Vertical Antenna Mounting Height

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These slides are a bit different from the preliminary set I gave Paul a week ago for inclusion in your books (and thumb drives). This final version, and tomorrow's talk about 43 Ft Verticals will be on my website as pdf files.

http://k9yc.com\publish.htm

Blame Ward Silver, N0AX

- **In 2000, Ward and Steve Morris, K7LXC, measured eight multi-band verticals**
- **Two basic types**
  - **λ/4 intended for use with radials**
  - **Center-fed vertical dipoles, no radials needed**
- **Most manufacturers were vague about mounting height (but not N6BT)**
- **All were set up over a large radial system just above ground level (about 18 inches)**

Blame Ward Silver, N0AX

- **In his report, Ward**
  - **speculated that the vertical dipoles may have been helped by the radial system**
  - **skirted the issue of mounting height**
- **But that got me thinking**
  - **What about mounting height?**
  - **What about radials for a vertical dipole?**
  - **I'd always suspected that getting an HF vertical above surrounding clutter was a good thing**

What I Wanted To Learn

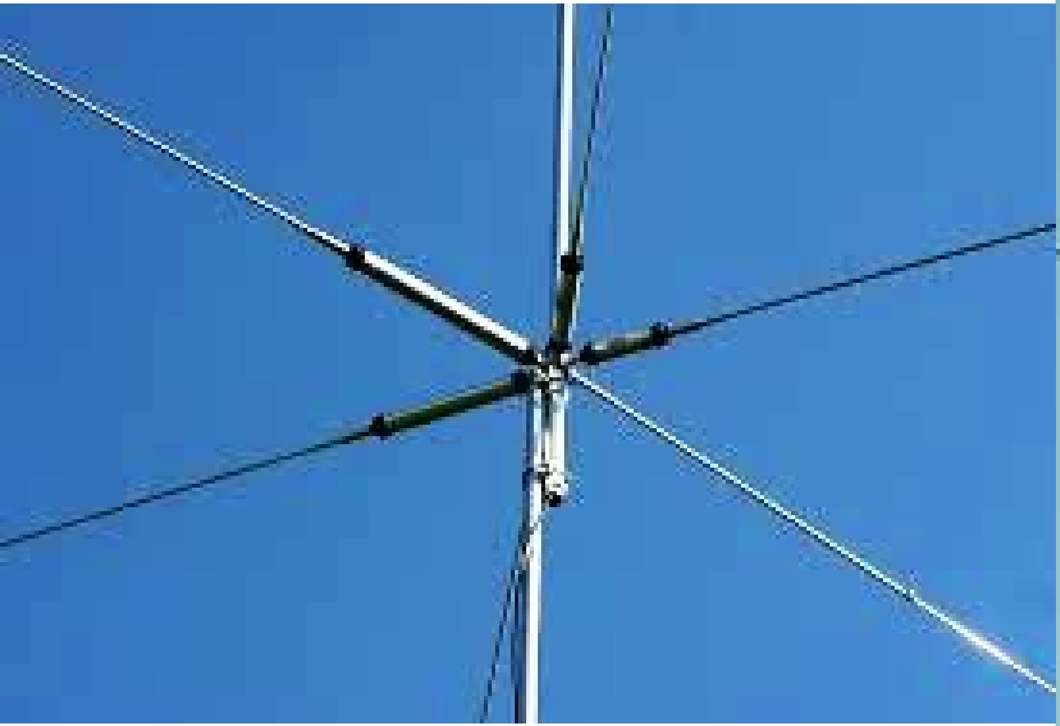
- If I can mount an HF vertical on my roof, should I do it?
  - Vertical dipoles
  - Verticals that need radials
- What happens to the pattern?
  - If higher is better, is there a limit?
- Do half-wave dipoles benefit from radials?
- What's the big deal with a 43 ft vertical?

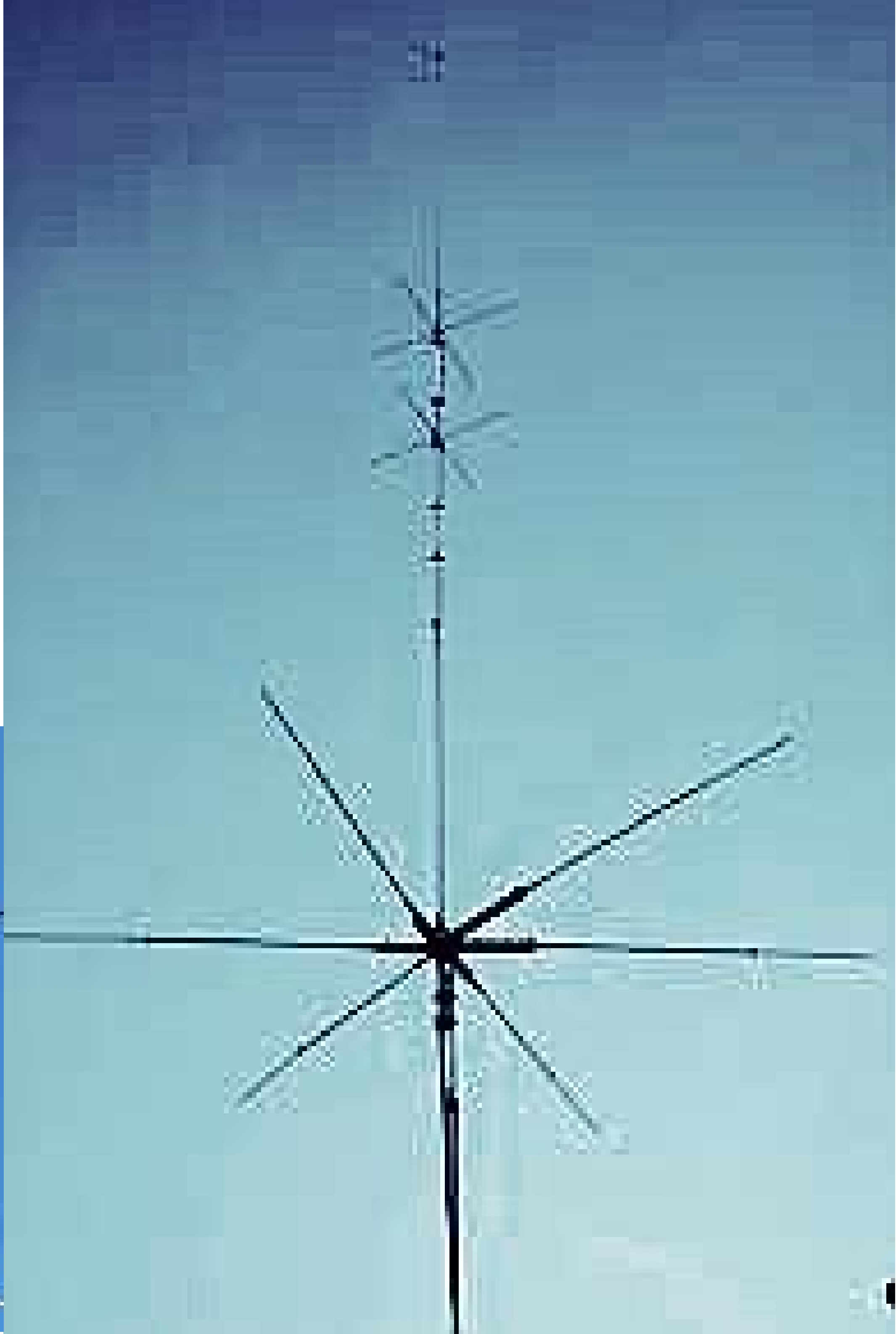
Two Fundamental Antenna Types

- **End-fed monopole, needs radials or counterpoise**
- **Center-fed dipole, radials are optional**
- **Both types can use traps, stubs, linear loading, matching sections to make them smaller, and to cover multiple bands**
- **This presentation addresses single element antennas – no directional arrays**

Diamond CP6
16 Ft Trapped λ/4
80/40/20/15/10/6

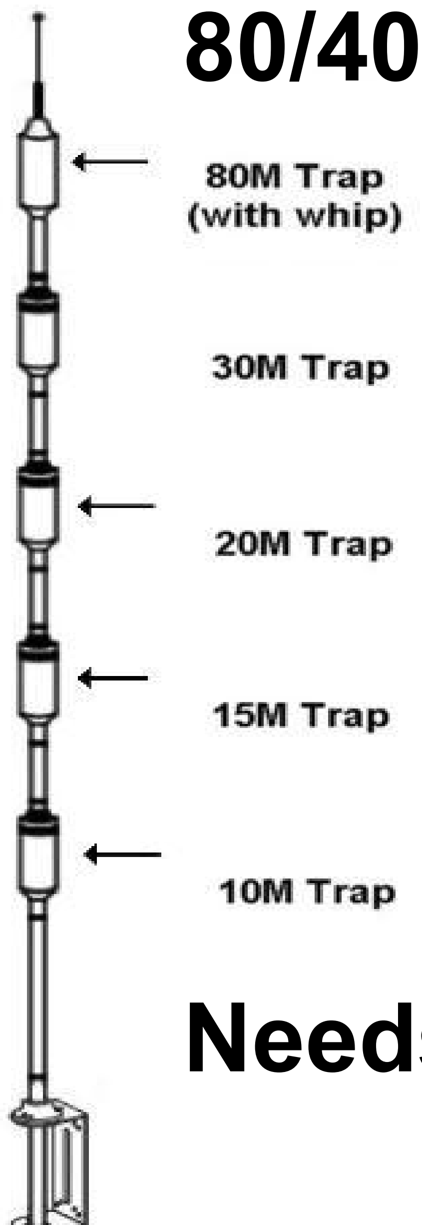
Intended for portable and urban use, has its own loaded radials





Hustler 6BTV 24 Ft Trapped λ/4

80/40/20/15/10M

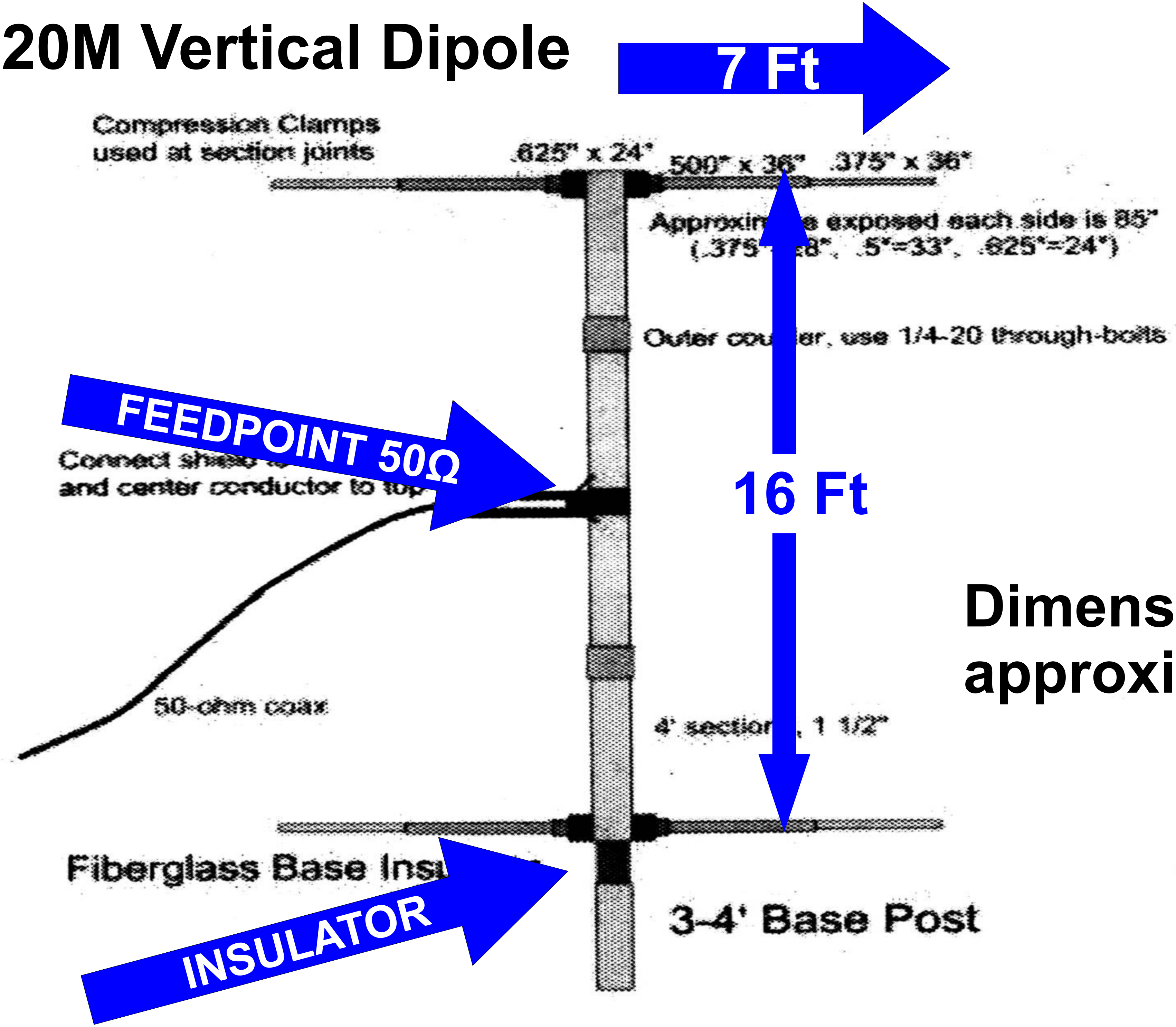


Needs radials

Force 12 V-3 25 Ft Dipole for 20/15/10

Linear loading used on 20M

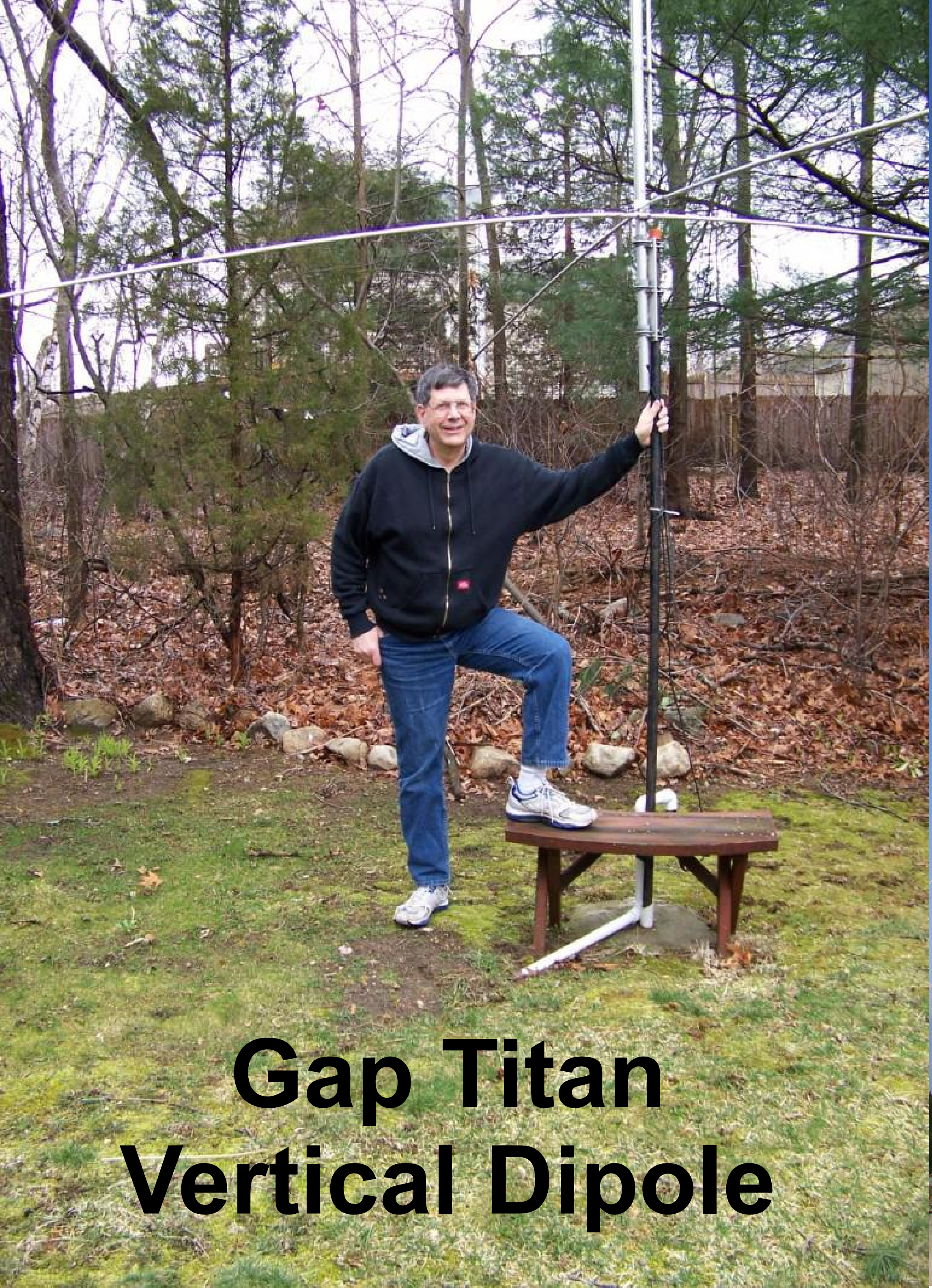
N6BT End-Loaded 20M Vertical Dipole



Dimensions are approximate

Force 12 ZR3

- Super-compact N6BT design for CQP county expeditions
- Only 5½ ft tall
- λ/2 vertical dipole
- For 20, 15, 10


Gap Titan
Vertical Dipole

My Method

- **Models of five simple antennas were constructed using W7EL's EZNEC (NEC2)**
  - **Quarter-wave monopole with 60 on-ground radials**
  - **Quarter-wave monopole with 4 elevated radials**
  - **Half-wave dipole**
  - **Shortened, end-loaded half-wave dipole (N6BT design)**
  - **4 Ft long vertical dipole**

My Method

- All antennas (except the monopole with 60 radials) were modeled near the ground and at heights representative of roof mounting
- Except for the very short dipole, the antennas were resonant on the band where they were modeled
- Modeling was done on 40M, 20M, and 10M
- Not all types were modeled on all bands
- N6BV verified representative results using NEC4

My Method

- **Each antenna was 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 probably have soil on the poor side of average – rocky, sandy, urban**
- **California farmland and rolling grassy hills are most likely 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, a model was constructed for a ground-mounted 43-ft vertical with 60 radials
- This antenna was modeled over several representative soil types, and on all bands 160-10M
- This work will be shown tomorrow morning

What I Learned

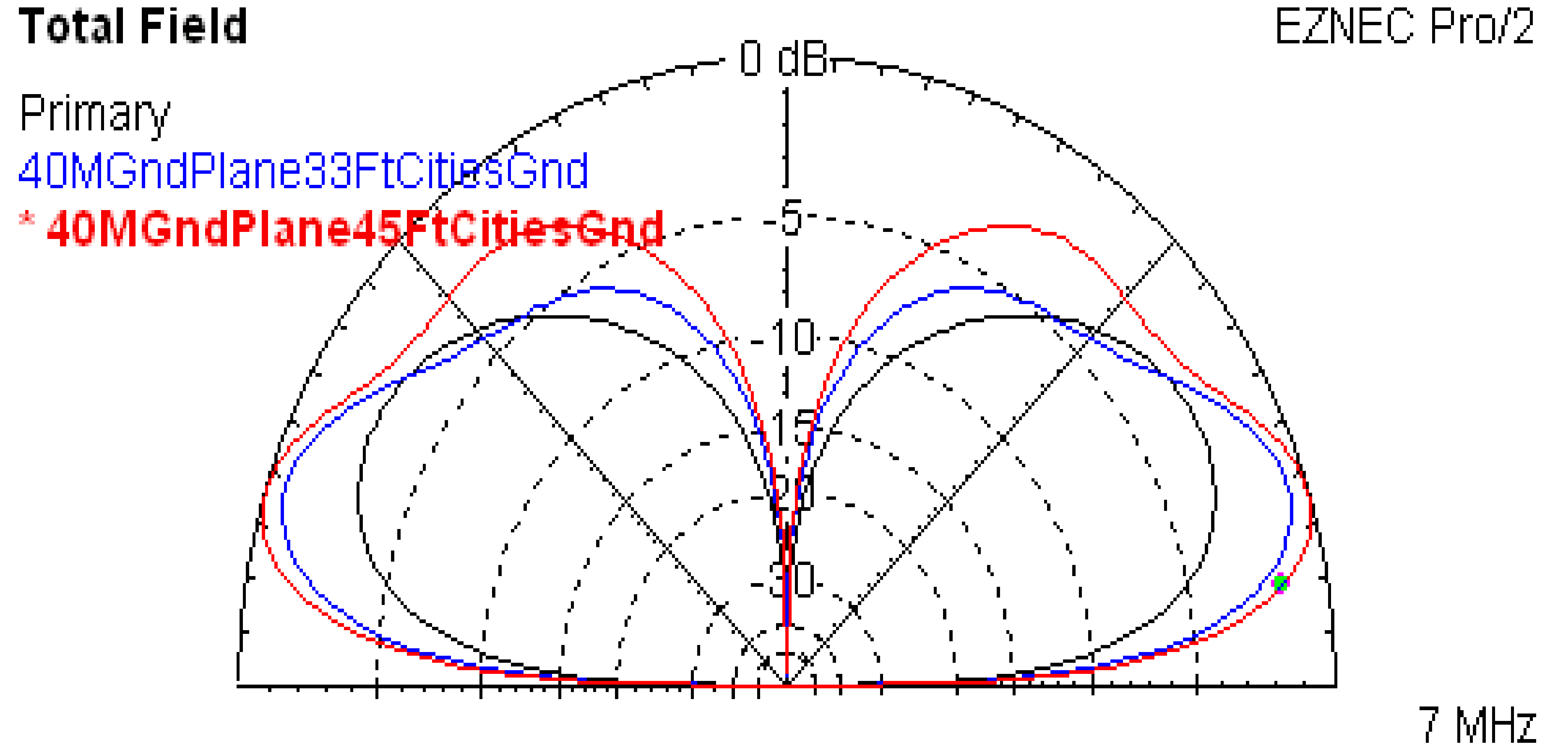
- Mounting an HF vertical in the range of λ/4 – λ/2 above ground improves performance for most soil conditions
- Improvement is greatest for the poorest soil
  - Near field ground losses are reduced
  - Low angle lobes are strengthened
  - Higher angle lobes develop, greater for best soil

What I Learned

- Radials improve the performance of ground-mounted half-wave antennas by 0.5 - 1dB at low angles, and by about twice that amount at higher angles
- Improvement is greatest for poorest soil
- I didn't look at roof-mounted dipoles
  - Radials not very practical

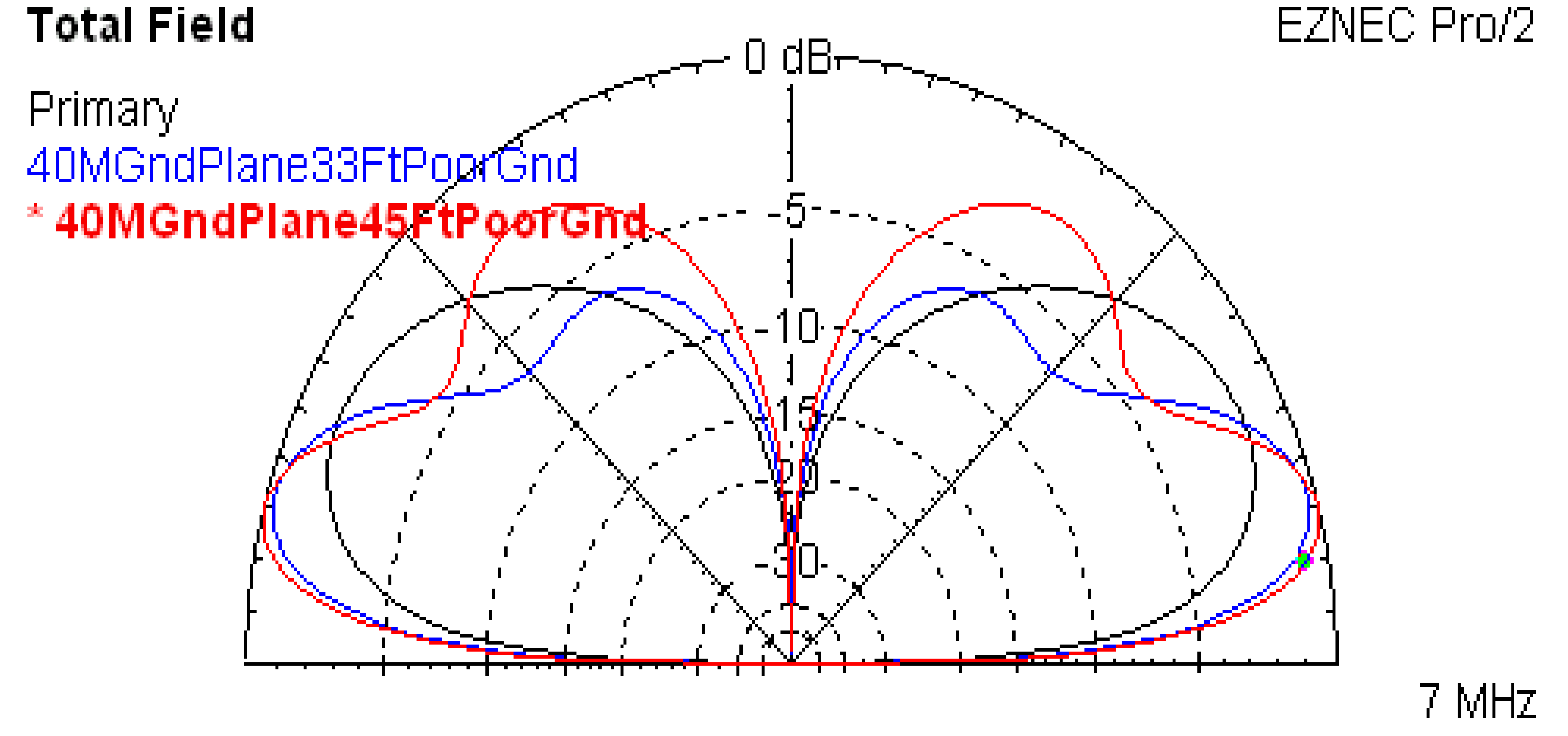
First Series – 40M Ground Plane

- $\lambda/4$ vertical over 32 $\lambda/4$ radials
  - Radials modeled at 0.75 inch above ground
- $\lambda/4$ vertical w/4-$\lambda/4$ radials @ 33 ft
- $\lambda/4$ vertical w/4-$\lambda/4$ radials @ 45 ft
- All were 3/4-in diameter
- Real High accuracy ground, NEC2



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.54 dBi
Outer Ring	0.92 dBi		-1.46 dBmax
			4.68 dBPrTrc

Very Poor Ground – Cities



Elevation Plot

Azimuth Angle 0.0 deg.

