RFI Monitoring and Mitigation for the Allen Telescope Array

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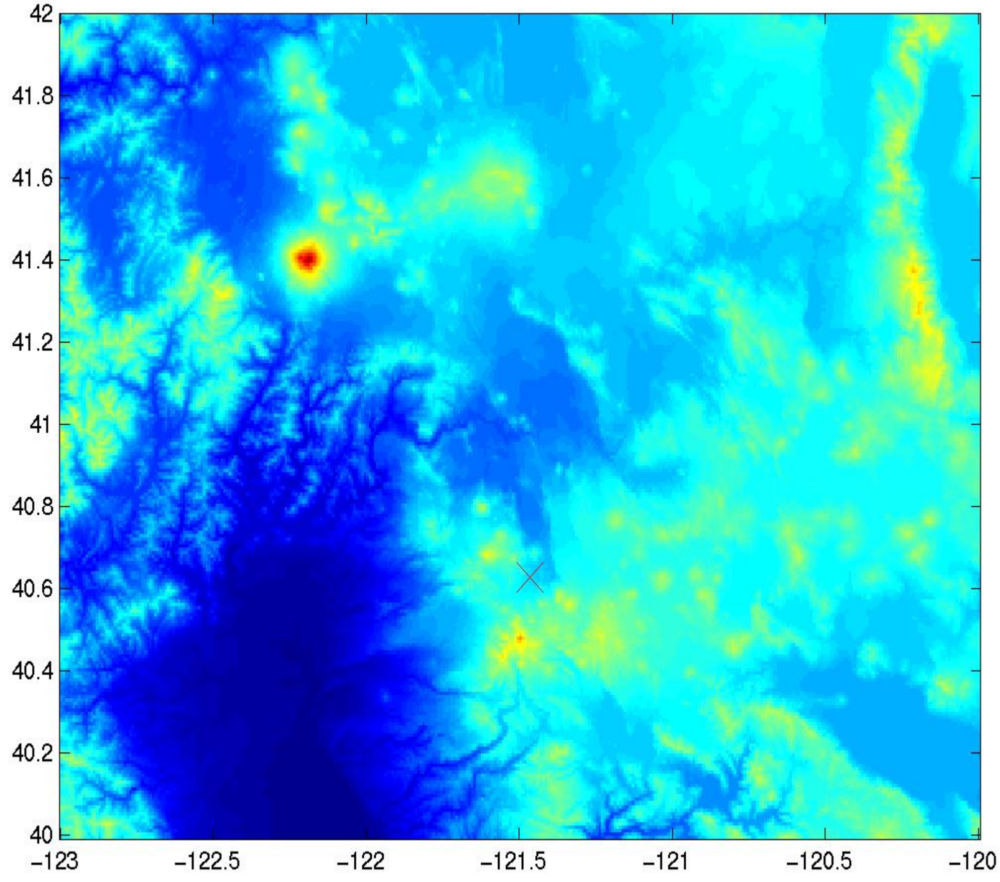
Strategy Overview

- Know the enemy
- Put many arrows in the quiver
  - No Magic Bullets
- Exploit large N capability
- Implement at all levels

Available Tools

- Modeling of environment
- Measurement
- Real time strategies

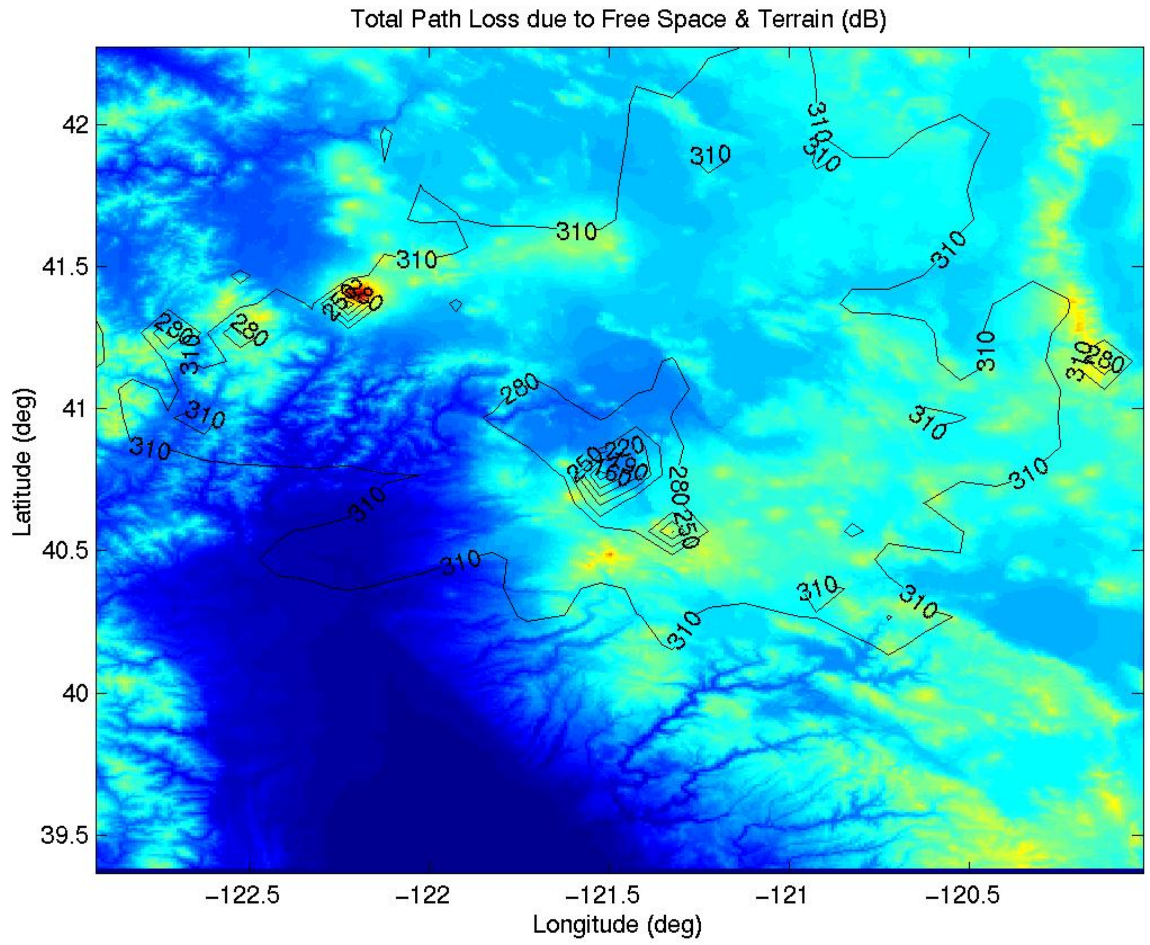
RFI Modeling: Hat Creek Terrain



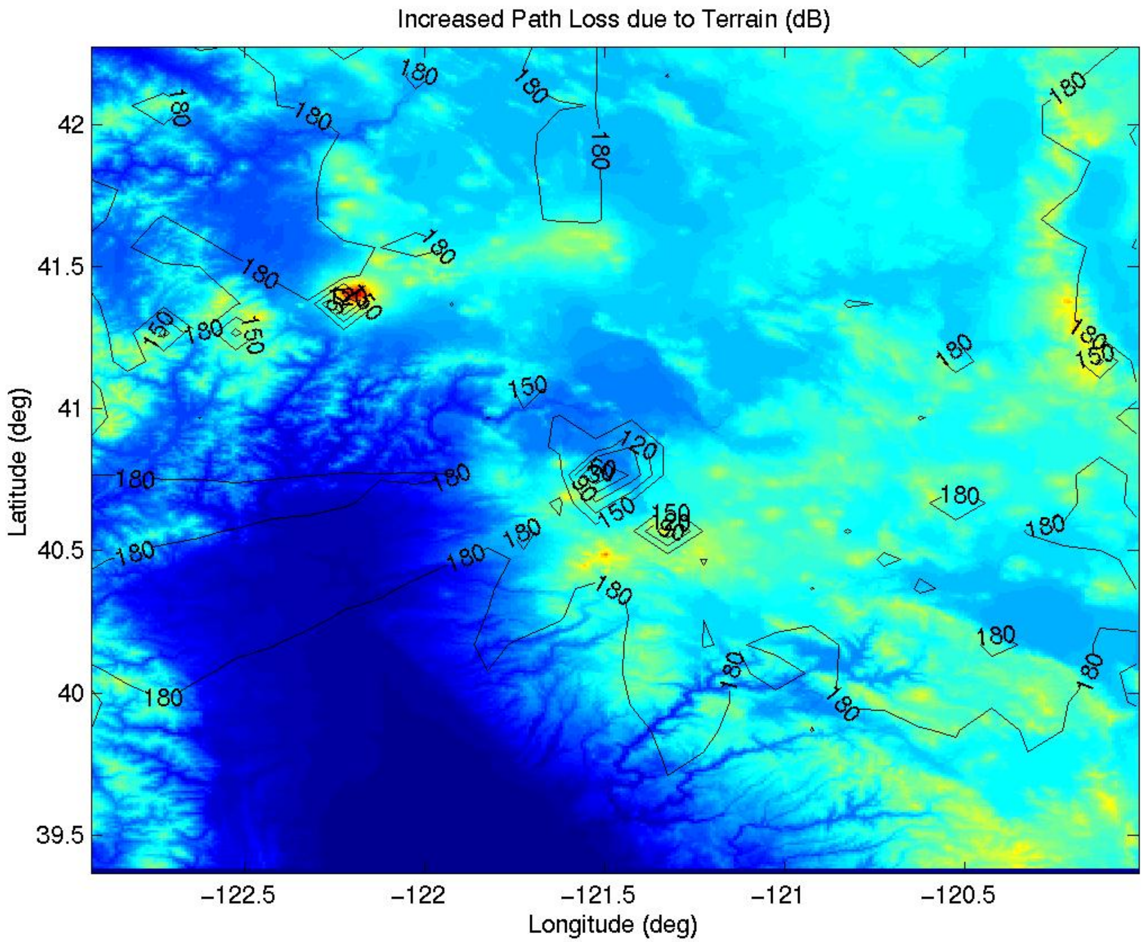
RFI Modeling

- Visualyse simulation
- Free space model
- ITU-R P.526
  - Model includes topography, diffraction, tropospheric scatter, ducting/layer reflection, fade
- Future modeling: frequency, scale, model parameters, Longley-Rice
- Calibrated test measurements

