2015

Wisconsin Broadcasters Association

SBE Broadcasters Clinic

Looking for a Pattern in Antenna Design

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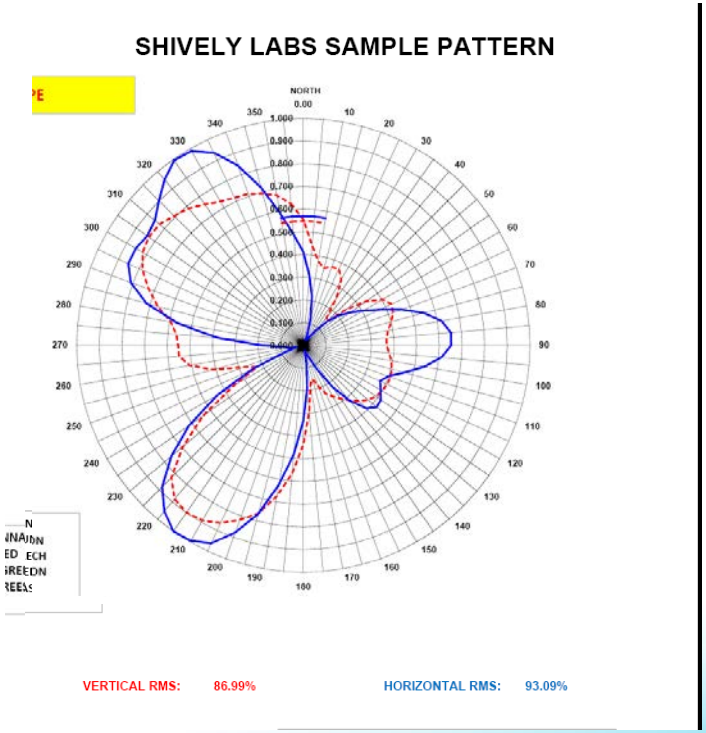
RF Designer

Shively Labs®

A Division of Howell Laboratories, Inc. Bridgton, Maine 04009 USA

What pattern are you looking for?

- Polarization:
  - Horizontal
  - Vertical
  - Circular
  - Elliptical
- Omni
- Somewhat Directional
- Very Directional
- Multi-lobed Directional
- Null Fill or Beam Tilt



Basic Equations and terms we will reference during the presentation

Polarization, Axial Ratio and Rotation

Wavelength (lambda) λ

Far Field, Power Density and Field Strength (dBu)

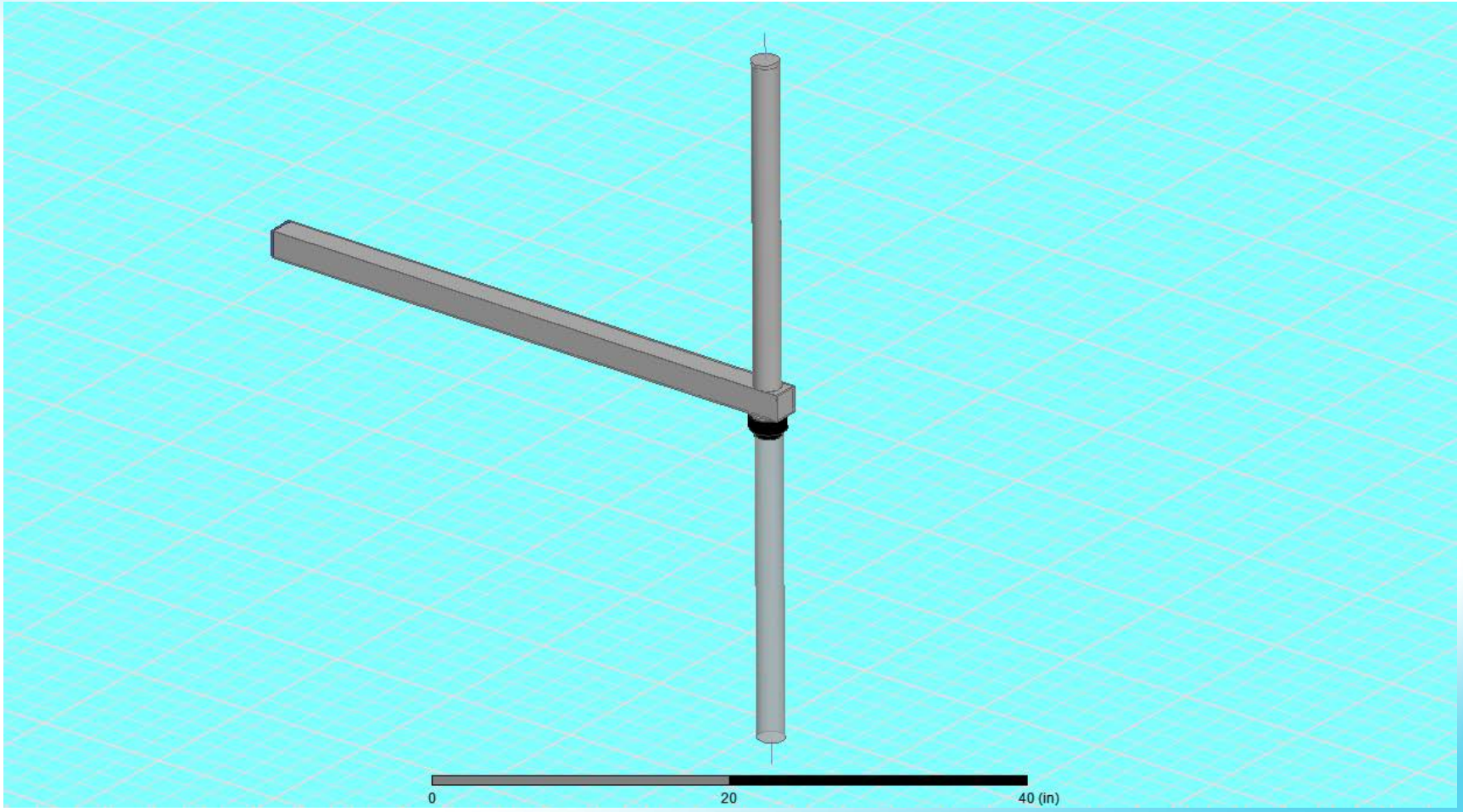
Elevation patterns of Isotropic point sources which define Array Factors

Prove that ½ wave spacing has maximum reduction in downward radiation

Show how bay to bay spacing effect downward radiation

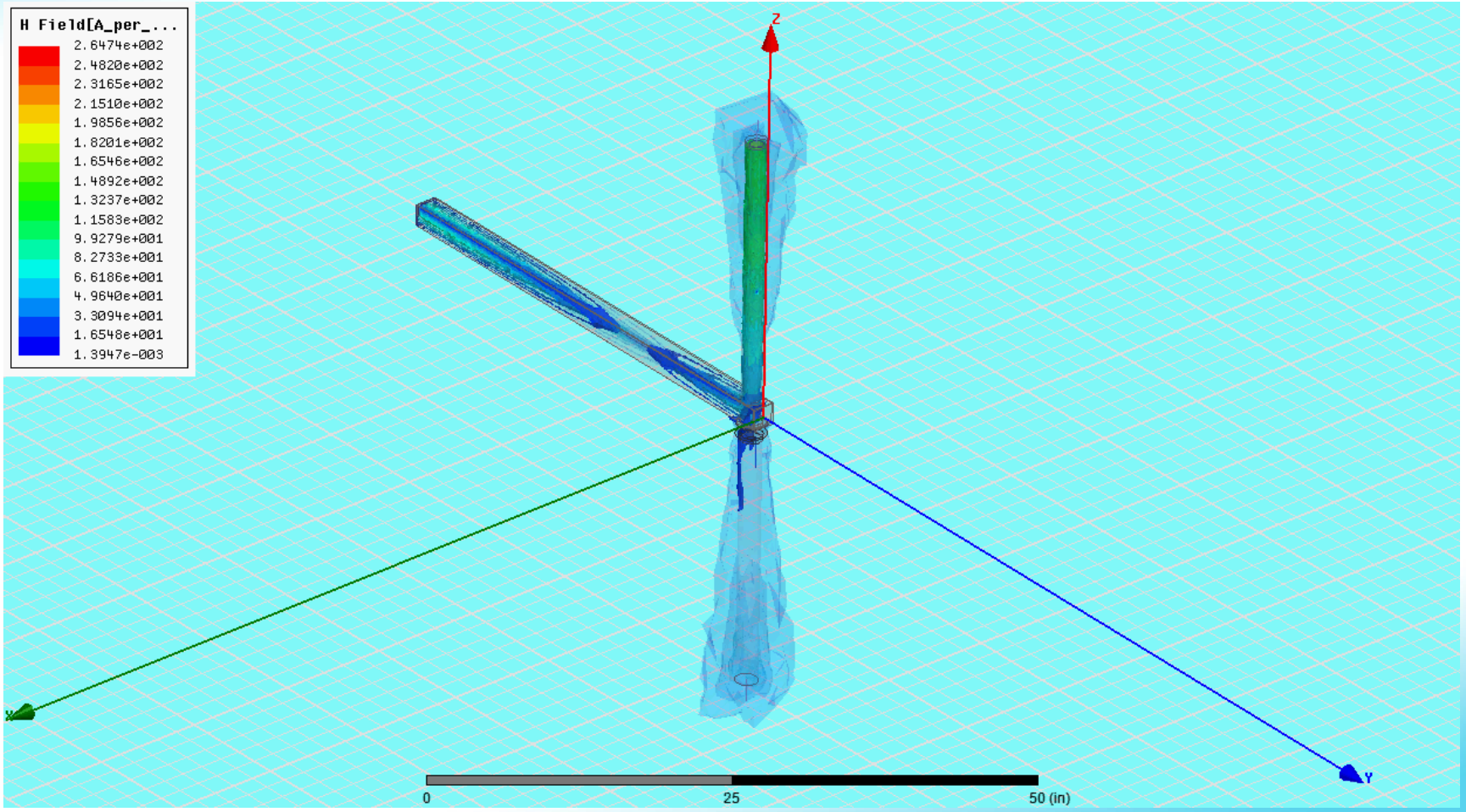
It All Starts with the Dipole

Vertical ½λ Dipole in free space



½λ Dipole Fields

The H fields form at the current maxima and the E fields form at the voltage maxima



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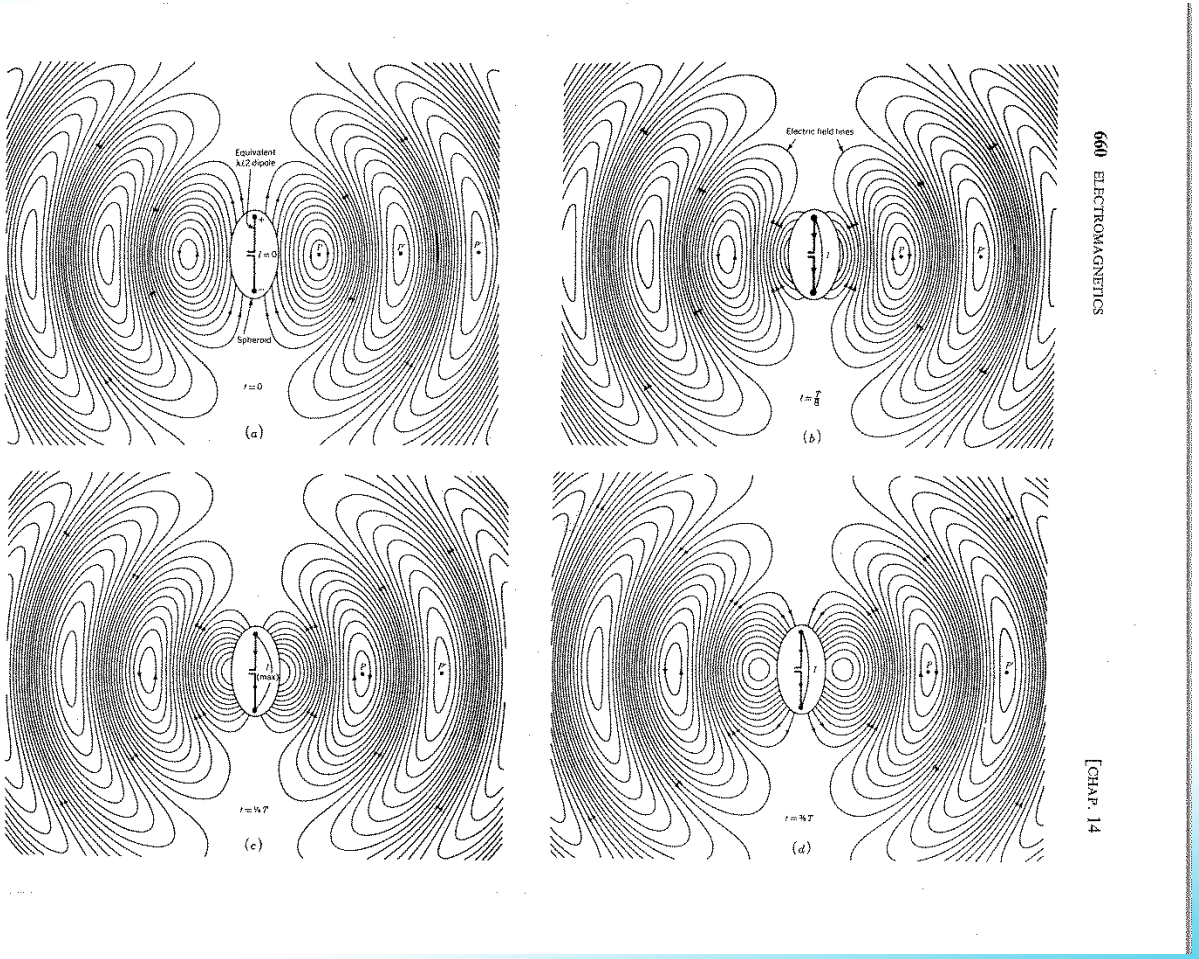
The electric field lines of a ½λ Dipole at four moments in time.

