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# paKo

## The Observer's User Interface to the New Control System at the IRAM 30-Meter Telescope

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### **Description - about this document:**

This is the documentation of the observer's user interface to the New Control System (NCS). The user IF program is nicknamed "PAKO" = "paKo for astronomers' K(c)ontrol of observations".

Revision v 1.1.14 introduced support for NIKA, and SUBSCAN /TUNE for NIKA.

Revision v 1.1.15 supports the upgrade of EMIR band E150 to full 2\*2\*8 GHz LSB+USB in both polarizations, and the E330 local oscillator to higher frequencies (2013-09).

*README. Observers who are new to the NCS are encouraged to read sections 1, 2, and ???. Note that much of the space in these sections is taken up by examples, so the actual text is not very long or hard to read!*

## References and Related Documents—Short List:

1. [New Control System for the 30m Telescope](#)

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## 1 paKo— Introduction and Overview

After this introduction follows section 2, a “Guide for the Perplexed”. Here we briefly explain some general features of PAKO as well as differences from the previous control system for the 30-M Telescope.

In Section 3 we give a very short recipe with the bare minimum to get started with Heterodyne observations.

Section ??, is “PaKo’s Cook Book”. It is meant to evolve into a gentle step-by-step and command-by-command explanation of how to do observations with the NCS.

Next is the “NCS User’s Guide”, ??, which follows the same outline as the “Cook Book”, but includes more details. The examples included here are all in the form of PAKO command language scripts.

The section “NCS Explained”, 6, contains detailed explanations of some aspects of the NCS.

Finally, the “PAKO Language Internal Help” is reproduced in section 7.

A lot of information is intentionally duplicated in different sections of this manual, so that, e.g., the “Cook Book” and the “User’s Guide” can be read independently. It should not be necessary to read all sections in this manual! Also much space is taken up by examples, so the actual text to read is not very long!

We recommend that all users who face the NCS for the first time should read the “Guide for the Perplexed”. Beginning observers and those who like to set up their observations one command at a time can then follow the “Cook Book”, section ??.

More experienced observers may prefer the “User’s Guide”, section ??, especially those who need more advanced options and those who like to prepare scripts with the specifications of their observations (recommended!).

All users may want to consult the section 6 “NCS explained” for general information, or look up details in the HELP section, 7, which is a complete reference for all commands and options.

Before starting observations, users should also review the up-to-date notes on the NCS wiki pages at:

NCS Wiki at <https://mrt-lx1.iram.es/mainWiki/FrontPage>

```

ssh - paKo - 140x32 - %2
I-BACKEND , no receiver name specified as parameter
I-BACKEND , no 2nd receiver name specified as parameter
I-BACKEND , Continuum total hardware used [%]: 0.0
I-BACKEND , 100kHz total hardware used [%]: 0.0
I-BACKEND , 1MHz total hardware used [%]: 0.0
I-BACKEND , 4MHz total hardware used [%]: 100.0
I-BACKEND , USB total hardware used [%]: 0.0
I-BACKEND , WILMA total hardware requested [%]: 100.0
I-BACKEND , VESPA total hardware used [%]: 33.3
I-BACKEND , 4MHz 1 4.000 4024.0 248.0 E090 horiz UO none 100.0 none
I-BACKEND , 4MHz 2 4.000 4024.0 -248.0 E090 verti UI none 100.0 none
I-BACKEND , WILMA 1 2.000 3720.0 265.0 E090 horiz UO none 100.0 none
I-BACKEND , WILMA 2 2.000 3720.0 -265.0 E090 verti UI none 100.0 none
I-BACKEND , WILMA 3 2.000 3720.0 265.0 E230 horiz LI none 100.0 none
I-BACKEND , WILMA 4 2.000 3720.0 265.0 E230 verti LI none 100.0 none
I-BACKEND , VESPA 1 0.040 40.0 0.0 E090 horiz UO none 90.0 CO-1-0
I-BACKEND , VESPA 2 0.040 40.0 0.0 E090 verti UI none 90.0 myLine2
I-BACKEND , VESPA 3 0.040 40.0 0.0 E230 horiz LI none 90.0
I-BACKEND , VESPA 4 0.040 40.0 0.0 E230 verti LI none 90.0 LIL0
PAKO> show
I-SHOW , paKo Revision v 1.1.1 2009-04-14
I-SHOW , Level. For standard output: 0. For file: 0
I-SHOW , Queue. doSubmit: F
I-SHOW , Project "111-22"
I-SHOW , PI "Dr. Jane D. Doe"
I-SHOW , Observer "John Doe"
I-SHOW , Operator "Pako"
I-SHOW , Topology "LOW"
I-SHOW , Pointing. azimuthCorrection: 0.000000E+00
I-SHOW , Pointing. elevationCorrection: 0.000000E+00
I-SHOW , Focus. focusCorrection: 0.000000E+00
PAKO>

```

Figure 1: Screen shot of PAKO running in a terminal window.

## 2 paKo — Guide of the Perplexed

### 2.1 paKo and SIC

PAKO uses the usual SIC command line interpreter, and can be run in any X-windows terminal, see Figure 1.

It includes the GREG and GUI languages for plotting and, of course, adding GUI widgets.

### 2.2 paKo and Linux

PAKO and the NCS run on Linux. Any files that are prepared off-line, e.g., command scripts and source or line catalogs, should follow Linux standards. (Files prepared on other operating systems may contain non-compliant control characters.)

### 2.3 Running paKo offline and several instances of paKo

PAKO can run independently of the NCS. This is useful, e.g., to prepare command scripts and source or line catalogs.

Several instances of pako should not be run in the same working directory (of the same project account.) Also, at most one instance of pako should try to send observations to the observation queue; other instances should SET DOSUBMIT NO, see below.

### 2.4 Help

There is help available, e.g., enter at the prompt `PAKO > :`

```
HELP CALIBRATE
```

The display for most commands corresponds directly to the syntax of the command. E.g., for each observing mode, the display shows the syntax of all options.

The most recent command, as pako interpreted it, is usually shown at the bottom of the display window.

The keywords for commands and options try to be meaningful and, if possible, self-explanatory. As usual with SIC, minimum match is supported, so you can also write compact (and cryptic) commands, e.g., enter at the prompt `PAKO > :`

```
OTF /B /C CROOR /NO 12 /REF /ST -20 20 /SY PR /TO 30 /TR 22 /Z
```

## 2.5 SET LEVEL for Errors, Warnings, and Infos

PAKO can be very “chatty” and display many “messages” in the command line window. They are marked with “I-” for “info”, “W-” for “warning”, or “E-” for “error”. “E-” “error” is reserved for true errors, something not accepted by PAKO.

You can control the number of messages you see with with `SET LEVEL`, e.g.,

```
SET LEVEL 1 1
```

will enforce that you get all messages.

```
SET LEVEL 3 3
```

will suppress most “I-” infos.

```
SET LEVEL 5 5
```

will suppress most “I-” infos and “W-” warnings.

At this time (2013-10-17) PAKO still displays some debug messages, which are not flagged “I-”, “W-”, or “E-”. They will be eliminated as soon as possible.

## 2.6 Saving and Restoring

For most commands you can save the parameters into a file, e.g., enter at the prompt `PAKO > :`

```
SAVE POINTING
```

This saves the parameters of observing mode `POINTING`. The format of the saved files is that of a valid script in the command language. Therefore you can restore it later: enter at the prompt `PAKO > :`

```
@ POINTING
```

In a similar way, you can save the parameters of the source, receiver and backend setup, and of the switching mode.

```
SAVE ALL
```

saves (nearly) all current parameters, as well as the current switching and observing modes. It saves the pointing and focus corrections only if used in the form:

```
SAVE ALL C[ORRECTIONS]
```

Normally **SAVE ALL** is meant to generate a **paKo** script that can be used to re-produce the setup at a later time, when one probably wants to use different pointing and focus corrections. On the other hand the idiomatic usage:

```
SAVE ALL C /FILE LAST
```

allows to save “really everything” in order to recover it with **@ LAST**.

The parameters of “unused” (unselected) hardware, switching modes, and observing modes are never saved.

Tip: check out the options of command **save**: enter at the prompt **PAKO > :**

```
HELP SAVE /FILE
```

```
HELP SAVE /APPEND
```

After using **@ ...** to restore a saved observing mode, e.g., **otfmap**, the graphic display may look confused. To clean it up, enter at the prompt **PAKO > :**

```
CLEAR PLOT
```

```
BOX
```

```
OTFMAP          ! i.e., the observing mode.
```

## 2.7 Observation Queues and Starting

In the NCS, all observations are handled through an observation queue. So far this is rather simple, first-in-first-out.

The operator has to set the “current observation queue” to be that of the project account. (Submission from other projects will not be accepted by the NCS).

enter at the prompt **PAKO > :**

```
SET doSubmit yes
```

to activate submission of observing commands to the NCS observing queue. **SET doSubmit no** is useful for debugging, so that scripts including **START** can excute without actually trying to submit observations.

To start any observation in the NCS enter at the prompt **PAKO > :**

```
START
```

which actually generates an XML file with a full and detailed specification of all subscans that will be excuted by the NCS “coordinator” software. This is done by the “scanAnalyzer”, which is an integral part of the **pako** software. If you are looking for an adventure, you are encouraged to explore these XML files, e.g., using a recent version of Mozilla, the XML editor oxygen, or emacs.

Several instances of **pako** should not be run in the same working directory (of the same project account.) Also, at most one instance of **pako** should try to send observations to the observation queue.

## 2.8 Source and Line Catalogs

The format of the source catalog, e. g., iram.sou, is similar to source catalogs at PdB. A source catalog for the NCS can be generated from standard “old” 30m catalogs (\*.cat) using ASTRO. The example source catalog, demo.sou, was generated from a historic version of IRAM.CAT using ASTRO.

The format of the line catalog, e. g., model.lin, is as in the old control system and at PdB.

NOTES. *In source names, line names, and parameters of type character, like Project ID, names of PI, observer, operator, one can not use characters that have a special meaning in XML, in particular don't use: & < or >; also don't use: ( or ) in source names.*

## 2.9 Switching Modes

In the NCS we distinguish the following 4 “Switching Modes”:

TOTAL POWER

BEAM SWITCHING

WOBBLER SWITCHING

FREQUENCY SWITCHING (only with heterodyne receivers)

The corresponding commands are:

SWTOTAL

SWBEAM

SWWOBBLER

SWFREQUENCY

BEAM SWITCHING, WOBBLER SWITCHING, and FREQUENCY SWITCHING are realized by a system with hardware synchronization signals that allow a precise and fast switching *within* subscans.

TOTAL POWER simply means that none of the other 3 switching modes is active.

The system switches through a regular cycle with several (1, 2, or 4) switching phases.

The 4 switching modes are mutually exclusive, i.e., at any time the system uses only one of them.

During the transitions between phases, e.g., while the Wobbler is moving between its positions, no data are taken during the short “blanking” time.

The switching mode and its parameters should normally be set before choosing an observing mode, because for some observing modes details of the setup depend on the switching mode.

## 2.10 Observing Modes

The NCS supports the following “Observing Modes”: CALIBRATE, POINTING, FOCUS, TIP, ONOFF, OTFMAP, <<TBD:RASTER not yet implemented >>, TRACK, VLBI.

All Observing Modes are realized by executing a sequence of 1 or more subscans. In most cases, the antenna moves between or during the subscans.

The observing modes are mutually exclusive, i.e., at any time the system executes only one of them.

