Interactions between Antennas in a 10/15/20m Stack

In 2000 I homebrewed a 5 element 10m Yagi and put it on a roof tower. In 2004 I added a 20m homebrew Moxon. Finally, in 2010 I added a homebrew 15m dipole.

Recently with the improving sunspot cycle, I now and then heard something I didn't understand. Recent modeling revealed counterintuitive antenna patterns.

Larry Banks, W1DYJ

Licensed: 1961 (KN1VFX)
W1DYJ since 1966
Amateur Extra

9B DXCC [298-Cnf / 300-Wkd]
DX Challenge: 1898
8B WAS
6M VUCC [615 grids-Cnf]
All Low Power

W1DYJ ~ Larry Banks

Interactions between Antennas in a 10/15/20m Stack

My Ham Interests *(and biases)*

- **DXing**
  - ✓ 160 → 6
- **Casual Contesting**
  - ✓ A "little pistol" station
  - ✓ ~25 / year → to support DXing
- **Antenna Systems & Station Building**
  - ✓ Your ***Antenna System*** is the most important part of your station
  - ✓ Modeling is essential if you play with antennas
  - ✓ Another hobby is woodworking
  - ✓ I used to be an EE
- **Club Activities**
  - ✓ Personal Connections
  - ✓ Growing Ham Radio

Agenda

- Some History

- 2000 - 10m Yagi
- 2004 - 20m Moxon
- 2010 - 15m Dipole

Construction
Modeling
Elevation/Azimuth Response

- 2023 – Analyzing the Stack

- Current Results

Some History

In 1996 – "in between marriages"…

I purchased a home at 33 Blueberry Hill Road in Woburn MA

I thought I would be there for about three years…

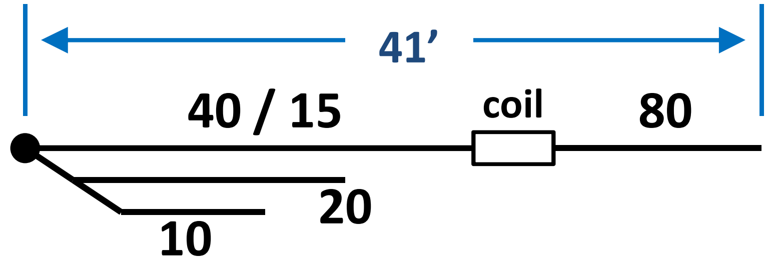
I'm still there!

In 1998: First roof tower: 6m|2m|432

In 2000: Second roof tower: 10m

Also in 2000 [38 years after KN1VHF…] Extra Class

Backyard >> Alpha Delta DX-CC Dipole [80/40&15, 20, 10]



Some History

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I purchased a home at 33 Blueberry Hill Road in Woburn MA

I thought I would be there for about three years…

I'm still there!

In 1998: First roof tower: 6m|2m|432

In 2000: Second roof tower: **10m**

Also in 2000 [38 years after KN1VHF…] Extra Class

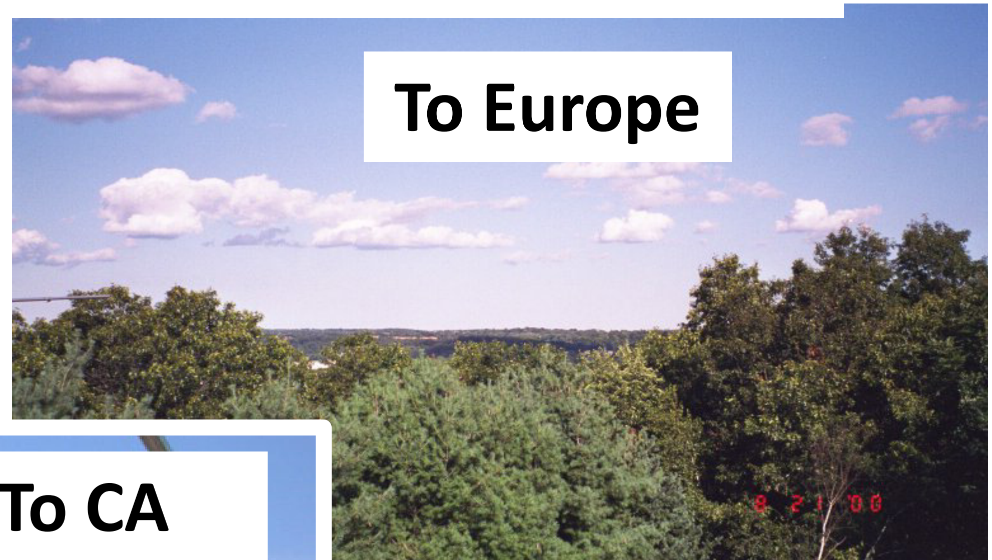
Then, on the 2nd roof tower: 20m (2004) | 15m (2010)

Interactions between Antennas in a 10/15/20m Stack

Those two roof towers in Woburn

Interactions between Antennas in a 10/15/20m Stack

Why am I still in Woburn? *It is on a 200' Hill*



From Roof

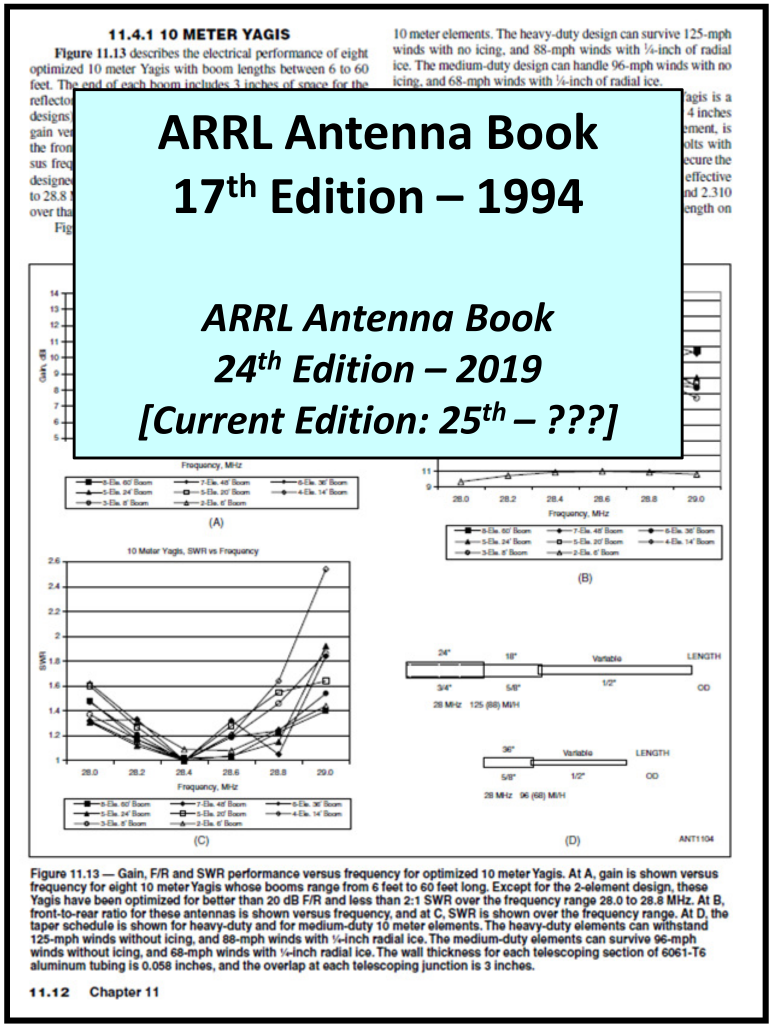
HB 10m 5EL Yagi

Interactions between Antennas in a 10/15/20m Stack

HB 10m 5EL Yagi

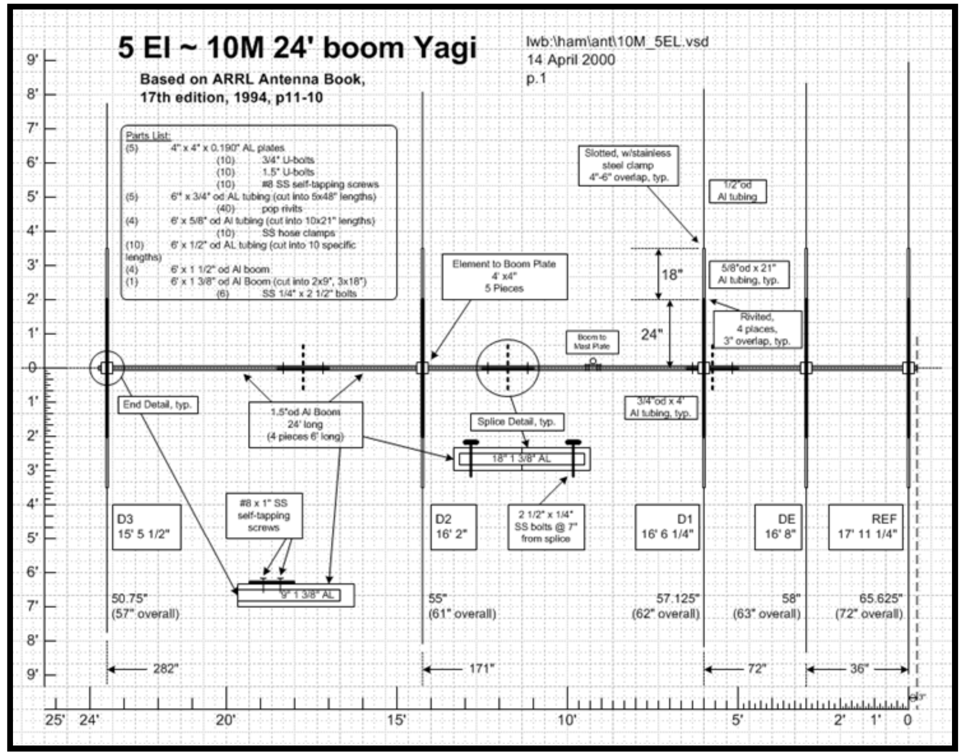
Interactions between Antennas in a 10/15/20m Stack

10m 5EL Yagi ~ Details



ARRL Antenna Book
17th Edition – 1994

ARRL Antenna Book
24th Edition – 2019
[Current Edition: 25th – ???]

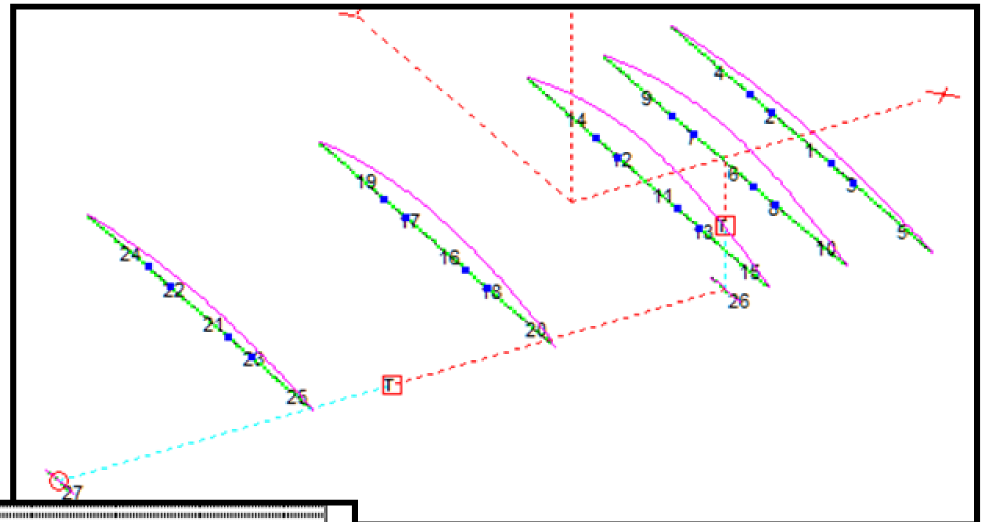


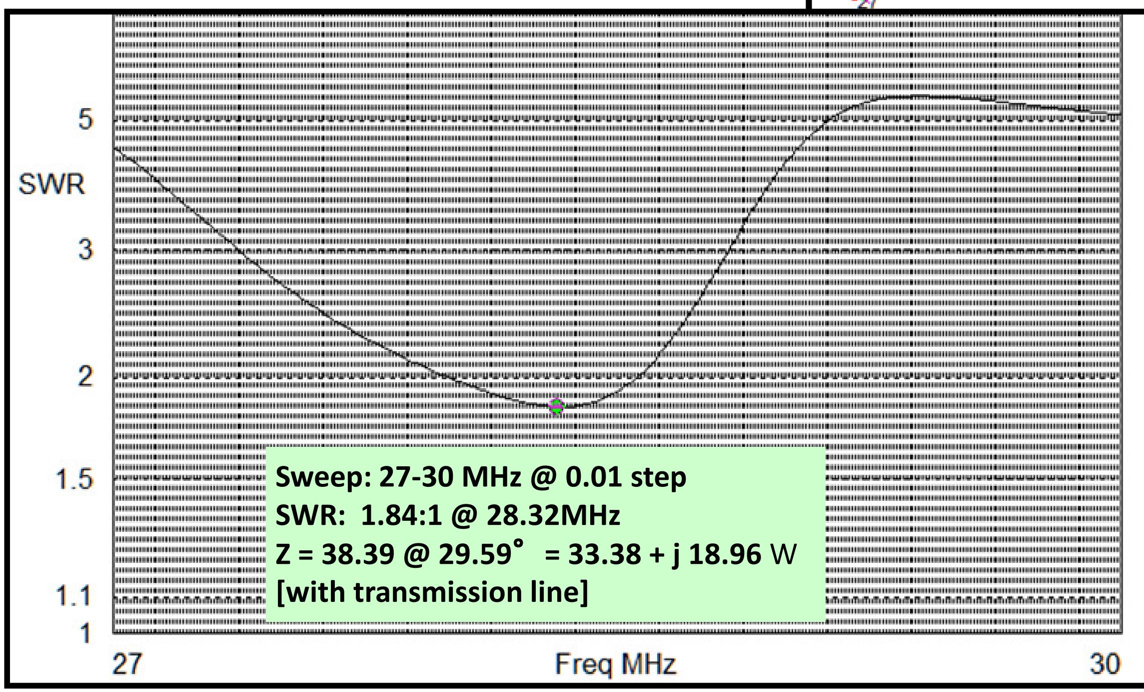
Five-element 10 meter Yagi, 24 foot boom			
Element	*Spacing, inches*	*Heavy-Duty Tip*	*Medium-Duty Tip*
File Name		510-24H.YW	510-24M.YW
Reflector	0.000"	65.625"	70.750"
Driven Element	36.000"	58.000"	63.250"
Director 1	36.000"	57.125"	62.375"
Director 2	99.000"	55.000"	60.250"
Director 3	111.000"	50.750"	56.125"
Compensator	12" behind Dir. 3	28.750"	26.750"

Interactions between Antennas in a 10/15/20m Stack

10m 5EL Yagi

EZNEC Model with Matching Section and Transmission Line





Model does not account for house and hill: assumes flat terrain → 1st order approximation.

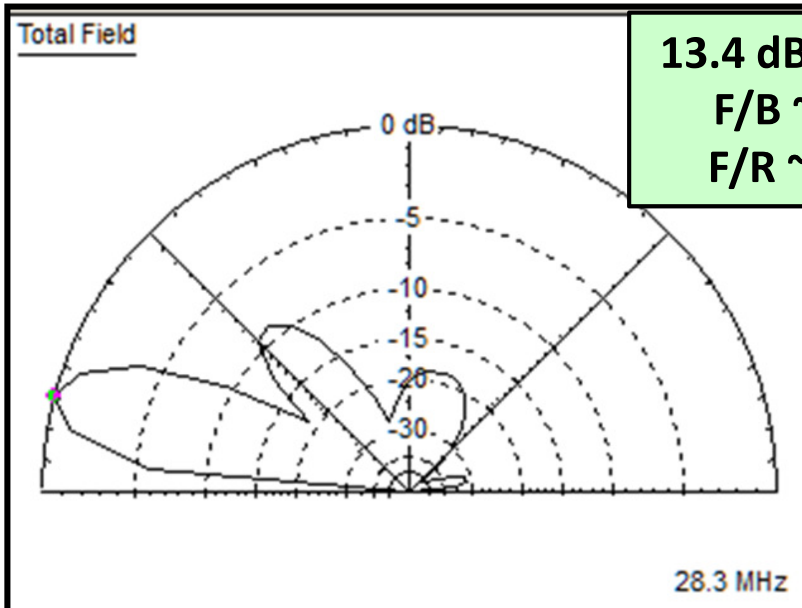
More Details in the Appendix of the on-line version. [qsl.net/w1dyj]

Interactions between Antennas in a 10/15/20m Stack

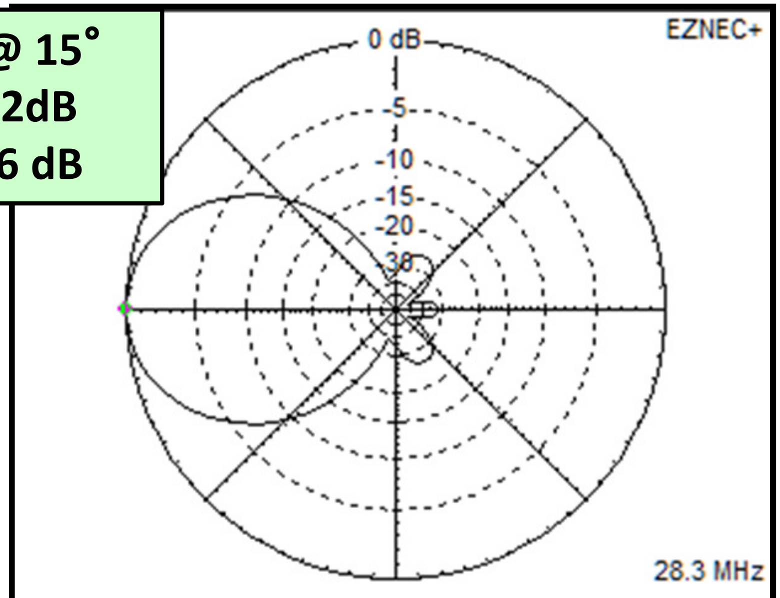
10m 5EL Yagi [@ 30' ~ 0.9λ]

EZNEC Model with Matching Section and Transmission Line

13.4 dBi @ 15°
F/B ~ 32dB
F/R ~ 26 dB



Elevation Plot		Cursor Elev	165.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.43 dBi
Outer Ring	13.43 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	13.43 dBi		
Slice Max Gain	13.43 dBi @ Elev Angle = 165.0 deg.		
Beamwidth	15.7 deg.; -3dB @ 156.2, 171.9 deg.		
Sidelobe Gain	4.55 dBi @ Elev Angle = 130.0 deg.		
Front/Sidelobe	8.88 dB		

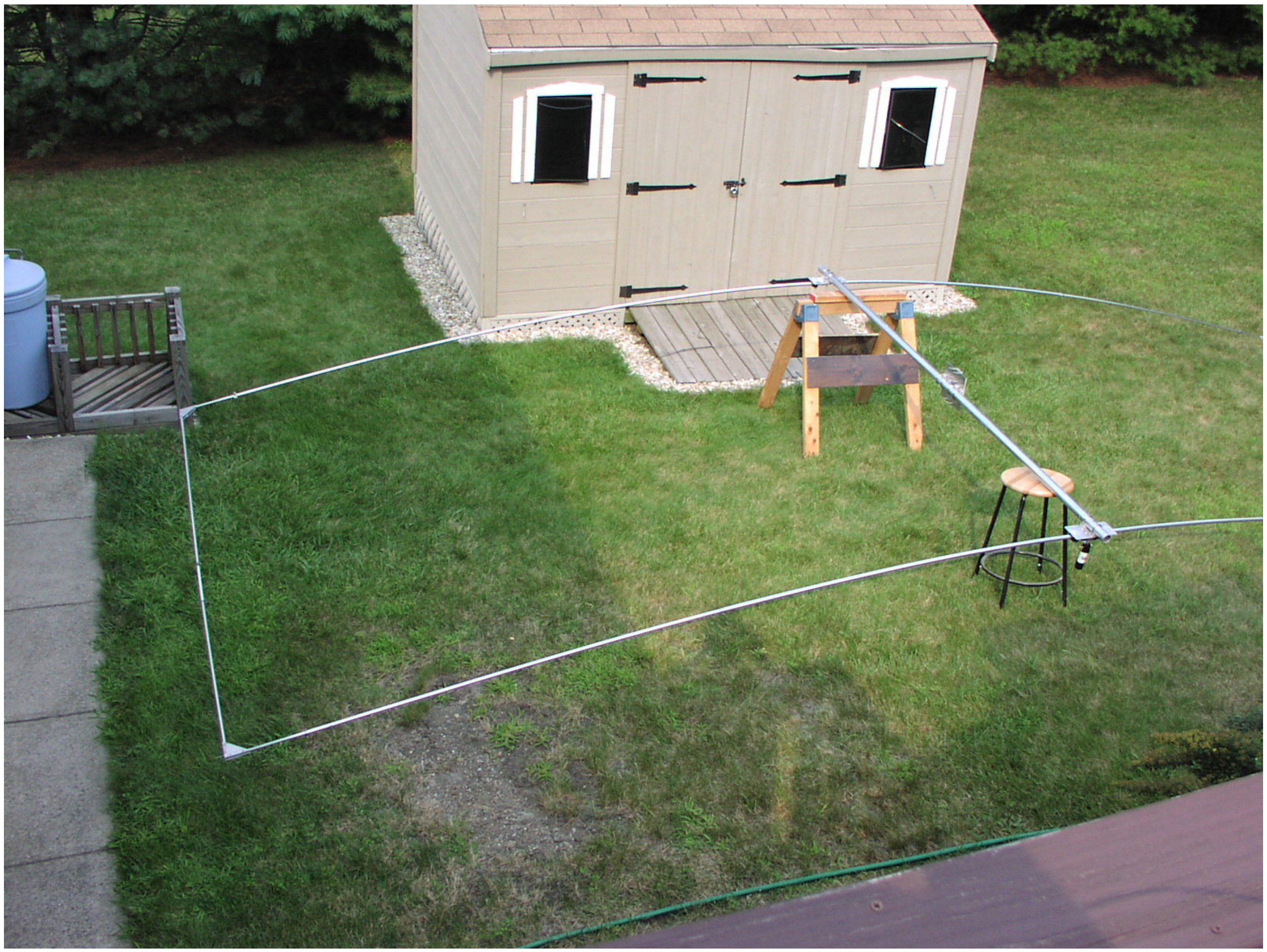


Azimuth Plot		Cursor Az	180.0 deg.
Elevation Angle	15.0 deg.	Gain	13.43 dBi
Outer Ring	13.43 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	13.43 dBi		
Slice Max Gain	13.43 dBi @ Az Angle = 180.0 deg.		
Front/Back	31.67 dB		
Beamwidth	53.4 deg.; -3dB @ 153.3, 206.7 deg.		
Sidelobe Gain	-12.32 dBi @ Az Angle = 300.0 deg.		
Front/Sidelobe	25.75 dB		

Interactions between Antennas in a 10/15/20m Stack

2004 – HB 20m Moxon

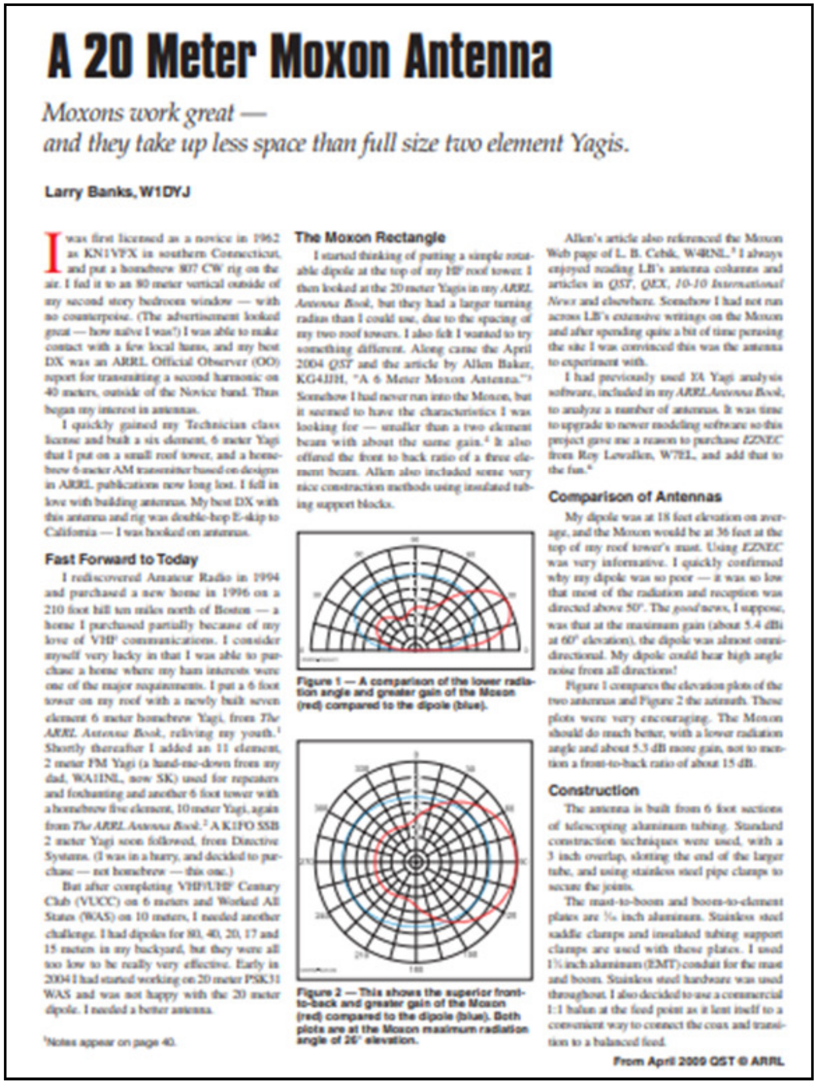
Wanted more "firepower" for 20m WAS / DXCC



Les Moxon
G6XN
SK - 2004

Interactions between Antennas in a 10/15/20m Stack

HB 20m Moxon



A 20 Meter Moxon Antenna

Moxons work great —
and they take up less space than full size two element Yagis.

Larry Banks, W1DYJ

I was first licensed as a novice in 1962 as KN1VFX in southern Connecticut, and put a homebrew 807 CW rig on the air. I fed it to an 80 meter vertical outside of my second story bedroom window — with no counterpoise. (The advertisement looked great — how naïve I was!) I was able to make contact with a few local hams, and my best DX was an ARRL Official Observer (OO) report for transmitting a second harmonic on 40 meters, outside of the Novice band. Thus began my interest in antennas.

I quickly gained my Technician class license and built a six element, 6 meter Yagi that I put on a small roof tower, and a homebrew 6 meter AM transmitter based on designs in ARRL publications now long lost. I fell in love with building antennas. My best DX with this antenna and rig was double-hop E-skip to California — I was hooked on antennas.