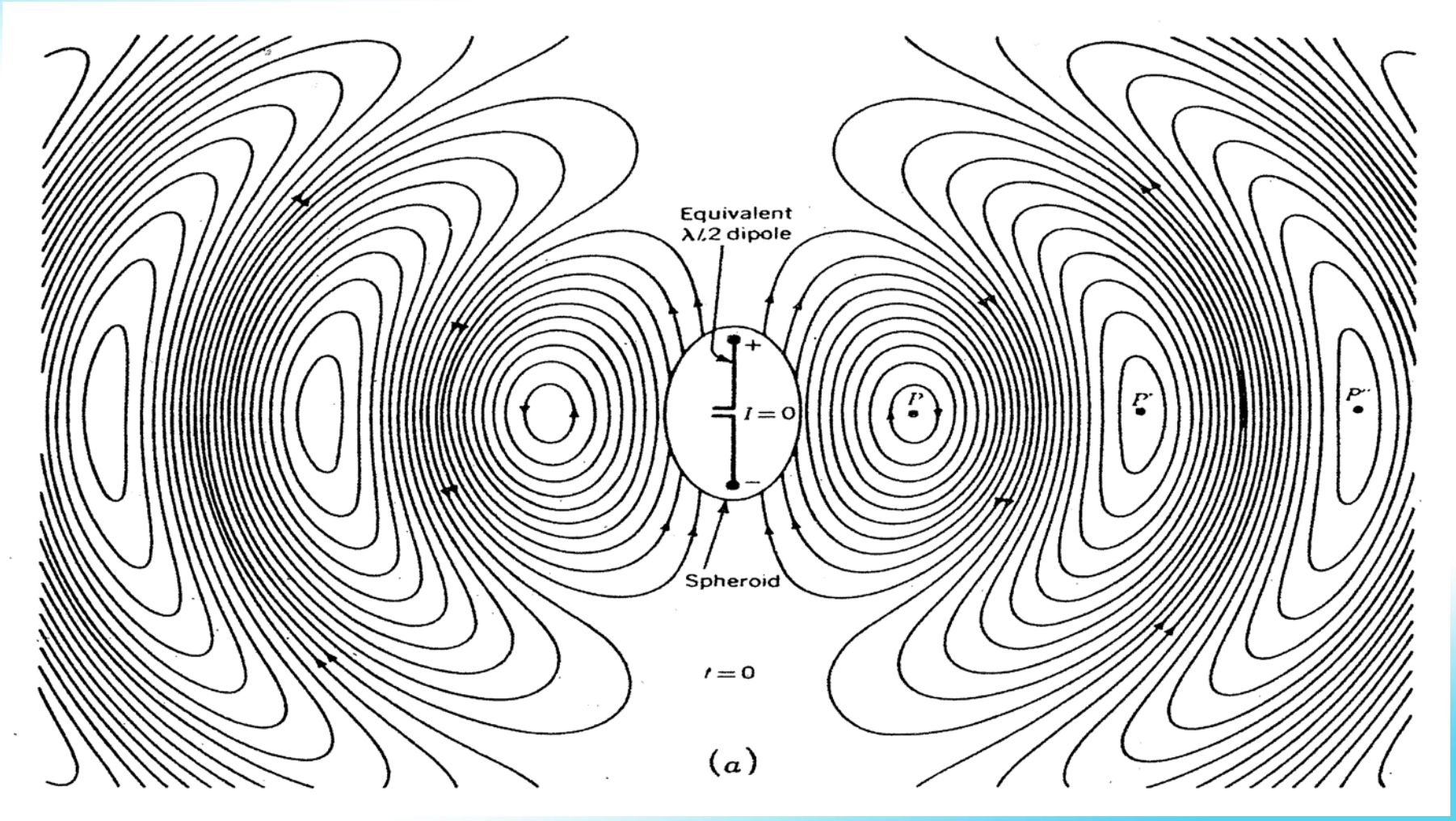


660 ELECTROMAGNETICS [CHAP. 14

"Electromagnetics" John D. Kraus

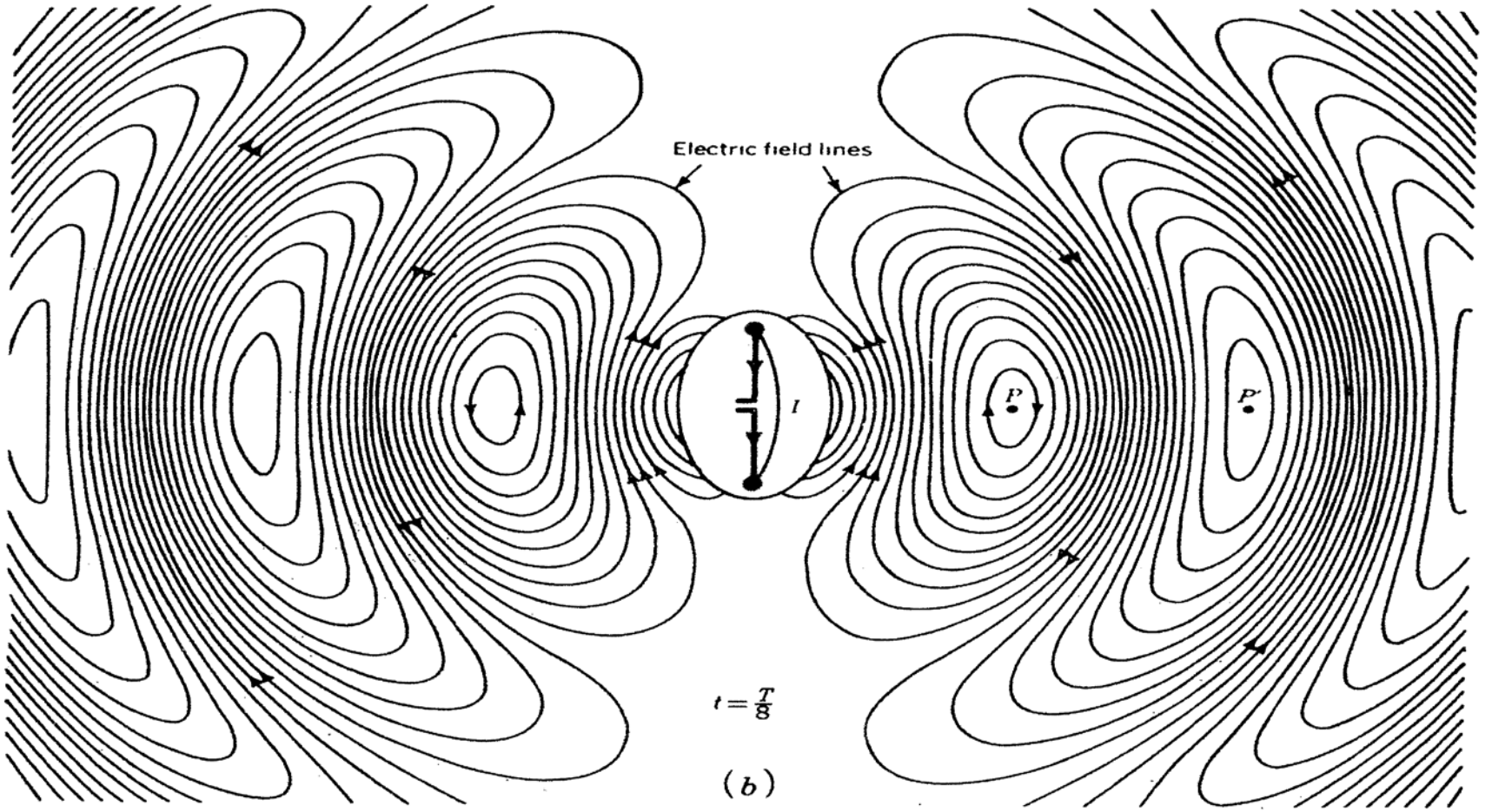
At t=0

Antenna Current is zero, and the charge at the ends of the dipole is a maximum



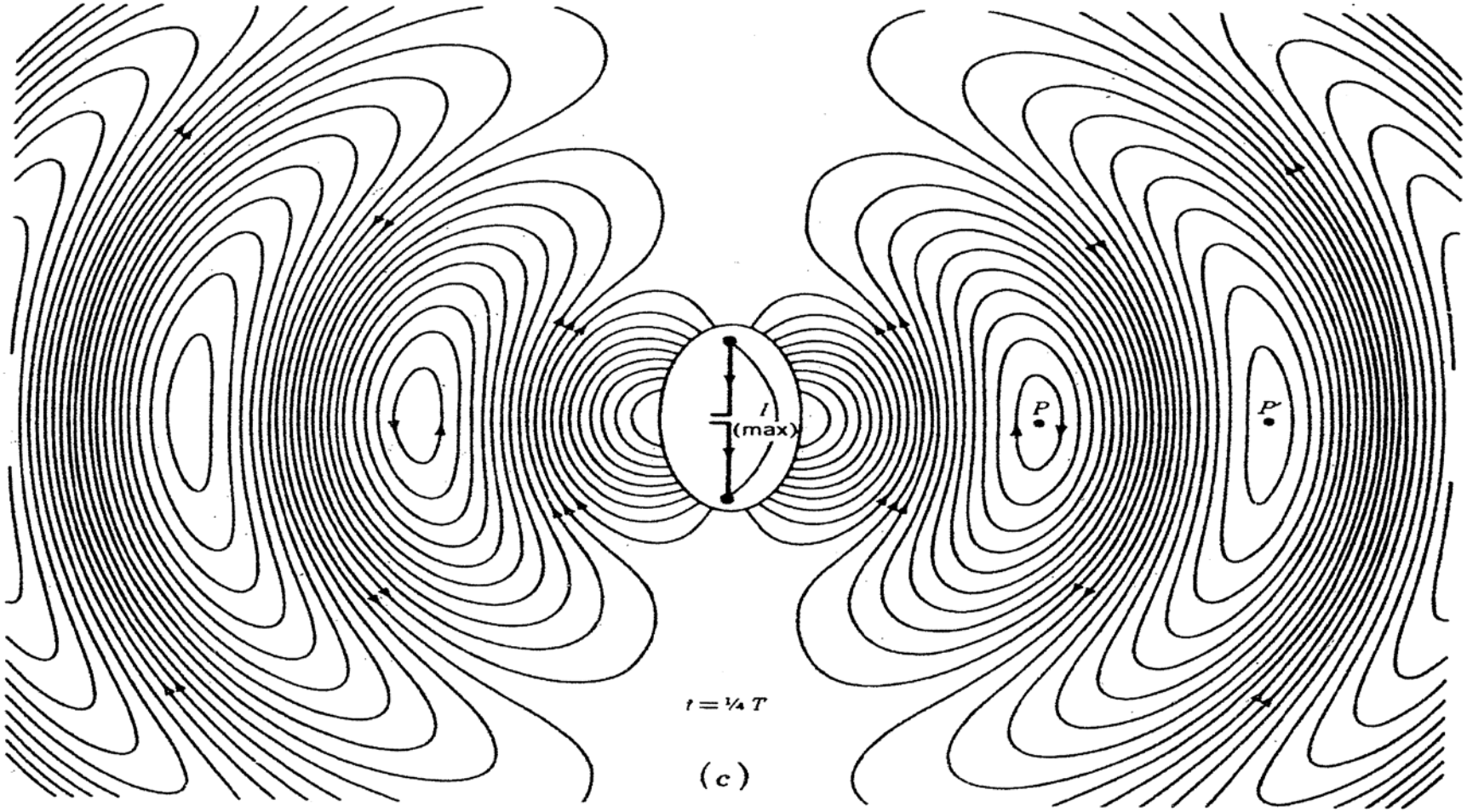
"Electromagnetics" John D. Kraus

1/8 of a period later the current has started to flow



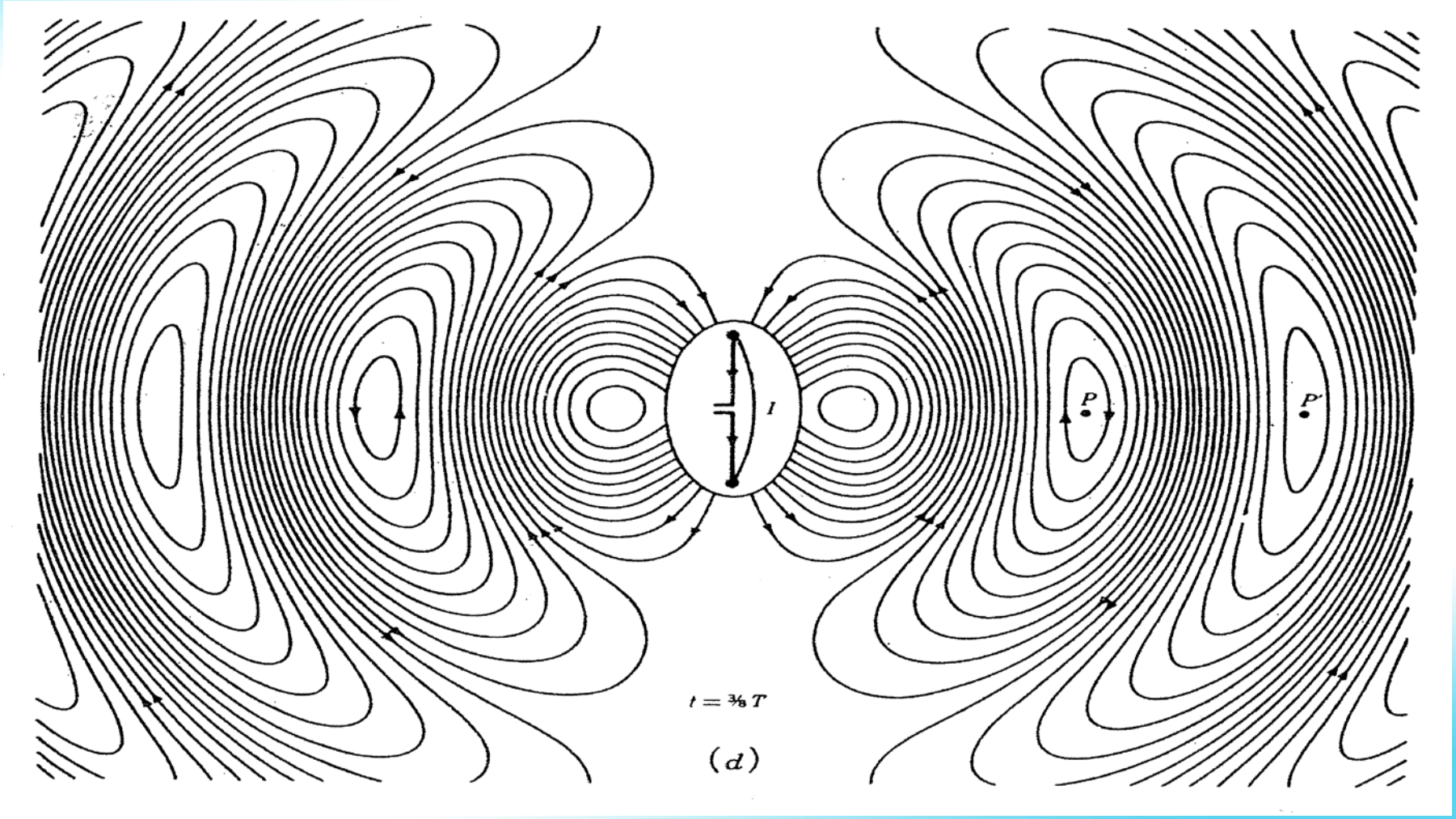
"Electromagnetics" John D. Kraus

At t=1/4 the current has reached its peak value,
and the charge at the ends is zero.



"Electromagnetics" John D. Kraus

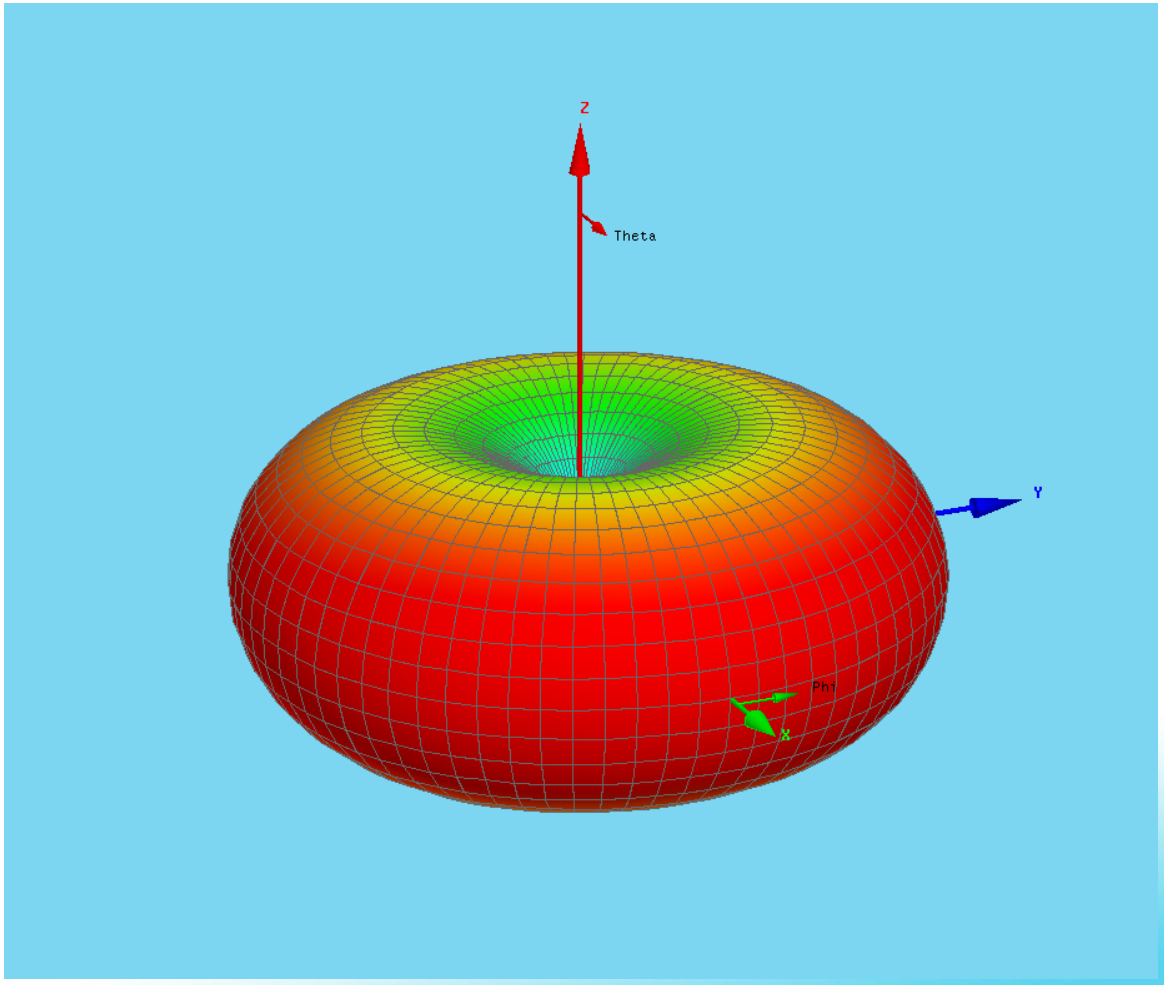
At t= 3/8 the current continues to flow but at a reduced magnitude. And then the cycle repeats for the second half-cycle but with the signs reversed.



"Electromagnetics" John D. Kraus

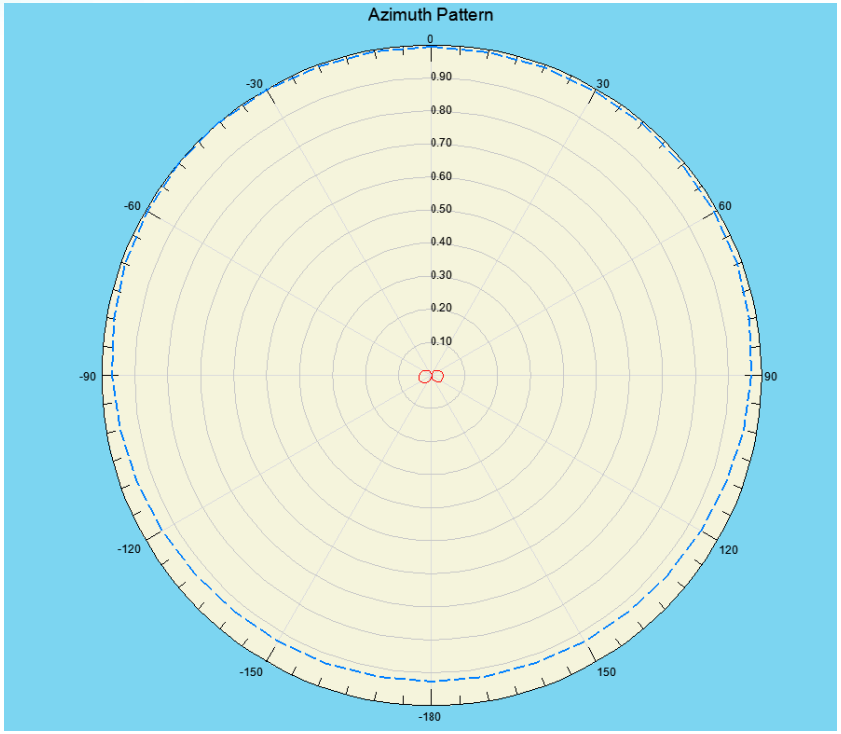
3D Dipole “donut” Pattern

in this case vertically polarized

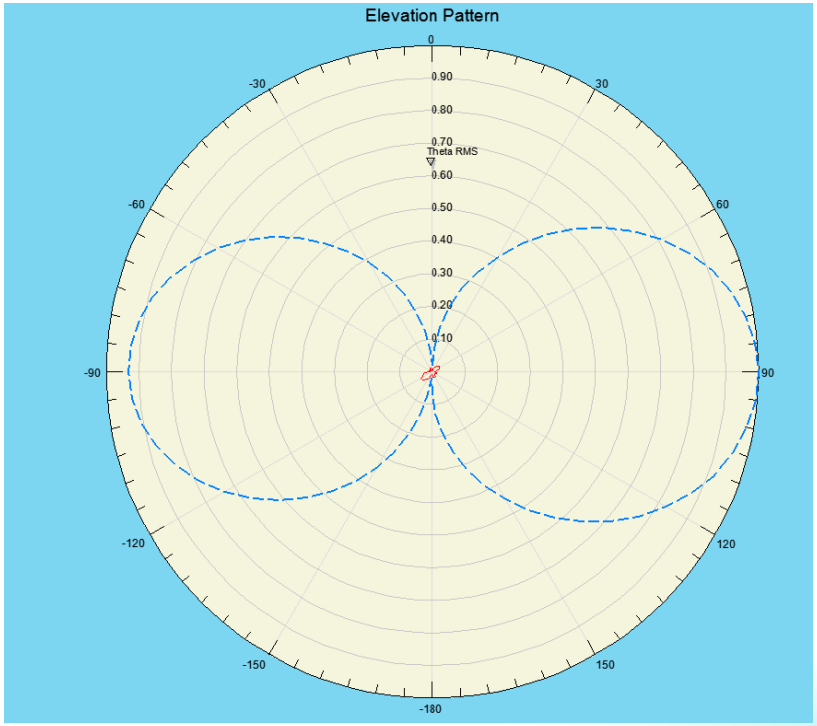


Dipole Pattern in 2D

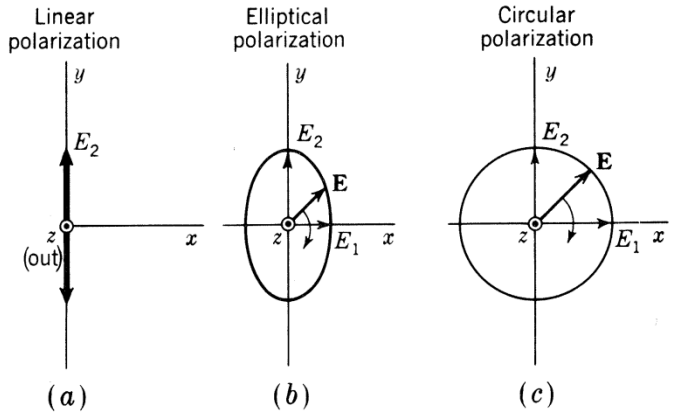
Azimuth “slice”

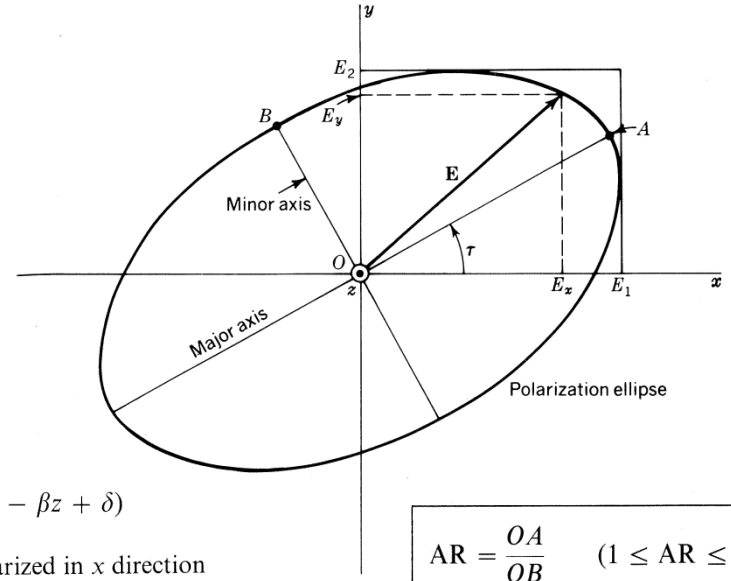


Elevation “slice”



Polarization, Axial Ratio, and Rotation (RHCP or LHCP)





$$\mathbf{E} = \hat{\mathbf{x}}E_1 \sin(\omega t - \beta z) + \hat{\mathbf{y}}E_2 \sin(\omega t - \beta z + \delta)$$

where E_1 = amplitude of wave linearly polarized in x direction
E_2 = amplitude of wave linearly polarized in y direction
δ = time-phase angle by which E_y leads E_x

$$\text{AR} = \frac{OA}{OB} \qquad (1 \le \text{AR} \le \infty)$$

If $E_1 = 0$, the wave is linearly polarized in the y direction.

If $E_2 = 0$, the wave is linearly polarized in the x direction.

If $\delta = 0$ and $E_1 = E_2$, the wave is also linearly polarized but in a plane at an angle of 45° with respect to the x axis ($\tau = 45°$).

If $E_1 = E_2$ and $\delta = \pm 90°$, the wave is circularly polarized. When $\delta = +90°$, the wave is *left circularly polarized*, and when $\delta = -90°$, the wave is *right circularly polarized*.

"Electromagnetics" John D. Kraus

How to Calculate Wavelength

λ = Speed of light / Frequency

Speed of light = 299,792,458 m/sec

39.371 inches = 1 Meter

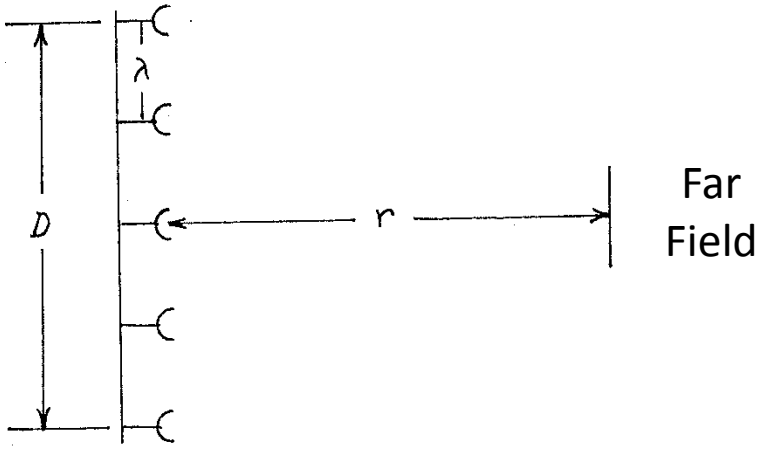
$299,792,458 \times 39.371 = 11803 \times 10^{6}$

$11803 \times 10^{6} / 1 \times 10^{6} = 11803$

$\lambda = 11803 / 98.1 = 120.3$”