Several Observing Modes can be combined with different Switching Modes, e.g., OTFMAP with TOTAL POWER, WOBBLER SWITCHING (for bolometer), or FREQUENCY SWITCHING. The Switching Mode should normally be specified before the Observing Mode.

## 2.11 Combinations of Switching and Observing Modes

The Switching modes and Observing modes are not fundamentally different from what they were in the old CS. However, in the NCS we try to be more explicit about this distinction in order to: (i) avoid having several commands that set up, e.g., parameters of the Wobbler, (ii) to support more combinations of Observing Modes and Switching Modes in the future.

## 2.12 Coordinate Systems, Map Projections, and Position Offsets

For a more detailed explanation, see Section 6.1.

The NCS will support a variety of astronomical coordinate systems and projections, as well as “descriptive” coordinate systems defined by the user. Up to now, 2013-10-17, only equatorial coordinates, J2000.0, are well tested and available for use.

**Map Projections and Offsets.** In general, a “map projection” describes the relation between 2 spherical coordinates, longitude  $l$  and latitude  $b$ ,<sup>1</sup> on the celestial sphere, and 2 Cartesian coordinates  $x$  and  $y$ , which in radio astronomy and the NCS we often call “position offsets”.

Up to now, 2013-10-17, only the “radio” projection is supported, for which:

$$x = (l - l_{source}) * \cos(b)$$

$$y = b - b_{source}$$

where  $l_{source}$  and  $b_{source}$  are the source coordinates specified with **SOURCE**.<sup>2</sup> Note that this is the same system of offsets as in “OBS” of the old control system.

If we want to observe several positions on the sky at or near the source position as specified with **SOURCE**, we often do this by requesting position offsets in the map projection. Also, the resulting data, e.g., images, are usually stored and displayed as a function of  $x$  and  $y$ .

For most observations, parameters and options of the observing mode are sufficient to specify the position offsets:

- for **TRACK** and **VLBI**  $x$  and  $y$  are fixed during the complete scan;
- for **ONOFF**  $x$  and  $y$  change from subscan to subscan;
- for **OTFMAP**  $x$  and  $y$  change continuously or “on-the-fly” (OTF) during the OTF subscans.

The PAKO commands for most Observing Modes expect fixed offsets (or start- and end-offsets for **OTFMAP**) as parameters. These can be either in the radio projection, specified with the option: **/SYSTEM projection** or in the true angle horizon system (see below), specified with the option: **/SYSTEM trueHorizon**

NOTES. For **POINTING**, the OTF offsets are always in system **trueHorizon**, and are specified implicitly though the angular length of the subscans.

<sup>1</sup> In particular for equatorial coordinates,  $l$  corresponds to Right Ascension and  $b$  to Declination.

<sup>2</sup> For the equations all angles are assumed to be in radian.

**Global Offsets.** On the other hand, the command **OFFSETS** can be used to specify additional position offsets in other systems. These globally defined offsets stay fixed during a complete scan. *They are only needed in special cases, e.g., the Nasmyth offsets or for ONOFF with wobbler switching, see below.*

At this time (2013-10-17), the command **OFFSETS** supports offsets in the following 3 systems:

**projection** Offsets in the “radio” projection (see above).

**trueHorizon** “true angle horizon” offsets in Azimuth and Elevation:

$$\Delta a = (a - a_{source}) * \cos(e)$$

$$\Delta e = e - e_{source}$$

where  $a$  and  $e$  are the Azimuth and Elevation of the telescope;  $a_{source}$  and  $e_{source}$  are the Azimuth and Elevation of the source, calculated from  $l$  and  $b$  (and the time and other parameters).

**Nasmyth** offsets in the Nasmyth (receiver cabin) system. The purpose of Nasmyth offsets is exclusively to re-position the telescope so that an off-center element of a multibeam receiver looks at the position where otherwise the center pixel would look. E. g., **OFFSETS -33 44 /SYSTEM Nasmyth** adds offsets -33 and 44 in the Nasmyth system (for all observing modes!)

**Example 1** Observe a single position with offsets 10 and 20 in system radio projection; typically used with **FREQUENCY SWITCHING**:

```
TRACK 10 20 /SYSTEM projection
```

**Example 2** Observe **ONOFF** (“position switching” with **TOTAL POWER**) with **ON** position at 30 40 and off-source reference at -600 -700, both in system radio projection:

```
ONOFF 30 40 /REFERENCE -600 -700 projection /SYSTEM projection
```

**Example 3** Pointing with subscans of length 120:

```
POINTING 120
```

NOTES. For **POINTING**, the **OTF** offsets are always in system **trueHorizon**, and are specified implicitly though the angular length of the subscans.

**Example 4** **ONOFF** observations with **WOBBLER SWITCHING** are a special case, because the offsets for the subscans must be in system **trueHorizon** and their values must be selected according to the offsets of the **WOBBLER SWITCHING**! E. g.,

```
SWWOBBLER -33 +33
ONOFF 33 0 /REFERENCE -33 0 trueHorizon /SYSTEM trueHorizon
```

This can also be achieved simply by saying

```
SWWOBBLER -33
ONOFF
```



PAKO “knows” the special requirements for onoff wobbler switching, and will set the offset parameters for **ONOFF** accordingly, if **SWWOBBLER** has been previously selected.<sup>3</sup>

In this special case, in order to map the source, the observer may add offsets on the source  $l$  and  $b$  using the command **OFFSETS** with the system “projection”, *e.g.*:

```
SWWOBBLER -33
OFFSETS 110 120 /SYSTEM projection
ONOFF
```

NOTES. *SOURCE* does not clear offsets set with **OFFSETS**.

NOTES. If you are unsure about any of this, read the additional information in Section 6.1, or ask an astronomer who is familiar with the NCS. For the time being, it is recommended not to try “fancy” combinations of offsets, which probably have not yet been fully tested and debugged.

### 2.13 Receiver Setup and Calibration Parameters

All parameters and options related to the setup of receivers and their calibration are specified with the command **RECEIVER**. This includes ambient and cold load temperatures, image sideband ratio, forward and main beam efficiencies, calibration scale antenna or (main) beam, and the HERA derotator.

### 2.14 Backends

Backend setup for all backends is done with the command **BACKEND**.

### 2.15 Continuous Data Acquisition and Data Streams

In the NCS, normally the data acquisition is continuous: fast independent data streams are generated by the backends as well as other subsystems, *e.g.*, by the antenna mount drive to describe the antenna’s movements. The data processing software synchronizes the data from different streams based on time stamps in the data. Most data streams keep continuously running even between subscans.

### 2.16 Display of Parameters

Most parameters set by the observer are displayed by a separate program, **pakoDisplay**, in another window, see Figure 2.

Several instances of this program can run at the same time, including on different screens, “desktops”, and Linux machines.

### 2.17 Preview Plots

Commands for some observing modes, *e.g.*, **otfmap**, automatically generate “preview” plots, see Figure 3.

The range of mapping offsets for these plots can be set with the usual GREG command limits, *e.g.*, enter at the prompt **PAKO > :**

---

<sup>3</sup> For special purposes, it is possible to overrule this with **/swWobbler no**, *e.g.*, **ONOFF 44 /swWobbler no**.



Figure 2: Screen shot of the PAKO Display.



Figure 3: Screen shot of the PAKO preview plot.

```

DEVICE IMAGE W
LIMITS 500 -500 -500 500
SET BOX MATCH
BOX

```

Similarly, you can use other commands from GREG to change the color of the plotting “pens” or background of the window.

## 2.18 Defaults

Most commands have an option `/DEFAULT` which will set all options and parameters to meaningful default values. You can combine this option with explicit values for some parameters and options, e.g., enter at the prompt `PAKO > :`

```
OTFMAP /DEF /NOTF 12
```

means: default values for `OTFMAP`, but 12 `OTF` subscans.

## 2.19 Ranges and checks

Most parameters are checked to be within 2 ranges:

1. limits of allowed values. If you try to enter a value outside that range, you get an error message and the value is not accepted, e.g., enter at the prompt `PAKO > :`

```
POINTING /TOTF 4000
E-TOTF      /, value 4000.000 outside limits 1.000000 to 3600.000
```

2. standard range. If you enter a value outside the standard range, you get a warning message, but the value is accepted, e.g., enter at the prompt `PAKO > :`

```
POINTING /TOTF 3000
W-TOTF      /, value 3000.000 outside standard range 10.00000 to 600.00000
```

## 2.20 Independence of Command Parameters

The parameters of each observing mode are independent from the parameters of other observing modes. The same is true for the different switching modes. For example, if you first enter at the prompt `PAKO > :`

```
OTFMAP /NOTF 12
```

and later:

```
POINTING /NOTF 4
```

the number of OTF subscans for OTFMAP is still at 12, as you can see with:

```
OTFMAP
```

Some options exist for several observing modes. E.g., options `/NOTF`, and `/TOTF` exist for `POINTING` and `OTFMAP`. The syntax, parameters and meaning of these options is then (almost) the same for all observing modes.

## 2.21 Option keywords

Options that start with:

```
/t... refer to times (durations), e.g., /t0tf = time per OTF subscan;
/n... refer to number of something, e.g., /n0tf = number of OTF subscans;
/f... refer to frequency of something;
/temp... refer to temperature of something.
```

## 2.22 Logical (YES/NO or ON/OFF) Options

Several options of commands are “logicals” which can have only one of 2 values: TRUE = YES, shown in the display as: T, or: FALSE = NO, shown in the display as: F. The command syntax and logic for ALL these options is the same, e.g., enter at the prompt `PAKO > :`

```
OTFMAP /ZIGZAG          ! TURN OPTION  ON/TRUE/YES : T
OTFMAP /ZIGZAG YES      ! TURN OPTION  ON/TRUE/YES : T
OTFMAP /ZIGZAG .TRUE.   ! TURN OPTION  ON/TRUE/YES : T
OTFMAP /ZIGZAG NO       ! TURN OPTION  OFF/FALSE/NO : F
OTFMAP /ZIGZAG .FALSE.  ! TURN OPTION  OFF/FALSE/NO : F
```

[Note: the default value for some logical options, e.g., `/ZIGZAG`, is T; for other logical options the default is F.]

### **2.23 Example Scripts and Catalogs**

Examples of PAKO scripts, source and line catalogs are available on the WWW and in each project account.

### 3 PaKo's simplest recipe

This section gives a very short and simple overview of the steps needed to start spectral line observations. Details and more explanations are in the following sections, also in user's guides for special topics.

The following simple example is for both polarizations of one sub band, LI or UO, of one band, E090, of the EMIR receiver, see the EMIR user's guide for more information.

- Prepare a source catalog file, e.g., my.sou, with one line for each source that looks like:

```
W3OH EQ 2000 02:27:03.8812 +61:52:24.572 LSR -45.000
```

- Prepare a line catalog file, e.g., my.lin, with one text line for each line frequency like:

```
CS(2-1)          97.980968      LI
12CO(1-0)        115.271204      UO
```

LI and LO refer to sub bands of the EMIR E090 band. See the EMIR user's guide for details.

- Start up PAKO (see local information how to do this).
- Enter some general options and information.

```
SIC PRIORITY 1 PAKO           ! PAKO commands get precedence
SET LEVEL    0 0              ! to get verbose chatter from pako
SET Project 111-22            ! project ID (project number)
SET PI       "Dr. Lilo D. Doe" ! principal investigator
SET Observer "John Doe"      !
SET Operator Pako             !
SET Topology low              ! topology for azimuth
SET doSubmit YES              ! allow submission to Queue
SHOW                        ! show parameters set with set
```

- Specify the line catalog and the receiver setup.

```
CATALOG line my.lin           ! specify (your) line catalog
RECEIVER /CLEAR                ! clear any previous RX setup
RECEIVER E090 12CO(1-0) /Horizontal /Vertical
```

The options `/Horizontal` `/Vertical` mean that both polarizations will be used.

