# LWA1 Beam Calibration

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# Disclaimer

This presentation applies to the following modes of LWA1 observations:

- DRX beam-formed raw voltage data
- DRX beam-formed spectrometer data
- Custom beam-formed data such as beam-dipole or dipole-dipole

# DRX gain for beam observations

- Did the DRX gain get set right?
  DRX gain compensates for bandwidth reduction

| Target | Full Bandwidth AT1=13, AT2=13 | Split Bandwidth AT1=08, AT2=06, ATS=15 |
|---|---|---|
| Cyg A/Cas A | 5 or 6 | 7 or 8 |
| Vir A/Tau A | 4 or 5 | 6 or 7 |

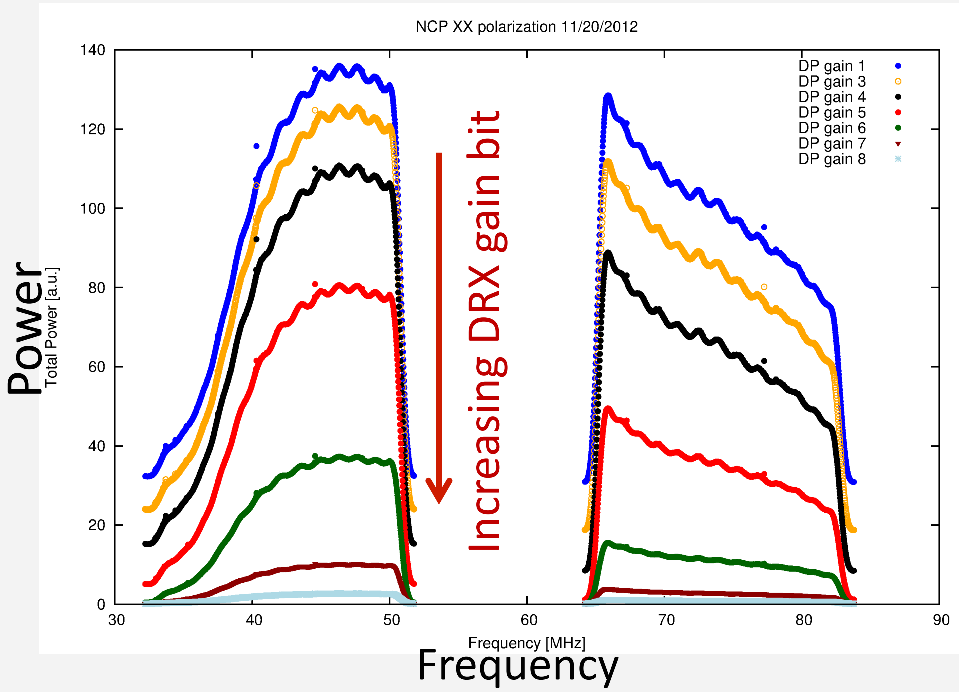
- Too low DRX gain can cause severe data clipping and skews the spectral response
- Too high DRX gain causes only few bits to toggle also skewing the spectral response

**Scheduler and Operator might not know the intent of the observation thus cannot always know the right DP gain.**

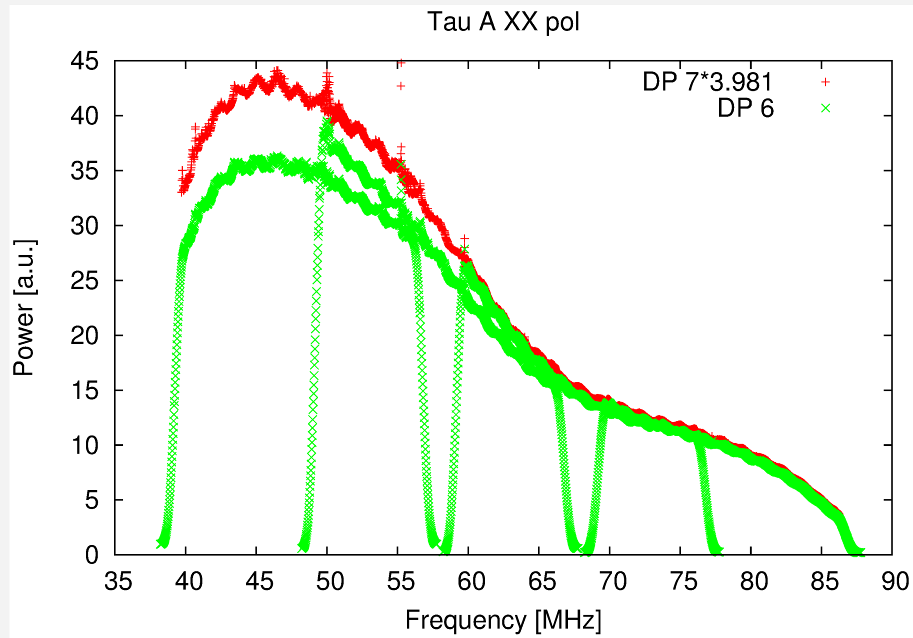
**See LWA Memo #199 for recommended DP gains.**

