VARIATIONS ON A DIPOLE

Antenna patterns are all about interference

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What is an Antenna?

- Transforms and electrical signal into a propagating electromagnetic wave OR vise versa. - Transducer – goes both ways.
- TX and RX antennas have different jobs. For TX want to generate as much propagated power, where you want it, as possible. For RX want to have very good S/N for your received signal.
- Impedance match – 50 Ω radio to 377 Ω free space EM wave.

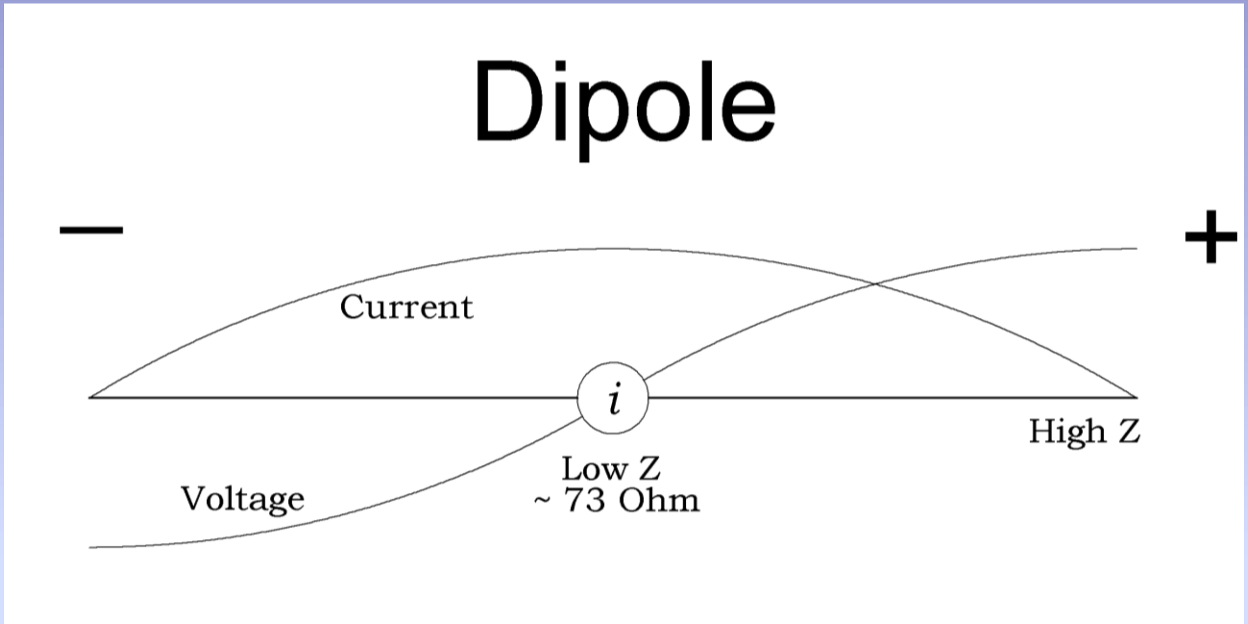
What to put up?

- What resources do you have?
  - Trees (I've got these)
  - Tall attic or barn for a fixed Yagi
  - Average for a Beverage
  - Room for a tower & stacked multi-element multi-band Yagis ($$$)!!
- Wires are flexible and inexpensive – nice if you have trees.
- Buy or Build?
- Do you want DX and/or Regional reach?
- What bands?

Resonant Wire Antennas

- Works for both TX and RX
- Work well for coupling electical power into EM wave.
- Waves on a wire – properties:
  - No current at the ends of the wire.
  - Impedance along the wire is v/i
  - Wire is both inductor and capacitor for the electrical activity on the wire.

A Wave on a wire



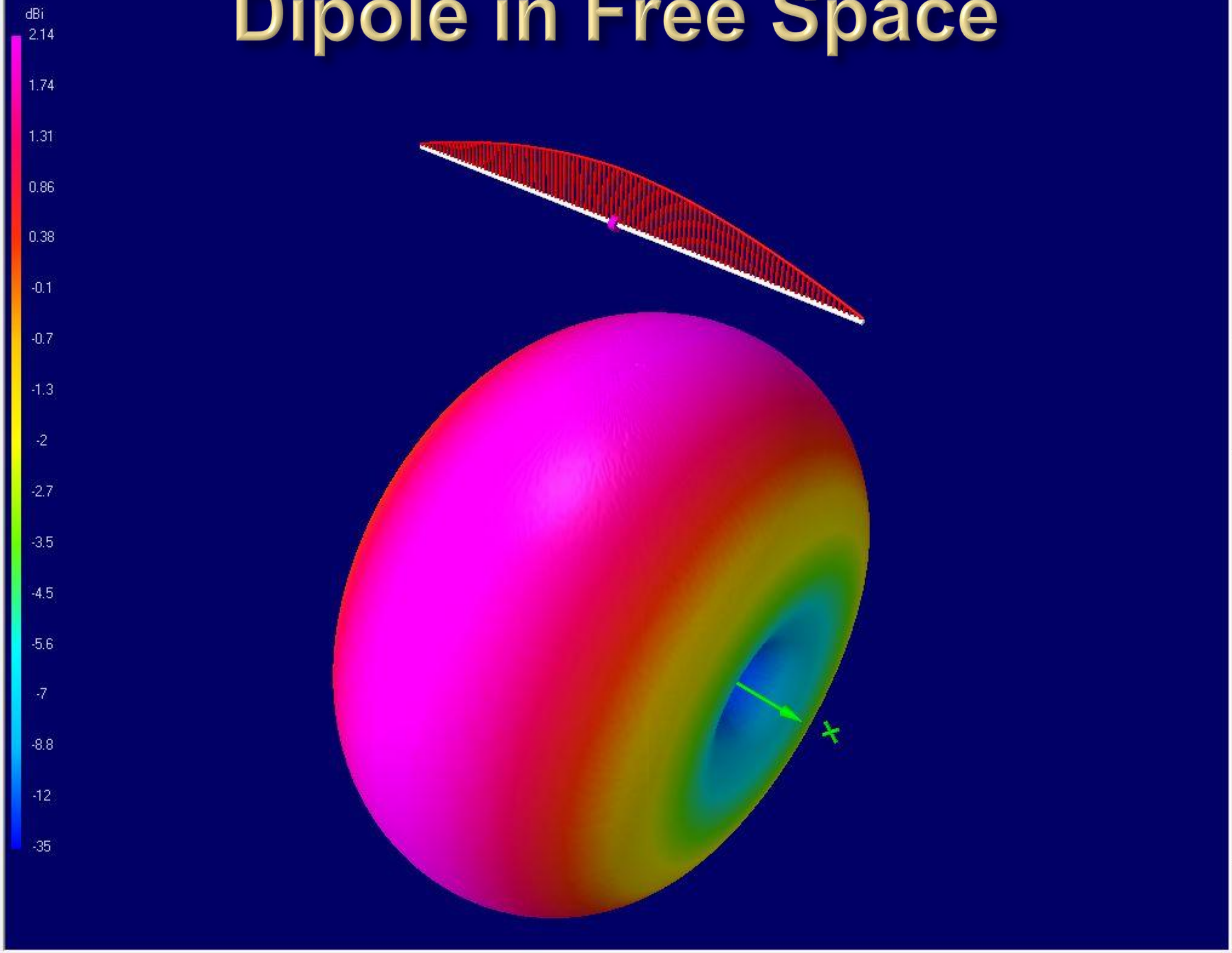
Ends of dipole are capacitive

Center of dipole is inductive

Impedance varies along the length of the wire

Resonance → $l = n\,\lambda/2$

Dipole in Free Space



Ground

- The perfect ground assumption
- Can't have E-fields along conductive surface
- **Images** help to understand antennas over ground. A mirror reflects left to right, but stays the same up and down. (Why!?!)

