SSC21-WKIV-02

Improving Ground Station by Reducing System Noise and Losses

Peter Pachowicz, Paul Chominski, Jay Deorukhkar

George Mason University
Dept. of Electrical and Computer Engineering, MS 1G5
4400 University Dr., Fairfax, VA 22030
ppach@gmu.edu

Introduction

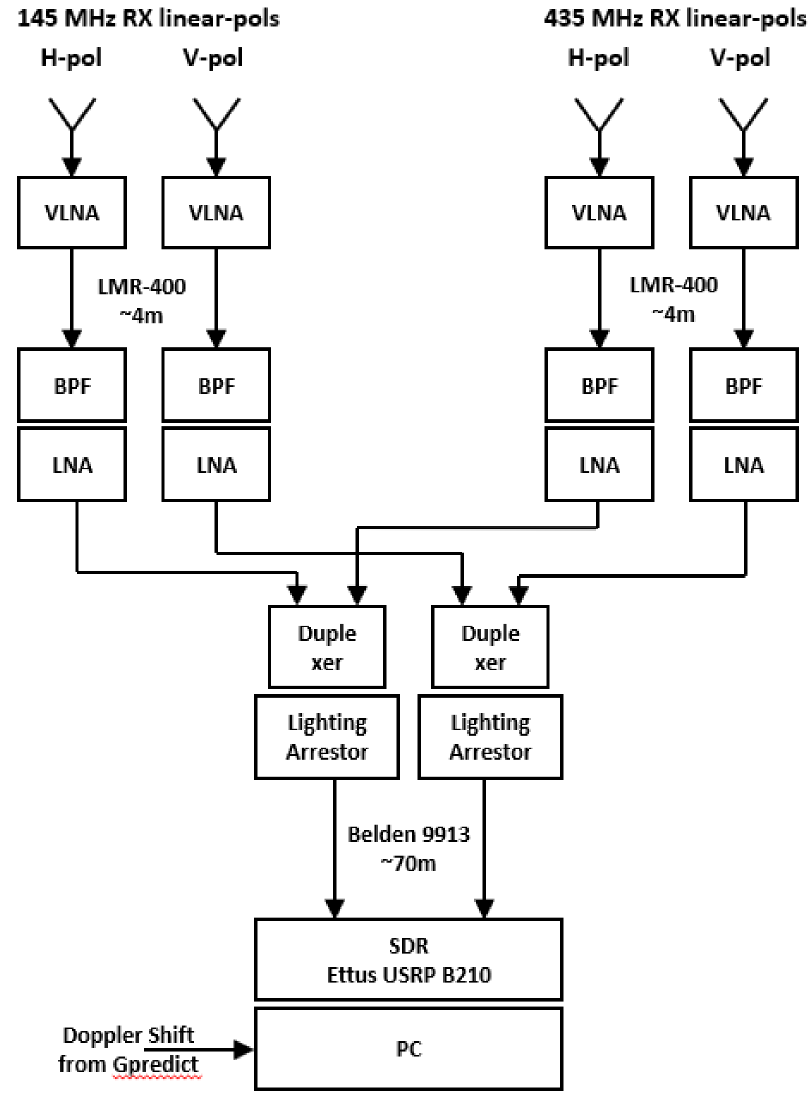
- **Motivation**
  - Continuous search for better performance
  - Availability of new and more accessible technology
- **Approach**
  - Focus on reduction of noise and losses in the entire RX path – from an antenna to a receiver
  - Inspiration came from Earth-Moon-Earth community (EME communications)
  - Minimize Signal-to-Noise ratio by reducing the denominator

$$\frac{\text{Signal}}{\text{Noise}\nearrow} \qquad \frac{\text{System Gain}}{\text{Temperature}\nearrow}$$

- **Potential outcome:**
  - A smaller Ground Station with better performance

Approach

- Separate RX and TX antennas
  - Elimination of RF switches
  - Placement of VLNAs right behind antenna reflector wires resulting in lower noise
- Two polarizations kept separate (no circular-pol antenna for the RX path)
  - Savings of up to 3dB loss of signal strength
  - Lower noise due to elimination of coaxial links and connectors
- Two stage signal amplification
  - 1st stage: Ultra low-NF VLNAs
  - 2nd stage: High IP3 LNAs
- Use of fiberglass booms and brackets
  - Less interactions with metallic elements
- Processing separate polarizations via two input channel SDR (USRP B210)

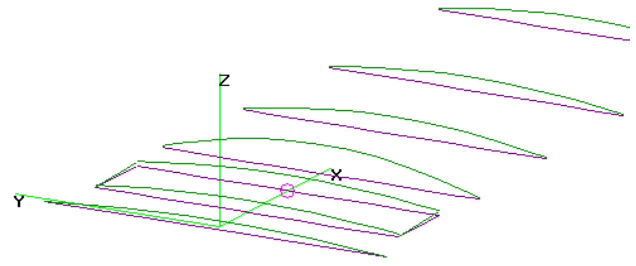


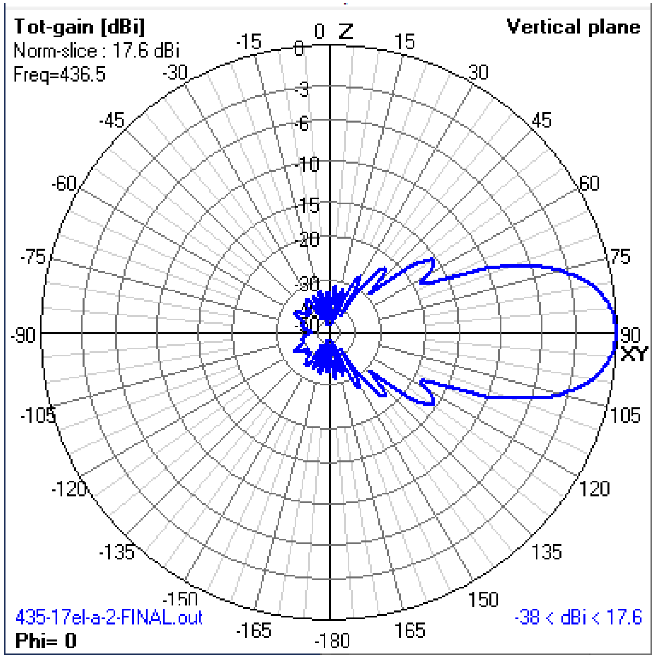
VHF/UHF Antennas

- **Separate TX and RX antennas**
  - **Radio amateur SatCom sub-bands**
  - **VHF: 145.8-146 MHz**
  - **UHF: 435-438 MHz**
- **TX antennas**
  - **Commercial M2 Inc.**
  - **Circular polarization**
- **RX antennas**
  - **Custom design and built**
  - **4.2m long**
  - **Linear polarizations**
- **Focus on the RX path – details provided in our paper**

