What little I ^ know about antennas

think I

B. Scott Andersen, NE1RD

Purpose of this talk

- Give you a new list of things to think about
- Give you ways to visualize things
- Talk about a whole different approach to wire antenna deployments


KB0HH
Bunkhouse
Antenna
Farm
9/11

Small money can produce results, also

- You don't need to build an antenna farm
- But, you can't just "hang it and hope" and expect to get great results, either
- The antenna farm was big money (certainly!) but it was also the result of science, measurement, and planning
- Even without big $ you should still THINK!

The Point

- "Hang it and hope" is a poor strategy
- Multiband antennas are a compromise on most or all bands
- Just because you can "tune it up" doesn't make it good
- I'll show a clever alternative for doing long-haul DX with an array of antennas

PART I

Concepts

Super-Stupendous Antenna™!

Works on all bands!
Is omnidirectional!
Handles up to 300 watts!
Tunes easily.
Very low visual impact (XYL friendly)!

Match load to maximize power transfer

- Most transceivers are expecting a 50 ohm load
- Dipoles in free space are about 70 ohms
- Verticals over perfect ground are about 35 ohms
- Seems like that 50 number is a compromise for both

Feedpoint Impedance

- Ohmic losses -- the wire has resistance
- Radiation resistance -- doing the work of sending a signal is work and needs to be accounted for
- Losses
  - Ground losses
  - Reactance in the system
  - ... and so on

Ohmic losses

- Wire has resistance
- Even at 0.004 Ohms per foot a 100 foot length of 16 gauge wire has 0.4 ohms of resistance just in the wire
- You might have losses in connectors
- This is usually a small percentage of the impedance -- but can be large in magnetic loop antennas!

Radiation resistance

The component of the antenna impedance associated with doing the work of producing a radio signal

It would be wonderful if 100% of our antenna's feedpoint impedance was from radiation resistance!

A well-deployed dipole is 97% efficient or better

Losses

- Anything that impedes current flow through our system reduces the power
- Poor soil conductivity around a vertical or too few radials will increase total resistance and reduce power
- If the antenna is not *resonant* then the system will have *reactance* impeding current flow and reducing power

Reactance, Resistance, and Impedance

- All these are measured in *Ohms*
- *Reactance* is the opposition to alternating current
  - Capacitive reactance
  - Inductive reactance
- *Impedance* (Z) represents the resistance and reactance of a system

First antenna

- A typical first antenna is a dipole
- Assume it is a monoband dipole for 10m
- Advice you get: “Hang it as high as you can and start making QSOs!”
- Good advice? Bad advice? The answer isn’t as simple as you might think!

Take-off angle

- Where is the bulk of your signal going?
- **Are you sending and receiving reasonably well in the directions you need?**
- The antenna radiation pattern in a model shows where your signal goes and provides a relative strength
- The *take-off angle* describes the direction relative to the horizon

Visualizing antenna patterns

- Two plots: azimuth and elevation
- Power gradients are shown relative to some maximum power
- Power reductions are displayed in dB (decibels)
- Note an S-unit is about 6dB

Decibel?

A "decibel" describes a relationship between two power levels. We use this system because these ratios can get very large. Decibels use a *logarithmic* scale.

$$L_{\mathrm{dB}} = 10 \log_{10} \left(\frac{P_1}{P_0} \right)$$

3dB = 2x	6dB=4x	10dB=10x	20dB = 100x	30dB = 1000x
40dB = 10,000x	50dB = 100,000x	60dB = 1M x	70dB = 10M x	80dB = 100M x

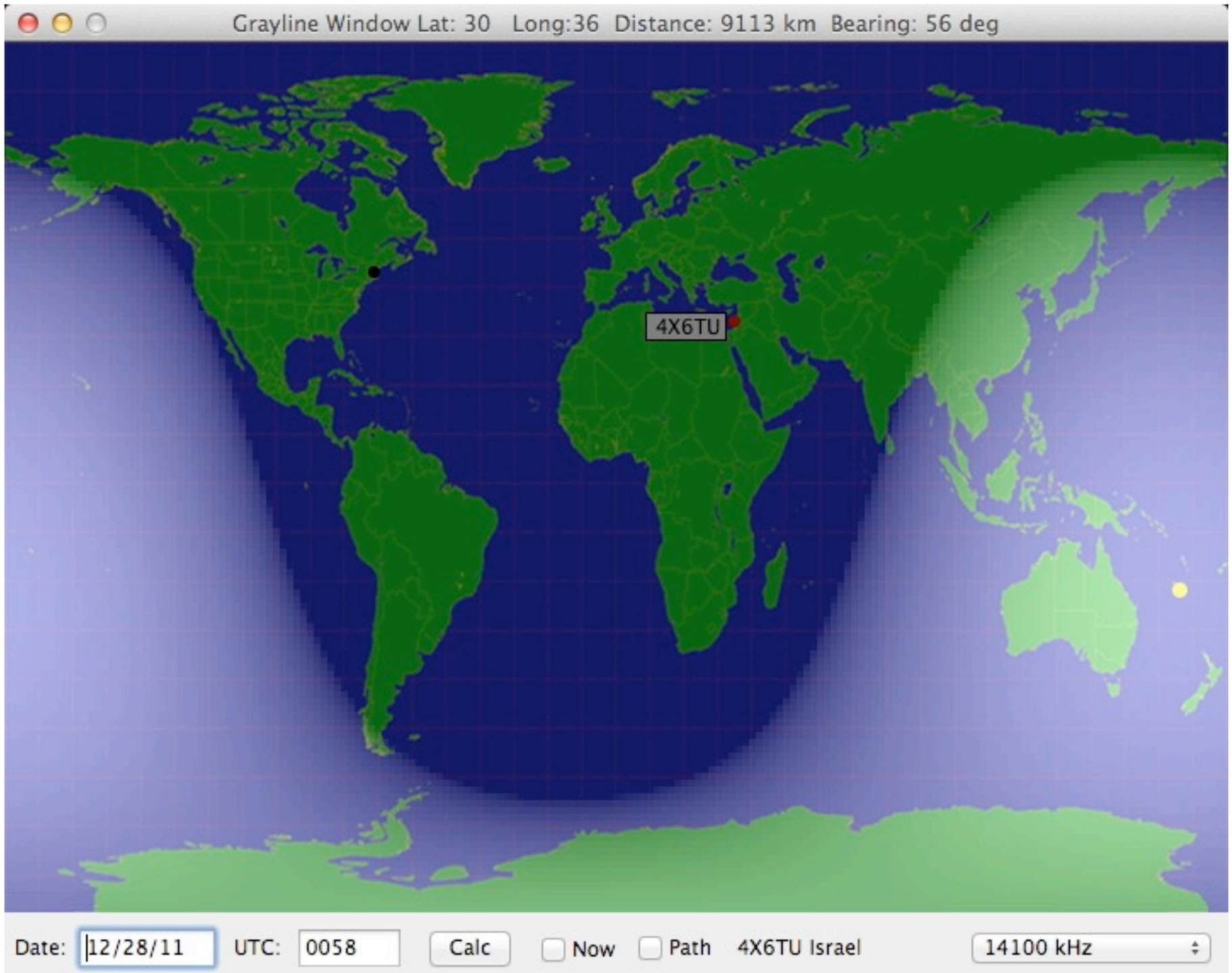
What is that in S-units?

- Radios vary (and even this definition varies!)
- Indulge me:
  - Assume one S-unit is 6dB
  - Assume station A is sending at 1000 watts
- What would you see on your meter at station B if they dropped power?

If an S-unit is 6dB

Power level of station A	What you see at station B
At 1000 watts	You see 10 over S9
At 100 watts	You see S9
At 25 watts	You see S8
At 5 watts	You see S7
At 1 watt	You see S6
At 1/4 watt	You see S5
At 1/10 watt	You see S4

Some of you don't believe me



Beacons on:

14.100

18.110

21.150

24.930

28.200

Power:

100 w

10 w

1 w

100 mW

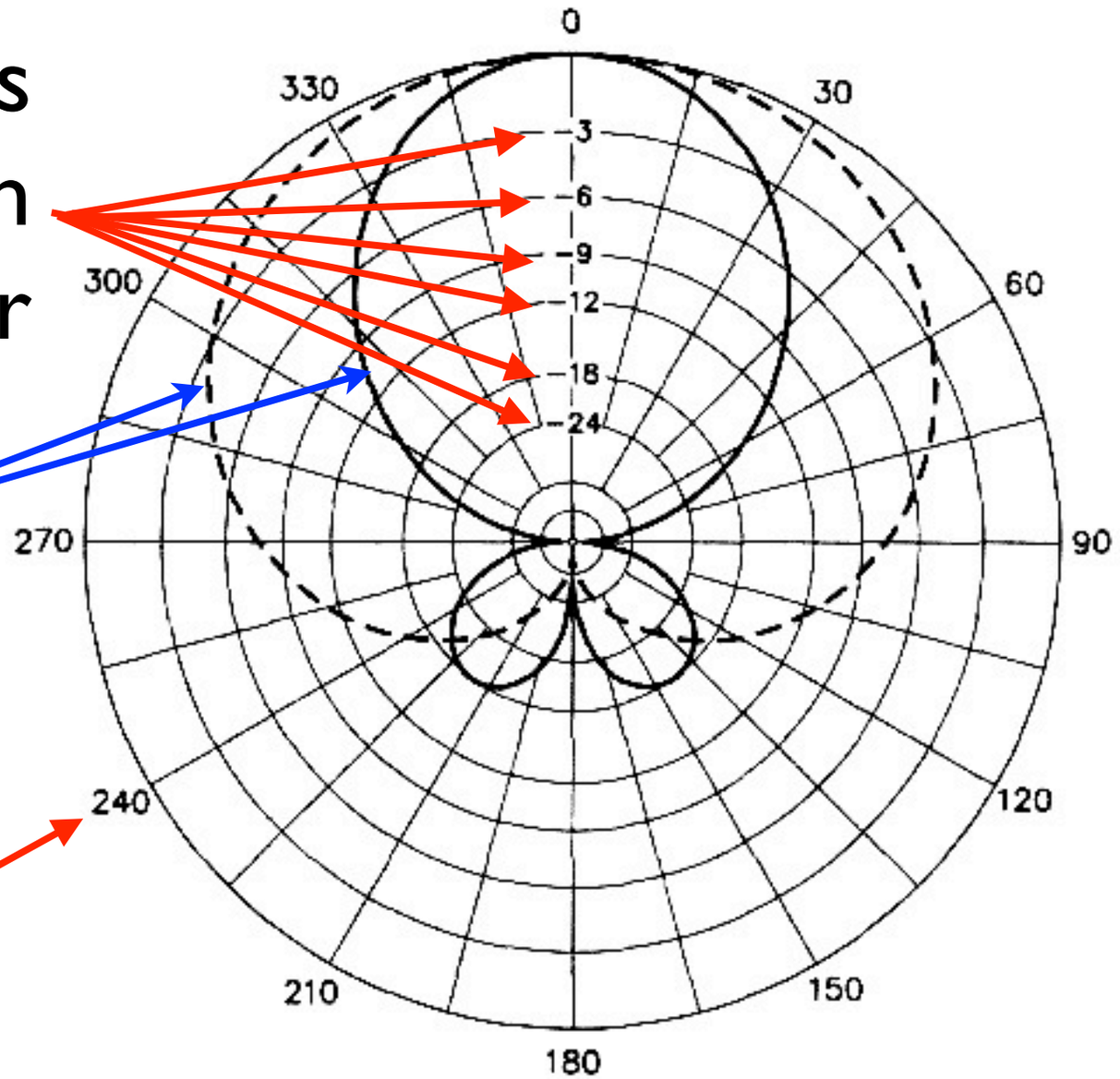
Azimuth plot

View from directly above the antenna looking down

Relative power levels shown as dB going down as you approach the center

This particular plot compares two antennas

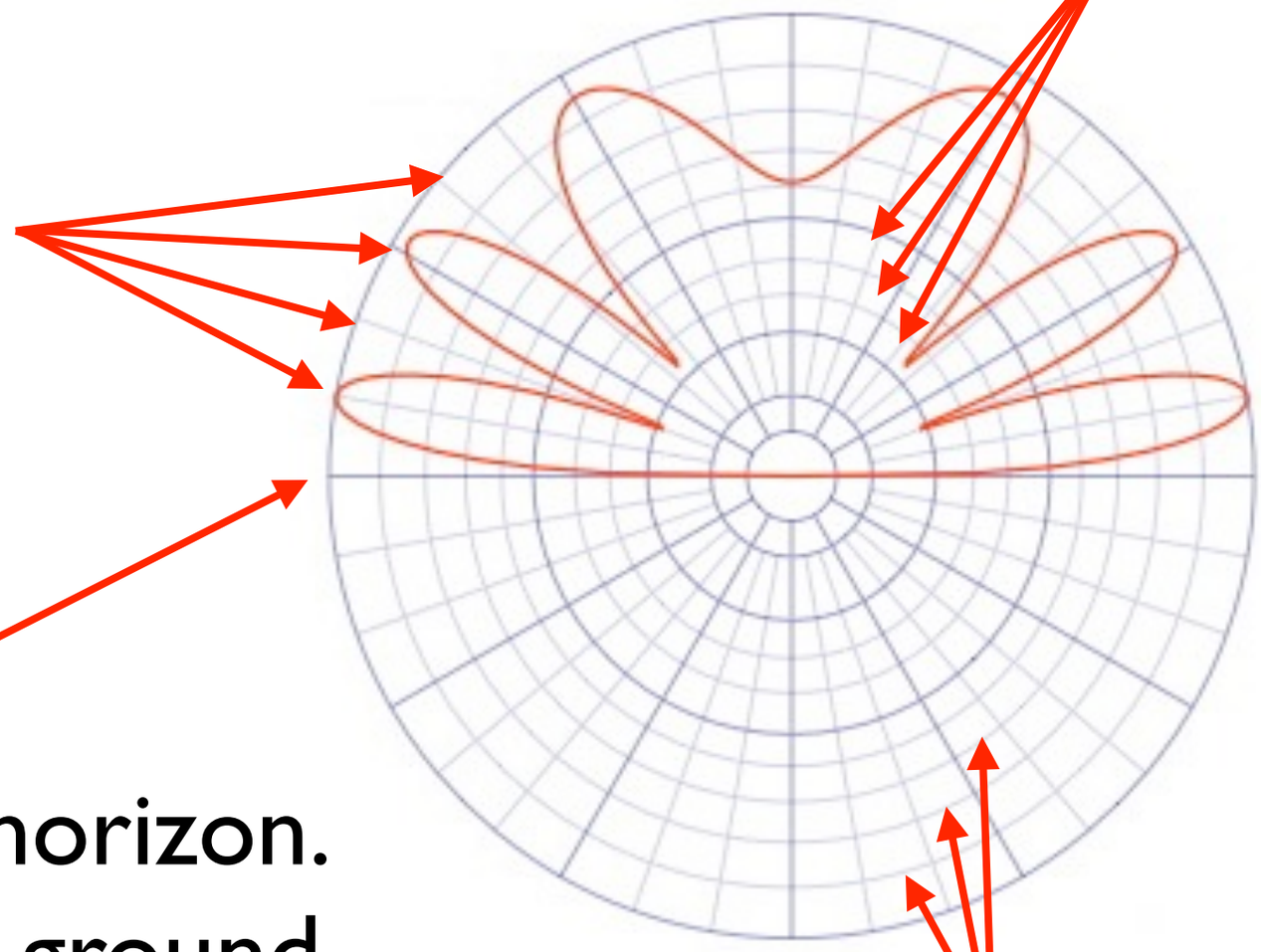
Compass headings around the circle



Elevation plot

3dB increments

10 degree increments in elevation



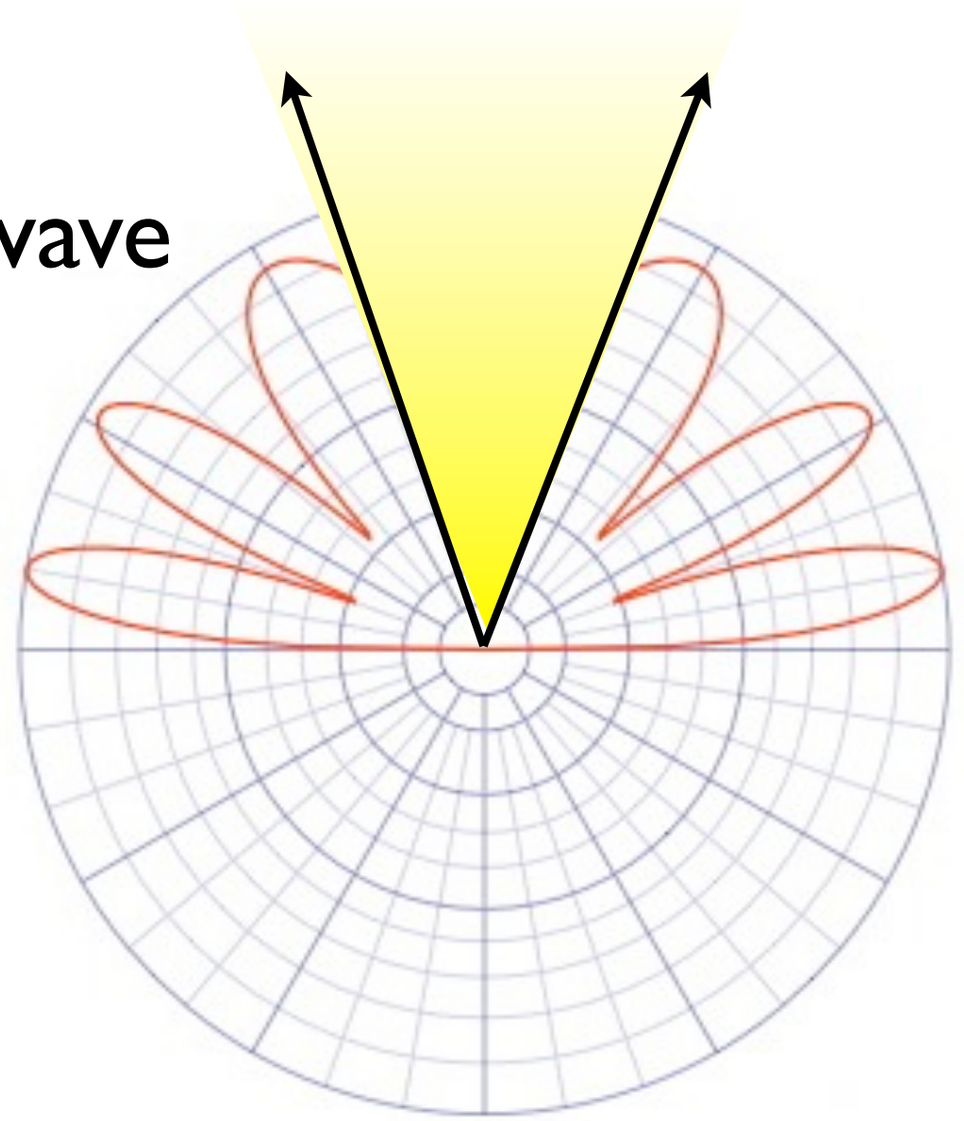
This line represents the horizon. For this talk it will be the ground (so nothing will be underneath it).

