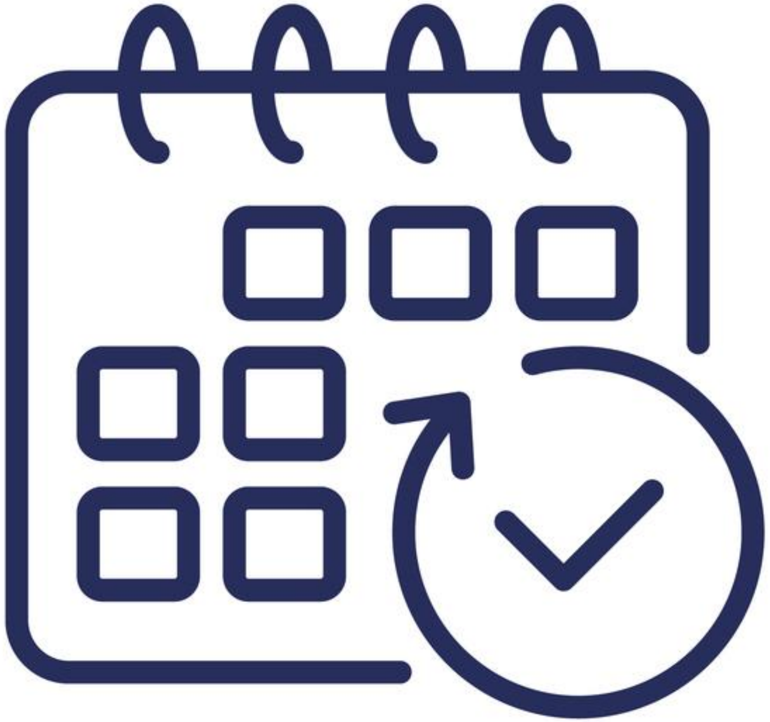
Advances in FM Antenna Technology

Presented By: Dave Benco

September 16th, 2025

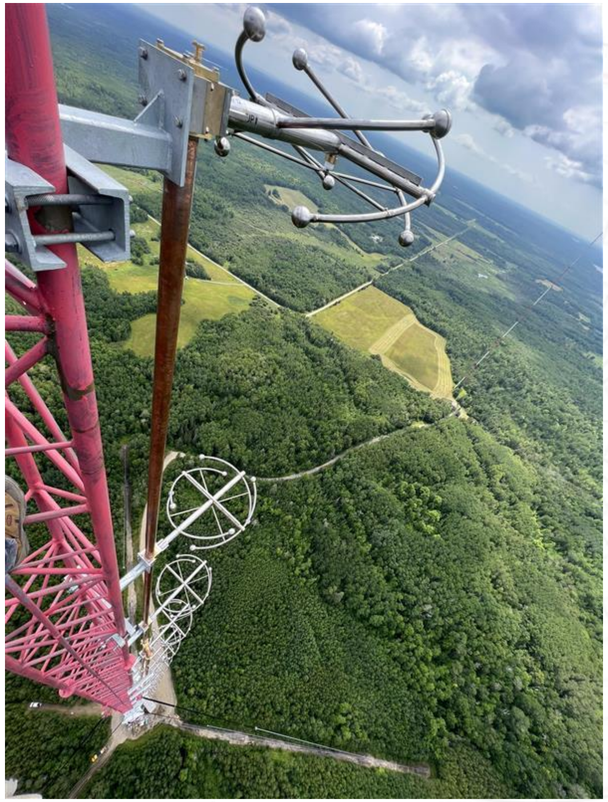
RF ALL THE TIME

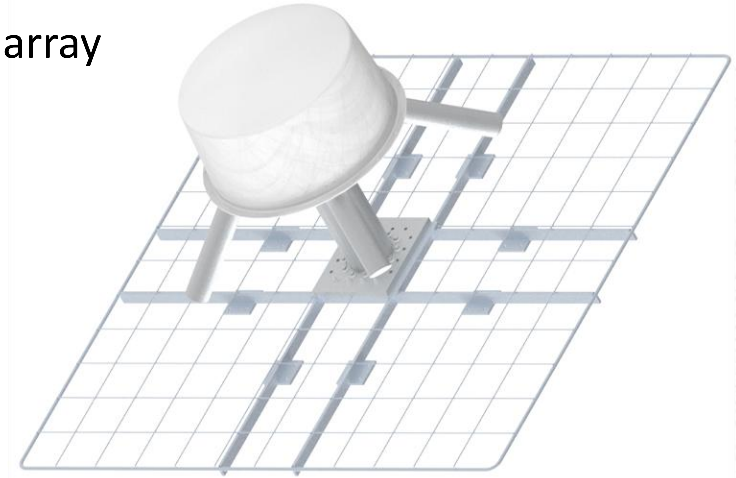


- Dielectric is known for the RCA & Harris brands.
  - TV - Products
  - FM - Products
- 2017 Dielectric Gears up for TV Repack
  - Supplies over 1200 TV Antennas
  - Met our Demand Inquires FM
  - Met our Demand Inquires International
  - Met our Demand Inquires RF Custom
- Post TV Repack
  - TV still Strong
  - International and RF Custom growing
  - FM Not Growing and Slow
- Partner with SCMS 2024
  - FM Growing Fast

Overview

- New FM Technology:
  - DCPC
    - New panel design to increase reliability/reduce cost
    - Maintains/improves performance of traditional panels
  - RingMaster™
    - Maximizes DCR performance
    - Broad bandwidth and low RFR with less bays
  - Ring360
    - Top mounted omni FM antenna
    - Better performance/more reliable than a panel array



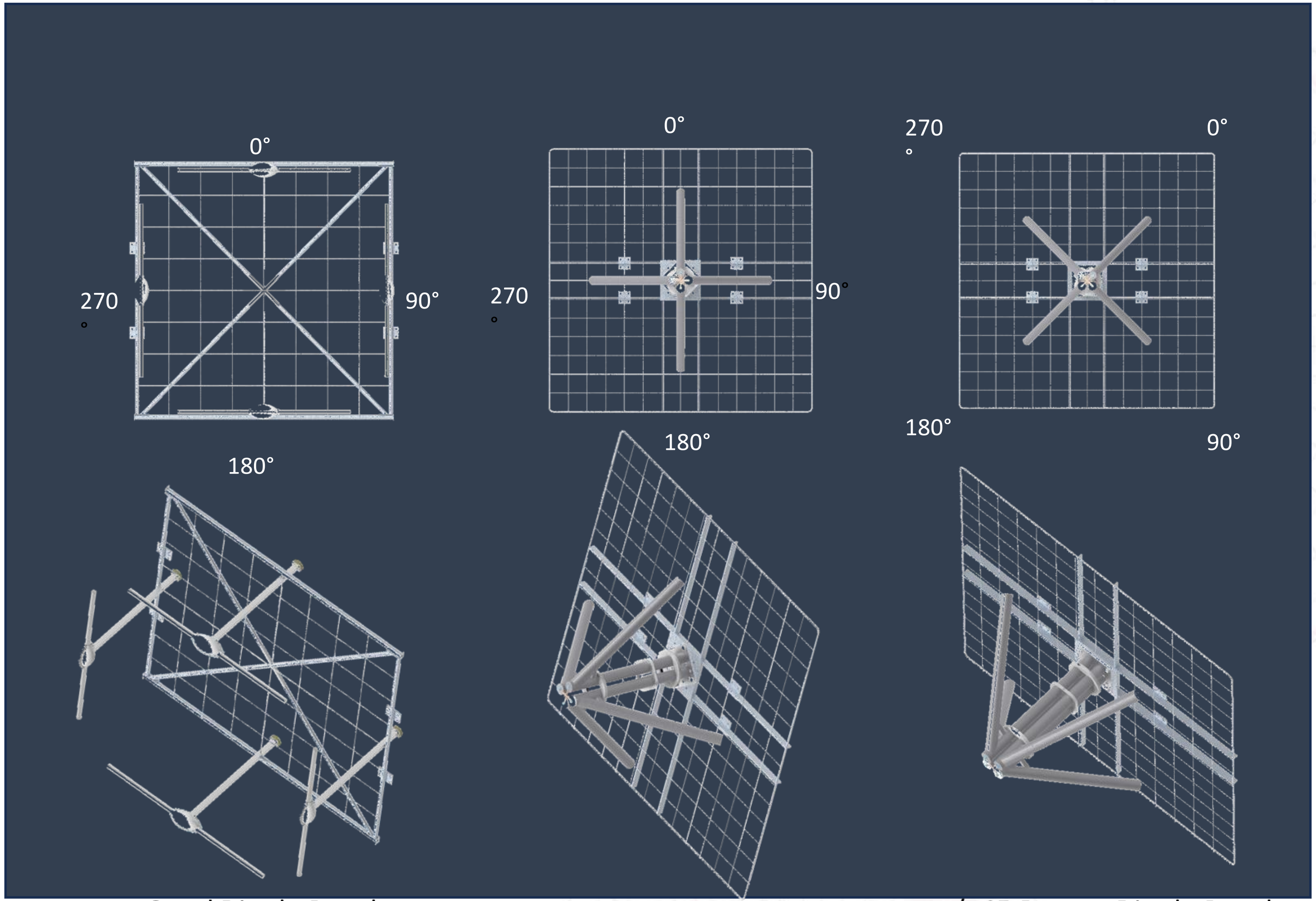


DCPC Panel

Conceptual Design

Historical Broadband Circularly Polarized FM Panel Antennas

- **All designs available today:**
  - **Utilize rotating phase**
  - **Are variations of:**
    - Quad dipole panel
    - Horizontal / Vertical dipole panel
    - +/- 45 Degree dipole panel
  - **Have either 2 or 4 inputs**
    - Single input requires a hybrid
    - Simplifies feed system but adds cost and complexity
  - **Have 4 balun tubes**

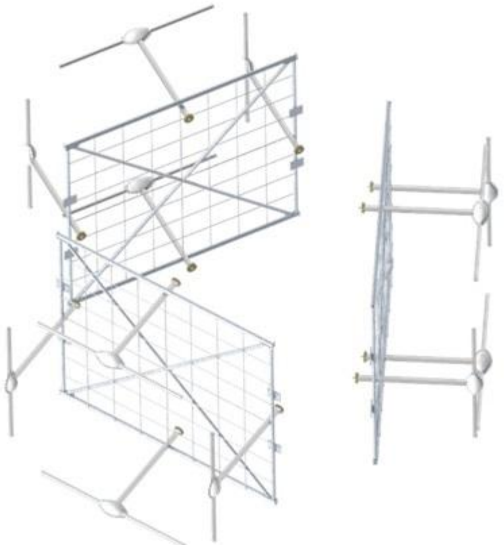


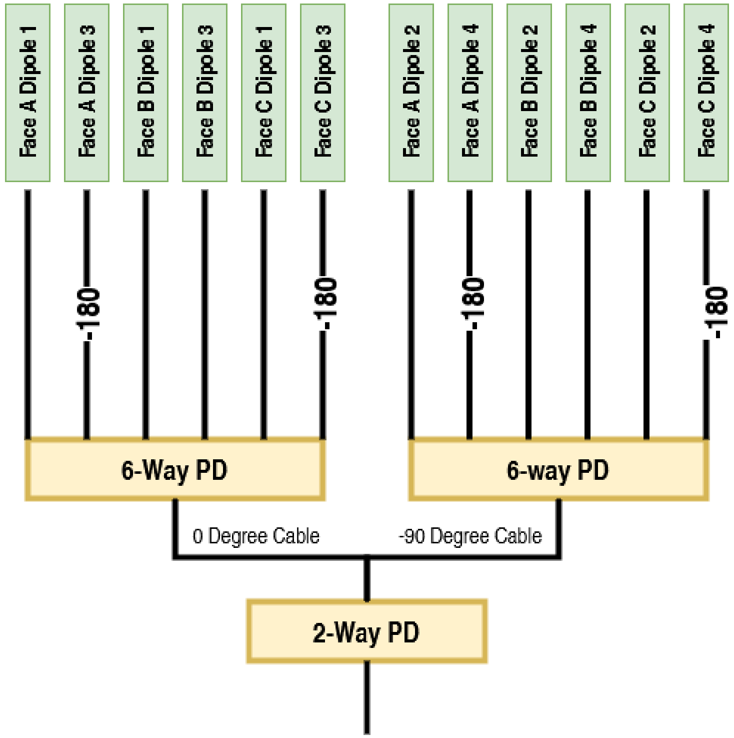
Quad Dipole Panel Horizontal / Vertical Dipole Panel +/- 45 Degree Dipole Panel

Conceptual Design

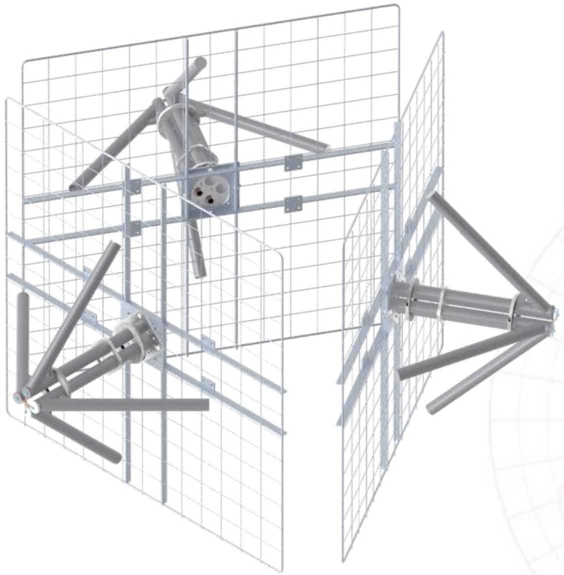
Feed System Comparison

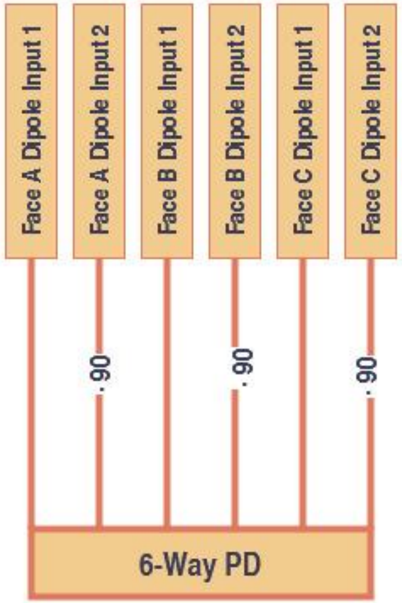
Quad Dipole Panel





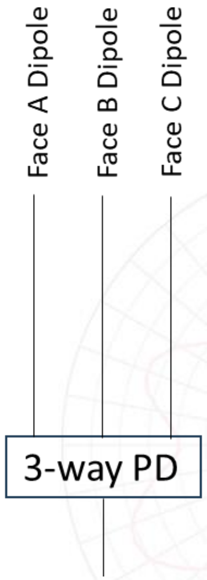
Horizontal / Vertical Dipole Panel
Or
+/- 45 Degree Dipole Panel





Conceptual Design

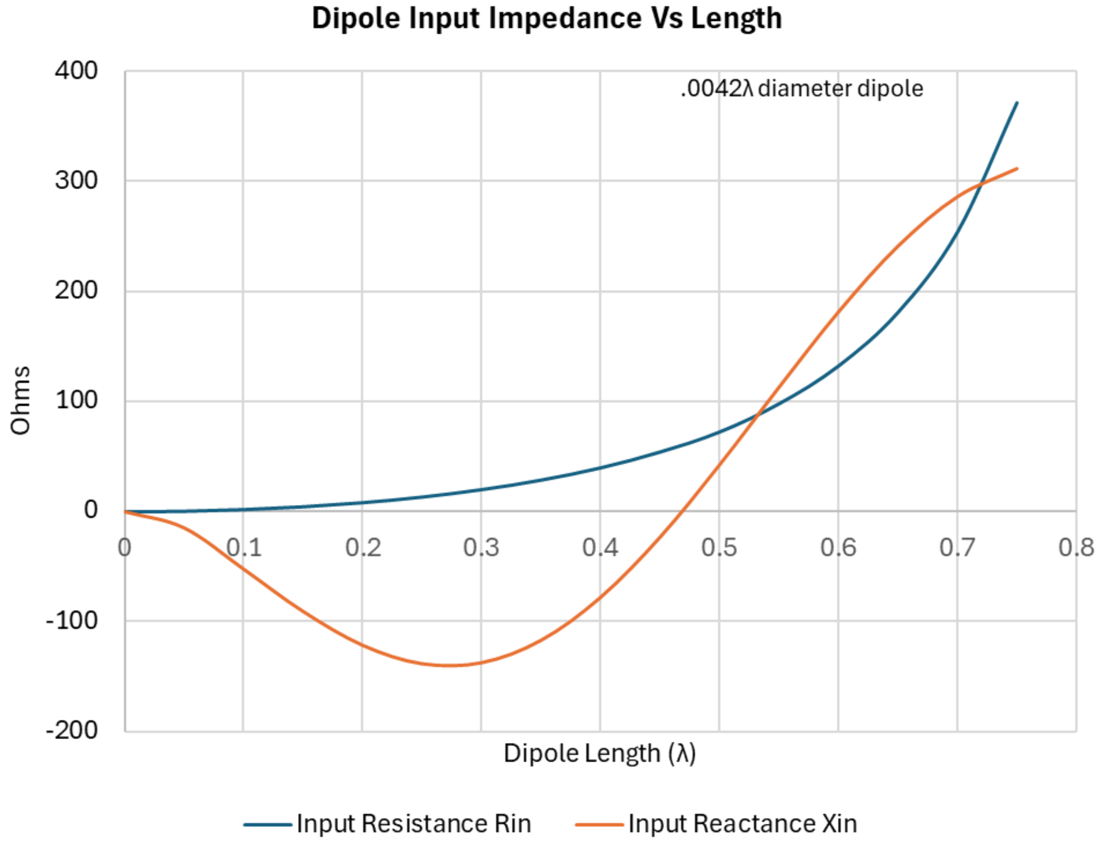
What if we could design a broadband panel with a single input without the use of hybrids and only have one balun tube…….

