FM Antenna Pattern Evaluation using Numerical Electromagnetics Code

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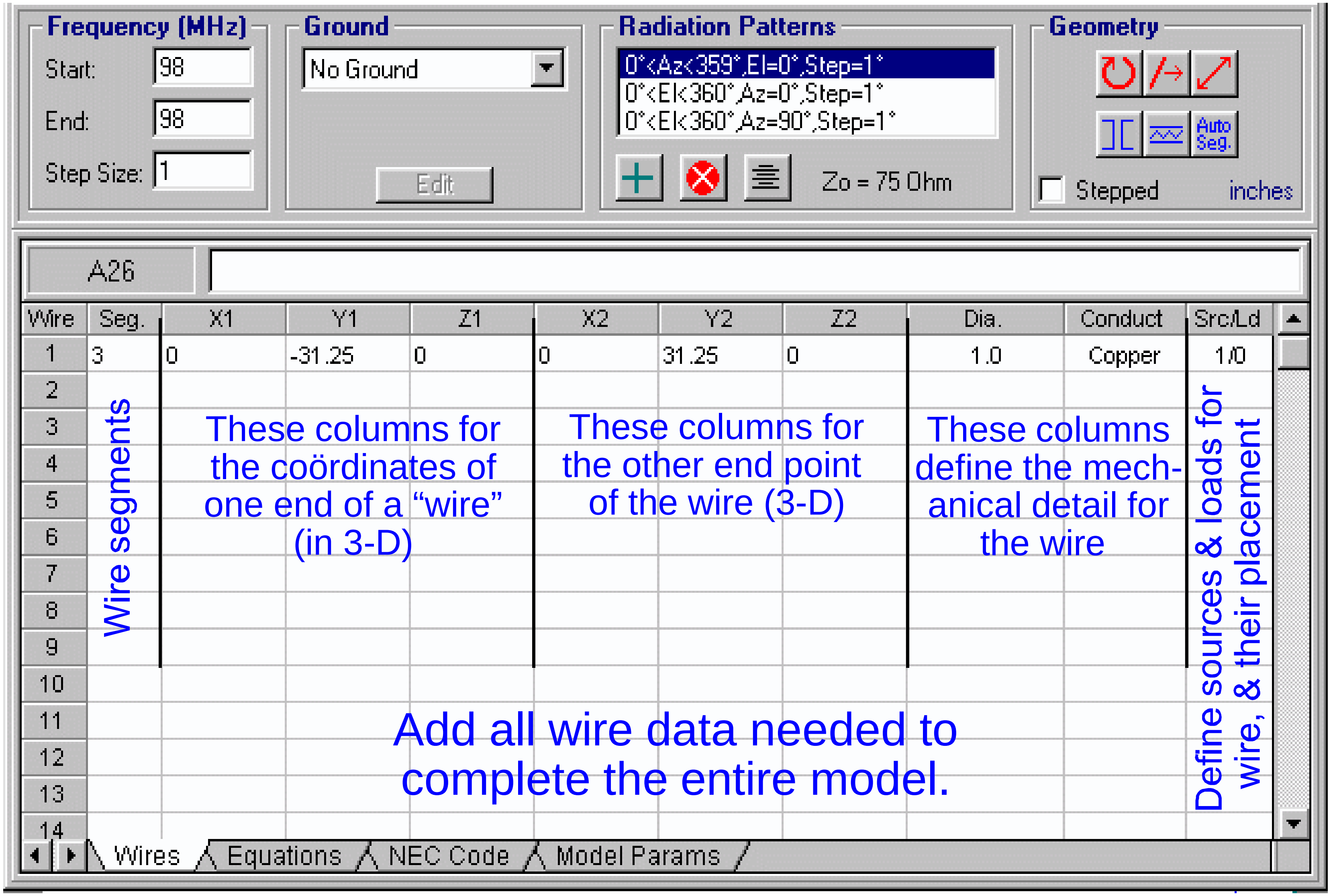
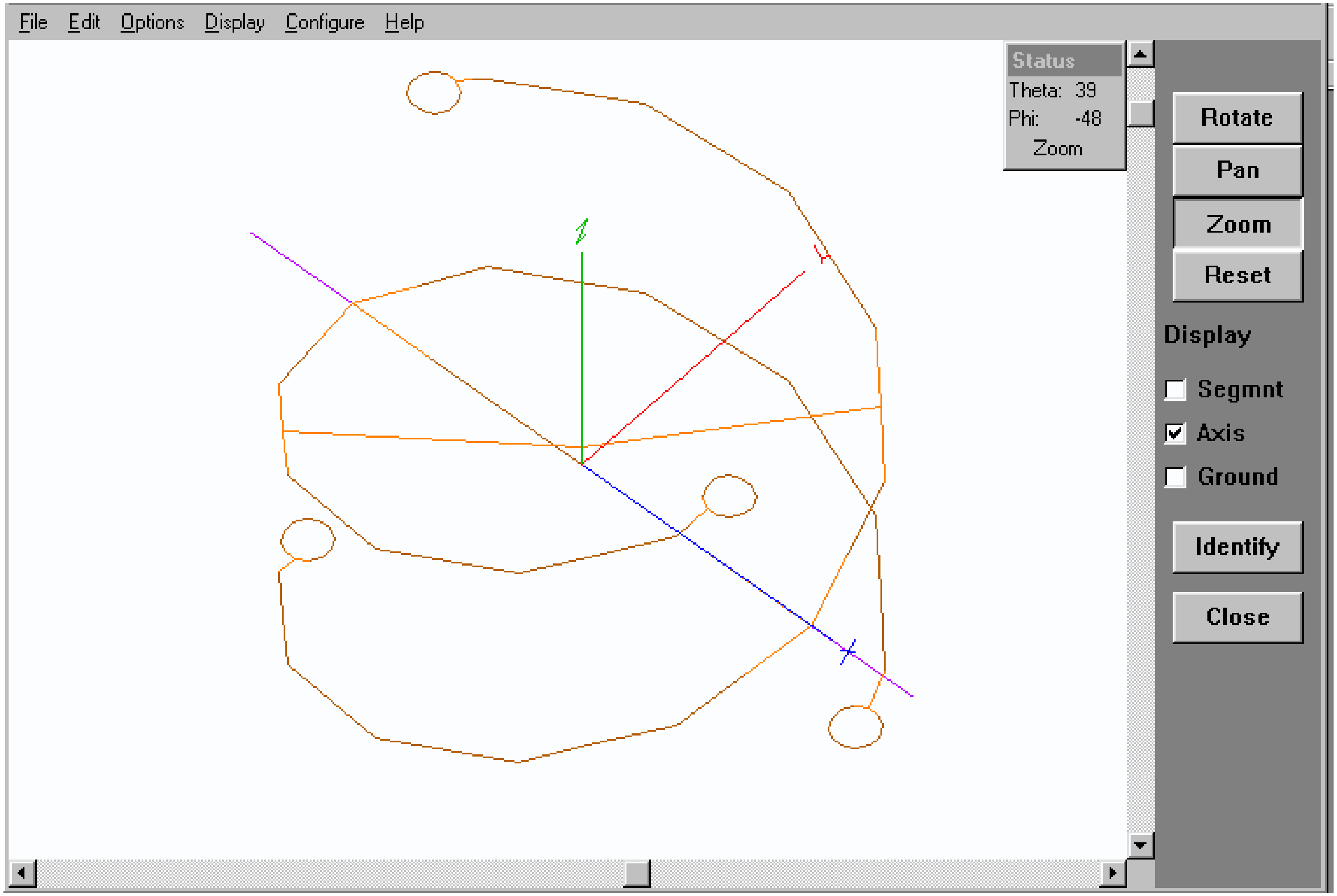
Numerical Electromagnetics Code (NEC)

- Simulates the electromagnetic response of antennas and metal structures.
- Written by J. Burke and A. Poggio in 1981 at Lawrence-Livermore Labs under contract to the U.S. Navy.
- Available to the public in various commercial forms.