2dB increments

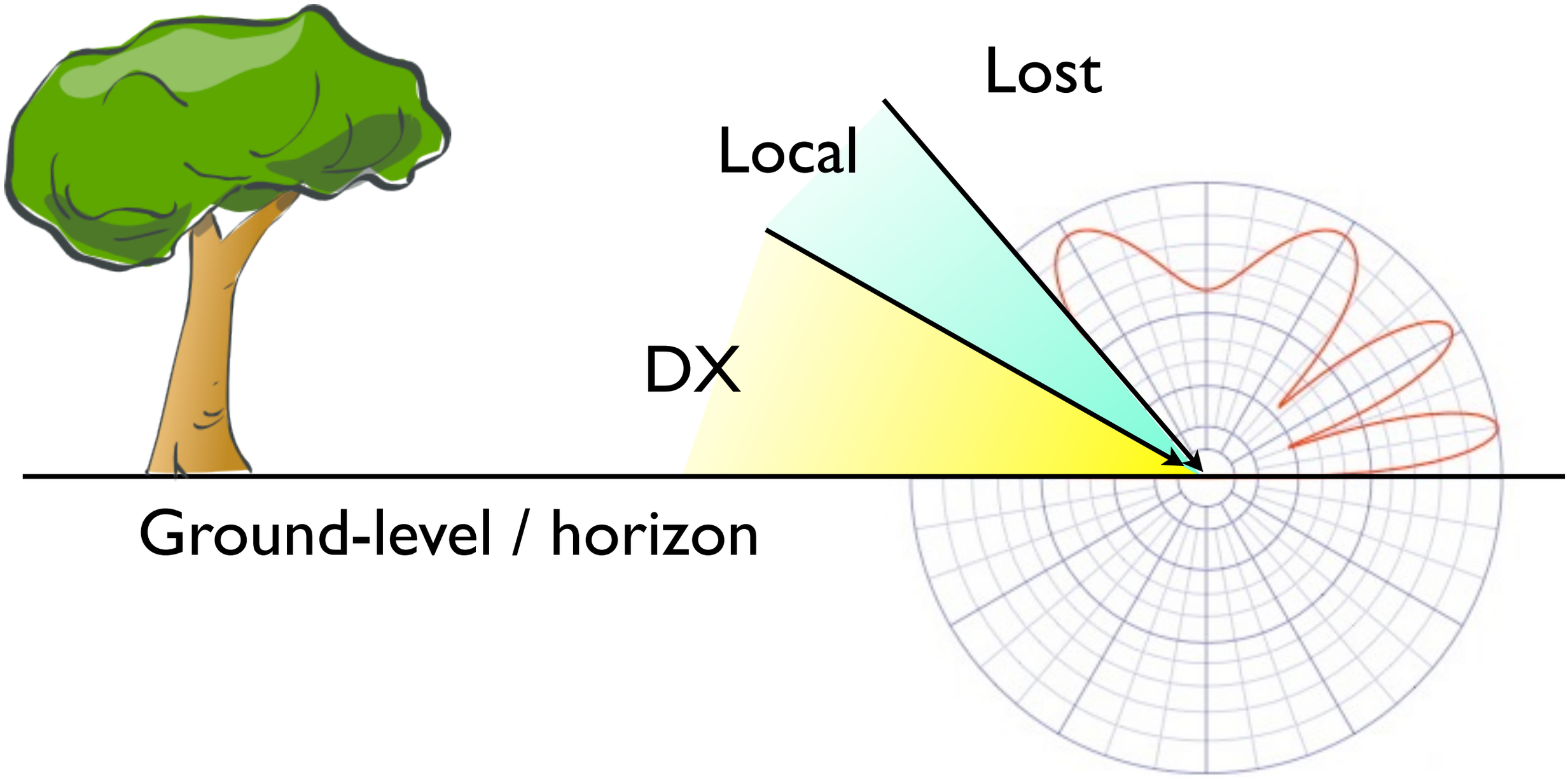
Cloud warmers

NVIS: Near Vertical Incident Skywave uses 160m and 80m at night, 80m or 40m during the day.

This is a very special case. Above these frequencies the signal is usually just lost!



Arrival angles



PART II

Horizontal Dipole

10m Horizontal Dipole

Let's design a 10m center-fed dipole:

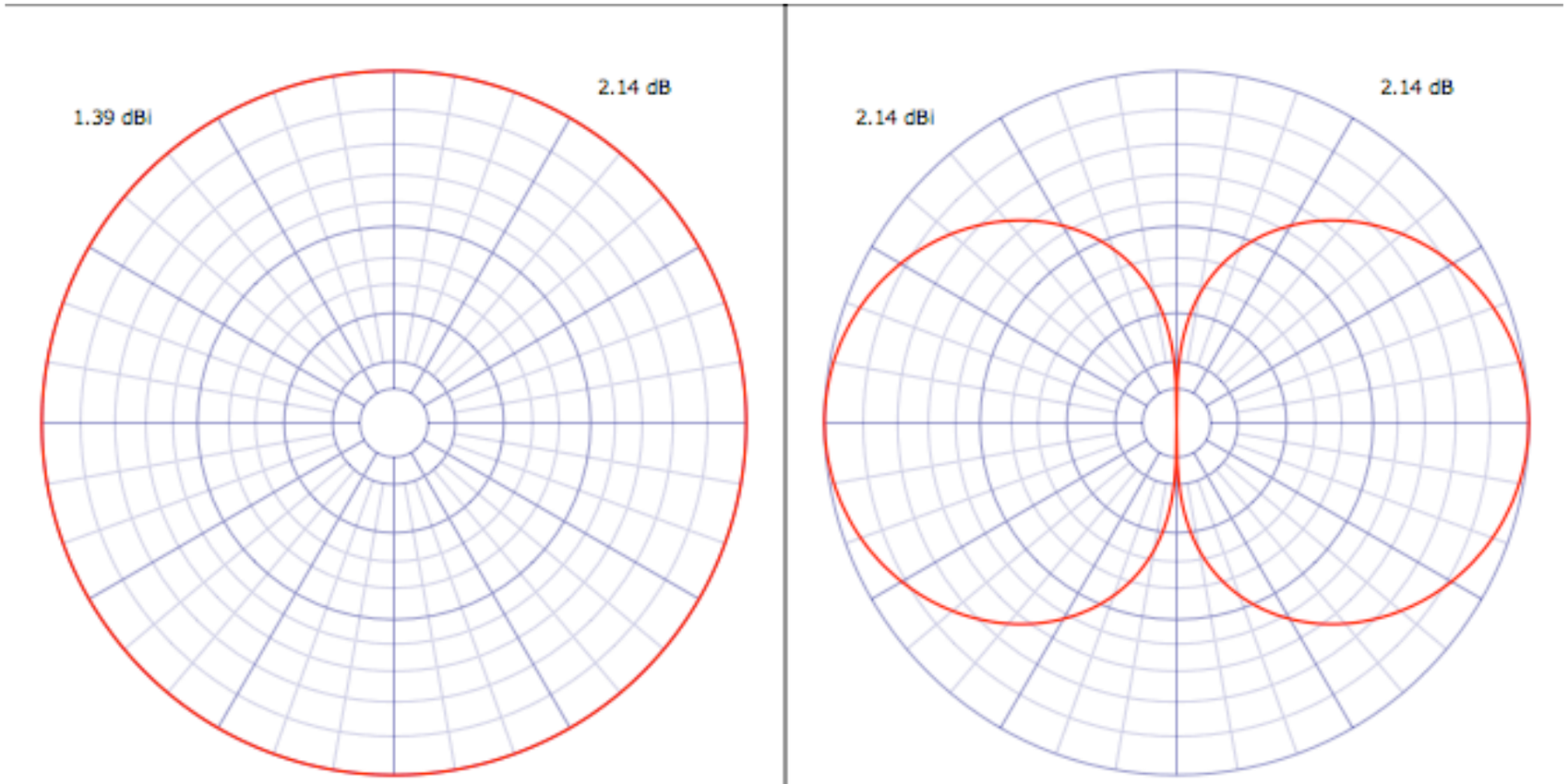
Use the formula 234 / f = arm length*

234 / 28.3 MHz = 8.27 feet

Each arm should be about 8-feet 4-inches.

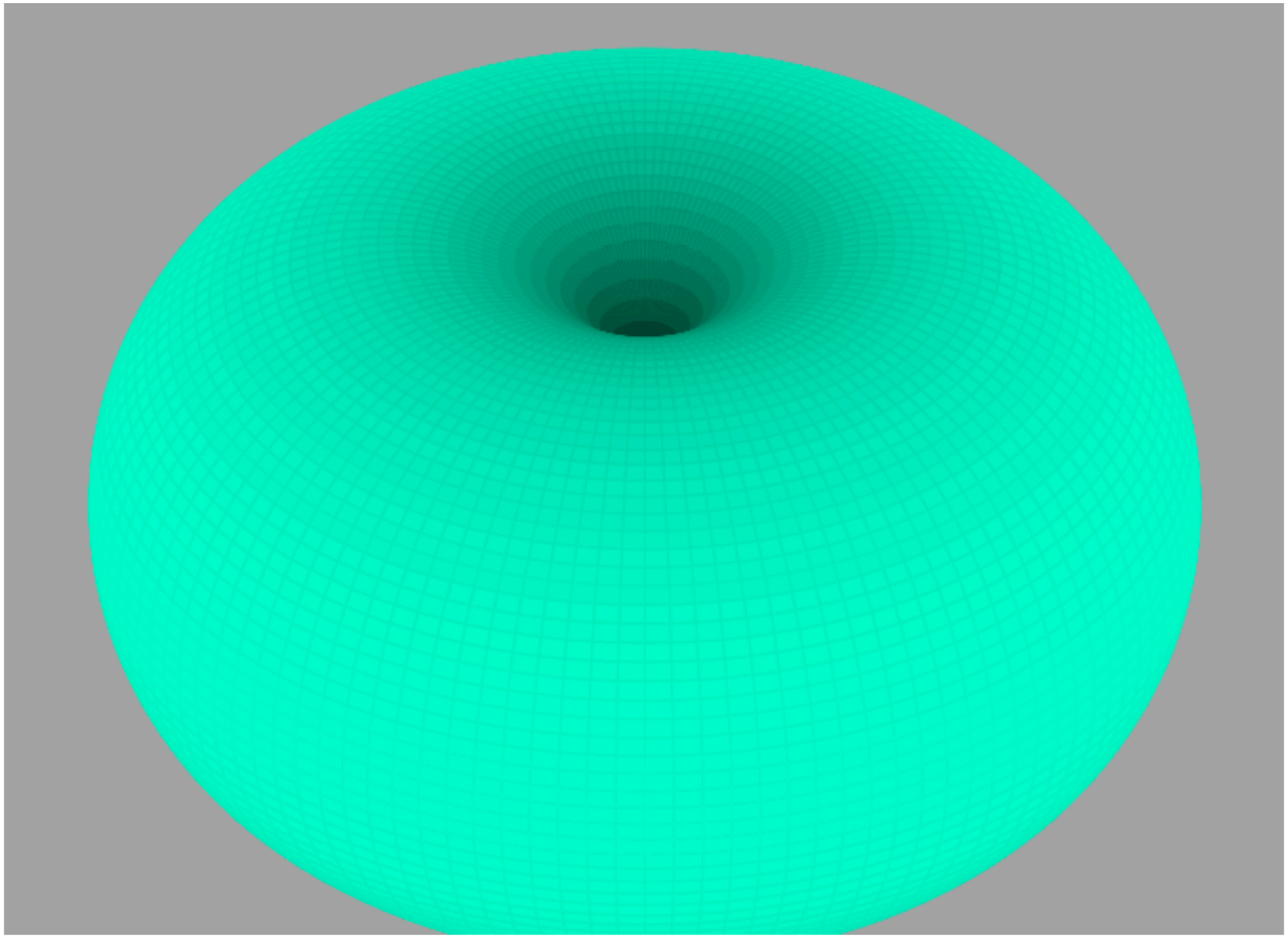
* See handout for why this formula works!

Dipole in free space

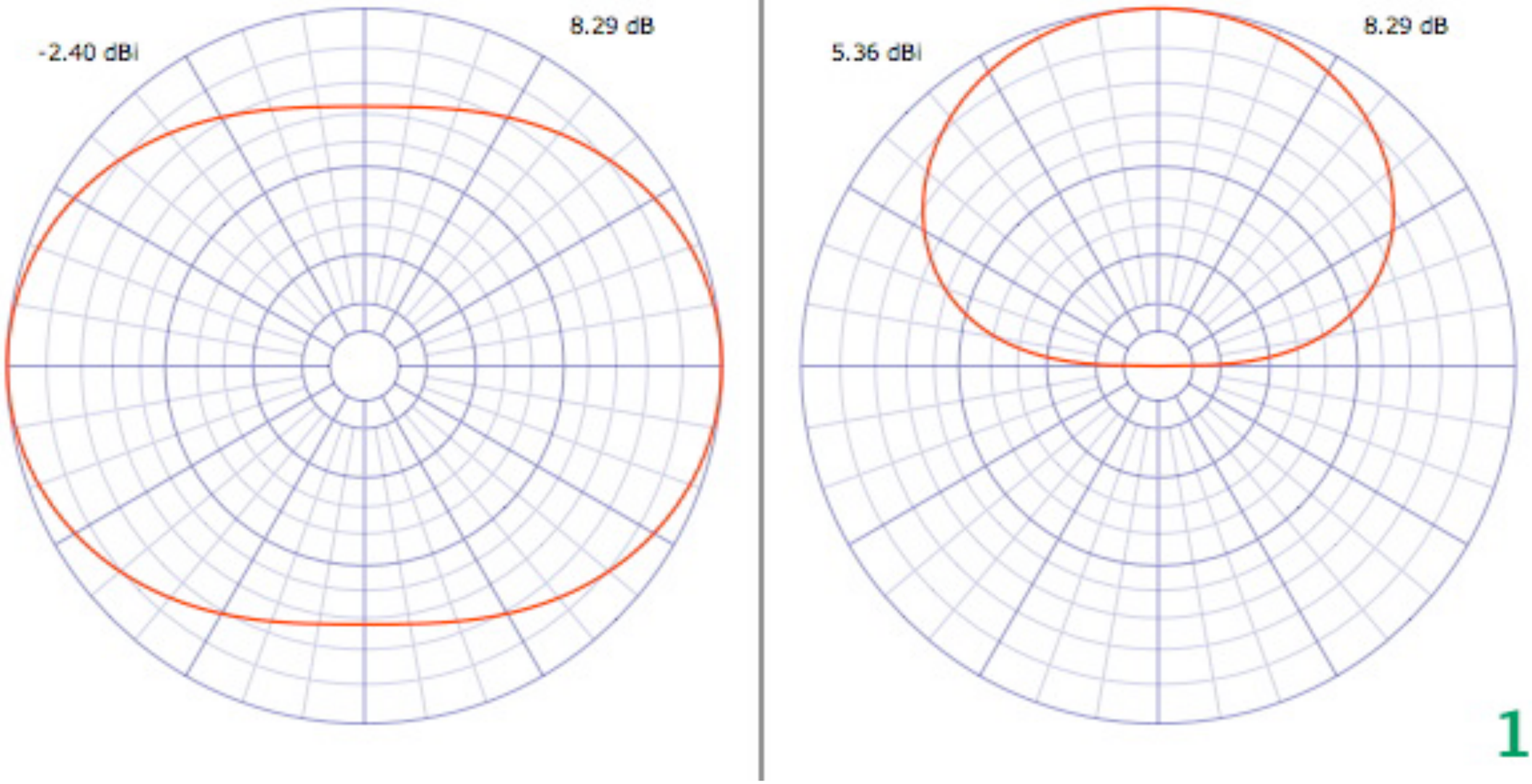


Frequency 28.300 MHz
Feedpoint(1) - Z: (73.616 + i 2.294) I: (1.0000 + i -0.0000)
VSWR(Zo=50 Ω): 1.5:1
Antenna is in free space.
Directivity: 2.14 dB
Max gain: 2.14 dBi (azimuth 180 deg., elevation 0 deg.)
Average Gain: 1.0077 (0.033 dB)

Dipole in free space 3D



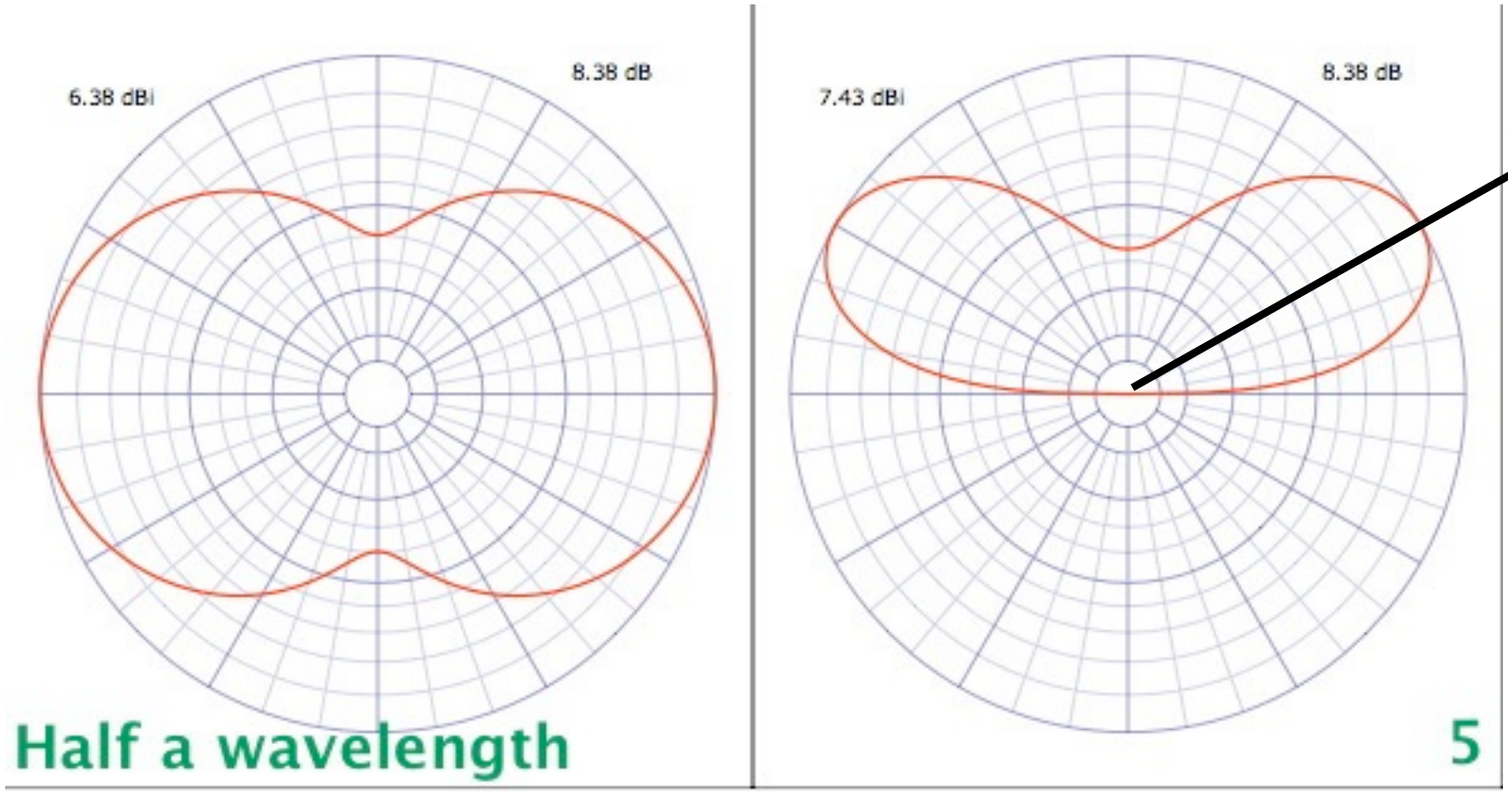
How high should we hang it?

