

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

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Updating the 4<sup>th</sup>-Generation  
Stealth All-Band  
Electrically Reversible  
Directional Array

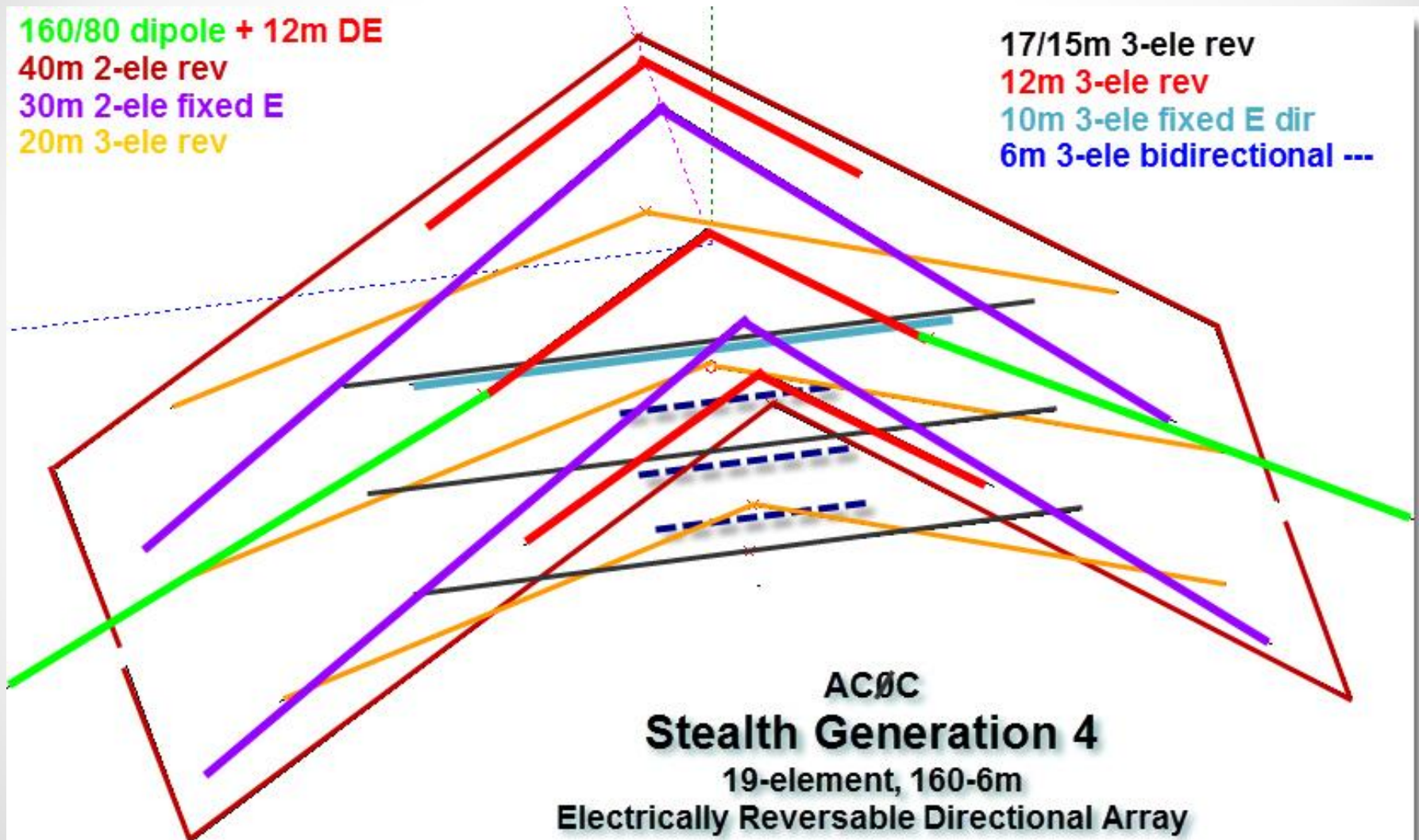
Jeff Blaine – ACØC

Presented to the KC DX Club – 25 April 2011

# Array Overview

160/80 dipole + 12m DE  
40m 2-ele rev  
30m 2-ele fixed E  
20m 3-ele rev

17/15m 3-ele rev  
12m 3-ele rev  
10m 3-ele fixed E dir  
6m 3-ele bidirectional ---



ACØC  
**Stealth Generation 4**  
19-element, 160-6m  
Electrically Reversible Directional Array

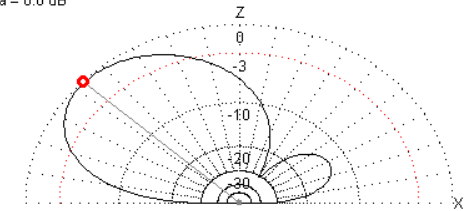
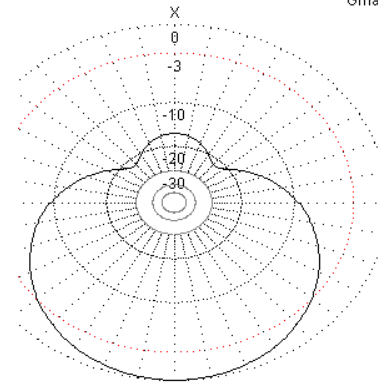
# 40m Simulation - MMANGAL

160/80 dipole + 12m DE  
 40m 2-ele rev  
 30m 2-ele fixed E  
 20m 3-ele rev

17/15m 3-ele rev  
 12m 3-ele rev  
 10m 3-ele fixed E dir  
 6m 3-ele bidirectional ---

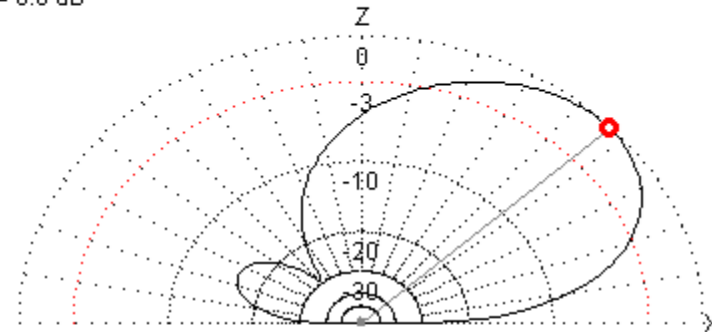
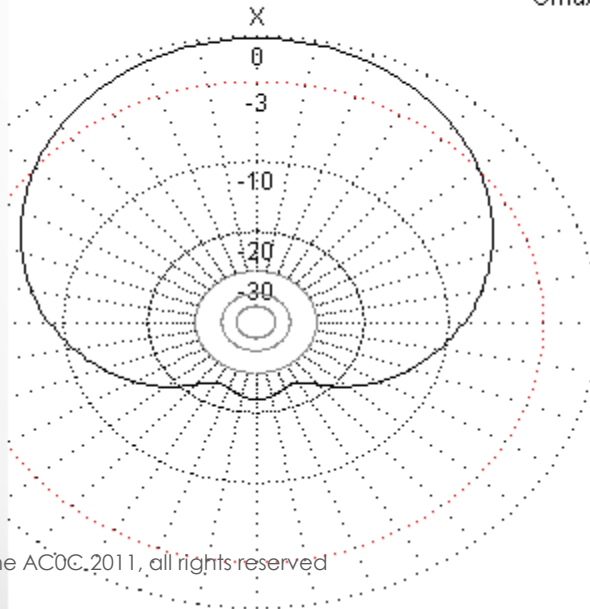
**40m 2-ele yagi reversible ENE**  
 AC0C  
**Stealth Generation 4**  
 19-element, 160-6m  
 Electrically Reversible Directional Array