- Select your target source from your catalog; select a backend and do a calibration without sky to send the receiver setup.

```
CATALOG SOURCE my.sou         ! select your source catalog
SOURCE W3OH                    ! source W3OH from your catalog
BACKEND /CLEAR                 ! clear any previous Backend setup
BACKEND WILMA /default         ! simple spectrometer setup for EMIR
BACKEND 4MHz /default          ! simple spectrometer setup for EMIR
CALIBRATE /SKY NO              ! doesn't need to move to sky position
START                          ! start
```

- Let the operator tune the receiver(s)
- Do a full calibration on the source, with default parameters:

```
CALIBRATE /DEFAULT      ! default calibration
START                  ! start
```

- Look at the results and check with the operator if the receiver noise temperature is OK.
- Select a strong compact continuum source for pointing and focussing; if possible, choose a source that is smaller than your beam!

```
SOURCE 2251+158 /catalog iram-J2000.sou ! pointing source from catalog
SOURCE Uranus                      ! OR: a 'small' planet
```

- Select the continuum backend for pointing and focus.

```
BACKEND /CLEAR
BACKEND BBC /Default
```

BACKEND BBC /Default connects one part of the continuum backend BBC to each polarization and sideband of each selected EMIR band.

- Select beam switching mode and do a pointing.

```
SWBEAM                ! to select beam switching
POINTING /default      ! pointing
START                  ! start
```

- After a pointing the data processing software displays the results and you can enter a correction for the observed pointing offsets with the command. Let's say, the results are +3.4 and -1.2 [arc sec]

```
SET POINTING 3.4 -1.2
```

- Do a focus measurement.

```
FOCUS          2.0      ! length [mm]
START          ! start
```

- After a focus the data processing software displays the results and you can enter a new focus correction, e.g., -2.1 mm, with the command:

```
SET FOCUS -2.1
```

- Select a pointing source that is near your target source and do another pointing measurement and enter the resulting correction.
- Select the target source from your catalog; select a backend and do a calibration.

```

SOURCE W30H                ! source W30H from your catalog
BACKEND /CLEAR              ! clear any previous Backend setup
BACKEND WILMA /default      ! simple spectrometer setup for EMIR
BACKEND 4MHz /default       ! simple spectrometer setup for EMIR
CALIBRATE /DEFAULT         ! default calibration
START                      ! start

```

BACKEND WILMA /Default connects one part of the WILMA spectrometer to each EMIR sub band selected with RECEIVER. BACKEND 4MHz /Default connects one part of the WILMA spectrometer to 2 EMIR sub bands selected with RECEIVER.<sup>4</sup>

- Select your switching and observing mode, e.g., wobbler switching and on-off, and start observing.

```

SWWOBBLER -120.0 120.0 /TPHASE 2.0      ! wobbler +/- 120 arc sec
                                         ! 2 seconds per phase
ONOFF /NSUBSCANS 12 /SYMMETRIC /TSUBSCAN 30 ! 12 subscans
                                         ! "symmetric" subscan sequence
                                         ! 30 sec per subscans

START

```

- Do a calibration at least every 15 minutes, or when you change sources, or when you change receiver and backend setups.
- Do a pointing every 2 hours or when you change to a different region of the sky.
- Do a focus every 6 hours and after sunset and sunrise.  
(Before focus, do a pointing on the focus source!)
- HAVE FUN!

NOTES.

PAKO has built-in help for all commands, e. g.,

```

HELP SWWOBBLER
HELP ONOFF /NSUBSCANS

```

Most commands can be abbreviated substantially, e. g., the following 2 are equivalent:

```

ON /NS 16 /SYM /TS 22
ONOFF /NSUBSCANS 16 /SYMMETRIC /TSUBSCAN 22

```

If you find that you enter the same command(s) very often, it is not necessary to type them every time! They can be put into command “scripts” either by editing a file or with PAKO’s SAVE command, see section 2.

---

<sup>4</sup> Other spectrometers, e.g., VESPA, offer much more flexibility, but also need more parameters and more explicit BACKEND commands, see the following sections.



## 4 PaKo's Cook Book

This section provides a basic step-by-step cook book for doing standard observations in an interactive session with the telescope. It only gives simple examples, details on all the options that are available can be found in later sections.

It starts with some general commands and the selection of a source catalog. Then two more subsections explain how to do “Spectral Line Observations with Heterodyne Receivers” and “Continuum Observations with Bolometers”.

Remember that in command language scripts based on SIC:

! starts a comment; - indicates that a command is continued on the next line; PAUSE pauses the execution of the script, e.g., in order to allow the user to review the parameters set; and the case (upper or lower) generally doesn't matter.

### 4.1 Set General Information

At the prompt `PAKO >` enter, e.g.:

```
SET PROJECT    111-22                ! project ID (project number)
SET PI         "Dr. Jane D. Doe"     ! principal investigator
SET OBSERVER   "John Doe"            !
SET OPERATOR   Pako                  !
SET TOPOLOGY   low                   ! topology for azimuth
SHOW
DEVICE image   w                     ! open window for plots
```

With the `set` commands we specify some basic information: the project number, the principal investigator (PI), the names of the observer and telescope operator.

`SHOW` lists everything previously set with `SET`.

`SET TOPOLOGY` deserves special attention: The 30m antenna has azimuth limits of 60 and 460 degrees. Azimuth 360 degrees is due North. Therefore there is an overlap range approximately toward Northeast, which the antenna can reach at a low azimuth 60 to 100 (from the South) or at a high azimuth 400 to 460 (from the North).

`SET TOPOLOGY LOW` selects to use the azimuth range 60 to 420 degrees

`SET TOPOLOGY HIGH` selects to use the azimuth range 100 to 460 degrees.

`DEVICE` is a standard command to open a graphics window for plots. It is used by `PAKO` to provide a preview plot for some observing modes.

### 4.2 Specify your Source Catalog

At the prompt `PAKO >` enter, e.g.:

```
CATALOG SOURCE demo.sou
```

With this command we select the “source catalog”, a special file, in which information about the sources is stored. A typical example of a source catalog looks like:

```
!
NameEq1 EQ 2000.0 02:23:16.50 61:38:57.0 LSR -45.0 FLUX 3.73 1.00
NameEq2 EQ 1950.0 02:23:16.50 61:38:57.0 LSR -45.0 FLUX 3.73 1.00
```

```

!
NameGa1 GA      03:23:16.50 63:38:57.0 LSR -33.0 FLUX 3.33 -0.33
NameGa2 GA      123.45      67.89      NUL -33.0 FLUX 3.33
!

```

An example of the source catalog can be found in file `demo.sou`.

Note that this format is like the format that can be used directly with the `SOURCE` (see `HELP SOURCE`) and also like the source catalog format used at PLATEAU DE BURE.

### 4.3 Spectral Line Observations with Heterodyne Receivers

#### 4.3.1 Specify your Line Catalog

#### 4.3.2 Setup of the Receivers (Frontends)

At the prompt `PAKO >` enter, e.g.:

```

RECEIVER A100                                ! defaults for all parameters
RECEIVER B100 12C0(1-0)                      ! using line catalog
RECEIVER A230 12C0(2-1) 230.537990 LSB       ! basic parameters explicit

```

Normally we use the `RECEIVER` command with 2 parameters: a receiver name and a line name. The line name must be the name of a line in the line catalog selected earlier.

Alternatively the frequency and sideband can be specified directly as the 3rd and 4th parameter.

One `RECEIVER` command is needed for each receiver.

After all receivers are set up, and a source has been selected, the telescope operator or receiver engineer will tune the receivers. After tuning, he can tell you for each receiver: the ambient and cold load temperatures needed for the calibration, as well as the image band gain ratio.

These values describe physical parameters of the system that are not directly controlled, but which are important for the calibration of the data during data processing.

You can set these values with options of `RECEIVER`.

```

RECEIVER B100 12C0(1-0) 115.271204 LSB -      ! all parameters explicit
          /doppler fixed          -          ! fixed: no Doppler correction
          /gain 0.002              -          ! image sideband gain
          /tempLoad 88 277         -          ! cold and ambient load temperatures
          /efficiency 0.96 0.77    -          ! forward and (main) beam efficiencies
          /scale beam              ! scale (main) beam brightness temperature
RECEIVER B230 /gain -22 db         ! image sideband gain in [dB]

```

Note that with the syntax `/GAIN -22 db` you can specify the image gain directly in [dB].

Option `/EFFICIENCY` allows to specify values for the forward and (main) beam efficiencies.

Normally the system will provide reasonable defaults for all these calibration parameters.

Option `/SCALE` allows to choose the calibration scale: `ANTENNA` temperature or (main) `BEAM` brightness temperature.

#### 4.3.3 Setup of the Backends (Spectrometers and Continuum)

At the prompt `PAKO >` enter, e.g.:

```

!
BACKEND CONTINUUM 1                /r A100 ! continuum backend
BACKEND CONTINUUM 2                /r B100
BACKEND CONTINUUM 3                /r A230
BACKEND CONTINUUM 4                /r B230
!
BACKEND 4MHz 1 4 1024 0 /r A230 ! 4MHz filters full syntax
BACKEND 4MHz 2                /r B230 ! 4MHz filters short syntax
!
BACKEND 1MHz 1 1 512 0 /r A230 ! 1MHz filters full syntax
BACKEND 1MHz 2                /r B230 ! 1MHz filters short syntax
!
BACKEND 100kHz 1 0.1 12.8 0 /r A100 ! 100kHz filters full syntax
BACKEND 100kHz 2                /r B100 ! 100kHz filters short syntax
!
BACKEND WILMA 1 2 1024 0 /r A100 ! WILMA setup full syntax
BACKEND WILMA 2                /r B100 ! WILMA setup short syntax
!
BACKEND VESPA 1 0.020 40.0 2 /r A100 ! standard VESPA setup
BACKEND VESPA 2 0.020 40.0 2 /r B100 !
BACKEND VESPA 3 0.040 80.0 -2 /r A230 !
BACKEND VESPA 4 0.040 80.0 -2 /r B230 !
!

```

Normally the command **BACKEND** has 5 parameters: backend name, part number, resolution [MHz], bandwidth [MHz], and frequency shift [MHz]. Option **/RECEIVER** connects this backend part to a receiver. This receiver must have been previously specified with **RECEIVER**.

For some backends the resolution, bandwidth, and/or frequency shift are fixed and a shorter syntax is possible, see, e.g., the example above for the continuum backends. See the **HELP** for complete information.

**/DISCONNECT** disconnects a backend (part) while retaining its parameters.

**/CONNECT** (re-)connects the specified backend (part).

Normally the continuum backends are used for pointing and focus.

#### 4.3.4 Calibration

#### 4.3.5 Pointing

For pointing, you normally select first a pointing source and the continuum backends as described above.

At the prompt **PAKO >** enter, e.g.:

```

POINTING      60                ! pointing with subscan length 80
START          ! start

```

After a pointing the data processing software displays the results and you can enter a correction for the observed pointing offsets with the command

```
SET POINTING azimuthCorrection elevationCorrection
```

**4.3.6 Focus**

**4.3.7 Observing Modes for Line Spectroscopy**

**4.4 Continuum Observations with Bolometers**

**4.4.1 Setup of the Bolometer**

**4.4.2 Pointing**

**4.4.3 Focus**

**4.4.4 Tip (“Skydip”)**

**4.4.5 Calibration**

**4.4.6 Observing Modes for the Bolometer**

## 5 NCS User's Guide

This section contains an extended guide about how to setup and execute observations. The examples are in the form of valid scripts in the command language. These example scripts are available to each observer who can edit them according to their needs. Comment out (or delete) those lines of the scripts that don't apply for your observations.