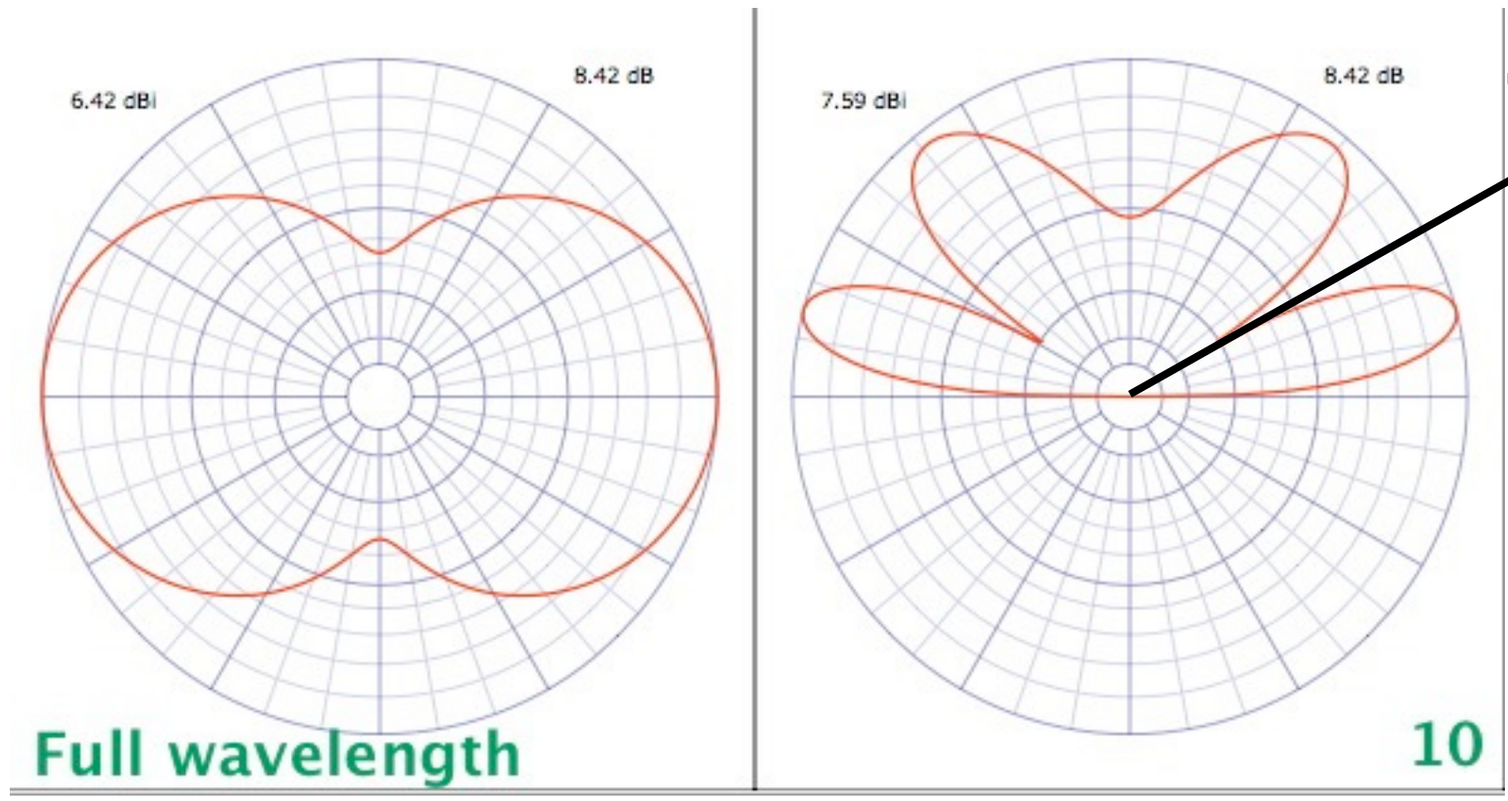


A good antenna... deployed badly... is a bad antenna

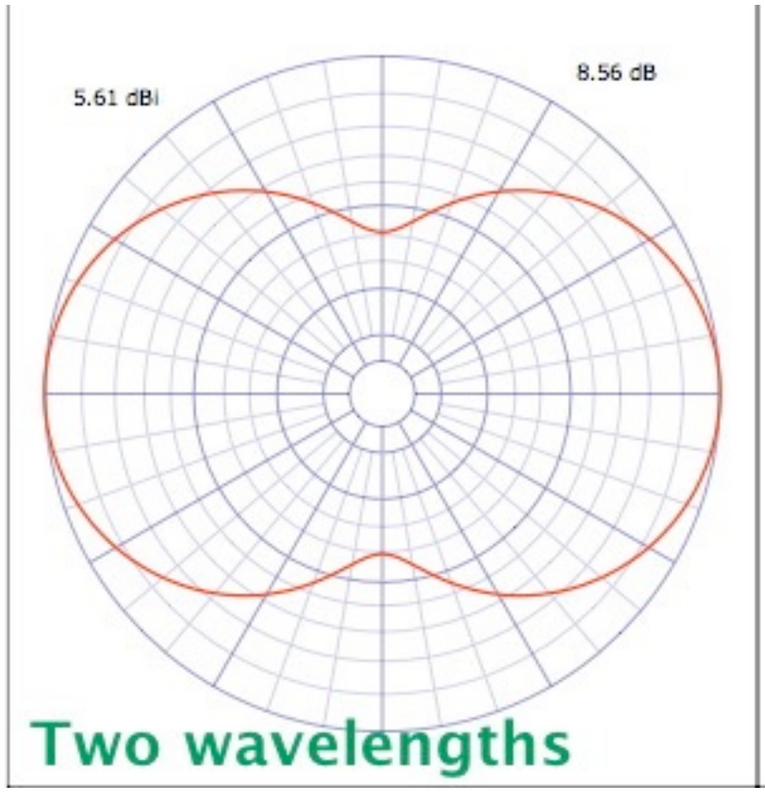
- Dubious advice:
  - Hang it as high as you can
  - Hang it E-W so it is broadside N-S
  - Trim it for lowest SWR

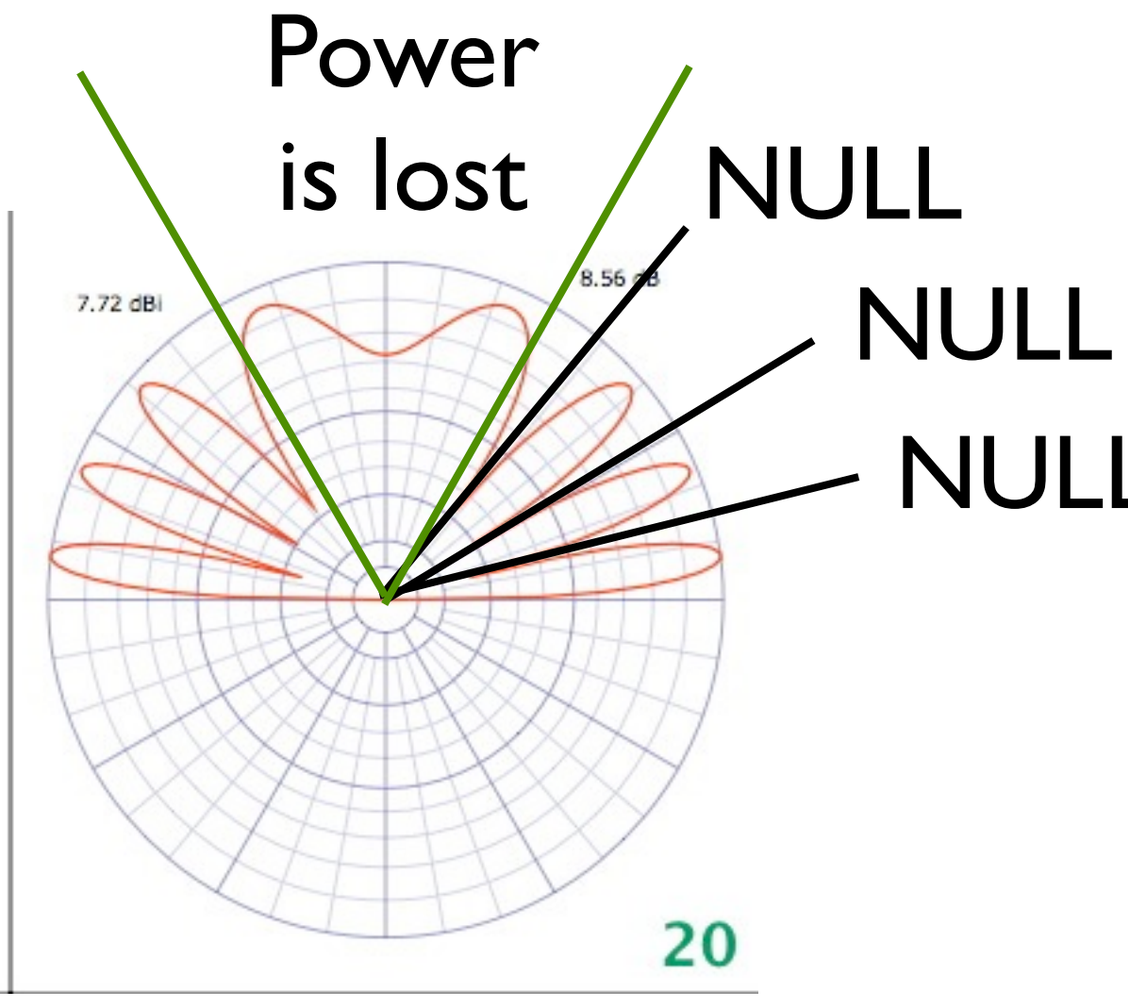
Hang it high?


6.38 dBi
8.38 dB
7.43 dBi
8.38 dB
30-degree
Half a wavelength
5

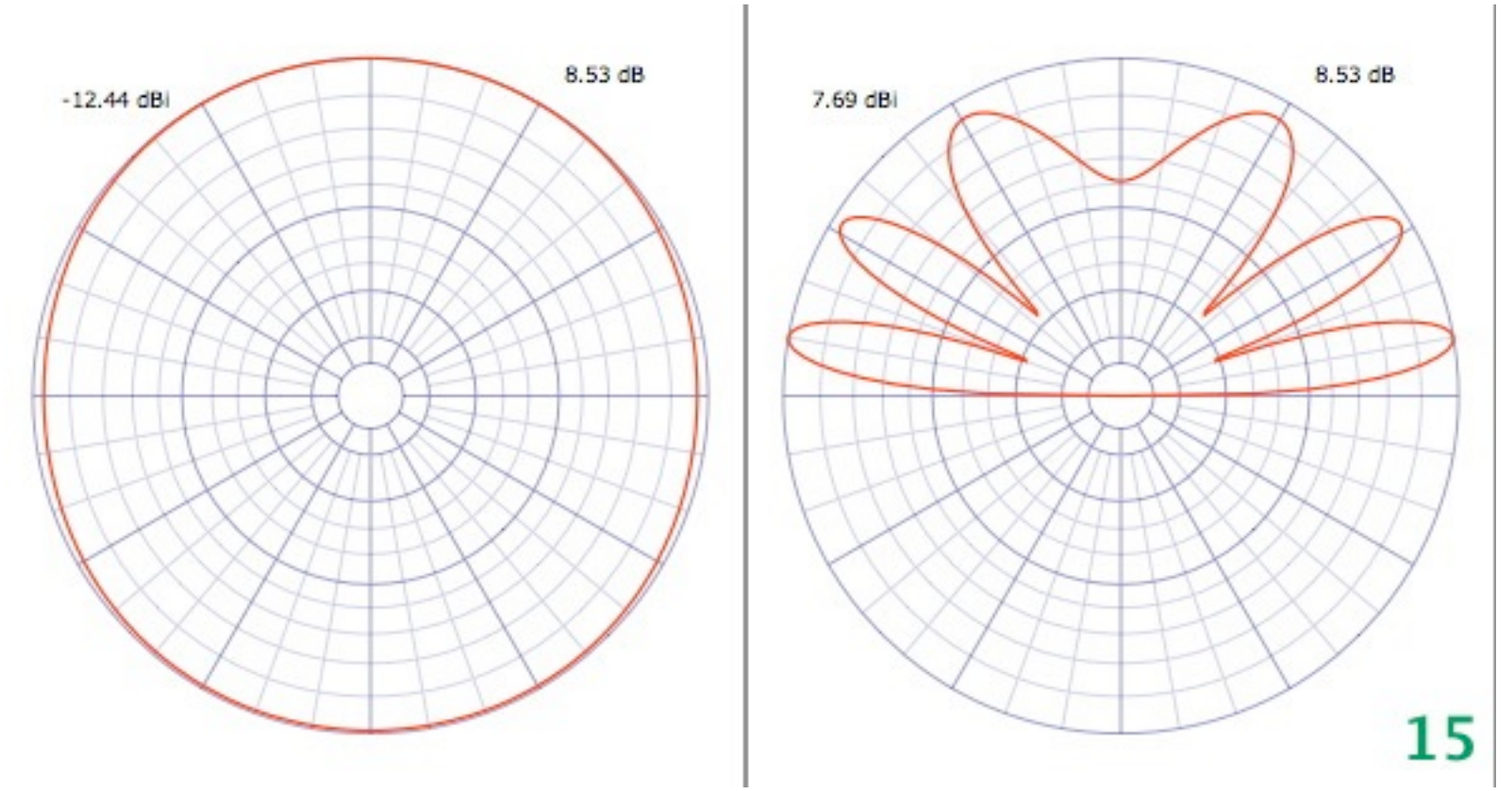

6.42 dBi
8.42 dB
7.59 dBi
8.42 dB
30-degree
null
Full wavelength
10

Hang it high?


5.61 dBi
8.56 dB
Two wavelengths


Power
is lost
NULL
NULL
7.72 dBi
8.56 dB
20

Hang it E-W for N-S?



