

KJ6ER Antennas Primer



PERformer Quarterwave
with 2 Elevated Radials

Greg Mihran



KJ6ER

Extra-Class

Amateur Radio Operator

July 2026

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Challenger Halfwave on
a Wide-Angle Tripod



Welcome! I am **Greg Mihran** (*mear'-on*)

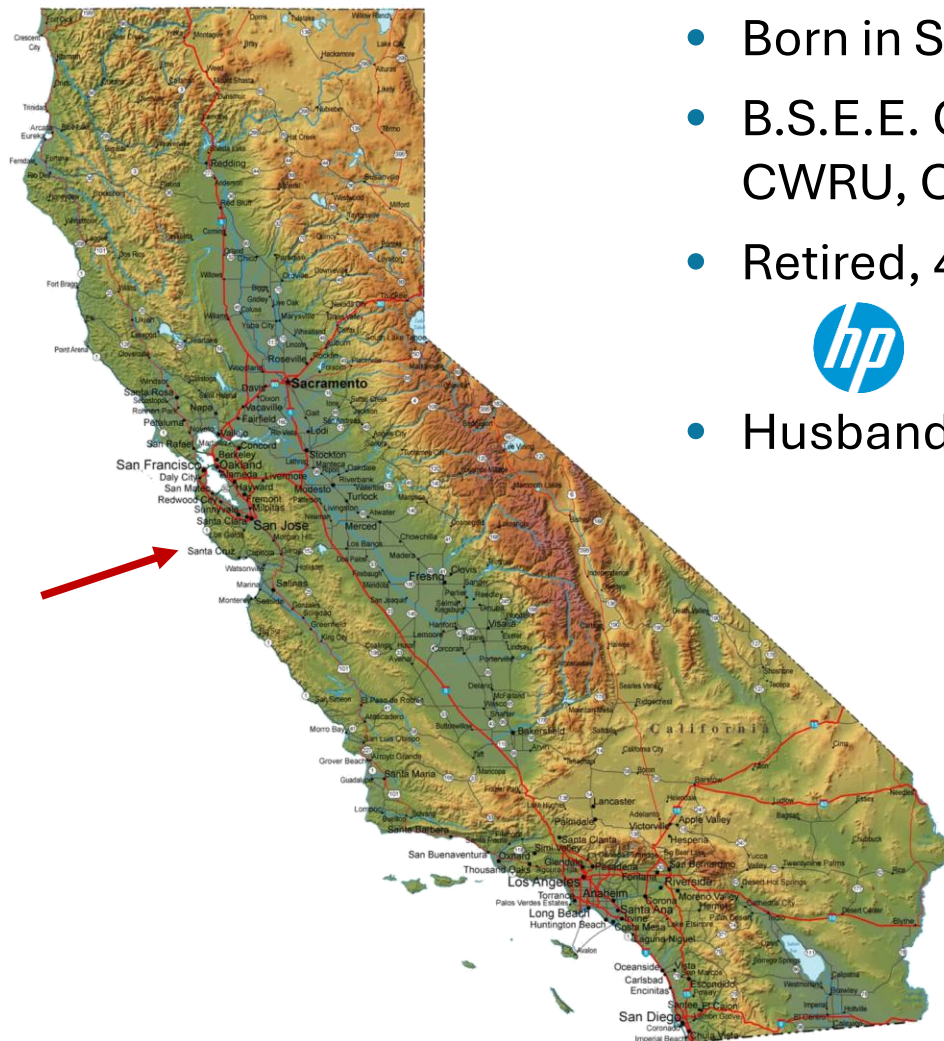


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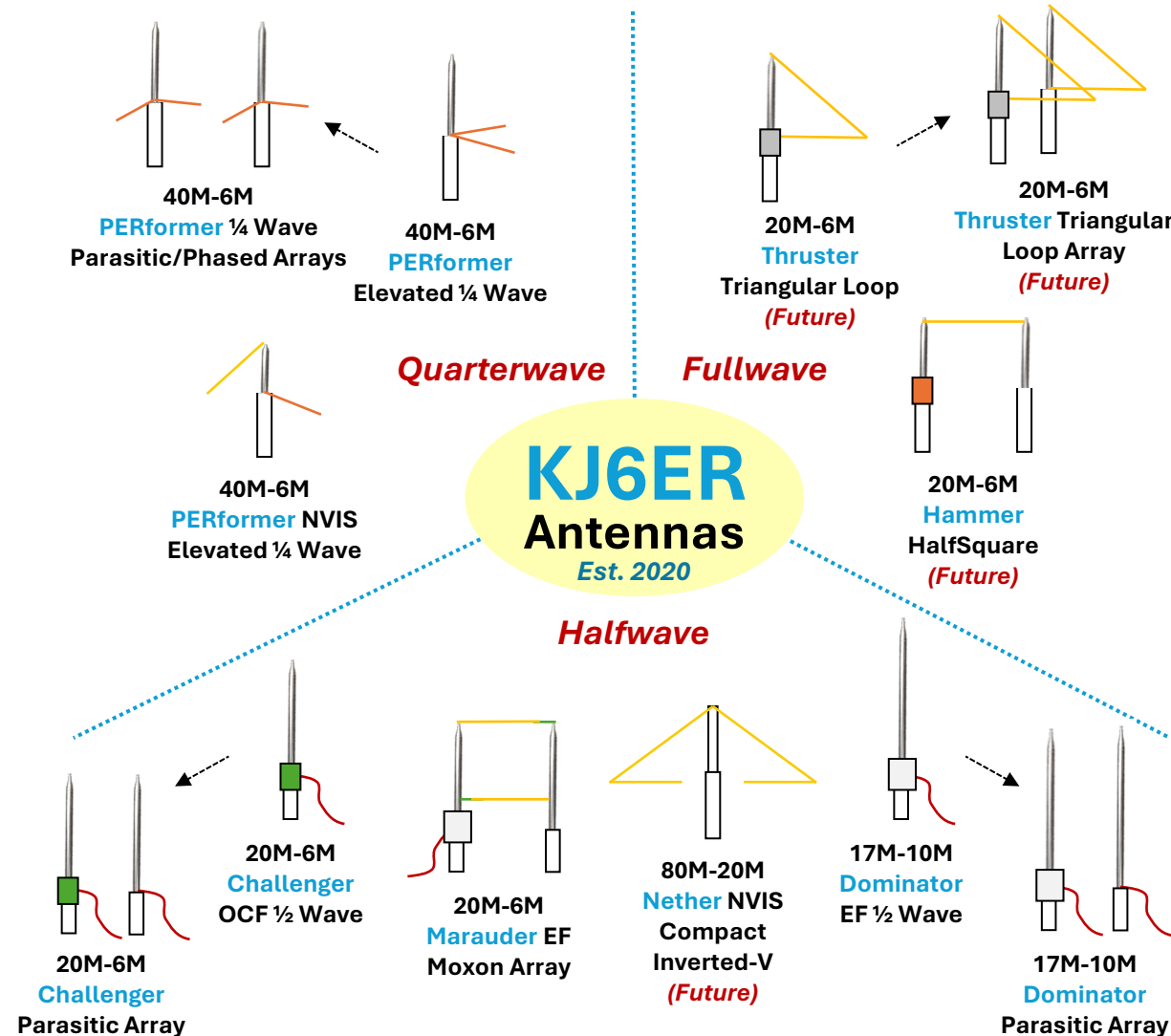
- Born in Schenectady, New York
- B.S.E.E. Case Institute of Technology, CWRU, Cleveland, Ohio
- Retired, 45 years in Silicon Valley
- Husband, 5 grown kids, 6 grandchildren



1,000+ Activations
80K+ SSB QSOs



KJ6ER Antennas Family: Quarterwave, Halfwave, Fullwave



KJ6ER Antennas Content Always **Free** on **KJ6ER.net**

RADIO STATION

AMATEUR EXTRA

LICENSED 1987 · ITU ZONE 6 · CQ ZONE 3

KJ6ER

GREG MIHRAN

Always-free portable antenna plans for the every-ham.
Computer modeled, homebrewed, and field-tested.

CAMPBELL, CA

GRID CM97AG

Shop Assembled Antennas

If you are unable to homebrew your own KJ6ER antenna, or do not have the time, you can purchase **assembled, handmade antennas and accessories** at our Etsy store. Feel free to browse through all of these high quality products. Since June 2025, over 200 products have been sold with over 50 5-star reviews.

VISIT J-SYSTEMS ON ETSY ↗

Favorite Ham Radio Sites

A curated list of my favorite ham radio websites that I use everyday.

HamDash

Ham Radio Dashboard

VISIT SITE ↗

SolarHam

Space Weather

VISIT SITE ↗

Free Antenna Plans

Here are my *always-free* antenna PDFs which are grouped by *type*. Scroll through the entire list or use the filter to narrow your search. These are all **living documents**. They are continuously being improved over time. Check back often for the latest revisions.

Q Filter by name, band, or category...

QUARTERWAVE VERTICALS

2

PERformer

40M-6M · Omni/Directional Elevated Tuned Linked Radials

DOWNLOAD PDF ↗

PERformer NVIS

40M-6M · Omnidirectional High Angle Radiation Variant

DOWNLOAD PDF ↗

Press & Interviews

Take a look at KJ6ER press coverage and watch one-on-one personal interviews.

YOUTUBE · MAY 2026

Interview with Stu Crawford VE9CF - Solar Minimum

YOUTUBE · APR 2026

Interview with Stu Crawford VE9CF - Antennas Family

Antenna Geeks Email List

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Summer Field Day and KJ6ER Antennas

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March 2026

KJ6ER Antennas Family

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greg@kj6er.net

Always-Free PDFs for the Amateur Radio Community!

Revision: July 2026



QST

June 2025

Announcing the Winners of the 2024 QST Antenna Design Competition

Out of the dozens of entries we received, these rose to the top.

The 2024 QST Antenna Design Competition sought entries in three categories: "160 Meters, LF or VLF," "80 Through 10 Meters," and "6 Meters and Up."

After weeks of evaluating the more than 300 pages of material supplied in the entries, as well as generating their own models, the judges have made their decisions.

First Place entries will be awarded \$500, Second Place entries will receive \$250, and Third Place will receive \$100. All entries listed here will be published.

QST extends sincere thanks to all the entrants, as well as our gratitude to the ARRL Lab staff and the QST Technical Editors for serving as the judges.

160 Meters, LF or VLF

First Place: Bob Glorioso, W1IS, and Bob Rose, KC1DSQ, "An All-Band 160-Meter OCF Antenna"

Honorable Mention: Jim Spaulding, WØUO, "Ground-Independent Beverage on the Ground"

80 Through 10 Meters

First Place: Jacek Pawłowski, SP3L, "Multi-V Rotary Broadband Antenna for the 14–30 MHz Range"

Second Place: Greg Mihran, KJ6ER, "PERformer (Portable, Elevated, Resonant) Antenna"

Third Place: Yasuhiro Kawai, JH1KOJ, "Exponential Spiral Antenna"

Honorable Mention: David Cutter, G3UNA, "80-Meter Portable Yagi-Uda Three-Element Array for Field Day, SOTA, or IOTA"

Honorable Mention: Hajime Nakajima, JR1OAO, "Desktop MLA"

6 Meters and Up

First Place: Fred Lass, K2TR, "The Tomato Stake Antenna: An Optimized 6-Meter Array"

Second Place: Charlie Dieterich, N2CTW, "Rigel-6 Antenna"

Honorable Mention: John Post, K7SKI, "Adjust-a-J Antenna"

www.arrl.org QST September 2025 31



Congratulations

September 2025
QST Cover Plaque Award Winner

Greg C. Mihran
KJ6ER

In his article, "The PERformer — A Portable, Elevated, and Resonant Quarter-Wave Antenna," Greg outlines the assembly, testing, and operation of his PERformer quarter-wave antenna, which earned him second place in the 80 through 10 meters category of the 2024 QST Antenna Design Competition.

QST Cover Plaque Awards are given to the author or authors of the most popular article in each issue. You choose the winners by casting your vote online at

www.arrl.org/cover-plaque-poll

Log in now and choose your favorite article in this issue!

The PERformer — A Portable, Elevated, and Resonant Quarter-Wave Antenna

This antenna won second place in the 80 through 10 meters category of the 2024 QST Antenna Design Competition; it covers 40 – 6 meters.

Greg Mihran, KJ6ER

I developed the PERformer quarter-wave antenna primarily for portable operations. Extensive computer modeling in 4NEC2 provided optimal whip and elevated tuned radial lengths for each of the bands. I typically measure a standing wave ratio (SWR) of 1.20:1 or better on each of the bands, so an external antenna tuner is not needed. Through extensive modeling, I have found that this elevated vertical is extremely effective, with high radiation efficiency of more than 90 percent on the 20 – 6-meter ham bands. Here, I will focus on the assembly, testing, and operation of the PERformer. The technical details can be found at www.arrl.org/qst-in-depth.

PERformer Description

The PERformer consists of a telescoping vertical element (radiator) and two elevated, tuned linked radials oriented 90 or 180 degrees apart. Within the radials' 90-degree span, it provides modest 0.3 – 0.5 dBi gain and a 3 – 4 dB front-to-back ratio at a 24-degree takeoff angle. For an omnidirectional radiation pattern, the two elevated radials are placed 180 degrees apart (opposite each other). Having elevated, tuned linked radials dramatically reduces near-field ground losses and increases radiation efficiency, versus a purely ground-mounted vertical with ground-coupled radials, window screen, or Faraday cloth. I modeled different numbers and spans of elevated radials, and I concluded that having more than two radials provided little benefit. Also, two elevated radials provide slightly more antenna gain, efficiency, and improved SWR than a single elevated radial. A good-quality RF choke must always be inserted directly at the feed point so that the coaxial feed line does not become part of the antenna system. A pictorial of the PERformer is shown in Figure 1, including the radial lengths for each band. Summarized notes on the radial system are in the sidebar, "PERformer Radial System," and these further illustrate Figure 1. Table 1 is my recommended list of parts; it includes links to where I sourced some products, but you can find several of them elsewhere.



The PERformer on a PVC mount.

PERformer Construction

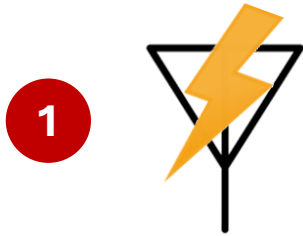
This telescoping whip covers 20 – 6 meters. For 40 meters, install an inductor (such as the Wolf River Coils Sporty Forty or the Chameleon CHA M-COIL) at the base of the whip. Clip the two 20-meter, 16.5-foot radials end to end with the two fiberglass stakes (one in the center and one at the end) to make one elevated 33-foot, 40-meter radial. While it works well, the efficiency will be lower than on the higher bands due to loading inductor Q, the lower radiation resistance of the shortened vertical element, and the single elevated radial.

I prefer using a PVC spike mount for my deployments, but you can use a lightweight tripod instead. A 40-inch furniture-grade PVC tube and the Chameleon spike mount permit me to easily reach the telescoping whip to adjust it for the desired band. Furniture-grade PVC

My *Portable* Antennas **Design Principles**

- Redesign classic antennas with *fresh* implementations for *portable* use
- Develop designs, share free PDF plans, **actively interact** with builders

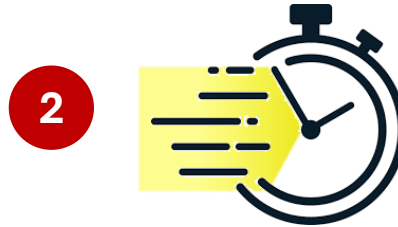
3 Design Principles:



Highly Efficient & Effective
(Resonant, One-Band-at-a-Time)

90% efficient or more

Performance



Fast & Simple Deployment
(Set-up and Take-down)

5 minutes or less

Elegance



Easy to Pack & Transport
(Backpack, Picnic Table, HOA)

5 pounds or less

Convenience

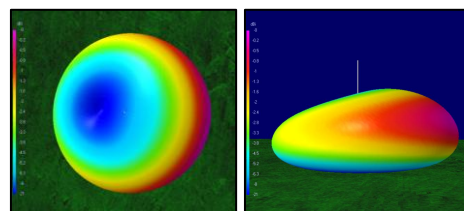
Portable Antennas from **Theory** to **Real-World Deployment**

KJ6ER Antennas designs *efficient* and *effective* portable antennas for the **every-ham** that focus on the optimal integration of **performance** (*high radiation efficiency*), **elegance** (*speed and simplicity of deployment*) and **convenience** (*ease of transport and storage*).



$$\begin{aligned} &= \frac{x^2}{2} \arctan x \Big|_0^{\frac{\pi}{4}} - \frac{1}{2} \int_0^{\frac{\pi}{4}} \frac{x^2}{x^2+1} dx \\ &= \frac{(\frac{\pi}{4})^2}{2} - \frac{1}{2} \int_0^{\frac{\pi}{4}} 1 - \frac{1}{x^2+1} dx \\ &= \frac{\pi^2}{32} - \frac{1}{2} (x - \arctan x) \Big|_0^{\frac{\pi}{4}} \\ &= \frac{\pi^2}{32} - \frac{1}{2} \left(\frac{\pi}{4} - 1 \right). \end{aligned}$$

5% of my time



15% of my time



80% of my time



Real-World Evaluation

★ Antenna Users
(Over 100,000 Worldwide)

KJ6ER Antennas TinkerToys® Components

Portable Antennas Designed to be Built from Components in your **Ham Radio Stuff Box**



25' and 17'
Telescoping
Whips

Mirror Mounts

RF Chokes



Ununs and Baluns

Tripods or
PVC Tube/Spikes



Mueller®
Clips



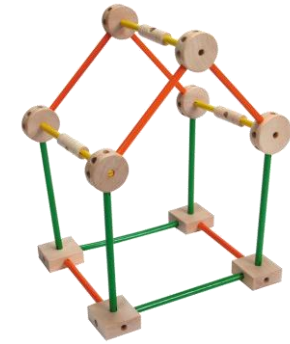
18 AWG
Silicon-Coated
Wire



Wago®
Connectors



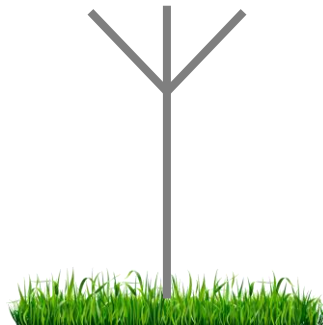
Wire
Ferrules



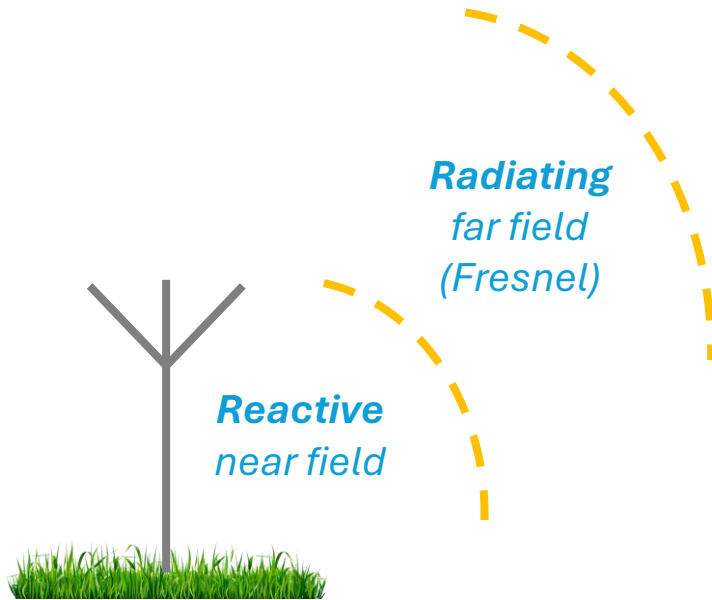
Non-conductive
Nylon Line



Understanding a Few Antenna Fundamentals (*Keeping it High-Level*)



Field Regions Around an Antenna



The effects of the ground and the *artificial* ground system are twofold:

- Near the antenna (in the *reactive near field*), you need a good ground system to **collect the antenna return currents without losses**. This will determine the **radiation efficiency** of the antenna.
 - ✓ Operators have *reasonable control* over the radiation efficiency.
- At distances farther away (in the *radiating far field*, the *Fresnel zone*), the wave is reflected from the earth and combines with the direct wave to generate the overall radiation pattern. The absorption of the reflected wave is a **function of the ground quality and the incident angle**. This determines the **reflection efficiency**.
 - ✓ Operators have *limited control* over reflection efficiency.

Source: ON4UN, John Devoldere & DJ2YA, Uli Weiss (2010)

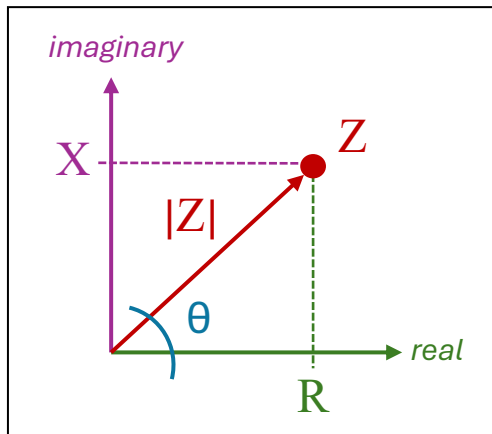
Understanding Antenna Impedance (Complex Number)

Impedance $Z = R \pm j X$ (ohms)

R = **Resistance** (real number)

$j = \sqrt{-1}$ (imaginary number)

X = **Reactance** (inductance, capacitance)



- **Impedance** Z (x, y point)
- **Resistance** R (real, x-axis)
- **Reactance** X (imaginary, y-axis):
(+) **inductive**, (-) **capacitive**
- **Impedance Magnitude:**
 $|Z| = \sqrt{(R^2 + X^2)}$
- **Phase** $\theta = \arctan (X / R)$

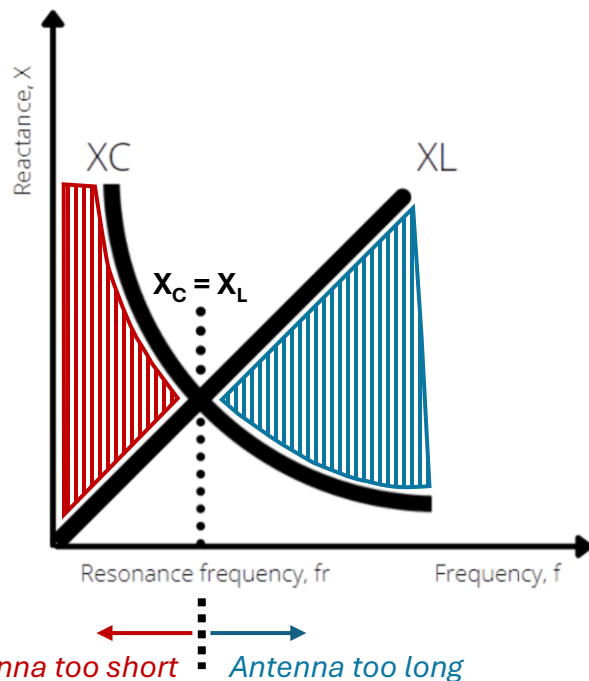
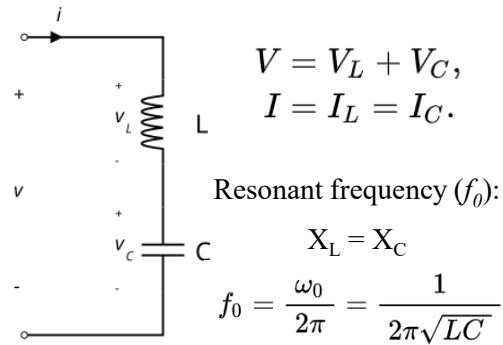
Inductors and capacitors introduce a *phase shift* between voltage and current but *do not* dissipate energy:

$X_{\text{Inductor}} (L) = 2\pi f L$, where L = Inductance (*henrys*) > current lags

$X_{\text{Capacitor}} = -1 / 2\pi f C$, where C = Capacitance (*farads*) > current leads

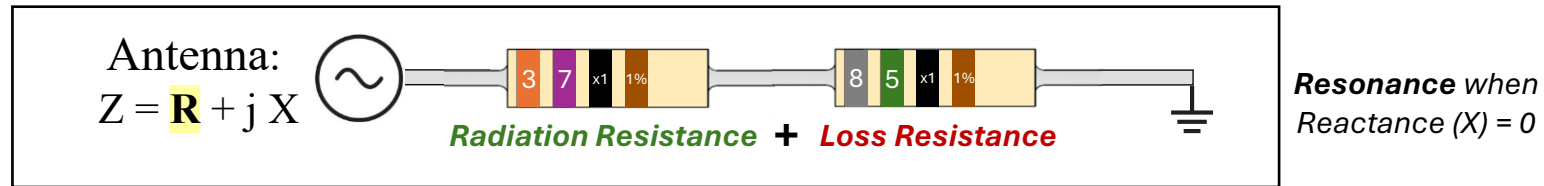
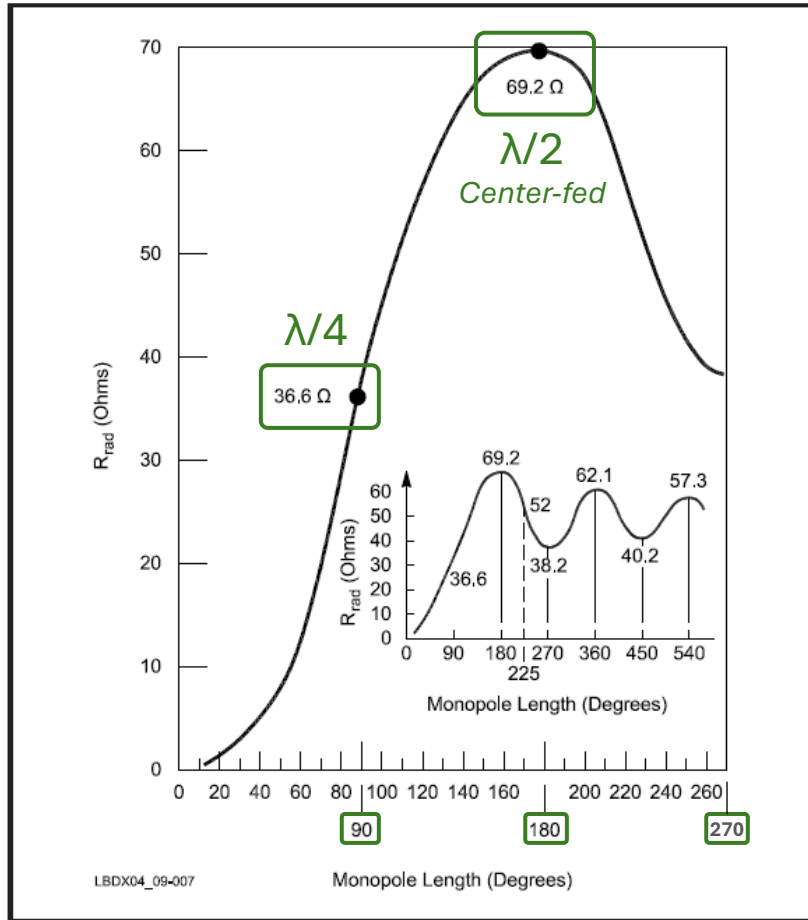
- Relates the sinusoidal voltage V to the current I at the input to an antenna and varies with *frequency*.
- Consists of two components:
 - ✓ **Resistance** R (*real*) represents power that is either *radiated* away or *absorbed* within the antenna.
 - ✓ **Reactance** X (*imaginary*) represents *non-radiated* power stored in the near field of the antenna.
- For a 50Ω transmission line (coax), *perfect* impedance is **purely resistive**: $Z = 50 + j 0$, where the voltage is in-phase with the current. This is considered a **resonant** antenna.
- If impedance is **purely imaginary**: $Z = 0 + j 50$, the voltage leads the current by 90 degrees. This is considered a **very bad** antenna.

Antenna as a Series RLC Network



- An antenna can be thought of as a **complex resistance, inductance and capacitance** (RLC) network in series. At some frequencies, it will appear like a **capacitive reactance** (X_C), while at others, like an **inductive reactance** (X_L). At the **resonant** frequency, these reactances will be equal in magnitude, but opposite in influence, canceling each other out. At **resonance**, the impedance is at its minimum being purely **resistive** (real, $Z = R + j X$, where $j X = 0$) and **efficiency** (current in the circuit = I) is at its maximum.
- When an antenna is not at its resonant length, the voltage source (V) will see something other than pure resistance (R). In this case, the impedance is now **complex** which includes reactance (X):
- ✓ If the antenna is too short, **capacitive reactance** (X_C) is present. To resolve this imbalance, *inductance* is added to offset capacitance.
- ✓ If the antenna is too long, **inductive reactance** (X_L) will be present. To resolve this imbalance, *capacitance* is added to offset inductance.

Radiation Resistance (R_{rad}) and Loss Resistance (R_{loss})



- Radiation resistance** (R_{rad}) is the total power radiated as electromagnetic waves in all directions – **productive energy**.
- Loss resistance** (R_{loss}) includes conductor RF resistance, losses of insulators and loading elements, ground losses of the antenna current return circuit and ground absorption in the near field – **wasted energy**.
- Radiation efficiency** ($\eta\%$) is dependent upon the sum of the **radiation resistance** (R_{rad}) of the antenna in series with the **loss resistance** (R_{loss}). These make up the **resistive (R)** part of the feed-point impedance.

$$\eta\% = \frac{R_{\text{rad}}}{R_{\text{rad}} + R_{\text{loss}}} \times 100\%$$

→ Goal: **minimize** R_{loss}

R_{rad} converted to radio waves (**productive**)

R_{loss} converted to heat (**wasted**)

Source: ON4UN, John Devoldere & DJ2YA, Uli Weiss (2010)

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Loss Resistance (R_{loss}) Components

$$\text{Eff} = \frac{R_{\text{rad}}}{R_{\text{rad(B)}} + R_{\text{loss}}} \quad (\text{Eq 9-4})$$

The loss resistance of a vertical is composed of:

Ground Ohmic

- Conductor RF resistance
- Parallel losses from insulators
- Equivalent series losses of the loading element(s)
- Ground losses part of the antenna current return circuit
- Ground absorption in the near field

Ohmic losses within the antenna:

- **Conductor RF resistance** includes the conductivity of the antenna components used.
- **Losses from base insulators** including dielectric material losses at high voltage points.
- **Equivalent series losses of loading element(s)** providing inductance (coils) and capacitance (hat).

Ground losses associated with the nearby soil:

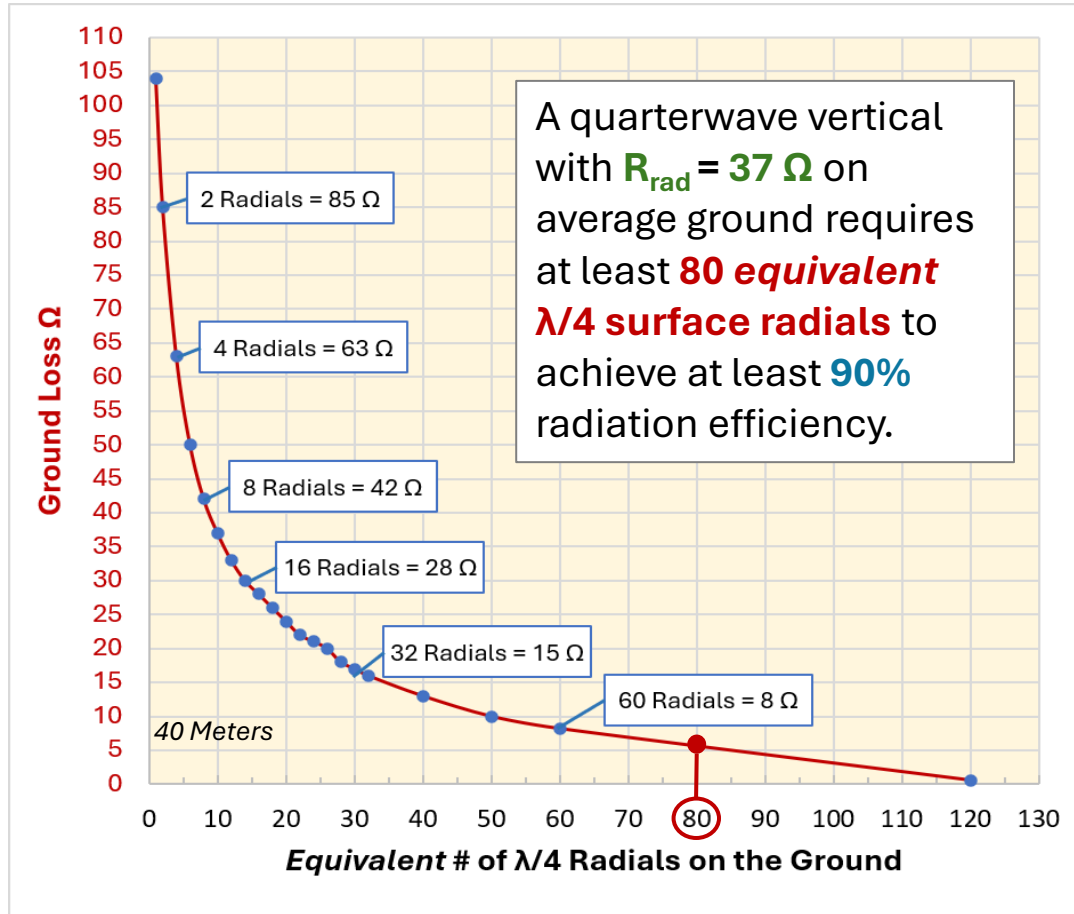
- **Ground losses through the antenna return circuit** include antenna return currents that *travel through the ground and back to the feed point*, right at the base of the antenna impacted by *resistivity ρ ($\Omega\text{-m}$)* of the soil.
- **Ground absorption in the near field** includes the *conductivity σ (mS/m)* and the *dielectric properties of the ground* that determine absorption losses, caused by an electromagnetic wave penetrating the ground.

Unless the vertical antenna uses *elevated radials*, **return current will flow through the lossy ground.**

Source: ON4UN, John Devoldere & DJ2YA, Uli Weiss (2010)

Loss Resistance (R_{loss}) of *Ground* Radials

# of $\lambda/4$ radials	Ground Loss Ω	$\lambda/4$ Efficiency
1	104	26%
2	85	30%
4	63	37%
6	50	43%
8	42	47%
10	37	50%
12	33	53%
14	30	55%
16	28	57%
18	26	59%
20	24	61%
22	22	63%
24	21	64%
26	20	65%
28	18	67%
30	17	69%
32	16	70%
40	13	74%
50	10	79%
60	8.2	82%
120	0.6	98%



Loss Resistance = *Measured Feedpoint Resistance* - *Calculated Radiation Resistance*

- If only **two $\lambda/4$ radials** are used, the **$R_{\text{loss}} = 85 \Omega$** . Given **$R_{\text{rad}} = 37 \Omega$** for a quarterwave vertical, the **radiation efficiency** = $37 \Omega / (37 \Omega + 85 \Omega) = 30\%$.

- Using that same efficiency formula for other numbers of $\lambda/4$ radials:

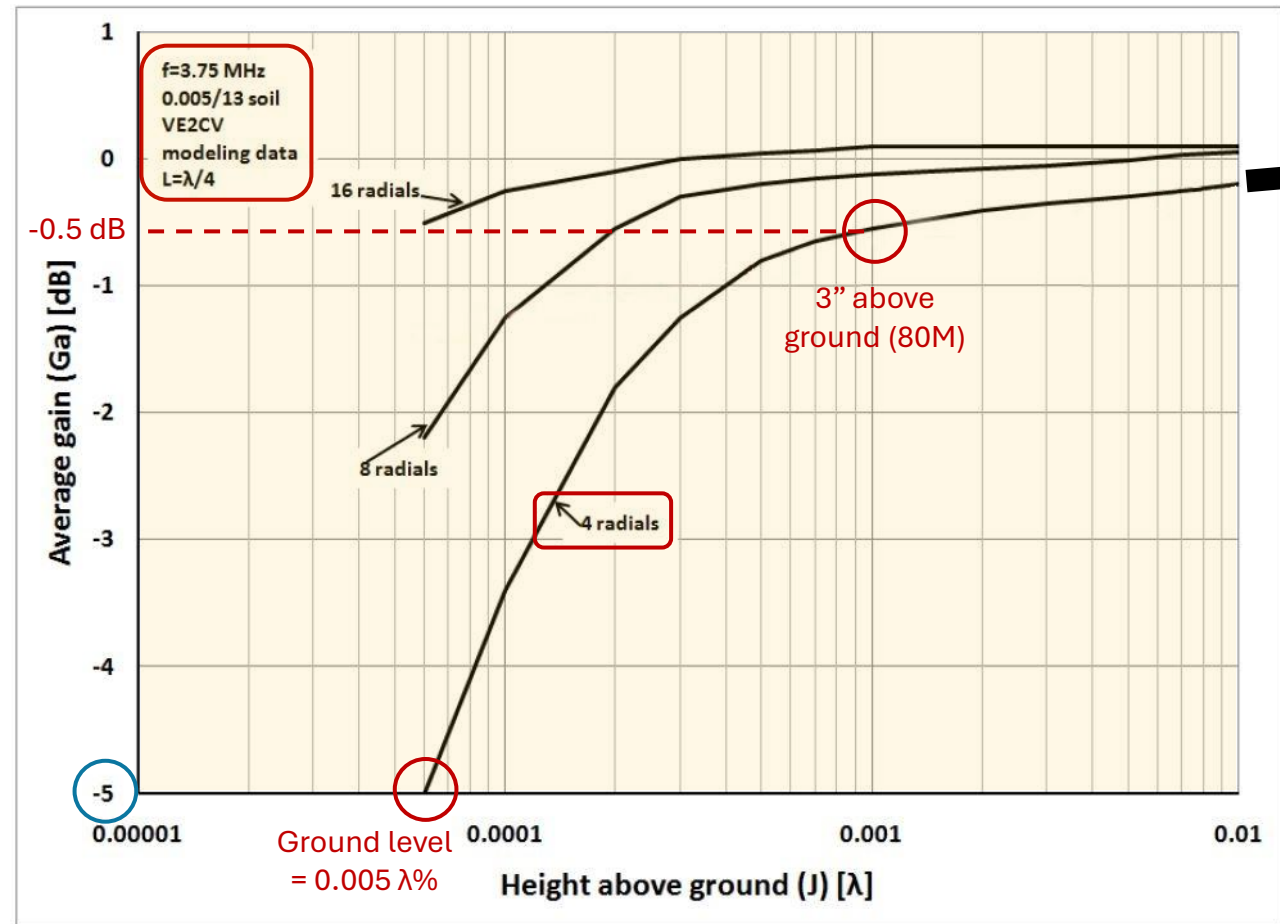
- ✓ 4 radials = **37%** efficiency
- ✓ 8 radials = **47%** efficiency
- ✓ 16 radials = **57%** efficiency
- ✓ 32 radials = **71%** efficiency
- ✓ 64 radials = **84%** efficiency

- Comparatively, computer models with **2 elevated radials @ 36"** indicate a **$R_{\text{loss}} \sim 4 \Omega$** , yielding a **radiation efficiency** = $37 \Omega / (37 \Omega + 4 \Omega) = 90\%$.

+3 dB

Source: KN5L, John Oppenheimer (2013), "Vertical Antenna Ground Radial Loss Study"

Loss Resistance (R_{loss}) of *Elevated* Tuned Radials



- As the radial height above ground is increased, the loss resistance (R_{loss}) is significantly reduced. As tuned radials are elevated above ground, capacitive coupling is decreasing as a reciprocal ($C = \epsilon_0 A / d$).
- Even a very small increase in radial height above ground will make a large difference in loss (*inversely proportional*), especially if number of radials is small.
- ✓ **Four 80M ground radials at 0.005% λ above ground** (laying on the ground, $\sim .02$ "), there is at least -5 dB loss of potential gain.
- ✓ Raising those same **4 radials to 0.100% λ above ground** (3.0" for 80M), the loss is reduced to just -0.5 dB of potential gain.
- Based upon my field testing, I recommend *at least 2% λ radial elevation* or, *if possible, 5% λ radial elevation above ground* (>39" on 20M).

Source: N6LF, Rudy Severns (QST, 2010)

4 to 64 Ground Radials versus 4 Elevated Radials

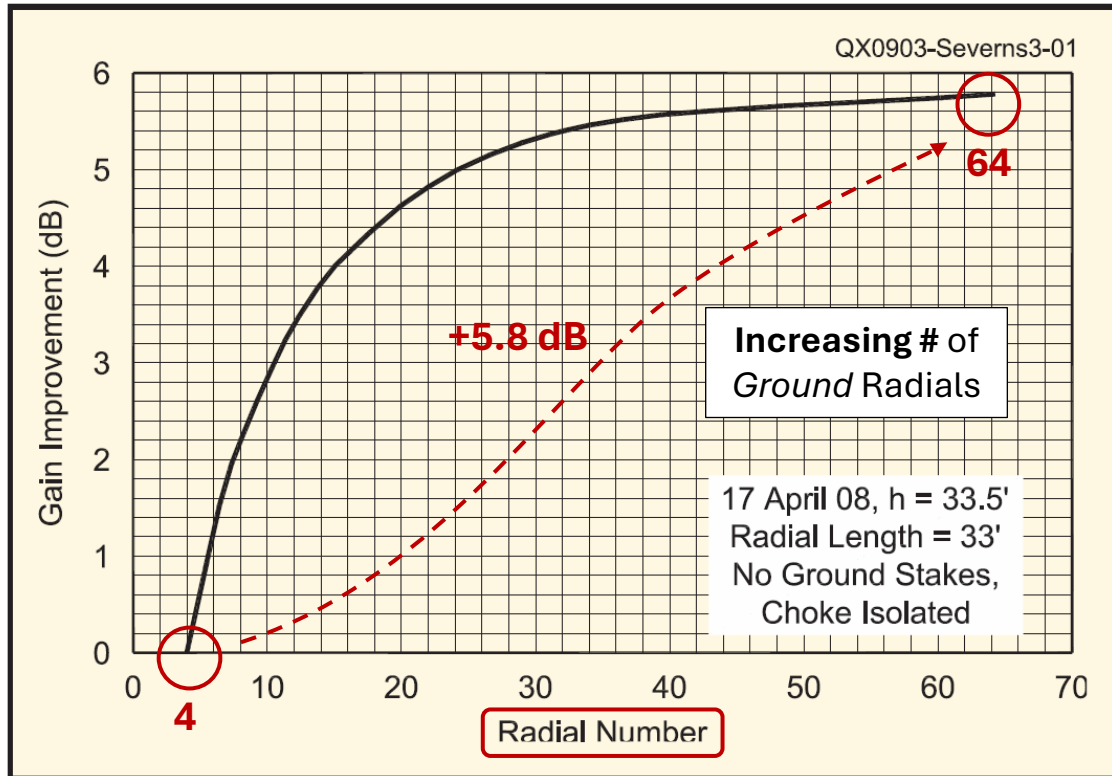


Figure 4 — Signal improvement as a function of radial number. All radials lying on the ground surface, F = 7.2 MHz.

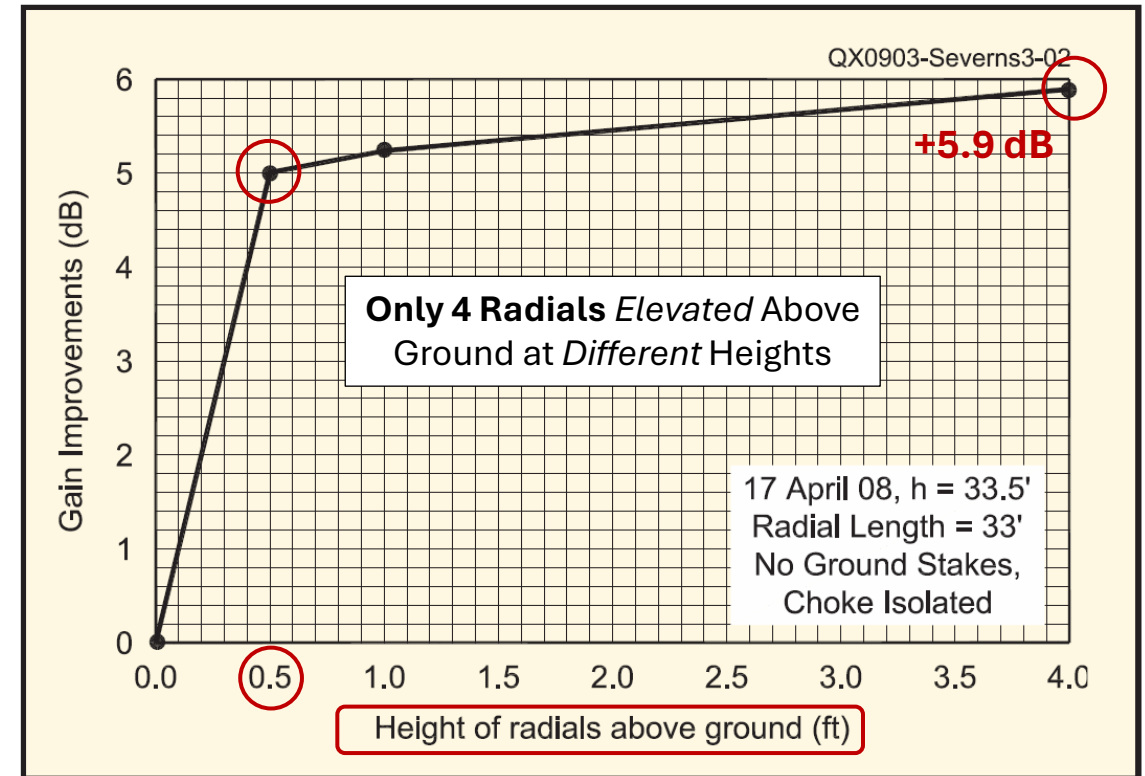
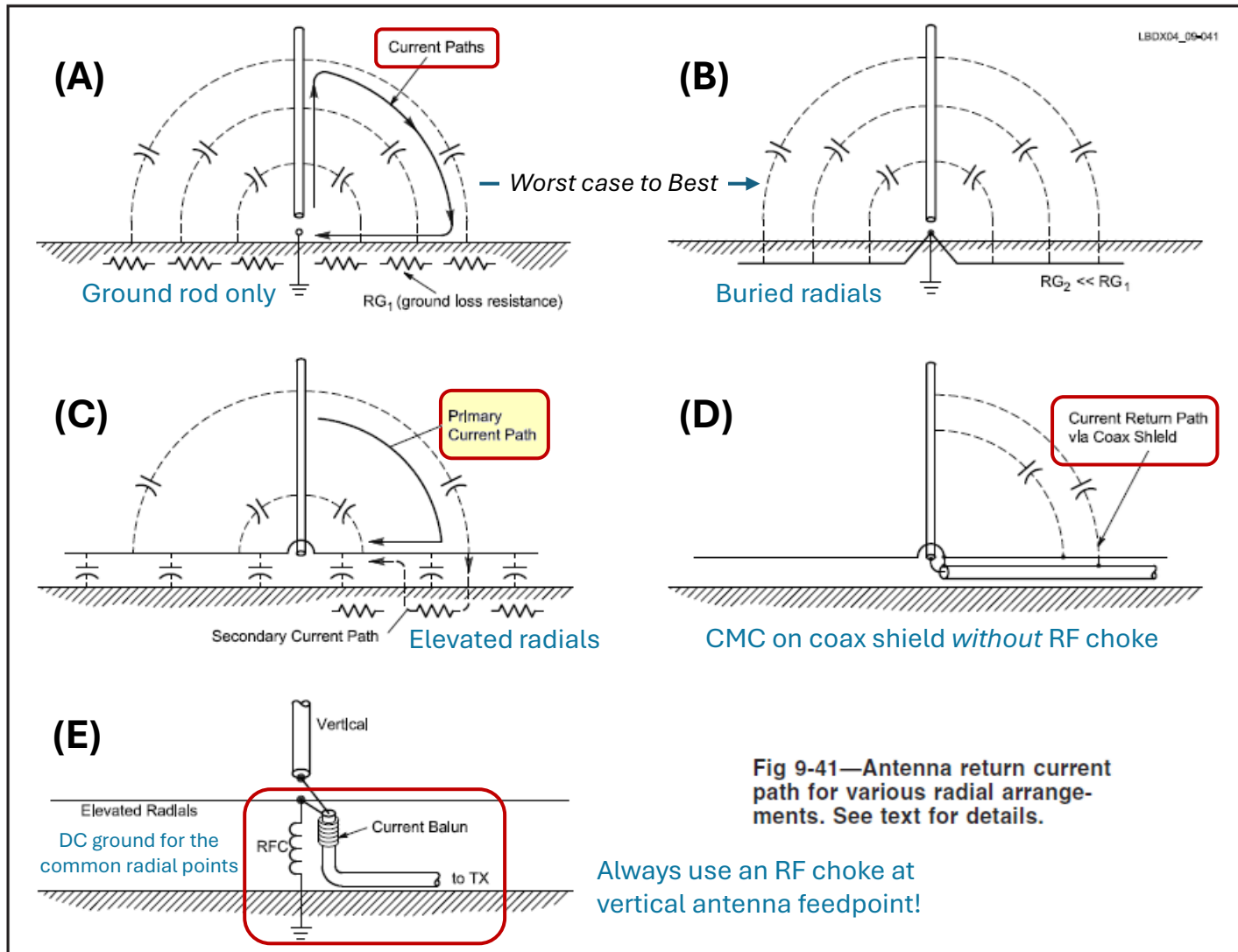


Figure 5 — Signal improvement with four radials and the antenna base at different heights. F = 7.2 MHz.

- 0 dB point is *normalized* to the signal strength of four $\lambda/4$ radials lying on the surface (0 dB).
- 4 elevated radials at a height of 4 feet are equivalent to sixty-four $\lambda/4$ radials lying on the ground.

Source: N6LF, Rudy Severns (QST, 2010)

Antenna Return Current Paths



- (A) **Using only a ground rod** forces return currents to travel entirely through lossy soil resulting in *very low* radiation efficiency.
- (B) **Buried radials reduce losses** improving efficiency through low-loss radial conductors in the ground.
- (C) **Two elevated radials** resulting in 2 current return paths: *lossless* path through radials and *potentially lossy* capacitive path through soil. Raising radials higher ($5\% \lambda$) *dramatically* reduces capacity to lossy soil.
- (D) **Unwanted common mode currents** (CMC) flow on the *coaxial shield* as a *random length radial* resulting in lower efficiency.
- (E) **Current balun and/or RF choke** at feedpoint *significantly* alleviates unwanted common mode currents on coax shield.

Source: ON4UN, John Devoldere & DJ2YA, Uli Weiss (2010)

Revision: July 2026

Ground Mounting versus Elevated Mounting: Efficiency

Ground Mounting

Advantages

- ✓ The radials are non-resonant so one length (.1 wl minimum at lowest frequency) works on all frequencies
- ✓ Easy to mount
- ✓ Easy access
- ✓ Lower visual profile

- ✓ Sixteen 0.25 wl (wavelength) radials of lowest intended frequency give 55%-60% efficiency

Disadvantages

- ✗ Takes 120 radials to equal an elevated vertical with 2 resonant radials (90% efficiency)
- ✗ Surrounding objects can reduce signal strength

Elevated Mounting

Advantages

- ✓ >90% efficient with two .25 wl radials

→ PERformer efficiency avgs 90.8% from 20M-6M

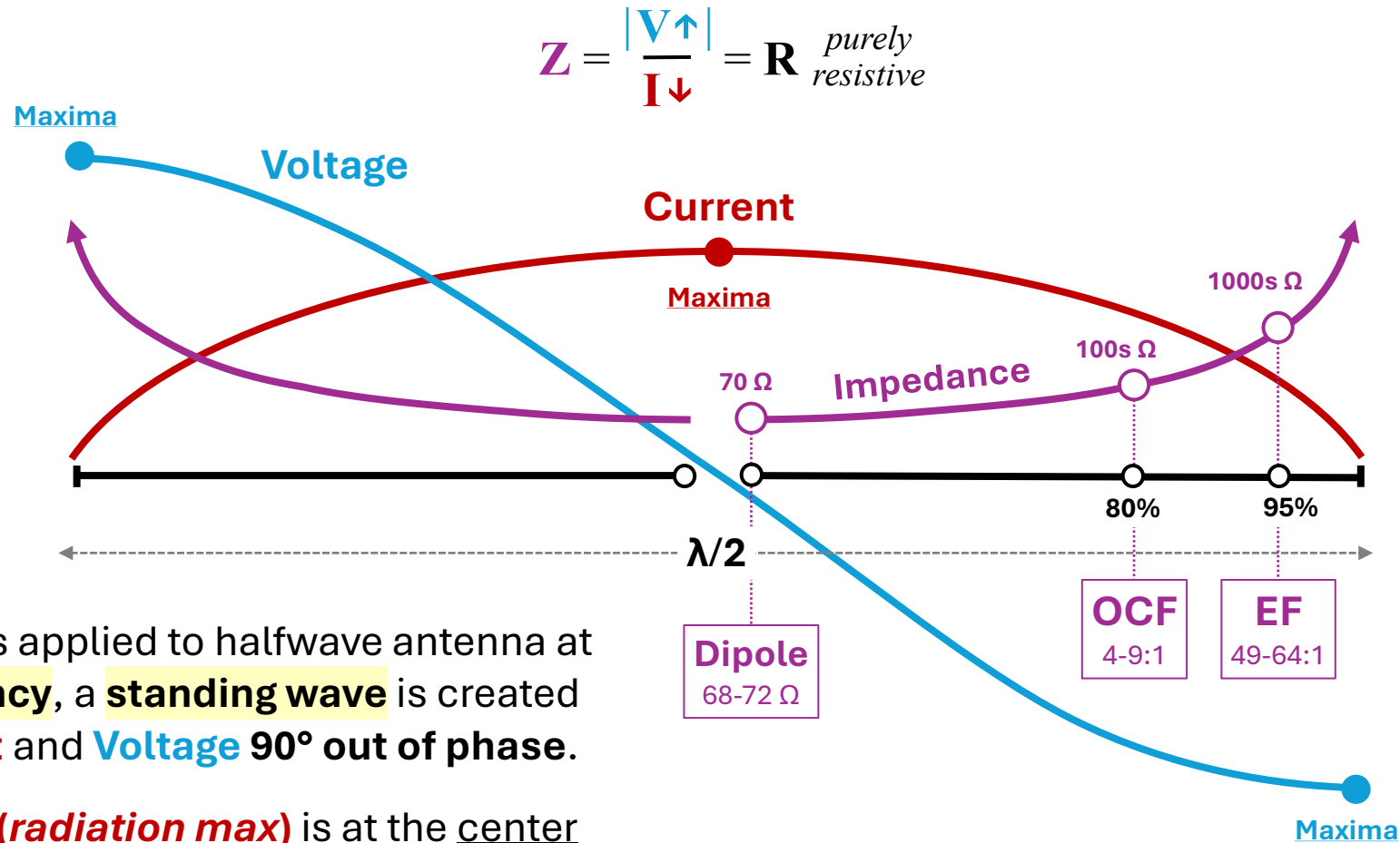
- ✓ Antenna is generally more “in the clear”, so surrounding objects don’t cause as much attenuation
- ✓ A peaked metal roof will make a very good all-frequency radial system
- ✓ Contrary to conventional wisdom the vertical doesn’t have to be elevated very high, 6 inches elevation results in much lower losses, even on 80m— 5 feet is just fine for 80m (2%λ)

→ PERformer elevated radial end height ranges from 5% λ on 20M to 16% λ on 6M

Disadvantages

- ✗ Mounting is generally more involved
- ✗ Requires two .25 wl radials (minimum) for each band of operation (radials interact, so spacing will affect length)
- ✗ Visually higher profile
- ✗ Must be mounted high enough so that people or animals will not accidentally make contact with the radials
- ✗ Elevating lowers the impedance so radials may need up to a 30 degree downward slope to achieve a reasonable match → PERformer droop angle = 5° - 22°

Halfwave Antenna at *Resonance* Creates a Standing Wave



When RF energy is applied to halfwave antenna at **resonant frequency**, a **standing wave** is created with both **Current** and **Voltage** 90° out of phase.

Current maxima (*radiation max*) is at the center with *low impedance* (68-72 Ω), **Voltage maxima** are at the ends with *high impedance* (1000s Ω).

Quarterwave Antenna Needs to be *Elevated* off the Ground

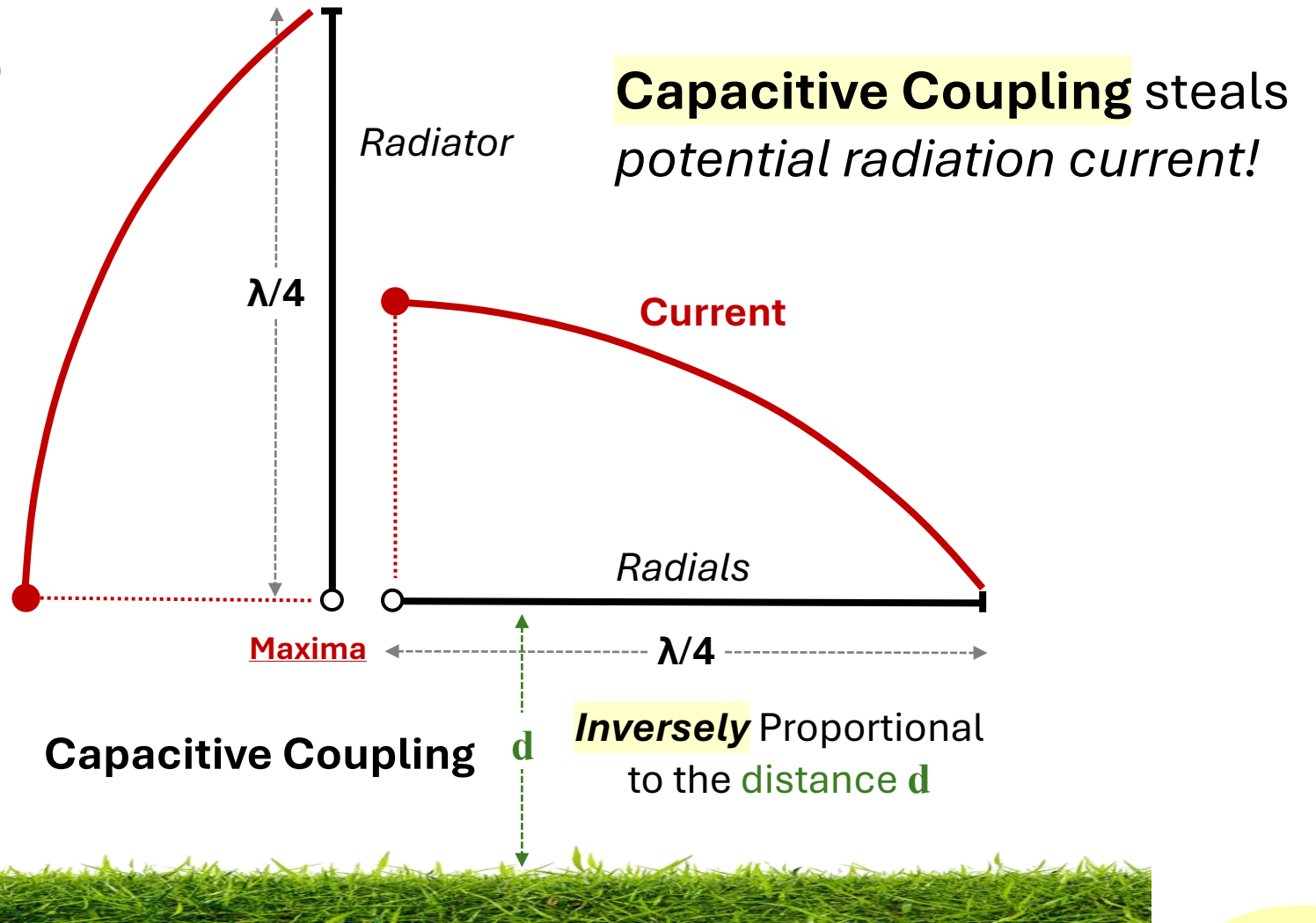
Capacitance (*Parallel Plates*)

$$C = \frac{\epsilon_0 A}{d}$$

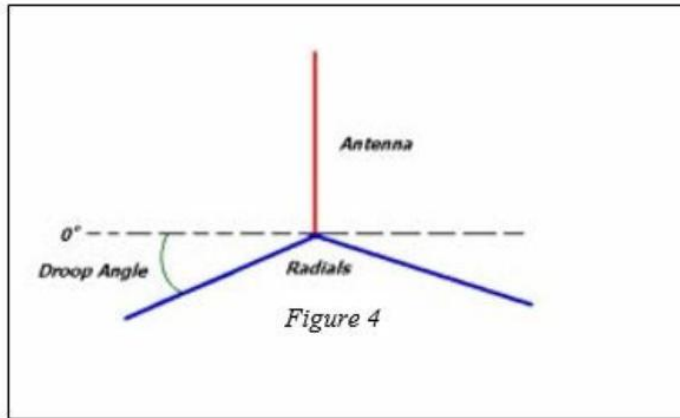
Area of Plates
distance between plates

The **closer** the plates, the **greater** the **Capacitance** ...
the **further** the plates, the **smaller** the **Capacitance**.

Imagine the quarterwave **radials** and **ground** as **two plates** of a capacitor.



Elevated Radials and the Droop Angle



Radial Droop Angle	=	Antenna Impedance
0°	=	22 Ohms
10°	=	28 ohms
20°	=	35 ohms
30°	=	47 ohms
40°	=	53 ohms
50°	=	55 ohms

Note: above 50° results in diminishing returns

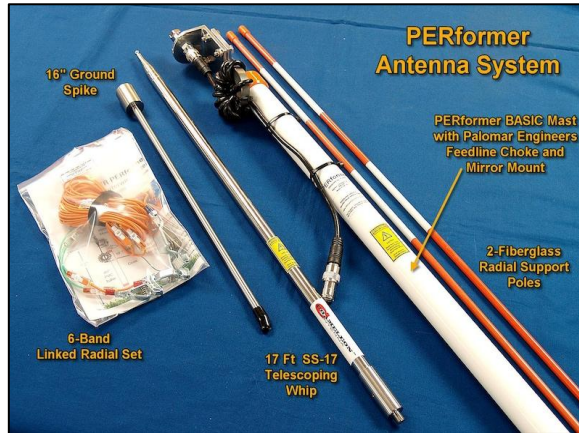
- As radials are elevated, the capacitive coupling losses go down dramatically. In fact, two elevated $\lambda/4$ radials have a loss resistance of a few ohms $\sim 4 \Omega$ versus ground $\lambda/4$ radials with a loss resistance of 85Ω .
- Thus, $\text{Eff\%} = 37 \Omega / (37 \Omega + 4 \Omega) = 90\%$ efficiency with 2 elevated radials, and $\text{Eff\%} = 37 \Omega / (37 \Omega + 85 \Omega) = 30\%$ efficiency with 2 ground radials. When 100W is applied to these antennas, delta dB increase = $10 \times \log(90 \text{ watts} / 30 \text{ watts}) = +4.8 \text{ dB gain!}$
- Elevated tuned radials will lower the resistive impedance of the antenna due to their lower loss resistance. To raise impedance closer to 50Ω , the elevated radials can be **drooped** or angled downward slightly.
- If droop angle cannot be angled downward enough, antenna element can be lengthened up to 20% longer to raise resistive impedance but the radials will need to be shortened accordingly for resonance. In essence, this can be thought of as off-center feeding (OCF) a dipole.

Summary of Key Points for a Quarterwave Vertical Antenna

- The ground system (radials) in the *reactive near field* of an antenna *primarily* determines *loss resistance* (R_{loss}) which, when coupled *in series* with the *radiation resistance* (R_{rad}), has a huge impact on *radiation efficiency*:
 $\text{Eff}\% = R_{\text{rad}} / (R_{\text{rad}} + R_{\text{loss}}) \times 100\%$, $\rightarrow$ goal is to *minimize* R_{loss}
- The *loss resistance* of *ground radials* becomes very *significant* when using a small number of $\lambda/4$ radials on a quarterwave. Two ground radials have a loss resistance of $85\ \Omega$ which yield a radiation efficiency of only 30% . At least 30 ground radials are required to have an efficiency over 70% .
- *Elevating radials* off the ground *significantly* reduces *loss resistance*. In fact, 120 ground radials are required to equal the $>90\%$ *radiation efficiency* of just 2 elevated tuned radials. As radials are raised off the ground, the *loss resistance* drops as the reciprocal of *distance* (d): $\text{capacitance} = \epsilon_0 \text{Area} / d$.

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PERformer 40M-6M
Elevated Quarterwave
Antenna includes 17'
Whip and 16" Spike



Challenger 20M-6M
Off-Center Fed Halfwave
Antenna with 25' Whip
and 16" Ground Spike



Dominator 17M-10M
End-Fed Halfwave
Antenna includes 25'
Whip and 16" Spike



Marauder 20M-10M
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Tripod Solution for
Non-Penetrating
Elevation Poles



16" Stainless Steel
Ground Mount Spike for
all **Antenna Systems**
with **PVC Mast Support**



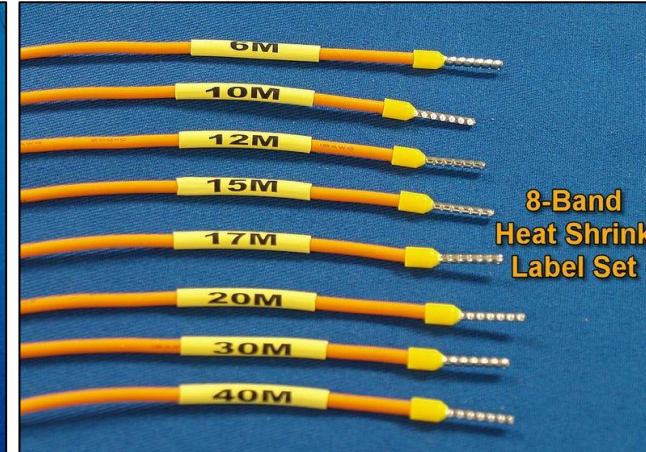
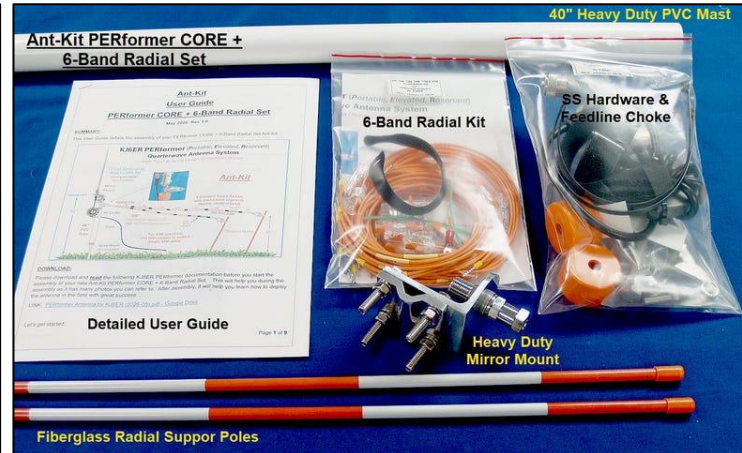
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PERformer Quarterwave Vertical Antenna with *two* Elevated Tuned Linked Radials



PERformer Quarterwave Vertical (Portable, Elevated, Resonant)



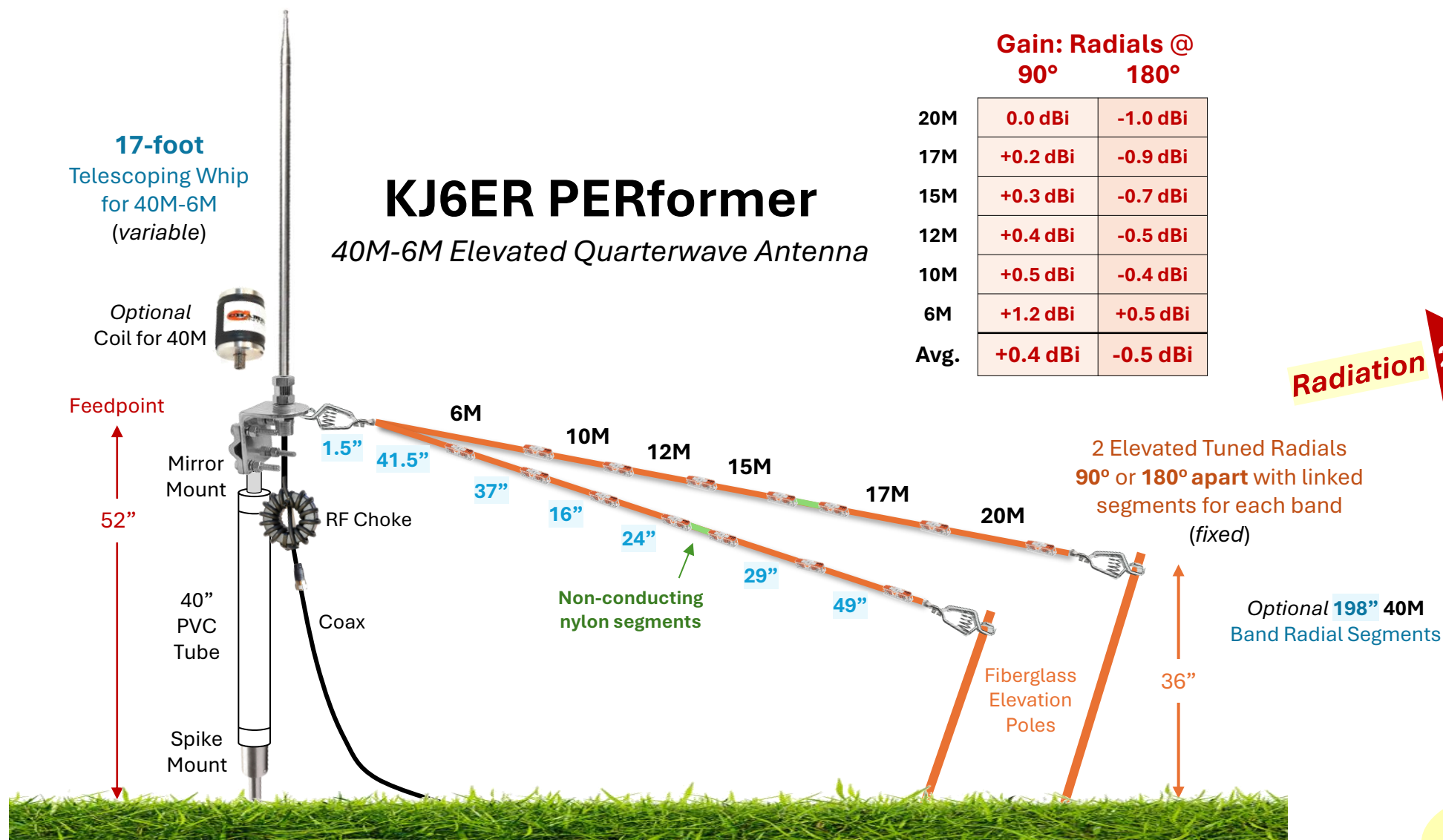
PERformer shown with a portable **78" Polarduck™** tripod with very broad and adjustable leg lengths.



