Space Weather Station Project

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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
  - Latest RTL-SDR.com v3 has TCXO, covers to <100 kHz
  - N1GP rtl_hpsdr on Raspberry Pi allows multiple dongles to appear on ethernet as a single HPSDR radio
- Hermes/Mercury/Anan have 14 or 16 bit ADC
  - Superb dynamic range
  - Multiple 384 kHz virtual receivers
  - Can’t do wider sample rates due to firmware architecture

SDR Hardware Capabilities

- Red Pitaya has dual 14 bit ADC for <$300
  - HPSDR emulation with 8 virtual receivers
  - 2.5 MHz bandwidth with native driver
  - High-impedance antenna input is (fixable) challenge
  - External frequency reference, but at 125 MHz
    - Internal reference pretty wobbly
  - Possible digital noise issue (being explored)

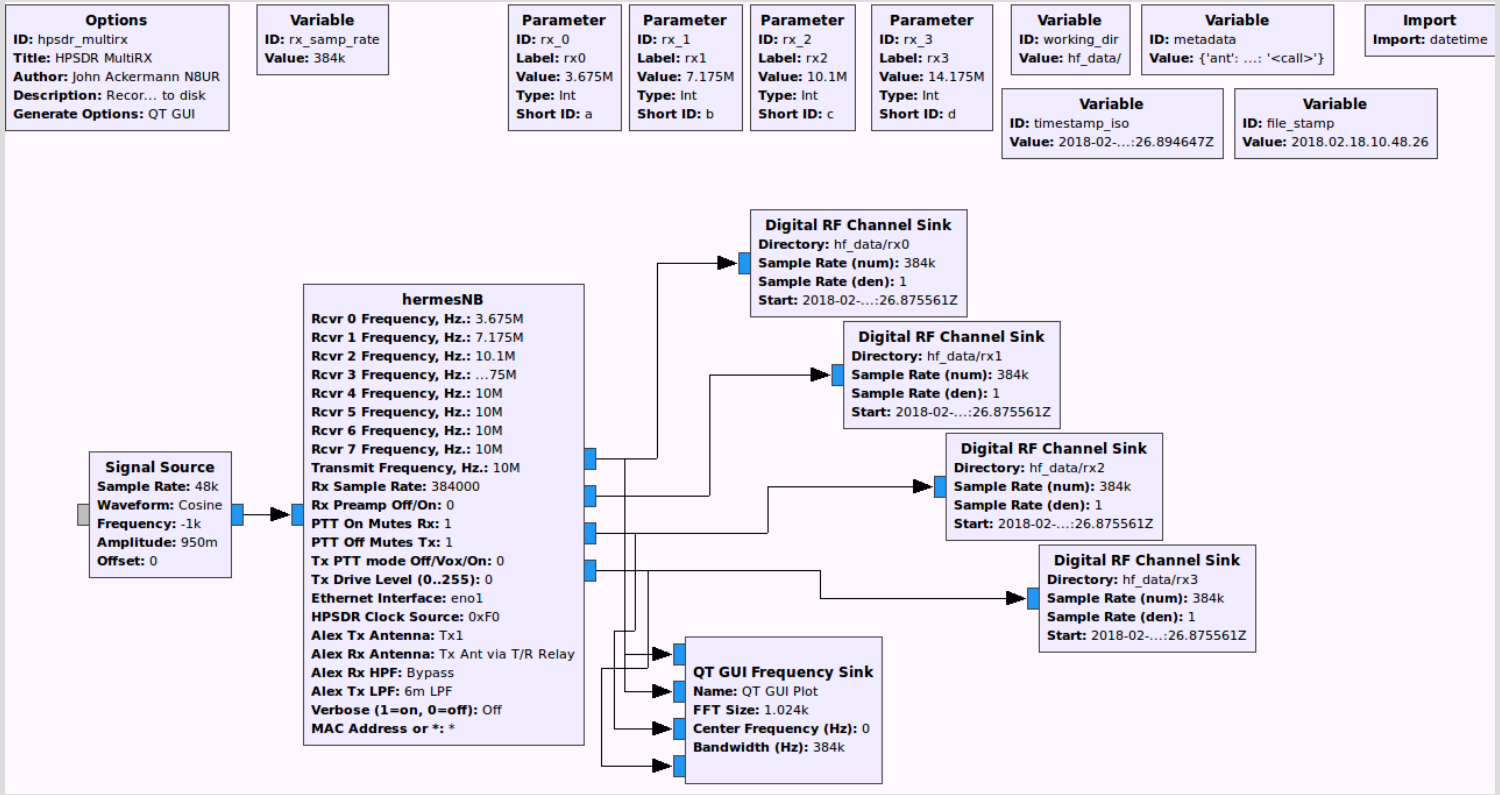
Wideband Data Recording

- The Eclipse experiment proved (to me, at least) the value of recording RF data rather than trying to analyze it in real time.
  - It's neat to take multiple passes through the band to look at different aspects.
  - Much less stress when you don't have to get it right the first time!
- Storage capacity now only a minor issue.
  - 4TB USB3 drive now ~$100
  - 384 kHz recording uses about 270 GB/day (96 kHz about 67.5)
  - Record continuously and replace oldest data with newest. Archive when something interesting happens.
  - (Data does **not** compress well)

Hardware and Software

- I’ve focused on Gnu Radio for capture and analysis
  - Open Source
  - Multi-platform (Linux, Mac, and now Windows)
  - Gnu Radio Companion allows WYSIWIG radio building
- Gnu Radio provides broad hardware support:
  - N5EG “HermesNB” driver for HPSDR compatible radios
    - Up to eight 384 kHz receiver streams, depending on radio
    - Red Pitaya emulates HPSDR
  - Red Pitaya wideband driver
    - Up to 2.5 MHz bandwidth
  - UHD driver for Ettus Research USRP
  - RTL-SDR driver for “dongles”
  - And others...

