

The Computer Model Design, Construction and Field Results – of the **WRTC 2014 TriBand Antenna**



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Overview

- World Radiosport Team Championship (**WRTC**) 2014
- **WRTC** Antenna Requirements
- Design Planning
- Electrical Optimization
- Physical Optimization
- Building and Testing the first prototypes
- Interesting Use Examples

World Radiosport Team Championship (**WRTC**) 2014

- An international contest held every 4 years within the **IARU** HF Championship
 - “As equal-as-possible” locations, antennas
 - With all else equal, who are the best operators?
- Two-operator teams
 - Team Leaders selected on the basis of performance in contests in “Qualifying Period”
 - Team Leader selects Team Member
- To be held in New England in July 2014



WRTC Antenna Requirements



WRTC Antenna Requirements (Cont.)

- 65 identical directive antennas that can operate on 10/15/20 Meters
- Ease of assembly / disassembly / reassembly
- Assembled Antenna Weight: 25 - 30 pounds or less as the target (excluding feedline)
- Boom length: 12 -18 feet
- VSWR: Less than 2:1 across the 20, 15, and 10-meter bands (28.0 - 28.5 segment of 10M is sufficient)
- Feed System: Single 50-ohm coax cable
- Material: Stainless-steel hardware, aluminum tubing
- 80 MPH windload handling capability
- Simultaneous operation on all three bands
- Price to performance value





Design Planning

- Stan Stockton (K5GO), Kevin Stockton (N5DX) and Scott McClements (WU2X) start planning November 1, 2011
- “Clean sheet of paper” designed exactly to the WRTC requirements
- Sought to deliver a new and exciting antenna design that would be fitting for this unprecedented international contesting event
- Goals for the antenna design:
 - Lightweight
 - Mechanically robust
 - True monopod performance
 - SWR < 1.6:1 across all the bands
 - Greater performance on 10 meters
 - **Most importantly** - Provide WRTC contestants with the very highest level of performance possible for the size



Design Planning (Continued)

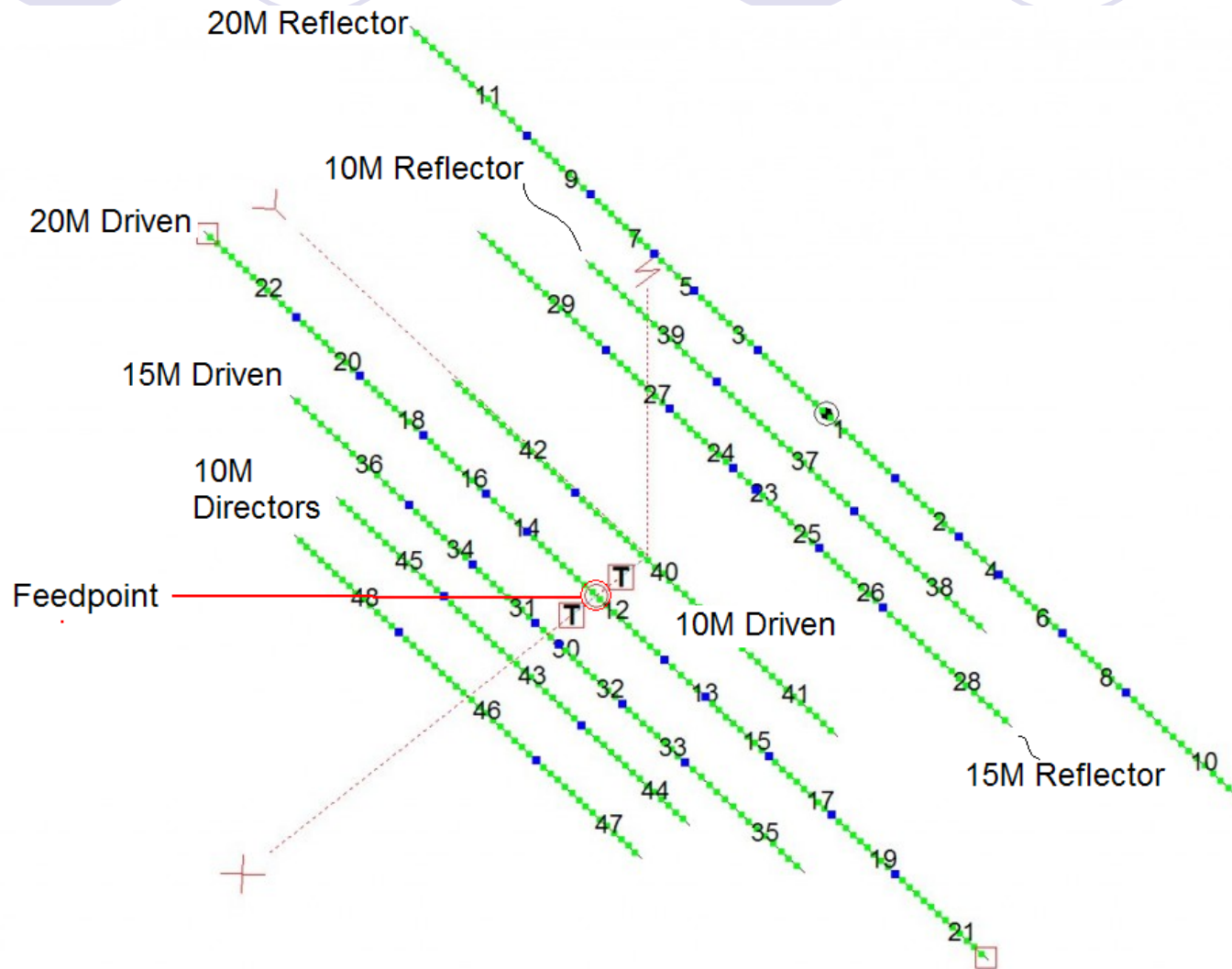
- Settled on:
 - 2 elements on 20 meters
 - 2 elements on 15 meters
 - 4 elements on 10 meters
 - Direct 50 Ohm feed, require no matching networks or tuning
- Time was tight – there was only 30 days to design, test and submit a proposal to the WRTC committee
 - Electrical and Mechanical design commenced in parallel
 - K5GO / N5DX = Mechanical design
 - WU2X = Electrical design