Elevation angle = 137 dg  
 Ga = 8.8 dBi  
 Gmax - Ga = 0.0 dB



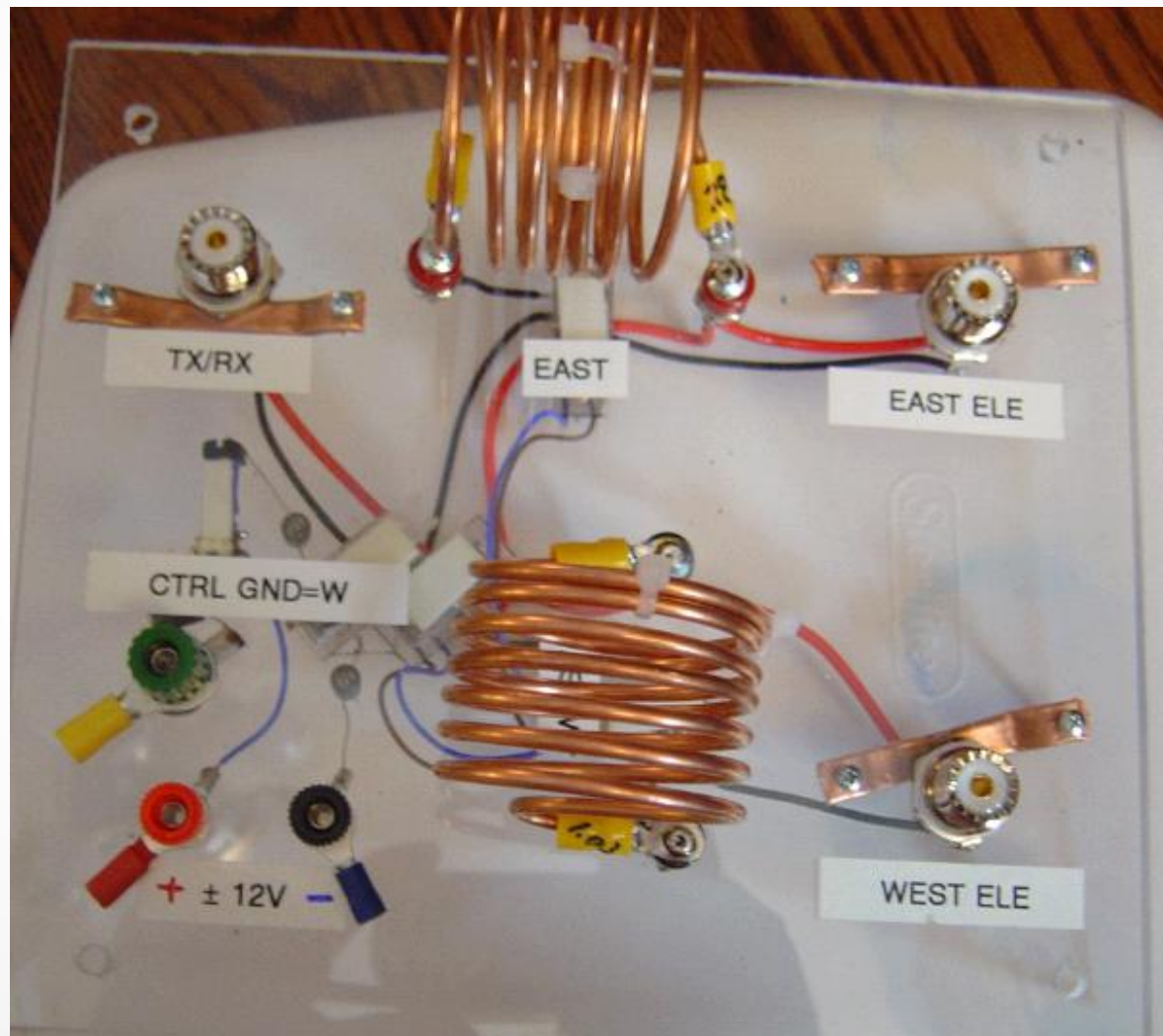
Ga : 8.75 dBi = 0 dB (Horizontal polarization)  
 F/B: -16.06 dB; Rear: Azim. 180 dg, Elev. 30 dg  
 Freq: 7.050 MHz  
 Z: 17.108 + j1.566 Ohm  
 SWR: 2.9 (50.0 Ohm),  
 Elev. 44.0 dg (Real GND :11.30 m height)

Elevation angle = 43 dg  
 Ga = 8.6 dBi  
 Gmax - Ga = 0.0 dB

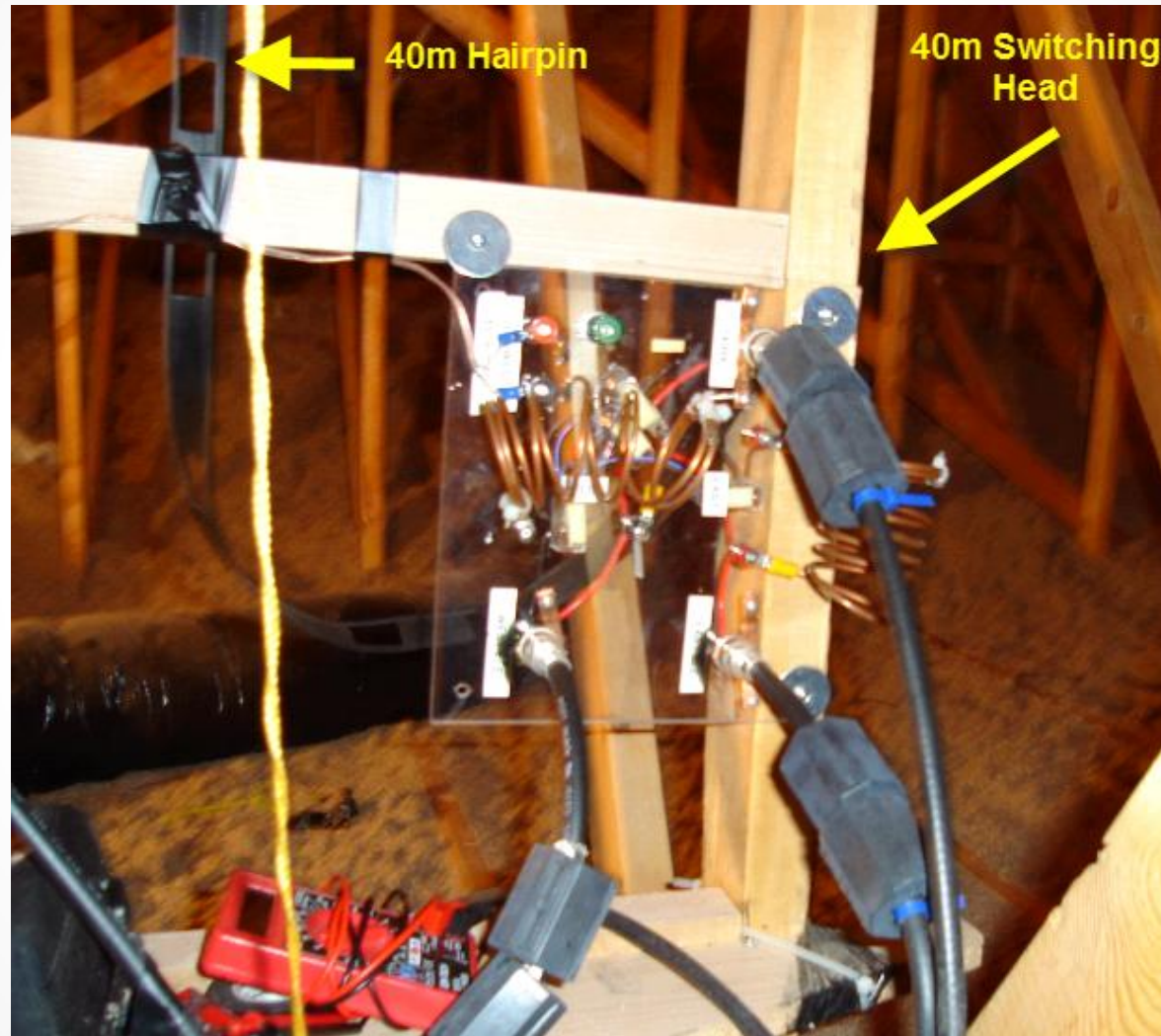


Ga : 8.6 dBi = 0 dB (Horizontal polarization)  
 F/B: 8.61 dB; Rear: Azim. 180 dg, Elev. 30 dg  
 Freq: 7.050 MHz  
 Z: 20.998 + j1.659 Ohm  
 SWR: 2.4 (50.0 Ohm),  
 Elev. 44.9 dg (Real GND :11.30 m height)

