OBS Users Guide
IRAM Plateau de Bure Interferometer

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This document summarizes the operating modes of the IRAM Plateau de Bure interferometer, accessed through the OBS user interface, with a brief description of the hardware and of the associated control commands.

Related information is available in:

- IRAM Plateau de Bure Interferometer: Introduction
- IRAM Plateau de Bure Interferometer: Foreign Commands
- IRAM Plateau de Bure Interferometer: Trouble Shooting Guide
- IRAM Plateau de Bure Interferometer: Frequency Setup
- IRAM Plateau de Bure Interferometer: Atmospheric Calibration
- CLIC Continuum and Line Interferometric Calibration

Contents

1 Description

The interferometer consists of :

- Five antennas, each controlled by a VME-based microprocessor,
- One off-axis optical telescope per antenna, for pointing,
- Two (4 on the long term, 2 simultaneous IF) receivers per antenna,
- Continuum detectors for each receiver and each antenna, read by a simple ADC by the "`phaser`" microprocessor.
- A 8-unit flexible correlator
- An HP-J200 computer named BURE1 for real-time command and acquisition,
- A dedicated Ethernet link between BURE1 and the correlator units.
- An HP-J200 computer named BURE2 for data reduction, with NFS mounted disks from the acquisition computer.
- A general Ethernet link between BURE1, BURE2, the antenna and receiver microprocessors, terminals, etc...
- Many cables : low and high quality for the IF transmission, twisted pairs for specific signals, etc...

The instrument may be used in several basic modes: `OPTICAL` pointing, `INTERFEROMETER` observing, or `TEST` mode. In addition, within the **OBS** program, there is a `CONFIGURE` mode, which is used to specify and modify the array configuration parameters. Optical pointing is done essentially to check the mechanical behaviour of the antennas. This is a very limited mode, with little associated software and it is seldom used.

1.1 Interferometer Backends

There are 2 interferometer backends :

- A 12-channel continuum detector (2 IFs, 6 antennas). Output from these detectors is read once per second (except when the acquisition software is waiting for tracking information).
- A 2-bit, 4 level spectral correlator.

The spectral correlator is entirely configured by software It consists in 8 independent, very flexible, *units*. Each unit can operate in 5 modes providing different bandwidth/resolution capabilities

1. 320 MHz bandwidth, with 128 channels and channel separation 2.5 MHz.
2. 160 MHz bandwidth, with 128 channels and channel separation 1.25 MHz.
3. 80 MHz bandwidth, with 256 channels and channel separation 0.312 MHz.
4. 40 MHz bandwidth, with 512 channels and channel separation 0.078 MHz.

5. 20 MHz bandwidth, with 512 channels and channel separation 0.039 MHz.

Each unit can be connected anywhere in the second IF band (100-800 MHz) by tunable local oscillators (LO3s), in step of 0.25 MHz. The 320 MHz bandwidth is obtained by concatenating the USB and LSB of an image rejection mixer (IRM) at the 3rd LO frequency. All the others are obtained by selecting either the USB or the LSB of the IRMs. These IRMs have sideband separation of about 30dB, and at most 10 kHz is lost around the LO3 frequency. The 160 and 80 MHz bandwidths may also be obtained like the 320 MHz bandwidth in DSB mode; then the channel separation is halved at the expense of a central hole arond the LO3 frequency.

The correlator is typically run with 4 units in broadband mode, and 4 units as a "zoom" on interesting spectral line(s) in either receiver.

1.2 Connections

No manual connection is required in the IF distribution box. However, a 5 dB "booster" can be turned on for antennas on the most remote stations, if their output is too low.

2 The Real Time system BURE1

2.1 HP Machines: BURE1 and BURE2

BURE1 is the HP workstation dedicated to telescope control and data acquisition. BURE2 is available for general purpose tasks. BURE2 shares (through an NFS mounted disk) the `/data` disk of BURE1.

Only a few users can log in BURE1, and only to do observations or tests during the maintenance periods. Allowed users are `operator, root, broguier, perrigou, lucas, guillote`.

2.2 The Tasks, Commands and Programs

The software is organised in three basic layers :

- Real-time tasks that monitor the antenna, receivers, or backend parameters. Among these are:
  - `flag1s`: this task run every second, and synchronizes all programs.
  - `interp`: this task interacts with the antenna control microprocessors every second.
  - `astrj`: task does the astronomical computations to prepare the input to the antennas. It is activated every hour and also every time a new source is requested.
  - `looplo1`: this task run every 10 seconds, and checks the status of the phase locks.
- Two tasks related to the correlator/fringe processing:
  - correl and correl_spectra : theses tasks control the correlators data acquisition, continuum detector, phasemeter and LO fringe rate.
- Control and display tasks, and high level control and data acquisition programs.
  - **OBS** : High level observing program, with integrated observing procedures. Only one occurence of OBS can run at a time.

- RDI : interferometric data acquisition program. It is launched automatically by **OBS**
- AFF: Display real-time amplitudes and phases, control alarms, etc... One copy is launched by **OBS** , but other copies can be run on other terminals.
- STSA : this program is used to display the antenna positions in real-time.
- STSH : this program is used to display the antenna deicing status and power control.

The **OBS** program is intended to provide complete normal operation of the instrument. However, **OBS** assumes it has complete control over the system. Using other commands (e.g. coo) while **OBS** is running may conflict with this assumption, and therefore should be avoided if possible.

The acquisition program RDI write the data on specified files, and also take care of several log files used for bookkeeping. All real-time tasks interact through global commons and a set of event flags that are used for synchronisation. More details on commons and flags are described in the "Trouble Shooting Guide"

2.3 Configuration and Initialisation Files.

The "hardware" configuration of the interferometer is listed in several files:

- `inter_base:config.dat`
  This file indicates some basic array parameters, specially the time corrections. It should never be changed by operators or astronomers.

- `inter_base:general.ank`
  These files contain antenna dependant parameters, such as pointing constants, focus and homology parameters. The parameters change only when the antenna is repaired or modified.

- `inter_base:tij.ank`
  These files contain parameters for antenna k on station Tij (e.g. W00, not W0): IAZ, IEL, IVE, IVN, DVE, DVN, position errors dX,dY,dZ and delay offset. They have to be updated each time the antenna is set on station.

- `inter_base:start.obs`
  This procedure indicates on which stations the antennas are currently located. It also indicates which is the antenna connected to the single-dish backends.

- `inter_base:memory.obs`

  This procedure is automatically executed when **OBS** starts, and updated when it finishes. It can also be updated using command `SAVE`. It defines the current status of the **OBS** program.

- `inter_base:attenuation.dat`

  This file contains the calibration data for the programmable attenuators in the receiver IFs.

- `inter_base:feff.dat`

  This file contains the forward efficiencies as a function of frequency for the antennas.

- `inter_base:jykel.dat`

  This file contains the Kelvin to Jansky calibration factors as a function of frequency for the antennas (inversely proportional to the aperture efficiencies).

It is of the utmost importance that these files be kept up to date.

These files should in practice never be edited using a text editor (with the exception of the `general.ank` files, and only after authorization). A special language in **OBS** has been implemented to allow modifications of the array configuration parameters: language SET\, which is available only in the CONFIGURE mode (see appropriate section). These files should not be purged as they are used for bookkeeping. Also, do not modify pointing constants using directly the shell command `put`.

2.4 Data and Log files

The data acquisition and control programs produce a number of data files, in directory INTER_DATA, and log files in directory INTER_LOG.

One data file is created by RDI: `date-proj.ipb` for interferometer data, where date is the current date in the form `dd-mmm-yyyy`. Three log files are created, `date-proj.log-obs` by **OBS** `date-proj.log-red` by RED and `date-proj.log-rdi` by RDI. These files should not be purged and must be archived.

2.5 Observing Procedures

Standard (general or observation specific) observing procedures are kept in directory `operator/PRO`, also known with the logical name PR: on BURE1. Temporary procedures must be created *only* in the default working directory, `operator`.

3 The OBS Modes

The **OBS** program is a general purpose command program for the interferometer. It offers 4 different operating modes, selected by the `OBS\SET MODE` command

`SET MODE CONFIGURE` is used to specify the hardware configuration of the array. This is not an observing mode. This mode must be used to indicate any hardware configuration change. Resuming observations while in this mode can only be done using the `SET\OBSERVE` command.

`SET MODE OPTICAL` is used for optical pointing of the telescopes. The optical pointing constants and refraction coefficients are sent to all antennas.

`SET MODE TEST` is used either to calibrate the correlator bandpass or for tests. No antenna motions, nor receivers are required in this mode. No delay and phase tracking is done.

`SET MODE INTERFEROMETER` is used for interferometric observations. It allows auto-correlation, cross-correlation and specific procedures for calibration (`OBS\CALIBRATE` and `OBS\SKYDIP`), pointing and focussing (commands `OBS\POINTING` and `OBS\FOCUS` use the correlators output).

