LWA Absolute Flux Calibration

a first order post-processing approach to calibrate DRX beam data

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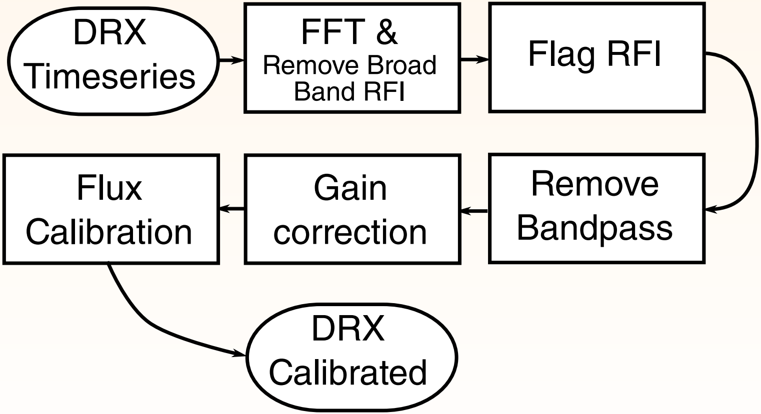
on behalf of the LWA collaboration

LWA Users Meeting 2012

Albuquerque, July 26, 2012

Calibration Strategy Flowchart



Preparing Beam Data

Converting DRX time series data to the frequency domain:

- Split data in chunks integrating t amount of seconds over data
- Determine average clipping levels and standard deviations for each time bin (if needed)
- Run SpecMaster (LSL) to FFT data and apply clipping levels
- Output results in .npz or .hdf format

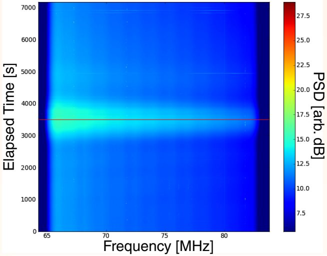
see e.g. commissioning scripts: drxWaterfall.py and hdfWaterfall.py

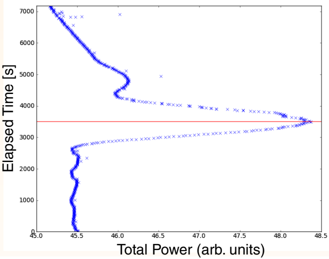
Example: Drift scan of Cygnus A on 2012-04-29

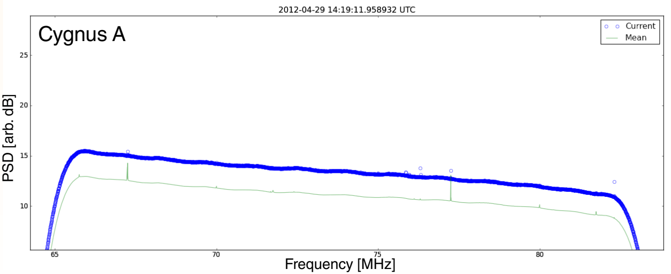
duration of observation:	2 hours
tunings	37.9 & 74.03 MHz
integration time/bin:	10s
clip threshold/bin:	5x standard deviation
NFFT	4096

Preparing Beam Data

Commissioning script plotWaterfall.py

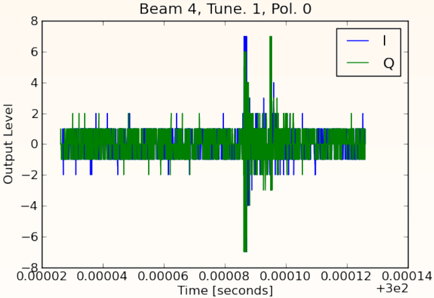




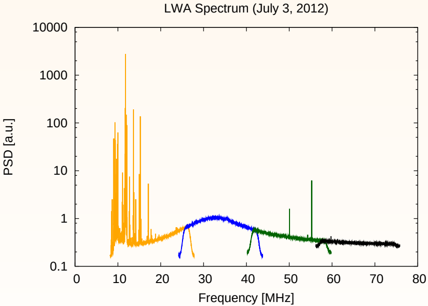


Radio Frequency Interference

Timeseries:



Spectrum:



Post-correlation RFI Flagging - Methods

Time domain:

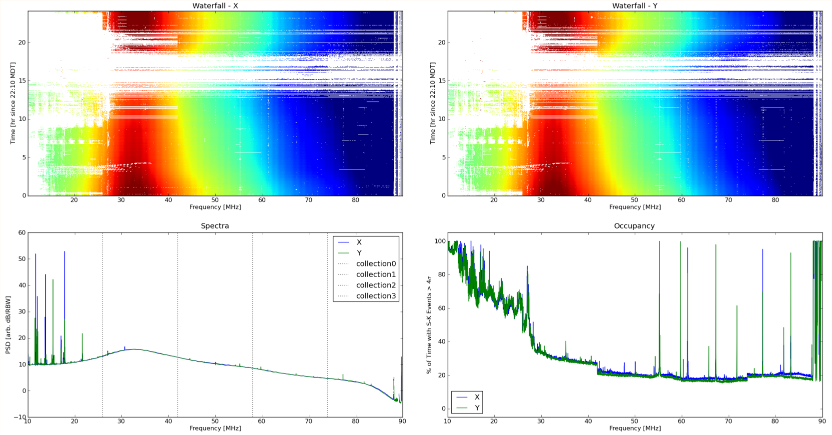
- Clipping levels can be used as a tool to remove strong broad-band bursts of RFI
- Weak broad-band RFI?

Frequency domain:

- Post-correlation thresholding
- Surface fitting and smoothing
- Combinatorial thresholding
- SumThresholding
- **Spectral Kurtosis** (implemented in LSL: lsl.statistics.kurtosis)

good references to start: LWA Memo #183; Nita & Gari PASP, 122, 595; Offringa et al., MNRAS 405,155

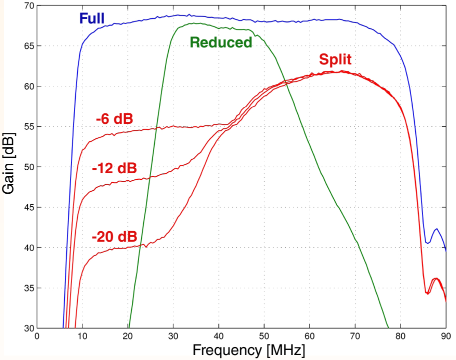
Spectral Kurtosis - Example (09/14/2011)



Obenberger & Dowell (LWA Memo #183)

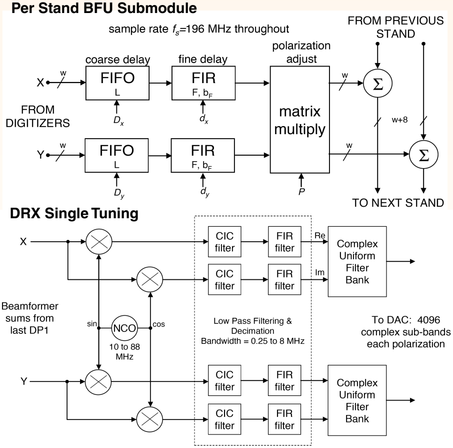
The Bandpass - a combination of two

1. ARX filter configuration



References: LWA Memos #161, #154

2. Digital filter



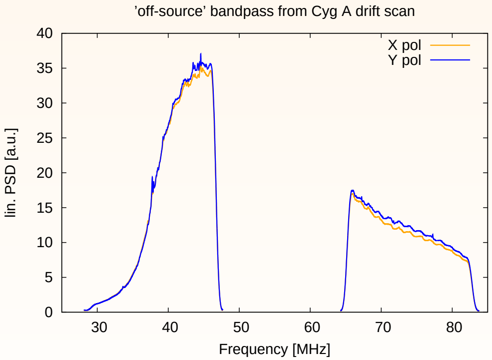
CIC: cascaded integrator-comb

FIR: finite impulse response

Bandpass Calibration - ’empty’ sky

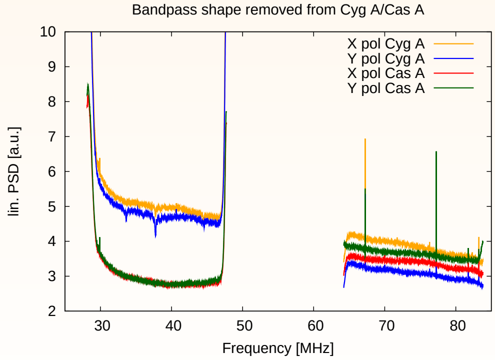
Procedure:

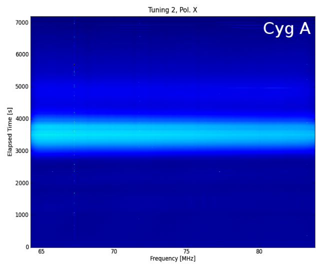
- Extract spectrum off-source
- Smooth data (Hanning)
- Scale bandpass to data
- Divide-out scaled bandpass

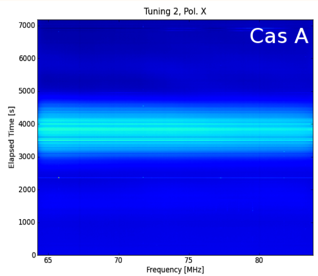


Bandpass Calibration - 'empty' sky

Applied to Cyg A & Cas A
(averaged 200 s)



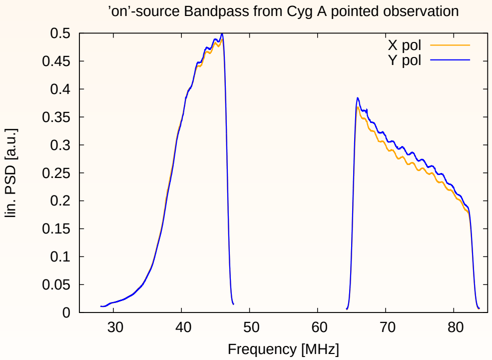




Bandpass Calibration - strong calibrator

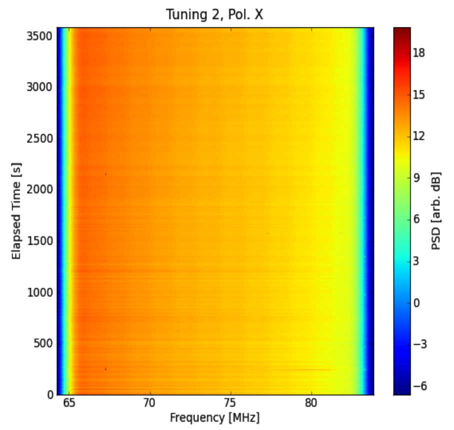
Procedure:

- Scale known spectral shape of calibrator to data
- Divide spectral shape from data
- Smooth data (Hanning)
- Scale bandpass to data to calibrate
- Divide-out scaled bandpass

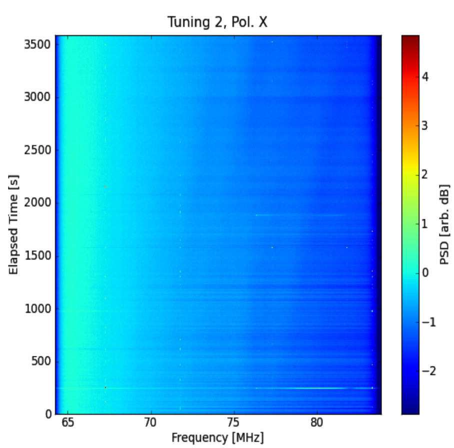


Cyg A bandpass ('on'-source) applied to Cas A

Cas A before



Cas A after



Gain Calibration for tracking observations

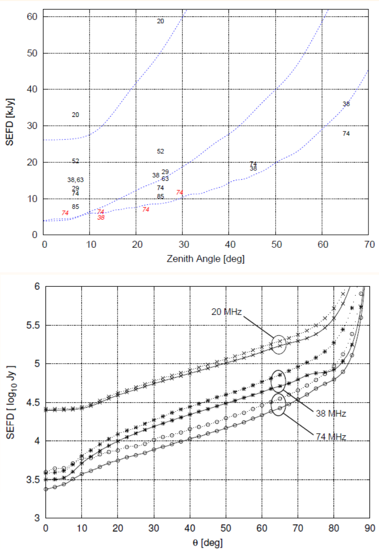
Gain variations introduced by changes in sensitivity as a function of frequency and zenith angle.

System Equivalent Flux Density can be estimated from drift scans:

$$SEFD = \frac{k\,T_{\rm sys}}{A_{\rm e}} = S\left(\frac{P_1}{P_0} - 1\right)^{-1}$$

S: source flux density;
P_1: on-source power;
P_0: off-source power

(see LWA Memo #186 & #166)



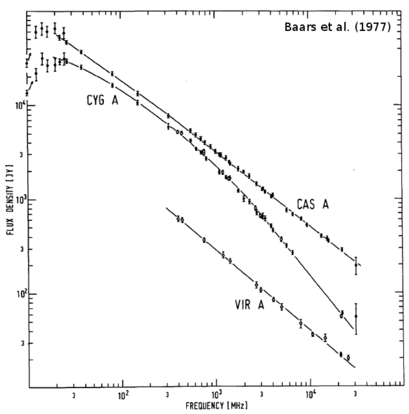
Flux Density Calibration

Last step: Apply the absolute flux density scale

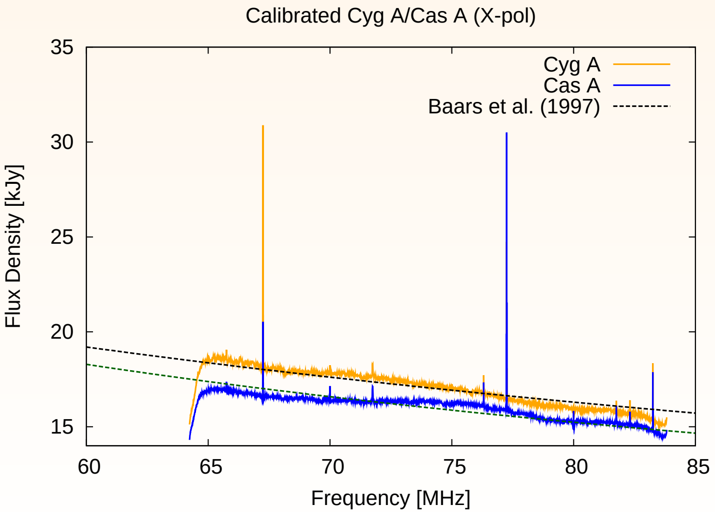
Requires a priori information on the calibrators spectral shape and absolute flux values. A good starting point is Baars et al. (A&A, 61, 99).

Helpful tool: VLSS bright source calculator: http://lwa.nrl.navy.mil/VLSS/calspec.html

Note: The flux of Cas A decays over time.

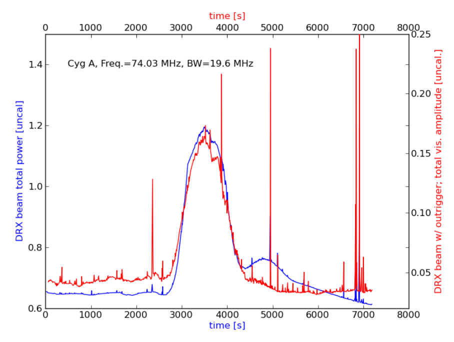


Cyg A scaled to Baars scale and applied to Cas A



Systematics & Errors

- Ignored contribution of diffuse Galactic emission and other sources within the beam & sidelobes.
- LWA1 can improve knowledge of spectral shapes of bright calibrators using the outrigger.
- Influence of ionosphere.
- Demonstrate repeatability and variability of calibration, especially for fainter targets.



Summary & Recommendations

- Presented a strategy capable to determine an absolute flux scale for LWA1 DRX beam data.
- Obtained spectra and absolute flux calibration for Cyg A and Cas A.
- Spectral kurtosis is currently the tool at hand to flag RFI.
- A basic gain calibration can be applied based on theoretical calculations. *Part of ongoing commissioning effort to better characterize source elevation dependend gains.*

Recommendations:

- Include a brief ($\sim$10 min) observation of a bright calibrator with known spectrum at small zenith angle for bandpass and absolute flux calibration.
- If possible: avoid observing at large zenith angles ($>30^\circ$).