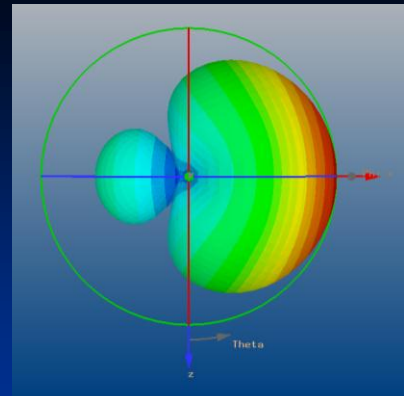
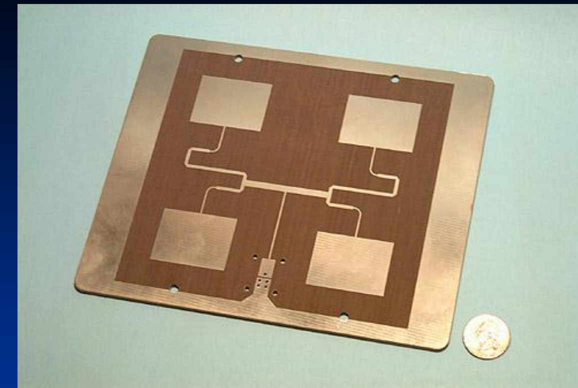





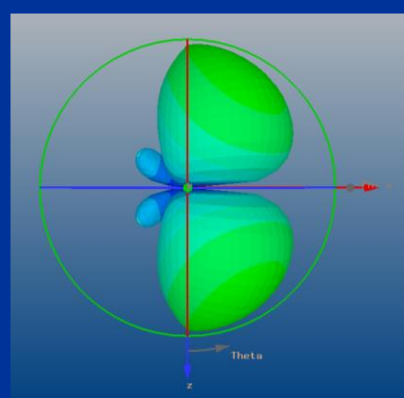
The Yagi, J-Pole and NVIS Dipole

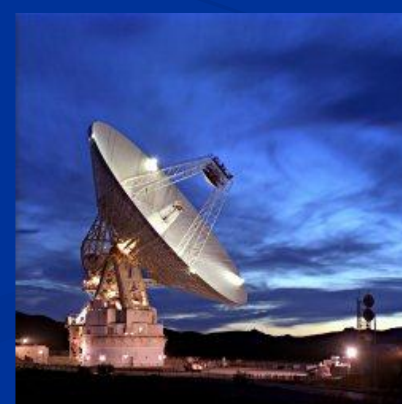
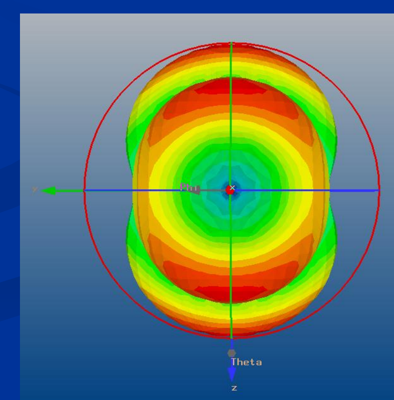
And a glance at Antenna Design using 3D EM Software

Brian Mileshosky N5ZGT

High Desert Amateur Radio Club

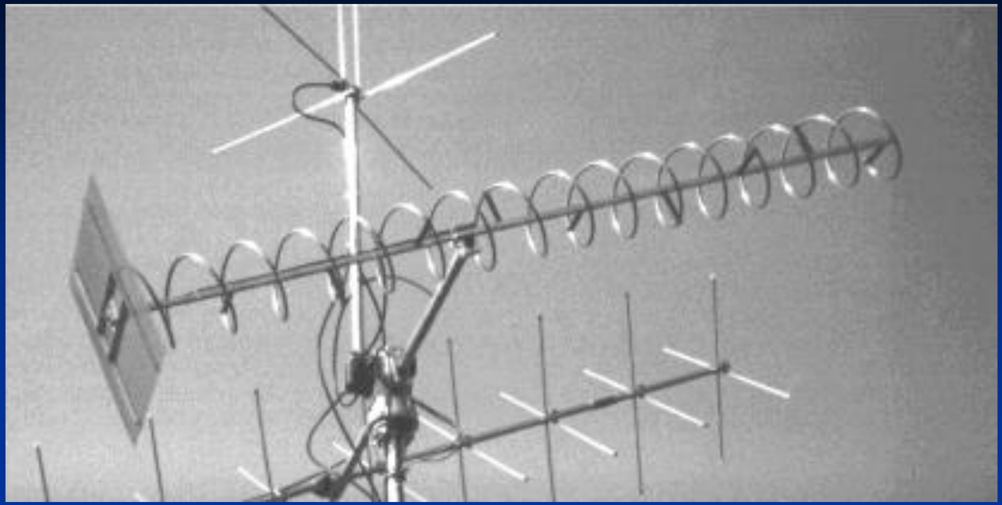
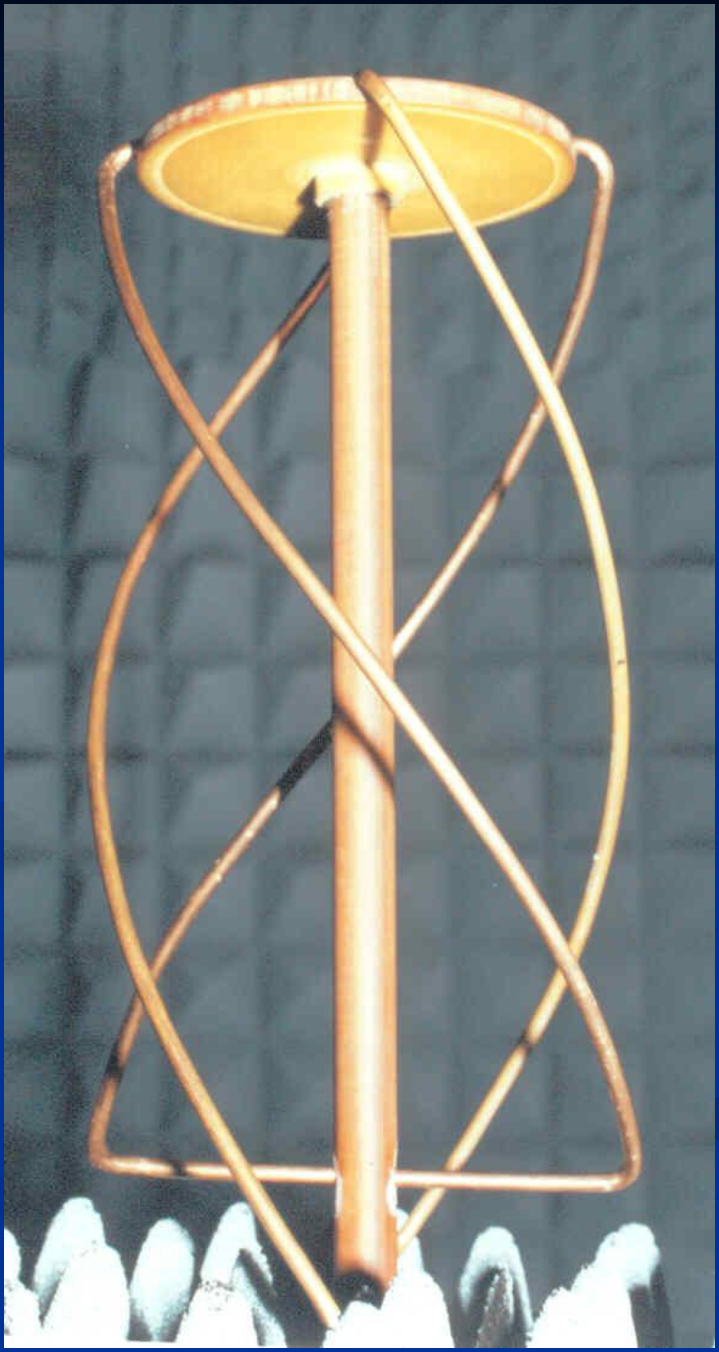
15 Feb 2013

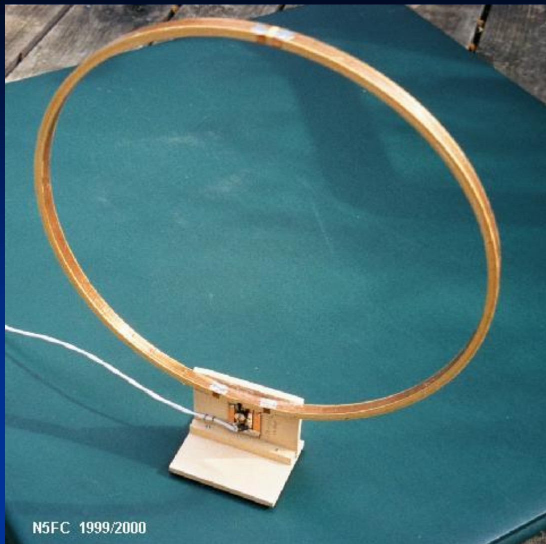



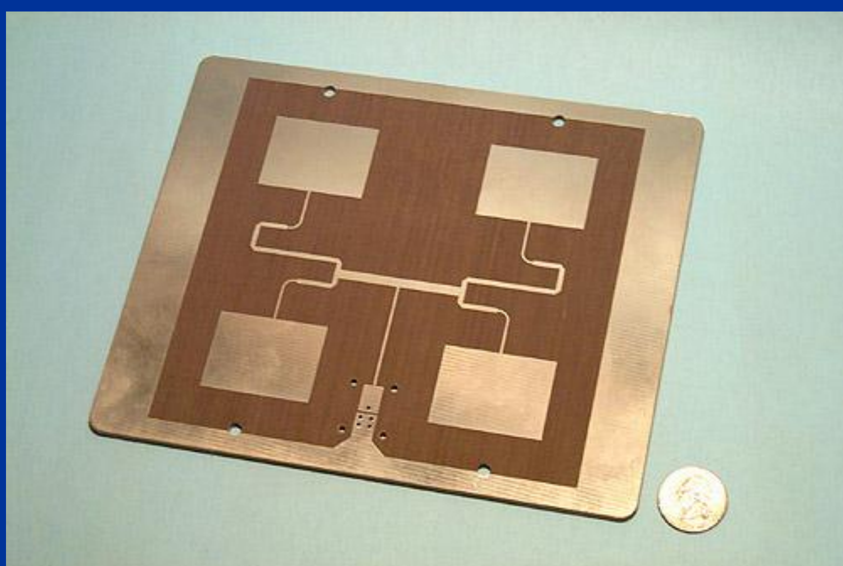
Antennas

- The most critical piece of any transmitting/receiving system.
- Come in many shapes (linear, helical, aperture, reflective, horns, loops, mixtures of each) and sizes (100+ foot tower down to something less than the size of a stamp).



N5FC 1999/2000


TELS



Antennas

- The most critical piece of any transmitting/receiving system.
- Come in many shapes (linear, helical, aperture, reflective, horns, loops, mixtures of each) and sizes (100+ foot tower down to something less than the size of a stamp).
- Design criteria: gain, bandwidth, physical size, directivity, polarization, efficiency, feed method, power handling, price, ease of fabrication, etc.
- **Key point:** Antennas are reciprocal devices – they behave the same while transmitting as they do while receiving (radiation pattern, gain, polarity, etc)
- Designed using a variety of theory and computational tools
  - NEC (Free)
  - 4NEC2 (Free, and pretty incredible)
  - EZ NEC ($89)
  - PCAAD ($499)
  - CST Microwave Studio or ANSYS HFSS (>$50,000)
- Other resources:
  - ARRL *Antenna Book*
  - LB Cebik's website (www.cebik.com)
  - *Antenna Engineering Handbook* (Johnson)
  - *Antenna Theory* (Balanis)
  - *Microwave Engineering* (Pozar)
  - Google

The Yagi Uda antenna

- Described and published by S. Uda and H. Yagi in the 1920s
- Did not receive full acclaim in the United States until 1928.
- Driven element is excited directly via feedline, all other elements excited parasitically.
- Element lengths/diameters and element spacing determine antenna behavior.
- Typical driven element: a bit less than $\lambda/2$.
- Typical director length: 0.4-0.45λ
  - If multiple directors are used, they are not necessarily the same length or diameter.
  - Typical separation between directors is 0.3-0.4λ, but not necessarily equally spaced.
- Typical separation between driven element and reflector: 0.25λ.
- Little performance is added with the addition of more than one reflector.
- Significant performance is added with the addition of more directors.
- Input impedance is usually low; Gamma matches often used to match to 50Ω.