4 The CONFIGURE mode and the SET\ language

The CONFIGURE mode in **OBS** is not an observing mode. While **OBS** is in this mode, several commands are available to specify the current hardware configuration, all pertaining to the SET\ language:

- ANTENNA to indicate the station and correlator entry for each antenna.
- DELAY to indicate the zero delay of one antenna
- PHASE to setup the zero phases (LO1 and LO3).
- OBSERVE to resume observations after a configuration change
- POINTING to change the Station and Antenna dependent parameters (`IAZ, IEL, IVE, IVN, DVE, DVN`)
- SHOW to list some configuration parameter
- XYZ to indicate the position offsets of one antenna on its station

The CONFIGURE mode is obtained by typing command `OBS\SET MODE CONFIGURE`. The `OBS\` language is then turned off, the `SET\` language turned on, and the prompt changes to `SETUP>`. Observations can only resume using the `SET\OBSERVE` command, which turns on the `OBS\` language, turns off the `SET\` language, and reset the prompt according to the previous observing mode.

Three commands change the Station.ANk files : `SET\DELAY, SET\POINTING and SET\XYZ`. One command is placed in the INTER_BASE:START.OBS file : `SET\ANTENNA`. A new INTER_BASE:START.OBS file is created each time a `SET\OBSERVE` command is typed, to ensure that all configuration changes are remembered.

5 Interferometric Observations

5.1 Data Types

In interferometric mode, the correlator produces two different types of data: *spectral* data, i.e. time-averaged values of amplitude, phases or total-power as a function of frequency, and *temporal* data, i.e. frequency-averaged values of amplitude, phases or total-power as a function time. *spectral* data is obtained once every *integration* time, while *temporal* data is obtained every *dump* time. The minimal dump time is 1 second.

Some actions will deal essentially with *spectral* data (e.g. `GAIN, BANDPASS`), while others utilize only the *temporal* data (e.g. `POINT, FOCUS, HOLOGRAPHY, STABILITY, FLUX`).

5.2 Setup

The interferometer mode is selected using command

```
SET MODE INTER
```

For receiver setup, proceed exactly as for multi-dish mode.

5.2.1 Level adjustments

Correlators must operate at the optimum sampling level. This is performed by adjusting the output power of the receivers using variable attenuators. Command `LEVELS` performs the adjustment. Note that this adjustment must be done after receiver tuning, but before the delay measurements, because the attenuators contribute to the effective delay.

5.2.2 Delay measurements

The delay can be measured from the phase slope across the IF band on a standard cross-correlation or `GAIN` on a strong celestial source. Data reduction is done with **CLIC** using command `CLIC\SOLVE DELAY`. Two different methods are available, depending on what is plotted (see **CLIC** manual for details). Command `CLIC\SOLVE DELAY /PRINT` produces a `delay.obs` command file which can be executed to enter the appropriate values.

It is also possible to use a scanning of the delay on one antenna to determine the delay offsets of the interferometer. This is done using the `OBS\DELAY` command. A strong continuum source is required. A zero delay (from the last measurement, or from a best guess) is taken from the configuration file Tij.ANk, and the scanning occurs around this value. Do a coarse scan with command `OBS\DELAY -50 50 2`, then use a cross-correlation to get enough precision.

5.2.3 Baseline measurements

To measure the baselines after a reconfiguration, it will be necessary to observe some (strong) continuum sources. A sideband average of the visibilities (weighted by the image-to-signal gain ratio, provided we know it) is used to remove instrumental phase offsets and get only geometric and atmospheric phases in the solution. No specific **OBS** command is necessary for this; the `OBS\START` command is used to make cross-correlation. Data are written in the Date.IPB file. Typically 4 minutes per source are required. Reduction is done within the **CLIC** program using the `CLIC\SOLVE BASELINE` command. The `CLIC\PRINT BASELINE` command produces a procedure named `dd-mmm-yyyy-base.obs`, which can be used to enter the appropriate values.

It is important to have good hour angle and declination coverage for a complete baseline determination. The observer must also avoid systematic scanning in azimuth, in order to disentangle atmospheric variations (time dependent) from baseline effects (hour angle and declination dependent). Low elevation sources must be avoided; high declination sources are necessary, but not low declination ones. finally, a baseline determination should not last longer than 2 hours; otherwise, time variations of the atmospheric phases begin to dominate. Even 2 hours may be too long for long baselines. A procedure `@ PR:BASELINE` is available to select automatically appropriate sources.

5.3 Bandpass Calibration of the Correlators

The bandpass (in phase) of the correlator units can be calibrated using the built-in noise source of each unit. Cross correlation on this noise source then gives the phases of each entry with a high signal-to-noise ratio since this input is 100% correlated. The `OBS\BANDPASS` command is intended for this measurement. It automatically switches the correlator input to the noise source, disables Walsh switching on the first LO, and disables delay and phase tracking. After the measurement, the original state is restored.

This procedure can be done while the antenna are slewing to a new pointing direction, so it introduces practically no loss of observing time when inserted at appropriate position in observing procedures. Some misfunctions of the correlators can be detected by this procedure.

5.4 Pointing

An interferometric mode for radio pointing is available with the `OBS\POINT` command. The idea is to make cross scans with some or all antennas simultaneously and to record the correlated output power as a function of position (instead of the total power for each antenna as in single-dish mode). Pointing parameters can be recovered if all the following conditions are satisfied

- At least 3 antennas are available OR at least 1 antenna is fixed.
- The pointing source MUST be a point-like object (with respect to the current baseline lengths).
- If all antennas are moved the pointing errors must be similar within 20".

The advantage over single-dish pointing is better sensitivity, due to two major reasons:

- Atmospheric total power fluctuations are eliminated, and
- Integration goes on all the time, instead of only a fraction of the time in beam-switch single-dish mode.

A signal to noise ratio of 10, corresponding to an accuracy of 1.5" on the pointing corrections, can be reached on 1 Jy sources at 3 mm with a standard drift (1 minute of time, 1 arcmin on the sky). The `/FAST` option is now available in INTER mode, and can be used on strong sources.

In this mode the correlator is used to measure the correlated power. Data are stored in the Date.IPB file and no real-time processing is done. Quasi real-time processing can be done within **CLIC** using the `CLIC\SOLVE POINTING` command. The reduced data can be used by the **POINT** program. **CLIC** command `CLIC\SOLVE POINTING /PRINT` produces a command procedure named `pointing.obs` which can be used in **OBS** to enter the appropriate corrections. These corrections are biased towards 0 by 1 σ to avoid unrealistic excursions.

Note that pointing (and focus) can be done in a "pseudo-continuum" mode if the correlator subband selects a narrow band around a spectral line. This is particularly useful for SiO masers.

5.5 Focus

An interferometric focussing mode working on the same principle as the interferometric pointing mode is available using the `OBS\FOCUS` command. Data are stored in the Date.IPB file, and a quasi real-time reduction is available within **CLIC** using the `CLIC\SOLVE FOCUS` command. **CLIC** command `CLIC\SOLVE FOCUS /PRINT` produces a command procedure named `focus.obs` which can be used in **OBS** to enter the appropriate corrections.

5.6 Calibration

5.6.1 Level adjustments

Correlators must operate at the optimum sampling level. This is performed by adjusting the output power of the receivers using variable attenuators. Command `LEVELS` performs the adjustment. Note that this adjustment must be done after each receiver tuning, before the final atmospheric calibration.

5.6.2 Skydip

The goal of "atmospheric calibration" is to estimate the receiver gain, the atmospheric transmission and the antenna efficiency in order to rescale the observed intensities onto the scale that would be obtained using a perfect antenna outside the atmosphere (Brightness Temperature scale). With the cold load, the skydip procedure (the `OBS\SKYDIP` command) allows the estimation of 3 parameters, namely the water vapor content (wH_2O in mm), the antenna forward efficiency Feff, and the receiver temperature Trec. In principle the antenna efficiency Feff is not a function of time, but it does depend on the surface state of the antenna, especially if there is any ice or condensed water. Under normal conditions Feff = 0.93 at 86 GHz.

Skydips are necessary if antenna efficiency variations are suspected (icing or condensing conditions). They can be done using `OBS\SKYDIP` command. The continuum detectors measure the total power with an integration time of 8 seconds on the cold load, then on the warm load (table), then on the sky. The measurement is repeated at 6 different elevations. The correlator sampling levels are adjusted (Tweaking) at each subscan. Data are stored in the Date.IPB file to maintain completeness of the calibration parameters in this file.

Reduction is done in **CLIC** by command `CLIC\SOLVE SKYDIP`

5.6.3 Atmospheric calibration

Atmospheric calibration works in basically the same way as in single-dish observing. Correlators are switched to auto-correlation mode. A tweak of the correlator is made. The receiver tables are used to make one auto-correlation measurement on source and one on the loads. The `OBS\CALIBRATE` command starts this procedure. It accepts optional argument `COLD` to measure also the cold load, and hence derive receiver temperatures.

Data, including the continuum detectors output, are stored in the Date.IPB files. The `CLIC\SOLVE ATMOSPHERE` command can be used in quasi-real time for data reduction.

