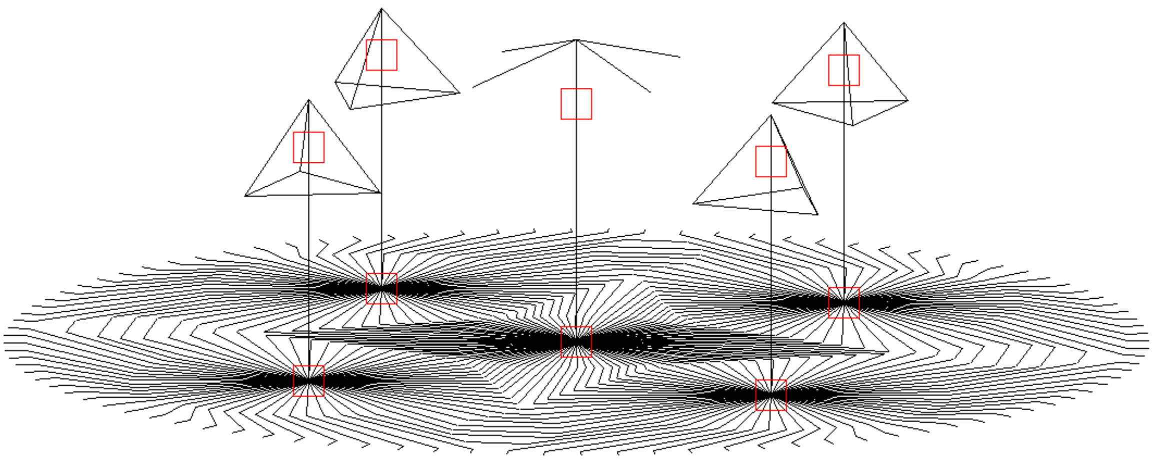


MYERS STEERABLE PARASITIC VERTICAL ARRAY

For 160 & 80 Meters

A Reduced-Size High-Gain Vertical Steerable Array for the Low Bands

Scott Myers AC8DE
Scottac8de@gmail.com
August 7, 2026
Revision 5

Myers Steerable Parasitic Vertical Array for 160 & 80 Meters
Scott Myers AC8DE – August 7, 2026 - REV 5

Contents

Abstract

This paper presents the design and simulation of a high-gain, dual-band, steerable vertical parasitic array optimized for the 160-meter and 80-meter amateur radio bands. Utilizing advanced antenna modeling techniques, the design achieves moderate physical size reduction while maintaining high efficiency and low radiation angles. The system utilizes a shared, full-size 160-meter radial ground field. By eliminating the requirement for traditional support towers or large concrete foundations, this design significantly reduces construction costs and simplifies compliance with local zoning, permitting, and inspection regulations.

Introduction

As an HF-focused amateur radio operator, I've had high interest in owning a low-band antenna combining a low take-off angle, high-gain, and directional steerability. The problem, of course, is that such antennas are traditionally massive and prohibitively expensive. While small commercial compromise antennas exist, there is no free lunch in antenna physics. To maintain efficiency, gain, and usable bandwidth on the low bands, size is mandatory. Therefore, while this paper promises a "reduced size" design, the reduction is deliberately moderate. You simply cannot cheat physics, but you *can* negotiate with it. Since most hams lack a 50-acre property and an endless cash supply, we must find the sweet spot between what we want and what we can manage to build.

My journey to this design started with a 160-meter dipole thrown over the trees long ago. At only 40 feet high and resting on branches, it was strictly a Near Vertical Incidence Skywave (NVIS) cloud-warmer that could not withstand high power. Next, I tried 35-foot verticals with loading coils; bandwidth was horribly narrow, and efficiency dropped into single digits. Shunt-loading my existing 80-foot self-supporting tower was an option, but its position on my property boundary made a proper radial field and parasitic steering elements impossible. However, I did have a blank canvas: a flat, open, 2-acre backyard measuring roughly 300 by 300 feet. Looking at DX superstations, I briefly hallucinated about building a full-size, 135-foot 160-meter vertical 4-square array before reality caught up with me. Inspired by others' vertical steerable arrays already in use today, I turned to EZNEC and the NEC-5 engine to see if a dual-band 160M/80M steerable array could be designed and still tick all the boxes. After extensive modeling and consulting with low-band veterans, the data said yes. It is possible to achieve excellent dual-band gain without a towering infrastructure, though it still requires a serious 260-foot diameter radial field to keep efficiency high. It is a large array by anyone's standards, but it is entirely doable by a greater percentage of ham radio operators than a traditional tower structure.

Design Objectives

To make it possible to transition this project from a theoretical simulation to physical reality, I established a strict set of design criteria. In order of priority, the array must satisfy the following constraints:

- **Target Budget:** $12,000 range. While subjective, this is remarkably economical for a steerable, directional dual-band 160/80-meter array that delivers genuine low-angle gain.
- **Reproducibility & Feasibility:** The design must use readily available, non-obsolete materials. Fabrication must require only standard tools owned by a typical amateur or easily sourced from a local tool rental.

- **Gain Performance:** The array must deliver a minimum of 4 dBi of forward gain alongside switchable directionality, otherwise, the complexity is unjustified.
- **Single-Operator Build Window:** Construction must be achievable by one person within a two-year timeline. Spreading the labor out accommodates daily commitments, with the extensive radial field remaining the primary bottleneck. (Some steps will require assistance, but no heavy equipment.)
- **Maintainability:** All mechanical and electrical subsystems must allow for straightforward, single-person servicing without specialized rigging equipment.
- **Decommissioning Ease:** The above-ground footprint must be easily removable to protect property resale value. While the subsurface radial field will be permanently abandoned, the vertical elements and extensive guy-wire network must come down without leaving a permanent scar on the property.
- **Property Integration:** The physical footprint must co-exist with daily life. This means maximizing clearance for lawn maintenance, ensuring structural resilience against yard hazards like mowers, children, roaming deer, etc.

Design Influences

Every complex antenna system stands on the shoulders of low-band pioneers. This project was first inspired by **Greg WB9DNZ**, who successfully deployed a steerable parasitic array for the 80-meter band. His impressive real-world forward gain and robust mechanical execution proved the original concept to launch my design.

Several other sources provided critical information as well:

- **VE6WZ:** His innovative use of 4-inch aluminum irrigation tubing as lightweight, freestanding vertical parasitic elements (on a shunt-loaded 160m tower) was a true "eureka" moment. It demonstrated that large vertical elements could be built without relying on expensive, heavy tower sections.
- **K3LR & ON4UN:** Tim K3LR's well-documented full-size 160-meter parasitic array at his legendary superstation—as detailed in John Devoldere's (*ON4UN*) seminal book *Low-Band DXiing*—served as another valuable reference for my theoretical baseline.
- **W5ZN:** Joel's published work provided important insights into optimizing parasitic vertical array behaviors.

Band Coverage & System Architecture

Because my property constraints dictate that I can only deploy a single large low-band transmitting array, dual-band operation on 160-meters and 80-meters was mandatory. Multi-band HF Yagi's successfully use loading coils, interlaced elements, and physical trade-offs to achieve multiband performance without destroying efficiency and gain; I aimed to apply similar principles to a vertical parasitic system.

Finding the equilibrium between bandwidth, forward gain, and material costs required hundreds of iterations in the modeling software. A critical design decision was made early on regarding pattern optimization: because this installation will pair with a dedicated 9-circle receive array for pulling out weak signals, the transmit array's pattern is optimized almost exclusively for maximum forward gain rather than deep front-to-back (F/B) rejection. (F/B ratio could also be targeted with this design with some modification.)

The resulting design achieves a highly efficient, dual-band balance—at least on paper.

System Design and Structural Trade-offs

Practicality and real-world site constraints heavily guided the theoretical design phase. I initially modeled two types of central vertical structures: flexible fiberglass poles supporting wire elements, and a lightweight, aluminum tilt-over tower. Having previously installed a large self-supporting tower at my QTH, I wanted to avoid another permanent structural installation. A traditional tower foundation requires backhoes, zoning hearings, building permits, and formal inspections—adding thousands of dollars and months of administrative delays to the project.

Modeling a 4-inch aluminum irrigation pipe alternative yielded a major breakthrough: the bandwidth deficit compared to a wide-faced tower was negligible and easily compensated for with minor base inductive loading adjustments. Transitioning to irrigation pipe reduced estimated structural costs by over $5,000. Furthermore, because a 54-foot section of this pipe weighs under 50 pounds and sits on a tiltable base, it qualifies as a temporary structure. It requires no more concrete than a heavy 6x6 fence post set below the frost line and can completely bypass local zoning and permitting hurdles in many jurisdictions.

For the parasitic elements, I initially attempted to mimic the K3LR and WB9DNZ designs by hanging wire elements from the guy lines. However, due to the compromised physical height of this array, the simulated coupling on 160-meters was insufficient unless excessive base inductance was added, which severely degraded forward gain. Consequently, I standardized all five elements (one driven, four parasitic) on the 4-inch aluminum irrigation pipe architecture.

Physical Element Geometry and Construction

The finalized computational model consists of a 4-inch diameter central driven element surrounded by four similar 4-inch parasitic elements arranged in a square layout with a 75-foot spacing radius from the center. This 75-foot spacing was the balance distance for electromagnetic coupling in simulation for both bands and still worked with the physical layout constraints of my 2-acre backyard.

Element fabrication relies on highly accessible materials:

- **Lower Center Section:** A 54-foot length of 4-inch aluminum irrigation pipe ending 55 feet above ground level.
- **Upper Center Section:** A fiberglass insulating tubing mounts a 2-inch aluminum tube vertically from the top of the 4-inch tubing, extending the total structural height to 70 feet.
- **Top Hat:** A 4-wire top hat is mounted at the 70-foot apex. The ends of the top-hat wires are connected to insulators and ropes and are supported by pulleys near the tops of the parasitic elements.
- **The Parasitic Elements:** Similar construction and layout of the center section, just slightly shorter overall.
- **Parasitic Element Top Hats:** Fully formed 3-sided pyramid-like wire shapes that also serve as part of the guy line system.
- **Band Switching:** High-voltage vacuum relays are installed inside the top of the 4-inch sections. Activating these relays connects the 160-meter top hats; deactivating them opens the circuit for 80-meter operation.

On 80 meters the top hats are disconnected and the physical element lengths are cut to be resonant just above the top of the band. This ensures that the base matching and steering circuits remain primarily inductive, minimizing component complexity and cost. On 160 meters, the top-hat geometry is similarly trimmed to be resonant just above the band edge to maintain inductive base tuning. The top-hat wires on the parasitic elements double as structural guy lines to streamline the mechanical footprint.

Directional Control and Pattern Steering

Azimuthal steering is achieved by switching discrete inductive loads at the bases of the parasitic elements. To render a parasitic element electrically "invisible" (RF-isolated) in the model, a 100 MΩ resistive load is applied to its base. This simulates an open relay contact disconnecting the element from the radial ground plane, reducing induced RF currents to near zero as to not affect the far-field pattern.

To shift the array from an on-axis inline pattern to a 45-degree broadside pattern, a control system switches both the LC network values at the driven element and the inductive loading/isolation states at the parasitic bases.

Electromagnetic Modeling Techniques

Simulating a 5-element array with a full radial field is computationally heavy. To accelerate optimization iterations, the physical radial wires were removed from the initial design models after learning what its approximate base resistance is. Instead, the system was initially simulated over a MININEC ground plane, substituting an Equivalent Series Resistance (ESR) load at the base ground-connection points. This ESR accurately mimics the calculated ground return losses of a physical 130-foot radius, 96/64-wire radial field while drastically reducing wire-segment counts and matrix solution times. The radial field was then added back in at the final stages of modeling to bring the final models into focus.

The optimization workflow prioritized far-field radiation patterns first, leaving impedance matching as a secondary step:

1. **Pattern Optimization:** Hundreds of iterations were run across both bands, adjusting element lengths, top-hat arrangements and parasitic inductive loads to maximize forward gain.
2. **Impedance Bounds:** While optimizing patterns, raw driven-element VSWR was kept below 10:1 at the band edges to ensure the final matching networks used realistic, low-loss component values.
3. **Matching Networks:** As expected, forward gain showed zero correlation with raw VSWR. While a builder could simply insert basic inductive loading at the base of the driven element and rely on a high-power transmatch (tuner) in the shack, I will use four switched L-networks with transformers at the base. These networks keep the system VSWR below approximately 2:1 across the entirety of both bands through the use of switchable segments on both bands.

