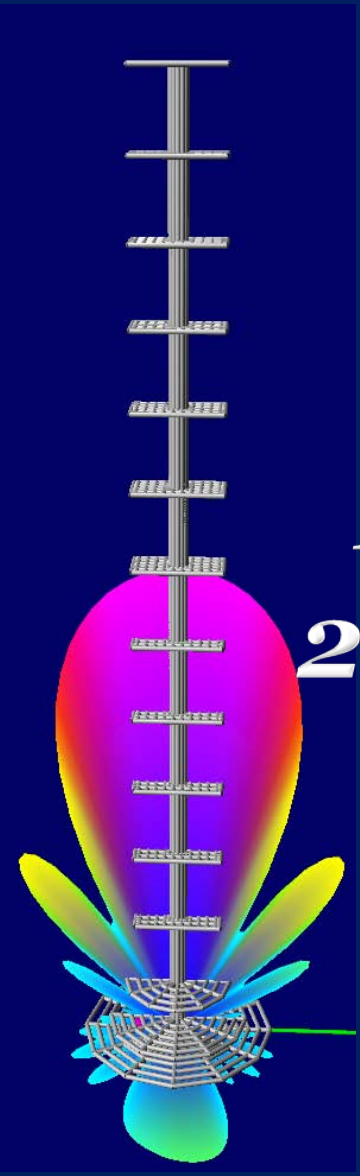
21cm Circular_Patch_Feed Plate_Director Yagi Antenna



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

b alex pettit jr *June 24*

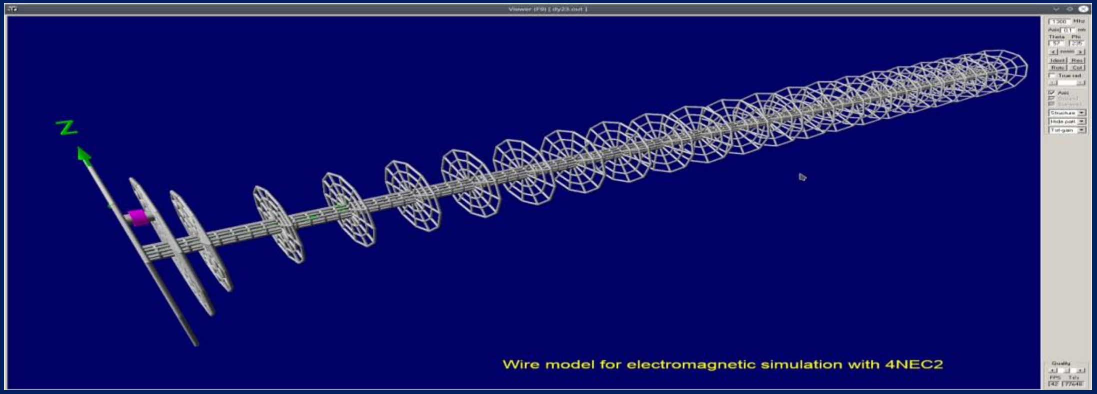
Background

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

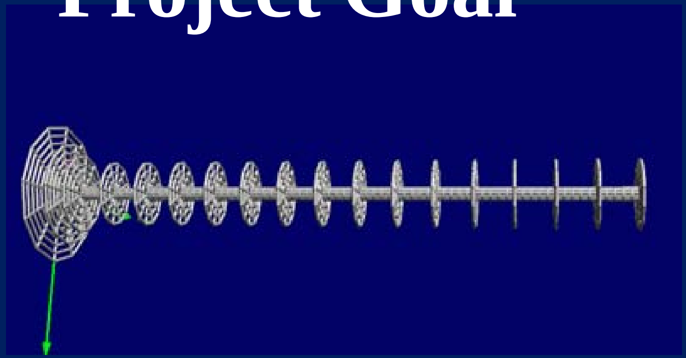
Matjaz Vidmar S53MV

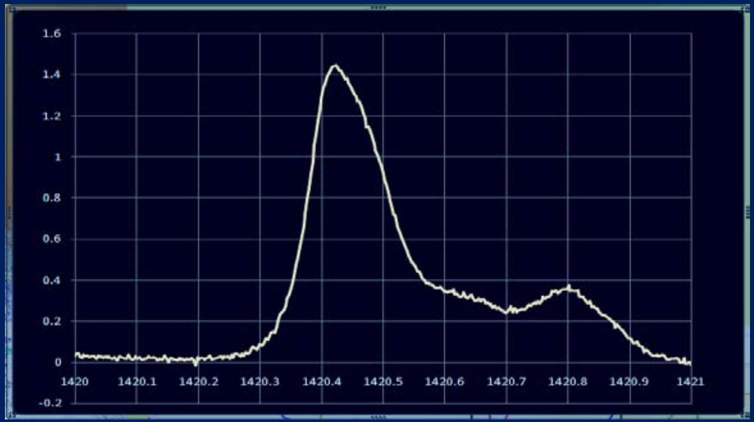
https://lea.hamradio.si/~s53mv/cigar/design.html
https://s53mv.s56g.net/

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.

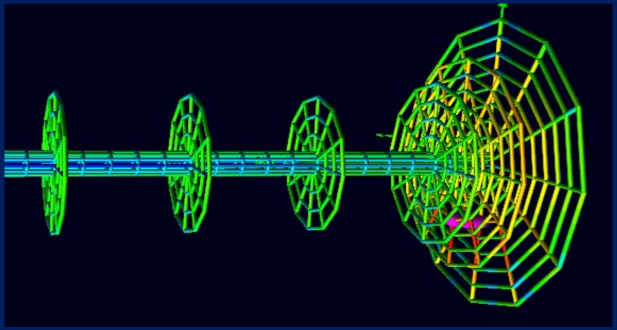
An investigation into manufacturing components for a low cost "*scope_in_a_box*" variant was begun. The Goal : a '$50 Antenna'

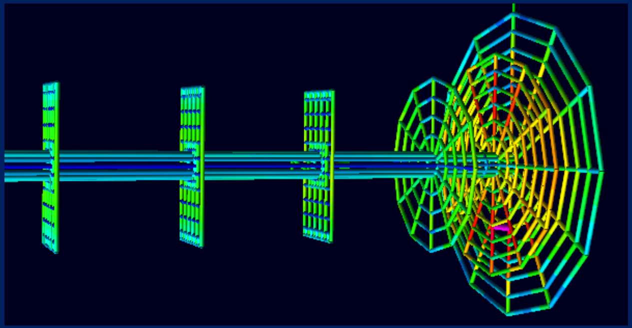
The Problem : A large number of elements is required, but a low cost source for the aluminum disks was never identified.
Quotes for fabrication via Water_Jet, Laser_Cutting, and Stamping were obtained, but in all cases, the cost was $4-6 each for the Directors alone.
This was beyond the intended budget .

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 :

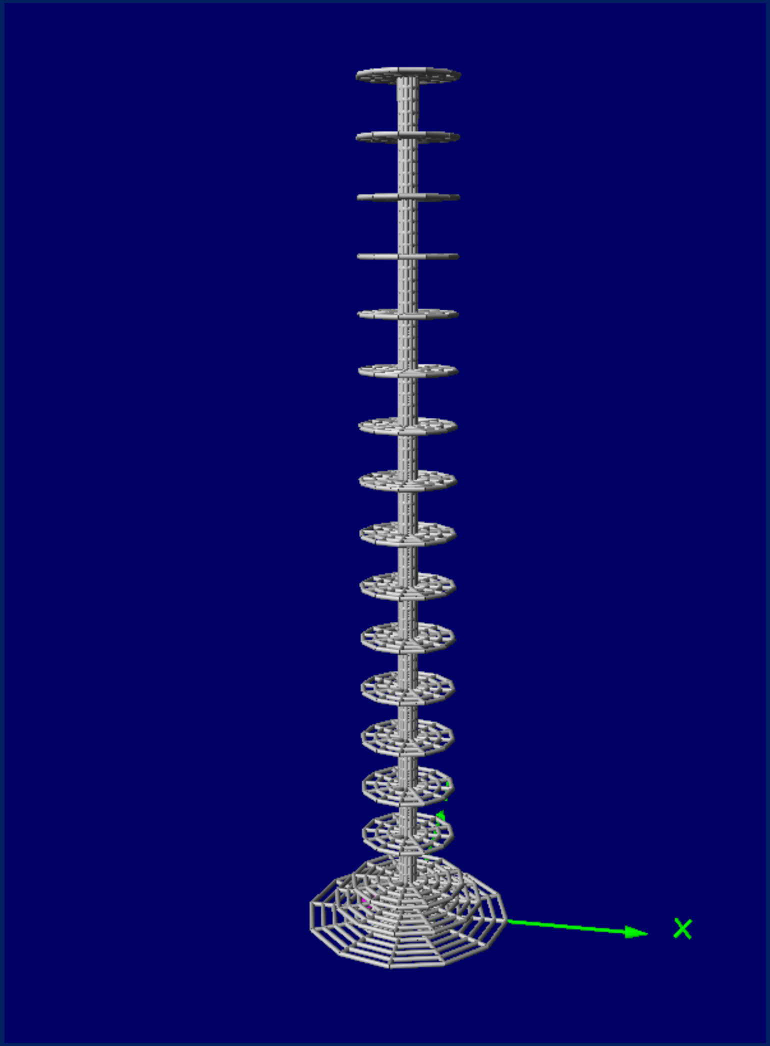
The circular disk directors could be replaced with rectangular plates with

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

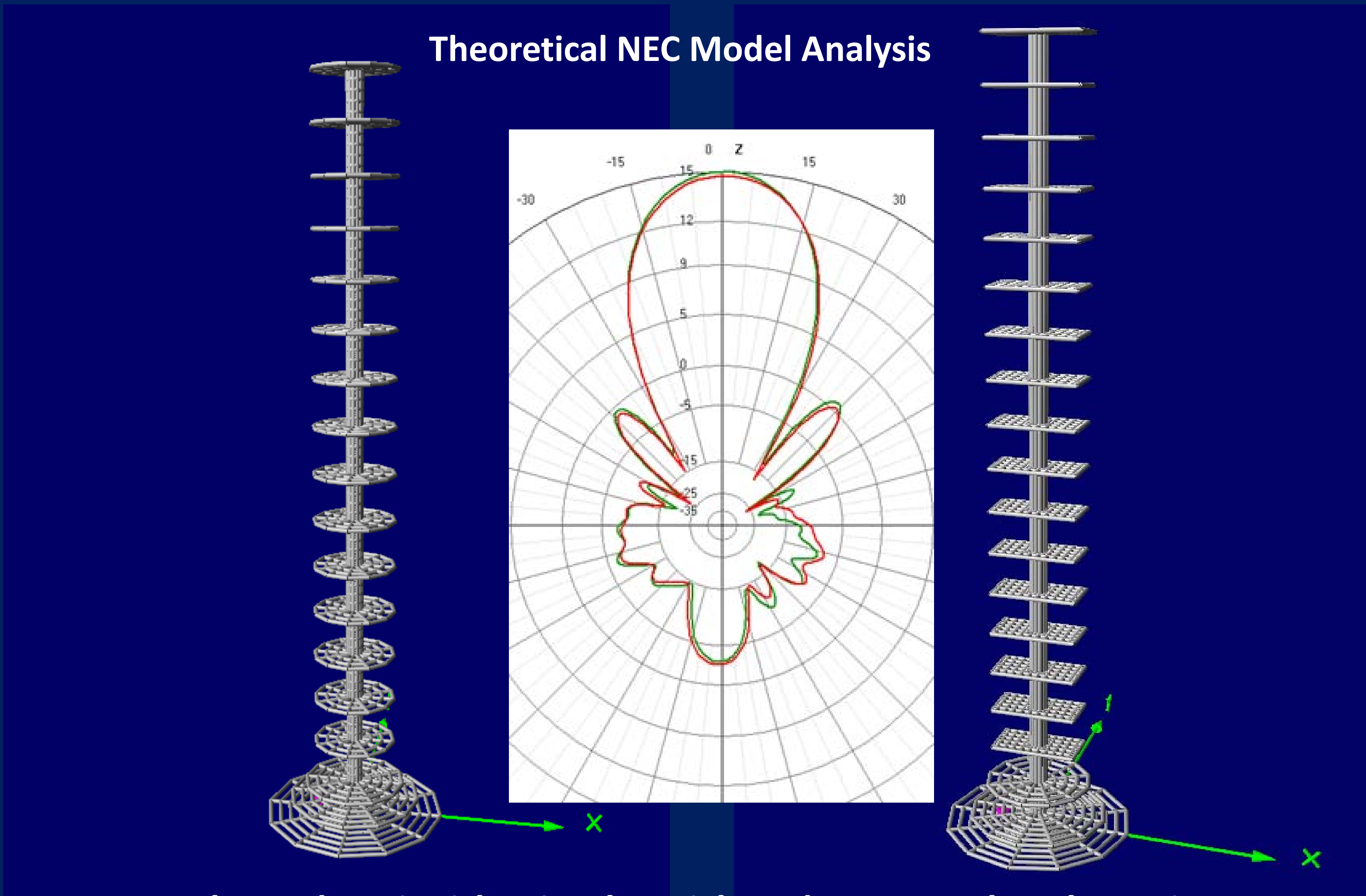


Patch Feed Yagi with Circular Disk Directors

works well, but difficult to fabricate disks

21cm Circular_Patch_Feed Disk vs Plate Yagi Antenna

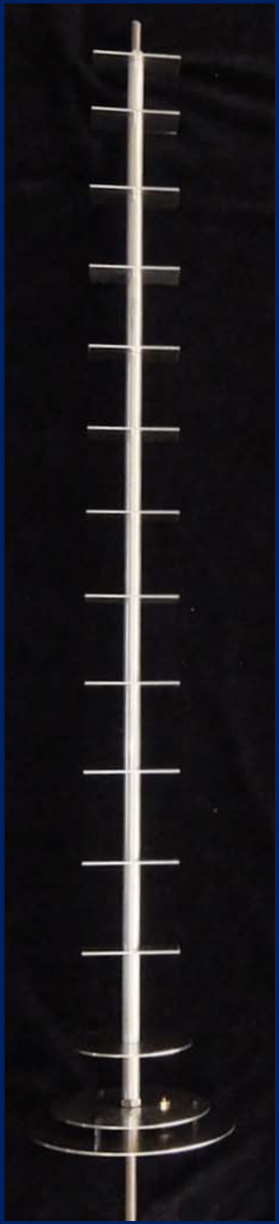
Theoretical NEC Model Analysis



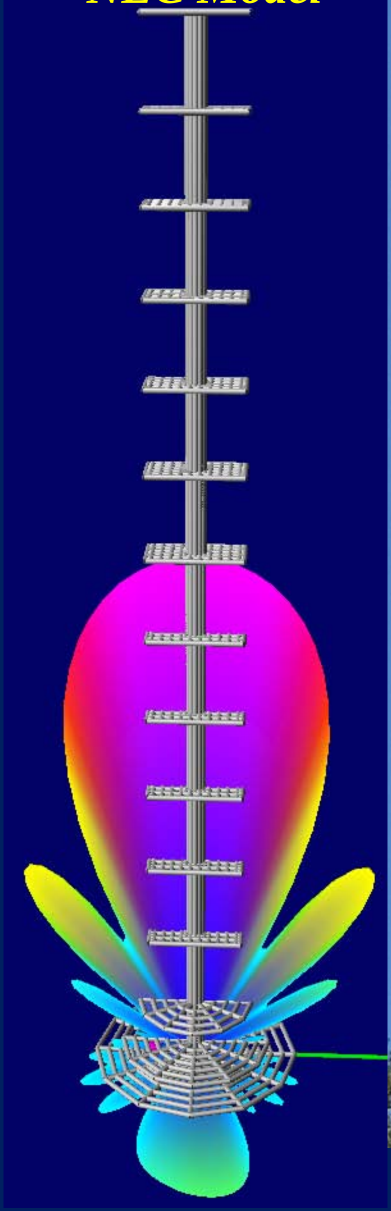
Patch Feed Yagi with Circular Disk and Rectangular Plate Directors

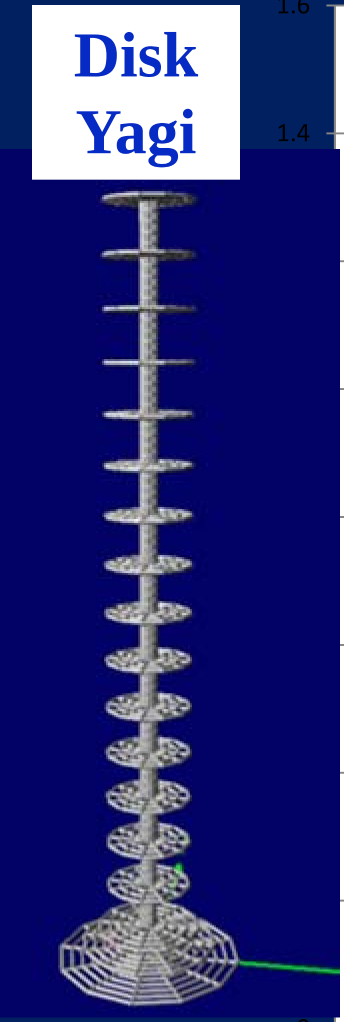
The model showed identical performance using rectangular plates

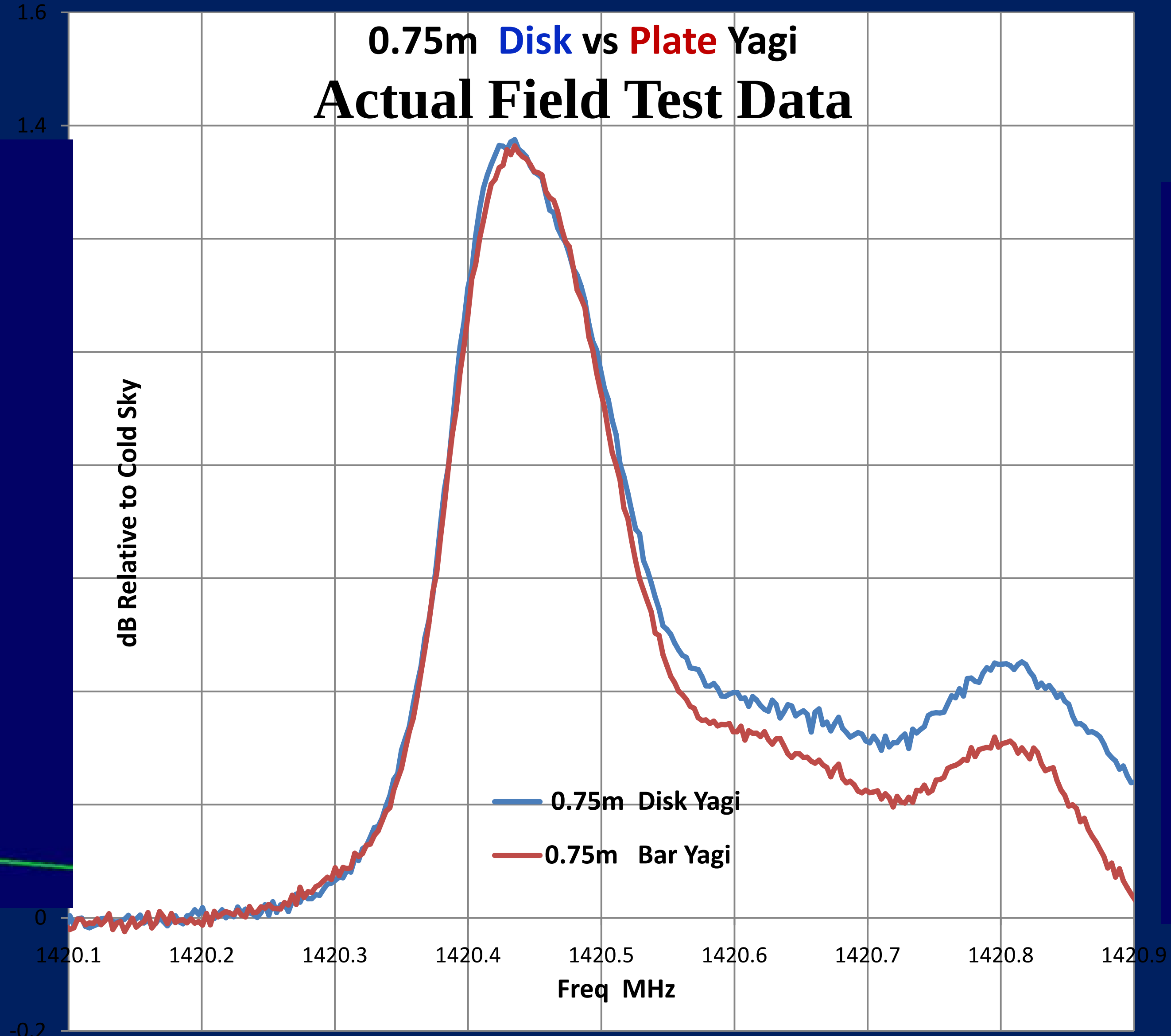
21cm Circular_Patch_Feed Plate Yagi Antenna