PERformer shown with a 40" furniture-grade **PVC tube** on a stainless-steel ground spike.

- The **PERformer** is a **Portable, Elevated and Resonant** *quarterwave* vertical antenna for **40M-6M** sitting on a PVC ground spike or tripod with the **feedpoint** about 4'-5' off the ground and **2 elevated tuned linked radials** which are placed **90 degrees** apart.
- **Computer modeled extensively** in **4NEC2** to design and optimize performance. **Efficiency** averages **over 90%** across all six bands with an **SWR less than 1.10:1** on each band (20M-6M).
- Designed to be **lightweight and easy to deploy** for all types of portable operations. Also used at HOAs and other types of locations that do not allow permanent antenna installations.

PERformer Elevated Quarterwave Antenna for 40M-6M



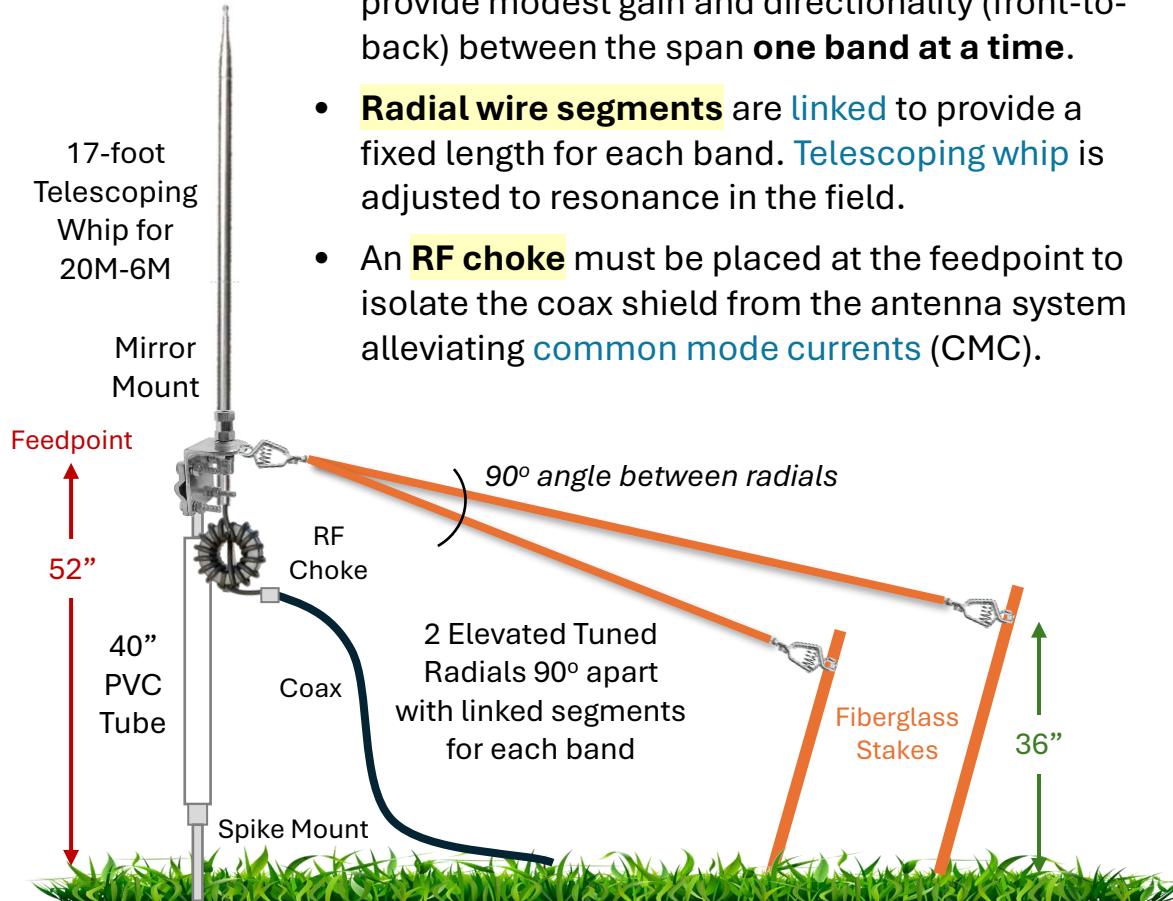
Revision: July 2026

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California

PERformer Vertical with Two Elevated Tuned Linked Radials

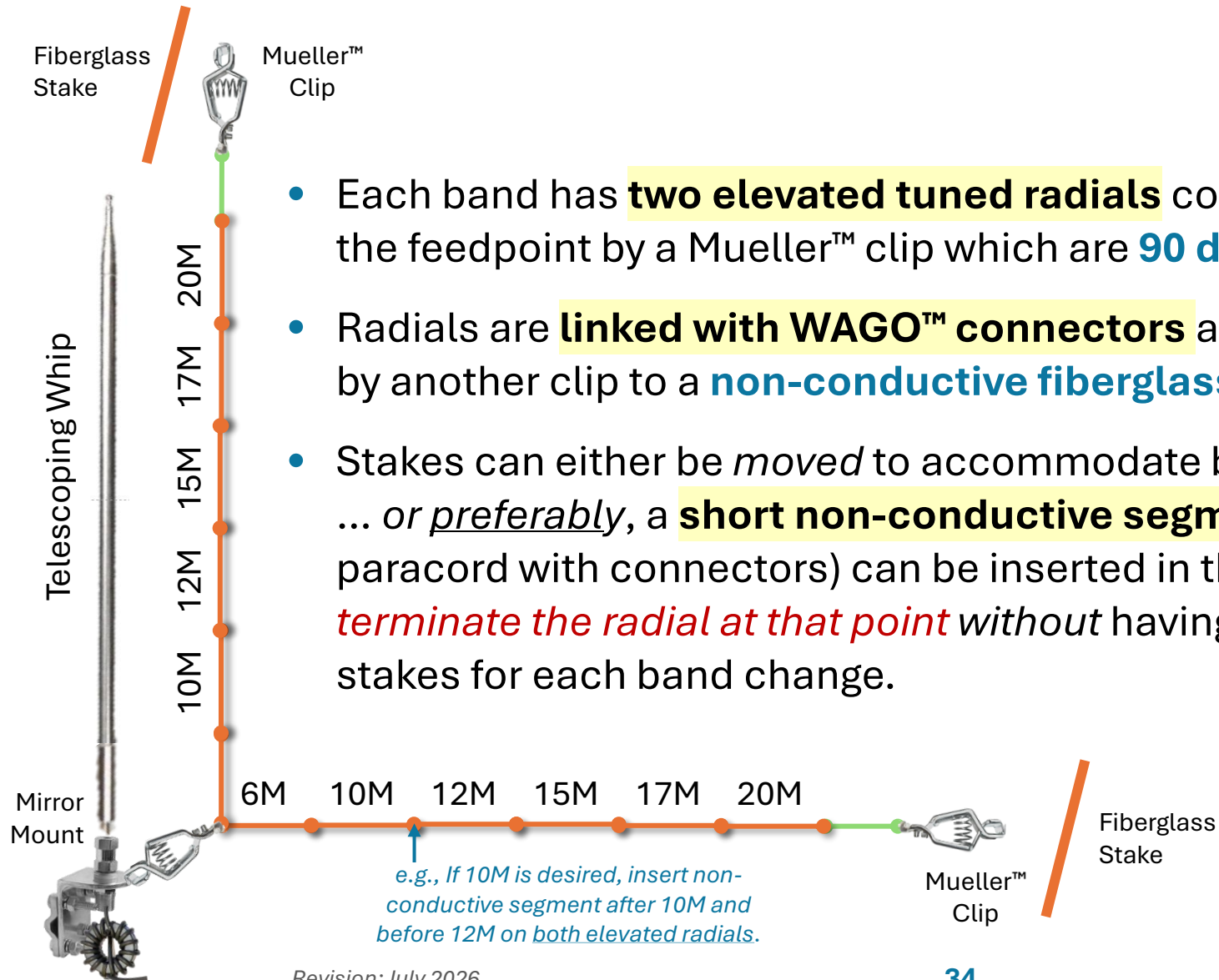


- **Two elevated radials** are placed 90° apart to provide modest gain and directionality (front-to-back) between the span **one band at a time**.
- **Radial wire segments** are linked to provide a fixed length for each band. **Telescoping whip** is adjusted to resonance in the field.
- An **RF choke** must be placed at the feedpoint to isolate the coax shield from the antenna system alleviating **common mode currents** (CMC).

Antenna System Parts List: *(substitute as desired)*

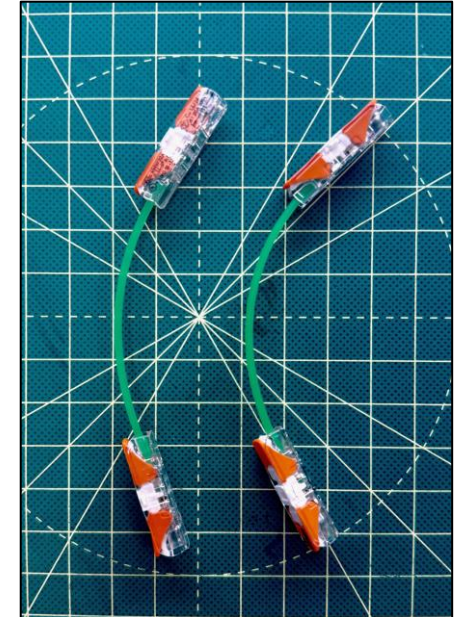
- Chameleon™ 17' telescoping whip
- WRC™ Sporty Forty coil for 40M operation
- Furniture grade 40" PVC 1" ID (*tripod alternative*) with Chameleon™ spike mount including end caps
- Polarduck™ 78" tripod with widespread, adjustable legs (*PVC alternative*)
- Palomar Engineers™ RF feedline choke at the feedpoint to isolate the coax shield
- Mirror mount with 3/8" x 24 nut to SO-239 stud mounted on a short (6"-8") threaded rod
- BNTECHGO™ bright orange 18-gauge wire radials
- Mueller™ clips to combine 2 radials at feedpoint and at each radial end to attach to end stakes
- Fiberglass 48" end stakes to elevate radials (*must be non-conductive without any interior metal*)

PERformer Vertical with Two Elevated Tuned Linked Radials



Revision: July 2026

- Each band has **two elevated tuned radials** connected to the feedpoint by a Mueller™ clip which are **90 degrees apart**.
- Radials are **linked with WAGO™ connectors** and terminated by another clip to a **non-conductive fiberglass stake**.
- Stakes can either be *moved* to accommodate band change ... *or preferably*, a **short non-conductive segment** (e.g., a paracord with connectors) can be inserted in the wire line to **terminate the radial at that point** without having to move the stakes for each band change.

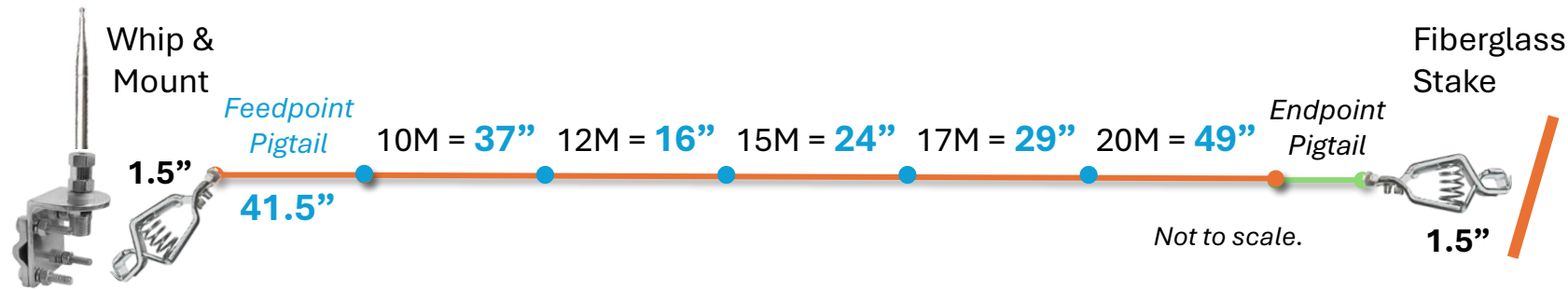


Trimming Line Insert

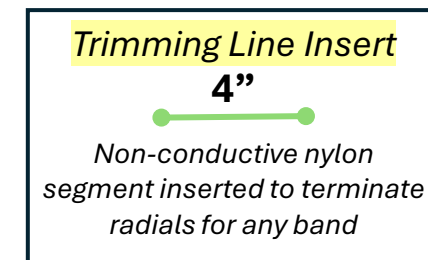
4"

Non-conductive nylon segment inserted to terminate radials for any band

PERformer Vertical with Two Elevated Tuned Linked Radials



- To construct this elevated radial system, first cut two **41.5"** pigtails connected together at the feedpoint for each linked radial string. The feedpoint clip of **1.5"** plus the **41.5"** 6M feedpoint pigtail becomes the **43"** 6M radial length.
- Next, cut a pair of **five band incremental wires**, one for each elevated radial. These sections extend the length of each radial wire for a particular band. Ultimately, the finetuning for each band resonance is accomplished by **adjusting the whip length**.
- When the **paracord segment** is inserted, the **total** length of each elevated radial is:
 - 6M = **43"** (1.5" feedpoint clip + **41.5"** feedpoint pigtail)
 - 10M = **80"** (43" 6M radial length + **37"** incremental 10M section)
 - 12M = **96"** (80" 10M radial length + **16"** incremental 12M section)
 - 15M = **120"** (96" 12M radial length + **24"** incremental 15M section)
 - 17M = **149"** (120" 15M radial length + **29"** incremental 17M section)
 - 20M = **198"** (149" 17M radial length + **49"** incremental 20M section)



PERformer Vertical Antenna Deployment on a Tripod



PERformer shown with a portable 78" **Polarduck™** tripod with very broad and telescoping leg lengths for stability. This portable tripod is recommended for its lightweight frame and adjustable broad leg spread for all types of locations.



A **Chameleon™** 17' whip on a mirror mount is attached securely to the tripod upper tube. A **Mueller™** clip is used to combine two elevated tuned radials and clipped firmly to the mount to provide an effective elevated counterpoise.



A **Mueller™** clip is used at the end of each elevated radial to attach onto a 48" fiberglass (non-conductive) stake. The clip can easily be slid up and down (droop) to finetune the feedpoint impedance for low SWR. These stakes are used for both deployment options.

- The **PERformer** antenna **tripod deployment** option is ideal for those locations where a spike mount into the ground is not available or permitted. It provides a very stable and effective base when the whip is extended.
- The **17' telescoping whip** is attached to a standard mirror mount up ~52" to provide the radiating element. The mount is attached to an aluminum tube which is inserted into the tripod. A rubber cap is installed at the top of the tube to insulate it from the elements.
- A **Mueller™ clip** is used to combine the two elevated radials and attach them to the mirror mount. A Mueller™ clip at the end of each radial is attached to a non-conductive fiberglass stake to keep it taut and elevated.

PERformer Vertical Antenna Deployment on a PVC Spike Mount



PERformer shown with a 40" furniture grade PVC tube (1" ID) on a **Chameleon™** spike mount. The non-conductive support structure provides both elevation and a secure mount for the telescoping whip and 2 elevated tuned radials.



A 3/8" hole is drilled into the **PVC bottom cap** to insert a 3/8"x 24 bolt (1.5"- 2" long) and nut to easily screw into a stainless-steel spike mount or short tripod, e.g. WRC Mini-Pod.



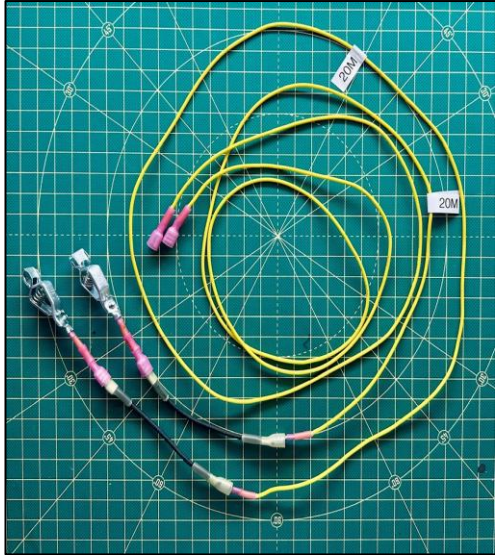
A 3/8" hole is drilled into the **PVC top cap** to insert a 3/8"x 24 bolt and nut (about 1.5" long) to accept a mirror mount that supports the 17' **Chameleon™** whip. A split lock and fender washer is used on both the inside and outside for a secure fit.



The mirror mount screws into the long bolt at the PVC top cap for the telescoping whip. A **Palomar Engineers™** RF choke (or suitable equivalent) must *always* be used at the feedpoint to isolate the coax shield from the antenna system.

- The **PERformer** spike mount deployment option is ideal for those locations where the ground can accept a spike that can be pushed in by hand or tapped in with a rubber hammer. *Alternatively*, it can screw into a short tripod on the surface.
- The 40" furniture PVC tube and spike is a sturdy mount for the telescoping whip. It provides a **non-conductive support structure** that elevates both the antenna feedpoint and the tuned radials about 52" above the earth when combined with the mirror mount.

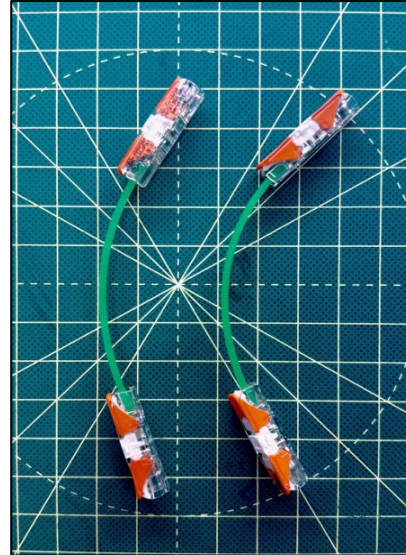
PERformer Vertical with Two Elevated Tuned Linked Radials



The **elevated radial system** is composed of pre-cut 18-gauge wire segments that are linked together within a string by spade connectors. These connectors allow the fast and easy insertion of a non-conductive segment to terminate the radial at that point for each band.



The **wire ferrule crimping tool** and standard **WAGO™ connectors** are used for fast and easy integration and attachment of band radial segments. The connectors with the wire ferrules provide a very strong and secure connection in the field that will last a long time.



Two 4" **non-conductive radial segments** (using nylon cord) have Wago™ connectors on each end. The segments are inserted in each elevated radial line to terminate it at the band of operation. By doing so, the fiberglass end stakes *do not* have to be moved for each band change.

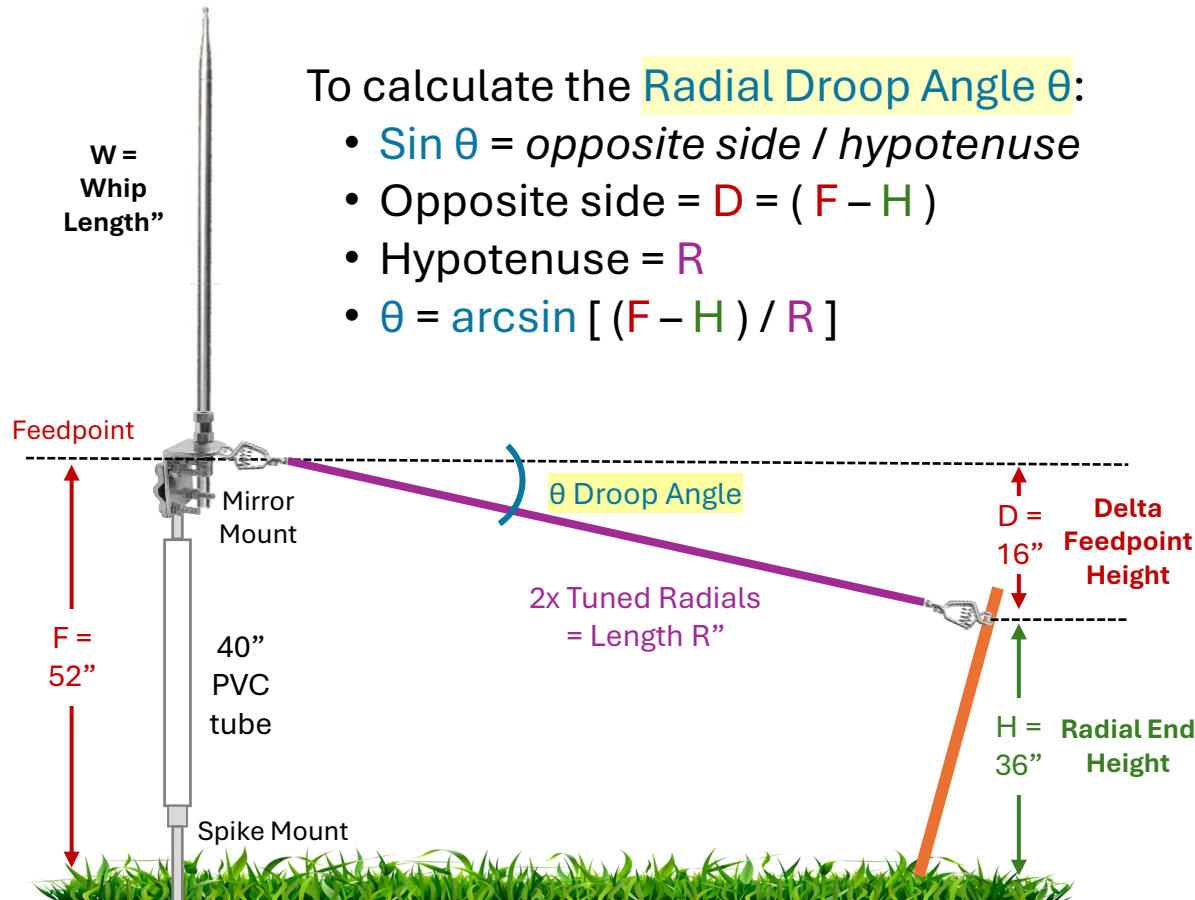


PERformer elevated radial system shown coiled up with a Velcro™ strap for easy transport and fast deployment. A **Mueller™ clip** is used at one end to combine the radials, and another at the end of each radial. Each band segment is clearly labeled.



A **zippered clear plastic bag** (commonly used for travel toiletries) provides the perfect enclosure for the radial system and accessories. It also holds the **Chameleon™ M-COIL** for 40M operation and a **RigExpert™ Stick** analyzer for easy antenna tuning resonance in the field.

4NEC2 PERformer Model Computations for Radial Droop Angle



To calculate the **Radial Droop Angle θ** :

- $\sin \theta = \text{opposite side} / \text{hypotenuse}$
- Opposite side = $D = (F - H)$
- Hypotenuse = R
- $\theta = \arcsin [(F - H) / R]$

If you move the end stakes for each band change, your radial droop angle will change. Alternatively, if you insert a non-conductive segment in the line, the droop angle will remain consistent at the 20M band droop.

Examples – 4NEC2 computes **W**, **R** for **H = 36"**:

- **20M** Whip Length (**W**) = **207"** (+4.8% longer than $234/f$)
- **Radial Length (R)** = **198"** (+0.5% longer than $234/f$)
- **Droop θ** = $\arcsin (D=16" / R=198") \times 180/\pi =$ **5°**



- **6M** Whip Length (**W**) = **64"** (+16.5% longer than $234/f$)
- **Radial Length (R)** = **43"** (-21.9% shorter than $234/f$)
- **Droop θ** = $\arcsin (D=16" / R=43") \times 180/\pi =$ **22°**

4NEC2 model calculations are a great *starting point* but field testing over real ground must be performed!

PERformer Backpack Configuration Options

- **Two-piece** (20" each, 3/4" O.D.) **furniture-grade PVC tube** with *coupler*, **shortened 3' fiberglass end stakes** and 17' Chameleon™ telescoping whip with ground spike (or WRC™ Megapod) fit easily in the side pocket.

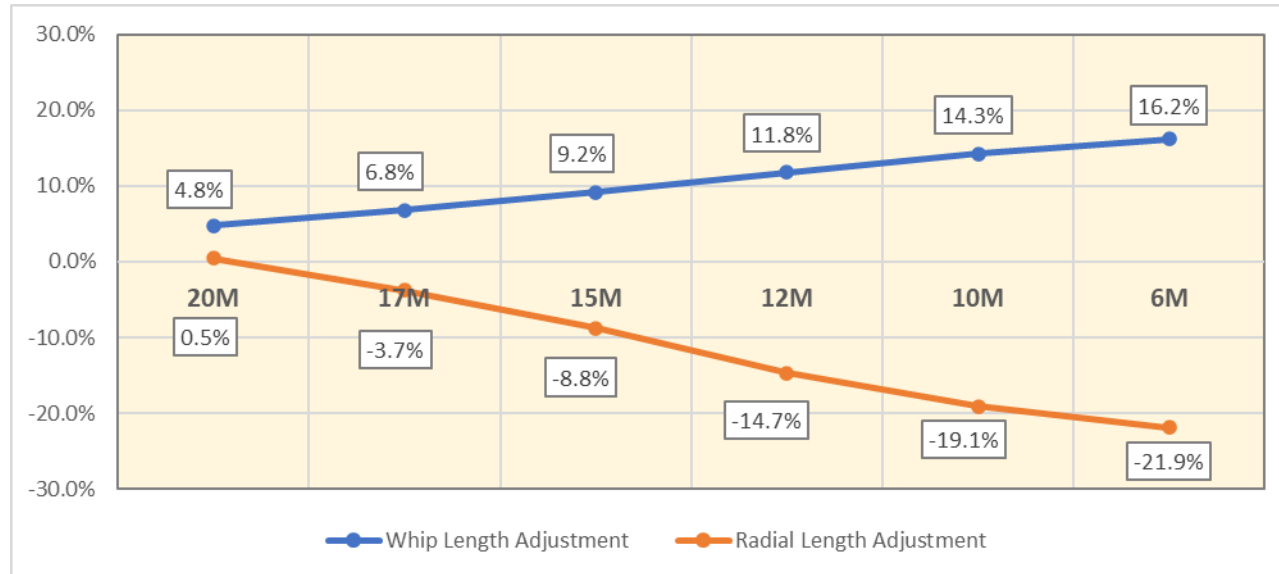


- 2 Linked Radials
- RigExpert™ Stick
- Chameleon™ M-Coil
- Messi & Paoloni™ Airborne 5 Coax



4NEC2 Model Computations for the PERformer Antenna

Band	Target Freq (Mhz)	234 / f		Radiator				Counterpoise					
		Length	Inches	Length	Inches	Whip vs. Calc	Whip OCF %	Length	Inches	Radial vs. Calc	Radial End (in)	Radial End vs. λ	Droop Angle (deg)
20M	14.250	16' 5"	197	17' 3"	207	4.8%	51.1%	16' 6"	198	0.5%	36	5%	5
17M	18.140	12' 11"	155	13' 9"	165	6.8%	52.6%	12' 5"	149	-3.7%	36	6%	6
15M	21.350	11' 0"	132	12' 0"	144	9.2%	54.5%	10' 0"	120	-8.8%	36	7%	8
12M	24.940	9' 5"	113	10' 6"	126	11.8%	56.7%	8' 0"	96	-14.7%	36	8%	10
10M	28.400	8' 3"	99	9' 5"	113	14.3%	58.5%	6' 8"	80	-19.1%	36	9%	12
6M	51.000	4' 7"	55	5' 4"	64	16.2%	59.8%	3' 7"	43	-21.9%	36	16%	22



- The model calculated **whip and radial lengths** for each of the six bands. Whip length ranges from **+5% $\lambda/4$ on 20M** to **+16% $\lambda/4$ on 6M**. Elevated radials from **+0.5% $\lambda/4$ on 20M** to **-22% $\lambda/4$ on 6M**. The whip OCF % from **51% on 20M** to **60% on 6M**.
- The **radial end height** is fixed at **36"** which provided great elevation for each band ranging from **5% $\lambda/4$ on 20M** to **16% $\lambda/4$ on 6M** at the end. The overall elevation reduces capacitive coupling to the ground and increases efficiency.
- With the feedpoint height at **52"** and the radial end at **36"**, the **radial droop angle** from the feedpoint to the radial end ranged from **5° on 20M** to **22° on 6M** which requires a longer radiator for $Z \approx 50$. If you don't move the end stake, the droop angle remains consistent at the 20M band droop.

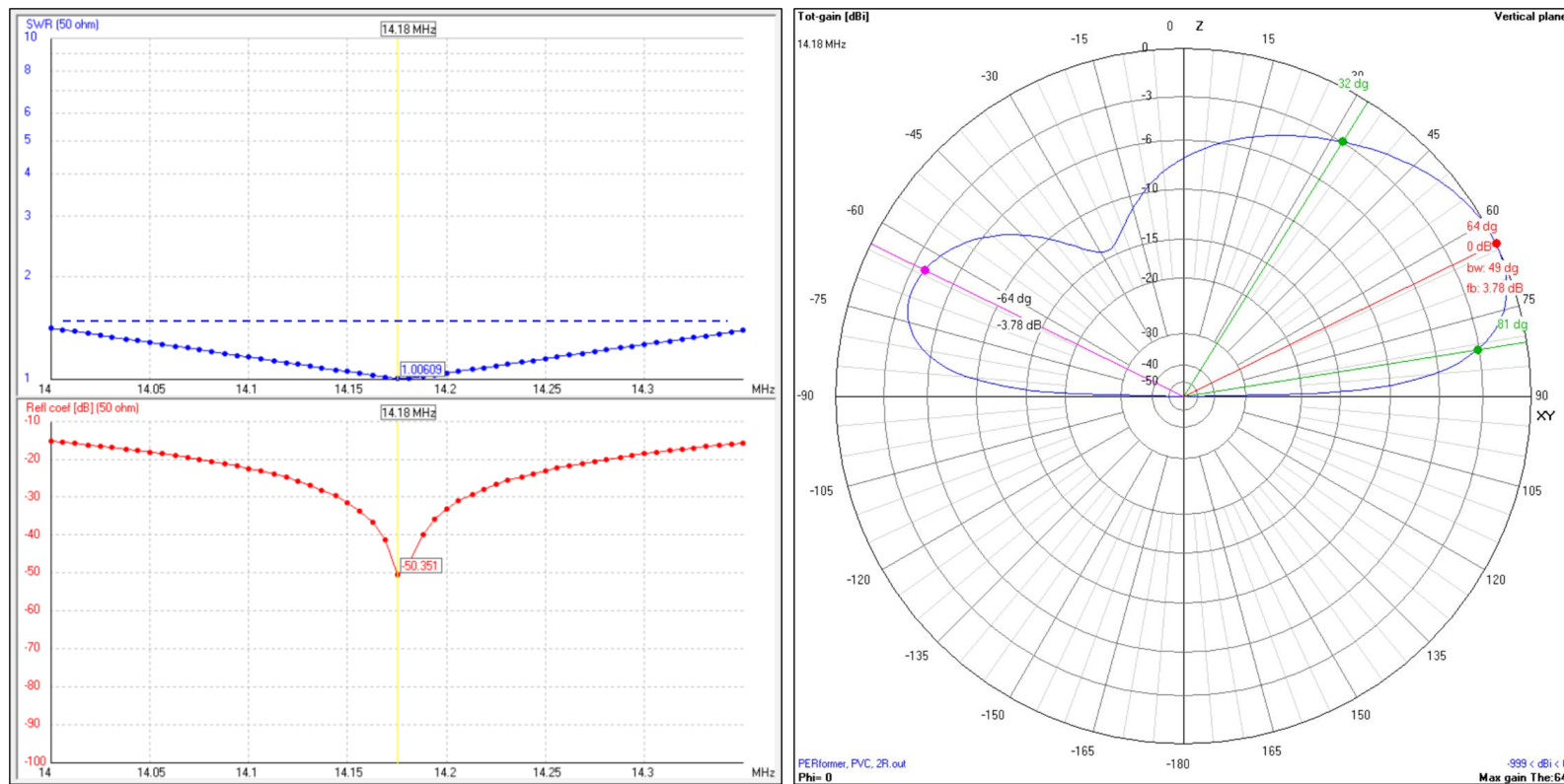
4NEC2 PERformer Model Specifications across 6 Bands

Band	Target Freq (Mhz)	234 / f		Radiator				Counterpoise						Specifications							
		Length	Inches	Length	Inches	Whip vs. Calc	Whip OCF %	Length	Inches	Radial vs. Calc	Radial End (in)	Radial End vs. λ	Droop Angle (deg)	SWR	Ref Coef (dB)	Rad Angle (deg)	Gain (dBi)	FtB (dB)	-3 dB BW (deg)	Efficiency	Impedance
20M	14.250	16' 5"	197	17' 3"	207	4.8%	51.1%	16' 6"	198	0.5%	36	5%	5	1.01	-47.4	26	0.00	3.55	49	88.1%	49.6 + j 0.14
17M	18.140	12' 11"	155	13' 9"	165	6.8%	52.6%	12' 5"	149	-3.7%	36	6%	6	1.02	-41.5	25	0.14	3.48	48	89.5%	49.2 + j 0.22
15M	21.350	11' 0"	132	12' 0"	144	9.2%	54.5%	10' 0"	120	-8.8%	36	7%	8	1.01	-50.3	24	0.26	3.19	46	90.4%	49.7 + j 0.12
12M	24.940	9' 5"	113	10' 6"	126	11.8%	56.7%	8' 0"	96	-14.7%	36	8%	10	1.01	-43.4	24	0.38	2.93	43	91.3%	50.7 - j 0.03
10M	28.400	8' 3"	99	9' 5"	113	14.3%	58.5%	6' 8"	80	-19.1%	36	9%	12	1.02	-40.7	23	0.50	2.66	41	91.9%	50.9 - j 0.29
6M	51.000	4' 7"	55	5' 4"	64	16.2%	59.8%	3' 7"	43	-21.9%	36	16%	22	1.02	-40.4	20	1.20	2.75	38	93.9%	49.1 + j 0.21

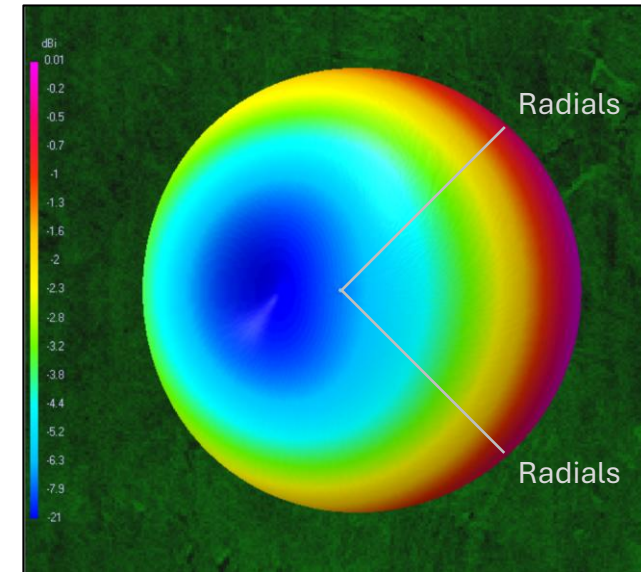
Averages: 1.02 -44.0 24 0.41 3.09 44 90.8% $Z = R + j X$

- The model computed several *performance* specifications including **SWR**, **reflection coefficient**, **peak radiation angle**, **gain**, **front-to-back**, **-3.00 dB beamwidth** as well as overall **antenna efficiency** and **impedance**.
- The *average* performance specifications *across all six bands* are:
 - ✓ Antenna Efficiency = **90.8%**
 - ✓ SWR = **1.02:1**
 - ✓ Reflection Coefficient = **-44.0 dB**
 - ✓ Gain = **0.41 dBi**, Front-to-Back = **3.09 dB**
 - ✓ Peak Radiation Angle = **24°** (*beamwidth* 54°, 9°)
 - ✓ -3.00 dB Beamwidth = **44°** (*delta* +30°, -15°)

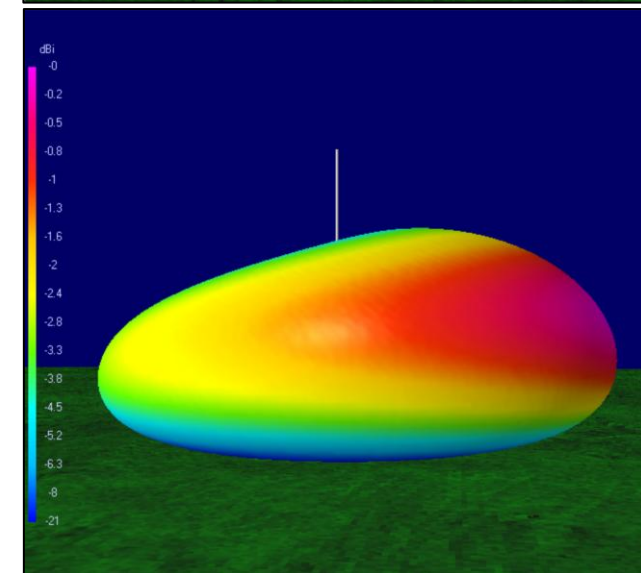
4NEC2 Model Graphics for the **PERformer**: 20M (14.250 MHz)



- The model calculated **SWR** to be **1.01:1** at **14.250 MHz** with a **reflection coefficient** of **-47.4 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 26°** with **+0.00 dBi gain** and **3.55 dB FtB** within a **-3dB beamwidth** of **49°** ($-17^\circ, +32^\circ$) = **9° to 58°**.

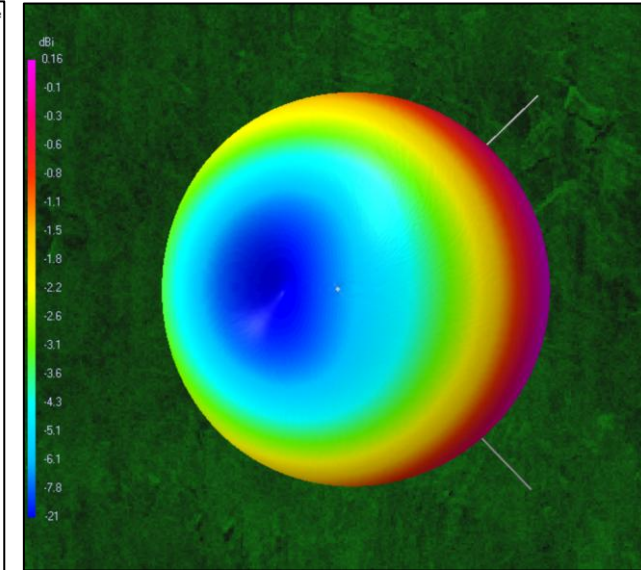
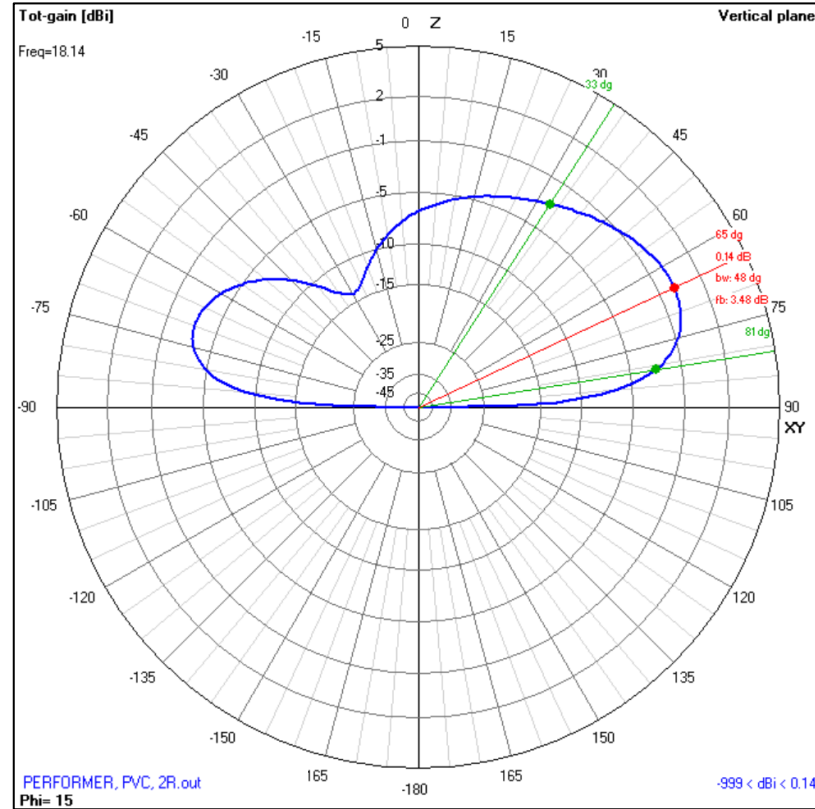
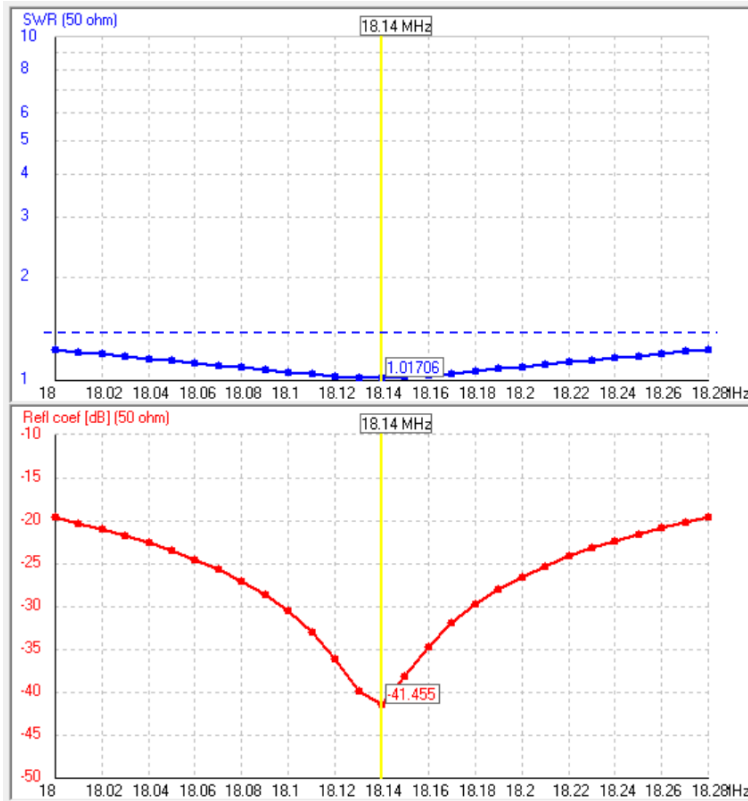


3D radiation modeling as seen from both the top and side views.

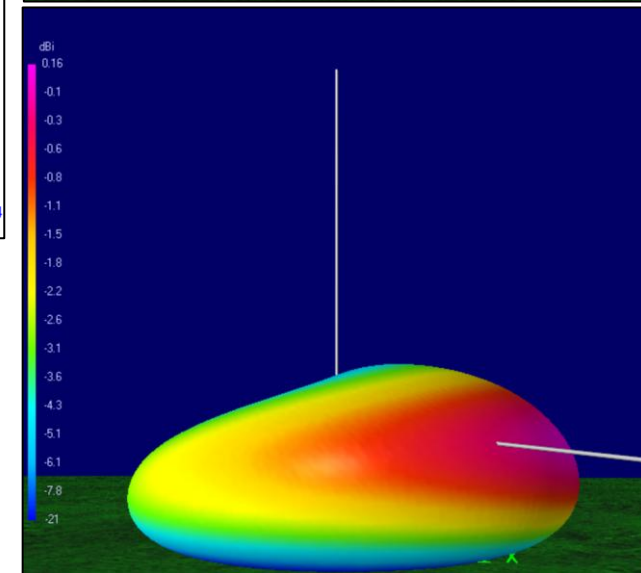


Note that **purple** and **red** are strongest radiation.

4NEC2 Model Graphics for the **PERformer**: 17M (18.140 MHz)



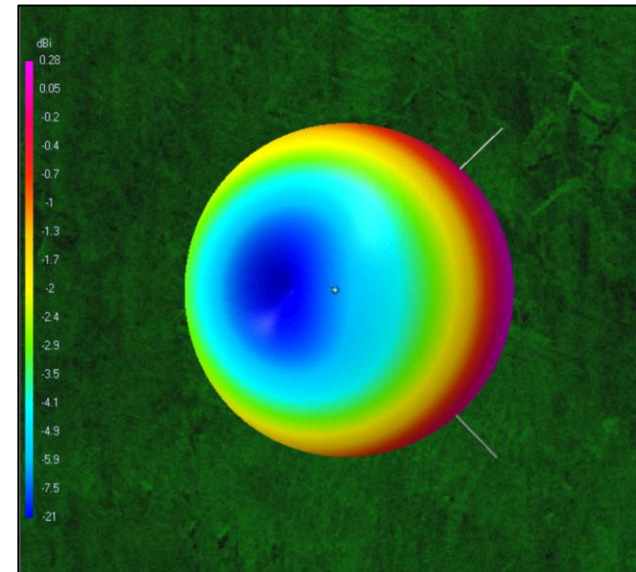
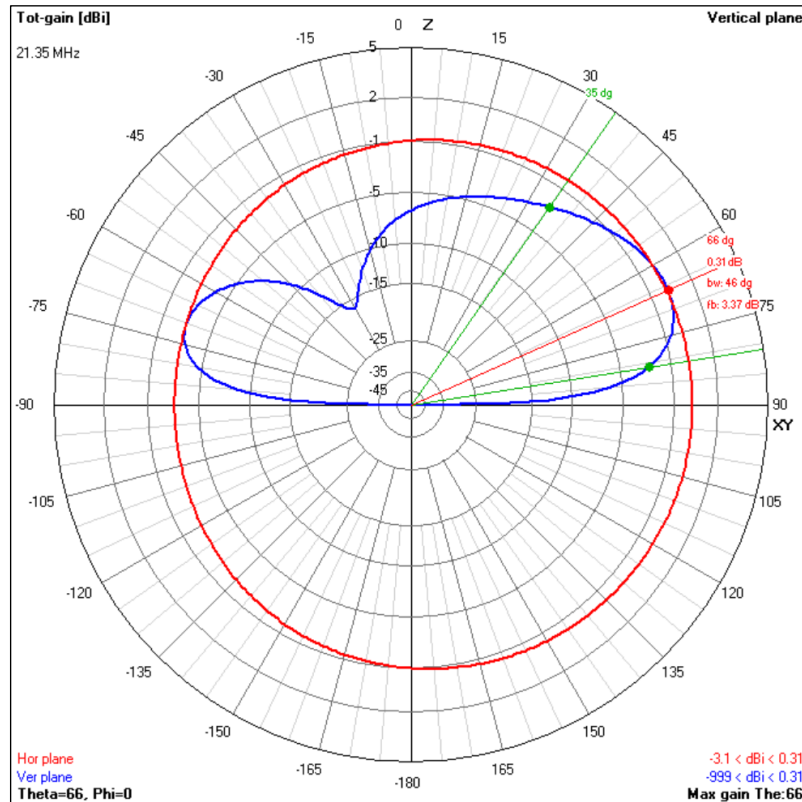
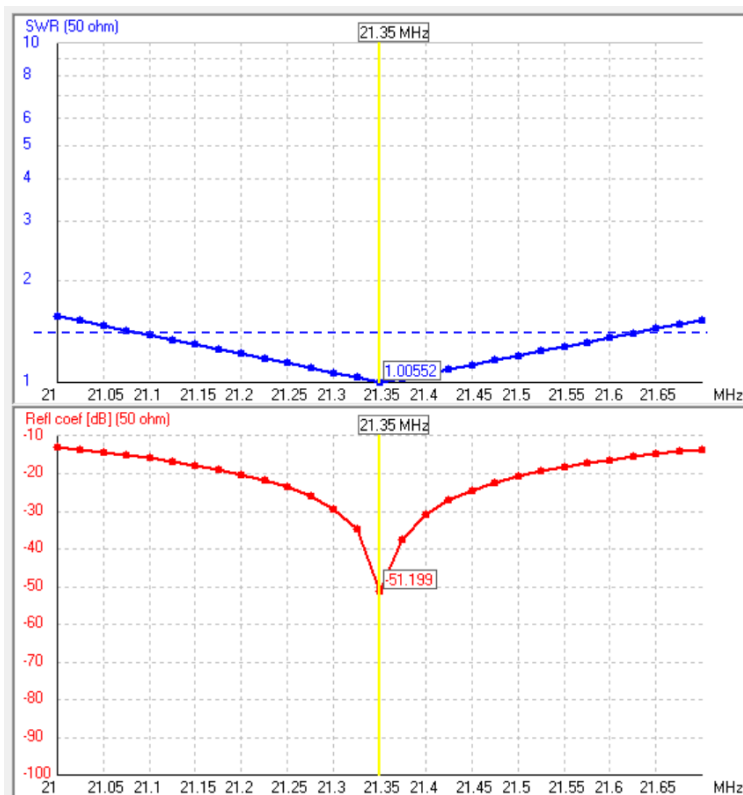
3D radiation modeling as seen from both the top and side views.



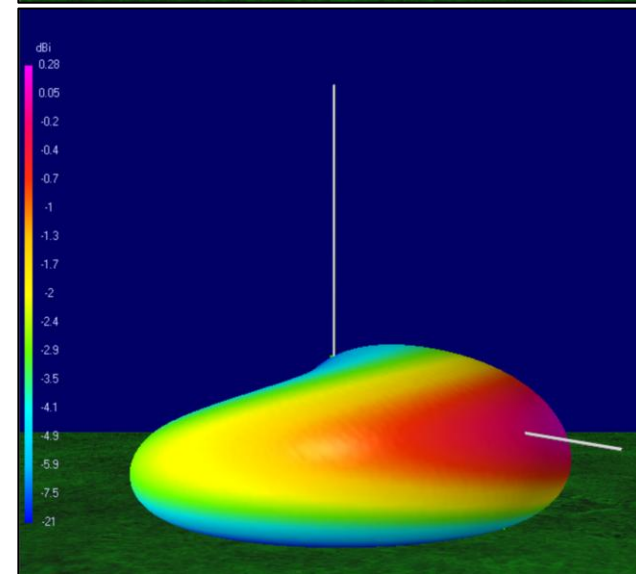
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.02:1** at **18.140 MHz** with a **reflection coefficient** of **-41.5 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 25°** with **+0.14 dBi gain** and **3.48 dB FtB** within a **-3dB beamwidth** of **48° (-16°, +32°) = 9 to 57°**.

4NEC2 Model Graphics for the **PERformer**: 15M (21.350 MHz)



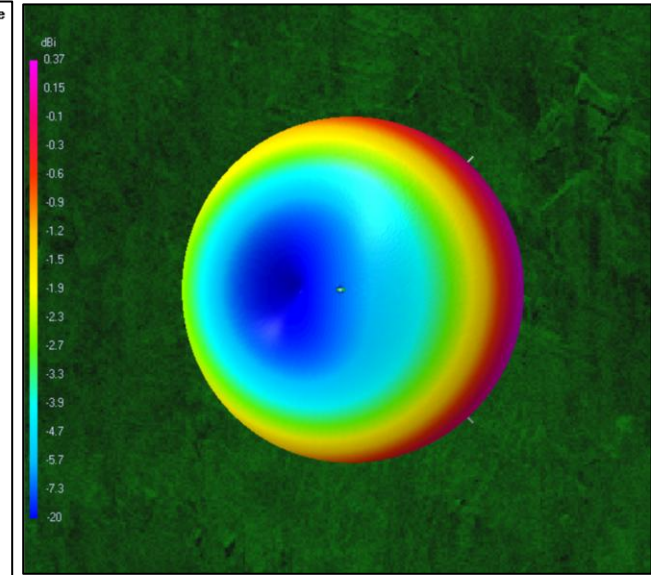
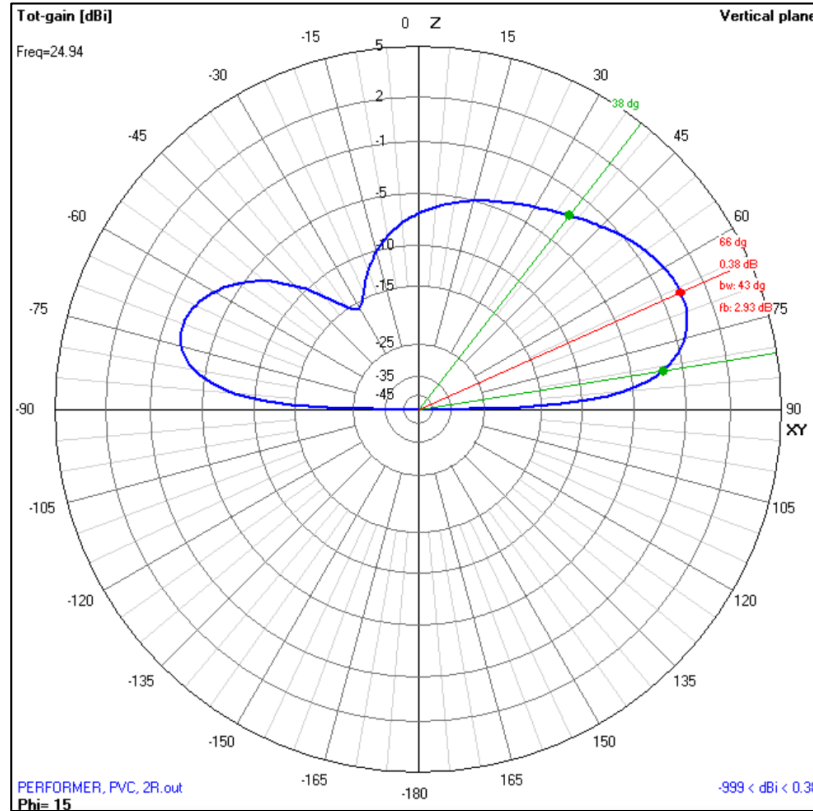
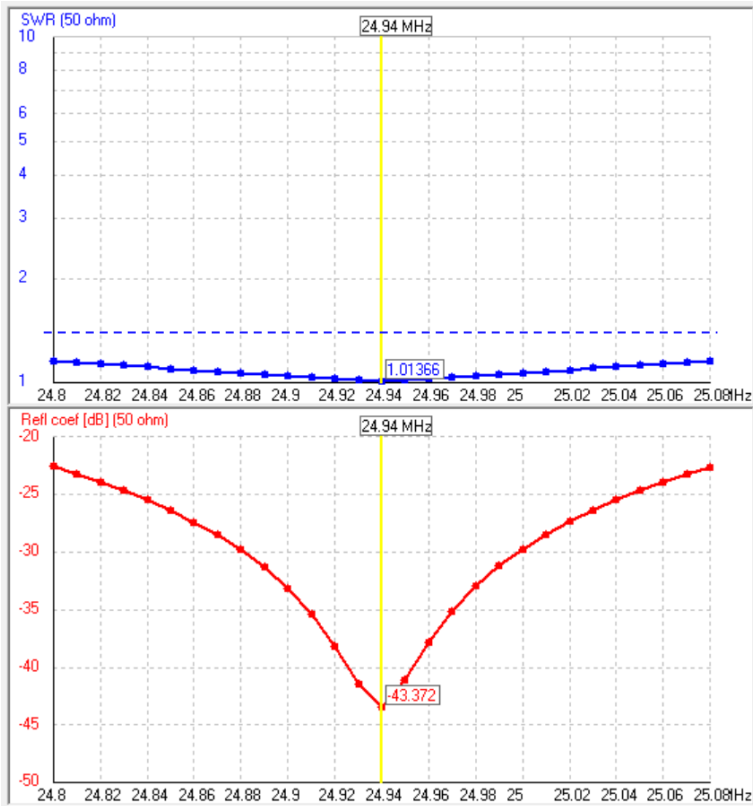
3D radiation modeling as seen from both the top and side views.



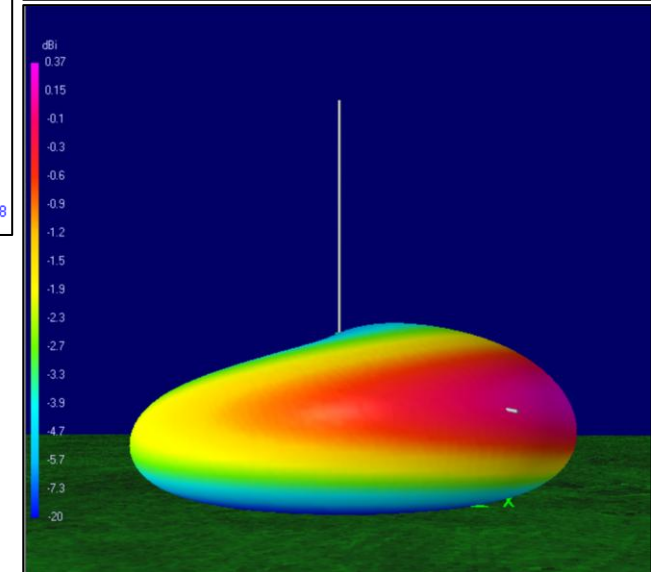
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.01:1** at **21.350 MHz** with a **reflection coefficient** of **-51.2 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 24°** with **+0.31 dBi gain** and **3.37 dB FtB** within a **-3dB beamwidth** of **46°** ($-15^\circ, +31^\circ$) = **9° to 55°**.

4NEC2 Model Graphics for the **PERformer**: 12M (24.940 MHz)



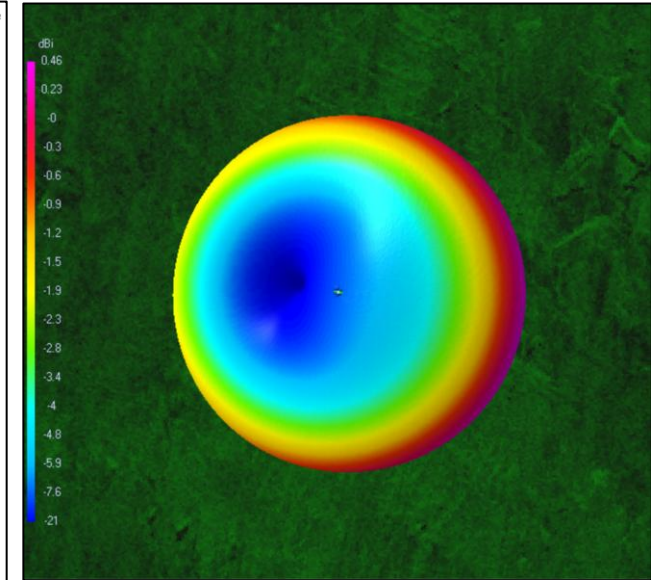
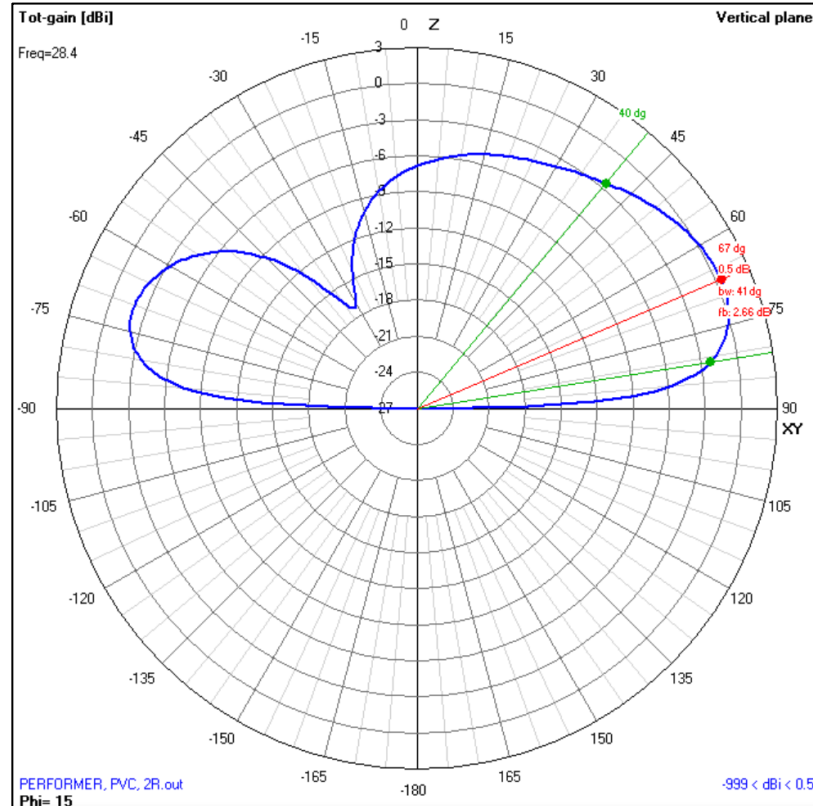
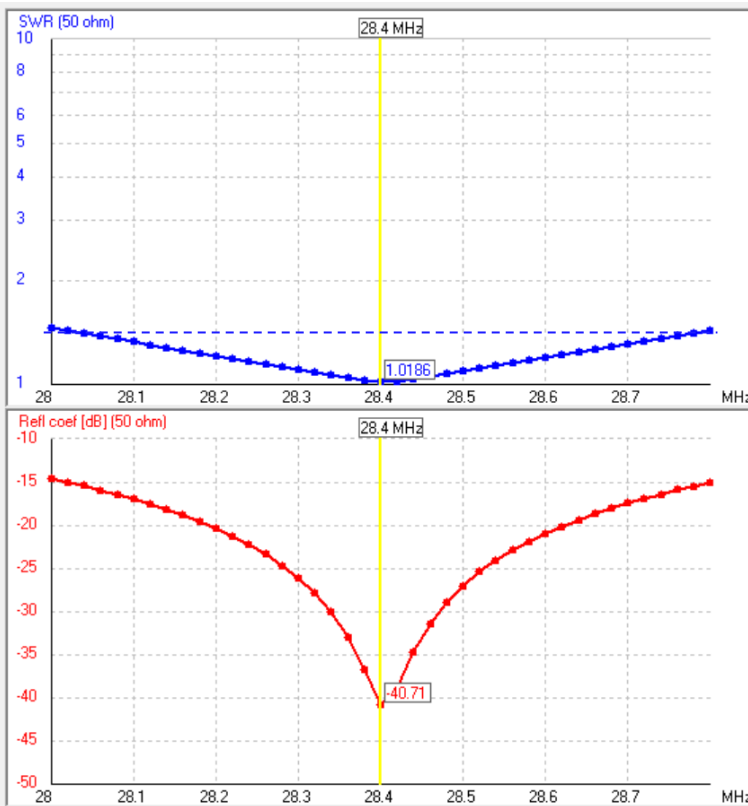
3D radiation modeling as seen from both the top and side views.



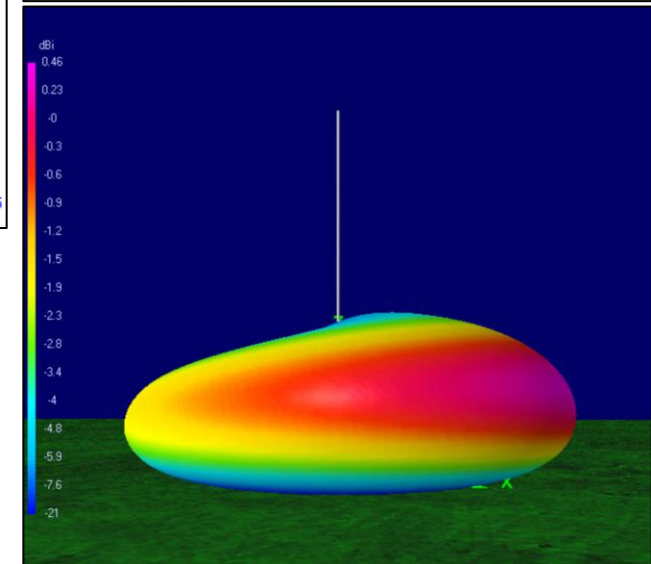
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.01:1** at **24.940 MHz** with a **reflection coefficient** of **-43.4 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 24°** with **+0.38 dBi gain** and **2.93 dB FtB** within a **-3dB beamwidth** of **43°** ($-15^\circ, +28^\circ$) = **9 to 52°**.

4NEC2 Model Graphics for the **PERformer**: 10M (28.500 MHz)



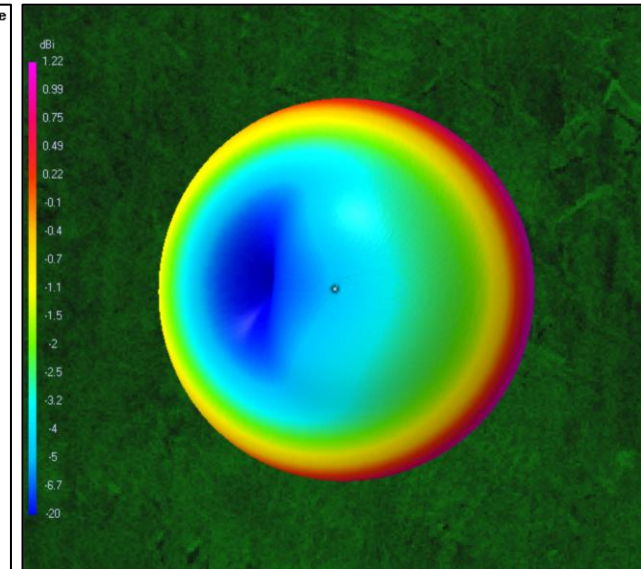
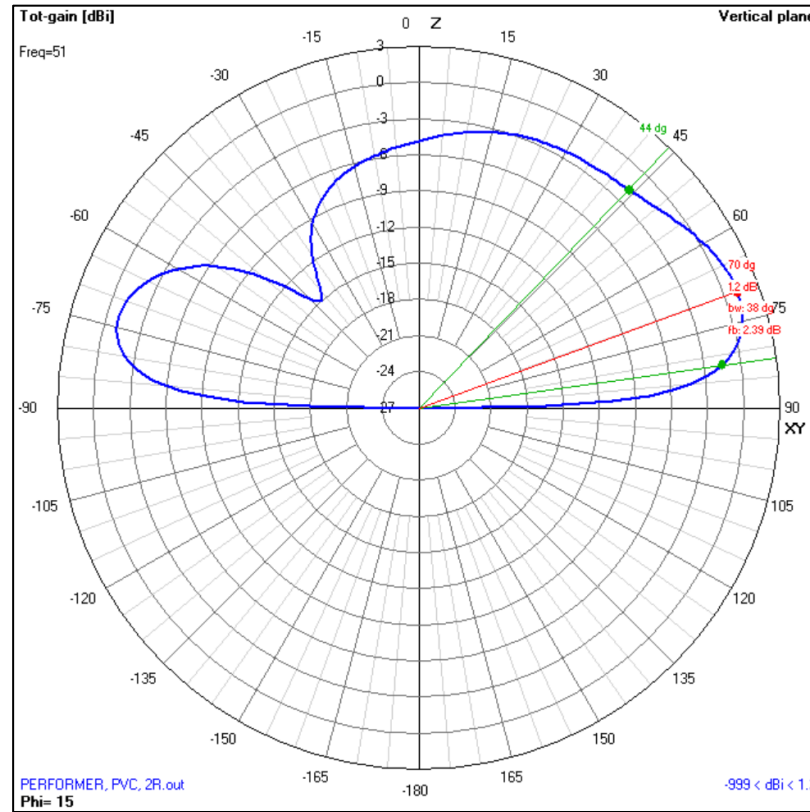
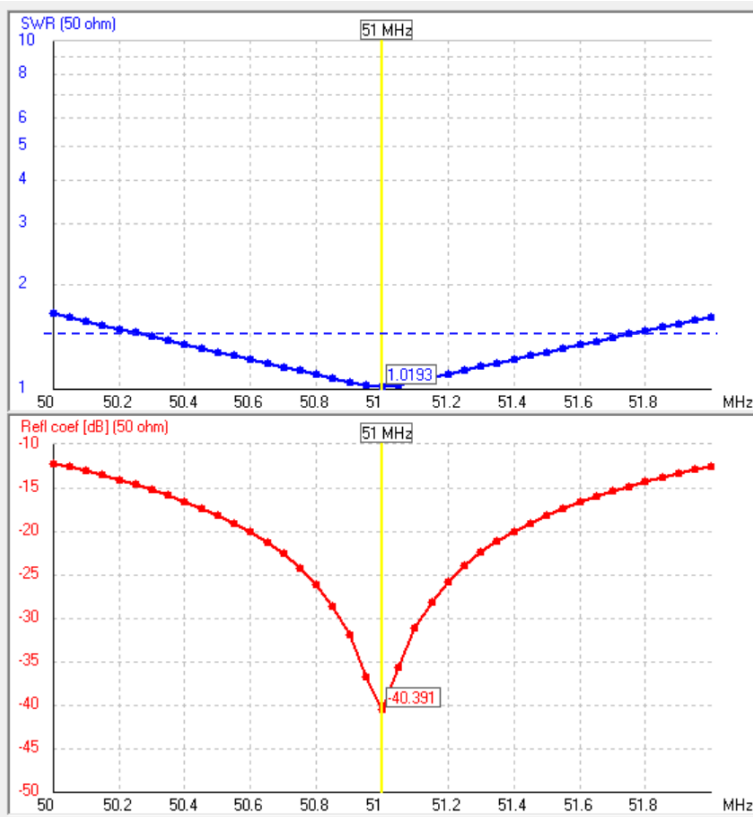
3D radiation modeling as seen from both the top and side views.