Outer Ring 0.89 dBi

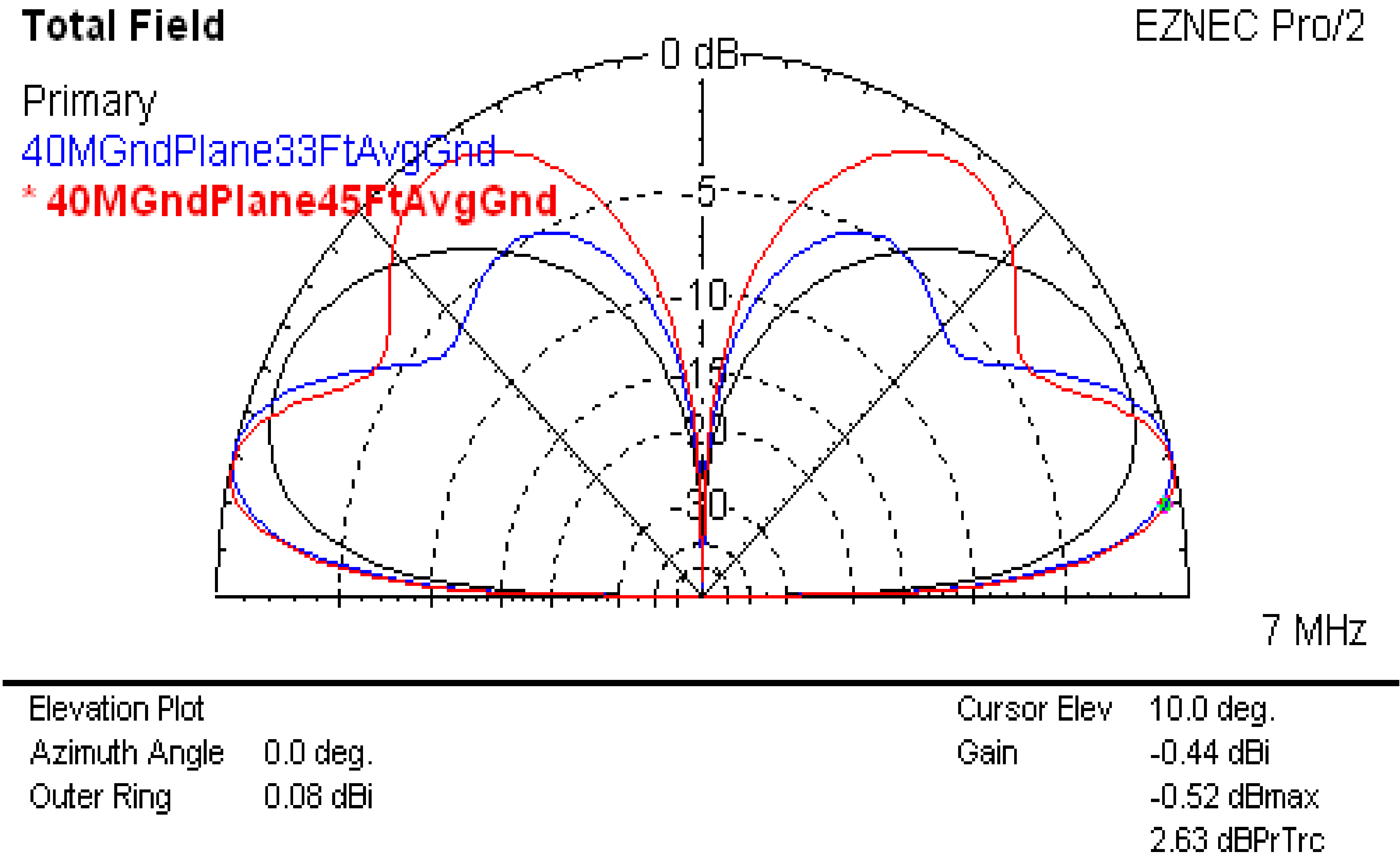
Cursor Elev 10.0 deg.

Gain 0.18 dBi

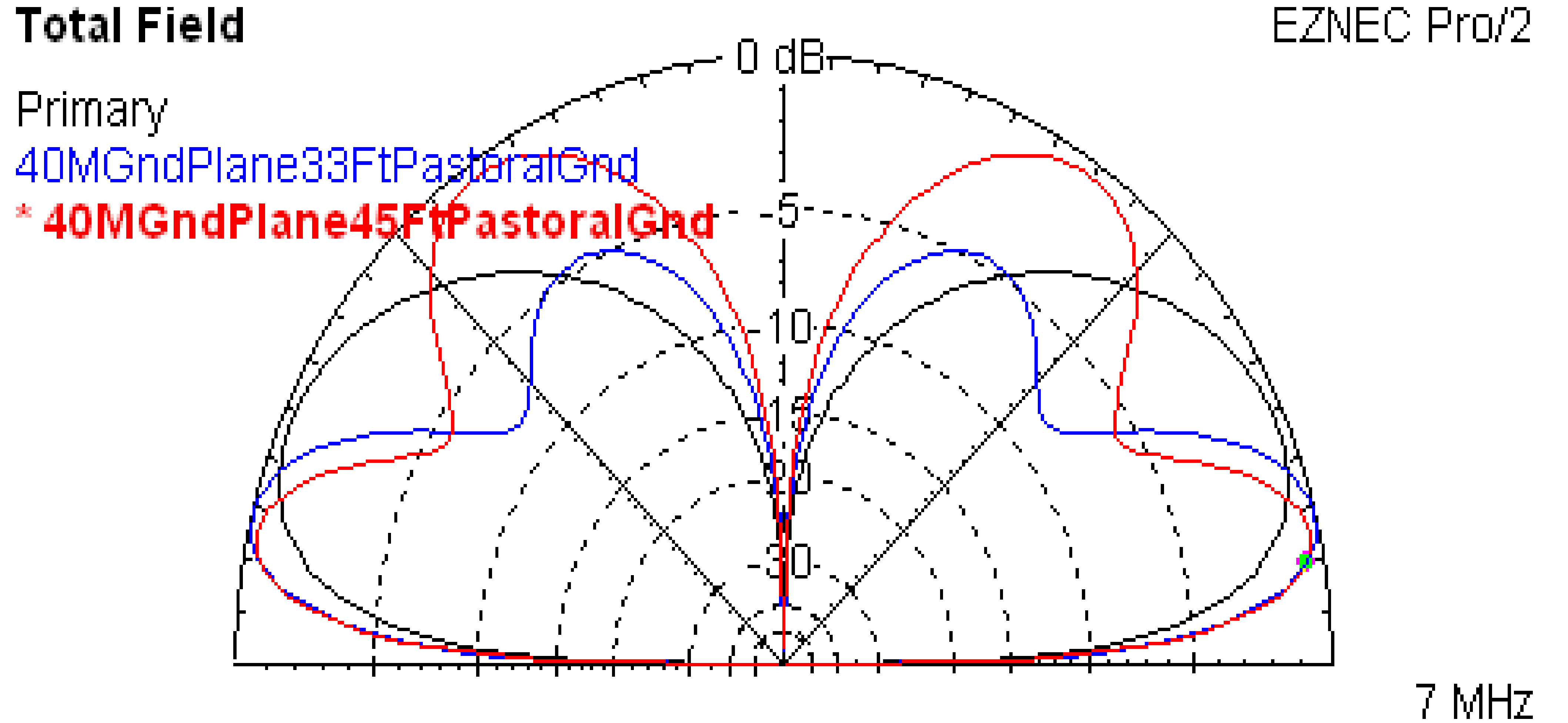
-0.71 dBmax

3.42 dBPrTrc

Poor Ground – Rocky, Sandy



Average Ground



Elevation Plot

Azimuth Angle 0.0 deg.

Outer Ring 0.17 dBi

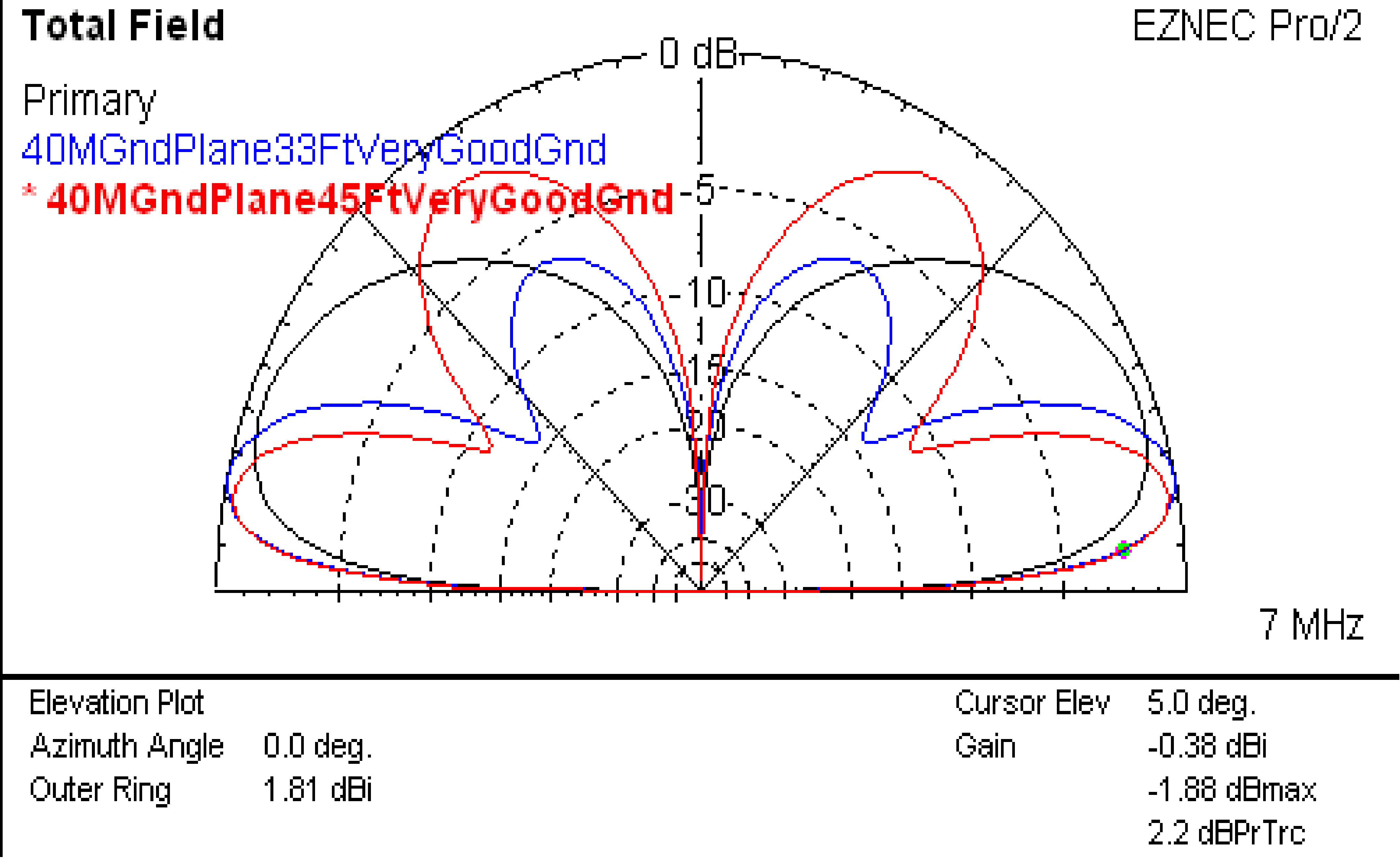
Cursor Elev 10.0 deg.

Gain -0.34 dBi

-0.25 dBmax

1.79 dBPrTrc

Pastoral Ground

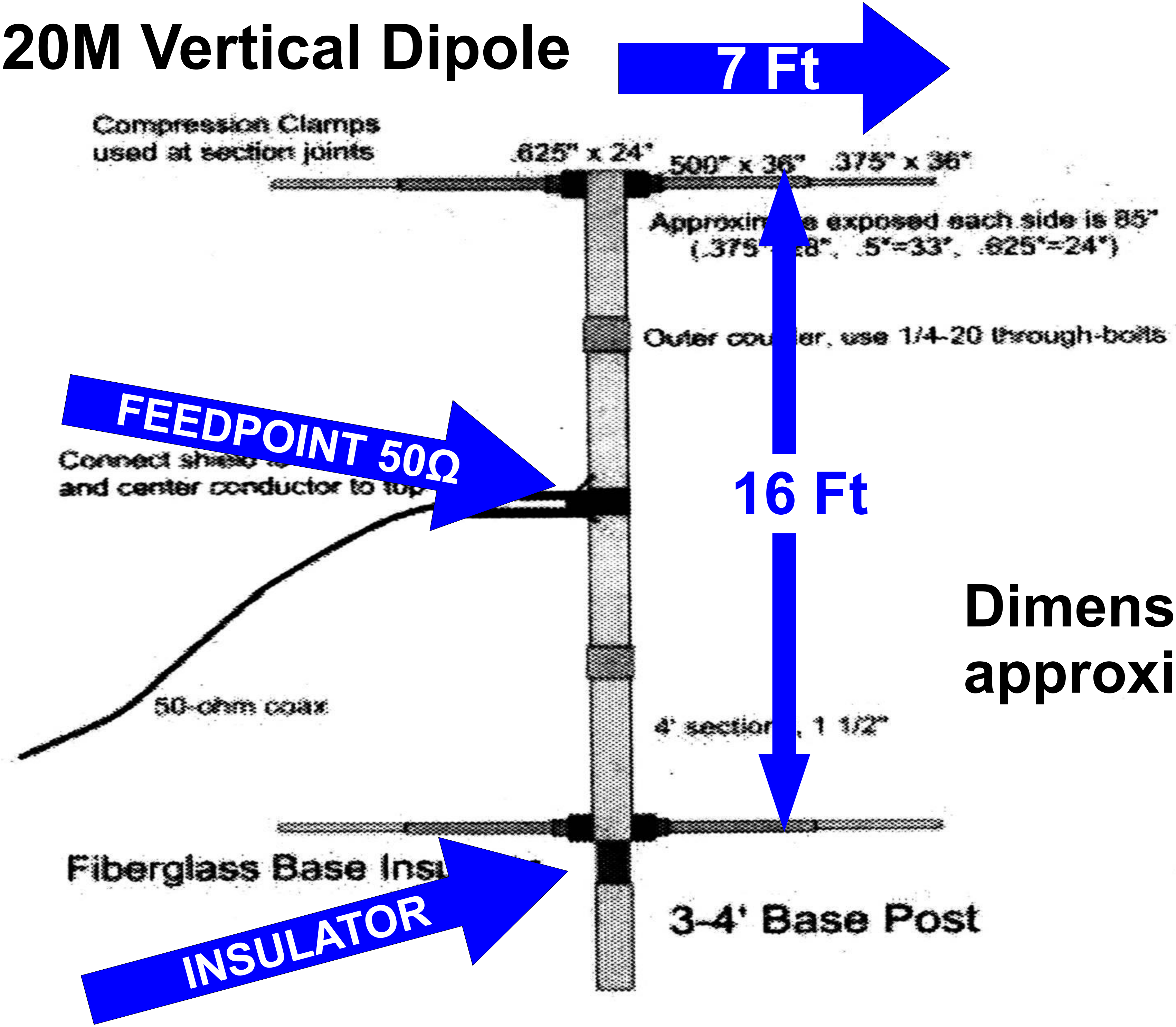


Very Good Ground

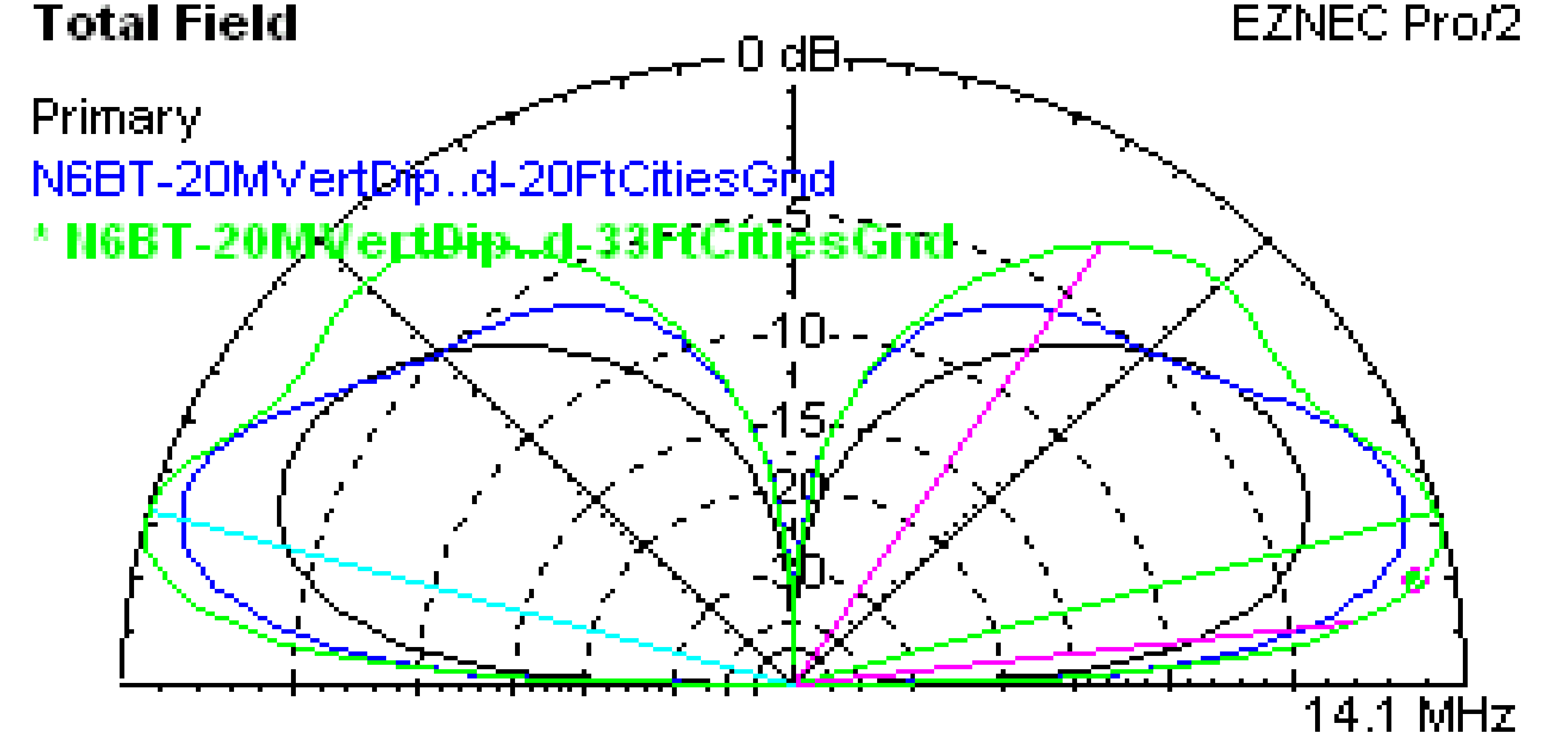
Second Series – N6BT 20M Vertical Dipole End Loaded

- N6BT Design, 16 Ft overall height, 14 ft horizontal loading at top and bottom, base 3 ft above ground
- Same antenna, base up 20 ft (~ λ/2)
- Same antenna, base up 33 ft
- Real High accuracy ground
- No radials
- Representative of a typical shortened vertical dipole

N6BT End-Loaded 20M Vertical Dipole

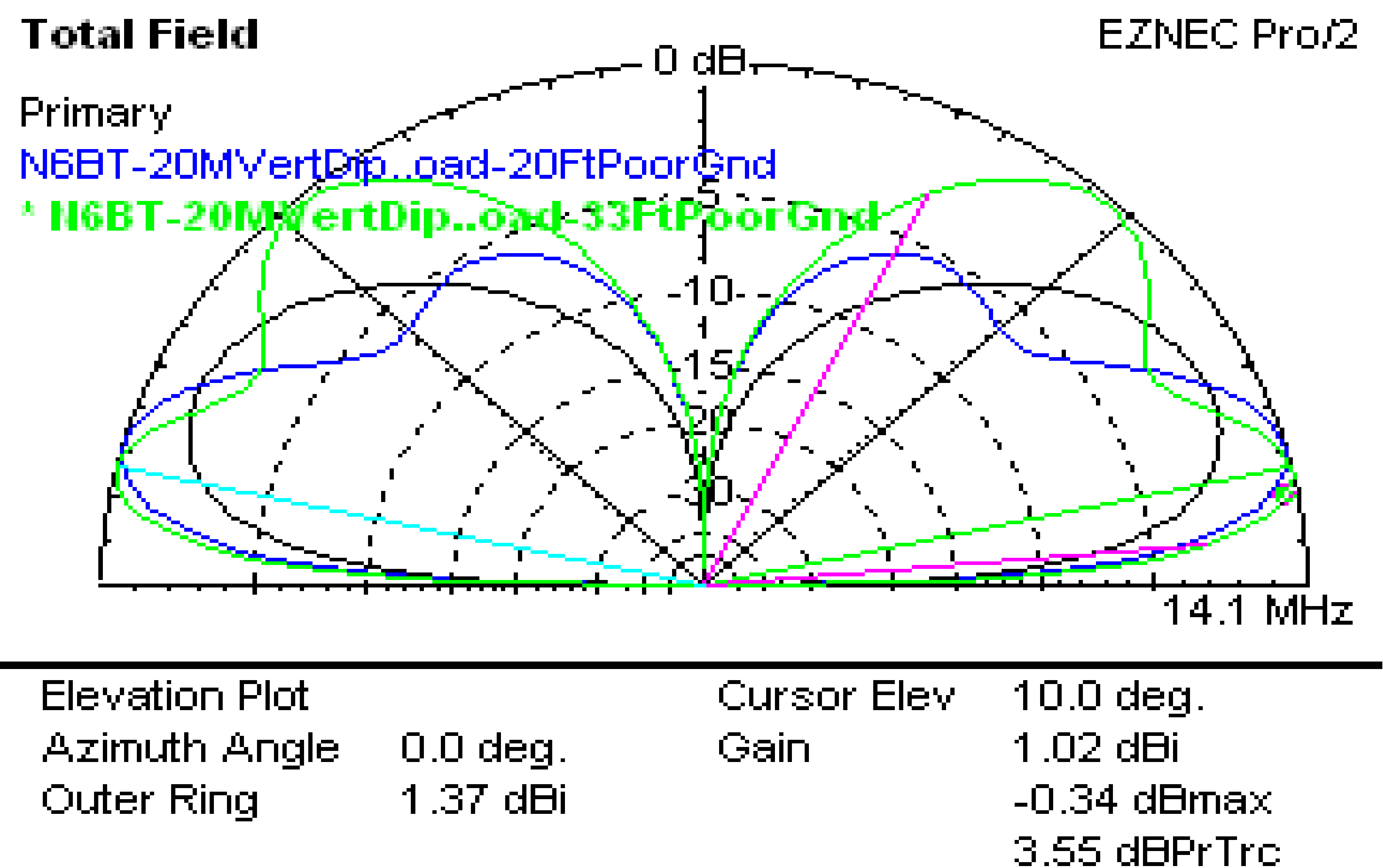


Dimensions are approximate

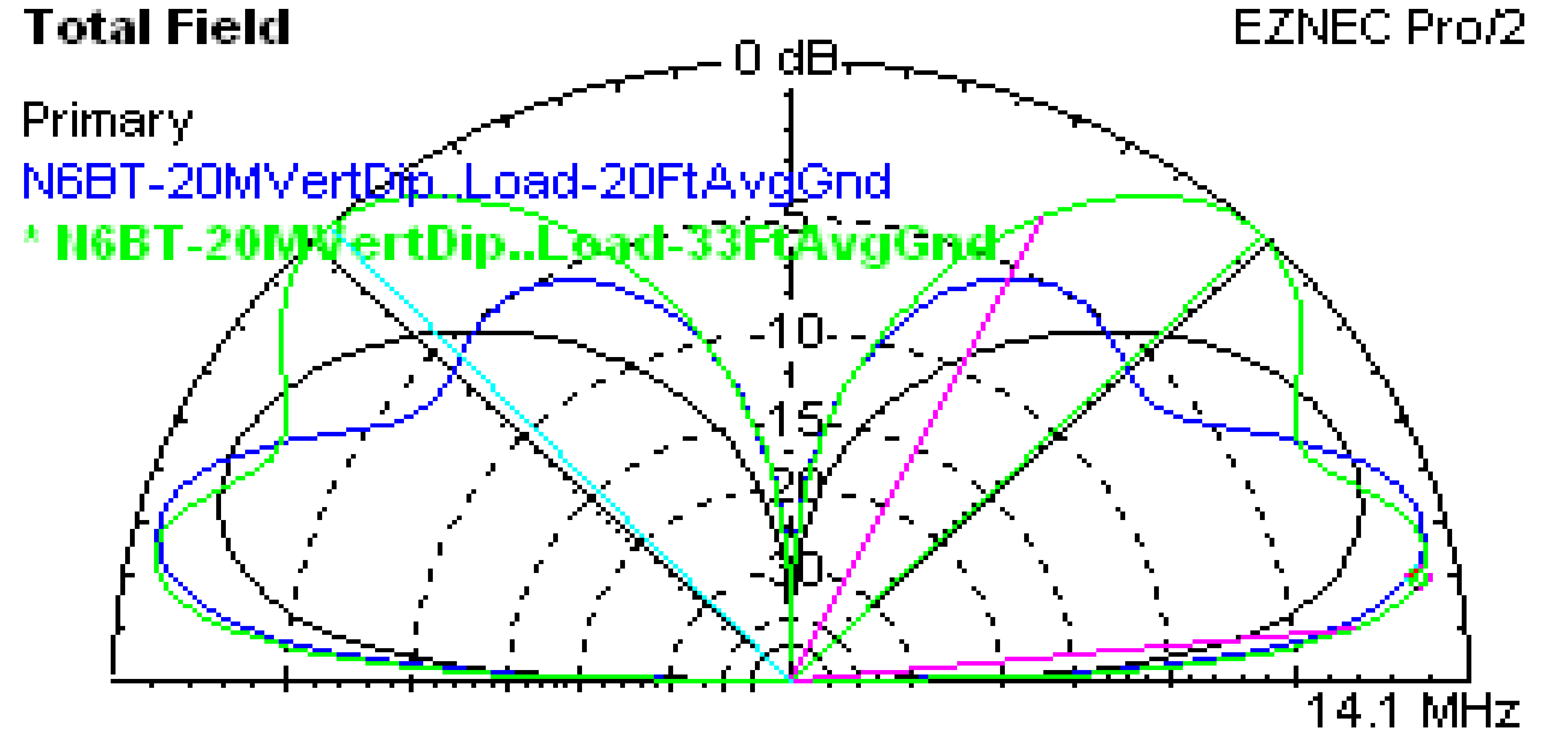


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.05 dBi
Outer Ring	1.99 dBi		-0.95 dBmax
			5.4 dBPrTrc

