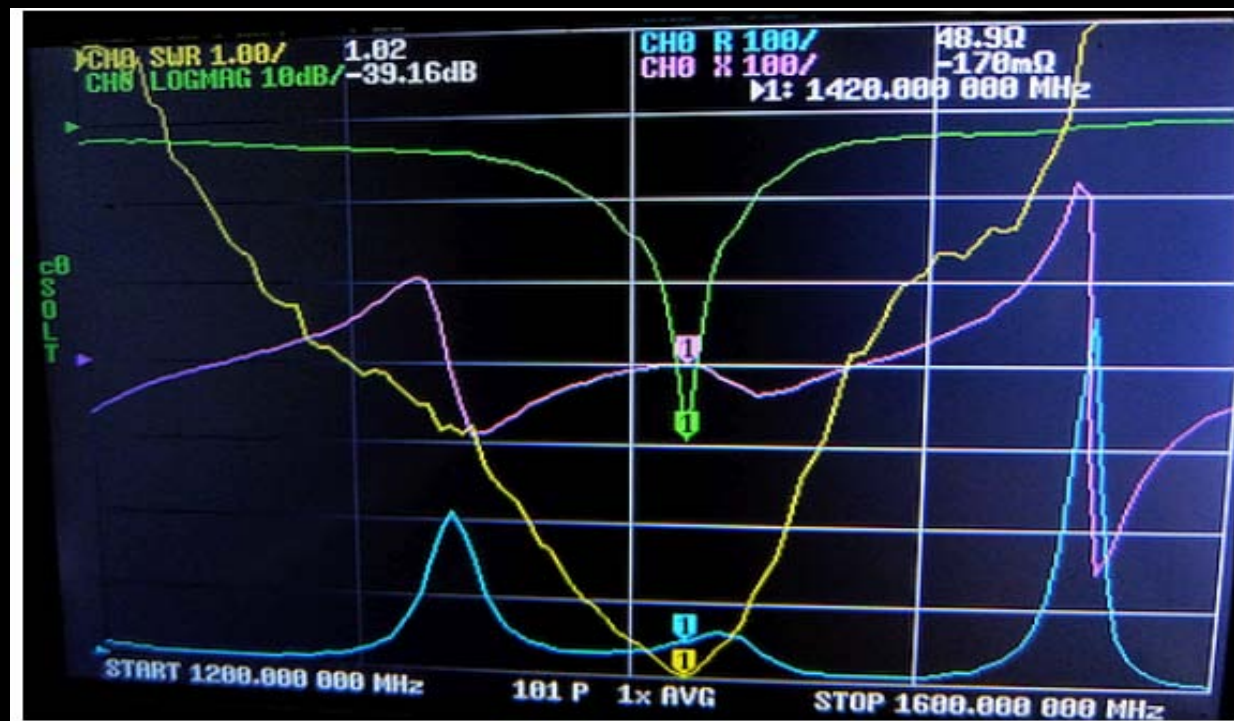


Cir Patch Feed Plate Yagi Dimensions



Cir Patch Feed Plate Yagi Antenna

Tuning via nano VNA



**** Improving Weather Resistance ****

Overnight Dew Shield : use a plastic polyethylene container



21cm Circular_Patch_Feed Plate_Director Yagi Antenna

The End