Ground Images

Horizontal Dipole

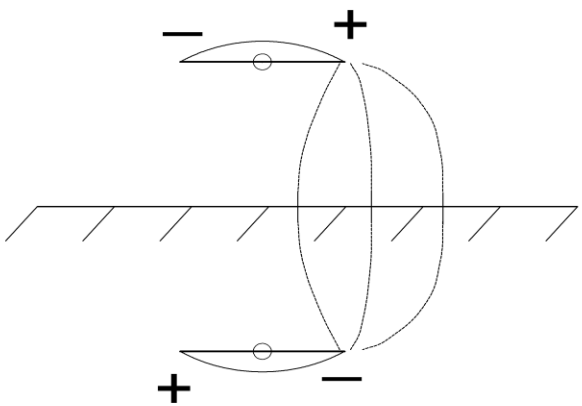


Image has
opposite phase

Vertical Dipole

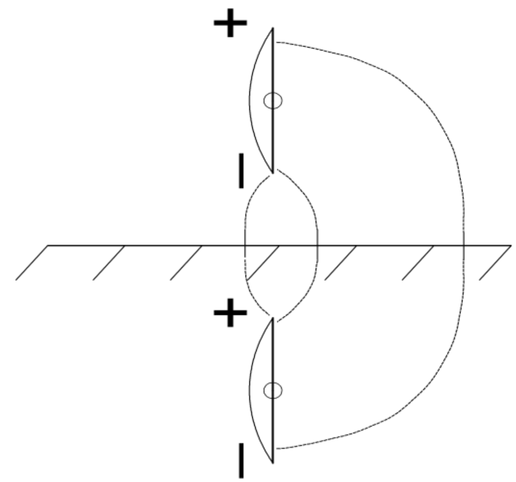
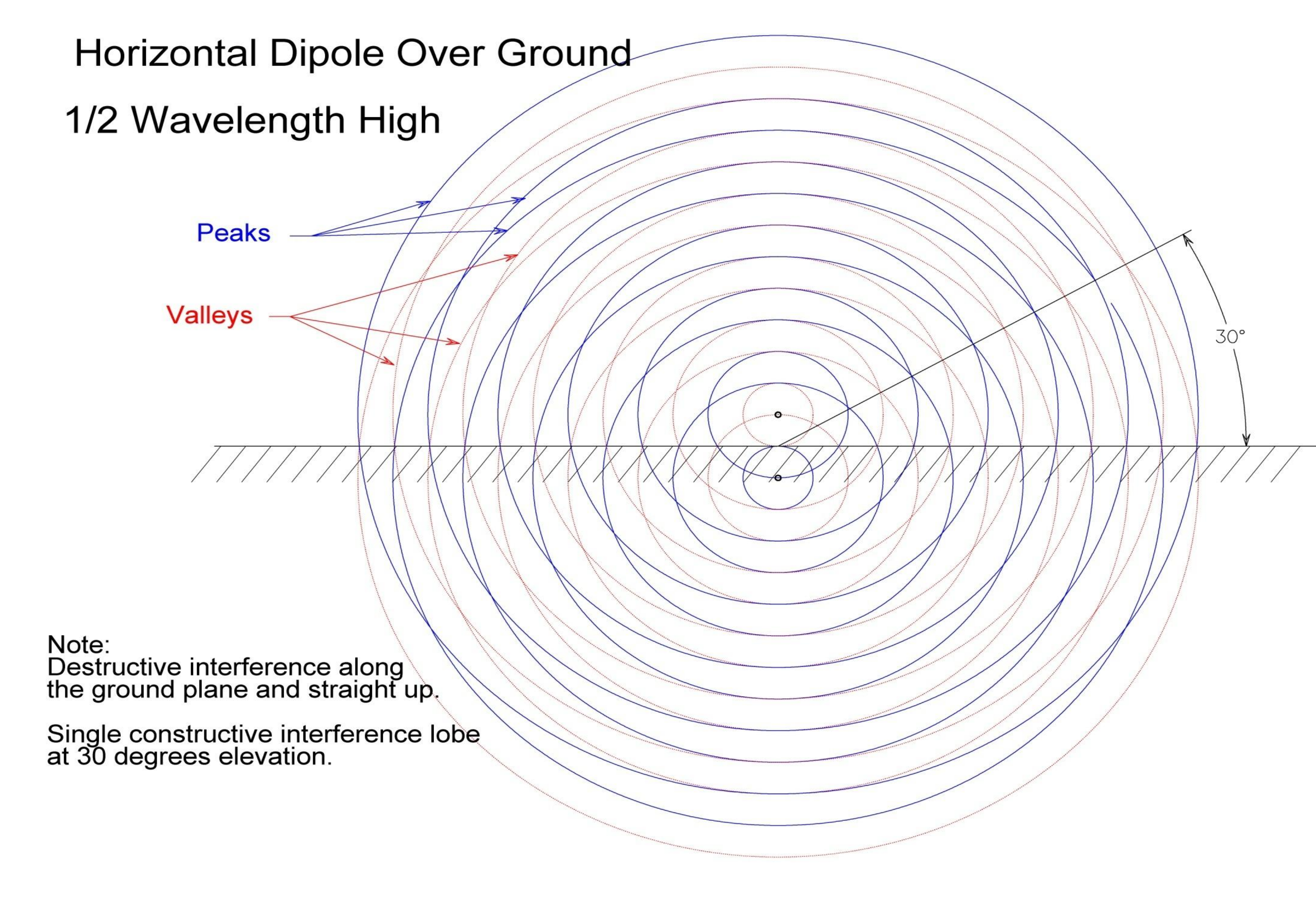


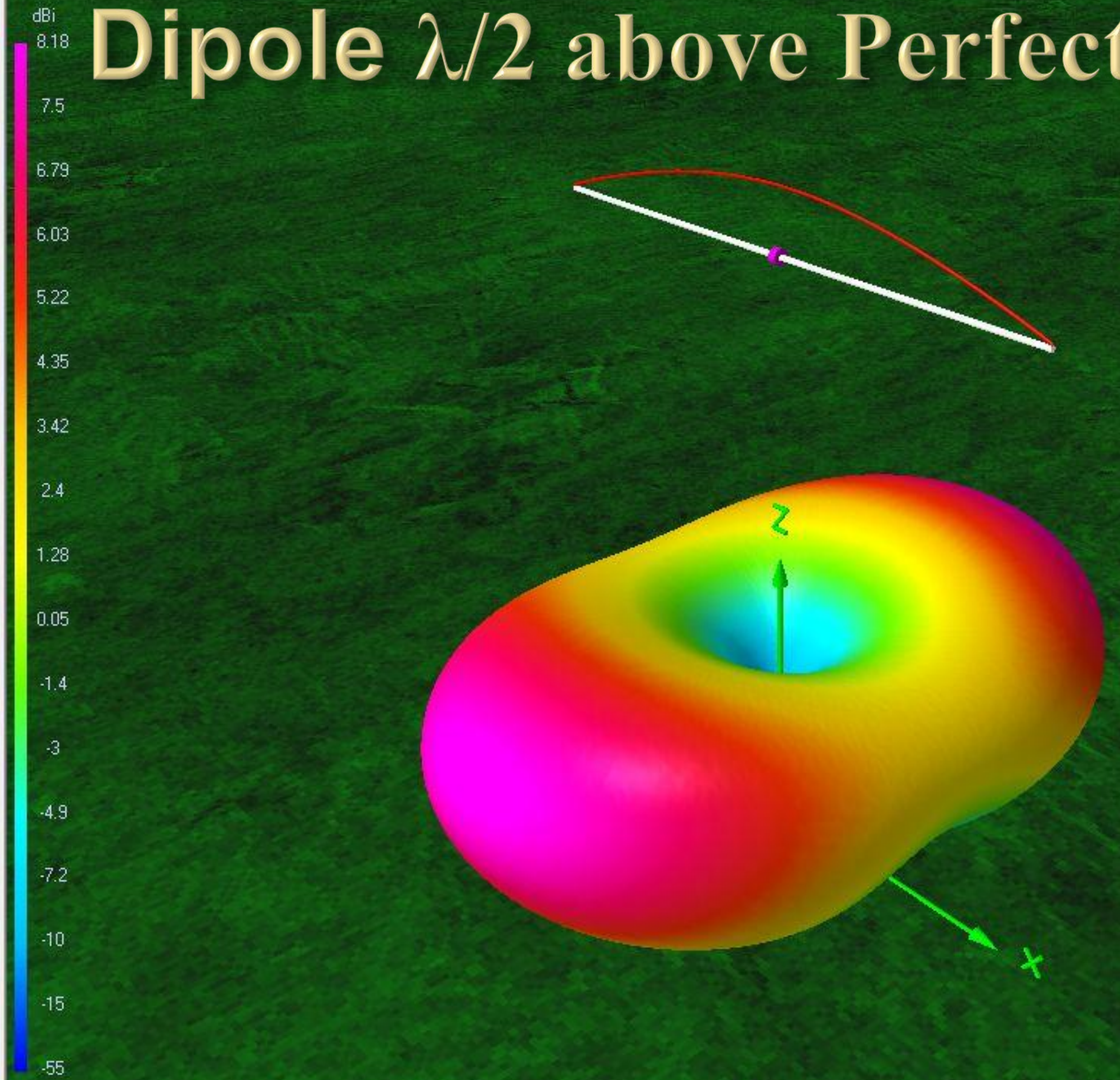
Image has
same phase

Charges on images require that Electric Field is prependicular to ground plane at its intersection. No tangential E-field can be supported in a conductor.

