Design, Analysis, Construction, and Testing of a Portable Antenna for 80M

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More Slides Than On USB Stick

- Don't bother taking notes
- Ray needed slides for USB stick a week before CQP, so I gave him what I had then
- These slides will be on my website in a few days
  - k9yc.com/publish.htm

Design Objectives

- For locations with no skyhooks
- Easy for old men to set up
- Maximize signal strength east of the Mississippi (high population density)
  - Maximize low angle radiation (< 25^{o})
  - Closer stations need less radiation
- Better than a practical inverted Vee that we could easily rig
- Moderate cost
- Modest footprint

Design Inspiration

- Maximize Radiation Efficiency by…
  - High Feedpoint
  - Minimal Top Loading
  - Minimize ground loss
- Tom Schiller, N6BT – bottom loading
- Chip, K7JA – surplus masts
- Barry Booth, W9UCW – measurement of short loaded verticals (QEX Jan-Feb, Mar/Apr 2014)

Antenna Concept

- It’s a shortened vertical dipole
- Make antenna as tall as practical
- Make feedpoint as high as practical
- Keep high current section as high as practical
- Use inductive loading for top section
- Use capacitive loading for bottom section (three horizontal wires)
- Vary loading to get 50Ω feedpoint Z

Design Process

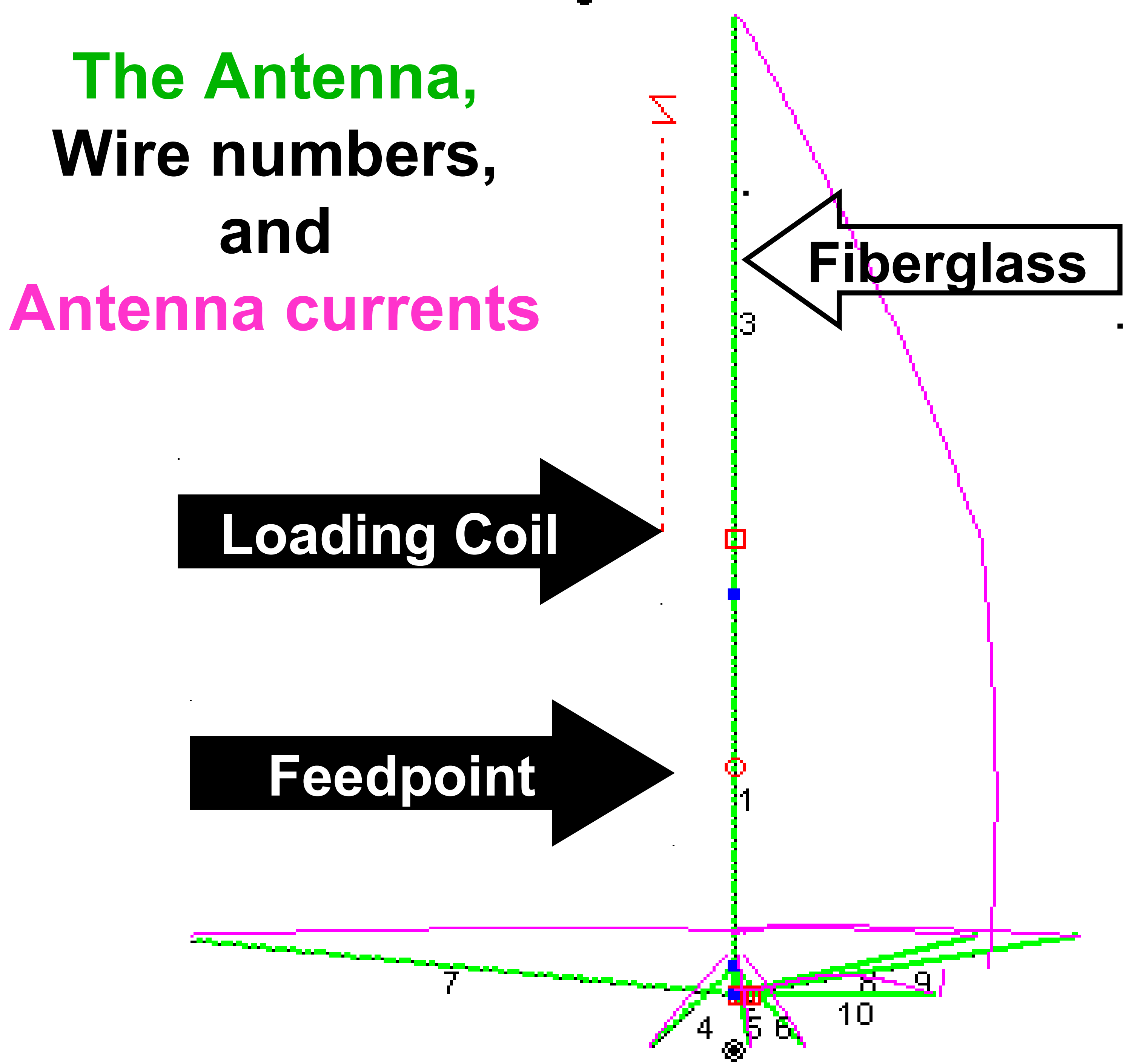
- **Start with surplus mast sections and tripod, with telescoping mast on top**
  - **How high can we go with surplus mast sections?**
  - **We set it up and tried it**
  - **Seven sections with 40 ft telescoping mast attached seems to be the limit**
  - **71 ft total height**
- **How high can we place loading coil?**
  - **Top of lowest fiberglass section**

Early Feasibility Test

- W6GJB mounts fiberglass pole to 2-in mast section
- More 2-in mast sections will be added to make antenna taller

Design Process

- What bottom loading?
  - Decided on horizontal wires attached at base (4 ft high)
- How high should the feedpoint be?
  - At junction of sections (seven total)
  - Three positions were modeled with both top and bottom loading optimized
  - 3, 4, and 5 sections below feedpoint
  - Studied field strength and SWR for each position


The Antenna,
Wire numbers,
and
Antenna currents
Fiberglass
Loading Coil
Feedpoint
3
1
7
4
5
6
8
9
10

NEC Data Entry

Wires

Wire Create Edit Other

Coord Entry Mode   Preserve Connections   Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
1	0	0	5.854	W2E2	0	0	31.5	W3E1	2	49
2	0	0	4	W7E1	0	0	5.854	W4E1	2	6
3	0	0	31.5	W1E2	0	0	71.5		#14	80
4	0	0	5.854	W5E1	5.65453	-1.51513	0.354		2	16
5	0	0	5.854	W6E1	-1.51513	5.65453	0.354		2	16
6	0	0	5.854	W1E1	-4.1394	-4.1394	0.354		2	15
7	0	0	4	W8E1	38	0	8		#14	76
8	0	0	4	W9E1	-19	32.909	8		#14	76
9	0	0	4	W10E1	-19	-32.909	8		#14	76
10	0	0	4	W2E1	0	-130	4		#14	200
*										

Design Process

- **Compared with reference antenna**
  - **Inv Vee, apex at 42 ft, ends at 20 ft**
- **All feedpoint heights beat the Inv Vee by at least 3 dB at low angles**
- **Final design uses 4 sections below feedpoint, 3 sections above**
- **Design is tweaked for CW**
  - **100 kHz for SWR < 1.5:1, 200 kHz < 2:1**
  - **Reduce both top and bottom loading to tune for SSB**