Very Poor Ground – Cities

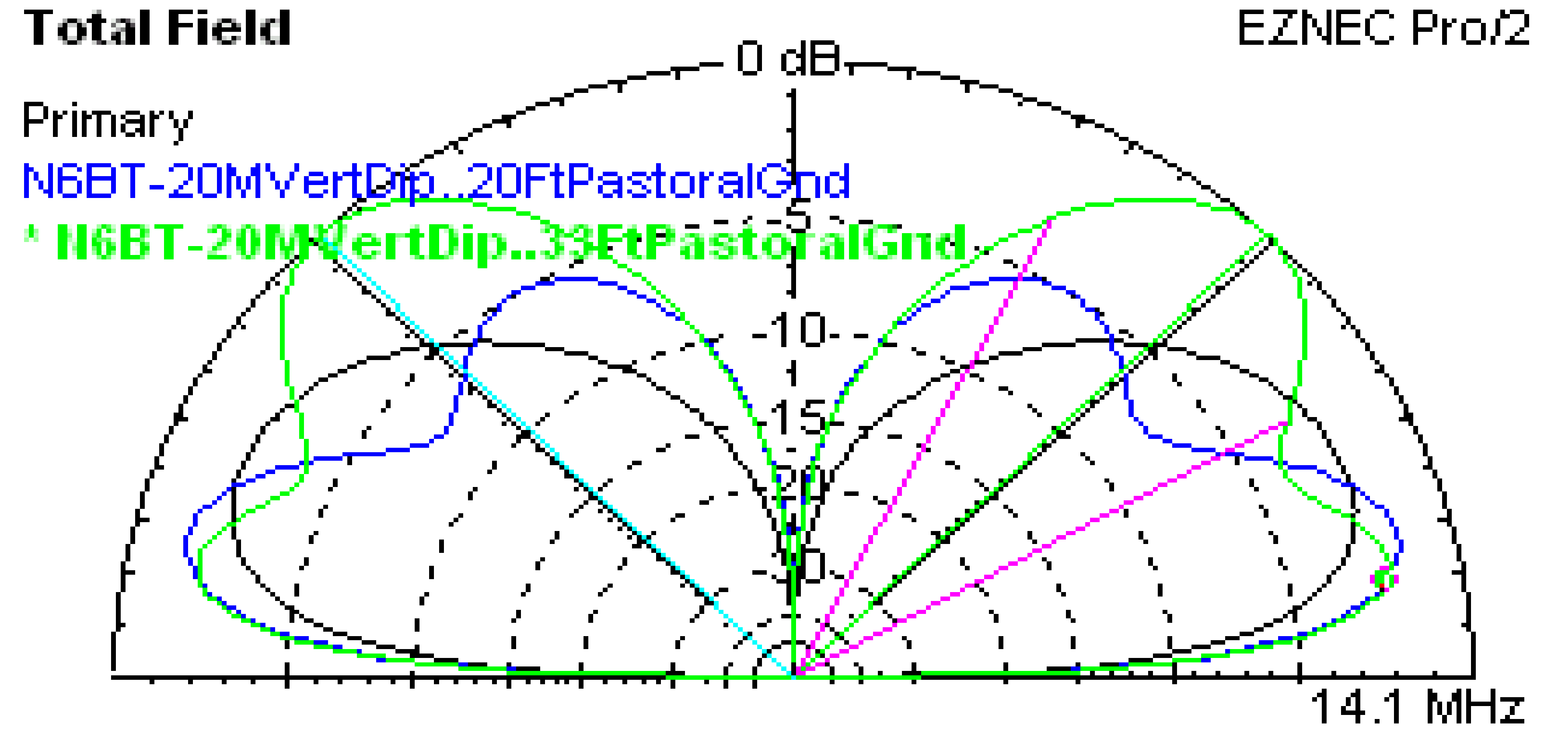


Poor Ground – Rocky, Sandy



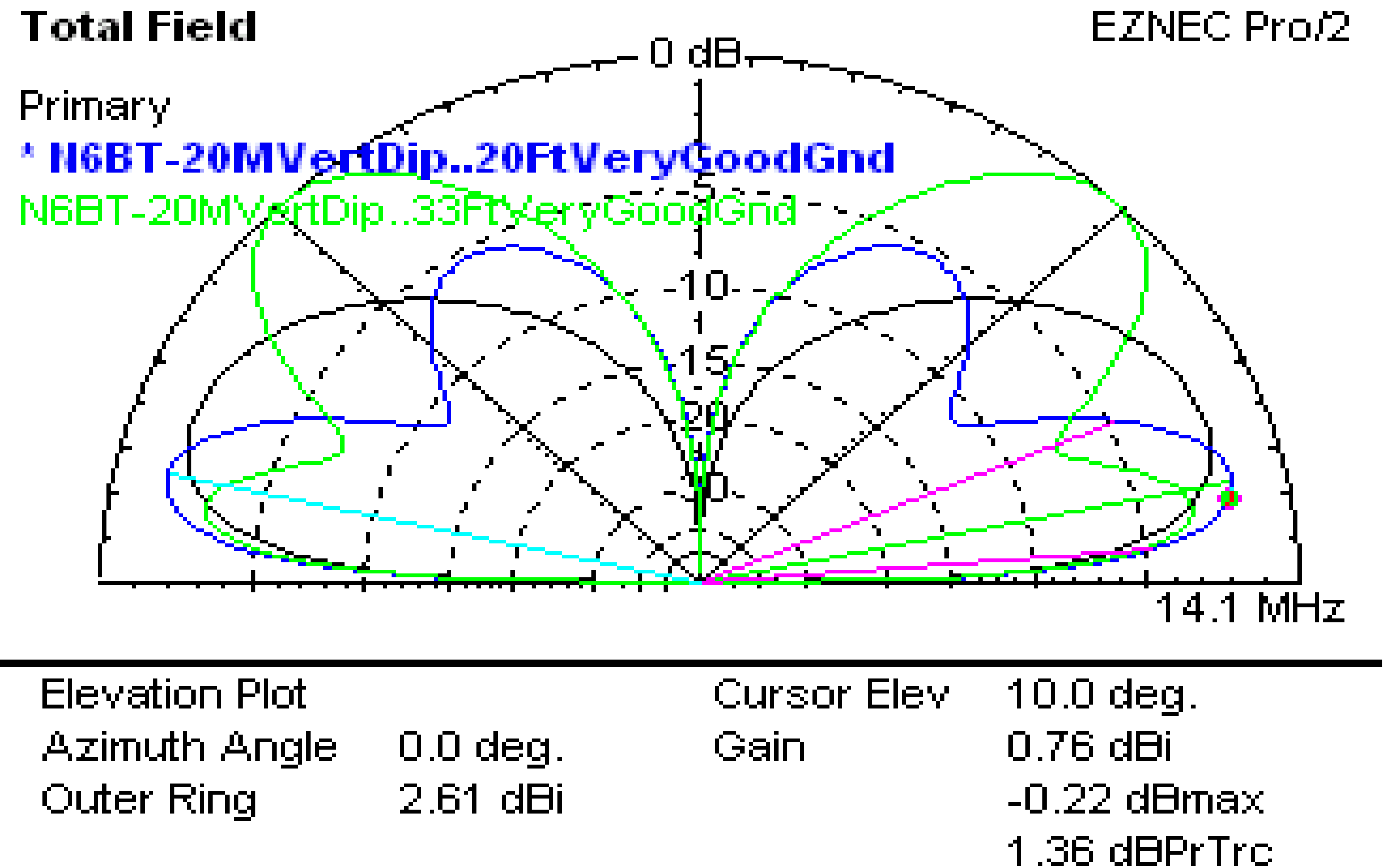
Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.45 dBi
Outer Ring	1.42 dBi		-0.97 dBmax
			3.14 dBPrTrc

Average Ground

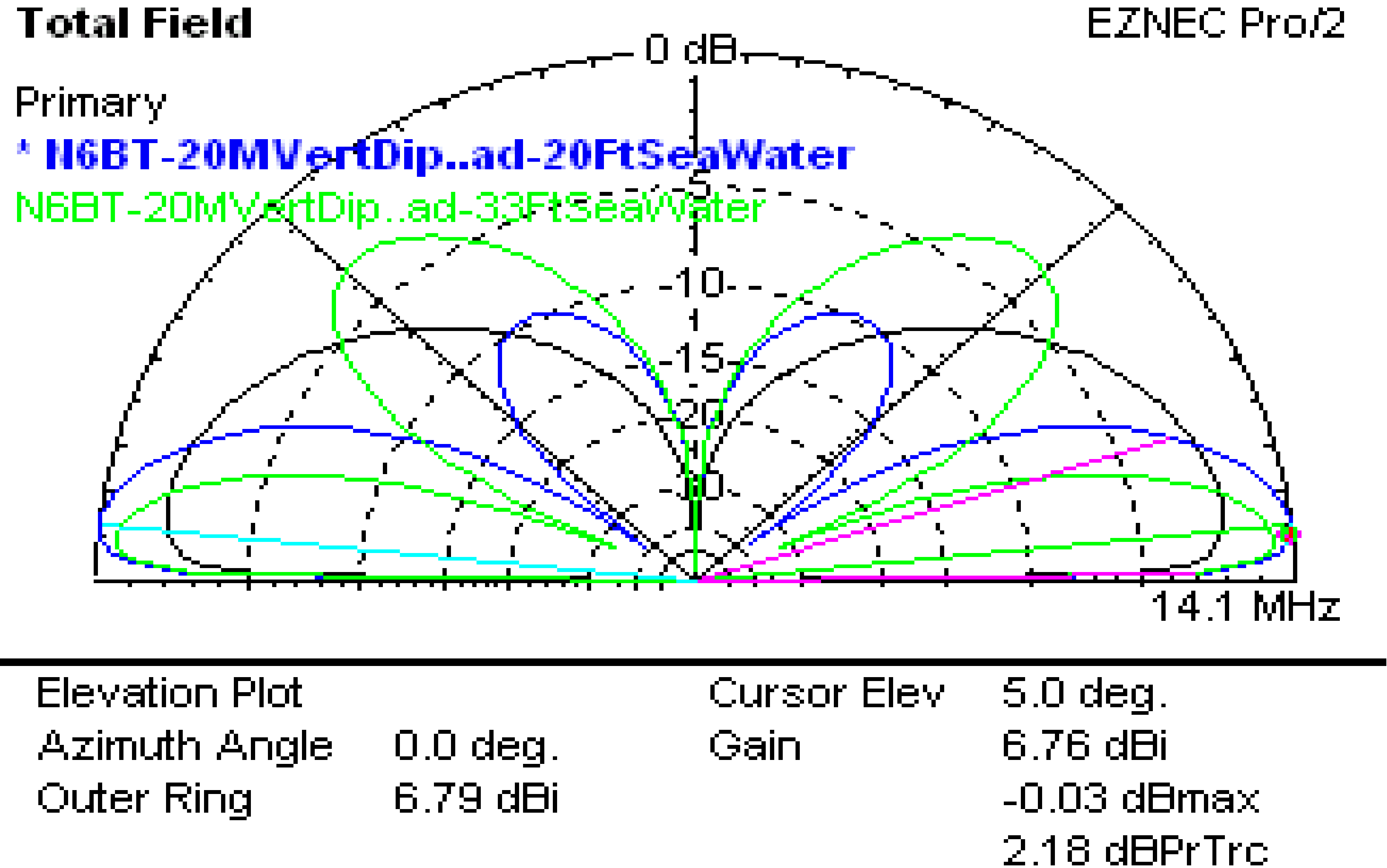


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.2 dBi
Outer Ring	1.87 dBi		-2.07 dBmax
			2.19 dBPrTrc

Pastoral Ground



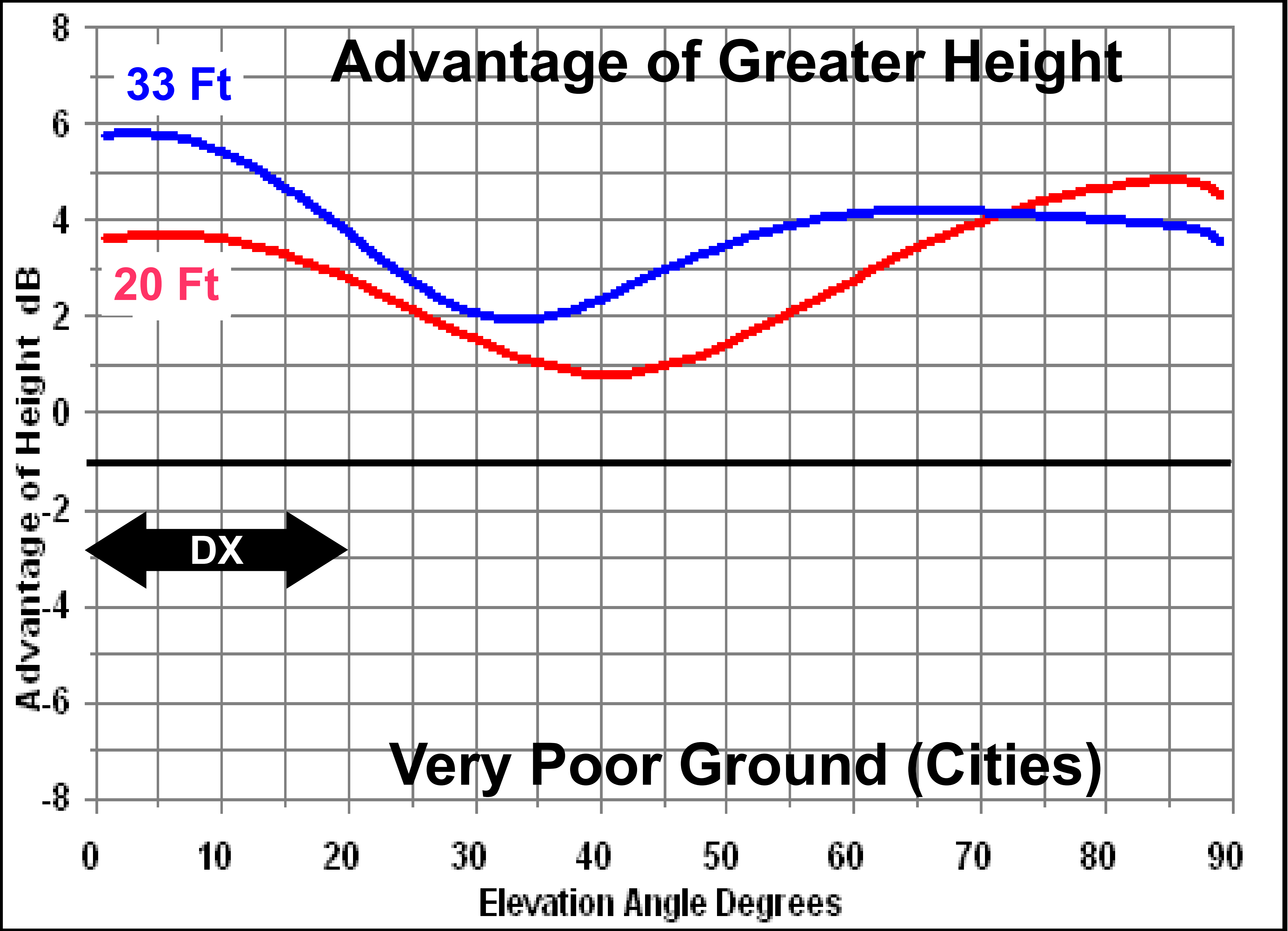
Very Good Ground


Total Field
EZNEC Pro/2
0 dB
Primary
* N6BT-20MVertDip..ad-20FtSeaWater
N6BT-20MVertDip..ad-33FtSeaWater
-5
-10
-15
-20
-30
14.1 MHz
Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 6.79 dBi
Cursor Elev 5.0 deg.
Gain 6.76 dBi
-0.03 dBmax
2.18 dBPrTrc

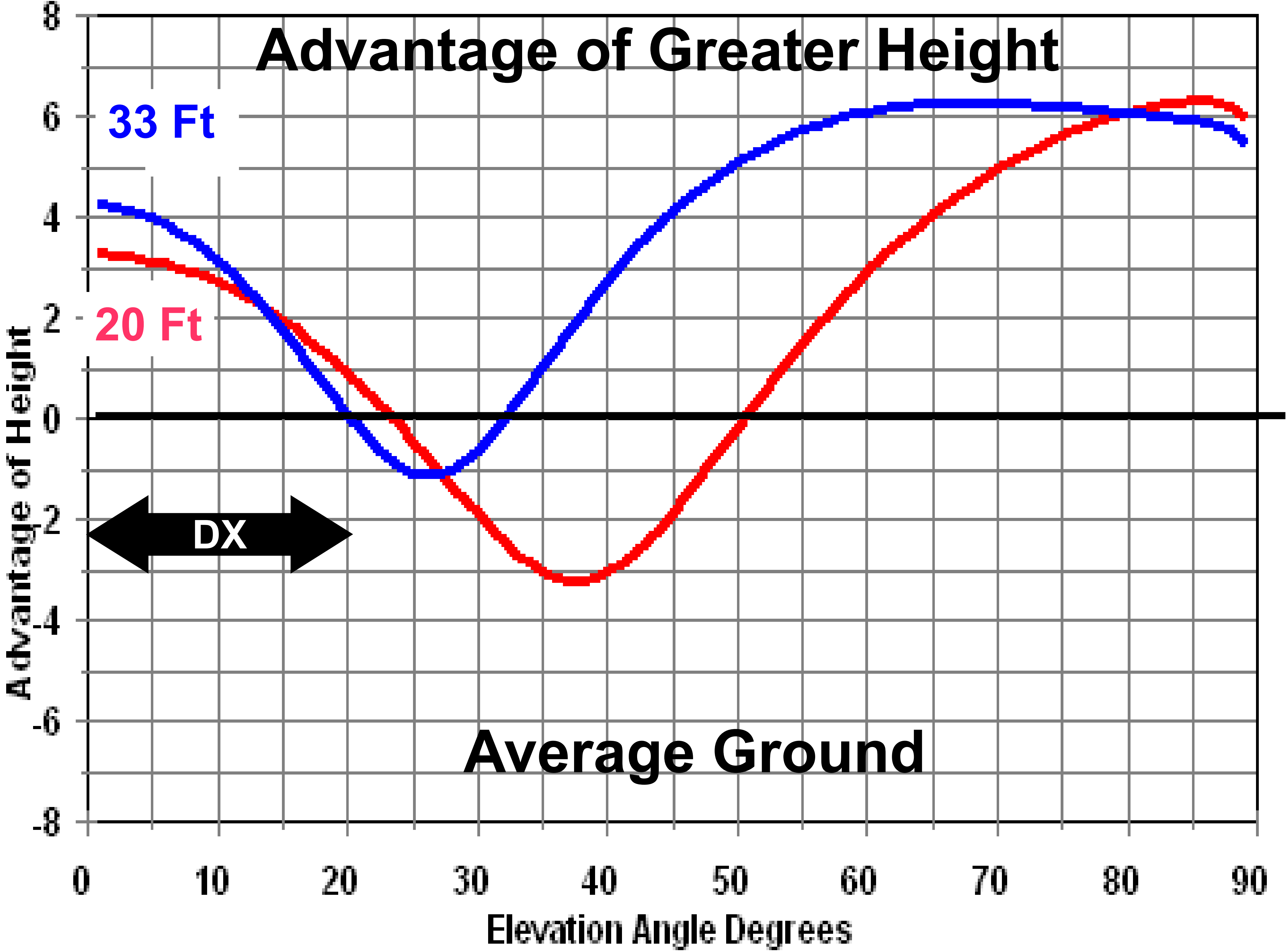
Sea Water

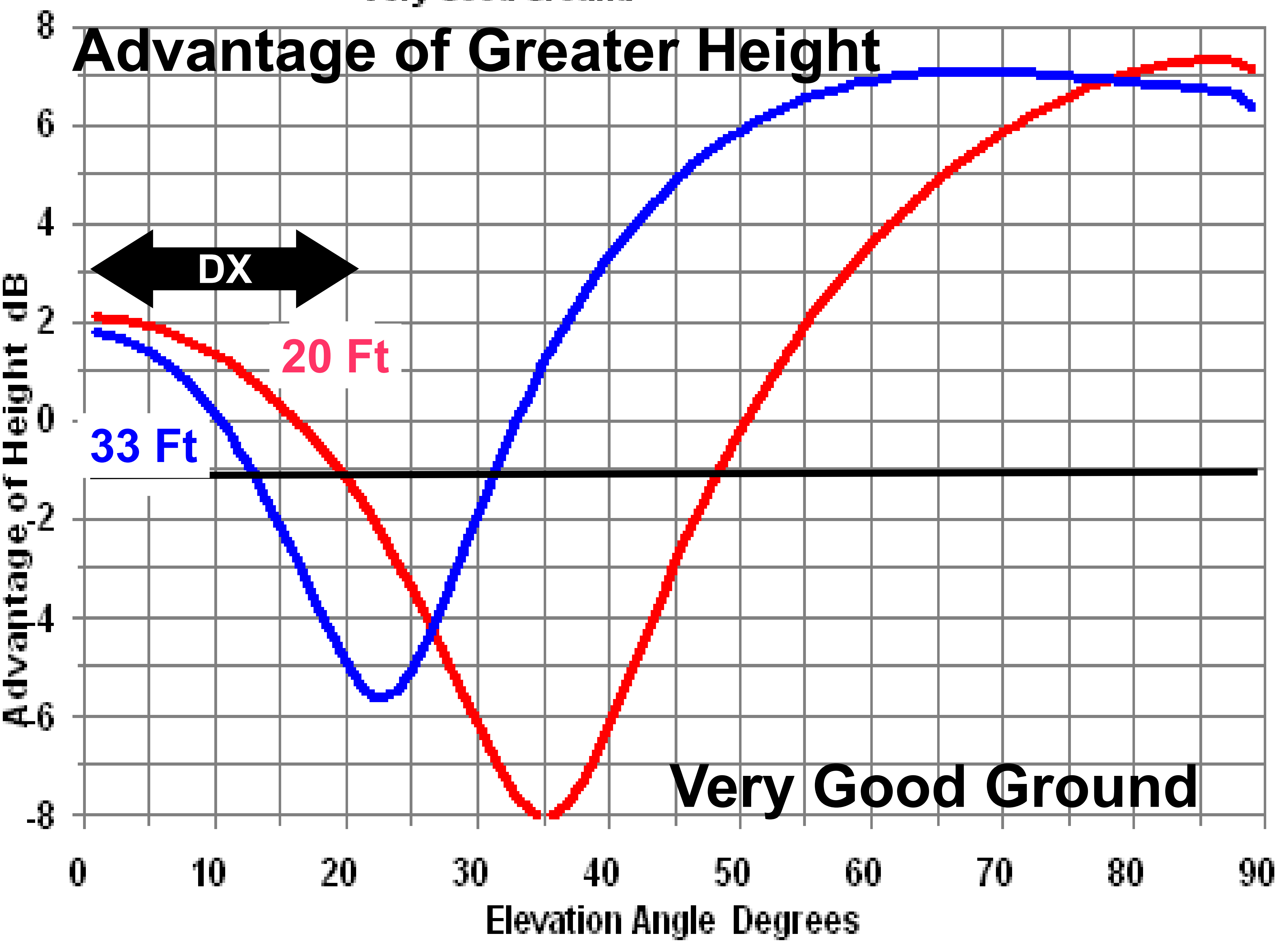
Often A Different View Helps

- Same data for N6BT end-loaded 20M dipole, but plotted on rectangular graph
- Improvement gained by greater height
    - Base at 20 ft or 33 ft, compared to base at 3 ft
- More clearly shows added gain at low angles where most DX is worked



Advantage of Greater Height
33 Ft
20 Ft
DX
Very Poor Ground (Cities)
Advantage of Height dB
8
6
4
2
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
80
90
Elevation Angle Degrees

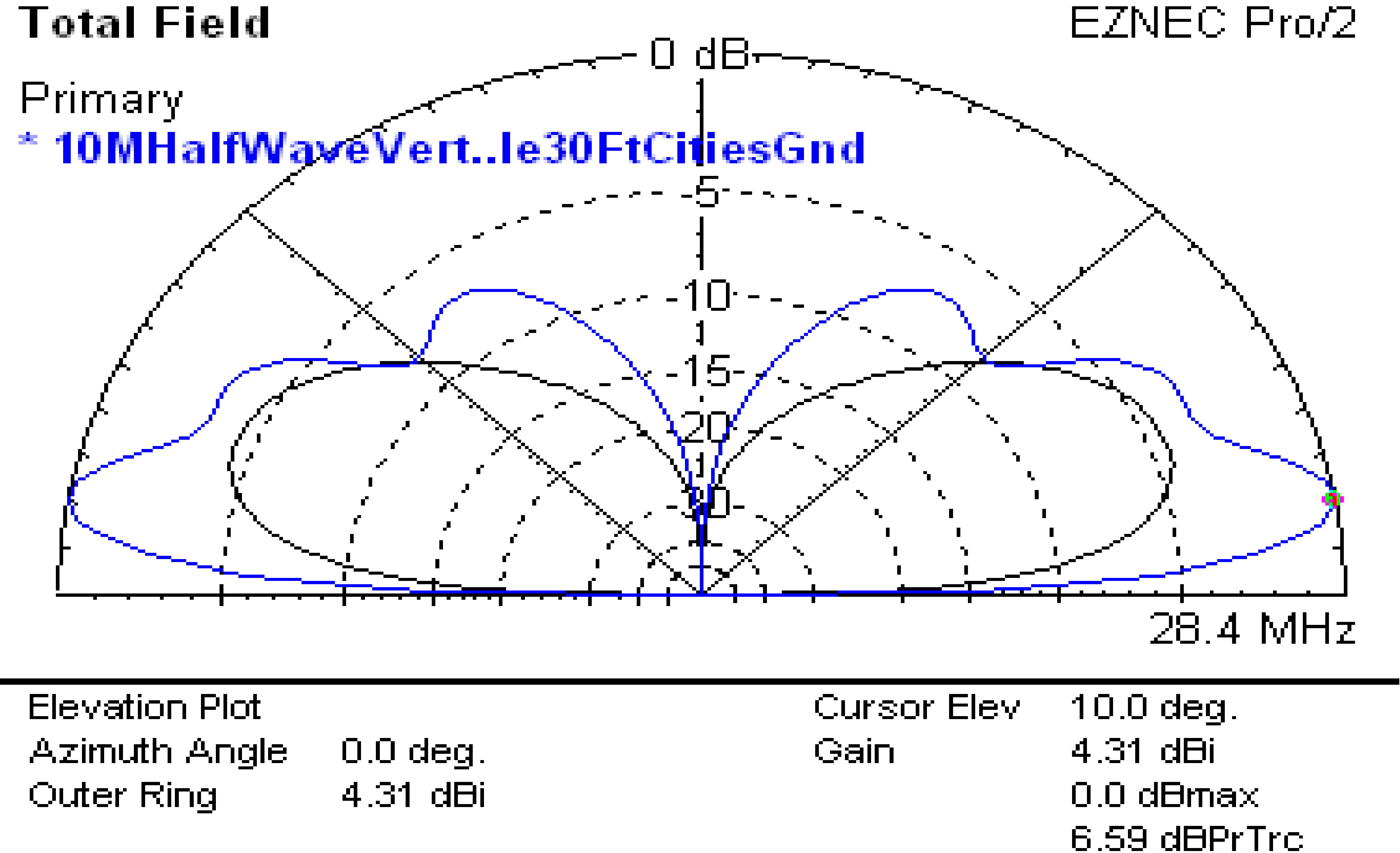

Advantage of Greater Height
33 Ft
20 Ft
DX
Average Ground
Advantage of Height
8
6
4
2
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
80
90
Elevation Angle Degrees