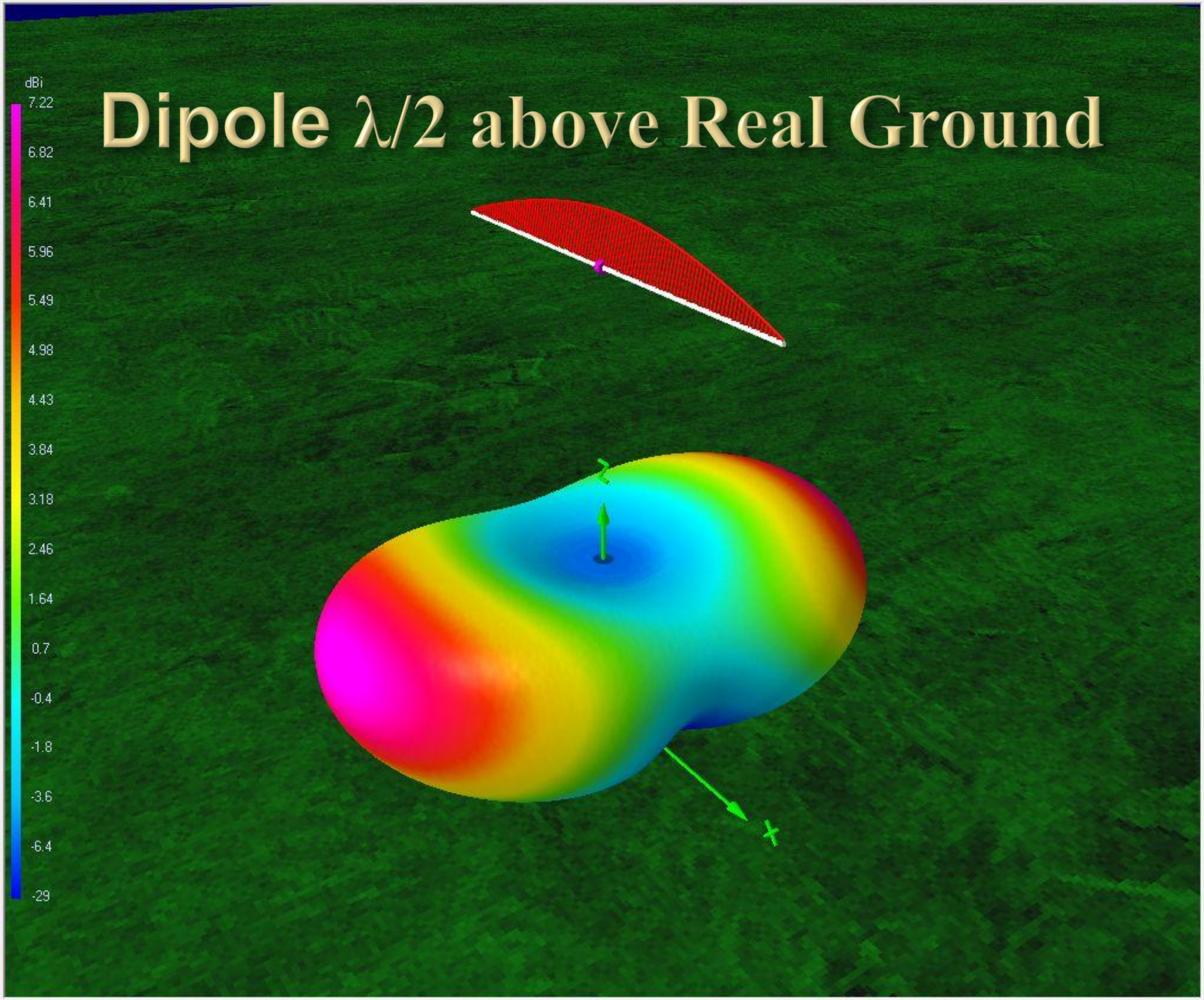
Interference from Ground Image



Dipole λ/2 above Perfect Ground



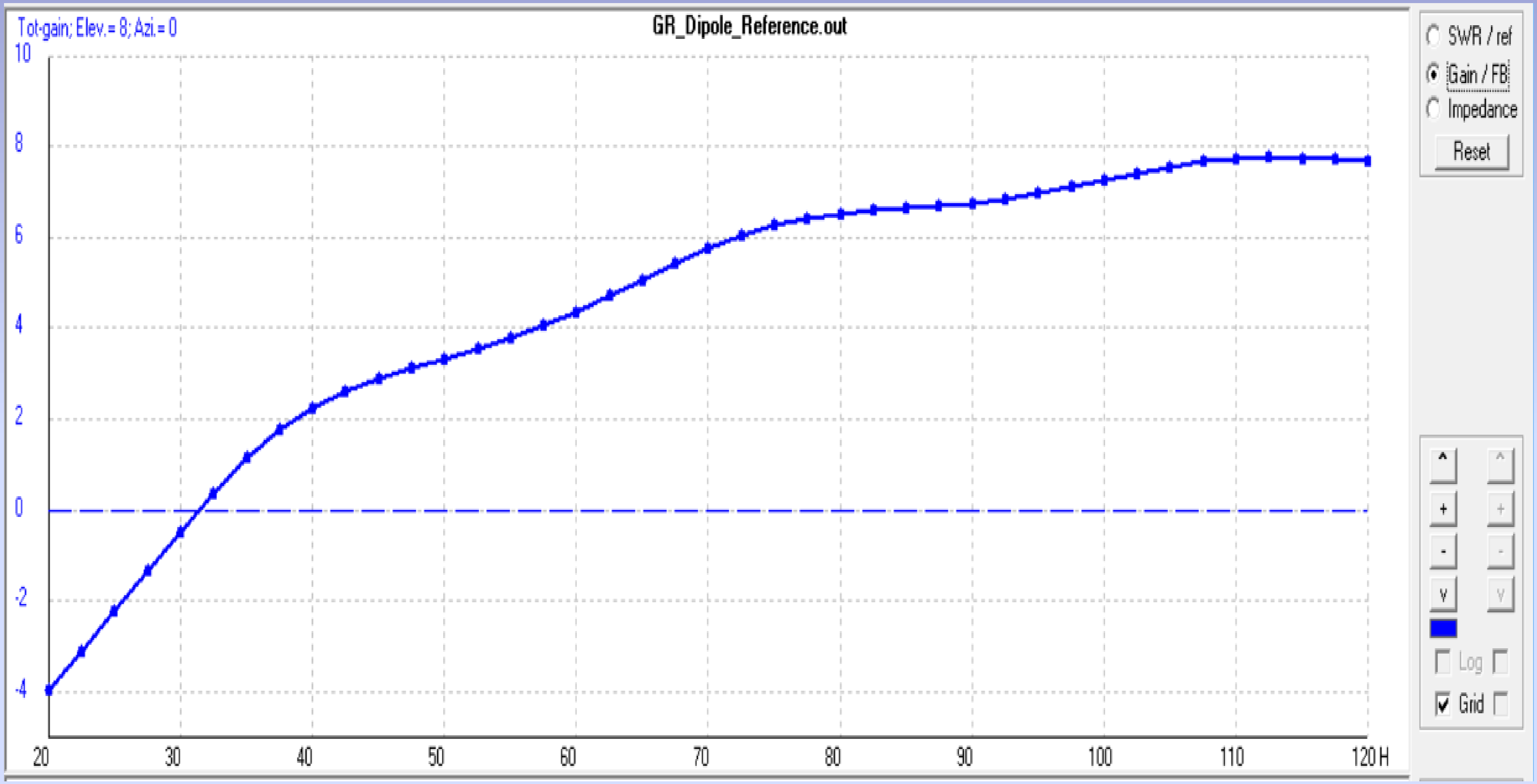
Dipole λ/2 above Real Ground



Horizontal Dipoles - Height Scaling

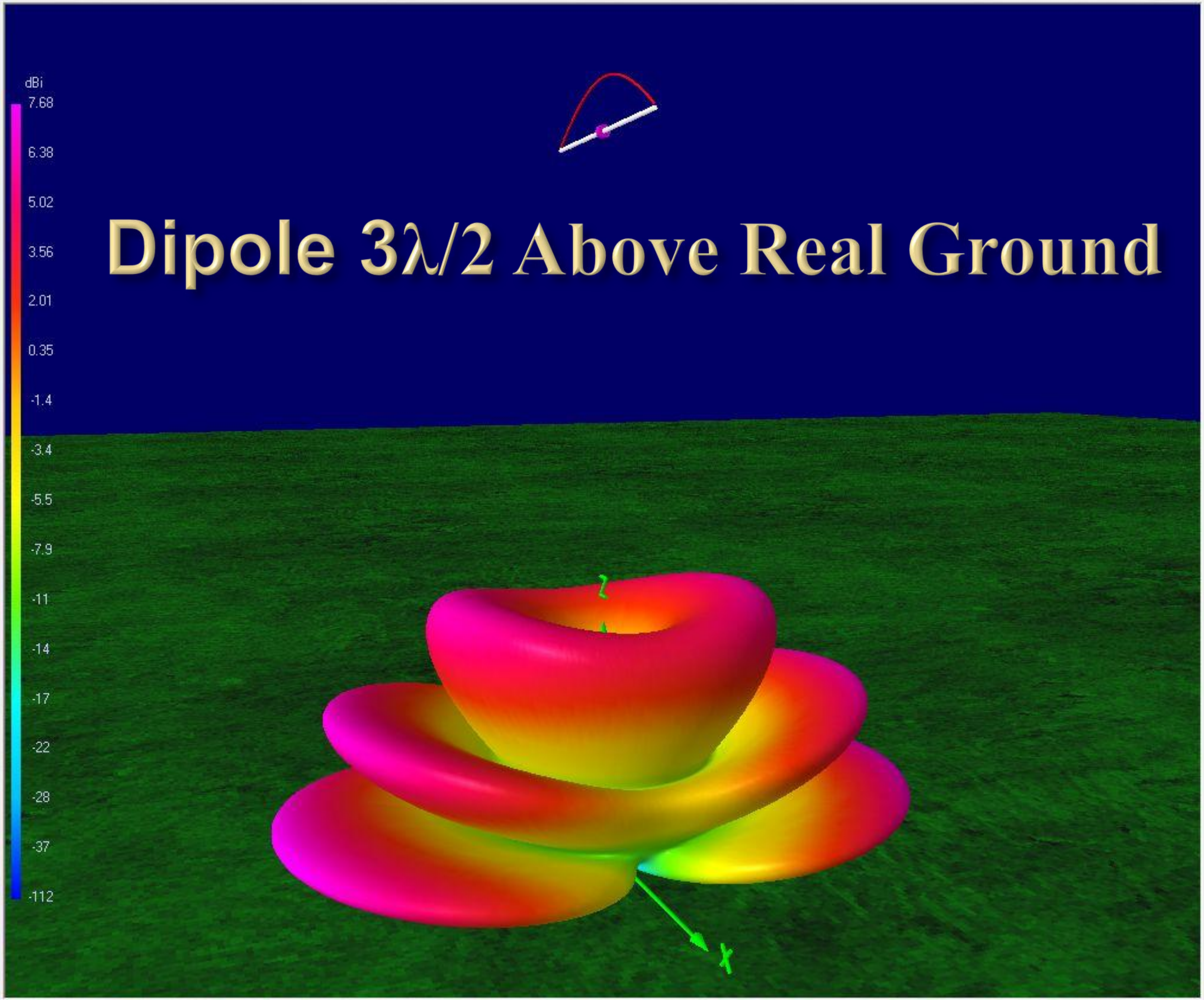
- Always a null at the horizon!
- For low antennas < ½ λ high, the positive interference moves skyward. Sky warmers and NVIS (Near Vertical Incidence Sky-wave) antennas.
- Elevation angle of first lobe gets closer to the horizon as the antenna goes up.
- You get more lobes as you go up.

Horz. Dipole Gain at 8° -vs- Height



Height in Feet for 20m Dipole

Dipole 3λ/2 Above Real Ground



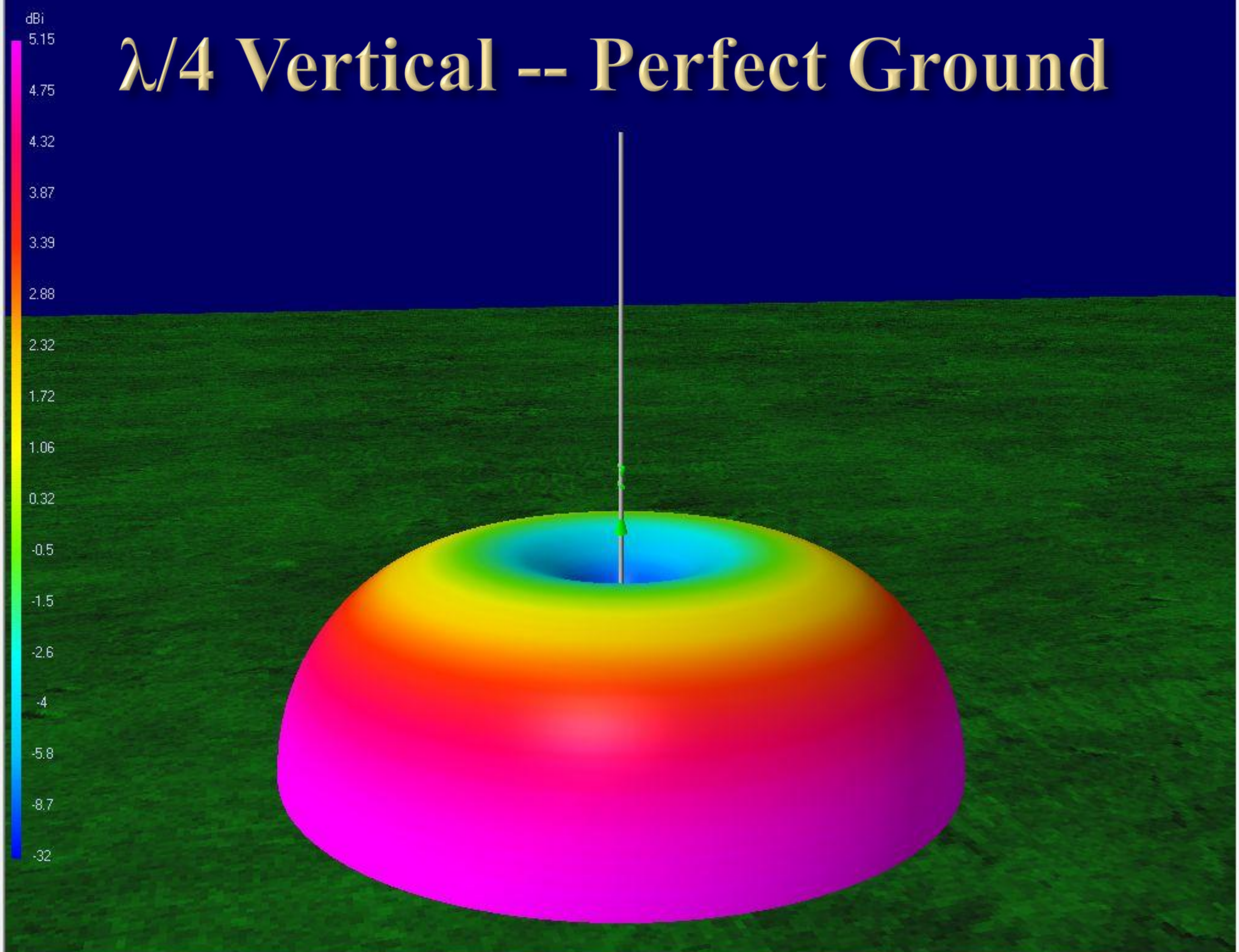
What about Verticals?