That is usually right, but not always

Trim for lowest SWR

- The obsession about SWR is unhealthy
- The point of this exercise is to put out the most power to the most places
- Low SWR does not necessarily help with either!
- **In the next section I'll show an example of how you can hurt yourself by blindly optimizing for low SWR**

Part III

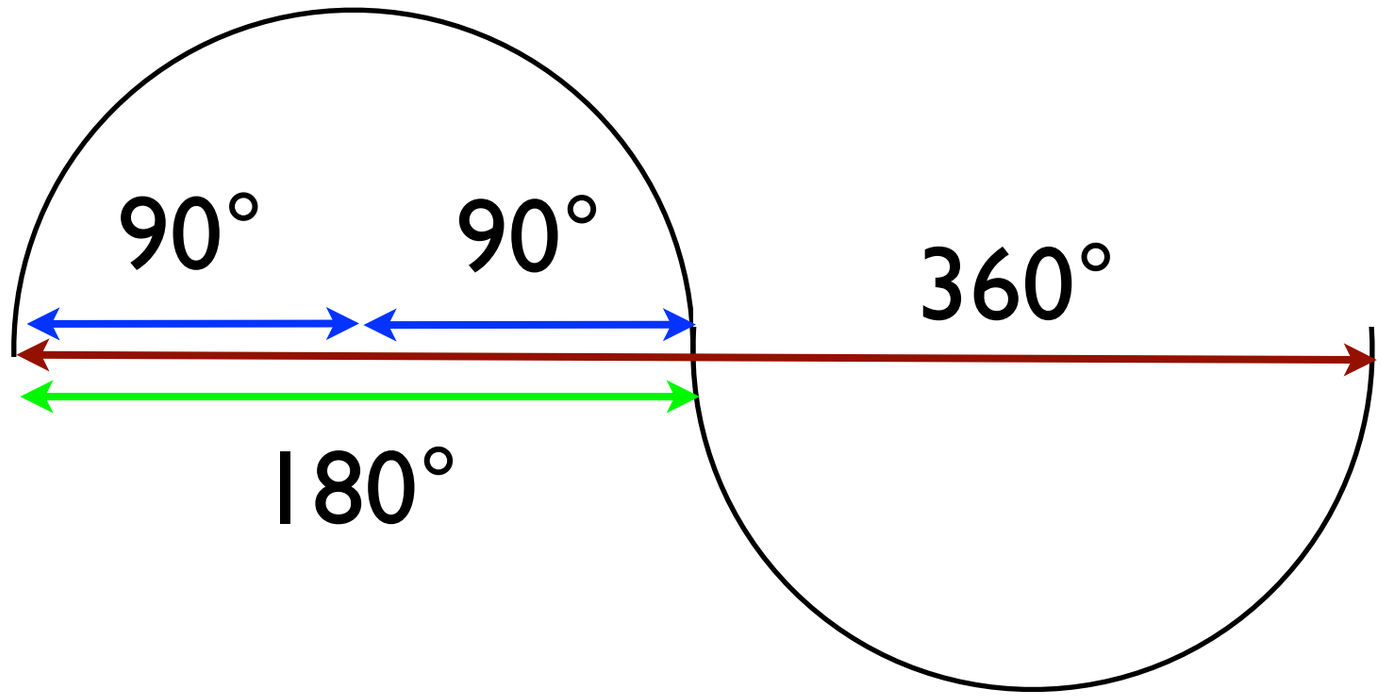
Verticals

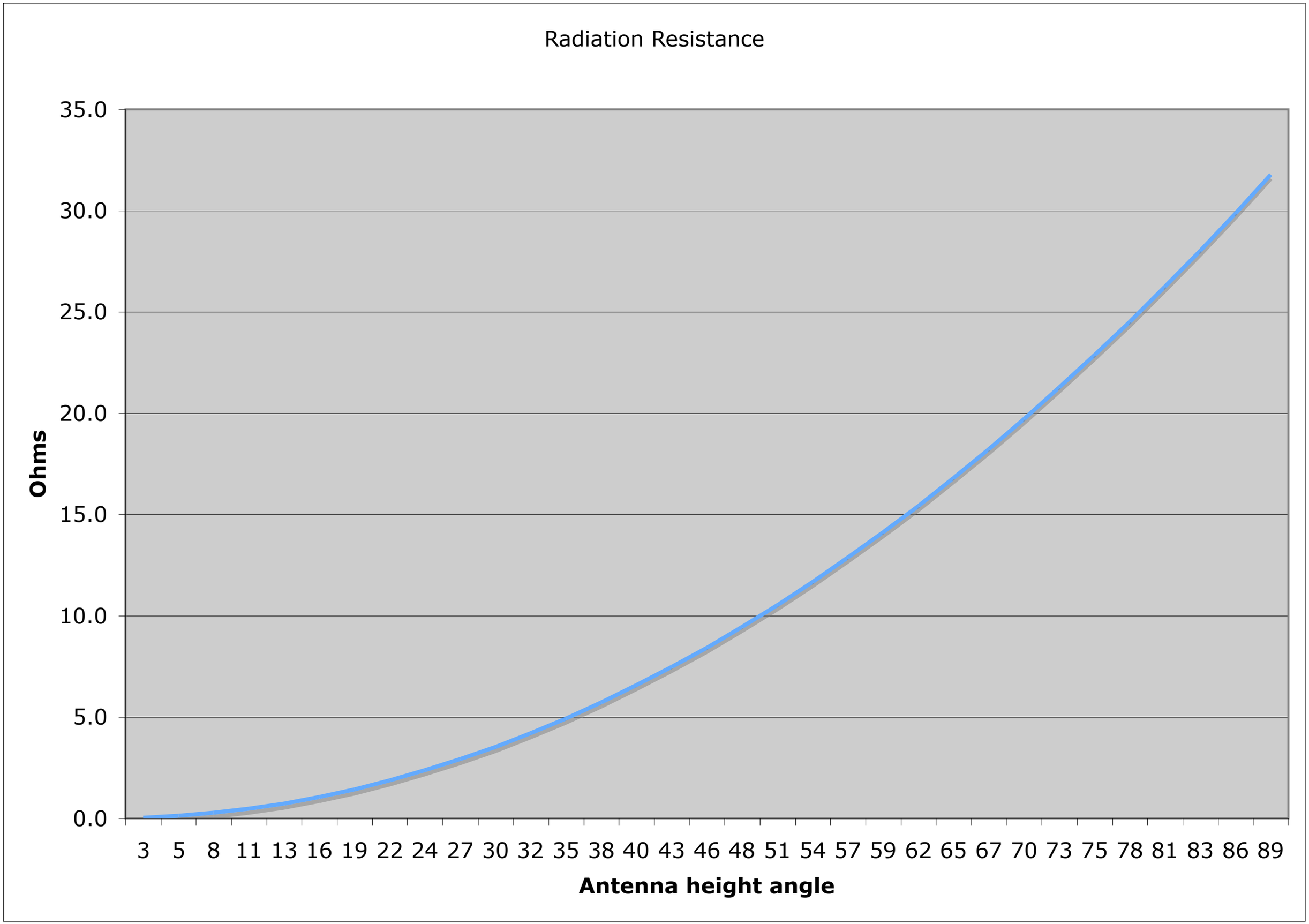
Shortened vertical

HamStick 40 Meter Mobile Antenna

- Low Profile Design
- Outstanding Performance
- 2 Piece Monoband
- 1/2" Hollow Fiberglass Base With Loading Coil Wound Directly On Covered With PVC Shrink Tubing
- Plate Brass Fitting
- 3/8" X 24 Male Threads That Fit Most Mobile Mounts
- 17-7 PH Tempered Stainless Steel Whip
- Slides Into Base For Easy Frequency Adjustment
- 7' Long

Angles

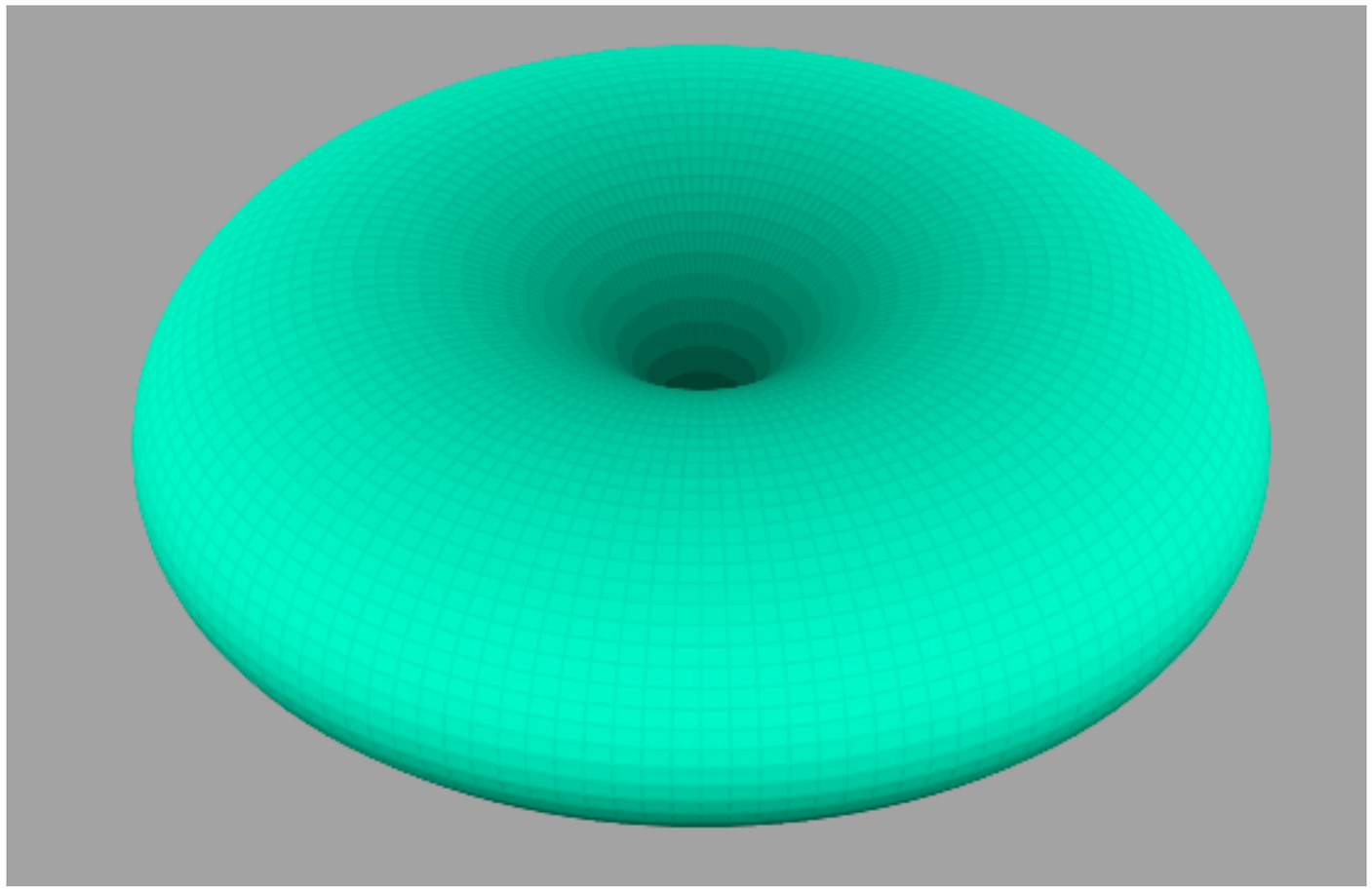



Radiation Resistance
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Ohms
3 5 8 11 13 16 19 22 24 27 30 32 35 38 40 43 46 48 51 54 57 59 62 65 67 70 73 75 78 81 83 86 89
Antenna height angle

1% efficient?!

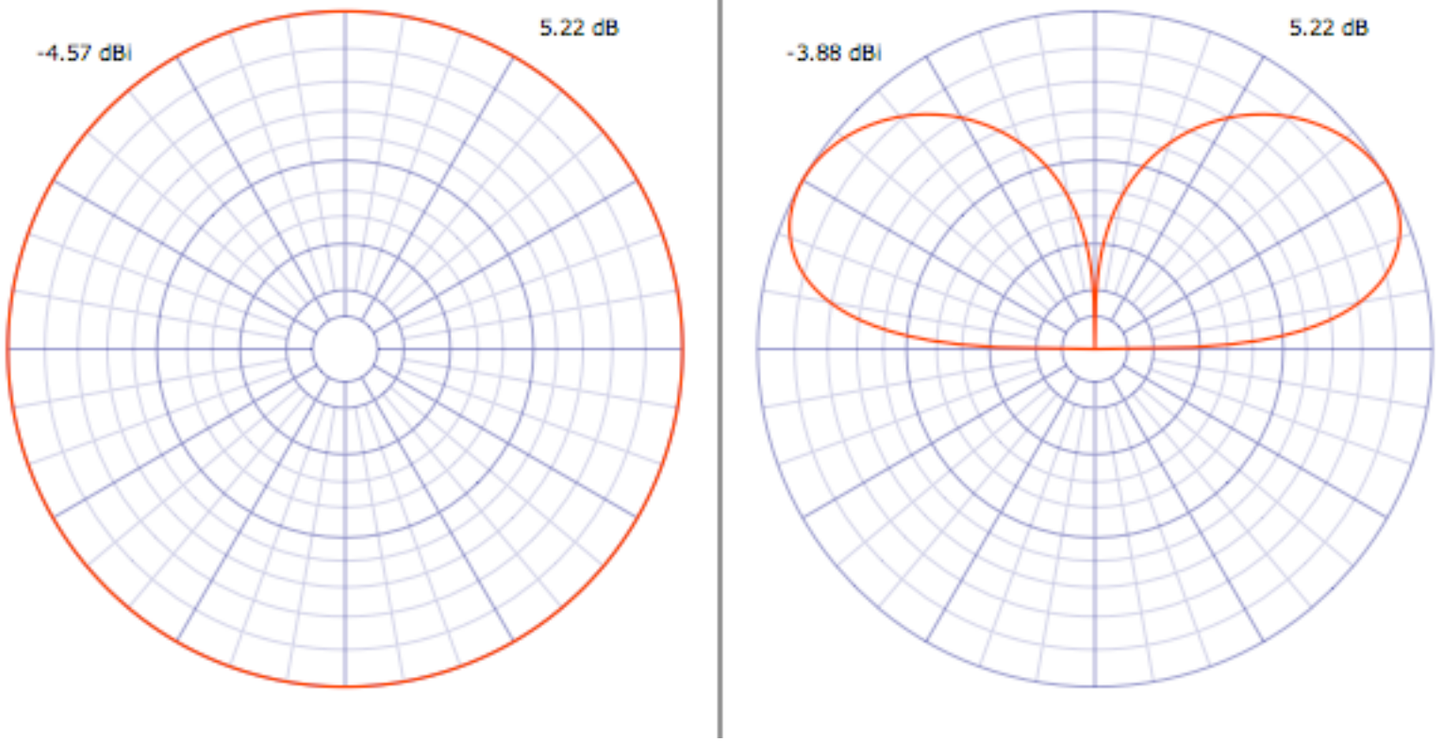
- Compare this to a full-sized dipole (which is nearly 100% efficient)
- Power ratio of 100:1
- This is about 20dB
- This comes out to be about 3-4 S-units
- (There are all sorts of assumptions in here! Reader beware!)

10m 1/4 wave vertical



This is the radiation pattern of a quarter-wave vertical radiator with 30 radials just above good ground

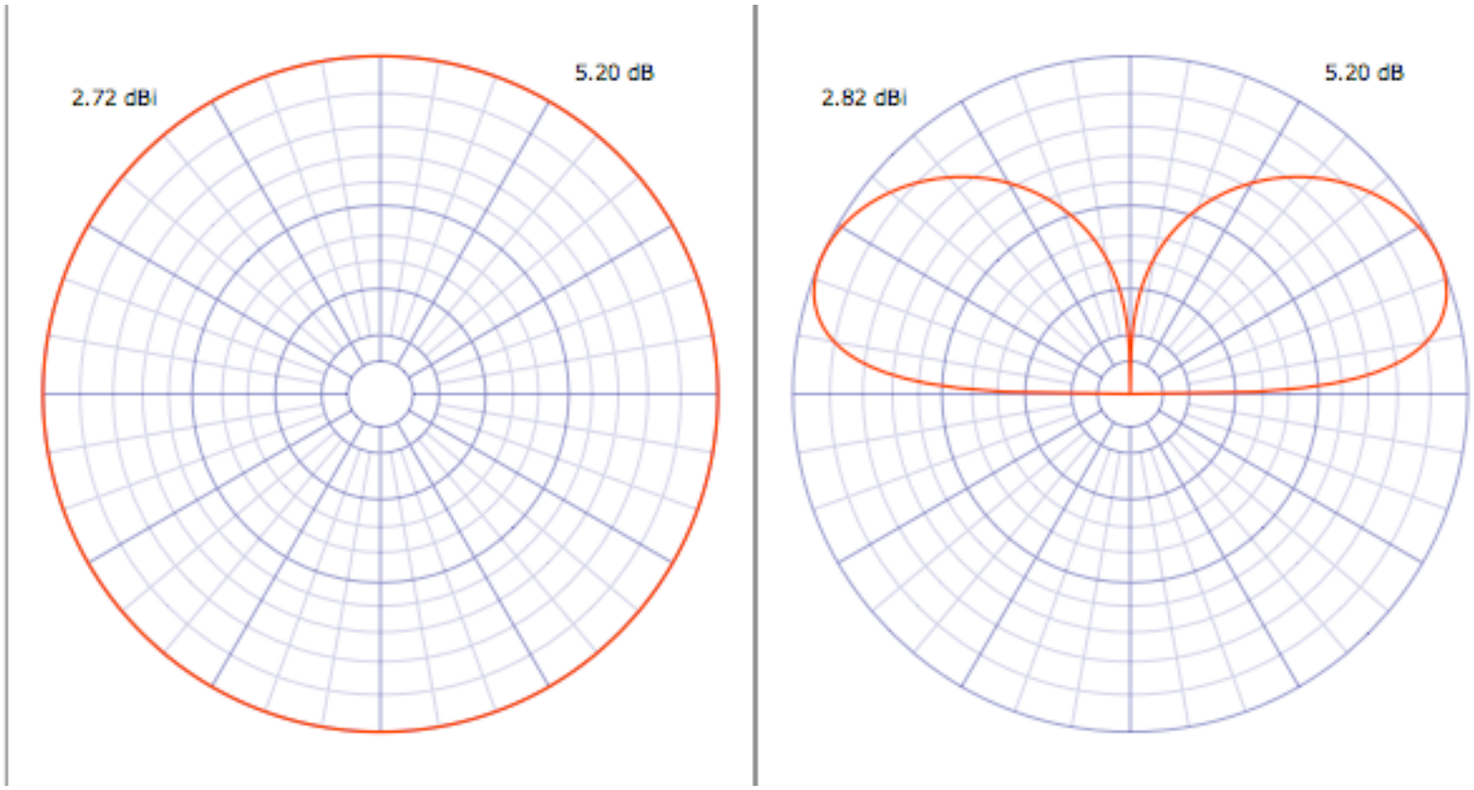
10m vertical
poor radials, resonant



Radiator length = 2.5m

Frequency 29.000 MHz
Feedpoint(1) - Z: (45.258 - i 4.131) VSWR(Zo=50 Ω): 1.1:1
Max gain: -3.88 dBi (azimuth 180 deg., elevation 30 deg.)
Average Gain: 0.1240 (9.065 dB)

10m vertical
16 radials, resonant



Radiator length = 2.5m

Frequency 28.300 MHz
Feedpoint(1) - Z: (18.668 - i 0.604) VSWR(Zo=50 Ω): 2.7:1
Max gain: 2.82 dBi (elevation 23 deg.)
Average Gain: 0.5834 (2.340 dB)

Comparing 10m verticals

	"Tuned"	**Correct**
Impedance	~46	~19
SWR	1.1:1	2.7:1
Max gain	-3.88 dBi	2.82 dBi
Efficiency	Very bad	Pretty good

The difference is 6.7 dB. This means
75% of your power is lost by
"tuning" the antenna for low SWR

SWR

- SWR tells you when the antenna impedance is close to some value
- SWR does not tell you when the antenna is resonant
- SWR does not help you find maximum current and radiation
- SWR tells you nothing about losses
- SWR tells you nothing about the pattern

Antenna tuners

- If you are not careful you could just be adding losses
- Autotuners can add losses quickly and easily! :-)
- This isn't to say tuners are bad; you just need to know what you are tuning
- Tuners should be used to make the system resonant, not just lower SWR