Fast Forward to Today

I rediscovered Amateur Radio in 1994 and purchased a new home in 1996 on a 210 foot hill ten miles north of Boston — a home I purchased partially because of my love of VHF communications. I consider myself very lucky in that I was able to purchase a home where my ham interests were one of the major requirements. I put a 6 foot tower on my roof with a newly built seven element 6 meter homebrew Yagi, from *The ARRL Antenna Book*, reliving my youth.[1] Shortly thereafter I added an 11 element, 2 meter FM Yagi (a hand-me-down from my dad, WA1INL, now SK) used for repeaters and foxhunting and another 6 foot tower with a homebrew five element, 10 meter Yagi, again from *The ARRL Antenna Book*.[2] A K1FO SSB 2 meter Yagi soon followed, from Directive Systems. (I was in a hurry, and decided to purchase — not homebrew — this one.)

But after completing VHF/UHF Century Club (VUCC) on 6 meters and Worked All States (WAS) on 10 meters, I needed another challenge. I had dipoles for 80, 40, 20, 17 and 15 meters in my backyard, but they were all too low to be really very effective. Early in 2004 I had started working on 20 meter PSK31 WAS and was not happy with the 20 meter dipole. I needed a better antenna.

[1]Notes appear on page 40.

The Moxon Rectangle

I started thinking of putting a simple rotatable dipole at the top of my HF roof tower. I then looked at the 20 meter Yagis in my *ARRL Antenna Book*, but they had a larger turning radius than I could use, due to the spacing of my two roof towers. I also felt I wanted to try something different. Along came the April 2004 *QST* and the article by Allen Baker, KG4JJH, "A 6 Meter Moxon Antenna."[3] Somehow I had never run into the Moxon, but it seemed to have the characteristics I was looking for — smaller than a two element beam with about the same gain.[4] It also offered the front to back ratio of a three element beam. Allen also included some very nice construction methods using insulated tubing support blocks.

Figure 1 — A comparison of the lower radiation angle and greater gain of the Moxon (red) compared to the dipole (blue).

Figure 2 — This shows the superior front-to-back and greater gain of the Moxon (red) compared to the dipole (blue). Both plots are at the Moxon maximum radiation angle of 26° elevation.

Allen's article also referenced the Moxon Web page of L. B. Cebik, W4RNL.[5] I always enjoyed reading LB's antenna columns and articles in *QST*, *QEX*, *10-10 International News* and elsewhere. Somehow I had not run across LB's extensive writings on the Moxon and after spending quite a bit of time perusing the site I was convinced this was the antenna to experiment with.

I had previously used *YA* Yagi analysis software, included in my *ARRL Antenna Book*, to analyze a number of antennas. It was time to upgrade to newer modeling software so this project gave me a reason to purchase *EZNEC* from Roy Lewallen, W7EL, and add that to the fun.[6]

Comparison of Antennas

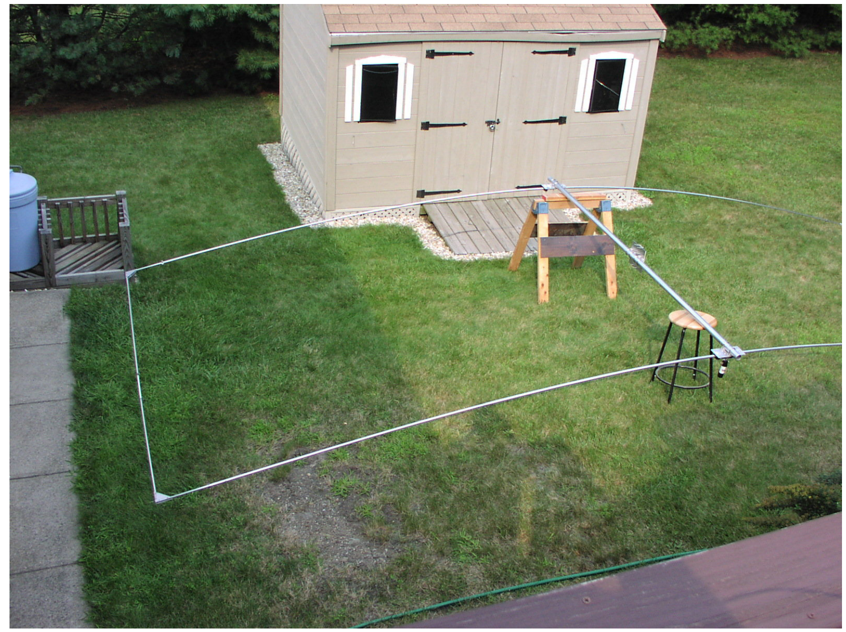
My dipole was at 18 feet elevation on average, and the Moxon would be at 36 feet at the top of my roof tower's mast. Using *EZNEC* was very informative. I quickly confirmed why my dipole was so poor — it was so low that most of the radiation and reception was directed above 50°. The *good news*, I suppose, was that at the maximum gain (about 5.4 dBi at 60° elevation), the dipole was almost omnidirectional. My dipole could hear high angle noise from all directions!

Figure 1 compares the elevation plots of the two antennas and Figure 2 the azimuth. These plots were very encouraging. The Moxon should do much better, with a lower radiation angle and about 5.3 dB more gain, not to mention a front-to-back ratio of about 15 dB.

Construction

The antenna is built from 6 foot sections of telescoping aluminum tubing. Standard construction techniques were used, with a 3 inch overlap, slotting the end of the larger tube, and using stainless steel pipe clamps to secure the joints.

The mast-to-boom and boom-to-element plates are ³⁄₁₆ inch aluminum. Stainless steel saddle clamps and insulated tubing support clamps are used with these plates. I used 1½ inch aluminum (EMT) conduit for the mast and boom. Stainless steel hardware was used throughout. I also decided to use a commercial 1:1 balun at the feed point as it lent itself to a convenient way to connect the coax and transition to a balanced feed.



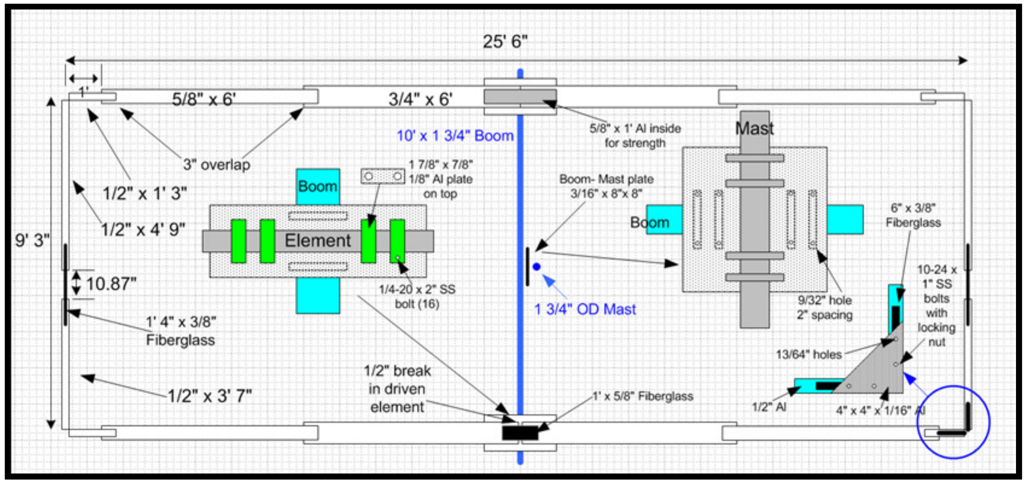
April 2009 QST

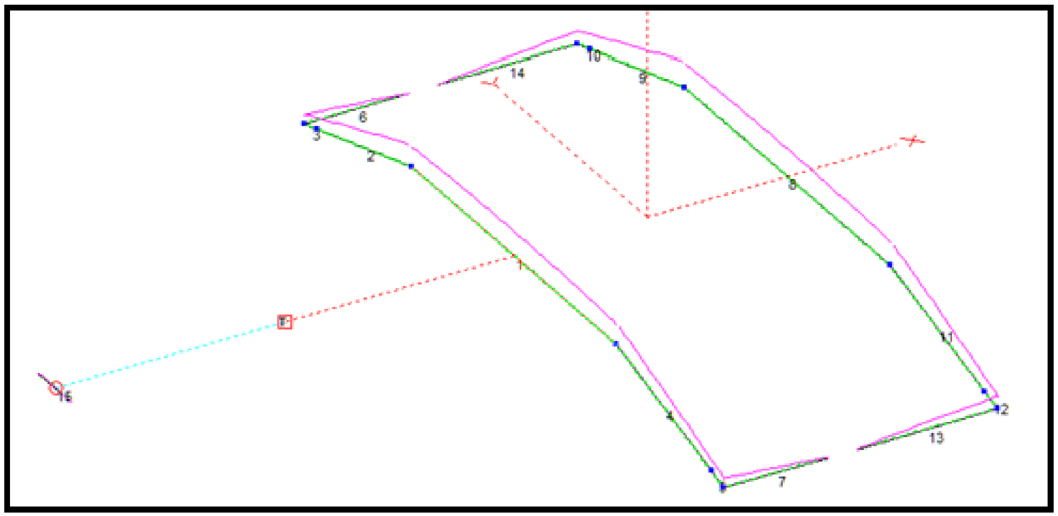
Won the "Cover Plaque" Award

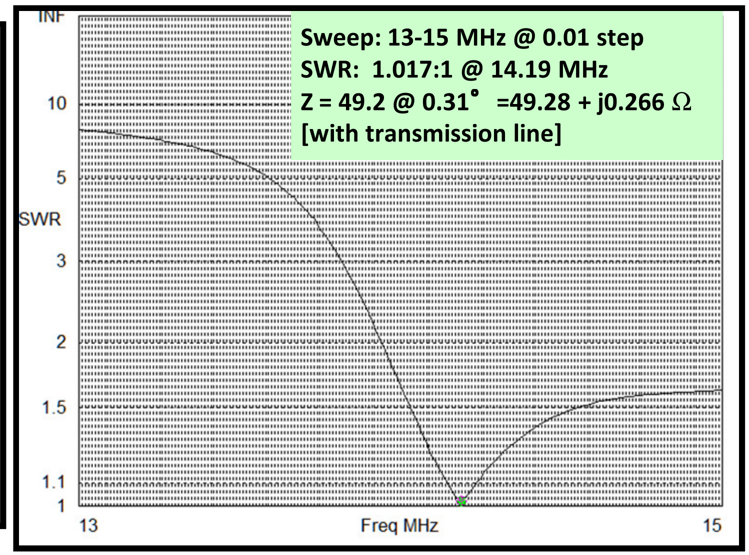
Also in Compendium V8 and Antenna Book 23rd Edition

Interactions between Antennas in a 10/15/20m Stack

HB 20m Moxon





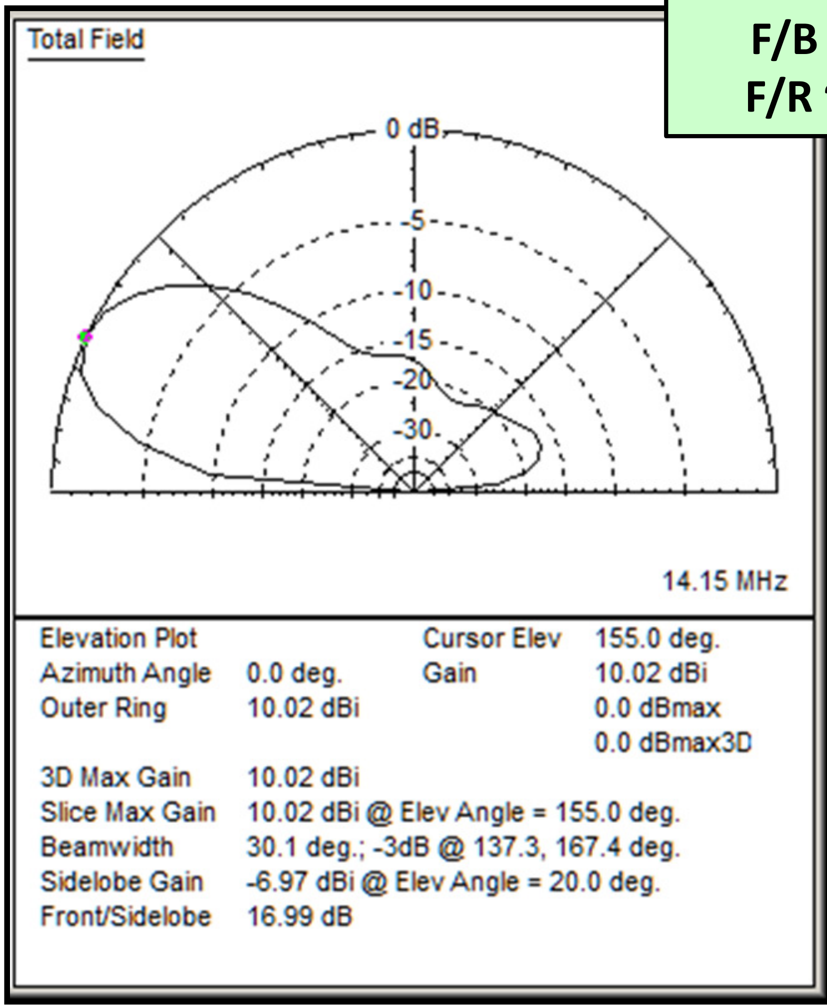


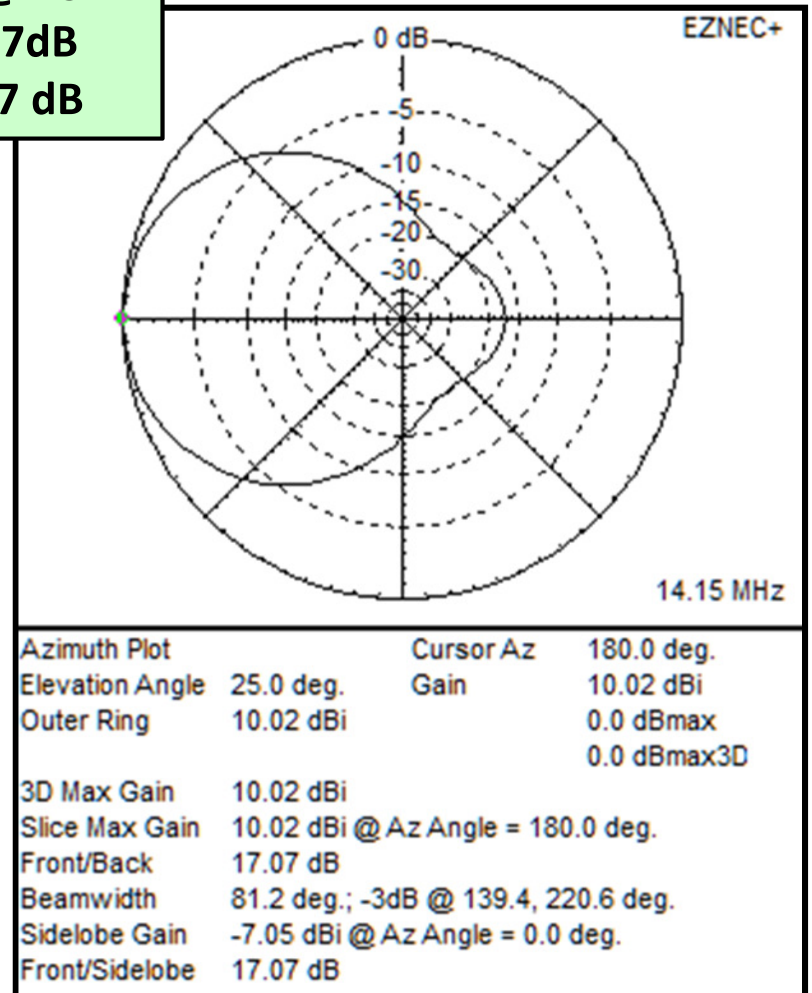
Interactions between Antennas in a 10/15/20m Stack

HB 20m Moxon

[@ 36’ ~ 0.55λ]

10.0 dBi @ 25°
F/B ~ 17dB
F/R ~ 17 dB





Interactions between Antennas in a 10/15/20m Stack

2010 – HB 15m Dipole

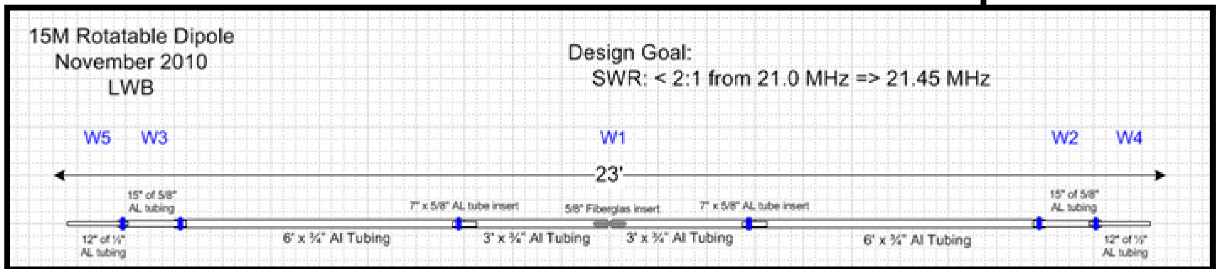
Wanted something better than 40m part of A/D DX-CC

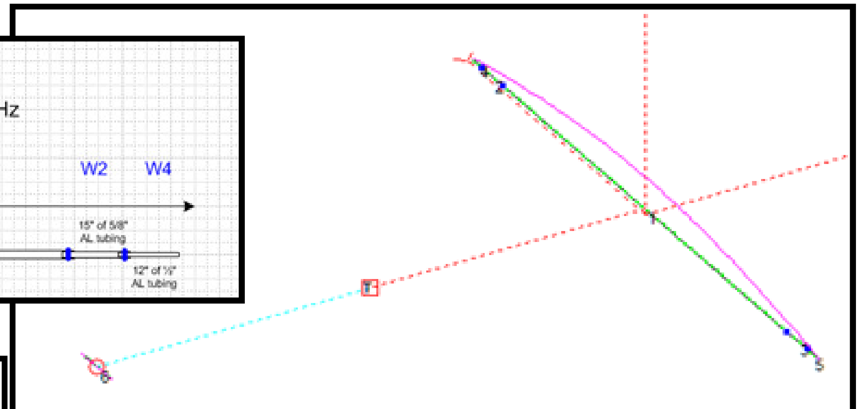
Threw it up a week before the CQ WW SSB contest as a temporary antenna.

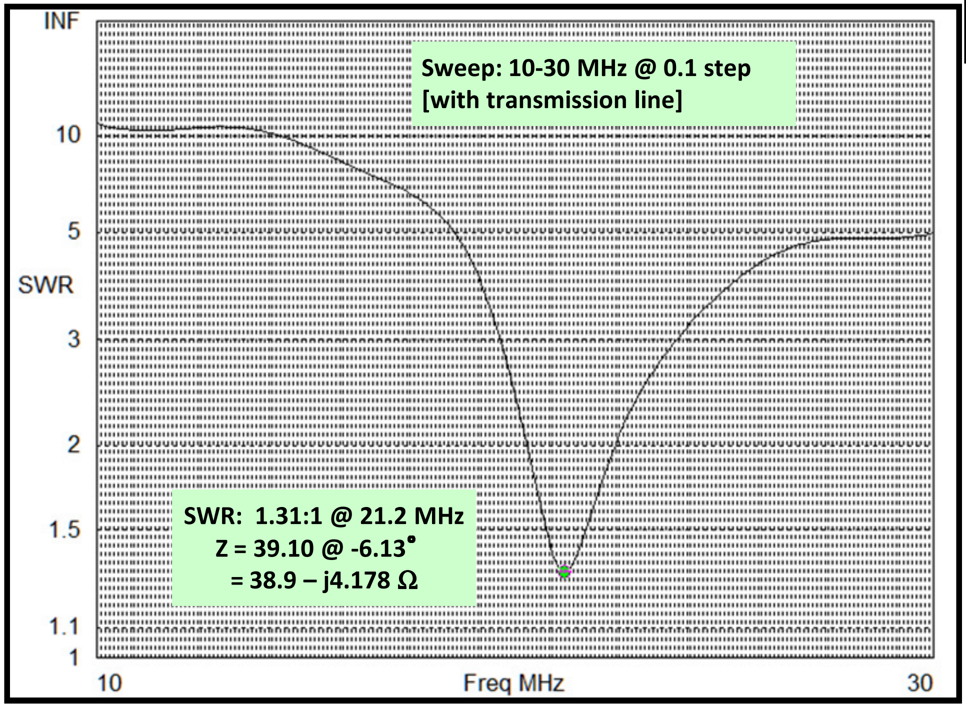
It's still There!

Interactions between Antennas in a 10/15/20m Stack

HB 15m Dipole







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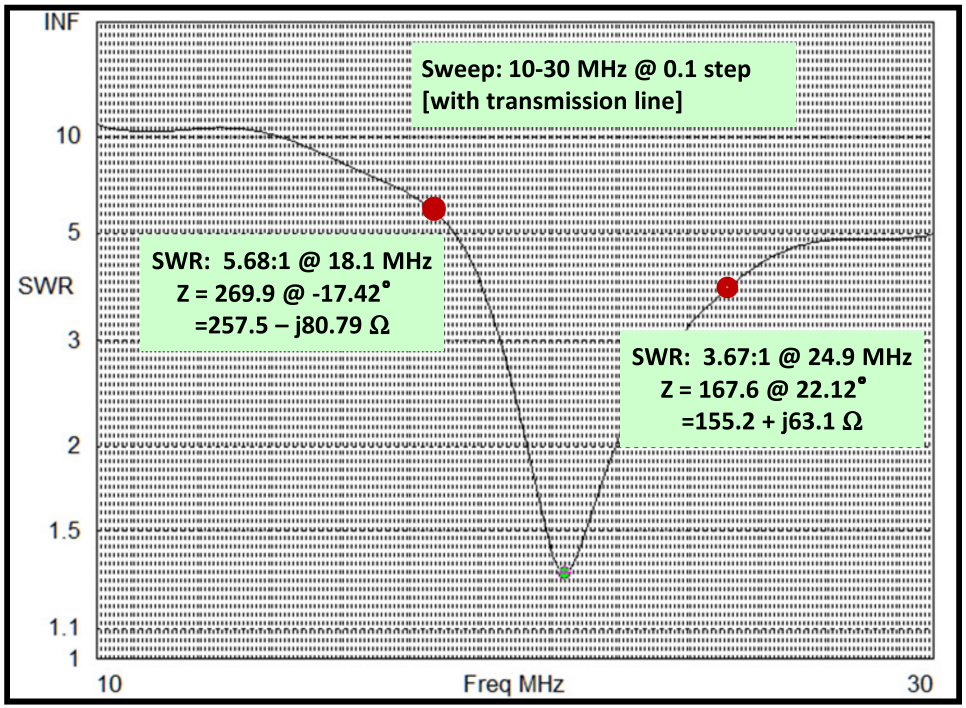
Interactions between Antennas in a 10/15/20m Stack

HB 15m Dipole

Why it's still there: it "works" on 12m and 17m!

SWR is not the sole measure of a good antenna!



Interactions between Antennas in a 10/15/20m Stack

HB 15m Dipole

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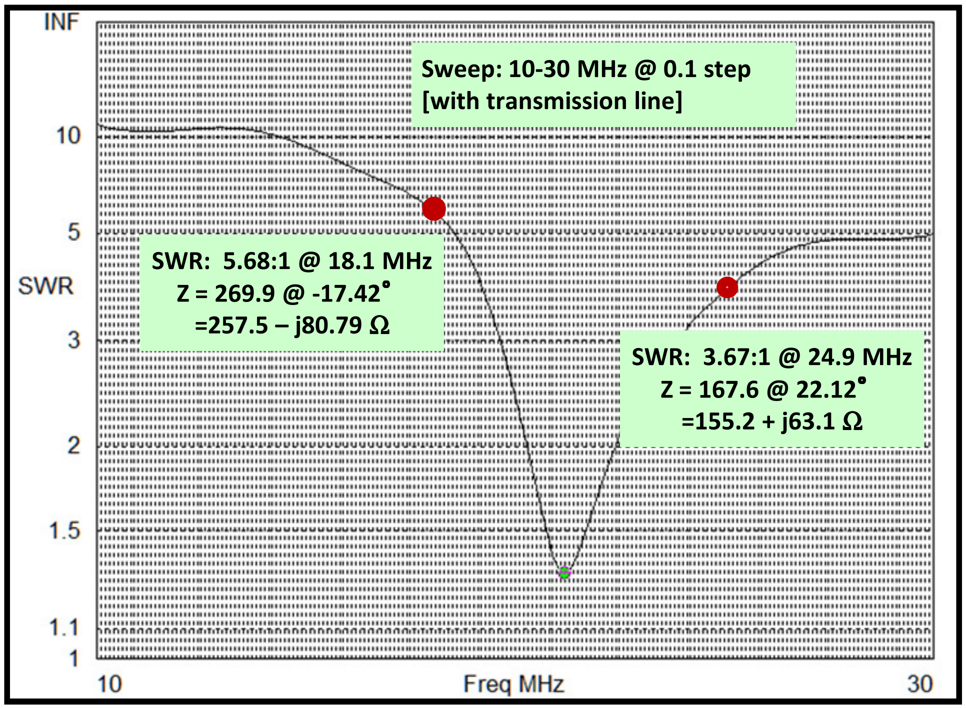


Extra SWR Power Loss:

[70' RG8X]

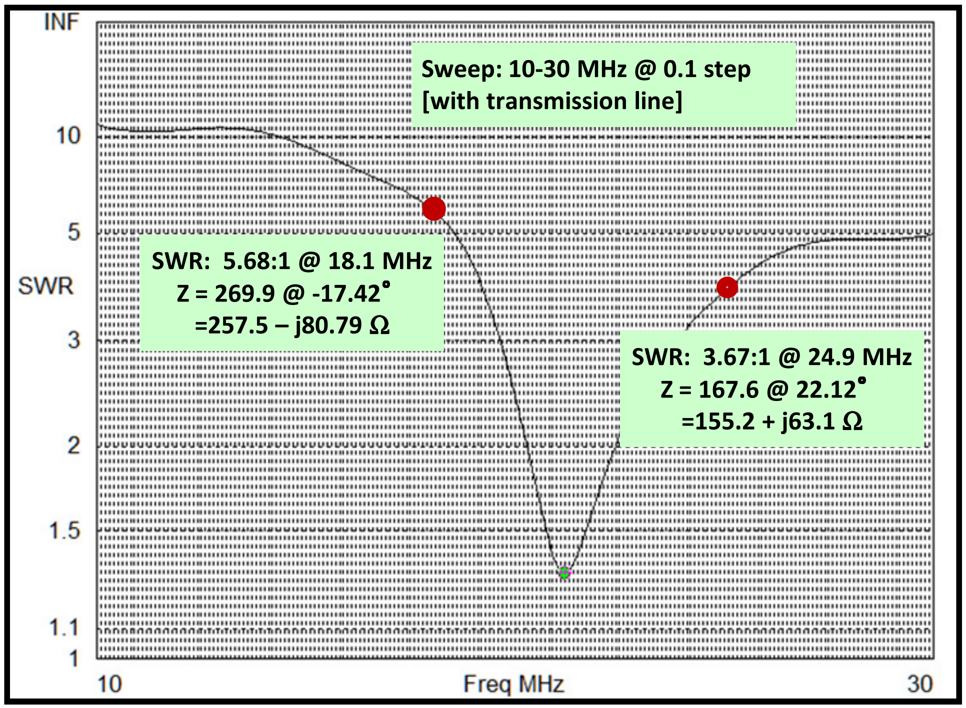
15m	1.3:1	0.3 dB
12m	3.7:1	1.9 dB
17m	5.7:1	3.3 dB

Interactions between Antennas in a 10/15/20m Stack

HB 15m Dipole

Why it's still there: it "works" on 12m and 17m!