# DE/Reflector Switching



# Control Board - As Mounted



# 4<sup>th</sup> 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)

- 40m Beam - Parasitic to Phased Conversion

# Measuring the Baseline

# W8WWV Reverse Simulation Overview

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

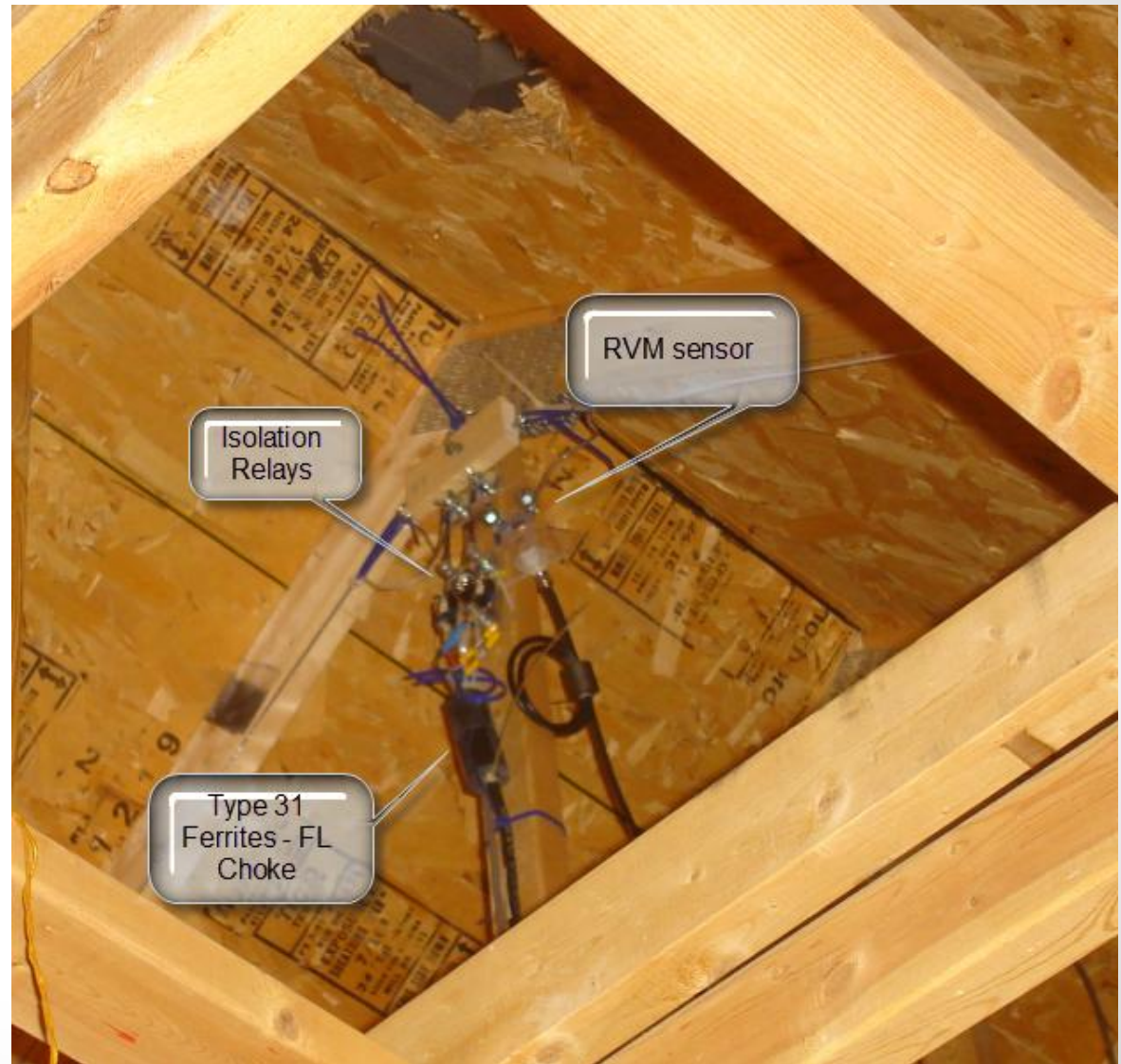
Load Data  
into  
Simulation Model

Simulation  
Generates  
Plot of **Actual**  
Antenna  
Performance



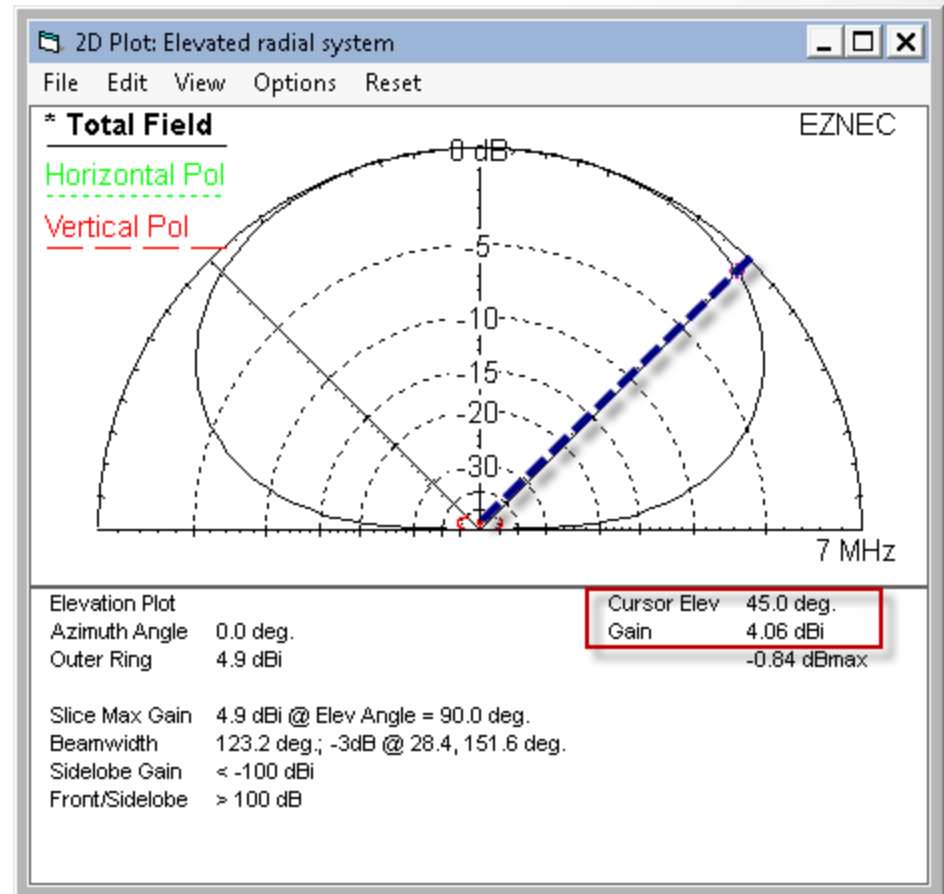
# W8WWV RVM System Sensor

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



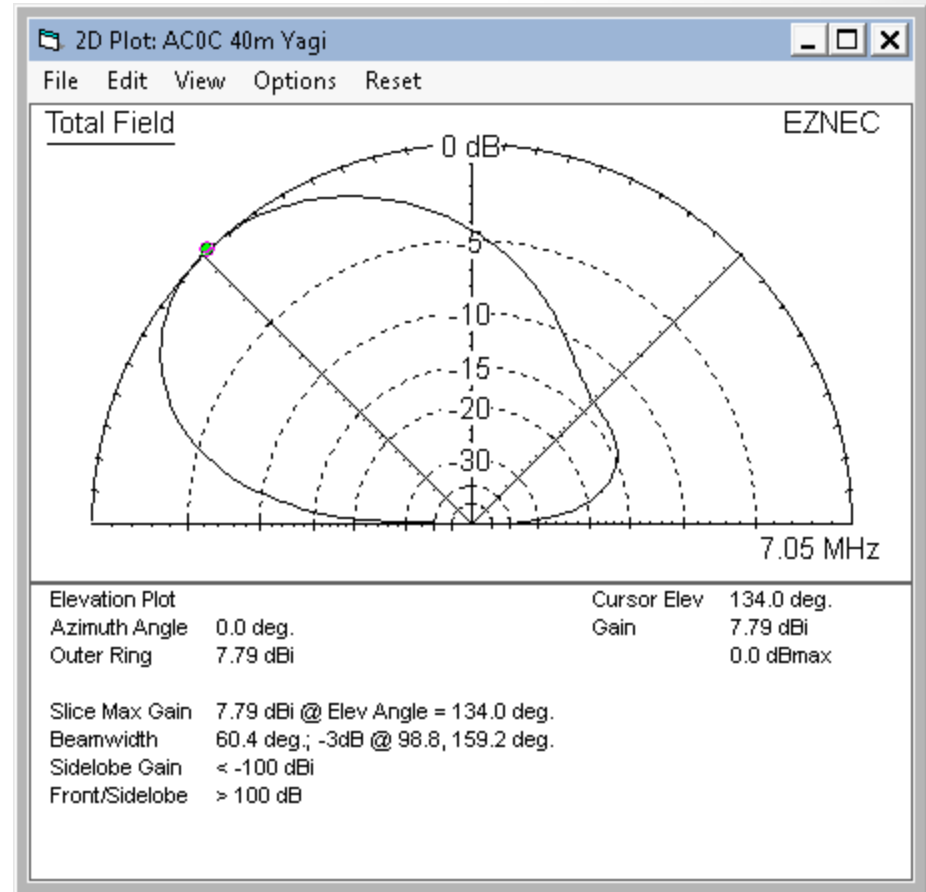
# Baseline for Perspective: Dipole

- 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

**rvm - Relative Vector Meter**

File Edit Control Tools Help

System Description

Element Descriptions

Enable	Ref.	Magnitude	Phase	Name
1	<input checked="" type="checkbox"/>	0.354	+147.	40m REF
2	<input checked="" type="checkbox"/>	0.004	-125.	
3	<input checked="" type="checkbox"/>	0.056	-23.	
4	<input checked="" type="checkbox"/>	0.018	-53.	
5	<input checked="" type="checkbox"/>	1.000	0	40m DE E
6	<input checked="" type="checkbox"/>	0.001	+154.	