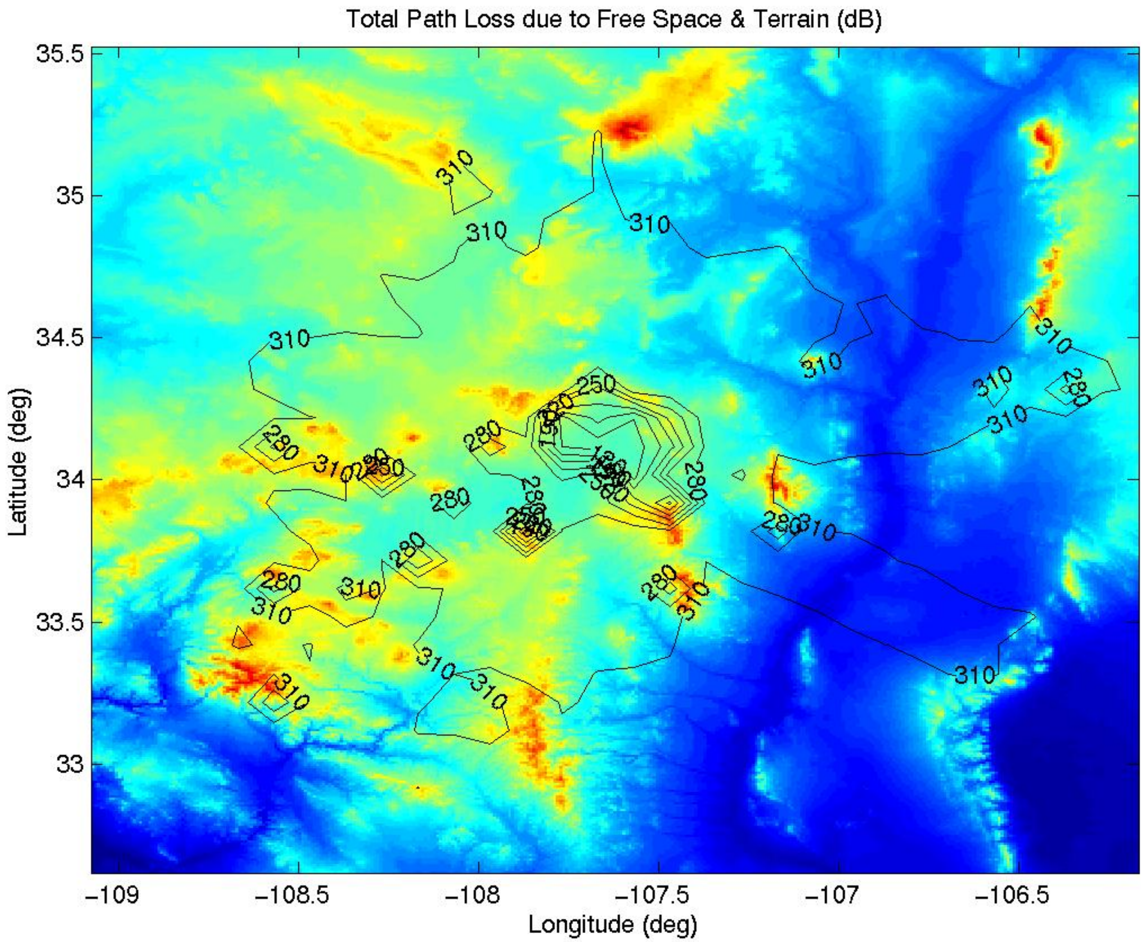
Hat Creek: Total Path Loss



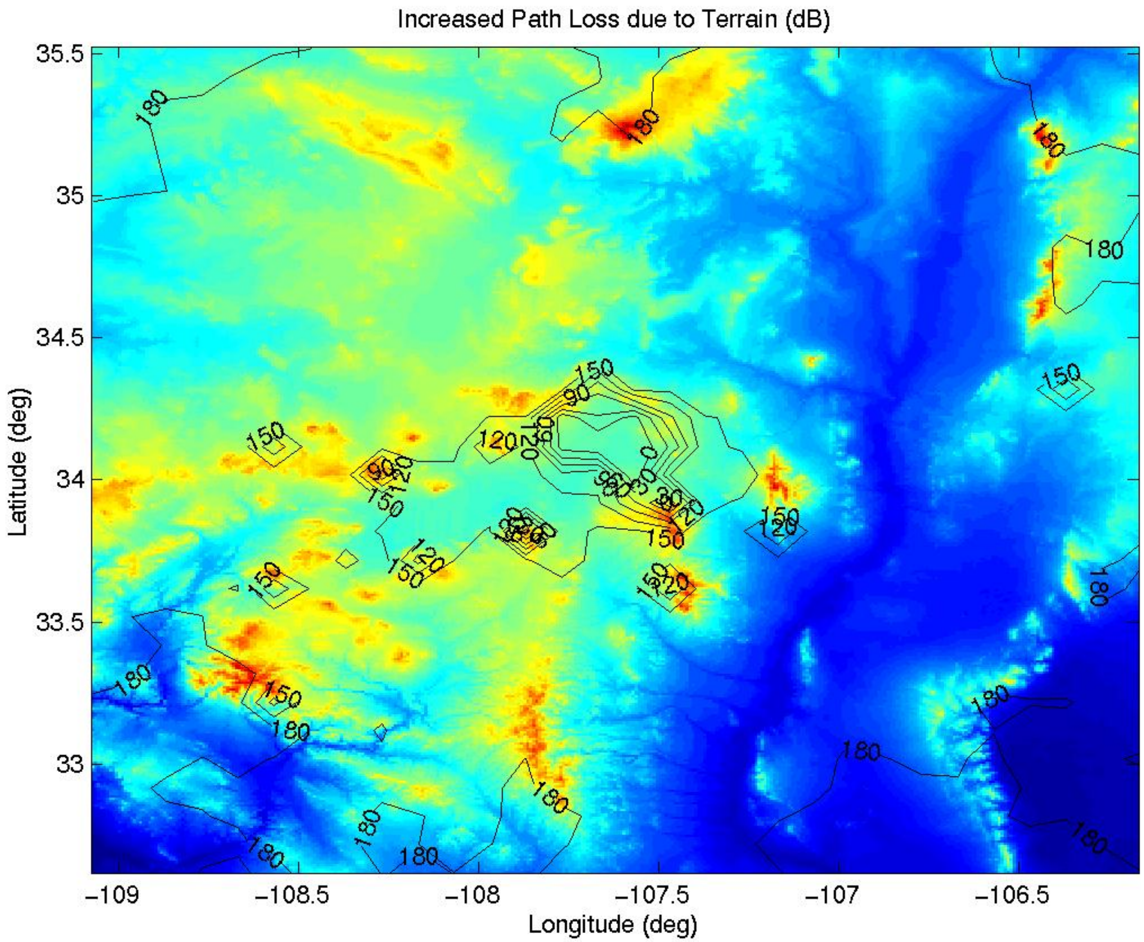
Hat Creek: Terrain Loss



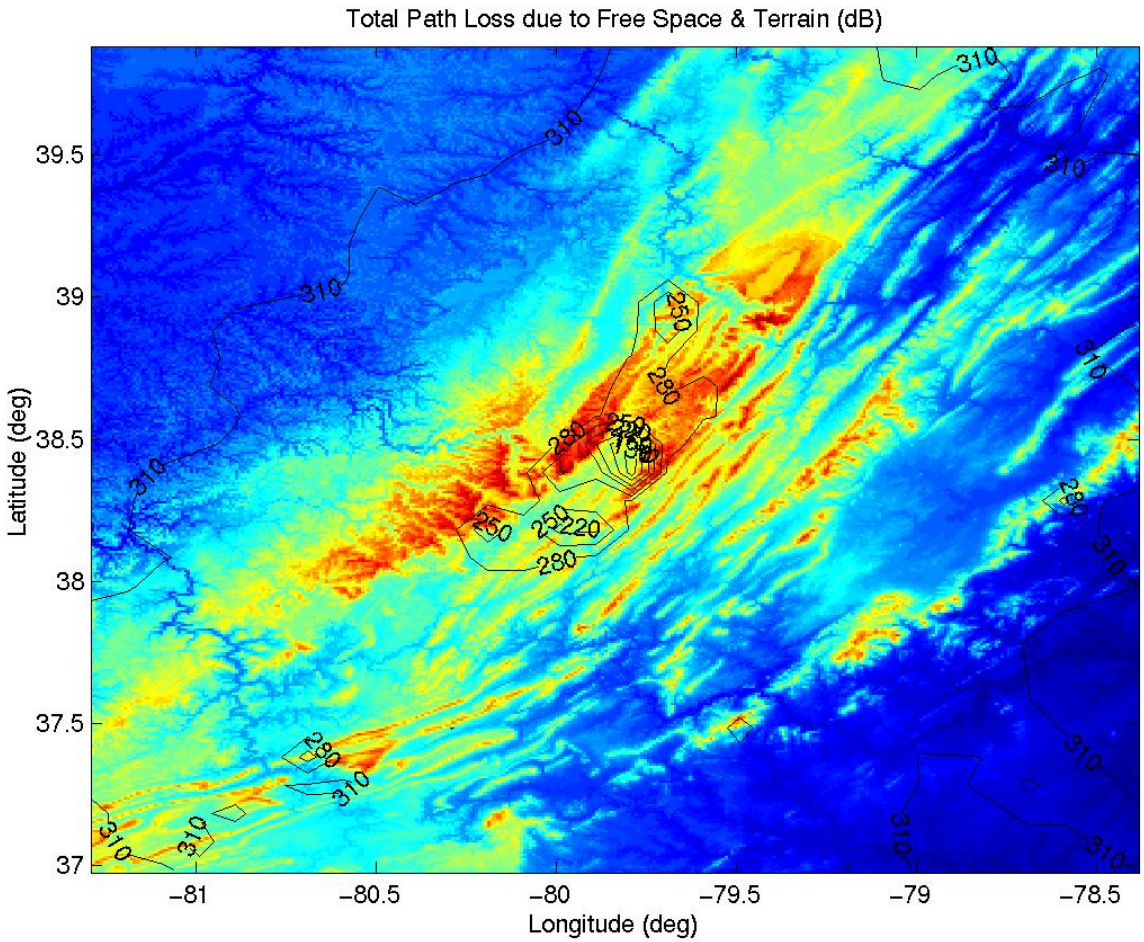
VLA: Total Path Loss



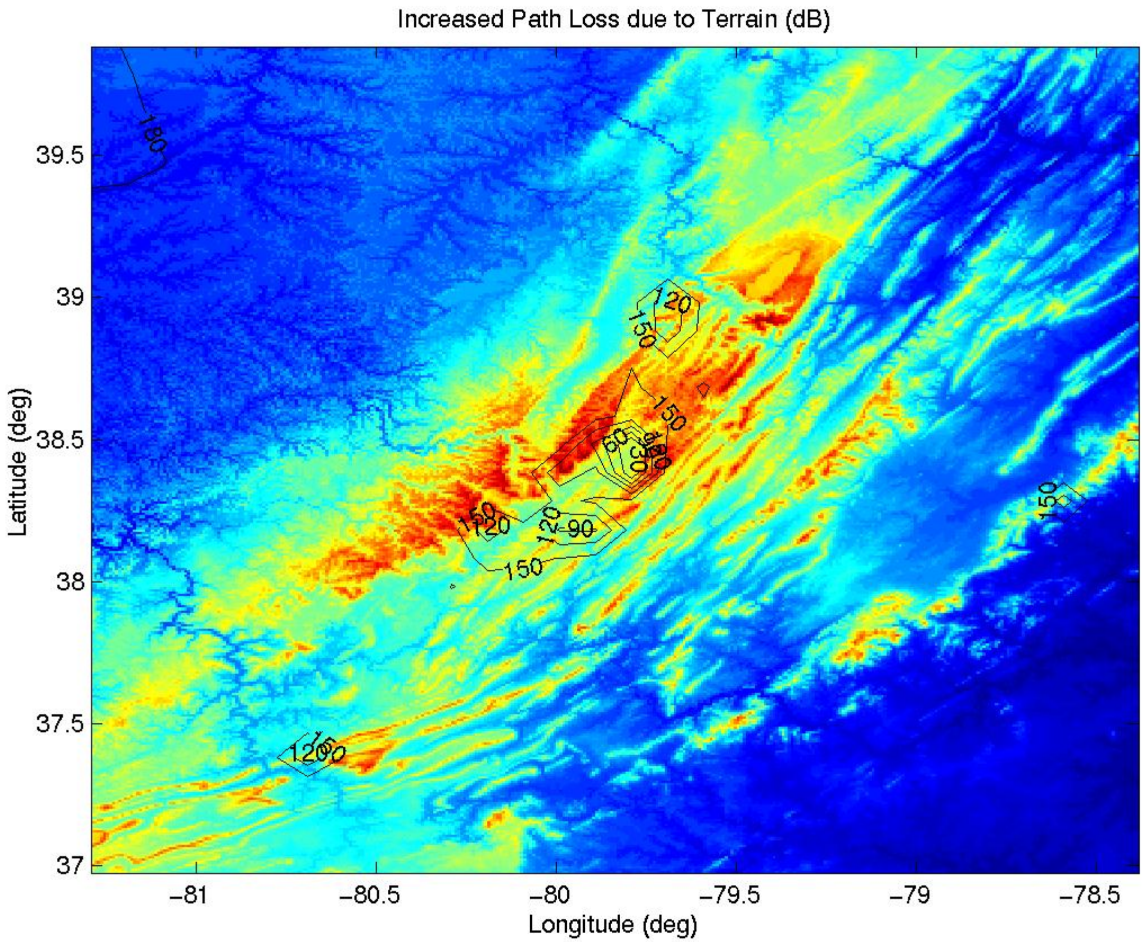
VLA: Terrain Loss



Green Bank: Total Path Loss



