Introduction to Antenna Basics

Week 5: Intro to Microwave Antenna Design

Karen Rucker

Housekeeping

Final quiz for certificate

NanoVNA document

- How to hold an antenna while conducting measurements

If you’re thinking of getting an amateur radio license...

Recap from last class

Slots are complements to λ/2 dipoles

- length of a slot determines the resonant frequency
- width of the slot determines the bandwidth

Patch antennas are known for their directional pattern, gain <8 dBi, and are linearly polarized along the width of the patch

The wider the microstrip, the lower the characteristic impedance (Z0)

Week 4 Class Outline

Waveguides

Horns

3D Printed Horns

Parabolic Reflectors

Waveguide

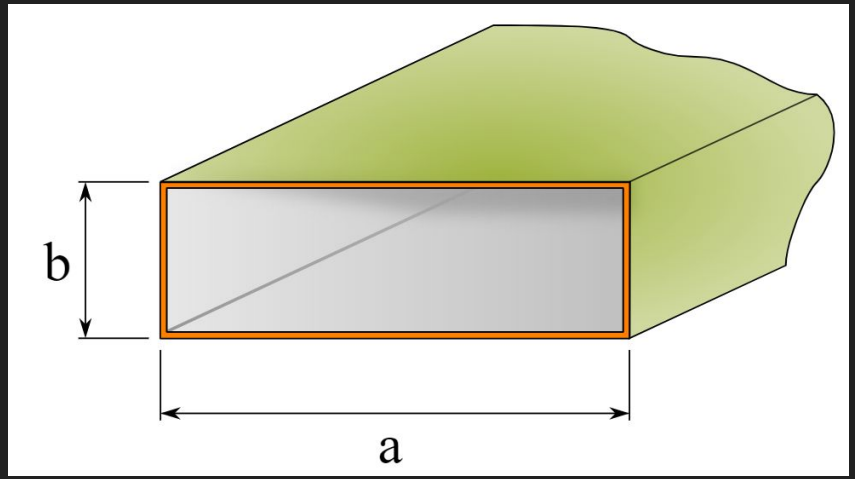
At higher frequencies, coax is too lossy

Commonly rectangular, can be circular

In the US, use EIA size

> Example: WR28 WG for DSN Deep Space Ka-band

If you're testing WG components on a VNA, you'll have to do a WG cal!



Waveguide Modes

Occur because of boundary conditions imposed on the wave by the waveguide

Transverse electromagnetic (TEM) modes

- Neither electric nor magnetic field in the direction of propagation.

Transverse electric (TE) modes

- No electric field in the direction of propagation.

Transverse magnetic (TM) modes

- No magnetic field in the direction of propagation.

Rectangular Waveguide Cutoff Frequency

cutoff frequency of an electromagnetic waveguide is the lowest frequency for which a mode will propagate in it

$f_c = c/2a$

Where:

- f_c = rectangular waveguide cut-off frequency in Hz
- c = speed of light within the waveguide in meters per second
- a = the large internal dimension of the waveguide in meters

Horn Antenna Basics

Aperture flare affects gain & directivity (beamwidth)

Waveguide dimensions affect frequency

Gain (usually) increases with frequency

Standard gain is good for testing/research - there are all kinds!

