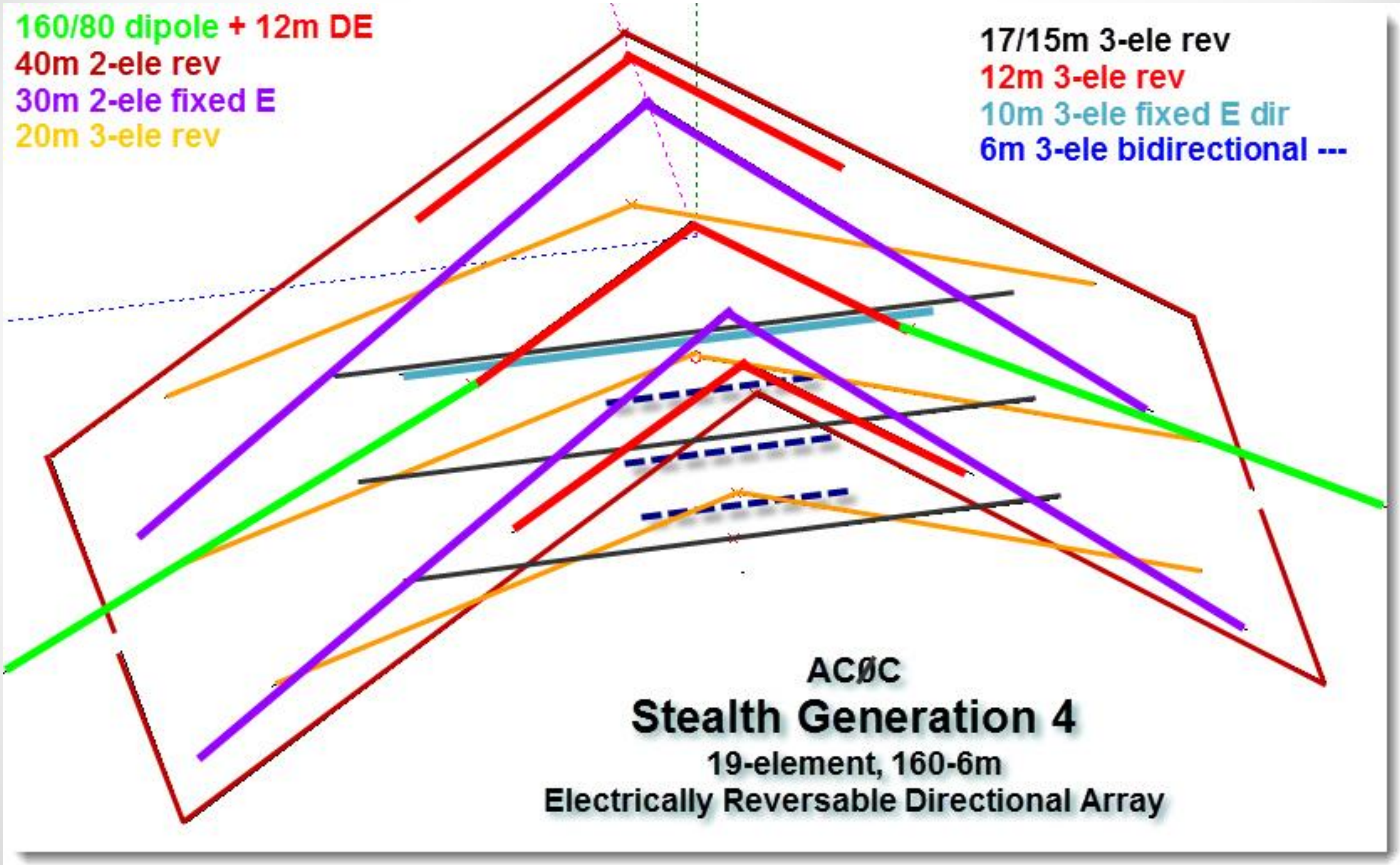
40m 2-element Wire Beam: Parasitic → Phased Array Conversion

Updating the 4th-Generation Stealth All-Band Electrically Reversible Directional Array

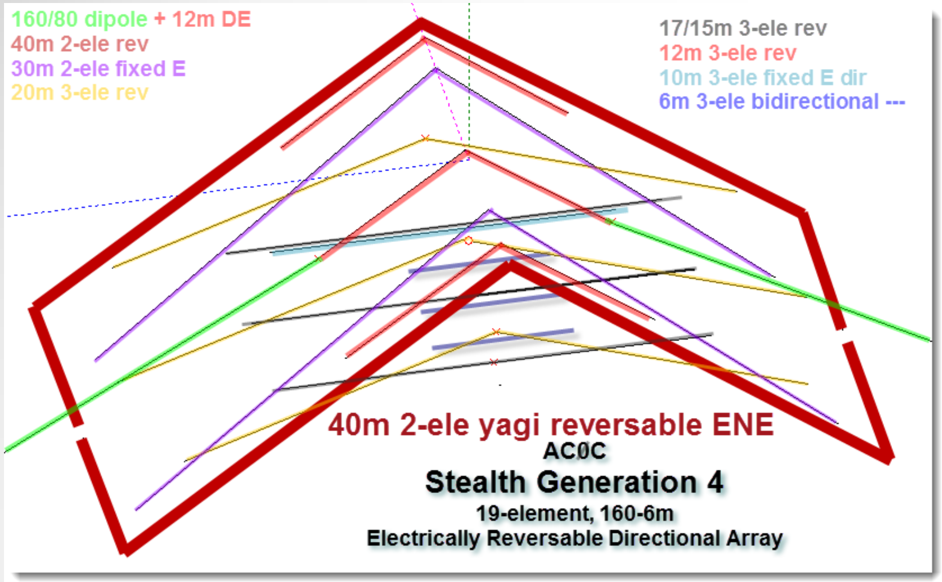
Jeff Blaine – ACØC

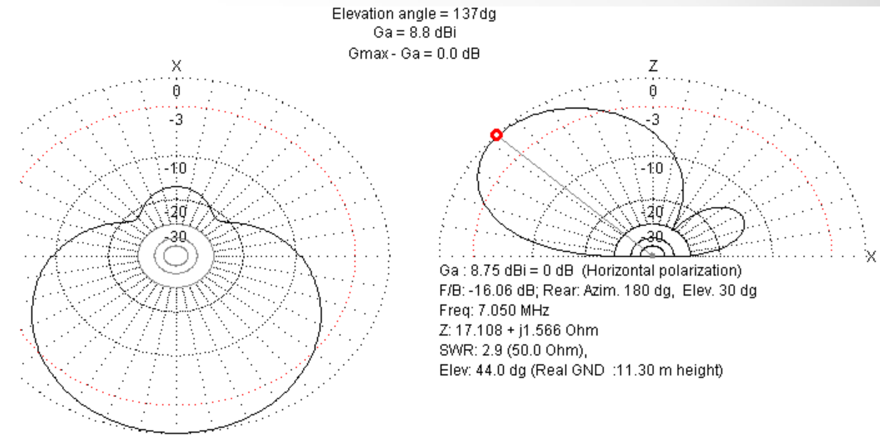
Presented to the KC DX Club – 25 April 2011