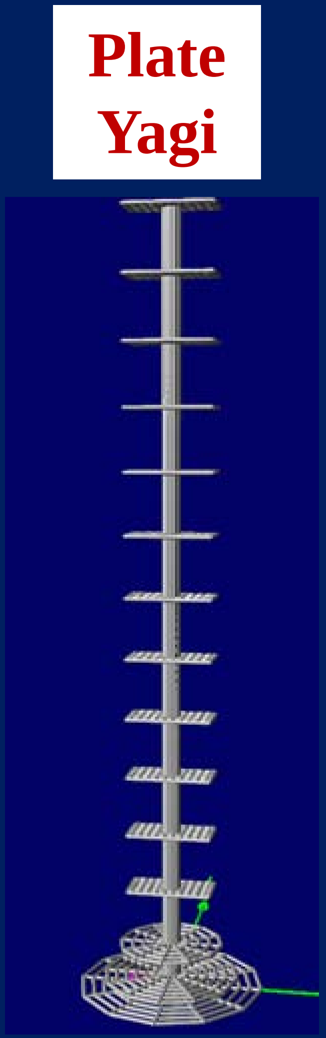


NEC Model









Patch Feed Yagi with Circular Disk and Rectangular Plate Directors

Field Tests verified "identical" performance between the two designs

b alex pettit jr Jun24

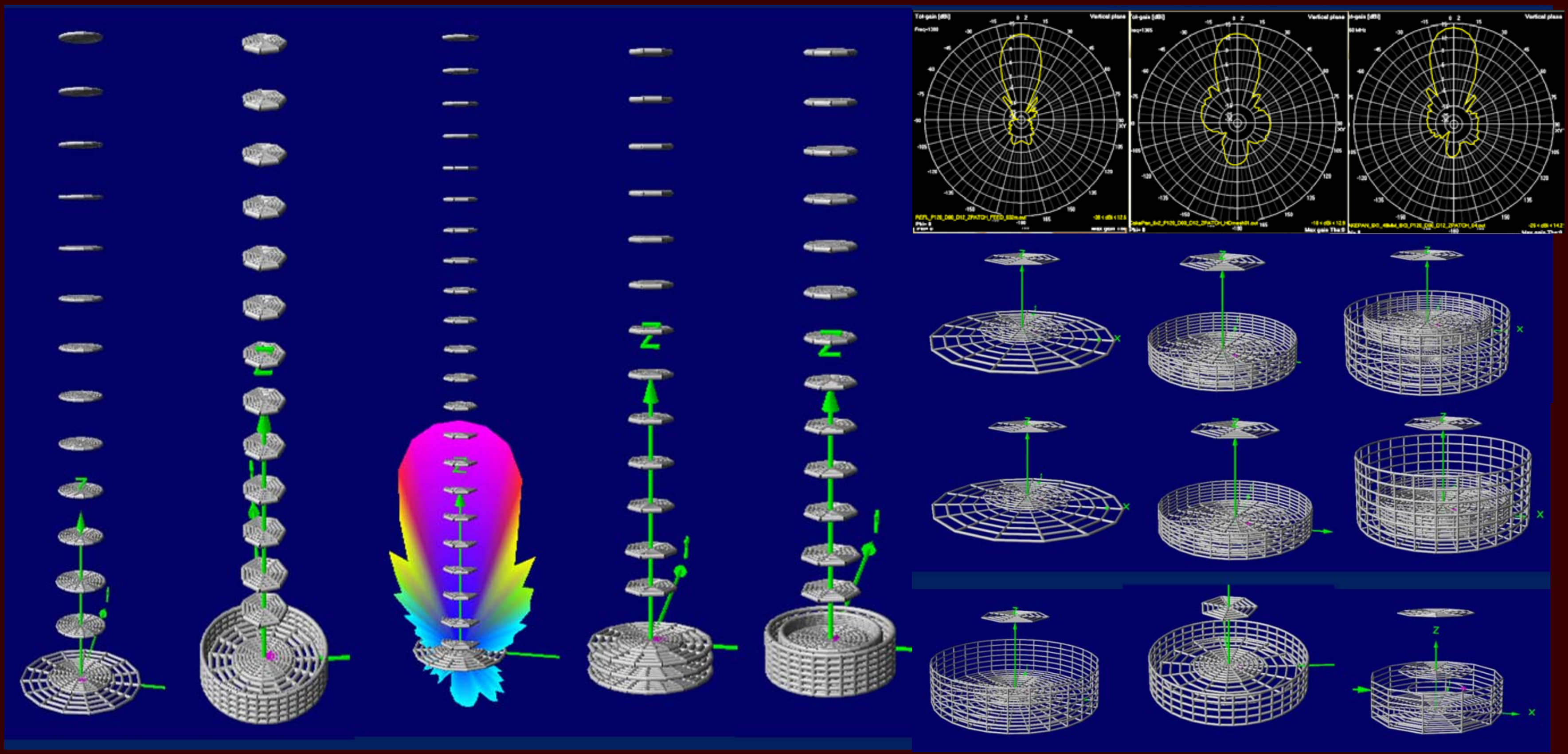
Analytical Modeling

NEC
Numerical Electromagnetics Code
Overview

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

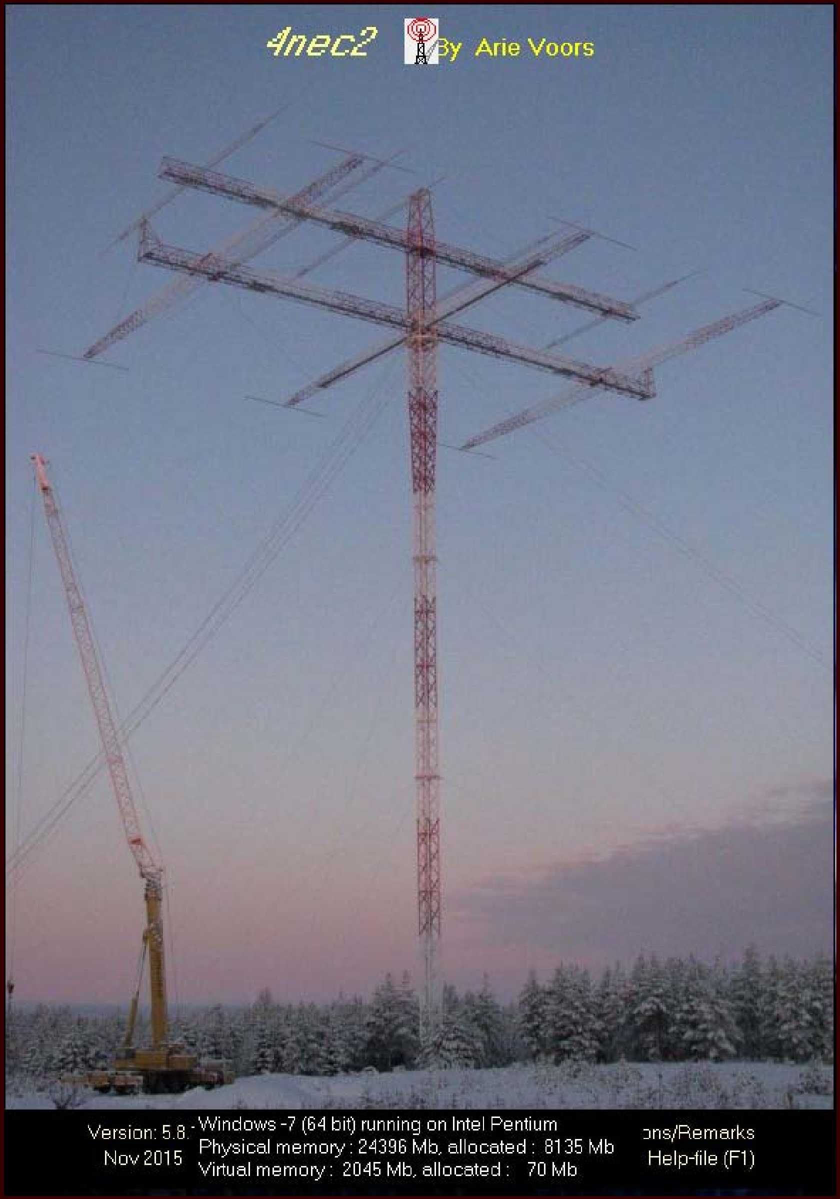
It was originally written in FORTRAN
during the 1970s by Lawrence Livermore National Laboratory.

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



Numerical Electromagnetics Code

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

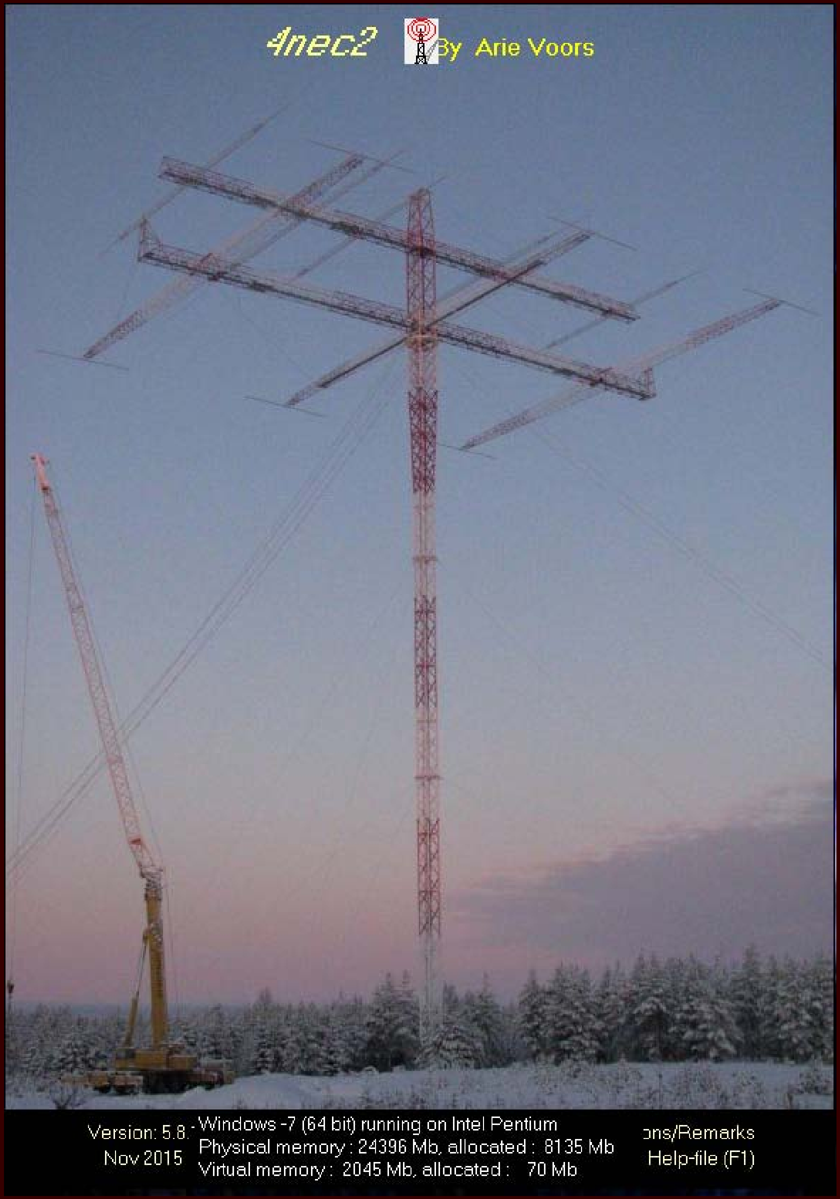
The **Numerical Electromagnetics Code** is an antenna modeling program for wire and surface antennas. It was originally written in FORTRAN during the 1970s by Lawrence Livermore National Laboratory.

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

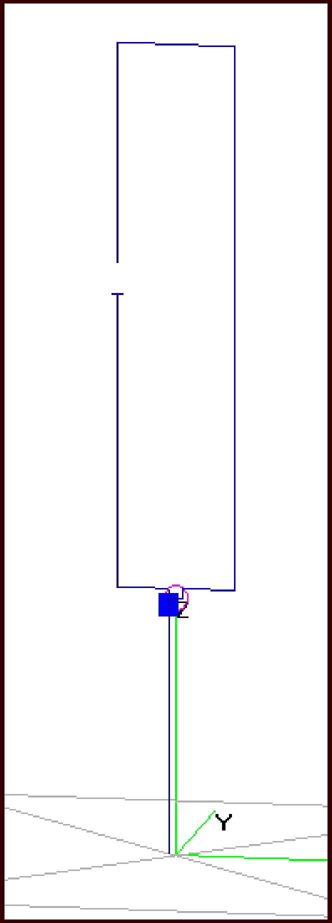
It performs an analysis of an antenna by Finite Element Analysis Techniques which divides wires into a number of small elements and computes their currents and resultant electric and magnetic fields

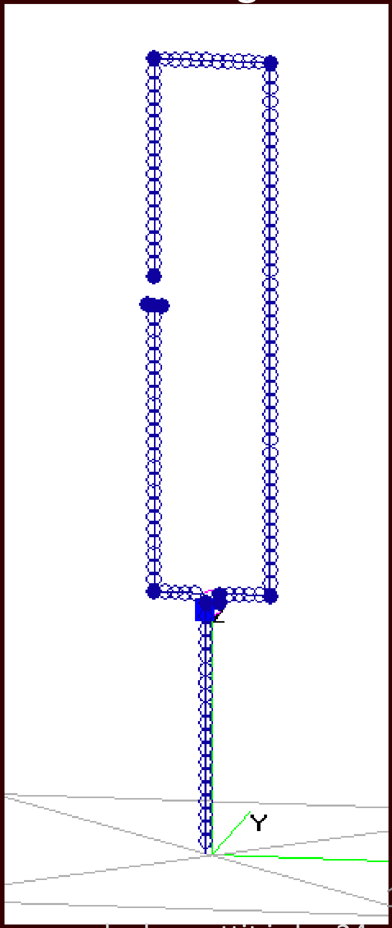
Numerical Electromagnetics Code

Antenna Modeling via Arie Voors' 4NEC2



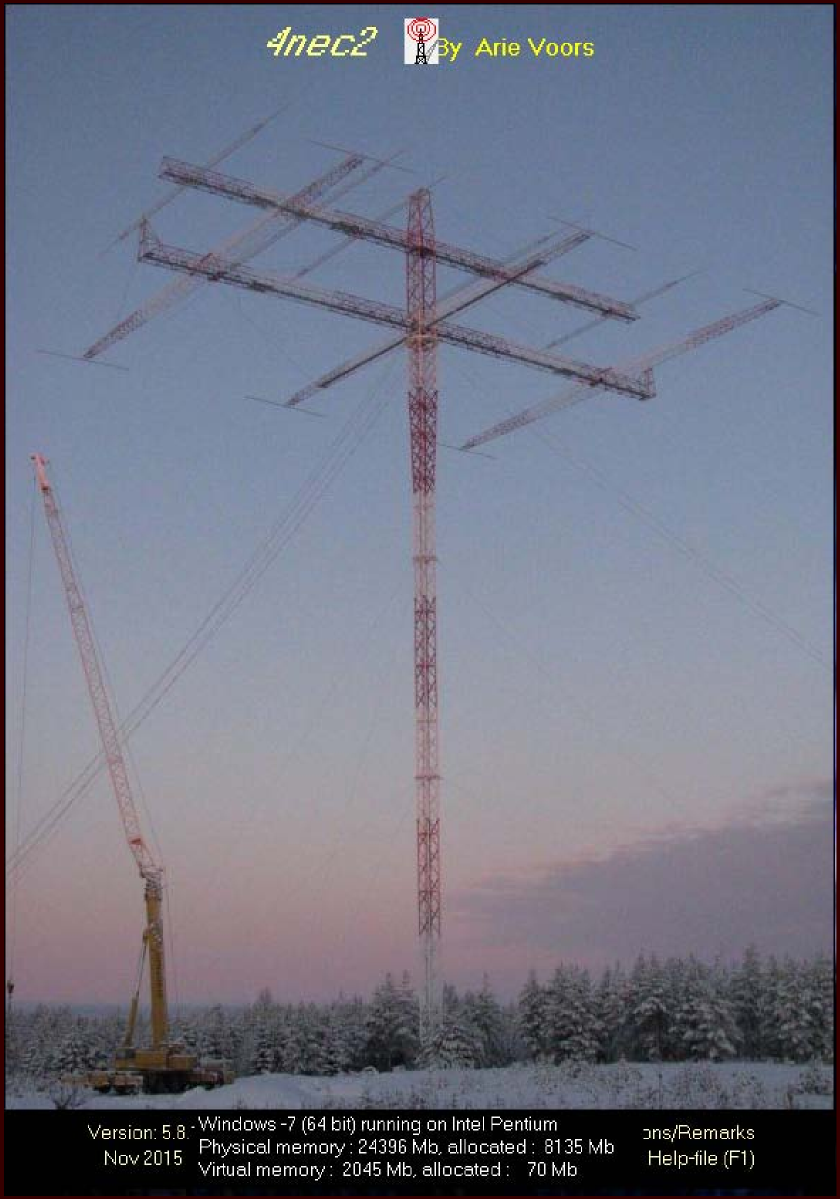
NEC Modeling
performs an antenna analysis by
Finite Element Analysis techniques
which divides wires into a number of
small elements and computes their currents
and resultant electric and magnetic fields