Reference Element Magnitude Level

Ready © Jeff Blaine AC0C 2011, all rights reserved. array 40m east - based 7050 KHz

**Sources**

Source Edit

Sources								
	No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
		Wire #	% From E1	% From E1	Seg			
	1	1	0	0	1	1	0	SI
▶	2	5	0	0	1	0.354	-147	SI
*								

**2D Plot: AC0C 40m Yagi**

File Edit View Options Reset

Total Field EZNEC

7.05 MHz

Elevation Plot

Azimuth Angle	0.0 deg.
Outer Ring	6.05 dBi
Cursor Elev	53.0 deg.
Gain	6.05 dBi
	0.0 dBmax

Slice Max Gain 6.05 dBi @ Elev Angle = 53.0 deg.  
 Beamwidth 108.5 deg.; -3dB @ 23.2, 131.7 deg.  
 Sidelobe Gain < -100 dBi  
 Front/Sidelobe > 100 dB

# Measured Reality – West Beaming

- RVM Measured Values
- Inverse Model Plot

**rvm - Relative Vector Meter**

File Edit Control Tools Help

System Description

Element Descriptions

Enable	Ref.	Magnitude	Phase	Name
<u>1</u>	<input checked="" type="checkbox"/>	1.000	0	40m de w
2	<input checked="" type="checkbox"/>	0.008	+98.	
3	<input checked="" type="checkbox"/>	0.039	+23.	
4	<input checked="" type="checkbox"/>	0.009	-180.	
5	<input checked="" type="checkbox"/>	0.320	+135.	40m re E
6	<input checked="" type="checkbox"/>	0.001	+169.	

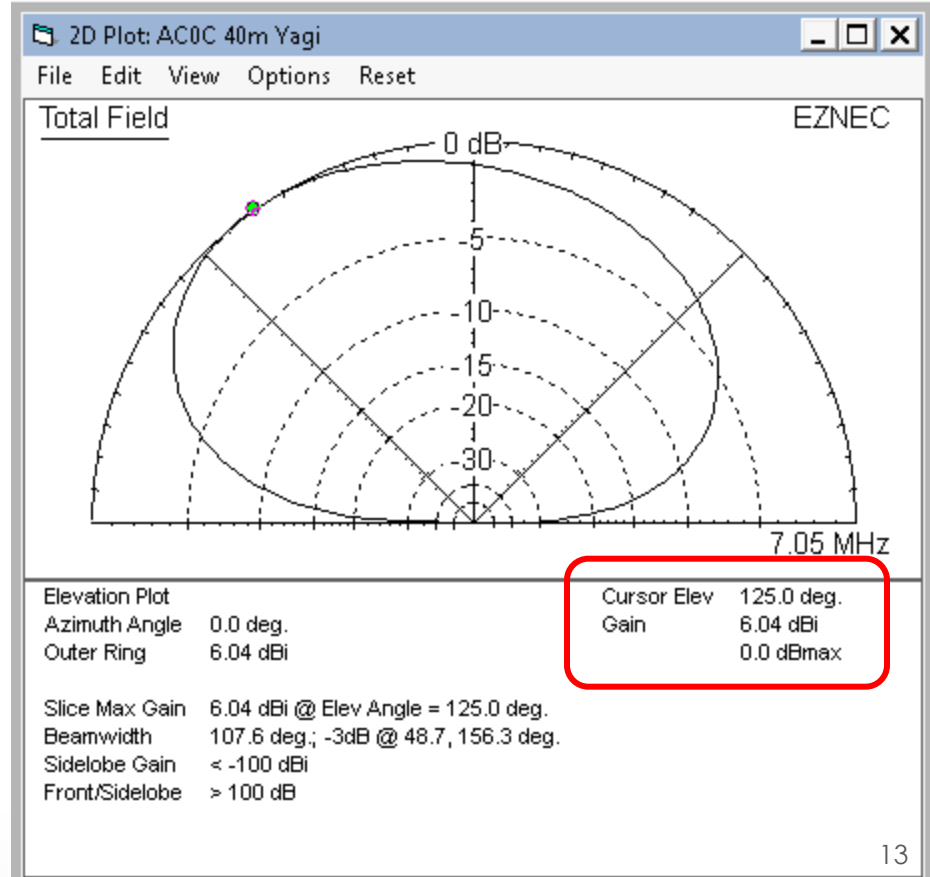
Reference Element Magnitude Level

Ready © Jeff Blaine AC0C 2011, all rights reserved. array 40m WEST - base 7050 KHz

Sources

Source Edit

Sources								
No.	Specified Pos.	Actual Pos.		Amplitude	Phase	Type		
	Wire #	% From E1	% From E1	Seg	[V, A]	(deg.)		
1	1	0	0	1	0.32	-135	SI	
2	5	0	0	1	1	0	SI	
*								



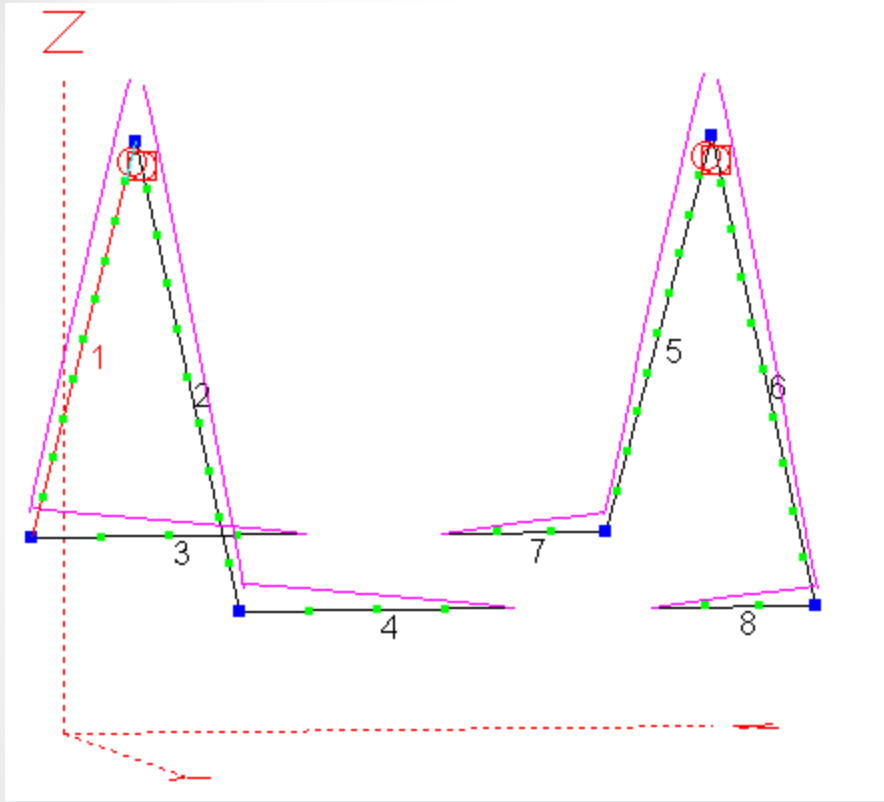
# Measured Reality - Conclusions

- 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...