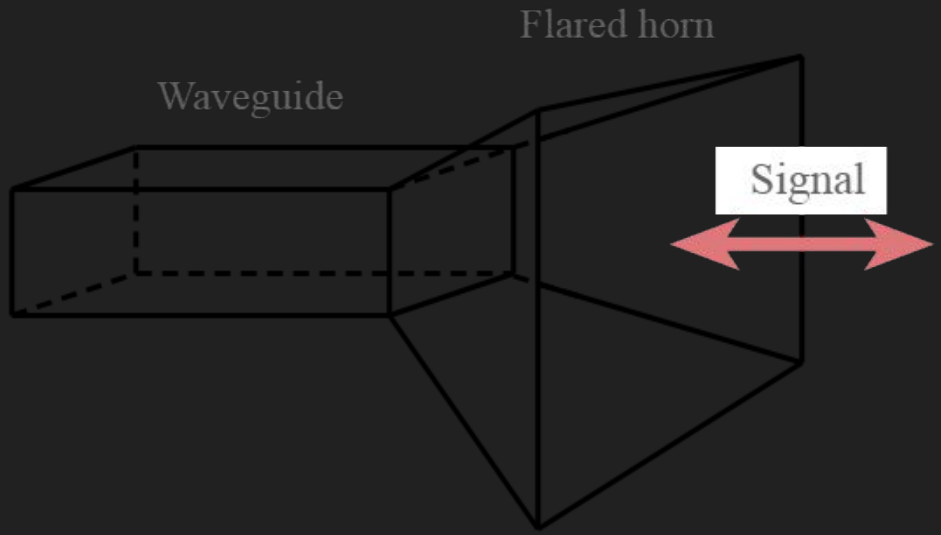


Image: electronics-notes.com

Horns

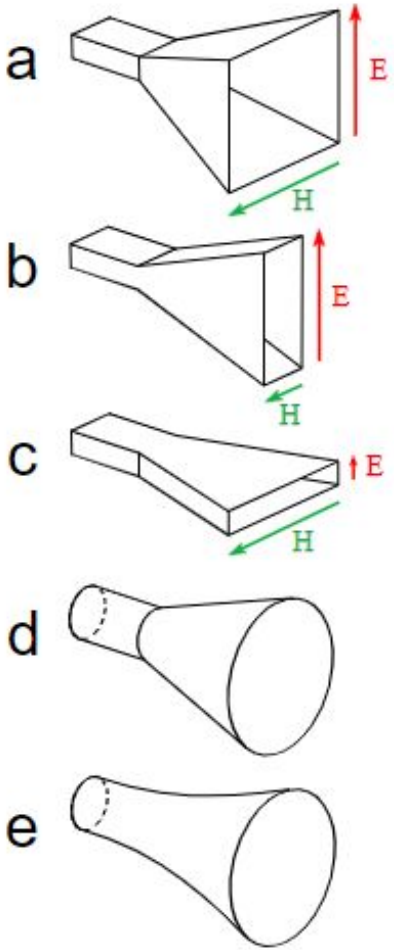
(a) Pyramidal horn (most widely used)