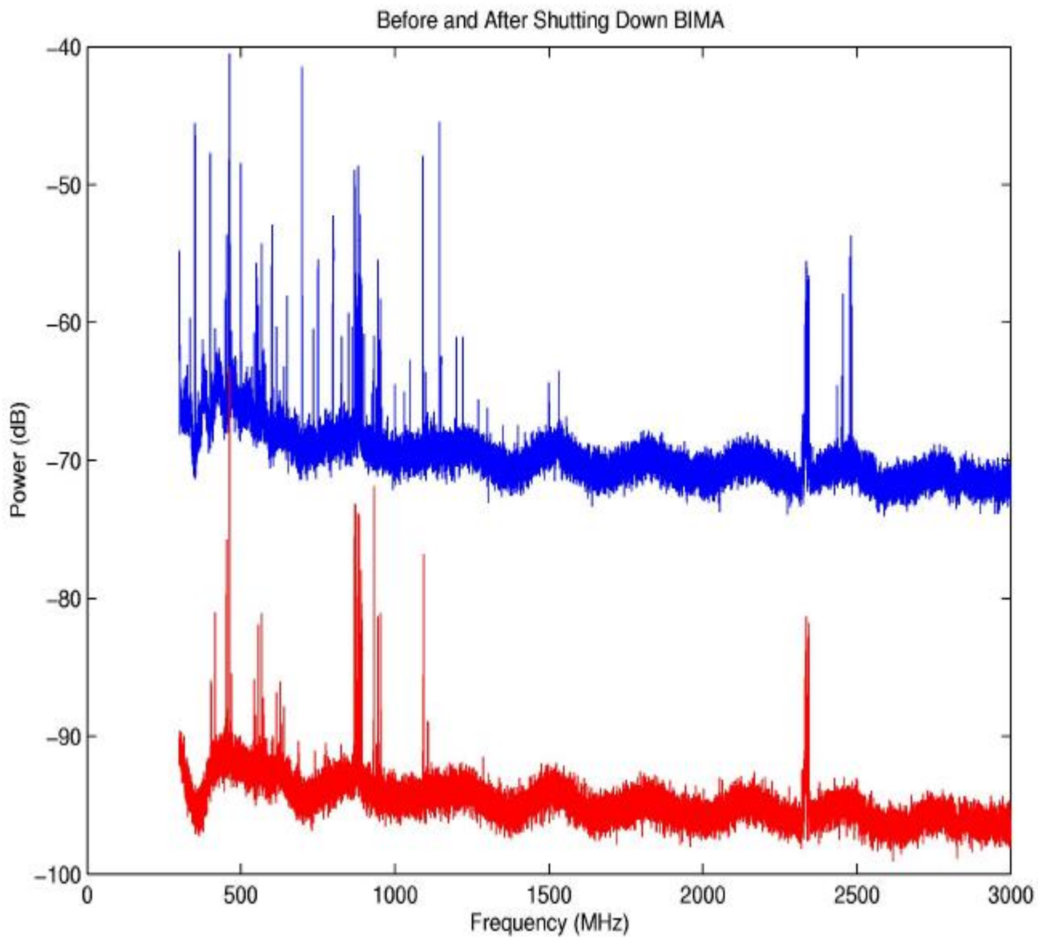
Green Bank: Terrain Loss



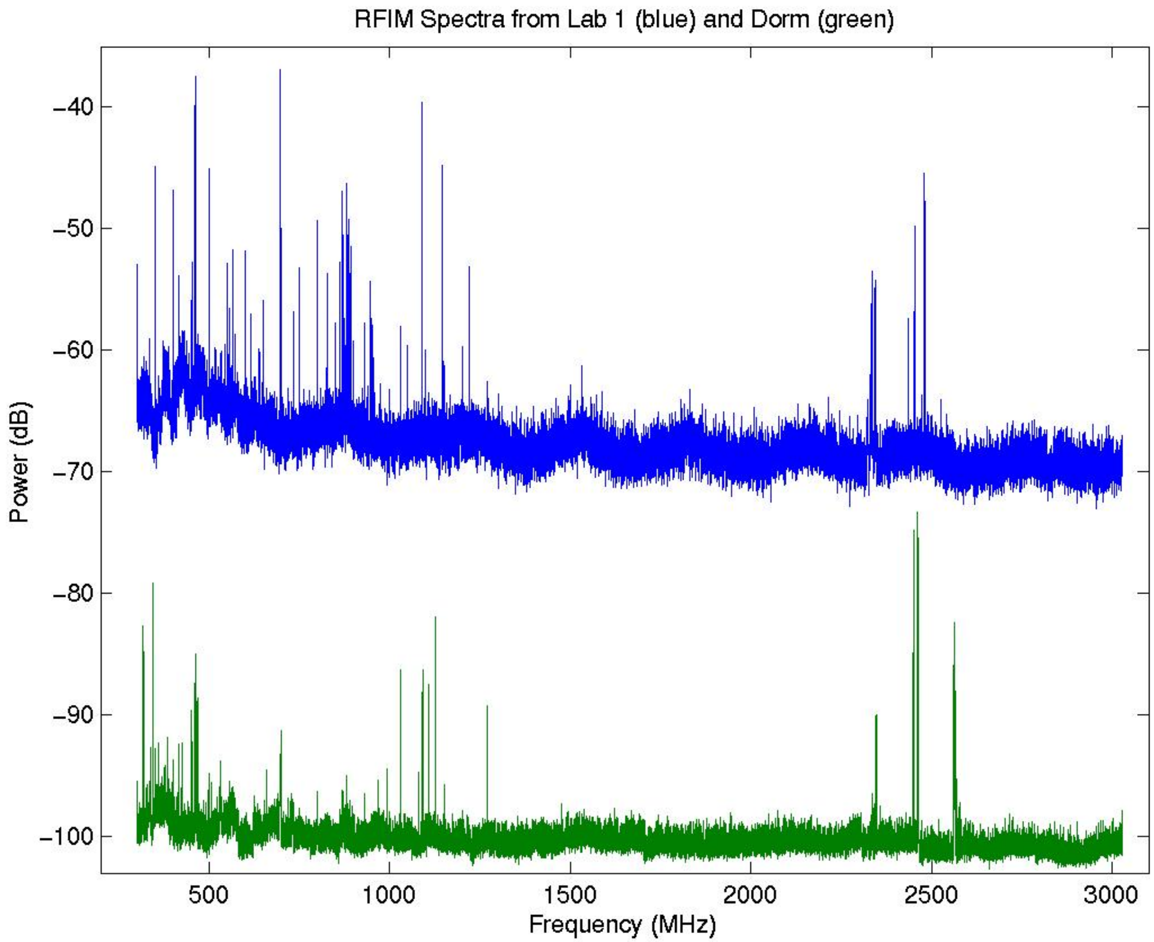
RFI Monitor

- Simple design
  - Discone antenna
  - Broadband amp
  - Spectrum analyzer
  - Linux PC on ‘net
- 0.1 to 10 GHz
  - 0.3 to 3 GHz currently
- Isotropic sensitivity

