A 40M λ/4 Vertical with Elevated Radials

Easy to construct and raise by one person

Larry Banks, W1DYJ

First licensed: 1962 (KN1VFX)

W1DYJ since 1966 – Amateur Extra

10 Matthews Way Harpswell ME

33 Blueberry Hill Road Woburn MA

http://www.qsl.net/w1dyj/

Presented to YCCC, December 2014

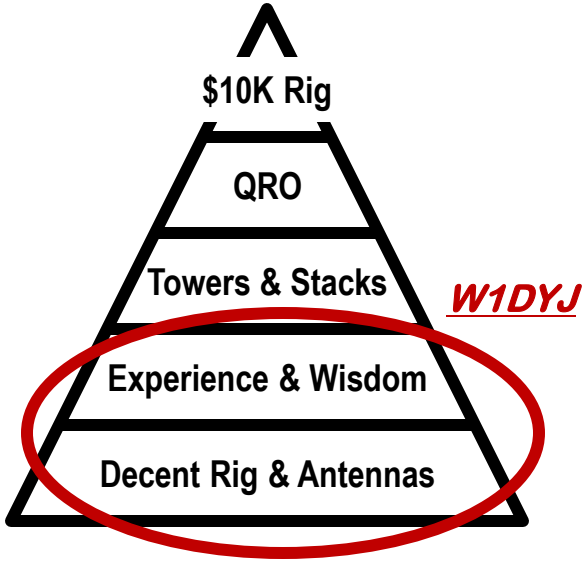
Contents

Contents

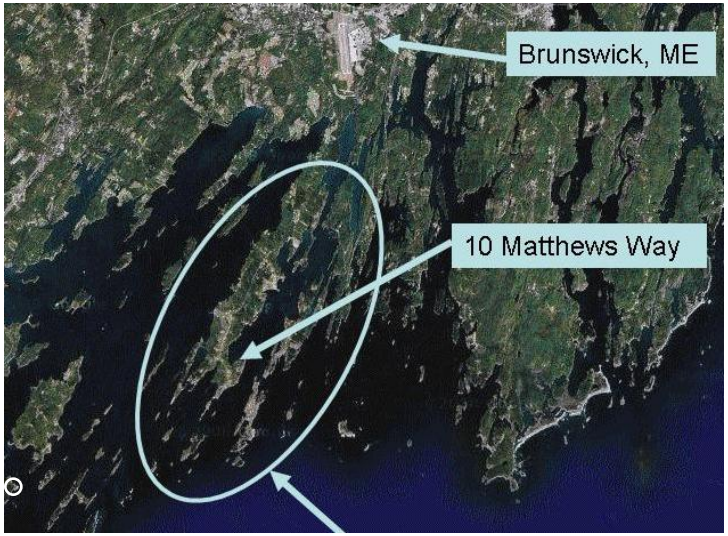
- **Background**

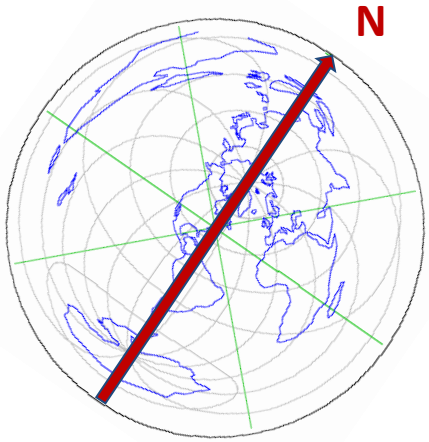
My Philosophy

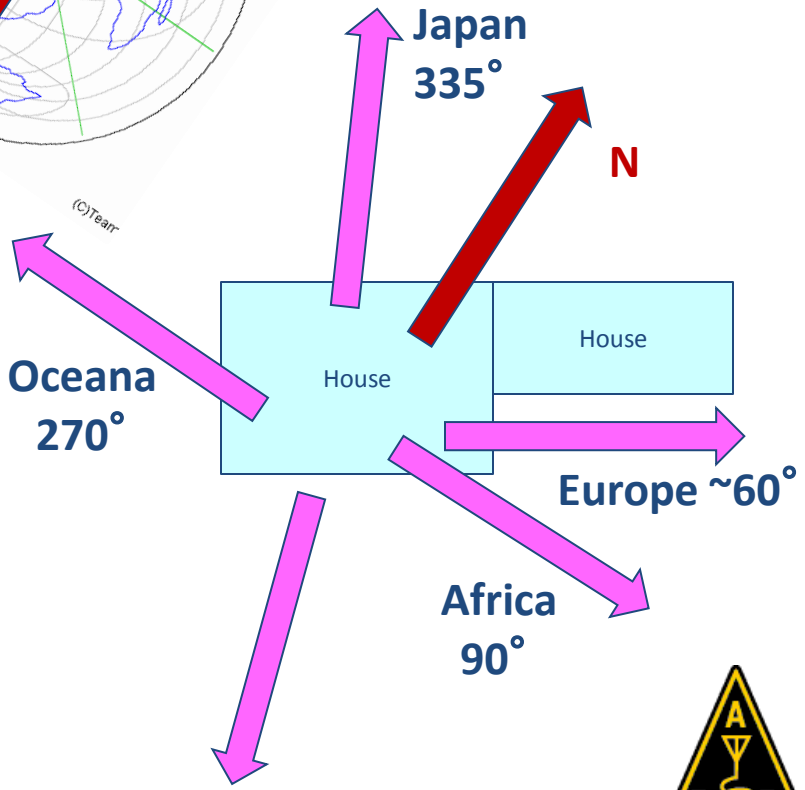
- ✓Station → KISS
  - Do It Myself
- ✓Believe in Modeling
  - Easier than Building
- ✓Contesting → SOLP
  - Only Blame Myself



Maine Location

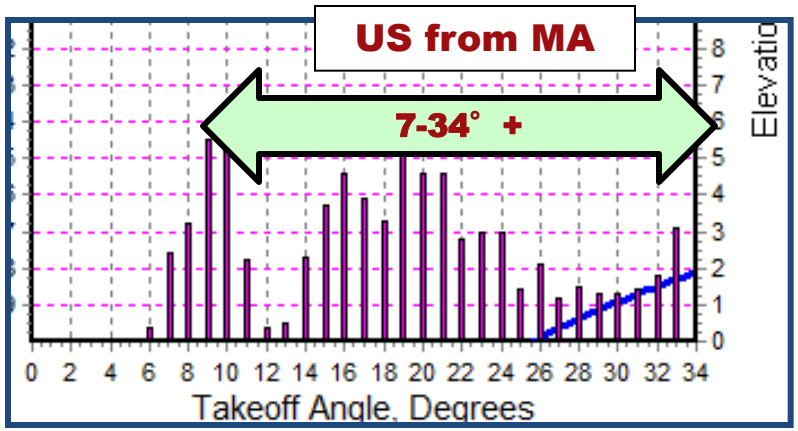


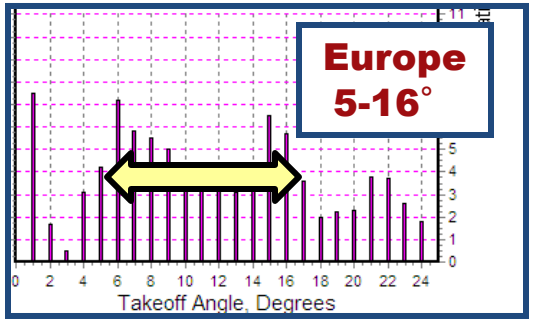




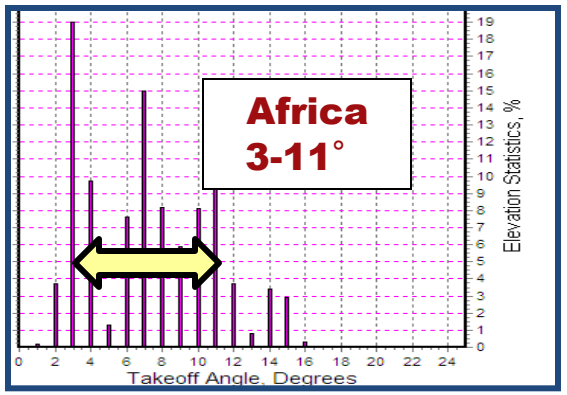
Elevation Statistics for New England – 40M

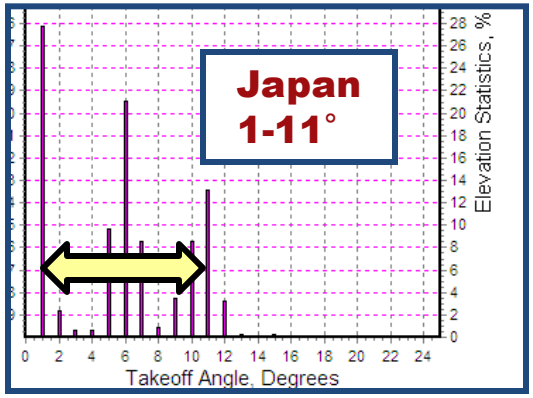
(From HFTA)

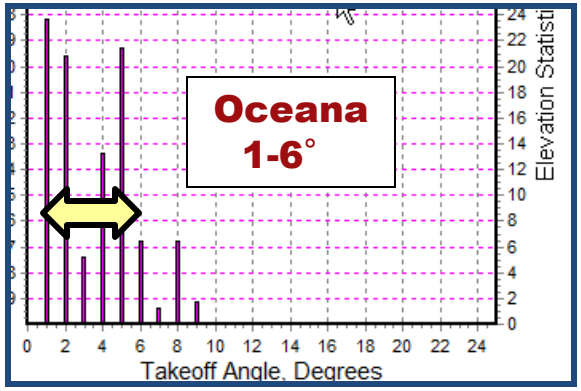


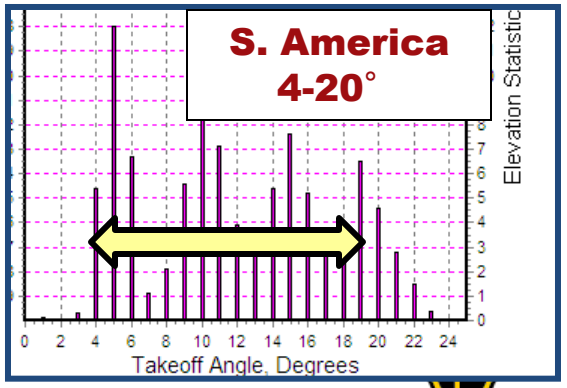


1-20°









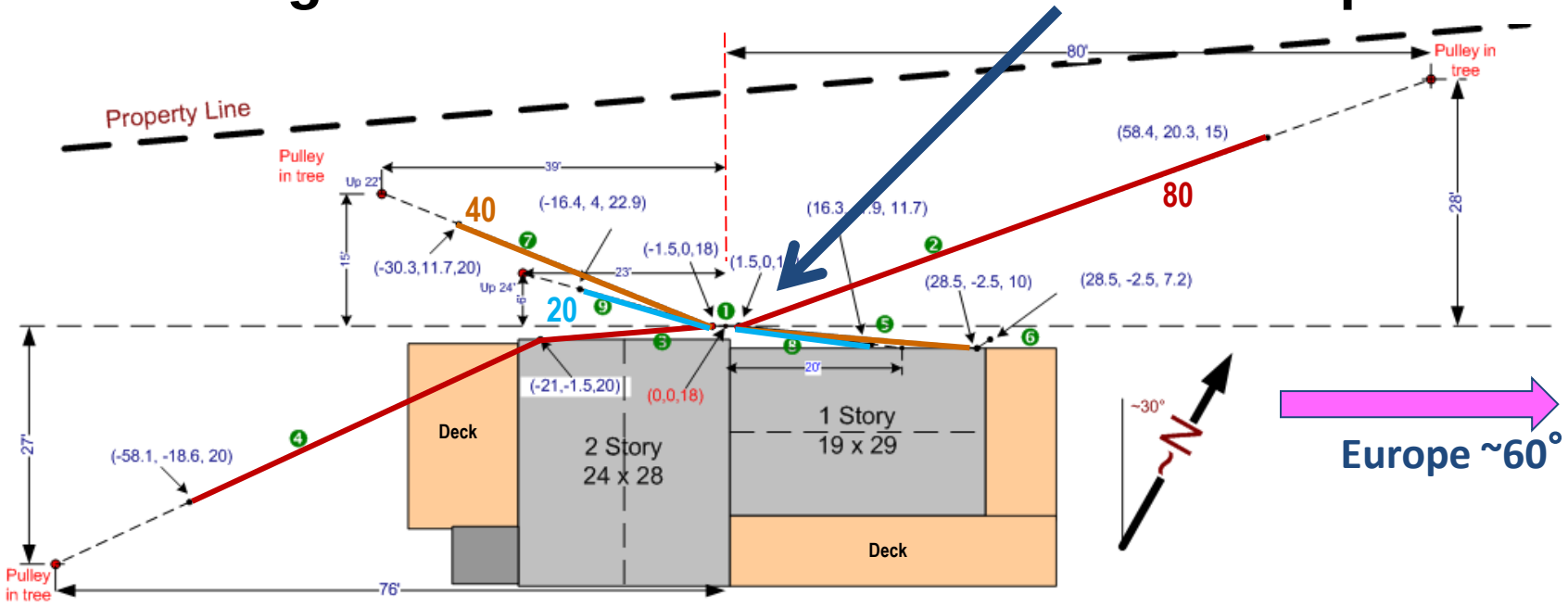
Contents

- Background
- **Original 40M Dipole**

Original 40M dipole

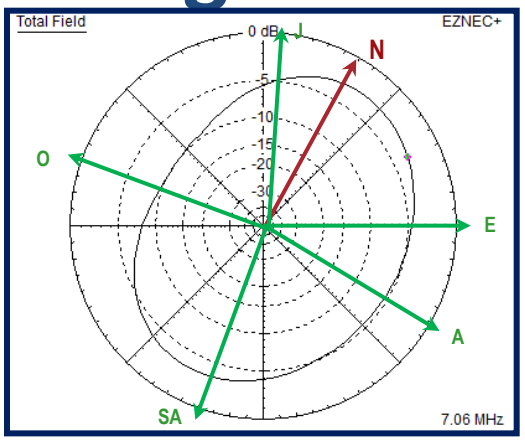
Simple Fan Dipole for 80, 40, 20

Using a corner of the house as the center point

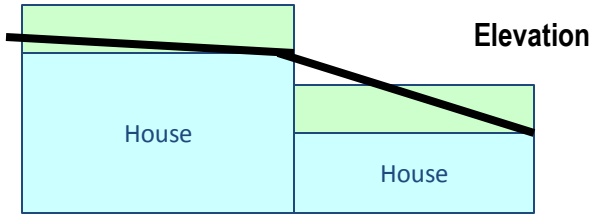


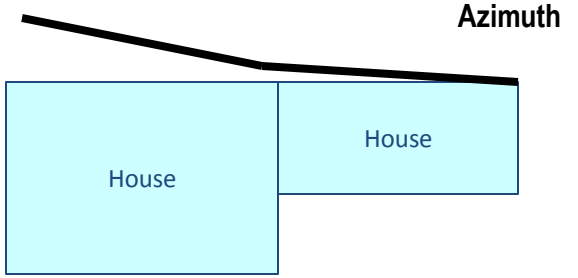
(The numbers on the wires are for use with EZNEC.)

Original 40M dipole: Limitations: Azimuth



Azimuth °	Gain (dBi) @ 20° El
60 (Europe)	- 1.6 dBi
90 (Africa)	- 2.4
170 (S. America)	- 0.8
210 (Oceana)	- 9.3
335 (Japan)	- 2.8

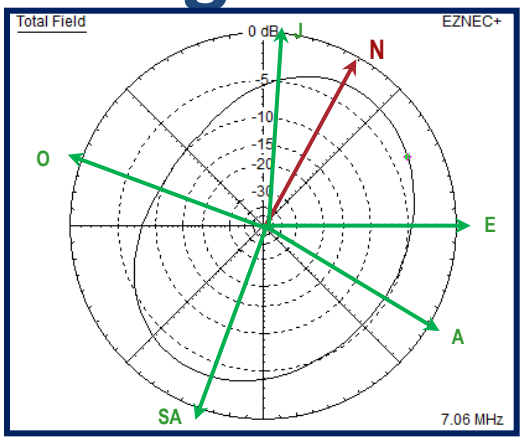




House

EZNEC Plots do not take into consideration the effect of being so near the house.

