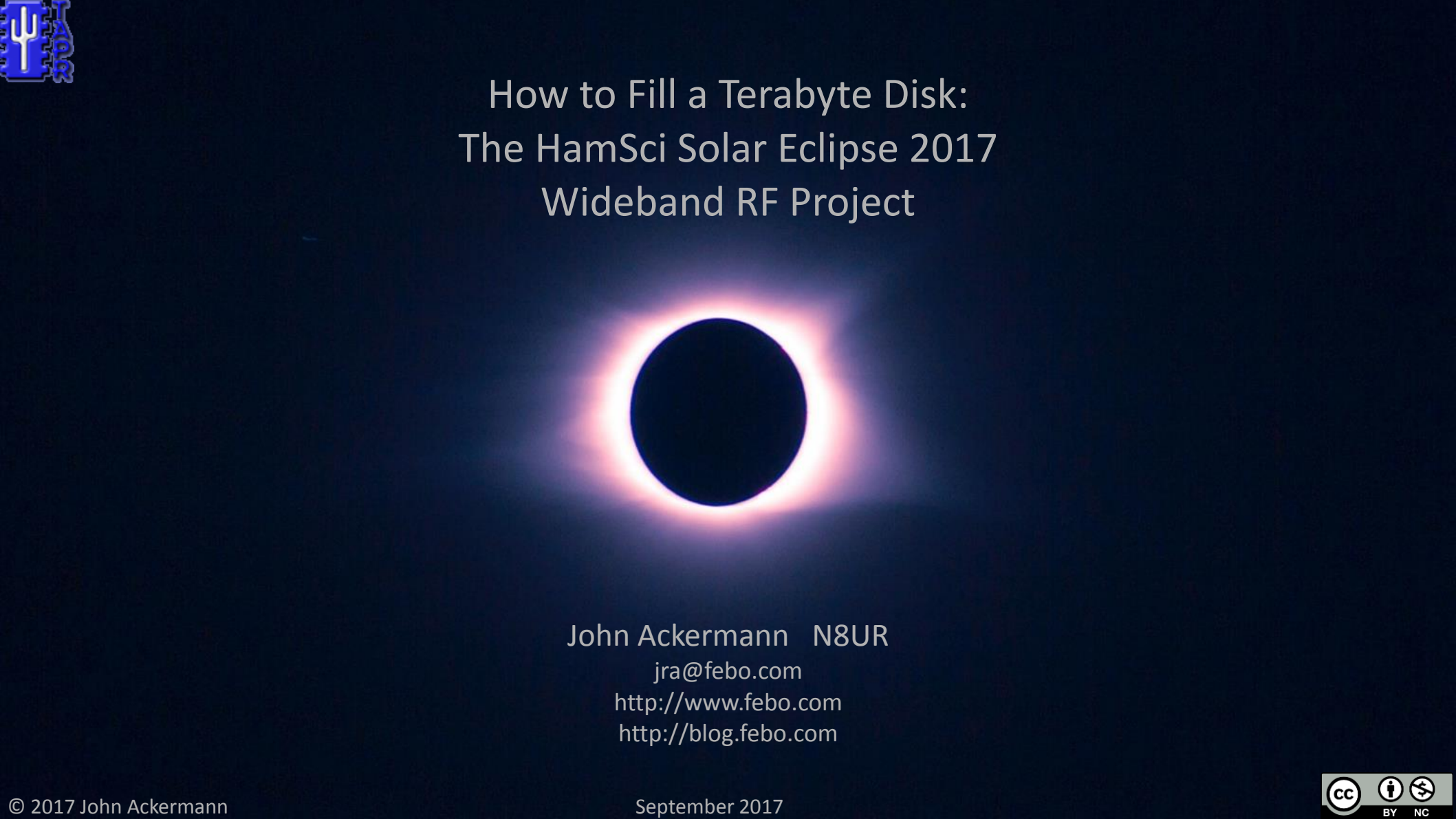
How to Fill a Terabyte Disk: The HamSci Solar Eclipse 2017 Wideband RF Project