Far Field

≡ $r = 2D^2 / \lambda$



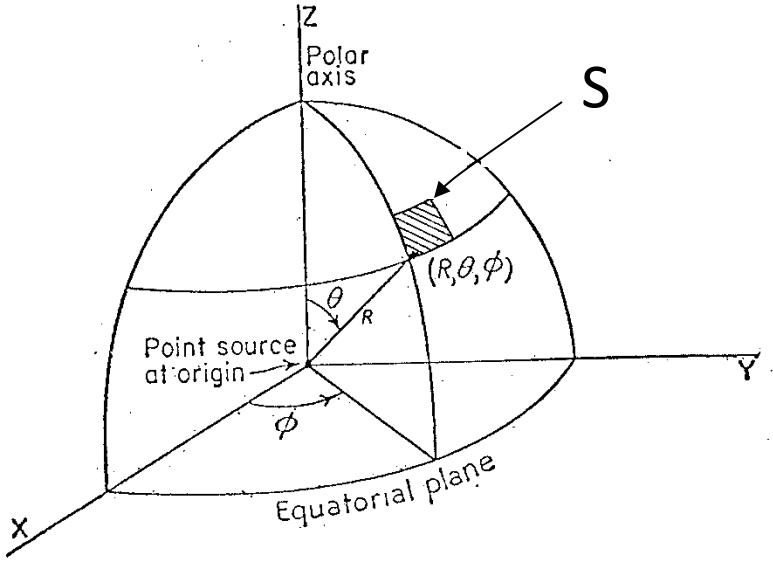
5 Bay @ 98.1 MHz

λ = **11803** / 98.1 = 120.3 inches ≈ 10 Feet

D = Length of Antenna = 40 Feet

r = Distance to Far Field

$r = 2D^2 / \lambda = 2(40)^2 / 10 = 320$ Feet



Surface Area = $4 \pi R^2$

Power Density = S

$= P / 4 \pi R^2$ = Watts / Meter ^{2}

Calculating Field Strength

100 kW at a distance of 30 Kilometers (≈ 20 Miles)

$$\text{Power Density} = S = P / 4 \pi R^2$$

$$S = 100{,}000 \text{ Watts} / 4 \pi (30{,}000 \text{ Meters})^2$$

$$S = 0.0000088 \text{ Watts / Meter}^2$$

$$S = 8.8 \times 10^{-6} \text{ Watts / Meter}^2$$

Calculate Electric Field from Power Density

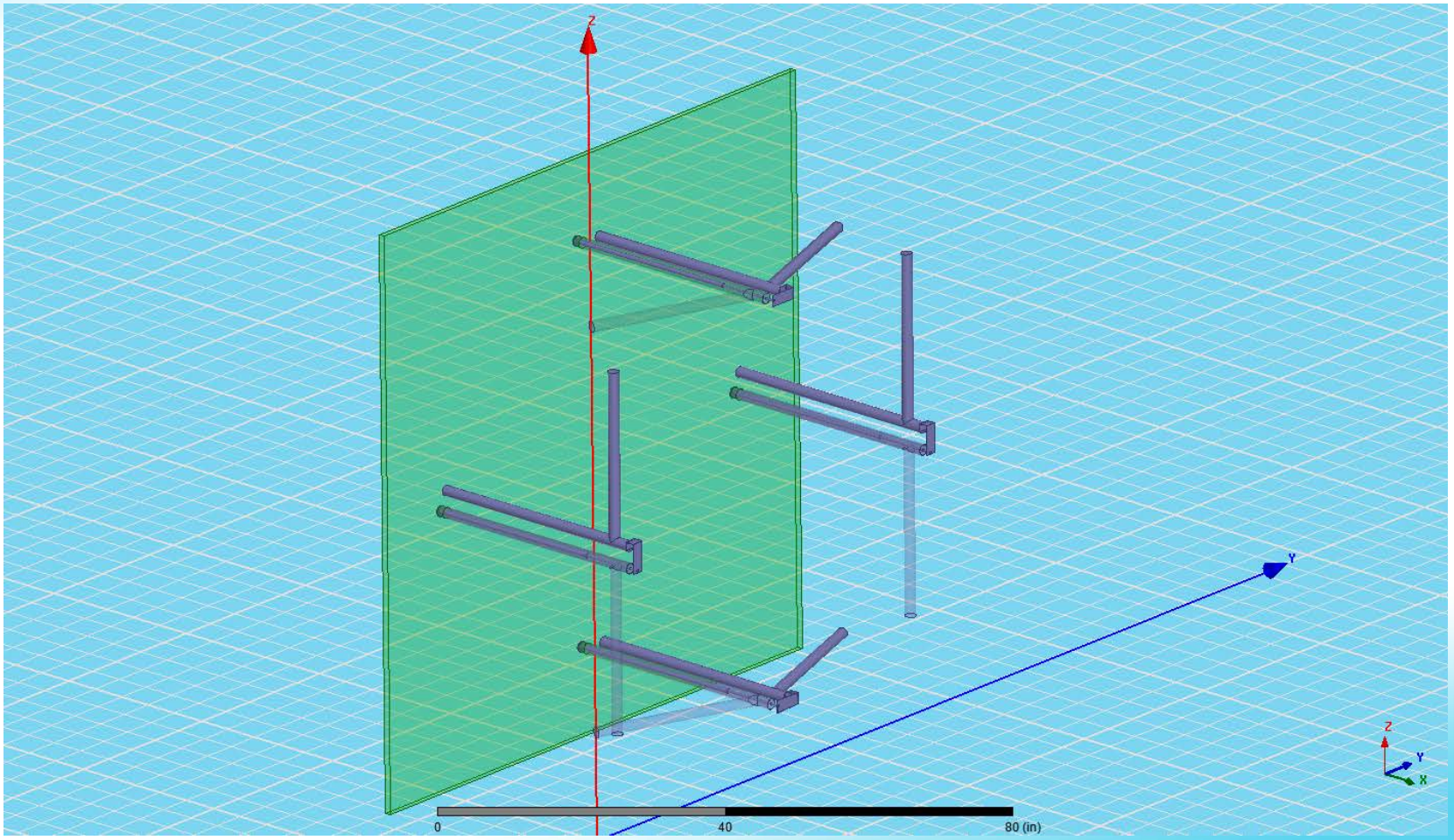
$$E = \sqrt{S \times Z_0} = \sqrt{8.8 \times 377} = 58 \text{ millivolts / meter}$$

$$E \text{ in dBu} = 20 \log E / 1 \times 10^{-6} = 20 \log 58 \times 10^{-3} / 1 \times 10^{-6}$$

E = 95 dBu

6016 CP Panel

Consists of 2 sets of dipoles
1 set is vertically oriented and 1 set is horizontally oriented
δ=-90



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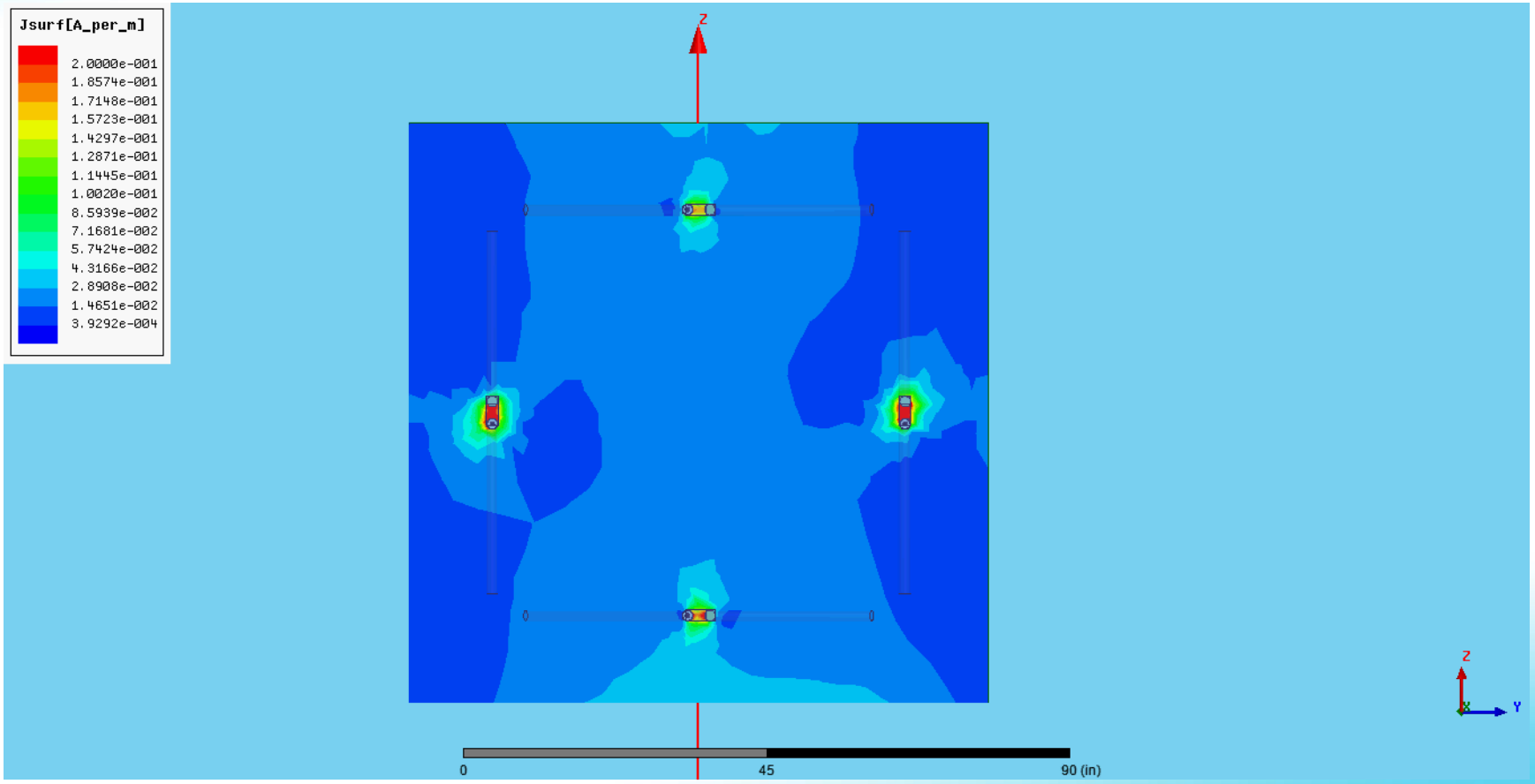
6016 Panel

rearview showing the surface currents on the front of the panel (RHCP)



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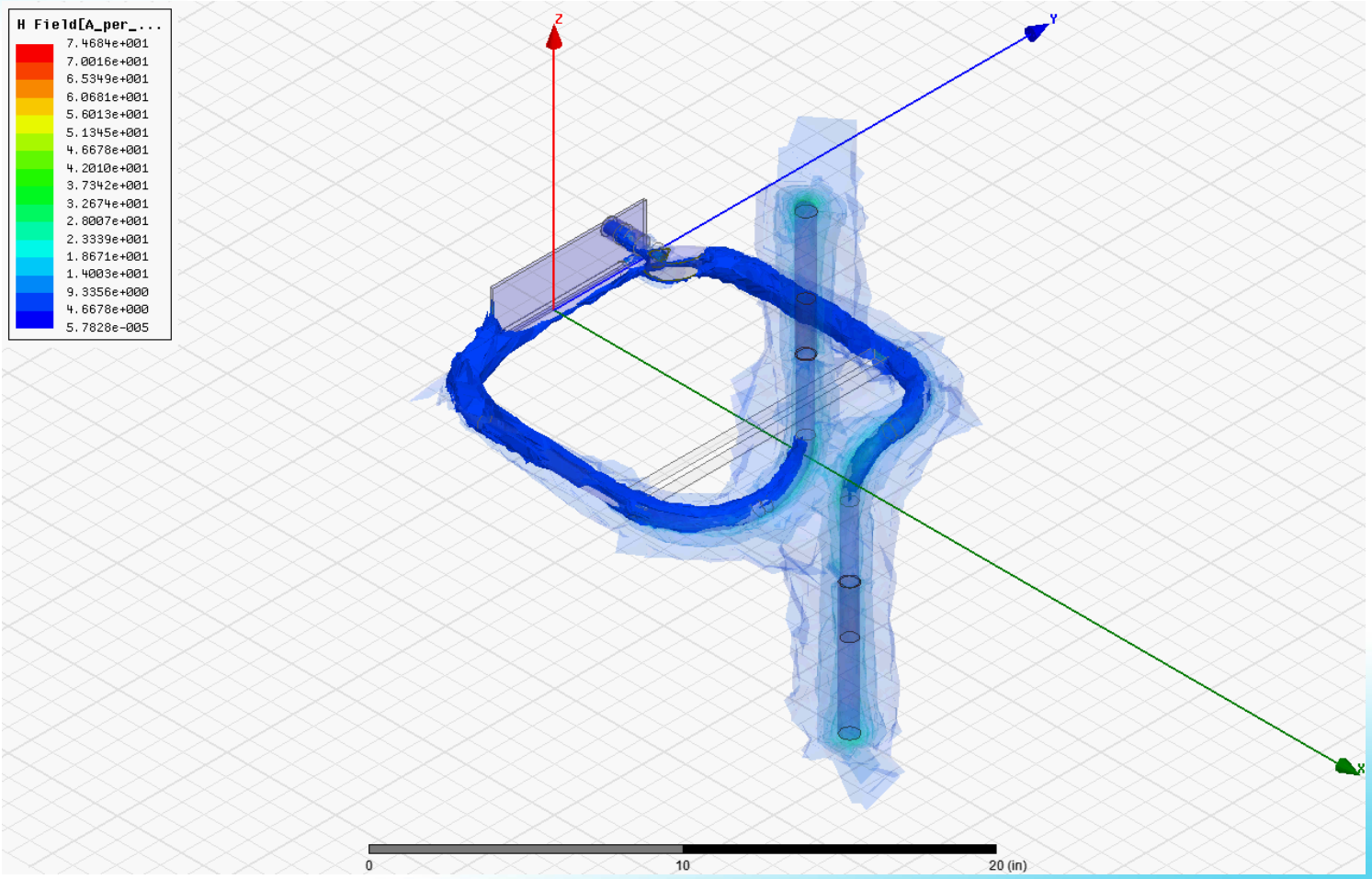
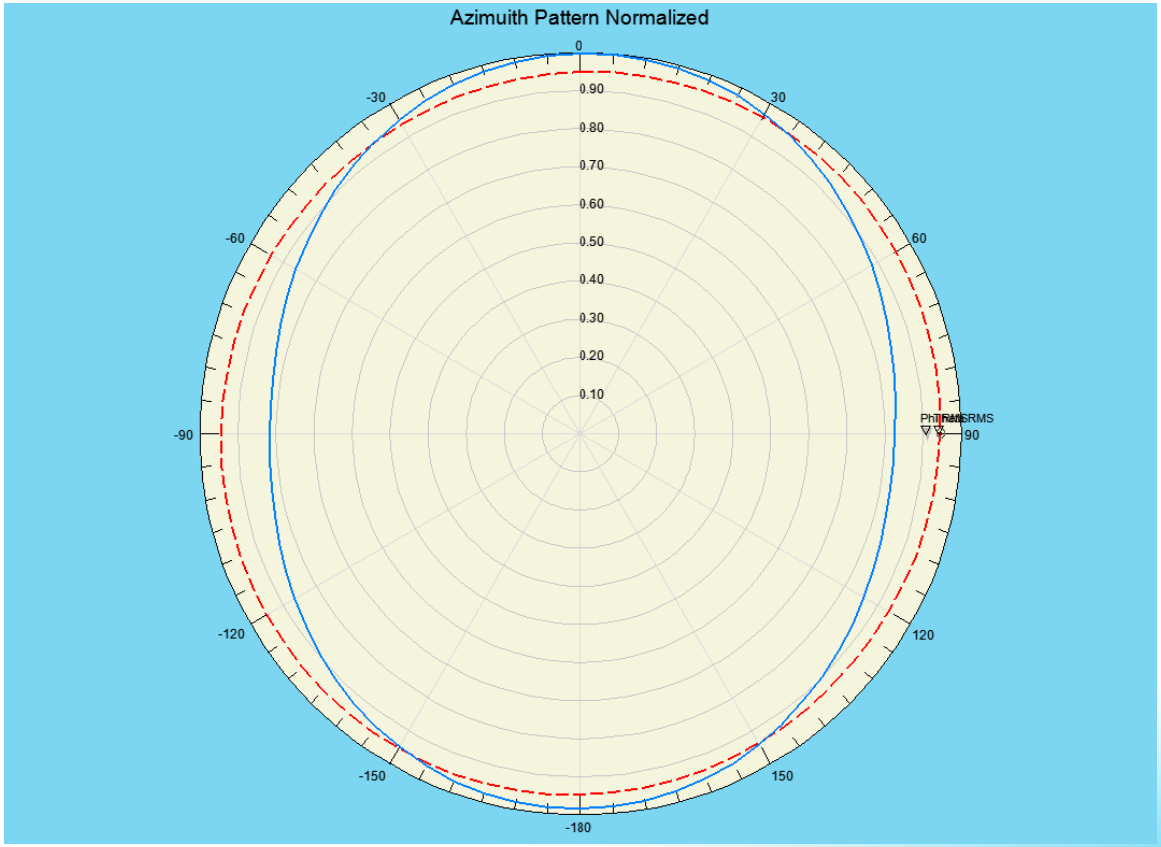
Ring Stub (6812)

The next logical progression. Produce both Vertical and Horizontal components from one element.

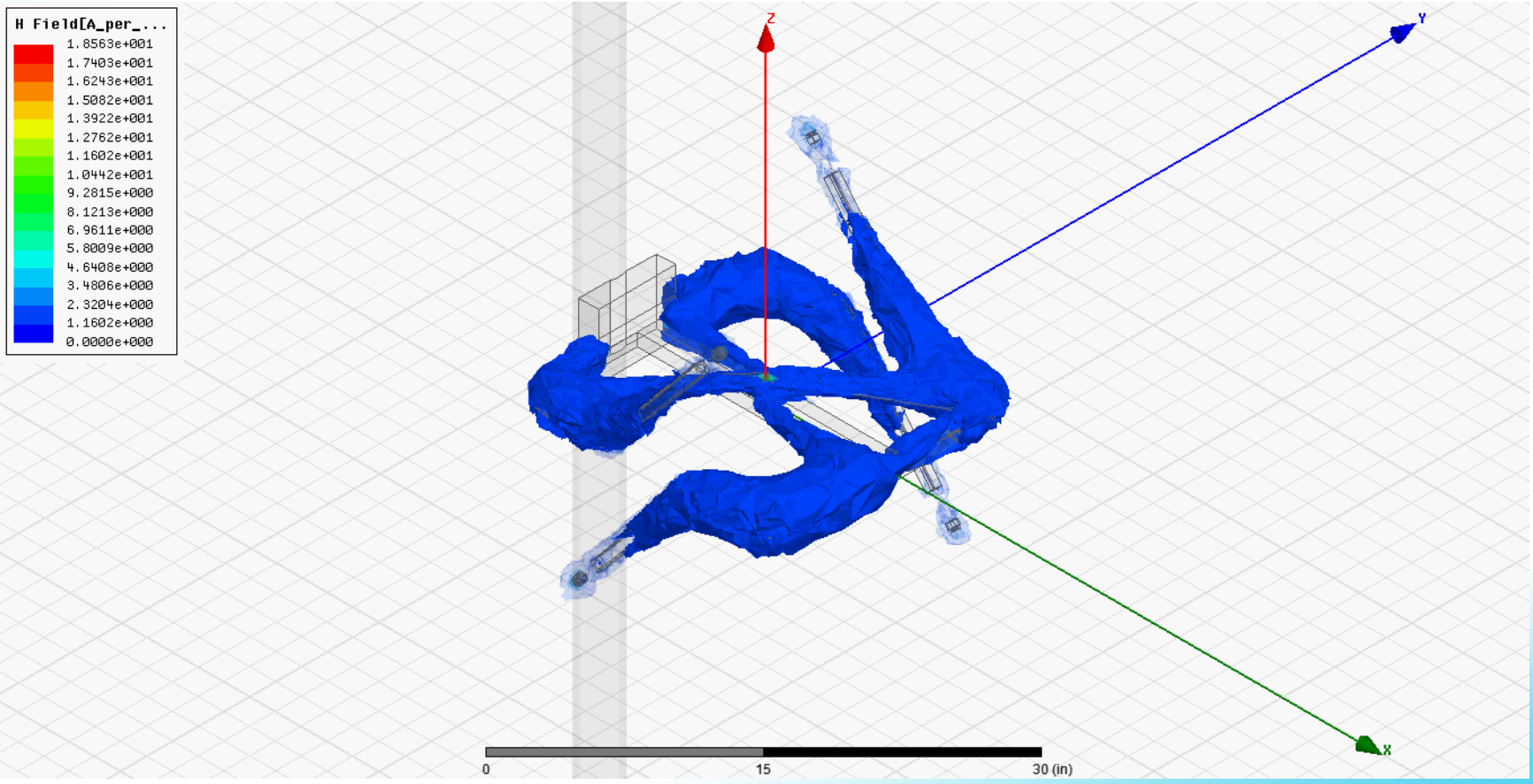


6812B produces a nice CP pattern albeit a bit oblong in the horizontal polarity



SLV Fields

This variation is more complex still. Notice that now there are 2 dipoles, back to back sharing the same ground plain. This enhances azimuth circularity.