Original 40M dipole: Limitations: Elevation



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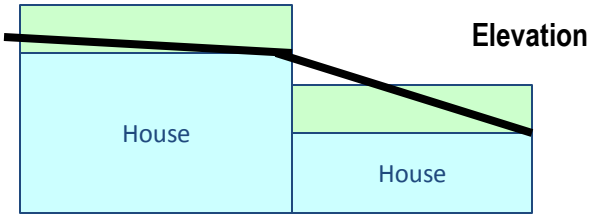
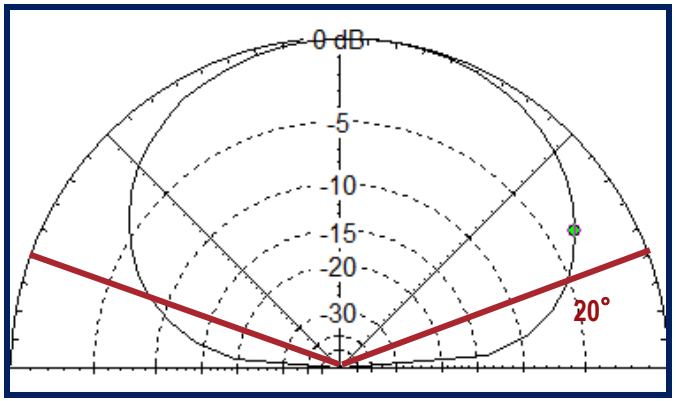
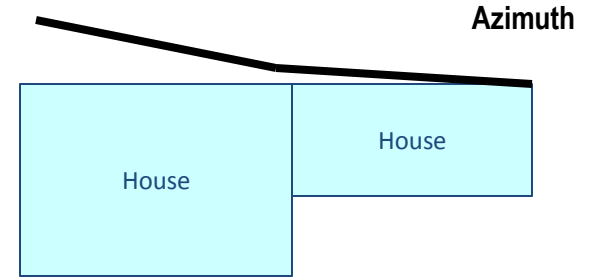
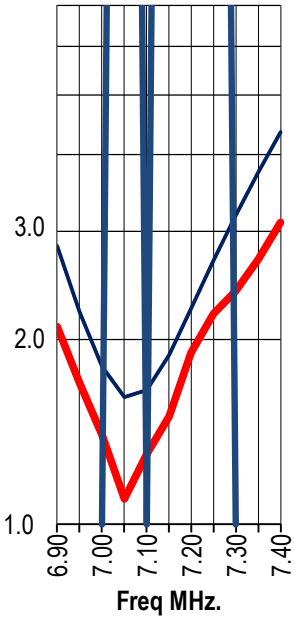






Elevation °	Gain @ 60° Azimuth
90	4.8 dBi
20	- 1.6
15	- 3.0
10	- 5.0
5	- 9.2



SWR
EZNEC
MEASURED

Coax feed: 35' of RG8x ~0.25 dB @ 7 MHz

Contents

- Background
- Original 40M Dipole
- **Why a Vertical?**

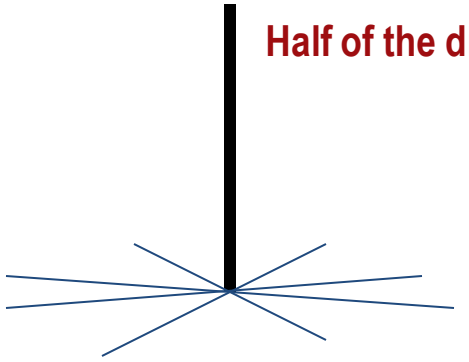
Why a Vertical?

Towers? Higher Dipoles?

- Remembering the KISS principle and "Do It Myself" →
- No Tall Trees → No High Dipoles

→ ¼λ Vertical

- An easy to build resonant antenna with a low elevation angle
  - One person can build, erect, and test
  - All parts are transportable in/on my car
- Negatives
  - No gain or F/B – Omnidirectional
  - Potentially noisy
- Radials? Where and How Many?



Radial Choice

From the ARRL Antenna Book:

Practical Suggestions For Vertical Ground Systems

At least 16 radials should be used if at all possible. Experimental measurements and calculations show that with this number, the loss resistance decreases the antenna efficiency by 30% to 50% for a 0.25 wavelength vertical, depending on soil characteristics. *In general, a large number of radials (even though some or all of them must be short) is preferable to a few long radials for a vertical antenna mounted on the ground.* The conductor size is relatively unimportant as mentioned before: #12 to #22 copper wire is suitable.

- If you install only 16 radials they need not be very long - 0.1 lambda is sufficient.
- If you have the wire, the space and the patience to lay down 120 radials (optimal configuration), they should be 0.4 lambda long. This radial system will gain about 3 dB over the 16-radial case.
- If you install 36 radials that are 0.15 lambda long, you will lose 1.5 dB (¼ s-unit) compared to the optimal configuration.

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From QST, March 2010, pp 30-33:

An Experimental Look at Ground Systems for HF Verticals
(and references)

Rudy Severns, N6LF

...four elevated radials at a height of 48 inches are within 0.2 dB of 64 radials lying on the ground.

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…four elevated radials at a height of 48 inches are within 0.2 dB of 64 radials lying on the ground.

Assume four elevated radials high enough to be safe:

~10 ft

Contents

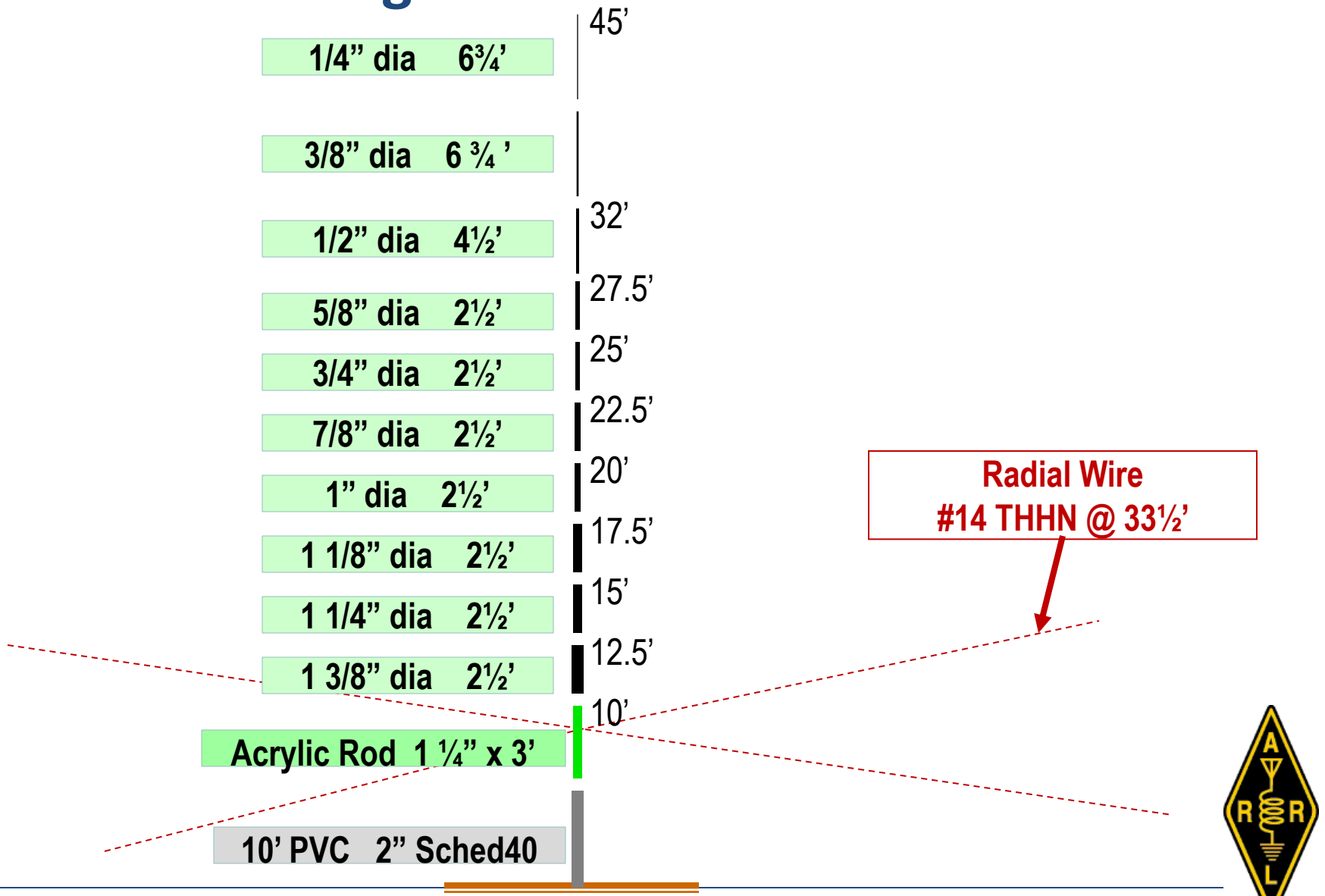
- Background
- Original 40M Dipole
- Why a Vertical?
- **The Design**

EZNEC Modeling ~ Lots of Models!

• Simple Wires: 2 Radials @ 8’		V = R = 34’, 34.5’, 34.7’
• Simple Wires: V = R = 34.7’		Radial H = 8’ 10’ 12’
• Simple Wires: V = R = 34.7’	2 Radials @ 8’	Ground = Sandy, Average, Very Good
• Simple Wires: V = R = 34.7’	Radials @ 8’	Number of Radials = 2, 4, 8
• *Simple Wires: V = R = 34.7’*	*Radials @ 10’*	*Number of Radials = 2, 4, 8*
• Al tubing	4 radials @ 35’ / 10’	V = 34’, 35.5’, 35’
• *Al tubing @ 35’*	*4 radials @ 35’ / 10’*	*With / Without Al mast*
• Al tubing @ 35’	4 radials @ 35’ / 10’	Radials with & w/o insulation

Slide included in appendix

The First Design



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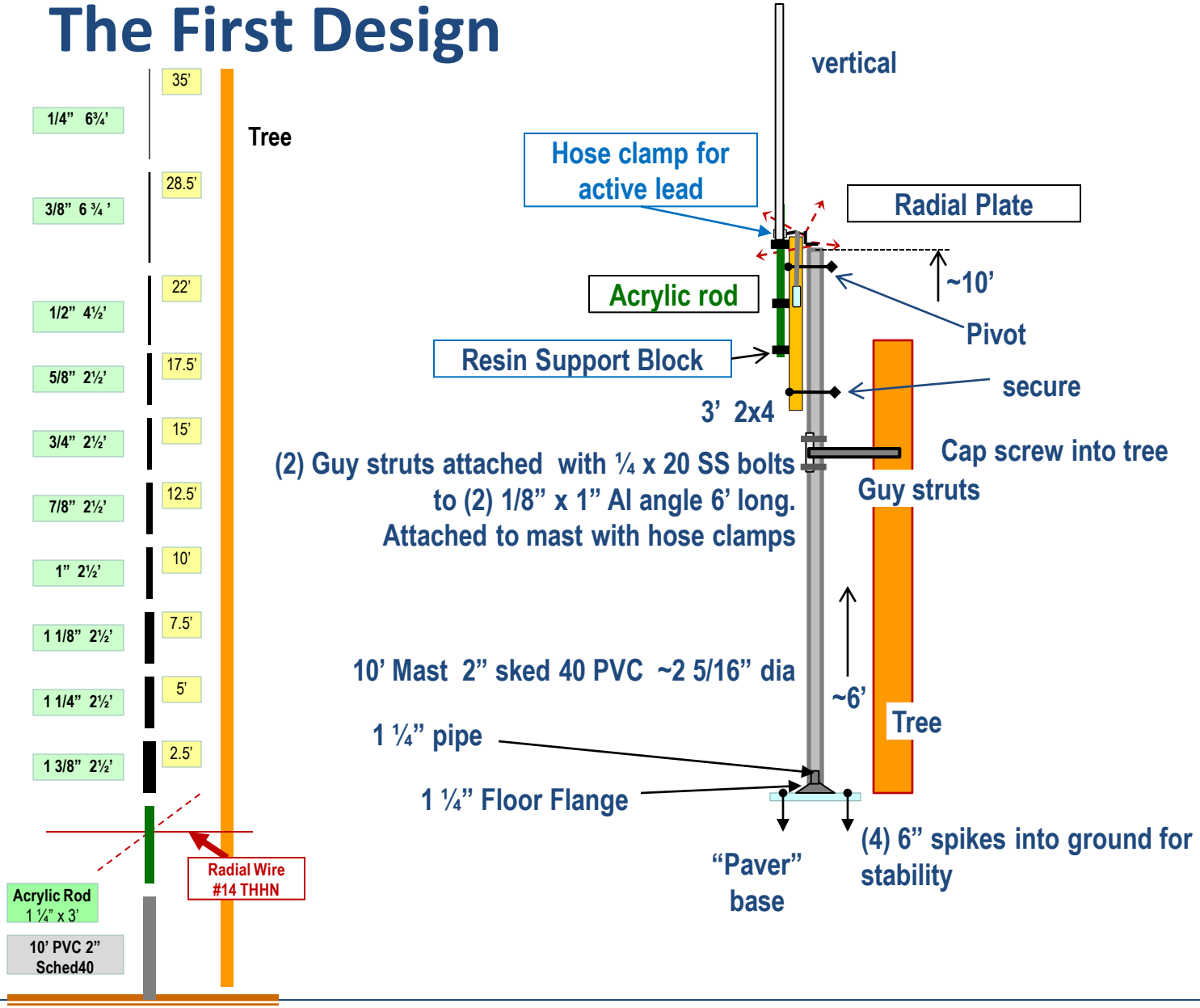

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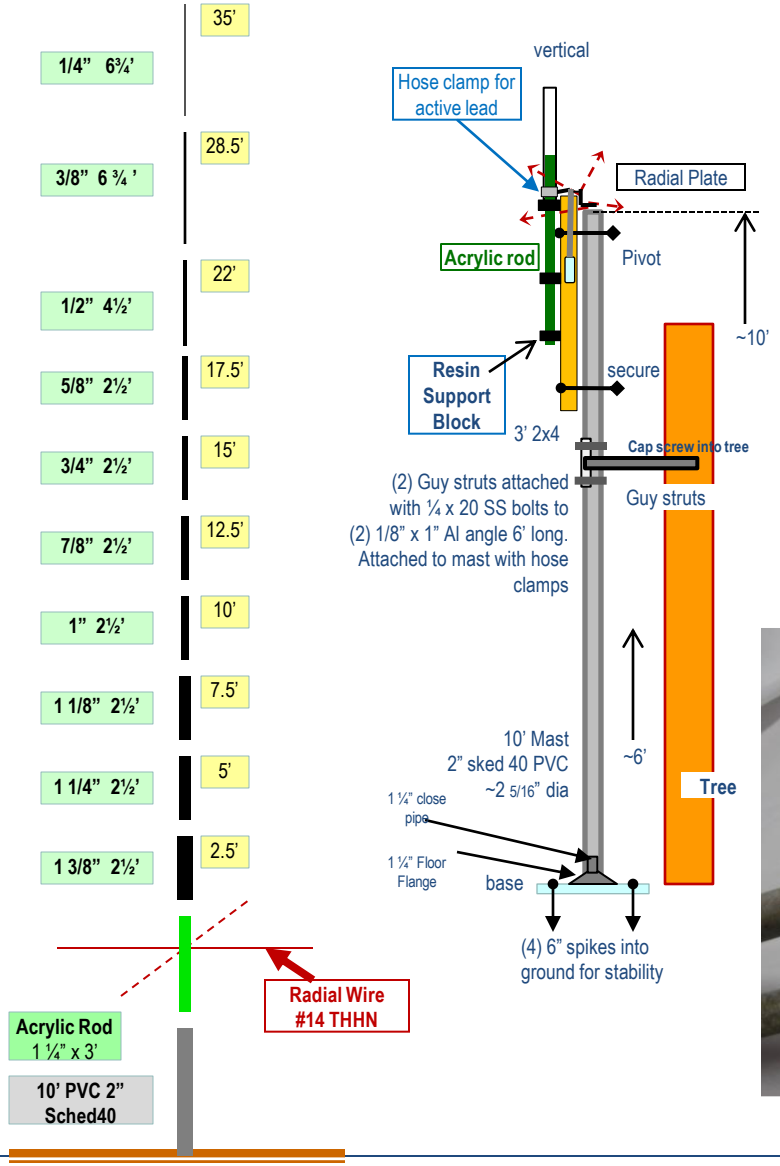