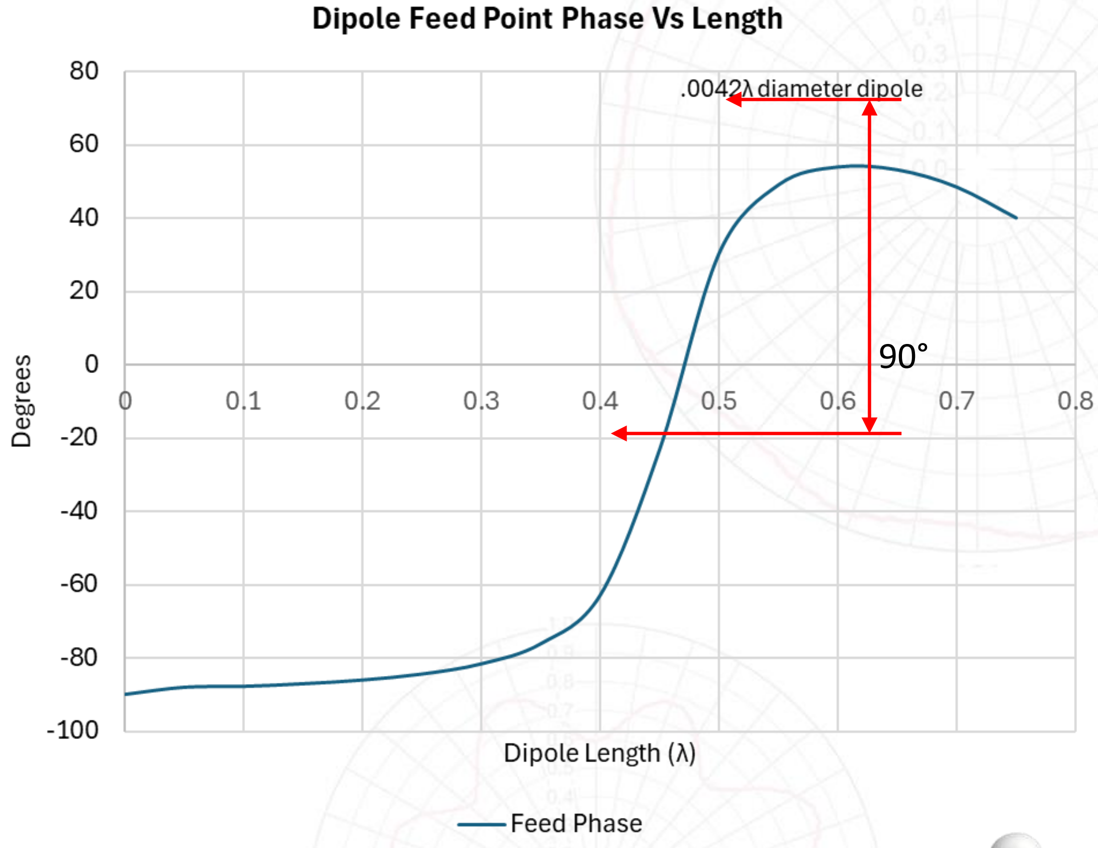


Conceptual Design

Impedance of a Dipole:

- real/imaginary parts are a function of both dipole length and radius





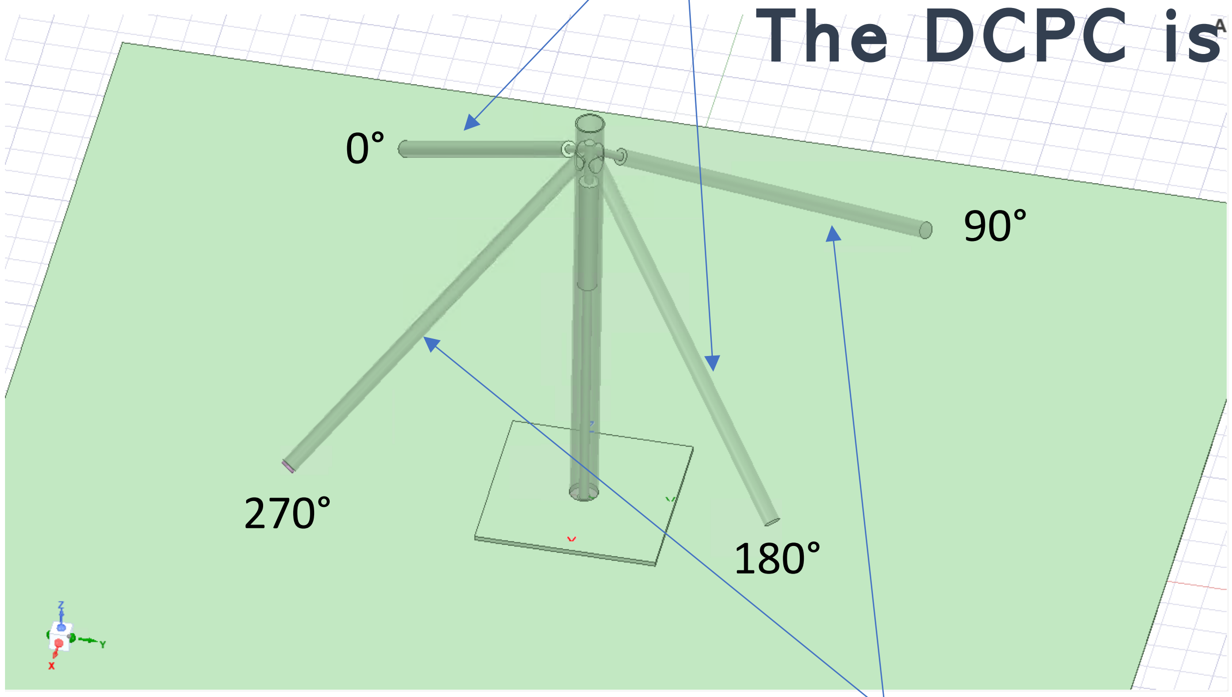
$$\text{Phase} = Tan^{-1}\left(\frac{X_{in}}{R_{in}}\right)$$

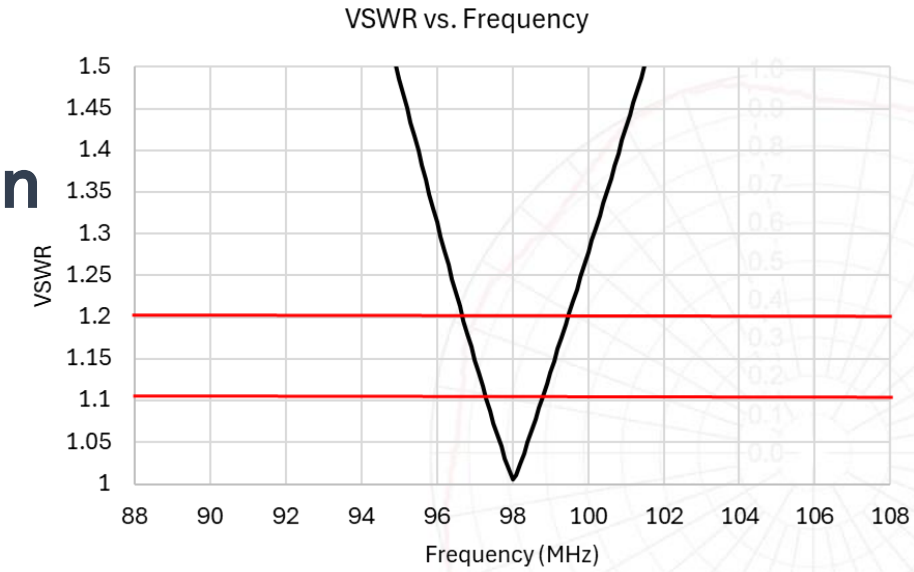
A Dipole with length .52λ will radiate 90° ahead of a dipole of length .43λ

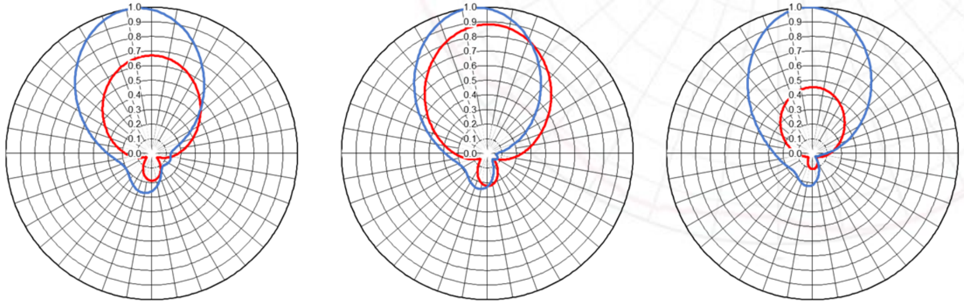
Trusted for Decades. Ready for Tomorrow.

Design

The DCPC is Born







Single input with single balun tube and phase rotation produces circular polarization

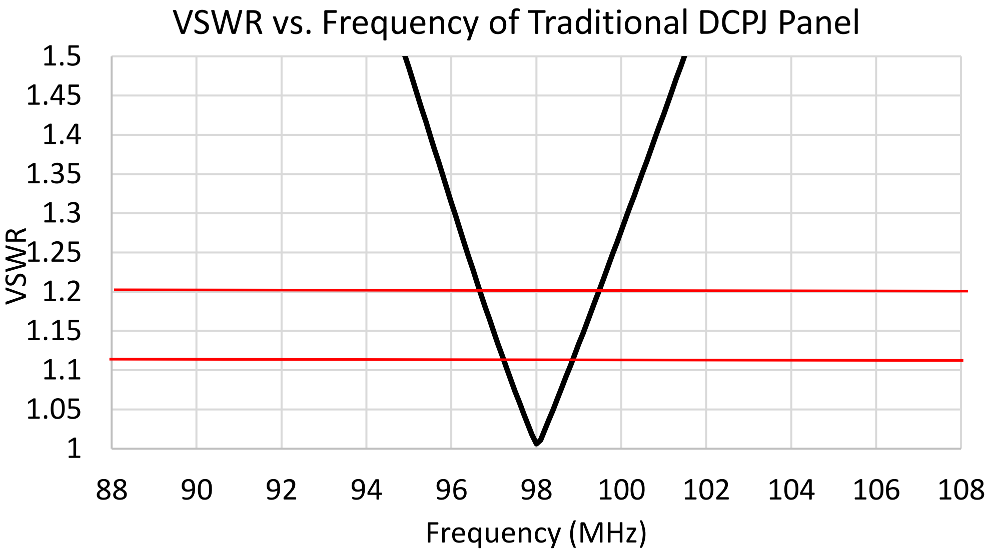
But…..The bandwidth is only 3 MHz and H/V ratio varies across the band

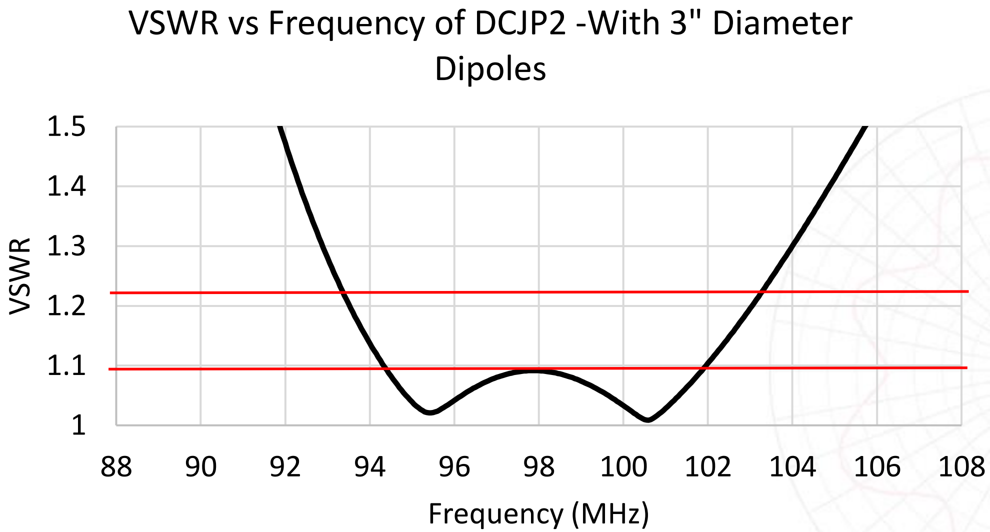
Design

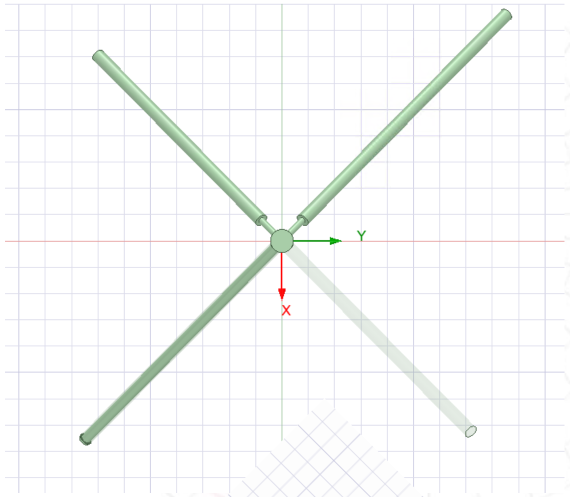
Increasing the Bandwidth – Dipole Diameter

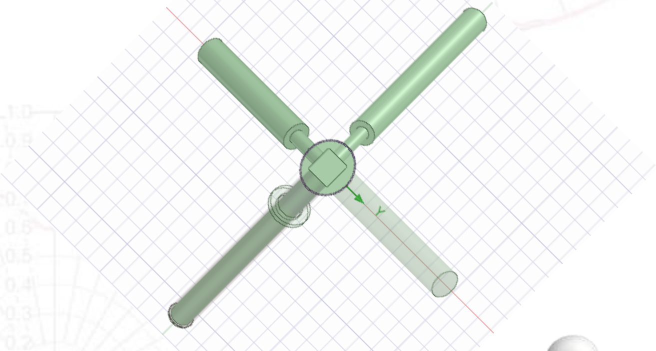
Why Does a Larger Radius Increase Bandwidth?