It starts with some general commands and the selection of a source catalog. Then two more subsections explain how to do "Spectral Line Observations with Heterodyne Receivers" and "Continuum Observations with Bolometers".

Remember that in command language scripts based on SIC:

! starts a comment; - indicates that a command is continued on the next line; PAUSE pauses the execution of the script, e.g., in order to allow the user to review the parameters set; and the case (upper or lower) generally doesn't matter.

### 5.0.1 Set General Information

```
!
! $Id$
!
symbol show "pako\show"           ! abbreviations for show
symbol sho  "pako\show"
symbol sh   "pako\show"
!
symbol poi  "pako\pointing"       ! abbreviations for pointing
symbol po   "pako\pointing"
symbol p    "pako\pointing"
!
!! set Level      2 4
set Project      111-22           ! project ID (project number)
set PI           "Dr. Jane D. Doe" ! principal investigator
set Observer     "John Doe"      !
set Operator     Pako            !
set angleUnit    arcsec          ! angle unit for observing modes
set Pointing     1.1 2.2         ! pointing corrections
set Focus        -2.22           ! focus correction
set Topology     low             ! topology for azimuth
!
show              ! show the values set with set
!
device image w    ! open window for plots
!
```

To execute this script, simply enter:

```
@ demo-set
```

This first sets some practical abbreviations that avoid confusion with the similar commands in other "languages", e.g., in GREG.

With the **set** commands we specify some basic information: the project number, the principal investigator (PI), the names of the observer and telescope operator.

**SHOW** lists everything previously set with **SET**.

**SET TOPOLOGY** deserves special attention: The 30m antenna has azimuth limits of 60 and 460 degrees. Azimuth 360 degrees is due North. Therefore there is an overlap range approximately toward Northeast, which the antenna can reach at a low azimuth 60 to 100 (from the South) or at a high azimuth 400 to 460 (from the North).

SET TOPOLOGY LOW selects to use the azimuth range 60 to 420 degrees

SET TOPOLOGY HIGH selects to use the azimuth range 100 to 460 degrees.

DEVICE is a standard command to open a graphics window for plots. It is used by PAKO to provide a preview plot for some observing modes.

## 5.1 Specify your Source Catalog

At the prompt PAKO > enter, e.g.:

```
CATALOG SOURCE demo.sou
```

With this command we select the “source catalog”, a special file, in which information about the sources is stored. A typical example of a source catalog looks like:

```
!
NameEq1 EQ 2000.0 02:23:16.50 61:38:57.0 LSR -45.0 FLUX 3.73 1.00
NameEq2 EQ 1950.0 02:23:16.50 61:38:57.0 LSR -45.0 FLUX 3.73 1.00
!
NameGa1 GA      03:23:16.50 63:38:57.0 LSR -33.0 FLUX 3.33 -0.33
NameGa2 GA      123.45      67.89      NUL -33.0 FLUX 3.33
!
```

An example of the source catalog can be found in file `demo.sou`.

Note that this format is like the format that can be used directly with the SOURCE (see `HELP SOURCE`) and also like the source catalog format used at PLATEAU DE BURE.

## 5.2 Spectral Line Observations with Heterodyne Receivers

### 5.2.1 Specify your Line Catalog

#### 5.2.2 Setup of the Receivers (Frontends)

```
!
! $Id$
!
RECEIVER      /DISCONNECT          ! disconnect all receivers previously set
RECEIVER A100                                ! defaults for all parameters
RECEIVER A230 12C0(2-1) 230.537990 LSB      ! basic parameters explicit
                                           ! defaults for other parameters
RECEIVER B100 12C0(1-0) 115.271204 LSB -    ! all parameters explicit
                                           /DOPPLER FIXED          -    ! fixed: no Doppler correction
                                           /GAIN 0.002             -    ! image sideband gain
                                           /TEMPLOAD 88 277        -    ! cold and ambient load temperatures
                                           /EFFICIENCY 0.96 0.77   -    ! forward and (main) beam efficiencies
                                           /SCALE BEAM            ! scale (main) beam brightness temperature
RECEIVER B230 /GAIN -22 db                ! image sideband gain in [dB]
!
PAUSE
!
RECEIVER      /DISCONNECT          ! disconnect all receivers previously set
RECEIVER C150
RECEIVER C270
RECEIVER D150
RECEIVER D270
!
```

```

PAUSE
!
RECEIVER      /DISCONNECT          ! disconnect all receivers previously set
RECEIVER HERA-ALL
!
PAUSE
!
RECEIVER HERA1
RECEIVER HERA2
!

```

To execute this script, simply enter:

```
@ demo-receivers
```

Normally we use the **RECEIVER** command with 2 parameters: a receiver name and a line name. The line name must be the name of a line in the line catalog selected earlier.

Alternatively the frequency and sideband can be specified directly as the 3rd and 4th parameter.

One **RECEIVER** command is needed for each receiver.

After all receivers are set up, and a source has been selected, the telescope operator or receiver engineer will tune the receivers. After tuning, he can tell you for each receiver: the ambient and cold load temperatures needed for the calibration, as well as the image band gain ratio.

These values describe physical parameters of the system that are not directly controlled, but which are important for the calibration of the data during data processing.

You can set these values with options of **RECEIVER**. Note that with the syntax **/GAIN -22 db** you can specify the image gain directly in [dB].

Option **/EFFICIENCY** allows to specify values for the forward and (main) beam efficiencies.

Normally the system will provide reasonable defaults for all these calibration parameters.

Option **/SCALE** allows to choose the calibration scale: **ANTENNA** temperature or (main) **BEAM** brightness temperature.

### 5.2.3 Setup of the Backends (Spectrometers and Continuum)

```

!
! $Id$
!
BACKEND /CLEAR          ! clear all backend definitions
!
!!      option /R is short for /RECEIVER
!!      name  # resolu bandw.fShift  RX
!!      -----
!
BACKEND CONTIN 1 500      500      0 /R A100 ! continuum backend full syntax
BACKEND CONTIN 2 500      500      0 /R B100
BACKEND CONTIN 3          /R A230 ! continuum backend short syntax
BACKEND CONTINUUM 4       /R B230
!
BACKEND 4MHz 1 4          1024     0 /R A230 ! 4MHz filters full syntax
BACKEND 4MHz 2           /R B230 ! 4MHz filters short syntax
!
BACKEND 1MHz 1 1          512      0 /R A230 ! 1MHz filters full syntax
BACKEND 1MHz 2           256       /R B230 ! 1MHz filters short syntax
!
BACKEND 100kHz 1 0.1      12.8     0 /R A100 ! 100kHz filters full syntax
BACKEND 100kHz 2          12.8     /R B100 ! 100kHz filters short syntax

```

```

!
BACKEND WILMA 1 2 1024 0 /R A100 ! WILMA setup full syntax
BACKEND WILMA 2 /R B100 ! WILMA setup short syntax
!
BACKEND VESPA 1 0.020 40.0 2 /R A100 ! standard VESPA setup
BACKEND VESPA 2 0.020 40.0 2 /R B100 !
BACKEND VESPA 3 0.040 80.0 -2 /R A230 !
BACKEND VESPA 4 0.040 80.0 -2 /R B230 !
!
BACKEND VESPA 5 0.020 40.0 2 - ! VESPA
                        /RECEIVER A100 B100 - ! with 2 receivers
                        /MODE POLARIZATION ! in polarization mode
!
BACKEND VESPA 6 0.040 80.0 -2 - ! VESPA
                        /RECEIVER A230 B230 - ! with 2 receivers
                        /MODE PARALLEL - ! in parallel mode
                        /PERCENTAGE 91 ! non-standard percentage used
!

```

To execute this script, simply enter:

```
@ demo-backends
```

Normally the command **BACKEND** has 5 parameters: backend name, part number, resolution [MHz], bandwidth [MHz], and frequency shift [MHz]. Option **/RECEIVER** connects this backend part to a receiver. This receiver must have been previously specified with **RECEIVER**.

For some backends the resolution, bandwidth, and/or frequency shift are fixed and a shorter syntax is possible, see, e.g., the example above for the continuum backends. See the **HELP** for complete information.

**/DISCONNECT** disconnects a backend (part) while retaining its parameters.

**/CONNECT** (re-)connects the specified backend (part).

Normally the continuum backends are used for pointing and focus.

## 5.2.4 Calibration

## 5.2.5 Pointing

```

!
! $Id$
!
BACKEND /DISCONNECT ! disconnect all backends
BACKEND CONTINUUM ! connect continuum backend
!
SET ANGLEUNIT arcsec ! make sure angle unit is arc sec
!
POINTING 80 - ! pointing with subscan length 80
    /CALIBRATE - ! do a standard calibration first
    /NOTF 4 - ! 4 OTF subscans
    /TOTF 40.0 ! 40 seconds per OTF subscan
!
PAUSE "POINTING OK? [c/q]" ! a chance to check
!
START ! start
!
RETURN
!

```



```
!! Comments:  
!! We assume here that the setup for the continuum backend has already  
!! been done earlier and that the pointing is to be done with the  
!! continuum backends. Then the backend commands above achieve that  
!! (only) the continuum backends are connected for the pointing.  
!!
```

To execute this script, simply enter:

```
@ demo-pointing
```

After a pointing the data processing software displays the results and you can enter a correction for the observed pointing offsets with the command

```
SET POINTING azimuthCorrection elevationCorrection
```

### **5.2.6 Focus**

### **5.2.7 Observing Modes for Line Spectroscopy**

## **5.3 Continuum Observations with Bolometers**

### **5.3.1 Setup of the Bolometer**

### **5.3.2 Pointing**

### **5.3.3 Focus**

### **5.3.4 Tip (“Skydip”)**

### **5.3.5 Calibration**

### **5.3.6 Observing Modes for the Bolometer**

## 6 NCS Explained

In this section we explain in more detail some general aspects of the NCS.

### 6.1 Coordinate Systems, Map Projections, and Position Offsets

The NCS will support a variety of astronomical coordinate systems and projections, as well as “descriptive” coordinate systems defined by the user. Up to now, 2013-10-17, only equatorial coordinates, J2000.0, are well tested and available for use.

**Map Projections and Offsets.** In general, a “map projection” describes the relation between 2 spherical coordinates, longitude  $l$  and latitude  $b$ ,<sup>5</sup> on the celestial sphere, and 2 Cartesian coordinates  $x$  and  $y$ , which in radio astronomy and the NCS we often call “position offsets”.

Up to now, 2013-10-17, only the “**radio**” projection is supported, for which:

$$x = (l - l_{source}) * \cos(b)$$

$$y = b - b_{source}$$

where  $l_{source}$  and  $b_{source}$  are the source coordinates specified with **SOURCE**.<sup>6</sup> Note that this is the same system of offsets as in “OBS” of the old control system.

If we want to observe several positions on the sky at or near the source position as specified with **SOURCE**, we often do this by requesting position offsets in the map projection. Also, the resulting data, *e.g.*, images, are usually stored and displayed as a function of  $x$  and  $y$ .

For most observations, parameters and options of the observing mode are sufficient to specify the position offsets:

- for **TRACK** and **VLBI**  $x$  and  $y$  are fixed during the complete scan;
- for **ONOFF**  $x$  and  $y$  change from subscan to subscan;
- for **OTFMAP**  $x$  and  $y$  change continuously or “on-the-fly” (OTF) during the OTF subscans.