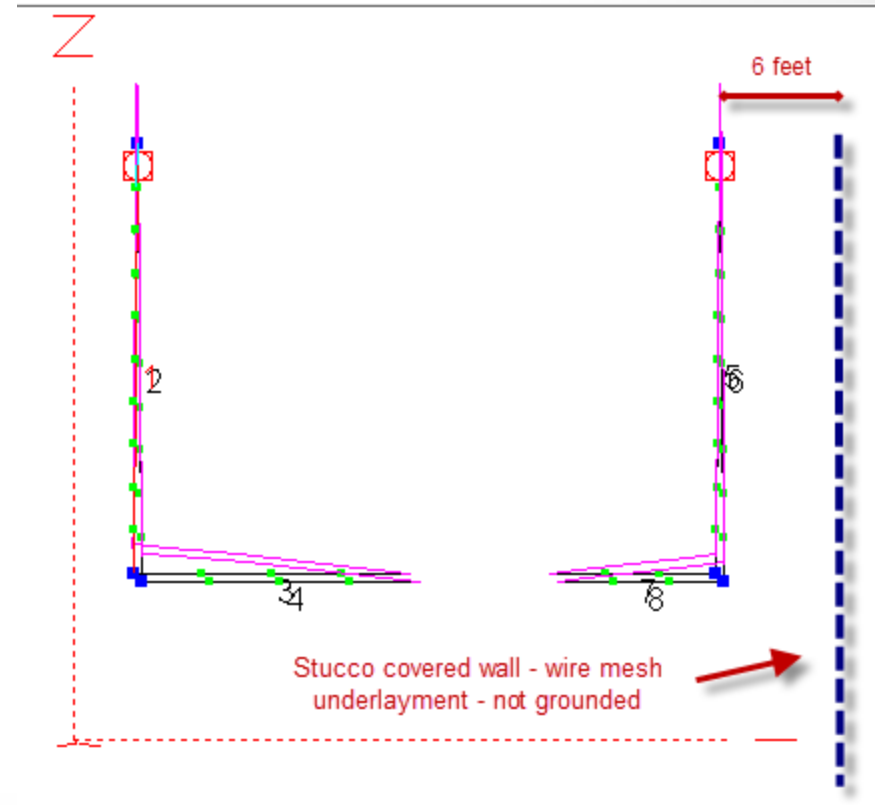
# The NEW Plan

- 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

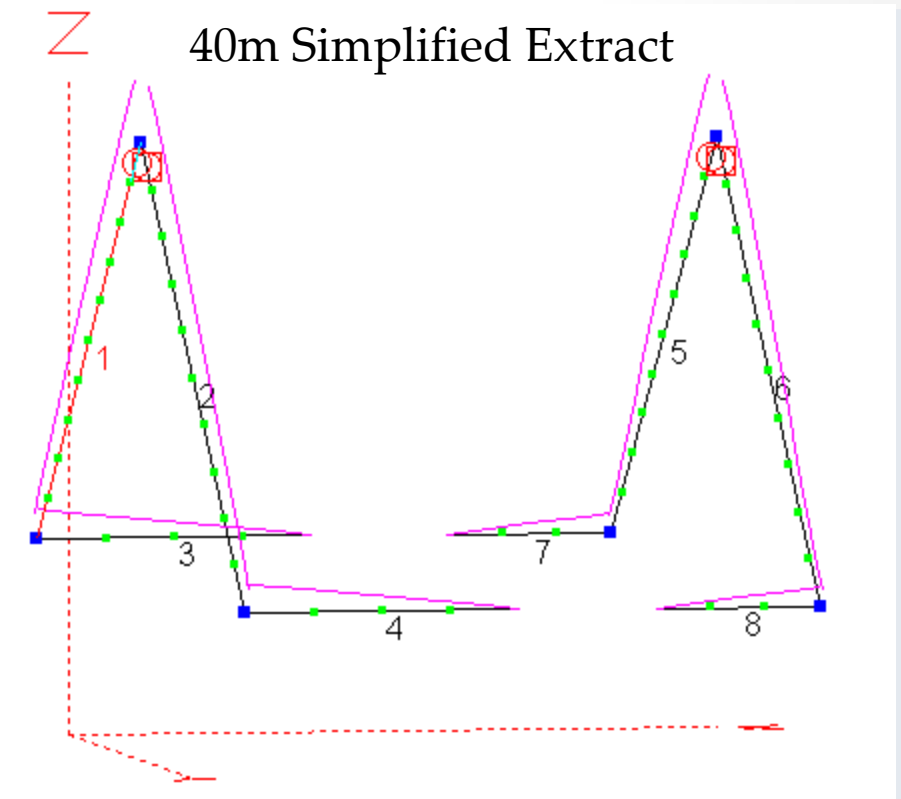
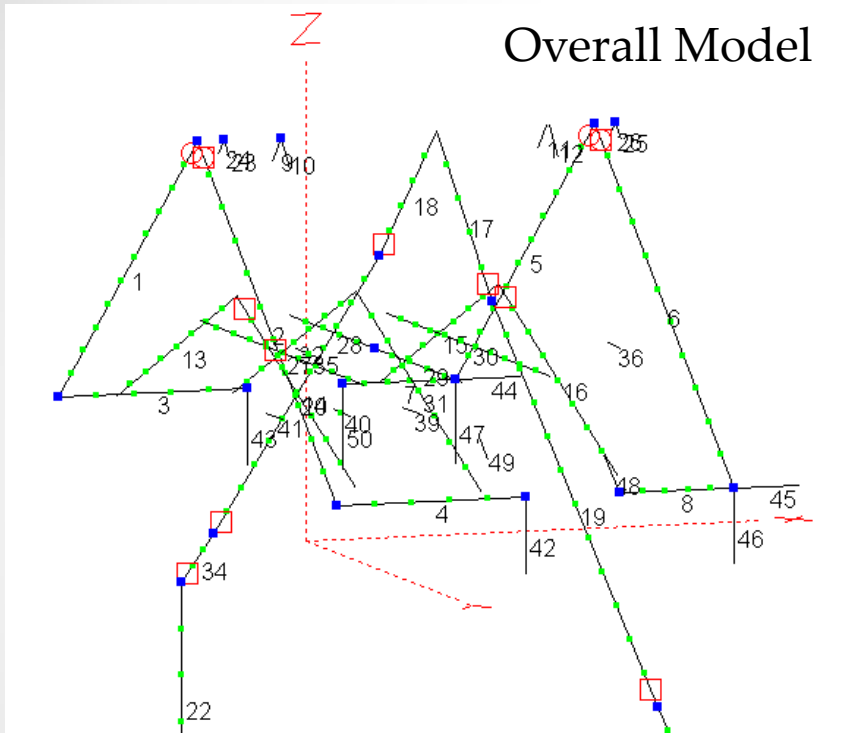


Implications?





# Migration to EZ-NEC5

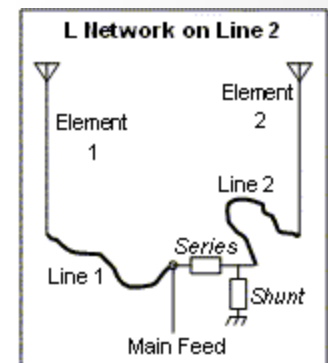
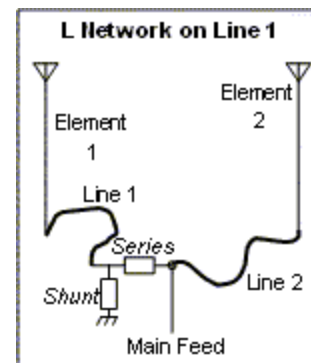
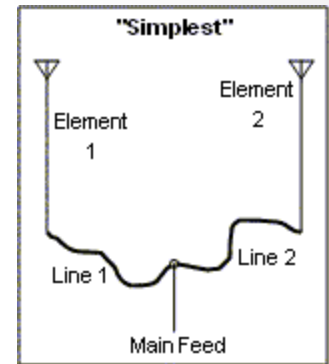


- 40m Beam - Parasitic to Phased Conversion

# Phased Drive Methodology

# Lewallen "Simplest" AKA Christman Feed System

- Ideal case:
  - Element 1 = Element 2 (exactly)
  - Phasing lines  $\frac{1}{2}$  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 ( $r+X_j$ )	With Element 2...
Self	Hidden
Coupled	Present

# Christman Phasing – Key Steps

- Measure antenna (self and coupled Z) (VNA/MFJ)
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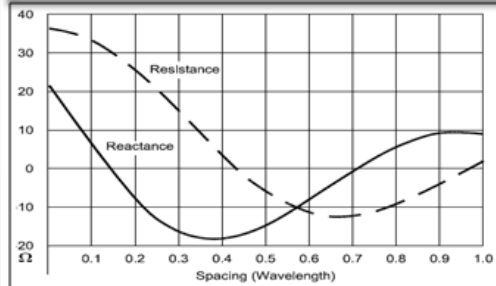
# Calculating Drive Z: ON4UN

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

## CALCULATING MUTUAL IMPEDANCE AND ARRAY DRIVE IMPEDANCES

by ON4UN - OH1TV

CALCULATING MUTUAL IMPEDANCE			
INPUTS	real	imag	
ENTER Z11 →	36.51	5.994	self-Z EL1
ENTER Z22 →	36.51	5.994	self-Z EL2
ENTER Z12 = Z21 →	16.05	11.0	Mutual Z12
RESULT:	Z12 =	-7.00	19.87 = mutual Z
Z11	Z12 =	7.00	-19.87 = mutual Z