The Yagi Uda antenna

***Typical* gain of Yagi-Uda antennas:**

3 elements: 7 dBi

4 elements: 9 dBi

6 elements: 10.5 dBi

8 elements: 12.5 dBi

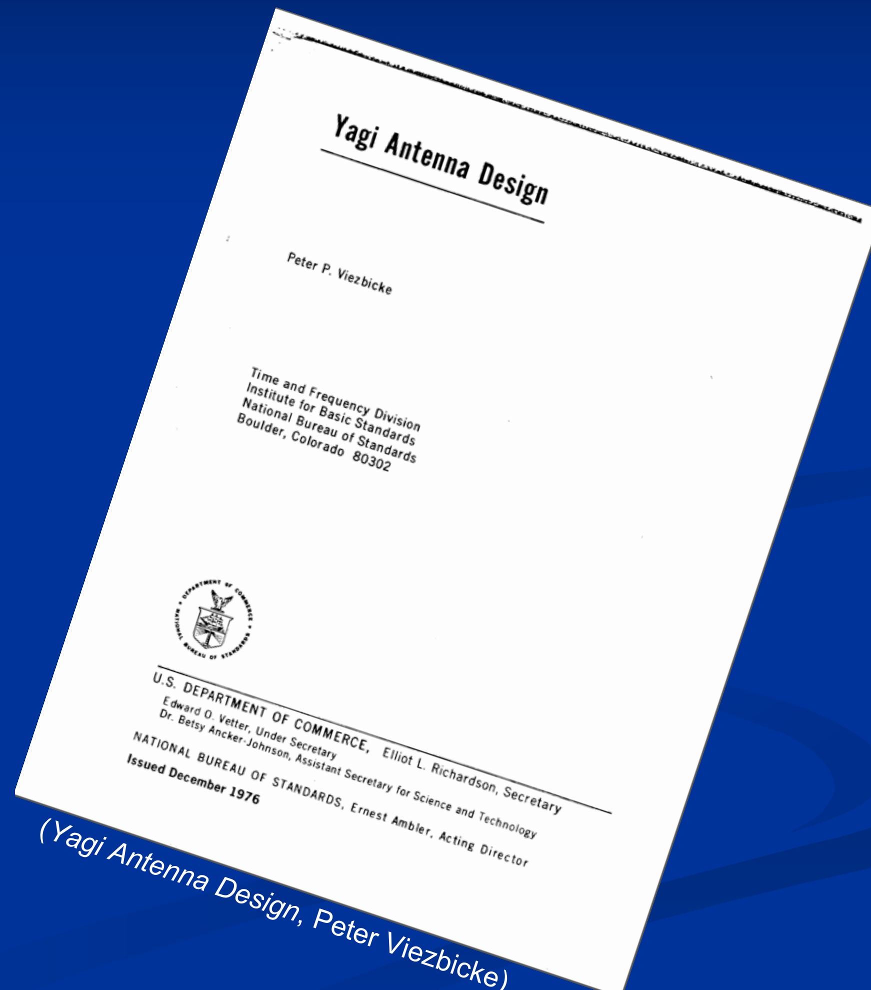
12 elements: 14.5 dBi

15 elements: 15.5 dBi

18 elements: 16.5 dBi

(Source: *Antenna Engineering Handbook*, Johnson)

dBi = dBd + 2.14



Yagi Antenna Design

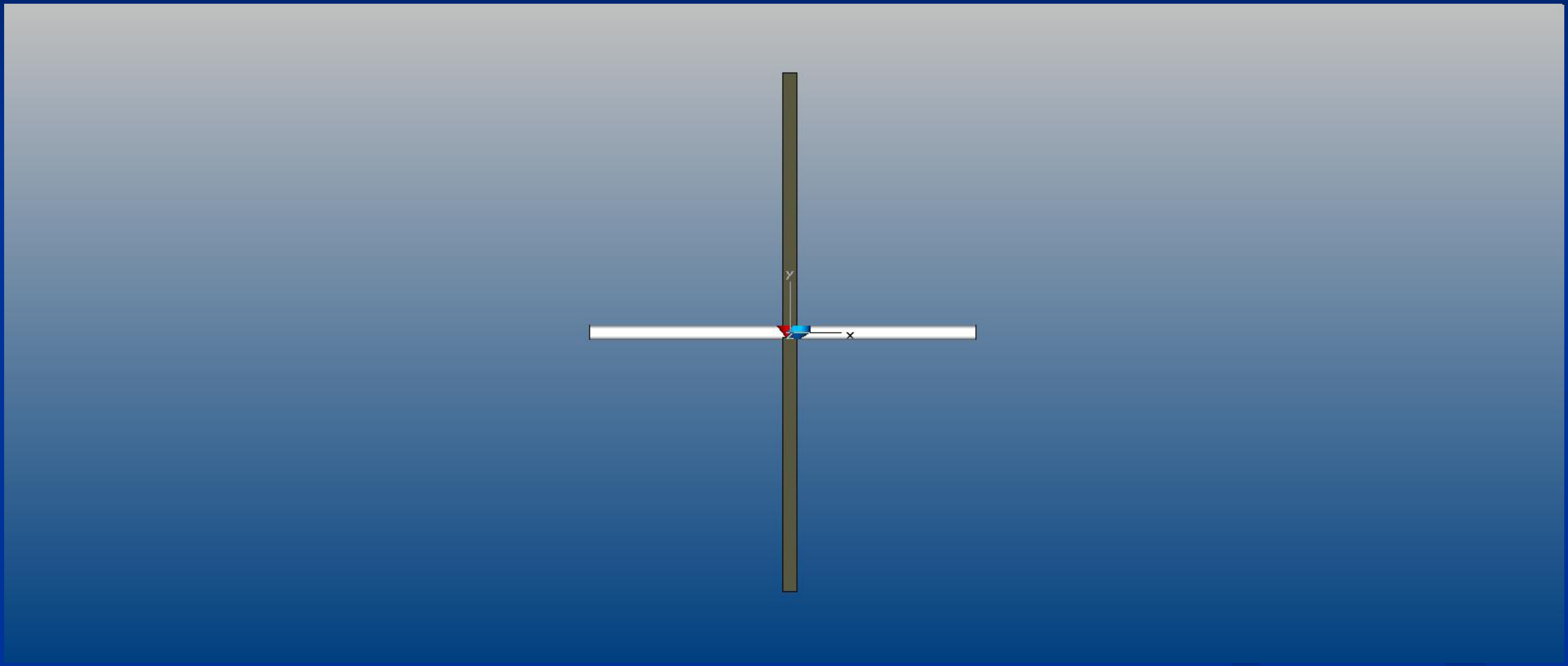
Peter P. Viezbicke

Time and Frequency Division
Institute for Basic Standards
National Bureau of Standards
Boulder, Colorado 80302

U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, Secretary
Edward O. Vetter, Under Secretary
Dr. Betsy Ancker-Johnson, Assistant Secretary for Science and Technology
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Acting Director
Issued December 1976

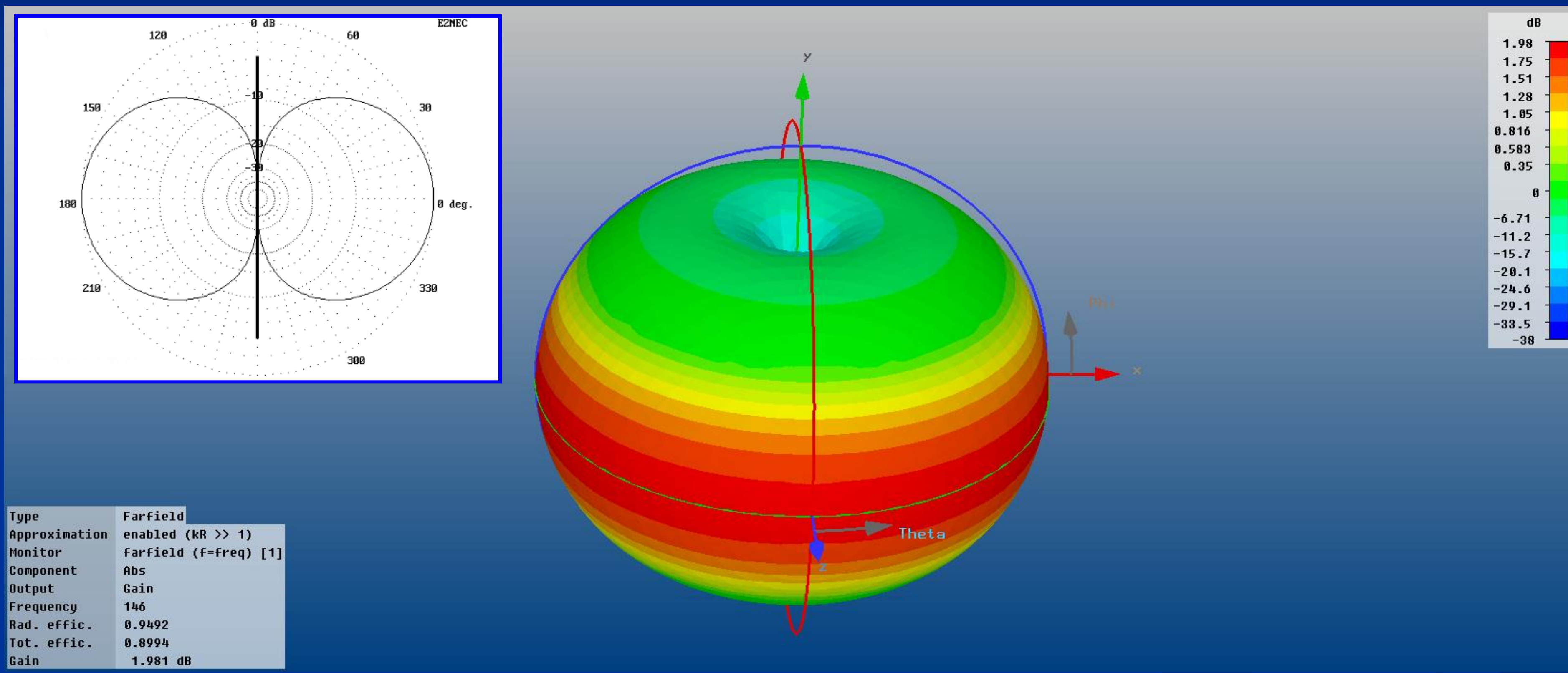
(Yagi Antenna Design, Peter Viezbicke)

Let's start with a Driven Element...



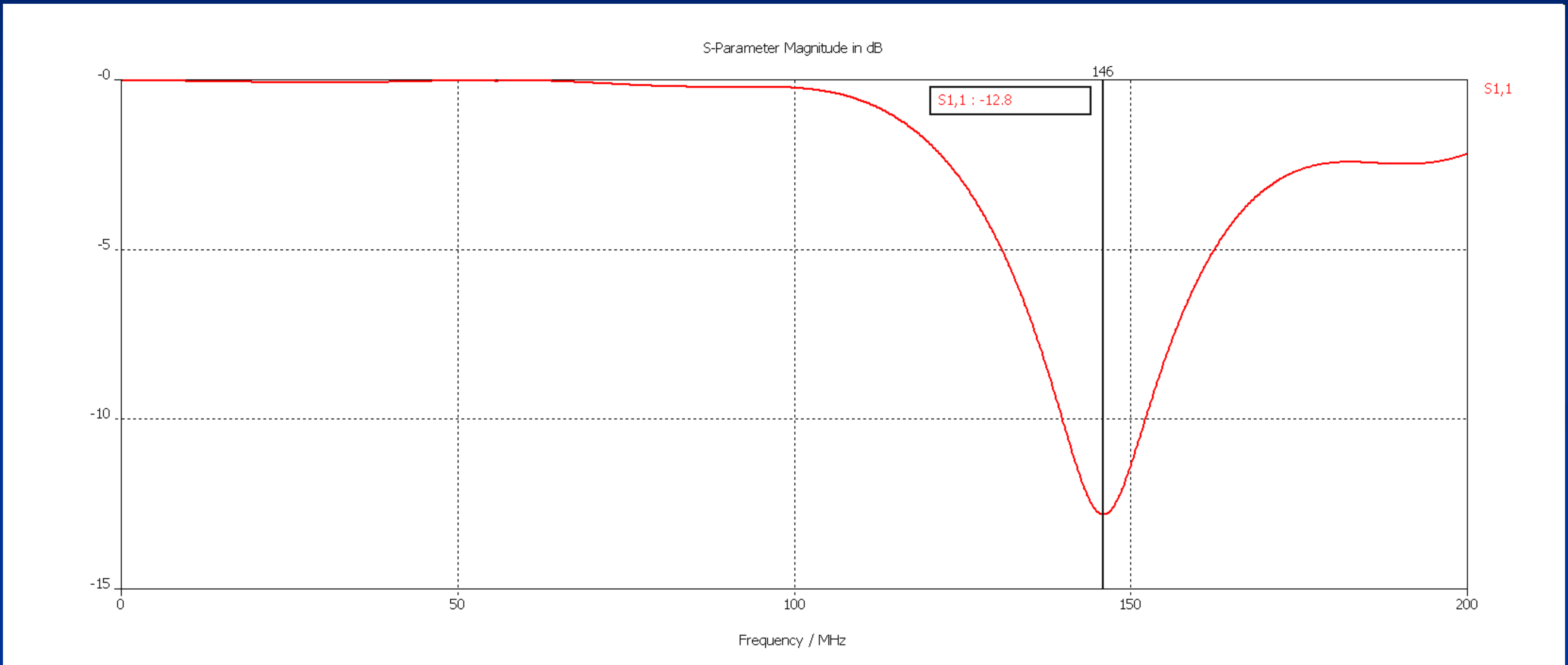
Driven element only…essentially a dipole
(PVC boom / handle shown, too)

Let’s start with a Driven Element...



Total gain (horizontal + vertical)

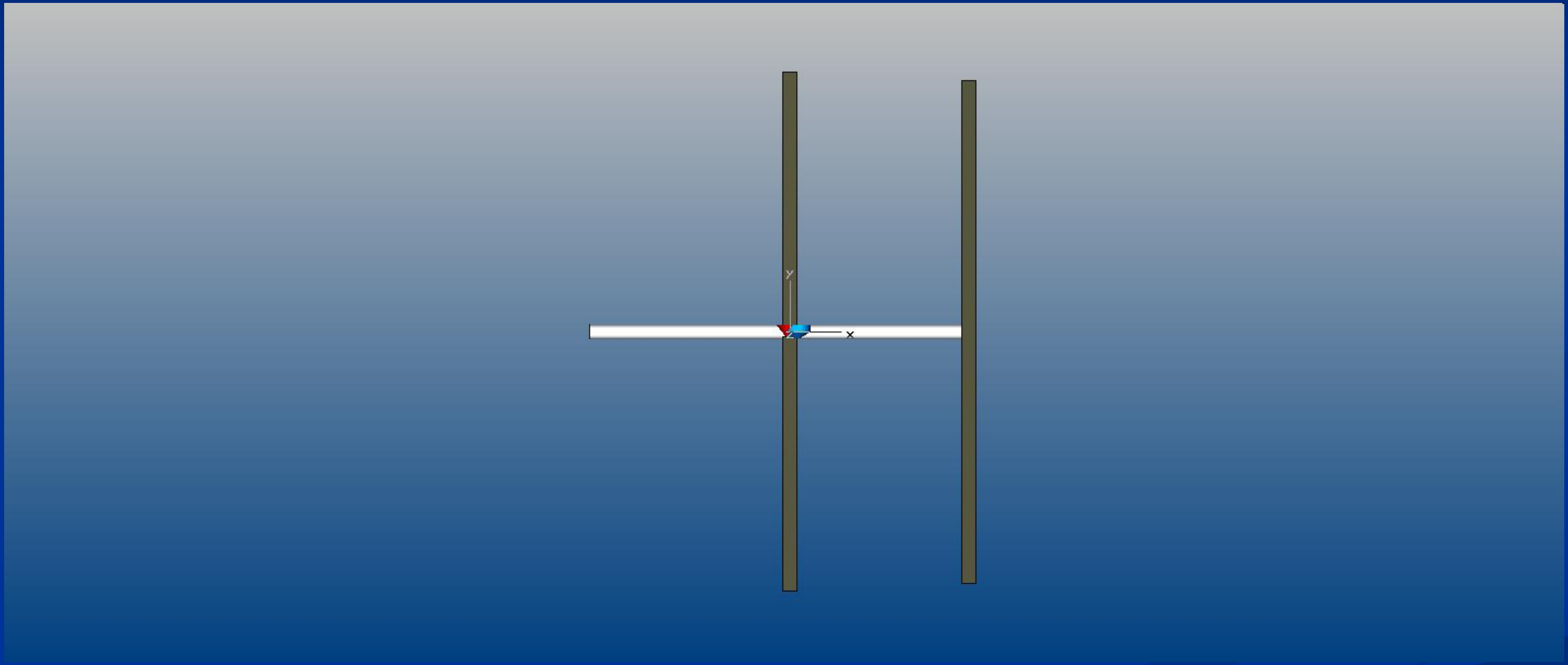
Let’s start with a Driven Element...