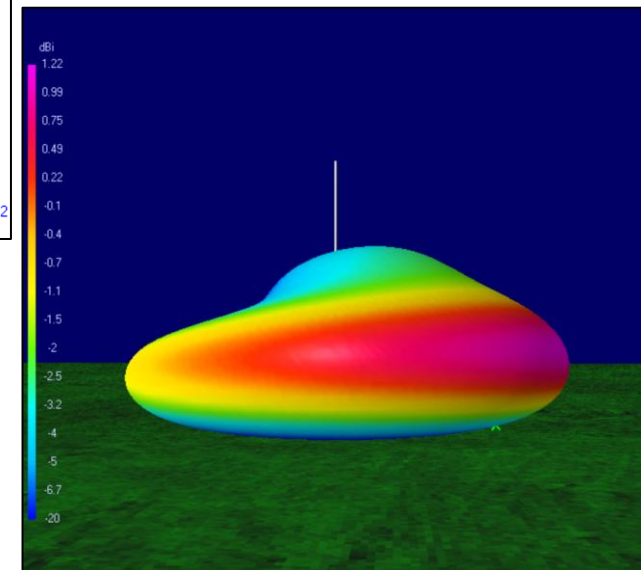
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.02:1** at **28.500 MHz** with a **reflection coefficient** of **-40.7 dB**. The $\pm 1.50:1$ SWR bandwidth is **800 kHz**.
- It also calculated **maximum radiation** at **angle 23°** with **+0.50 dBi gain** and **2.75 dB FtB** within a **-3dB beamwidth** of **41°** ($-14^\circ, +27^\circ$) = **9° to 50°**.

4NEC2 Model Graphics for the **PERformer**: 6M (51.000 MHz)



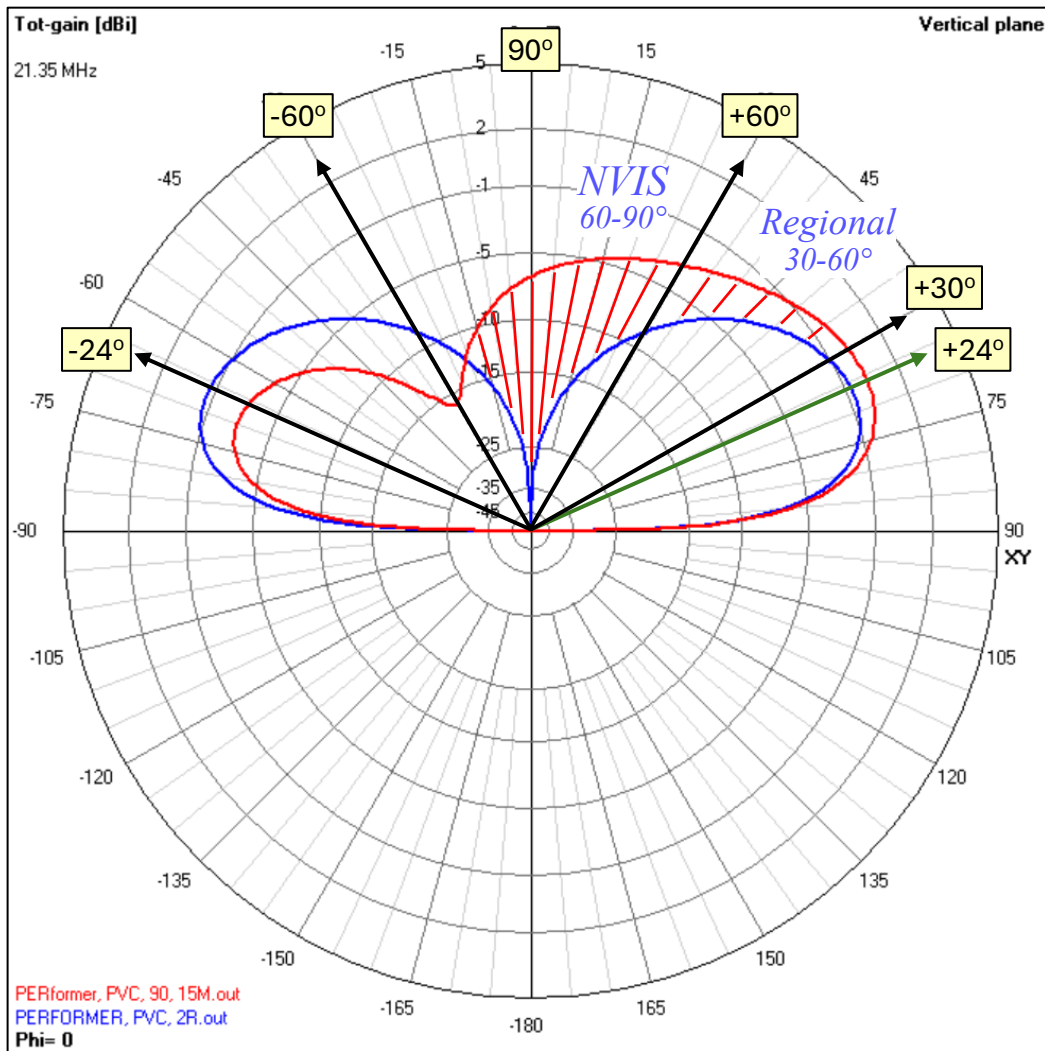
3D radiation modeling as seen from both the top and side views.



Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.02:1** at **51.000 MHz** with a **reflection coefficient** of **-40.4 dB**. The $\pm 1.50:1$ SWR bandwidth is **1400 kHz**.
- It also calculated **maximum radiation** at **angle 20°** with **+1.20 dBi gain** and **2.38 dB FtB** within a **-3dB beamwidth** of **38° (-12°, +26°) = 9 to 46°**.

PERformer Radials @ 90° versus 180°: 15M (21.350 MHz)

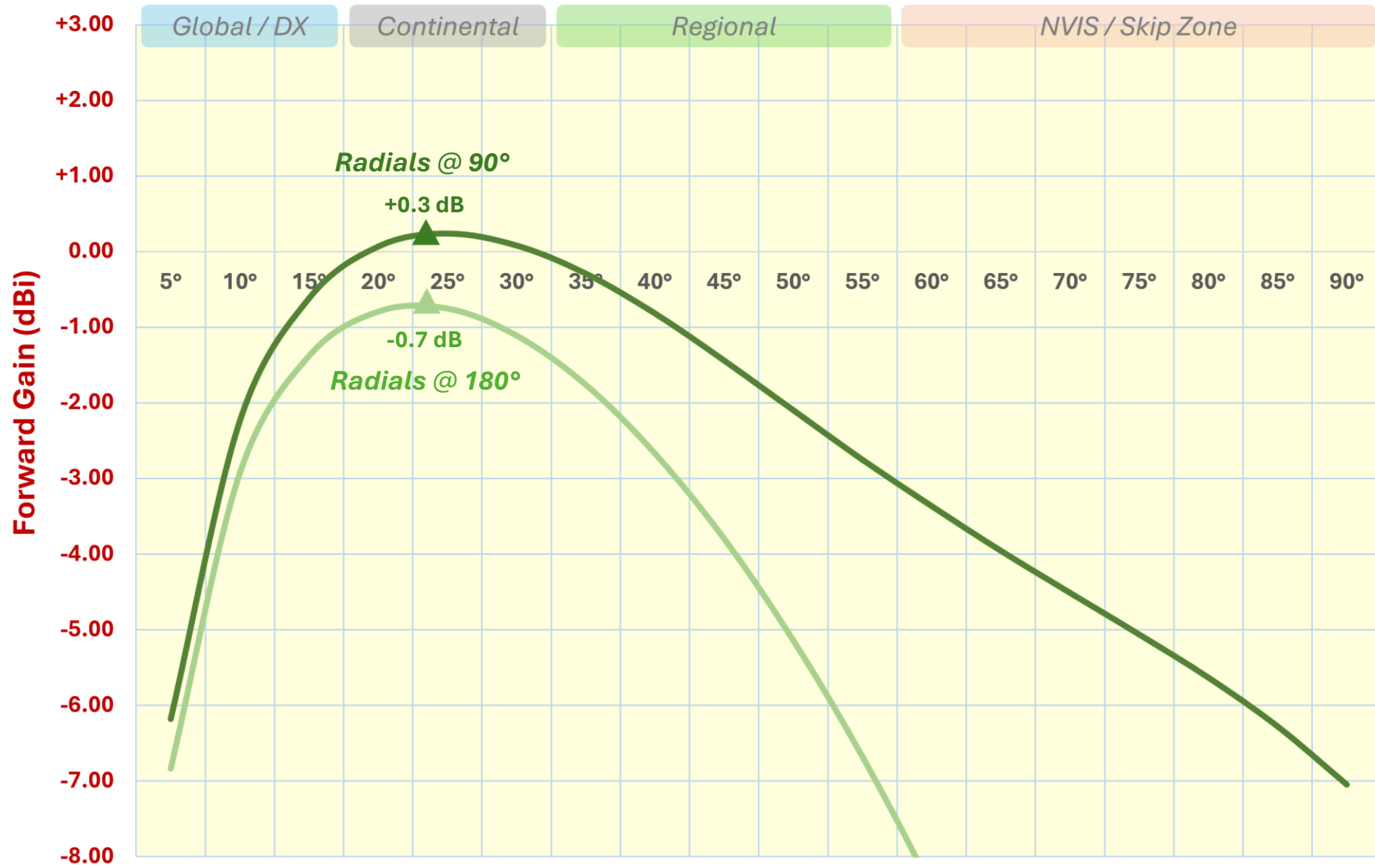


- Comparing the **PERformer** computer model performance with *directional* radials @ 90° versus *omnidirectional* @ 180°

Elevation off Horizon	90° Span (<i>directional</i>)	180° Span (<i>omni</i>)	Delta
+24° <i>Forward</i>	+0.31 dBi ✓	-0.67 dBi	+0.98 dB
+30° <i>Regional</i>	+0.29 dBi ✓	-1.11 dBi	+1.40 dB
+60° <i>NVIS</i>	-3.26 dBi ✓	-8.53 dBi	+5.27 dB
-24° <i>Rear</i>	-3.09 dBi	-0.67 dBi ✓	+2.42 dB

- Directional configuration provides **3.37 dB front-to-back** at 24° elevation
- Radial span does not impact antenna **radiation efficiency** of **90.4%**

PERformer Radiation Sweep on the 15M Band



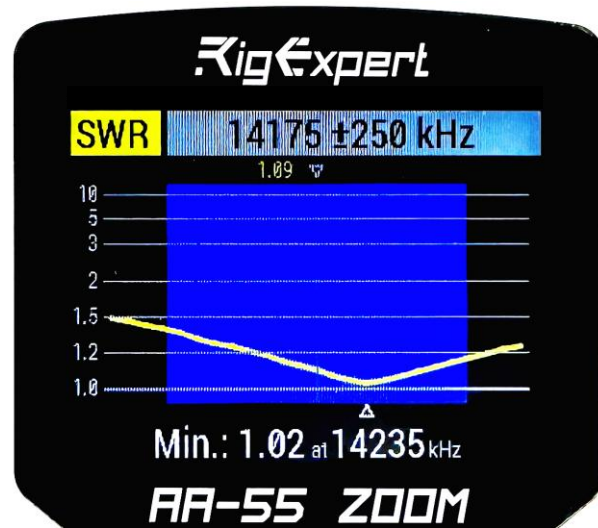
Revision: July 2026

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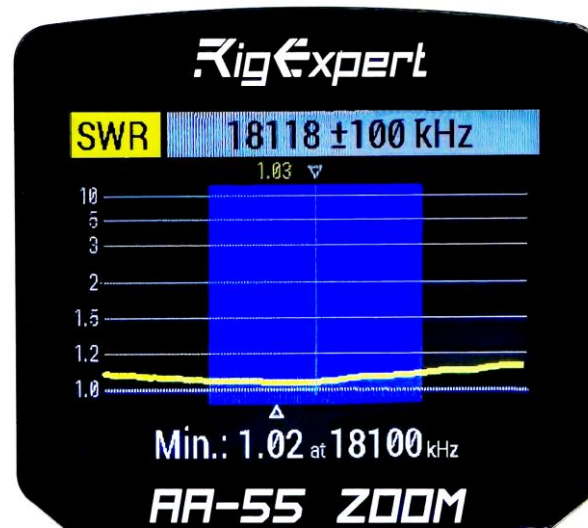
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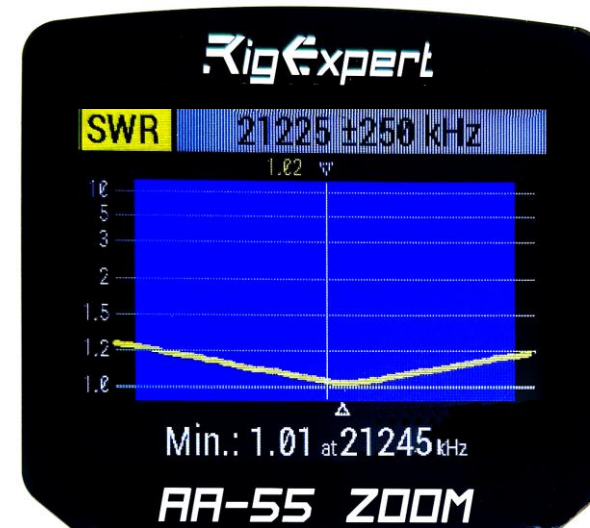
Field SWR Measurements for **PERformer** Quarterwave: 20M-6M



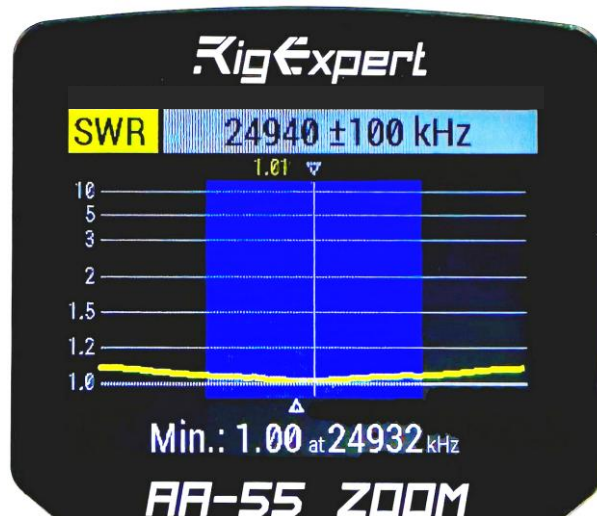
20M Band



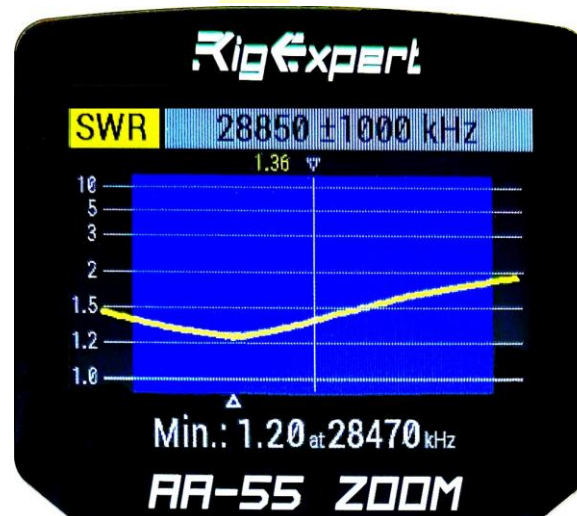
17M Band



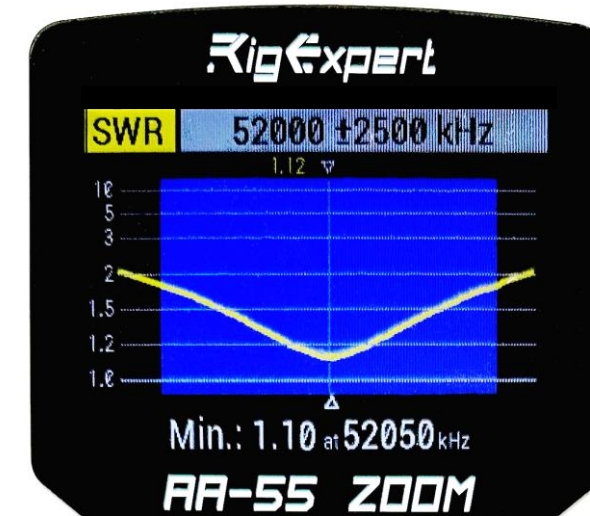
15M Band



12M Band



10M Band



6M Band

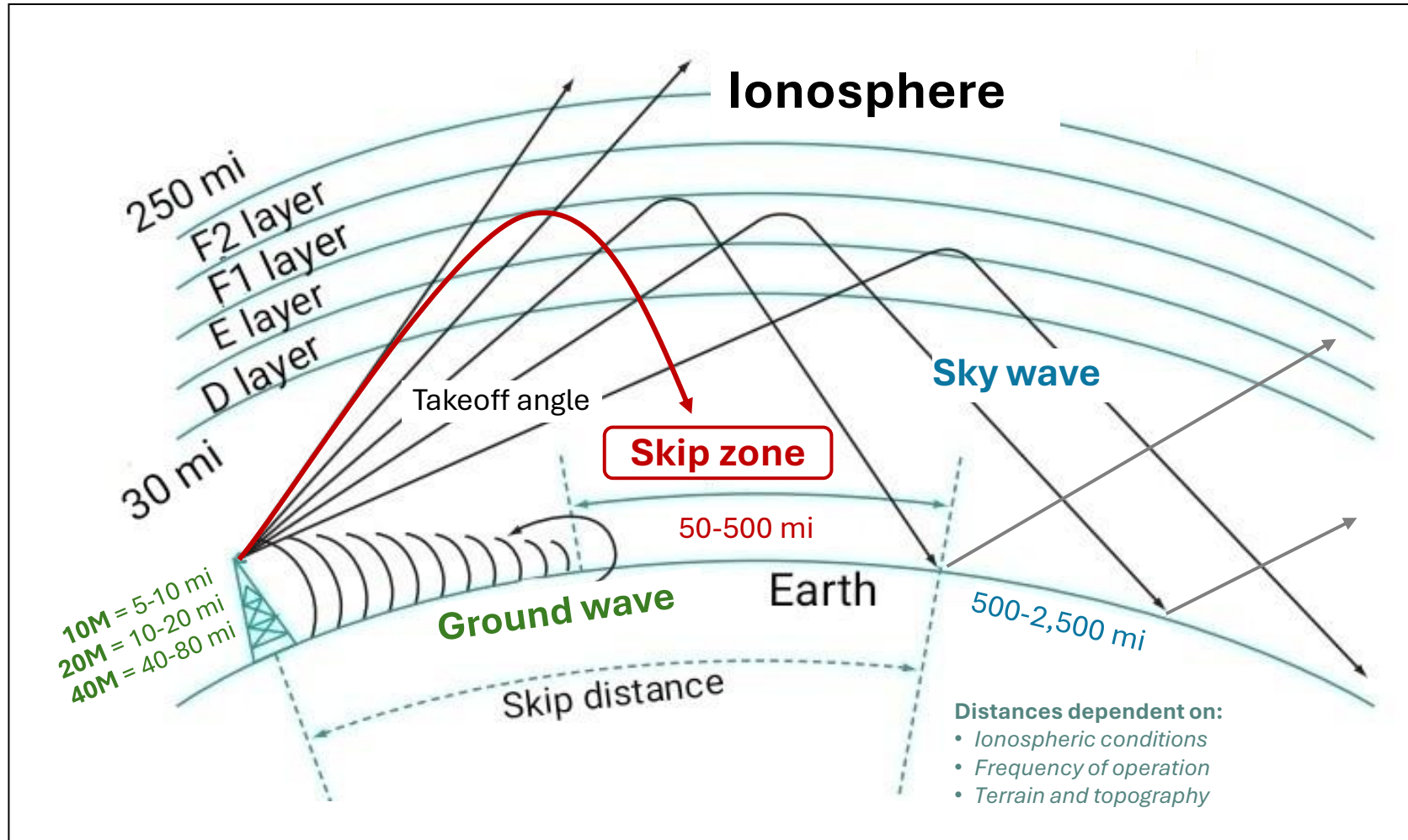
SWR Matching:

- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

PERformer **NVIS** Quarterwave Vertical Antenna System *for high angle radiation*



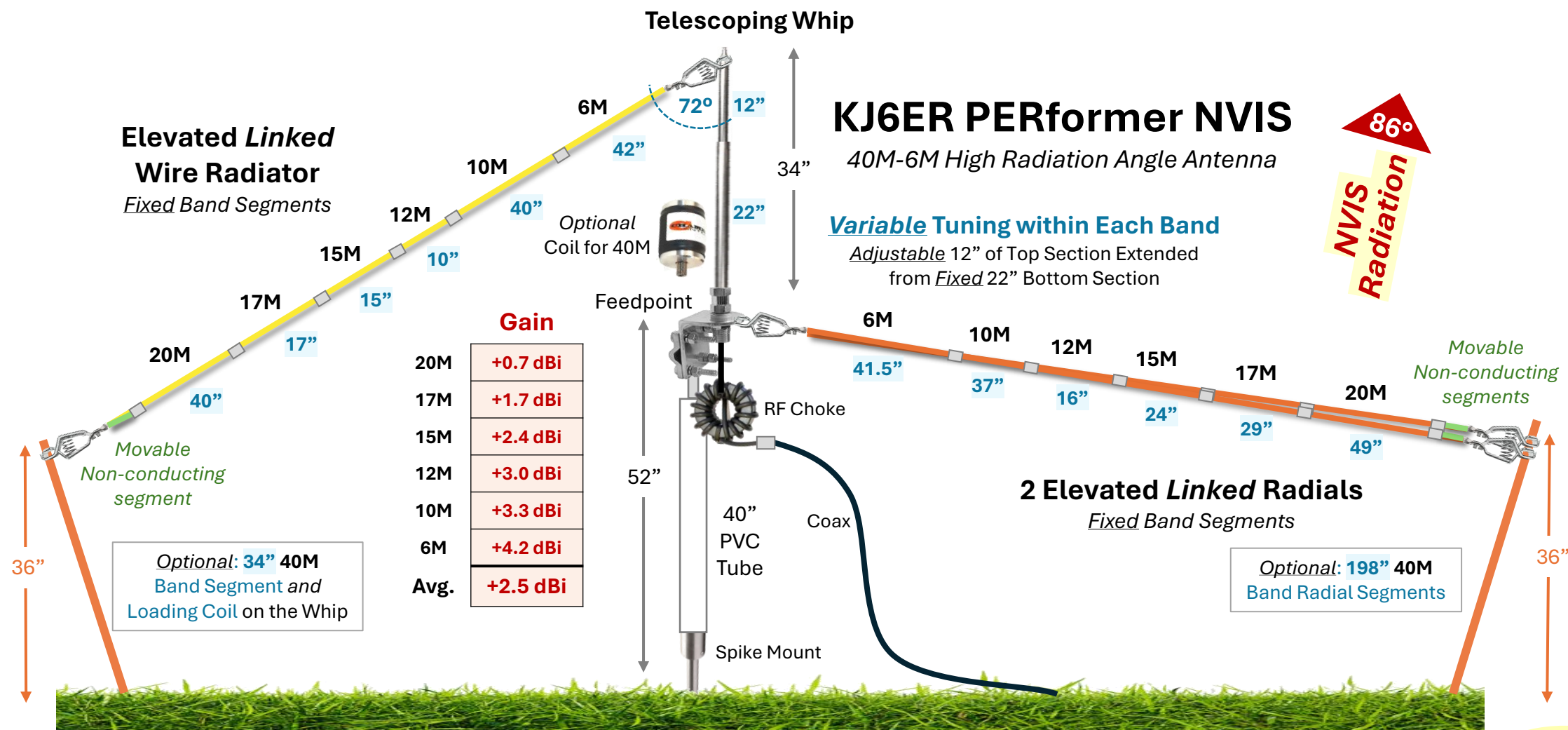
PERformer **NVIS** for *High Angle* Radiation on **40M-6M**



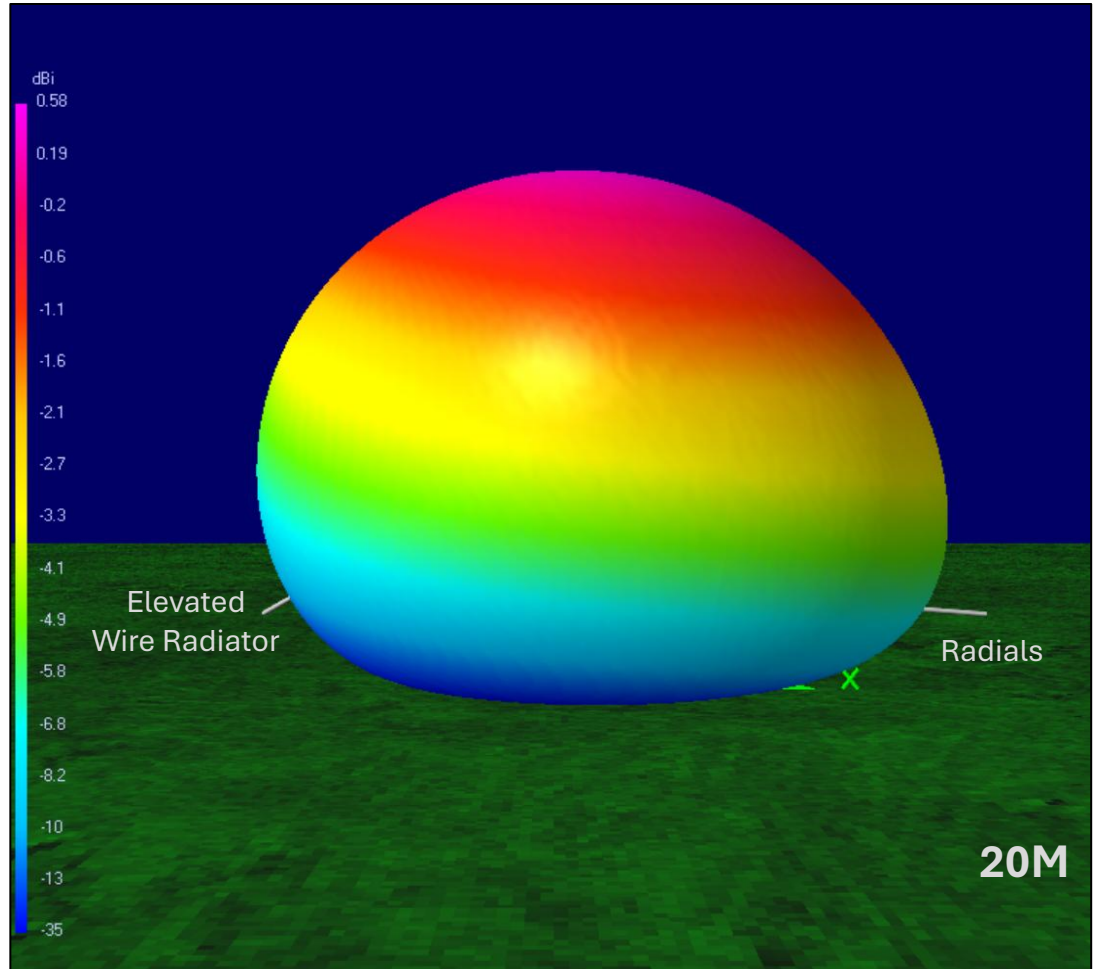
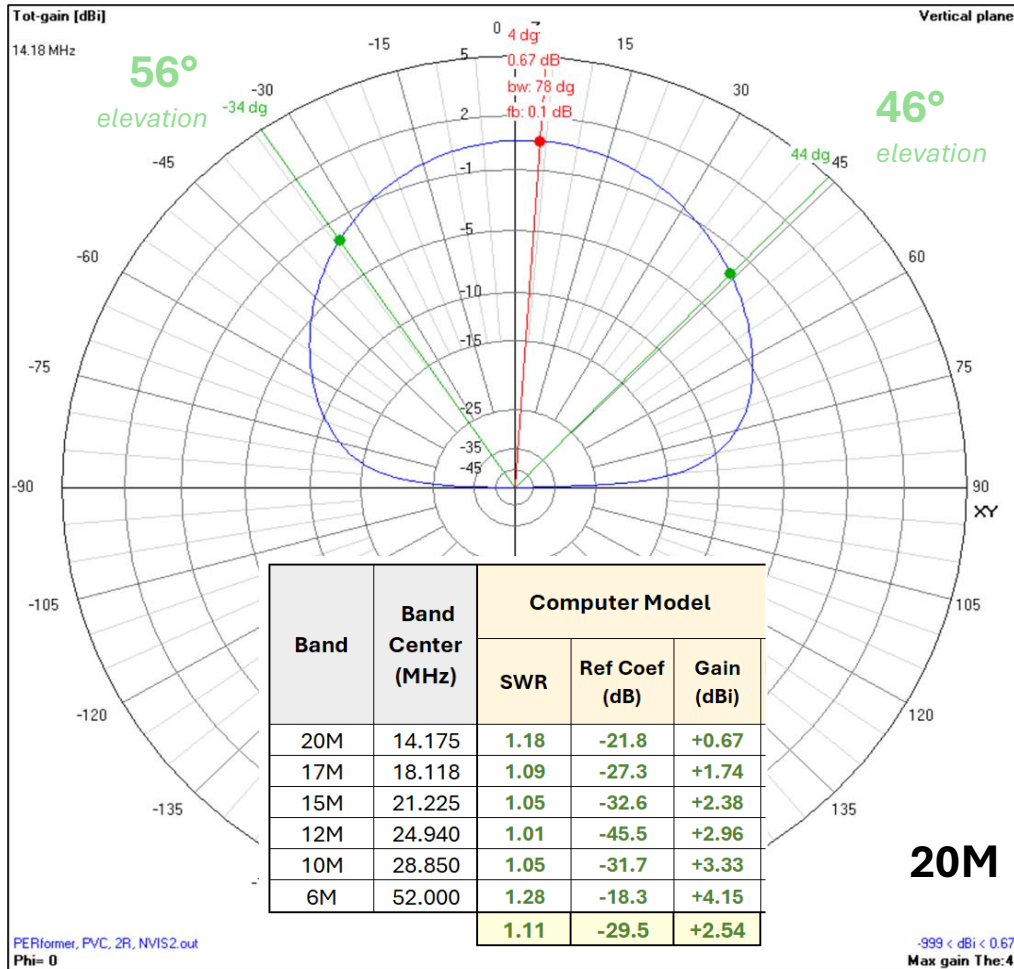
- **Traditional NVIS** at **10 MHz and below** for skip zone coverage beyond ground wave
- **High angle radiation** for **10 MHz-30 MHz** for *amazing skip zone* regional coverage

Near Vertical Incidence Skywave

PERformer NVIS Adds an *Elevated Linked Wire Radiator*

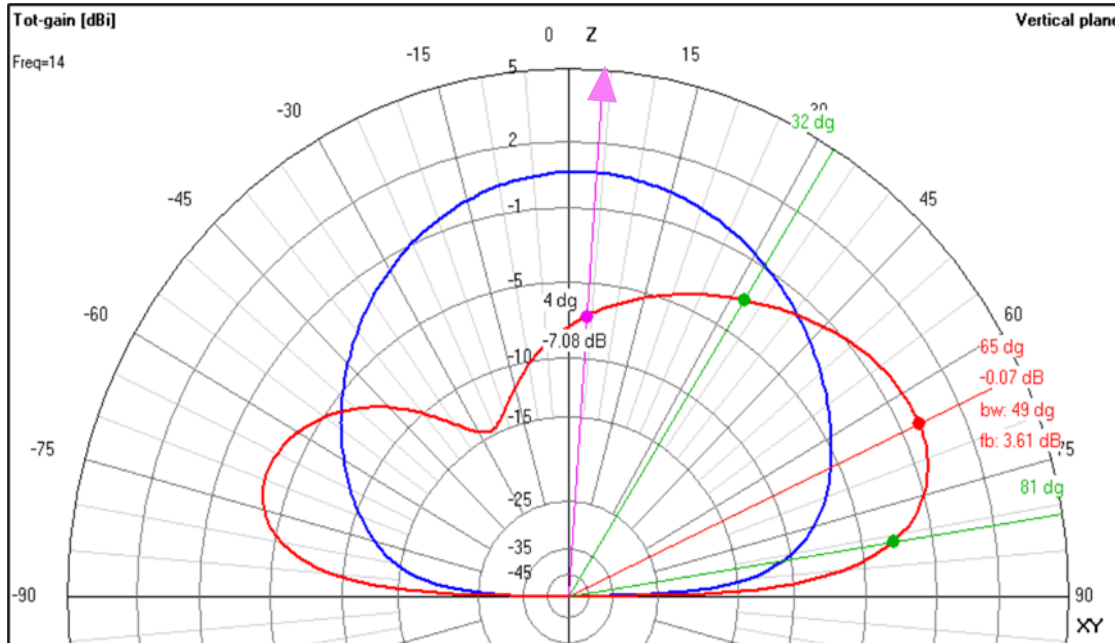


PERformer NVIS Creates a *Big Beautiful Bubble* of Radiation



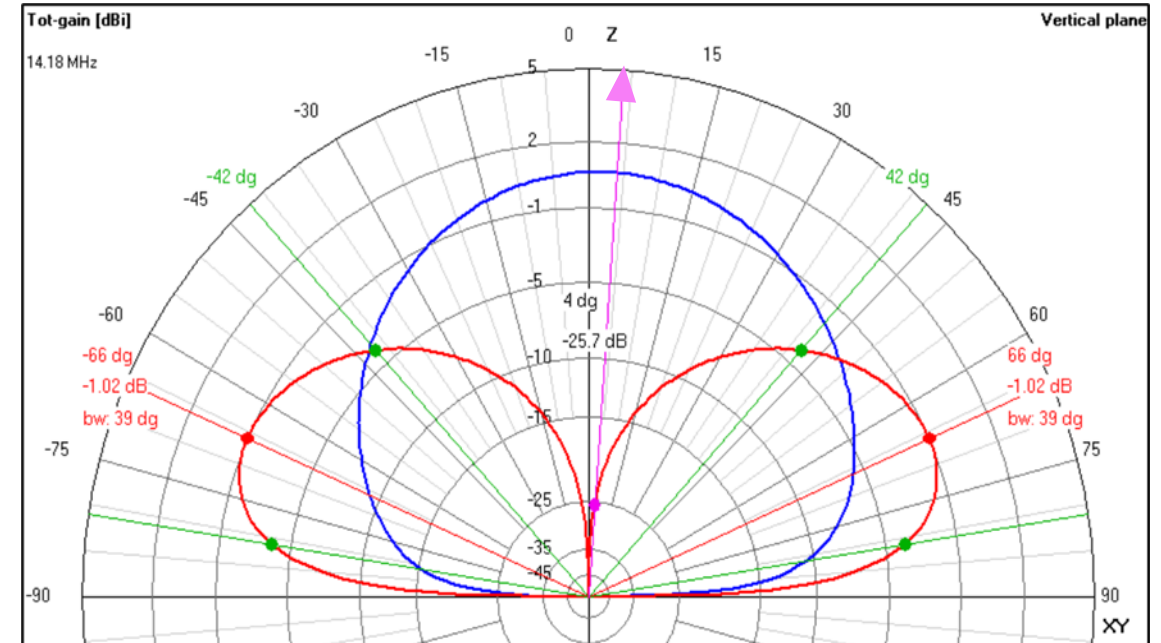
- **+0.67 dBi gain** @ **86°** takeoff angle
- **3 dB** elevation beamwidth = **78°**

PERformer NVIS Compared to *Original* PERformer @ 90°, 180°



Original PERformer (**red**) with Radials @ **90°**

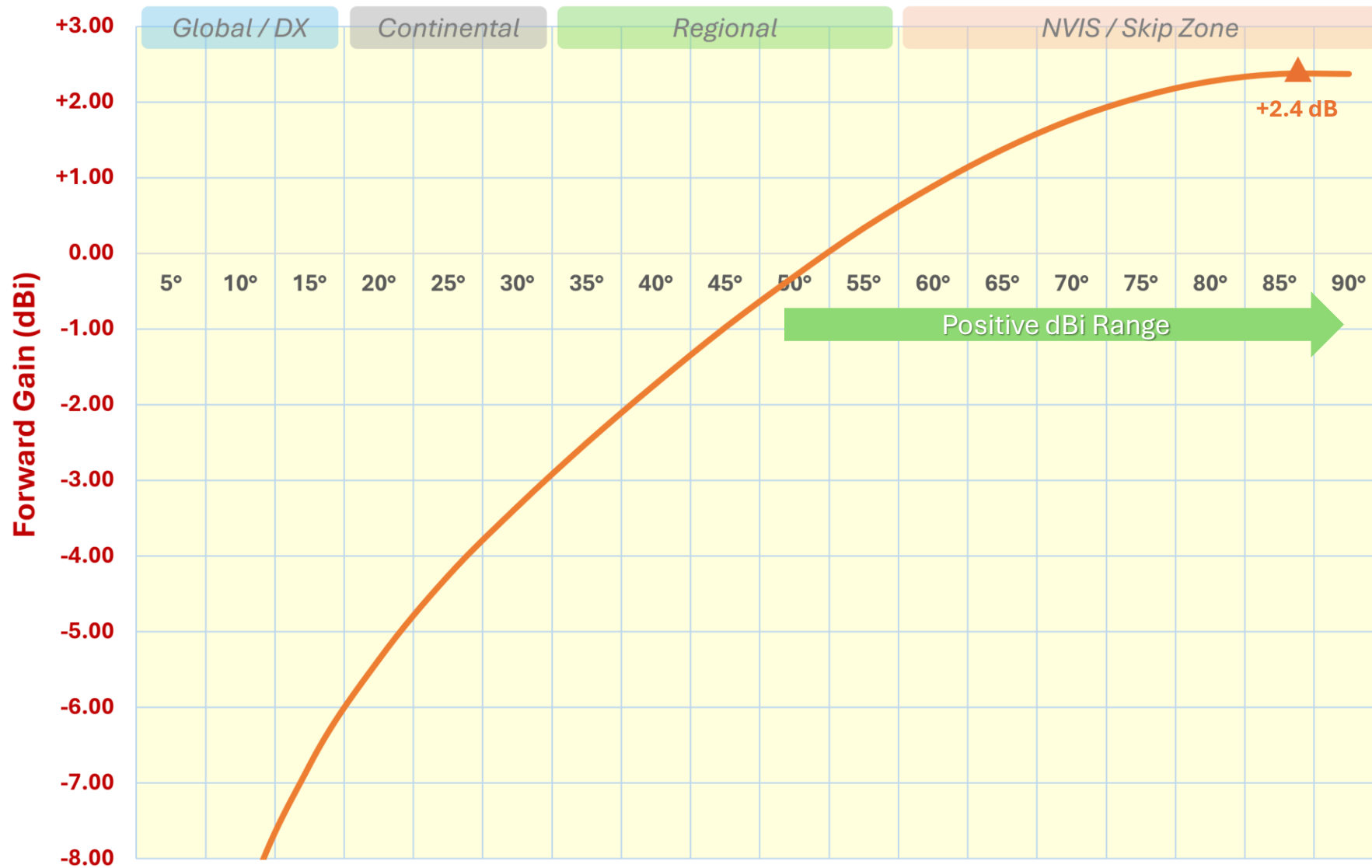
- At **PERformer NVIS** takeoff angle of **86°**, the *original* PERformer has **-7.09 dBi** of gain versus the **NVIS** which has **+0.67 dBi** for **+7.76 dB** more high angle radiation.



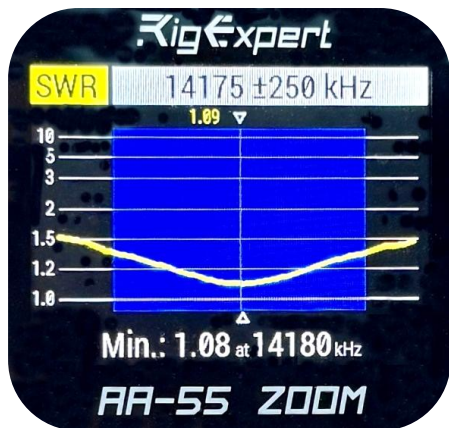
Original PERformer (**red**) with Radials @ **180°**

- At **PERformer NVIS** takeoff angle of **86°**, the *original* PERformer has **-25.7 dBi** of gain versus the **NVIS** which has **+0.67 dBi** for **+26.4 dB** more high angle radiation.

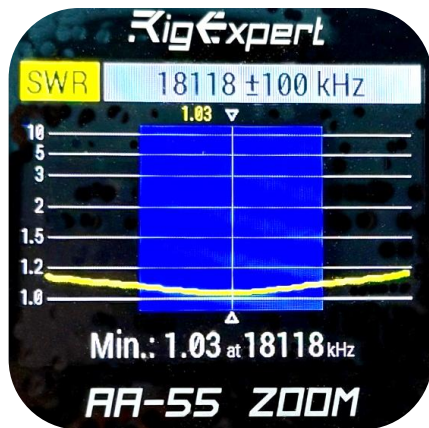
PERformer NVIS Radiation Sweep on the 15M Band



PERformer NVIS is Very Broadbanded with Great Gain @ 86°



20M Band



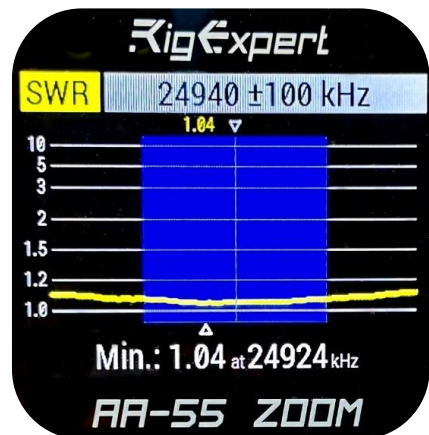
17M Band

Band	Band Center (MHz)
20M	14.175
17M	18.118
15M	21.225
12M	24.940
10M	28.850
6M	52.000

Computer Model Specifications							
SWR	Ref Coef (dB)	Gain (dBi)	Rad Angle (deg)	FtB (dB)	-3 dB BW (deg)	Efficiency	Impedance
1.18	-21.8	+0.67	86	0.10	78	85.5%	58.8 - j 0.63
1.09	-27.3	+1.74	86	0.11	77	86.1%	54.55 - j 0.22
1.05	-32.6	+2.38	86	0.10	76	86.5%	52.4 - j 0.21
1.01	-45.5	+2.96	86	0.10	76	86.7%	50.6 + j 0.67
1.05	-31.7	+3.33	86	0.10	75	86.5%	47.2 - j 2.94
1.28	-18.3	+4.15	86	0.09	131	87.7%	39.3 + j 1.52
1.11	-29.5	+2.54		0.10	86	86.5%	Z = R + j X



15M Band



12M Band



10M Band



6M Band

SWR Matching:

- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

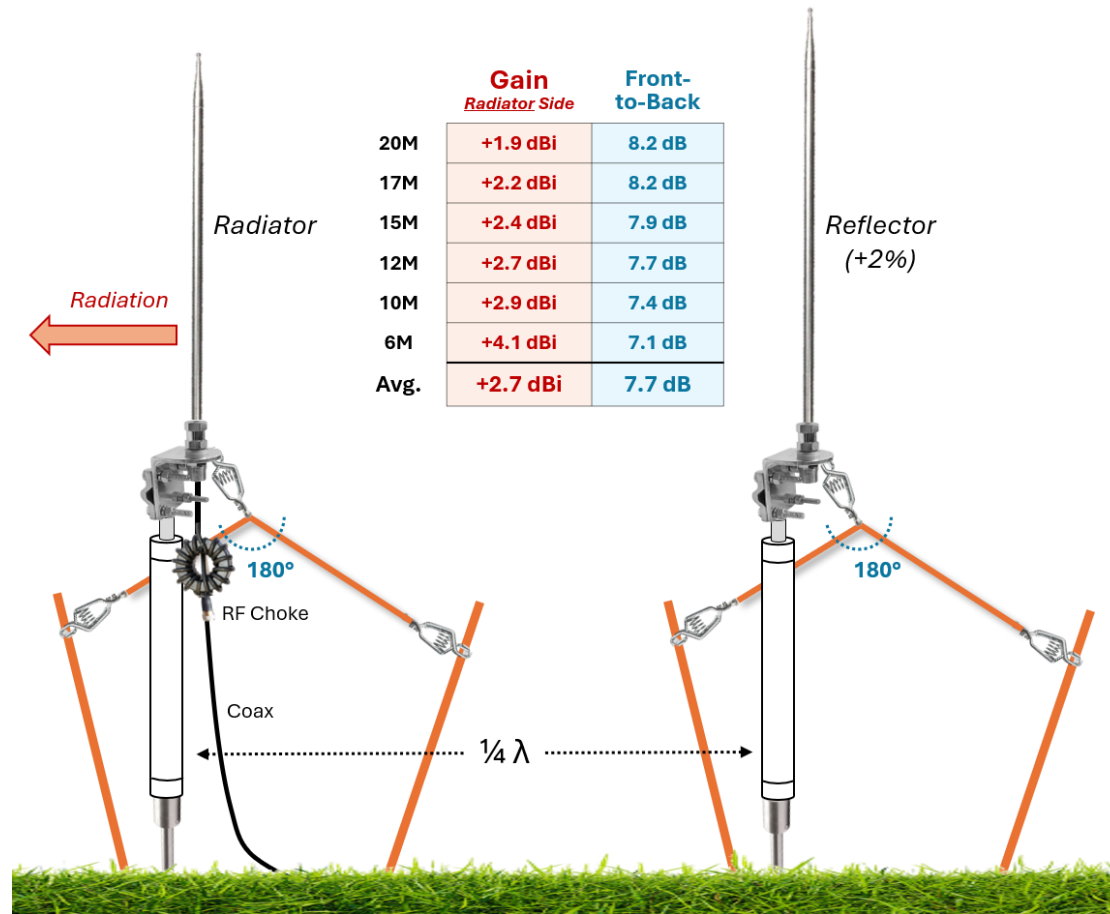
2- Element Parasitic PERformerArray Quarterwave Vertical Antenna System



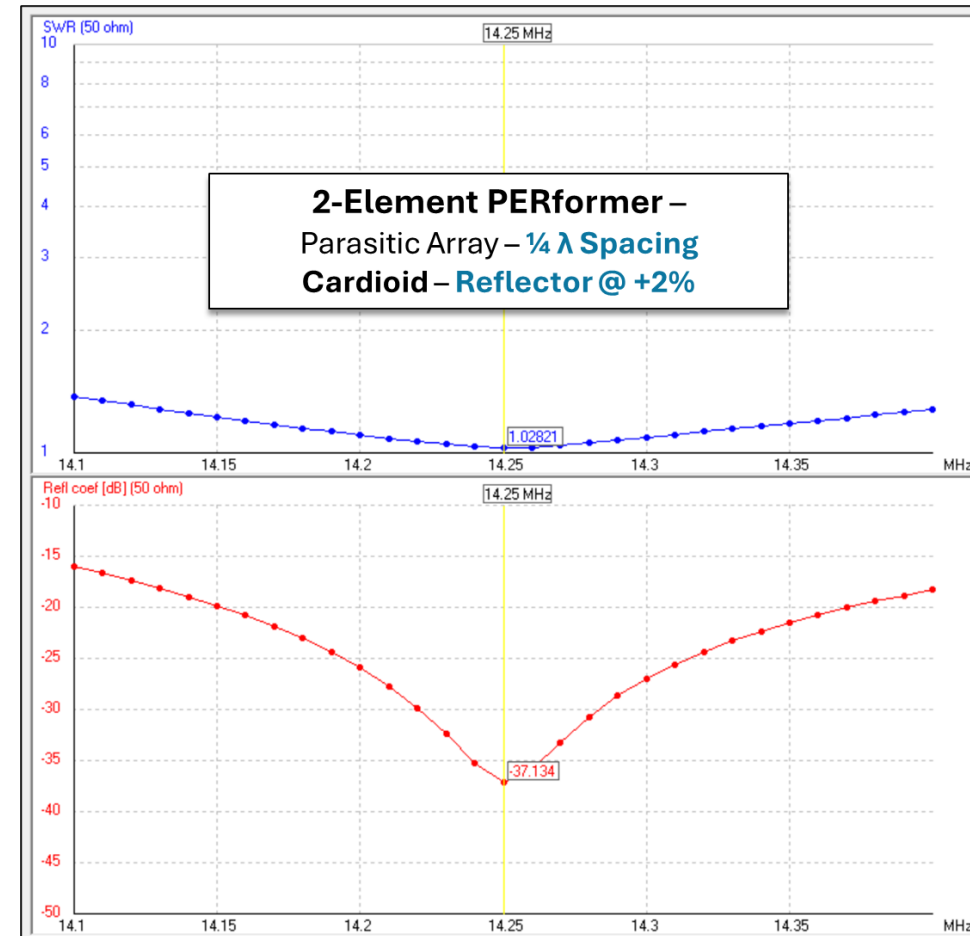
PERformer Parasitic Array with Two PERformer Antennas

Parasitic PERformerArray with Reflector

$$\text{SWR} = 1.03:1 / \text{Ref Coeff} = -37 \text{ dB}$$



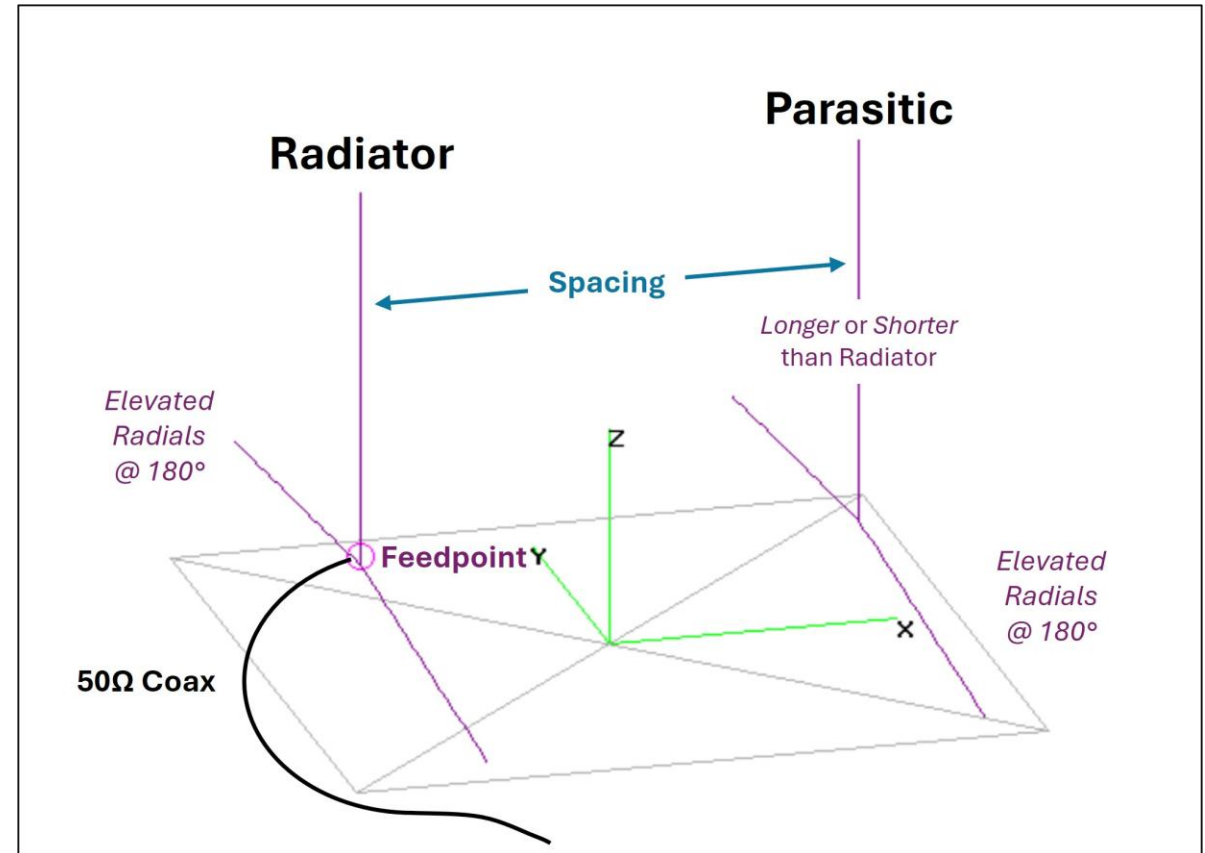
2 PERformers: Radiator and +2% Reflector



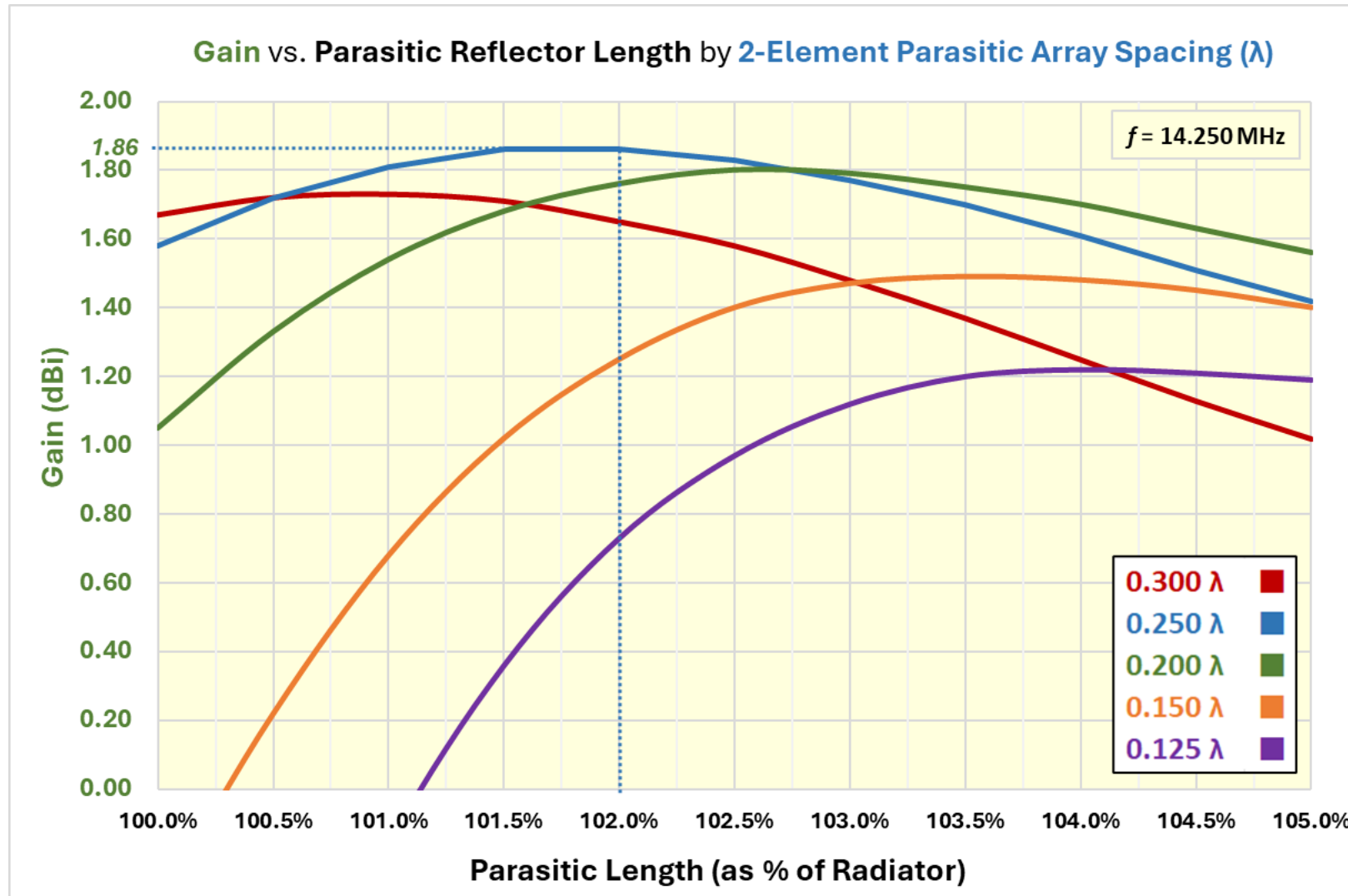
Low SWR, Very Broadbanded

PERformerArray Parasitic Array with 2 Antennas

- A **parasitic antenna array** uses a single driven element (*radiator* connected to the feedline) and another *parasitic* element (not connected to the feedline) as a *director* or *reflector*.
- A **parasitic element**, based upon its **proximity** and **dimensions**, interacts with the *electromagnetic field* of the driven element through mutual coupling, influencing the *radiation pattern* to increase **gain** and **directivity**.

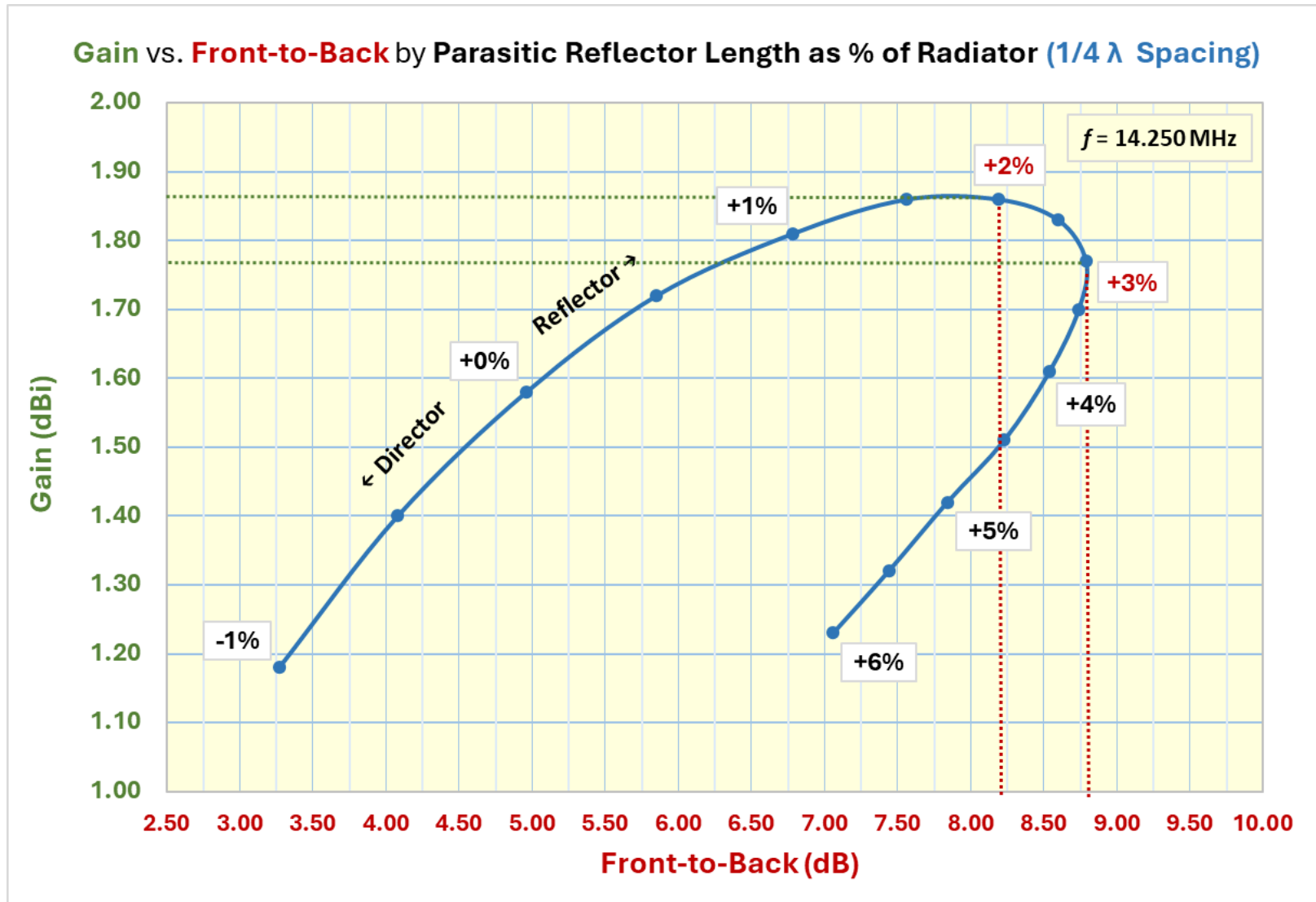


PERformerArray Parasitic Array with 2 Antennas



- Gain versus parasitic length is determined by spacing between the elements.

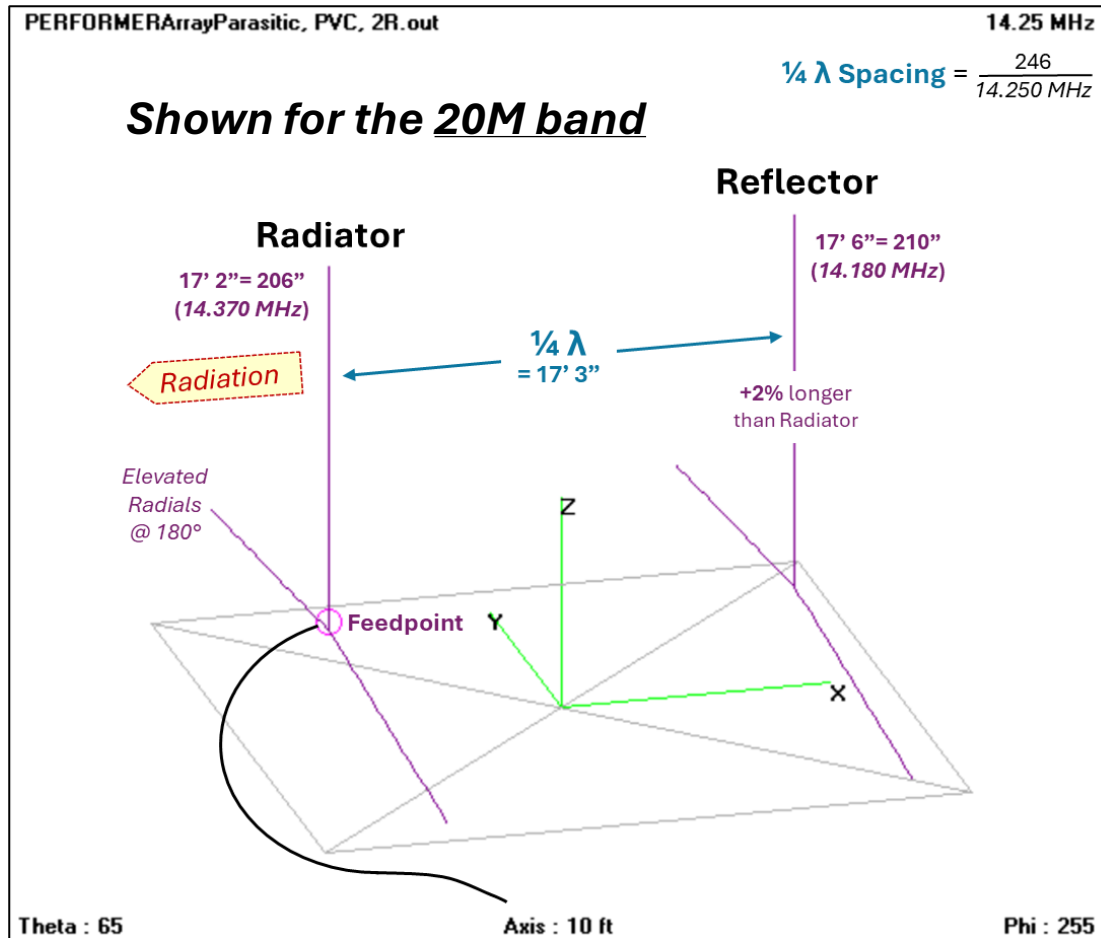
PERformerArray Parasitic Array with 2 Antennas



- **Gain** versus **front-to-back** is always a tradeoff for a parasitic array design.