SWR is not the sole measure of a good antenna!



Extra SWR Power Loss:

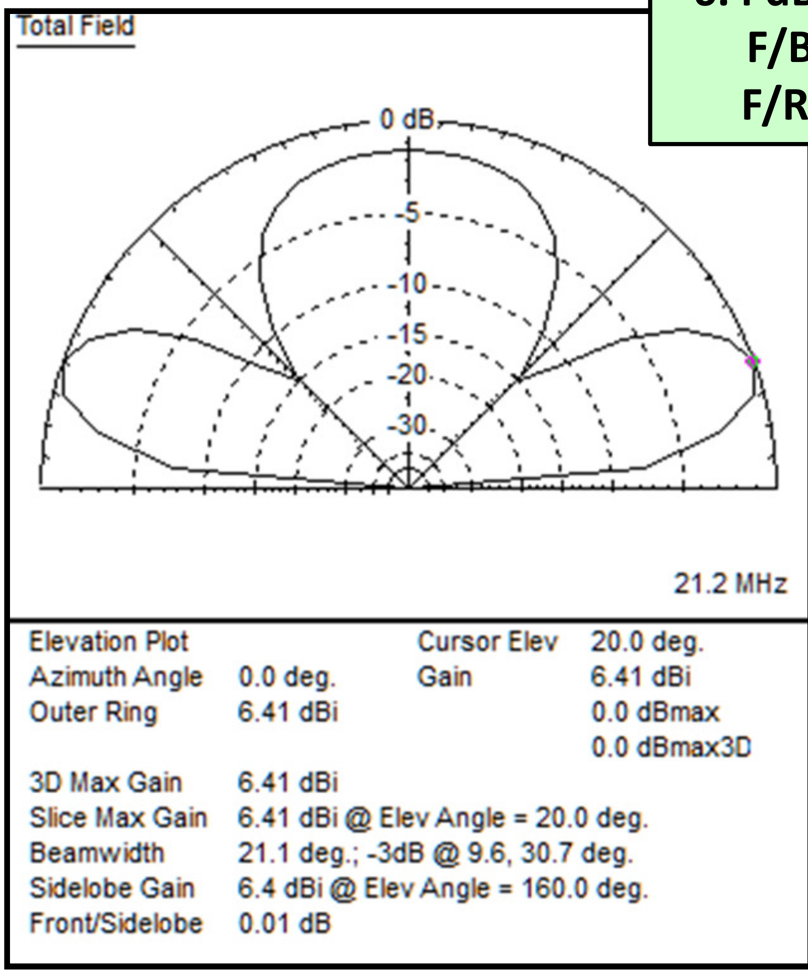
[70' RG8X]

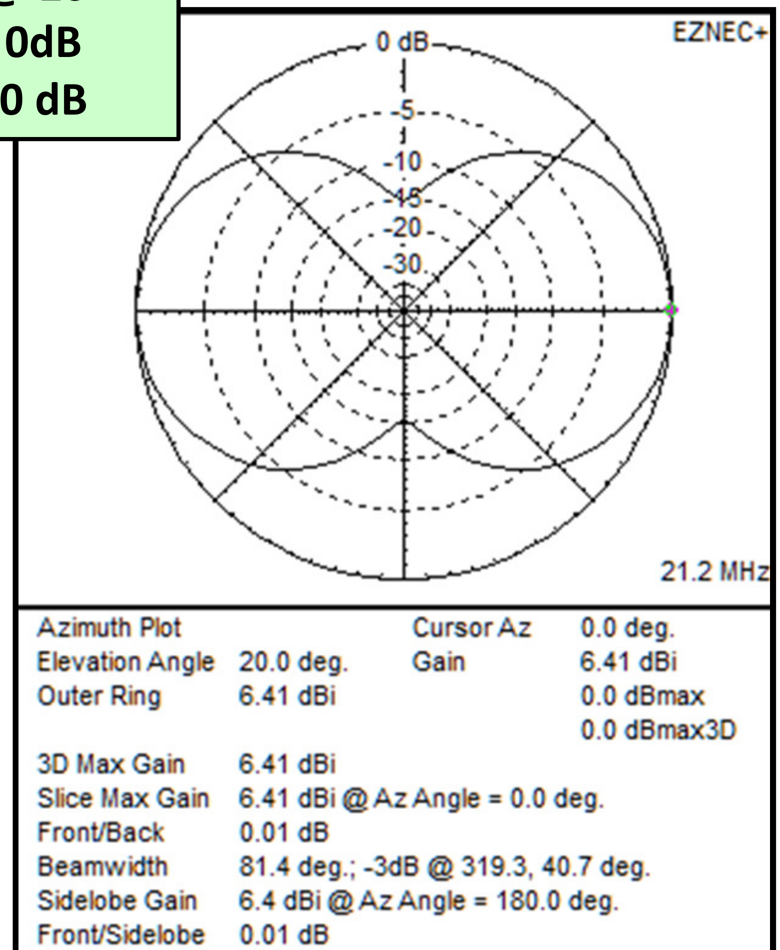
15m	1.3:1	0.3 dB →	93w
12m	3.7:1	1.9 dB →	65w
17m	5.7:1	3.3 dB →	47w

Interactions between Antennas in a 10/15/20m Stack

15m Dipole~ El/Az Patterns on 15m [@ 33' ~ 0.67λ]

6.4 dBi @ 20°
F/B ~ 0dB
F/R ~ 0 dB





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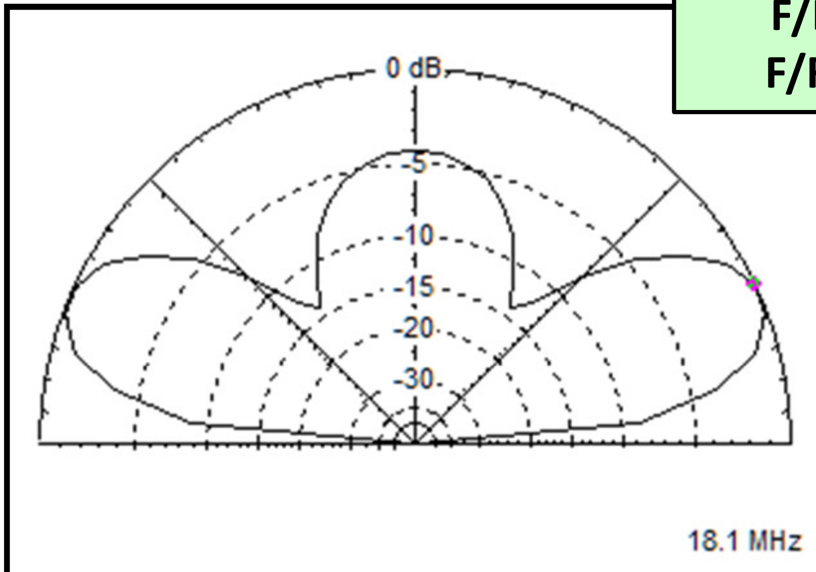
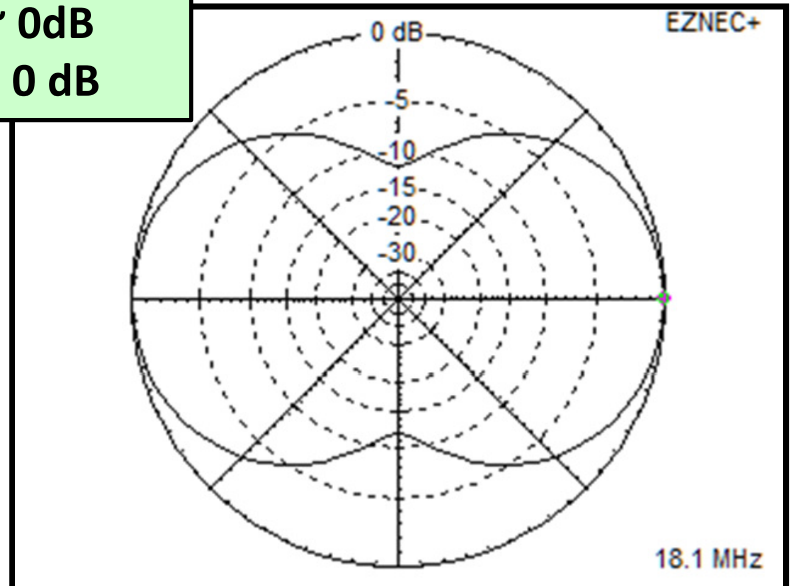
Interactions between Antennas in a 10/15/20m Stack

15m Dipole~ El/Az Patterns on 17m [@ 33' ~ 0.6λ]

3.4 dBi @ 25°
F/B ~ 0dB
F/R ~ 0 dB



Elevation Plot		Cursor Elev	25.0 deg.
Azimuth Angle	0.0 deg.	Gain	3.41 dBi
Outer Ring	3.41 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	3.41 dBi		
Slice Max Gain	3.41 dBi @ Elev Angle = 25.0 deg.		
Beamwidth	25.6 deg.; -3dB @ 11.1, 36.7 deg.		
Sidelobe Gain	3.4 dBi @ Elev Angle = 155.0 deg.		
Front/Sidelobe	0.01 dB		

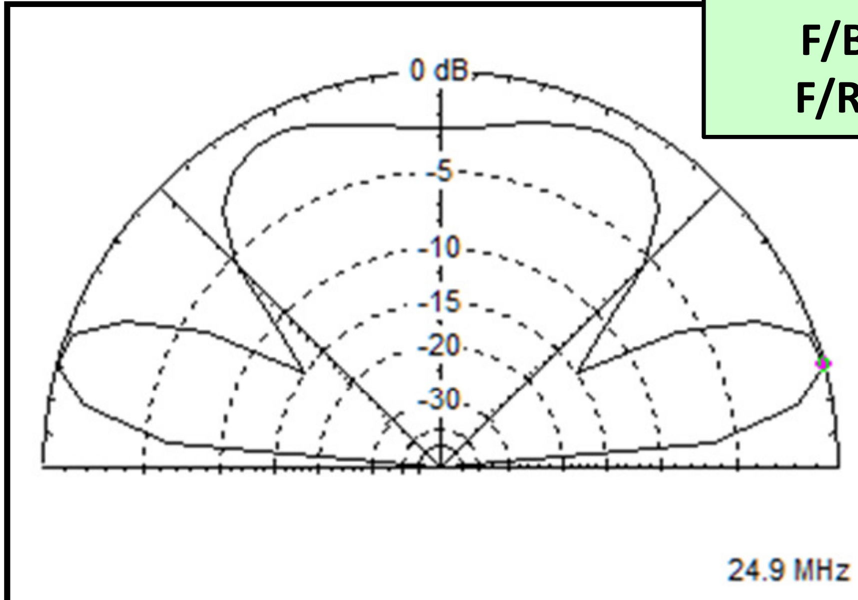


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	25.0 deg.	Gain	3.41 dBi
Outer Ring	3.41 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	3.41 dBi		
Slice Max Gain	3.41 dBi @ Az Angle = 0.0 deg.		
Front/Side	11.77 dB		
Beamwidth	87.4 deg.; -3dB @ 316.3, 43.7 deg.		
Sidelobe Gain	3.4 dBi @ Az Angle = 180.0 deg.		
Front/Sidelobe	0.01 dB		

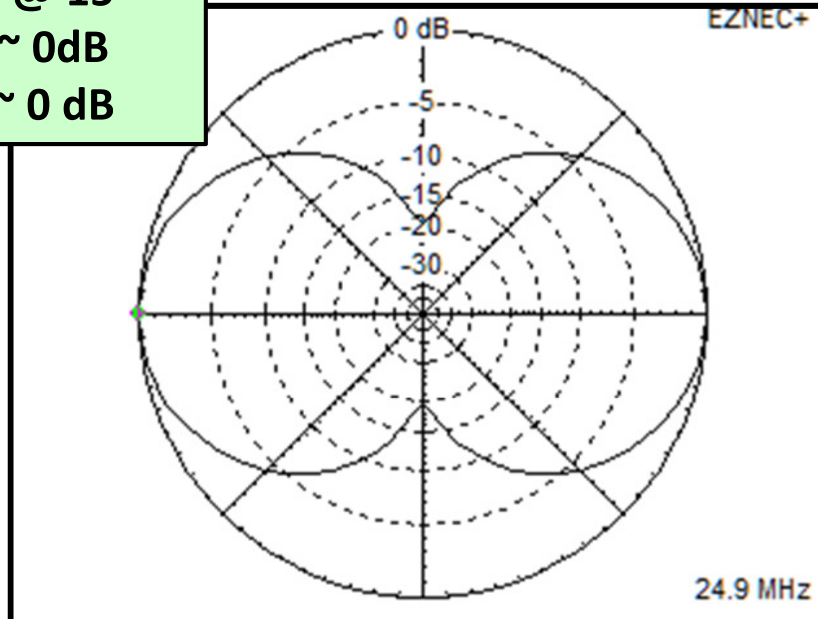
Interactions between Antennas in a 10/15/20m Stack

15m Dipole~ El/Az Patterns on 12m [@ 33' ~ 0.8λ]

4.4 dBi @ 15˚
F/B ~ 0dB
F/R ~ 0 dB



Elevation Plot		Cursor Elev	15.0 deg.
Azimuth Angle	180.0 deg.	Gain	4.38 dBi
Outer Ring	4.38 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	4.38 dBi		
Slice Max Gain	4.38 dBi @ Elev Angle = 15.0 deg.		
Beamwidth	17.3 deg.; -3dB @ 8.6, 25.9 deg.		
Sidelobe Gain	4.38 dBi @ Elev Angle = 165.0 deg.		
Front/Sidelobe	0.0 dB		



Azimuth Plot		Cursor Az	180.0 deg.
Elevation Angle	15.0 deg.	Gain	4.38 dBi
Outer Ring	4.38 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	4.38 dBi		
Slice Max Gain	4.38 dBi @ Az Angle = 0.0 deg.		
Front/Side	19.42 dB		
Beamwidth	75.6 deg.; -3dB @ 322.2, 37.8 deg.		
Sidelobe Gain	4.38 dBi @ Az Angle = 180.0 deg.		
Front/Sidelobe	0.0 dB		

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NORTHERN CALIFORNIA DX FOUNDATION, INC.

Interactions between Antennas in a 10/15/20m Stack

Summary of response of antennas by themselves

Band	~Gain dBi	@ Elev	~F/R dB
20	10.0	25°	17
17	3.4	25°	0
15	6.4	20°	0
12	4.4	15°	0
10	13.4	15°	26

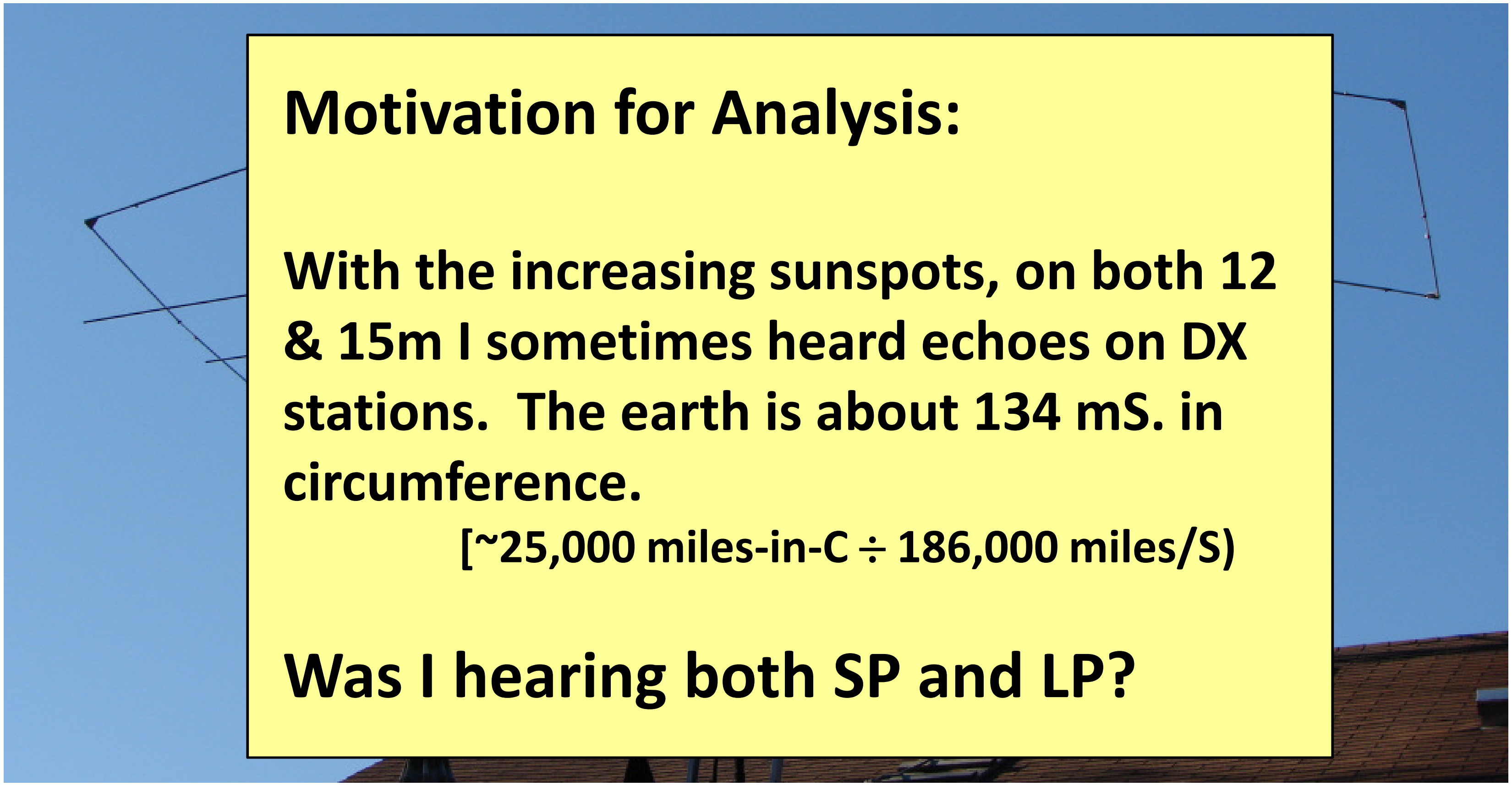
Does not include SWR Loss.

A dipole in "free space" is 0 dBd or ~2.15 dBi

Interactions between Antennas in a 10/15/20m Stack

All 3 Antennas

All 3 Antennas



Motivation for Analysis:

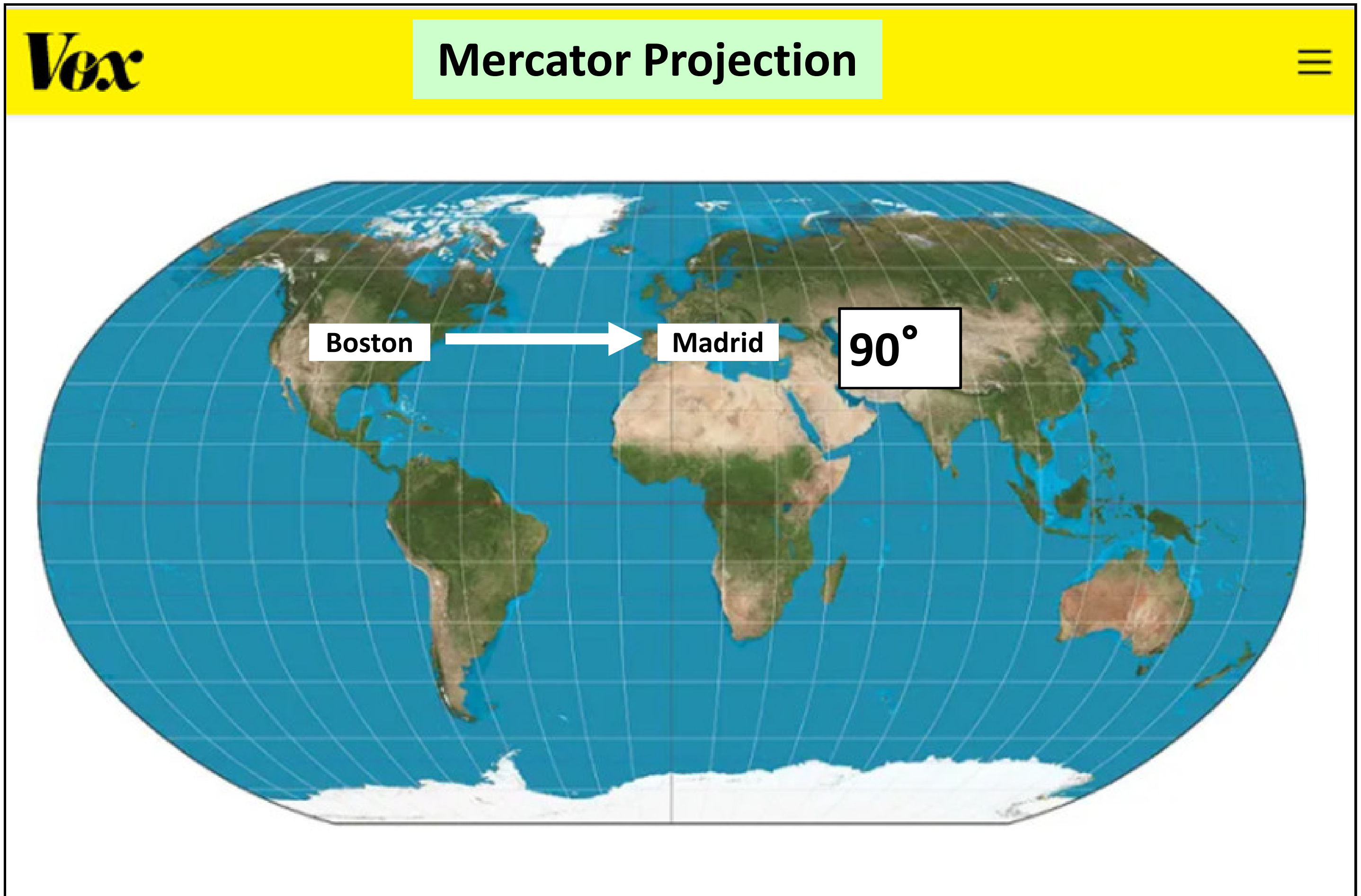
With the increasing sunspots, on both 12 & 15m I sometimes heard echoes on DX stations. The earth is about 134 mS. in circumference.

[~25,000 miles-in-C ÷ 186,000 miles/S)

Was I hearing both SP and LP?

Interactions between Antennas in a 10/15/20m Stack

Short Path / Long Path?

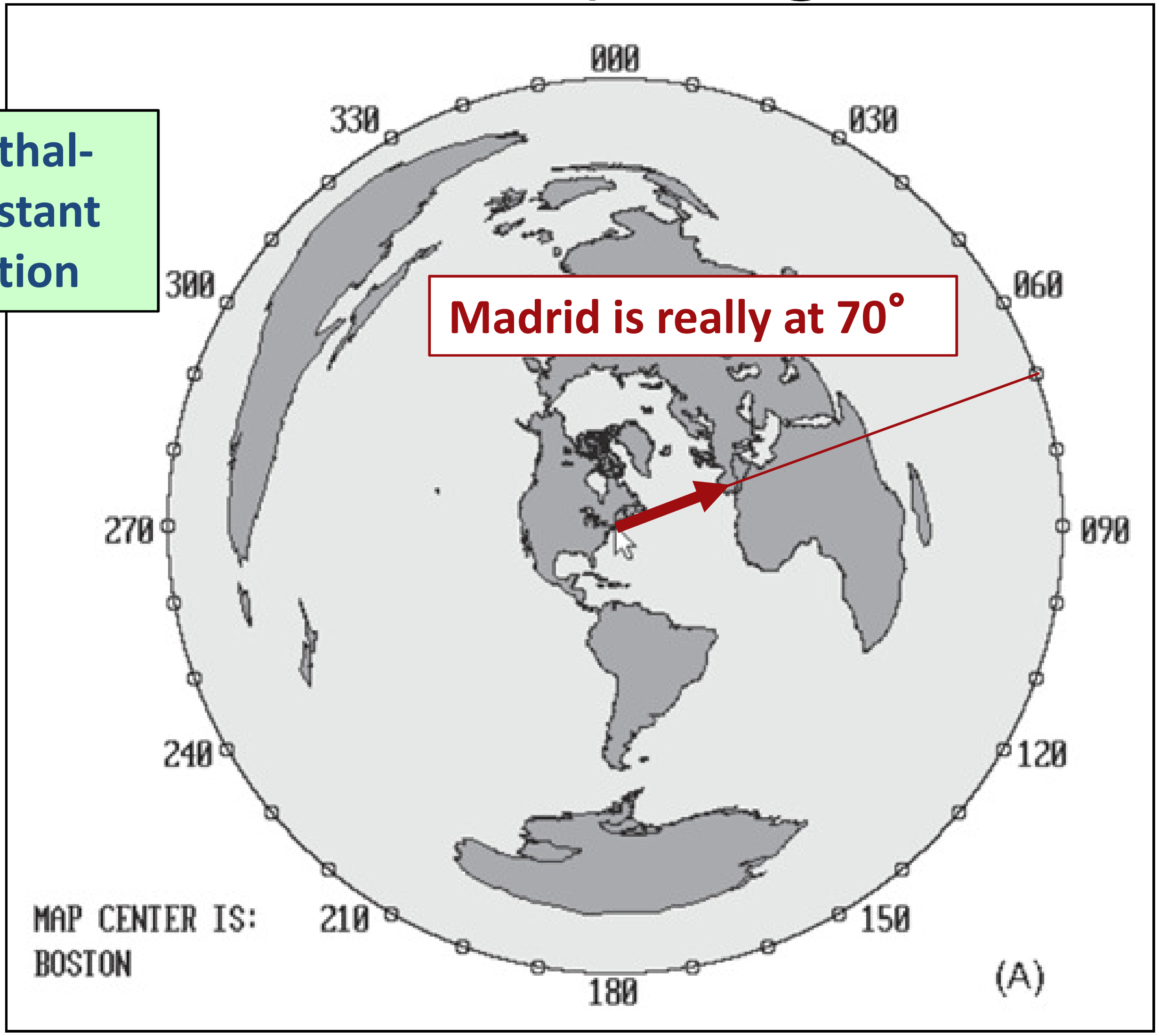


The Robinson Projection (Wikimedia Commons)

Interactions between Antennas in a 10/15/20m Stack

Short Path / Long Path?