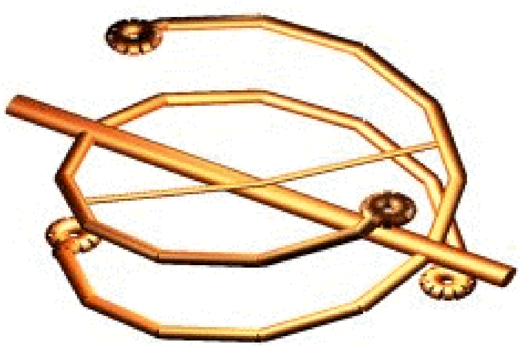
Input Screen



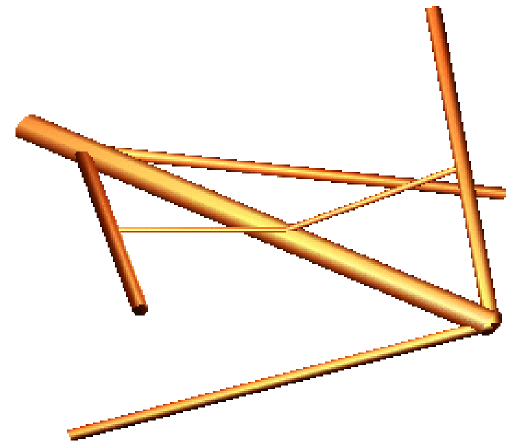
Wire Model Graphic of Helical Element
(based on spreadsheet entries)



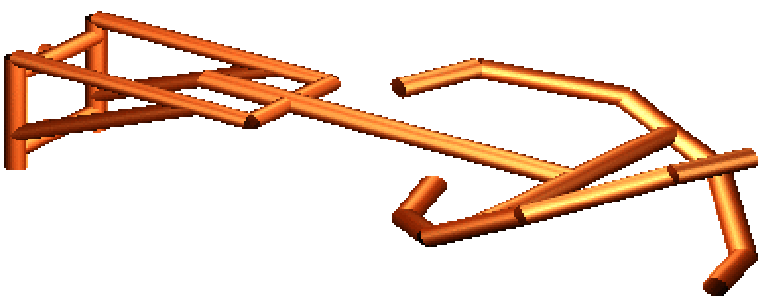
Rendered Views of NEC Wire FM Element Models



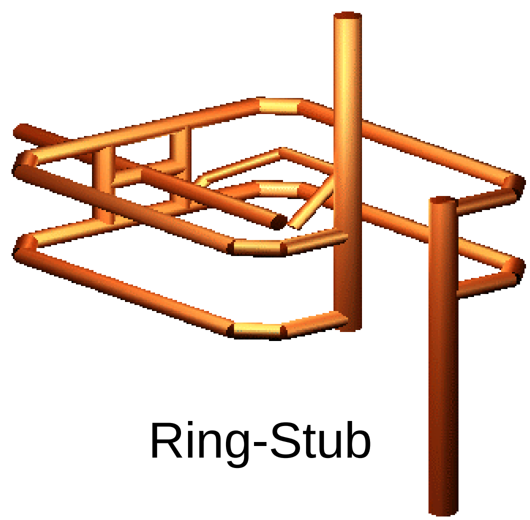
Helical



Opposed Vee

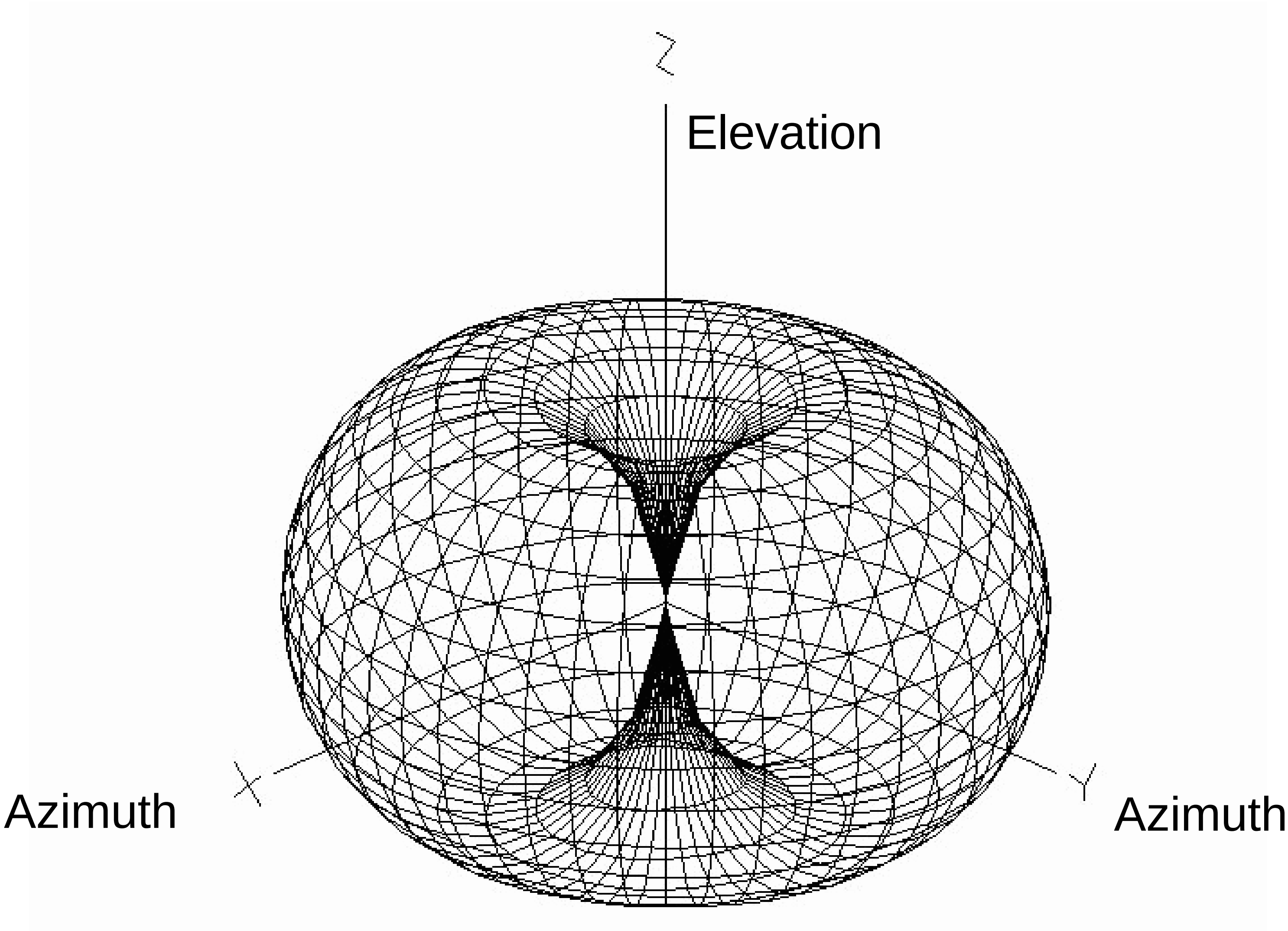


"Rototiller"



Ring-Stub

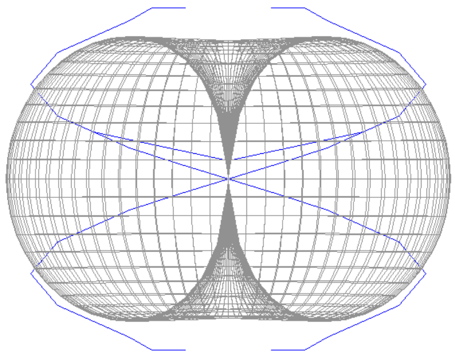
Surface Plot: Sum of H-pol and V-pol Fields



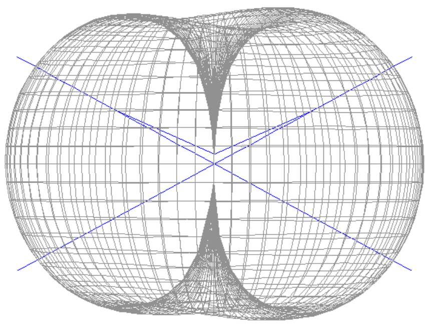
"Perfect" omnidirectional C-pol element shown

FM Element Patterns Compared

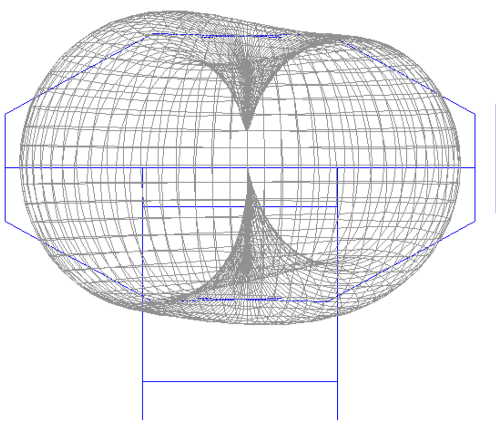
- Sum of h-pol and v-pol
- View from front, along element boom
- **Less coax and tower effects**
- NEC-2 analysis