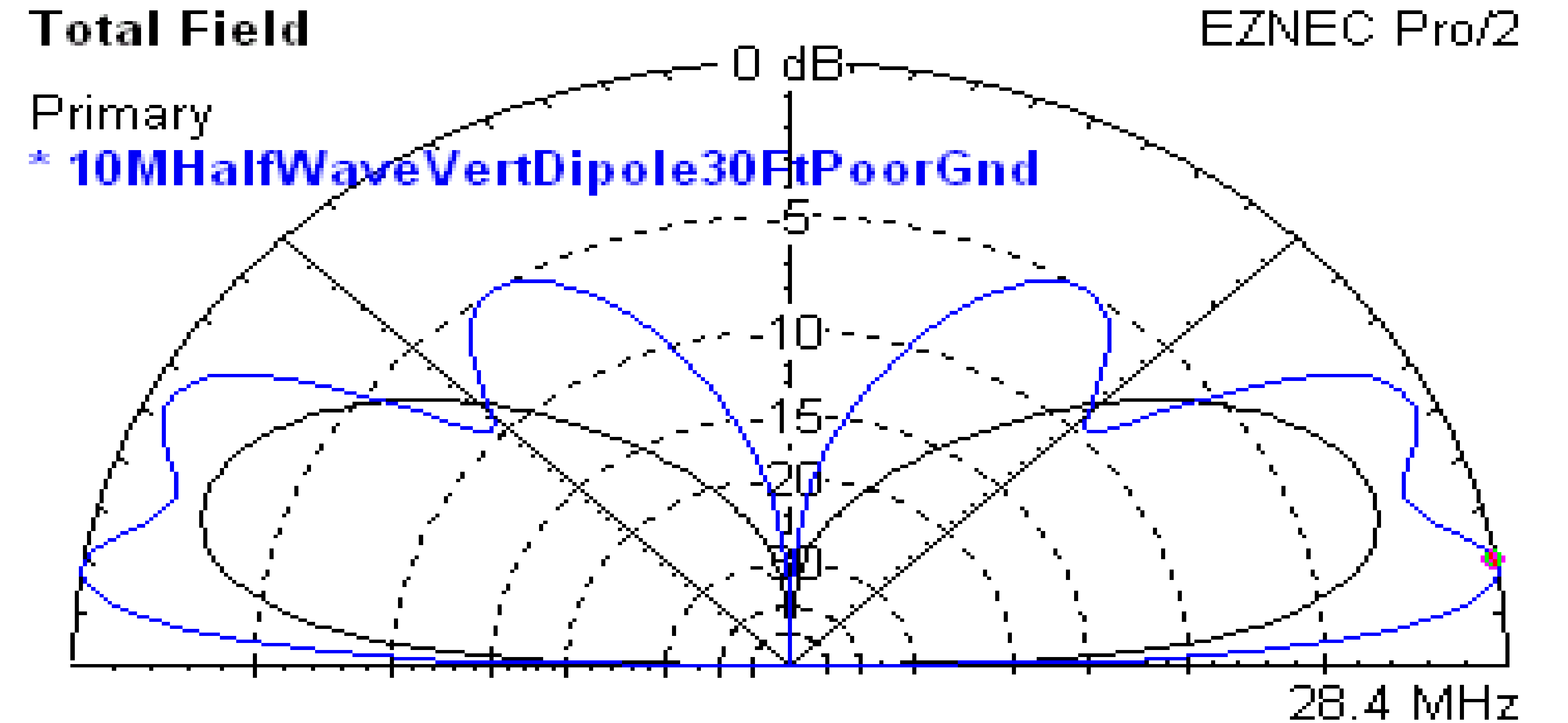
Advantage of Greater Height
DX
20 Ft
33 Ft
Very Good Ground
Advantage of Height dB
8
6
4
2
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
80
90
Elevation Angle Degrees

Third Series – 10M Vertical Dipole

- **1/2-in diam λ/2, base 6 inches above ground**
  - **Real High accuracy ground**
- **Same antenna, base 30 ft above ground**
  - **Real High accuracy ground**

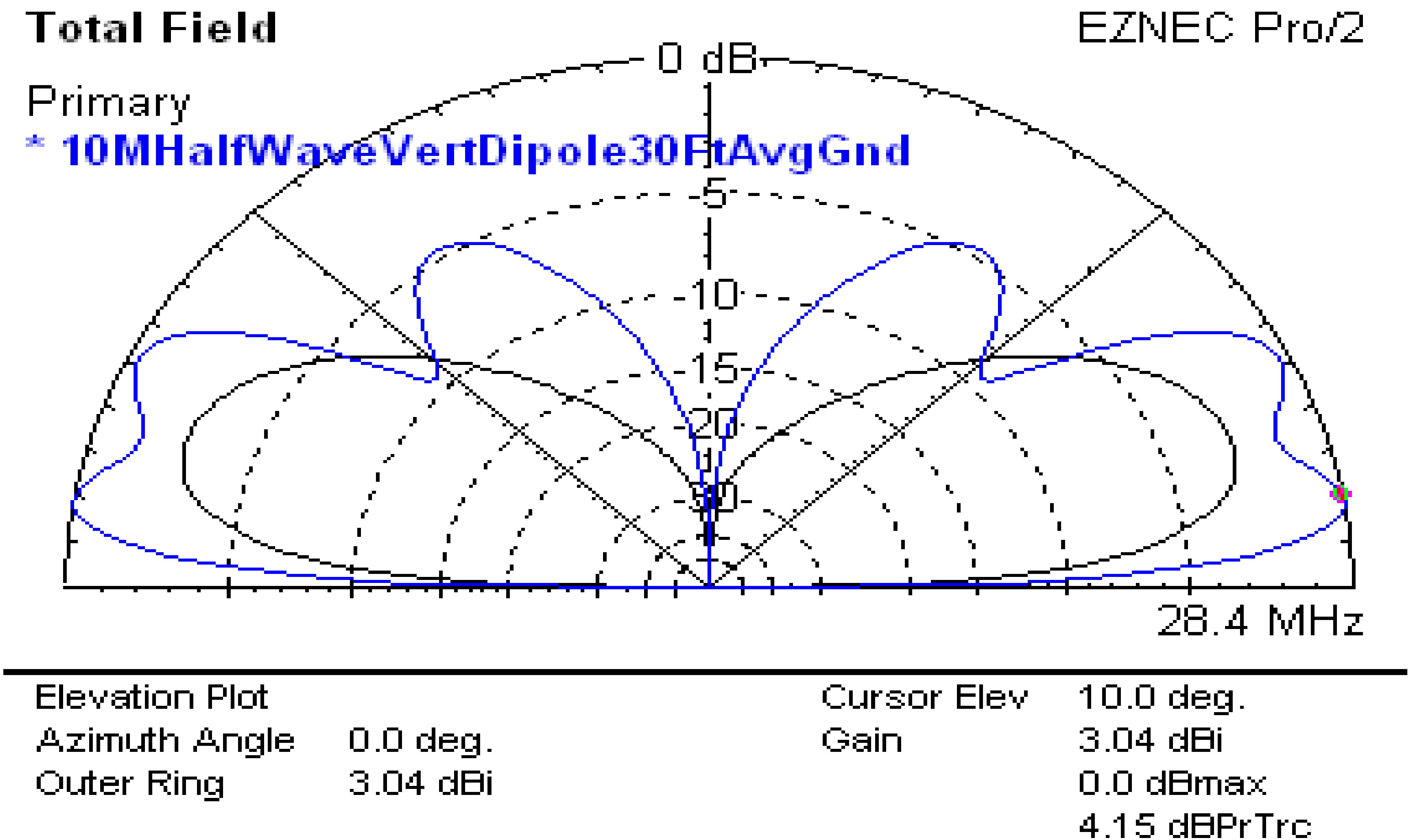


Very Poor Ground – Cities

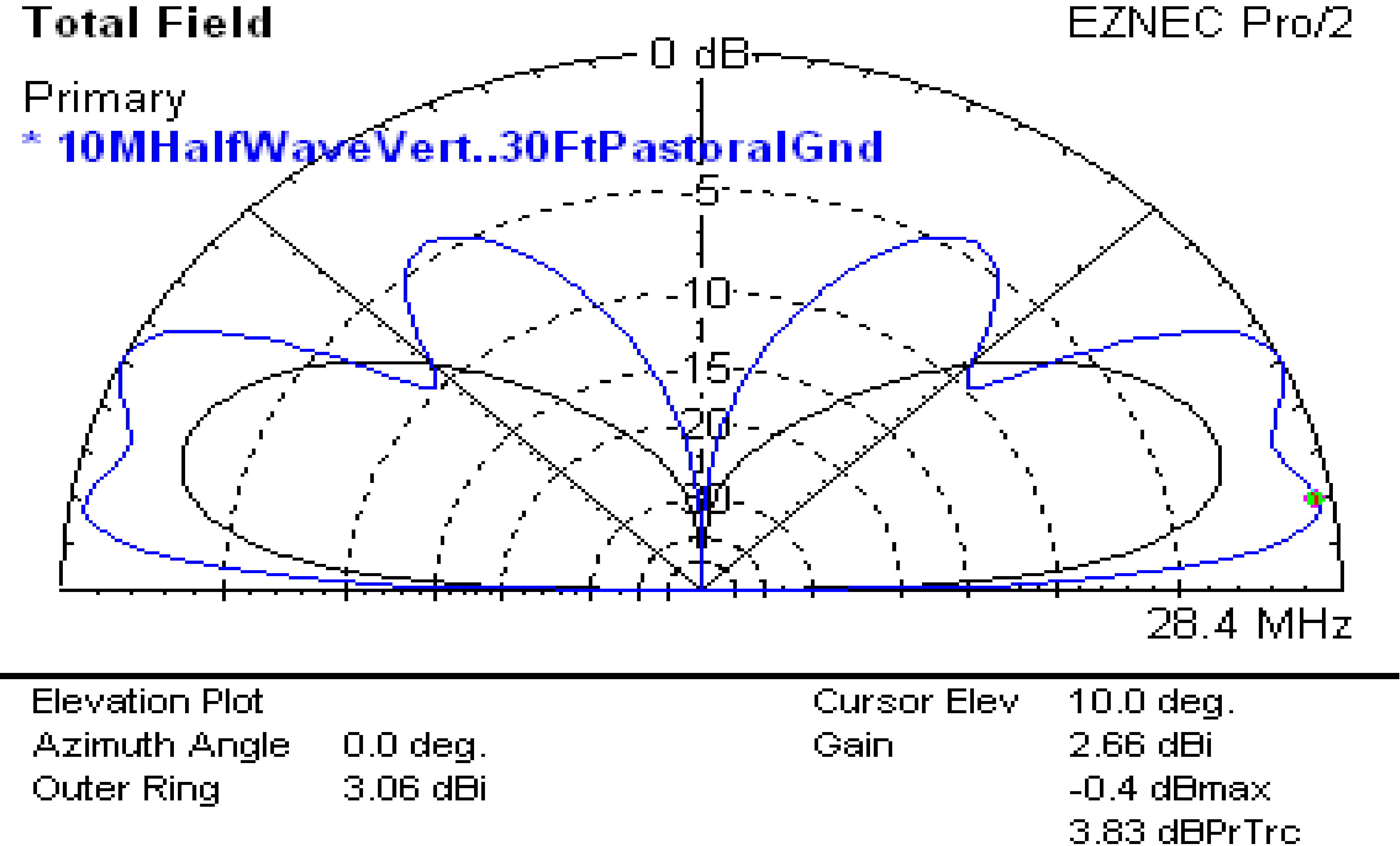


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	3.2 dBi
Outer Ring	3.23 dBi		-0.03 dBmax
			4.12 dBPrTrc

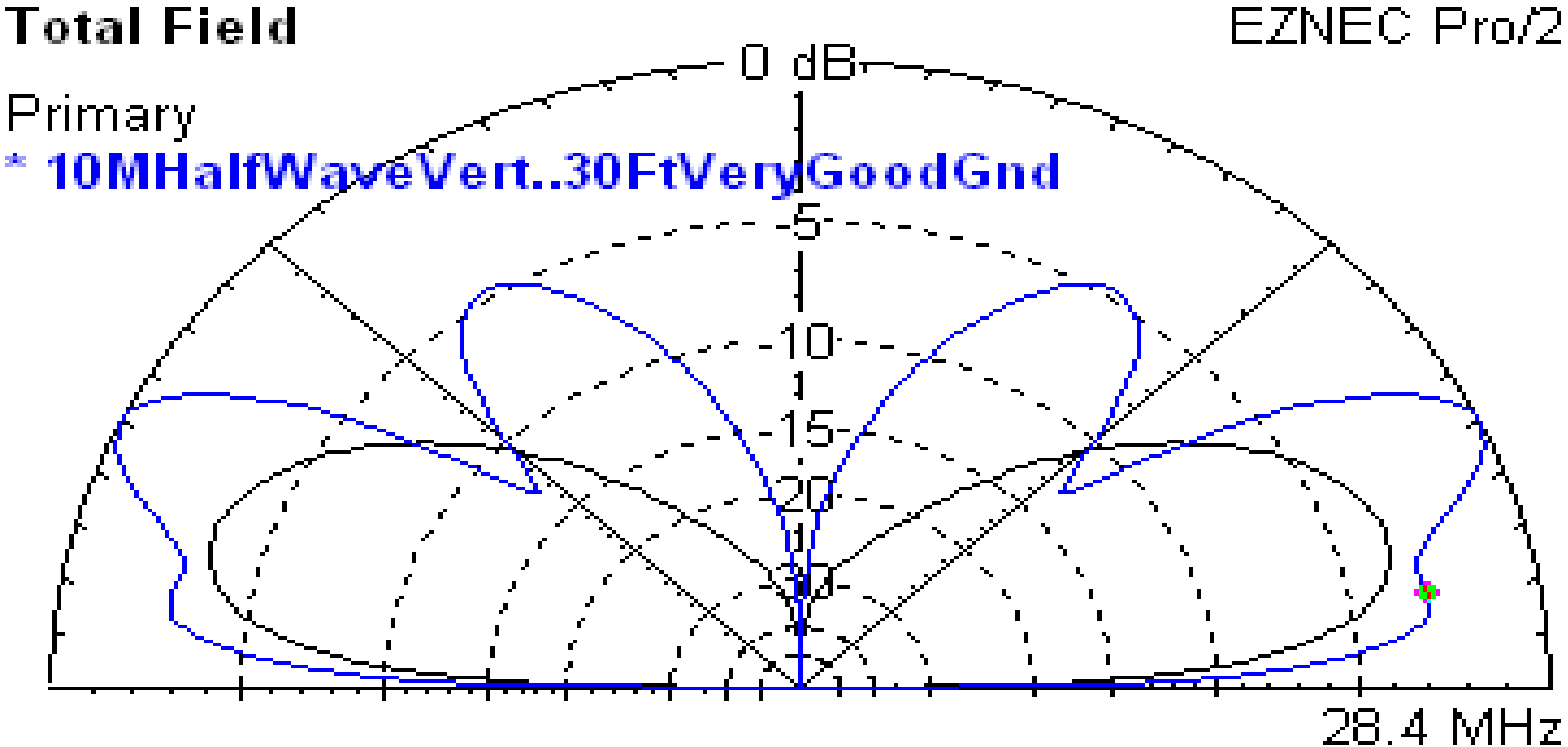
Poor Ground – Rocky, Sandy



Average Ground

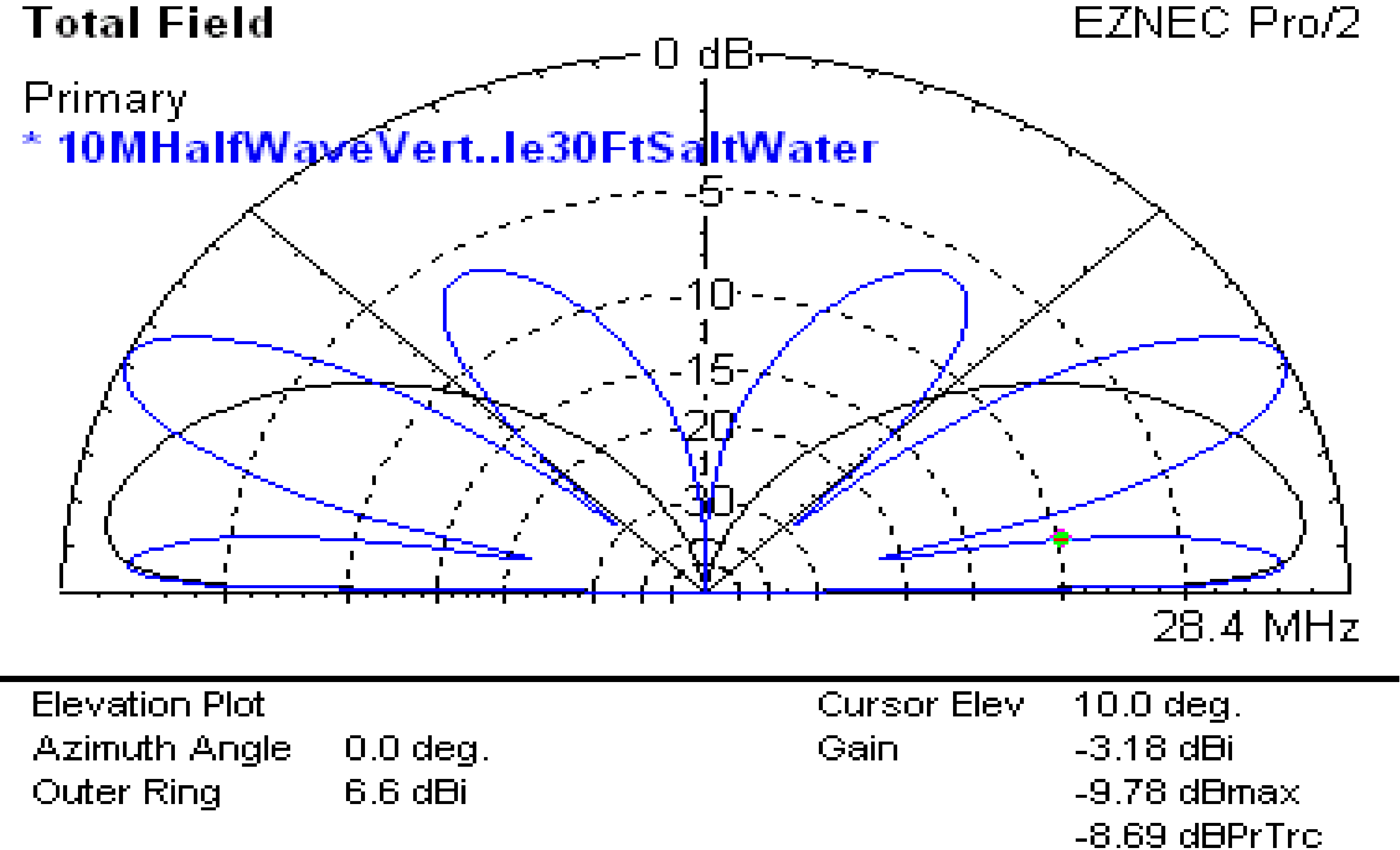


Pastoral Ground



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.24 dBi
Outer Ring	4.03 dBi		-2.79 dBmax
			1.66 dBPrTrc

Very Good Ground

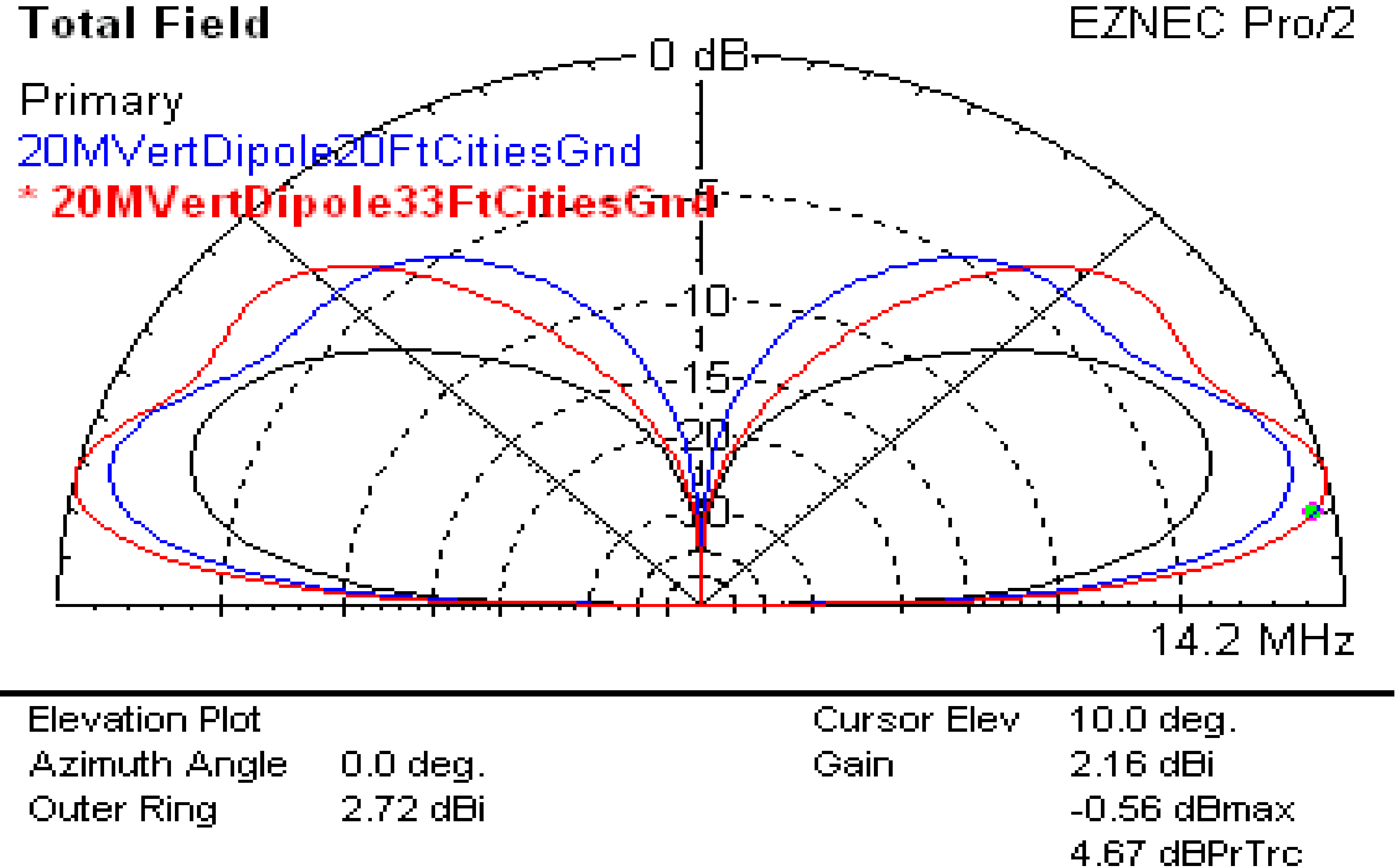


Total Field
EZNEC Pro/2
Primary
* 10MHalfWaveVert..le30FtSaltWater
0 dB
-5
-10
-15
-20
-30
28.4 MHz
Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 6.6 dBi
Cursor Elev 10.0 deg.
Gain -3.18 dBi
-9.78 dBmax
-8.69 dBPrTrc

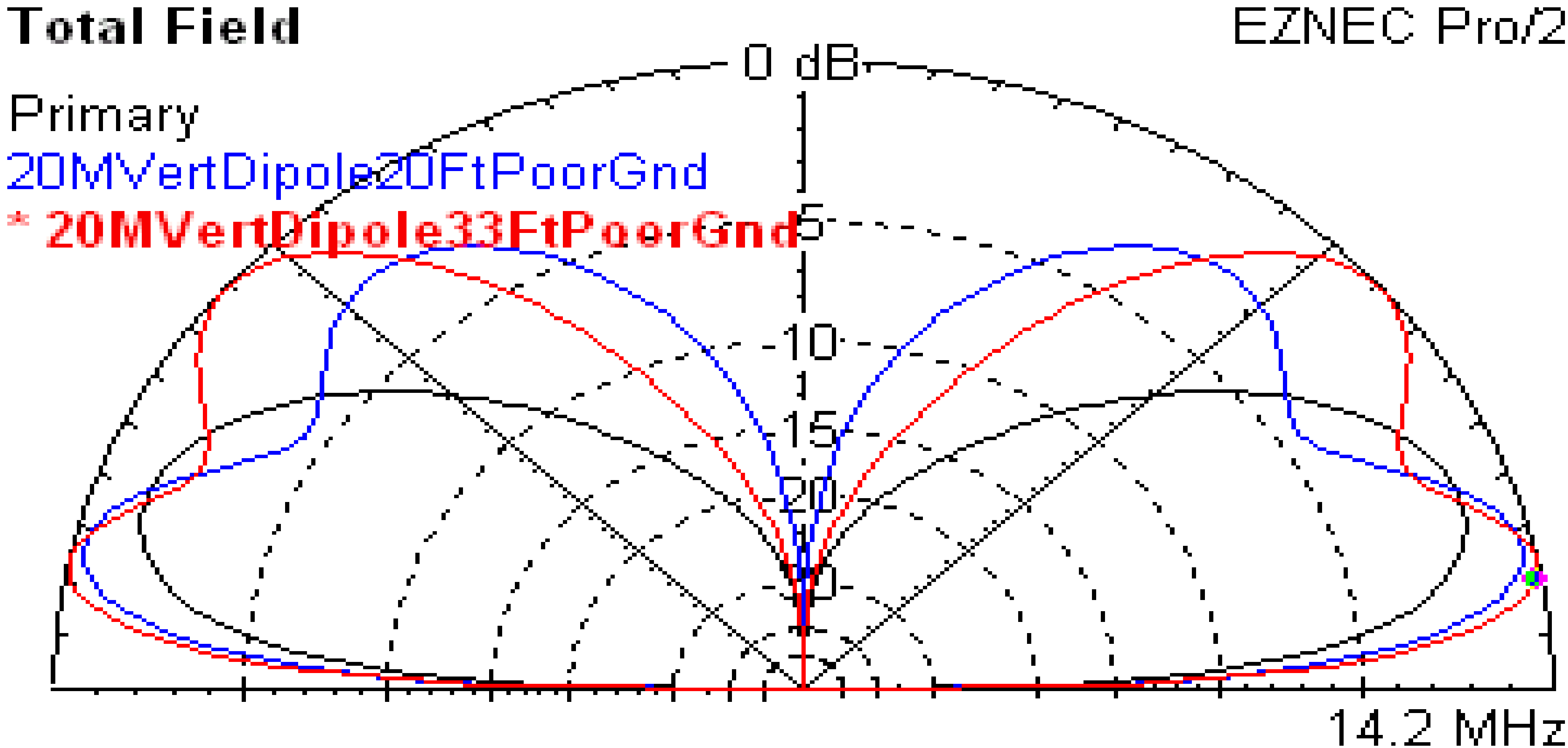
Sea Water

Fourth Series – 20M Vertical Dipole

- 3/4-in diam λ/2, base 1 ft above ground
- Same antenna, base 20 ft above ground
- Same antenna, base 33 ft above ground
- Real high accuracy ground for all