Electrical Optimization

- **Numerical Electromagnetics Code (NEC) v4.1** used for antenna simulation
- Custom front end software used to drive NEC automatically
- Software automatically adjusts antenna model and runs NEC 4.1
- Four Intel i7 quad core machines running in a cluster, operating simultaneously
- Brute force search, every combination tried in $\frac{1}{4}$ " increments
- All results above a certain figure of merit were saved to disk
- Took five days to run – and two days to hand evaluate some of the higher figure of merit models to select the version to build

Electrical Optimization (Continued)





Physical Optimization

- **YagiStress by K7NV**
 - Boom Construction - Light weight boom with minimal sag
 - Element Construction
 1. Center sections for 20, 15, and 10 are 1", $\frac{3}{4}$ " and $\frac{1}{2}$ " respectively
 2. Element tips – long and .040 wall thickness.
- Single socket head cap screw for each element joint
- WRTC – Special provisions
 1. Pre-assembly of element plates and element sections up to 6 feet
 2. Color coding for ease of final assembly
 3. Pop Rivets were not allowed for final assembly of antenna.

Physical Optimization (Continued)

C:\ YS.EXE

Designer: K5GO **AREA & WEIGHT** CYCLE 24 TX38 WRTC TRIBANDER

No.	ELEMENTS	Location (In)	Proj AREA (SqIn)	WEIGHT (Lb)	Sag (In)	Speed (Mph)
1	20m Reflector	2.500	282.750	4.96	21.889	80
2	10m Reflector	22.180	87.750	1.16	5.075	82
3	15m Reflector	41.872	133.875	2.03	9.194	82
4	10m Driven Element	89.704	84.563	1.13	4.243	87
5	20m Driven Element	113.027	273.844	4.86	17.540	83
6	15m Driven Element	136.360	129.938	1.98	7.792	85
7	10m Director 1	152.840	78.375	1.06	2.943	94
8	10m Director 2	174.500	77.250	1.05	2.746	96
			1148.344	18.23		

Units Area Print ESC

Physical Optimization (Continued)

