S-Band Radar Transmitter

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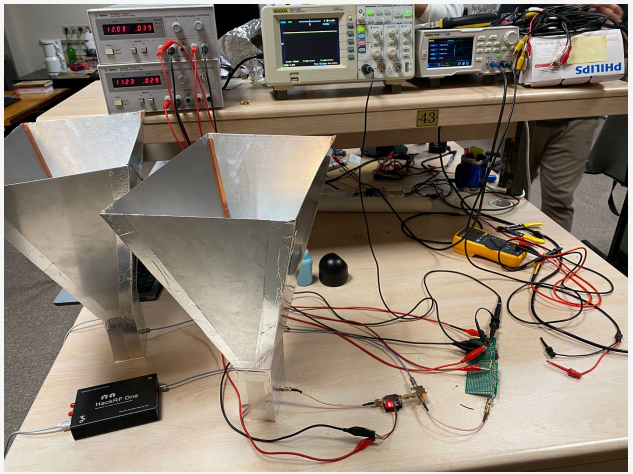
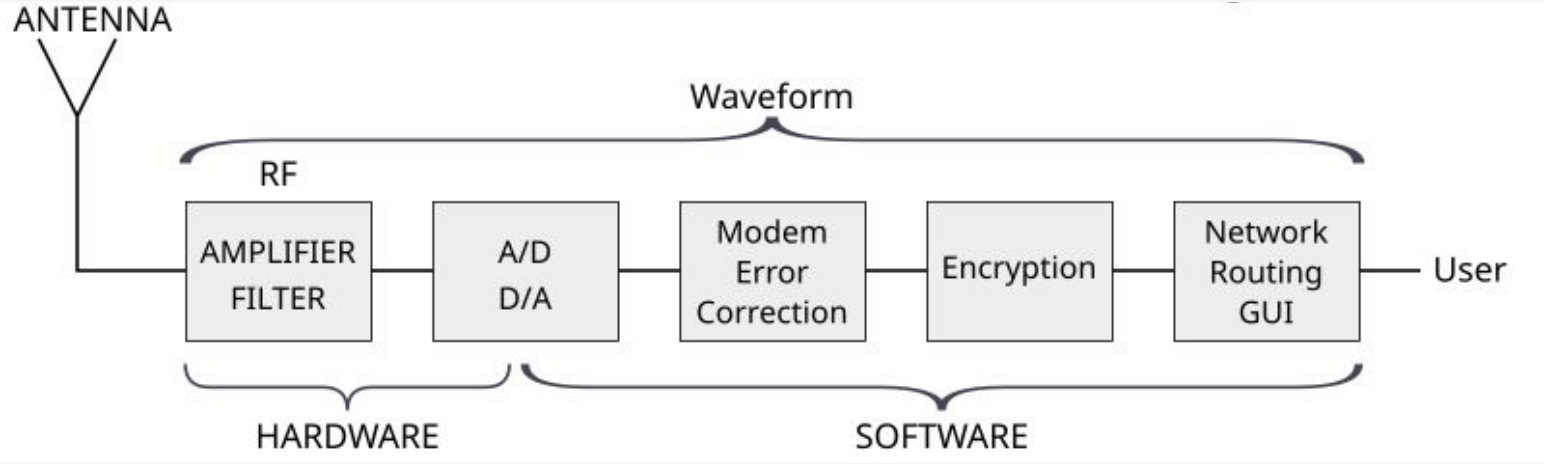
Fundamentals of Radars

- **Radio Detection and Ranging**
- RADARs utilize propagation of EM waves to determine the speed, position, size, shape and composition of objects depending on the type of RADAR



Signal Source

- **Software Defined Radio:** The roles of the components filters, mixers, amplifiers, and modulators/demodulators are replaced by software.