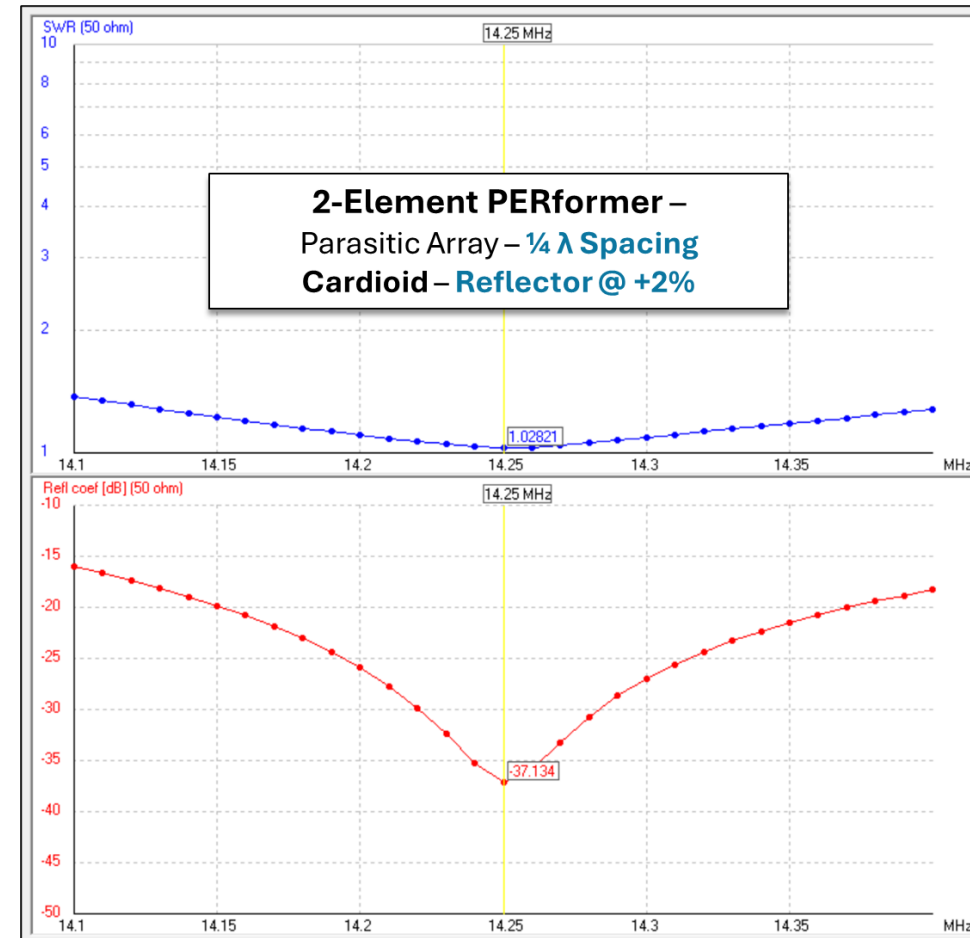
PERformerArray Parasitic Array with 2 Antennas

Parasitic PERformerArray with Reflector



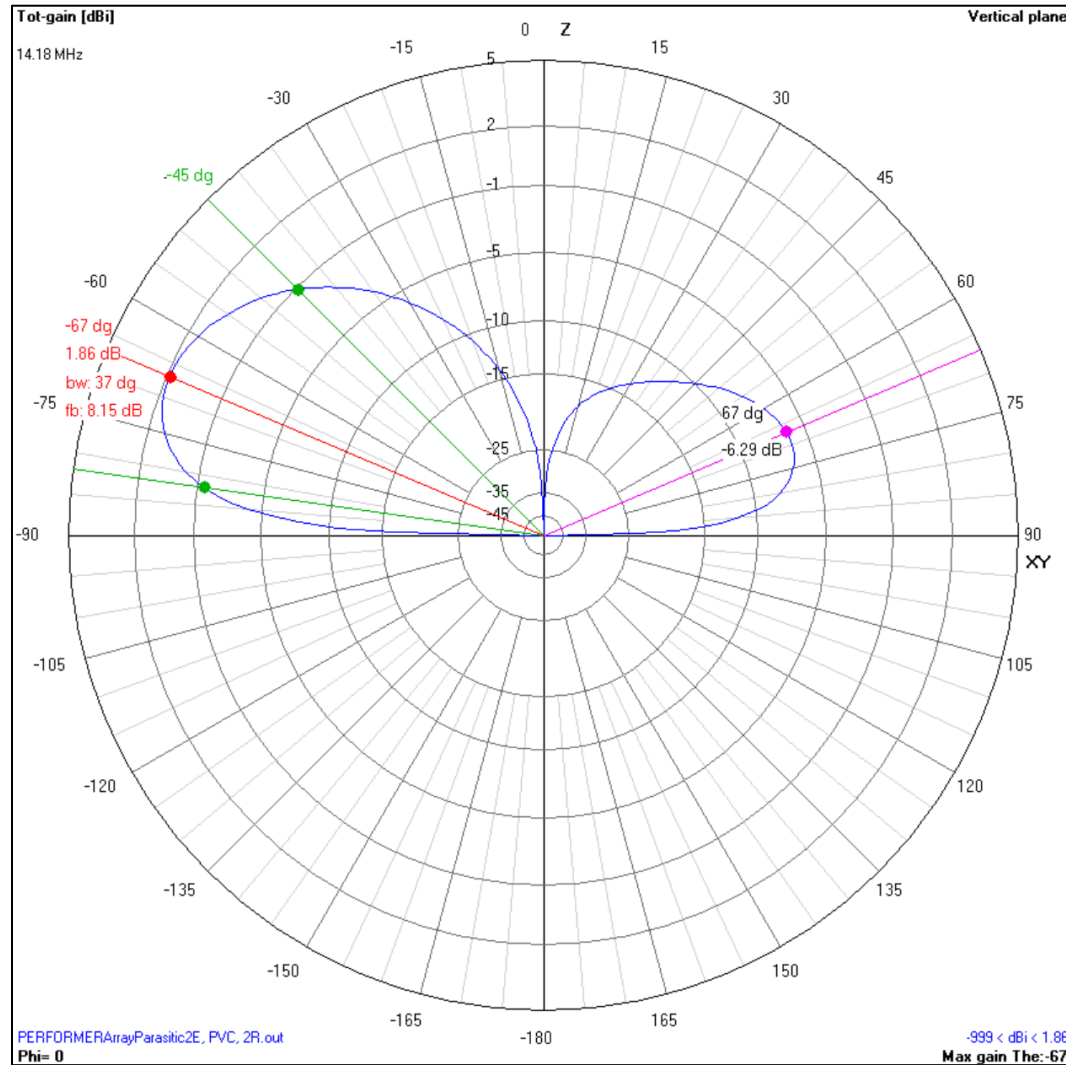
2 PERformers: Radiator and +2% Reflector

$$\text{SWR} = 1.03:1 / \text{Ref Coeff} = -37 \text{ dB}$$



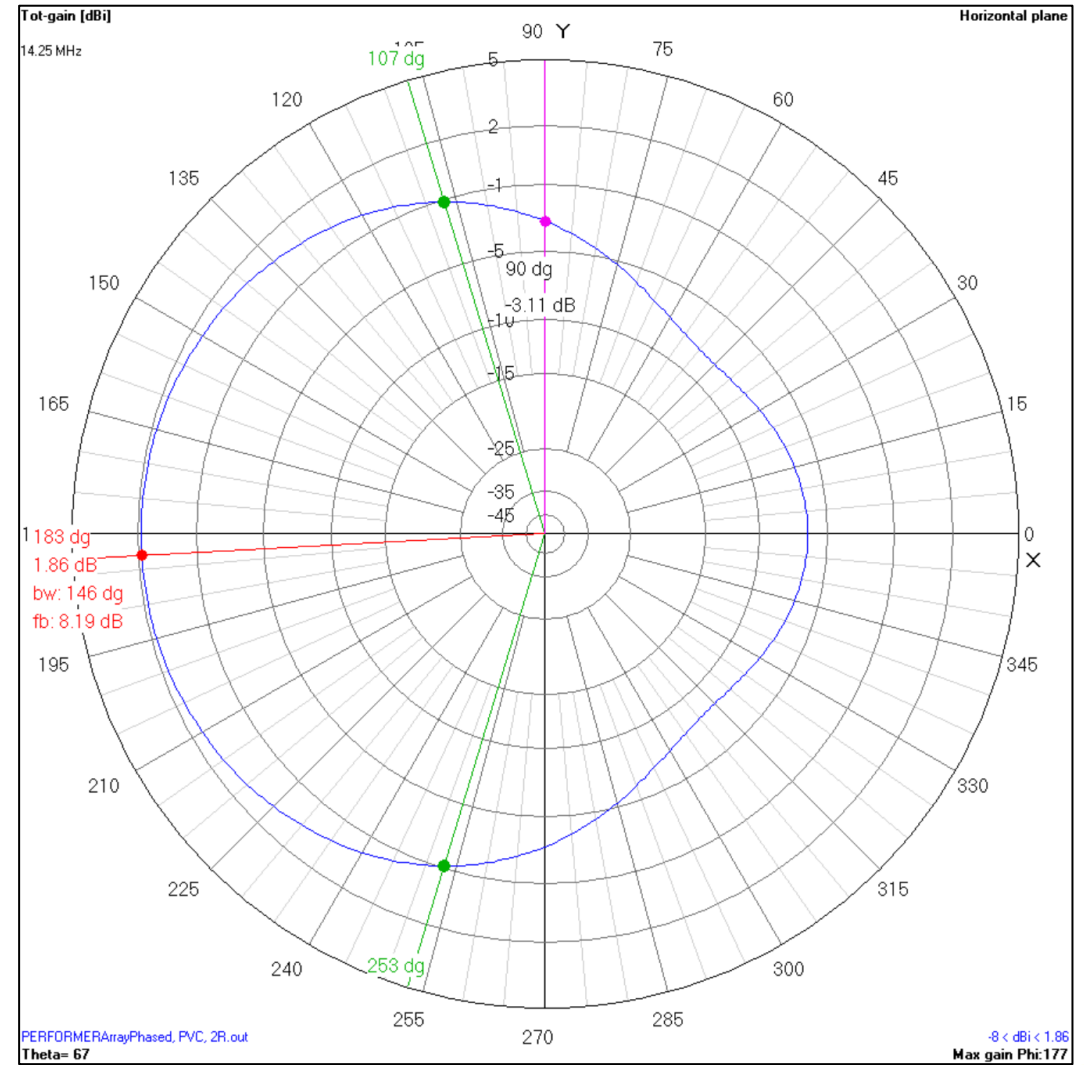
Low SWR, Very Broadbanded

PERformerArray Parasitic Array with 2 Antennas



+1.9 dBi Gain (+2.9 dB over one PERformer), 8.2 dB Front-to-Back

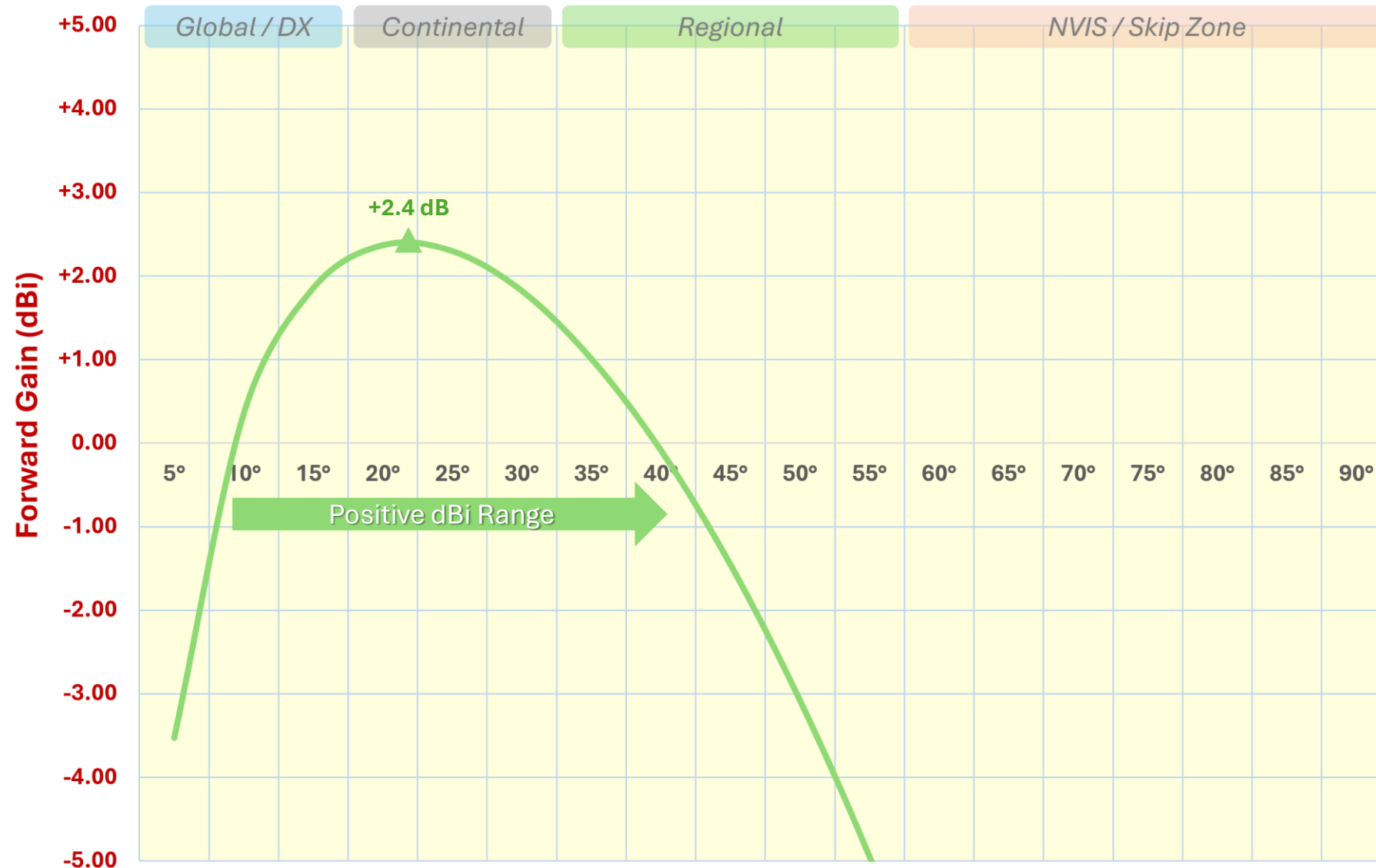
Revision: July 2026



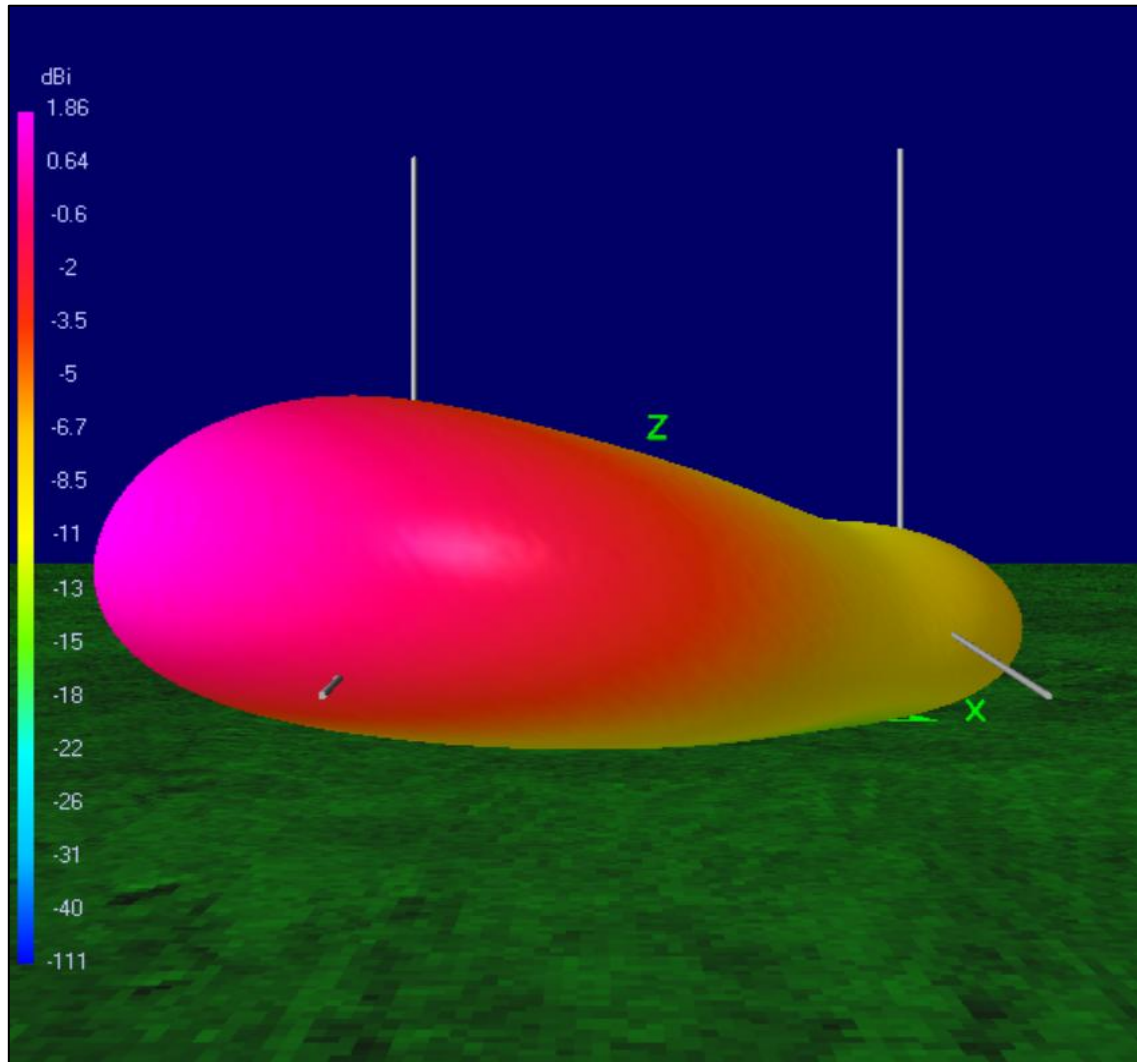
5.0 dB Front-to-Side

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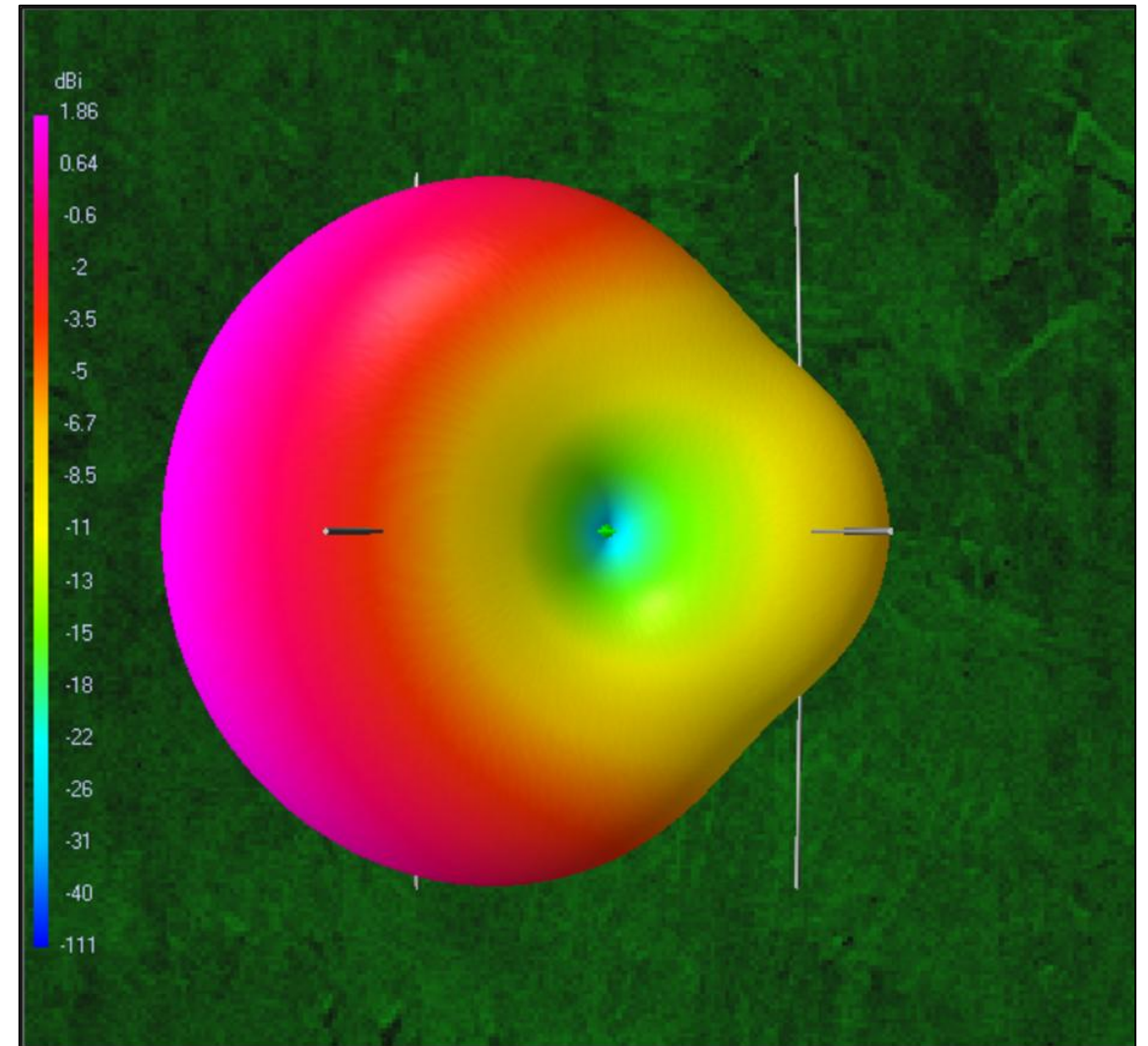
PERformer Parasitic Array Radiation Sweep on the 15M Band



PERformerArray Parasitic Array with 2 Antennas



+1.9 dBi Gain (+2.9 dB over one PERformer), 8.2 dB Front-to-Back



5.0 dB Front-to-Side

PERformerArray Parasitic Array with 2 Antennas

Band	Target Freq (Mhz)	Radiator				$\lambda/4$ Spacing		Reflector							Counterpoise	
		Feet	Inches	Tuned to (MHz)	Relative to Target	Feet	Inches	Feet	Inches	Longer by (in)	Longer by (%)	Freq Delta %	Tuned to (MHz)	Relative to Target	Feet	Inches
20M	14.250	17' 2"	205.56	14.370	+0.84%	17' 3"	207.20	17' 6"	209.67	4.1	+2.0%	-1.3%	14.180	-0.49%	16' 6"	198
17M	18.140	13' 8"	164.30	18.300	+0.88%	13' 7"	162.78	14' 0"	167.59	3.3	+2.0%	-1.3%	18.060	-0.44%	12' 5"	149
15M	21.250	11' 11"	143.29	21.470	+1.04%	11' 6"	137.66	12' 2"	146.16	2.9	+2.0%	-1.4%	21.180	-0.33%	10' 0"	120
12M	24.940	10' 5"	124.69	25.220	+1.12%	9' 10"	118.40	10' 7"	127.18	2.5	+2.0%	-1.3%	24.880	-0.24%	8' 0"	96
10M	28.400	9' 3"	111.11	28.750	+1.23%	8' 8"	103.98	9' 5"	113.33	2.2	+2.0%	-1.4%	28.350	-0.18%	6' 8"	80
6M	51.000	5' 0"	60.07	51.600	+1.18%	4' 10"	57.90	5' 1"	61.27	1.2	+2.0%	-1.3%	50.950	-0.10%	3' 7"	43

Band	Target Freq (Mhz)	Specifications										
		SWR	Ref Coef (dB)	Takeoff (deg)	Gain 2- Elem (dBi)	Gain 1- Elem (dBi)	Relative to 1-Elem (dB)	FtB (dB)	Bw θ (deg)	Bw ϕ (deg)	Efficiency	Impedance
20M	14.250	1.03	-37.0	23	+1.9	-1.0	+2.9	8.2	37	146	85%	48.7 + j 0.39
17M	18.140	1.05	-32.6	22	+2.2	-0.8	+3.0	8.2	35	144	86%	47.9 + j 0.84
15M	21.250	1.05	-32.4	22	+2.4	-0.7	+3.1	7.9	34	142	87%	47.8 + j 0.88
12M	24.940	1.03	-35.8	21	+2.7	-0.5	+3.2	7.7	32	140	88%	48.6 + j 0.79
10M	28.400	1.02	-38.6	20	+2.9	-0.3	+3.2	7.4	31	138	89%	48.9 + j 0.37
6M	51.000	1.15	-22.9	18	+4.1	+0.6	+3.5	7.1	26	136	90%	44.0 + j 3.13
		1.06	-33.2	21	+2.7	-0.4	+3.1	7.7	33	141	87%	Z = R + j X

Once the *parasitic reflector* is **tuned**, the radiator must be **shorted** to the elevated radials.

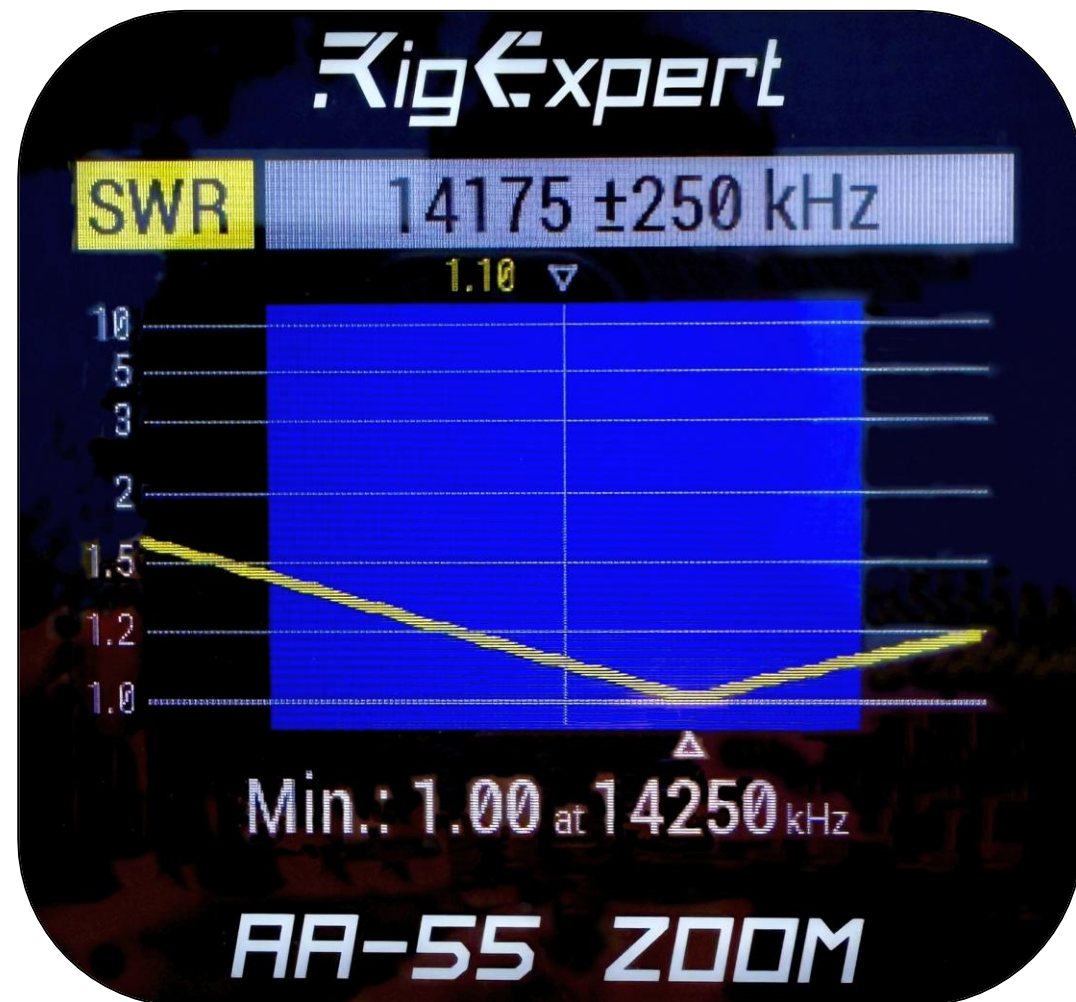
PERformerArray Parasitic Array with 2 Antennas



US-3473 with J-Systems PERformers

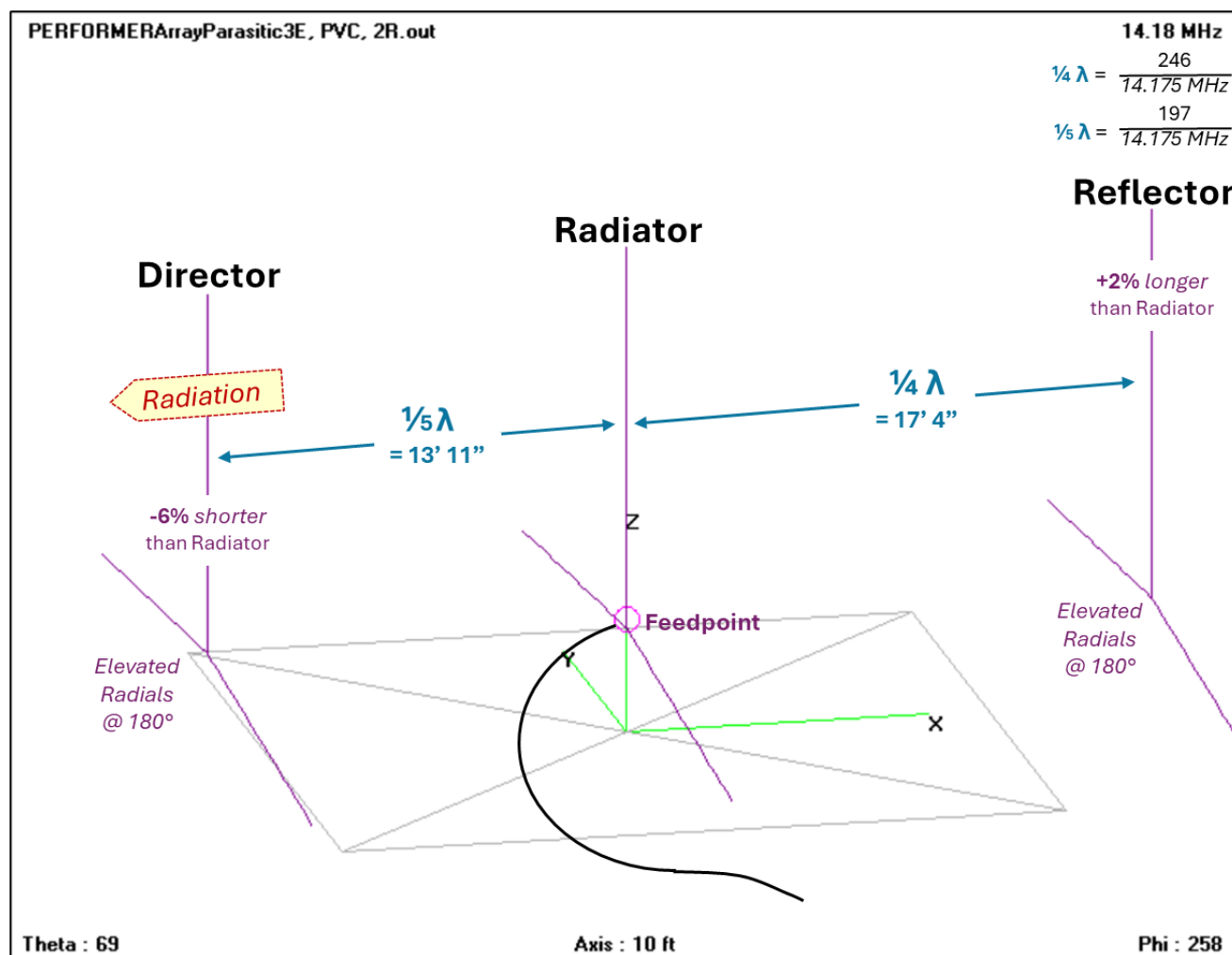


US-4571 with Tripod PERformers

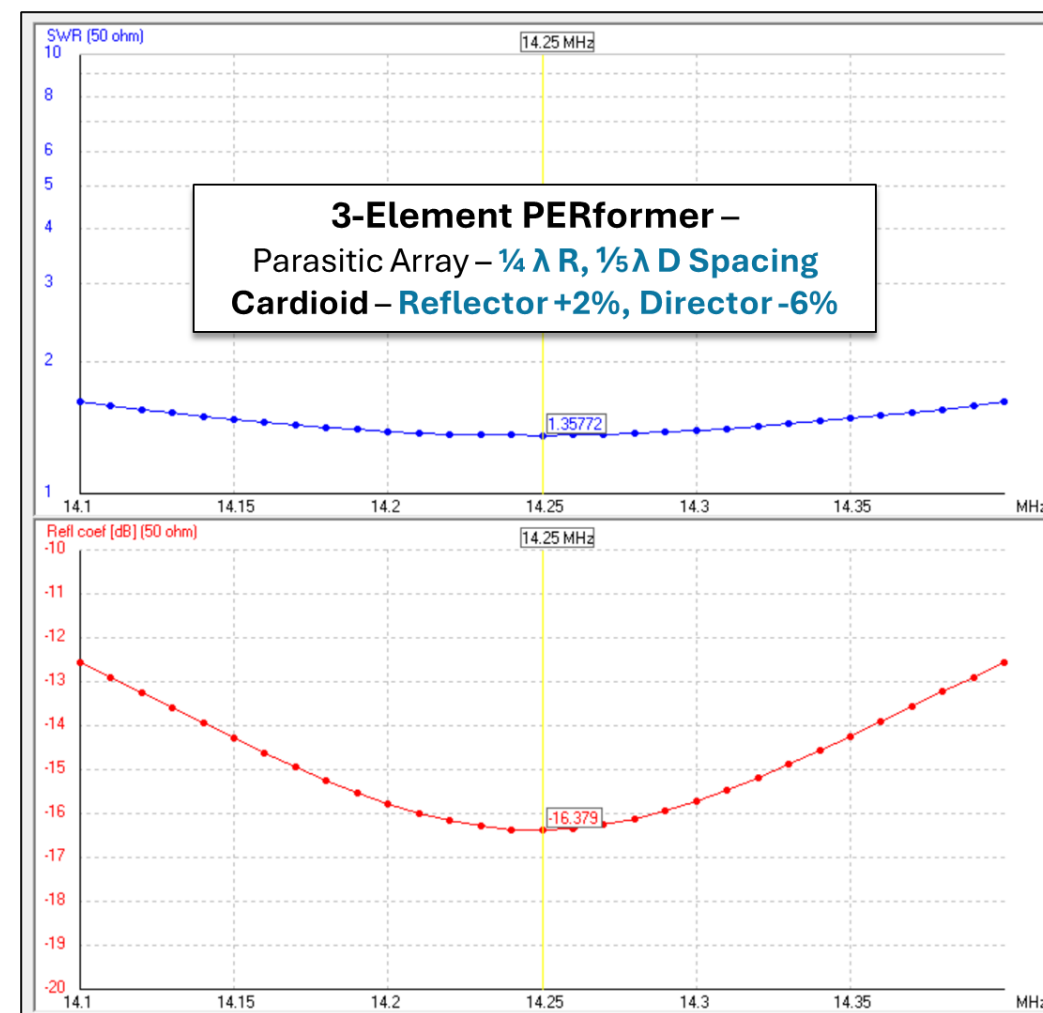


Low SWR, Very Broadbanded

PERformerArray Parasitic Array with 3 Antennas

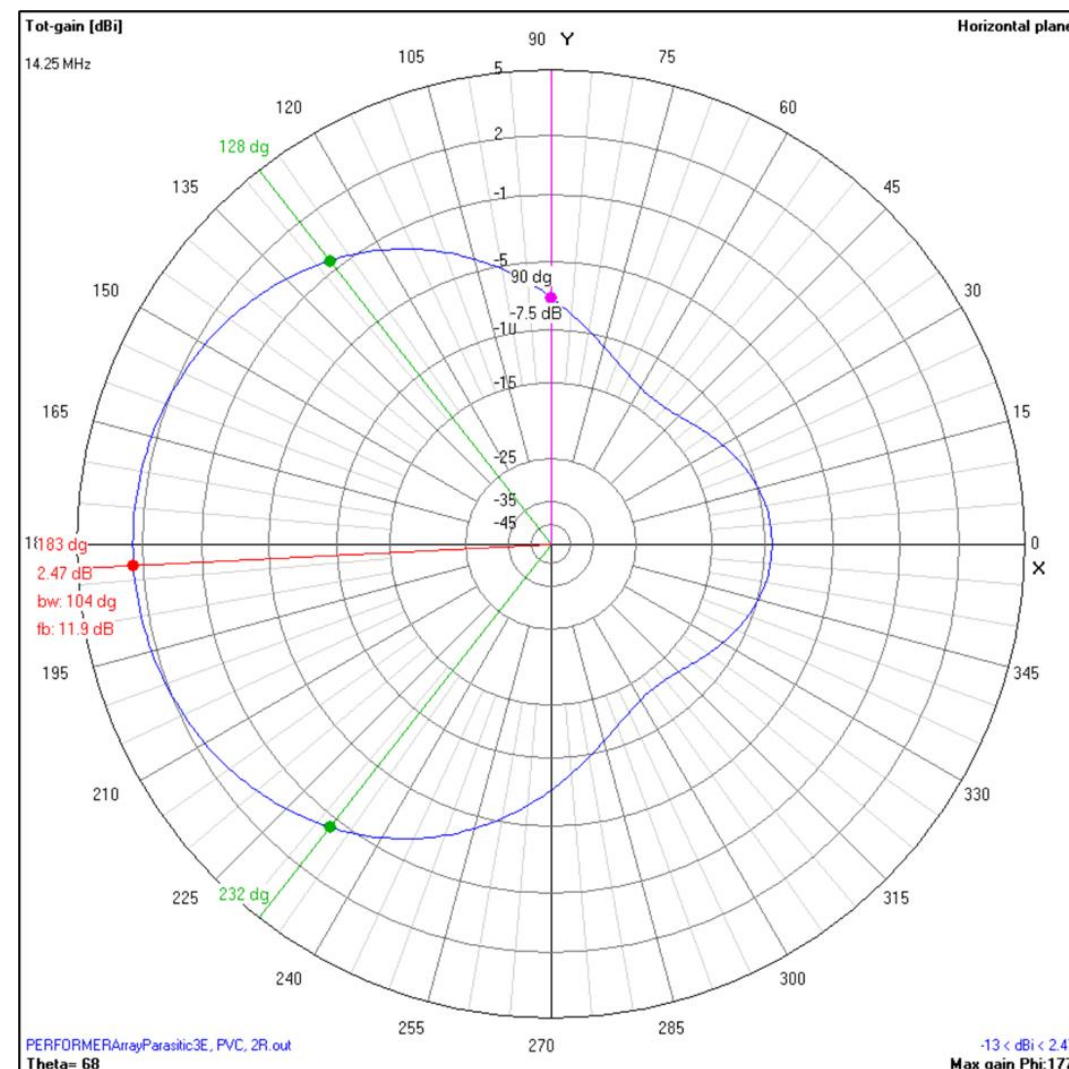
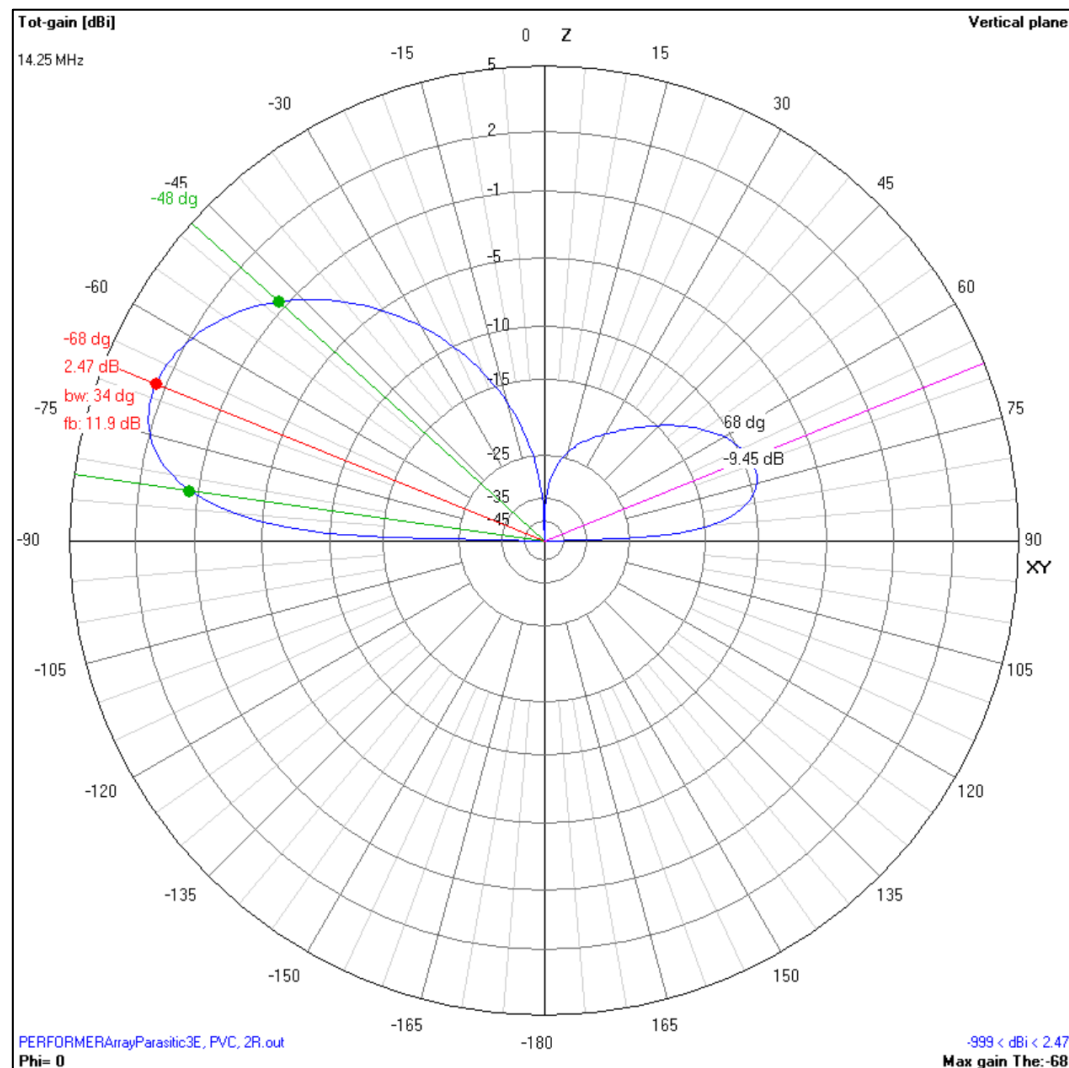


3 PERformers: -6% Reflector, Radiator, +2% Reflector



Low SWR, Very Broadbanded

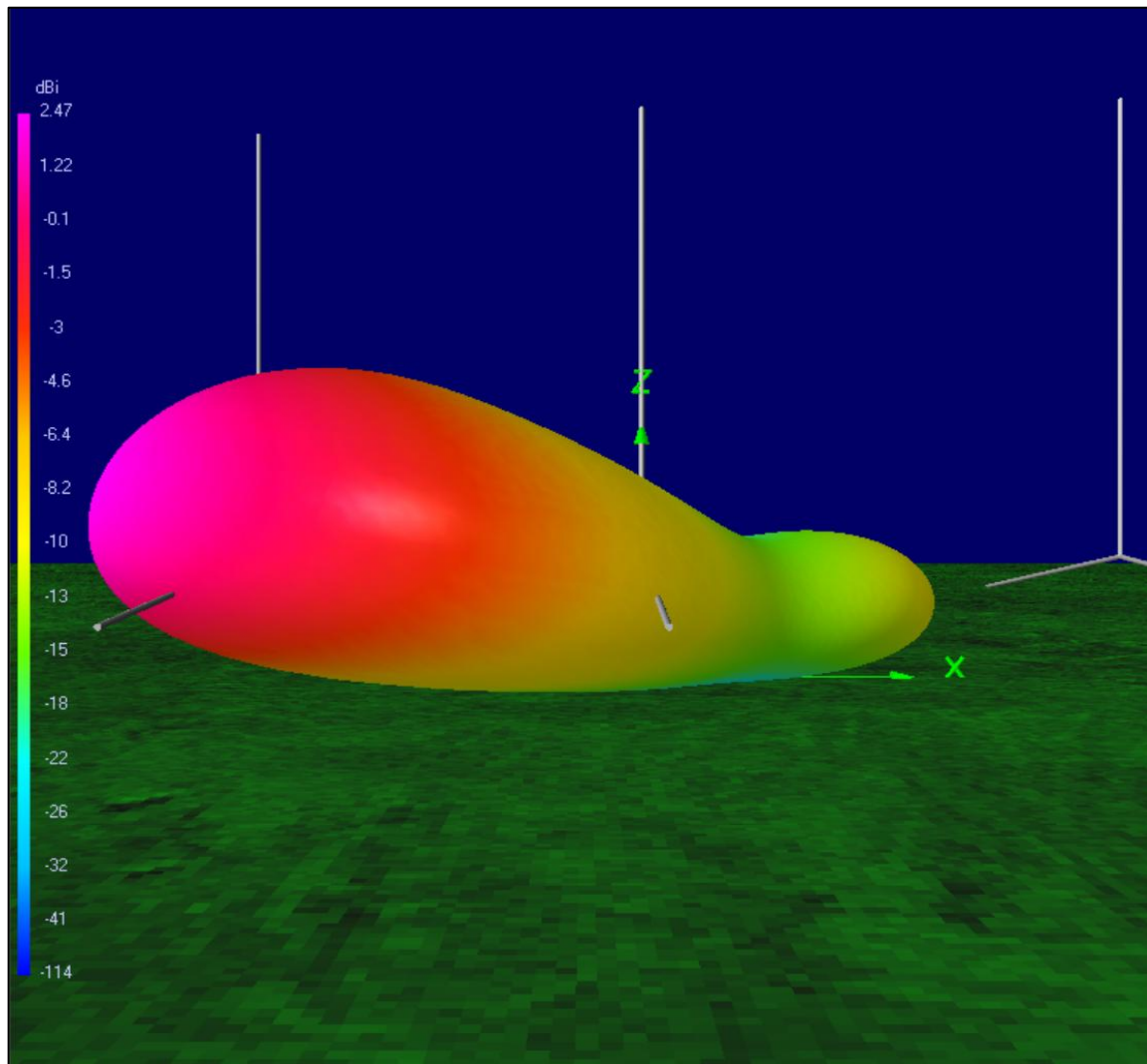
PERformerArray Parasitic Array with 3 Antennas



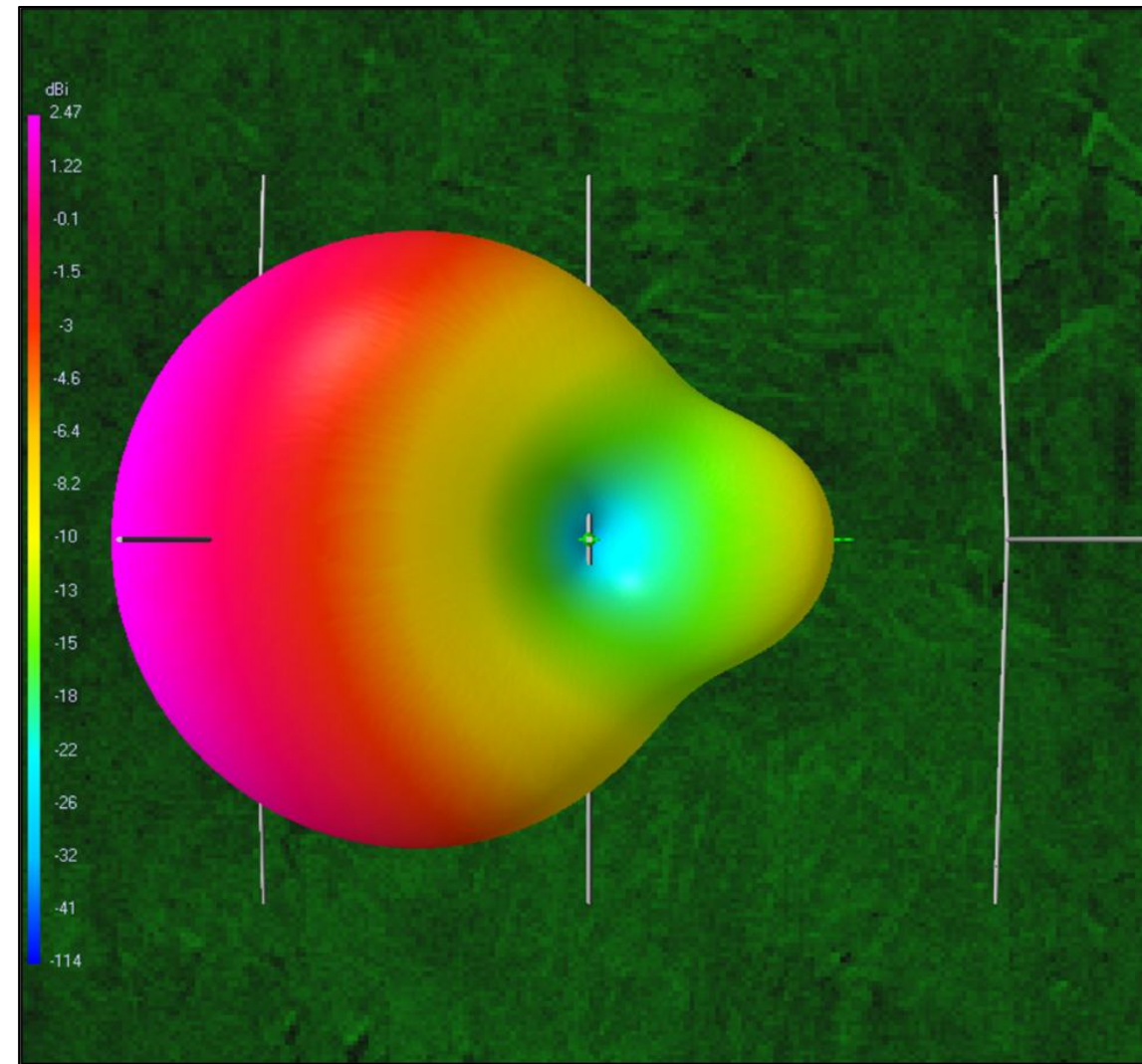
+2.5 dBi Gain (+3.5 dB over one PERformer), 11.9 dB Front-to-Back

10.0 dB Front-to-Side

PERformerArray Parasitic Array with 3 Antennas



+2.5 dBi Gain (+3.5 dB over one PERformer), 11.9 dB Front-to-Back



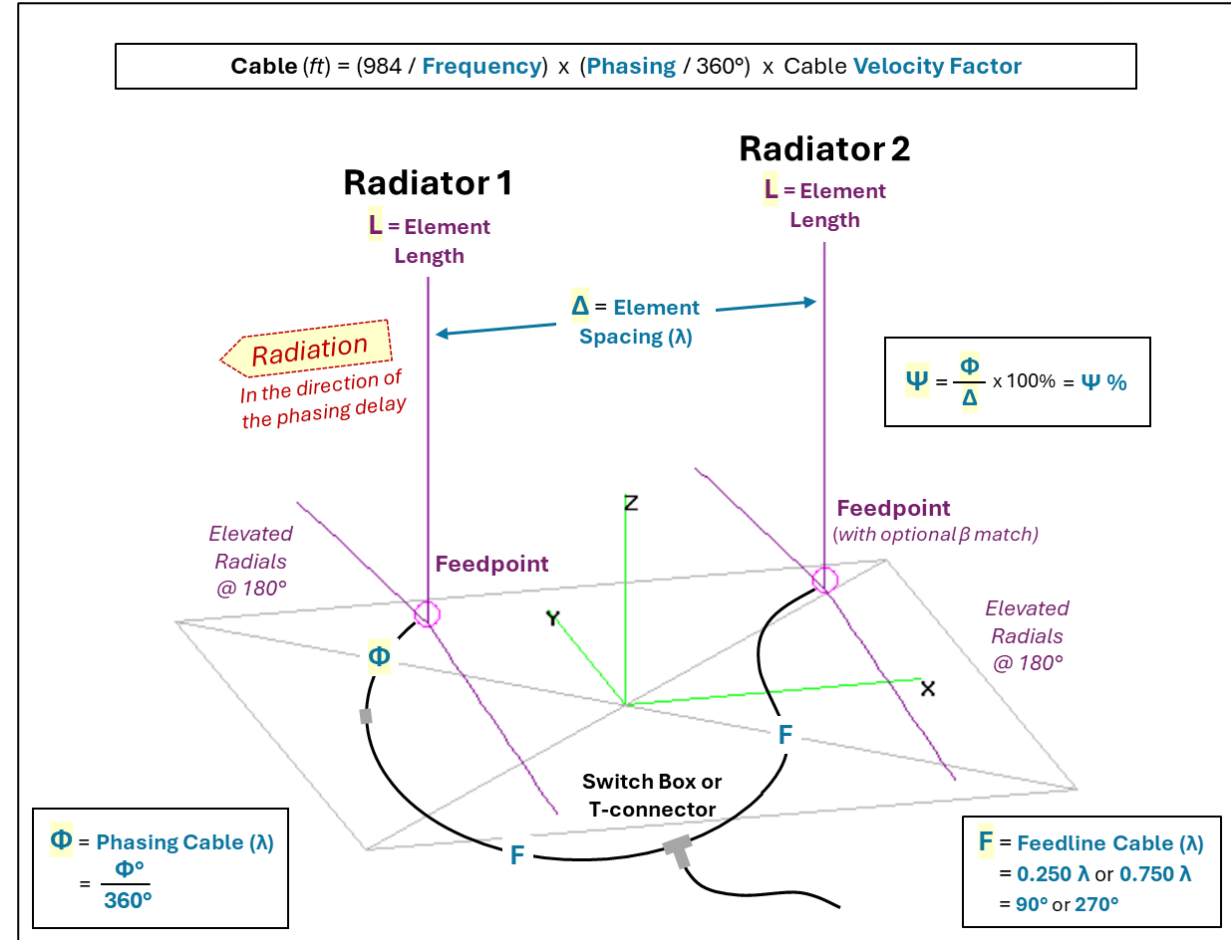
10.0 dB Front-to-Side

2- Element Phased PERformerArray Quarterwave Vertical Antenna System

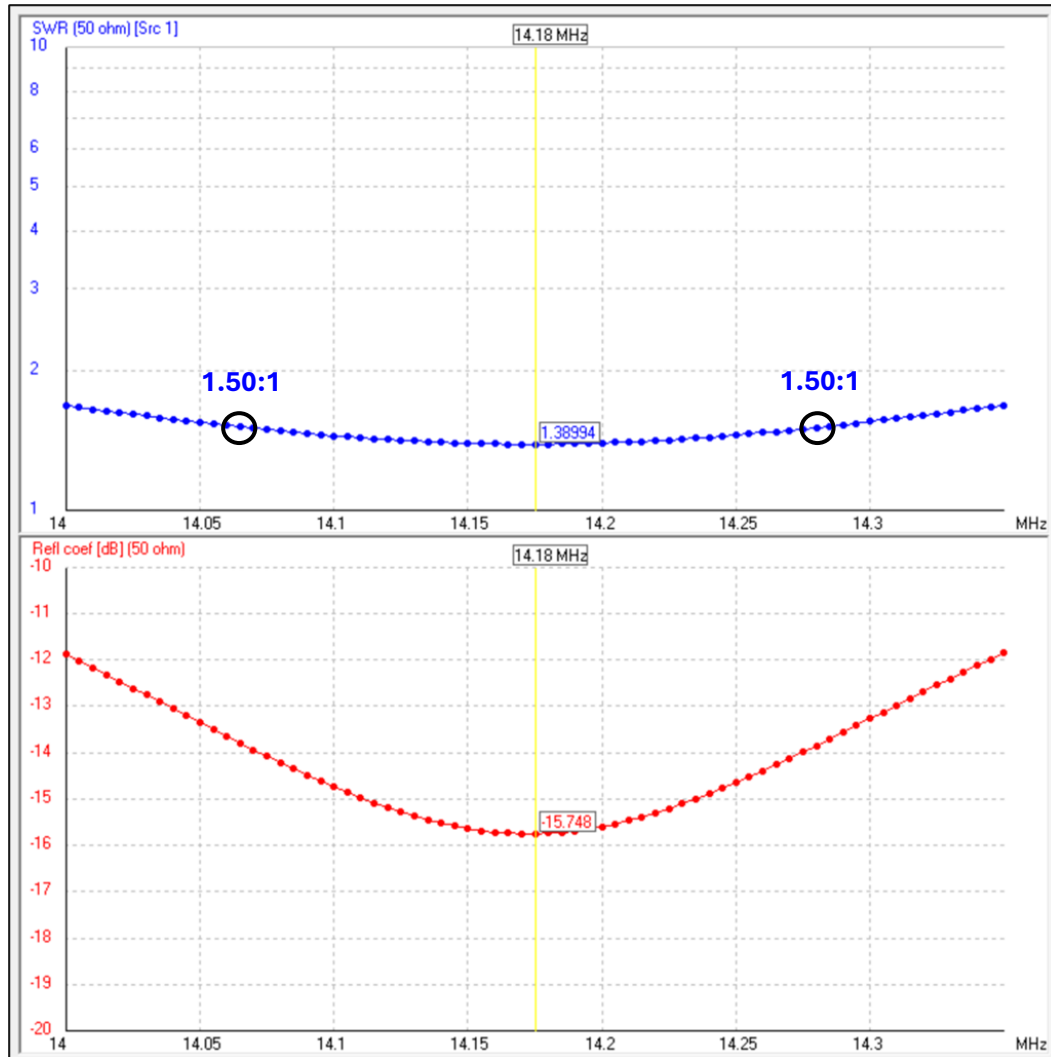


PERformerArray Phased Array with 2 Antennas

- A **phased antenna array** uses two identical driven elements (radiators connected to combined feedlines) with a specific *phase delay line* applied to one of the two antennas.
- A **phased element**, based upon its **proximity** and **phasing**, *interacts* with the *electromagnetic field* of the other driven element, influencing the *radiation pattern* to increase **gain** and **directivity**.

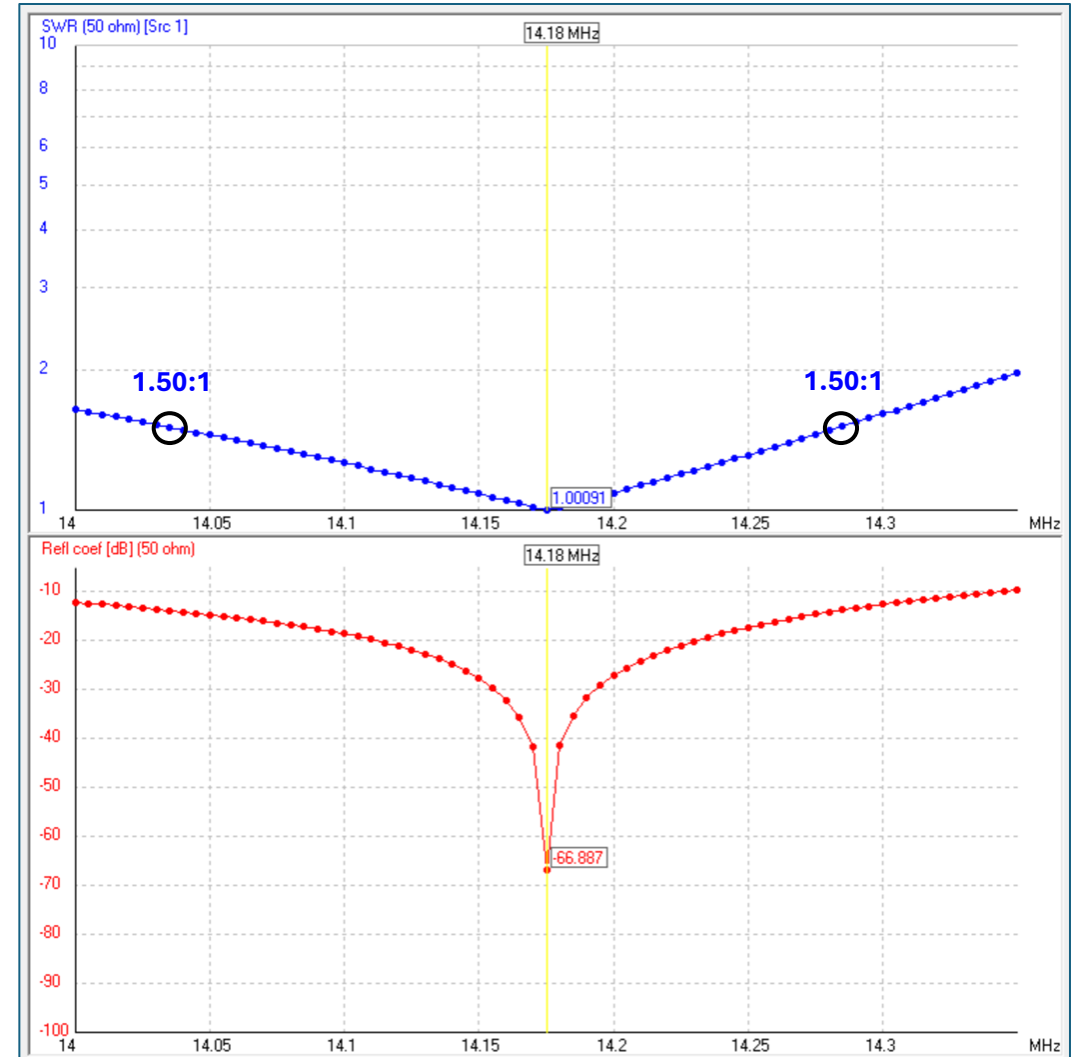


PERformerArray Phased Array with 2 Antennas



Bidirectional Figure-8 Phased Array (20M)

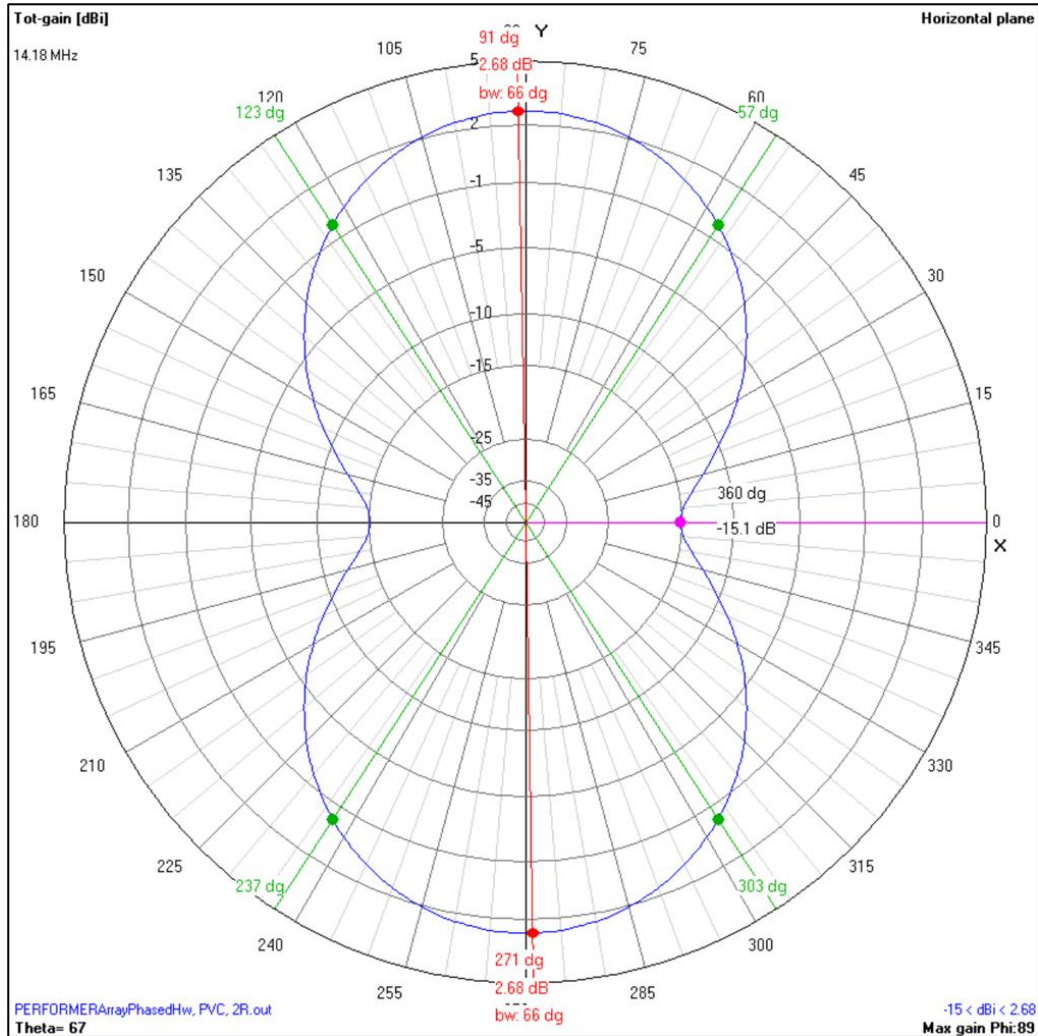
Revision: July 2026



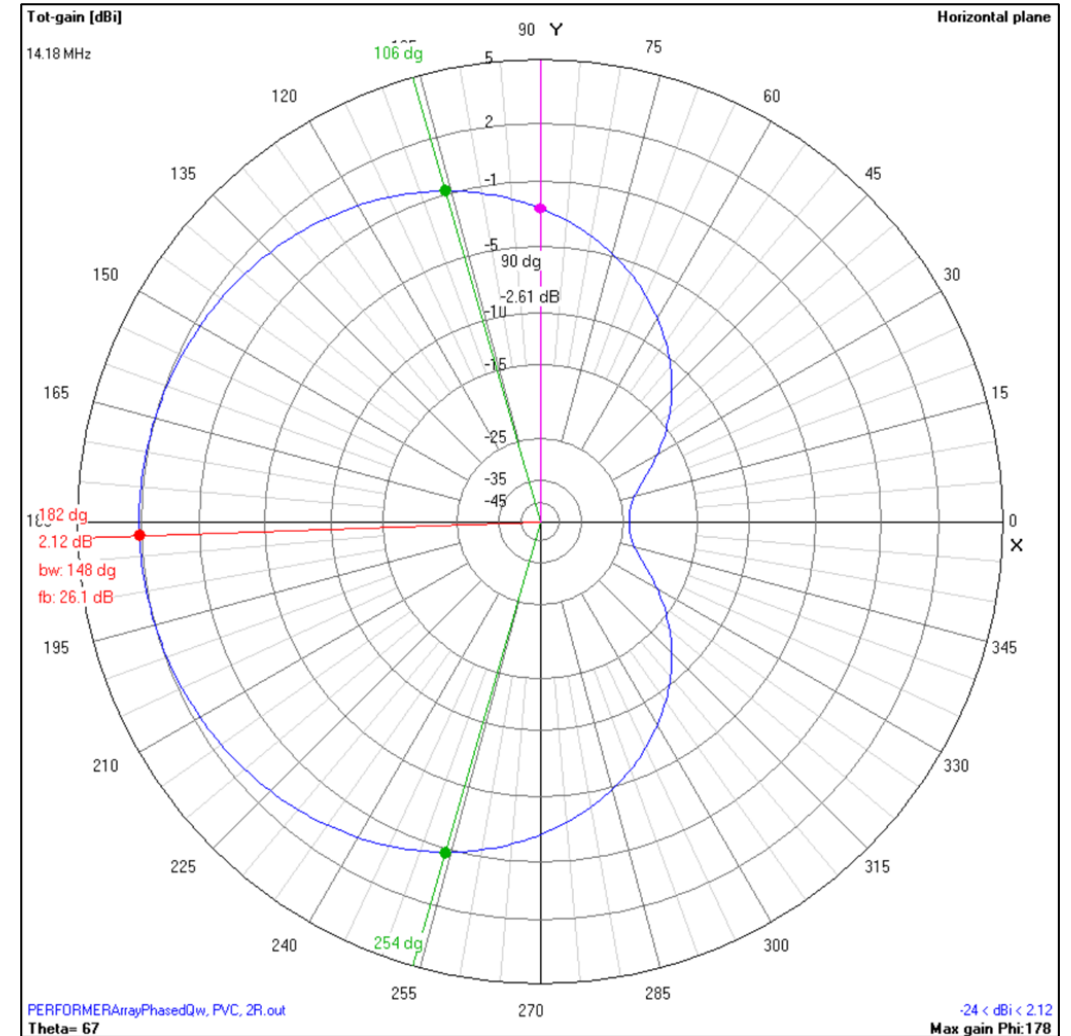
Unidirectional Cardioid Phased Array (20M)

© 2026 by Greg Mihran, KJ6ER

PERformerArray Phased Array with 2 Antennas

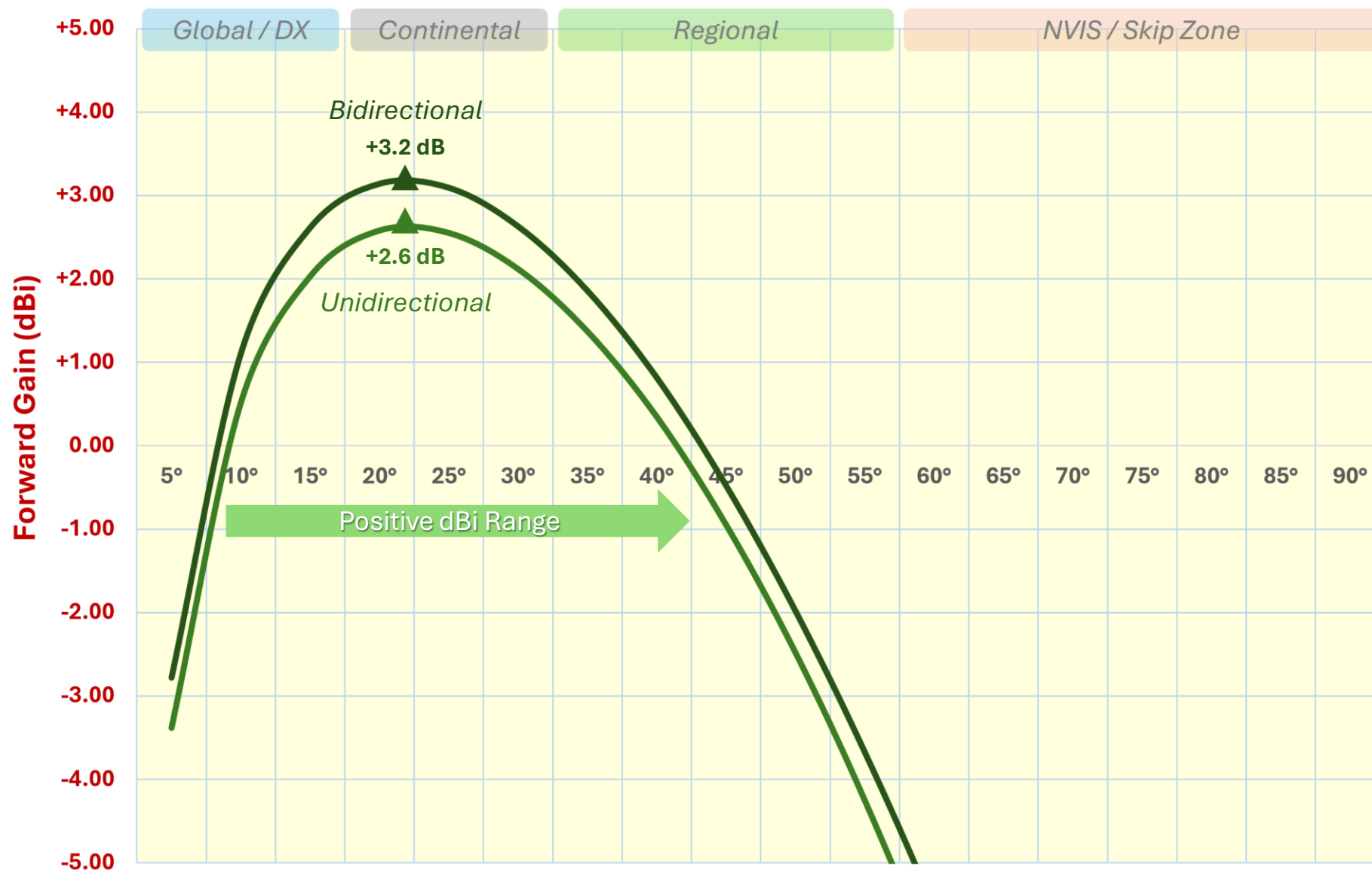


Bidirectional Figure-8 Phased Array (20M)



Unidirectional Cardioid Phased Array (20M)

PERformer Phased Array Radiation Sweeps on the 15M Band



Revision: July 2026

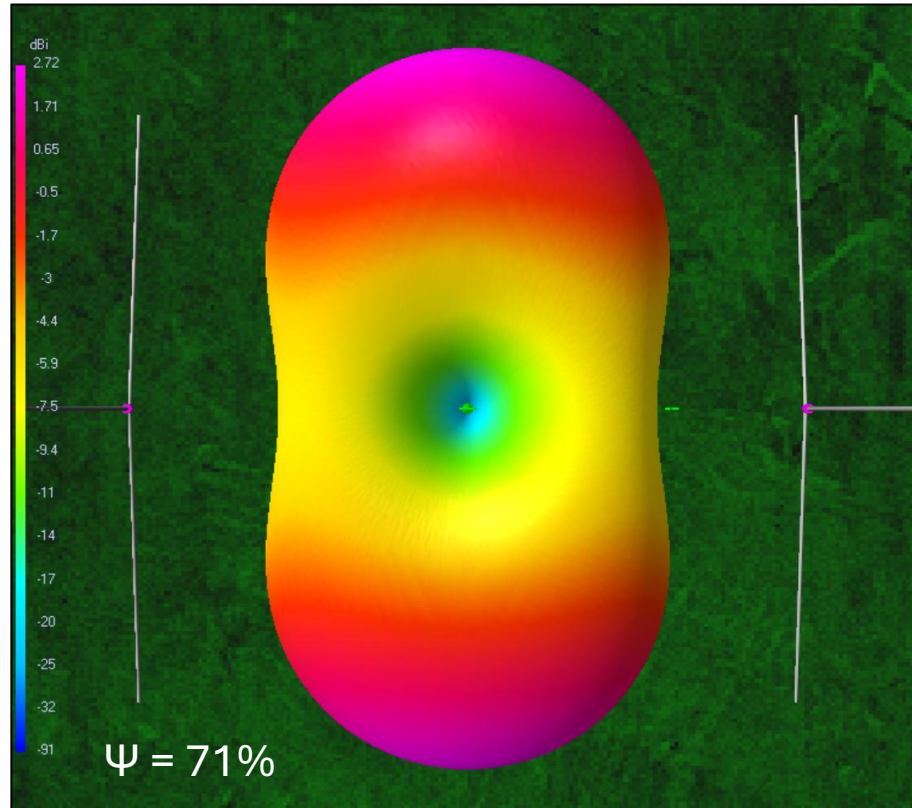
77

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KJ6ER
California

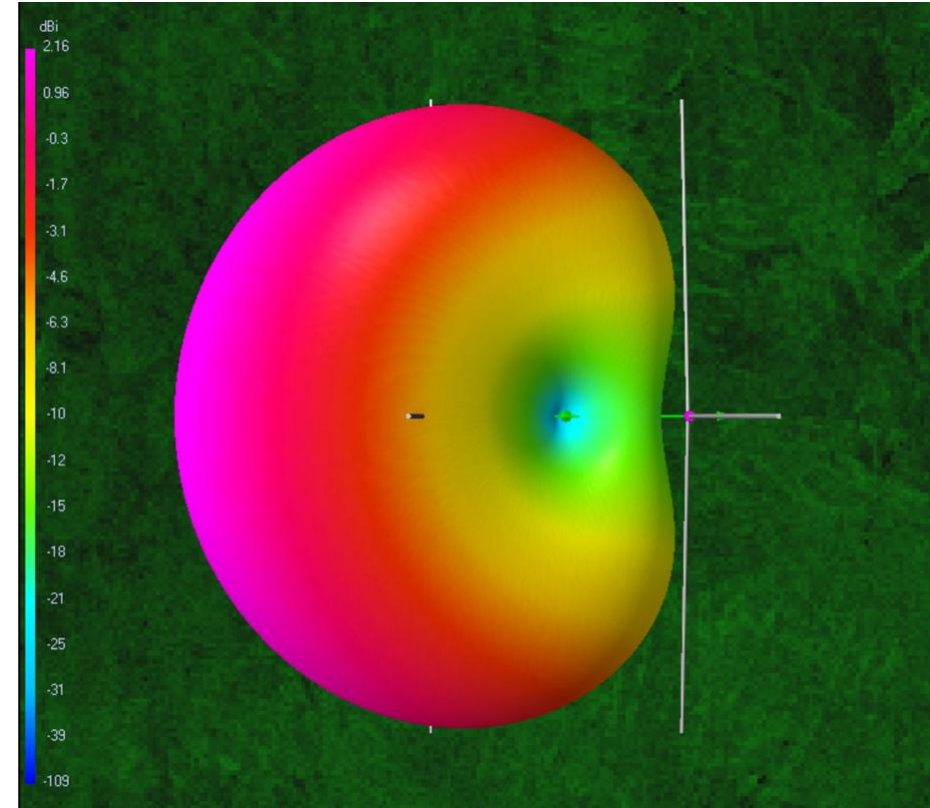
PERformerArray Phased Array with 2 Antennas