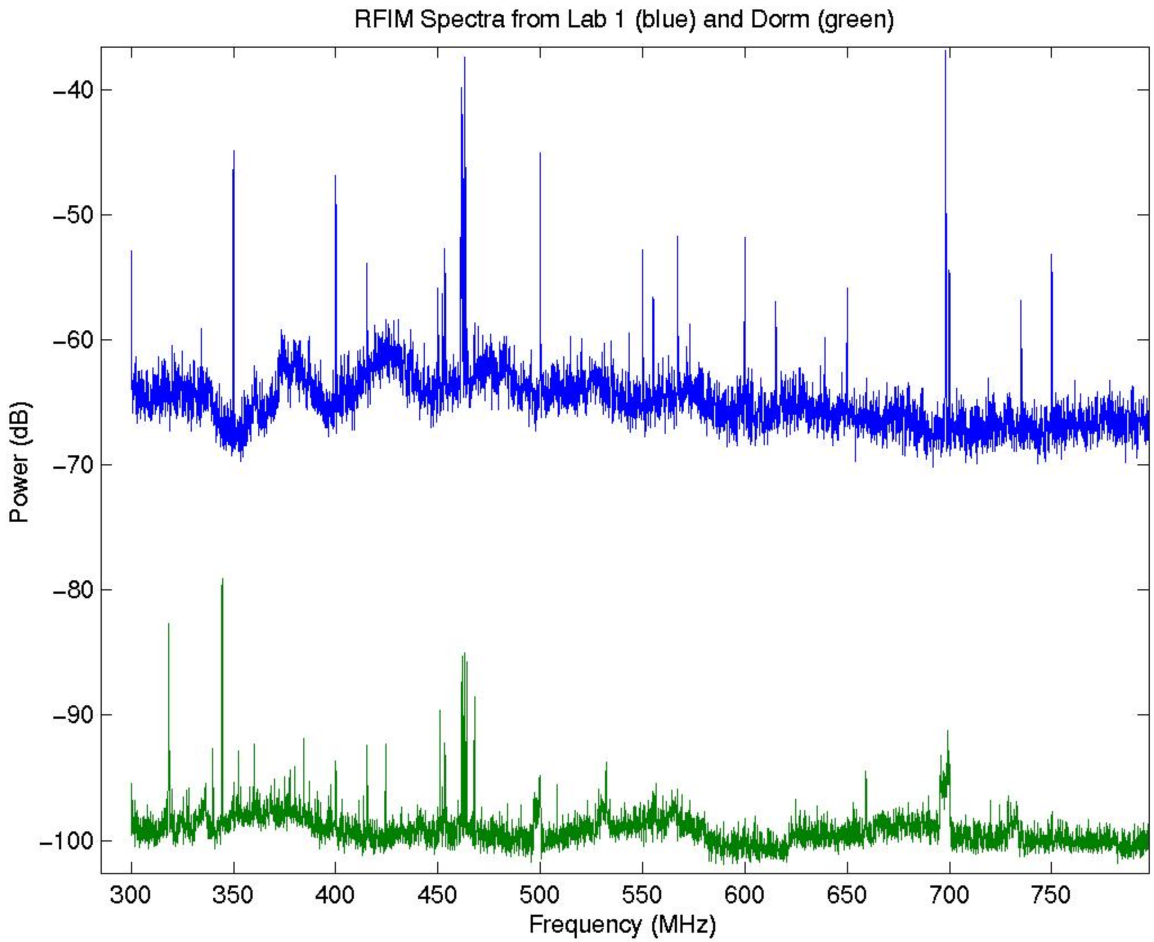
… (One of) the Enemies is Us



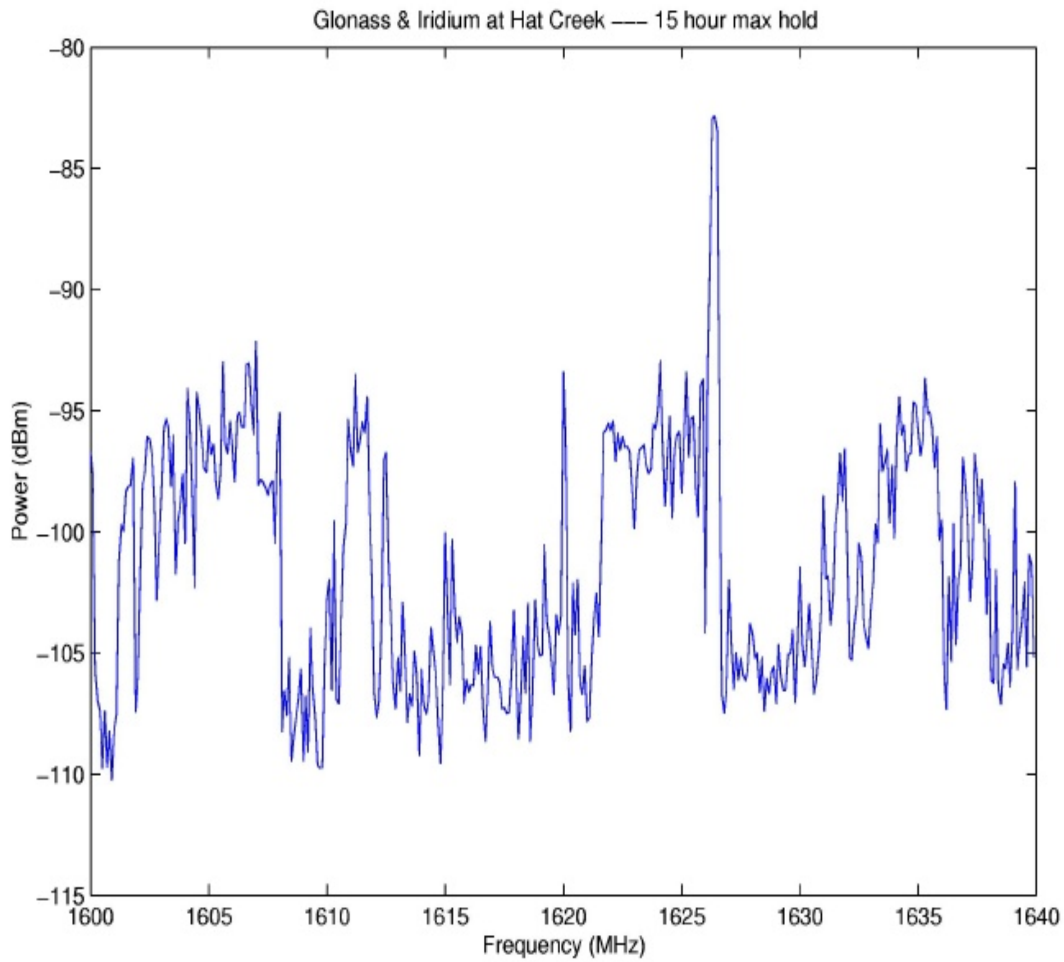
Moved the RFIM



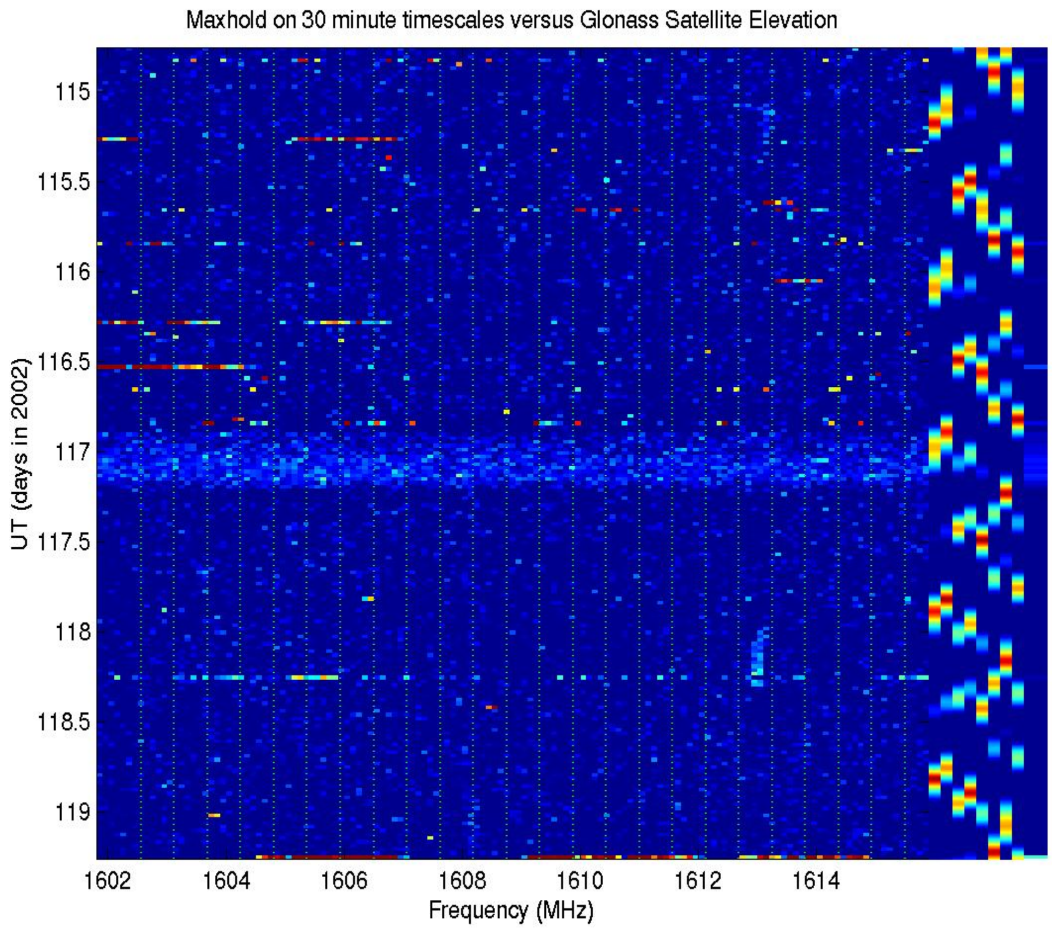
Moved the RFIM
Low Frequency Spectrum



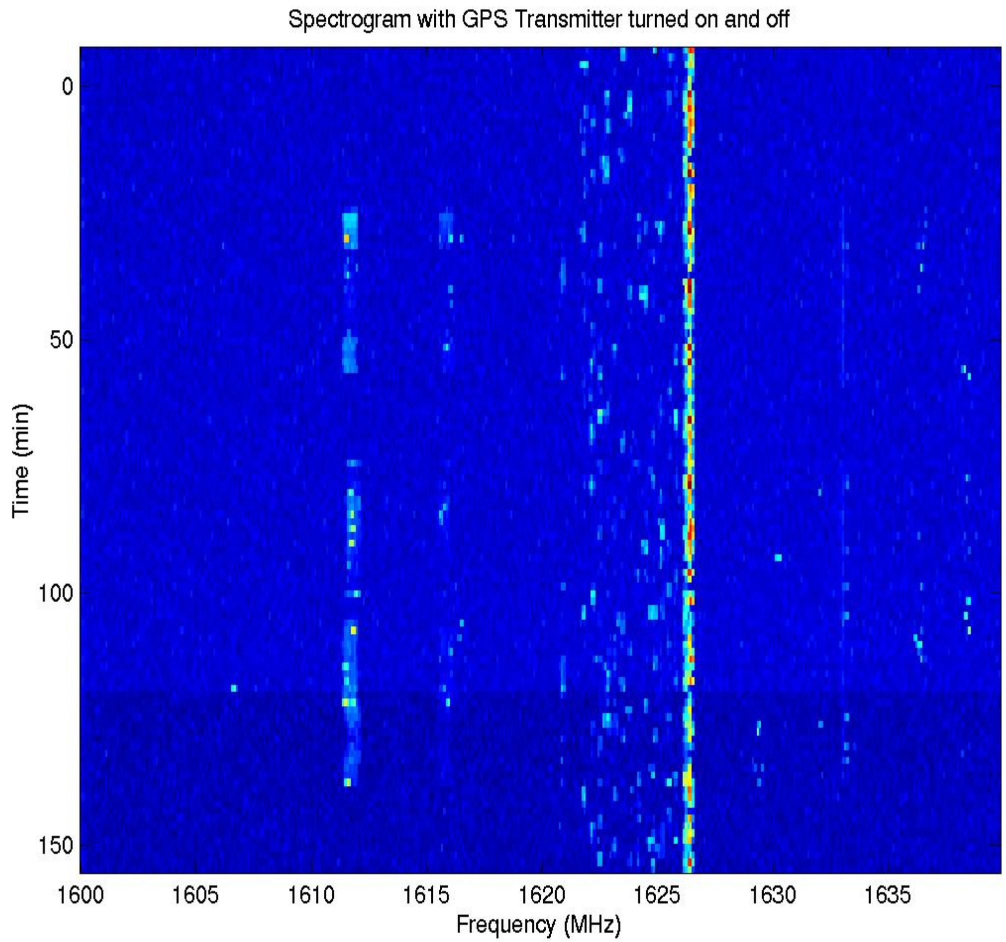
Is Glonass Present at 1612 MHz?