CALCULATING ARRAY DRIVE IMPEDANCES			
action	real	imag	what?
ENTER Z11 (EL1)	36.51	5.994	self-Z EL1
ENTER Z22 (EL2)	36.51	5.994	self-Z EL2
ENTER Z33 (EL3)			self-Z EL3
ENTER Z44 (EL4)			self-Z EL4
ENTER Z55 (EL5)			self-Z EL5
ENTER Z66 (EL6)			self-Z EL6
ENTER Z77 (EL7)			self-Z EL7
ENTER Z88 (EL8)			self-Z EL8
ENTER Z99 (EL9)			self-Z EL9
ENTER Z12 = Z21	7	-19.87	Mutual Z12
ENTER Z13 = Z31			Mutual Z13
ENTER Z14 = Z41			Mutual Z14
ENTER Z15 = Z51			Mutual Z15
ENTER Z16 = Z61			Mutual Z16
ENTER Z17 = Z71			Mutual Z17
ENTER Z18 = Z81			Mutual Z18
ENTER Z19 = Z91			Mutual Z19
ENTER Z23 = Z32			Mutual Z23
ENTER Z24 = Z42			Mutual Z24

You can only specify currents in two elements at a time

	magn	angle	
ENTER I1 (mag, °)	1	0	curr el # 1
mag rad	1.00	0	
ENTER I2 (mag, °)	1	-145	curr el # 2
mag rad	1.00	-2.53	
ENTER I3 (mag, °)	0	0	curr el # 3
mag rad	0.00	0.00	
ENTER I4 (mag, °)	0	0	curr el # 4
mag rad	0.00	0.00	
ENTER I5 (mag, °)	0	0	curr el # 5
mag rad	0.00	0.00	
ENTER I6 (mag, °)	0	0	curr el # 6
mag rad	0.00	0.00	
ENTER I7 (mag, °)	0	0	curr el # 7
mag rad	0.00	0.00	
ENTER I8 (mag, °)	0	0	curr el # 8
mag rad	0.00	0.00	
ENTER I9 (mag, °)	0	0	curr el # 9
mag rad	0.00	0.00	
DRIVE IMPEDANCE	Real	Imag	
Zin EL1 =	19.38	18.26	Ω
Zin EL2 =	42.17	26.29	Ω

- 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](http://ac6la.com/feed2el.html)

**Feed System for Two Element Phased Array**

Type:  "Simplest"  L Network Zoom In/Out

Freq: 7.15 MHz

Element 1 Z and I		Element 2 Z and I	
R	X	R	X
Zload: 37.53	-19.1	68.97	18.49
I Mag (A)	Phase (deg)	I Mag (A)	Phase (deg)
Iload: 1	0	1	-90

Swap Elem1/Line with Elem2/Line:

Line 1 Attributes		Line 2 Attributes	
Ro	Xo	Ro	Xo
Zo: 75.605	-1.125	75.605	-1.125
dB/100ft	VF	dB/100ft	VF
Loss & VF: 0.719	0.8234	0.719	0.8234

Set Line 2 = Line 1

Find (Next) Solution

Line 1 Length		Line 2 Length	
127.71	Degrees	183.40	Degrees
40.181	Feet	57.705	Feet
12.247	Meters	17.588	Meters

Reset

At Line 1 Input End		At Line 2 Input End	
Ein Real/Imag: -23.111	72.548	2.084E-09	-23.111
Ein Mag/Phase: 76.140	107.67	76.140	107.67
Zin (R/X): 111.80	-57.92	71.80	17.67

Line Length Difference	55.70	degrees
(Main Feed) Junction Z	49.52	-j 1.04
SWR(50) / swR(75)	1.023	1515
Total Feed System Loss	0.800	dB

Use this area to see element currents given a specified junction voltage

Junction Voltage	
E Mag (V)	Phase (deg)
100	0

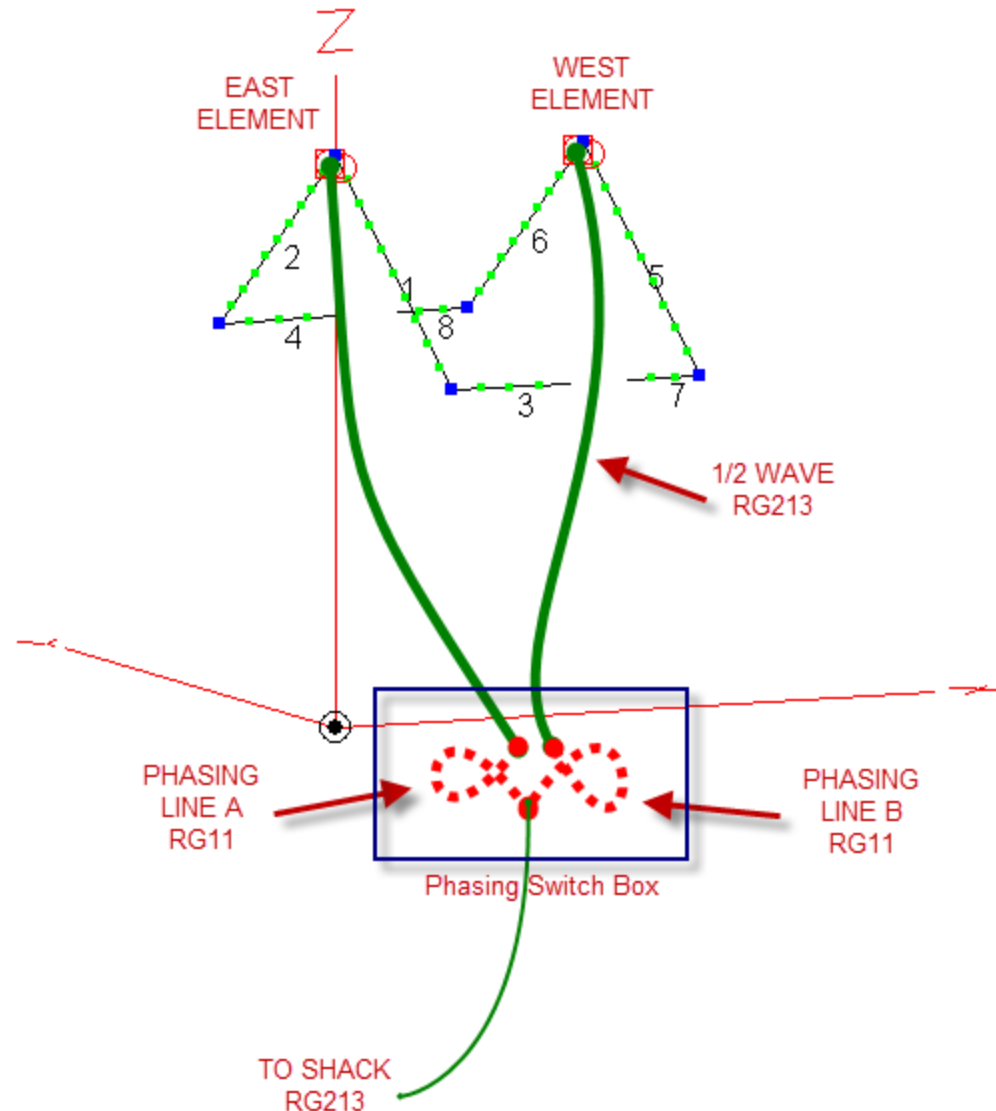
Element 1 Current		Element 2 Current	
I Mag (A)	Phase (deg)	I Mag (A)	Phase (deg)
1.313	-107.67	1.313	162.33

