



Cost effective, flexible ground architecture using software defined radio and GNU Radio

U.S. Naval Research Laboratory

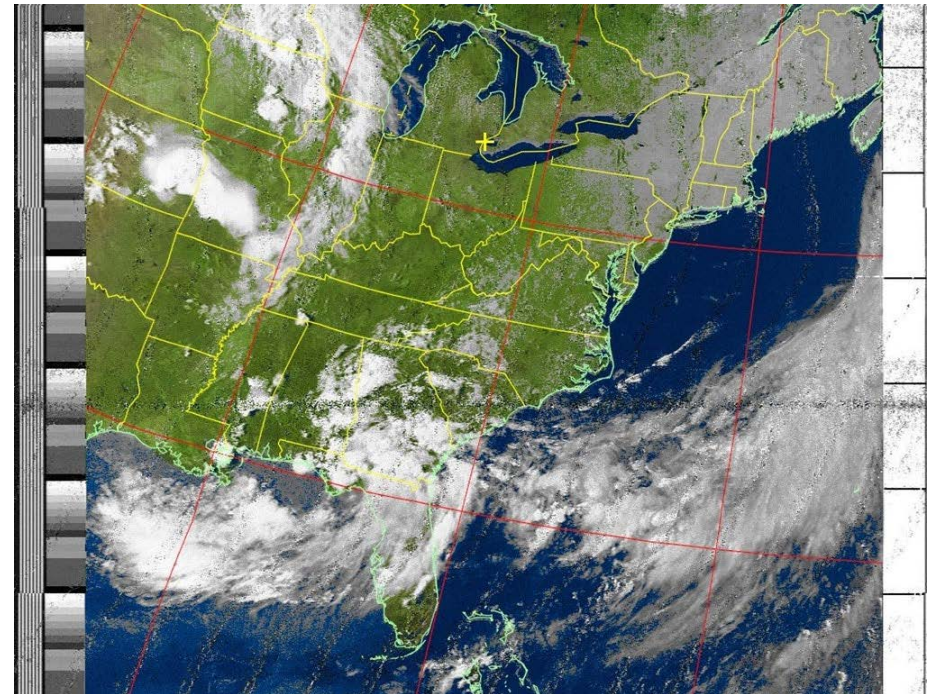
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NRL PR # 18-1231-2876

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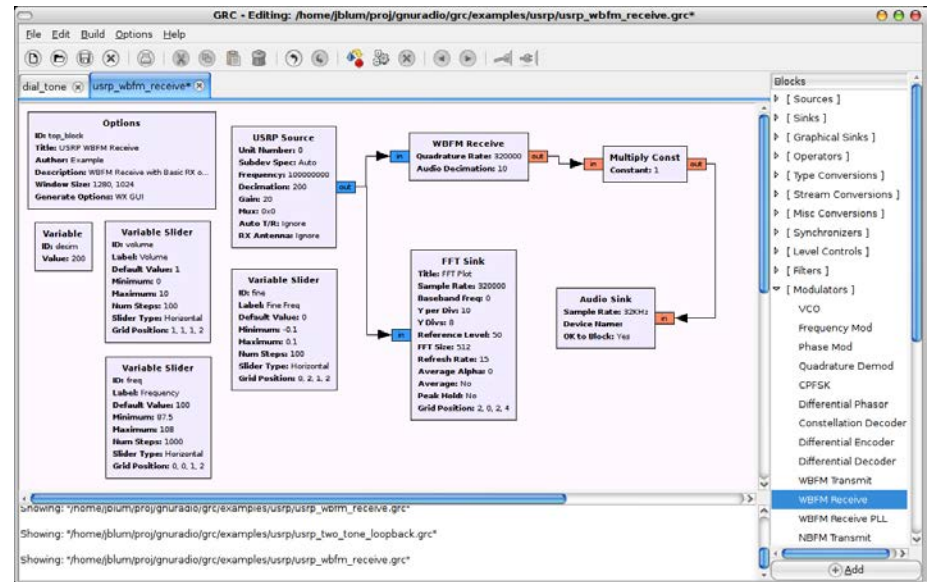
- Introduction
- Design
- Testing
- Results
- Conclusion

- Software defined radios have become widespread
- Ground Station providers offering SDR as option
 - KSAT Lite
 - NPS MC3
 - Do not have to provide any hardware just SDR software
- Questions
 - Can SDRs replace traditional ground equipment as primary ground radios?
 - Can it be made reliable?
 - What are the trade offs?