UHF Antenna Design

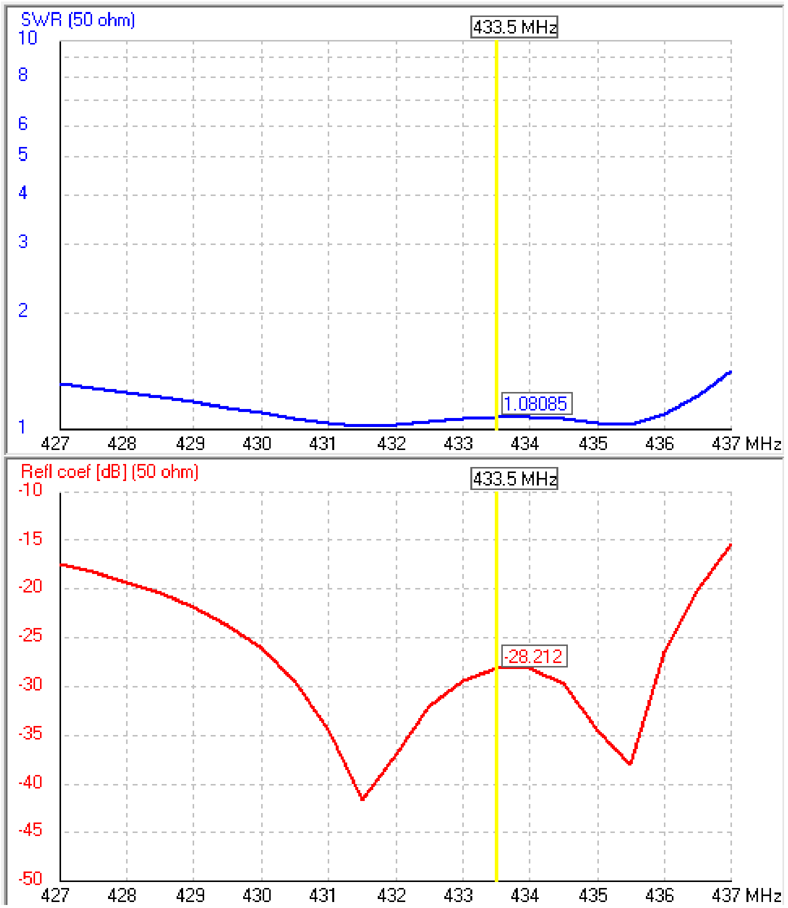
- Starting point: W2PU antenna designed for EME comms
  - Inventor: Justin Johnson (G0KSC)
  - Low-noise LFA antenna type with wide bandwidth characteristics
  - 15-element antenna for 432 MHz
- Final antenna
  - Redesigned and extended to 17 elements
  - Gain slightly increased from 16.9 to 17.6
  - Antenna params: F/B and F/R improved significantly (next slide)
  - 50Ω resistance maintained over 5 MHz bandwidth with very little reactance
  - NEC4 engine used for simulations