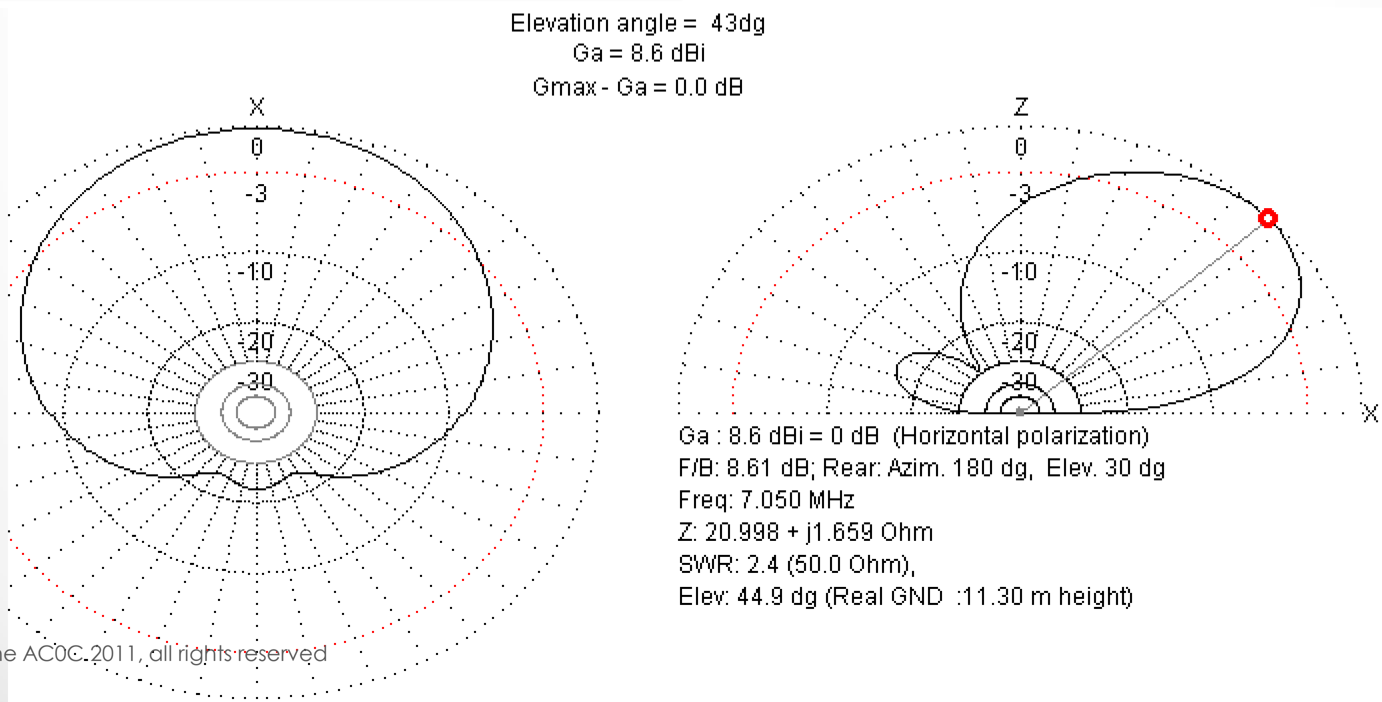
Array Overview



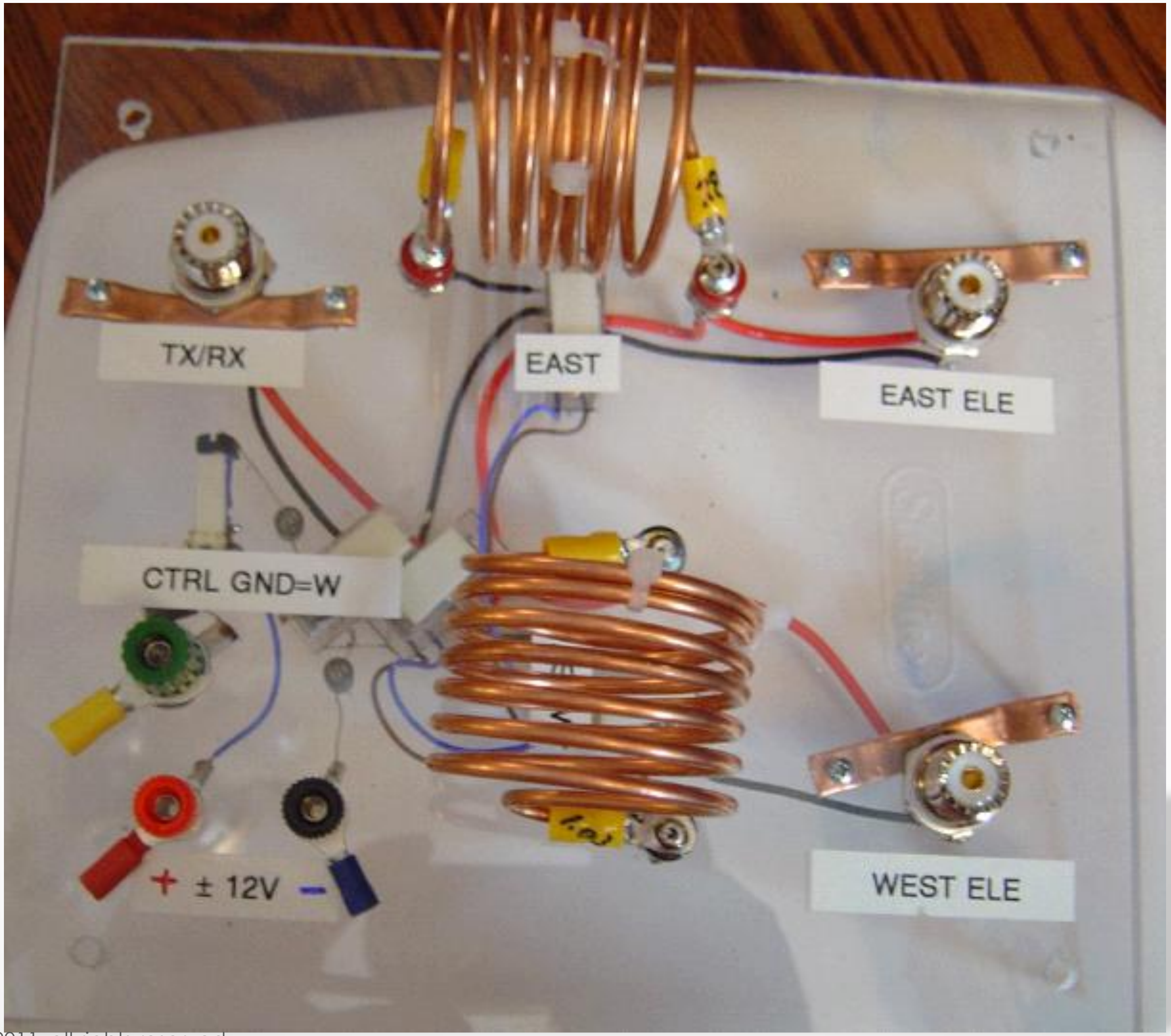
40m Simulation - MMANGAL



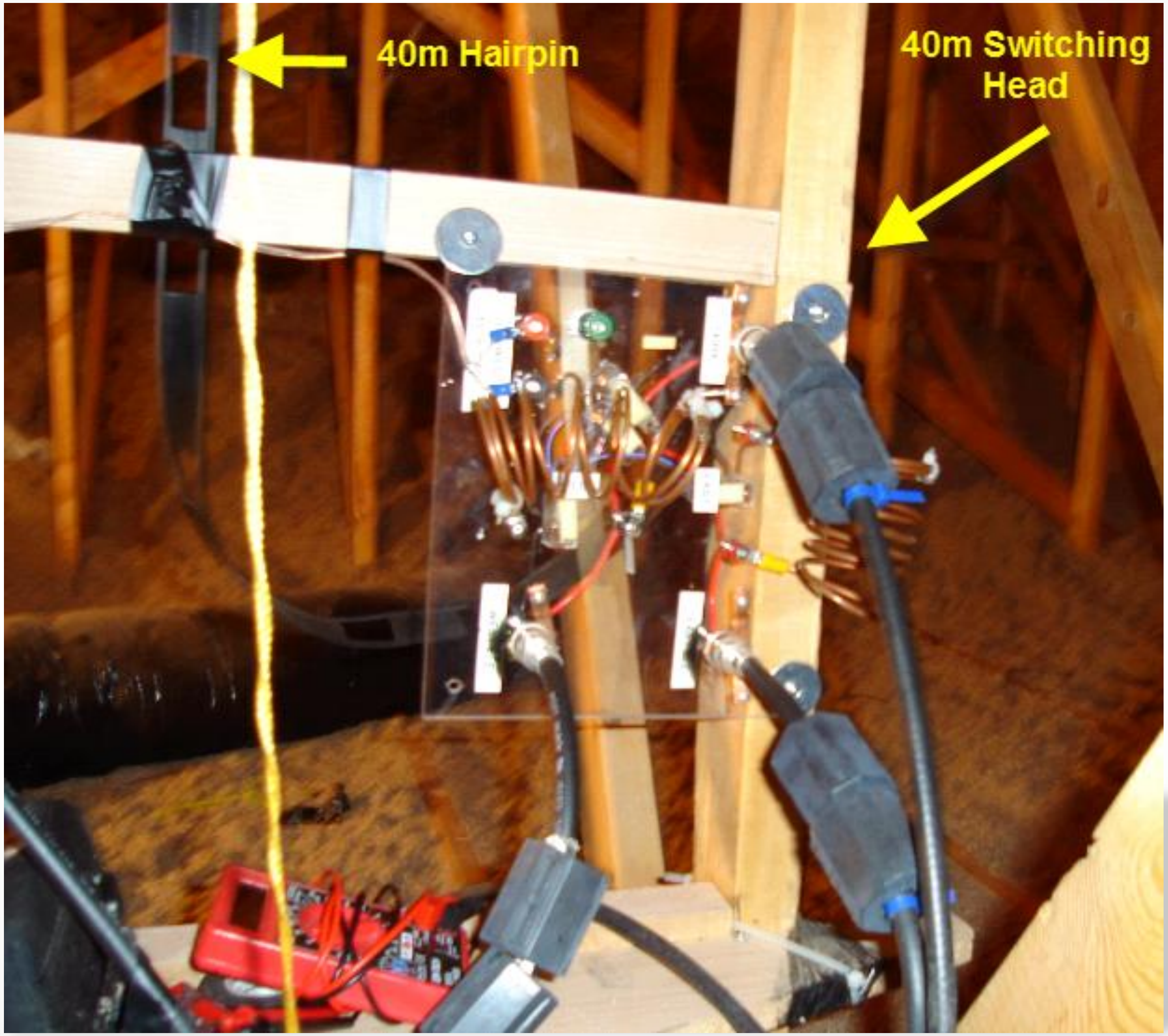




DE/Reflector Switching



Control Board - As Mounted



4th Gen 2-ele Wire Beam - Results

- Informal testing of gain/fb:
  - Consistently strong signal East (beaming east)
  - Consistently weak signal West (beaming west)
  - SWR swing between direction change too great
  - F/B poor beaming East, worse beaming West
- In contest performance:
  - Far better performance than prior design
  - Good 40m East beaming results
  - Poor 40m West beaming results
  - Consistently high Q count in contests – often better than 20m!
- Anecdotal vs. Measured
  - RVM results needed
  - West element hard to tune (very broad response)

Measuring the Baseline

W8WWV Reverse Simulation Overview

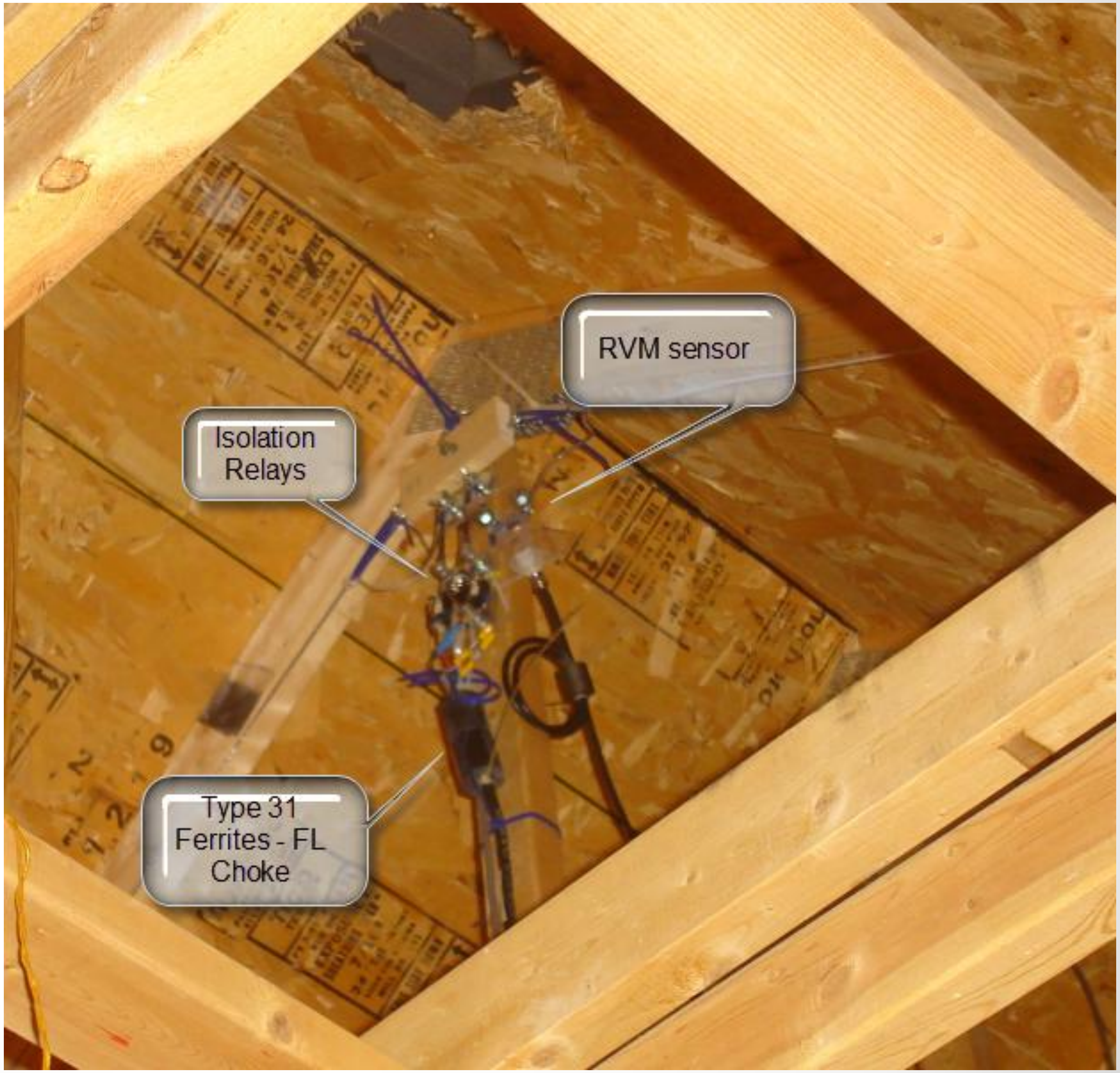
Measure Element RF Currents with VNA + Mux - Magnitude/Phase

