UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

L & S-Band LEO Satellite Ground Station

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Team 61

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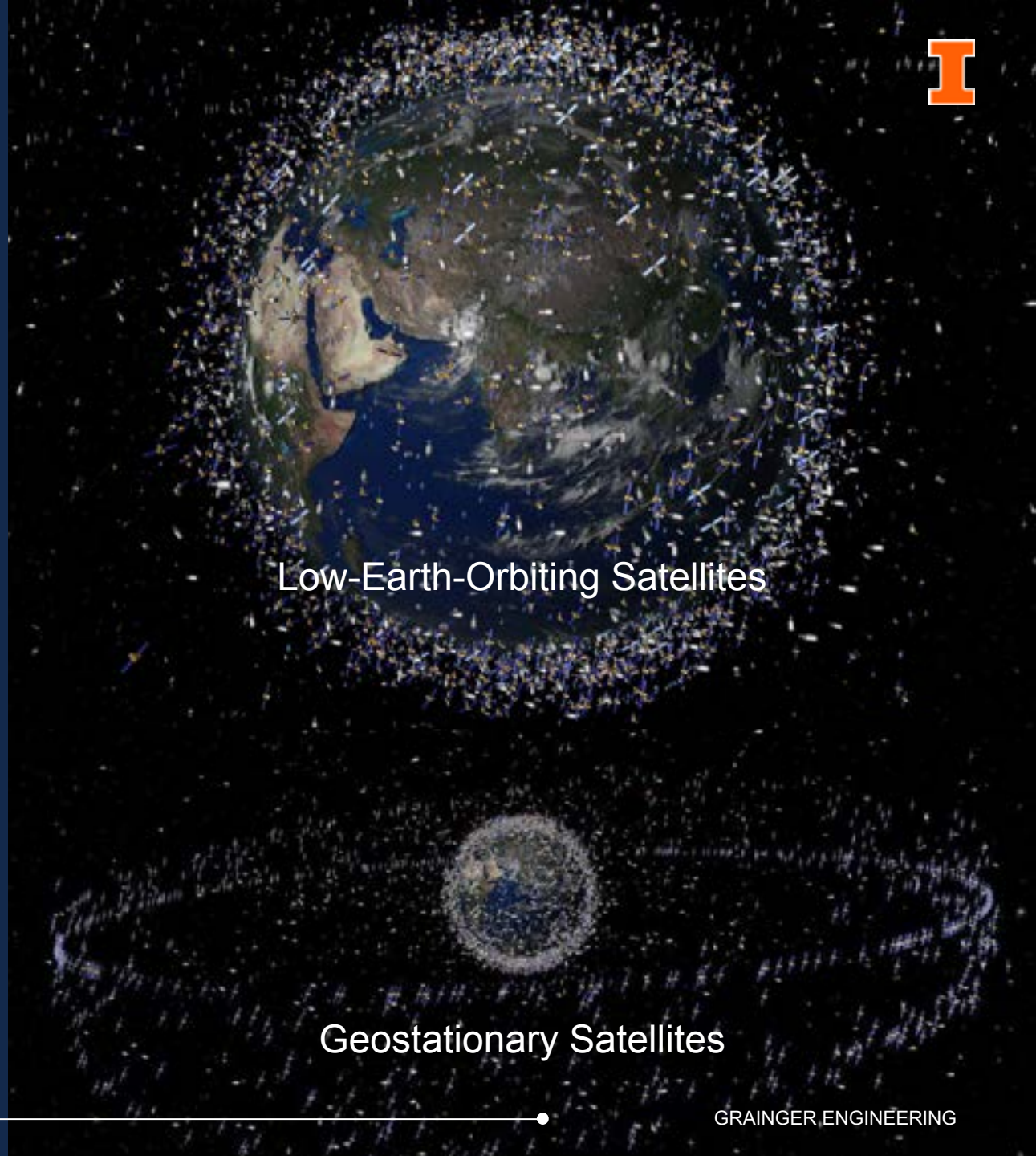
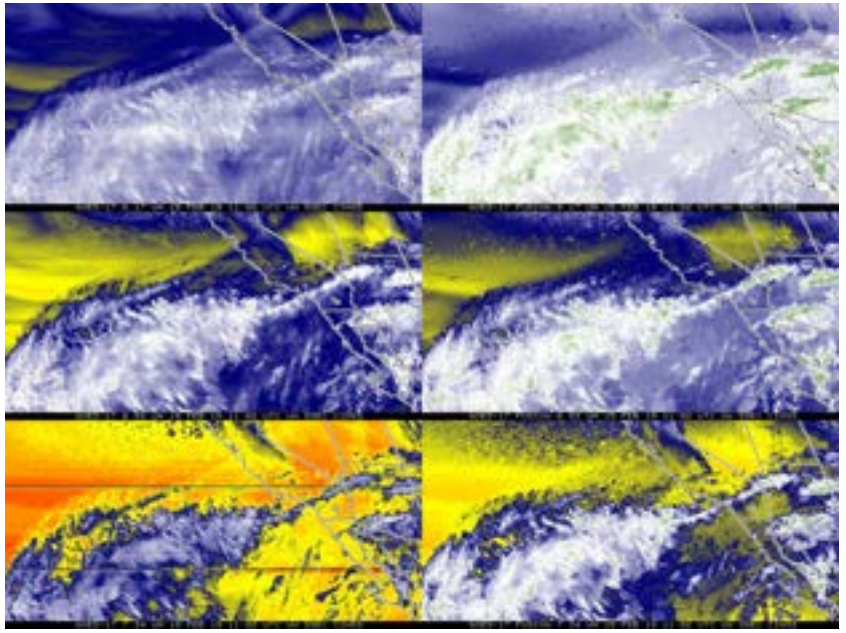
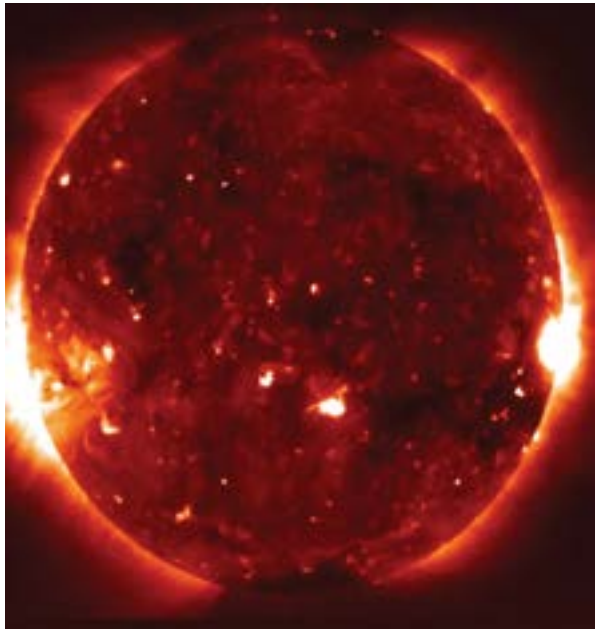
Over 14,000 Satellites Orbiting Earth

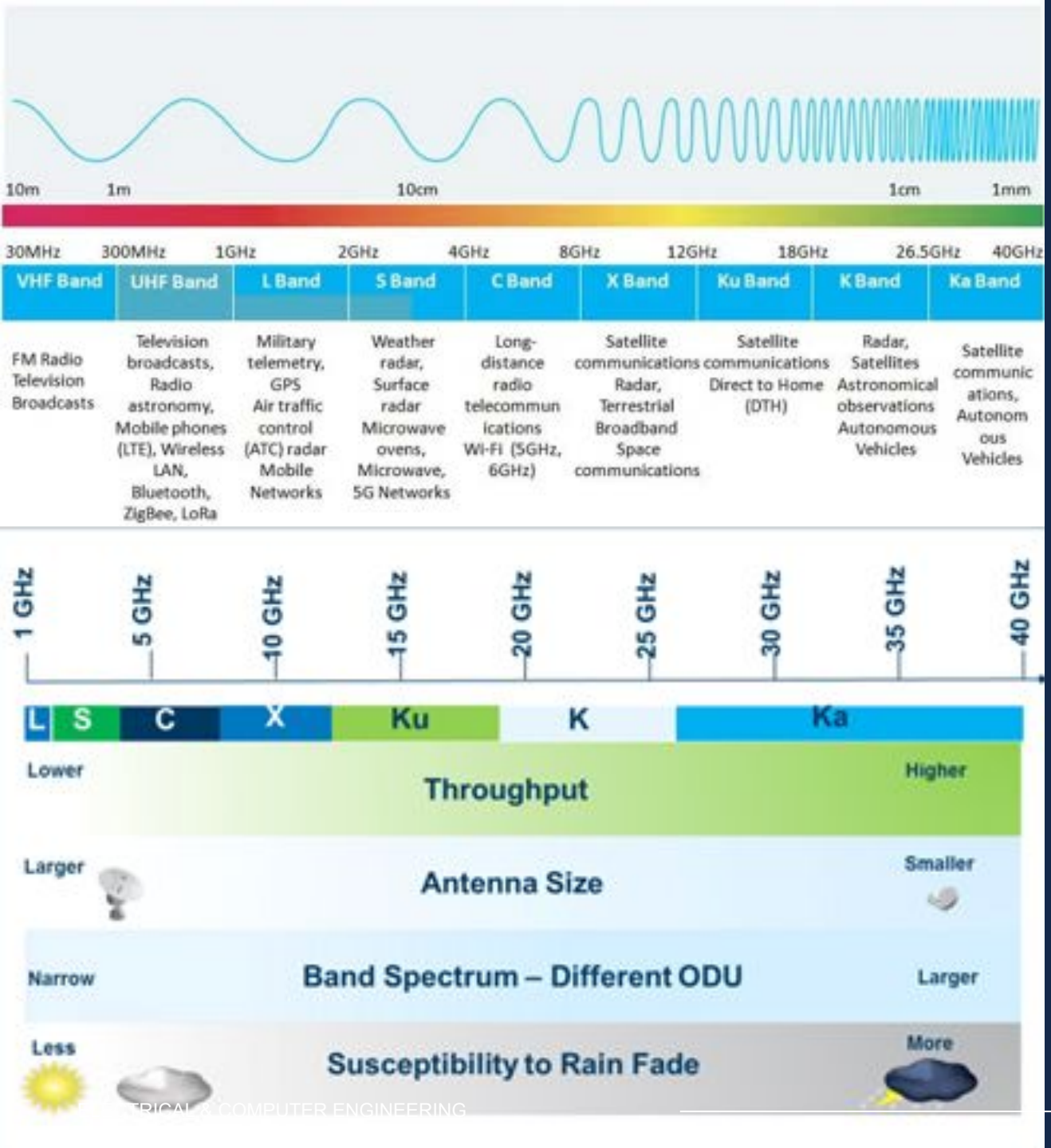


What data can we attempt to receive?

- Weather images: track warm and cold fronts, storm developments, and precipitation
- Solar emissions
- Sea levels
- Unencrypted military communications?