NEC-5 Engine Note

This simulation requires the NEC-5 engine for high-fidelity accuracy, particularly when evaluating the final physical radial ground integration. While creative segmentation tricks can force the model to run under the legacy NEC-2 engine, the severe proximity of the elements to the ground plane compromises NEC-2's mathematical validity.

Material Specifications and Mechanical Assembly

Vertical Element Fabrication and Splicing

- **Main Tubing:** The vertical elements are constructed from standard 30-foot sections of 4-inch aluminum irrigation tubing.
- **Splicing Technique:** To achieve the required heights, sections are joined using an internal coupler fabricated from a 2-foot piece of scrap 4-inch tubing. The scrap piece is slit lengthwise, reformed, and inserted into the main tubes. The joint is secured using six rows of 1/8-inch heavy-duty aluminum blind rivets. For maximum mechanical strength against wind loading, the spliced joints are kept as close to the base of the element as possible.
- **Top-Hat Support:** A 2-inch aluminum top section extends from the apex of the 4-inch pipe to support the top-hat wire infrastructure. To isolate and mount this top section, a heavy-wall fiberglass tube is slipped inside the 2-inch aluminum element and securely clamped to the top OD of the 4-inch irrigation pipe. This avoids unnecessary concentric machining and simplifies apex fabrication.

Base Feedpoint and RF Ground Connections

- **Feed Point Geometry:** The electrical connection points of the 4-inch vertical element bases cuts overlapping tabs from scrap 4-inch tubing to form mechanical "ears" clamped to the bottom outer diameter of the element with stainless steel hose clamps and bent into curves that meet under the elements. This tubing junction is wrapped in self-amalgamating silicone tape and protected with a heavy UV-rated vinyl electrical tape wrap.
- **Integral Tail Alternative:** To eliminate an electromechanical joint as described in the previous paragraph, an alternative approach cuts two 6-8 inch vertical "tails" directly into the bottom of the main element. These integral aluminum straps bend under the element and bolt directly together at a single, centralized apex. This single-piece configuration will be finalized during the physical build phase.
- **Enclosure Interface:** Connection from the centralized base apex to the matching networks uses a 3-inch wide, 1/16-inch thick 6061-T6 aluminum strap secured with stainless steel hardware. The RF ground return from the radial rings connects to the matching networks and parasitic load enclosures via a 2-inch wide copper strap.

3D-Printed Structural Base Inserts

- **Wall Stiffening:** The thin wall of standard irrigation tubing cannot support point-loaded hinge pressures on its own. To prevent deformation, an 8-inch long, heavy-wall internal sleeve is 3D-printed from polycarbonate filament, sized to a -0.010 inch tolerance relative to the inner diameter of the aluminum tube. (Not strictly off-the-shelf, but highly available today among ham radio operators.)
- **Sleeve Specifications:** The bottom 3/8-inch thickness of the sleeve's outer wall is printed at 100% infill to provide a solid substrate for stainless steel sheet metal screws driven through the irrigation pipe. The screw heads are sealed externally with self-amalgamating silicone tape.
- **Pivot Bushing:** A perpendicular axle hole is printed through the center of the polycarbonate sleeve to accept a 1-inch solid fiberglass (FRP) rod. This rod serves as the main structural pivot and hinge pin. A perpendicular hole is drilled through the aluminum tubing to match the hole in the 3-D printed sleeve hole. It passes through heavy Fiber-Reinforced Plastic (FRP) or Ultra-High-Molecular-Weight (MHMW) polyethylene U-channels embedded in a concrete post-hole foundation dug below the local frost line.

Enclosure Bulkhead Design

- **Environmental Sealing:** To feed high-RF voltages into the NEMA-4 enclosures for the LC and inductive loads, surplus ceramic bowl or commercial high-voltage bulkhead insulators can be used if available. If surplus options are unavailable, custom high-density polycarbonate bulkhead panels featuring an integrated drip edge will be designed and 3D-printed.

Structural Foundations and Enclosure Support

- **Pivot Mounts:** Each vertical element is supported at the base by two vertically installed parallel Fiber-Reinforced Plastic (FRP) structural fiberglass channels embedded in concrete. These channels extend 12 inches above grade to hold the 1-inch hinge fiberglass rod. Because structural fiberglass features an exceptionally low dissipation factor at HF, these channels double as heavy-duty base insulators that remain impervious to UV and RF degradation.
- **Enclosure Mounting:** Two additional FRP channels are set in the concrete to support the NEMA-4 matching and loading enclosures. These channels extend 18 inches above grade, positioning the enclosures within one inch of the vertical element. This ensures that the interconnecting aluminum and copper feed straps remain ultra-short (under 12 inches) to minimize stray inductance, while leaving adequate physical clearance for the element to move in the wind and tilt over without striking the enclosure.
- **Enclosure Material:** All matching networks and parasitic load housings utilize non-metallic FRP fiberglass NEMA-4 enclosures. This non-inductive material ensures zero electromagnetic interaction with the internal high-Q loading coils and capacitors.

Guying and Ground Anchors

- **Rigging Lines:** The vertical elements rely exclusively on their guying networks for vertical structural support. The design utilizes common high-tensile, low-stretch, UV-resistant polyester rope (such as Mastrant-M or high-grade Dacron) configured as guy lines.
- **Anchor Geometry:** The driven element utilizes four ground anchor points, while the parasitic elements utilize three. Each anchor point secures three guy lines tiered along the length of the element.
- **Ground Anchor Posts:** Guy ropes terminate at eight ground posts set 3 feet deep in concrete, extending 5 feet above grade to ensure lawnmower clearance and prevent accidental pedestrian contact. To eliminate wood rot and string-trimmer damage, these posts are fabricated from heavy structural fiberglass. *(Note: If treated 4x4 or 6x6 lumber is substituted, the subsurface portion will be coated in thick roofing tar prior to pouring concrete).* Under a 75 MPH wind load, the maximum calculated pull on any single anchor point is under 200 pounds at an average upward angle of 40 degrees, making structural fiberglass an exceptionally resilient choice.
- **Element Attachment Points:** Guy lines secure to the 4-inch aluminum tubes via heavy-duty stainless steel hose clamps looped through solid stainless steel D-rings or smaller hose clamps (As used by VE6WZ). Ceramic or glass "dog-bone" strain insulators are integrated at all high-voltage attachment nodes for guy line attachment on the vertical elements to prevent RF leakage.

Top-Hat Vacuum Relays and Control Lines

- **Faraday Cage Isolation:** The high-voltage vacuum relays responsible for engaging the 160-meter top hats are housed entirely inside the top apex of the 4-inch aluminum elements. By running the relay control lines down the inside of the aluminum tubing, the elements act as a natural Faraday cage, shielding the control lines from intense local RF fields.

- **High-Voltage Insulation:** Where the 2-inch and 4-inch tubing are electrically connected, the wire used for the connection is jacketed in heavy-wall silicone tubing to withstand the high RF voltages present at the element tips. The control lines to the vacuum relays are shorted with small capacitors at the relay and aggressively choked with ferrite beads at the 4-inch element base as an insurance policy against induced RF.

Conduit and Cable Routing

- **Main Runs:** Feedlines and control cables are routed underground through 2-inch High-Density Polyethylene (HDPE) continuous conduit, which is significantly more cost-effective and easier to deploy than individual 10-foot PVC sticks.
- **Layout Topology:** The underground infrastructure requires roughly 750 total feet of conduit on my property as I cannot make a direct run to the driven element. Branching from the base of the existing main tower (the location of my main remote coax switch), the primary run connects to the driven element's subterranean ground box. From there, four separate 75-foot runs branch out to individual ground boxes at the base of each parasitic element. A final run extends from the driven element to the far corner of the yard to feed the separate 9-circle receive array not directly associated with this project. Intermediate ground boxes may be added mid-run to ease cable pulling. All ground boxes are backfilled with gravel.

Radial Ground System and Base Integration

- **Radial Ring Construction:** The radial bus rings at the base of each element are fabricated from 1/2-inch soft copper pipe bent and split into two C-shaped halves. The ends are smashed flat and drilled to accept a heavy binding bolt. Half of the radial wires are soldered to each C-section, and the solder joints are sealed with weather-proof silicone conformal coating.
- **Physical Layout:** The radial wires rise to the surface at 1.5-foot radius around each element base. The subterranean ground boxes are installed flush with the soil (roughly 1 inch above grade). Liquid-tight flexible outdoor conduit exits the bottom of the ground box and routes directly into the bottom of the NEMA-4 enclosure via weatherproof bulkhead fittings.
- **Weed Control and Final Assembly:** To prevent vegetation growth around the central base connections, a 2-foot radius shallow circle is dug out around the antenna base is lined with heavy plastic landscaping fabric and backfilled with gravel flush to the top of the ground box. The split copper ground rings are bolted together over the gravel around the element base, bonded directly to localized ground rod, and tied to the internal circuits within the NEMA-4 enclosures using 2-inch-wide solid copper strap. All exterior mechanical and electrical bolted connections are treated with Jet-Lube SS-30 anti-seize and sealed with self-amalgamating silicone tape where practical.
- **Moisture Management:** To prevent the underground conduit from acting as a humidity pump into the NEMA-4 housings during temperature swings, the internal conduit entryways are packed with a gas-tight sealant inside the enclosures. If necessary, large reusable desiccant packs can be placed inside each NEMA-4 box to manage moisture, but these must be recharged often during damp weather periods.

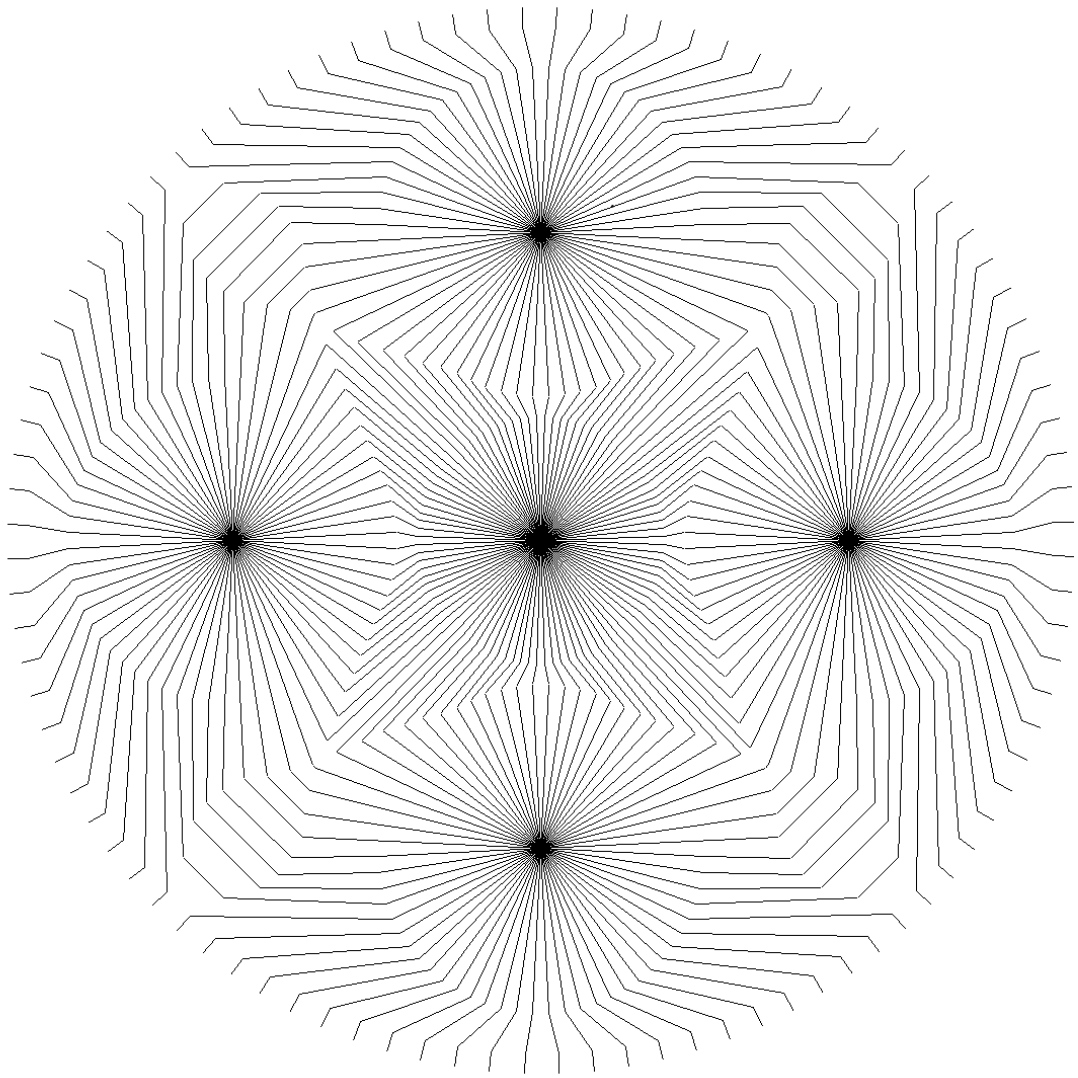
Erection and Deployment Mechanics

- **Falling Derrick Method:** Raising the 55-foot, 75-pound vertical elements will be accomplished using a temporary falling derrick fashioned from a rugged 20-foot aluminum extension ladder and 2x4’s. Accounting for the distribution of weight of the vacuum relay, top-hat wires, and drooping guy ropes, the initial vertical lift force required at the apex of the derrick is calculated at a maximum of 100 pounds. A simple block-and-tackle system will handle the initial lift. Once the element rotates past a 45-degree angle, the tension drops off drastically, allowing the operator to easily hand-guide the elements to their vertical stops.