- Azimuthally Symmetric
- Ground image ***Adds*** at the Horizon
- No propagation perfectly upward

- Ground plane ¼ wave antenna (radials)

- Raised vertical dipole antenna (no radials)

λ/4 Vertical -- Perfect Ground



How do EM Waves Propagate?

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

Charges give rise to Electric fields

$$\nabla \cdot \mathbf{B} = 0$$

There are no Magnetic monopoles

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

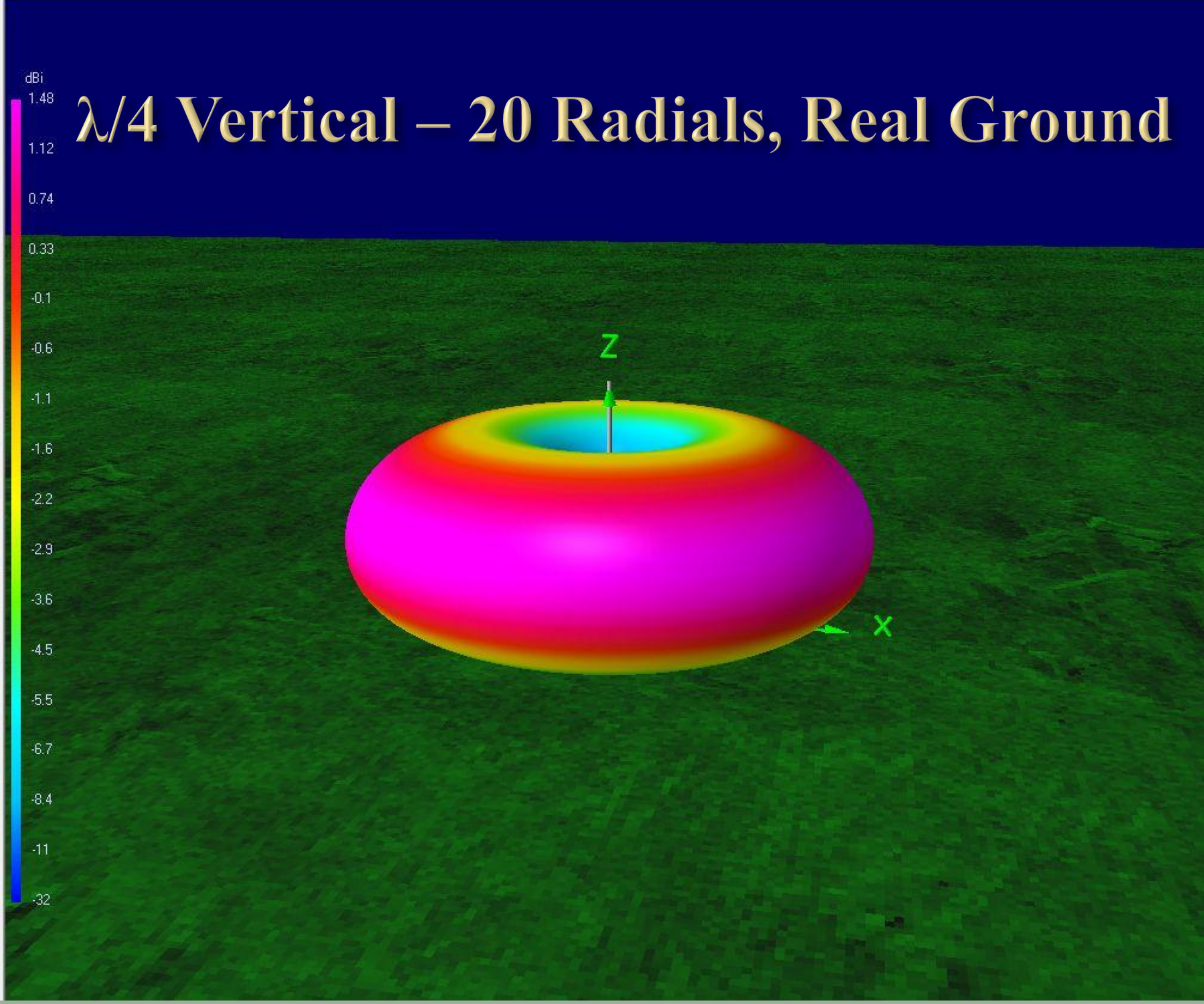
Changing magnetic fields make electric fields in a curly way.

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Changing electric fields and currents make magnetic field in a curly way.

In free space there is no current (J=0) and EM wave comes from last two equations. But where the wave meets the ground you will drive currents!

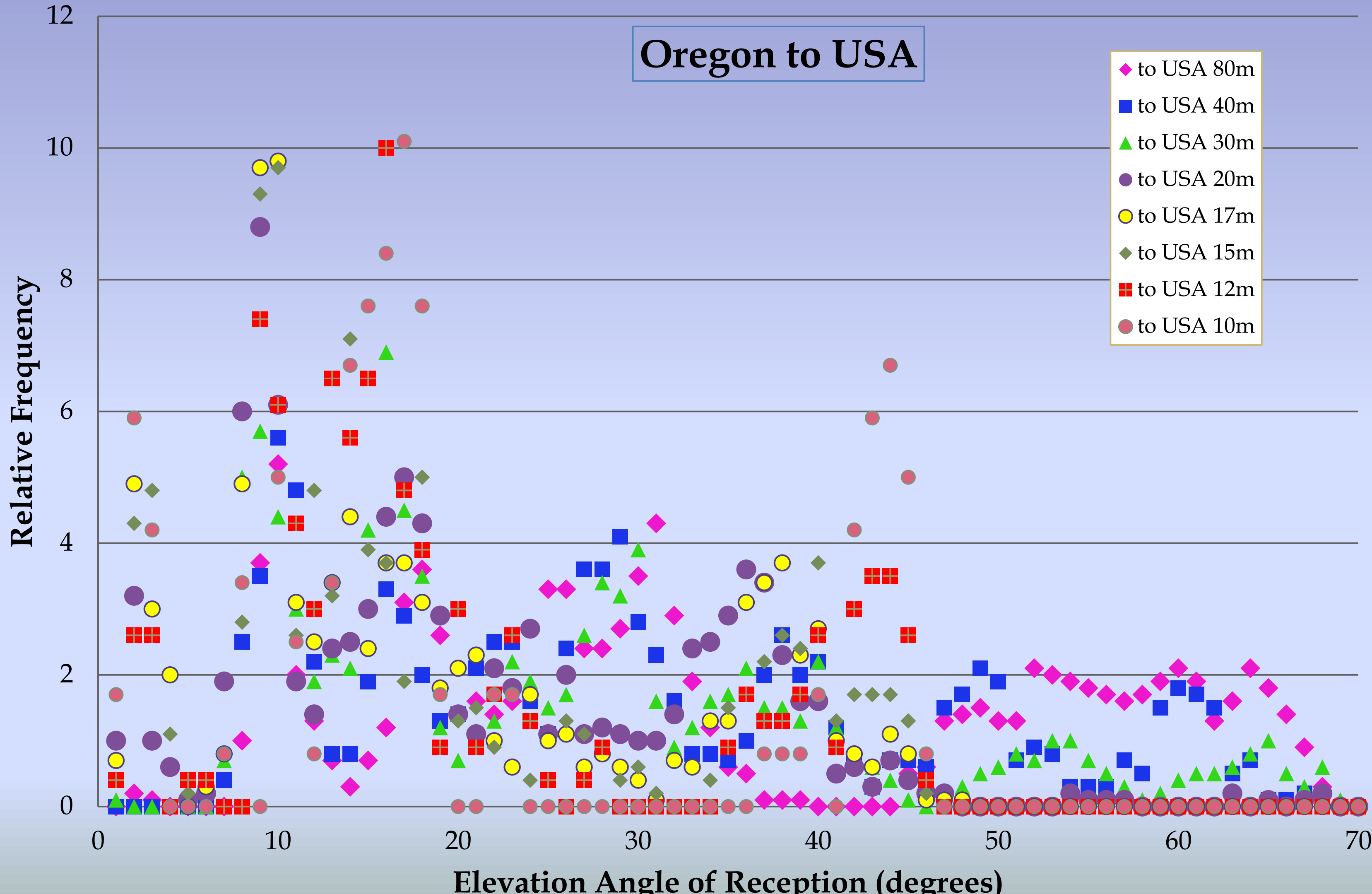
λ/4 Vertical – 20 Radials, Real Ground



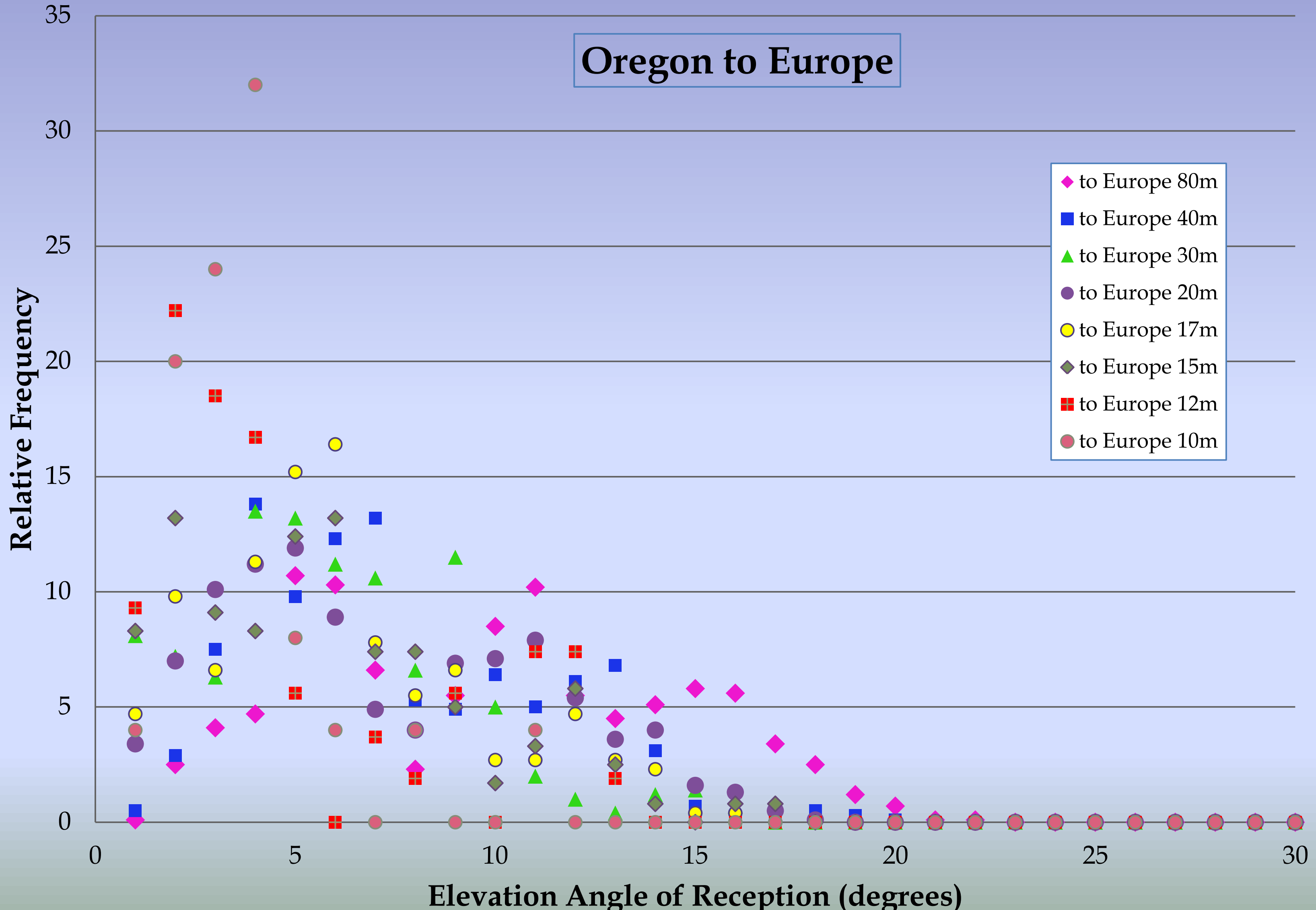
Where is the Power Going?

