

Test Interferometer Control Software Requirements

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1 Introduction

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1.1 Overview

The purpose of this document is to collect and summarize the software requirements for the ALMA Test Interferometer Control Software (TICS). This software will be developed as part of Phase 1 of the ALMA project.

The intended audience is project reviewers and software developers for ALMA TICS.

The Test Interferometer Control System software will be a prototype to guide the final (Phase 2) ALMA development in conjunction with the requirements being developed by the Science Software Requirements committee.

1.2 Scope

These requirements specifications are intended to cover the development and testing of the Test Interferometer which will comprise the two prototype antennas and a test correlator. The TI will also comprise a reasonable amount of interferometer electronics and photonics. The requirements are focused on the characterization of antenna performance both singly and in interferometric use. The software to be developed for the Test Interferometer is not intended for astronomical operational use.

For the purposes of this document, functional requirements are categorized as a feature list in each of the following areas:

- Telescope operations
- High Level Command Interface
- Timing and Synchronization
- Data Reduction

Further requirements for system-wide are expressed in the form of use cases for observing modes and calibration sequences.

2 Feature List

2.1 Telescope Operations

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2.1.1 General

2.1.1.1 Display handler

A display handler should provide user access to pre-built graphical displays of monitor data and simple control of instrumentation and antennas.

2.1.1.2 Observing scripts

Users may create and execute command scripts that are command line, command stream, or file based. Command streams are piped commands originating from sources such as external programs.

2.1.1.3 Logging System

The system shall provide a flexible, dynamic reporting system which includes errors and alarms. User commands shall also be logged. The logging system shall be capable of providing user feedback and data filtering. A log history shall also be kept.

2.1.1.4 Archive

Monitor points, calibration data and configuration data shall be archived in a database. The data shall be retained indefinitely.

2.1.1.5 Access

The system shall provide local and remote control of the TICS system.

2.1.1.6 Monitor

The system shall provide a means of monitoring hardware sub-system sampled data values.

2.1.1.7 Control

The system shall provide a means of configuring and controlling hardware sub-systems.

2.1.2 Configuration Database

A configuration database shall be provided which contains both default control values and a snapshot of the current control values. There should be a clear distinction in the database system between static values and snapshot values. It should also be easy to move values between the two classes.

Some calibration values and system properties shall also be stored in the database.

2.1.3 Initialization

The system shall be capable of restoring state based on logged monitor points and system commands. There shall be a choice of different initialization levels.

When the hardware control is rebooted, there are many values to be set at least to reasonable defaults. However, values such as T_{sys} (System Noise Temperature), focus offsets, delay offsets to T_{sys} and pointing offsets should be reasonably close to their values prior to the reboot and may not require resetting to default values. Other values such as front end voltage setting should match defaults well, but may have been tweaked by software to improve the signal.

There shall be different levels of initialization available which restore system state according to how lost the system is. These levels of initialization are elaborated in the following sections.

2.1.3.1 Cold Restart

Upon a such a reset, all default values are reloaded. In effect, the current state of the system is dumped and whole system state is reloaded.

2.1.3.2 Warm Restart

A warm restart performs a partial restore. Some defaults are reloaded, but important current values are restored from the value saved immediately prior to the restart. These values may have taken some time to determine or set up, and this set up time may be skipped by restoring the most recently used values.

Such current values are:

- Selected front end
- LO setup
- Down-converter setup
- Sky coordinates
- Mount offsets
- Doppler mode
- T_{sys}
- Focus offsets
- Delay offsets to T_{sys}
- Pointing offsets
- Correlator configuration
- Online, off-line and "not available" hardware configurations.

2.1.3.3 Device Self-tests

For hardware devices which have built-in testing, the software shall command such devices to perform power on self-tests. These tests will be performed on system initialization and by user command.

2.1.4 System Security and Privileges

For the TI control system, the model is that any user with a validated login may perform all control functions. The system will rely on operating system security levels for user login. Logins and windows associated with logins shall be logged.

2.1.5 Command System

The command system shall be able to accept control commands from a number of sources. Sources create command execution streams that run asynchronously, and users can control the streams. Sources are ASCII files or other software.

2.1.5.1 Built-in Command Interface

A command language interpreter (CLI) shall be provided. The following capabilities shall be available.

2.1.5.1.1 Multi-user control

The ability to run multiple parallel command streams as control threads sharing the TI resources is required. There is no resource locking for single users. Each user session may alter any component of the system. Note that the correlator may be shared by both antennas, but only one may control its configuration. Both antenna must use the same configuration, although they may be observing at different frequencies.

2.1.5.1.2 External command stream control

Scripts may be controlled externally as follows:

- Start: begin script execution
- Break: pause execution
- Continue: resume execution after a break
- Abort: process exceptions and terminate gracefully

2.1.5.1.3 Command stream deletion

After execution, scripts shall terminate and release allocated computing resources.

2.1.5.1.4 Command synchronization

Commands may be synchronized to events such as:

- Hardware alarms
- Completion of user initiated action
- Command invocation errors

2.1.5.1.5 Time

Command interfaces may refer to time in the following formats:

- External time: LST, UTC, TAI
- Relative delays and durations: seconds

2.1.5.2 Scripting language

2.1.5.2.1 General

The scripting language for the Test Interferometer will be used for both scientific and technical high level programming.

2.1.5.2.2 Command line interface

The scripting language must provide a CLI. This CLI must provide at least the following capabilities:

- logical operations on variables.
- macros for the abbreviation of frequently typed sequences
- tab completion of commands and file names

2.1.5.2.3 Programmability

The scripting language shall provide:

- The ability to define variables and aliases to control points
- Mathematical operations on variables and aliases
- Flow control and branching
- Tables. Tables help organize related parameters in a list and are useful for configuring common variations before executing an inner loop.
- The ability to define procedures as a collection of commands and function and procedure calls
- Argument passing

2.1.5.2.4 Script execution logging

Script name and contents shall be logged upon invocation. All Built-in commands and script commands are logged during execution.

2.1.5.2.5 Script validation

There is *no* requirement to validate scripts prior to execution.

2.1.6 User Interface

2.1.6.1 General

2.1.6.1.1 Platform independence

Platform independent GUIs shall be provided. It is expected that operator GUIs shall use X windows (from Linux) and some engineering GUIs will be Windows based.

2.1.6.1.2 Screen printing

A "print screen" facility shall be provided to capture a screen image into a file or to a printer.

2.1.6.1.3 Cut and paste

Information transfer shall be provided between windows and applications.

2.1.6.1.4 GUI creation

It shall be possible for users to build GUI displays.

2.1.6.1.5 Display over the network

Displays and control shall be possible over network links.

2.1.6.2 Operator Displays

2.1.6.2.1 Monitor and Control

Parameters, configurations, monitor and control points shall be displayed and shall use a hierarchical decomposition. It shall be possible to edit control points and monitor characteristics.

Monitor data may also be displayed with a multi-channel chart recorder and scatter plots. That is, any monitor value may be plotted against any other monitor value, or against time.

2.1.6.2.2 Scripting interface window

This window shall provide:

- a command editor capable of creating and modifying command scripts
- observing script control
- command entry CLI

2.1.6.2.3 Message window

A message window shall display log entries, error messages and alarms. The message display shall be persistent and able to be purged. It shall contain a scrollable buffer and provide filtering based on selectable time ranges and message types.

2.1.6.2.4 Errors and Warnings

Errors and warnings at user specified levels shall be archived. Errors and warnings vary in degree. Some high level errors are results of low level errors; to reduce error cascades, the error system needs to produce a single error message for the root cause of the error.