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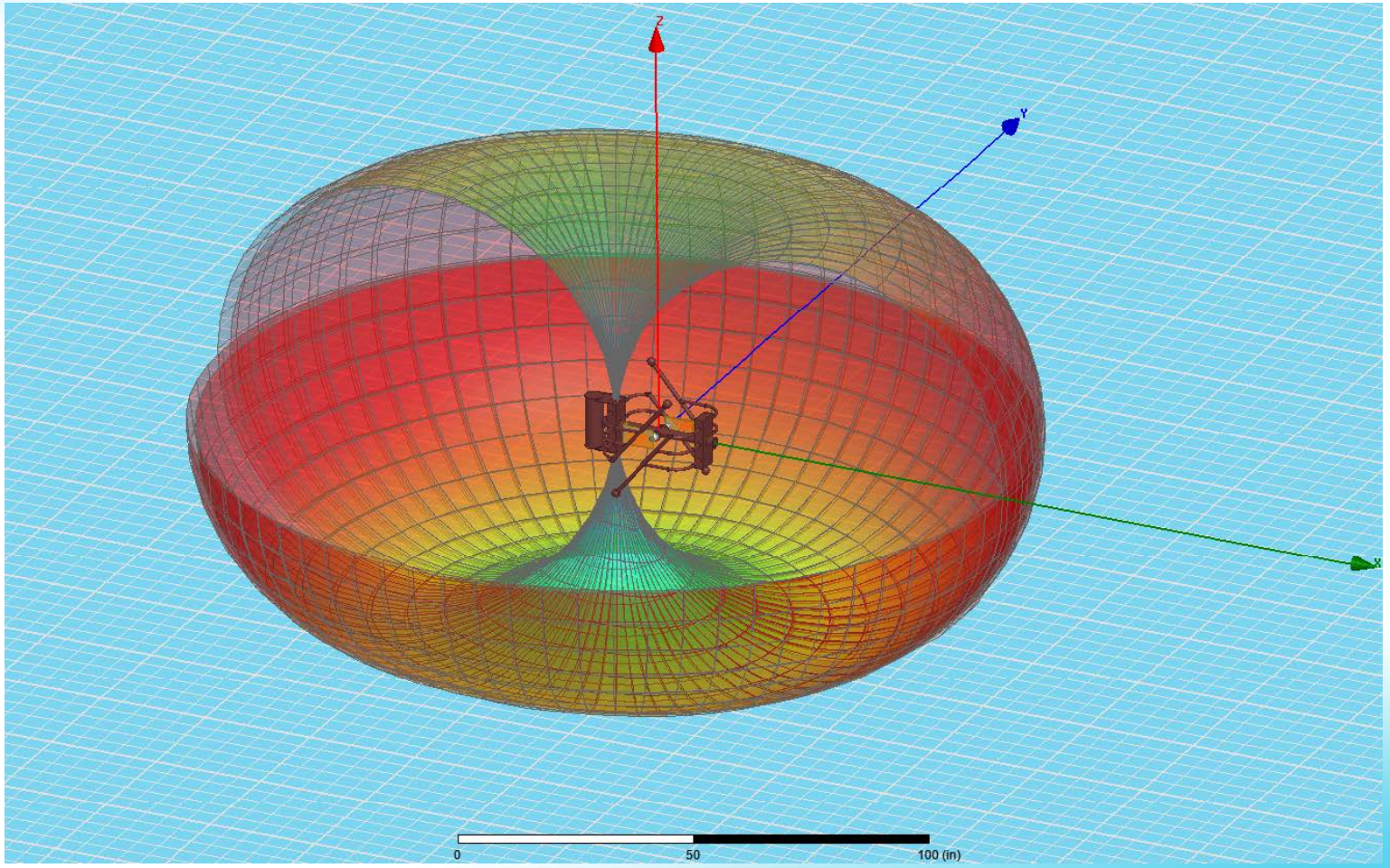
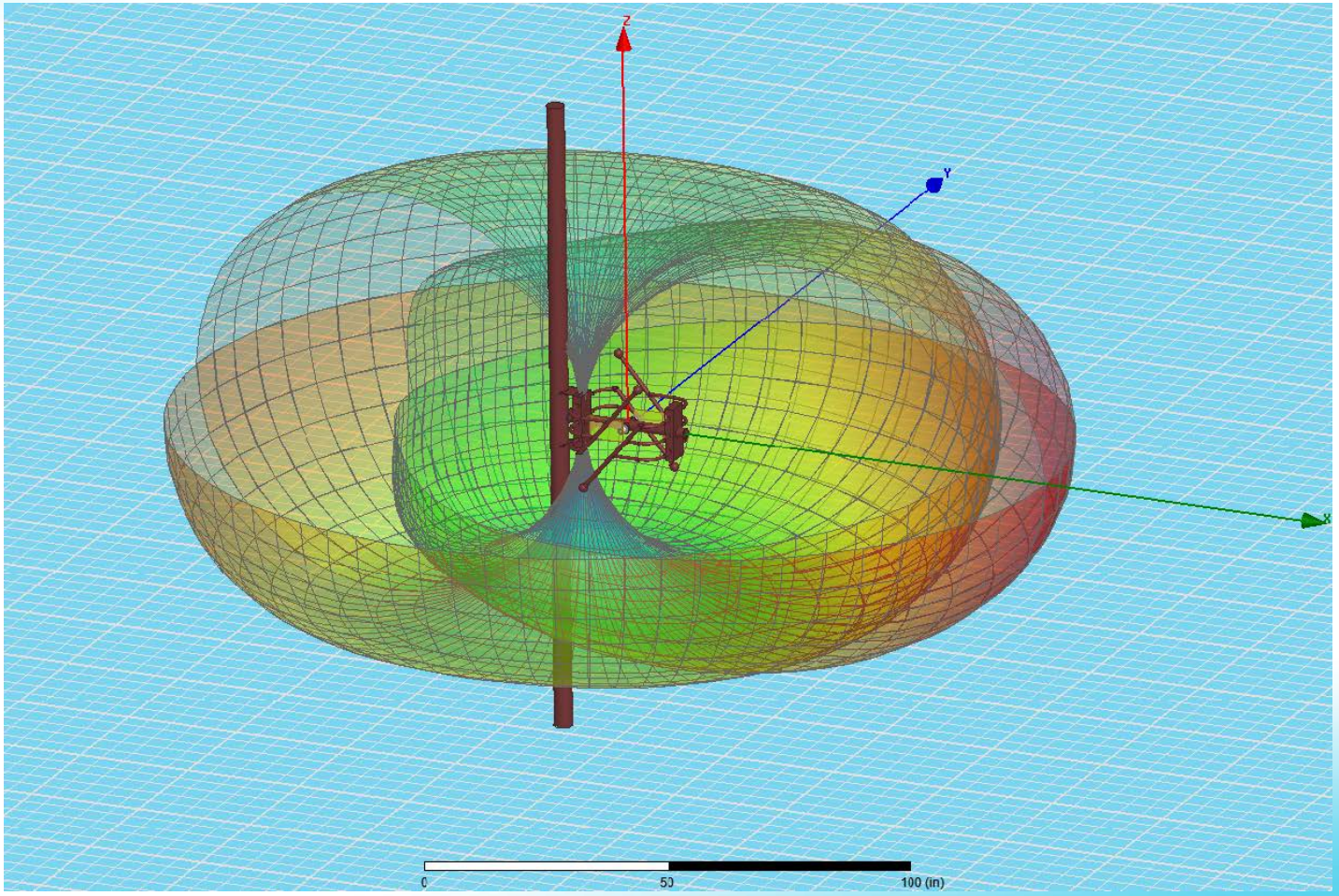
6814 in Free Space

SLV derived from our model 6814 SHP Antenna

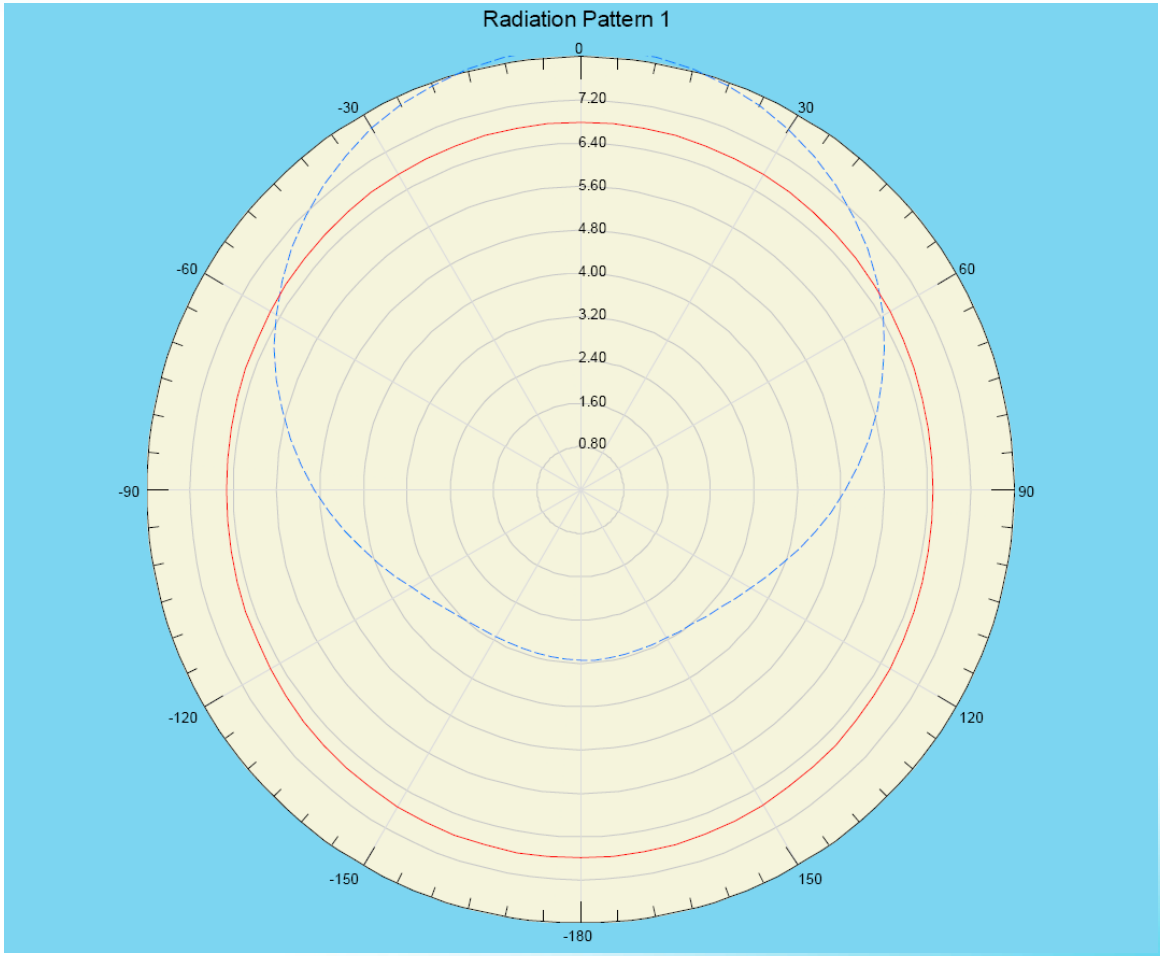


6814 on Pole

Now the vertically polarized field is effected by the vertical mounting structure

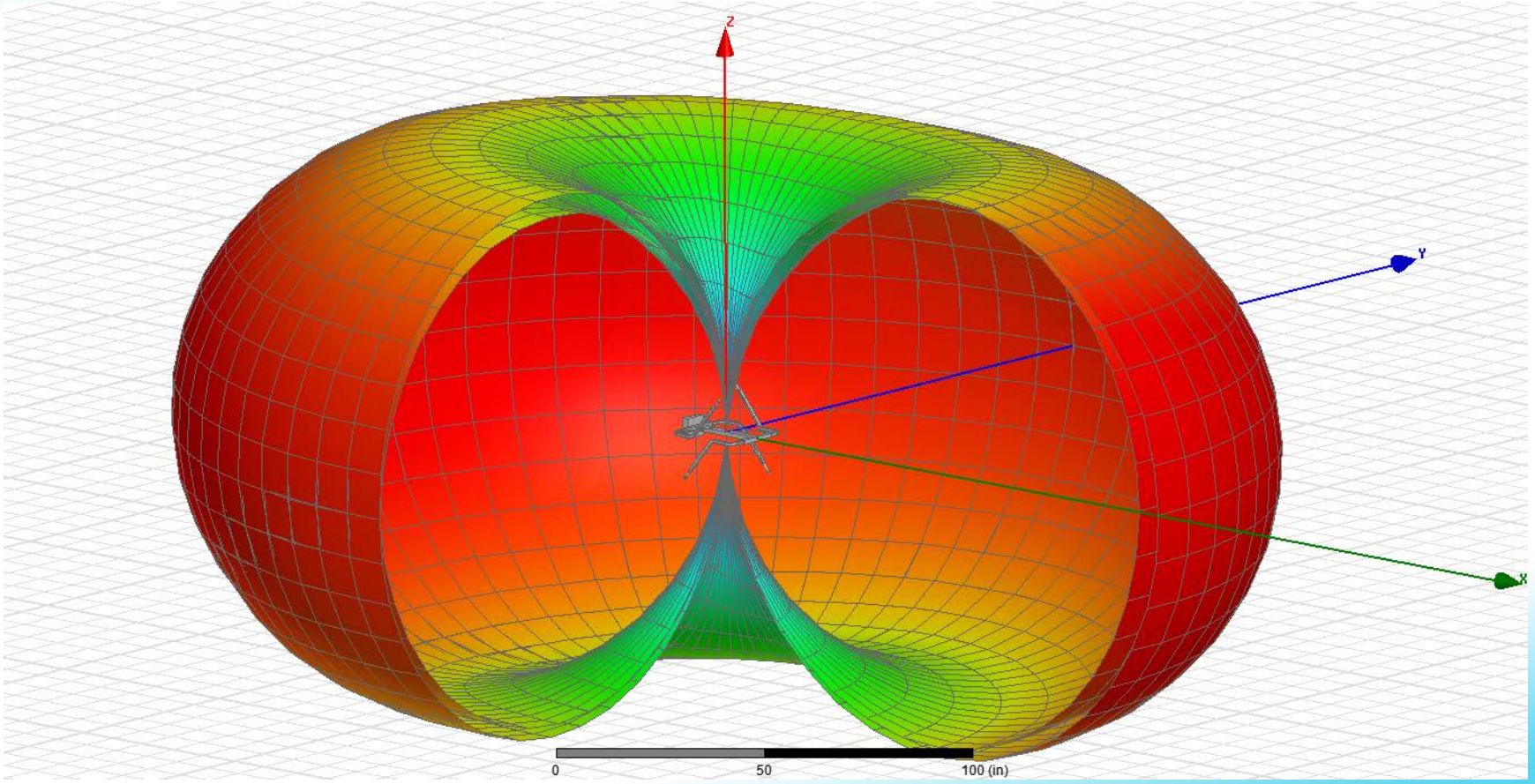


Notice the forward push to the vertical component



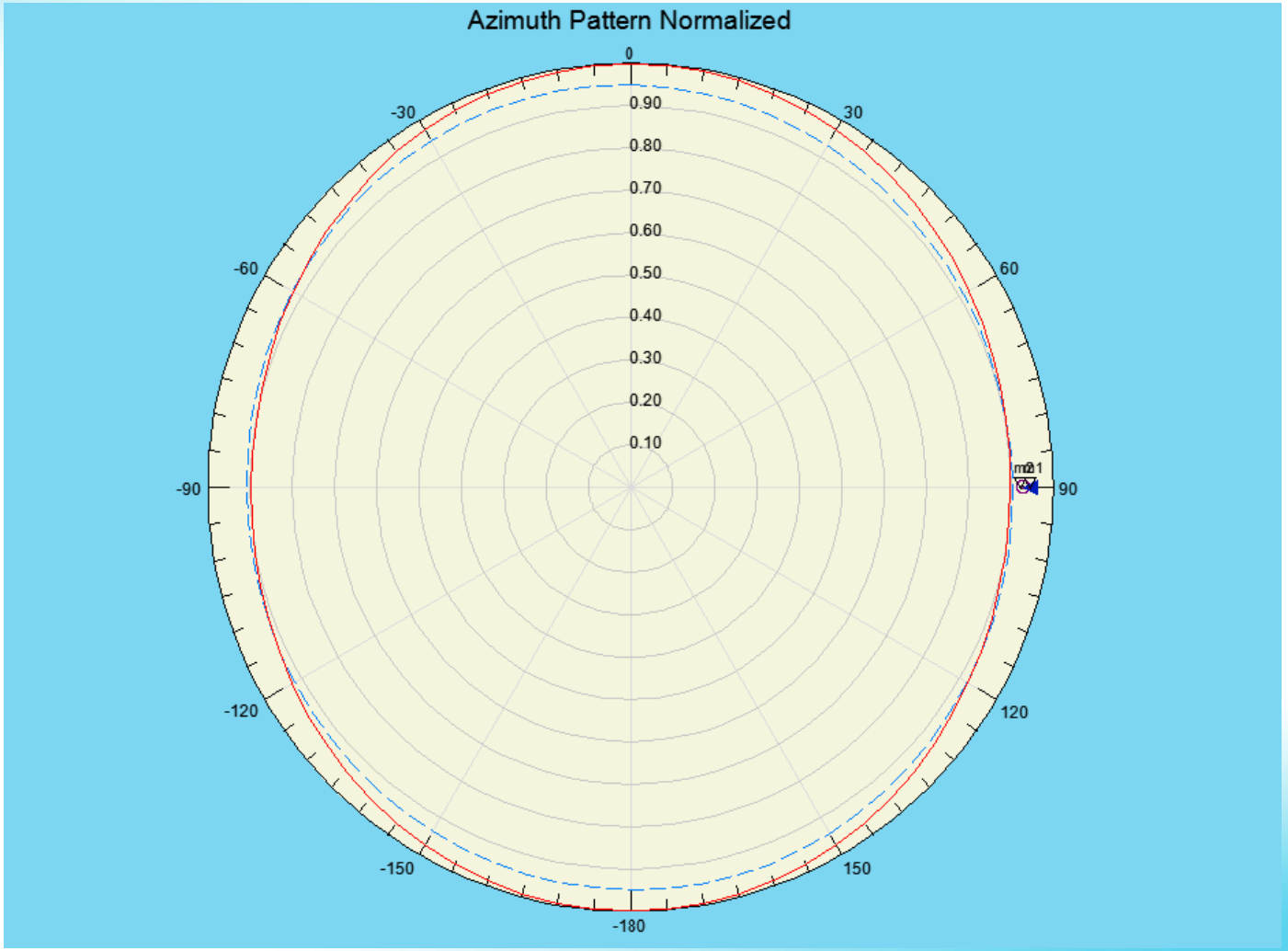
SLV Free space

Again we are starting with a classic “donut” pattern,
but now distributed among both the vertical *and* horizontal polarity