(b) E-plane sectoral horn

(c) H-plane sectoral horn

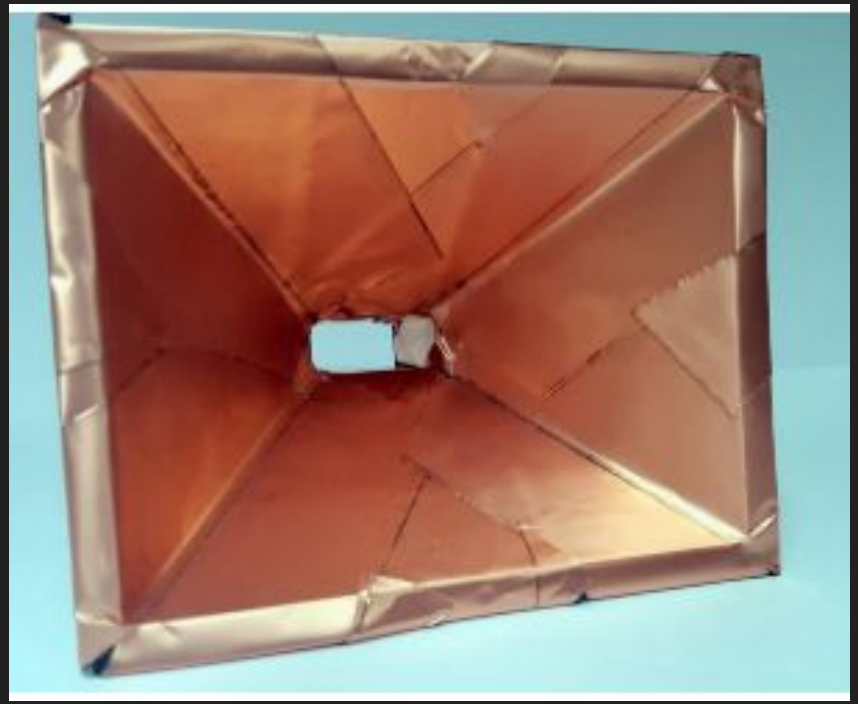
(d) Conical horn

(e) Exponential horn



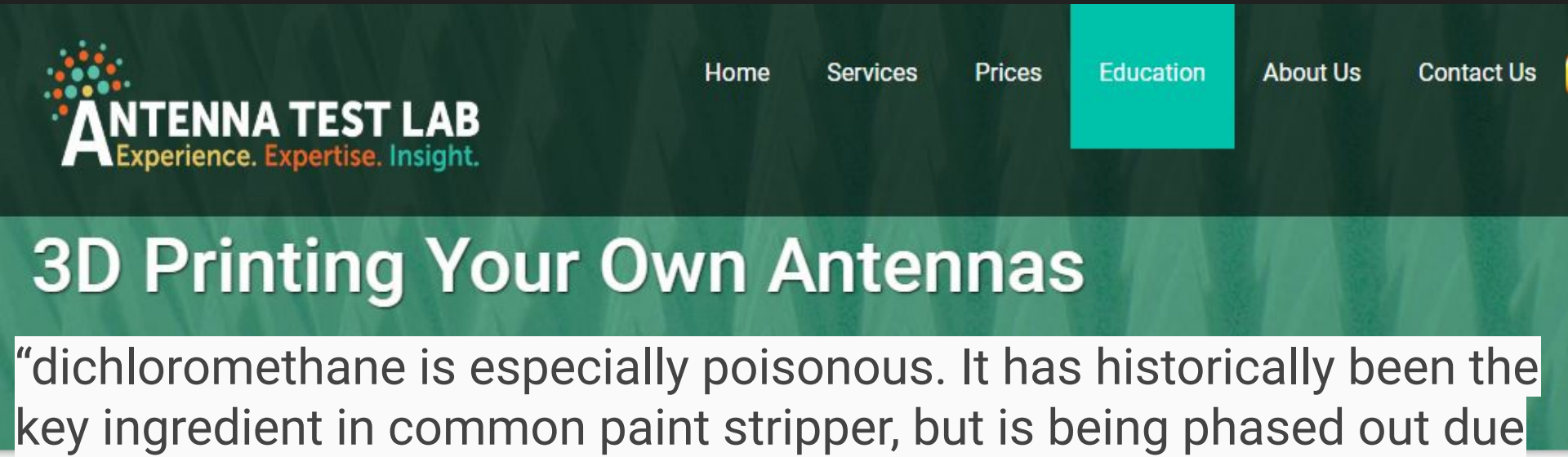
Chetvorno, CC0, via Wikimedia Common

How Would You 3D Print an Antenna in Space?



X-band, 15dBi standard gain horn dimensions

What if I Did What They Did... But Worse?



"dichloromethane is especially poisonous. It has historically been the key ingredient in common paint stripper, but is being phased out due to its toxicity when used for DIY home projects."

It Works, and You Can Do It!