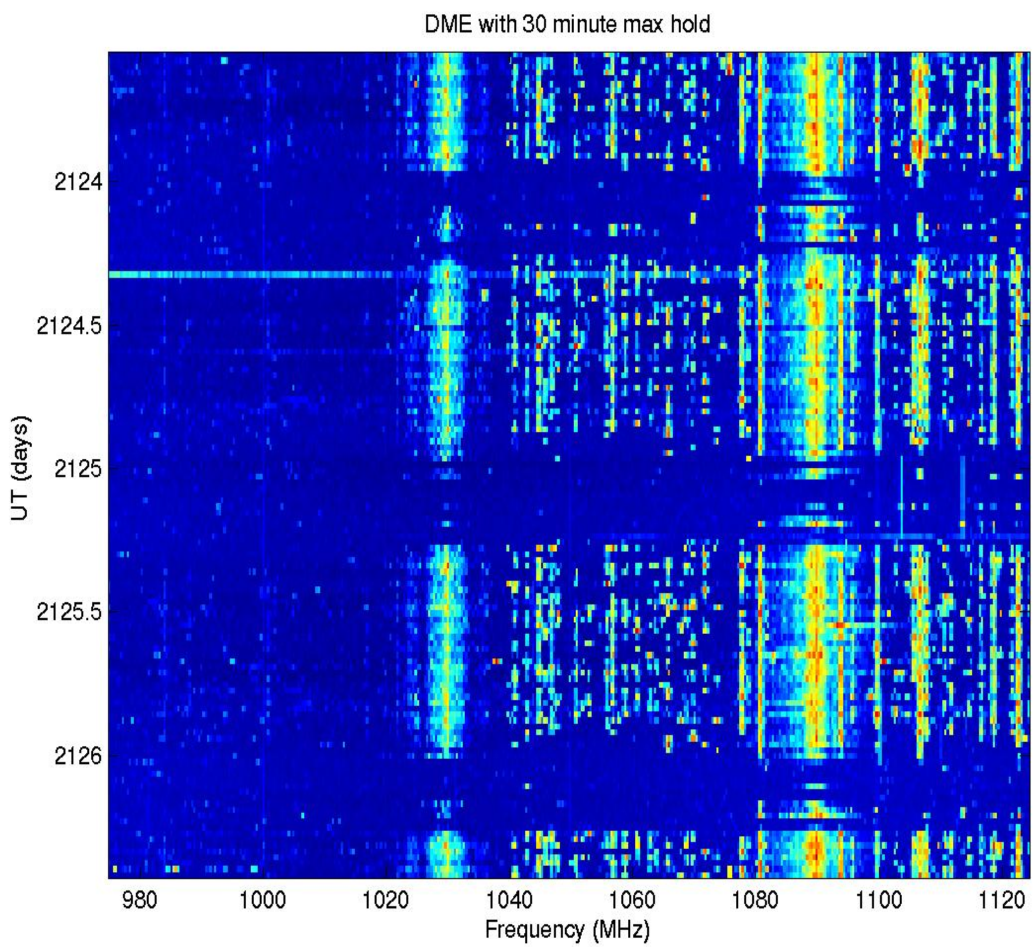
Tracking Glonass



…The Enemy is Us, Part 2



Aircraft DME



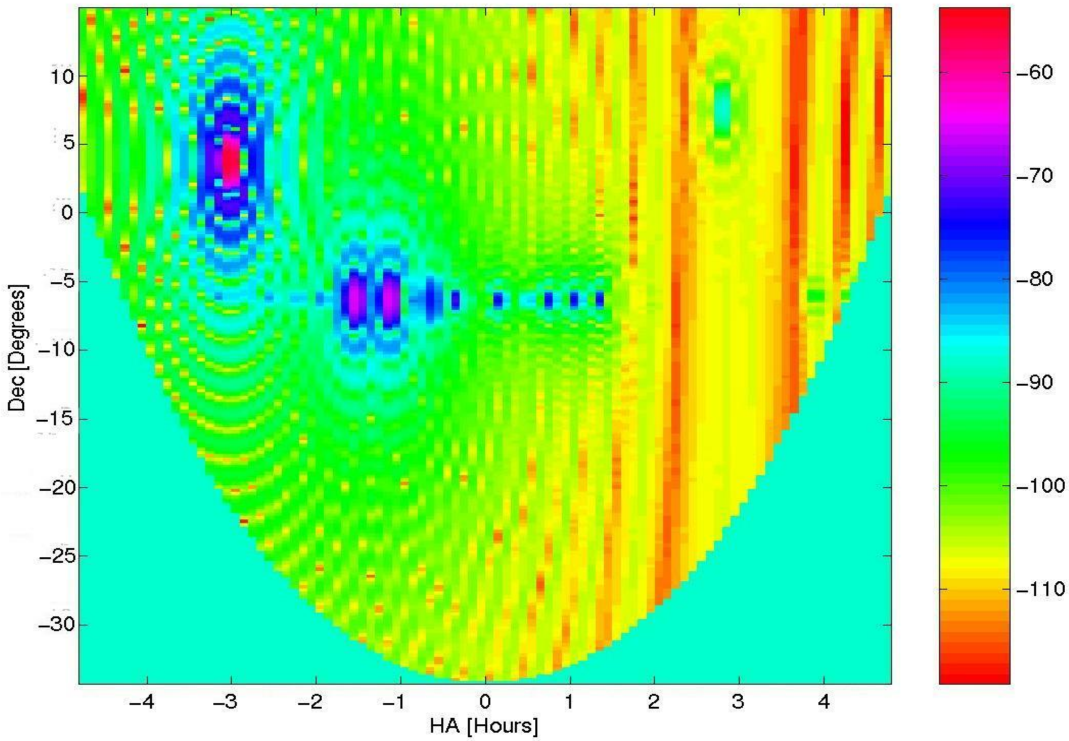
RFI Sources Detected at Hat Creek

- Self-interference
- Satellites --- GPS, Iridium, DARS, etc.
- Aircraft
- Radar
- TV, cell phone, pager
- Microwave ovens

Real Time RFI Mitigation

- Monitoring
- Artificial horizons around known interferers

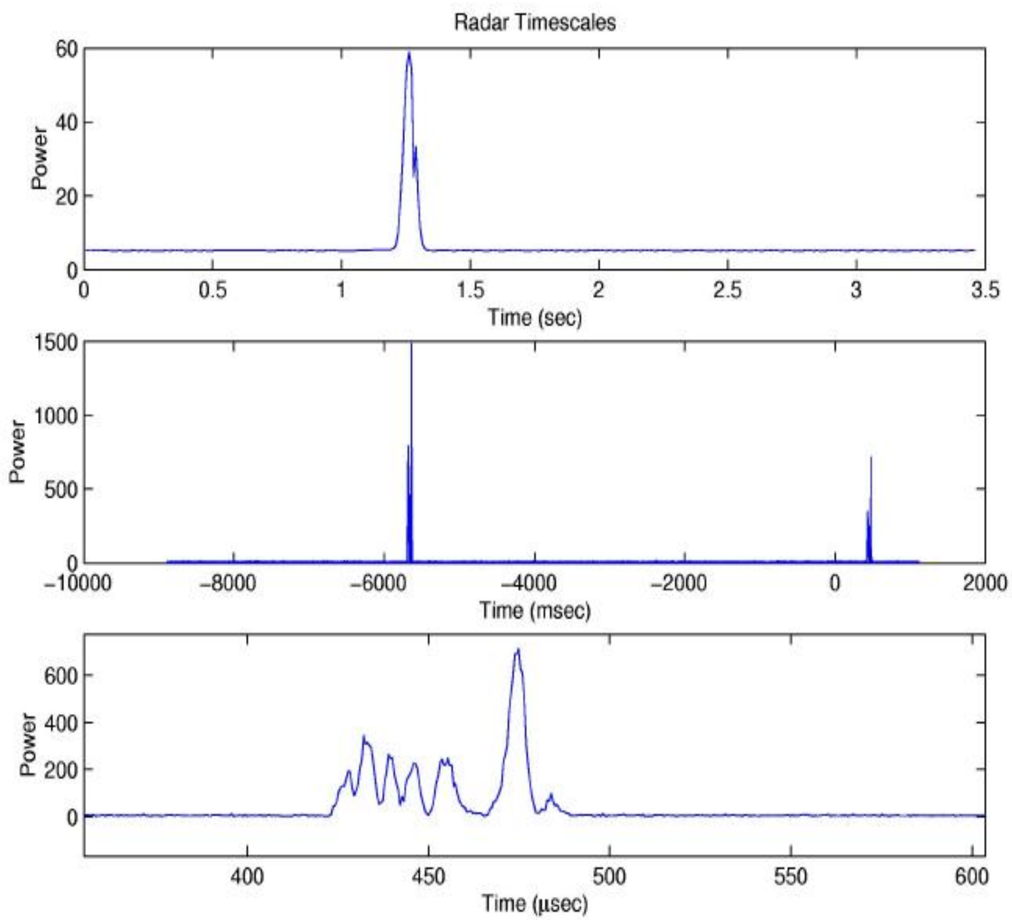
- Time Blanking
- Adaptive canceling
- Interferometric Nulling
- Postcorrelation Analysis