The **PAKO** commands for most Observing Modes expect fixed offsets (or start- and end-offsets for **OTFMAP**) as parameters. These can be either in the radio projection, specified with the option:

**/SYSTEM projection**

or in the true angle horizon system (see below), specified with the option:

**/SYSTEM trueHorizon**

**NOTES.** For **POINTING**, the OTF offsets are always in system **trueHorizon**, and are specified implicitly though the angular length of the subscans.

**Global Offsets.** On the other hand, the command **OFFSETS** can be used to specify additional position offsets in other systems. These globally defined offsets stay fixed during a complete scan. *They are only needed in special cases, e.g., the Nasmyth offsets or for ONOFF with wobbler switching*, see below.

At this time (2013-10-17), the command **OFFSETS** supports offsets in the following 3 systems:

**projection** Offsets in the “radio” projection (see above).

**trueHorizon** “true angle horizon” offsets in Azimuth and Elevation:

$$\Delta a = (a - a_{source}) * \cos(e)$$

$$\Delta e = e - e_{source}$$

where  $a$  and  $e$  are the Azimuth and Elevation of the telescope;  $a_{source}$  and  $e_{source}$  are the Azimuth and Elevation of the source, calculated from  $l$  and  $b$  (and the time and other parameters).

<sup>5</sup> In particular for equatorial coordinates,  $l$  corresponds to Right Ascension and  $b$  to Declination.

<sup>6</sup> For the equations all angles are assumed to be in radian.

**Nasmyth** offsets in the Nasmyth (receiver cabin) system. The purpose of Nasmyth offsets is exclusively to re-position the telescope so that an off-center element of a multibeam receiver looks at the position where otherwise the center pixel would look. E. g., `OFFSETS -33 44 /SYSTEM Nasmyth` adds offsets -33 and 44 in the Nasmyth system (for all observing modes!)

**Example 1** Observe a single position with offsets 10 and 20 in system radio projection; typically used with `FREQUENCY SWITCHING`:

```
TRACK 10 20 /SYSTEM projection
```

**Example 2** Observe `ONOFF` (“position switching” with `TOTAL POWER`) with `ON` position at 30 40 and off-source reference at -600 -700, both in system radio projection:

```
ONOFF 30 40 /REFERENCE -600 -700 projection /SYSTEM projection
```

**Example 3** Pointing with subscans of length 120:

```
POINTING 120
```

NOTES. For `POINTING`, the `OTF` offsets are always in system `trueHorizon`, and are specified implicitly through the angular length of the subscans.

**Example 4** `ONOFF` observations with `WOBBLER SWITCHING` are a special case, because the offsets for the subscans must be in system `trueHorizon` and their values must be selected according to the offsets of the `WOBBLER SWITCHING`! E. g.,

```
SWWOBBLER -33 +33
ONOFF 33 0 /REFERENCE -33 0 trueHorizon /SYSTEM trueHorizon
```

This can also be achieved simply by saying

```
SWWOBBLER -33
ONOFF
```

PAKO “knows” the special requirements for onoff wobbler switching, and will set the offset parameters for `ONOFF` accordingly, if `SWWOBBLER` has been previously selected. <sup>7</sup>

In this special case, in order to map the source, the observer may add offsets on the source  $l$  and  $b$  using the command `OFFSETS` with the system “projection”, *e.g.*:

```
SWWOBBLER -33
OFFSETS 110 120 /SYSTEM projection
ONOFF
```

**Example (i)** Observe an `OTF` map with first `OTF` subscan from offsets -300 -300 to +300 -300, and off-source reference at -600 -700, all in system radio projection:

```
OTFMAP -300 -300 300 -300 /REFERENCE -600 -700 projection /SYSTEM projection
```

---

<sup>7</sup> For special purposes, it is possible to overrule this with `/swWobbler no`, *e.g.*, `ONOFF 44 /swWobbler no`.

**Example (ii)** Observe an OTF map with first OTF subscan from offsets  $-300 -300$  to  $+300 -300$ , in system trueHorizon (and no off-source reference) This is typical for bolometer OTF maps:

```
OTFMAP -300 -300 300 -300 /REFERENCE no /SYSTEM trueHorizon
```

NOTES. Visiting observers have also used ONOFF in trueHorizon combined with OFFSETS ... /SYSTEM projection with TOTAL POWER, apparently with success.

NOTES.

- one should not specify offsets for the same system with the observing mode and OFFSETS (and there is not need to do this!).
  - If the observing mode uses /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).
  - If the observing mode uses /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).
- in the commands for the observing modes, the offsets for off-source reference positions must be in the same system as those of the on-source or OTF positions, i.e., /REFERENCE ... and /SYSTEM must select the same system (normally, PROJECTION).

Details at a technical level about these and more offsets can be found in the documentation of “NCS Antenna Mount Drive” by Alain Perrigouard.

NOTES. More explanations about coordinate systems, projections, and how to define descriptive coordinate systems will be added as they become available for general use.

NOTES. *SOURCE does not clear offsets set with OFFSETS.*

## 6.2 Azimuth Topology

The 30m antenna has azimuth limits of 60 and 460 degrees. Azimuth 360 degrees is due North. Therefore there is an overlap range approximately toward East-Northeast, which the antenna can reach at a low azimuth 60 to 100 (from the South) or at a high azimuth 420 to 460 (from the North).

SET TOPOLOGY LOW selects to use the azimuth range 60 to 420 degrees.

SET TOPOLOGY HIGH selects to use the azimuth range 100 to 460 degrees.

Note that SET TOPOLOGY only has an effect for sources with an azimuth in the overlap range; when a source is in the azimuth range 100 to 420 degrees SET TOPOLOGY does not matter.

Compare Figure 4.

## 6.3 Switching Modes

In the NCS we distinguish the following 4 “Switching Modes”:

TOTAL POWER

BEAM SWITCHING

WOBBLER SWITCHING

FREQUENCY SWITCHING (only with heterodyne receivers)

The corresponding commands are:

SWTOTAL

SWBEAM

SWWOBBLER

SWFREQUENCY

BEAM SWITCHING, WOBBLER SWITCHING, and FREQUENCY SWITCHING are realized by a system with hardware synchronization signals that allow a precise and fast switching *within* subscans.

TOTAL POWER simply means that none of the other 3 switching modes is active.

The system switches through a regular cycle with several (1, 2, or 4) switching phases.

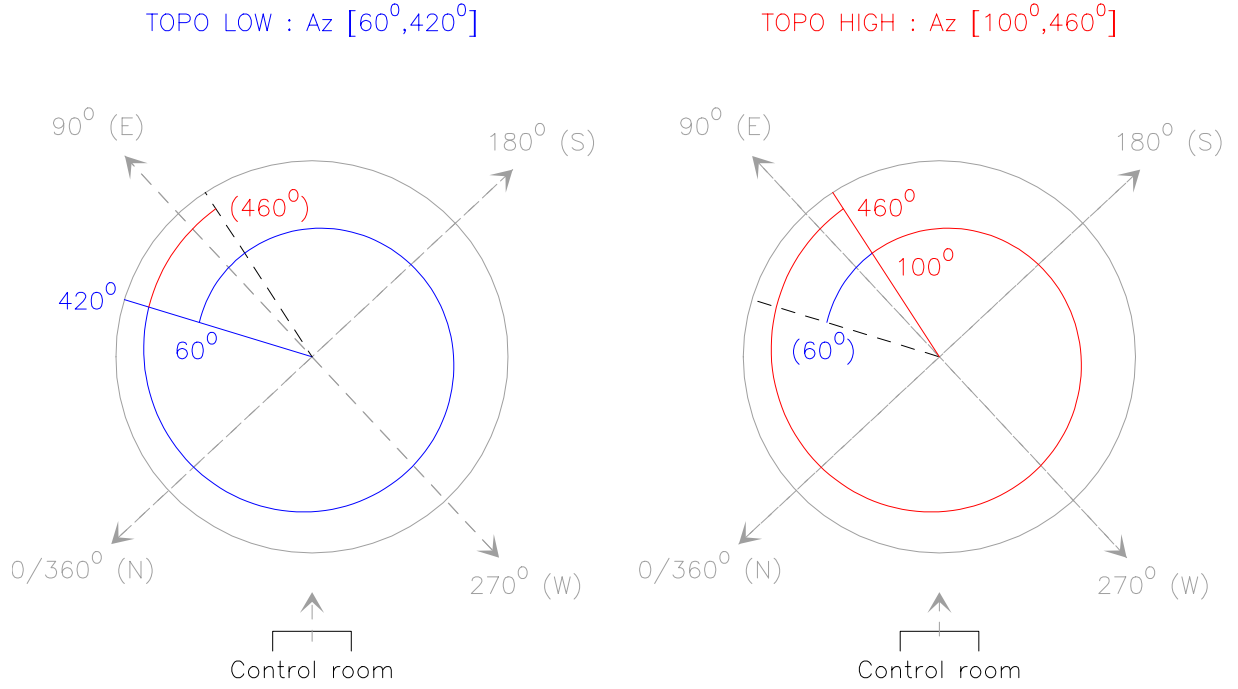


Figure 4: Azimuth Topology. The left side shows in blue the range for SET TOPOLOGY LOW, the right side shows in red the range for SET TOPOLOGY HIGH. (Compare Section 6.2; figure prepared by Joaquín Santiago)

The 4 switching modes are mutually exclusive, i.e., at any time the system uses only one of them.

During the transitions between phases, e.g., while the Wobbler is moving between its positions, no data are taken during the short “blanking” time.

The switching mode and its parameters should normally be set before choosing an observing mode, because for some observing modes details of the setup depend on the switching mode.

```
!
! Id: demo-switching.pako,v 1.1.1 2009-05-05 Hans Ungerechts
!
SWTOTAL                /tphase 0.2      ! Total Power
PAUSE
!
SWBEAM                 ! Beam Switching
PAUSE
!
SWFREQUENCY            /default          ! Frequency Switching
PAUSE
!
SWFREQUENCY  -3.3      3.3                ! for all RXs
PAUSE
!
SWFREQUENCY  -3.9      3.9 /receiver E090  ! select frequency switching
SWFREQUENCY  -11.7     11.7 /receiver E230  ! for EMIR band E230
SWFREQUENCY                /tphase 0.20    ! same for all receivers
PAUSE
!
SWWOBBLER  -22  +22      /tphase 0.25     ! Wobbler Switching
```

PAUSE

!

!! NOTE:

!! after changing the switching modes, always (re-)execute a command

!! for an observing mode, because internal parameters and error checks

!! of the observing modes depend on the switching mode!

### 6.3.1 Beam Switching

BEAM SWITCHING is realized through a rotating chopper wheel in the receiver cabin, which during each rotation (= switching cycle) moves 2 reflecting (!) blades into the beam path in front of the 4th mirror, for a total of 4 phases: direct beam path to the source (same as in TOTAL POWER!), beam path offset by one blade of the chopper wheel, direct beam path to the source (same as in TOTAL POWER!), beam path offset by the other blade of the chopper wheel. The offset, rotation period, and blanking times are fixed. BEAM SWITCHING is normally only used for POINTING and FOCUS.

The source signal is calculated as difference between the direct and offset phases.

(NOTES. This “beam-switching” chopper wheel, should not be confused with a “calibration chopper wheel” as it is used at some other mm-wave observatories. Calibration at the 30-M Telescope is done with different hardware.)