Gain = **+4.3 dB** / Front-to-Side = **19.2 dB**



Δ = Spacing = **0.500 λ**
 Φ = Phase Delay = **0° = 0.000 λ**
Bidirectional Figure-8 Pattern
Switchable in 2 Directions

Gain = **+3.9 dB** / Front-to-Back = **22.0 dB**



Δ = Spacing = **0.203 λ**
 Φ = Phase Delay = **52° = 0.144 λ**
Unidirectional Cardioid Pattern
Switchable in 2 Directions

PERformerArray Phased Array with 2 Antennas

Bidirectional Figure-8 Phased Array (40M-6M)

Band	Target Freq. (MHz, λ in)		Radiation Pattern					
			Gain (dB)	Takeoff°	Front-to-Back (dB)	Front-to-Side (dB)	±3 dB Elevation°	±3 dB Azimuth°
40M	7.150	1651	+2.46	23	0.0	17.7	40	68
20M	14.175	833	+2.68	23	0.0	17.8	37	66
17M	18.118	652	+2.96	22	0.0	18.7	36	66
15M	21.225	556	+3.18	22	0.0	18.7	36	66
12M	24.940	473	+3.41	21	0.0	19.5	33	66
10M	28.850	409	+3.62	21	0.0	19.5	32	66
6M	52.000	227	+4.47	18	0.0	22.3	27	64
			+3.25	21	0.0	19.2	34	66

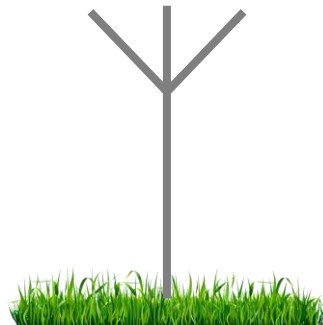
Average Gain = +4.3 dB / Front-to-Side = 19.2 dB
over single PERformer

Unidirectional Cardioid Phased Array (40M-6M)

Band	Target Freq. (MHz, λ in)		Radiation Pattern					
			Gain (dB)	Takeoff°	Front-to-Back (dB)	Front-to-Side (dB)	±3 dB Elevation°	±3 dB Azimuth°
40M	7.150	1651	+1.72	23	17.7	4.5	39	148
20M	14.175	833	+2.12	23	26.1	4.7	36	148
17M	18.118	652	+2.40	23	24.2	4.8	36	150
15M	21.225	556	+2.63	22	23.7	4.9	35	150
12M	24.940	473	+2.89	22	22.4	5.0	33	148
10M	28.850	409	+3.13	21	20.5	5.1	32	148
6M	52.000	227	+4.12	18	14.9	5.1	27	150
			+2.88	22	22.0	4.9	33	149

Average Gain = +3.9 dB / Front-to-Back = 22.0 dB
over single PERformer

Understanding a Few *More* Antenna Fundamentals (Keeping it *High-Level*)

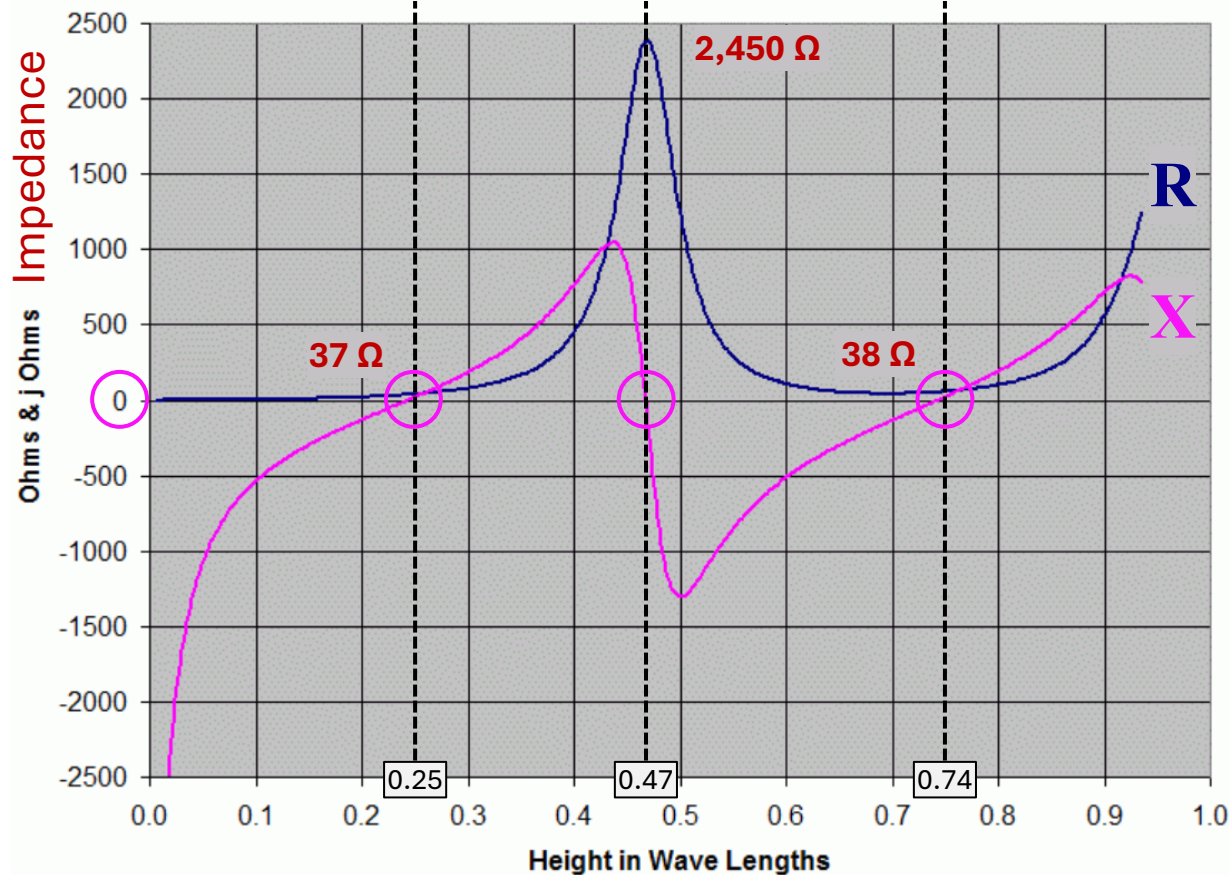


Comparing Quarterwave and Halfwave *Vertical* Antennas

Elements	Quarterwave	Halfwave
Antenna Height	Quarterwave, Shorter 	2 x Quarterwave, Taller
Ground Configuration	Ground plane <i>required</i> with $\lambda/4$ <i>equivalent</i> radials	Single counterpoise wire <i>recommended</i>, 5% - 40% λ 
Radiation Resistance	34 - 38 Ω, when fed at <i>base</i>	68 - 72 Ω, when fed at <i>center</i> 
Feedpoint Impedance	45 - 75 Ω, reasonable match for traditional 50 Ω coax 	1,800 - 5,000 Ω, LC tuned circuit or transformer required for 50 Ω coax
Radiation Efficiency	20% - 90%, depending on type of the ground plane utilized	95% - 99%, <i>not</i> including the transformer insertion loss 
Radiated Gain	Higher at angles > 25 degrees	Higher at angles < 25 degrees
Peak Radiation Angle	25 - 35 degrees	10 - 25 degrees
Radiation Beamwidth -3dB	Wider, broader, more regional	Narrower, concentrated, more DX
Primary Reach	Regional, Continental	Continental, Global

Feedpoint Impedance as Monopole Length Increases

Impedance versus Monopole Height

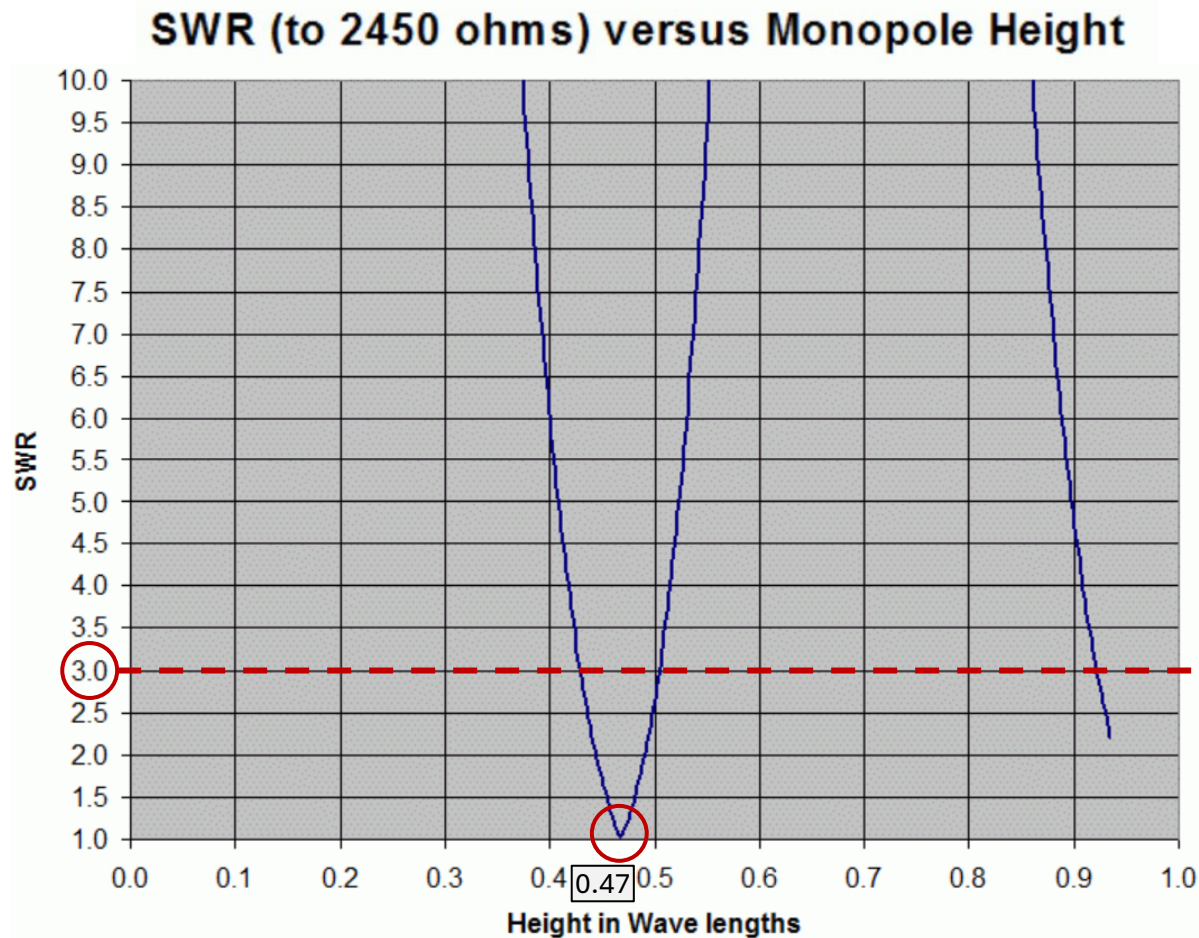


$$\text{Impedance: } Z = R \pm j X \text{ (ohms)}$$

- According to modeling, **impedance (Z)** of a vertical monopole varies as its length is increased between **0.01 λ** and **1.00 λ**.
- Assuming the ground plane is perfectly electrically conducting (*not* real world), note the points where $j X = 0 \Omega$. These are where the antenna is purely *resistive* and *resonant*: **0.25 λ**, **0.47 λ**, and **0.74 λ**.
- The most significant difference between these points is the **impedance (Z)**. For a monopole length of **0.25 λ**, the *purely resistive* impedance is **37 Ω**. At **0.47 λ**, it is **2,450 Ω**, and at **0.74 λ**, it is about **38-40 Ω**.

Source: AA5TB, Steve Yates (2010)

SWR with a 49:1 or 56:1 Unun as Monopole Length Increases

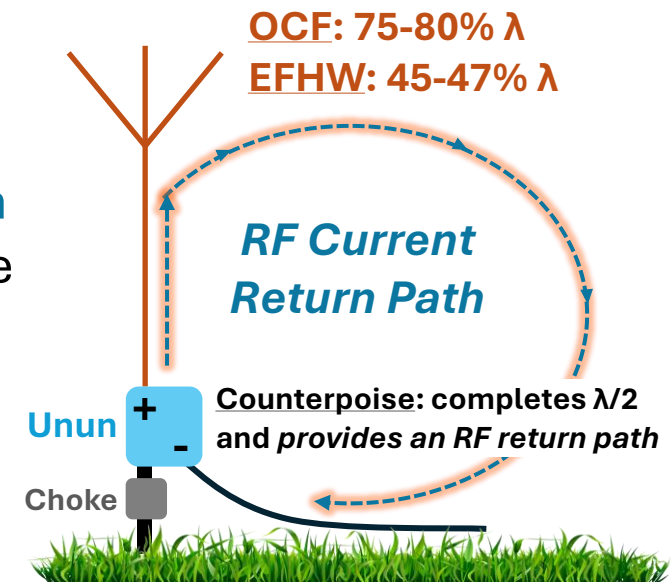


- The key to matching any end-fed halfwave vertical is to ensure an efficient and effective matching system for the antenna feedpoint **impedance** of **2,450 Ω** .
- Through modeling, it can be seen that a slightly shorter $\lambda/2$ vertical length of **0.47 λ** creates a *purely resistance* impedance component where **$jX = 0 \Omega$** which provides optimal SWR with a 49:1 or 56:1 unun.
- But when the antenna is installed in the *real world*, many other factors impact resonance including the ground type and near field surroundings. Through Dominator field testing, **0.45 λ** is found to be most effective.

Source: AA5TB, Steve Yates (2010)

Halfwave Vertical Antennas and the Counterpoise

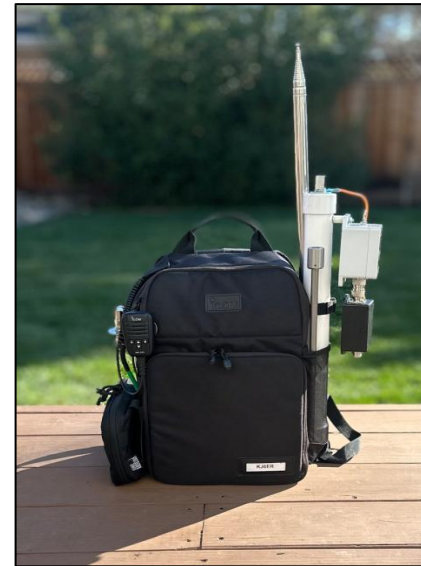
- An **unbalanced antenna** such as an **OCF** or **EF halfwave** is typically fed by **50Ω coax** which is an *unbalanced* feedline requiring an **unun** at the feedpoint. A dipole is a *balanced* antenna which uses a **balun** instead.
- A **counterpoise** for an **unbalanced** halfwave **finishes the half wavelength** and **provides an RF return path** within an electromagnetic field to facilitate the **maximum flow of current** to radiate – **completing the RF circuit**.
- A **counterpoise is strongly recommended** for **optimal RF performance** to provide: 1) appropriate feedpoint impedance, 2) full radiation efficiency, and 3) predictable radiation pattern. *Always* attach a counterpoise wire.
- An **RF choke at the feedpoint** prevents the radiated RF current from flowing on the coax shield back to the rig which generate **common mode currents** (CMC) and **radio frequency interference** (RFI). If *no choke is used*, the feedline becomes a *random and uncontrolled* second counterpoise!



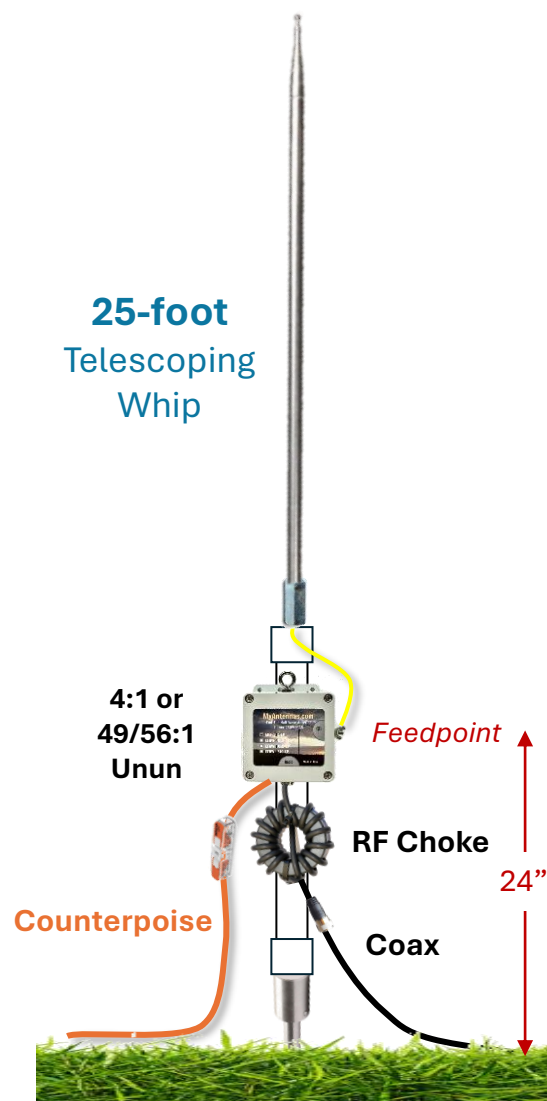
Summary of Key Points for a Halfwave Vertical Antenna

- When a vertical antenna is fed at the base, the radiation resistance R_{rad} increases from 37Ω at the 0.25λ length to $\sim 2,450 \Omega$ at the 0.47λ length. This significant increase in *good resistance* promotes a *high radiation efficiency*:
 $\text{Eff\%} = R_{\text{rad}} / (R_{\text{rad}} + R_{\text{loss}}) \times 100\%$, $\rightarrow$ in this case, R_{rad} is *maximized*
- The large radiation resistance R_{rad} of a halfwave vertical *significantly minimizes* the impact of any loss resistance R_{loss} associated with the required ground counterpoise wire. Assuming a modeled loss of $\sim 12 \Omega$ in the counterpoise, $\text{Eff\%} = 2,450 \Omega / (2,450 \Omega + 12 \Omega) \times 100\% = 99.5\% \text{ efficiency}$
- It would require over 100 equivalent $\lambda/4$ ground radials for a quarterwave vertical to reach a radiation efficiency of over **90%** to come close to the efficiency of a halfwave vertical. Additionally, the halfwave vertical provides a *lower radiation angle for DX* and about *double the peak radiation gain*.

Challenger and Dominator Halfwave Vertical Antennas with a Linked Counterpoise



Challenger and Dominator OCF / EF Halfwave Antennas



Challenger Off-Center Fed Halfwave (20M-6M)



LDG 4:1 Unun

Insertion Loss:
-0.50 dB
Matching Efficiency:
89.1%

Dominator End-Fed Halfwave (17M-10M)



TennTennas
49:1 Unun

Insertion Loss:
-0.96 dB
Matching Efficiency:
80.1%

Extra Matching Efficiency +



Palomar 4:1 Unun

Insertion Loss:
-0.15 dB
Matching Efficiency:
96.6%



MyAntennas
56:1 Unun

Insertion Loss:
-0.40 dB
Matching Efficiency:
91.2%

20M
17M
15M
12M
10M
6M
Avg.

Gain Challenger Dominator

Challenger	Dominator
-0.7 dBi	---
-0.5 dBi	+0.3 dBi
-0.3 dBi	+0.6 dBi
-0.2 dBi	+0.8 dBi
-0.1 dBi	+1.0 dBi
+0.3 dBi	---
-0.3 dBi	+0.7 dBi



Challenger and Dominator Halfwave Vertical Antennas



Challenger and **Dominator** shown on a portable **78" Polarduck™ tripod** with very broad and adjustable leg lengths.



The **LDG™ 4:1 unun** or the **TennTennas™ 49:1** with **RF choke** are already mounted to the tripod for fast and easy deployment.

- The **Challenger** is a portable, elevated, resonant **OC-fed** halfwave vertical antenna for **20M-6M**, the **Dominator** is a portable, elevated, resonant **End-Fed** halfwave vertical antenna for **17M-10M** sitting on a tripod with the feedpoint about 3-4' off the ground and a linked counterpoise wire.
- **Computer modeled extensively** in **4NEC2** to design and optimize performance. **Efficiency** averages **over 90%** across all bands with an **SWR less than 1.10:1** on each band.
- Designed to be **lightweight and easy to deploy** for all types of portable operations. Also used at HOAs and other types of locations that do not allow permanent antenna installations.

Challenger and Dominator Halfwave Vertical Antennas

Challenger Halfwave Vertical Antenna System (20M-6M)

Mirror mount with 3/8" x 24 coupling nut on top and *insulated* 3/8" x 24 bolt at bottom

Whip pigtail (12") off unun positive with **ring terminal** attached to bolt on mirror mount

Tripod to elevate feedpoint **12-48"** above ground

Radiating element is an adjustable 25' (or 17') telescoping whip for finetuning on each band

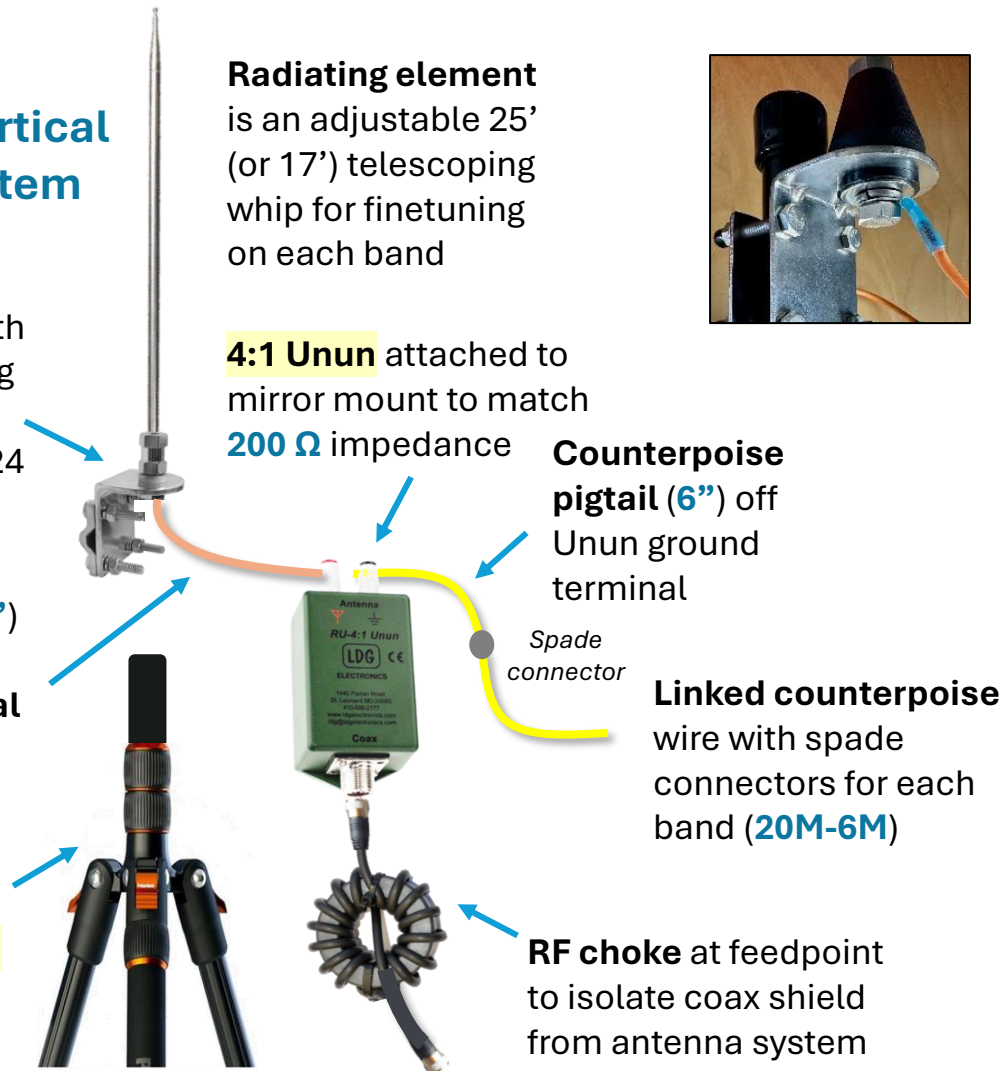
4:1 Unun attached to mirror mount to match **200 Ω** impedance

Counterpoise pigtail (6") off Unun ground terminal

Spade connector

Linked counterpoise wire with spade connectors for each band (**20M-6M**)

RF choke at feedpoint to isolate coax shield from antenna system



Dominator Halfwave Vertical Antenna System (17M-10M)

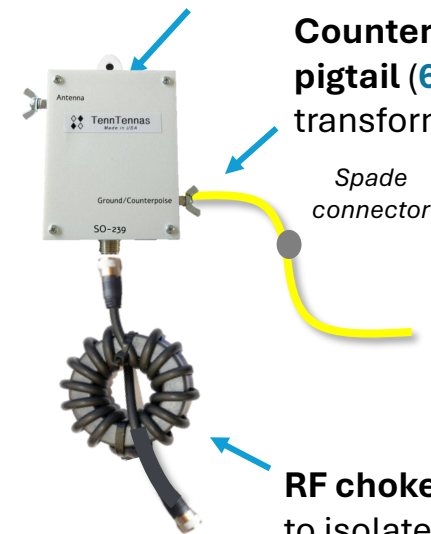
49:1 transformer to match **2450 Ω** impedance at feedpoint

Counterpoise pigtail (6") off transformer negative

Spade connector

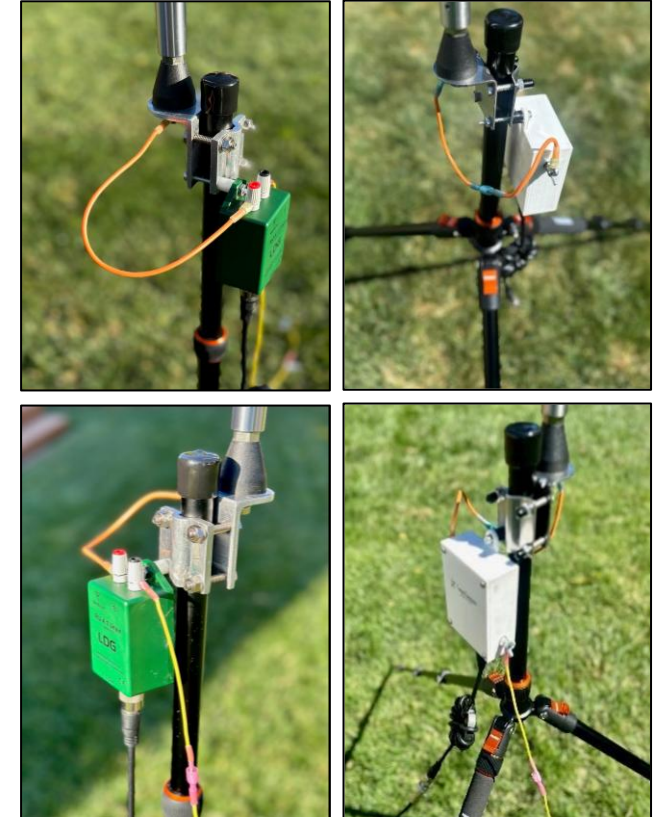
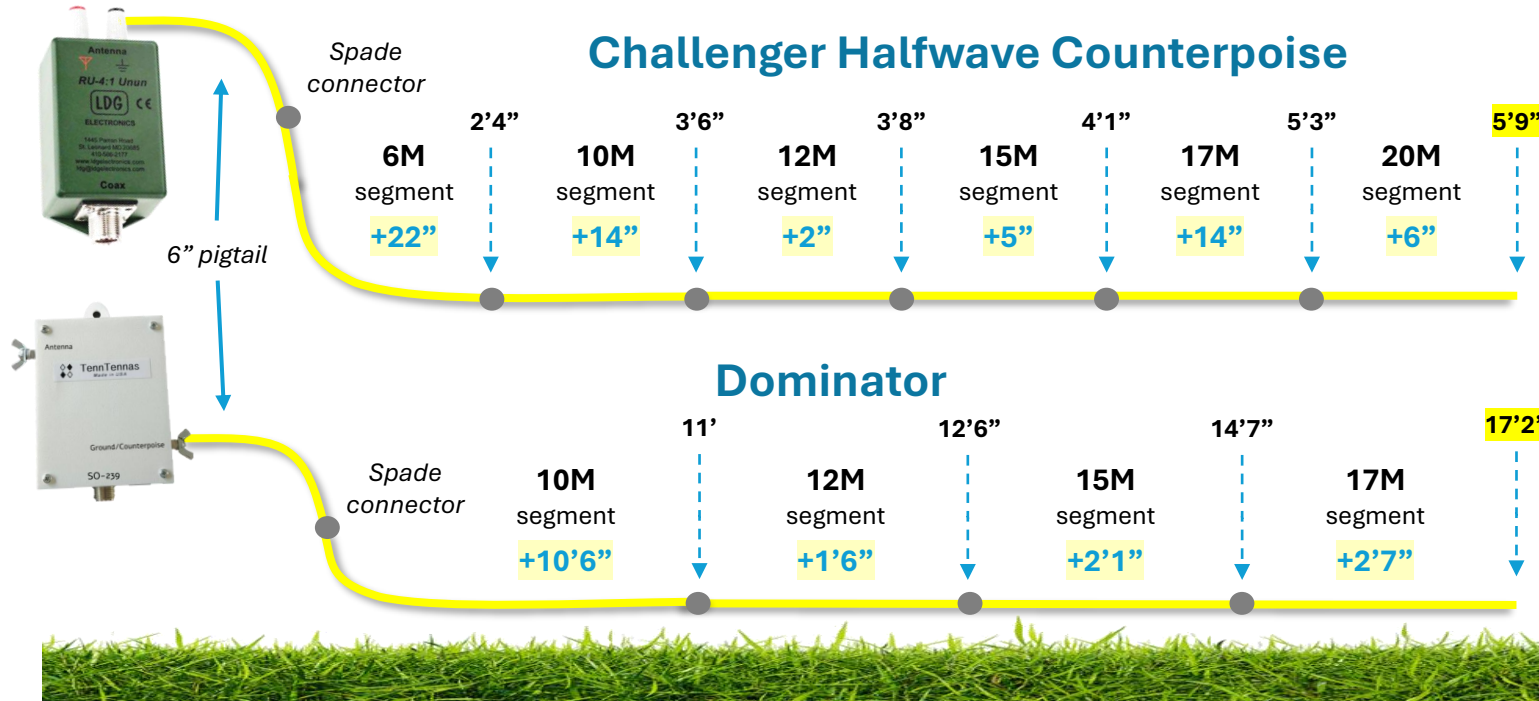
Linked counterpoise wire with spade connectors for each band (**17M-10M**)

RF choke at feedpoint to isolate coax shield from antenna system



Challenger and Dominator Linked Counterpoise Wires

- A **counterpoise** completes the remaining halfwave for the **Challenger and Dominator**, and also provides a **return path** for the nearfield radiated RF current to get back to the transmitter on both antennas.
- An **RF choke** is required at the **feedpoint** to prevent the **coax shield** from becoming a *random and uncontrolled counterpoise* which typically results in *unpredictable* radiation patterns, efficiency and impedance.



Challenger and Dominator Impedance Matching Components



Challenger

**LDG
RU-4:1**

\$30

Insertion Loss:

-0.34 dB

Efficiency:

92.4%

**FT-140-43
Toroid**

**Palomar
JC-1-1500**

\$30

Insertion Loss:

-0.12 dB

Efficiency:

97.3%

-0.46 dB

**FT-240-31
Toroid**

Power Range:
200 watts
Bandwidth:
1.8-30 MHz

Power Range:
1,500 watts
Noise
Reduction:
-32 dB
Bandwidth:
1.8-65 MHz



Challenger+

**Palomar
Bullet-4U-100**

\$70

Insertion Loss:

-0.24 dB

Efficiency:

94.6%

**Dual Port
Ferrite Bead
Mix 43**

**Palomar
MC-1-500-50**

\$70

Insertion Loss:

-0.11 dB

Efficiency:

97.4%

-0.35 dB

Power Range:
100 watts
Bandwidth:
1.8-61 MHz

Power Range:
500 watts
Noise
Reduction:
-42 dB
Bandwidth:
1-60 MHz

**Ferrite Bead
Mix 31**



Dominator

**TennTennas 49:1
Transformer**

\$45

Insertion Loss:

-0.96 dB

Efficiency:

80.1%

**FT-240-43
Toroid**

**Palomar
JC-1-1500**

\$30

Insertion Loss:

-0.12 dB

Efficiency:

97.3%

-1.08 dB

Power Range:
100 watts
Bandwidth:
1.8-30 MHz

Power Range:
1,500 watts
Noise
Reduction:
-32 dB
Bandwidth:
1.8-65 MHz

**FT-240-31
Toroid**



Dominator+

**MyAntennas 56:1
MEF-130-LP
Transformer**

\$89

Insertion Loss:

-0.40 dB

Efficiency:

91.2%

**FT-140-43
Toroid**

**Palomar
MC-1-500-50**

\$70

Insertion Loss:

-0.11 dB

Efficiency:

97.4%

-0.51 dB

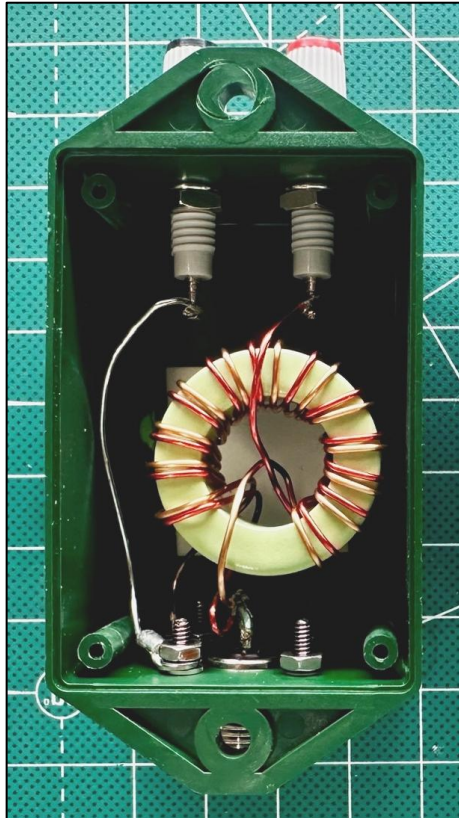
Power Range:
250 watts
Bandwidth:
1.8-30 MHz

Power Range:
500 watts
Noise
Reduction:
-42 dB
Bandwidth:
1-60 MHz

**Ferrite Bead
Mix 31**

Challenger and Dominator Impedance Matching Components

Challenger
LDG
RU-4:1



FT-140-43 Toroid Mix 43
1.4" O.D. x 0.9" I.D. x 0.5" Height



Challenger+
Palomar
Ferrite Beads

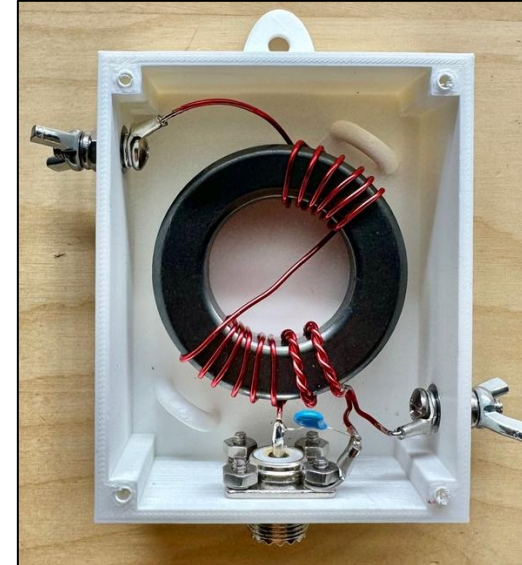


Bullet-4U-100
Dual 1/4" Port
Ferrite Bead
Mix 43
1.125" Height x
1.125" Width x
0.5" Depth



MC-1-500-50
Ferrite Bead
Mix 31
0.687" O.D. x
0.375" I.D. x
1.125" Height

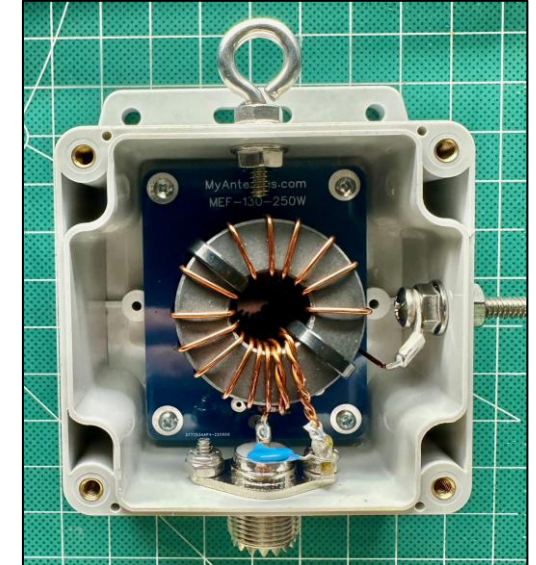
Dominator
TennTennas 49:1
Transformer



FT-240-43 Toroid Mix 43
2.4" O.D. x 1.4" I.D. x 0.5" Height



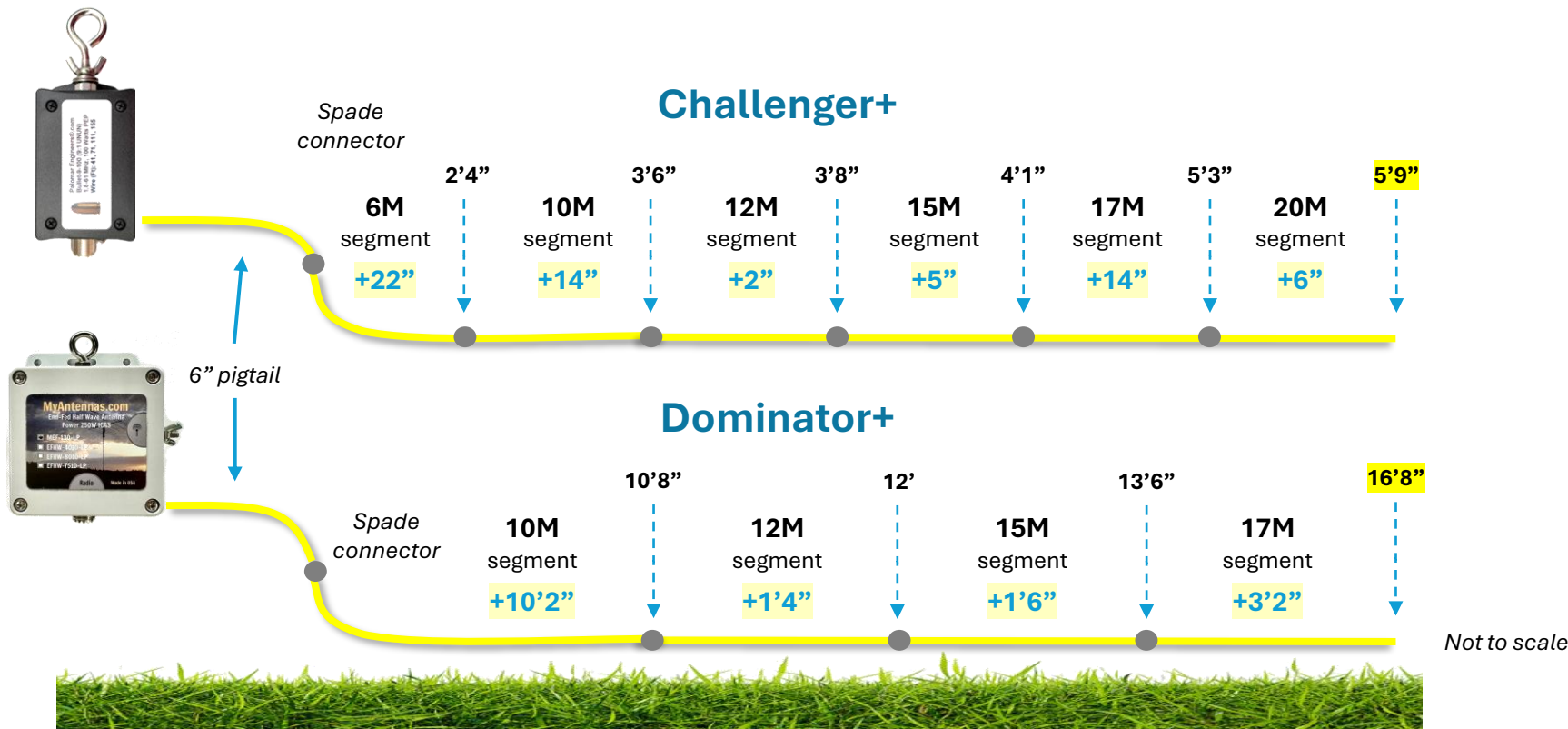
Dominator+
MyAntennas 56:1
Transformer



FT-140-43 Toroid Mix 43
1.4" O.D. x 0.6" I.D. x 1.0" Height
"Equivalent to 3x FT-140-43 Toroids"

Challenger+ and Dominator+ Linked Counterpoise Wires

- **Challenger+** leverages a Palomar™ 4:1 dual port ferrite bead unun which is a similar impedance match as the **Challenger** LDG™ 4:1 toroid unun.
- **Dominator+** leverages a MyAntennas™ 56:1 transformer which requires shorter counterpoise lengths than **Dominator** with a TennTennas™ 49:1.



Dominator+ and Challenger+ mounted side-by-side on the Polarduck™ tripod.

Challenger+ and Dominator+ Backpack Configuration Options

- Redesigned configuration to fit in **ICOM™ backpack** side pocket with **ICOM™ IC-705** QRP transceiver.
- **16" long 1-¼" O.D.** PVC tube with mounted unun and choke. Chameleon™ 25' whip / ground spike or WRC™ Megapod depending on ground conditions. Linked counterpoise, RigExpert™ Stick, and 25' Messi & Paoloni™ Airborne 5 coax are all stored in the front zippered compartment.



Challenger+ and **Dominator+** side-by-side with Chameleon™ whip and ground spike.



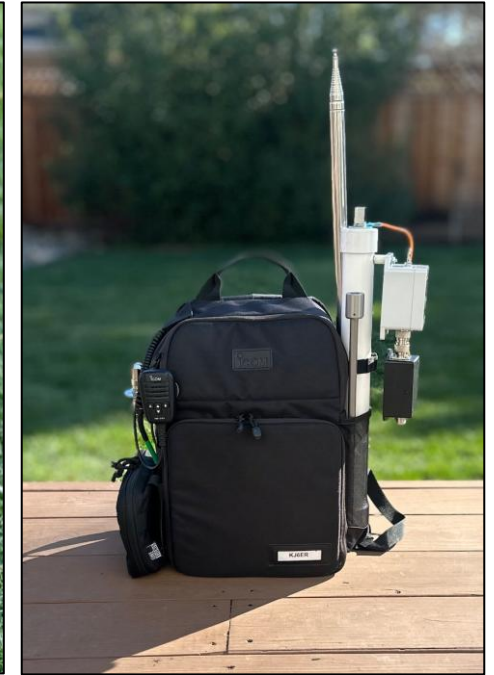
Challenger+



Dominator+



Dominator+ on WRC™ Megapod



Dominator+ in ICOM™ backpack

4NEC2 Challenger Model Specifications across 6 Bands

Band	Target Freq. (MHz)	468 / f		Radiator		Counterpoise		OCF %	Total % λ	Specifications						
		Length	λ (in)	Inches	% λ	Inches	% λ			SWR	Ref Coef (db)	Rad Angle (deg)	Gain (dBi)	-3 dB BW (deg)	Structural Efficiency	Impedance
20M	14.250	32' 10"	788	304	38.6%	99	12.5%	75.5%	51.1%	1.04	-34.9	21	-0.66	35	93.0%	193 - j 1.78
17M	18.140	25' 10"	619	240	38.7%	76	12.3%	75.9%	51.0%	1.02	-38.9	21	-0.54	34	93.8%	196 + j 1.46
15M	21.350	21' 11"	526	205	39.0%	65	12.3%	76.0%	51.2%	1.04	-34.2	21	-0.32	33	94.0%	192 + j 1.25
12M	24.940	18' 9"	450	175	38.9%	56	12.4%	75.9%	51.3%	1.06	-30.8	20	-0.23	31	94.5%	189 + j 3.34
10M	28.400	16' 6"	395	154	39.0%	49	12.3%	76.0%	51.3%	1.06	-30.3	20	-0.12	31	94.7%	189 + j 3.31
6M	51.000	9' 4"	220	87	39.6%	26	11.8%	77.1%	51.4%	1.04	-34.8	20	0.27	30	95.9%	193 + j 2.30
Averages:				38.9%		12.3%		76.1%	51.2%	1.04	-34.0	21	-0.27	32	94.3%	Z = R + j X

- The model computed several *performance* specifications including **SWR**, **reflection coefficient**, **peak radiation angle**, **gain**, **-3.00 dB beamwidth** as well as overall **antenna efficiency** and **impedance**.
- The *average* performance specifications *across all six bands* are:
 - ✓ Structural Efficiency = **94.3%**
 - ✓ OCF Unun Efficiency = **92.4% - 94.6%**
 - ✓ SWR= **1.04**, Ref. Coef. = **-34.0 dB**
 - ✓ Peak Radiation Gain = **-0.27 dBi**
 - ✓ Peak Radiation Angle = **21°** (*beamwidth* 8° - 40°)
 - ✓ -3.00 dB Beamwidth = **32°** (*delta* -13°, +19°)

4NEC2 Dominator Model Specifications across 4 Bands

Band	Target Freq. (MHz)	468 / f	
		Length	Inches
17M	18.140	25' 10"	310
15M	21.350	21' 11"	263
12M	24.940	18' 9"	225
10M	28.400	16' 6"	198

Radiator		Counterpoise	
Inches	λ %	Inches	λ %
315	50.8%	206	33.3%
272	51.8%	175	33.3%
233	51.7%	150	33.3%
204	51.7%	132	33.4%

Specifications						
SWR	Ref Coef (db)	Rad Angle (deg)	Gain (dBi)	-3 dB BW (deg)	Structural Efficiency	Impedance
1.00	-54.8	18	0.33	28	99.4%	2442 - j 3.33
1.01	-50.0	18	0.60	28	99.4%	2463 + j 8.75
1.02	-40.4	18	0.79	27	99.5%	2404 + j 0.38
1.04	-33.8	18	0.96	27	99.5%	2353 - j 15.0

Averages: 51.5%

33.3%

1.02

-44.8

18

0.67

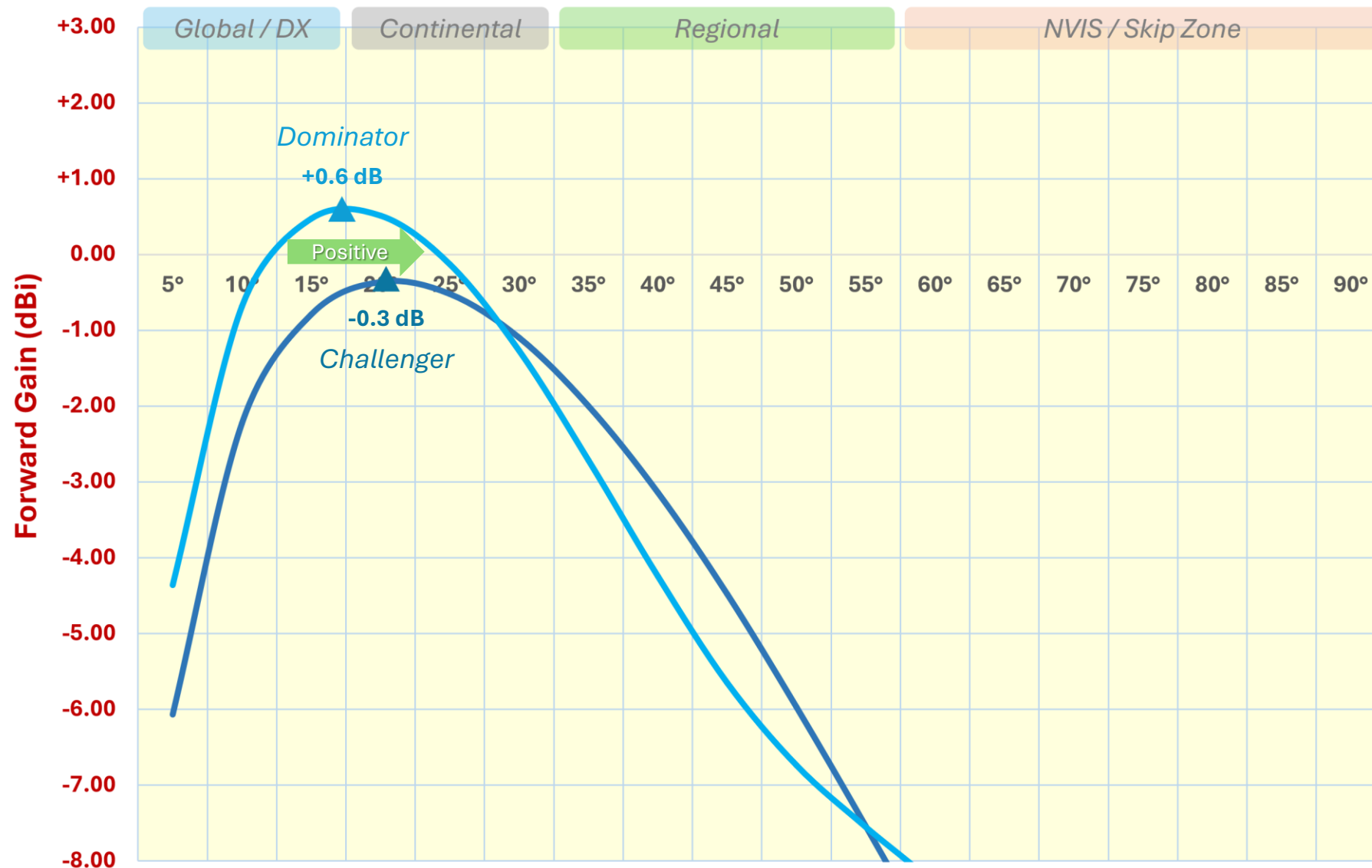
28

99.5%

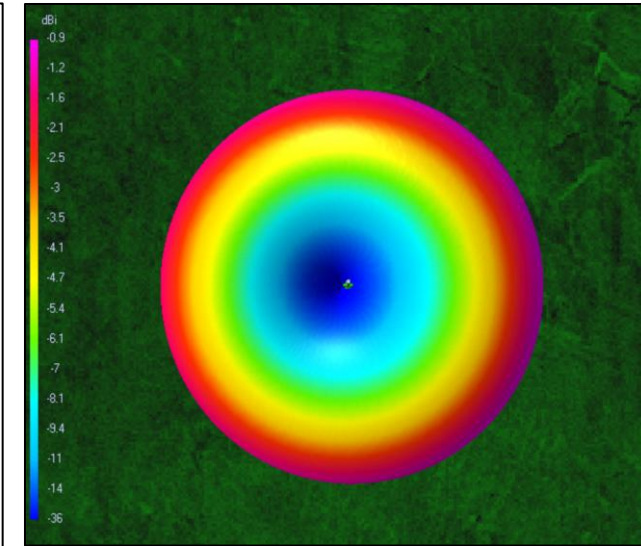
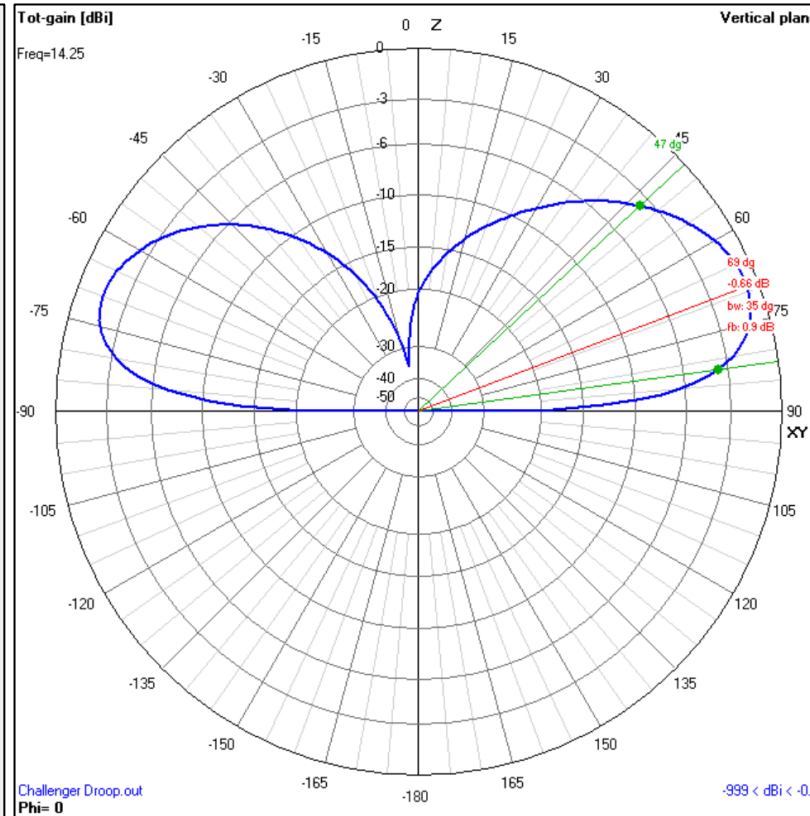
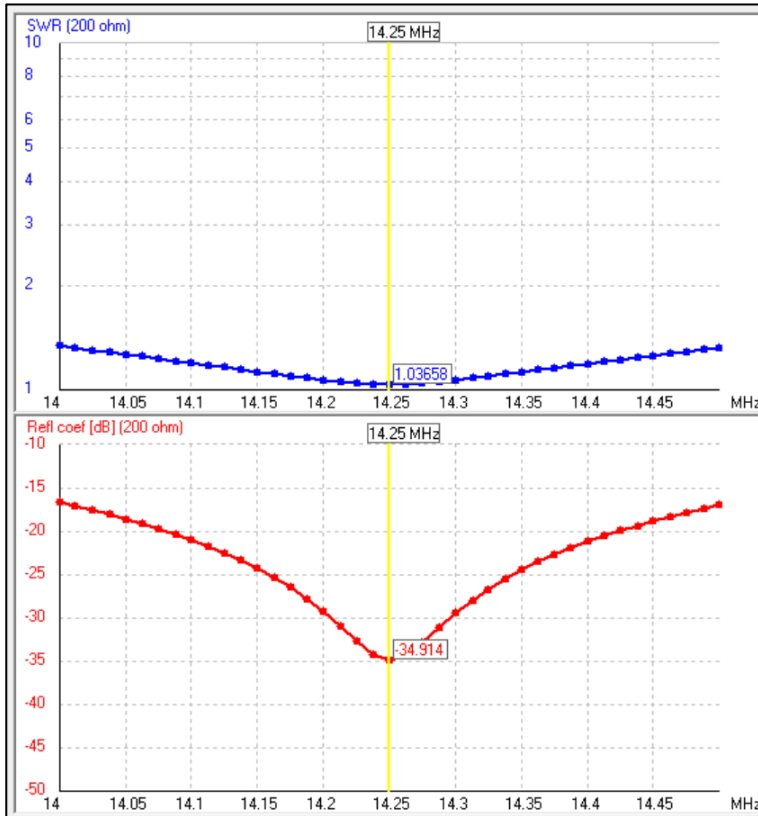
$Z = R + j X$

- The model computed several *performance* specifications including **SWR**, **reflection coefficient**, **peak radiation angle**, **gain**, **-3.00 dB beamwidth** as well as overall **antenna efficiency** and **impedance**.
- The *average* performance specifications *across all six bands* are:
 - ✓ Structural Efficiency = **99.5%**
 - ✓ EF Xformer Efficiency = **80.1% - 91.2%**
 - ✓ SWR= **1.02**, Ref. Coef. = **-44.8 dB**
 - ✓ Peak Radiation Gain = **+0.67 dBi**
 - ✓ Peak Radiation Angle = **18°** (*beamwidth* 7° - 35°)
 - ✓ -3.00 dB Beamwidth = **28°** (*delta* -11°, +17°)

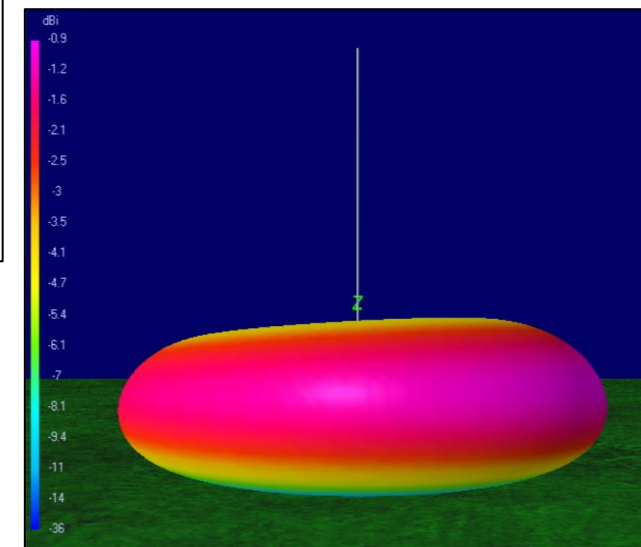
Challenger and Dominator Radiation Sweeps on the 15M Band



4NEC2 Model Graphics for the **Challenger**: 20M (14.250 MHz)



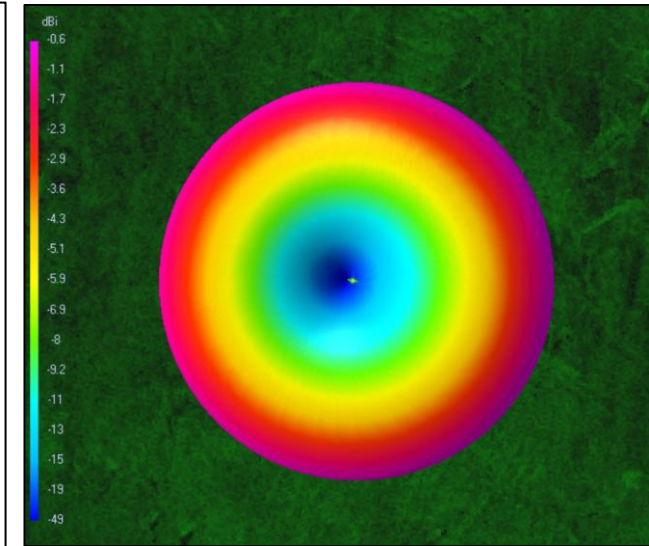
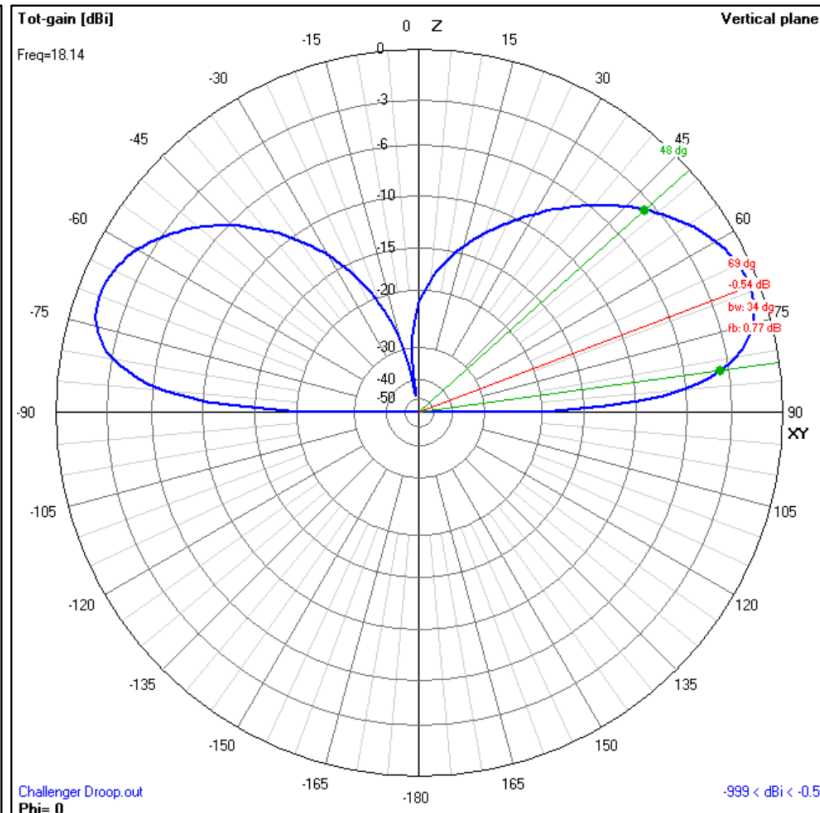
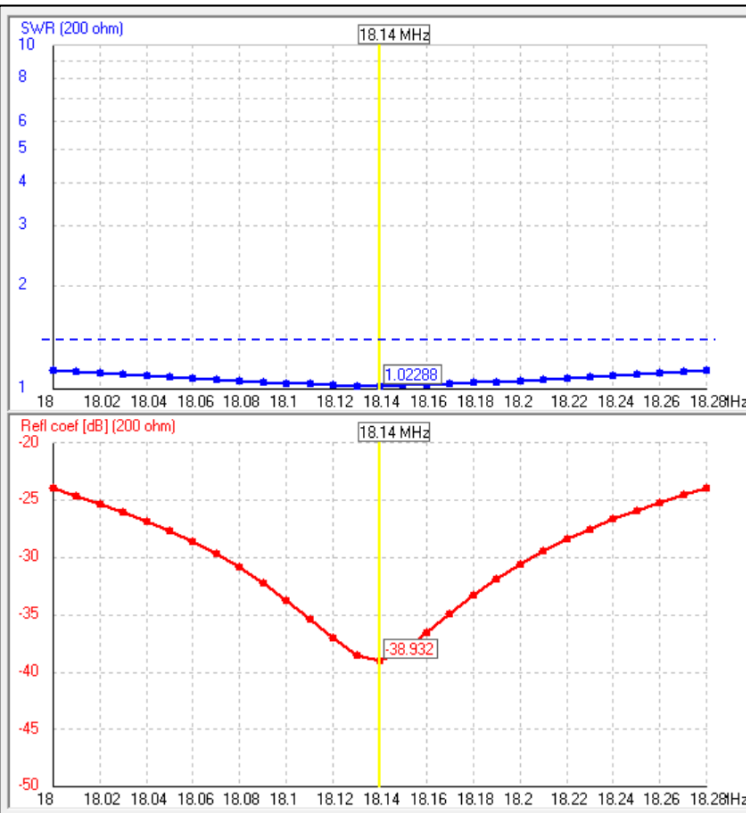
3D radiation modeling as seen from both the top and side views.



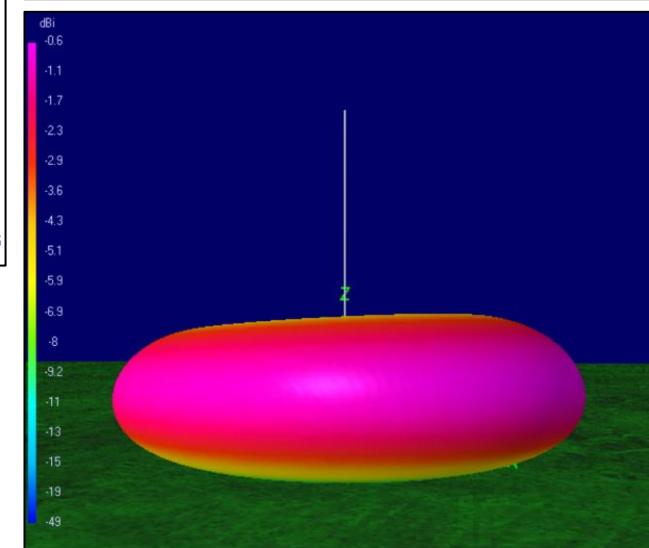
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.04:1** at **14.250 MHz** with a **reflection coefficient** of **-34.9 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 21°** with **-0.66 dBi gain** within a **-3dB beamwidth** of **35°** (-13° , $+22^\circ$) = **8° to 43°**.

4NEC2 Model Graphics for the **Challenger**: 17M (18.140 MHz)



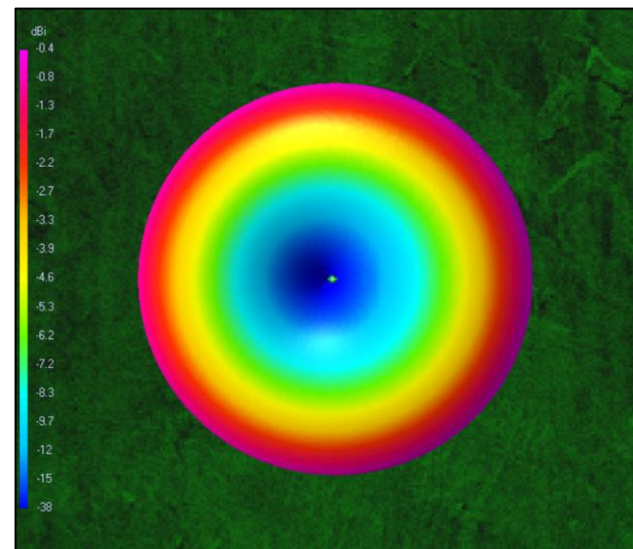
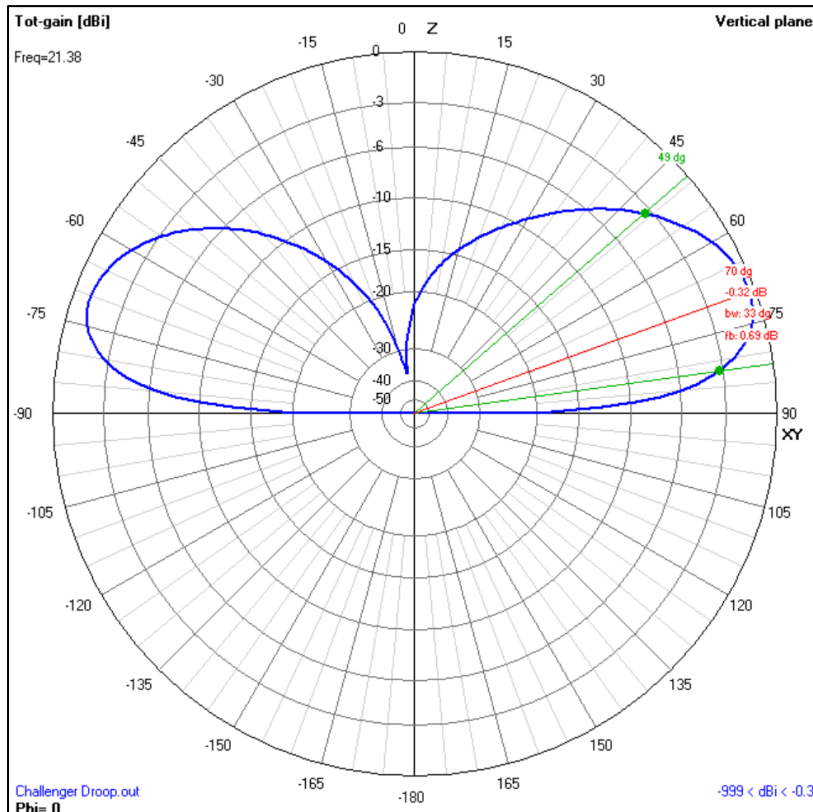
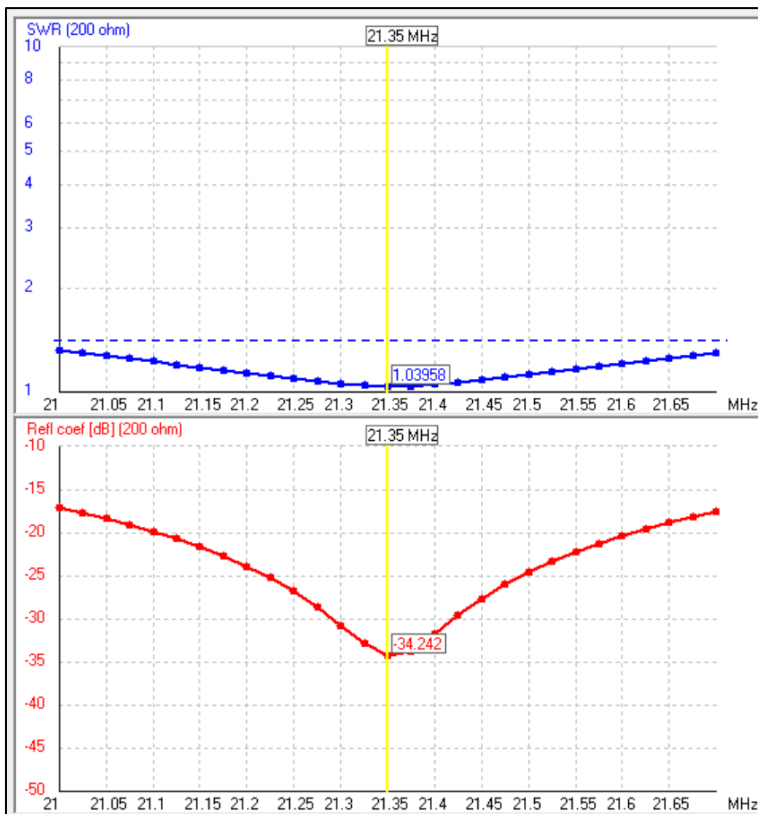
3D radiation modeling as seen from both the top and side views.