The system shall be monitored for error conditions:

- Hardware crashes such as no response.
- Monitor points fault conditions - see under **monitor points**.
- Communication failures.
- Software status reports

Alarm reports shall be described by rules.

Off-line or not available sub-systems shall not generate alarm messages. Access attempts to off-line or not available systems shall nevertheless produce alarms.

The cause of an alarm shall be available when the alarm is queried.

The alarm system shall be dynamically configurable. It shall be possible to turn off alarm generation at specific points.

2.1.6.2.5 Observing status window

An observing status window shall display the following information:

- Source information
- Frequency band
- Visibility (baseline data)
- Doppler tracking
- Correlator configuration
- Subreflector position/motion
- Position of calibrating system
- Integration status : number of integrations in observation obtained/total), integration time current/total

2.1.6.2.6 On-line catalog browser

A browser shall provide the ability to edit and build source catalogs. Source entries may be filtered by sky position (RA and DEC), name, red and blue optical magnitude, radio strength (flux by band).

It shall be possible to find the closest astronomical reference. Optical and radio versions of this should be available.

A number of catalogs are needed for setting frequencies and positions.

On-line catalogs shall include:

- Calibration sources
- Astronomical objects
- Line Frequencies

On-line catalogs shall support these features:

- Searchable database
- Integrated into the software such that information about the selection can be transferred into other applications.

2.1.6.2.7 Data viewer window

A data viewer window shall display spectra, total power and other real-time uncalibrated data products. Pointing observation data (both optical and radio) shall also be available for graphical display.

2.1.6.2.8 AZ/EL plot window

This window shall display the sky as an AZ/EL plot with the following optional display items:

- Source trajectory.
- For the selected telescope, commanded position, current position and cable wrap status.
- Position of the sun, moon and a configurable set of calibration planets.
- Position of top of holographic tower as seen from each antenna

2.1.6.2.9 Meteorology display

A meteorology window shall display the current wind vector, water vapor radiometry and phase meter.

2.1.6.3 Engineering Displays

The purpose of engineering displays are for quick look views of equipment status. Detailed hardware-specific displays are the responsibility of the engineering groups.

2.1.6.3.1 Front Ends

- Mixer bias voltages
- Power supply status
- Mixer current
- Mixer IF power

2.1.6.3.2 First Local Oscillators

- Lock status
- Photo-detector current

2.1.6.3.3 Cryogenics

- Status
- System pressures
- Cryogenic temperatures

2.1.6.3.4 Correlator

- State
- Current configuration
- Monitor data
- Digitizer reference levels

The test correlator software shall record alarms, errors and warnings corresponding to the operation of the test correlator hardware or the test correlator computer. A reporting mechanism for these errors shall exist making them available to external computer systems as needed.

2.1.6.3.5 Round-trip phase correction

- Path length vs time

2.1.6.3.6 Tracking/drive system

- Tracking error strip chart
- Motor currents, torques

2.1.6.3.7 Second Local Oscillators

- Laser temperatures

2.1.6.3.8 Downconverter

TBD

2.1.6.3.9 Secondary and nutator

- Position

2.1.6.3.10 Digital Data Transmission

- Laser temperatures
- Synchronization status

2.1.6.3.11 Total Power Data Chain

- Graphical display of data path with instantaneous total power

2.1.6.3.12 Calibration Load

- Prime focus calibration system status

2.1.6.3.13 Holography

TBD

2.1.7 Monitor System

2.1.7.1 Monitor points

2.1.7.1.1 Unique identifiers

Unique identifiers shall identify all monitor and control points. These identifiers shall be human-readable and related to the physical location of the monitor point.

2.1.7.1.2 Recording

Monitor data may be recorded at either its natural rate (see the monitor and control list, *Monitor and Control Points for the MMA*), or it may be sampled at a faster rate, or suppressed altogether.

The default is to archive all monitor data at its natural rate. Archiving implies persistent storage.

2.1.7.1.3 Retrieval

Monitor data shall be easy to access by a unique name and time range from the persistent storage. It shall also be possible to retrieve all monitor data from a certain device or a device and all sub-devices, like all monitor data from a certain antenna.

2.1.7.1.4 Monitor data quality

The following fault conditions affecting monitor data shall be detected:

- Transmission errors, including loss of transmission
- Failed hardware.

2.2 High Level Command Interface

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High level commands shall be used to control the array through the script interpreter. These commands are bound to distributed objects via a CORBA interface. The commands shall also be accessible programmatically through CORBA. Some of these commands modify the state of the control session and this state will be mapped onto properties of the control session so that the current values will be available to other routines and so that the current values can be made persistent in the configuration database.

Many commands have an AntennaNumber parameter that specifies which antennas to apply the command. This parameter contains a vector of antenna numbers, with a value of zero indicating all antennas.

Many of the commands are simple and map to a limited manipulation of the hardware. Other commands initiate more complex sequences representing observing modes or calibrations. A subset of the commands is supplied solely for the purpose of debugging the test interferometer.

All commands are blocking and will hold the script interpreter until complete. The commands may be classified according to their time duration as *interactive* or *long*. Interactive commands should complete on timescales appropriate for human interaction, a few tenths of a second. Long duration commands can extend for many minutes before completing, and are distinguished in the following command list by a trailing asterisk (*).

Some of the following commands initiate data collection of total power values. When total power data is recorded, all of the total power values (front end and downconverters) for the selected band will be recorded.

Some commands return values, including data. The return values can be used to build powerful and versatile scripts.

Some of the commands refer to the receiver bands by name using the following convention:

B40: 31.3-45 GHz (Band1)
B100: 83-116 GHz (Band3)
B240: 210-270 GHz (Band6)

2.2.1 Help System

A help system shall be an integral part of the high level commands. The help system shall include the full syntax for each command, including argument datatypes and units, and a detailed technical description of the command. It shall be possible to sort and search commands by different categories and keywords, including command duration. The help contents will be embedded in the code, IDL, or script that defines the commands and

automatically used to build the help system to facilitate keeping the help system in sync with the code.

2.2.2 Monitor and Control Point Access

All the monitor and control points have simple *get()* and *set()* interfaces that are wrapped by the GetMC and SetMC commands described below in the Basic Commands section to provide high level access. These commands will make available monitor items such as mount coordinates (requested and actual), wind, temperature, and allow access to all control points.

2.2.3 Basic Commands

These commands implement limited manipulation of the hardware or are fundamental building blocks for yet higher level commands. They do not include commands that will be implemented as scripts or that implement Observing Modes. These will be described in subsequent sections.

2.2.3.1 AcquiredTolerance

Sets tracking acquisition tolerance that is used to determine if tracking is in error.

Return: None

Params:

AntennaNumber: Antenna number

Tolerance: Tracking error tolerance for acquisition, in arcseconds on the sky

2.2.3.2 ApertureEfficiency

Sets aperture efficiency used for conversion of antenna temperature to flux.

Return: None

Params:

B40: Conversion for B40 in Janskys/Kelvin

B100: Conversion for B100 in Janskys/Kelvin

B240: Conversion for B240 in Janskys/Kelvin

2.2.3.3 ArtificialDelays

Set up artificial delay rates and offsets. Useful for debugging and testing. Not used unless enabled by the DelayControl command. See also DelayControl.

Return: None

Params:

AntennaNumber: Antenna number (zero not allowed).

Rate: Artificial delay rate in nanoseconds/sec.