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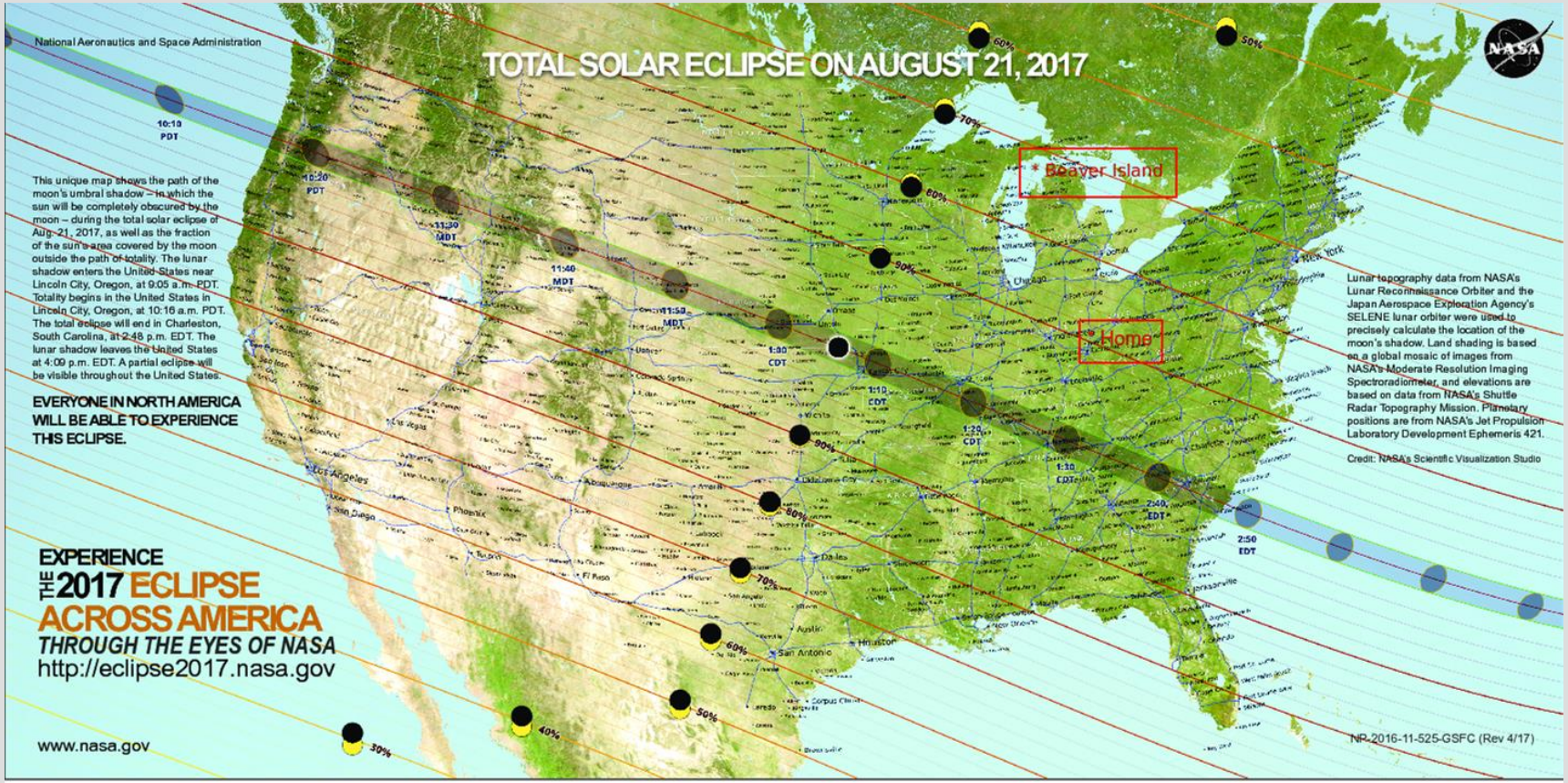
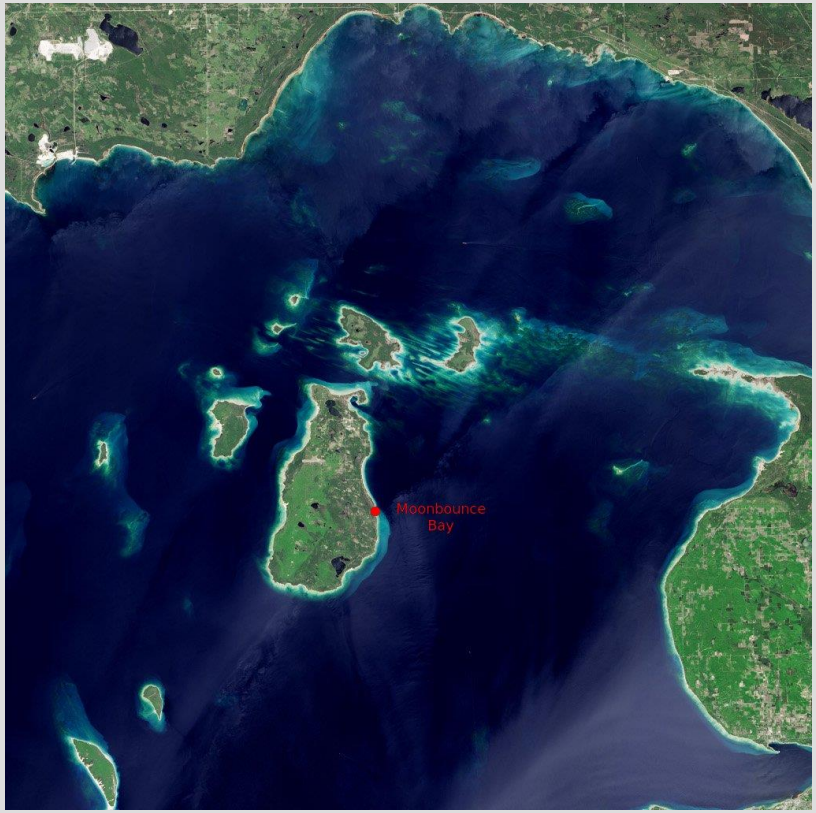
September 2017