NOAA Satellite Image received using
low-cost SDR

- GNU Radio is free software library that provides the software tools to implement software defined radios
- Is the de-facto standard for implementing software defined radios
- Supported by various SDR vendors from hobbyist level to professional
- GNU Radio Companion – GUI based development tool. Similar to format to MATLAB Simulink



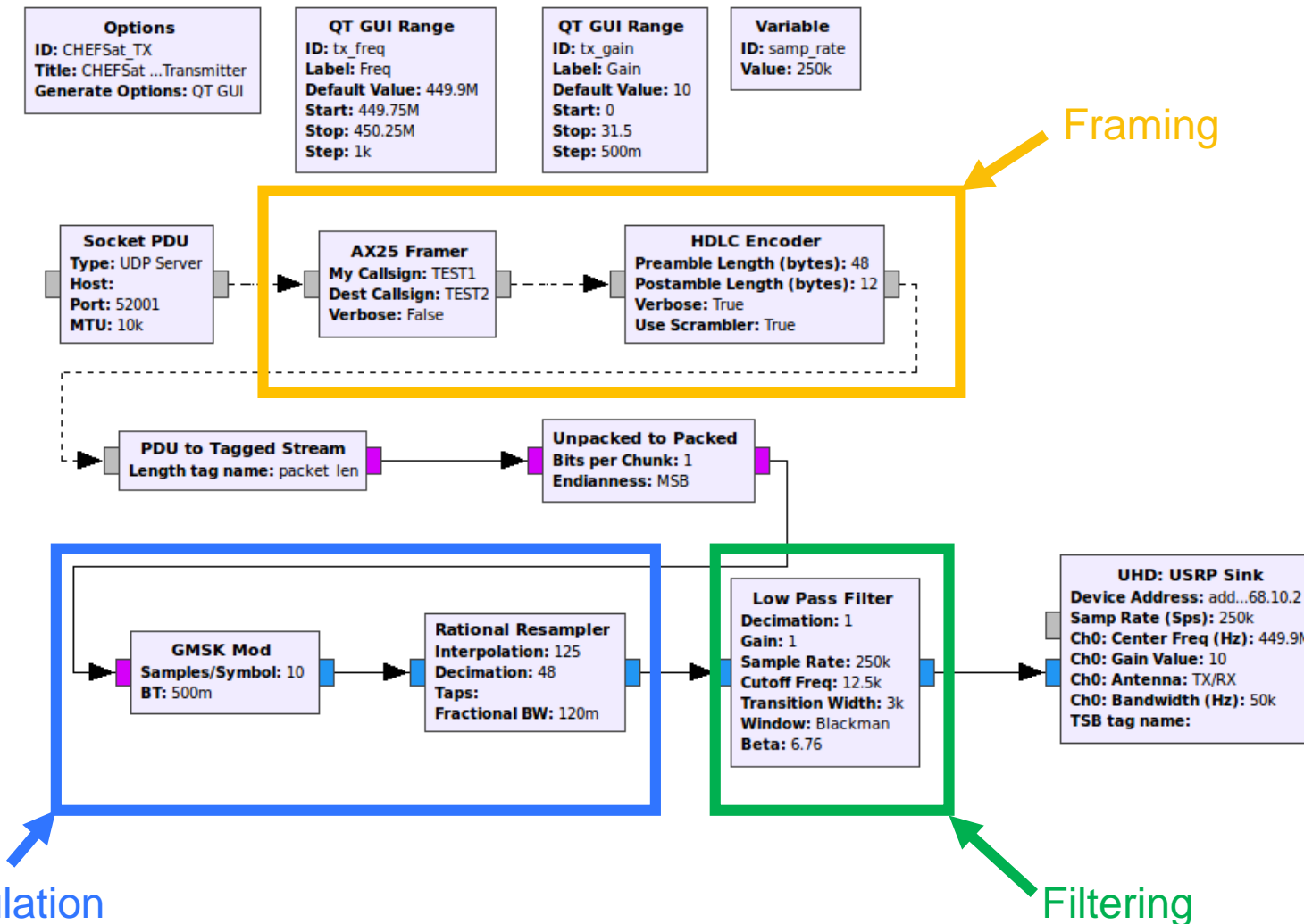
GNU Radio Companion

Design

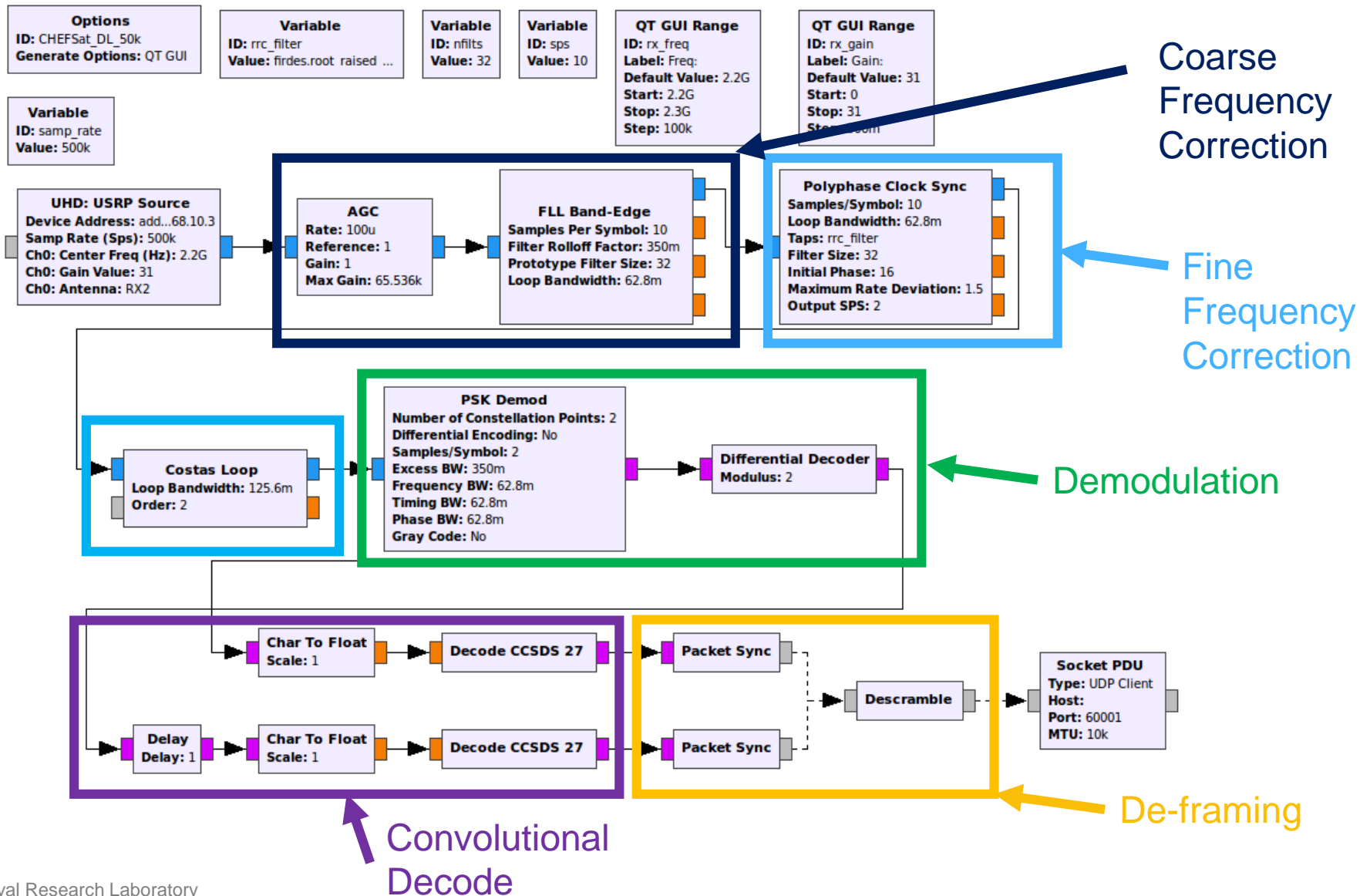
