

ALMA Calibration Plan

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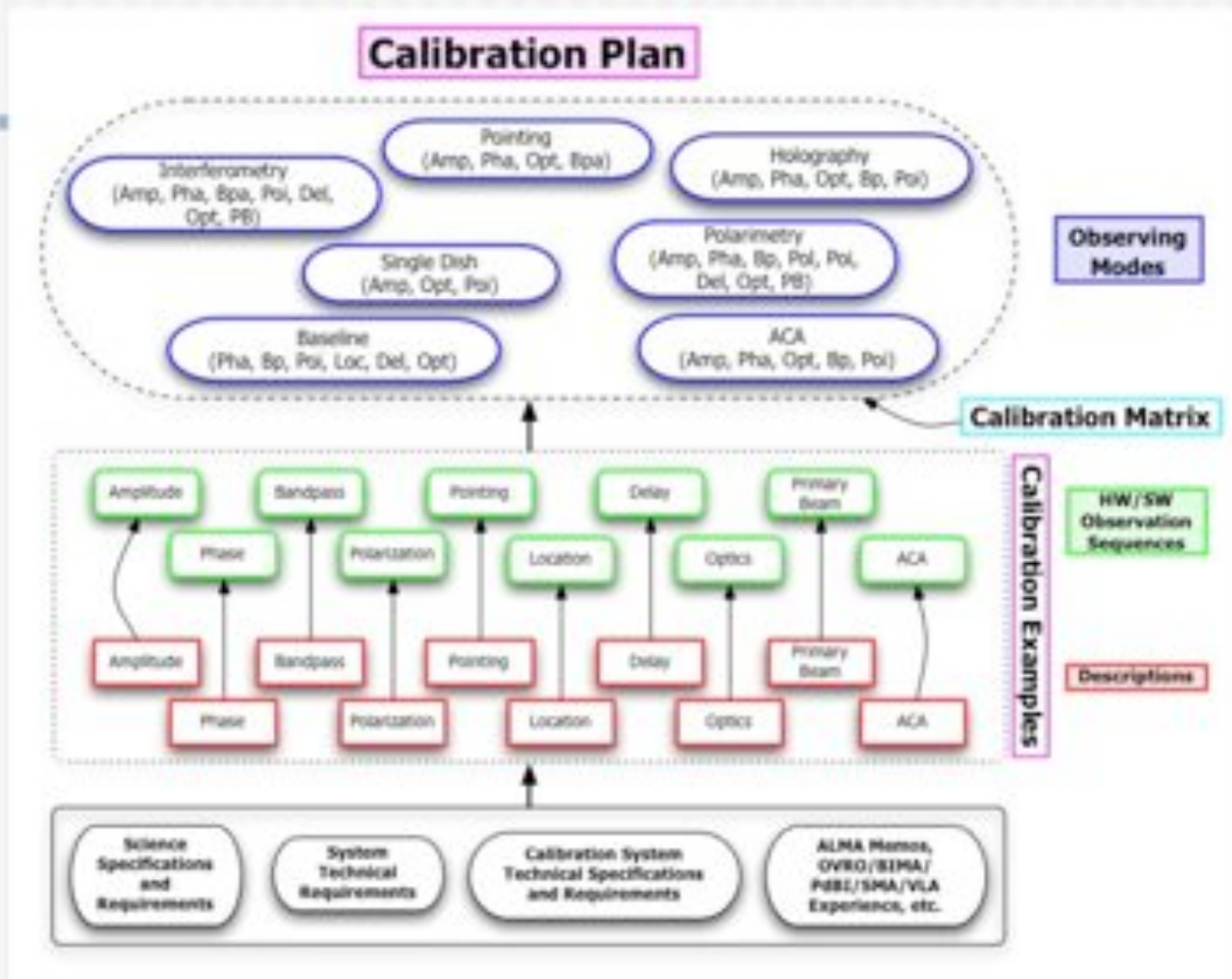
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ALMA Calibration Development