Load Data into Simulation Model

Simulation Generates Plot of **Actual** Antenna Performance

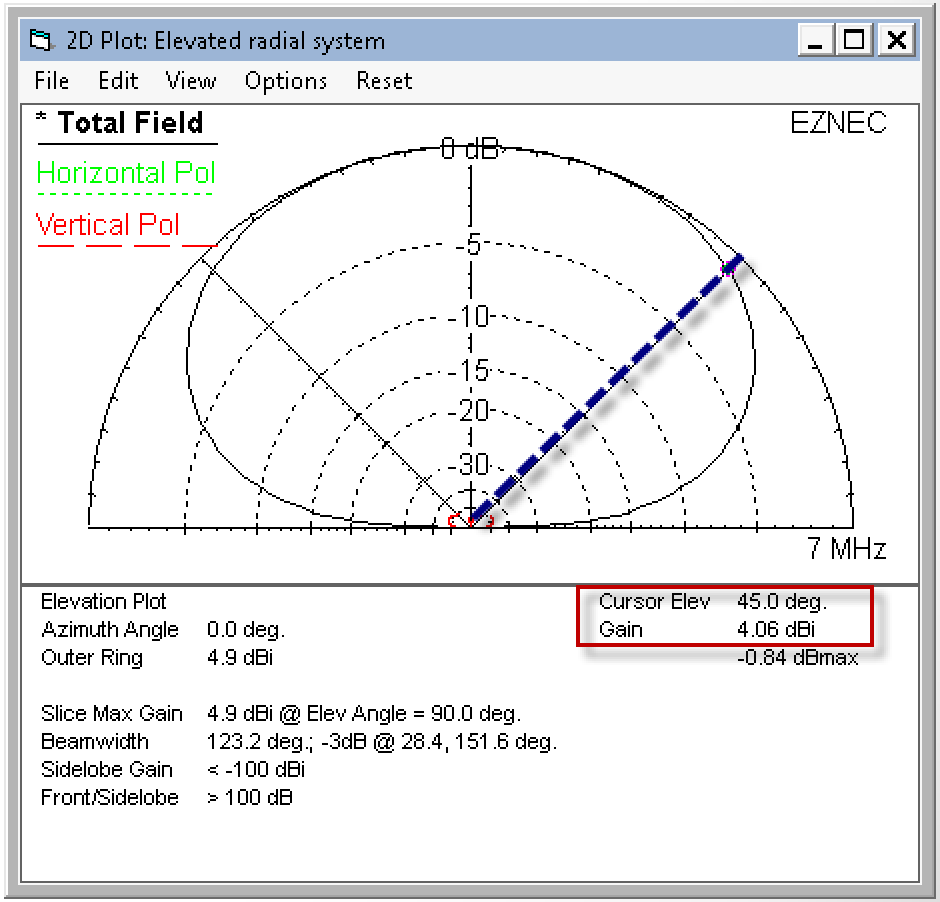
W8WWV RVM System Sensor

- Sensor located at each element
- Feeds N2PK VNA
- Measures relative current/phase for each element



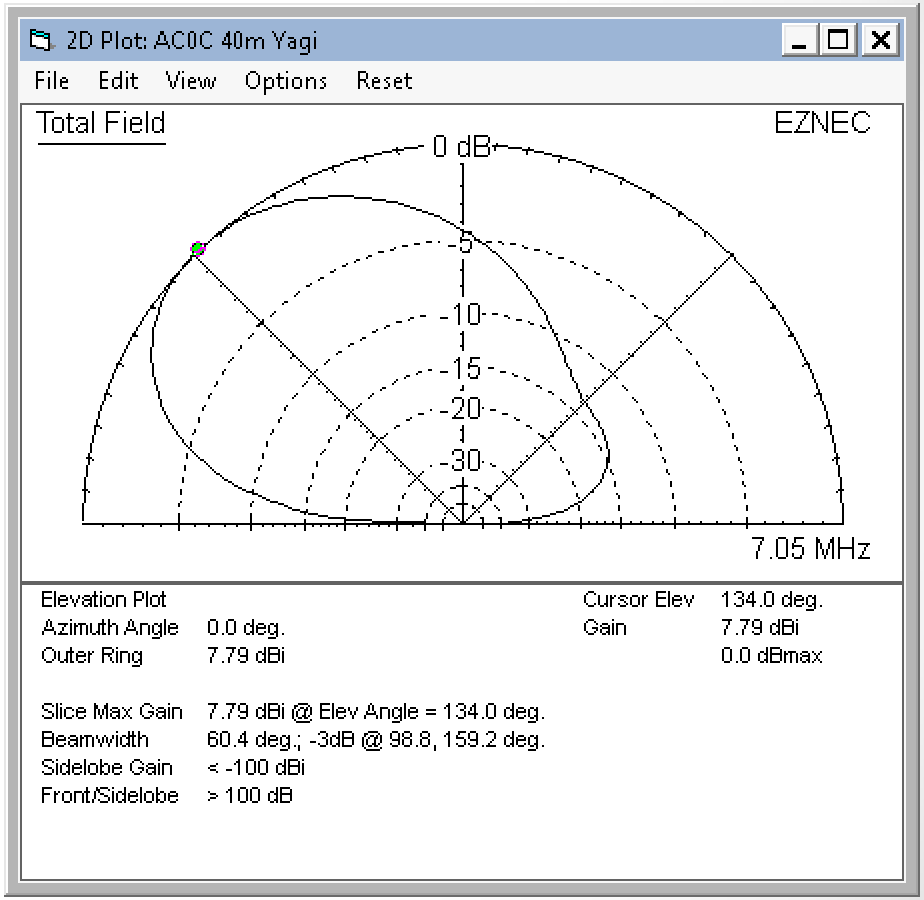
Baseline for Perspective: Dipole

- Dipole at same height and same geometry as wire beam elements
- Gain
  4.06 dBi @ 45 deg
- Serves as baseline



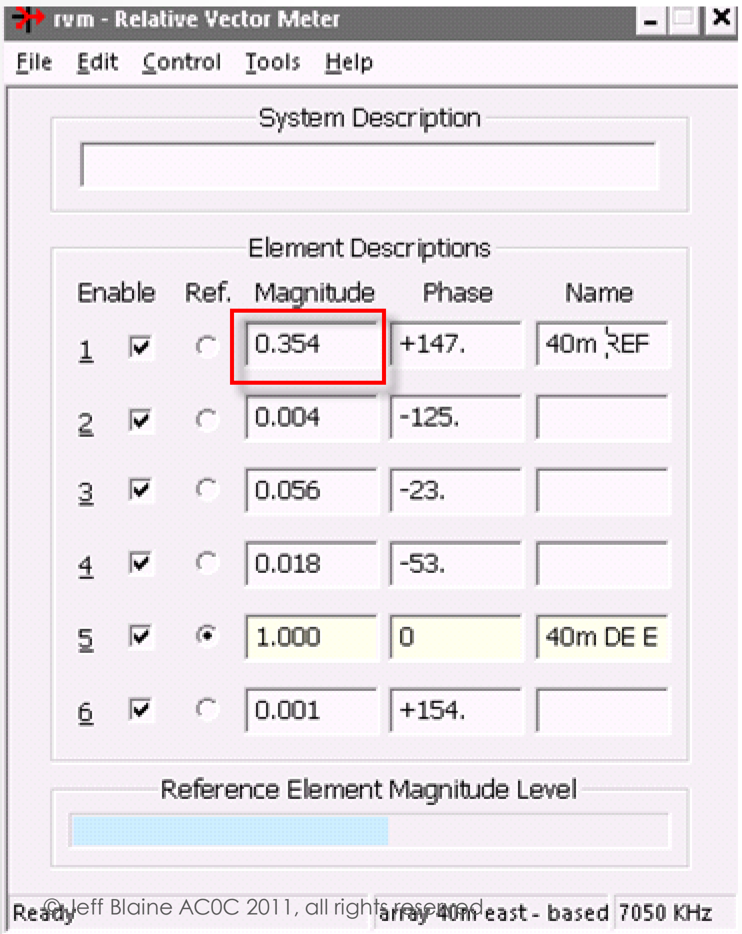
Ideal Parasitic Model Predictions

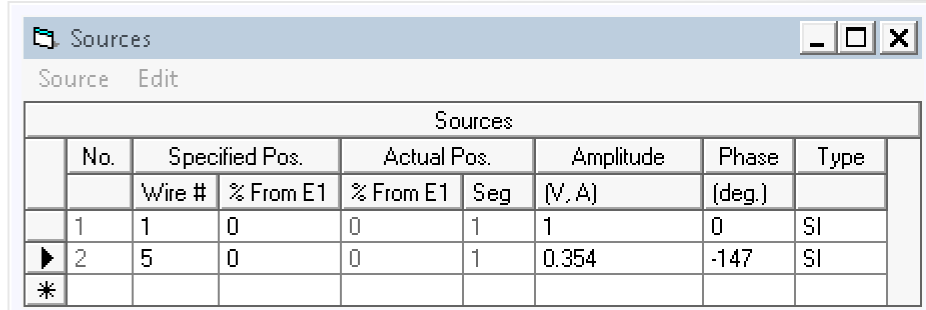
- DE:
  - 1 A
  - 0 deg
- REF:
  - **0.817 A**
  - -149 deg
- Performance
  - Gain 7.8 dBi @ 45 deg = 3.75 **dBd** @ 45 deg
  - 13 db f/b approx @ 45 deg