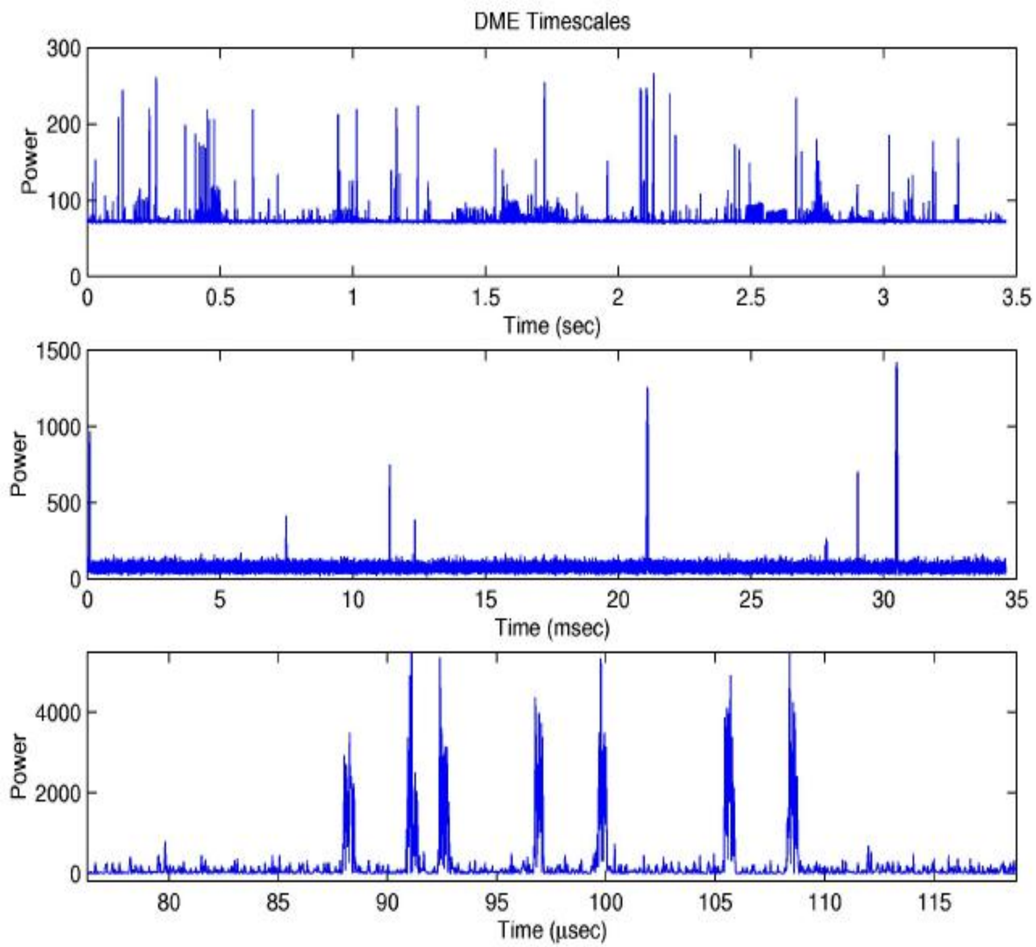
Artificial Horizons

		GPS	Iridium	Satellite radio	Radarsat
Power density (dBm/m^2)		-95	-60	-76	0
MB	**Power available at LNA (dBm)**	-83	-48	-64	+12
	Dynamic range (dB)	2.5	34	18	!!!
	Source equivalent in 11 GHz band	2.9 kJy 140 Hyd A	9MJy 3.5 Quiet Suns	230 kJy 212 Cas A	9 TJy 39k Active Suns
10dBi	**Power available at LNA (dBm)**	-110	-75	-91	-26
	Source equivalent in 11 GHz band	5 Jy	16 kJy 15 Cas A	455 Jy 5 Vir A	13 MJy 6 Active Suns

Time Blanking: Radar



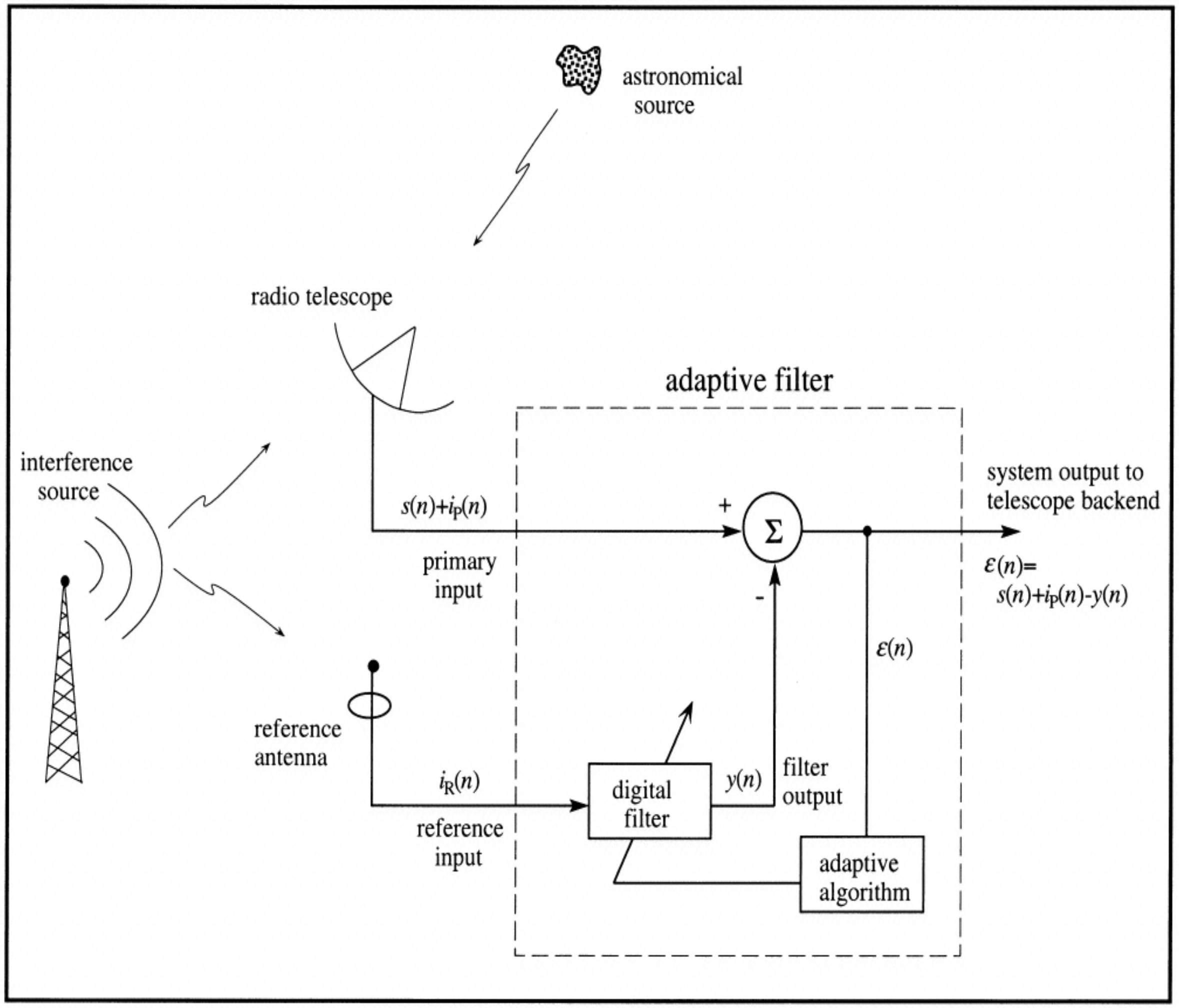
Time Blanking: DME



Time Blanking Implementation

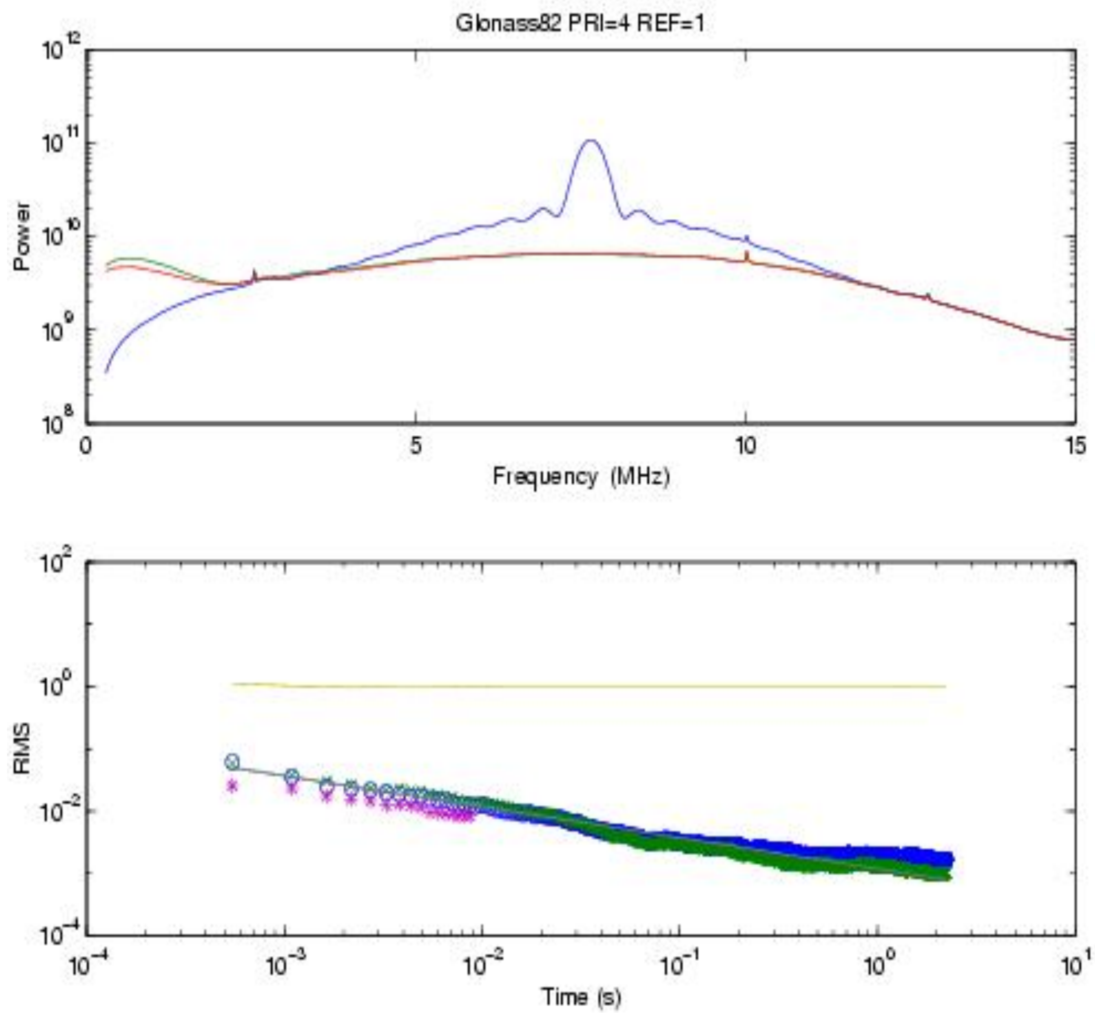
- Done in backends
- Correlator will have
  – 100 μsec precision
  – External & Internal Triggers
  – Channel, Antenna Configuration Undetermined