Numerical Electromagnetics Code

Antenna Modeling via Arie Voors' 4NEC2



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performs an antenna analysis by
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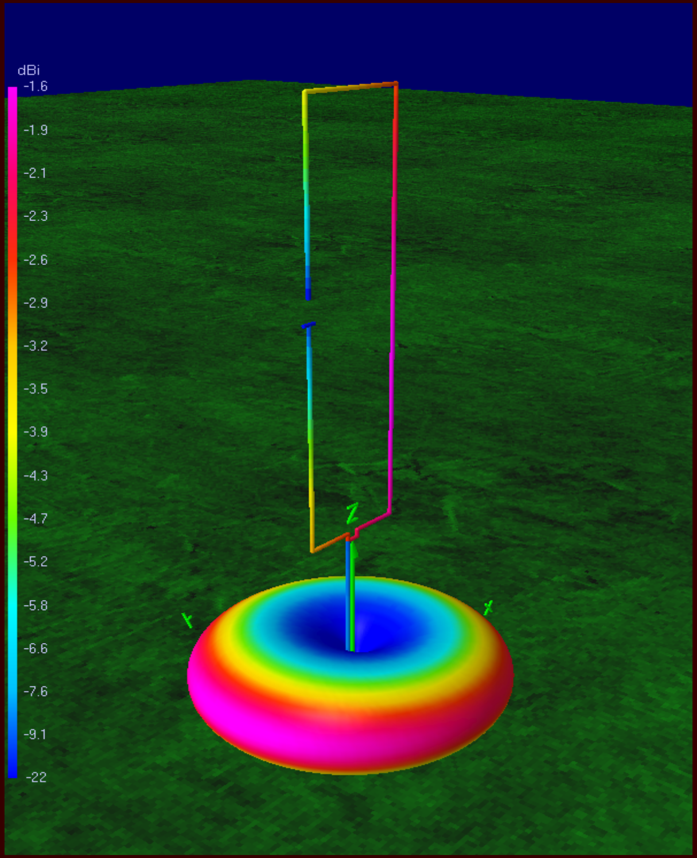
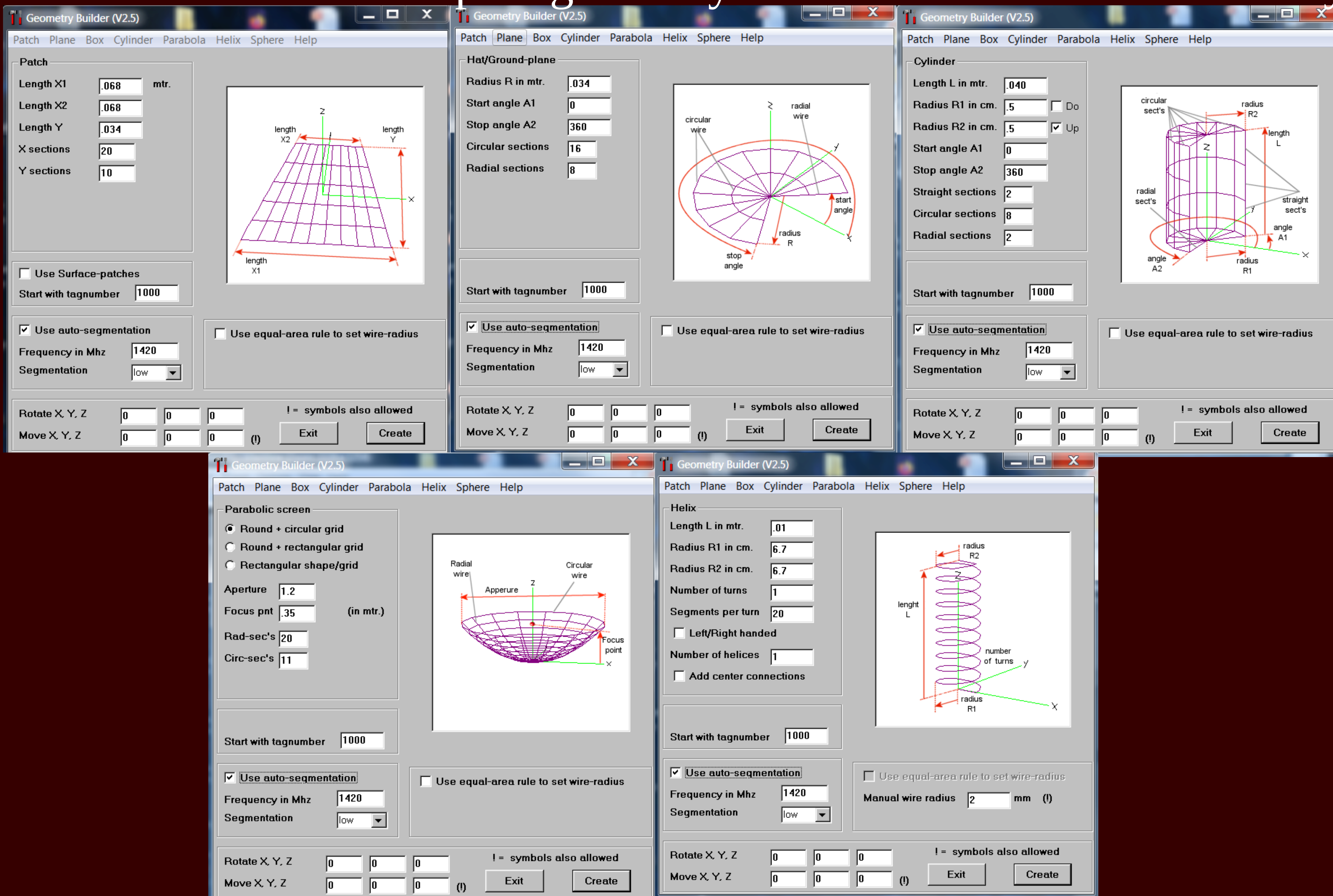


Numerical Electromagnetics Code

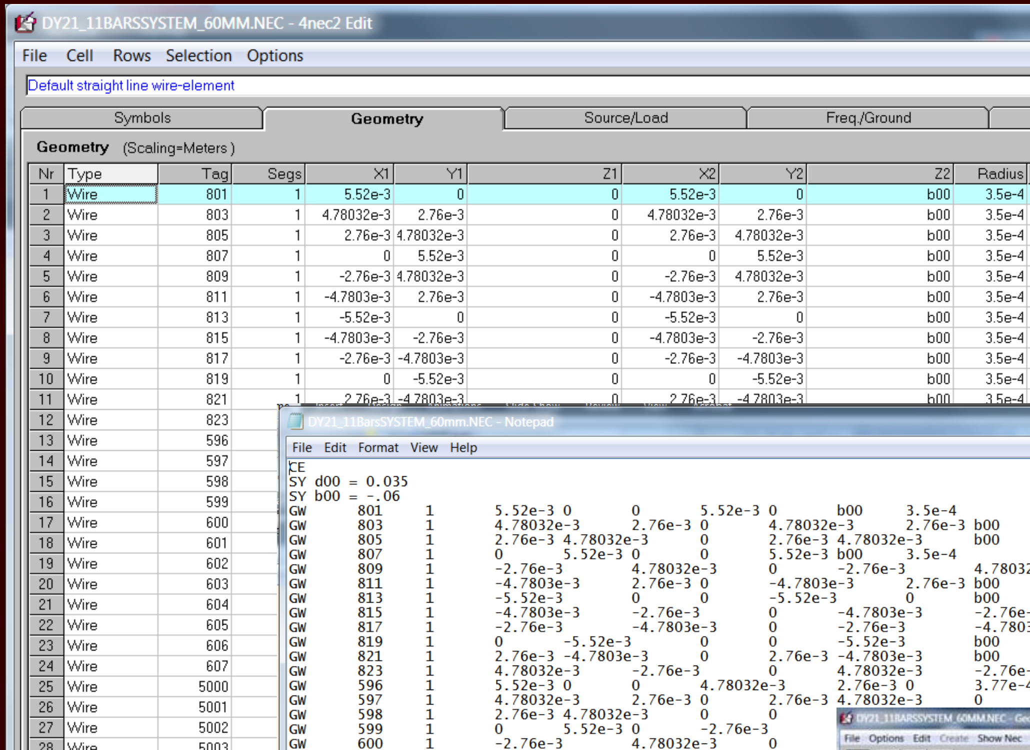
Complex Structure Geometry Builder

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								
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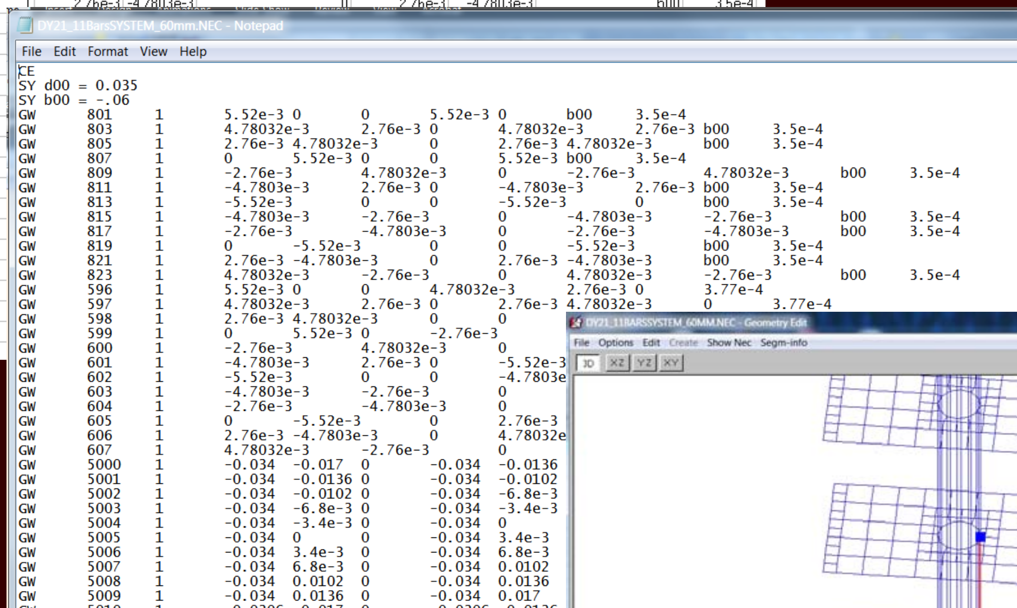
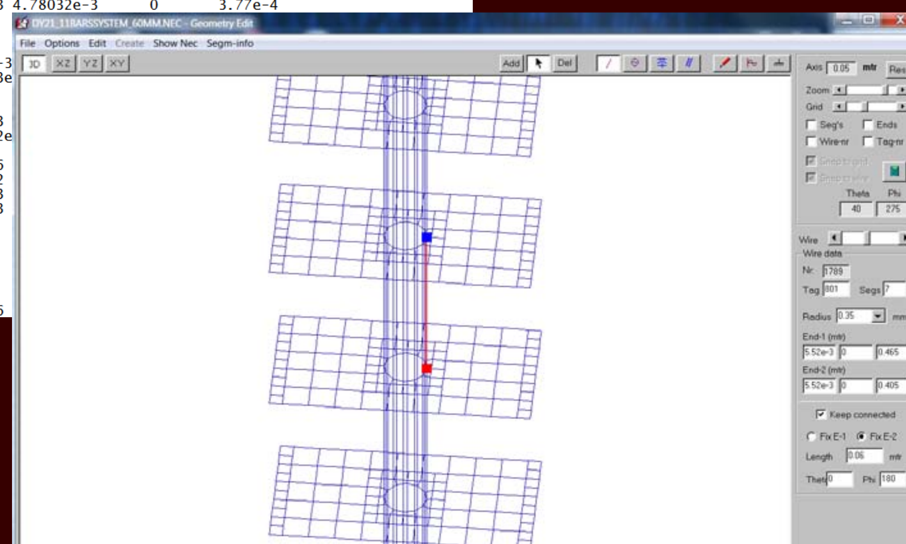
24	Wire	607								
25	Wire	5000								
26	Wire	5001								
27	Wire	5002								
28	Wire	5003								