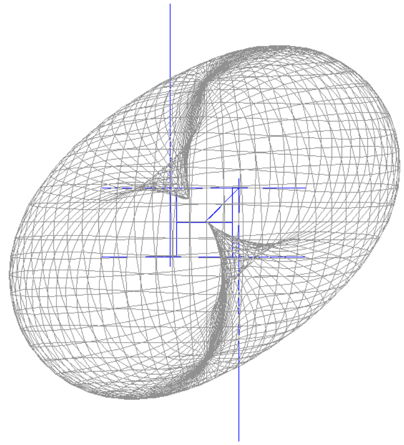
Helical



Opposed Vee



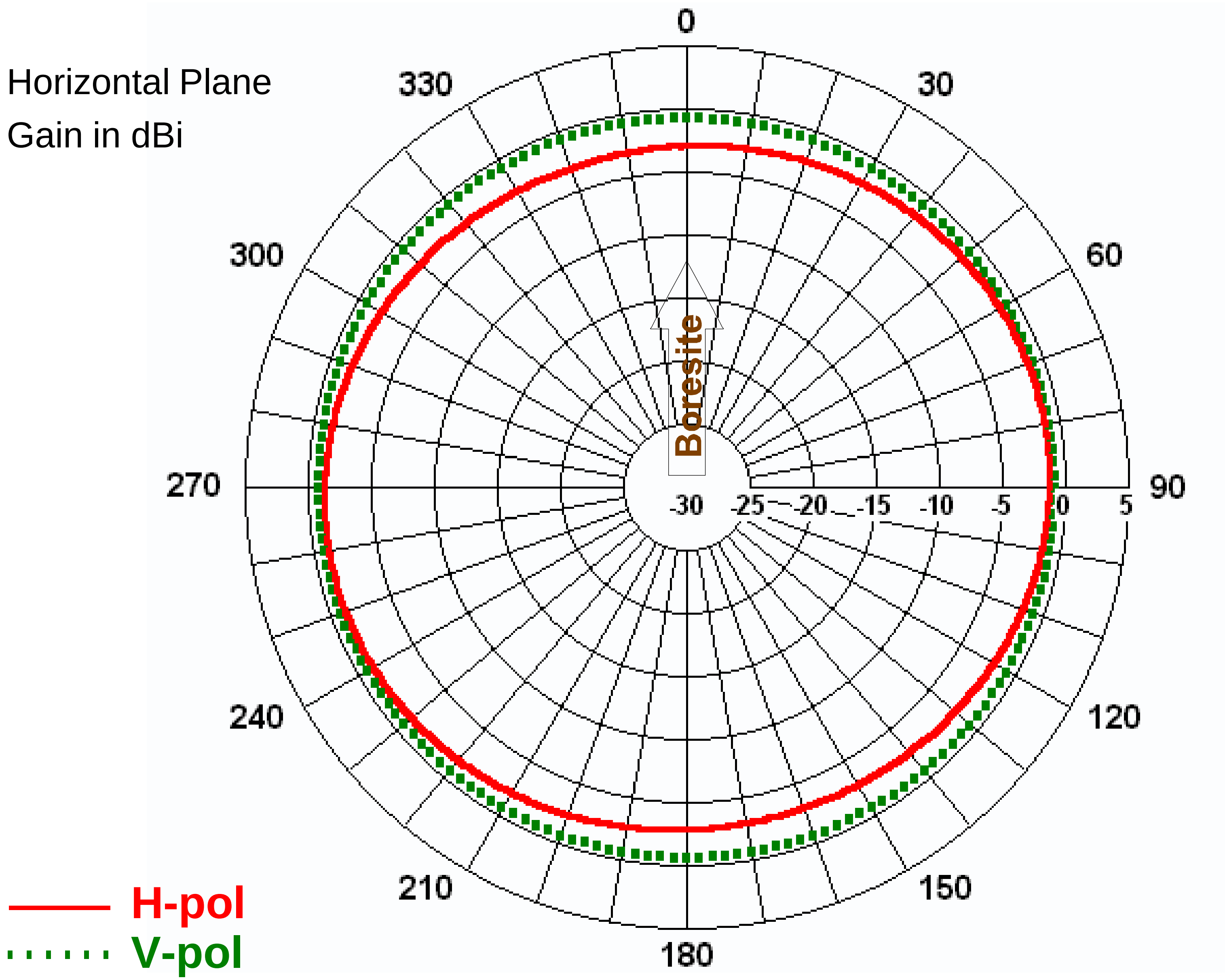
"Rototiller"



Ring-Stub

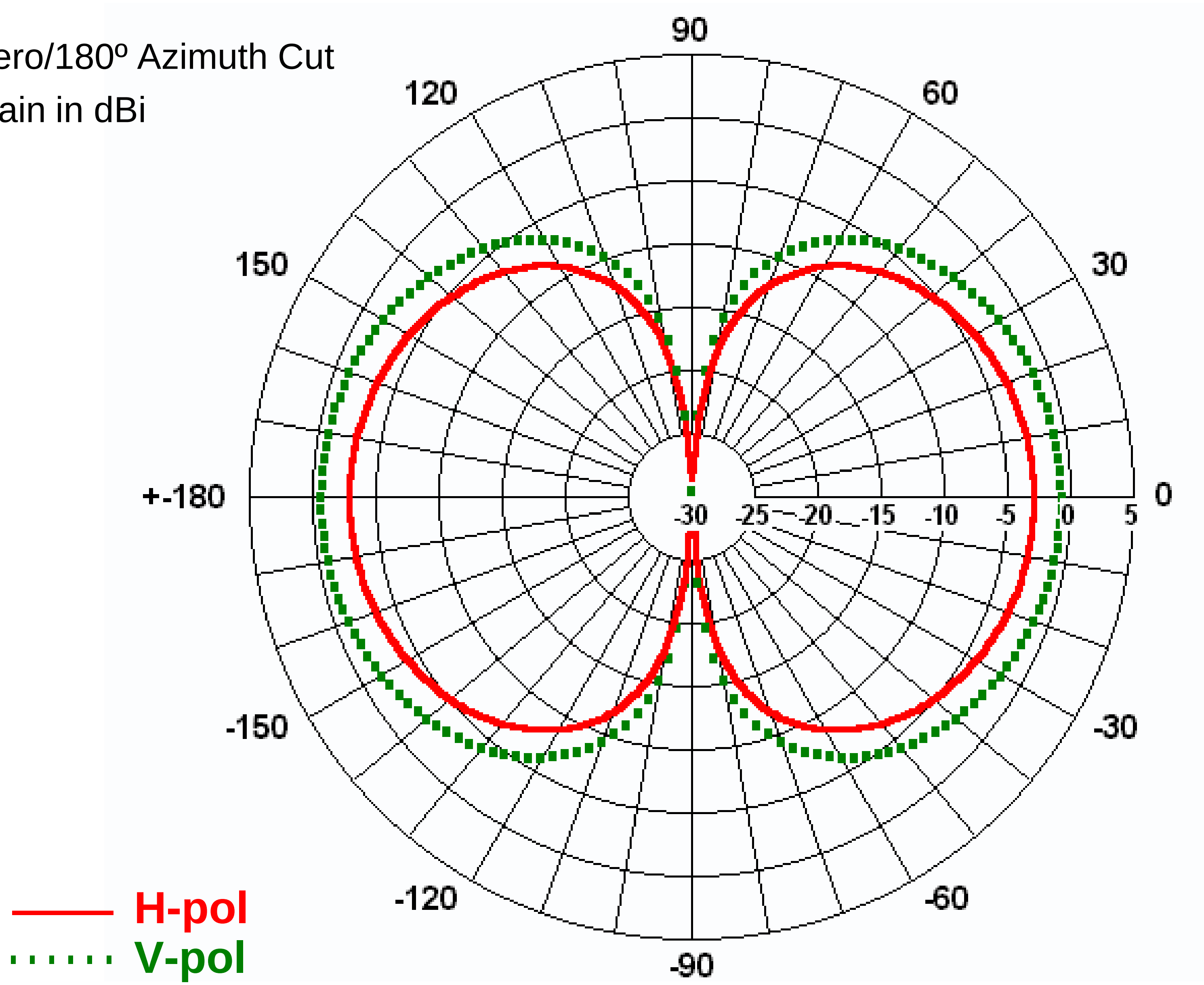
Azimuth Patterns for Helical Element in Free Space