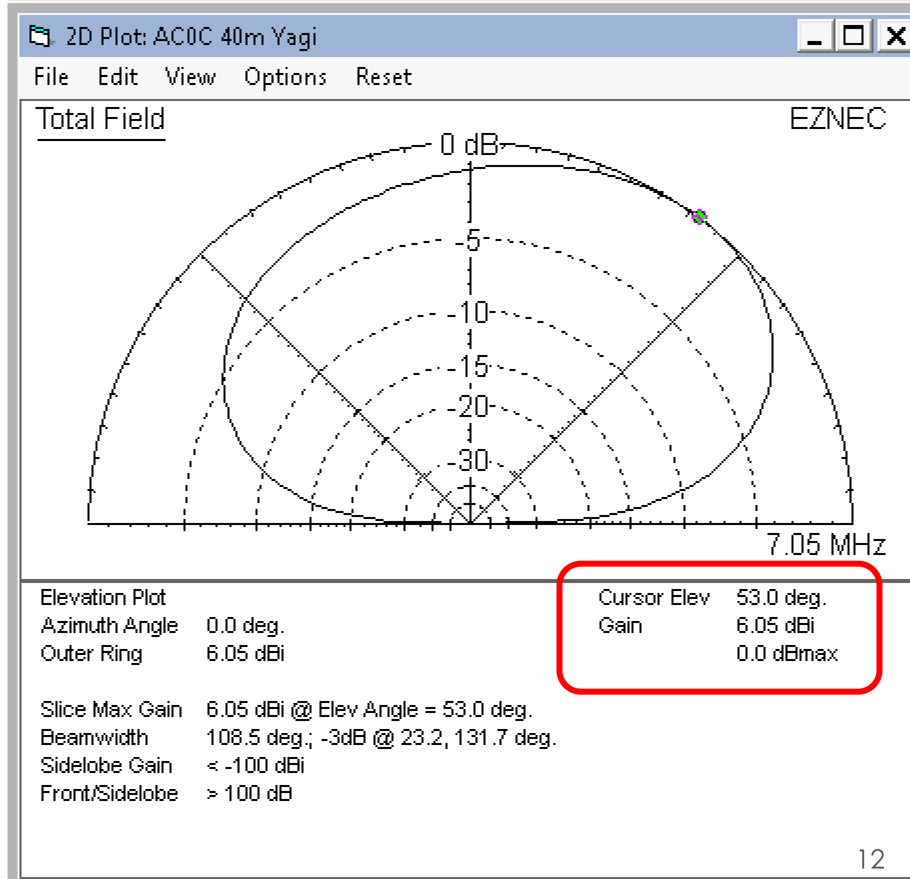


Measured Reality – East Beaming

- RVM Measured Values
- Inverse Model Plot

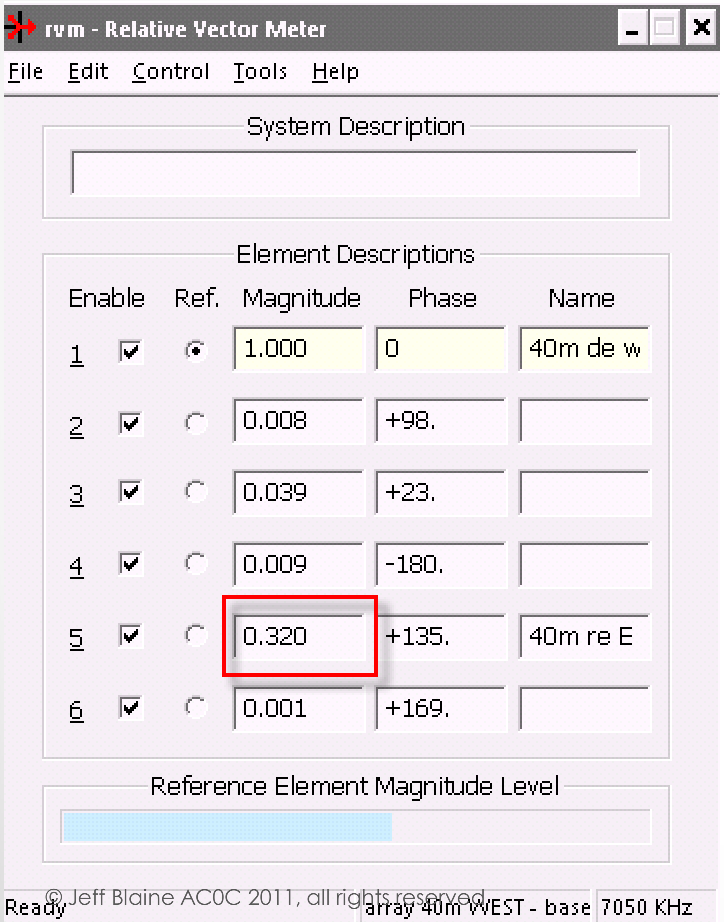


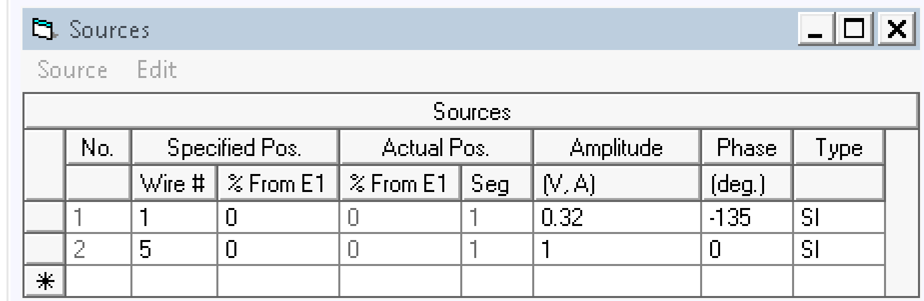


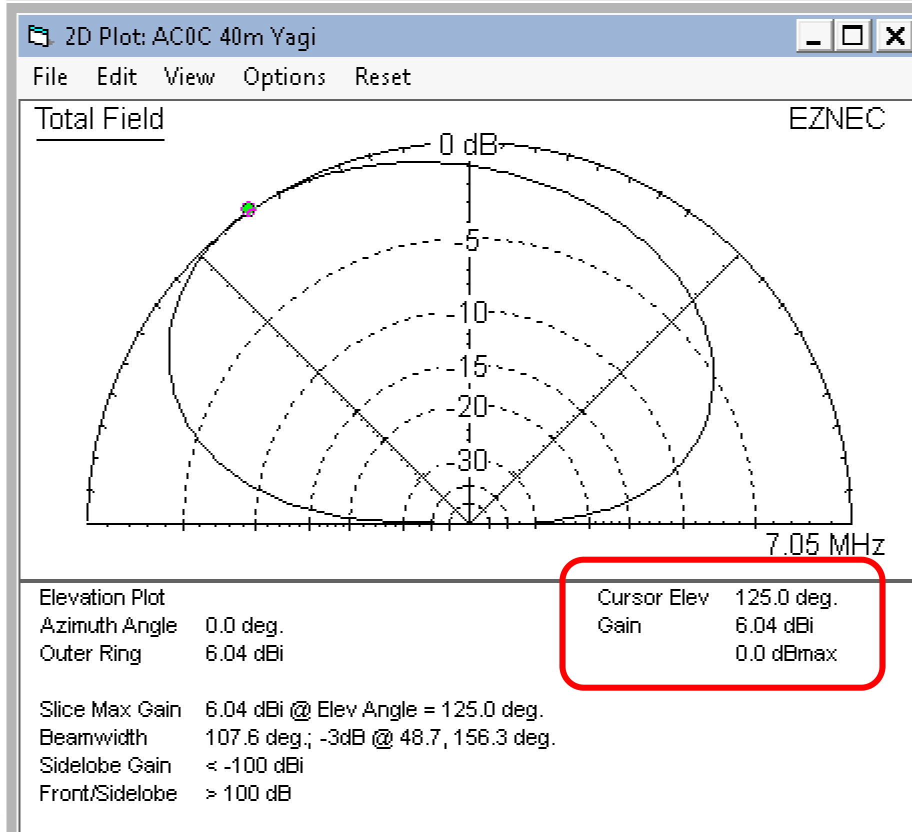


Measured Reality – West Beaming

- RVM Measured Values
- Inverse Model Plot







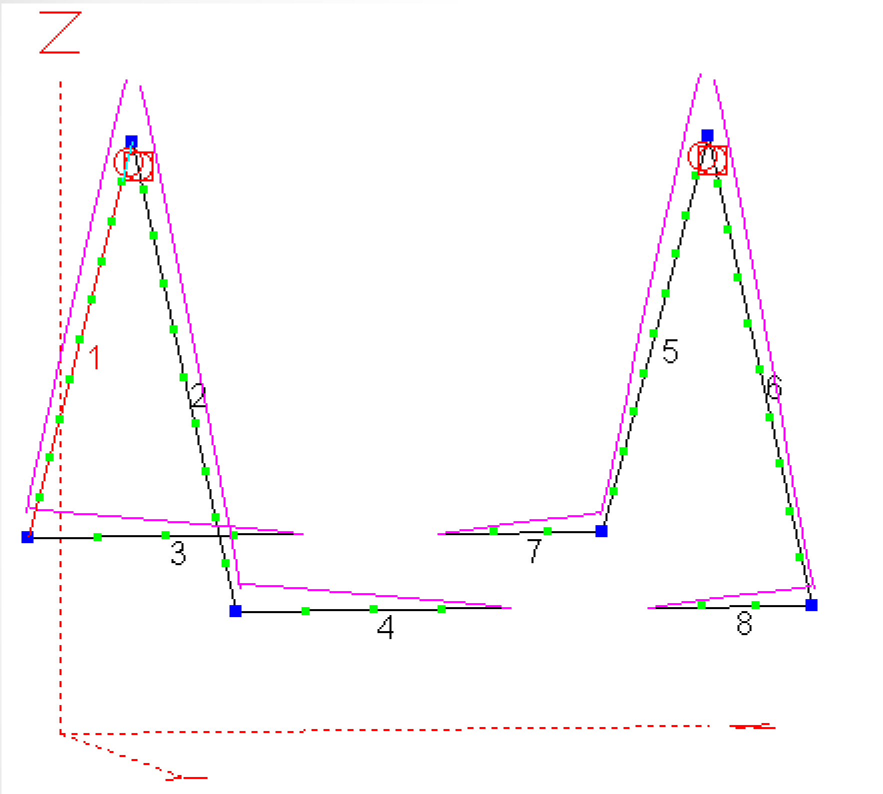
Measured Reality - Conclusions

- Actual vs. Ideal:
  - Gain 1.5 db less than ideal (EZ-NEC5)
  - TOA ~10 degrees higher than ideal
  - Good response to 90 degree signals → more noise pickup
- Root cause of poor pattern:
  - Antenna trimmed for phase, current considered "given"
  - But phase & current do interact – AND vary with frequency
  - Best: lengths and spacing independently adjustable
- Complications:
  - Adjacent metal items → unmodeled coupling and re-radiation effects
  - The stucco factor?
- There must be a better way…