ALMA Calibration Development Roadmap

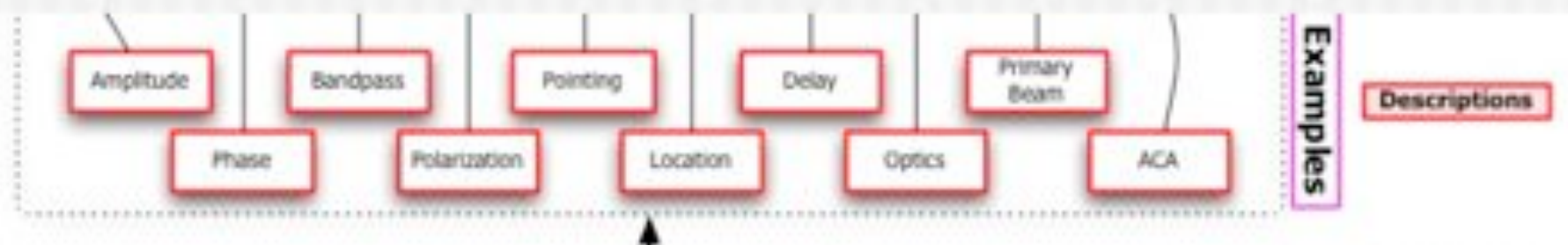


ALMA Calibration Plan



Calibration Examples: Descriptions

- Atomic-level descriptions of each type of calibration.
- Derive from science and system requirements and characteristics coupled with experience.
- Evolve into hardware and software observation sequences which implement each type of calibration.



Calibration Examples: HW/SW Observation Sequences

- Method-level descriptions of each type of calibration.
- Detailed descriptions of how hardware is commanded by software to effect each calibration measurement.



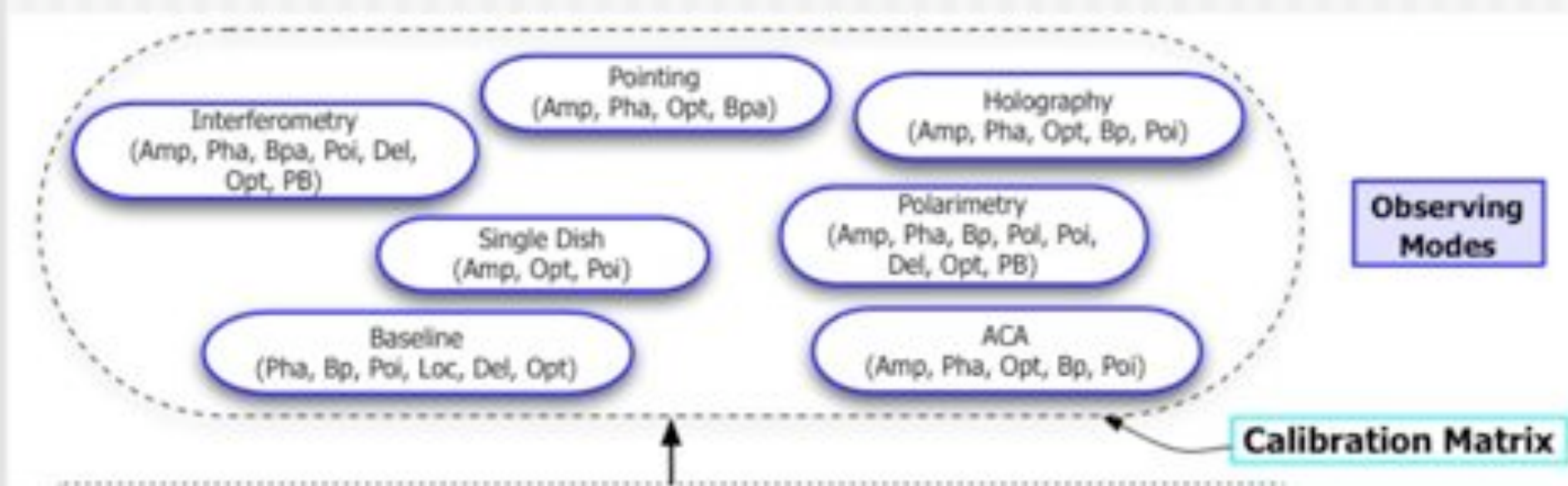
Calibration Examples

Document	Author(s)
Amplitude and Flux	Lucas & Mangum
Phase	Holdaway
Bandpass	Lucas
Polarization	Fomalont, Myers, & Holdaway
Pointing	Mangum & Lucas
Antenna Location	Mangum, Fomalont, & Holdaway
Antenna and Electronic Delay	Lucas
Optics	Vila-Vilaro
Primary Beam	Mangum & Holdaway
ACA Calibration Issues	Fomalont & Holdaway

Green = Complete; Blue = Reviewed / In Revision

Observing Modes

- Integration of HW/SW Observation Sequences into scheduling blocks.
- Will integrate during 2007/09/01 through 2008/06/01 at ATF.