- NEC simulations can tell us losses.
  (assume perfect antenna conductors)
- Over Perfect Ground 100% of energy in EM wave for both Horizontal and Vertical cases.
- Horz. Dipole, $\lambda/2$ high with “Real Ground”: 75%
- Vertical w/20 radial and “Real Ground”: 43%
- If you aim the EM wave at resistive ground you will get losses.

Elevation Angles - LOCAL



Elevation Angles - DX



The DX Conundrum

How to get low elevation angles without heating the ground plane or throwing away energy into wasted sky modes.

- High dipoles (wasted sky modes)
- Yagi (can't beat a tower and a beam! $$$)
- Elevated Vertical Antennas
- Other Multi-Element Antennas

Elevated Vertical Dipole

Pros:

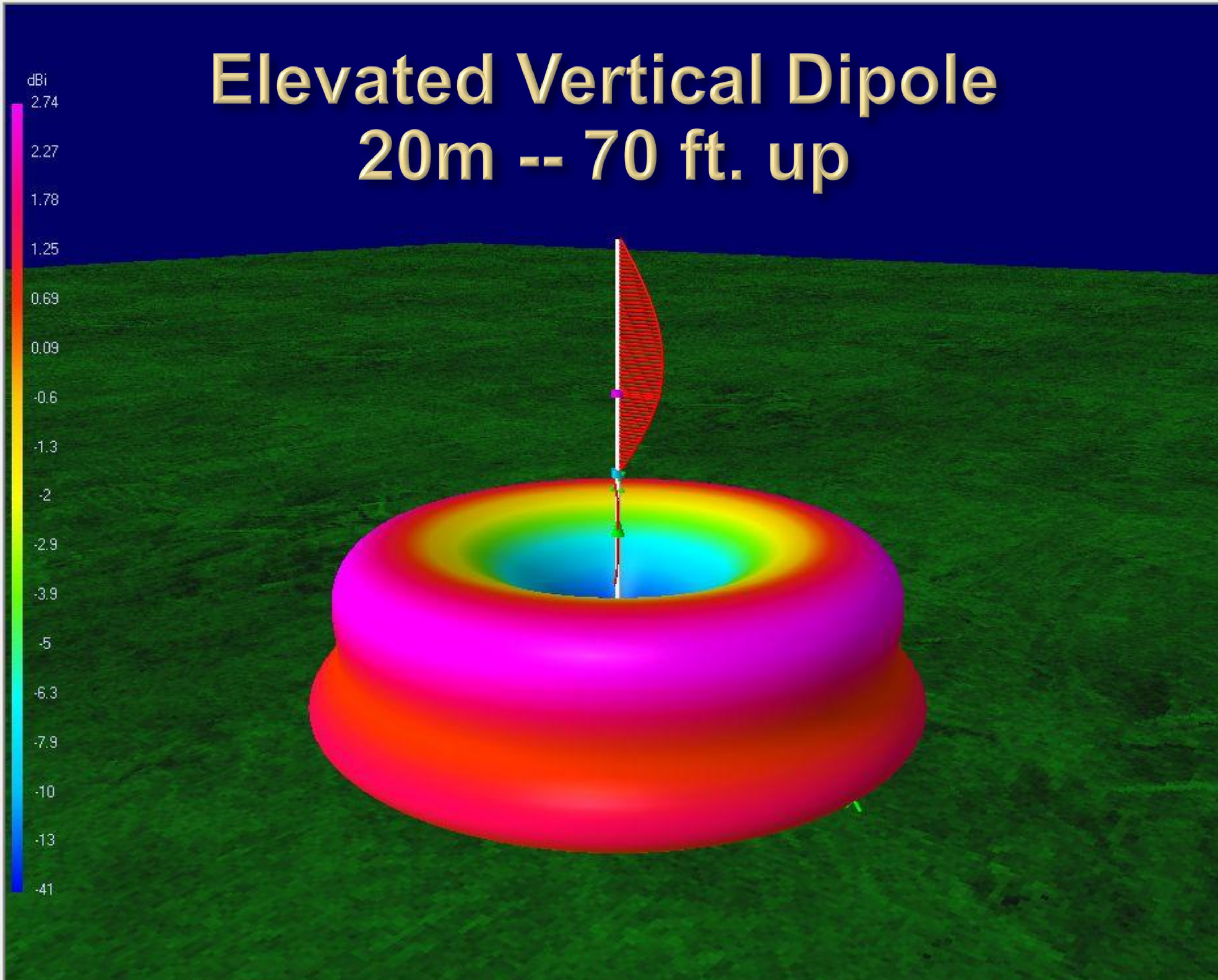
- No radials!
- Good efficiency
- Low angle Pattern

Cons:

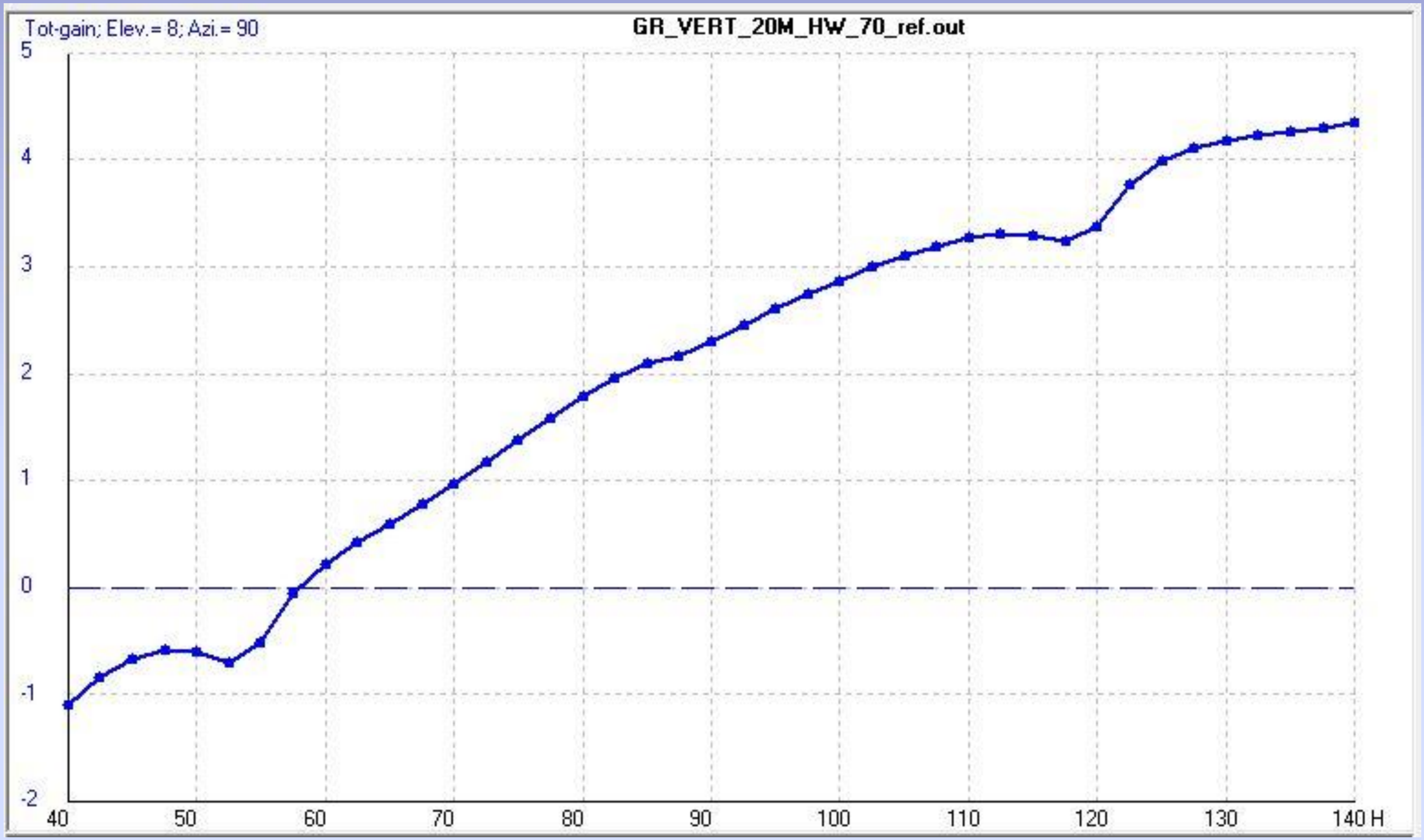
- Tall – needs a tree

Plans: see AF7NX at qrz.com

Elevated Vertical Dipole
20m -- 70 ft. up



Vert. Dipole Gain at 8° -vs- Height

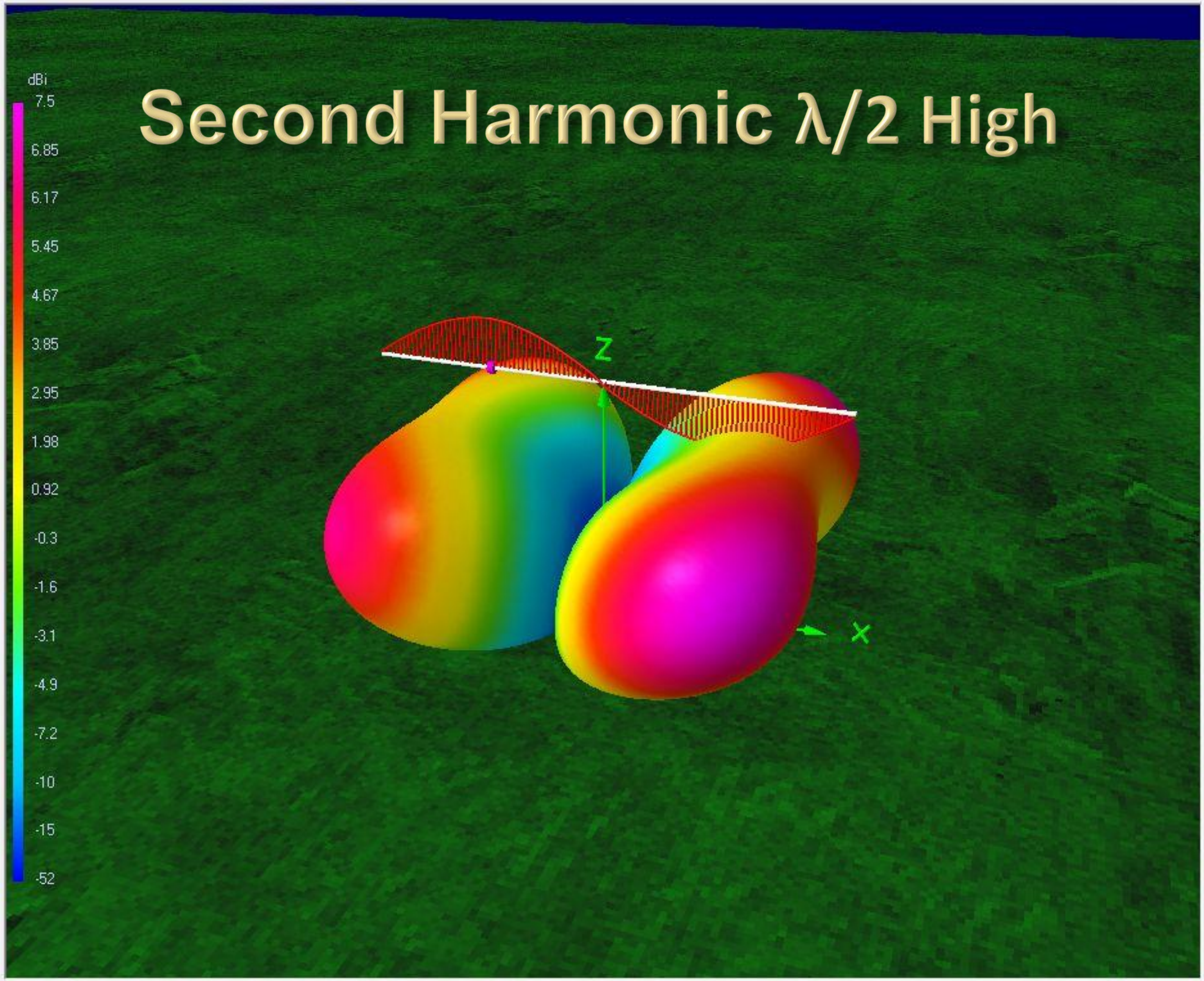


Top Height in Feet for 20m Vertical Dipole

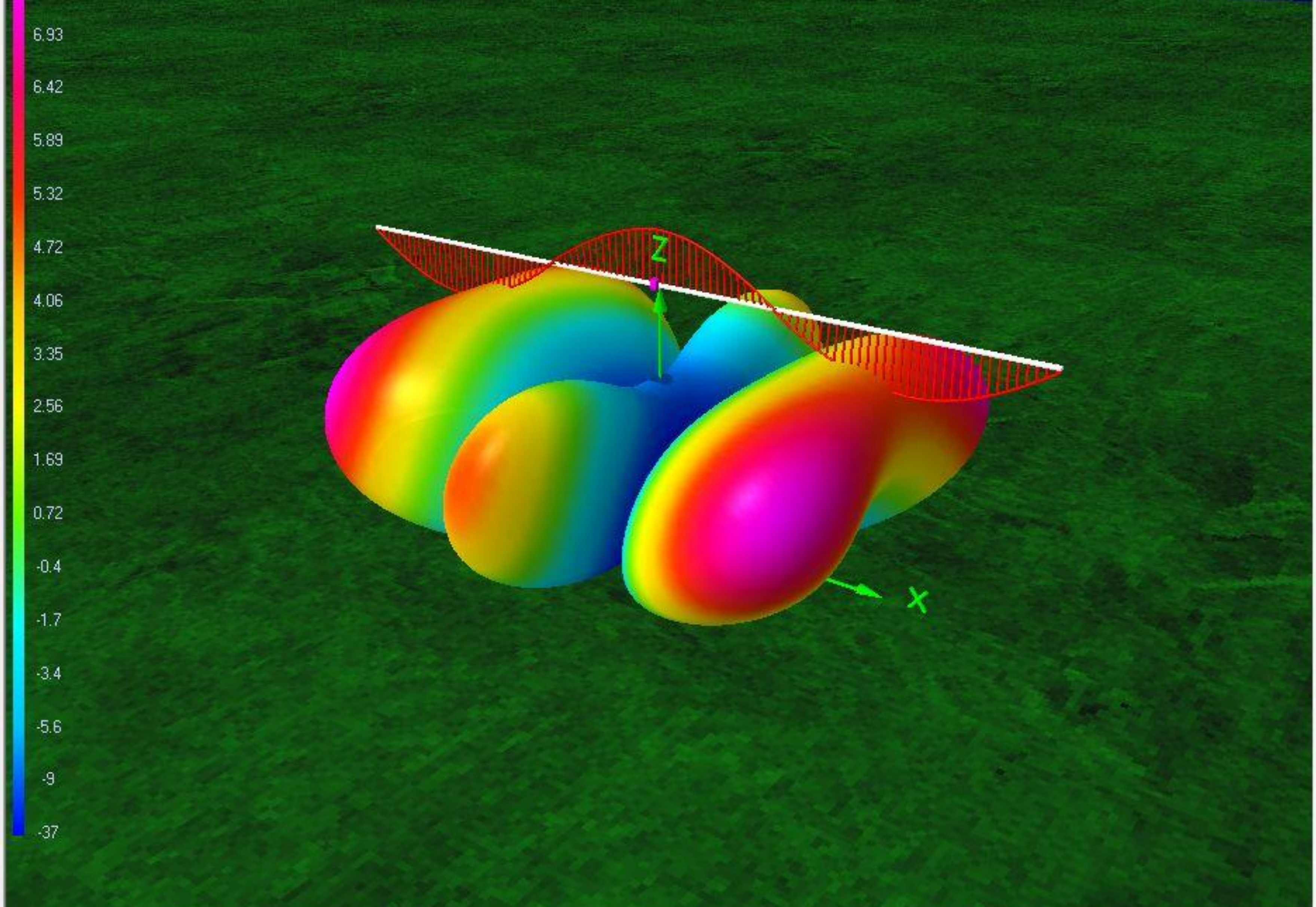
Long Wires and Multi-Band Antennas

- Harmonics on the wires
- Spacing of the ham bands helps (sort-of)
- Many tricks to make them all resonant and able to be matched to the feed line.
- Many compromises!
- **Modes structures of higher harmonics generate predictable patterns.**