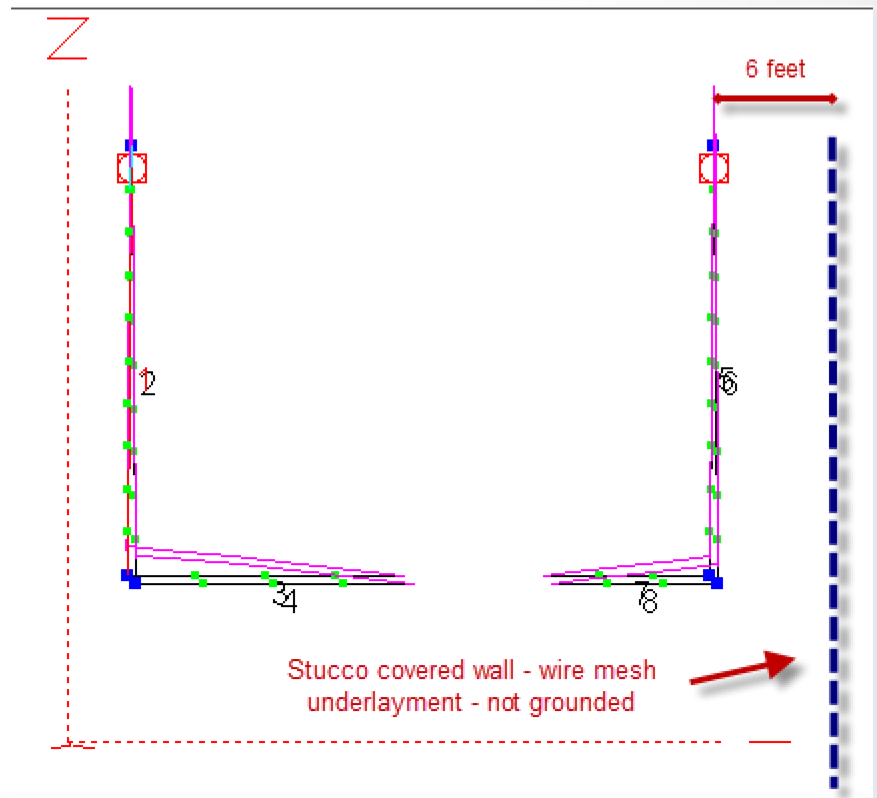
The NEW Plan

- Move west elements away from stucco wall
- Move models to EZ-NEC5 (easier help)
- Closer look at inadvertent parasitic interactions
- Use phased drive to force proper current/phase
- RVM system used to measure actual element phase/currents

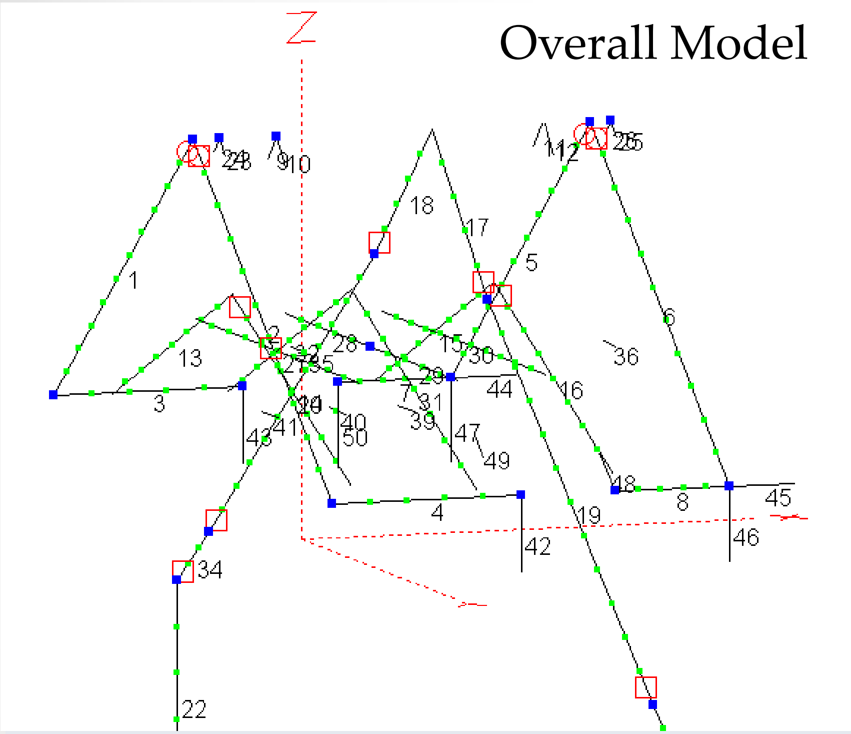
Sidebar: The Stucco Factor

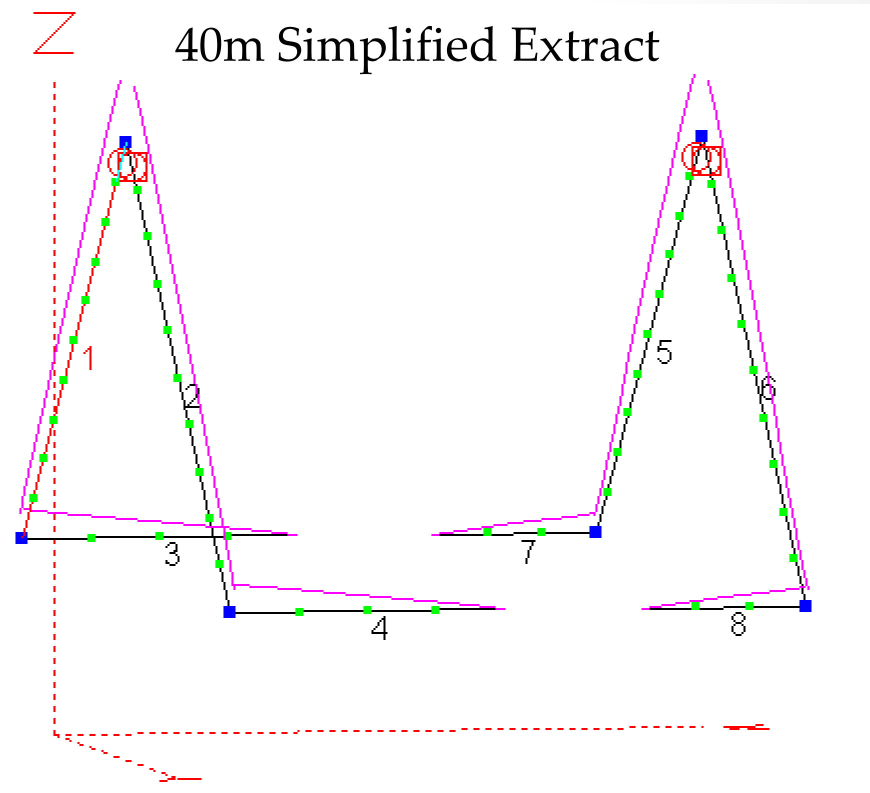


Implications?



Migration to EZ-NEC5

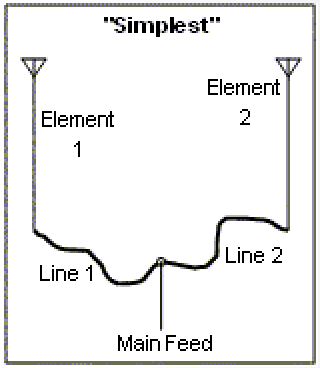




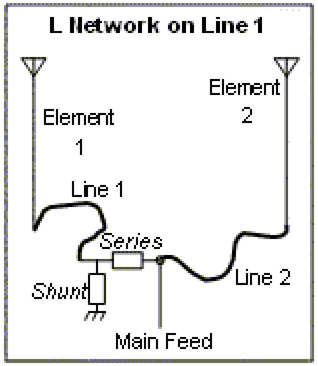
Phased Drive Methodology

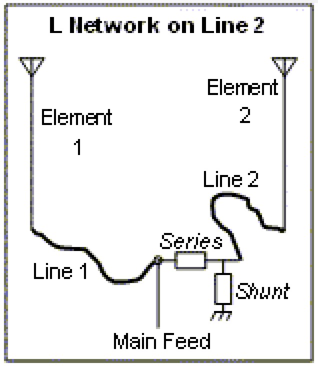
Lewallen "Simplest" AKA Christman Feed System

- Ideal case:
  - Element 1 = Element 2 (exactly)
  - Phasing lines ½ are adjusted in length until each element has the right current/phase drive – and – the voltage and phase match at the feed point
  - Further SWR match may be needed between "main feed" and shack coax run



- Phasing:
  - Via coax lines or L-net
  - **NOT** simple delay based system
- See ON4UN LBDX for more





Christman Phasing – Key Steps

- Measure antenna (self and coupled Z) (VNA/MFJ)
- Calculate drive Z from measured data (ON4UN)
- Optional: Measure phase line values (VNA+ZPLOTS)
- Calculate phase line lengths (FEED2EL)
- Assembly & test
- Optional: SWR match to feed point

Measure Elements

- Drive Z - calculated on element measurements or model data
- Each element - alone and in combination
- Compensates for ACTUAL parasitic action
- 2-element array – measure:

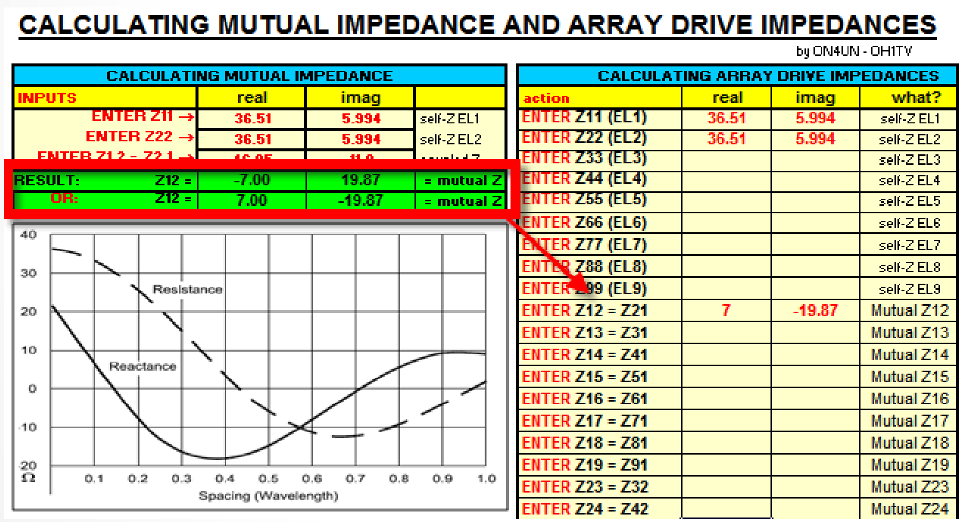
Measure Element 1 (r+Xj)	With Element 2…
Self	Hidden
Coupled	Present

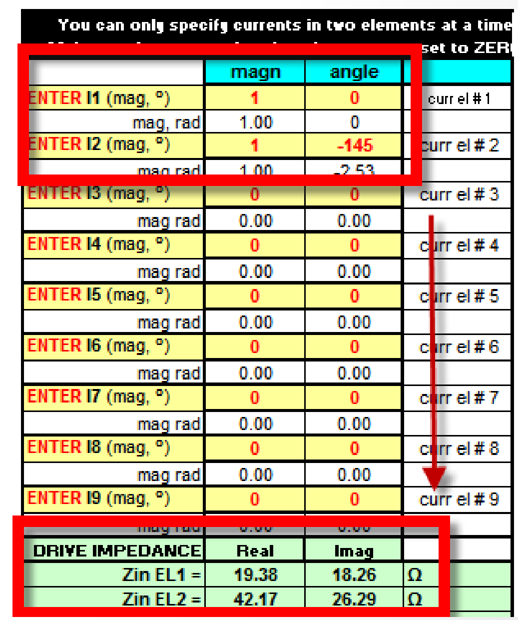
Christman Phasing – Key Steps

- Measure antenna (self and coupled Z) (VNA/MFJ)
- Calculate drive Z from measured data (ON4UN)
- Optional: Measure phase line values (VNA+ZPLOTS)
- Calculate phase line lengths (FEED2EL)
- Assembly & test
- Optional: SWR match to feed point

Calculating Drive Z: ON4UN

- ON4UN LBDX book → spread sheet tool
- w1mk-on4un-oh1tv-arrays.xls
- Big spread sheet → simple to use





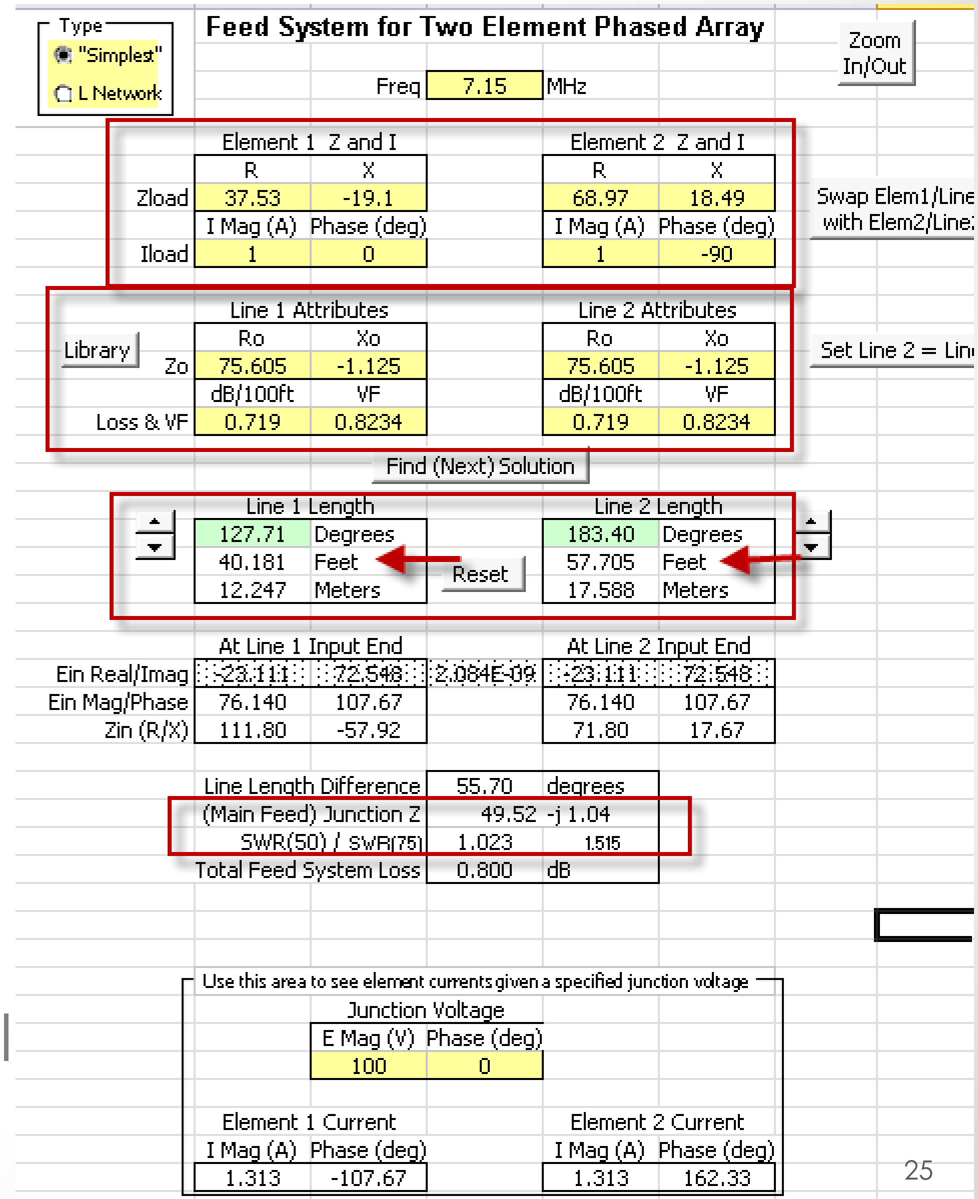
- Get it: ON4UN LBDX book

Christman Phasing – Key Steps

- Measure antenna (self and coupled Z) (VNA/MFJ)
- Calculate drive Z from measured data (ON4UN)
- Optional: Measure phase line values (VNA+ZPLOTS)
- Calculate phase line lengths (FEED2EL)
- Assembly & test
- Optional: SWR match to feed point

Calculating Lengths: FEED2EL

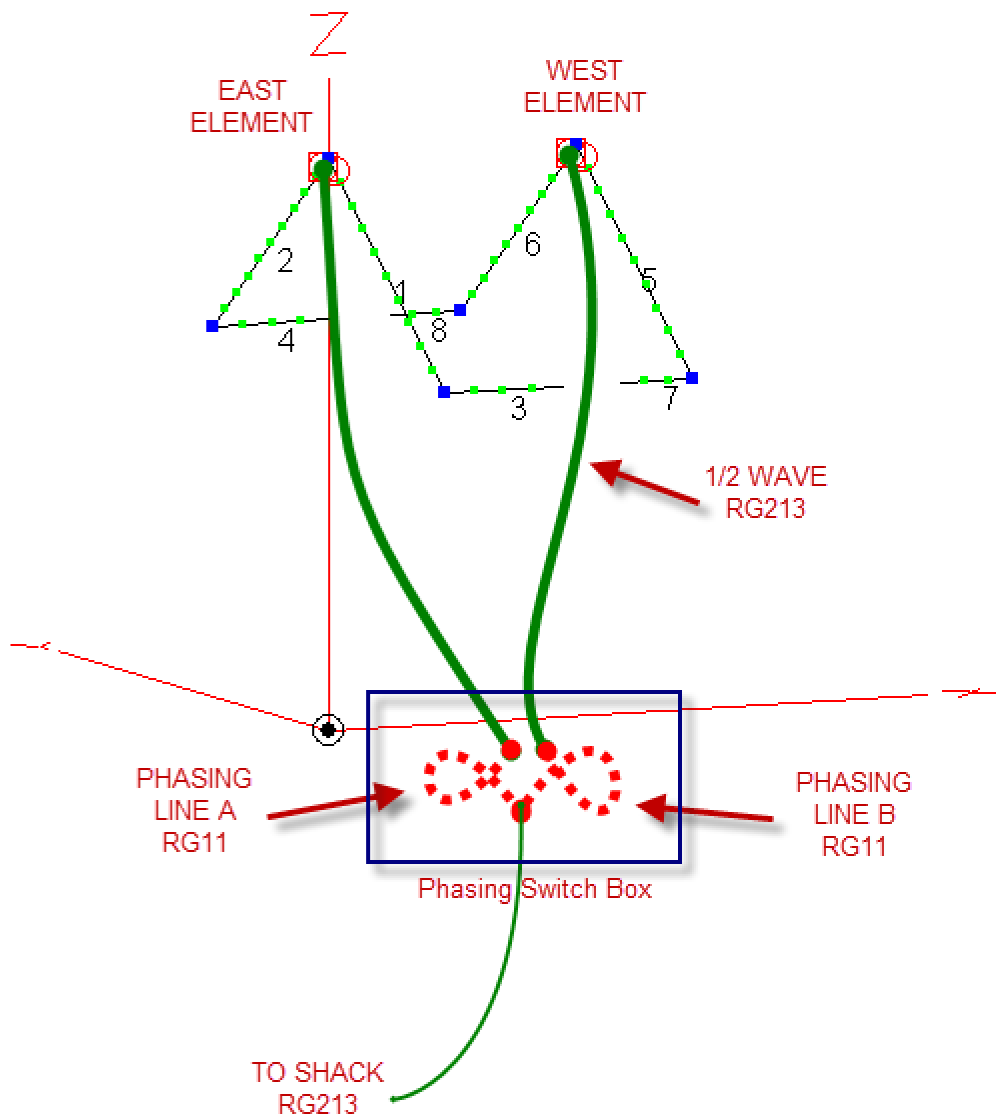
- From Feedline Master AC6LA Dan Maguire
- Tool inputs:
  - Individual element drive Z
  - Coax attributes Zo, VF, Loss
- Tool outputs:
  - Phase line lengths
  - Feed system loss
  - Feed point Z and SWR
- ac6la.com/feed2el.html