Return loss of -10 dB = SWR of 1.92. SWR of 2 means approx. 90% power is transmitted.
Return loss of -15 dB = SWR of 1.43
Return loss of -20 dB = SWR of 1.22

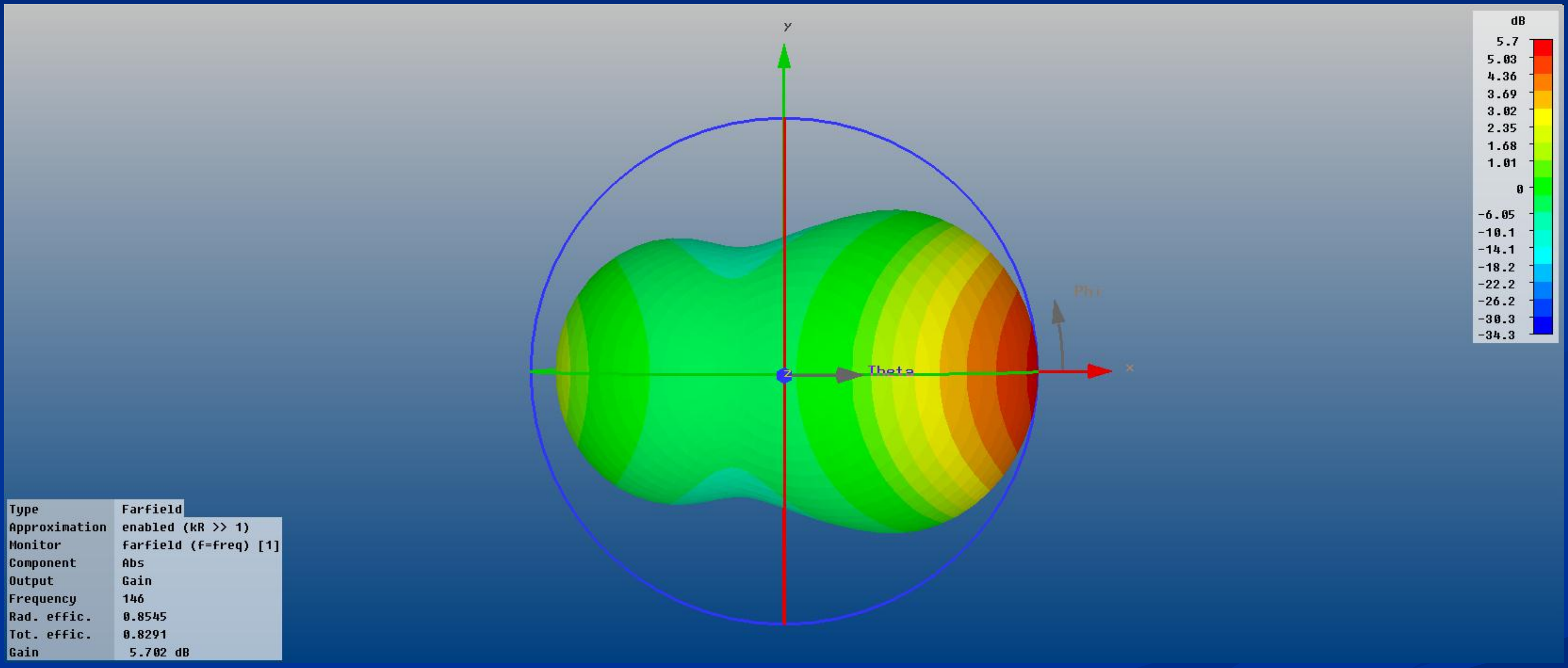
Return loss (resonance at 146.0 MHz)

Then add a Director.



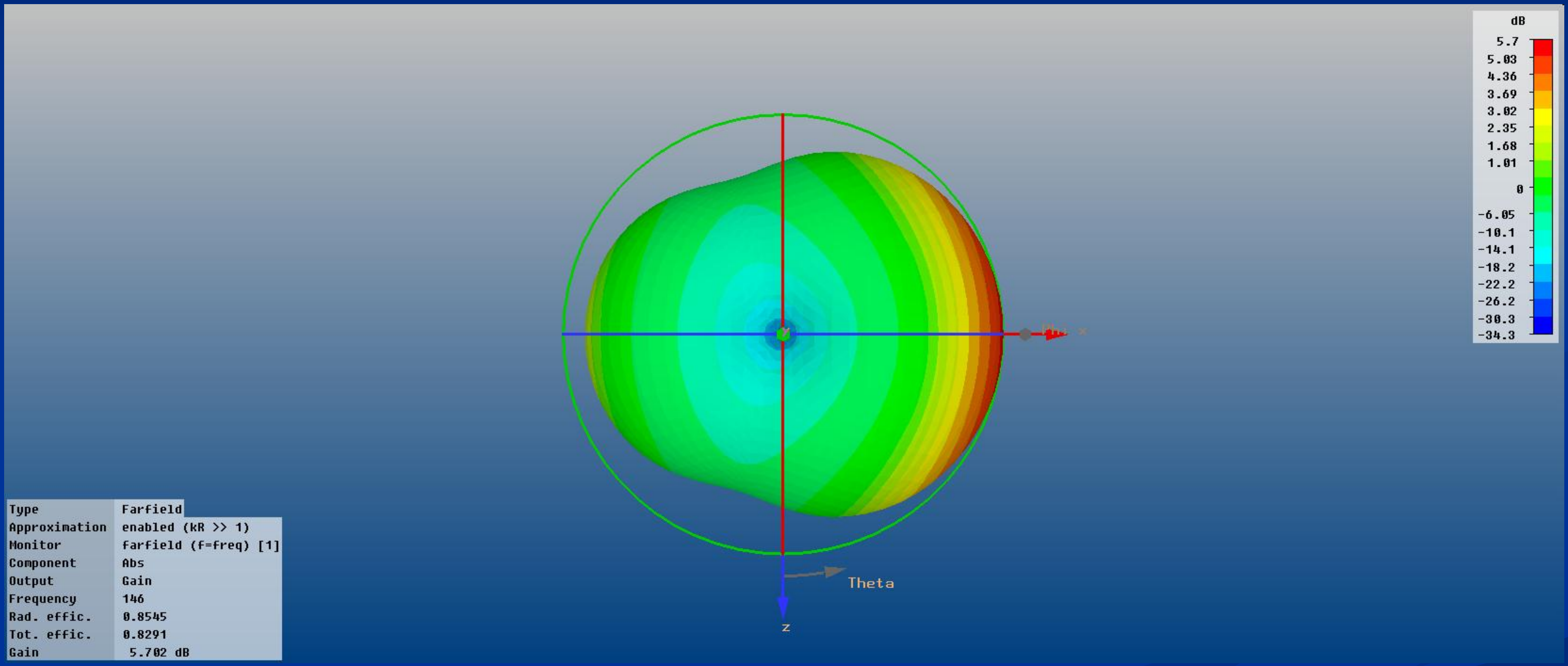
Driven element plus director

Then add a Director.



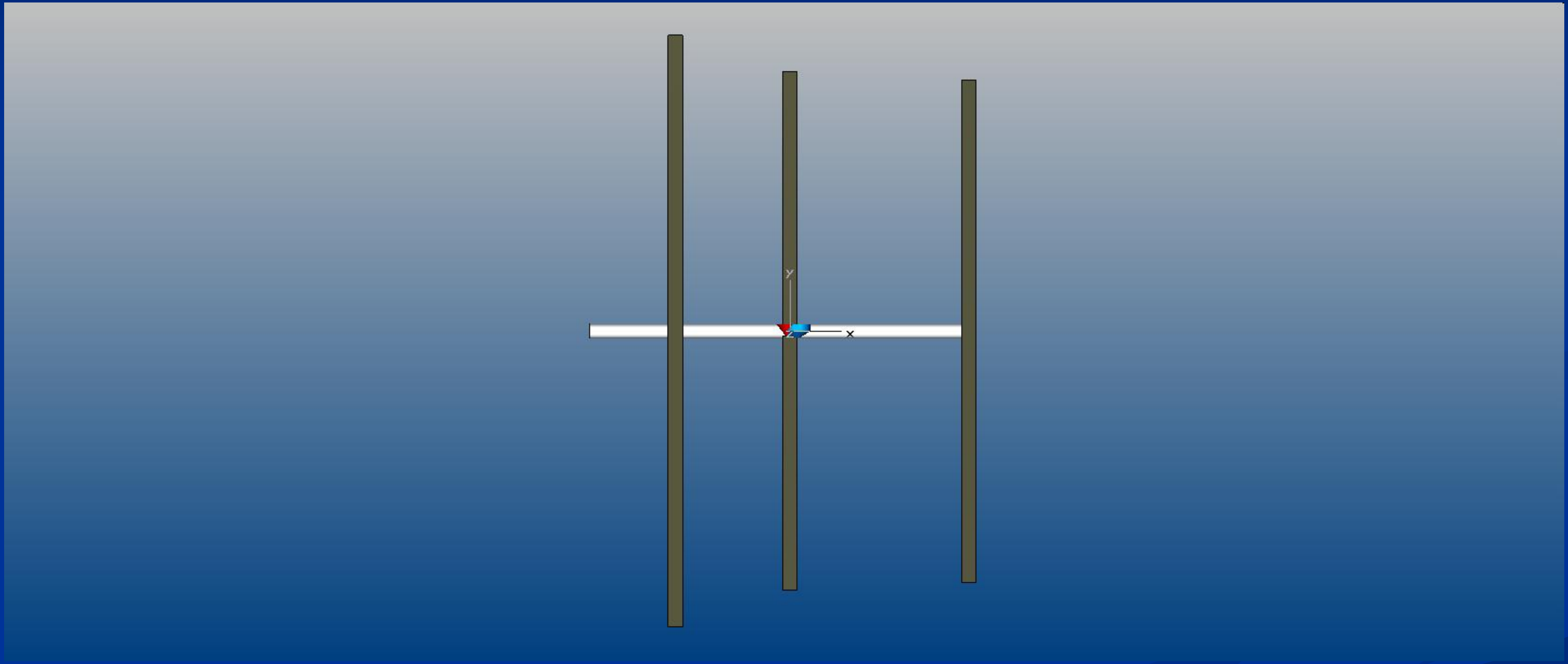
Total gain (horizontal + vertical; elevation)

Then add a Director.



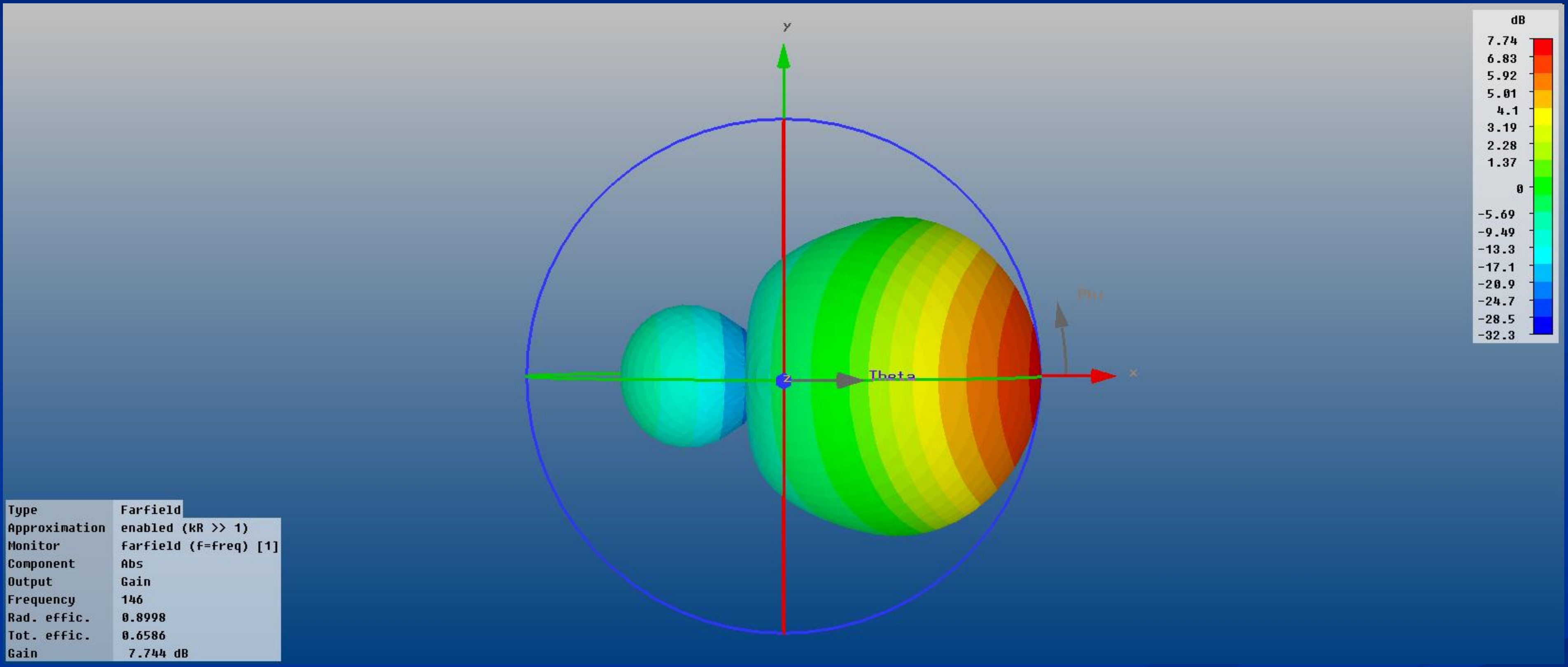
Total gain (horizontal + vertical; azimuth)

And finally, add a Reflector.