### 6.3.2 Frequency Switching

FREQUENCY SWITCHING switches between 2 different frequencies, so that there are 2 phases. The (source) signal is calculated as the difference between these 2 phases.

FREQUENCY SWITCHING is normally used with TRACK or OTFMAP.

NOTES. IMPORTANT:

FREQUENCY SWITCHING *is very powerful and efficient for some projects, e. g., mapping of narrow spectral lines in cold dark clouds outside the plane of the Milky Way. However, before deciding to use frequency switching one should consider some potential drawbacks:*

*The target lines should be narrow enough so that line signals from the 2 phases of the switching cycle are well separated.*

*The spectral baseline will generally be less flat than in other switching modes.*

*Some spectral lines are also emitted in the earth’s mesosphere, e.g., the mesospheric lines from (12)CO are rather strong, and they will be seen in FREQUENCY SWITCHING spectra taken toward astronomical sources with a low Doppler shift. The mesospheric lines will appear at a frequency and velocity that corresponds to the rest frame of the atmosphere, i. e., the observatory. Care must be taken that they are not confused with the lines from the astronomical source. (Information computed by the ASTRO software can help with this decision).*

*When observing sources near the plane of the Milky Way, line emission from clouds at other velocities than the target source, e. g., other spiral arms, can cause confusion.*

*In case of doubt, consult the special memo on FREQUENCY SWITCHING or ask an experienced FREQUENCY SWITCHING observer!*

### 6.3.3 Wobbler Switching

During WOBBLER SWITCHING the wobbling secondary mirror is switched between 2 positions, which are offset from the telescope axis by  $\pm$  a fixed amount.

Thus there are 2 phases, and the signal is calculated as the difference between these 2 phases.

As the positions in both phases are offset from the telescope axis, in some observing modes, e.g., POINTING, FOCUS, ONOFF, the telescope position needs to be adjusted to compensate — this is done automatically.

WOBBLER SWITCHING is normally used with ONOFF or, for bolometer continuum mapping, with OTFMAP.

Note that for OTFMAP with WOBBLER SWITCHING, special restoration algorithms are needed to recover an image of the source brightness distribution. These are available, e. g., in the MOPSIC software.

If WOBBLER SWITCHING and ONOFF are combined in the standard way, we effectively take data at 3 positions: 1. the source position; 2. the `source position + throw` (offset in the “true-angle” horizontal system); 3. the `source position - throw` (offset in the “true-angle” horizontal system), with `throw = ABS(wOffset2-wOffset1)`. Data from 1. are treated as source signal, data from 2. and 3. as off-source reference signal. Note that in the astronomical coordinates, positions 2. and 3. will rotate around the source position 1. Therefore one must normally be sure that the extent of the source is less than `throw-beamWidth (/2)`.

### 6.3.4 Total Power

TOTAL POWER refers simply to data acquisition without any of the other 3 fast Switching Modes. (Even in this case the same type of hardware synchronization signals is used to control the regular readout of the backends. In this case there is only one switching phase.)

Normally, when using TOTAL POWER one or several positions “ON” the source are observed alternating with one or several “OFF”-source reference positions, and the signal is calculated as the difference between “ON” and “OFF”.

## 6.4 Observing Modes

The NCS supports the following “Observing Modes”: CALIBRATE, POINTING, FOCUS, TIP, ONOFF, OTFMAP, <<TBD:RASTER not yet implemented >>, TRACK, VLBI.

All Observing Modes are realized by executing a sequence of 1 or more subscans. In most cases, the antenna moves between or during the subscans.

The observing modes are mutually exclusive, i.e., at any time the system executes only one of them.

Several Observing Modes can be combined with different Switching Modes, e.g., OTFMAP with TOTAL POWER, WOBBLER SWITCHING (for bolometer), or FREQUENCY SWITCHING. The Switching Mode should normally be specified before the Observing Mode.

### 6.4.1 CALIBRATE

In a standard calibration for heterodyne receivers, we observe 3 subscans, “SAC”: on a Sky position, an Ambient temperature load (a.k.a., “hot” load), and a “Cold” load. Calibrations are always and automatically done in TOTAL POWER.

A calibration needs to be done for any heterodyne observation in order to get data with a calibrated intensity scale. It is normally done before the target observations. It must always be done after changing receiver and/or backend setups. It should also be done when changing sources and often enough to follow any variation of the atmosphere, about every 15 minutes.

After you enter a calibrate setup manually, we recommend to “save” it, optionally to a named file:

`SAVE CALIBRATE [/FILE calibrate-1]`

It can then at any later time be reloaded with `@ calibrate[-1]`, see `HELP SAVE`.

The special calibration subscans are done by switching the beam optics so that the receivers see a special calibration unit in the receiver cabin.

### 6.4.2 POINTING

POINTING observations are done to optimize the positioning of the telescope in Azimuth and Elevation. This is normally done by continuum observations of a cross scan in azimuth and elevation on a point source (or at least a small source) near the intended target source.

It is normally used with BEAM SWITCHING or WOBBLER SWITCHING; it is also possible with TOTAL POWER. (With the bolometer POINTING is done with WOBBLER SWITCHING).

A calibration is not needed for POINTING, if one is only interested in the pointing corrections, and not in the source intensity.

After a pointing the data processing software displays the results and you can enter a correction for the observed pointing offsets with the command

```
SET POINTING azimuthCorrection elevationCorrection
```

Note that this is the total correction, i.e., the previous correction plus the additional offset found with the POINTING observation.

After you enter a pointing setup manually, we recommend to “save” it, optionally to a named file:

```
SAVE POINTING [/FILE pointing-1]
```

It can then at any later time be reloaded with @ pointing[-1], see HELP SAVE.

### 6.4.3 FOCUS

FOCUS measurements are done to optimize the position of the subreflector (secondary) along the telescope axis by maximizing the intensity of the radiation focussed into the receiver(s). It is best done on a strong point source, e.g., on a planet if or when its angular diameter is less than the beam width at the frequency to be observed. It is strongly recommended to do a POINTING on the same source before a FOCUS.

FOCUS is normally used with BEAM SWITCHING or WOBBLER SWITCHING. (With the bolometer FOCUS is done with WOBBLER SWITCHING).

A calibration is not needed for FOCUS, anyhow it will probably already have been done before the POINTING before the FOCUS!

After a focus the data processing software displays the results and you can enter a correction for the observed focus offset with the command

```
SET FOCUS focusCorrection
```

Note that this is the total correction, i.e., the previous correction plus the additional offset found with the FOCUS observation.

The optimal focus correction for different receiver bands may be slightly different, by a few times 0.1 mm, and the observer can decide to optimize for one particular band or use a compromise value.

After you enter a focus setup manually, we recommend to “save” it, optionally to a named file:

```
SAVE FOCUS [/FILE focus-1]
```

It can then at any later time be reloaded with @ focus[-1], see HELP SAVE.

### 6.4.4 TIP

TIP (antenna tipping or “skydip”) observations are done to measure the transmission of the Earth’s atmosphere, by taking data at several points with the same azimuth but different elevations, spaced by equal steps in “air mass”.

It is ESSENTIAL that the switching mode is TOTAL POWER during TIP.

This is in particular an important step in the calibration of observations with the bolometer.

The basic parameters of this observing mode and its options are: the azimuth, the range and step in airmass, and the time per subscan.

### 6.4.5 ONOFF

In its first form ONOFF is used with TOTAL POWER. Subscans are taken alternating between a position that’s considered to be “ON-source” and a reference position that’s normally assumed to be “OFF-source”, i.e., free of emission.

The source signal is then calculated as the difference between “ON” and “OFF”.

The basic parameters are the offsets for the ON position, parameters of the options are the offsets for the reference position, the (total) number of subscans, and the time per subscan in [s].

After you enter an ON-OFF setup manually, we recommend to “save” it, optionally to a named file:

```
SAVE ONOFF [/FILE onoff-1]
```

It can then at any later time be reloaded with @ onoff[-1], see HELP SAVE.

You may want to save the switching mode separately or with ONOFF into the same file:



```
SAVE SWITCHING /FILE onoff-2
SAVE ONOFF      /FILE onoff-2 /APPEND
```

When **ONOFF** is used with **WOBBLER SWITCHING** (command **SWWOBBLER**), the position offsets must be set to very specific values in **TRUE (ANGLE) HORIZON** depending on the parameters of **SWWOBBLER**. This is achieved by using the special option **/SWWOBBLER** of the command **ONOFF**.

Subscans are then taken alternating between 2 positions in such a way that: (*a*) in some subscans (one position of the antenna) the source is in the first of the two Wobbler phases, (*b*) in the other subscans (the other position of the antenna) the source is in the second of the two Wobbler phases. During the data processing, the source signal is computed as a double difference: 1st the difference of the 2 Wobbler phases; 2nd the difference between **ONOFF** subscans (*a*) and (*b*).

This form of **ONOFF** is also called “Wobbler-Onoff” or sometimes simply “Wobbler Switching”.

The combination(!) of **ONOFF** and **WOBBLER SWITCHING** provides a very high sensitivity in continuum bolometer observations of compact sources, and excellent baselines for spectroscopy.

It has the disadvantage that the (emission-free?) off-source positions are very close to the source (limited by the maximum Wobbler throw). Also, the Wobbler direction is fixed in the horizontal system relative to the telescope, and therefore in the source system the off-source positions rotate around the source position.

For continuum observations, usually a short time per Wobbler phase, 0.25 s, is used with small Wobbler offsets (throws); for spectroscopy, largest possible Wobbler offsets (throws), up to  $\pm 120''$  are preferred, but then the time per phase must be longer, 1 – 2 s.

#### 6.4.6 OTFMAP

In **OTFMAP** (on-the-fly) observations, the antenna moves relative to the source while recording its position and taking data at a high rate, thus performing “scans” in the strict sense of the word. This is a very fast mode for mapping.

The basic parameters of the command are the position offsets of the start and end of the first **OTF** subscan; the basic parameters of the options are: the number of **OTF** subscans, the offsets of an off-source reference position, the step (shift) in x- and y-offsets between subsequent **OTF** subscans, the time per **OTF** subscan in [s], and the time per off-source reference subscan [s].

This observing mode is normally used either with:

- (i) **TOTAL POWER** with an off-source reference for spectral line observations, or
- (ii) **FREQUENCY SWITCHING** without off-source reference for spectral line observations (see below), or
- (iii) **WOBBLER SWITCHING** and **TRUE (ANGLE) HORIZON** offsets for continuum mapping with the bolometer.

After you enter an **OTF-map** setup manually, we recommend to “save” it, optionally to a named file:

```
SAVE OTFMAP [/FILE otfmap-1]
```

It can then at any later time be reloaded with **@ otfmap[-1]**, see **HELP SAVE**.

You may want to save the switching mode separately or with **OTFMAP** into the same file:

```
SAVE SWITCHING /FILE otfmap-2
SAVE OTFMAP    /FILE otfmap-2 /APPEND
```

#### 6.4.7 RASTER

<< **RASTER** (not yet implemented), will be similar to **ONOFF** and **TRACK** but allow to observe several “ON” positions. To be used with **TOTAL POWER** or (maybe) **FREQUENCY SWITCHING**. In any case it is recommended to use **ONOFF** instead of **RASTER** with several **ON** per **OFF**. >>

#### 6.4.8 TRACK

The **TRACK** observing mode simply tracks one position relative to the source. It is normally used with **FREQUENCY SWITCHING** and offsets in **/SYSTEM** projection.

The basic parameters are the offsets for the position to track; parameters of the options are the (total) number of subscans, and the time per subscan in [s].