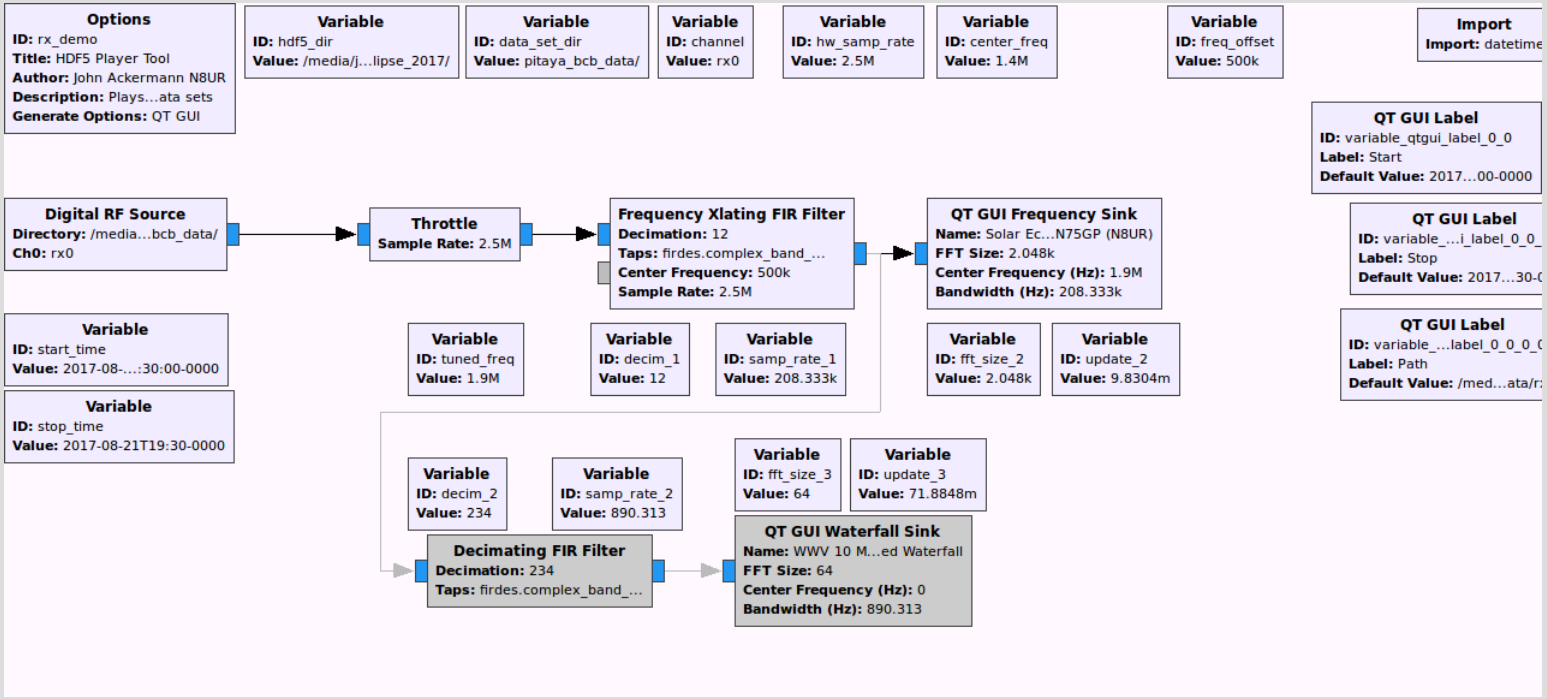
Gnuradio Data Recorder



Recorder Wish List

- Current recorder requires parameters to be set in Gnu Radio Companion, and GRC has some limits on functionality (can’t change some values “on the fly”).
- Would like a cross-platform GUI front-end to make it easy for anyone to use
- Current wish-list on my blog: http://blog.febo.com/wp/?p=293
- I’m not a GUI guy, so looking for a volunteer. Any takers?

Gnuradio Playback Script



Playback Tool Wish List

- imilarly, GUI front-end to Gnu Radio Companion:
  - Source file sample rate and center frequency
