



ALMA Offline Interferometric Calibration

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Intro

- ◇ The following calibration steps should be applied to all the data from a single Observing Session: phase cal, amp cal, bandpass cal, and target source
- ◇ Approach here is baseline based calibration, no closure quantities. Final solution should be antenna based cal for most steps.



Intro (2)

- ◇ Polarization has been ignored for simplification
- ◇ All steps should record corrections applied so that any step can be interactively reversed and redone



Tsys (DSB) Temperature Scale

- ◇ Determine double sideband (DSB) system temperature as a function of frequency
- ◇ Inputs: TotalPowerLoad, TempLoad, TotalPowerSky, Antenna auto-spectra (each load and each sky integration)
- ◇ Output: Antenna Tsys spectra



Determine SSB Temperature Scale

- ◇ Inputs: receiver sideband gain ratio $SBR(\text{measured})$, elevation, frequency (each channel), $T_{\text{sys}}(f)$, temperature, pressure, for each integration
- ◇ Atmospheric model calculates $\tau_o(f)$
- ◇ Output: Single sideband temperature scale $T_{\text{usb}}(f)$, $T_{\text{lsb}}(f)$ for each integration, each antenna
- ◇ Not necessary for large sideband rejection ($> 100:1$), $T_{\text{ssb}} = T_{\text{dsb}}$



Sideband Separate

- ◇ Take in-phase and quadrature raw data cross-correlation function spectra $CCF(f)$ and produce sideband separated spectra, $CCF_{usb}(f)$ and $CCF_{lsb}(f)$.
- ◇ Not necessary for sideband suppressed data or if receiver sideband rejection is very large ($>100:1$)



Convert to Antenna Temperature

- ◇ Scale raw baseline data, $CCF_{usb}(f)$ and $CCF_{lsb}(f)$, by the single sideband temperatures $T_{usb}(f)$ and $T_{lsb}(f)$ for both antennas (geometric mean) to produce antenna temperature baseline data, $TA_{usb}(f)$ and $TA_{lsb}(f)$



Convert to Flux

- ◇ Multiply baseline antenna temperatures by flux conversion factors (based on frequency dependent antenna efficiency) to get baseline spectra in Janskies, $S_{usb}(f)$, $S_{lsb}(f)$



Atmospheric Pathlength

- ◇ Use corrected data for all preceding steps (done!)
- ◇ Or, use uncorrected and derive some new correction based on raw WVR data
- ◇ Correction limited if data already integrated to a timescale longer than WVR temporal resolution



Bandpass Calibration

- ◊ Normalize bandpass cal integrations to unity area to create bandpass correction
- ◊ Will have different bandpass cal if target and amp/phase cal are at different frequencies
- ◊ Apply bandpass correction to all target, phase cal, amp cal and bandpass cal integrations



Get phase calibration

- ◇ Sum phase cal spectra over channel ranges specified in PPII, e.g. continuum, maser lines, exclude lines. Ranges completely flexible, interaction possible.
- ◇ Fit sum phase vs. time with polynomial, resolve 2PI problems, remove bad data; possible interaction



Get phase calibration (2)

- ◇ Determine phase offset between phase calibration frequency and target frequency using data taken on a very strong source at both frequencies. This may be the bandpass cal data. Summing over channels is again required.



Apply phase calibration

- ◇ Scale phase calibration vs. time to target source frequency.
- ◇ Apply phase calibration vs. time and phase offset to all target integrations



Amplitude Calibration

- ◇ Integrate amp cal integrations over channels to produce single flux (like phase cal). Amp cal source may be the phase cal source.
- ◇ Use known amp cal flux to get gain vs. time. If flux unknown, use average over all baselines for flux.
- ◇ Apply fit of gain vs. time to all data (interactive if desired)



Amplitude Calibration (2)

- ◇ Careful control of pointing, focus and delay during target data collection may allow data to be taken without any amplitude calibration



Other Amplitude Calibrations

- ◇ Coherence correction. If WVR not used then a baseline length based amplitude correction can be applied.
- ◇ Correct for any known resolution effects on amp cal source (if not true point source)
- ◇ Correct amplitude for pointing errors, using pointing errors measured while collecting data



Absolute Flux Calibration

- ◇ If amp cal has known flux, done
- ◇ Link amp cal to know flux standards (planets, stars, asteroids), perhaps using archive data outside of Observing session, watching for time & frequency variations.
- ◇ ALMA bandwidth large enough to have flux changes with frequency (thermal sources)
- ◇ Put deduced amp cal flux into archive
- ◇ Scale data using new amp cal flux



Iterate Until Done

- ◇ Inspection of calibrated data may reveal errors on a per antenna or baseline basis that require repeat of some calibration steps until satisfactory results are achieved.