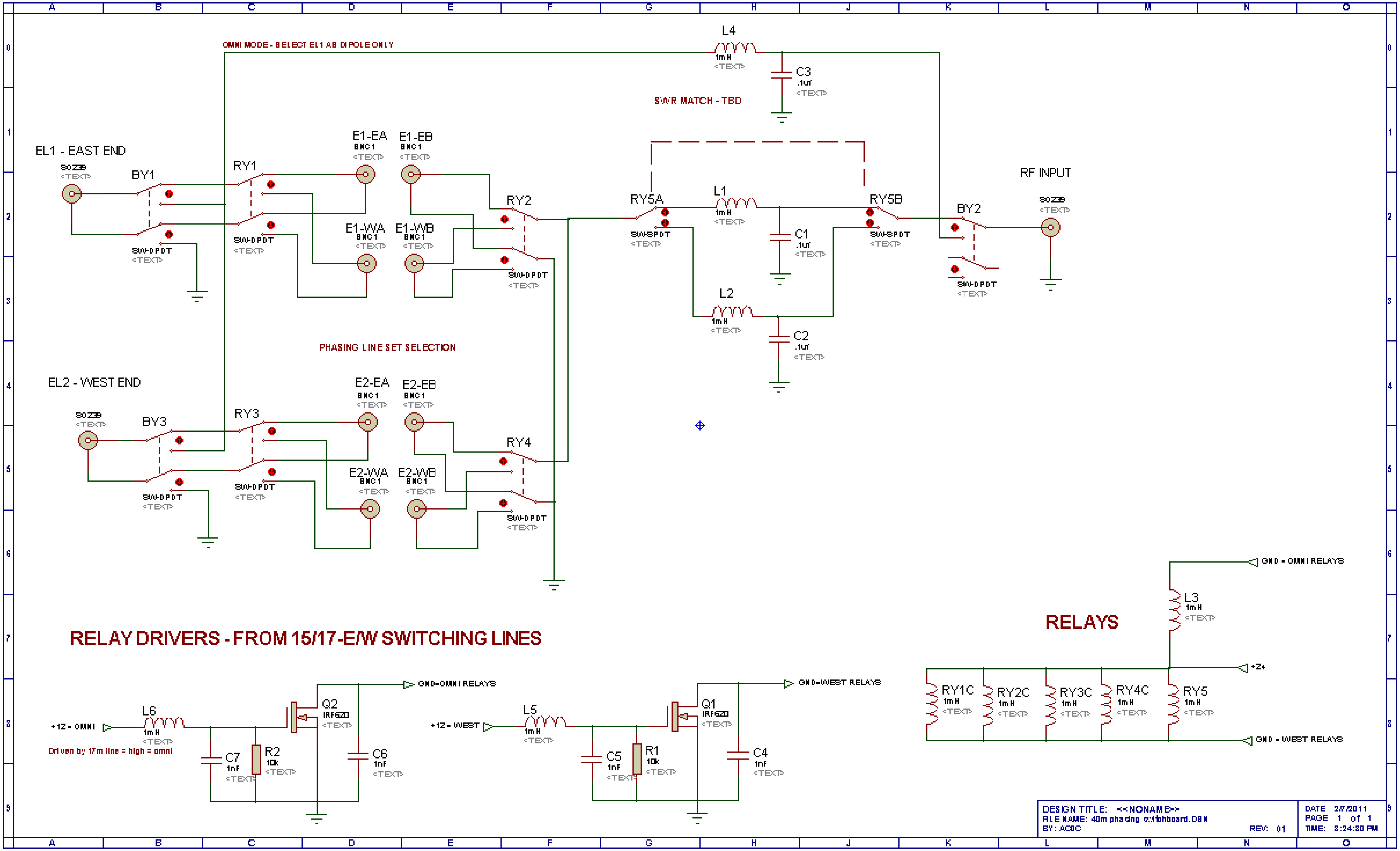
Construction Details

AC0C 40m Wire Phased V-Beam

- 2 wire v-elements
- Ends turned in Moxon-style, but no Moxon coupling
- ½ wave RG213 feedlines bring feedpoint to attic floor
- Phasing switch box mounted near array master control board

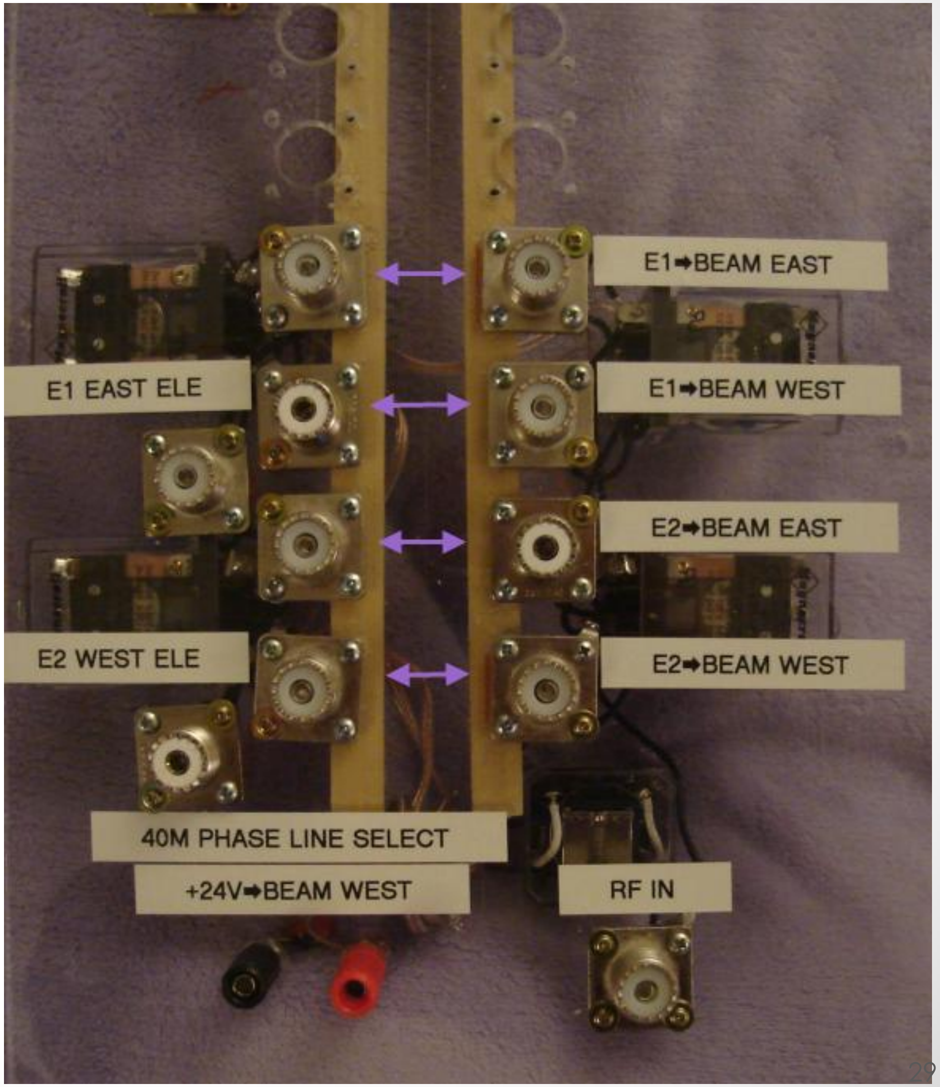


Phasing Box - Schematic



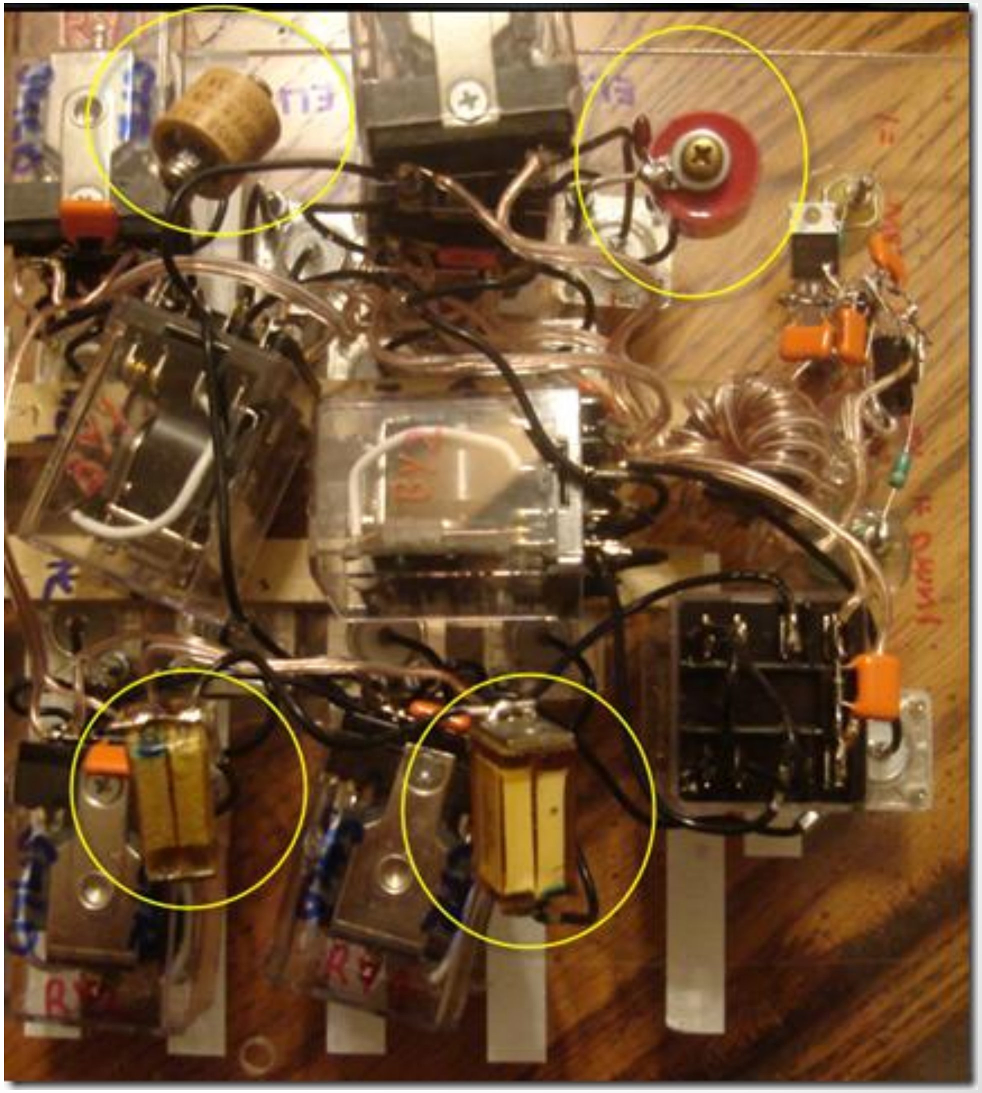
Phasing Box – Front View

- Control switching integrates with shack antenna system master
- Separate phasing for each direction
- Board supports 2 bands (40/30m)
- Added OMNI mode