YS.EXE

Designer: K5GO Element No. 1 --> 20m Reflector File: TX-38

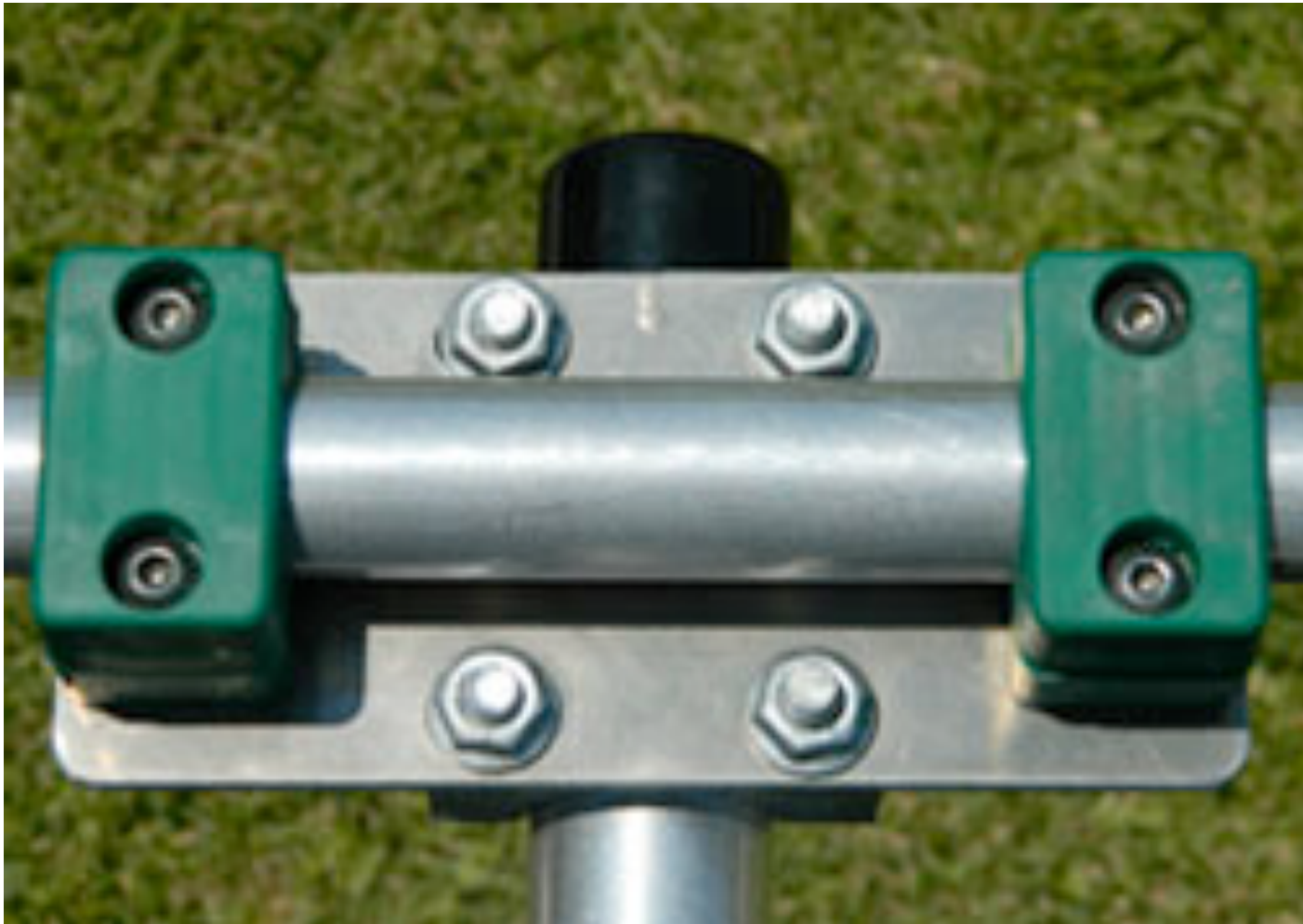
Location <In> Eff Area <SqIn> Weight <Lb> Sag <In> Safe @ 80 Mph
 2.500 188.500 4.96 21.889

Section No	Diameter In	Wall In	Exposed	Length In	Total	Stress Max = 35.00 Ksi
Tip--> 1	0.375	0.040	63.000		66.000	27.73
2	0.500	0.058	33.000		36.000	26.73
3	0.625	0.058	33.000		36.000	30.72
4	0.750	0.058	21.000		24.000	28.84
5	0.875	0.058	33.000		36.000	33.05
6	1.000	0.058	27.000		27.000	34.70
7 Dblr	1.000	0.116	9.000		9.000	23.02

Half Length = 219.000 In
 Res Frequency = 13.565 Mhz

View Edit Add/Rem Move Wind/F1 Next El Name Units Tubing Print ESC

Physical Optimization (Continued)



Physical Optimization (Continued)



Physical Optimization (Continued)

8450 holes to drill – WHAT?!