Radial Field Modeling and Optimization Bounds

- **Radial System Modelling Layout:** The radial geometry was loosely adapted from Tim Duffy K3LR's optimized 160-meter system detailed in Chapter 13 of ON4UN's *Low Band DXing*. Due to the limitations of drawing a complex geometric pattern, a highly segmented multi-point radial system was applied in EZNEC, making initial modeling of this system time consuming.
- **Diminishing Returns:** Starting at 128 radials, the simulation was iteratively scaled back to determine the threshold of diminishing returns regarding ground-return efficiency. Reducing the system to a combination 96/64 radial system maintained outstanding efficiency without double the material cost and deployment complexity of a 128-wire system. Inversely, 32 radials proved unacceptable for my goals of gain and efficiency.

Radial system



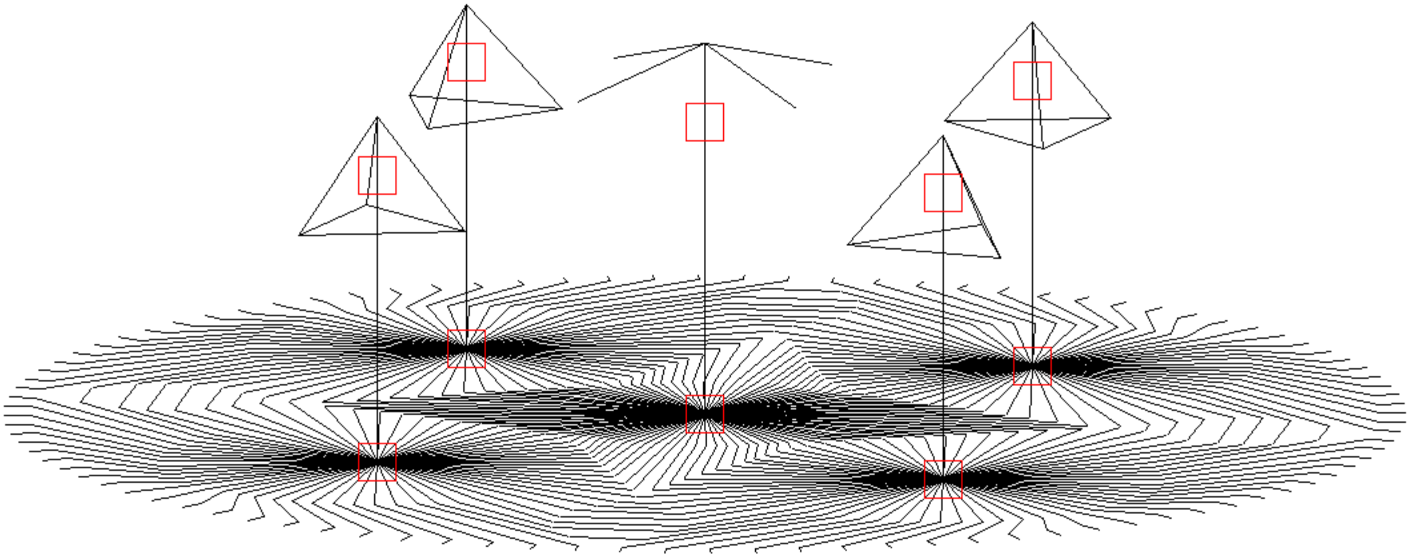
For ground-mounted verticals, minimizing ground resistance and shielding the array from the earth's lossy capacitive effects is critical. The radial system on vertical ground-mounted antennas should never be compromised if good performance is expected.

The above figure shows the plan view of the 230-foot diameter combination 96/64-wire radial system. In reality these wires will be laid in gentle arcs; they are modeled with sharp angles only because EZNEC cannot easily simulate curved wires. This integrated layout allows for continuous wire runs, avoiding complex bonding between the parasitic and driven radial fields while maximizing capacitive shielding.

Simulation yields an exceptional equivalent ground resistance between **1.4 Ω** and **2.2 Ω**. Doubling the system to 128 radials drops resistance by only approximately 0.1 Ω average and yields a trivial 0.10-0.15 dBi gain increase. That minor improvement does not justify doubling the installation labor, adding another 19,000 feet of wire, and spending an extra $2,400.

The seemingly odd 128/96/64 radial counts was chosen out of layout habit. There is nothing magical about those numbers. In standard radial systems I've installed, starting with four radials at 0, 90, 180, and 270 degrees makes even distribution of radials in multiples of four in the field easy. Because this dual-band interlaced pattern is highly complex and lacks simple symmetry, no such simply field layout will be possible and careful site mapping will be required before installation.

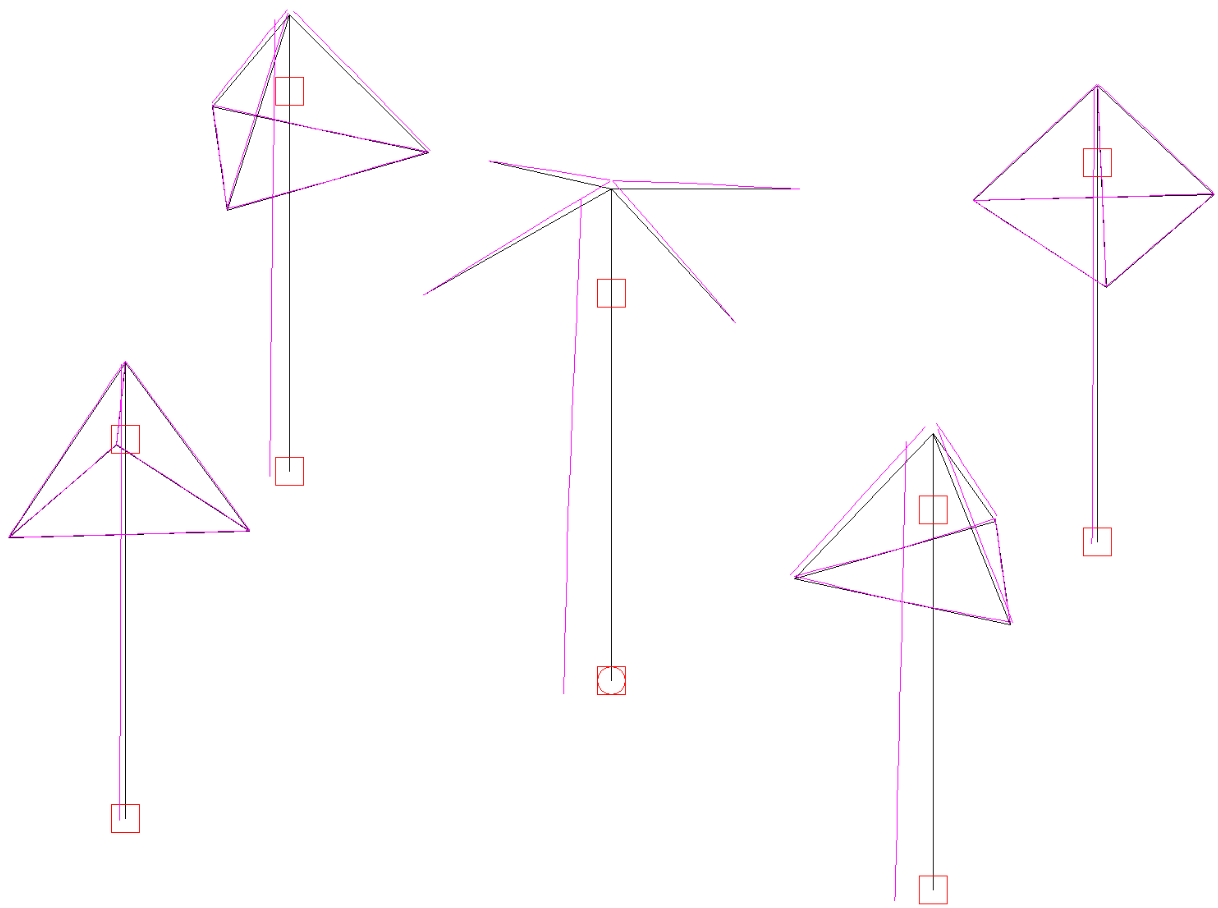
Antenna Array Representation



This shows the complete array modeled in EZNEC Pro/2+ featuring the central driven element and four parasitic elements on a 75-foot radius on center. All five elements include top hats for 160-meter operation.

The main ground plane incorporates a combined 96 and 64 radial system within a 260-foot diameter footprint using #16 AWG insulated copper wire. Modeling this complete radial field validates the faster iteration method: substituting 1.4 Ω to 2.2 Ω base resistances over a MININEC ground yields identical far-field gain results. This shortcut is essential for optimization; running simulations with all radial wires fully drawn requires 1-2 minutes per iteration on a high-power workstation, making continuous tweaks impractical.

Loaded Antenna Array Model



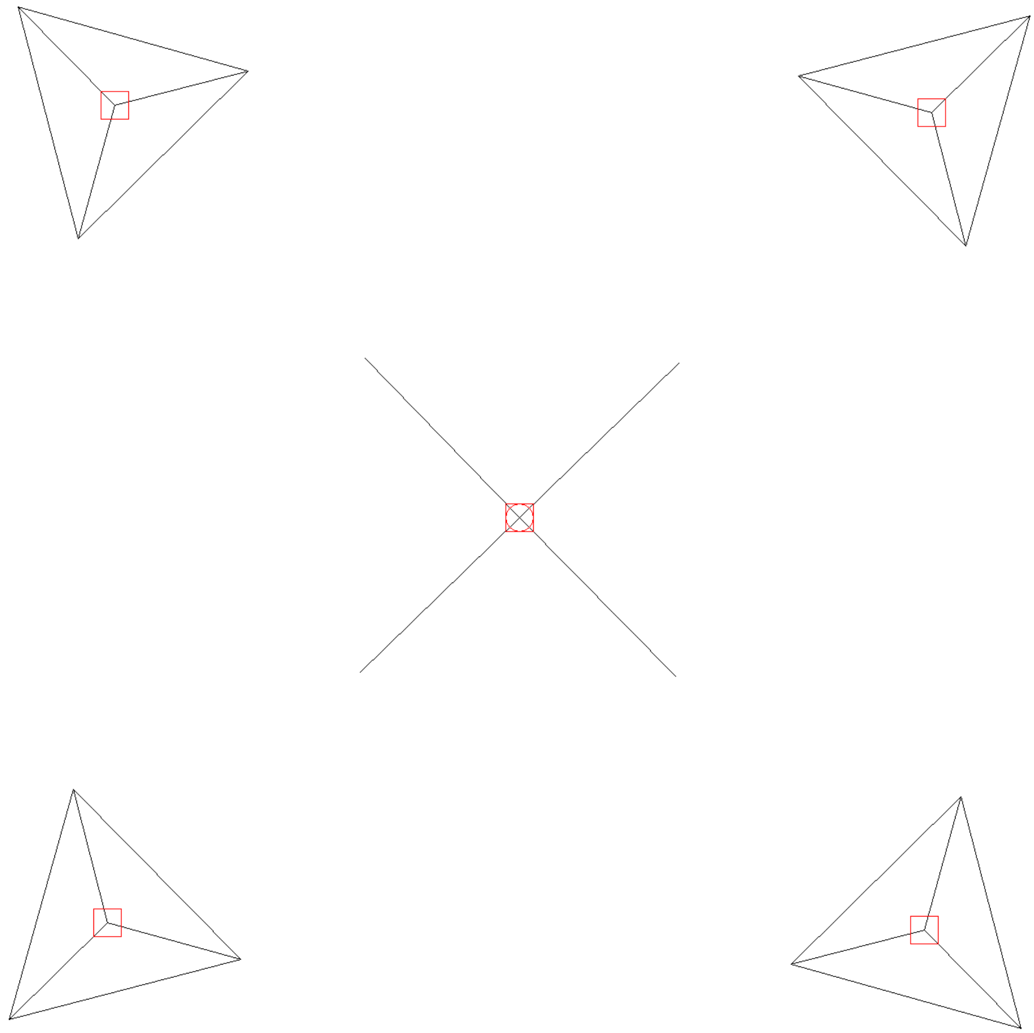
Above shows the streamlined simulation model, where the physical radial field is replaced by base load resistances. This drops iteration times from over one minute to seconds while maintaining similar far-field accuracy.