- **Thicker (larger-radius) dipole → Lower Q (quality) factor**
  - Q ∝ 1 / bandwidth
- **Lower Q = Wider bandwidth**



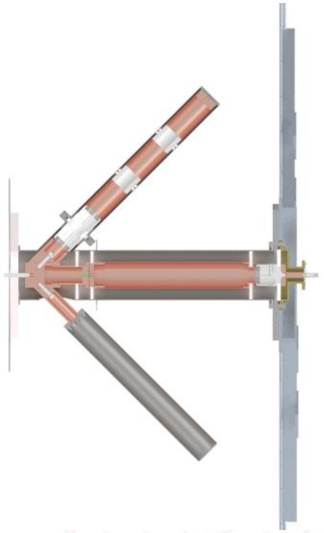






Design

Increasing the Bandwidth – Adding Short Circuit Stub



Using a Short-Circuit Stub for Impedance Matching
Concept Overview:

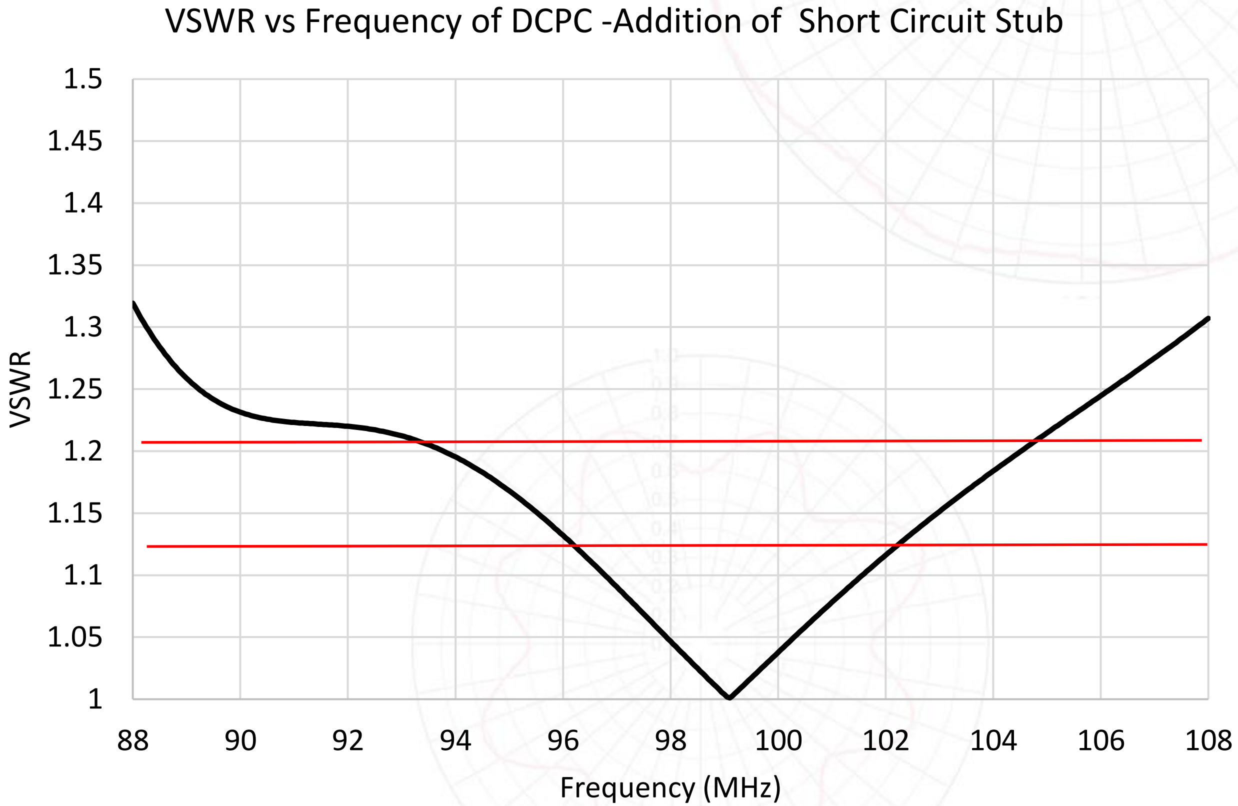
- A **short-circuit stub** placed on a transmission line acts as a **reactive element**.
- It can be sized and positioned to **cancel out the reactive component** of a load impedance.

Benefits:

• Effectively **broadens the usable bandwidth (BW)**.
• Helps achieve a better impedance match over a wider frequency range.

Design Tip:

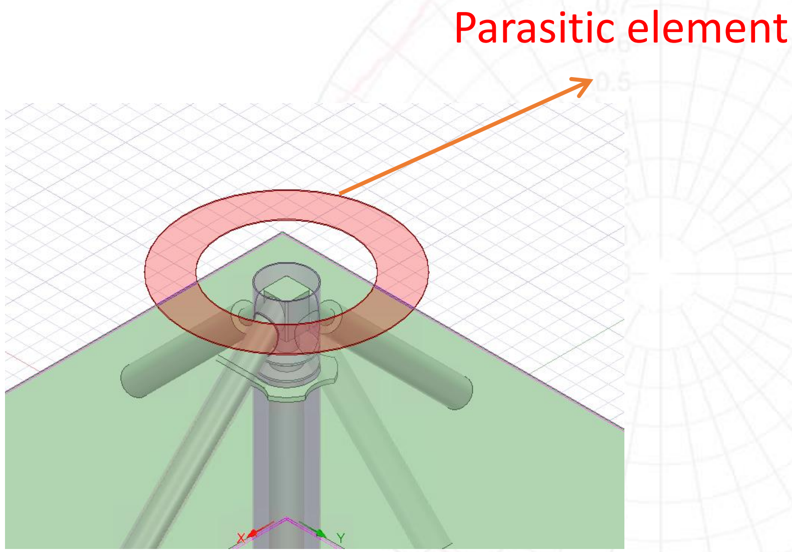
• **Place the stub as close to the load as possible** to maximize the bandwidth improvement.

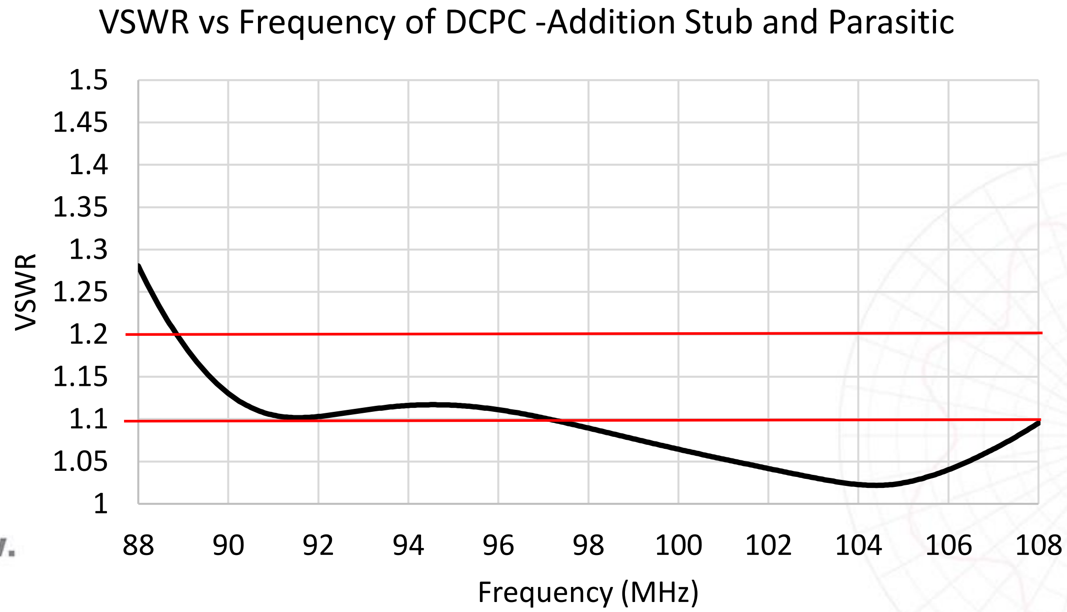


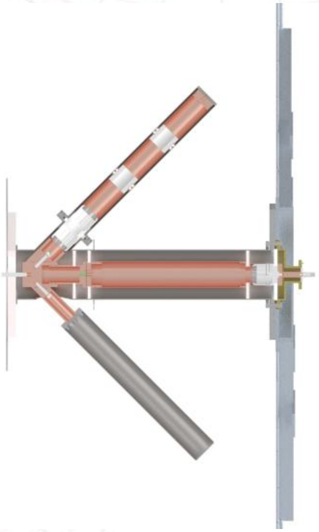
Design

Increasing the Bandwidth – Adding A Parasitic Element

- Parasitic element (e.g., rods, discs, rings) **not directly powered**.
- Electromagnetically **coupled to the driven antenna** (e.g., dipole).
- **Resonate at slightly different frequencies**, expanding the composite response.
- **Enhances bandwidth** by combining the response of driven and parasitic elements.
- **Common in wideband designs** like **log-periodic antennas** and **Yagi-Uda arrays**.







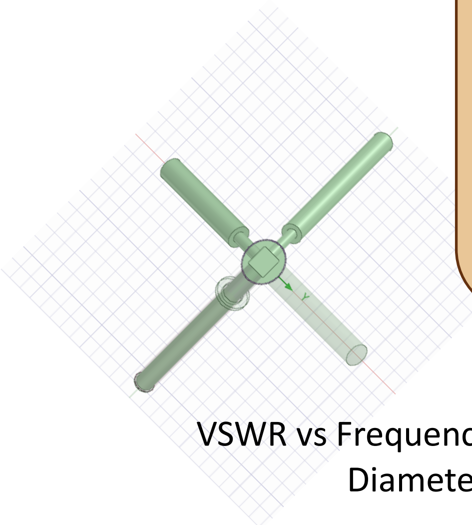
Trusted for Decades. Ready for Tomorrow.

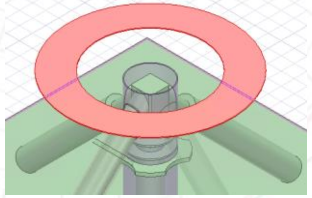
Design

Dipole Diameter → **Increase diameter from 1 inch to 3 inches**

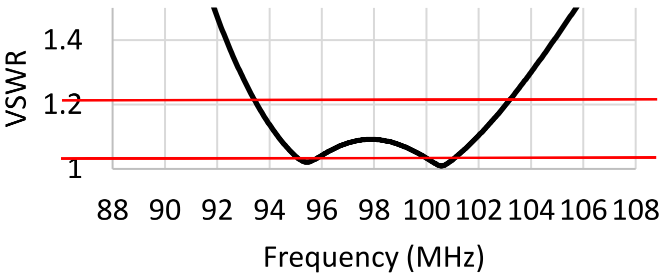
Short Stub → **Helps achieve a better impedance match over a wider frequency range**

Passive Parasitic Element → **Adding a passive Cone or a Disc Resonate at slightly different frequencies.**

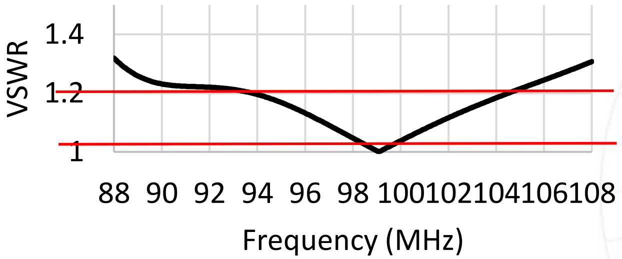




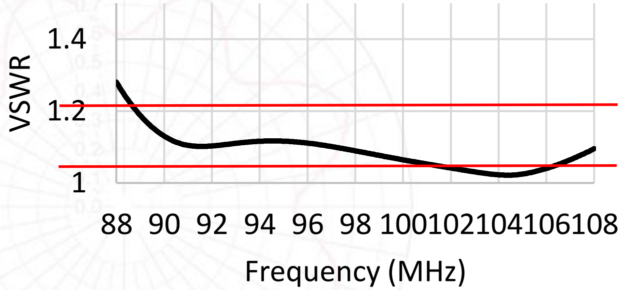
VSWR vs Frequency of DCPC -With 3" Diameter Dipoles



VSWR vs Frequency of DCPC - Addition of Short Circuit Stub



VSWR vs Frequency of DCPC - Addition Stub and Parasitic



Performance

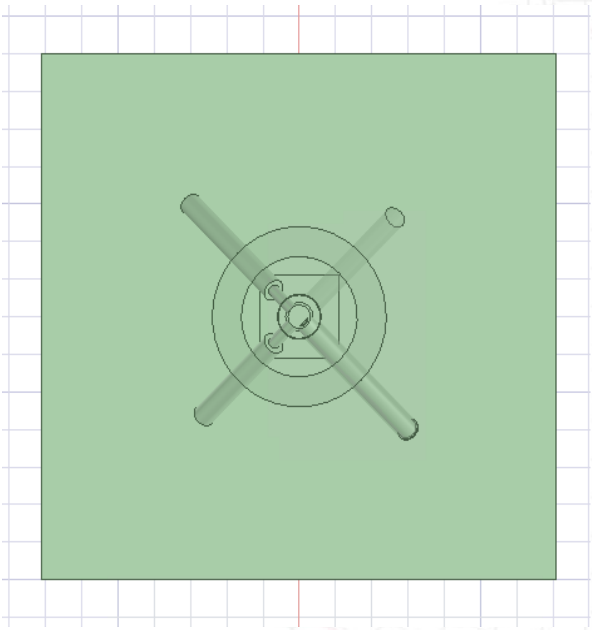
H/V Polarization Ratio as a Function of Differential Dipole Length on DCPC

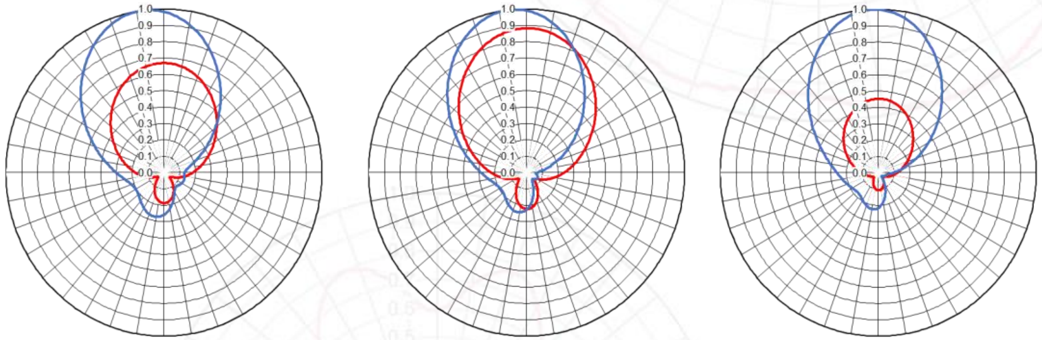
- The **Horizontal-to-Vertical (H/V) polarization ratio** is frequency-dependent due to variations in **differential dipole length** on the **DCPC** panel.
- At the **center frequency of 98 MHz**, the dipole geometry is designed so that: $\mathbf{H/V\ Ratio} \approx 1$

This achieves **equal horizontal and vertical components**, optimizing polarization balance.

- However, due to frequency sensitivity:
    - At **88 MHz**: $\mathbf{H/V\ Ratio} \approx 0.67$
    - At **108 MHz**: $\mathbf{H/V\ Ratio} \approx 0.45$

- The polarization ratio drops at the edges of the band because the dipole lengths become less effective at those frequencies.





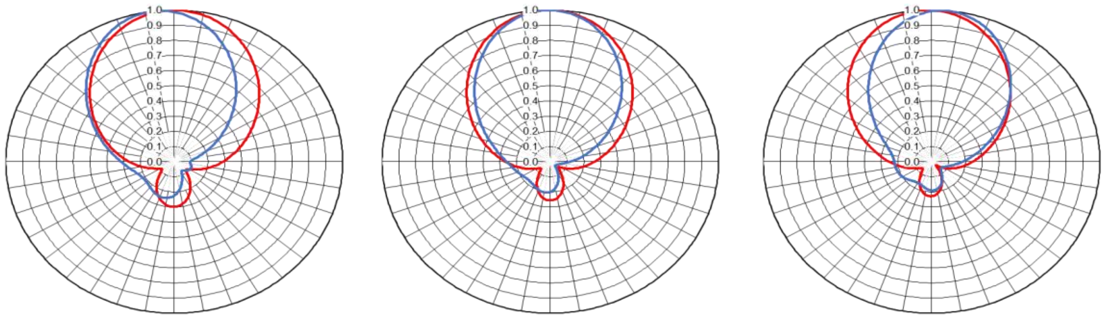
88 MHz | 98 MHz | 108 MHz

Blue – Horizontal Polarization   Red – Vertical Polarization

Performance

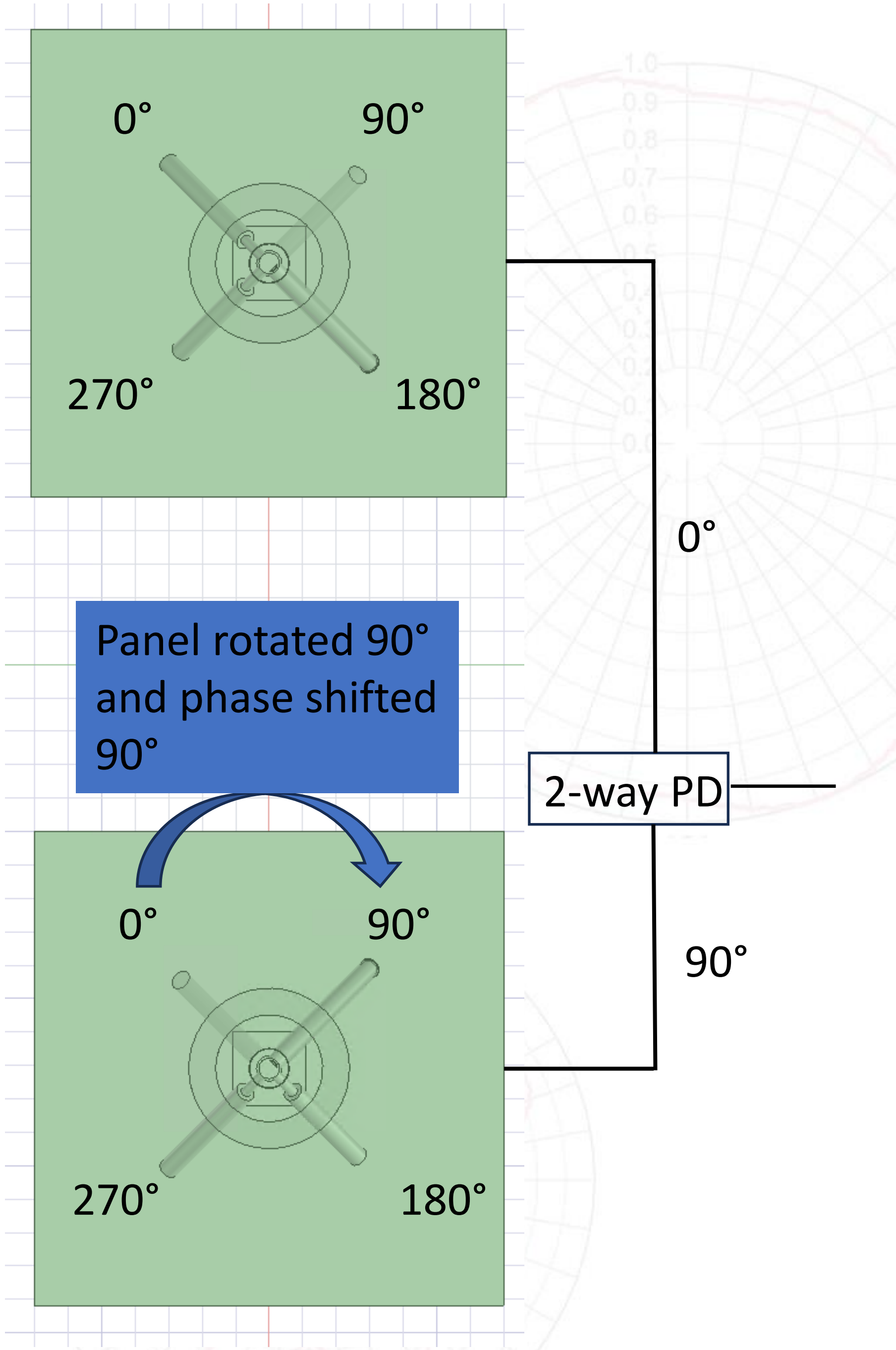
Azimuth Pattern and H/V Ratio

Stabilized H/V Ratio of the DCPC FM panel antenna across the band of a two-layer array using bay rotation