Offset: Artificial delay offset in nanoseconds.

2.2.3.4 ArtificialFringes

Set up artificial fringe rates and offsets on top of other fringe rate controls. Useful for debugging and testing. Not used unless enabled by the FringeControl command. Could be implemented directly by the device.

Return: None

Params:

AntennaNumber: Antenna number (zero not allowed).

Rate: Artificial fringe rate in Hz.
Offset: Artificial fringe offset in turns.

2.2.3.5 AzEl

Points the antenna(s) at the requested Az/El in the Horizon coordinate system. See also RaDec, Track.

Return: Estimate of time to acquire new position.

Params:

AntennaNumber: Antenna number
Azimuth: Azimuth, null means don't change.
Elevation: Elevation, null means don't change.

2.2.3.6 BandSelect

Chooses the current receiver band. The band is put on axis by setting the radio beam offsets to the values of the band specific properties in the configuration database. The local oscillator is also switched to feed this band. See also RadioCoefficients.

Return: None

Params:

Select: Chooses from B40, B100, B240.

2.2.3.7 BeamSwitchIntegrate*

Takes single dish beam switched (nutated) integration data with the correlator and/or total power as selected by an input parameter. The nutator is automatically turned on at the start and turned off at the end of the integration.

Return: An object containing the normalized differenced results ((ON-OFF)/OFF), the ON, and the OFF values over all cycles.

Params:

Type: Selects between auto-correlation plus total power or total power only.
DwellTimeOn: Sets dwell time of each OnSource position in seconds.
DwellTimeOff: Sets dwell time of each OffSource position in seconds.
NumberOfCycles: Number of complete cycles of the beam switch pattern to do.
BeamPattern: An array of offset position triples (AZ, EL, on/off) to define the beam switchings.
CorrelatorParams: All correlator configuration parameters, with sensible defaults.

2.2.3.8 CalibrationLoad

This assumes a three position vane which is one of two calibration options currently being considered for temperature (amplitude) calibration. This should map directly to a device controller.

Return: None

Params:

AntennaNumber: Antenna number.
Position: Selects from one of three positions: sky, ambient, cal.

2.2.3.9 CelestialPoleCoefficients

IERS polar wobble terms to be used as input to the mount interface and CALC. These terms may also be updated automatically using this interface by a program directly accessing IERS or from a file previously transferred from IERS.

Return: None

Params:

MJD1: Date and time of first offsets.
X1: Pole x offset at MJD1.
Y1: Pole y offset at MJD1.
MJD2: Date and time of second offsets.
X2: Pole x offset at MJD2.
Y2: Pole y offset at MJD2.

2.2.3.10 DelayOffset

The offset in nanoseconds to be added to the geometric delay. These will be added into the delay model produced by the DelayServer before it is sent to the correlator. See also DelayControl.

Return: None

Params:

AntennaNumber: Antenna number (zero not allowed).
Offset: Delay offset in nanoseconds.

2.2.3.11 DelayControl

Selects mode of delay tracking. The default mode is Tracking, but the other modes are useful for debugging. In Tracking mode, the DelayOffsets are added to the delay model gotten from the DelayServer. In Artificial mode, the DelayOffsets and delay model calculations are ignored. When NotTracking, only the DelayOffsets are used. See also ArtificialDelay, DelayOffsets.

Return: None

Params:

Mode: Selects delay tracking mode to Tracking, NotTracking, or Artificial.

2.2.3.12 Doppler

Specifies the Doppler correction parameters. See also Track.

Return: None

Params:

VelocityReferencePosition: Direction to use to calculate velocity. This should be a source obtained from the catalog. If line length stabilization is not used and if the LO cables to the antennas are a different length then the TI interferometric phase will be a function of frequency and the interferometer phase will change with the Doppler correction to different parts of the sky. If this is the case, Doppler tracking must be done on a single source (position), if not then the source can be the one currently being observed. See also Frequency.
Velocity: Velocity to use for Doppler calculation in km/sec.
VelocityReferenceType: Reference frame of specified velocity: radial (geocentric), topocentric, LSR, heliocentric.
VelocityCalculationType: Optical convention, radio convention, relativistic.

2.2.3.13 FringeControl

Controls states of fringe control algorithms for debugging. There may be other parameters to control the phase switching algorithm selection. Could probably also be implemented directly by the device. See also ArtificialFringes.

Return: None

Params:

RateType: Selects between stopped fringe rate (default) and natural fringe rate.
Artificial: Turns on or off (default) the artificial fringe feature for testing and debugging (see ArtificialFringes).
Quadrature: Turns on or off the 90 degree quadrature phase switching.
SignSwitching: Turns on or off the 180 degree phase switching.

2.2.3.14 FrequencySetup

Sets up all local oscillators. Should automatically do a BandSelect based on the requested frequency. See also Doppler, BandSelect.

Return: None

Params:

Frequency: Rest frequency of final LO.
ManyOtherParameters: These may include harmonic numbers or hints on how to resolve ambiguities in the oscillator settings.

2.2.3.15 FreqSwitchIntegrate*

Takes single dish frequency switch integration data (auto-correlations) with the correlator.

Return: None

Params:

DwellTime: Duration of integration in a single frequency, in seconds.
NumberOfCycles: Number of complete frequency switched cycles
FreqSwitchParams: Define the frequency switching pattern.
CorrelatorParams: All correlator configuration parameters, with sensible defaults.

2.2.3.16 GetMC

Gets the value (property) of a monitor and control point. This gives the capability to read the value of any hardware in the system.

Return: The value of the property.

Params:

ControlPoint: Full hierarchical control point name.

2.2.3.17 GetTime

Gets the current time.

Return: An object containing the current time in UT, TAI, and LST.

Params:

None

2.2.3.18 Holography*

Takes a set of holography data.

Return: None

Params:

Action: AcquirePhaseLock, Go, Abort.
HolographyParameters: Parameters used for holography (FIXME).

2.2.3.19 Integrate*

Takes simple integration data with the correlator, either auto-correlations or cross-correlations. A series of integrations are recorded.

Return: An object containing the last data taken.

Params:

Type: Choose between auto and cross spectra.
IntegrationTime: Duration of a single integration.
NumberOfIntegrations: Number of integrations in the series.
CorrelatorParams: All correlator configuration parameters, with reasonable defaults.

2.2.3.20 Log

Place text directly into the observing log. Message will be tagged with the time and the userid of the person submitting the command.

Return: None

Params:

Text: Text to be place in the log.

2.2.3.21 MakeNewFITSfile

Close the old data file and create a new one. Named by start date and time.

Return: None

Params:

None

2.2.3.22 MeasureOpticalCentroid*

Instruct the optical camera to measure and record the star centroid. This should map directly to a device controller.

Return: Offsets of the centroid.

Params:

AntennaNumber: Antenna number

2.2.3.23 MountCoefficients

Pointing coefficients for the mount bore sight. These should not change very often. Coefficients for the receiver bands and optical camera are carried on top of these. See OpticalCoefficients and RadioCoefficients.

Return: None

Params:

AntennaNumber: Antenna number

C1: First coefficient.

....

Cn: Last coefficient.

2.2.3.24 NutatorProgram

Controls the nutator use of stored program – used for debugging and development. The check program feature of the nutator is always called after the nutator program is loaded and the result of the check is used as the return value. This command should map directly to a device controller. See also NutatorMove and BeamSwitchedIntegration.

Return: Boolean (check OK = true, check failed = false).

Params:

AntennaNumber: Antenna number

Action: Action to take for the current program: Start, Stop, Abort, Stow.