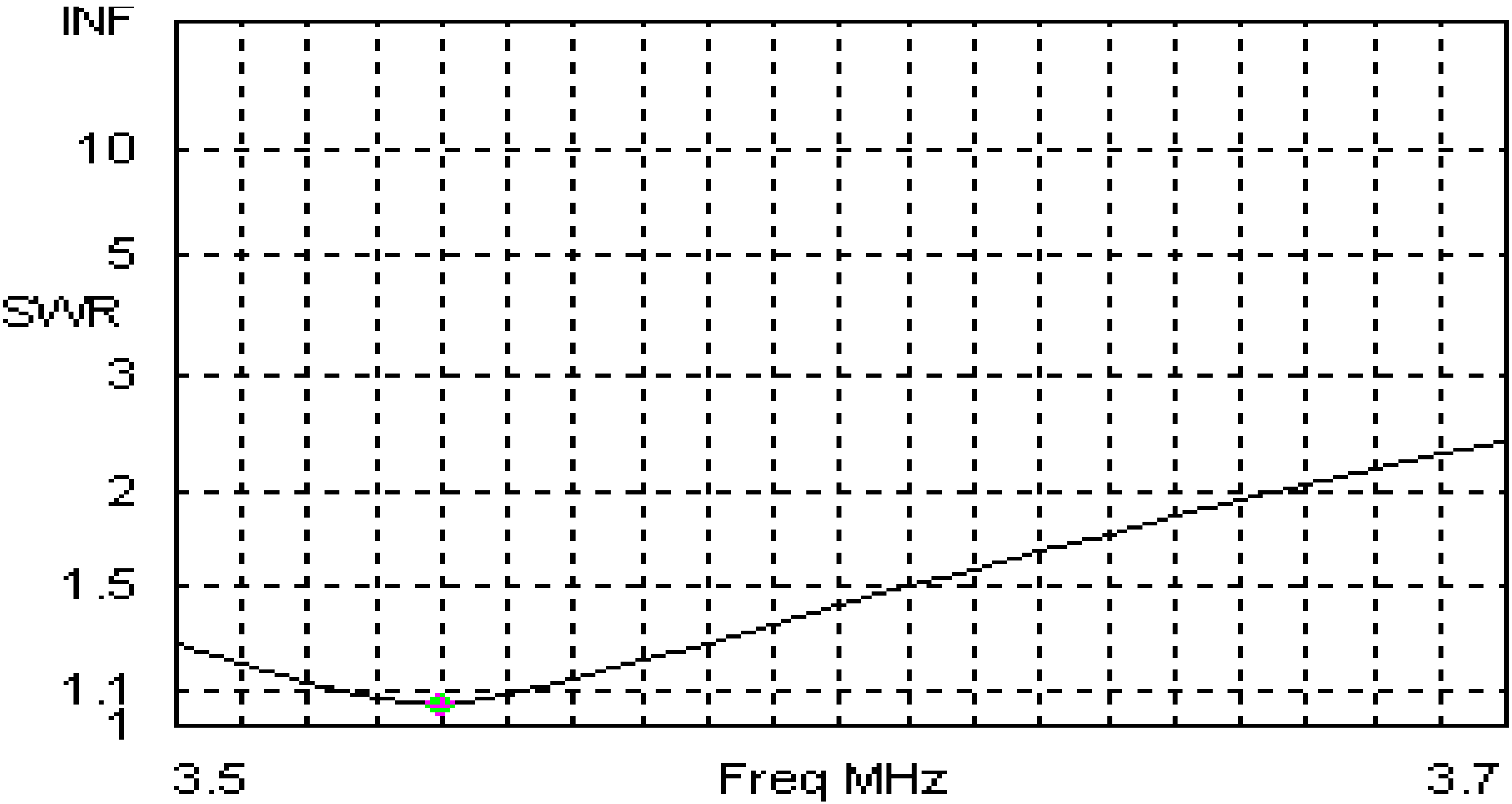
Optimization

- Bottom loading wires
  - 8 ft above ground at far end produced greatest signal strength
  - < 8 ft increases ground loss, > 8 ft effectively shortens the radiator
  - 3 wires used, allowing guy wires to act as supports for the elevated ends

Optimization

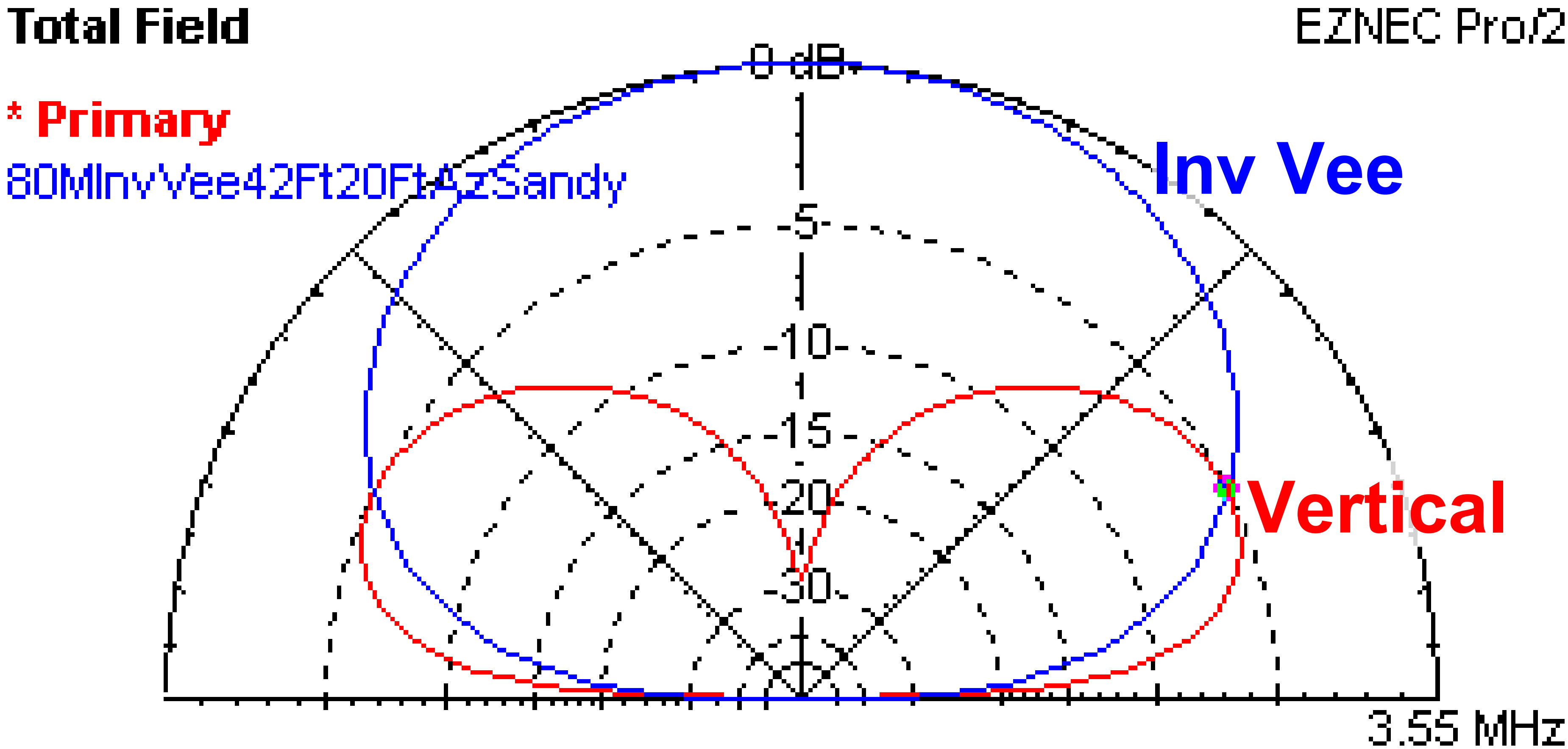
- Varied top and bottom loading to achieve best match to 50Ω
  - Less coil, longer bottom loading wires
  - More coil, shorter bottom loading wires
- Design was tweaked for 3540 kHz
- Measured resonance was 3510 kHz
  - Easily moved up by shortening bottom loading wires