Azimuthal-Equidistant Projection



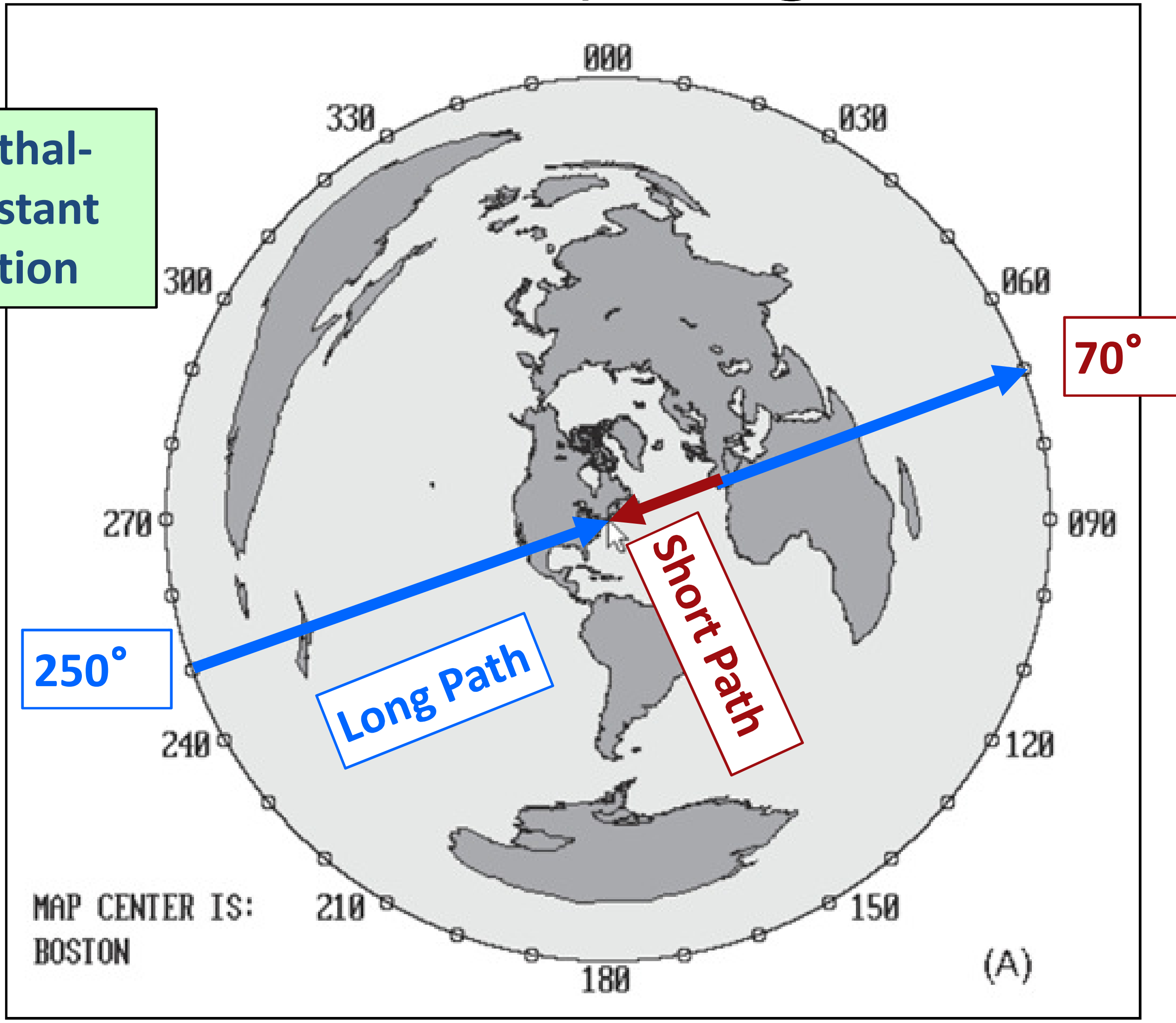
Good for Great-Circle Route

Low-Band DXing Fig 1-28 ON4UN

Interactions between Antennas in a 10/15/20m Stack

Short Path / Long Path?

Azimuthal-Equidistant Projection



Low-Band DXing Fig 1-28 ON4UN

All 3 Antennas

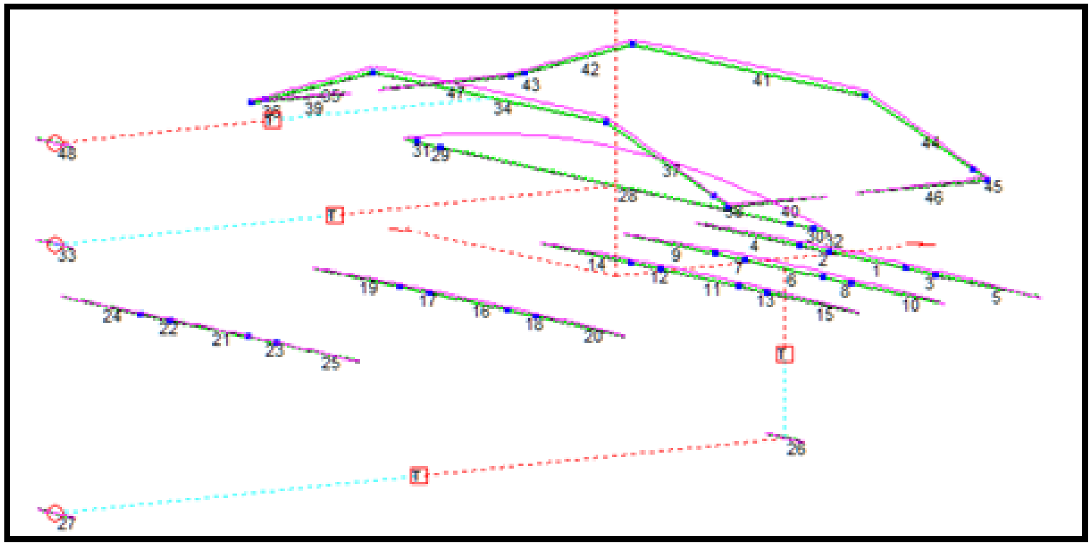
Interactions between Antennas in a 10/15/20m Stack

All 3 Antennas

EXNEC Input ▶

Model with 15m currents

▼



Wires

No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15
16	-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
17	-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
18	-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
19	-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
20	-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
21	-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
22	-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
23	-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
24	-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
25	-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14
26	6	-1	25		6	1	25		#14	5
27	-20	-1	25		-20	1	25		#14	5
28	0	-9	33	W30E2	0	9	33	W29E1	0.75	53
29	0	9	33	W28E2	0	10.25	33	W31E1	0.625	3
30	0	-10.25	33	W32E2	0	-9	33	W28E1	0.625	3
31	0	10.25	33	W29E2	0	11	33		0.5	3
32	0	-11	33		0	-10.25	33	W30E1	0.5	3
33	-20	1	33		-20	-1	33		0.5	7
34	-4.5	-6	36	W37E1	-4.5	6	36	W35E1	0.75	49
35	-4.5	6	36	W34E2	-4.5	11.55	34.5	W36E1	0.625	23
36	-4.5	11.55	34.5	W35E2	-4.5	12.3	34.3	W39E1	0.5	3
37	-4.5	-6	36	W34E1	-4.5	-11.55	34.5	W38E1	0.625	23
38	-4.5	-11.55	34.5	W37E2	-4.5	-12.3	34.3	W40E1	0.5	3
39	-4.5	12.3	34.3	W36E2	-0.92	12.3	34.3		0.5	14
40	-4.5	-12.3	34.3	W38E2	-0.92	-12.3	34.3		0.5	14
41	4.75	-6	36	W44E1	4.75	6	36	W42E1	0.75	49
42	4.75	6	36	W41E2	4.75	11.55	34.5	W43E1	0.625	23
43	4.75	11.55	34.5	W42E2	4.75	12.3	34.3	W47E1	0.5	3
44	4.75	-6	36	W41E1	4.75	-11.55	34.5	W45E1	0.625	23
45	4.75	-11.55	34.5	W44E2	4.75	-12.3	34.3	W46E1	0.5	3
46	4.75	-12.3	34.3	W45E2	0	-12.3	34.3		0.5	19
47	4.75	12.3	34.3	W43E2	0	12.3	34.3		0.05	19
48	-20	1	36		-20	-1	36		0.5	7

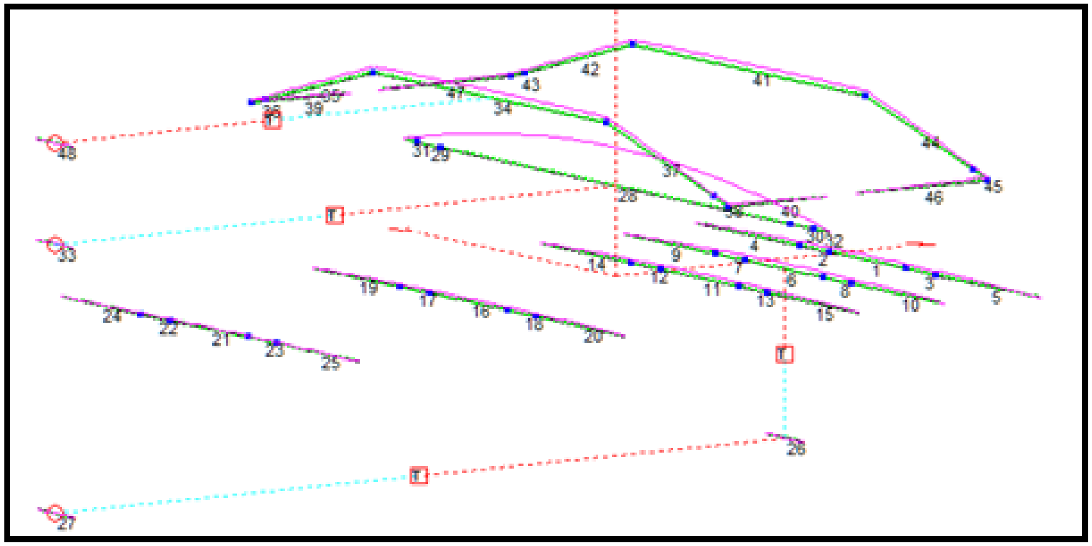
INDEXA

Interactions between Antennas in a 10/15/20m Stack

All 3 Antennas

EXNEC Input ▶

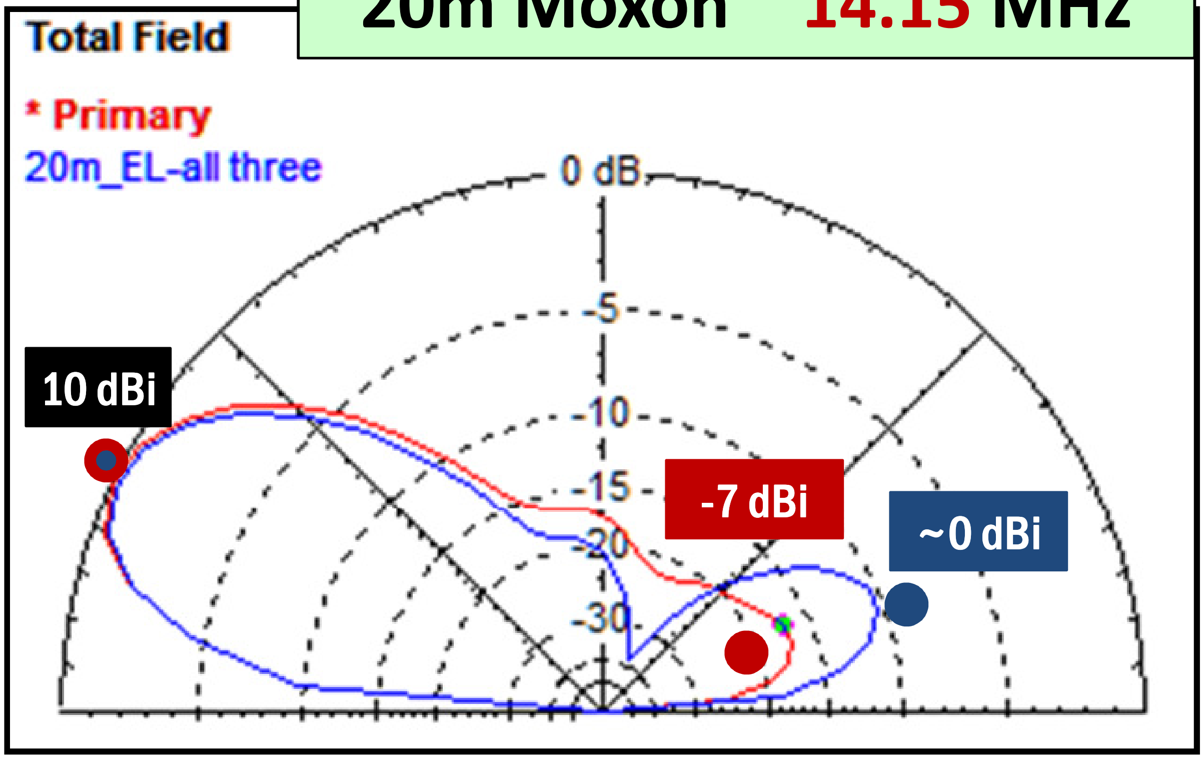
Model with 15m currents ▼

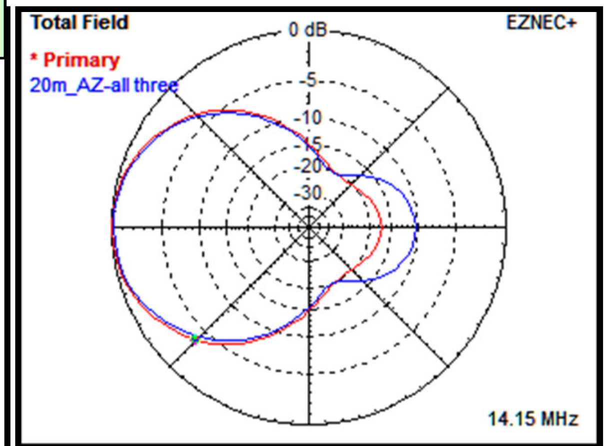


Wires										
No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15
16	-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
17	-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
18	-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
19	-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
20	-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
21	-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
22	-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
23	-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
24	-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
25	-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14
26	6	-1	25		6	1	25		#14	5
27	-20	-1	25		-20	1	25		#14	5
28	0	-9	33	W30E2	0	9	33	W29E1	0.75	53
29	0	9	33	W28E2	0	10.25	33	W31E1	0.625	3
30	0	-10.25	33	W32E2	0	-9	33	W28E1	0.625	3
31	0	10.25	33	W29E2	0	11	33		0.5	3
32	0	-11	33		0	-10.25	33	W30E1	0.5	3
33	-20	1	33		-20	-1	33		0.5	7
34	-4.5	-6	36	W37E1	-4.5	6	36	W35E1	0.75	49
35	-4.5	6	36	W34E2	-4.5	11.55	34.5	W36E1	0.625	23
36	-4.5	11.55	34.5	W35E2	-4.5	12.3	34.3	W39E1	0.5	3
37	-4.5	-6	36	W34E1	-4.5	-11.55	34.5	W38E1	0.625	23
38	-4.5	-11.55	34.5	W37E2	-4.5	-12.3	34.3	W40E1	0.5	3
39	-4.5	12.3	34.3	W36E2	-0.92	12.3	34.3		0.5	14
40	-4.5	-12.3	34.3	W38E2	-0.92	-12.3	34.3		0.5	14
41	4.75	-6	36	W44E1	4.75	6	36	W42E1	0.75	49
42	4.75	6	36	W41E2	4.75	11.55	34.5	W43E1	0.625	23
43	4.75	11.55	34.5	W42E2	4.75	12.3	34.3	W47E1	0.5	3
44	4.75	-6	36	W41E1	4.75	-11.55	34.5	W45E1	0.625	23
45	4.75	-11.55	34.5	W44E2	4.75	-12.3	34.3	W46E1	0.5	3
46	4.75	-12.3	34.3	W45E2	0	-12.3	34.3		0.5	19
47	4.75	12.3	34.3	W43E2	0	12.3	34.3		0.05	19
48	-20	1	36		-20	-1	36		0.5	7

Interactions between Antennas in a 10/15/20m Stack

20m Moxon ~ 14.15 MHz

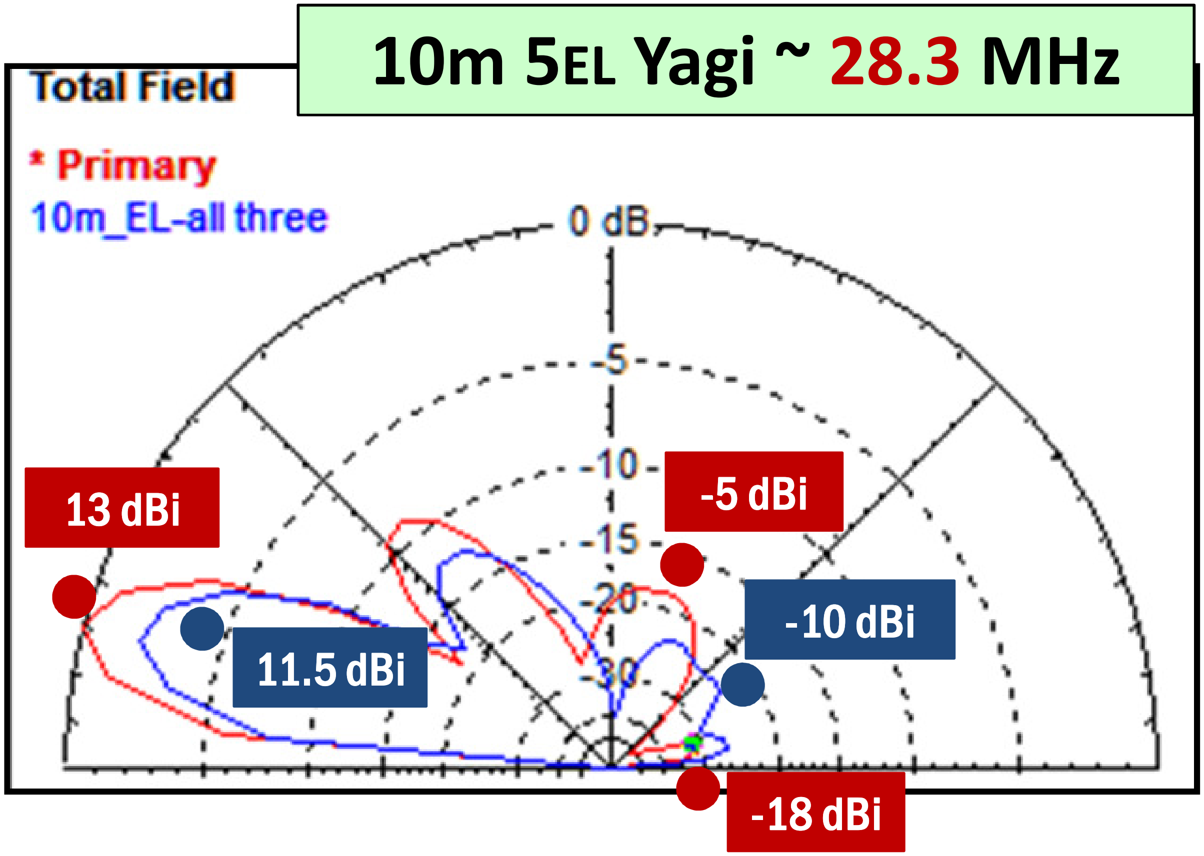


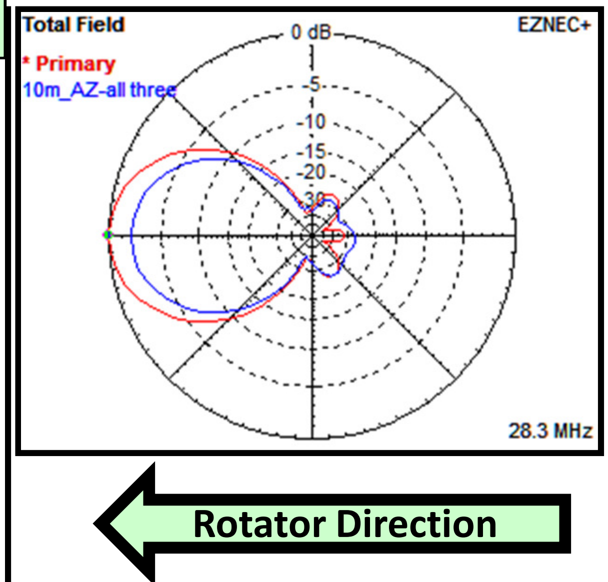


Rotator Direction

RED – by itself:	FG ~ 10dBi	F/R ~ 17 dB
Blue – all three:	FG ~ 10dBi	F/R ~ 10 dB
Δ:	±0 dB	-7 dB

Interactions between Antennas in a 10/15/20m Stack

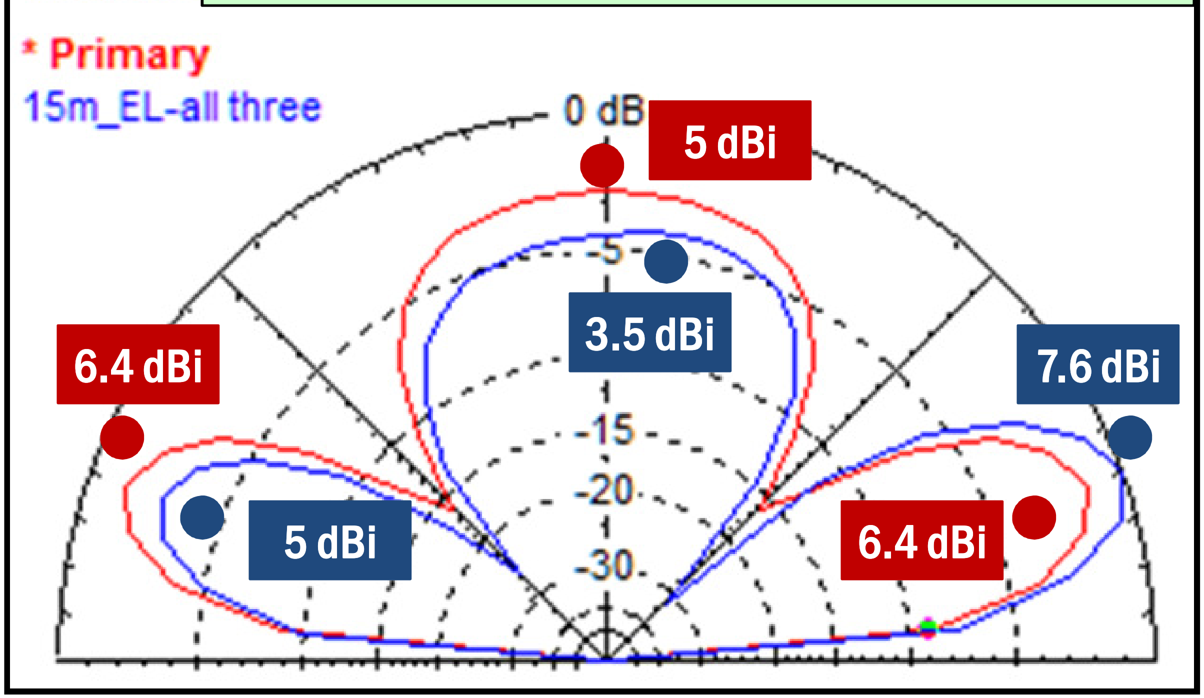


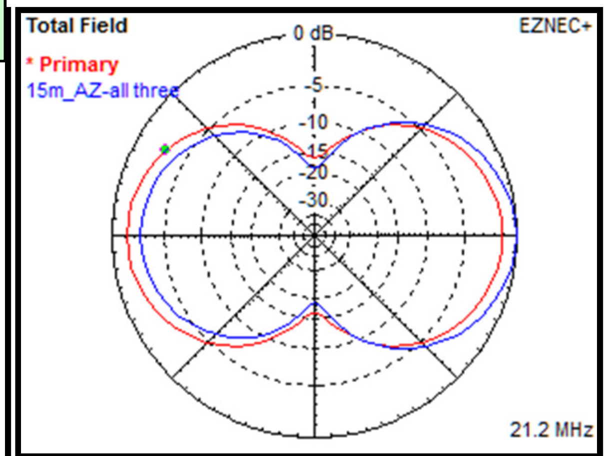


RED – by itself:	FG ~ 13dBi	F/R ~ 18 dB	*[F/B ~ 31 dB]*
Blue – all three:	FG ~ 11.5dBi	F/R ~ 21.5 dB	
Δ:	- 1.5 dB	+3.5 dB	