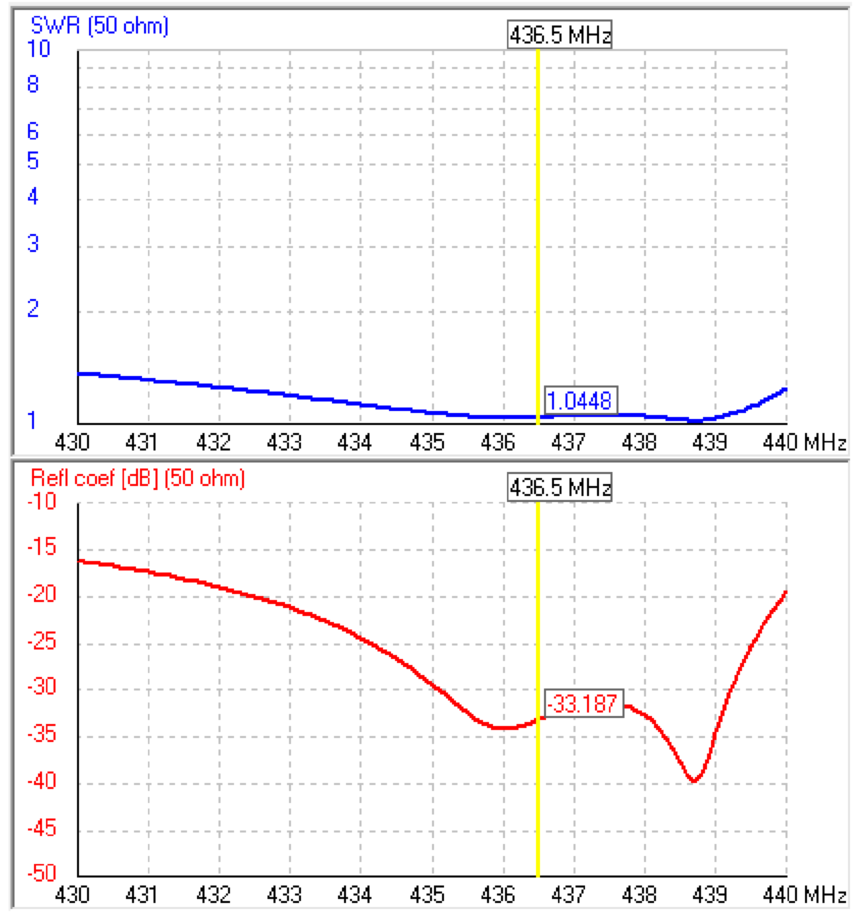


➢ UHF antenna SWR characteristics

W2PU

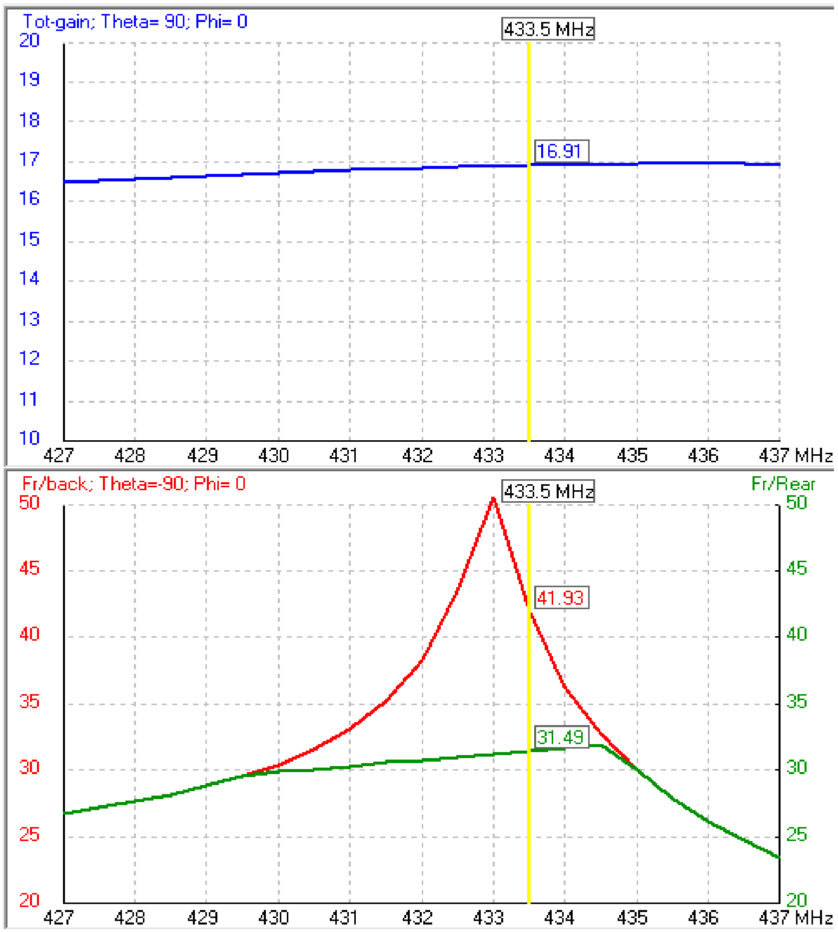


GMU

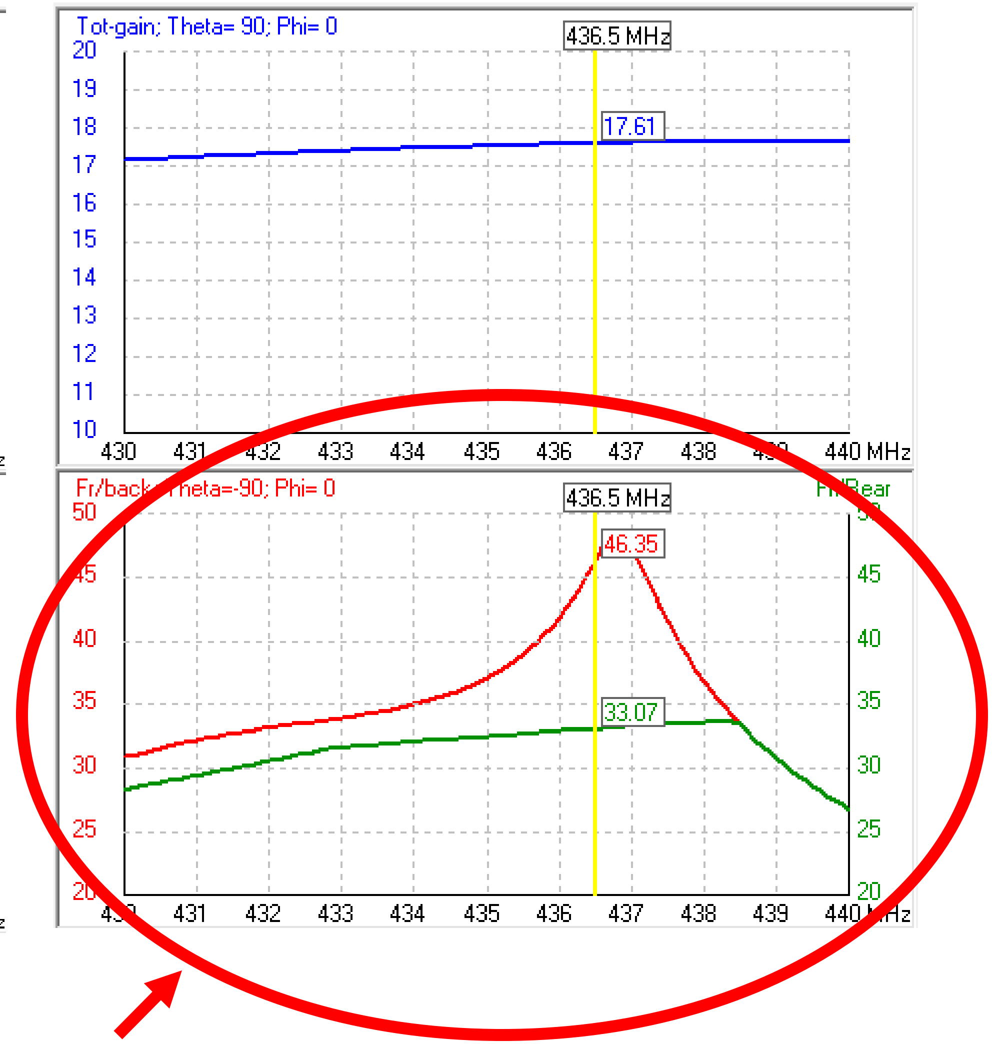


➢ UHF antenna low-noise characteristics

W2PU

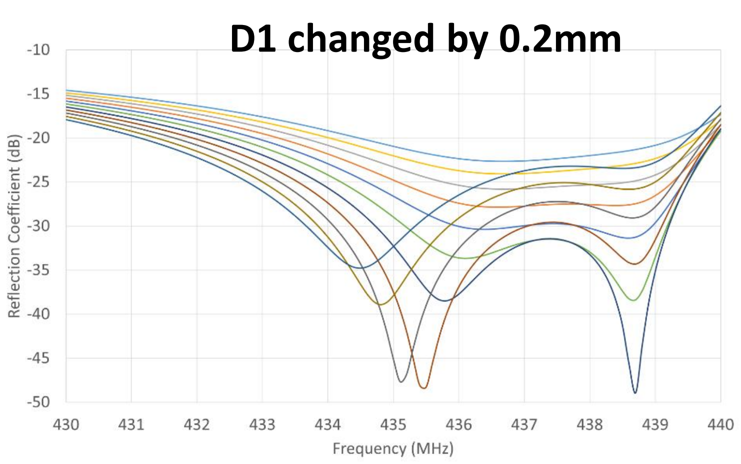


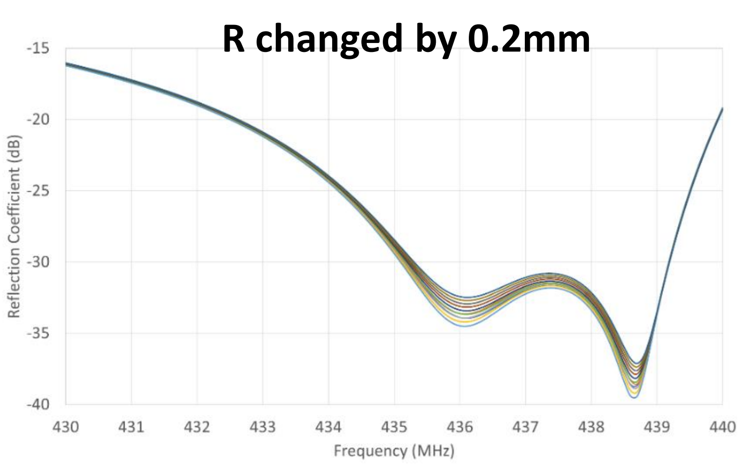
GMU



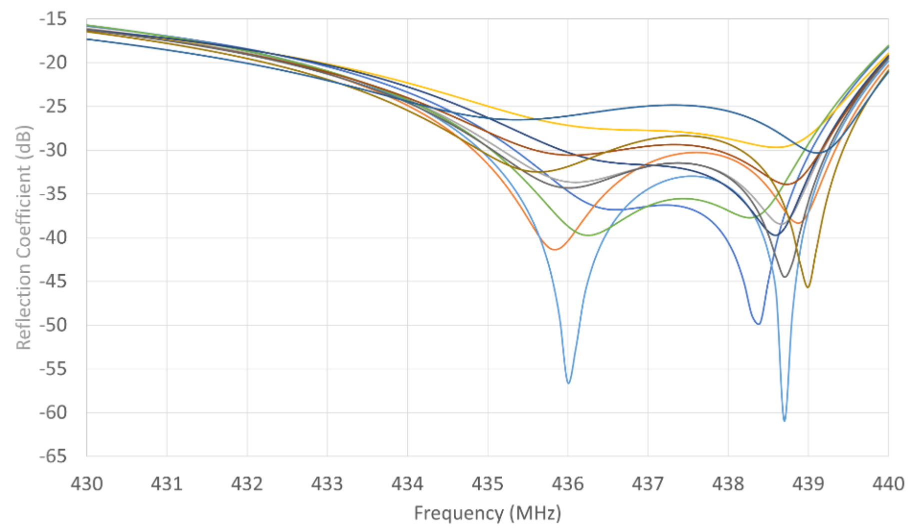
UHF Antenna Sensitivity Analysis

- **Objectives:**
  - **Understanding the influence of fabrication errors on antenna characteristics**
  - **Define fabrication accuracy**
- **Step 1: Find the most sensitive element(s)**