  - Destination file sample rate and center frequency
  - Output format (HDF5, Complex64, WAV)
  - Channelizer with multiple outputs?
  - Etc.

VHF/UHF Reverse Beacon Network

The Question

From Bob, K8TQK:
“Can we come up with a way to automatically monitor VHF/UHF beacons and report on propagation?”

Is there a wheel that’s already been invented???

An Answer

Yes.

1. Leverage Existing Reverse Beacon Network and Cluster Tools (DXMap, etc.) to display VHF/UHF spots from beacons and other users.

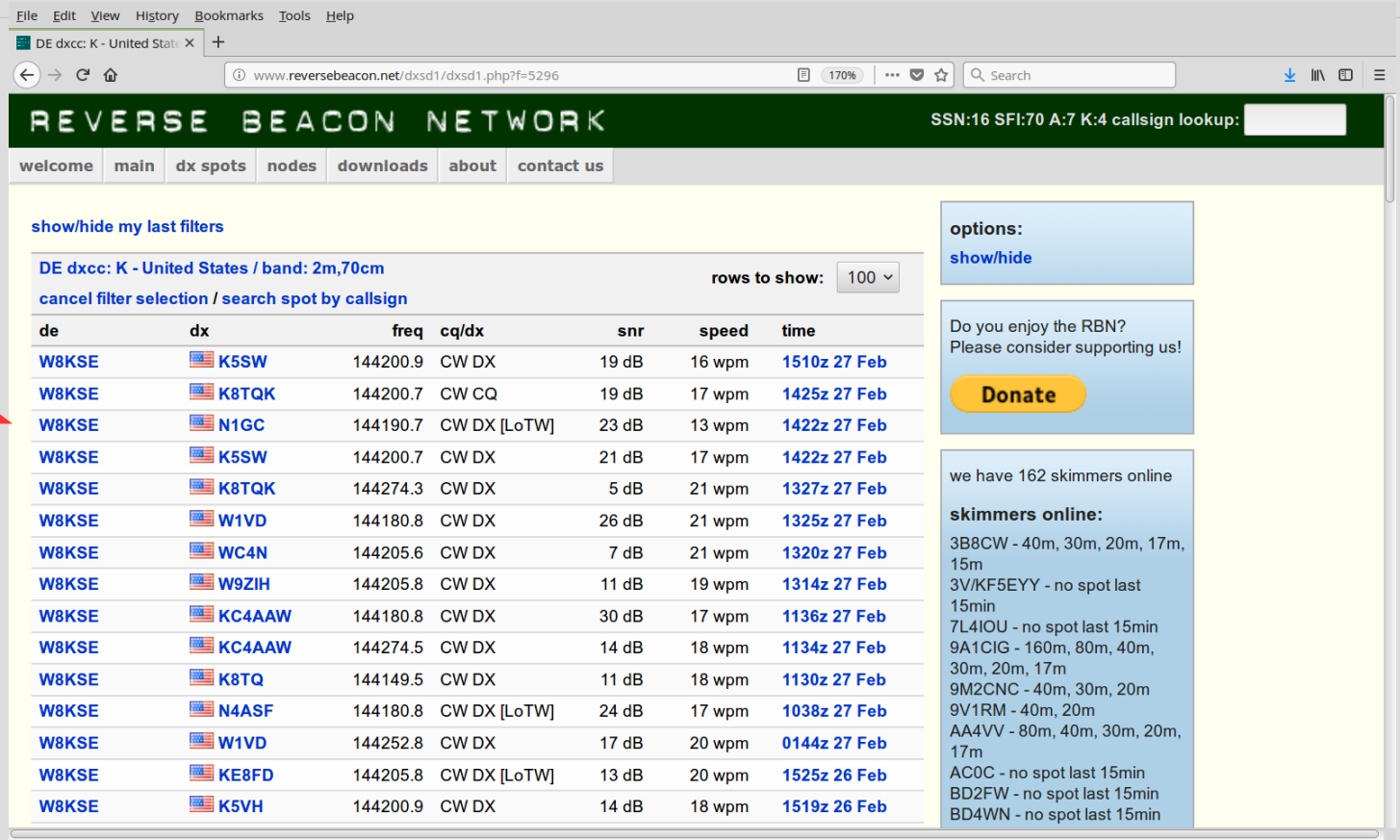
2. There’s a way to leverage low-cost hardware to feed multiple VHF/UHF bands into CW Skimmer.