SWR From Model



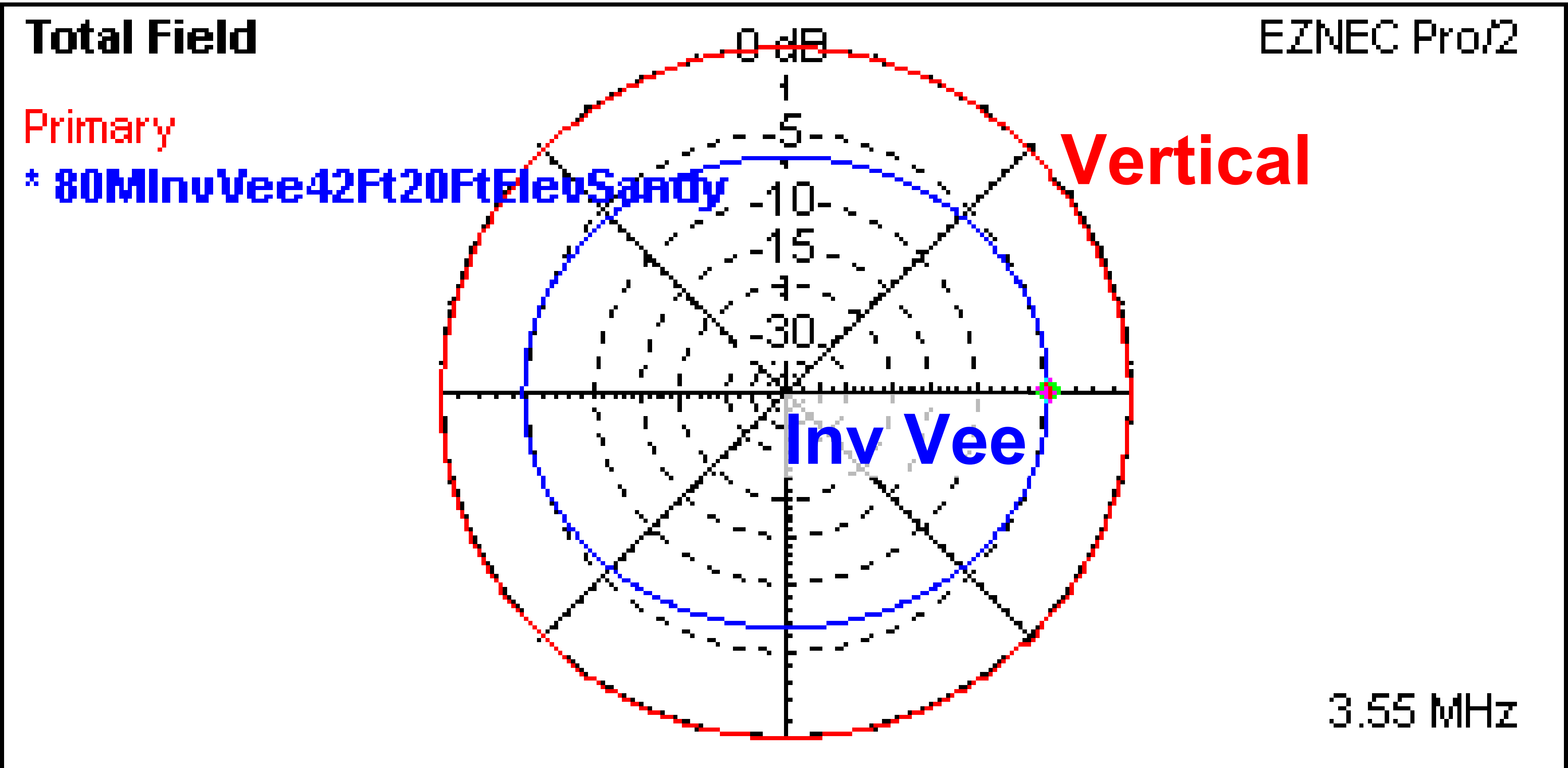
Freq	3.54 MHz	Source #	1
SWR	**1.053**	Z0	50 ohms
Z	52.64 at 0.17 deg.		

Vertical Pattern Broadside to Inv Vee



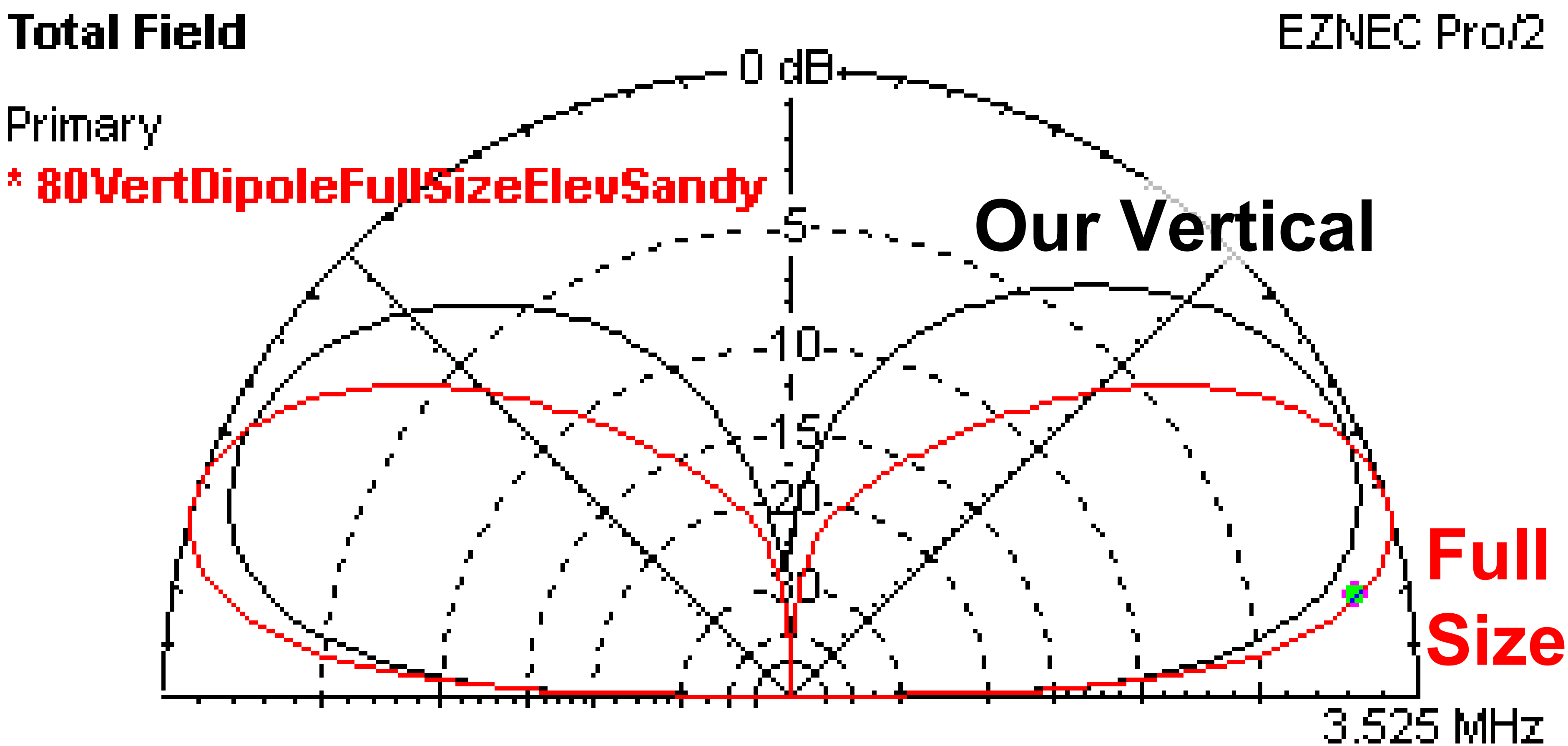
Elevation Plot		Cursor Elev	26.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.97 dBi
Outer Ring	4.11 dBi		-0.04 dBmax
			-0.19 dBmax3D