The specific model shows a 160-meter inline configuration utilizing three reflectors and one director. The purple lines display relative current distribution; greater distance from the black element line indicates higher current, with the main reflector carrying the highest load.

Key simulation behaviors include:

- **RF Isolation:** Opening a base relay drops the purple line directly onto the black element line, indicating near-zero current and zero pattern interaction.
- **Component Mapping:** The upper red squares mark the apex vacuum relays, the lower red squares indicate the base inductive steering loads, and the red circle/square marks the driven element's matching network and feed point.

Antenna Array Bird's-Eye-View



The above shows the plan view of the top-hat infrastructure and relative element spacing. The array spans 150 feet across between opposing parasitic elements on center.

The physical geometry relies entirely on structural guy lines:

- **Driven Element:** Employs a symmetric 4-wire top hat attached via ropes to the tops of the parasitic elements via pulley and then down to the anchor points.
- **Parasitic Elements:** Utilize a 3-wire triangular top-hat configuration matching their 3-guy layout.

Early design iterations connected the outer tips of the 4-wire driven hat into a completed perimeter square. This was abandoned because the flat perimeter wire complicated the pulley tensioning network at the parasitic apexes without yielding any simulated performance benefits.

Conversely, reducing the parasitic elements from a 3-wire triangular loop to three simple straight wires affected far-field radiation gain and patterns on both 160 meters and 80 meters. Retaining the closed triangular geometry on the parasitic hats is mandatory for a good balance of gain and FF pattern on both bands for this model.

Guy-Line and Achor-Point Layout

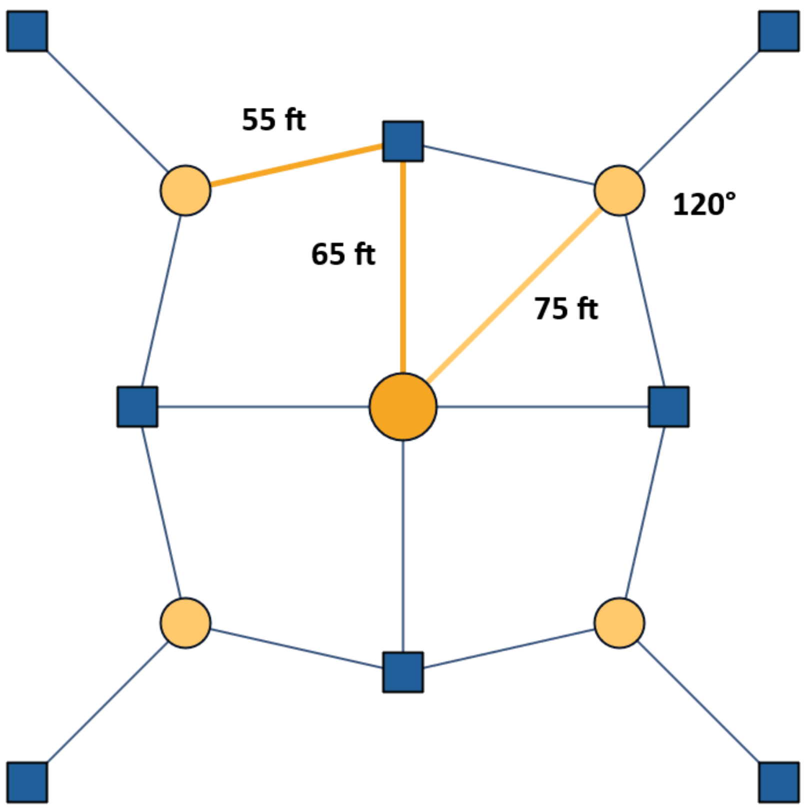
Below illustrates the finalized guy-line anchoring layout. The geometry was optimized to use eight shared anchor points to handle all elements, ensuring uniform wind-load angles.

Key rigging constraints include:

- **Driven Element:** Utilizes four anchor points, dictating its 4-wire top-hat shape.
- **Parasitic Elements:** Utilize three anchor points each, dictating their 3-wire triangular top-hat shapes.
- **Site Footprint:** Consolidating the lines into eight total perimeter anchor posts minimizes property clutter and allows symmetrical guying angles.

Vertical element

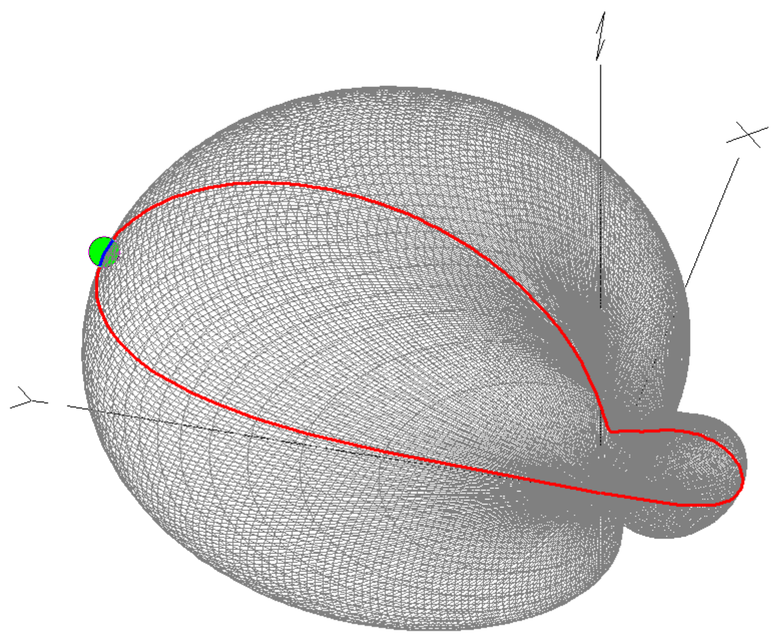
Anchor point

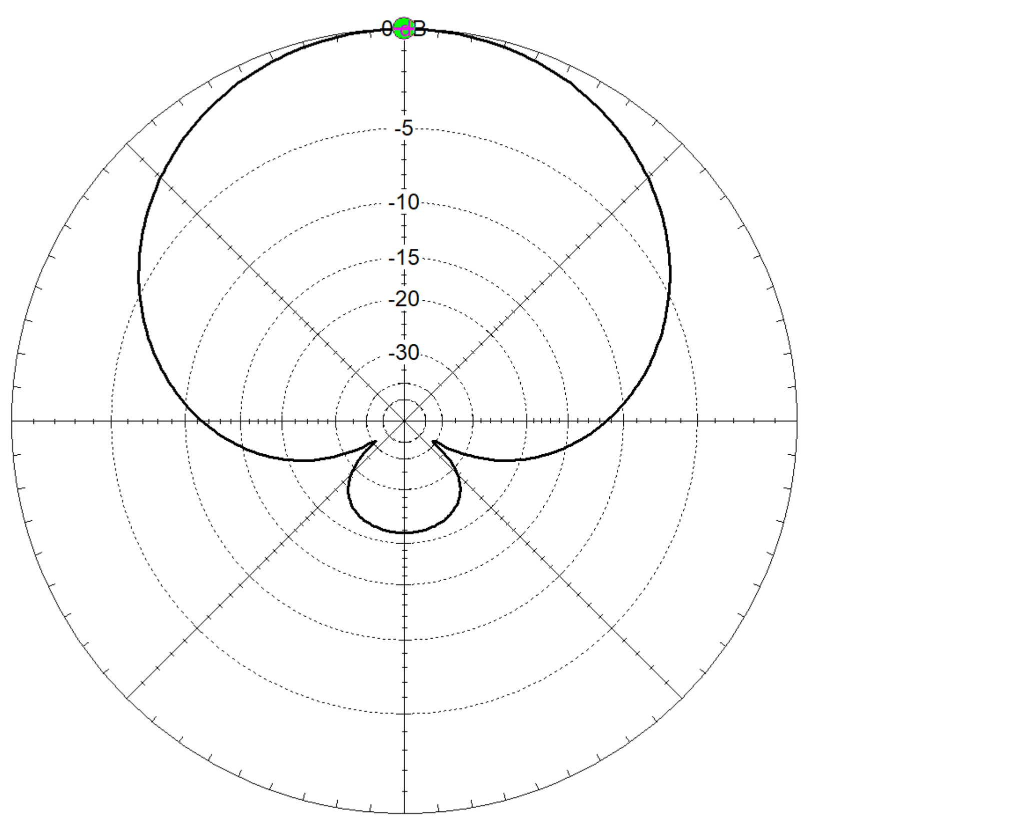


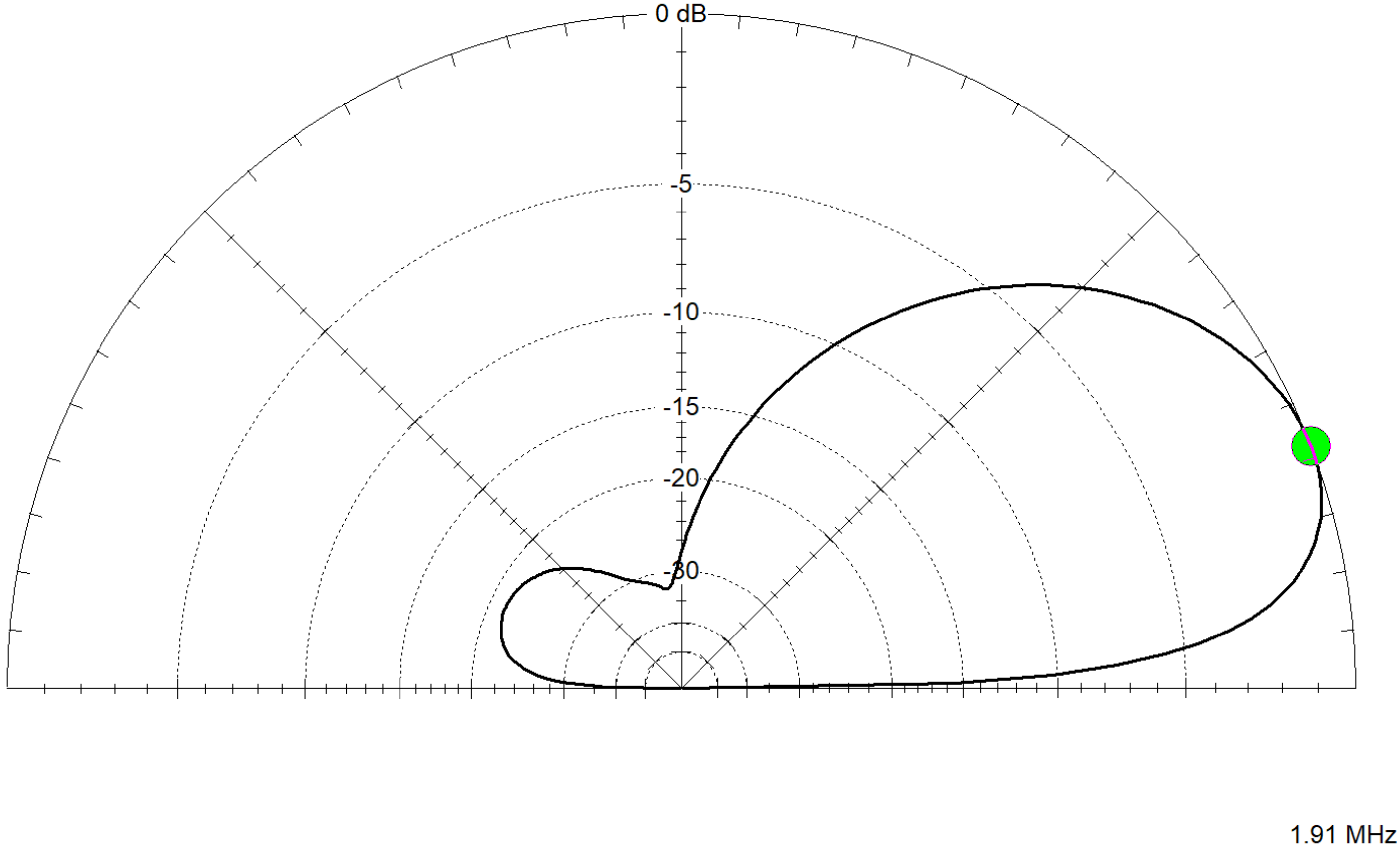
Far-Field Patterns & Gain Plots

This section displays the simulated radiation patterns and mid-band gain values calculated using the NEC-5 engine. These far-field patterns were done with the radial field in place and not the equivalent base resistances. While these metrics provide an accurate computational baseline, real-world tuning will vary based on proximity to local structures and real-world components.

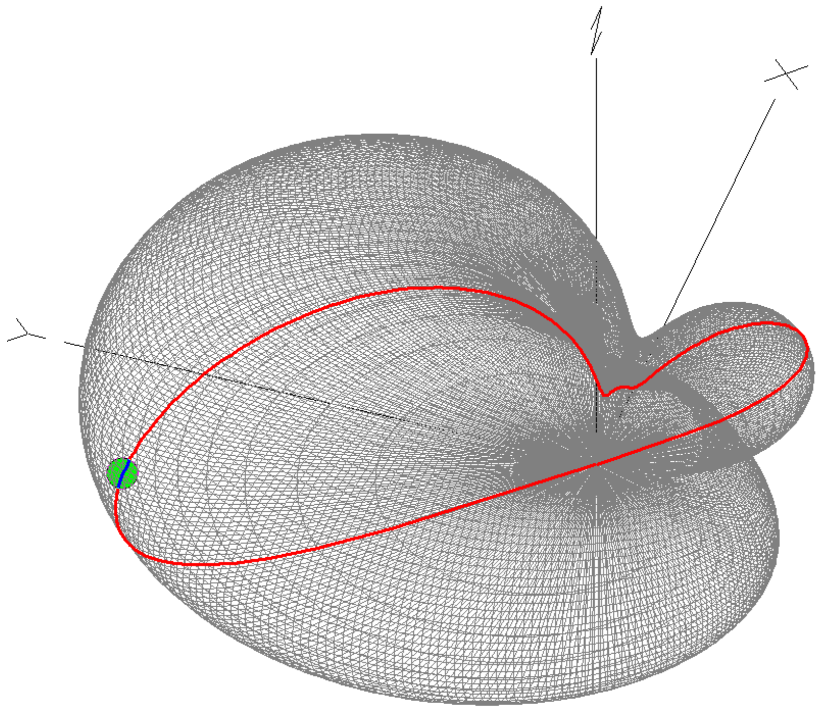
Inline triple reflector and single director radiation pattern at 1.91 MHz – 5.22 dBi max gain

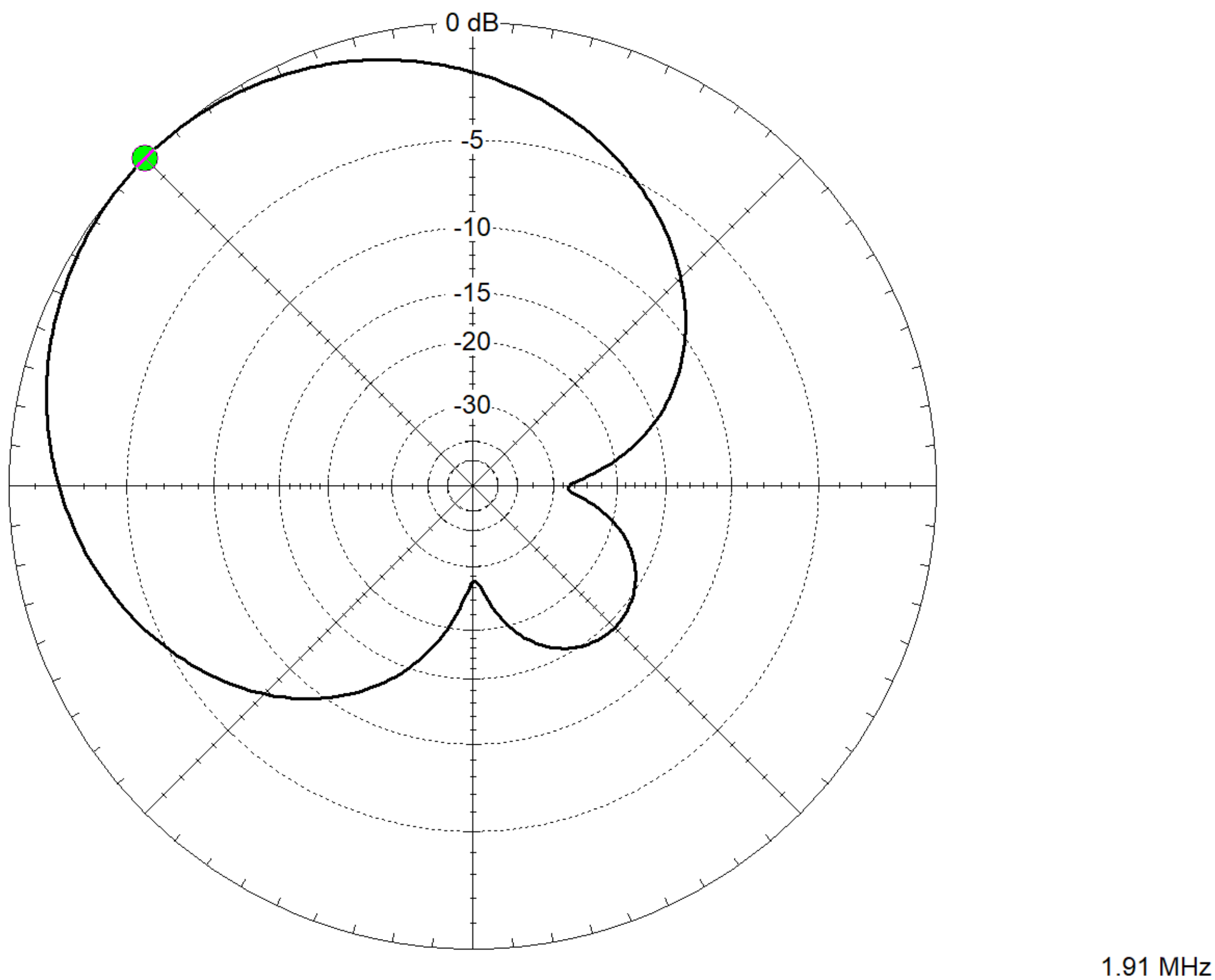


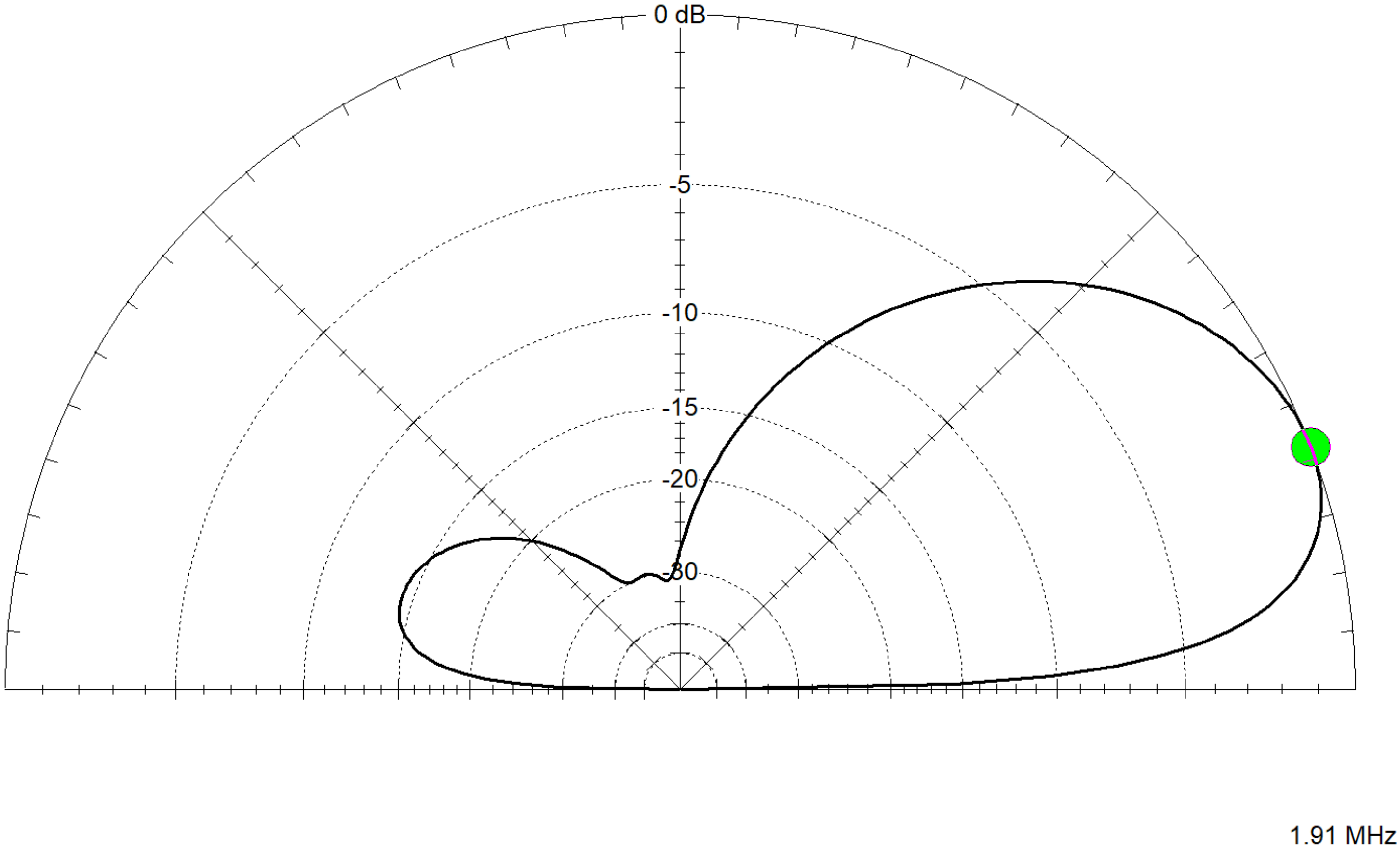



0 dB
-5
-10
-15
-20
-30
1.91 MHz

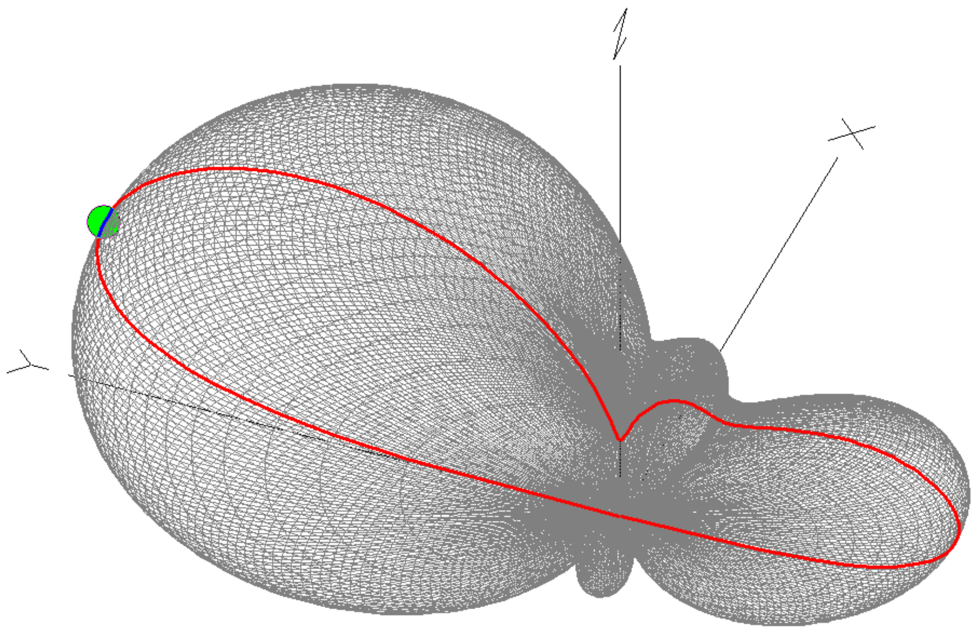
Broadside dual reflector dual director radiation pattern at 1.91 MHz – 4.91 dBi max gain

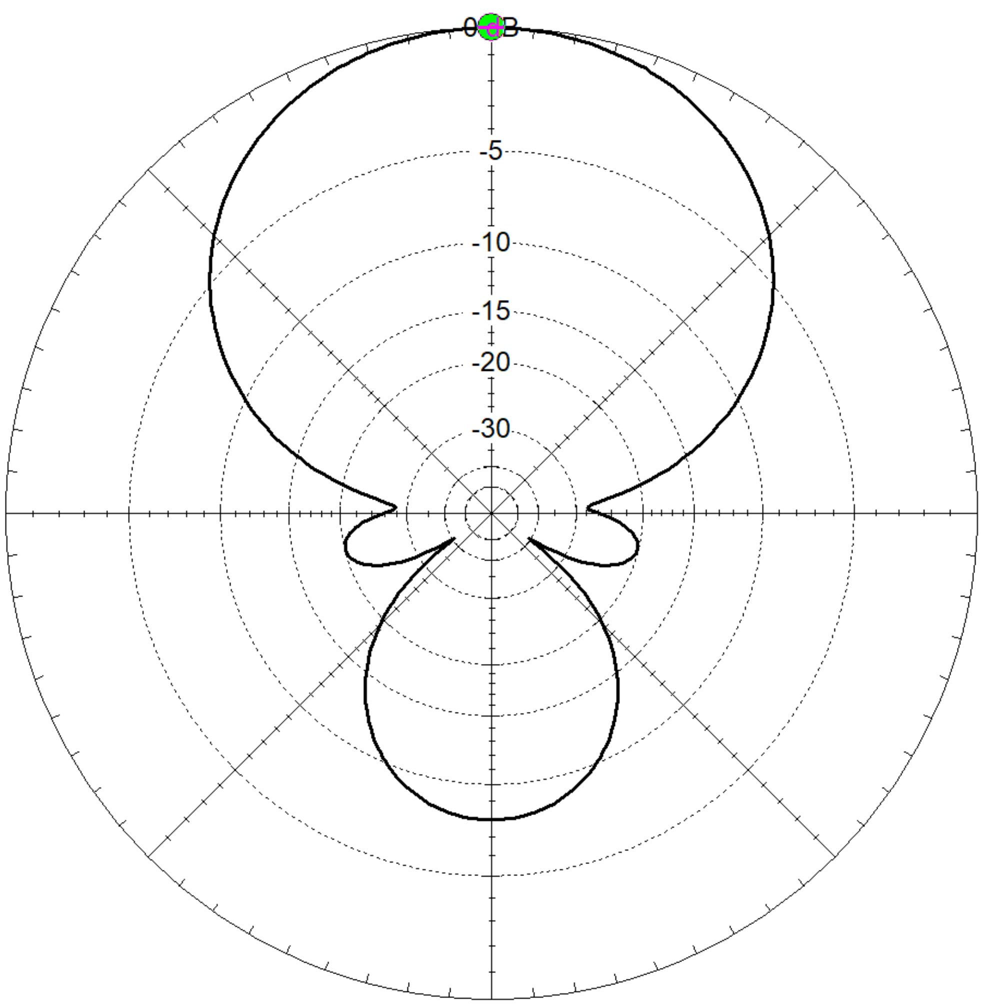




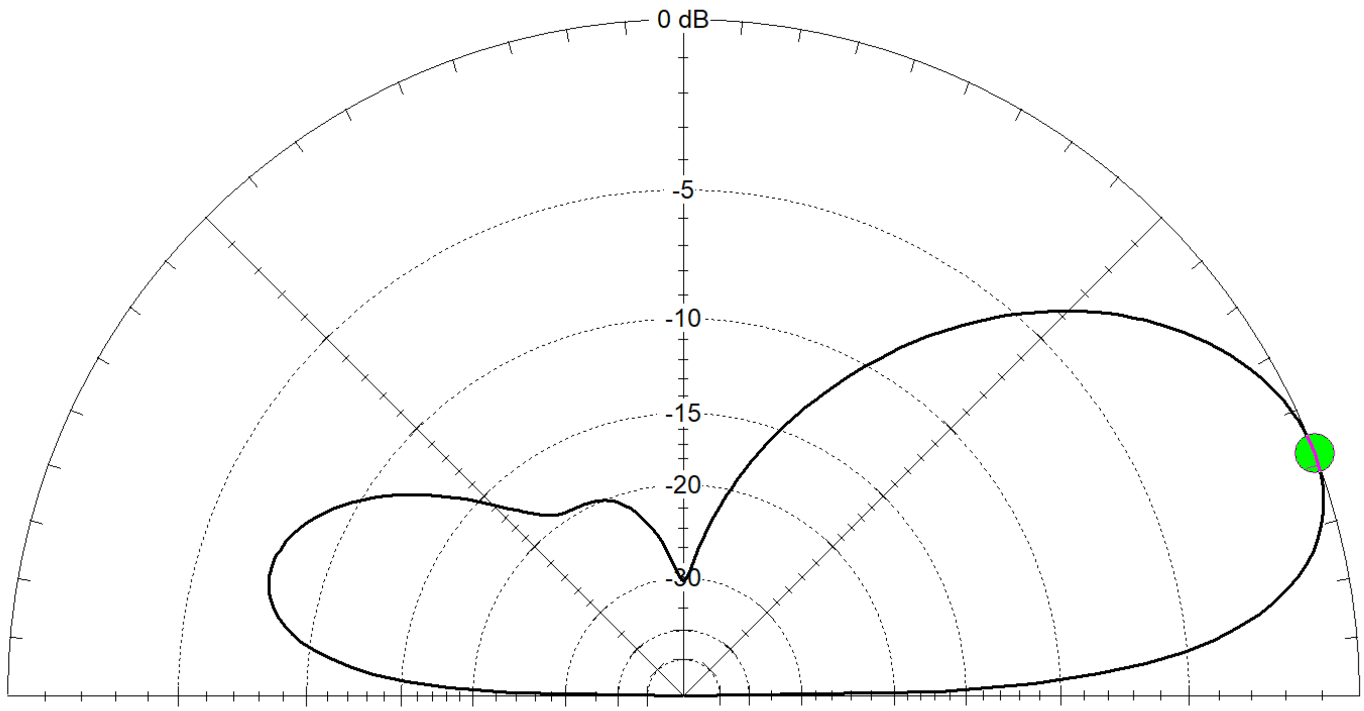

0 dB
-5
-10
-15
-20
-30
1.91 MHz

Inline triple reflectors and single director radiation pattern at 3.71 MHz – 5.82 dBi max gain



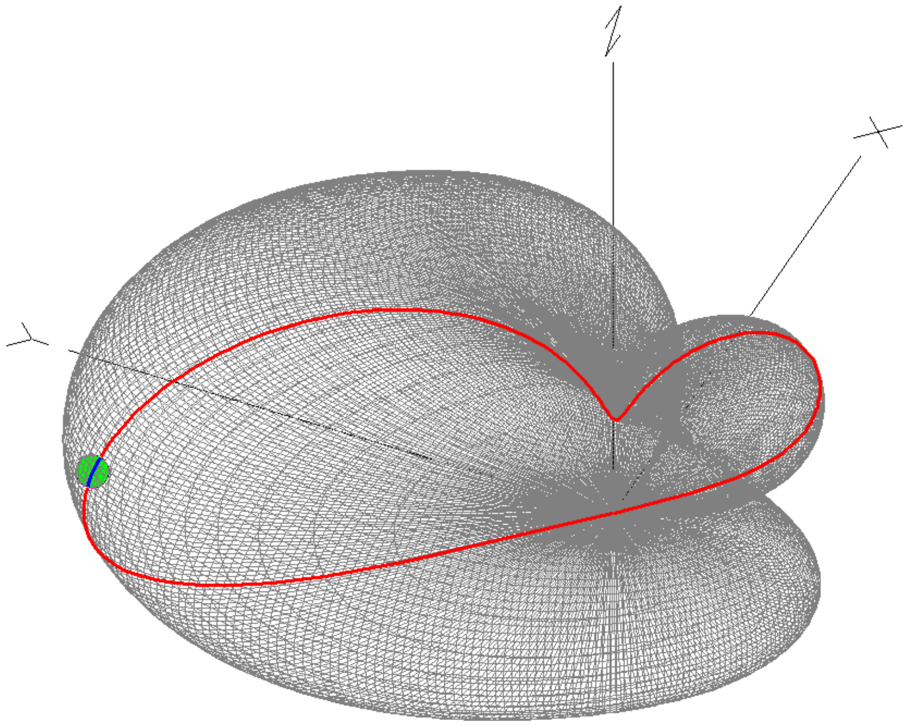


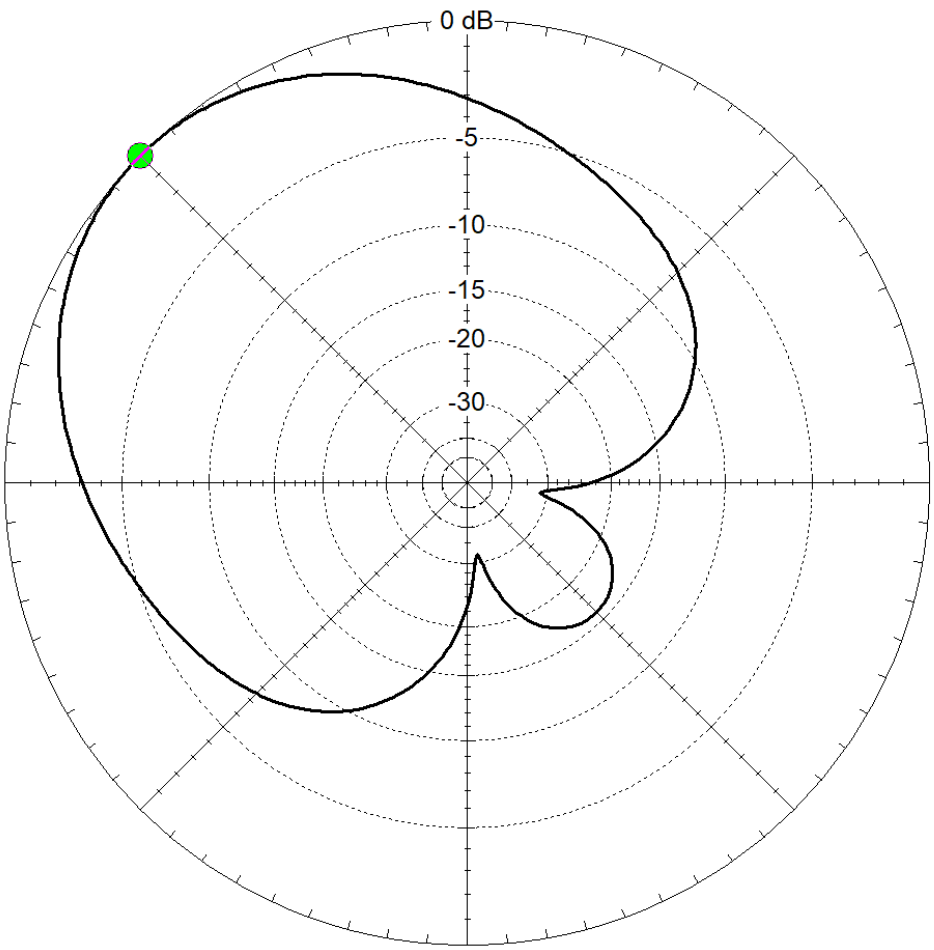
3.71 MHz



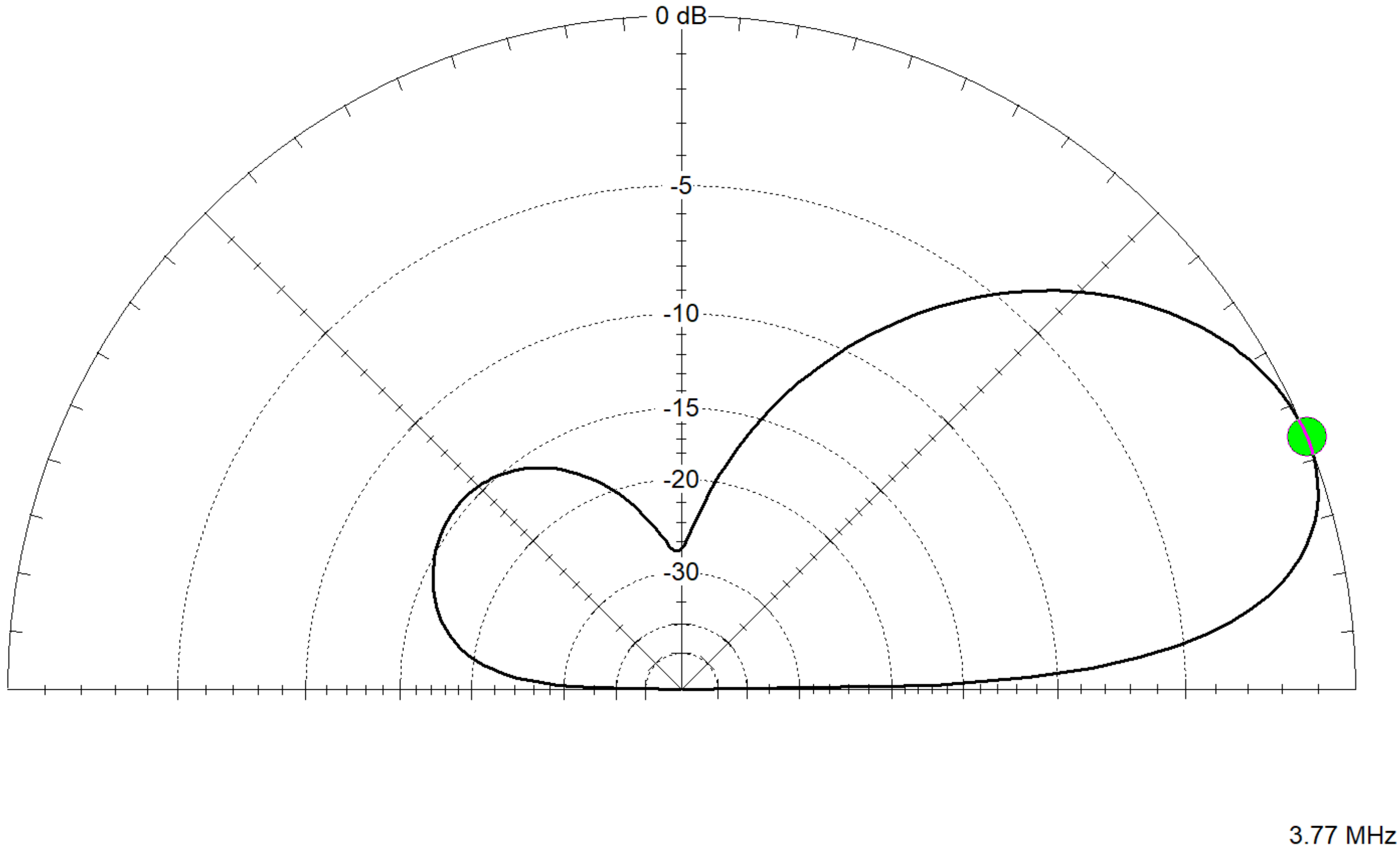
3.71 MHz

Broadside dual reflectors and dual director radiation pattern at 3.77 MHz – 5.64 dBi max gain





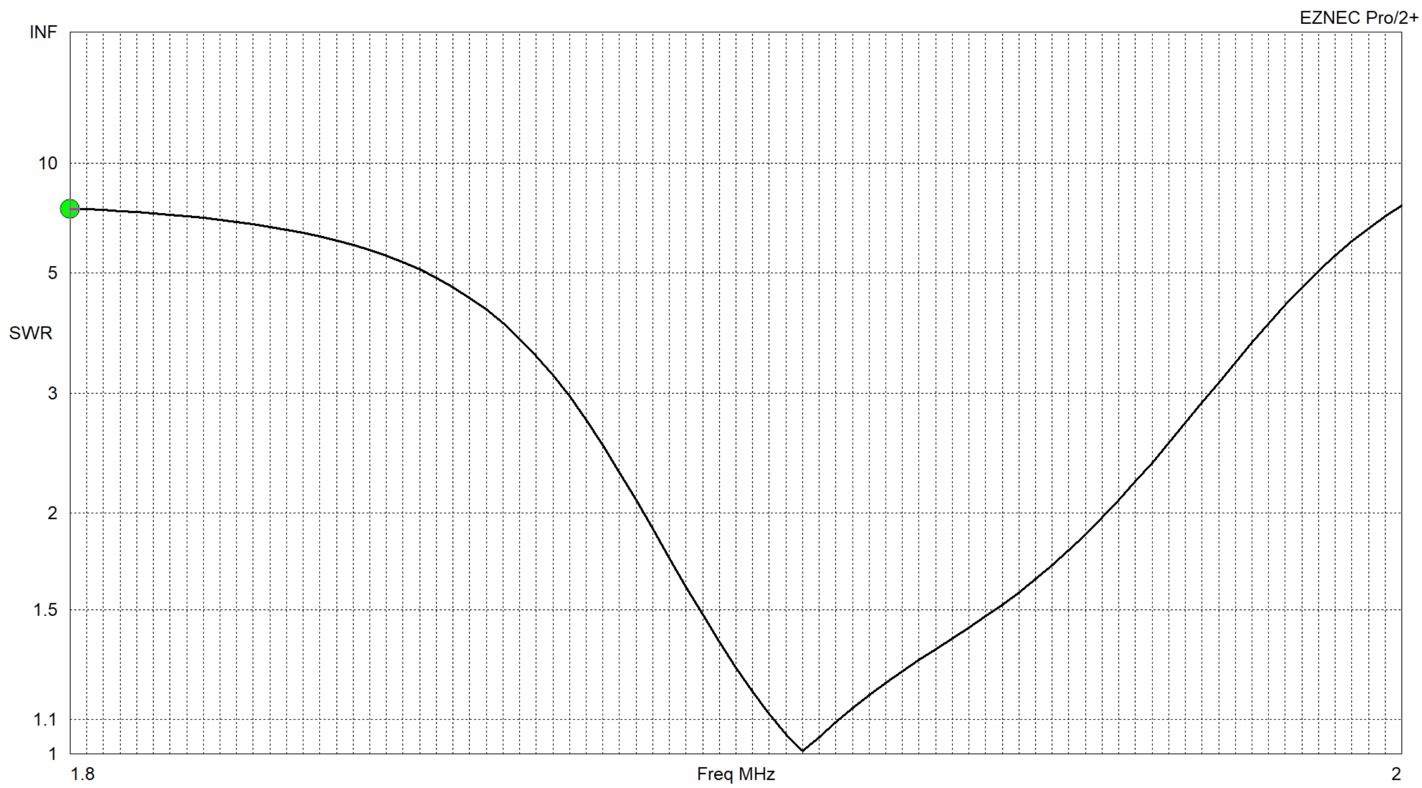
3.77 MHz


0 dB
-5
-10
-15
-20
-30
3.77 MHz

SWR Charts

160 Meters

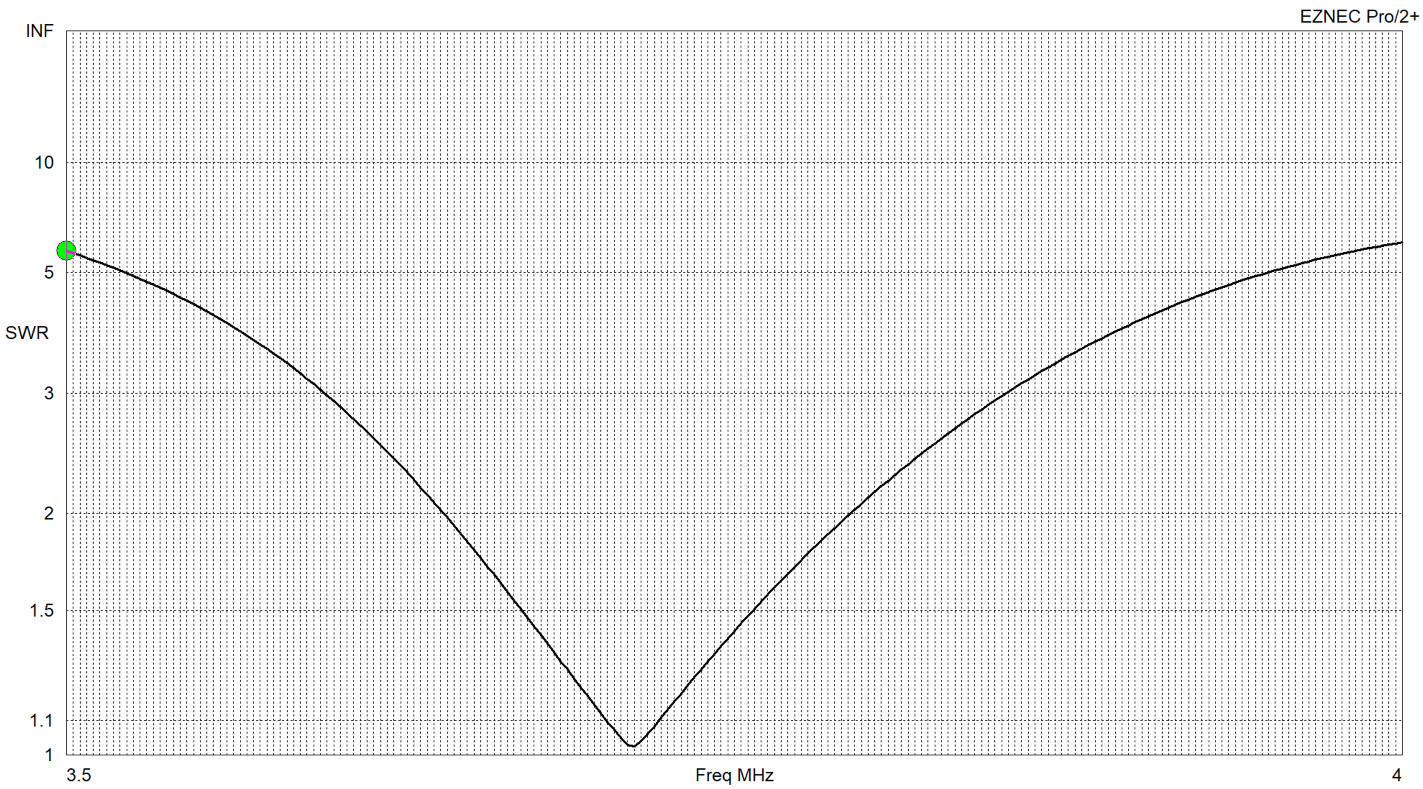
This is a typical SWR chart for the array on 160 meters after a matching network is introduced in the model. This SWR model utilizes appears nearly identical for either the unun or lump LC matching approach. In order to cover the entire band, it will take 4 different inductive loading coil values and 3-4 unun taps, providing 60-70 KHz of bandwidth below 2:1 as shown.



SWR Chart

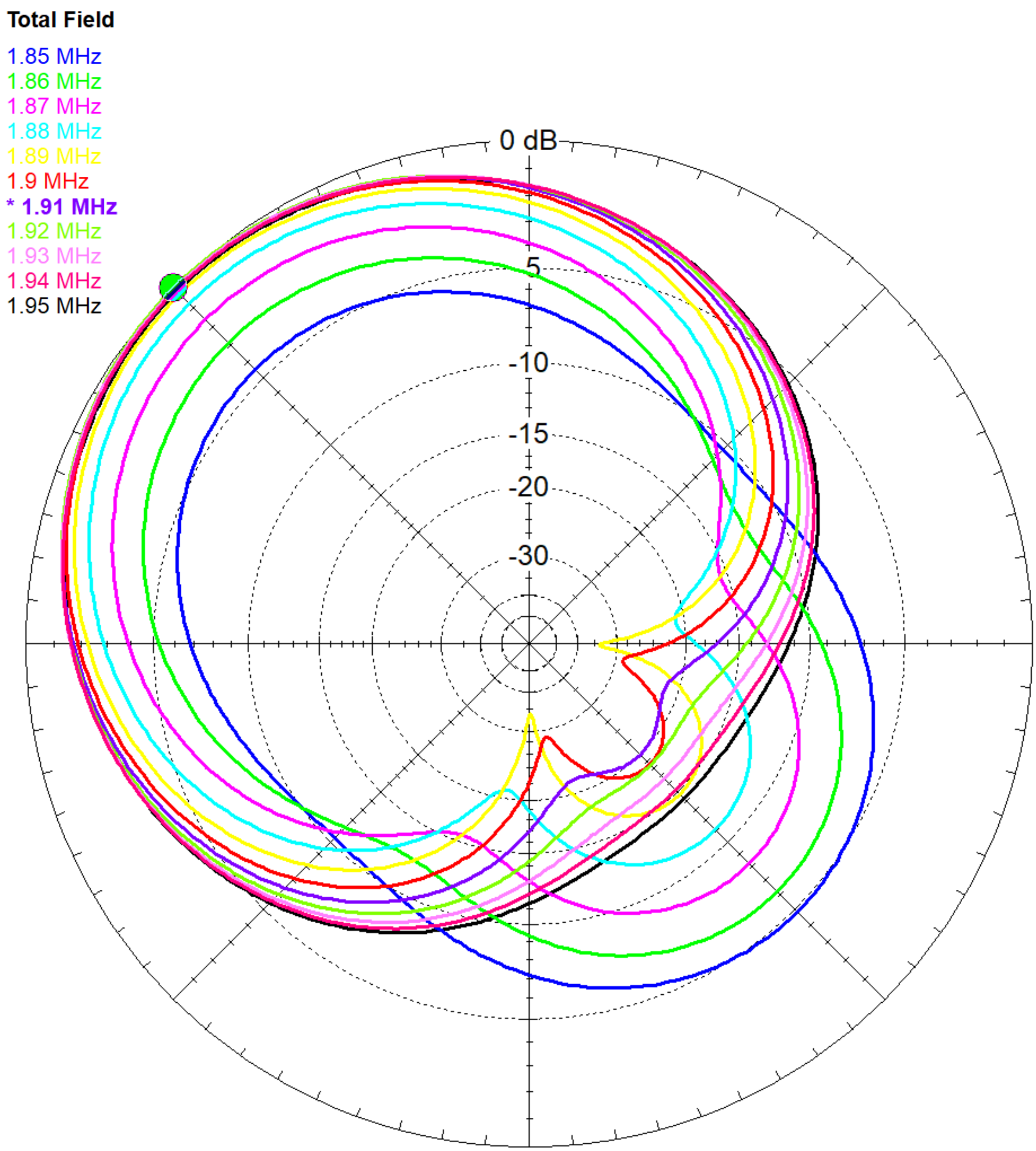
80 Meter Array

This is a typical SWR chart for the array on 80 meters. This SWR model utilizes appears nearly identical for either the unun or lump LC matching approach. In order to cover the entire band, it will take 4-5 different inductive loading coil values and 4 unun taps to provide 125 KHz of bandwidth below 2:1 as shown.



Forward Gain Pattern Sweep & F/B Ratio Sweep

When considering the bandwidth of a directional antenna, the most important factor is the far field pattern. Sweeping the model in steps will show exactly the bandwidth for best forward gain VS F/B ratio. Below you can see how the pattern changes as the driven frequency changes for a single set of inductive loads on the parasitic elements.



Impedance Charts, Element Loading and Matching Networks

Complex Impedance Chart Values with Parasitic Elements Active

Below are the theoretical complex impedance values on the driven element when affected by the loading coils for far-field gain on the parasitic element. Electrical current is induced on the parasitic elements when connected at their base loading coils so they have major effect on the driven element complex impedance.

In-Line Values (0-Degree Azimuth)							
	Driven Element		Parasitic Elements				Vacuum Relay Condition
Frequency in MHz	Resistance	j Value	0 degrees	90 degrees	180 degrees	270 degrees	
1.81	8.779	-52.04	6.5	9	4.7	9	closed
1.86	11.03	-36.00	5.4	7	2.6	7	closed
1.91	11.36	-24.26	4.2	6	1.6	6	closed
1.96	10.31	-13.72	3.1	5	1.1	5	closed
3.52	13.90	-77.30	4.5	8	3.3	8	open
3.61	14.74	-66.03	3.8	7.5	2.7	7.5	open
3.71	17.41	-50.25	3.2	6.5	2	6.5	open
3.81	21.08	-37.00	2.6	6	1.2	6	open
3.91	26.39	-22.74	2.2	4.5	0.3	4.5	open

Broadside Values (45-Degree Azimuth)					
	Driven Element		Parasitic Elements		Vacuum Relay Condition
Frequency in MHz	Resistance	j Value	0 & 90 degrees	180 & 270 degrees	
1.80	13.23	-53.60	7.4	2.9	closed
1.86	13.08	-37.42	5.8	0.9	closed
1.91	13.07	-25.30	4.6	coil shorted	closed
1.96	12.58	-15.21	3.6	coil shorted	closed
3.55	18.48	-73.19	4.6	coil shorted	open
3.67	19.80	-58.05	3.9	coil shorted	open
3.77	21.10	-45.16	3.4	coil shorted	open
3.87	22.88	-31.74	3.0	coil shorted	open

Complex Impedance Chart Values with Parasitic Elements Neutralized

Below are the theoretical complex impedance values without the loading coils for far-field gain when the parasitic elements are neutralized. The parasitic elements are neutralized by opening the electrical connection to the base loading coils and radial field, aka “floating” the element. No electrical current is induced on the parasitic elements when they are not connected to their base loading coils so they have negligible effect on the driven element complex impedance and hence, no effect on the far-field pattern.

Vertical Radiator Only Values, Parasitic Elements Neutralized					
	Driven Element		All Parasitic Elements	Driven Element Vacuum Relay Condition	Parasitic Elements Vacuum Relay Conditions
Frequency in MHz	Resistance Ohms	j Value	Base Coil Condition		
1.81	18.19	-63.46	coil opened	closed	open
1.86	19.47	-50.69	coil opened	closed	open
1.91	20.83	-38.05	coil opened	closed	open
1.96	22.28	-25.53	coil opened	closed	open
3.52	20.10	-91.10	coil opened	open	open
3.61	21.35	-80.68	coil opened	open	open
3.71	23.31	-67.06	coil opened	open	open
3.81	25.02	-55.73	coil opened	open	open
3.91	26.89	-44.52	coil opened	open	open

Driven Element Loading with Unun and Parasitic Loading Element Values

While lumped LC circuit matching is possible on the driven element, it is neither practical nor cost effective. I consider utilizing a transformer with series inductor on the driven element to be the best real-world approach to matching the driven element for reasonable SWR values. This approach greatly reduces the circuit complexity and total number of relays involved.

The simplest approach to the unun is to make it a single autotransformer style on stacked type 52 ferrite toroidal cores with multiple taps for the appropriate transformer ratios. The loss associated with well designed unun VS a lump LC network is negligibly higher (1% roughly), which is well worth it for the simplification of the matching network. A minimum of 3-4 stacked toroidal cores should be used if 1500 watts legal limit is to be used. Core saturation and heating must be considered carefully based on expected input power and duty cycle.

In-Line Values (0-Degree Azimuth)								
	Driven Element			Parasitic Elements				Vacuum Relay Condition
Frequency in MHz	Series Inductor in μH	Unun Ratio	SWR at Target Freq	0 degrees	90 degrees	180 degrees	270 degrees	
1.81	4.6	6:1	1.	6.5	9	4.7	9	closed
1.86	3.1	5:1	1.10	5.4	7	2.6	7	closed
1.91	2.0	4:1	1.10	4.2	6	1.6	6	closed
1.96	1.1	5:1	1.04	3.1	5	1.1	5	closed
3.50	3.5	3.5:1	1.02	4.5	8	3.3	8	open
3.61	2.9	3.5:1	1.04	3.8	7.5	2.7	7.5	open
3.71	2.2	3:1	1.08	3.2	6.5	2.0	6.5	open
3.81	1.5	2.5:1	1.08	2.6	6	1.2	6	open
3.91	0.9	2:1	1.06	2.2	4.5	0.3	4.5	open

Broadside Values (45-Degree Azimuth)						
	Driven Element			Parasitic Elements		Vacuum Relay Condition
Frequency in MHz	Series Inductor in μH	Unun Ratio	SWR at Target Freq	0 & 90 degrees	180 & 270 degrees	
1.80	4.7	3.5:1	1.08	7.4	2.9	closed
1.86	3.2	3.5:1	1.09	5.8	0.9	closed
1.91	2.1	3.5:1	1.09	4.6	coil shorted	closed
1.96	1.2	3.5:1	1.14	3.6	coil shorted	closed
3.55	3.3	2.5:1	1.08	4.6	coil shorted	open
3.67	2.5	2.5:1	1.02	3.9	coil shorted	open
3.77	1.9	2.5:1	1.06	3.4	coil shorted	open
3.87	1.3	2.5:1	1.15	3.0	coil shorted	open

Driven Element Loading with Unun Values and Parasitic Loading Elements Neutralized

Below are the values for the driven element series inductor and unun when the parasitic elements are neutralized for an omni FF radiation pattern.

Omni Pattern Values (Parasitic Elements Neutralized)						
	Driven Element			Parasitic Elements	Driven Element Vacuum Relay Condition	Parasitic Elements Vacuum Relay Conditions
Frequency in MHz	Series Inductor in µH	Unun Ratio	SWR at Target Freq	Series Inductor Coil		
1.82	5.6	3:1	1.09	coil opened	closed	open
1.86	4.3	2.5:1	1.03	coil opened	closed	open
1.91	3.2	2.5:1	1.05	coil opened	closed	open
1.96	2.1	2.5:1	1.12	coil opened	closed	open
3.52	4.1	2.5:1	1.02	coil opened	open	open
3.61	3.6	2.5:1	1.09	coil opened	open	open
3.71	2.9	2:1	1.07	coil opened	open	open
3.81	2.3	2:1	1.03	coil opened	open	open
3.91	1.8	2:1	1.08	coil opened	open	open

Installation Order & Procedure

The installation order of major components to this antenna array needs to be considered carefully. If not done in the proper order, it will become impossible to complete some of the component installations as designed, especially the radial system and conduit run.

1. Establish exact vertical element and guy line anchor post positions. Stake those positions.
2. Dig post holes for vertical elements and guy line anchor posts. Set all posts and element foundations with support U-channels and rebar in concrete. Use round carboard formers to keep edges of concrete clean and sharp. Slightly crown concrete.
3. Dig rough holes for ground boxes next to element foundations.
4. Install ground rods in ground box hole. Run ground wire from ground rod to approximate radial ring position.
5. Vibe plow/trench in the HDPE conduit to ground box hole positions.
6. Install Liquidtight conduit for NEMA 4 box run in ground box hole. Install ground boxes so that top is approximately 1inch above grade. Backfill around ground boxes with dirt. Fill bottom of ground boxes with gravel.
7. Install NEMA 4 enclosures at element locations. Terminate Liquidtight conduit to bottom of NEMA 4 boxes with bulkhead connectors.
8. Pull in feedline and control lines to ground boxes, then run into NEMA 4 boxes. Close ground boxes.
9. Dig out 2-foot radius 3” deep circle around element positions. Line with heavy plastic. Half fill with small rounded gravel. (large heavier gravel can damage radials)
10. Install radial system. Complete fill of circle with gravel to grade.
11. Solder radials to radial ring halves. Conformal coat. Bolt radial rings halves together.
12. Build elements with vacuum relays and erect.
13. Connect feed straps to elements and ground straps to radial rings. Run straps into NEMA 4 boxes through insulating bulkheads.
14. Complete loading and LC circuits in NEMA 4 enclosures.
15. Tune the system.

Cost Analysis

No project is complete without a rough cost analysis before the start of the build. This is only a rough estimate at this point.

Major components

Qty	Description	Each	Ext
10	4" aluminum irrigation pipe	250	2,500
4	5000' rolls of 16-gauge primary wire	600	2,400
5	2" OD 1/4" wall fiberglass tubing, 23.25" length	38	190
2	polycarbonate printer filament for base tube stiffener	145	290
5	12x18.8 Fiberglass (FRP) NEMA 4 enclosures	200	1,000
6	10x15x10 ground box (valve box)	29	174
1	2" HDPE conduit, 1000-foot spool	750	750
1	3" FRP channel, 20-foot length	250	250
2	1" solid fiberglass rod, 46.5" long, black	25	50
12	4.4mm Mastrant-M, 330-foot rolls	55	660
8	4x4 treated post	12	96
5	Jennings RJ1A vacuum relay	250	1,250
1	Various other components, feedline, control lines, etc.	3,000	3,000
	Total		$13,110

References & Tools

Modelling Software – EZNEC Pro/2+

EZNEC Modelling Software Enhancement – AutoEZ by Dan Maguire AC6LA

Modelling Engine – NEC-5

Greg Buchanan, WB9DNZ, Schematics & Diagrams for his 80-meter steerable array

John Devoldere, ON4UN, *Low-Band DXing*, ARRL, 5th addition, 2010

Steve Babcock, VE6WZ, various videos on construction of 4-inch aluminum elements and tuning of parasitic arrays, Youtube.com

Greg Ordy, W8WWV, *K3LR 160m 2024 Revisit* Notes, November 10, 2024, Version 1.01

Joel Harrison, W5ZN, A *5 Element Switchable Vertical Parasitic Array for 160 Meters* article, National Contest Journal, September/October 2018