Interactions between Antennas in a 10/15/20m Stack

15m Dipole @ 15m ~ 21.2 MHz





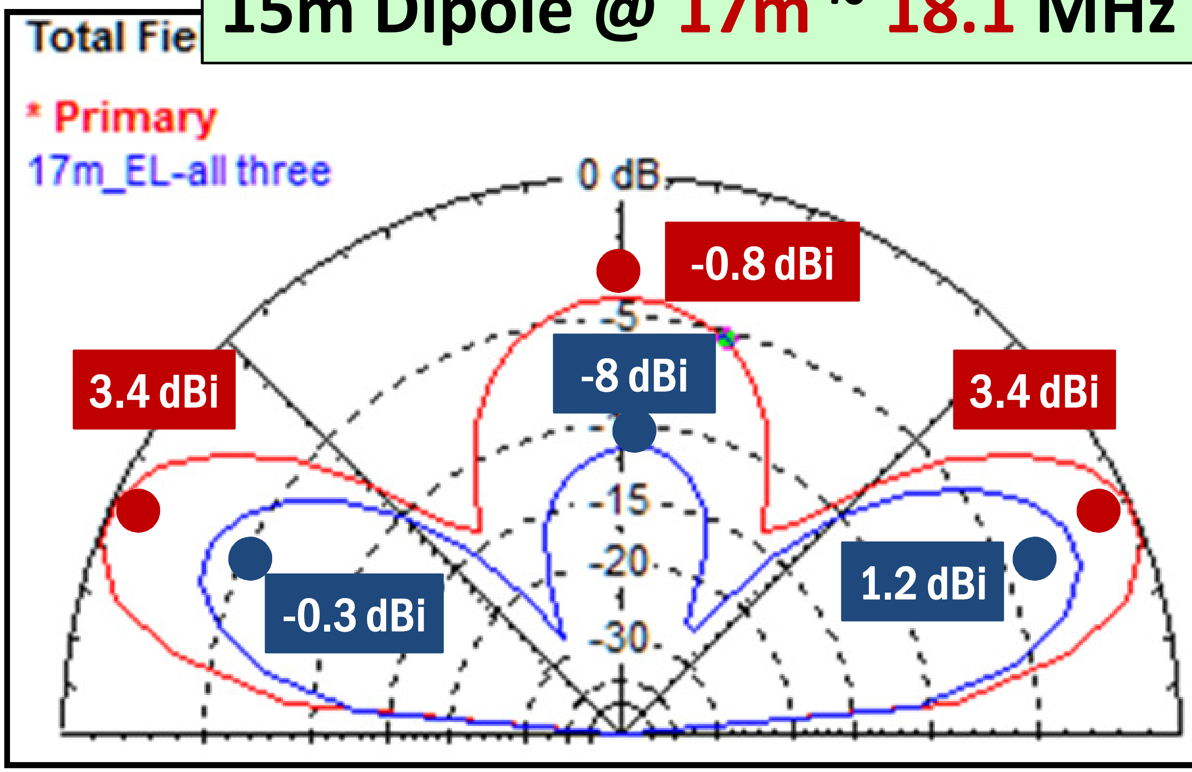
Rotator Direction

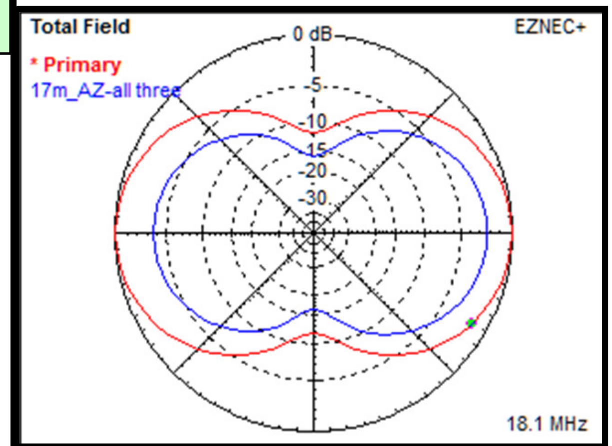
Gain Direction

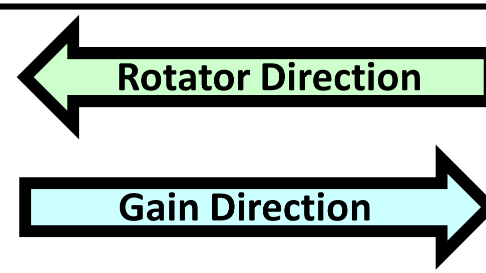
RED – by itself: FG ~ 6.4dBi	F/R ~ 0 dB *[G@90° – 1.5dB]*
Blue – all three: FG ~ 7.6dBi	F/R ~ 2.6 dB
Δ: + 1.2 dB	+2.6 dB

Interactions between Antennas in a 10/15/20m Stack

15m Dipole @ 17m ~ 18.1 MHz



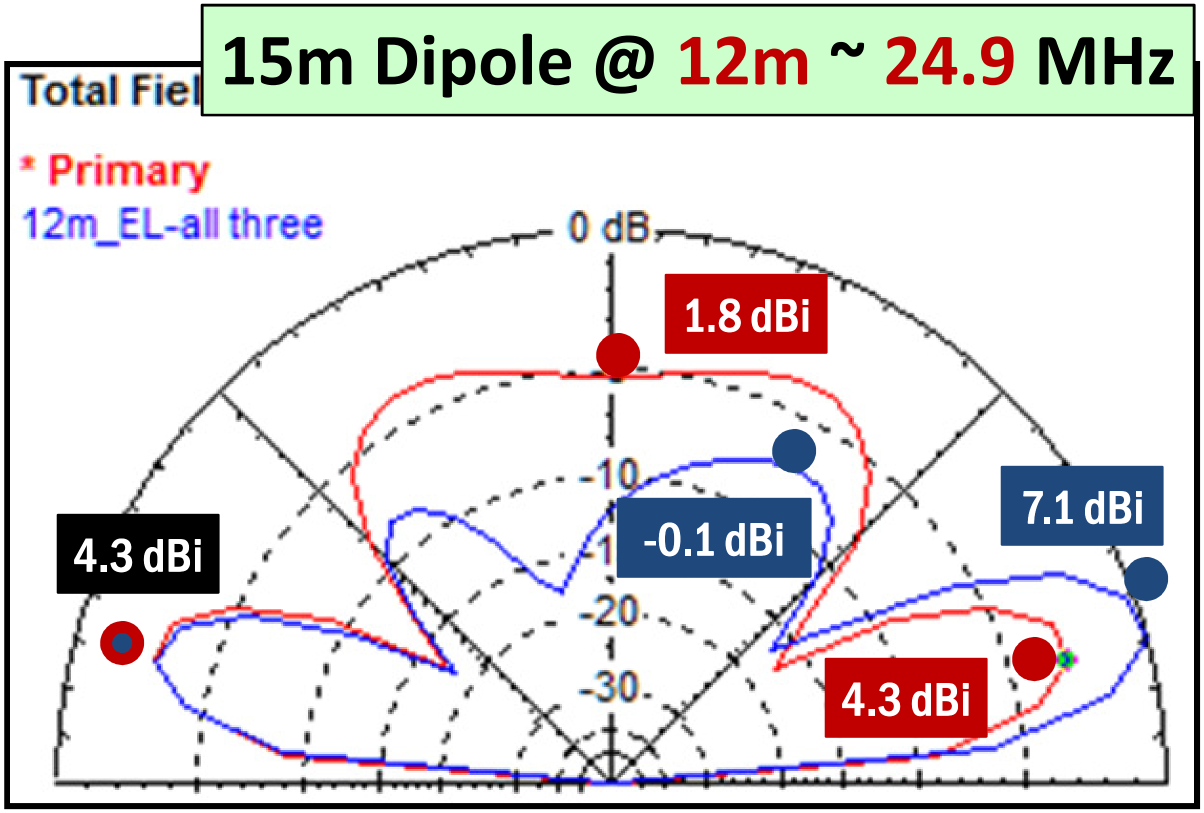


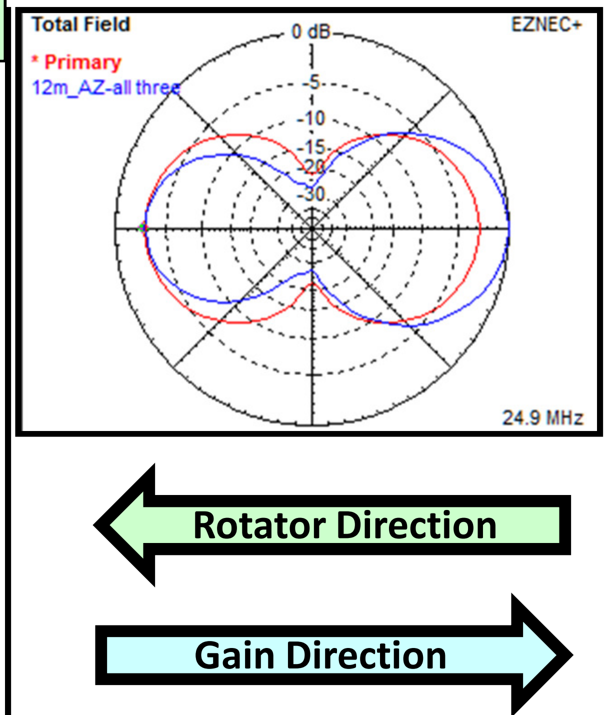


RED – by itself:	FG ~ 3.4dBi	F/R ~ 0 dB *[G@90° – 7.2dB]*
Blue – all three:	FG ~ 1.2dBi	F/R ~ 1.5 dB
Δ:	- 2.2 dB	+1.5 dB

Interactions between Antennas in a 10/15/20m Stack

15m Dipole @ 12m ~ 24.9 MHz





RED – by itself:	FG ~ 4.3dBi	F/R ~ 0 dB *[G@90° – 1.9dB]*
Blue – all three:	FG ~ 7.1dBi	F/R ~ 2.8 dB
Δ:	+2.8 dB	+2.8 dB

Conclusions

	Δ Fwd Gain*	Δ F/R*	Usage
• 20m	±0 dB	-7 dB	normal
• 17m	- 2.2dB	+1.5dB	reverse
• 15m	+1.2dB	+2.6dB	reverse
• 12m	+2.8 db	+2.8 dB	reverse
• 10m	-1.5dB	+3.5 dB	normal

• From model results of antennas by themselves.

Interactions between Antennas in a 10/15/20m Stack

Current Results: as of *3 April* ~ all at Low Power / ≤ 100w.

Confirmed Countries

Band	Overall	Phone	CW	Digital
20	262	187	171	155
17	228	52	38	191
15	248	155	155	183
12	216	26	33	173
10	230	177	140	127

Confirmed States

Band	Overall	Phone	CW	Digital
20	50	50	48	50
17	50	5	1	50
15	50	42	43	50
12	50	1	0	50
10	50	50	49	50

Overall:

DXCC:
298c/300w
[max = 340]
[Honor Roll = 331]

DX Challenge:
1898c/1924w
[max = 3129?]

Interactions between Antennas in a 10/15/20m Stack

However… More work to be done…

6m Yagi nearby with 22' boom: resonant @ ~23 MHz.
2m Yagi nearby with 17.3' boom: resonant @ ~28.5 MHz.
432 Yagi nearby with 11.4' boom: resonant @ ~43 MHz.

Thank You!

https://www.qsl.net/w1dyj/

Appendix

Abstract, etc.

Analysis Methodology

Details of Models of Individual Antennas
- **20m Moxon**
- **10m Yagi**
- **15m Dipole**

Details of Models of All Three Antennas

Abstract

Interactions between Antennas in a 10/15/20m Stack

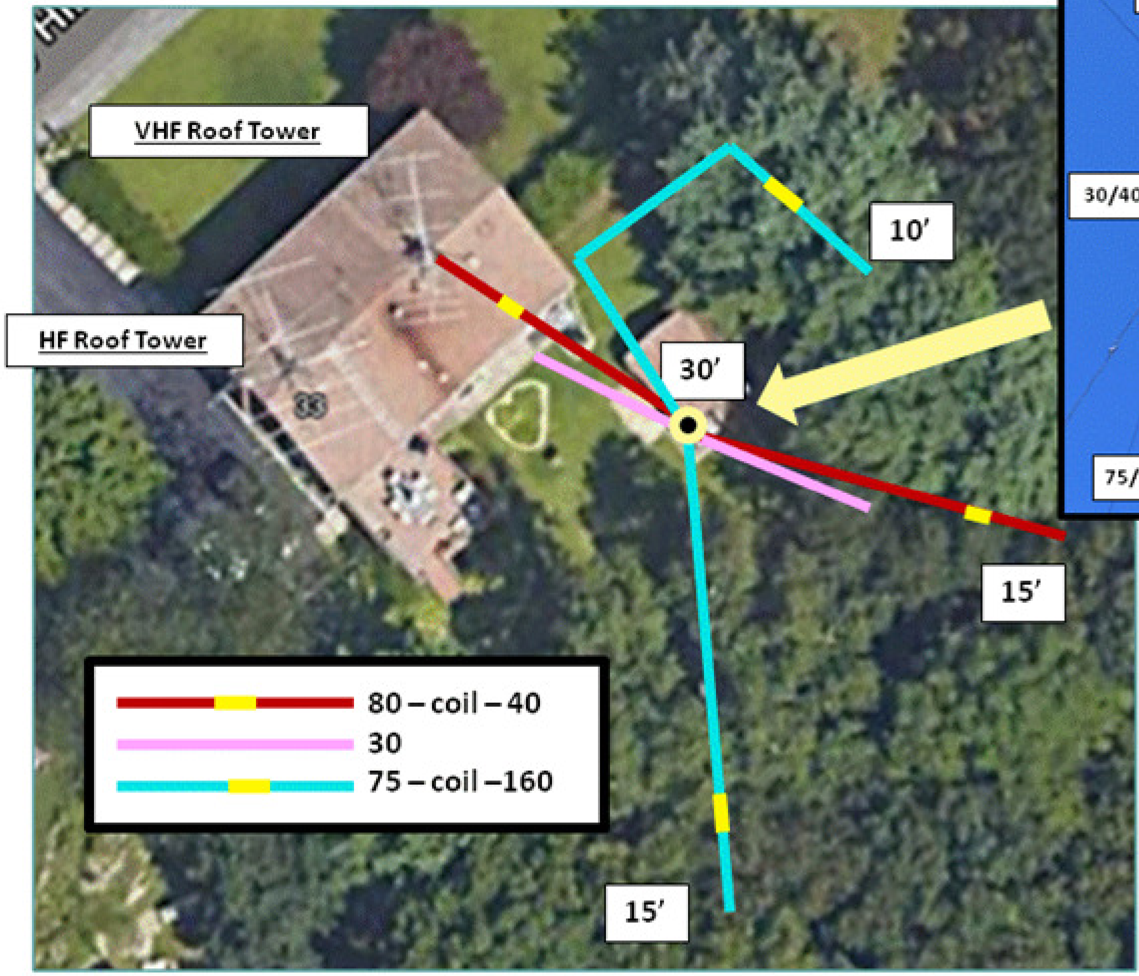
In 2000 I homebrewed a 5-element 10m Yagi and put it on a roof tower. In 2004 I added a 20m homebrew Moxon. Finally, in 2010 I added a homebrew 15m dipole. Recently with the improving sunspot cycle, I now and then heard something I didn't understand. Recent modeling revealed counterintuitive antenna patterns.

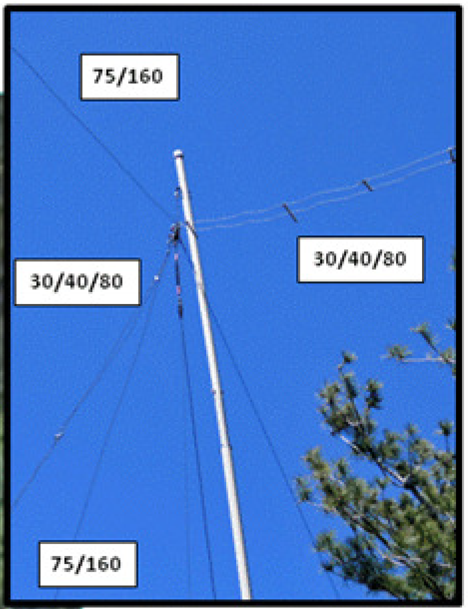
Licensed in 1961 as novice KN1VFX, Larry became W1DYJ in 1966. After acquiring three degrees in EE from MIT, Larry was hired in 1969 by Hewlett-Packard Medical's Cardiac lab in Waltham MA (later in Andover MA,) working on Electrocardiographs and then Cardiac Ultrasound systems. He moved to HP Medical Education in 1993, responsible for technical and project management training. When HP split apart, he became Agilent Technology's global program manager for their Learning Management System. "Retiring" in 2005, he consulted for Avago (now Broadcom) on eLearning technologies through 2012. He now spends his time chasing DX and contesting in Woburn, playing with antennas, traveling with his wife Maren, and attending many jazz and classical concerts. He is the net manager and newsletter editor for the MMRA, publications editor for HamXposition, and a member of the YCCC.

Ham Radio ~ Who Am I?

- **Mom was a high School cafeteria worker. Dad was an electrician and had a dual workshop: *woodworking* and *electronics* (my two continuing favorite hobbies). They both highly valued education.**
- **As a kid: I "played" in his workshop, had an erector set,**
  and read all the Tom Swift books…
- **Built a crystal radio when I was 12 (1958) –the first station heard was the BBC**
  and I was hooked on radio.
- **Obtained my ham radio license at 15 in 1961 (a junior in HS).**
- **Went to MIT (SBEE'67, SMEE'69, EE'70)**
  in part because of my ham radio experience.
- **Hired (1969) by HP Medical (Waltham/Andover) developing hospital cardiac instrumentation (electrocardiographs, then real-time cardiac ultrasound)**
  in part because of my practical experience with ham radio.
- **Moved to HP/Agilent Corp Ed (project management experience) in 1993**
- **"Retired" in 2005; then part-time consulted for Avago (now Broadcom) as their eLearning platform WW PM**
- **Finally retired (for real) in 2012 – now play with ham radio**

W1DYJ 160m – 30m Antennas



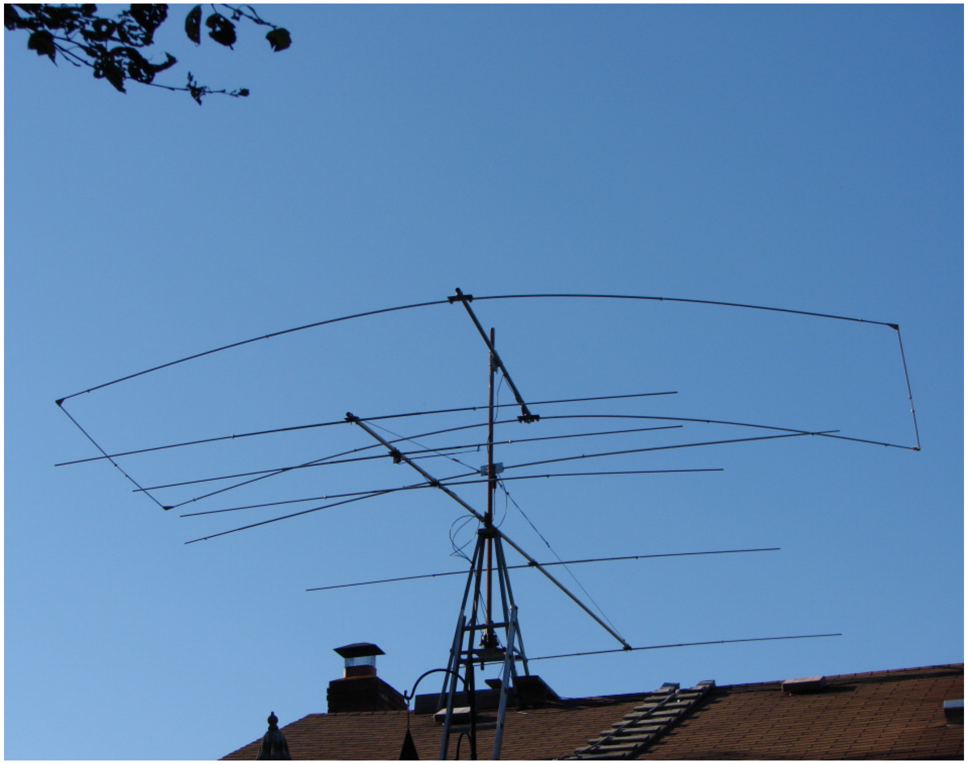


N

W1DYJ 20m – 70cm Antennas

Analysis Methodology

- EZNEC analysis of each antenna
  - 20m Moxon
    - Model Details
    - Frequency sweep: 10 → 30 MHz
    - Detailed sweep @ 20m
    - El / Az RF pattern @ 20m (@ SWR_{min})
  - 15m dipole
    - As above, but for 17, 15, & 12m
  - 10m 5el HB Yagi
    - As above
- EZNEC Analysis of the three antennas combined together
  - Including *SARK 110* SWR measurements of each antenna

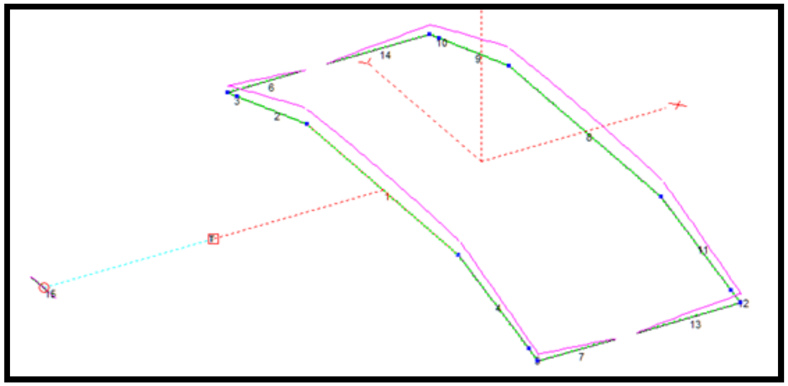


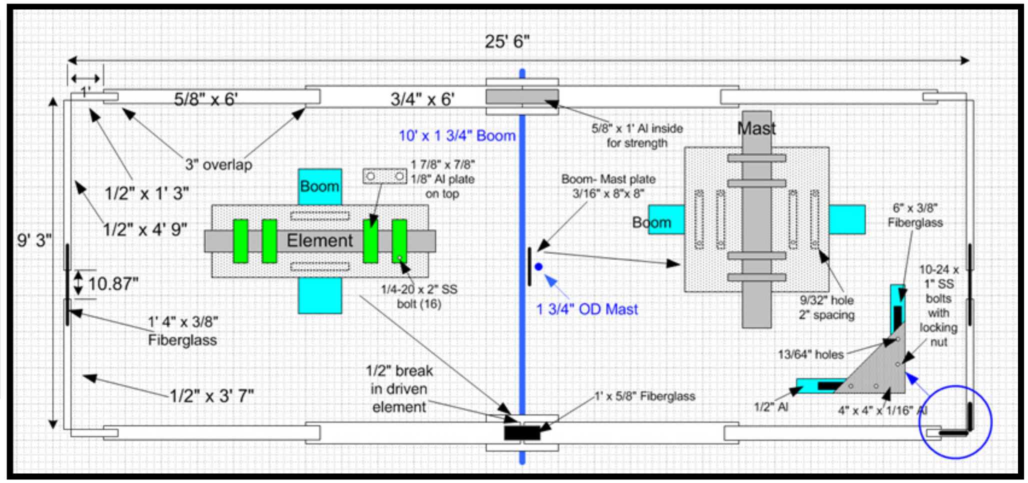
Upper HF Antenna Stack

20m HB Moxon

2004

20m Moxon ~ Model Details [built in 2004]





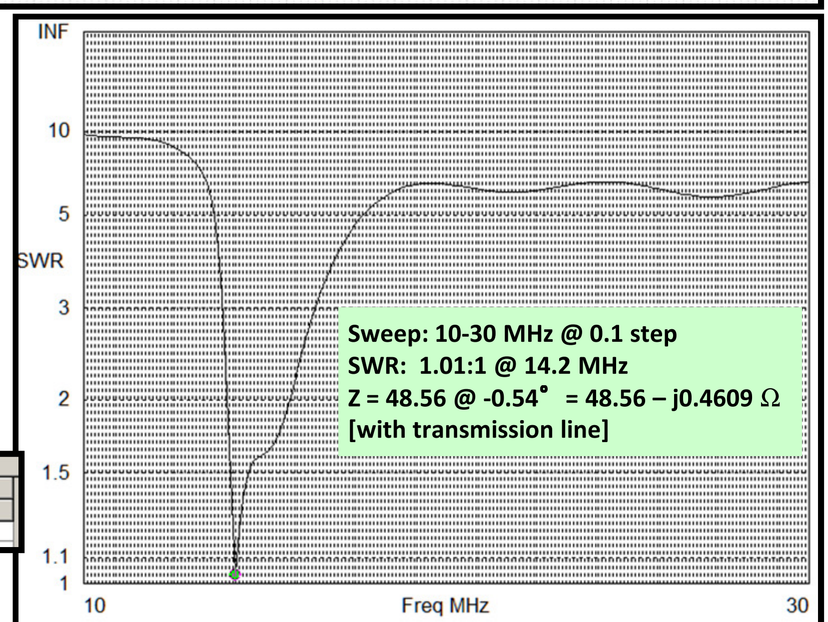
No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	-4.5	-6	36	W4E1	-4.5	6	36	W2E1	0.75	49
2	-4.5	6	36	W1E2	-4.5	11.55	34.5	W3E1	0.625	23
3	-4.5	11.55	34.5	W2E2	-4.5	12.3	34.3	W6E1	0.5	3
4	-4.5	-6	36	W1E1	-4.5	-11.55	34.5	W5E1	0.625	23
5	-4.5	-11.55	34.5	W4E2	-4.5	-12.3	34.3	W7E1	0.5	3
6	-4.5	12.3	34.3	W3E2	-0.92	12.3	34.3		0.5	14
7	-4.5	-12.3	34.3	W5E2	-0.92	-12.3	34.3		0.5	14
8	4.75	-6	36	W11E1	4.75	6	36	W9E1	0.75	49
9	4.75	6	36	W8E2	4.75	11.55	34.5	W10E1	0.625	23
10	4.75	11.55	34.5	W9E2	4.75	12.3	34.3	W14E1	0.5	3
11	4.75	-6	36	W8E1	4.75	-11.55	34.5	W12E1	0.625	23
12	4.75	-11.55	34.5	W11E2	4.75	-12.3	34.3	W13E1	0.5	3
13	4.75	-12.3	34.3	W12E2	0	-12.3	34.3		0.5	19
14	4.75	12.3	34.3	W10E2	0	12.3	34.3		0.5	19
15	-20	1	36		-20	-1	36		0.5	7

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(ft)	(ohms)			(dB/100 ft)	(MHz)
1	15	50	50	1	50	50	70	50	0.82	N	1.25	14

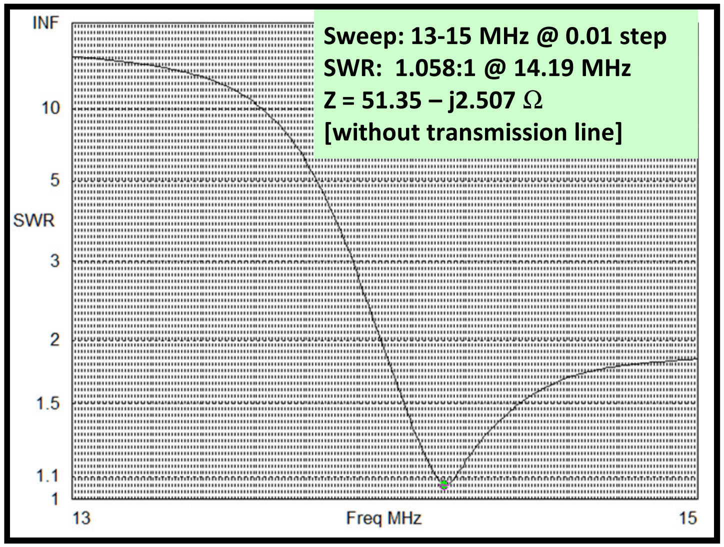
Sources

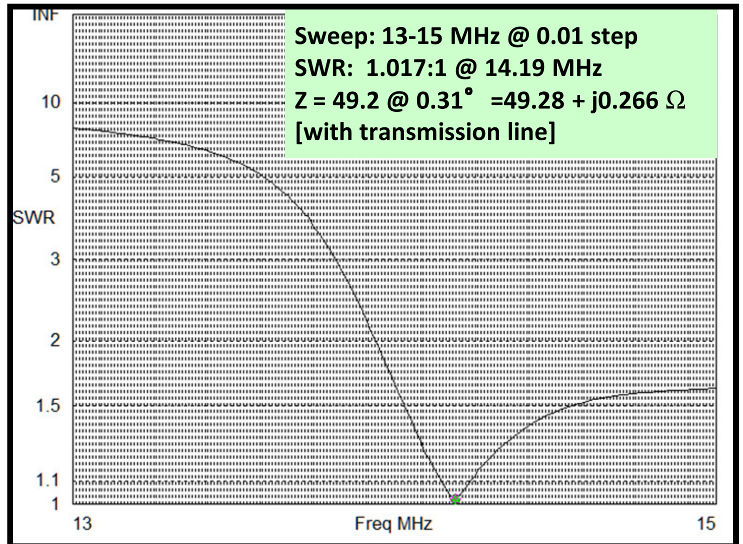
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	15	50	50	4	1	0	I