Polar Pattern at 10° Elevation



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	-8.23 dBi
Outer Ring	-3.43 dBi		0.0 dBmax
			-4.64 dBPrTrc

Compare to Full Size Vertical Dipole



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -0.44 dBi

Cursor Elev 10.0 deg.
Gain -1.91 dBi
-1.47 dBmax
1.56 dBPrTrc

Building It

Most of The Parts

4-Ft Mast Sections

- **4-inch mating section reduces effective length to 3 ft – 8 in**
- **7 sections = 25 ft – 3 in**
- **Center insulator = 18 in**

Center Insulator – coax exits at bottom of 2-in mast, not perpendicular to antenna

Guy Ring

Delrin Base Insulators

Loading Coil

32 turns, #8 bare copper, tapped. Turns can be compressed or expanded for tuning

Jack, Tripod Fixture

Common Mode Chokes on Feedline

- Feedline is fed through center of lower dipole section
- No need for coax perpendicular to antenna
- Common mode chokes are used to decouple feedline from antenna
- Keeps RF off the coax
- At CQP, we run 600W, so multiple chokes are used to prevent destructive overheating
  - 7 turns on “largest #31 clamp-on”

Spiderbeam HD 12m fiberglass pole

HEAVY DUTY professional telescopic pole (12m / 40ft) high strength fiberglass pole for quick portable wire antennas

Antenna Components

- **14 4-ft sections of 2-in o.d. surplus mast (3’- 8” when mated)**
  - **6 sections in tripod base**
  - **7 sections in vertical section**
  - **1 section sacrificed to make center insulator**
- **Spiderbeam 40 ft telescoping fiberglass mast**
- **Tripod fitting**
- **Cylindrical insulating feet for tripod base**

Antenna Components

- Loading coil,design value 13 uH
  - 32 turns #8 bare copper
- 154 ft #12 THHN (house wire)
  - 40 ft taped to fiberglass tube
  - 114 ft (three 38 ft outriggers)
- Rope to guy antenna at top of 2-in mast

Antenna Components

- RG8X from center insulator, fed through mast sections, wound onto ferrite cores
  - RG8X used so more turns could fit through cores, making resonance low enough for good 80M suppression
- 2 Fair-Rite 1-in i.d. #31 “big clamp-ons”
  - We started with 3, two is enough
- Add RG213 for run to rig

Erecting the Antenna

- **Set up tripod base**
  - **Two sections in each leg**
  - **Tape them together (plumber's tape)**
  - **Insulators in each leg**
- **Place top section in base**
- **Add guy ring at top**
- **Mount loading coil to fiberglass mast**
  - **36-ft wire to top of loading coil (heavy alligator clip allows adjustment)**

Erecting the Antenna

- **Mount fiberglass mast, w/wire attached, to top section of 2-in mast**
  - **Extend it one section at a time**
  - **Tape each section so it won’t collapse**
- **Attach guy lines (antenna rope)**

Erecting the Antenna

- **When fiberglass mast is at full length, start adding 2-in mast sections**
  - **Add below top of tripod base, push up**
- **Here's where the tower jack comes in handy**

Erecting the Antenna

- When fiberglass mast is at full length, start adding 2-in mast sections
  - Three sections, then center insulator
  - Four more sections, feed coax thru them
  - Bottom section has paint stripped
  - Bottom section has attachments for horizontal loading wires
- Bottom section should be 4-ft high

Erecting the Antenna

- **Antenna will start to be "wobbly" with 3 - 4 of the 2-in mast sections raised**
  - **Need someone on each guy line to maintain tension as it is raised to full height**
- **Tie off the guys when antenna is at full height**
  - **It helps to drive guy points before raising antenna**
- **Attach horizontal loading wires, rig them to guy lines**

Erecting the Antenna

- Rig the common mode chokes on the feedline
  - Make sure clamp-on clicks to lock
  - Add ty-wrap to maintain the lock
- Connect to rig or antenna analyzer to check for resonance

Performance Testing

Performance Testing

- Set up both the vertical and an Inv Vee in a field about 50 ft apart
- Inv Vee apex @ 42 ft, ends about 20 ft
  - Ferrite common mode choke at feedpoint
- Used Reverse Beacon Network (RBN) to compare the antennas

W6GJB 42 Ft Pneumatic Mast Used to Support Inverted Vee (shown here on Field Day supporting a C3SS)

RBN Testing

- K3 was used with KPA500 amp (600W) and KAT500 tuner
- Difference between antennas can be less than normal QSB
- Propagation changes through the night
- Many data points must be averaged to reach a valid result
- Rule out interference between the antennas

RBN Test Method

- **Compare two or more antennas via Reverse Beacon Networks spots…**
  - **Over a short period of time**
  - **With identical TX conditions**
  - **Get multiple spots per RX station**
- **The most rigorous comparisons are obtained when more RX stations each spot (or fail to spot) both antennas multiple times over a short period of time**

RBN Test Method

Assign a unique callsign to each antenna, then…

1. Send “TEST TEST callsign1” x3
2. Switch antennas
3. Send “TEST TEST callsign2” x3
4. QSY and repeat x5
5. Repeat different times, different nights

RBN Test Method

- RBN spots include S/N ratio
- Spots were entered in Excel, plotted vs. distance (from qrz.com)

Interference Between Antennas

- First night testing showed poor performance of the vertical
- The vertical was set up near a steel tower trailer with a crankup tower mounted, raised to about 30 ft, and with a tribander on top