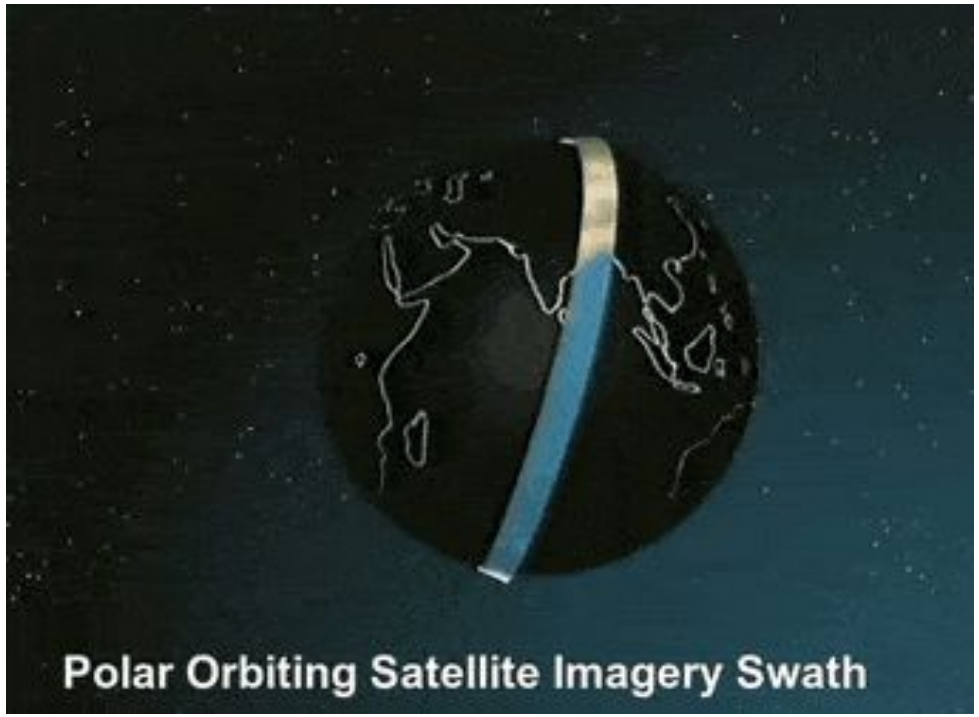


L-Band v.s. S-Band: Why cover these frequencies?

L & S-Band contain some of the most interesting information, and are relatively the most accessible.

Still they can require With a few simple components, L & S-Band are the most accessible.

Tracking LEO Issues?



- A single pass lasts only **10-15 minutes**
- Reception often requires precise tracking with only **2-5 degrees of tolerance**
- Repurposed/built *dish antennas are very heavy*

What hardware issues prevent accessibility?

Software Defined Radio (SDR)

Only reaches 1.7 GHz

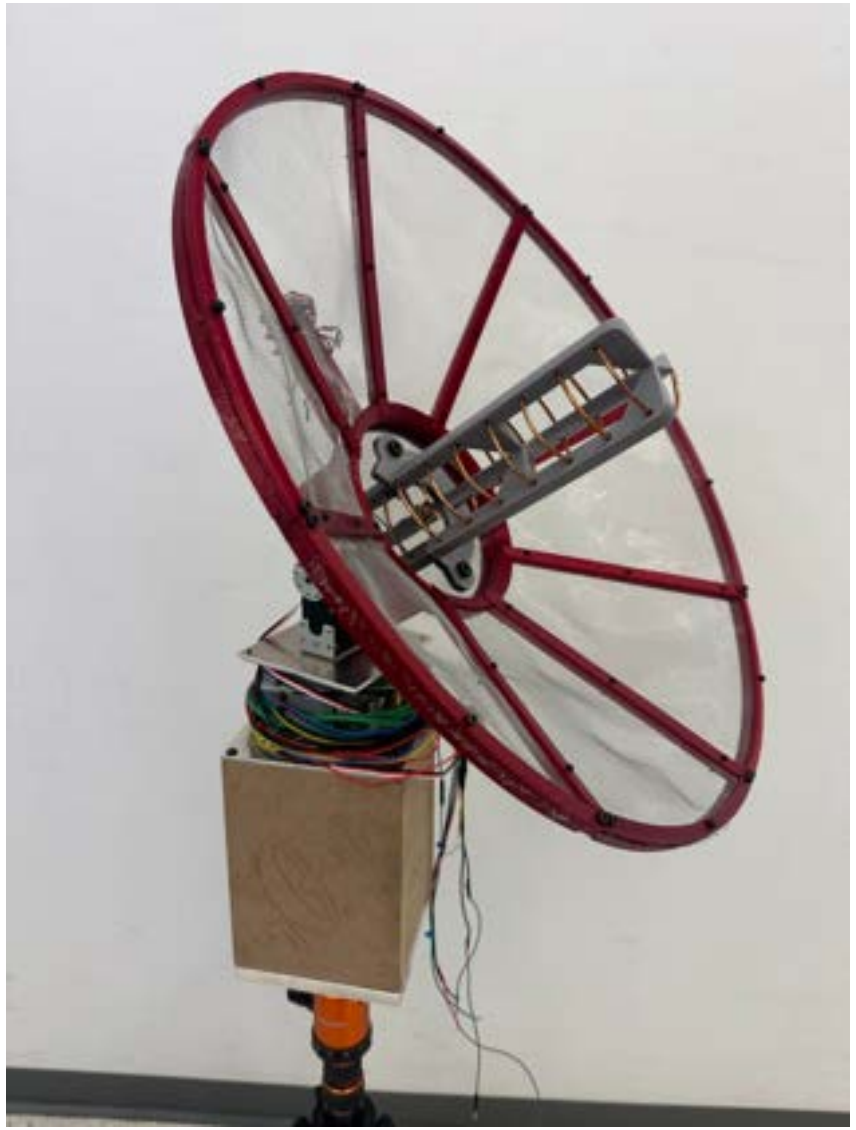
Low Noise Amplifier (LNA)

Downconverter/Cavity Filter

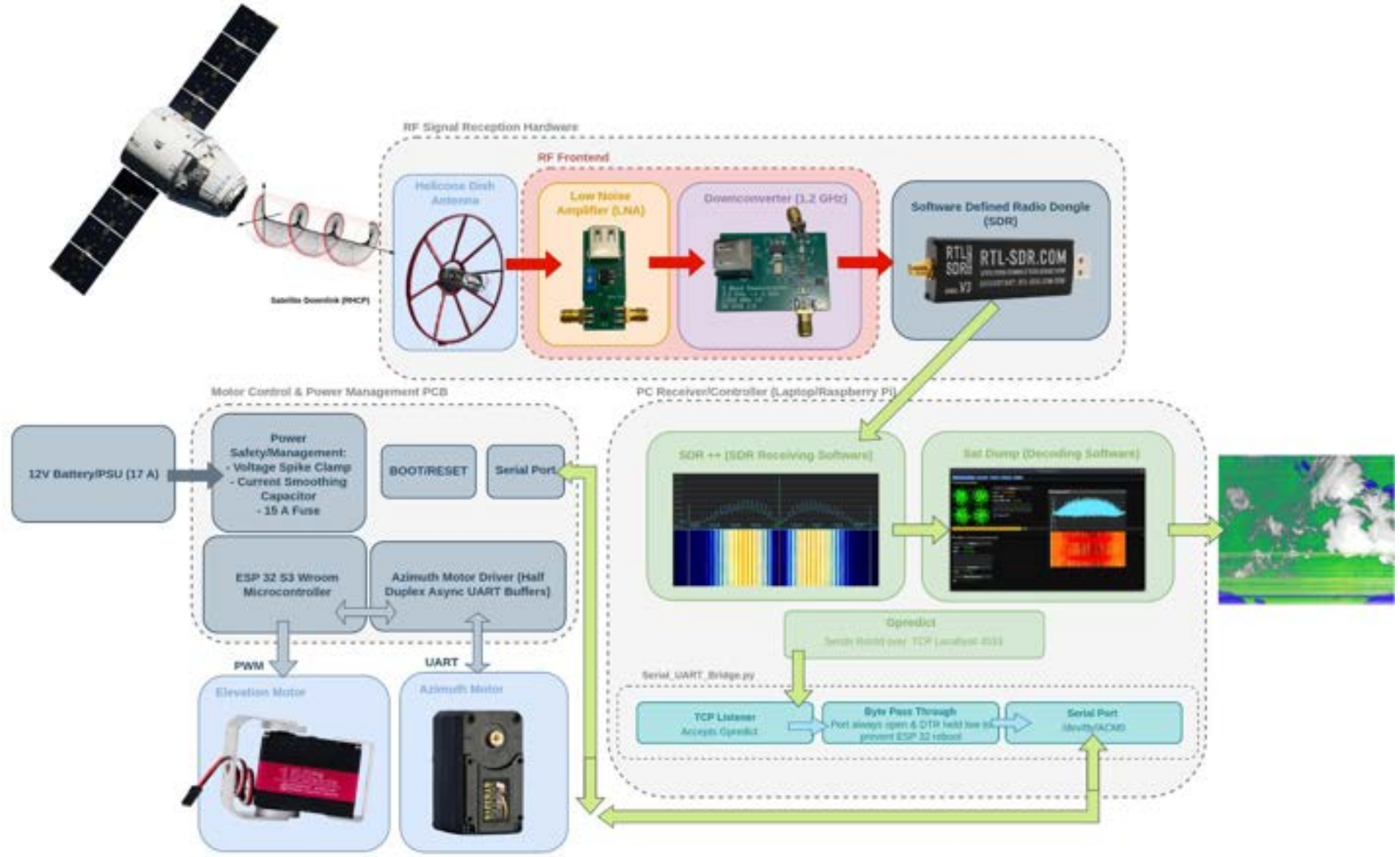
Stock extremely limited/non-existent OR $100+

How can we make this information more accessible?

Solution Component #1: Motorized Tracking Mount & L/S-Band Antennas



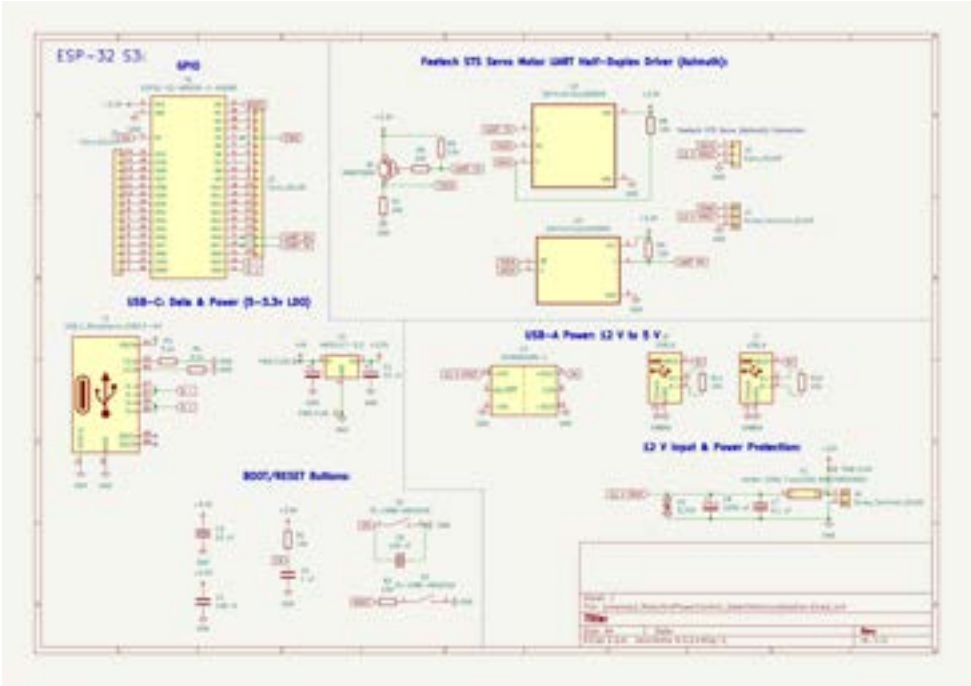
High Level Overview



Main Components

- ESP 32
- Azimuth communication motor driver:

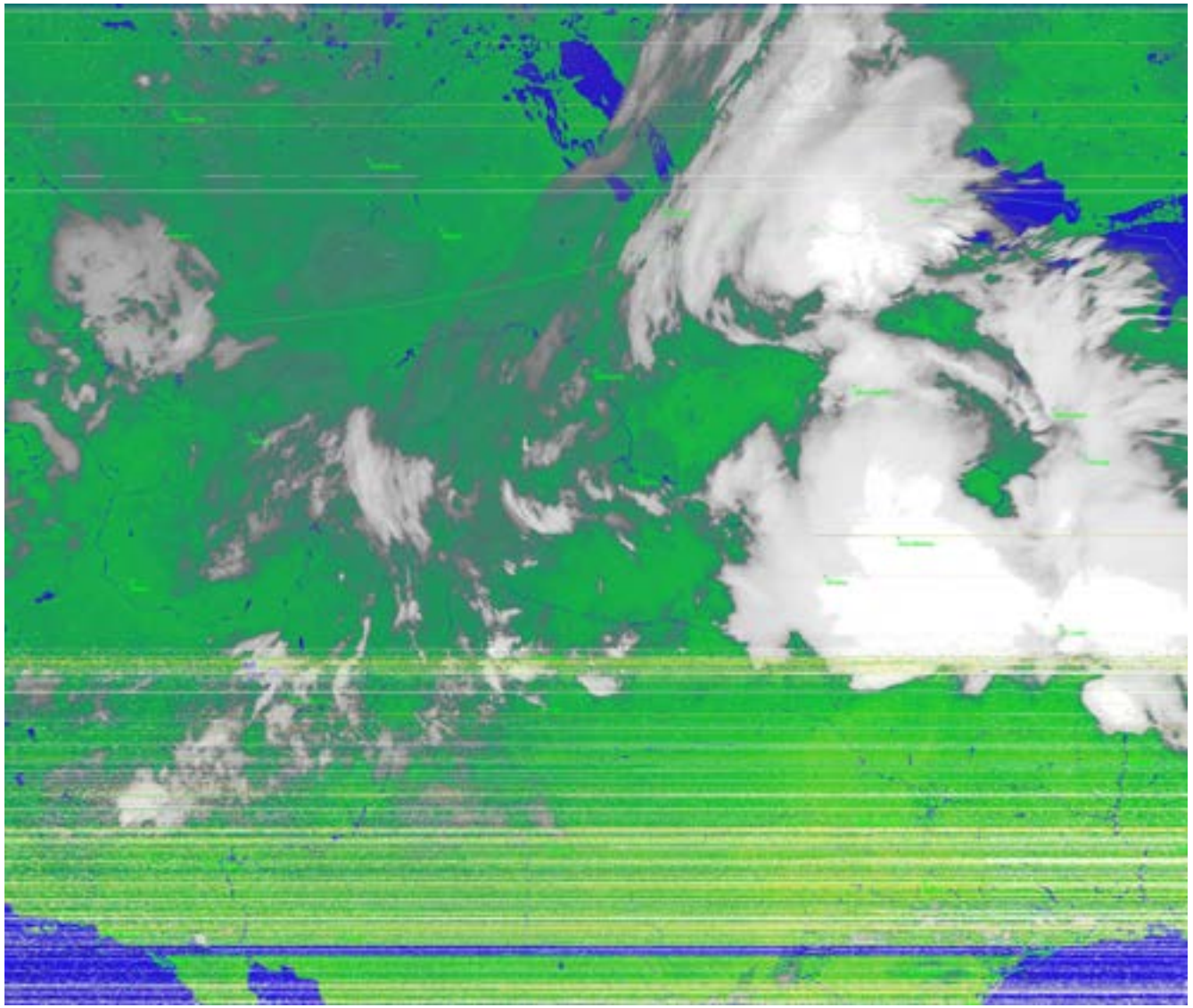
  UART half duplex asynchronous
- Power safety & management:
  - Fuses
  - LDO
  - Voltage spike clamping

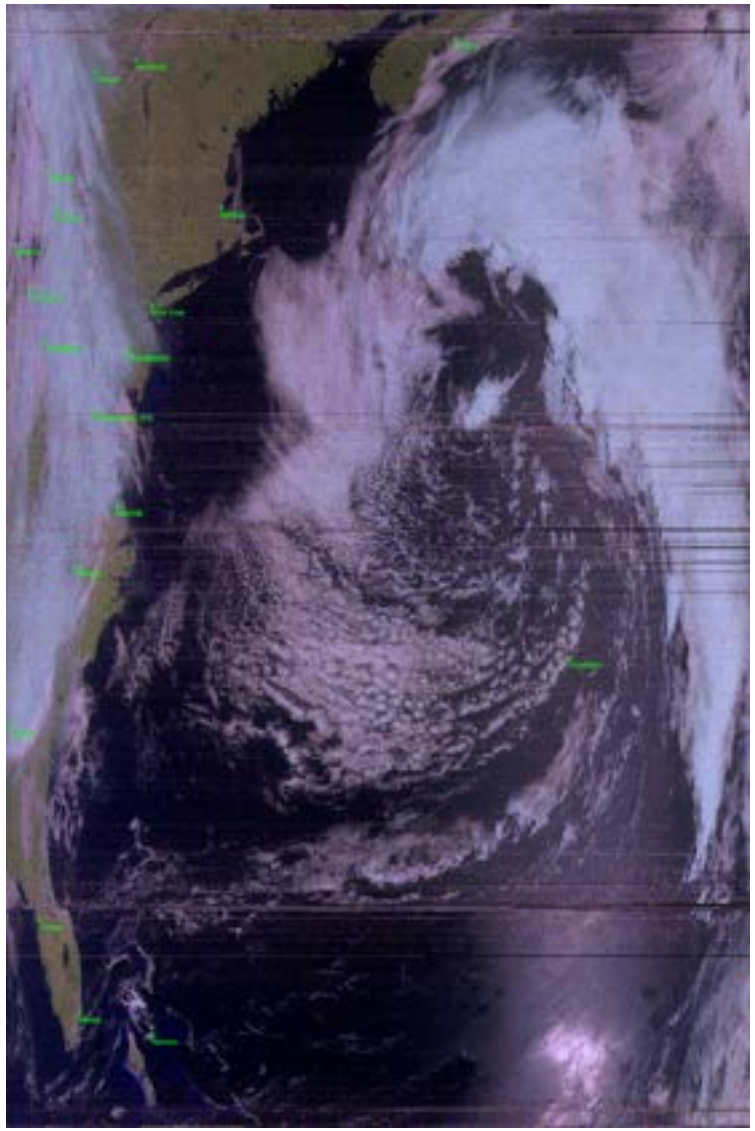


Final Product

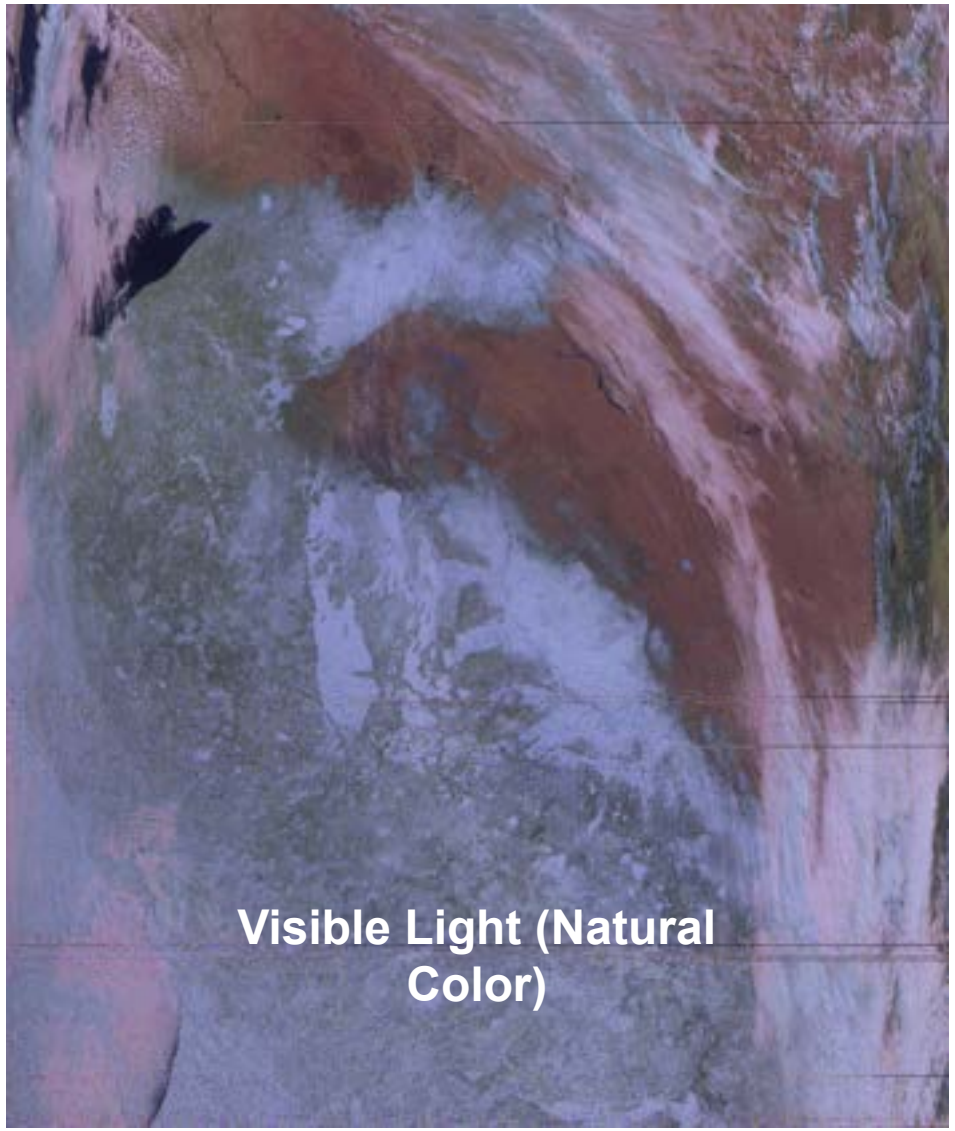
Was Tracking Good Enough?