Load: Program – an array of triples representing Position, SettleTime, DwellTime. A null array means use previously loaded program.

2.2.3.25 NutatorMove

Controls the position of the nutator – used for debugging and development This command should map directly to a device controller. See also NutatorProgram and BeamSwitchedIntegration.

Return: None

Params:

AntennaNumber: Antenna number
Position: Offset position for nutator.

2.2.3.26 Offsets

Position offsets. These are transient offsets on top of the mount, radio and optical coefficients and the radio or optical offsets. They are used to offset the pointing and phase center from the catalog source position.

Return: None

Params:

AntennaNumber: Antenna number
CoordSystem: RA/Dec or Az/El.
Offsets: RA/Dec or Az/El offset.

2.2.3.27 OpticalCamera

Control the optical camera. This should map directly to a device controller.

Return: None

Params:

AntennaNumber: Antenna number
State: Turn on or off.
Filter: Select filter.
Lenscap: Make aperture open or covered.

2.2.3.28 OpticalCoefficients

Pointing coefficients for the optical camera relative to the mount bore sight representing a collimation error and a sag term. Should be relatively constant. There are three coefficients: AzOffset, ElOffset, CosEl. The units of all coefficients are arc seconds. See also MountCoefficients, OpticalCoefficients.

Return: None

Params:

AntennaNumber: Antenna number
OffsetAz: Azimuth offset (on the sky: $\Delta Az = \text{coeff}/\cos(\text{el})$).
OffsetEl: Elevation offset.
CosEl: Cosine elevation (sag) term ($\Delta El = \text{coeff} * \cos(\text{el})$)

2.2.3.29 OpticalOffsets

Offset of the optical camera relative to the mount bore sight. May change on short time scales. Could be modified by a closed loop with MeasureOpticalCentroid. Systematic changes in these offsets should be reduced and used to set the OpticalCoefficients. See also MountCoefficients, OpticalCoefficients.

Return: None

Params:

AntennaNumber: Antenna number

Offset: Az/El offset.

2.2.3.30 PositionSwitchIntegrate*

Collect position switched data in auto-correlation or total power.

Return: An object containing the normalized differenced results ((ON-OFF)/OFF) over all cycles.

Params:

Mode: Selects between auto-correlation plus total power or total power only.

DwellTimeOn: Duration of integration in a single position, single cycle, of on source.

DwellTimeOff: Duration of integration in a single position, single cycle, of off source.

NumberOfCycles: Number of complete cycles in the whole procedure.

Positions: Defines the positions in the cycle

CorrelatorParams: All correlator configuration parameters, with sensible defaults.

2.2.3.31 PreTrack

Checks position of the requested source but does not change the position of the antenna(s). Also optionally sets the LO to the Doppler shifted frequency. Assumes the existence of a source catalog that can be accessed by source name which will contain positions. Several preset Az/El positions are also included. See also Track.

Return: Azimuth, elevation, RA, Dec, and estimate of time to acquire new position.

Params:

AntennaNumber: Antenna number

Source: Source name from the catalog or one of the special positions HolographyTransmitter, MaintenanceStow, EmergencyStow, Zenith, etc..

2.2.3.32 RaDec

Point the antenna(s) at the requested J2000 Right Ascension and Declination. Some of the parameters are exposed for debugging and would default for normal operation. The source catalog will normally be used instead of this command. See also AzEl, Track.

Return: None

Params:

AntennaNumber: Antenna number

RA: Right ascension.

Dec: Declination.

RA: Right ascension proper motion (arcsec/year).

Dec: Declination proper motion (arcsec/year).

MeanPosition: Flag that indicates whether position is mean or apparent, defaults to mean.

Parallax Correction: Parallax correction for nearby objects. Defaults to zero.

2.2.3.33 RadioCoefficients

Pointing coefficients of the different receiver bands camera relative to the mount bore sight, representing a collimation error and a sag term. Should be relatively constant. There are three coefficients: AzOffset, ElOffset, CosEl. The units of all coefficients are arc seconds. See also MountCoefficients, OpticalCoefficients.

Return: None

Params:

AntennaNumber: Antenna number

OffsetAz: Azimuth offset (on the sky: $\Delta Az = \text{coeff}/\cos(\text{el})$).

OffsetEl: Elevation offset.

CosEl: Cosine elevation (sag) term ($\Delta El = \text{coeff} * \cos(\text{el})$)

Return: None

Params:

AntennaNumber: Antenna number
B40OffsetAz: Azimuth offset (on the sky).
B40OffsetEl: Elevation offset.
B40CosEl: Cosine elevation term.
B100OffsetAz: Azimuth offset (on the sky).
B100OffsetEl: Elevation offset.
B100CosEl: Cosine elevation term.
B240OffsetAz: Azimuth offset (on the sky).
B240OffsetEl: Elevation offset.
B240CosEl: Cosine elevation term.

2.2.3.34 RadioOffsets

Common offset of all receiver bands relative to the mount bore sight. Might change on short time scales. Used to transfer pointing in one band to another. Units are arc seconds. See also MountCoefficients, RadioCoefficients.

Return: None

Params:

AntennaNumber: Antenna number
AzOffset: Azimuth offset (on the sky).
ElOffset: Elevation offset.

2.2.3.35 SecondaryPosition

Controls the position of the secondary mirror. If focus curve tracking is implemented it can be turned on and off. The focus curve is implemented as an increment to the nominal best focus position. The tilt/rotation parameters are ignored for the EIE antenna. This should map directly to a device controller.

Return: None

Params:

AntennaNumber: Antenna number
Tracking mode: Sets to track or not track Z distance as a function of elevation.
Xposition: Secondary X axis position in millimeters.
Yposition: Secondary Y axis position in millimeters.
Zposition: Secondary Z axis position in millimeters (nominal center of tracking focus).
Xtilt: Secondary tilt angle in X coordinate (Vertex only).
Ytilt: Secondary tilt angle in Y coordinate (Vertex only).
Zrotation: Secondary rotation in Z coordinate (Vertex only).

2.2.3.36 SetMC

Sets the value (property) of a control point. This gives the capability to change any hardware in the system.

Return: None

Params:

ControlPoint: Full hierarchical control point name.
Value: Value to be set into the hardware (there are data type issues here that need to be resolved).
Time: UT time to set the parameter, defaults to immediate.

2.2.3.37 SidebandSelect

Controls separation or suppression of sidebands.

Return: None

Params:

Sideband: Choose from UPPER, LOWER, or BOTH.

2.2.3.38 SidebandRatio

Set receiver band sideband ratio for any bands with a backshort (both polarizations). This is to be used for calibrating data. B40 has a sideband ratio that is always unity.

Return: None

Params:

AntennaNumber: Antenna number (zero not allowed).

B100hor: Sideband ratio.

B100vert: Sideband ratio.

B240hor: Sideband ratio.

B240vert: Sideband ratio.

2.2.3.39 Sleep*

Sleep for the requested time period. Python may already provide this. If not, we need it.

Return: Time slept.

Params: Sleptime: amount of time to sleep, in seconds

2.2.3.40 Stop*

Immediately stops tracking. See Track.

Return: None

Params:

None

2.2.3.41 Stow*

Sends antenna to MaintenanceStow position. Implemented for convenience. See also Track.

Return: None

Params:

None

2.2.3.42 SubsystemState

Enables and disables different subsystems.

Return: None

Params:

AntennaNumber: Antenna number (zero not allowed).

Action: Enable or disable.