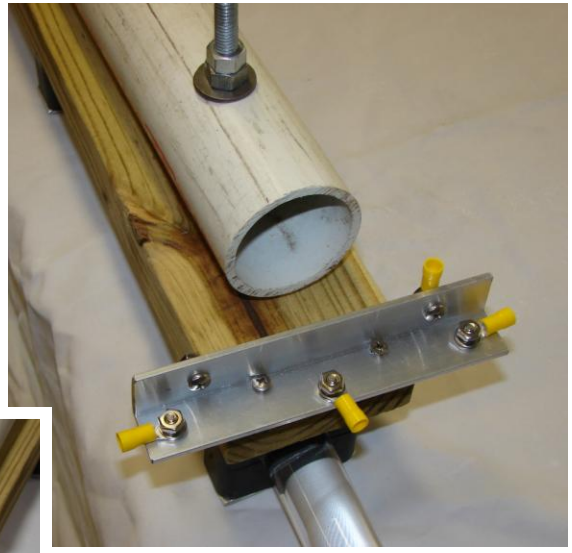

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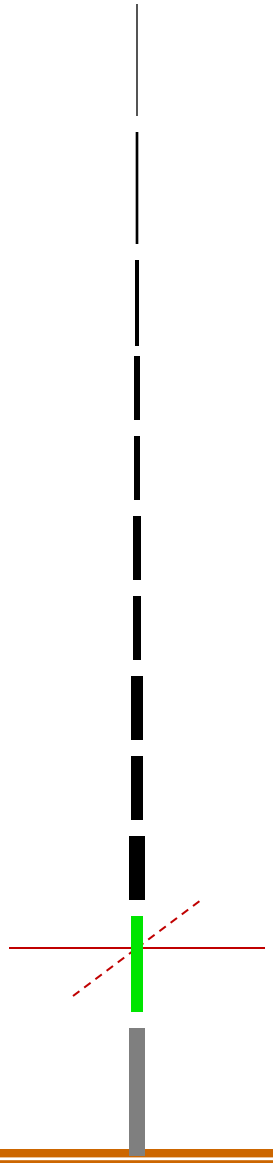
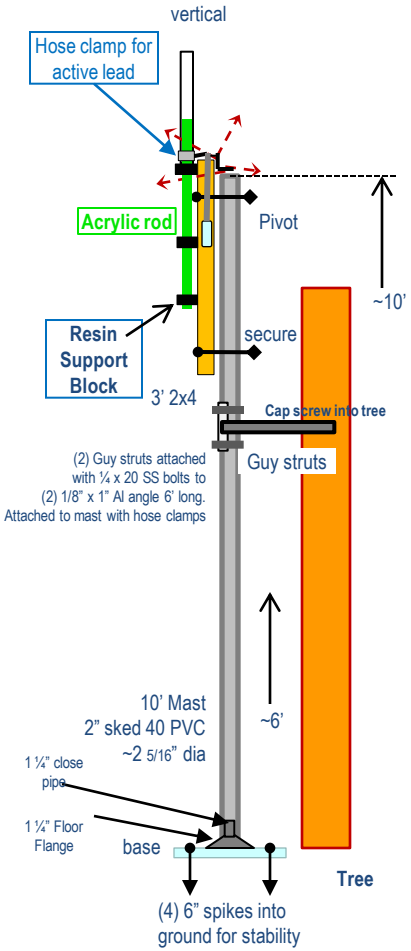
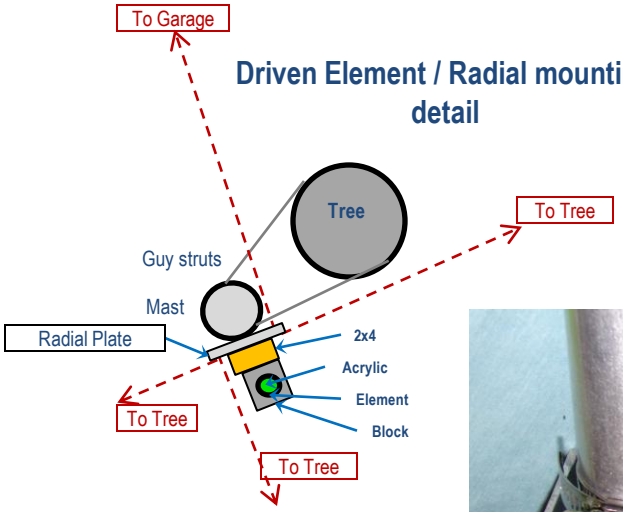
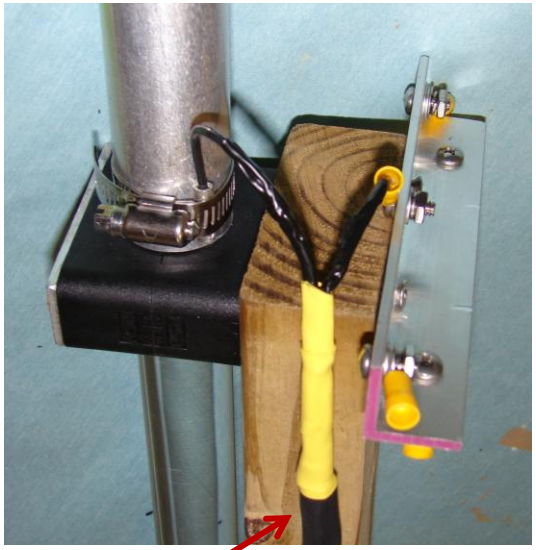


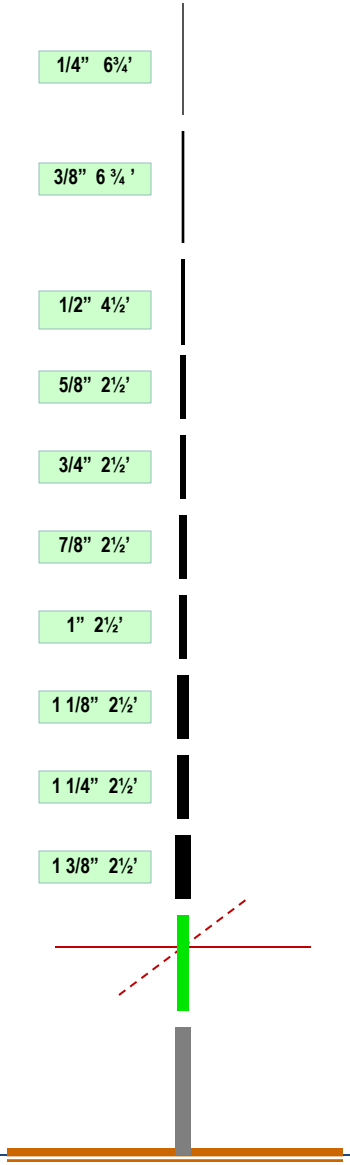






Common Mode Choke

The First Design



Too Flimsy!

EZNEC Modeling ~ More Models!

- Simple Wires: 2 Radials @ 8' V = R = 34', 34.5', 34.7'
- Simple Wires: V = R = 34.7' Radial H = 8' 10' 12'
- Simple Wires: V = R = 34.7' 2 Radials @ 8' "Gnd" = Sandy, Avg, Very Good
- Simple Wires: V = R = 34.7' Radials @ 8' Number of Radials = 2, 4, 8
- *Simple Wires: V = R = 34.7' Radials @ 10' Number of Radials = 2, 4, 8*

- Al tubing, first design 4 radials @ 35' / 10' V = 34', 35.5', 35'
- *Al tubing, first design @ 35' 4 radials @ 35' / 10' With / Without Al mast*
- Al tubing, first design @ 35' 4 radials @ 35' / 10' Radials with & w/o insulation

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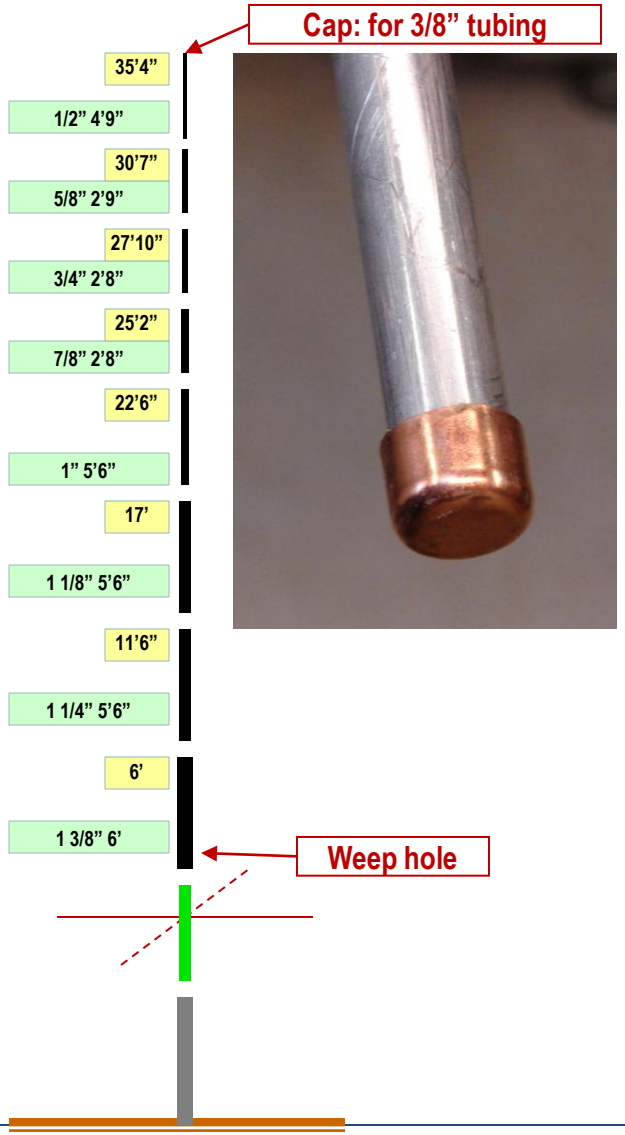
- New, Stronger Al tubing/ 4 radials @ 10' R = 34', 33.5' V = 35', 34.5' (4 cases)
- New, Stronger Al tubing/ 4 radials @ 10' / 33.5' V = 35' 6", 35', 35' 4"
- *New, Stronger Al tubing @ 35'4" / 4 radials @ 10' / 33.5' "Gnd" = Sandy, Avg, Very Good*

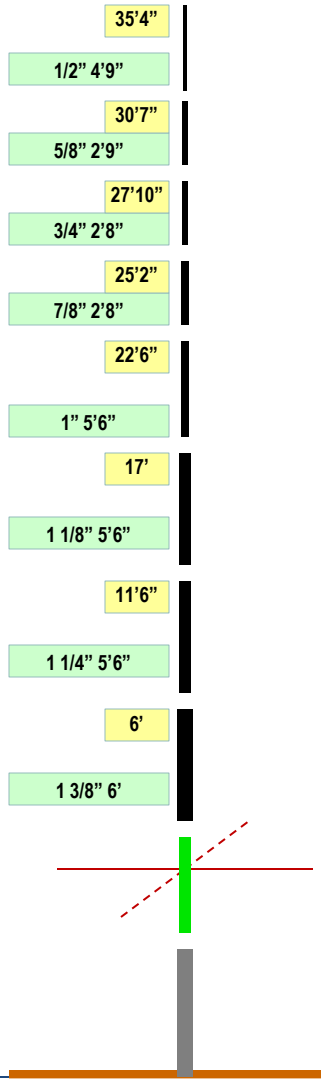
Slide included in appendix

The Final Design



The Final Design

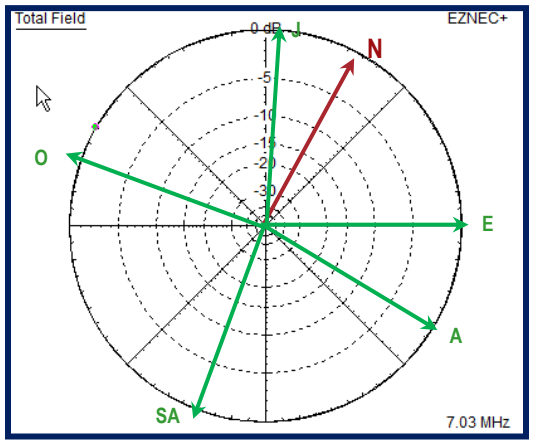
"One Person" Design



Contents

- Background
- Original 40M Dipole
- Why a Vertical?
- The Design
- **40M Results**

EZNEC model – 40M λ/4 vertical



Azimuth °	Gain (dBi) @ 20° El
Max	- 0.87 dBi
Min	- 0.88

40M

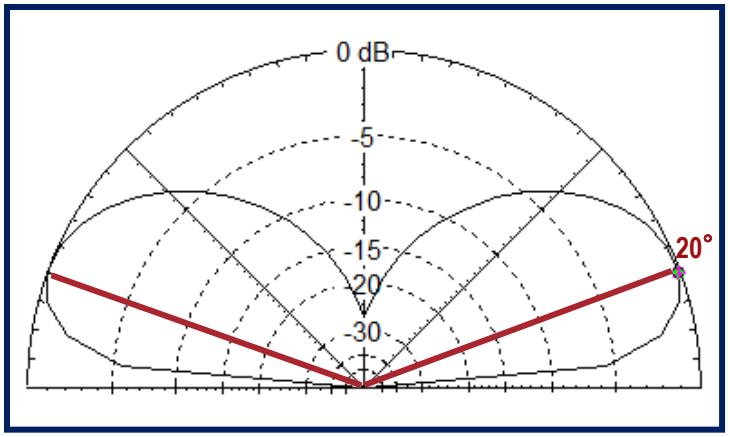
MODEL (vs. reality):

35' 4" graduated Al pole *(no tree)*

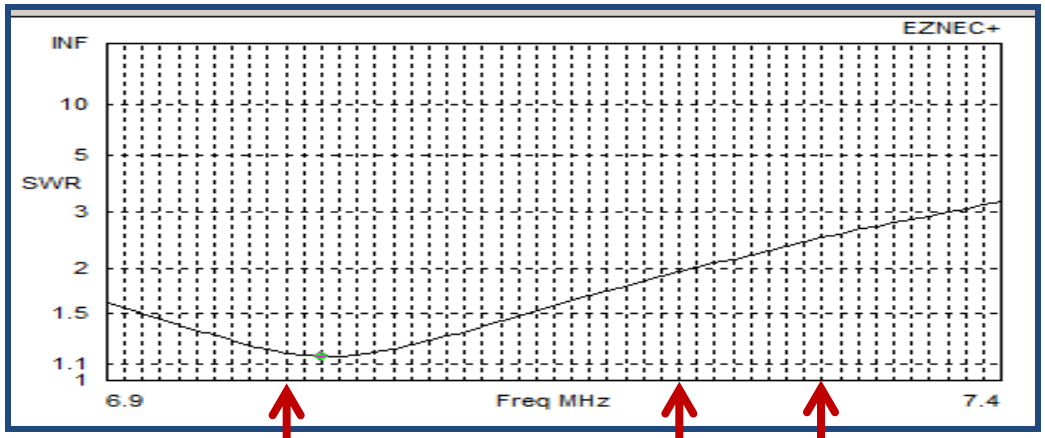
4 elevated radials @ 10' *(not "real")*

Very Good *(and consistent)* ground

Local structures not modeled



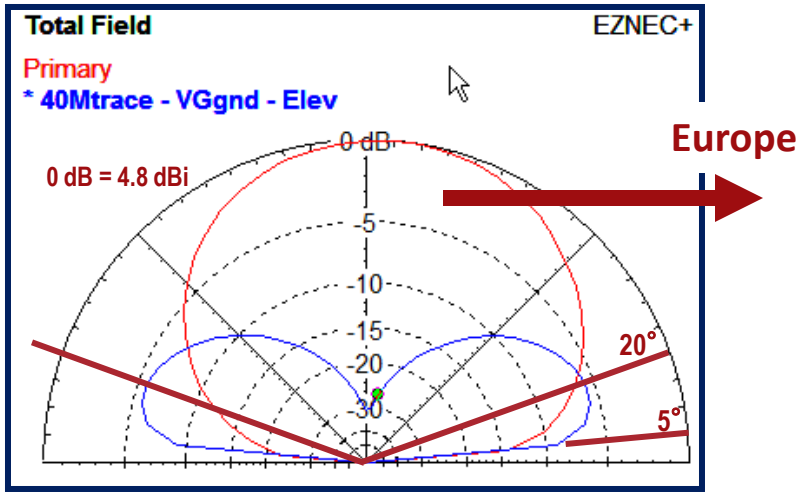
Elevation °	Gain @ 60° Azimuth
90	- 26.4 dBi
20	- 0.88
15	- 0.91
10	- 1.64
5	- 4.23