# DRX gain examples

**Example: NCP XX pol. Split bandwidth**




**Example: Tau A good and bad gain**

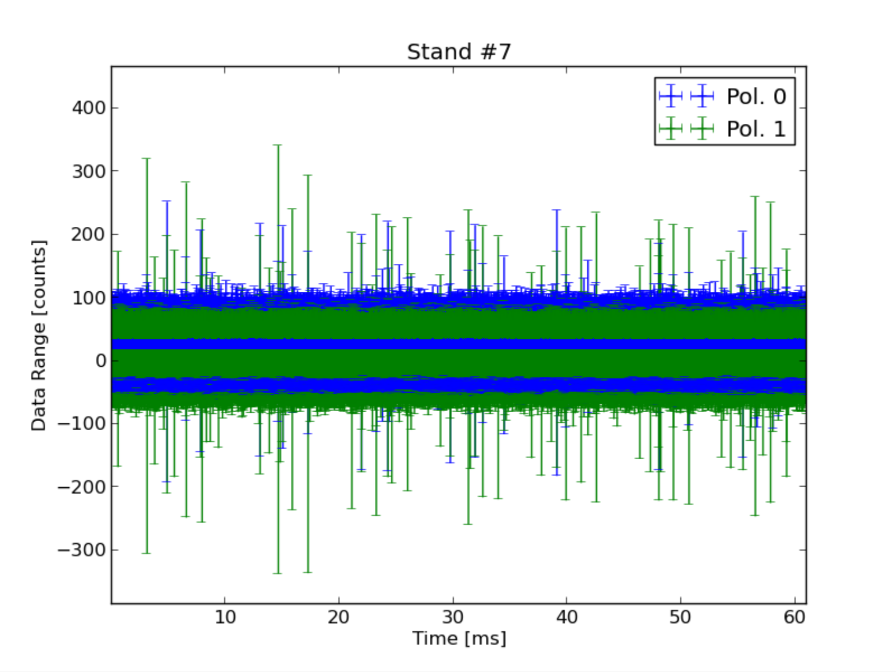



Here optimal gain for NCP is 5 or 4; optimal gain for Tau A is 7

Difference of 1 digit of DRX gain corresponds to ~ 6 dB (power ratio 4)

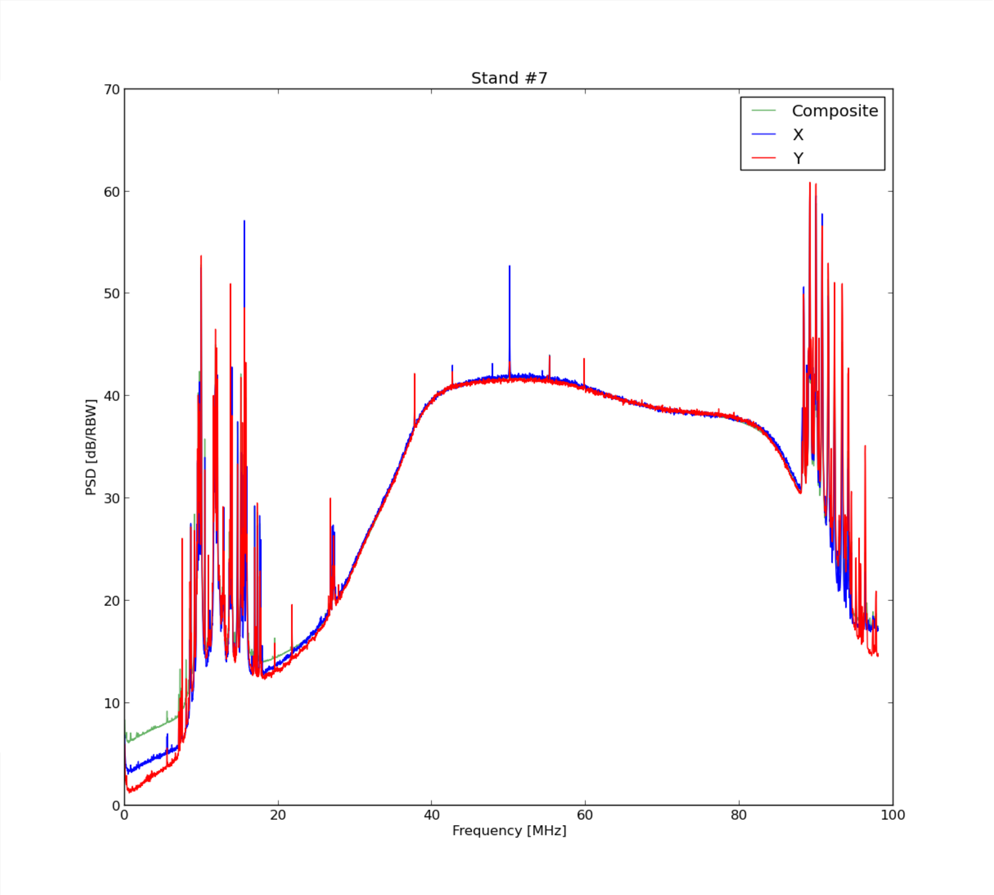
# Radio Frequency Interference

## Timeseries




Powerline RFI

## Spectrum




TV carriers, Amateur Radio, AM, FM, etc.