Simple geometry can be defined in tables

Complex can be combined and modified

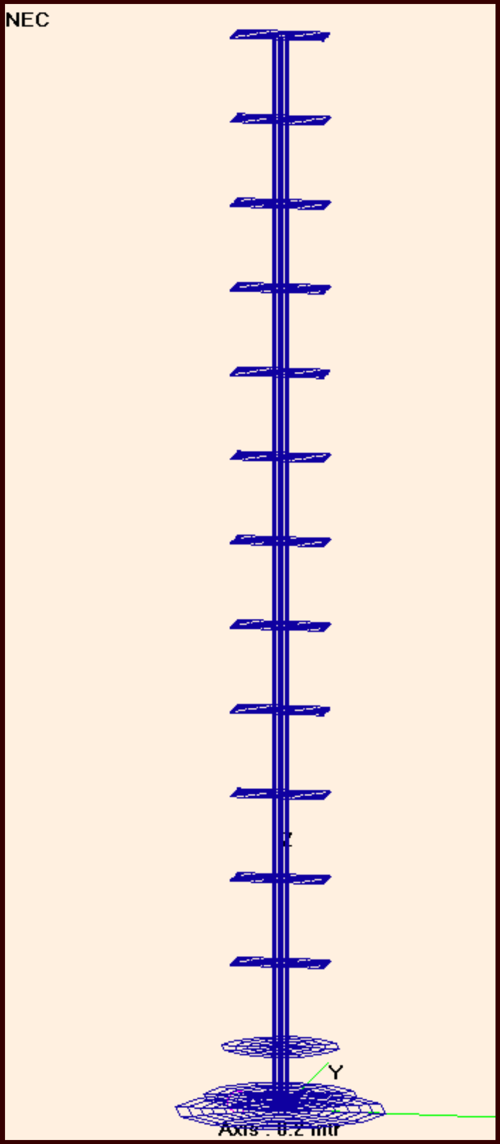
via

NEC Text Editor

MS Notepad Editor

NEC 3D view Editor

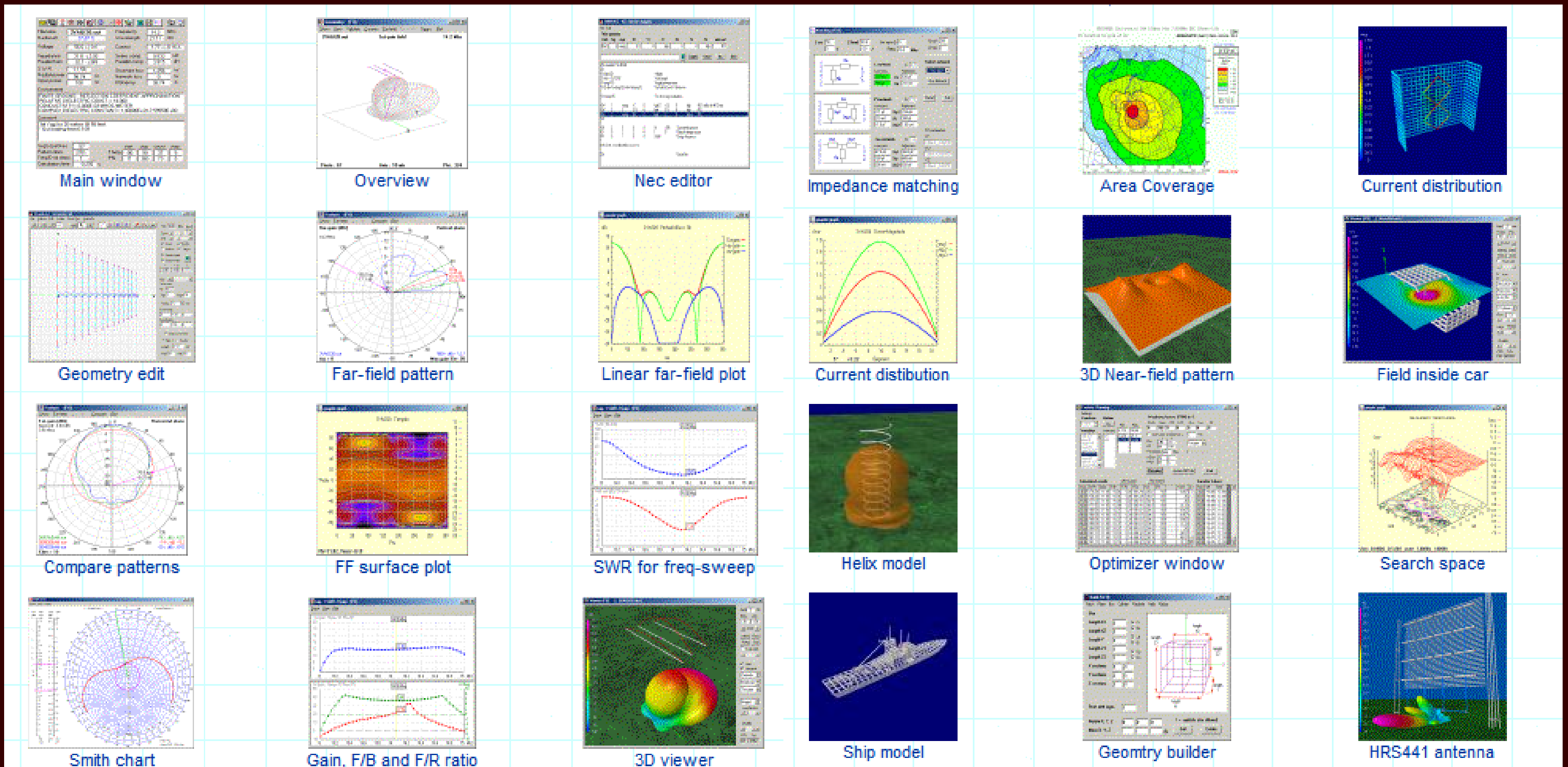
Geometry Entry / Modification Editors



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

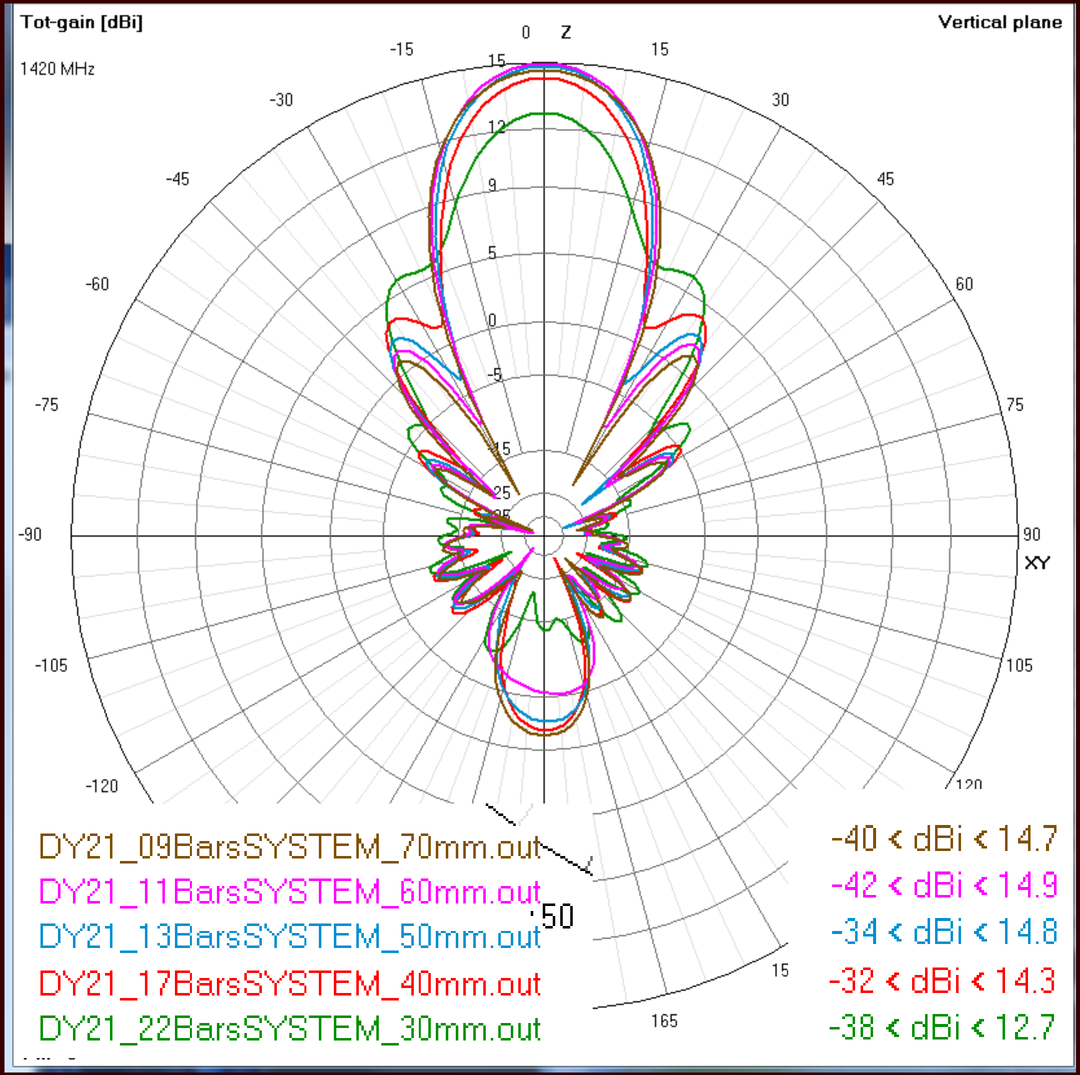
Numerical Electromagnetics Code

Screenshots of 4NEC2 Analysis Capability



Numerical Electromagnetics Code

Beam Pattern vs Director Spacing Study

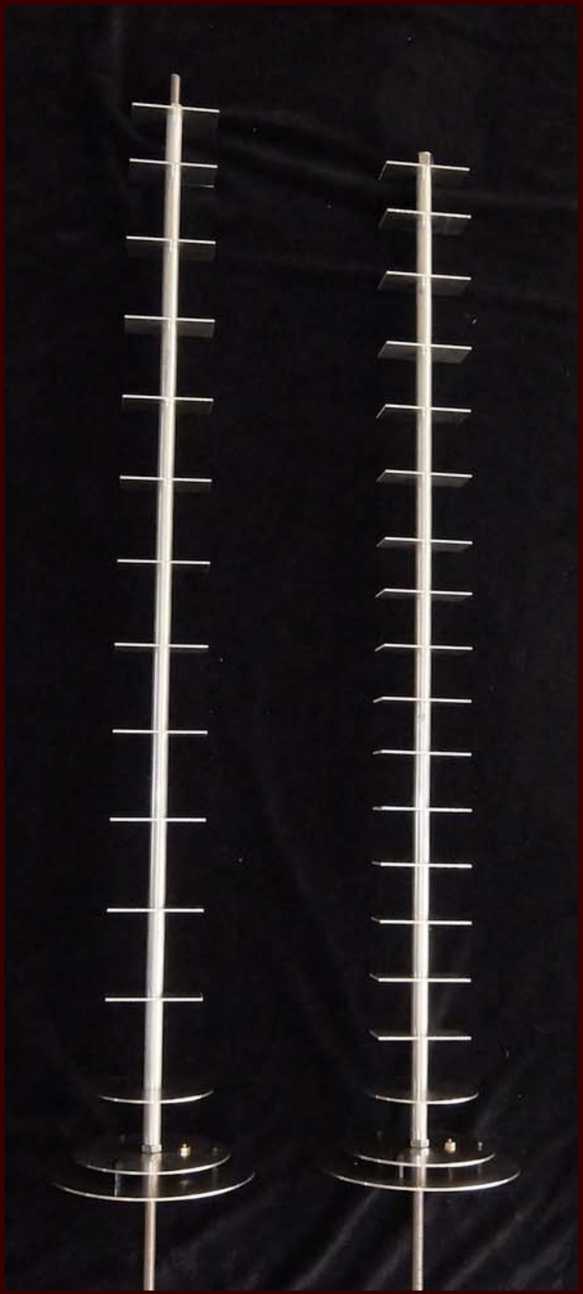


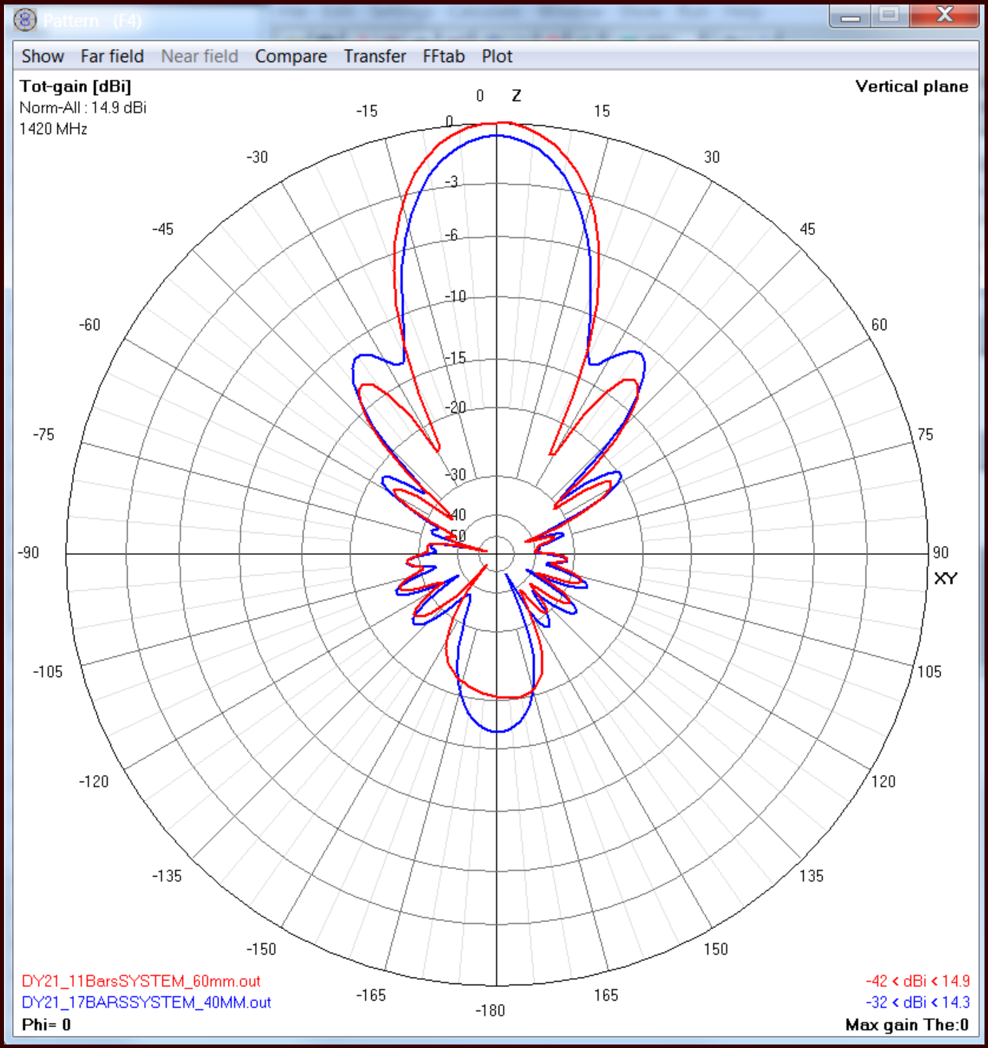
an NEC Study was performed to optimize the Front/Back Gain

60mm Director Spacing was selected

Numerical Electromagnetics Code

40mm vs 60mm Plate Director Spacing Study

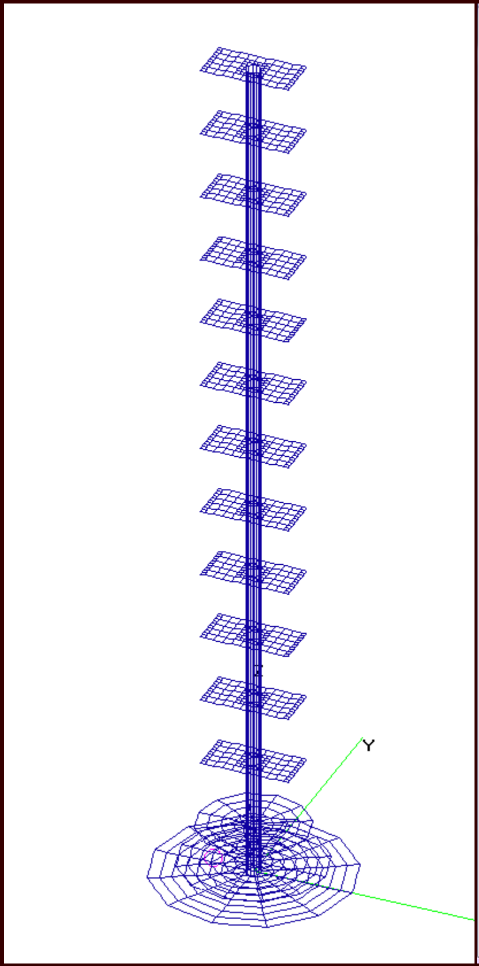


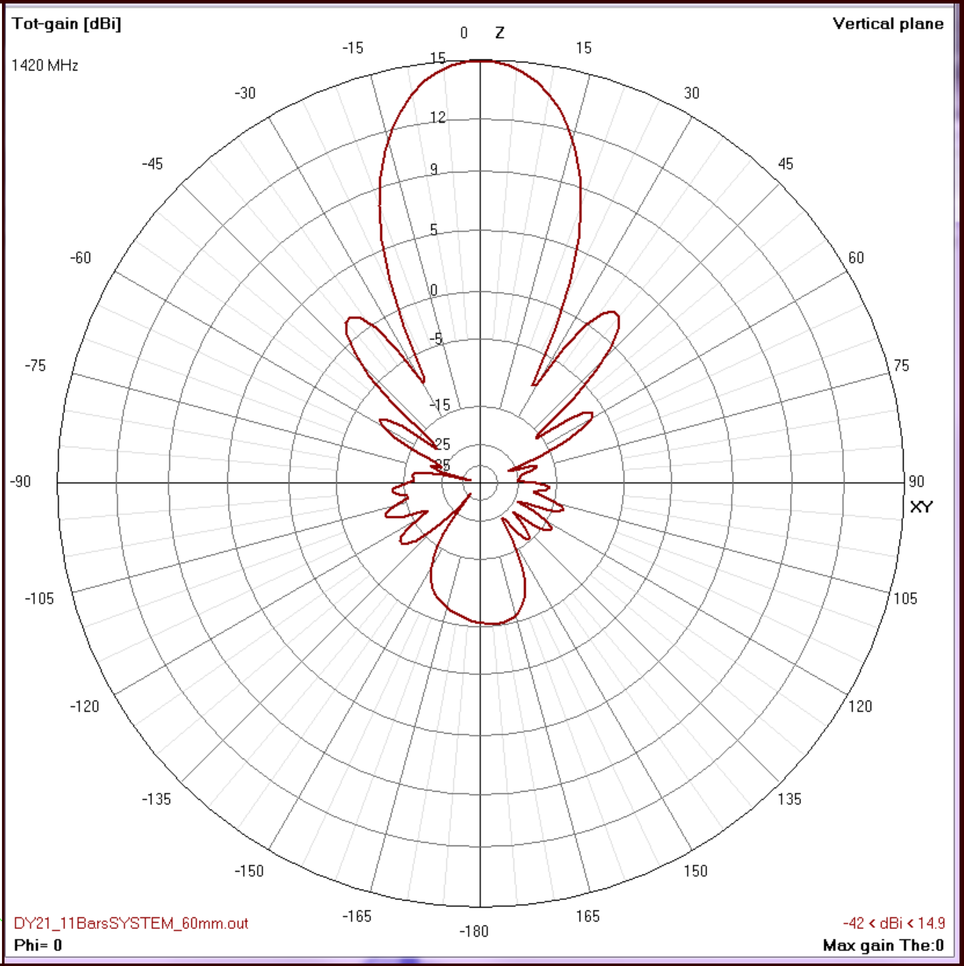


40mm and 60mm Director Spaced Antennas were modeled, fabricated, and tested to verify NEC model results

Numerical Electromagnetics Code

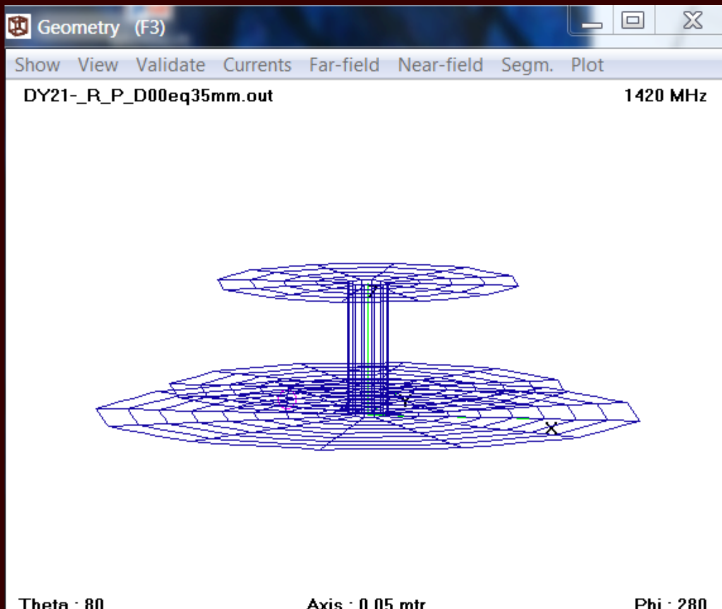
Beam Pattern / Gain Analysis

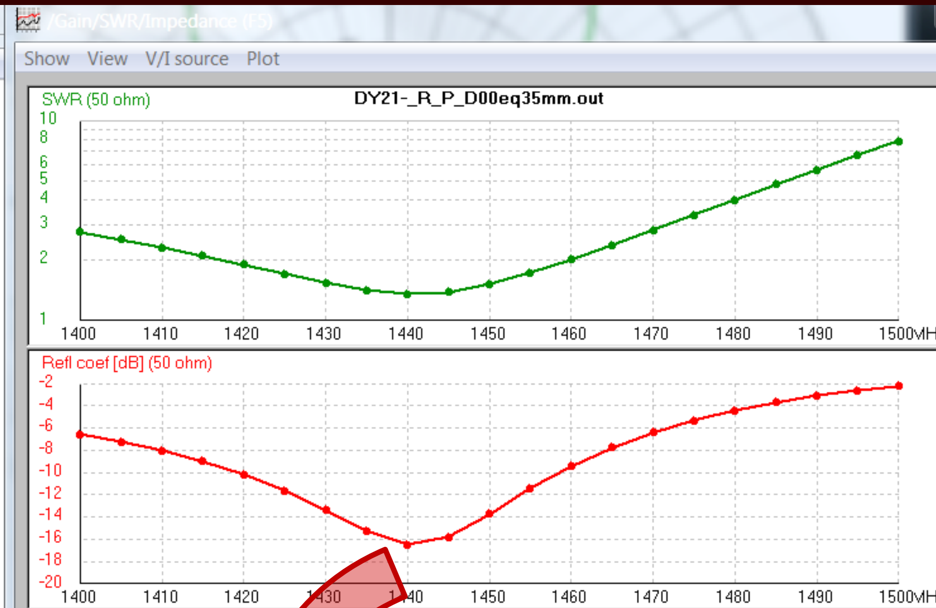




60mm Director Element Spaced Antenna Selected

Numerical Electromagnetics Code   Model Data vs VNA Analysis





Virtually IDENTICAL Results

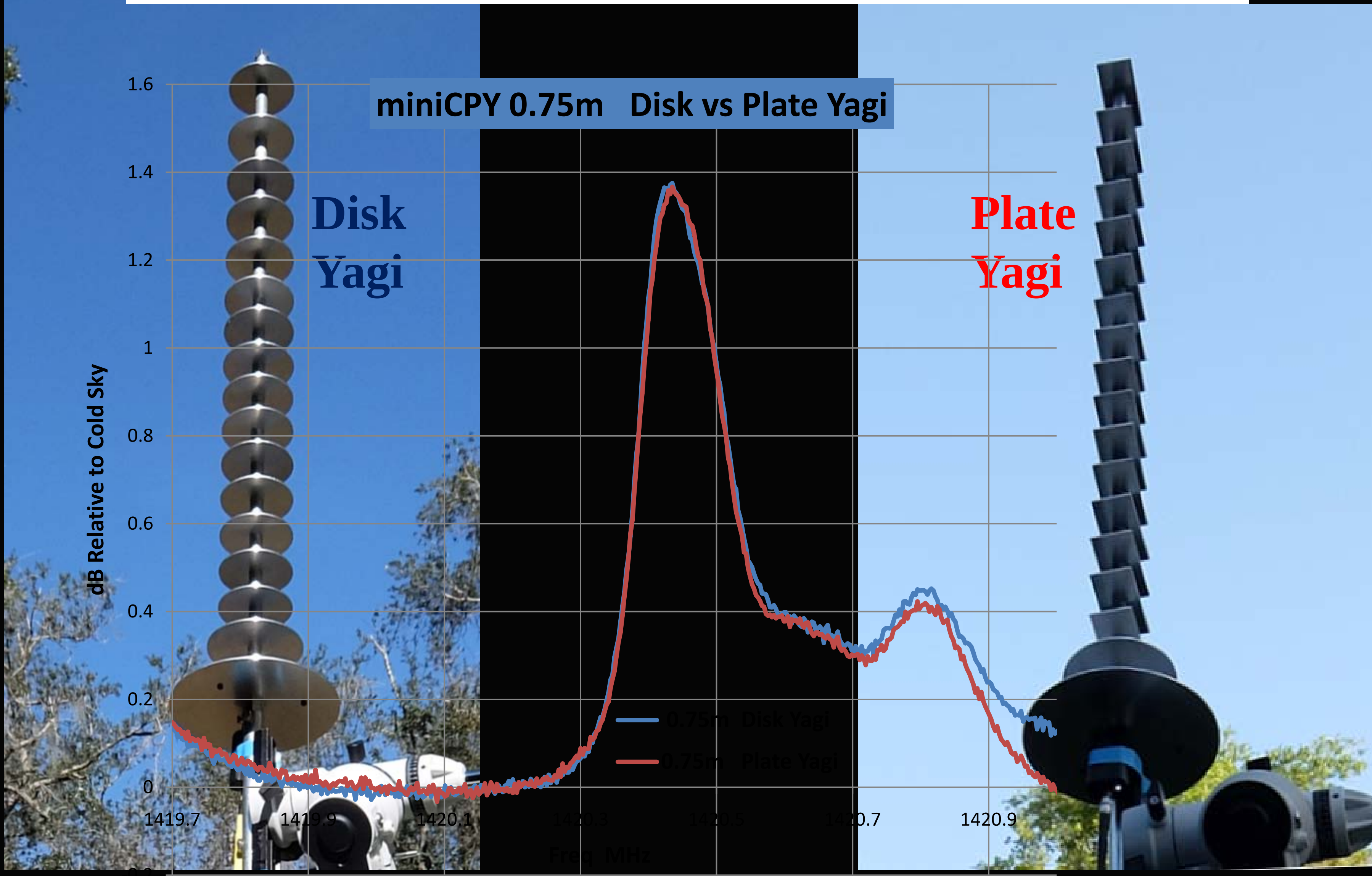
Field Tests

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

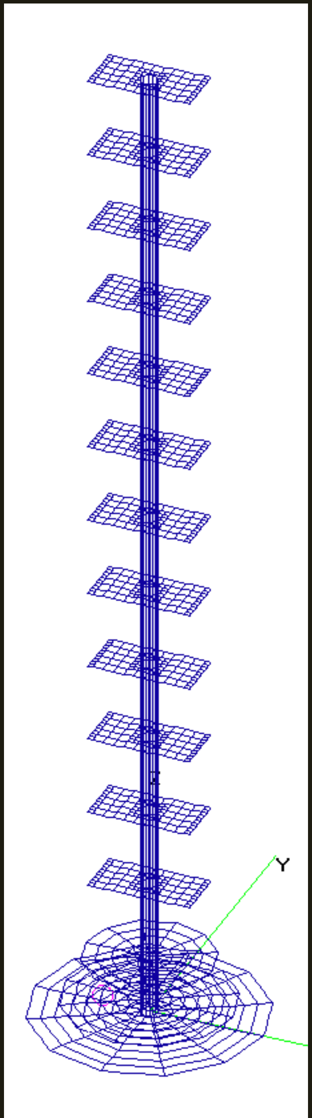
2) characterize the antenna's relative S/N by measuring the Hydrogen Spectra Peak at a reference point
(declination + 40 dg right_assension 20:30 hrs)
vs
background 'Cold_Sky' signal level