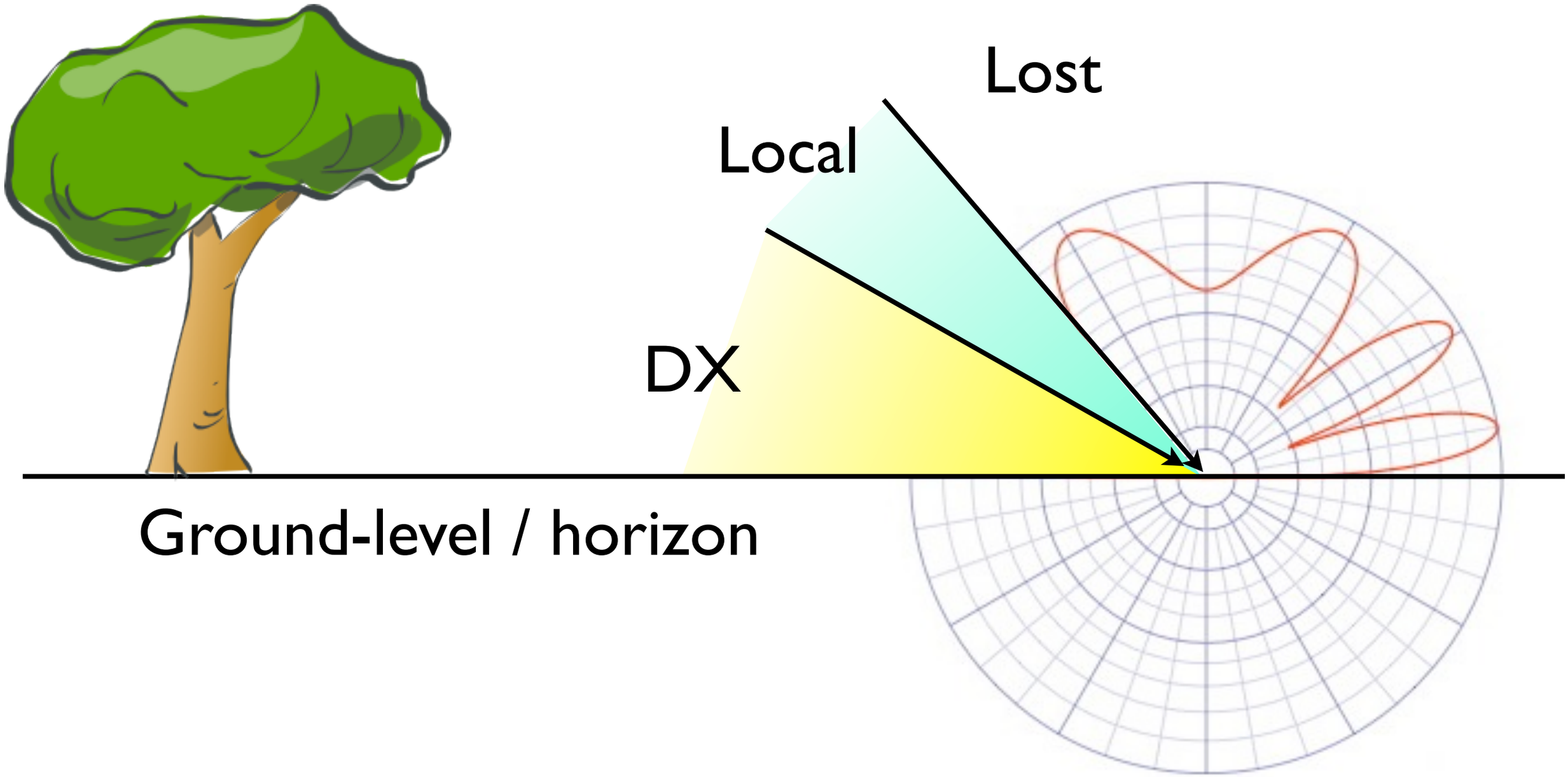
PART IV

Multi-band antennas

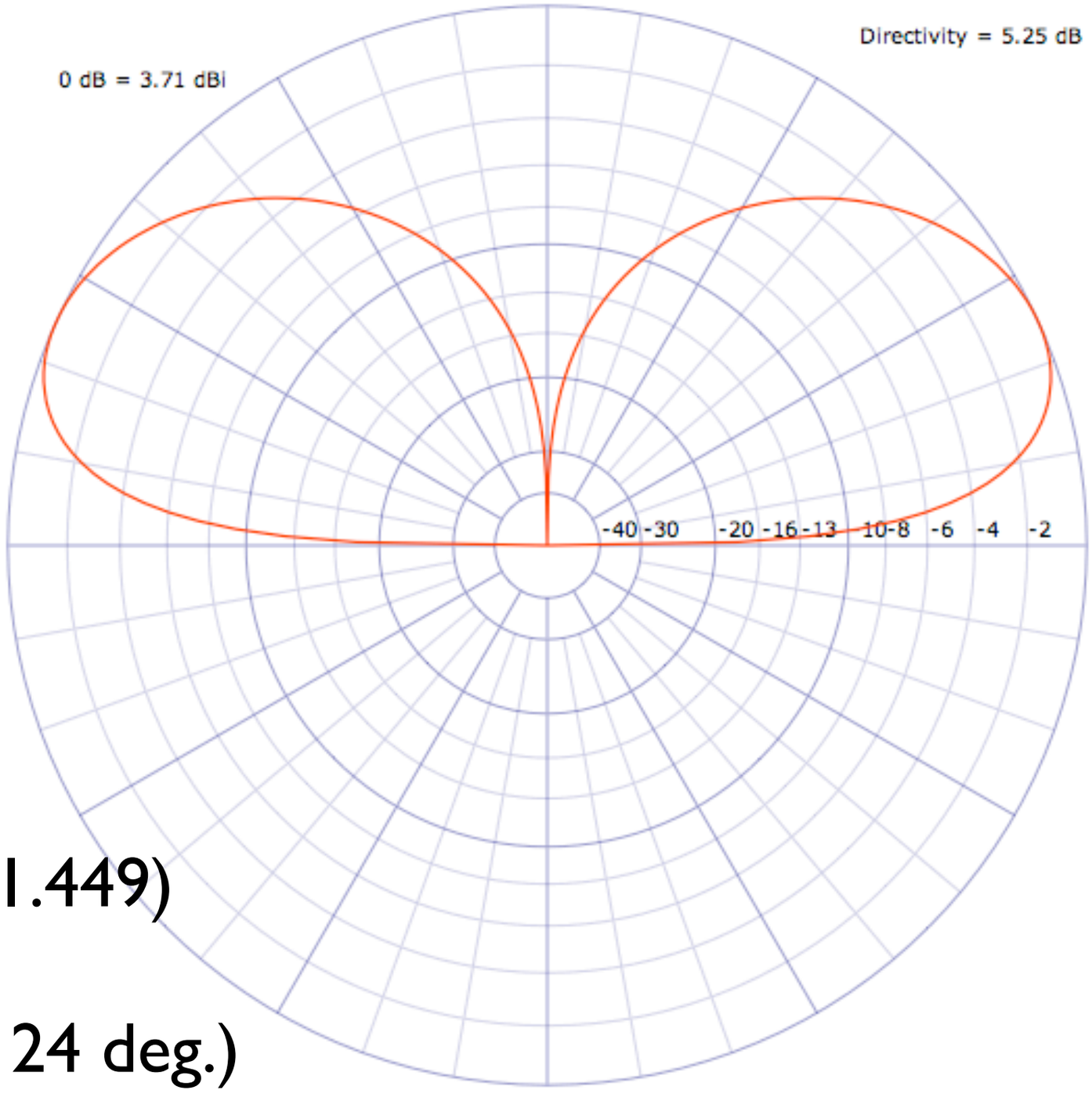
43 foot vertical

- Very popular multiband antenna
- Single radiator 43-foot high with radials
- 4:1 unun used to feed it (50 ohms to 200)
- Matches on 10m-80m with tuner
- Even 160m is in reach with additional loading
- BUT: are multiband antennas effective on all bands?

Arrival angles

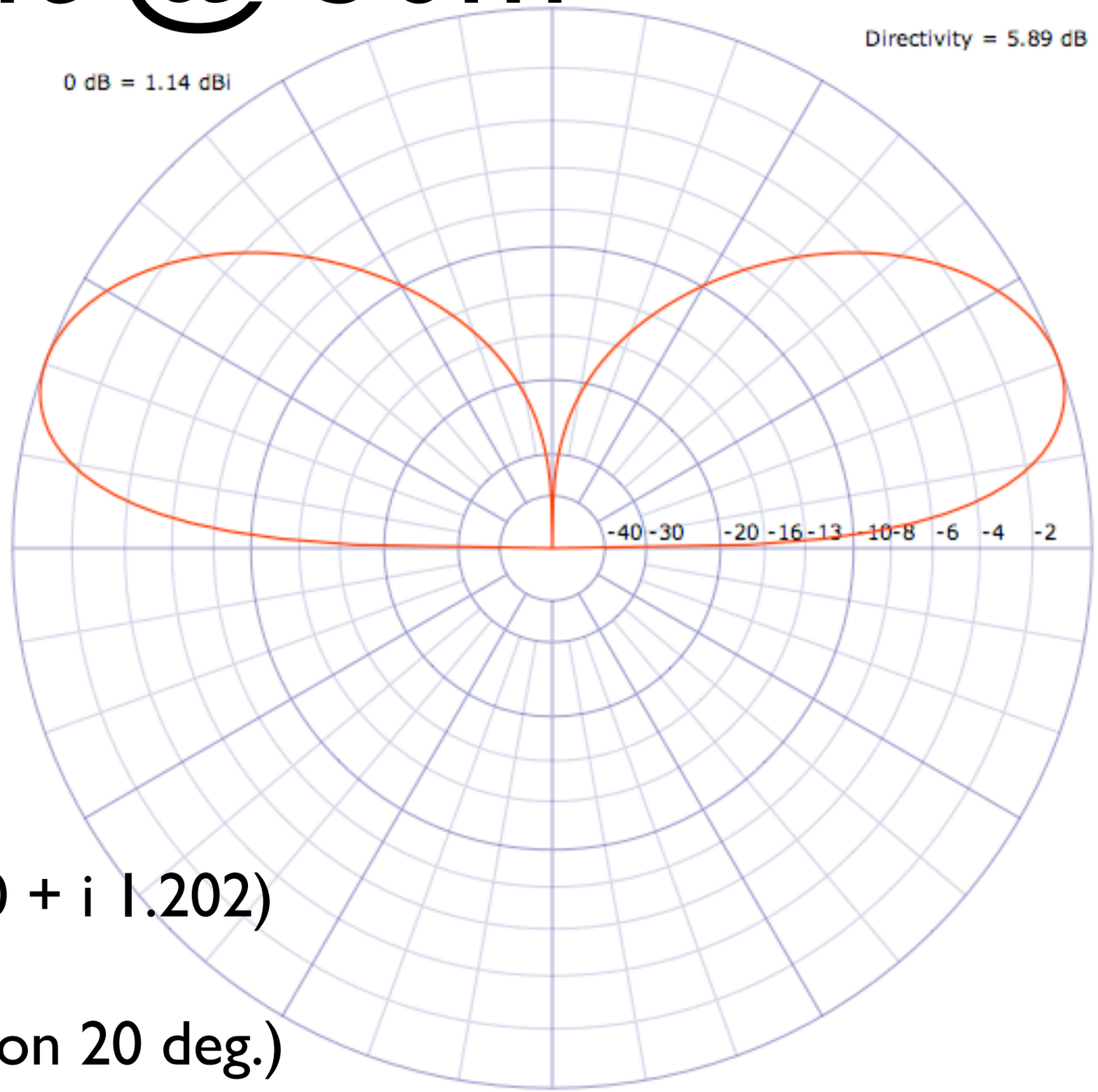


43ft @ 40m



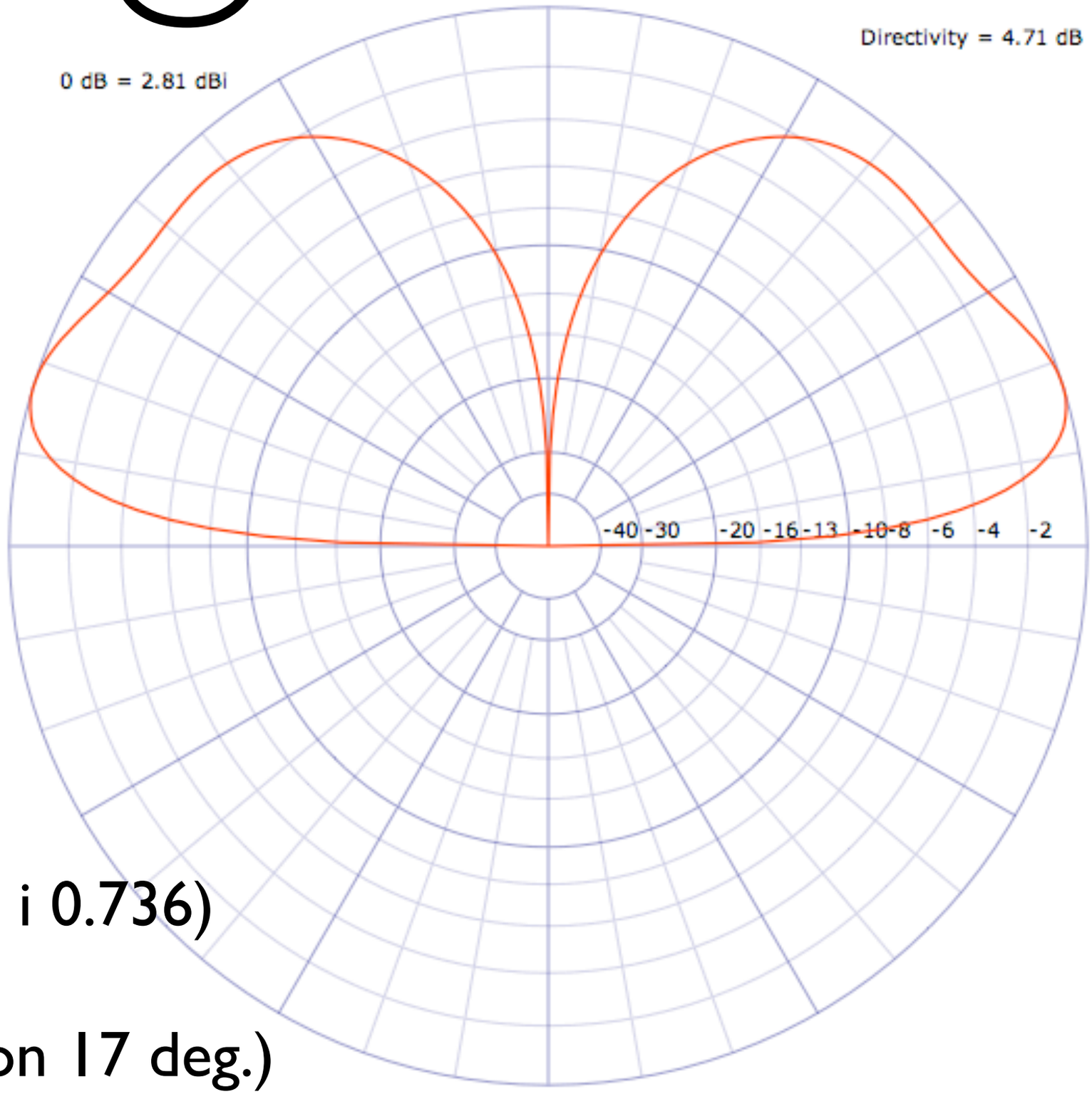
Frequency 7.000 MHz
Feedpoint(1) - Z: (29.536 - i 1.449)
VSWR(Zo=200 Ω): 6.8:1
Max gain: 3.71 dBi (elevation 24 deg.)

43ft @ 30m



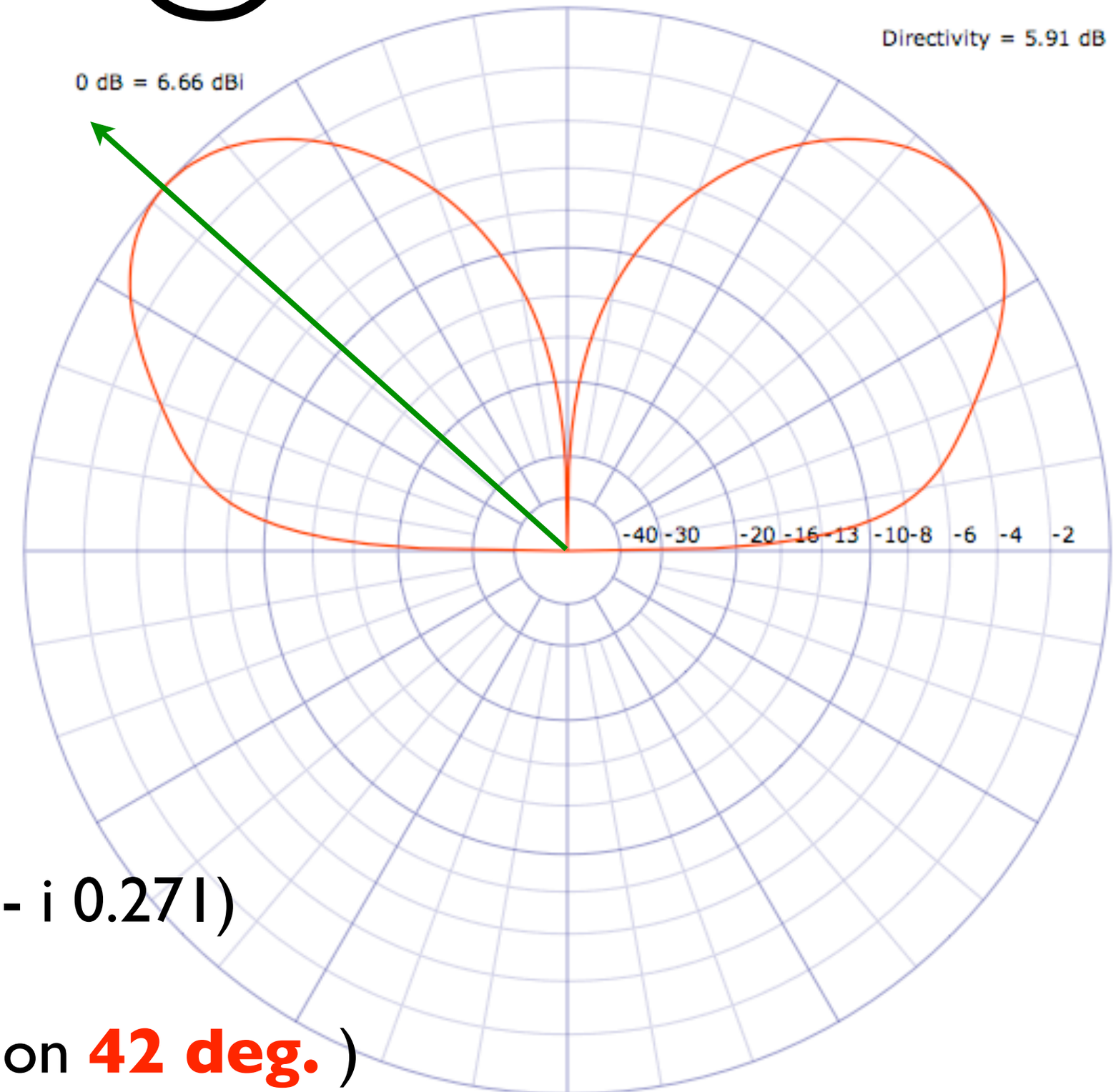
Frequency 10.100 MHz
Feedpoint(1) - Z: (409.590 + i 1.202)
VSWR(Zo=200 Ω): 2.0:1
Max gain: 1.14 dBi (elevation 20 deg.)