Adaptive Canceling

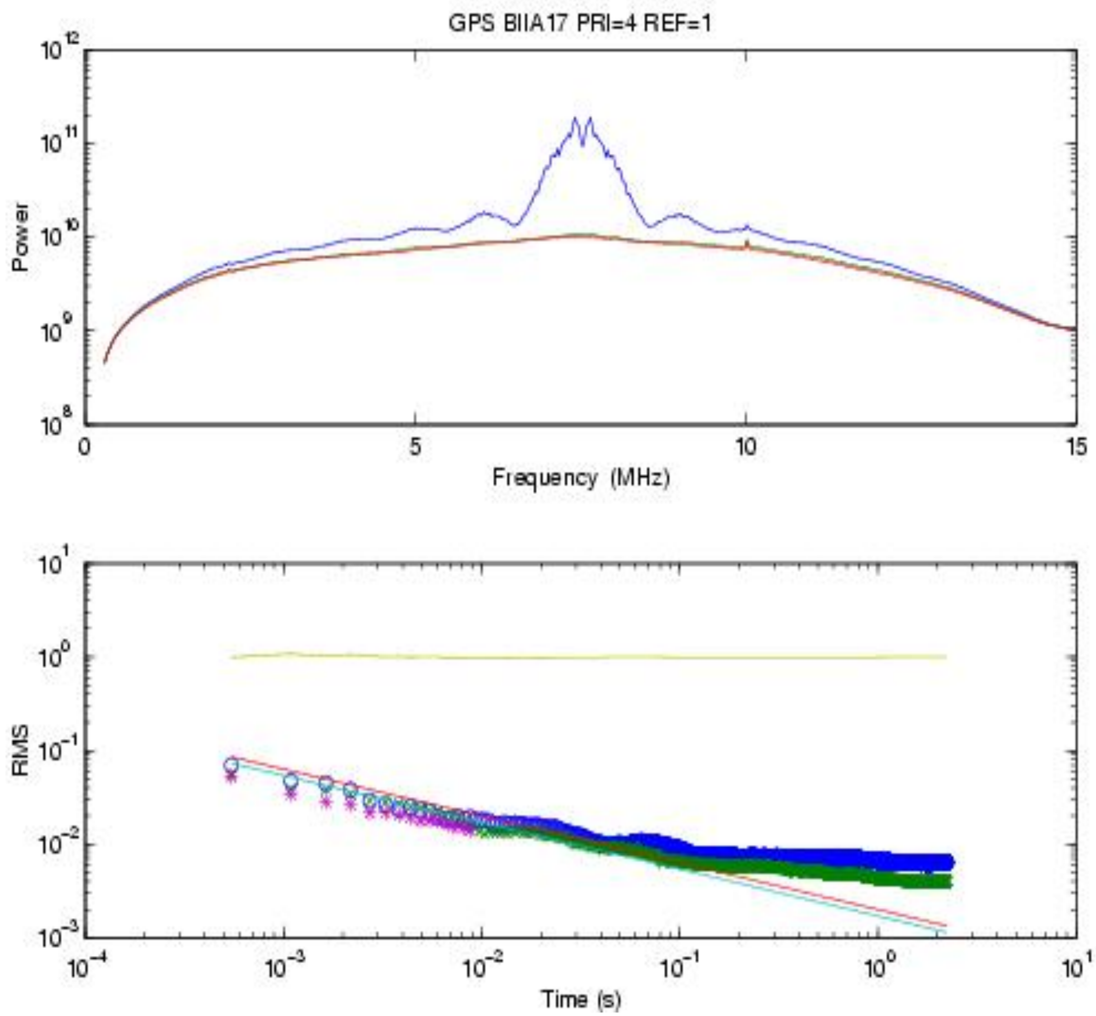


Rapid Prototyping Array

Cancellation of Glonass



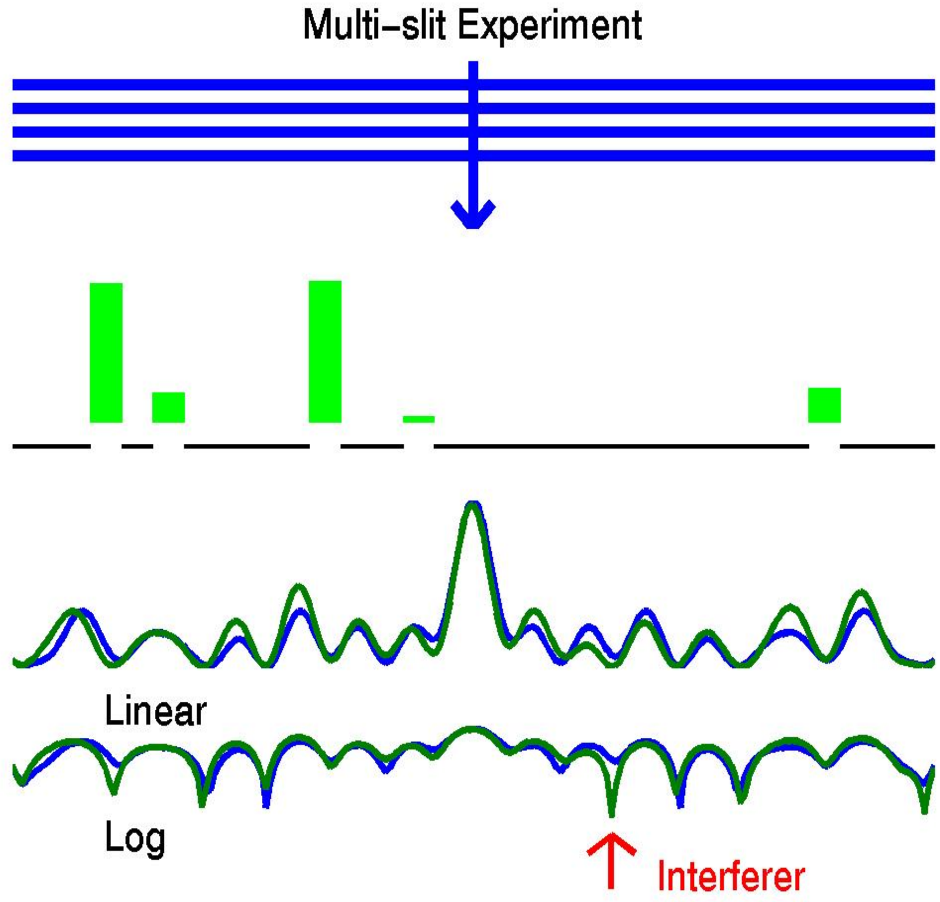
Cancellation of GPS



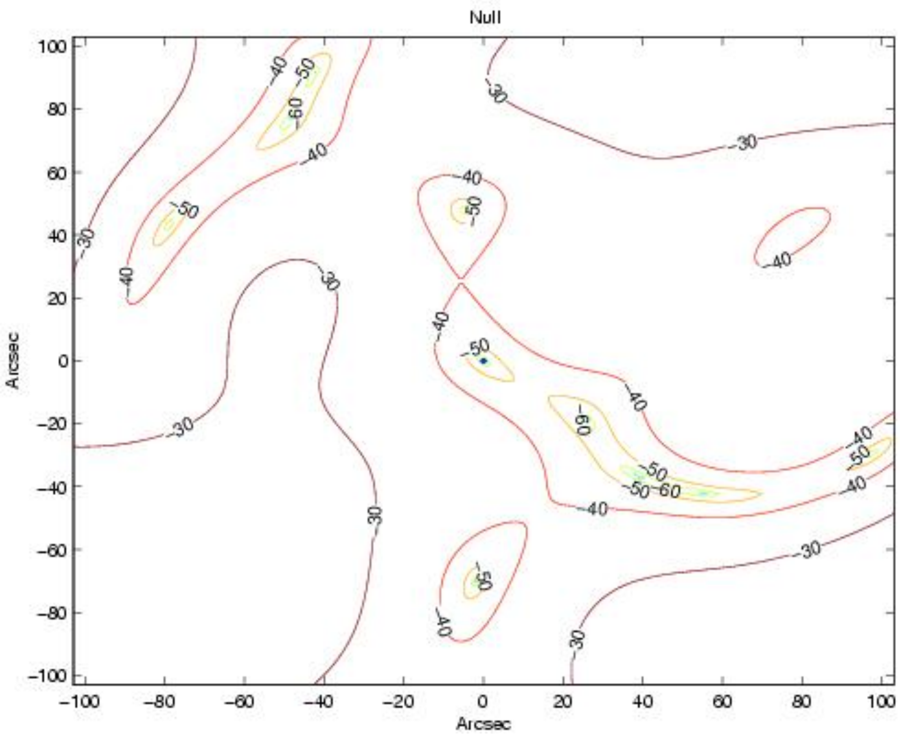
ATA Implementation of Canceling

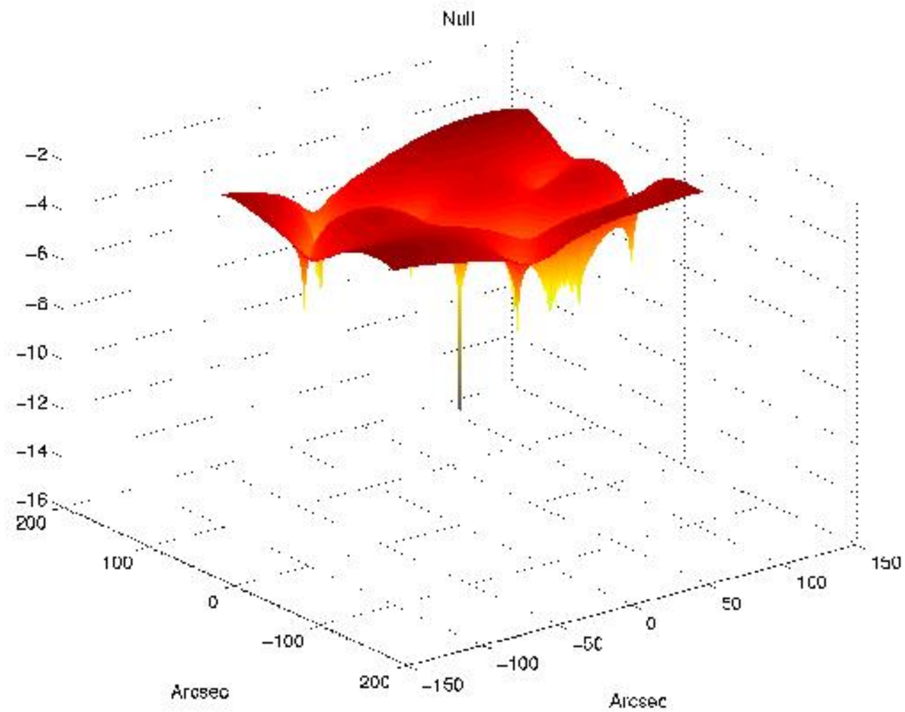
- Multiple reference antennas (~10)
- Correlator/black box operating on phased-array signal
- Wiener or LMS solutions