- 40m Beam - Parasitic to Phased Conversion

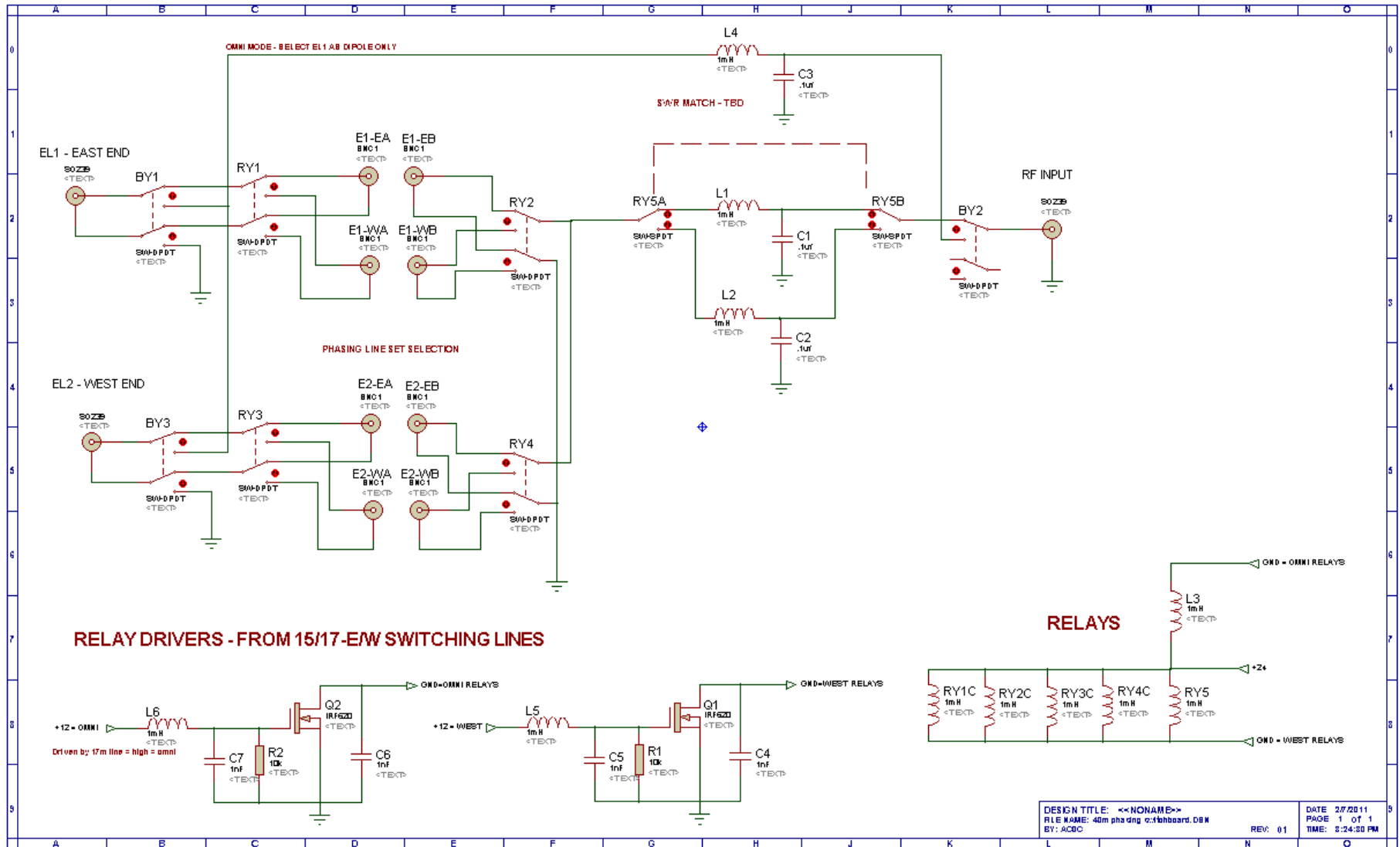
# Construction Details

# AC0C 40m Wire Phased V-Beam

- 2 wire v-elements
- Ends turned in Moxon-style, but no Moxon coupling
- $\frac{1}{2}$  wave RG213 feedlines bring feedpoint to attic floor
- Phasing switch box mounted near array master control board



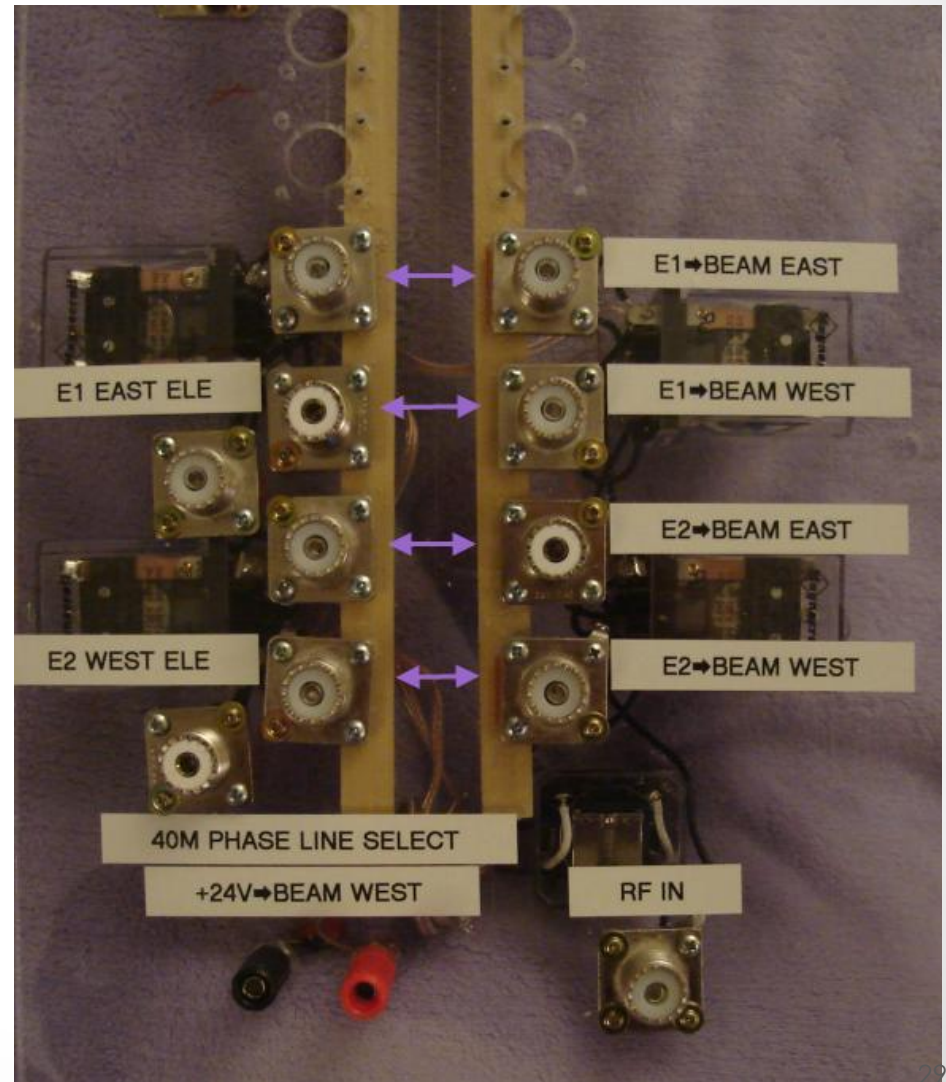
# Phasing Box - Schematic



DESIGN TITLE: <<NONAME>>  
 FILE NAME: 40m phasing v2.fishboard.DBW  
 BY: ACBC  
 DATE: 2/7/2011  
 PAGE: 1 of 1  
 TIME: 3:24:30 PM  
 REV: 01

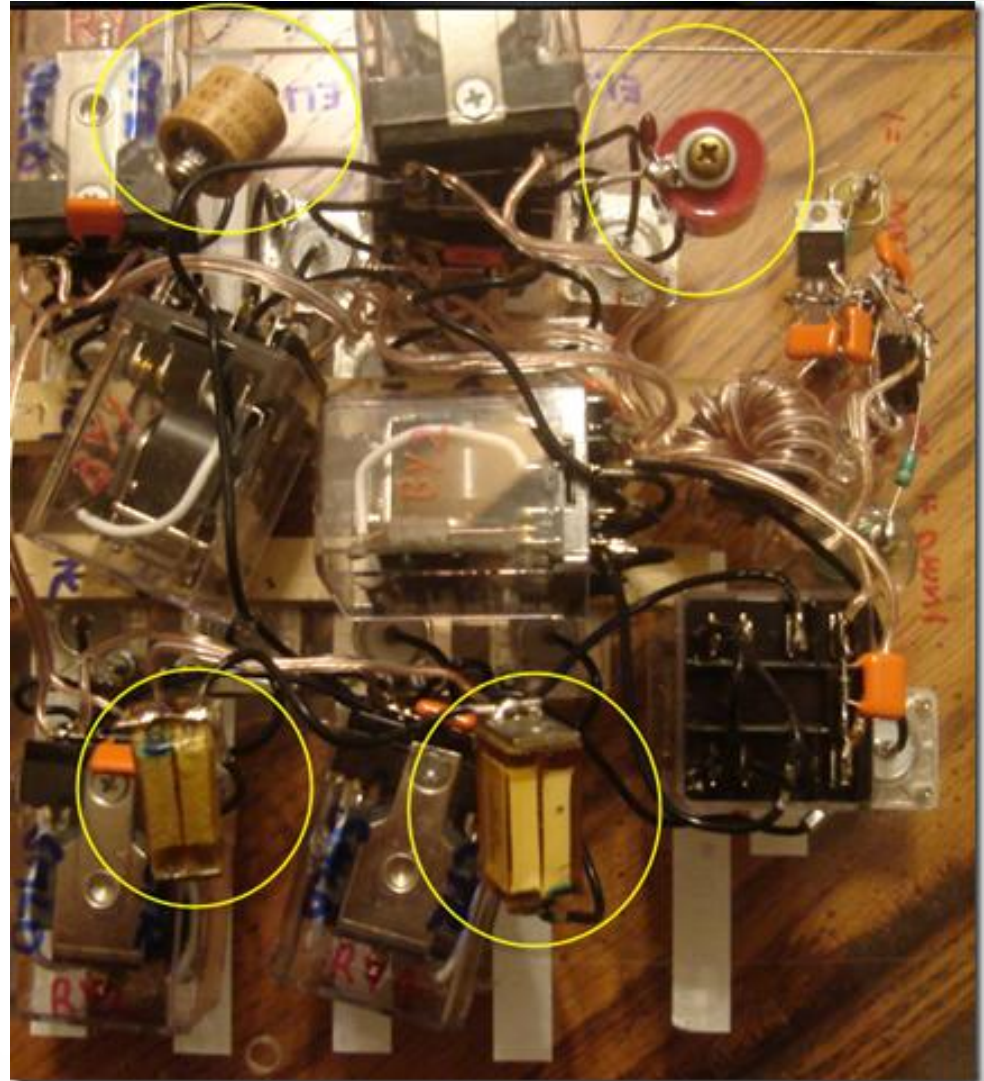
# Phasing Box – Front View

- 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 XI

- Relay line length runs provide XI
- 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