7.0 7.22 7.3

COMPARE ~ Old vs. New

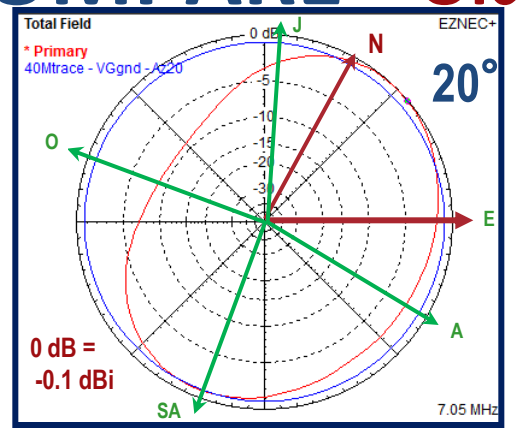
40M

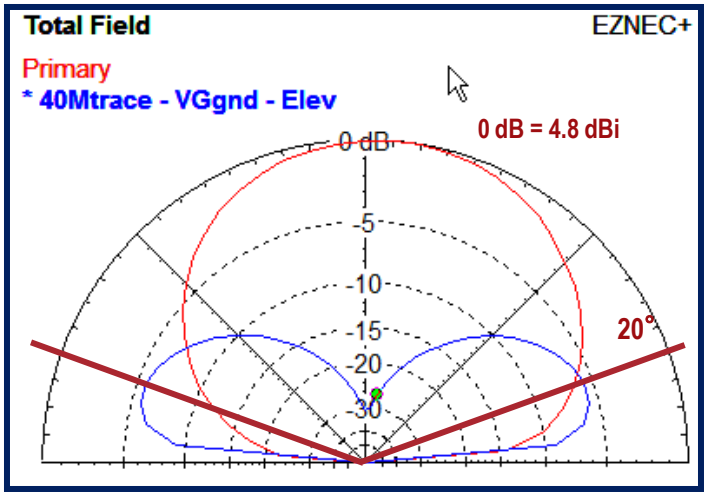


Elevation °	Gain @ 60° Azimuth (Europe)		
	Dipole	Vertical	Δ
90	4.8 dBi	- 26.4	- 31.2 dB
20	- 1.6	- 0.88	+ 1.5
15	- 3.0	- 0.91	+ 2.1
10	- 5.0	- 1.64	+ 3.7
5	- 9.2	- 4.23	+ 5.0

COMPARE ~ Old vs. New

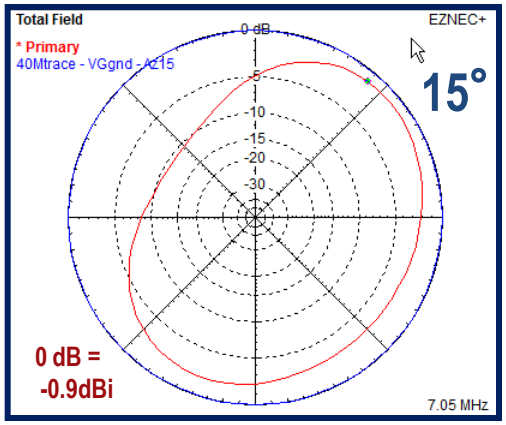
40M

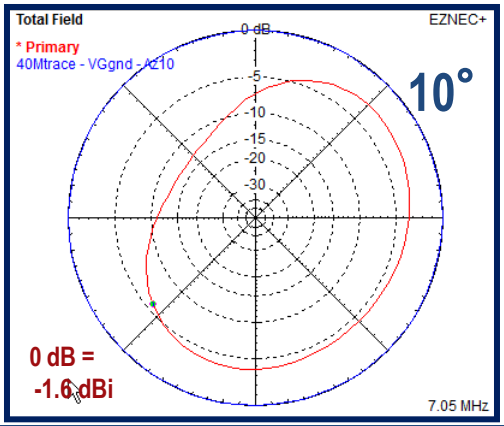


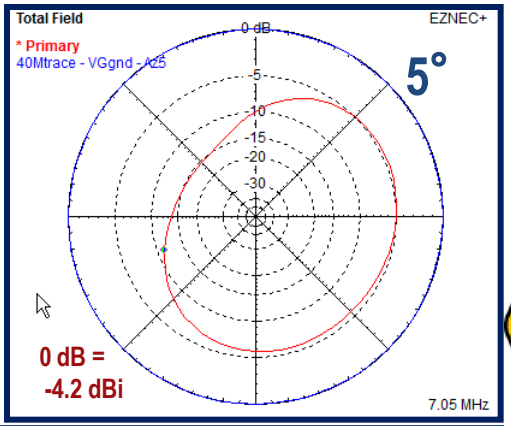


Azimuth °	Gain (dBi) @ 20° Elevation		
	Dipole	Vertical	Δ
60 (Europe)	- 1.6 dBi	- 0.88	+ 0.7
90 (Africa)	- 2.4	- 0.88	+ 1.5
170 (S. America)	- 0.8	- 0.87	- 0.1
210 (Oceana)	- 9.3	- 0.87	+ 8.4
335 (Japan)	- 2.8	- 0.88	+ 1.9

Elevation °	Gain @ 60° Azimuth (Europe)		
	Dipole	Vertical	Δ
90	4.8 dBi	- 26.4	- 31.2 dB
20	- 1.6	- 0.88	+ 1.5
15	- 3.0	- 0.91	+ 2.1
10	- 5.0	- 1.64	+ 3.7
5	- 9.2	- 4.23	+ 5.0

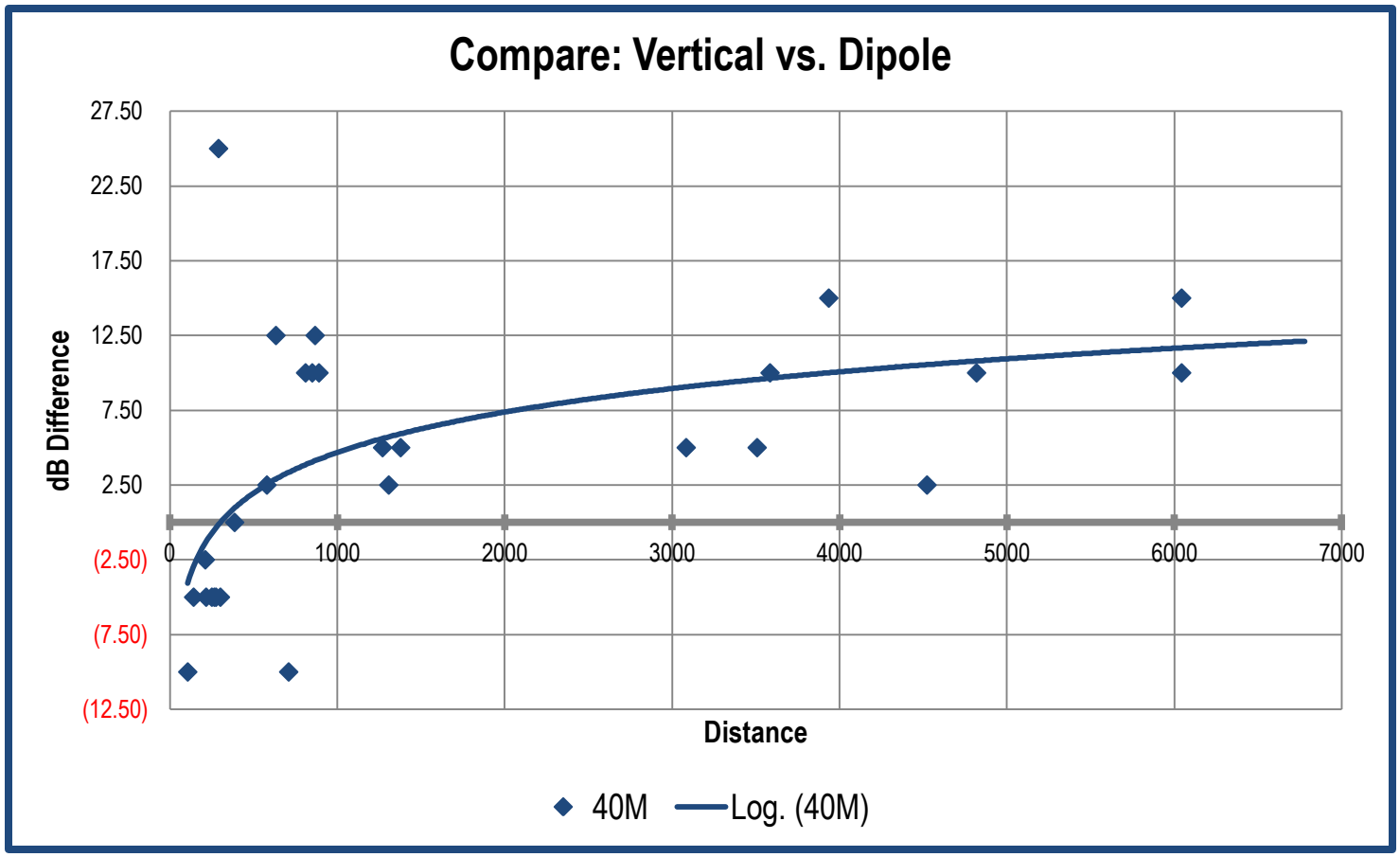






COMPARE ~ 40M Reality

Noise:
Worse on 40M by ~1-1.5 S-units



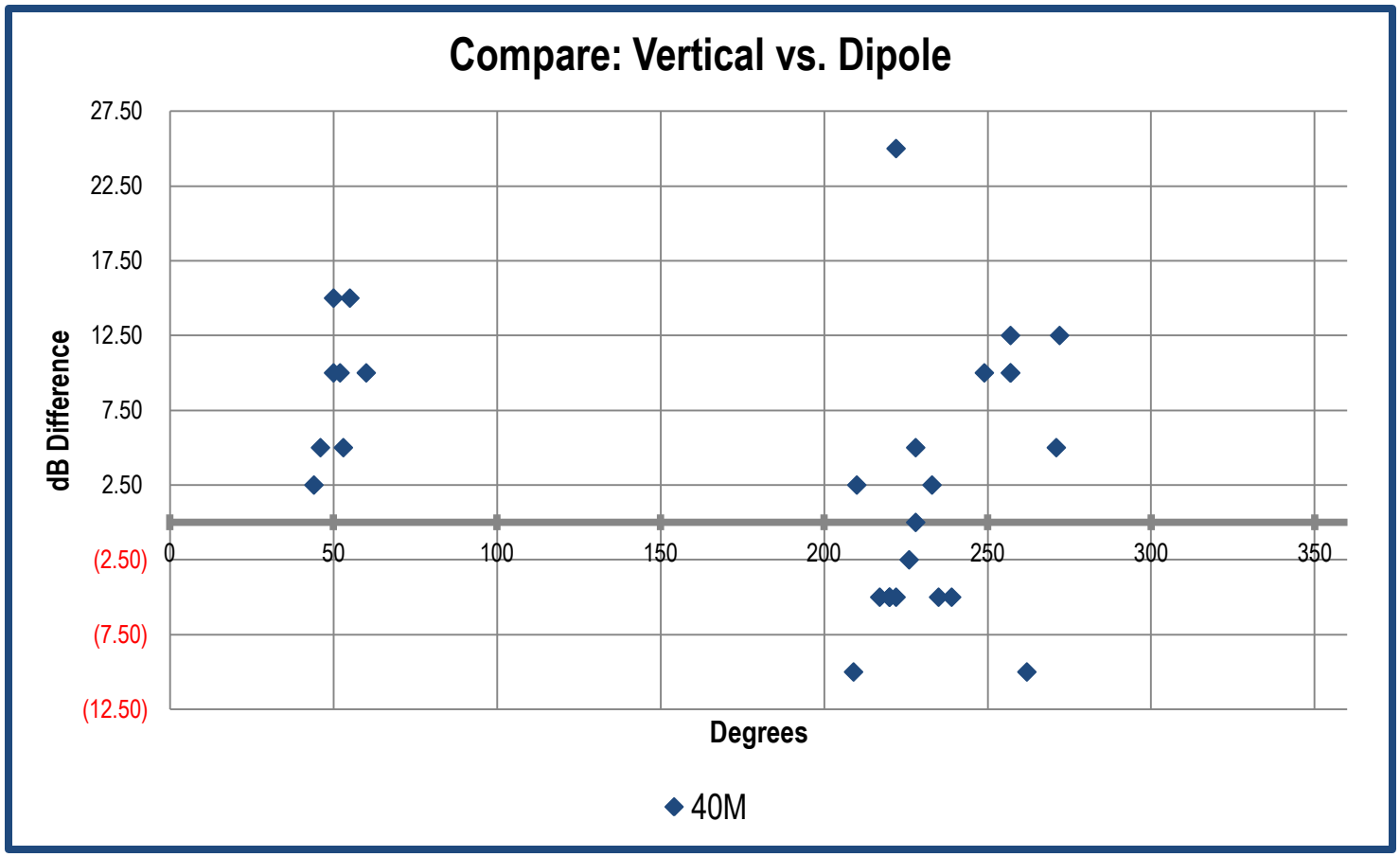
See Appendix for data

Coax feed: Δ = – 0.25 dB @ 7.1 MHz.

Dipole → 35' of RG8x = 0.25 dB @ swr 1.5:1 = .29 dB

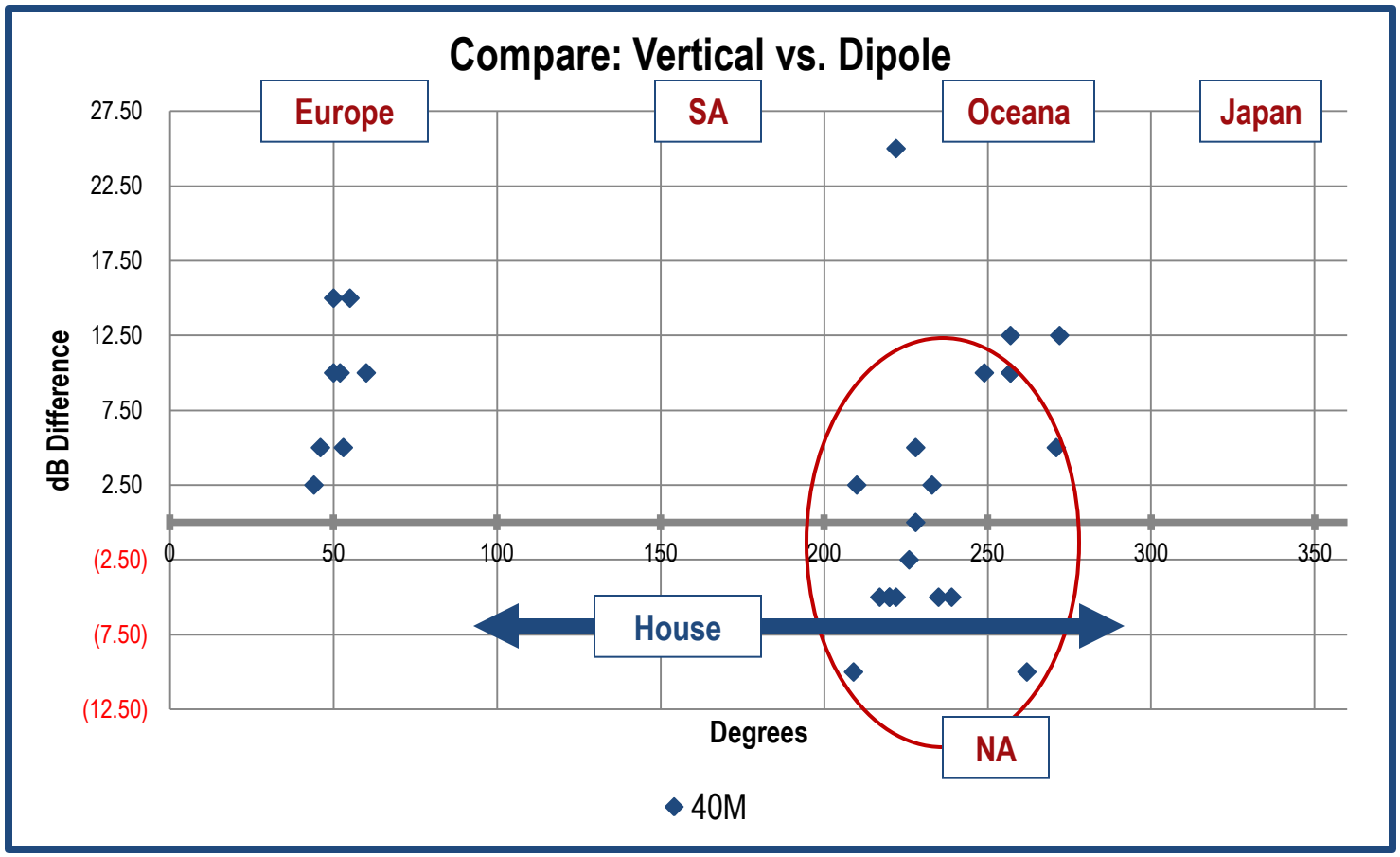
Vertical → 15' of RG8x + 105' of Bury-Flex = 0.5 dB. @ swr 1.5:1 = .55 dB