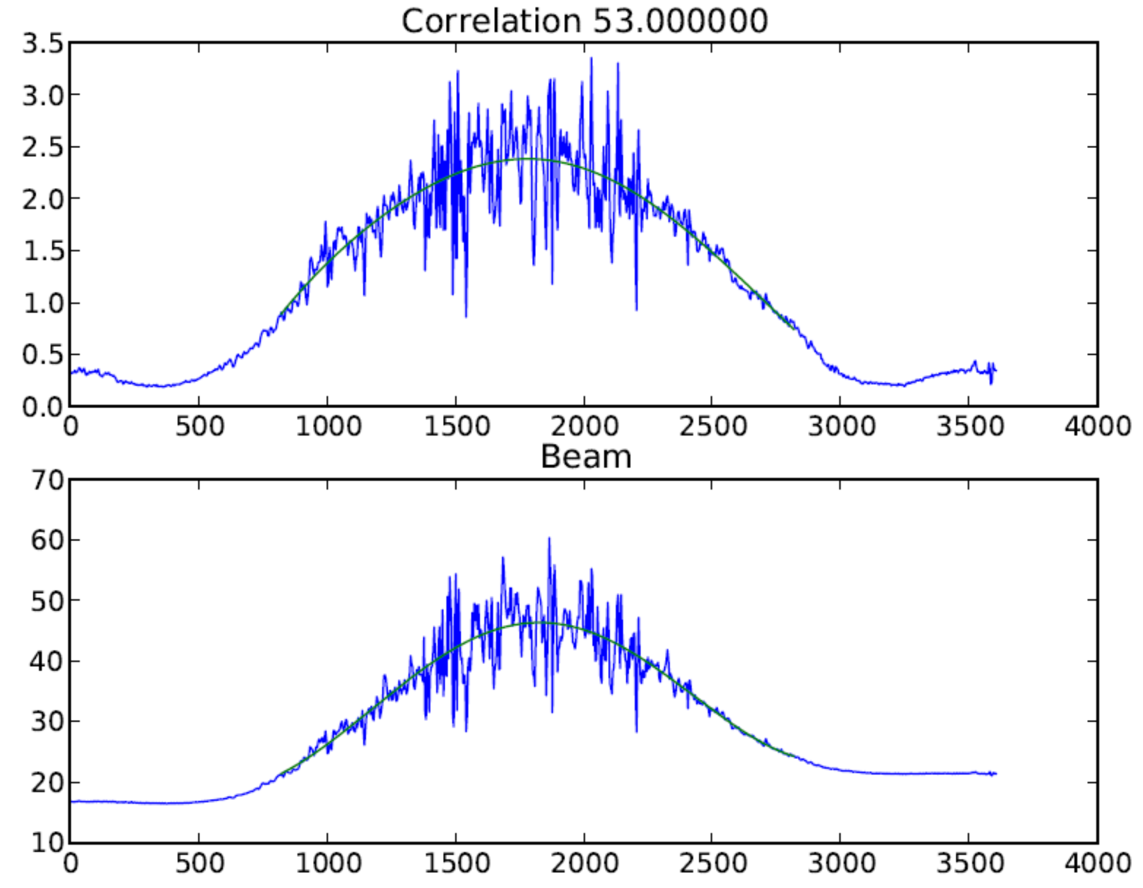
# Post-correlation Flagging Methods

- 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 #143, Nita & Gari PASP, 122, 595; Offringa et al., MNRAS 405, 155*