Gee, let's go *the other way*!



Off the Beaten Path



Solar Eclipse Computer

U.S. Naval Observatory
Astronomical Applications Department

Solar Eclipse of 2017 Aug. 21

Sun in Partial Eclipse at this Location

Beaver Island, MI (Longitude W 85° 29' 50.0", Latitude N 45° 39' 18.0", Height 180m)

August 21, 2017 Universal Time (UT1) Delta T: 69.4s

Phenomenon	Day	Time (UT1)	Sun's Altitude (°)	Sun's Azimuth (°)	Position Angle (°)	Vertex Angle (°)
Eclipse Begins	21	16:58:20.3	54.8	159.9	277.8	292.1
Maximum Eclipse	21	18:19:31.1	55.4	195.0		
Eclipse Ends	21	19:38:14.3	48.5	224.5	126.4	96.4

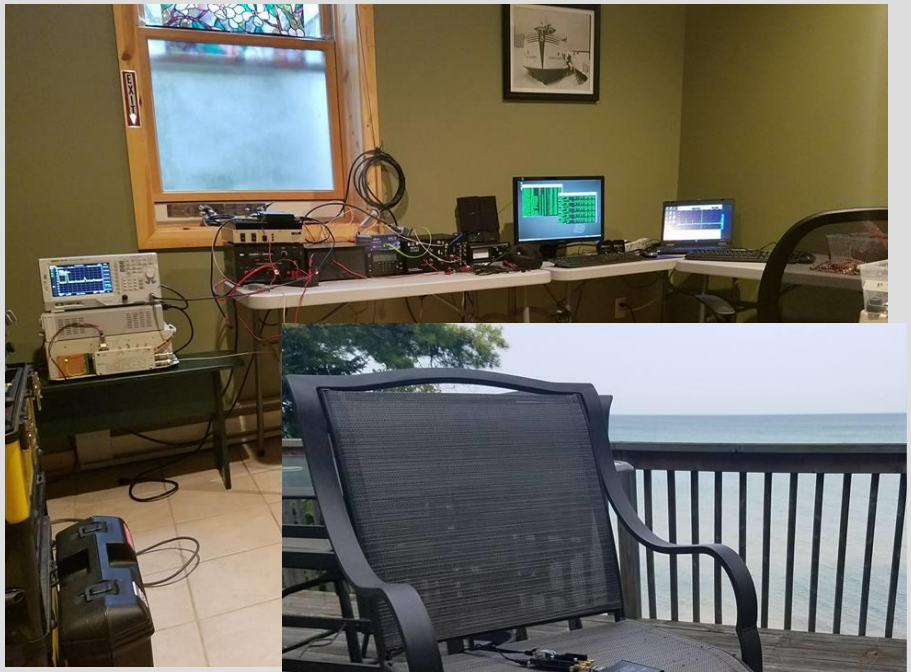
Duration	2h 39m 53.9s
Magnitude	0.775
Obscuration	72.3%

Back to form

Pros & Cons of This Location

- Low RF noise
  - 1 other occupied house within 500 feet
  - No high-voltage power lines
- No powerful signals nearby
  - Nearest intentional radiator <30 MHz is NDB ~5 miles away
  - Nearest AM broadcaster is about 25 miles away
  - Only 8 AM stations shown as “hearable” by Radio-Locator.com
- Few local ham signals for reference
- Many potential AM stations beneath even low noise
- Land rises to the west (at lake level to east)
- Northern location puts us far from, well, everything

Eclipse Research Station Beaver Island



- Hermes (80, 40, 30, 20M)
- Atlas/Mercury (Kiss Konsole)
- Red Pitaya (AM BCB; also captured 160M)
- 43 foot vertical antenna (HF)
- ~50 foot slanted wire (BCB)
- FTS-4100 Cesium standard*
- Two i7 and one i5 computers

* What, you thought I could do this without time-nuttery???