The atmospheric transmission can be estimated using a single measurement by the `OBS\CALIBRATE` command. This should be done rather frequently to monitor atmospheric variations. Depending on the calibration mode (`HUMIDITY, TREC, AUTO, MANUAL`), the observer should specify the receiver temperature (`SET TREC`), the water vapor content (`SET WATER`, or the atmospheric temperatures and opacities `SET ATMOSPHERE and SET OPACITY`). In the `HUMIDITY` mode, theoretical water vapor content is derived from the humidity, temperature and pressure measured by the meteo station.

5.6.4 Sideband measurement

The interferometer has the ability to separate the upper and lower sidebands of the receiver output. Accordingly, it is possible to measure the receivers'sideband ratios provided at least 3 antennas are available. (With 2 you get only the product of the sideband ratios). This is done using the `OBS\GAIN` command, which simply does a cross-correlation. A continuum source must be observed (strong, but not necessarily point-like). Quasi real time data reduction is available within **CLIC** using the `CLIC\SOLVE GAIN` command, and real-time reduction is done to give the result.

Because atmospheric calibration depends on the sideband ratio, and vice-versa if the optical depth is different in the two bands, it may be necessary to iterate between the `OBS\CALIBRATION` and `OBS\GAIN` commands. **CLIC** command `CLIC\SOLVE GAIN /PRINT` produces a command procedure which can be used in **OBS** to enter the appropriate gain values. It also allows to set the LO1 and LO3 phases to obtain a zero phase on all baselines in both sidebands.

5.6.5 Bandpass calibration

In the calibration procedure bandpass normalisation by the auto-correlation functions of the antennas is applied (visibilities on a baseline are divided by the square root of the autocorrelation function of each antenna). The correlator's intrinsic phase bandpass is removed with the dedicated `OBS\BANDPASS` procedure. Except possibly for very narrow spectral bands, a bandpass calibration with a celestial source is still necessary to compensate for receiver—cable—antenna induced phase slopes.

No specific procedure is required as this is only a long integration on a strong continuum source (not necessarily a point source). The phase calibrator may even be used for such a measurement. A qualifier is available in the Date.IPB file to identify bandpass calibrator observations; this information comes from the `OBS\SOURCE` command in the **OBS** program (option `/TYPE BANDPASS`. The qualifier is then used by **CLIC** for data reduction. Bandpass calibration can be applied to observation of other sources within **CLIC** using the `CLIC\SOLVE RF_PASSBAND` command.

5.6.6 Flux calibration

Since almost all quasars are variable, it is necessary to determine the flux densities of the calibrators before starting observations. The command `FLUX` assumes pre-determined antenna efficiencies to convert the antenna temperature scale into flux densities, and sets the flux in the data file header. This command should be issued once before starting normal observations.

5.6.7 Phase Calibration

The goal of phase calibration is to compensate for slow atmospheric phase drifts. As in the bandpass calibration, a qualifier is available in the Date.IPB file to identify phase calibrators and the information comes from the `OBS\SOURCE` command in the **OBS** program. Phase calibrators have their velocity type forced to NULL, to indicate that the receiver frequency should not be changed at all (no doppler shift).

Phase calibration can be applied to observations of other sources within **CLIC** using the `CLIC\SOLVE PHASE` command.

5.7 Source Observation

The `OBS\START` command starts a cross-correlation measurement on the source specified by the `OBS\SOURCE` command.

The software allows mosaicing techniques through the use of the `OBS\OFFSET` command. A mosaic is done using SIC procedures:

```
SIC\FOR I -40 TO 40 BY 40
SIC\FOR J -40 TO 40 BY 40
OBS\OFFSET I J/BASIS
OBS\START
SIC\NEXT
SIC\NEXT
```

The `OBS\OFFSET` command defines antenna and delay tracking offsets as appropriate for mosaicing using the **GILDAS** task MAKE_MOSAIC and the **MAPPING** program.

Since integration time may be low in mosaicing, dead time should be reduced as much as possible. The present implementation is not optimised in this respect and a faster scheme should be investigated later.

5.8 ONOFF procedure

The purpose of the `CLIC\ONOFF` command is to make single-dish spectra on all antennas simultaneously, using the current spectral correlator configuration in autocorrelation mode. It can be used to check frequencies, by observing a know line source, or to provide the zero spacing flux in spectral line mapping. It is recommended (but not compulsory) to calibrate before. The procedure is started by the command

```
ONOFF Off1 Off2 [System] /TIME Time
```

where `Off1` and `Off2` are the offsets in arcseconds, `System` is the type of offsets, and `Time` the integration time in seconds (rounded to a multiple of 4 seconds).

6 Procedures and Variables

6.1 Variables and Functions

OBS being based on **SIC** includes Variables and Functions which can be used to tailor observing procedures.

Two important variables exist

- `DSUN` the distance to sun corresponding the time implied by the last call to function `ELEV`, or the last `OBS\SOURCE` command. It can be used to check Sun avoidance.
- `SCAN` the next scan number.

Three functions have been implemented

- `ELEV(Dm)` Returns the source elevation in degrees Dm minutes from current time (`ELEV(0)` is the current source elevation). A call to `ELEV` updates the `DSUN` variable.
- `UT()` Returns the current UT in hours.
- `LST()` Returns the current LST in hours.

6.2 Sample procedures

Here are several procedures used to observe. A typical observing sequence using these procedure is :

```
@PR:DEFINE                ! If needed
@PR:Source_1              ! Define parameters for source_1
@PR:OBSERVE               ! Observe source_1
@PR:Source_2              ! Define parameters for source_2
@PR:OBSERVE               ! Observe source_2
etc...
```

The `PR:DEFINE.OBS` procedure contains all general definitions used in the setup, startup and observation procedure

```
! PR| DEFINE.OBS                define general variables
!--------------------------------------------------------------------------
if run_window then
   @pr:x_obs
endif
DEFINE CHARACTER NAME*12                /GLOBAL ! source name
DEFINE CHARACTER CALIBRATOR_1*12        /GLOBAL ! main calibrator
DEFINE CHARACTER CALIBRATOR_2*12        /GLOBAL ! suppleant
DEFINE CHARACTER CALIBRATOR_3*12        /GLOBAL ! innovation g016
DEFINE CHARACTER CALIBRATOR_B*12        /GLOBAL ! RF Passband calibrator
DEFINE REAL LOW_LIMIT                   /GLOBAL !
DEFINE REAL SUN_LIMIT                   /GLOBAL !
DEFINE REAL LST_DEFLIM                  /GLOBAL !
! RECEIVER  is the receiver that should be pointed on source
! POINT-RECEIVER is the receiver used for pointing scans
! FOCUS-RECEIVER is the receiver used for focus  scans
DEFINE INTEGER RECEIVER                 /GLOBAL
DEFINE INTEGER POINT_RECEIVER           /GLOBAL
DEFINE INTEGER FOCUS_RECEIVER           /GLOBAL
DEFINE INTEGER N_SCANS                  /GLOBAL ! Number of scans per source
DEFINE INTEGER N_SUBSCANS               /GLOBAL ! Number of subscans per scan
DEFINE INTEGER N_DUMPS                  /GLOBAL ! Number of dumps
DEFINE INTEGER N_BAND                   /GLOBAL ! Number of subscans for RF
DEFINE INTEGER N_MOSAIC                 /GLOBAL ! Number of mosaic positions
DEFINE INTEGER N_SHARE                  /GLOBAL ! Share several sources
DEFINE INTEGER STOP_ALARM               /GLOBAL ! 1 stop alarm ; 0 set ala 200
DEFINE INTEGER I_CAL                    /GLOBAL ! Current calibrator
DEFINE INTEGER N_CALIBRATORS            /GLOBAL ! Share several sources
DEFINE INTEGER N_SUBS_CAL[3]            /GLOBAL ! Nb subscans / calibrator scan
DEFINE INTEGER N_SCANS_CAL[3]           /GLOBAL ! Nb scans / calibrator
DEFINE INTEGER   N_SOURCES              /GLOBAL
DEFINE CHARACTER NAME_SOURCE*12[20]     /GLOBAL
DEFINE INTEGER   N_SCANS_SOURCE[20]     /GLOBAL
DEFINE LOGICAL   CHANGE_SPECTRAL        /GLOBAL
DEFINE CHARACTER TYPE_SOURCE*6          /GLOBAL
DEFINE INTEGER   FSWI_SCANS_CAL         /GLOBAL ! Nb scans /calibrator in FSWI
DEFINE INTEGER   FSWI_SUBS_CAL          /GLOBAL ! Nb subscans /calibrator in FSWI
DEFINE INTEGER   FSWI_SCANS             /GLOBAL ! Nb scans /source in FSWI
DEFINE INTEGER   FSWI_SUBS              /GLOBAL ! Nb subscans /source in FSWI
DEFINE LOGICAL   FSWI_CAL               /GLOBAL ! Do or not a Fast-Switch
!
!--------------------------------------------------------------------------
! Global variables for auto_snap procedure
!
DEFINE INTEGER NUMBER_SOURCES   /GLOBAL
DEFINE INTEGER N_RF_PASSBAND    /GLOBAL
DEFINE INTEGER N_SNAP           /GLOBAL
```

```
DEFINE REAL LST_INTERVAL        /GLOBAL
DEFINE CHARACTER SNAP_NAME*12   /GLOBAL
DEFINE LOGICAL NO_RF            /GLOBAL
DEFINE LOGICAL DO_RF_PASSBAND   /GLOBAL
DEFINE LOGICAL INIT_SNAP        /GLOBAL
LET N_RF_PASSBAND 3
LET LST_INTERVAL 2.
LET N_SNAP 2
!----------------------------------------------------------------------
! Pointing session or Baseline measurements
!
SYMBOL P_COMMAND "POINT"
SYMBOL A_COMMAND "AUTO 4 TWEAK"
SYMBOL PC "@ PR:PHASE-ALL"      ! Phase calibration
SYMBOL LAST "@ PR:PHASE-LAST"   ! Last phase calibration
SYMBOL BC "@ PR:BAND"           ! Bandpass calibration
SYMBOL GM "@ PR:GAIN"           ! Image Gain measurement
SYMBOL OLD "@ pr:setup-type 1"  ! Switch to OLD procedures = ../OLD
SYMBOL NEW "@ pr:setup-type 2"  ! Switch to NEW procedures = ../PRO
!
!----------------------------------------------------------------------
! RDI solves for focus and/or  pointing
!
DEFINE LOGICAL SOLVE_FOCUS SOLVE_POINT  /GLOBAL
DEFINE CHARACTER POINT_SOURCE_1*12      /GLOBAL ! main Pointing source
DEFINE CHARACTER POINT_SOURCE_2*12      /GLOBAL ! next choice
DEFINE CHARACTER FOCUS_SOURCE_1*12      /GLOBAL ! main Pointing source
DEFINE CHARACTER FOCUS_SOURCE_2*12      /GLOBAL ! next choice
DEFINE REAL T_FOCUS LAST_FOCUS          /GLOBAL
DEFINE REAL T_POINT LAST_POINT          /GLOBAL
DEFINE LOGICAL DO_FIVE  /GLOBAL
!
!---------------------------------------------------------------------
! Start with default values
!
@ pr:defaults
!
```