Freq      I-ratio      Phase

=====

7000      1.11      -134

7040      1.03      -137

7080      0.86      -138

### BEAMING EAST

I-ratio      Phase

=====

1.39      -145

1.21      -148

1.05      -151

Target values: 1.00i      -145 degrees



# Inverse Model Predictions

Sources

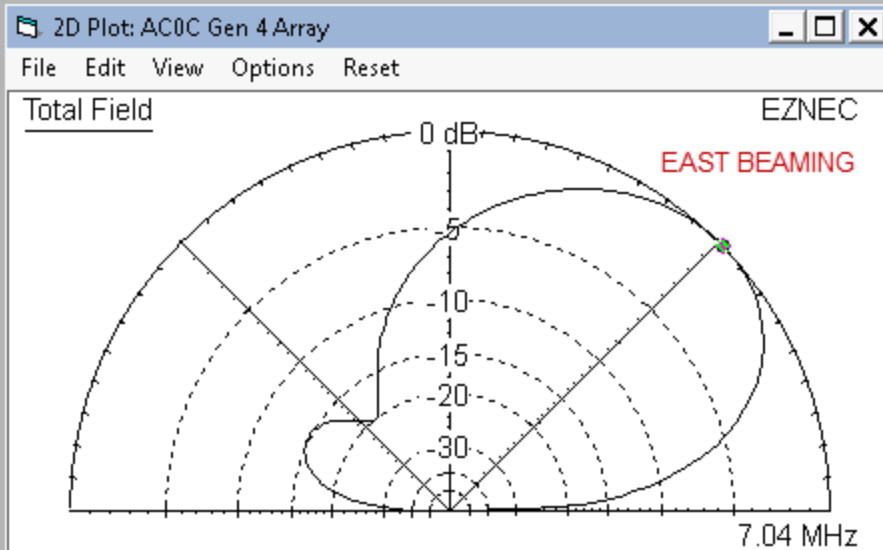
Source Edit

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

Sources

Source Edit

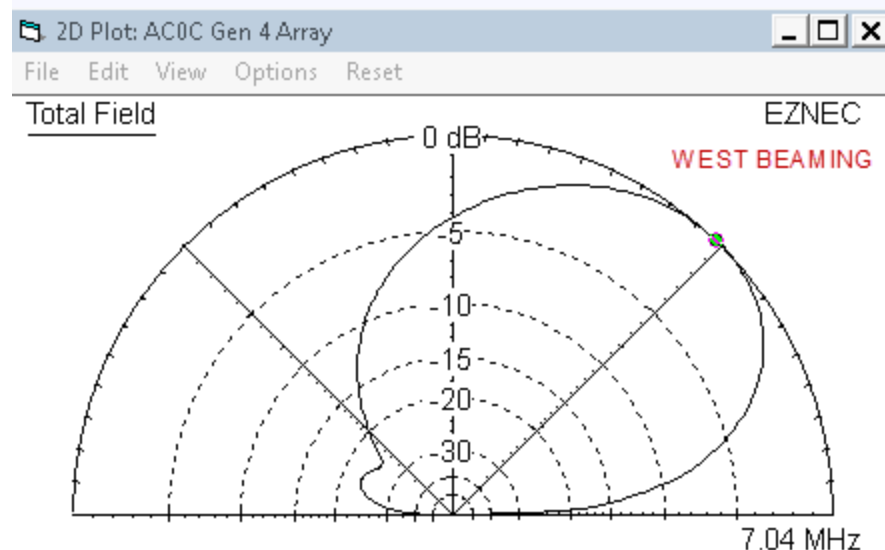
Sources								
	No.	Specified Pos.		Actual Pos.		Amplitude (V, A)	Phase (deg.)	Type
		Wire #	% From E1	% From E1	Seg			
	1	1	0	0	1	1	0	SI
	2	5	0	0	1	1.03	-137	SI
*								



Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 7.95 dBi

Cursor Elev 44.0 deg.  
Gain 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



Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 7.83 dBi

Cursor Elev 46.0 deg.  
Gain 7.83 dBi  
0.0 dBmax

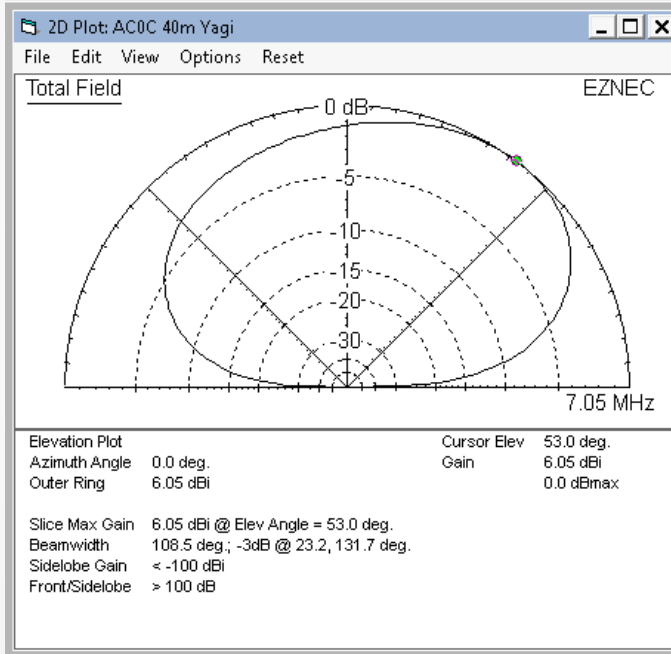
Slice Max Gain 7.83 dBi @ Elev Angle = 46.0 deg.  
Beamwidth 61.6 deg.; -3dB @ 20.9, 82.5 deg.  
Sidelobe Gain -15.51 dBi @ Elev Angle = 159.0 deg.  
Front/Sidelobe 23.34 dB

# Parasitic vs. Phased

Sources

Source Edit

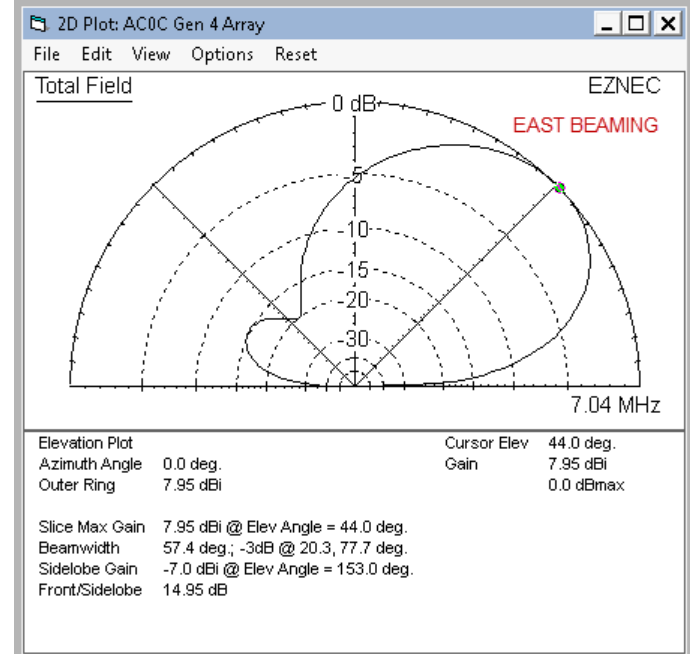
Sources							
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	1	0	0	1	1	0	SI
2	5	0	0	1	0.354	-147	SI
*							



Sources

Source Edit

Sources							
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
*							



**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

----- 3<sup>rd</sup> Gen Array ----- 4<sup>th</sup> 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
  - Dan Mcguire, AC6LA
  - EZDZ, RVM
  - FEED2EL, ZPLOTS
- For materials contributed
  - Jack Holzer, KD0MDA
  - Rob Underwood, K0RU
  - Jerry Chamberlin, WA0JRJ
  - Dewey “Lucky” Jones, W0DRJ