SDR Hardware Capabilities

- $20 RTL-SDR not the best choice for HF
  - 8 bit analog-to-digital converter limits dynamic range
  - But can do >2 MHz bandwidth
- Hermes/Mercury have 16 bit ADC
  - Superb dynamic range
  - Bandwidth up to 384 kHz per receiver
  - Hermes supports 4 receiver slices; Mercury 3
- Red Pitaya has dual 14 bit ADC for <$300
  - HPSDR emulation
  - Up to 2.5 MHz bandwidth with other driver
  - High-impedance antenna input is (fixable) challenge
  - External frequency reference, but at 125 MHz

SDR Software Capabilities

With appropriate PC software, we can capture I and Q data from these receivers, record to disk, and reconstruct later – for example, we can play back 40M as if we were listening live.

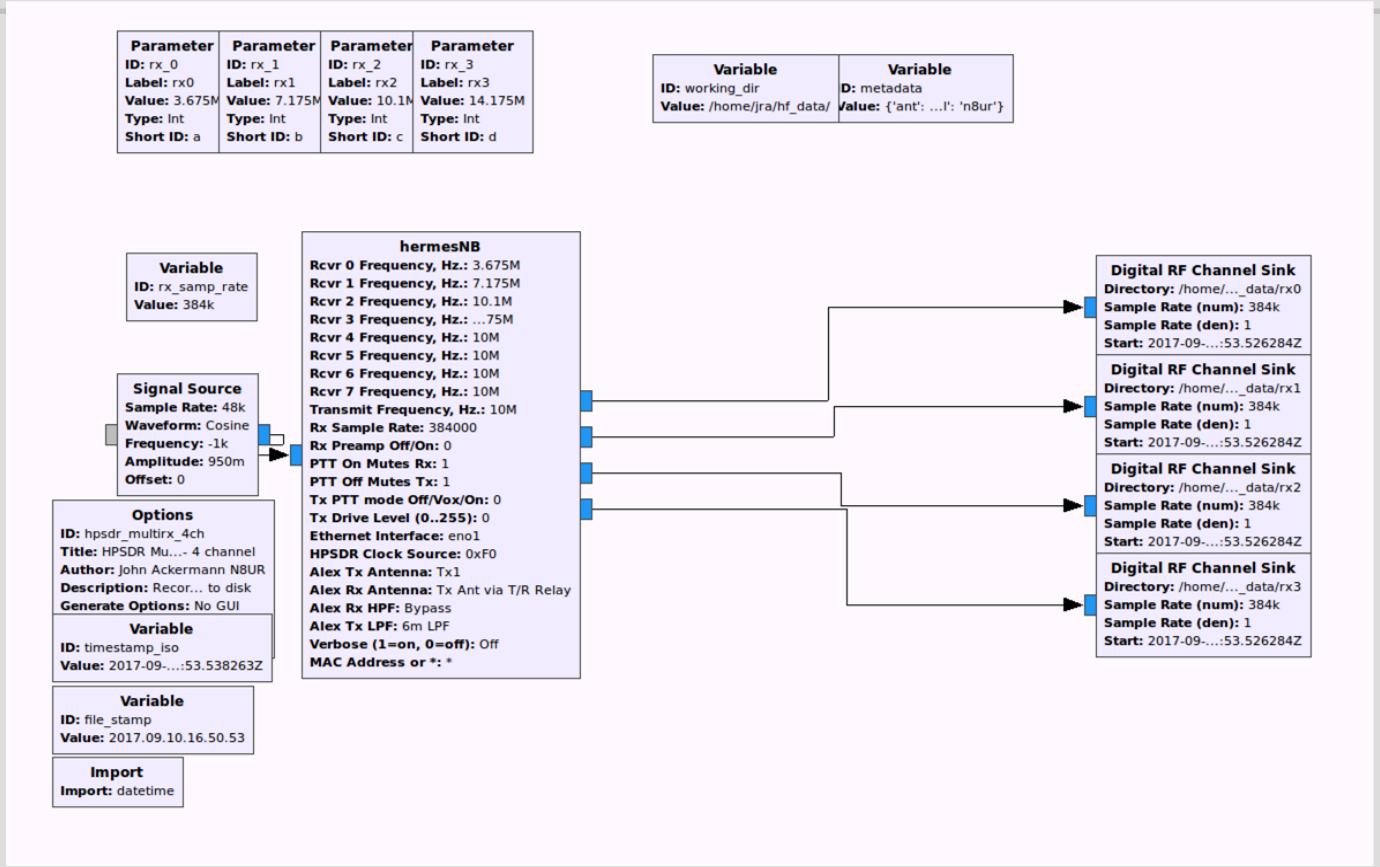
- HPSDR radios have Gnuradio driver, thanks to N5EG
- Red Pitaya emulates HPSDR with six 384 kHz receivers.
- Pitaya can also run a single receiver up to 2.5 MHz wide!