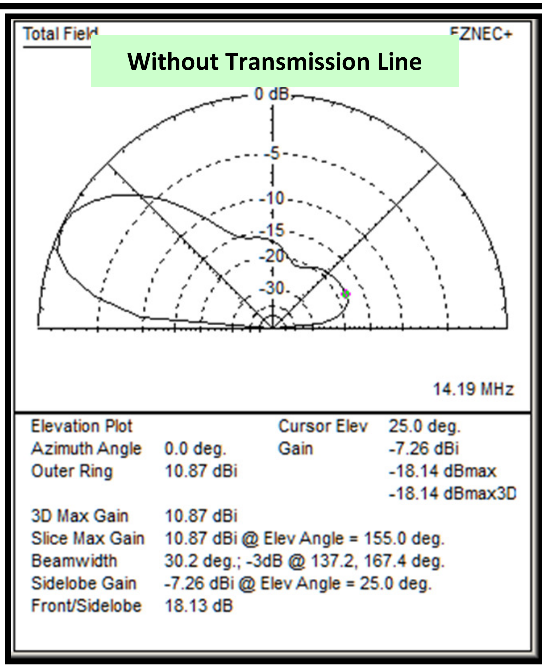


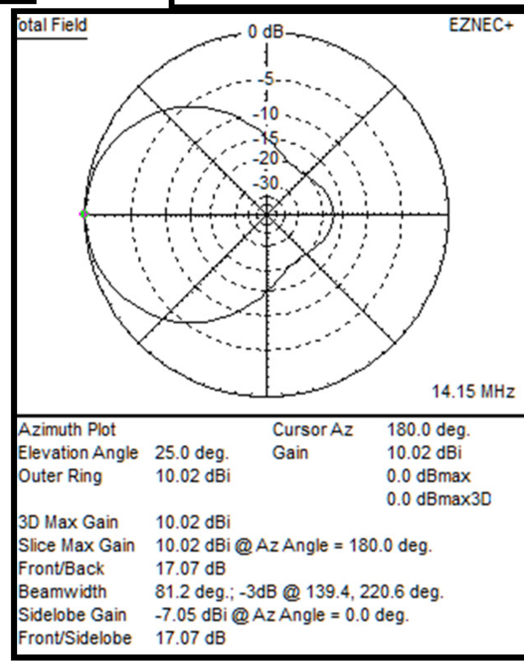
File: 20m-droop_XmsLn_2023_0514

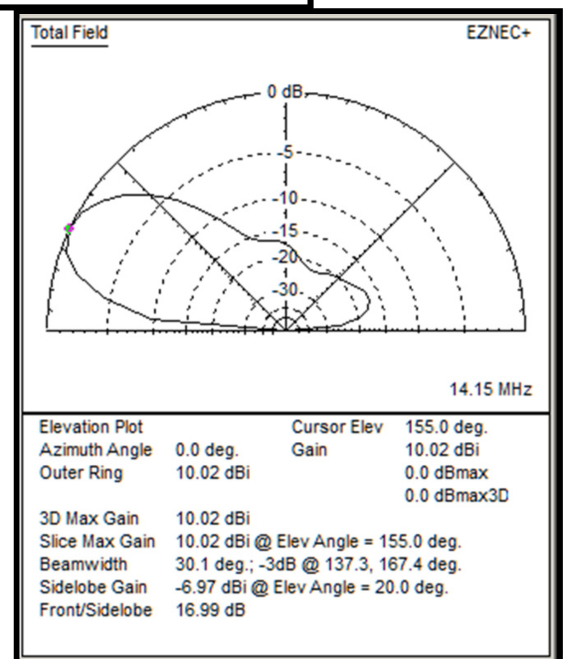
20m Moxon ~ EZNEC Simulation Results











Upper HF Antenna Stack

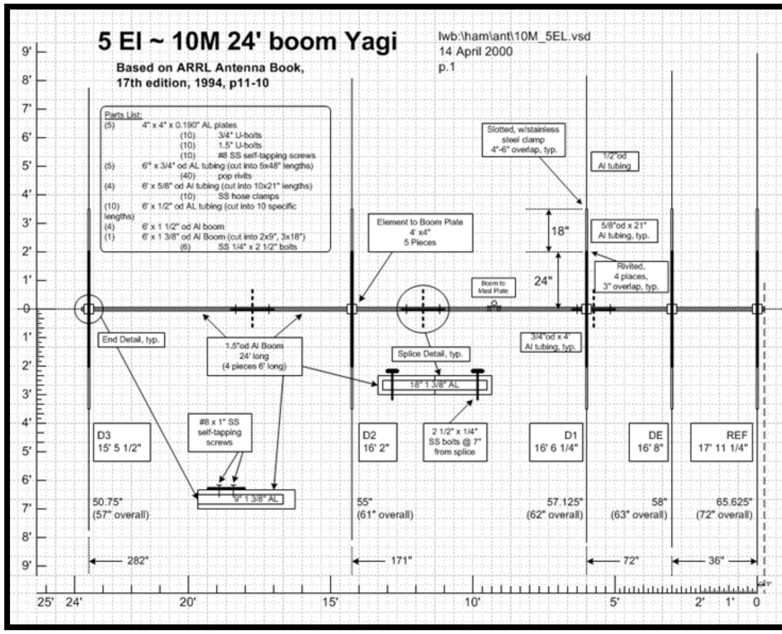
10m HB 5-EL Yagi

2000

10m 5el Yagi I~ Model Details from YW [built in 2000]

```
LWB-510-24H.YW, 510-24H.YW, 5-ele., 24' boom, heavy-duty elements
28.0   28.4   28.8 MHz
 5 elements, inches
             2.405    0.750    0.625    0.500
   0.000     2.000   22.000   18.000   65.625
             2.405    0.750    0.625    0.500
  36.000     2.000   22.000   18.000   58.000
  72.000     2.000   22.000   18.000   57.125
 171.000     2.000   22.000   18.000   55.000
 282.000     2.000   22.000   18.000   50.750

Match frequency: 28.4 MHz
Driven-element tip: 58.0 inches
Cable Z0: 50.0 ohms
Gamma rod diameter:  0.25 inches
Gamma rod spacing:  6.0 inches
Gamma capacitance = 45.8 pF
Gamma rod length = 15.44 inches

Original file name: C:\PROGRAM FILES (X86)\ARRL\ANTBK21\YAGIS\510-24H.YW


NOTE: the lengths of the 0.750" o.d. sections have been reduced by the
lengths of the 2.405" o.d. sections which simulate mounting plates, which
are elements will withstand 125 mph winds.

This design was optimized for F/R over band > 20 dB, and SWR over the band
< 2:1, and a mid-band free-space gain of 10.4 dBi.
```

ARRL Design, YW Simulation



		10m 5 el Homebrew Yagi				W1DYJ		20-May-23	
		End 1			End 2			Diameter	Segments
Element	Wire #	X (ft)	Y (ft)	Z (ft)	X (ft)	Y (ft)	Z (ft)	(in)	#
Ref	1	9	-2	30	9	2	30	0.75	13
	2	9	2	30	9	3.5	30	0.625	5
	3	9	-2	30	9	-3.5	30	0.625	5
	4	9	3.5	30	9	8.97	30	0.5	18
	5	9	-3.5	30	9	-8.97	30	0.5	18
DE	6	6	-2	30	6	2	30	0.75	13
	7	6	2	30	6	3.5	30	0.625	5
	8	6	-2	30	6	-3.5	30	0.625	5
	9	6	3.5	30	6	8.33	30	0.5	16
	10	6	-3.5	30	6	-8.33	30	0.5	16
DIr1	11	3	-2	30	3	2	30	0.75	13
	12	3	2	30	3	3.5	30	0.625	5
	13	3	-2	30	3	-3.5	30	0.625	5
	14	3	3.5	30	3	8.26	30	0.5	15
	15	3	-3.5	30	3	-8.26	30	0.5	15
DIr2	16	-5.25	-2	30	-5.25	2	30	0.75	13
	17	-5.25	2	30	-5.25	3.5	30	0.625	5
	18	-5.25	-2	30	-5.25	-3.5	30	0.625	5
	19	-5.25	3.5	30	-5.25	8.08	30	0.5	15
	20	-5.25	-3.5	30	-5.25	-8.08	30	0.5	15
DIr3	21	-14.5	-2	30	-14.5	2	30	0.75	13
	22	-14.5	2	30	-14.5	3.5	30	0.625	5
	23	-14.5	-2	30	-14.5	-3.5	30	0.625	5
	24	-14.5	3.5	30	-14.5	7.73	30	0.5	14
	25	-14.5	-3.5	30	-14.5	-7.73	30	0.5	14

Sheet1 Sheet2

Ready 100%

No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15

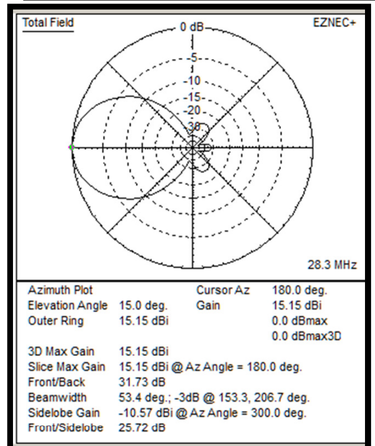
INDEXA

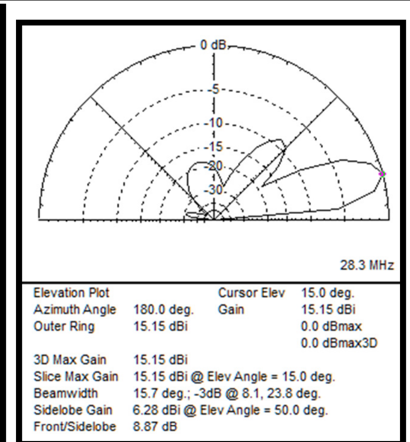
10m 5el Yagi II ~ Model Details >> EZNEC

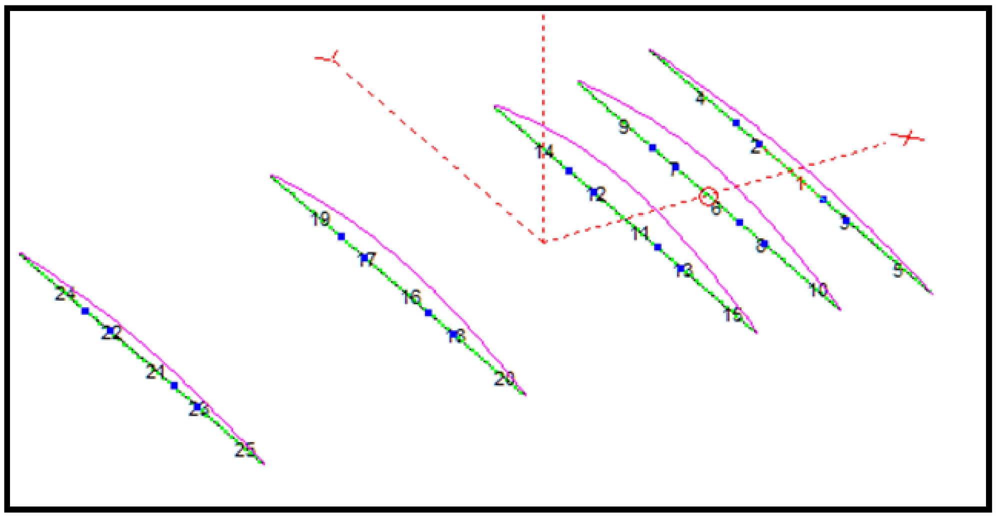
No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15
16	-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
17	-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
18	-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
19	-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
20	-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
21	-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
22	-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
23	-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
24	-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
25	-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14

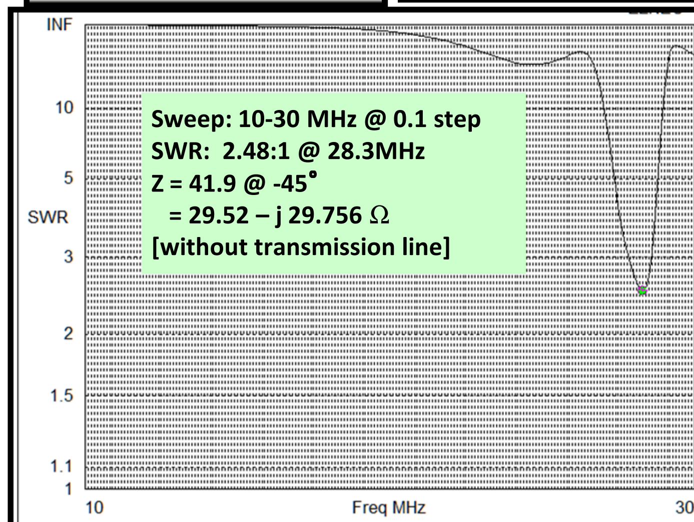
Sources

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	6	50	50	7	1	0	I









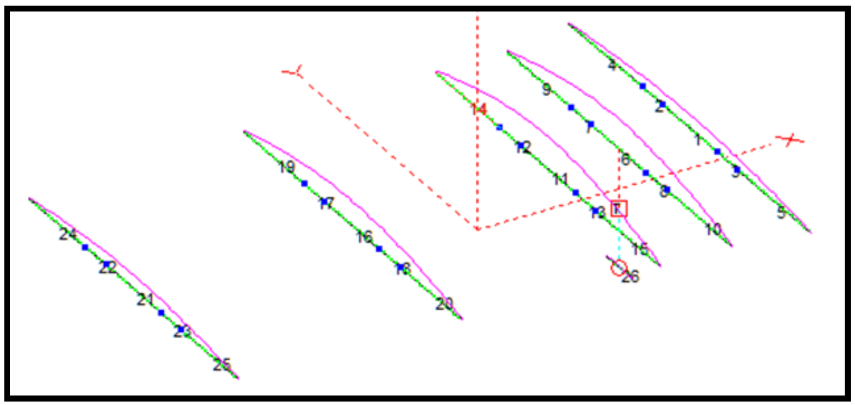
INDEXA

10m 5el Yagi III ~ Add matching section

No.	End 1 X (ft)	End 1 Y (ft)	End 1 Z (ft)	End 1 Conn	End 2 X (ft)	End 2 Y (ft)	End 2 Z (ft)	End 2 Conn	Diameter (in)	Segs
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15
16	-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
17	-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
18	-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
19	-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
20	-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
21	-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
22	-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
23	-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
24	-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
25	-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14
26	6	-1	25		6	1	25		#14	5

Transmission Lines

No.	End 1 Specified Pos. Wire #	End 1 Specified Pos. % From E1	End 1 Act % From E1	End 2 Specified Pos. Wire #	End 2 Specified Pos. % From E1	End 2 Act % From E1	Length (ft)	Z0 (ohms)	VF	Rev/Norm	Loss (dB/100 ft)	Loss Freq (MHz)
1	26	50	50	6	50	50	8.7	46	1	N	0	28

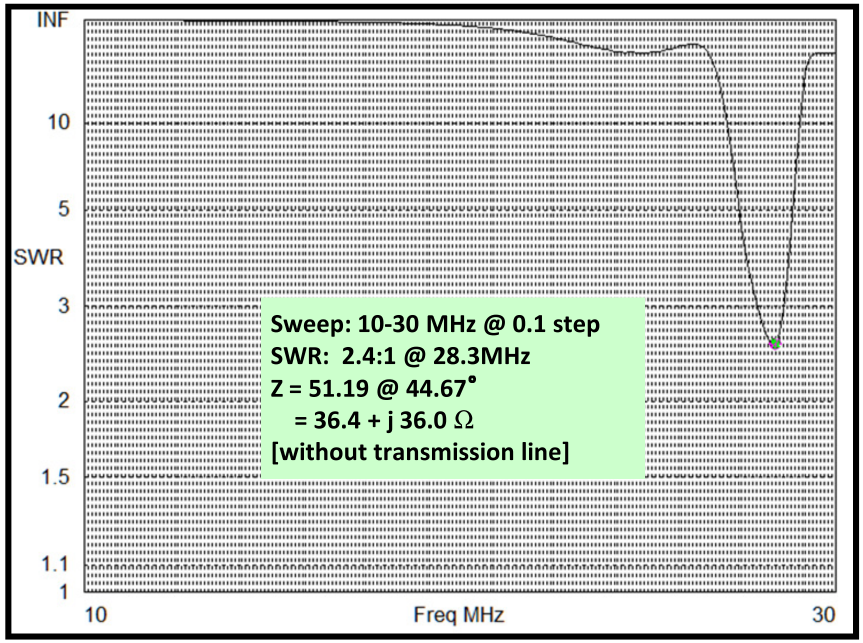


How to match this to 50 Ω coax? A gamma match is hard to model. 1st attempt: use a matching ¼ʎ length of ??? Coax.

$Z_{coax} = [50 \times 42]^{1/2} \sim 46$ $\lambda/4_{28.3MHz} = 2.65m = 8.7'$

Sources

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	26	50	50	3	1	0	I



¼ wave section	Z	
None	41.91 @ -45.23°	29.52 – j43.23
45 Ω	48.97 @ 44.70°	38.81 + j34.44
46 Ω	51.19 @ 44.67°	36.40 + j35.99

10m 5el Yagi IV.1 ~ Add transmission line

End 1				End 2				Diameter	Segs
X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
9	-2	30	W3E1	9	2	30	W2E1	0.75	13
9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
9	3.5	30	W2E2	9	8.97	30		0.5	18
9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	-2	30	W8E1	6	2	30	W7E1	0.75	13
6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
6	3.5	30	W7E2	6	8.33	30		0.5	16
6	-3.5	30	W8E2	6	-8.33	30		0.5	16
3	-2	30	W13E1	3	2	30	W12E1	0.75	13
3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
3	3.5	30	W12E2	3	8.26	30		0.5	15
3	-3.5	30	W13E2	3	-8.26	30		0.5	15
-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14
6	-1	25		6	1	25		#14	5
-20	-1	25		-20	1	25		#14	5

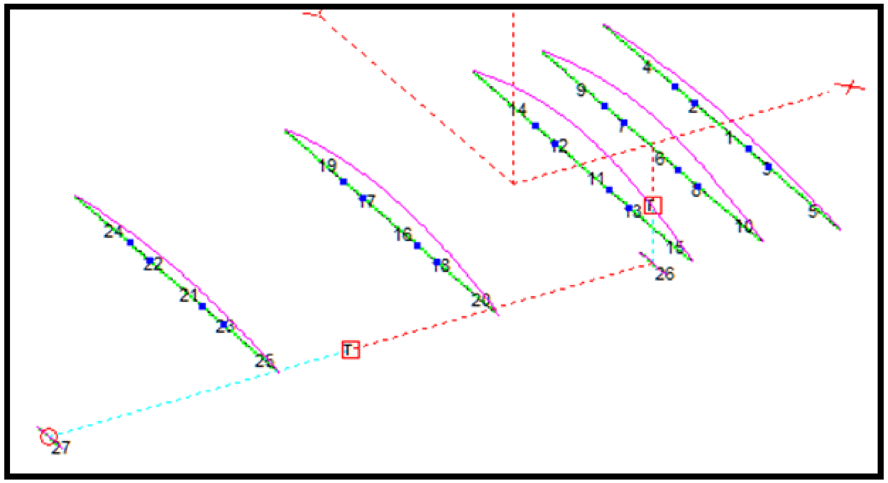
Add a Transmission Line: RG-8X of 70'

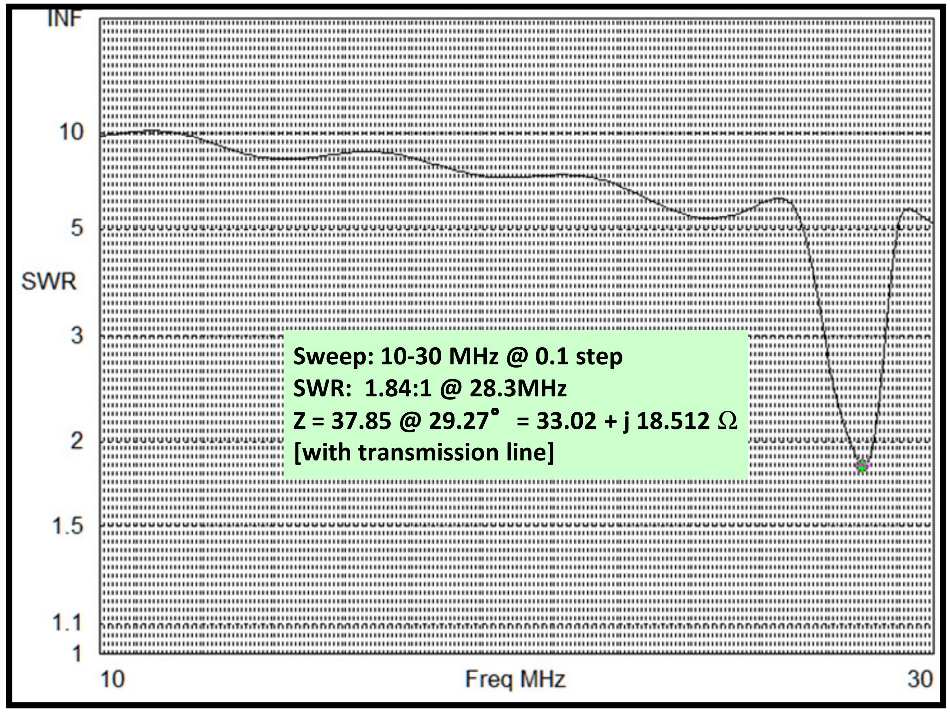
Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(ft)	(ohms)			(dB/100 ft)	(MHz)
1	26	50	50	6	50	50	8.7	46	1	N	0	28
2	27	50	50	26	50	50	70	50	0.82	N	1.9	28

Sources

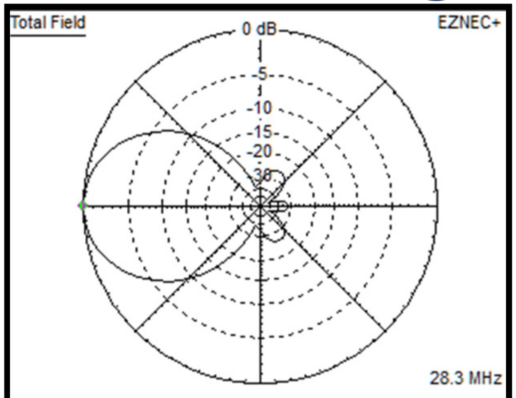
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	27	50	50	3	1	0	I





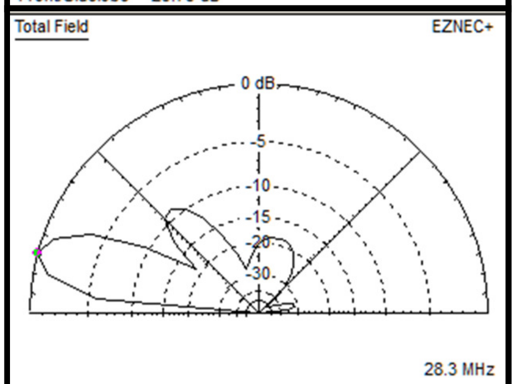
File: 10m-HB-5el-Yagi_matched-XmsLn.EZ

10m 5el Yagi IV.2 ~ Response @ 10m



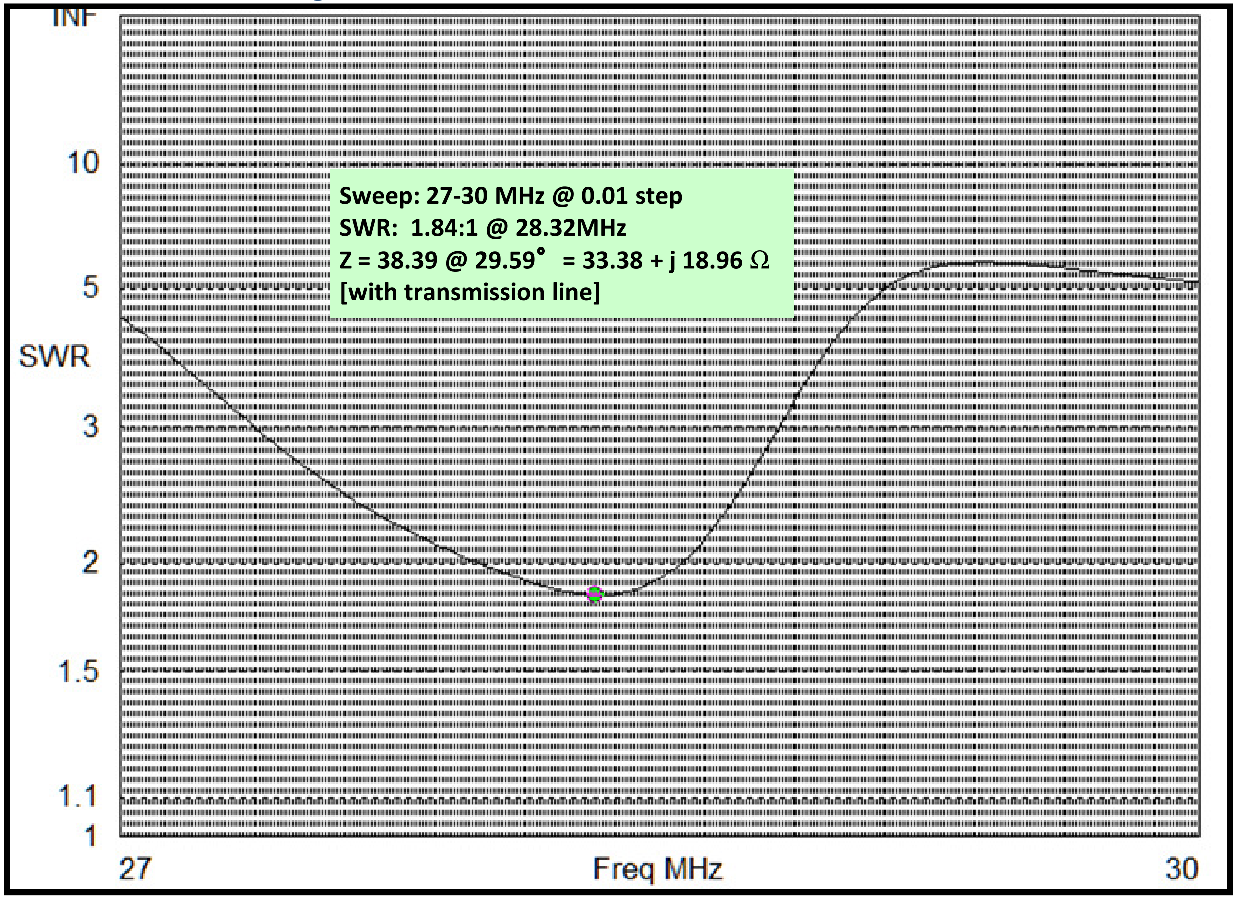
Azimuth Plot		Cursor Az	180.0 deg.
Elevation Angle	15.0 deg.	Gain	13.43 dBi
Outer Ring	13.43 dBi		0.0 dBmax
			0.0 dBmax3D