Subsystem: Subsystem name (FrontEnd#n, Mount, LO, IFtransmission).

2.2.3.43 TotalPower*

Record a series of total power integrations on the front end detector. The integrations are boxcar integrals of the 2 msec data samples.

Return: Vector of integration results.

Params:

AntennaNumber: Antenna number

IntegrationTime: Boxcar integration time in multiples of 2 msec.
NumberOfIntegrations: Number of integrations to take.

2.2.3.44 Track

Point the antenna(s) at the requested source. Also optionally sets the LO to the Doppler shifted frequency. Assumes the existence of a source catalog that can be accessed by source name. The catalog will contain positions, distances, proper motions, and velocities or point to ephemeris files containing the same information as a function of time. Proper motion and parallax will be automatically applied in computing the apparent positions. Several preset Az/El positions are also included. See also AzEl, Doppler, RaDec, Stop, Stow.

Return: Estimate of time to acquire new position.

Params:

AntennaNumber: Antenna number
Source: Source name from the catalog or one of the special positions HolographyTransmitter, MaintenanceStow, EmergencyStow, Zenith, etc.
DopplerSelect: Chooses a source for the information for the Doppler calculation. Choices are:
Catalog: Use the velocity from the catalog or ephemeris (default).
DontChange: Don't make a change to the current velocity and type.
InputFollows: Use the velocity input from the parameters that follow.
VelocityReferencePosition: Direction to use to calculate velocity. This should be a source gotten from the catalog. If the TI phase is not a function of frequency (don't know yet if that is the case), then the source can then be the one currently being observed. See also Frequency.
Velocity: Velocity to use for Doppler calculation in km/sec.
VelocityReferenceType: Reference frame of specified velocity: radial (geocentric), topocentric, LSR, heliocentric.
VelocityCalculationType: Optical convention, radio convention, or relativistic.

2.2.3.45 UTcorrection

UT1 minus UTC correction from IERS. Needed by mount and CALC. These terms may also be updated automatically using this interface by a program directly accessing IERS or from a file previously transferred from IERS.

Return: None

Params:

MJD: Date of correction.
UT1minusUTC: In seconds.
DerivativeUT1minusUTC: In seconds per day.

2.2.3.46 Wait*

Wait for an absolute time.

Return: None

Params:

Type: Selects LST, UT, or TAI.
Time: Time at which the wait completes.

2.2.3.47 WaitAll*

Wait until the antenna(s) have satisfied the conditions for WaitCalibrationVane, WaitMount, WaitNutator, and WaitSecondary. See also AcquiredTolerancet.

Return: None

Params:

AntennaNumber: Antenna number

2.2.3.48 WaitCalibrationVane*

Wait until the calibration vane is in the requested position. See also WaitAll.

Return: None

Params:

AntennaNumber: Antenna number

2.2.3.49 WaitMount*

Wait until the antenna(s) are tracking a new position and the tracking error is below the acquisition limit. See also AcquiredTolerance.

Return: None

Params:

AntennaNumber: Antenna number

2.2.3.50 WaitNutator*

Wait until the nutator has acquired the requested position. See also WaitAll.

Return: None

Params:

AntennaNumber: Antenna number

2.2.3.51 WaitSecondary*

Wait until the secondary is not moving. See also WaitAll.

Return: None

Params:

AntennaNumber: Antenna number

2.2.4 Observing Mode Commands

Observing modes are high level constructs that define the use of the instrument by the end users. Some are implemented with an interface directly available to the interpreter and are given here, while others are implemented as scripts and are described in the next section. The details will be defined by the ALMA SSR Committee Use Cases (in preparation) and are currently not completely defined so the parameters are unknown.

2.2.4.1 Point

Interferometric: Measure pointing offsets of the current receiver band

Return:

Params:

2.2.4.2 Spoint

Single dish: Measure pointing offsets of current receiver band

Return:

Params:

2.2.4.3 OTFmapping

Single dish: On the fly mapping.

Return:

Params:

2.2.4.4 PSmapping

Single dish: Position switched mapping.

Return:

Params:

2.2.4.5 BSmapping

Single dish: Beam switched (nutator) mapping.

Return:

Params:

2.2.5 Calibration Sequence Commands

These calibration sequences are implemented in code with the interface provided by these commands.

2.2.5.1 Tilt

Measure tilt meter offsets by rotating the antenna at least 180 degrees in azimuth.

Return: Object containing tilt meter offsets.

Params:

AntennaNumber: Antenna number.

2.2.5.2 TipCurve

Perform a tipping curve and estimate the zenith opacity from the data. Returns opacity estimate for all three bands, both polarizations.

Return: Object containing measured opacity in all bands.

Params:

AntennaNumber: Antenna number.

2.2.6 Calibration Sequences Implemented by Scripts

2.2.6.1 Optical pointing calibration session

Measure full sky pointing constants with optical camera.

2.2.6.2 Pointing calibration session

Measure full sky pointing constants in the radio, using either single dish or interferometric mode.

2.2.6.3 Baseline calibration session

2.2.6.4 Delay calibration session

2.2.6.5 Interferometric holography

2.2.7 Correlator Setup Parameters

Several of the commands described in the earlier sections accept a CorrelatorParameters as input. See the correlator design document at :
http://www.alma.nrao.edu/development/computing/docs/joint/draft/ALMA_TestCorrelatorDesign.pdf
for the parameters.

2.2.8 Tracking Patterns

Several of the commands described in the earlier sections accept a TrackingPattern as input. The possible patterns are:

Arc: A section of circular arc on the celestial sphere
Raster: A rectangular raster pattern
Spiral: A spiral pattern

2.3 Timing and Synchronization

M. Brooks

Last Changed: 2000-10-07

All sub-systems requiring precise synchronization including real-time computer systems shall have access to the pervasive 48ms Timing Event (TE). Array time is maintained in the control system and is synchronized to these Timings Events.

Sub-systems requiring synchronization are:

- Correlator
- Phase switching and fringe rotation
- Nutator
- Antenna motion
- Total power
- Holography

The accuracy and resolution of the TEs and the delivery of control and monitor transactions to synchronized devices is given in ALMA Memo #298, Timing and Synchronization, Larry R. D'Addario, 13 March 2000.

2.4 Data Reduction

R. Lucas

Last Changed: 2000-11-27

2.4.1 General

The goal of the test interferometer is to test the prototype antennas. There is no need for sophisticated astronomical analysis software. As a consequence the approach is not to develop new software but to re-use existing software which had been developed for IRAM instruments (30-m, Plateau de Bure Interferometer).

The optical pointing data processing (see ALMA memo 288) is not in the scope of this document. Optical pointing determination software will be based upon existing NRAO 12m software and the pointing analysis will be done using the TPOINT software of P. Wallace.

2.4.2 File Format

Science data from the Test Interferometer shall be read in the form of FITS files, written by the Test Interferometer Software. The format of those files is described in a separate document. These files include:

- General header data
- Total power data from one or two antennas
- Autocorrelation data from one or two antennas
- Correlation data.
- Single Dish holography data.
- Data associated parameters

2.4.3 Calibration Data

Convert all data to T_a^* scale using the receiver calibration system (TBD: ambient temperature vane ?)

2.4.4 Science Data

Plot science data (frequency averaged correlation or autocorrelation, total power) as a function of monitor data present in the raw data file, including time, antenna position offsets, ...

Plot time-averaged correlation or auto correlation data versus channel number, frequency, velocity.

2.4.5 Antenna Position Offsets

Solve for antenna position offsets and axes offsets using phase data on calibrators all across the sky.