SDR Software Capabilities

- Gnuradio toolkit makes it easy to build wideband data-recording receivers.
  - HPSDR receivers supported by N5EG's HermesNB source block.
  - Pitaya wideband mode uses "OsmoSDR" source block.
  - Gnuradio supports HDF5 format data recording.

- Kiss Konsole (K9TRV) wideband record mode
  - Captures full spectrum up to ~56 MHz.
  - Shows wideband display like a spectrum analyzer.
  - Can't demodulate signals, though.
  - (N5EG's HermesWB block also does this in Gnuradio.)

Gnuradio Data Recorder



Data Captured

Recorded 8 hours from 1400 – 2200 UTC, 21 Aug. 2017

Band	Center Freq	Bandwidth	Dataset Size
80M	3.675 MHz	384 kHz	91.1 GB
40M	7.175 MHz	384 kHz	91.1 GB
30M	10.100 MHz	384 kHz	91.1 GB
20M	14.175 MHz	384 kHz	91.1 GB
AM BCB	1.400 MHz	2.5 MHz	555.4 GB
KK “Spec An”	~28 MHz	~56 MHz	35.8 GB

TOTAL: 956.8 GB

So, what did we see?

(1 minute video; eclipse max

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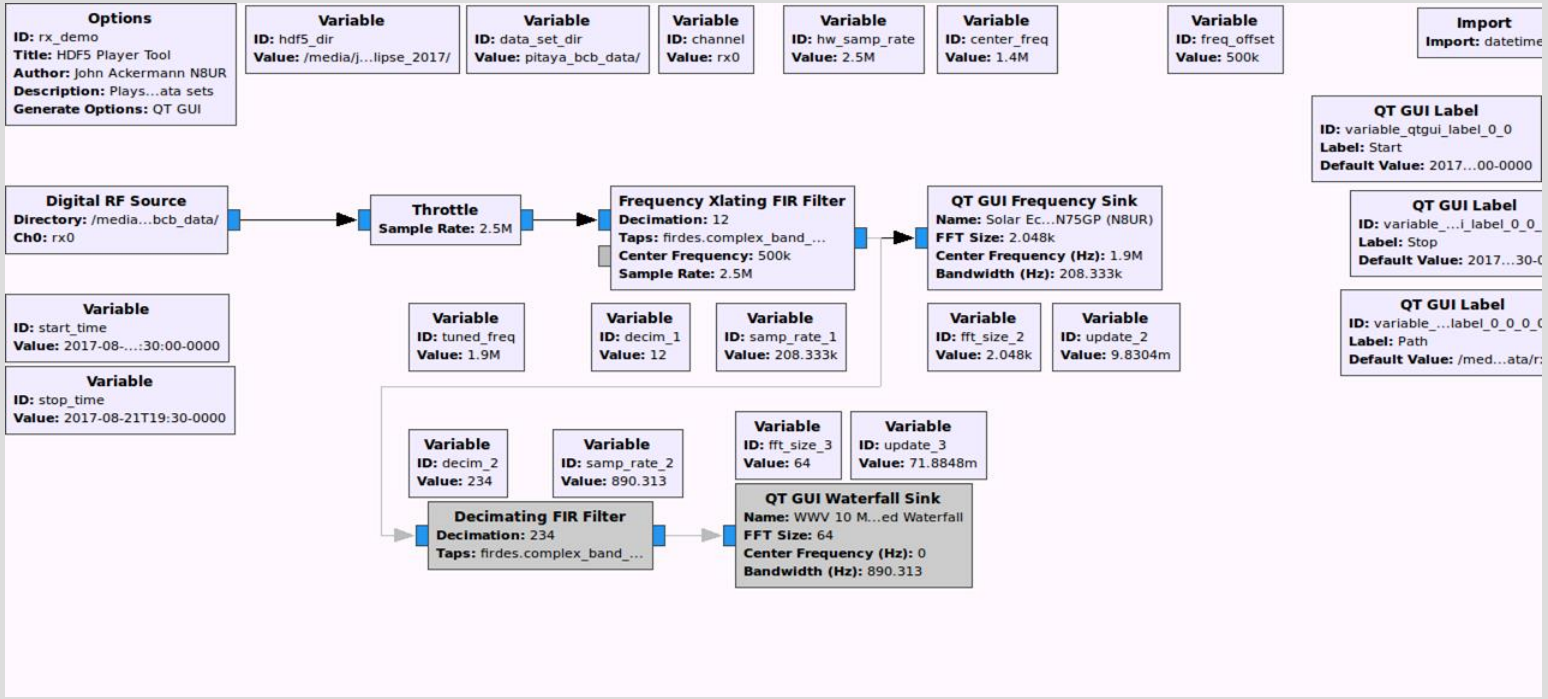
(1 minute video; eclipse max