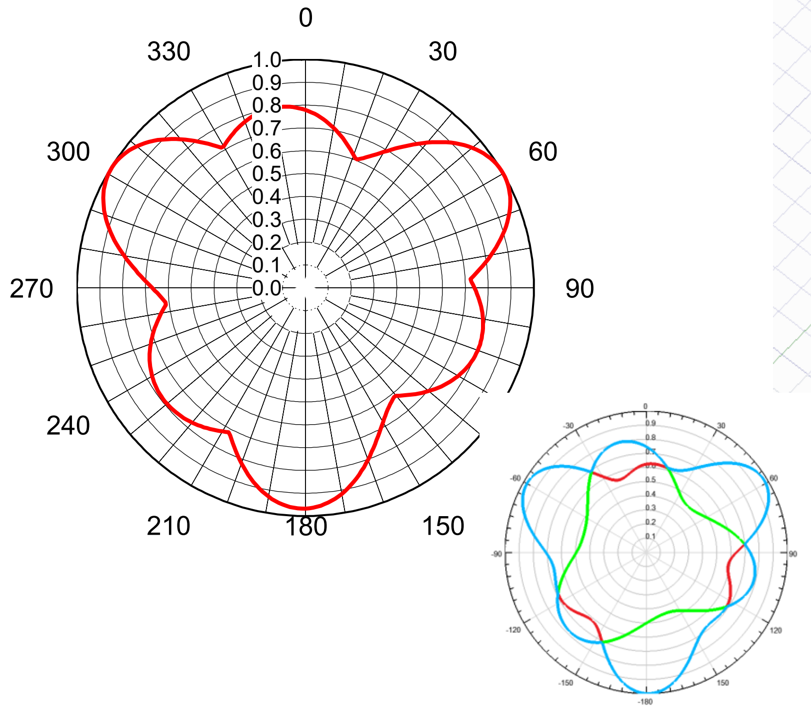
88 MHz | 98 MHz | 108 MHz

Blue – Horizontal Polarization   Red – Vertical Polarization

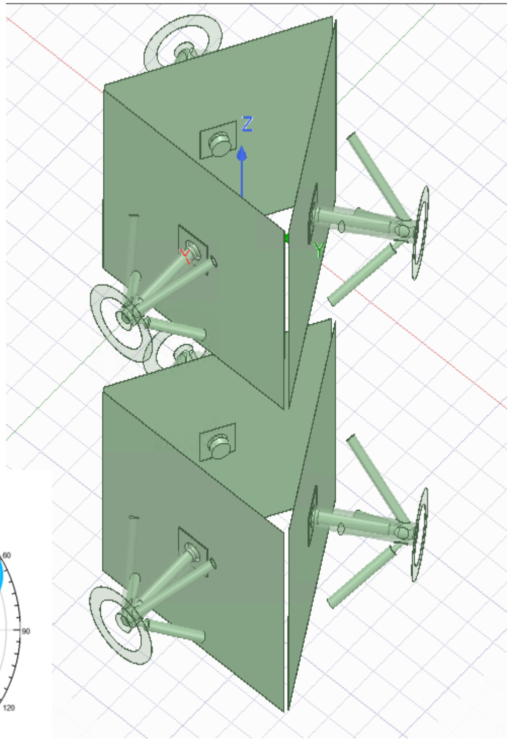


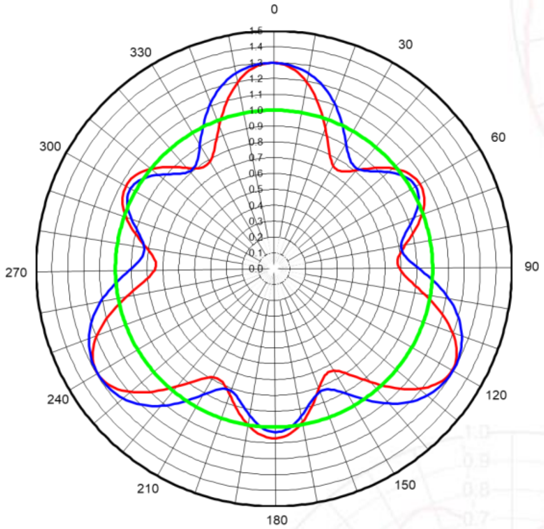
Performance

Fully Circular Stabilized Pattern in 6 Panel Configuration



DCPC panels circular pattern





CBR panels circular pattern

Trusted for Decades. Ready for Tomorrow.

Performance

High-Power Handling in the DCPC Broadband FM Antenna

Traditional broadband FM master antennas must handle **high combined power** from multiple stations.

In conventional designs, the limiting factor is either:

- The **balun tube**
- The **flat feed strap** used to connect the balun's inner conductor to the dipole

These components are prone to electrical breakdown, especially under high power.

DCPC Design Improvements

- The **new DCPC** uses a **single, large 6-inch balun tube**

✅ **No feed straps required**

✅ **Reduces breakdown risk significantly**

- This is a **major improvement** over older designs that rely on **multiple small balun tubes and fragile feed straps**.

Power Applied (Single Bay): 10 kW

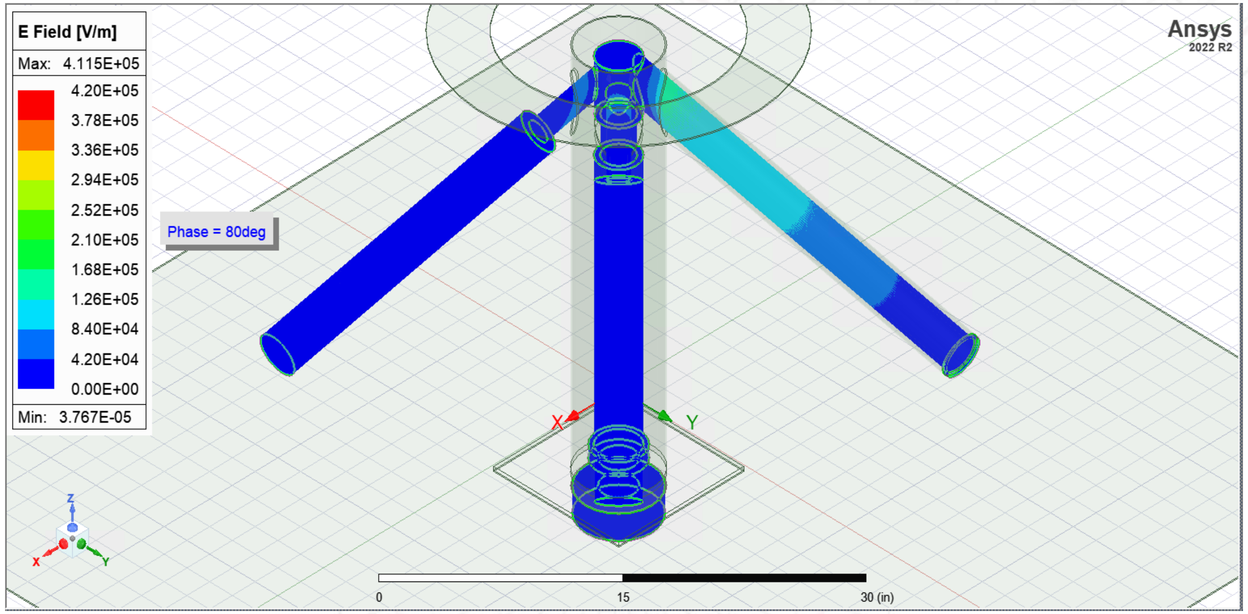
- **Measured Peak Voltage:** 4.11 kV/cm
- **Air Breakdown Threshold:** 22.8 kV/cm

Voltage safety factor

$$\frac{22.8}{4.11} \approx \mathbf{5.5:1}$$

Peak power safety factor

$$> \mathbf{30:1}$$



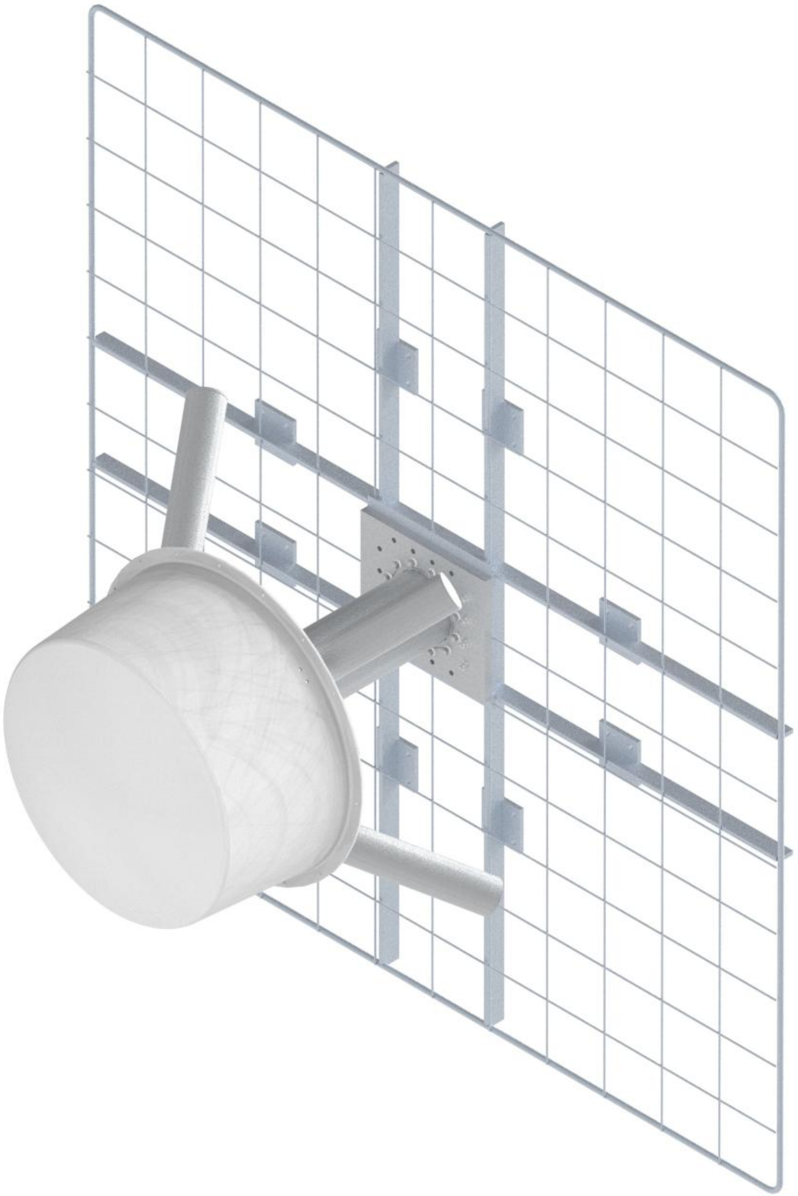
Conclusion

The new DCPC Panel:

- Has increased reliability due to reduced complexity and number of components
  ie: Power Dividers, Feed lines, Balun tubes

- Eliminates power vulnerable components
  ie: Hybrids, Feed straps

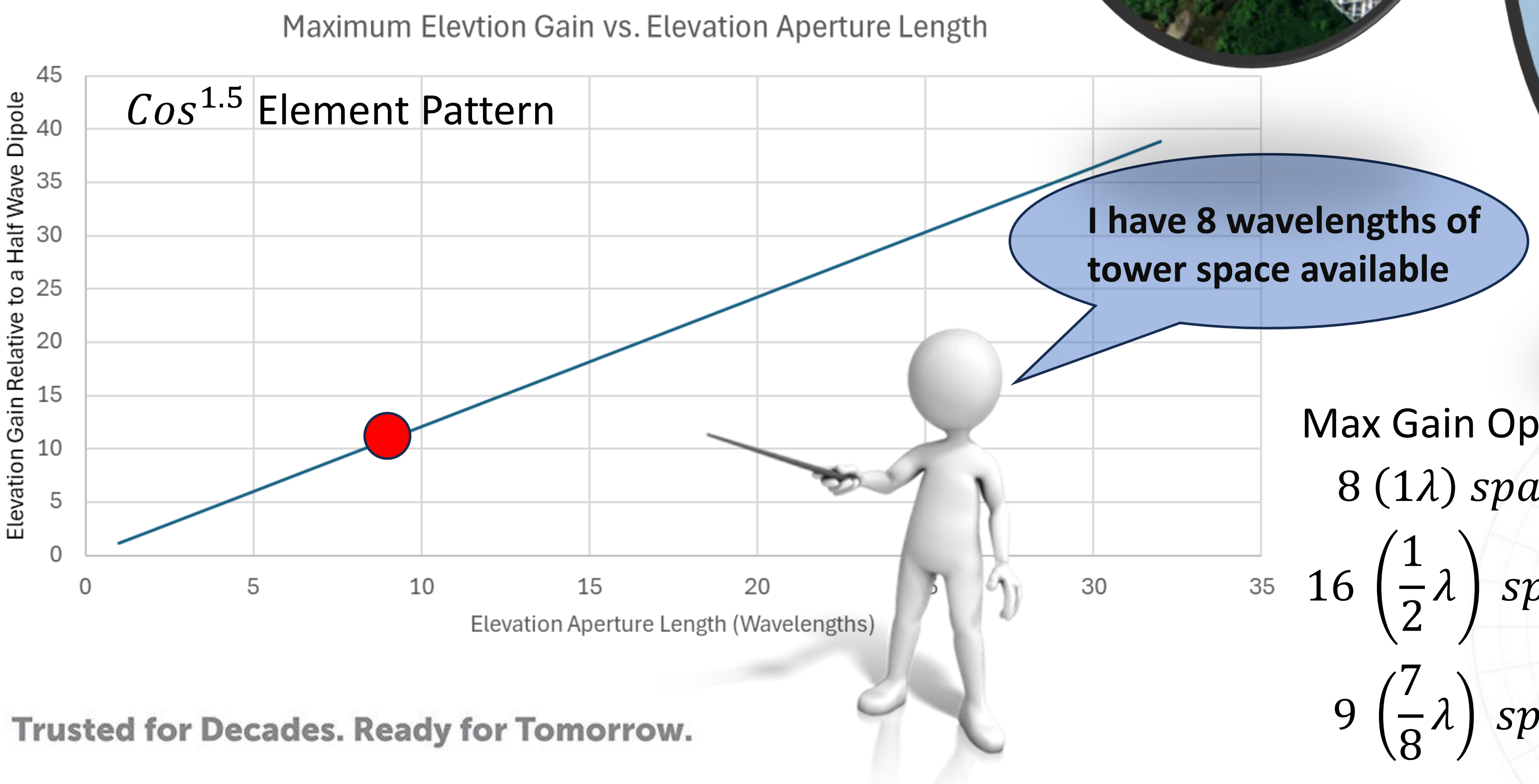
All this means reduced cost!!