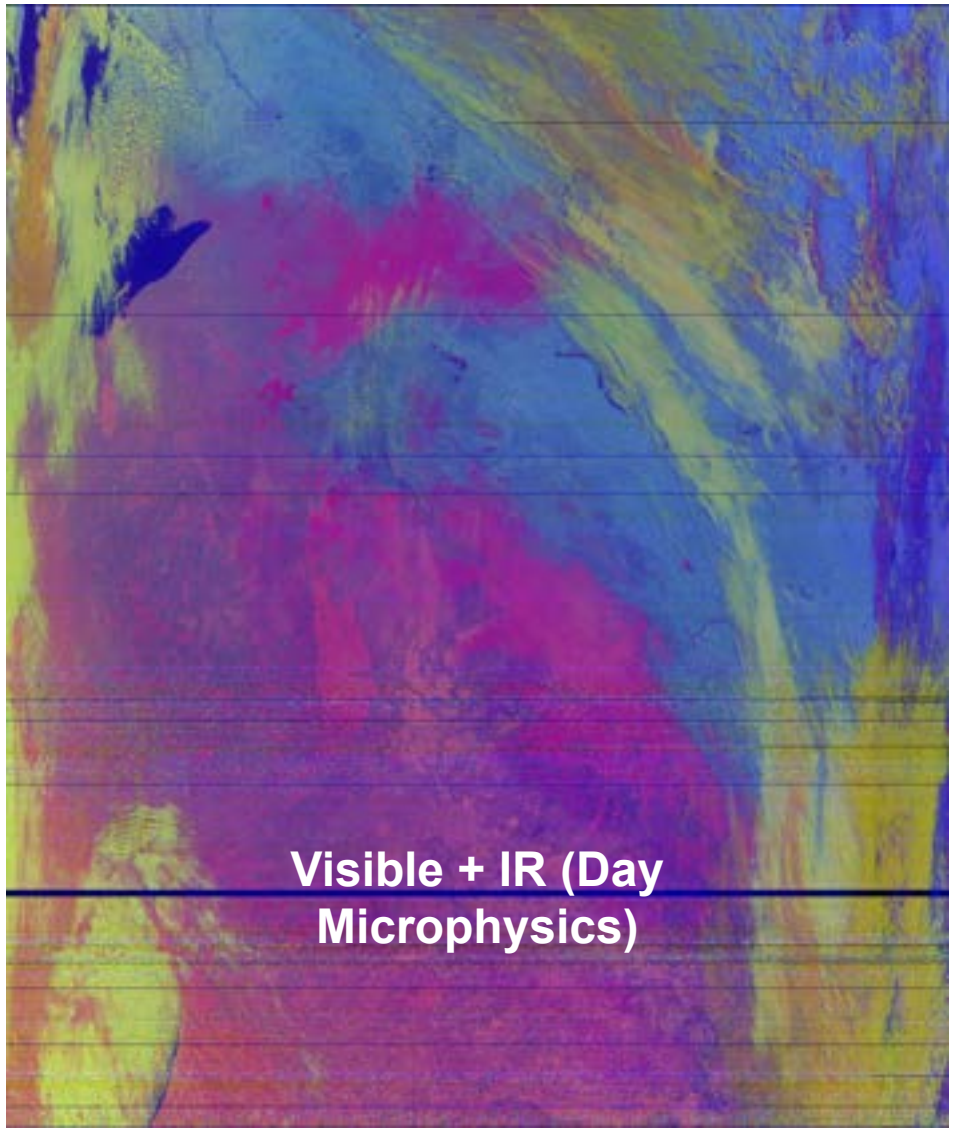
Verification Results: High Resolution Picture Transmission (HRPT)





Test Results





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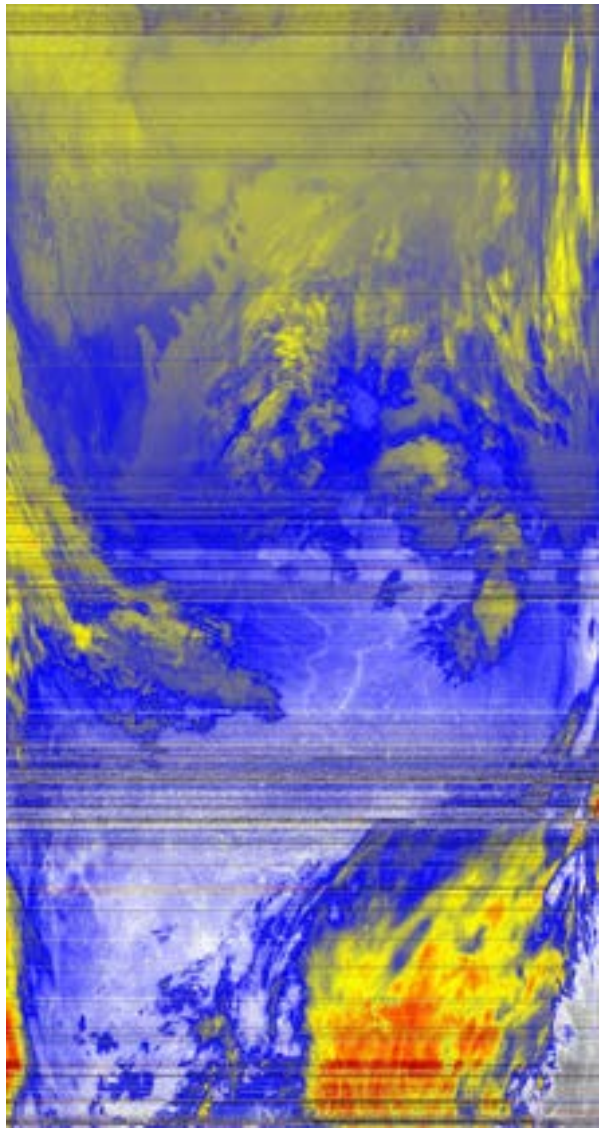
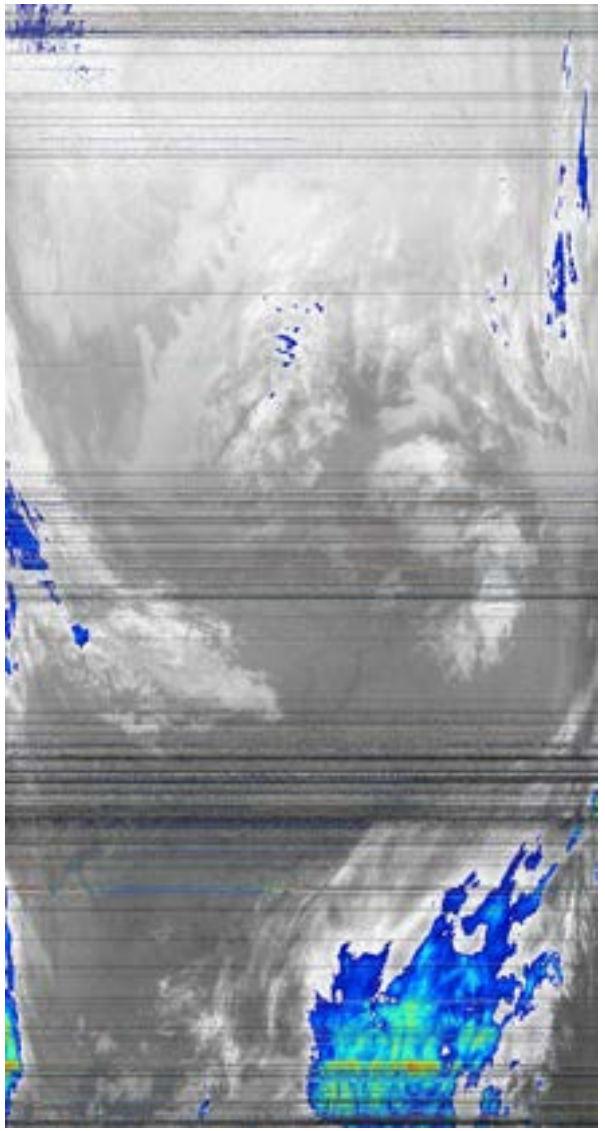
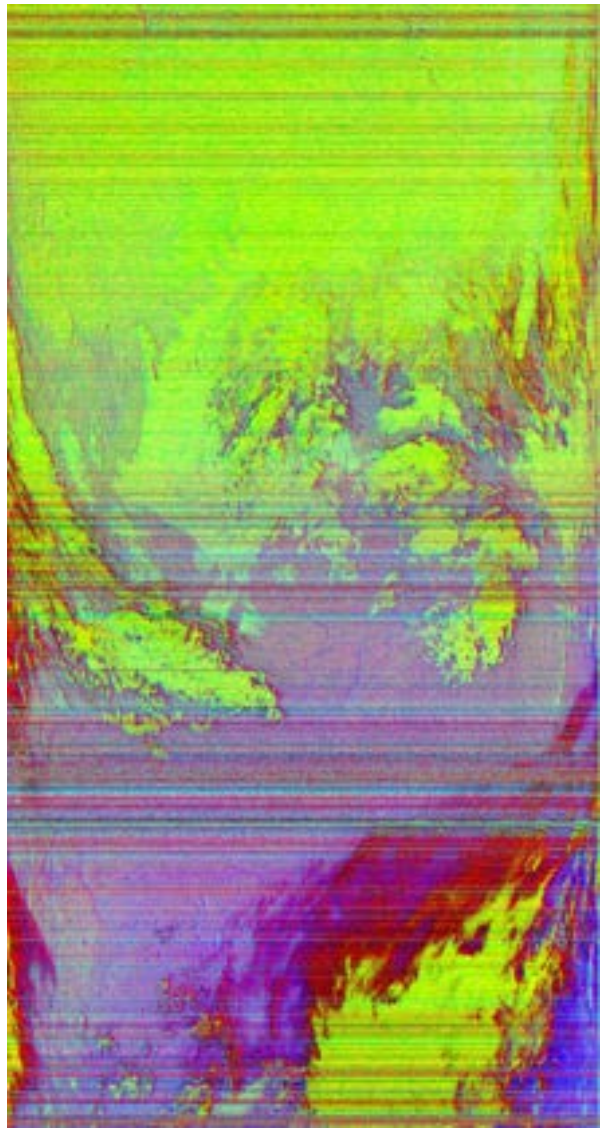
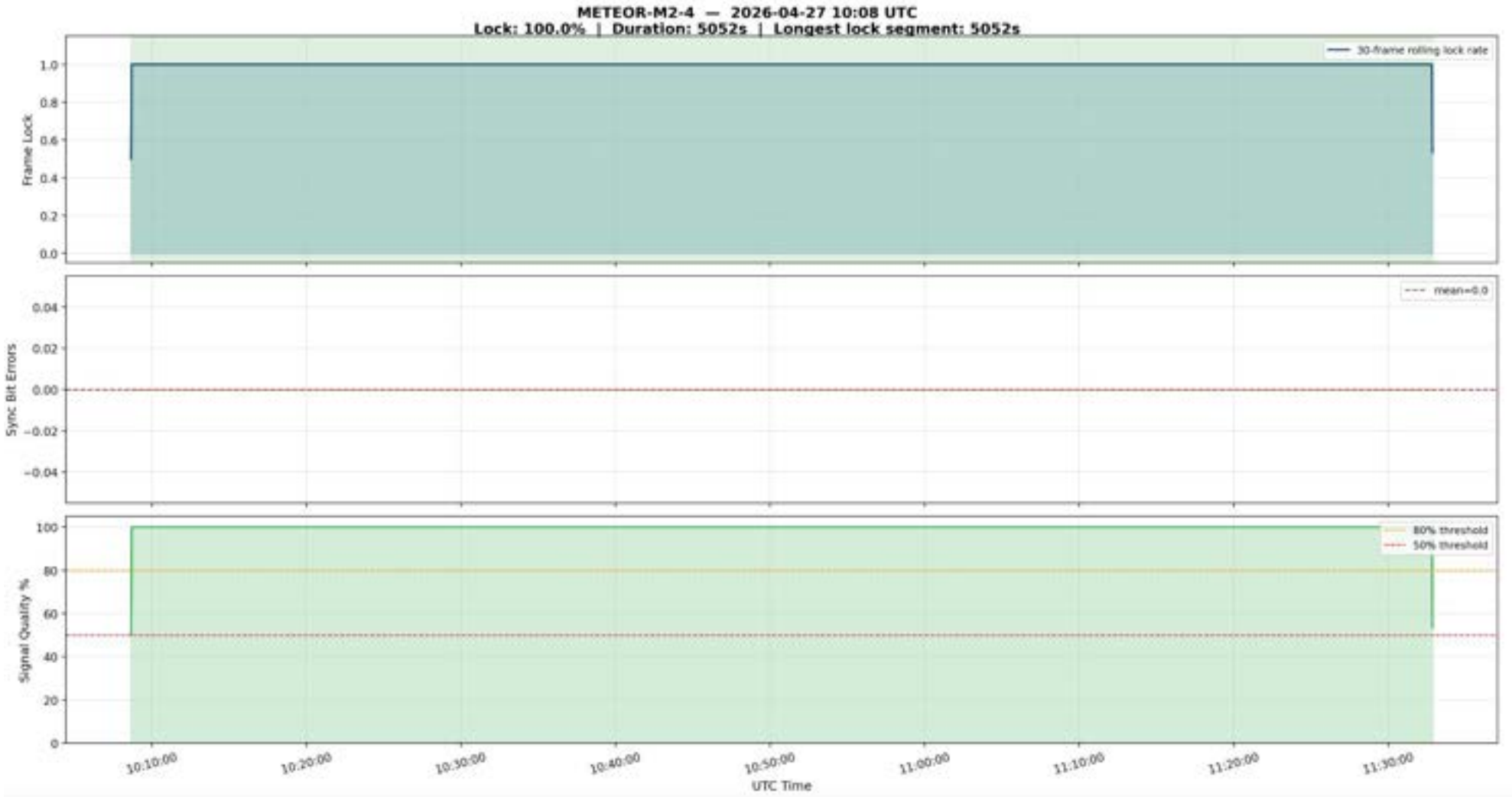