Calls for a six foot wing span and SO2DP

K1DG 8450 M K5GO 67 AR



Building and Testing the first prototypes

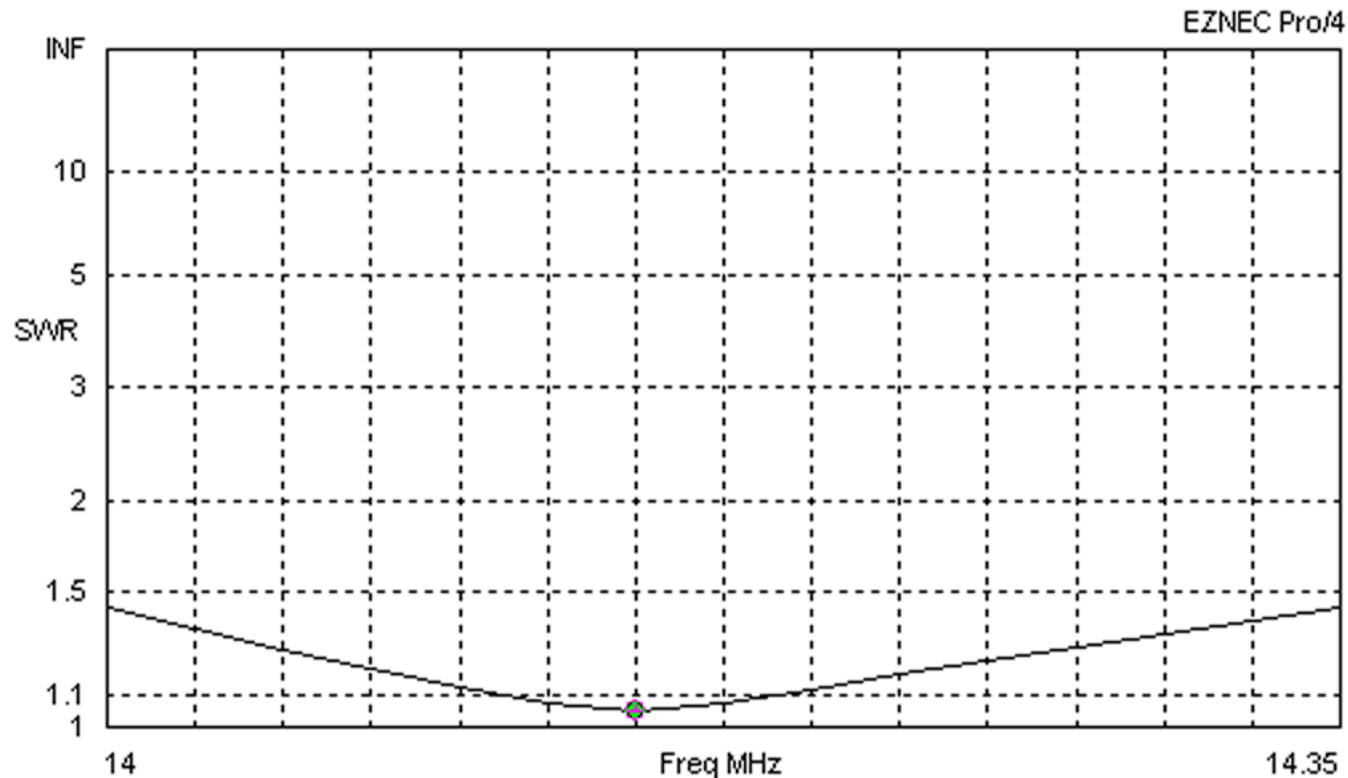
- In the second week of November 2011, two physical prototypes were built and tested independently
- Discovered a NEC anomaly related to transmission lines
- SWR curve and resonance frequency on 15M and 10M are a dead match with NEC 4.1
- Higher resonance frequency on 20M required lengthening the reflector and driven element 1.5" per side, to bring both resonance and F/R curve into the band
- Both models demonstrated the same SWR curves and performance
- PowerSDR/IF Stage used to plot azimuth pattern (0.1dB resolution)



Building and Testing the first prototypes



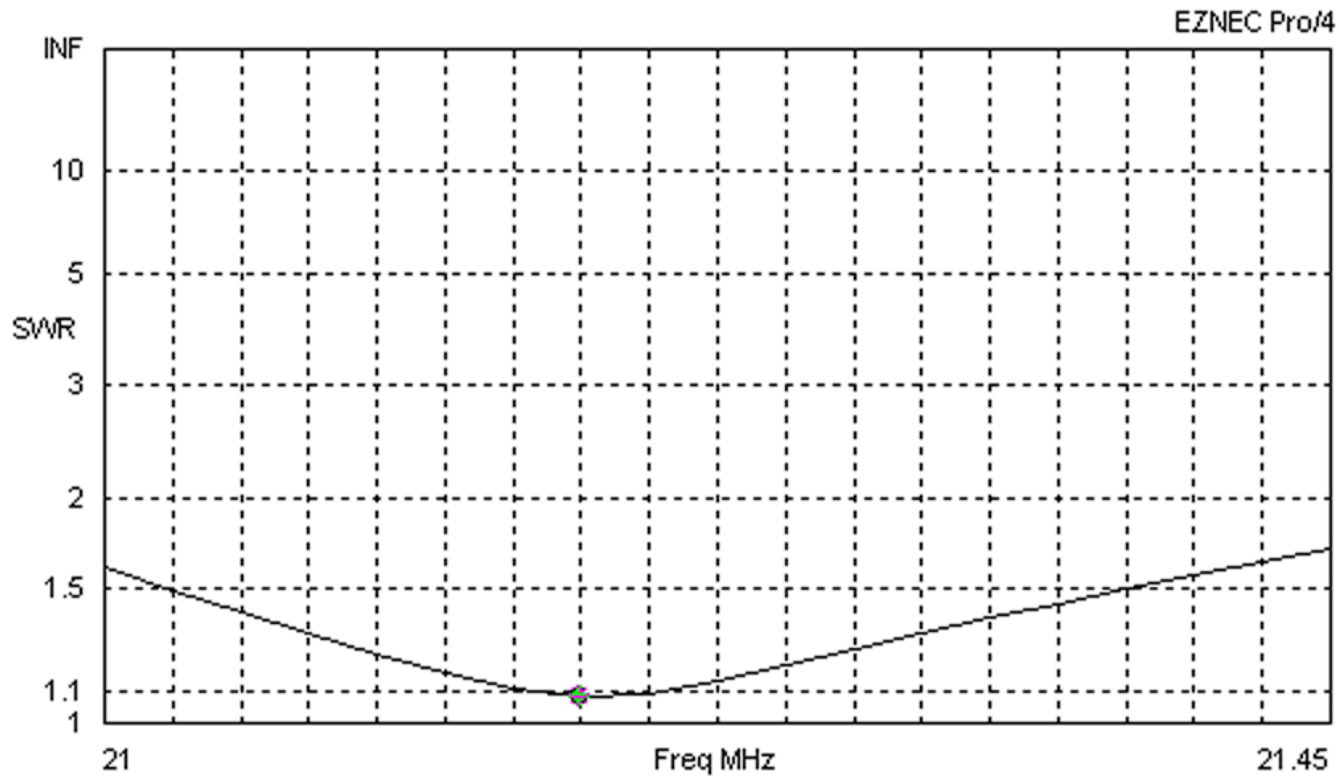
Building and Testing the first prototypes (Continued)