The Tower Trailer

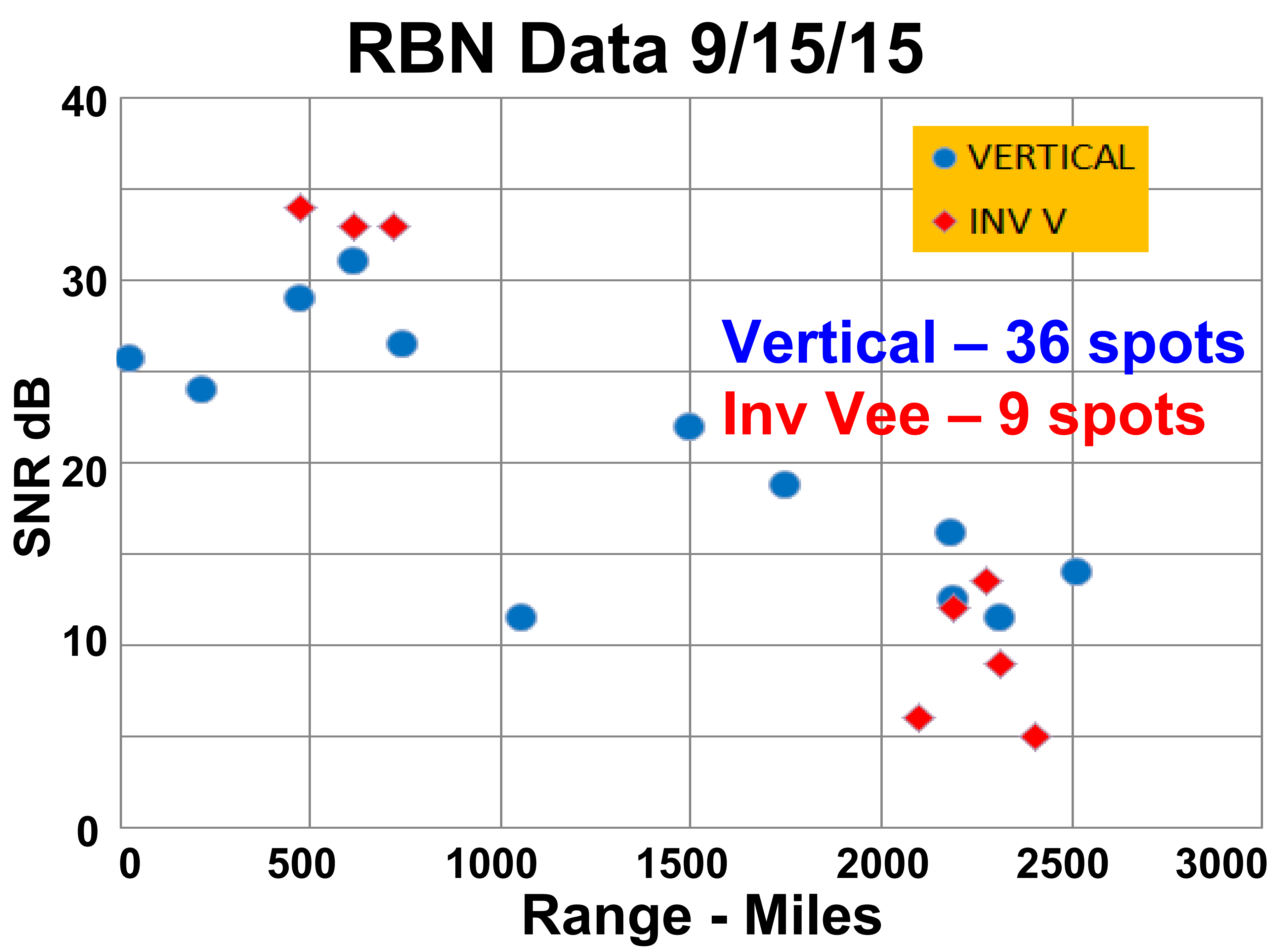
Interference Between Antennas

- **On a hunch, we lowered the tower, removed the tribander, rotated the tower so it was flat on the trailer, then resumed testing**

The Tower Trailer

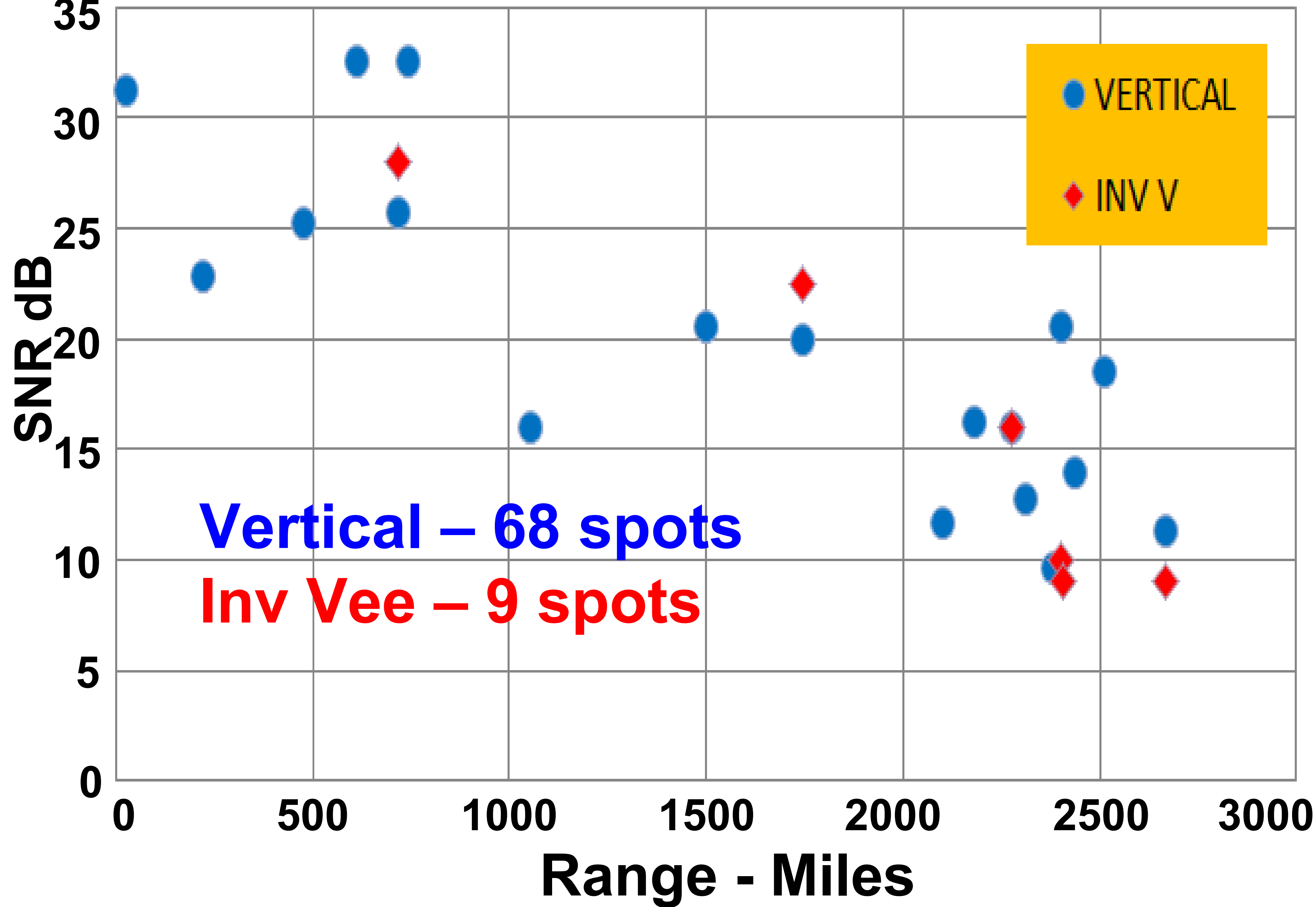
Resuming RBN Tests

- Without the tower trailer, the vertical was clearly working much better
  - Many stations heard Vertical, but not Inv Vee
  - Few stations heard Inv Vee, but not Vertical
- Also tried vertical with Inv Vee on the ground
  - No difference in performance, so no interference from Inv Vee



RBN Data 9/15/15
VERTICAL
INV V
Vertical – 36 spots
Inv Vee – 9 spots
SNR dB
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
Range - Miles

RBN Data – 9/17/15



Summary Of Results

- The antenna can easily be erected by old men, but five are required
  - One on each guy line, two at the antenna
  - The 40 ft fiberglass acts like a wet noodle
- The antenna works well
  - At low angles, beats an Inv Vee with apex at 42 ft, ends at 20 ft
  - Enough high angle radiation to work closer stations

Summary Of Results

- **No heating at all with three chokes**
  - **Can be feedline length dependent**
  - **Two is probably enough, and only one might be**

Verticals and Ground Losses

Two Kinds of Ground Loss

- **Loss under the antenna as the antennas fields (and current) return via lossy earth**
  - **Radials reduce this loss by acting as a <u>shield</u> between antenna and the earth**
  - **Current and field are in low resistance wires rather than high resistance soil**
- **Vertical dipoles have far less of this kind of loss – bottom half of dipole is the return for top half**

Two Kinds of Ground Loss

- **Loss in the far field where the wave-front strikes the earth, is reflected, and added to the direct wave to produce the vertical pattern**
  - **We can reduce this loss only by moving to a QTH with better soil!**

Horizontal Antennas and Ground Loss

- Ground quality does <u>not</u> affect field strength from horizontal antennas
  - 2dB stronger high angle from Good ground
  - No difference below 45 degrees
- Ground quality <u>does</u> affect feedpoint impedance of horizontal antennas