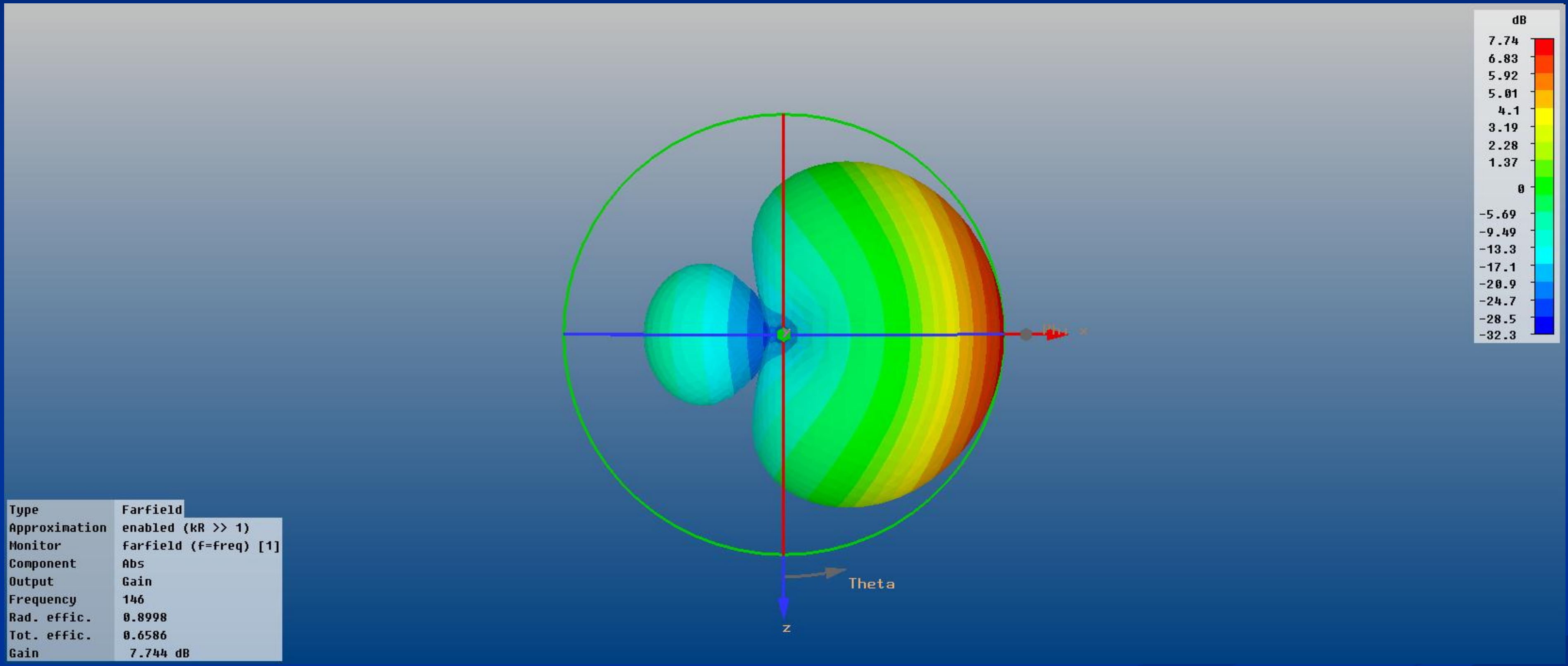
Driven element, reflector, and director. A 3-element yagi.

And finally, add a Reflector.



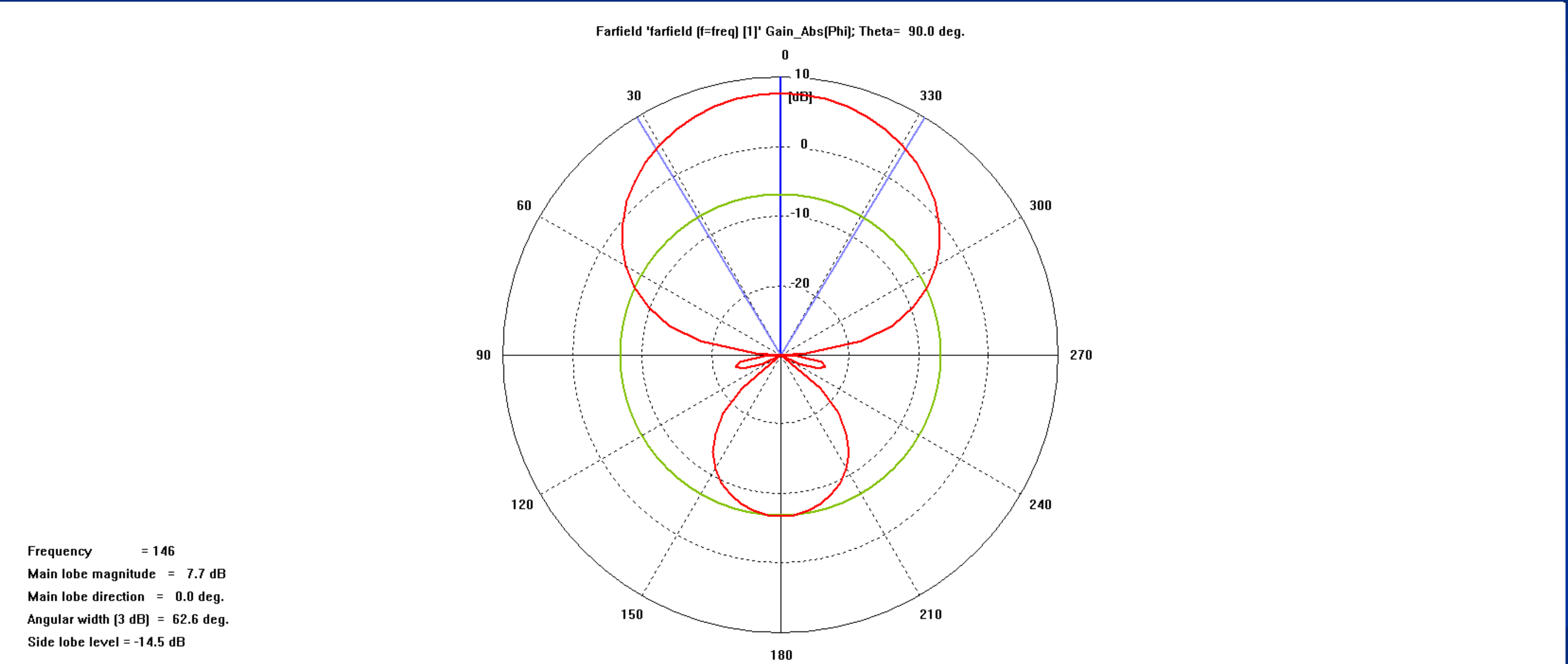
Total gain (horizontal + vertical; elevation)

And finally, add a Reflector.



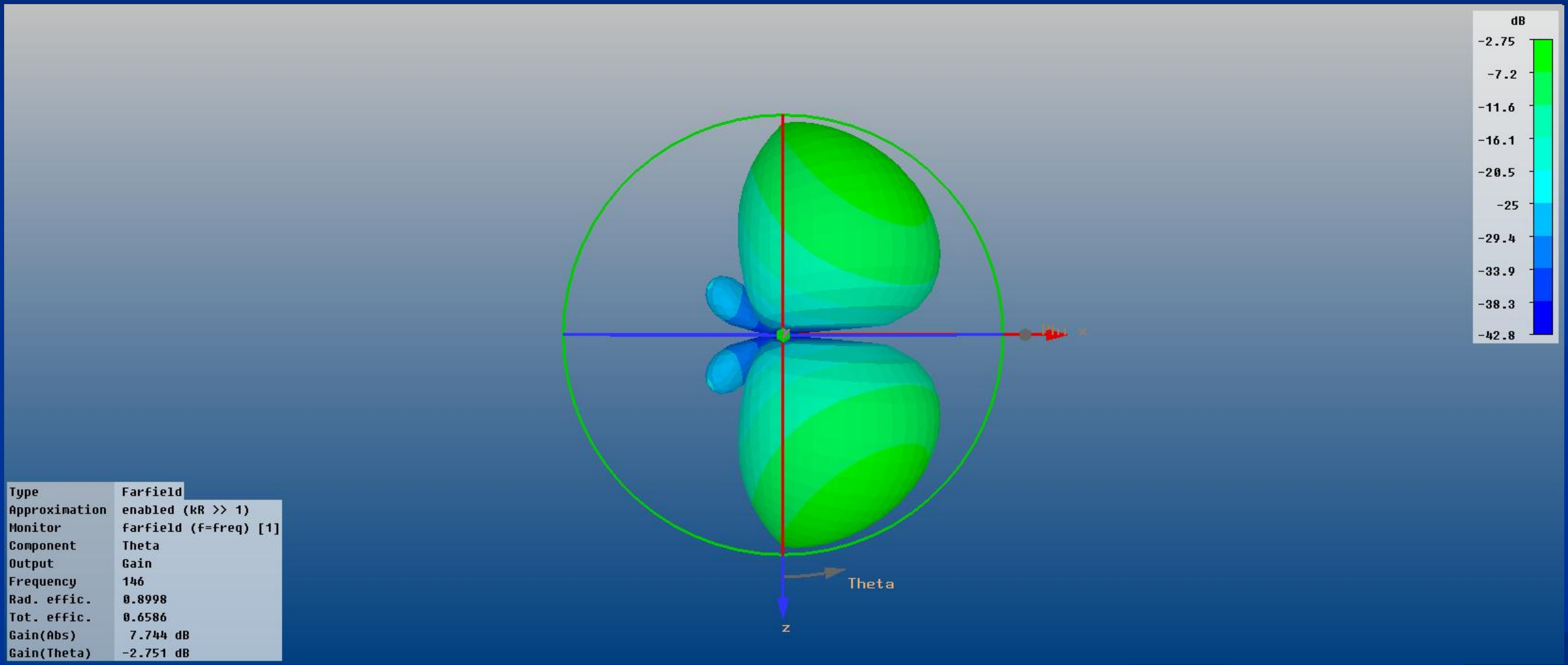
Total gain (horizontal + vertical; azimuth)

And finally, add a Reflector.



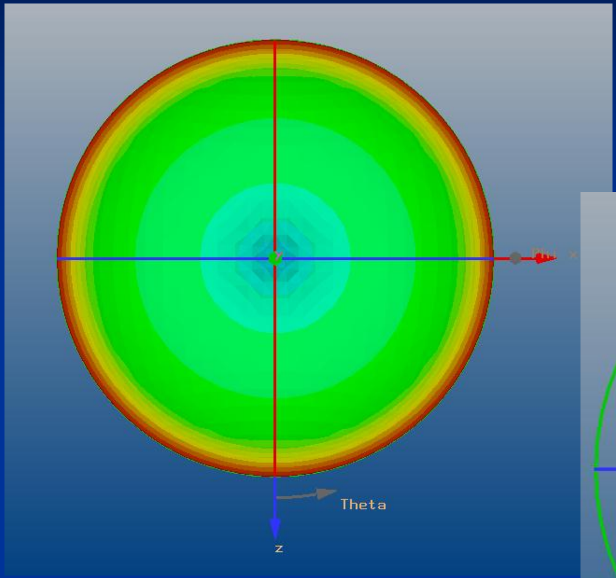
2D antenna pattern cut – there is room to optimize this yagi to reduce the backlobe further

And finally, add a Reflector.

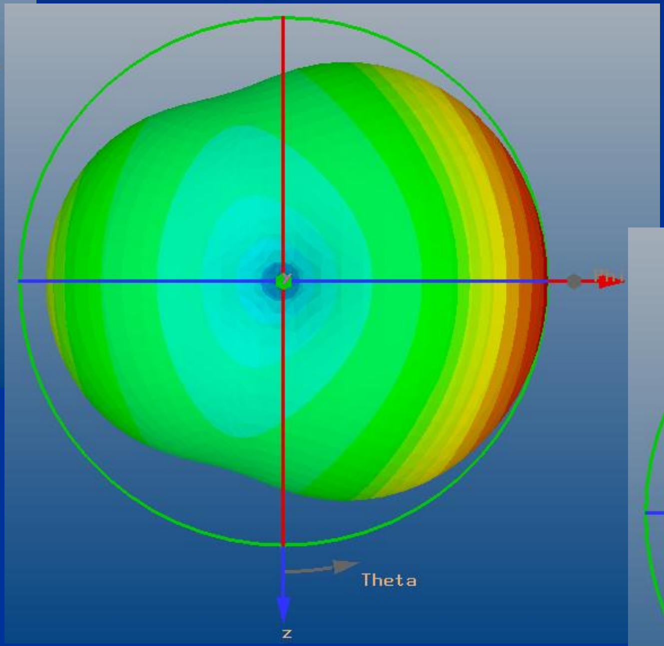


Cross-polarization gain

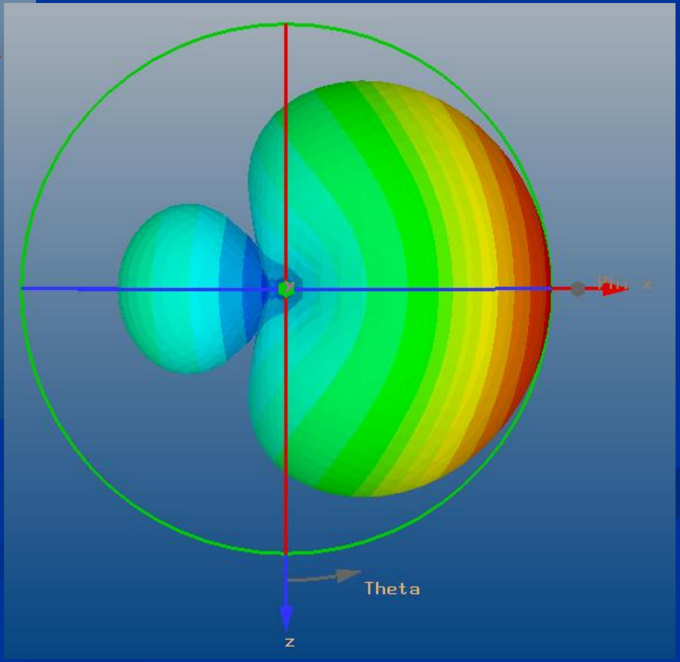
How the Yagi shapes up.



Driven element only
Gain: 1.98 dBi



Driven element and director
Gain: 5.7 dBi



Driven element, director and reflector
Gain: 7.74 dBi

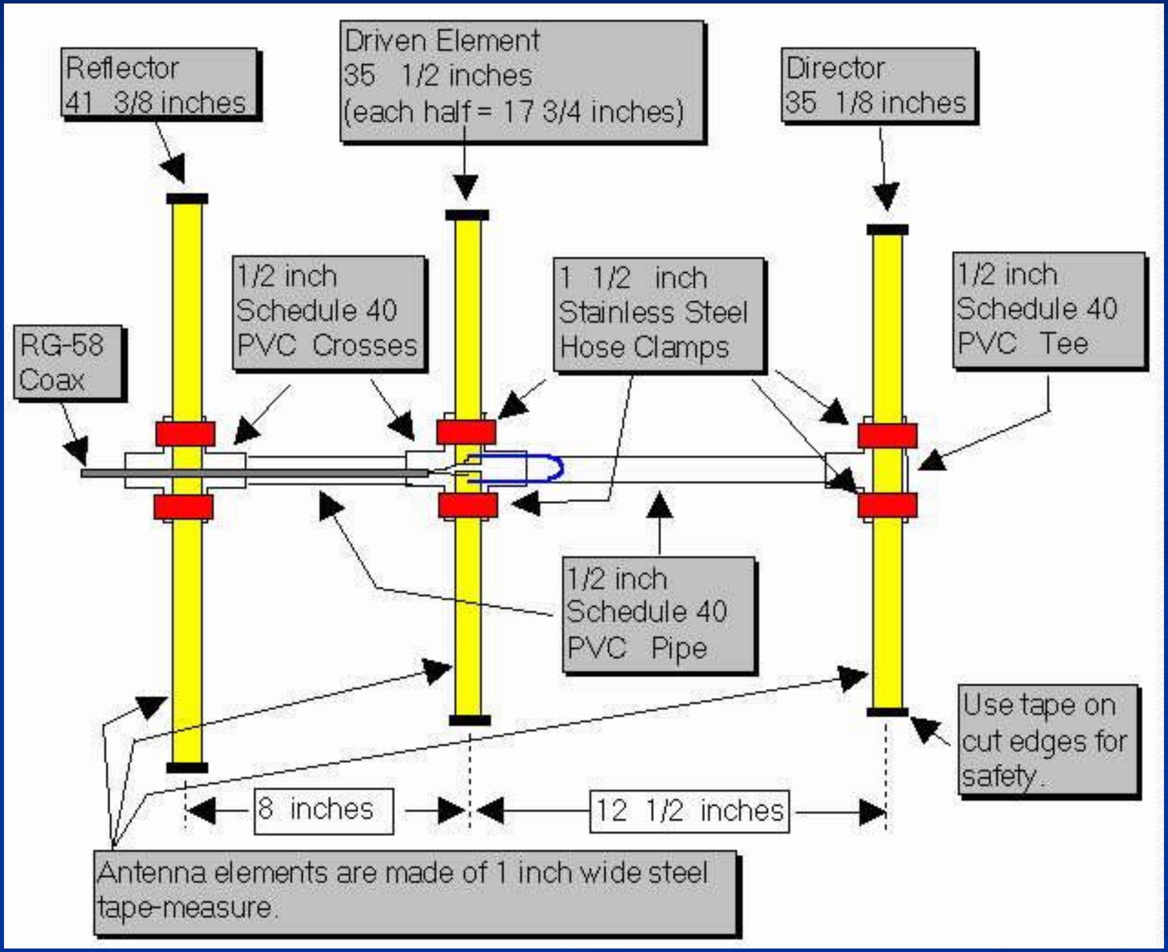
The Tape Measure Yagi…

The Tape Measure Yagi

- Original design by Joe Leggio WB2HOL at: http://theleggios.net/wb2hol/projects/rdf/tape_bm.htm
- Easily built from PVC, tape measure material, hose clamps and a short piece of coax.
- Total cost, on average: < $15 if you have some parts lying in your garage.
- Can achieve up to 7-dBi of gain from this simple antenna – perfect for use in the field, or from home. Excellent antenna for direction finding on 2 meters. Just as excellent for reaching distant stations or repeater while in the field, public service applications, etc.
- Not intended for permanent installation – elements will collapse briefly when blown by a gust of wind, affecting SWR.
- Not intended for high power use – you will be in the near-field of this antenna when transmitting. Common sense and safety highly encouraged.

- **Tip**: Use silver solder since tape measure material is generally stainless steel.
- **Tip**: Don't use RG-58…too clumsy. RG-174 with BNC or SMA recommended.
- **Tip**: Round off metal corners, laminate with electrical tape, or dip in liquid rubber to prevent cuts.

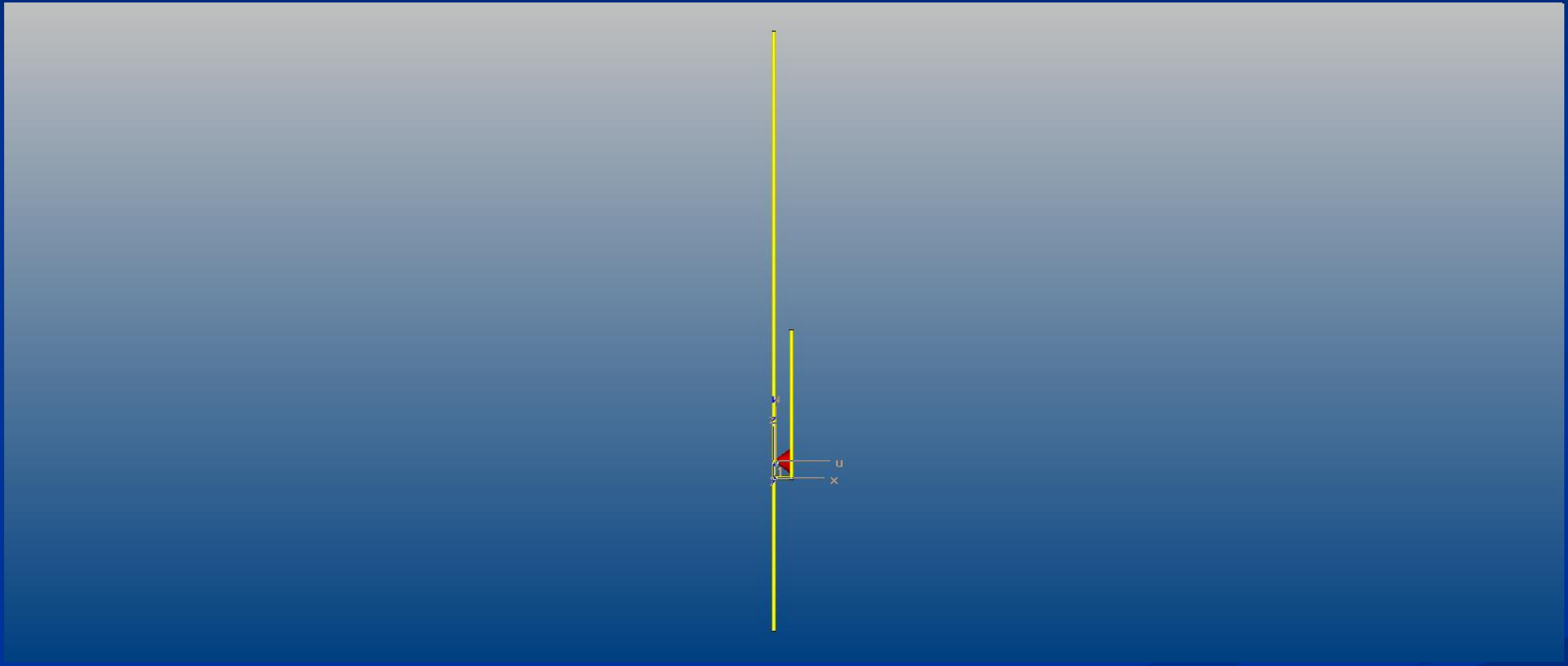
The Tape Measure Yagi



Courtesy Joe Leggio WB2HOL

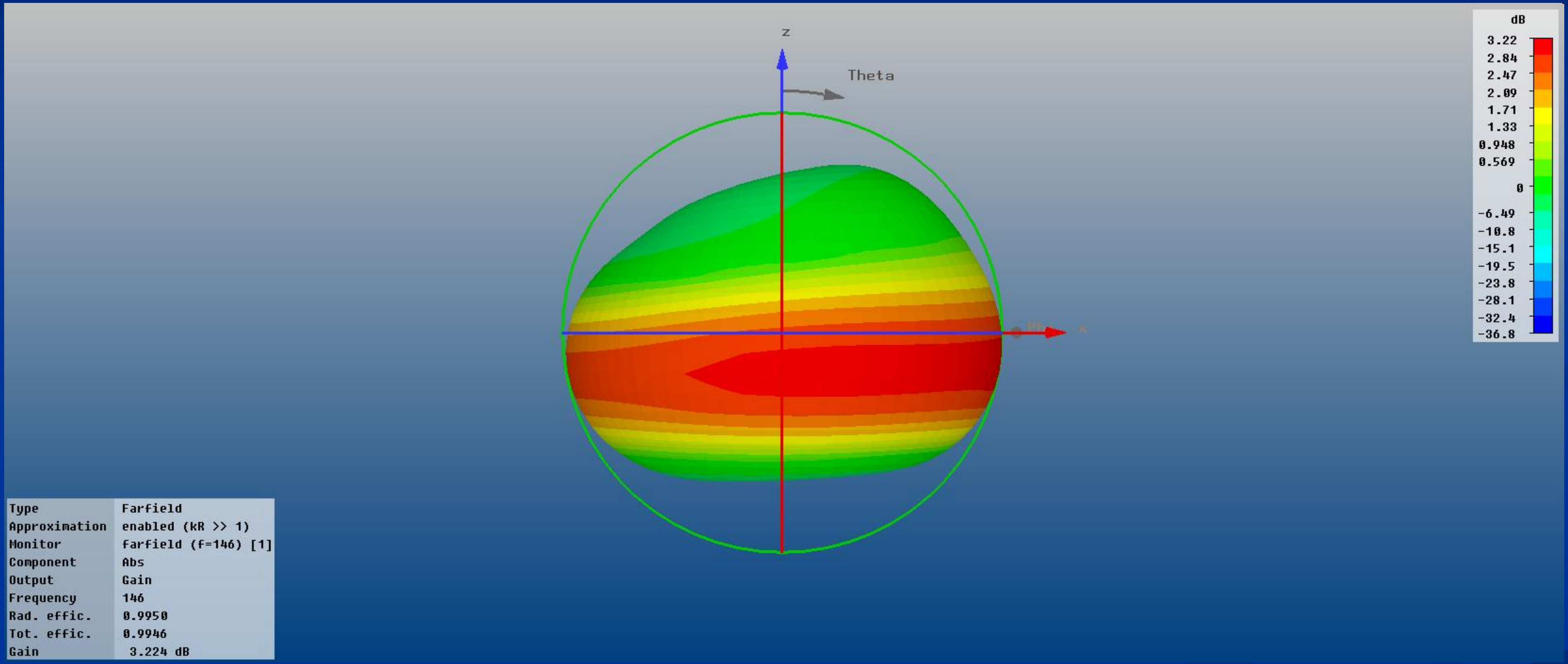
A brief look at other antennas…

2-meter J-Pole antenna



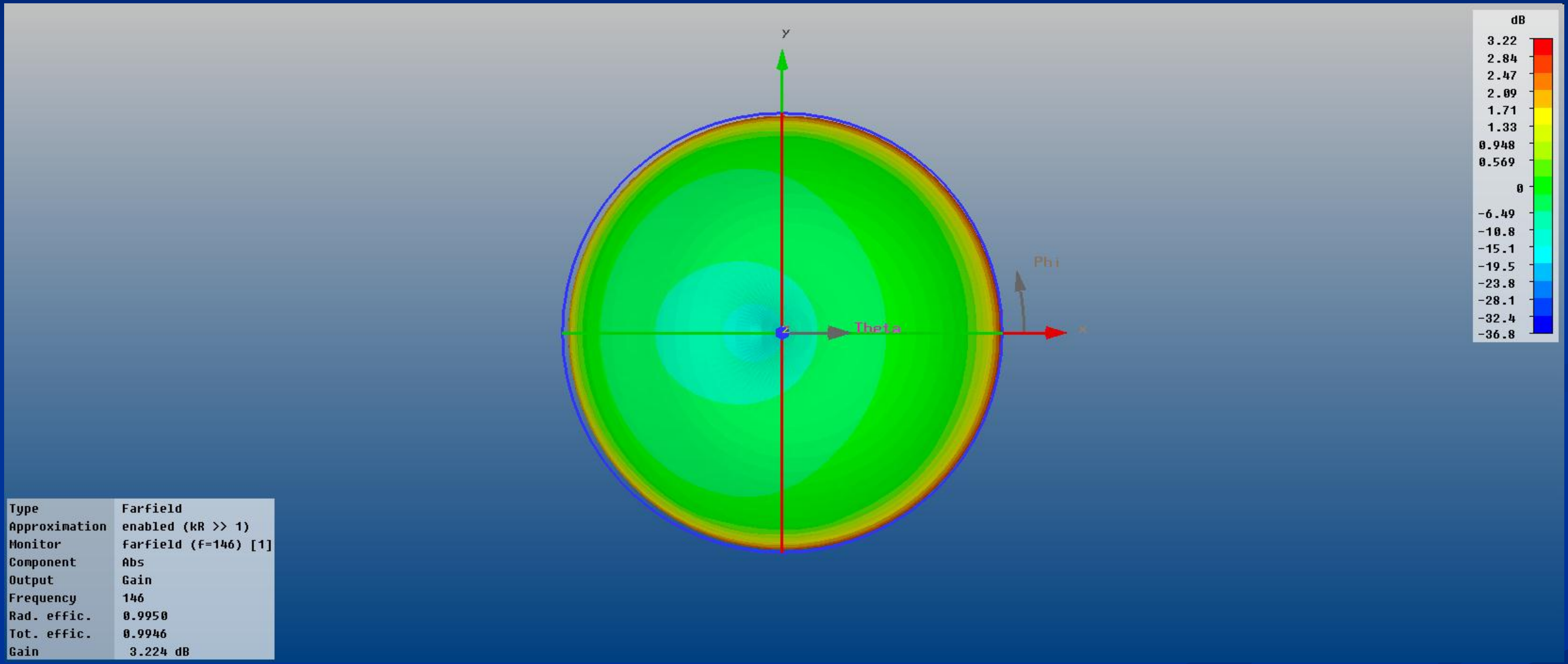
Model of 2-meter copper J-Pole antenna

2-meter J-Pole Antenna



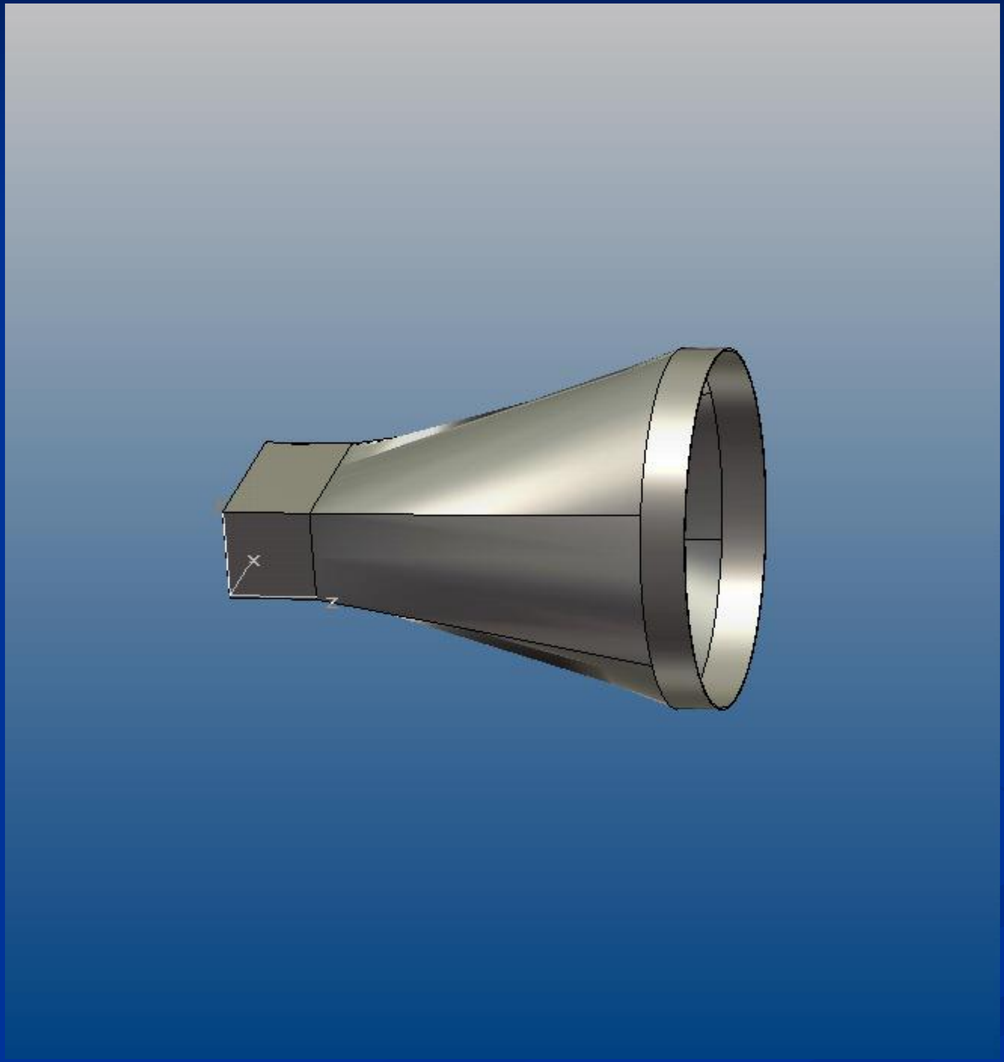
Total gain (horizontal + vertical; elevation)

2-meter J-Pole Antenna



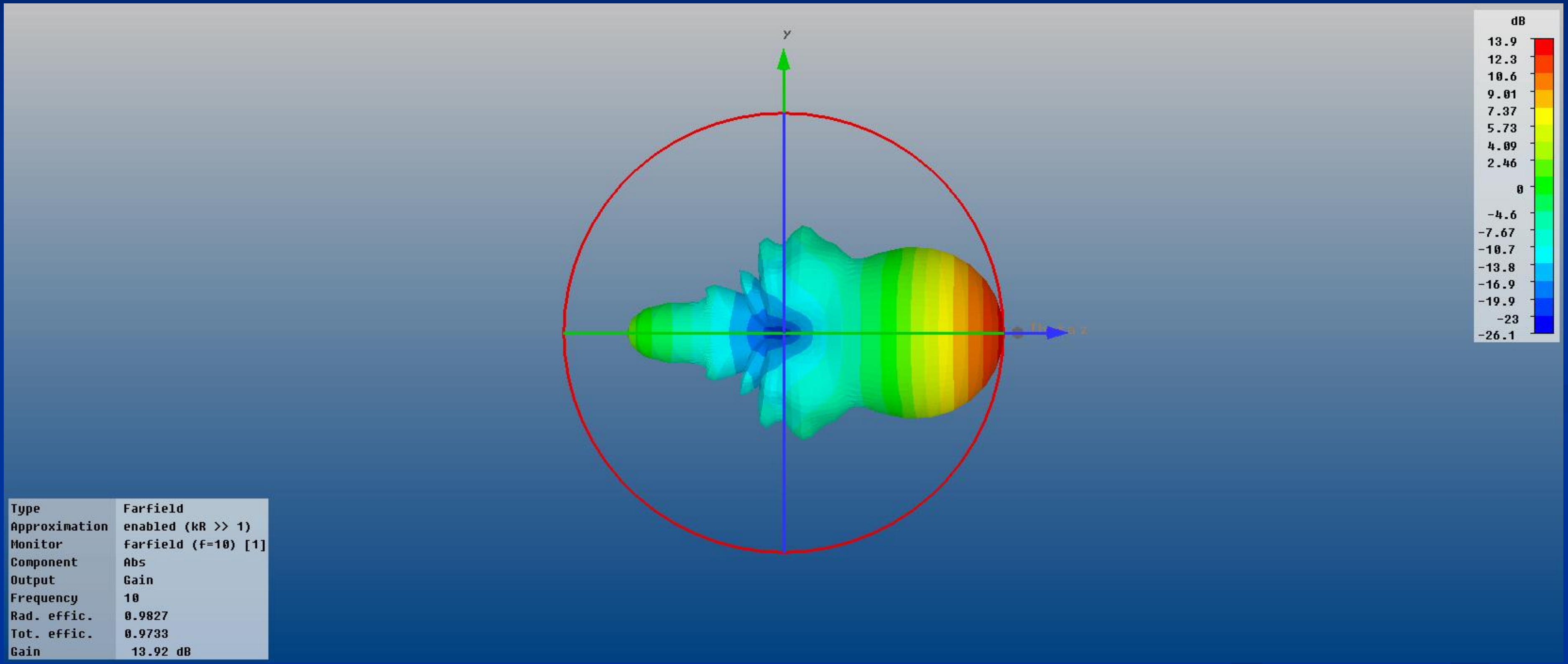
Total gain (horizontal + vertical; azimuth)

10 GHz Horn antenna



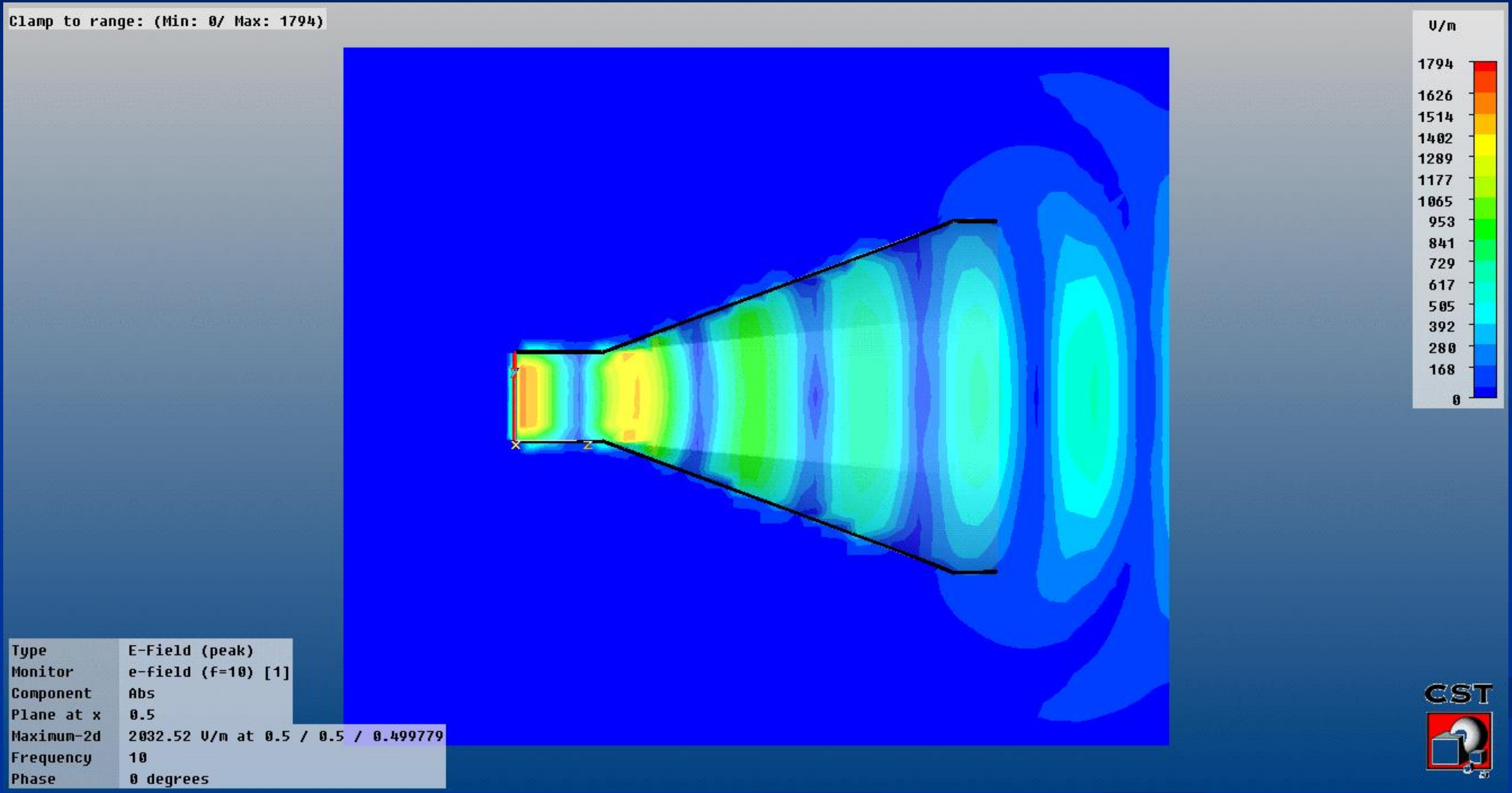
Model of a round horn antenna fed by rectangular waveguide

10 GHz Horn antenna



Total gain (horizontal + vertical; elevation)

10 GHz Horn antenna

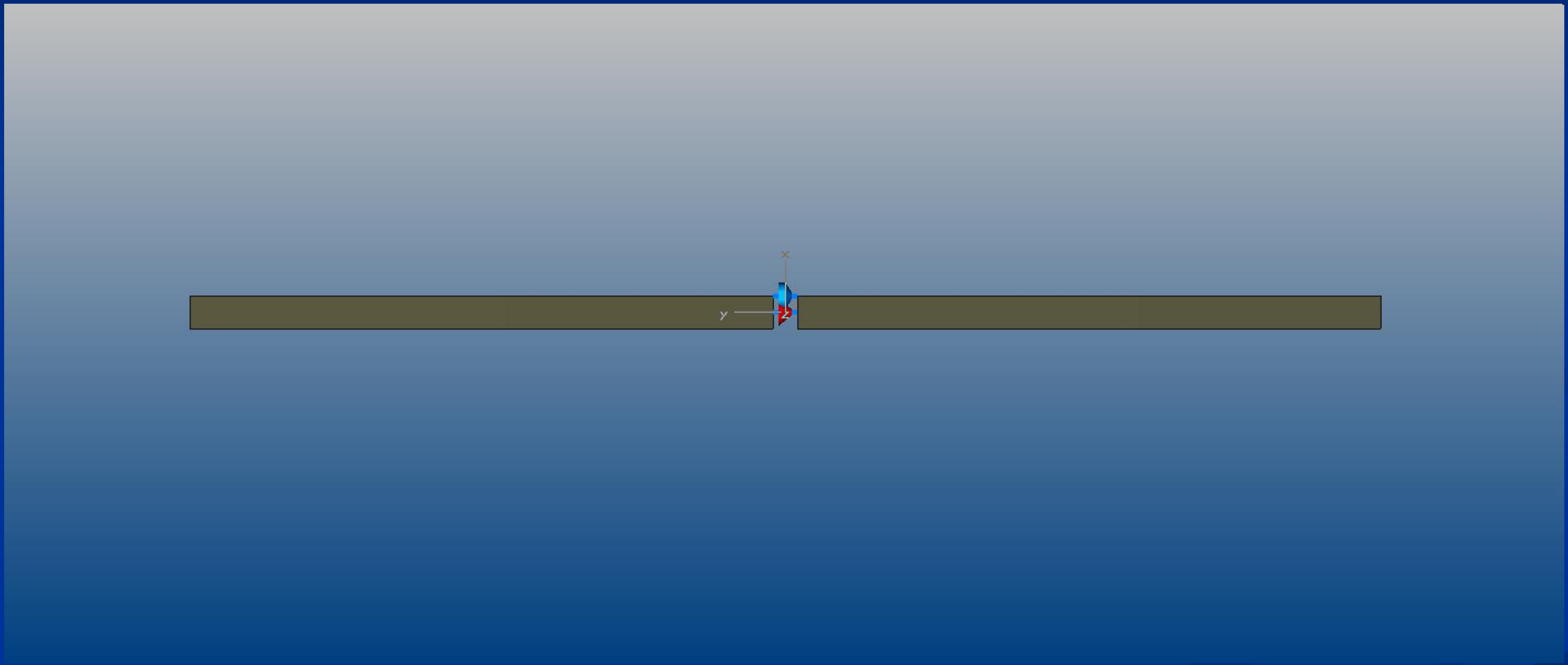


10 GHz horn antenna field view

A quick look at Dipoles and NVIS

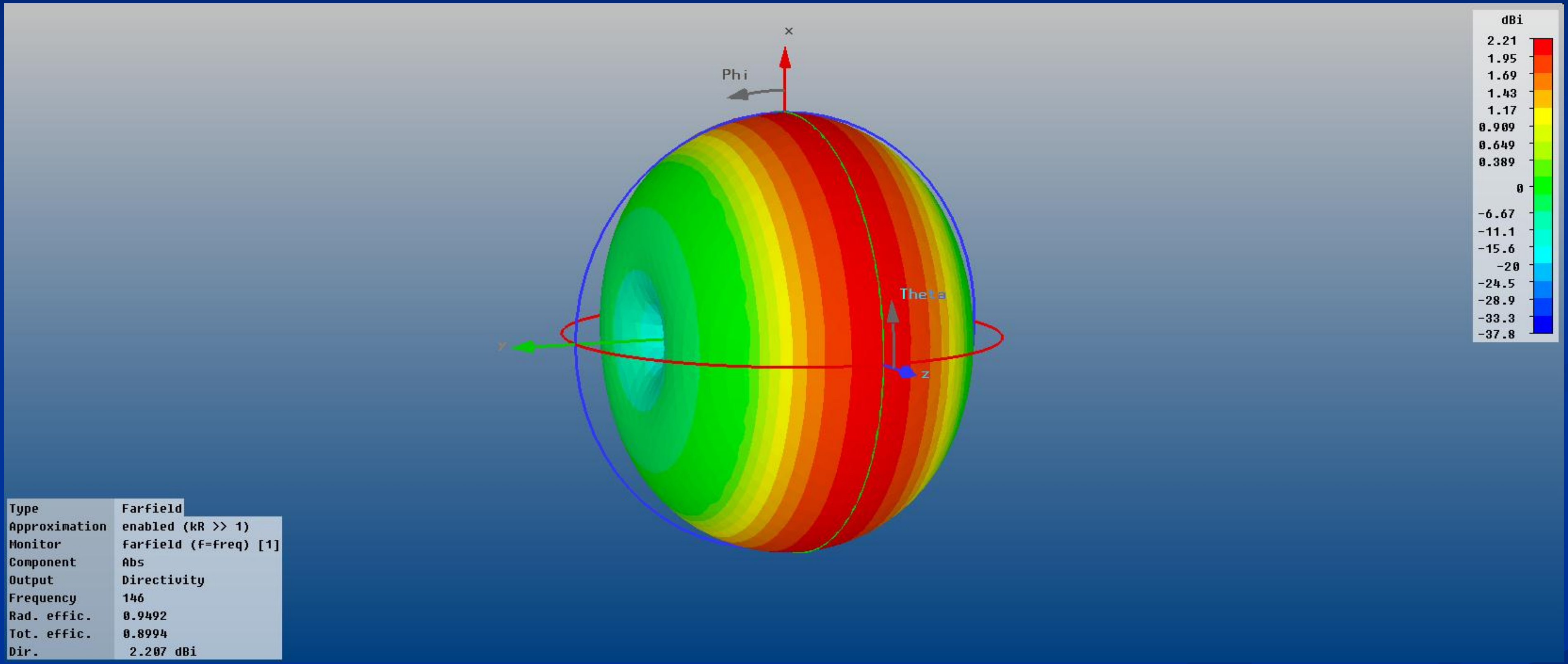
An excellent presentation on what Near Vertical Incidence Skywave (NVIS) is all about:
http://www.arrl.org/nvis

Dipole in free space (no ground effects)



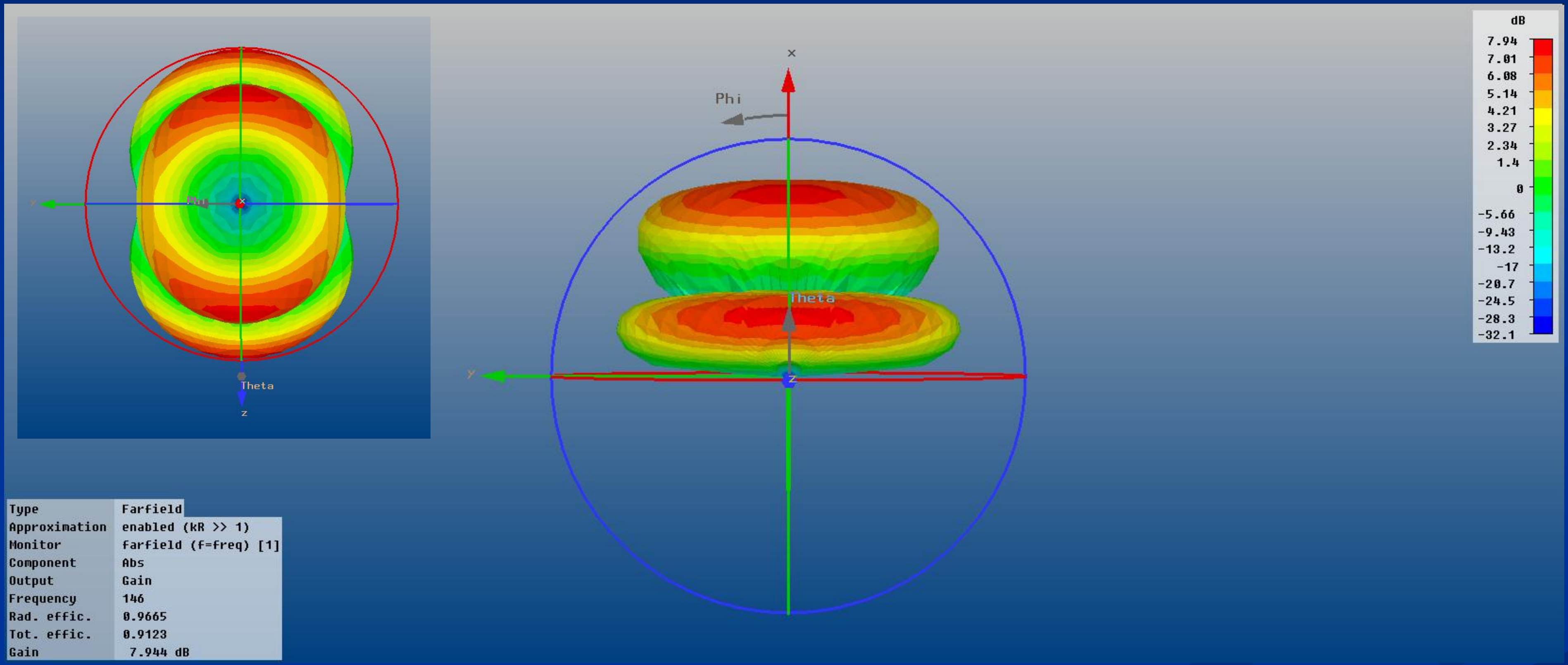
Dipole, no ground plane

Dipole in free space (no ground effects)



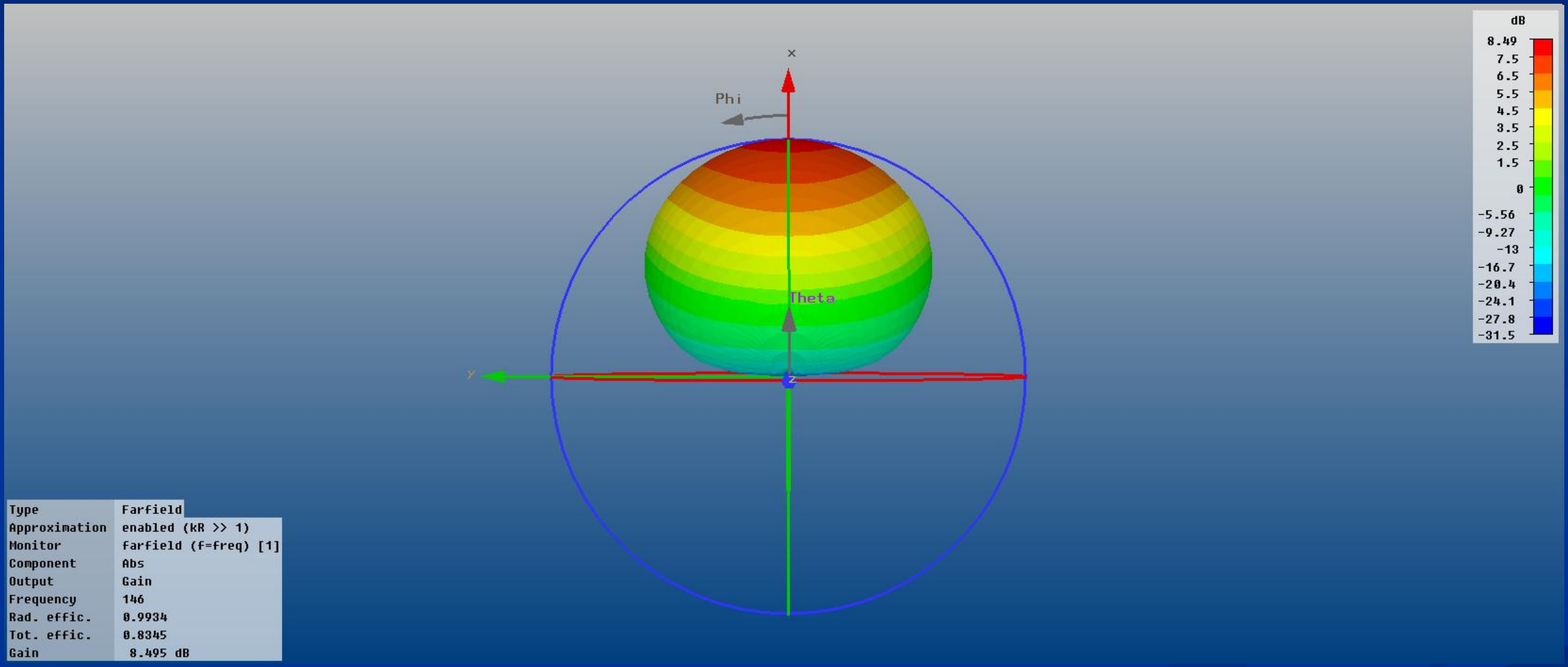
Free space; no ground effects
Total gain (horizontal + vertical polarization)

Dipole (1λ above ground)



Dipole modeled over *perfect, infinite* ground. Total gain (horizontal + vertical polarizations). Note that most of radiation is taking off at a somewhat low angle. This is a non-NVIS case.

Dipole (0.1λ above ground)



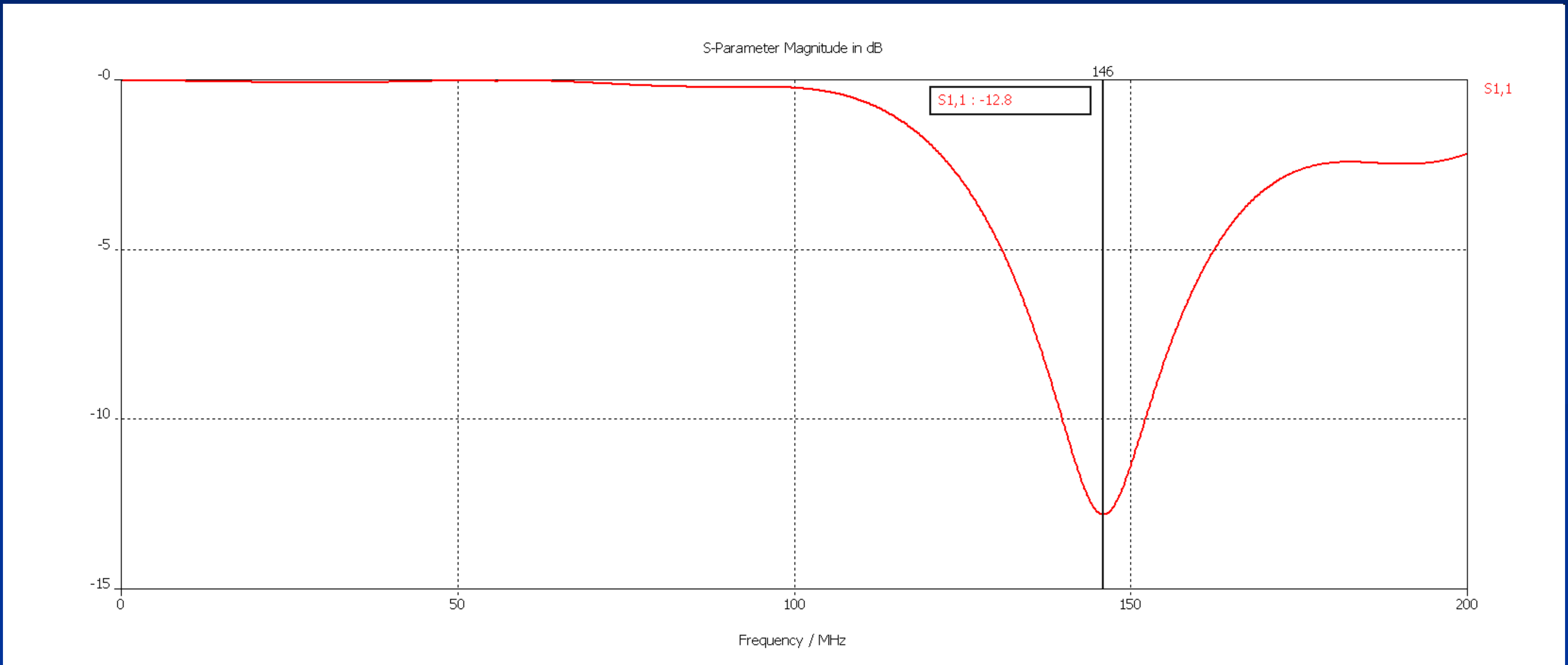
Dipole modeled over *perfect, infinite* ground. Total gain (horizontal + vertical polarizations).
Note that antenna now radiates almost entirely upward – perfect for NVIS operations.

Selected Web Resources

- **Yagis:**
  - *Yagi Antenna Design*, Peter Viezbicke, December 1976: http://tf.nist.gov/timefreq/general/pdf/451.pdf
- **J-Poles:**
  - Compilation of articles: http://www.arrl.org/vhf-omni
- **NVIS:**
  - Excellent Powerpoint presentation with links to websites: http://www.arrl.org/nvis
- **Antenna design & software:**
  - L.B. Cebik W4RNL (SK): http://www.cebik.com
  - ARRL Technical Information Service: http://www.arrl.org/technical-information-service
  - NEC: http://www.nec2.org
  - 4NEC2: http://home.ict.nl/~arivoors
  - EZ NEC: http://www.eznec.com
  - ANSYS HFSS: http://www.ansys.com/Products/Simulation+Technology/Electromagnetics
  - CST Microwave Studio: http://www.cst.com/Content/Products/MWS/Overview.aspx

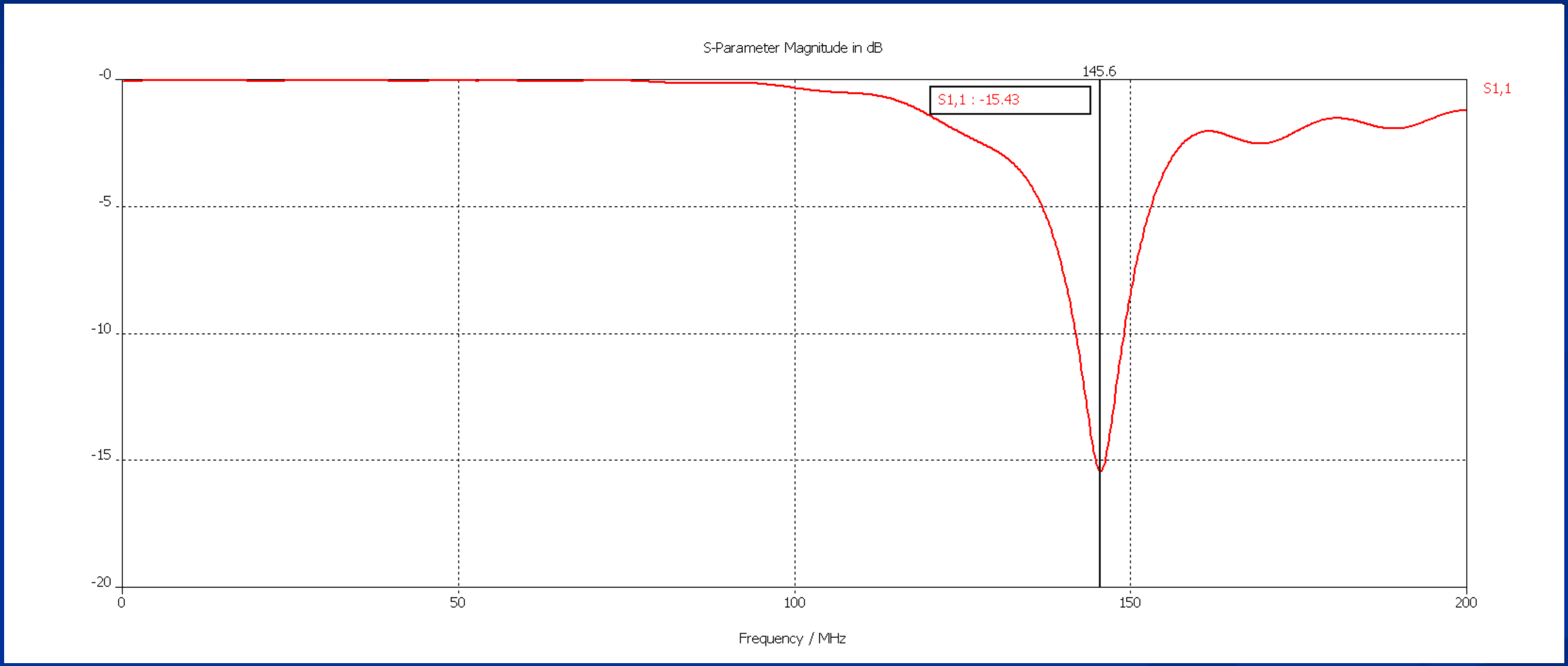
Backup

Driven element only



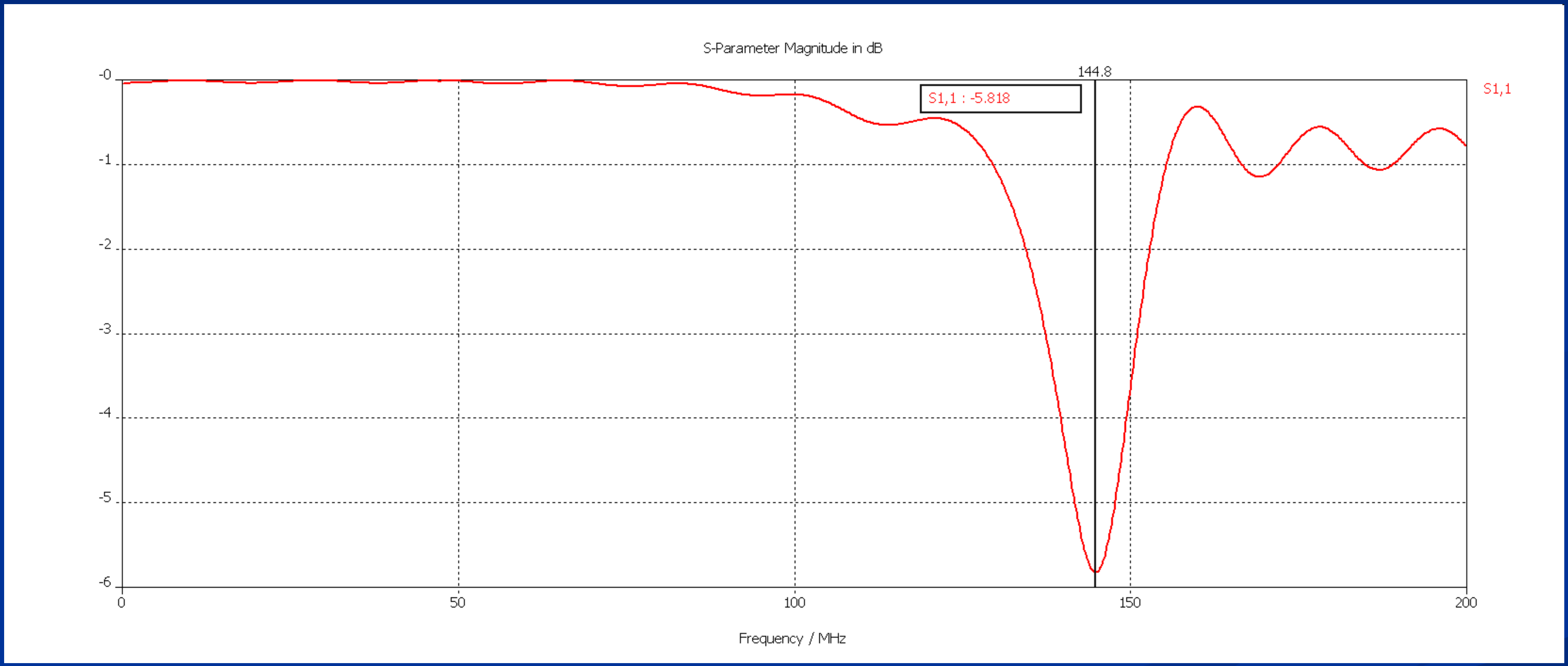
Return loss (resonance at 146.0 MHz)

Driven element plus director



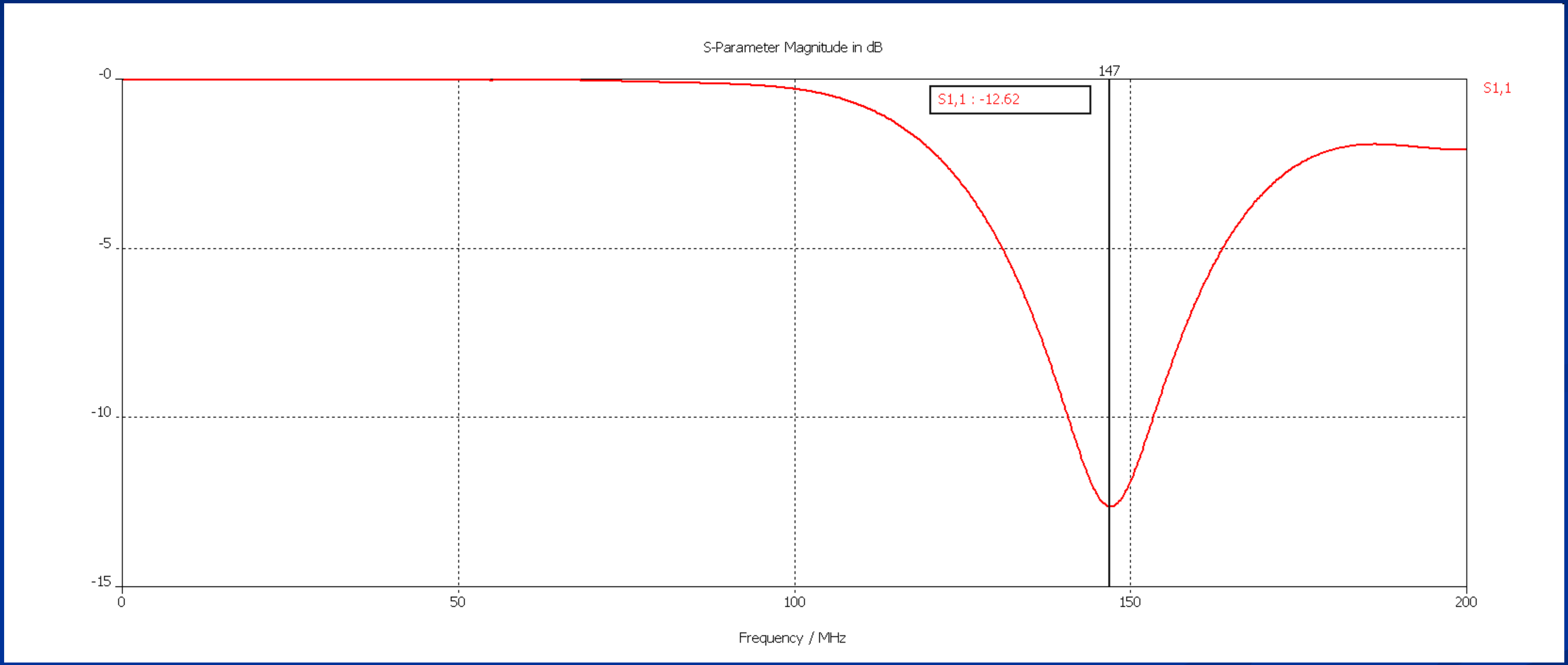
Return loss (resonance at 145.60 MHz)

Driven element, reflector & director



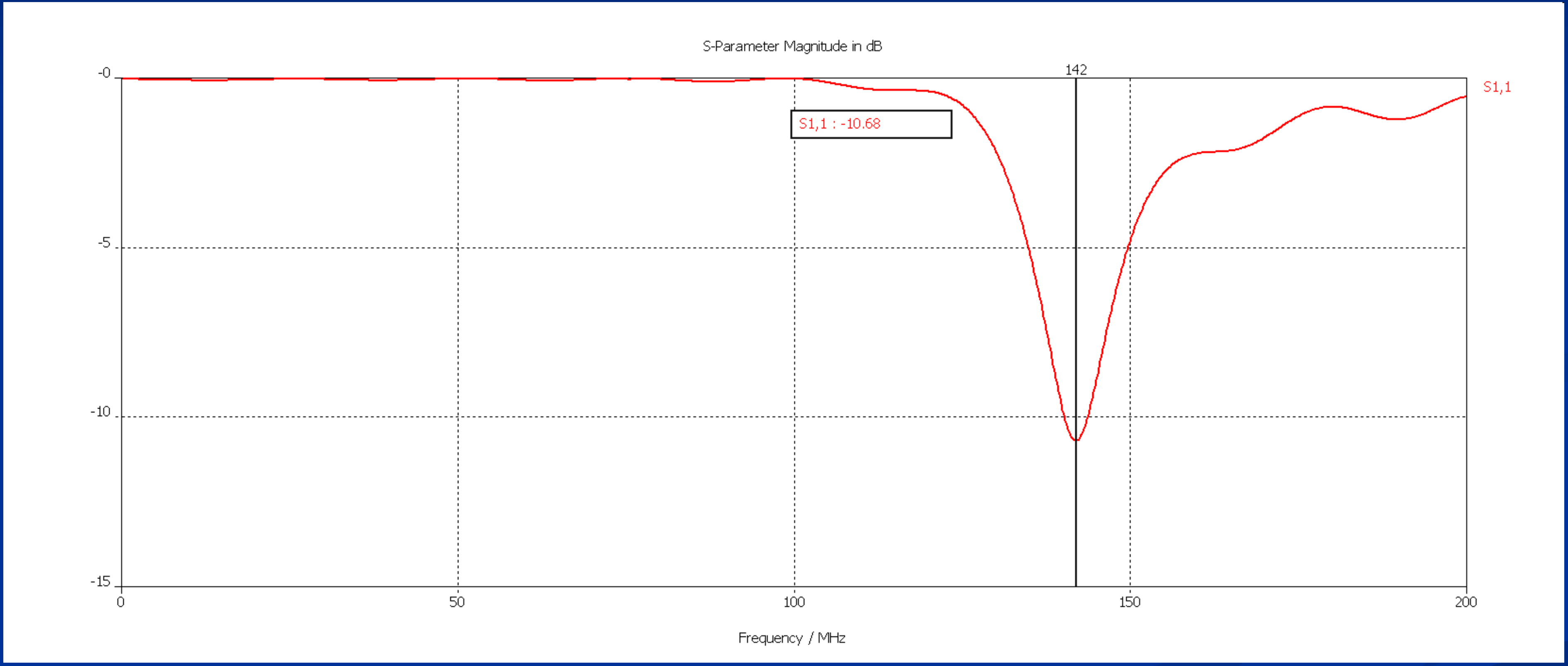
Return loss (resonance at about 144.8 MHz)

Dipole (1λ above ground)



Return loss (resonance at about 147.00 MHz)

Dipole (0.1λ above ground)



Return loss (resonance at about 142.00 MHz)