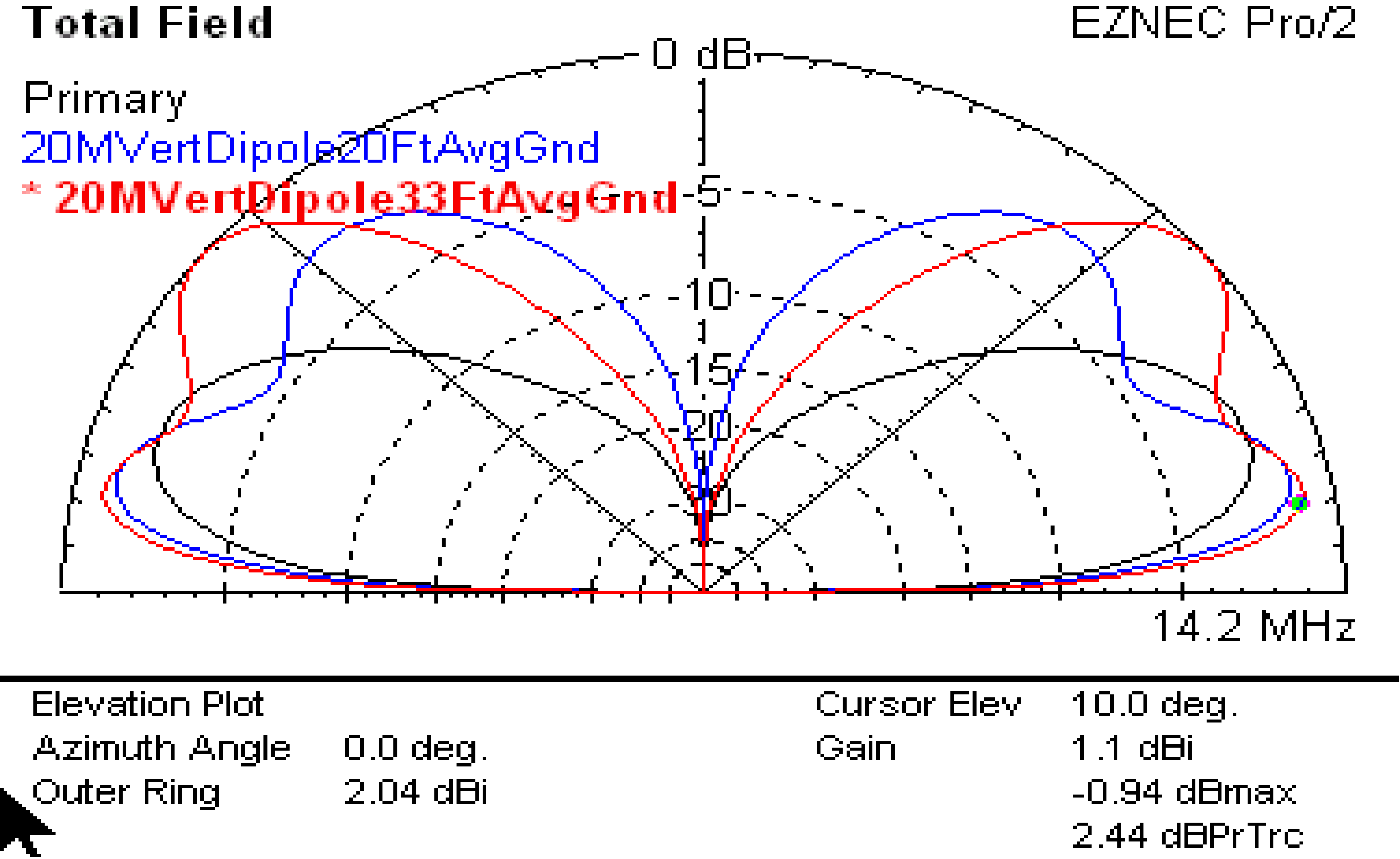


Very Poor Ground – Cities

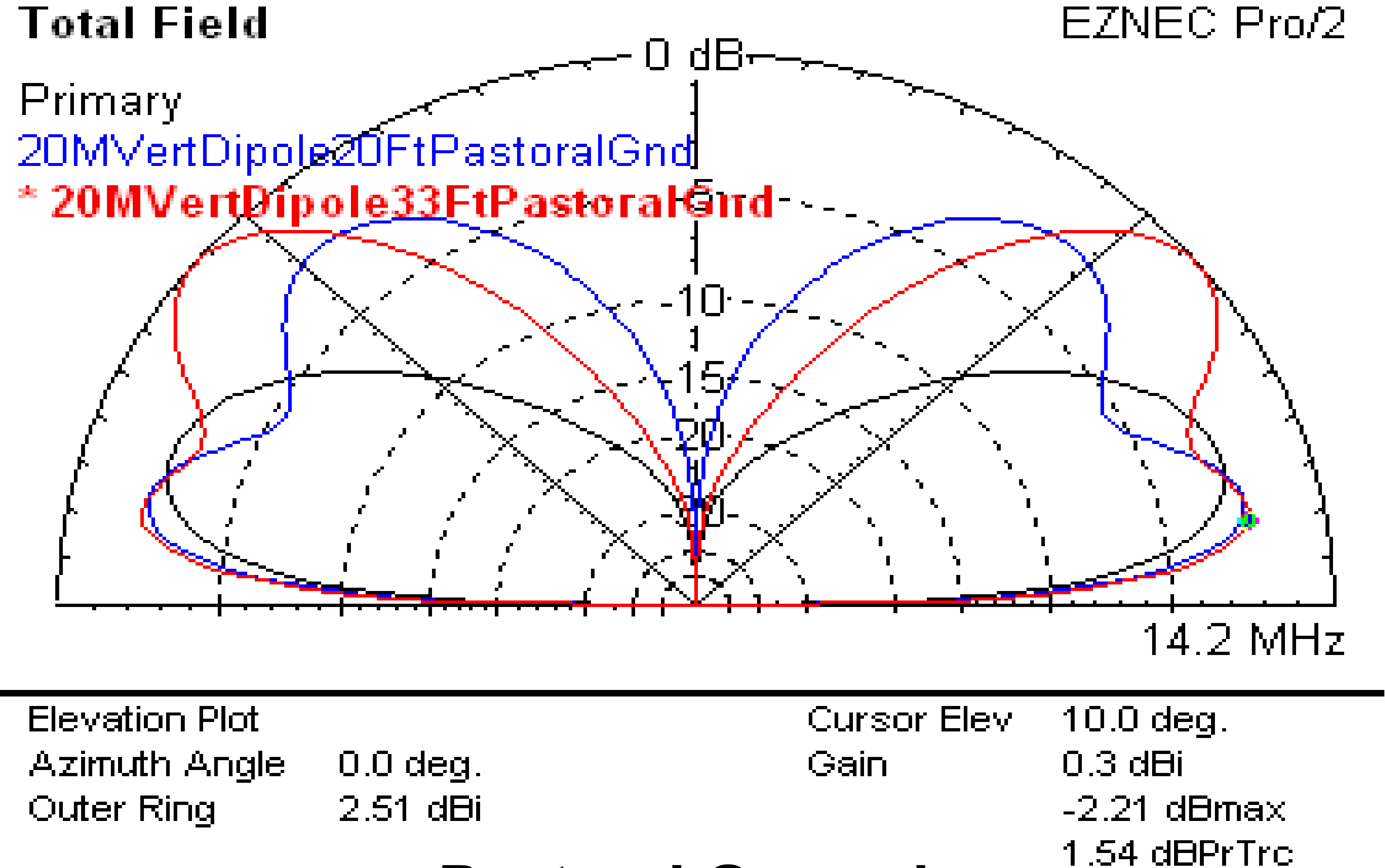


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.67 dBi
Outer Ring	1.8 dBi		-0.13 dBmax
			2.74 dBPrTrc

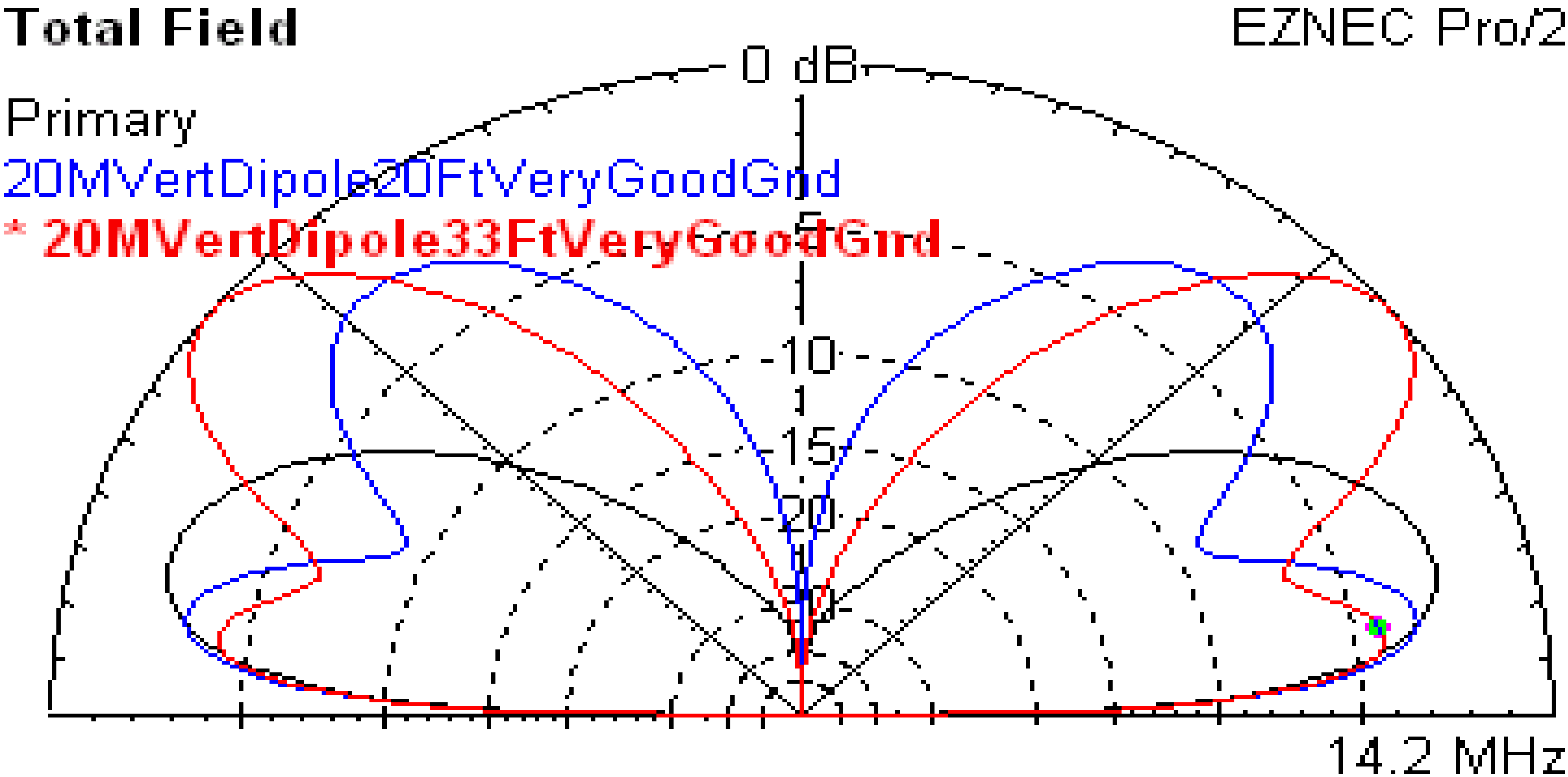
Poor Ground – Rocky, Sandy



Average Ground

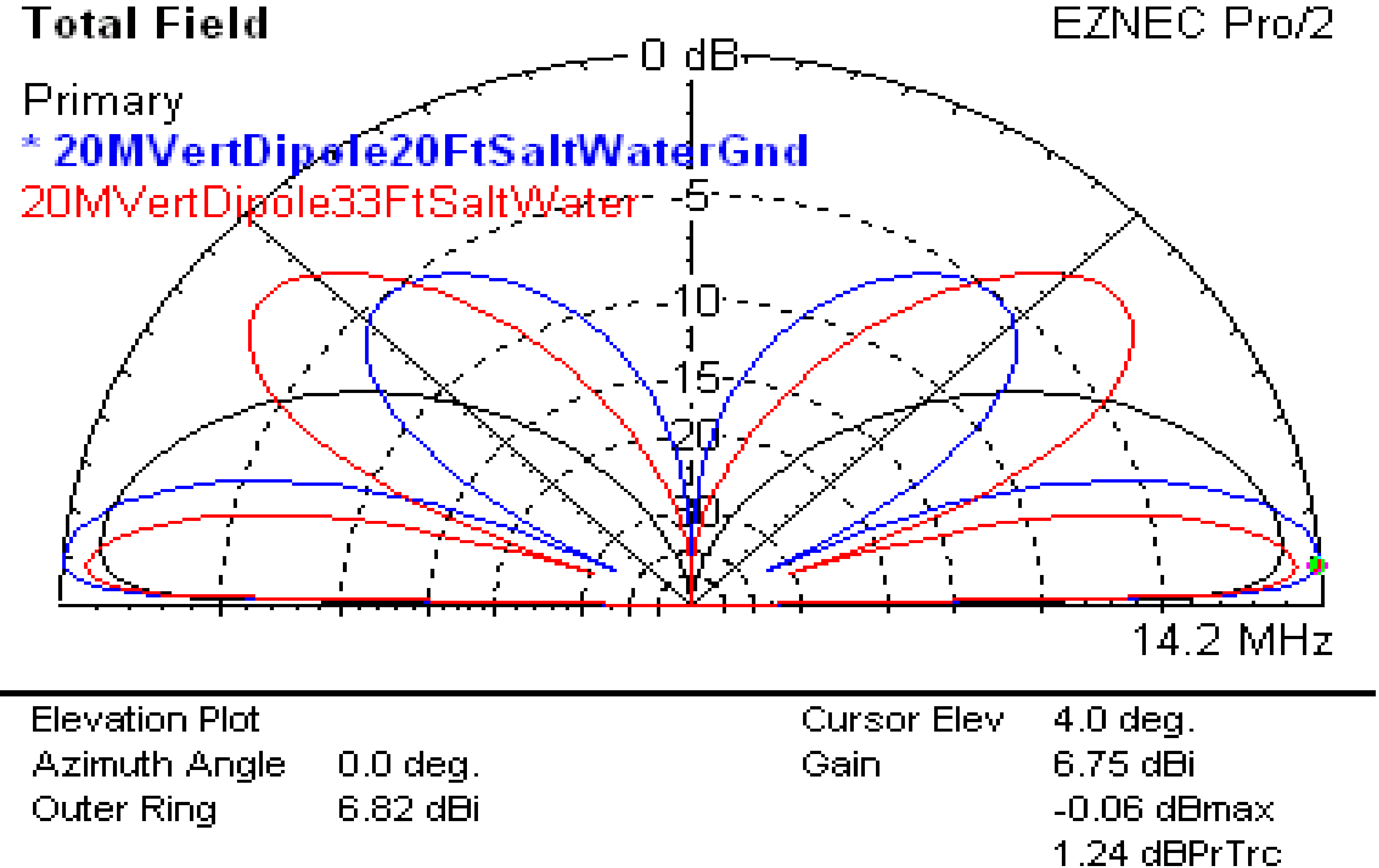


Pastoral Ground



Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.86 dBi
Outer Ring	3.35 dBi		-4.21 dBmax
			-1.14 dBPrTrc

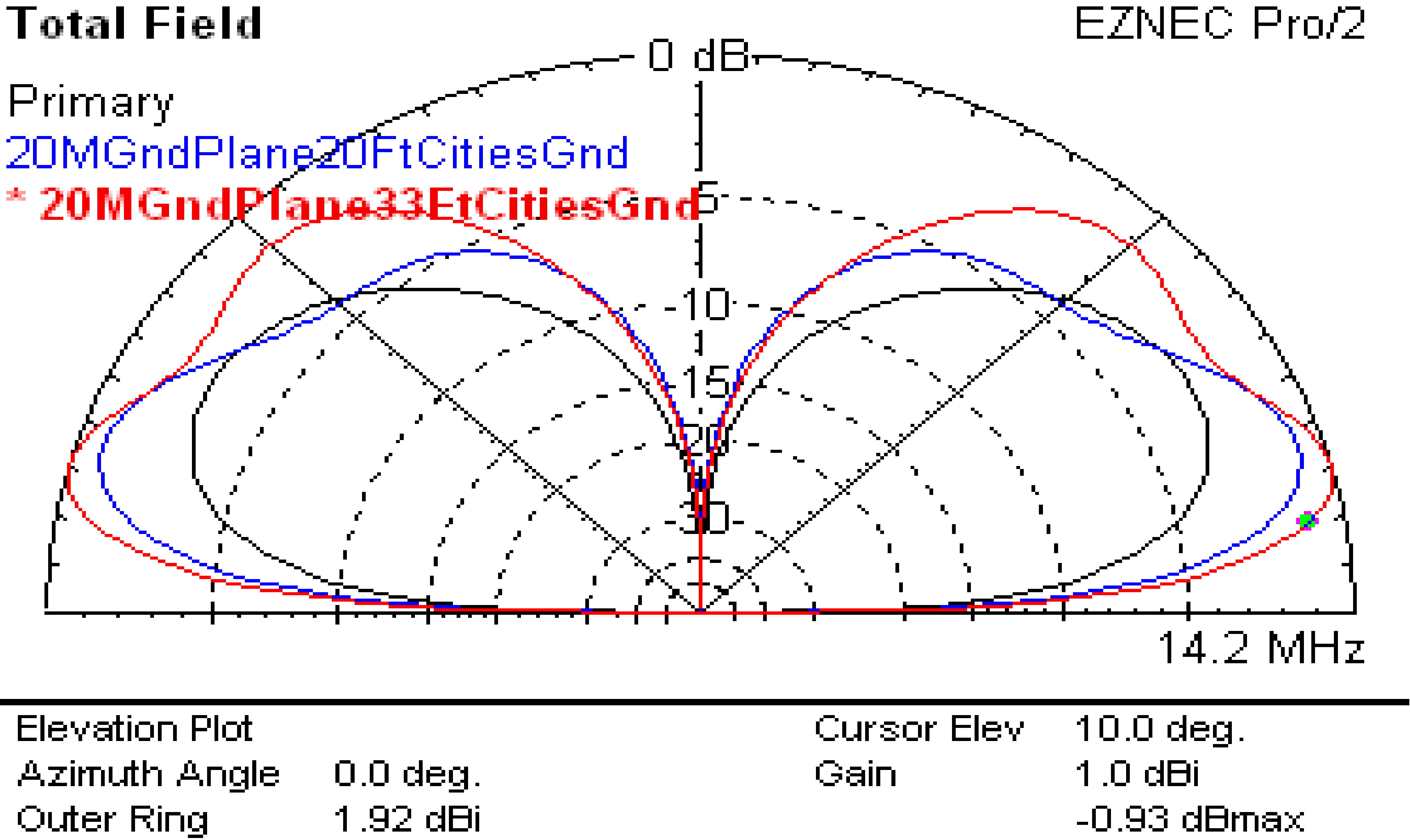
Very Good Ground


Total Field
EZNEC Pro/2
Primary
* 20MVertDipole20FtSaltWaterGnd
20MVertDipole33FtSaltWater
0 dB
-5
-10
-15
-20
-30
14.2 MHz
Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 6.82 dBi
Cursor Elev 4.0 deg.
Gain 6.75 dBi
-0.06 dBmax
1.24 dBPrTrc

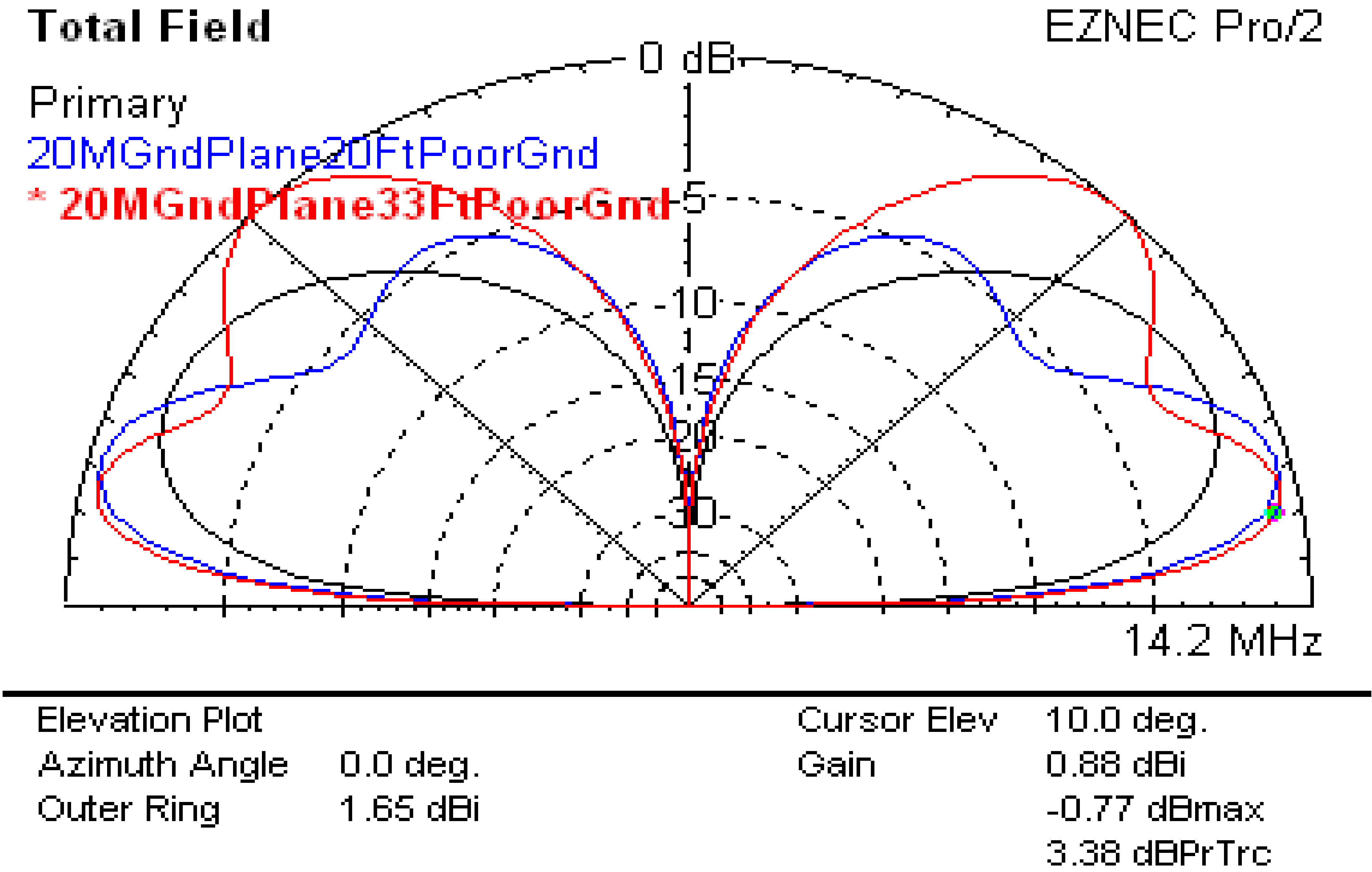
Sea Water

Fifth Series – 20M Ground Plane

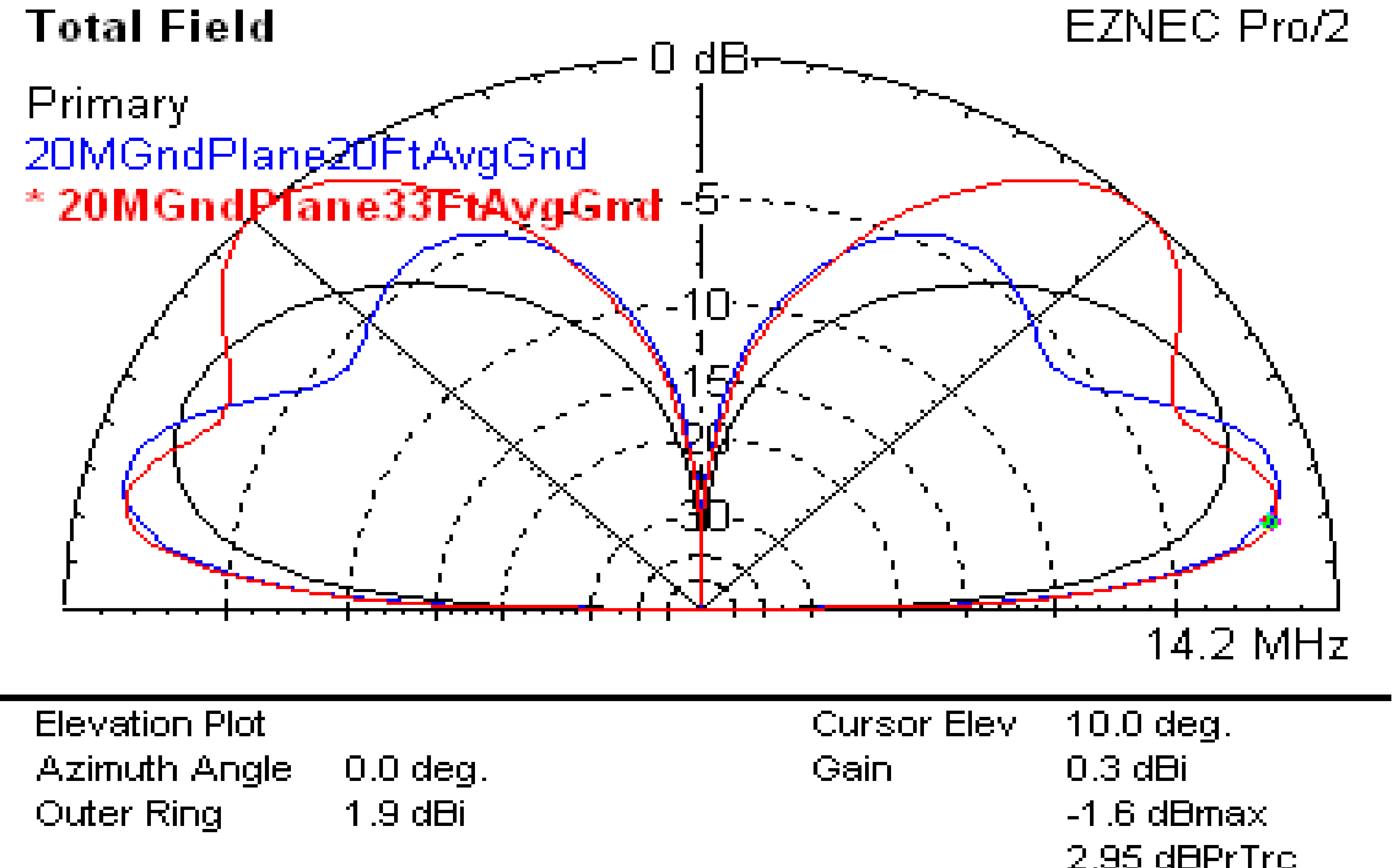
- **λ/4 vertical over 32 λ/4 radials**
  - **Radials modeled at 1 inch above ground**
- **λ/4 vertical w/4-λ/4 radials @ 20 ft**
- **λ/4 vertical w/4-λ/4 radials @ 33 ft**
- **Real High accuracy ground, NEC2**
- **All modeled with 3/4-in Al tubing**