COMPARE ~ 40M Reality



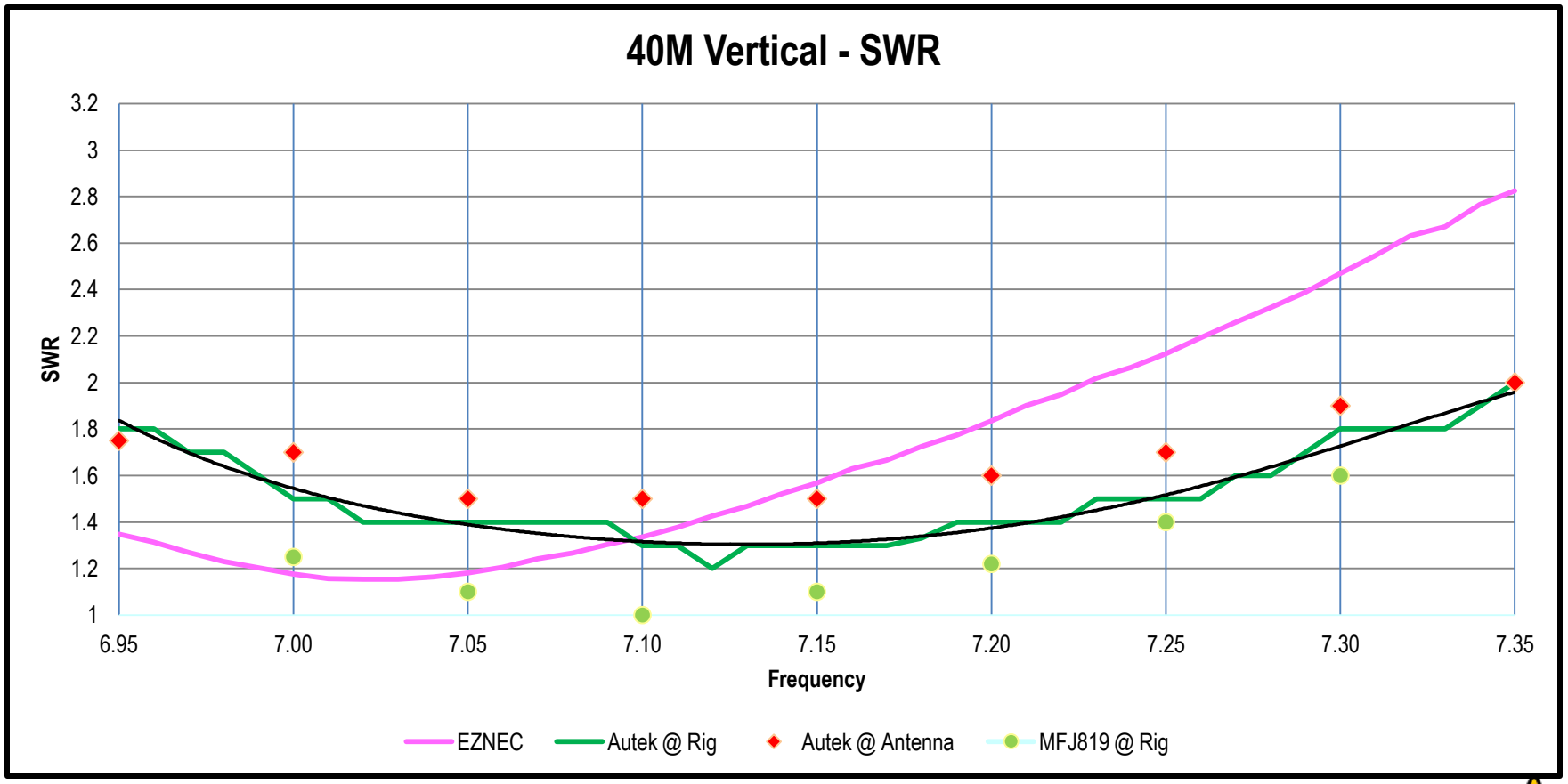
See Appendix for data

COMPARE ~ 40M Reality



See Appendix for data

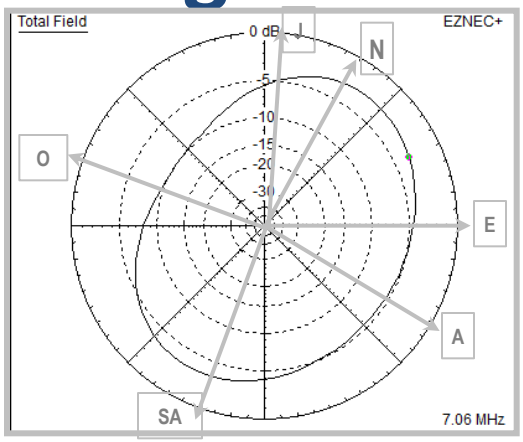
SWR Graph

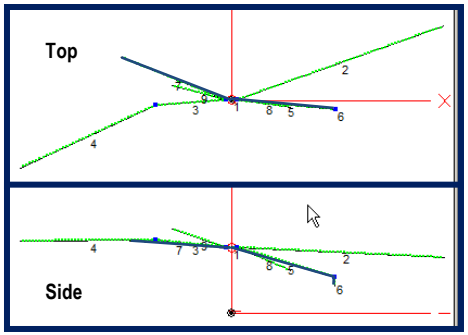

40M Vertical - SWR
SWR
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
6.95
7.00
7.05
7.10
7.15
7.20
7.25
7.30
7.35
Frequency
EZNEC
Autek @ Rig
Autek @ Antenna
MFJ819 @ Rig

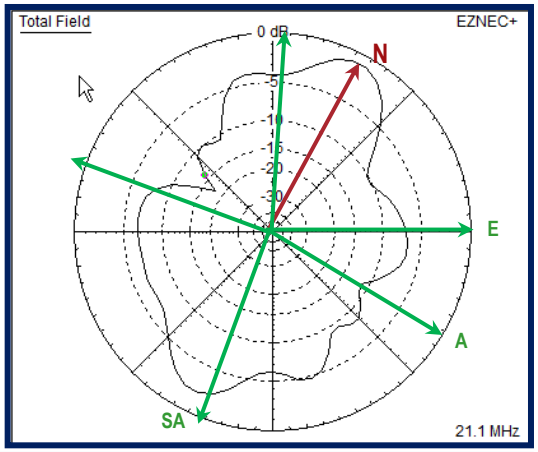
Contents

- Background
- Original 40M Dipole
- Why a Vertical?
- The Design
- 40M Results
- **15M Results**

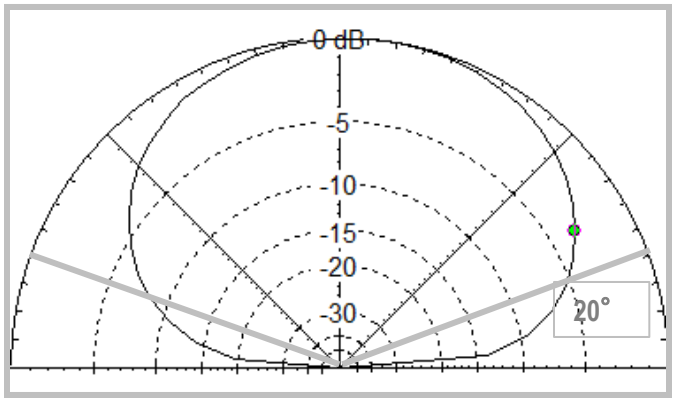
Original Fan Dipole @ 15M

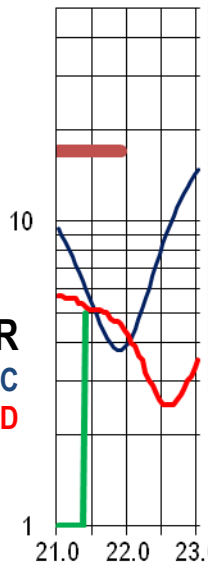




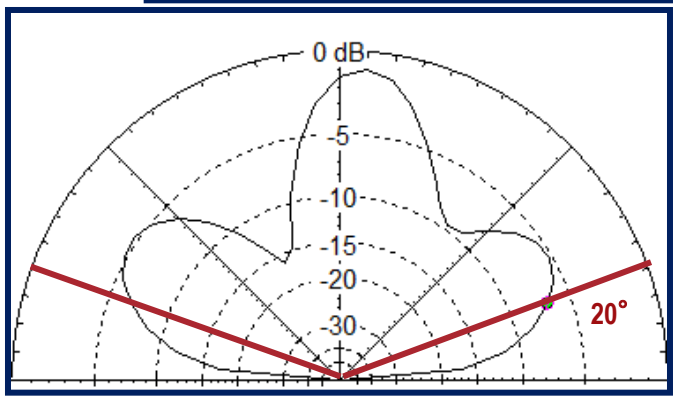


15M





SWR
EZNEC
MEASURED



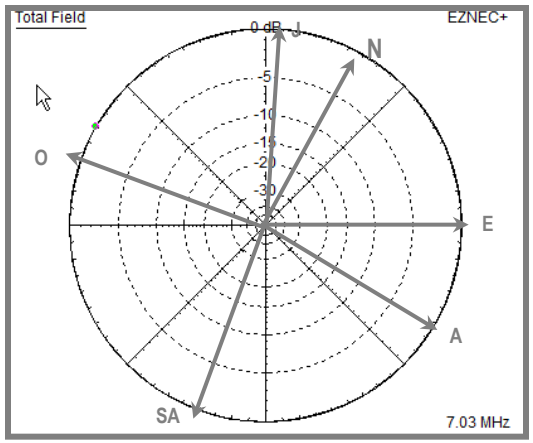
Elevation °	Gain @ 60° Azimuth
90	4.8 dBi
20	- 1.6
15	- 3.0
10	- 5.0
5	- 9.2

El °	Gain (dBi) @ 60° Az
90	6.7 dBi
20	1.5
15	- 0.4
10	- 3.3
5	- 8.8

Coax feed: 35' of RG8x ~0.25 dB @ 7 MHz // ~0.47 dB @ 21 MHz

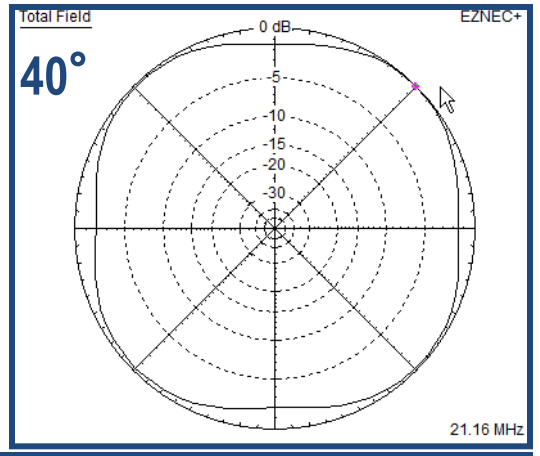
EZNEC model – 40M λ/4 vertical

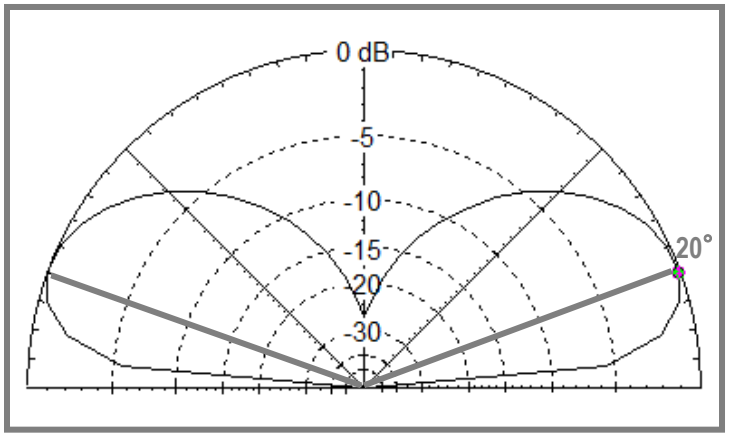
4 elevated radials @ 10'
Very Good ground

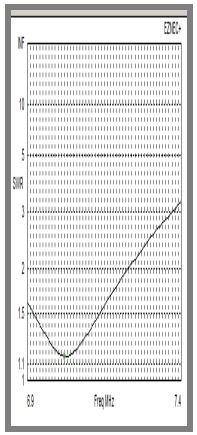


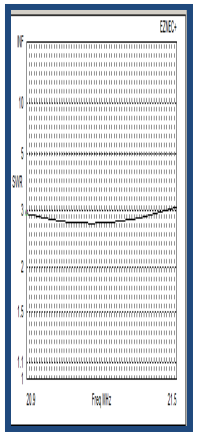
Azimuth °	Gain (dBi)	
	@ 20° El	@ 40° El
Max	- 0.87 dBi	+3.57 dBi
Min	- 0.88	+2.09

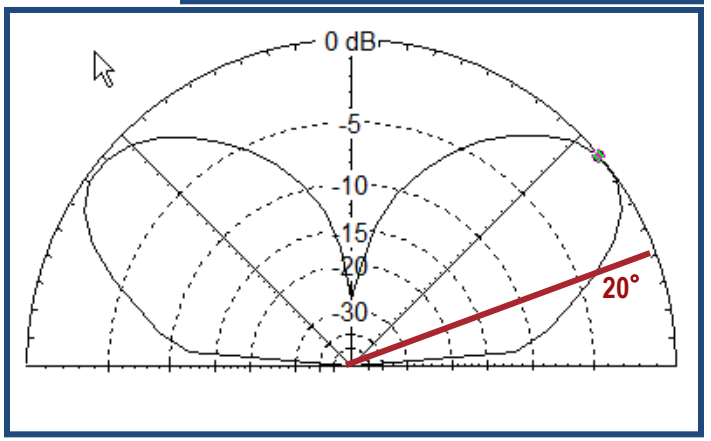
@15M









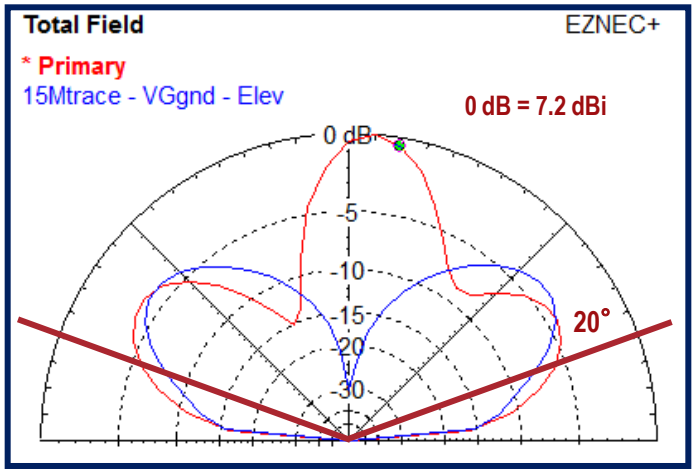


Elevation °	Gain @ 60° Azimuth
90	- 26.4 dBi
20	- 0.88
15	- 0.91
10	- 1.64
5	- 4.23

Elevation °	Gain @ Max Azimuth
90	- 23.7 dBi
20	- 0.44
15	- 2.78
10	- 4.84
5	- 7.99

COMPARE ~ Old vs. New

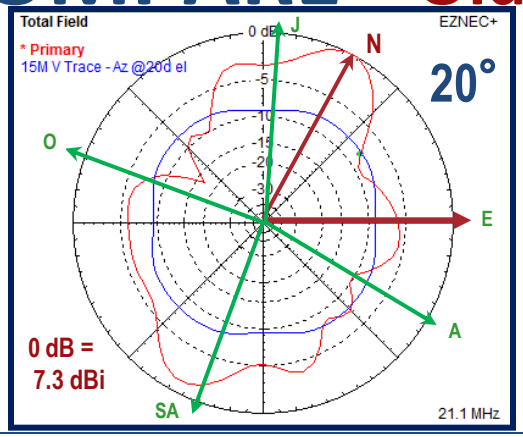
15M

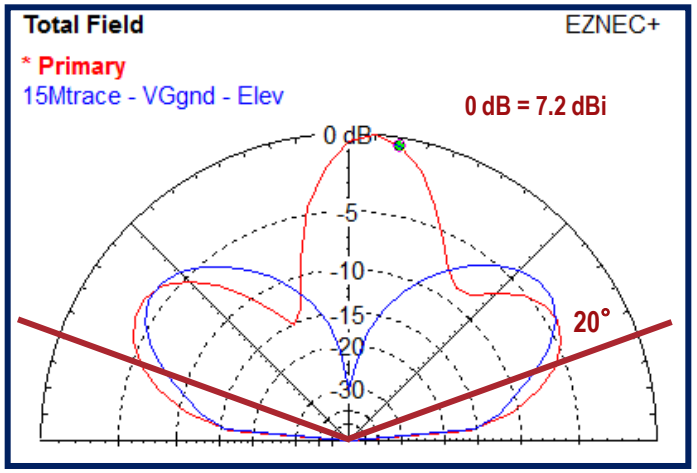


Elevation °	Gain @ 60° Azimuth (Europe)		
	Dipole	Vertical	Δ
90	6.7 dBi	- 23.7	- 30.4 dB
20	1.5	- 0.44	- 1.9
15	- 0.4	- 2.78	- 2.4
10	- 3.3	- 4.84	- 1.5
5	- 8.8	- 7.99	+ 0.8