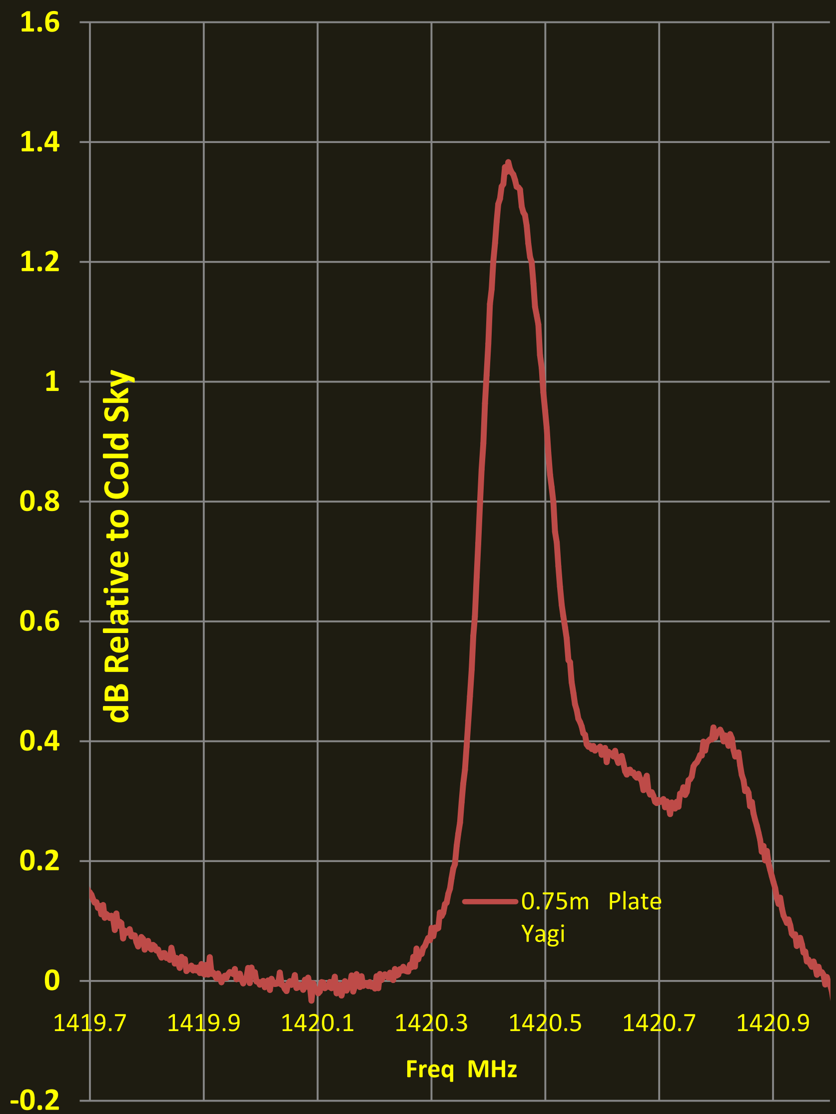
0.75m Disk and Plate Yagi H-Line Data Milky Way Cygnus Region



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





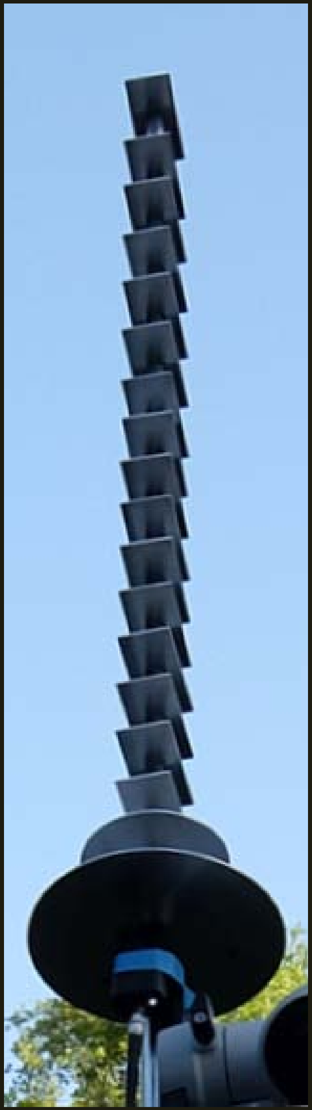
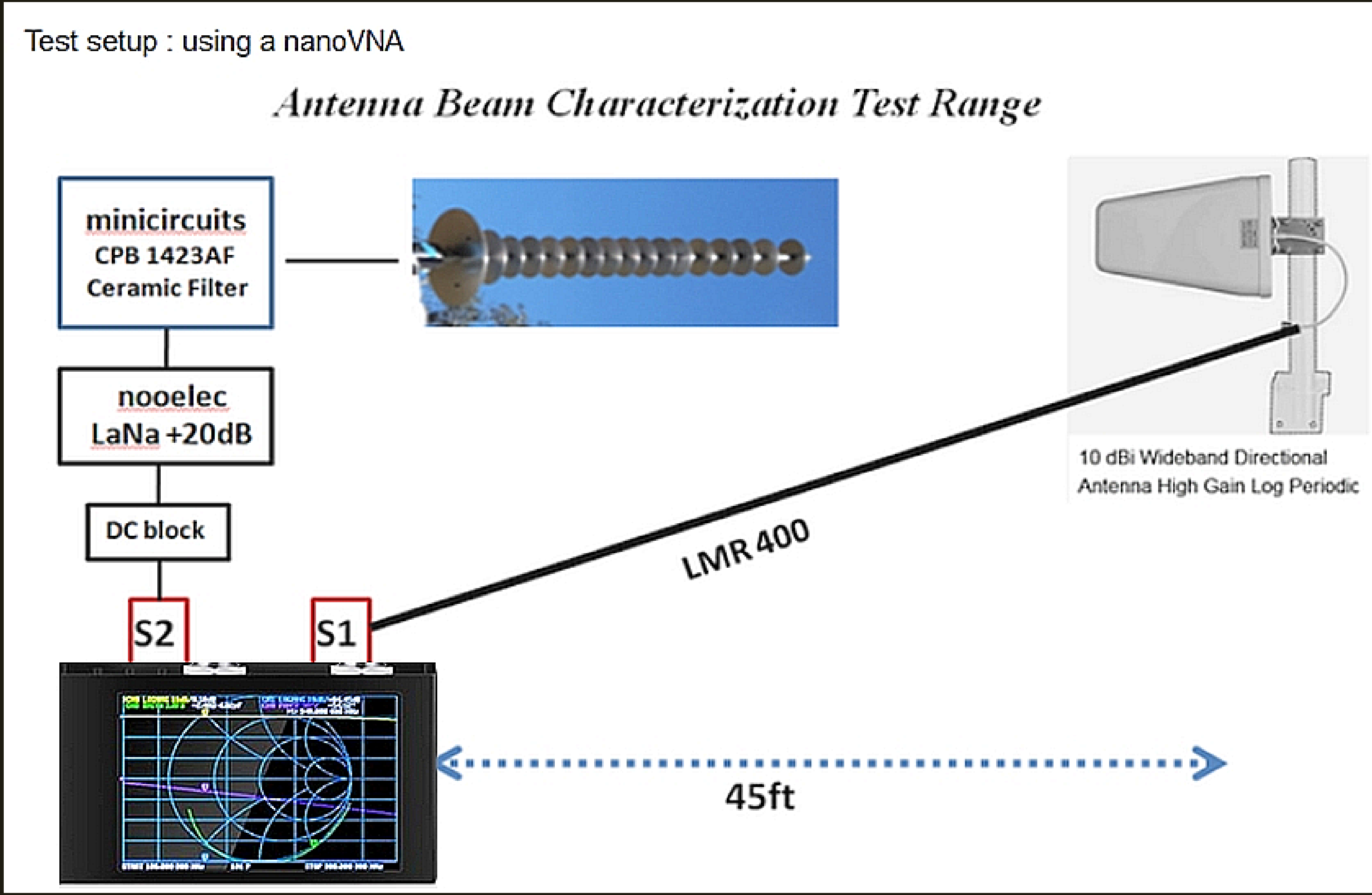


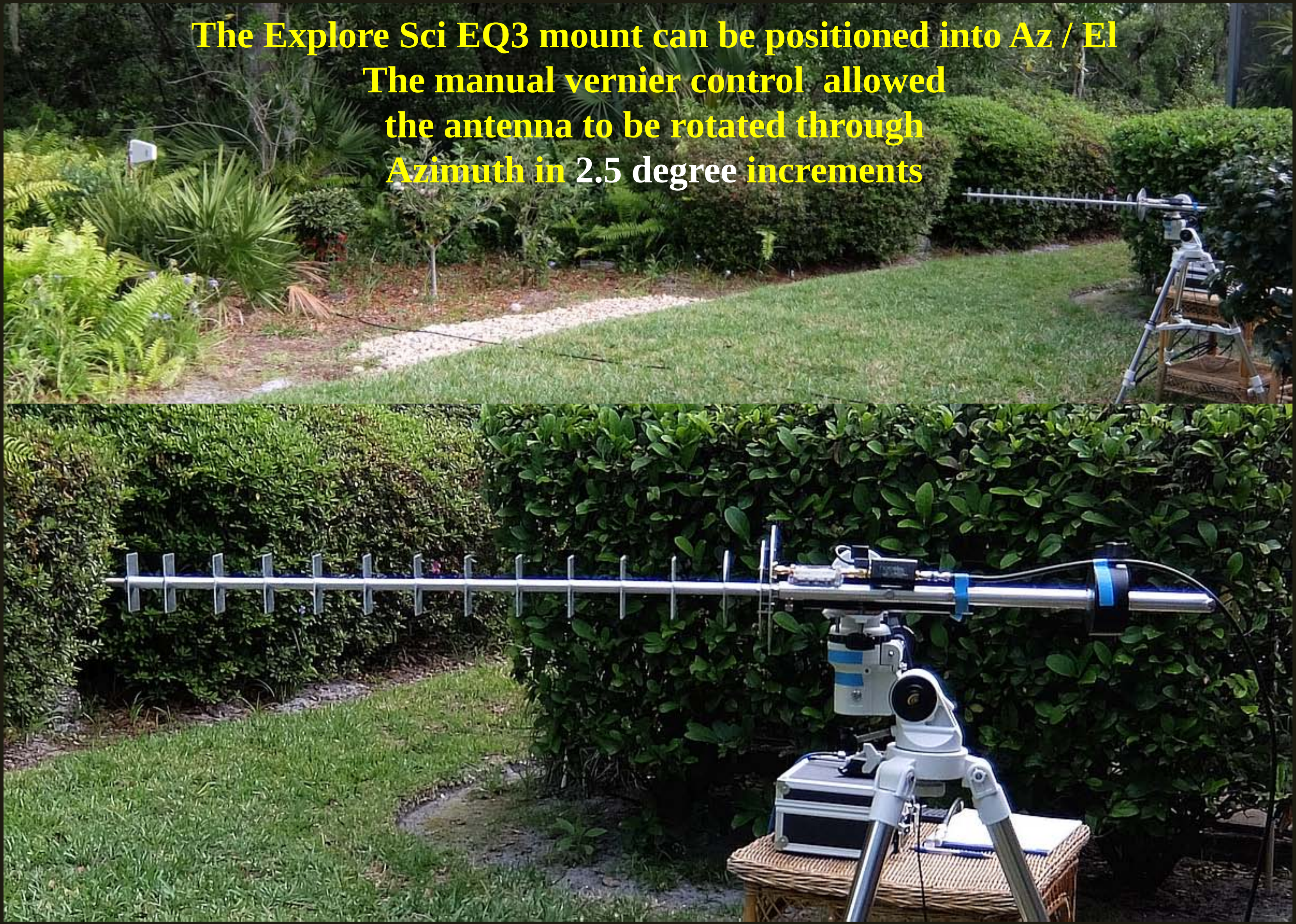
Plate Director Antenna NEC model and Fabricated Antenna

Antenna Beam Pattern Characterization Tests

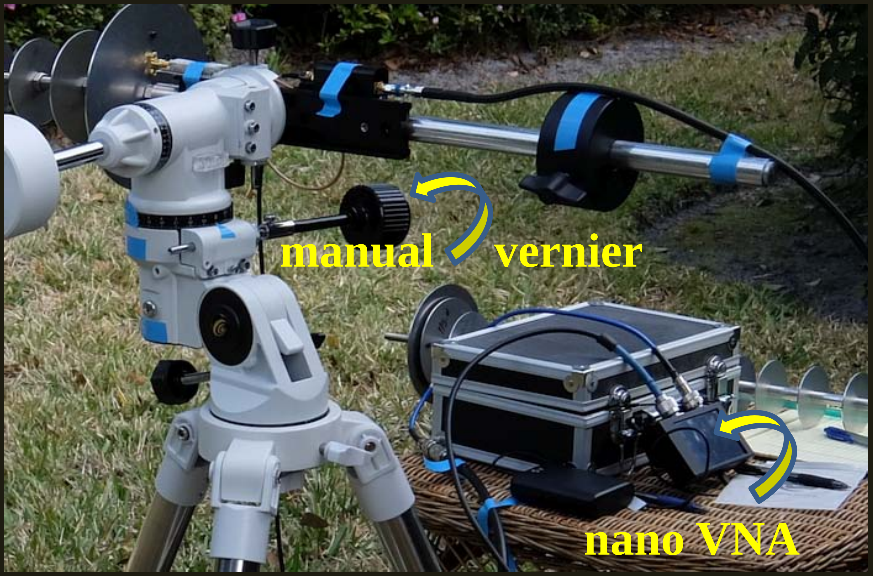


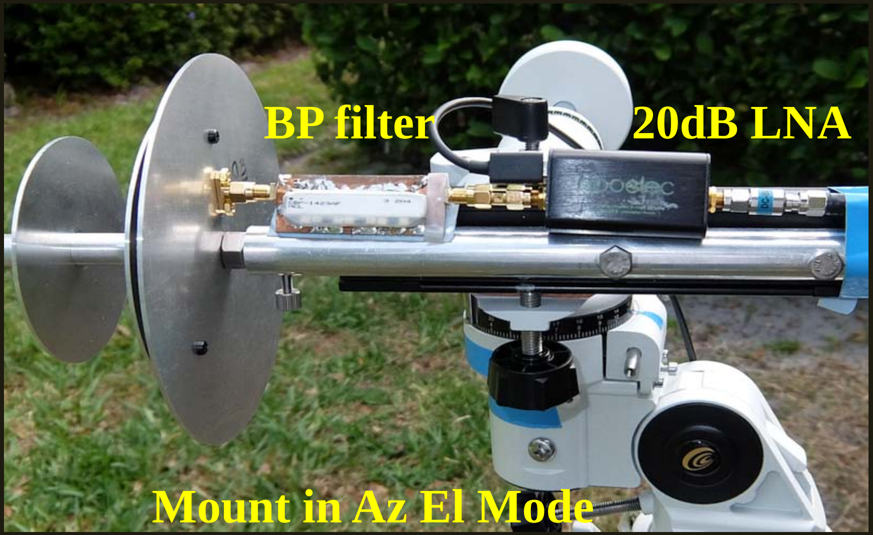
A Test Range was designed based on a nanoVNA to characterize the antenna's BEAM PATTERN

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

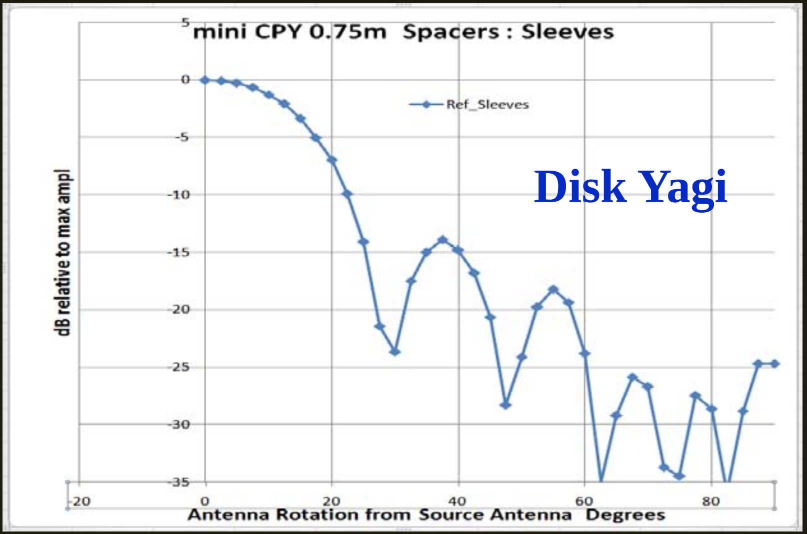


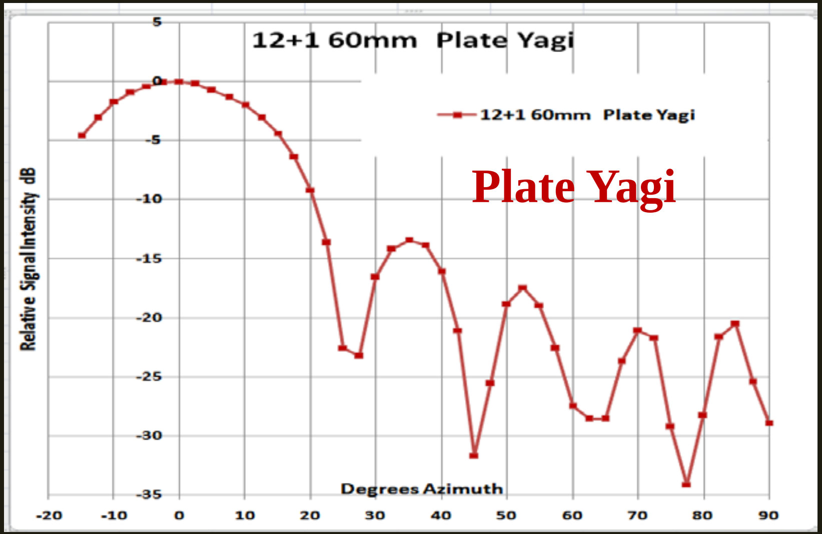
Circ Patch Feed Plate Yagi **Beam Pattern Field Testing Setup**