RingMaster™

Historical Side Mount FM Antenna Configurations

- FM antenna configurations:
  - Full-wave
  - Half-wave
  - (N-1)/N $\left(\frac{2}{3}, \frac{3}{4}, \frac{4}{5}, \frac{5}{6}, \frac{6}{7}, \frac{7}{8}, \text{ ...wave}\right)$



Max Gain Options

$8\ (1\lambda)$ *spaced bays* (Narrow Band Applications)

$16\ \left(\frac{1}{2}\lambda\right)$ *spaced bays* (Broadband Applications)

$9\ \left(\frac{7}{8}\lambda\right)$ *spaced bays* (Low RFR Applications)

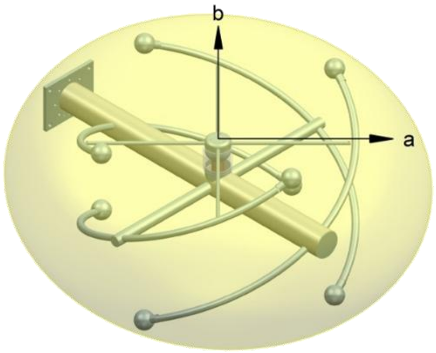
Full-Wave Spacing - Bandwidth

Simplest of all the options

- IEEE -2015 “Considerations for -10 dBc IBOC Combined Station Side-mount Master FM Antenna Design”
    - Maximum achievable bandwidth of a circularly polarized FM ring antenna radiator is given by:

John Schadler, 2015

$$bw = 3.9 \cdot \left[\frac{VSWR - 1}{\frac{a}{2b}\left(\frac{1}{k^3 a^3} + \frac{2}{ka}\right)\sqrt{VSWR}} \right]$$



Where : a and b are the major and minor ellipse radii
VSWR is the maximum allowed within the passband

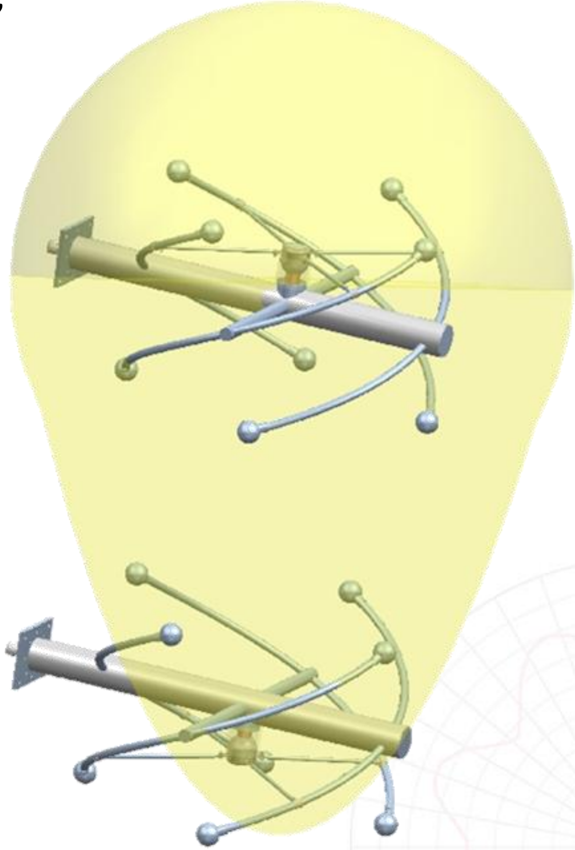
BW is Purely a function of Volume

So….Is making the bay bigger the only way to increase the bandwidth?

Half-Wave Spacing - Bandwidth

What happens in a ½ wave spaced configuration?

- When bays are brought close together (1/2 wave spaced), there is heavy mutual coupling.
- Coupling “stretches” the volume
  - Increases the apparent volume and thus the achievable bandwidth

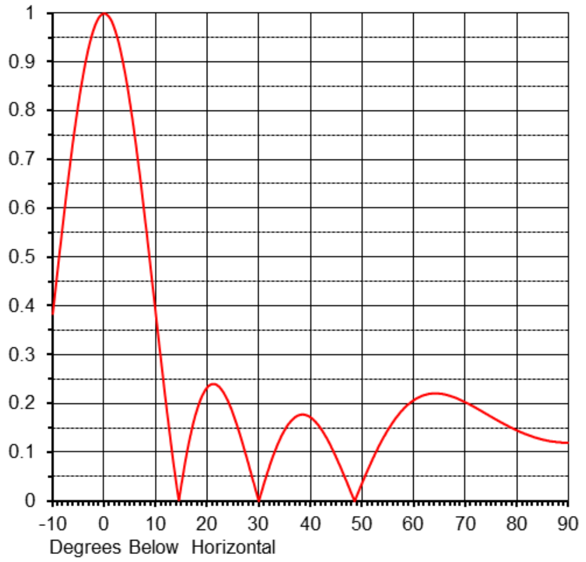


N-1/N and Downward Radiation

- The null locations in an elevation pattern are defined by:

$$\delta = sin^{-1}\left(\frac{k\lambda}{nd}\right)$$

Where:
$\delta =$ Null angle
$n =$ Number of layers
$d =$ Layer spacing
$k =$ Integer
$k \neq n$



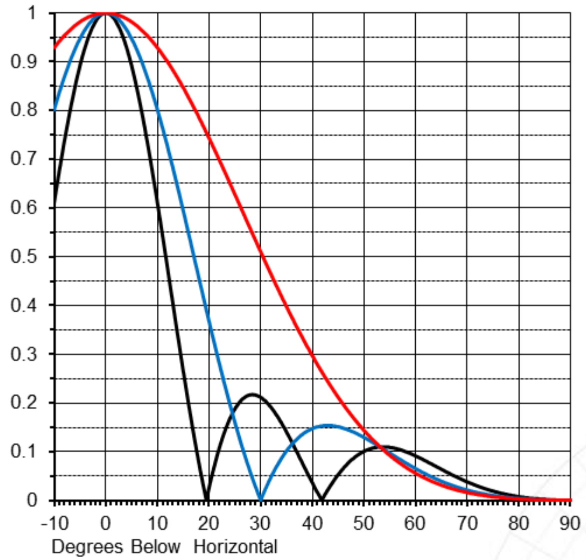
Example : n=4
d=1
Gain = 4.6

k	Null angle
1	14.5
2	30.0
3	48.6

- A null at 90 degrees will eliminate downward radiation

$$90 = sin^{-1}\left(\frac{k\lambda}{nd}\right) \quad \text{or} \quad \left(\frac{k\lambda}{nd}\right) = 1 \;\rightarrow\; d = \frac{k\lambda}{n}\; for\; k = 1,2,3 \ldots.$$

Example: For n=4, k=1,2,3 The solutions are $d = \frac{\lambda}{4}, \frac{2\lambda}{4}, \frac{3\lambda}{4}$

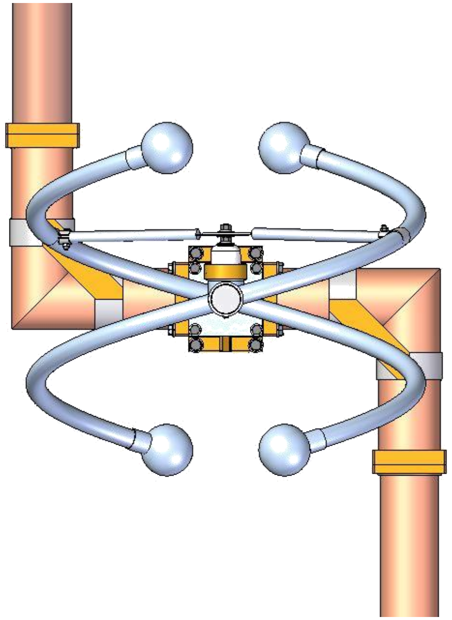


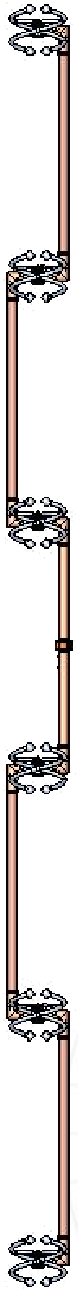
d=.25 Gain = 1.6
d=.5 Gain = 2.7
d=.75 Gain = 3.8

Note k = 3 or $\frac{(n-1)\lambda}{n}$ provides the most gain efficient solution for zero downward radiation

N-1/N Spacing

- N-1/N spacing is achieved by "The Funky Elbow"
- Zigzag the feedline to keep the bays in phase but shorten the distance between them
- 2 Extra elbows per bay





Historical FM Side Mount Antenna Configurations – Pro's and Con's

For the same aperture space and gain:

	Full-wave spaced	Half-wave spaced	(N-1/N) spaced
Pro's	• Min # of elements • Lowest Wind load	• BW increased (full band achievable) • Reduced sensitivity • No downward radiation • Higher power / voltage handling	• No downward radiation
Con's	• Limited BW • Downward radiation	• Max # of elements • Cost • Highest wind load	• Limited BW • Cost: elbows • More connections

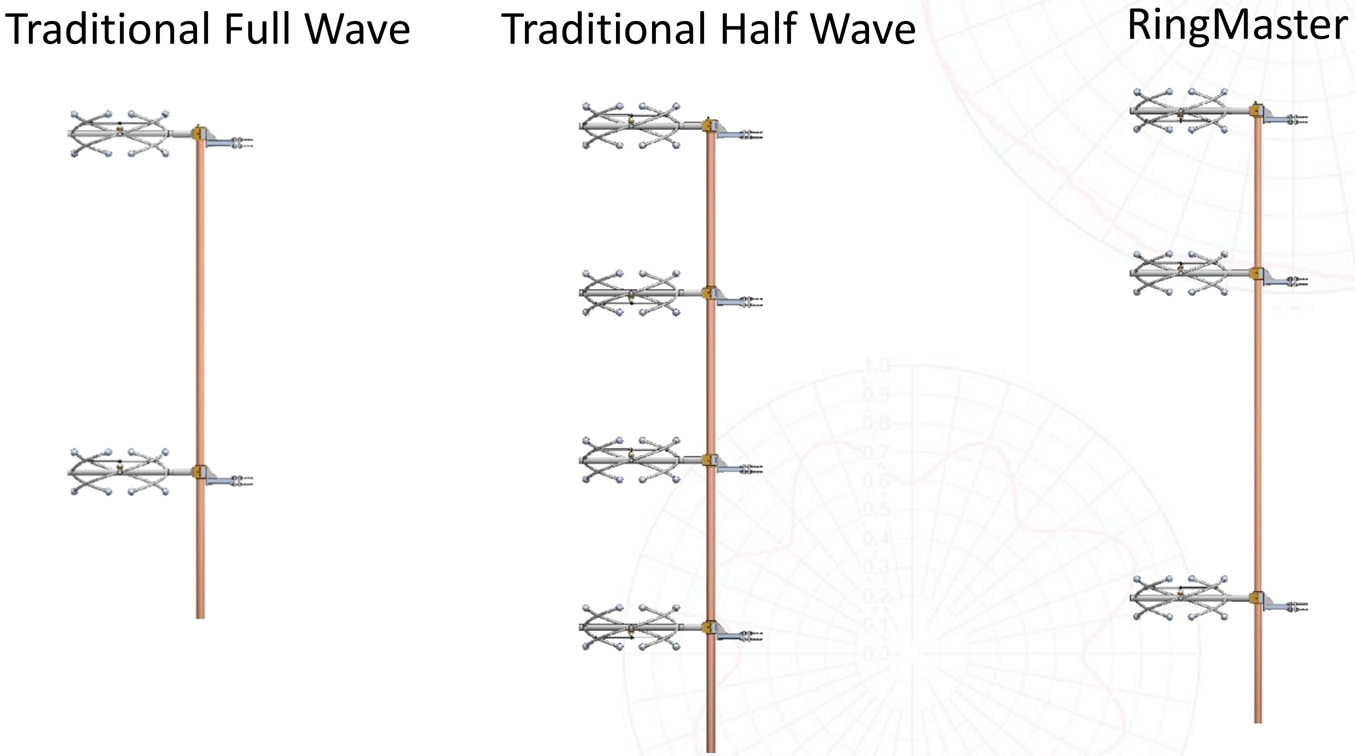
A New Option

- **RingMaster ™**
  - Combinations of half and full wave spaced bays
  - Reduces number of bays in the same aperture
  - Maintains broadband characteristics
  - Simple concept
  - New technique incorporating known technology

RingMaster™

Maximizing DCR Antenna Performance

Patent Pending



Variety of Options and Combinations

- Not limited to any particular bay type (Q, M, S, C, H……bay)
- Flexibility in combinations

DCRM-6 Center fed $\left[\frac{1}{2},1,1,1,\frac{1}{2}\right]$

DCRC-6 End Fed $\left[1,\frac{1}{2},\frac{1}{2},\frac{1}{2},\frac{1}{2}\right]$

DCRU-8 Dual Center fed $\left[\frac{1}{2},1,\frac{1}{2},1,\frac{1}{2},1,\frac{1}{2}\right]$

Note : ½ wave pairs will provide low RFR

For 3 to 12 Bays:
Possible full wave / half wave combinations for each bay type

Bays	Spacing Combinations
3	2
4	6
5	14
6	30
7	62
8	126
9	254
10	510
11	1022
12	2046
16	32766

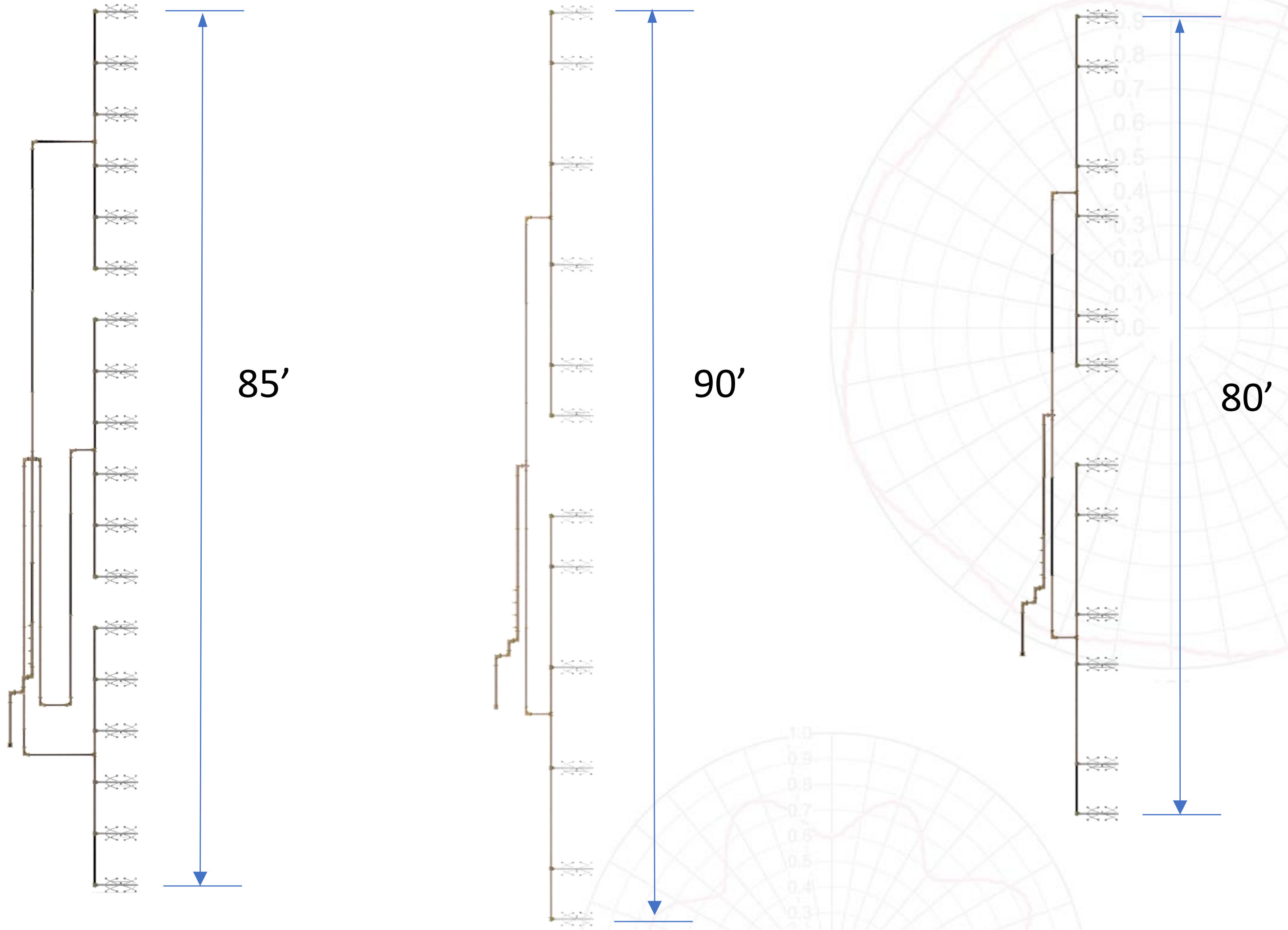
Providing the Best Bandwidth with the Least Number of Elements

Example

- Available aperture space of 90’
- Side mount
- Broadband - Multi frequency
- Options
  - 18 Bay - Half wave spaced
  - 12 Bay - RingMaster
  - 12 Bay - RingMaster low RFR
- If Low RFR is a requirement, the two choices are either the 18 bay ½ wave spaced or the RingMaster Low RFR