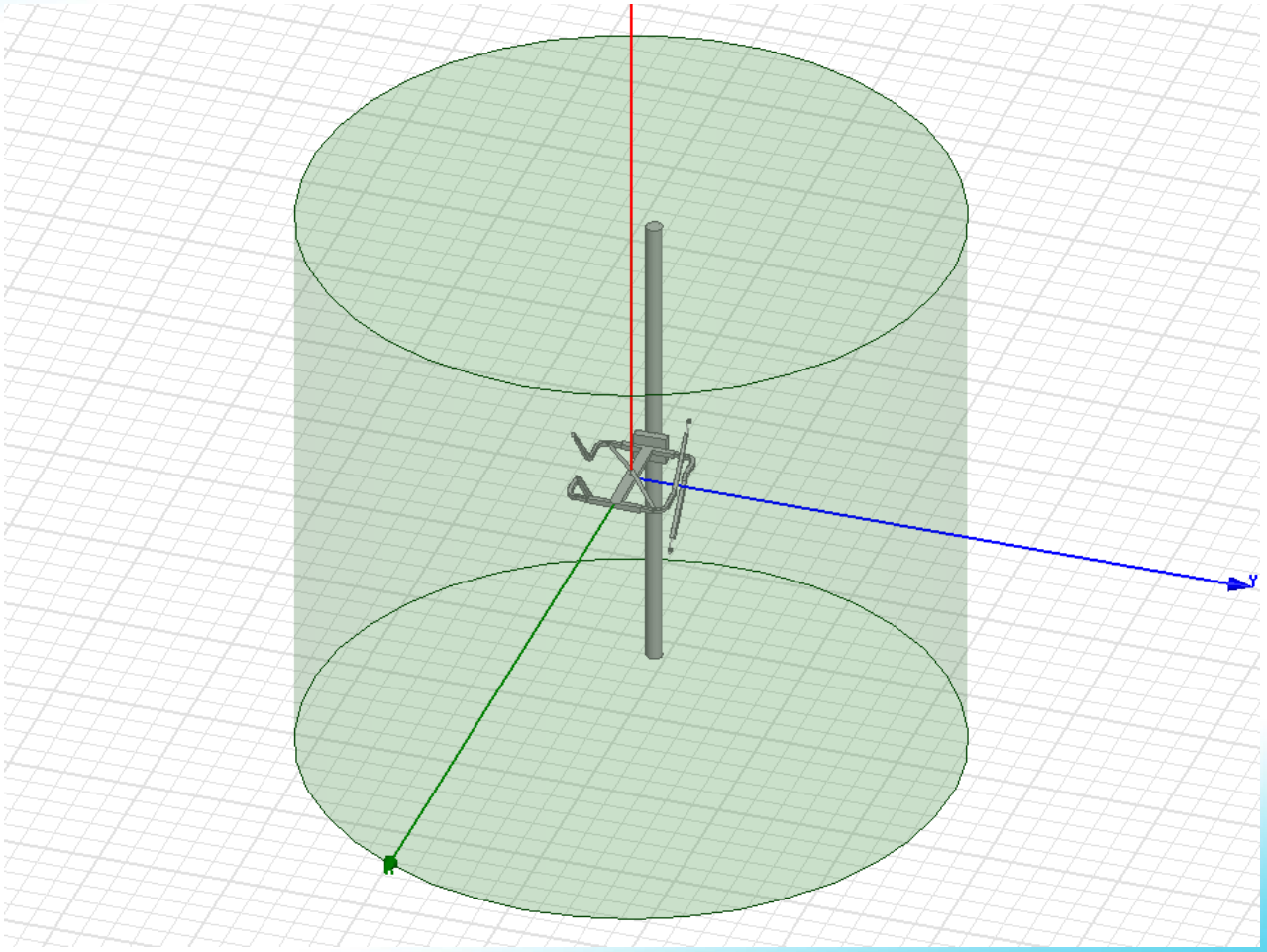


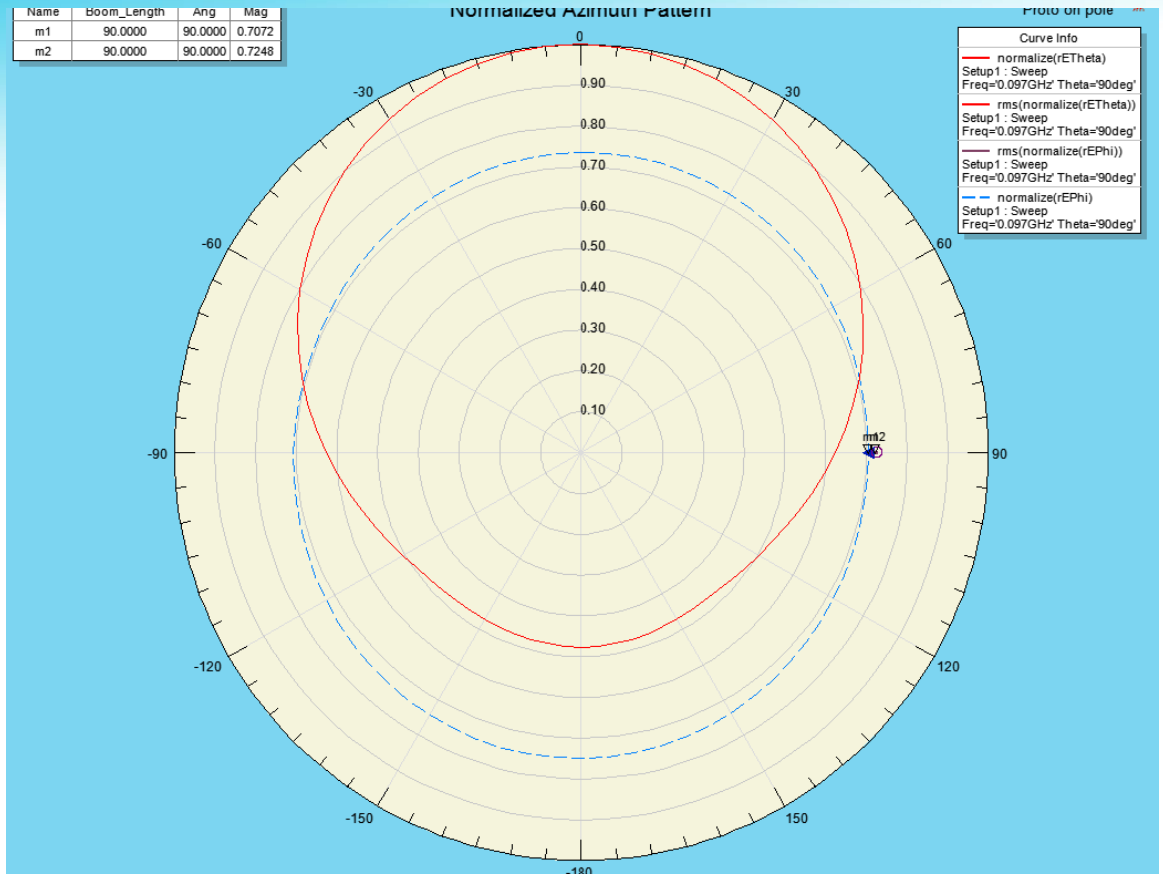
SLV Free space

The azimuth circularity on the horizontal component has improved over the 6812



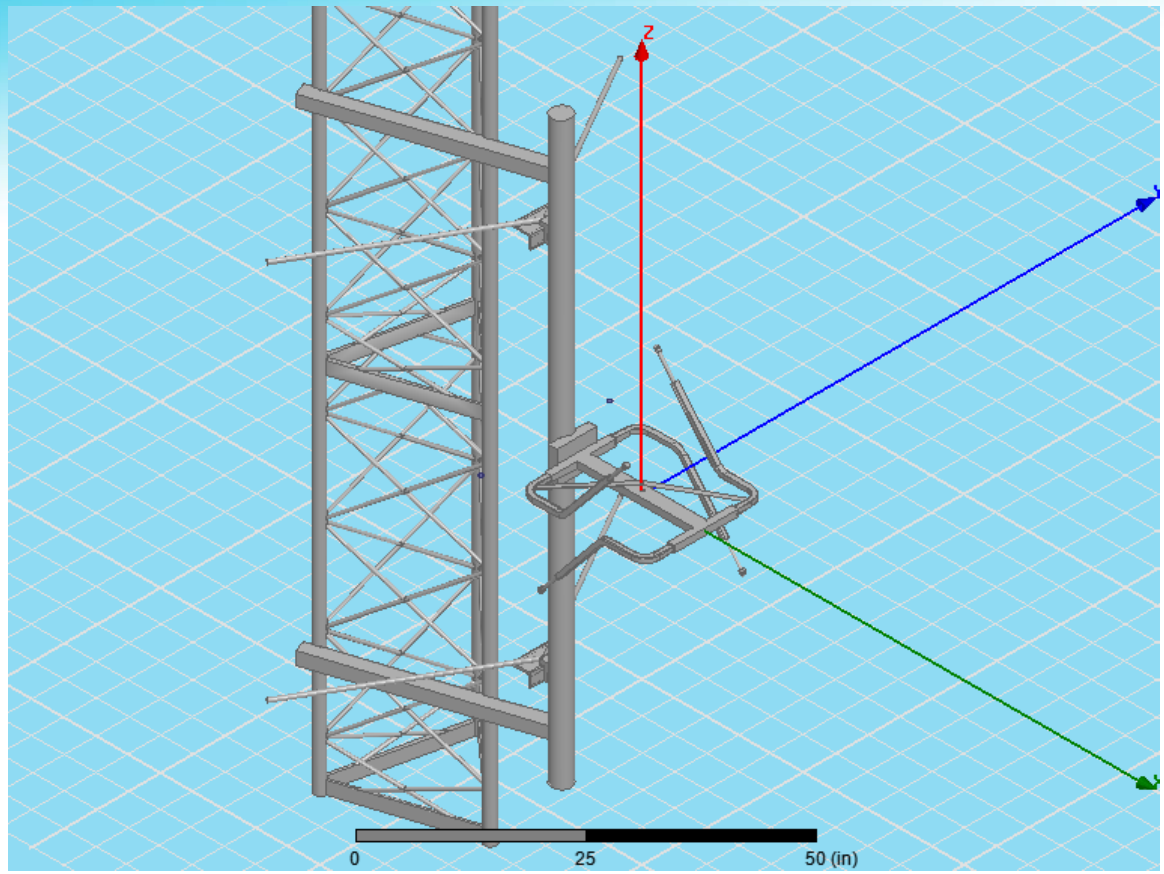
SLV Versa2une on pole





SLV “Versa2une” on a pole

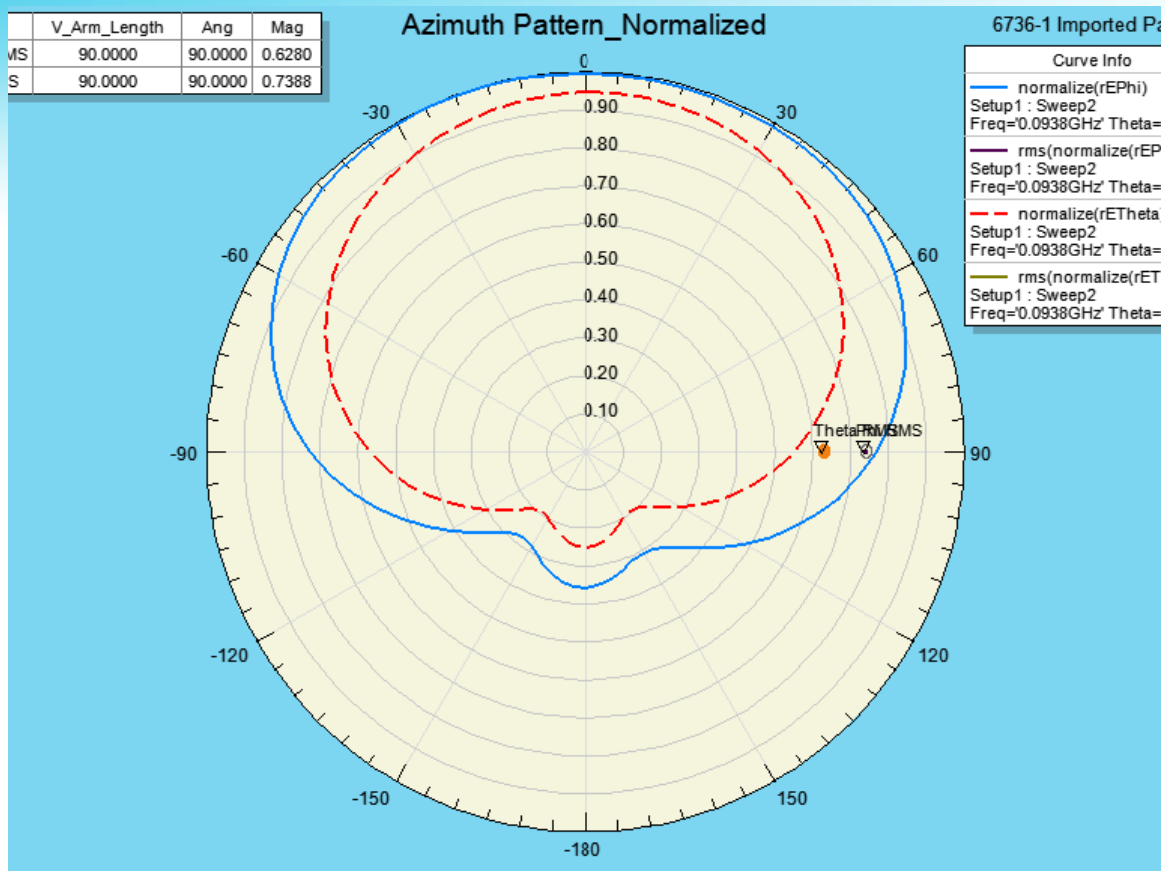
Again note how the vertically polarized energy is “pushed” forward



SLV-1-DA

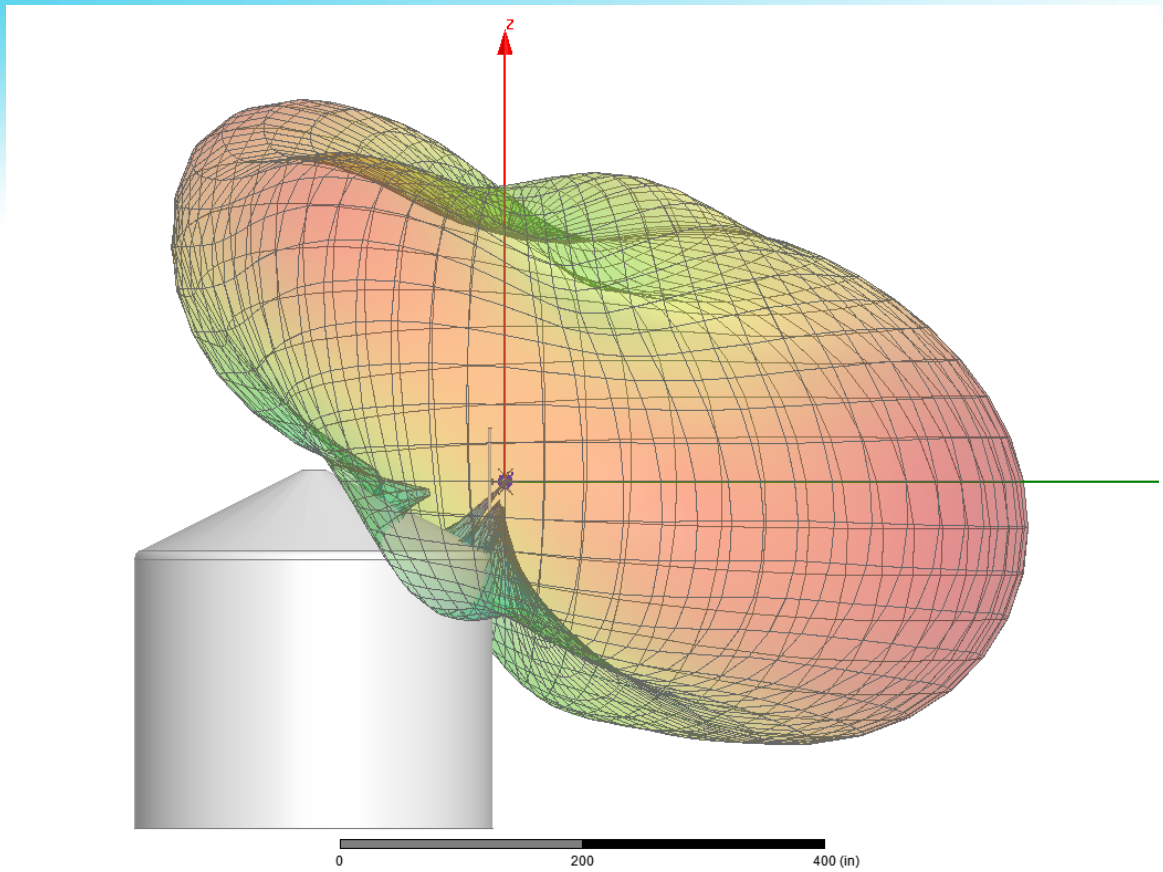
2 leg pick-up with Bent Horizontal Parasitic Element

Through a process of optimization various directional patterns are realized and cataloged.



SLV Directional Pattern

Here is one example a directional pattern



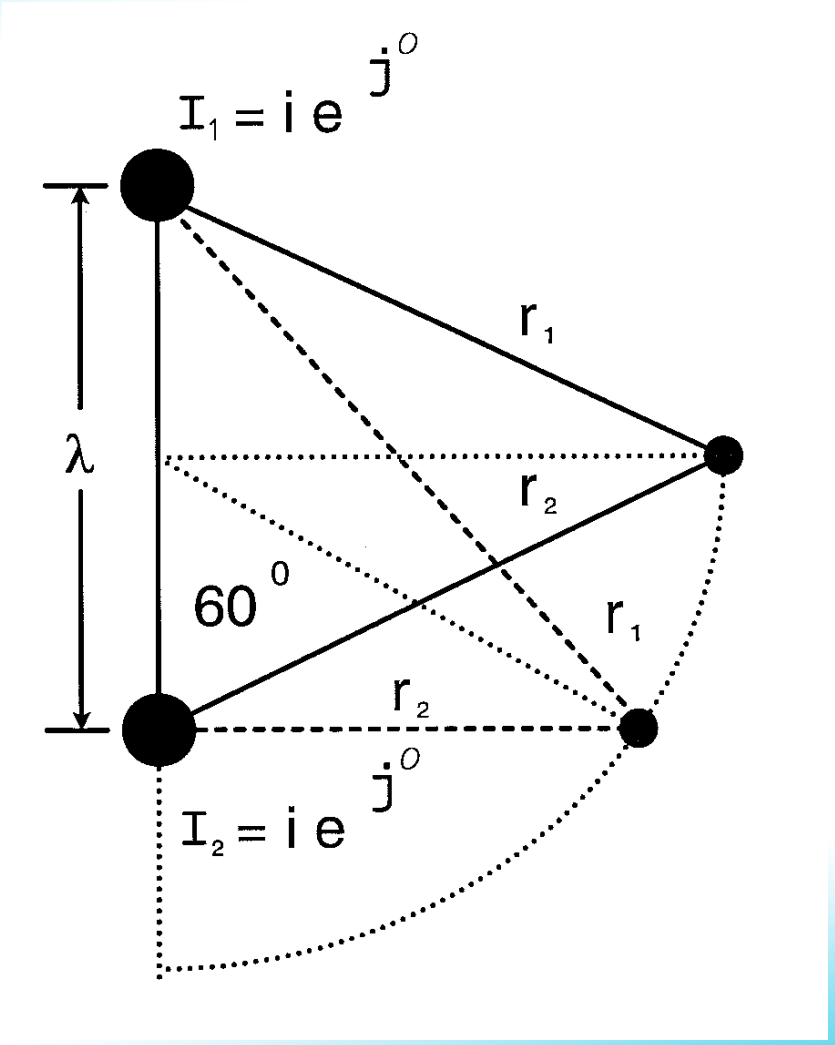
SLV on Water Tower

This analysis was done to determine the water tower's effect on the antennas reflected power but in the process we obtain the resulting radiated pattern which was in step with the local engineer's observations.

Questions

Tools for realizing patterns:

Array Factor



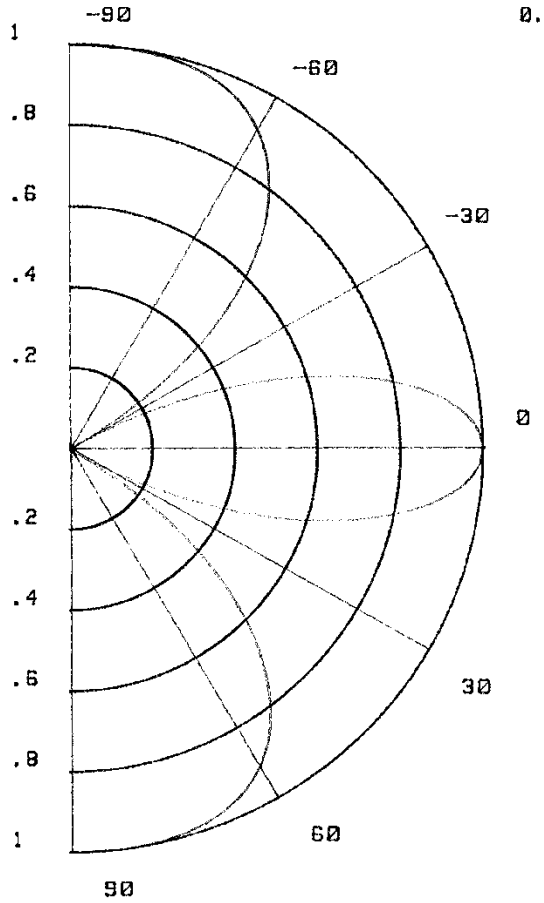
Array Factor

FIELD ELEVATION PATTERN

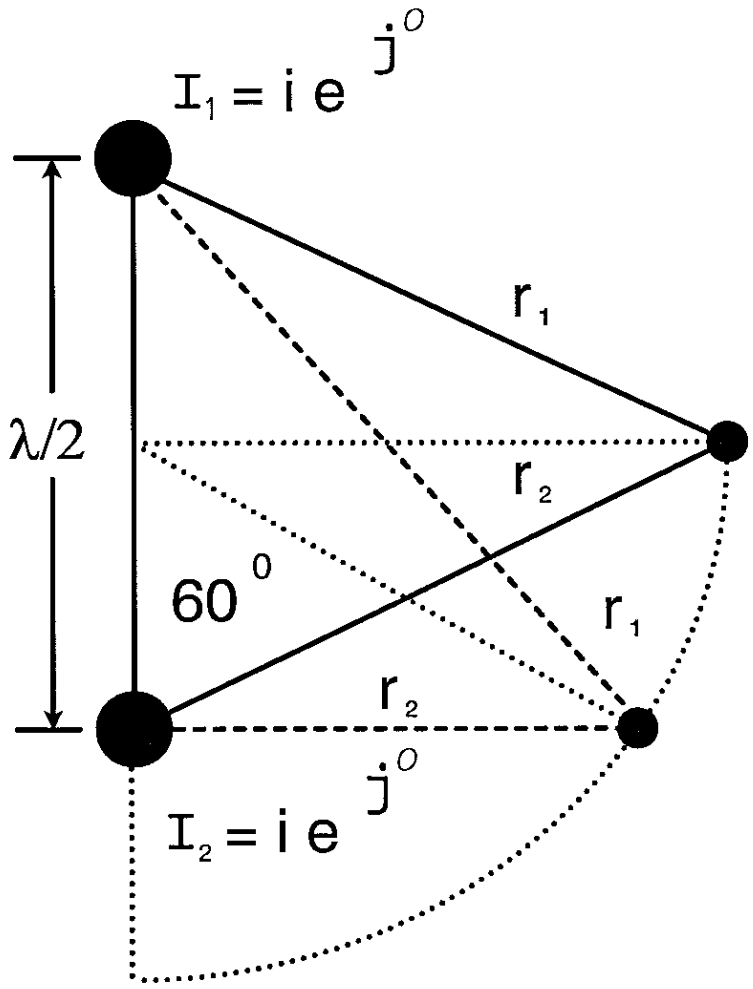
ANT. MFG.: SHIVELY LABS

GAIN	POWER	dB
-90.00DEG.	.61	-2.15
0.00DEG	.61	-2.15

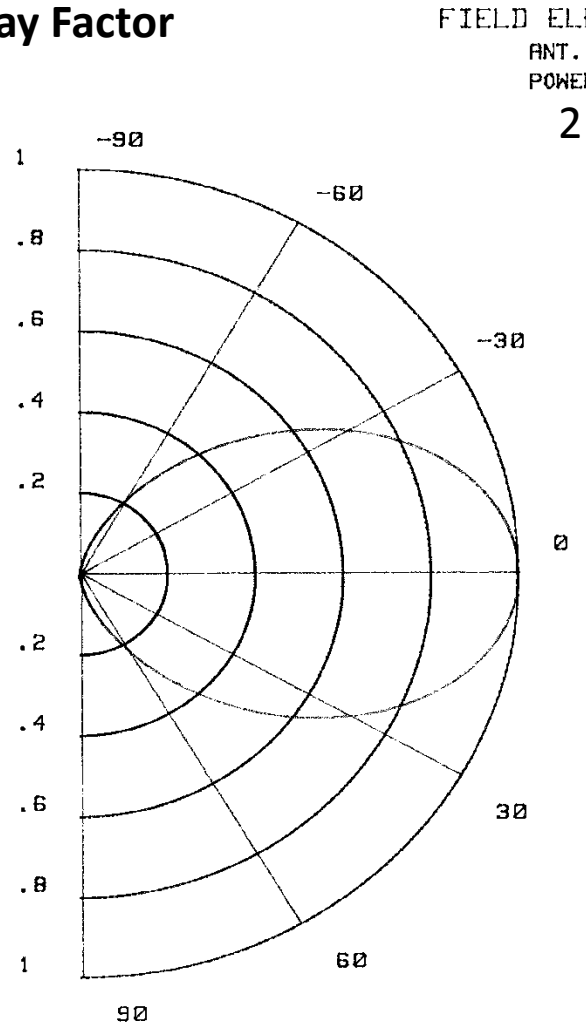
2 bay Full



Array Factor



Array Factor



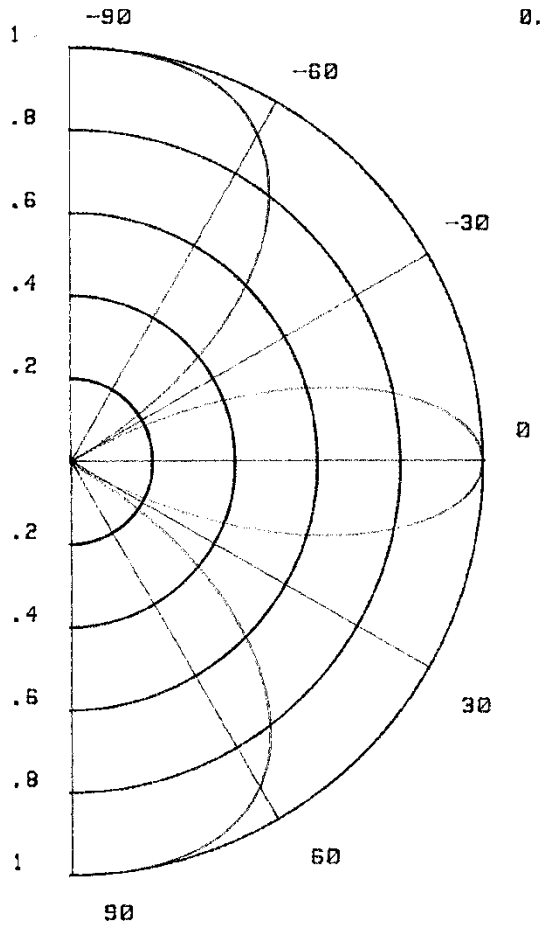
2 Bay 1/2

Array Factor

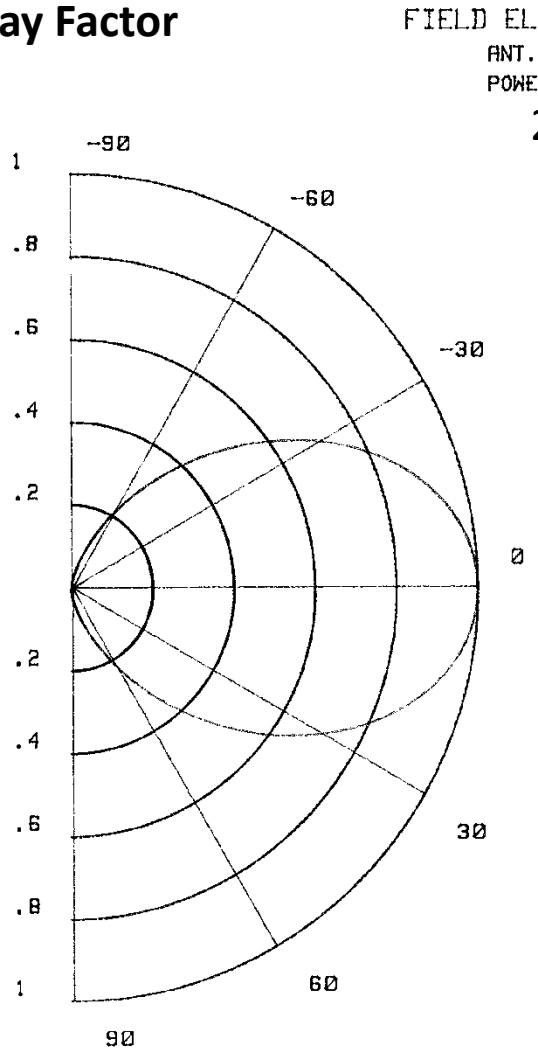
FIELD ELEVATION PATTERN
ANT. MFG.: SHIVELY LABS