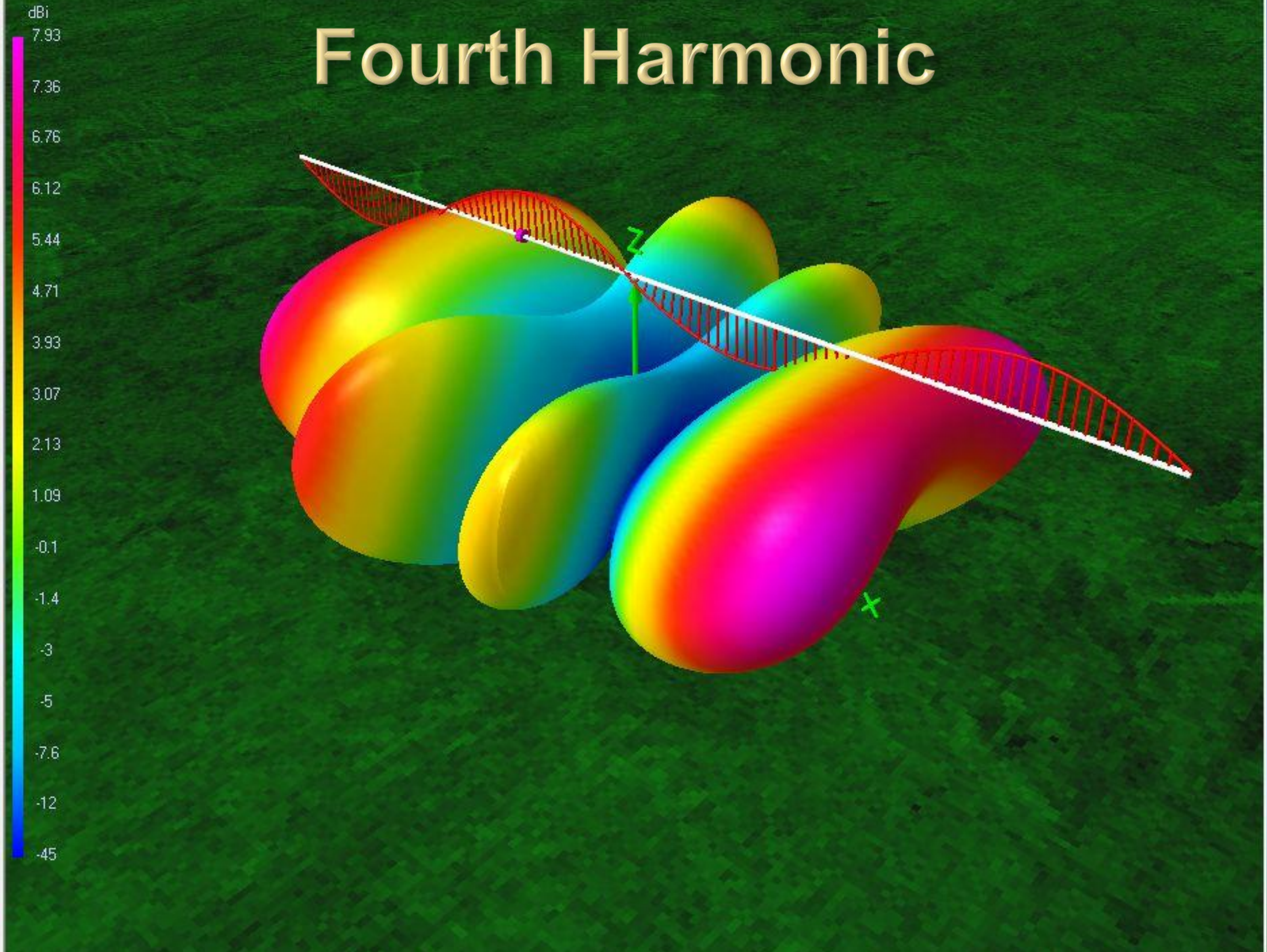
Second Harmonic λ/2 High



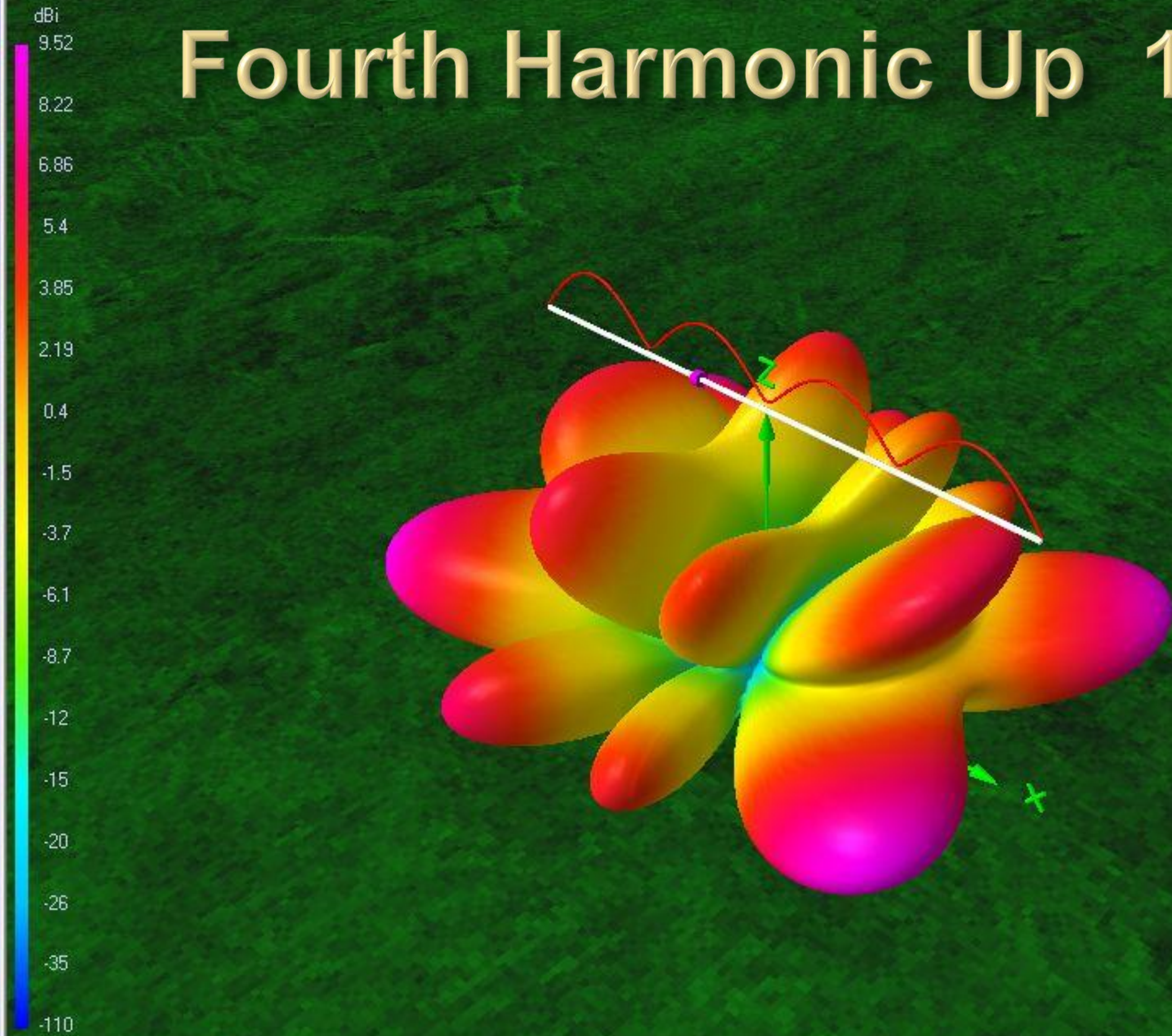
Third Harmonic



Fourth Harmonic



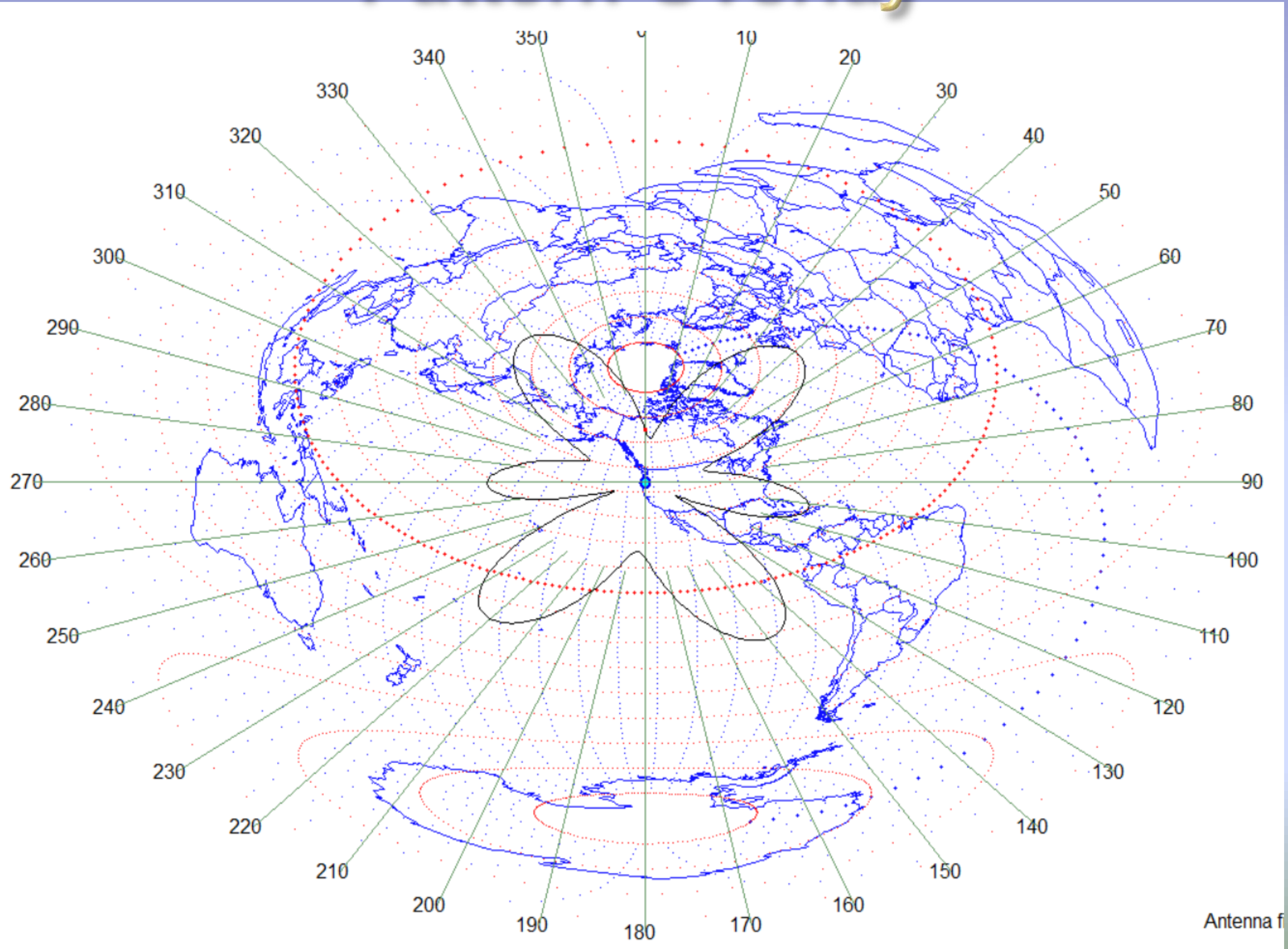
Fourth Harmonic Up 1 x λ



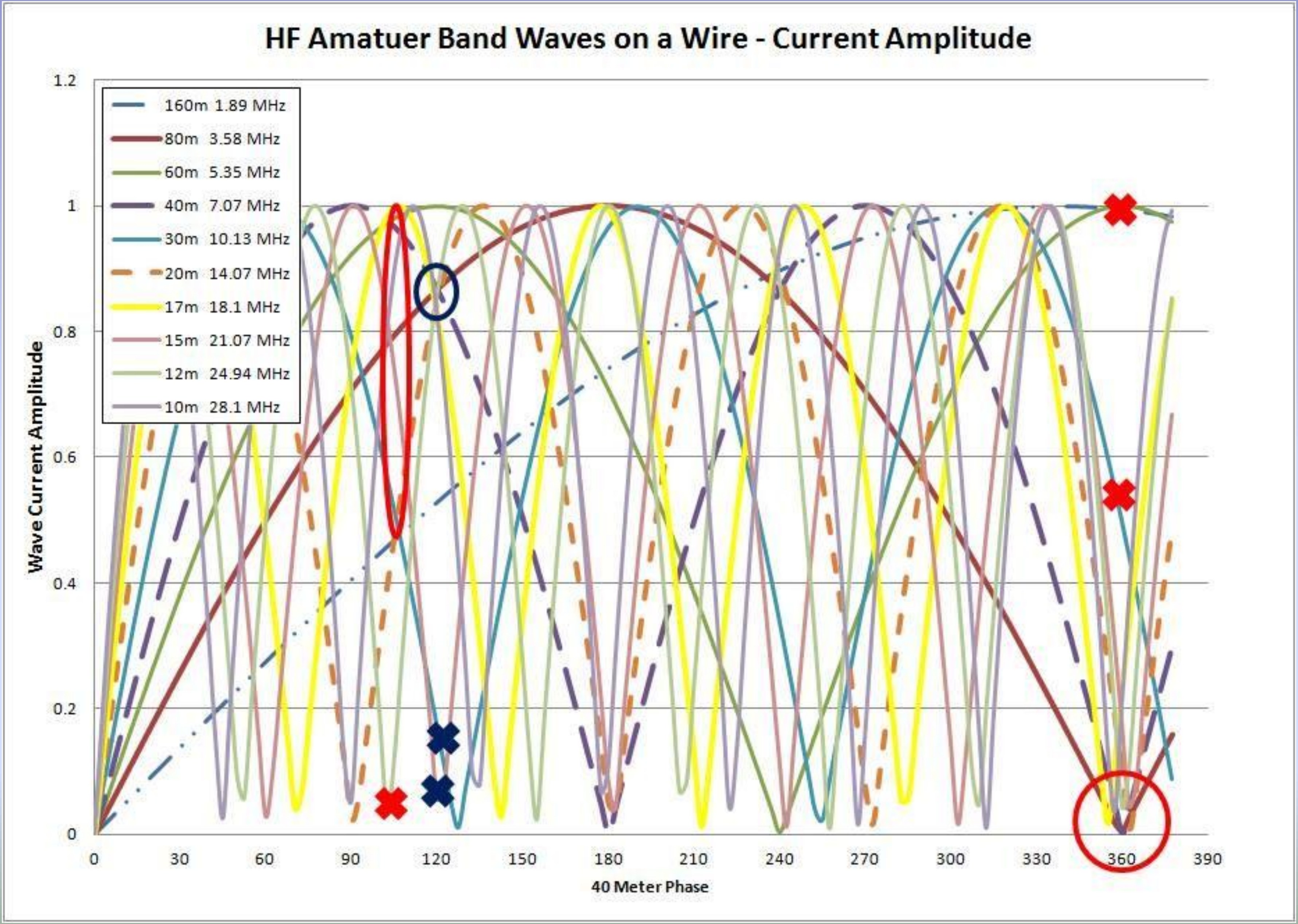
Multi-Band Wires

- Ham bands are harmonic (sort of) so multiple bands can be resonant on the same piece of wire.
- "Broadside" to the wire doesn't apply to higher harmonics.
- Harmonic interference can give you strong lobes!
- But aiming is important.