Effect of Ground Conductivity

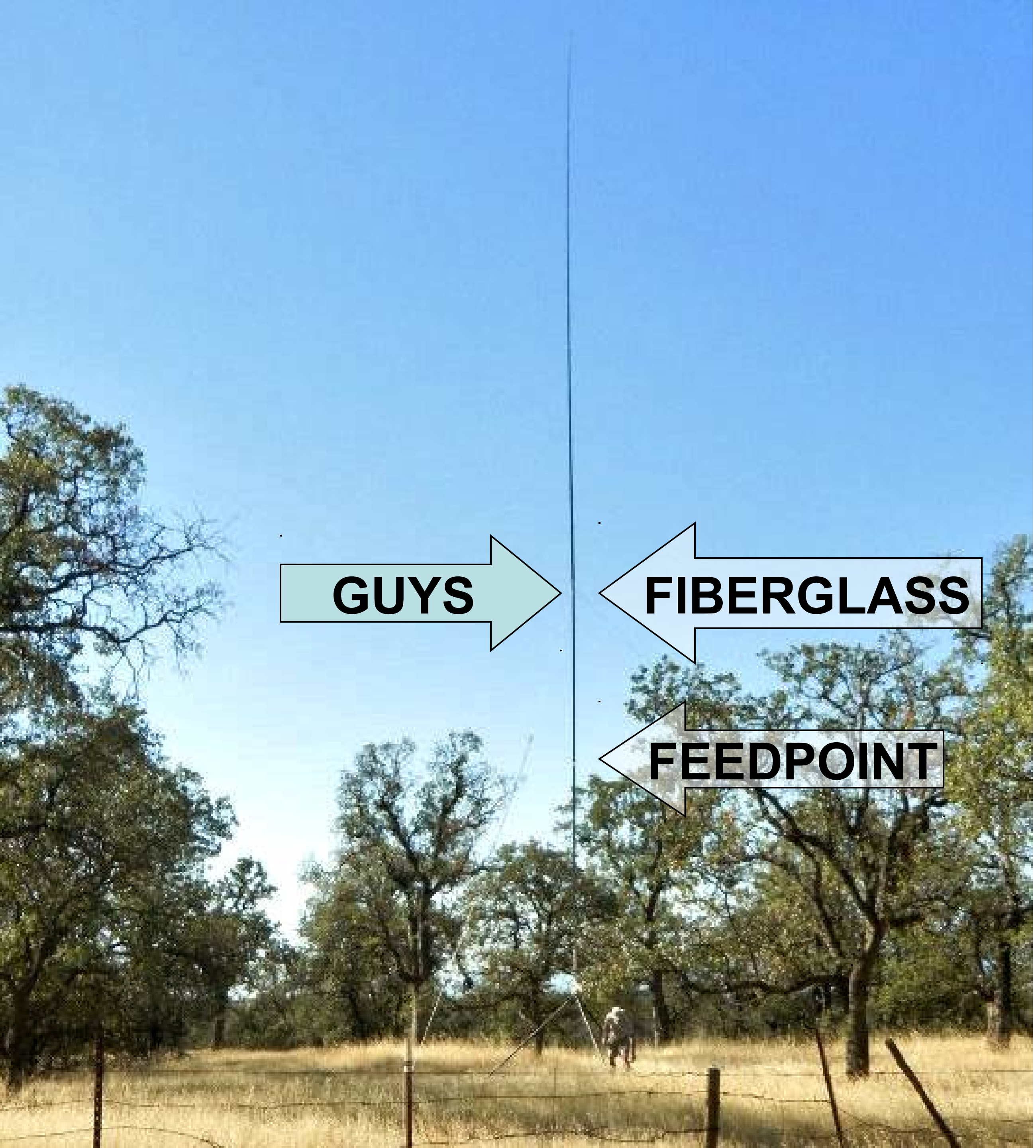
- **Model assumed Poor ground (Sandy)**
- **Testing done with Poor ground**
- **Tehama Co CQP site has Poor ground**
- **Vertical antennas work better with better (higher conductivity) ground**
- **This vertical will work even better than a horizontal dipole over good soil**
  - **5.25 dB better over Poor ground**
  - **6.75 dB better over Average ground**
  - **10 dB better over Very Good ground**

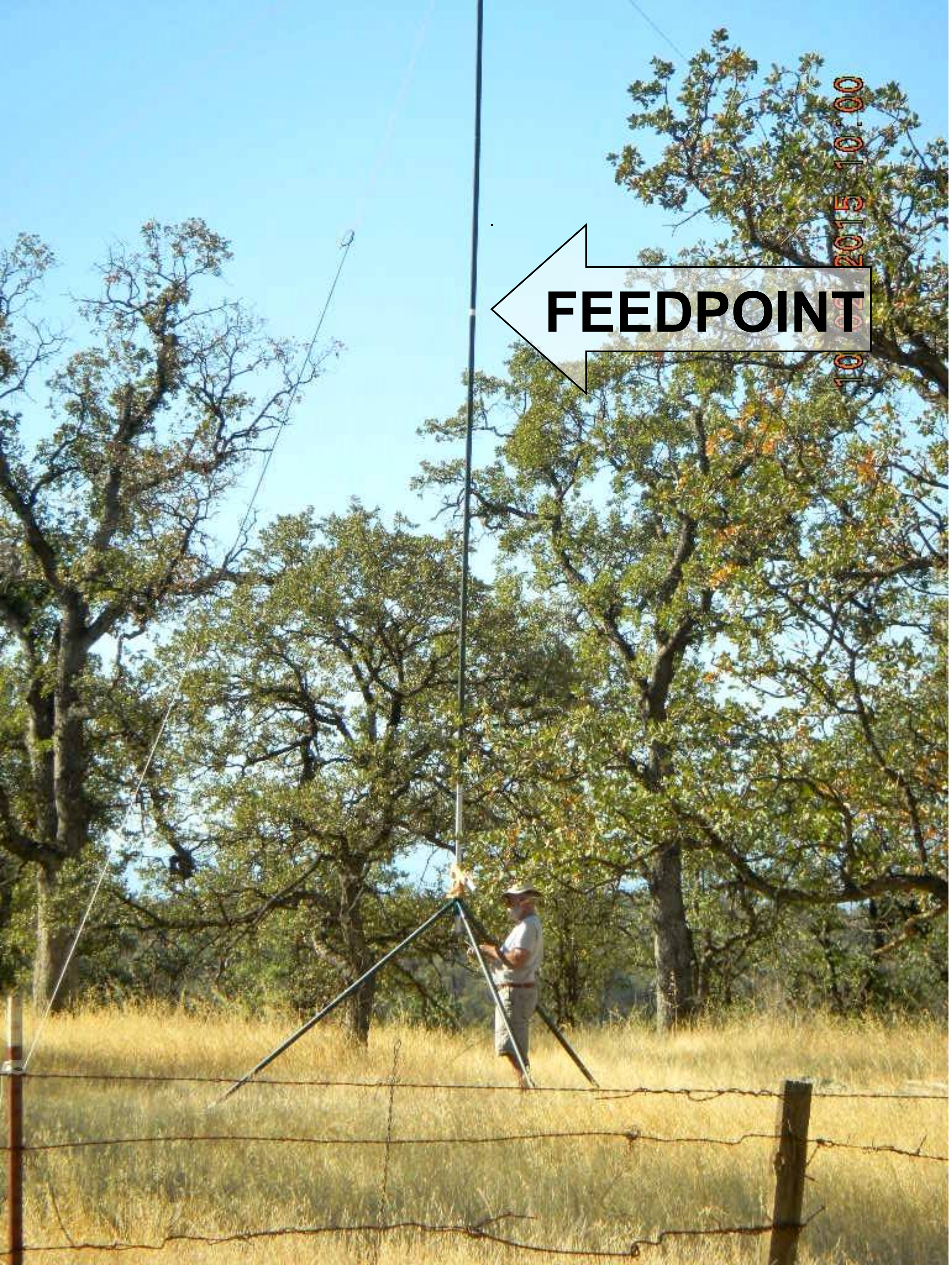
California QSO Party

- **CQP (California QSO Party) was held the first weekend in October, and was the first planned use of this antenna**
- **Here are photos of setup at the site**