After you enter a track setup manually, we recommend to “save” it, optionally to a named file:

```
SAVE TRACK [/FILE track-1]
```

It can then at any later time be reloaded with @ track[-1], see `HELP SAVE`.

You may want to save the switching mode separately or with TRACK into the same file:

```
SAVE SWITCHING /FILE track-2
SAVE TRACK      /FILE track-2 /APPEND
```

#### 6.4.9 VLBI

VLBI, a special observing mode to track the source position specified with `SOURCE` during VLBI scans. It should only be used for VLBI and is always used with `TOTAL POWER`.

### 6.5 Receivers

This section remains to be written. For the time being please refer to the information available on the web pages about the 30-M Telescope.

### 6.6 Backends

This section remains to be written. For the time being please refer to the information available on the web pages about the 30-M Telescope.

## 7 **PAKO Language Internal Help**

From here follows a reproduction of the Internal Help available in paKo with `HELP PAKO`. Please consult the internal help itself, which may be more up to date than an old printout of the user's manual.

NOTES.

<< and << TBD mark items that are foreseen in the NCS but that are not yet available.

## 7.1 Language

NEW in v1.2.3 (2014-11-11)

=====

LISSAJOUS	/FOCUS	f1 f2 [... f18]	[direction]	!	for NIKA
LISSAJOUS	/POINTING			!	for NIKA
LISSAJOUS	/TUNE	xOffsetT	yOffsetT	!	for NIKA
	/TTUNE	tTune		!	for NIKA
FOCUS	/TUNE	xOffsetT	yOffsetT	!	for NIKA
	/TTUNE	tTune		!	for NIKA
OTFMAP	/TUNE	xOffsetT	yOffsetT	!	for NIKA
	/TTUNE	tTune		!	for NIKA
POINTING	/TUNE	xOffsetT	yOffsetT	!	for NIKA
	/TTUNE	tTune		!	for NIKA
RECEIVER	BOLOMETER	NIKA	pixel	!	for NIKA

### SUMMARY OF PAKO\ COMMANDS v1.2.3

Examples how to use HELP:

for detailed HELP on a command:	HELP OTFMAP
	HELP OTFM
one subtopic or option:	HELP OTFMAP /NOTF
examples:	HELP OTFMAP EXAMPLES
all subtopics and options:	HELP OTFMAP *
options in general:	HELP OPTIONS
news about paKo:	HELP PAKO\ NEWS

NOTE: <<TBD      ... >>      (To BE DONE) or  
       <<            ... >>      flag items that are planned for the NCS, but  
                                  not yet implemented or properly tested.  
                                  Observers should not try to use these features  
                                  without consulting the NCS team.

setup:	
SET & SHOW	set general parameters (project, observer, ...)
CATALOG	select source or line catalogs
SOURCE	specify a source
OFFSETS	specify source offsets
RECEIVER	set up receivers
BACKEND	set up backends

switching modes (select 1)	
SWBEAM	select and set up beam switching

```

SWFREQUENCY      select and set up frequency switching
SWTOTAL          select total power (no switching)
SWWOBBLER        select and set up wobbler switching

    observing modes (select 1)
CALIBRATE        specify a calibration
FOCUS            specify a focus measurement
POINTING         specify a pointing measurement
TIP              specify an antenna tipping (a.k.a., "skydip")
TRACK            specify tracking of a single position, e.g., with SWFRE
ONOFF            specify on-off (a.k.a., "position switching")
OTFMAP           specify an On-The-Fly (OTF) map
LISSAJOUS        specify an On-The-Fly map along a Lissajous curve
VLBI             specify tracking of a single position for VLBI

    start:
START            start an observation, i.e., send it to the queue

    save:
SAVE            save parameters to file, i.e., a .pako script

```

NEW in v1.2.3 (2014-11-11)

=====

```

LISSAJOUS /FOCUS    f1 f2 [... f18] [direction]    ! for NIKA
LISSAJOUS /POINTING                                ! for NIKA
LISSAJOUS /TUNE      xOffsetT      yOffsetT        ! for NIKA
                  /TTUNE          tTune            ! for NIKA

FOCUS      /TUNE      xOffsetT      yOffsetT        ! for NIKA
          /TTUNE      tTune            ! for NIKA
OTFMAP     /TUNE      xOffsetT      yOffsetT        ! for NIKA
          /TTUNE      tTune            ! for NIKA
POINTING   /TUNE      xOffsetT      yOffsetT        ! for NIKA
          /TTUNE      tTune            ! for NIKA

RECEIVER   BOLOMETER NIKA            pixel          ! for NIKA

```

NEW in v1.1.15:

=====

Support for the upgrade of EMIR band E150 to full 2\*2\*8 GHz LSB+USB in both polarizations, and the E330 local oscillator to higher frequencies (2013-09).

There are NO new commands in v1.1.15

NEW in 1.1.14:

=====

RECEIVER BOLOMETER NIKA                   ! Receiver (bolometer) NIKA

SUBSCAN xOffset yOffset /TUNE                   ! for NIKA

DIY                                       /PURPOSE "play my Tune"   ! for NIKA

NEW in 1.1.12:

=====

RECEIVER BOLOMETER GISMO           ! Receiver (bolometer) GISMO

LISSAJOUS                           ! Observing Mode Lissajous for GISMO, i.e.,  
! an On-The-Fly map along a Lissajous curve

UPDATED in 1.1.11:

=====

RECEIVER EMIR                       ! Receiver EMIR, upgrade of E230 and E330

BACKEND FTS                       ! Fourier Transform Spectrometer

BACKEND BBC                       ! Broad Band Continuum Backend

SET           EMIRcheck           ! limit checking for EMIR

SET           UserLevel           !

NEW in v1.1.5:

=====

BACKEND BBC                       ! Broad Band Continuum Backend

BACKEND NBC                       ! Narrow Band Continuum Backend

NEW in v1.1.4:

=====

BACKEND FTS                       ! Fourier Transform Spectrometer

SET           EMIRCheck           ! "strict"|"relaxed"|"loose"

NEW in v1.1.1: SUPPORT FOR EMIR

=====

--> major changes in

CALIBRATE

BACKEND

RECEIVER

-----

NOTE: <<TBD ... >>           (To BE DONE) or

```
<<    ... >>    flag items that are planned for the NCS, but
                  not yet implemented or properly tested.
                  Observers should not try to use these features
                  without consulting the NCS team.
```

## 7.2 BACKEND

```
BACKEND  name          nPart resolution bandwidth fShift
                  receiverBand [polarization subband|sideband]
```

```
BACKEND  /CLEAR
```

Alternative short syntax (only for the backends shown here!):

```
BACKEND  BBC    nPart          /REC receiverBand [polarization sideband]
BACKEND  NBC    nPart          /REC receiverBand [polarization subband]
BACKEND  4MHz   nPart          /REC receiverBand [polarization subband]
BACKEND  WILMA  nPart          /REC receiverBand [polarization subband]
BACKEND  FTS    nPart          /REC receiverBand [polarization subband]
BACKEND  FTS    nPart /FINE    /REC receiverBand [polarization subband]
```

Set up backends for heterodyne receivers.

```
Character :: name          ! name of backend
Integer   :: nPart         ! (logical) number of backend part
Real      :: resolution    ! [MHz]
Real      :: bandwidth    ! [MHz]
Real      :: fShift        ! frequency shift [MHz]
Character :: receiverBand  ! receiver band      to connect to backend part
Character :: polarization  ! EMIR: polarization to connect to backend part
Character :: subband       ! EMIR: subband      to connect to backend part
Character :: sideband      ! EMIR: sideband     to connect to backend part
```

Choices for (backend) name are:

```
BBC          ! Broad Band Continuum Backend
NBC          ! Narrow Band Continuum Backend
4MHz         ! filter spectrometers with fixed resolution
WILMA        ! autocorrelation spectrometers
FTS          ! Fourier Transform Spectrometer
VESPA        ! autocorrelator with variable resolution
```

Choices for receiverBand are (compare RECEIVER command):

```
E090 E150 E230 E330 HERA1 HERA2
```

Choices for polarization are (for EMIR; compare RECEIVER command):

```
Horizontal Vertical
```

```
Choices for subband | sideband, when observing with EMIR, are:
      LO LI UI UO   |   LSB USB
```

LSB and USB apply only to EMIR bands with 8 GHz bandwidth (E090, E230, and E330) and Backend BBC.

fShift can be used to shift (offset) the backend band within the receiver band; this only applies to some backends, in particular VESPA. For VESPA, the range for fShift is much smaller than the 4GHz subbands of EMIR. For wide-bandwidth backends, fShift is fixed, corresponding to the frequency pattern of the EMIR subbands and backend bands. See EMIR and backend documentation.

/CLEAR completely clears the backend setup.

If option /CLEAR is present, all other parameters and options are ignored.

NOTE: EMIR subbands, IF cables, and Backends

The output signals from EMIR are transmitted to the spectrometers and NBC through 8 IF cables. Each IF cable carries one subband of bandwidth 4 GHz. This subbands are L0, LI, UI, or U0.

NBC, 4MHz, WILMA, and VESPA can only(!) be connected to IF cables 1 to 4. FTS parts 1 to 4 can also be connected to IF cables 1 to 4.

The command options RECEIVER /HORIZONTAL and RECEIVER /VERTICAL allow to select up to 4 EMIR subbands that will be transmitted through IF cables 1 to 4 (compare HELP RECEIVER /HORIZONTAL and the EMIR user documentation). This selection can include Outer subbands.

In addition, the IF cables 5 to 8 carry the 4 Outer subbands corresponding to the subbands selected for IF cables 1 to 4. E.g., if we select for IF 1 to 4:

E230 ver U0	E090 ver UI	E230 hor UI	E090 hor UI
-------------	-------------	-------------	-------------

then the IF cables 5 to 8 will transmit:

E230 ver U0	E090 ver U0	E230 hor U0	E090 hor U0.
-------------	-------------	-------------	--------------

Only FTS parts 5 to 8 can be connected to IF cables 5 to 8.

BACKEND NBC|WILMA|FTS /DEFAULT will automatically set the maximum number of backend parts for all available subbands.

BACKEND BBC is completely independant of the sub band selections for the IF cables.

#### NOTES:

- for some backends the resolution and/or bandwidth are fixed and the short syntax can be used. (The full syntax is supported for all backends).
- for VESPA always use the full syntax!
- after changing the receiver configuration: BACKEND /CLEAR is recommended followed by the backend setup for the new receivers; without that it is possible that pako will not accept BACKEND commands because of unresolved conflicts between the RECEIVER and BACKEND setups.
- However, the backend command will automatically try to disconnect backends that were connected to receiver (sub)bands that are not connected anymore.



### 7.2.1 BACKEND BBC

BBC ! Broad Band Continuum Backend

BBC works only with the EMIR receiver. One part of BBC always covers the full 8 GHz bandwidth of each sideband of each polarization of each EMIR band selected with the RECEIVER command.

Band	Sidebands	IF [GHz]	Width [GHz]	Polariz.	# BBC parts -----
E090	LSB and USB	4--12	8	H and V	4
E150	LSB and USB	4--12	8	H and V	4
E230	LSB and USB	4--12	8	H and V	4
E330	LSB and USB	4--12	8	H and V	4

Shortcut: after selecting EMIR bands and subbands, BACKEND BBC /DEFAULT automatically sets all this appropriately!

### 7.2.2 BACKEND FTS

FTS ! Fourier Transform Spectrometer

The FTS supports two modes:

- wide bandwidth, up to ~ 4000 MHz on EMIR (~ 1000 MHz on HERA), with a resolution of ~ 0.195 [MHz], or
- fine resolution, ~ 0.049 MHz, with a bandwidth up to 1820 MHz on EMIR (~ 500 MHz on HERA)

All parts of the FTS must use the same resolution.