3D Max Gain 13.43 dBi
Slice Max Gain 13.43 dBi @ Az Angle = 180.0 deg.
Front/Back 31.67 dB
Beamwidth 53.4 deg.; -3dB @ 153.3, 206.7 deg.
Sidelobe Gain -12.32 dBi @ Az Angle = 300.0 deg.
Front/Sidelobe 25.75 dB



Elevation Plot		Cursor Elev	165.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.43 dBi
Outer Ring	13.43 dBi		0.0 dBmax
			0.0 dBmax3D

3D Max Gain 13.43 dBi
Slice Max Gain 13.43 dBi @ Elev Angle = 165.0 deg.
Beamwidth 15.7 deg.; -3dB @ 156.2, 171.9 deg.
Sidelobe Gain 4.55 dBi @ Elev Angle = 130.0 deg.
Front/Sidelobe 8.88 dB



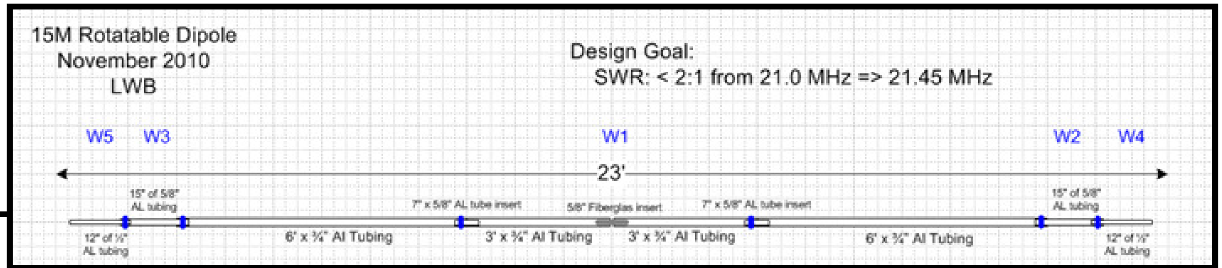
File: 10m-HB-5el-Yagi_matched-XmsLn.EZ

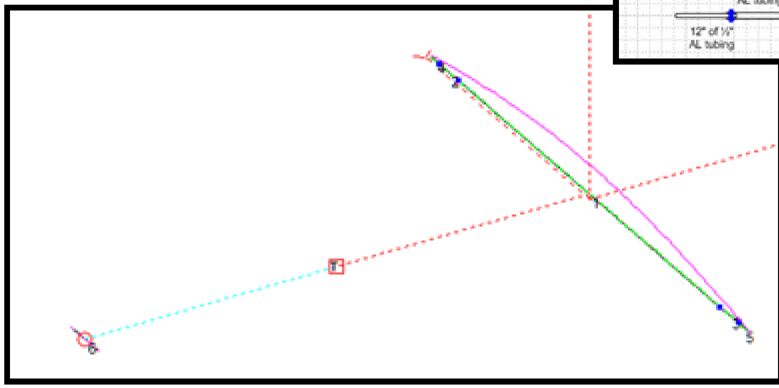
Upper HF Antenna Stack

15m HB Dipole

2010

15m Dipole~ Model Details [built in 2010]





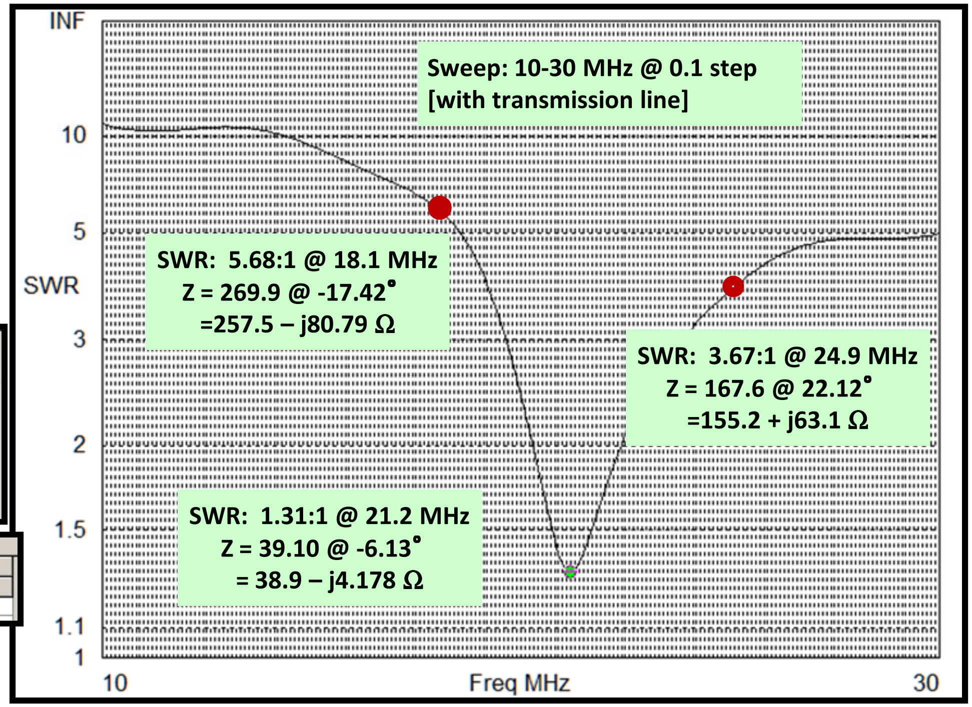
No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	0	-9	33	W3E2	0	9	33	W2E1	0.75	53
2	0	9	33	W1E2	0	10.25	33	W4E1	0.625	3
3	0	-10.25	33	W5E2	0	-9	33	W1E1	0.625	3
4	0	10.25	33	W2E2	0	11	33		0.5	3
5	0	-11	33		0	-10.25	33	W3E1	0.5	3
6	-20	1	33		-20	-1	33		0.5	7

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(ft)	(ohms)			(dB/100 ft)	(MHz)
1	6	50	50	1	50	50	65	50	0.82	N	1.57	22

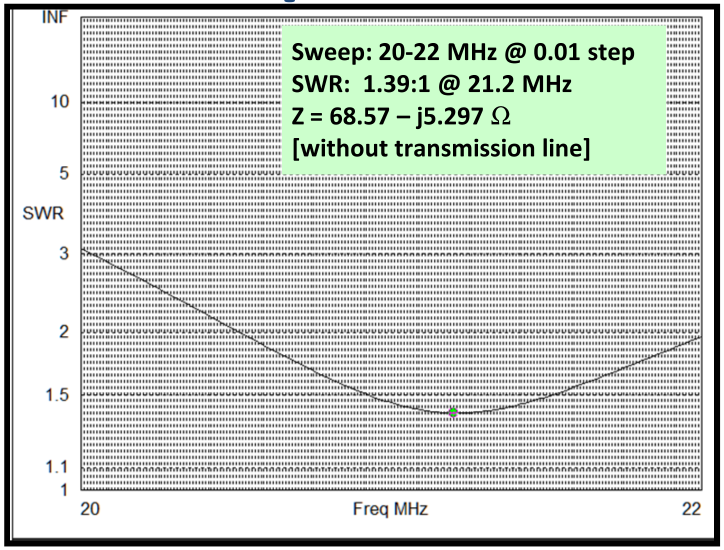
Sources

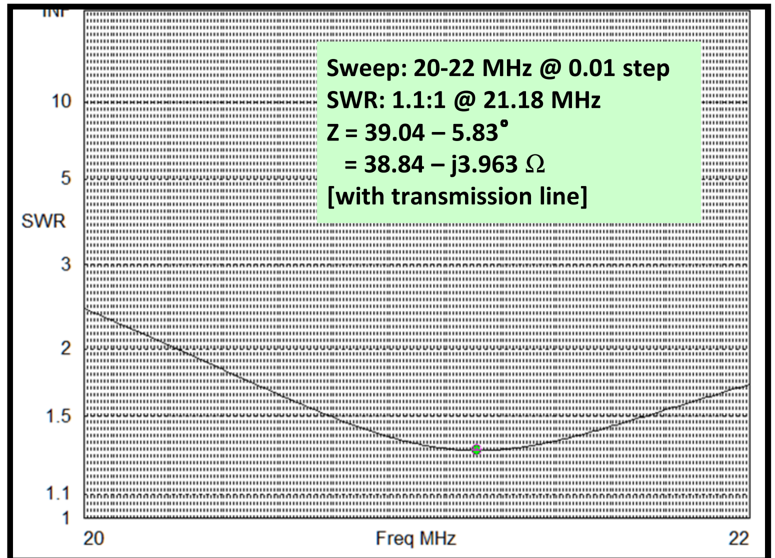
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	6	50	50	4	1	0	I

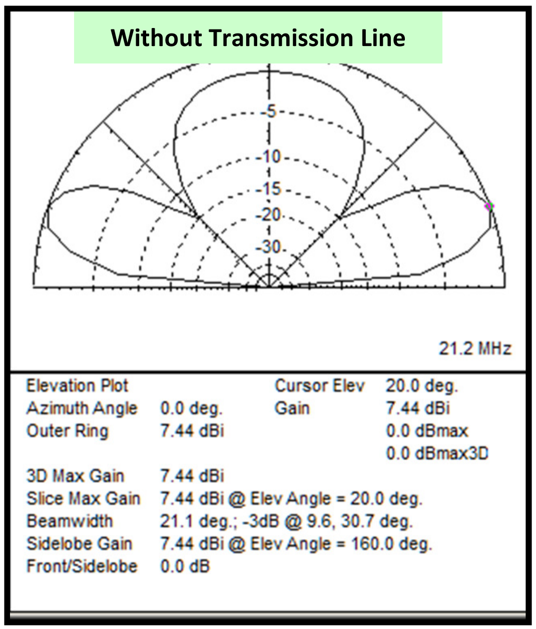


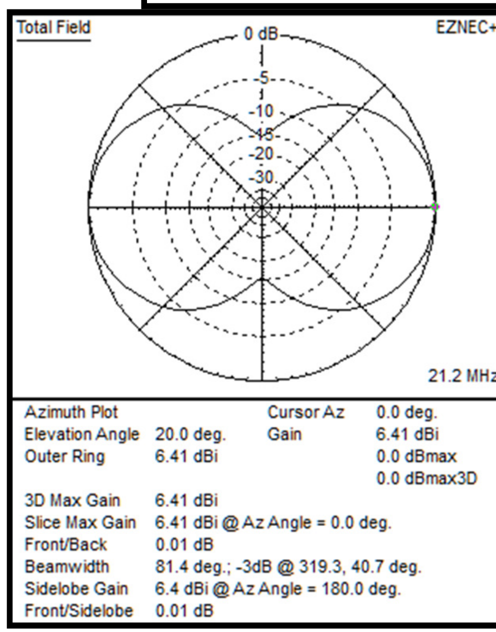
File: 15M_Rot_DP-XmxLn.EZ

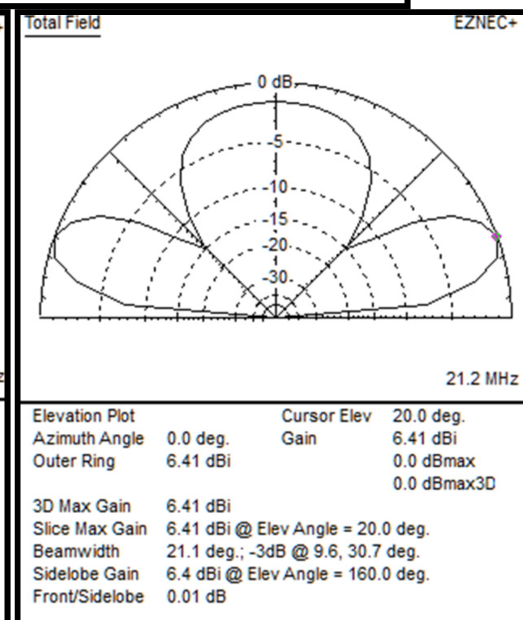
15m Dipole~ EZNEC Simulation Results: 15m











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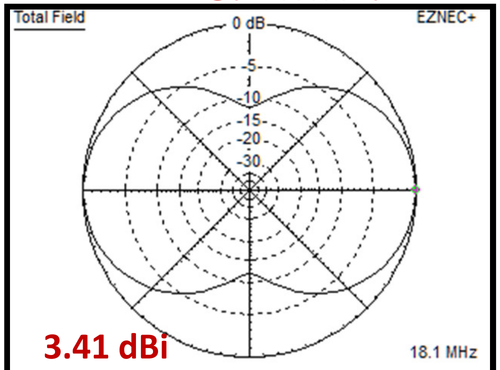
NORTHERN CALIFORNIA DX FOUNDATION, INC.

15m Dipole~ El/Az Patterns on 17m, 15m, & 12m

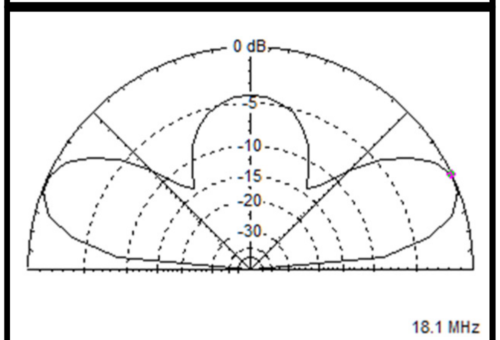
With Transmission Line

18.1 MHz.



Azimuth Plot
Elevation Angle 25.0 deg.
Outer Ring 3.41 dBi
Cursor Az 0.0 deg.
Gain 3.41 dBi
0.0 dBmax
0.0 dBmax3D

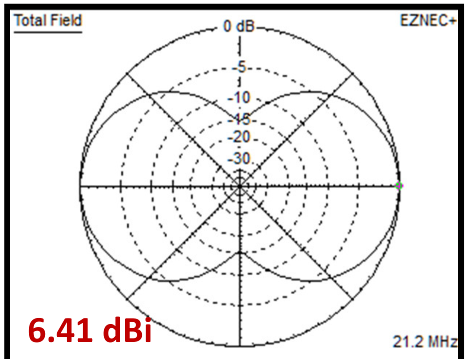
3D Max Gain 3.41 dBi
Slice Max Gain 3.41 dBi @ Az Angle = 0.0 deg.
Front/Side 11.77 dB
Beamwidth 87.4 deg.; -3dB @ 316.3, 43.7 deg.
Sidelobe Gain 3.4 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 0.01 dB



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 3.41 dBi
Cursor Elev 25.0 deg.
Gain 3.41 dBi
0.0 dBmax
0.0 dBmax3D

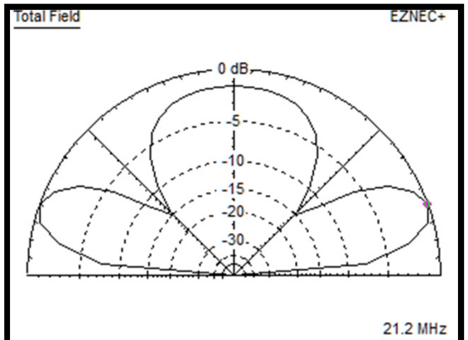
3D Max Gain 3.41 dBi
Slice Max Gain 3.41 dBi @ Elev Angle = 25.0 deg.
Beamwidth 25.6 deg.; -3dB @ 11.1, 36.7 deg.
Sidelobe Gain 3.4 dBi @ Elev Angle = 155.0 deg.
Front/Sidelobe 0.01 dB

21.2 MHz.



Azimuth Plot
Elevation Angle 20.0 deg.
Outer Ring 6.41 dBi
Cursor Az 0.0 deg.
Gain 6.41 dBi
0.0 dBmax
0.0 dBmax3D

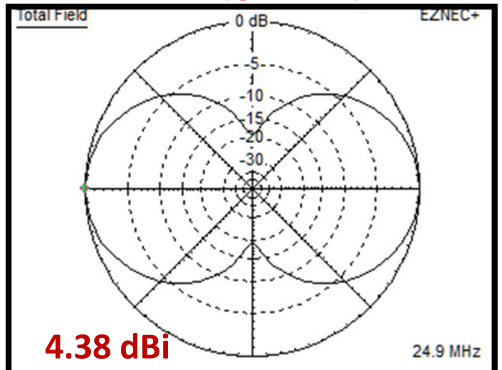
3D Max Gain 6.41 dBi
Slice Max Gain 6.41 dBi @ Az Angle = 0.0 deg.
Front/Back 0.01 dB
Beamwidth 81.4 deg.; -3dB @ 319.3, 40.7 deg.
Sidelobe Gain 6.4 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 0.01 dB



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 6.41 dBi
Cursor Elev 20.0 deg.
Gain 6.41 dBi
0.0 dBmax
0.0 dBmax3D

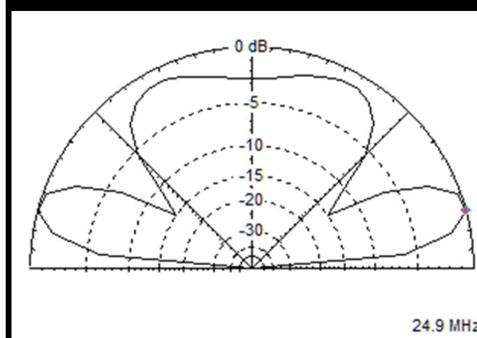
3D Max Gain 6.41 dBi
Slice Max Gain 6.41 dBi @ Elev Angle = 20.0 deg.
Beamwidth 21.1 deg.; -3dB @ 9.6, 30.7 deg.
Sidelobe Gain 6.4 dBi @ Elev Angle = 160.0 deg.
Front/Sidelobe 0.01 dB

24.9MHz.



Azimuth Plot
Elevation Angle 15.0 deg.
Outer Ring 4.38 dBi
Cursor Az 180.0 deg.
Gain 4.38 dBi
0.0 dBmax
0.0 dBmax3D

3D Max Gain 4.38 dBi
Slice Max Gain 4.38 dBi @ Az Angle = 0.0 deg.
Front/Side 19.42 dB
Beamwidth 75.6 deg.; -3dB @ 322.2, 37.8 deg.
Sidelobe Gain 4.38 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 0.0 dB



Elevation Plot
Azimuth Angle 180.0 deg.
Outer Ring 4.38 dBi
Cursor Elev 15.0 deg.
Gain 4.38 dBi
0.0 dBmax
0.0 dBmax3D

3D Max Gain 4.38 dBi
Slice Max Gain 4.38 dBi @ Elev Angle = 15.0 deg.
Beamwidth 17.3 deg.; -3dB @ 8.6, 25.9 deg.
Sidelobe Gain 4.38 dBi @ Elev Angle = 165.0 deg.
Front/Sidelobe 0.0 dB

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NORTHERN CALIFORNIA DX FOUNDATION, INC.

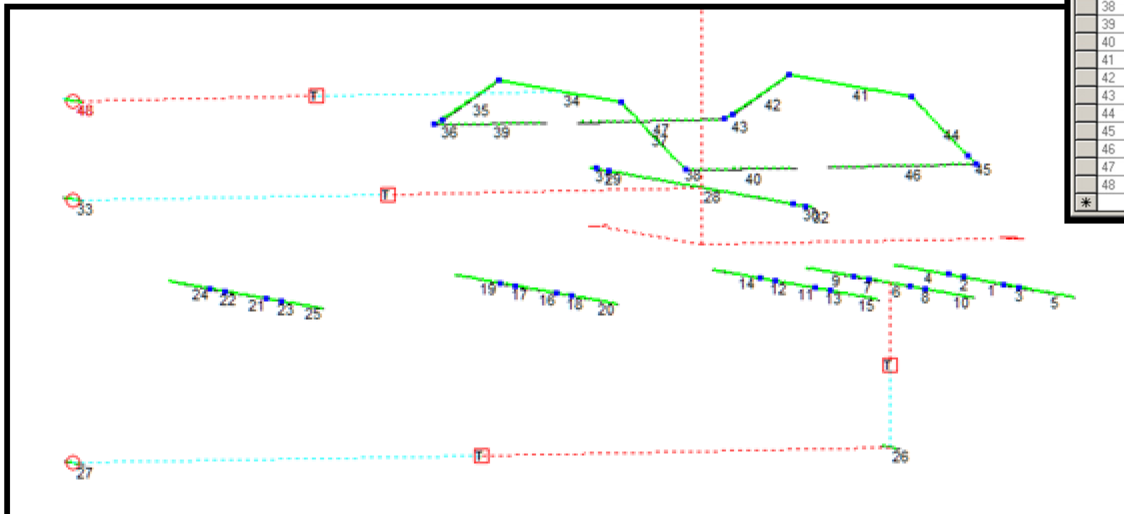
All 3 Antennas

All Three Antennas

Sources							
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	27	50	50	3	1	0	V
2	33	50	50	4	1	0	V
3	48	50	50	4	1	0	V

Source 1: 10m w27s3
Source 2: 17, 15, 12m w33s4
Source 3: 20m w46s4

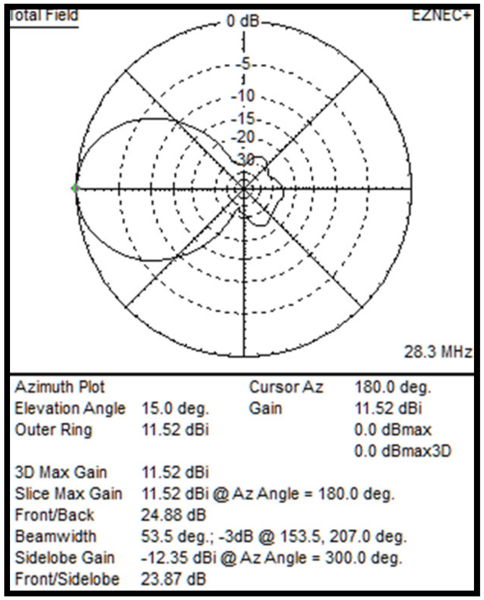
Transmission Lines												
No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss	Loss Freq
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(ft)	(ohms)			(dB/100 ft)	(MHz)
1	6	50	50	6	50	50	8.7	46	1	N	0	28
2	27	50	50	26	50	50	70	50	0.82	N	1.9	28
3	33	50	50	28	50	50	65	50	0.82	N	1.57	22
4	34	50	50	48	50	50	70	50	0.82	N	1.25	14

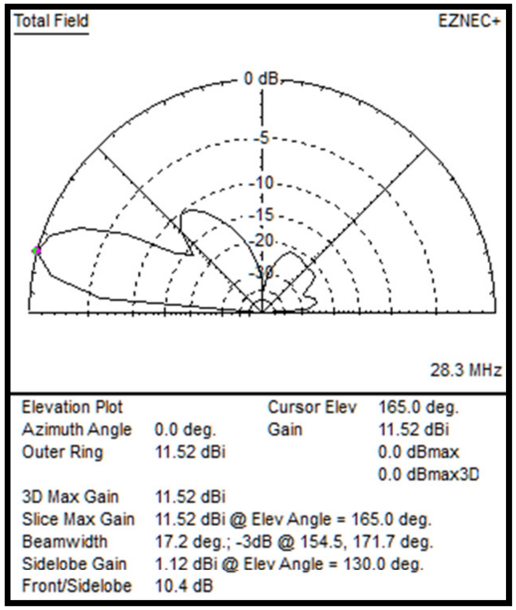


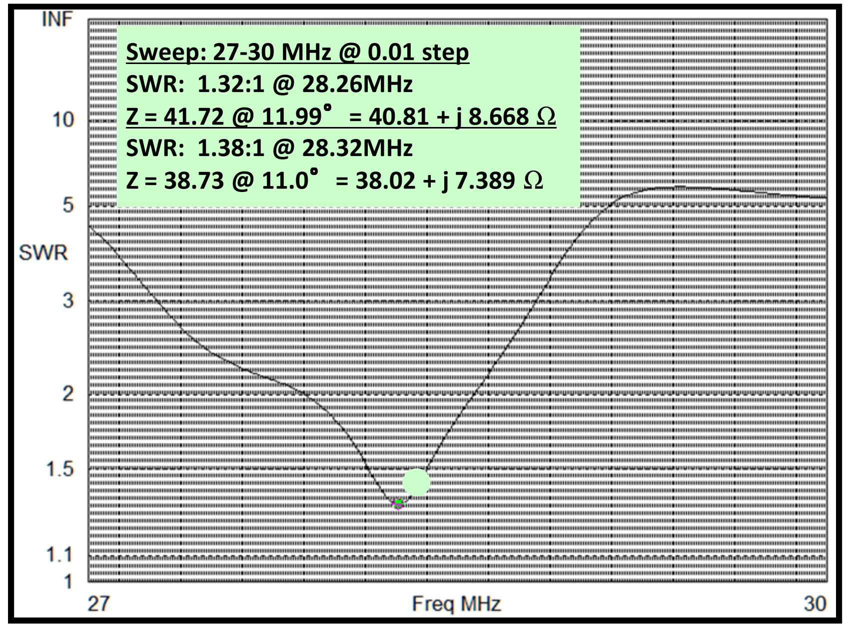
Wires										
No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	9	-2	30	W3E1	9	2	30	W2E1	0.75	13
2	9	2	30	W1E2	9	3.5	30	W4E1	0.625	5
3	9	-2	30	W1E1	9	-3.5	30	W5E1	0.625	5
4	9	3.5	30	W2E2	9	8.97	30		0.5	18
5	9	-3.5	30	W3E2	9	-8.97	30		0.5	18
6	6	-2	30	W8E1	6	2	30	W7E1	0.75	13
7	6	2	30	W6E2	6	3.5	30	W9E1	0.625	5
8	6	-2	30	W6E1	6	-3.5	30	W10E1	0.625	5
9	6	3.5	30	W7E2	6	8.33	30		0.5	16
10	6	-3.5	30	W8E2	6	-8.33	30		0.5	16
11	3	-2	30	W13E1	3	2	30	W12E1	0.75	13
12	3	2	30	W11E2	3	3.5	30	W14E1	0.625	5
13	3	-2	30	W11E1	3	-3.5	30	W15E1	0.625	5
14	3	3.5	30	W12E2	3	8.26	30		0.5	15
15	3	-3.5	30	W13E2	3	-8.26	30		0.5	15
16	-5.25	-2	30	W18E1	-5.25	2	30	W17E1	0.75	13
17	-5.25	2	30	W16E2	-5.25	3.5	30	W19E1	0.625	5
18	-5.25	-2	30	W16E1	-5.25	-3.5	30	W20E1	0.625	5
19	-5.25	3.5	30	W17E2	-5.25	8.08	30		0.5	15
20	-5.25	-3.5	30	W18E2	-5.25	-8.08	30		0.5	15
21	-14.5	-2	30	W23E1	-14.5	2	30	W22E1	0.75	13
22	-14.5	2	30	W21E2	-14.5	3.5	30	W24E1	0.625	5
23	-14.5	-2	30	W21E1	-14.5	-3.5	30	W25E1	0.625	5
24	-14.5	3.5	30	W22E2	-14.5	7.73	30		0.5	14
25	-14.5	-3.5	30	W23E2	-14.5	-7.73	30		0.5	14
26	6	-1	25		6	1	25		#14	5
27	-20	-1	25		-20	1	25		#14	5
28	0	-9	33	W30E2	0	9	33	W29E1	0.75	53
29	0	9	33	W28E2	0	10.25	33	W31E1	0.625	3
30	0	-10.25	33	W32E2	0	-9	33	W28E1	0.625	3
31	0	10.25	33	W29E2	0	11	33		0.5	3
32	0	-11	33		0	-10.25	33	W30E1	0.5	3
33	-20	1	33		-20	-1	33		0.5	7
34	-4.5	-6	36	W37E1	-4.5	6	36	W35E1	0.75	49
35	-4.5	6	36	W34E2	-4.5	11.55	34.5	W36E1	0.625	23
36	-4.5	11.55	34.5	W35E2	-4.5	12.3	34.3	W39E1	0.5	3
37	-4.5	-6	36	W34E1	-4.5	-11.55	34.5	W38E1	0.625	23
38	-4.5	-11.55	34.5	W37E2	-4.5	-12.3	34.3	W40E1	0.5	3
39	-4.5	12.3	34.3	W36E2	-0.92	12.3	34.3		0.5	14
40	-4.5	-12.3	34.3	W38E2	-0.92	-12.3	34.3		0.5	14
41	4.75	-6	36	W44E1	4.75	6	36	W42E1	0.75	49
42	4.75	6	36	W41E2	4.75	11.55	34.5	W43E1	0.625	23
43	4.75	11.55	34.5	W42E2	4.75	12.3	34.3	W47E1	0.5	3
44	4.75	-6	36	W41E1	4.75	-11.55	34.5	W45E1	0.625	23
45	4.75	-11.55	34.5	W44E2	4.75	-12.3	34.3	W46E1	0.5	3
46	4.75	-12.3	34.3	W45E2	0	-12.3	34.3		0.5	19
47	4.75	12.3	34.3	W43E2	0	12.3	34.3		0.05	19
48	-20	1	36		-20	-1	36		0.5	7