  - **Result: D1 change causes greatest change in antenna params**
  - **Best if: All wires fabricated to ±0.2mm accuracy**
  - **Still acceptable: when below ±0.5mm**

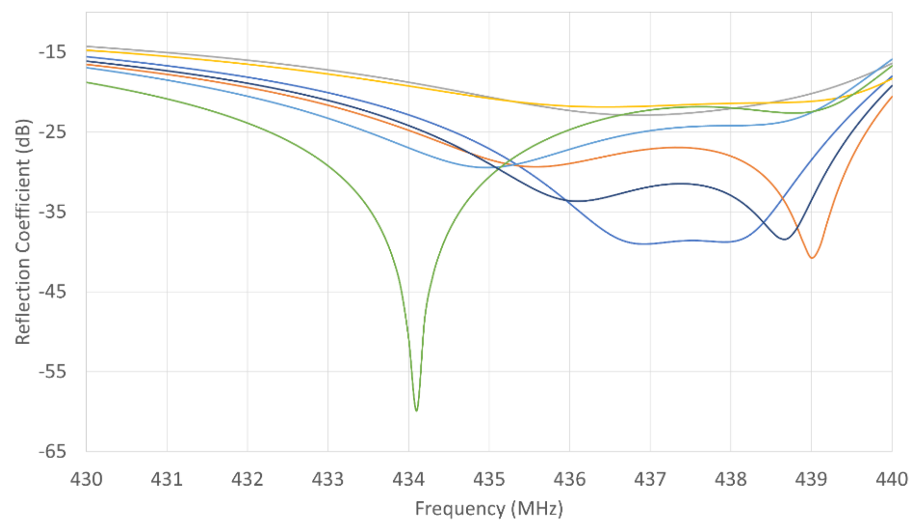




- **Step 2: Define drilling accuracy**
  - **Best if: Drilling executed with ±0.5mm accuracy**
  - **Still acceptable: below ±1mm**



- **Step 3: Define tunning strategy**
  - **Have a set of prefabricated D1 wires with lengths changed by 0.5mm**
  - **For each D1, adjust DE span for optimal characteristics**