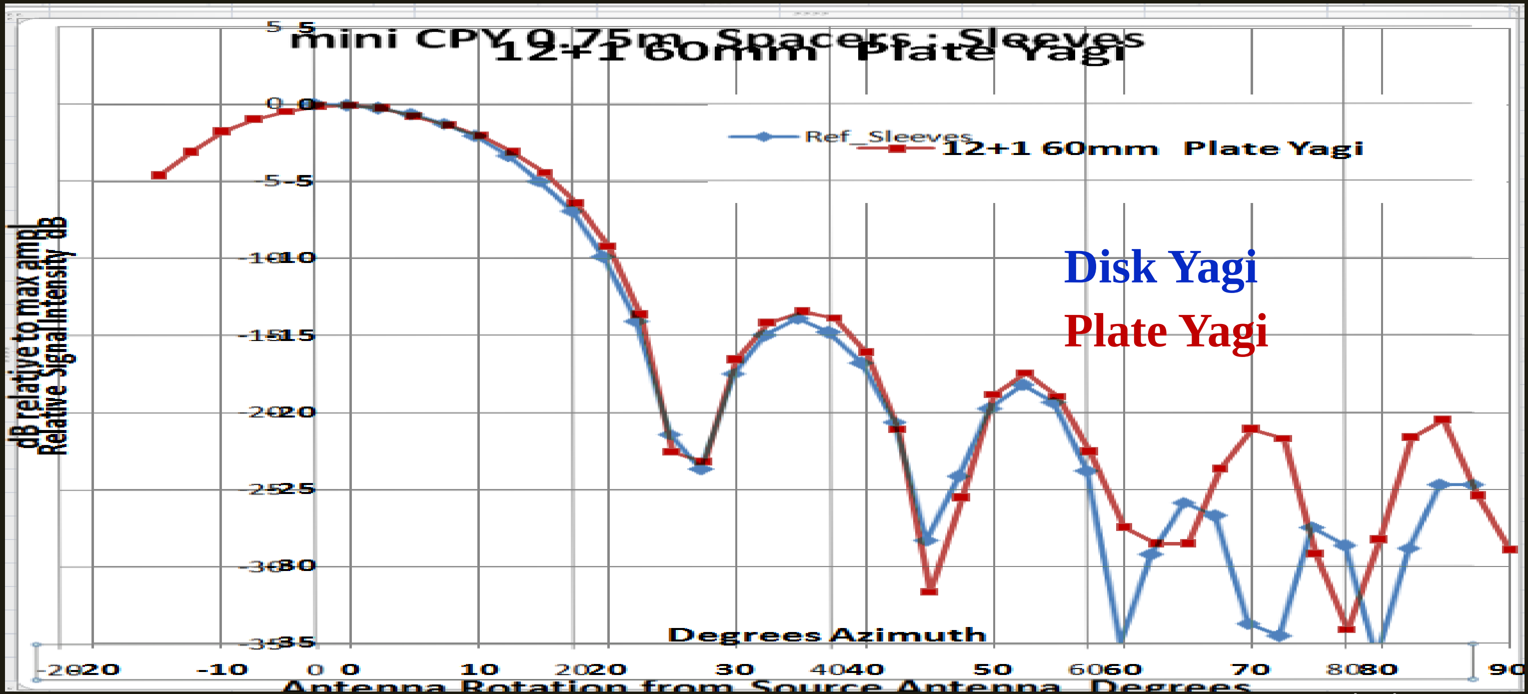




Antenna Beam Pattern Field Characterization Tests

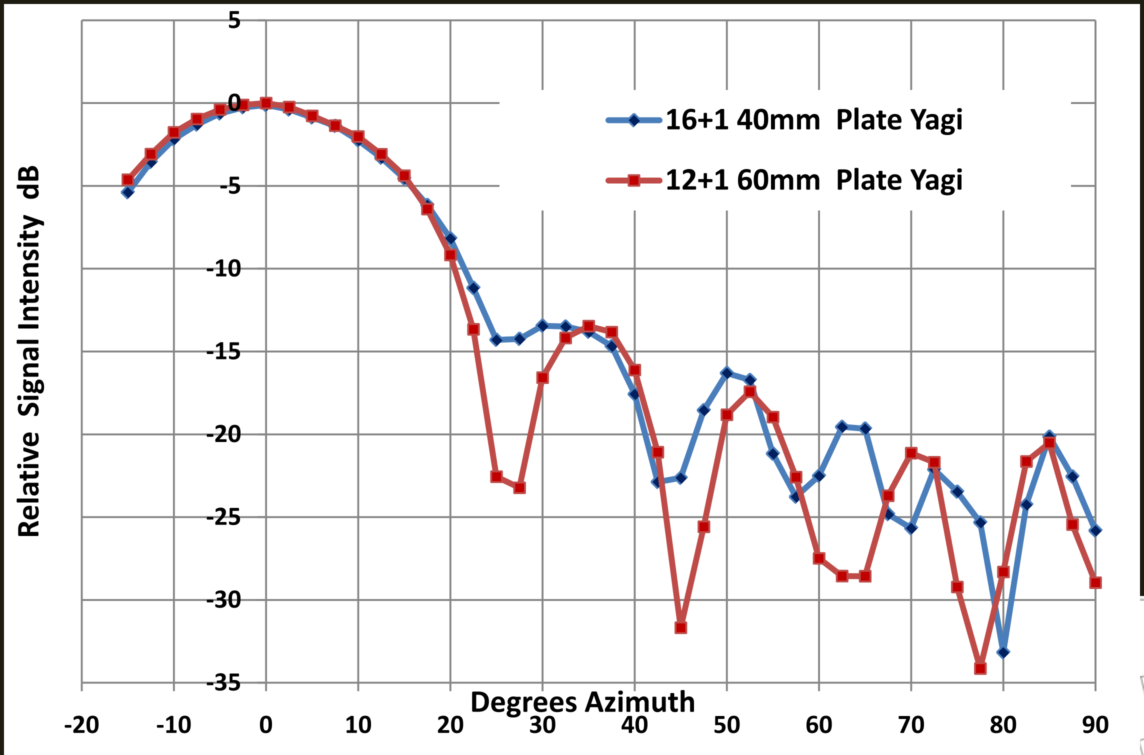


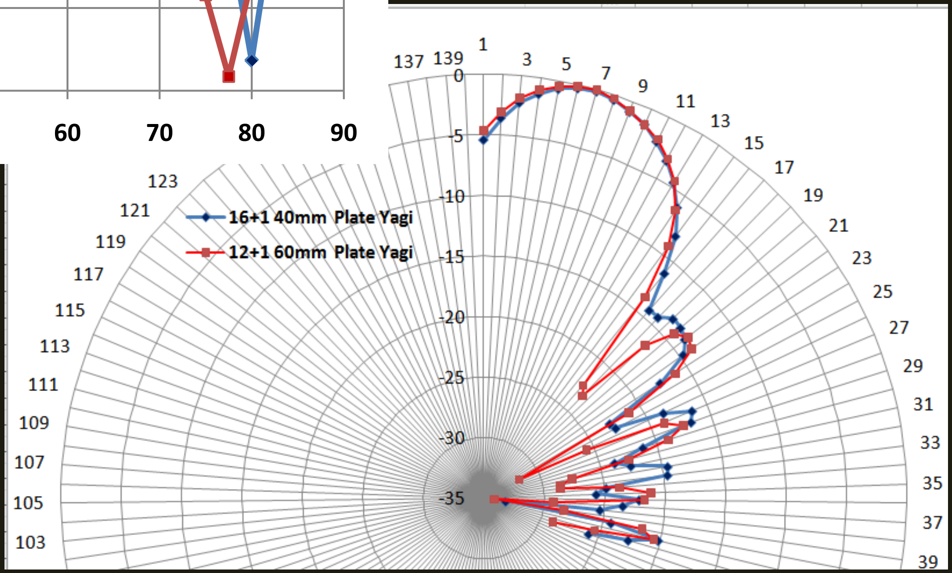




Circ Patch Feed Plate Yagi **Beam Pattern Field Test Data Results**

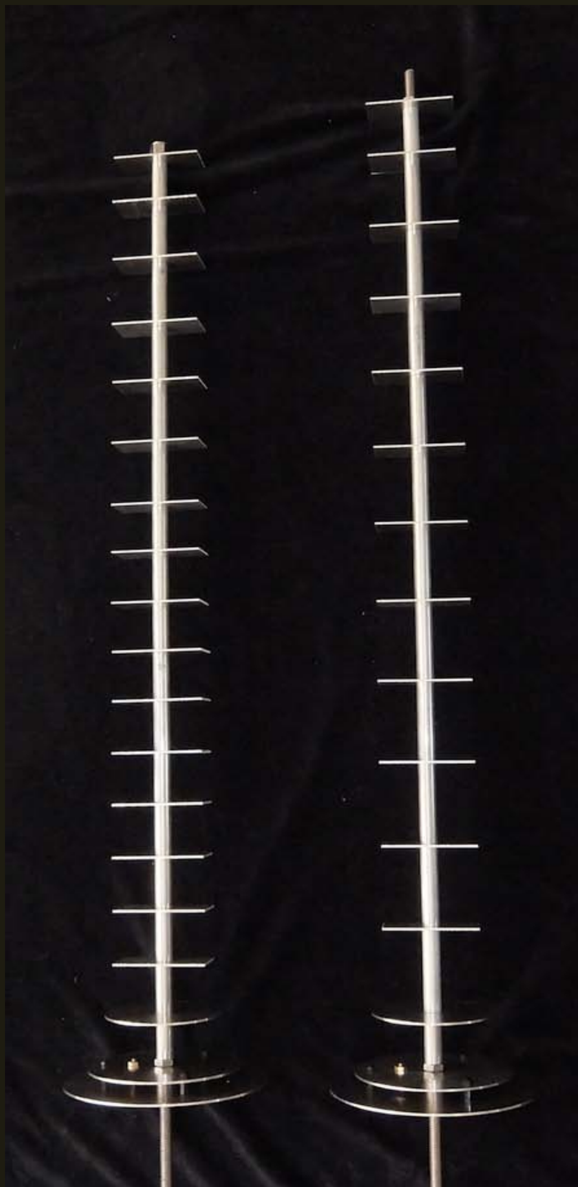
0.75m long Yagi w/ 40mm vs 60mm Director Spacing Comparison



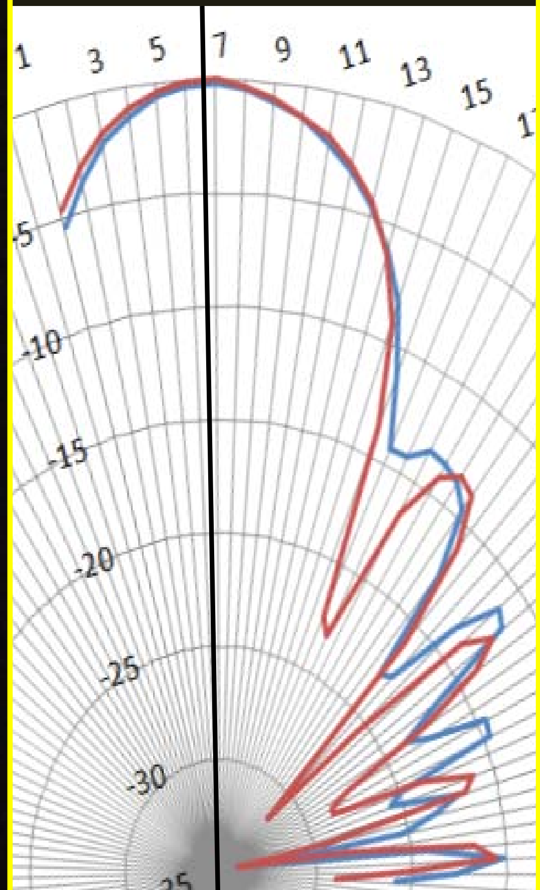


Cir Patch Feed Plate Yagi   0.75m long

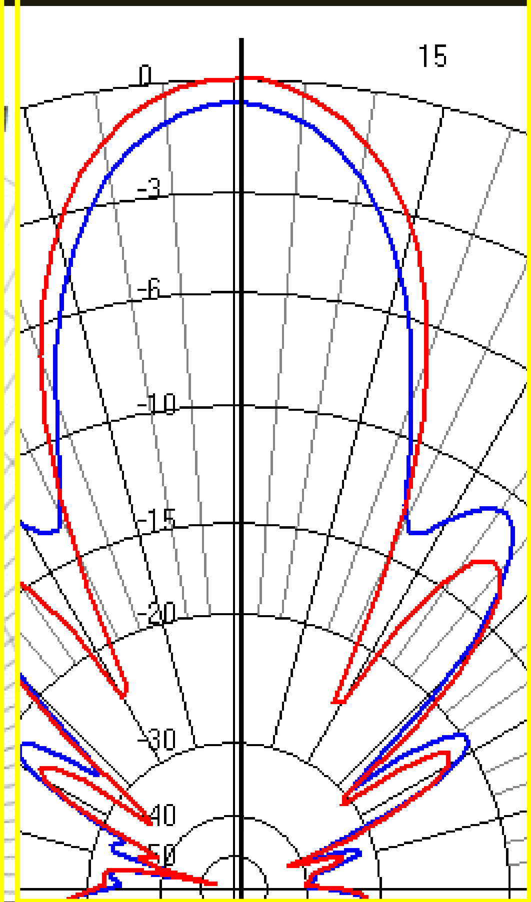
Beam Pattern Field Testing   vs   Numerical Electromagnetics Code



Field Test Data



NEC Analysis



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 ^{o}

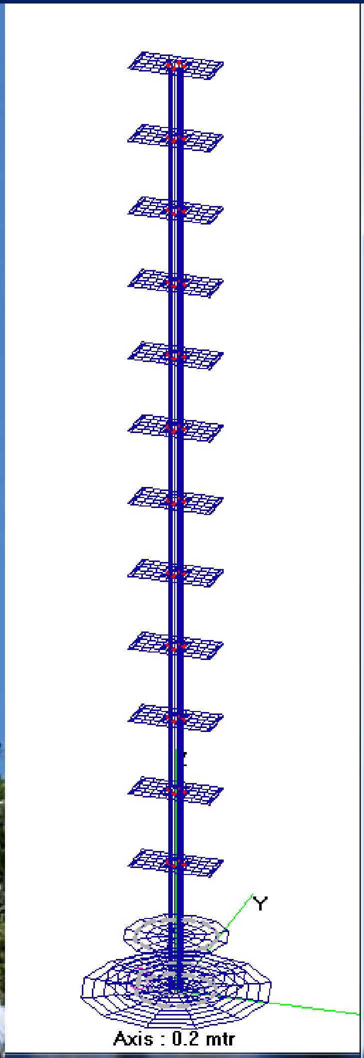
Max Signal to Cold Sky

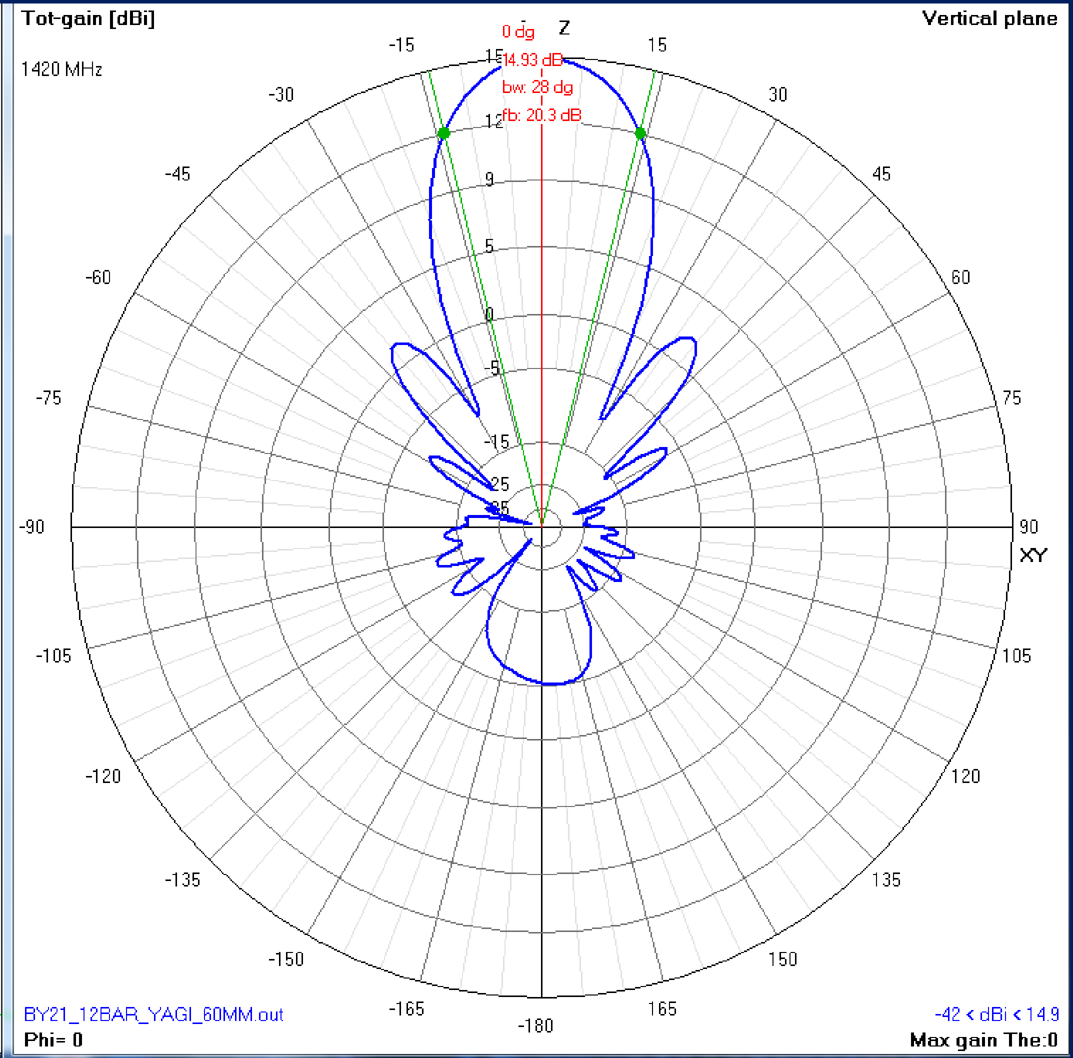
@ Declination + 40 ^{o} RA 20:30 Hrs Cygnus :

+1.35 dB *(using nooelec SAWbird H1 LNA)*

Performance Specifications :

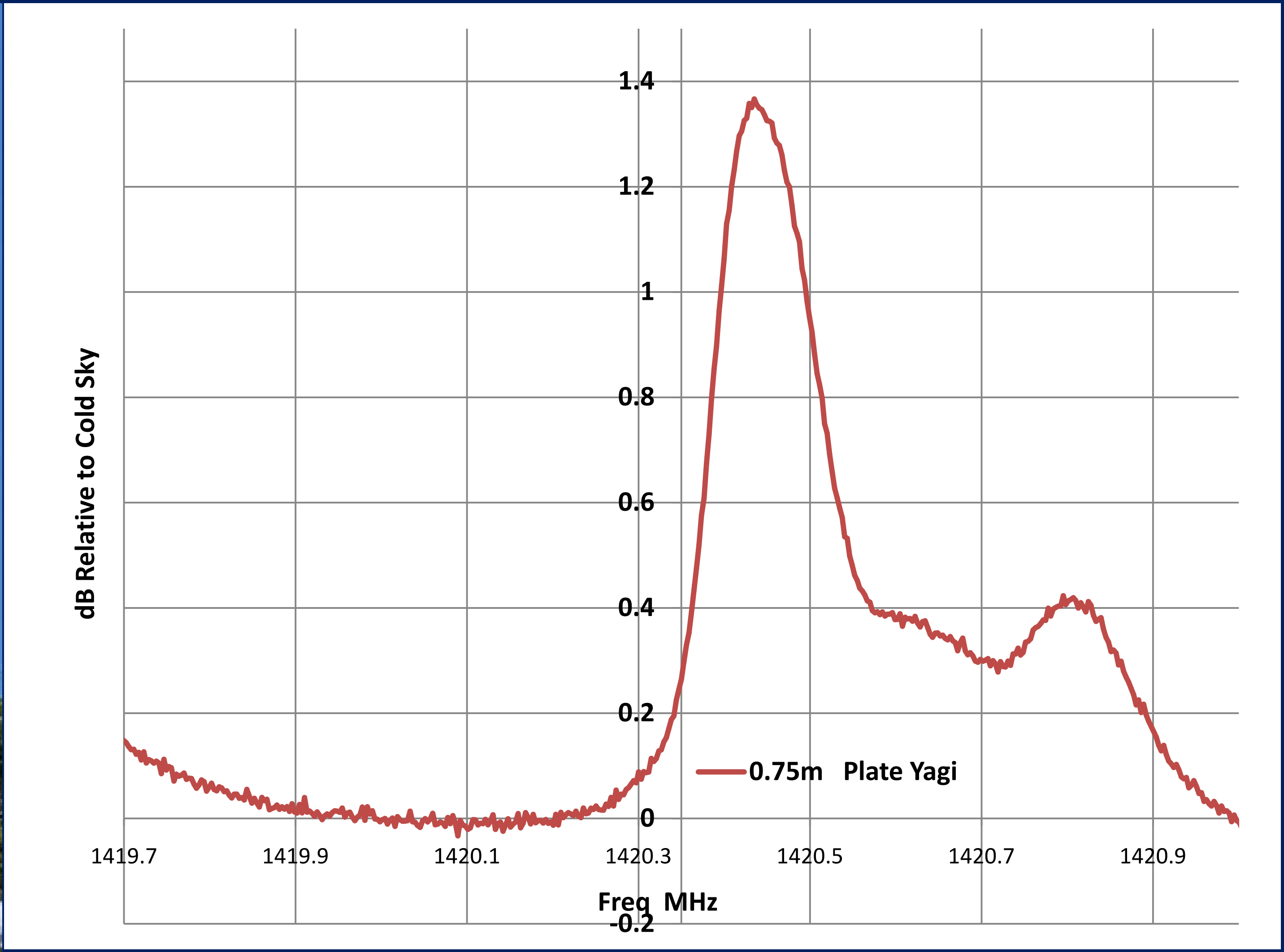
Fwd Gain : +14.9 dB Front-Back Ratio: 56.9 dB ½ Power Beam_width : 28 º