GAIN	POWER	dB
-90.00DEG.	.61	-2.15
0.00DEG	.61	-2.15

2 bay Full



Array Factor



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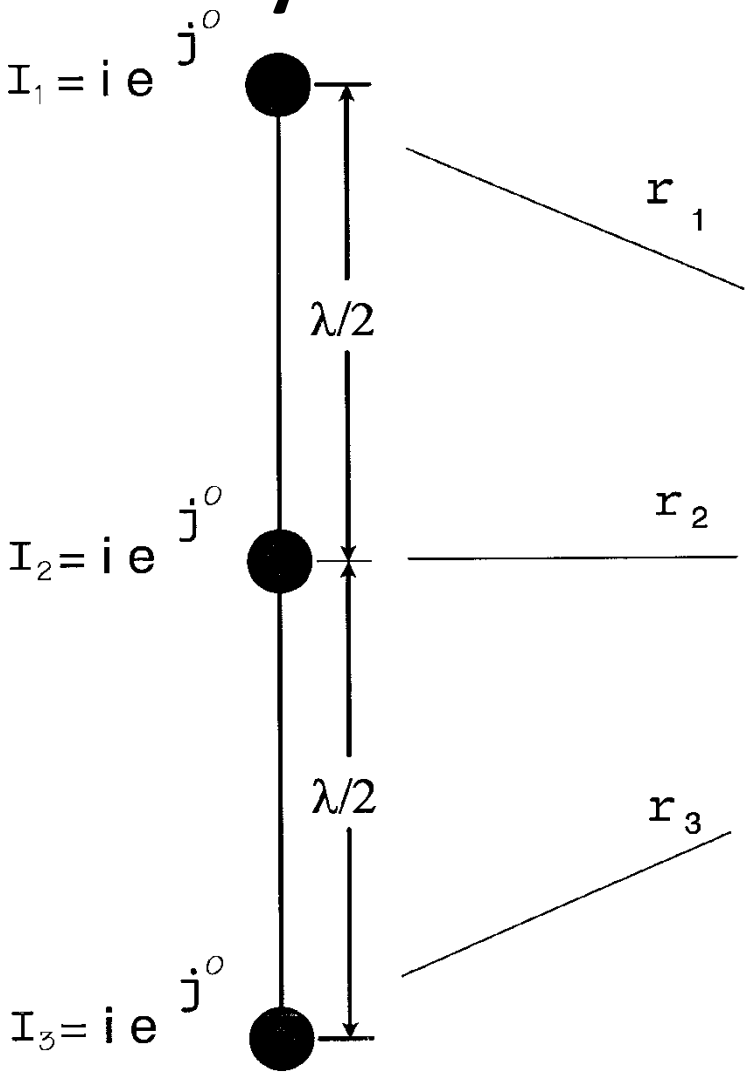

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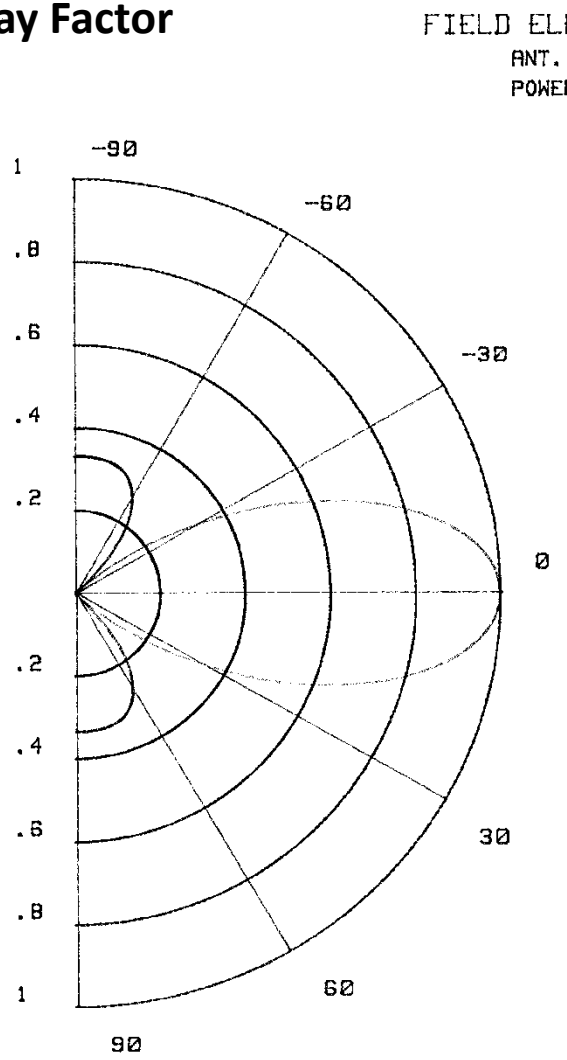


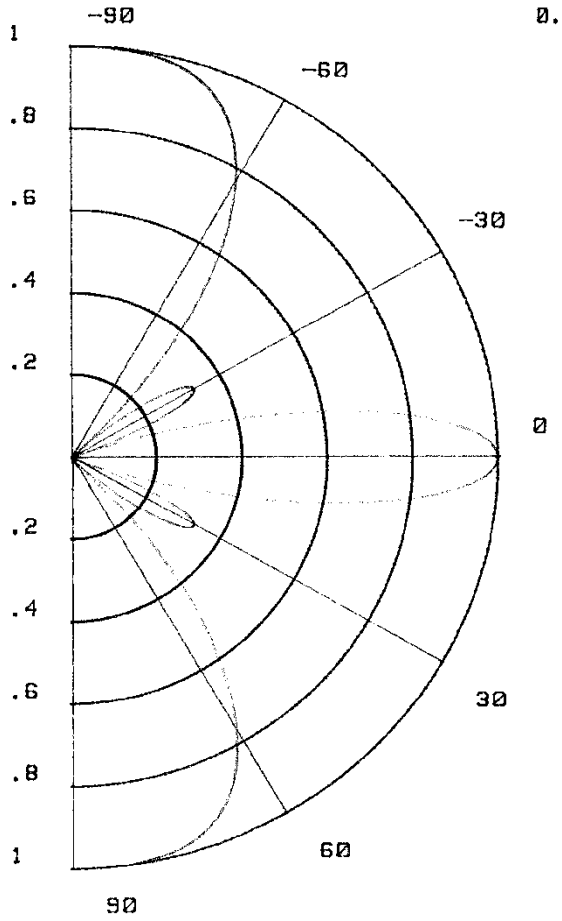
3 Bay 1/2

Array Factor

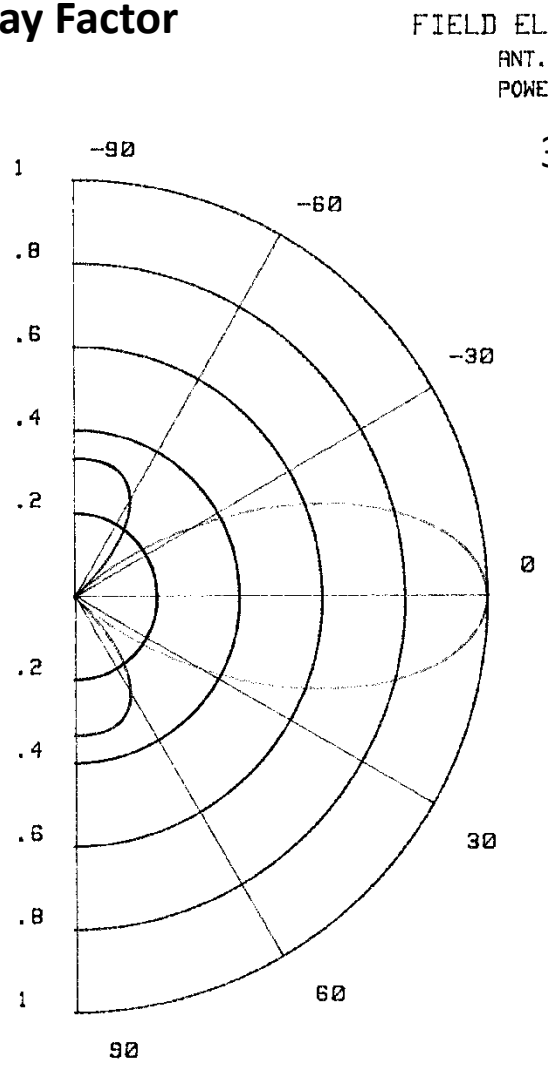
FIELD ELEVATION PATTERN
ANT. MFG.: SHIVELY LABS

GAIN	POWER	dB
-90.00DEG.	.91	-.39
0.00DEG	.91	-.39

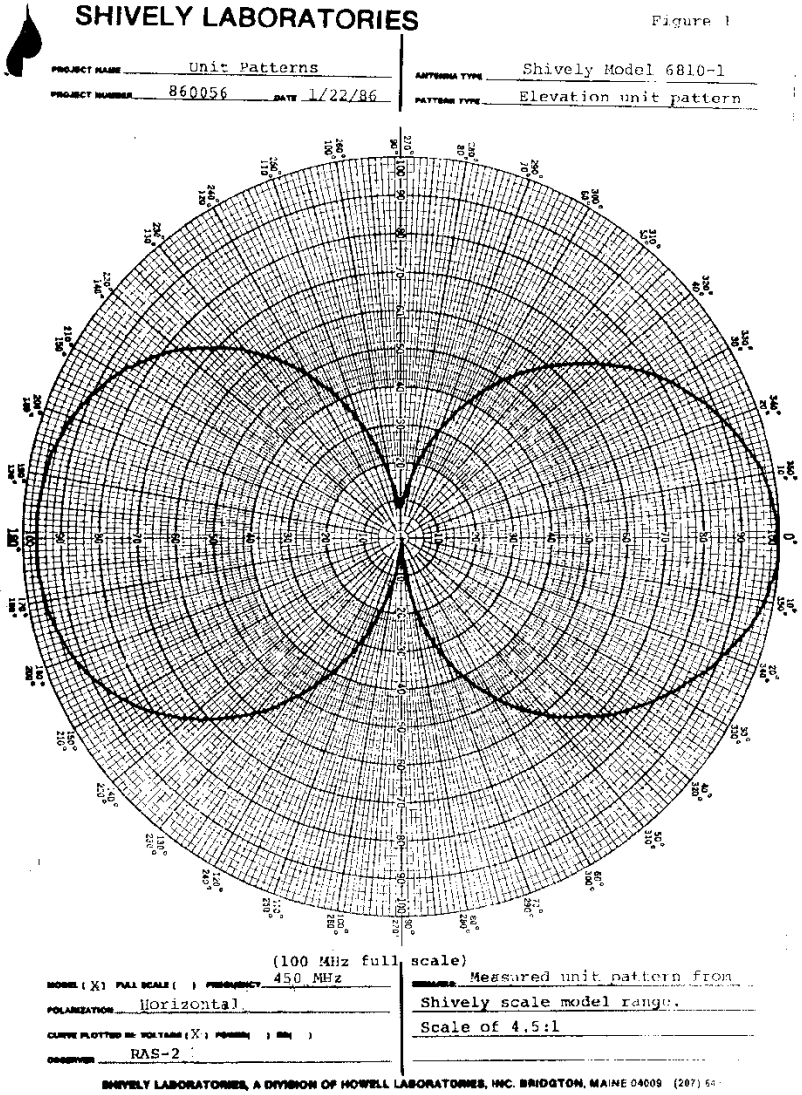
3 Bay Full



Array Factor



3 Bay 1/2



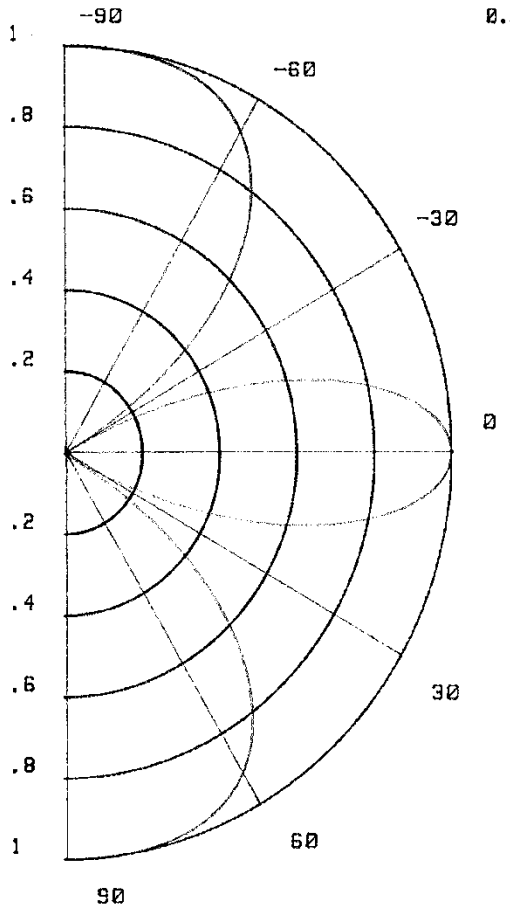
Unit Pattern

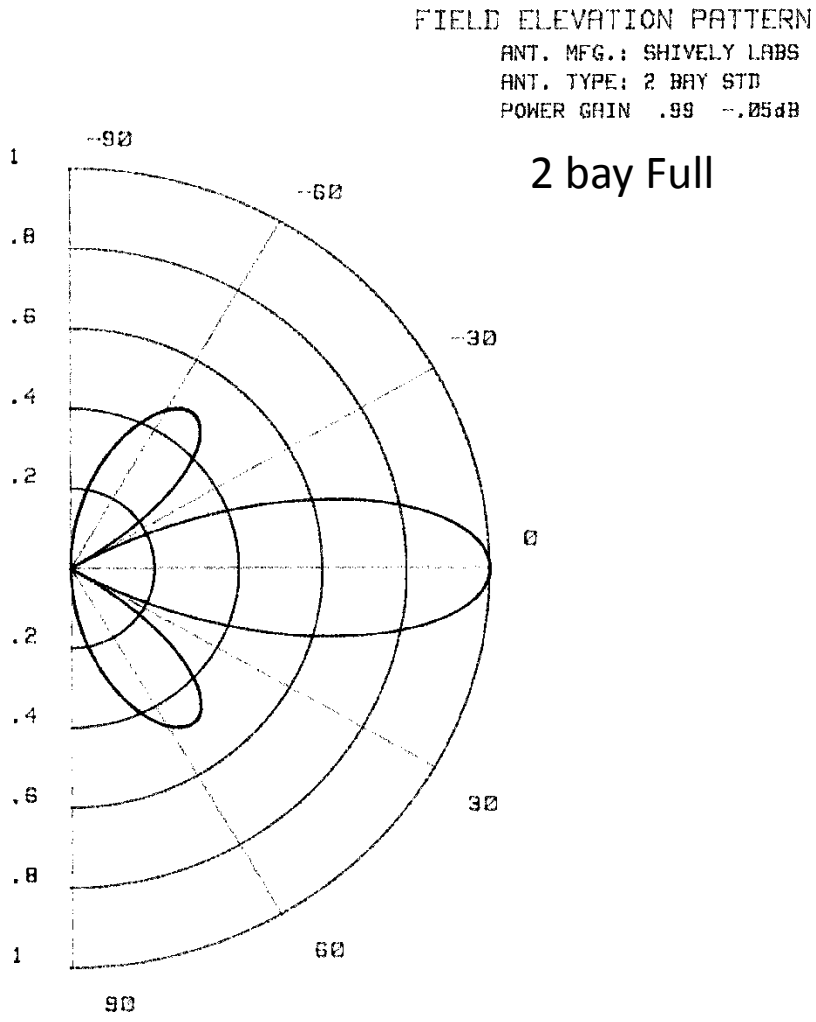
Array Factor

FIELD ELEVATION PATTERN
ANT. MFG.: SHIVELY LABS

GAIN	POWER	dB
-90.00DEG.	.61	-2.15
0.00DEG	.61	-2.15

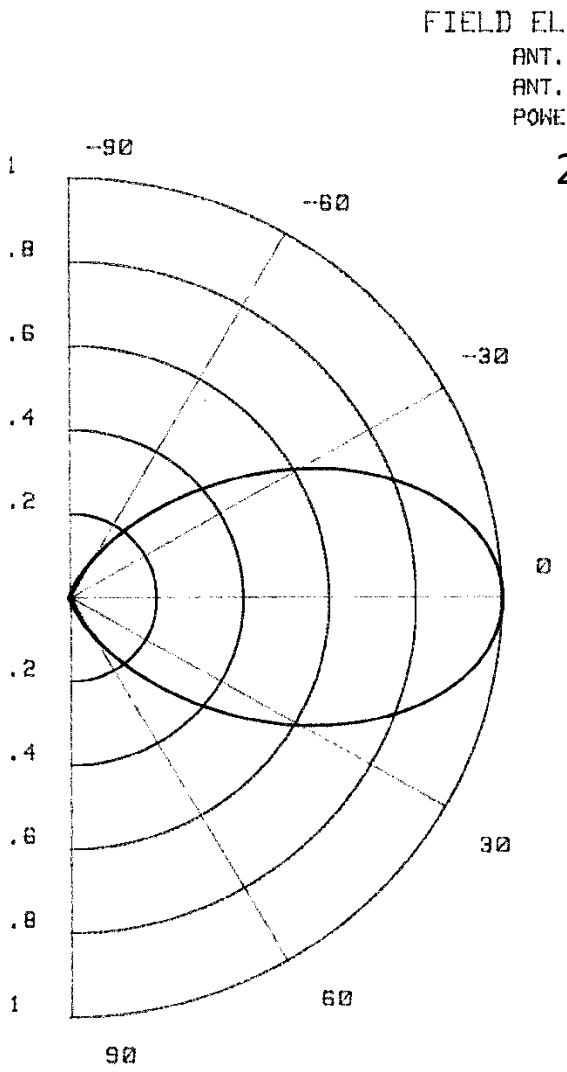
2 bay Full



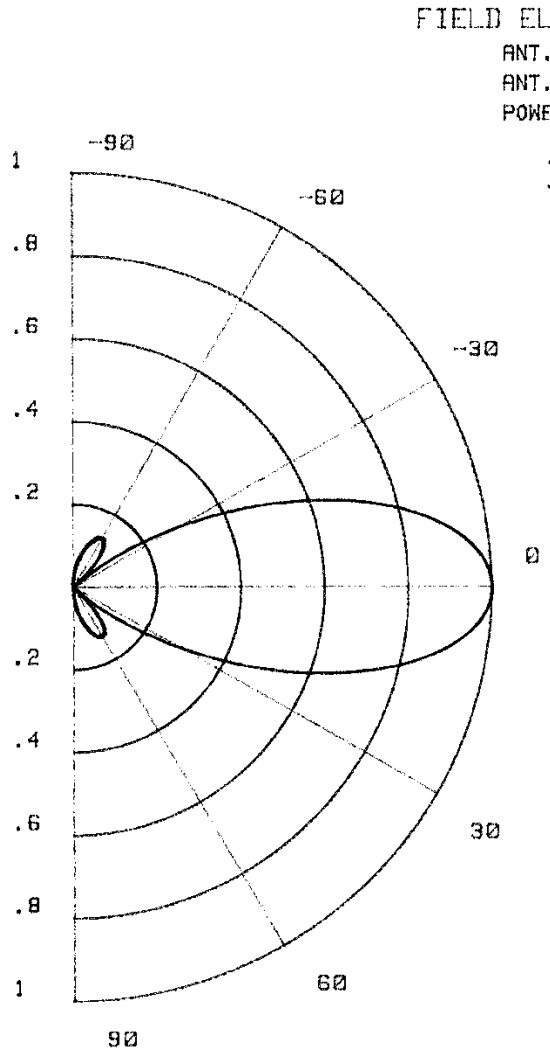


2 bay Full

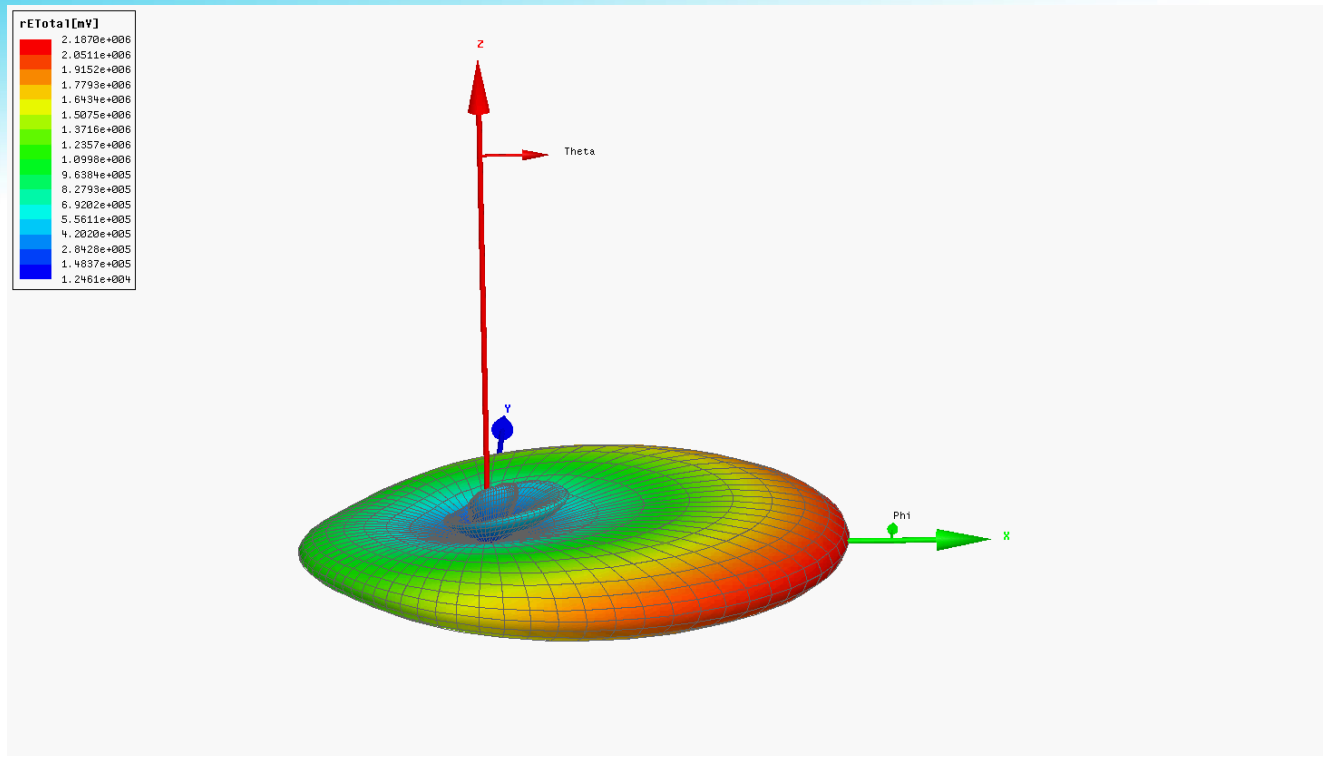
Array Factor x Unit Pattern = Elevation Pattern