Antenna Construction

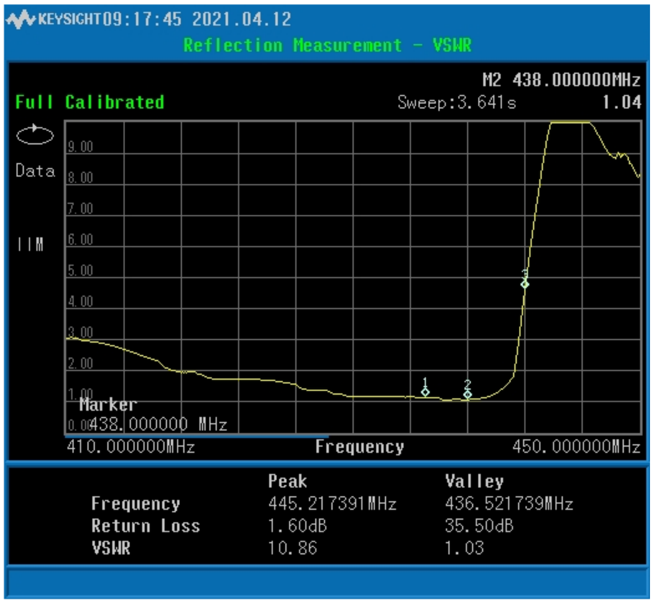
- Proper construction is extremely important to hold simulated characteristics

- Fiberglass boom and bracket
  - Position of mounting screws simulated for optimal location

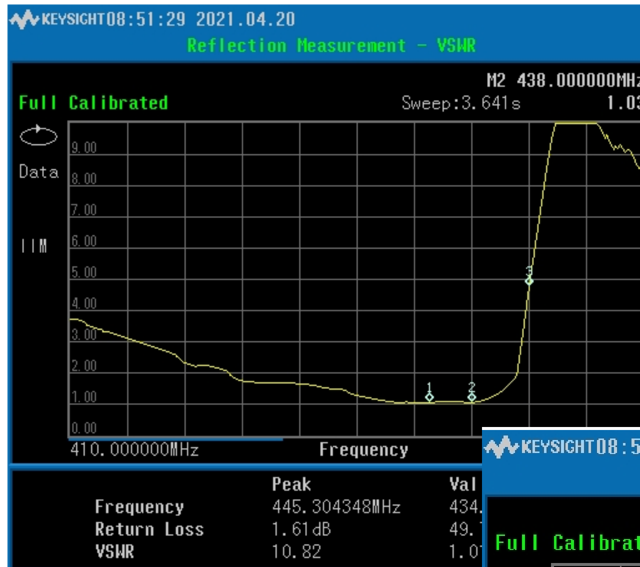
- RG-383 coax feed connection
  - Easy to work with
  - Coax routed inside the boom
  - Ferrites used for current leakage blocking