Design Constraints

- Keep design SDR hardware agnostic
- Minimize use of Out of Tree Modules
 - Out of Tree Module is a standardized method for implementing custom processing blocks in GNU Radio
- Keep interfaces simple
 - Control interface – XMLRPC
 - Gives access to program methods through simple HTTP interface
 - Used to set frequency, change gain, etc.
 - Data interface
 - Transmitter – UDP Server
 - Receiver – UDP Client
- Perform framing and de-framing within GNU Radio
- CHEFSat mission needs
 - 9.6 kbps, GMSK, AX.25 encoded uplink
 - 50-400 kbps, BPSK, CCSDS encoded downlink
 - option for convolutional encoding ($k=7$, $\text{rate}=1/2$)

Transmitter

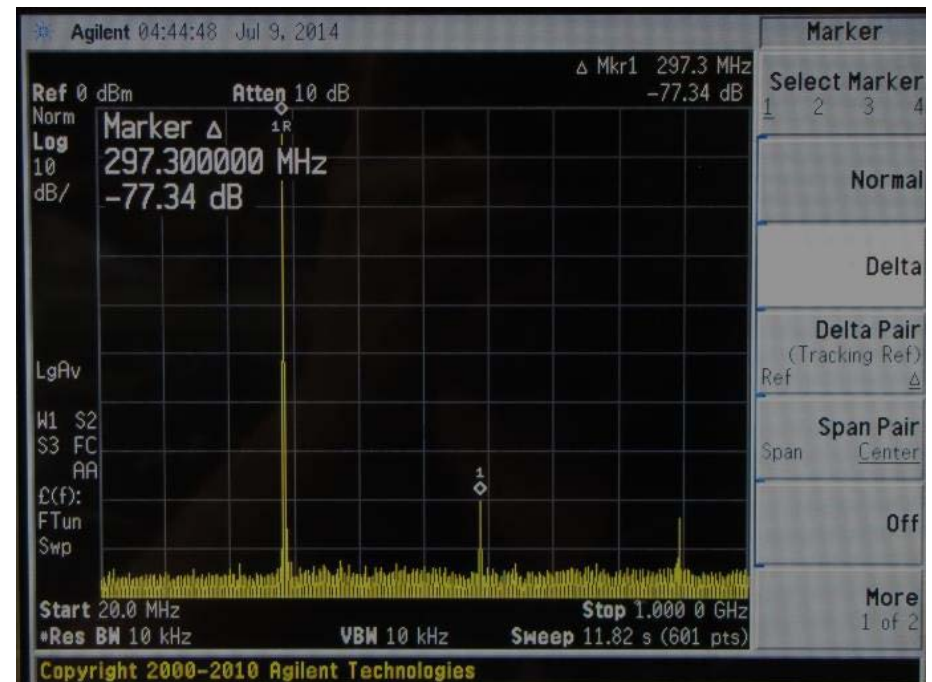


Receiver



Testing

- Verified occupied bandwidth
- Measured spurs and harmonics
 - Iterated on filter design to further reduce spurs and harmonics
- Tested against flight radio verified similar performance to commercially available transmitter