# Ionosphere

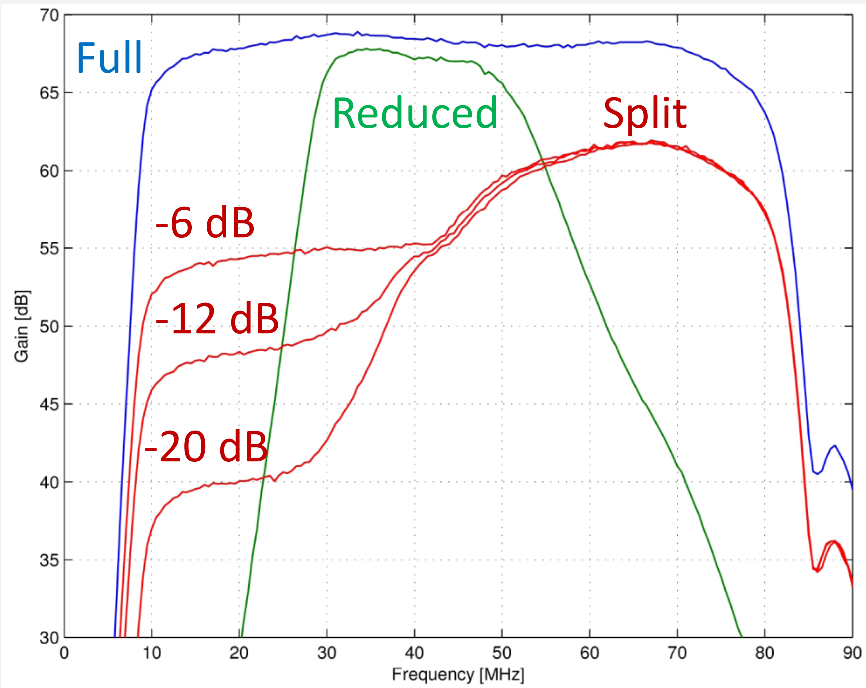
Example Cas A




**Here: strong scintillation on 340m baseline (top), but station beam also affected (bottom)**

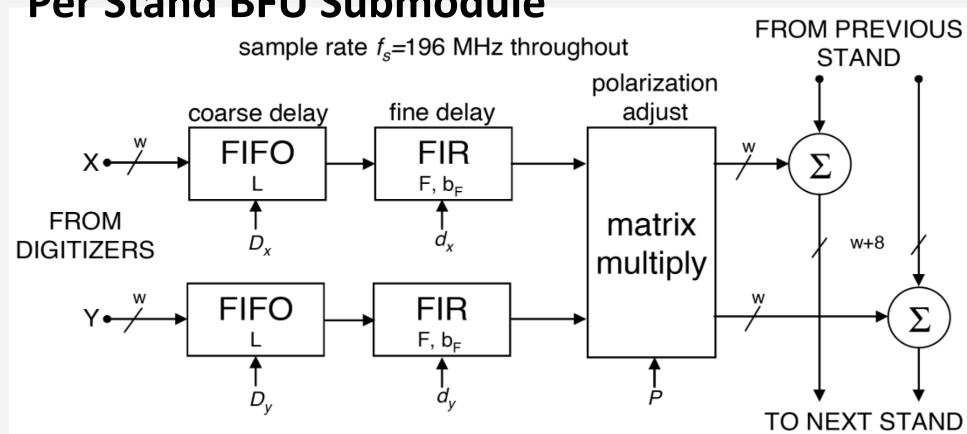
# Bandpass

1. ARX filter configuration

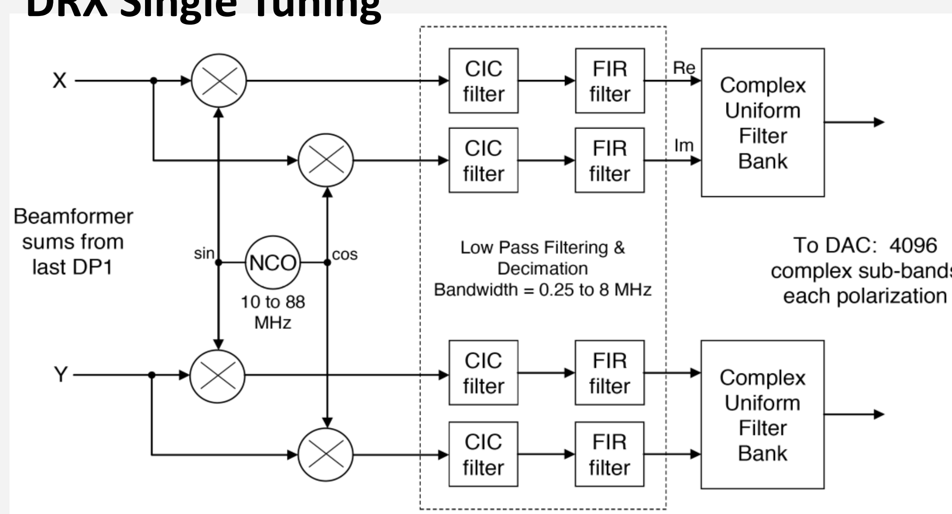



2. Digital filter

**Per Stand BFU Submodule**




**DRX Single Tuning**




3. Antenna & cable response, ground losses, etc.

*References: LWA Memos #161, #154*

# Off-source calibration

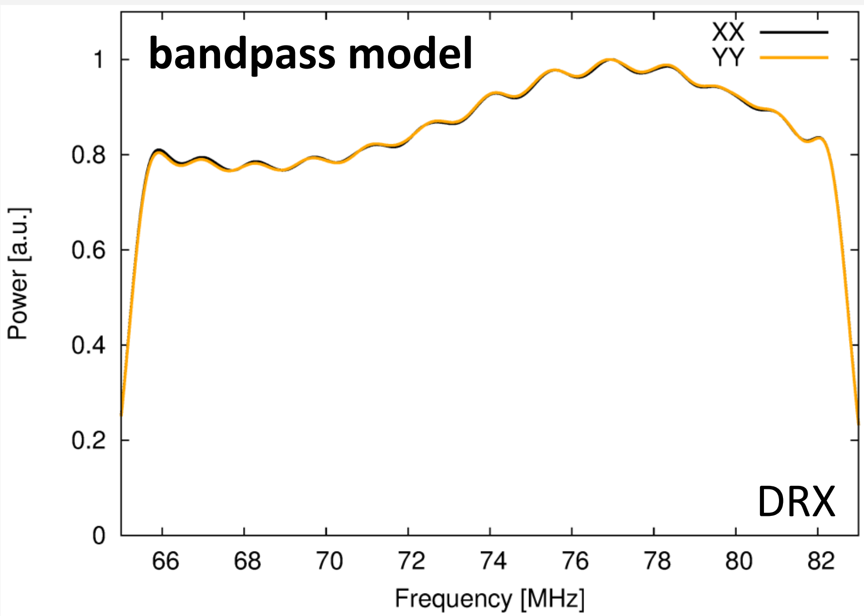
Approaches tried:

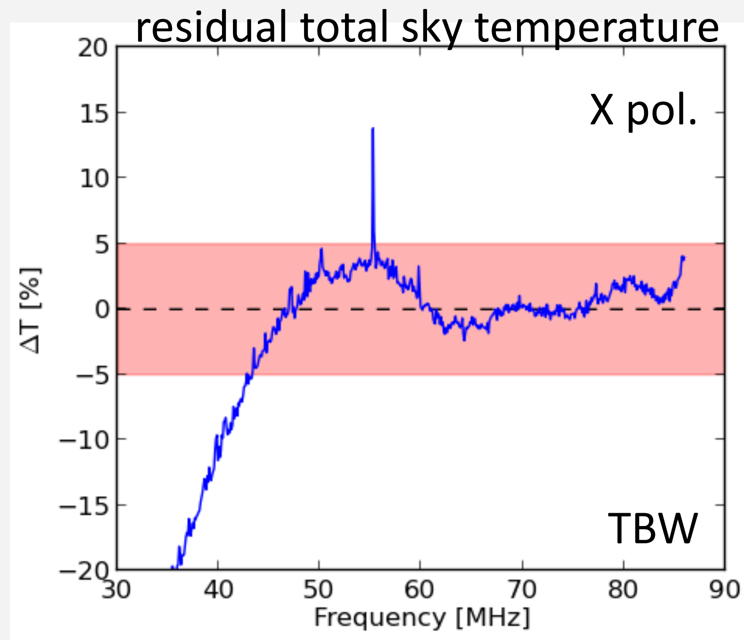
- **'empty' sky off-source**
  caveat: pick-up sidelobes from target or nearby sources etc.
- **NCP as 'empty' sky reference**
  caveat: large beam, picking-up a lot of other stuff
- **Strong calibrator**
  caveat: spectral properties at <60 MHz not well known, beam confusion not well known