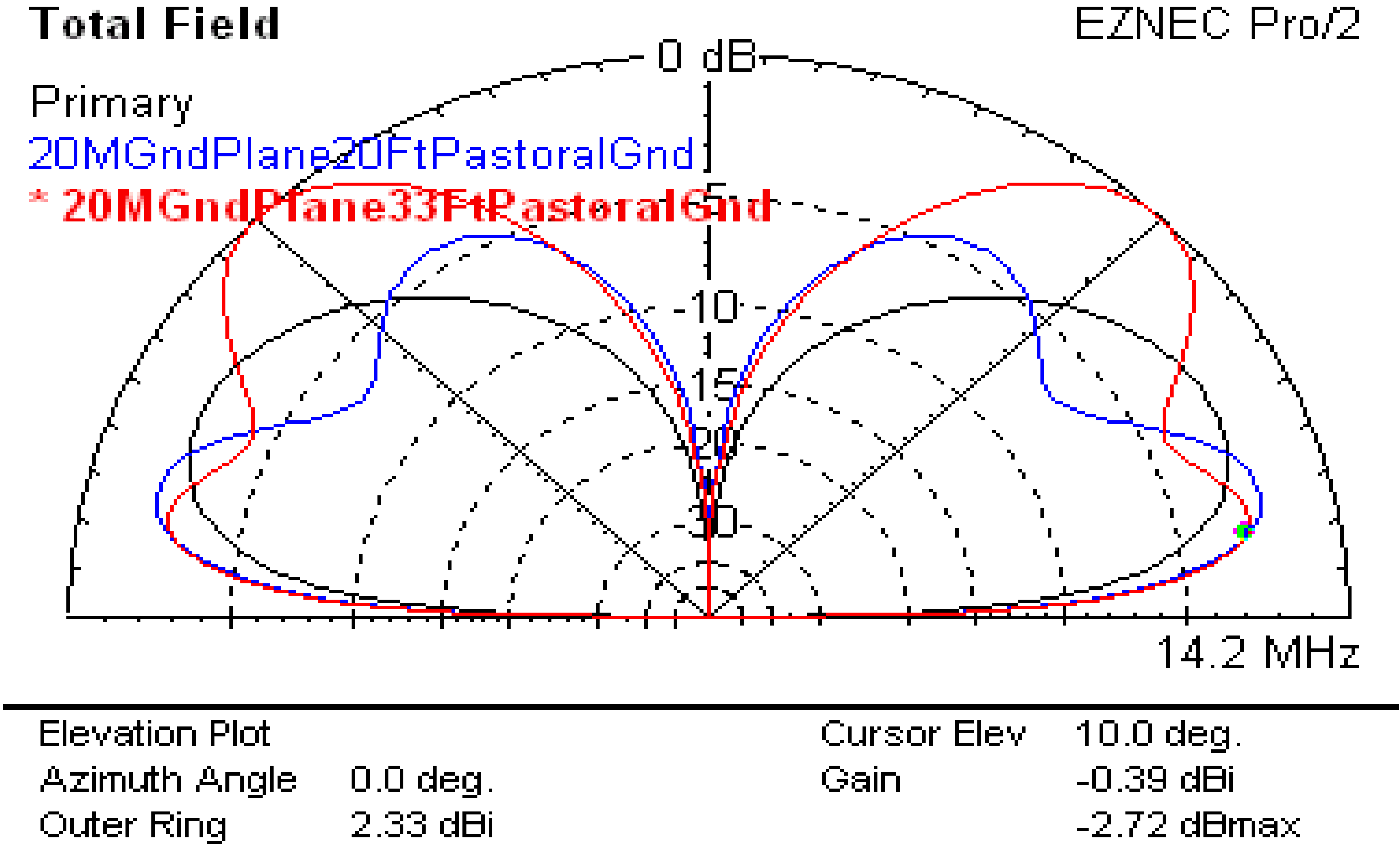
Very Poor Ground – Cities



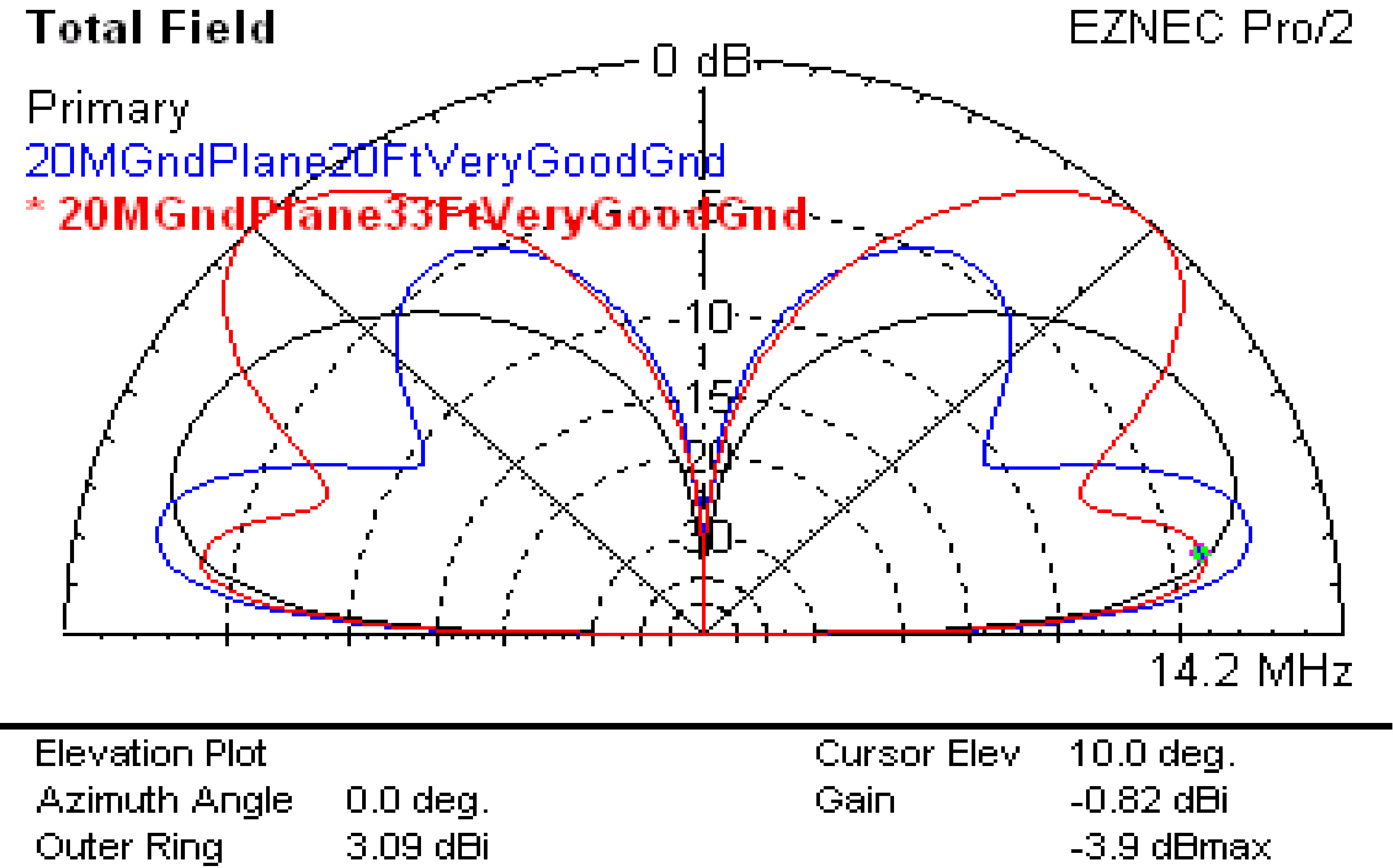
Poor Ground – Rocky, Sandy



Average Ground



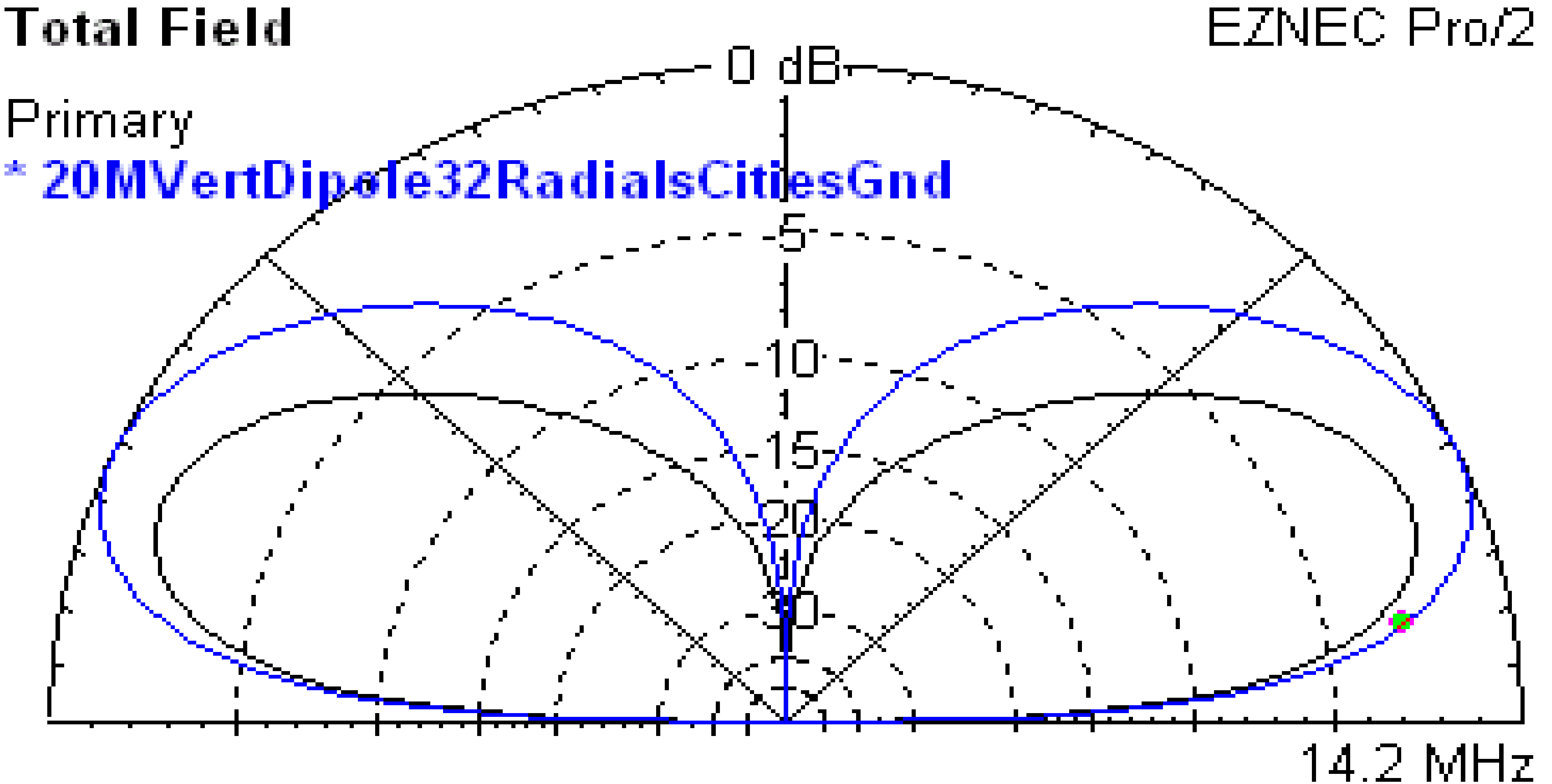
Pastoral Ground



Very Good Ground

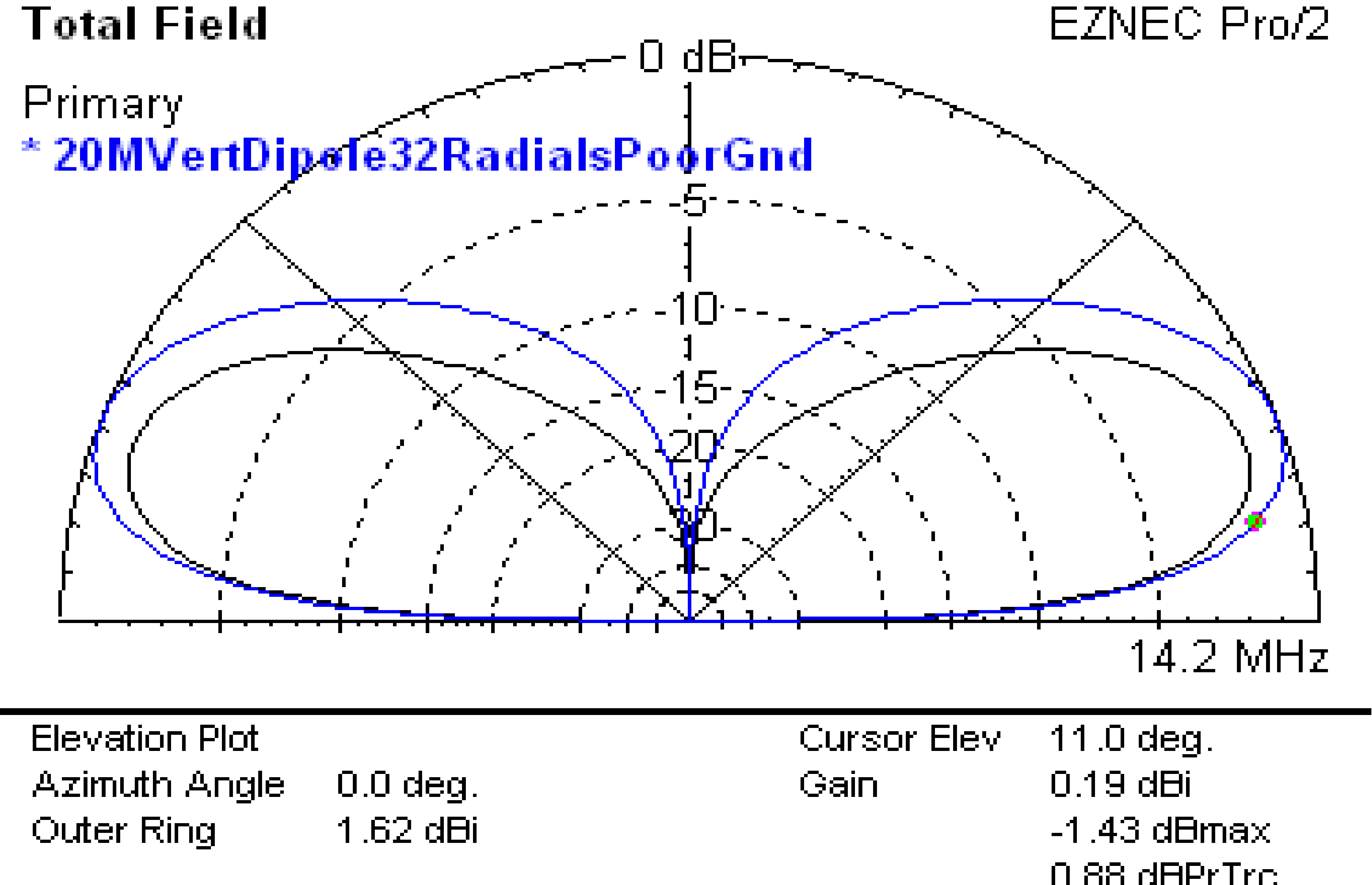
Sixth Series – Radials For a Dipole?

- **Does a λ/2 vertical dipole need radials?**
- **3/4-in diam λ/2, base 1 ft above ground**
- **Same antenna with 32 on-ground radials not connected to antenna (modeled at 0.75 in)**
- **Modeled over real high accuracy ground**

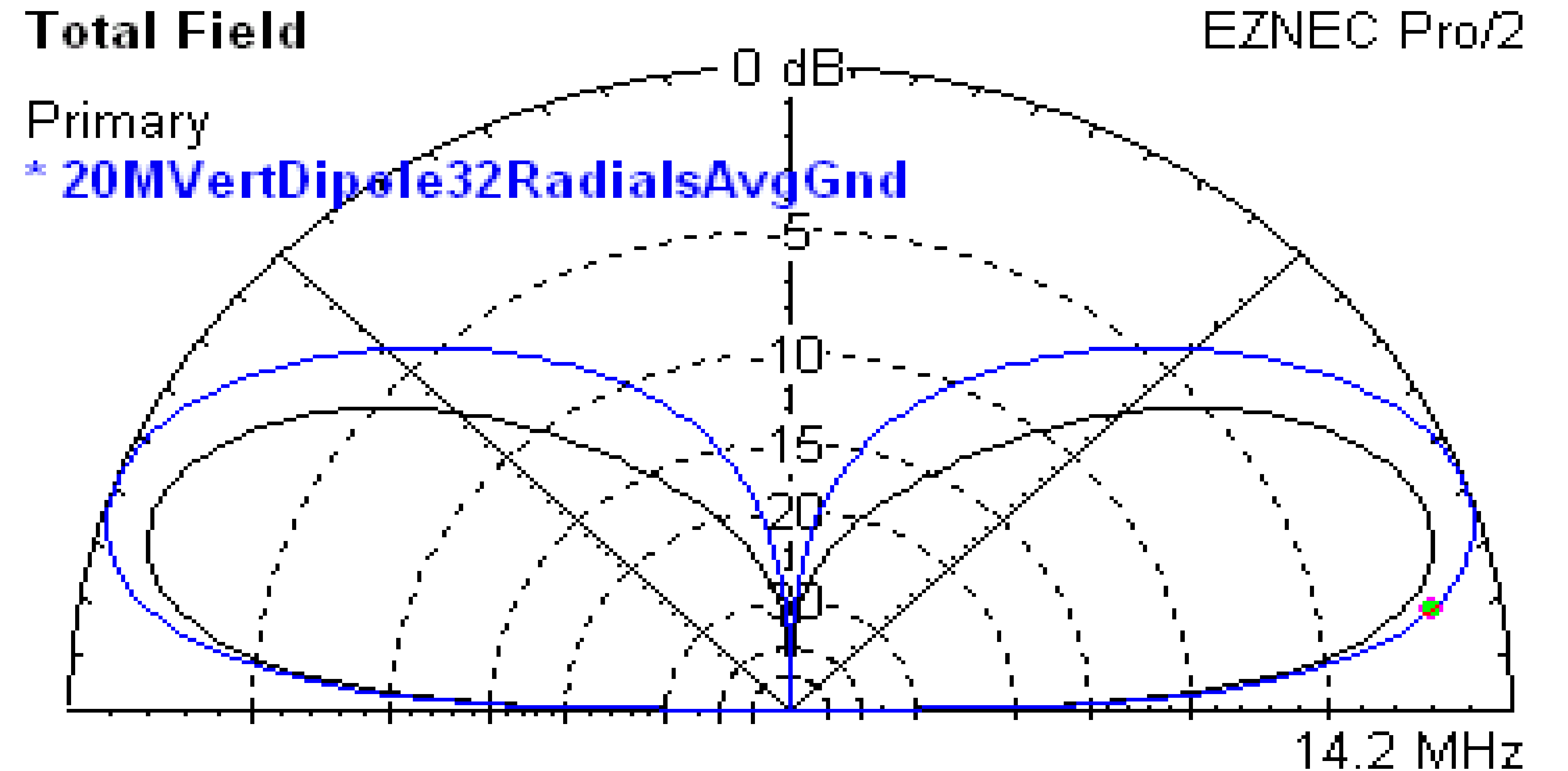


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-1.35 dBi
Outer Ring	1.39 dBi		-2.74 dBmax
			1.16 dBPrTrc

Very Poor Ground – Cities

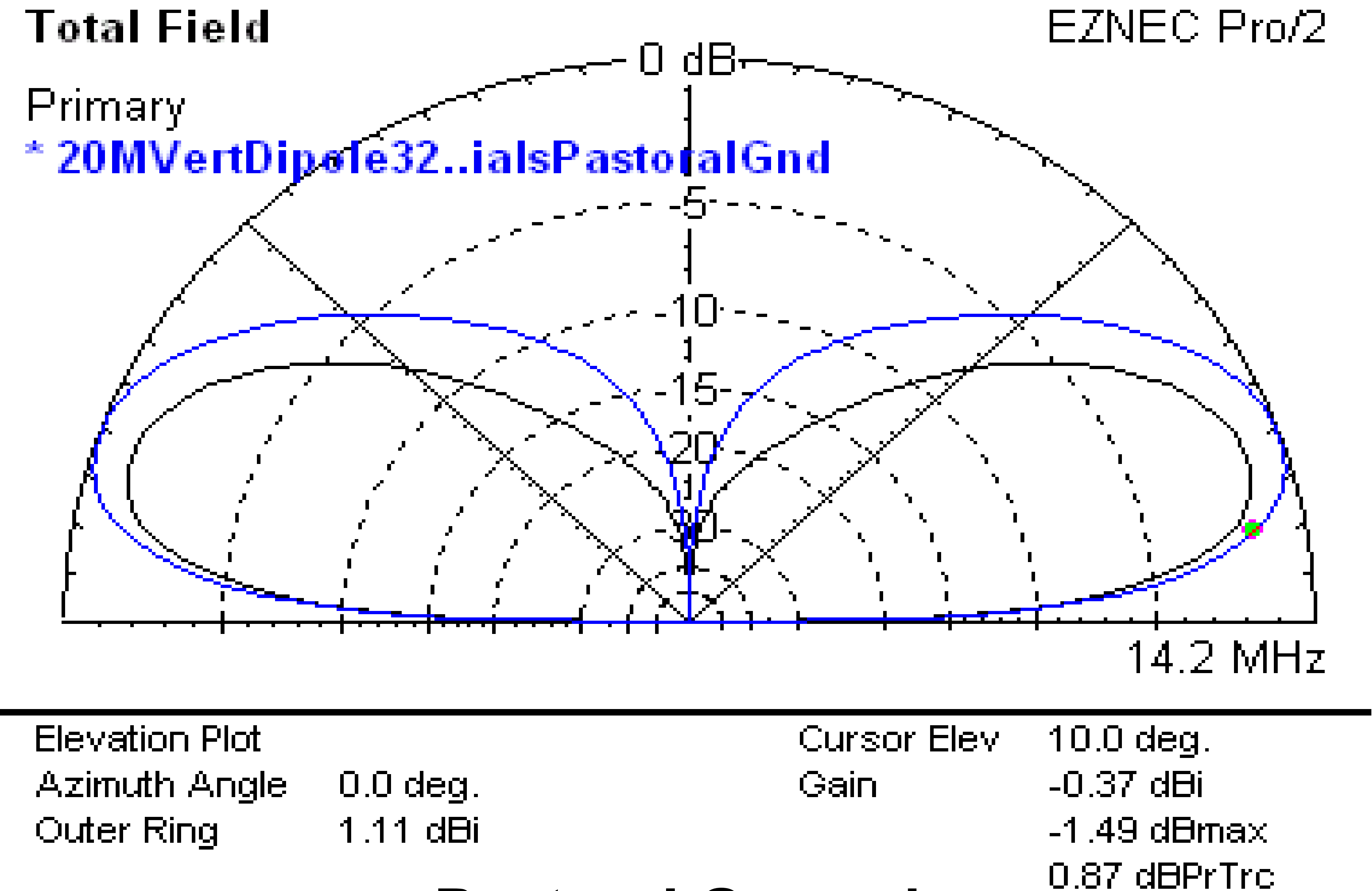


Poor Ground – Rocky, Sandy

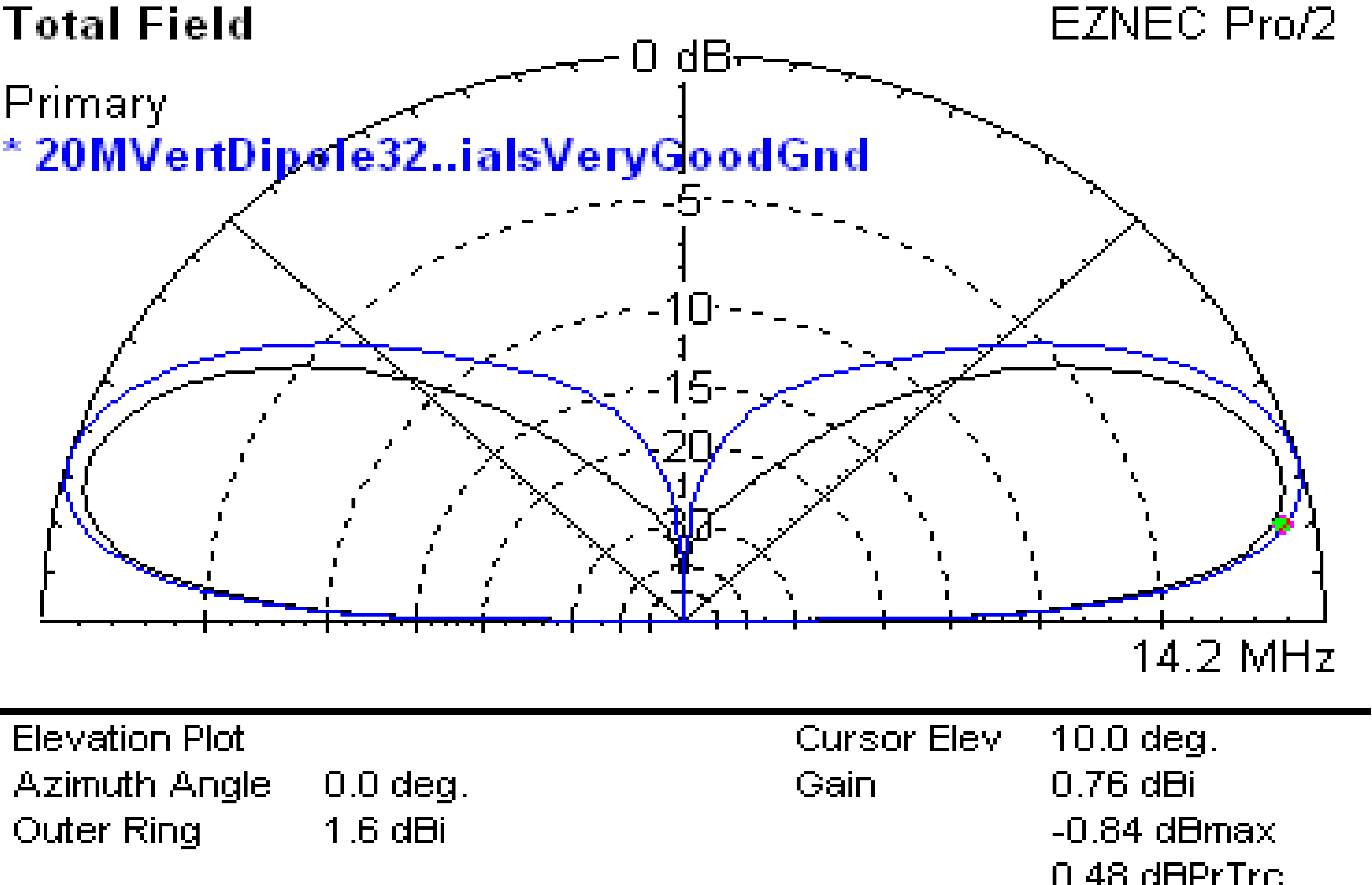


Elevation Plot		Cursor Elev	10.0 deg.
Azimuth Angle	0.0 deg.	Gain	-0.42 dBi
Outer Ring	1.32 dBi		-1.73 dBmax
			0.92 dBPrTrc