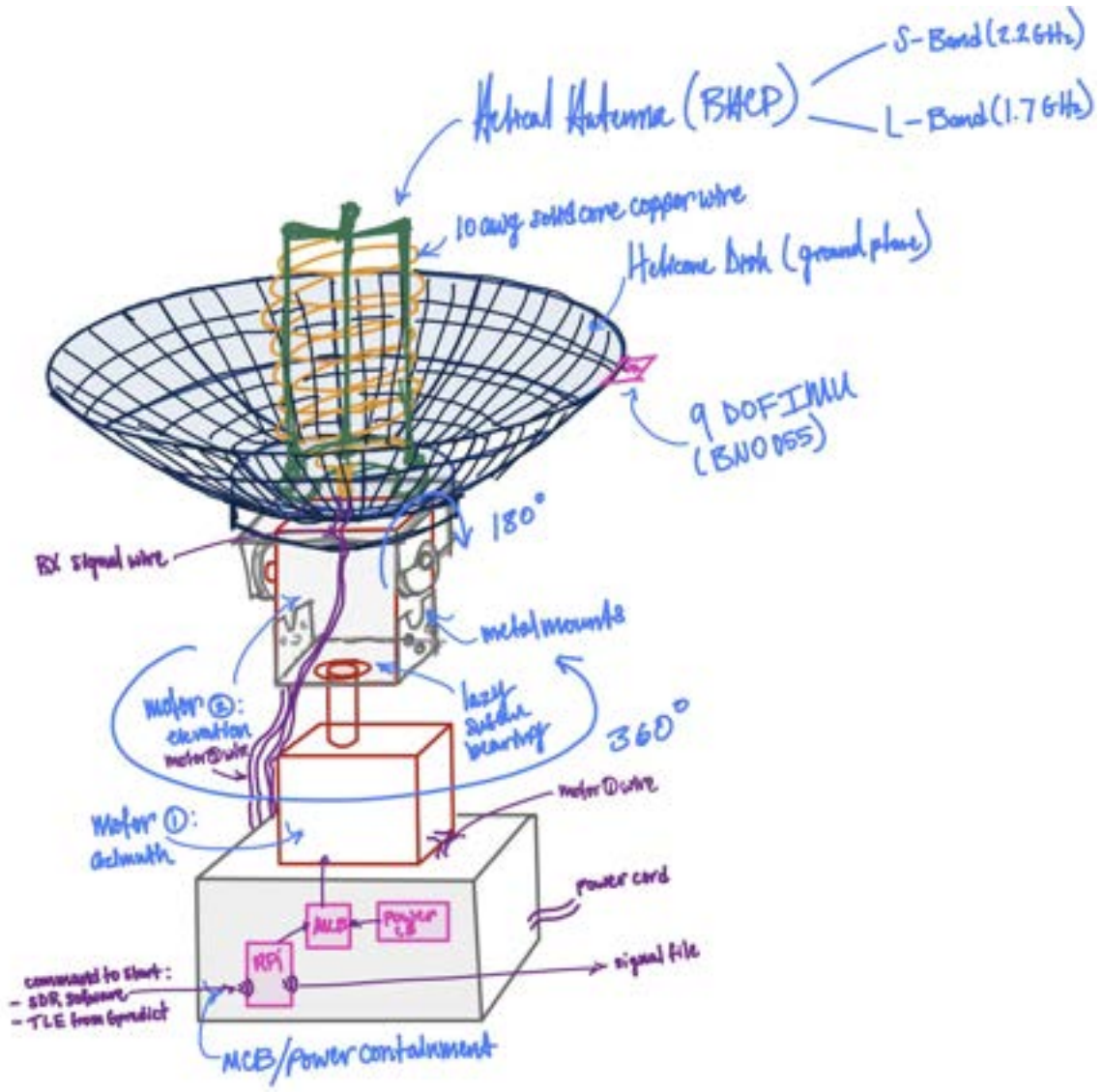




Verification Results

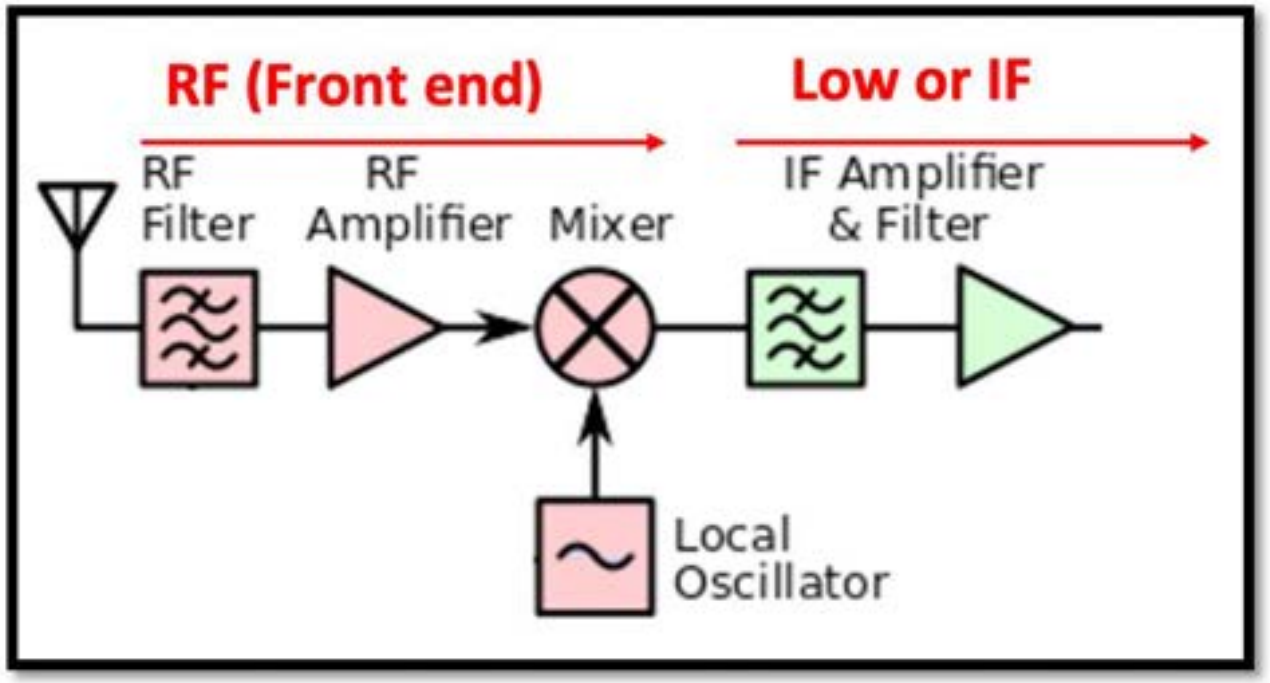


Original Design: IMU Calibration



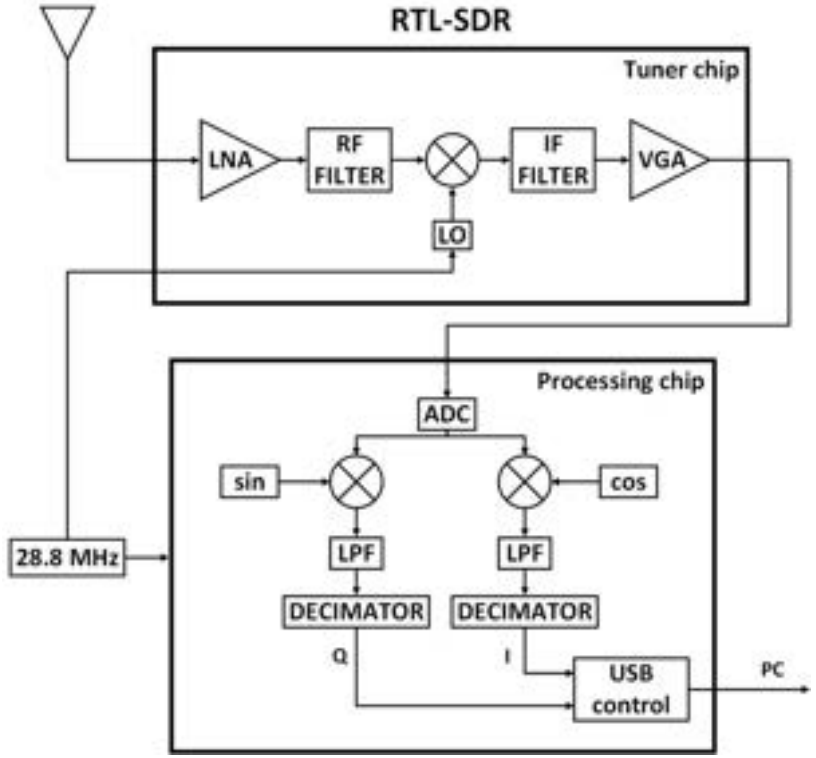
RF Section

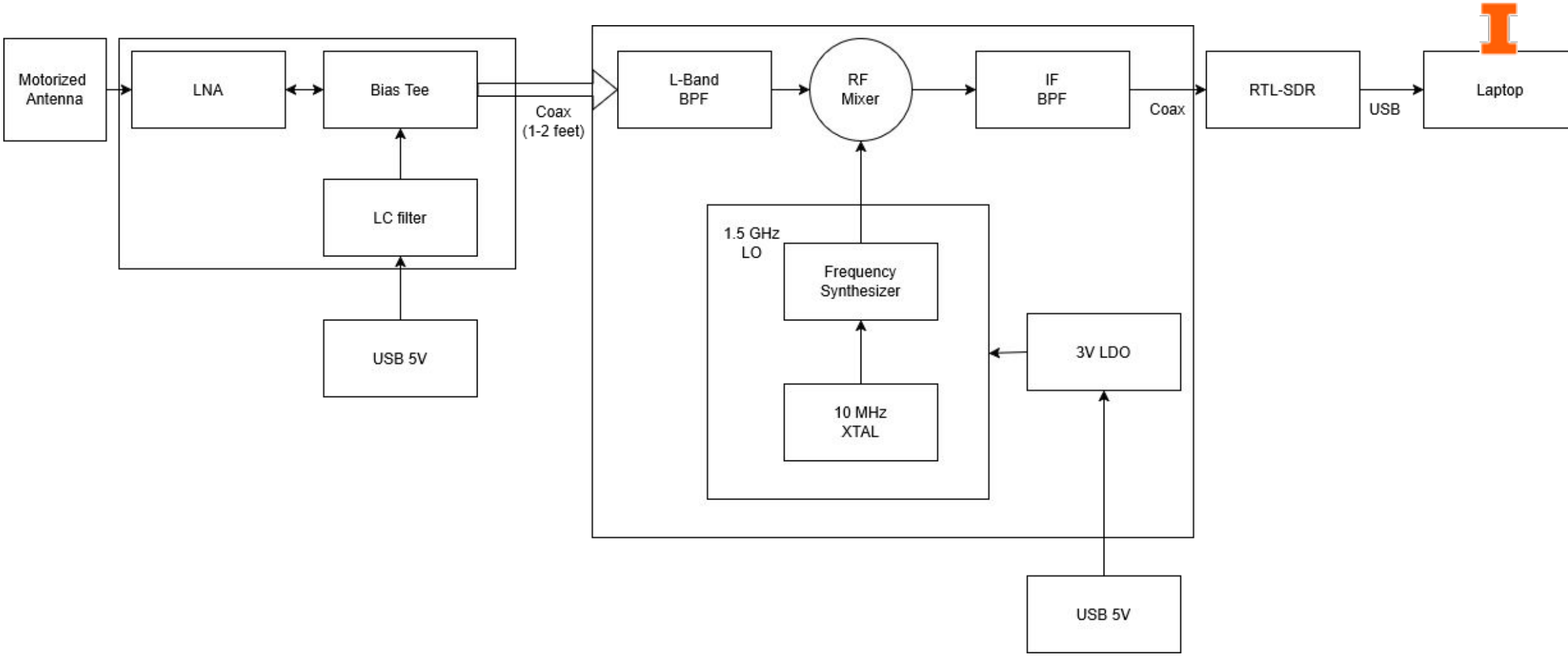
Solution Component #2: S-Band LNA & Downconverter



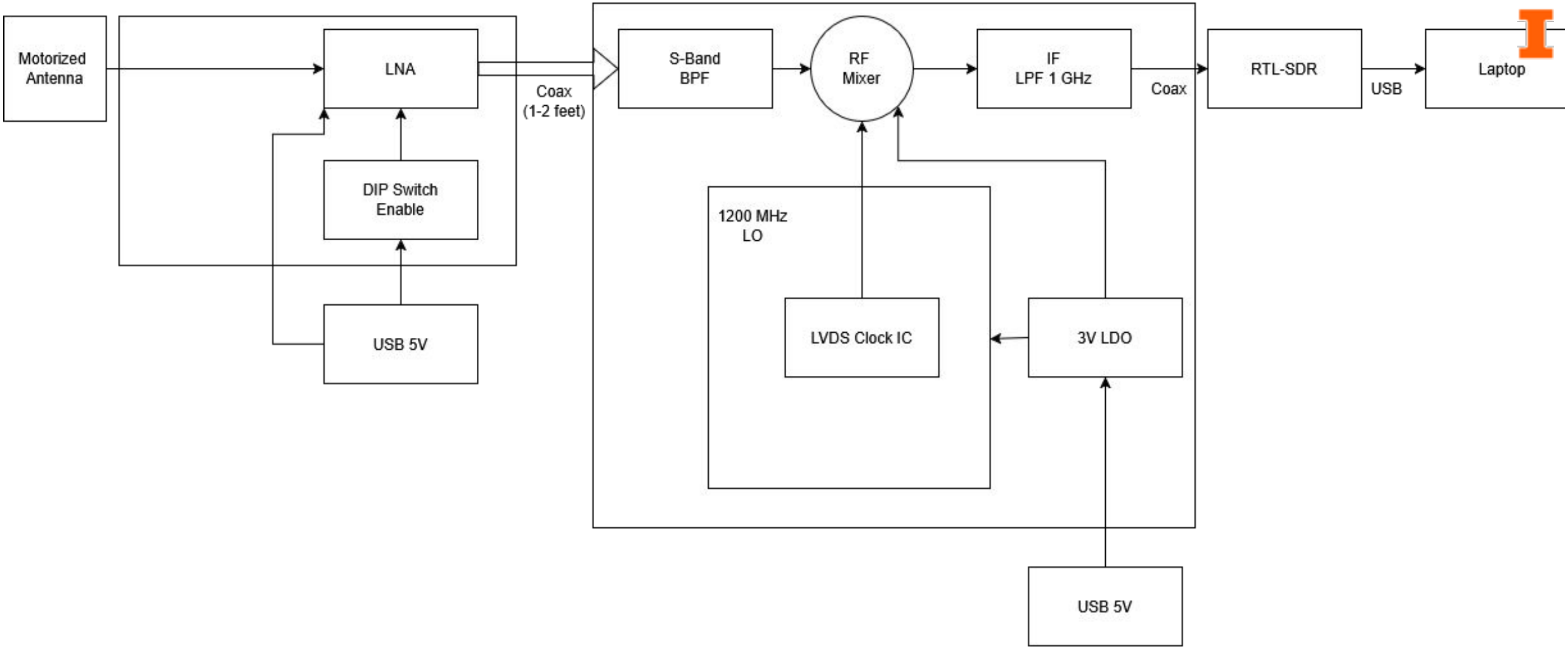
RTL-SDR

- Takes in RF up to 1.7 GHz
- Contains its own RF frontend
- Gain control