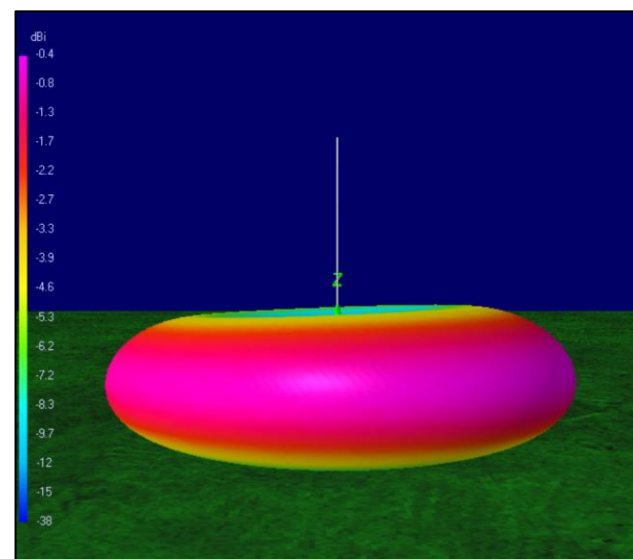
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.02:1** at **18.140 MHz** with a **reflection coefficient** of **-38.9 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 21°** with **-0.54 dBi gain** within a **-3dB beamwidth** of **34°** (-13° , $+21^\circ$) = **8° to 42°**.

4NEC2 Model Graphics for the **Challenger**: 15M (21.350 MHz)



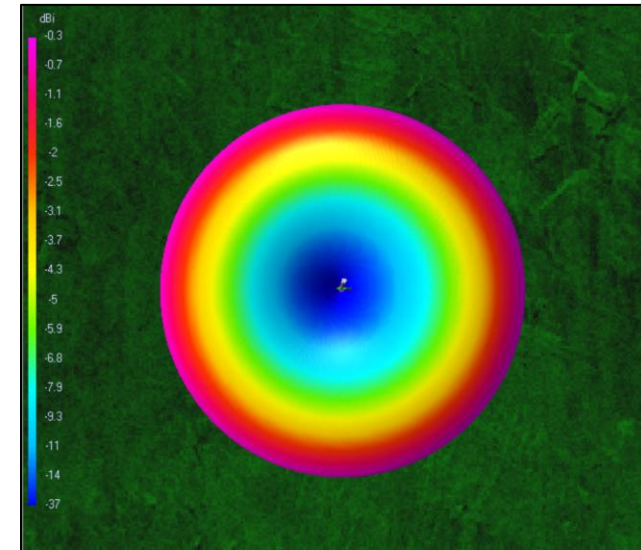
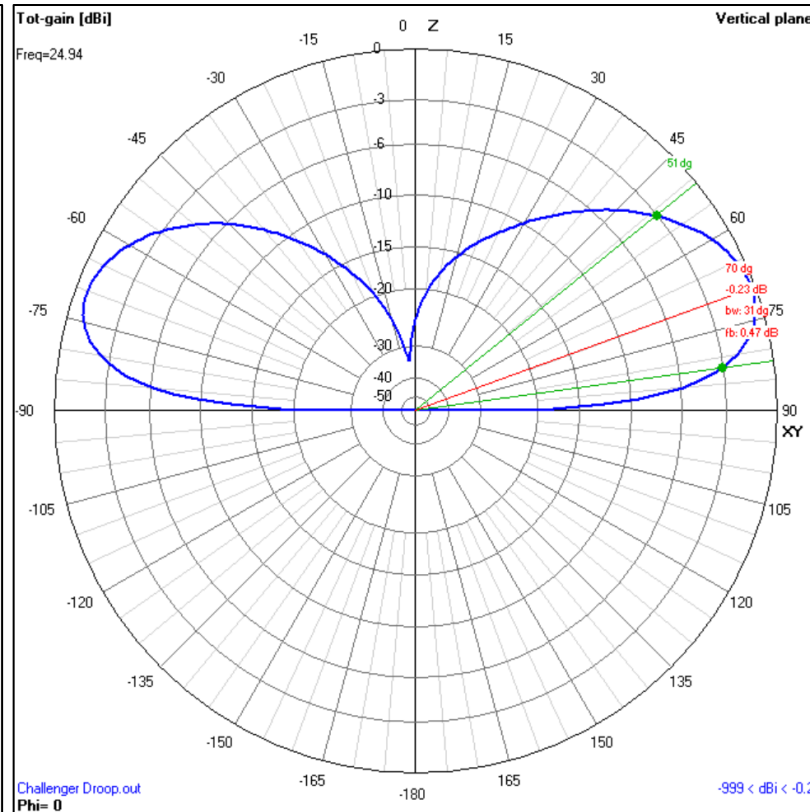
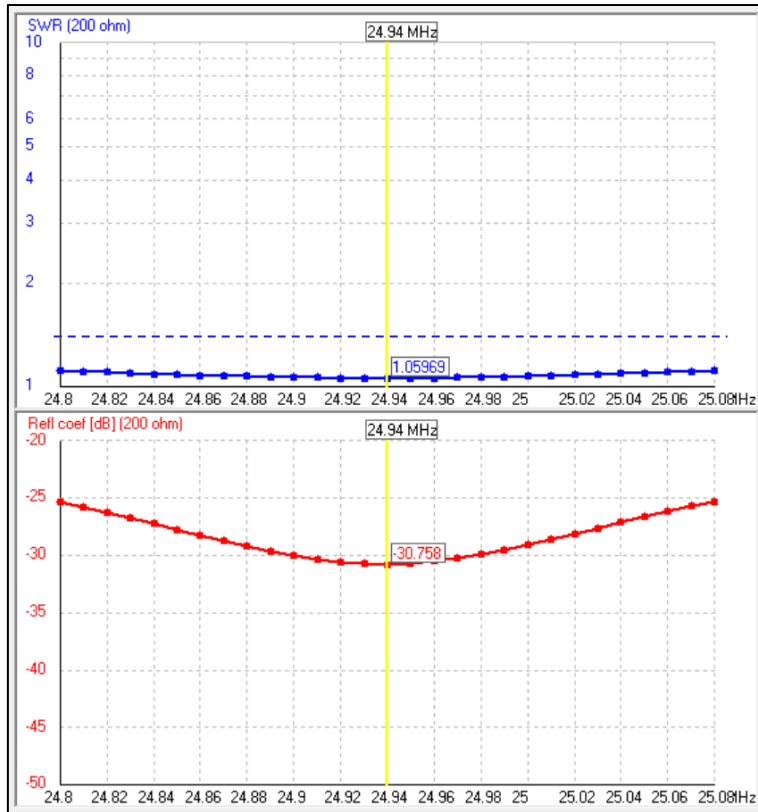
3D radiation modeling as seen from both the top and side views.



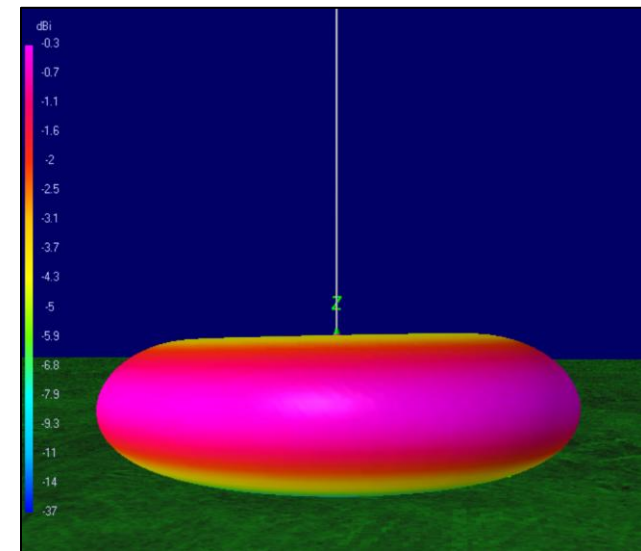
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.04:1** at **21.350 MHz** with a **reflection coefficient** of **-34.2 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 20°** with **-0.32 dBi gain** within a **-3dB beamwidth** of **33°** (-13° , $+20^\circ$) = **8° to 41°**.

4NEC2 Model Graphics for the **Challenger**: 12M (24.940 MHz)



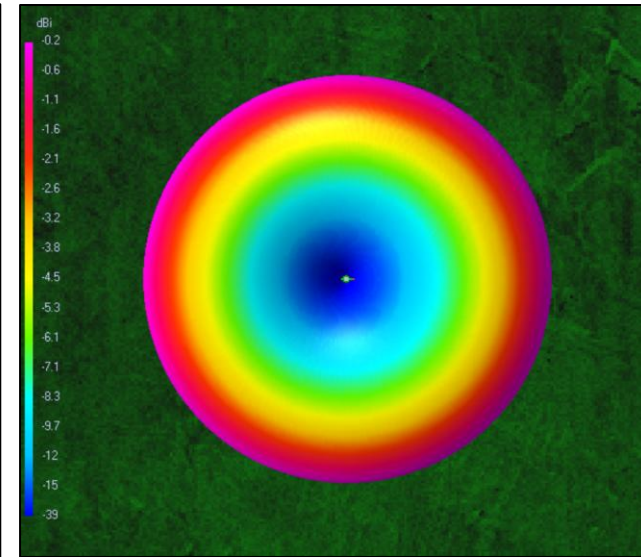
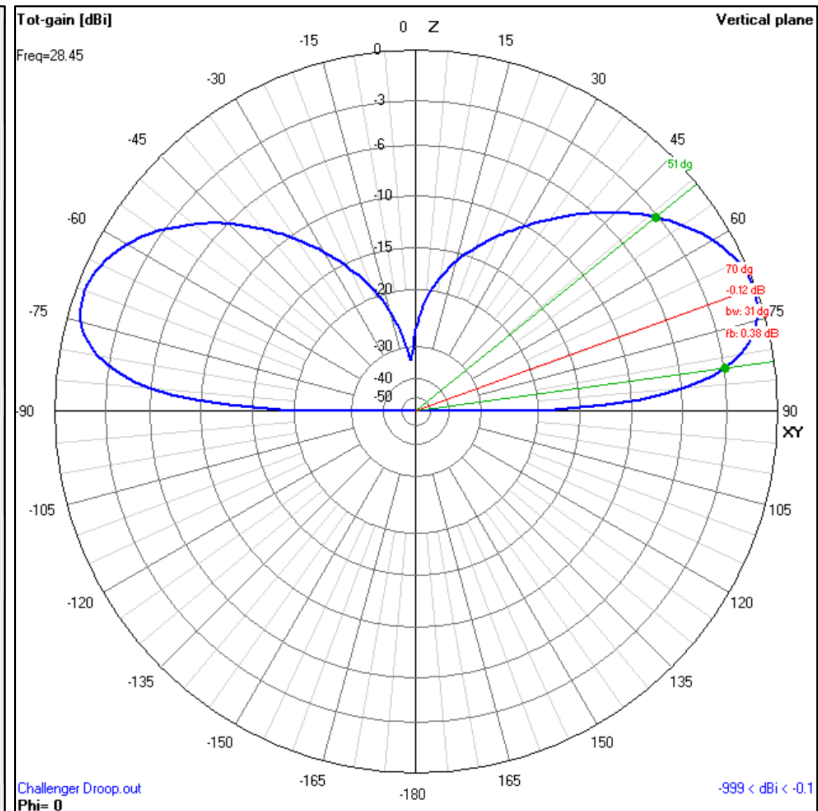
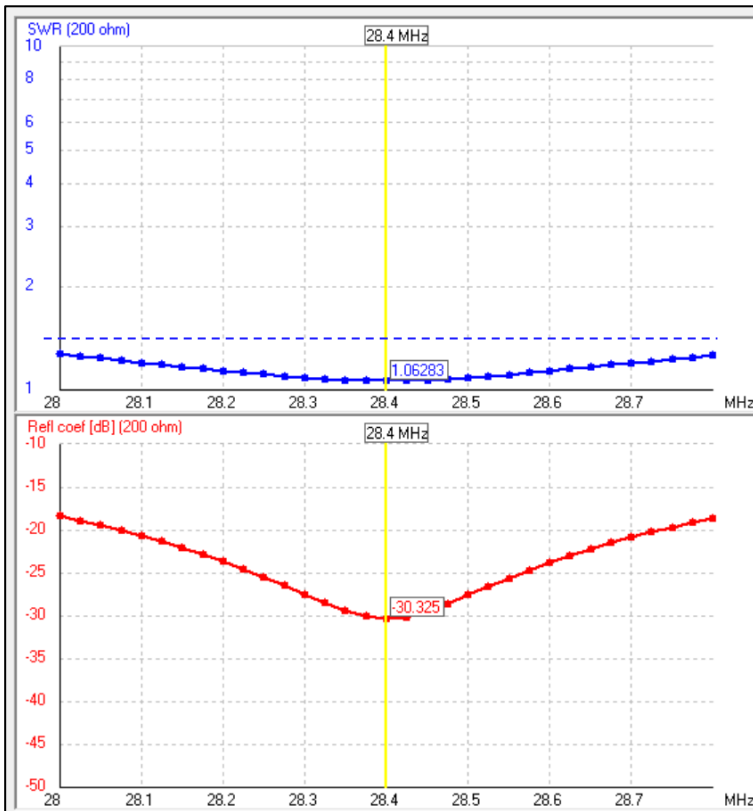
3D radiation modeling as seen from both the top and side views.



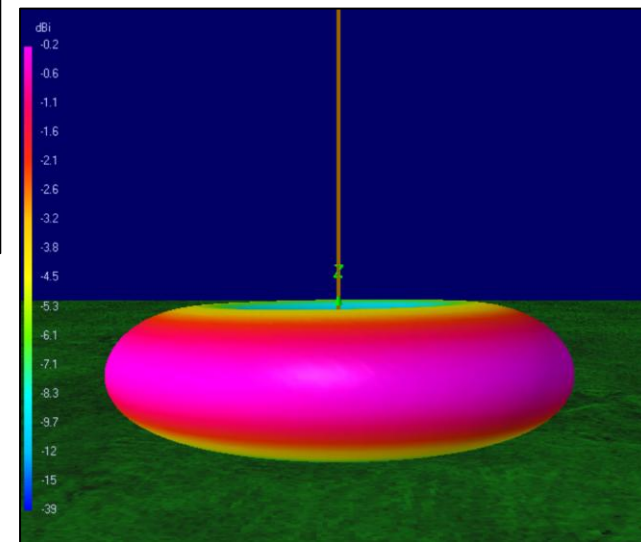
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.06:1** at **24.940 MHz** with a **reflection coefficient** of **-30.8 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 20°** with **-0.23 dBi gain** within a **-3dB beamwidth** of **31°** ($-12^\circ, +19^\circ$) = **8° to 39°**.

4NEC2 Model Graphics for the **Challenger**: 10M (28.400 MHz)



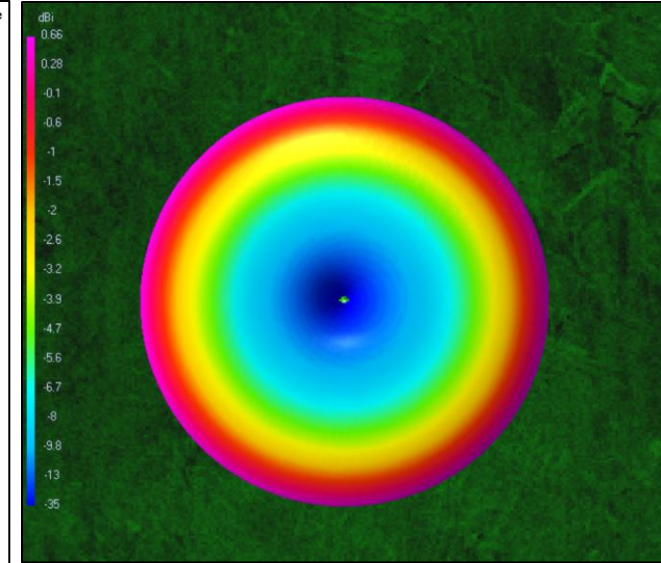
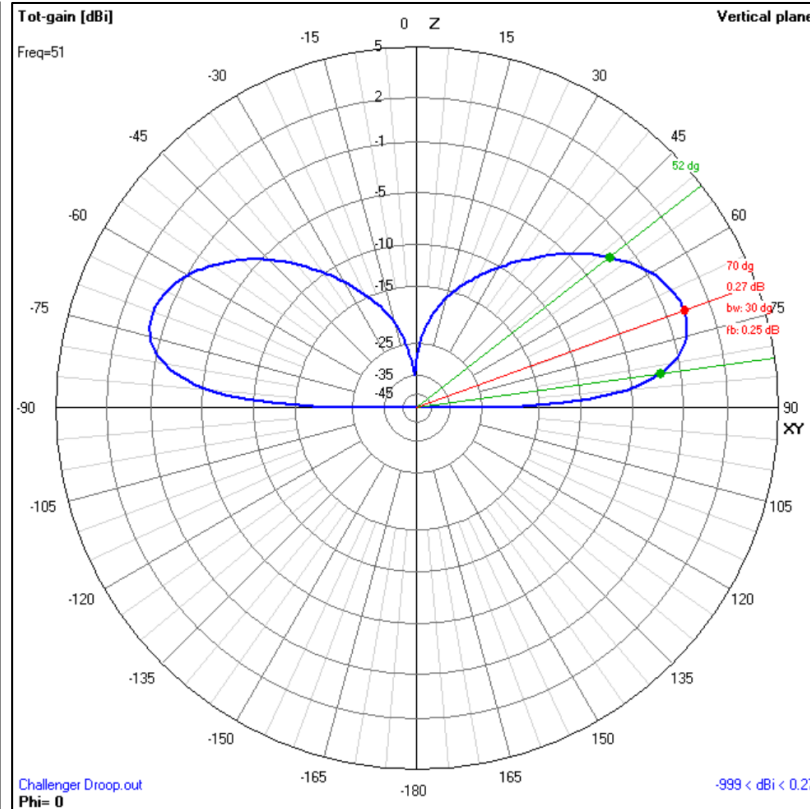
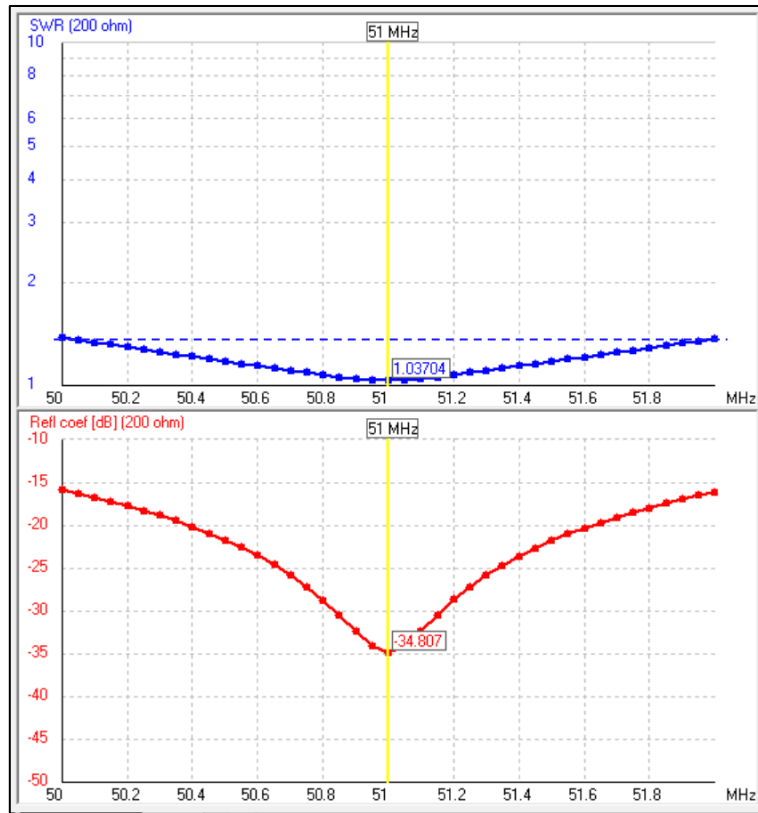
3D radiation modeling as seen from both the top and side views.



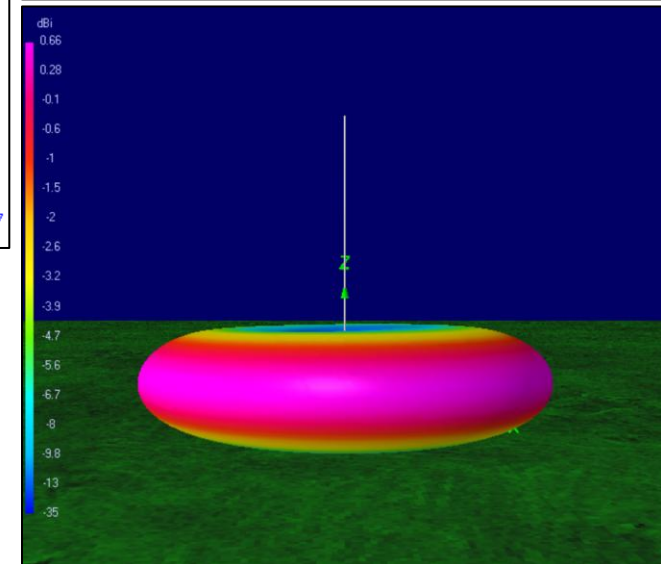
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.06:1** at **28.400 MHz** with a **reflection coefficient** of **-30.3 dB**. The $\pm 1.50:1$ SWR bandwidth is **1000 kHz**.
- It also calculated **maximum radiation** at **angle 20°** with **-0.12 dBi gain** within a **-3dB beamwidth** of **31°** ($-12^\circ, +19^\circ$) = **8° to 39°**.

4NEC2 Model Graphics for the **Challenger: 6M** (51.000 MHz)



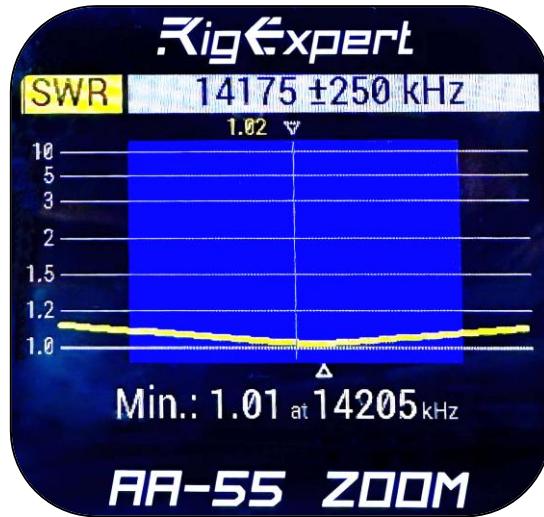
3D radiation modeling as seen from both the top and side views.



Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.04:1** at **51.000 MHz** with a **reflection coefficient** of **-34.8 dB**. The $\pm 1.50:1$ SWR bandwidth is **2000 kHz**.
- It also calculated **maximum radiation** at **angle 20°** with **+0.27 dBi gain** within a **-3dB beamwidth** of **30°** (-12° , $+18^\circ$) = **8° to 38°**.

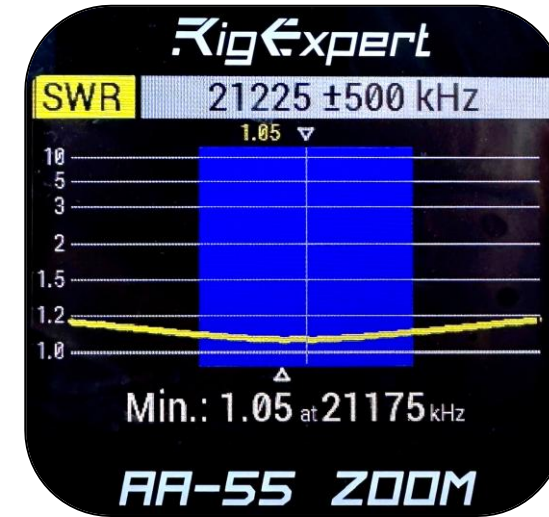
Field SWR Measurements for the Challenger: 20M-6M



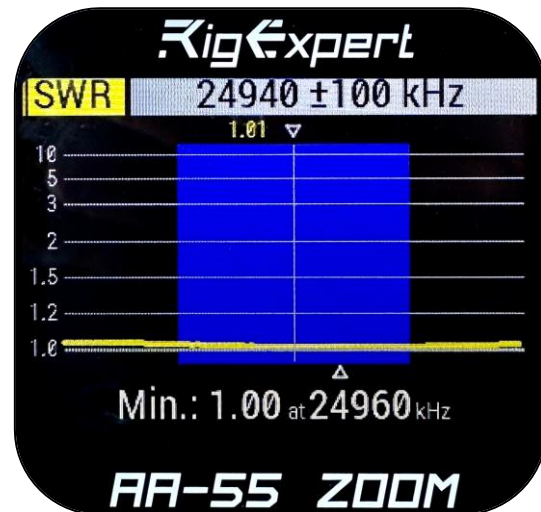
20M Band



17M Band



15M Band



12M Band



10M Band



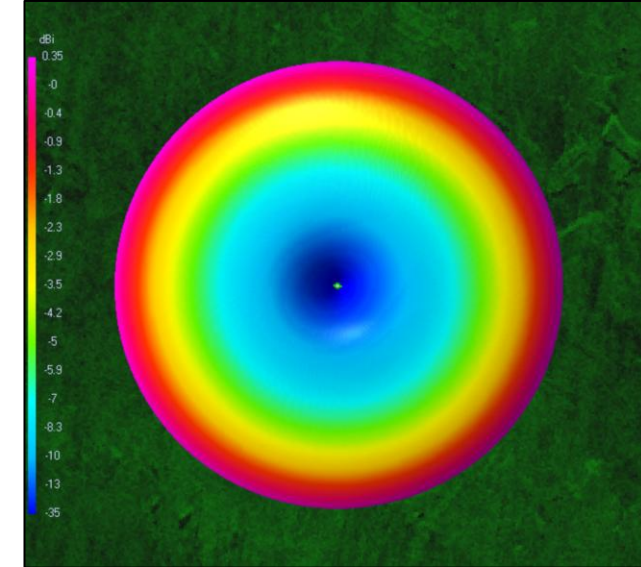
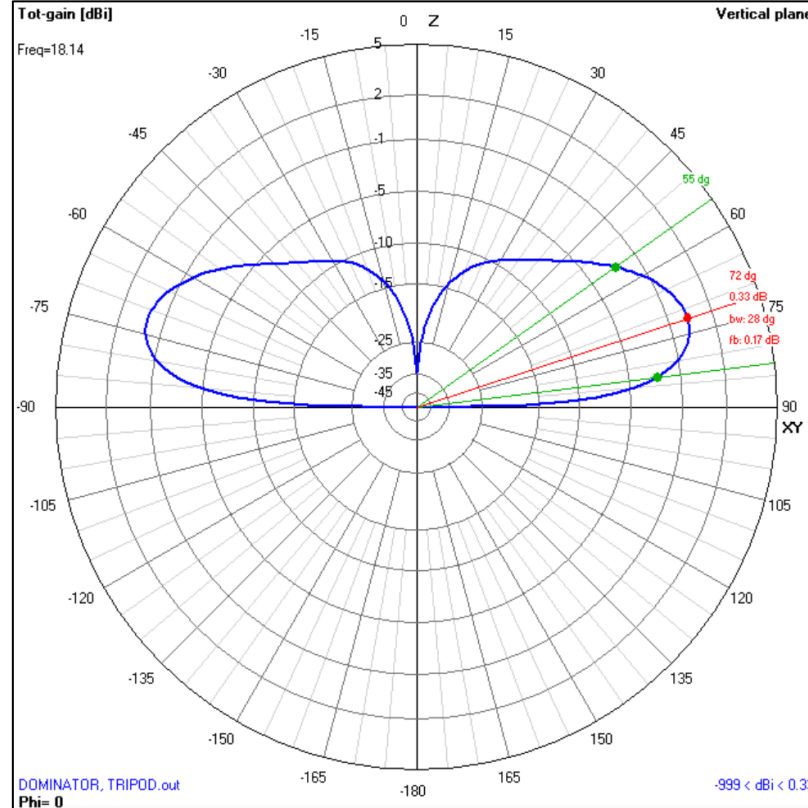
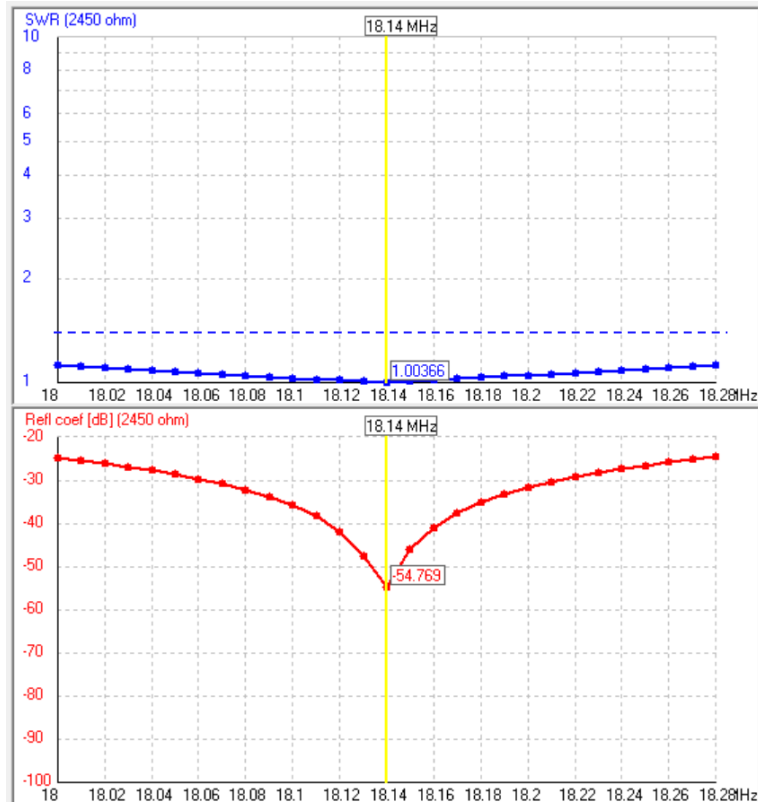
6M Band

SWR Matching:

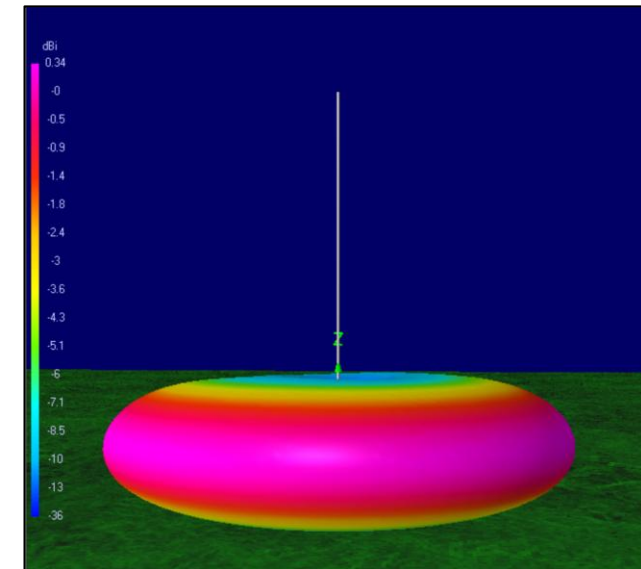
- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

Note: A 17' whip instead of a 25' whip covers 17M-6M.

4NEC2 Model Graphics for the Dominator: 17M (18.140 MHz)



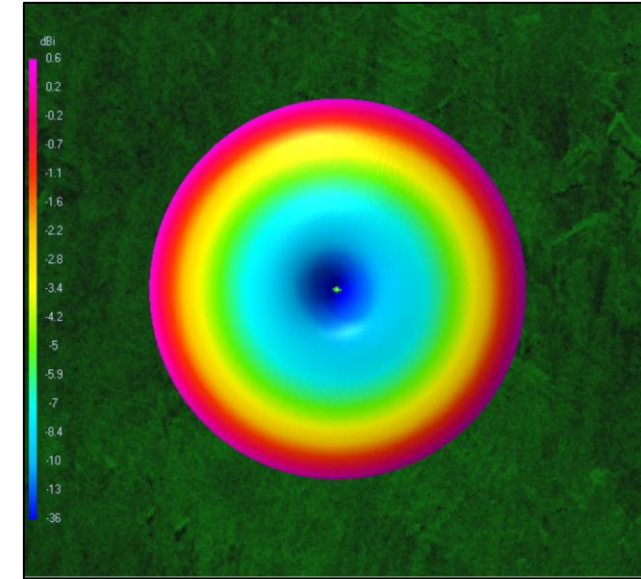
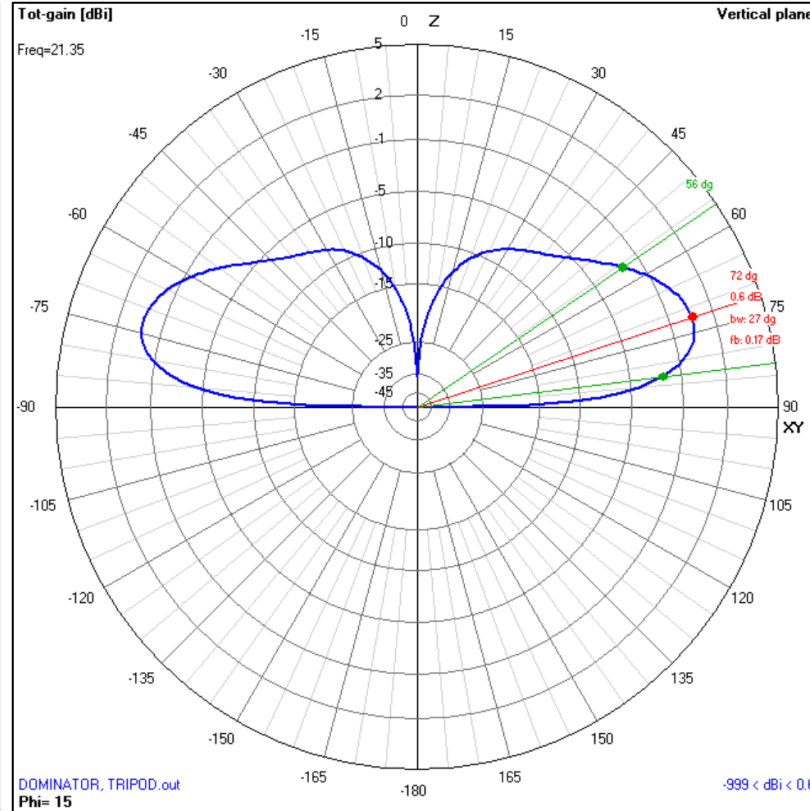
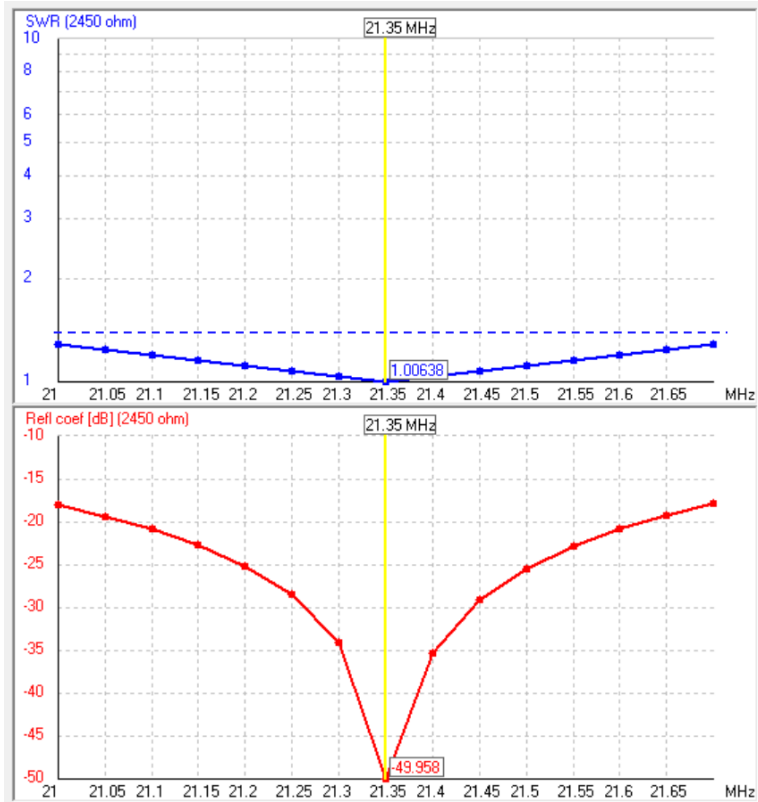
3D radiation modeling as seen from both the top and side views.



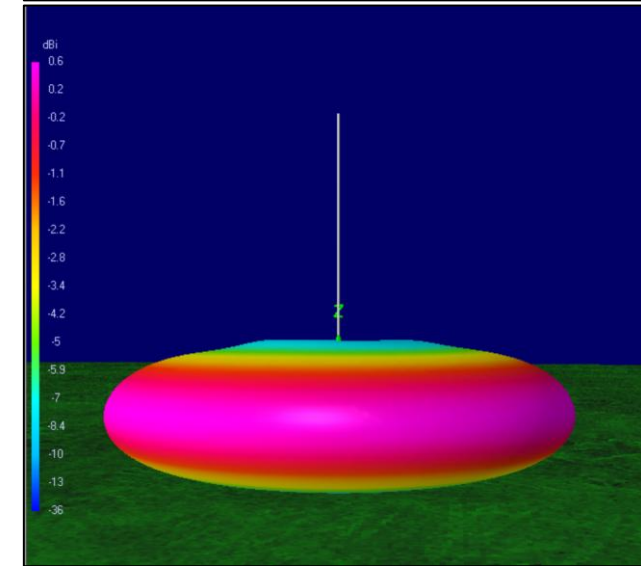
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.00:1** at **18.140 MHz** with a **reflection coefficient** of **-54.8 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 18°** with **+0.33 dBi gain** within a **-3dB beamwidth** of **28°** ($-11^\circ, +17^\circ$) = **7° to 35°**.

4NEC2 Model Graphics for the Dominator: 15M (21.350 MHz)



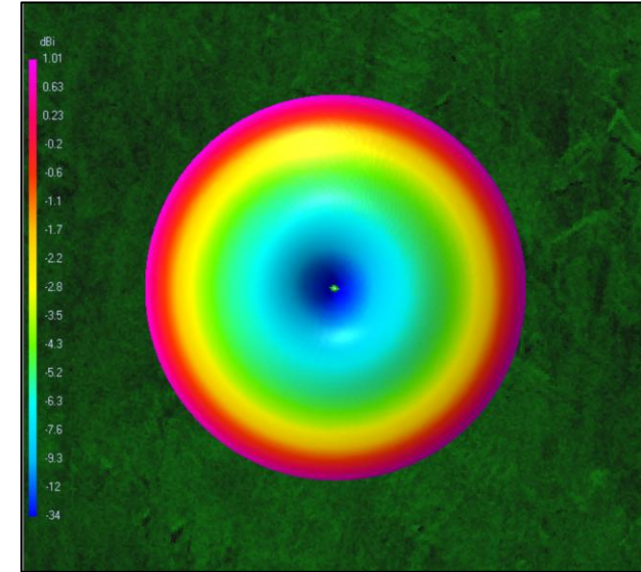
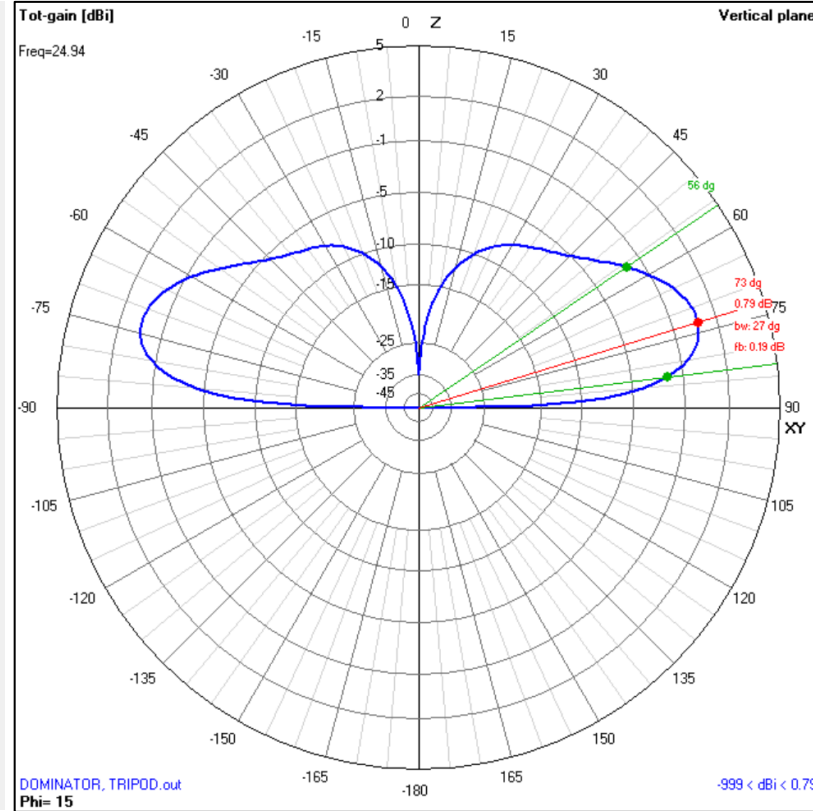
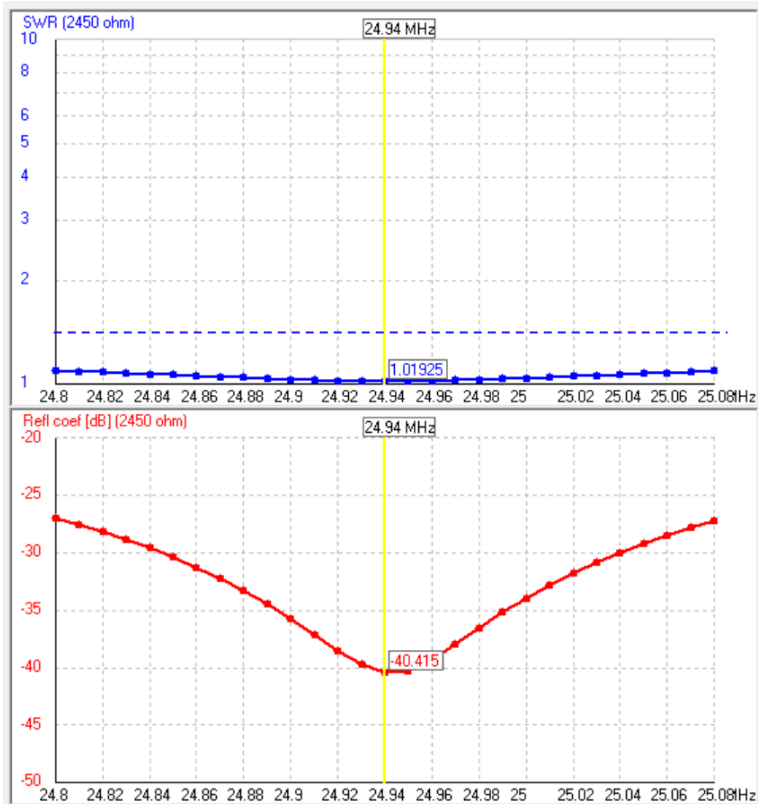
3D radiation modeling as seen from both the top and side views.



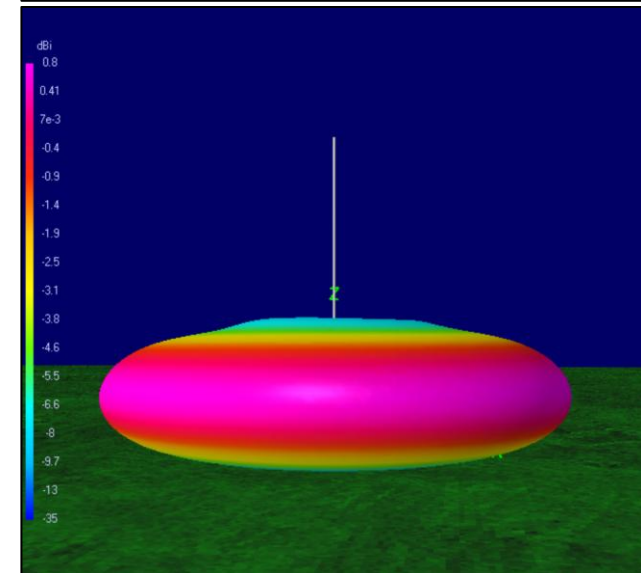
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.01:1** at **21.350 MHz** with a **reflection coefficient** of **-50.0 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 18°** with **+0.60 dBi gain** within a **-3dB beamwidth** of **27°** ($-11^\circ, +17^\circ$) = **7° to 34°**.

4NEC2 Model Graphics for the Dominator: 12M (24.940 MHz)



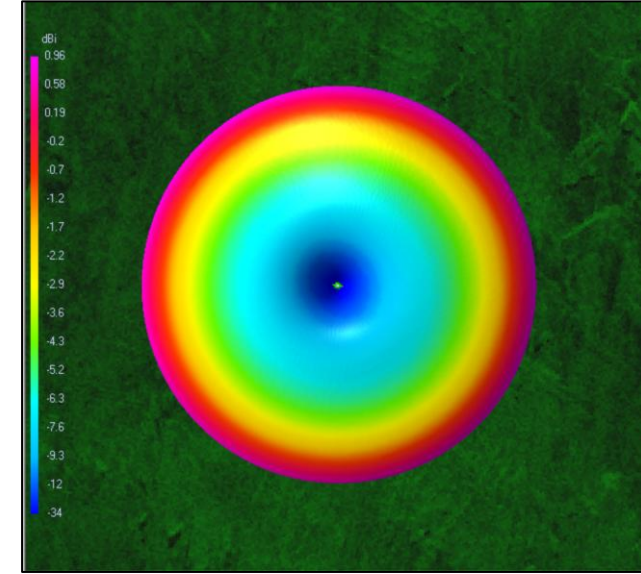
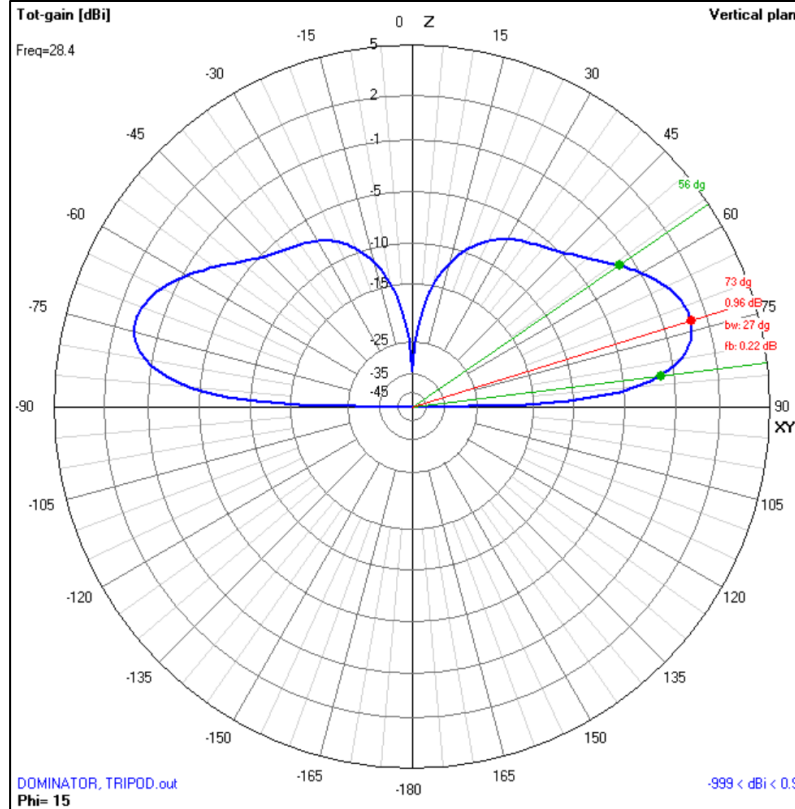
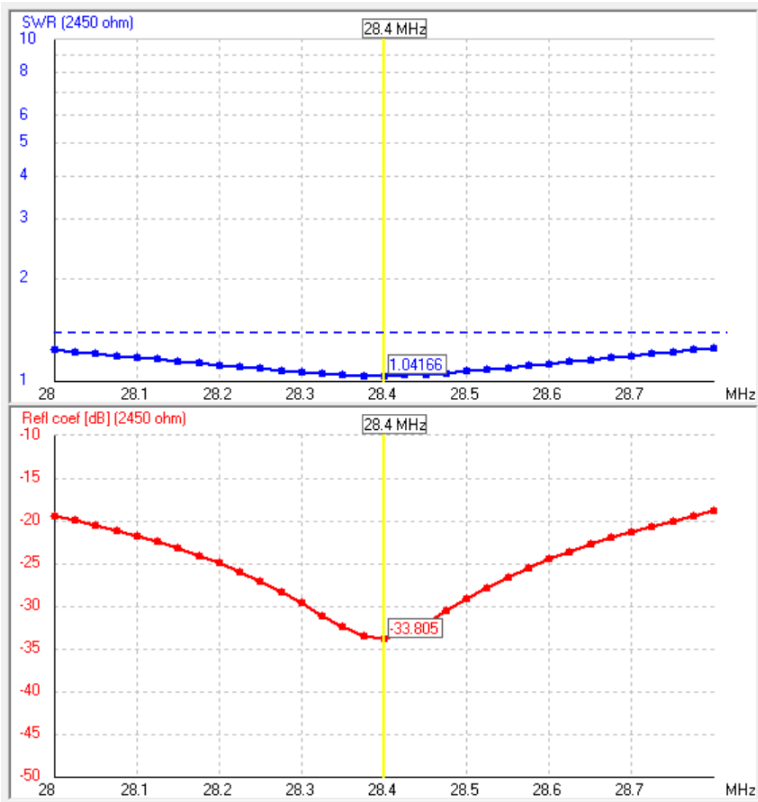
3D radiation modeling as seen from both the top and side views.



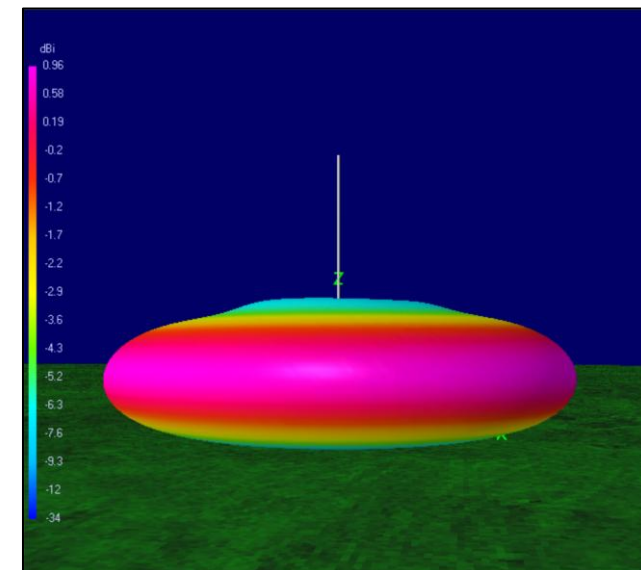
Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.02:1** at **24.940 MHz** with a **reflection coefficient** of **-40.4 dB**. The $\pm 1.50:1$ SWR bandwidth covers *the band*.
- It also calculated **maximum radiation** at **angle 18°** with **+0.79 dBi gain** within a **-3dB beamwidth** of **27°** ($-11^\circ, +16^\circ$) = **7° to 34°**.

4NEC2 Model Graphics for the Dominator: 10M (28.400 MHz)



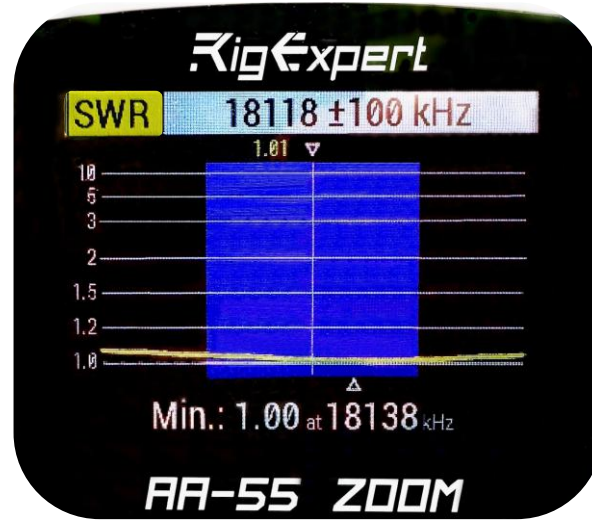
3D radiation modeling as seen from both the top and side views.



Note that **purple** and **red** are strongest radiation.

- The model calculated **SWR** to be **1.04:1** at **28.400 MHz** with a **reflection coefficient** of **-33.8 dB**. The $\pm 1.50:1$ SWR bandwidth is **1200 kHz**.
- It also calculated **maximum radiation** at **angle 18°** with **+0.96 dBi gain** within a **-3dB beamwidth** of **27°** (-11° , $+16^\circ$) = **7° to 34°**.

Field SWR Measurements for the Dominator: 17M-10M



17M Band



15M Band



12M Band



10M Band

SWR Matching:

- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

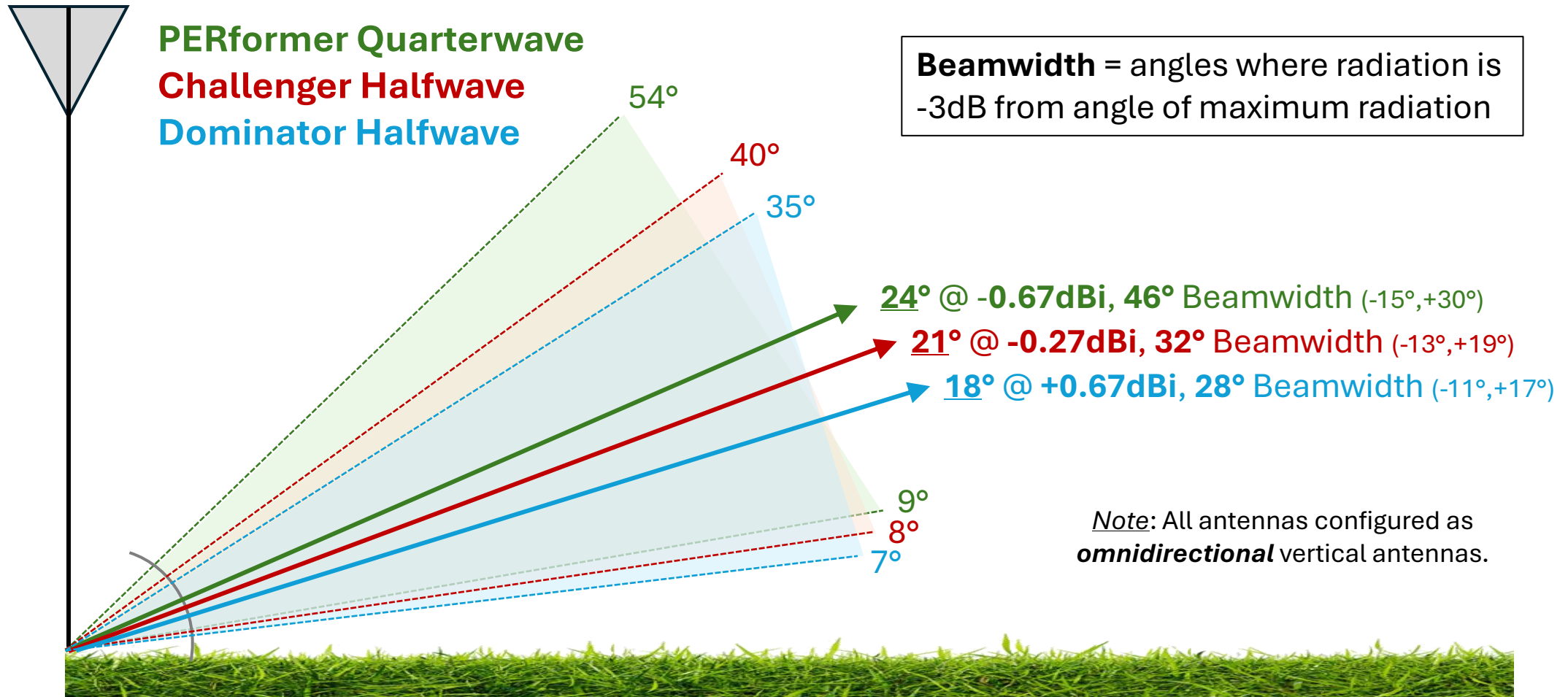
Note: A 17' whip instead of a 25' whip covers 12M-10M.

Summary: Comparing the **PERformer, Challenger and Dominator Vertical Antennas**

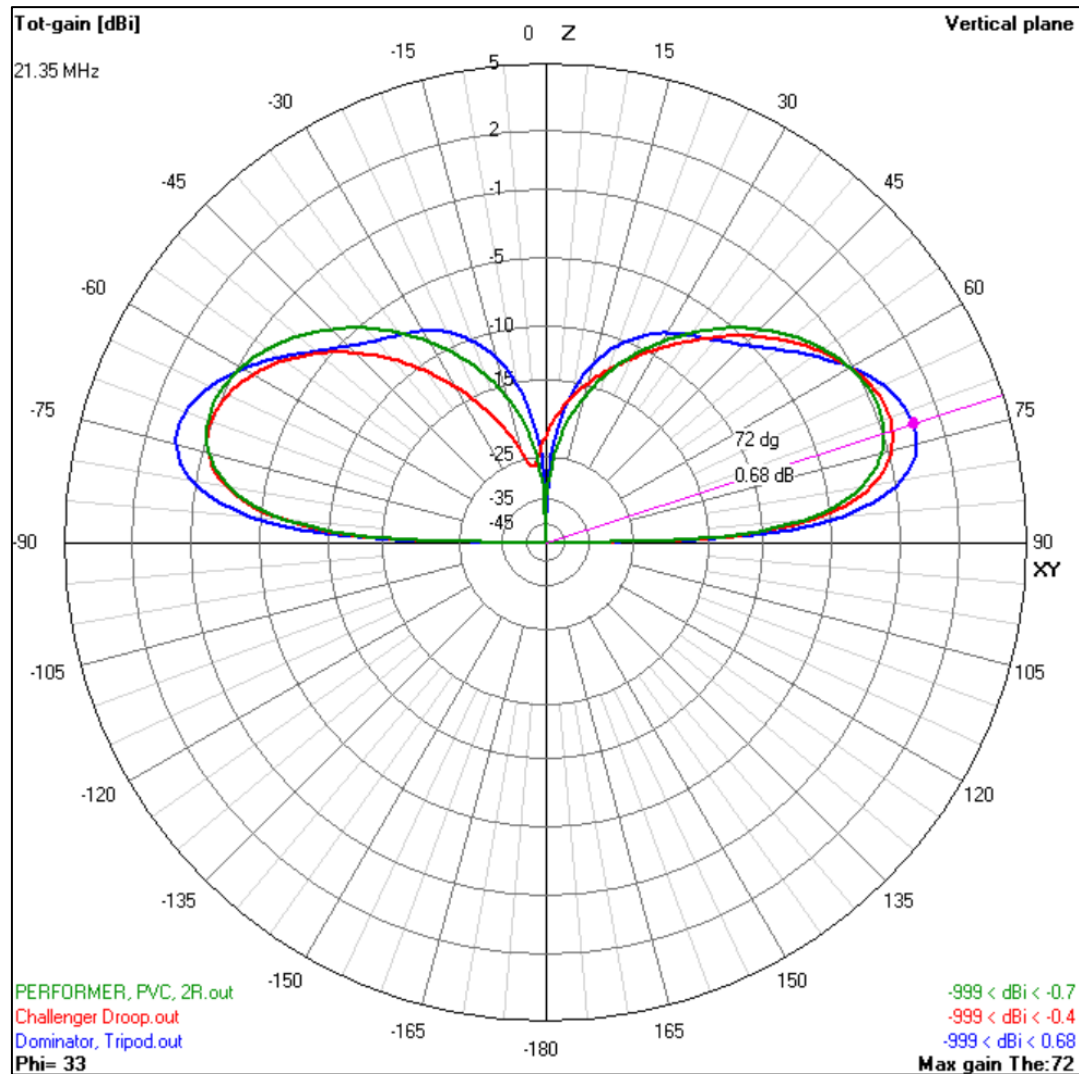
Comparing PERformer, Challenger and Dominator Antennas

Specifications	PERformer	Challenger	Dominator
Vertical Wavelength	• Quarterwave	• Halfwave	• Halfwave
Antenna Configuration	• Omni/Directional • 2 Elevated Tuned Linked Radials 90/180° apart	• Omnidirectional • 1 Linked Counterpoise, ~10% λ per band	• Omnidirectional • 1 Linked Counterpoise, ~33% λ per band
Band Coverage	• 40M-6M	• 20M-6M	• 17M-10M
Structural Efficiency	• 90.8%	• 94.3%	• 99.5%
50 Ω Impedance Match	• ---	• 4:1 Unun Off-Center Fed	• 49/56:1 Xformer End-Fed
Key Component Loss	• -0.12 dB (<i>toroid choke only</i>)	• -0.46 to -0.35 dB	• -1.08 to -0.51 dB
Peak Radiation	• -0.67 dBi / +0.41 dBi	• -0.27 dBi	• +0.67 dBi
Angle of Peak Radiation (-3 dB BW)	• 24° (9° to 54°)	• 21° (8° to 40°)	• 18° (7° to 35°)
-3.00 dB Beamwidth	• 46° (-15°, +30°)	• 32° (-13°, +19°)	• 28° (-11°, +17°)
Primary Reach	• Regional, Continental	• Continental, Global	• Global

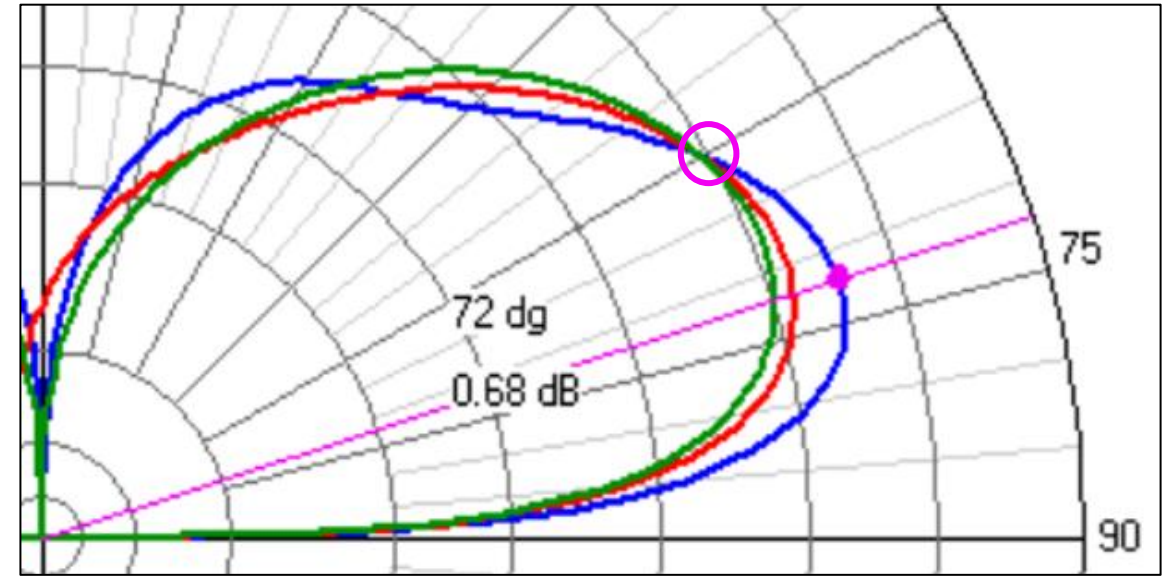
Comparing Max Radiation Angles and Beamwidths



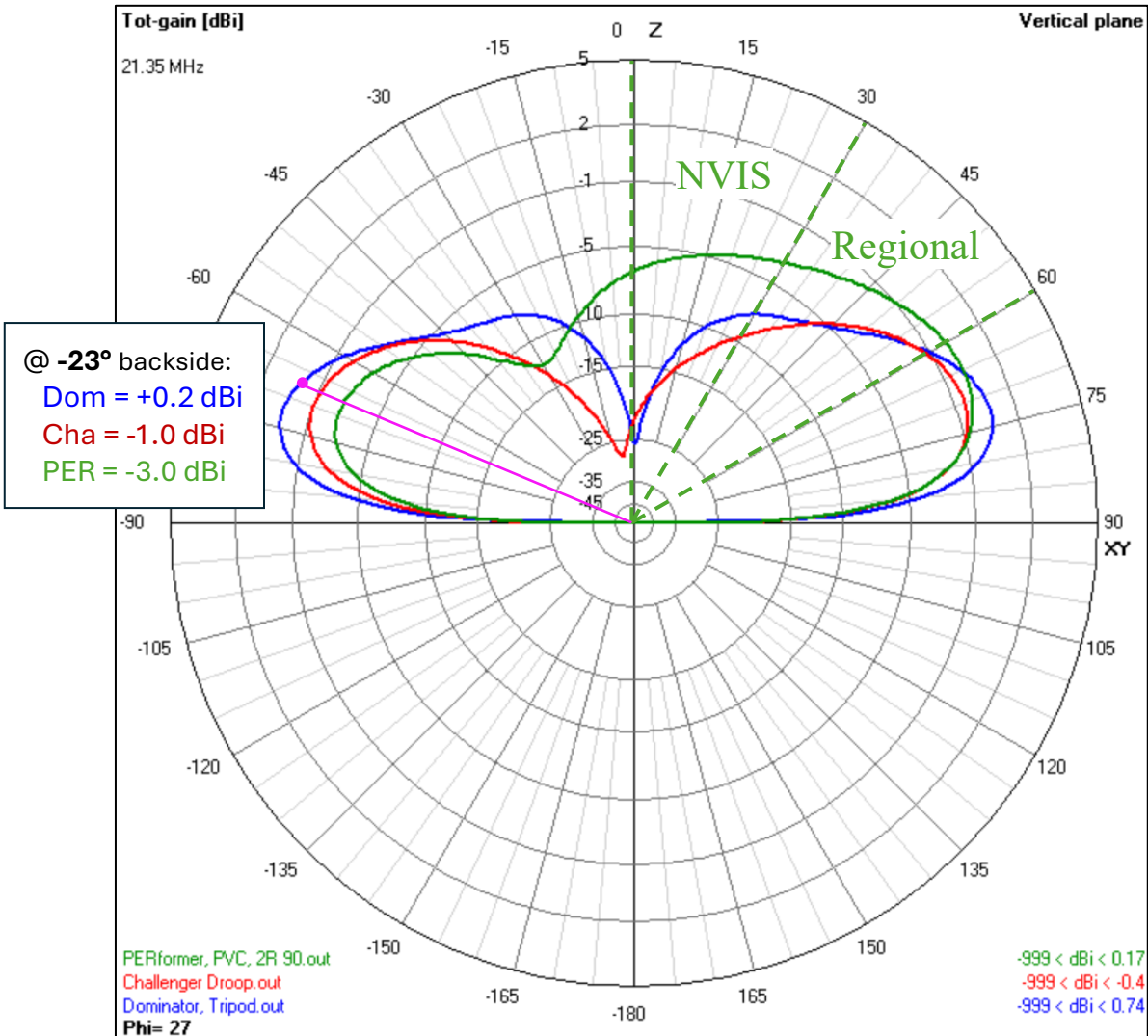
Comparing Omnidirectional Radiation Patterns of 3 Antennas



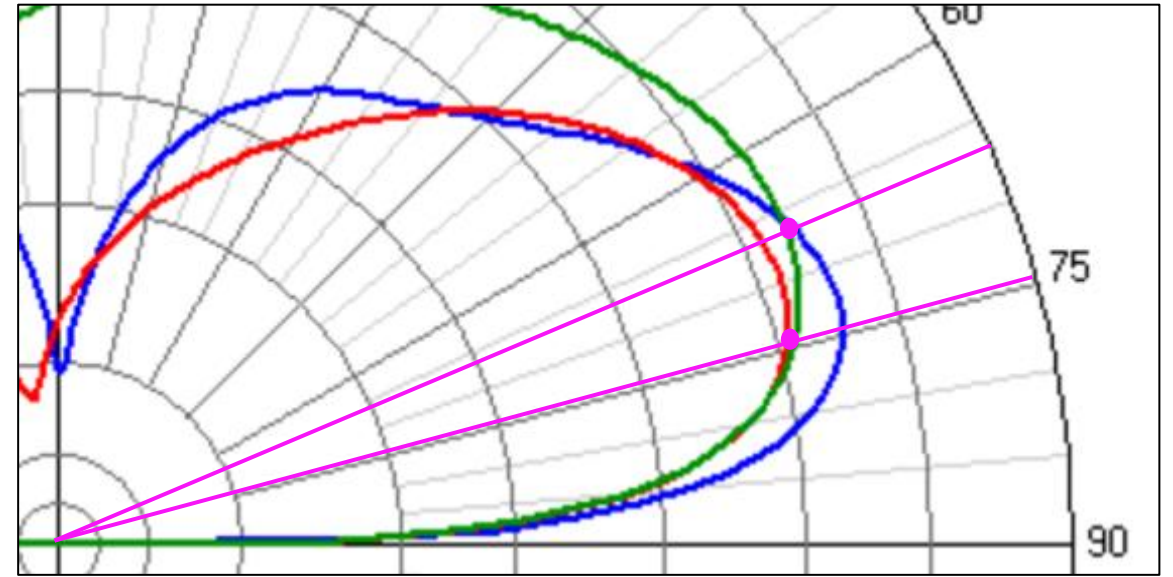
- Looking at the **far field** radiation patterns of all three antennas on **15M** (21.350 MHz): **PERformer** quarterwave, **Challenger** halfwave and **Dominator** halfwave.
- Comparing **radiated gain** at **18°** off the horizon: **Dominator: +0.68 dBi**, **Challenger: -0.32 dBi**, **PERformer: -1.00 dBi**.