2.4.6 Residual Delay Offsets

Solve for residual delay offsets by fitting, to phase data on a strong calibrator, a linear dependence of phase as a function of frequency.

2.4.7 Pointing Measurements

Process pointing measurements in various modes, to obtain pointing offsets in antenna frame:

- interferometric pointing: crossed scans and five-point scans using correlator data averaged over all channels (for continuum sources) or a specified frequency window (for maser lines).
- total power pointing: crossed scans using unswitched total power (detector) data.
- pseudo-continuum pointing: crossed scans or five-point scans using the difference data from two specified frequency windows in autocorrelation mode (for maser lines).
- beam-switched pointing: crossed scans(?) or five-point scans using the difference from the on-source and off-source positions of the nutator.

The output of these scans shall be written in a format to be read by TPOINT.

2.4.8 Focus Measurements

Process focus measurements in various modes, to obtain pointing offsets in antenna frame:

- interferometric focus scans (3, 5 points ?) using correlator data averaged over all channels (for continuum sources) or a specified frequency window (for maser lines).
- total power focus scans using total power (detector) data.
- pseudo-continuum focus scans using the difference data from two specified
- frequency windows in autocorrelation mode (for maser lines).
- beam-switched focus scans using the difference from the on-source and
- off-source positions of the nutator.

2.4.9 Single-dish Holography

Reduction of Single-dish holography maps. These use the dedicated holography receiver at the prime focus and the transmitter on a specially built tower on the VLA site. The data reduction has been described at the Holography CDR (2000-10-10 in Tucson).

2.4.10 Interferometric Holography

Reduction of interferometer holography maps, using SiO maser sources. Data reduction is identical to that of Single-dish Holography, minus the near-field corrections.

2.4.11 Spectral Plots

Plot ON-OFF spectra, as a function of frequency.

2.4.12 On-the-Fly Mapping

Reduction of single-dish beam maps on celestial sources (planets) obtained in OTF mode, using total-power data or correlator data (pseudo-continuum mode)

3 Non-functional requirements

M. Brooks

Last Changed: 2001-01-14

3.1 Efficiency

3.1.1 Lost Observing Time

Lost observing time due to overhead within the control system software shall amount to no more than 5%.

3.1.2 Boot Time

The boot-up for the entire system shall be 5 minutes or less.

3.1.3 Failure

Failures attributable to software shall be limited to no more than 4 per day.

3.2 Security and Privacy

Control and monitoring of the TI from off-site shall require a login to the system. Standard NRAO security practices shall be observed for such access.

User access to comparison data between two prototype antennas shall be strictly controlled? Need to check with Jeff Kingsley here.

3.3 Safety

No safety critical factors will be handled by the TI control software. All safety interlocks shall be performed by hardware.

3.4 Environmental

The TI will be constructed at the VLA site at 2124m at the Plains of San Augustin. Both the correlator and central building systems will be maintained in a temperature controlled environment. All antenna-based computer systems shall be housed in environmentally controlled cabinets on azimuth platform, or in receiver cabin.

Effective temperature ranges for computer systems: 0 - 50 C.

CAN interface hardware which may be mounted externally: -20 – 70 C.

3.5 Hardware

The following hardware constraints are required:

- Embedded real-time systems are Motorola MVME 2700 SBCs
- X86 hardware for Linux and windows systems
- ATM transmission systems

3.6 Software

Commercial operating systems shall be used in all systems. These will comprise:

- VxWorks
- Linux
- Windows NT

3.7 Communications

The distance from the central control building to the antennas is less than 300m. The communications systems tested should be able to support the 25 km antenna distances envisaged for the final array.

Monitor and control data rates amount to less than 10 kBps per antenna.

Commercial communications equipment shall be used wherever possible.

It shall be possible to prioritize and allocate bandwidth within the communication system so as to give Control System traffic quasi-deterministic transmission and response latencies between the central control building and the antennas.

Voice over IP microphones and web cameras shall also be situated on the antennas and shall be supported within the TICS communications system.

4 Top-Level Use Cases

R. Lucas, M. Brooks

Last Changed: 2001-01-14

4.1 Observing Modes

4.1.1 Single Field Interferometric

4.1.2 Single Dish On-the-Fly Total Power Mapping

4.1.3 Position Switched Total Power Mapping

4.1.4 Single Dish Beam Switched Total Power

4.1.5 Single Dish Autocorrelation

4.2 Calibration and Engineering

4.2.1 Single Dish Holography

Use Case: Perform Holography Observation

Move the antenna in a raster scan pattern centered on the source without stopping. Simultaneously collect time-stamped and position-stamped amplitude and phase data. At the end of a scan row be able to stop the observing and perform system calibrations. Be able to start an observation beginning at any scan row.

Role(s)/Actor(s):

Primary: Operator

Secondary: None

Priority: Critical

Performance:

Entire scan must take less than one hour, with a half hour as a goal.

Frequency:

During antenna testing and whenever panel adjustments have been made.

Preconditions:

Holography receiver must be installed at apex.

First LO reference source must be switched to provide signal to holography transmitter.

The following parameters should be specified:

1. Source Position: This position is tracked (if necessary) to remain at the scan center at all times.
2. Scan Direction: The coordinate in which the map rows will be acquired. It can be either azimuth, elevation, right ascension, declination.
3. Map Row Size: The map dimension of the coordinate given by Scan Direction. This excludes the antenna movement required to reach the Scan Velocity.
4. Map Column Size: The map dimension orthogonal to the coordinate given by Scan Direction.
5. Number of Rows: Number of passes to be made across the map in the Scan Direction. This must be a number typically between 29 and 513, inclusive.
6. Data Integration Time: This sets the time between each data point, and must be a multiple of 12 ms
7. Scan Starting Row: The row number at which to begin the observation. Rows are numbered beginning with zero.
8. Scan Velocity: The rate at which the antenna is to be moving during data collection (arc-second per second).
9. Rows per Calibration: The number of observation rows between periods spent acquiring signal calibration data.
10. Calibration Integration Time: The time spent acquiring boresight calibration data per boresight calibration observation.
11. Rows per Pointing: The number of observation rows between periods spent acquiring pointing data.

12. Pointing Integration Time: TBD depending on the pointing calibration method.

13. Rows per Focus Calibration: The number of observation rows between periods spent maximizing the boresight signal by near-field focus adjustment.

Basic Course:

1. Start holography backend data production at desired integration time
2. Begin scan with mount
3. Accumulate antenna position and holography data
4. If calibration required perform appropriate calibration
5. If scan complete, transfer data to analysis software, else go to 3.

Exception Course:

- 3a-0. The scan has been canceled.
- 3a-1. Exit the scan loop.

Postconditions:

Issues to be Determined or Resolved:

1. Poll or interrupt
2. Is dump rate a parameter?
3. Do we really care if the integration is interrupted?
4. Where do we want to check for quit an integration?
5. Is blanking required?

Notes:

4.2.2 Interferometric Holography

Use Case: TI Interferometric Holography

The observing actions required for an Interferometric Pointing Holography map measurement.

An astronomical SiO Maser source or a continuum point source is observed. The antenna to be characterized scans across the source in antenna coordinates while the other (reference) antenna continuously tracks the source. The correlator data (amplitude and phase are recorded) will be gridded into a square map, then Fourier transformed to obtain a complex map of the antenna aperture. The amplitude map traces the amplitude illumination by the feed horn while the phase map will, after correction from the phase of the horn, trace the antenna surface deformations, which can then be monitored as a function of elevation, weather conditions, ...