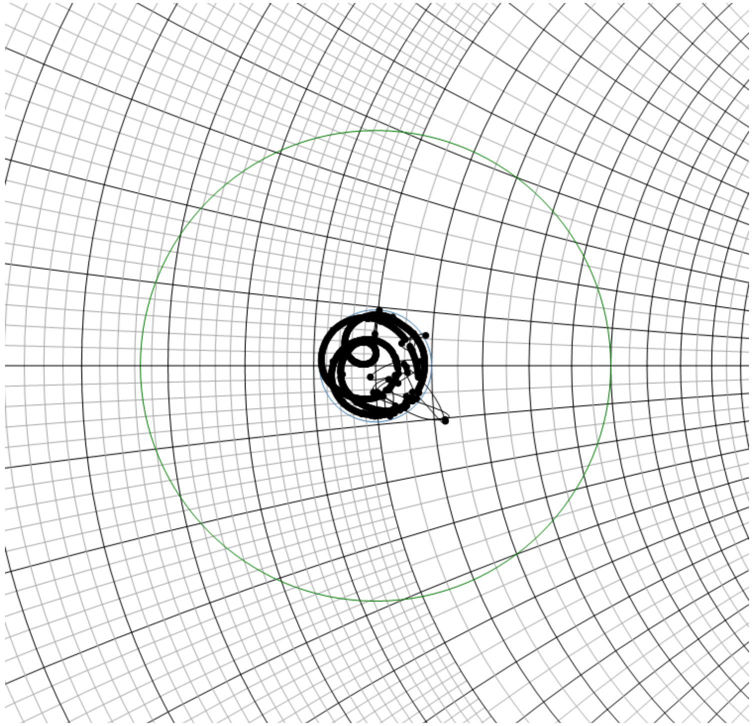
Bottom Line: The RingMaster designs require 33% less radiators

18 Bay ½ wave spaced | 12 Bay – RingMaster | 12 Bay – RingMaster Low RFR



Installed Example

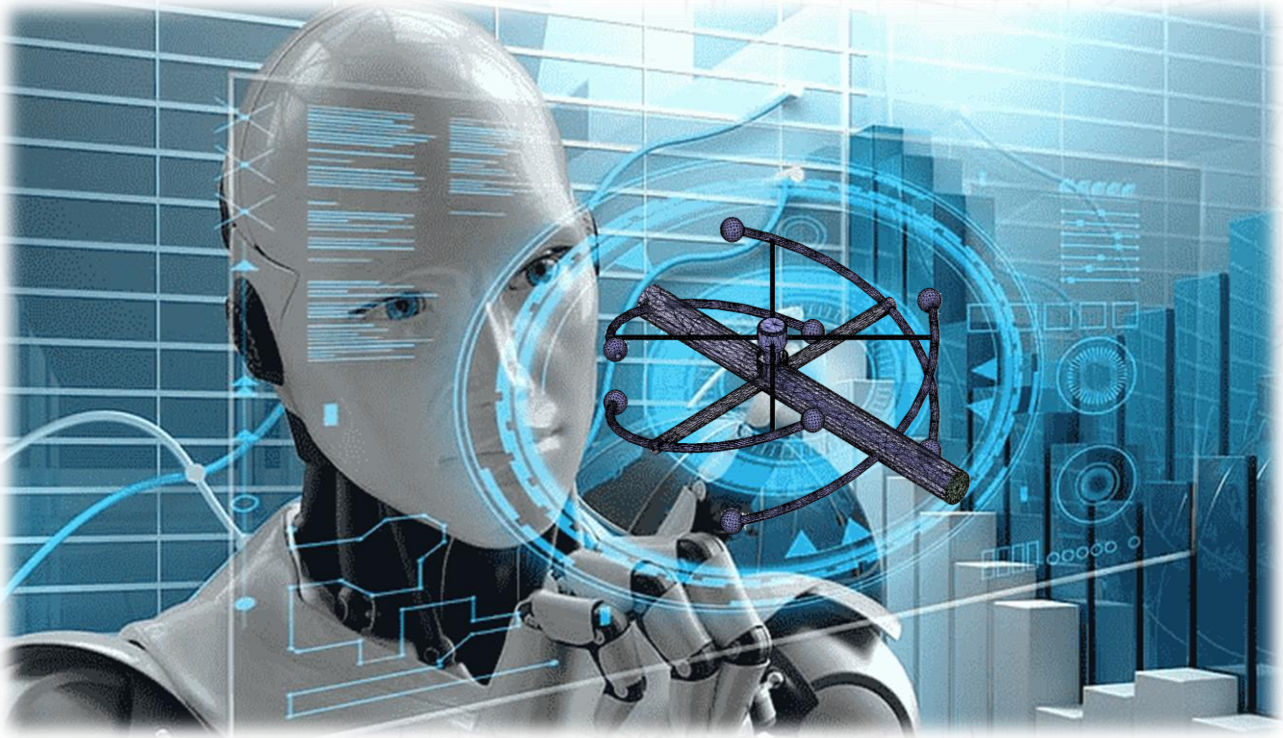
- DCRU16DC(SP)RF10
  - 16 bay – Low RFR
  - 13 channels of operation between 90.9 and 106.7 MHz
  - Channels under 1.1:1 VSWR, Band under 1.1:1 VSWR
  - Same gain as a 24 Bay ½ wave spaced
  - **33% Less Radiators!**



Trusted for Decades. Ready for Tomorrow.

RingMaster™ Conclusions

- The RingMaster maximizes DCR performance
  - Technique providing broad bandwidth and low RFR with less bays
    - Less connections
    - Less wind load
    - Less weight
    - Lower cost



Ring360

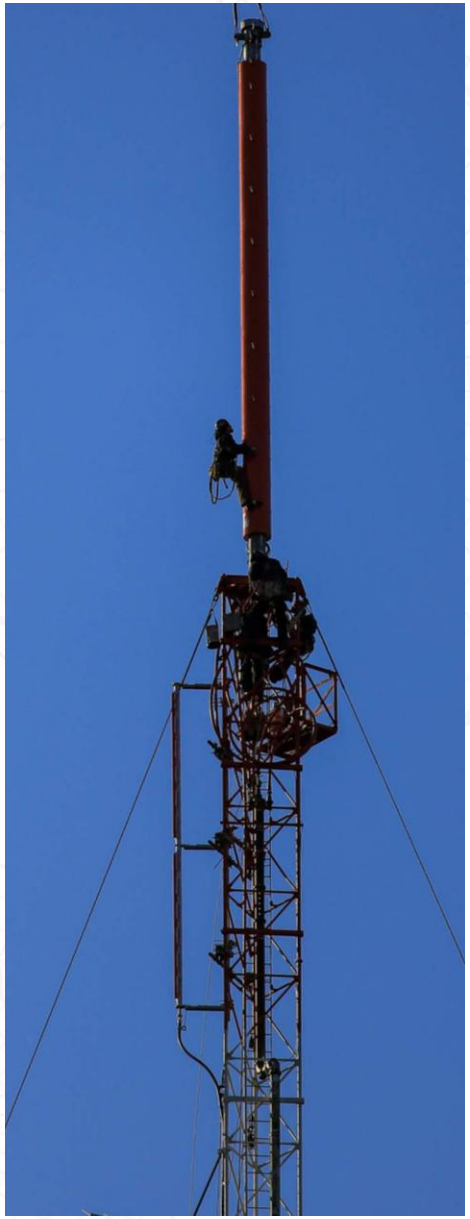
PYLON ANTENNAS

- Term coined by RCA
- Top mounted slotted coaxial antenna
- Long, thin, round structures
- Smaller in size and less wind load than other broadcast antennas
- Fewer parts/connections
  - Simplicity = Reliability!

- One disadvantage: inherently narrow bandwidth

$$\%bw = \frac{f_h - f_l}{f_0} x100$$

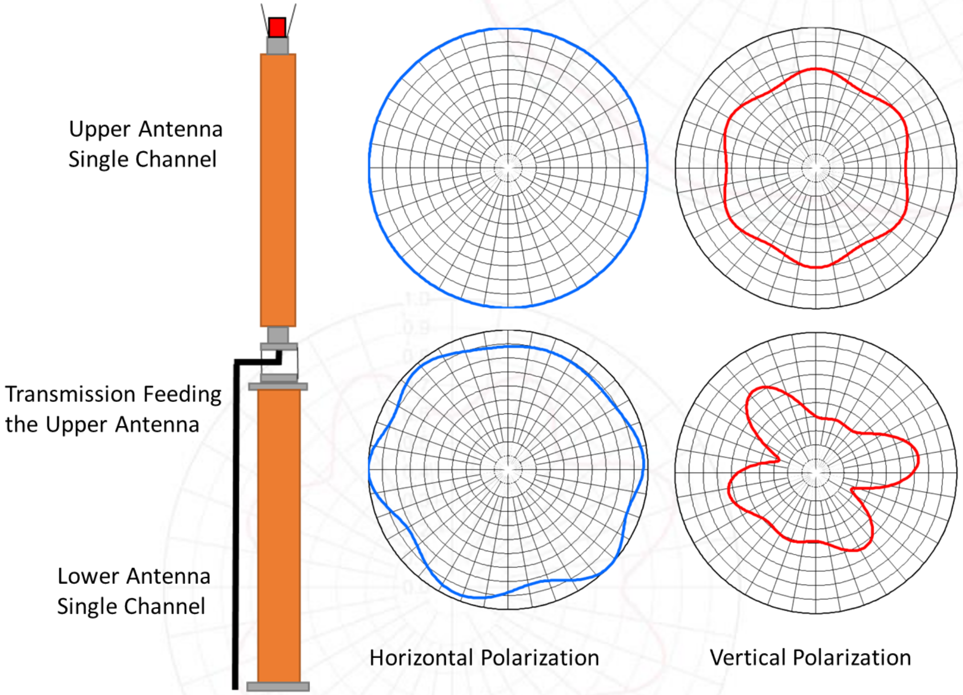
- Natural bandwidth: 1-2% at UHF



STACKED PYLON ANTENNAS

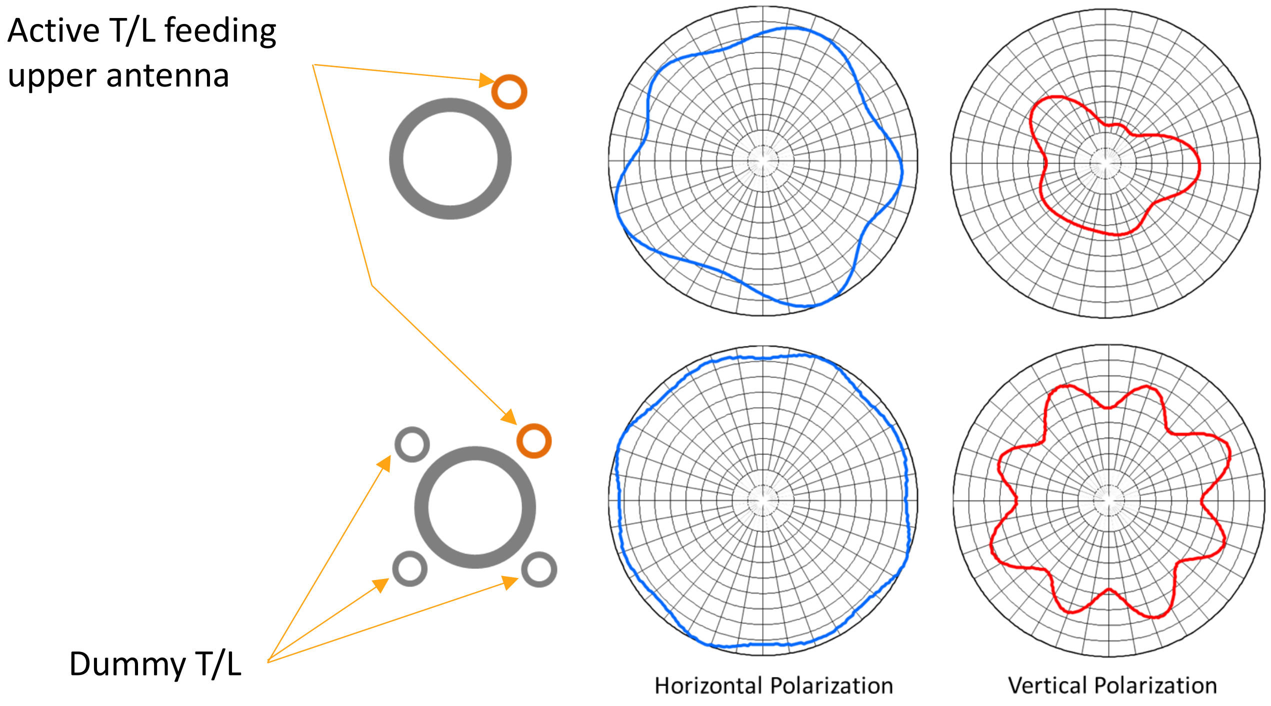
- Historically top mounted multi-channel pylons are single channel antennas structurally stacked
- Each are center fed by a harness
    - Mechanically end fed but electrically center fed

- Disadvantages:
    - Twice the height of single antenna
    - TL feeding top antenna affects the pattern of the lower antenna



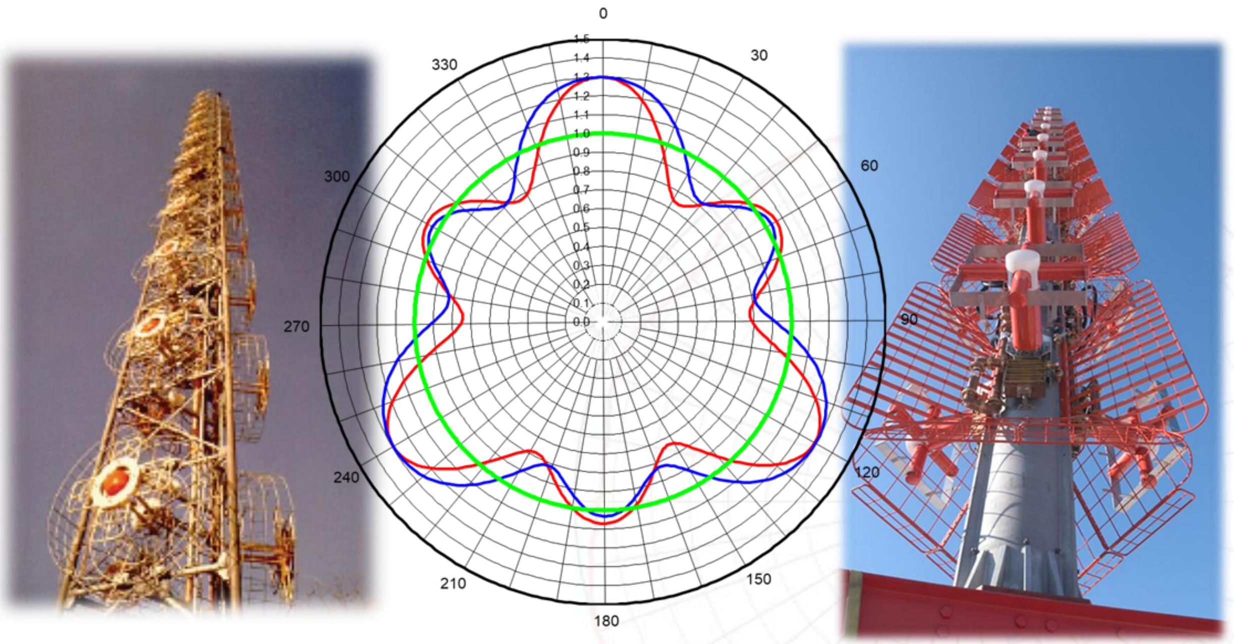
CIRCULARITY IMPROVEMENT

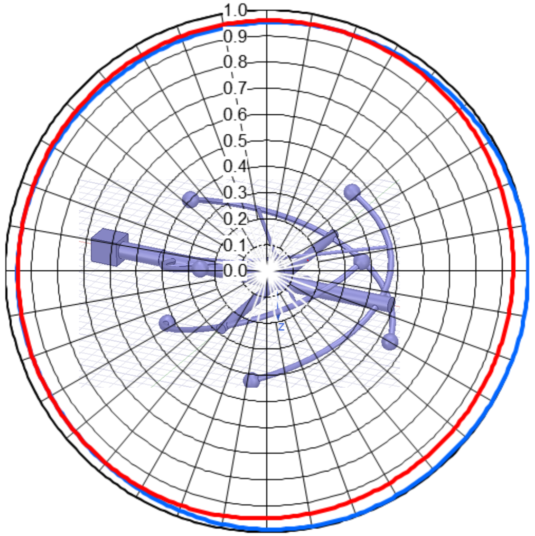
- Accomplished by adding dummy cylindrical lines around the antenna instead of a single line