43ft @ 20m



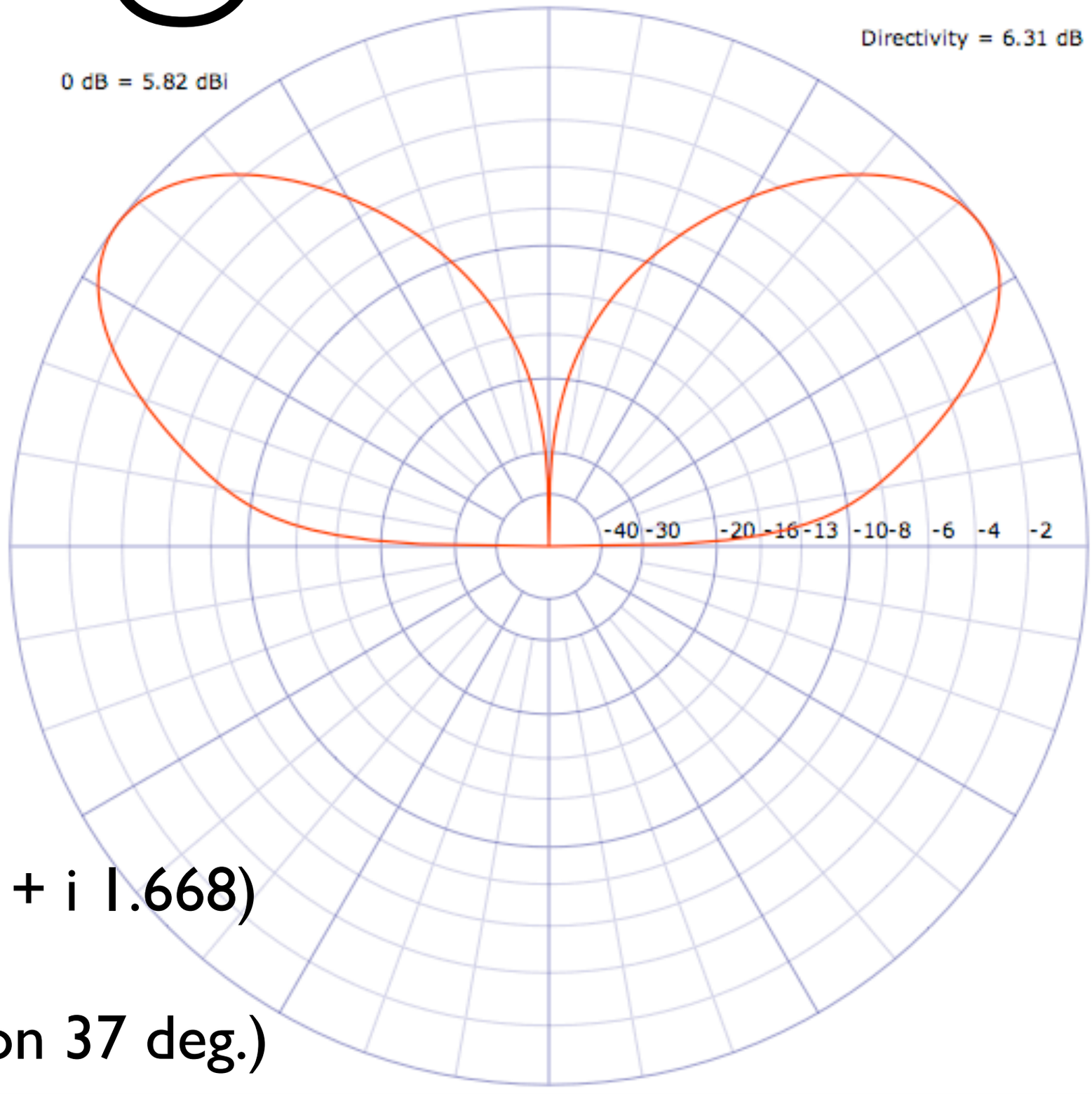
Frequency 14.100 MHz
Feedpoint(1) - Z: (61.080 - i 0.736)
VSWR(Zo=200 Ω): 3.3:1
Max gain: 2.81 dBi (elevation 17 deg.)

43ft @ 17m



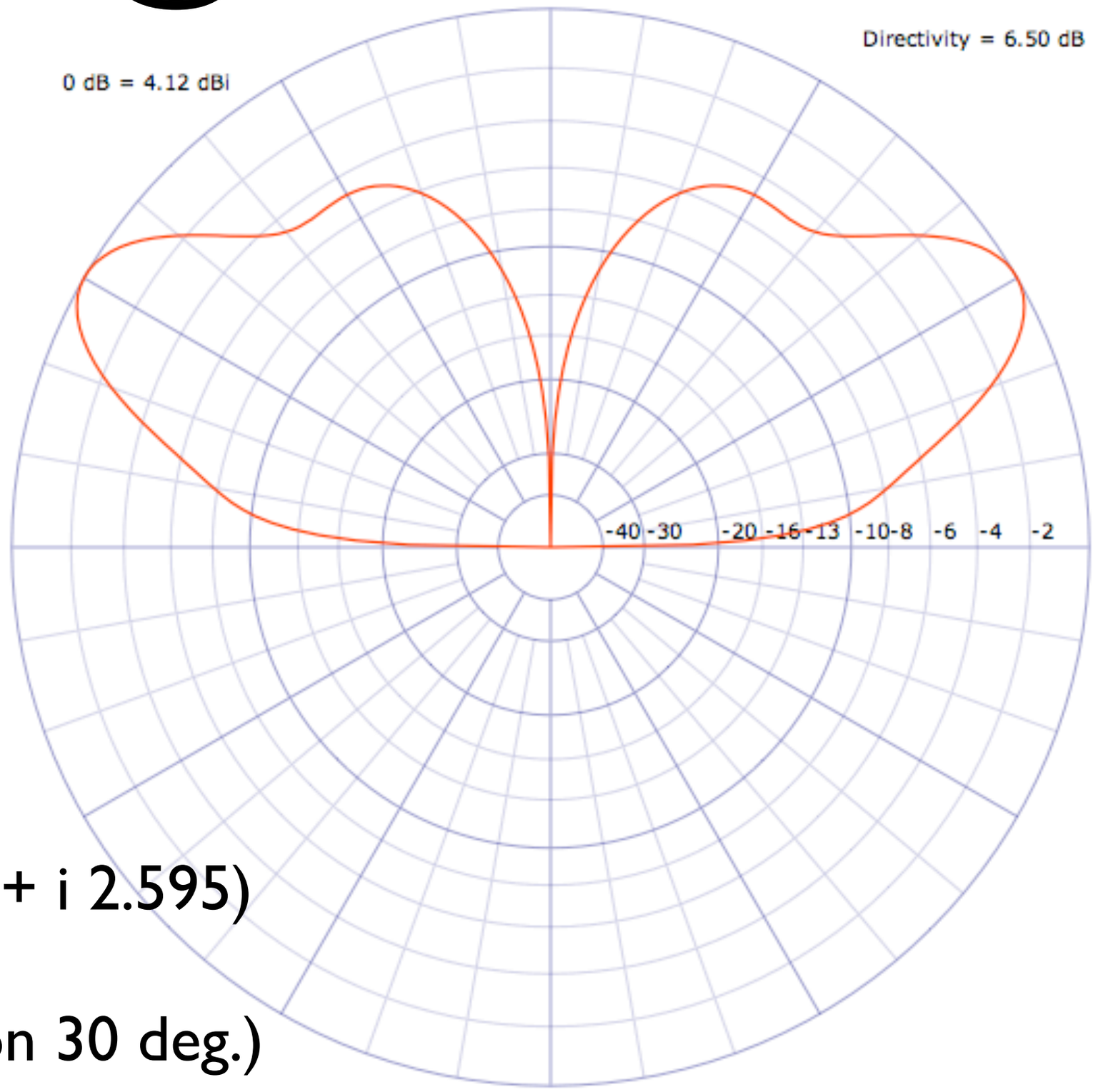
Frequency 18.100 MHz
Feedpoint(1) - Z: (59.412 - i 0.271)
VSWR(Zo=200 Ω): 3.4:1
Max gain: 6.66 dBi (elevation **42 deg.**)

43ft @ 15m



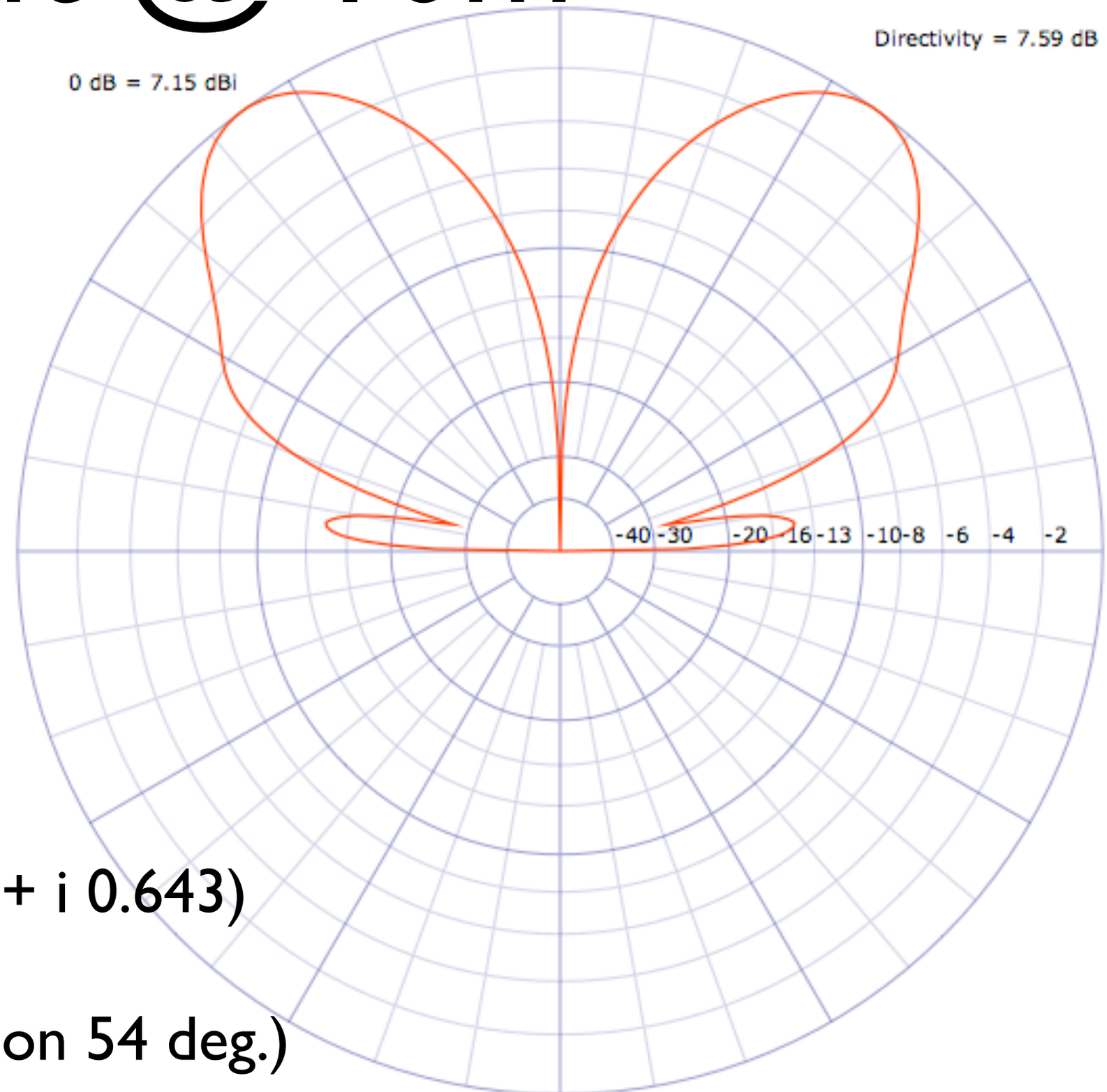
Frequency 21.100 MHz
Feedpoint(1) - Z: (239.500 + i 1.668)
VSWR(Zo=200 Ω): 1.2:1
Max gain: 5.82 dBi (elevation 37 deg.)

43ft @ 12m



Frequency 24.900 MHz
Feedpoint(1) - Z: (191.960 + i 2.595)
VSWR(Zo=200 Ω): 1.0:1
Max gain: 4.12 dBi (elevation 30 deg.)

43ft @ 10m



Frequency 28.400 MHz
Feedpoint(1) - Z: (47.996 + i 0.643)
VSWR(Zo=200 Ω): 4.2:1
Max gain: 7.15 dBi (elevation 54 deg.)

Multi-band antennas...

- ... are a compromise on most bands
- They are either too long or too short for a given band
- Great SWR means nothing if the pattern is awful
- Cloud-warming and deep nulls mean you miss out on lots of cool DX

All that said...

Any antenna is better than no antenna!

Just don't confuse "any antenna" for "a great antenna"

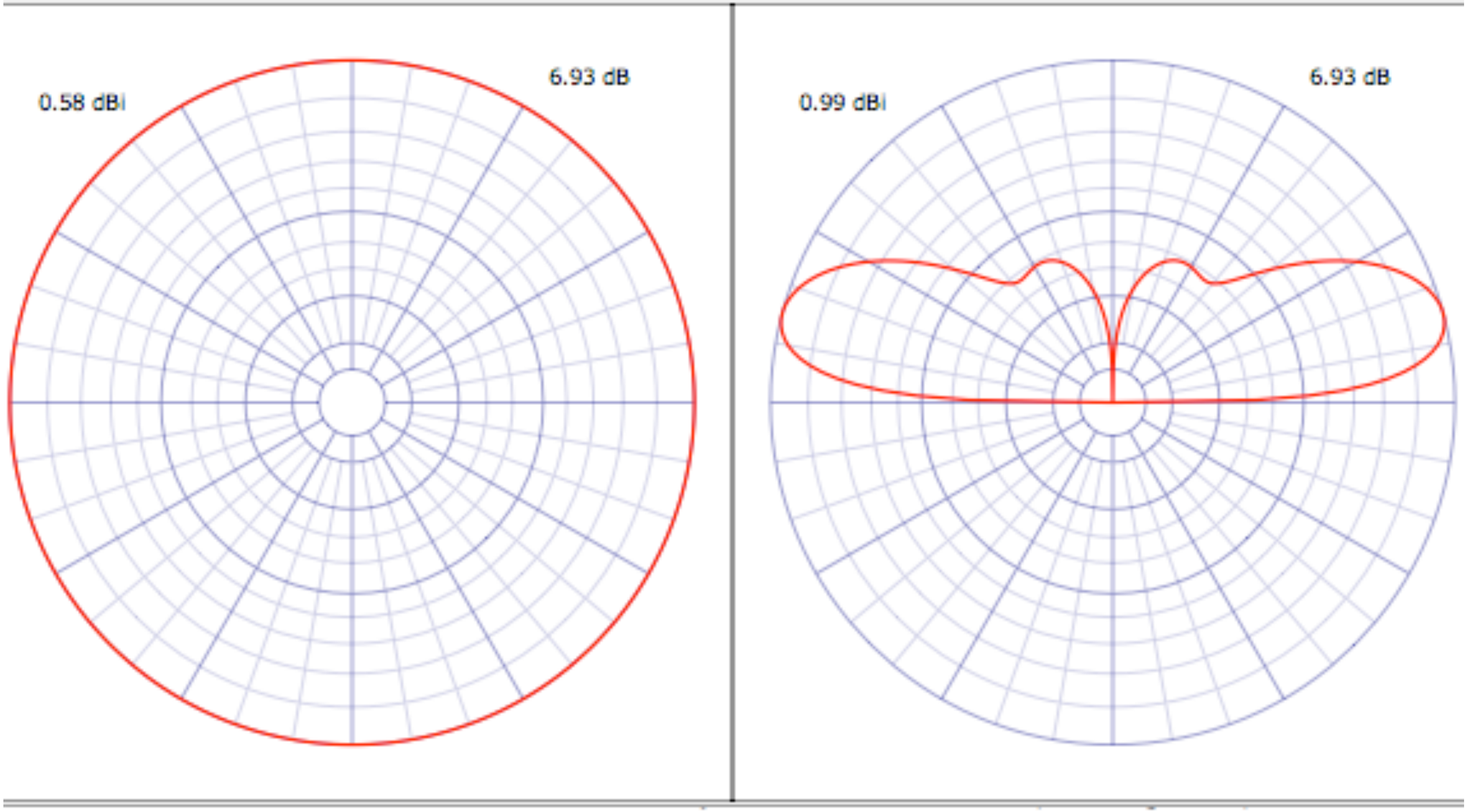
PART V

Vertical Dipoles

Vertical dipoles

- Built like a regular dipole
- Hung vertically instead of horizontally
- Feedline pulled away at ~45-degree angle
- Only requires one rope to hang it
- Can be hung easily even in densely forested area
- Can be center-fed or fed other ways
- Monoband, center-fed units can be made cheaply