Phasing Box – Cancelling the Xl

- Relay line length runs provide Xl
- Easiest solution – use caps to offset
- Problem: currents are high, 10A++
- Doorknobs best solution



- 40m Beam - Parasitic to Phased Conversion

Results

Measured Element Response

Following Christman Phased Drive Modification

	BEAMING WEST		BEAMING EAST	
Freq	I-ratio	Phase	I-ratio	Phase
7000	1.11	-134	1.39	-145
7040	1.03	-137	1.21	-148
7080	0.86	-138	1.05	-151

Target values: 1.00i -145 degrees

Inverse Model Predictions

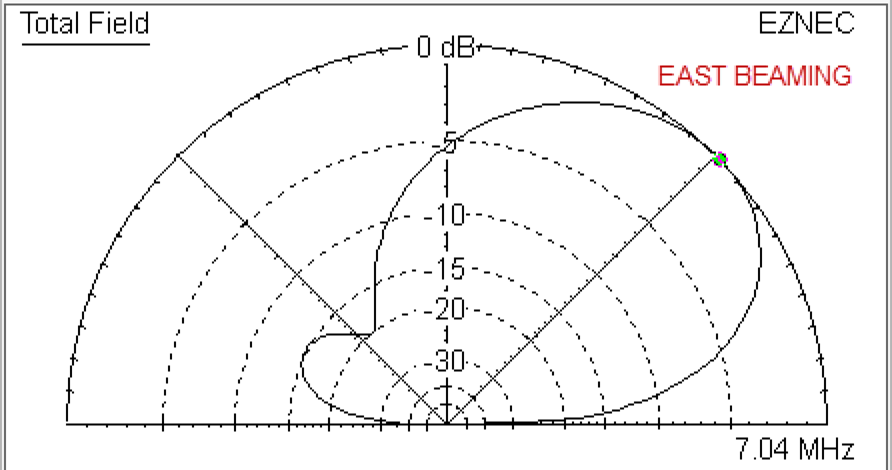
Sources

Source Edit

	No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
		Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
	1	1	0	0	1	1	0	SI
▶	2	5	0	0	1	1.21	-148	SI
*								

2D Plot: AC0C Gen 4 Array

File Edit View Options Reset



Elevation Plot		Cursor Elev	44.0 deg.
Azimuth Angle	0.0 deg.	Gain	7.95 dBi
Outer Ring	7.95 dBi		0.0 dBmax

Slice Max Gain 7.95 dBi @ Elev Angle = 44.0 deg.
Beamwidth 57.4 deg.; -3dB @ 20.3, 77.7 deg.
Sidelobe Gain -7.0 dBi @ Elev Angle = 153.0 deg.
Front/Sidelobe 14.95 dB

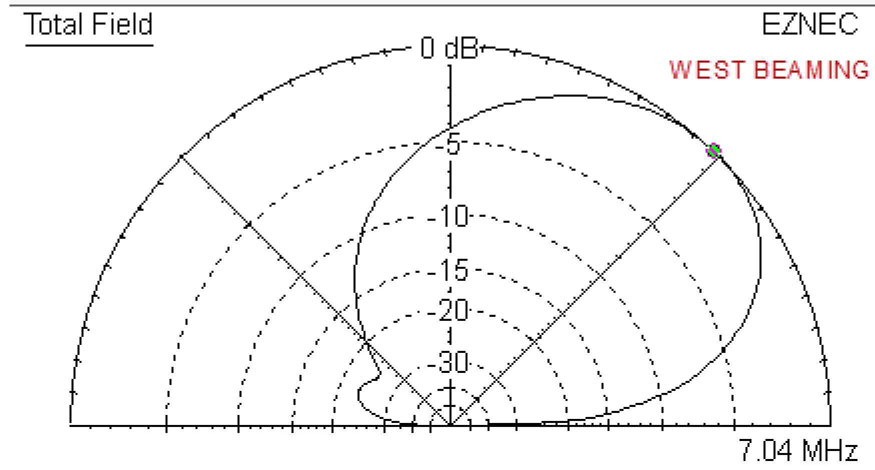
Sources

Source Edit

	No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
		Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
	1	1	0	0	1	1	0	SI
	2	5	0	0	1	1.03	-137	SI
*								

2D Plot: AC0C Gen 4 Array

File Edit View Options Reset



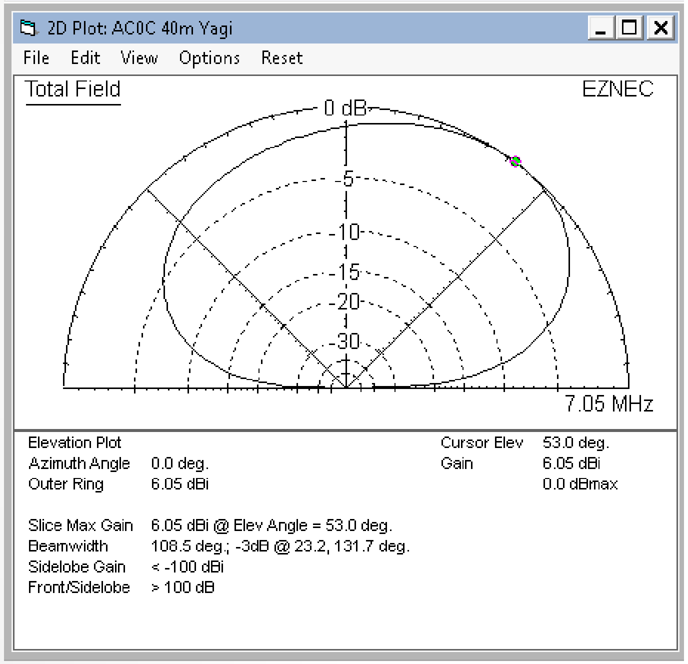
Elevation Plot		Cursor Elev	46.0 deg.
Azimuth Angle	0.0 deg.	Gain	7.83 dBi
Outer Ring	7.83 dBi		0.0 dBmax

Slice Max Gain 7.83 dBi @ Elev Angle = 46.0 deg.
Beamwidth 61.6 deg.; -3dB @ 20.9, 82.5 deg.
Sidelobe Gain -15.51 dBi @ Elev Angle = 159.0 deg.
Front/Sidelobe 23.34 dB

Parasitic vs. Phased

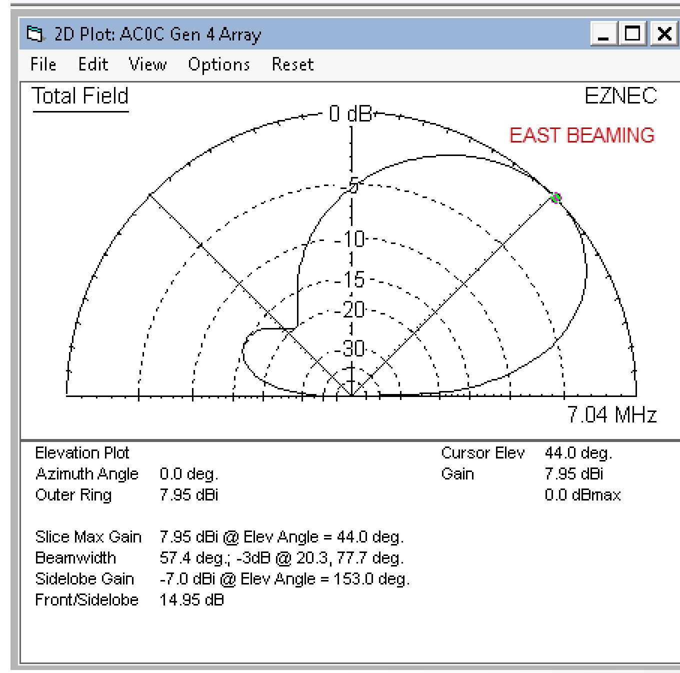
Sources

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	1	0	0	1	1	0	SI
2	5	0	0	1	0.354	-147	SI



Sources

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V, A)	Phase (deg.)	Type
1	1	0	0	1	1	0	SI
2	5	0	0	1	1.21	-148	SI



Gain:+2dB FB:+15db Noise:++ TOA:-9 deg SWR: Sweet

Conclusions

- Phased drive benefits:
  - Predictable current/phase
  - Accommodates variations in mutual coupling
  - Minimal trimming after assembly
  - Delivers improved gain, F/B in real-world environments

- Phased drive problems:
  - Build complexity greater
  - More similar elements are → simpler to make bidirectional
  - Antenna changes → redo phasing lines

Contest Performance

	---- 3rd Gen Array ----		----------- 4th Gen Array -----------		
Q's	2010	2010	2010	2011	2011
Contest	RTTY RU	RTTY WPX	RTTY CQ DX	RTTY RU	RTTY WPX
80	208	177	11	134	150
40	83	147	503	427	452
20	565	419	348	389	352
15	24	184	111	72	141
			------- Parasitic -------		Phased

Special Thanks To:

- For Elmering a "phasing novice," and cooking up excellent tools for the ham world's benefit…
  - Greg Ordy, W8WWV — EZDZ, RVM
  - Dan Mcguire, AC6LA — FEED2EL, ZPLOTS

- For materials contributed
  - Jack Holzer, KD0MDA
  - Rob Underwood, K0RU
  - Jerry Chamberlin, WA0JRJ
  - Dewey "Lucky" Jones, W0DRJ