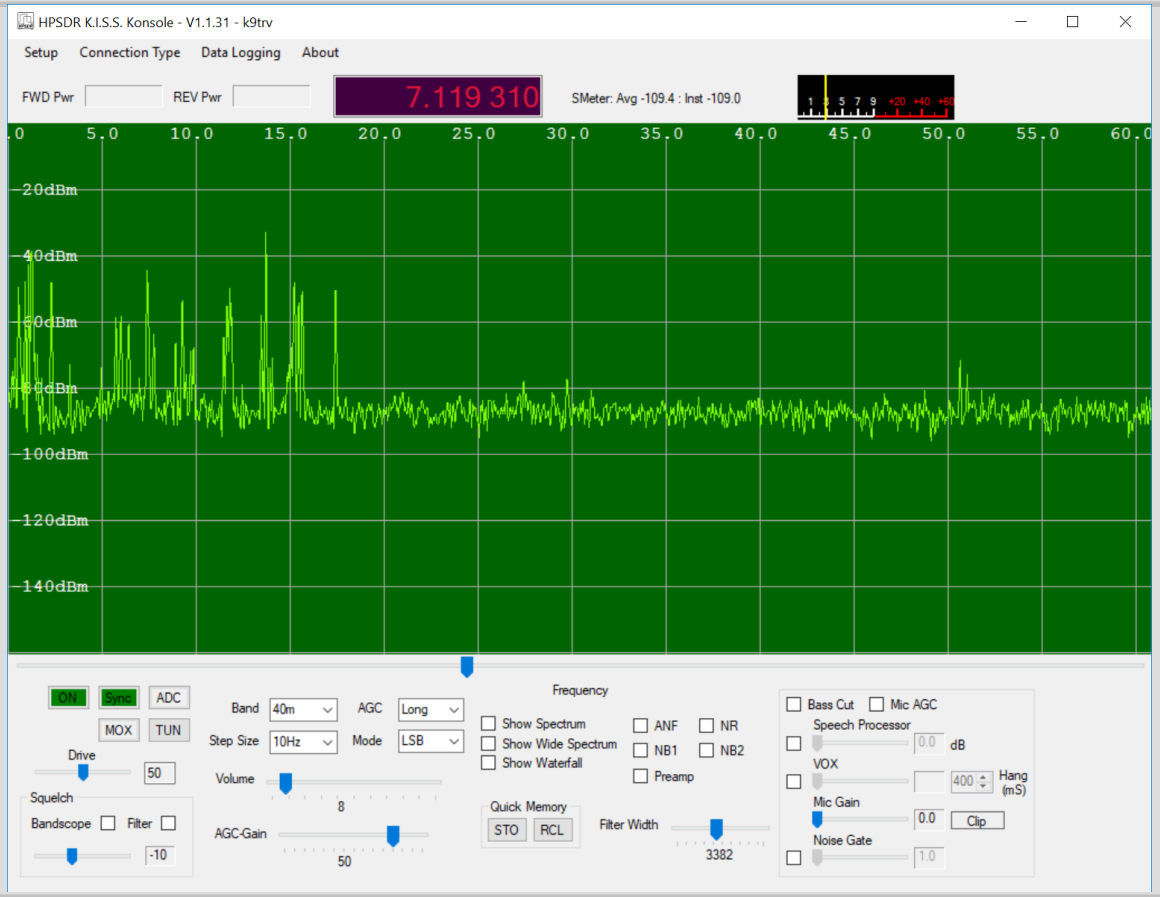
Data Display Challenges

- How to display narrowband signals across wide band over long time period?
- Waterfall has practical limitations
- Steps to make previous slide's "movie":
  - Simple Gnuradio script to run data through FFT at real-time rate
  - Shell script to take snapshot of FFT window every five seconds
  - ffmpeg to convert images to .mp4 at 30 fps
  - Result: 8 hours of data displayed in ~3:15 video
  - (This is a process for the patient person...)