Freq 14.15 MHz
SWR 1.046
Z 49.42 at 2.5 deg.
= 49.37 + j 2.153 ohms
Refl Coeff 0.02255 at 104.96 deg.
= -0.005821 + j 0.02179
Ret Loss 32.9 dB

Source # 1
Z0 50 ohms

Building and Testing the first prototypes (Continued)

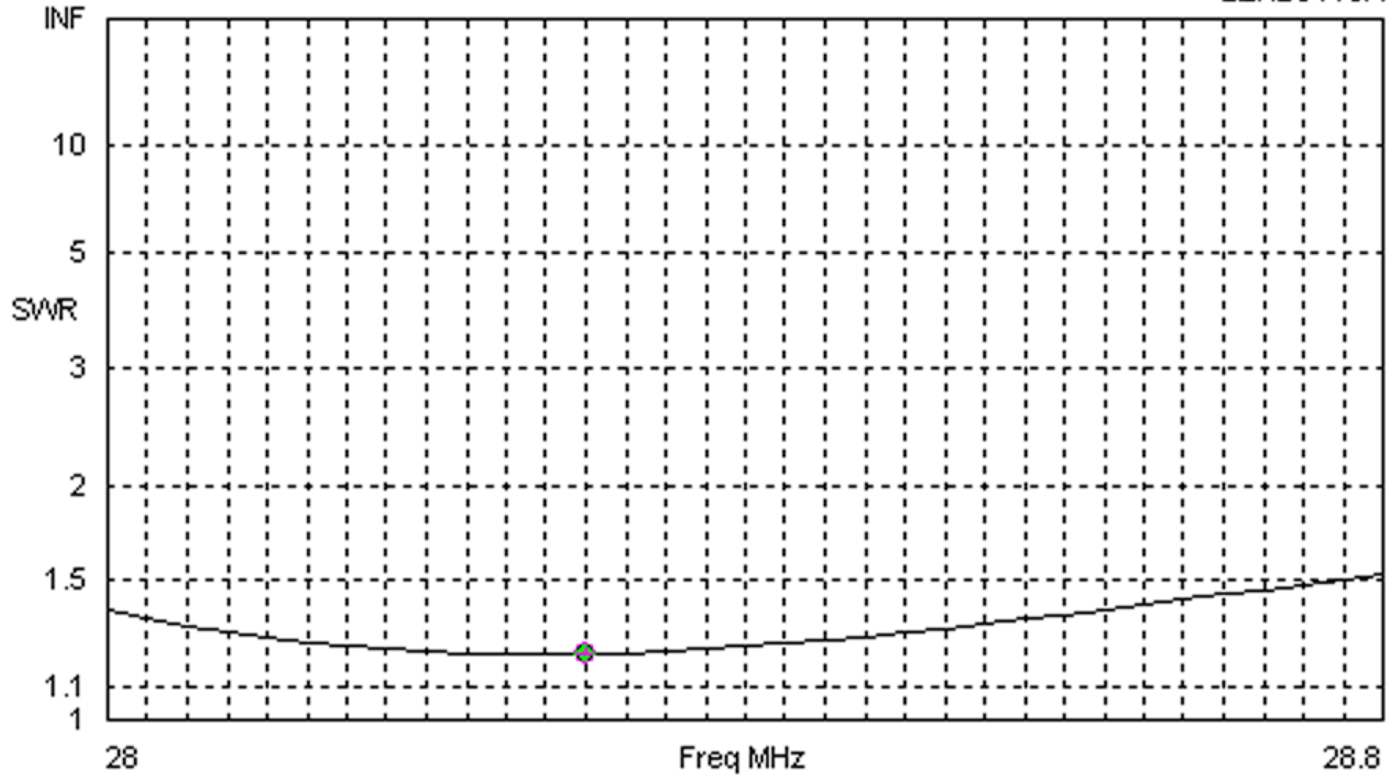


Freq 21.175 MHz
SWR 1.077
Z 50.29 at -4.26 deg.
= 50.15 - j 3.734 ohms
Refl Coeff 0.03729 at -85.55 deg.
= 0.002895 - j 0.03718
Ret Loss 28.6 dB