The 3D model

15 dBi standard gain horn

Filament: PLA

Infill: 10%

Pattern: standard diamond fill

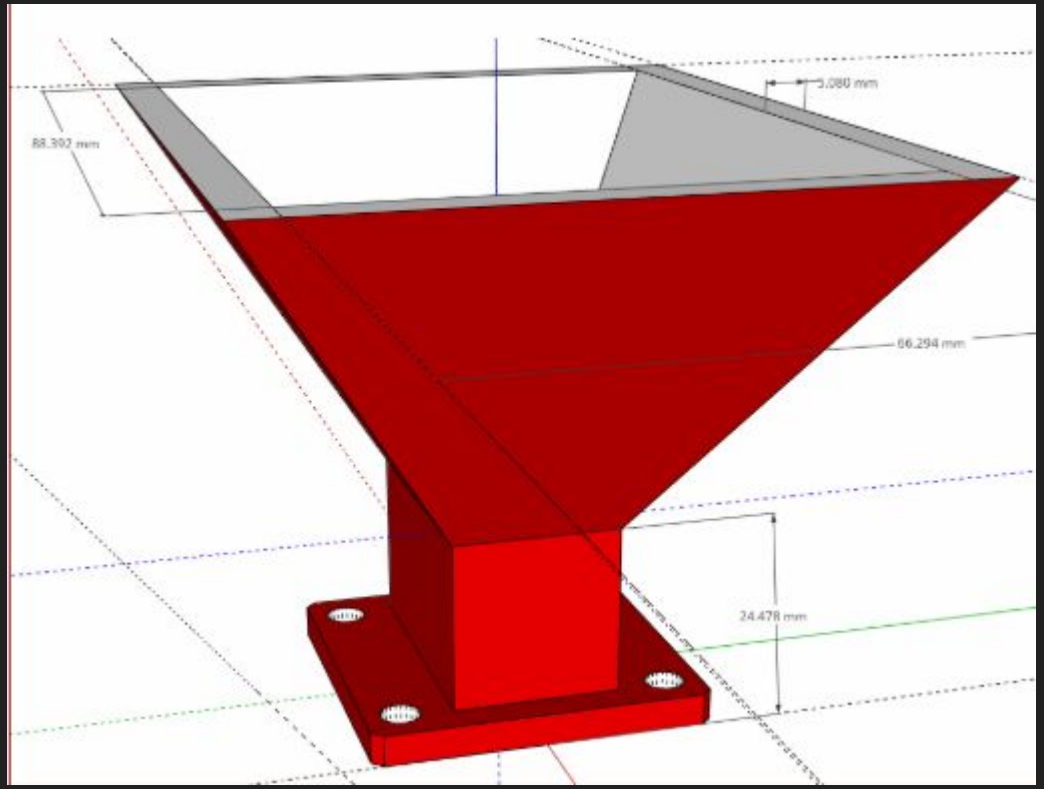
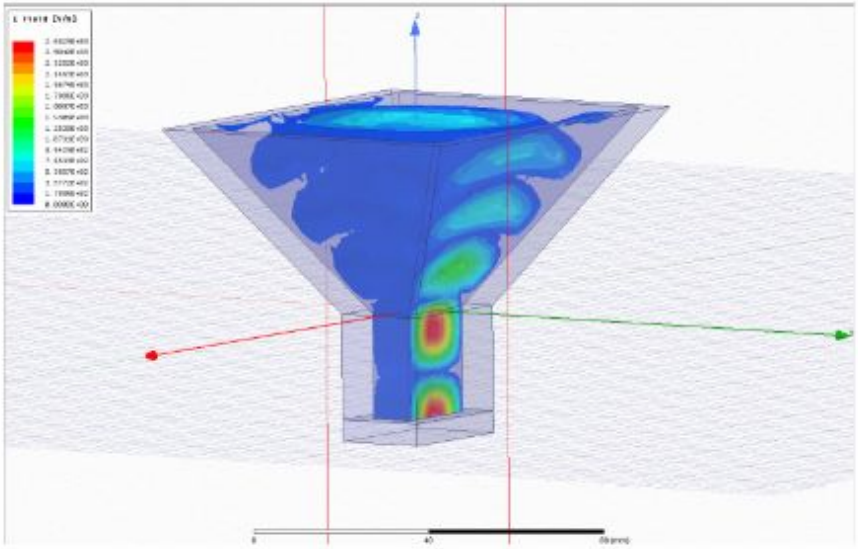
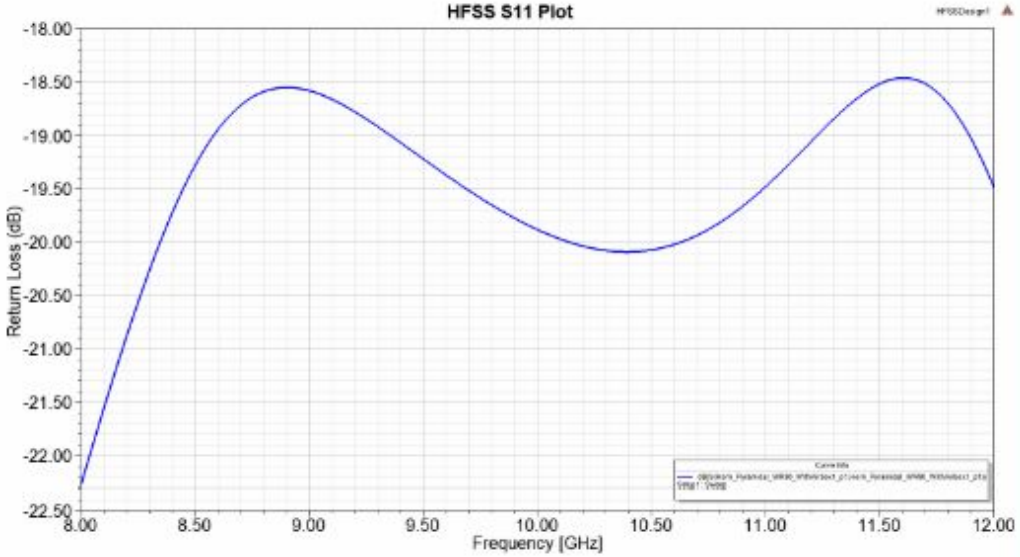


Image: K. Rucker

The Simulation



3D Model, E Field magnitude



Return Loss

Image: K. Rucker

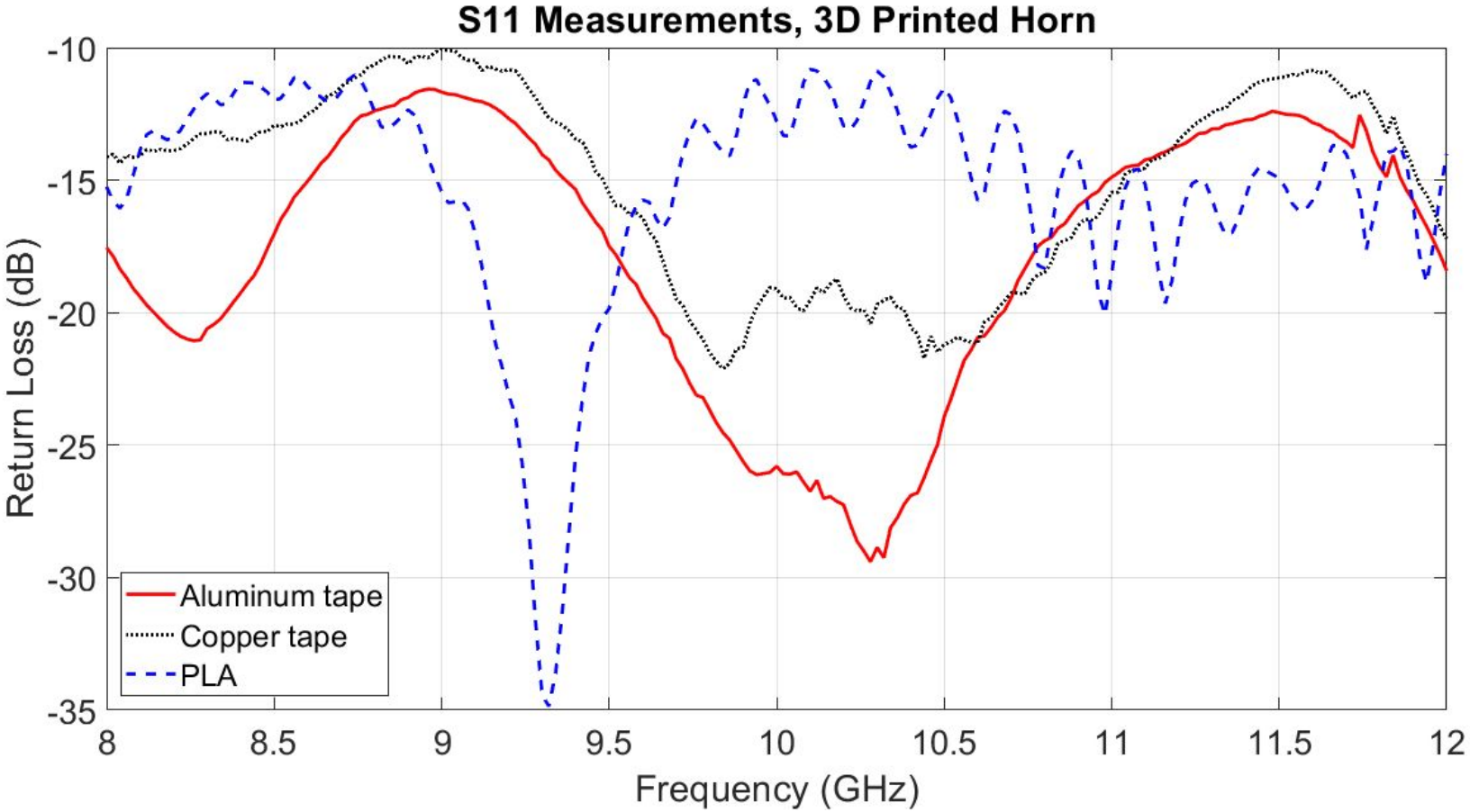


Image: K. Rucker

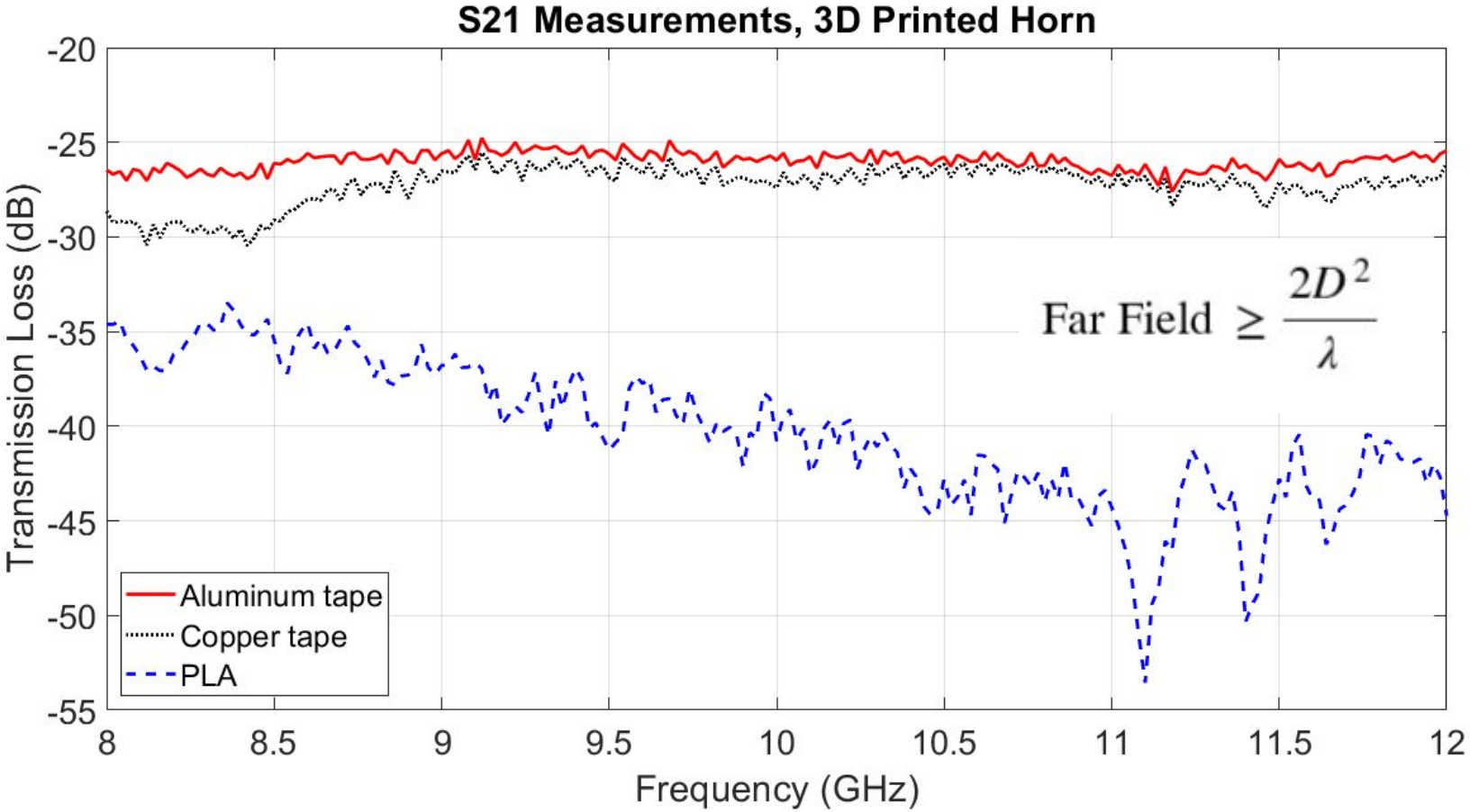


Image: K. Rucker

Parabolic Reflectors

Used for space communication

High gain antennas (HGAs) on spacecraft

NASA Deep Space Network (DSN), Space Network (SN) ground stations

May have to use physical optics solver like Ticra GRASP

If large enough, have to consider mechanical, material, and thermal constraints

I like big gain and I cannot lie

Gain determined by diameter (D) and antenna efficiency (k)

$$Gain\ (dB) = 10 \times \log_{10} k \left(\frac{\pi D}{\lambda}\right)^2$$

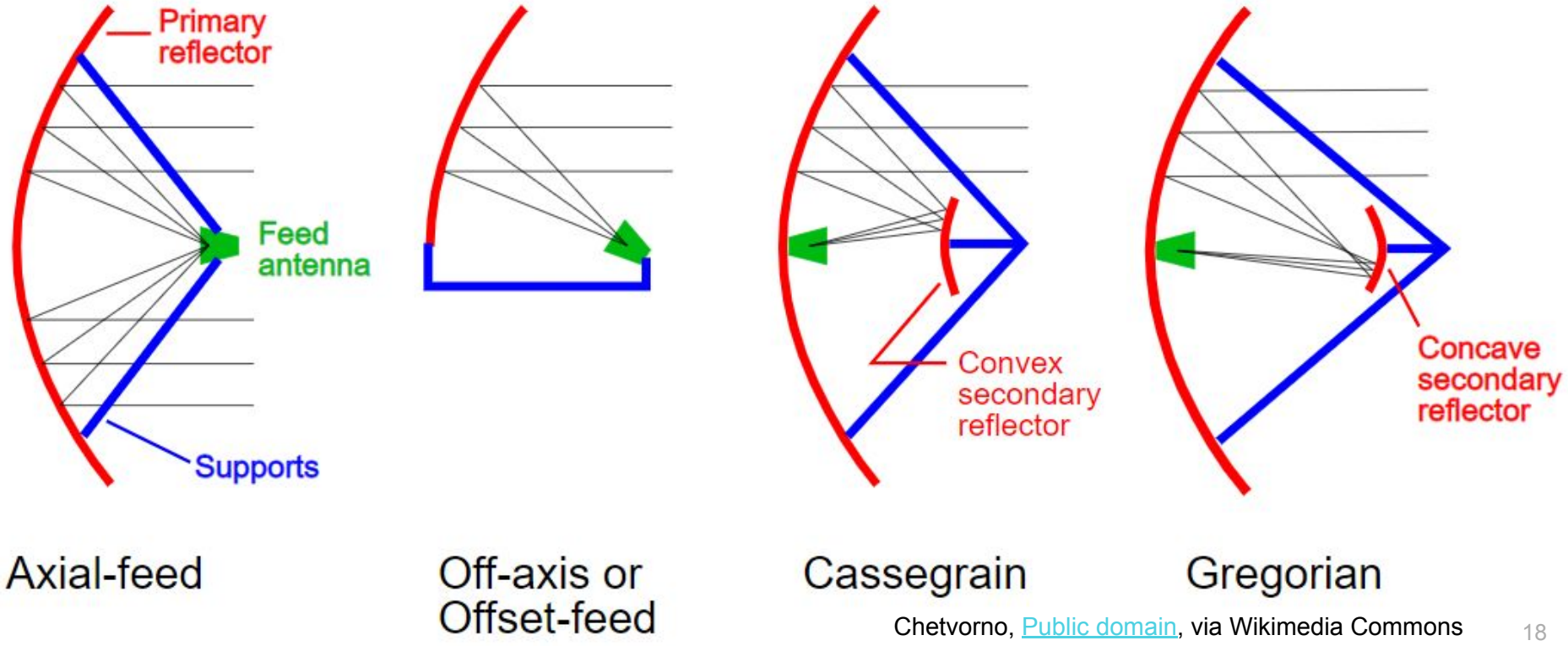
Examples:

Cassini 4-m HGA 56.4 dBi gain

DSN 70-m ~67 dBic

Image: YouTube
Pretty Woman - Big Mistake. Big. Huge
Uploaded by: MoviQuotes, Dec 30, 2014

Parabolic reflector feeds



Chetvorno, Public domain, via Wikimedia Commons

Class Recap

The cutoff frequency is the lowest frequency for which a mode will propagate in waveguide.

The a (width, largest) dimension of rectangular waveguide sets the cutoff frequency

In a waveguide horn antenna:

- Waveguide sets the frequency
- Aperture flare sets the gain

Resources

Waveguide Sizes
Microwave Horn Antenna

Antenna Test Lab, 3D Printing Your Own Antennas
Pyramidal Horn Calculator
Parabolic Reflector Antenna Gain calculator
Cassini Orbiter Telecommunications

Signing off

Thank you!

Want to teach? HackadayU instructor proposal

Questions?