Mounting Fiberglass Mast to Surplus Mast

The Complete Antenna





Zooming In

And then it got windy

Spiderbeam Pole Broken in Wind

Spiderbeam HD 12m fiberglass pole

HEAVY DUTY professional telescopic pole (12m / 40ft) high strength fiberglass pole for quick portable wire antennas

From The SpiderBeam Website

These are extremely strong poles, with a much greater wall thickness (up to 2mm!) than the usual "fishing rod" types. A special reinforcing winding technique - several layers of fiberglass are wound in alternating direction (criss/cross winding) - provides greatly increased lateral and linear strength.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The Failed Spiderbeam Mast

What Went Wrong?

- **Spiderbeam failed to deliver what they advertised – a specially reinforced mast with criss/cross windings, and a bottom section with 2mm wall thickness**
- **The section that broke, the bottom section, had a wall thickness of only 1.75mm, and it did <u>NOT</u> have reinforcing criss/cross winding(s)**

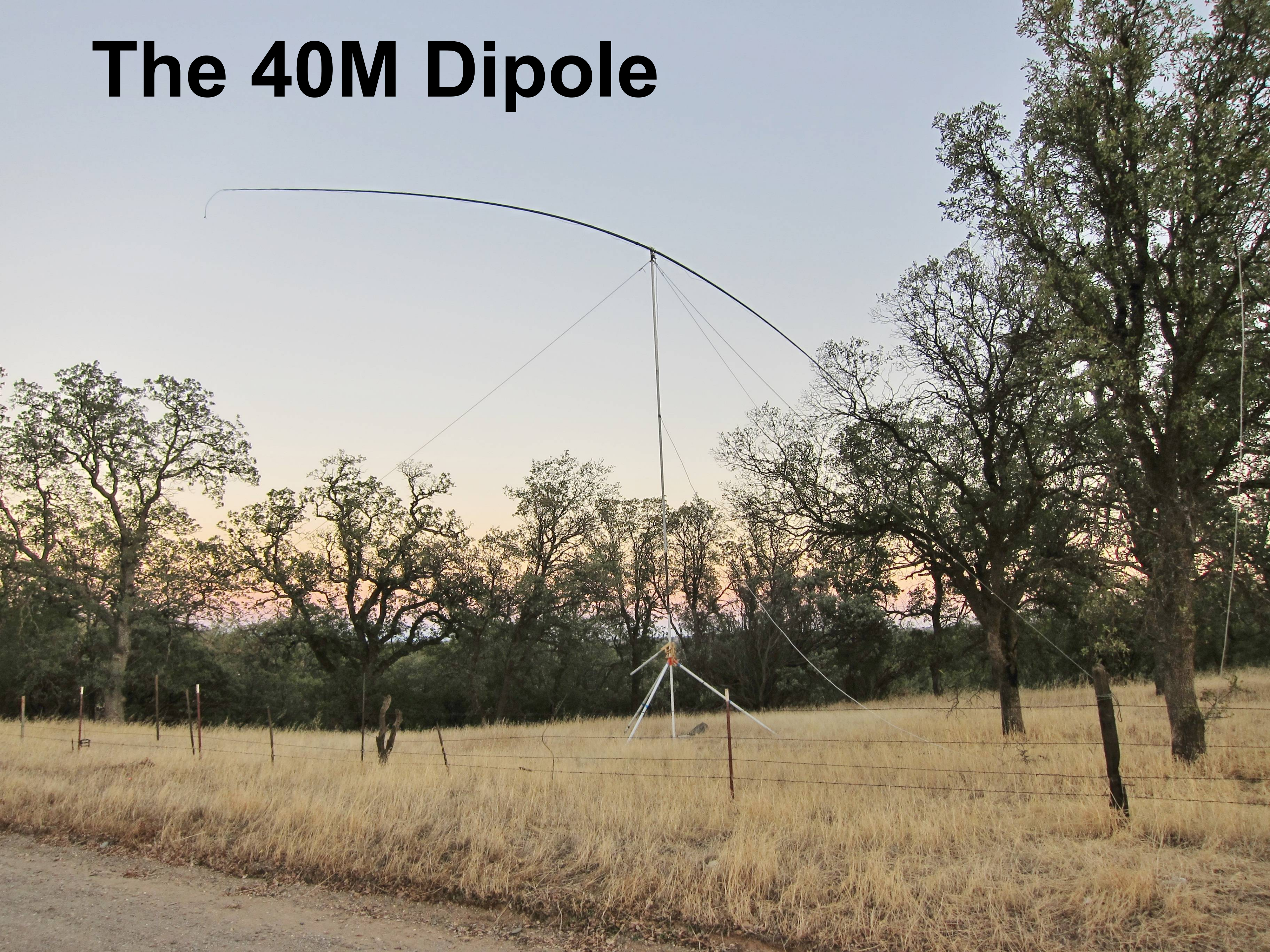
The Failed SpiderBeam Mast

Back to the Drawing Board!

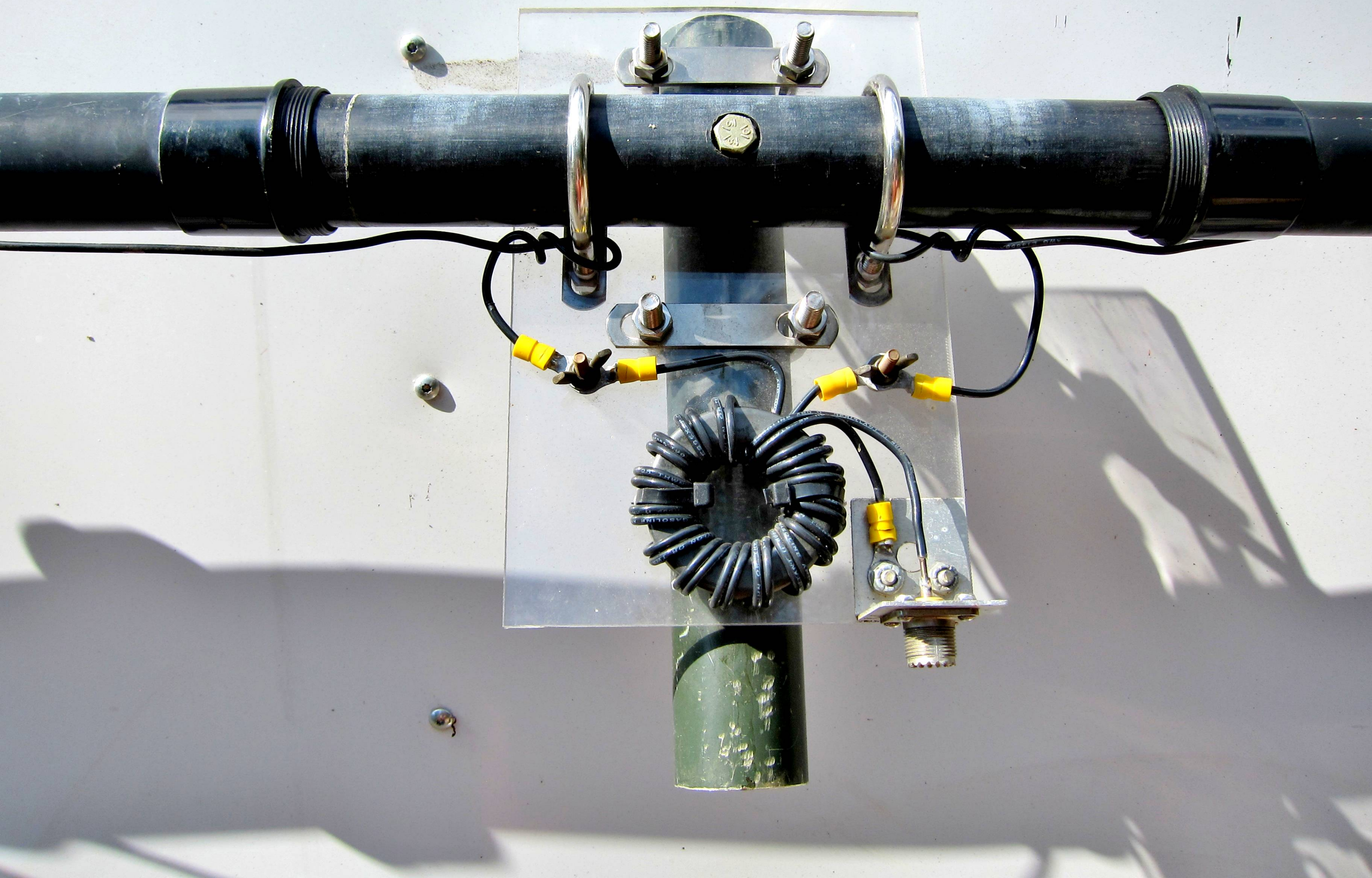
Where Do We Go From Here?