COMPARE ~ Old vs. New

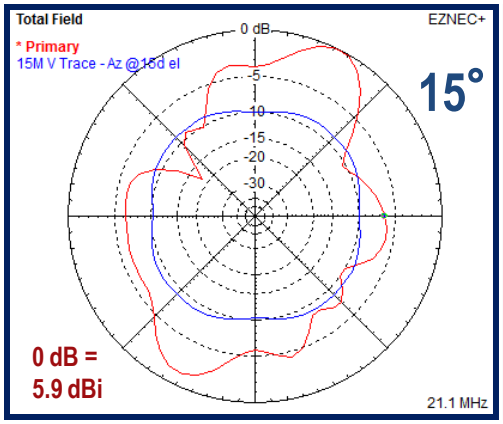
15M

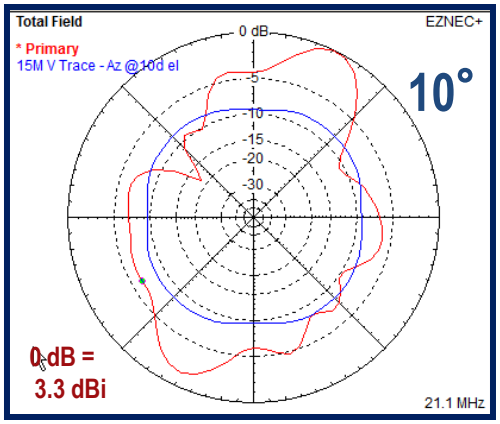


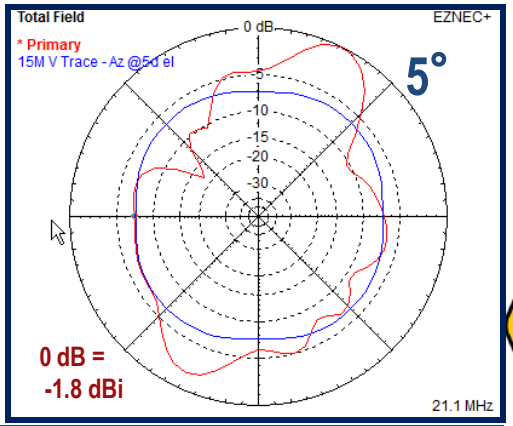


Azimuth °	Gain (dBi) @ 20° Elevation		
	Dipole	Vertical	Δ
60 (Europe)	1.5 dBi	- 1.8	- 3.3
90 (Africa)	- 3.0	- 0.6	+ 2.4
170 (S. America)	5.7	- 1.1	- 6.8
210 (Oceana)	0.2	- 1.1	- 1.3
335 (Japan)	4.2	- 1.7	- 5.9

Elevation °	Gain @ 60° Azimuth (Europe)		
	Dipole	Vertical	Δ
90	6.7 dBi	- 23.7	- 30.4 dB
20	1.5	- 0.44	- 1.9
15	- 0.4	- 2.78	- 2.4
10	- 3.3	- 4.84	- 1.5
5	- 8.8	- 7.99	+ 0.8

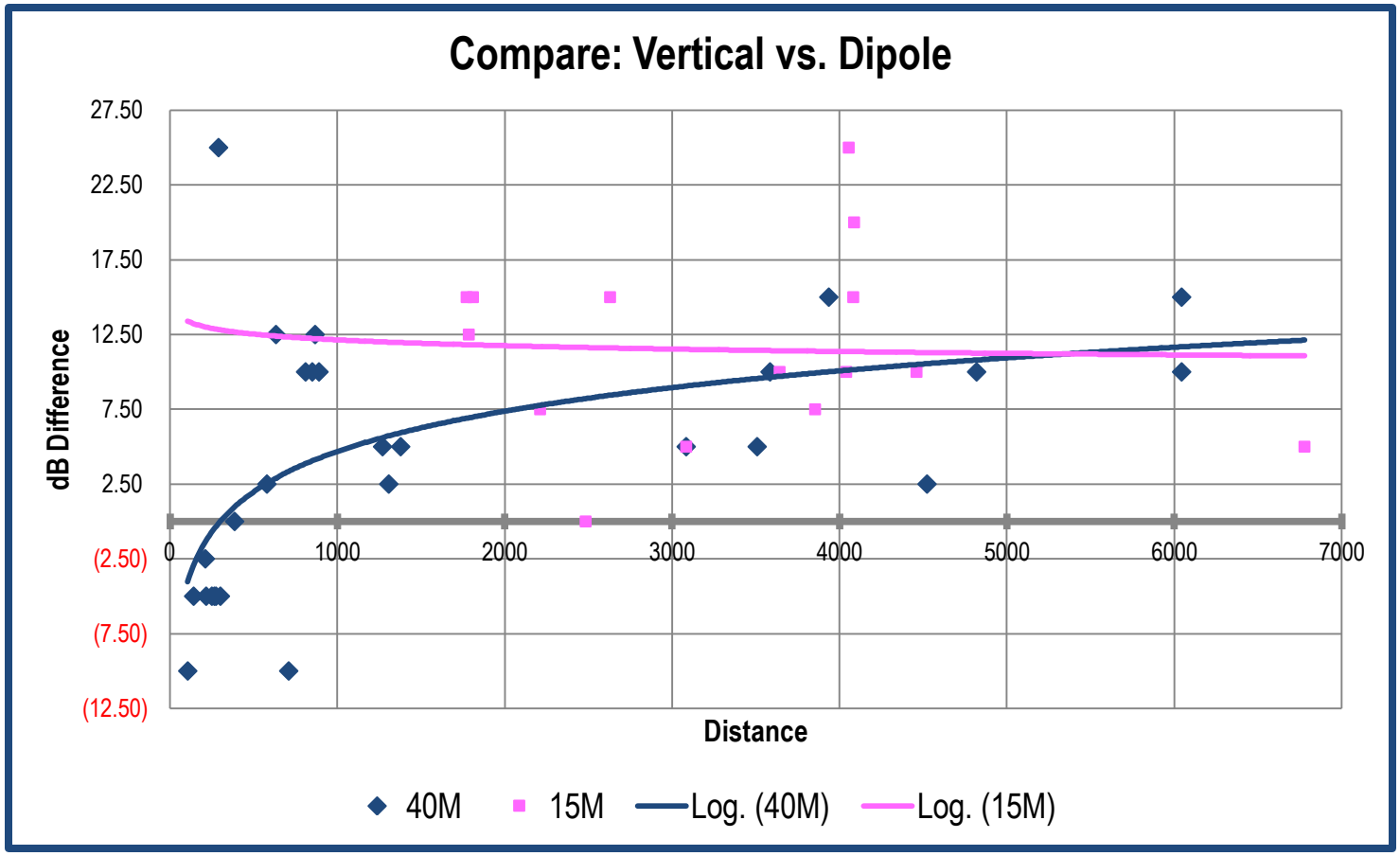






COMPARE ~ 15M Reality

Noise
Worse on 40M by ~1-1.5 S-units
Better on 15M by ~ 0.5-1.5 S-unit

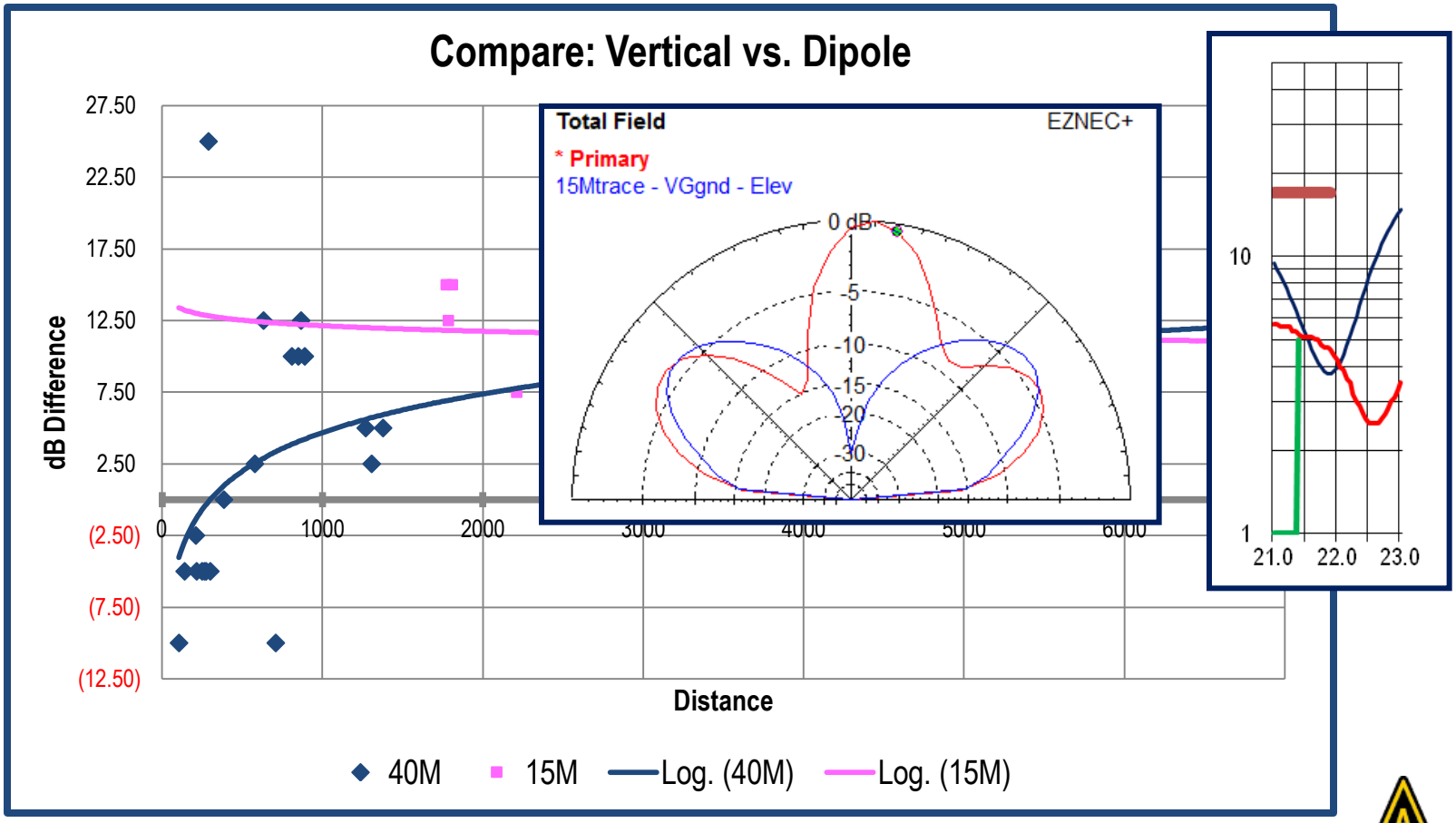


Coax feed: Δ = 0 dB @ 21.1 MHz.

Dipole → 35' of RG8x = 0.47 dB @ swr 5:1 = 1.1 dB
Vertical → 15' of RG8x + 105' of Bury-Flex = 0.88 dB. @ swr 2:1 = 1.1 dB