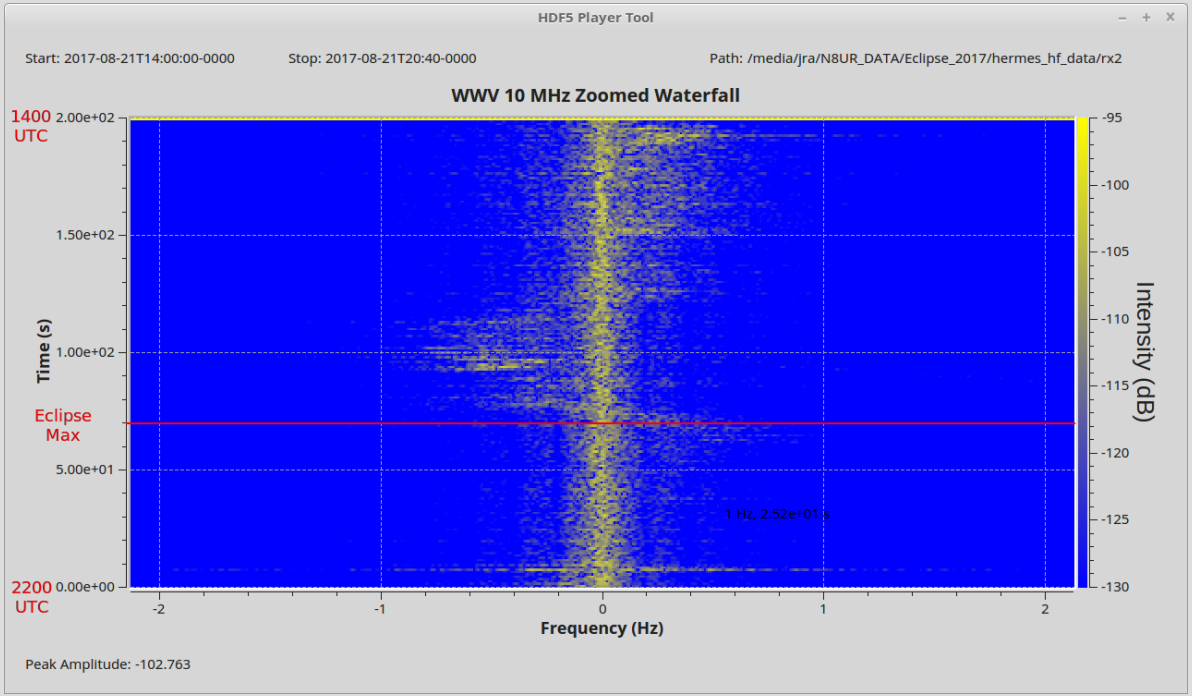
Gnuradio Playback Script



Wideband View with Kiss Konsole



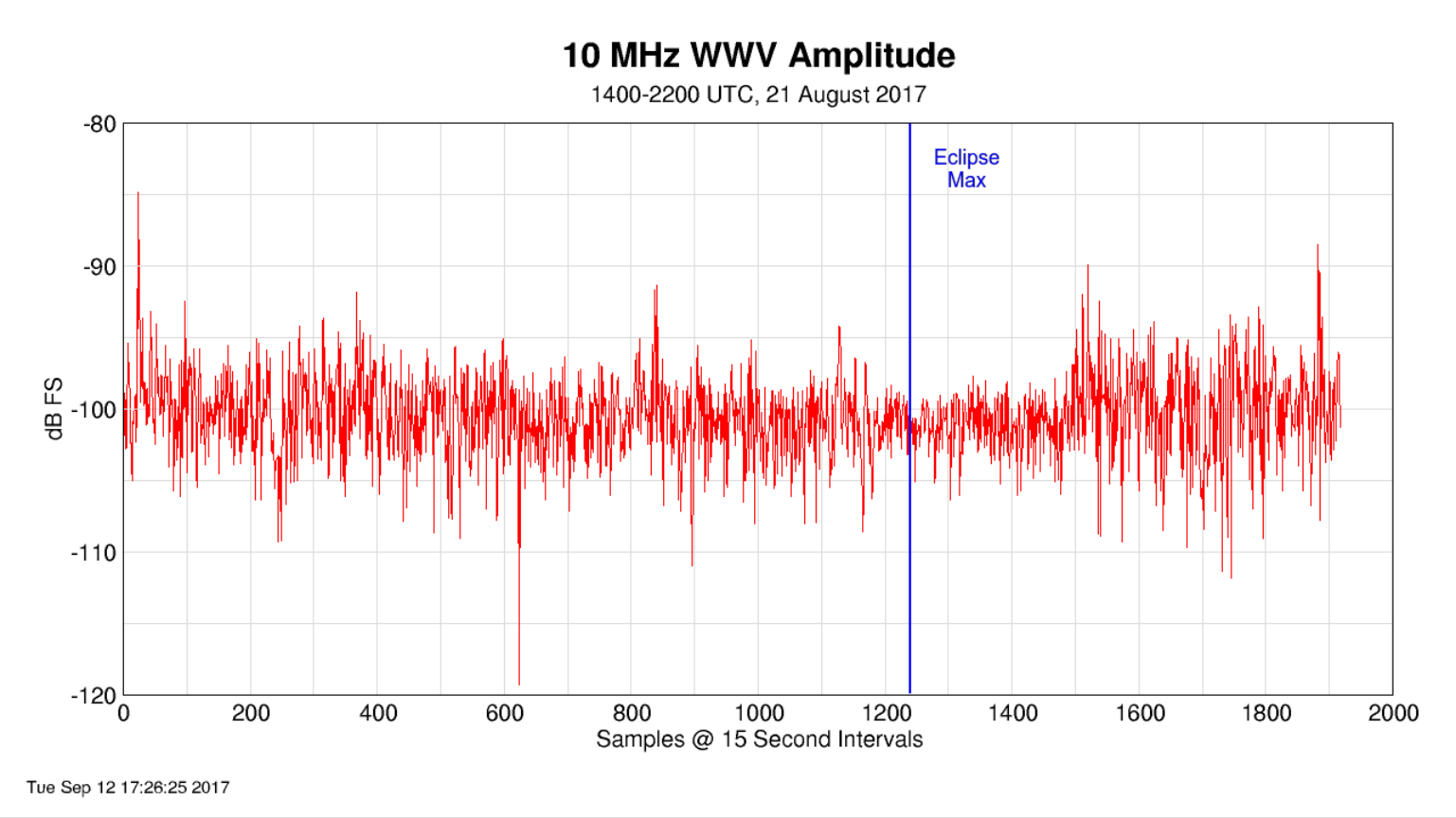
10 MHz WWV Doppler Shift?



Long-Duration Waterfall

- Gnuradio waterfall sink has limit on number of pixel rows and doesn’t scroll
- So goal was to set up decimation rate so that playback length, decimation, and FFT size are balanced to generate just enough rows of data to fill the display (about 1200).
- In this case original Metis data was decimated down to 4.xxx samples/second, and FFT was 1023.
- Data was trimmed to 6h40m (24k seconds)
- Result was one FFT “frame” about every 2 minutes, e.g. 1200 lines to fill the waterfall.

10 MHz WWV Amplitude vs. Time



Measuring Amplitude with Gnuradio

- Previous data generated with decimation and 256 bin FFT that resulted in one FFT every 15 seconds.
- GR blocks selected FFT bin with maximum value and wrote that to disk file.
- Result was dB data every 15 seconds over 8 hour period.
- Graph created with “Grace” plotting tool.

- (My Hermes has been calibrated and dBm = dBFS + 25.0; conversion not done for this graph.)

AM Broadcast Band

AM Broadcast Band

Conclusions

- SDR systems let us capture enormous amounts of propagation data
  - Good thing TB disks are ~$60!
- Analysis takes ***much*** longer than recording
  - Need to work on high-speed playback
  - Best tools for narrow signals/wide bandwidth/long time?
- Red Pitaya is a real contender for SDR
  - 14 bit @ 125 msps @ <$300 ain't bad!
  - RF input impedance is a problem, but easily fixed
  - External frequency reference is doable but more complex
- I can't wait for the next eclipse!!!


8.21.17