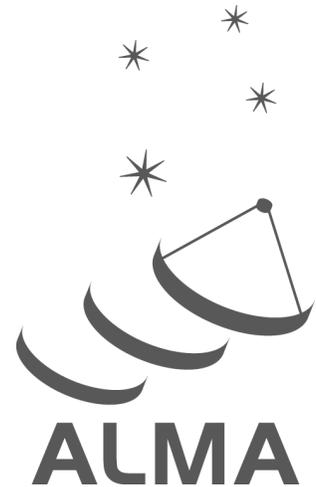


# ALMA Observing Tool Reference Manual

Rein H. Warmels, Andy Biggs



[www.almascience.org](http://www.almascience.org)

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## Revision History:

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Version	Date	Editors
0.6, Ver. 1.0	March 2011	Rein Warmels
0.6, Ver. 1.1	August 2011	Rein Warmels
1.6, Ver. 1.0	May 2012	Rein Warmels
1.6, Ver. 1.2	November 2012	Andy Biggs
1.6, Ver. 1.3	February 2013	Andy Biggs
2.6, Ver. 1.0	October 2013	Andy Biggs

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## Contributors

The ALMA OT Team, and the many Testers.

In publications, please refer to this document as:

**OT Reference Manual 2.6, Version 1.0**

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# Chapter 1

## Introduction

The OT Reference Manual provides a concise description of the inputs to the ALMA Observing Tool (OT) that is used to prepare observing proposals (Phase 1) and to schedule approved observations (Phase 2) for the Atacama Large Millimeter/submillimeter Array (ALMA). The OT is a Java-based application consisting of a set of user interfaces that are needed to prepare an ALMA observing project. This consists of a valid observing proposal and/or an observing program containing one or more Scheduling Blocks that are executed at the telescope.

### 1.1 How to Use this Manual

For most users preparing to submit a proposal to ALMA or who are preparing SBs for observation, the User Manual gives the fullest description of how the OT actually works. However, this does not go into detail of what every button in the OT does and what the meaning of every parameter is. When this kind of information is required, the OT tooltips (revealed by hovering the mouse over an input field) will often help. However, these are by their very nature very concise and thus the OT Reference Manual is provided as a source of detailed information on each parameter, particularly where the meaning of that parameter is not obvious.

Chapter 2 provides descriptions of the main OT menu and its tool bar at the top of the OT as well as some additional information about the OT graphical interface. Chapter 3 describes the buttons of the Tools and Simulators e.g. the ALMA Sensitivity Calculator (ASC) and the calibration selection tools. In Chapter 5, information is provided for the parameters required for completing Phase-1 and Phase-2 Science Goals whilst Chapter 6 provides references for constructing Phase-2 Scheduling Blocks (SBs). Note that defining SBs requires a solid knowledge of interferometry in general and ALMA in particular. Descriptions for the Visual Spatial and the Visual Spectral Editors are provided in Chapter 7.

### 1.2 Release Information

This version of the manual is intended to be used with the OT that will be used to create Phase-1 proposals for ALMA Cycle 2, either a one submitted at the standard deadline, or a Director's Discretionary Time (DDT) proposal that can usually be submitted once observing has begun. A completely separate version of the OT is currently available for the preparation of Phase-2 programs and DDT proposals for Cycle 1.

### 1.3 Credits and Acknowledgements

The ALMA OT is a software product of the ALMA Observation Preparation Software Team and is developed on the basis of the ALMA Science Software Requirements (SSR) and the ALMA High Level Analysis (HLA) documents, produced by the respective groups. The OT software group acknowledges the valuable inputs of

these groups during the development phases of the OT. Also, the OT software groups thank the OT external community testing group for their testing efforts of the various versions of the OT.

## Chapter 2

# Overview of the Observing Tool

The OT main GUI contains three major components: the Menu bar at the top, followed by the toolbar containing the most frequently used Menu functions. To the left is the Project Structure tree and, to the right of this, are the various editors (Forms, Spectral and Spatial) that allow a user to complete the information required for each node within the Project tree. The appearance of the main OT GUI is similar to that shown in Figure 2.1.

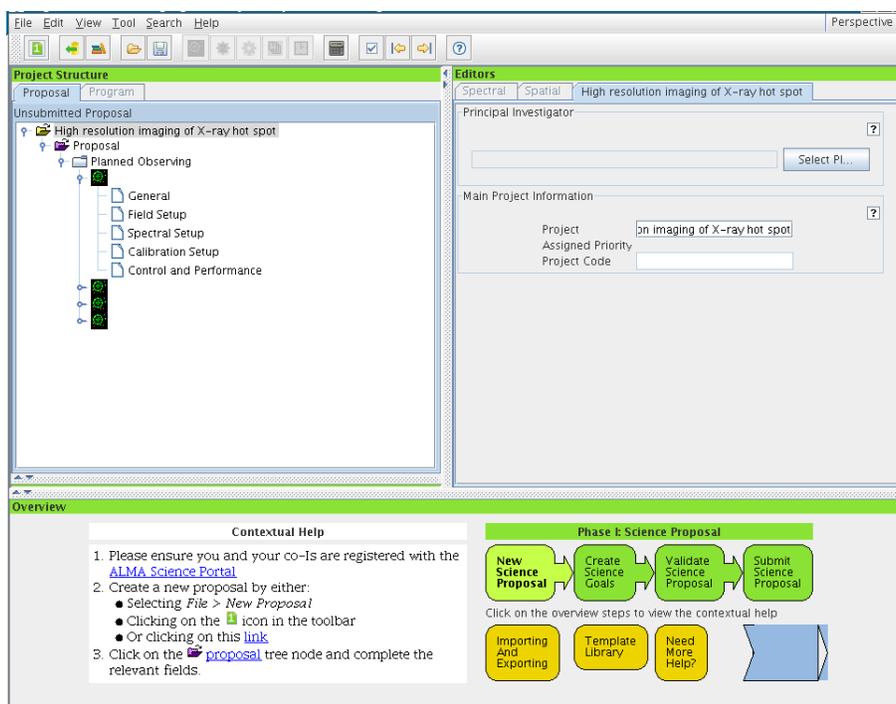


Figure 2.1: The Observing Tool main GUI.

### 2.1 Menu Bar

The **Menu** bar gives access to a variety of OT functions and tools.



Figure 2.2: The Menu Bar of the Observing Tool main GUI.

### 2.1.1 File

**File** contains submenus for managing projects (project validation, open, save, retrieve, import and export, etc), for handling standard or project libraries, and to exit the OT.

- **New Proposal:** Create a new proposal for the standard submission deadline and scientific and technical review process.
- **New DDT Proposal:** Create a proposal for submission under the auspices of Director's Discretionary Time. This has no fixed deadline and can be submitted at any point during the observing period of the current cycle.
- **New Program:** Create a new Phase-2 program using Science Goals or Scheduling Blocks.
- **New Commissioning Program:** Create a new Phase-2 program if you are working on commissioning in Chile. Such projects follow a different lifecycle than a standard PI-submitted one.
- **Open Project:** Open a project from the local disk or use the Project Finder. A project can also be retrieved from the ALMA Archive.
- **Save:** Save a project to the local disk by overwriting the previous version.
- **Save As:** Save a project to the local disk as a new file. The filename prefix must contain at least 3 characters.
- **Show ALMA Template Library:** Open the ALMA Template Library in a new Project tree window.
- **Use Project as Template:** Open a local ALMA project and show it in read-only mode.
- **Validate:** Validate the project currently loaded in the OT.
- **Submit Project:** Submit the project to the ALMA Archive for validation and proposal review if appropriate.
- **Submit As New:** Submit the current project to the ALMA archive as a new project. The project will obtain a new project code and so should be used with caution. It is only available to users with special privileges.
- **Preferences:** Set various appearance and behavioural preferences.
- **Quit:** Exit the OT.

### 2.1.2 Edit

**Edit** is used for project editing functions (cut, paste, delete, rename) and for adding/deleting project components like Science Goals or SB parameters. Note that the availability of the function depends on which component of a project has been selected.

- **Cut:** Cut a selected Science Goal or Scheduling Block item.
- **Copy:** Copy a selected Science Goal or Scheduling Block item. The copied item will turn pink.
- **Paste:** Paste a copied item.
- **Rename:** Rename various Project tree items.

- **New Phase 1 Science Goal:** Create a new Phase-1 Science Goal.
- **New Phase 2 Science Goal:** Create a new Phase-2 Science Goal.
- **Add Observatory Setup:** Add a special Observatory setup as part of the Science Plan. Observatory setups can be: Holography setup, Astro-Holography setup, Optical Pointing Science Goal, Radiometric Pointing Goal, Baseline Calibration Goal, Calibration Survey Goal.
- **Add ...:** Add a component to the Project Structure (OUS, SB, Target, etc.).
- **Attach/Detach ...:** Attach/detach a SB Field Source, Instrument Setup or Observing Parameter to/from a SB Target.
- **Delete:** Delete a selected Science Goal or Scheduling Block item.
- **Suspend:** Suspend the observation of this Scheduling Block. Not used.
- **Resume:** Allow further observation of the Scheduling Block. Not used.
- **Mark as Repaired:** Mark the Scheduling Block as repaired. Not used.
- **Terminate:** Terminate the observation of the Scheduling Block. Not used.

### 2.1.3 View

- **Feedback:** Enable or disable the Feedback panel.
- **Overview:** Enable or disable the Overview panel.
- **Show ALMA Template Library:** Show the ALMA Template Library in the Project Structure tree.

### 2.1.4 Tools

- **ALMA Calibration Selection Tool...:** Search for calibrators either using the ALMA online calibrator database, or using a more limited internal OT version. The tool is only available for Phase-2 programs.
- **ALMA LO Configuration Tool...:** Experiment with LO setups. Only recommended for expert users.
- **Sensitivity Calculator...:** Start up the ALMA Sensitivity Calculator.
- **Generate SBs from the Selected Goal:** Create one or more SBs from the selected Phase-1 or Phase-2 Science Goal.
- **Generate Phase 1 SBs from all the Science Goals:** Create one or more SBs from all of the Phase-1 Science Goals.
- **Generate Phase 2 SBs from all the Science Goals:** Create one or more SBs from all of the Phase-2 Science Goals.
- **Show Printable Summary...:** Depending on which node of the Project tree is currently selected, this will give the option to view a summary of the proposal (displays the cover sheet, Technical Assessment flag sheet and summary of each Science Goal) or subsets of these.
- **Generate a PDF for the Whole Proposal:** Create a PDF for the whole proposal.
- **Disable Edit Protect:** If OUS Write Protection has been enabled in the Preferences menu (available to privileged users only) it can be disabled here.

## 2.1.5 Search

If warnings or errors have been found during the validation process, it is possible to scroll through them using the following menu items.

- **Go to previous Problem:**
- **Go to next problem:**

## 2.1.6 Debug

This menu item is only displayed when activated via the Preferences menu and is only available for privileged users i.e. developers.

## 2.1.7 Help

Various sources of information can be displayed in a searchable and indexed GUI.

- **Quick Start Guide:** A concise guide to creating a Phase 1 Proposal.
- **User Manual:** This provides detailed descriptions of how the OT is used in practice.
- **Reference Manual:** This document.
- **About...:** Bring up a dialogue that reveals various information about the OT.

## 2.2 Tool Bar

The **Toolbar** contains buttons for executing frequently-used OT functions and tools that are otherwise available from the various menu items. Note that the availability of the tools and functions depends on which phase of project is being worked on and the user's permissions.

The only function that is not available elsewhere is the contextual help icon (question mark) which displays help (from this Manual) depending on which section/panel of the OT is clicked.



Figure 2.3: The Toolbar of the Observing Tool main GUI.

## 2.3 Panes

### 2.3.1 Project Structure

The Project Structure pane shows the overall structure of the project. The visualisation of the project structure depends on which view is chosen. The tabs (which will be at the bottom or top) enable a user to select either Proposal (Phase 1) or Program (Phase 2).

#### 2.3.1.1 Proposal

When selecting the Proposal tab the Phase-1 Project Tree becomes visible. The Phase-1 Proposal node contains all the administrative information needed for a proposal whilst the the Science Goals are contained in the Planned Observing folder. They are organised as follows:

- **General:** The name and description of the Science Goal are provided here.
- **Field Setup:** This specifies target parameters, such as the name, coordinates, velocity and proper motion.
- **Spectral Setup:** Contains fields to specify the frequencies/transitions that should be observed.
- **Calibration Setup:** The details of the calibration are given here. User-defined is possible, but system-defined is recommended.
- **Control and Performance** This displays configuration information for the available arrays and accepts input for important control parameters such as the required sensitivity and largest source angular scale to be imaged.

### 2.3.1.2 Program

When selecting the Program tab, Phase-2 details can be added either in terms of Science Goals or by specifying Scheduling Block. The Phase-2 Science Goals forms are located under the Science Plan node and are identical to the forms for Phase 1 (see above). For each Science Goal, Science Plan contains an Observing Unit Set (ObsUnitSet) that allows the user to specify dependency rules for the SBs and hence the construction of a complex and detailed observing program. ObsUnitSets contain Scheduling Blocks (SBs) which are the key executable units of a project. SBs contain all necessary observing information to execute a “single” observation. A SB can be repeated several times to achieve the desired sensitivity or to reach the maximum allocated time. An SB consists of:

- **Targets:** Contains the sources to be observed, for science and calibration. Each of these has a Field Source, an Instrument Setup and a set of Observing Parameters. These are together called Resources.
- **Resources:**
  - **Field Sources:** Each field source defines the details of the source to be observed e.g. positions, velocities, observing pattern.
  - **Instrument Setup:** Specifies the various parameters for the frequency, baseband and correlator settings.
  - **Observing Parameters:** Contains for each target a set of representative observing and sensitivity parameters e.g. cycle and integration times, pointing offsets.

### 2.3.1.3 Template Library

The lower section of the Project Structure pane can be use to load the ALMA Template Library or to display a local ALMA project in read-only mode. Parts of the templates can be copied and used for an active project.

## 2.3.2 Editors

The Editors pane contains the forms for entering spatial and frequency information of the observations in a project. The tabs can be used to choose between entering the data using the Visual Spatial/Spectral Editors or a plain form.

The Editors pane has three tabs:

- **Spectral:** Enables the Visual Spectral Editor to graphically visualise the frequency information for the receiver bands, sub-bands and correlator.
- **Spatial:** Enable the Visual Spatial Editor to display the science object obtained from one of the image servers available via the network.

- **Forms:** Displays the form corresponding to the mode that has been selected in the Project Tree. This can be part of a Science Goal or of a SB. While the forms for the Science Goals are relatively simple, more complex and elaborate forms need to be completed for creating a Scheduling Block. Note that the label of the tab depends on the node that has been selected in the Project Tree.

### 2.3.3 Feedback

The Feedback pane is for provides errors and/or warning when running the validator. There are three tabs: Validation, Validation History and Log.

- **Validation:** Shows a table of the errors and warning, and offers the possibility to jump directly to the erroneous item in the Project Tree. This is the main feedback window.
- **Validation History:** Enables previous validations to be viewed.
- **Log:** Miscellaneous application errors.

### 2.3.4 Overview

This panel displays an overview of the main tasks that an OT user needs to carry out in creating and submitting a Phase-1 proposal, followed by retrieving and completing the Phase-2 observing program. It aims to provide a quick, top-level guide, with brief contextual help. This is aimed at novice users; more experienced users can shrink the panel.