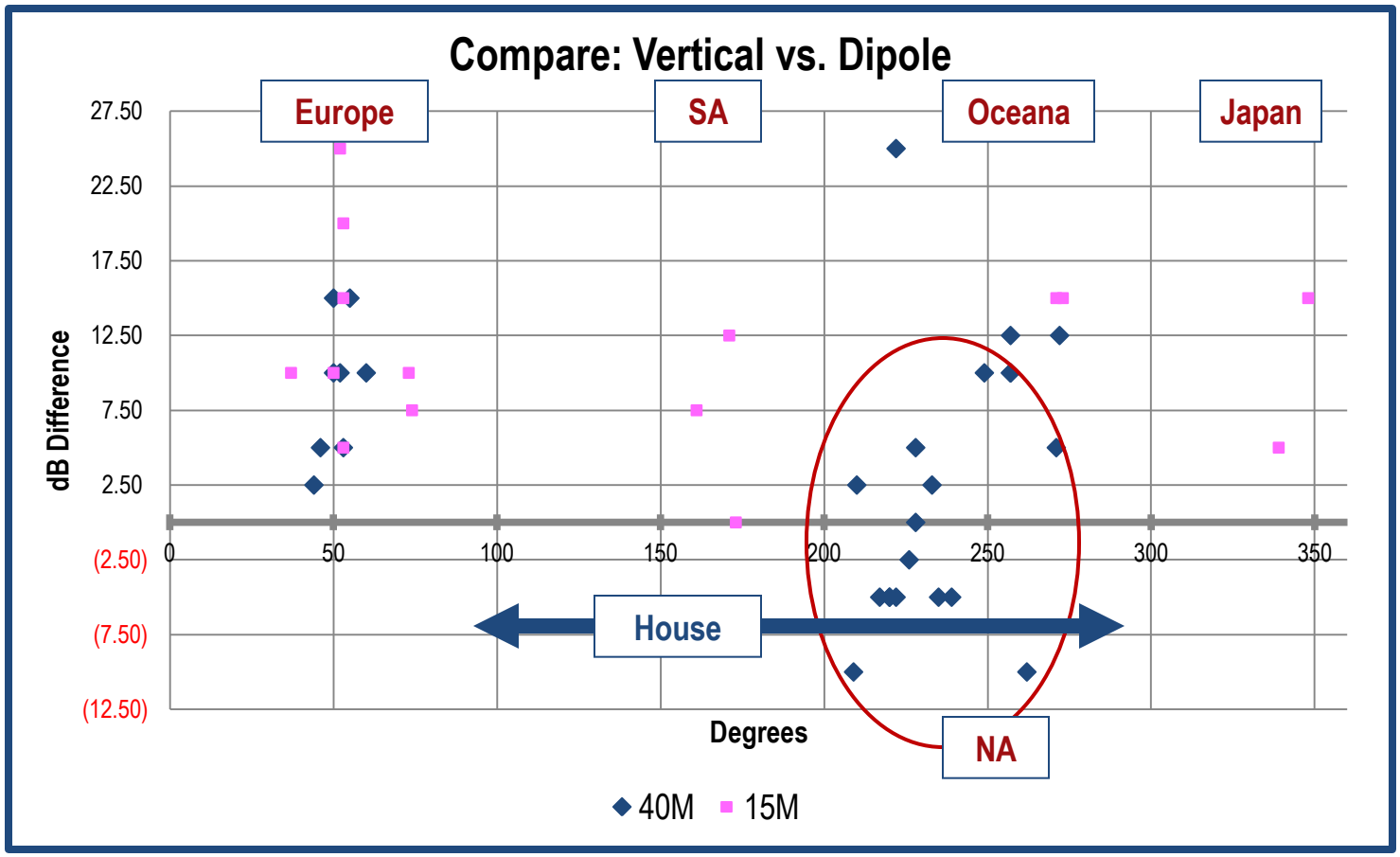
See Appendix for data

COMPARE ~ 15M Reality



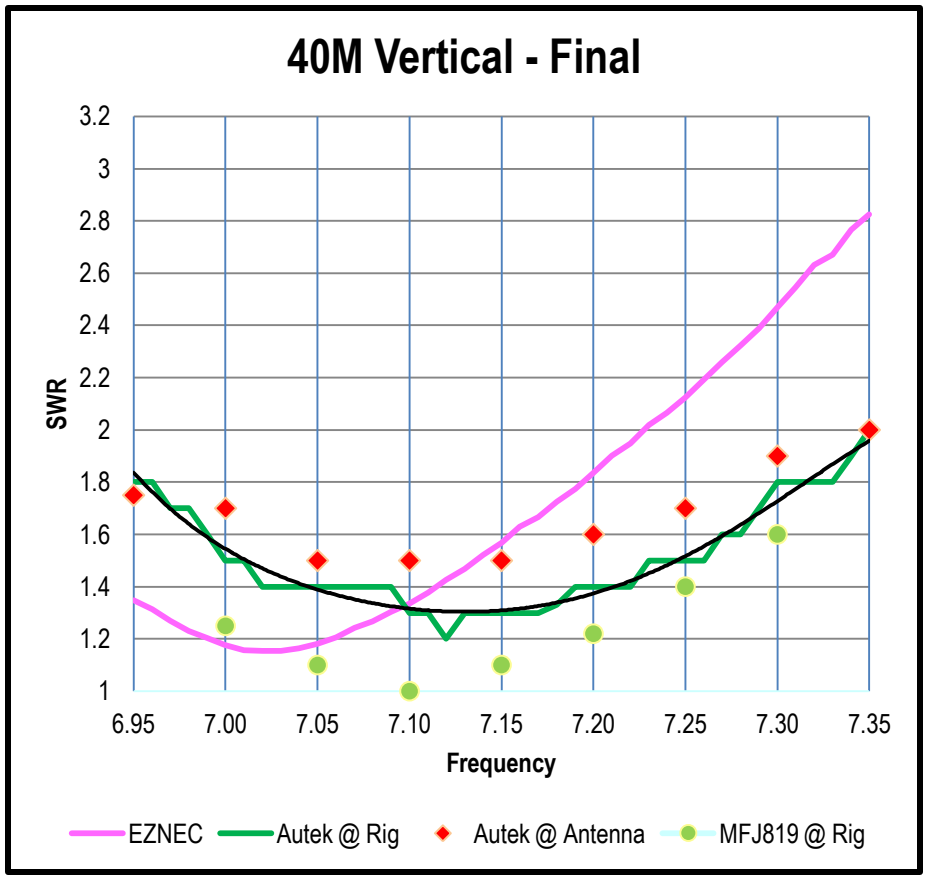
See Appendix for data

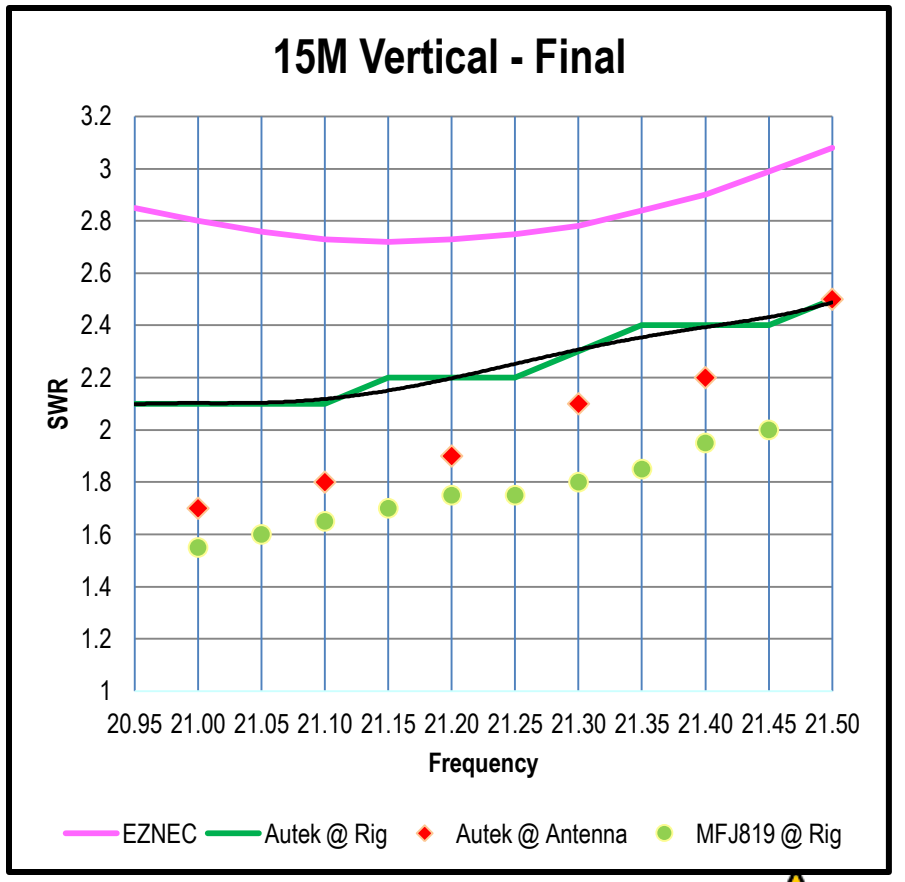
COMPARE ~ Reality



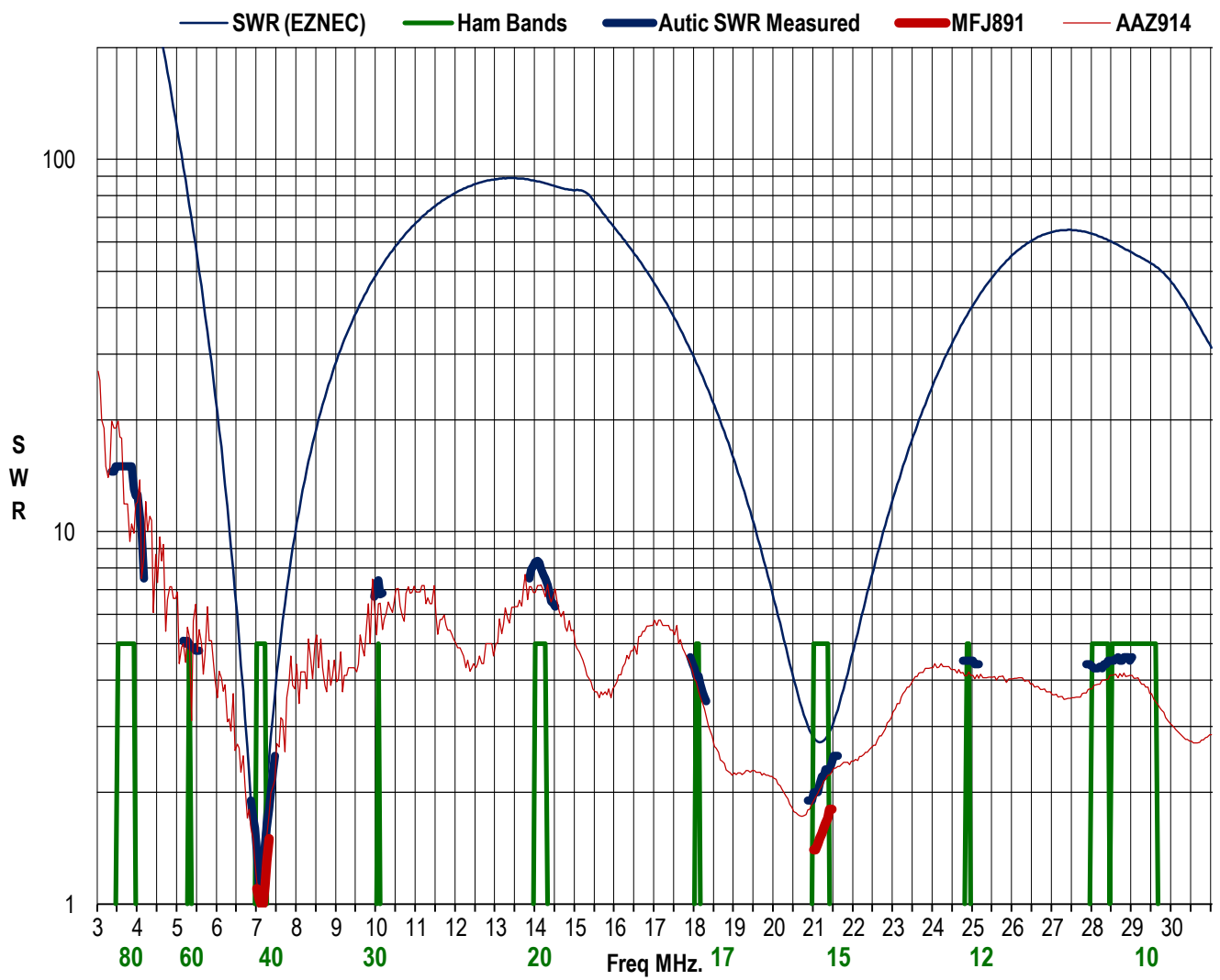
See Appendix for data

SWR Graphs


40M Vertical - Final
SWR
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
6.95 7.00 7.05 7.10 7.15 7.20 7.25 7.30 7.35
Frequency
EZNEC
Autek @ Rig
Autek @ Antenna
MFJ819 @ Rig


15M Vertical - Final
SWR
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
20.95 21.00 21.05 21.10 21.15 21.20 21.25 21.30 21.35 21.40 21.45 21.50
Frequency
EZNEC
Autek @ Rig
Autek @ Antenna
MFJ819 @ Rig

SWR Graphs


40M Vertical
SWR (EZNEC)
Ham Bands
Autic SWR Measured
MFJ891
AAZ914
100
10
1
SWR
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
80 60 40 30 20 17 15 12 10
Freq MHz.

Appendix

- Measured comparison data
- Plot Plan of Vertical
- EZNEC Models
- Results - WPX Scores

http://www.qsl.net/w1dyj/

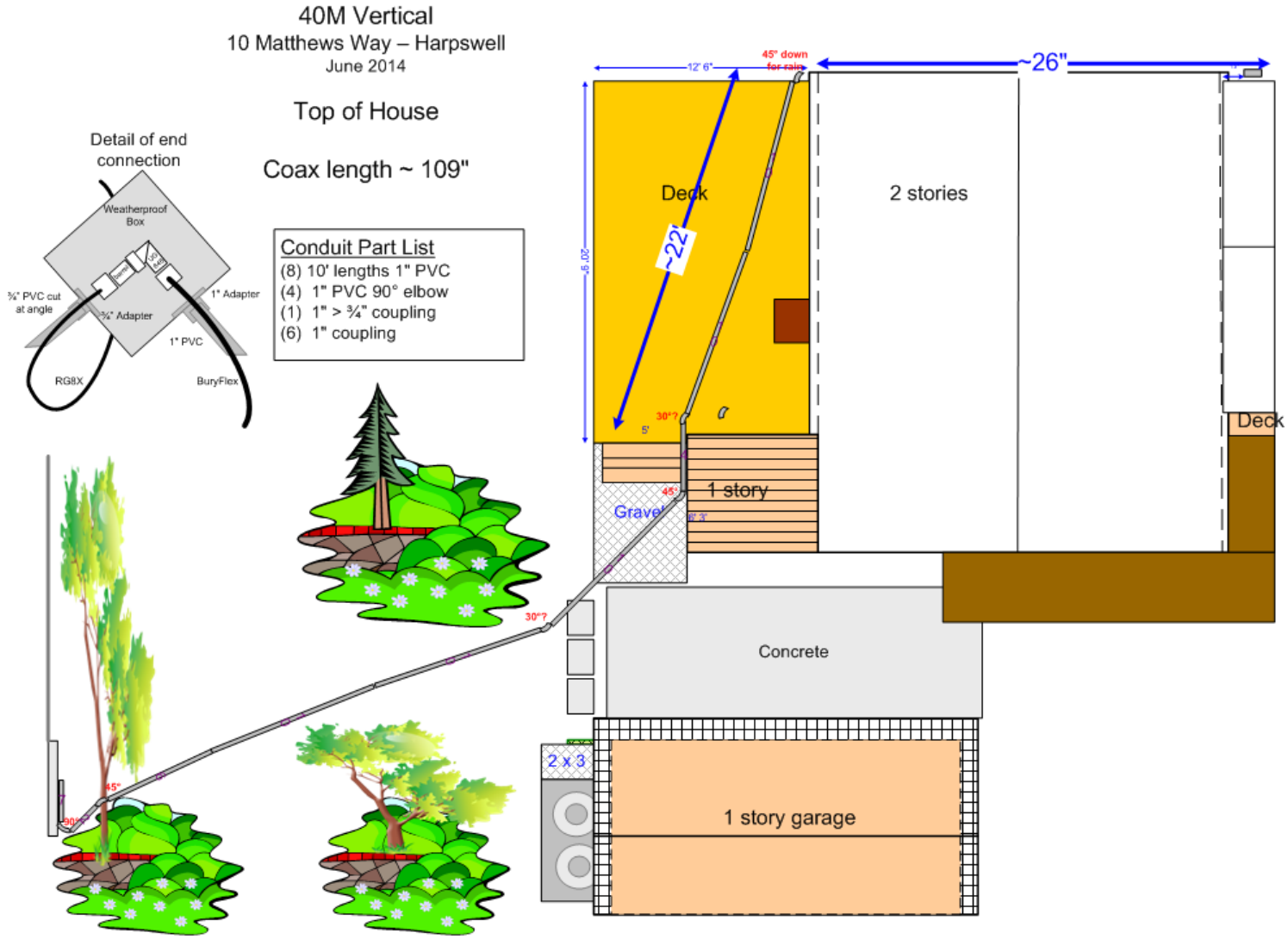
Appendix ~ Measured Comparison Data Example

Actually took about 50+ data points

Date	UTC	Freq	Station	Location	peak S-meter *			15M	40M	Station Location	
					Dipole	Vertical	Delta	dB (@ 5/)	dB (@ 5/)	Distance	Degrees
28-Apr	1541	7220	w2rox	OH	8.5	6.5	-2		(10.00)	709	262
"	"	7224	noise	-	2.5	4	1.5		7.50		
"	1605	7255	ka1se	CT	8	7	-1		(5.00)	216	222
"	"	"	w1prk	CT	9	8.5	-0.5		(2.50)	211	226
"	1826	7146	k2kri	MA	9	8	-1		(5.00)	141	217
"	"	"	wa1ayy	MA	10	8	-2		(10.00)	106	209
"	1843	21275	7x3wpl	Algeria	4	5.5	1.5	7.50		3854	74
"	"	21267.5	noise	-	3.5	3	-0.5	(2.50)			
"	2058	21280		FL	6	7	1		5.00	1270	228
"	2100	21277	7x4rj	Algeria	4	6	2	10.00		3642	73
"	2106	7174	n2mun	NY	9	8	-1		(5.00)	275	220
29-Apr	235	7192	w1aw/2	NJ	9	8	-1		(5.00)	301	235
"	244	7158	m1den	England	8	9	1		5.00	3084	53
9-May	101	7190	w1aw/0	NE	8.5	9.5	1		5.00	1378	271
"	107	7185	n4jt	NY	12	11	-1		(5.00)	265	239
"	2011	21279	ha4xh	Hungary	5	8	3	15.00		4082	53
"	2129	21270	rn3dnm	Moscow	7.5	9.5	2	10.00		4460	37
"	2130	2120	noise		4	2.5	-1.5	(7.50)			
"	2140	21325	om3tvm	Slovakia	3	5	2	10.00		4040	50
"	2208	21270	yv4kw	Venezuela	5	5	0	0.00		2483	173
10-May	35	7270	wa5lou	IN	7	9.5	2.5		12.50	867	257
"	40	7215	noise		5	6	1		5.00		
"	47	7258	kd4jm	FL	9	9.5	0.5		2.50	1307	210
"	49	7258	ou5u	Denmark	8.5	9.5	1		5.00	3508	46

* peak S-meter: TS590 reading with AGC slow=8 | one S-unit = 5dB
above s9 => adjusted to represent dB | i.e. s9+10db = s11 / s9+20dB = s13

Appendix ~ Plot Plan of Vertical



Appendix ~ EZNEC Modeling

- Simple Wires: 2 Radials @ 8' V = R = 34', 34.5', 34.7'
- Simple Wires: V = R = 34.7' Radial H = 8' 10' 12'
- Simple Wires: V = R = 34.7' 2 Radials @ 8' "Gnd" = Sandy, Avg, Very Good
- Simple Wires: V = R = 34.7' Radials @ 8' Number of Radials = 2, 4, 8
- *Simple Wires: V = R = 34.7' Radials @ 10' Number of Radials = 2, 4, 8*

- Al tubing, first design 4 radials @ 35' / 10' V = 34', 35.5', 35'
- *Al tubing, first design @ 35' 4 radials @ 35' / 10' With / Without Al mast*
- Al tubing, first design @ 35' 4 radials @ 35' / 10' Radials with & w/o insulation

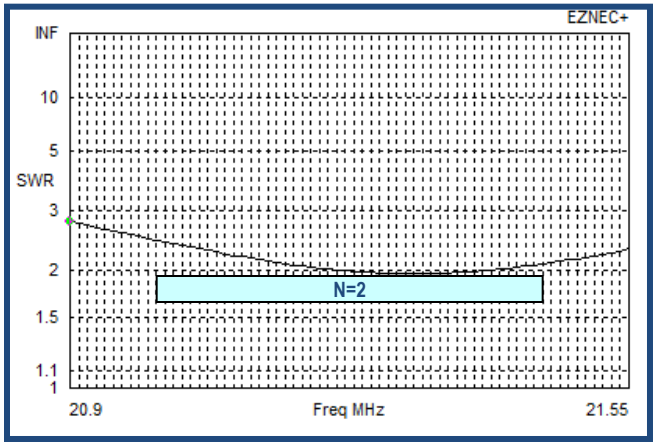
- New, Stronger Al tubing/ 4 radials @ 10' R = 34', 33.5' V = 35', 34.5' (4 cases)
- New, Stronger Al tubing/ 4 radials @ 10' / 33.5' V = 35' 6", 35', 35' 4"
- *New, Stronger Al tubing @ 35'4" / 4 radials @ 10' / 33.5' "Gnd" = Sandy, Avg, Very Good*