Interferometric Nulling

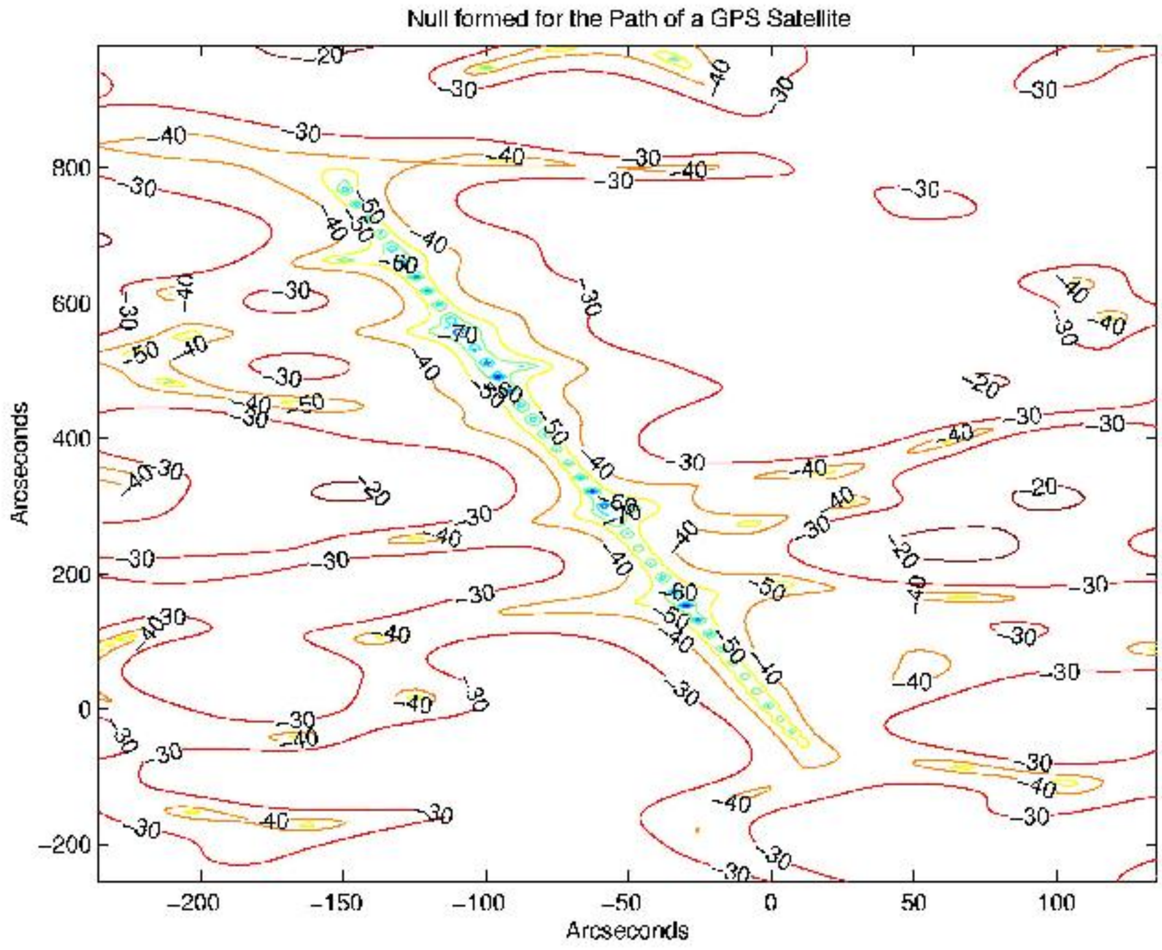


Nulls with the ATA

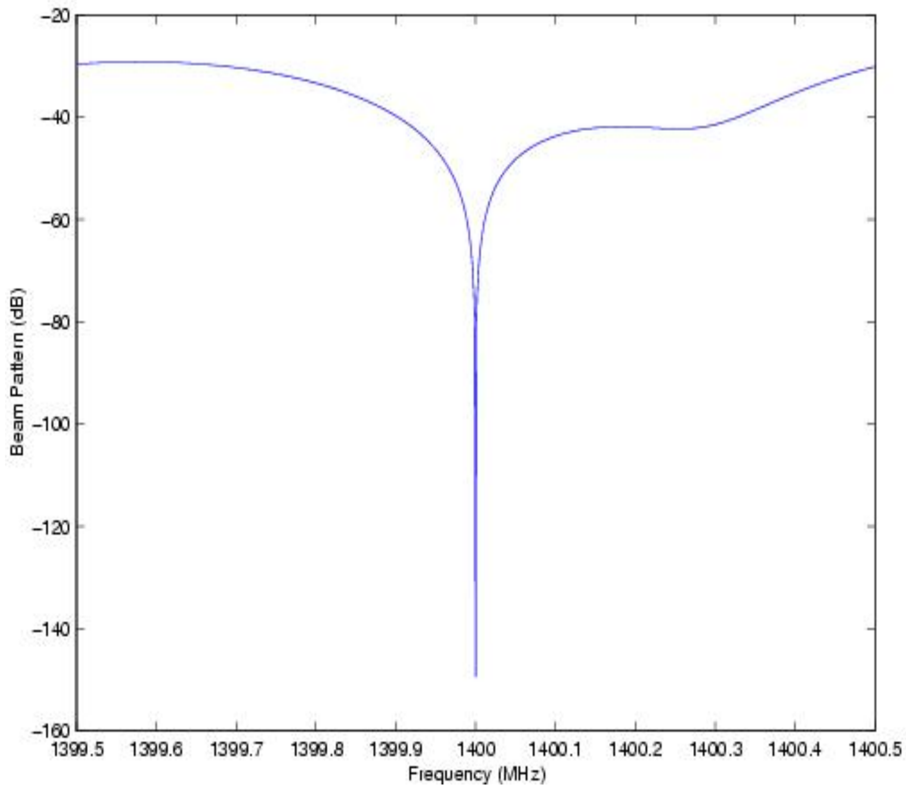




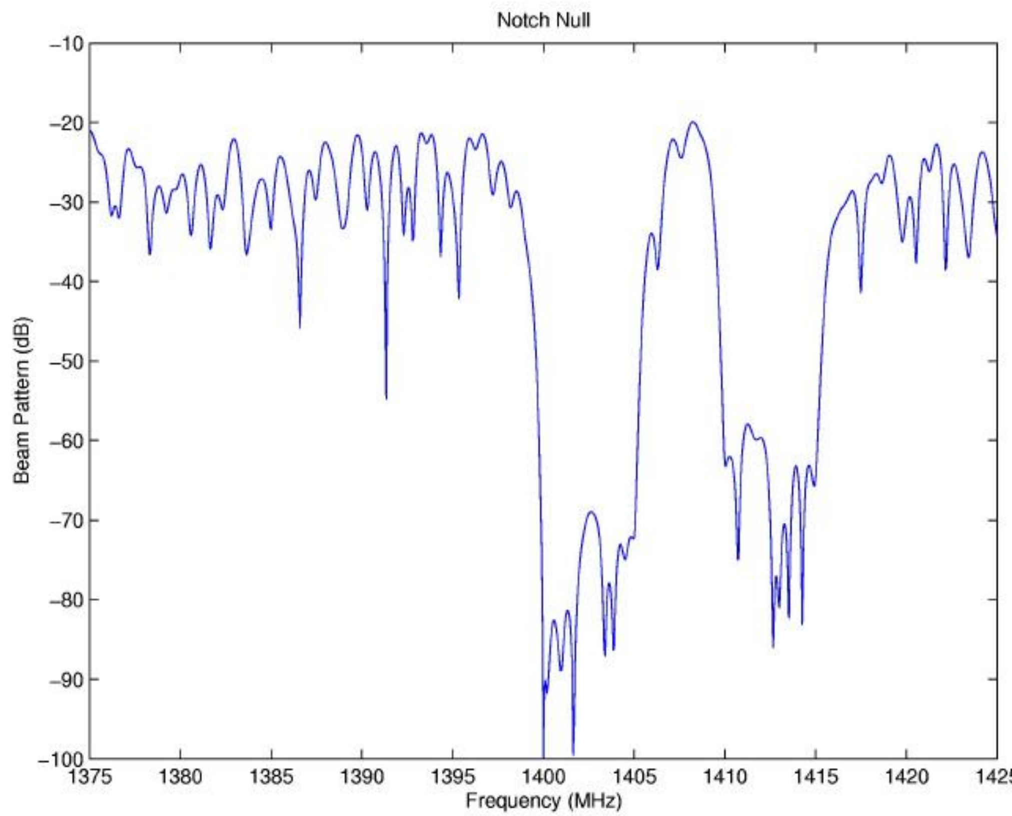
Multiple Nulls



Nulls in Frequency Space

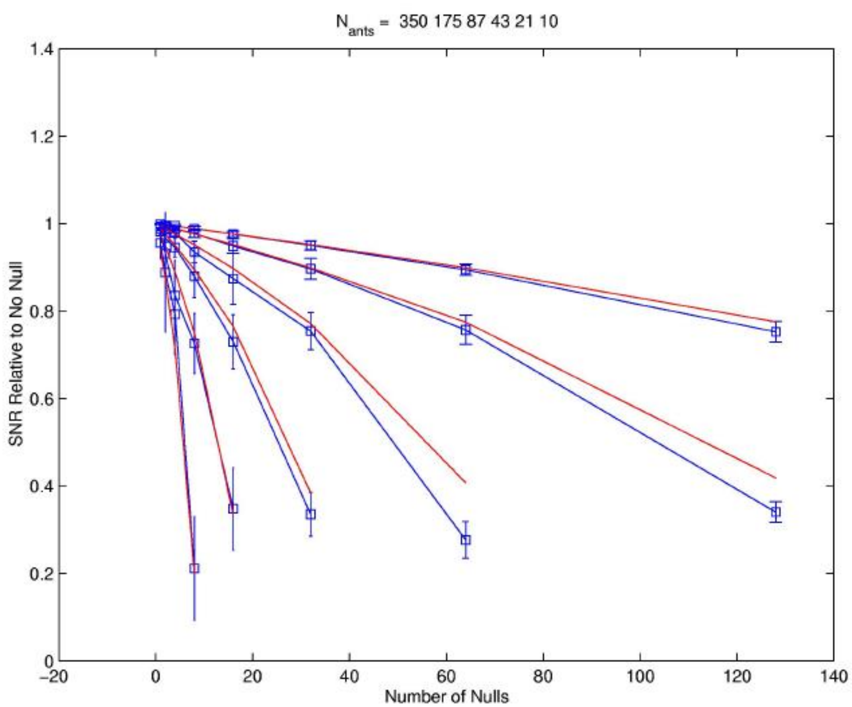


100 kHz



10 MHz

The Wages of Nulling



- Requires large-N to be effective
- Loss in SNR with number of nulls
- Must be able to update complex gains at ~100 Hz
- Matrix inversion is computationally expensive

Postcorrelation Analysis

- Examine output of correlator/visibility matrix
- ~100 element PC cluster
- Data rate:
  - 350x349/2
  - 4 Stokes
  - 1024 Channels
  - 32 bit
  - complex
  - 100 Hz sampling

→ 1.600 Tbits/sec: too much!

How to Use the Tools

- Blanking
  - Radar, Aircraft, intermittent signals
- Adaptive Canceling
  - Reference antenna(s) on transmitter
- Interferometric Nulling
  - Predictable trajectories: satellites, fixed transmitters
- Postcorrelation Analysis
  - Broadly adaptable

Future Steps

- Algorithm development
- More modeling of environment
- Angle of arrival methods

- Implementation!