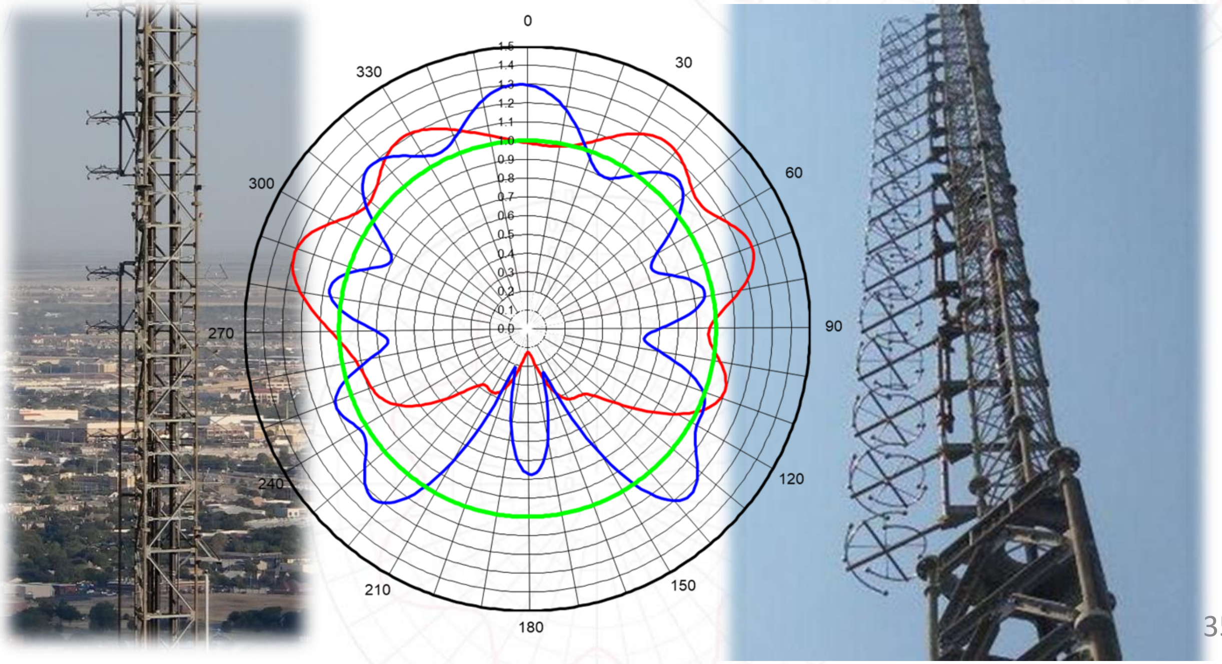


Omni Directional Master FM Antenna

- What antenna choices are available today?
  - Panel style (CBR / HDCBR)
    - Pro's – Omni directional with excellent circularity
    - Con's – Complicated and expensive!
- Master Ring Style antenna
  - DCRU
    - Usually considered for master AUX
    - Pro's – Economical and reliable – High power handling
    - Con's – Side mounted - Circularity is compromised by tower effects



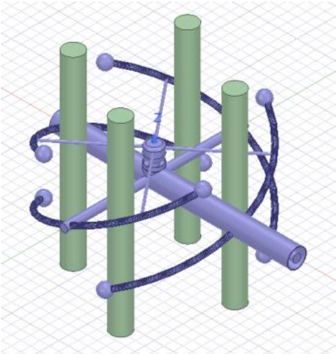


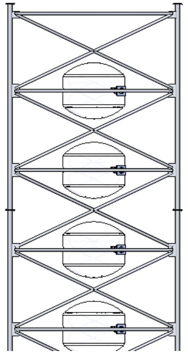


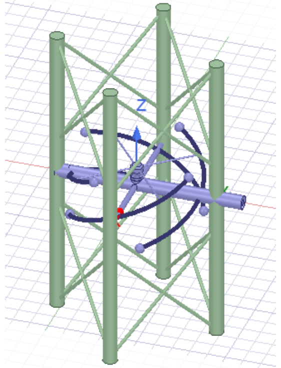
What the industry needs is a ring style antenna that is not affected by a tower so we can top mount it

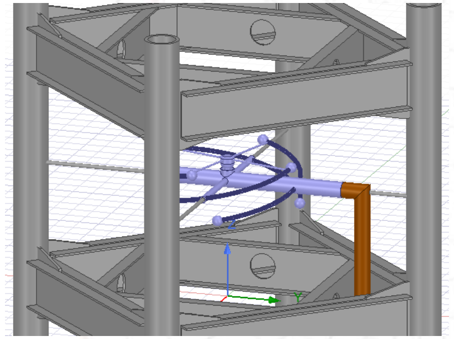
Failure Is Not An Option

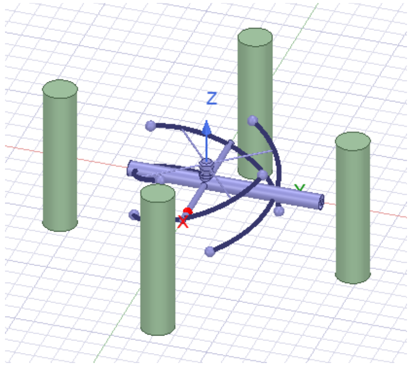
- Failure is necessary
- We try…We fail…We learn…We adjust

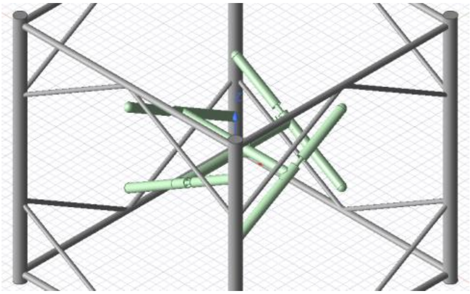


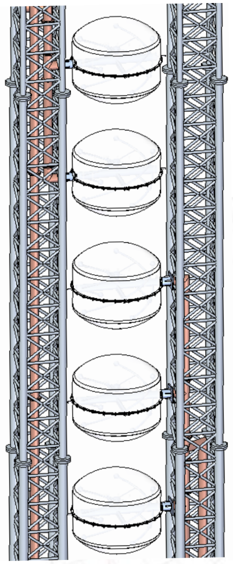


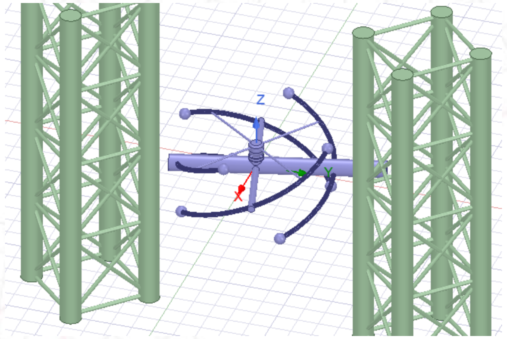


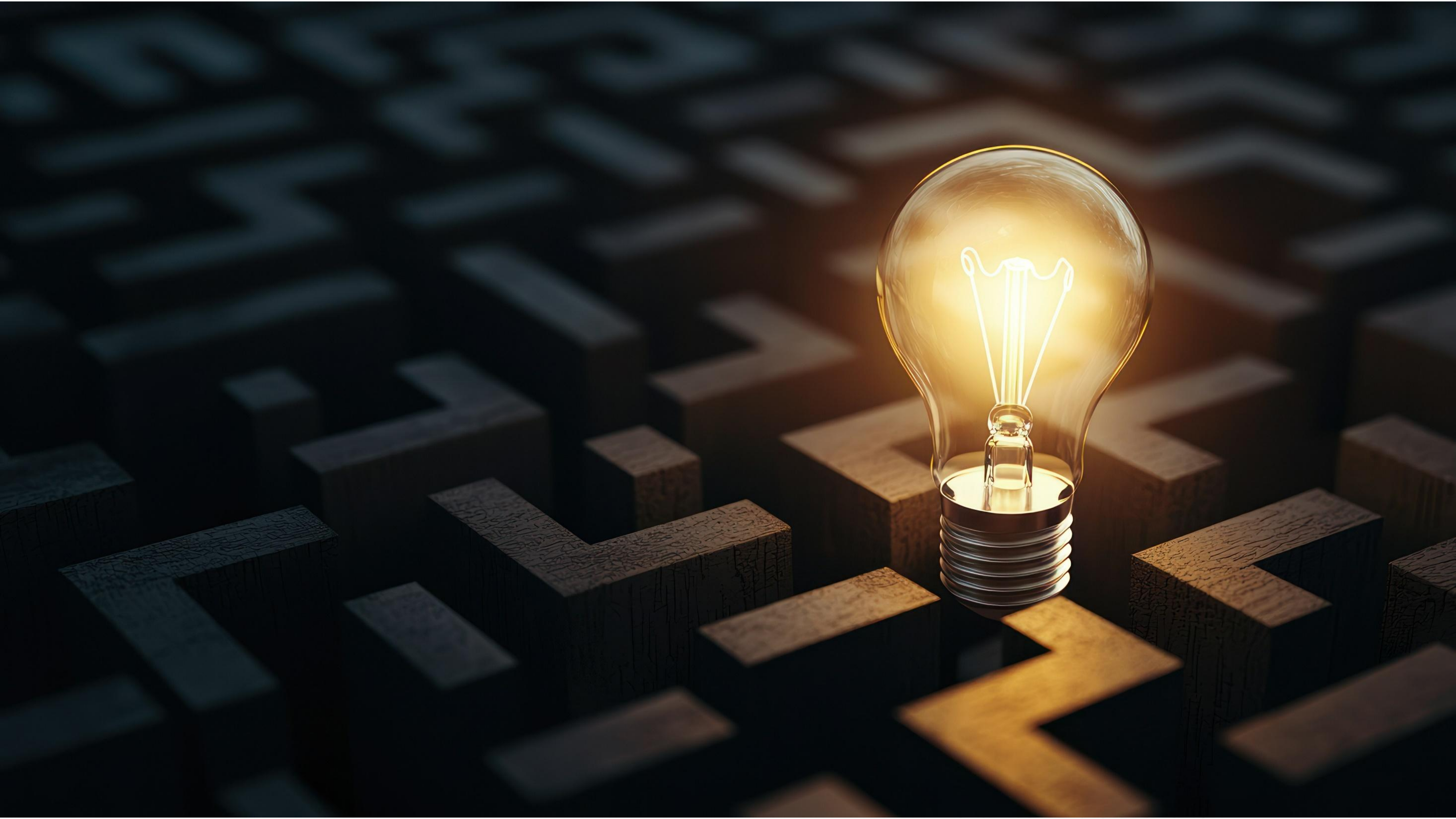






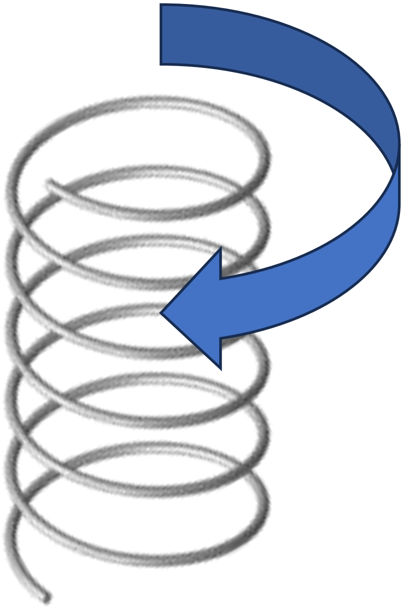




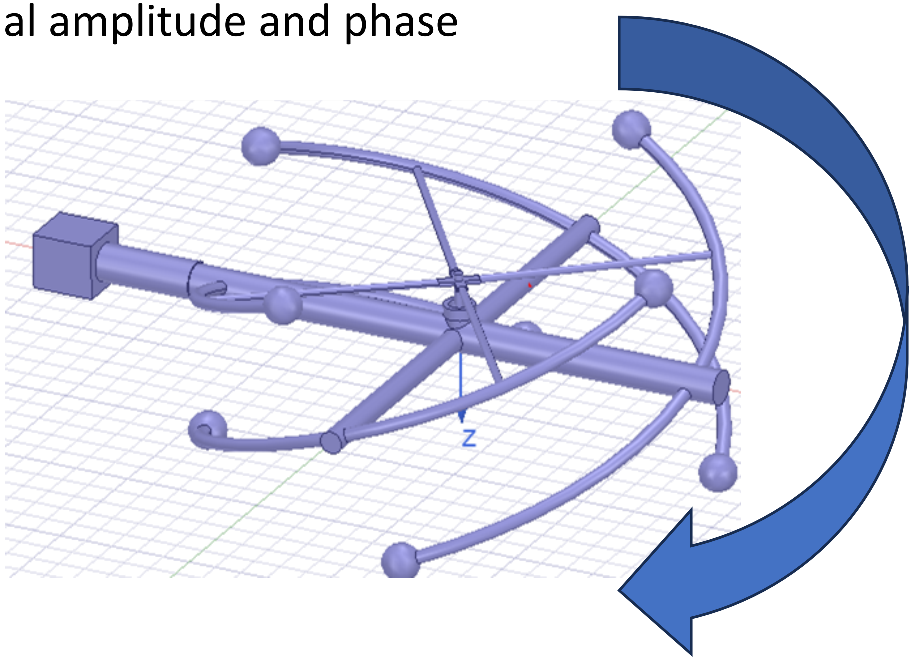


Helical Nature of a Ring Style Antenna

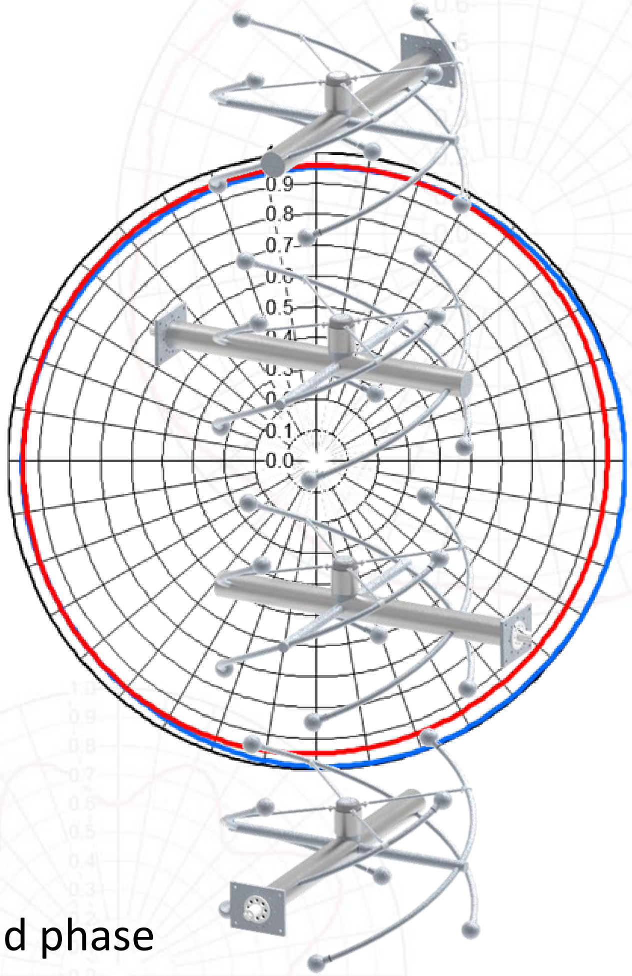
- The basic broadside helical antenna radiates equal amplitude and equal phase in all azimuth directions
- DCR ring style antennas are truncated helices



