GRCon 2019

GNU Radio Enhancements for Space-Based Research

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DELTA RISK
A CHERTOFF GROUP COMPANY

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Introduction

Mike Piscopo

- Delta Risk LLC – Director Cybersecurity Professional Services
- Worked with GNU Radio Since about 2013
- Authored a Number of Add-on Modules (gr-correctiq, lfast, grnet, clenabled,…)

- BS Aerospace Engineering – Virginia Tech
- Aerospace Contractor – Real-time distributed centrifuge team
- Developer – embedded C++ and later application architect
- Network Field Engineer and IT architect

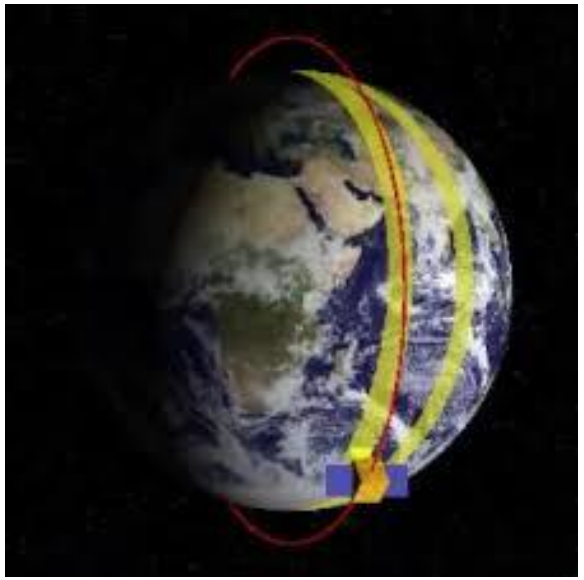
- Amateur Radio
- Licensed Remote Pilot (Drones)

What We'll Cover

- Enhancing the Basics Between Good Antennas and Flowgraph Logic
- Polar Orbiters - Multiple Remote Receivers and Enhanced Doppler Correction
- New Open Source Tools for Pointing Antennas at Celestial Targets (Moon, Mars, and RA)
- Work from the Berkeley/SETI/GNU Radio Hackathon at the Allen Telescope Array

Polar Orbiting Scenario

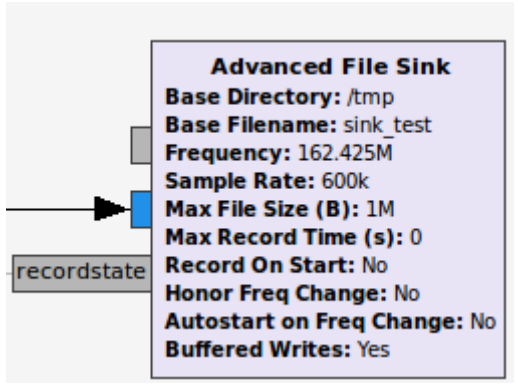
- [Re]Started with ISS SSTV Event
- Passes occurred at different relative angles
- Sometimes the house is in the way
- Would be nice to go about my day and analyze the data when I had time
- Record IQ streams for troubleshooting, but only when there was a signal

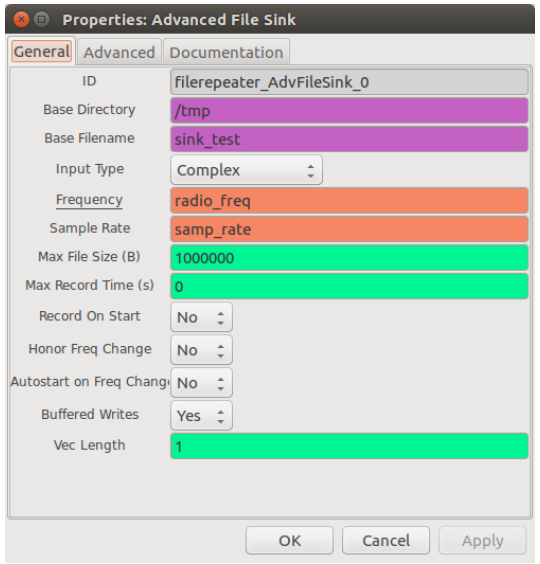


- Problem 1: Intelligent recording
- Problem 2: Split signal coverage

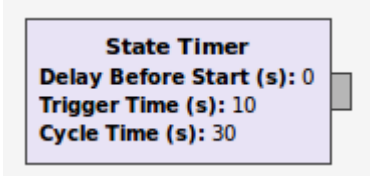
Smarter Storage – New gr-filerepeater Blocks

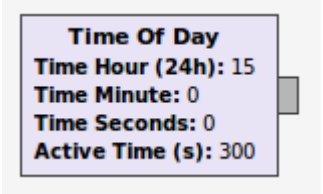
Smarter Storage





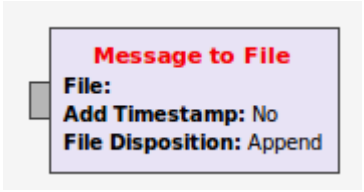
Time-of-Day / Cycle Control





More Complex Decision Logic

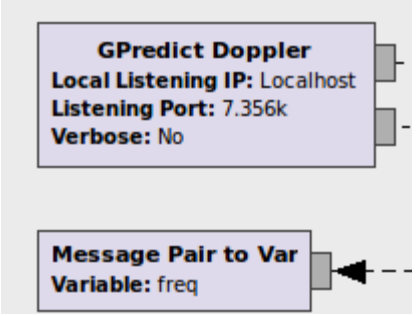
Debugging:
When did state messages occur?



Bringing Doppler and Az/El into GNURadio

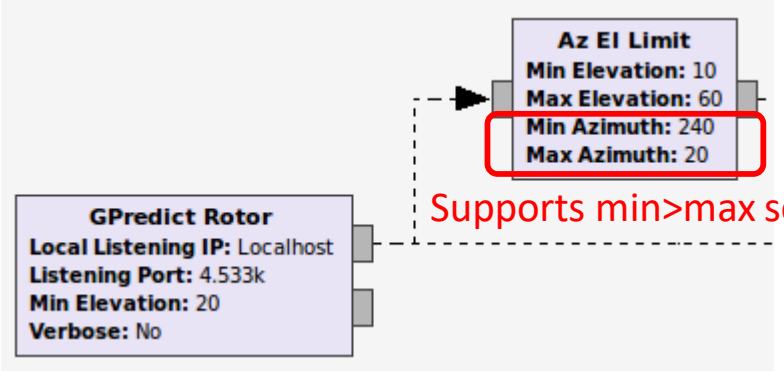
Refactored GPredict Doppler

Doppler Blocks



Setting a Variable From a Message

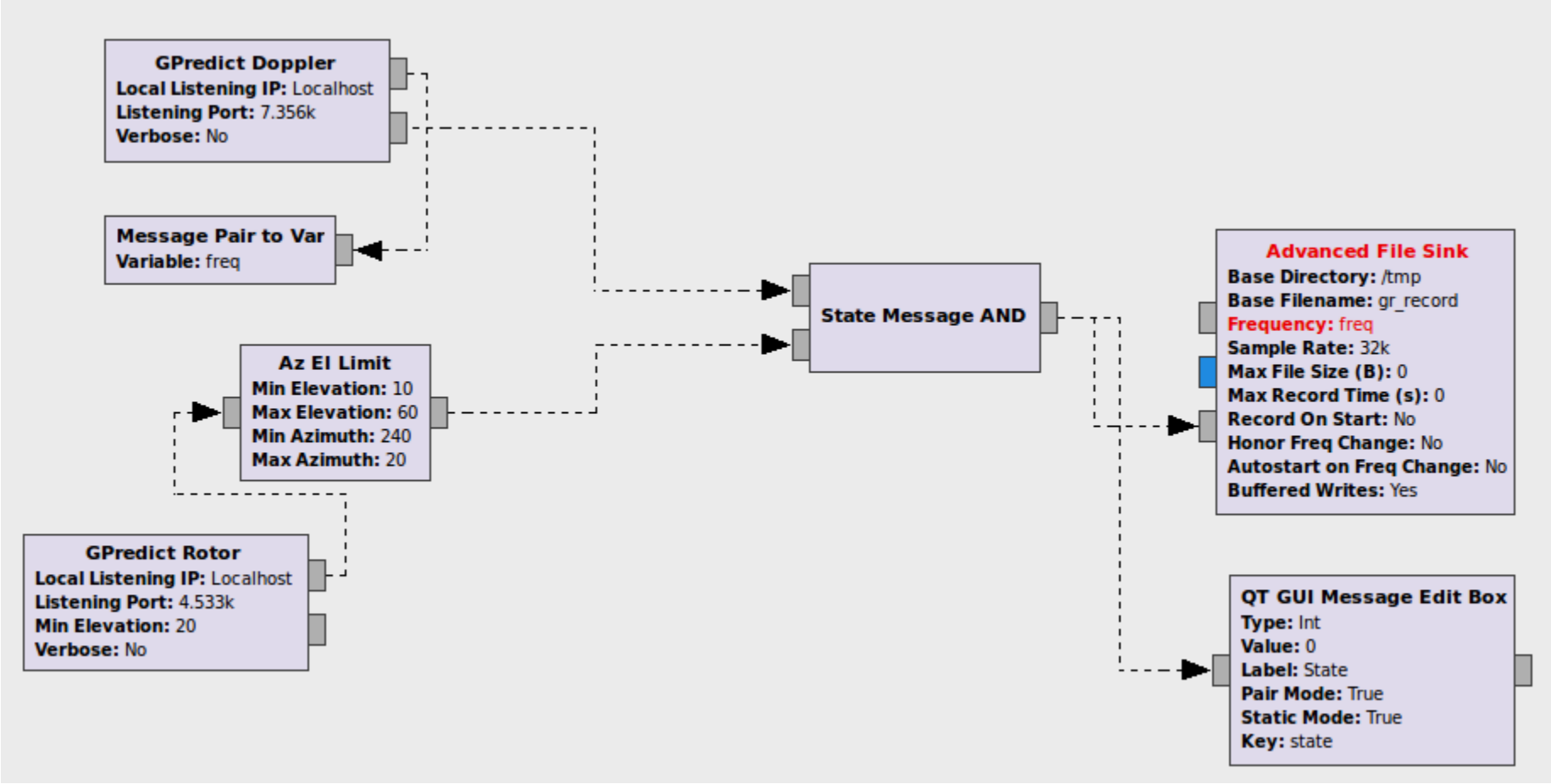
Az/El Blocks



NOTES

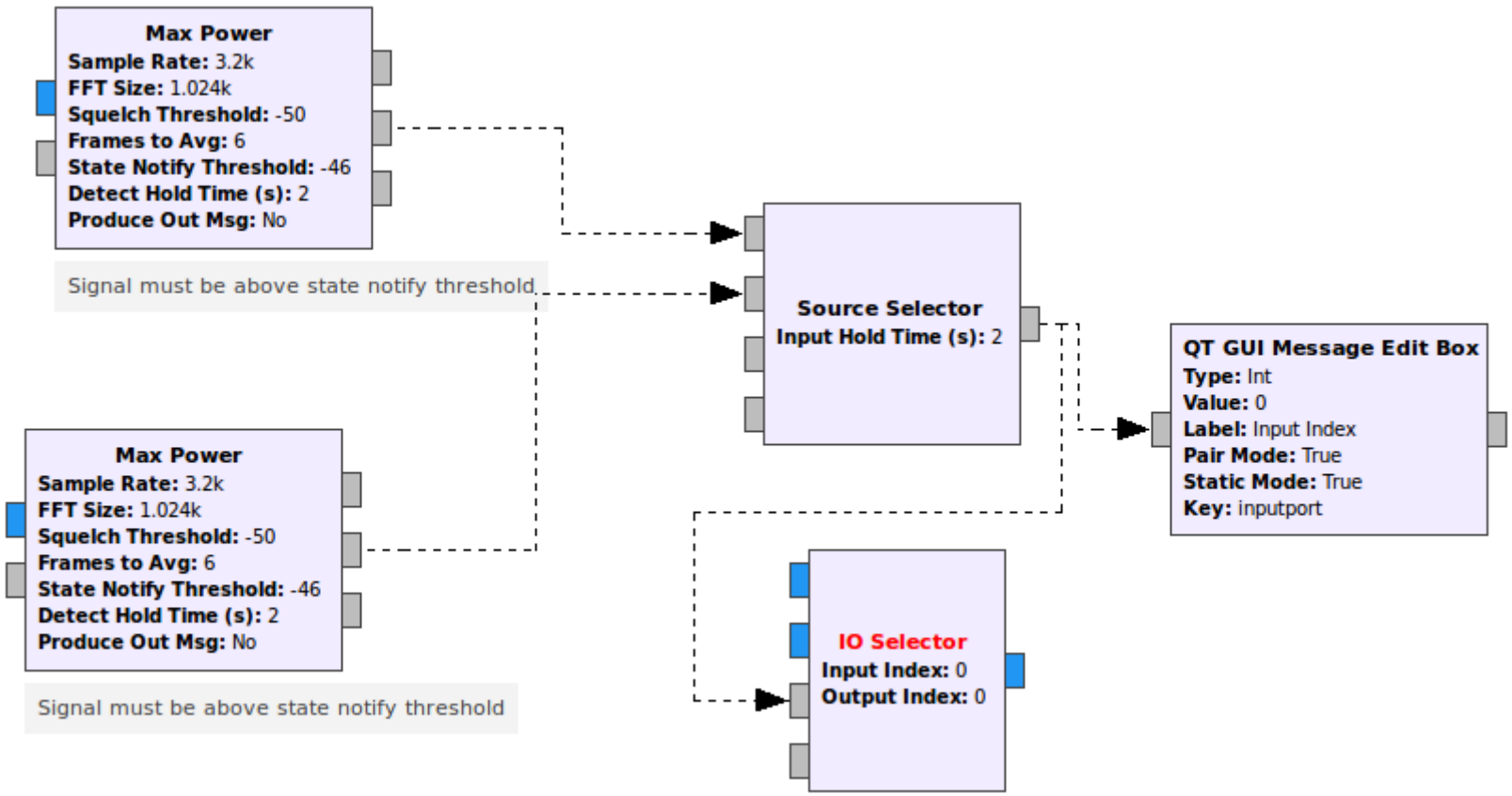
- ✓ All blocks output state:1/0 pair
- ✓ Gpredict sends AOS/LOS at horizon
- ✓ NOTE: If Gpredict connects in the middle of a pass, no AOS is sent
- ✓ File sink does have a flag to set start recording state on/off

GPredictDoppler – Complex Recording Rule



- Gpredict-Doppler Velocity-based Doppler
- Gr-mesa - Auto-Doppler Correct Block

Split Coverage Problem: Auto-Select The Best Signal



Relevant gr-mesa Blocks

- Source Selector
- Refactored IO Selector
- Max Power Block

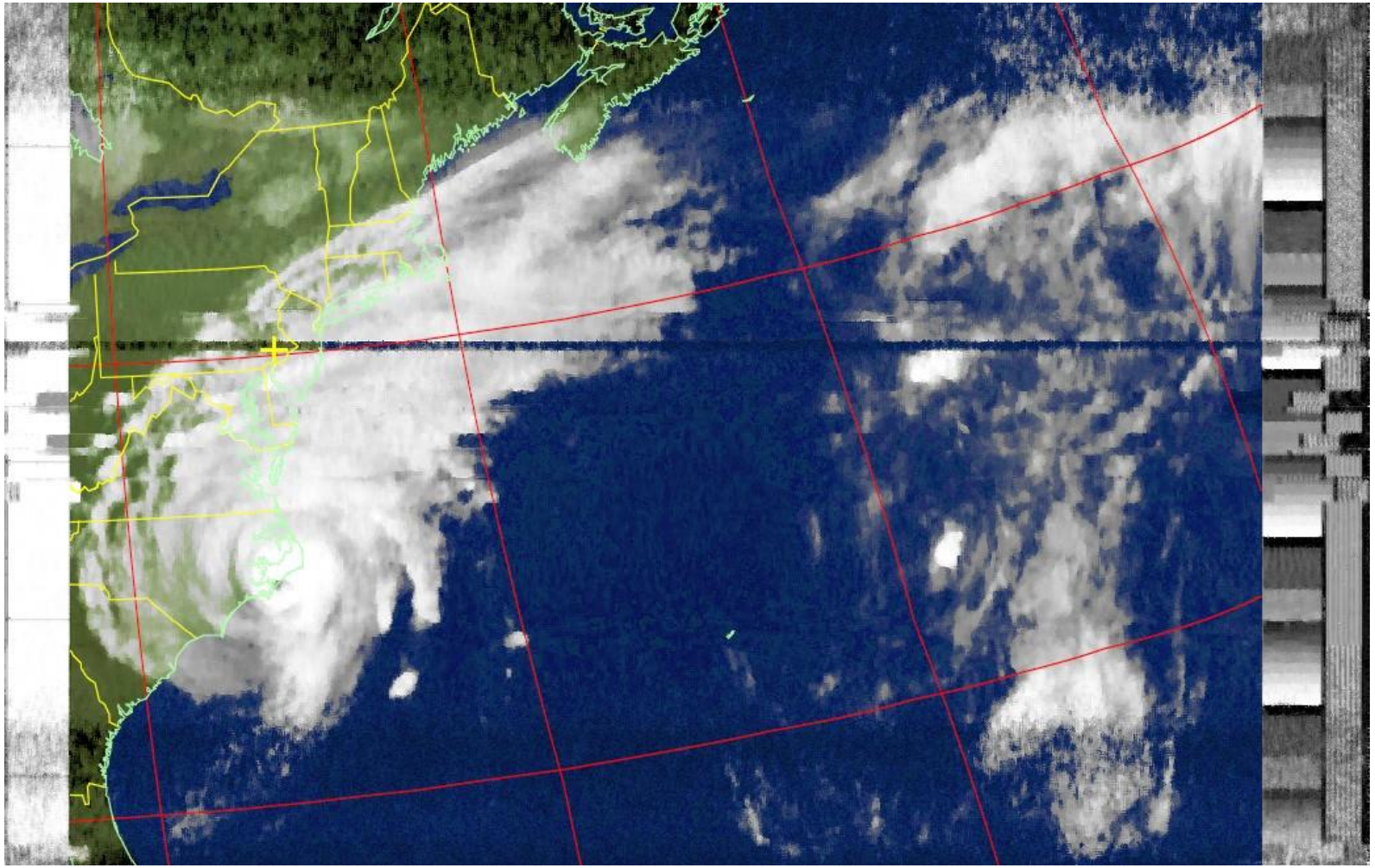
- Extensible: source selector looks for a “decisionvalue” dictionary entry in the message
- New IO Selector rewritten in C++ - Messages or variable updates to control ports
- Source Selector output is UI friendly (message pair “inputport” index)

Distributed Antennas – Watching the Transition (NOAA-19)

Complete flowgraphs are in gr-mesa/examples noaa.grc*

The Result – Processed With wxtoimg Running Under Wine

Hurricane Dorian 09/06/2019 – Low-Res APT



“Gray Thing on The Deck”

“House” →

“Black Can in Front”

Signals From Celestial Targets, Moons, or Their Orbiters

"NASA: Return To the moon by 2024!"

- Really far away
- Need to know where to look
- They're constantly moving
- Hand-tracking is tough (and distracting)
- GPredict only supports satellites with TLE's (Earth-based model), not celestial bodies

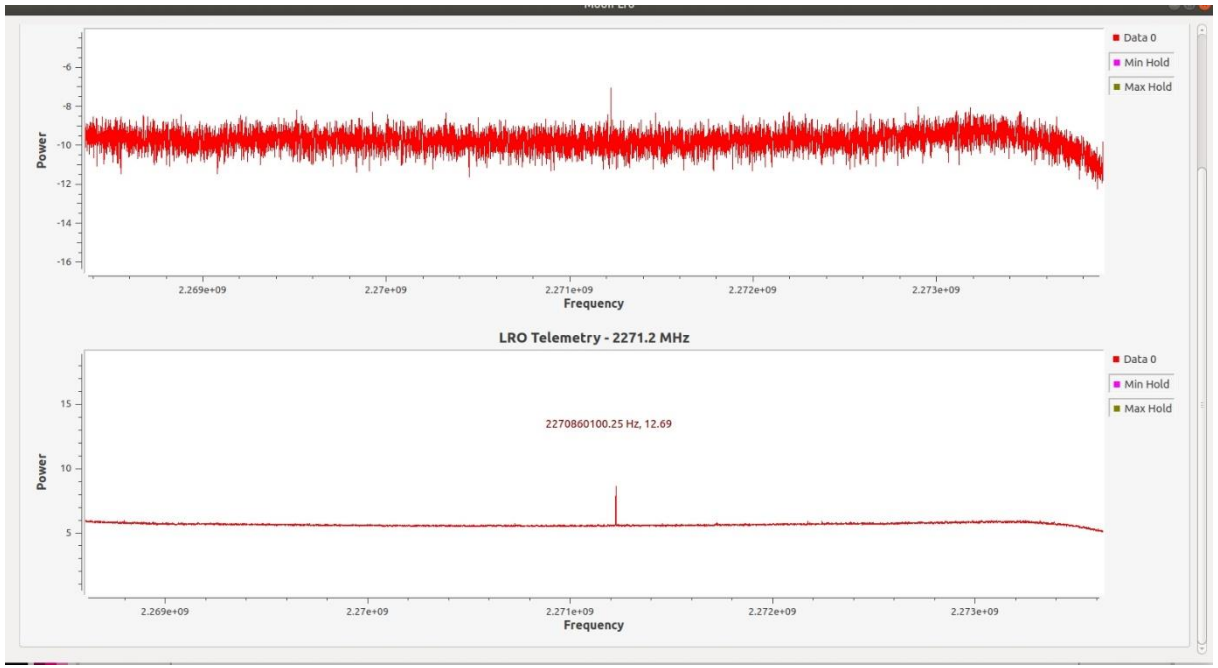
- Problem 1: Pointing at the Moon, Mars,…
- Problem 2: Pointing based on RA / Dec – Radio Astronomy

Pointing at Solar System Targets - SkyTrack

- Solution: **skytrack.py** for Solar System Targets
  - Python-based - uses the new skyfield module
  - Can interface via hamlib/rotctl to rotators
  - "Looks" to GNU Radio and rotctld just like GPredict
  - GitHub: *https://github.com/ghostop14/skytrack.git*

Quick Command:

../skytrack.py --body=moon --lat=<lat> --long=<long> --rotor=127.0.0.1:4533 --azoffset=-12.0 --delay=120

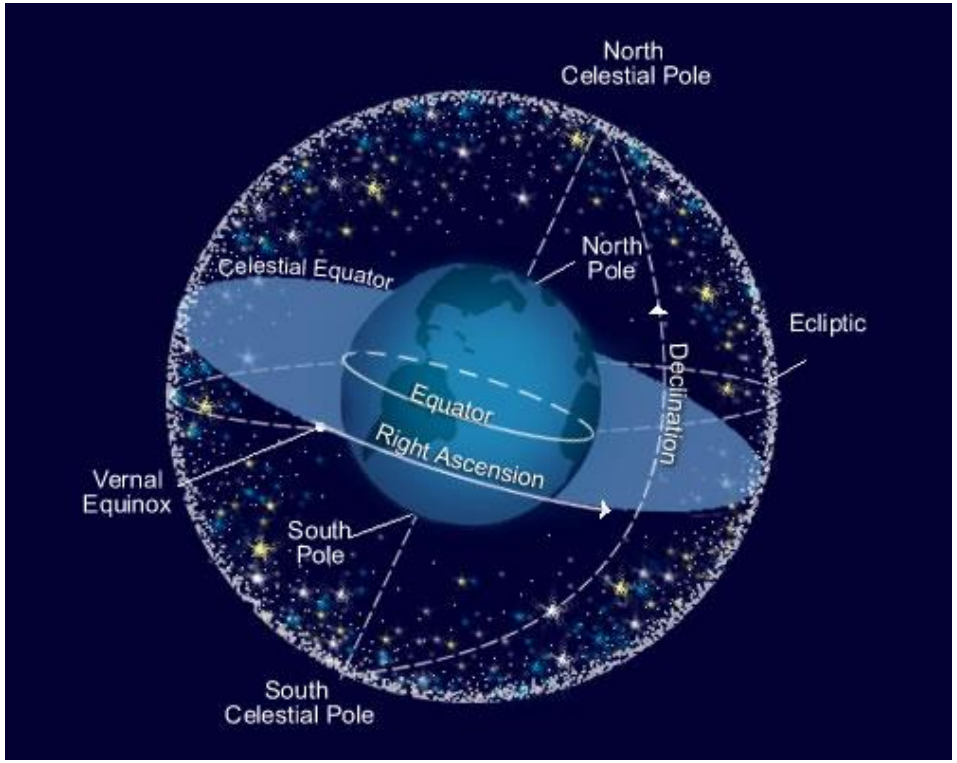


Offset-tuned LRO telemetry integration with too small an antenna (0.9m)

Pointing at Celestial Targets – By RA / Dec

- RA / Dec Celestial Coordinates
- Targets so far they're relatively fixed
- Trivia: RA=0: Point where sun appears to cross the celestial equator from S->N "Vernal Equinox"
- Earth Moves and Rotates Continuously
- Az / El is Location ***and*** Date/Time Dependent

- Solution: **radecl.py** (part of Skytrack repo)
  - Takes RA, Dec, Lat and Long as Inputs
  - Outputs local Az / El Based on [Current] Time for rotator control (hamlib/rotctld/GNU Radio compatible)



The Celestial Sphere. (Image Courtesy of the Lunar and Planetary Institute)

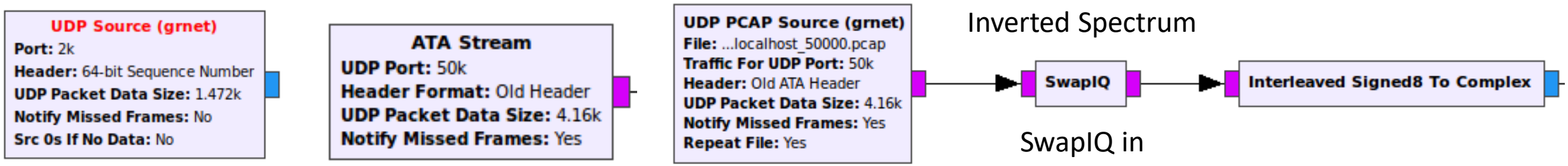
Allen Telescope Array - *The Ultimate Remote Feed!*

- Raw SDR Potential!
  - 42 6m Dishes, 2 feeds/dish (H/V)
  - Frequencies 500 MHz – 10 GHz (log periodic feed)
  - Cryo-cooled feed to reduce system noise
  - 104.8576 MCS/s (8-bit signed) per polarization
  - Beamformer - 1.677 / 3.354 Gbps, Jumbo UDP Frames
  - RFCBs – Downconverted constant IF (629.1456 MHz center)
- Several Groups focusing on:
  - Metadata – SigMF
  - **Array beamformer stream ingestion into GNURadio and Array Control**
  - Tapping new USRP hardware directly into antenna feeds
  - Detecting Voyager-2
  - Working on GNU Radio 3.8 and some OOT ports

Allen Telescope Array Beamformer Feed

- **New!** GRNet PCAP UDP Source for Playback (tcpdump –i eth0 –w pcap_src.pcap “udp”)
- **New!** Gr-correctiq has a SwapIQ block (more intuitive than multiply-conjugate for beginners)
- **New!** GR-ATA (Work in Progress) - ATA stream block based on GRNet UDP source, Examples
- **New!** GRNet csdr-style Type Converters (SC8 and SC16 <-> FC32, direct SC8 decimator)
- Completely refactored the GRNet UDP source block for speed and flexibility
- Tested at full speed (104.8576 MCS/s) with very few missed packets
- UDP Source Sink Optional Headers (64-bit sequence, ATA, CHDR)
- Defined Packet Size
- Optional Notifications on Missed Frames

From a PCAP of Beamformer Captured While On-site

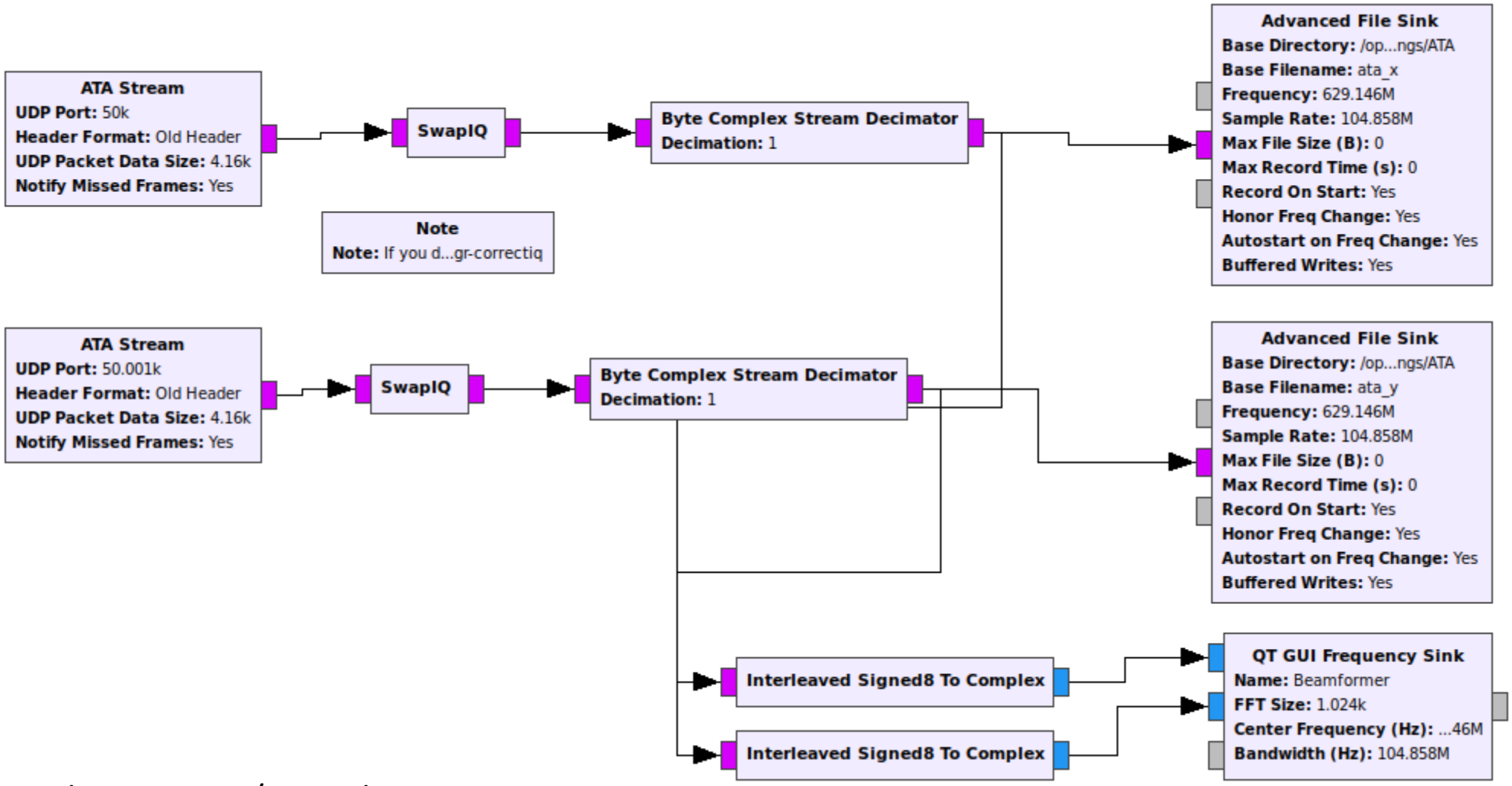


Inverted Spectrum

ATA Live (grnet UDP wrapper)

SwapIQ in
Gr-CorrectIQ

GR-ATA Example Record



* Flowgraph is in gr-ata/examples

Q & A

- Download code at https://github.com/ghostop14 or via pybombs
- GR 3.8 conversions already complete (master and maint-3.7 branches)
- GNU Radio Mailing List
- GNU Radio Slack Channel