All this did not work reliably in a broad range of applications, some might get away with it.

# Bandpass Model

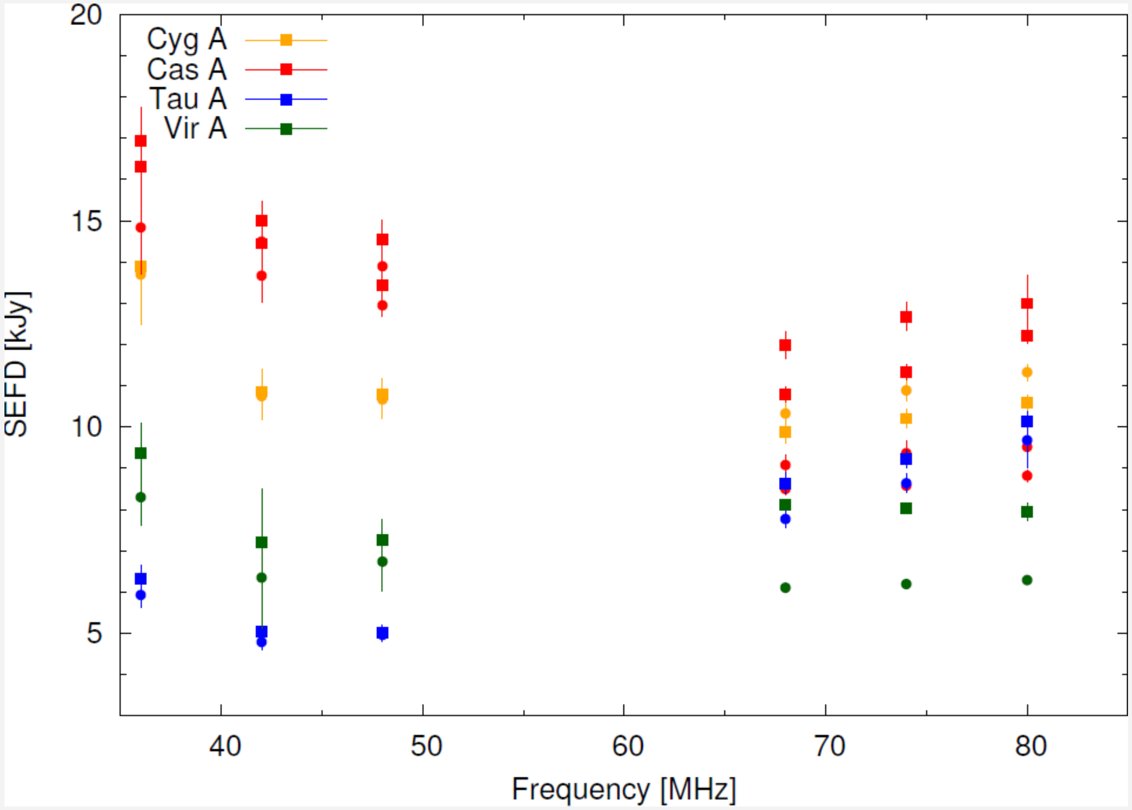
1. Measured ARX response - *lsl: arx.response*
2. Theoretical DP response – *lsl: dp.drxFilter*
3. Simulated antenna response