CW Skimmer and the Reverse Beacon Network

- CW Skimmer by Alex, VE3NEA
  - Magic software that decodes all CW signals in the bandpass
  - Can listen to 8 192kHz chunks simultaneously
  - Generates “Spots” showing time, call, freq, speed, SNR
  - Runs on Windows; $75 license fee
- Reverse Beacon Network
  - www.reversebeacon.net
  - Receives spots from many skimmers – usually 150+ on line
  - Feeds info to DX Cluster and to places like www.dxmaps.com
  - However, almost **no** VHF+ spots from the US!!!
    - This morning (2 Feb 2018) three VHF+ skimmers shown, all on 6M

RBN Spot Page

W8KSE is only US station reporting above 6M!



V+RBN Configuration

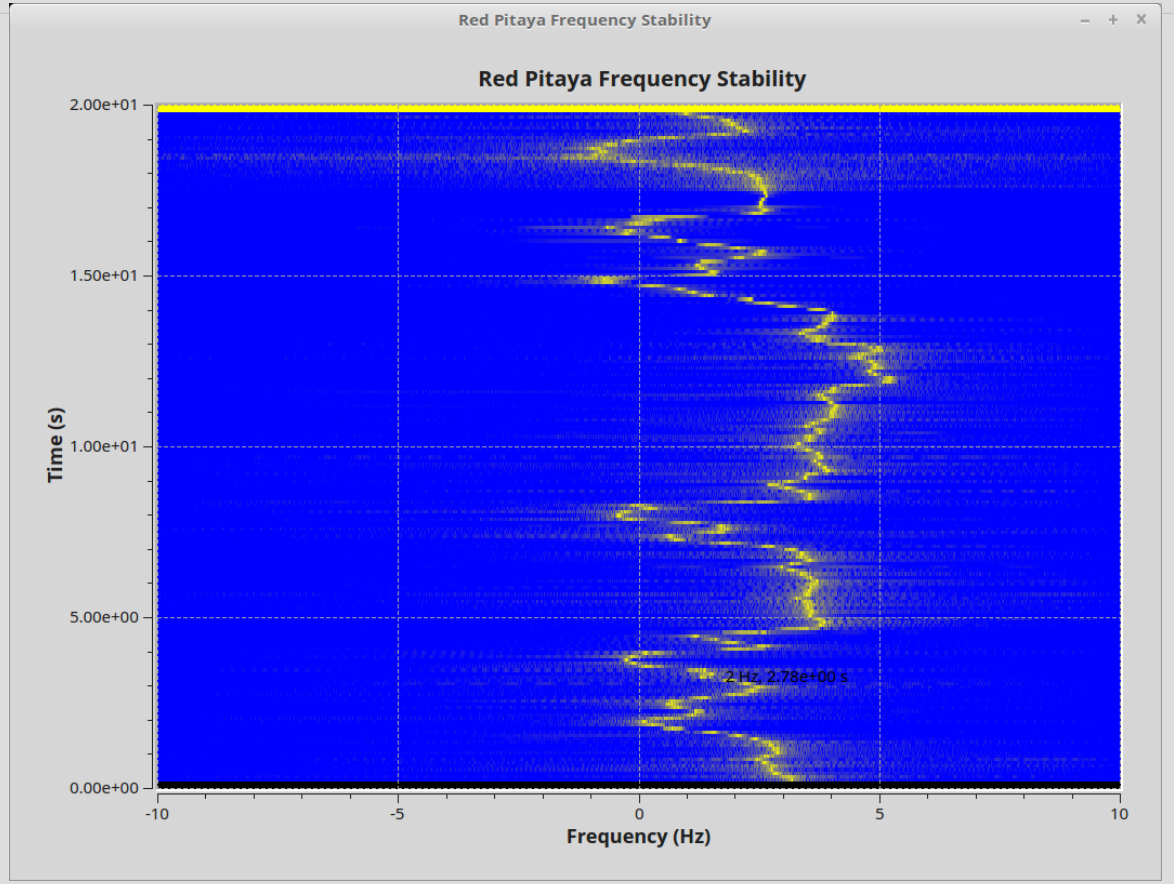
- The magic bit is N1GP's rtl_hpsdr software:
  - Presents up to 8 RTL-SDR "dongles" on USB side as a single multi-receiver HPSDR device on the Ethernet side
  - Open Source and runs on Raspberry Pi 3
  - Source available from https://github.com/n1gp/librtlsdr, and an Rpi image is at http://febo.com/pages/os_images/
- Dongles have good sensitivity, but limited dynamic range. Suitable for use in many locations, but some may require filtering.
- **Dongles plus rtl_hpsdr create a low cost RF deck covering many VHF/UHF bands**

Complete V+RBN Station

- Windows computer (i5 class is fine)
  - CW Skimmer Server ($75 license fee)
  - RBN Aggregator software (free)
  - Low-rate Internet connection; DHCP OK
- Raspberry Pi 3 with rtl_hpsdr image
- Several RTL-SDR.com dongles (1 per 192 kHz segment)
- Powered USB Hub (Dongles draw some juice)
- Antennas:
  - Ideally horizontal polarization, some gain, up 40+ feet
    - Stacked halos seem a good choice
  - Consider LNA at antenna followed by RG6 coax to shack

Red Pitaya Frequency Control

Environmental Test Chamber



Stabilizing the Red Pitaya

- 125 MHz onboard crystal oscillator; specs not known
  - Clearly has poor temperature compensation
- Pads available to install external oscillator
- Goal is to develop synthesizer that allows Pitaya (and other devices) to be locked to quality 10 MHz reference (like GPSDO)
- Does RP have digital noise issues?
  - W1PJE and N8UR exploring