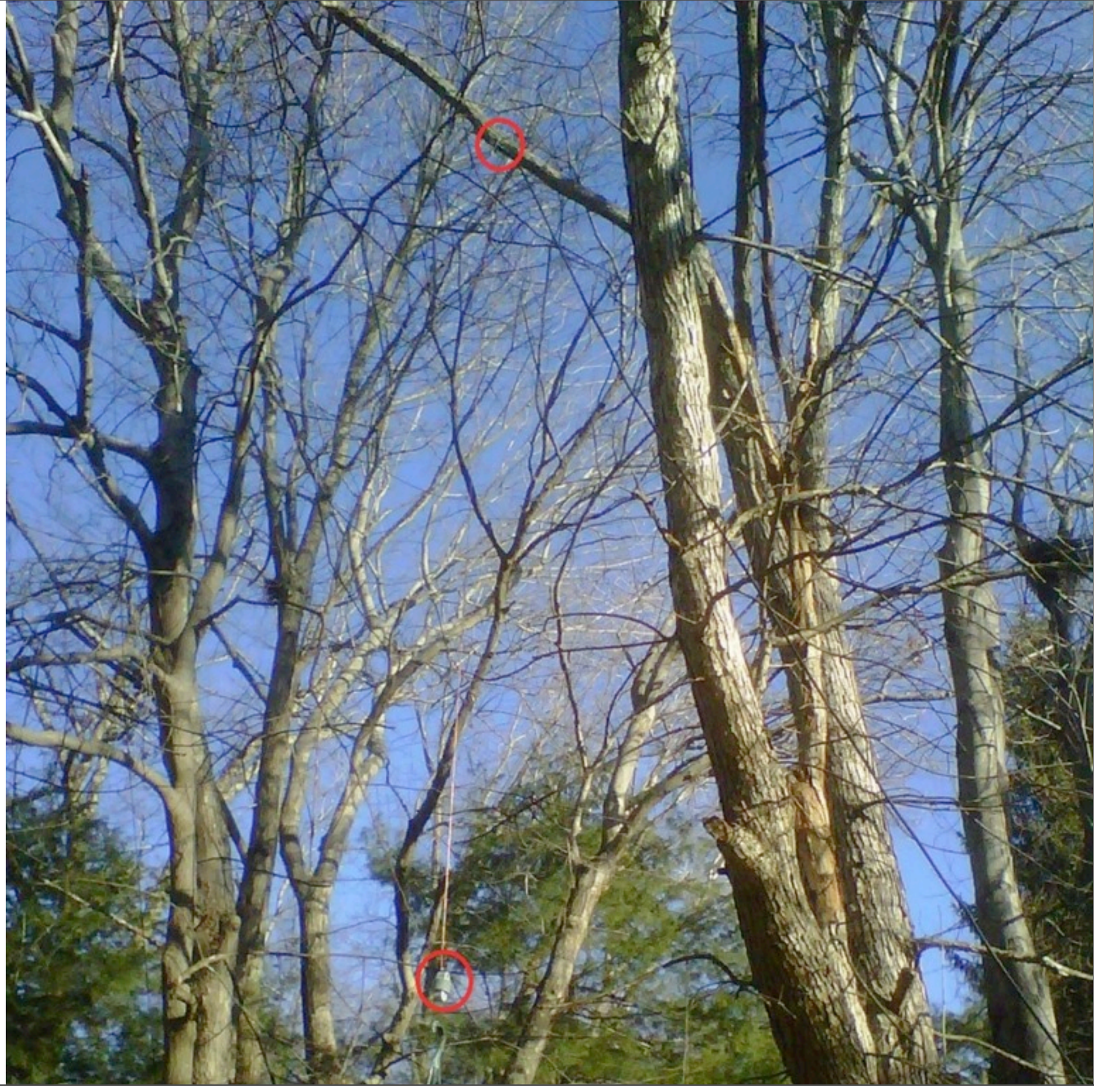
Center piece

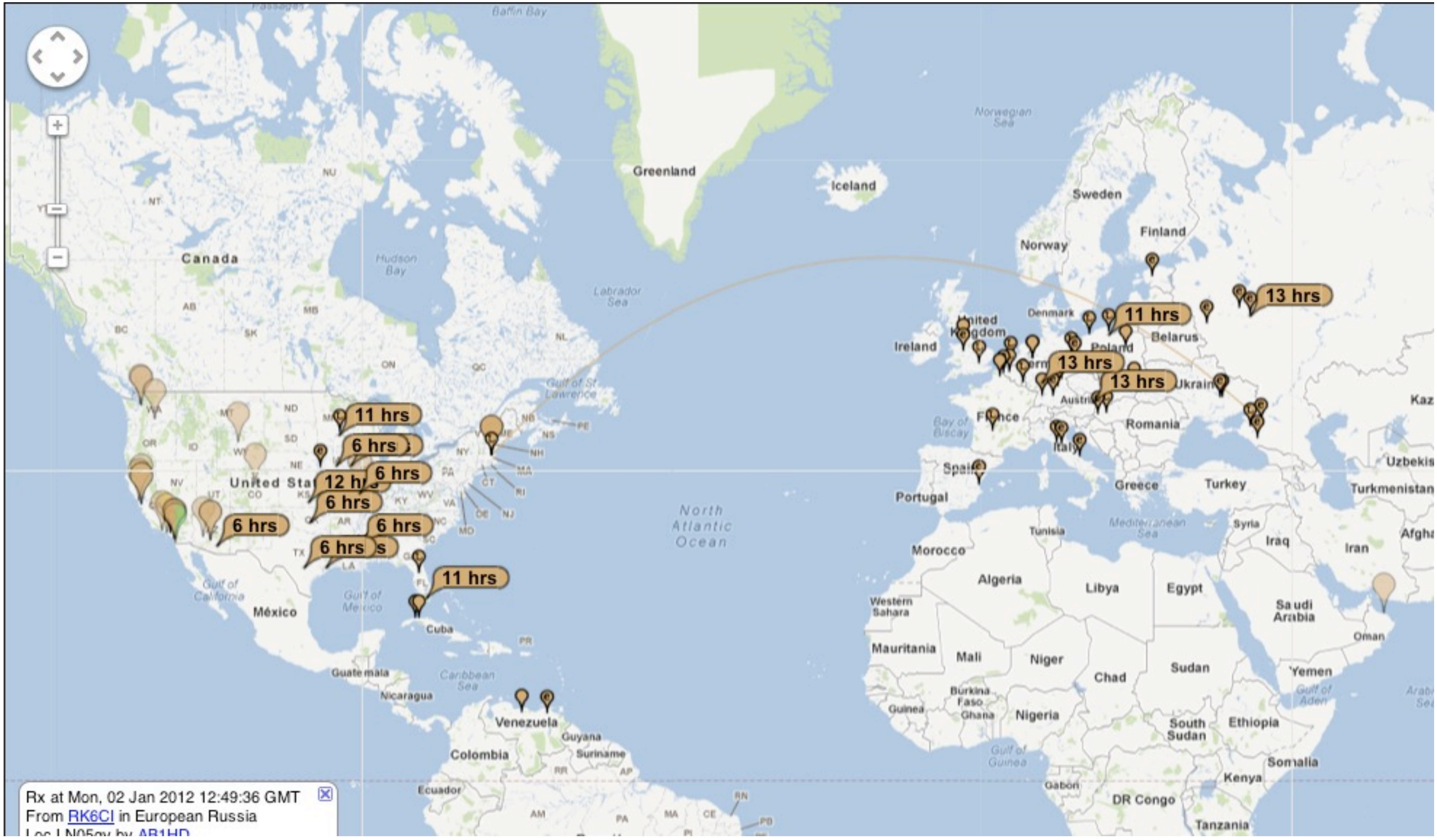


15m up 1m

ABIHD

15m vertical dipole

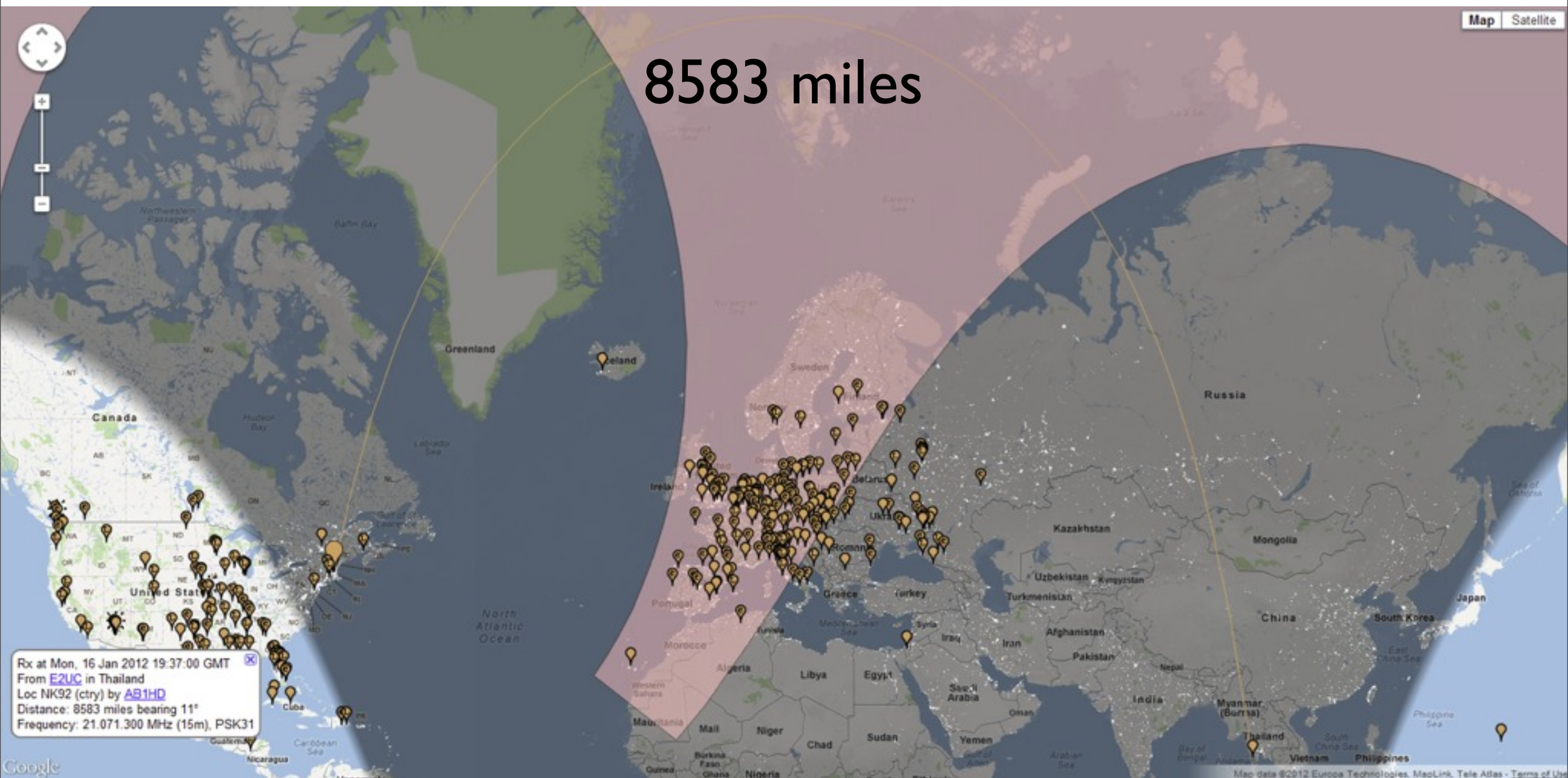


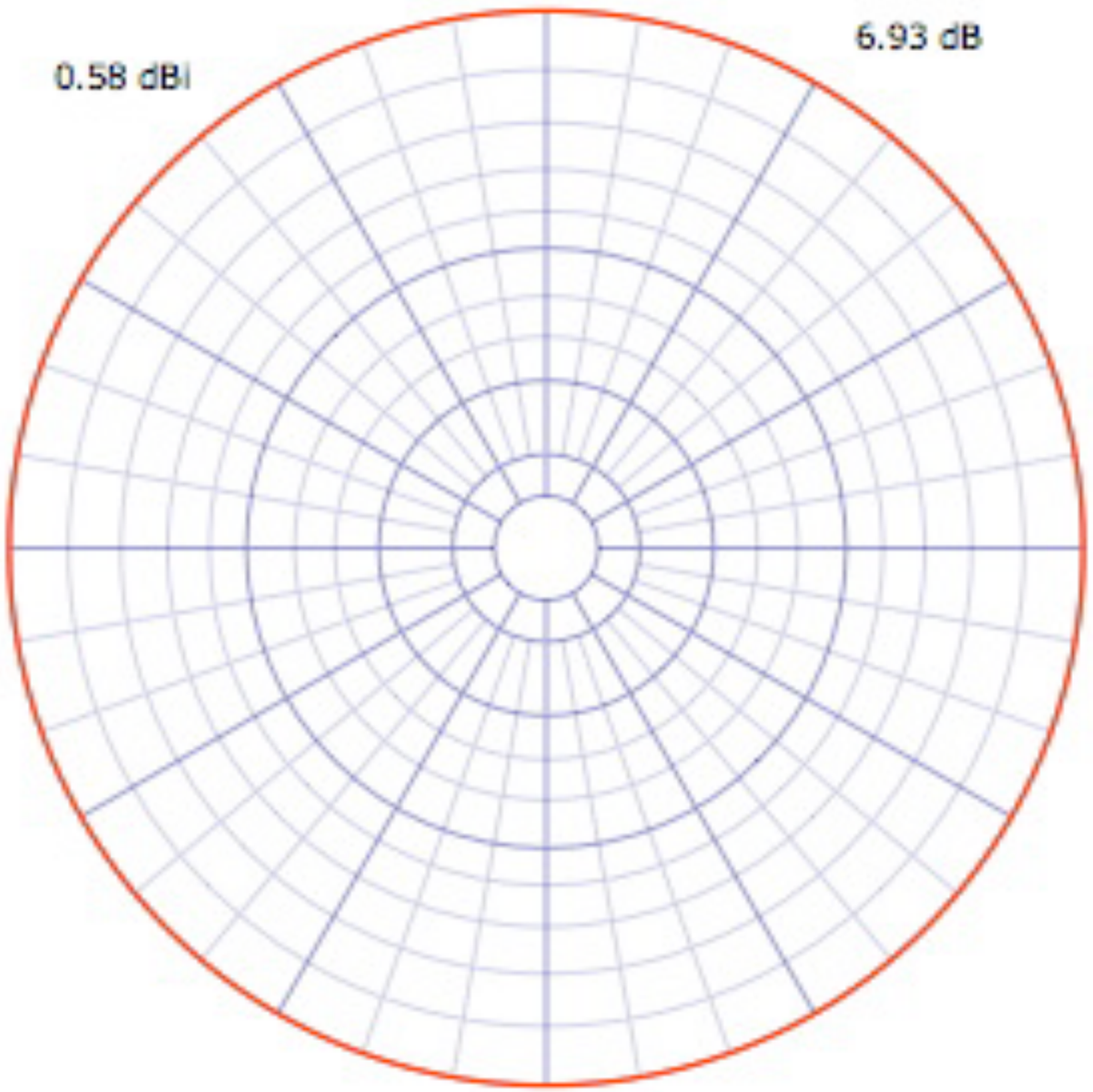


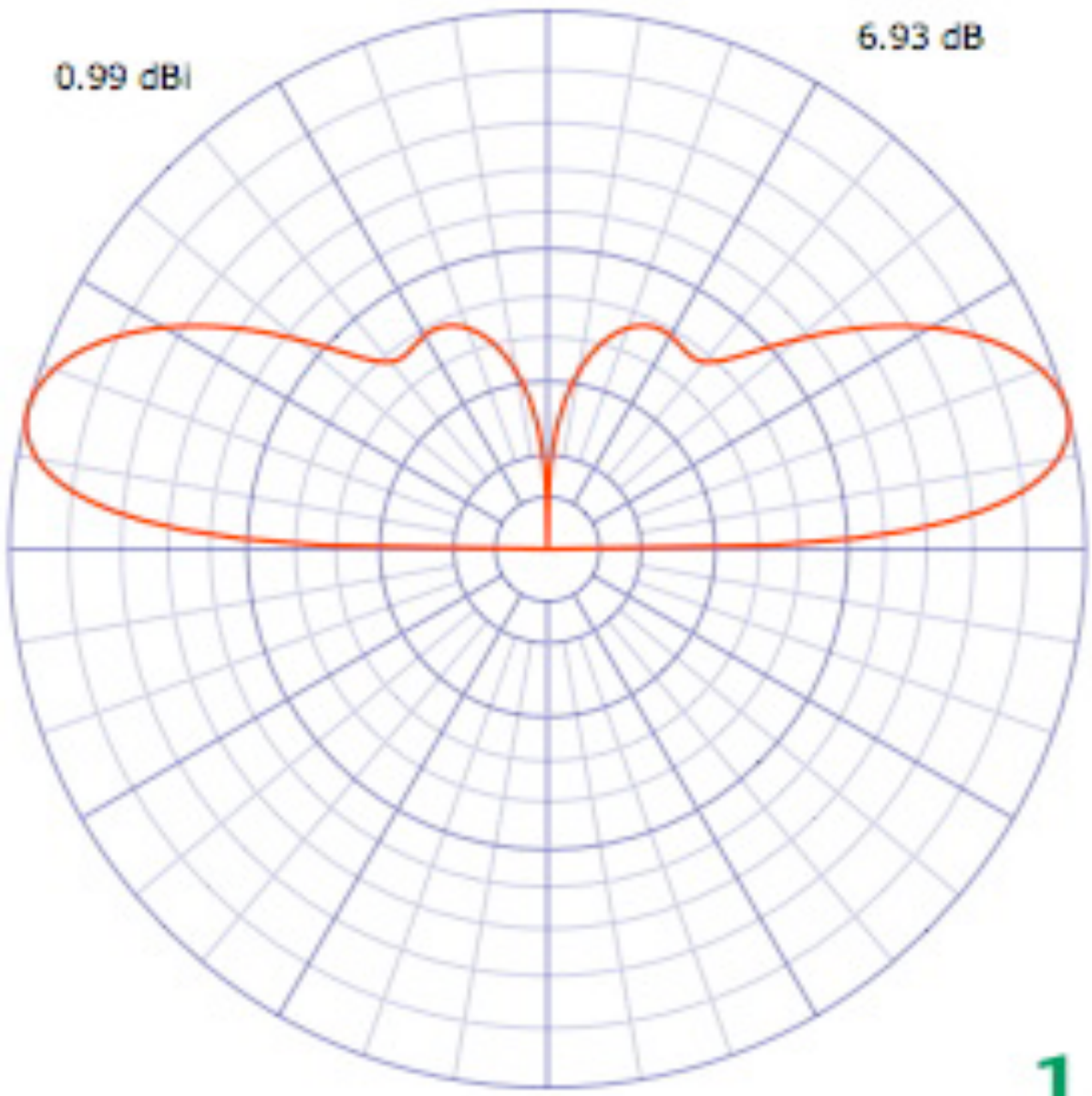
Rich (AB1HD) PSK Reporter
15m dipole with 5 watts
2 January 2012

Thailand
AB1HD 16 Jan 2012

8583 miles







What if we raise it?