The setup procedure configures the correlator, select the observing frequency, and leaves the system ready for receiver tuning.

```
!----------------------------------------------------------------------
!
! PR:SETUP-Z023.OBS     ! Setup procedure for project "Z023"
!
!    - Date:        Wed May 21 12:17:48 MET 1999
!------------------------------------------------------------------------
SET\END                            ! Finish previous observation
```

```
@ PR:defaults                     ! Restore defaults parameters
!
SET\PROJECT Z023                  !**! Specify project number for further
!
SYMBOL GO "@ pr:observe-all Z023" !* ! data processing
CATA SOU inter_base:iram.sou        !* !
CATA PHA inter_base:phase-pdb.sou !* !
LET RECEIVER 1                    !* ! Observing reference: receiver 1
!
LET LOW_LIMIT 15.                 !* ! Low elevation limit 15 degrees
SAY "Project 'PROJECT' starting"  !
!
SYMBOL NAME "M2-56 EQ 2000 23:56:36.081 70:48:17.4 LSR -27"   !**! Source
!
LET N_SOURCES 1                          !* ! use SYMBOL NAME if N_SOURCES.EQ.1
LET N_SUBSCANS 60                !* ! Scan length (in seconds)
LET N_SCANS 20                    !* ! Number of scans on SOURCE (20 minutes)
!
LET CALIBRATOR_1 "1928+738"        !* ! 2nd phase calibrator
LET CALIBRATOR_2 "0224+671"        !* ! 3rd phase calibrator (if necessary)
LET CALIBRATOR_3 "......."        !* ! 3rd phase calibrator (if necessary)
LET N_CALIBRATORS 1 ! 2 (RL)      !* ! Use 2 phase calibrators every N_SCANS
LET N_SUBS_CAL  45                !* ! Scan length on calibrator (in seconds)
LET N_SCANS_CAL 3                 !* ! Nb scans on each calibrator (3 scans)

LET N_MOSAIC 3                    !* ! No mosaic mode
IF (N_MOSAIC.NE.0) THEN
   DEFINE REAL X_MOSAIC[N_MOSAIC] Y_MOSAIC[N_MOSAIC] T_MOSAIC[N_MOSAIC] /GLOBAL
   LET X_MOSAIC -11  0 11         !* !
   LET Y_MOSAIC   0  0  0         !* !
   LET T_MOSAIC   7  7  7         !* !
ENDIF
!
LET SOLVE_POINT YES         !
LET SOLVE_FOCUS YES         !
LET FOCUS_RECEIVER 1              !* ! Focussing on receiver 1
LET POINT_RECEIVER 1              !* ! Pointing on receiver 1
LET POINT_SOURCE_1 "1928+738"     !**! 1st pointing source
LET POINT_SOURCE_2 "0224+671"     !* ! 2nd pointing source
LET FOCUS_SOURCE_1 "1928+738"     !**! 1st focusing source
LET FOCUS_SOURCE_2 "0224+671"     !* ! 2nd focusing source
!
LET CHANGE_SPECTRAL .FALSE.       !* ! .TRUE. if need to switch to broad_band
!
SPECTRAL 1  20  350 /RECEIVER 1   !**! Define software correlator configuration
SPECTRAL 2  80  350 /RECEIVER 1   !**! Define software correlator configuration
SPECTRAL 3 160  350 /RECEIVER 1   !**! Define software correlator configuration
```

```
SPECTRAL 4 160  350 /RECEIVER 2   !**! Define software correlator configuration
SPECTRAL 5 160  278 /RECEIVER 2   !**! Define software correlator configuration
SPECTRAL 6 160  422 /RECEIVER 2   !**! Define software correlator configuration
!
LINE CO(10) 115.271 USB LOW 350  /REC 1    !**! Define observing frequency
LINE CO(21) 230.538 LSB LOW 350  /REC 2    !**! Define observing frequency
!
IF (N_SOURCES.GT.1) THEN
  SOURCE 'NAME_SOURCE[1]' /TYPE OBJ         !
 ELSE
  SOURCE 'NAME' /TYPE OBJ         !
ENDIF
LOAD /FREQUENCY                    ! Load frequency, but don't move antenna now
CENTER_LO2                        !
!
SET SHOW OFF
! Make sure any changes in the spectral configuration will be detected:
SET\LOCK
!
TYPE PR:CLEAN.OBS
SAY "Project Z023   Type: Mapping /  Category: Dual frequency"     !**!
SAY " "
SAY "               Tuning Receiver 1:              USB, tuning SSB" !**!
SAY "               Tuning Receiver 2:              DSB, tuning DSB" !**!
SAY "               Observing on Receiver:          "'RECEIVER'    !
SAY "               Receiver Stability (1.3mm):     2-3 (Average)" !**!
SAY " "
!
! Insert here any other instructions to the operator/astronomer
!
SAY "Frequency sent, receivers may be tuned"
SAY "Execute all observations by typing GO"
SAY " "
SAY "Type END when project is finished"
SAY " "
SYMBOL PROCEED /INQUIRE "Type RETURN to remove this page: "
SET SHOW ON
SET SHOW ON
```

The procedure PR:OBSERVE.OBS is used to perform standard observations

```
! PR:OBSERVE Project_Number [LST_limit]
!
! Check the required project has been specified
IF (PROJECT.NE."&1") THEN
    SAY "Wrong project 'PROJECT', expected &1"
    RETURN
ENDIF
```

```
!
DEFINE CHARACTER ARG*12
LET ARG "&2"
IF (ARG.NE." ") THEN
    LET LST_LIMIT &2
ELSE
    LET LST_LIMIT LST()+12.
ENDIF
SOURCE 'NAME' /TYPE OBJ
IF (ELEV(0).LT.LOW_LIMIT) THEN
    SAY "Source not up, retry later"
    RETURN
ENDIF
IF (LST().GE.LST_LIMIT) THEN
    LET LST_LIMIT = LST_LIMIT+24.
ENDIF
!
SET INTEGRATION N_DUMPS
FOR/WHILE (ELEV(0).GE.LOW_LIMIT).AND.(LST().LE.LST_LIMIT)
! Normal phase calibration
    @ PR:PHASE-CAL
!
! Now Source observation
    SET SCAN N_SCANS
    SET SUB  N_SUBSCANS
    SOURCE 'NAME' /TYPE OBJECT
    LOAD
    BANDPASS
    CALIBRATE
    START      ! Start N_SCANS
NEXT
!
! Last phase calibration
@ PR:PHASE-LAST
! And says project is finished
@ PR:END
```

The procedure `PR:PHASE-CAL.OBS` is used to perform standard phase calibrations, selecting one of the two phase calibrators:

```
SOURCE 'CALIBRATOR_1' /TYPE PHASE
SET SUB 60
SET SCANS 4
IF (ELEV(0).GE.LOW_LIMIT).AND.(LST().LE.LST_LIMIT)-
    .AND.(DSUN.GT.SUN_LIMIT) THEN
    LOAD
    BANDPASS
    CALIBRATE
    START
```

```
ELSE
    SOURCE 'CALIBRATOR_2' /TYPE PHASE
    IF (ELEV(0).GE.LOW_LIMIT).AND.(LST().LE.LST_LIMIT)-
    .AND.(DSUN.GT.SUN_LIMIT) THEN
LOAD
BANDPASS
CALIBRATE
START
    ENDIF
ENDIF
```

The procedure PR:PHASE-LAST.OBS is similar, but does not check the time limit and accepts lower elevation:

```
SOURCE 'CALIBRATOR_1' /TYPE PHASE
SET SUB 60
SET SCANS 4
IF (ELEV(0).GE.LOW_LIMIT).AND.(DSUN.GT.SUN_LIMIT) THEN
    LOAD
    BANDPASS
    CALIBRATE
    START
ELSE
    SOURCE 'CALIBRATOR_2' /TYPE PHASE
    IF (ELEV(0).GE.5.0).AND.(DSUN.GT.SUN_LIMIT) THEN
        LOAD
        BANDPASS
        CALIBRATE
        START
    ENDIF
ENDIF
```

The procedure PR:END.OBS just notify the system that the project is complete :

```
IF (PROJECT.NE." ") THEN
    NOTE "Project 'PROJECT' complete"
    DELETE/SYMBOL GO
    LET PROJECT " "
ENDIF
```

7 Data Reduction

7.1 General Organisation

All data reduction is done off-line on the HP workstation BURE2. BURE1 also contains the data analysis programs for safety, but it should not normally be used. Data reduction is done using programs in the **GILDAS** package (originally developed at the Groupe d'Astrophysique, but containing mostly IRAM specific reduction tools). This includes large programs like **CLASS**, **GRAPHIC**, **ASTRO**, **CLIC**, many image processing tasks, and a few specific programs such as **POINT** for the pointing fit. Large programs are all based on the same command processor, **SIC**, and some familiarity with **SIC** will be necessary for regular users.

Some useful programs are:

- **CLASS**: Continuum and Line Analysis Single-dish Software
  This program is used to analyse single dish data
- **GreG**: Grenoble Graphique
  A general purpose drawing program, for everything except 3-D plots.
- GRAPHIC
  A program that uses **GreG** to make contour plots and other graphic displays from images. Suitable for analysis of data cubes using the image processing tasks in the **GILDAS** package.
- **CLIC**: Continuum and Line Interferometer Calibration
  The main interferometer reduction task before map making. Uses **GreG** for display.
- **ASTRO**
  An astronomical utility, that computes apparent positions of celestial objects. Uses **GreG** for graphic display. Can do plots of UV coverage and solve for calibrator flux densities.
- **CFITS**
  A **CLASS** to FITS and vice-versa conversion program.
- **GFITS**
  A **GILDAS** image to FITS and vice-versa conversion program.
- **POINT**
  A **GreG** based program for pointing data analysis and display.

Most programs are well documented. Suggested order the first chapters of these documents: **Introduction** (giving general software organisation), **SIC** (the command monitor), **GreG**, **CLASS**, **CLIC**and **GILDAS**. Do not be afraid of the document sizes; many chapters are useful only for programmers or advanced users. Image processing tasks are described on-line in the **GILDAS** document.

7.2 Naming Conventions

To help bookkeeping and enable recognition of file types based on their extensions, observers and operators *MUST* use the following file extension conventions:

- The file extension length should not exceed 12 characters.
- `.LOG-OBS` for **OBS** logfiles, `.LOG-RDI` for RDI logfiles,
- `.IPB` for **CLIC** data files.
- `.OPT` for optical pointing data, `.OPTICAL` for optical pointing fits, `.RAD` for radio pointing data, `.RADIO` for radio pointing fits,
- `.OBS, .CLASS, .GREG, .CLIC, .ASTRO,` etc... for commands procedures for **OBS**, **CLASS**, **GreG**, **CLIC**, **ASTRO**, and other SIC based programs.

- `.GDF` for **GILDAS** images, or `.LMV` (and its permutations) for data cubes (to indicate Longitude Latitude Velocity cube and other possible orders), and `.UVT` for UV-tables.
- `.GILDAS` for **GILDAS** tasks logfiles (compulsory).

Data files from RDI (`.IPB` respectively) are named from the observing date, DD-mmm-YYYY. The same name should be kept for the corresponding reduced data files, additional keywords should be appended to the extension in this case.

7.3 Directory Tree

To further help organizing the reduced data area, the following directory tree has been created :

- INTER_RAW:
  where .IPB files from the real-time acquisition are store. This is on BURE1, and should only be accessed by the "copy" job, or in case of problems.
- INTER_DATA:
  where .IPB files from the "copy" job are stored on BURE2.
- INTER_TMP:
  where temporary files created during the data reduction process should be created.
- PR:
  where all standard observing procedures are kept on BURE1.
- PR:
  where all standard data reduction procedures are kept on BURE2.

7.4 Quasi Real Time Processing and Quick-look

The operator is responsible for running the copy job on BURE2. The "copy" job (launched by c̈lic @ pr:copy) copies data from BURE1 to BURE2, copying `INTER_RAW:Date.IPB` to `INTER_DATA:Date.IPB`. This job processes data on a scan per scan basis, as soon as the scans are completed by the RDI program.

The INTER_DATA:Date.IPB file can be opened by OBSERVER for a quick look on the data, or also as input for further processing such as phase calibration, or rf passband calibration, etc..., without any burden on the real-time computer.

8 OBS\ Language Help

8.1 AUTO

```
OBS\AUTO Time TWEAK|NOTWEAK
```

Starts a simple auto-correlation measurement, optionally preceded by a tweak (sampling level adjustment) of the spectral correlator. Time defines the integration time in seconds. The continuum correlator output is used to derive further Van Vleck corrections.

8.2 BANDPASS

```
OBS\BANDPASS [Time]
```

Start a specific procedure to calibrate instrumental phases of the spectral correlator. Default integration time is 5 seconds. The spectral correlator is automatically connected to a noise source for this purpose. Delay and phase tracking are cancelled during the measurement.

8.3 CALIBRATE

```
OBS\CALIBRATE [SKY|COLD|WVR|ATTENUATORS]
```

- Starts an atmospheric amplitude calibration. The calibration is done by measurements on the absorber, on the sky, and optionally on the internal cold load when argument COLD is given, by moving the receiver tables and mirrors. An extra attenuation can be inserted in the receiver 1 when measuring the power on the absorber; this attenuation is specified by command OBS\SET ATTENUATION. The calibration mode can be specified by the OBS\SET CALIBRATION command.

In INTERferometric mode, the total power Detectors are used. The spectral correlator is always tweaked in this procedure.

This command is not available in OPTICAL or TEST modes.

- With argument SKY, only the sky will be measured, unless no ambient load (absorber) measurement has been obtained recently (i.e. during the last calibration interval, of duration specified by SET CALIBRATION INTERVAL); in that case the command is executed like CALIBRATE with no argument, and a new calibration interval is started.

- With argument WVR, a specific sequence is performed to calibrate the 22GHz Water Vapour Radiometers. The correlators run an autocorrelation while the 22GHz radiometers measure their own ambient load and noise tubes. The actual observing sequence is given in the command line as a list of observing times (in seconds) and codes ('OFF','NOISE', or 'LOAD'). The default sequence is given by:

```
CALIBRATE WVR 4 OFF 4 NOISE 4 OFF
```

8.4 CANCEL

```
OBS\CANCEL [CANCEL|KILL|STOP]
```

The command CANCEL interrupts the data acquisition process.

```
OBS\CANCEL
```

Cancels current scan loop. Data acquisition is stopped at end of the next subscan. A CANCEL is implicitely done by C in multi subscans procedures, such as FOCUS, POINTING and SKYDIP.

```
OBS\CANCEL KILL
```

Aborts current scan. Data acquisition is stopped as soon as possible (depending on observing procedure) and the data are flagged "Deleted" in the output file. CANCEL KILL may be used after C has been pressed during a multi subscans command (FOCUS, POINTING, or SKYDIP). A CANCEL KILL is implicitely done by a command MICRO.

```
OBS\CANCEL STOP
```

Requests reduction programs (RDI and AFF) to stop.

```
OBS\CANCEL WAIT
```

Allows OBS to proceed when it would normally say ``Waiting for ...'' This command has to be used only when something abnormal happened in the acquisition (e.g. RDI crash).

8.5 CATALOG

```
OBS\CATALOG [SOURCE|LINE|PHASE] Name
```

Select a new catalog for sources, line frequencies, or phase calibrators. Default catalogs are

```
Sources   INTER_BASE:iram.sou
Line      INTER_BASE:iram.lin
```

```
Phase     INTER_BASE:phase.sou
```

8.6 CENTER_LO2

```
OBS\CENTER_LO2 [antenna]
```

Send centering commands to the both LO2's in specified antenna, or, by default, to all connected antennas. The LO2s are set to the center of their electronic tuning range.

8.7 CORRECTIONS

```
OBS\CORRECTIONS Caz Cel [Focus] [/ANTENNA Iant]
```

Enters pointing corrections and the focus zero for antenna Iant. Caz and Cel are offsets from respectively -COH and -COV, the radio collimations, while Focus is an offset from HF00 the nomi focus. Using * instead of a numerical value means do not change this parameter. Caz and Cel are in arcseconds, while Focus is in millimeters. In single-dish mode, Iant defaults to the single-dish antenna

Command CORRECTIONS is intended to be used for temporary changes only, for example to help in a pointing session, or to refine the current pointing on a particular source. Corrections are remembered by OBS using the MEMORY.OBS procedure, and NOT reset to 0 by a SET\OBSERVE or SET\POINTING command. To change permanent pointing parameters, the SET\POINTING command is recommended, and corrections should normally be set to zero.

8.8 DELAY

```
OBS\DELAY Dmin Dmax Dstep/ANTENNA Iant
```

Starts a delay-scanning measurement on antenna Iant. Dmin and Dmax are the minimum and maximum delays in nanosec. Dstep is the scan rate in nanosec/sec. The scanning is centered around the current delay offset.

8.9 DRIFT

```
OBS\DRIFT [Length Speed Angle [Integration]] [/HORIZON] [/BASIS]
```

Define a continuum drift single-dish procedure.
- Length is the length of the drift in current angle units.

- Speed is the drift speed ins arcseconds per second of time.
- Angle is the orientation angle of the drift in degrees, and the option /HORIZON or /BASIS indicates whether this angle is in the Horizontal coordinate system or in the current Basis coordinate system. Standard orientation angles are

```
+AZ   -90 degrees
-AZ   +90 degrees
+EL     0 degrees
-EL   180 degrees
```

- Integration is the integration time for each dump of the continuum detectors in seconds.

8.10 FLUX

```
OBS\FLUX
```

Start a cross-correlation (with default integration time) and use default antenna efficiencies to determine the source flux density. Subsequent correlations on the same source will compare the measure flux density with this value, and issue a warning in case of excessive losses. This command should be used once on each phase calibrator at start of a given project for proper monitoring.

8.11 FOCUS

```
OBS\FOCUS [Length [Npos]] [/ANTENNA A1 ...  An]
```

In INTERferometric mode, starts an interferometric focus measurement. A1 ... An is the list of antennas to focus (default: all antennas). Three or more antennas must be connected, or one must be fixed. Npos is the number of focus position to check (3 or 5, default 3).

Length is the focus displacement in millimeter (default 2.0 at 86 GHz). The command is forbidden in OPTICAL or TEST modes.

8.12 GAIN

```
OBS\GAIN
```

Starts a receiver gain-ratio measurement. At least three antennas are required for this procedure. This procedure is available only in INTERferometric mode. This is just a standard correlation, but identified specially to help data reduction. The current number of subscans is used.

8.13 HOLOGRAPHY

```
OBS\HOLOGRAPHY dAz dEl Length Speed Direction /ANTENNA [A1
... An]
```

Start an holography measurement for antennas A1 .. An. Normally, only one antenna should be specified, but the command can also be used to initiate a drift to measure e.g. an azimut encoder. This command makes a drift in interferometric mode, centered around the specified dAz and dEl horizontal offsets. Direction can be +AZ, -AZ, +EL or -EL. Length and Speed are in " and "/sec respectively. For example the following procedure could be used to make a complete 32x32 beam map :

```
DEFINE INTEGER BEAM
LET BEAM 56
SET ANGLE SEC
SET SUB 4
OFFSET 0 0/HORIZON
CALIBRATE
START
FOR I -16 TO 15 BY 1
    IF (MOD(I,2).EQ.0) THEN
        HOLOGRAPHY BEAM|2     I*BEAM|2 16*BEAM BEAM|8 +AZ/AN 1
    ELSE
        HOLOGRAPHY BEAM|2 (I+1)*BEAM|2 16*BEAM BEAM|8 -AZ/AN 1
    ENDIF
    OFFSET 0 0/HORIZON
    CALIBRATE
    START
NEXT
```

8.14 LEVELS

```
LEVELS [Goal] [/READ]
```

Adjust the receiver attenuators to optimize the total power and correlator levels. Goal is the desired total power level, and should be between 100 and 200 (default 170, giving best efficiency). The adjustment should be made around the lowest elevation used for the observation.

If option /READ is present, do not adjust the attenuator, but read their values from the microprocessors.

8.15 LINE

```
LINE Name [Frequency Band [Lock [Center [Harm]]]]
 /RECEIVER Irec
 [/BEST best\ ]]
```

Specifies the observing frequency in MHz for all antennas. If no Frequency is given, the line is selected from the line catalog. The catalog format is the same as the LINE command format.
Frequency is the observing rest frequency in GHz.
Band is USB or LSB
Lock is HIGH or LOW.
Center is the IF frequency (in MHz) corresponding to the specified rest frequency. Default is 350 MHz.

Harm is the harmonic number used to generate the LO1 from the LO2. By default, Harm is computed in order to give LO2 as close as possible to 'best\
/BEST best\ ptional and defaults to 1860. for the 3mm receiver and 1875. for the 1mm receiver.

The command is accepted in all modes, but sent (by command LOAD) only if the observing mode is INTERferometric. The relationship between the various frequencies is defined in the ''Frequency Setup'' document, and summarized below. (the signs defined according to the Band and Lock)

```
3mm receiver
        FLO2 = (FSKY +|- CENTER +|- EPS) / (HARM +|- 1)
                   USB|LSB   HIGH|LOW          USB|LSB
1.3mm receiver
        FLO2 = (FSKY +|- CENTER +|- 3*EPS) / (3*HARM +|- 1)
                   USB|LSB   HIGH|LOW              USB|LSB

where   FSKY = FREST*(1-v/c) is the Doppler corrected frequency
        EPS  = 100 + 50/512
```

8.16 LOAD

```
OBS\LOAD [/AZIMUTH Dir] [/FREQUENCY]
```

Loads observing parameters. This command sends source position, frequency information, and a number of other things to the telescope control program, but data acquisition is not started. A LOAD is implicitly done by all acquisition commands.

The Option /AZIMUTH can be used to force antenna to chose a slew direction; Dir can be +AZ or -AZ. A LOAD command is necessary before receiver tuning. The Option /FREQUENCY will only send the frequency with Doppler corection for the new source, but without antenna movement.

8.17 MICRO

```
OBS\MICRO
```

Aborts the current acquisition and put all antennas under Micro control. To be used in case of emergency such as antenna oscillations.

8.18 OFFSETS

```
OBS\OFFSET Off\ Off\Beta [Off\Focus] [/HORIZON] [/BASIS]
```

Defines source or focus offsets for ALL antennas. Position offsets are in the current angle units. In the BASIS coordinate system, they define the antenna and delay tracking center; in the HORIZONTAL coordinate system, only the antenna tracking center is modified. Focus offsets are in millimeters.

```
OBS\OFFSET Off\ Off\Beta [/DELAY]
```

Defines only the delay tracking offsets (a useful feature to avoid artificial sources at the source position caused by correlator errors).

8.19 ONOFF

```
OBS\ONOFF Off1 Off2 [System] [/TIME Tsub] [/SUBSCANS Nsub]
```

Start a on-off multi-dish procedure. Tsub is the integration time on each position (subscan duration). Off1 and Off2 are the angular offsets (in current angle units) for the reference position, and System is the coordinate system in which they are defined (Horizon or Basis, default as specified in SET OFFSET). Nsub is the number of subscans pair; default value is the number of subscans defined for single-dish measurements.

Auto correlation are made without tweaking. Data is written in the the compressed file INTER\COMP:Date.IPB) using the following CLIC procedure :

```
CLIC\SET X IF
CLIC\SET ANTENNA 1 2 3 4 ! As available
CLIC\SET Y AUTO
CLIC\FIND/PROC ONOF
CLIC\PLOT
```

8.20 POINTING

```
OBS\POINTING [PSEUDO] [/ANTENNA A1 ...  An]
[/FAST] [/LENGTH Length] [/AZIMUT +-Az] [/ELEVATION +-El]
```

In INTERferometric mode, starts an interferometric pointing measurement using the correlators in cross-correlation mode. Three or more antennas must be connected, or one must be fixed. A1 ... An is the list of antennas to move (default: all antennas moved).

If argument PSEUDO is specified, the pointing is done in ‘‘pseudo-continuum’’ mode, i.e. in auto correlation. One subband of the correlator should have been selected to match a strong spectral line in this case.

Four drifts are made (Az increment, Az decrement, El increment, El decrement). The command is forbidden in OPTICAL and TEST modes. Option /FAST can be used to scan twice faster than usual. Option /LENGTH can be given to modify the scanning length: the argument is actually half the scanning length in arcseconds. Options /AZIMUT and /ELEVATION can be used to select which drifts are actually performed among the 4 possible: +Az, -Az, +El, -El.

8.21 SAVE

```
OBS\SAVE
```

The SAVE command creates a new version of the INTER\BASE:MEMORY.OBS file, which contains current values for antenna variables parameters (efficiencies, calibration parameters, current source, etc...). This file is automatically executed each time OBS is activated, and updated each time OBS terminates.

8.22 SET

```
OBS\SET Parameter Value [/ANTENNA Iant]
```

Specifies some observing parameter.

8.22.1 SET ALARM

```
SET ALARM Status
     [DELAY delay]
     [LOSS loss]
     [WIND wind_limit]
```

Specifies the parameters of the OBS Alarm:

- Status is ON or OFF

- delay is the time duration (in seconds) after which the alarm signals abscence of data acquisition. It can be set to any time duration between 10 and 7*86400 (7 days).

- loss is the amplitude loss (0-100) which is tolerated on the calibrat amplitudes, relative to the previously measured flux (FLUX command), in percent. If the loss is higher, the alarm is activated.

- wind_limit is the minimum wind speed (in m/s) for which the wind direction alarm is activated. If the wind is higher, the alarm rings if any antenna is pointed to a direction within 90 degrees of the wind direction.

8.22.2 SET ANGLE

```
SET ANGLE Degree|Minute|Second|Radian
```

Define the current angle unit

8.22.3 SET ARRAY

```
SET ARRAY A1 A2 A3
```

Specifies the antennas currently available in the interferometer. This command is intended for temporary unavailability of antennas still on station. The CONFIGURE mode command SET\ANTENNA should be used otherwise.

8.22.4 SET AMBIENT

```
SET AMBIENT T_amb P_amb or SET AMBIENT Auto
```

Defines the external temperature (in K) and pressure (in mbar, reduced to sea level), or specifies use of the meteo station.

8.22.5 SET ATMOSPHERE

```
SET ATMOSPHERE T_atm_s T_atm_i /ANTENNA Iant
```

Defines the atmospheric temperatures in signal and image bands. This is required in the CAL MANUAL mode only.

8.22.6 SET ATTENUATION

```
SET  ATTENUATION att1 att2
```

Specify the additional attenuation applied on the ambient load measurement for receivers 1 and 2 (in dB); both should be in the range

0-8, with 2dB steps.

8.22.7 SET PHASE_CORR

```
SET  PHASE_CORR BOTH|ON|OFF
```

Specify the radiometric phase correction policy: ON means one keeps only the corrected data; OFF only the uncorrected data; BOTH means one keeps both the corrected and the uncorrected data.

8.22.8 SET DRIFT_BLANK

```
SET  DRIFT_BLANK blank_time
```

Specify the reaction time of the system for drift scans: the starting offsets are computed so that the antennas will pass through the actual drift starting position 'blank_time' seconds after the command is sent.

8.22.9 SET SOLVE

```
SET  SOLVE [POINTING  ON|OFF]  [FOCUS  ON|OFF]  [RECEIVER
1|2]
 [PLOT LANDSCAPE|PORTRAIT|NONE]
```

Switch on or off the automatic on-line reduction of pointing and focus scans by RDI. Also optionally input the receiver to be used for that reduction, and the shape of the plotting window.

8.22.10 SET BEAM_THROW

```
SET BEAM_THROW Bs /ANTENNA Iant
```

Indicate the beam separations Bs (in arcsecond) for beam-switch observations. This is a hardware value, not a software controlled parameter.

8.22.11 SET CALIBATION

```
SET                                          CALIBRATION
AUTO|MANUAL|NONE|TREC|HUMIDITY|ON|OFF|INTERVAL  argument  /ANTENNA  Iant
```

```
/RECEIVER Irec

     Defines the calibration mode
NONE:     uncalibrated spectra & data
MANUAL:   Manual guess of atmospheric transmission
AUTO:     fix Water to argument (in mm), compute Trec
TREC:     fix Trec to argument (in K), compute Water
HUMIDITY: estimate water from umidity ant temperature
OFF:      temporarily disable atmospheric calibration
ON:       Restore caibration in previous mode
INTERVAL: Interval between two measurements of ambient load (in hours)
```

8.22.12 SET CHOPPER

```
SET CHOPPER T_warm T_cold /ANTENNA Iant /RECEIVER Irec
```

Defines the absorber chopper and cold load temperatures for antenna Iant and receiver Irec (only in MANUAL mode; otherwise read from actual hardware and receiver data files).

8.22.13 SET DEBUG

```
SET DEBUG On|Off On|Off On|Off
```

For authorized users only.

8.22.14 SET FORWARD

```
SET FORWARD F_eff /ANTENNA Iant /RECEIVER Irec
```

Specifies the forward efficiency of antenna Iant. Beam efficiency is assumed equal to forward efficiency in all cases (antenna temperature scale). (Used only in MANUAL mode; otherwise F_eff is read from data file INTER_BASE feff.dat).

8.22.15 SET GAIN_IMAGE

```
SET GAIN_IMAGE G /ANTENNA Iant /RECEIVER Irec
```

Specifies the image to signal gain ratio for antenna Iant

8.22.16 SET HUMIDITY

```
SET HUMIDITY Humidity
```

Specifies the humidity (for refraction correction) if the meteo station is not used.

8.22.17 SET INTEGRATION

```
SET INTEGRATION Time
```

Specifies the integration times between dumps for the cross-correlation

8.22.18 SET LEVEL

```
SET LEVEL terminal file
```

Specifies the level of printout (0 many messages, 2 Normal, 4 extremely limited) for terminal and log file (INTER_LOG:Date.LOG-OBS).

8.22.19 SET MODE

```
SET MODE Imode [/ANTENNA Iant]
```

Specifies the observing mode Imode, which can take the values

INTERferometer: Select interferometric observing mode, allowing AUTO, CALIBRATE, GAIN, FOCUS, POINTING, SKYDIP and Cross correlation observing procedures. The correlators are used for pointing and focusing in cross correlation mode. In addition an ONOFF procedure allows spectra to be taken with all antennas at the same time.

OPTICAL: This mode is used for optical pointing. The only allowed commands are SOURCE and LOAD in this mode. The optical pointing constants and refraction model are used for tracking.

CONFIGURE: This mode is used to specify a change of hardware configuration, such as new position of antennas, new IF connections, new pointing constants, etc... The OBS\ language becomes inactive, and the SET\ language is turned on. Observations can be resumed only using the SET\OBSERVE command.

TEST: This mode is used for tests of the correlators. LO1 Walsh switching, phase and delay tracking are suppressed. The spectral correlator is automatically connected to the noise source. The continuum correlator must be manually connected to another noise source to be tested. Antennas are unused and several commands become unavailable in this mode.

8.22.20 SET OFFSETS

```
SET OFFSETS Basis|Horizon
```

Specifies the coordinate system to be used for offsets.

8.22.21 SET OPACITY

```
SET OPACITY Tau_S Tau_I /ANTENNA Iant
```

Specifies the atmospheric opacities in signal and image band for antenna Iant. Required only in CAL MANUAL mode.

8.22.22 SET SHOW

```
SET SHOW ON|OFF
```

Selects or disables the "full-display".

8.22.23 SET SCAN

```
SET SCAN Ns
```

Specifies the number of scans requested by each START command.

8.22.24 SET SUBSCAN

```
SET SUBSCAN Ns
```

Specifies the number of subscans for each scan.

8.22.25 SET TABLE

```
SET TABLE Sky
```

Specifies the table position for observation on Sky, as a percentage of total displacement (0 : sky only, 100 absorber only). This value is common for all antennas.

8.22.26 SET TREC

```
SET TREC Trec /ANTENNA Iant
```

Specifies the receiver temperature for antenna Iant. Required only in CAL TREC mode.

8.22.27 SET WATER

```
SET WATER wH2O
```

Specifies the water vapor content of the atmosphere (in millimeter). Required only in CAL AUTO mode.

8.22.28 SET WVR

```
SET WVR [ON|OFF|GAIN|EFFICIENCY|TREC|FREQUENCY|BANDWIDTH] /ANTENNA Iant
```

Specifies the Water vapour radiometers parameters for antenna Iant:

SET WVR ON|OFF : enables/disables WVR

SET WVR GAIN tcal1 tcal2 tcal3 : enter the noise diode values in K, for each channel.

SET WVR EFFICIENCY eff1 eff2 eff3 : enter the forward efficiencies, for each channel.

SET WVR TREC trec1 trec2 trec3 : enter the receiver temperature in K, for each channel.

SET WVR FREQUENCY f1 f2 f3 : enter the central frequency in MHz, for each channel.

SET WVR BANDWIDTH b1 b2 b3 : enter the bandwidth in MHz, for each channel.

8.23 SHOW

```
            OBS\SHOW [* | Item]

    OBS\SHOW      : Refreshes the "full-screen" display
    OBS\SHOW *    : Lists all parameter values.
    OBS\SHOW item : List one parameter.

 The available parameters are
    ANGLE       D|M|S                  : Angle unit type
    AMBIANT     Tamb Pamb | AUTO       : Meteo parameters and mode
    ARRAY       List                   : Antennas in array
    ATMOSPHERE  T_atm_s T_atm_i        : Atmospheric temperature (*)
    ATTENUATION Att_1  Att_2           : Attenuation for calibration
    BEAM_THROW  Value                  : Chopper throw (*)
    CALIBRATION AUTO|MANUAL|NONE|TREC : Calibration mode (*)
    CHOPPER     T_warm T_cold          : Chopper temperatures (*)
    CORRECTIONS -COH -COV HF00         : Pointing and focus corrections (*)
    DEBUG       On | Off               : Debug flags (for test only)
    FORWARD     F_eff                  : Forward (=Beam) efficiencies (*)
    FIT         On | Off               : Fit pointing scans ?
    GAIN_IMAGE  G                      : Gain/Signal band ratio (*)
    LEVEL       terminal file          : message priority level
    MODE                               : OBS operating mode
    OFFSETS     Basis | Horizon        : Offsets type
    OPACITY     Tau_S Tau_I            : Atmospheric opacities (*)
    PHASE       Atm | Noatm | Both     : Atmospheric phase compensation
    SCAN        Ns                     : Number of scans per START
    SUBSCAN     Ns                     : Number of subscan per scan
    TABLE       Sky                    : Table OFF position
    TREC        Trec Tsys              : Receiver and System temperature (*)
    WATER       wH2O                   : Water vapor content  (*)

 Parameters marked (*) may depend on antenna.  All antennas are listed in
 this case.
```

8.24 SKYDIP

```
            OBS\SKYDIP Azi [/ANTENNA A1 ...  An]

     Starts a skydip measurement with the  specified  or  all  connected
 antennas   at  azimuth  Azi.   The  continuum  detectors  are  used.   A
 measurement on the tables  is  made  first  then  the  sky  emission  is
 measured  at  6  different  elevations  equally  spaced  in  air masses,
 starting from 45 degrees elevation.  The data is  written  in  the  .IPB
```

file, and no real time reduction is available.

The command is forbidden in OPTICAL and TEST modes.

8.25 SOURCE

OBS\SOURCE Name [Coordinates ...] /TYPE OBJECT|PHASE|BAND [/VELOCITY Vtype [Vvalue]] [/FLUX Fvalue]

Selects a source of the specified type: OBJECT for sources to study, PHASE for Phase calibrator, BAND for Bandpass calibrator. The SOURCE catalog is searched for OBJECT type sources, while the PHASE catalog is searched for PHASE and BAND sources. Source coordinates may be in the command line, in the same format as the source catalog, i.e.

```
NAME  Syst [Epoch] Lambda       Beta        Vtype  [Velo] [FLUX Value]
W3OH  EQ   1950.0  02:23:16.50  61:38:57.0  LSR    -45.0   FLUX 3.73
```

Where

- Syst is the coordinate system (EQ, HO, GA) and Epoch its optional epoch.
- Lambda and Beta are the coordinates (in hours and degrees for EQ coordinates, in degrees only for HO and GA coordinates).
- Vtype is the reference frame (LSR, EARTH, HELIO, or NULL which means no Doppler tracking) and Velo the velocity in km/s.
- FLUX is a keyword indicating a value for the continuum flux (in Jy) at 3mm.

The /TYPE option is compulsory, and indicates in wich catalog the source should be searched. PHASE and BAND sources have a velocity type NULL to avoid changing the observing frequency between the source and the calibrator.

The /VELOCITY Vtype Vvalue and /FLUX Fvalue options can be used to override the velocity or flux specified in the catalog.

8.26 SPECTRAL

OBS\SPECTRAL Unit Bandpass IF_2 [/CONTINUUM Band_C LO2_C] [/RECEIVER Irec] [/BAND code]

Configures the spectral correlator unit number Unit. Bandpass indicates the contiguous bandpass to be used (20, 40, 80, 160 or 320 MHz). IF_2 is the second IF frequency of the bandpass center. It is rounded to the nearest multiple of 0.25 MHz (the LO3 frequency step).

The /CONTINUUM option specified which bandpass should be analyzed to produce the temporal data. The default is 80 % of the original band.

Option /RECEIVER is used to indicate to which receiver the unit should be connected.

Option /BAND is used to indicate the sideband code for the fourth frequency conversion: 'U', 'L', or 'D'. Only D is available for 320 MHz bandwidth; only U or L are available for 20 and 40 MHz bandwidths. D gives twice as many channels than U or L for the same bandwidth but the central channels suffer from Gibbs effect.

8.27 STABILITY

```
OBS\STABILITY Time [TWEAK|NOTWEAK]
```

Perform an autocorrelation of specified integration time on the calibration table ("Hot" load), and analyse the result in terms of receiver stability. Time should be at least 60 sec.

8.28 START

```
OBS\START
```

In INTERferometric or TEST mode, starts a cross-correlation measurement, using the number of scans and subscans specified by the SET SCANS and SET SUBSCANS commands and integration time specified in SET INTEGRATION.

9 SET\ Language Help

9.1 ANTENNA

```
SET\ANTENNA Iant ON Station TO Correlator_Entry
```

Define position of antenna Iant and associated correlator entry. This command is available only in CONFIGURE mode, selected using SET MODE CONFIGURE command. After configuration has been specified, observations can be resumed using the OBSERVE command.

9.2 CABLE

```
SET\CABLE Irec
```

Reset phasemeter counter for specified receiver.

9.3 CHECK

```
SET\CHECK
```

Check the current spectral correlator setup, by comparing it to its state when the latest SET\LOCK command was issued. An error is declared if there is a difference, interrupting the current procedure. This command is used in the standard observing procedure.

9.4 DELAY

```
SET\DELAY Del/ANTENNA Iant
```

Specify the delay offset (in nanoseconds) of antenna Iant. The Station.Antenna file is updated. The delay can be determined using the CLIC\SOLVE DELAY command, which produces a file containing the appropriate SET\DELAY commands.

9.5 LOCK

```
SET\LOCK
```

Lock the current spectral correlator setup. Further spectral commands will require a confirmation from the operator. This command should be used in the setup procedure of every project after the SPECTRAL commands.

9.6 UNLOCK

```
SET\UNLOCK
```

Reset the lock status of the the current spectral correlator setup. Further spectral commands will not require a confirmation from the operator.

9.7 OBSERVE

```
SET\OBSERVE
```

This command send all configuration parameters to the shared commons, and reload the Station.Antenna files. It turns off the SET\ language, and activates the OBS\ language to allow observing.

Note that all temporary changed specified by OBS\CORRECTIONS command are overwritten.

9.8 PROJECT

```
SET\PROJECT name
```

Change the current project name (a 4-character chain).

The current project is ended, if its name was different.

The script /control/obs/obs-project is executed to manage the data and log files.

9.9 PHASE

```
SET\PHASE LO1|LO3 Phase /ANTENNA Iant /RECEIVER irec
```

Define the LO1 and LO3 phases of the specified receiver and antenna. LO3 phases allow to recenter the phases of the USB and LSB to the same value, and LO1 phases allow to set this value to zero. Appropriate values are computed by CLIC command SOLVE GAIN.

9.10 POINTING

```
SET\POINTING [IAZ Value] [IEL Value] [DVE Value] [DVN Value] [IVE Value] [IVN Value] /ANTENNA Iant
```

Specify new (station dependent) pointing constants for antenna Iant. The Station.Antenna file is updated. IAZ is the zero of azimuth, IEL of elevation, IVE and IVN the inclinations from the inclinometers, DVE and DVN offset from these inclinations. IVE and IVN are normally determined by the INCLINOMETER procedure, while DVE and DVN should be zero. Values can be arithmetic expressions, e.g. as in command

```
SET\POINTING IEL IEL-6 IAZ IAZ+15 /ANT 3
```

1 RESTART

```
[SET\]RESTART [Program]
```

Restart a program. The program can be RDI, CORREL or AFF. This command is typically used after a OBS\CANCEL STOP command, or when the program died of unnatural causes (crash...).

By default, RESTART waits for end of observation. In case of abnomalous death of RDI or CORREL, this may never happen. Pressing C interrupts the wait state in this case. If OBS stills wait for start of scan, you may have to type a CANCEL WAIT command to be able to restart.

9.11 SHOW

```
SET\SHOW Item
```

Show some configuration parameters

```
SET\SHOW ANTENNA Iant
```

will list the Station.Antenna file, giving pointing constants, position from station, and zero delay. It is equivalent to the command

```
SIC\TYPE INTER_BASE:Station.Antenna
```

except for an automatic determination of the file name.

```
SET\SHOW ARRAY
```

shows the current array configuration.

9.12 SINGLE

```
SET\SINGLE Isin
```

Define the single-dish antenna, i.e. the antenna connected to the precision detector.

9.13 XYZ

```
SET\XYZ dX dY dZ /ANTENNA Iant
```

Specify position (difference from station coordinates) of antenna Iant. The Station.Antenna file is updated. dX dY dZ can be measured by a baseline calibration, and using the CLIC\SOLVE BASELINE command in CLIC, which will create a procedure containing the appropriate SET\XYZ commands for all antennas. dX dY dZ are in meters.