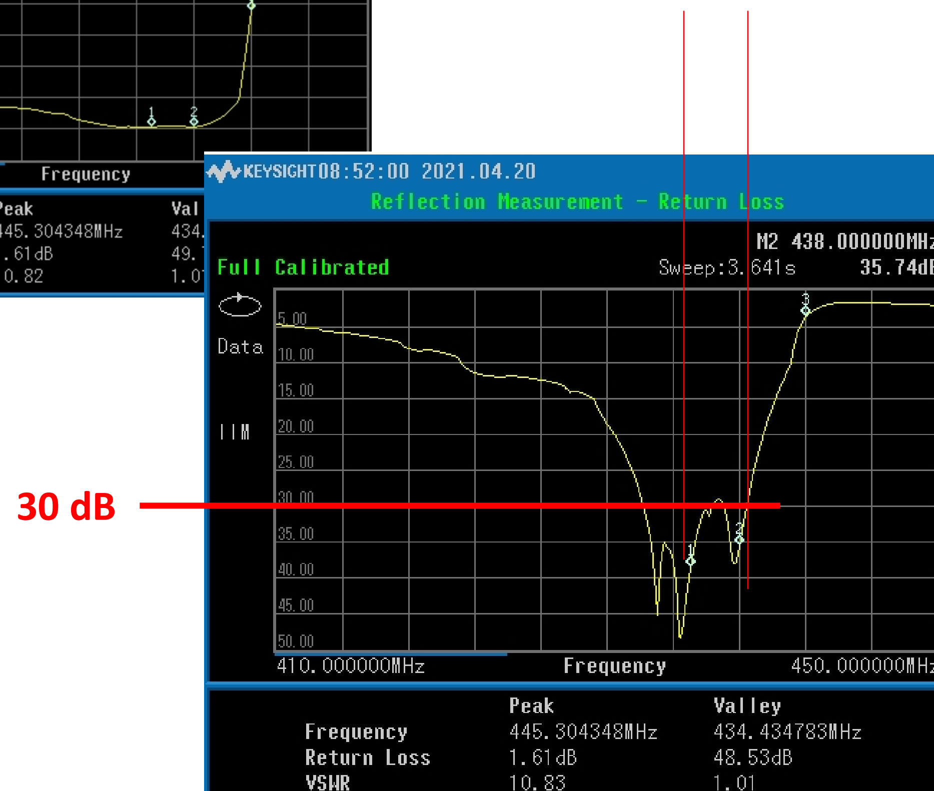
Testing Results

Initial result



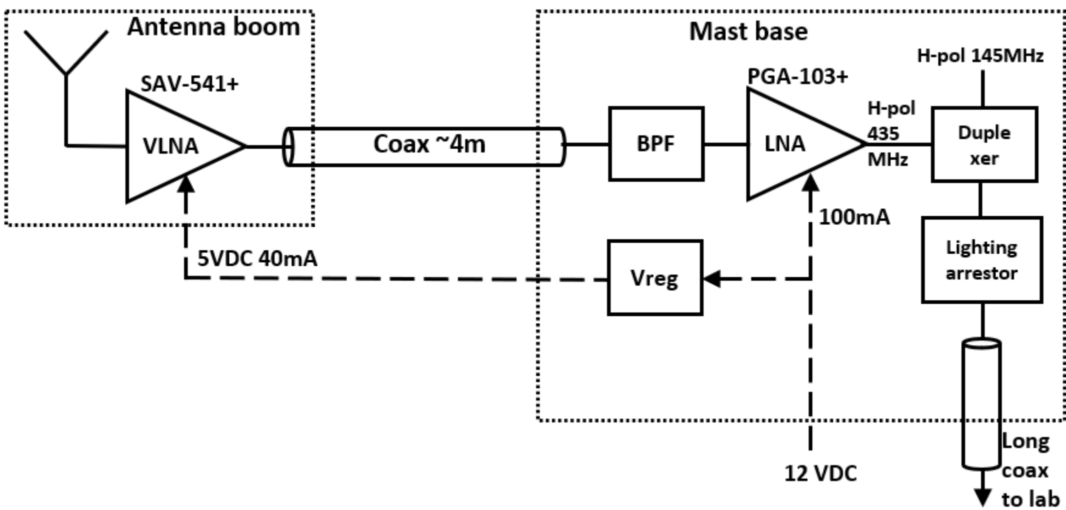
Final tunning





Signal Amplification and Conditioning

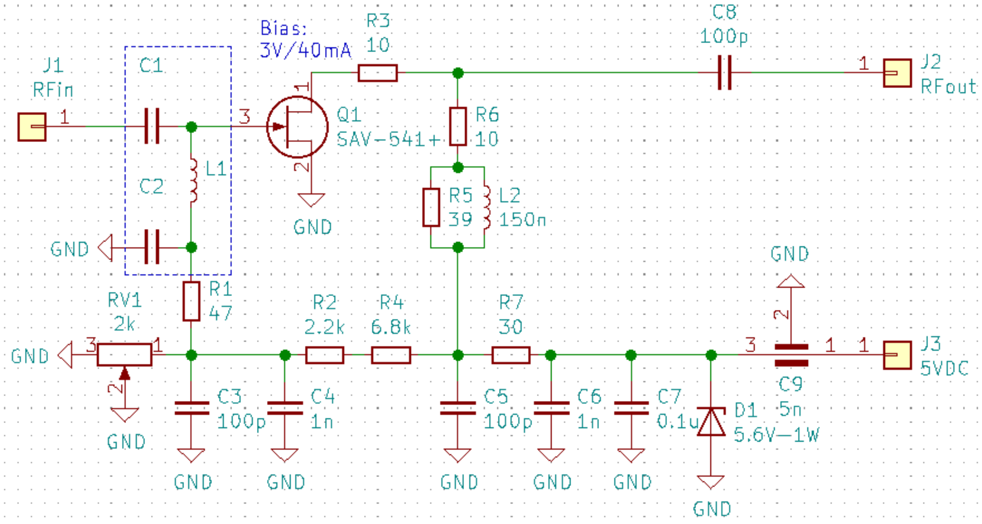
- **Built for each separate polarization**

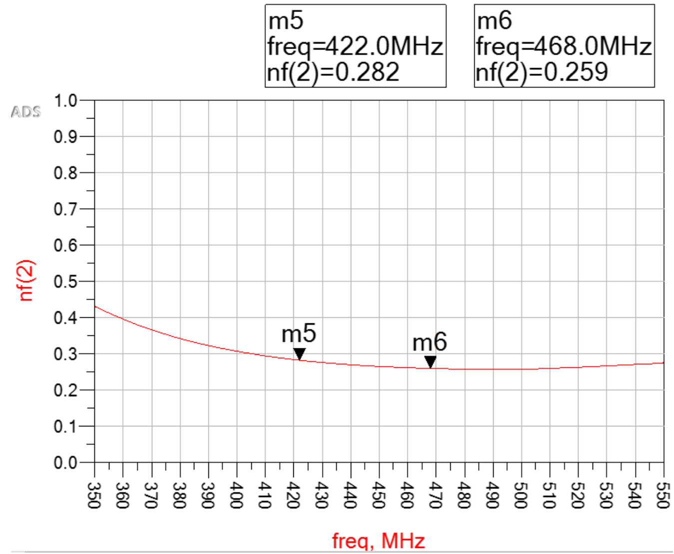


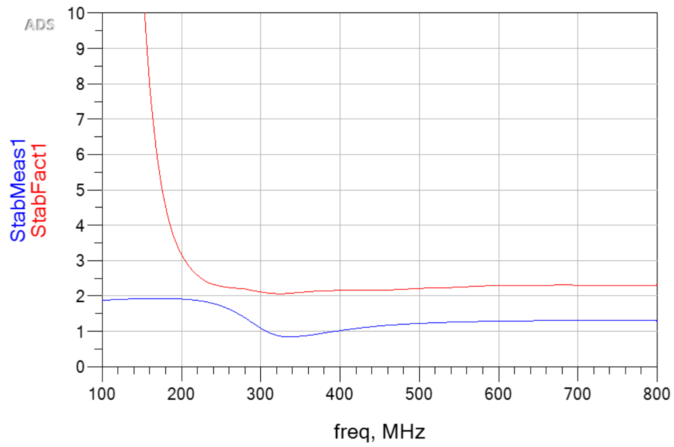
- **1st Stage LNA: Ultra low-NF VLNA**
  - **Own design based on SAV-541+**
- **Bandpass filter**
  - **Own design with chip components**
- **2nd Stage LNA: High linearity LNA**
  - **Own design based on PGA-103+**

1st Stage VLNA

- **Minicircuit SAV-541+**
  - **Simple design**
  - **Schematics for VHF and UHF**
  - **NF and Stability diagrams**