- -130 dBm MDS
- Robust community and software





Bias Tee
Programmable PLL, MCU not shown
1.5 GHz LO

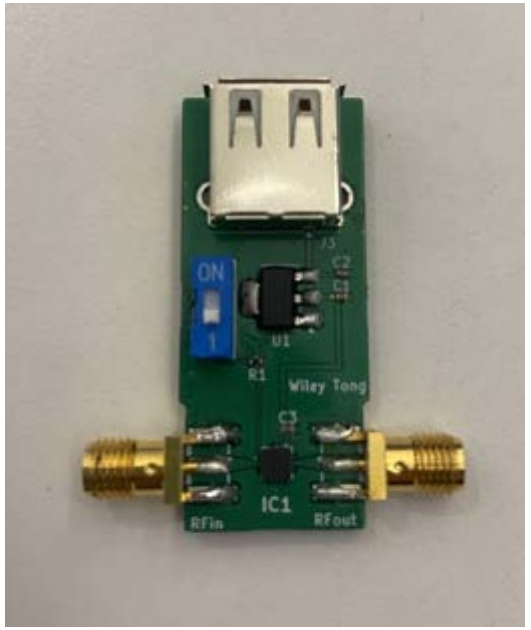


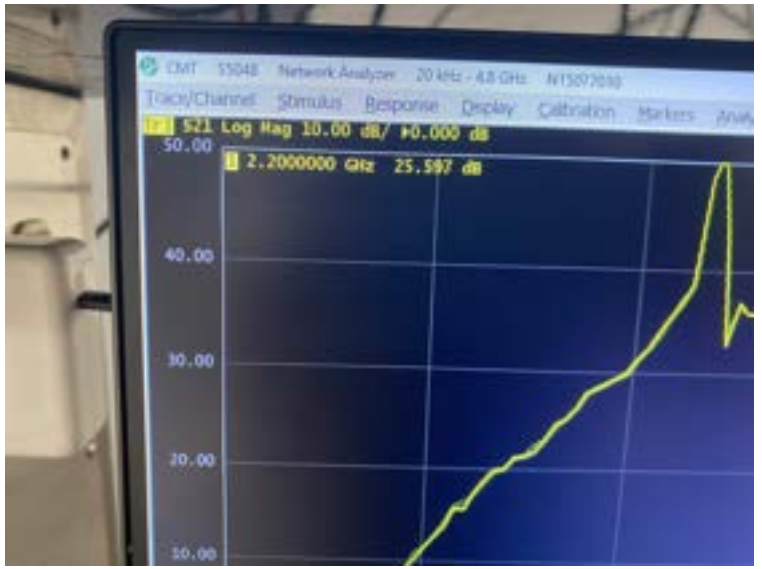
No Bias Tee
Single Frequency PLL
1.2 GHz LO

LNA Results

Measurements

- Uncalibrated Copper Mountain VNA Station L
- 20 dB Gain at 2.2 GHz at -50 dBm input
- 25 dB Gain at 2.2 GHz at 0 dBm input
- 43 mA current draw 0.215 Watt

