43 Ft Verticals – What's the Big Deal?

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What I Wanted To Learn

- How does it work?
- What are strengths and weaknesses?
- If I can mount one on my roof, should I do it?
- What about radials?
- Is it really an “all band” antenna?

Don't Bother Taking Notes

- pdf of these slides is on my website
  k9yc.com/publish.htm

The 43 Ft Vertical

- **Is designed to be a ground-mounted antenna with on-ground radials**
- **Is advertised as covering all bands 160-10M**

Let's Review How Verticals Work

Let's Review How Verticals Work

- The transmitter feeds a vertical conductor, with the coax shield connected to radials

Why Radials?

- **Earth is a relatively poor conductor – that is, it's a (very big) resistor**
- **Even the best connection to earth is bad for an antenna – it drives current to that lossy earth**
- **Current in lossy earth burns transmitter power ($P_G = I^2R_G$) before it can be radiated**

Why Radials?

- **An ideal radial system:**
  - **<u>shields</u> the antenna from the earth**
  - **provides a path for return <u>current</u>**
  - **Provides a return path for fields produced by the antenna**

Why Radials?

- **With no radials, the outside of the coax forms a single radial**
  - **It's better than nothing, but not very effective**
  - **It does not shield the antenna from lossy earth**
  - **And it can put RF in the shack**

Guidelines for Radials

- **Insulated wire holds up longer**
- **#18 minimum size for durability**
  - **Large spools hard to buy**
- **#14 THHN (house wire) works well**
  - **Mass market items often less expensive and easy to find**

On-Ground Radial Systems

- **Four λ/4 radials per band for multiband vertical (N6LF)**
- **<u>Symmetry</u> is good, but most radial systems must be shorter in some directions because they run into buildings, roads, property lines**

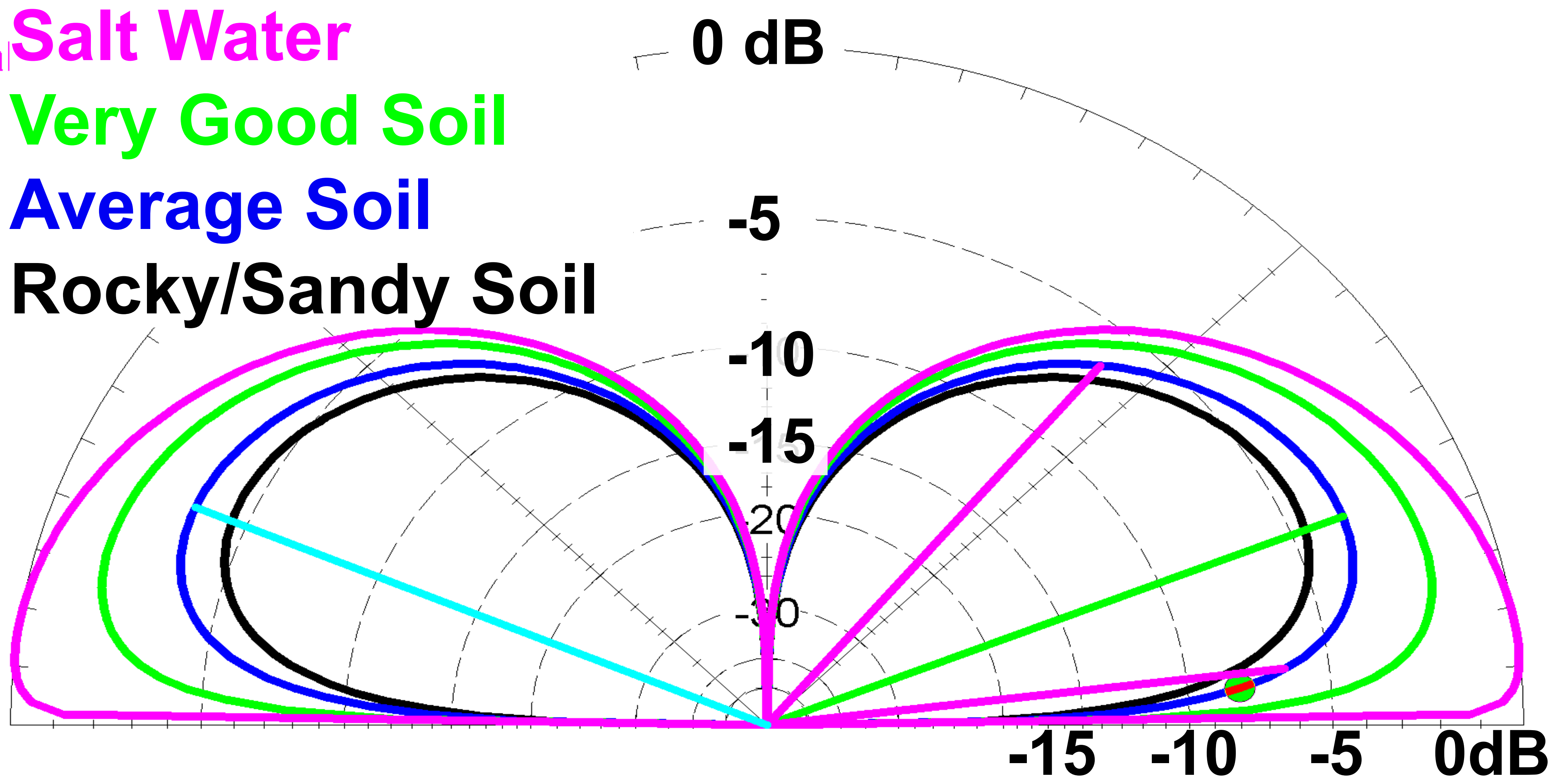
How Earth Affects Verticals

- **Power is <u>lost</u> in earth <u>very</u> <u>near</u> the antenna <u>before it can be radiated</u>**
  - **Radials reduce this loss**
  - **Radials make the most difference with poor soil**

How Earth Affects Verticals

- **Radiated signal is <u>reflected</u> by the earth <u>far</u> from the antenna**
  - **Reflection adds to direct signal**
  - **Shapes the vertical pattern**
  - **Better soil helps low angle most**
- **Radials don’t help the <u>reflection</u>, but they strengthen the radiated signal that gets reflected**

The Power of Earth Reflections



Vertical Pattern

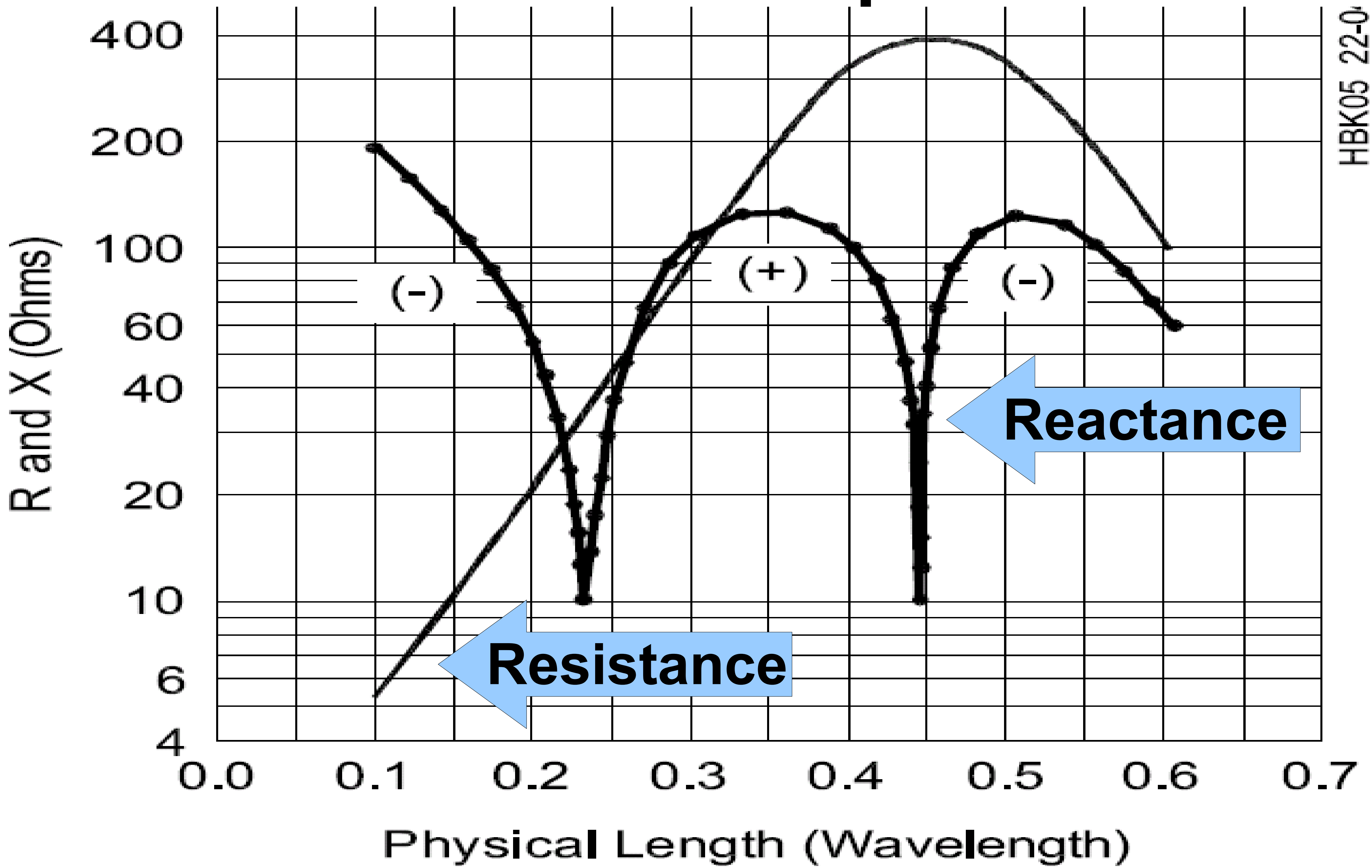
What Kind of Soil Do I Have?

- **Most of the Bay Area has “Average” soil**
- **Some of the North Bay and the fertile valleys have “Good” soil**
- **Desert and rocky areas have “Poor” to “Very Poor” soil**

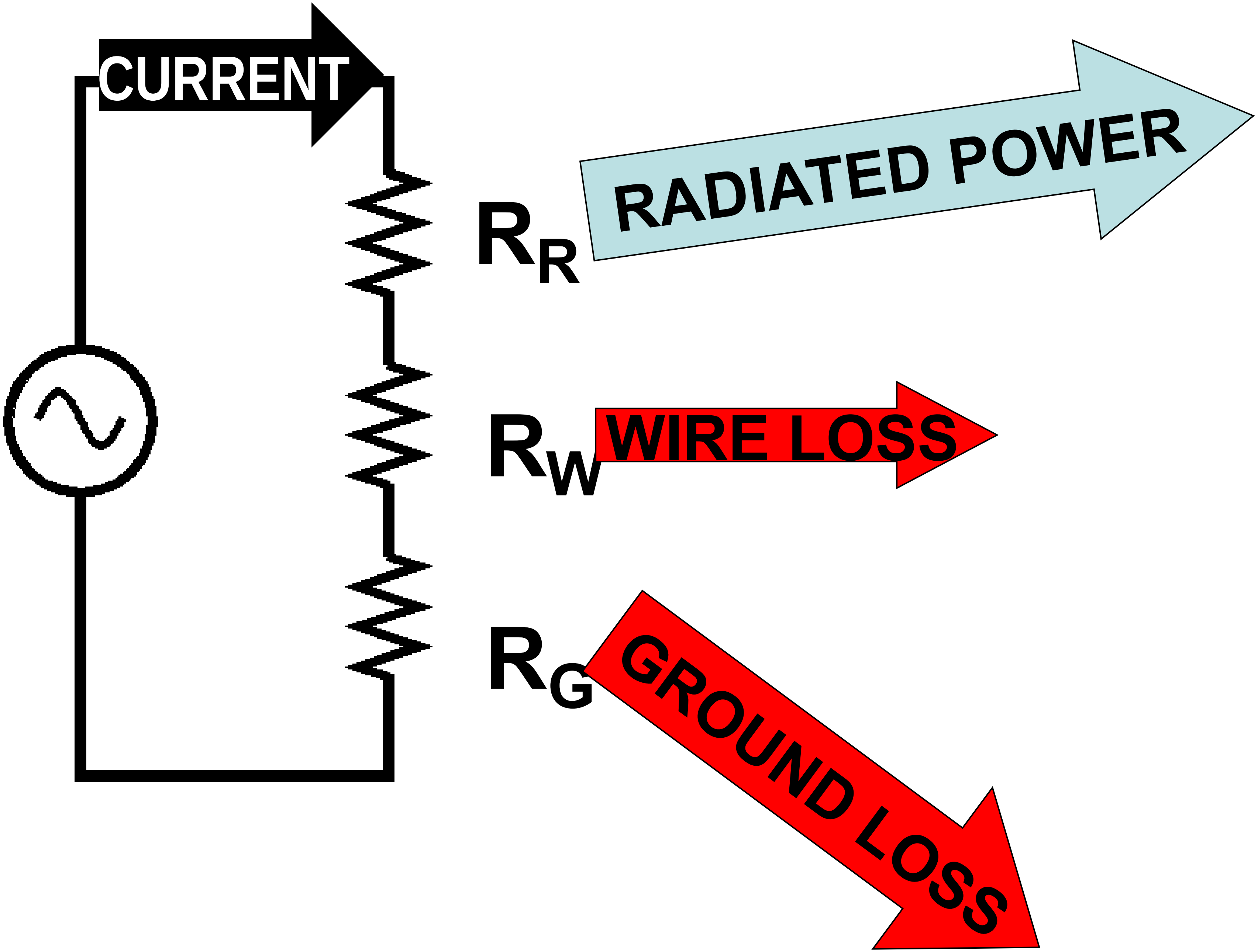
Vertical Antenna Efficiency – It's All About Resistance

- Radiation resistance (R_R) is the part of the feedpoint impedance that accounts for radiated power
- R_R mostly determined by vertical height of the radiator
- R_R is “good” resistance, more is better

Radiation Resistance vs Length of Vertical Monopole



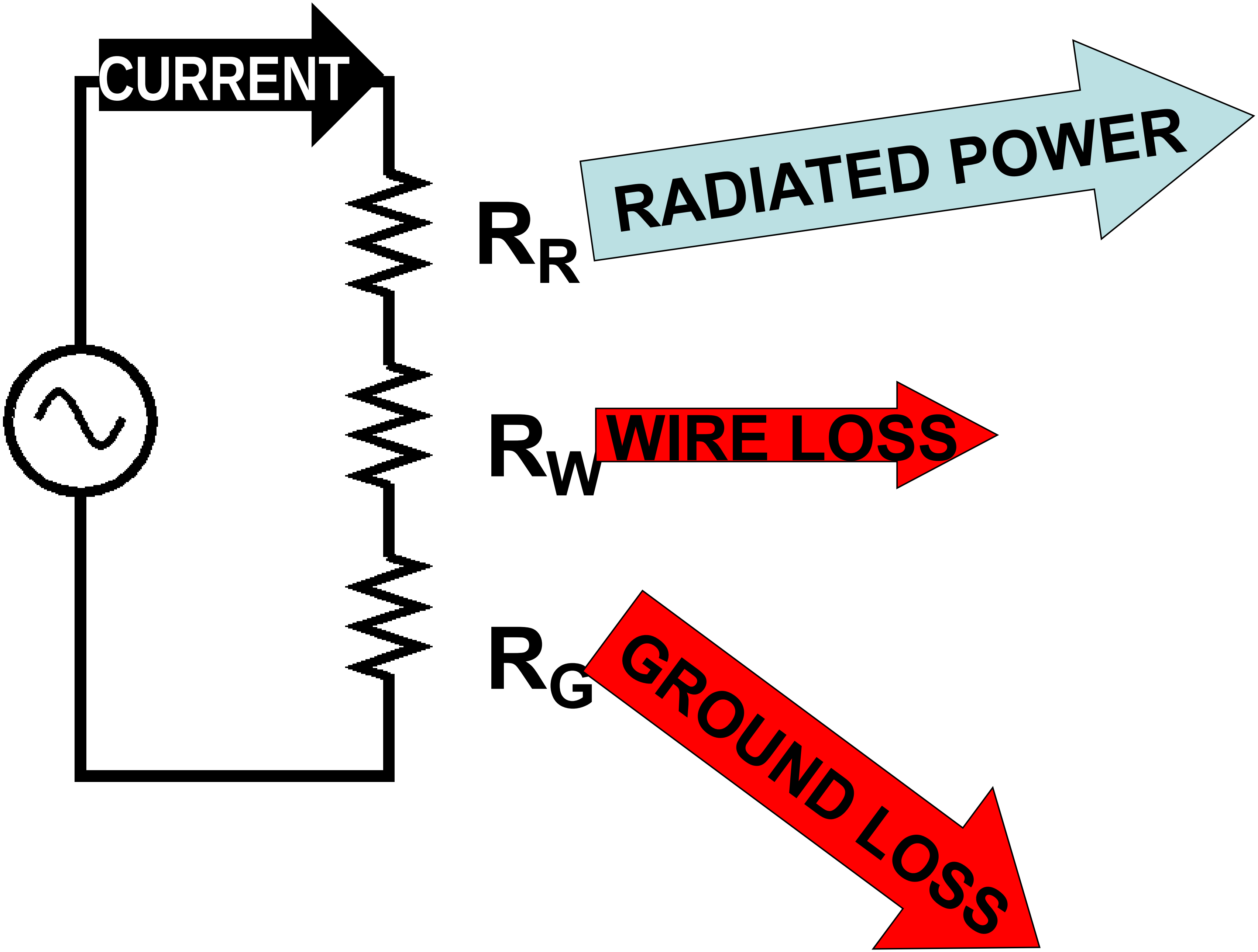
It's A Simple Series Circuit



Resistance Matters

- Ground resistance (R_G) combines with wire resistance (R_W) to burn transmitter power