Source # 1
Z0 50 ohms

Building and Testing the first prototypes (Continued)

EZNEC Pro/4



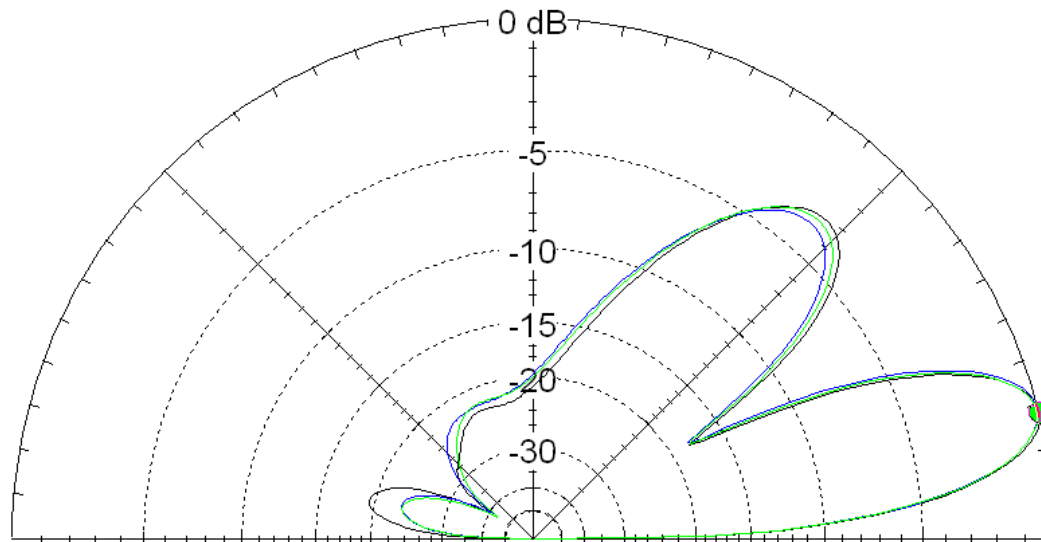
Freq	28.3 MHz	Source #	1
SWR	1.21	Z0	50 ohms
Z	51.48 at 10.53 deg. = 50.61 + j 9.411 ohms		
Refl Coeff	0.09333 at 80.92 deg. = 0.01473 + j 0.09216		
Ret Loss	20.6 dB		

Building and Testing the first prototypes (Continued)

Total Field

28 MHz
28.4 MHz
* 28.8 MHz

EZNEC Pro/4



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.17 dBi

Slice Max Gain 13.17 dBi @ Elev Angle = 14.0 deg.
Beamwidth 15.2 deg.; -3dB @ 6.9, 22.1 deg.
Sidelobe Gain 9.98 dBi @ Elev Angle = 47.0 deg.
Front/Sidelobe 3.19 dB

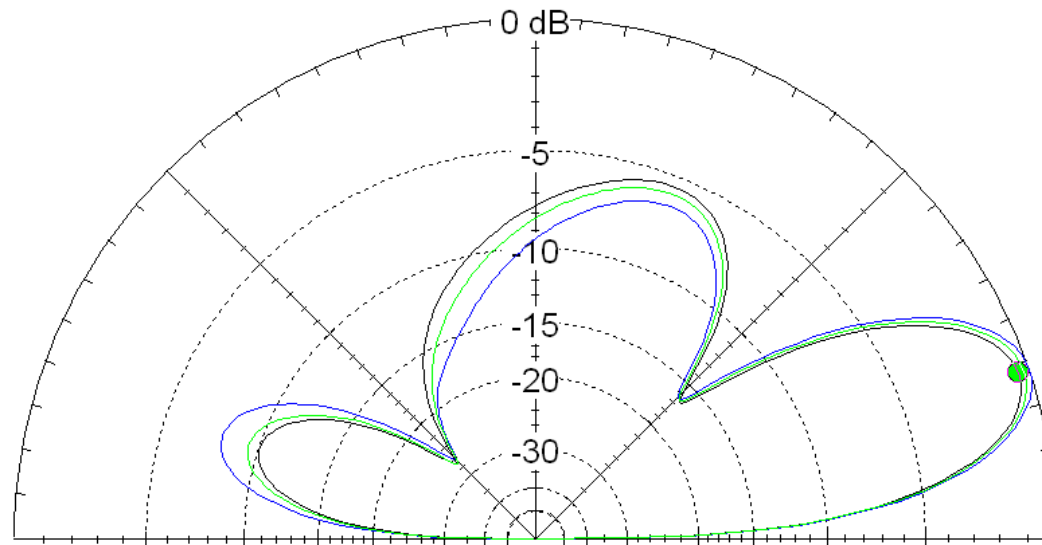
Cursor Elev 14.0 deg.
Gain 13.17 dBi
0.0 dBmax