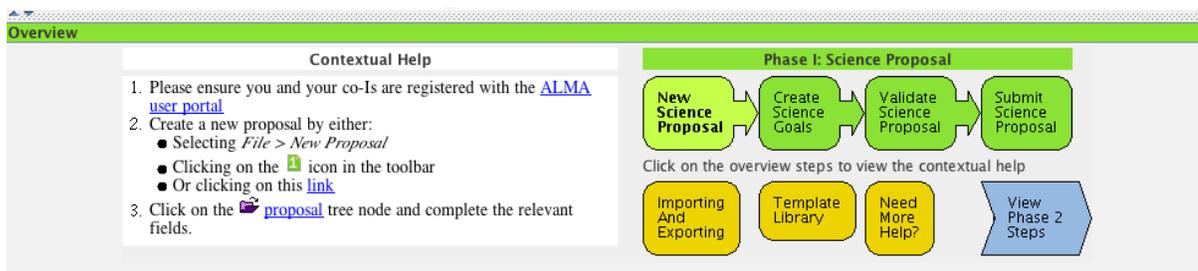


Figure 2.4: The Overview Panel.

# Chapter 3

## Tools and Simulators

The OT is equipped with a number of tools: the Calibration Selection Tool, the Spectral Lines Selection Tool, the Sensitivity Calculator and the LO Configuration Tool. The input for each of these tools is described below.

### 3.1 Calibrator Selection Tool

The tool allows the user to find calibrators within a defined distance from the target source. Note that the tool is only available for Phase-2 programs. The Calibrator Query Editor is available for Phase-1 proposals and Phase-2 programs, and looks very similar. The various filters are enabled with non-zero input.

- **RA:** The centre R.A. coordinate of the cone search.
- **Dec:** The centre Declination coordinate of the cone search.
- **Radius:** The search radius in degrees around the cone centre coordinates - 0 will use the whole sky.
- **Flux Min:** Minimum flux for the search.
- **Flux Max:** Maximum frequency for the search.
- **Frequency Min:** Minimum frequency for the search.
- **Frequency Max:** Maximum frequency for the search.
- **Max Results:** Maximum number of source to return [1-100].
- **Submit Query:** Query the ALMA Calibrator Database for possible calibrator given the constraints. Select either the ALMA Online Calibrator catalogue or the OT's internal (and less extensive) version.
- **Non-Sidereal Calibrators:** Display non-sidereal sources from the Calibrator Source Catalogue.
- **Select As ...:** Use the selected calibrator for one or more calibration types (amplitude, phase, pointing, polarization, focus, or bandpass). The button will display a window to make the selection for calibration purpose and the spectral specification.
- **Close:** Close the tool.

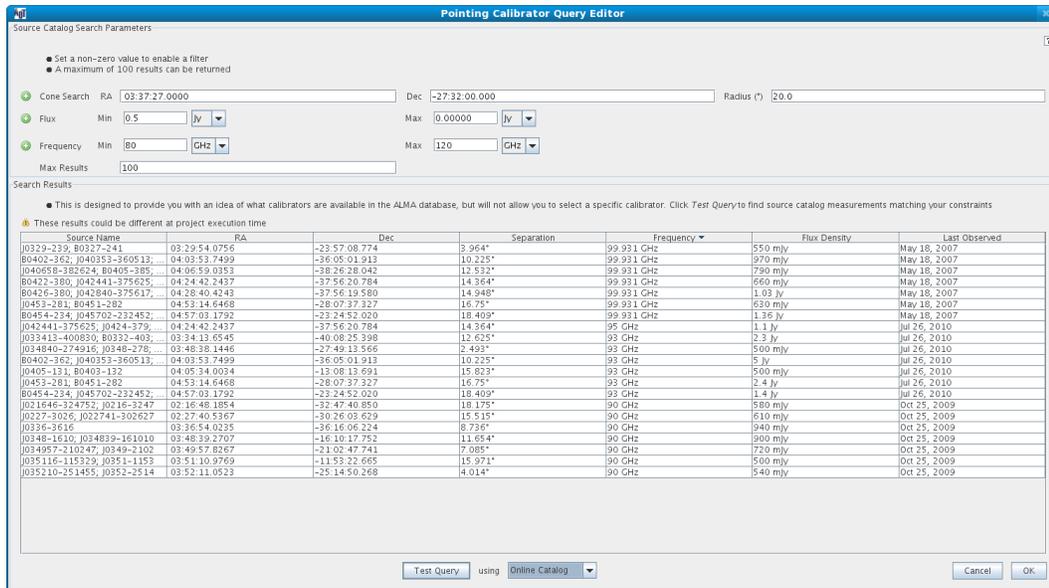


Figure 3.1: The Calibration Selection Tool.

## 3.2 Spectral Lines Selection Tool

The ALMA spectral line catalogue contains the rest frequencies of millions of spectral line transitions. These transitions can be inspected and selected via this tool. The tool can be launched with the button **Select Lines to Observe** when defining the Spectral Setup of a Science Goal, or via the button **Line Catalogue** when defining the Instrument Setup of an SB.

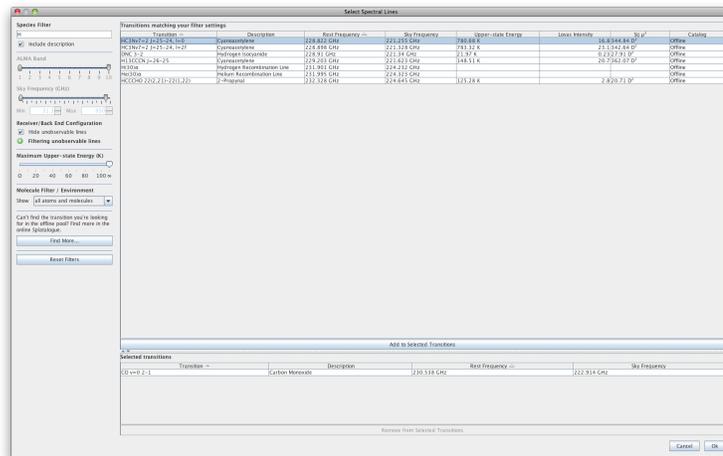


Figure 3.2: The ALMA Spectral Lines Selection Tool.

- **Species Filter:** Text string for selecting the transitions. Note that quantum numbers are ignored. The description fields can be searched at the same time and this is enabled by default.
- **Frequency Filters:**
  - **ALMA Band:** To search in the selected ALMA bands.
  - **Sky Frequency:** Search in a certain frequency range. The range can be defined more precisely using the Min and Max fields.

- **Receiver/Back End Configuration:** If enabled, only lines will be displayed that could be observed with any others spws that have already been selected i.e. it checks to see that all lines can fit in the receiver sidebands.
- **Maximum Upper-state Energy:** This filter sets the maximum energy level of the upper state of the transition.
- **Molecule Filter/Environment:** Narrow the candidate molecular transitions by selecting the category of lines to be shown.
- **Find More...:** Also search the on-line catalogue. The lines found are added to the OT's list of available lines, for the duration of a particular OT session.
- **Reset Filters:** Reset the filters to the original values.

### 3.3 ALMA Sensitivity Calculator

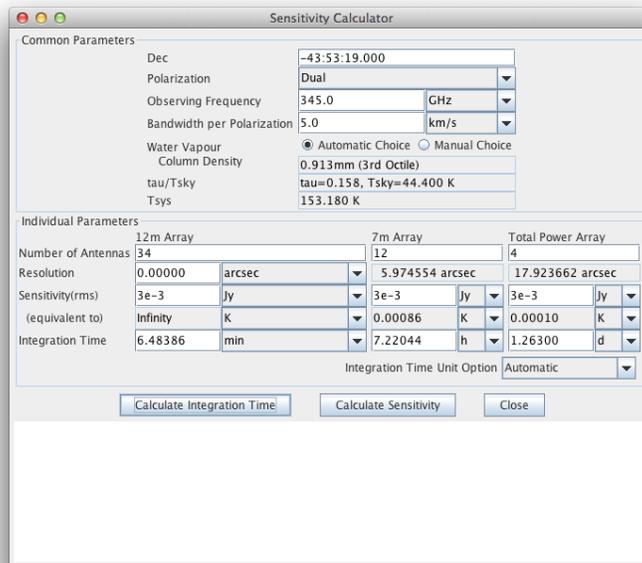


Figure 3.3: The Sensitivity Calculator.

#### 3.3.1 Common Parameters

- **Dec:** Declination of the target. This gives the source's maximum elevation.
- **Polarization:** Dual or Single polarization.
- **Observing Frequency:** Only frequencies falling within the 10 envisaged ALMA bands are allowed.
- **Bandwidth per polarization:** Bandwidth (frequency resolution) per polarization. Valid range is between 0 and 16 GHz. This value multiplied by the number of polarizations gives the effective bandwidth.
- **Water Vapour Column Density:** Precipitable water vapour column density in mm. A number of standard values can be selected or these can be automatically determined by the OT based on the observing frequency.

- **tau0/Tsky:** Displays the zenith opacity and sky temperature (at the target’s maximum elevation).
- **Tsys:** Displays the derived system temperature.

### 3.3.2 Individual Parameters

- **Number of Antennas:** The maximum number of antennas per array.
- **Resolution:** Desired angular resolution.
- **Sensitivity (rms):** Requested/derived sensitivity. May be specified in Jy or K. Note that using the Alt key when changing the unit choice will perform a conversion of the value. Also displayed are the equivalent values of sensitivity, in K or Jy.
- **Integration Time:** Requested/derived integration time. This only includes the time on source – no overheads e.g. for calibration, are included.

### 3.3.3 Buttons

- **Calculate Integration Time:** Calculate observing time based on the system setup and the desired sensitivity.
- **Calculate Sensitivity:** Calculate sensitivity based on the system setup and the desired integration time.
- **Close:** Close the GUI.

## 3.4 LO Configuration Tool

This tool allows the user to experiment with baseband (*not* spectral window) frequencies, independently of the OT spectral setups. It acts as a user interface to the LO Solutions software that is used to calculate the tuning solutions for SBs and Science Goals. It is not recommended for anyone other than expert users.

### 3.4.1 Hardware Info

This panel provides information about the hardware for the various Bands.

### 3.4.2 Settings

- **Receiver Type:** Select the desired receiver/receiver type. The details of the receiver bands are provided at the top of the display.
- **Request LO1:** If the check box is selected then a specific LO1 may be entered.
- **SSB or DSB Baseband Specs:** Up to 4 basebands may be added and the following items entered for each:
  - **Sideband Pref:** Preferred sideband. Choose between LSB, USB, either (in which the system will make the choice), or both (only for the case of DSB receivers i.e. Bands 9 and 10).
  - **Sky Frequency:** The desired sky frequency.
  - **Weight:** A weighting for this side band selection to apply when calculating the LO setup.
  - **IF Frequency:** A suggested IF frequency calculated on the basic of the sky and LO1 frequencies (not guaranteed).

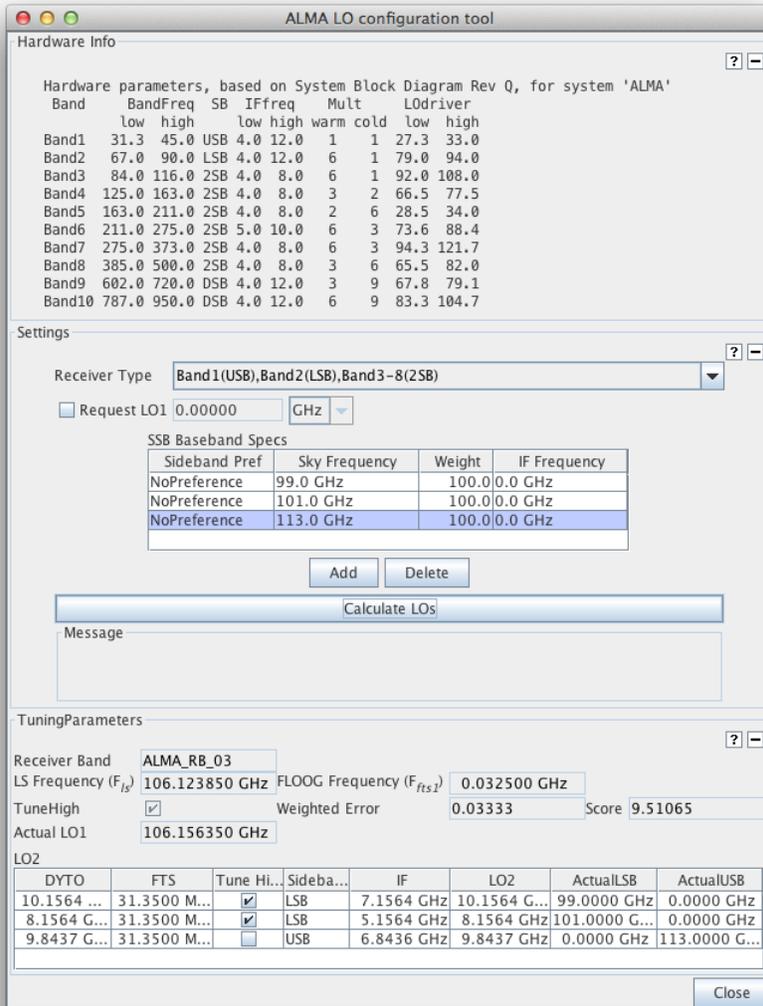


Figure 3.4: The LO Configuration Tool.

### 3.4.3 TuningParameters

- **Receiver Band:** The OT notation of the receiver type cartridge that will be used.
- **LS Frequency:** The Laser synth frequency.
- **FLOOG Frequency:** The First LO Offset Generator (FTS1) frequency.
- **TuneHigh:** Tick the box if the FLOOG frequency is added to the first LO frequency
- **Weighted Error:** The weighted sum of the abs(actual - requested) frequency over all basebands. This is one measure of the goodness of the tuning.
- **Score:** This is a measure of the relative desirability of the tuning.
- **Actual LO1:** The actual LO1 frequency that will be used.
- **LO2 Table:**

- **DYTO:** Digital YIG Tuned Oscillator.
- **FTS:** Fine Tuned Synthesiser.
- **Tune High:** See above.
- **Sidebands:** The sideband that is used.
- **IF:**The Intermediate Frequency.
- **LO2:** The LO2 frequency.
- **Actual LSB:** Actual frequency of the LSB.
- **Actual USB:** Actual frequency of the USB.

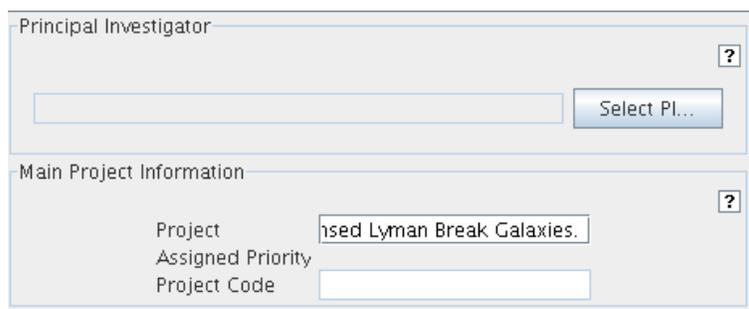
## Chapter 4

# The Phase 1 Proposal: Basic Details

To submit a proposal to ALMA, it is necessary to provide a number of administrative details, before going on to define one or more Science Goals. The former are covered in this chapter, whilst Science Goals are discussed in Chapter 5.

The Project node (common to both Phase 1 and 2) contains the Principal Investigator and Main Project Information panels, with the following fields:

- **Select PI...:** Select the Principle Investigator from the list of registered ALMA users.
- **Project:** Title of the project.
- **Assigned Priority:** Not yet used.
- **Project Code:** A unique code for the project, assigned automatically upon its first submission.



The image shows two panels from a web interface. The top panel, titled "Principal Investigator", has a search box and a "Select PI..." button. The bottom panel, titled "Main Project Information", has three fields: "Project" (filled with "Used Lyman Break Galaxies."), "Assigned Priority", and "Project Code".

Figure 4.1: The Project node panels.

### 4.1 Proposal Information

- **Proposal Title:** A title for the proposal.
- **Proposal Cycle:** The current proposal cycle – set automatically upon first submission.
- **Abstract:** A short abstract for the proposal. Limit of 1200 characters.
- **Proposal Type:** The type of the proposal. Currently only Standard (<100 hours) and Target of Opportunity are available.
- **Scientific Category:** A set of radio buttons for selecting the proposal’s science category:

- Cosmology and the High Redshift Universe
  - Galaxies and Galactic Nuclei
  - ISM, star formation and astrochemistry
  - Circumstellar disks, exoplanets and the solar system
  - Stellar Evolution and the Sun
- **Keywords:** Assign a maximum of two keywords to the project.
  - **Student Project:** Check the box if the proposal concerns a PhD or other major student project.
  - **Continuation:** Check the box if this is a continuation of a previous project.
  - **Related Proposals:** Proposals to ALMA from this Cycle that are related to the current project. Project code, title and PI name should be given.
  - **Previous Proposals:** Details of any related ALMA proposals from previous Cycles. Project code, title and PI name should be given.

Figure 4.2: The Proposal Information Panel.

This contains basic information about the proposal.

## 4.2 Investigators

This contains information about the proposal investigators. All investigators must already be registered with ALMA via the Science Portal. The Principal Investigator is required and one or more Co-Investigators may also be added.

For each investigator the following details are required:

- **Type:** Is this a PI or a co-I?
- **Full Name:** Full name of the investigator as stored in the ALMA user database.
- **Email:** The email address of the investigator.
- **Affiliation:** The affiliation/institute of the investigator.
- **ALMA ID:** This is the username used to access the Science Portal.
- **Executive:** This determines how a project’s time will be “charged”. Taiwanese users can choose between EA and NA. For everyone else, this is fixed to the value entered in the Science Portal.



Figure 4.3: The Investigators panel in the proposal Forms editor.

The buttons below the panel can be used to complete the table of investigators:

- **Set PI:** To fill in the PI data by accessing the ALMA user database.
- **Add CoI:** To fill in the co-I data.
- **Remove CoI:** To delete a highlighted Co-I from the table. Note that PI's can only be changed, not deleted.
- **Add from Proposal...:** Opens a window to select an ALMA Proposal and to append its users to the current project.

### 4.3 Science Case and Supporting Documents

In this section, the mandatory science case can be added to the proposal. Note that the format must be PDF and have a maximum of four pages.

**In contrast to previous cycles, the PDF should no longer contain the technical case, this instead being captured by a dedicated Science Goal node. Figures that might be referred to as part of the technical justification should though be included in the PDF.**

The buttons are:

- **Attach:** This will launch a file browser dialogue to allow the user to choose the PDF file.
- **Detach:** This will remove a previously attached file from the proposal.
- **View:** This will ask the desktop operating system to launch a viewer to display the document. *Note:* this relies on the operating system being setup and an appropriate application installed.

### 4.4 Observatory Use Only

This section contains proposal information that is used by observatory staff only.



# Chapter 5

## Phase 1 and Phase 2 Science Goals

Science Goals are designed to capture the scientific aims of a particular observation i.e. the technical details of the observations are hidden from the user. These are contained within the Scheduling Blocks which can be automatically generated from the information contained within the Science Goal.

Clicking on the top node of a Science Goal will display either a Science Goal summary table or all of the Forms editors, depending on the user preferences. Descriptions of the sixScience Goals Forms editors (General, Field Setup, Spectral Setup, Calibration Setup, Control and Performance and Technical Justification) follow.

### 5.1 General

This General form is to provide the title and the description of the Science Goal. Both are optional.

### 5.2 Field Setup

In the Field Setup form, the user is asked for target parameters such as the name, coordinates, velocity and proper motion. Either individual (one or more) pointings or a single rectangle (that will be automatically mosaiced) can be defined. All pointings must lie within 10 degrees of each other.

The bottom of the form shows five buttons that control the source list:

- **Add Source:** Add a science source, the details of which can either be “resolved” or added manually.
- **Load from File...:** Add one or more sources, including their properties, using a local ASCII file.
- **Export to File...:** Write the source positions to a local ASCII file.
- **Delete Source:** Delete a source.
- **Delete All Sources:** Delete all sources.

#### 5.2.1 Source

- **Source Name:** The source name. The source names should only contain the following characters: a-z, A-Z, 0-9, -,+, \_ or a . (full stop). Characters other than these will be removed or replaced when the project is validated.
- **Resolve:** Query the servers using the entered source name. Either the SIMBAD or NED servers and will fill in the source properties if a match is found. Check the details very carefully!

Figure 5.1: The Source panel in the Field Setup form of the Science Goal.

- **Choose a Solar System Object:** A number of solar system objects are recognised by the telescope control system and can be selected here. It is also possible to enter an ephemeris for any non-sidereal source. The source coordinates and velocity definitions are not displayed if a solar system object is selected as the system that controls the observations has detailed ephemeris information for each object.
  - **Name of Object:** Recognised objects are:
    - \* Stars: The Sun.
    - \* Planets: Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune.
    - \* Satellites: The Moon, Ganymede, Callisto, Io, Titan.
    - \* Dwarf planets: Pluto, Ceres.
    - \* Asteroids: Pallas, Juno and Vesta.
    - \* Ephemeris: Load a JPL HORIZONS format ephemeris.
- **Source Coordinates:**
  - **System:** Only J2000 is formally supported by the telescope control system. If Galactic coordinates are entered, changing the system will cause the OT to convert the coordinates. This only works between Galactic and J2000.
  - **Sexagesimal display?:** Coordinates in J2000 or ICRS will be displayed in sexagesimal format if this is ticked (default). Unclicking this will allow input in degrees for these systems.
  - **RA:** Source Right Ascension. Default input formats are sexagesimal for J2000 and ICRS and degrees for everything else.
  - **DEC:** Source Declination. Ditto.
- **Parallax:** Source parallax. Note that negative values are possible when resolving the source using an external server. This is due to the parallax being small compared to the measurement error.
- **PM RA:** Proper motion in the R.A. (cross-declination) direction. Units should be milliarcsec/yr. Proper motions are used to calculate the current source position assuming that the J2000 position refers to Epoch J2000.
- **PM DEC:** Proper motion in the declination direction; Units should be milliarcsec/yr.
- **Source Radial Velocity:** The radial velocity of the source can be entered as either a velocity or a redshift. It is used to convert source rest-frame frequencies to their observable (sky) equivalents. The full set of options are:
  - **Velocity:** Upon entering this, the redshift will also be set according to the Doppler Type (velocity definition). For Single Continuum setups, automatic SB generation will set the velocity to zero (in the SB only).
  - **Doppler Frame:** A number of options are available: barycentric, lsrk, topocentric and lsr. Heliocentric can be chosen, but is not currently supported and during SB generation will be converted to barycentric (these differ by a maximum of approximately 12 m/s). If the frame is changed, no conversion is performed of an already-entered velocity/redshift.

- **z**: Redshift. Upon entering this, the velocity will also be set according to the Doppler Type (velocity definition). For Single Continuum setups, automatic SB generation will set the redshift to zero (in the SB only).
- **Doppler Type**: This sets the velocity definition (radio, optical or relativistic). Changing this will make the velocity agree with the entered redshift.
- **Target Type**: The supported observing patterns: “Individual pointing(s)” and “1 rectangular field”. Only one source per Science Goal is allowed if a rectangular field is defined.

### 5.2.2 Expected Source Properties

One of the reasons for providing this information is to aid in technical assessment. All relevant items should be filled in or the project will not validate. This means that a continuum flux must be entered for a continuum project and a line flux and width must be filled in for a spectral line project. If full polarization is selected, at least one of the line or continuum polarization percentages must also be given.

- **Peak Continuum Flux Density per Beam**: The expected flux density per beam of the source continuum. The weakest component that is to be detected should be entered for each source.
- **Continuum Polarization Percentage**: The expected degree of polarization for the source, expressed as a percentage of the peak continuum flux. The polarization of the weakest component should be entered.
- **Peak Line Flux Density per Beam**: The expected peak flux density per beam of the line emission. The weakest component that is to be detected should be entered for each source. If the line is seen in absorption against a continuum, enter the depth of the line as a positive quantity.
- **Line Polarization Percentage**: The expected degree of polarization for the source, expressed as a percentage of the peak line flux. The polarization of the weakest component should be entered.
- **Line Width**: The expected line width for the lines in this Science Goal (FWHM). The narrowest line that is to be detected should be entered for each source. A width in velocity units is usually entered but, if a frequency is entered, this should refer to the width in the observed frame.

The screenshot shows a window titled "Expected Source Properties" with a help icon and a close button in the top right. It contains the following fields:

- Peak Continuum Flux Density per Beam: 50.00000 mJy
- Continuum Polarization Percentage: 0.0%
- Peak Line Flux Density per Beam: 100.00000 mJy
- Line Width: 350.0 km/s
- Line Polarization Percentage: 0.0%

Figure 5.2: The Expected Source Properties panel in the Field Setup form for the Science Goal. This is taken from a redshift-survey (spectral scan) project for which the source also has a significant continuum.

### 5.2.3 Field Center Coordinates

This panel is visible if Individual Pointing(s) has been selected in the Source panel. Up to 150 pointings can be defined per Science Goal, distributed between multiple sources.

- **Custom Mosaic**: If the pointings overlap and should be processed as a mosaic, select this option (set as default if individual pointing(s) is selected). Each pointing must be a maximum of one antenna beamsize away from its nearest neighbour.
- **PointingPattern**: Field centre in absolute or relative coordinates. Offsets are determined with respect to the source coordinate. Absolute coordinates have not been demonstrated to work and should not be used.

- **Offset Unit:** Select the units for the offset. This is selected by default and should not usually be changed.
- **RA:** Absolute coordinate of the centre of the pattern or the offset from the field centre in Right Ascension.
- **DEC:** Absolute coordinate of the centre of the pattern or the offset from the field centre in Declination.

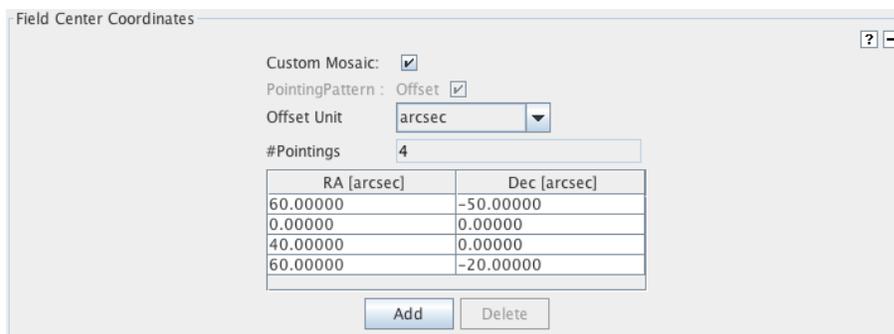


Figure 5.3: The Field Centre Coordinates panel for the case of individual pointings.

## 5.2.4 Rectangle

This panel is only visible when “1 rectangular field” is selected in the Source panel. Choosing this means that only one source can be defined. The rectangle defines a continuous area that should be mapped by ALMA and will be mosaiced by the 12-m and 7-m arrays and continually scanned by the Total Power array. A maximum of 150 12-m array pointings is allowed.

- **Coords Type:** Field centre in absolute or relative coordinates. Relative positions are offset from the source coordinate and are recommended (absolute coordinates have not been demonstrated to work at the telescope).
- **Field Centre Coordinates (Absolute)**
  - **System:** Coordinate System.
  - **Sexagesimal display?:** Check to switch between the coordinates formats.
  - **RA:** The centre coordinate of the rectangle in Right Ascension.
  - **DEC:** The centre coordinate of the rectangle in Declination.
- **Field Centre Coordinates (Relative)**
  - **Offset(Longitude):** Longitude offset of the centre of the rectangle from the source coordinate.
  - **Offset(latitude):** Latitude offset of the centre of the rectangle from the source coordinate.
- **p length:** Length of one side of the rectangle.
- **q length:** Length of the other side of the rectangle.
- **Position Angle:** Position angle of the “p” side of the rectangle from the vertical direction.
- **Spacing:** Spacing of the data required within the rectangle. Can be specified in arcmin or in fraction of the antenna beam. Nyquist spacing is the default. If Nyquist sampling is not used, the reasons for this should be given in the Technical Justification node.
- **Reset to Nyquist:** Reset the spacing to the Nyquist sampling.
- **#Pointings:** The number of pointings calculated by the OT is displayed here, for the 12-m and (if required based on the Control & Performance parameters) 7-m arrays.
- **Export:** Export the pointings (12-m and 7-m array) to disk.

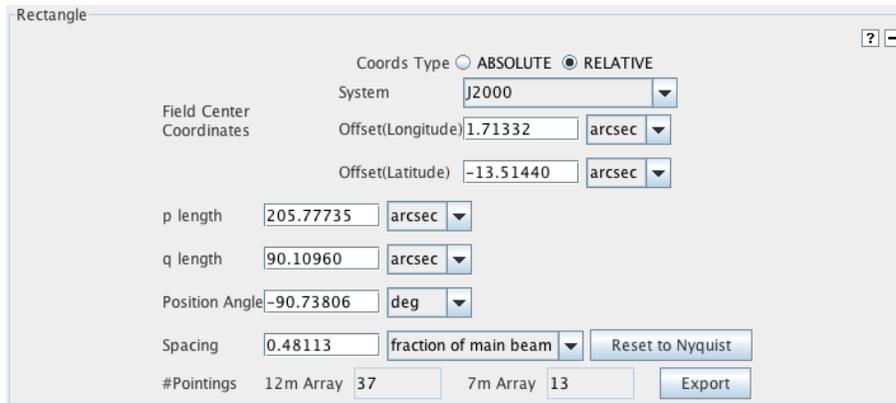


Figure 5.4: The Rectangle panel of a Science Goal's Field Setup.

## 5.3 Spectral Setup

This contains fields to specify spectral setup parameters.

### 5.3.1 Spectral Type

- **Spectral Type:** The kind of spectral type observations. Choices are: “Spectral Line”, “Single Continuum”, or “Spectral Scan”. The display in the next panel is configured depending on the selected option.
- **Polarization:** Options are XX, DUAL (XX and YY) or FULL (XX, YY, XY and YX), where X and Y are the linear orthogonal polarizations detected by the ALMA receivers. Full polarization is only available for standard Single Continuum setups in bands 3, 6 and 7 and should be chosen if a measurement of the source polarization (magnitude and position angle) is desired.

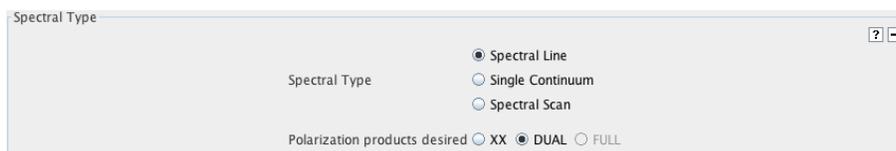


Figure 5.5: The Spectral Type panel in the Science Goals Spectral Setup.

### 5.3.2 Spectral Setup Errors

This panel will display errors and warnings for the spectral specifications, if any. Note that not all are shown – additional ones may appear upon validation.

### 5.3.3 Spectral Line

Four panels for each baseband will be visible and up to four spectral windows can be added to each. Adding a spectral window is done either by selecting spectral lines from the spectral line catalogue or by adding them manually. One of the spectral windows should be selected as that which will set the Representative Frequency. This defaults to the centre of the spectral window, but can be changed at the bottom of the page. This sets the size of the antenna beams drawn in the Visual Spatial Editor and is also used to work out the time estimate for the Science Goal. The Spectral Line interface is not allowed if full polarization has been selected.

- **Select Lines to Observe in BaseBand...:** Opens the Spectral Line Selection Tool allowing a huge list of transitions to be searched.
- **Add:** Add a blank row to the table that can then be completed manually.
- **Delete:** Delete the selected row from the table.

Fraction	Center Freq (Rest)	Center Freq (Sky)	Transition	Bandwidth, Resolution (smoothed)		Spec Avg.	Representatn Window
1/2	115.12300 G...	115.02934 G...	Line of mystery	117.188 MHz( 305 km/s),	61.035 kHz( 0.159 km/s)	1	○
1/4	114.22176 G...	114.12883 G...	CO v=1 1-0	58.594 MHz( 154 km/s),	61.035 kHz( 0.160 km/s)	1	●
1/4	115.27120 G...	115.17742 G...	CO v=0 1-0	58.594 MHz( 153 km/s),	61.035 kHz( 0.159 km/s)	1	○

Figure 5.6: The spectral window table for a single baseband. Three spectral windows have been defined, one of which takes up half of the available correlator mode and two others which use a quarter each. Note that each has the same spectral resolution (this must be the case) and that the bandwidths are proportional to the assigned fraction. Further note that if there were different spectral averaging factors per spectral window, the spectral resolutions would not appear to be the same, although the bandwidths would still indicate the chosen fraction.

The spectral window table has the following columns. Most accept input by being double-clicked.

- **Fraction:** Each baseband can currently only support a single correlator mode i.e. a bandwidth and number of channels, where the latter is 8192 for high-resolution modes (FDM) and 256 for low-resolution (TDM). These channels can be spread over the chosen number of polarization products and, from Cycle 2, be split into multiple spectral windows. This splitting is indicated using the Fraction parameter where e.g. a factor of 1/2 indicates that the spectral window should contain half of the maximum number of available channels. For dual-polarization and FDM, a factor of 1/2 indicates that the channel should contain  $8192/2/2=2048$  channels. As each mode has a different total bandwidth, spectral windows with different bandwidths can therefore be created. Up to four spectral windows are allowed per baseband and thus only the values 1, 1/2 and 1/4 are appropriate. Depending on what fraction is selected, the available bandwidths and spectral resolutions in the drop-down list change. As each spectral window stems from the same correlator mode, each must have the same spectral resolution (before spectral averaging).
- **Centre Freq Rest:** The centre rest frequency of the window. This can be set for each spectral window separately by double-clicking on the table cell, but the total extent of each spectral window must lie fully within the total extent of the baseband (2 GHz).
- **Centre Freq Sky:** The centre sky frequency of the currently-selected field source. The sky frequency can be set by the user and the rest frequency will change according to the velocity of the source selected in the Targets table (located at the bottom of the Spectral Setup editor page and described in Section 5.3.6).
- **Transition:** A standard name to identify the purpose of the spectral window. Some kind of label identifying the main goal of this spectral window must be entered. The Spectral Line Selection tool will automatically enter the name of the chosen transition. If the window is to be used for continuum purposes, entering “continuum” should be entered.
- **Bandwidth, Resolution:** The bandwidth and spectral resolution of the spectral window. Only allowed modes may be chosen from a drop-down list and, within a baseband, each must have the same spectral resolution (before spectral averaging). The resolution is calculated assuming Hanning smoothing i.e. twice the channel spacing. This is applied by default to the reported spectral resolution, as is the value of the spectral averaging factor. TDM correlator modes are shown in bold font and are usually used to observe continua or broad spectral lines.
- **Spec. Avg.:** Spectral averaging factor. This can be any power of two up to a maximum value of 16. The value chosen will be reflected in the reported spectral resolution. Note that the resulting resolution is not a simple multiple of the channel spacing due to the application of Hanning smoothing. TDM spectral windows cannot be spectrally averaged.

- **Representative Window:** Select one of the spectral windows to set the Representative Frequency. This is the parameter that together with the sensitivity requirement sets the required time. It is therefore a very important parameter. If the spectral setup lies in areas of variable atmospheric opacity, which spectral window is set as the representative one can greatly influence the time estimate.

The value of the Representative Frequency is displayed below the table of spectral windows. Its value will default to the centre of the chosen spectral window, but can be changed to another frequency within that spectral window if the transition of greatest interest is not at the centre. It is very important to realize that for spectral line setups this is defined in the rest frame of the source. This is so that sources with different velocities end up with the appropriate Representative Frequency in the observed frame.

### 5.3.4 Single Continuum

This allows a maximum-bandwidth setup to be defined using only a single receiver band or frequency. Upon choosing a band, the OT will automatically set the spectral window frequencies to recommended defaults. If full polarization has been selected, these have to be used. Otherwise, it is possible to change the spectral windows by moving the position of the average frequency of the setup. For a two sideband receiver the requested frequency actually lies in the gap between the two sidebands. A low-resolution correlator mode (TDM) is chosen for each spectral window.

- **Receiver band:** Only bands 3, 6 and 7 are available if full polarization has been selected.
- **Sky Frequency:** Enter a frequency in the observed (sky) frame. This is only possible if full polarization has not been selected. It is possible to reset to the band default frequencies using the button provided.
- **Rest Frequency:** The rest frequency corresponding to the sky frequency is displayed for reference only. It corresponds to the first source defined in the Field Setup node.

The value of the Representative Frequency is displayed below the table of spectral windows. Its value will default to the centre of the chosen spectral window, but can be changed to another frequency within that spectral window if the transition of greatest interest is not at the centre.

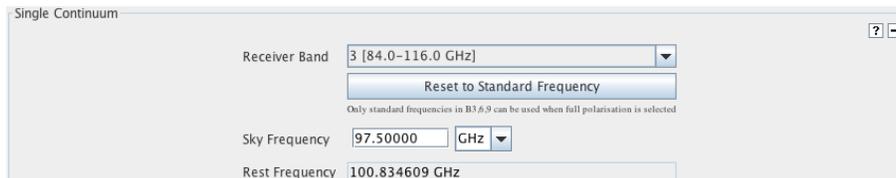


Figure 5.7: The Single Continuum panel in the Science Goals Spectral Setup.

### 5.3.5 Spectral Scan

It is possible to define a complicated setup involving multiple tunings that are meant to cover a contiguous range in frequency using the spectral scan interface. Given a start and stop frequency, and a correlator mode, the OT will devise a set of tunings that achieve the requested frequency range.

- **Requested start frequency (sky):** Frequencies can only be entered in the sky (observed) frame.
- **Requested stop frequency (sky):**
- **Requested range (rest):** The requested range is also shown in the rest frame of the first target defined in the Field Source editor.
- **Achieved scan range (sky):** In general, the OT will not achieve the exact frequency range requested and this is displayed here.

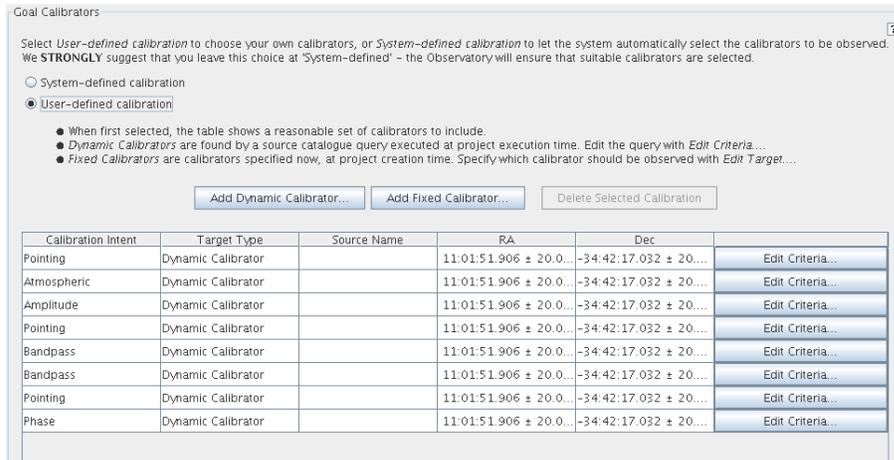


Figure 5.8: The Science Goal Calibration Setup Forms editor.

- **Bandwidth:** One of four correlator modes (the four widest available) should be chosen from the drop-down menu. The displayed values of spectral resolution include Hanning smoothing and spectral averaging.
- **Spectral averaging:** A single spectral averaging factor can be applied to all spectral windows.
- **Representative frequency (sky):** The default value (centre of requested range) can be changed.

Once enough information has been added, the OT will calculate a tuning setup and display the derived spectral windows. Spectral scans are only allowed of sources with a single offset pointing and only a single 12-m configuration is allowed (no ACA).

### 5.3.6 Targets

This panel contains a table of the scientific targets that were defined in the Field Setup node. Clicking on one will update various aspects of the Spectral Setup page, including the rest frequencies and sidebands and spectral windows displayed in the Visual Spectral Editor, as well as the velocities displayed in the spectral window table.

## 5.4 Calibration Setup

In this Forms editor, the user can specify how to calibrate the data. Almost all proposals should request “system-defined” – the observatory will ensure that suitable calibrators are observed. The available choices are:

- **System-defined calibration:** The system will decide on the calibrators and the calibration strategy.
- **User-defined calibration:** When checked, the calibration table is enabled with the following buttons:
  - **Add Dynamic Calibrator...:** Set some constraints that will be used to dynamically select a suitable source at SB execution time.
  - **Add Fixed Calibrator...:** Choose a specific calibrator source.
  - **Delete Selected Calibration:** Delete a selected row in the calibration table.

In the table with the Calibration types, use the **Edit Criteria...** button to edit the search criteria to be used for the calibration selection. It is **STRONGLY** suggested to choose system-defined calibration!

## 5.5 Control and Performance

One panel at the top of the page shows array and telescope configuration information. This should be used to guide a user in the choice of parameters in the panel below, that control predominantly the time required and whether the ACA is required.

Figure 5.9: The Science Goal Control and Performance parameters.

The configuration information (all calculated assuming the sky-frame equivalent of the Representative Frequency for the first source in the Science Goal) are:

- **Antenna Beamsize:** Display of the antenna beam size for the 12- and 7-m dishes.
- **Number of antennas:** The number of baselines assumed for each of the arrays. As the 7-m and TP array times are actually based on the times required for the 12-m configuration, only the number of 12-m antennas has any practical effect on the OT's operation. These numbers are set by default in the ALMA Sensitivity Calculator.
- **Longest baseline:** The maximum baselines available for the most compact and extended 12-m array configurations. For the two highest bands (8 and 9) the largest configuration is not available.
- **Synthesized beamsize:** The synthesised beam sizes for the corresponding maximum baselines.
- **Shortest Baseline:** The minimum baselines available for the most compact and extended 12-m array configurations. For the two highest bands (8 and 9) the largest configuration is not available.
- **Maximum recoverable scale:** The largest structures that it is possible to image with the most compact and extended configurations.

The user-entered parameters are the following:

- **Desired Angular Resolution:** The desired angular resolution (synthesized beam size). Must be between the best resolution achievable (i.e. with the most extended configuration) and twice that achievable with the most compact configuration. The latter allows a modest amount of smoothing during data reduction. Based on this value, the OT will choose an appropriate 12-m array configuration. If this is one of the more extended configurations, it is possible that a second 12-m configuration might be selected, depending on the largest structures that need to be imaged.

- **Largest Angular Structure in source:** The angular extent of the largest components in the source that need to be imaged. This parameter (also sometimes referred to as the Largest Angular Scale) sets whether more than one 12-m configuration is required. Potentially, multiple 12-m configurations, the ACA 7-m and Total Power arrays might be necessary to reliably image the indicated size of the source structure. Point Source should only be selected if the target(s) will be unresolved in even the largest available configuration.
- **Desired sensitivity:** The sensitivity goal for each source. If a rectangle has been defined, this value should be what is desired in the final mosaic i.e. including beam overlaps. For “Individual Pointing(s)”, it is the value per pointing, even if a custom mosaic has been defined.
- **Bandwidth used for Sensitivity:** Specify which bandwidth should be used to calculate the time required. This is used in conjunction with the desired sensitivity and the Representative Frequency. A number of shortcuts are possible or a user-defined value can be entered. “RepresentativeWindowResolution” is the usual default and will use the narrowest spectral resolution (including Hanning smoothing and spectral averaging) of the spectral window chosen as the sensitivity driver for the observations. “FinestResolution” refers to the smallest spectral resolution of any of the defined spectral windows. For spectral scans, FinestResolution should be chosen.
- **Do you request complementary ACA observations?:** Based on the user-entered values of largest angular scale, angular resolution and Representative Frequency, the OT will suggest whether the ACA is required and set the choice automatically. Changing this must be justified and is not recommended. The ACA choice will be reset if the angular resolution and largest angular scale in source change.
- **Time Estimate:** Request an estimate of how long it will take to achieve the scientific objectives of the Science Goal. This brings up a dialogue that contains a lot of information about the times required and parameters used in their derivation. The times reported include calibration and overheads (hardware and software) for each array required.
- **Is more time required due to u,v coverage issues?:** If complicated and bright sources are being observed, the sensitivity target might not be reached due to limited u,v coverage. The sensitivity-based time estimate can be overridden here, but this must be rigorously justified. The time entered must be equal to the total time required for all the arrays, including calibration and overheads. This option is probably only useful for experts and it is not expected that it will be used very much.
- **Are the observations time-constrained?:** Clicking this reveals a interface for setting various scheduling constraints for the observations. When specifying dates, it is important to bear in mind that anything with a scheduling margin of less than  $\pm 7$  days may not be possible. Time-constrained observations that require more than a single 12-m configuration are not allowed. Three options are available:
  - Specific dates – multiple time windows can be entered, during **one of which** the SG should be executed.
  - Multiple epochs – multiple dates (either absolute or relative to one of the epochs) at **each of which** the SG should be executed.
  - Continuous monitoring – if the scientific goals are not driven by sensitivity, but rather by the need to observe a source for a fixed amount of time for monitoring purposes, the time required for this should be entered here and should be the total required for the single 12-m configuration, plus calibration and overheads. As it is expected that this will be used when the sensitivity requires less time than that for the monitoring, a validation warning will appear if this is not the case. This option is not allowed if the time has been overridden due to u,v coverage issues.

If time constrained observing is selected, it must be thoroughly justified in the Technical Justification node.

## 5.6 Technical Justification

The technical justification for the various parameters entered by the user into the OT is now placed into a SG node. This presents the various inputs that need to be justified to the user on a single page and includes a text box into which the technical case should be entered. This node is laid out as follows:

- Relevant science parameters – these are simply a repeat of various important parameters that should be mentioned in the technical case. They mainly relate to the amount of time and arrays required to achieve the scientific goals.
- Expected source properties – these are taken from the Field Setup node, but include additional information such as the implied SNR.
  - Continuum: aggregate bandwidth and sensitivity – the bandwidth is the sum of the non-overlapping bandwidth of the defined spectral windows. For single-continuum setups the sensitivity is just the requested Science Goal sensitivity. For spectral line setups the sensitivity is calculated using the aggregate bandwidth and the on-source time required to meet the requested line sensitivity.
  - Continuum: peak flux density and SNR – this is the flux density of the faintest source defined and the SNR is the ratio of this to the continuum sensitivity.
  - Continuum: polarization and SNR – the polarization will be printed of the source that had the lowest value of polarized continuum flux i.e. percentage polarization multiplied by peak flux density. The SNR is equal to the polarized continuum flux divided by the continuum rms.
  - Line: peak flux density and SNR – this is the flux density of the faintest source defined and the SNR is the ratio of this to the requested line sensitivity.
  - Line: polarization and SNR – the polarization will be printed of the source that had the lowest value of polarized line flux i.e. percentage polarization multiplied by peak flux density. The SNR is equal to the polarized line flux divided by the line rms.
  - Line: line width and number of resolution elements – the line width is the narrowest that was entered and is divided by the spectral resolution of the Representative Window to form a measure of how many resolution elements cover the line’s FWHM.
  - Line: Dynamic Range – this is the ratio of the continuum flux to the requested line sensitivity and is a measure of how good a bandpass is required i.e. detecting faint lines on a strong continuum is difficult. The continuum flux is therefore the largest of the values entered on the Field Setup page.
- Non-standard choices – this panel highlights parameters that might be perfectly reasonable, but which require specific mention in the justification text. These are:
  - Non-Nyquist mosaic sampling – non-Nyquist values are usually used when the scientific goal is to cover a large survey area and large-scale structures are not being observed.
  - Single polarization – dual polarization is more usual and single polarization only used when the highest spectral resolution is required.
  - High data rate – if many high spectral-resolution spectral windows are defined, this will lead to a large data rate and associated data volume which impacts on the observatory’s resources i.e. for data storage.
  - Low max elevation – sources with low declinations will suffer large atmospheric attenuation and be difficult to schedule because of limited time above the horizon.
  - User-defined calibration – this is **strongly** discouraged and must be rigorously justified.
  - ACA choice overridden – the OT will recommend whether the ACA is required based on the largest angular scale that needs to be imaged. This recommendation can be overridden, but must be justified.
  - Additional time required (for u,v coverage reasons) – if your source has a complicated structure, but the sensitivity requirement is such that not enough time is needed to build up sufficient u,v coverage, the OT’s sensitivity-based time estimate may have been overridden. In the TJ node there must be a detailed explanation of why this is necessary and how the new time estimate was calculated. This must include calibrations and overheads.
  - Time-constrained observing – these imply significant constraints on the scheduling of all ALMA projects and must therefore be fully justified. In addition, if “continuous monitoring” is selected, the time entered (which must include calibrations and overheads) must be explained.
- Justification text – up to 4000 characters of plain text can be written here. The text should justify the Science Goal setup, particularly in light of the parameters displayed above.



# Chapter 6

## Phase 2 Program Scheduling Blocks

Planning of an Observing Program can be done in great detail by defining the Phase 2 Observing Unit Sets and Scheduling Blocks. How this is actually done is described in Chapter 6 of the OT User Manual.

### 6.1 Observing Unit Set

Observing Unit Sets contain either other OUSs or one or more Scheduling Blocks. Although an arbitrarily-deep nested structure would be possible, in practice all ALMA SBs should be contained in a standard structure of a top-level Science Goal OUS, a Group OUS and a Member OUS – the SBs go in the latter. The following panels are present in all OUSs.

#### 6.1.1 Basics

The Basics panel contains very basic non-technical information only.

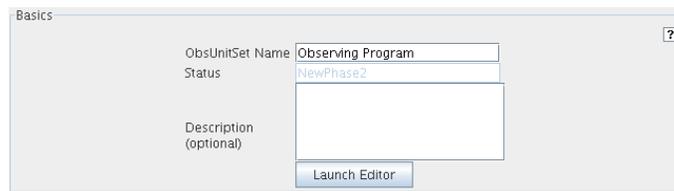


Figure 6.1: The Basics panel of Observing Unit Set form.

- **ObsUnitSet Name:** A user entered name for this OUS. SB generation will default to standard names and differentiate between the Science Goal, Group and Member ObsUnitSets.
- **Status:** Shows the current status of this particular OUS. The allowed states are shown in this diagram of the OUS Life Cycle.
- **Description:** Optional description of the OUSs purpose/contents.
- **Launch Editor:** Fancy editor for the Description field.

#### 6.1.2 Control

The Control panel provides the execution control limits for the OUS, in terms of items like the maximum time allowed, the user and scheduling constraints. Quite probably none of the information in the panel is currently used.

Figure 6.2: The Control panel of Observing Unit Set form.

- **Maximum Time:** This is the sum of allowed execution times for all parts of this OUS. It will accumulate the maximum times of all other OUSs and SBs below it in the hierarchy.
- **Execution Time:** This is the estimated actual execution time as calculated by the OT.
- **Array Type:** The array configuration to be used. Options are the 12-m Array, the ACA, the 7-m Array and the Total Power Array.

The following fields are definitely currently not used:

- **User Priority:**
- **TAC Priority:**
- **Pointing Accuracy:**
- **Bandpass Accuracy:**
- **Polarization Accuracy:**

The remaining three panels, Unit Dependencies, ObsUnitSet and Data Processing are also not used.

## 6.2 The Scheduling Block

The Scheduling Blocks are the key executable units of a project and contain all the information necessary to execute a single observation. In addition to the SB overview form itself, SB Target details are stored in the Field Sources, Instrument Setup and Observing Parameters forms. The panels Unit Dependencies and Temporal Constraints in the SB form are currently not used and the fields in these panels are not listed below.

### 6.2.1 Basics

Figure 6.3: The Basics panel of the Scheduling Block form.

- **SchedBlock Name:** A user-entered name for this SB.

- **Status:** Shows the current status of the SB. The allowed states are shown in this diagram of the SB Life Cycle.
- **Description:** Optional description of the SchedBlock.
- **Launch Editor:** Fancy editor for the Description field.

### 6.2.2 Control

Figure 6.4: The Control panel of the Scheduling Block form.

The Control panel provides various constraints on the observation, but very few, if any, of the parameters are used at present.

- **Maximum Time:** This is the maximum allowed execution time for this SB.
- **Execution Time:** This is the estimated actual execution time as calculated by the OT.
- **Array Type:** The array configuration to be used. Options are the 12-m Array, the ACA, the 7-m Array and the Total Power Array.

In the next subpanel the following fields are currently not used:

- **User Priority:**
- **TAC Priority:**
- **Pointing Accuracy:**
- **Bandpass Accuracy:**
- **Polarization Accuracy:**

### 6.2.3 Preconditions

The Preconditions panel specifies the conditions that must be met before this SB can be executed. None are probably yet used.

- **Baseline cal:**

The Preconditions panel includes the following fields:

- Baseline cal:  Polarization
- MaxPWVC: 2.00000 mm
- Seeing: 0.20000 arcsec
- Phase Stability: 1.00000 deg
- Max Wind Velocity: 5.00000 km/s
- Min Allowed HA: 100.00000 deg
- Max Allowed HA: 359.99999 deg

Figure 6.5: The Preconditions panel of the Scheduling Block form.

- **Max PWVC:**
- **Seeing:**
- **Phase Stability:**
- **Max Wind Velocity:**
- **Min Allowed HA:**
- **Max Allowed HA:**

## 6.2.4 SchedBlock

The SchedBlock panel includes the following fields:

- Standard Mode:
- Mode Name: Standard Interferometry
- Mode Type: User
- Execution Count: 1 Indefinite Repeat
- Max. Time: 1800.00000 s
- Obs. Procedure: StandardInterferometry.py
- Buttons: Commit Changes, Launch Editor
- Run Quick Look:

Figure 6.6: The SchedBlock panel of the Scheduling Block form.

- **Standard Mode:** If true, this SB is part of a supported, “standard ALMA observing mode”, such as single-field interferometry or interferometric mosaicing. This is set automatically depending on which mode is selected.
- **Mode Name:** The name of the observing mode. For science observations, only Standard Interferometry is currently supported.

- **Mode Type:** The type of the observing mode: Observatory, User or Expert. This parameter is set automatically depending on which mode is selected.
- **Execution Count:** The number of times that the SB should be run. Once this is reached it is impossible to execute the SB again so this is often set to a larger number than required.
- **Max. Time:** Maximum time for a single execution of this SB.
- **Obs. Procedure:** Name of the script that will be used to run the observation. Alternatively, the script can itself be entered into the text field. For science observations, only StandardInterferometry.py is currently available.
- **Run Quick Look:** If true, as it usually should be, the ALMA Quicklook display will be run during the observation and provide rapid feedback as to the quality of the data.

### 6.2.5 Advanced Parameters

The Advanced Parameters panel allows the specification of parameters that will be passed to the observing script. The keyword-value pairs must exactly match what is expected by the script. The displayed parameters depend on which mode has been selected. For StandardInterferometry.py, the currently-available Advanced Parameters are:

- NumPhaseCal
- NumAmplitudeCal
- NumBandpassCal
- NumFocusCal
- NumPointingCal
- ElLimit
- MaxPointingSeparation
- SourceCycleTime

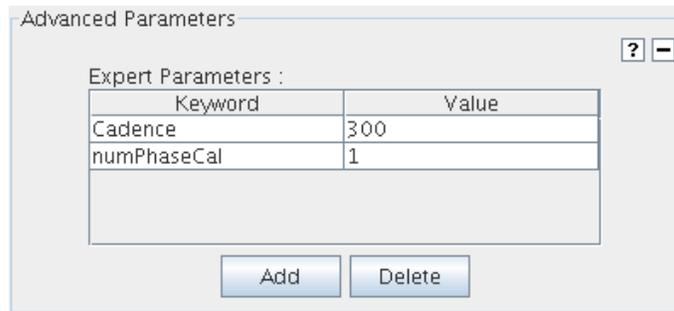


Figure 6.7: The Advanced Parameters panel.

### 6.2.6 Performance Goals and Scheduling Constraints

The Performance Parameters panel defines the science performance required for this SB.

- **Representative Target:** A Phase-2 program needs a Representative Target in order to validate and generation will usually set this to the first Field Source. The Doppler settings will be set based on the Representative Target.

Figure 6.8: The Performance panel of the SB form.

- **Representative Coordinates:** The coordinates of the Representative Target.
- **Representative Frequency:** The frequency to be used when determining whether the SB has achieved its sensitivity goal or not.
- **Representative Receiver Band:** Band corresponding to the Representative Frequency.
- **Min. Angular Resolution:** This can be set to ensure that the SB is observed using an appropriate array configuration. Not currently used.
- **Max. Angular Resolution:** See above.
- **Dynamic Range:** Not currently used.

### 6.2.7 Temporal Constraints

This panel is not currently used.

### 6.2.8 Observing Groups

This panel shows the currently-defined Observing Groups and their index. Their order can be changed using the arrows.

## 6.3 Field Sources

The following panels are visible for each Field Source node. Together with a Instrument Setup and an Observing Parameters, a Target is created which can be used to observe one or more scans during SB execution.

### 6.3.1 Query Status

Checking this allows a set of search criteria to be defined that will be used at runtime to select a calibrator in real time. Alternatively, it can be used to search the ALMA calibrator database for a specific source.

Figure 6.9: The Field Source Panel of the SB Field Sources form.

### 6.3.2 Field Source

If a Field Source query has been selected, this panel is not used. It contains:

- **Field Source Name:** This should be a unique identifier for the Field Source. It is usually used to describe the purpose of the Field Source e.g. amplitude.
- **Source Name:** The source name – this can be used to automatically complete the source details using the Resolve button. This can potentially add the coordinates, proper motions and velocity information. Please check the information carefully!
- **Choose a Solar System Object:** Selecting this brings up a list of solar-system bodies that are known to the telescope control system. Alternatively, an ephemeris can be entered.
- **Source Coordinates:** The coordinates of the source. This item includes:
  - **System:** Only J2000 is currently supported.
  - **Parallax:**
  - **RA:**
  - **Dec:**
  - **Proper Motion RA:** Proper motion in the Right Ascension (cross-declination) direction. Typical units are milliarcsec/yr.
  - **Proper Motion Dec:** Proper motion in the Declination direction.
- **Source Radial Velocity:** The radial velocity of the source can be entered as either a velocity or a redshift. It is used to convert source rest-frame frequencies to their observable (sky) equivalents. The full set of options are:
  - **Velocity:** Upon entering this, the redshift will also be set according to the Doppler Type (velocity definition). For Single Continuum setups, automatic SB generation will set the velocity to zero (in the SB only).
  - **Doppler Frame:** A number of options are available: barycentric, lsrk, topocentric and lsr. However, heliocentric should not be chosen as it is not currently supported. Resolving the source details will often cause heliocentric to be set and, if this is the case, automatic generation will convert it to barycentric (these differ by a maximum of approximately 12 m/s). If the frame is changed, no conversion is performed of an already-entered velocity/redshift.
  - **z:** Redshift. Upon entering this, the velocity will also be set according to the Doppler Type (velocity definition). For Single Continuum setups, automatic SB generation will set the redshift to zero (in the SB only).

- **Doppler Type:** This sets the velocity definition (radio, optical or relativistic). Changing this will make the velocity agree with the entered redshift.

In the source properties table that follows frequency, flux and diameter can be provided. If the source has been selected from the ALMA Calibrator Database, these details will be filled in automatically. Finally:

- **Visible Magnitude:** Visible magnitude for the source (used in optical pointing). Not currently used.
- **Use Reference:** If checked, a reference position can be defined.

### 6.3.3 Reference Position (Offset)

Figure 6.10: The Reference Position, Field Pattern panel in the SB Field Source form.

Up to two reference positions can be specified if this option has been selected in the panel above. These can be used to define offsets for On The Fly observing or for system temperature measurement. The parameters are:

- **Reference Coordinates:**
  - **Coords Type:** Choose between absolute or relative (to the Field Source) coordinates. It is not absolutely clear if absolute coordinates are supported – it’s therefore safest to use relative. Only J2000 and horizon offsets are currently supported.
    - \* Absolute offset inputs:
      - **System:**
      - **RA:**
      - **DEC:**
    - \* Relative offset inputs:
      - **System:**
      - **Offset(Longitude):**
      - **Offset(Latitude):**
- **Integration Time:** Time spent integrating per visit.
- **Cycle Time:**
- **Sub Scan Duration:** Must be an integer multiple of the integration duration. If an approximation is entered (the real value normally has lots of decimal places), a button is available to adjust this to the nearest legal value.

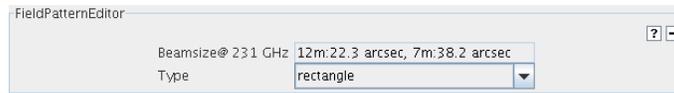


Figure 6.11: The upper part of the Field Pattern panel of the SB Field Source form.

### 6.3.4 FieldPatternEditor

The choice of the field pattern determines the name and the fields in the next panel in which the properties of the field pattern are defined. The available patterns are:

- Point – used for most interferometric observations i.e. where an antenna is stationary whilst integrating.
- Circle – not currently supported.
- Rectangle – defines an area which can be scanned by a telescope, usually a single dish. It can also be used to create a mosaic of single pointings.
- Spiral – not currently supported.
- Cross – allegedly supported.

### 6.3.5 Point

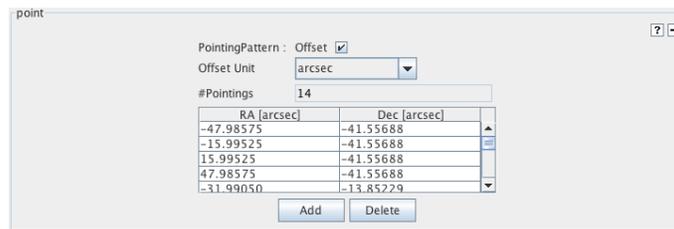


Figure 6.12: The Point field pattern panel for the SB Field Source form.

This interface consists of a table where the list of pointings should be added. Each will be observed one by one, each for the appropriate subscan duration, until the total integration time has been reached. The inputs are:

- **PointingPattern: Offset:** Tick if the pointing pattern position is an offset relative to the source position. If not, absolute positions are used.
- **Offset Unit:**

These are followed by the table, above which is reported how many pointings have been created.

### 6.3.6 Rectangle

- **Pattern Centre Coords:**
  - **Coords Type:** Choose between absolute or relative (to the Field Source) coordinates. Only J2000 and horizon systems are currently supported.
    - \* Absolute offset inputs:
      - **System:**
      - **RA:**

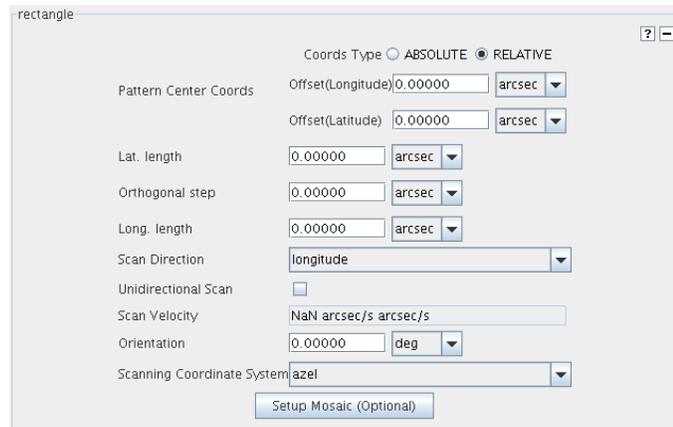


Figure 6.13: The Rectangle field pattern panel for the SB Field Source form.

- **DEC:**
- \* Relative offset inputs:
  - **System:**
  - **Offset(Longitude):**
  - **Offset(Latitude):**
- **Lat. length:** Length of one side of the rectangle.
- **Orthogonal step:** For raster scans – step size in the direction orthogonal to the scan direction.
- **Long. length:** Length of the other side of the rectangle.
- **Scan Direction:** For raster scans – the scanning direction for the raster, either in longitude or latitude.
- **Unidirectional Scan:** For raster scans – if checked, each scan will be made in the same direction.
- **Scan Velocity:** This cannot be set by the user.
- **Orientation:** Position angle of the rectangle.
- **Scanning Coordinate System:**
- **Setup Mosaic (Optional):** If desired, the above-entered rectangle *size* can be converted to a pointed mosaic. After filling in the following parameters and performing the conversion, the Field Pattern editor will revert to Point and the list of derived pointings will be shown.
  - **Frequency:**
  - **Overlap:**
  - **Spacing:**
  - **Antenna:**
  - **Layout Type:** Triangle patterns are usually used.

### 6.3.7 Cross

It is far from certain that this field pattern is supported or used. Just on the off chance, the inputs are:

- **Pattern Centre Coords:**
  - **Coords Type:** Choose between absolute or relative (to the Field Source) coordinates. Only J2000 and horizon systems are currently supported.

Figure 6.14: The Cross field pattern panel for the SB Field Source form.

- \* Absolute offset inputs:
  - **System:**
  - **RA:**
  - **DEC:**
- \* Relative offset inputs:
  - **System:**
  - **Offset(Longitude):**
  - **Offset(Latitude):**
- **Lat. length:** Length of one arm of the cross.
- **Long. length:** Length of the other arm of the cross.
- **Initial Scan Direction:** Choose which arm of the cross to begin with.
- **Scan Velocity:**
- **Orientation:** Position angle of the cross.

## 6.4 Instrument Setup

The following panels are visible for each Instrument Setup node.

### 6.4.1 Spectral Spec

Figure 6.15: The Spectral Spec panel of the Instrument Setup form.

- **Spectral Spec Name:** This should be a unique and descriptive identifier for the Spectral Spec.
- **Rest Frequency:** This isn't used by anything and cannot be set by the user.
- **Receiver Band:** Once a baseband has been defined, the receiver band and type (2SB, DSB, SSB) will be set automatically.
- **Add Total Power with square law detector to this correlator setup:** Please ignore.

## 6.4.2 Switching

The Switching panel contains the following elements:

- Switching Type: NUTATOR\_SWITCHING
- Total Dwell Time: 0.00000 s
- Number of positions: 0
- Switching Mode: STEPS
- Table with columns: Bin, Dwell Time, Position, Transition
- Buttons: Add switching state, Remove switching state

Figure 6.16: The Switching panel of the Instrument Setup form.

No switching possibilities are yet implemented at the telescope, but the basic interface is already in place in the OT. The options are:

- NO\_SWITCHING
- NUTATOR\_SWITCHING
- FREQUENCY\_SWITCHING

As none of these options are yet enabled, discussion of the inputs is deferred to the future.

## 6.4.3 Correlator Configuration

The Correlator Configuration panel contains the following elements:

- Integration Duration: 2.01600 s
- Channel Average Duration: 1.00800 s
- Atmos. Phase Correction Data To Save: AP\_UNCORRECTED
- Accumulation Mode: NORMAL
- LO Offsetting Mode: TWO\_LOS
- Enable 90deg Walsh Function:
- Enable 180deg Walsh Function:
- Dump Duration: 1.00800 s
- Buttons: ADJUST (for Integration and Channel Average Duration)

Figure 6.17: The Correlator Configuration panel in the Instrument Setup, for the 64-input correlator.

- **Integration Duration:** This sets the averaging interval of the output data points. If an approximation is entered (the real value normally has lots of decimal places), a button is available to adjust this to the nearest legal value. Typical values are 2 s for TDM correlator modes and 6 s for FDM.
- **Channel Average Duration:** This sets the averaging interval of the channel averaged data. For the 64-input correlator, this must be a multiple of the dump duration. Other restrictions apply for the ACA correlator. Firstly, it must be a multiple of 1 or 16 ms, depending on whether FAST or NORMAL has been selected for the accumulation mode. Secondly, if the integration duration is greater than 1008 ms, the channel average duration must be at least 512 ms. Otherwise, the channel average and integration durations must be equal. Approximations can be automatically adjusted to the nearest legal value.
- **Atmos. Phase Correction Data To Save:**
- **Accumulation Mode:** This is the fundamental averaging time of the correlator chips, after which further averaging is usually performed. There are two choices:
  - FAST (1 msec)
  - NORMAL (16 msec)

If cross-correlations are desired (together with auto-correlations) NORMAL must be chosen and this is the default. For FAST, only auto-correlation products are produced.

- **LO Offsetting Mode:** LO offsetting is used to suppress signals from unwanted sidebands. Sideband separation of DSB receivers is usually done with 90-degree Walsh switching, but the *rejection* of one sideband is possible using LO offsetting. The main use of LO offsetting is to provide additional suppression of the leakage from one sideband into the other, for 2SB receivers. Offsetting with two LOs uses LO1 and LO2, whilst FDM modes can also offset a third LO, that corresponding to the TFB offset frequency (usually known as LO4).
- **Enable 90deg Walsh function:** Allows the sidebands for DSB receivers to be separated in the correlator. Although also technically available to suppress the leakage from the other sideband for 2SB receivers, this will usually be done using LO offsetting.
- **Enable 180deg Walsh function:** This is used to remove spurious signals and DC offsets introduced into the signal path by the ALMA electronics e.g. the digitizer. It is usually enabled.
- **Dump Duration – 64-input correlator only:** The 64-input correlator is designed such that the dump interval must be a multiple of 16 ms for the NORMAL accumulation mode. At present, however, multiples of 48 ms (FDM) and 32 ms (TDM) are recommended. Values of around 1 s (e.g. 1.008 s) are usually selected for interferometric observations. For the FAST accumulation mode, the dump duration must be set to 1 ms.
- **Modulation – ACA correlator only:** If true, perform 180-degree anti-demodulation in the DTS receiver.
- **Demodulation – ACA correlator only:** This performs 180-degree demodulation in the CIP module. If modulation is chosen, then this must also be set.

#### 6.4.4 BaseBand Configurations

The core of defining an Instrument Setup is the setting of a maximum of 4 basebands (each 2 GHz wide) and the (potentially multiple) spectral windows that sample the baseband signals.

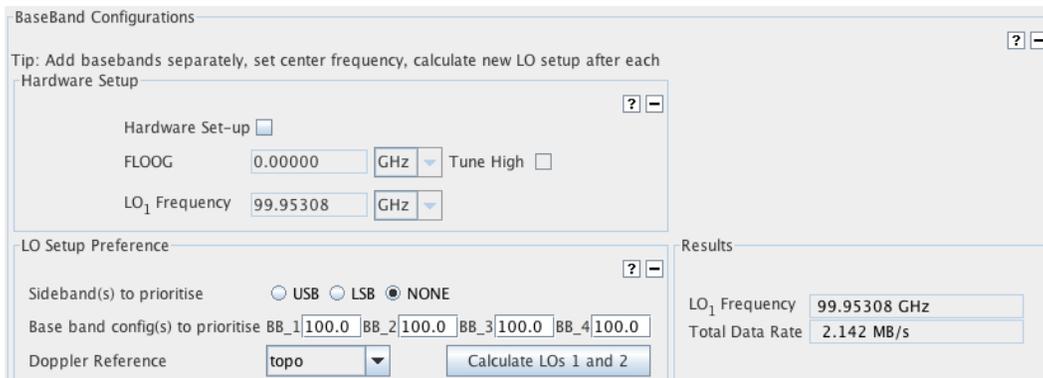


Figure 6.18: The top part of the Baseband Configurations panel.

##### 6.4.4.1 Hardware Setup

It is usually the case that the various LOs are set based on the requested baseband frequencies. It is, however, possible to request specific settings of the first local oscillator (LO1) and the First Local Oscillator Offset Generator (FLOOG):

- **Hardware Set-up:** Enable the following options.

- **FLOOG**: Note that this is sometimes referred to as the first Fine-Tuned Synthesizer. Ticking the “Tune High” box will add this frequency to LO1 (as opposed to subtracting it). The allowed range is 20 to 45 MHz and a value of 32.5 MHz is usually used.
- **LO1 Frequency**:

Enabling this option also allows certain other parameters to be set per baseband e.g. the use of the 12-GHz filter.

#### 6.4.4.2 LO Setup Preference

- **Sideband(s) to prioritise**: If set, the algorithm will try to place the requested frequencies in the designated sideband.
- **Base band config(s) to prioritise**: Weights (0 to 100) allow the basebands to be prioritised. This could be useful as, due to LO2 not having a continuous range, it is not always possible to tune to the exact frequencies requested. The weights are usually left at the defaults of 100.
- **Doppler Reference**: If the usual route of entering rest frequencies and a source velocity has been followed, this should be set to “rest”. However, for high-redshift sources where the desired frequencies have been manually corrected to the lsrk frame, the “lsrk” option should be selected. This will only correct for Earth motion relative to this frame and ignore the source velocity. Finally, if no correction should be made whatsoever, e.g. for pointing and continuum setups, “topo” should be chosen.
- **Calculate LOs 1 and 2**: After the baseband frequencies and the various priorities have been entered, see below, the ability of the system to find a tuning solution should be checked by clicking this button. It is not actually necessary to do this as the telescope control system will calculate the various LOs itself when the SB is run, but it’s a very useful check and should in fact always be done.
- **LO1 Frequency**: The LO1 frequency as determined in the OT, either by the tool itself, or entered by the user. This is an estimate used to help the user in correlator setup - the actual value used will depend on the time of observation.
- **Total Data Rate**: Estimate of the total data rate summed over all basebands. This is the *output* data rate from the correlator i.e. this number together with the total observing time determines how much data ends up in the ASDM and thus the archive.

#### 6.4.4.3 Basebands

Up to four basebands can be defined and these are shown in a tabbed format (Fig. 6.19). A summary table of the basebands is visible above the tabs, into which various properties (most obviously the centre frequencies) of the basebands can be conveniently entered. Some baseband settings are only available via the tabs. The table also shows the LO2 frequency and the instantaneous data rates that can be expected for each baseband configuration. Note that the LO2 frequency is determined within the OT, by the tool itself. This is an estimate to help the user in preparing a correlator setup - the actual LO2 used may vary depending on the time of observation, and is set by Control at execution time. The LO2 value cannot be edited unless hardware setup has been selected.

- **Baseband Name**: The four available baseband names must be chosen such that basebands 1 and 2 (or 3 and 4) lie in the same sideband.
- **Desired Centre Frequency**: The *desired* centre frequency for this baseband. How these frequencies are interpreted depends on the value of the Doppler Reference. If this has been set to “rest”, then they will be corrected for the source velocity.
- **Actual Centre Frequency (Rest)**: The actual centre frequency (in rest units) for this baseband. Note that this will usually differ from the desired value, albeit only slightly.
- **Actual Centre Frequency (Sky)**: The actual centre frequency in observed units.

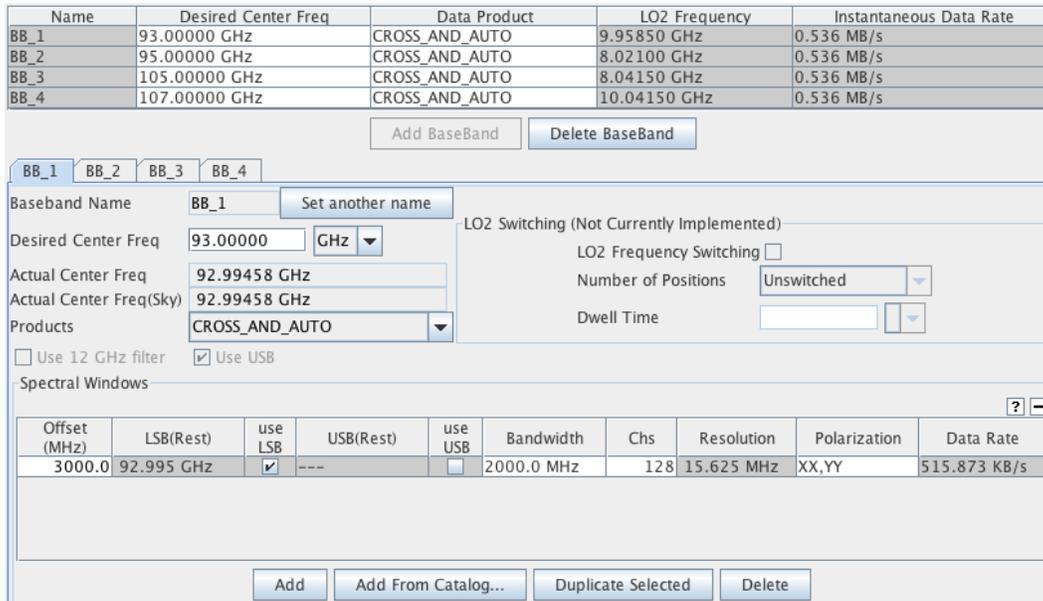


Figure 6.19: The tabs used to specify the basebands (64-input correlator) with the summary table at the top.

- **Products:** Allows the user to select both auto- and cross-correlations, auto-correlations only. When the accumulation mode is FAST, only the auto-correlations should be available.
- **Use 12 GHz filter:** This selects the 12-GHz low-pass filter that precedes the IF processor – otherwise the 8-GHz filter is used. It is usually required when LO2 exceeds a value of 10.5 GHz. This can only be selected if hardware setup has been enabled.
- **Use USB:** The input to the IF processor can, for 2SB receivers, select either the LSB or USB as input. LSB is assumed unless this is checked. A baseband pair (either 1 and 2 or 3 and 4) must use the same setting. This can only be selected if hardware setup has been enabled.
- **LO2 Frequency Switching:** Not currently implemented.
  - **Number of Positions:**
  - **Dwell Time:**
- **Polarization mode – ACA correlator only:** For the ACA correlator, it is only possible to select the polarization mode of the spectral window per baseband i.e. each spectral window in a baseband *must* produce the same polarization products. It is possible that this is not always the case for the 64-input correlator.
- **Center Freq of Residual Delay – ACA correlator only:**
- **Allows ACA Specific Modes – ACA correlator only:** The ACA correlator is able to reproduce all the modes that have been defined for the 64-input correlator. However, it is also capable of producing many more modes than this and, if this option is checked, it is possible to define these in the spectral window tabs below. Unfortunately, the restrictions on what is allowed in these cases are quite complicated and, although it is attempted to give an idea of these in this document, the ultimate arbiter will be the correlator validator.

#### 6.4.4.4 Spectral Windows

For each baseband it is possible to define multiple spectral windows and these are shown in a tabbed format (Fig. 6.20). A summary table of the spectral windows is visible above the tabs, into which various properties of the spectral windows can be conveniently entered. The full set of options is only available from the tabs.

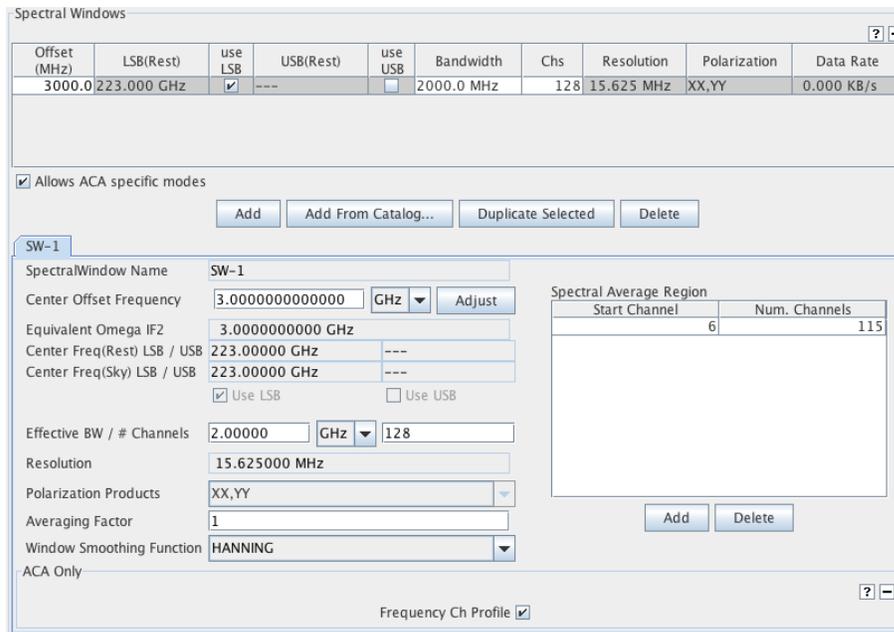


Figure 6.20: The Spectral Window tabs used to specify the spectral windows (ACA correlator) with the summary table at the top.

- **SpectralWindow Name:** Automatically set and non-editable.
- **Centre Offset Frequency:** This is used to set the position of the spectral window within the baseband. Technically speaking, it is equal to the frequency of the astronomical signal after down-conversion by the analogue to digital converter (also known as LO3), plus 2 GHz (don't ask). Using this convention, the available baseband signal covers a range of 2000 to 4000 MHz, and 3000 MHz therefore refers to the baseband's centre. Note that, LSB and USB behave differently – values above 3000 MHz will move the spectral window to higher sky frequencies for USB, but to lower sky frequencies for LSB. As it is not possible to move any part of a spectral window outside of its baseband, the effective range of this parameter is 2000 MHz minus the effective bandwidth. The exact value of the offset frequency is quantised and is equal to 30.517578125 kHz for the 64-input correlator. The step frequency for the ACA correlator depends on the bandwidth and number of channels and is calculated as follows:

```

hwSWCh = effectiveBandwidthMHz / (2000.0MHz * 1024 / 2 ** 19)
swCh = max(hwSWCh, effectiveNumberOfChannels)
chWidth = effectiveBandwidthMHz / swCh
step = chWidth * 8

```

To put this into context, for a 62.5 MHz-wide window with 4096 channels (FDM) the step frequency is equal to ~122 kHz, whilst for 2 GHz and 128 channels (TDM) it is 31.25 MHz. For both correlators a button is available to adjust an approximation to the nearest legal value.

- **Equivalent Omega IF2:** This shows the Centre Offset Frequency using a different definition (non-editable). It is equal to the frequency of the signal immediately after the down-conversion carried out by LO2.
- **Centre Freq(Rest) LSB/USB:** The centre frequency of the spectral window, in rest-frequency units. If sideband separation has been enabled, the value for each sideband will be displayed.
- **Centre Freq(Sky) LSB/USB:**
- **Use LSB:** This tells the correlator to save this sideband's data. If only a single sideband is being produced per spectral window e.g. for SSB and 2SB receivers, then this will be set appropriately and not be editable.

For DSB receivers though when the sidebands are being separated i.e. both are produced by the correlator, it is possible to turn one off.

- **Use USB:** As above.
- **Nominal BW / # Channels:** A number of correlator modes have been defined that must be made available by both the 64-input and ACA correlators. These can be formed by chosen suitable values for the nominal bandwidth and number of channels from a drop-down menu. If ACA-specific modes have been chosen (see above), this field is not displayed.
- **Effective BW / # Channels:** The displayed values are usually based on the nominal values and not editable. FDM modes produced by the 64-input correlator have effective bandwidths that are 15/16 that of the nominal, due to overlapping of the digital filters. If ACA-specific modes have been chosen, this field becomes editable and any values can be entered. However, these must still conform to various restrictions and the validator will complain about illegal inputs. The restrictions are somewhat complicated, but essentially every ACA bandwidth is built up from individual chunks with a width equal to the ACA step frequency. For example, whilst 2 GHz and 128 channels is a valid mode, discarding two chunks (each with a bandwidth of 31.25 MHz) results in a bandwidth of 1937.5 MHz. As each of these chunks contains two actual correlator channels, the number of channels must also be reduced to 124. In addition, the number of channels must be equal or greater to 16 and the minimum allowed bandwidth is  $\sim 61$  kHz.
- **Channel spacing:** This non-editable parameter displays the effective bandwidth divided by the number of channels.
- **CorrConfigMode/Filtermode – 64-input correlator only:** Correlator configuration internal mode number and filter type (TDM or TFB – the latter is synonymous with FDM).
- **Polarization Products:** Dual polarization (XX and YY) should normally be chosen unless the highest spectral resolution is required, but all four polarization products must be chosen if source polarization is to be determined. These must be the same for all spectral windows within the same baseband. This is not settable for the ACA which has a separate baseband-based polarization field (see above).
- **Averaging Factor:** Specifies the number of spectral channels to average together for each subband – this can greatly reduce the data rate when a correlator mode is being used that has much more spectral resolution than actually required. The allowed values are 1, 2, 4, 8 and 16 for the 64-input correlator and any power of 2 less than the total number of channels for the ACA correlator.
- **Window Smoothing Function:** Ringing in the output spectrum can be reduced by applying a window function. Hanning is usually applied by default, although other choices are available. Uniform means apply no windowing function.
- **Correlation Bits – 64-input correlator only:** The number of bits used in the correlation. Higher numbers will increase the sensitivity but will reduce the spectral resolution. Only 2-bit sampling is currently supported. The ACA correlator always uses 4-bit sampling.
- **Oversampling – 64-input correlator only:** The input data stream is usually sampled at the Nyquist rate. This can be doubled, slightly increasing the sensitivity, but the spectral resolution will be halved. Oversampling is not currently supported.
- **Quantization Correction – 64-input correlator only:** This corrects the derived visibilities for inaccuracies due to the limited number of bits used to sample the data. This is also known as the Van Vleck correction.
- **Frequency Ch Profile – ACA correlator only:** Due to the two correlators performing the cross-correlations and Fourier transforms in the opposite order, the spectra of an unresolved spectral line has a different profile in each case (sinc for the 64-input and sinc<sup>2</sup> for the ACA). Selecting this option will trigger an algorithm that converts the ACA spectral profile to that of the 64-input correlator.

For each spectral window it is possible to define up to 10 Spectral Average Regions (also known as Channel Average Regions). Note that these parameters are based on the effective channels and are zero-based.

## 6.5 Observing Parameters

The Observing Parameters node allows the intent of a Target to be defined i.e. science or one of various calibrations. The OT allows more than one to be associated with a single target, but this is not yet supported by the telescope control software and should not be attempted.

### 6.5.1 Science Parameters

The screenshot shows a software window titled "Observing Parameters" with a tabbed interface. The "Science" tab is selected. The window contains the following elements:

- Tabbed menu: BandpassCal, OpticalPointing, RadiometricPointing, Holography, FocusCal, AtmosphericCal, DelayCal, SidebandRatioCal, **Science**, PhaseCal, PointingCal, AmplitudeCal, PolarizationCal.
- Text: "This ScienceParameters is used by 1 target."
- Section: "Science Parameters" (collapsible, currently expanded).
  - Science Parameters Name: Science Params
  - Representative Bandwidth: 7.50000 GHz
  - Representative Frequency: 93.00000 GHz
  - Sensitivity Goal: 3.00000 mJy
  - Integration Time on Source: 140.00000 s
  - Sub Scan Duration: 10.08000 s
  - Adjust subscanduration to a correct value: [ADJUST Subscan button]
  - Force Atmospheric Calibration:
- Section: "Advanced Parameters" (collapsible, currently collapsed).

Figure 6.21: The Observing Parameters form to provide the parameters for the targets in the SB. The Science parameters tab is visible.

The Science Parameters have the following items:

- **Science Parameters Name:** This should be a unique and descriptive identifier for the Science Parameters.
- **Representative Bandwidth:** This is the bandwidth that will be used to determine whether the requested sensitivity has been reached. It will usually be the spectral resolution for spectral line observations and the maximum usable bandwidth (7.5 GHz) for continuum.
- **Representative Frequency:** This is the frequency that will be used to determine whether the requested sensitivity has been reached.
- **Sensitivity Goal:** The desired rms sensitivity. ALMA should observe an SB until this has been achieved. Not yet implemented!

- **Integration Time on source:** Desired integration time for this source in this SB. As the sensitivity criteria are not yet used, an SB will instead be observed for this amount of time. It normally consists of an integer multiple of subscans, each of which must run to completion.
- **Sub Scan Duration:** A subscan describes the smallest amount of data that can be continuously observed whilst the telescope is pointing in a specific direction, perhaps with associated scanning movement. This means that changing the telescope pointing (e.g. by changing the scan direction or moving to a new pointing direction) requires a new subscan and thus this parameter sets how long each position in a mosaic, or each scan in a raster is observed for. If an approximation is entered (the real value normally has lots of decimal places), a button is available to adjust this to the nearest legal value. A value of 30 s is typical. Once begun, a subscan will always run to completion.
- **Force Atmospheric Calibration:** Whether a system temperature measurement is needed will often be determined by the observing script, but checking this will ensure what one is taken every time the science Target is observed.
- **Advanced Parameters:** Not yet implemented.

## 6.5.2 Calibration Parameters

Many of the calibrator intents share the majority of their parameters. A number of the commonly-used calibrators require some additional parameters (e.g. pointing, bandpass) whilst some others, especially observatory modes such as holography and optical pointing, have completely unique sets of parameters.

### 6.5.2.1 Common Parameters

The parameters that are commonly shared are:

- **Parameters Name:** This should be a unique and descriptive identifier for the Science Parameters.
- **Cycle Time:** How often this calibrator should be observed.
- **Default Integration Time:** A nominal time for observing this calibrator. This will in general be exceeded as a subscan (for pointing observations a group of subscans), once started, must be completed. Might one day be overridden by the time taken to achieve some level of calibration accuracy.
- **Data Origin:** Type of data to use for deriving the calibration – the channel average data will often be used.
- **Sub Scan Duration:** This has a similar meaning to that for science observations i.e. the integration time will be made up of one or more subscans and, once a subscan has started, it will be completed. In addition, for calibrations that only make sense with some number  $n$  of distinct observations e.g. a five-position pointing, the subscan duration sets how long the telescope points at each position and an integer number of  $n$  subscans will always be observed.
- **Force Atmospheric Calibration:** Whether a system temperature measurement is needed will often be determined by the observing script, but checking this will ensure what one is taken every time the science Target is observed.
- **Force Execution:** It is possible that a calibration Target will not actually be observed as the script may decree that it is not necessary e.g. a sufficient calibration exists from a previously-executed SB. This can be overridden using this checkbox.
- **Advanced Parameters:** Not yet implemented.

Amplitude, phase, delay and sideband ratio calibrations *only* use the above parameters.

### 6.5.2.2 Bandpass-only Parameters

- **Desired Phase Accuracy:** Not yet implemented.
- **Maximum Elapsed Time:** Maximum time allowed to achieve the requested accuracy. Not yet implemented.
- **Desired Amplitude Accuracy:** Not yet implemented.

### 6.5.2.3 Pointing-only Parameters

- **Desired Accuracy:** Not yet implemented.
- **Pointing Method:** Of the various options, FIVE\_POINT is always used and probably the only one implemented.
- **Maximum Elapsed Time:** Maximum time allowed to achieve the requested accuracy. Not yet implemented.
- **Excursion:** This should be set to half of the antenna beam size.

### 6.5.2.4 Focus-only Parameters

- **Axis to adjust:** Specify the axis to focus, i.e. the X, Y or Z axis. The Z-axis is defined by the pointing direction towards the sky and the X and Y axes are perpendicular to this, with the X-axis pointing horizontally towards the right and the Y-axis downwards.

### 6.5.2.5 Polarization-only Parameters

- **Desired Polarization Accuracy:** Not yet implemented.

### 6.5.2.6 Atmospheric-only Parameters

Note that these are usually no longer required as the atmospheric calibration is taken care of by the observing script for science observations.

- **Use Hot Load:**
- **Coords Type:**
- **Sky Position:**

### 6.5.2.7 Optical Pointing-only parameters

The following lists all the Optical Pointing parameters i.e. these do not share any of the common parameters given above.

- **Randomize Order:**
- **Elevation Limit:**
- **Antenna Position Tolerance:**
- **Max Magnitude:**
- **Min Magnitude:**

### 6.5.2.8 Radiometric Pointing-only parameters

The following lists all the Radiometric Pointing parameters i.e. these do not share any of the common parameters given above.

- **Randomize Order:**
- **Elevation Limit:**
- **Antenna Position Tolerance:**

### 6.5.2.9 Holography-only Parameters

The following lists all the Holography parameters i.e. these do not share any of the common parameters given above.

- **Tower:**
- **Frequency:**
- **Number of Rows:**
- **Row Size:**
- **Scan Direction:**
- **Speed:**
- **Start Fraction:**
- **Calibration Mode:**
- **Calibration Time:**
- **Calibration Rows:**
- **uniDirectionalScan:**



# Chapter 7

## The Visual Editors

### 7.1 The Visual Spatial Editor

The Visual Spatial Editor is a graphical tool to aid in choosing input parameters for the Field Setup of a Science Goal or the Field Source of a Scheduling Block. It consists of a graphical interface that is described here, but also contains the Forms editors that are described in Sections 5.2 and 6.3. An example of the image display can be seen in Figure 7.1.

#### 7.1.1 Tool Bar and Zooming Functions

A toolbar is visible above the graphical interface. It provides the following functions:

- **Open a FITS file:** Load a FITS file on the display. Note that only the J2000 coordinate system is currently properly supported. FITS extensions are supported, but only the first one can be read.
- **Save image as ...:** Save the displayed image. The format can be selected in a separate window.
- **Cut selected FOVs:** Remove a telescope pointing position.
- **Select FOVs in a rectangular region:** Use the cursor to select a number of pointings.
- **Set the target centre (Source Coordinates):** Mark the centre of the target.
- **Add a FOV:** User the cursor to define an individual pointing. Individual pointings are drawn in red to indicate the antenna beamsize (field of view) and surround a green, dashed circle that indicates the inner third of the beamsize - beyond this the sensitivity will be significantly lower than requested.
- **Draw a rectangular map:** Use the cursor to define a rectangular region to be mapped. Via the colour anchors the region and be reshaped and rotated. This region will be automatically turned into a mosaic for use by the 12-m array and possibly the ACA 7-m array. A larger turquoise rectangle represents the area that will be observed using the ACA TP array (if necessary and available).
- **Show Pointing Positions:** Show the automatically derived mosaic positions for a rectangle field.
- **Image Cut levels:** Set the image cut level and pixel value distribution using a separate interface.
- **Show/Hide Grid:** Display a coordinate grid (RA and Dec).

At the bottom of the display, dragging the mouse within the colourbar will change the displayed contrast – right-clicking in the same area will reset the display to the default contrast. Below this, four buttons are available for zooming functions. In addition the zoom factor, the pixel and sky coordinates at the cursor position and pixel value are visible. The image file name that is loaded is also displayed.

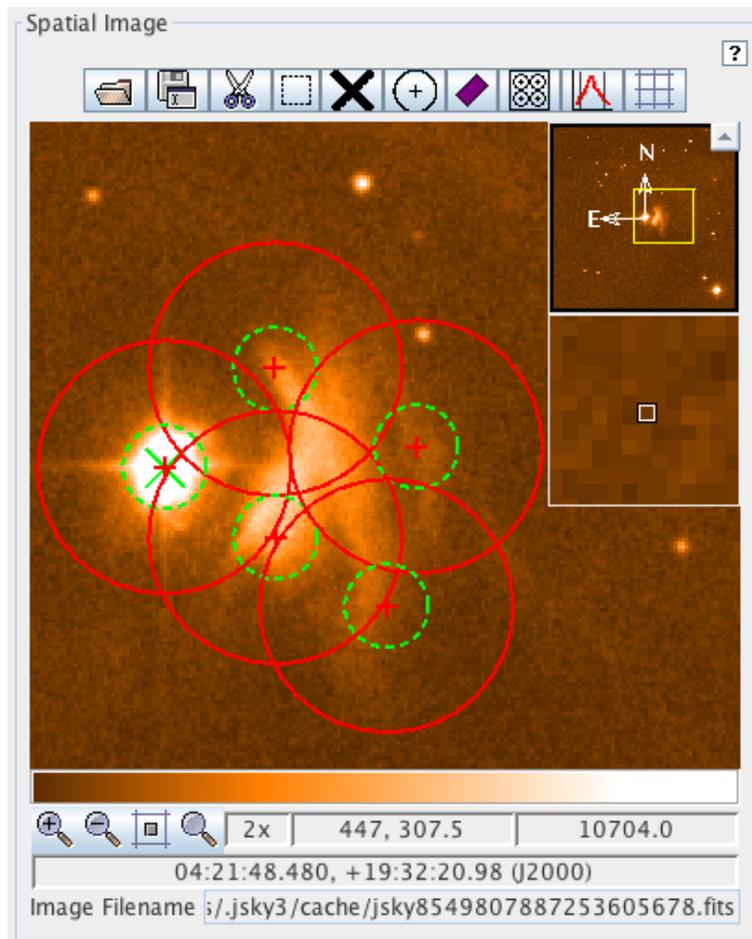


Figure 7.1: An example of the image display area of the Visual Spatial Editor. This is for a custom mosaic and shows the antenna beamsize (field of view) of the individual pointings (in red). The green, dashed circles indicate the inner third of the field of view. This is to emphasise to the user that the sensitivity drops off away from the pointing centre.

### 7.1.2 Fov Parameters

Below the graphical window are two panels that control the loading of images and various display options.

- **Representative Frequency (sky):** The sky equivalent of the Representative Frequency is used to determine the antenna beamsize.
- **Antenna Diameter:** Antenna diameter that shall be used for calculating the antenna beamsize. Choices are 12- (12-m and TP arrays) and 7 m (7-m array).
- **Antenna Beamsize:** Diameter of the chosen antenna beam.
- **Show FOV (circle):** Tick to display the chosen antenna beamsize and 1/3 of the beamsize markers.

### 7.1.3 Image Query

- **Image Server:** Select the image server from which the image shall be retrieved.
- **Image Size (arcmin):** Set the size of the image to be uploaded. Larger images take more time.
- **Query:** Retrieve and upload the image from the server.

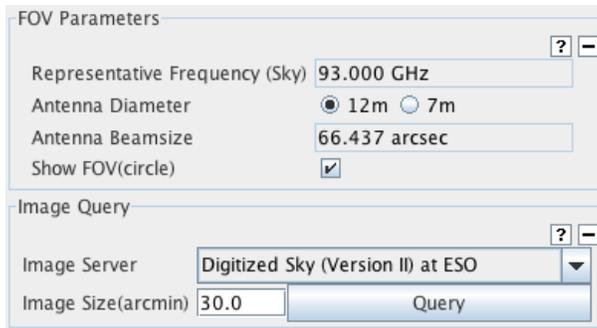


Figure 7.2: The antenna beamsize and server query controls of the Visual Spatial Editor.

## 7.2 The Visual Spectral Editor

The purpose of the Spectral Editor is, apart from the graphical presentation of the various parameters settings, to offer the possibility of adjusting and optimising various frequency setting parameters interactively using the cursor. The defined spectral windows are shown along with the tuning solution derived from them. This consists of the receiver sidebands (the spectral windows must all fit inside these) and the first local oscillator frequency (LO1). If a tuning solution has been found, the sidebands will be coloured yellow and, if shifted by dragging LO1 with the cursor, will spring back to their original position once the mouse button is released. If a tuning solution cannot be found, the sidebands turn grey. A project cannot be submitted unless a tuning solution has been found by the OT. A table at the bottom contains all sources that are specified in the Field Setup. Selecting these will move the spectral windows in the graphical interface, but note that the sidebands and LO1 frequency will not shift – these remain at the position appropriate for the first source.

### 7.2.1 Visual Spectral Editor for Science Goals

The Visual Spectral Editor for Science Goals is divided into five panels. The first section is described below. The other four panels are described in Section 5.3.1.

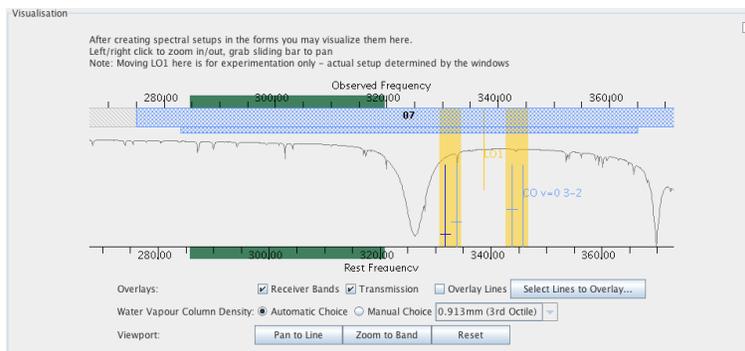


Figure 7.3: The graphical representation of the frequency information for Science Goals. The yellow sidebands indicate that a valid tuning solution has been found.

#### 7.2.1.1 Visualisation

- **Overlays**

- **Receiver Bands:** Displays the available receiver bands as a hatched bar along the top of the display.
- **Transmission:** Display the atmospheric transmission curve. This will change depending on what is selected for the Water Vapour Column Density.

- **Overlay Lines:** Display lines selected with the Spectral Line Selection tool.
  - **DSB Image:** For DSB receivers (bands 9 and 10) this displays the “image” counterpart of each spectral window. The image spectral window lies in the other sideband (equidistant from the LO1 frequency) and will show sources of contamination or excess noise e.g. other lines and atmospheric absorption, that will also affect the requested spectral window.
  - **Select Lines to Overlay:** Choose lines to overlay using the Spectral Line Selection tool.
- **Spectral Scan**
    - **Requested scan:** Show the range over which the spectral scan was supposed to cover. This will rarely exactly correspond to what was achievable in practice.
    - **Tuning 1, 2, etc.:** Display the spectral windows corresponding to a specific tuning. Each tuning is coloured differently and is offset vertically.
- **Water Vapour Column Density**
    - **Automatic Choice:** Allow the OT to automatically select the appropriate value of PWV according to the Representative Frequency and draw the corresponding transmission plot. This is recommended.
    - **Manual Choice:** Override the OT’s choice. This is for experimentation only – the OT will ignore this when calculating the time required for a Science Goal.
- **Viewport**
    - **Pan To Line:** Pan to the rest frequency.
    - **Zoom To Band:** Zoom to the current receiver band.
    - **Reset:** Reset the display settings.

## 7.2.2 Visual Spectral Editor for Scheduling Blocks

The Visual Spectral Editor is similar to that used in Science Goals, but there are some differences. As with the Science Goal version, a graphical interface is displayed along with the Forms editor – this is described in Section 6.4.1.

### 7.2.2.1 Receiver, Basebands & LO Visualisation

- **Track Selection:** Control whether or not to zoom to a newly selected baseband.
- **Fold Spectral Windows:** Optimize the use of the vertical space for drawing the spectral windows.
- **Fold Basebands:** Optimize the use of the vertical space for drawing the basebands.
- **Basebands:** Display the baseband ranges.
- **Other Transitions:** Toggle drawing of the other transitions that have been selected.
- **BBC Centre Frequencies:** Display the centre frequencies of the baseband configurations.
- **Receiver Bands:** Displays the available receiver bands 1 to 10.
- **Side Bands:** Display the LSB and USB ranges.
- **Transmission:** Display the atmospheric transmission curve.
- **Select Other Transitions:** Click to start up the Spectral Lines Selecting Tool to select lines to be displayed.
- **Pan To Line:** Pan to the rest frequency.

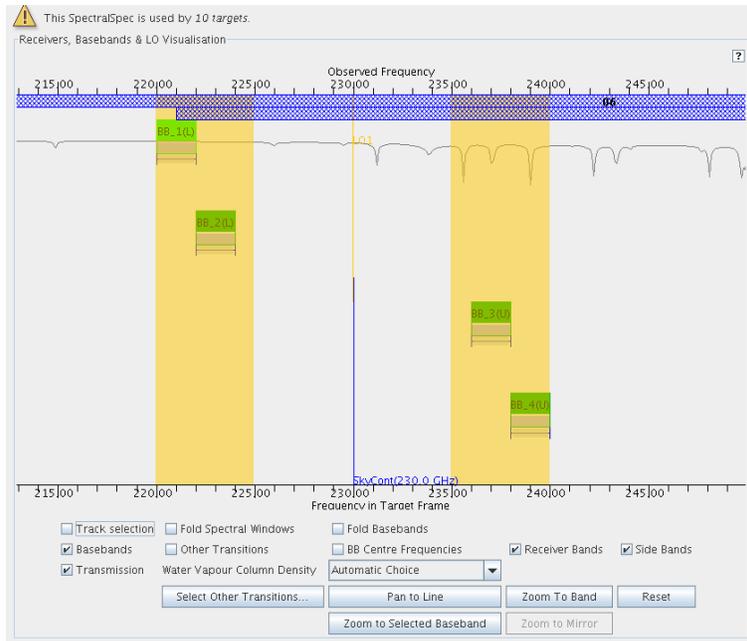


Figure 7.4: Visualisation of frequency information about receivers, basebands and LO frequencies. Visible are part of the frequency band (hashed), the transmission curve, four basebands and their spectral windows.

- **Zoom To Band:** Zoom to the current receiver band.
- **Reset:** Reset the display settings.
- **Zoom to Selected Baseband:** Zoom to the selected baseband.
- **Zoom to Mirror:** Zoom to the mirror (in the LO1 frequency) of the current window.



# Chapter 8

## Acronym List

**2SB:** Two sideband  
**ACA:** Atacama Compact Array  
**ALMA:** Atacama Large Millimeter/submillimeter Array  
**ARC:** ALMA Regional Centre  
**ASC:** ALMA Sensitivity Calculator  
**BBC:** Baseband Converter  
**DFS:** Data Flow System  
**FOV:** Field Of View  
**LO:** Local Oscillator  
**LSB:** Lower Side Band  
**OT:** Observing Tool  
**OTF:** On The Fly (mapping)  
**OUS:** Observation Unit Set  
**PI:** Principal Investigator  
**SB:** Scheduling Block  
**TFB:** Tunable Filter Bank  
**USB:** Upper Side Band



The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