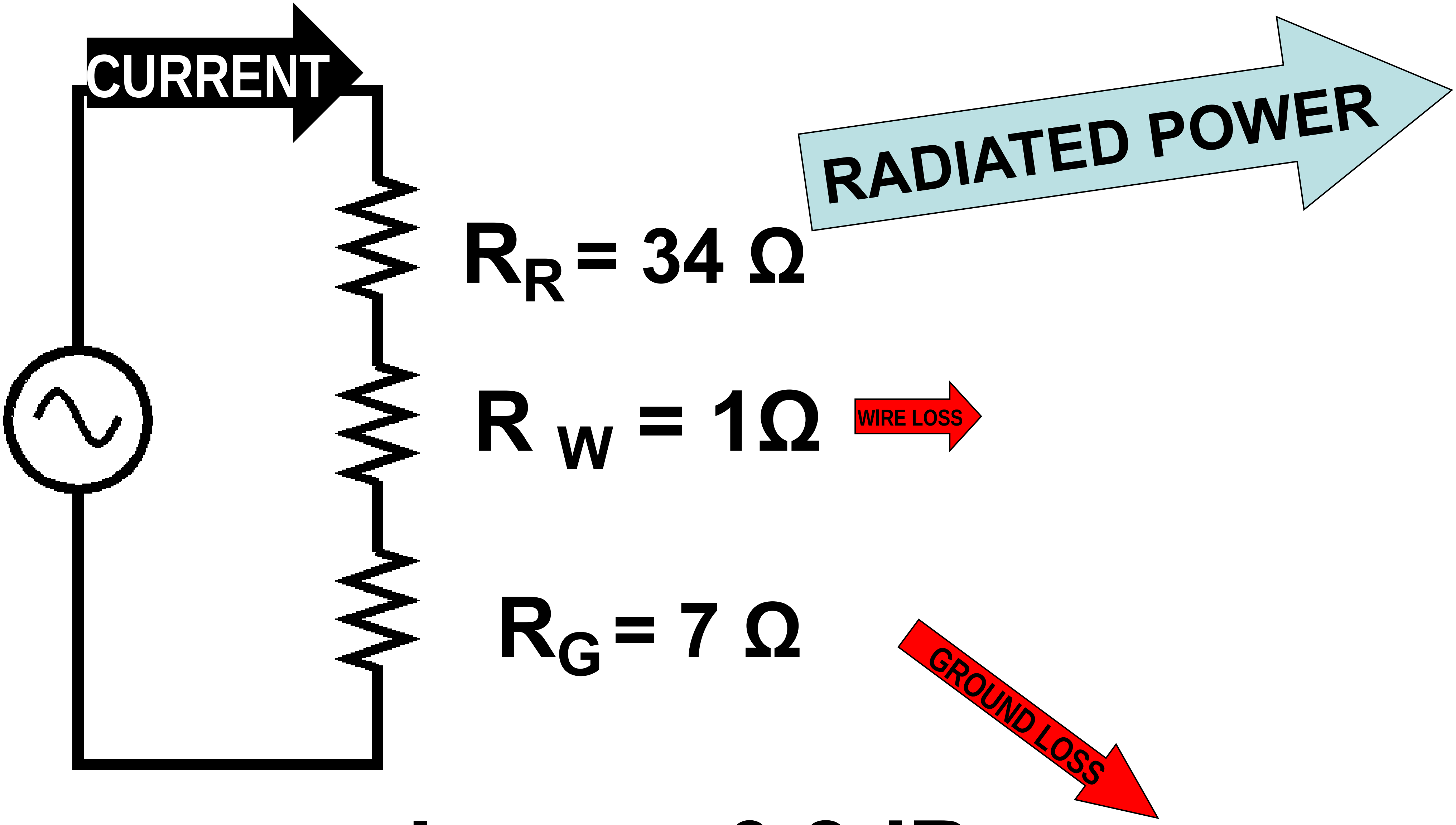
It's A Simple Series Circuit



Ground Resistance

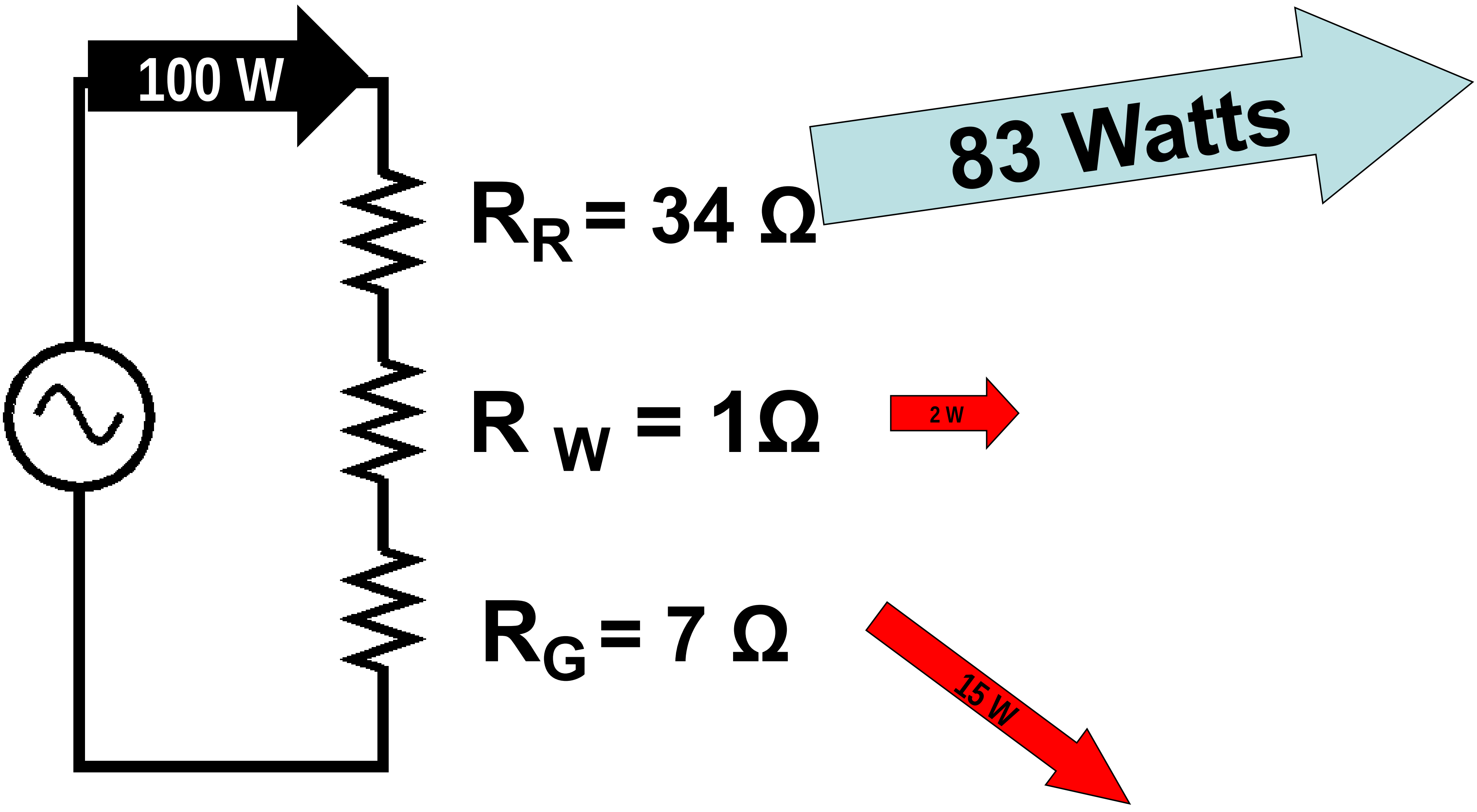
- Depends on the nature of the earth around the antenna
  - We can’t change it except by moving
- Depends on the radial system
- Make R_G smaller by using
  - more radials and longer radials
  - a good counterpoise
  - a ground screen

Tall Antenna, “Very Good” Radials



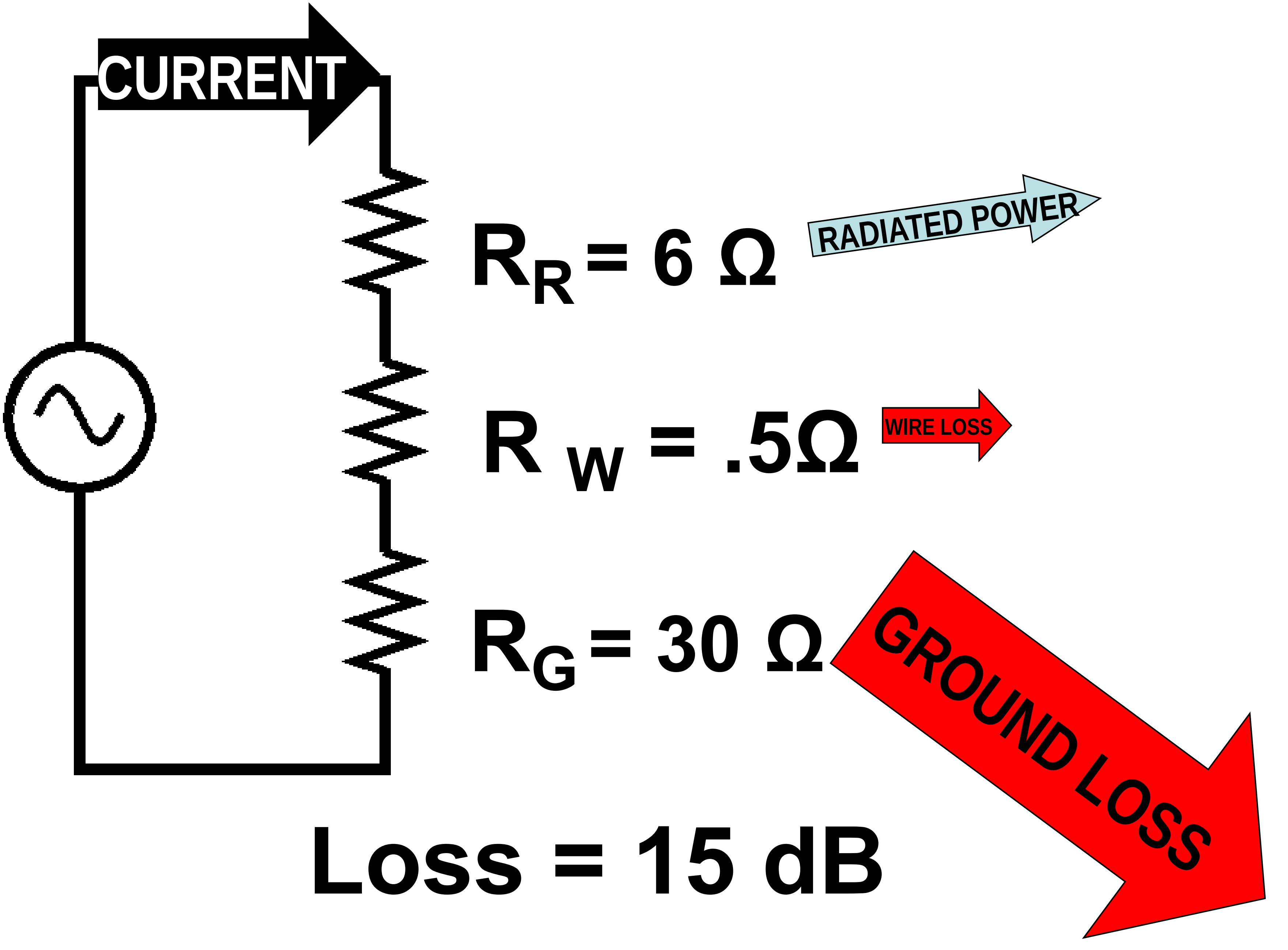
Loss = 0.8dB

Tall Antenna, "Very Good" Radials



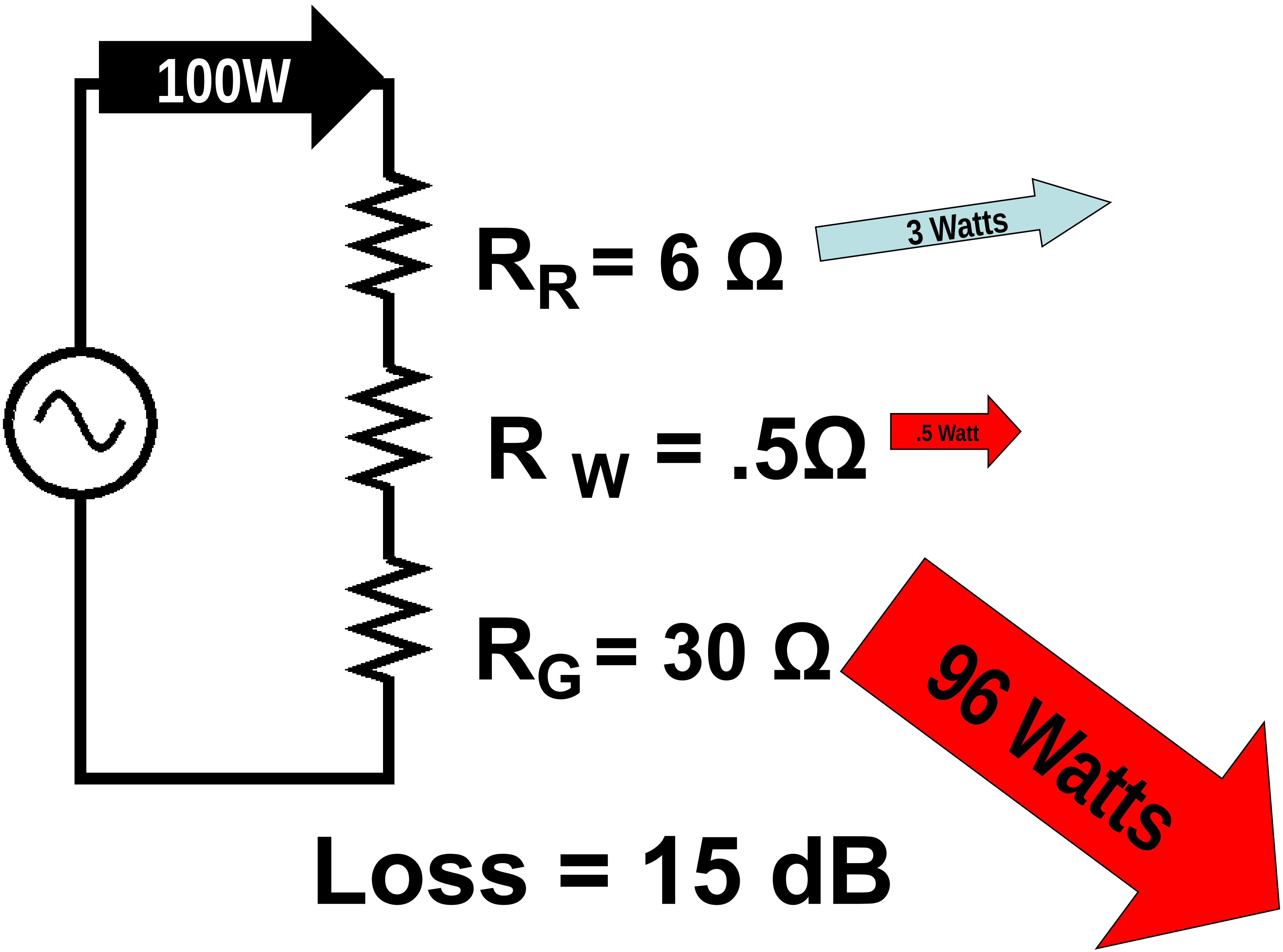
Loss = 0.8dB

Short Antenna, Limited Radials



Loss = 15 dB

Short Antenna, Limited Radials

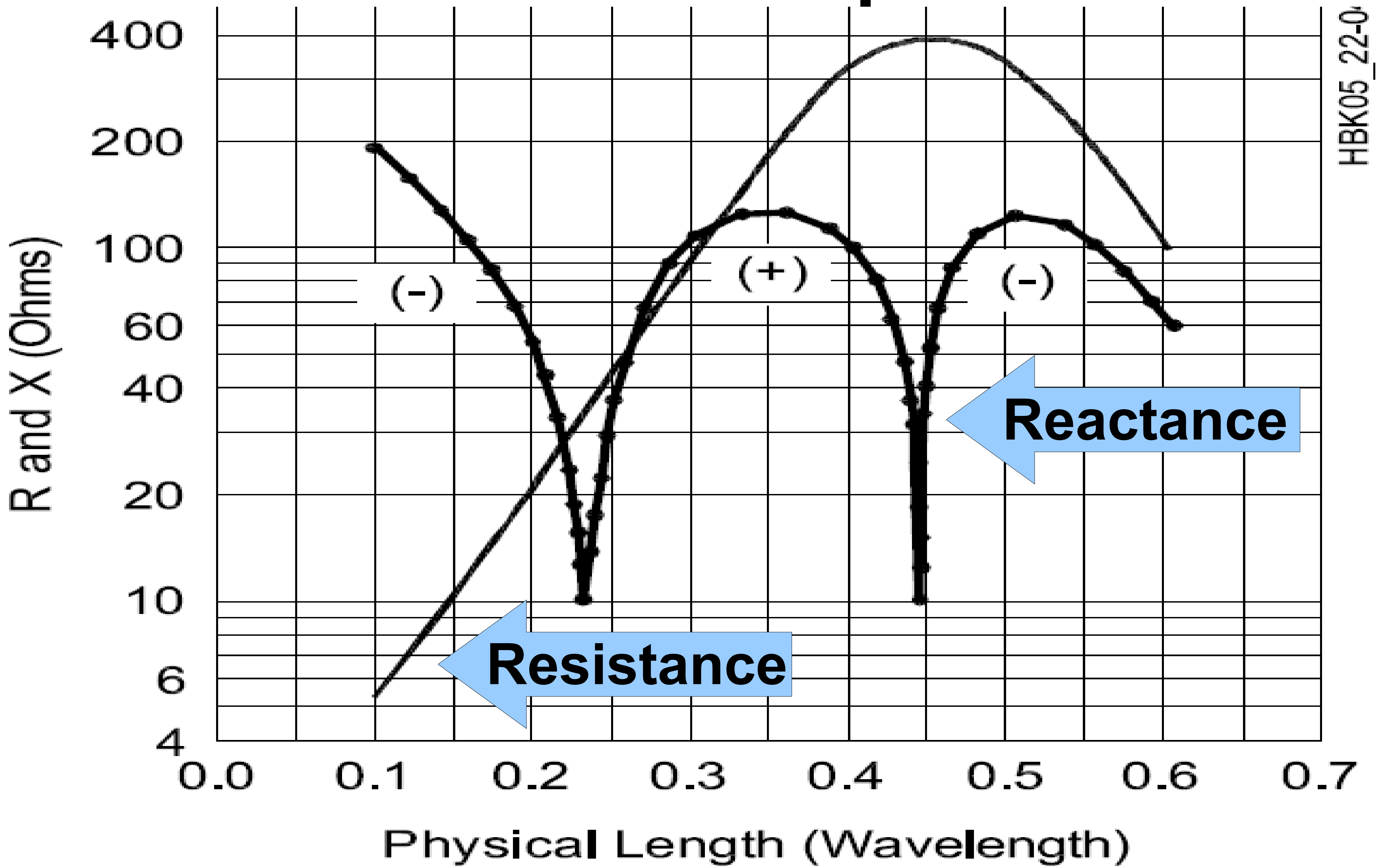


Loss = 15 dB

Typical Loss Resistances

- R_W for 43 ft Al tubing ~ 0.2 ohm
- R_G ranges from 2 – 4 Ω for a great radial system to 20 Ω for a poor one
- So – ignore R_W and concentrate on trying to make R_G smaller and R_R larger

Radiation Resistance vs Length of Vertical Monopole



R_R, Electrical Length, Ground Loss (assumes 10 ohm radial system)

- A 43 Ft vertical
  - On 160M, 0.08λ, so R_R = 2.7 Ω, -13 dB
  - On 80M, 0.16λ, so R_R = 12.7 Ω, -2.5 dB
  - On 40M, 0.32λ, so R_R = 93 Ω, -0.9 dB
- Losses can be reduced with a better radial system

What About the Vertical Pattern?

- How does it compare to a quarter-wave vertical?
- How does it compare to a roof-mounted multi-band vertical dipole?
- Let's study the vertical radiation pattern on each band

Vertical Radiation Patterns

- **Models of two 43 ft antennas were constructed using W7EL's EZNEC (NEC2)**
  - **Simple 43-ft monopole with 10 Ω radial system (~32 on-ground wire radials)**
  - **Simple 43-ft monopole with base at 33 ft, with two resonant radials each for 40M, 20M, 15M, and 10M (not easy to build)**
- **Compare with quarter-wave ground-mounted vertical with 10 Ω radial system**

My Method

- All antennas were modeled over six soil types
  - Very poor – cities, industrial
  - Poor – rocky, mountainous
  - Average – pastoral, heavy clay
  - Pastoral, rich soil, US Midwest
  - Very good, central US
  - Salt water

What Soil Do We Have?

- **Most of us in Northern California have soil on the poor side of average – rocky, sandy, urban**
- **California farmland and rolling grassy hills are probably between average and a bit better than average**
- **Some soil may be a bit better in rainy season, poorer when it's dried out**
- **Skin depth of soil can be 5-50 ft (depends on frequency and soil), so changes in surface moisture may not have much effect**

My Method

- As a separate study, I also modeled several resonant vertical antenna types
- Those antenna were modeled
  - over the same six soil types
  - on 40M, 20M, and 10M
  - on the ground and at several heights representative of roof mounting
- This work was shown yesterday as part of the Antenna Forum

What I Learned

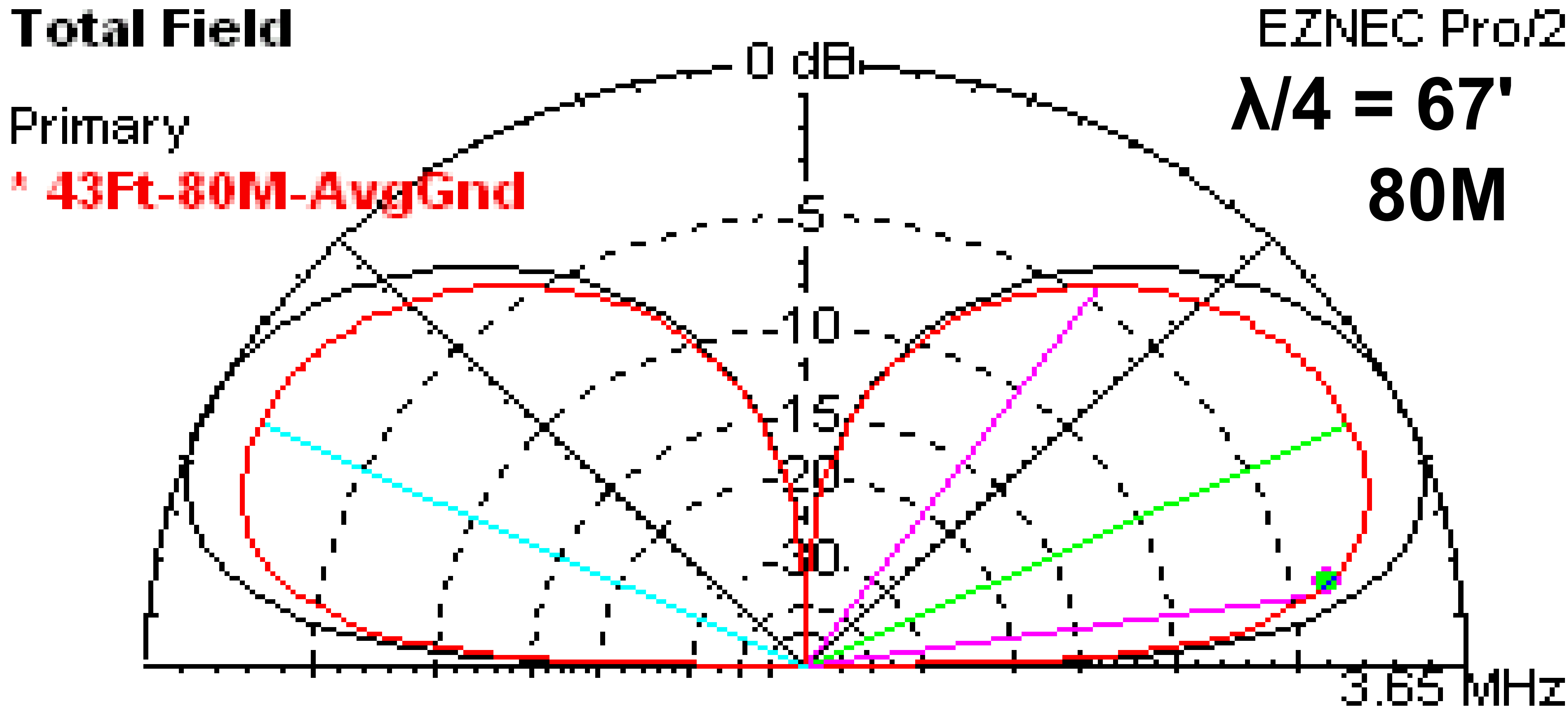
- Mounting almost any HF vertical in the range of λ/4 – λ/2 above ground improves performance for most soil conditions
- Greatest improvement with the poorest soil
  - Near field ground losses are reduced
  - Making the feedpoint higher increases radiation at low angles (good for DX)
- With increasing height, higher angle lobes develop, more pronounced for better soil
  - Nulls at intermediate elevation angles between the lobes

What I Learned

- A 43 ft vertical
  - below 17M, is a pretty decent radiator if it has a good radial system
  - Much better than average on 20M 5/8 λ
  - Is a cloud-warmer above 20M
  - Is quite difficult to match
  - High SWR on most bands
  - Requires a serious tuner
  - Works 2-3 dB better at roof level – <u>if</u> it has at least 2 radials per band (not easy)

Vertical Radiation Patterns

- Reference trace is λ/4 vertical at ground level, resonant on each band
- 43 ft vertical is at ground level
- Both are modeled over MiniNEC Average ground with 10Ω ground loss



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-4.24 dBi
Outer Ring	-0.44 dBi		-2.3 dBmax
			-1.72 dBPrTrc

Zo = 14.5 – j 220 SWR 70:1

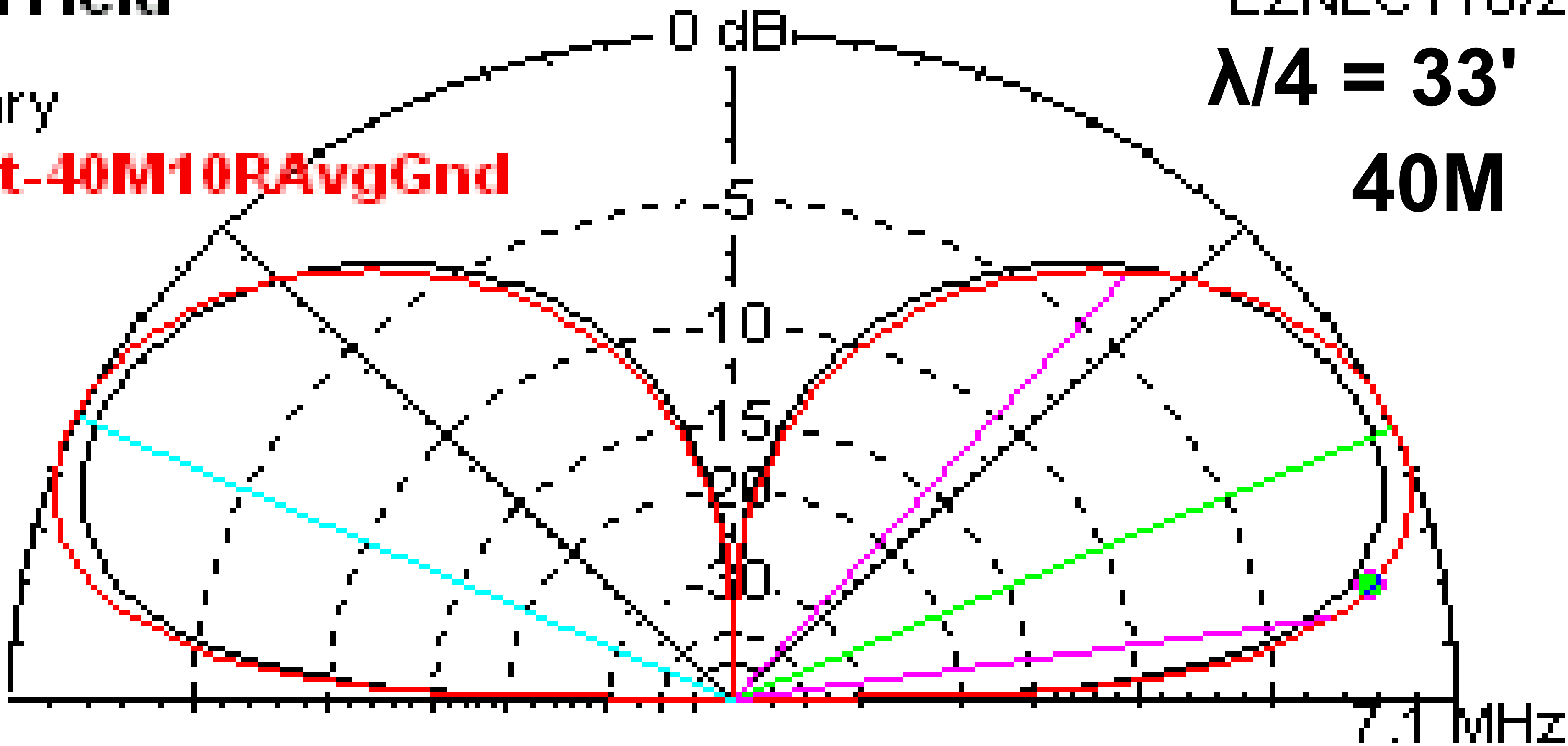
Total Field EZNEC Pro/2

Primary

λ/4 = 33'

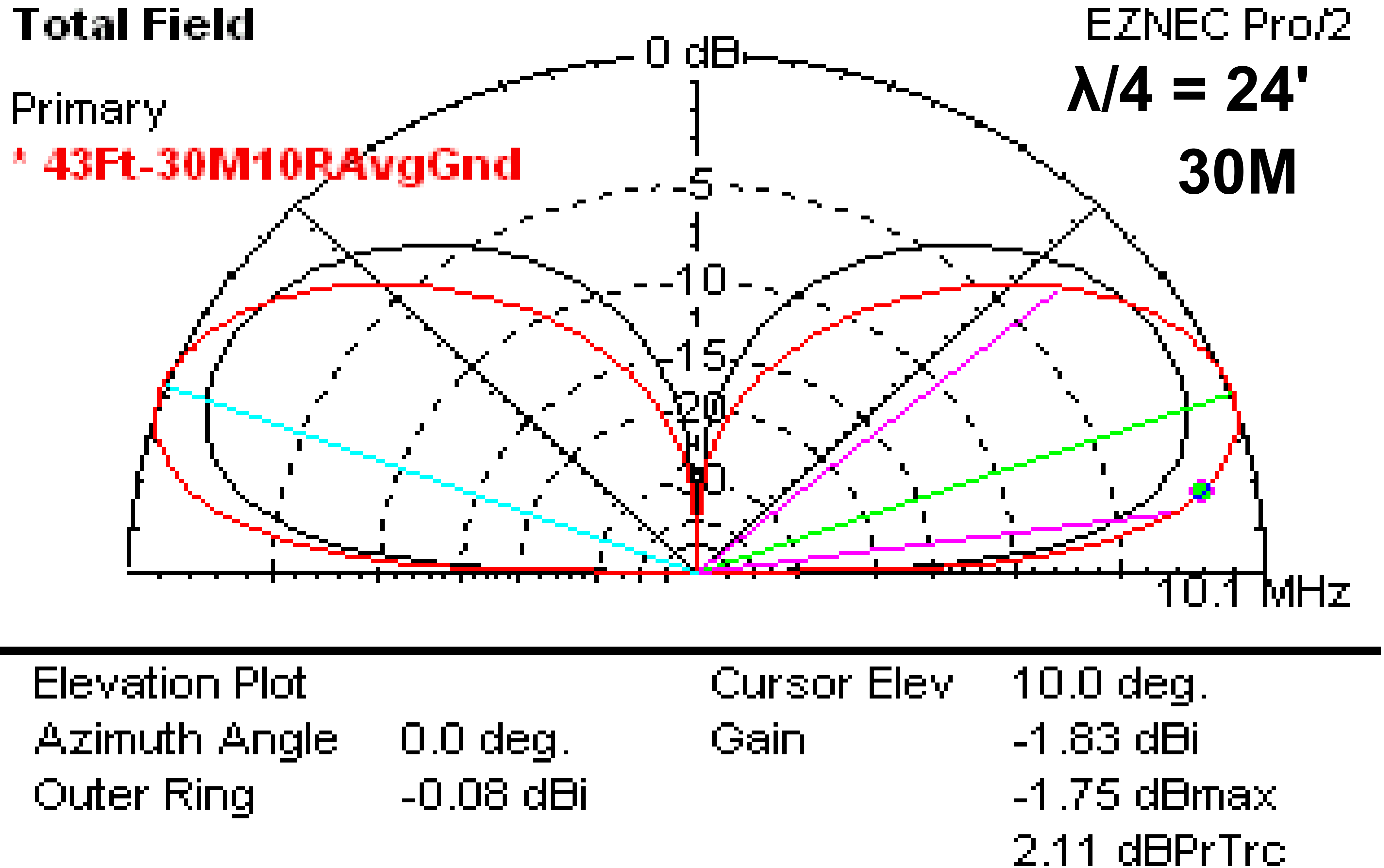
* **43Ft-40M10RAvgGnd**

40M

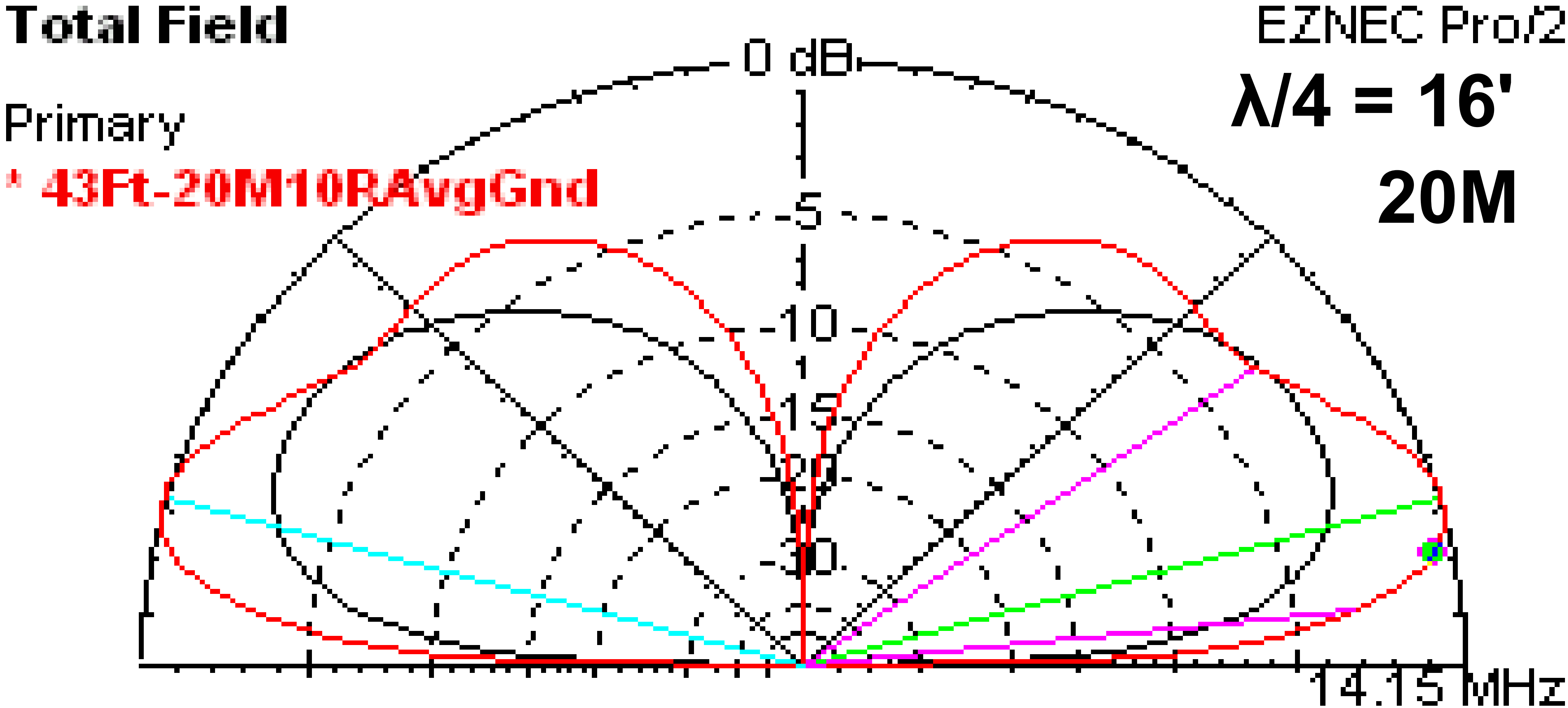


Elevation Plot		Cursor Elev	11.0 deg.
Azimuth Angle	0.0 deg.	Gain	-2.44 dBi
Outer Ring	-0.58 dBi		-1.86 dBmax
			0.78 dBPrTrc

Zo = 95 + j 195 SWR 10:1



Zo = 1050 + j 570 SWR 27:1

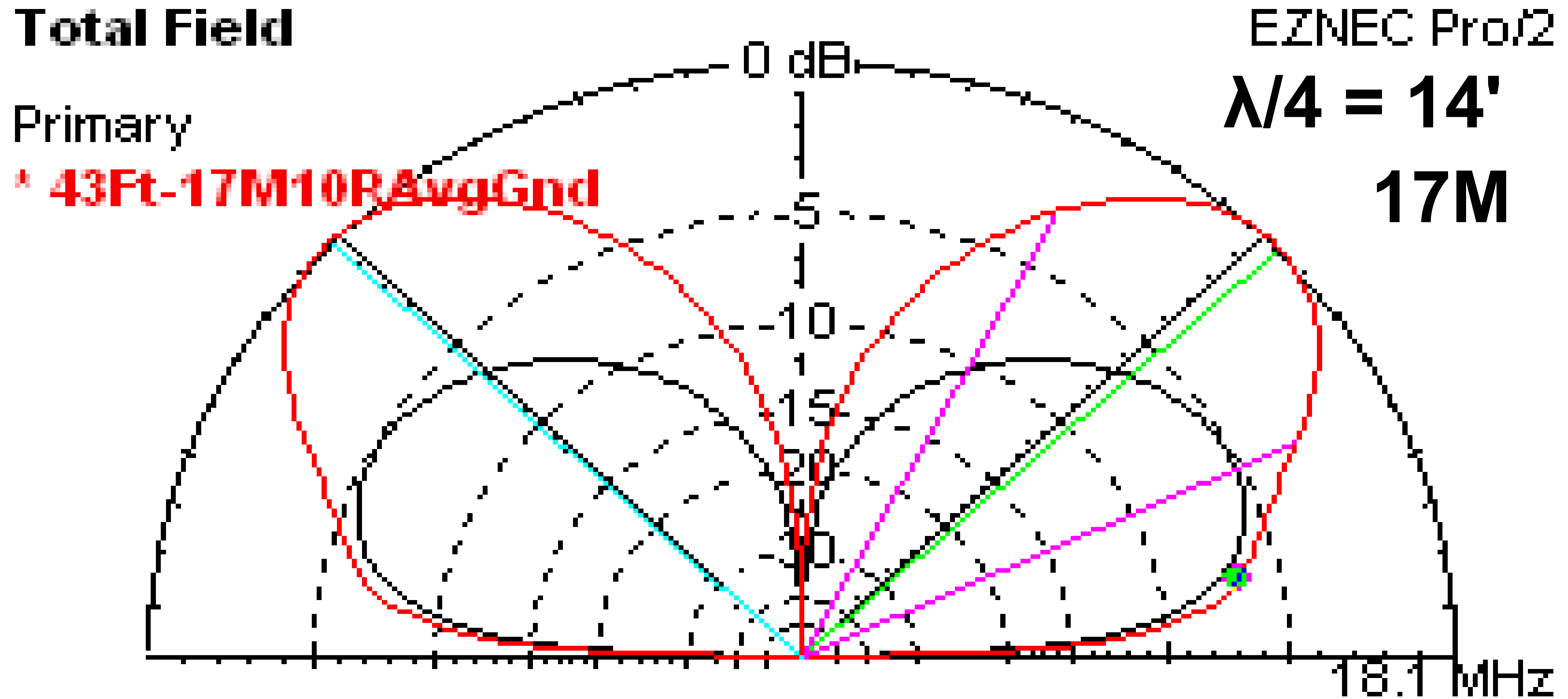


λ/4 = 16'

20M

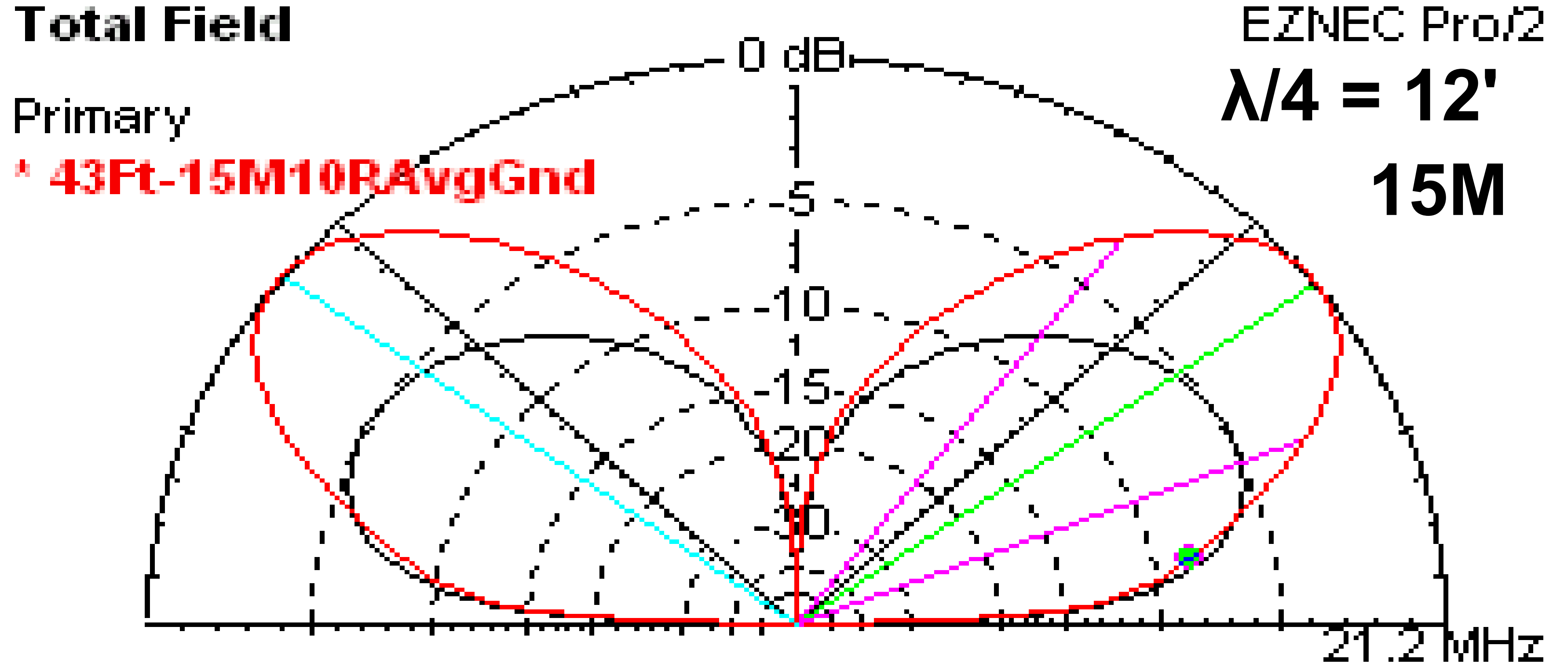
Elevation Plot		Cursor Elev	11.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.61 dBi
Outer Ring	1.23 dBi		-0.62 dBmax
			4.23 dBPrTrc

Zo = 80 – j 300 SWR 26:1



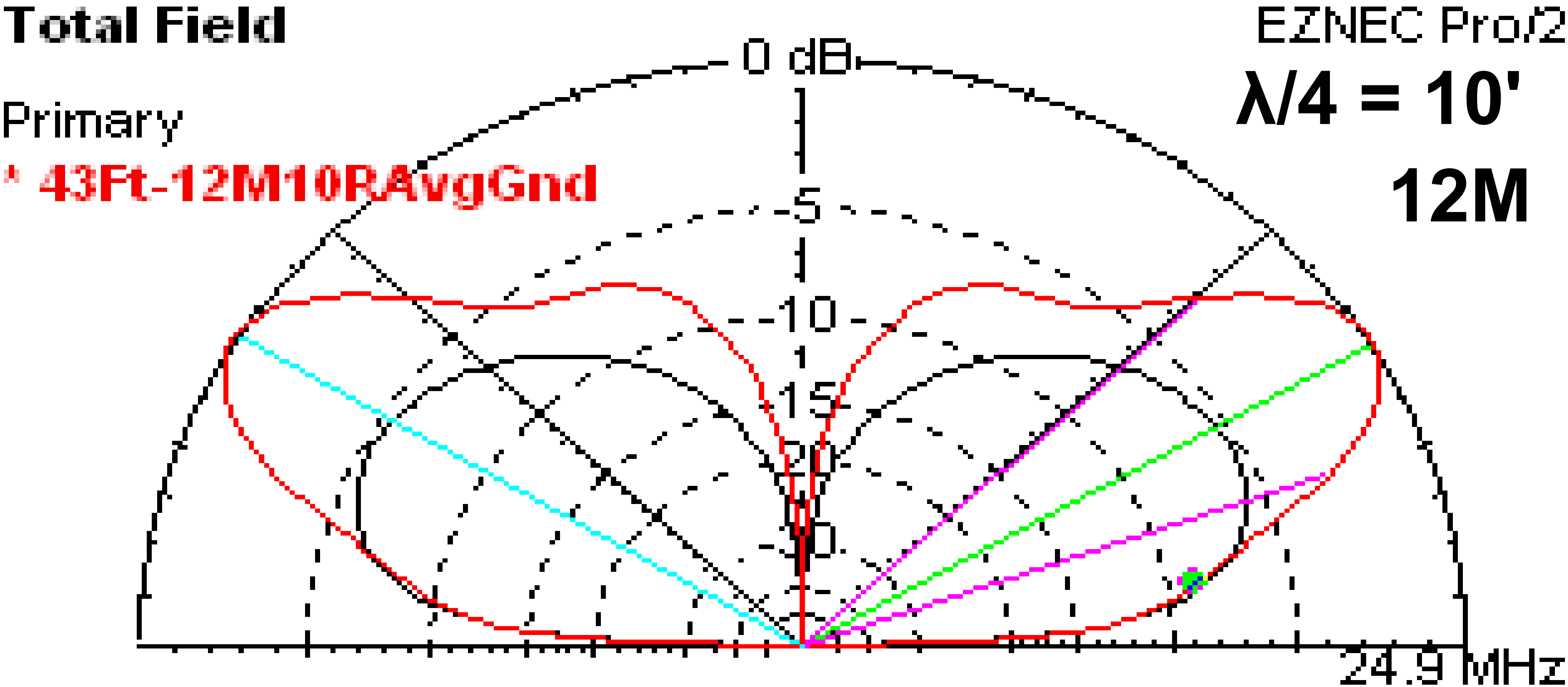
Elevation Plot		Cursor Elev	11.0 deg.
Azimuth Angle	0.0 deg.	Gain	-2.66 dBi
Outer Ring	3.95 dBi		-6.61 dBmax
			1.01 dBPrTrc

Zo = 43.1 + j 20.9 SWR 1.6:1



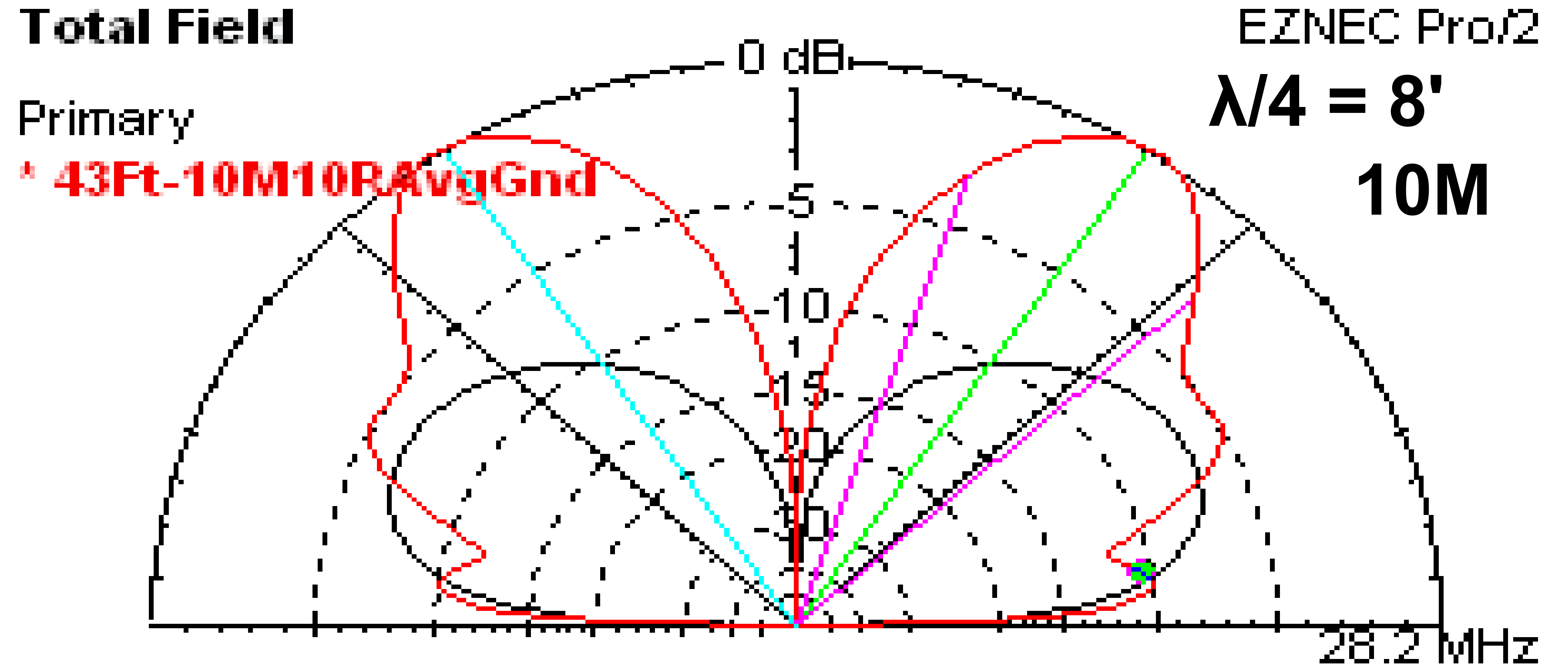
Elevation Plot		Cursor Elev	11.0 deg.
Azimuth Angle	0.0 deg.	Gain	-4.47 dBi
Outer Ring	3.72 dBi		-8.19 dBmax
			-0.79 dBPrTrc

Zo = 645 – j 374 SWR 17:1



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-4.75 dBi
Outer Ring	4.12 dBi		-8.87 dBmax
			-0.62 dBPrTrc

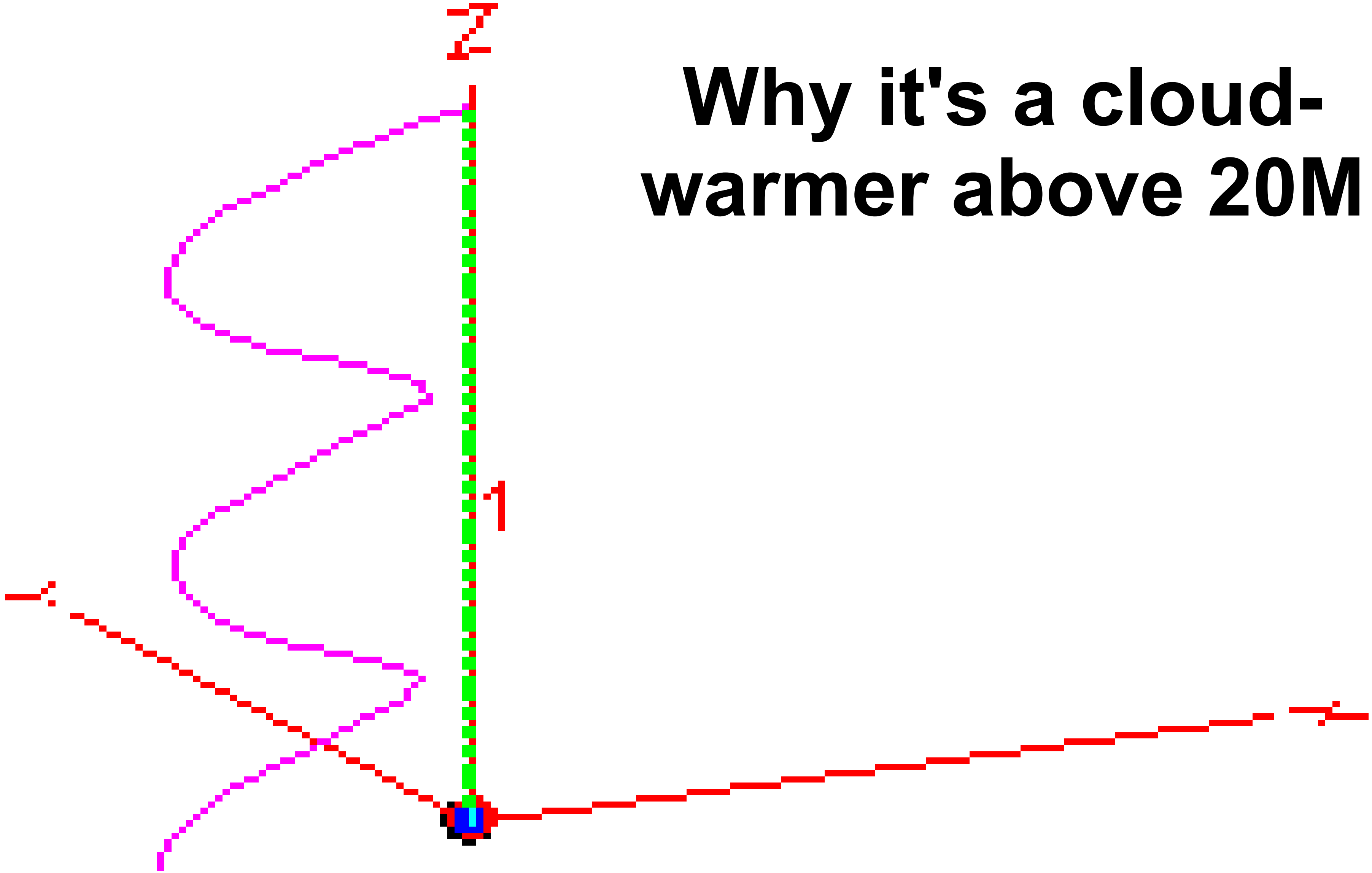
Zo = 165 – j 355 SWR 19:1



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-5.16 dBi
Outer Ring	5.33 dBi		-10.49 dBmax
			-1.06 dBPrTrc

Zo = 62.7 – j 2.5 SWR 1.2:1

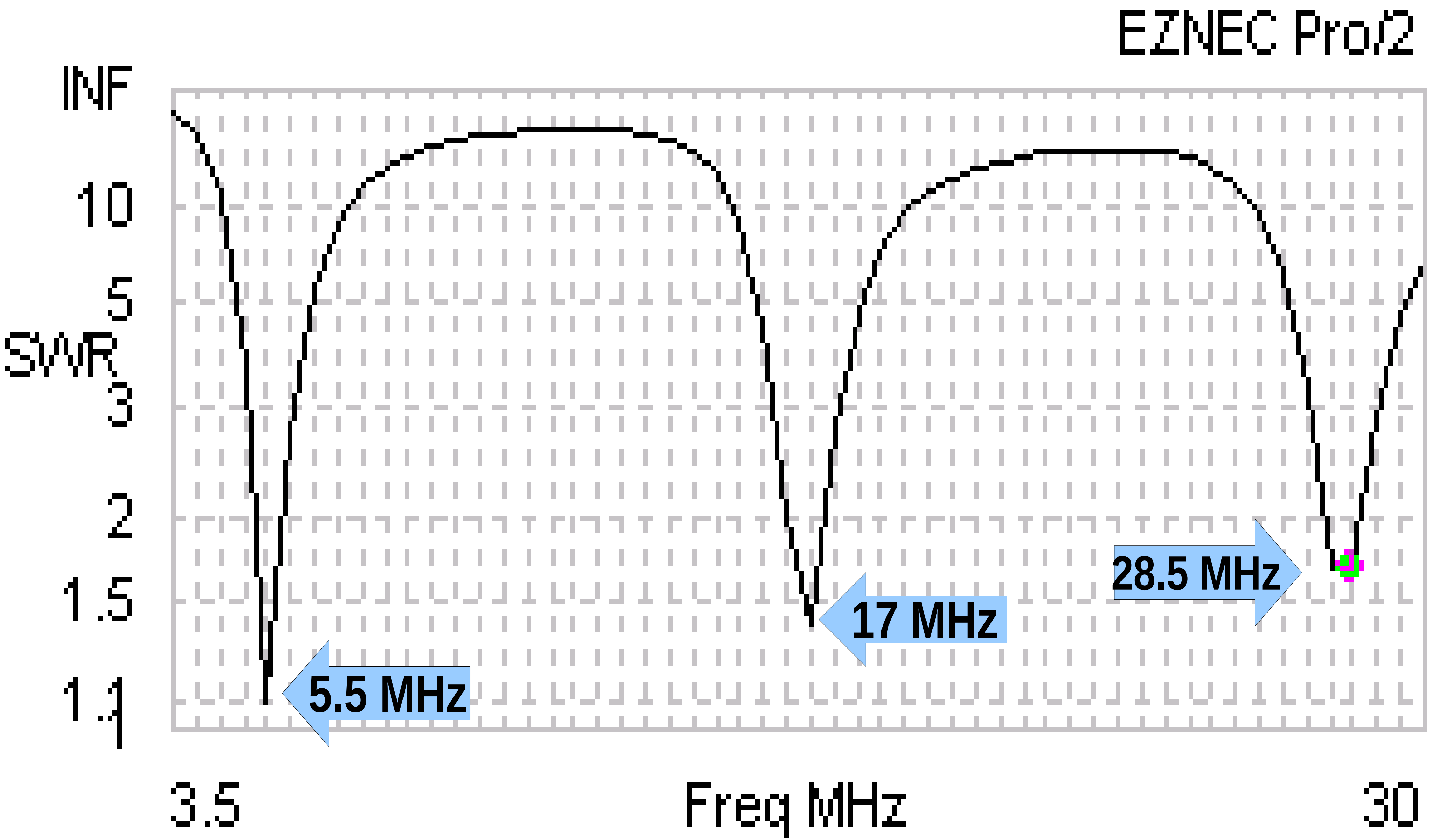
Why it's a cloud-warmer above 20M



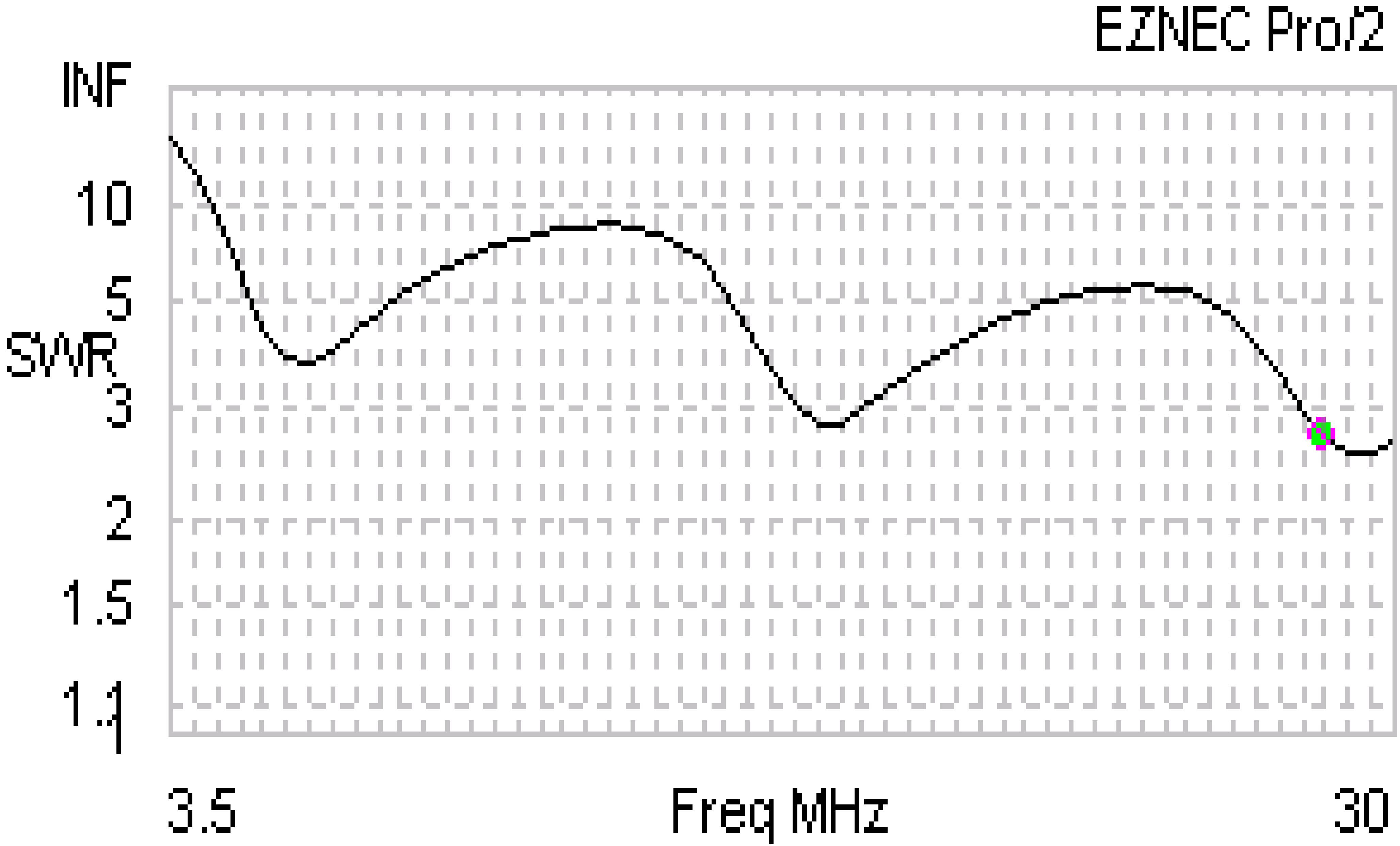
Antenna Current on 10M

It's Not An Easy Antenna to Feed

SWR In 50Ω System



Add A 4:1 Transformer (Unun)



R_R, SWR, Loss in 10Ω Radial System

Band	Z_O = 50Ω	Z_O = 200Ω	R_R	Loss
160	> 100:1	> 100:1	2.7 Ω	– 13.5 dB
80	70:1	19:1	12.7 Ω	– 2.5 dB
40	10:1	4:1	93 Ω	– 0.9 dB
30	27:1	7:1	1,090 Ω	0 dB
20	21:1	7.5:1	779 Ω	0 dB
17	5.3:1	2.9:1	90 Ω	– 0.9 dB
15	17.5:1	4.1:1	665 Ω	– 0.07 dB
12	18:1	5.5:1	162 Ω	– 0.26 dB
10	1.7:1	2.7:1	63 Ω	– 0.7 dB

How To Match It on 40M – 10M

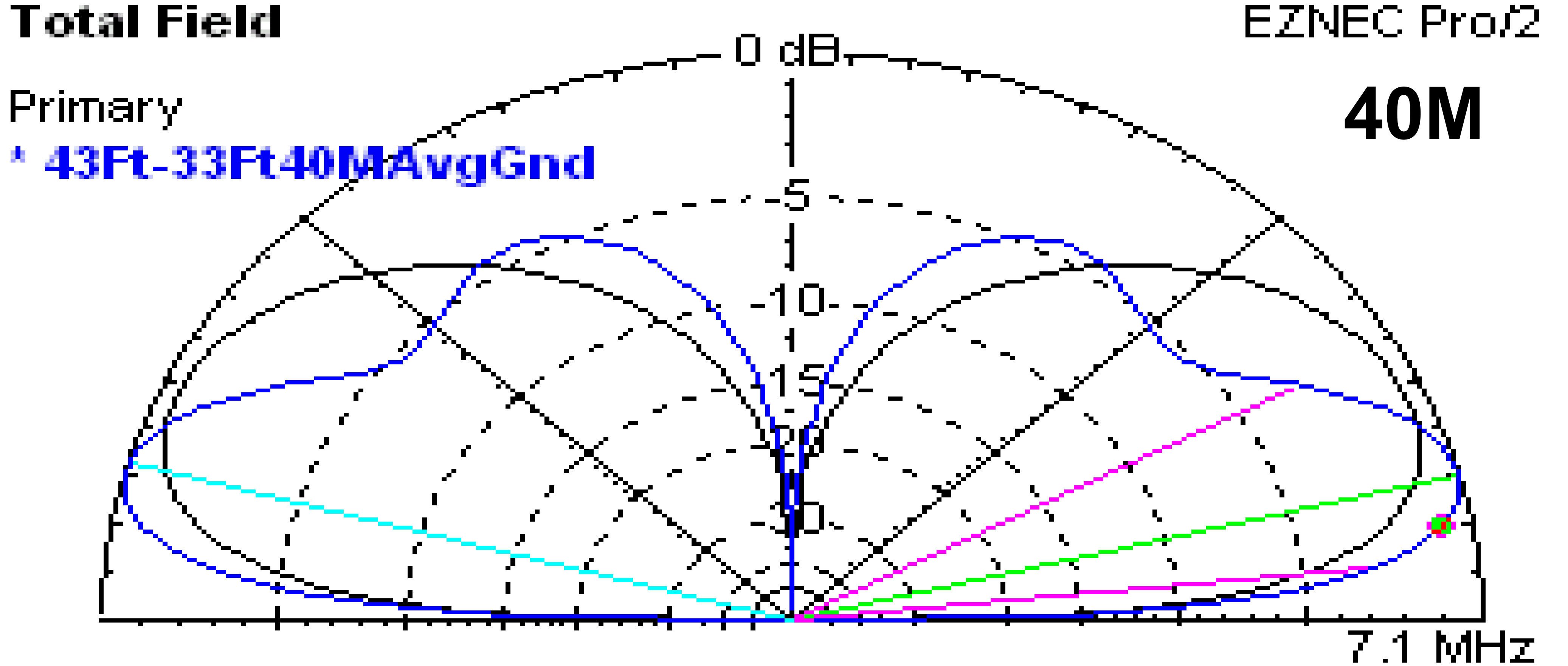
- **Add 1:4 transformer at antenna**
- **Run <u>big</u> coax to the shack**
  - **60 ft good RG213 or LMR400 < 0.7dB**
  - **Use a good tuner in the shack**
- **Or buy dedicated tuner from antenna manufacturer (expensive)**

How To Match It on 160M and 80M

- Add loading coils, one for each band
  - Use relays at feedpoint to switch between coils and transformer
  - Use a good tuner in the shack
- Or buy dedicated tuner from antenna manufacturer (expensive)
- See AD5X's solutions
  - http://www.ad5x.com

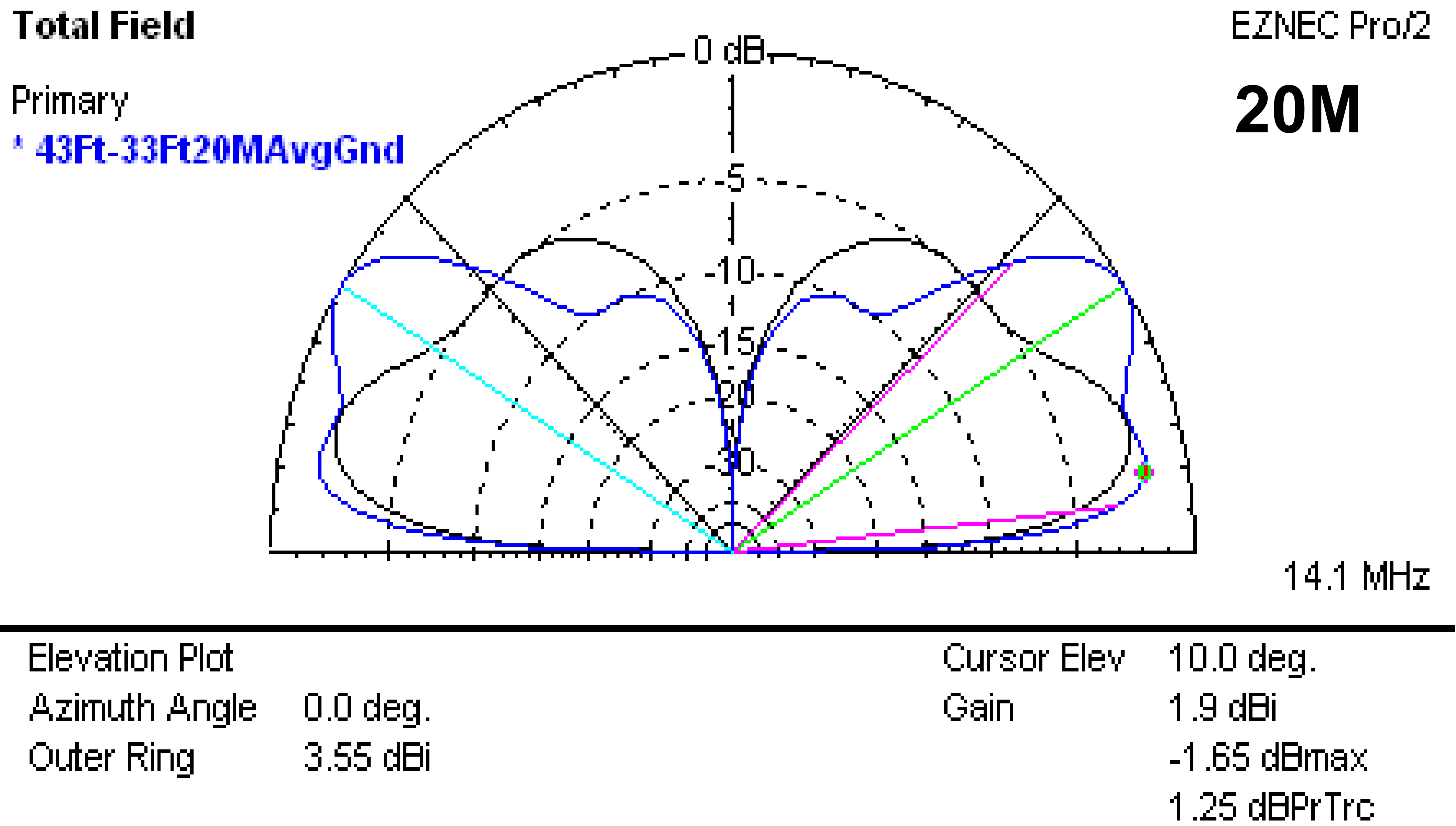
How About Roof-Mounting?

- Reference trace is 43 ft vertical at ground level
- Blue trace is 43 ft vertical at 33 ft, with two-each radials for 40M, 20M, 15M, and 10M

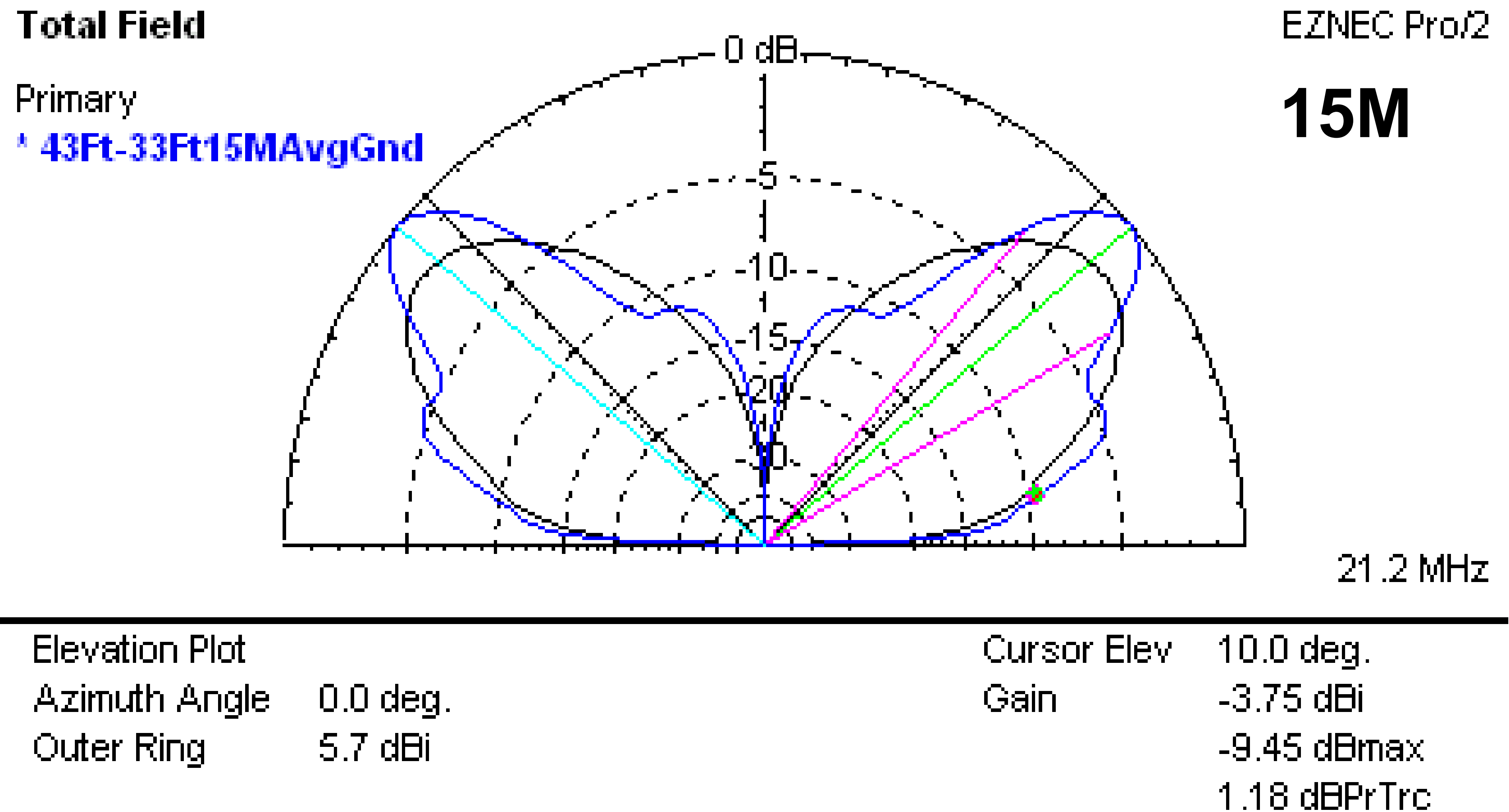


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.61 dBi
Outer Ring	0.17 dBi		-0.78 dBmax
			1.93 dBPrTrc

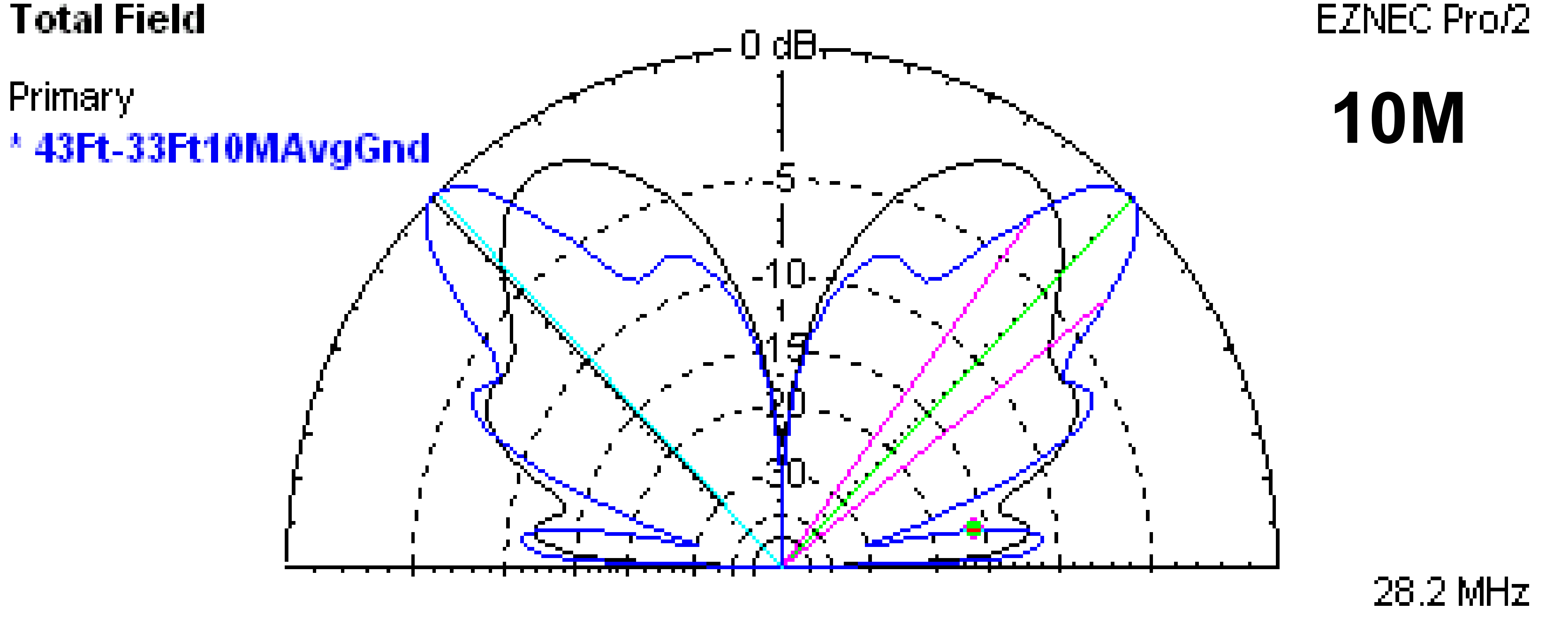
On the ground and on the roof, average soil



On the ground and on the roof, average soil



On the ground and on the roof, average soil



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 7.5 dBi

Cursor Elev 10.0 deg.
Gain -8.38 dBi
-15.88 dBmax
-3.67 dBPrTrc

On the ground and on the roof, average soil

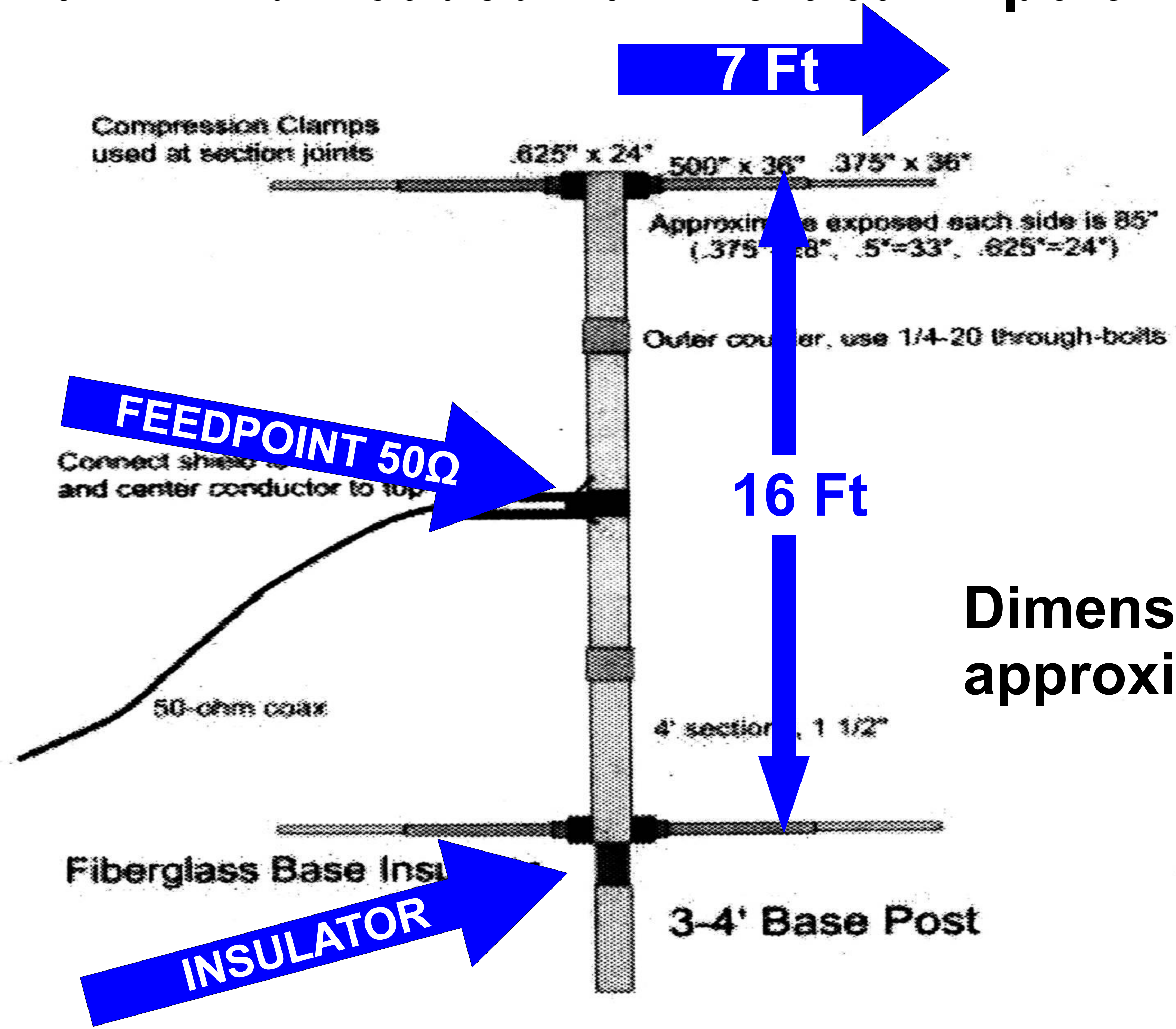
Are There Better Solutions?

- Put a multi-band vertical dipole on your roof, no radials needed
- Roof-mounting reduces ground losses, increases low-angle radiation

Some Multi-band Vertical Dipoles

- **Antennas rated for legal limit**
  - **Cushcraft R-8 covers 40M – 6M (very good in N0AX/K7LXC tests)**
  - **Cushcraft R-9 covers 80M – 6M (newer than N0AX/L7LXC tests)**
  - **Gap Titan covers 80M – 10M (was poor on 80M and 10M in N0AX/K7LXC tests)**
  - **Hy-Gain AV-640 covers 40M-6M (700W)**
- **Antennas rated for 200W**
  - **Force 12 Sigma GT-5 covers 20M – 10M**