Building and Testing the first prototypes (Continued)

Total Field

21 MHz
21.225 MHz
* 21.45 MHz

EZNEC Pro/4



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 11.94 dBi

Slice Max Gain 11.56 dBi @ Elev Angle = 19.0 deg.
Beamwidth 20.8 deg.; -3dB @ 9.1, 29.9 deg.
Sidelobe Gain 6.46 dBi @ Elev Angle = 68.0 deg.
Front/Sidelobe 5.1 dB

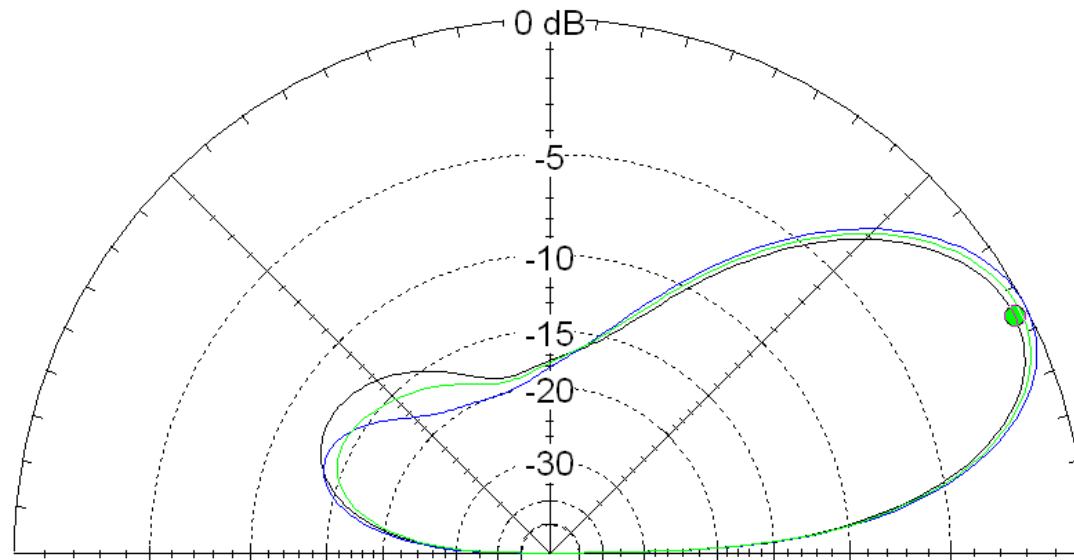
Cursor Elev 19.0 deg.
Gain 11.56 dBi
0.0 dBmax

Building and Testing the first prototypes (Continued)

Total Field

14 MHz
14.175 MHz
* 14.35 MHz

EZNEC Pro/4



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 11.09 dBi

Slice Max Gain 10.64 dBi @ Elev Angle = 27.0 deg.
Beamwidth 33.0 deg ; -3dB @ 12.9, 45.9 deg.
Sidelobe Gain -1.47 dBi @ Elev Angle = 148.0 deg.
Front/Sidelobe 12.11 dB

Cursor Elev 27.0 deg.
Gain 10.64 dBi
0.0 dBmax

Interesting Use Example # 1

Triplexing

- Using a triplexer device allows 3 different transceivers to operate a single antenna on the 3 different bands simultaneously
- **Field Day** operations can have three stations operating into one antenna at once
- **WRTC** 2 person teams will be able to operate simultaneously on different bands during the contest



Interesting Use Example # 2

Stacking

- Reasons to stack antennas
 - More gain
 - Better angle coverage
- WRTC antenna is light on a tower weight and windload wise
- 47" opening at mounting point – wide enough for even side arms
- Optimum stacking distance is 25'
 - Wider is not recommended as 10 Meters will suffer with a major secondary high angle lobe
- Cost effective compared to stacking monobanders on a single tower

Interesting Use Example # 2 Stacking (Continued)

Single ant. @ 121 feet

~+3.36 dB

3 ant. @ 121/96/71 feet

The screenshot displays the NEC software interface for two antenna configurations. The top configuration is for a single antenna at 121 feet, and the bottom configuration is for a stacked antenna array at 121/96/71 feet. Both configurations are simulated at a design frequency of 14.000 MHz. The radiation pattern plots show the gain in dBi, with the stacked array showing a higher gain of 15.98 dBi compared to the single antenna's 12.62 dBi. The gain difference is approximately +3.36 dB.