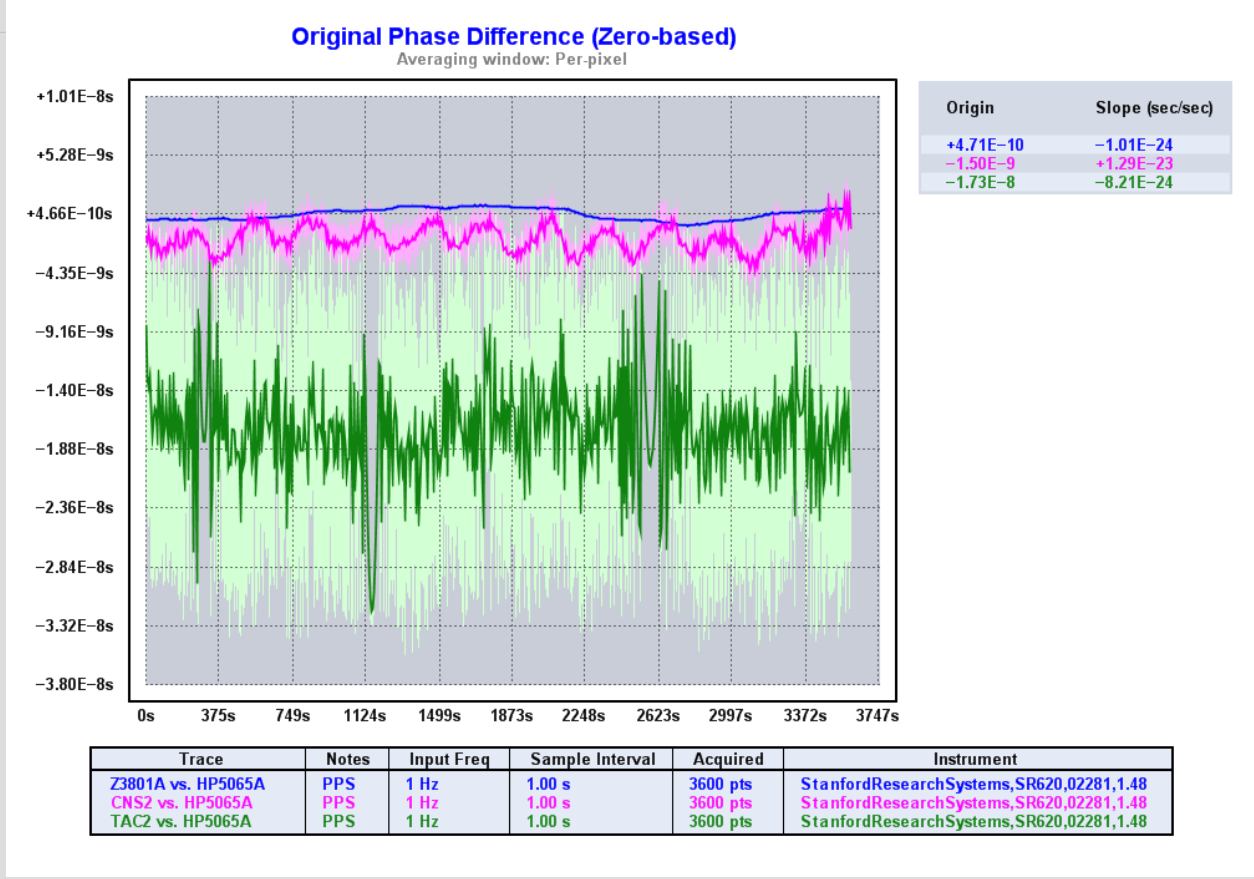
Stabilizing the Red Pitaya

- Silicon Labs has a bewildering variety of clock generator chips
  - Si5351A
    - Three outputs up to 160 MHz
    - Moderate jitter/phase noise
    - Seems to want 25 MHz reference
  - Si5340/5342/5348 family
    - Frequency resolution to fractional Hz
    - 4 or 10 independent outputs to 1 GHz
    - Extremely good jitter/phase noise possible
    - QFN44 package
- I’m working on a couple of “chip carrier” designs
  - Will require motherboard with MCU and signal conditioning

Wideband Data Timestamping

- Ethernet Stream Timestamper?
  - FPGA with 2 Ethernet and 1 PPS input
  - Adds timestamp to HPSDR data stream
  - Would require new receive block in software
- Pulse Stamper
  - Inject sharp pulse edge at antenna input; creates pulse visible across HF spectrum
  - Also interferes with desired signal
  - If you inject pulse per minute (or per 100 seconds), reduces interference and still maintains phase assuming GPSDO frequency control
  - Testing this method begins soon

GPS PPS Jitter



Trace	Notes	Input Freq	Sample Interval	Acquired	Instrument
Z3801A vs. HP5065A	PPS	1 Hz	1.00 s	3600 pts	StanfordResearchSystems,SR620,02281,1.48
CNS2 vs. HP5065A	PPS	1 Hz	1.00 s	3600 pts	StanfordResearchSystems,SR620,02281,1.48
TAC2 vs. HP5065A	PPS	1 Hz	1.00 s	3600 pts	StanfordResearchSystems,SR620,02281,1.48