- Horizontal Plane
- Gain in dBi



Elevation Patterns for Helical Element in Free Space

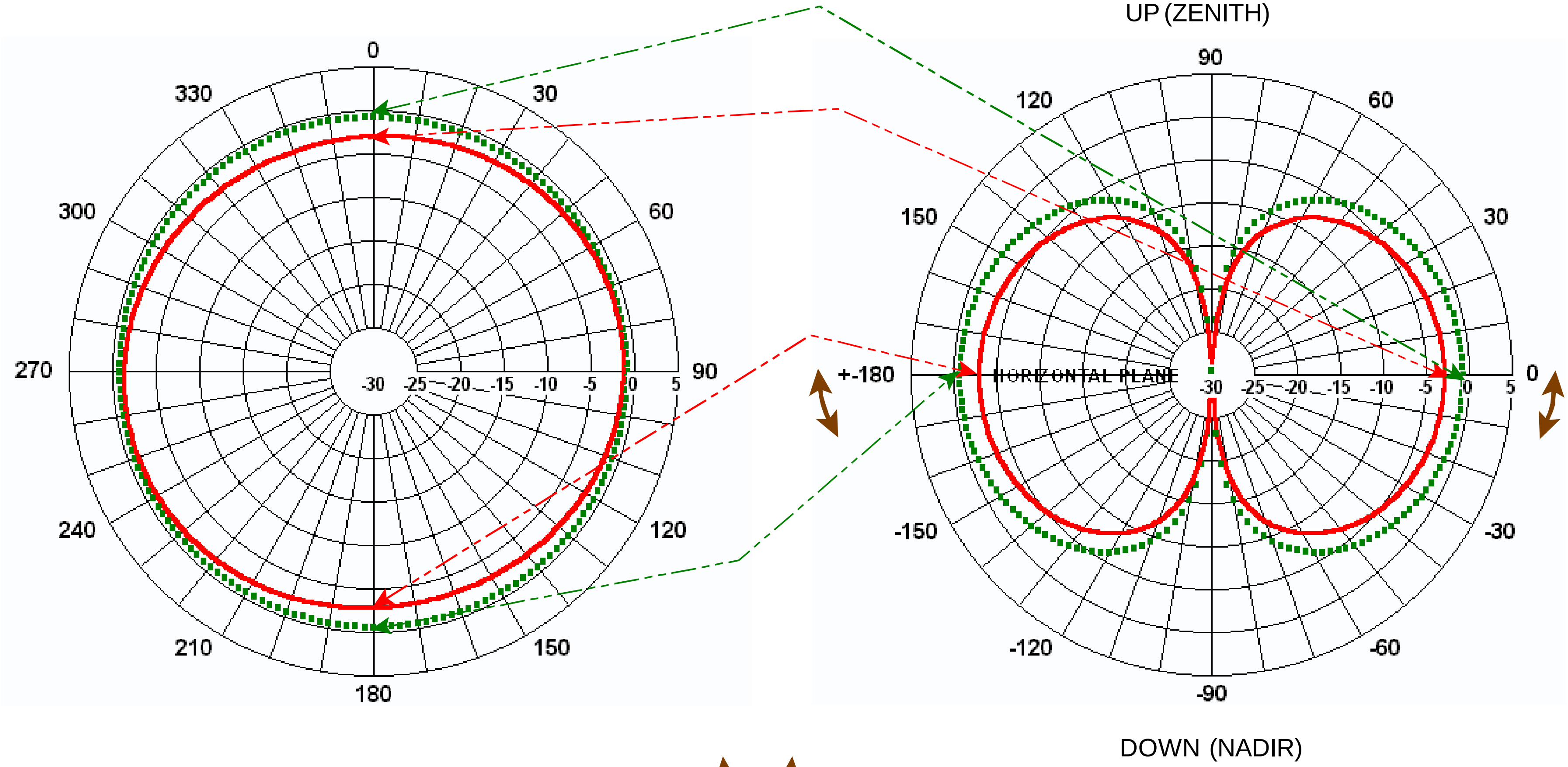
- Zero/180º Azimuth Cut
- Gain in dBi



Review: Pattern Reading & Correlation

Azimuth Pattern
at 0º Elevation

Elevation Pattern,
Zero/180º Azimuth Cut



These sectors of the elevation patterns serve most of the coverage area.

Review: Antenna Gain Determination

- Total Gain is the product of the elevation gain and the azimuth gain of the array (or the sum of their gains if expressed in decibels).

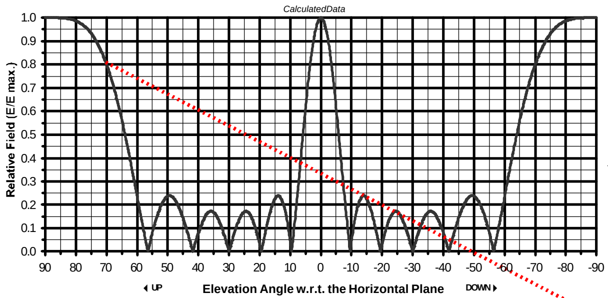
- The azimuth gain of an omnidirectional antenna is unity, by definition.

Elevation Gain Determination

Example for Six, Full-wave Spaced Elements

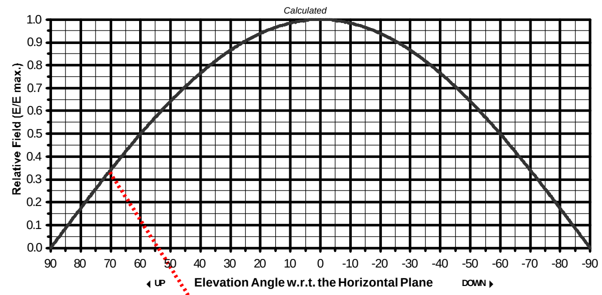
- Product of Array Factor and Element Response

Array Factor



X

Element ($\cos^1$)



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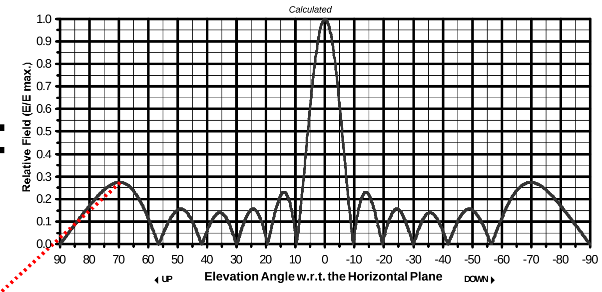
Final Elevation Pattern



- Array factor maximum gain for six $\cos^1$ elements with equal power and phase and one lambda spacing is 6.56X (see antenna texts for formulas)
- Maximum gain is a function of the number of elements, their spacing, and their elevation response

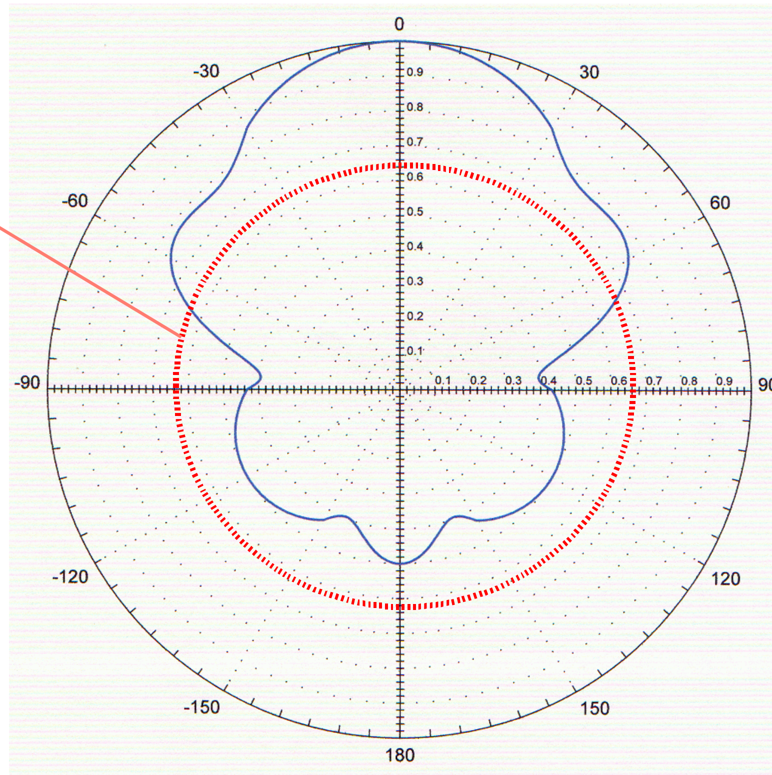
0.8 x 0.34 = 0.27 relative field at +70º elevation.

Normalized patterns

- Maximum elevation gain for the array therefore is **6.56X** (linear polarization)
- Elevation gain at +70º is 6.56 x 0.27 = 1.77X
- C-pol gain is ½ the linear values

Azimuth Gain Determination

RMS = 0.64



- Pattern RMS is the radius value of a circle having the same area as the azimuth pattern
- Maximum azimuth gain for the pattern (at 0º here) is

$$\frac{1}{RMS^2} = 2.44X$$

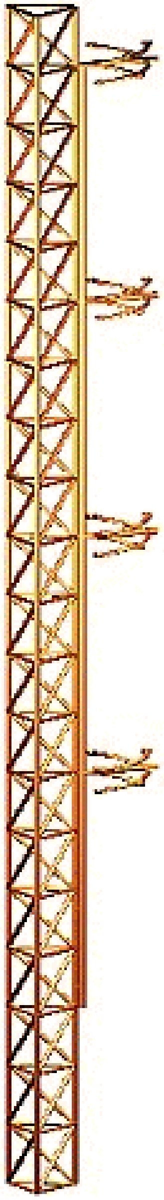
- Other azimuths = (Relative Field)^2 × Peak Gain
- Gain at RMS = $0.64^2 \times 2.44 = 1X$ (rounded)

- If this azimuth pattern was specified by the FCC for FM station “A” using the 6-bay antenna shown on the last slide, the final gain = 6.56 x 2.44 = 16X
- If FM station “B” was licensed as omni, but had a pattern shaped like this (tower distortion, etc) it would still use 6.56X as the gain: omni azimuth gain is unity, by definition
- The difference in maximum ERP of stations “A” & “B” would be 244%, in favor of “B”

CP Gain = ½ the values shown (reminder)