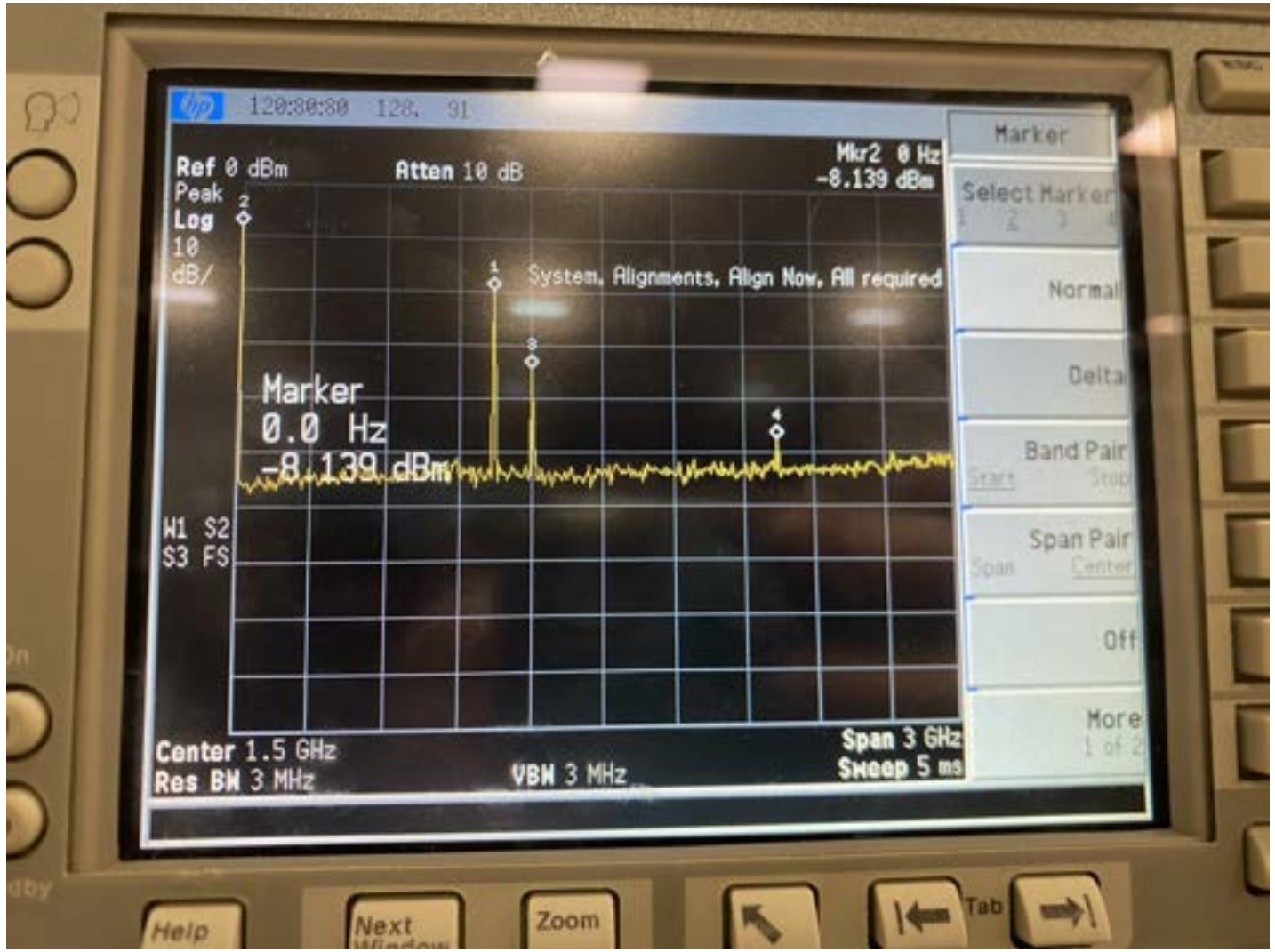




Mixer Results

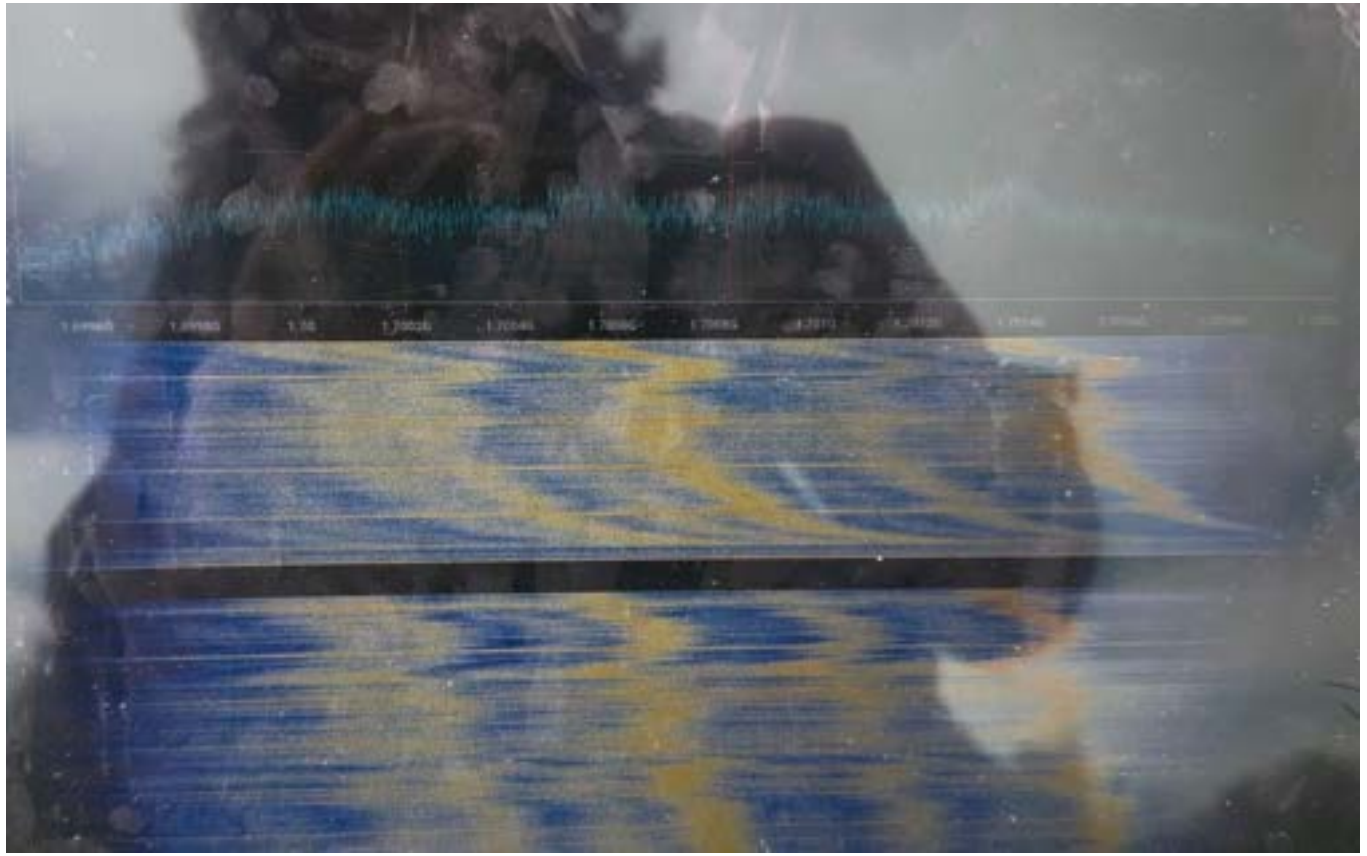
Measurements

- VNA as 2.2 GHz source
- Spectrum analyzer
- -34 dBm LO leakage
- 20-28 dB insertion loss



S-Band Results: Undecodable

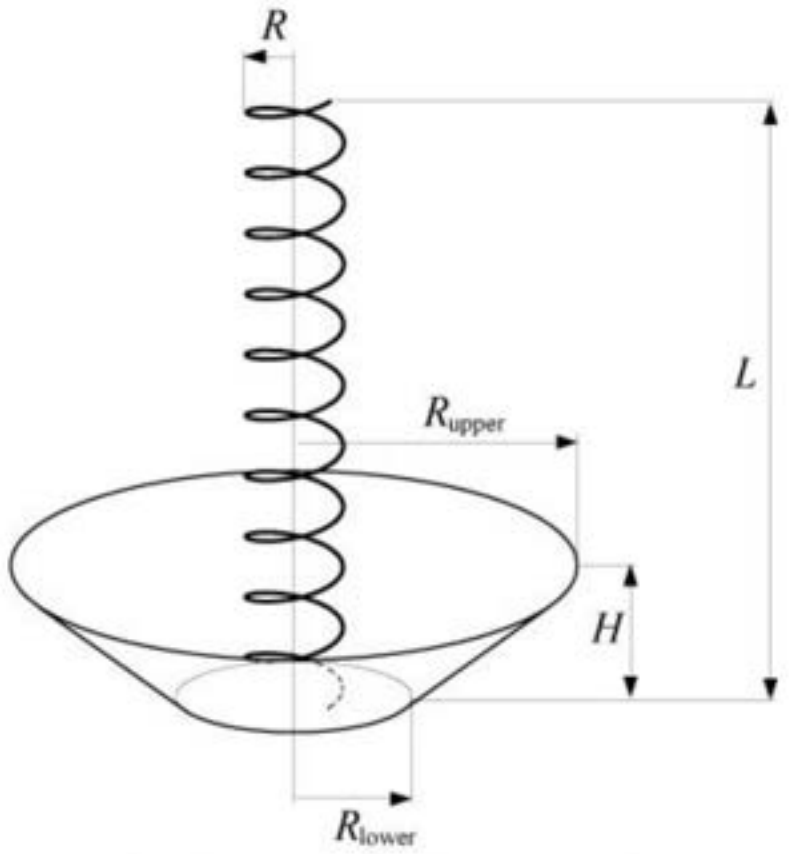
- S-Band antenna: not enough gain
- LNA: poor impedance matching creating reflections
- Downconverter: 20-28 dB insertion loss



Engineering Challenges

Motorized Mount & Antennas

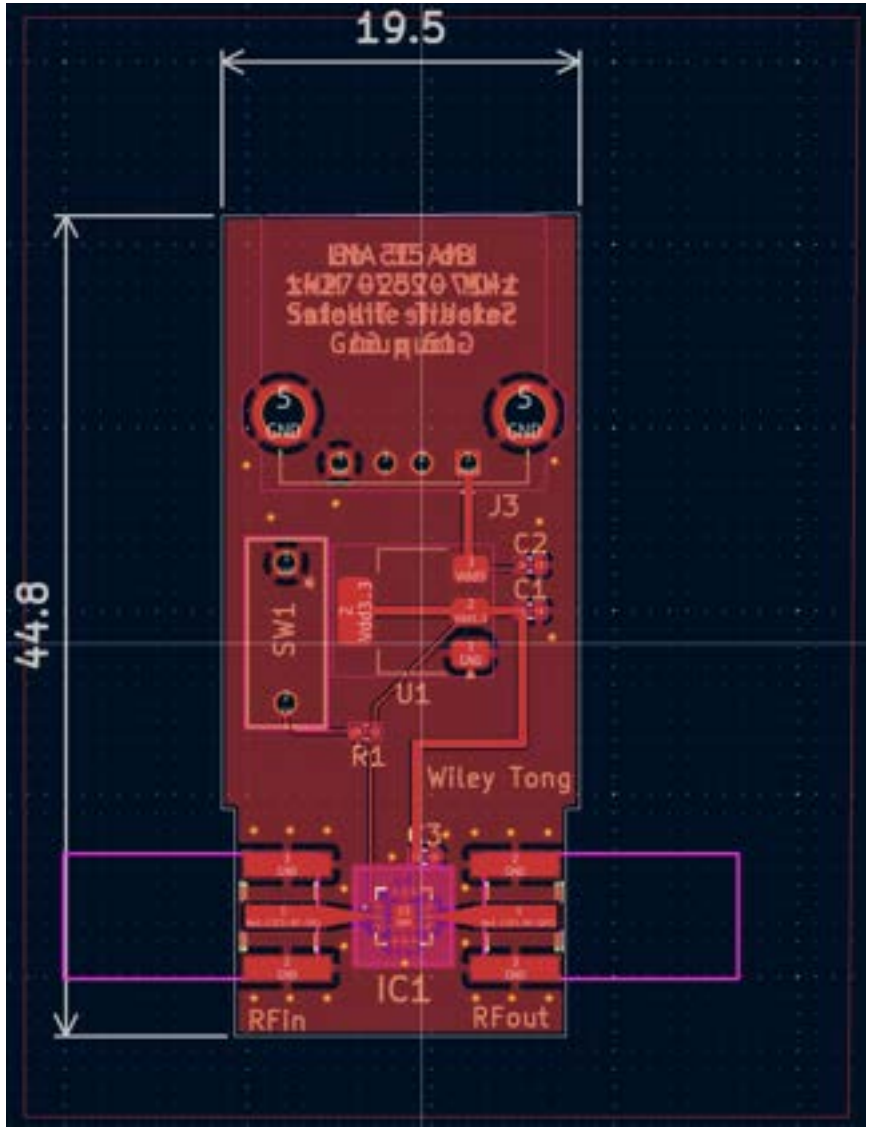
- Shorting & killing Azimuth communication chip
- Accurate & precise tracking
- Calibrating relative orientation with north and horizon
- Tuning Azimuth PID function
- S Band antenna dimensions