Role(s)/Actor(s):

Primary: The User (Engineer, Operator, Astronomer)

Secondary:

Priority: Major

Performance:

Frequency: Up to several times per hour to trace elevation dependence on a source.

Preconditions:

1. The User has selected a source.
2. The User has selected a receiver band and the receivers are tuned to that band; band specific pointing corrections have been selected.
3. The User has measured and entered delay offsets.
4. Pointing offsets and focus offsets have been measured and entered.

Basic Course:

1. The User specifies:
 1. The antenna to be scanned
 2. The size of the surface map to achieve ($N \times N$; $N=16, 32, \dots$)
 3. The correlator setup including the actual frequency window to be averaged in real time (for maser lines). This defaults to the total bandwidth (for continuum).
2. The correlator is setup.
3. The antenna is scanned across the source along a pattern: e.g. raster scans in Az or El. (other patterns could be tested: spiral, ...). A circular area around boresight must be fully sampled; its radius in radians is about $N \cdot \lambda / 20$ where λ is the wavelength in meters.

Postconditions:

The correlator data collected during the measurements are available in the FITS data files. Data header parameters include the time-variable pointing offsets used to scan the antenna.

Issues to be Determined or Resolved**Notes:**

4.2.3 Pointing Session

Use Case: **TIPointingSession**

Starting from User input, determine all parameters necessary to perform a Pointing Session. The goal of a Pointing Session is to determine the parameters of the pointing models for one or both antennas. The session is performed by making individual pointing measurements in the direction of a set of N sources covering the whole visible sky in a quasi-uniform way; N must be large enough to allow a determination of the pointing model coefficients by the method of least squares; the session must be short enough so that thermal effects are kept to a minimum. Describe the actual observing actions needed to perform those observations.

All pointing measurements in a session are performed in the same way, using one of the following pointing modes:

- interferometry mode,
- pseudo-continuum mode (using maser line sources),
- continuum total power mode (with nutators),
- optical mode (with optical telescopes).

Role(s)/Actor(s):

Primary: Staff Astronomer, Operator

Secondary: Line Catalog, Pointing Source Catalogs

Priority: Critical**Performance:** One to a few hours**Frequency:** Quite often for the TI...**Preconditions:**

1. Must have access to one or both of the prototype antennas (two are needed for interferometry mode!).
2. For Interferometry mode, delay offsets must have been measured and entered. RF Bandpass calibration should have been performed.
3. For all radio modes, the receivers must have been tuned; focus offsets must have been measured and entered.
4. For optical modes, the focus offsets must have been measured and entered.

Basic Course:

1. User specifies the number of sources to be observed.
2. User specifies the setup parameters to be used for all pointing measurements, including which pointing mode will be used (UC_PointingCalibration).
3. The receivers, correlator, optical telescopes, are set up and tuned.
4. The system calculates a homogeneous sky distribution for the current LST and the time duration of the upcoming session using the specified number of sources, from the appropriate Pointing Catalog
5. The system calculates the optimum sequence in which to observe the sources.
6. The system records data for each source in turn (UC_PointingCalibration).

Postconditions:

1. In radio pointing modes, the correlation or autocorrelation and the total power data are written into FITS files for data reduction.
2. In optical pointing mode, ... (TBD)

Issues to be Determined or Resolved**Notes:**

1. Optimum sequence means a sequence that realizes a good sky coverage in a short amount of time. The effect of time drifts in the resulting pointing model constants must be kept to a minimum. For instance, to first order, the mean azimuth and the mean elevation in the first and second halves of the session should be equal to mid-range values.
2. The requirement on observing conditions depends on the actual pointing mode chosen

4.2.4 Radio Pointing Calibration

Use Case: TI-RadioPointingCalibration

The observing actions required for an Radio Pointing Calibration measurement. This is implemented as a single command.

The Radio Pointing Calibration may be performed in the following four modes:

1. Interferometric Mode: using the amplitude of the continuum correlation signal.

2. Total Power Pseudo Continuum mode: Using the autocorrelation signal (difference between a line frequency window and a reference frequency window).
3. Total Power Beam-switched Continuum mode: Using the difference between source and reference phases of the nutating subreflector switching cycle.
4. Total Power Continuum mode: using the total power signal from the detectors (strong planets only!).

Role(s)/Actor(s):

Primary: The User (Engineer, Operator, Astronomer)

Secondary:

Priority: Major

Performance: Near realtime feedback of pointing offsets into the system.

Frequency: Several to hundreds per hour.

Preconditions:

1. The User has selected a source.
2. The User has selected a receiver band and the receivers are tuned to that band; band specific pointing corrections have been selected.
3. The User has measured and entered delay offsets if interferometric mode is used.

Basic Course:

1. The User specifies in the command arguments:
 1. The scanning pattern (five point or cross; only cross for Total power Continuum mode).
 2. The antenna(s) to be scanned (only one in interferometry mode).
 3. The maximum offset from central position (size of the pattern in arc seconds).
 4. The integration time on each observation in seconds.
 5. The correlator setup including the actual frequency window to be averaged in real time (for maser lines). This defaults to the total bandwidth (for continuum).
2. The correlator is setup if needed (modes 1 and 2).
3. Pointing calibration measurements are executed, and the correlator / total power / switched power output is recorded as a function of time.

Postconditions:

The correlator / total power / beam switched power data collected during the measurements are available in the FITS data files. Data header parameters include the time-variable pointing offsets used to scan the antenna.

Issues to be Determined or Resolved

Other details of the pointing calibration algorithm, starting with ALMA Memo 189 (Lucas).

Notes:

1. Other scan patterns (3-point, circular scan) may be tested later.

4.2.5 Optical Pointing Characterization

4.2.6 Temperature Scale Characterization

Use Case: TI Temperature Scale Calibration

This Use Case outlines the basic process of Temperature Scale Calibration with ALMA-TI. Temperature scale calibration is the process of converting total power measurements from a receiver into system temperatures which have been corrected for the opacity due to the Earth's atmosphere.

Role(s)/Actor(s):

Primary: Observer

Secondary: The Operator, the Staff Astronomer

Priority: Critical

Performance: seconds

Frequency: seconds

Preconditions:

1. The Alma TI Control System has reached at least partial operational state.

Basic Course:

1. The Temperature Scale Calibration system operates continuously during all observations.
2. The TI Control System measures total power or wide bandwidth autocorrelation signals from calibration loads in front of the receivers. The physical temperature of these loads is measured in synchronization with data acquisition.
3. The zenith opacity at frequency of observation is derived from tipping curves.
4. The calibration scale is derived from the differences between calibration load total power measurements, physical load temperature differences, and opacity at current elevation.
5. The calculated calibration scale is stored in accessible area.
6. The system temperature versus frequency for each antenna is derived from the above information. This will be used for data weighting in subsequent data processing.

Postconditions:

1. Calculated calibration scale is available for application to data.

Issues to be Determined or Resolved:

- Exact design for Temperature Scale Calibration system.

Notes:...

4.2.7 Focus Calibration

Use Case: TI-FocusCalibration

The observing actions required for a Focus Calibration measurement. This is implemented as a single command.

The Focus Calibration may be performed in the following four modes:

1. Interferometric Mode: using the amplitude of the continuum correlation signal.
2. Total Power Pseudo Continuum mode: using the autocorrelation signal (difference between a line frequency window and a reference frequency window).