Helical Array Mounted on Tower

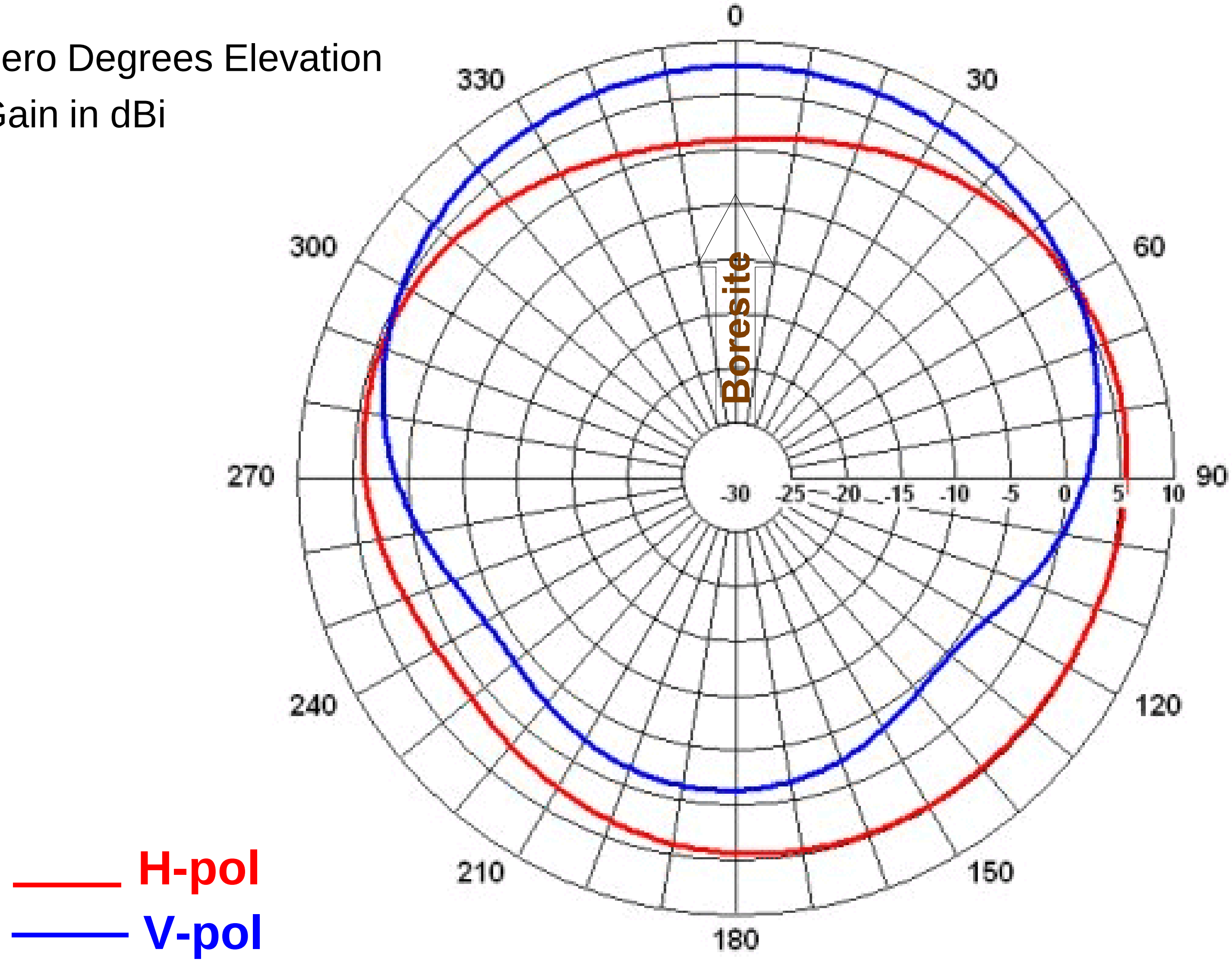
- Full-wave Vertical Spacing
- Leg Mounted on 50' of 24" Face Triangular Tower



(Rendered view)

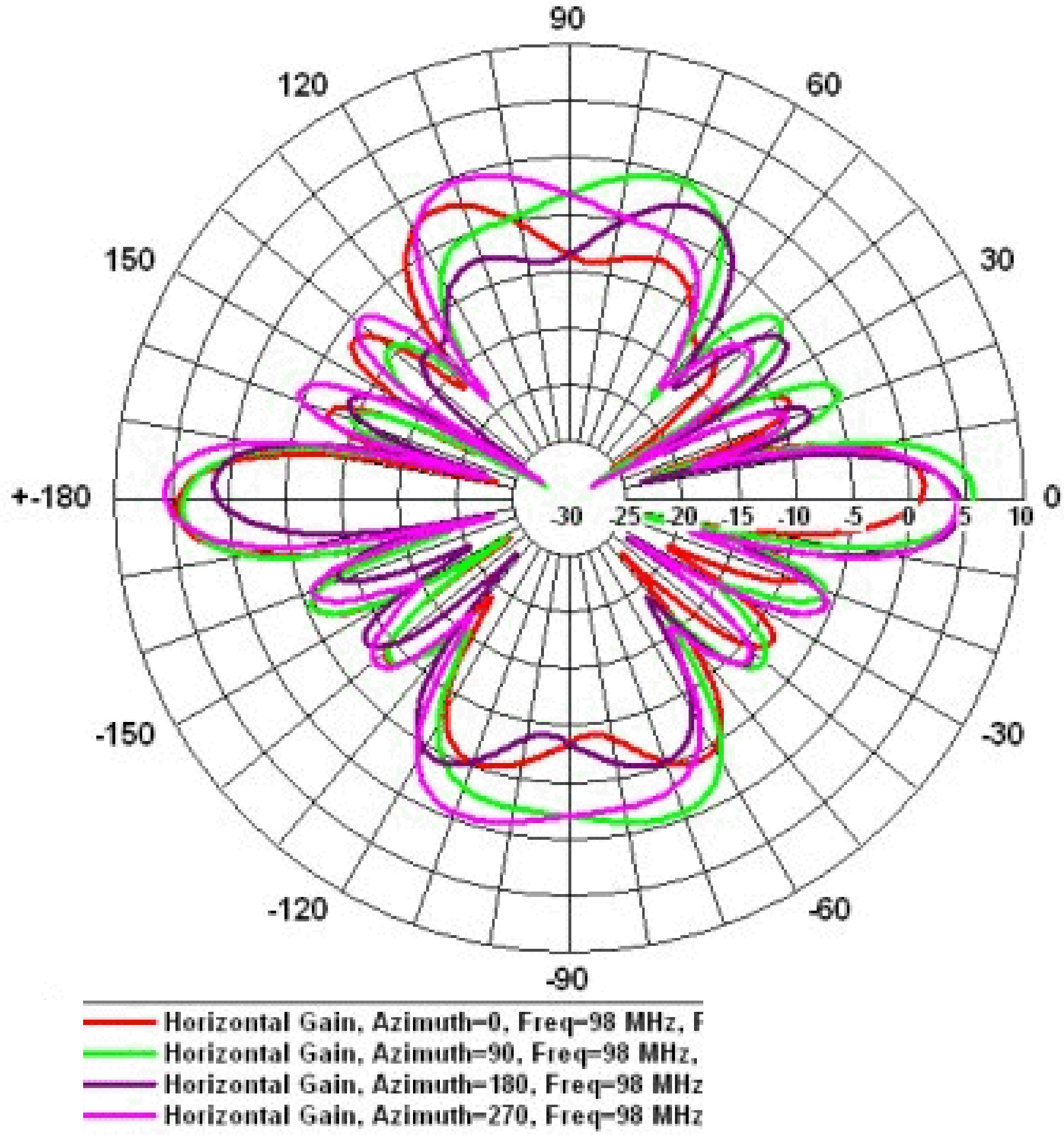
Azimuth Patterns for Helical Array on Tower

- Zero Degrees Elevation
- Gain in dBi



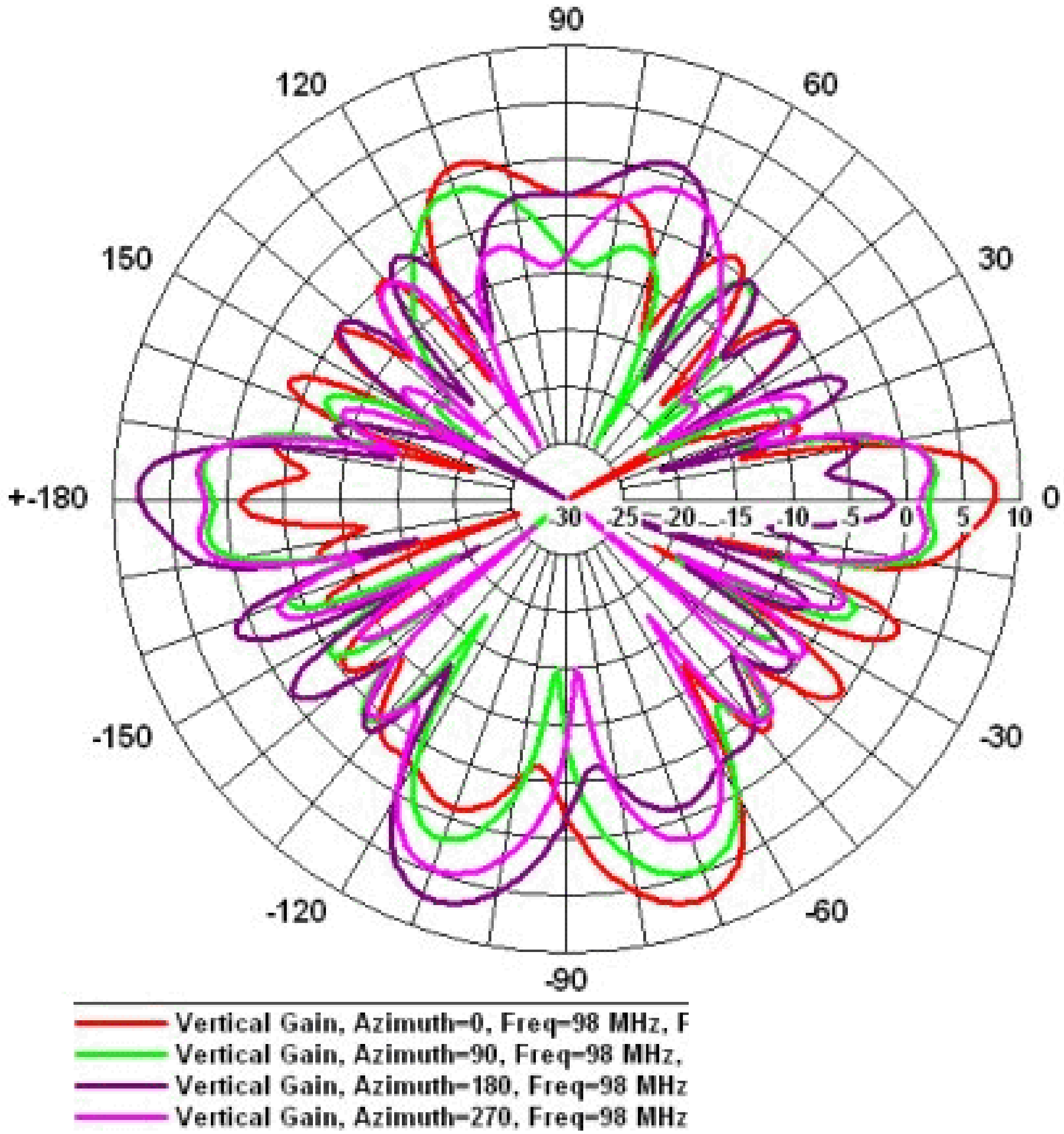
H-pol Elevation Patterns for Helical Array on Tower

- Gain in dBi

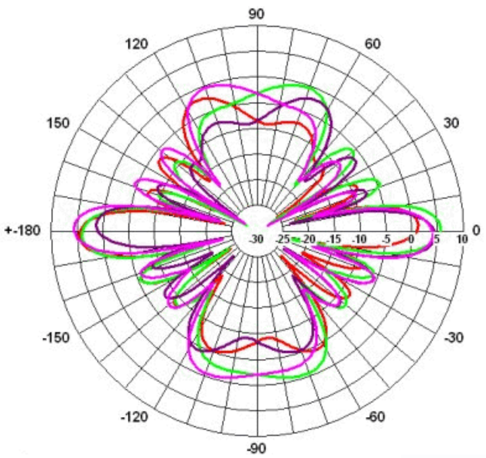


V-pol Elevation Patterns for Helical Array on Tower

- Gain in dBi

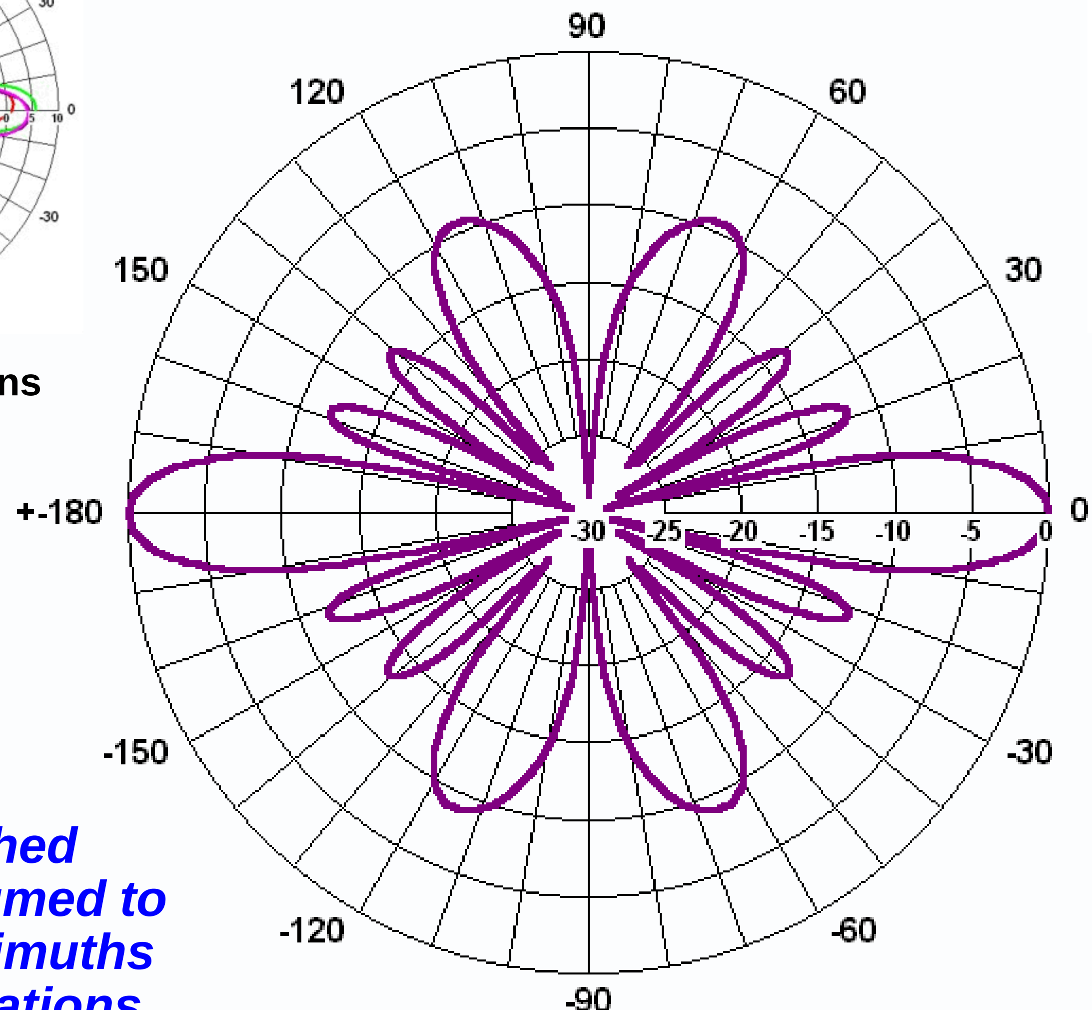


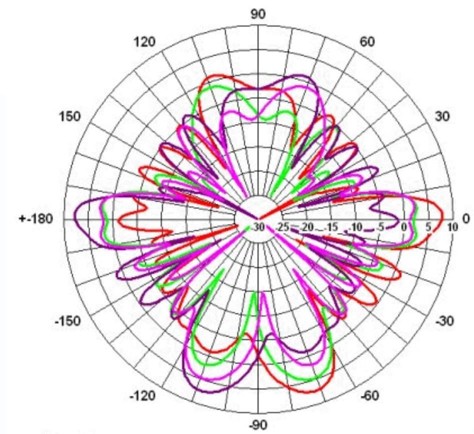
Elevation Pattern Comparison: 4-bay Helical Antenna



H-pol NEC Patterns
(this study)

"Published" Pattern
E/E_{max} dB (normalized)





V-pol NEC Patterns
(this study)

The published pattern is assumed to apply to all azimuths and all polarizations.

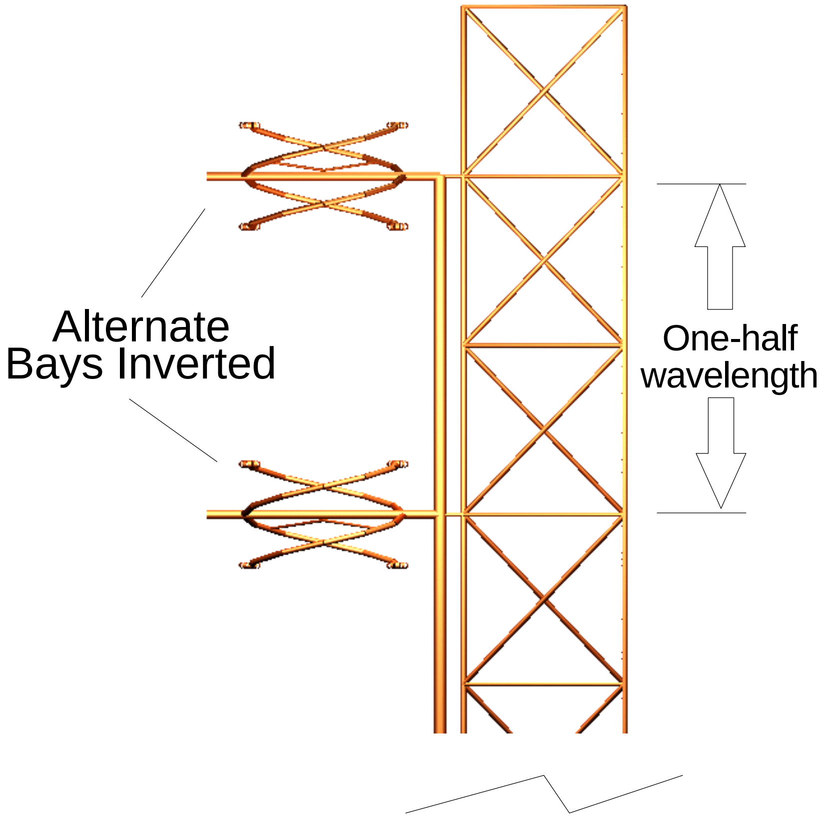
Reduced Sidelobe Configurations

! Half Wave Vertical Bay Spacing

< Alternate bays are physically inverted to accomodate the 180º progressive RF phase shift in the antenna "spine" in this configuration.