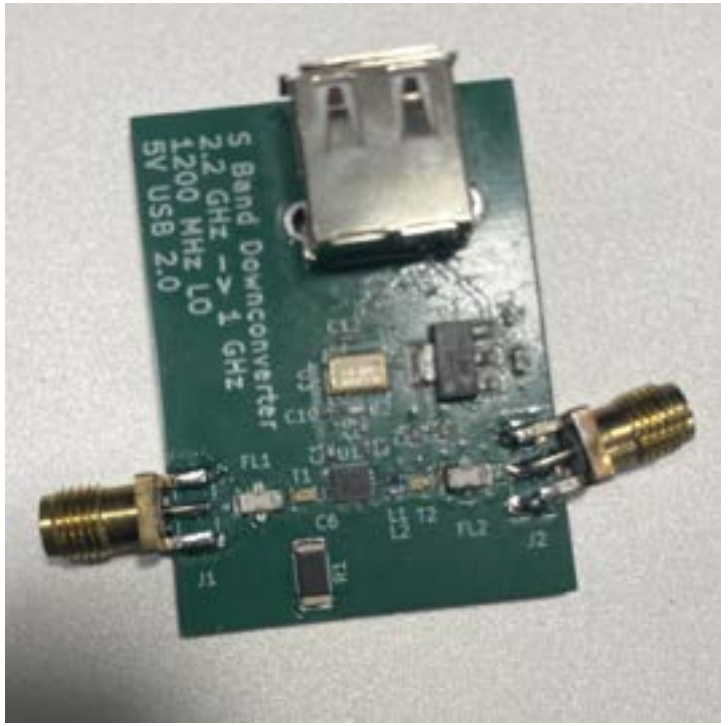


Layout Errors

- Ideal gain of 35 dB
- Incorrect SMA launch to line
- Mixer board insertion loss
- Tiny smd
- board was thicker than

  1.57mm!





Wrap up and Future Work

Motorized Antenna

- Weatherproofing antenna and motors
- Make more rugged
- Replace 3D printing
- Foldable dish antenna

RF Section

- Lumped IF BPF
- Programmable PLL to extend freq
- Casing and weather proof
- Digitally enable LNA
- Four layer

Questions

Thank You

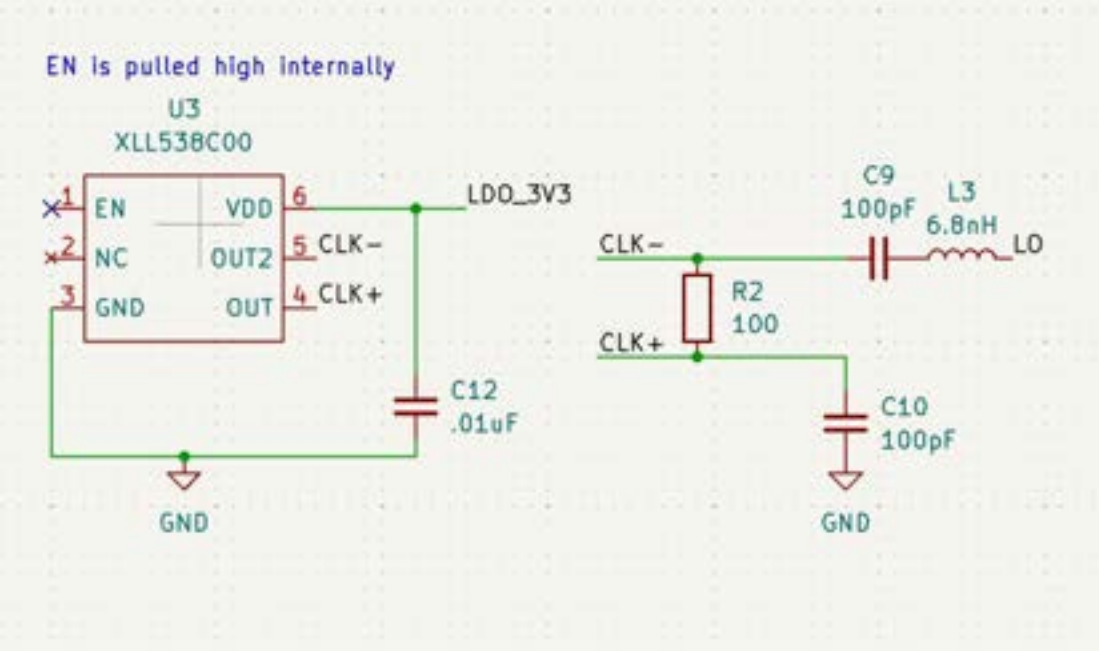
Appendix

LVDS Clock

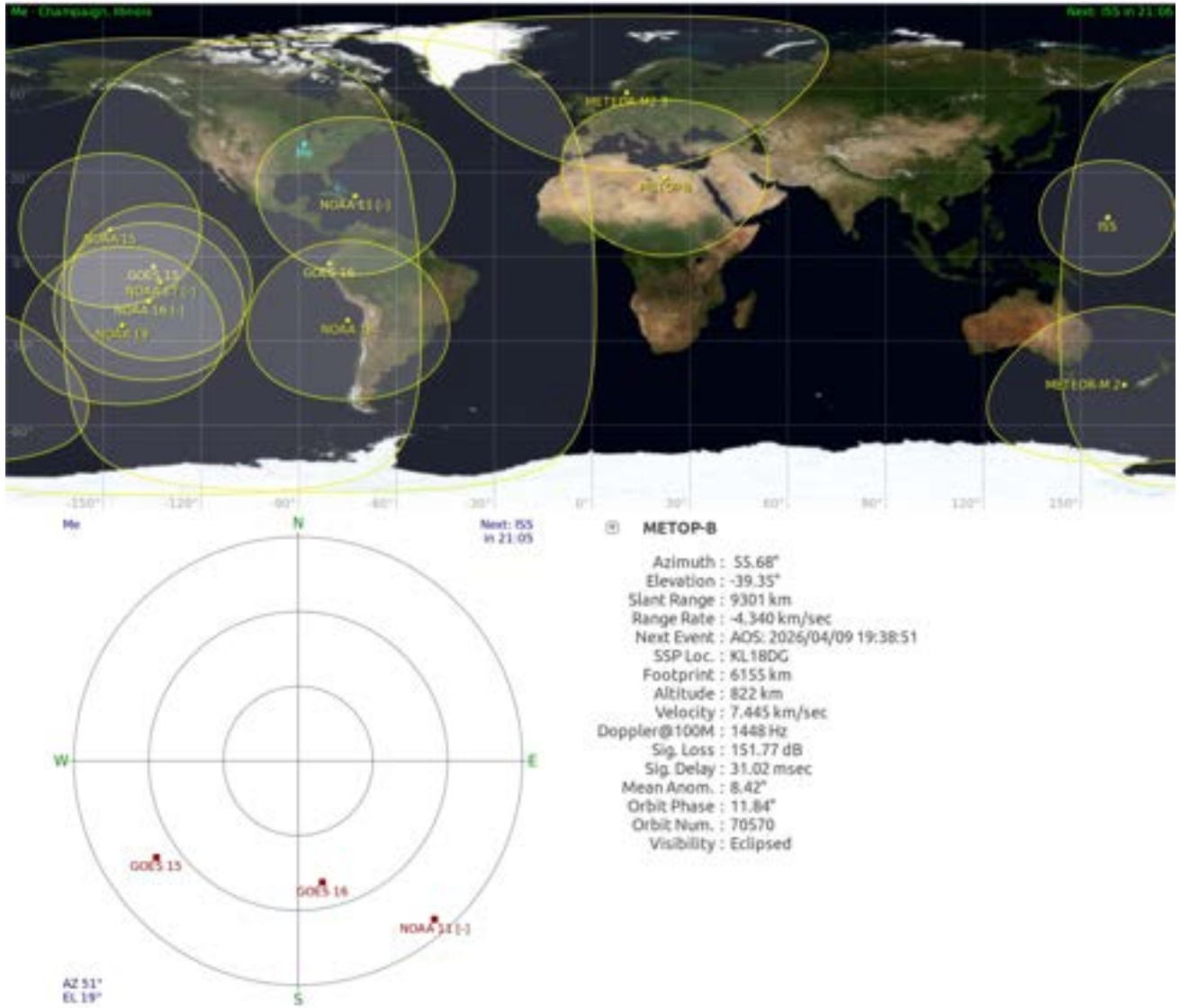
Low-Voltage Differential Signaling

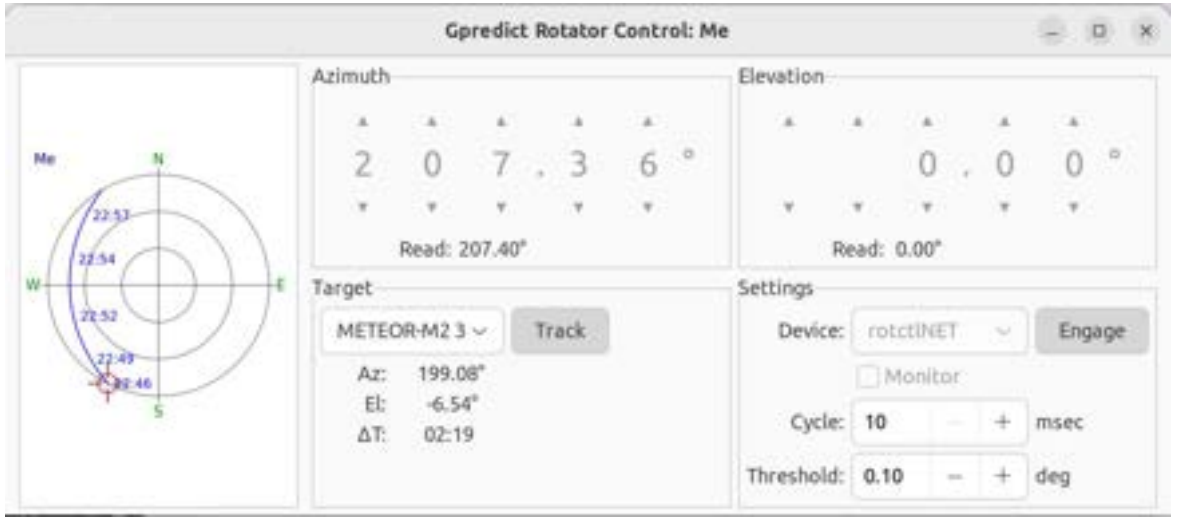
Single frequency clock

Specified termination with impedance transform



How Do We Track The Satellites?





Ethics: “Dont Look Up Paper”