Comparing Directional PERformer: Radial Span @ 90°



- Looking at the **far field** radiation patterns of all three antennas on **15M** (21.350 MHz): **PERformer** Directional Radial Span, **Challenger** halfwave and **Dominator** halfwave.
- Comparing **radiated gain**, **PERformer** exceeds **Challenger** @ **16°** off the horizon and exceeds **Dominator** @ **23°** off the horizon.



Comparing PERformer, Challenger and Dominator Antennas

- All three vertical antennas are actively used in the field because each has its own **best use case**. Considering all performance specifications, ***one antenna is not necessarily better than the other.***

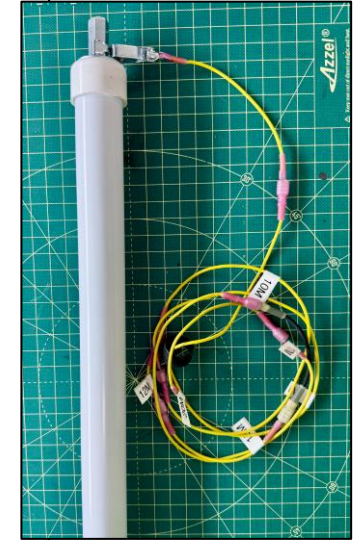
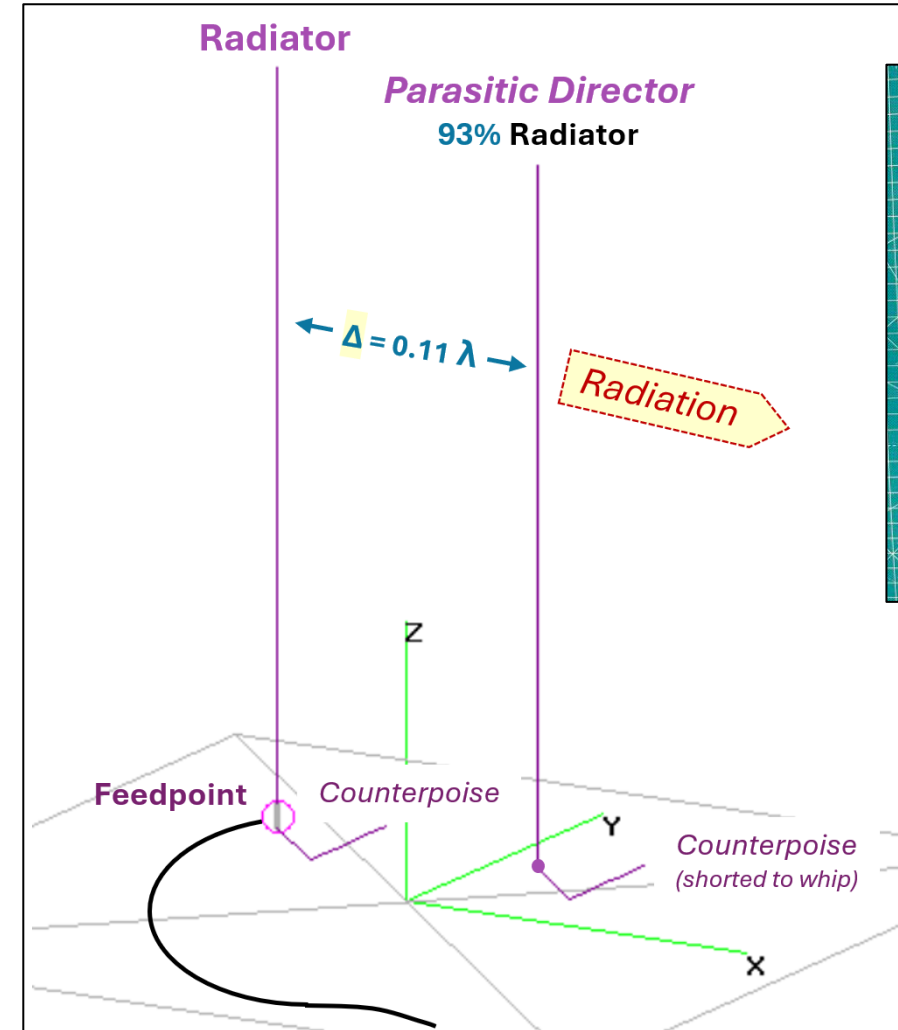
All Three Antennas	PERformer Quarterwave (40M-6M)	Challenger OCF Halfwave (20M-6M)	Dominator EF Halfwave (17M-10M)
• 90%+ structural efficiency • Less than 5 minutes deployment • Easy to pack and transport	• 40M resonance unlike other two antennas • Directional option with 3 dB+ f-to-b • Best antenna for 30°-60° regional coverage	• 94%+ highest radiation efficiency • 20M and 6M halfwave resonance • Best antenna for balanced coverage	• 18° lowest angle of radiation • Strongest maximum radiation of +0.67 dBi • Best antenna for 5°-20° global coverage

2- Element Parasitic ChallengerArray Quarterwave Vertical Antenna System



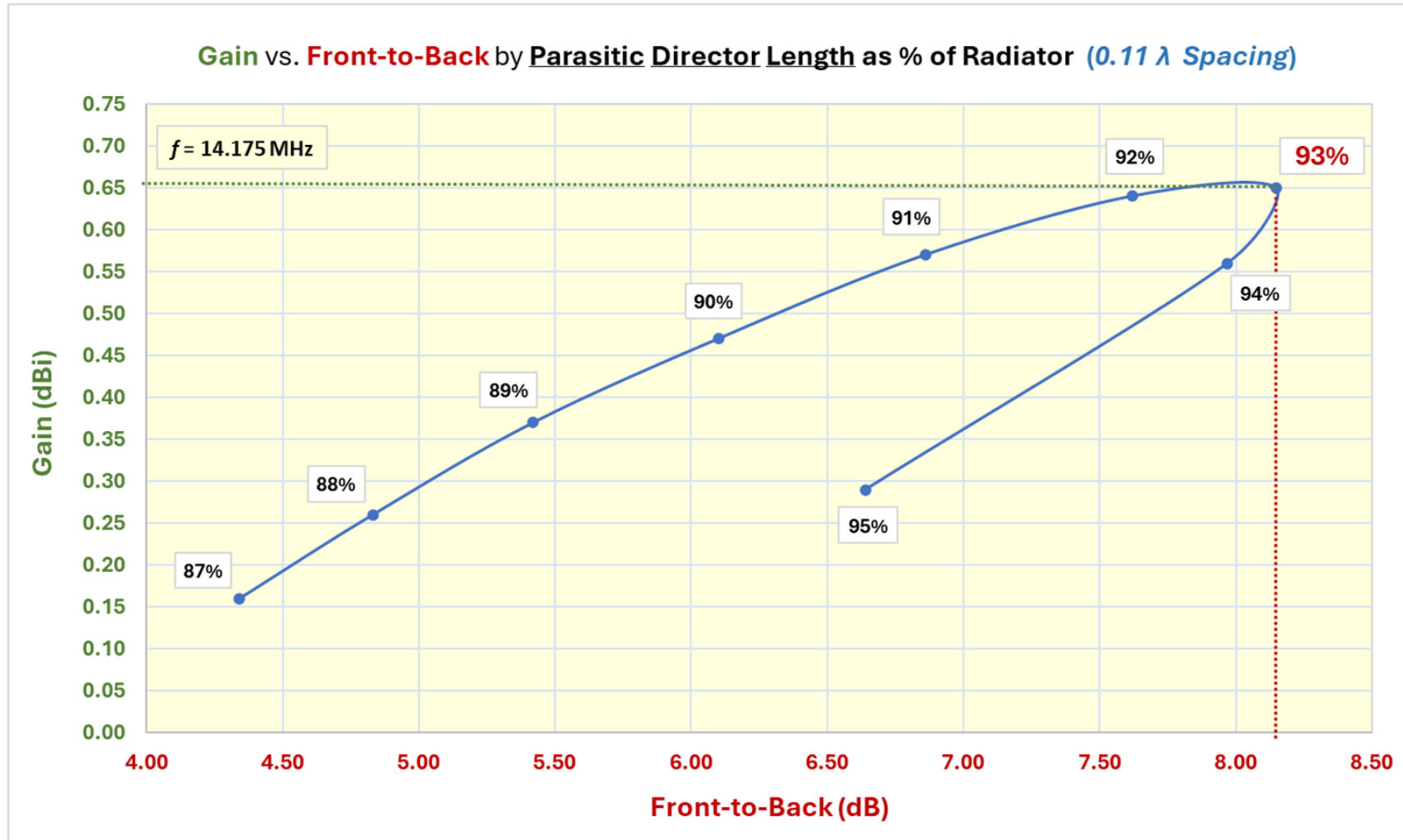
2-Element Parasitic Challenger Array (20M-6M)

- A **parasitic antenna array** uses a single driven element (*radiator* connected to the feedline) and another *parasitic* element (not connected to the feedline) as a *director* or *reflector*.
- A **parasitic element**, based upon its **proximity** and **dimensions**, interacts with the *electromagnetic field* of the driven element through mutual coupling, influencing the *radiation pattern* to increase **gain** and **directivity**.



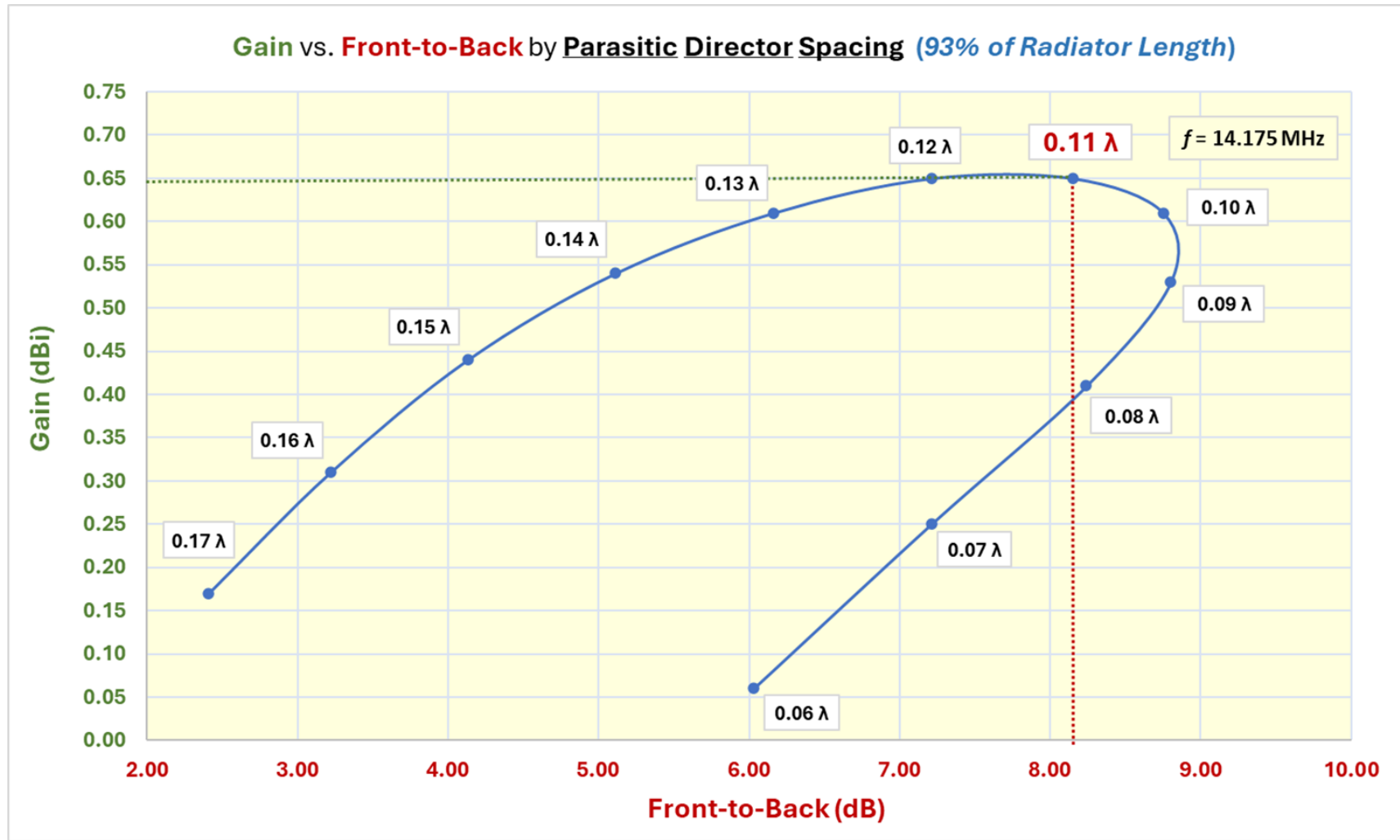
- Parasitic director counterpoise shorted to its telescoping whip

2-Element Parasitic Challenger Array Director Length



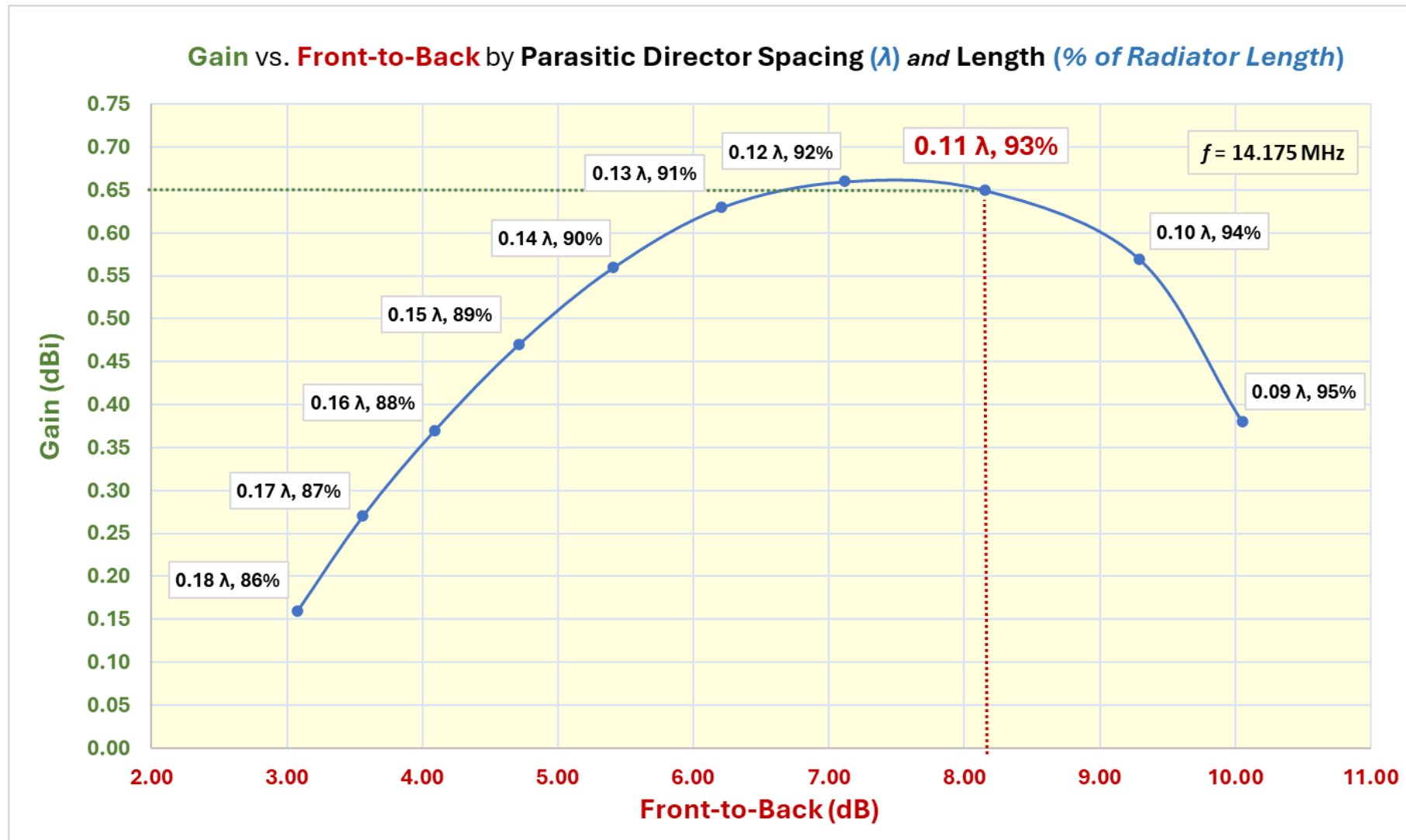
- Gain versus **Front-to-Back** by **Parasitic Director Length**
- As a % of Driven Radiator Length

2-Element Parasitic Challenger Array Director Spacing



- Gain versus Front-to-Back by Parasitic Director Spacing
- When Director is 93% of Radiator

2-Element Parasitic Challenger Array Director Length / Spacing



2-Element Parasitic Challenger Array Performance Specifications

Traditional Calculations			
Band	Band Center (MHz)	468 / f	
		Feet	Inches
20M	14.175	33.0	396
17M	18.118	25.8	310
15M	21.225	22.0	265
12M	24.940	18.8	225
10M	28.850	16.2	195
6M	52.000	9.0	108

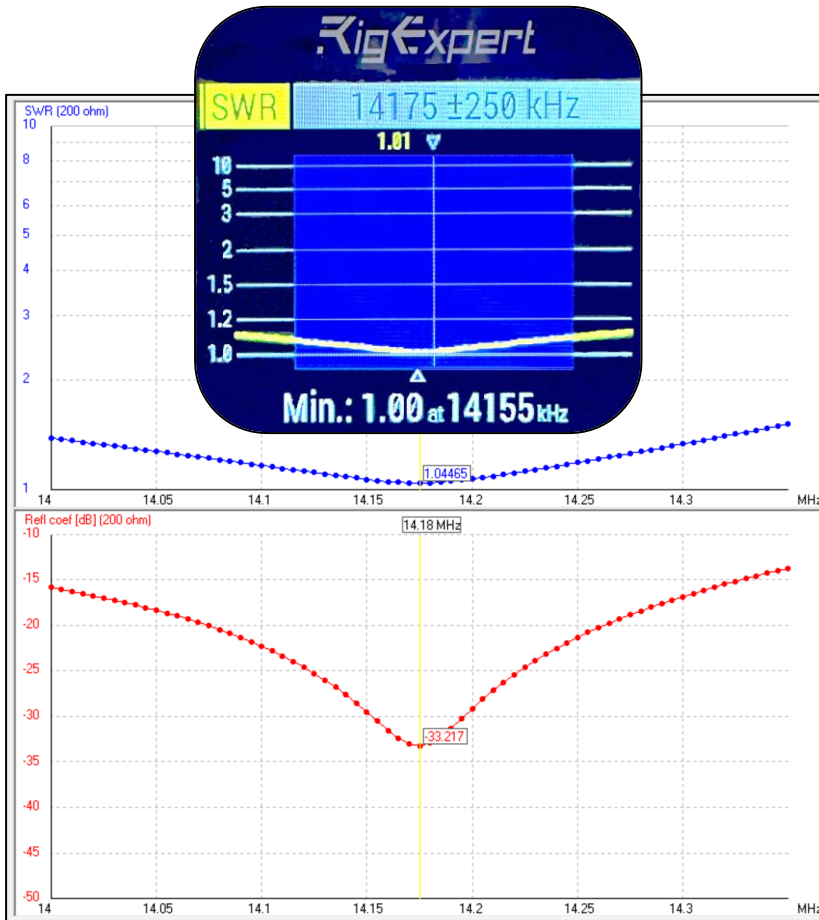
Field Measurements															
Radiator				Spacing				Parasitic				Counterpoise			
Inches	Ft	In	% λ	% λ Physical	Inches	Ft	In	% Rad	Inches	Ft	In	Rel to Rad (In)	Inches	Incr. Seg.	% λ
271	22	7	34.2%	11%	91.63	7	8	93%	252	21	0	-19	69	6	8.7%
208	17	4	33.6%	11%	71.69	6	0	93%	194	16	2	-15	63	14	10.2%
183	15	3	34.6%	11%	61.20	5	1	93%	170	14	2	-13	49	5	9.3%
157	13	1	34.9%	11%	52.08	4	4	93%	146	12	2	-11	44	2	9.8%
132	11	0	34.0%	11%	45.02	3	9	93%	123	10	3	-9	42	14	10.8%
73	6	1	33.9%	11%	24.98	2	1	93%	68	5	8	-5	28	28	13.0%

Band	Band Center (MHz)	468 / f	
		Feet	Inches
20M	14.175	33.0	396
17M	18.118	25.8	310
15M	21.225	22.0	265
12M	24.940	18.8	225
10M	28.850	16.2	195
6M	52.000	9.0	108

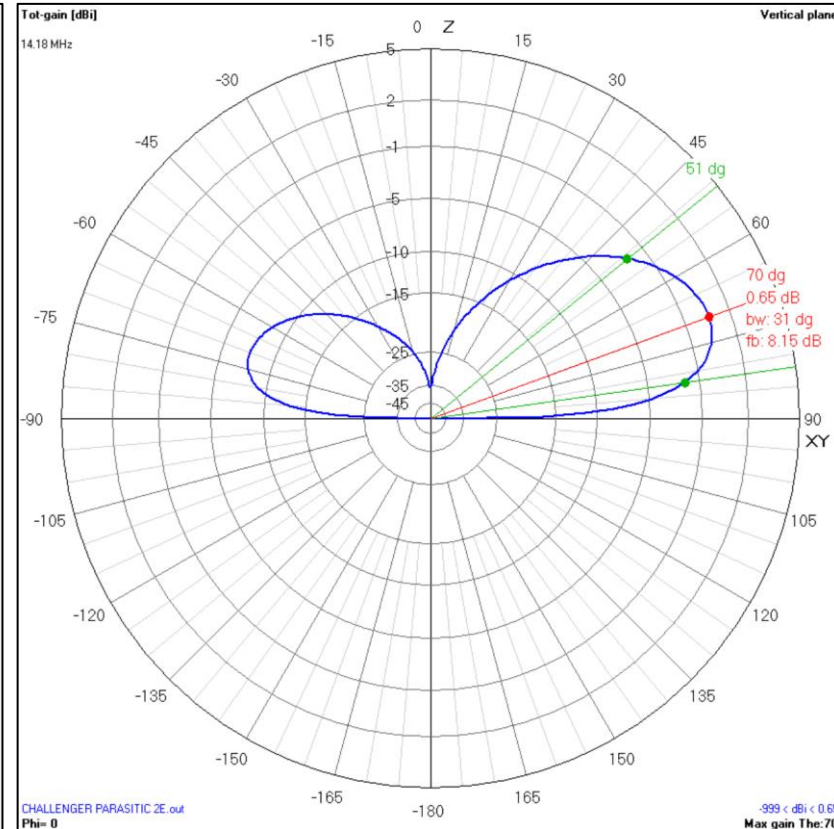
Specifications											
SWR	Ref Coef (db)	Rad Angle (deg)	Gain 2E (dBi)	Gain 1E (dBi)	Gain 2E/1E (dB)	FtB (dB)	-3 dB BW (deg)	-3dB -BW	-3dB +BW	Structural Efficiency	Impedance
1.04	-33.2	20	+0.65	-0.66	+1.31	8.15	31	8	39	85.9%	209 + j 1.15
1.22	-20.3	20	+0.92	-0.54	+1.46	8.39	31	8	39	86.7%	165 + j 3.85
1.07	-29.8	20	+1.32	-0.32	+1.64	8.61	30	8	38	87.1%	188 - j 2.53
1.18	-21.8	20	+1.54	-0.23	+1.77	8.70	30	8	38	87.8%	170 - j 5.44
1.39	-15.8	20	+1.69	-0.12	+1.81	8.49	30	8	38	89.2%	147 - j 22.2
1.44	-15.1	21	+2.30	+0.27	+2.57	7.94	28	8	36	91.9%	141 - j 13.1

Averages: 1.22 -22.7 20 +1.40 -0.27 +1.76 8.38 30 8 38 88.1% Z = R + j X

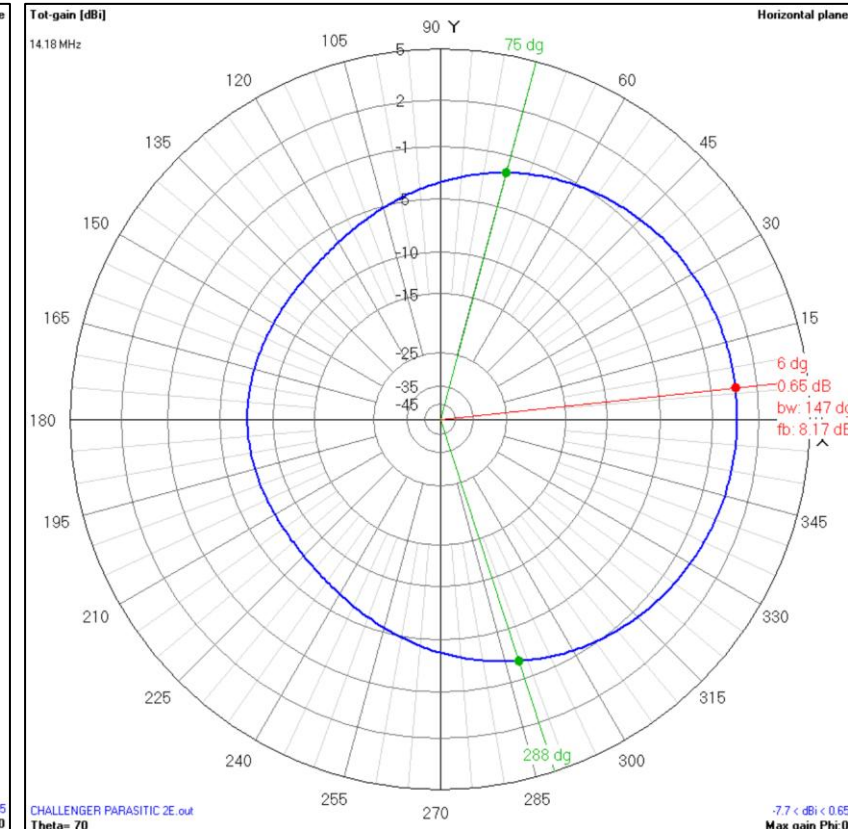
2-Element Parasitic ChallengerArray 4NEC2 Model Graphics



- 20M SWR Band Sweep

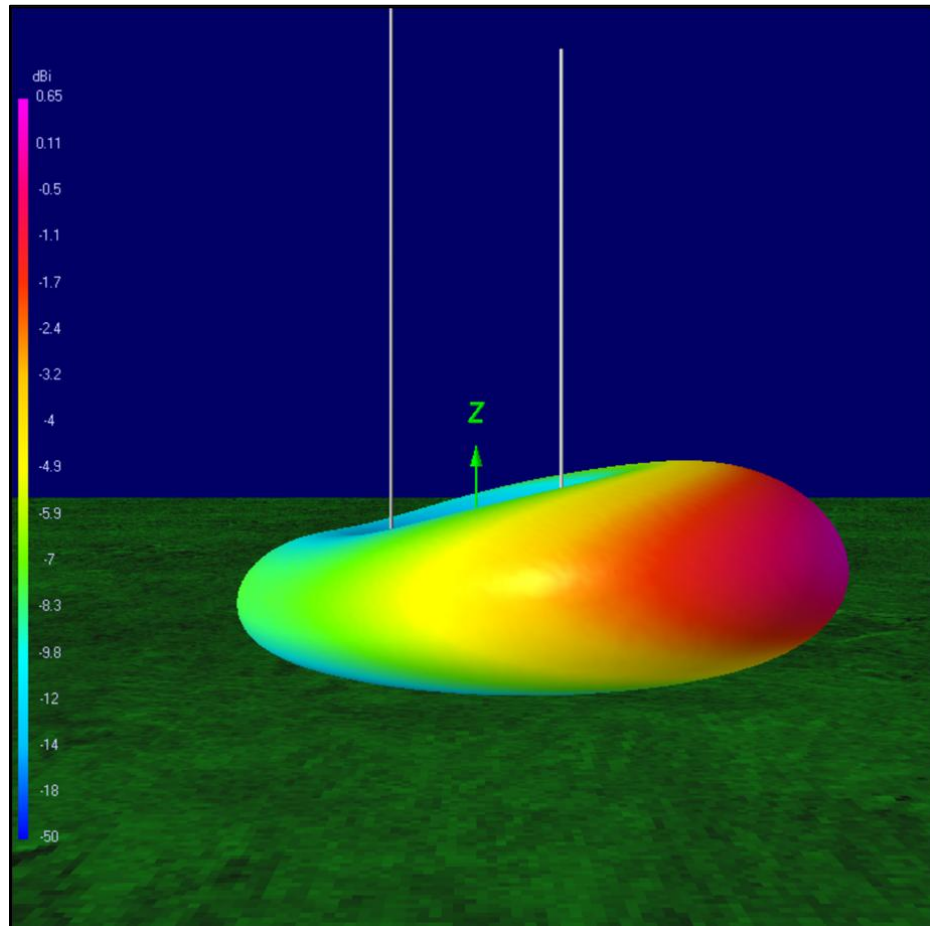


- 20M Radiation Pattern (side)

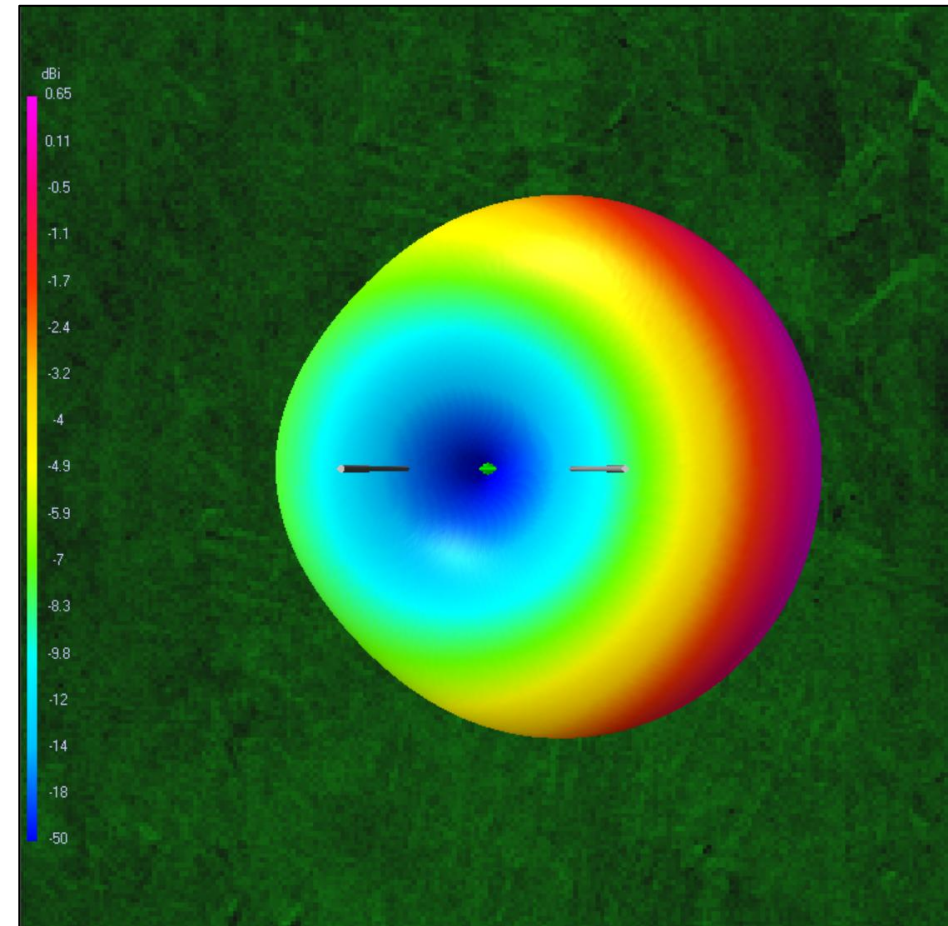


- 20M Radiation Pattern (top)

2-Element Parasitic Challenger Array 3D Radiation Patterns



Purple and red edges of the radiation pattern highlight the **strongest forward gain** of the antenna **20 degrees off the horizon** on 20M.



The *array* generates **8.2 front-to-back** due to the **mutual coupling** of the **parasitic director** to the **driven radiator element** on 20M.

2- Element Parasitic DominatorArray Quarterwave Vertical Beam Antenna System



2-Element Parasitic Dominator Array (17M-10M)



Dominator 2-Element Vertical Beam for 10M pointed east at **US-3473** in California. **Parasitic director** creates up to **+4 dB** gain across four bands: 17M-10M.



Each band requires different **element lengths** (director is *always* **6%** shorter) and **element spacing**. The horizontal **PVC tube telescopes like a trombone** to accommodate band spacing.



Horizontal PVC section **rests on top of the tripod mirror mount** which can be manually **rotated** to any direction. The **counterpoise** wire runs under **director**.

2-Element Parasitic Dominator Array is Very Portable

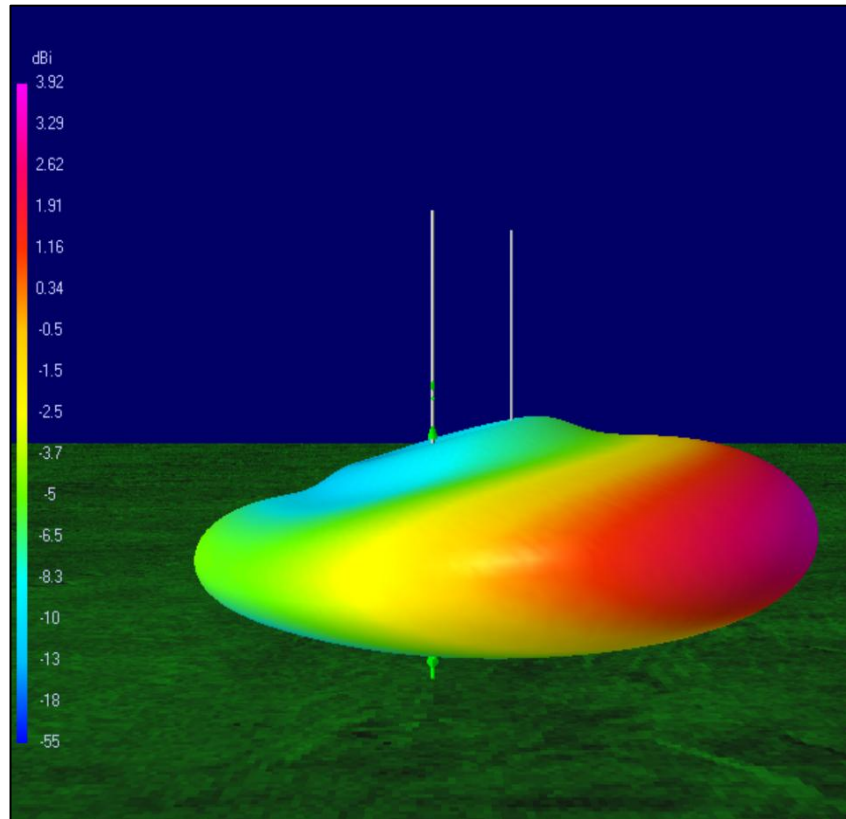


Dominator Halfwave Beam on a **Polarduck™ tripod** easily fits within a zippered **36" long photography bag** including both 25' (or 17') whips.

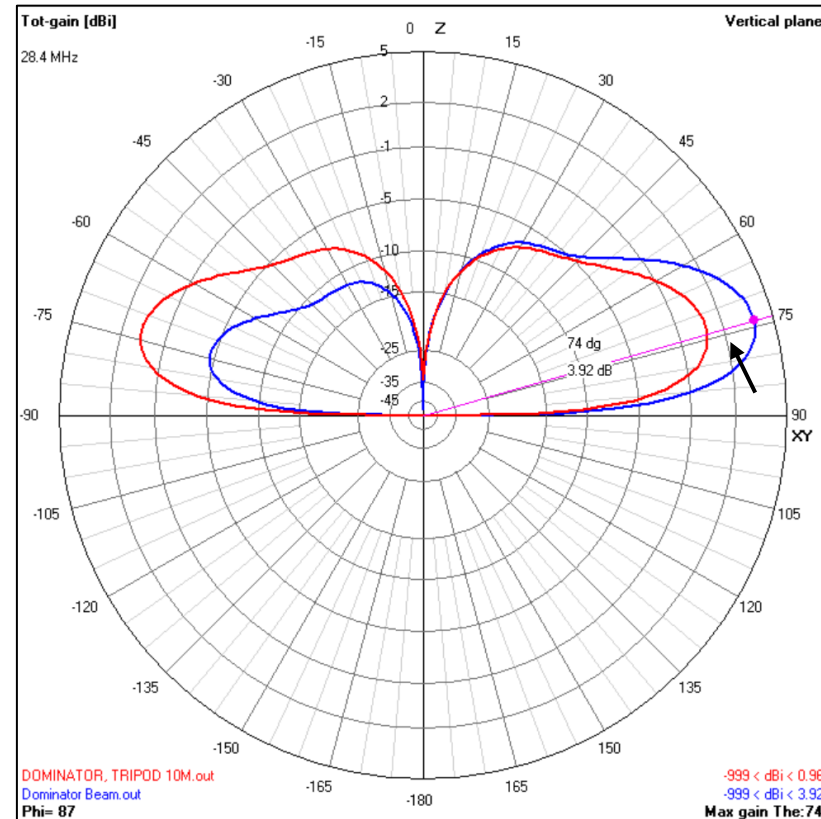


Dominator Halfwave Beam Parasitic Director PVC Add-On easily comes apart into three sections for **flat transport** and **fast deployment**:
① horizontal telescoping trombone, ② vertical support for the director, and ③ ground support base at the bottom of the vertical support.

4NEC2 Model Graphics for the **DominatorArray: 10M** (28.400 MHz)



Purple and red edges of the radiation pattern highlight the **strongest forward gain** of the antenna **16 degrees off the horizon** on 10M.



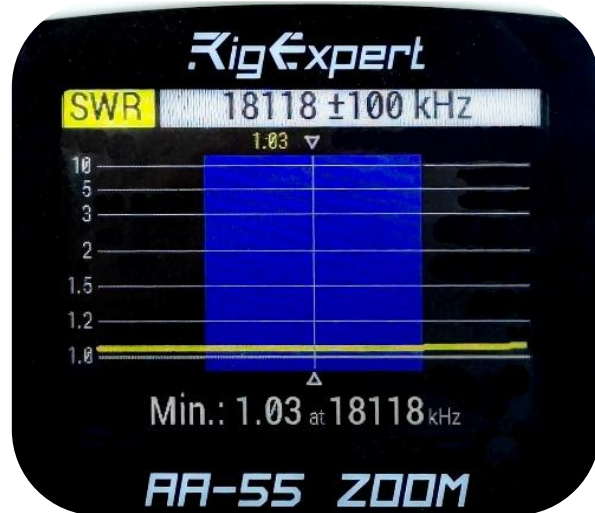
Model Specifications (10M):

- SWR 1.00:1
- Ref. Coef. -54.0 dB
- **Gain** 3.92 dBi
- **Rad. Angle** 16°
- Beamwidth 24°
- Front-Back 8.54 dB
- **Efficiency** 99.5%
- Impedance 2460 - j 1.24

The *beam* generates **+3.92 dBi forward gain** at **16 degrees** off the horizon *versus* the *omnidirectional Dominator* with **+0.96 dBi**.

Field SWR Measurements for the DominatorArray (17M-10M)

17M



15M



12M



10M



Very broad bandwidth with two 25' whips across **every band!**
Two 17' whips cover 12M-10M only.

SWR Matching:

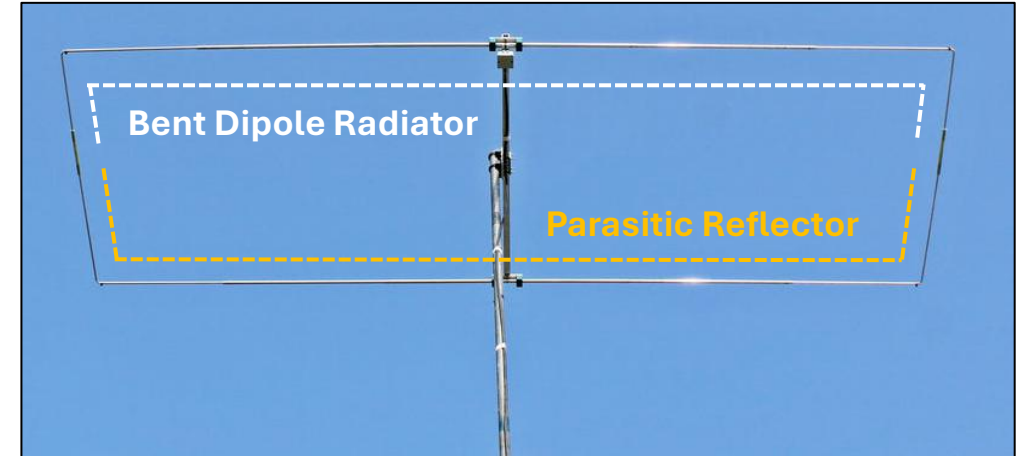
- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

Comparing PERformer, Challenger and Dominator Antennas

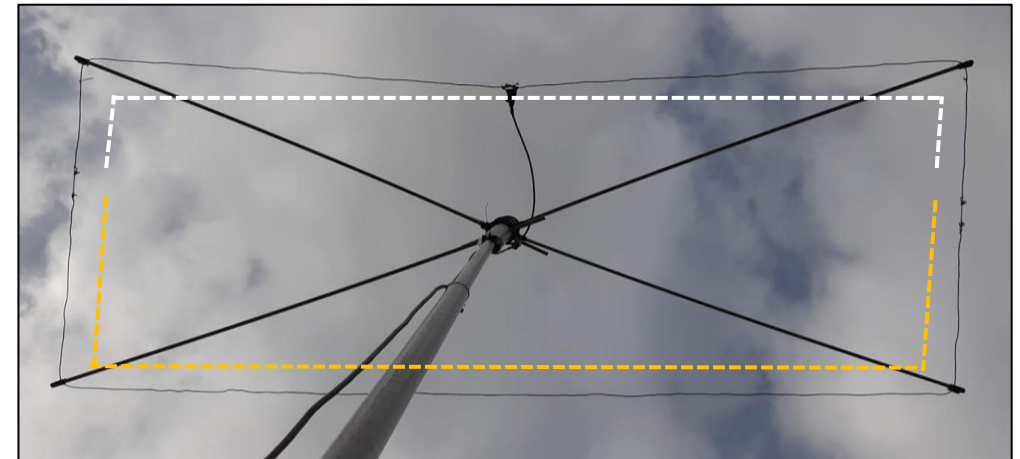
Specifications	PERformer	Challenger	Dominator	Dominator Beam
Vertical Wavelength	Quarterwave	Halfwave	Halfwave	Halfwave
Antenna Configuration	- Omni/Directional 2 Elevated Tuned Linked Radials 90/180° apart	- Omnidirectional 1 Linked Counterpoise, ~10% λ per band	- Omnidirectional 1 Linked Counterpoise, ~33% λ per band	- Directional 2-Element Vertical Beam with Parasitic Director
Band Coverage	40M-6M	20M-6M	17M-10M	17M-10M
Structural Efficiency	90.8%	94.3%	99.5%	99.5%
50 Ω Impedance Match	---	4:1 Unun <i>Off-Center Fed</i>	49/56:1 Xformer <i>End-Fed</i>	49/56:1 Xformer <i>End-Fed</i>
Key Component Loss	-0.12 dB (<i>toroid choke</i>)	-0.46 to -0.35 dB	-1.08 to -0.51 dB	-1.08 to -0.51 dB
Peak Radiation	-0.67 dBi / +0.41 dBi	-0.27 dBi	+0.67 dBi	+3.58 dBi
Angle of Peak Radiation (with -3 dB Beamwidth)	24° (9° to 54°)	21° (8° to 40°)	18° (7° to 35°)	16° (7° to 31°)
-3.00 dB Beamwidth	46° (-15°, +30°)	32° (-13°, +19°)	28° (-11°, +17°)	24° (-9°, +15°)
Primary Reach	Regional, Continental	Continental, Global	Global	Global

Moxon Rectangle Parasitic Array is a Compact Horizontal Beam

- **Moxon Rectangle** antenna was formally introduced to the amateur radio community over **40 years ago** in the early 1980s by British engineer **Les Moxon, G6XN**.
- It was inspired by the **VK2ABQ Square** antenna introduced **10 years earlier** by **Fred Caton** in Australia.
- Its **bent dipole design** is roughly 70% of the size of an equivalent Yagi-Uda antenna and provides high performance for its compact size.

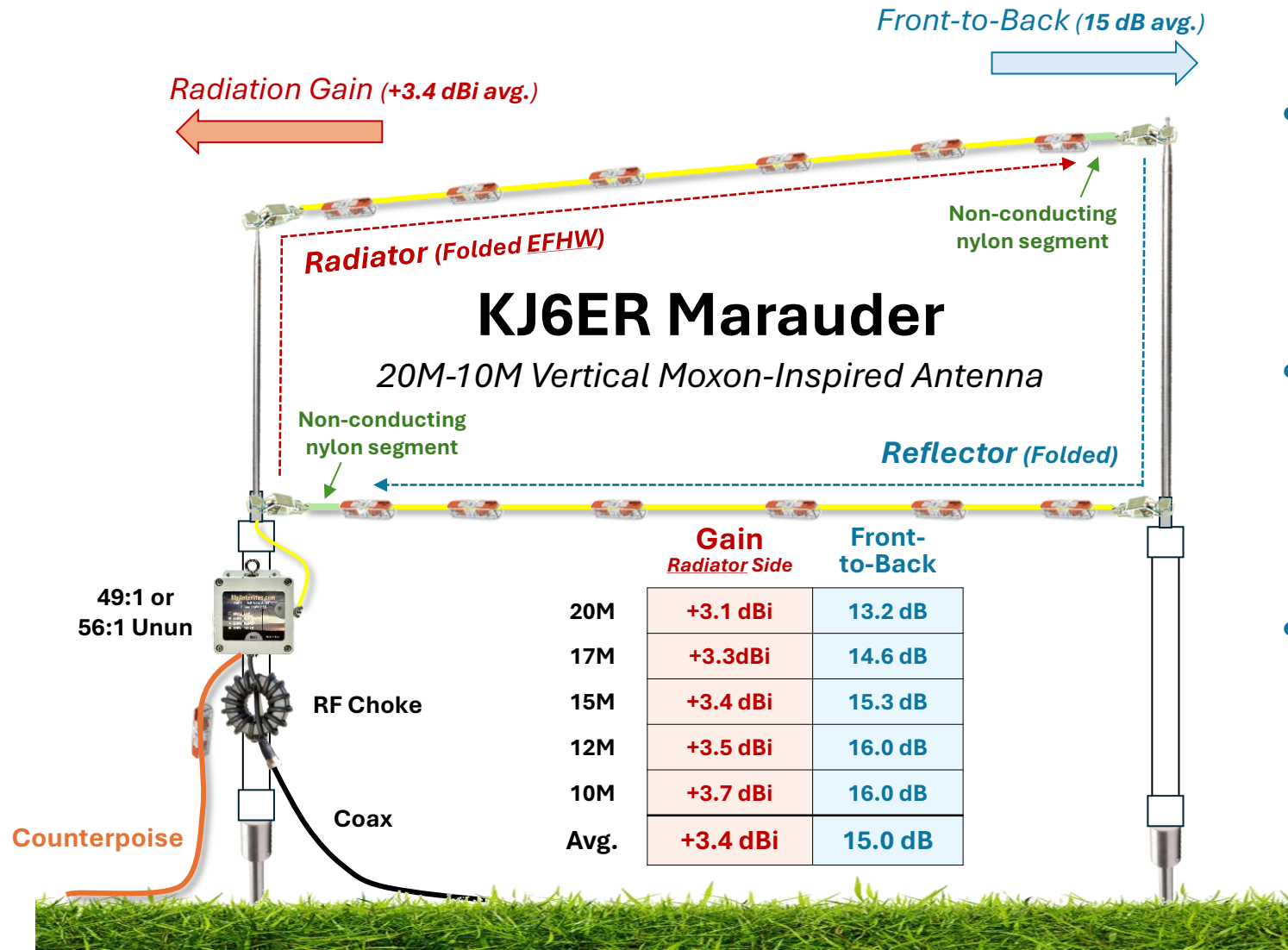


Horizontal **Tubing** Implementation – $\frac{1}{2} \lambda$ above ground



Horizontal **Wire** and **Spreaders** Implementation

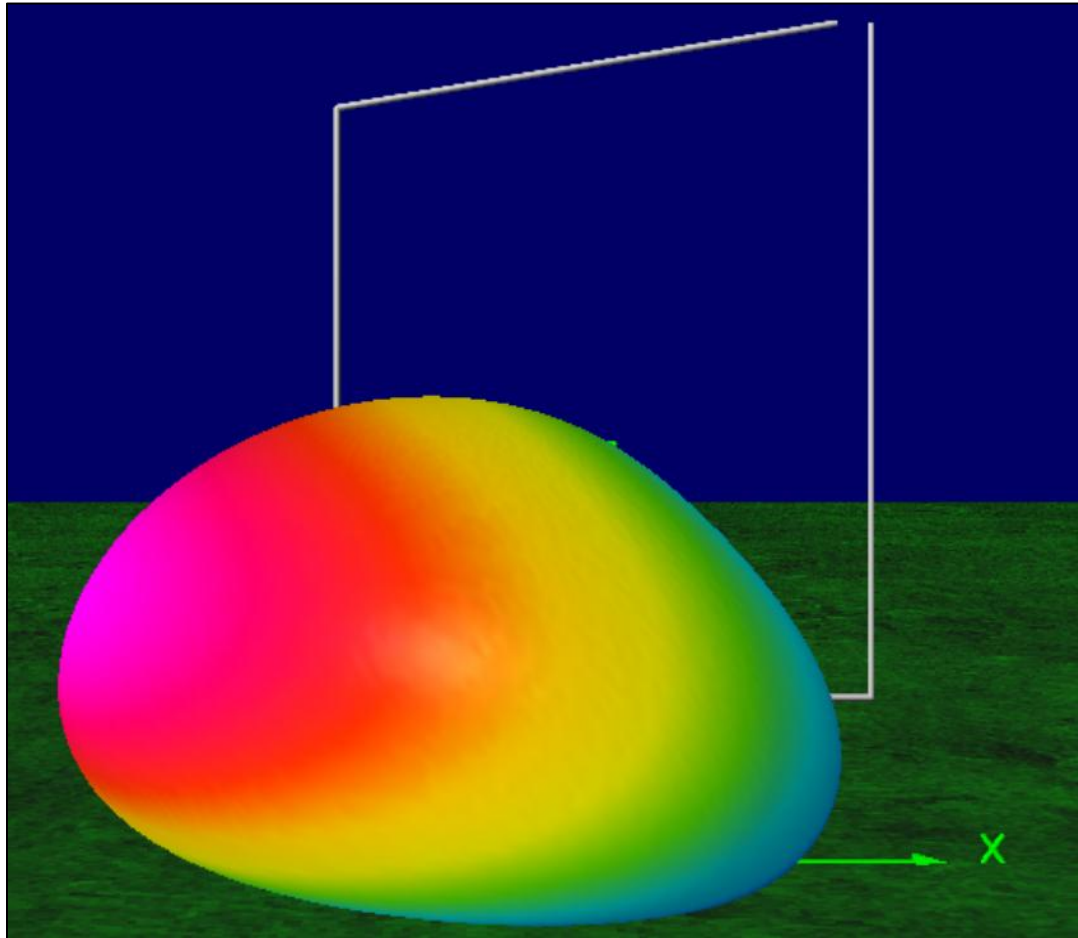
Marauder End-Fed Vertical Moxon-Inspired Antenna



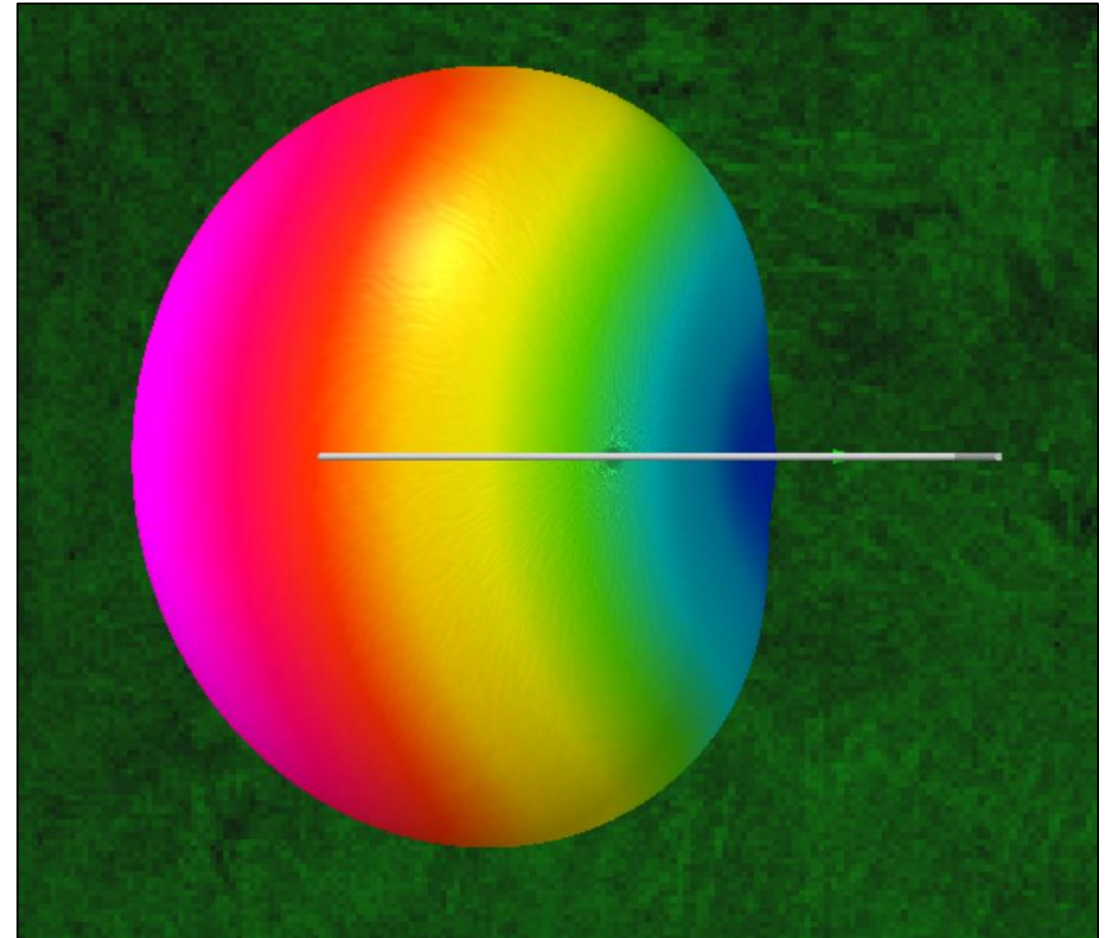
- Marauder is a *unidirectional halfwave portable* antenna using a **49/56:1 unun** that is **vertically-polarized** for the **20M-10M** bands.
- Instead of using a *bent dipole* fed in the *middle*, it deploys an efficient **end-fed halfwave radiator** that is configured as an **inverted-L**.
- For strong **directional gain** and a **front-to-back ratio**, it integrates a **parasitic reflector** opposite the radiator in a **mirrored L-shape**.

Marauder Generates Significant *Gain* and *Front-to-Back*

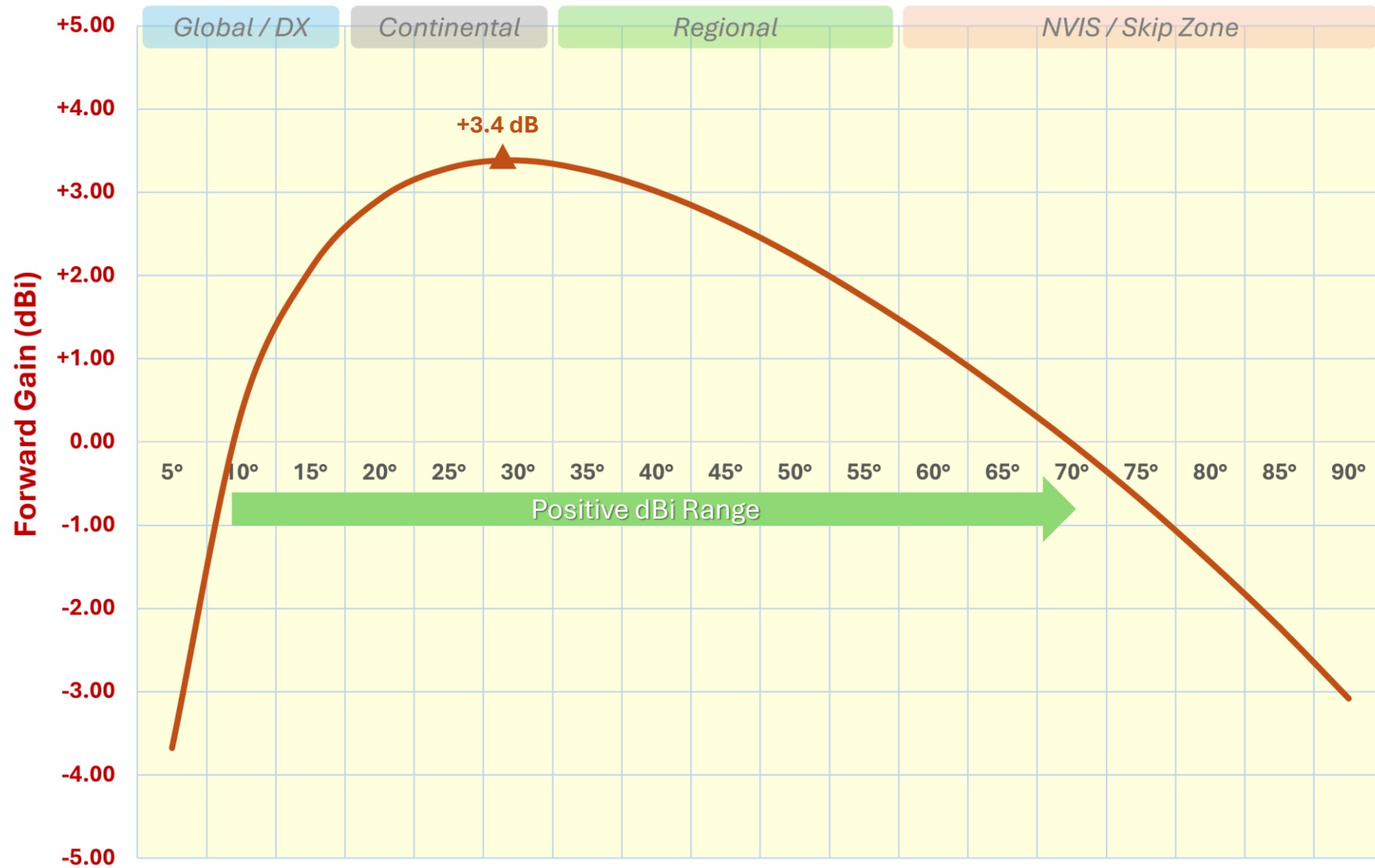
Gain = **+3.4 dBi @ 29° Unidirectional**



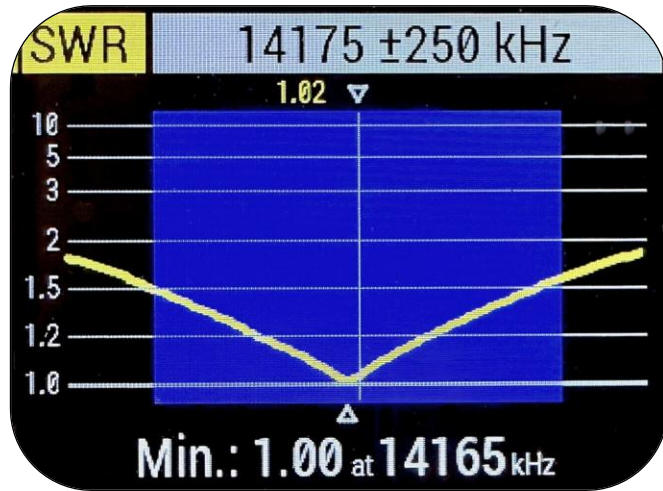
Front-to-Back = **15.0 dB**



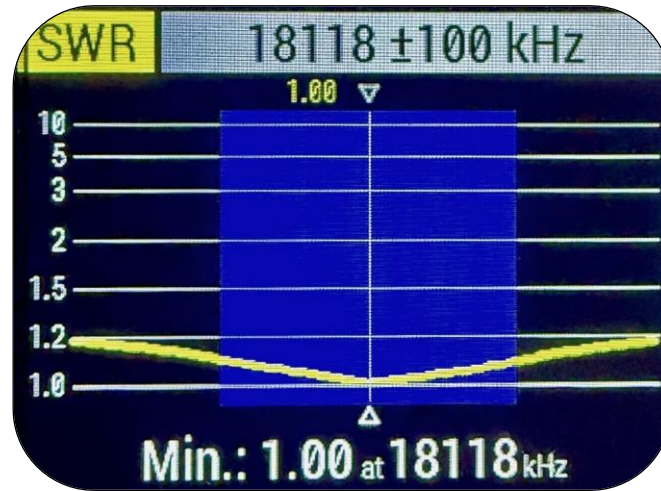
Marauder End-Fed Moxon Radiation Sweep on the 15M Band



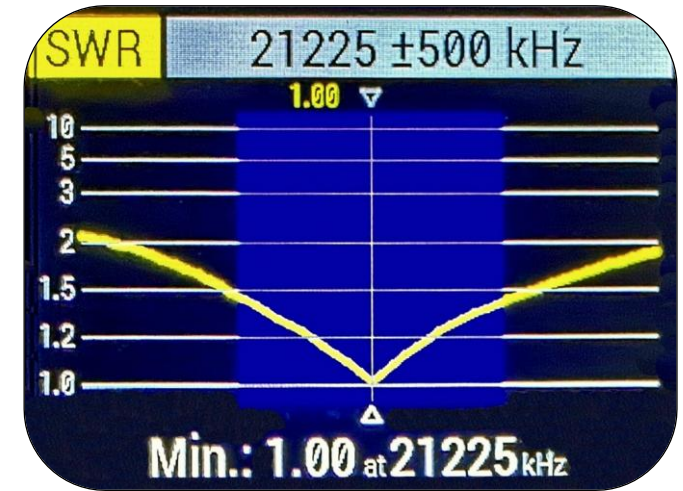
Marauder SWR Sweeps with *Low SWR* and *Broad Bandwidth*



20M Band



17M Band



15M Band



12M Band



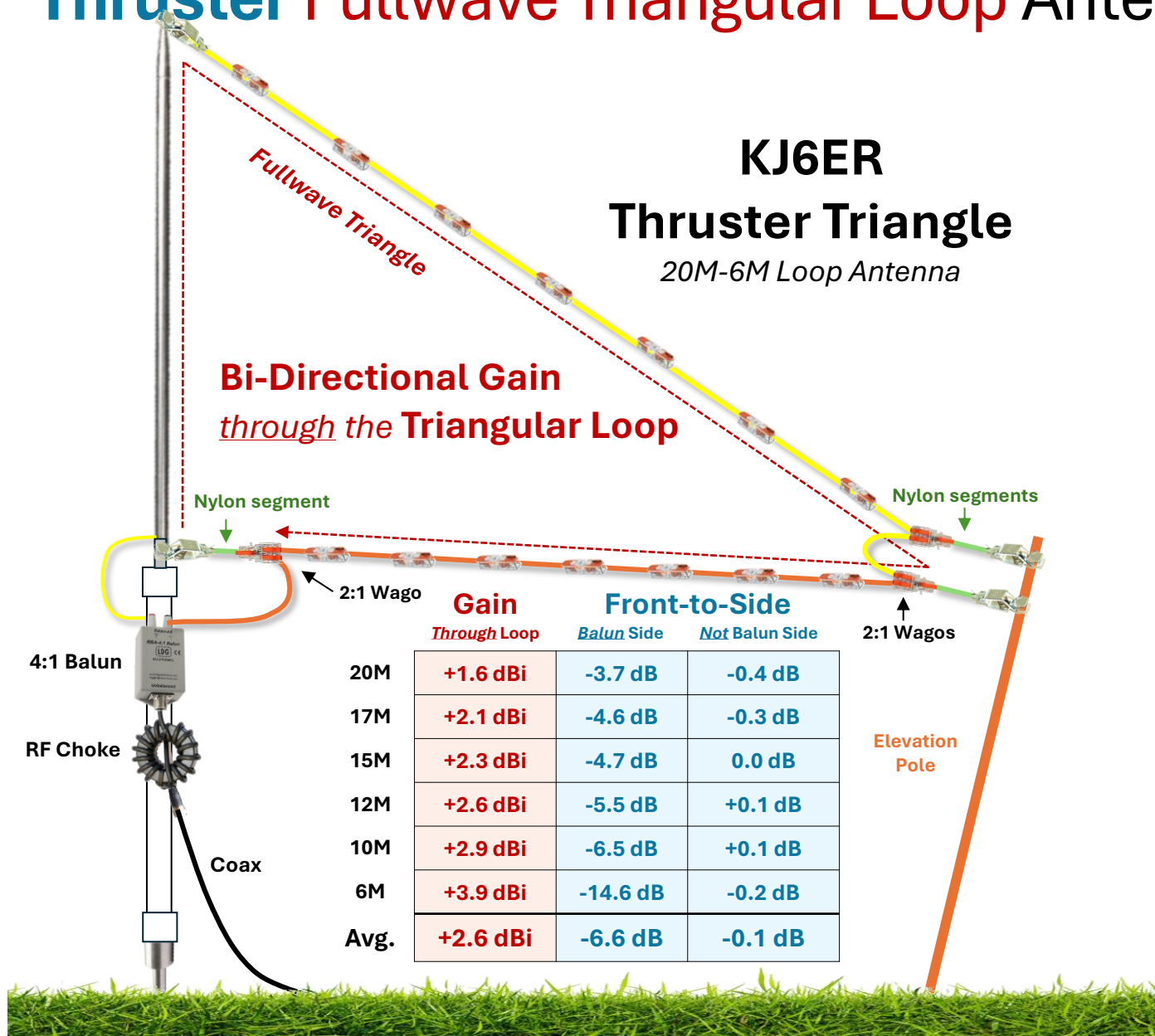
10M Band

SWR Matching:

- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

Thruster Fullwave Triangular Loop Antenna (Future)

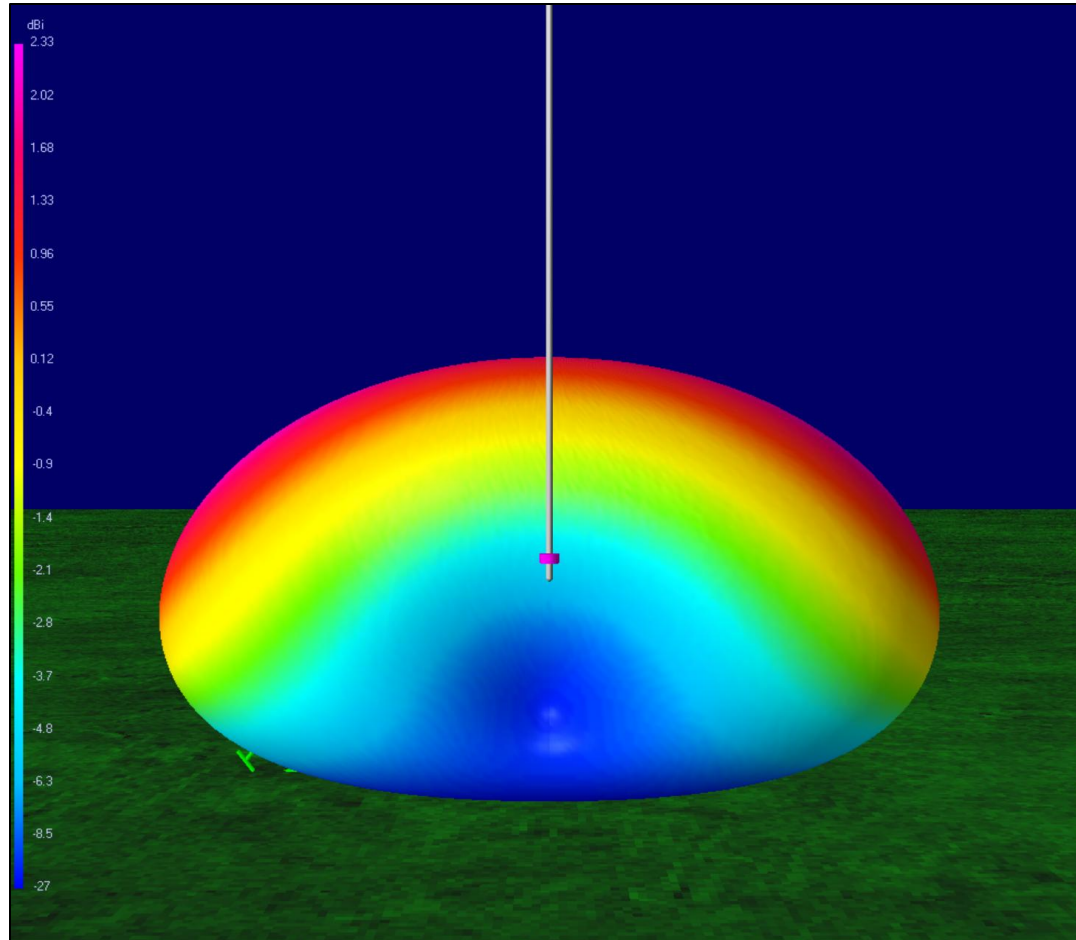
Get on my **Antenna Geeks List** to receive these **free plans**!