"Pizza" Map with Antenna Pattern Overlay



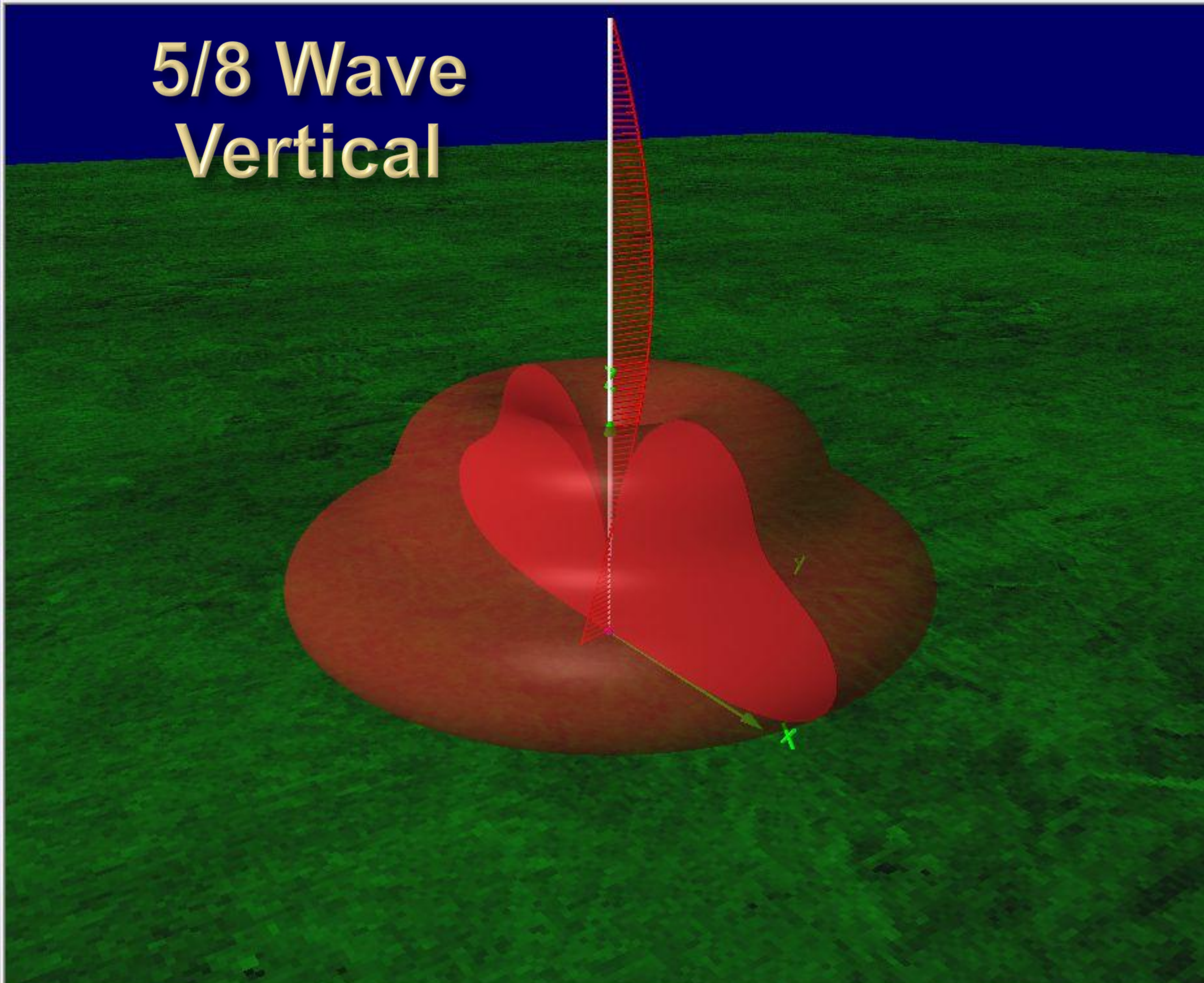
Fitting Waves on a Wire



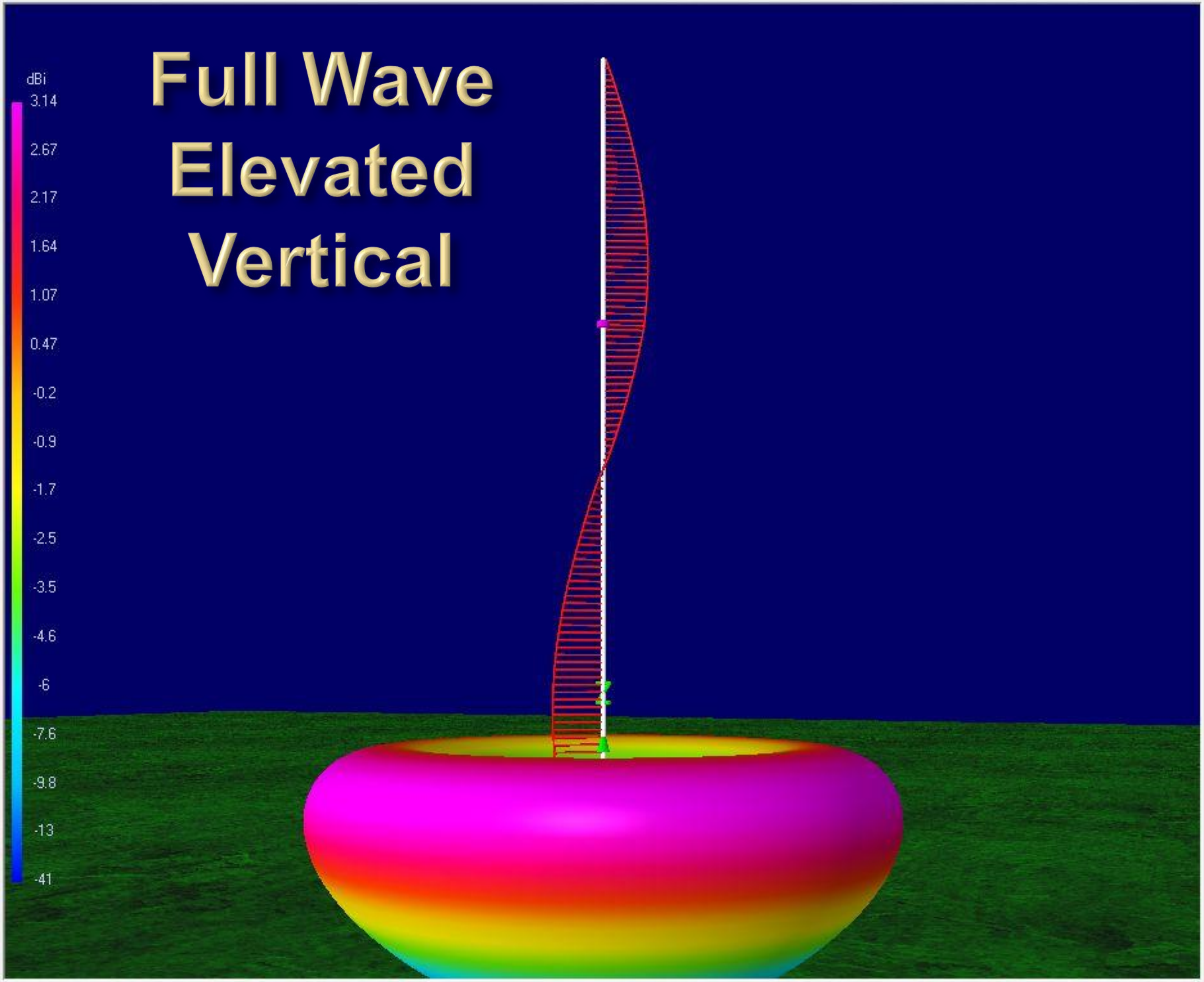
Harmonics on Verticals

Any guesses?

5/8 Wave Vertical



Full Wave Elevated Vertical



Antenna Comparisons

Description	Gain 30°	Gain 8°	Azimuthal Coverage	RDF (dB)	Top Height for 20 m	Comments
Dipole at λ/2 High	7.2 dBi	0.4 dBi	2X 60° lobes	8.5	10 m	Pretty good regional coverage.
4th Harmonic Wire at λ High	~ 0 dBi	7.6 dBi	4X 25° lobes	10.2	20 m	Pretty good DX if aimed where you want it.
λ/4 Ground Plane Antenna	1.5 dBi	-2.9 dBi	360°	5.2	5 m	
5/8 λ Ground Plane Antenna	~ 0 dBi	~ 0 dBi	360°	5.25	12.5 m	
Elevated Dipole top 1 λ High	1.4 dBi	0.6 dBi	360°	5.3	20 m	
Elevated Dipole top 2λ High	~ 0 dBi	4.2 dBi	360°	6.5	40 m	Pretty good DX all around
Elevated Full Wave Vertical λ High	2.6 dBi	-9 dBi	360°	6.3	20 m	Good regional - Lousy DX
Elevated Collinear Dipole 2λ High	~ -5 dBi	4.9 dBi	360°	8.1	40 m	My Experiments
Elevated Collinear Dipole 2λ High Tilted 6°	~ -5 dBi	5.2 dBi	>180°	8.4	40 m	My Experiments
3 El Yagi at λ/2 High	12 dBi	5.8 dBi	1X 60° lobes	13	10 m	
3 El Yagi at λ High	~0 dBi	11.1 dBi	1X 60° lobes	14.2	20 m	Why you want a beam!

How much is a dB worth?

- 3 dB doubles your radio's output and sensitivity.
- 10 dB makes your 100W rig as good as a 1kW rig for TX.
- 10dB will triple the possible reception area under marginal conditions. (assumes $1/r^2$ intensity for radiation bounded by ionosphere.)

Conclusions

- Using Wires for HF antennas is a common practice. Knowing what you should expect from the radiation patterns for waves on your wires will help you choose what will work best for your needs.
- The principles of interference can lend insight into what to expect from a wire antenna.