- **For several years, we have used a 40M dipole made by mounting two 31-ft Jackite poles to a fitting that W6GJB made to attach to the top of the same surplus mast sections, with #12 THHN taped to the poles**
- **This antenna survived the same winds with no damage, and has always performed well**
- **These poles ARE reinforced at their base, cost is $80 each**

The 40M Dipole



The 40M Dipole



Where Do We Go From Here?

- NEC computes the field strength of our loaded 80M dipole as 0.4 dB less than a full size λ/4 vertical with 4 radials elevated 6 ft
  SO ---
- Maybe we've made it too complicated!
- Forget about the vertical dipole
- Forget about the SpiderBeam pole
- Build a λ/4 vertical using our surplus mast sections and a Jackite pole

Where Do We Go From Here?

- Mount a 31 ft Jackite pole to the top of 9 sections of surplus mast, add a 16μh coil to resonate it
- Guy at top of surplus mast sections
- Add 4 λ/4 (67 ft) radials elevated 6 ft
  - Elevating radials reduces ground loss
  - 67 ft too long to fit in available space
  - Add loading coil to each radial
- NEC predicts 28 Ω feedpoint Z
- We'll need a simple matching network

Where Do We Go From Here?

OR –

- Reinforce the SpiderBeam pole and stick with the vertical dipole design
- Big advantage – 38 ft bottom loading wires barely fit in the available footprint, easy to rig to guy lines
- No matching network needed

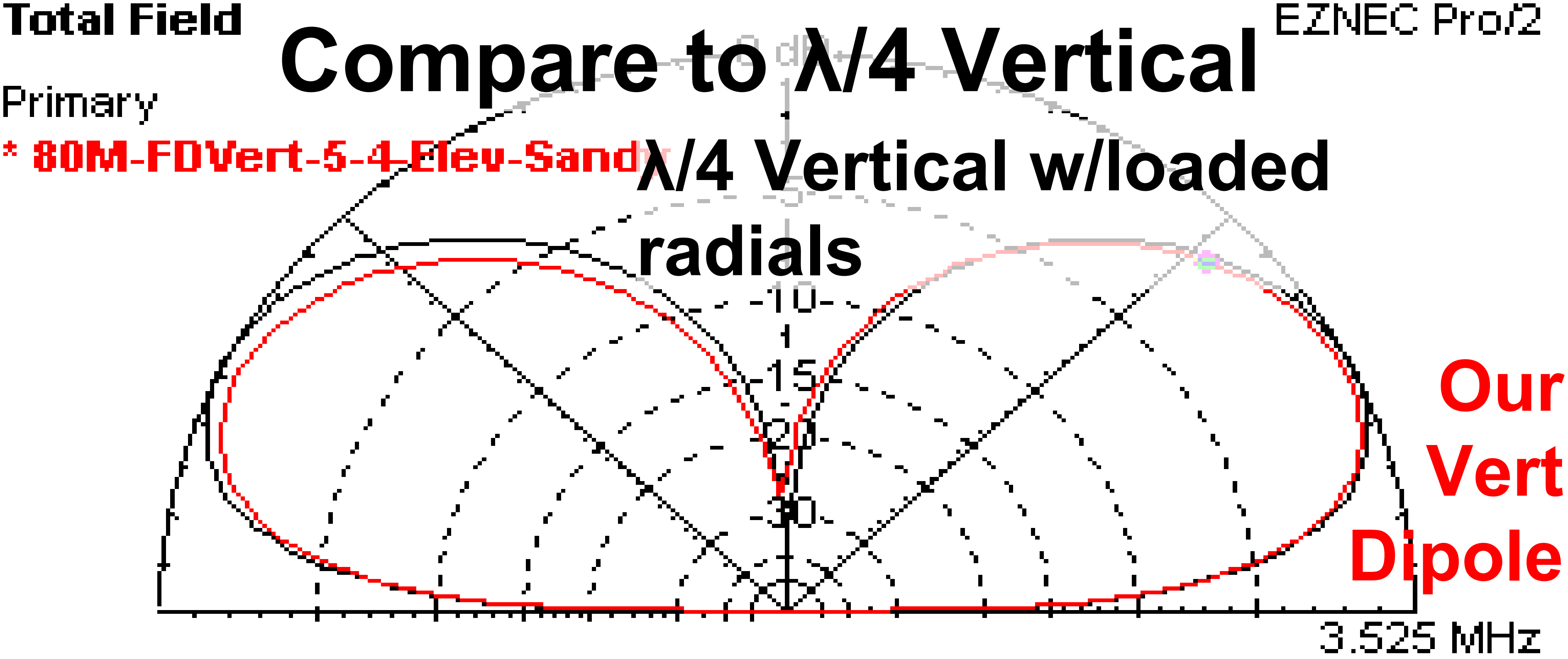
Where Do We Go From Here?

- **Build one or the other, leave it up for a season to see how it survives the elements**
- **Do some more RBN performance testing**

Things We Learned

- **Our half-size dipole, with all the things we did to maximize efficiency, turned out to be λ/4 tall**
- **Performance (field strength and pattern) models almost identically to simple λ/4 “ground plane” with low loss radial system**

Compare to λ/4 Vertical



Elevation Plot		Cursor Elev	43.0 deg.
Azimuth Angle	10.0 deg.	Gain	-2.08 dBi
Outer Ring	-0.55 dBi		-1.3 dBmax
			-0.22 dBPrTrc
3D Max Gain	-0.55 dBi		
Slice Max Gain	-0.78 dBi @ Elev Angle = 26.0 deg.		
Beamwidth	43.4 deg.; -3dB @ 9.3, 52.7 deg.		
Sidelobe Gain	-1.09 dBi @ Elev Angle = 154.0 deg.		
Front/Sidelobe	0.31 dB		

Things We Learned

- **Tape on joints is not sufficient to prevent pole sections from loosening in the wind**
- **Don’t believe everything you read on the website of any company selling ham gear**
  - **“We’ve sold thousands”**
  - **“Used by major DXpeditions” usually means they were donated**

Wait ‘til next year!

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