Variable Names and Values	Feedline	SWR Zo					
Freq (MHz)	R at Src1	X at Src1	SWR(50)	Max Gain	@ EI°	Fr / Back	Fr / Rear
14.000	30.92	-2.27	1.622	12.62	8		6.80
14.200	47.57	11.58	1.274	12.25	8		5.69
14.350	64.01	20.74	1.551	11.98	8		5.21

Variable Names and Values	Feedline	SWR Zo					
Freq (MHz)	R at Src1	X at Src1	SWR(50)	Max Gain	@ EI°	Fr / Back	Fr / Rear
14.000	32.16	-2.00	1.559	15.98	10		13.80
14.200	61.26	8.02	1.283	15.84	10		17.42
14.350	83.06	6.81	1.679	15.73	10		17.79

Interesting Use Example # 2 Stacking (Continued)

Single ant. @ 121 feet

+4.43dB

3 ant. @ 121/96/71 feet

The screenshot displays two panels of the NEC software interface, comparing the performance of a single antenna versus a stacked antenna array at 21.000 MHz. Each panel includes a control area with buttons like 'Calculate All Rows', a 'Variable Names and Values' table, a 'Feedline' table, a radiation pattern plot, and a table of performance metrics.

Top Panel: Single ant. @ 121 feet

Variable Names and Values			
Freq (MHz)			
21.000			
21.250			
21.450			

Feedline		SWR Zo					
R at Src1	X at Src1	SWR(50)	Max Gain	@ EI °	Fr / Back	Fr / Rear	
40.26	-3.52	1.259	12.98	6		8.69	
67.37	0.05	1.347	12.71	5		10.10	
90.71	-6.45	1.827	12.52	5		8.07	

Max Gain: 12.98 dBi

Bottom Panel: 3 ant. @ 121/96/71 feet

Variable Names and Values			
Freq (MHz)			
21.000			
21.250			
21.450			

Feedline		SWR Zo					
R at Src1	X at Src1	SWR(50)	Max Gain	@ EI °	Fr / Back	Fr / Rear	
42.04	-12.05	1.368	17.41	7		11.71	
61.52	-15.48	1.414	17.45	7		19.55	
72.63	-22.23	1.683	17.37	7		23.82	

Max Gain: 17.41 dBi

Interesting Use Example # 2 Stacking (Continued)

Single ant. @ 121 feet

+4.79dB

3 ant. @ 121/96/71 feet

13.87 dBi

28.000 MHz

18.66 dBi

28.000 MHz

Engine	Design Frequency (MHz)	R at Src1	X at Src1	SWR(50)	Max Gain	@ El°	Fr / Back	Fr / Rear
NEC-4 via GoNec.bat	14.000	39.08	11.58	1.431	13.87	4		15.48
NEC-4 via GoNec.bat	14.000	50.43	14.38	1.331	13.82	4		15.30
NEC-4 via GoNec.bat	14.000	61.06	18.87	1.482	13.86	4		15.62
NEC-4 via GoNec.bat	14.000	35.13	17.71	1.724	18.66	5		12.77
NEC-4 via GoNec.bat	14.000	50.63	25.63	1.656	18.57	5		11.65
NEC-4 via GoNec.bat	14.000	69.85	31.46	1.858	18.58	5		11.50

Interesting Use Example # 2 Stacking (Continued)

- Stack spacings wider than 25' hurt 15M and 10M performance

The screenshot shows the NEC software interface. On the left, there are control buttons like 'Clear All', 'Calculate Selected Row', and 'Calculate All Rows'. The center features a radiation pattern plot at 28.000 MHz with a peak gain of 17.55 dBi. On the right, there are settings for ground type (Real - Sommerfeld), salt water characteristics, and wire loss. Below the plot is a table with columns for 'Feedline', 'SWR Zo', 'Plot/Slice Type', 'Azimuth Angle', 'Step Size', 'R at Src1', 'X at Src1', 'SWR(50)', 'Max Gain', '@ EI²', 'Fr / Back', and 'Fr / Rear'. The table contains three rows of data for frequencies 28.000, 28.300, and 28.600 MHz.

Design Frequency (Equations sheet)	Variable Names and Values	Feedline	SWR Zo	Plot/Slice Type	Azimuth Angle	Step Size	R at Src1	X at Src1	SWR(50)	Max Gain	@ EI ²	Fr / Back	Fr / Rear
14.000				Elevation	0	1°	42.82	6.77	1.237	17.55	5		15.00
							50.82	6.90	1.148	17.49	5		15.61
							57.51	11.13	1.284	17.53	5		16.43

121 / 86 / 50 (35 feet)