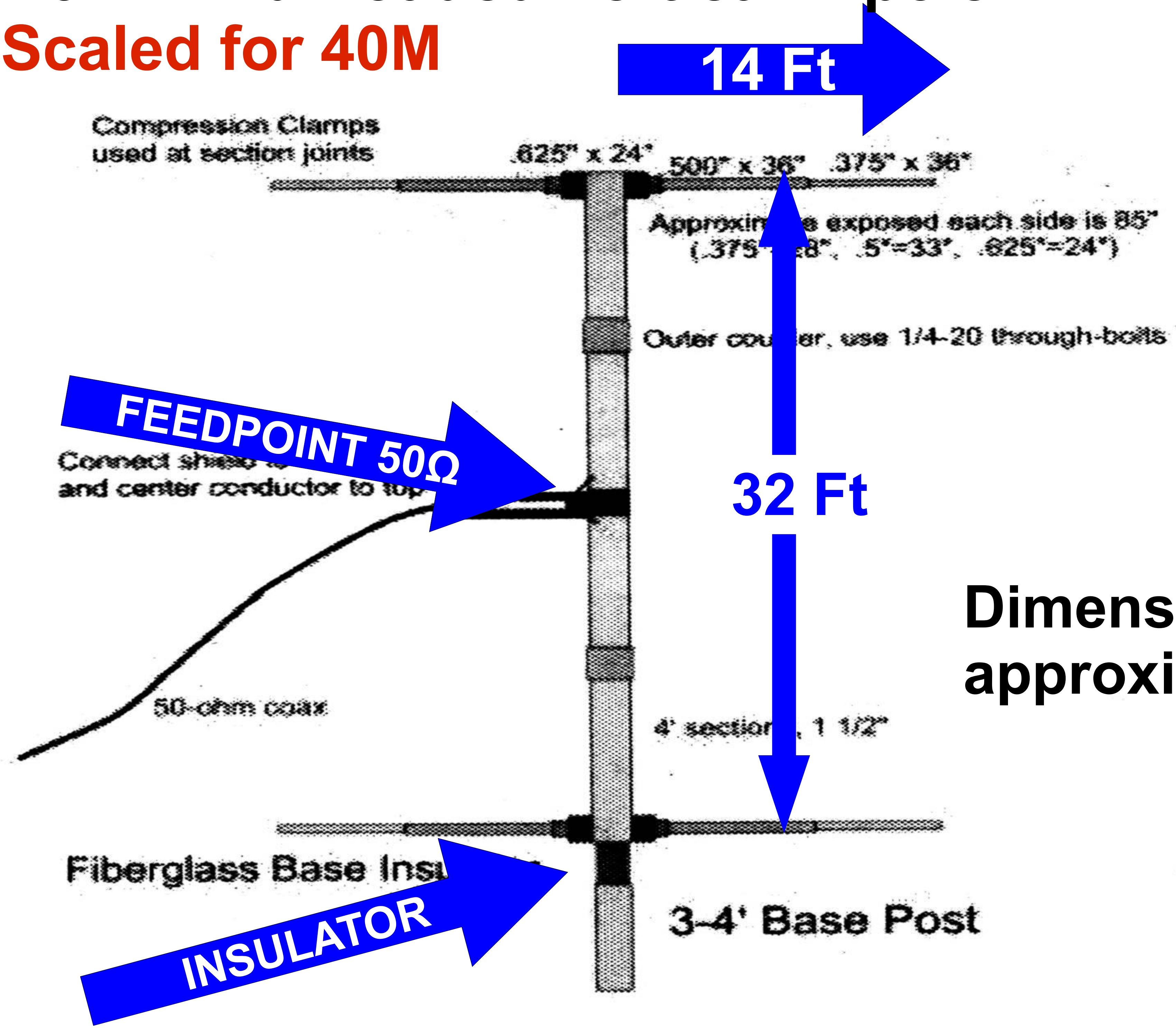
N6BT End-Loaded 20M Vertical Dipole



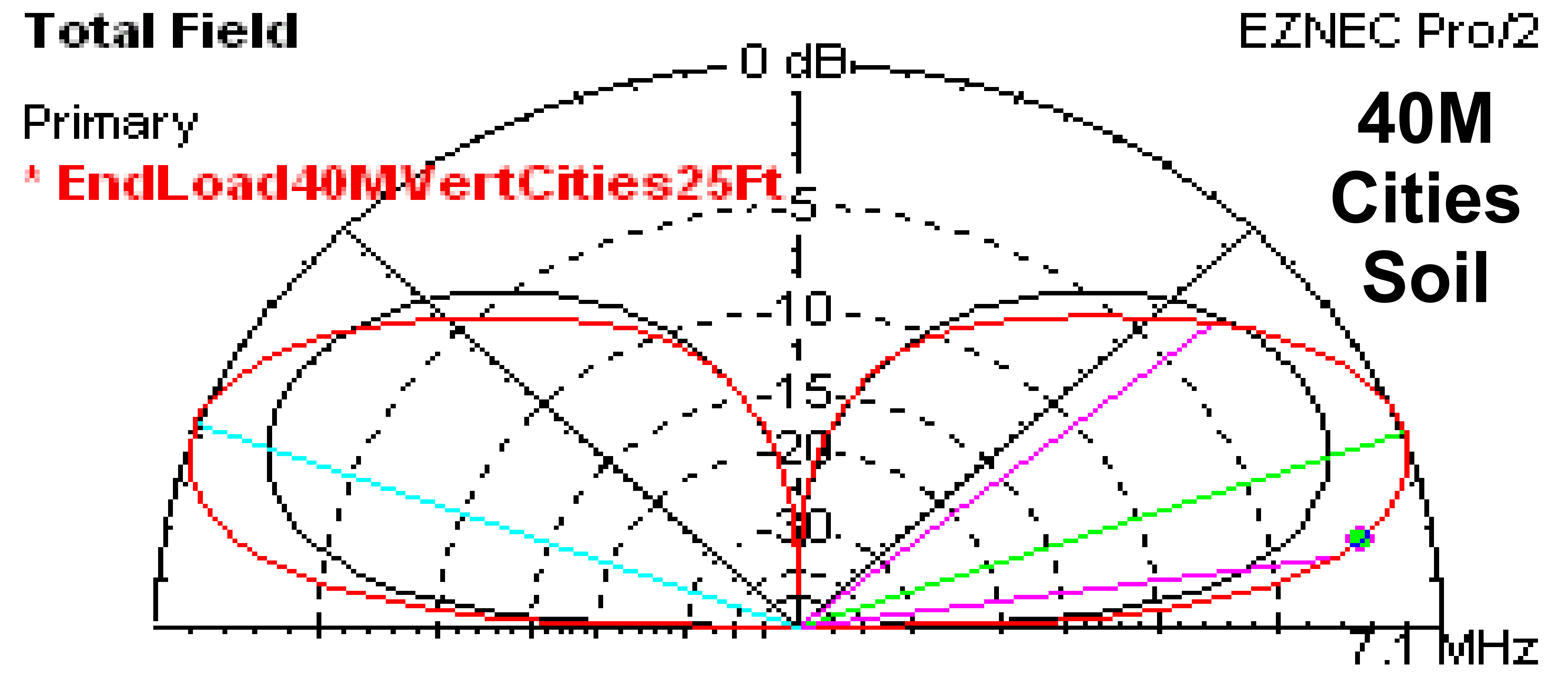
Dimensions are approximate

N6BT End-Loaded Vertical Dipole

Scaled for 40M



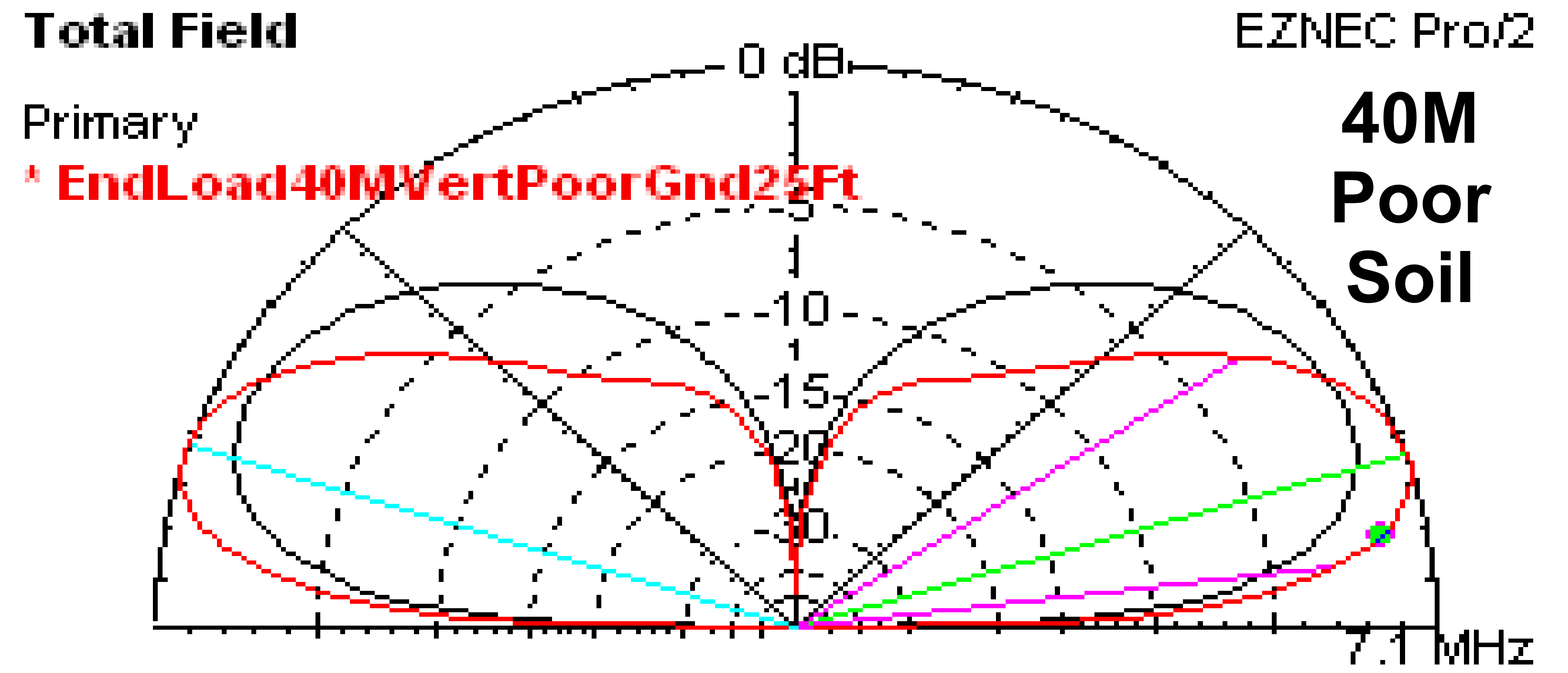
Dimensions are approximate



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-2.04 dBi
Outer Ring	0.06 dBi		-2.11 dBmax
			3.06 dBPrTrc

Black is 43 ft Vertical on ground, 10 Ω radials

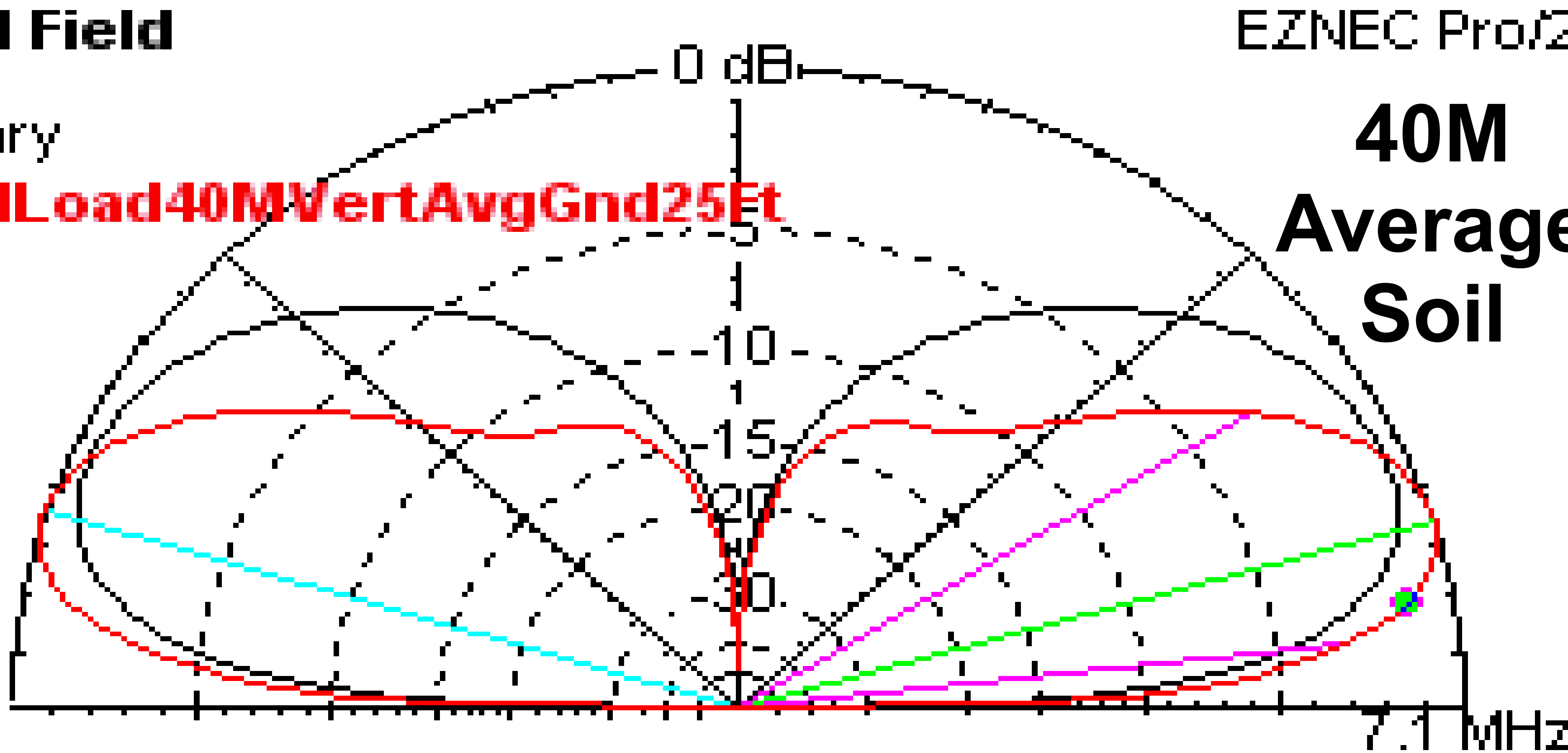
Red is loaded vertical dipole @ 25 ft



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.66 dBi
Outer Ring	0.73 dBi		-1.39 dBmax
			2.22 dBPrTrc

Black is 43 ft Vertical on ground, 10 Ω radials

Red is loaded vertical dipole @ 25 ft

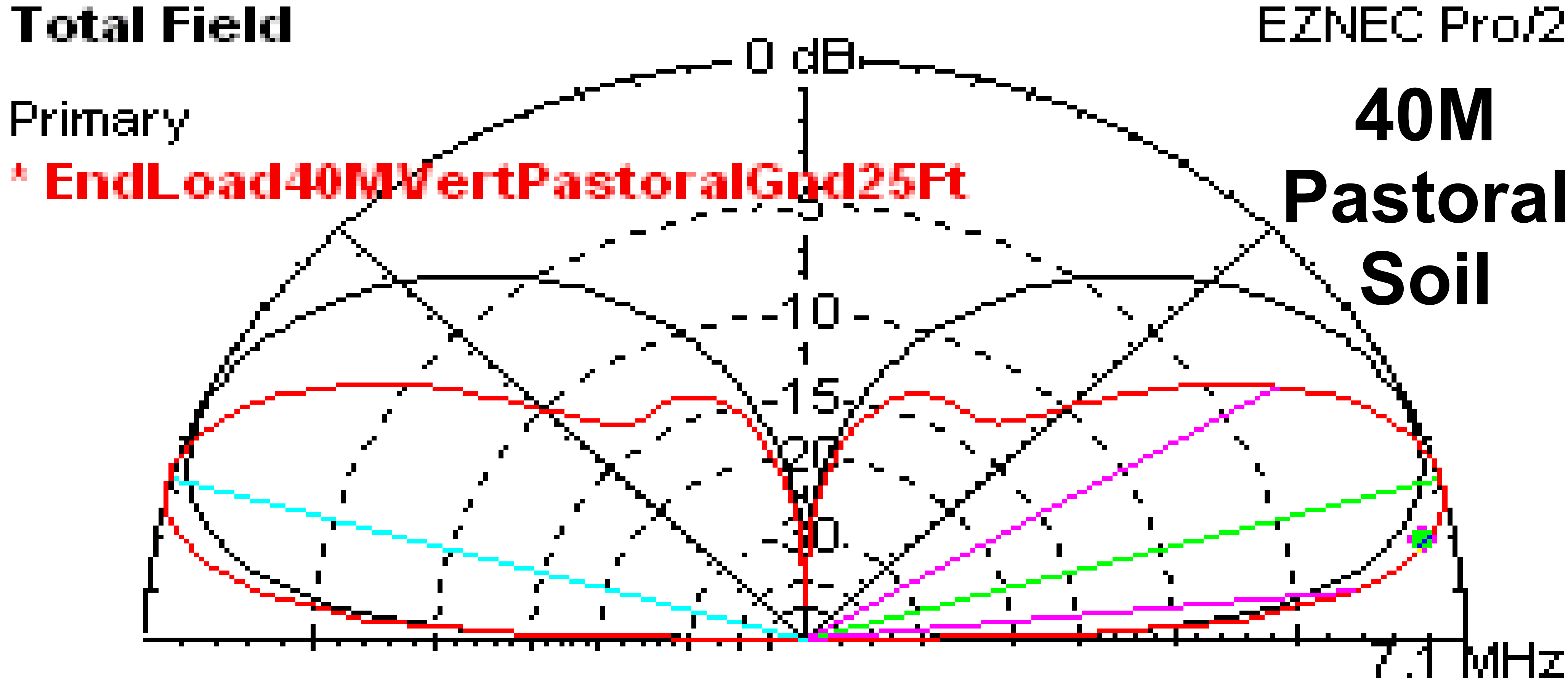


Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 0.31 dBi

Cursor Elev 10.0 deg.
Gain -0.85 dBi
-1.16 dBmax
1.63 dBPrTrc

Black is 43 ft Vertical on ground, 10 Ω radials

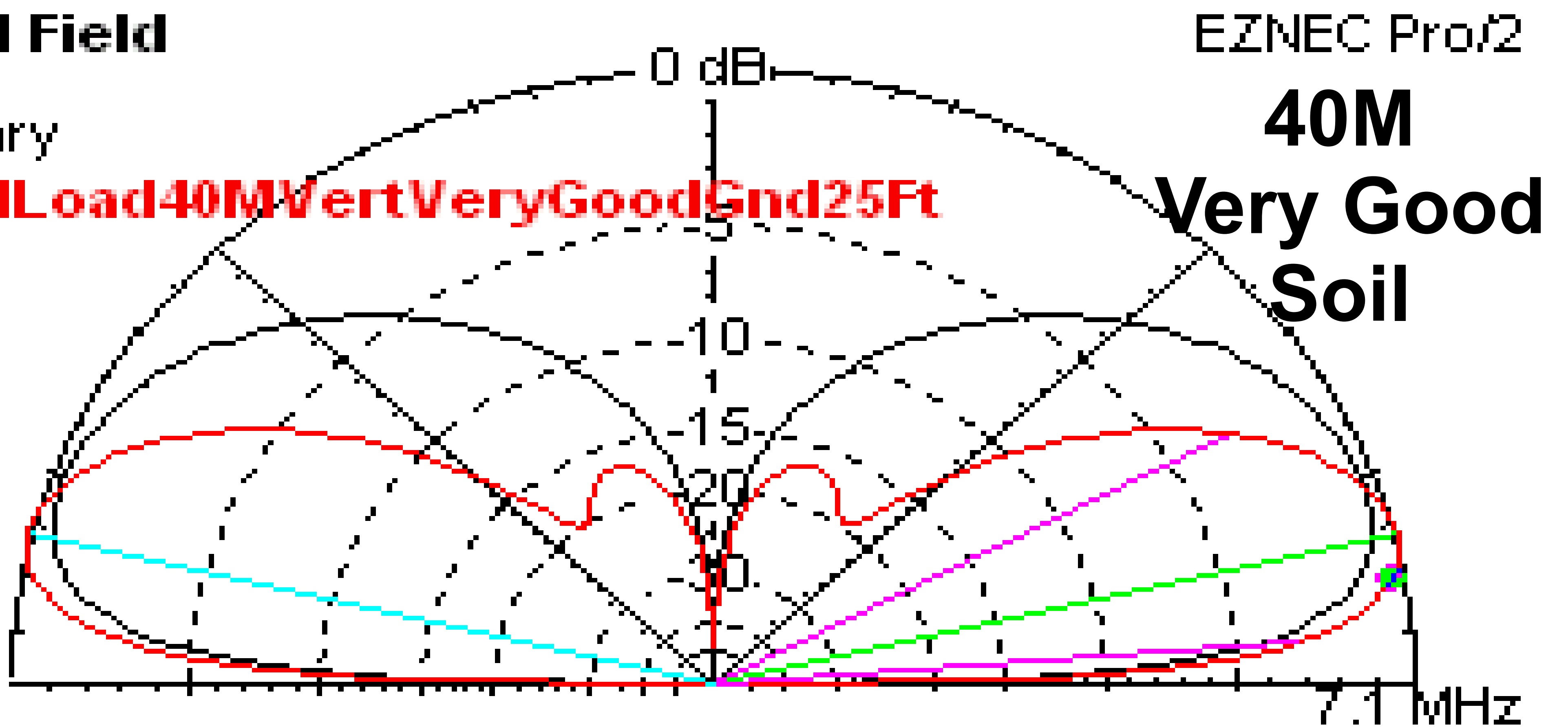
Red is loaded vertical dipole @ 25 ft



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.26 dBi
Outer Ring	0.58 dBi		-0.84 dBmax
			1.16 dBPrTrc

Black is 43 ft Vertical on ground, 10 Ω radials

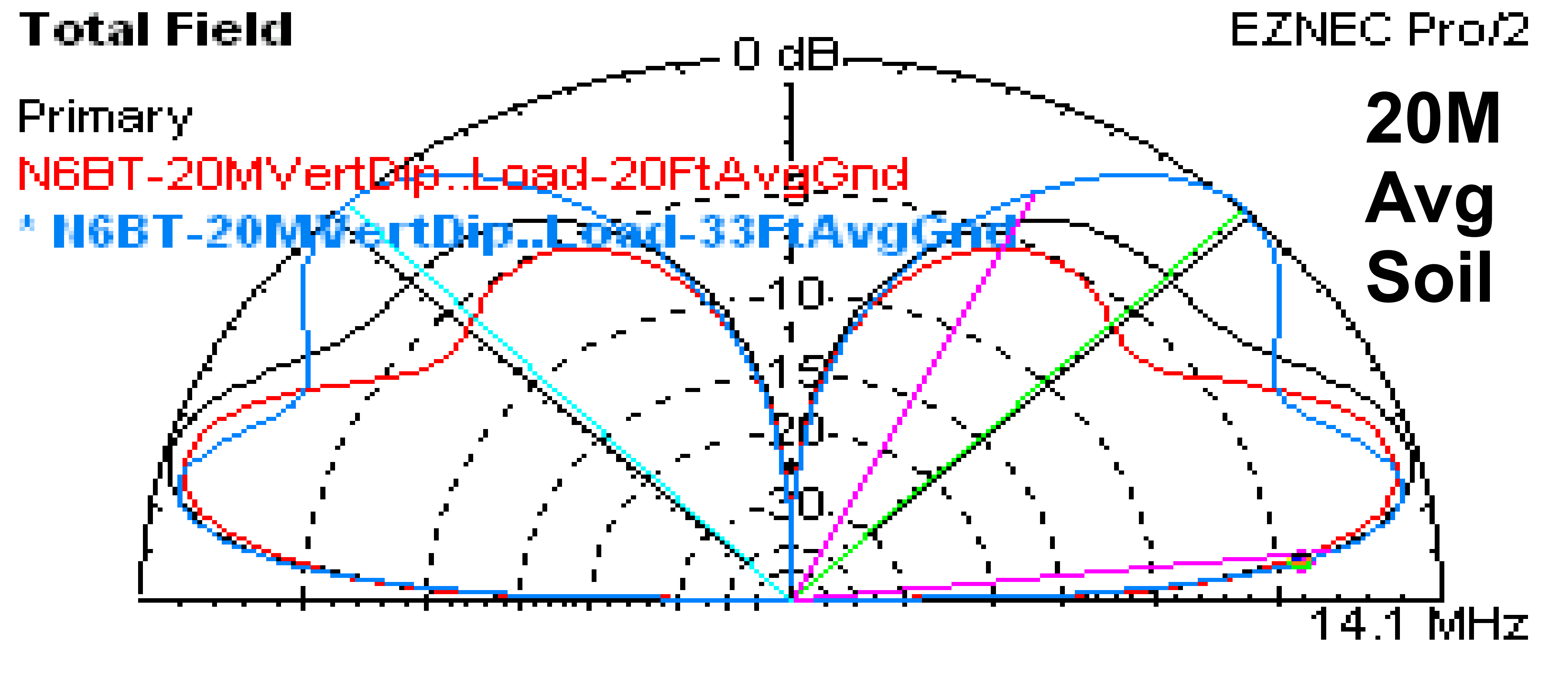
Red is loaded vertical dipole @ 25 ft



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.81 dBi
Outer Ring	2.17 dBi		-0.36 dBmax
			1.02 dBPrTrc

Black is 43 ft Vertical on ground, 10 Ω radials

Red is loaded vertical dipole @ 25 ft

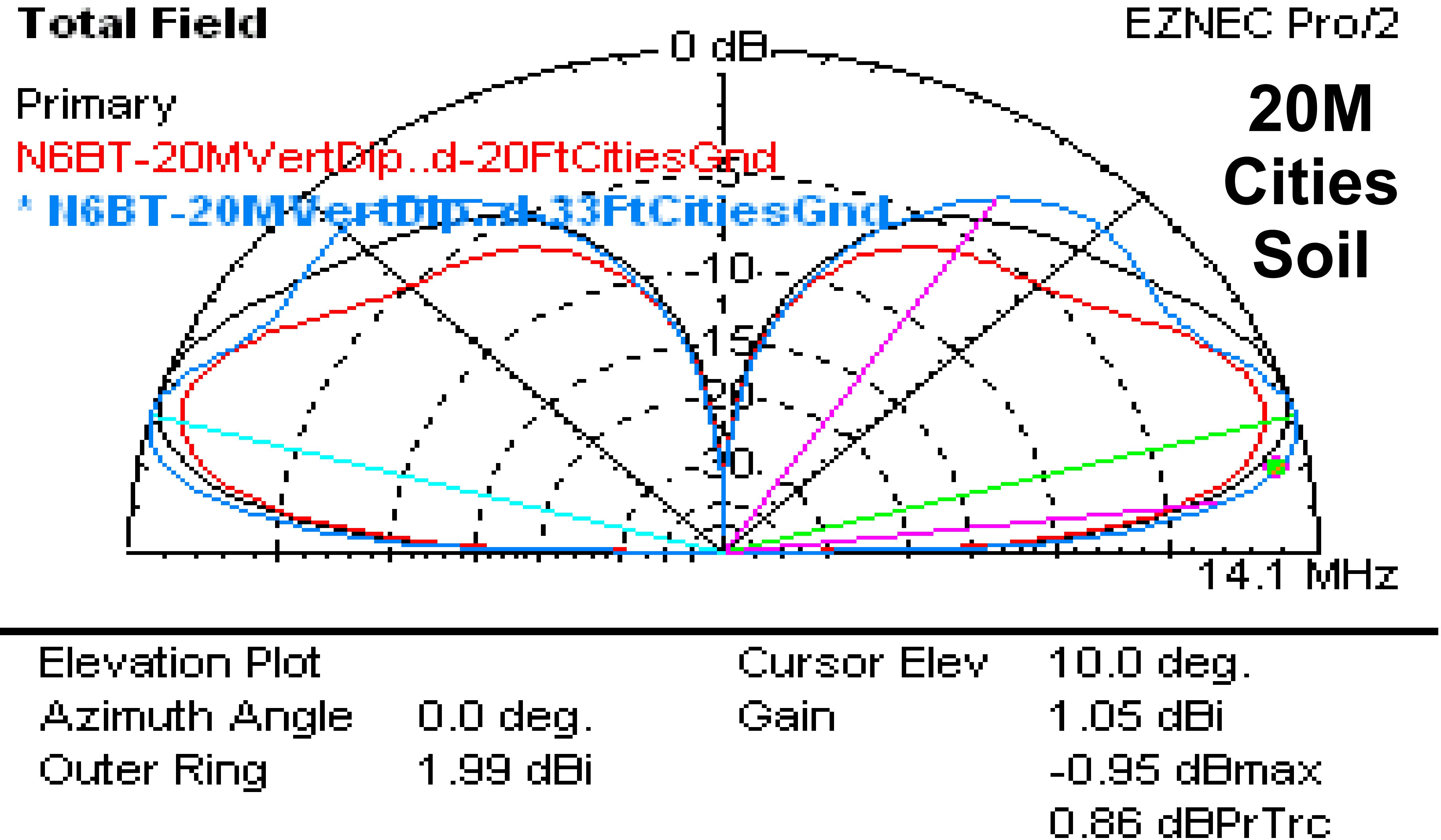


Elevation Plot		Cursor Elev	5.0 deg.
Azimuth Angle	0.0 deg.	Gain	-2.54 dBi
Outer Ring	1.42 dBi		-3.97 dBmax
			0.49 dBPrTrc

Black is 43 ft Vertical on ground 10Ω radials

Red is N6BT end-loaded vertical dipole @20 ft

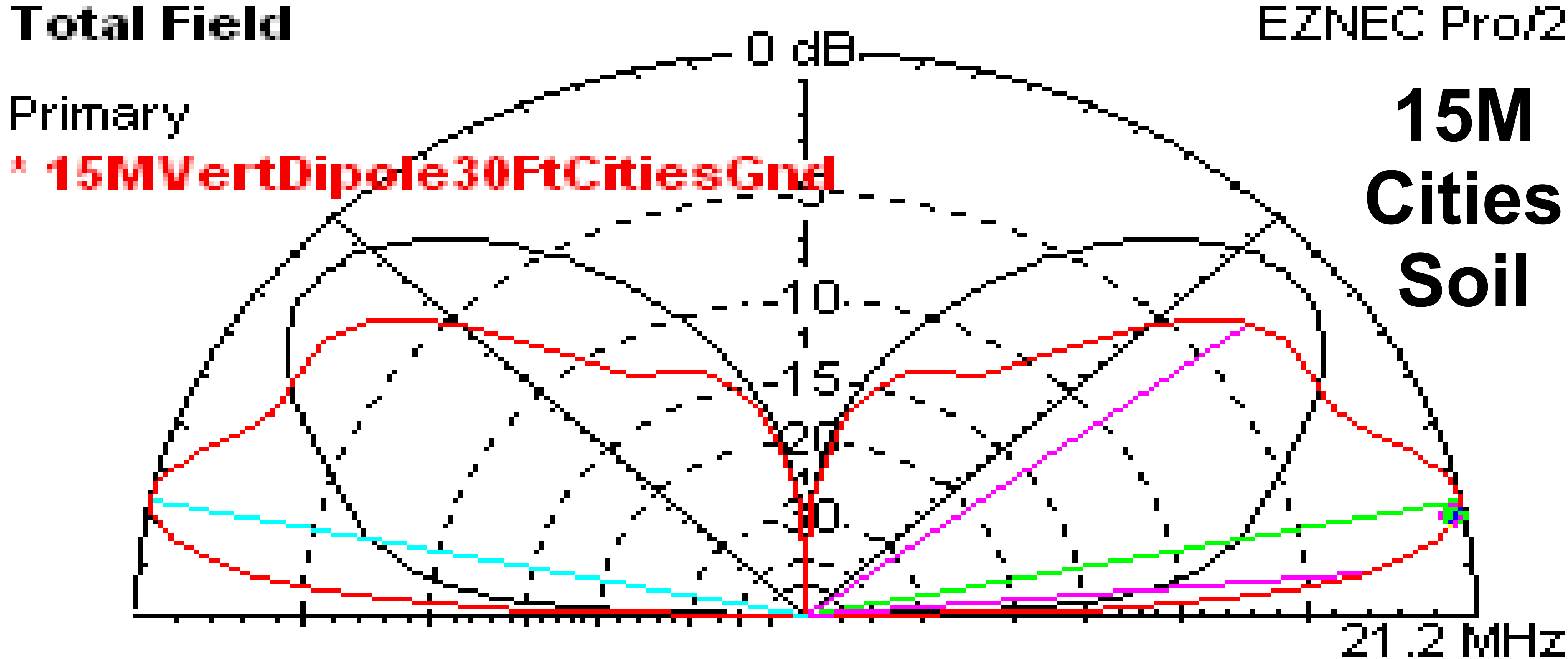
Blue is N6BT end-loaded vertical dipole @33 ft



Black is 43 ft Vertical on ground, 10Ω radials

Red is N6BT end-loaded vertical dipole @20 ft

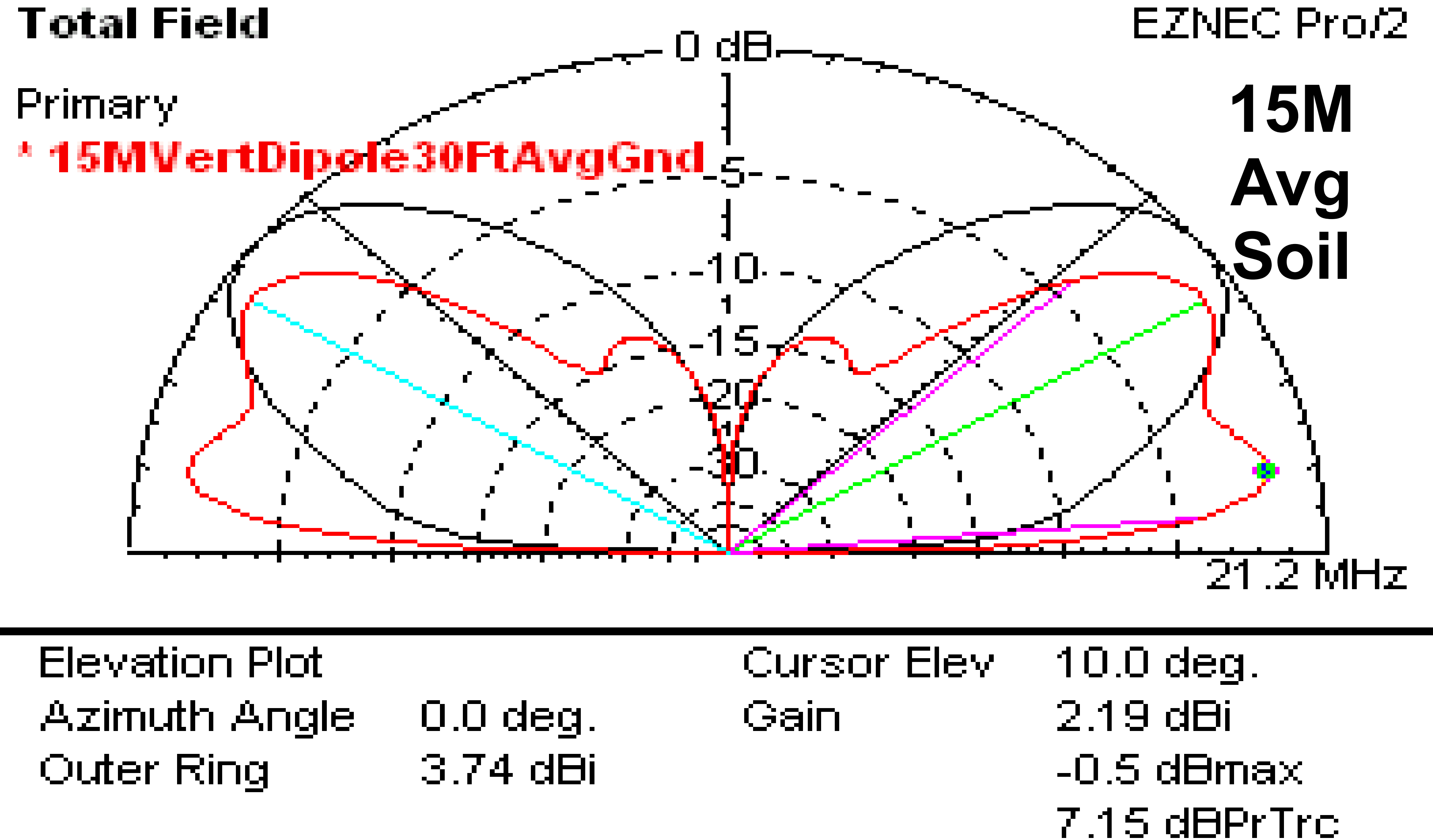
Blue is N6BT end-loaded vertical dipole @33 ft



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	3.36 dBi
Outer Ring	3.59 dBi		-0.23 dBmax
			7.6 dBPrTrc

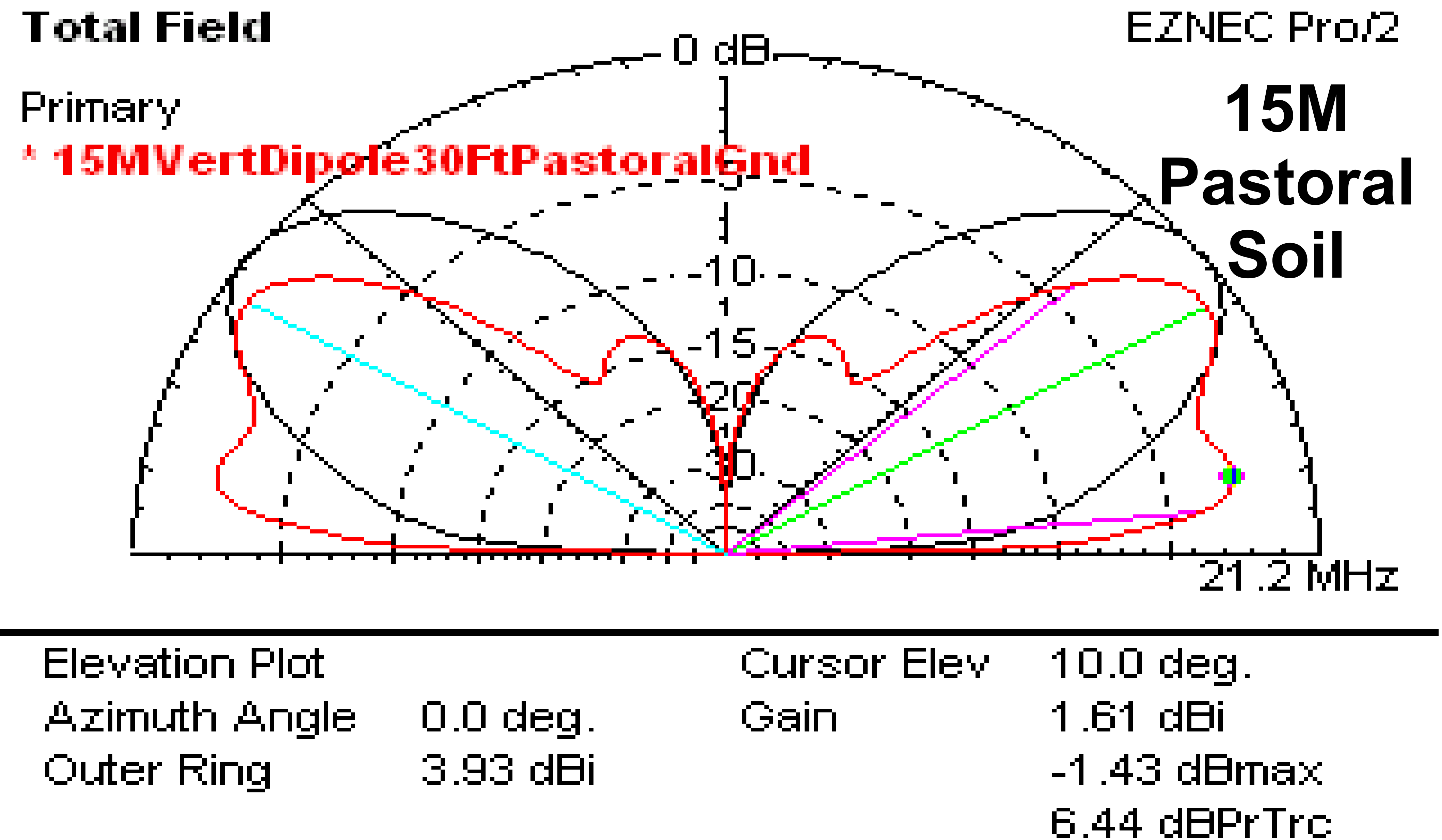
Black is 43 ft Vertical on ground, 10Ω radials

Red is λ/2 vertical dipole @ 30 ft



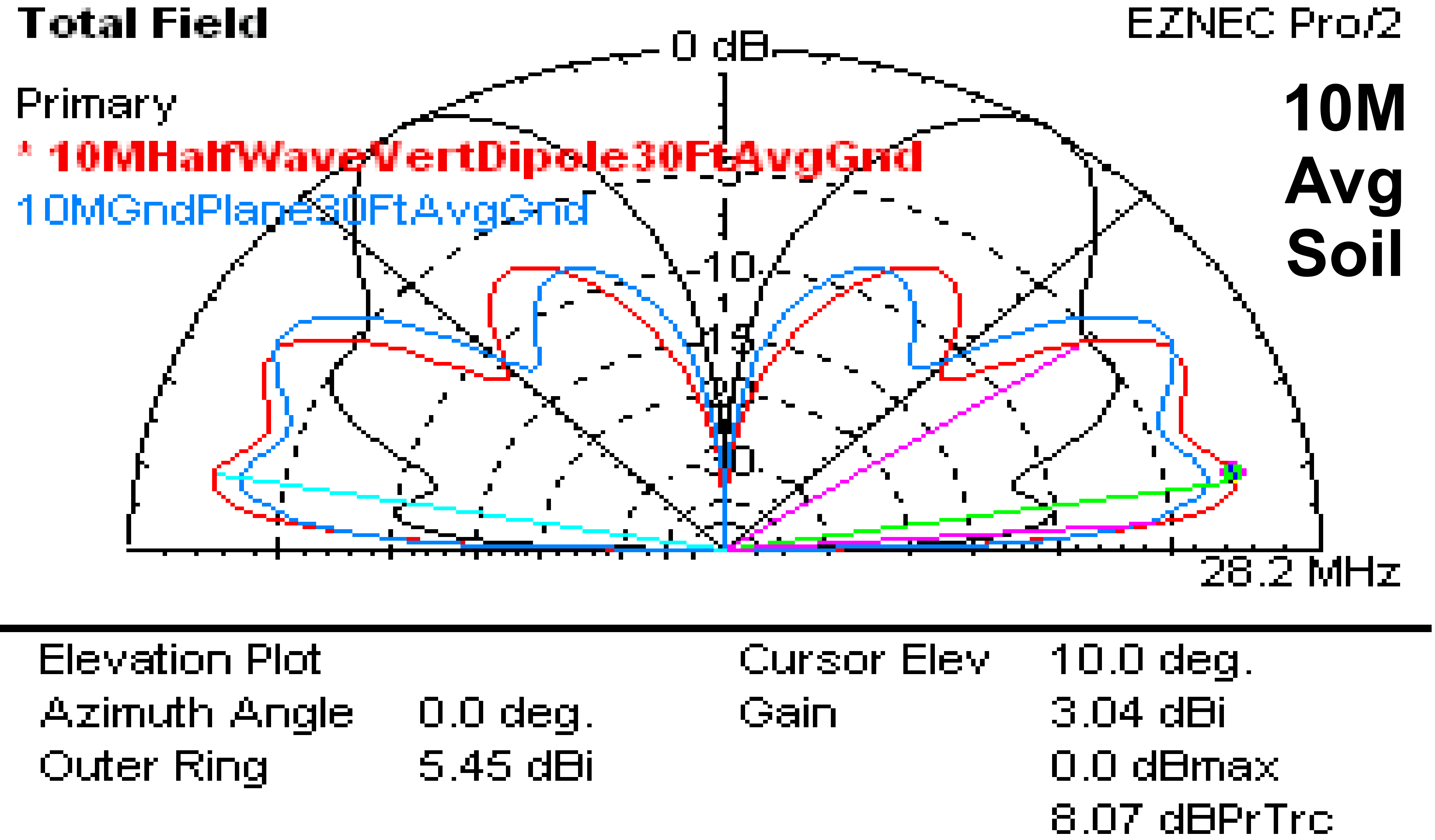
Black is 43 ft Vertical on ground, 10Ω radials

Red is λ/2 vertical dipole @ 30 ft



Black is 43 ft Vertical on ground, 10Ω radials

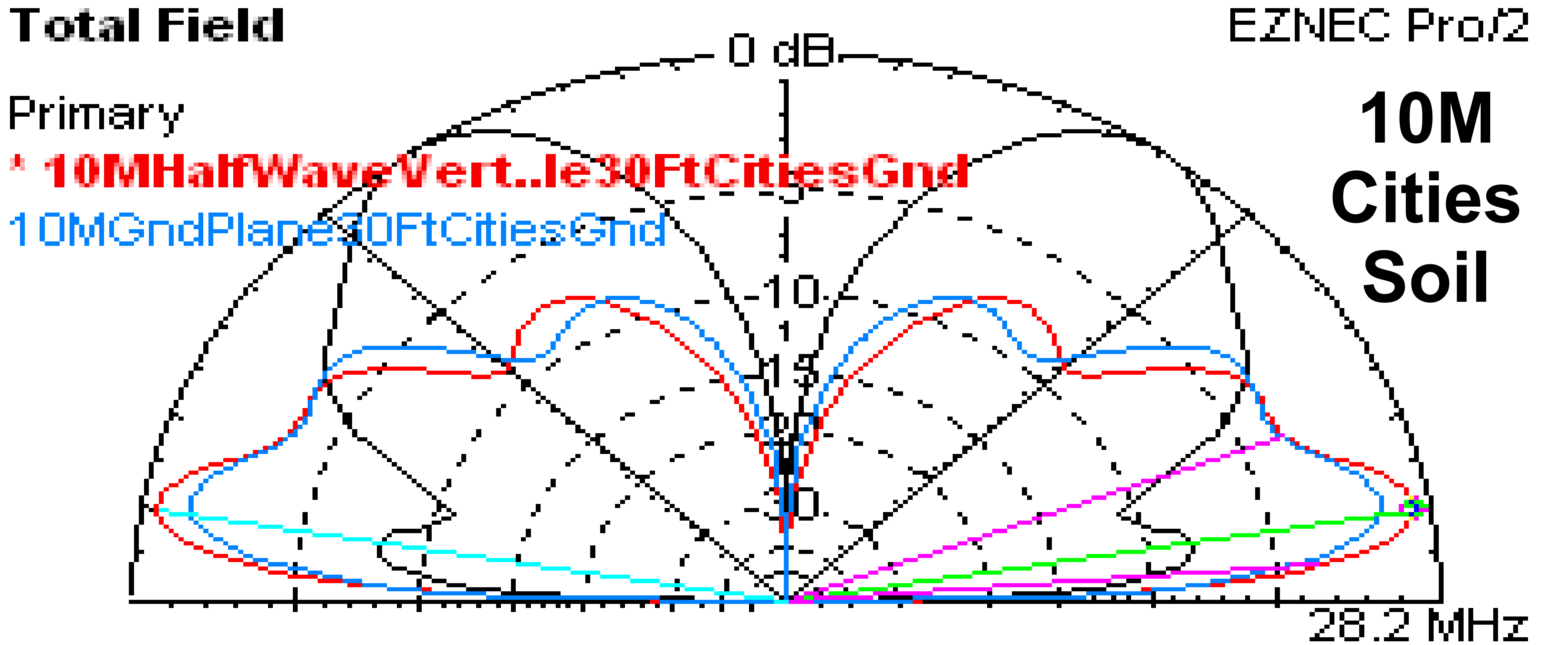
Red is λ/2 vertical dipole @ 30 ft



Black is 43 ft Vertical on ground 10Ω radials

Red is 10M vertical dipole @30 ft

Blue is 10M ground plane @33 ft

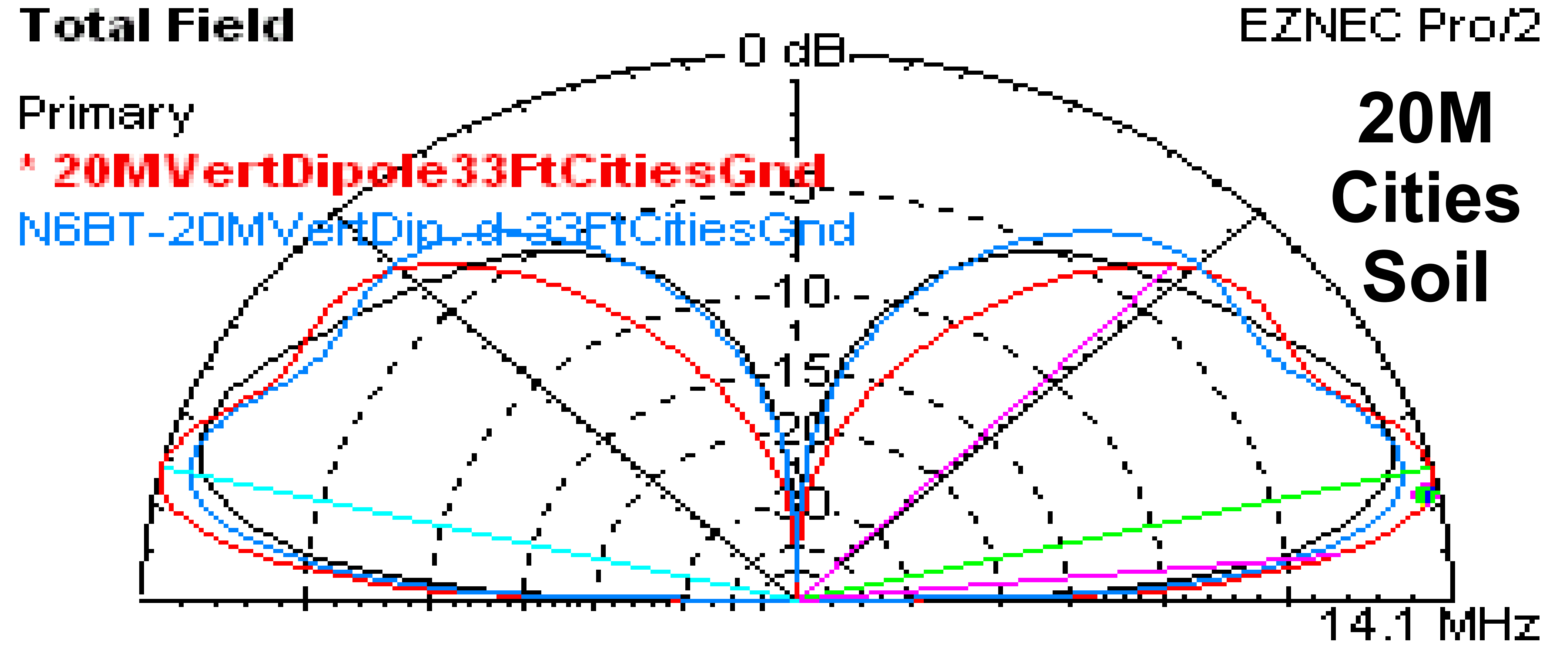


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	4.31 dBi
Outer Ring	4.7 dBi		0.0 dBmax
			7.58 dBPrTrc

Black is 43 ft Vertical on ground 10Ω radials

Red is 10M vertical dipole @30 ft

Blue is 10M ground plane @33 ft

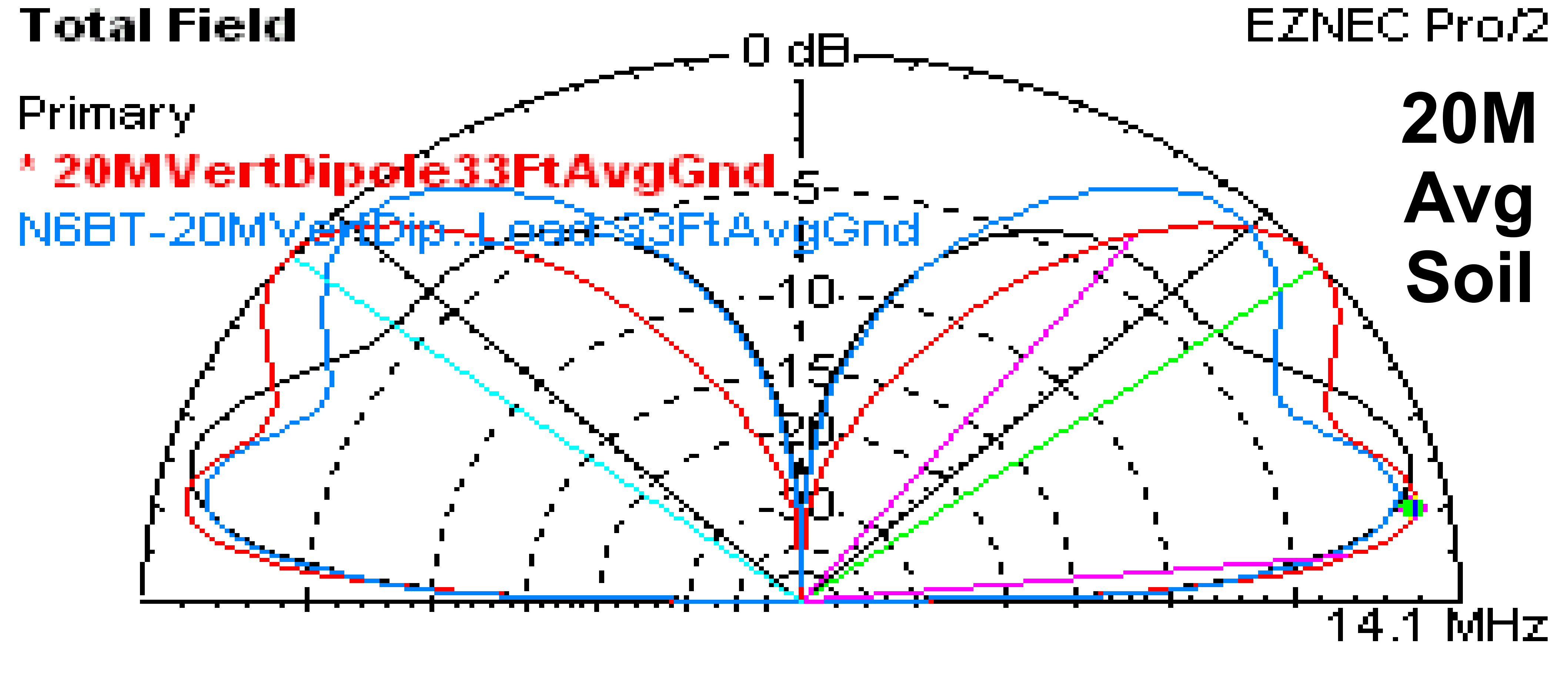


Elevation Plot		Cursor Elev	11.0 deg.
Azimuth Angle	0.0 deg.	Gain	2.42 dBi
Outer Ring	2.72 dBi		-0.3 dBmax
			1.82 dBPrTrc

Black is 43 ft Vertical on ground, 10Ω radials

Red is λ/2 vertical dipole @33 ft

Blue is N6BT end-loaded vertical dipole @33 ft

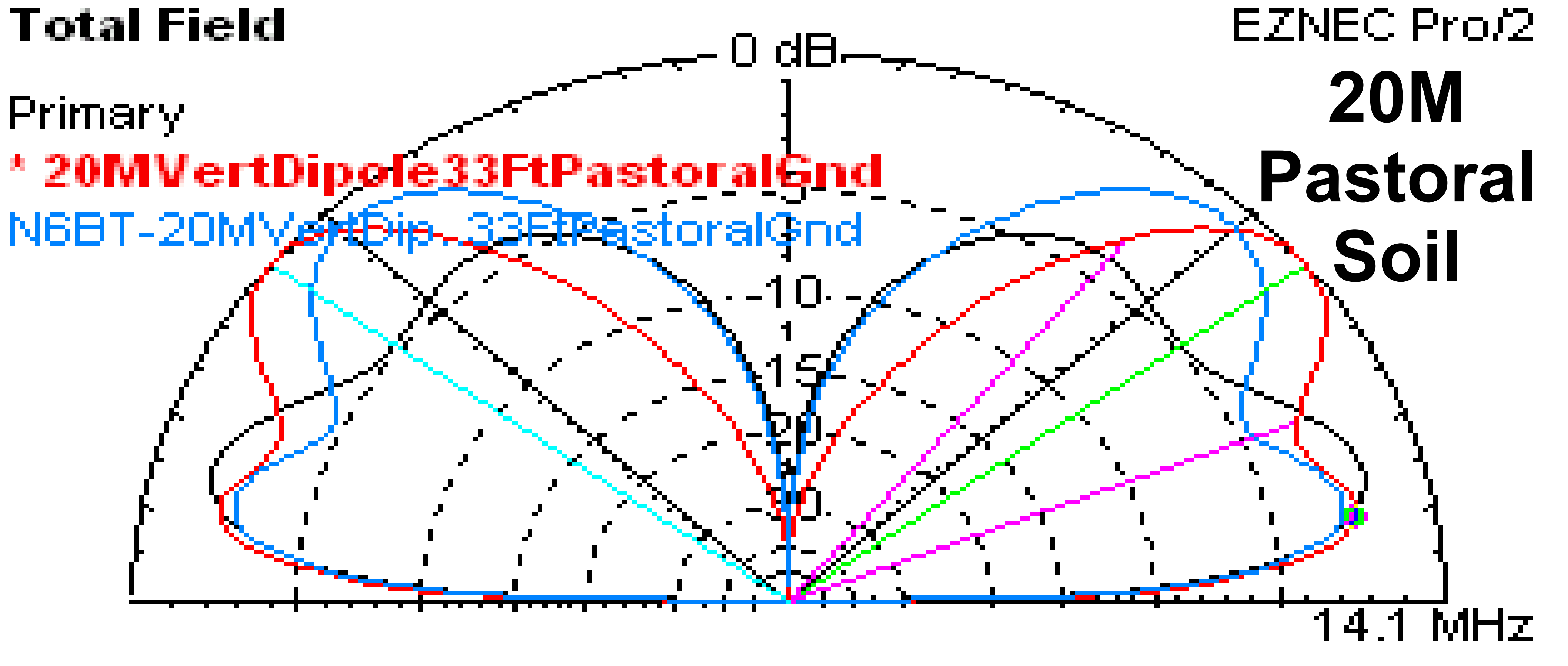


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.1 dBi
Outer Ring	2.04 dBi		-0.94 dBmax
			0.7 dBPrTrc

Black is 43 ft Vertical on ground, 10Ω radials

Red is λ/2 vertical dipole @33 ft

Blue is N6BT end-loaded vertical dipole @33 ft



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.3 dBi
Outer Ring	2.51 dBi		-2.21 dBmax
			0.18 dBPrTrc

Black is 43 ft Vertical on ground, 10Ω radials

Red is λ/2 vertical dipole @33 ft

Blue is N6BT end-loaded vertical dipole @33 ft

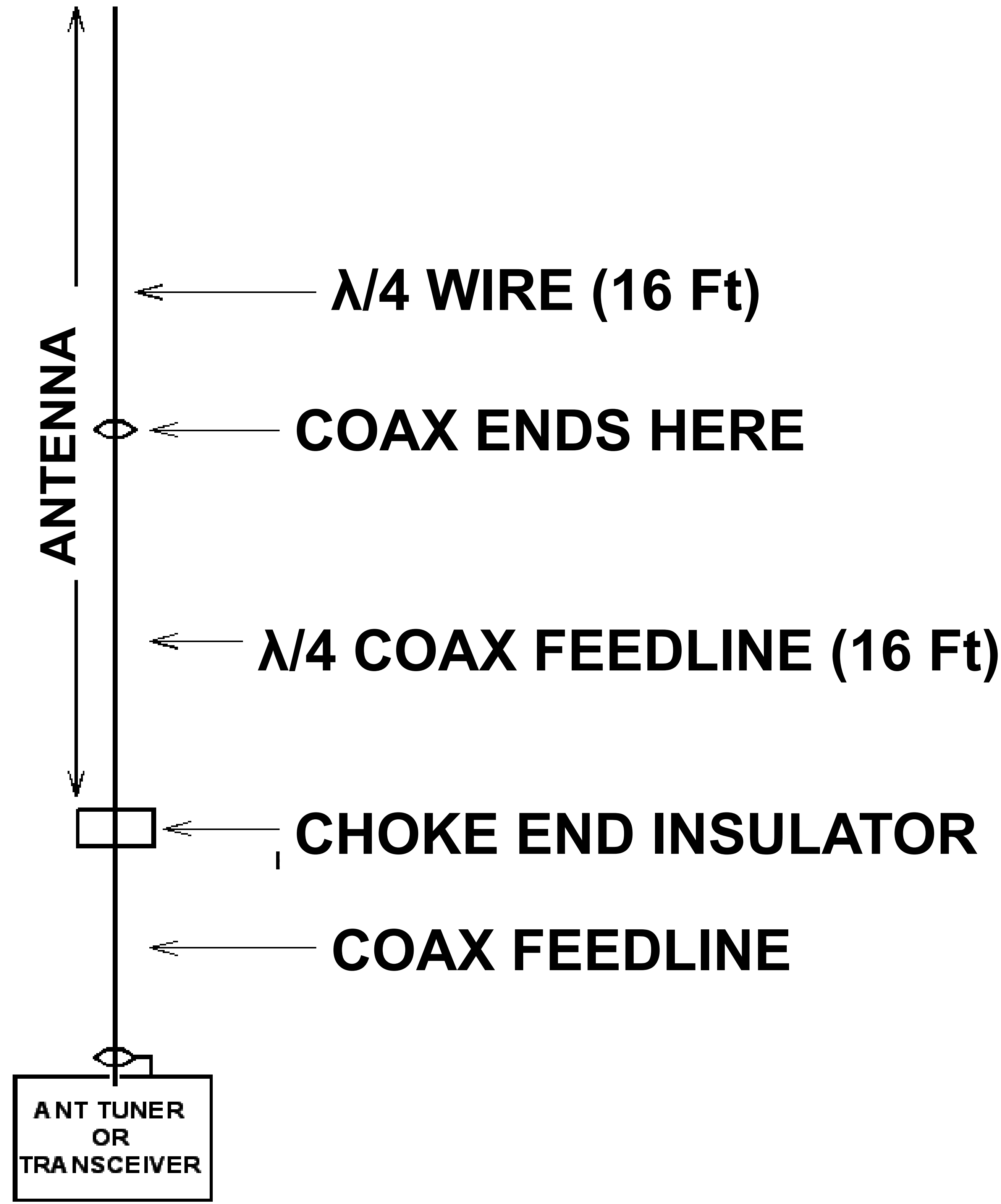
Re-Cap

- As compared to other compact multiband verticals, a 43-ft vertical
  - Is difficult to match on nearly all bands
  - A good performer on 80, 60, 40, 30, 20M
  - Requires a very good radial system for good performance
  - Becomes a high angle radiator above 20M
  - Works better on 40-10M if roof mounted with two resonant radials per band
  - Is relatively inexpensive, but matching is complex and expensive

Re-Cap

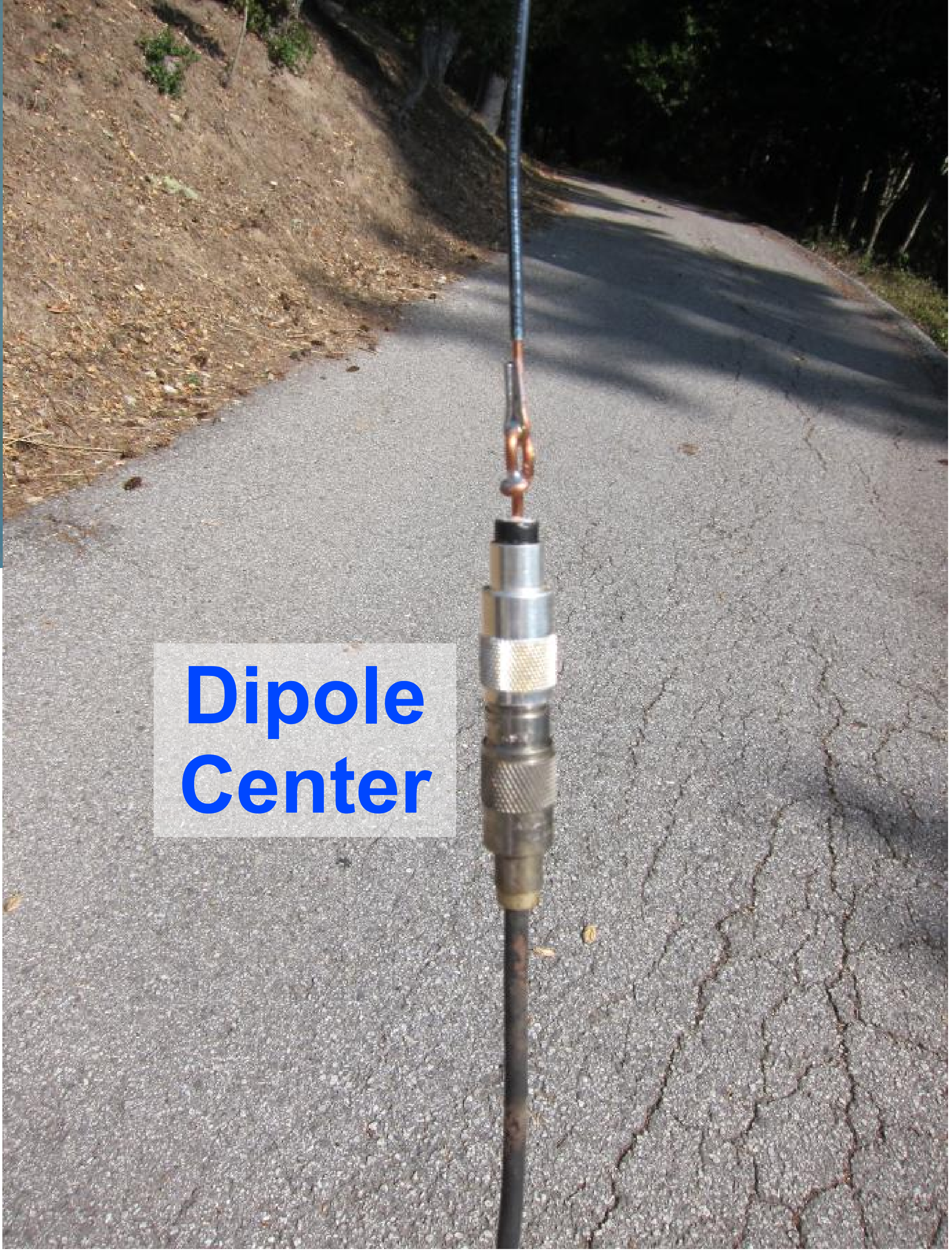
- A good roof-mounted multi-band vertical dipole is
  - As good or better on 40M and 20M
  - A superior DX performer above 20M
  - Much easier to match
  - More expensive for the antenna, but little or no cost to match to transmitter
  - Weak on 80M, next to useless on 160M
- Antennas using traps typically underperform those without traps

An Easy to Build End-Fed Single-Band Vertical Dipole


λ/4 WIRE (16 Ft)
ANTENNA
COAX ENDS HERE
λ/4 COAX FEEDLINE (16 Ft)
CHOKE END INSULATOR
COAX FEEDLINE
ANT TUNER
OR
TRANSCEIVER

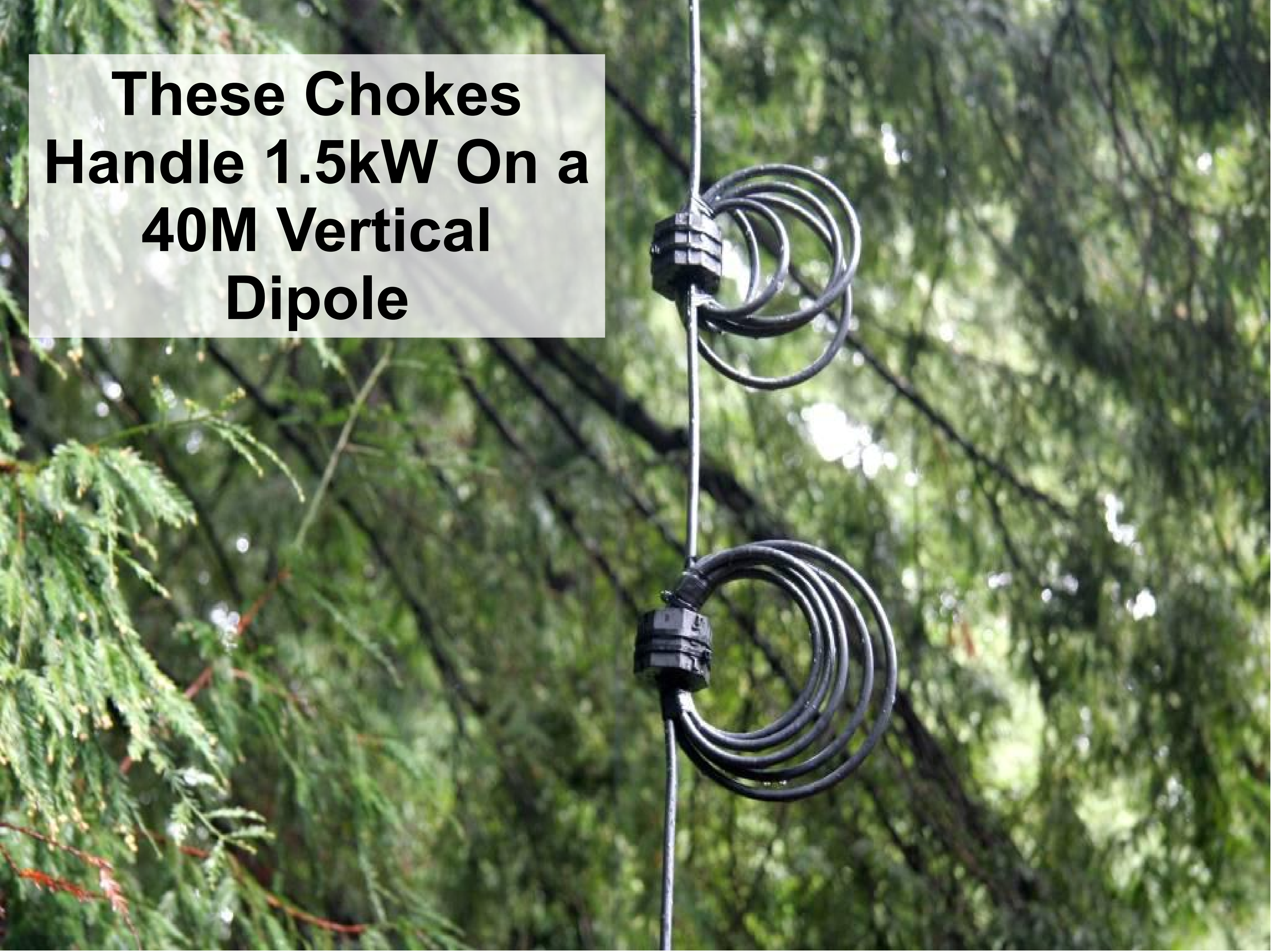

Feedpoint


The Choke


Dipole
Center

The Dipole Rigged From Support Rope for an 80M Dipole

A More Robust Choke For Higher Power


These Chokes
Handle 1.5kW On a
40M Vertical
Dipole

Recommended Study

- **Get NEC or 4NEC and learn to use it! These antennas are very simple to model.**
- ***HF Vertical Performance Test Methods and Results*, Ward Silver, N0AX, and Steve Morris, K7LXC, Champion Radio Products, 2000 championradio.com**
- **Rudy Severns' website http://www.antennasbyn6lf.com/**
- **ARRL Antenna Book**
- ***Antenna Modeling for Beginners*, Ward Silver, N0AX, ARRL**

43 Ft Verticals – What's the Big Deal?

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