< Gain is reduced, for the same number of bays, and

< Main vertical-plane lobe becomes wider, which can increase signal levels on the ground near the antenna site (blanketing issue?)



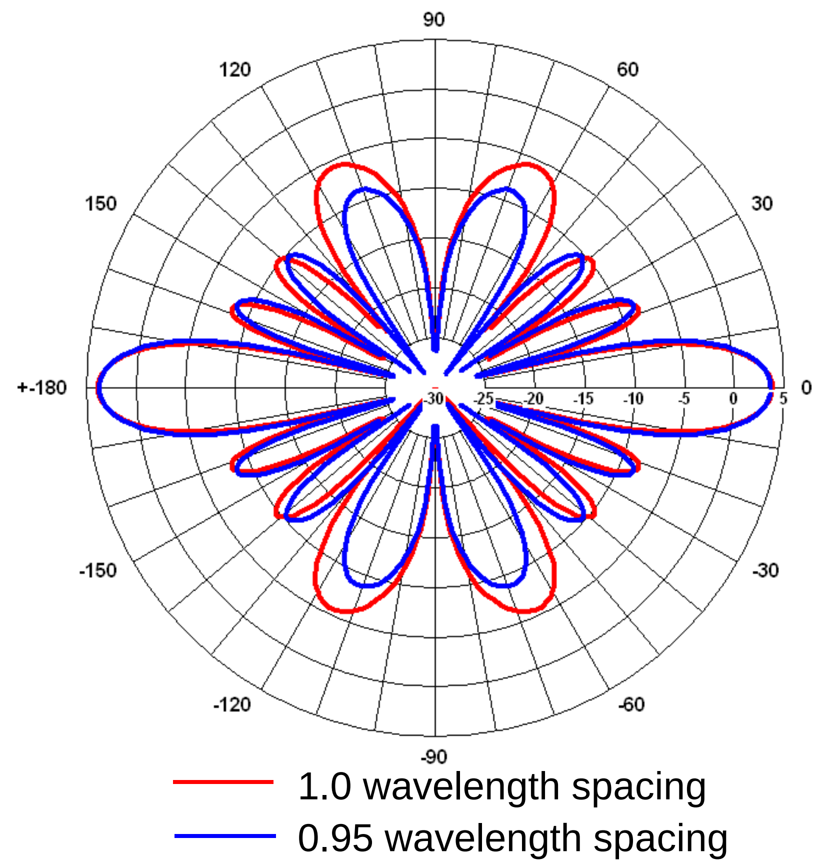
Reduced Sidelobe Configurations, cont'd

- "Zero Sidelobe" Designs
  - Half-wave vertical bay spacing
  - Typically requires branch feeding using an "n-way" power divider and separate (usually flex-type) lines to each bay.
  - Excitation of each bay is determined by ~binomial distribution. Example for a 6-bay, zero-sidelobe antenna (bays 1-6):
    0.1, 0.5, 1, 1, 0.5, 0.1
    - Manufacture of power dividers with output ratios of ~0.1 and less are a practical challenge (limits the number of bays in this design)
  - Gain is reduced (even over a conventional ½-wave spaced antenna), for the same number of bays, and
  - Main vertical-plane lobe becomes wider, which can increase signal levels on the ground near the antenna site (blanketing issue?)
  - More expensive to buy and install

Reduced Sidelobe Configurations, cont'd

- Other Vertical Bay Spacing
  - Bays can be spaced at any fractional wavelength between about ½ wavelength and 1 wavelength.
  - Spacings of about 0.95 wave-length generally will reduce high-angle sidelobes with only a small affect on gain in the horizontal plane.
  - Typically requires branch feeding using an "n-way" power divider and separate (usually flex-type) lines to each bay.
  - More expensive to buy, and install.

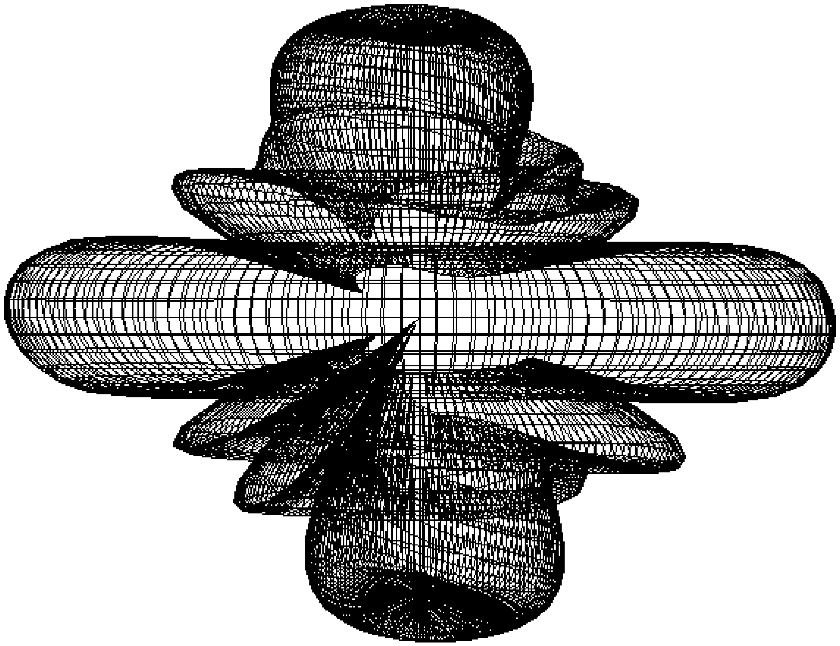
Relative Field in dBi vs
Vertical Plane Bay Spacing
for Four Bays (no coax or tower)



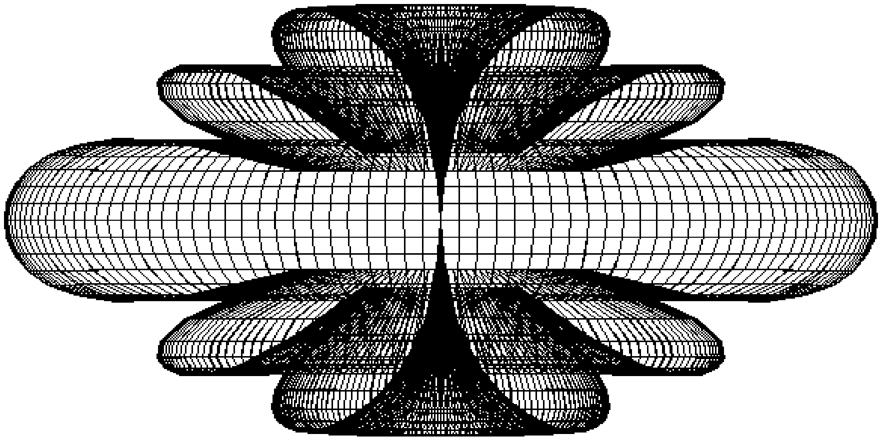
Half-wave Spaced Antenna Surface Patterns

Six Bays of Helical Elements

Leg-mounted on 24" face triangular tower



Elements only, no rigid line or tower (typical “published” pattern)