3. Total Power Beam-switched Continuum mode: using the difference between source and reference phases of the nutating subreflector switching cycle.
4. Total Power Continuum mode: using the total power signal from the detectors (strong planets only!)

Role(s)/Actor(s):

Primary: The User (Engineer, Operator, Astronomer)

Secondary:

Priority: Major

Performance: seconds

Frequency: Several to hundreds per hour.

Preconditions:

1. The User has selected a source.
2. The User has selected a receiver band and the receivers are tuned to that band; band specific pointing corrections have been selected.
3. Pointing Calibration has been performed and pointing offsets are applied.
4. The User has measured and entered delay offsets if interferometric mode is used.

Basic Course:

1. The User specifies in the command arguments:
 1. The antenna(s) to be scanned (only one in interferometry mode).
 2. The maximum offset from nominal position (size of the pattern in millimeters).
 3. The total number of focus positions (e.g. 3, 5, ...)
 4. The integration time for each position in seconds.
 5. The correlator setup including the actual frequency window to be averaged in real time (for maser lines). This defaults to the total bandwidth (for continuum).
2. The correlator is setup.
3. Focus calibration measurements are executed: the subreflector is moved in turn to each focus position and correlator / total power / switched power output is recorded as a function of time.

Postconditions:

The correlator / total power / beam switched power data collected during the measurements are available in the FITS data files for data reduction. Data header parameters include the time-variable focus positions.

Issues to be Determined or Resolved

Notes:

1. When the focus correction Δz will be applied, a compensating delay offset ($d \cdot \Delta z / c$) must be introduced on the same antenna.
2. Other scan patterns (continuous scan) may be tested later. I've included only the ones currently supported by CLIC.

4.2.8 Receiver Tuning

4.2.9 Amplitude Calibration

4.2.10 Gain Calibration

4.2.11 Bandpass Calibration

4.2.12 Flux Calibration

4.2.13 Polarization Calibration

4.2.14 Array Pointing Characterization

4.2.15 Baseline Calibration

Use Case: TI-BaselineCalibration

Starting from user's input, determine all parameters necessary to perform an interferometric Baseline Calibration observation. Describe the actual observing actions.

Role(s)/Actor(s):

Primary: Staff Astronomer

Secondary: Line Catalog, Baseline Calibration Point Source Catalog(s), Array Configuration Catalog

Priority: Critical

Performance: One to a few hours

Frequency: After moving one or both antennas; maybe more often, and after earthquakes or volcanic eruptions (I hope this does not apply to VLA site ...)

Preconditions:

1. Receiver setup (frequency) is defined and receivers are tuned in both antennas.
2. Both antennas point reliably: the pointing models are good enough so that there is no significant amplitude loss in either antenna across the sky.
3. Both antennas are properly focussed.
4. The delay offsets have been measured for both antennas.
5. A passband calibration has been performed and recorded.

Basic Course:

1. User specifies which Baseline Calibration point source catalog to be used.
2. The correlator is setup to maximum bandwidth for optimal sensitivity.
3. The system selects sources from the baseline calibrator catalog for a homogeneous sky distribution for the current LST.
4. The system calculates the optimum sequence in which to observe the sources.
5. The system records the correlator output at the observing frequency for each source in the sequence for a specified time.

Postconditions:

1. The correlator data are written in the FITS output files.

Issues to be Determined or Resolved

Notes:

1. The optimum sequence does not minimize the travel time between two consecutive sources. On the opposite, sources with highly different hour angles and declinations should be observed consecutively.

4.2.16 Delay Calibration

Use Case: TI-Delay Calibration

Starting from user's input, perform an Interferometric Delay Offset Calibration using an astronomical source. Delay calibration makes sure no sensitivity is lost in interferometric continuum observations, in particular for the phase calibration. Residual small delay errors are nevertheless compensated by RF passband calibration.

There is one delay offset for each antenna, frequency band, and baseband.

Role(s)/Actor(s):

Primary: Observer

Secondary:

Priority: Critical

Performance: real-time; overhead should be minimal and dominated by hardware.

Frequency: at least once per receiver tuning

Preconditions:

1. Receiver and correlator setup have been specified and have been set up properly.
2. Baseline is known with relatively good accuracy; large errors (1cm) produce small, time varying delay errors.

Basic Course:

1. User specifies a point-source calibrator strong enough to achieve the measurement.
2. User specifies the integration time in seconds.
3. System records correlator output on that calibrator for the specified time.

Postconditions:

1. The correlator data is written into the FITS data files and available for data reduction.

Issues to be Determined or Resolved

1. One should (ideally!) be able to separate the delay offsets into:
 1. one stable component (the same for all frequency bands),
 2. one stable component depending on the frequency band,
 3. one variable (frequency band independent) component with small time variations, due to changes in the electrical (or optical) length of the IF transmission system.

For each setup one would only need to update that third component by observing at the calibration frequency. The relative delays of the various frequency bands would need to be measured on strong sources from time to time. The first component would only need to be measured on antenna moves and other hardware modifications.

2. Calibrator can be far away from the target source.

Notes:

1. The correlator setup need not be the same as for the for the target source.
2. The correlator should be set at maximum bandwidth to improve accuracy, but in the case of very large delay offsets where the frequency resolution should be high enough: for 1 ms delay the frequency resolution should be better than about 100 kHz.
3. Quite often a specific observation will not be needed; the delay will be easily determined from a pointing or a focus measurement.
4. One should not change the delay offsets during an Observing Session as a phase discontinuity would be produced.

4.2.17 Beam Shape Calibration

Use Case: TI Beam Shape Calibration

The observing actions required for an Beam Shape Calibration measurement with one of the prototype antennas..

The goal of this measurement is to obtain a power map of the antenna beam pattern, in single-dish mode. In interferometric mode, the same information can be extracted from an Interferometric Holography measurement (UC_TI-InterferometricHolography; which in addition provides the phase of the beam pattern).

The Beam Shape Calibration may be performed in the following modes:

1. Total Power Pseudo Continuum mode: Using the autocorrelation signal (difference between a line frequency window and a reference frequency window.
2. Total Power Beam-switched Continuum mode: Using the difference between source and reference phases of the nutating subreflector switching cycle.
3. Total Power Continuum mode: using the total power signal from the detectors.

Role(s)/Actor(s):

Primary: The User (Engineer, Operator, Astronomer)

Secondary:

Priority: Major

Performance:

Frequency: Several to hundreds per hour.

Preconditions:

1. The User has selected a source.
2. The User has selected a receiver band and the receivers are tuned to that band; band specific pointing corrections have been selected.
3. The User has measured and entered pointing offsets.
4. The User has measured and entered focus offsets.

Basic Course:

1. The User specifies:
 1. The antenna(s) to be scanned.
 2. The scanning pattern.
 3. The integration time on each observation in seconds.

4. The correlator setup including the actual frequency window to be averaged in real time (for maser lines in Pseudo-continuum Mode). This defaults to the total bandwidth (for continuum).
5. The nutating subreflector cycle description (switching frequency, direction, beam throw, ... TBD).
2. The correlator is setup if needed (Pseudo-continuum Mode).
3. The scanning measurements are executed. Individual raster scans may be interspersed by:
 1. Temperature scale calibrations (executed off-source)
 2. Radio Pointing Calibrations and Radio Focus Calibrations on boresight, in the same data acquisition mode.

Postconditions:

The correlator / total power / beam switched power data collected during the measurements are available in the FITS data files. Data header parameters include the time-variable pointing offsets used to scan the antenna.

Issues to be Determined or Resolved

Notes: