# ALMA Observing Tool Reference Manual

Andy Biggs, Rein H. Warmels

ALMA

www.almascience.org

## User Support:

For further information or to comment on this document, please contact your regional Helpdesk through the ALMA User Portal at **www.almascience.org** . Helpdesk tickets will be directed to the appropriate ALMA Regional Centre at ESO, NAOJ or NRAO.

## Revision History:

| 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 |
| 3.6, Ver. 1.0 | March 2015 | Andy Biggs |
| 4.6, Ver. 1.0 | March 2016 | Andy Biggs |
| 4.6, Ver. 2.0 | May 2016 | Andy Biggs |
| 5.6, Ver. 1.0 | March 2017 | Andy Biggs |

## Contributors

The ALMA OT Team and the many testers.

In publications, please refer to this document as:
   **OT Reference Manual 5.6, Version 1.0**

# Contents

This page was intentionally left almost blank

# 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.

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 submit proposals for Cycle 5.

## 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.

## 2.1 Menu Bar

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

### 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. Only available to privileged users.

- **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. Only available to privileged users.

- **New VLBI Program**: This will create a new Phase-2 program and any Science Goals added to this will be in VLBI format. If it is desired to copy a Science Goal from a Phase-1 proposal into a new Phase-2 program, this option must be used.

- **Open Project**: Open a project from the local disk or the ALMA Archive. There is also a project-finding tool, but this is of limited value and may not even work anymore.

- **Open Project as New Proposal**: The purpose of this is to allow a project that is in Phase 2 (possibly containing SBs) to be "recycled" as a new proposal. The new proposal will contain all the previous Phase-1 information (including Science Goals) whilst the Phase-2 information is removed.

- **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 an ALMA project (either from the local disk or the archive) 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 Project 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. Only available to privileged users.

- **Preferences**: Set various appearance and behavioural preferences.

- **Save Preferences**: Save the preferences of the current session to disk.

- **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 of SB parameters. On Linux, the modifier key is Ctrl, whilst on a Mac it is the Command key. On both systems, Ctrl-A will highlight all the text contained within a text field.

- **Cut**: Cut highlighted text from a text field.

- **Copy**: Copy some highlighted text or an item from the Project Tree (the latter will turn pink).

- **Paste**: Paste copied text into a text field, or a Project Tree item into a folder e.g. a copied Phase-1 Science Goal into the Planned Observing folder.

- **Rename**: Rename various Project tree items.

- **New Phase 1 Science Goal**: Create a new Phase-1 Science Goal. This will only work if a Phase-1 Proposal is active.

- **New Phase 2 Science Goal**: Create a new Phase-2 Science Goal. This will only work if a Phase-2 Project is active.

- **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. There is no undo action.

- **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. The inputs are independent of those entered into the main OT GUI, but will be remembered if the calculator is shut and subsequently re-opened.

- **Generate SBs from the Selected Goal**: Create one or more SBs from the selected Phase-1 or Phase-2 Science Goal.

- **Display Project Time Summary**: This brings up a dialogue that contains the time required for each Science Goal. This is broken down into the different arrays, time spent calibrating (where this can be calculated) and time spent observing non-standard modes. It also includes data volume and rate information.

- **Generate Phase 1 SBs from all the Science Goals**: Create one or more SBs from all of the Phase-1 Science Goals. This option is only available if the Proposal node has been clicked and if the user has enabled privileged operations.

- **Generate Phase 2 SBs from all the Science Goals**: Create one or more SBs from all of the Phase-2 Science Goals. This option is only available if the Science Plan folder has been clicked.

- **Export selected SchedBlock to File**: Privileged users can export a single SB to disk by highlighting it in the Project Tree and selecting this option. The file extension "xml" will be enforced.

- **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 whole proposal or of all or individual Science Goals.

- **Generate a PDF for the Whole Proposal**: This PDF contains the cover sheet, Science Goal summary sheets (including technical justification information) and the scientific justification.

- **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 double-click on them to be taken to the location in the Project Tree that is causing the problem. Alternatively, one can 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.

- **Release Notes...**: This jumps to the "Release Notes" section of the "About..." menu. It contains information on new features, improvements and bug fixes.

## 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.

## 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 whist 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.

- **Technical Justification**: This node allows a user to justify various technical aspects of the Science Goal and displays a lot of information in order to guide this.

### 2.3.1.2 Program

Using the Program tab, Phase-2 details are usually added by defining a Science Goal (basically identical to that found in the Proposal tab) and then generating Scheduling Blocks automatically from this. It is also possible to build the SB manually, but this is not recommended. SBs contain all necessary observing information to execute a "single" observation and consist of:

- **Resources**: These are the building blocks of an SB and detail various aspects of the observations:
    - **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.

- **Targets**: Each of these consists of a Field Source, an Instrument Setup and an Observing Parameters.

- **Observing Groups**: Each Target must be placed into an Observing Group or else it will not be observed. Amplitude and bandpass calibration are usually only carried out in the first Observing Group.

In addition, Scheduling Blocks must be placed into Observing Units Sets, or OUSs. There must always be three levels of OUS under the Science Plan folder:

- **Member OUS**: SBs are stored in the MOUS folder. Each MOUS currently corresponds to a different array configuration i.e. 12-m, 7-m and TP Array.

- **Group OUS**: This folder can contain multiple MOUSs, the SBs of which will be combined together during data processing. Multiple GOUSs are possible, each of which corresponds to an observation that is separate i.e. data from different GOUSs will not be combined. For example, each visit of a multiple-visit, time-constrained observation is contained within a separate GOUS.

- **Science Goal OUS**: There is only one of these per Science Goals and contains all the Group OUSs.

### 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 (or dragged and dropped) 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.

# Chapter 3

# Tools and Simulators

The OT is equipped with a number of tools: the Calibration Selection Tool, the Spectral Line Picker (SLP), 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.

## 3.2 Spectral Line Picker

The spectral-line catalogue used by the OT is the Splatalogue[1] and the millions of spectral-line transitions contained within this can be searched for and selected using the Spectral Line Picker. This appears at various

---

[1] http://www.splatalogue.net

points in the OT where it fulfills different functions: creating spectral windows, overlaying lines in the Visual Spectral Editor and defining rest frequencies. The OT itself contains a useful subset of the whole Splatalogue, but there is also the option to search the whole Splatalogue on-line.

- **Transition 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

### 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.

- **Trx, tau, Tsky**: Receiver temperature, 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 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).

### 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 (PI) and Main Project Information panels, with the following fields:

- **Select PI...**: This opens a tool that allows the PI to be selected from the user database.

- **Project**: The title of the project can be entered here and is limited to 120 characters.

- **Assigned Priority**: Not yet used.

- **Project Code**: A unique code for the project, assigned automatically upon its first submission. The format consists of four separate fields:

    - Year of submission (4 digits)
    - Period of submission (single digit or, for DDT proposals, a single character)
    - Order of submission (5 digits)
    - Letter Code (single character).

    For example, the first DDT submission of Cycle 4 will have the code `2016.A.0001.S`, if it is a Regular proposal.

## 4.1 Proposal Information

- **Proposal Title**: The title of the project can be entered here and is limited to 120 characters.

- **Proposal Cycle**: This is formed from the proposal year and the submission period. If a non-submitted proposal created during a previous cycle is read into the OT the old proposal cycle will be shown, but this will be updated to the current cycle if the project is then submitted.

- **Abstract**: The abstract can be entered as plain text and is limited to 1200 characters.

- **Proposal Type**: Four projects types are currently available

    - Regular (Letter Code = `S`): This type of project is essentially the opposite of Large i.e. the total time required must be less than the criteria for Large projects.
    - Large (Letter Code = `L`): If >50 hours of 12-m Array or stand-alone ACA time is requested, this Proposal Type must be selected. Projects must receive an A grade in order to receive time and are allowed a longer Scientific Justification.

- **Target of Opportunity (Letter Code = T)**: These projects will need to be triggered during the observing period. It is not necessary to enter the source coordinates as these may not be known at proposal submission time.
- **VLBI (Letter Code = V)**: Selecting this will significantly change the information that must be entered into the Science Goal. A proposal must also be submitted to the other telescopes that will form the VLBI array.

- **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. The second keyword is added by holding down the Shift or Ctrl key in the way that you're probably used to.

- **Student Project**: Check the box if the data will form part of a PhD or other major student 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 with each separated by a comma e.g. "2015.1.54321.S, Other Proposal Title, Proposer Name" (without the quotes).

- **Previous Proposals**: Details of any related ALMA proposals, graded A, B or C in previous Cycles. Project code, title, PI name and publication status should be given. A comma-separated format is again required e.g. "2013.1.54321.S, Previous Proposal Title, Proposer Name, Published" (without the quotes).

## 4.2 Investigators

This contains information about the proposal investigators. All investigators must already be registered with ALMA via the Science Portal. The PI is required and one or more co-PIs (Large Programs only) and co-Investigators (co-Is) may also be added.

For each investigator the following details are required:

- **Type**: Is this a PI, a co-PI or a co-I? Co-PIs are only allowed for Large Programs and VLBI proposals and have equal access rights to the data. The time for the proposal is charged to the different Executives in accordance with the number of co-PIs from each.

- **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.

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

- **Select PI**: Complete the PI data by accessing the ALMA user database.

- **Add CoPI**: Complete the co-PI data in the same way.

- **Add CoI**: Complete the co-I data in the same way.

- **Remove Collaborator**: Delete a highlighted investigator from the table. If multiple rows are highlighted i.e. using the Shift or Ctrl/Cmd keys (depending on your operating system) these can be deleted simultaneously using a single click. Note that PI's can only be changed, not deleted.

- **Add from Proposal...**: Add the investigators from a previous project as co-Is.

## 4.3   Science Case

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, or 6 pages for Large Programs.

**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**: Launch a file browser dialogue to allow the user to choose the PDF file.

- **Detach**: Remove a previously-attached file from the proposal.

- **View**: Ask the desktop operating system to launch a viewer to display the document. *Note:* this relies on the operating system being correctly configured and an appropriate application installed.

## 4.4   Duplicate observations

Before a proposal is submitted, the ALMA Science Archive should be checked to see that duplicate observations do not already exist. If they do, it should be explained here why the observations need to be repeated. A single panel is provided for free-format text as well as a clickable link to the ALMA duplication policy.

## 4.5   Observatory Use Only

This panel is not currently used.

# Chapter 5

# Phase 1 and Phase 2 Science Goals

Science Goals are designed to capture the scientific aims of a particular observation whilst hiding the technical details of the observations from the user. The technical information is contained within Scheduling Blocks (Section 6) that are automatically generated from the (Phase-2) Science Goal.

Clicking on the top node of a Science Goal will display either a summary table of the Science Goal contents, or all of the Forms editors, depending on the user preferences. Descriptions of the six Science 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 name and description of the Science Goal. Whilst the latter is optional, it is necessary that all SGs in a proposal have unique names. These can also be changed by right-clicking on a Science Goal in the Project Tree.

This form also includes a checkbox that indicates whether the SG has been descoped by the proposal review process. Therefore, this can only even be checked in a Phase-2 SG. If it is checked, it will not be possible to generate SBs.

## 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. The OT includes a clustering algorithm that will attempt to split the sources into multiple clusters such that all the pointings lie within 10 degrees of each other, with a maximum of 150 pointings per cluster. At Phase 2 each cluster is written into a separate Scheduling Block.

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

- **Add Source**: Add a science source, the details of which can either be "resolved" from SIMBAD or NED, or added manually.

- **Load from File...**: Add one or more sources, including their properties, using a local ASCII file. The format of the file is as follows:

```
Name, RA(sex), Dec(sex), PMRA(mas/yr), PMDec(mas/yr), vel(km/s), Ref frame, Doppler type,
peak cont flux(mJy), peak line flux(mJy), cont pol(%), line pol(%), line width(km/s)
--   This signals end of the header
```

```
ngc253, 00:47:33.134, -25:17:19.68, 0.0, 0.0, 258.688, lsrk, RADIO, 200, 1000, 2, 0, 1500
ngc1068, 02:42:40.771, -00:00:47.84, 0.0, 0.0, 1142.075, topo, OPTICAL, 1100.0, 30, 0, 0, 20
```

- **Export to File...**: Write the source positions to a local ASCII file.

- **Clone Source**: Create a copy of the currently-selected source.

- **Delete Source**: Delete the currently-selected source.

- **Delete All Sources**:

### 5.2.1 Source

- **Source Name**: 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. Spaces are replaced by underscores.

- **Resolve**: Fill in source details by searching for the entered source name in SIMBAD or NED. SIMBAD is checked first and then NED if no match was found. Check the details very carefully! Note that the so-called IAU format e.g. B0218+357, is no longer allowed – an acronym must be placed before the coordinates e.g. JVAS B0218+357.

- **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. This is a special target as it requires that an ephemeris be entered. This can be generated using the Solar Ephemeris Tool that is located within the Science Portal.
        * Planets: Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune.
        * Satellites: The Moon, Ganymede, Callisto, Io and Titan.
        * Dwarf planets: Pluto and Ceres.
        * Asteroids: Pallas, Juno and Vesta.
        * Ephemeris: Load a JPL HORIZONS format ephemeris[1]. The source name will be extracted from the ephemeris and inserted into the appropriate field.

- **Source Coordinates**: Note that these fields do not appear for solar-system objects.

    - **System**: Only ICRS or Galactic should be chosen. ICRS is effectively the only system that is supported by the telescope control system and all calibrator positions are measured within this frame. This means that even if FK5 were selected, the position will be interpreted as ICRS and the output image will be in this coordinate system. Given that all ALMA observations are implicitly made in the ICRS frame, the OT will simply change an FK5 label to ICRS during SB generation. The coordinates will not be transformed, but this is not a problem as the offset between ICRS and FK5 is so small (tens of mas). Therefore, the source may not appear at the expected location within the image, but the image coordinate axes will be correct. Any offset would in any case only be noticeable for very high angular resolution observations. If Galactic coordinates are entered, these will be properly converted to ICRS as part of SB generation.

    - **Sexagesimal display?**: ICRS (and FK5) coordinates 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 ICRS (or FK5) and degrees for everything else.

    - **DEC**: Source Declination. Ditto.

---

[1]http://ssd.jpl.nasa.gov/horizons.cgi

- **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 FK5 position refers to Epoch J2000.
  - **PM DEC**: Proper motion in the declination direction. Units should be milliarcsec/yr.

- **Source Radial Velocity**: Note that these fields do not appear for solar-system objects. 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 and topocentric. Heliocentric can also be chosen, but is not currently supported by the telescope control system 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. If lsrk is selected, the user-entered spectral window frequencies are converted to the barycentric frame when calculating tuning solutions.
  - **z**: Redshift. This is set automatically if a velocity is entered, but the redshift can also be entered and will set the velocity accordingly. 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". All sources in a Science Goal must use the same Target Type.

## 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 Synthesized Beam**: The expected flux density per synthesized 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 **linear** polarization for the source, expressed as a percentage of the peak continuum flux. The polarization of the weakest component should be entered. Note that if the polarization percentage is very low, then the OT will issue a validation error as it will not be possible to calibrate the data. The limits are 0.1 per cent for compact sources (LAS smaller than the angular resolution) and 0.3 per cent for extended sources. Circular polarization observations are not yet supported by ALMA.

- **Peak Line Flux Density per Synthesized Beam**: The expected peak flux density per synthesized 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 **linear** polarization for the source, expressed as a percentage of the peak line flux. The polarization of the weakest component should be entered, where the limits are stricter than in the case of continuum – 1 per cent for compact sources (LAS smaller than the angular resolution) and 3 per cent for extended sources. Circular polarization observations are not yet supported by ALMA.

- **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. The line width must be in velocity units.

If observing the sun, there will only be two choices:

- **Quiet Sun**:

- **Active Sun**:

To compensate for the sun's prodigious flux density, solar observations will often make use of a special observing mode known as mixer debiasing. Which mode will be used will depend on the level of solar activity and the frequency band.

### 5.2.3   Field Center Coordinates

This panel is visible if Individual Pointing(s) has been selected in the Source panel. The number of pointings that can be defined is nominally 150 per Science Goal, distributed between multiple sources. In practice, more pointings can be created if the source list can be split into multiple clusters. It is possible to define multiple pointings per source, but each one must overlap such that they form a single mosaic. If multiple mosaics are required, they must be placed in separate Field Sources.

- **Coords Type**: Field centre in relative or absolute coordinates. Relative positions are offset from the source coordinate and are recommended. Absolute coordinates can be entered, but will be converted to offsets from the source coordinate during SB generation as absolute coordinates cannot be used with the telescope control system.

- **Offset Unit**: If relative coordinates have been selected, set the unit of the offset (usually arcsec).

- **#Pointings**: A count of how many pointings have been defined, useful when there are many.

- **RA** and **Dec**: The position of each pointing should be entered in this table, usually relative to the source coordinate. Absolute coordinates are also possible, but are not recommended.

At the bottom of the panel are buttons which allow a user to add and delete pointings manually, but also to import and export them from and to an external ASCII file. The file format is very flexible and allows a user to write out the pointing positions in either offset or absolute coordinates and will automatically do the conversion between the two i.e. one can export in a different system to what is displayed. An example of the format for absolute coordinates in sexagesimal is shown here:

```
RA , Dec, Coordinate Type, Coordinate Units
--   This signals end of the header
 04:31:38.4369, 18:13:57.651,Absolute,Sexagesimal
 04:31:40.5426, 18:13:57.650,Absolute,Sexagesimal
 04:31:36.3312, 18:13:57.650,Absolute,Sexagesimal
```

The "Absolute" coordinate type can be combined with the units "Sexagesimal", "Degrees" or "Radians", whilst "Offset" pointings can be defined in "Arcsecs", "Arcmin" or "Degrees". Both the unit and coordinate type are case-insensitive.

### 5.2.4   Rectangle

This panel is only visible when "1 Rectangular Field" is selected in the Source panel. It is possible to define multiple sources, each of which uses a rectangular field pattern. To do this, one must start with only a single source in the Science Goal. This can be set up as a rectangular mosaic and any further sources that are defined will be forced to use rectangular field patterns.

For each rectangle, the OT will calculate a mosaic pattern for the 12- and 7-m Arrays based on the spacing parameter. A larger version of the user-drawn rectangle will be used for raster scanning with the TP Array. A total of 150 12-m array pointings is allowed, summed over all rectangles.

- **Coords Type**: Field centre in absolute or relative coordinates. Relative positions are offset from the source coordinate and are recommended. Absolute coordinates can be entered, but will be converted to offsets from the source coordinate during SB generation as absolute coordinates cannot be used with the telescope control system.

- **Field Centre Coordinates (Relative)**

  - **Offset(Longitude)**: Longitudinal offset of the centre of the rectangle from the source coordinate.
  - **Offset(latitude)**: Latitudinal offset of the centre of the rectangle from the source coordinate.

- **Field Centre Coordinates (Absolute)**

  - **System**: The system used for the coordinates. This should be set to ICRS.
  - **Sexagesimal display?**: View the coordinates in sexagesimal or decimal degrees.
  - **RA**: The R.A. coordinate of the centre of the rectangle.
  - **DEC**: The Declination coordinate of the centre of the rectangle.

- **p length**: Length of one side of the rectangle. For a rectangle with zero rotation, this refers to the horizontal axis.

- **q length**: Length of the other side of the rectangle.

- **Position Angle**: Position angle (North through East) of the "p" side of the rectangle from the vertical direction.

- **Spacing**: Distance between mosaic pointings. This can be specified in arcsec or in fraction of the antenna beamsize, the latter being the default. Nyquist spacing ($\lambda/\sqrt{3}D$ where $D$ is the antenna diameter) is assumed and should usually be selected, unless the sources being observed are relatively small. The spacing is usually shown as a fraction of the antenna beamsize ($1.13\,\lambda/D$) and thus in these units is approximately equal to 0.51. If Nyquist sampling is not used, the reasons for this should be given in the Technical Justification node, but values between 0.7 and 0.8 are fairly typical for observing wide-fields of relatively small sources. A button is provided to reset to the Nyquist value.

- **#Pointings**: The number of pointings calculated by the OT is displayed, for the 12-m and (if required based on the Control & Performance parameters) 7-m Arrays.

A button is provided to export the pointings (12-m and 7-m Array) to an ASCII file on disk. If desired, this can be used as the basis of a set of individual pointings that can be read into the Field Source.

## 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.

- **Produce image sidebands**: Bands 9 and 10 are DSB receivers for which special processing (90-degree Walsh switching) is required to produce both sidebands. This is particularly useful for wide-bandwidth modes such as Single Continuum and Spectral Scan as it doubles the bandwidth and is therefore always

enabled. Optionally, it can also be enabled for Spectral Line. It is common to refer to the spw that is defined in the table as the "signal" and the other as the "image". In order to select this mode, a spw in either Band 9 or 10 must first be created and all spws must have the maximum bandwidth of 1875 MHz.

- **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 should be chosen if a measurement of the source polarization (magnitude and position angle) is desired, but is not yet available for Bands 8, 9 or 10.

### 5.3.2 Spectral Setup Errors

This panel will displays 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 (spw) 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 beamsize drawn in the Visual Spatial Editor and is also used to work out the time estimate for the Science Goal. The Spectral Line and Spectral Scan interfaces can not be used with full polarization.

For each baseband, the following buttons are available:

- **Add spectral window centred on a spectral line**: This opens the Spectral Line Picker which allows a huge list of transitions to be searched. For each line selected, a spectral window will be added to the table centred on the line and the transition information filled in.

- **Add spectral window manually**: This adds a blank row to the table that can then be completed manually.

- **Delete**: Delete the selected row from the table.

- **Show image spectral windows**: If 90-degree Walsh switching has been selected, the details of the image spws can be displayed by clicking here.



Figure 5.1: The spectral window table for a single baseband. Two spectral windows have been defined, each of which take up half of the available correlator capacity. 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 (Fig. 5.1) 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 i.e. the rest frequency corrected for the source velocity. If lsrk was given as the Doppler frame, the sky frequency will have been converted to the barycentric frame. Otherwise, no frame conversion is made. Sources are selected using the Targets table (located at the bottom of the Spectral Setup editor page and described in Section 5.3.7).

- **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 Picker will automatically enter the name of the chosen transition. Enter "Continuum" if the spw is to be used.

- **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 and can be useful for reducing the correlator output data rate – if the average data rate exceeds a maximum value the project will not validate. The default value is 2 as this halves the data rate whilst only degrading the spectral resolution by ∼15 per cent (the non-linearity is due to Hanning smoothing also being applied in the correlator). Spectral averaging can be turned off, but this can lead to very high data rates if many FDM spws are defined, and particularly if 90-degree Walsh switching is also used. The value chosen will be reflected in the reported spectral resolution. TDM spectral windows cannot be spectrally averaged.

- **Store Image**: If 90-degree Walsh switching has been selected, not all image spws must be written out by the correlator. If the image is not required for a particular spw, it can be de-selected here. This will reduce the data rate out of the correlator.

- **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 and is therefore very important. 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. *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, such that the sensitivity is maximised. In Band 6, this involves avoiding the inner portions of the sidebands as these are somewhat (∼20 per cent) noisier. See the Technical Handbook for more details. In receiver bands 3 to 8 two

spws are placed in each sideband and the total bandwidth is 7.5 GHz. For Bands 9 and 10, 90-degree Walsh switching is enabled allowing four spws per sideband and a total bandwidth of 15 GHz. It is possible to change the absolute positions of the spectral windows by changing a single parameter, the average frequency of the setup, but the relative separations remain the same. A low-resolution correlator mode (TDM) is chosen for each spectral window.

- **Receiver Band**: Selecting a band will set up default spectral window frequencies. Full polarization is not yet available for Bands 8, 9 and 10.

- **Sky Frequency**: This is the average frequency of the defined spectral windows and more-or-less corresponds to the value of the first local oscillator (LO1). There is a default for each band, but this can be changed here by entering a frequency in the observed (sky) frame. 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 whichever source has been selected in the Targets table at the bottom of the Spectral Setup page.

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.

## 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. The tunings are overlapped to ensure that bad edge channels can be flagged without leading to gaps in the combined spectrum. The overlaps are greatest for the 1875 MHz-wide spectral windows ($\sim$170 MHz) and smaller ($\sim$31 MHz) for the remainder.

- **Requested start frequency (sky)**: Frequencies can only be entered in the sky (observed) frame. The OT will start placing its spectral windows at this frequency.

- **Requested stop frequency (sky)**: The OT will attempt to achieve this frequency by creating up to five tunings. The OT will rarely achieve this exact frequency as there are fixed gaps between each tuning and each tuning implies a fixed amount of extra frequency coverage.

- **Requested range (rest)**: The requested range is also shown in the rest frame of the first target defined in the Field Source editor. The OT will warn if the requested range was not achieved.

- **Achieved scan range (sky)**: In general, the OT will not achieve the exact frequency range requested and this is displayed here.

- **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 for sources with a single offset pointing and for a single 12-m configuration (no ACA).

### 5.3.6    Rest Frequencies

This panel contains a link to a version of the Spectral Line Picker (Rest Frequency SLP or RFSLP) that allows the user to enter the rest frequencies that will be observed. These will be written to the SB at Phase 2 and used during data reduction to set the velocity scale and as part of archive searches to identify relevant data.

When this tool is first opened, it will automatically include any rest frequencies that were used to define a spectral window. It will also ask the user if they would like to add the frequencies of any overlaid lines that fall into spws. Therefore, we recommend that this tool be used once the spectral setup has been fully defined. This default list of rest frequencies can then be edited i.e. rest frequencies added or deleted. Adding or deleting spws and re-opening the tool will update the list of rest frequencies accordingly.

If a spectral window is moved such that a defined rest frequency no longer falls within an spw, this will cause a validation error and the offending line will be highlighted in red if the RFSLP is opened. It should be deleted and the tool closed. This includes spws that were created using the SLP and these must be deleted and re-entered if the line used to define the spw no longer falls within it. Users will find that Science Goals which have been extensively edited and used as the basis for new projects, perhaps in different bands, now give such validation errors.

If it is desired to start again with a revised spectral setup and/or additional overlaid lines, all rest frequencies should be deleted and the rest-frequency tool re-opened.

### 5.3.7    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 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

For the vast majority of projects, standard observatory calibration observing strategies will be perfectly adequate and the first (default) option should be selected. The options are:

- **System-defined calibration**: The default calibration strategy whereby a single observation of a bright quasar is used to calibrate both the flux scale and the bandpass. A phase calibrator will also be scheduled, as well as a polarization calibrator if full polarization was requested.

- **System-defined calibration (force separate amplitude calibration)**: This is similar to the first option, but differs in that the amplitude (flux) calibration will be done using a separate observation of a solar-system object. Only select this if particularly high amplitude accuracy is required.

- **User-defined calibration**: If this option is selected, the user can define their own calibration sources. This is not recommended and should only be selected if you really know what you're doing. All user-defined calibrations must be fully explained in the Technical Justification. The options are:

  - **Add Dynamic Calibrator...**: In this case, the source is chosen at SB execution time based on some criteria (usually a search radius around a position and perhaps a minimum flux constraint) entered by the user.

  - **Add Fixed Calibrator...**: Using this interface a specific calibrator source can be chosen when creating the proposal.

  - **Delete Selected Calibration**: In principle, all calibrations can be deleted, although there must an incredibly good reason for doing that.

## 5.5 Control and Performance

At the top of the page, a panel (not shown for VLBI projects) shows array and telescope configuration information. 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**: The HPBW of both the 12- and 7-m dishes. This roughly sets the field of view of a single telescope pointing. Sources larger than this, or multiple sources spread over a larger area, must be mosaiced together using multiple pointings.

- **Number of antennas**: The number of atennas 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, as well as the ACA 7-m Array. The baseline lengths are a function of receiver band as the larger configurations cannot be observed at higher frequencies. All baseline lengths are *unprojected* i.e. they are not a function of source declination. Projection effects are though taken into account when calculating the synthesized beamsize.

- **Synthesized beamsize**: The synthesized beam sizes for the corresponding maximum baselines. Since Cycle-3, this number is dependent on the source declination, or the average declination if there is more than one source. The best angular resolution is possible when observing a source at the same declination as the latitude of the observatory ($-23$ degrees). As the magnitude of the declination difference increases, the angular resolution deteriorates for a given configuration.

- **Shortest Baseline**: The minimum baselines available for the most compact and extended 12-m Array configurations, as well as the ACA 7-m Array. The baseline lengths are a function of receiver band as the larger configurations cannot be observed at higher frequencies. All baseline lengths are *unprojected* i.e. they are not a function of source declination. Projection effects are though taken into account when calculating the maximum recoverable scale.

- **Maximum recoverable scale**: The largest structures that it is possible to image with the most compact and extended configurations. Like the angular resolution, this is now also declination dependent.

Based on the configuration information, the user should then enter desired performance parameters in the bottom panel. These will determine which configurations are required (including ACA) and how much time is required. The following fields are included:

- **Desired Angular Resolution**: A number of options are available to request the desired angular resolution or synthesized beam size i.e. the finest detail that will be visible in the map of the source. These are:

  - **Single**: A user may request a single value of angular resolution, although in practice a value within approximately $\pm 20$ per cent of this will be delivered.

  - **Range**: If the science could be done using one of several nominal configurations, this can be indicated by entering a range. In principle this increases the chances of a project being observed as it gives the observatory more flexibility when scheduling. Note that if the possible configurations include a mixture of long-baseline and smaller configurations, the long-baseline possibilities will be disregarded as the observing overheads are much higher.

  - **Any**: By selecting this the user indicates that the SBs could be observed on any of the available configurations. As with a specific range of values, long-baseline configurations will not be considered by the OT or by the Scheduler.

  - **Standalone ACA**: Instead of entering an angular resolution, the stand-alone ACA is selected using this option. No 12-m configuration will be selected, but the TP array might be added depending on the requested LAS.

Any value that is entered must lie in the range provided by the available configurations i.e. given in the Configuration Information panel. Unless the Standalone ACA was requested, the OT will select one or more 12-m configurations according to the various restrictions mentioned above. If any of these require additional (smaller) array configurations (including the 7-m and TP array) to achieve the source LAS, only those combinations that require the smallest number of configurations will be considered. An angular resolution is never entered for VLBI proposals.

- **Largest Angular Structure in source**: The angular extent of the largest components in the source that need to be imaged. If this parameter (also sometimes referred to as the Largest Angular Scale – LAS) is smaller than the max recoverable scale of the selected 12-m configuration, smaller configurations must be added. 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. There are restrictions on this though including, for example, that the very largest configurations cannot be combined with any other configuration. Note that the LAS is not the same as the field of view – a source might contain separate components, each with a different angular scale. If the source size is very small indeed, a value of zero is acceptable. This is not shown for VLBI observations.

- **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. For a continuum observation, this should be the sensitivity desired in the final continuum map. For a line observation, the sensitivity should be that desired in a single channel map, where one usually wants to have several channels across each line profile. If the angular-resolution choice was "Any", the sensitivity must be entered in flux units. This is not shown for VLBI or Solar observations.

- **Equivalent sensitivity**: If the requested sensitivity were in flux units then the OT will also display the equivalent in temperature units, and vice versa. Things are more complicated if a range is entered. A desired sensitivity in flux units will be converted to the equivalent temperature for the angular resolutions of the smallest and largest nominal configurations within the range. If the user-requested value is in kelvins however, the flux-equivalent is first shown for the largest possible nominal configuration. As this flux sensitivity is what the observatory will deliver regardless of what configuration is actually scheduled (the time estimates are always based on the flux sensitivity) it is then converted into a temperature-equivalent using the angular resolution of the largest requested angular resolution.

- **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. This is usually a good choice for observations of spectral lines. If additional smoothing is envisaged post-observation, then a user-defined value can be entered – velocity units are preferred. For continuum observations where the spectral line interface has been used, the entered value should be the total non-overlapping bandwidth that is free from significant line emission. The "AggregateBandWidth" option will calculate the total non-overlapping bandwidth automatically and is the only option for Single Continuum setups. "FinestResolution" refers to the smallest spectral resolution of any of the defined spectral windows. This is not shown for VLBI observations.

- **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. For Solar and VLBI observations, the user must enter their own time estimate, including calibration.

- **Override OT's sensitivity-based time estimate?**: If complicated and bright sources are being observed, the sensitivity target might not be reached due to limited *uv*-coverage. Alternatively, a user might not be interested in sensitivity, but rather in observing a source for a fixed amount of time in order to follow source variability. In either case, 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. This is not shown for VLBI or Solar observations.

- **Are the observations time-constrained?**: Clicking this reveals an interface for setting various scheduling constraints for the observations. Currently there are two types of time constraint.

  - If the observations require a single 12-m configuration and the 7-m array only, it is possible to request that these be observed simultaneously. This is thought to be most useful for the planetary community and will result in the 7-m time being set to the same as that of the 12-m array.

  - It is also possible to specify the times at which the observations should take place, including relative to other observations e.g. monitoring. Unless the 12-m/7-m simultaneous mode has been selected, this is not allowed if more than a single 12-m configuration is required. Two options are available:

    * Single visit – multiple time windows can be entered, during **one of which** the SG should be executed. It is possible to import these windows from an external ASCII file. Each visit should go on a separate row and each row should contain two comma-separated values of format YYYY-MM-DDThh:mm:ss e.g.

      ```
      2015-03-19T01:30:00, 2015-03-19T01:30:00
      2015-03-21T01:30:00, 2015-03-21T01:30:00
      2015-03-23T01:30:00, 2015-03-23T01:30:00
      2015-03-25T01:30:00, 2015-03-25T01:30:00
      ```

    * Multiple visits – multiple dates (either absolute or relative to one of the epochs) at **each of which** the SG should be executed.

  - Also included is a free-format text box that can be used to enter relevant information.

  - 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 dealt with in a dedicated node. For most projects, this is split into four main sections. For Solar and VLBI observations, a single free-format box is provided.

### 5.6.1 Sensitivity

In this section, the OT first presents a number of sensitivity-related parameters based on user input entered elsewhere in the Science Goal. These are designed to help users with the textual discussion of the sensitivity goals to be entered in the free-format text box below. Note that for multiple sources the most restrictive values of the Expected Source Properties are used i.e. the flux of the weakest source and the narrowest line width is assumed. If the OT detects potentially problematic issues, a message will appear in blue text and special attention should be paid to addressing these in the justification text.

The parameters reported by the OT vary depending on the contents of the Science Goal. The full list is:

- The signal to noise ratio (SNR) over the user-requested bandwidth for sensitivity: This calculation divides either the continuum or line flux by the requested rms. The continuum flux is used for single continuum setups (or where the bandwidth for sensitivity is more than twice the line width) and the line flux in the remaining situations. The user is notified if this or any of the other SNR values in the TJ node are less than three.

- The SNR over the aggregate, non-overlapping bandwidth: For spectral line (not single continuum) setups, this calculates the rms that would be achieved over the full, non-overlapping bandwidth (continuum rms) and subsequently the continuum SNR (continuum flux / continuum rms). This assumes that the entire bandwidth is free of spectral lines.

- The SNR over one third of the line width: For any Science Goal that includes line parameters in Expected Source Properties, the OT will calculate the rms over one third of the line width and calculate the corresponding line rms. In order to properly sample a spectral line profile, it is common to have approximately three spectral bins over the spectral line width.

- The ratio of the line width to the bandwidth for sensitivity: Again, if line parameters have been entered in Expected Source Properties, this calculation will be presented. Three spectral points are often placed across each line, although higher values are often used if the shape of the line profile is to be measured. The user is notified if this value is less than three.

- Spectral dynamic range: If both spectral line properties and a continuum flux have been entered, the ratio of the continuum and the line rms are reported as the "spectral dynamic range". The line rms is taken as the requested sensitivity, unless the bandwidth for sensitivity is greater than twice the line width, in which case the rms is that which would be achieved over one third of the line width. The spectral dynamic range is relevant as detecting weak lines against a strong continuum is difficult and requires good bandpass calibration. The OT will issue a warning message if the band-dependent limit is exceeded.

When calculating many of these parameters, the OT will use the time that will actually be observed, rather than the time implied by the sensitivity alone. For example, a minimum time per source is enforced and when calculating the rms over one third of the line width, the OT would use this time if the sensitivity request meant that the limit had not been reached.

### 5.6.2 Imaging

Discuss the imaging goals of the project in the text box, particularly with regard to the desired angular resolution and source LAS.

### 5.6.3 Correlator configuration

Here the OT reports some basic parameters of the correlator configuration, specifically the number of spectral resolution elements (including Hanning smoothing and spectral averaging) per line width and the bandwidth of the Representative Window. In the free-form textbox the user should discuss the correlator configuration, particularly with regards to how many resolution elements there will be across each spectral line.

### 5.6.4 Choices to be justified

The following is a list of additional user settings that require a brief discussion so that the technical assessors can be sure that the choice is justified. A free-format box appears for each.

- 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.

- 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: As the observatory guarantees appropriate calibration without user input, this must be rigorously justified.

- Override of OT's sensitivity-based time estimate: This may be necessary if you want to monitor a source over a certain time span or if your source has a complicated structure but the sensitivity-based time estimate does not allow for sufficient $uv$-coverage. You must give a detailed justification for the time override, and explain how the new time estimate was calculated. The time override 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.

# Chapter 6

# Phase 2 Program Scheduling Blocks

Actual observing is done using Scheduling Blocks. Due to their complexity, these are nearly always generated automatically from Science Goals. Privileged users though can create them from scratch or edit their contents. **PIs cannot edit the contents of SBs.**

## 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. Little of the information is yet used.

### 6.1.1 Basics

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

- **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.

- **Description**: Optional description of the OUSs purpose/contents.

### 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.

- **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, Pipeline Information and Data Processing Parameters 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

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

- **Status**: Shows the current status of the SB. These typically go through the sequence, 'NewPhase2', 'Phase2Submitted', 'Ready', 'PartiallyObserved' and 'FullyObserved'.

- **Description**: Optional description of the SB.

### 6.2.2 Control

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 time for all executions of this SB. It is equal to the maximum time per SB (given in the SchedBlock panel) multiplied by the number of expected executions.

- **Execution Time**: This is the estimated actual execution time for all executions of this SB. During automatic SB generation, it is currently set to the same as the maximum SB time.

- **Array Type**: The array configuration to be used. Options are the 12-m Array, the ACA, the 7-m Array, the Total Power Array and ALMA.

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

- **User Priority**:

- **TAC Priority**:

- **Pointing Accuracy**:

- **Bandpass Accuracy**:

- **Polarization Accuracy**:

### 6.2.3 Unit Dependencies

For time-constrained observations, it is often the case that one visits are defined relative to others. In this case, this information is conveyed using the Unit Dependencies panel.

- **Dependency List**: This opens an editor which shows the SBs that the one being edited could depend upon. Use of the arrow buttons will allow the requisite dependency to be set.

- **Delay**: How to long to wait after the dependent SB's execution before attempting the one being edited.

- **Execution Count**: Not yet used.

- **Expression**: Not yet used.

- **Control Script**: Not yet used.

### 6.2.4 Preconditions

The Preconditions panel specifies the conditions that must be met before this SB can be executed. It is very unlikely that any of these are yet being used by the observing system and hence we do not give details of what each does.

- **Baseline cal**:

- **Polarization cal**:

- **Max PWVC**:

- **Seeing**:

- **Phase Stability**:

- **Max Wind Velocity**:

- **Min Allowed HA**:

- **Max Allowed HA**:

### 6.2.5 SchedBlock

- **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. Interferometric and total power observing of PI projects normally use "Standard Interferometry" and "Standard Single Dish" respectively.

- **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.

- **Indefinite Repeat**: The Execution Count can be overridden if this is selected.

- **Max. Time**: Maximum time for a single execution of this SB. It is probable that execution of the SB will be automatically terminated if this time is exceeded.

- **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. Interferometric and total power observing of PI projects normally use StandardInterferometry.py and StandardSingleDish.py respectively.

- **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.

### 6.2.6 Advanced Parameters

The Advanced Parameters panel allows the specification of ad hoc parameters ("expert" parameters) that will be passed to the Science Observing Scripts (SOS). The ability to create keyword-value pairs on the fly allows SOS to test new functionality, although some values are set automatically during SB generation. This should be a short-term measure only – each parameter should eventually have its own entry in the APDM i.e. become a "proper" field in the OT. The keyword-value pairs must exactly match what is expected by the script, although they are now case-independent. **This panel is only shown to users who can and have enabled advanced privileges.**

### 6.2.7 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.

- **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 gives the angular resolution of the nominal configuration (see below) minus 10 per cent. **This field is not used at all during scheduling so changing its value has no effect whatsoever.**

- **Max. Angular Resolution**: This gives the angular resolution of the nominal configuration (see below) plus 10 per cent. **This field is not used at all during scheduling so changing its value has no effect whatsoever.**

- **Dynamic Range**: Not currently used.

- **Desired angular resolution**: This is the value that was entered in the Science Goal.

- **Largest Angular Scale**: This is the value that was entered in the Science Goal.

- **Nominal Configuration**: This indicates the configuration required to achieve the angular resolution and LAS. In practice, the scheduling software may observe with different configurations. If a range of angular frequency was entered, it's possible that multiple configurations are listed.

### 6.2.8 Temporal Constraints

If an SB should be observed on one of possible multiple fixed dates, an editor will display each time constraint in this panel.

### 6.2.9 Observing Groups

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

## 6.3 Observing Groups

ALMA observations are constructed out of Targets (Section 6.4). In order to be observed, each must be placed into an Observing Group (OG) with each OG being observed sequentially. There are usually two OGs, the first ("Calibrators") usually containing amplitude and bandpass calibrators and the second ("Science") the science source and phase calibrator. If the SB contains multiple tunings, each will be placed in a separate Science OG.

Clicking on an OG will show an editor that allows the required Targets to be selected. This contains a column entitled "Doppler Target". This defines which source will be used to convert from rest to observed frequencies and used by the telescope control system to set up the tuning for that OG. The Target which is selected as the Doppler Target is marked with a D$n$ in the Project Tree, where $n$ refers to the index of the *Science* tuning group (one-based).

## 6.4 Targets

A Target is a fundamental building block of an SB and consists of three specific Resources: a Field Source, an Instrument Setup and an Observing Parameters. These are described in more detail below.

## 6.5 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.

### 6.5.1 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.

### 6.5.2 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. "Sun" will require that an ephemeris be attached.

- **Source Coordinates**: The coordinates of the source. This item includes:

  - **System**: FK5 should no longer be selected and will not be supported in the future. Changing between ICRS and Galactic will cause a coordinate conversion to be performed.

- **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 and topocentric. 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.

### 6.5.3   Reference Position (Offset)

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 coordinates. All offsets are relative to the source coordinate i.e. not to the requested pointing positions which can themselves be offsets from the source coordinate. It is not absolutely clear if absolute coordinates are supported – it's therefore safest to use relative. Only FK5 J2000 and horizon offsets are currently supported.

    * Absolute offset inputs:
      · **System**:
      · **RA**:
      · **DEC**:
    * Relative offset inputs:
      · **System**:
      · **Offset(Longitude)**: Relative to the source coordinate.
      · **Offset(Latitude)**: Relative to the source coordinate.

- **Integration Time**: Time spent integrating per visit. Set, but almost certainly not used by the telescope control system.

- **Cycle Time**:

- **Sub Scan Duration**: Set, but almost certainly not used by the telescope control system. It must though be an integer multiple of both the integration duration and 48 ms or else the project will not validate. 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.

### 6.5.4   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.

### 6.5.5   Point

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.

### 6.5.6   Rectangle

- **Pattern Centre Coords**:
  - **Coords Type**: Choose between absolute or relative (to the Field Source) coordinates. Only FK5 J2000 and horizon systems are currently supported.
    * Absolute offset inputs:
      · **System**:
      · **RA**:
      · **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.

### 6.5.7   Cross

This field pattern is not yet supported.

- **Pattern Centre Coords**:

    - **Coords Type**: Choose between absolute or relative (to the Field Source) coordinates. Only FK5 J2000 and horizon systems are currently supported.
        * 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.

## 6.6   Instrument Setup

The following panels are visible for each Instrument Setup node.

### 6.6.1 Spectral Spec

- **Spectral Spec Name**: This should be a unique and descriptive identifier for the Spectral Spec.

- **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**: Not used.

### 6.6.2 Switching

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.

### 6.6.3 Correlator Configuration

- **Integration Duration**: This sets the averaging interval of the data written by the correlator (to the ASDM). If an approximation is entered (the real value normally has lots of decimal places), a button is available to adjust up 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. For NORMAL accumulation it must be a multiple of 16 ms, whilst for FAST it must be 1, 2, 4, 8, or a multiple of 16 ms. Also, it cannot exceed 1024 ms and, if <0.5 s, must be equal to the integration duration. Otherwise, the channel average and integration durations must be equal. Approximations can be automatically adjusted up to the nearest legal value.

- **Atmos. Phase Correction Data To Save**: It is possible to perform an on-line phase correction based on the measurements of PWV. Either this, the uncorrected data, or both may be written out by the correlator.

- **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 (only commissioned for ACA Correlator)
  - 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). No LO offsetting is used if 90-degree Walsh switching is enabled.

- **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, although 2.048 s **must** be used if 90-degree Walsh switching is enabled. For the FAST accumulation mode, the dump duration must be set to 1 ms. A button is available to adjust up to the nearest legal value.

- **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.

## 6.6.4   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.

### 6.6.4.1   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.

### 6.6.4.2   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.

### 6.6.4.3   Basebands

Up to four basebands can be defined and are shown in a tabbed format. 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 date 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.

- **Products**: Allows the user to select both auto- and cross-correlations or auto-correlations only. When the accumulation mode is FAST, only the auto-correlations can be produced.

- **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 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 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 additional modes 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. These modes are generally only required when peforming Frequency Profile Synthesis (see below) in the ACA Correlator (not in the ACA_CDP).

### 6.6.4.4 Spectral Windows

For each baseband it is possible to define multiple spectral windows and these are shown in a tabbed format. 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.

- **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 freqeuency 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.

- *Uncorrected* **Centre Offset Frequency**: In determining a tuning solution, the OT calculates the baseband and offset frequencies that are required. However, due to quantisation of LO2, the actual baseband frequencies are often different to those requested. The OT compensates for this, where possible, by **correcting** the offset frequency such that the spectral window is placed as close to the requested central frequency as possible. However, when the SB is run at the telescope and the observations are not being performed in the topocentric frame, the Doppler shift causes the requested spectral window frequencies to be different to those assumed by the OT. The tuning solution will therefore be different, as will the differences between the desired and actual baseband frequencies. This means that the OT's offset frequency corrections are no longer applicable. The OT therefore passes the **uncorrected** centre offset frequencies to the Control system who then re-calculate the necessary corrections in real time.

- **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 are common to 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 GHz and is required when frequency profile synthesis (see below) is performed in the ACA Correlator (a method which is actually now deprecated). 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 ∼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 synomynous 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 sub-band – 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 64-input and ACA Correlators performing the cross-correlations and Fourier transforms in the opposite order (the former is XF and the latter FX), the spectra of an unresolved spectral line has a different profile in each case (sinc for the 64-input and $sinc^2$ for the ACA). Selecting this option will trigger an algorithm that converts the ACA spectral profile to that of the 64-input Correlator – this is known as Frequency Profile Synthesis (FPS). If this is selected, the available 2-GHz baseband is shrunk at each edge by the ACA step frequency (defined in Centre Offset Frequency above) and requires that the nominal 2000 MHz-wide mode be replaced by one with a bandwidth of 1937.5 MHz and 124 channels (TDM). However, this way of requesting FPS is now deprecated and has been removed from recent versions of the OT.

- **Synth. Profile – ACA Correlator only**: Frequency Profile Synthesis is now specified via this new parameter. The number of options has increased to three, but the fundamental change is that it is now possible to request that this correction be made in the Correlator Data Processor (CDP), instead of the correlator itself. This will be the default from Cycle 3. If ACA_CDP is selected, the requirement to use ACA-only modes disappears i.e. the full 2000-MHz bandwidth is available.

For each spectral window it is possible to define up to 32 Spectral Average Regions (also known as Channel Average Regions). Note that these parameters are based on the effective channels and are zero-based.

## 6.7 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 contron software and should not be attempted.

### 6.7.1 Science Parameters

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**: This is the sensitivity goal for the attached science sources. For the largest 12-m configuration, it is simply equal to the value requested by the user in the Science Goal. For the other arrays though, the full sensitivity calculation is performed using the time that will be observed. For the TP Array, the sensitivity is calculated using the "time per pointing", where this is equal to the total time divided by $m$ (= map area / antenna beam area).

- **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 often 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 i.e. and integration time of 31 s and a subscan duration of 30 s will produce 60 s of data. All subscan durations must be integer multiples of the integration duration and 48 ms.

- **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.

### 6.7.2 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.

### 6.7.2.1 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. The subscan duration must be an integer multiple of the integration duration and 48 ms.

- **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.

### 6.7.2.2 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.

### 6.7.2.3 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.

### 6.7.2.4 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.

### 6.7.2.5 Polarization-only Parameters

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

### 6.7.2.6 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**:

### 6.7.2.7 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**:

### 6.7.2.8 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**:

### 6.7.2.9 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 6.5. 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 FK5 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.
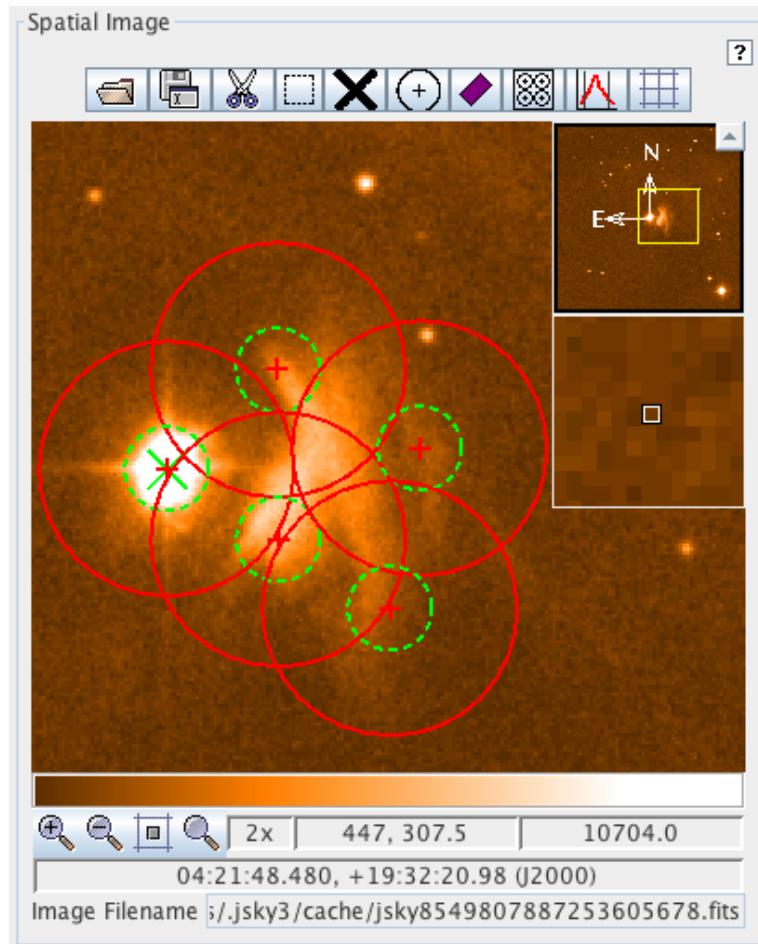
Figure 7.1: An example of the image display area of the Visual Spatial Editor. This is for a custom mosaic and shows the antenna beamsize (field of view) of the individual pointings (in red). The green, dashed circles indicate the inner third of the field of view. This is to emphasise to the user that 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.

## 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.
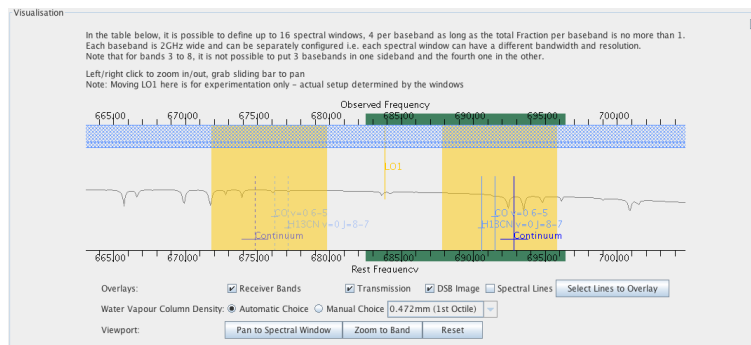


Figure 7.2: The graphical representation of the frequency information for Science Goals. The yellow sidebands indicate that a valid tuning solution has been found – these would otherwise appear grey. The green bars can be grabbed by the mouse and used to drag the display.

#### 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.
  - **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.
  - **Spectral Lines**: Display lines selected with the Spectral Line Picker.
  - **Select Lines to Overlay**: Choose lines to overlay using the Spectral Line Picker.

- **Spectral Scan**

  - **Requested scan**: Show the range over which the spectral scan was supposed to cover. This will rarely exactly correspond to what was achieveable in practice.
  - **Tuning 1, 2, etc.**: Display the spectral windows corresponding to a specific tuning. Each tuning is coloured differently and is offset vertically.
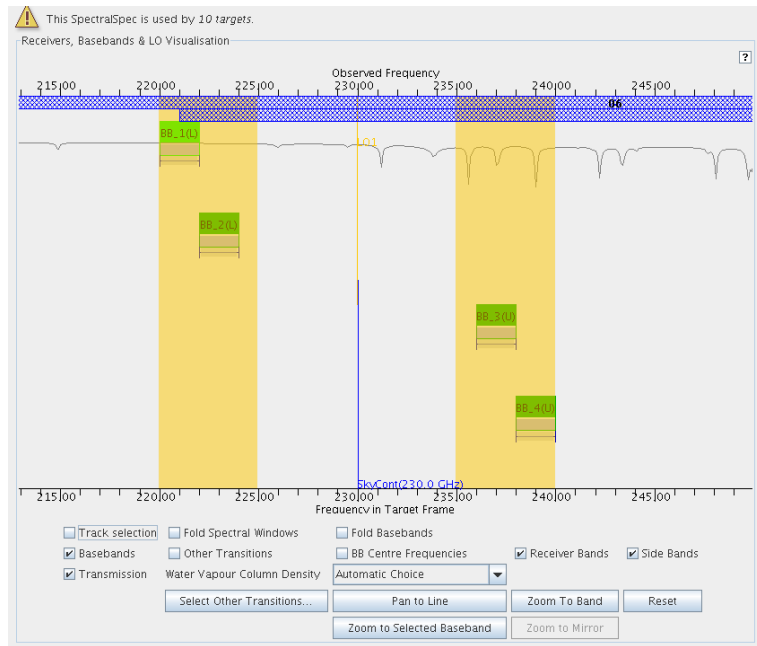
Figure 7.3: Visualisation of frequency information about receivers, basebands and LO frequencies. Visible are part of the frequency band (hashed), the transmission curve, four basebands and their spectral windows.

- **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 Spectral Window**: This will centre the visualiser on the currently selected spectral window.

    - **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 6.6.1.

### 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.

- **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 (receiver)
**ACA**: Atacama Compact Array
**ALMA**: Atacama Large Millimeter/submillimeter Array
**APDM**: ALMA Project Data Model
**ASA**: ALMA Science Archive
**ASDM**: ALMA Science Data Model
**ARC**: ALMA Regional Centre
**ASC**: ALMA Sensitivity Calculator
**BBC**: Baseband Converter
**DSB**: Double Sideband (receiver)
**EB**: Execution Block
**FOV**: Field Of View
**GOUS**: Group Observing Unit Set
**LAS**: Largest Angular Scale
**LO**: Local Oscillator
**LSB**: Lower Side Band
**MOUS**: Member Observing Unit Set
**MRS**: Maximum Recoverable Scale
**OG**: Observing Group
**OT**: Observing Tool
**OTF**: On The Fly
**OUS**: Observing Unit Set
**PI**: Principal Investigator
**PWV**: Precipitable Water Vapour
**SB**: Scheduling Block
**SG**: Science Goal
**SSB**: Single Sideband (receiver)
**SFI**: Single Field Interferometry
**SLP**: Spectral Line Picker
**SPW**: Spectral Window
**TFB**: Tunable Filter Bank
**TP**: Total Power
**USB**: Upper Side Band

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organization for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.