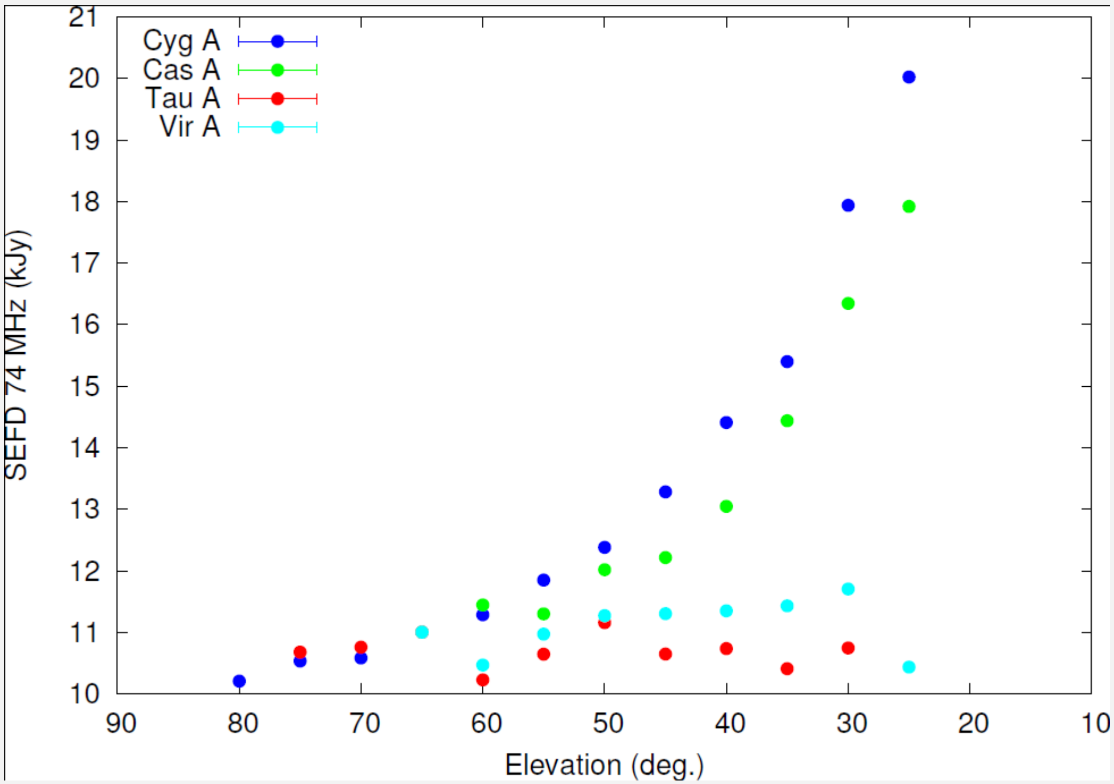

**Bandpass residuals <10%; future improvement through better antenna response characterization possible**

# SEFD – Frequency Dependence




**Little frequency dependence of sensitivity across most of the LWA band.**

# SEFD – Elevation Dependence

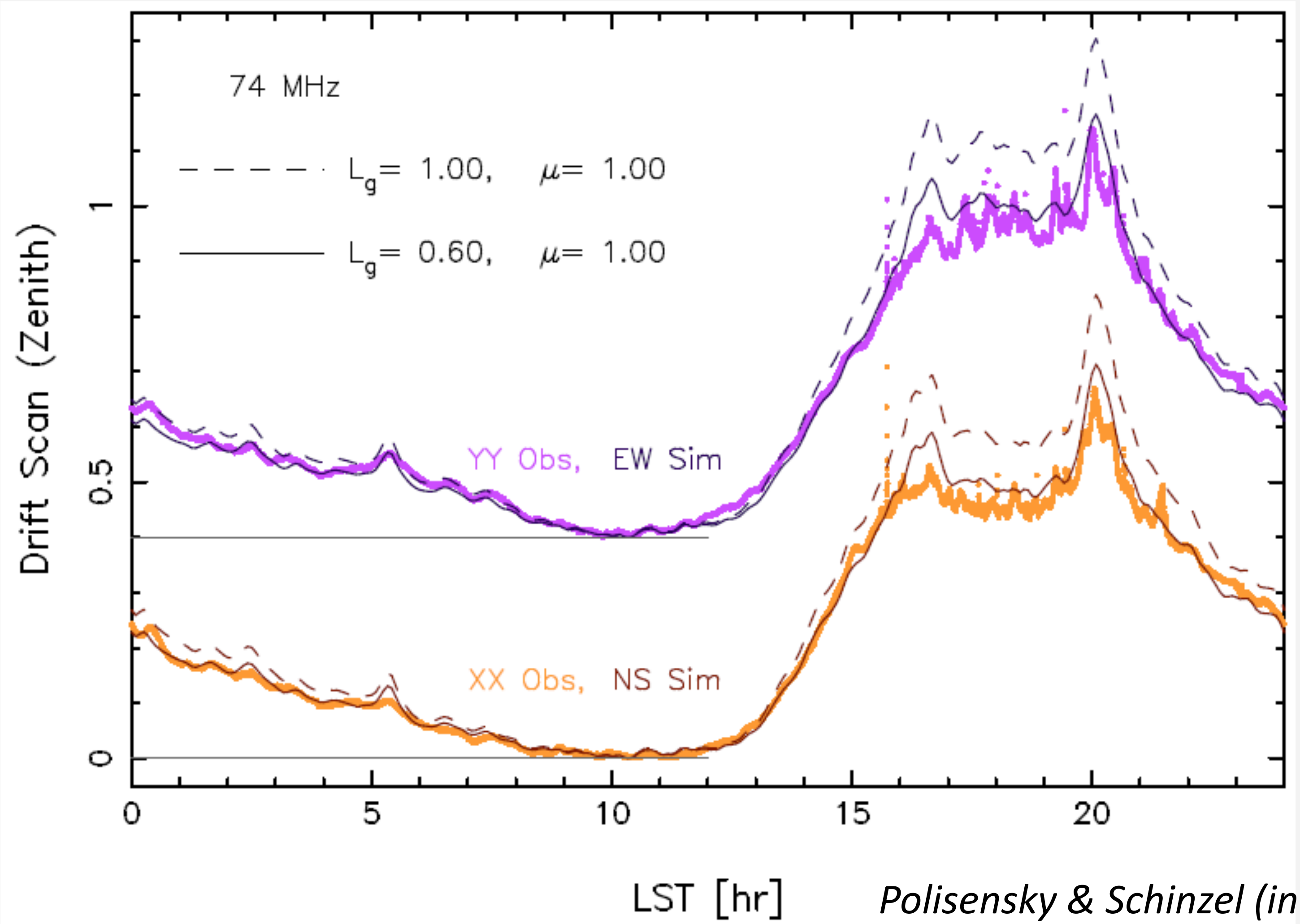



**Instrument sensitivity varies mainly with elevation**

Needs to be corrected especially for beam tracking observations.

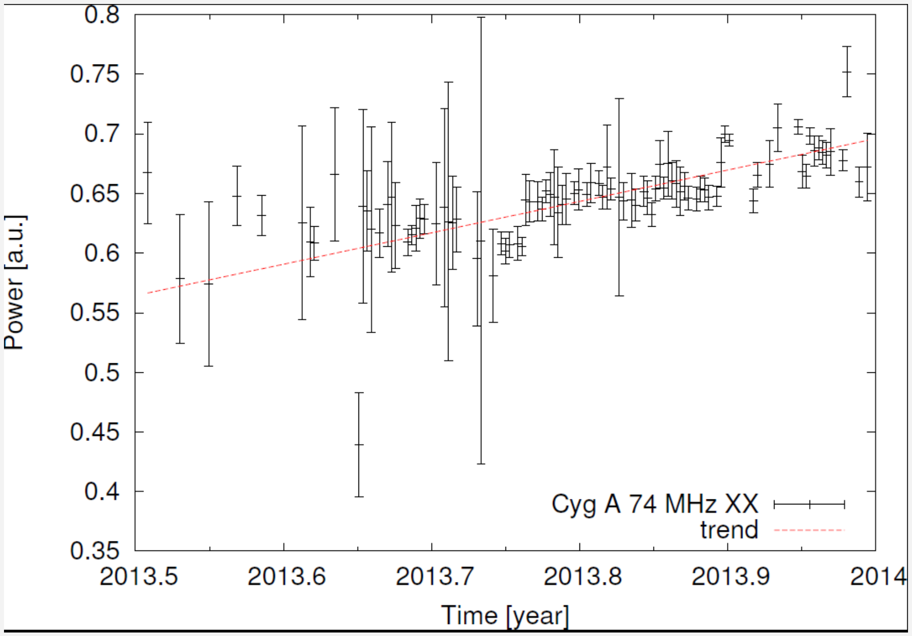
(see LWA memos #186, #166, #202)

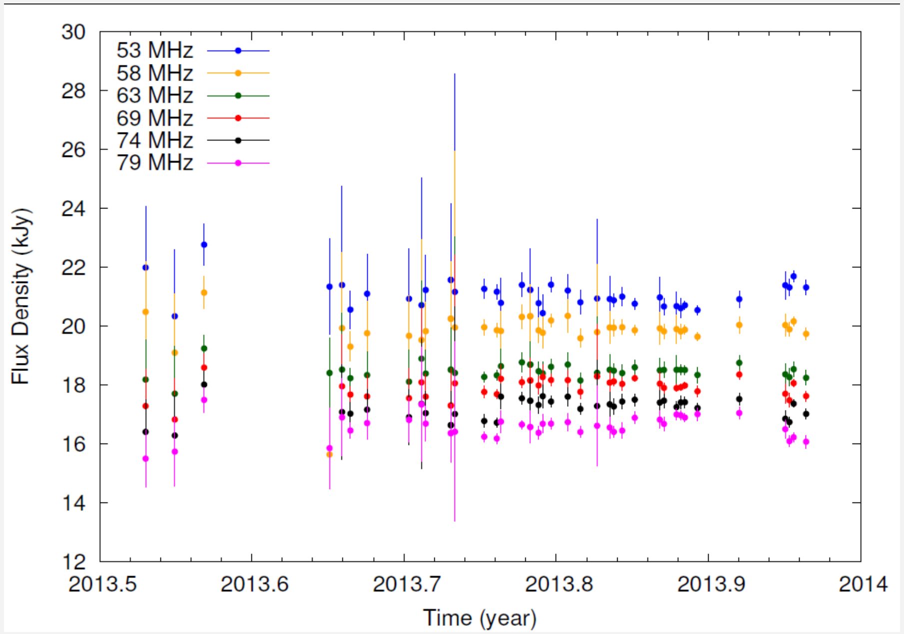
# LST Dependence




*Polisensky & Schinzel (in prep.)*

# Day-to-day stability/Lightcurve




Cygnus A (E-W pol.) raw light curve

Cyg A calibrated light curve

**Day-to-day stability of measured power levels <5%**

***Need to correct for shelter temperature variations and outside temperature for higher accuracy (see LWA memo #198).***

# Flux Density Calibration

Translate total power measured by LWA1 station beam to an absolute flux density.

Required steps:

1. *RFI flagging*
2. *Bandpass calibration based on model*
3. *Correction for receiver temperature variations (optional)*
4. *Apply gain/flux density calibration based on all-sky model (in preparation)*