FIELD ELEVATION PATTERN
ANT. MFG.: SHIVELY LABS
ANT. TYPE: 2 BAY 1/2WAVE
POWER GAIN .70 -1.54dB
-90
-60
-30
0
30
60
90
1
.8
.6
.4
.2
.2
.4
.6
.8
1

2 Bay 1/2


FIELD ELEVATION PATTERN
ANT. MFG.: SHIVELY LABS
ANT. TYPE: 3 BAY 1/2WAVE
POWER GAIN 1.01 .05dB
-90
-60
-30
0
30
60
90
1
.8
.6
.4
.2
.2
.4
.6
.8
1

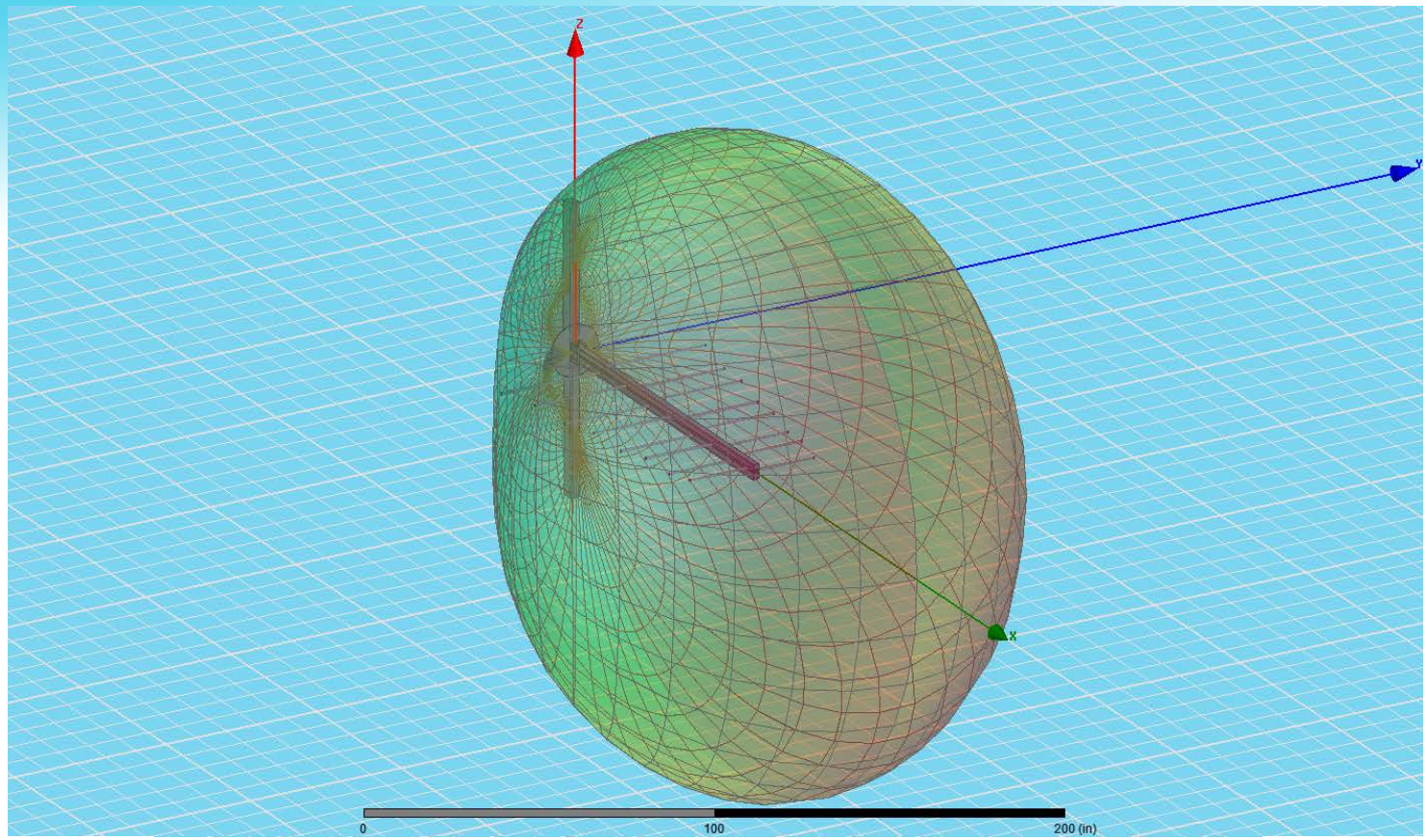
3 Bay 1/2



3 Bay Array 120 inch spacing

This clip shows the change in side lobe energy as a function of frequency from 88-108 MHz

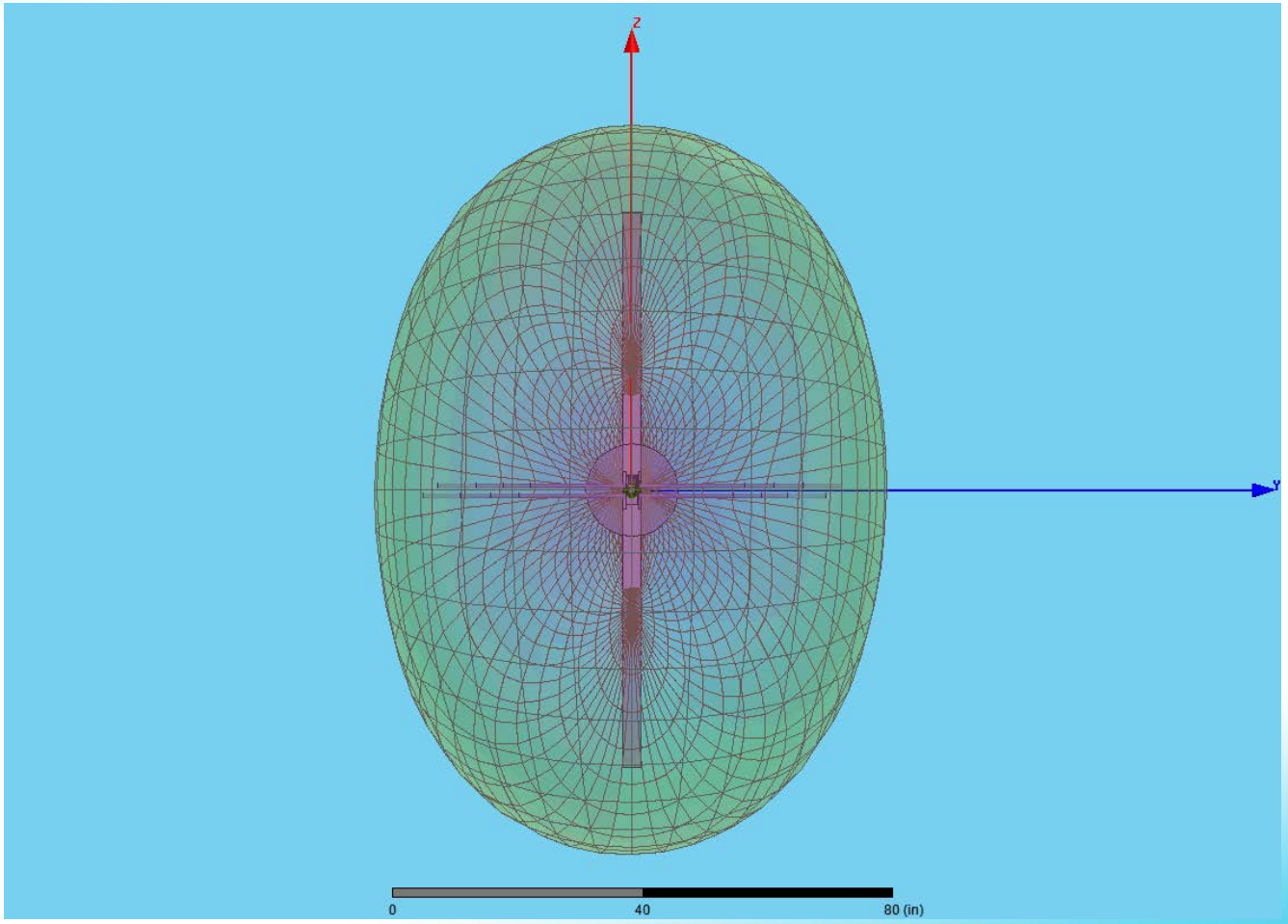
Questions

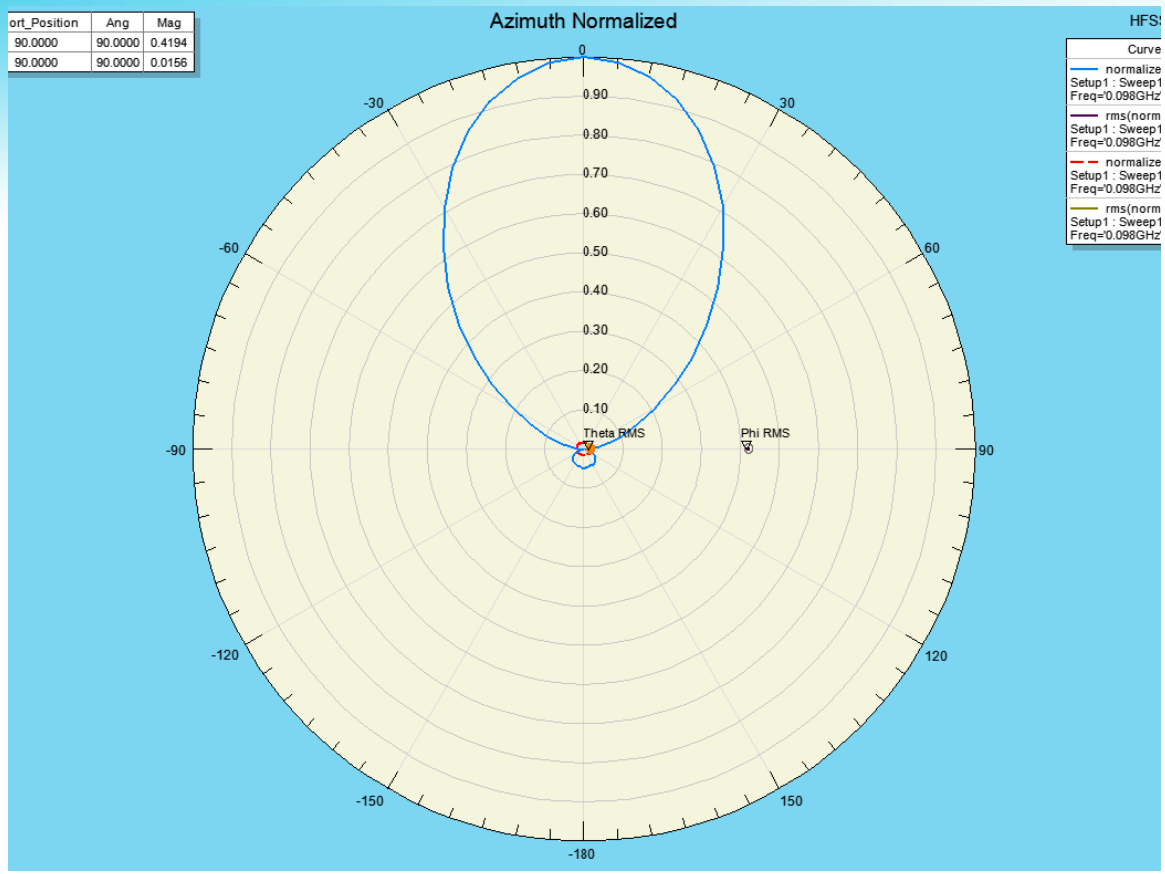


6025 Log Periodic Antenna

Building block for highly directional sites and multi-lobe patterns

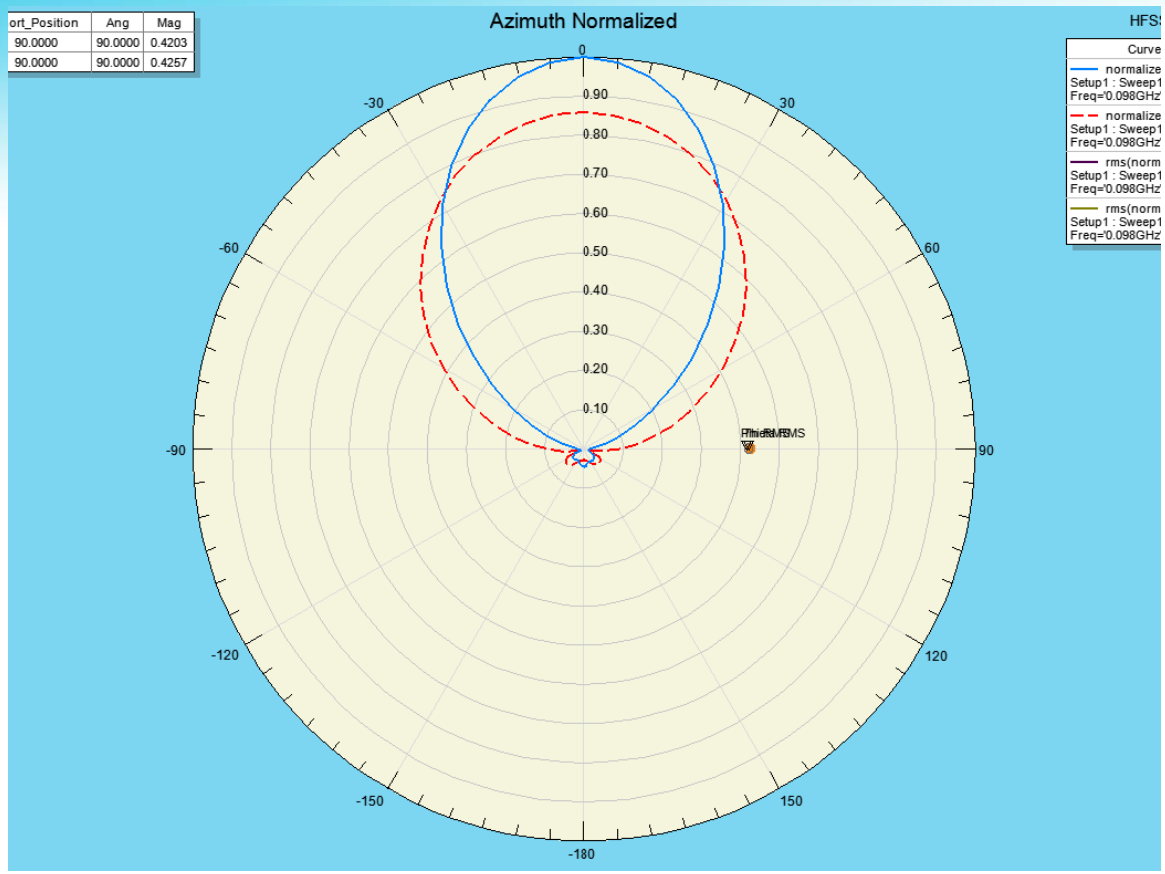
6025 in 4 successive orientations





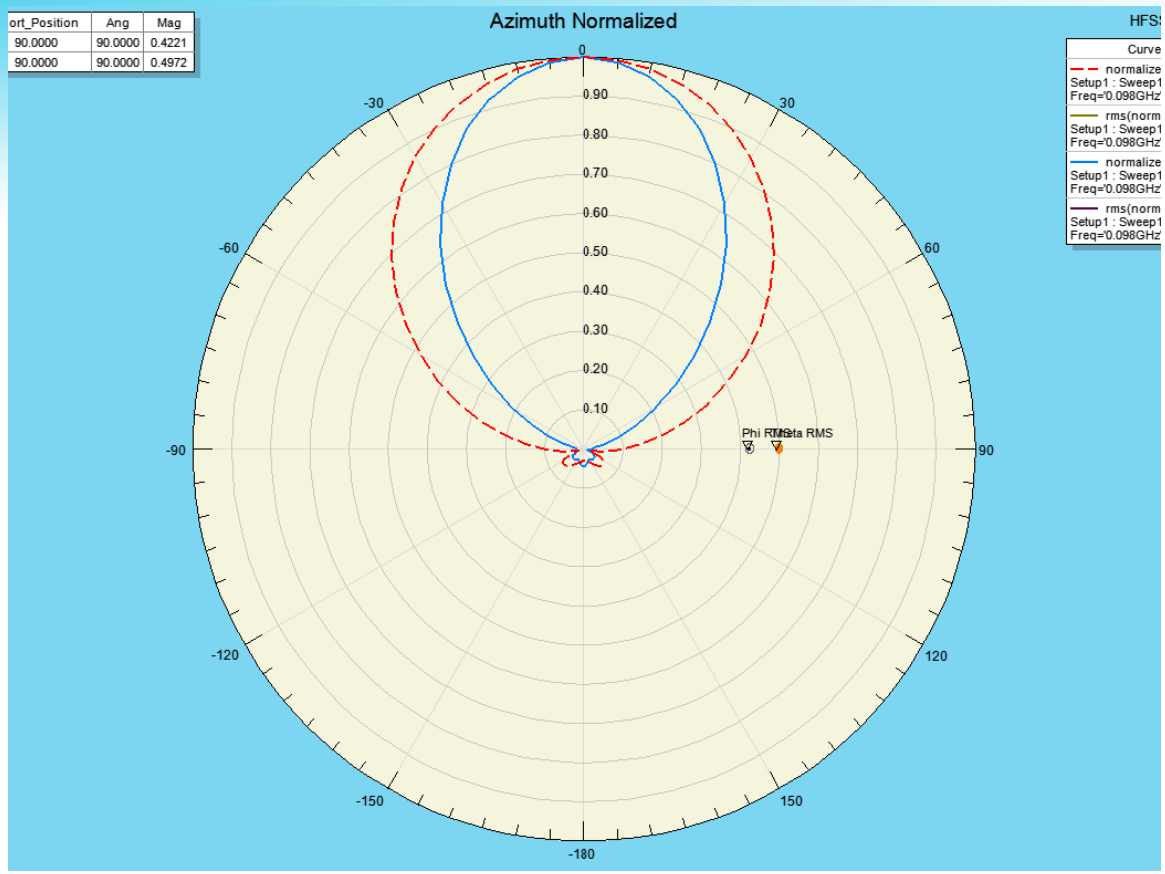
6025 Horizontally Polarized

The Half Power Beam Width (HPBW) is about 60 degrees



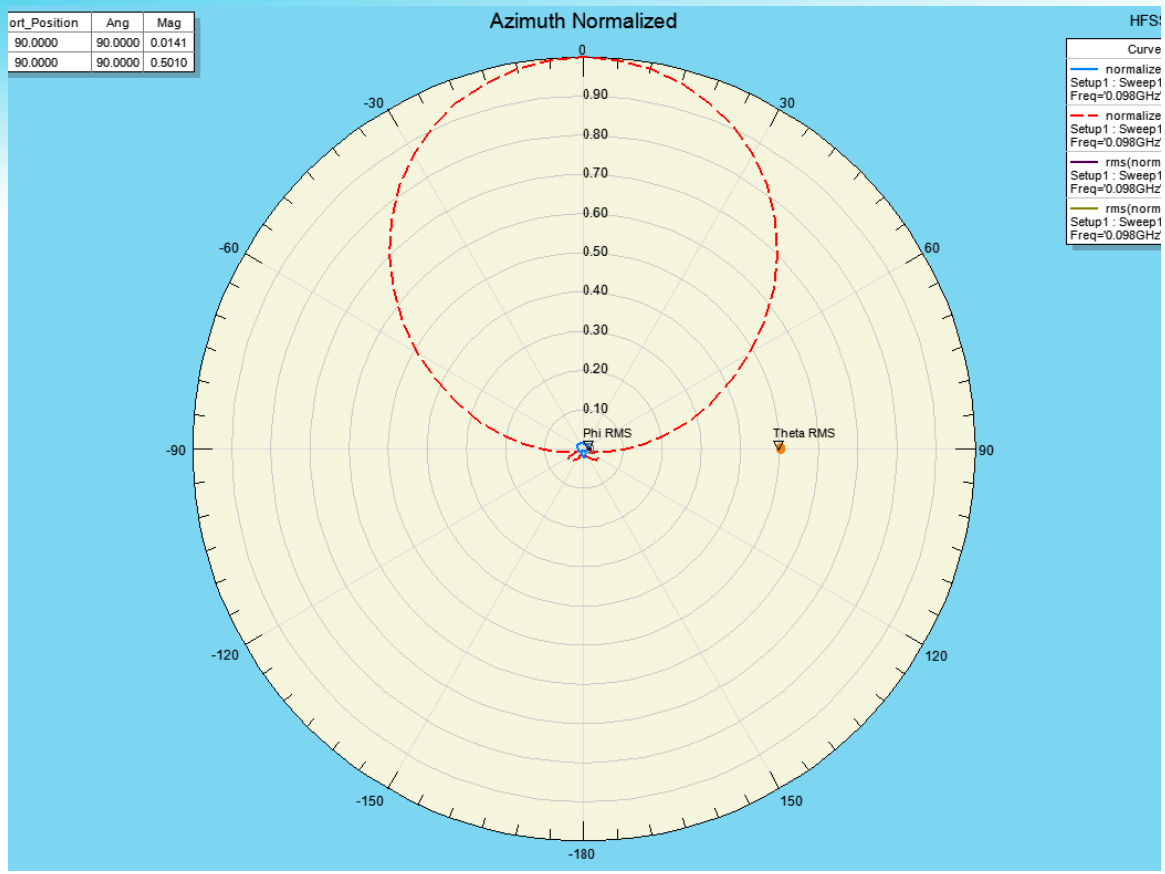
6025 @ 50 DEGREES

Now the RMS values are equal but the peaks are not.



6025 @ 45 Degrees

The peaks are equal but the RMS value is not



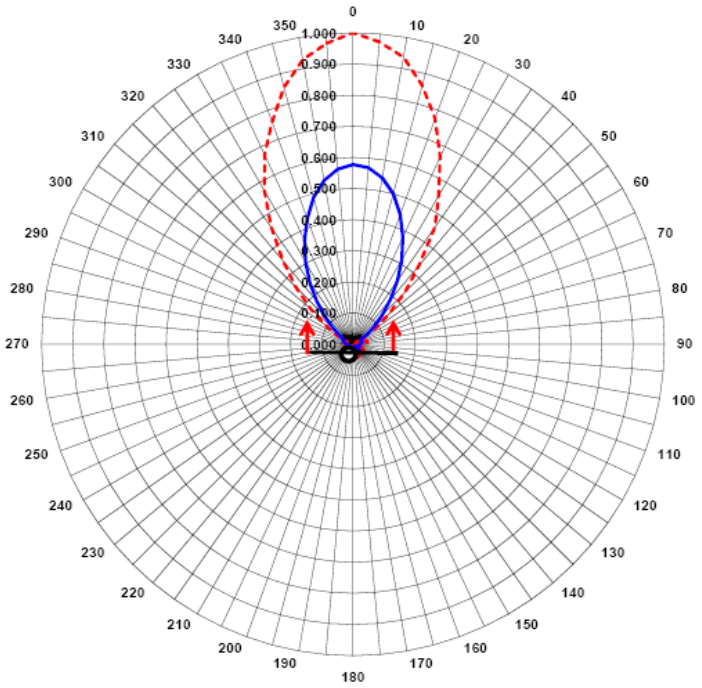
6025 Vertically Polarized

HPBW is about 100 degrees

6025 Log Periodic antennas are versatile

Special H/V ratios

SHIVELY LABS SAMPLE PATTERN



6025 DUAL BOOM 60-INCHES APART
6025'S 30-DEGREE ROTATION POWER SPLIT 75-V 25-H

VERTICAL RMS: 36.70% HORIZONTAL RMS: 21.02%

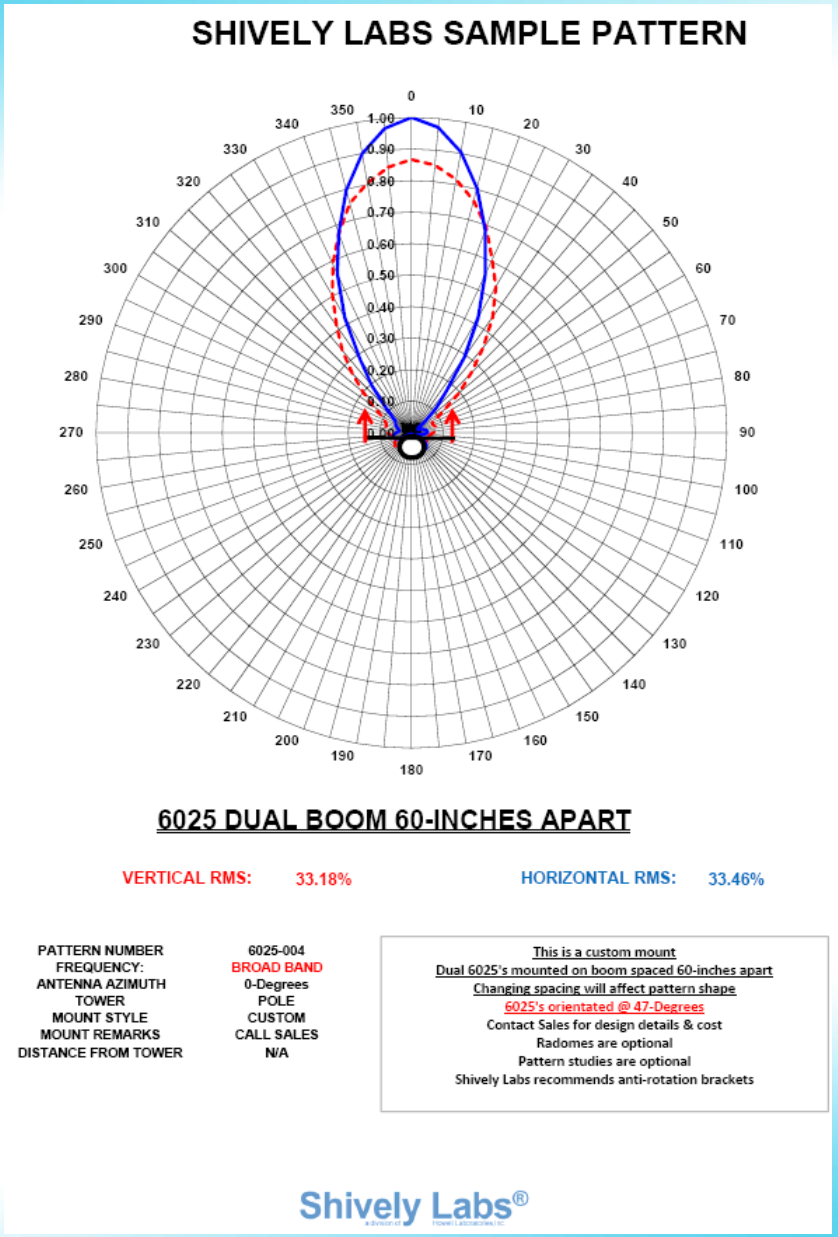
PATTERN NUMBER	6025-014
FREQUENCY:	BROAD BAND
ANTENNA AZIMUTH	0-Degrees
TOWER	POLE
MOUNT STYLE	CUSTOM
MOUNT REMARKS	CALL SALES
DISTANCE FROM TOWER	N/A

This is a custom mount
Dual 6025's mounted on boom spaced 60-inches apart
Changing spacing will affect pattern shape
6025's orientated @ 30-Degrees
Contact Sales for design details & cost
Radomes are optional
Pattern studies are optional
Shively Labs recommends anti-rotation brackets

Shively Labs®

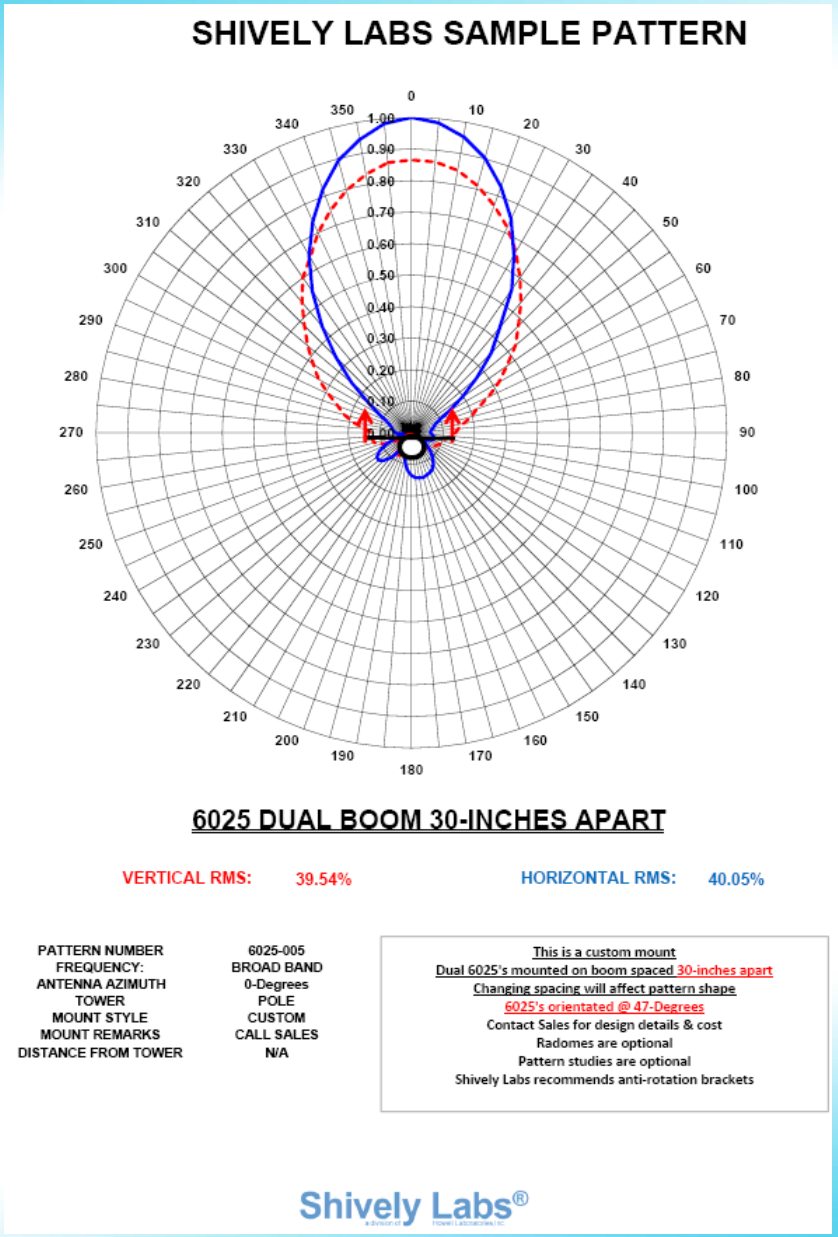
2 Log Periodic antennas 60 inches apart

By placing elements side by side we can control the HPBW and by rotating achieve EP.



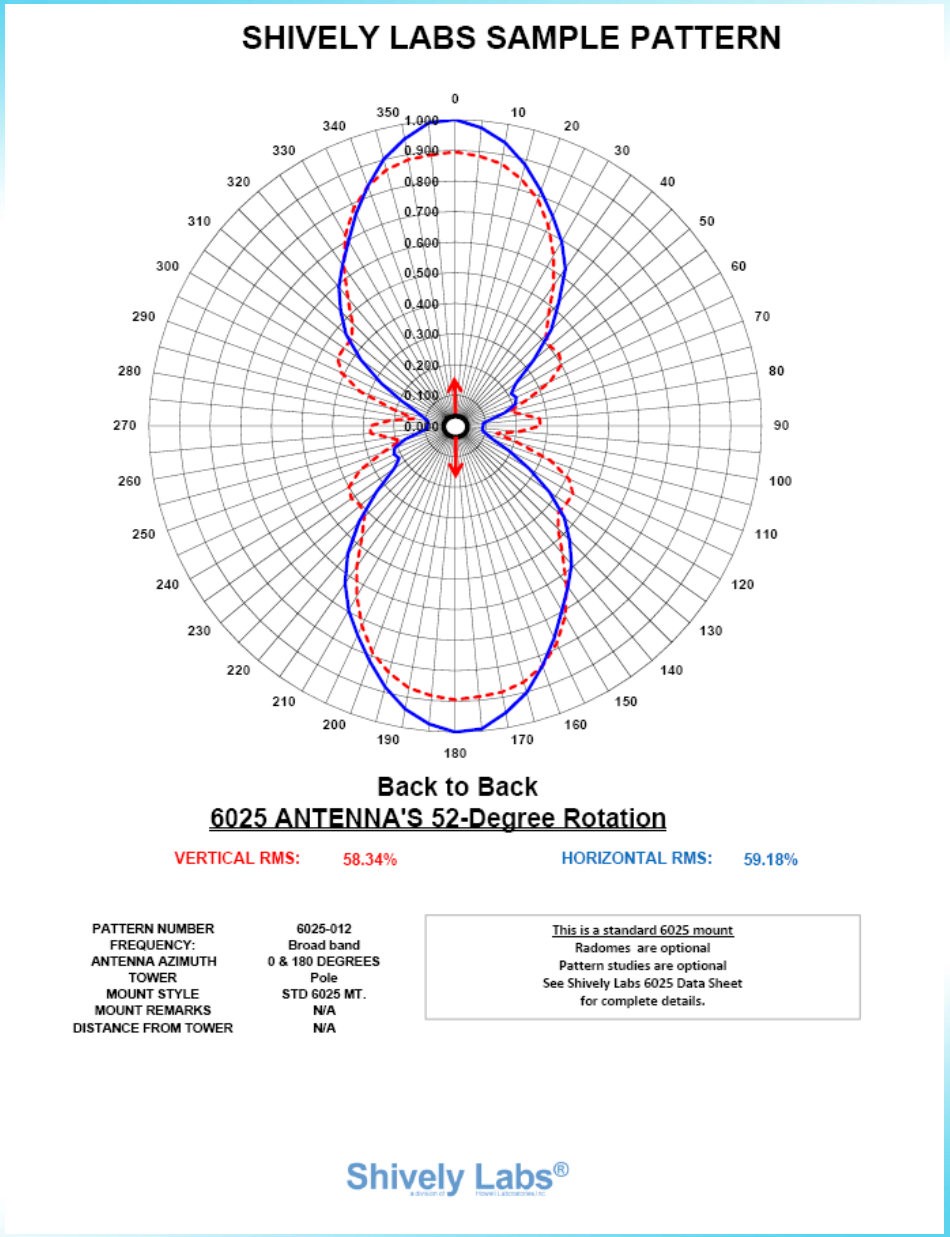
2 Elements side by side but now at 30” separation

Changing the spacing to change the beamwidth



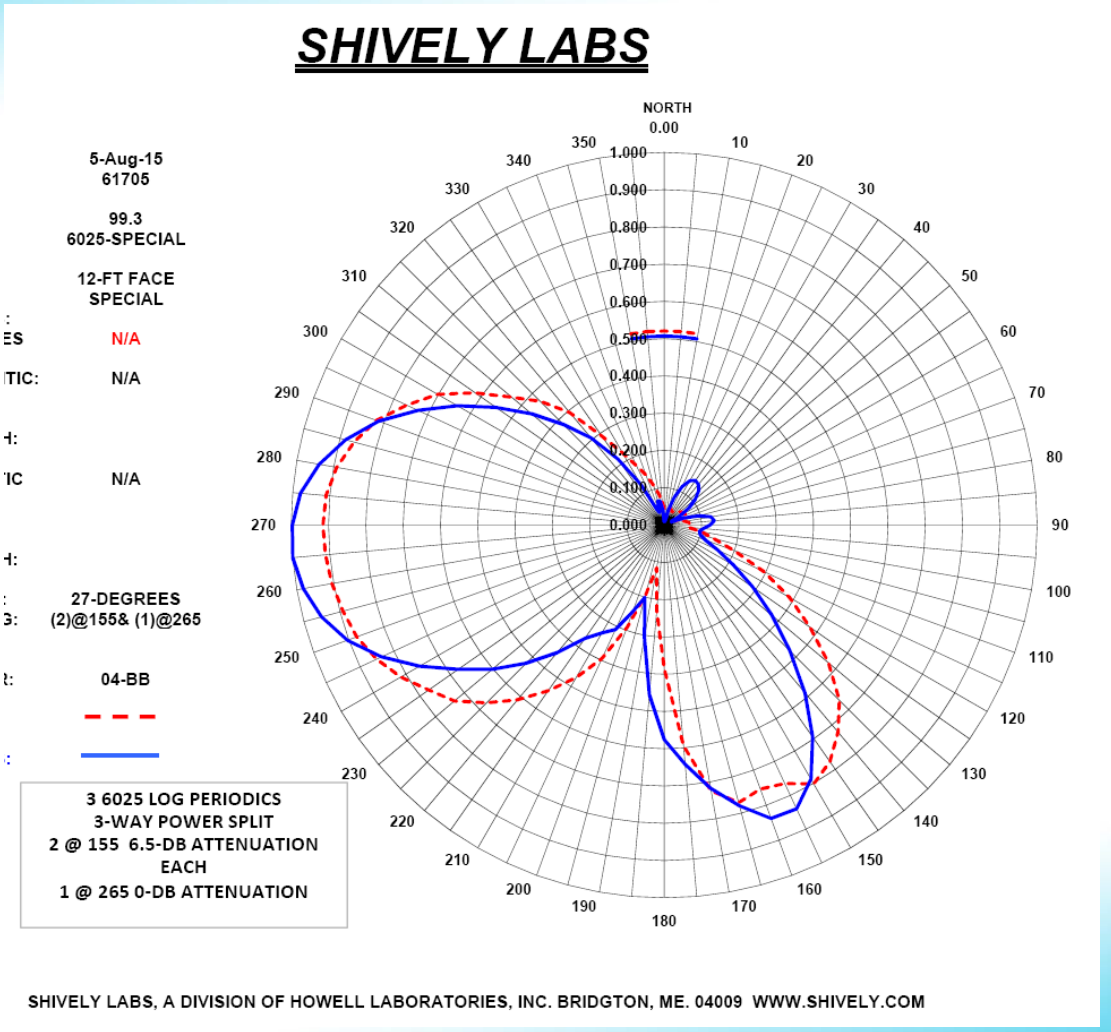
2 Antennas Back to Back

Produces fairly symmetric pattern lobes

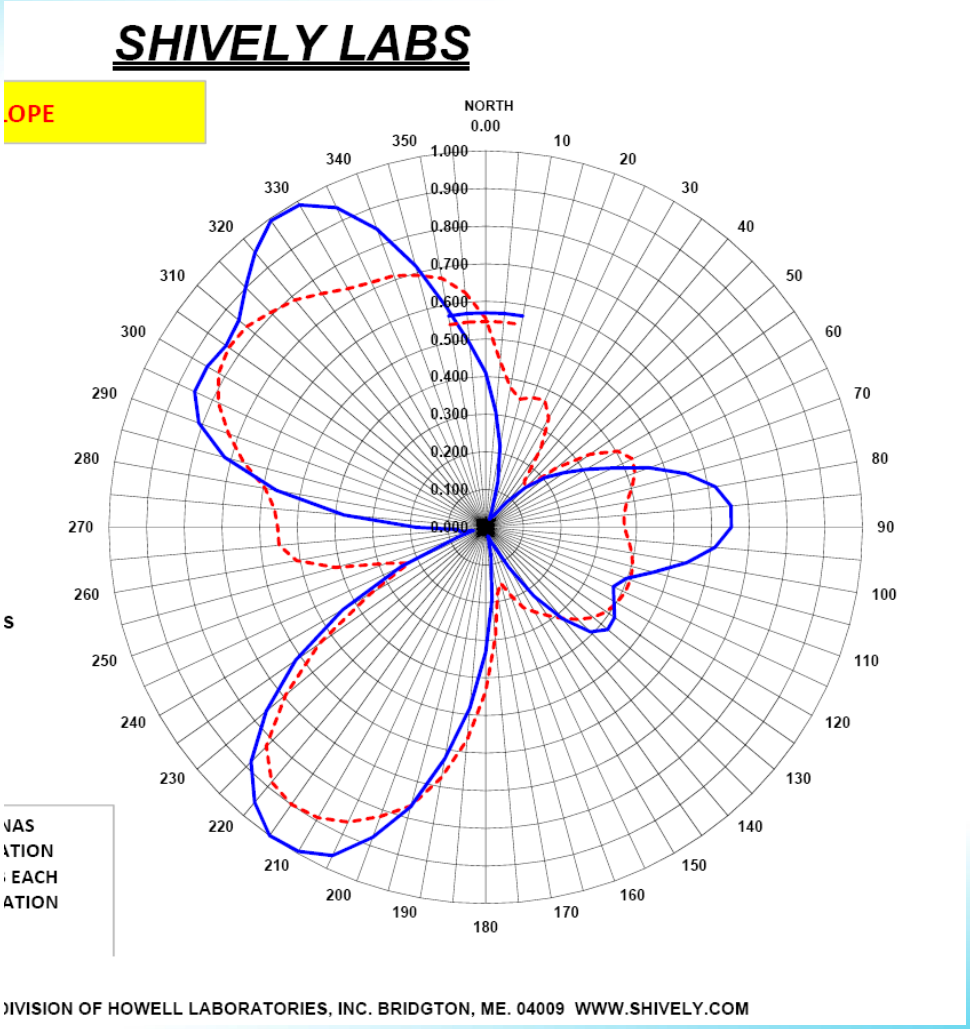


3 6025 elements placed around the tower

Using antenna placement/orientation, array factor, phasing and unequal power division specific patterns can be realized.



6025 elements with special power division



Thank you

References:
“Electromagnetics”, John D. Kraus
“Antenna Theory” Constantine A. Balanis
“Electromagnetic Waves and Radiating Systems” Edwards C. Jordan/ Keith G. Balmain
“Antennas 101” Robert A. Surette
Simulation Software:
ANSYS Electronic Desktop HFSS /RF Designer