Calibration Matrix

Calibration Measurements	Potential Predecessors								
	Amplitude Flux	Phase	Bandpass	Polarization	Pointing	Antenna Location	Antenna and Electronic Delay	Optics	Primary Beam
		NOP: Required for absolute amplitude and time-dependent phase distribution calibration.			NRP: Need to well-pointed for better SNR.	NRP: Antenna position errors will result in dipole position-dependent phase errors across the bandpass which will cause some deconvolution.	NRP: Needed for SNR.	NRP: Focus time at band (only amplitude errors in amplitude at higher freq).	NRP: Need to have PB response for proper amplitude calibration of extended objects (the primary).
	Amplitude Flux								
			NRP: Control for phase response of RF.		NRP: Need to well-pointed for better SNR.	NRP: Part of data analysis.	NRP: Needed for SNR.	NRP: Path length changes due to thermal deformation of optics independent of support.	
	Phase								
		NRP: Needs frequency dependence of atmospheric attenuation.	NRP: Phase calibration required for best RF calibration.		NRP: Need to well-pointed for better SNR.	NRP: Location errors will result in position-dependent phase errors across the RF. Off-band phase errors will be associated with different positions (and require) on the sky, leading to incorrect RF calibration.	NRP: Needed for SNR.	NRP: Tracking calibration to the optics cause a ripple pattern in frequency domain.	
	Bandpass								
			NRP: Phase calibration required for polarization calibration.		NRP: Need to well-pointed for better SNR.		NRP: Needed for SNR.	NRP: Effects of atmospheric optics with misalignment cause variable polarization character.	NRP: Need to have PB structure for proper polarization calibration.
	Polarization								
		NRP: Phase calibration required for pointing analysis.	NRP: Calibration of relative bandpass phases requires SNR.			NRP: Need good fringe tracking for good SNR.	NRP: Needed for SNR.	NRP: Optics misalignment brings focus-ripple between flux.	NRP: Need to measure the polarization beam.
	Pointing								
		NRP: Phase calibration required for antenna position analysis.	NRP: Calibration of relative bandpass phases requires SNR.		NRP: Need to well-pointed for better SNR.		NRP: Needed for SNR.	NRP: Misalignment effect caused by optics misalignment results in error in antenna location.	
	Antenna Location								
		NRP: Need to remove atmospheric phase errors.	NRP: Fringeless response, flat-topped spot sizes.					NRP: Fringeless response dependent upon optics focus.	
	Antenna and Electronic Delay								
		NRP: Need to remove atmospheric phase errors.	NRP: Calibration of relative bandpass phases requires SNR.		NRP: Need to well-pointed for better SNR.		NRP: Needed for SNR.		NRP: Unwanted systematic artifacts pattern when in radio-frequency misalignment.
	Optics								
		NRP: Phase calibration required for best PB measurement.	NRP: Control for frequency-dependent amplitude response.	NRP: For polarization to use atmospheric or corrections as well polarization calibration must be done first.	NRP: Need to well-pointed for better SNR and proper primary beam measurement (needed for imaging later).	NRP: Without measurements, subgratings for PB measurement.	NRP: Needed for SNR.	NRP: Optics must be subject for proper PB determination.	
	Primary Beam								

NOP = Necessary Observational Predecessor
NRP = Necessary Reduction Predecessor

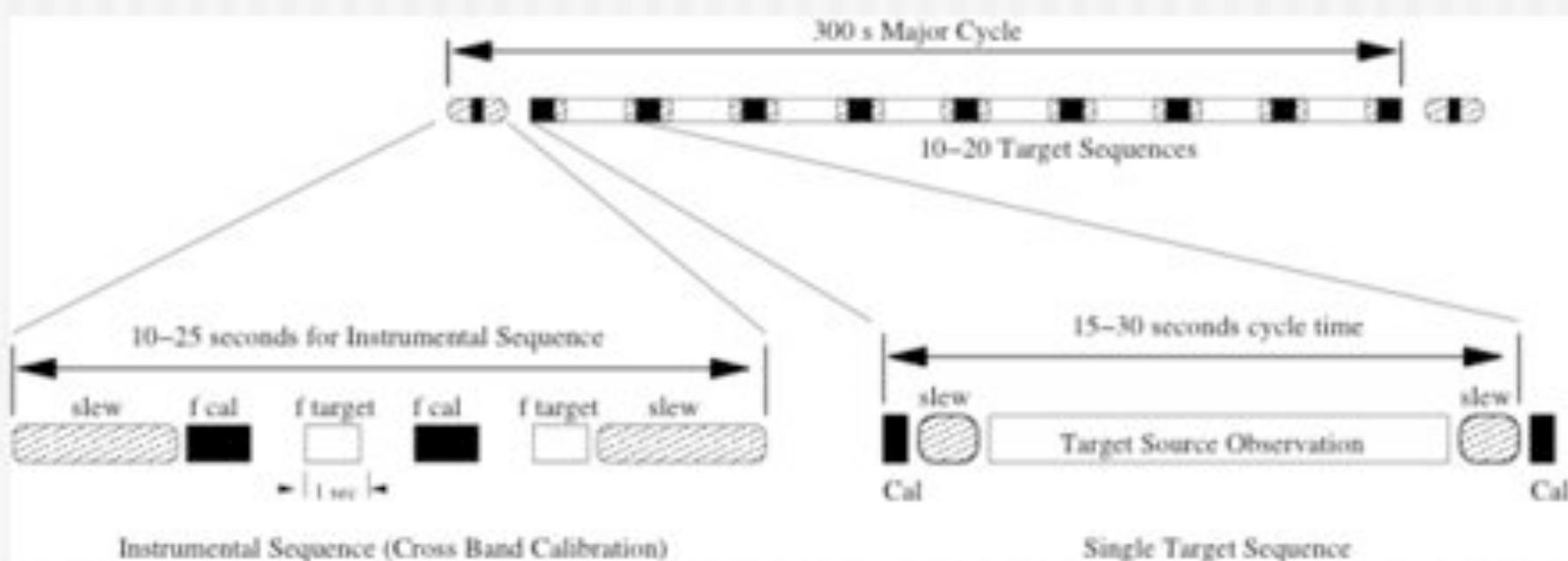
Calibration Matrix

	<i>Potential Predecessors</i>					
	Amplitude Flux	Phase	Bandpass	Polarization	Pointing	Antenna Location
Amplitude Flux		<i>NRF.</i> Required for absolute amplitude and time-dependent phase decorrelation calibration.			<i>NOF.</i> Need to well-pointed for correct amplitude scaling and better SNR.	<i>NRF.</i> Antenna position errors will result in sky-position-dependent phase slopes across the bandpass which will cause some decorrelation.
Phase			<i>NRF.</i> Correct for phase response of BP.		<i>NOF.</i> Need to well-pointed for better SNR.	<i>NRF.</i> Part of data analysis.
Bandpass	<i>NOF.</i> Derive frequency dependence of atmospheric attenuation.	<i>NRF.</i> Phase calibration required for final BP calibration.			<i>NOF.</i> Need to well-pointed for better SNR.	<i>NRF.</i> Location errors will result in position-dependent phase slopes across the BP. Different phase slopes will be associated with different positions (and sources) on the sky, leading to incorrect BP calibration.

Phase Calibration

- *Target Sequence:* Over a period of 15 to 30 seconds the following measurement sequence is observed involving the target and phase calibration source located typically less than or equal to 2 degrees away from the target source:
 1. Tune to the calibration frequency if cross-band calibration required.
 2. Phase calibrator measurement (tint \leq 1 second).
 3. Tune to the source frequency if cross-band calibration required.
 4. Target source measurement (tint \leq 25 seconds).
 5. Tune to the calibration frequency if cross-band calibration required.
 6. Phase calibrator measurement (tint \leq 1 second).
- *Instrumental Sequence:* This cycle of measurements is required for cross-band calibration of dual-frequency fast switching measurements. Over a period of 10 to 25 seconds a strong phase calibrator source which can be detected at both the target and calibration frequency is used to provide the phase scaling from the target (usually higher) frequency to the calibration (usually 90 GHz) frequency:
 1. Tune to calibration frequency.
 2. Phase calibrator measurement (tint \leq 1 second).
 3. Tune to target frequency.
 4. Phase calibrator measurement (tint \leq 1 second).
 5. Repeat this sequence.

Phase Calibration Sequence



Absolute Amplitude Calibration

- Research topic
- Absolute Amplitude Calibration Focus Group
 - Bryan Butler (NRAO)
 - Mark Gurwell (SAO)
 - Jack Welch (Berkeley)
- Charter:
 - Develop list of potential primary and secondary flux calibration sources
 - Planets (Mars, Uranus, etc.)
 - Asteroids
 - Stars (Main Sequence, Giant, Supergiant)
 - Large Ice Bodies (Titan, Galilean Satellites, Triton, etc.)
 - For each candidate define measurements or calculations required to define status as a primary or secondary flux calibrator
 - Initiate measurement program where appropriate (CARMA, SMA, ALMA, etc.)

Calibration and ALMA Operations

- **Operations/Maintenance Calibration**

- Pointing
- Polarization
- Antenna Location
- Antenna and Electronic Delay
- Optics
- Primary Beam

- **User Calibration**

- Reference Pointing
- Amplitude
- Phase
- Bandpass
- Polarization

Calibration and ALMA Operations

- How does calibration planning get incorporated into ALMA Operations? Example: Pointing
 - Pointing calibrator list development and maintenance
 - Calibrator database development currently underway
 - Coordination with similar efforts for EVLA/VLBA/GBT
 - Required interval
 - Monitoring requirements for antenna/array vital signs
 - Weather monitoring analysis and requirements
 - Antenna-based behavior and trends