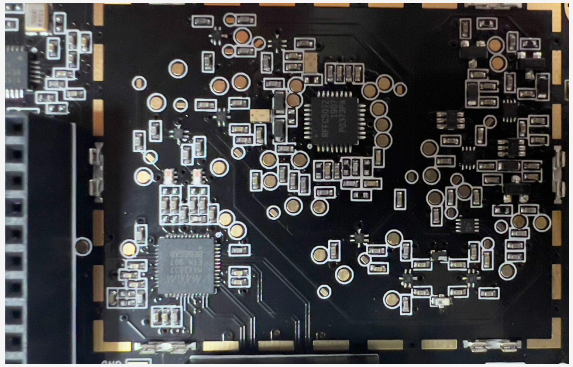


Signal Generation and Transmission

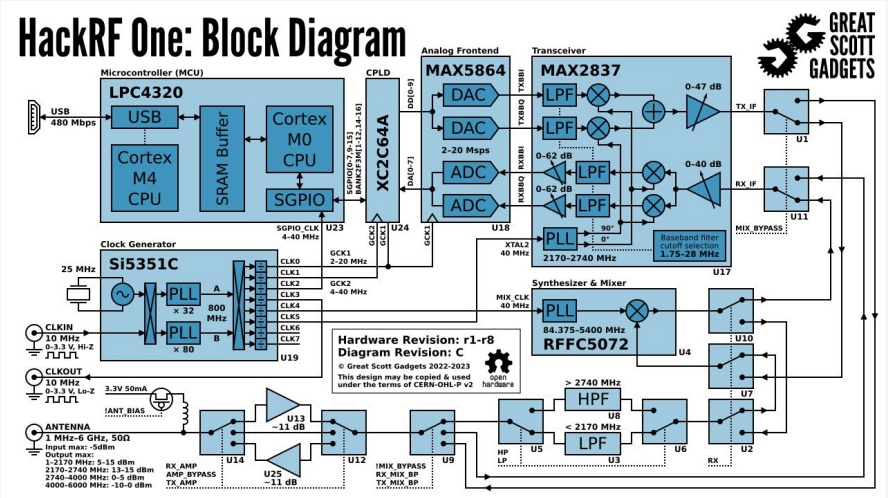
- **Creating a Baseband Waveform:** Desired signal is converted to baseband I/Q samples at low frequency
- **I/Q Representation:** On board FPGA feeds I/Q samples to DAC
  - I (In-Phase): signal that is in phase with the reference wave.
  - Q (Quadrature): signal that is π/2 radians out of phase with the reference wave
- **Upconverting to RF:** The Local Oscillator (LO) and mixers translate the baseband analog signal to the chosen frequency.

Signal Source: Signal Generation

- **HackRF One:** Capable of transmitting from 1MHz to 6 GHz
  - 5 dBm output power, 20 MHz Bandwidth
  - Easy to access, Flexible



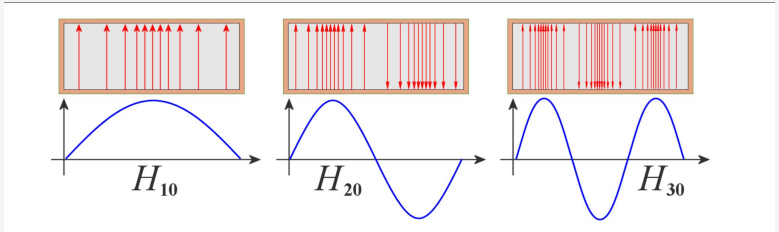
Transreciever of HackRF

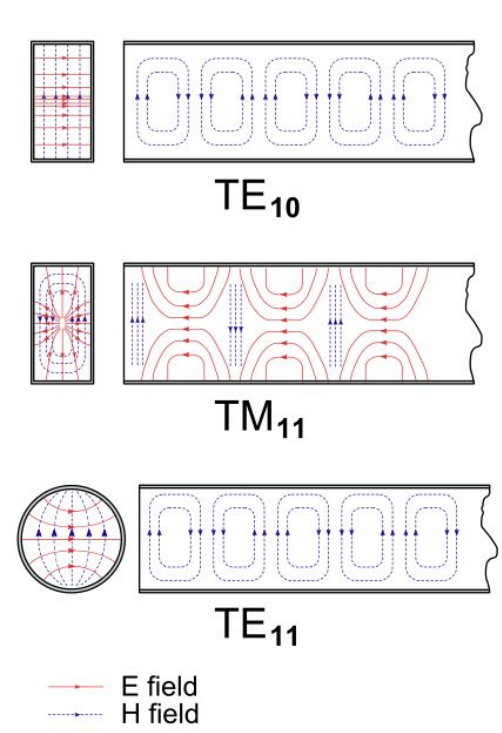


Antenna: Waveguide

- Transmitting and receiving with

  low-loss and **high efficiency**
- Direction control
- **Transverse Electric Mode (TE Mode):** Solution to Maxwell's equation under boundary conditions of the waveguide