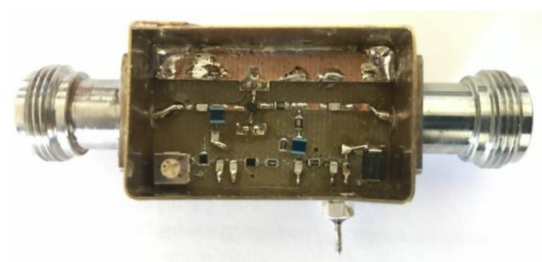


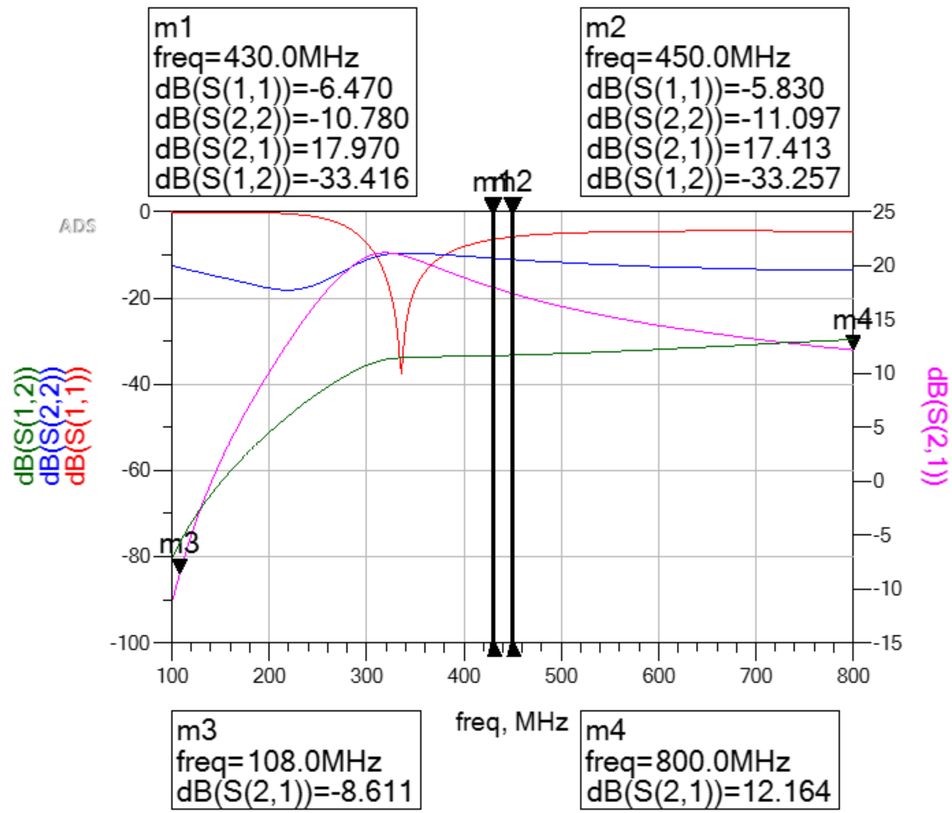




1^{st} Stage VLNA Testing Results

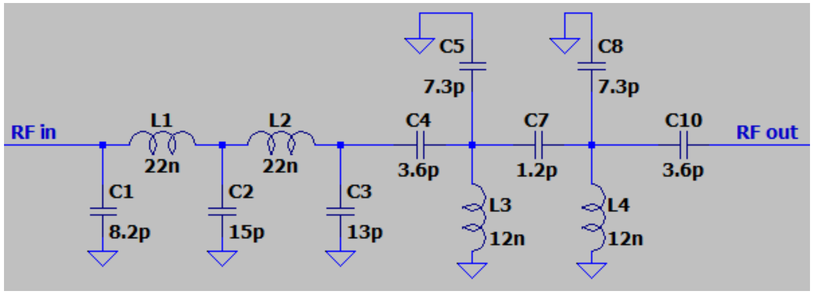
- **Gain: >17dB**
- **NF=0.35 dB**

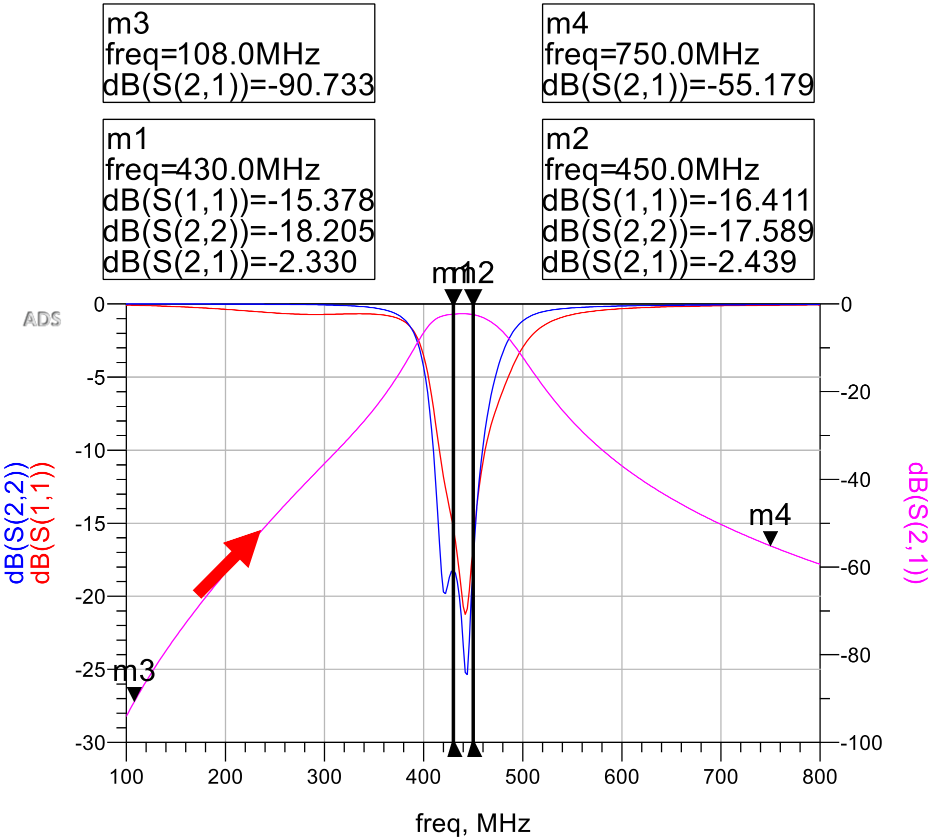




Band-Pass Filter

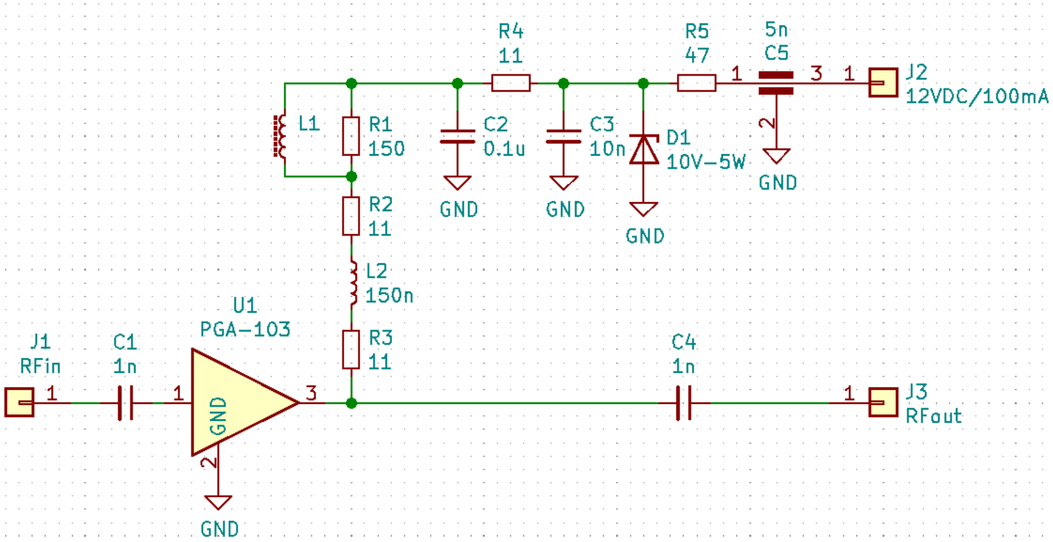
- **Rejection of:**
  - **FM radio bands**
  - **Telcom bands**





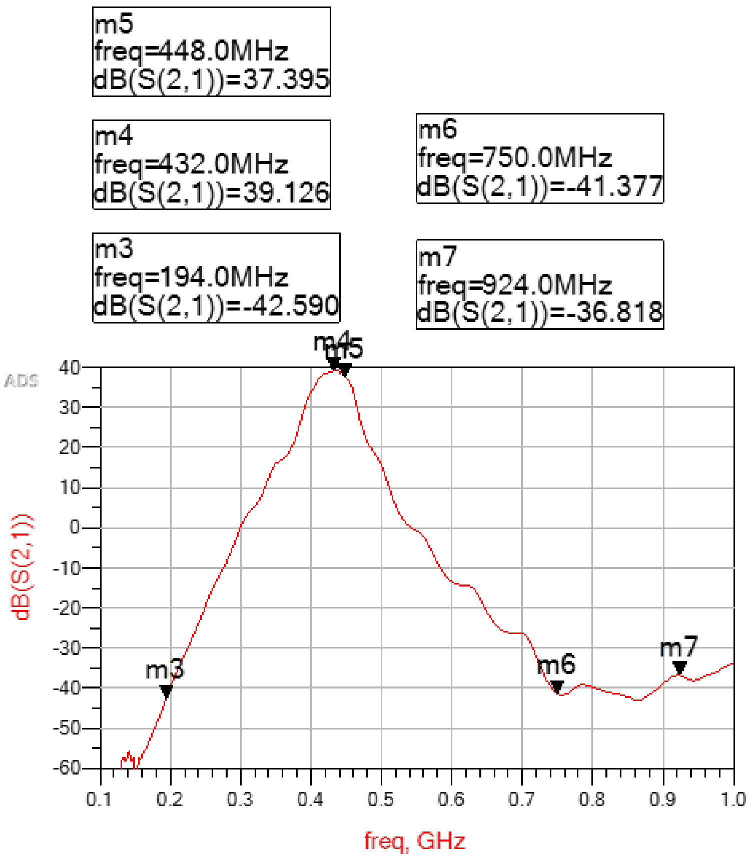
2nd Stage LNA

- **Minicircuit PGA-103+**
  - **Simple design**
  - **High linearity: 39dB**
  - **Low NF: 0.5dB**

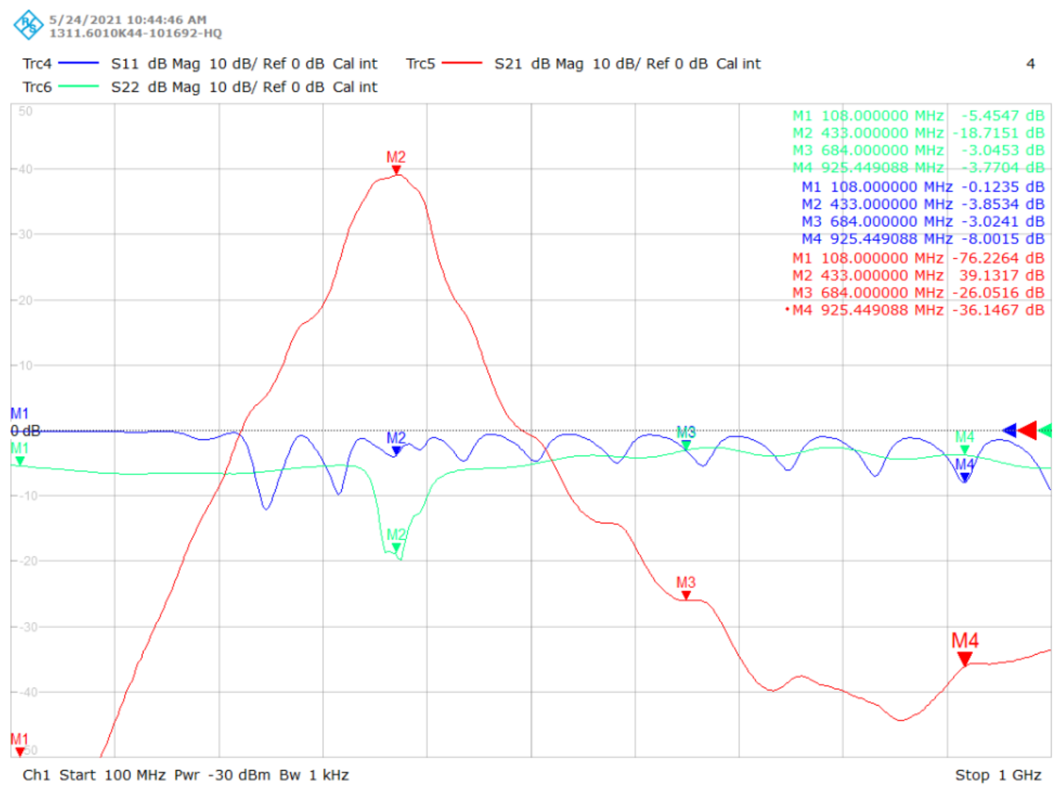


Testing Combined VLNA+BPF+LNA

Simulated result



Tested result



Overall gain: 39dB

Conclusions

- Design of the GMU Ground Station
  - Presentation focused on UHF RX antenna and path
  - Details of VHF RX path are described in the paper
- Strategy:
  - Reduction of noise and losses in the entire path: Antenna→ Receiver
  - Leading to a smaller ground station of excellent characteristics
  - Use of SDR for subsequent signal processing, fusion, and demodulation
- All components of the system designed and fabricated in-house
  - Took much longer than expected
  - Provides great education value