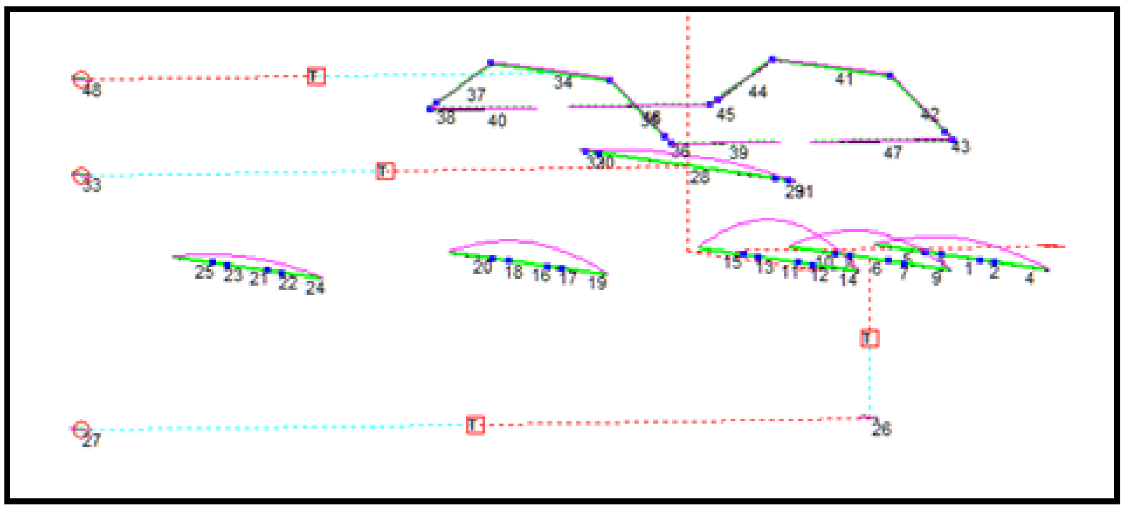
All Three Antennas @ 10m

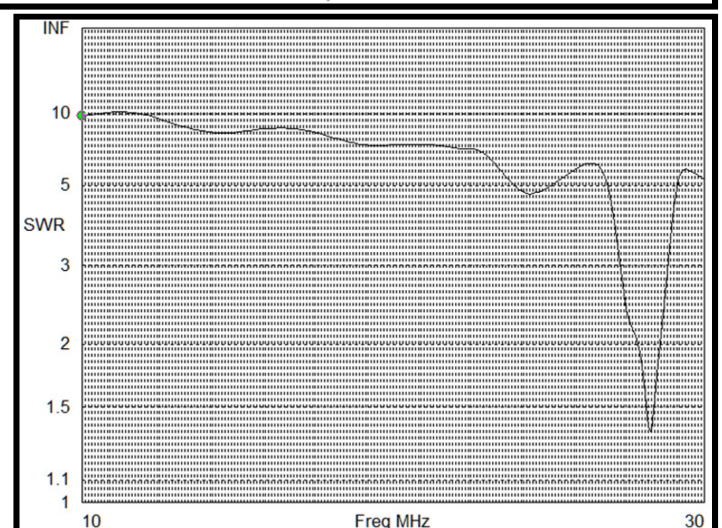
Source 1: 10m	w27s3	1v drive
Source 2: 17, 15, 12m	w33s4	0v
Source 3: 20m	w48s4	0v





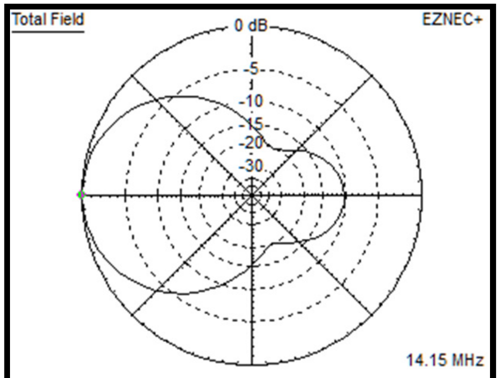




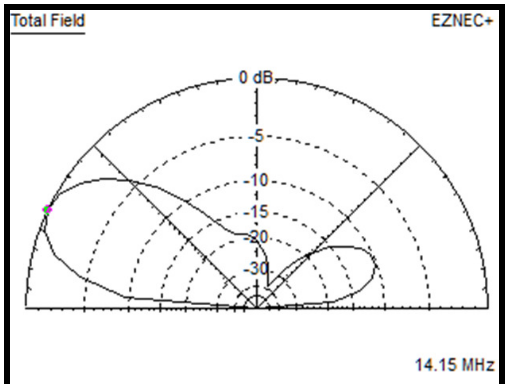


All Three Antennas @ 20m

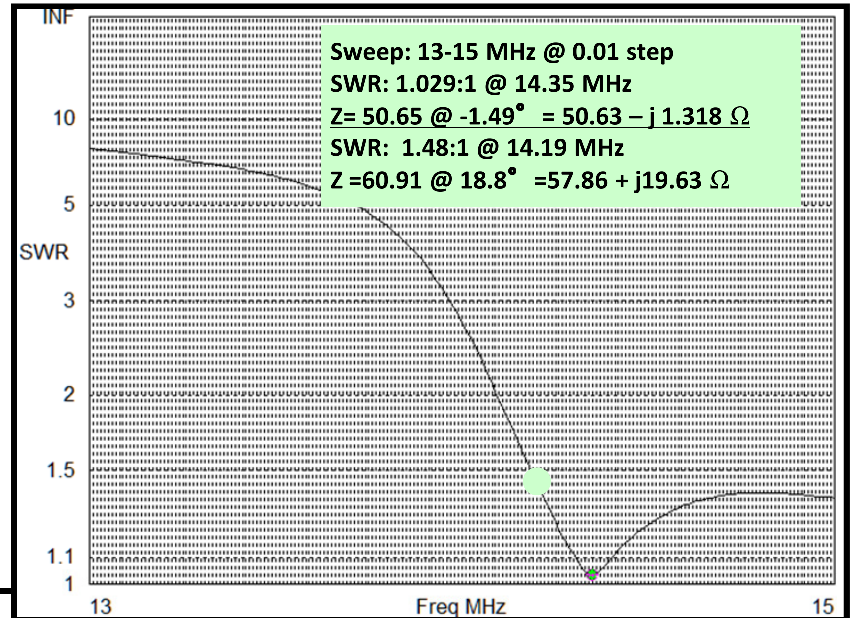
Source 1: 20m	w48s4	1v drive
Source 2: 10m	w27s3	0v
Source 3: 17, 15, 12m	w33s4	0v

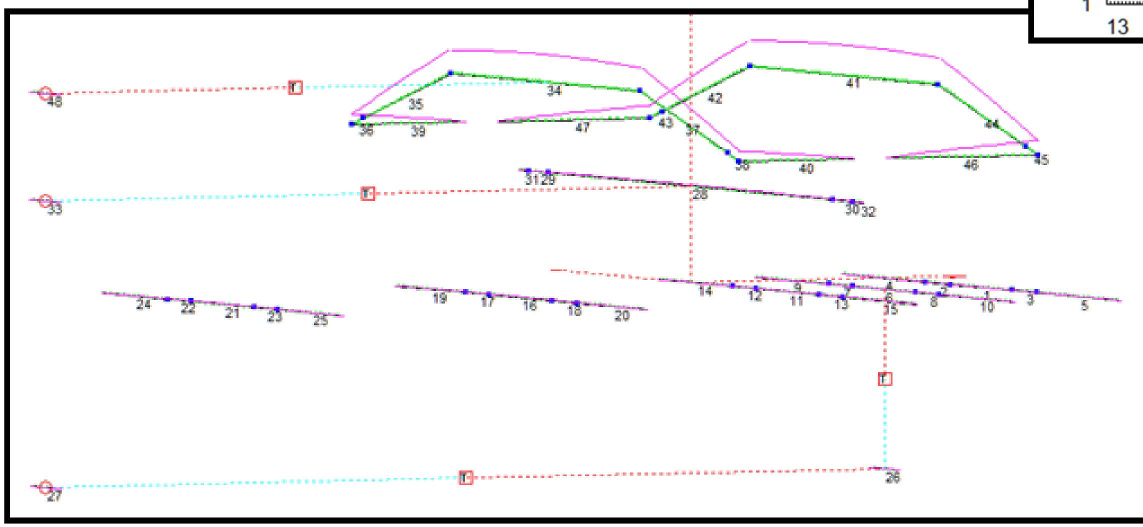


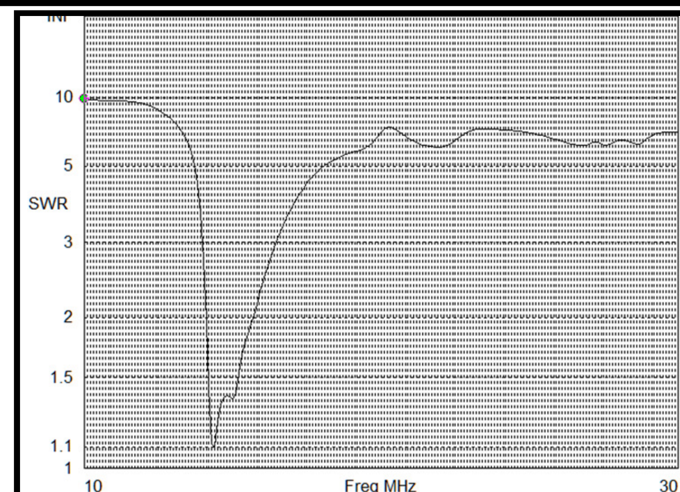
Azimuth Plot		Cursor Az	180.0 deg.
Elevation Angle	25.0 deg.	Gain	9.91 dBi
Outer Ring	9.91 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	9.91 dBi		
Slice Max Gain	9.91 dBi @ Az Angle = 180.0 deg.		
Front/Back	10.43 dB		
Beamwidth	78.5 deg.; -3dB @ 140.3, 218.8 deg.		
Sidelobe Gain	-0.52 dBi @ Az Angle = 0.0 deg.		
Front/Sidelobe	10.43 dB		



Elevation Plot		Cursor Elev	155.0 deg.
Azimuth Angle	0.0 deg.	Gain	9.91 dBi
Outer Ring	9.91 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	9.91 dBi		
Slice Max Gain	9.91 dBi @ Elev Angle = 155.0 deg.		
Beamwidth	29.4 deg.; -3dB @ 138.2, 167.6 deg.		
Sidelobe Gain	-0.47 dBi @ Elev Angle = 20.0 deg.		
Front/Sidelobe	10.38 dB		

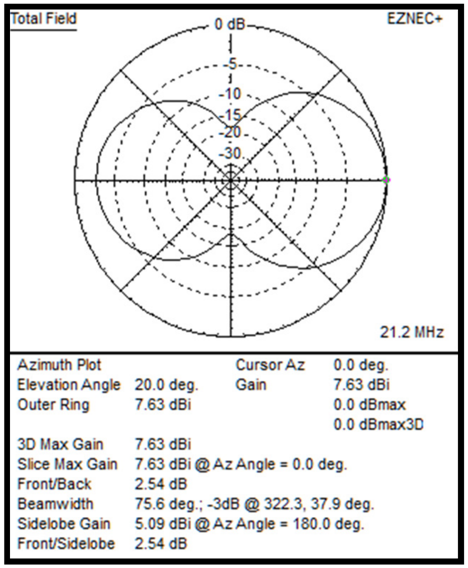


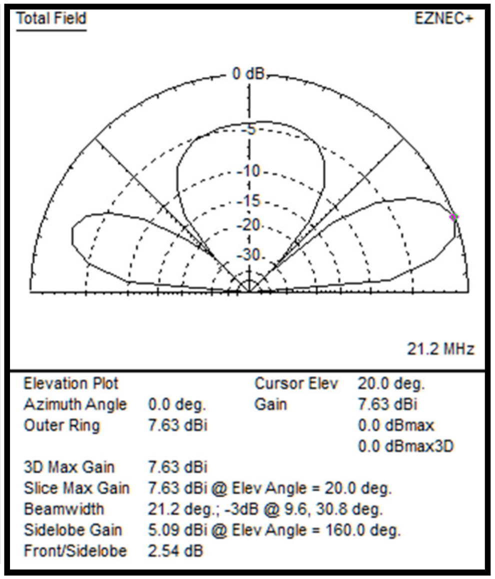


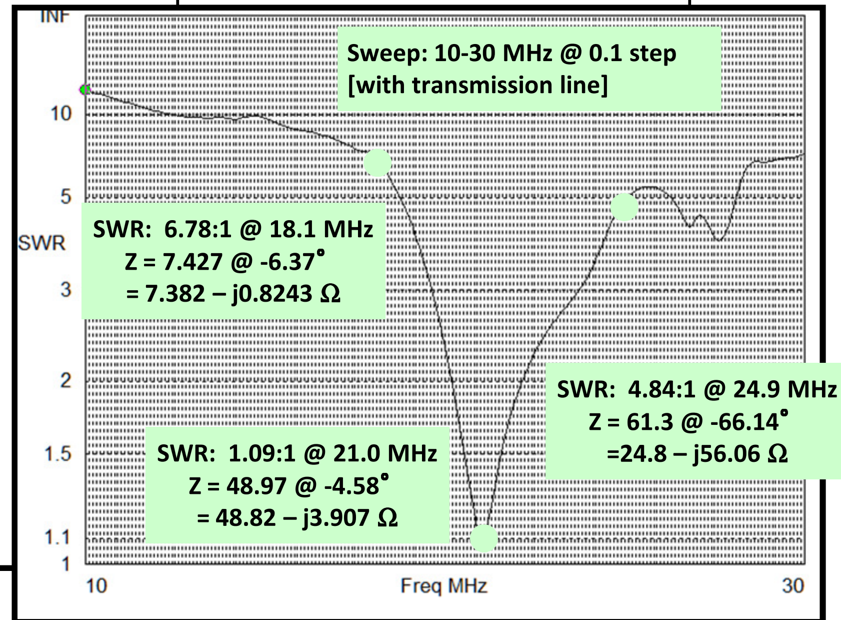


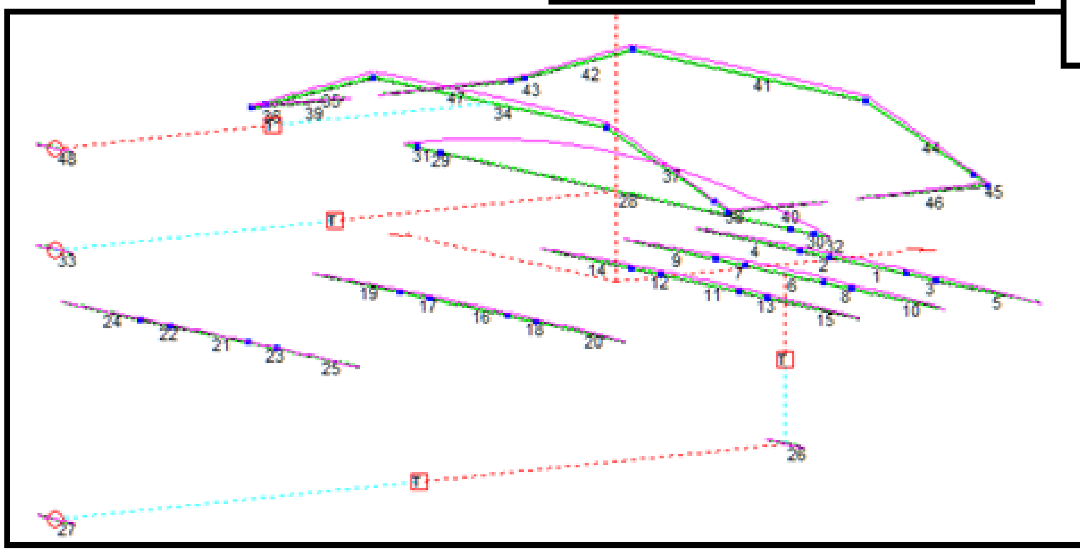
All Three Antennas @ 15m

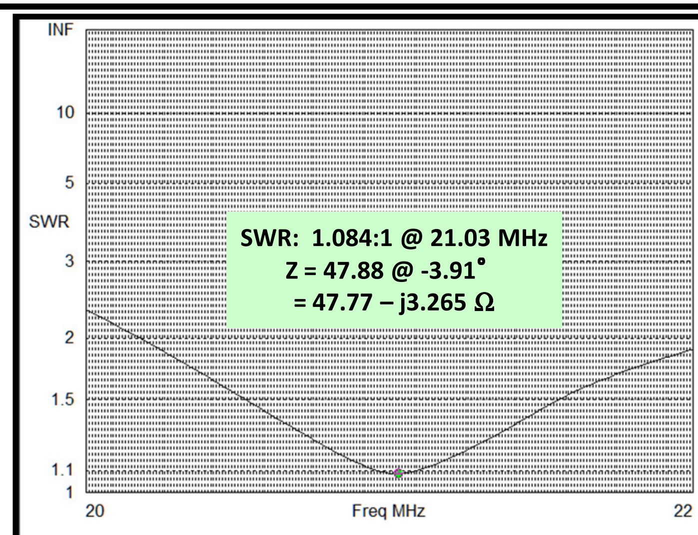
Source 3: 17, 15, 12m	w33s4	1v drive
Source 2: 20m	w48s4	0v
Source 3: 10m	w27s3	0v







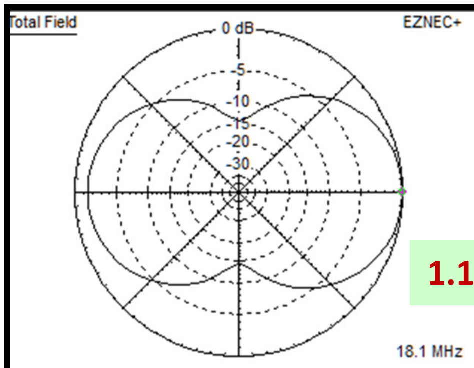




All 3 Antennas ~ El/Az Patterns on 17m, 15m, & 12m

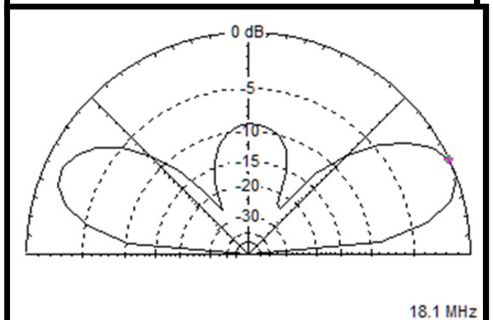
With Transmission Line

18.1 MHz.



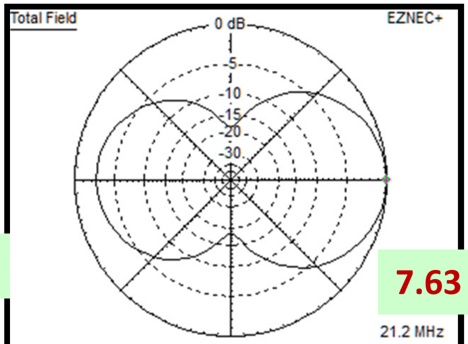
Azimuth Plot | Cursor Az 0.0 deg.
Elevation Angle 25.0 deg. | Gain 1.15 dBi
Outer Ring 1.15 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 1.15 dBi
Slice Max Gain 1.15 dBi @ Az Angle = 0.0 deg.
Front/Back 1.39 dB
Beamwidth 80.5 deg.; -3dB @ 319.9, 40.4 deg.
Sidelobe Gain -0.24 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 1.39 dB

1.15 dBi



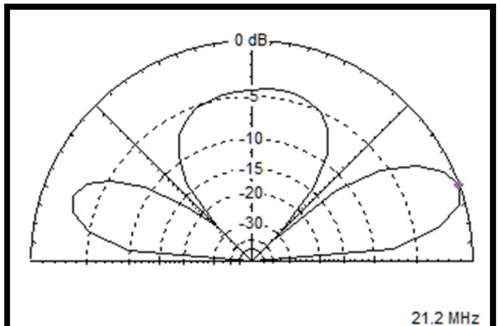
Elevation Plot | Cursor Elev 25.0 deg.
Azimuth Angle 0.0 deg. | Gain 1.15 dBi
Outer Ring 1.15 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 1.15 dBi
Slice Max Gain 1.15 dBi @ Elev Angle = 25.0 deg.
Beamwidth 25.8 deg.; -3dB @ 10.9, 36.7 deg.
Sidelobe Gain -0.24 dBi @ Elev Angle = 155.0 deg.
Front/Sidelobe 1.39 dB

21.2 MHz.



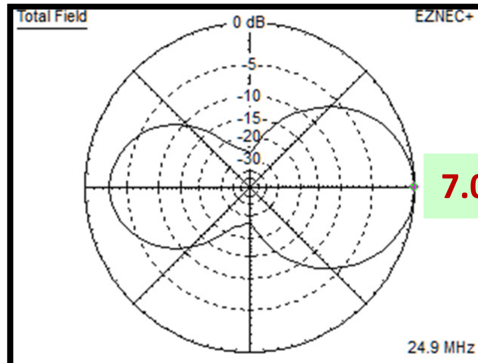
Azimuth Plot | Cursor Az 0.0 deg.
Elevation Angle 20.0 deg. | Gain 7.63 dBi
Outer Ring 7.63 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 7.63 dBi
Slice Max Gain 7.63 dBi @ Az Angle = 0.0 deg.
Front/Back 2.54 dB
Beamwidth 75.6 deg.; -3dB @ 322.3, 37.9 deg.
Sidelobe Gain 5.09 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 2.54 dB

7.63 dBi



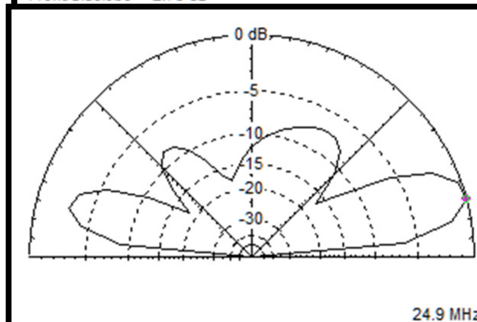
Elevation Plot | Cursor Elev 20.0 deg.
Azimuth Angle 0.0 deg. | Gain 7.63 dBi
Outer Ring 7.63 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 7.63 dBi
Slice Max Gain 7.63 dBi @ Elev Angle = 20.0 deg.
Beamwidth 21.2 deg.; -3dB @ 9.6, 30.8 deg.
Sidelobe Gain 5.09 dBi @ Elev Angle = 160.0 deg.
Front/Sidelobe 2.54 dB

24.9MHz.



7.07 dBi

Azimuth Plot | Cursor Az 0.0 deg.
Elevation Angle 15.0 deg. | Gain 7.07 dBi
Outer Ring 7.07 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 7.07 dBi
Slice Max Gain 7.07 dBi @ Az Angle = 0.0 deg.
Front/Back 2.78 dB
Beamwidth 62.5 deg.; -3dB @ 328.5, 31.0 deg.
Sidelobe Gain 4.29 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 2.78 dB



Elevation Plot | Cursor Elev 15.0 deg.
Azimuth Angle 0.0 deg. | Gain 7.07 dBi
Outer Ring 7.07 dBi | 0.0 dBmax
0.0 dBmax3D
3D Max Gain 7.07 dBi
Slice Max Gain 7.07 dBi @ Elev Angle = 15.0 deg.
Beamwidth 17.9 deg.; -3dB @ 8.5, 26.4 deg.
Sidelobe Gain 4.29 dBi @ Elev Angle = 165.0 deg.
Front/Sidelobe 2.78 dB