Performance Specifications :

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



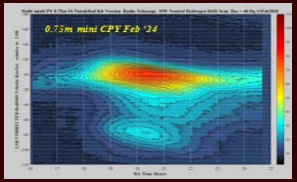
b alex pettit jr Jun24

Results

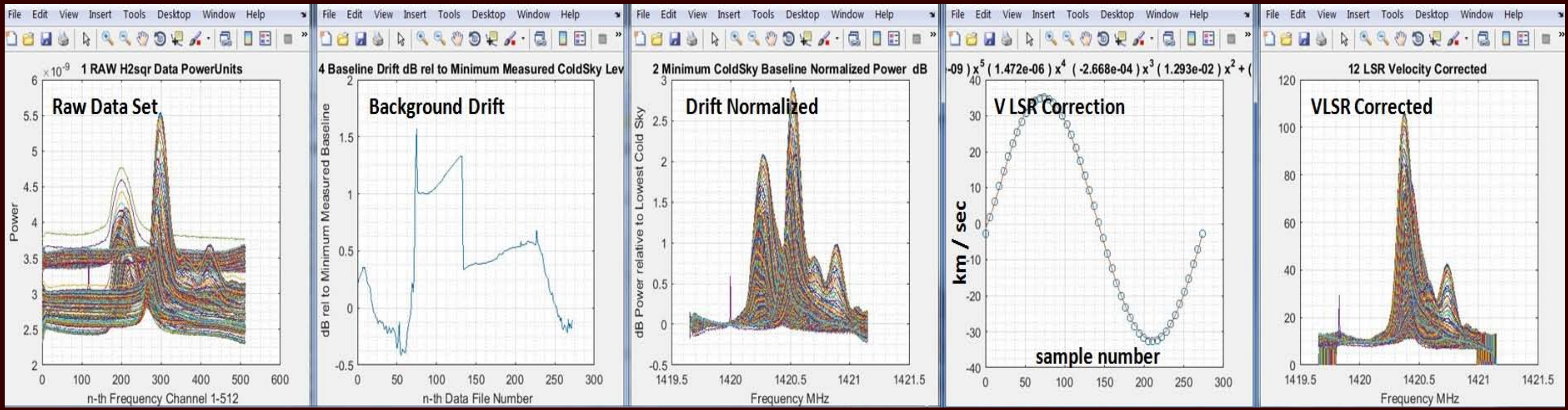
Data was acquired using AirSpy SDR# Studio and D.Kaminski IF_Average

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



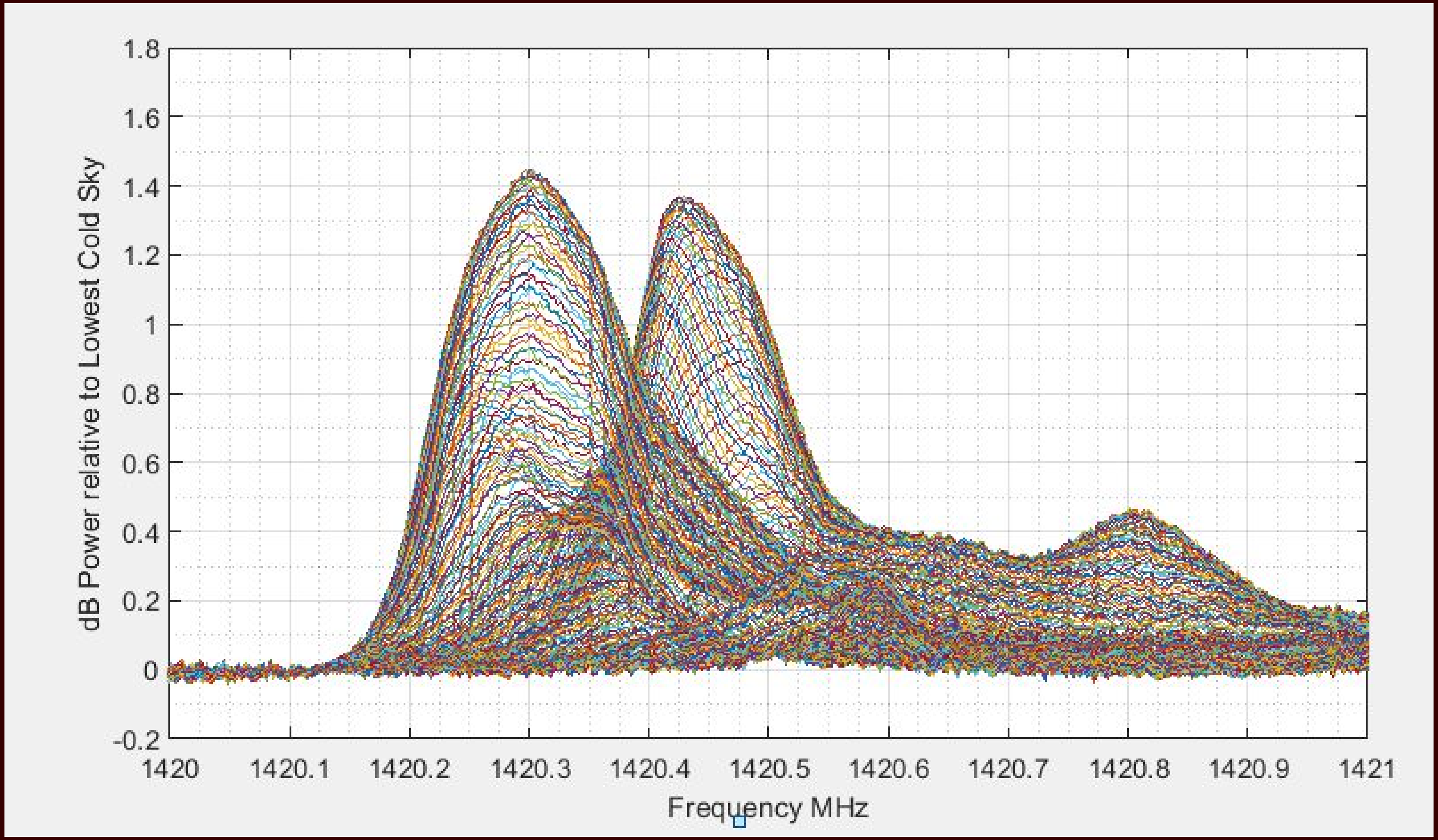
Matlab pre-processing removed drift from electrical / environmental changes and corrected for Earth's Rotational and Orbital Velocity (VLSR correction)



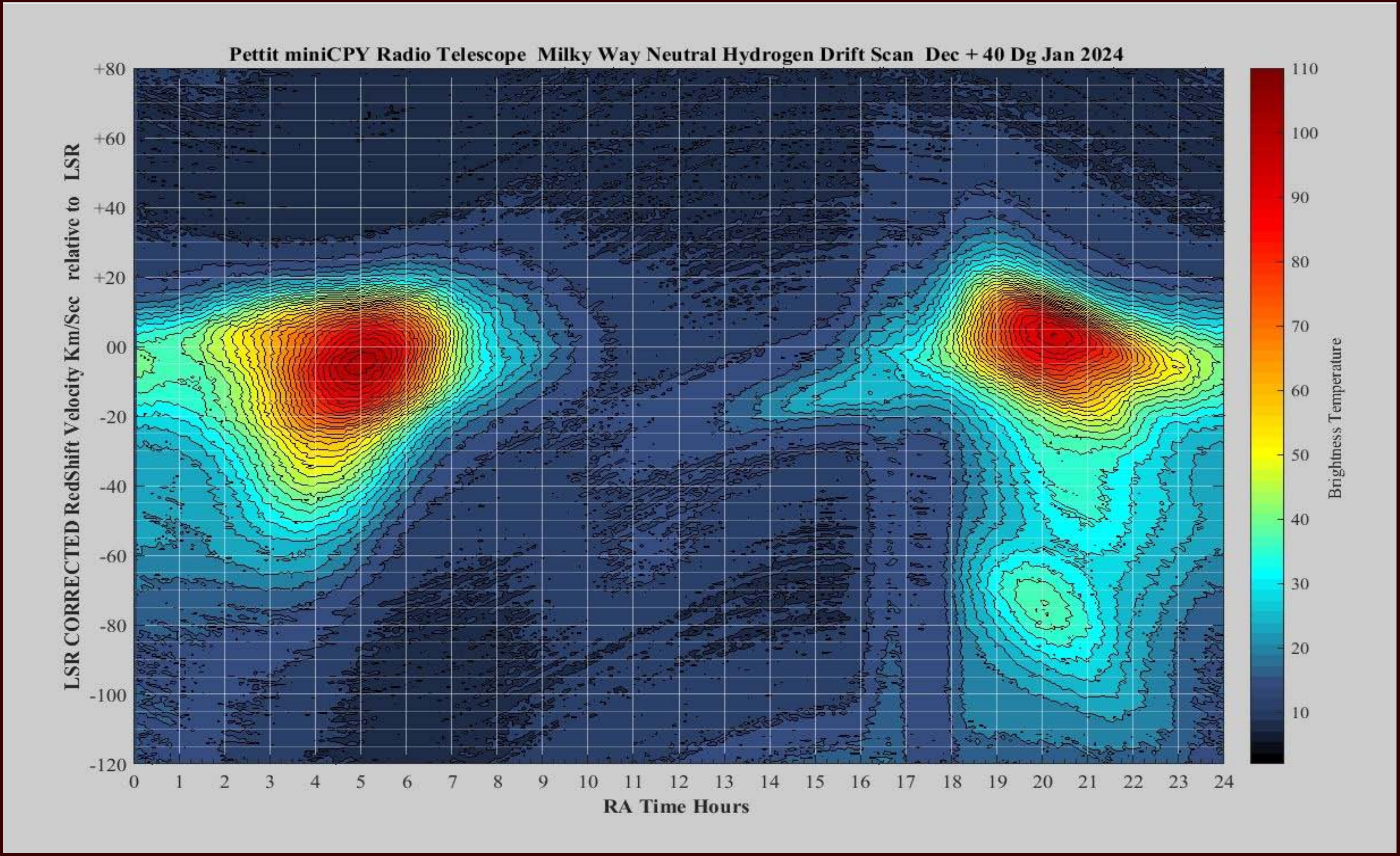
0.75m mini 13 disk CPY

AirSpy SDR# Studio and D.Kaminski IF_Average

Declination +40dg
24 hour drift scan spectrum set



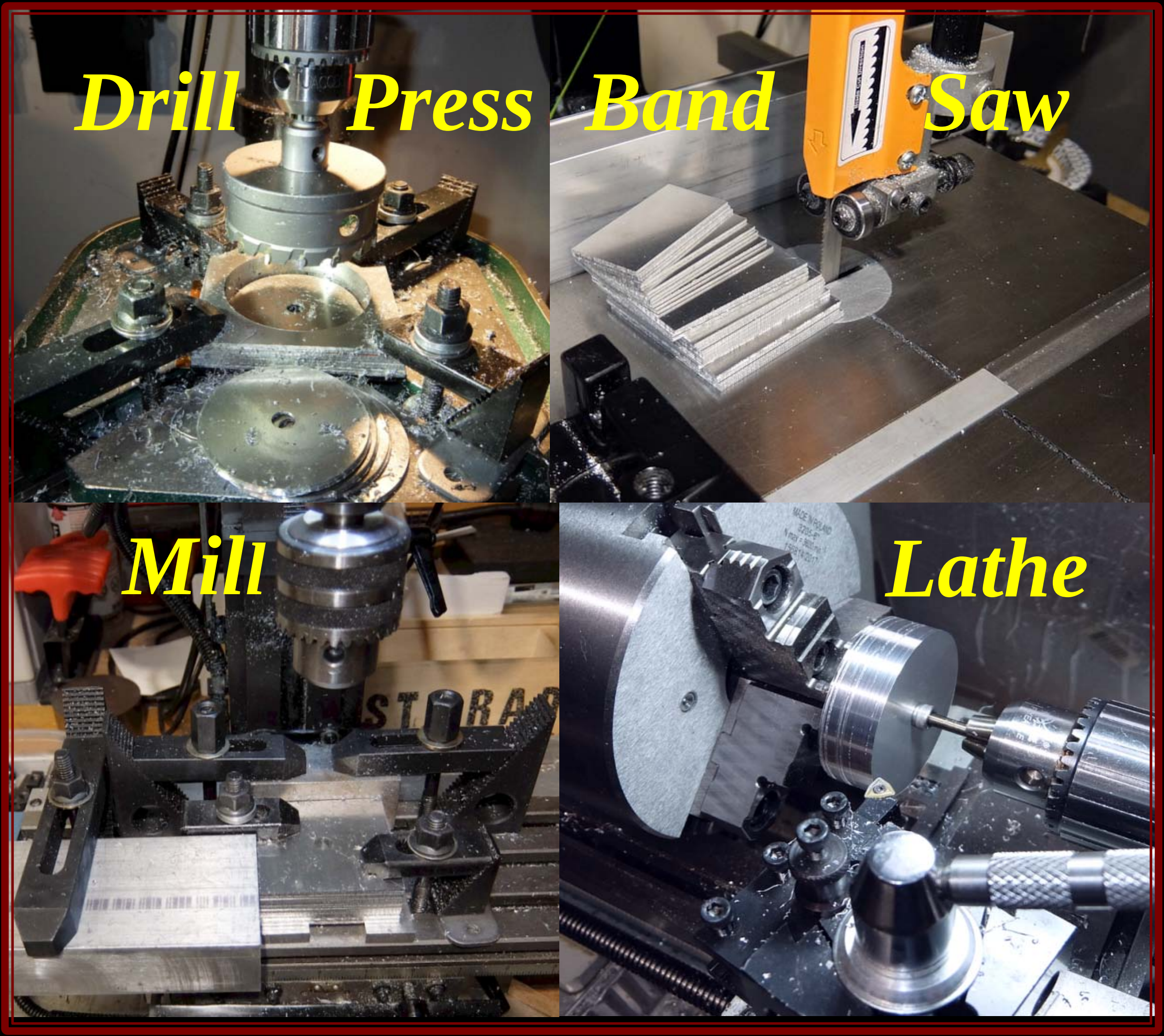
Declination +40dg
24 hour drift scan Contour Plot



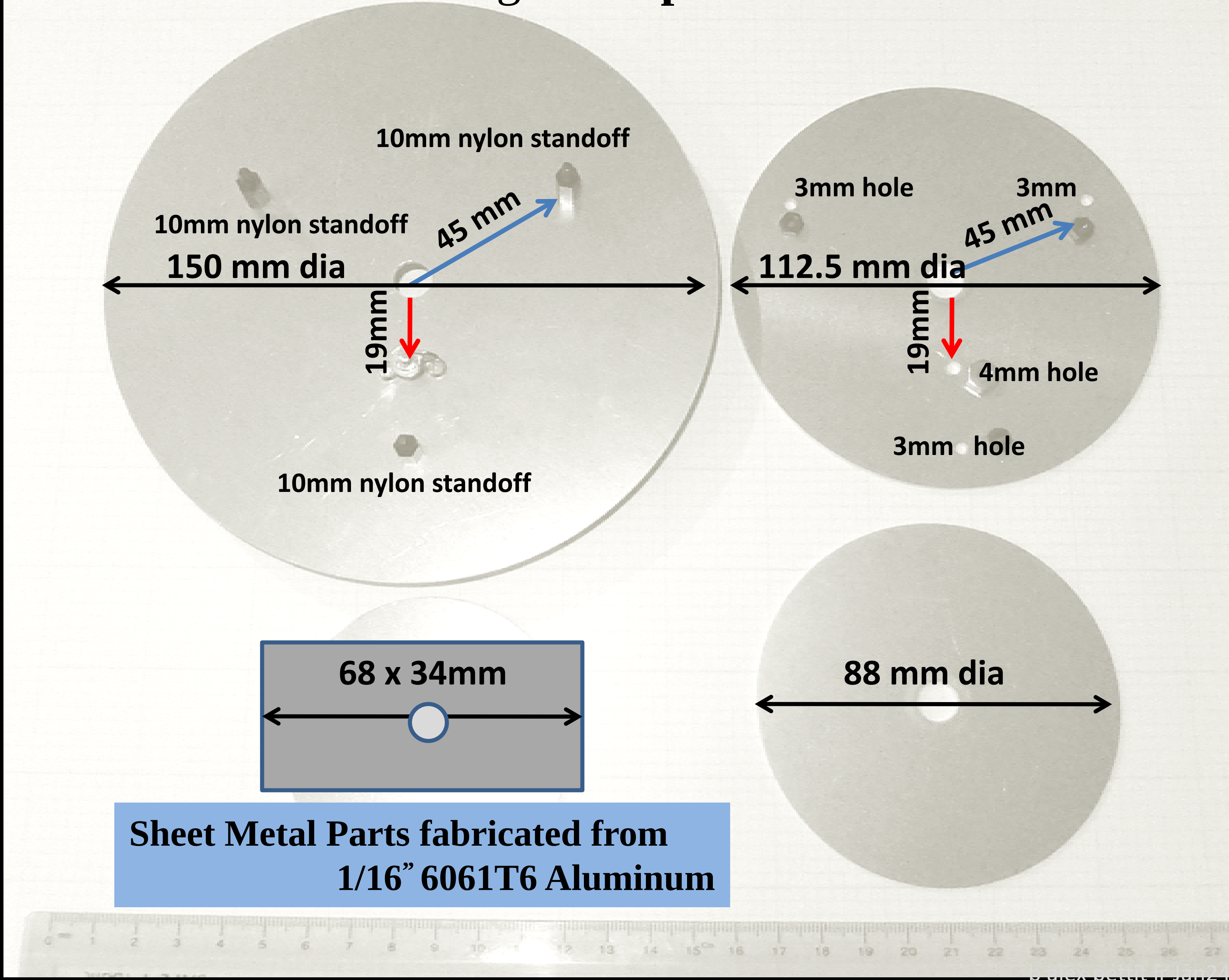
Fabrication

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

Fabrication
the processes



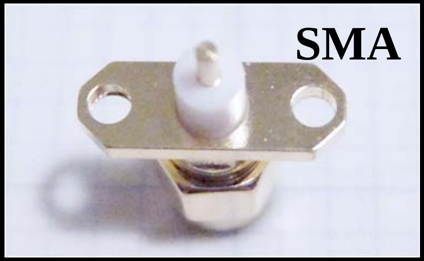
Cir Patch Feed Plate Yagi **Component Dimensions**



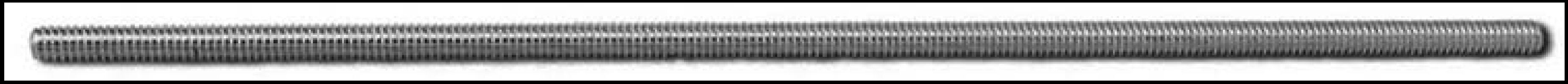
Sheet Metal Parts fabricated from 1/16" 6061T6 Aluminum