15m vertical dipole from 1-12m high

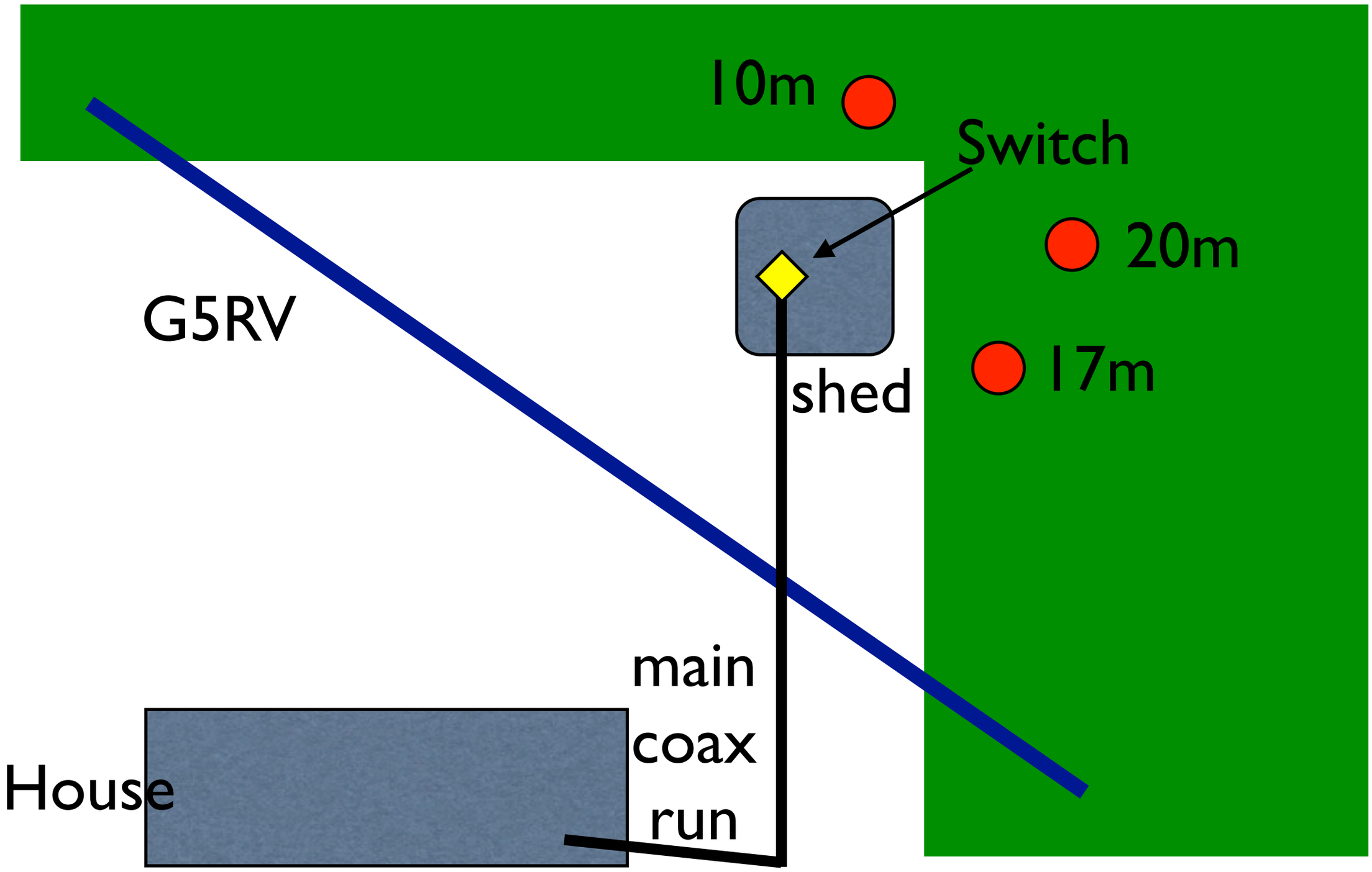
KBIOIQ

Switches up to four antennas on one piece of coax. No separate controller cable is needed; switching is done via DC-bypass on the coax.

HRO price: $150

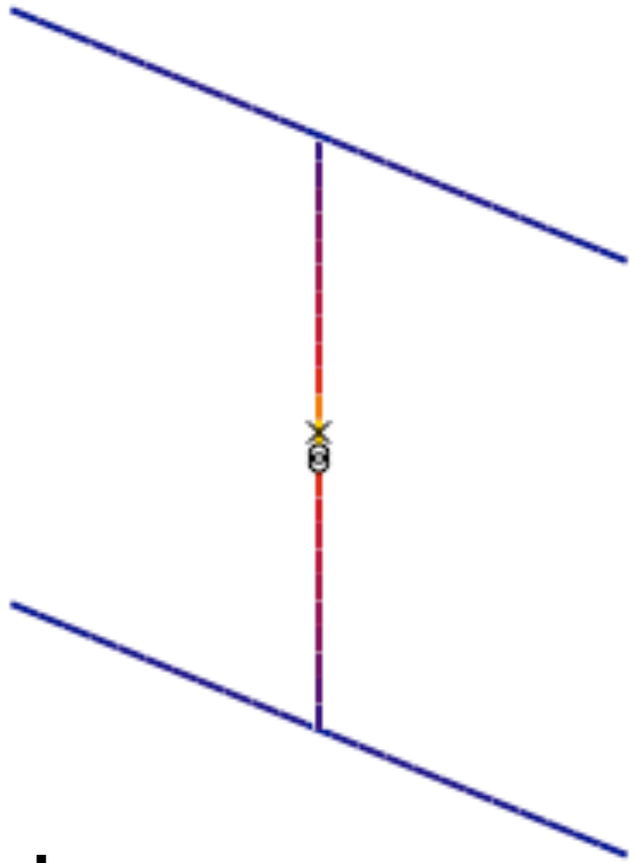
Ameritron
RCS-4
Remote antenna switch

KB1OIQ setup



NEIRD

SIGMA-10



8’1” high
12’3” with base

Antenna	Frequency	Bandwidth	Height	Weight	Ratings and Options
Sigma-10	28-29.700MHz	Full Band <1.6:1	8'	10#	5KW & 90mph, guyed once

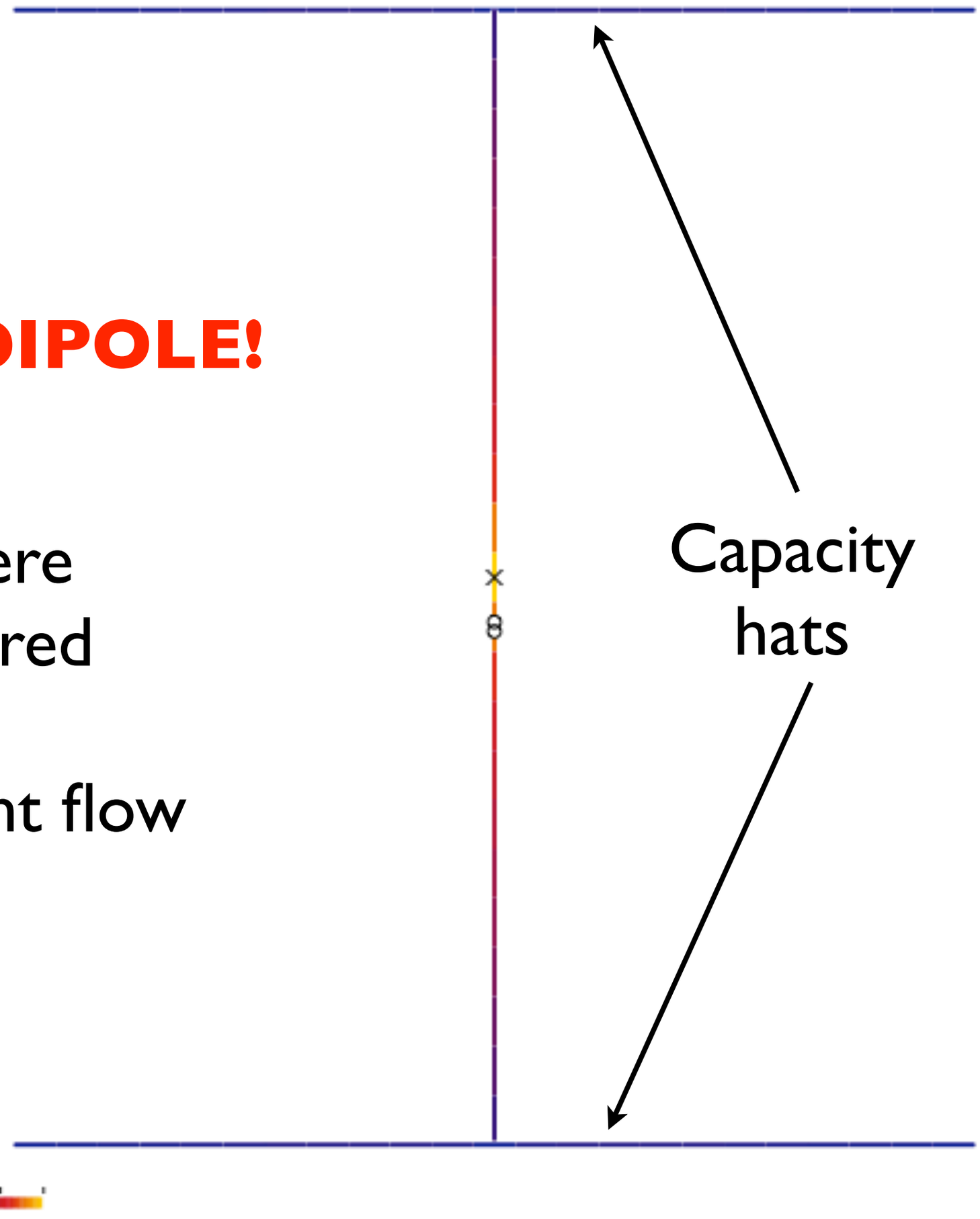
16x

1x

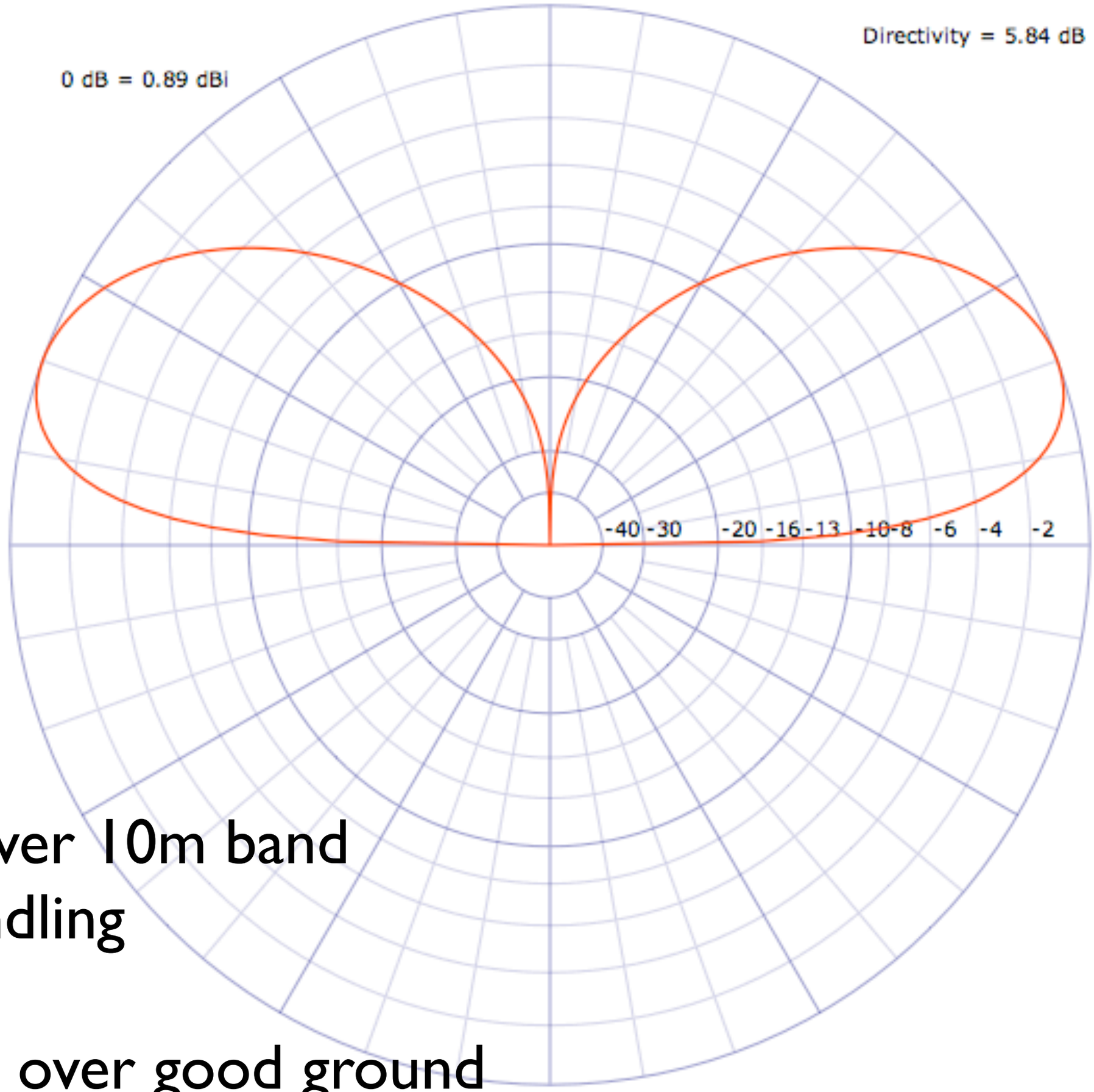
THIS IS STILL A DIPOLE!

Software shows where high currents are in red

Note the low current flow in the capacity hats



SIGMA-10
8’1” high
12’3” with base



VSWR < 1.6:1 over 10m band
5KW power handling
99.8% efficient
TOA 21-degrees over good ground

SIGMA-40

24 feet tall
31 pounds
300 kHz < 2:1

NE1RD QSO with
VU2ELJ (India)
2011-12-07 01:26:36
40M SSB 7.14700

Wrapping up

Think about

- ... how to put the most current through your antenna system by reducing losses
- ... where your signal is going and where it isn't because of those nasty nulls
- ... deploying monoband antennas properly configured and at the right height for DX

Stop thinking

- ... about SWR. Yes, having a match so your transceiver is happy is important, but...
- ... about coax loss. Compared to what you're losing because of nulls it is small
- ... that multiband antennas will always give you good performance on all bands. They may not.

Stop working the same old countries

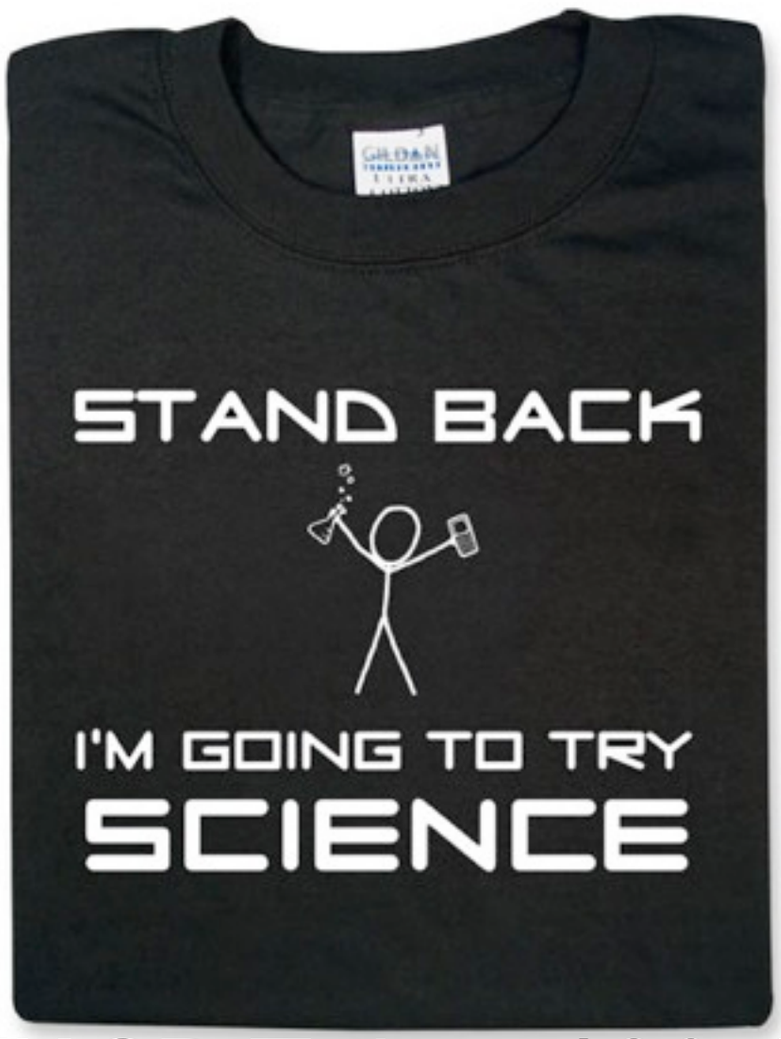
- Have you heard a station from
  - Mongolia?
  - India?
  - China?
- Stop working only Florida, Spain, and Germany! There are other countries out there -- but you have to work for it!

THINK

- There are a lot of great resources out there for antennas

- Don't just rely on your small samples from on-air experiences

- Put a little science into this and you'll likely get a big return on your investment



XKCD T-shirt $20 @ thinkgeek.com

Extra credit

2011 NEIRD DXCC

80	60	40	30	20	17	15	12	10	6	4	2	70	Total	Slots
36	0	78	3	56	21	68	17	91	1	0	0	0	124	371

- 124 DXCC entities
- 371 Band-entity combinations
- All vertical antennas
- Longest distance (VU2ELJ — India):
  - 7115 miles (short path)
  - 17741 miles (long path)
- Most made in the last 6 months of 2011

NEIRD 2011
QSO totals

January	67
February	27
April	20
August	109
September	55
October	340
November	721
December	387
Total	**1726**

CW	455
FM	2
PSK31	5
SSB	1,264
Total	**1,726**