Equal amplitude and phase



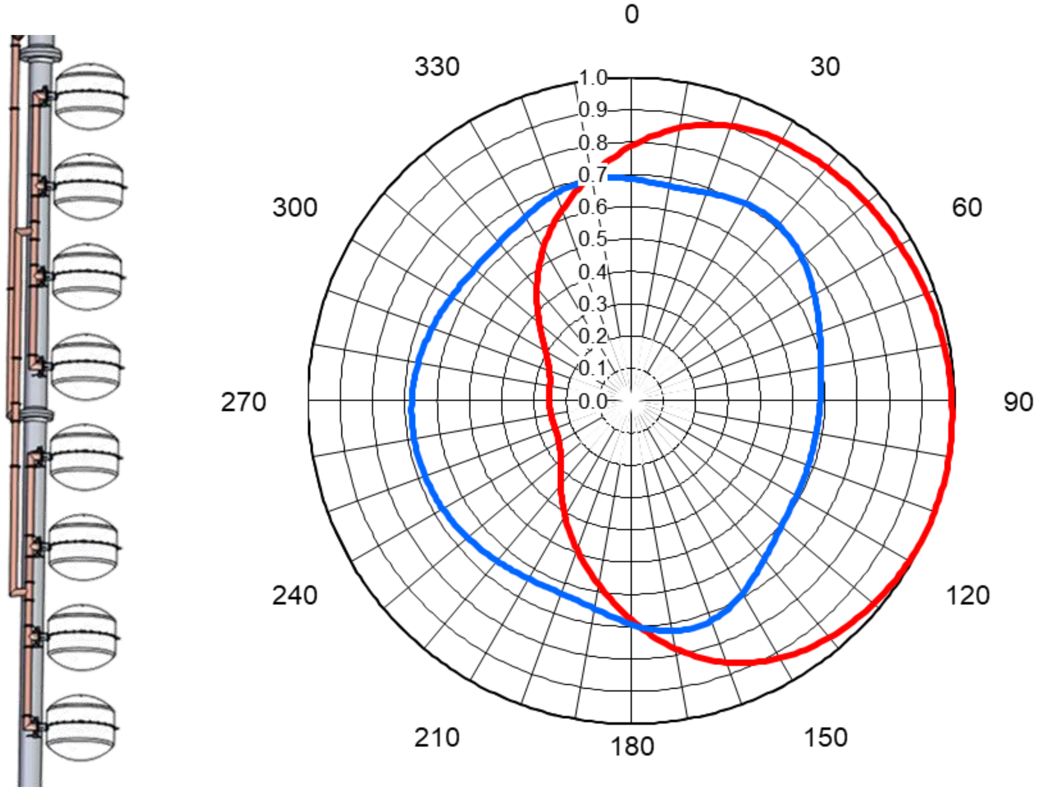
⇒



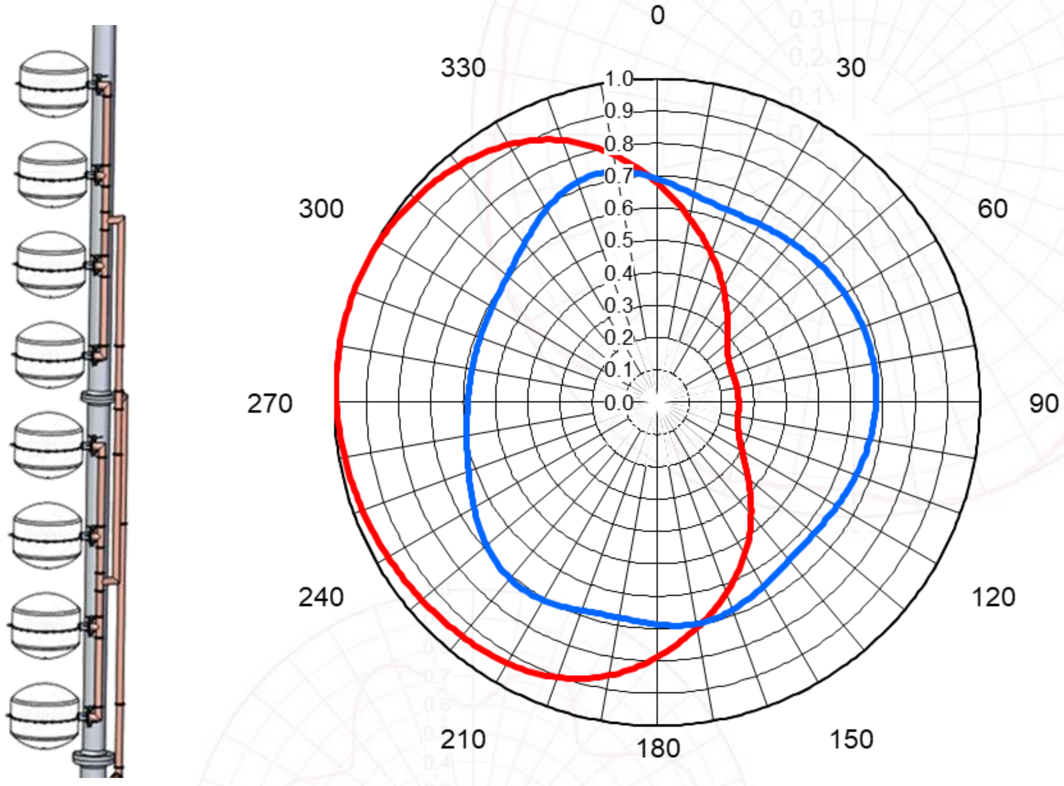
- Bays can be rotated in any azimuth direction and the resulting radiated amplitude and phase will be the same

How Can This Feature Be Utilized?

- Two standard pole mounted ring antennas
  - Each produce an expected pattern on a large pipe
  - Facing in opposite directions



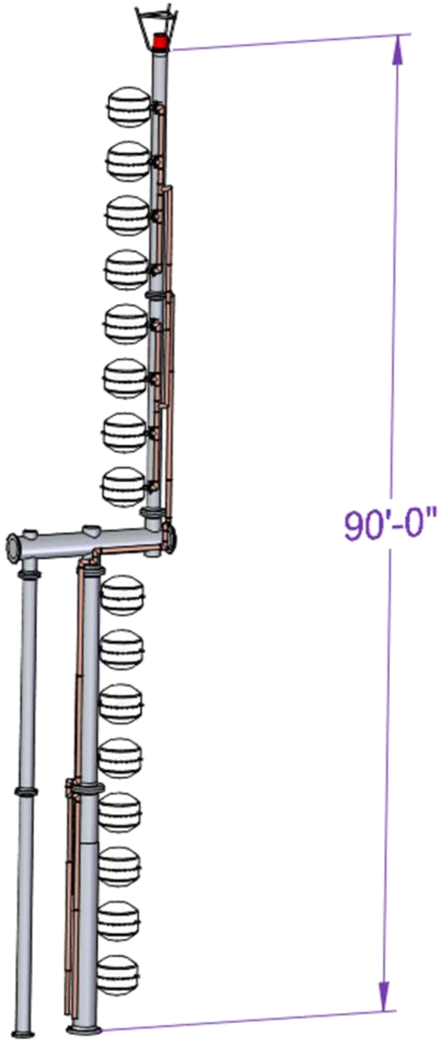
HPOL
VPOL

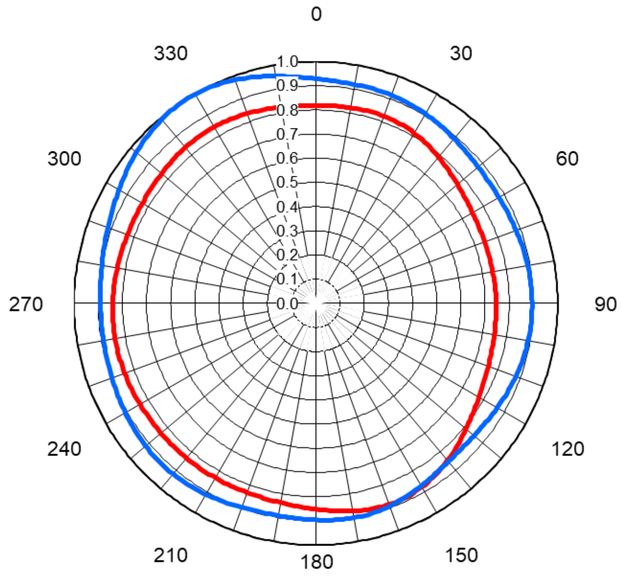


HPOL
VPOL

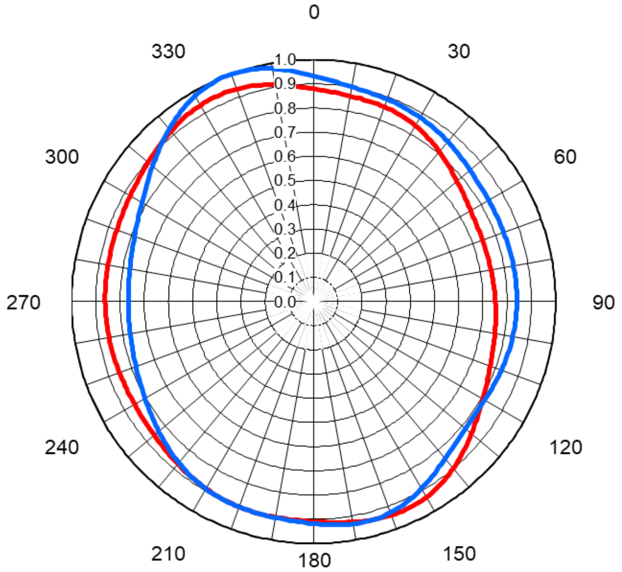
Adding the Two Together in a Mechanical Solution

HPOL
VPOL

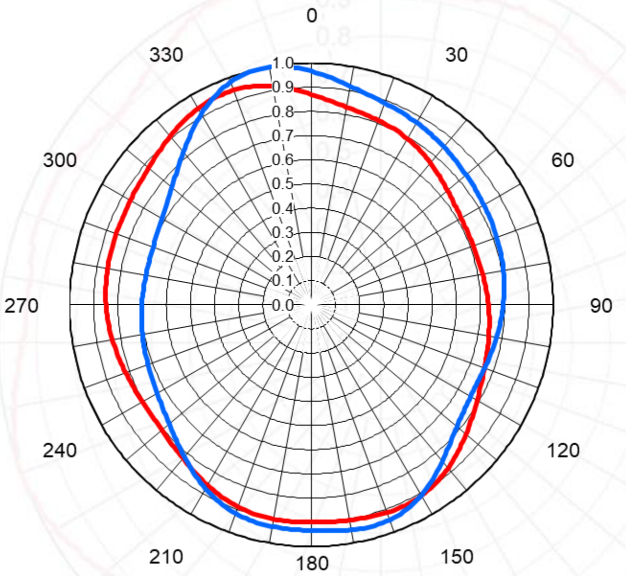




88 MHz



98 MHz

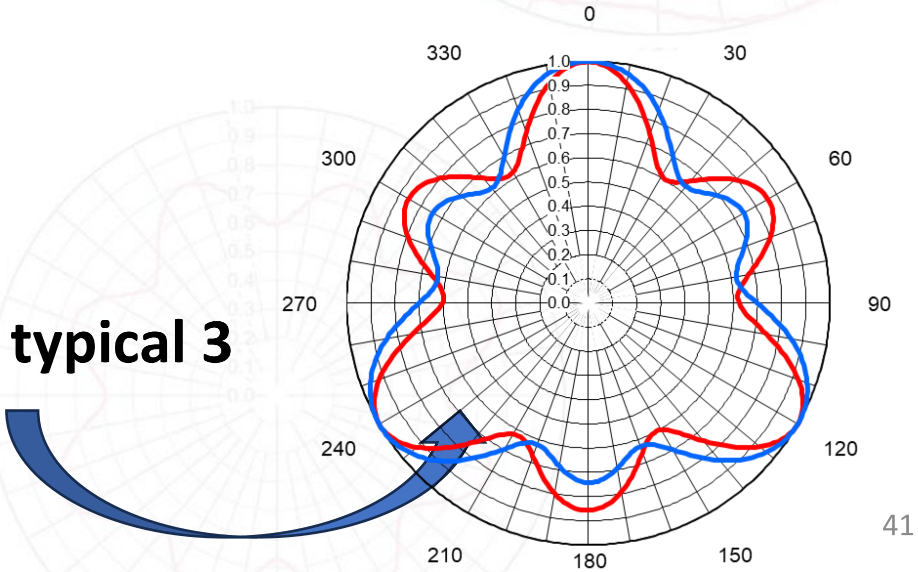


108 MHz

- Patterns incorporate
  - Real pipe sizes
  - Feed system
  - Mechanical counter pipe

Circularity better than typical 3 around panel!!!!

Patent Pending



Mechanical Review of Ring360 Antenna Final Design Concept

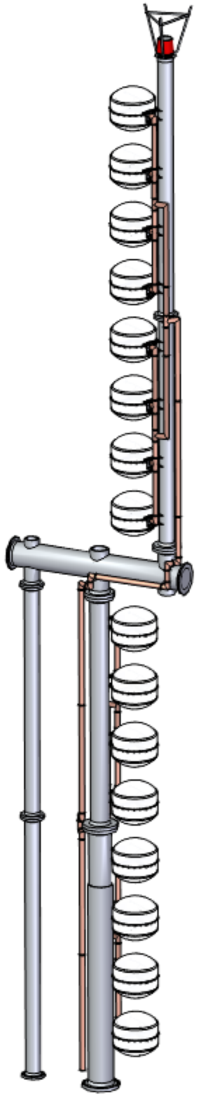
Offset Mast Design:

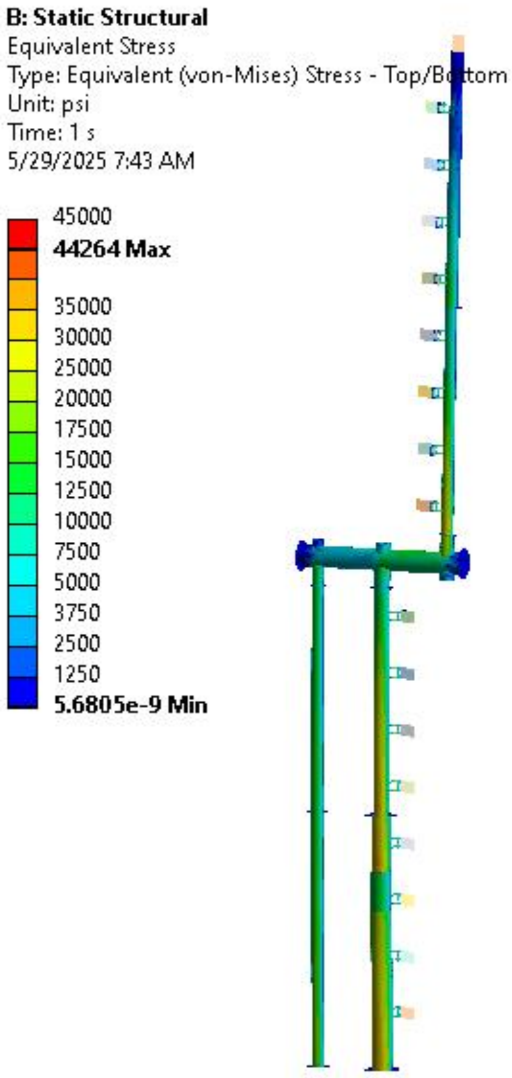
Balances the effect of the mast between the top and bottom halves.

Mechanically this has proven to a sound solution.

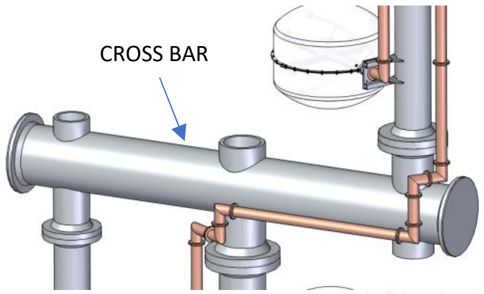
Design leverages Dielectric's long experience with tubular pipe structures.

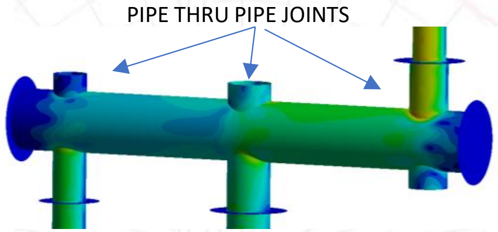
EPA = 272 ft^2
(a comparable panel array is about 300 ft^2 ***without*** the support structure)



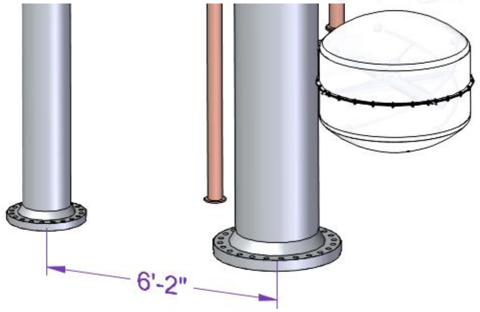


Patent Pending





CROSS BAR DESIGN



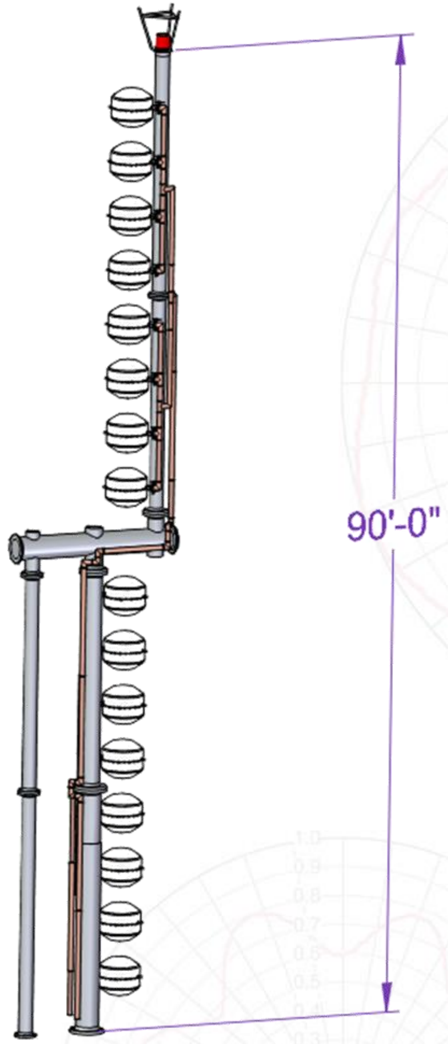
DUAL FLANGES AT TOWER TOP

Unique challenges
- Cross Bar design
- Dual flange tower mounting
- Managing fabrication/install tolerances will be critical

Ring360 Conclusions

The Ring360 antenna is:

- Simple solution to a complex problem
- Better performance than a panel array
- Much less complex than a panel array
  - Parts count directly proportional to reliability
  - 10X more reliable than a panel
- Adaptable to other antenna configurations
- 60% lower wind load compared to panel array antenna



PATENT PENDING

THANKS FOR YOUR TIME!
ANY QUESTIONS?

Dielectric®

Dielectric.com