Average Ground



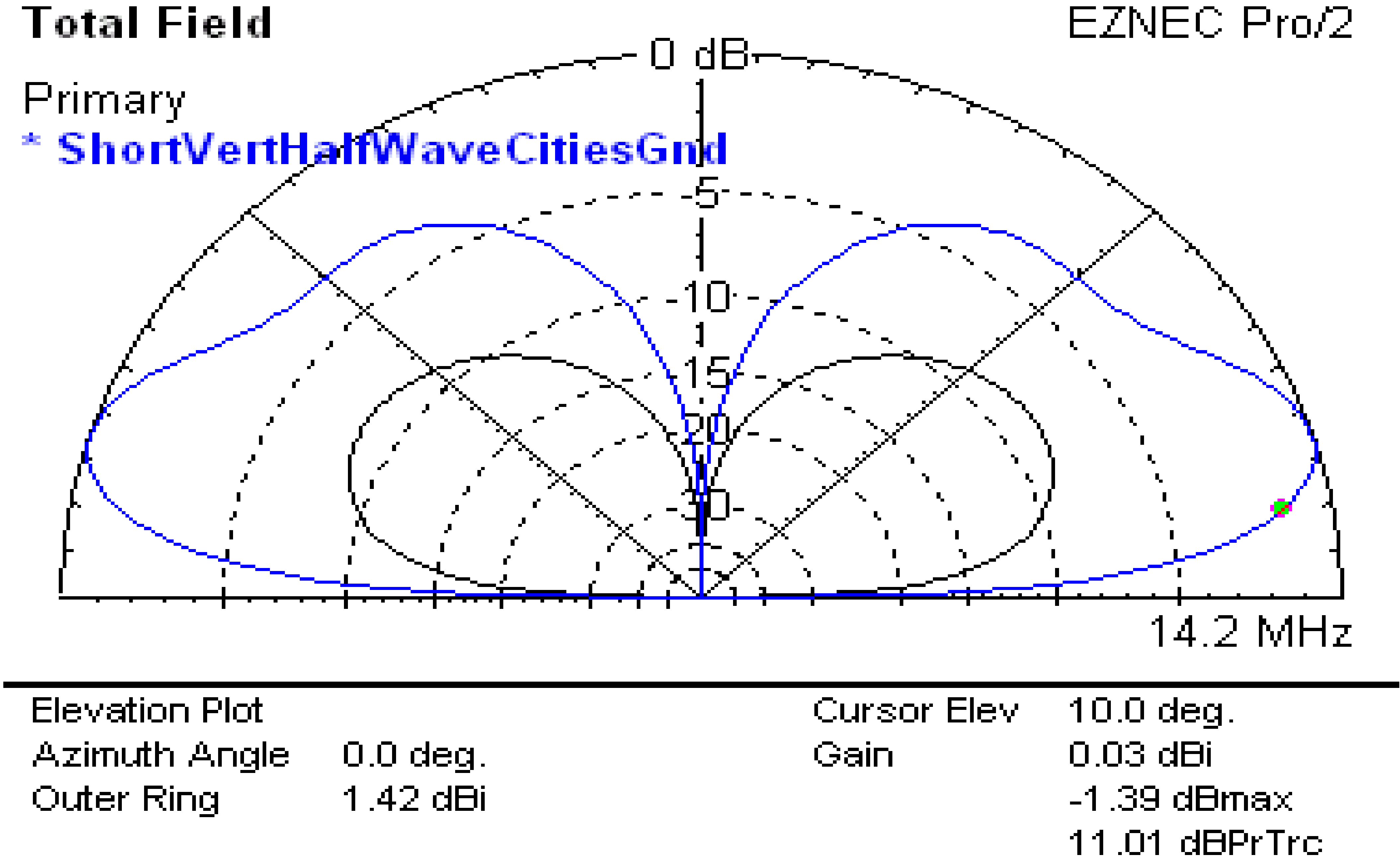
Pastoral Ground



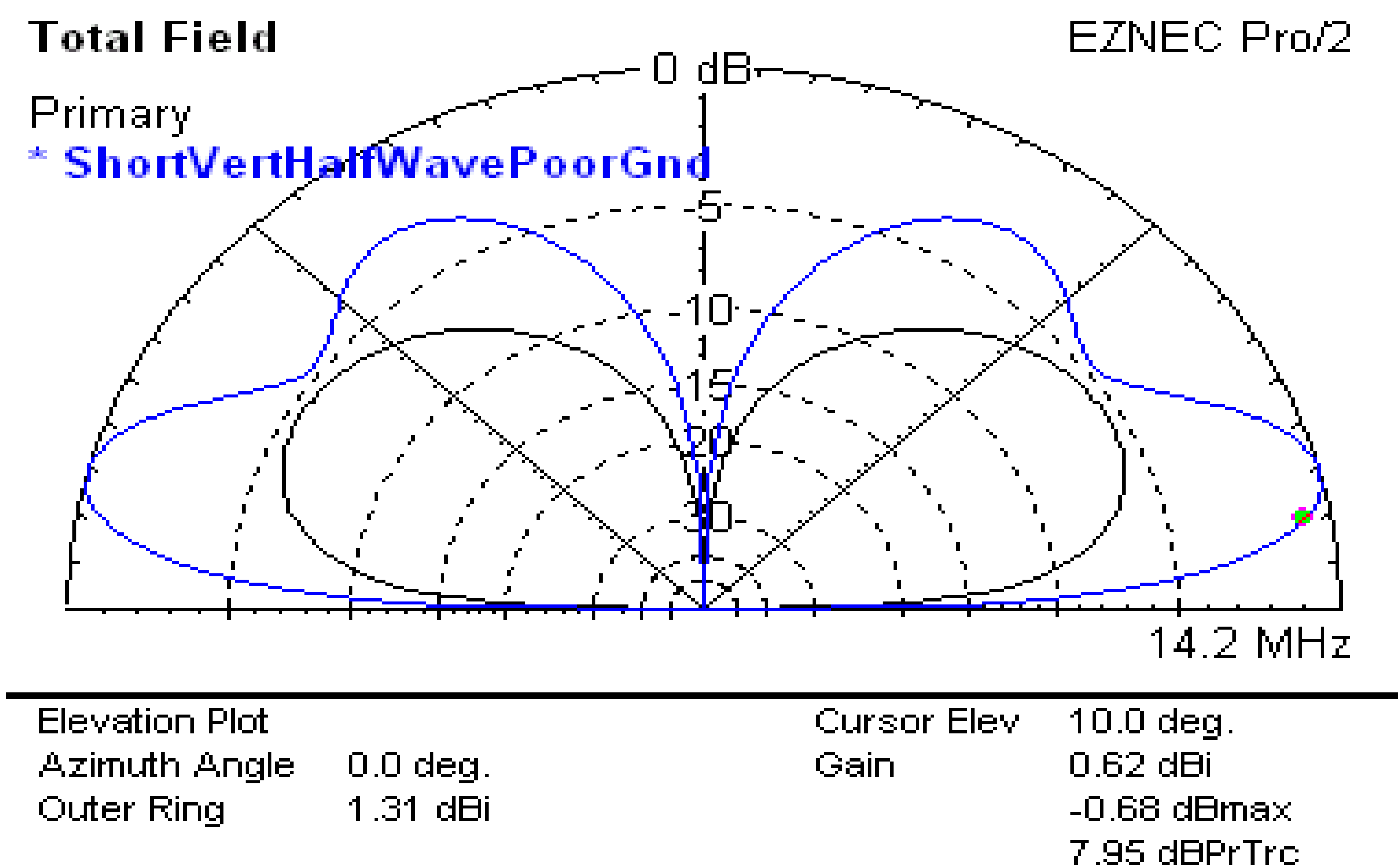
Very Good Ground

Seventh Series – 20M, Very Short

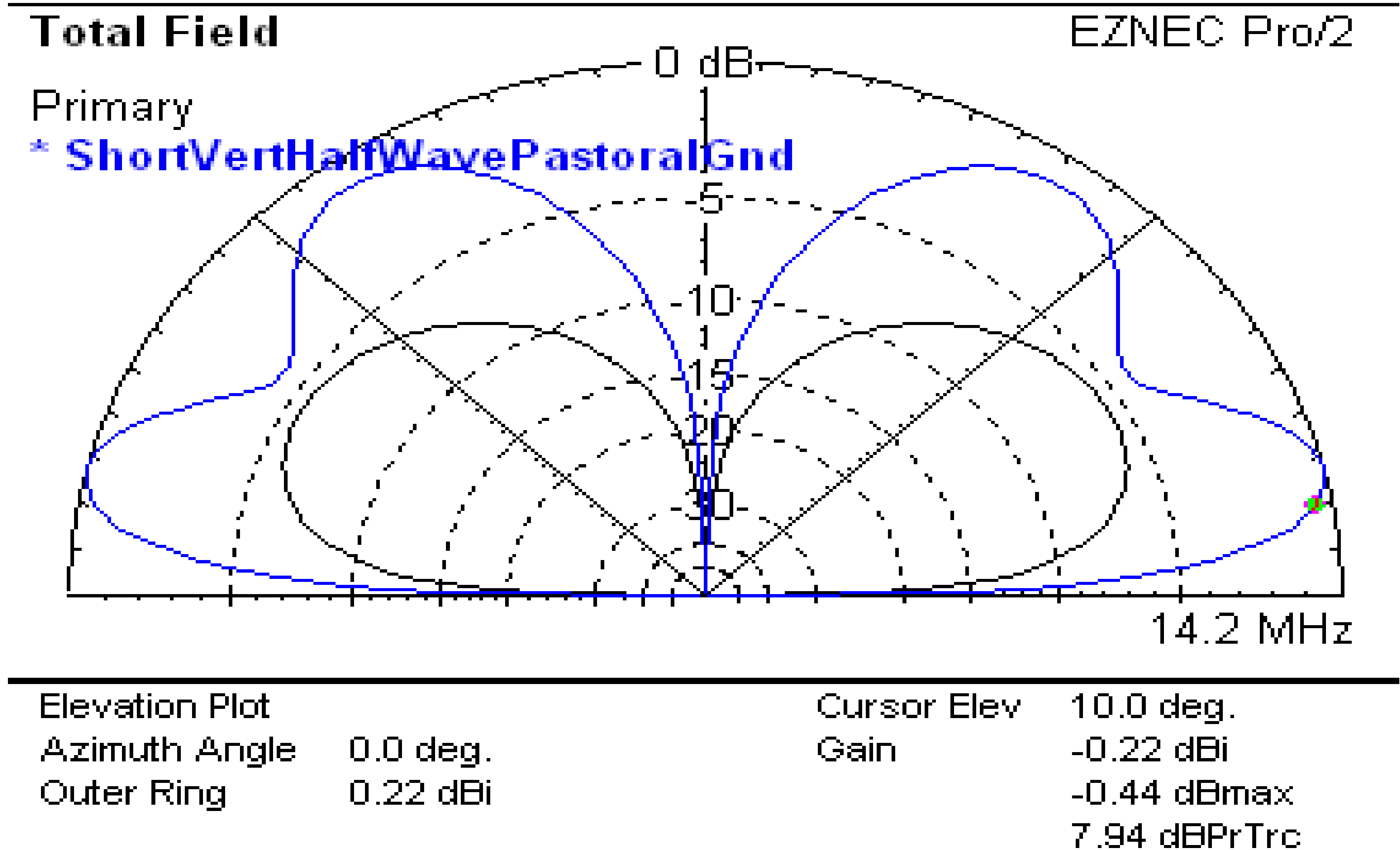
- 1/2-in diam 4 Ft vertical dipole, base up 6 inches
  - Real High accuracy ground
- Same antenna, base up 30 ft (~ $\lambda/2$)
  - Real High accuracy ground



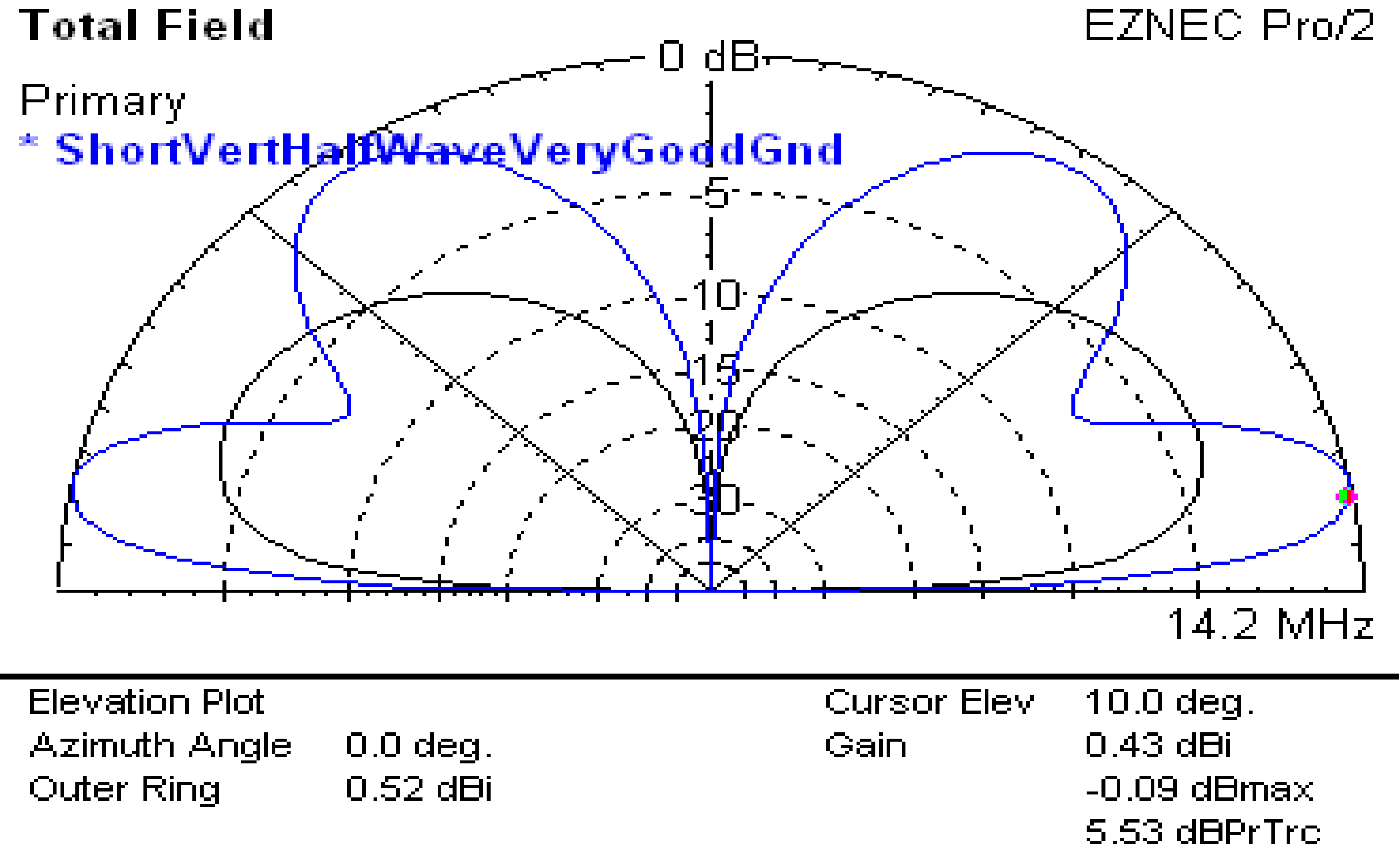
Very Poor Ground – Cities



Poor Ground – Rocky, Sandy



Pastoral Ground



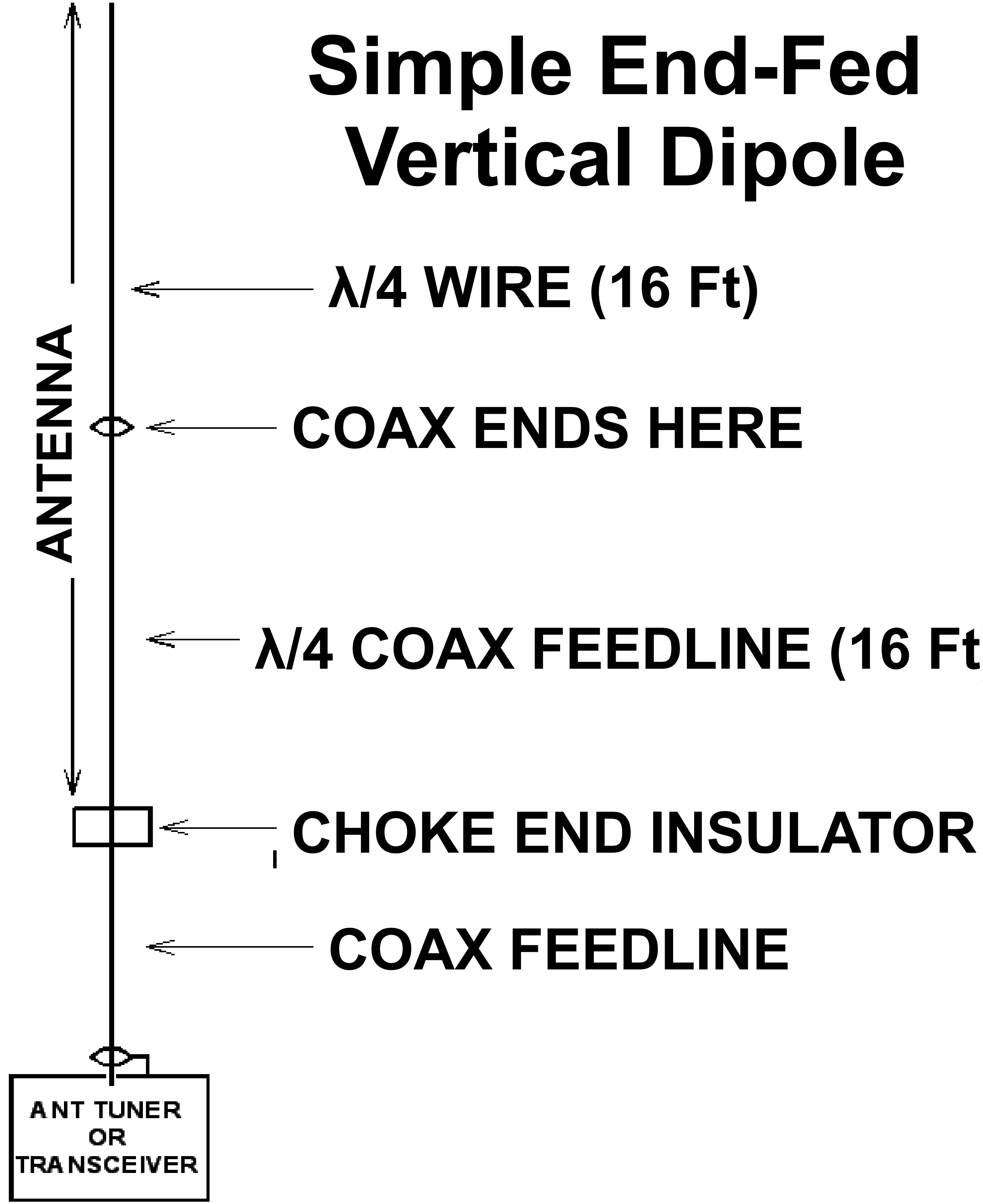
Very Good Ground

Experimental Verification

- **Half-wave end-fed vertical dipole suspended from a redwood at W6GJB**
- **Glen transmitted with 3W with the base at 6-in, 10 ft, 20 ft, 30 ft, and 40 ft**
- **I measured his signal using the dB-reading voltmeter function of my K3, using a ground-mounted quarter-wave vertical with two radials**
- **Both of us are in the mountains with very rocky soil ("poor" to "very poor" ground)**
- **We are five miles apart**

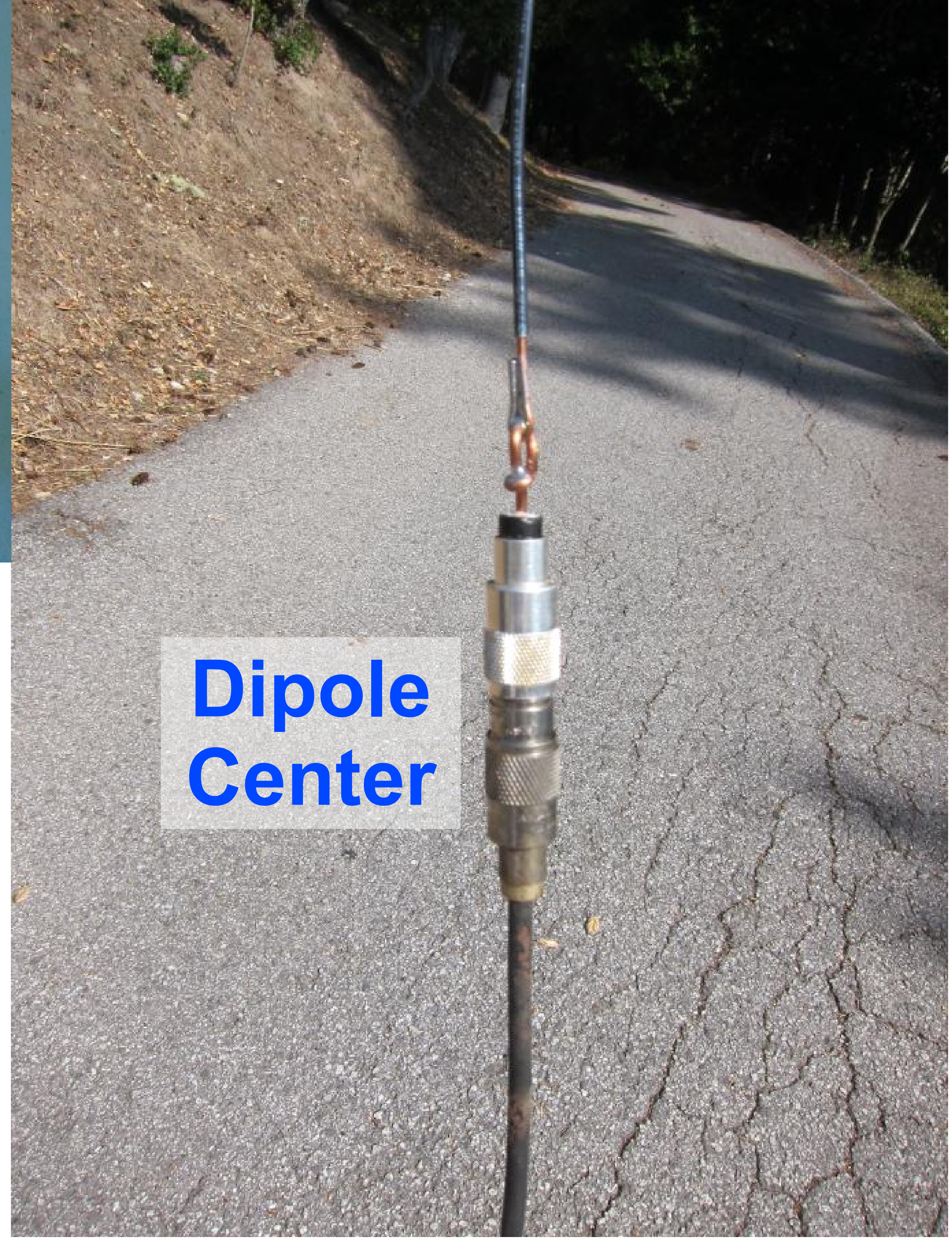
The End Fed Vertical Dipole

Simple End-Fed Vertical Dipole




Feedpoint

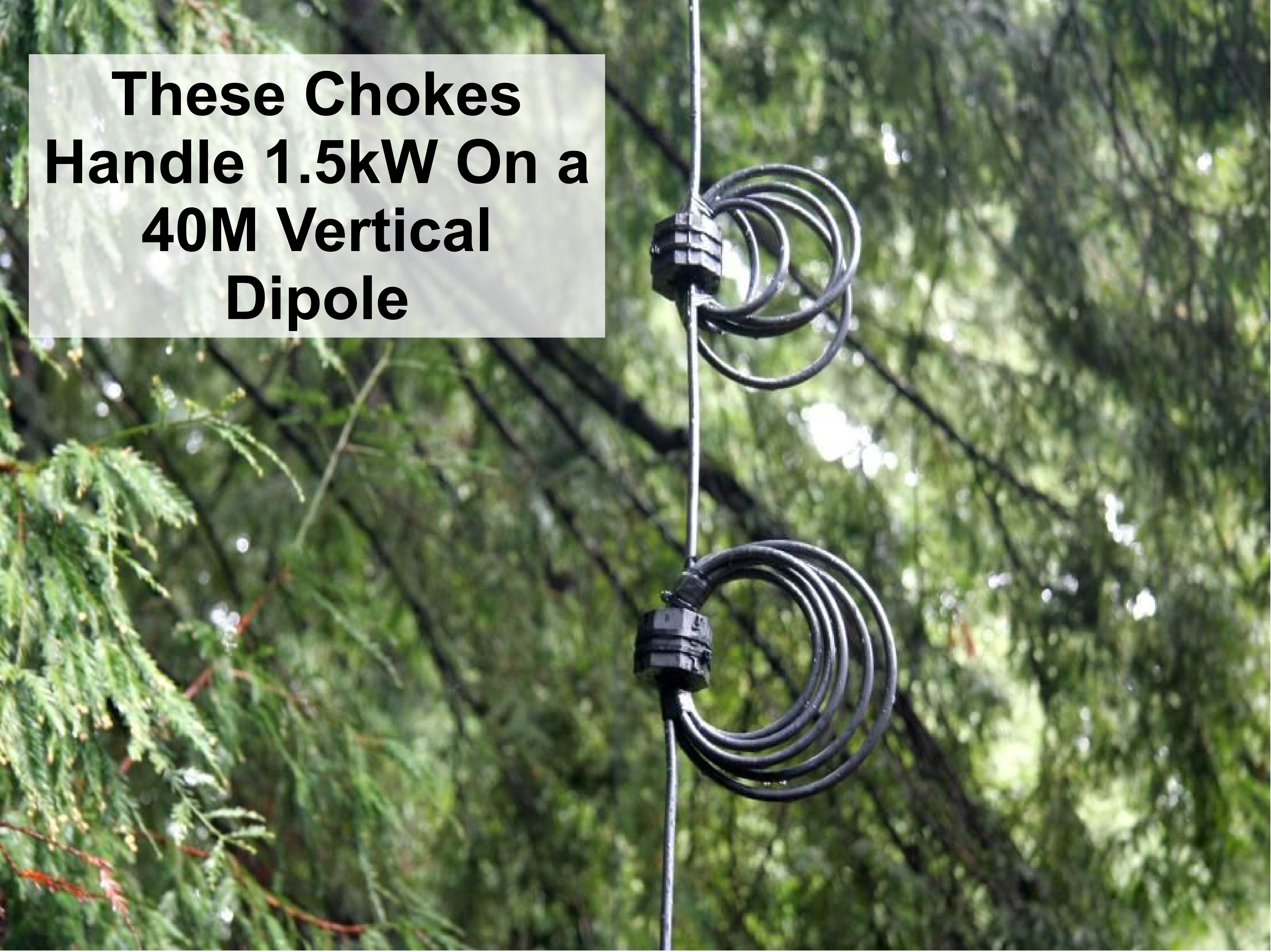

The Choke


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



Field Test of 20M Vertical Dipole Over 5 Mile Path

Height of Choke	RX Signal
Center on ground	-4 dB
6 In	0 dB
10 Ft	+0.5 dB
20 Ft	+3.2 dB
30 Ft	+6.5 dB
40 Ft	+9.5 dB

This result confirms that the ground at W6GJB is quite poor!

What I Learned

- Mounting an HF vertical in the range of λ/4 – λ/2 above ground improves performance for most soil conditions
- Greatest improvement for poorest soils
  - Near field ground losses are reduced
  - Higher angle lobes develop, greater for best soil
  - Low angle radiation increased

What I Learned

- Radials improve the performance of ground-mounted half-wave antennas by 0.5 - 1dB at low angles, and by about twice that amount at higher angles
- Greatest improvement for poorest soils
- I didn't look at roof-mounted dipoles
  - Radials not very practical

Why Does It Work This Way?

Ground Losses

- **Antennas produce fields that couple to nearby conductors**
  - **If those conductors are lossy, they burn transmitter power**
- **Radials near the earth shield the field from the lossy earth, and provide a low loss return path for fields**

Why Does It Work This Way?

- **Radials also provide a path for return current**
- **If no radials, antenna will use the feedline and the earth as a return**
  - **Greatly increased ground loss if feedline runs horizontal and close to earth**
  - **Screws up the vertical pattern if it's feeding an elevated antenna**

Ground Losses and Radials

- **Radial currents couple into the lossy earth beneath them, which burns transmitter power**
  - **Power is I^2R, dividing current between more radials reduces that lost power**
  - **Raising the radials reduces the coupling, so fewer radials are needed**
  - **That's why only 2 or 4 radials work for elevated "ground plane" antennas**
  - **Radials on an elevated antenna keep return current off the coax**

Vertical Dipoles and Ground Losses

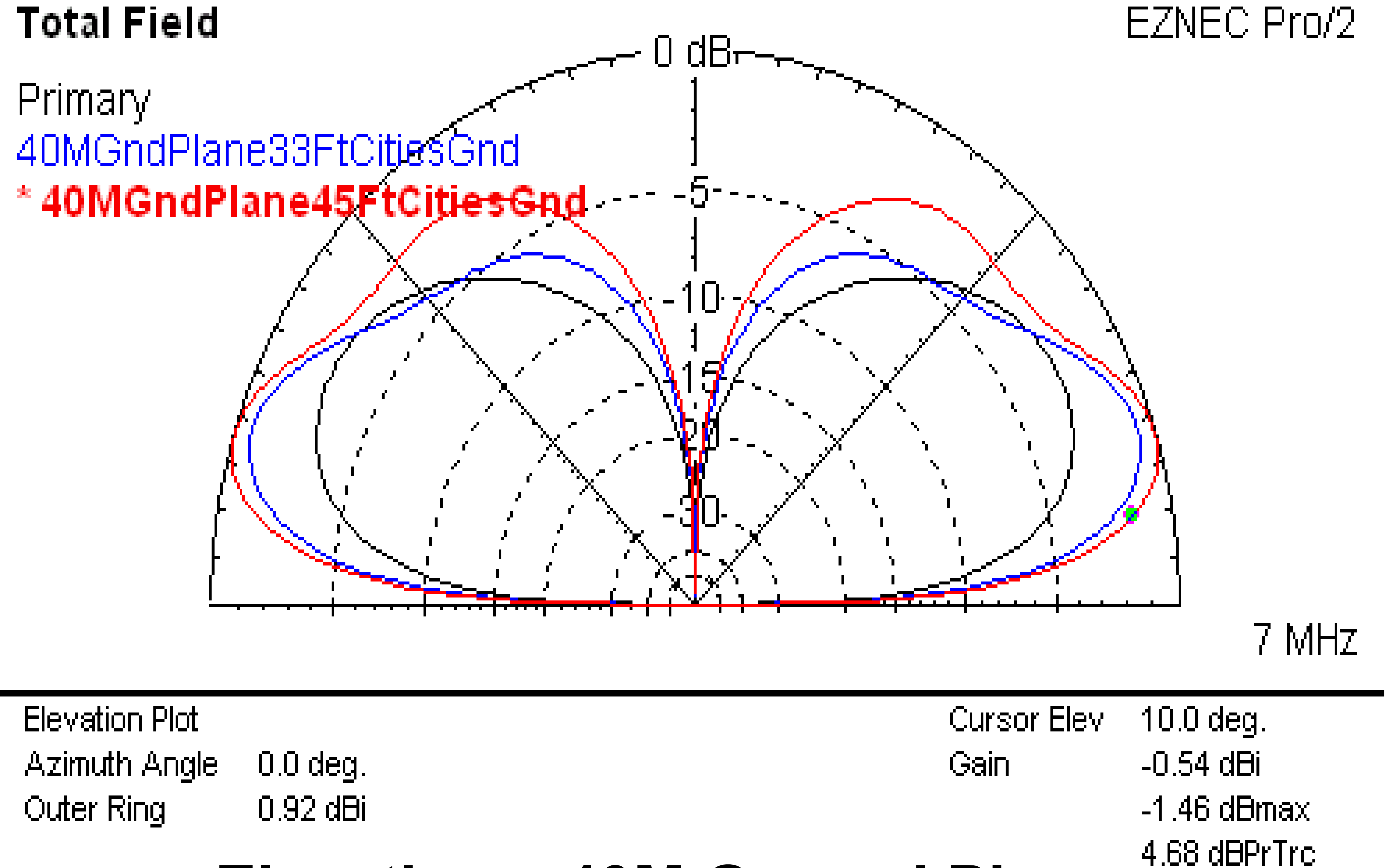
- Vertical dipoles also produce fields that couple to the earth, burning TX power
- Raising the antenna reduces the coupling and ground losses
- Raising the high current point reduces coupling and ground losses

Why The Vertical Pattern Changes

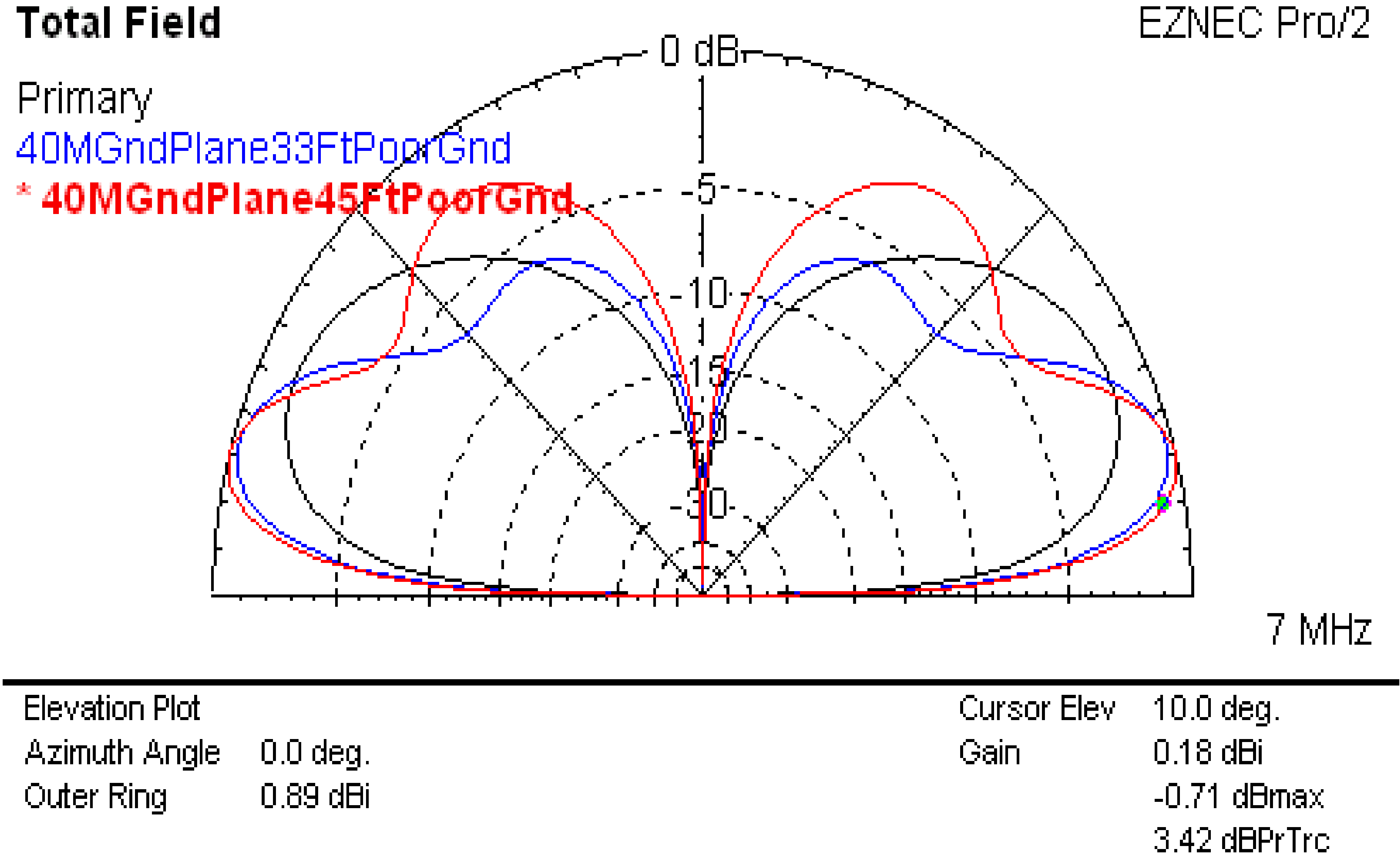
- Radiation is produced by current
- The electrical length of the antenna establishes the current distribution
- In the far field, the vertical pattern is produced by the combination of the direct radiation from the antenna with the reflection of radiation from the earth

Why The Vertical Pattern Changes

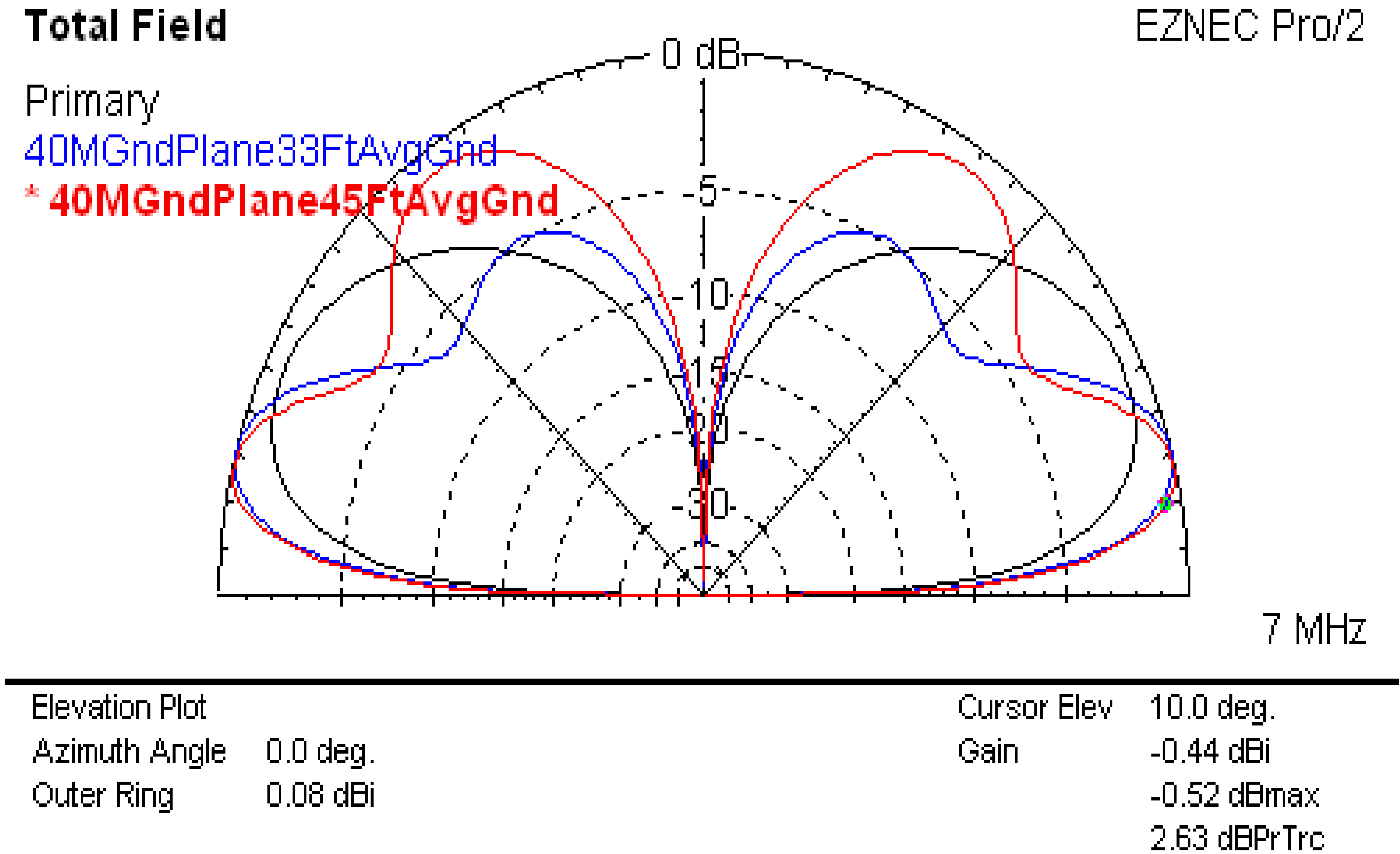
- **Elevating the high current part of the antenna (where the impedance is lowest) strengthens the reflection and changes the distance where the reflection occurs**
- **A greater distance means more phase shift**
- **Makes peaks and dips in the vertical pattern as the phase difference between direct and reflected varies with elevation angle**
- **Phase differences close to 180° produce nulls, close to 0° or 360° produce lobes**



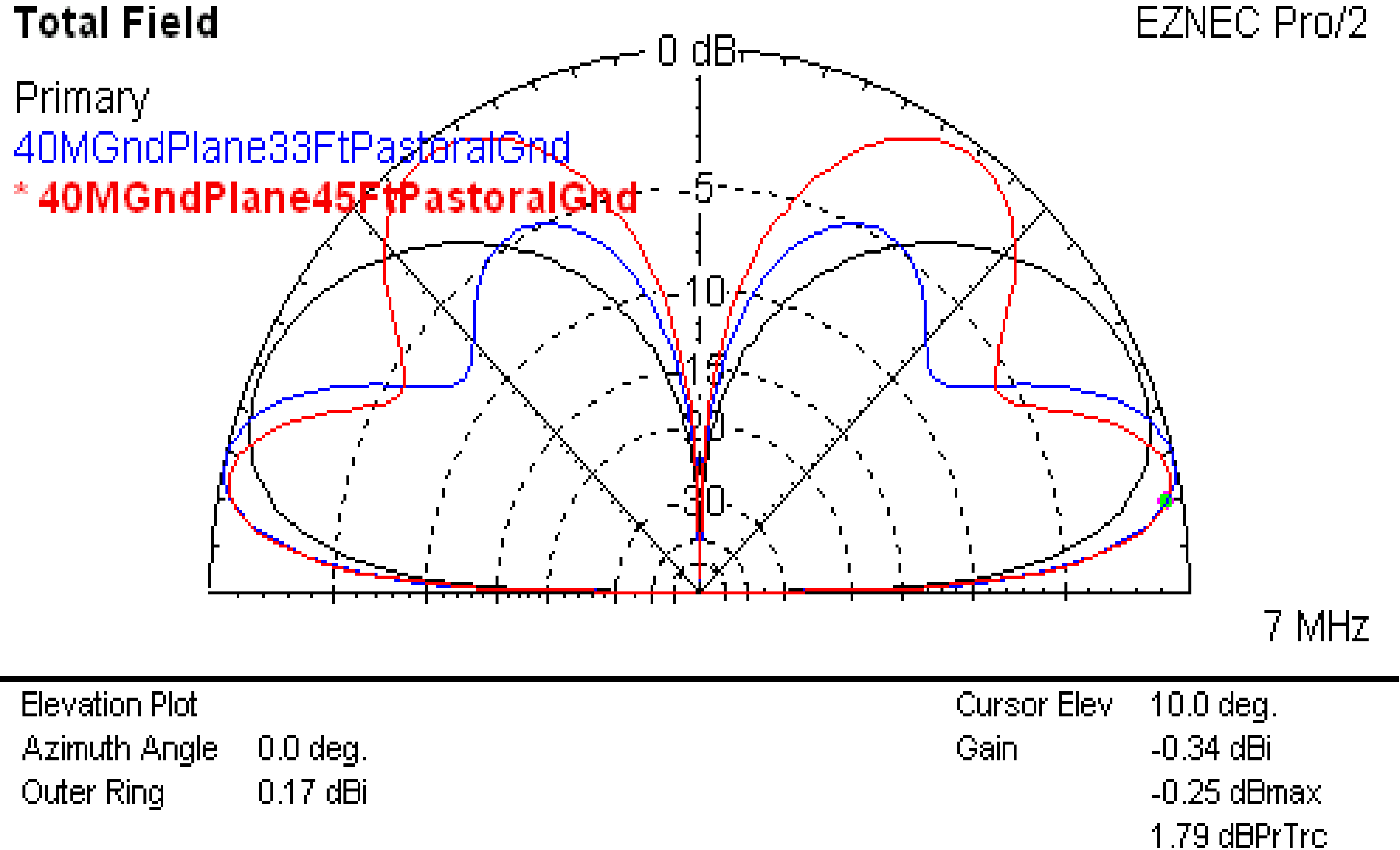
Elevating a 40M Ground Plane Cities Soil



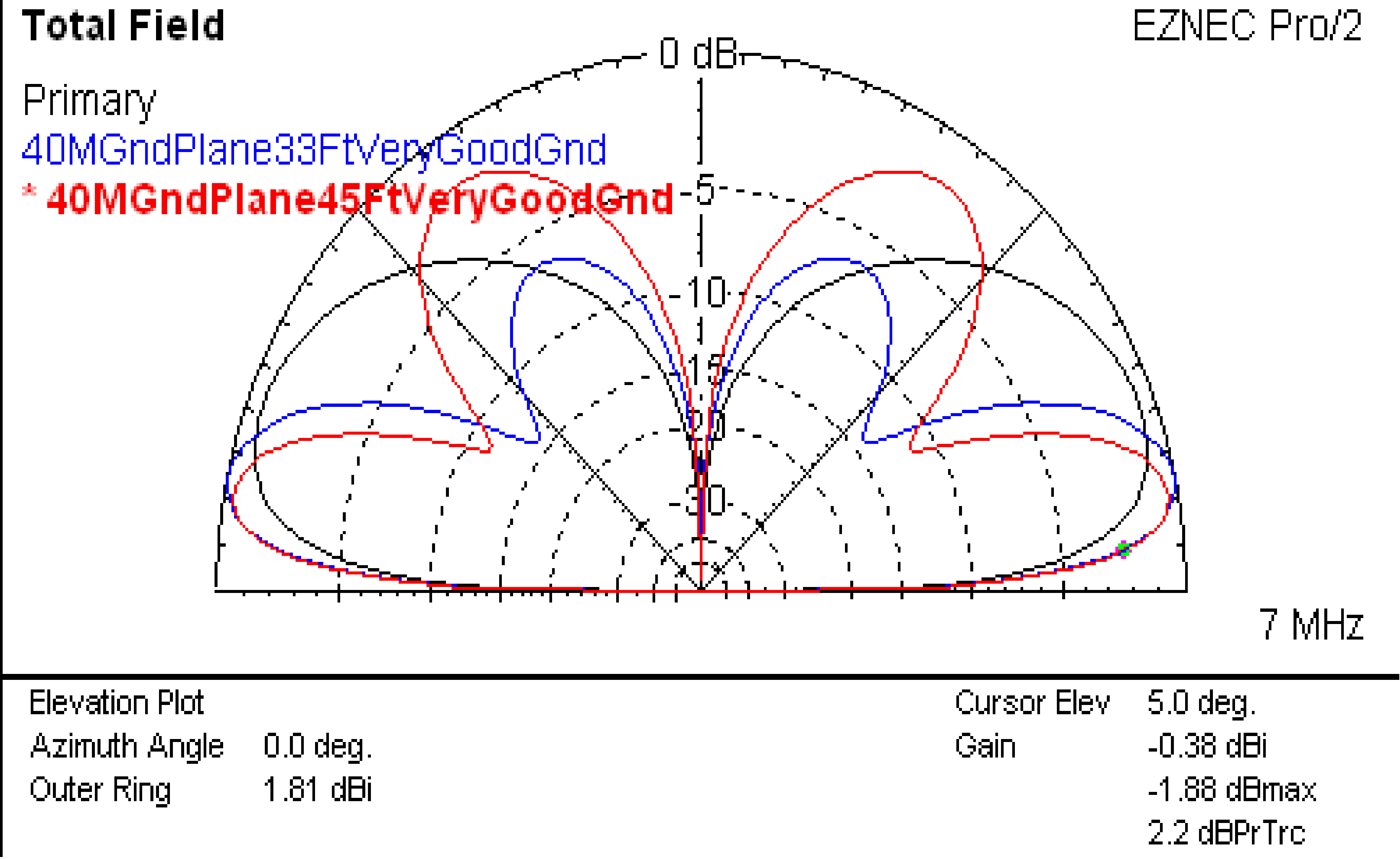
Poor Ground – Rocky, Sandy



Average Ground



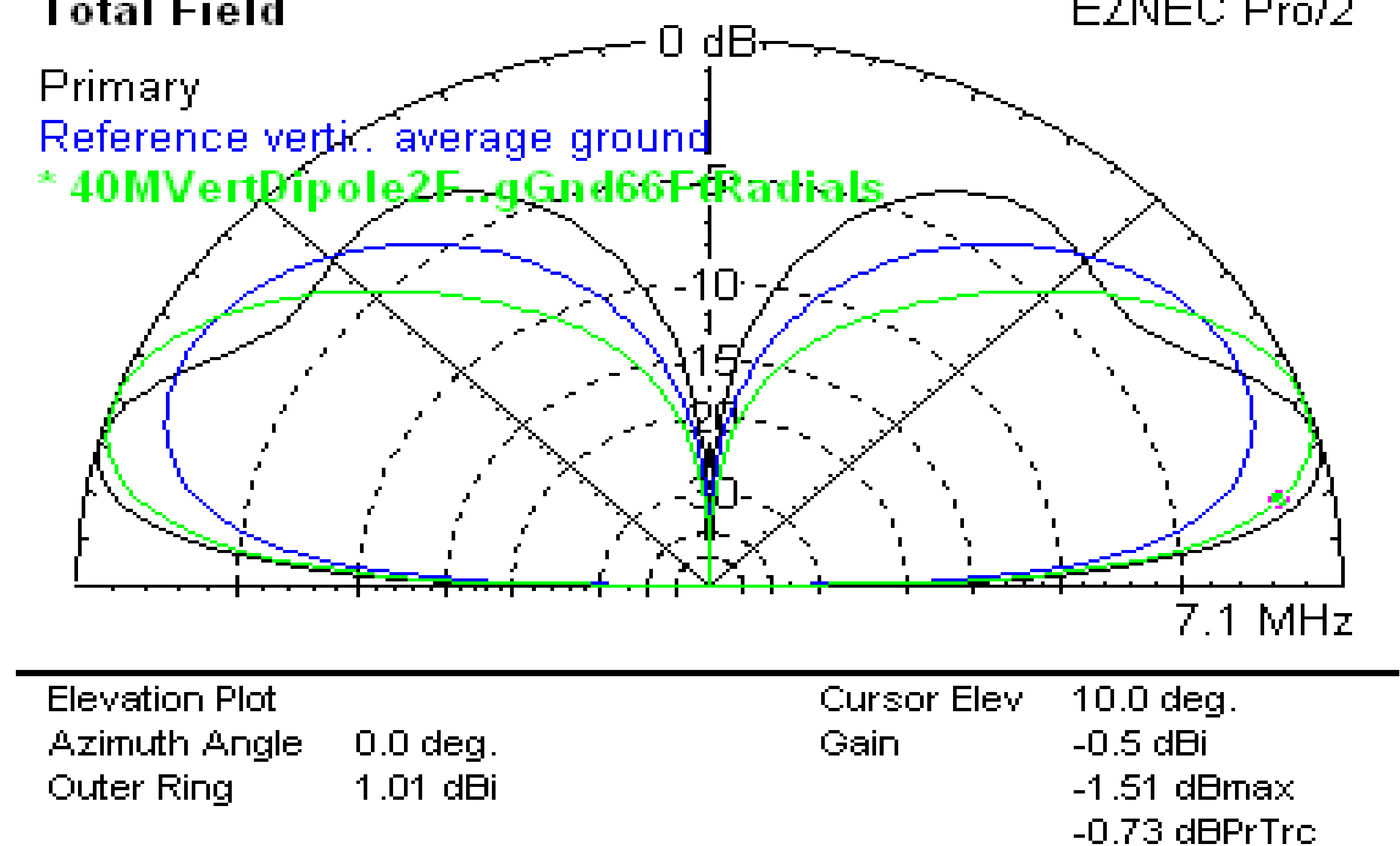
Pastoral Ground



Very Good Ground

λ/4 and λ/2 Patterns

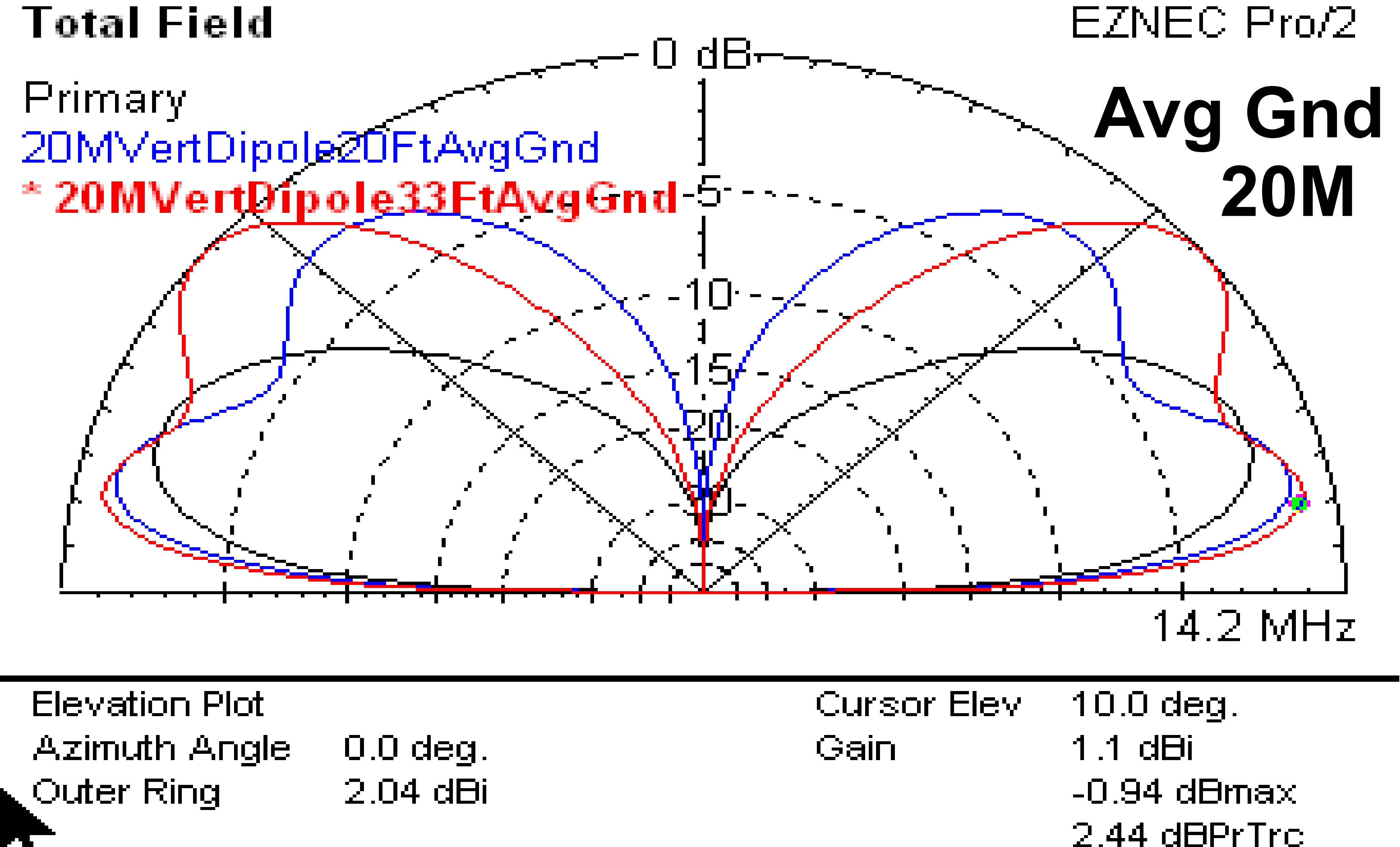
- Elevating the high current part of the antenna (where the impedance is lowest) strengthens the reflection and changes the distance where the reflection occurs
- The high current point of a λ/4 antenna is at the base
- The high current point of a λ/2 antenna is in the center



Black curve is 5/8 wave MiniNEC, 2 Ω loss

Blue curve is λ/4, 32 radials, NEC4 model

Green curve is λ/2 vertical dipole w/32 radials



Black curve is λ/2 dipole, base at ground level

Blue curve is λ/2 vertical dipole, base up 20 ft

Red curve is λ/2 vertical dipole, base up 33 ft

Why The Vertical Pattern Changes

- Ground conductivity varies the strength of the reflection
- Better ground = stronger lobes
- That's why the patterns are so “lobey” for sea water and the “very good” ground

The Very Short Vertical

- **Because the antenna is so short, radiation resistance is quite small, so it takes a lot of current to radiate little bit of power**
- **More current means more ground loss**
- **That's why elevating it makes such a large difference**
- **Modeling suggests that N6BT's innovative ZR-3 design would work a lot better on your roof (or on a small mast for Field Day or a CQP expedition)**

Guidelines for Multiband HF Verticals

- Unless you're on salt water or really good ground, try to get it up in the air if you can
  - 20-30 ft is good on all bands, 40M is good to 60 ft
- Dipoles are much more practical to elevate because they work without radials
- Traps waste transmitter power (2-3 dB)
- A monopole (classic ground plane) works fairly well with one or two radials per band
- Verticals do need a coaxial ferrite choke

Recommended Study

- **Get NEC or 4NEC and learn to use it! These antennas are <u>very</u> 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**

Vertical Antenna Mounting Height

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