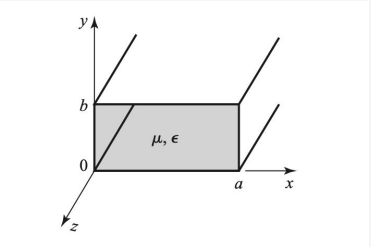




Antenna: Rectangular Waveguide

- **TE10 Mode Dominates:** TE10 Mode has the lowest cut-off frequency

$$f_{c_{mn}} = \frac{k_c}{2\pi\sqrt{\mu\epsilon}} = \frac{1}{2\pi\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

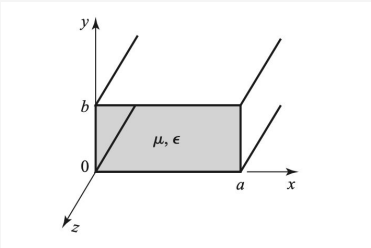


- For wide-band operation, the cut-off frequencies are determined to be **≈ 1.75 GHz**

Antenna: Rectangular Waveguide

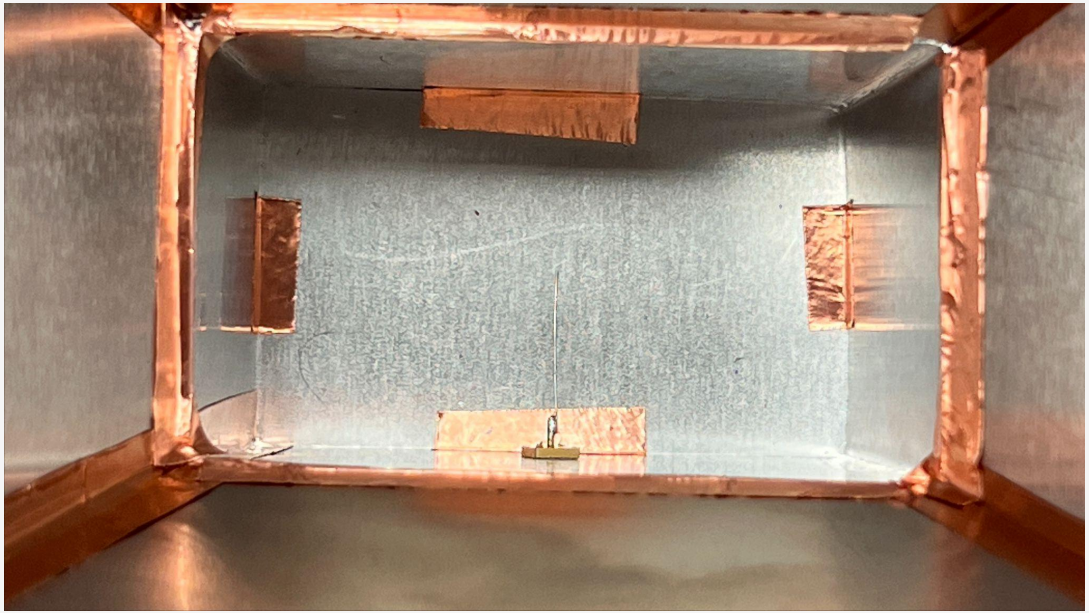
- Solving for fc10 = 1.75 GHz yields: **a = 86mm, b = 50mm**

$$f_{c_{10}} = \frac{1}{2a\sqrt{\mu\epsilon}}$$



- **Constructive Interference:** The monopole is placed λ/4 = **25 mm** from back of the waveguide

Antenna: Waveguide



Antenna Design

- Directional Antenna
- Weak Source
- **Directivity:** Ratio of Radiation Intensity in a specified direction to the averaged radiation intensity in all directions

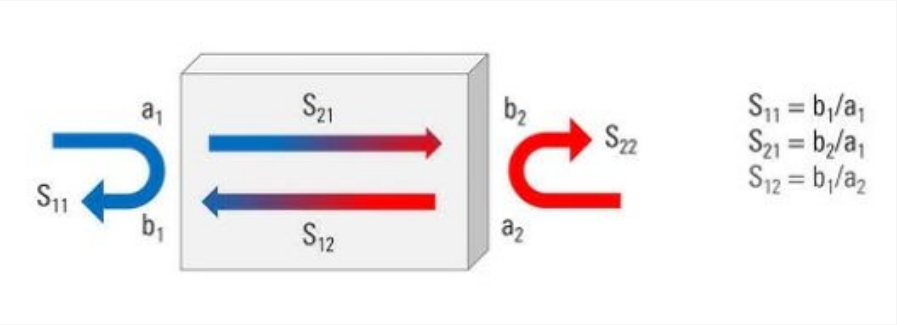
$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{\text{rad}}}$$

- **Gain:** Ratio of intensity in a specified direction to the intensity if the power was radiated isotropically

$$G = \frac{4\pi U(\theta, \phi)}{P_{in}\,(\text{lossless isotropic source})}$$

Antenna Design

- **S11:** Represents how much input power is reflected from the antenna
- Return Loss
- **VSWR:** Voltage Standing Wave Ratio, how efficiently power is transmitted
- Reflection of power due to impedance mismatches

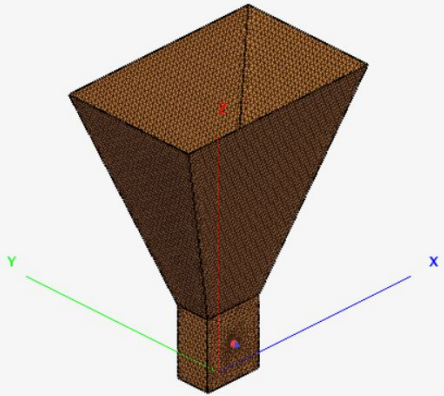


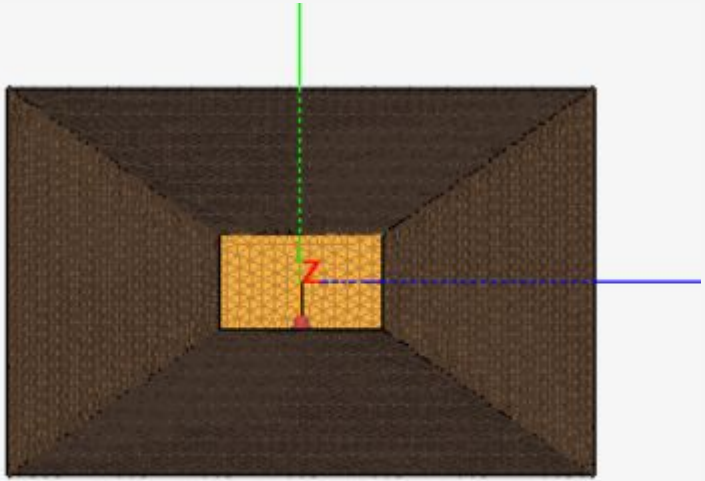
Horn Antenna

- Transitions EM waves from a waveguide to free space
- Flared shape improves efficiency by gradually increasing the impedance of the waveguide to match the radiation impedance of free space
- Focus energy: High Gain

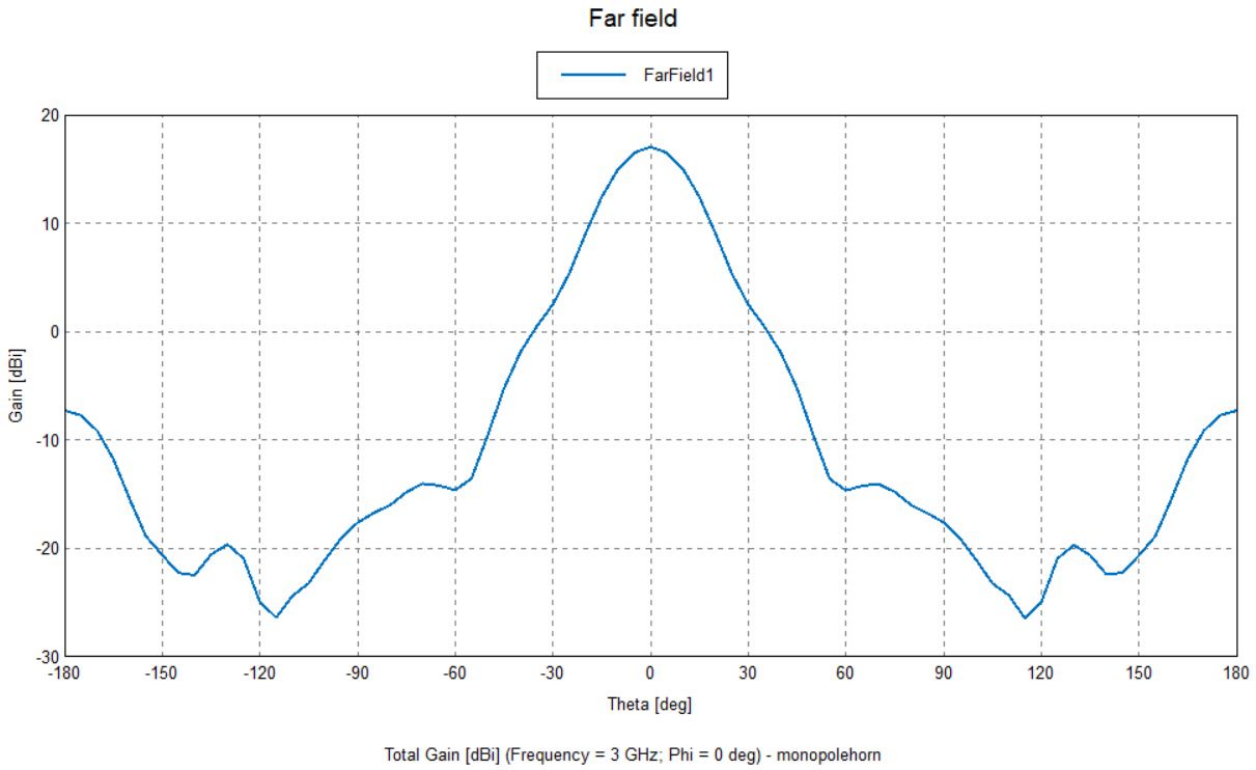
Horn Antenna

- Altair FEKO Software

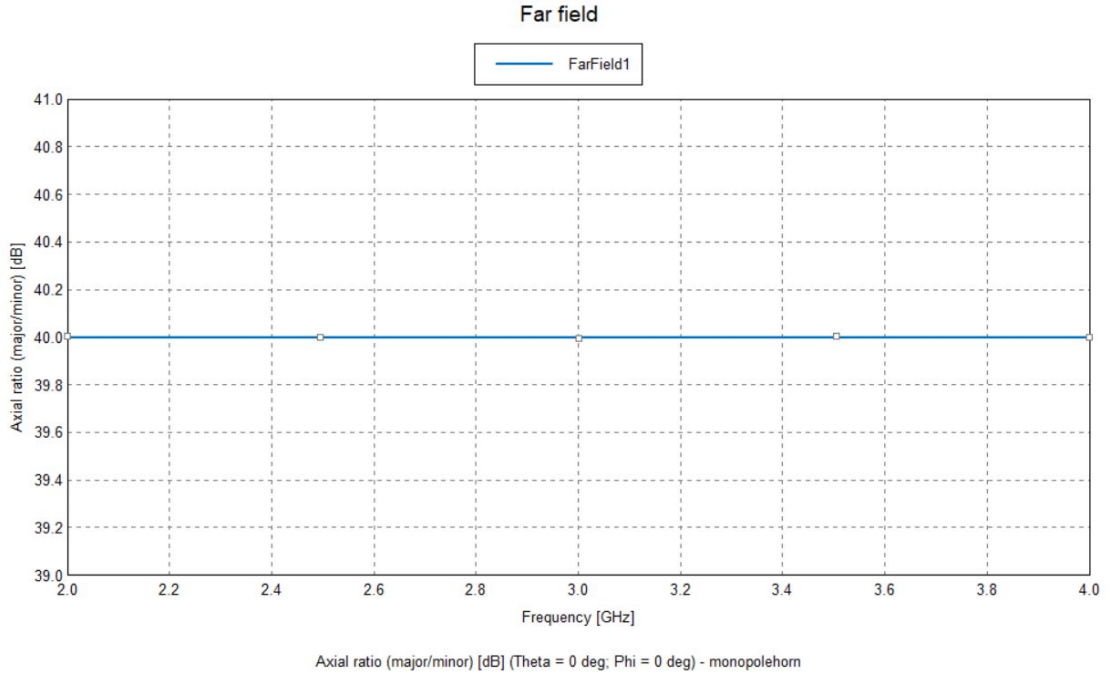


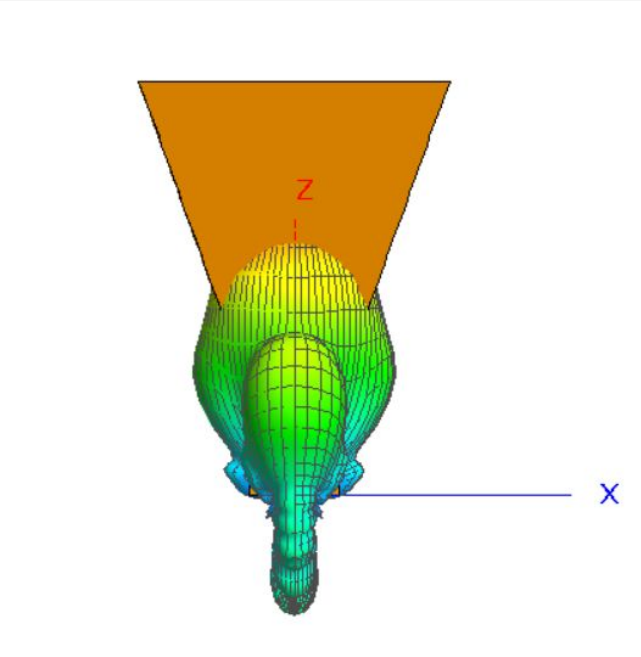


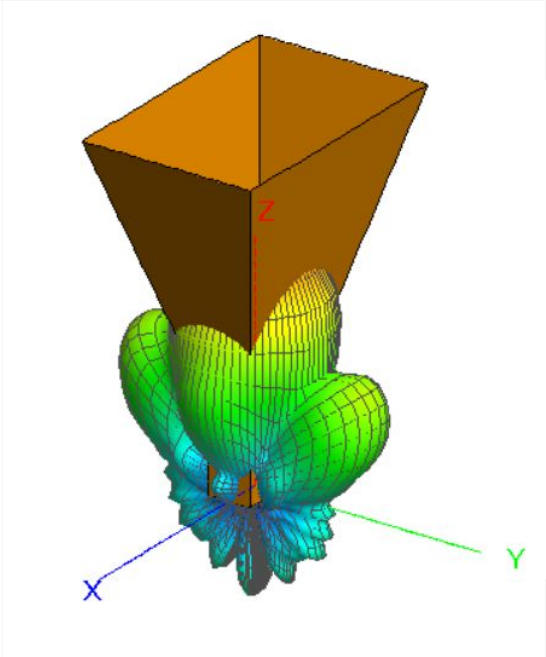
Gain

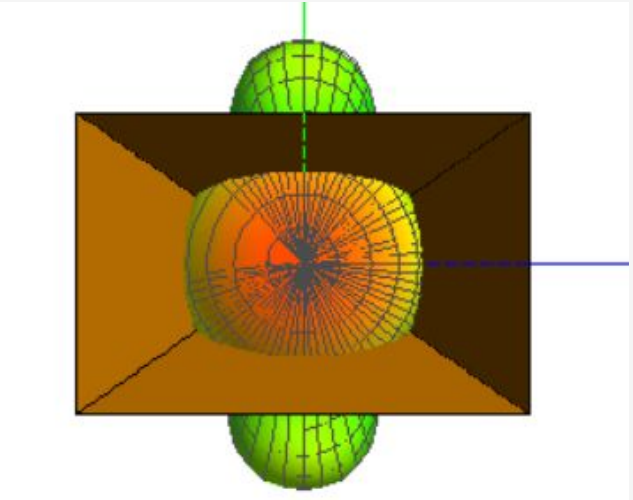

Far field
FarField1
20
10
0
-10
-20
-30
Gain [dBi]
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
Theta [deg]
Total Gain [dBi] (Frequency = 3 GHz; Phi = 0 deg) - monopolehorn

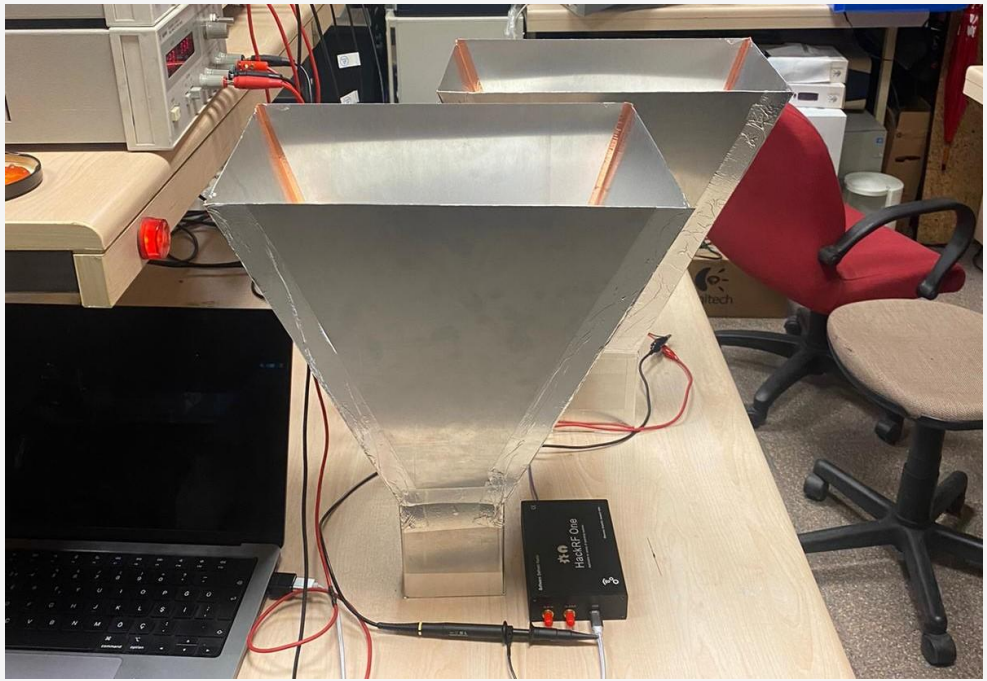
Axial Ratio


Far field
FarField1
41.0
40.8
40.6
40.4
40.2
40.0
39.8
39.6
39.4
39.2
39.0
Axial ratio (major/minor) [dB]
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
Frequency [GHz]
Axial ratio (major/minor) [dB] (Theta = 0 deg; Phi = 0 deg) - monopolehorn


Z
X

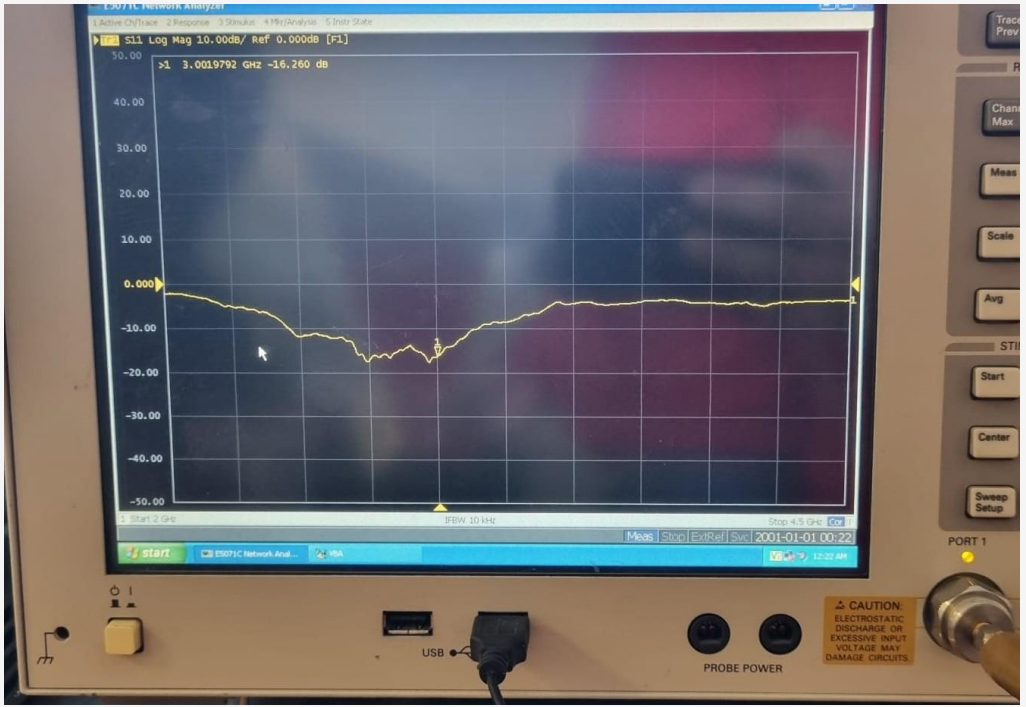

Z
Y
X




HackRF One

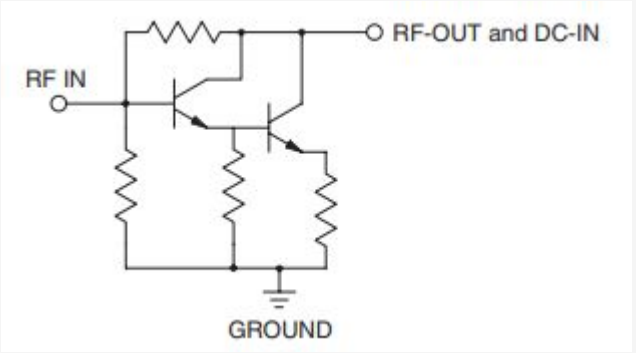
VNA

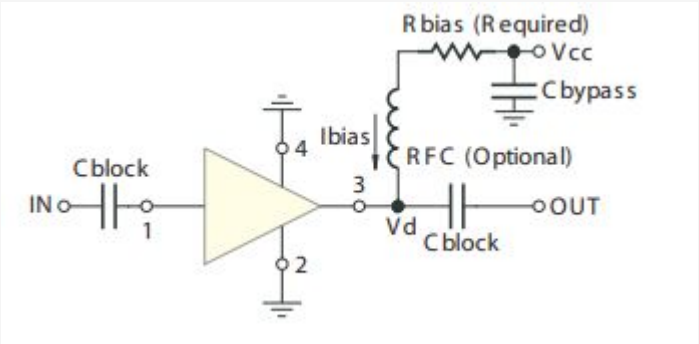
- Vector Network Analyzer
- Thanks to Sobhan Gholami
- -16.26 dB at 3GHz
- 2.4% is reflected back

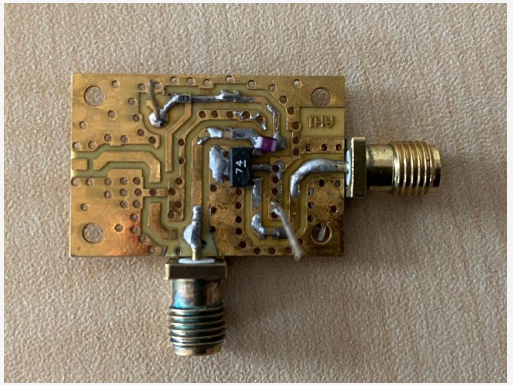


Power Amplifier

- **Gali74+**, Wideband amplifier
- ~12dB gain at 3GHz
- Bias-tee required
- Saturated our output

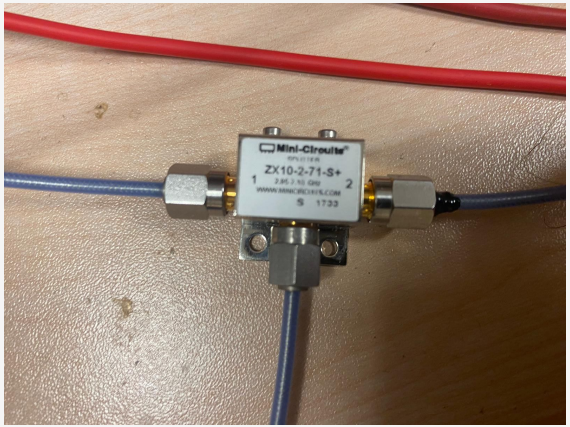






Power Splitter

- Distributes signals efficiently to different electronic systems
- **ZX10-2-71+**
- Signal is splitted to the transmitting antenna and to the mixer at the receiving side



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References

[1] “HackRF One — HackRF documentation,” hackrf.readthedocs.io. https://hackrf.readthedocs.io/en/latest/hackrf_one.html

[2] C. A. Balanis, “Advanced Engineering Electromagnetics,”, John Wiley & Sons, Inc., 1989.

[3] C. A. Balanis, “Antenna Theory Analysis and Design,” 2nd Edition, John Wiley & Sons, Inc., New York, 1997.

[4] Pozar, D.M. (2012) Microwave Engineering. 4th Edition, John Wiley & Sons, Inc., Hoboken.