- Bit Error Rate Testing

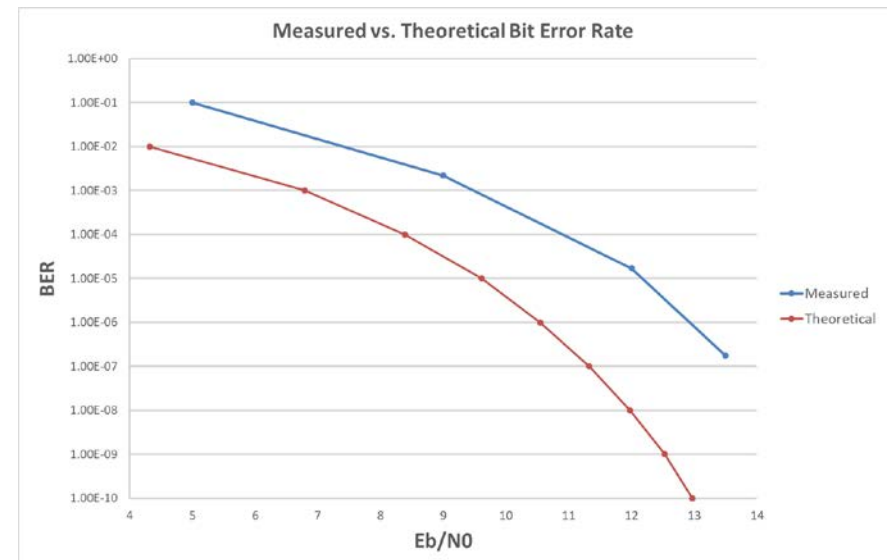
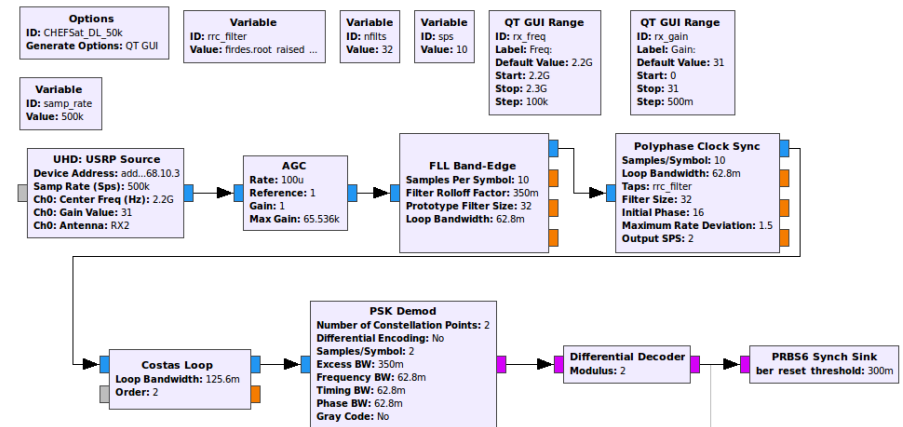
- Transmitted pseudo-random bit sequence
- Created GNU Radio block to synchronize to sequence and count bit errors
- Due to implementation BER testing only could test up to convolutional decode

- Packet Error Rate Testing

- Using measured BER data calculated estimated packet error rate
- Packet error rate allowed verification of convolutional decode and de-framing blocks

- Results

- BER testing showed ~2dB implementation loss



Results

- Using radio to make all contacts with CHEFSat since December 6th 2017
 - Over 1,500 contacts
- Only issue has been random segmentation fault error has occurred ~6 times
 - Due to infrequency and lack of error messages have not been able to determine root cause
- Able to rapidly develop and test designs which allowed true end to end RF testing earlier in I&T process
- Performance similar to traditional ground radios

- Able to use GNU Radio to rapidly develop ground solution
- Possible to use SDR as primary ground radio
- Hardware costs much lower than traditional radios
- Trade offs
 - Time to develop and test SDR software non-trivial
 - GNU Radio documentation is lacking
 - GNU Radio is free open source software, developers are mainly volunteers
 - Bugs fixes not implemented rapidly
 - Compatibility between versions not guaranteed

Questions?