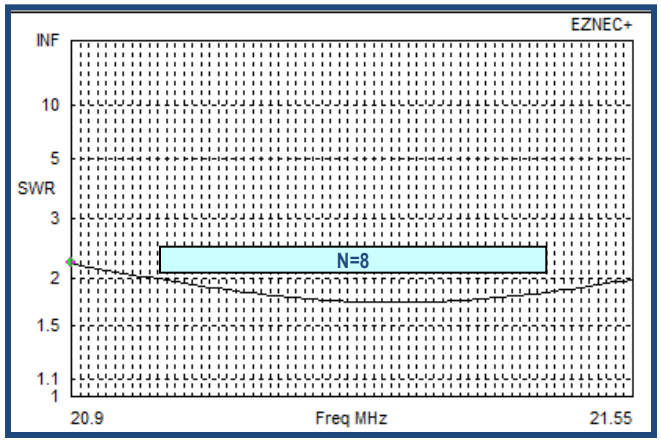
Slide included in appendix

Simple Wires: V = R = 34.7' Radials @ 10'
Number of Radials = 2, 4, 8

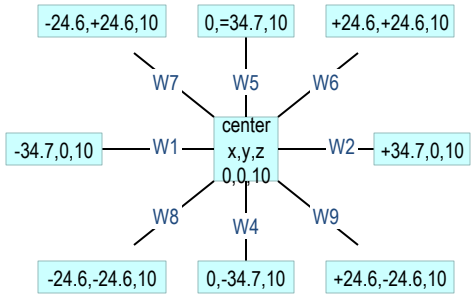
N	h	R=V	SWR_{min} 40 (50 Ω)	2:1	$GAIN_{max}$	$GAIN_{min}$	SWR_{min} 15 (75 Ω)	2:1	$GAIN_{max}$	$GAIN_{min}$
2	10	34.7					1.95:1 @ 21.3 Z=97.56-j0.09187Ω	21.21-21.31	5.23dBi @ 40°	2.16dBi @ 35°
4	10	34.7					1.68:1 @ 21.3 Z=83.76+j0.01401Ω	21.04-21.55+	5.11 dBi @ 40°	3.5dBi @ 40°
8	10	34.7					1.72:1 @ 21.28 Z=85.88+j0.2432Ω	20.99-21.55+	4.76 dBi @ 40°	4.66dBi @ 40°

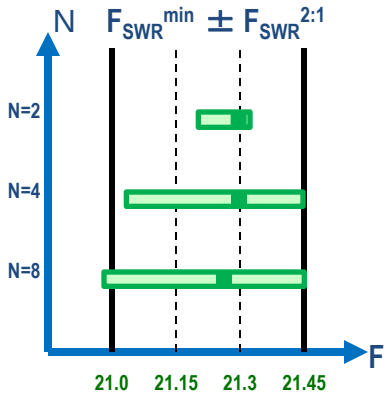
Little Difference @ 40M

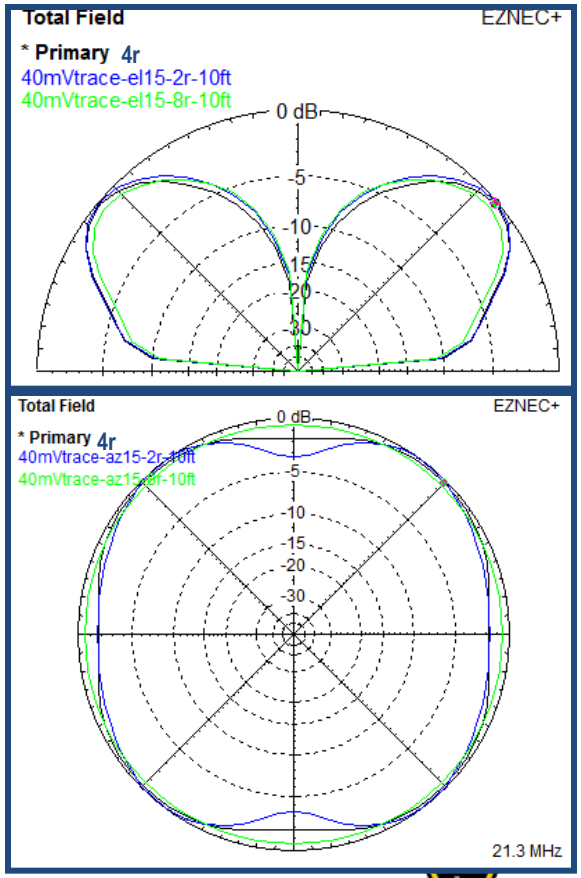




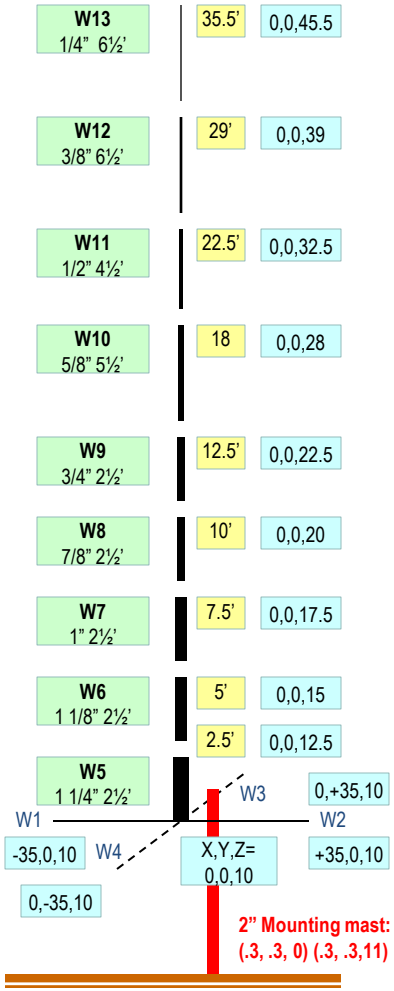
@ 15M



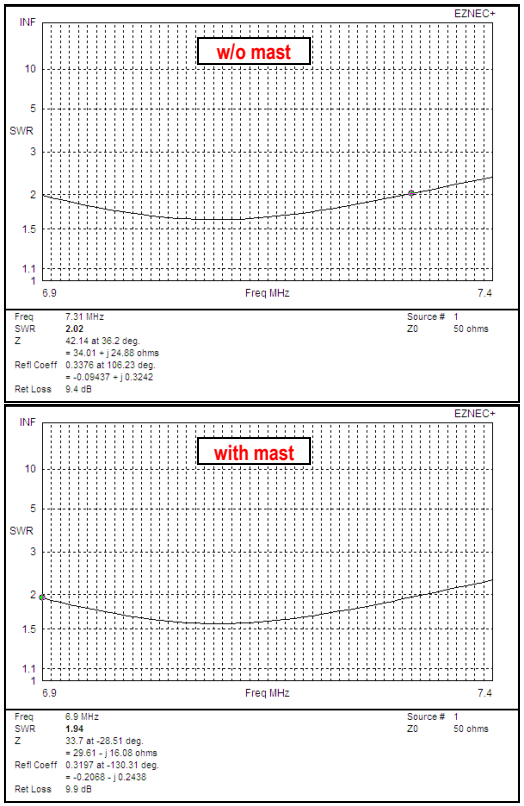


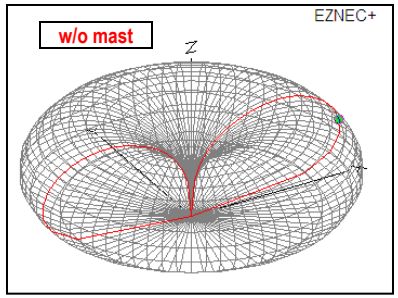


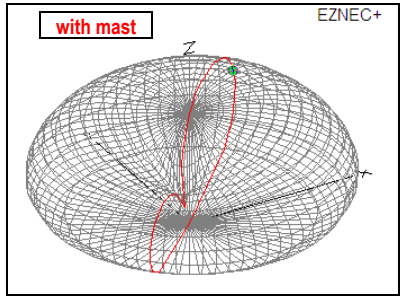
Al pole, "thin" design @ 35'4 radials @ 35'
10' Al Steel mast ➔Connected / not connected



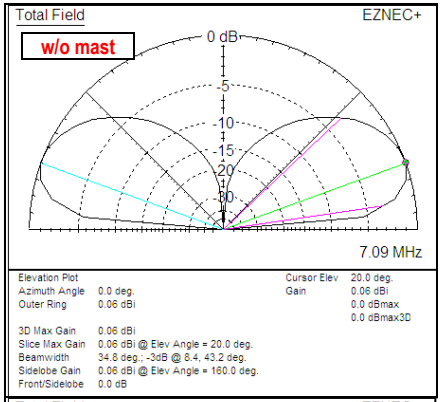
Mast	SWR_{min} 40 (50 Ω)	2:1	$GAIN_{max}$	$GAIN_{min}$	SWR_{min} 15 (50 Ω)	2:1	$GAIN_{max}$	$GAIN_{min}$
no	1.62:1 @ 7.09 Z=28.31.67+j2.83	6.9-7.31	0.06dBi @ 20°	0.06dBi @ 20°				
yes	1.57:1 @ 7.09 Z=32.05.67+j2.685	<6.9-7.32	1.38dBi @ 25°	-1.39dBi @ 160°				

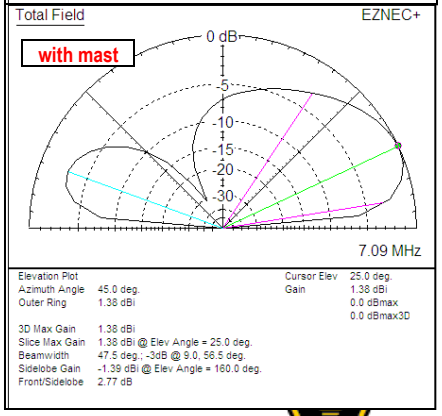






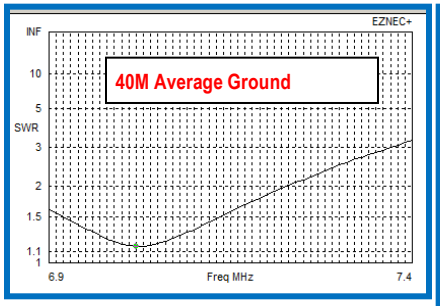
Note: in order to show the effect of a metal mast for mounting, a ground type of Real/MININEC must be used

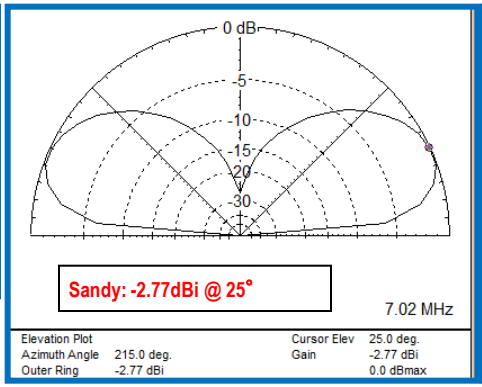


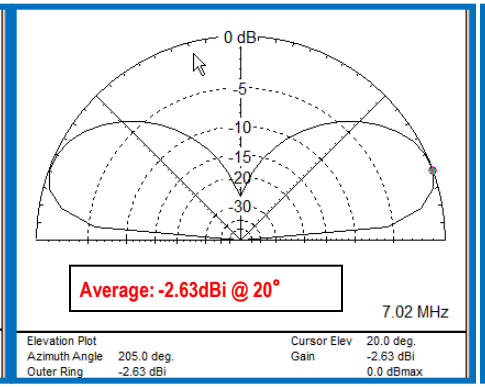


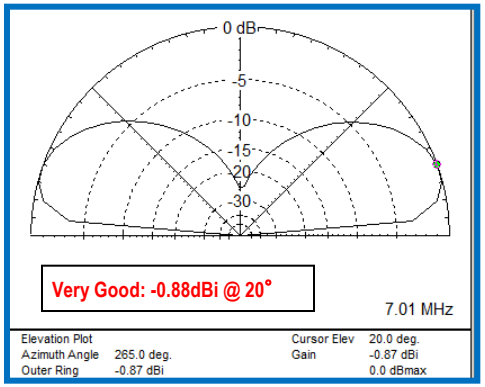
New, Stronger Al pole @ 35'4" / 4 radials @ 10' / 33.5'
Ground = Sandy, Average, Very Good

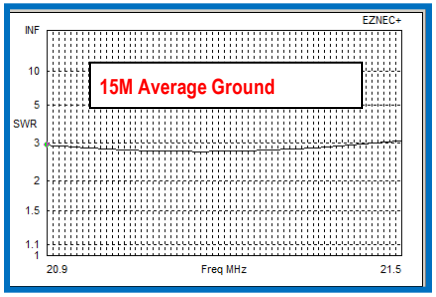
Ground Type: **Real / High Accuracy**:	SWR_{min} 40 (50 Ω)	2:1	GAIN max	GAIN @ 5°	SWR_{min} 15 (50 Ω)	2:1	$GAIN_{max}$	GAIN @ 5°
Very Good: pastoral, rich, central US (0.0303 S/m, 20 Diel Const)	1.23:1 @ 7.01 Z=61.21-j1.13Ω	<6.9-7.22	-0.88dBi / 20°	-4.23 dBi	2.82:1 @ 21.17 Z=140.7-j5.101Ω	>2:1	3.57 dBi @ 40°	-7.99 dBi
Average: pastoral, heavy clay (0.005, 13)	1.15:1 @ 7.02 Z=57.52+j1.499Ω	<6.9-7.23	-2.63dBi / 20°	-8.17 dBi	2.72:1 @ 21.16 Z=135.7-j5.908Ω	>2:1	3.03 dBi @ 40°	-6.66 dBi
Sandy, dry (0.002, 10)	1.11:1 @ 7.02 Z=55.39-j1.165Ω	<6.9-7.23	-2.77dBi / **25°**	-9.01 dBi	2.69:1 @ 21.16 Z=134.1-j5.648Ω	>2:1	2.83 dBi @ 40°	-6.34 dBi

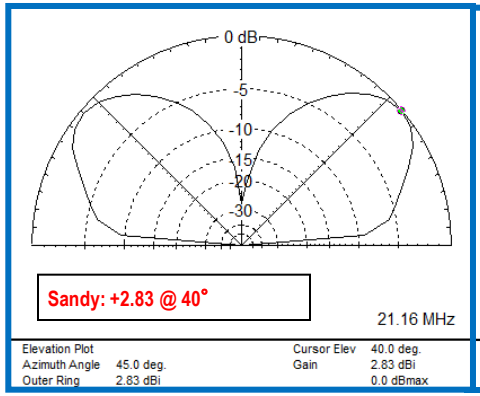


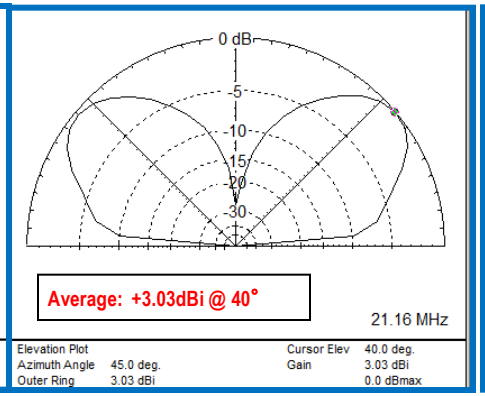


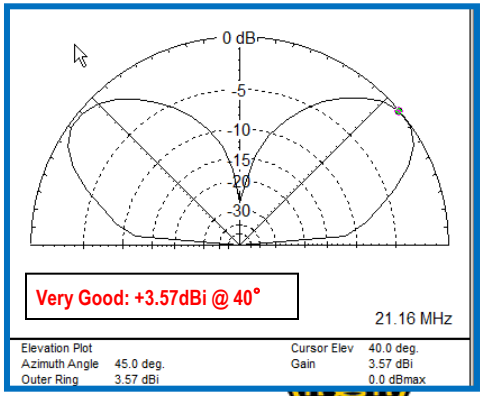












Results

March CQ WPX SSB Contest

	YEAR	Location	Score	Antenna	US	NA	WORLD
SOLP 40M Unassisted	2012	Harpswell	37026	Dipole @ 18'	2nd	3rd	41st
	2013	Woburn	61472	Dipole @ 20'	1st	3rd	36th
	2014	Harpswell	76986	Vertical	4th	6th	17th
Overlay							
SOLP 40M Tribander/ Wires	2012	Harpswell	37026	Dipole @ 18'	1st	2nd	5th
	2013	Woburn	61472	Dipole @ 20'	1st	2nd	10th
	2014	Harpswell	76986	Vertical	1st	2nd	4th

Results

March CQ WPX SSB Contest

	YEAR	Location	Score	Antenna	US	NA	WORLD
SOLP 40M Unassisted	2012	Harpswell	37026	Dipole @ 18'	2nd of 13	3rd of 16	41st of 91
	2013	Woburn	61472	Dipole @ 20'	1st of 12	3rd of 18	36th of 96
	2014	Harpswell	76986	Vertical	4th of 11	6th of 15	17th of 65
Overlay							
SOLP 40M Tribander/ Wires	2012	Harpswell	37026	Dipole @ 18'	1st of 3	2nd of 4	5th of 11
	2013	Woburn	61472	Dipole @ 20'	1st of 4	2nd of 6	10th of 18
	2014	Harpswell	76986	Vertical	1st of 2	2nd of 4	4th of 11

Thanks

http://www.qsl.net/w1dyj/

Thanks to the following Tower Talkians for suggestions:

K1TTT
KZ1W
N2WN
K3ND
KK4CPS
WA4JQS
N6RK
K9YC
XE2K/AD6D