# Summary

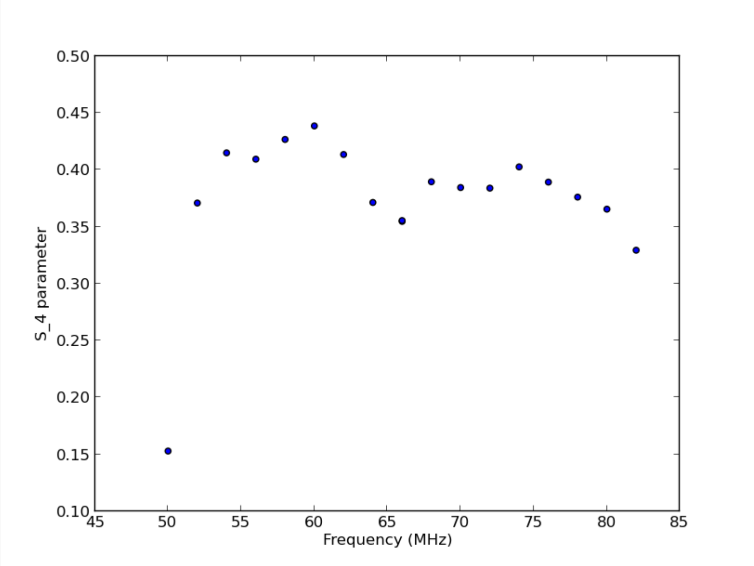
For typical observing parameters we are now able to correct for:

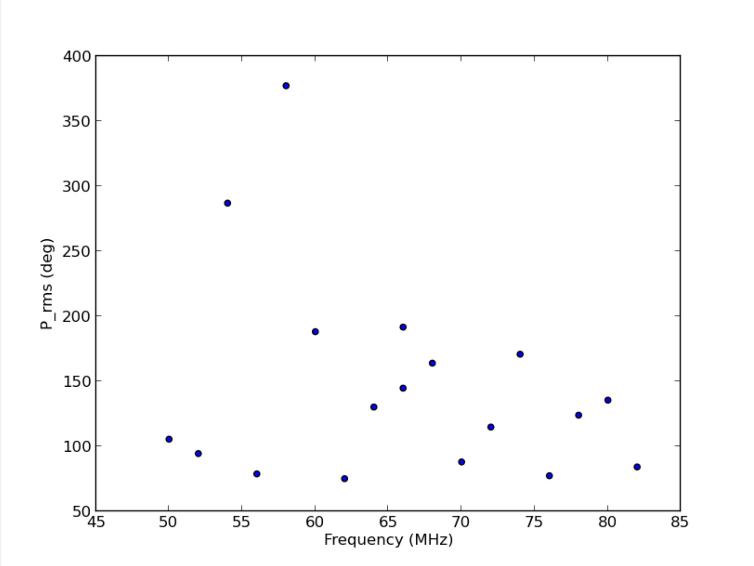
1. Bandpass shape (better than 10%)
2. Temporal gain variations from receiver temperature changes (better than 5%)
3. Sky model for LST, frequency, and elevation dependent flux density transfer in place - *needs still verification, first results are promising*

With this we expect to achieve a relative flux density calibration of better than 20%, pending verification.

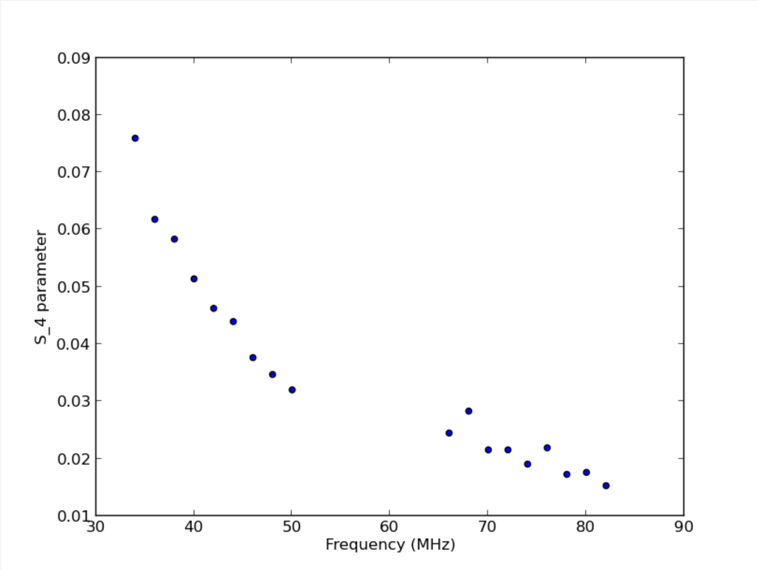
# Ionosphere

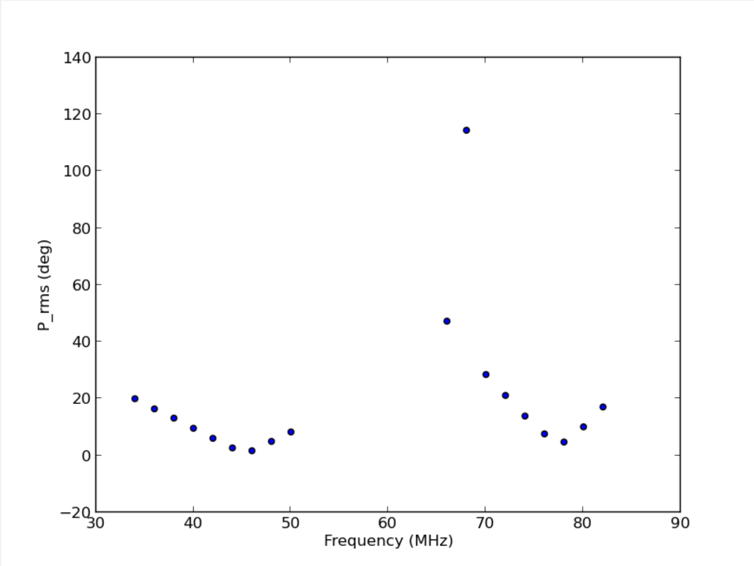
strong




weak



# Ground Reflection