Cir Patch Feed Plate Yagi Element Spacer and Feed Components

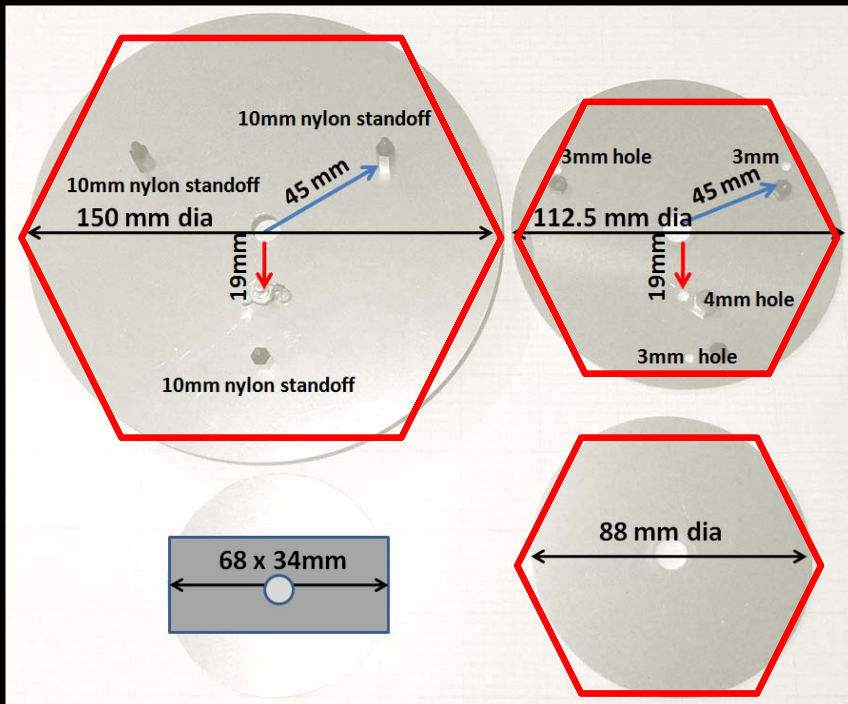
Sleeving : 0.50" OD / 0.038" ID Aluminum Tube

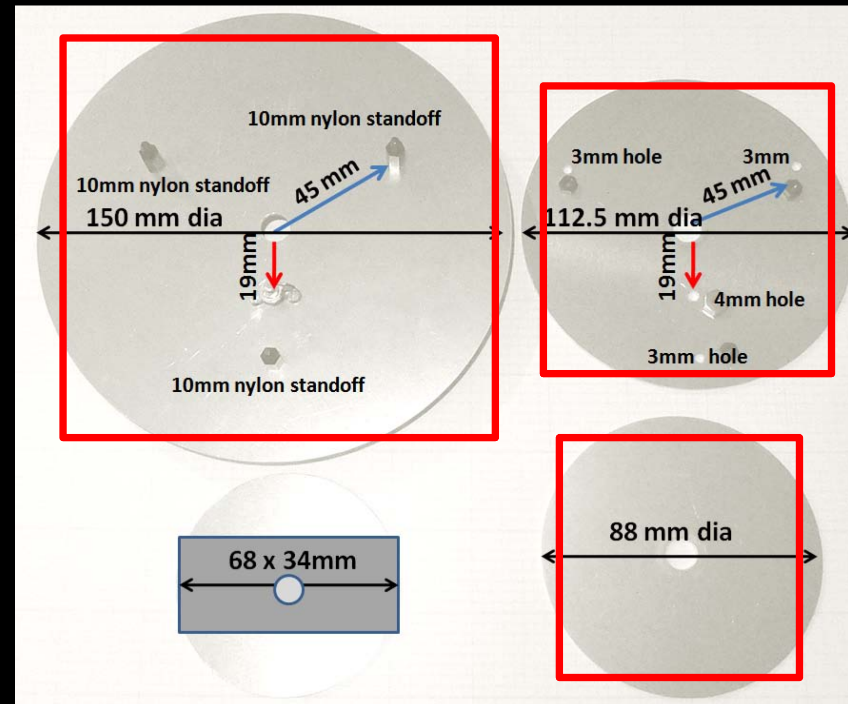


Stainless Steel 3/8"- 16 Thread   Threaded Rod 36" Length

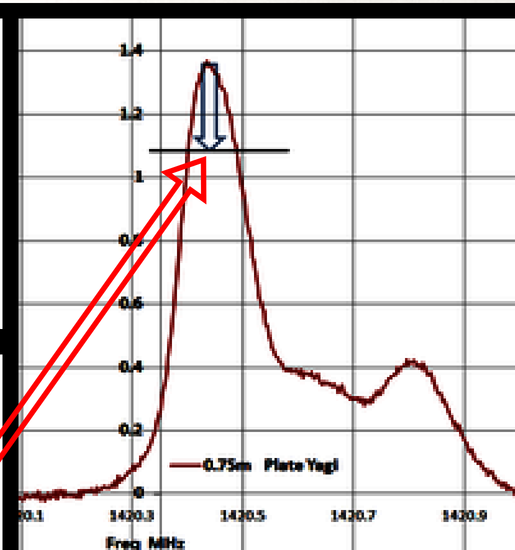


Patch Feed Plate Yagi **Alternate Designs**





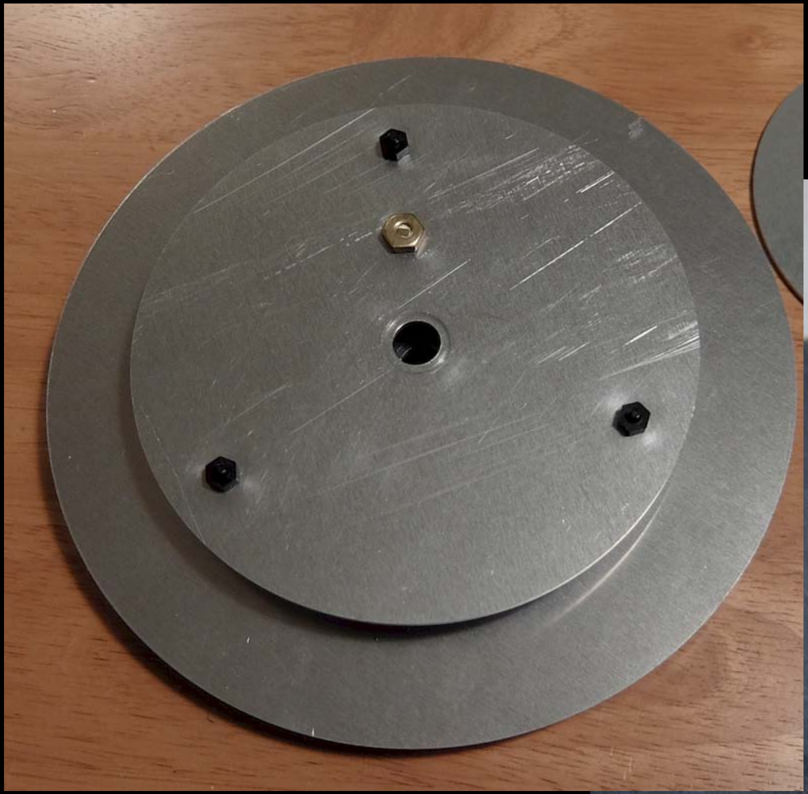
Simplified fabrications of the design should perform equally well
Maintain the same physical area of the Patch Feed ..
For a Square, that would = *100mm x 100mm*
I would NOT recommend rectangular shapes for these
3 components as this may increase 290K Ground Noise Reception
(*= reduce S/N*) by altering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

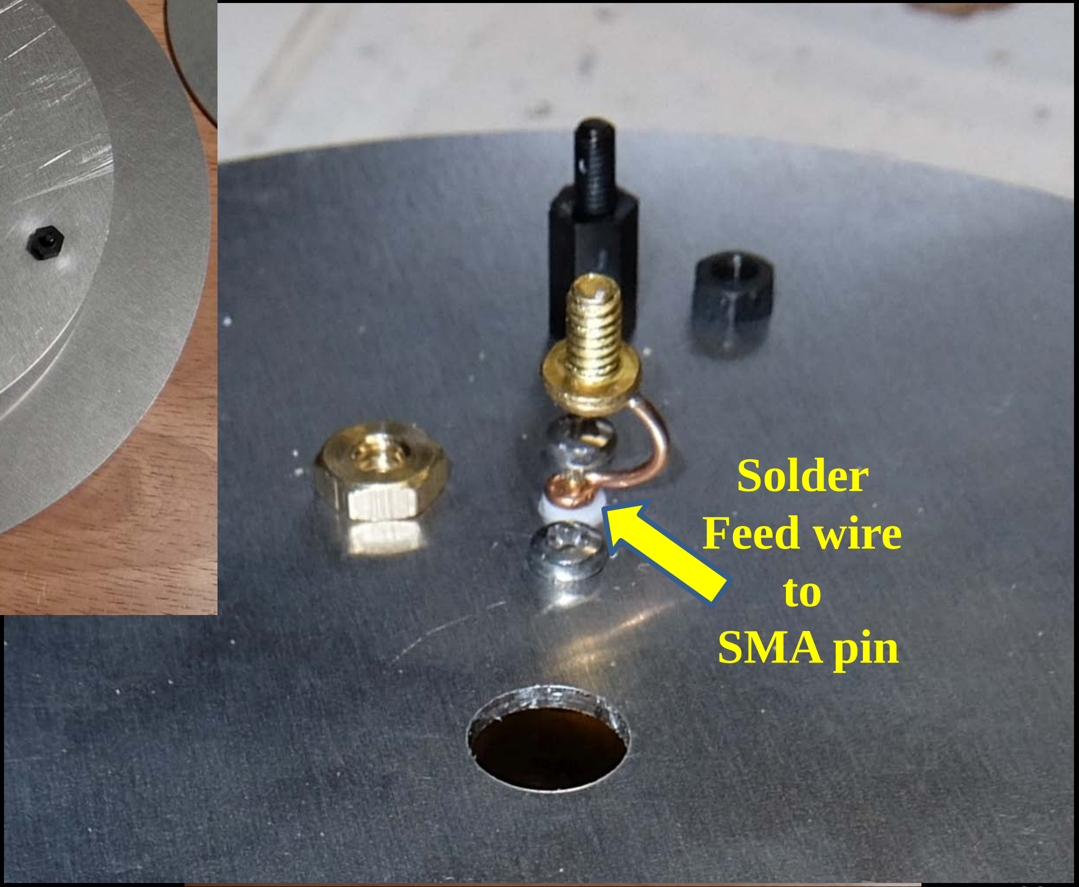


SS Nuts vs Aluminum Spacers
Degrades the Cygnus performance
spec from 1.35 dB to 1.10 dB

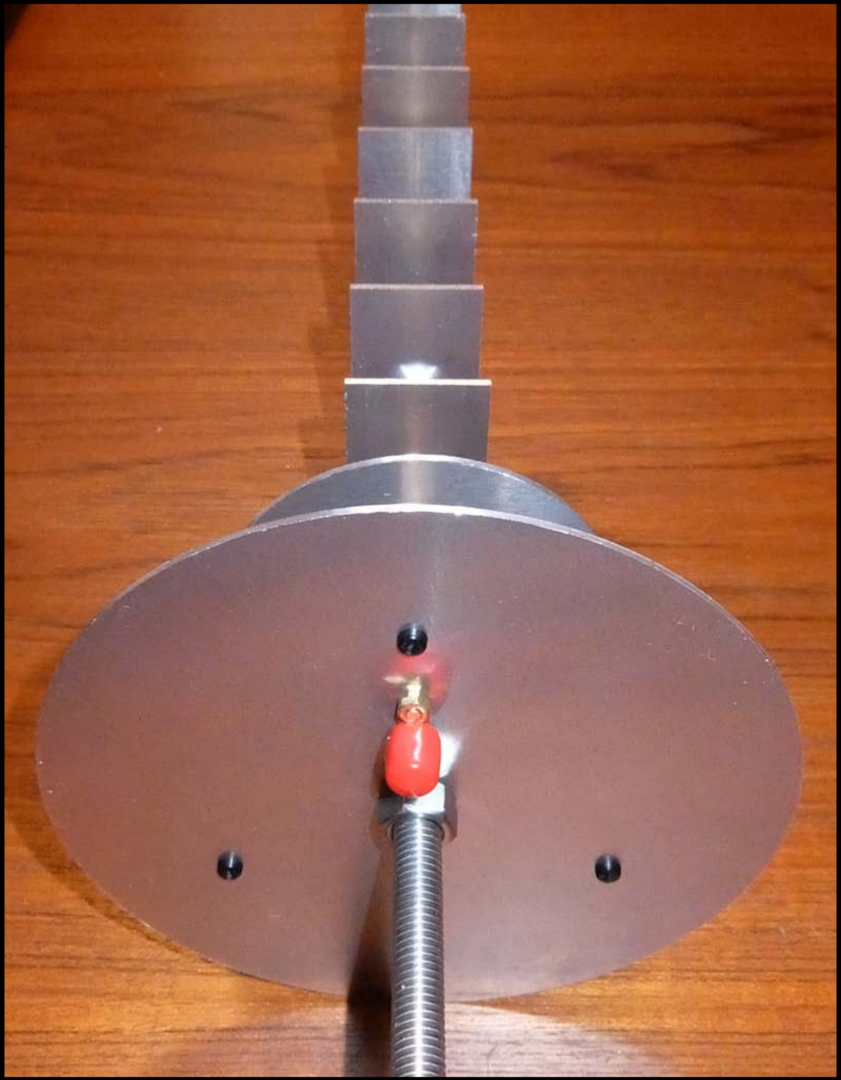
Cir Patch Feed Plate Yagi **Reflector / Feed details**

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

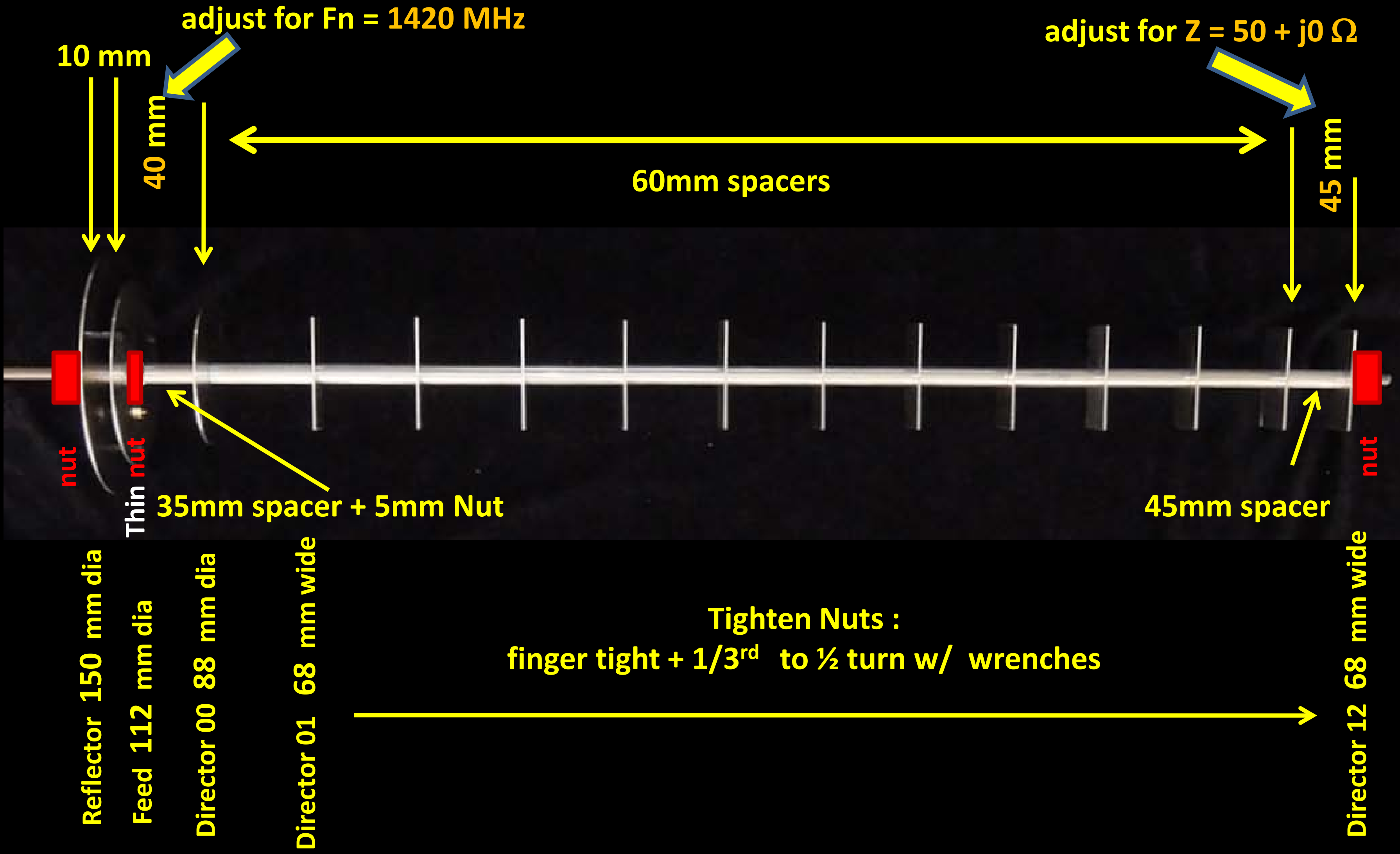




Cir Patch Feed Plate Yagi **Reflector / Feed assembly**
CORRECT Feed < > Director Orientation



Cir Patch Feed Plate Yagi **Dimensions**



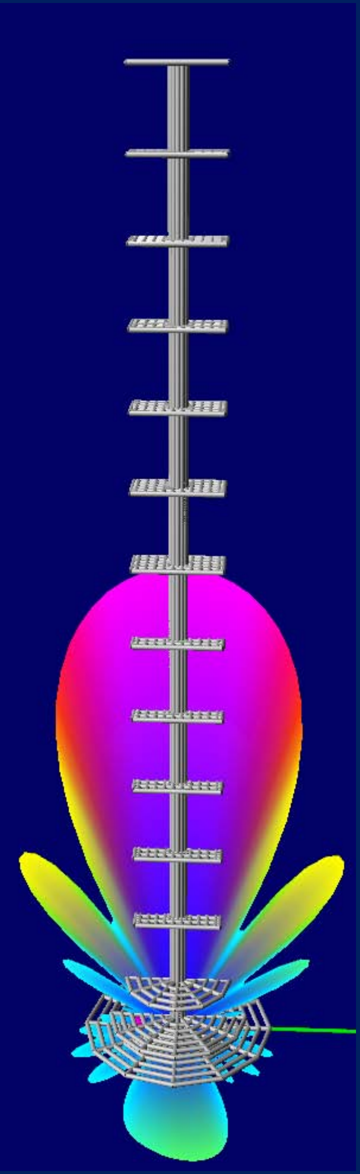
Cir Patch Feed Plate Yagi Antenna

Tuning via nano VNA

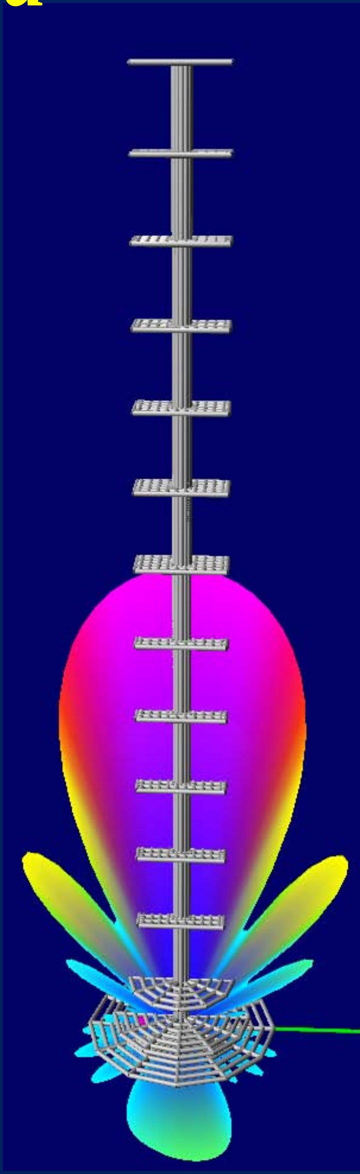
** Improving Weather Resistance **

Overnight Dew Shield : use a plastic polyethylene container

21cm Circular_Patch_Feed Plate_Director Yagi Antenna



The End



b alex pettit jr Jun24