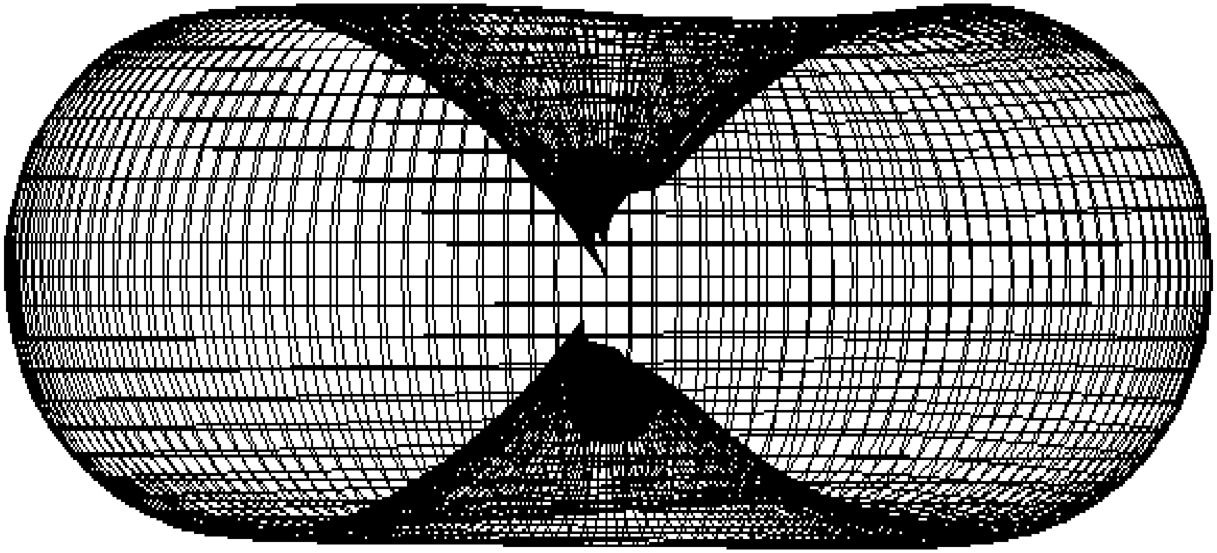


Conclusion: Theory ≠ Reality

Zero Sidelobe Antenna Surface Patterns

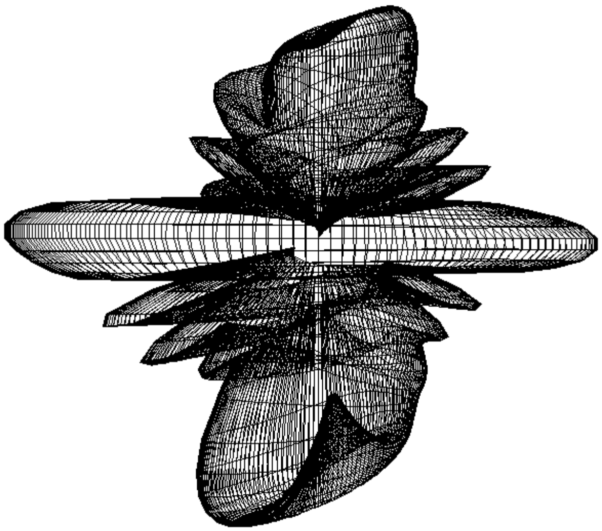
Six Bays of Helical Elements

Leg-mounted on 24" face
triangular tower

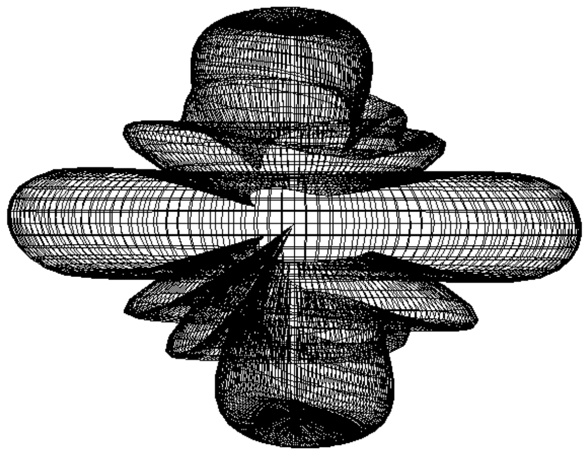


Surface Patterns Compared

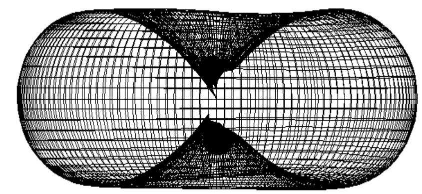
Helical Elements Leg Mounted on 24" Face Triangular Tower



4-bay Full Wave Spaced
RMS Gain = 2.1X



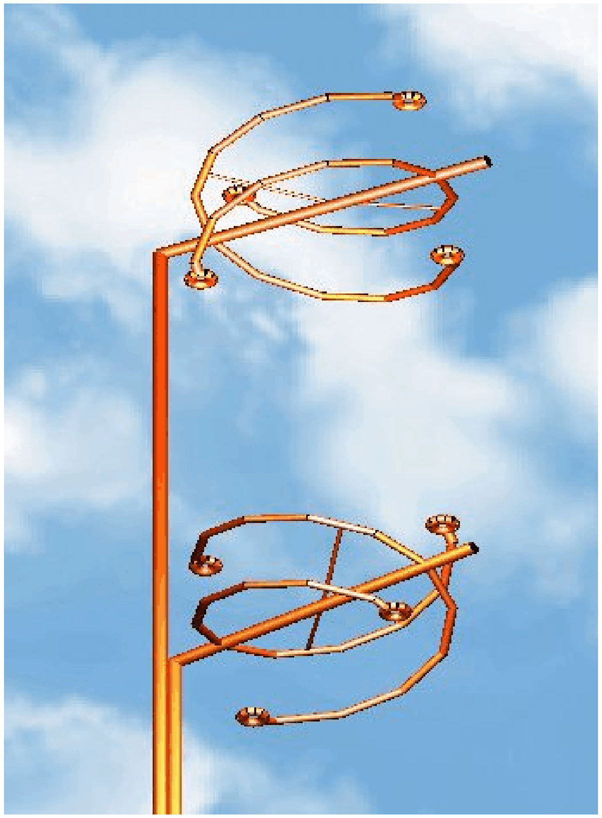
6-bay Half Wave Spaced
RMS Gain = 1.8X



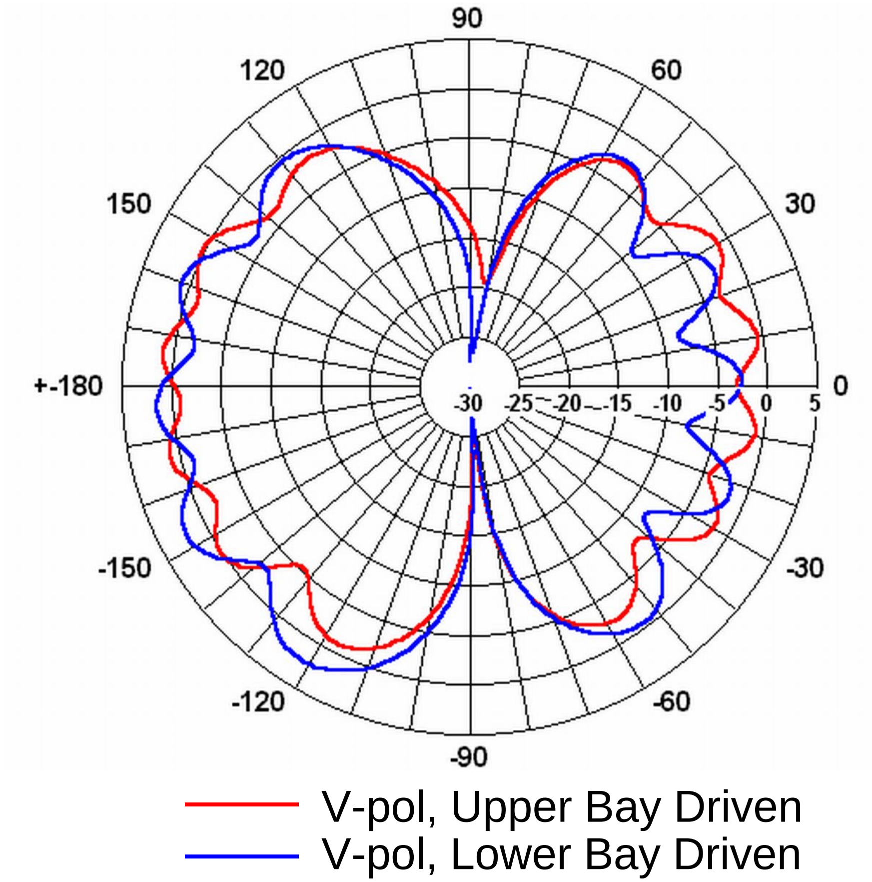
6-bay Zero Sidelobe
RMS Gain = 1.28X

NEC-2 Radiation Patterns of Interleaved Antenna Elements and Adjacent Transmission Lines (proposed for HD Radio)

* Elevation Patterns at Zero-180 Degree Azimuth Bearing
* LH & RH CP Elements at ½-wave Vertical Spacing



Transmission lines extend to a point 25 feet below the bottom bay.



http://rfry.org

List of Technical Papers and Data

Home Page | Technical Papers | Author Background | Contact Author

September 2, 2003

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1. **FM/HD Radio RF System Planning**
   Comprehensive system planner with built-in database for many types of antennas and coax, and extensive error-checking.
2. **FM/HD Radio Interleaved Antenna Patterns**
   Overlay of NEC-2 radiation patterns for two FM elements of opposite polarization sense and 1/2-wave spacing, driven one bay at a time.
3. **Co-sited FM Antennas**
   Considerations when two or more FM stations share a site.
4. **Sidemount FM Antenna Patterns**
   NEC-2 analysis showing the pattern effects of structure adjacent to an operating FM transmit antenna.
5. **FM/HD Radio Antenna Choices**
   Antenna choices to be made for various possible FM/HD Radio system configurations.
6. **Cost Planning for Implementation of FM/HD Radio**
   Includes basic worksheet to capture and organize probable cost elements.
7. **Transmitter Cooling**
   The importance of transmitter cooling system design in improving on-air reliability.

8. **Download a ZIP file with all seven papers above (451 KB).**

Master FM Antenna Peak Power
Development of the peak powers present in Master FM antennas.

Thanks for stopping by.

Caveats

- The patterns shown in this presentation are subject to any limitations of the software utilized, and the knowledge and skill of the operator. They may or may not apply literally to the elements or installed arrays of any specific antenna manufacturer.
- Patterns vary ***widely*** with element type, frequency, mounting configuration, tower geometry and other factors.
- Each case is unique.

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