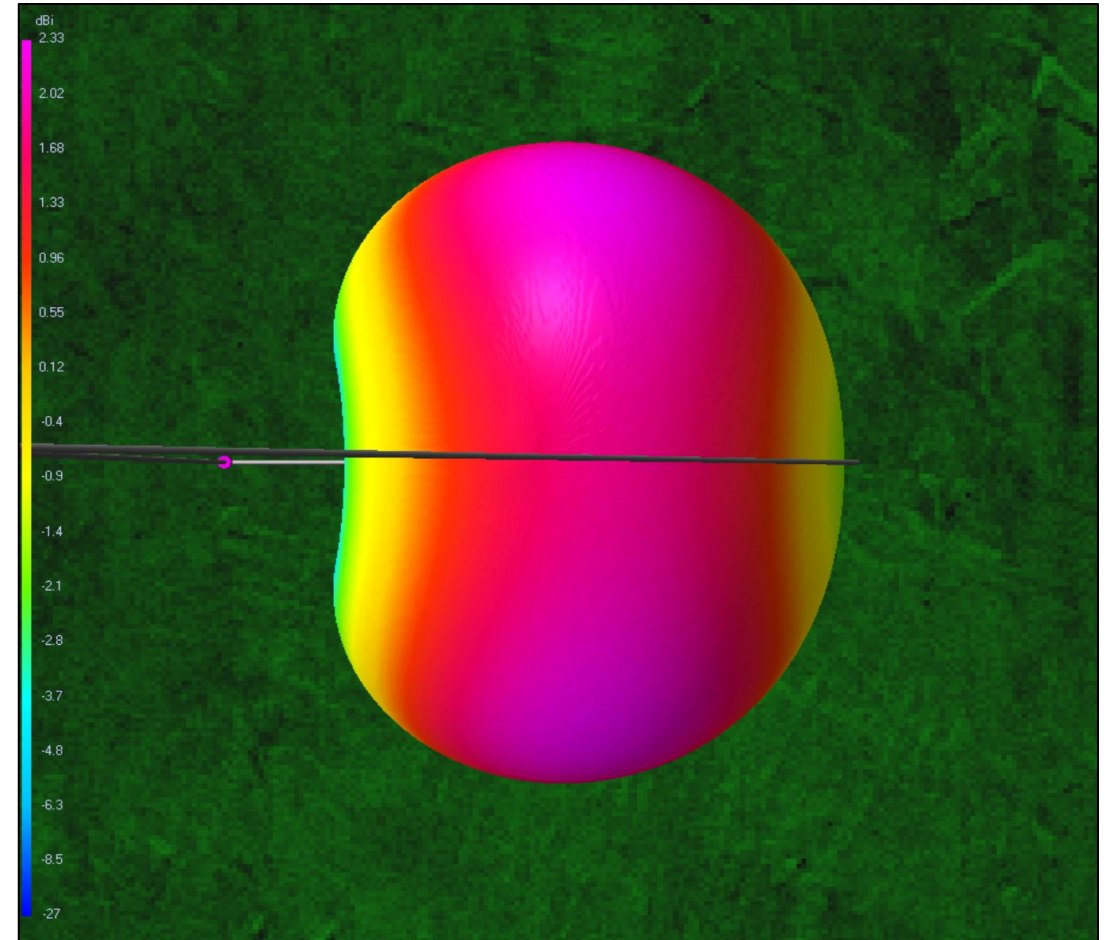
- Thruster is a *bi-directional* **fullwave triangular loop** portable antenna using a **4:1 balun** and **band-linked crosswires** for the **20M-6M** bands.
- It leverages the same **PVC tube mount (or tripod)** and one **elevation pole** as the popular **PERformer elevated quarterwave**.
- A **second** parasitic triangular loop deployed a quarter wavelength behind the radiating loop provides an average of **+5 dBi forward gain**.

Thruster Fullwave Triangular Loop Antenna (*Future*)

Gain = **+2.6 dBi @ 48° Bidirectional**

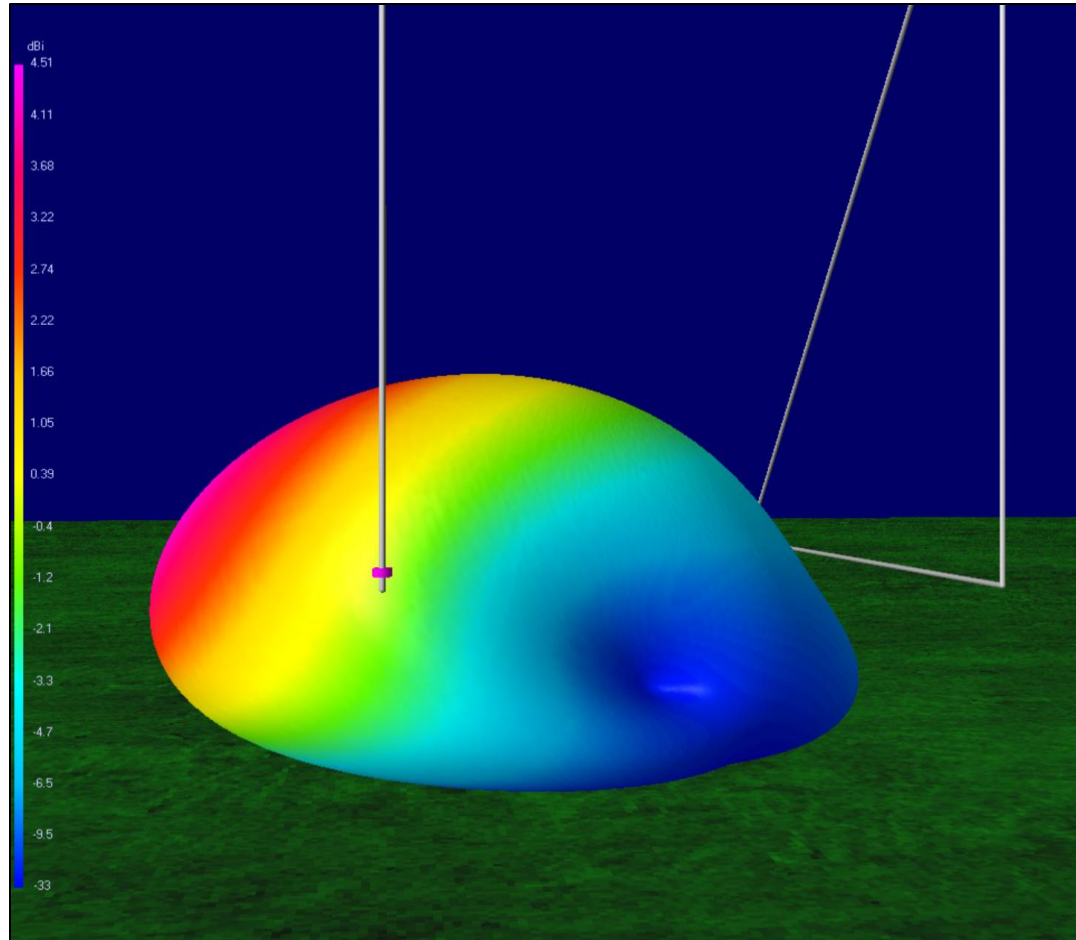


Front-to-Balun Side = **9.2 dB**

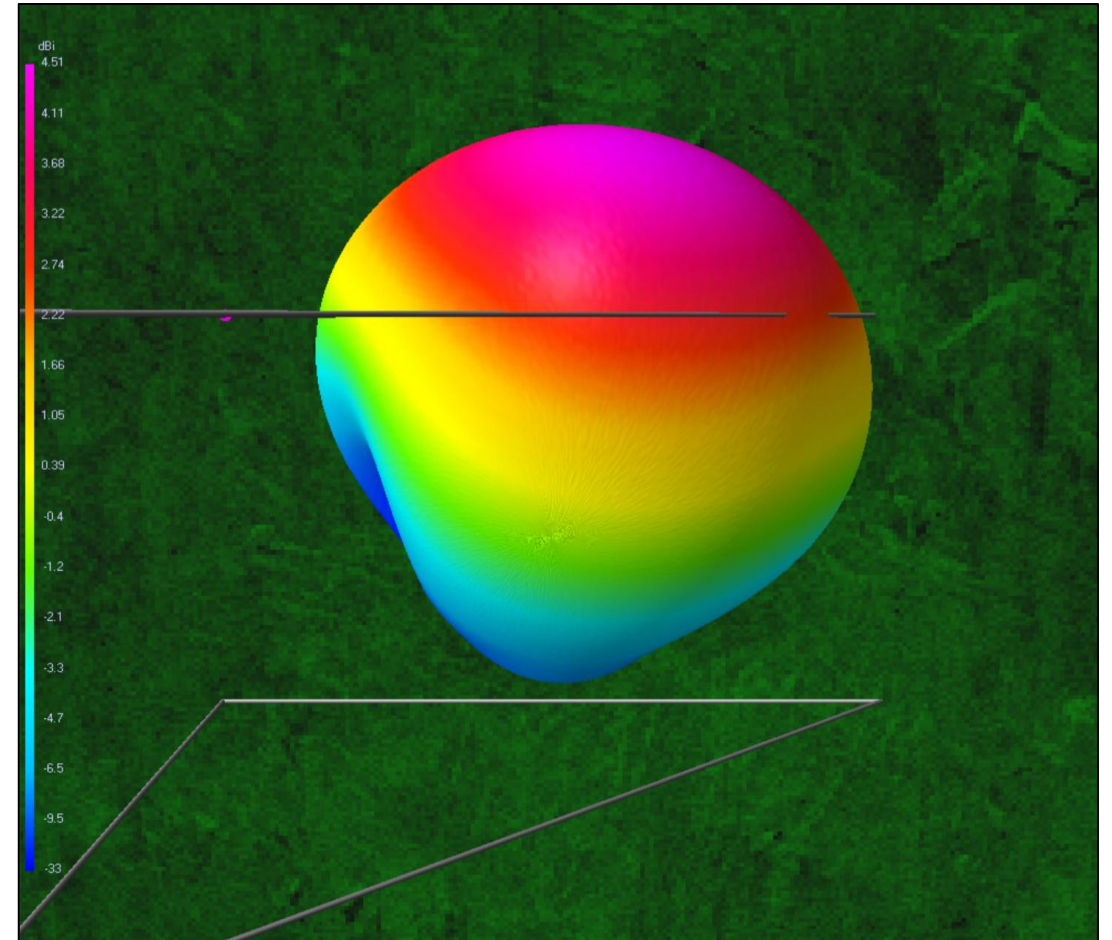


Thruster Fullwave Triangular Parasitic Loop Antenna (*Future*)

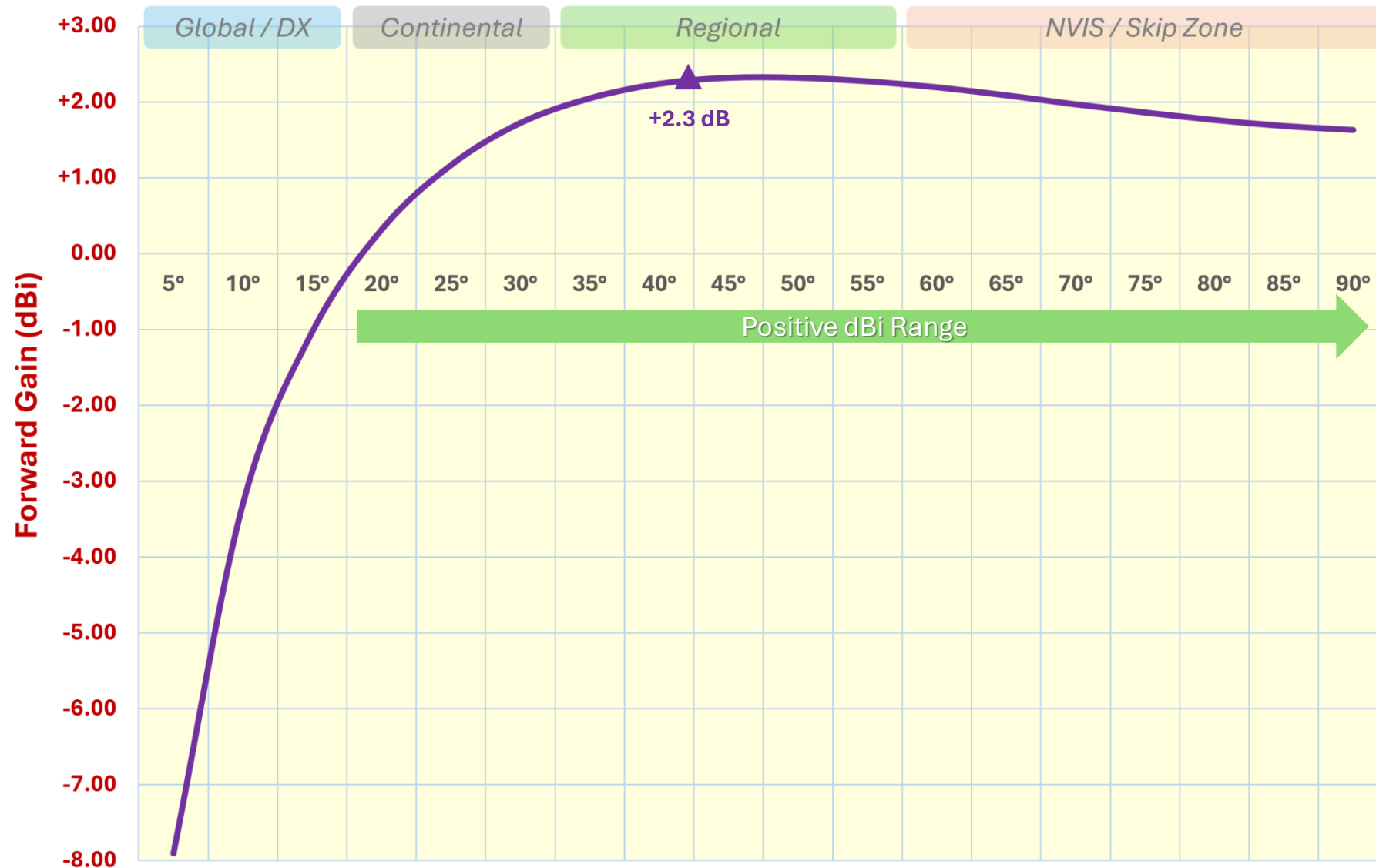
Gain = **+4.9 dBi @ 31° Unidirectional**



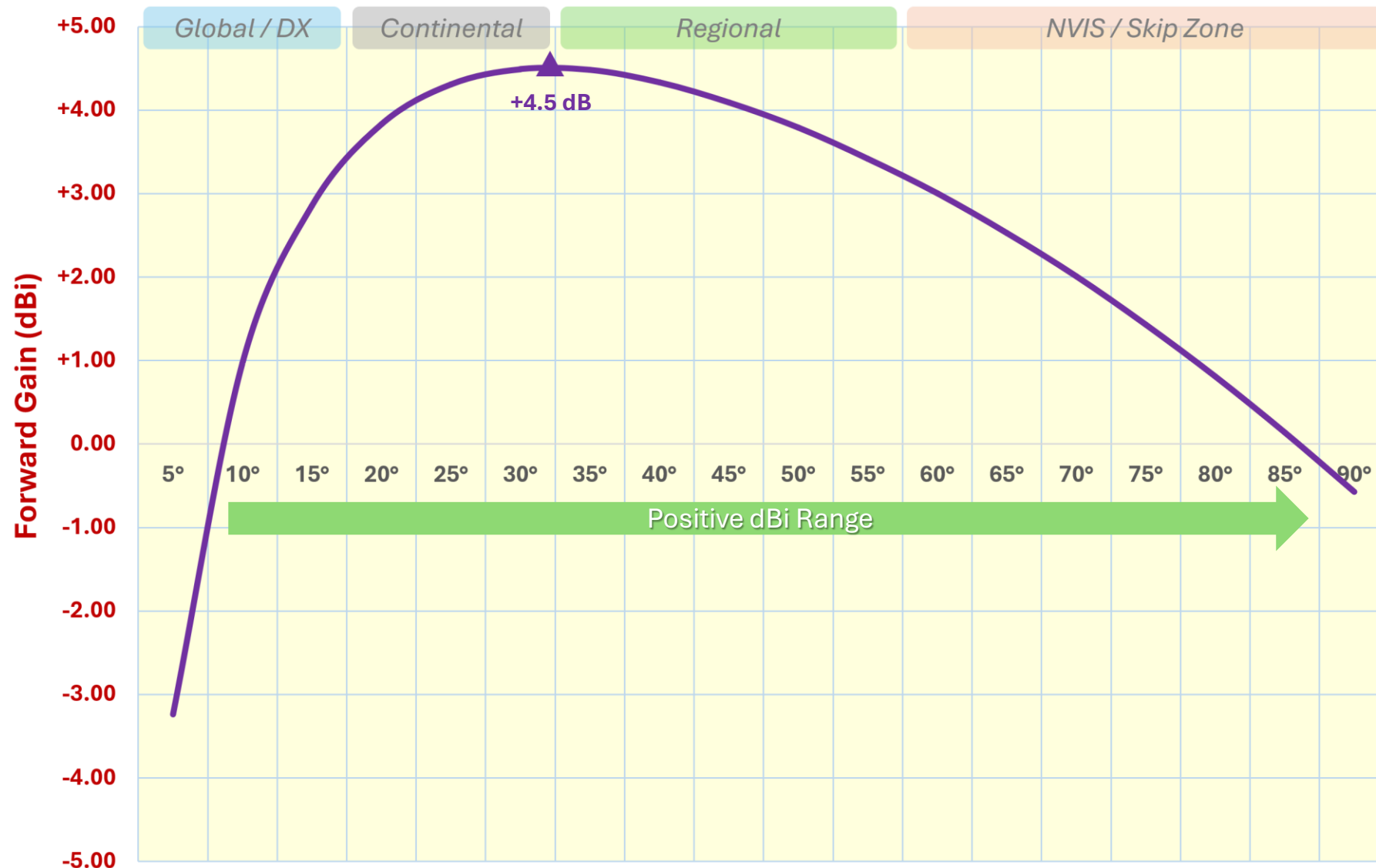
Front-to-Back = **12.9 dB**



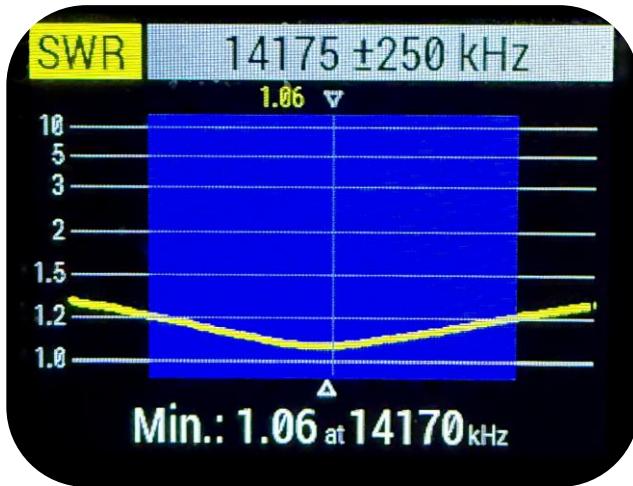
Thruster Triangular Loop Radiation Sweep on the 15M Band



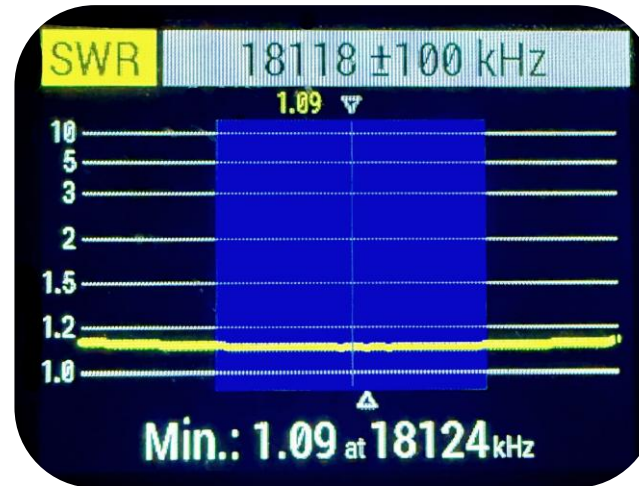
Thruster Triangular Parasitic Loop Radiation Sweep on 15M



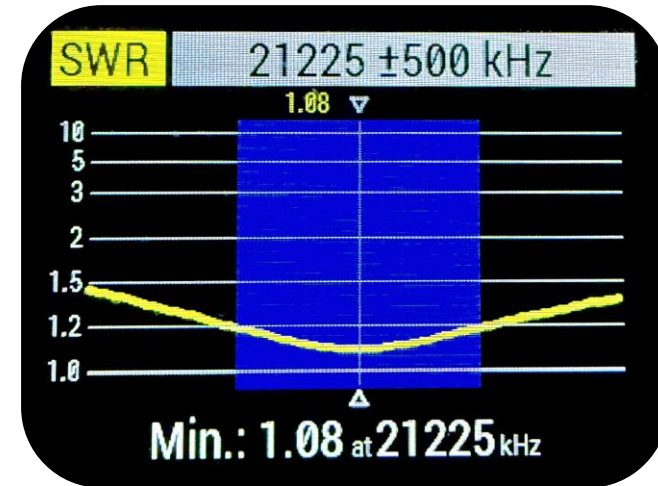
Thruster SWR Sweeps with *Low SWR* and *Broad Bandwidth*



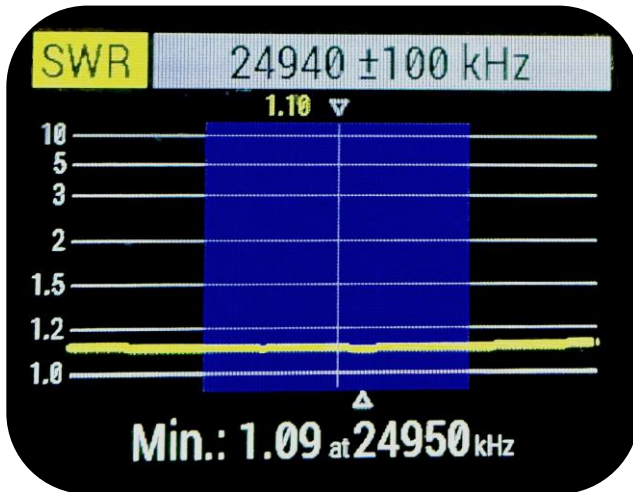
20M Band



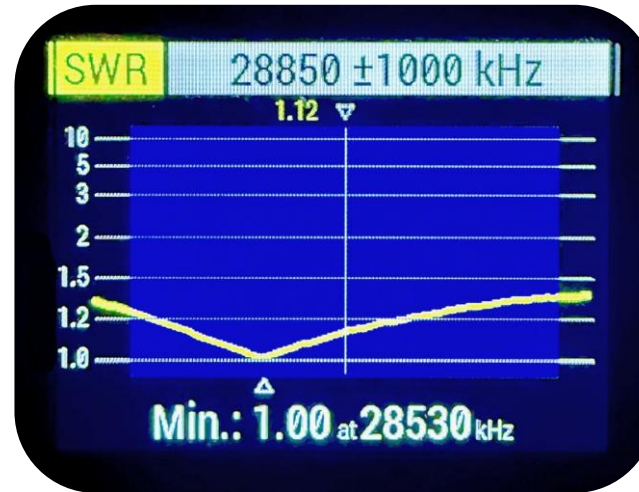
17M Band



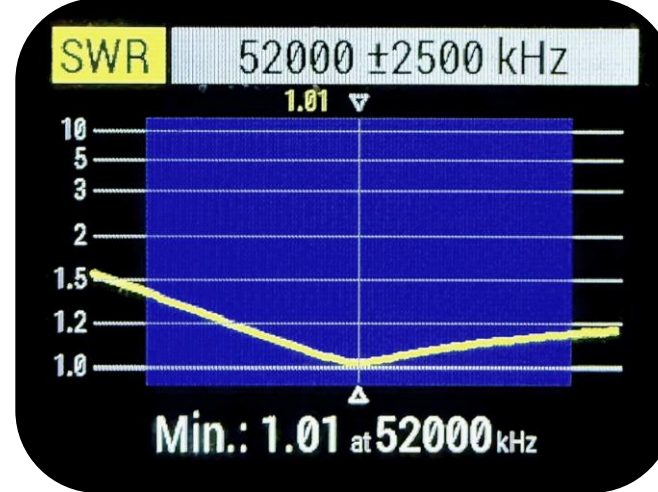
15M Band



12M Band



10M Band



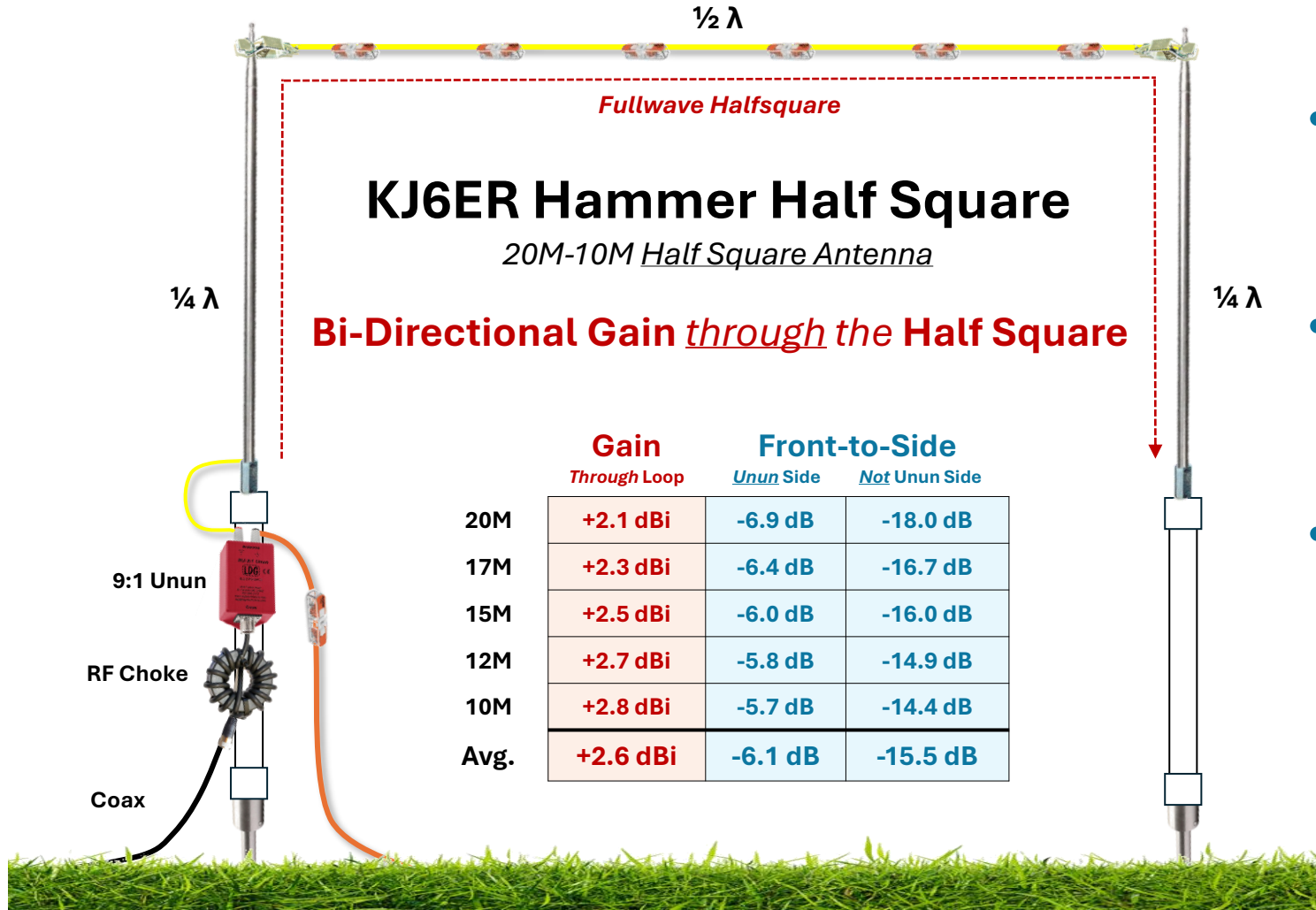
6M Band

SWR Matching:

- 1.10:1 = 99.8%
- 1.20:1 = 99.2%
- 1.30:1 = 98.3%
- 1.40:1 = 97.2%
- 1.50:1 = 96.0%

Hammer Fullwave Half Square Antenna (Future)

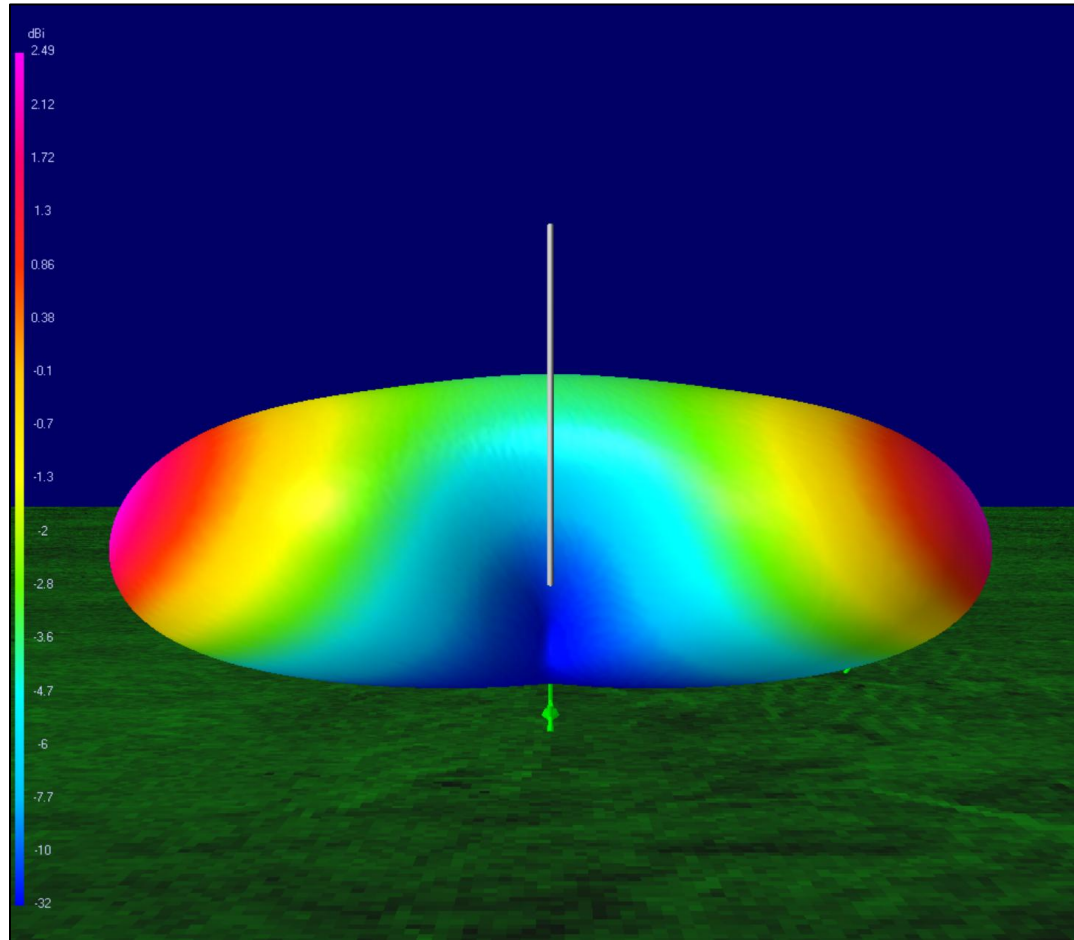
Get on my **Antenna Geeks List** to receive these **free plans**!



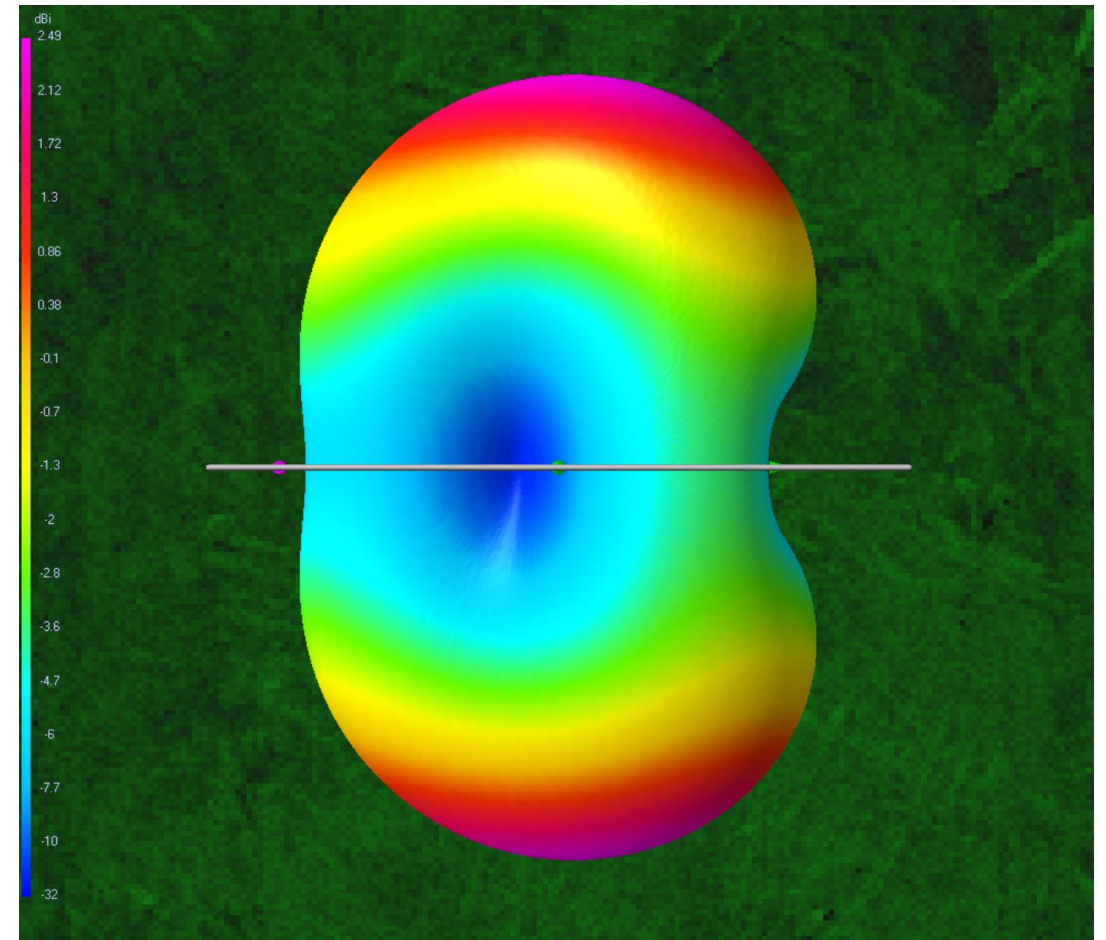
- Hammer is a *bi-directional* **fullwave half square** portable antenna using a **9:1 unun** for the **20M-10M** bands.
- It leverages **two telescoping whips** and a **top band-linked crosswire** to form the half square for each band.
- It features a **low angle of peak radiation** (*takeoff angle*) with excellent gain for potential DX and continental communications.

Hammer Fullwave Half Square Antenna (*Future*)

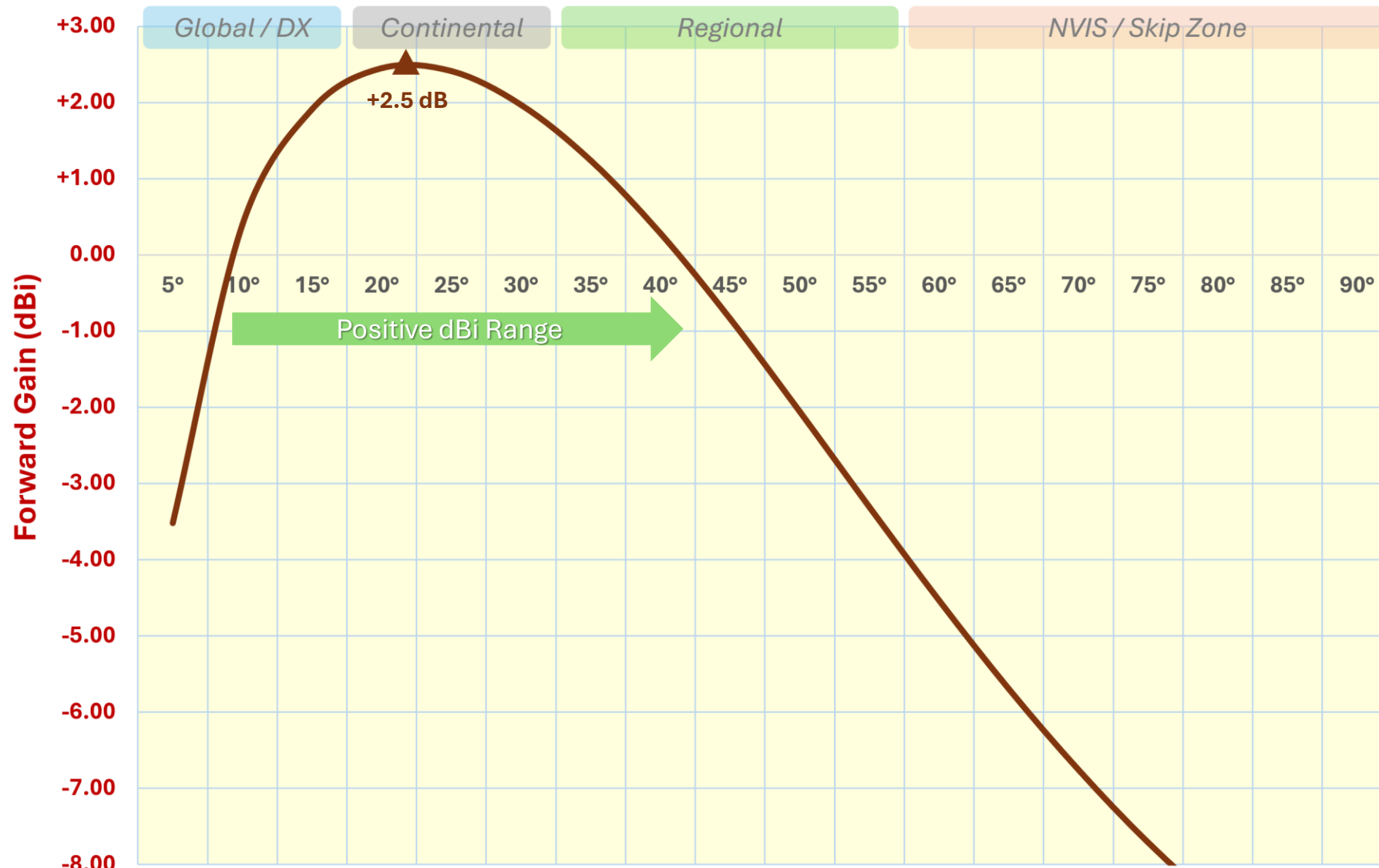
Gain = +2.6 dBi @ 22° *Bidirectional*



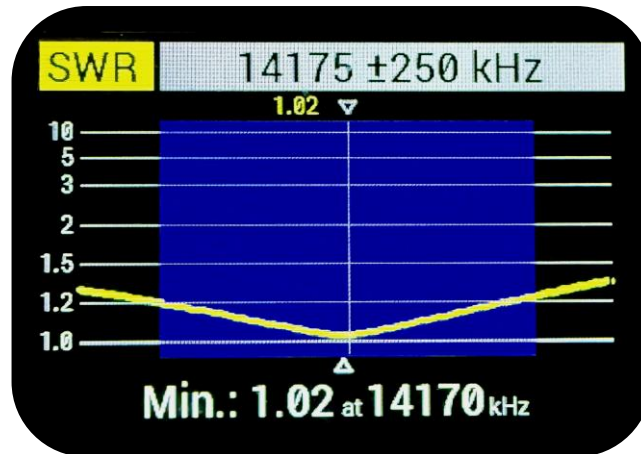
Front-to-Not Unun Side = 18.1 dB



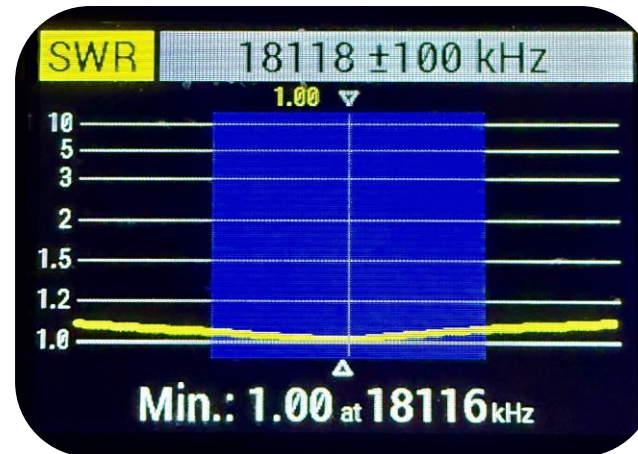
Hammer Half Square Radiation Sweep on the 15M Band



Hammer SWR Sweeps with *Low SWR* and *Broad Bandwidth*



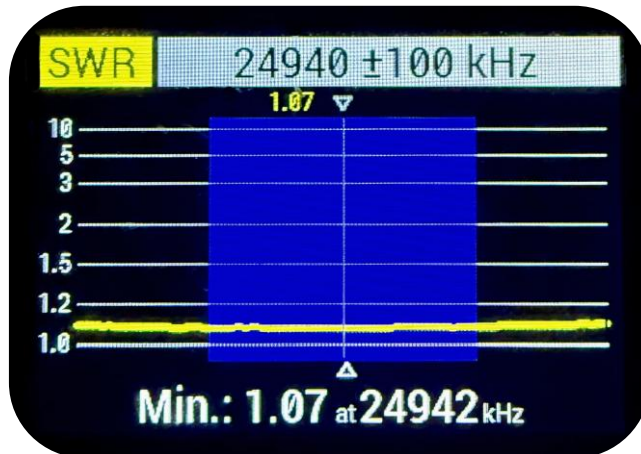
20M Band



17M Band



15M Band



12M Band

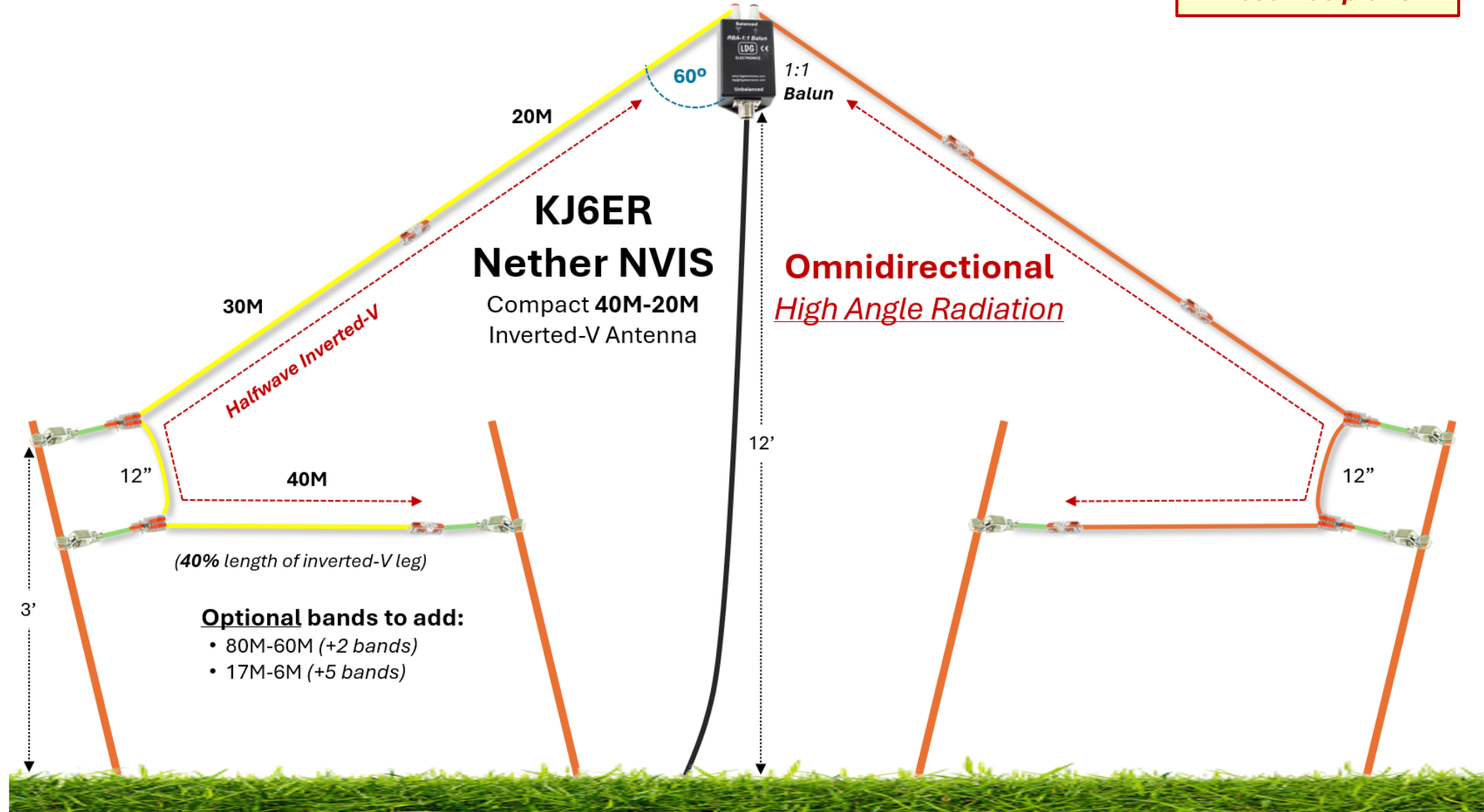


10M Band

SWR Matching:	
• 1.10:1	= 99.8%
• 1.20:1	= 99.2%
• 1.30:1	= 98.3%
• 1.40:1	= 97.2%
• 1.50:1	= 96.0%

Nether Compact Inverted-V Antenna (*Future*)

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J-Systems Products on **Etsy** • KJ6ER Antennas and Accessories

J-Systems is a **US-based technology company** that sells high-quality *handmade* **KJ6ER antenna systems**:



PERformer 40M-6M
Elevated Quarterwave
Antenna includes 17'
Whip and 16" Spike



Challenger 20M-6M
Off-Center Fed Halfwave
Antenna with 25' Whip
and 16" Ground Spike



Dominator 17M-10M
End-Fed Halfwave
Antenna includes 25'
Whip and 16" Spike



Marauder 20M-10M
Moxon-Inspired
Parasitic Array
Antenna System

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J-Systems Products on **Etsy** • KJ6ER Antennas and Accessories

In addition to selling high-quality **KJ6ER antenna systems**, J-Systems also sells handmade **accessories**:



Guy Rope Kit for the
PERformer Quarterwave
and **Challenger OCF**
Halfwave Antennas



Pole-Pod Radial
Tripod Solution for
Non-Penetrating
Elevation Poles



16" Stainless Steel
Ground Mount Spike for
all **Antenna Systems**
with **PVC Mast Support**



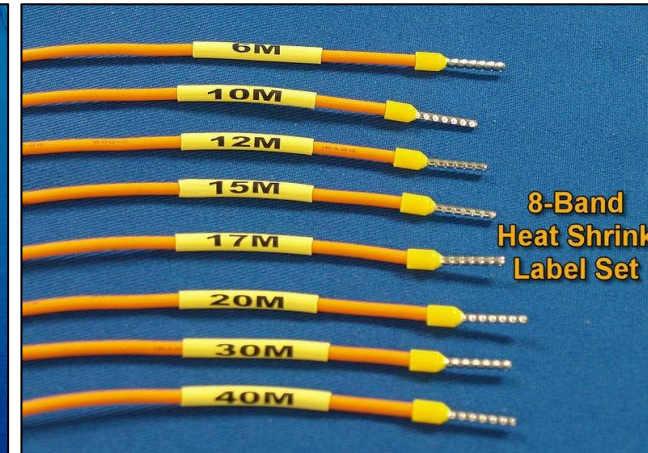
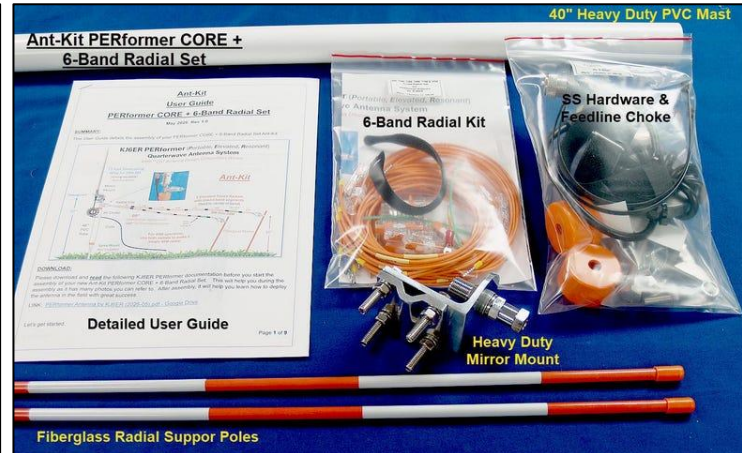
CAMO PVC Wraps Kit for
Low Visibility Deployments
in **Restricted Neighborhoods**
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Buy High Quality **ABR Cables** at a 10%-20% Discount!



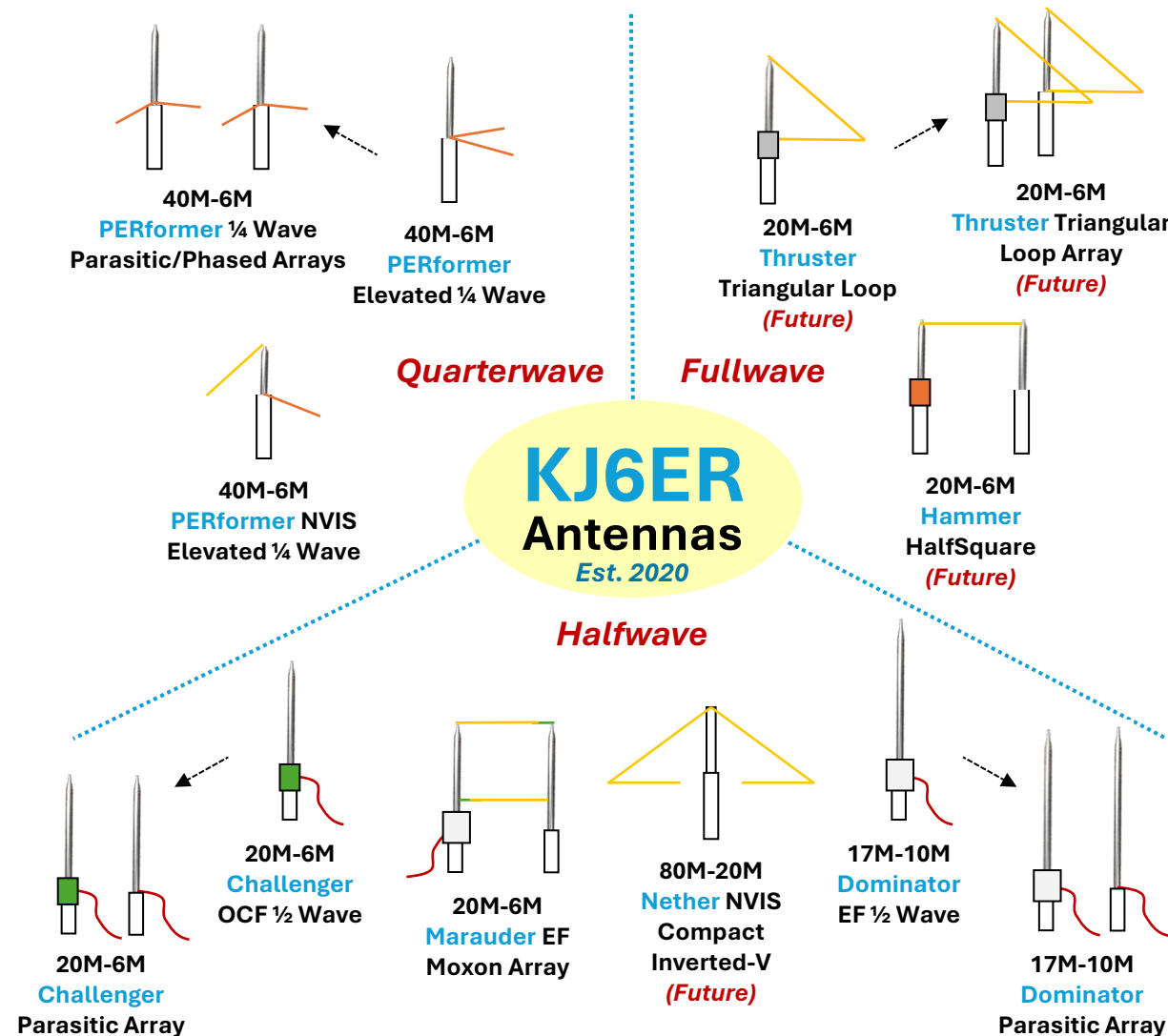
The screenshot shows the ABR Industries website. The header includes the ABR Industries logo with a '15 Year Anniversary' badge, a search bar, and a 'CONTACT US FOR HELP OR INQUIRIES' button. The navigation bar lists: HOME, PRODUCT INFORMATION, WHY US?, FIND A DEALER, VIDEOS, CONTACT, LOGIN, and a shopping cart icon showing \$0.00.

The main content area features a large image of a coaxial connector with the title 'Amateur Radio Coax Builder'. To the right of the image, the breadcrumb trail is 'HOME > CABLE ASSEMBLY BUILDER > AMATEUR RADIO COAX BUILDER'. The section title 'Amateur Radio Coax Builder' is followed by navigation arrows. Below the title, there are three links: 'Not sure which cable to buy? Click [here](#) for the cable descriptions.', 'Click [here](#) for the cable data sheets.', and 'Click [here](#) for color sheath cables.'

The 'Coax' section has a dropdown menu labeled 'Choose an option'. Below it, the 'Connector A' section also has a dropdown menu labeled 'Choose an option'.

- **ABR Industries of Houston, Texas** has now officially partnered with **KJ6ER antenna builders and users!**
- **ABR** will now offer a **10%-20% discount** on your total order for any ABR cables online!
- Use the **coupon code KJ6ER** at checkout or use the link: bit.ly/ABRCoaxBuilder
- ABR is also selling custom **electrical length cables** for the **new Phased PERformerArray**: bit.ly/ABRPhasedCoax

KJ6ER Antennas Family: Quarterwave, Halfwave, Fullwave



KJ6ER Antennas Content Always **Free** on **KJ6ER.net**

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AMATEUR EXTRA

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KJ6ER

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If you are unable to homebrew your own KJ6ER antenna, or do not have the time, you can purchase **assembled, handmade antennas and accessories** at our Etsy store. Feel free to browse through all of these high quality products. Since June 2025, over 200 products have been sold with over 50 5-star reviews.

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Favorite Ham Radio Sites

A curated list of my favorite ham radio websites that I use everyday.

HamDash

Ham Radio Dashboard

VISIT SITE ↗

SolarHam

Space Weather

VISIT SITE ↗

Free Antenna Plans

Here are my *always-free* antenna PDFs which are grouped by *type*. Scroll through the entire list or use the filter to narrow your search. These are all **living documents**. They are continuously being improved over time. Check back often for the latest revisions.

Q Filter by name, band, or category...

QUARTERWAVE VERTICALS

2

PERformer

40M-6M · Omni/Directional Elevated Tuned Linked Radials

DOWNLOAD PDF ↗

PERformer NVIS

40M-6M · Omnidirectional High Angle Radiation Variant

DOWNLOAD PDF ↗

Press & Interviews

Take a look at KJ6ER press coverage and watch one-on-one personal interviews.

YOUTUBE · MAY 2026

Interview with Stu Crawford VE9CF - Solar Minimum

YOUTUBE · APR 2026

Interview with Stu Crawford VE9CF - Antennas Family

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Email me if you would like to be added to my **antenna geeks list!** Be the first to get *updates* as well as *new portable antenna PDF plans!* 😊



100% of your donation goes to fund my research and purchase of experimental antenna parts and accessories.

Additional Content

Chameleon™ Telescoping Whip Antennas

25-foot Telescoping Whip (CHA SS25) \$100

Section from Top	Section Length (in)	Radiation Length (Bottom + Exposed Sections Above)			
		Inches	Feet	Ft-In	Meters
1	22.00	45.25	3.77	3' 9"	1.15
2	21.00	66.25	5.52	5' 6"	1.68
3	21.00	87.25	7.27	7' 3"	2.22
4	21.00	108.25	9.02	9' 0"	2.75
5	21.00	129.25	10.77	10' 9"	3.28
6	21.00	150.25	12.52	12' 6"	3.82
7	21.00	171.25	14.27	14' 3"	4.35
8	21.00	192.25	16.02	16' 0"	4.88
9	21.00	213.25	17.77	17' 9"	5.42
10	21.00	234.25	19.52	19' 6"	5.95
11	21.00	255.25	21.27	21' 3"	6.49
12	21.25	276.50	23.04	23' 1"	7.02
13	21.25	297.75	24.81	24' 10"	7.56
Bottom	23.25				

Total
297.75 Inches
24.81 Feet
7.56 Meters

17-foot Telescoping Whip (CHA SS17) \$75

Section from Top	Section Length (in)	Radiation Length (Bottom + Exposed Sections Above)			
		Inches	Feet	Ft-In	Meters
1	21.500	43.50	3.625	3' 8"	1.11
2	20.250	63.75	5.313	5' 4"	1.62
3	20.250	84.00	7.000	7' 0"	2.13
4	20.125	104.13	8.677	8' 8"	2.65
5	20.125	124.25	10.354	10' 4"	3.16
6	20.125	144.38	12.031	12' 0"	3.67
7	20.125	164.50	13.708	13' 9"	4.18
8	19.875	184.38	15.365	15' 4"	4.68
9	20.125	204.50	17.042	17' 1"	5.20
Bottom	22.000				

Total
204.50 Inches
17.04 Feet
5.20 Meters

Forward (P_f) Power and Reflected (P_r) Power % by SWR

VSWR	RETUR N LOSS (db)	TRANS. LOSS (db)	VOLT. REFL. COEFF.	POWER TRANS. (%)	POWER REFL.
1.00	—	0.000	0.00	100.0	0.0
1.01	46.1	0.000	0.00	100.0	0.0
1.02	40.1	0.000	0.01	100.0	0.0
1.03	36.6	0.001	0.01	100.0	0.0
1.04	34.2	0.002	0.02	100.0	0.0
1.05	32.3	0.003	0.02	99.9	0.1
1.06	30.7	0.004	0.03	99.9	0.1
1.07	29.4	0.005	0.03	99.9	0.1
1.08	28.3	0.006	0.04	99.9	0.1
1.09	27.3	0.008	0.04	99.8	0.2
1.10	26.4	0.010	0.05	99.8	0.2
1.11	25.7	0.012	0.05	99.7	0.3
1.12	24.9	0.014	0.06	99.7	0.3
1.13	24.3	0.016	0.06	99.6	0.4
1.14	23.7	0.019	0.07	99.6	0.4
1.15	23.1	0.021	0.07	99.5	0.5
1.16	22.6	0.024	0.07	99.5	0.5
1.17	22.1	0.027	0.08	99.4	0.6
1.18	21.7	0.030	0.08	99.3	0.7
1.19	21.2	0.033	0.09	99.2	0.8
1.20	20.8	0.036	0.09	99.2	0.8
1.21	20.4	0.039	0.10	99.1	0.9
1.22	20.1	0.043	0.10	99.0	1.0
1.23	19.7	0.046	0.10	98.9	1.1

VSWR	RETUR N LOSS (db)	TRANS. LOSS (db)	VOLT. REFL. COEFF.	POWER TRANS. (%)	POWER REFL.
1.23	19.7	0.046	0.10	98.9	1.1
1.24	19.4	0.050	0.11	98.9	1.1
1.25	19.1	0.054	0.11	98.8	1.2
1.26	18.8	0.058	0.12	98.7	1.3
1.27	18.5	0.062	0.12	98.6	1.4
1.28	18.2	0.066	0.12	98.5	1.5
1.29	17.9	0.070	0.13	98.4	1.6
1.30	17.7	0.075	0.13	98.3	1.7
1.32	17.2	0.083	0.14	98.1	1.9
1.34	16.8	0.093	0.15	97.9	2.1
1.36	16.3	0.102	0.15	97.7	2.3
1.38	15.9	0.112	0.16	97.5	2.5
1.40	15.8	0.122	0.17	97.2	2.8
1.42	15.2	0.133	0.17	97.0	3.0
1.44	14.9	0.144	0.18	96.7	3.3
1.46	14.6	0.155	0.19	96.5	3.5
1.48	14.3	0.166	0.19	96.3	3.7
1.50	14.0	0.177	0.20	96.0	4.0
1.52	13.7	0.189	0.21	95.7	4.3
1.54	13.4	0.201	0.21	95.5	4.5
1.56	13.2	0.213	0.22	95.2	4.8
1.58	13.0	0.225	0.22	94.9	5.1
1.60	12.7	0.238	0.23	94.7	5.3
1.62	12.5	0.250	0.24	94.4	5.6

VSWR	RETUR N LOSS (db)	TRANS. LOSS (db)	VOLT. REFL. COEFF.	POWER TRANS. (%)	POWER REFL.
1.64	12.3	0.263	0.24	94.1	5.9
1.66	12.1	0.276	0.25	93.8	6.2
1.68	11.9	0.289	0.25	93.6	6.4
1.70	11.7	0.302	0.26	93.3	6.7
1.72	11.5	0.315	0.26	93.0	7.0
1.74	11.4	0.329	0.27	92.7	7.3
1.76	11.2	0.342	0.28	92.4	7.6
1.78	11.0	0.356	0.28	92.1	7.9
1.80	10.9	0.370	0.29	91.8	8.2
1.82	10.7	0.384	0.29	91.5	8.5
1.84	10.6	0.398	0.30	91.3	8.7
1.86	10.4	0.412	0.30	91.0	9.0
1.88	10.3	0.426	0.31	90.7	9.3
1.90	10.2	0.440	0.31	90.4	9.6
1.92	10.0	0.454	0.32	90.1	9.9
1.94	9.9	0.468	0.32	89.8	10.2
1.96	9.8	0.483	0.32	89.5	10.5
1.98	9.7	0.497	0.33	89.2	10.8
2.00	9.5	0.512	0.33	88.9	11.1
2.50	7.4	0.881	0.43	81.6	18.4
3.00	6.0	1.249	0.50	75.0	25.0
3.50	5.1	1.603	0.56	69.1	30.9
4.00	4.4	1.938	0.60	64.0	36.0
4.50	3.9	2.255	0.64	59.5	40.5

VSWR	RETUR N LOSS (db)	TRANS. LOSS (db)	VOLT. REFL. COEFF.	POWER TRANS. (%)	POWER REFL.
4.50	3.9	2.255	0.64	59.5	40.5
5.00	3.5	2.553	0.67	55.6	44.4
5.50	3.2	2.834	0.69	52.1	47.9
6.00	2.9	3.100	0.71	49.0	51.0
6.50	2.7	3.351	0.73	46.2	53.8
7.00	2.5	3.590	0.75	43.7	56.2
7.50	2.3	3.817	0.76	41.5	58.5
8.00	2.2	4.033	0.78	39.5	60.5
8.50	2.1	4.240	0.79	37.7	62.3
9.00	1.9	4.437	0.80	36.0	64.0
9.50	1.8	4.626	0.81	34.5	65.5
10.00	1.7	4.807	0.82	33.1	66.9
11.00	1.6	5.149	0.83	30.6	69.4
12.00	1.5	5.466	0.85	28.4	71.6
13.00	1.3	5.762	0.86	26.5	73.5
14.00	1.2	6.040	0.87	24.9	75.1
15.00	1.2	6.301	0.88	23.4	76.6
16.00	1.1	6.547	0.88	22.1	77.9
17.00	1.0	6.780	0.89	21.0	79.0
18.00	1.0	7.002	0.89	19.9	80.1
19.00	0.9	7.212	0.90	19.0	81.0
20.00	0.9	7.413	0.90	18.1	81.9
25.00	0.7	8.299	0.92	14.8	85.2
30.00	0.6	9.035	0.94	12.5	87.5



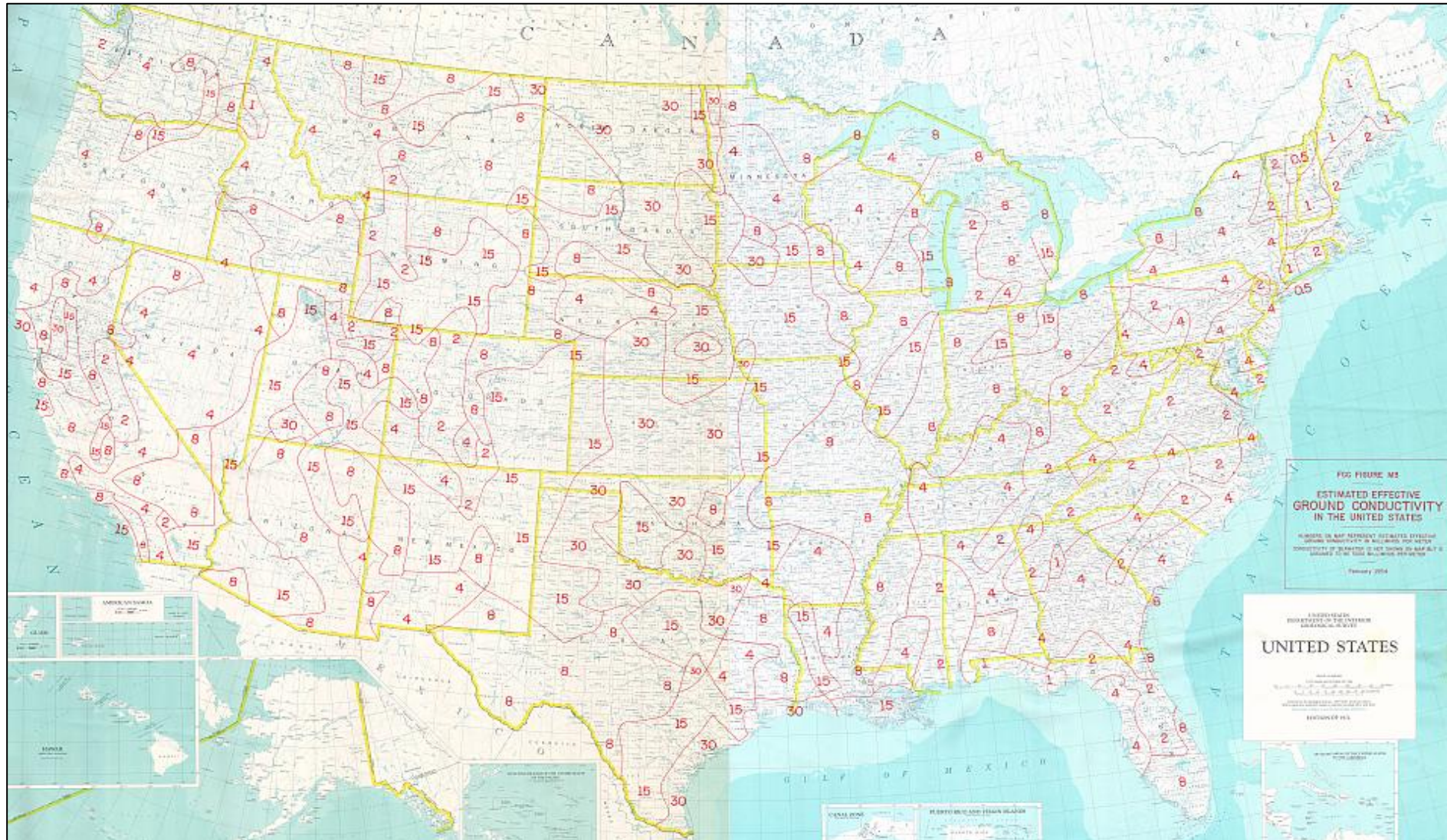
No tuner is recommended if SWR is less than or equal to 1.50:1 which implies 96% power delivered to antenna structure

$$SWR = \frac{1 + \sqrt{P_r/P_f}}{1 - \sqrt{P_r/P_f}}$$

P_f = forward power
 P_r = reflected power

Source: Menace Radio Control Ltd. (2019)

Ground Conductivity in the United States (0.5-30 milliSiemens per meter)



Source: FCC (1975)
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Seawater = 5,000 mS/M

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