NOTE: EMIR subbands, IF cables, and Backends

The output signals from EMIR are transmitted to the spectrometers and NBC through 8 IF cables. Each IF cable carries one subband of bandwidth 4 GHz. This subbands are L0, LI, UI, or UO.

NBC, 4MHz, WILMA, and VESPA can only(!) be connected to IF cables 1 to 4. FTS parts 1 to 4 can also be connected to IF cables 1 to 4.

The command options RECEIVER /HORIZONTAL and RECEIVER /VERTICAL allow to select up to 4 EMIR subbands that will be transmitted through IF cables 1 to 4 (compare HELP RECEIVER /HORIZONTAL and the EMIR user documentation). This selection can include Outer subbands.

In addition, the IF cables 5 to 8 carry the 4 Outer subbands corresponding to the subbands selected for IF cables 1 to 4. E.g., if we select for IF 1 to 4:

```
E230 ver U0    E090 ver UI    E230 hor UI    E090 hor UI
then the IF cables 5 to 8 will transmit:
E230 ver U0    E090 ver U0    E230 hor U0    E090 hor U0.
```

Only FTS parts 5 to 8 can be connected to IF cables 5 to 8.

BACKEND NBC|WILMA|FTS /DEFAULT will automatically set the maximum number of backend parts for all available subbands.

BACKEND BBC is completely independant of the sub band selections for the IF cables.

NOTE: bandwidth selection with EMIR

The pako command already allows some flexibility that is not yet fully supported by the data handling, e.g., to select only part of the full bandwidth.

NOTE: FTS on HERA

With HERA, the FTS can be connected to HERA1 and/or HERA2.

On HERA, the FTS provides some extra bandwidth, which is not symmetrical to the point where the line (the commanded frequency) gets centered.

With HERA /width wide, the line gets centered at the center of WILMA and 4MHz. Relative to this point, the FTS in wide mode covers IF offset frequencies from < -512 to > +512. In pako the nominal value of the bandwidth is 1024, symmetric around the line.

With HERA /width narrow, the line gets centered at the center of VESPA. Relative to this point, the FTS in fine mode covers IF offset frequencies from < -256 to > +360. In pako the nominal value of the bandwidth is 512, symmetric around the line.

It is also possible to connect FTS in fine mode on HERA /width wide or FTS in wide mode on HERA /width narrow. However, in these cases the FTS band coverages are very asymmetric to the line. (See HERA and FTS documentation for the exact details of the IF ranges).

### 7.2.3 BACKEND /DEFAULTS

/DEFAULTS [yes|no]

Set default values.

If EMIR sub bands have been selected with the RECEIVER command, this option has a special function for some Backends:

BACKEND BBC	/Defaults	connects one BBC part to each sideband (!) of each selected EMIR band (up to 8)
BACKEND NBC	/Defaults	connects one NBC part to each selected EMIR sub band (up to 4)
BACKEND 4MHZ	/Defaults	connects one 4MHz part to each of the 1st and 2nd selected EMIR sub band
BACKEND WILMA	/Defaults	connects one WILMA part to each selected EMIR sub band (up to 4)
BACKEND FTS	/Defaults	connects one FTS part in "wide" bandwidth to each EMIR sub band (up to 4) selected for IF cables 1 to 4, and additionally one part to each of the available Outer subbands (up to 4) on IF cables 5 to 8
BACKEND FTS /Fine	/Defaults	connects one FTS part in "fine" resolution to each EMIR sub band (up to 4) selected for IF cables 1 to 4, and additionally one part to each of the available Outer subbands (up to 4) on IF cables 5 to 8

#### 7.2.4 BACKEND /CLEAR

/CLEAR [yes|no]

Completely clear a list of connected hardware, e.g., receivers, backends, or parameters of the associated command.

After changing the receiver configuration: BACKEND /CLEAR is recommended followed by the backend setup for the new receivers; without that it is possible that pako will not accept BACKEND commands because of unresolved conflicts between the RECEIVER and BACKEND setups.

#### 7.2.5 BACKEND /CONNECT

/CONNECT [yes|no]

connect (or disconnect) the specified hardware, e.g., backend or backend part.

--> DEPRECATED. PROTECTED (needs SET userLevel)

### 7.2.6 BACKEND /DISCONNECT

/DISCONNECT

disconnect the specified hardware, e.g.,  
backend or backend part.

--> DEPRECATED. PROTECTED (needs SET userLevel)

### 7.2.7 BACKEND /FINE

/FINE

for BACKEND FTS select the "fine" mode with a resolution of ~ 0.049 [MHz]

Note: with the option /DEFAULT or the short syntax, this allows to  
select the fine resolution without explicitly entering the values of  
resolution and bandwidth.

### 7.2.8 BACKEND /MODE

/MODE mode

Character :: mode ! backend mode

Choices for mode are:

SIMPLE ! simple (standard)

PARALLEL ! parallel mode

POLARIZATION ! polarimetry

Select special mode for VESPA.

See VESPA user's guide for details.

For EMIR, /MODE PARALLEL or /MODE POLARIZATION connect VESPA  
to the same band and subband in both polarizations; they must  
previously have been selected with the RECEIVER command. For  
examples, see:

HELP BACKEND Examples

### 7.2.9 BACKEND /LINENAME

```
/LINENAME lineName
```

```
Character :: lineName          ! name of line. don't use @ < >
```

```
--> OPTION OF BACKEND COMMAND FOR USE WITH EMIR
```

This allows to set a "line" name for each backend part.

If a line name is set for a backend part, it will be used in the CLASS header of the spectrum from that backend part.

If no line name is set for a backend part (default), the line name from the corresponding RECEIVER band will be used in the CLASS header.

This is an optional convenience feature to make it easier to identify spectra by appropriate names, in particular in cases where several different lines are observed simultaneously with the same receiver band.

This is only a name or label, and has no influence on any frequencies or other control parameters.

## 7.2.10 BACKEND /PERCENTAGE

```
/PERCENTAGE percentage
```

```
Real :: percentage ! percentage of bandwidth to use
```

This is a special option for the autocorrelators, VESPA and WILMA.

For autocorrelators normally some channels at both ends of the band are blanked because they do not contain usable data, and only the central 'percentage' of the "theoretical" bandwidth is used, typically about 90%. Reasonable conservative defaults are automatically applied: in general 90%, but 82% for VESPA with bandwidth 640. This option allows the observer to adjust the percentage for special purposes.

For WILMA connected to EMIR, the useful bandwidth is 3720 MHz, and counted as 100%.

See VESPA user's guide for details.

## 7.2.11 BACKEND /RECEIVER

```
/RECEIVER receiverBand [polarization subband|sideband]
```

```
Character :: receiverBand ! receiver band      to connect to backend part
Character :: polarization ! EMIR: polarization to connect to backend part
```



```

backend /clear
BACKEND WILMA      /Default      ! connect 1 part to
!                               ! each selected EMIR subband
pause
!
!
!                               ! EMIR 4MHz
!                               ! NOTE: 4MHz has only 2
!                               !       parts with EMIR
backend /clear
BACKEND 4MHz       /Default      ! connect 1 part to each of
!                               ! the first 2 EMIR subbands
pause
!
BACKEND 4MHz 1     /Receiver E090 Horiz LI ! connect 1 part to E090 Ho LI
BACKEND 4MHz 2     /Receiver E230 Verti LI !       2nd part to E230 Ve LI
pause
!
!                               ! EMIR FTS wide bandwidth mode
!                               !       /Fine is NOT present
backend /clear
BACKEND FTS        /Default      ! connect 1 part to
!                               ! each selected EMIR subband
!                               ! plus 1 part to each of the
!                               ! 4 outer subbands of E090
pause
!
backend /clear
!                               ! short syntax (still wide)
BACKEND FTS 1      /Receiver E090 hor LI !
BACKEND FTS 2      /Receiver E090 ver LI !
BACKEND FTS 3      /Receiver E230 hor LI !
BACKEND FTS 4      /Receiver E230 ver LI !
BACKEND FTS 5      /Receiver E090 ver LO !
BACKEND FTS 6      /Receiver E230 ver LO !
BACKEND FTS 7      /Receiver E090 hor LO !
BACKEND FTS 8      /Receiver E230 hor LO !
!                               !
pause
!
!                               ! EMIR FTS fine resolution
!                               !       because /Fine is present
backend /clear
BACKEND FTS /Fine /Default      ! connect 1 part to
!                               ! each selected EMIR subband
!                               ! plus 1 part to each of
!                               ! the 4 outer subbands of E090
pause
!
backend /clear
!                               ! short syntax (fine)
BACKEND FTS 1 /Fine /Receiver E090 hor LI !
BACKEND FTS 2 /Fine /Receiver E090 ver LI !
BACKEND FTS 3 /Fine /Receiver E230 hor LI !

```

```

BACKEND FTS 4 /Fine /Receiver E230 ver LI      !
BACKEND FTS 5 /Fine /Receiver E090 ver LO      !
BACKEND FTS 6 /Fine /Receiver E230 ver LO      !
BACKEND FTS 7 /Fine /Receiver E090 hor LO      !
BACKEND FTS 8 /Fine /Receiver E230 hor LO      !
!
pause
!
!
!                                     ! EMIR WILMA + 4MHz + VESPA
backend /clear
BACKEND WILMA      /Default                  !
BACKEND 4MHz       /Default                  !
BACKEND VESPA  1   0.040  40.0    0.0  E090  Horiz  LI
BACKEND VESPA  2   0.040  40.0    0.0  E090  Verti  LI
BACKEND VESPA  3   0.040  40.0    0.0  E230  Horiz  LI
BACKEND VESPA  4   0.040  40.0    0.0  E230  Verti  LI
say                                     " ! backends can be combined"
pause
!
!
!! EMIR VESPA autocorrelator -- basic mode with fShift. optional: line name
!
backend /clear
BACKEND VESPA  1   0.040  40.0  -120.0 E090  Horiz  LI /line E0HU0-M
BACKEND VESPA  2   0.040  40.0   120.0 E090  Horiz  LI /line E0HU0-P
BACKEND VESPA  3   0.040  40.0  -100.0 E090  Verti  LI /line myLine3
BACKEND VESPA  4   0.040  40.0   110.0 E090  Verti  LI /line myLine4
BACKEND VESPA  5   0.040  80.0  -150.0 E230  Horiz  LI /line ""
BACKEND VESPA  6   0.040  80.0   150.0 E230  Horiz  LI /line apple
BACKEND VESPA  7   0.040  80.0  -200.0 E230  Verti  LI /line orange
BACKEND VESPA  8   0.040  80.0   200.0 E230  Verti  LI /line red
pause
!
!! EMIR VESPA autocorrelator -- basic and parallel modes
!
backend /clear
BACKEND VESPA  1   0.320  240.0    0.0  E090  Horiz  LI
BACKEND VESPA  2   0.320  240.0    0.0  E090  Verti  LI
BACKEND VESPA  3   0.320  240.0    0.0  E230  Horiz  LI /mode parallel
pause
!
!! NOTE: BACKEND VESPA ... E230 Horiz LI /mode parallel
!!       connects one VESPA part in parallel to
!!       E230 Horiz LI and E230 Verti LI
!!       (both must be selected in RECEIVER command)
!
!
!! HERA with FTS wide bandwidth
!
receiver /clear
RECEIVER HERA1 /WIDTH wide
RECEIVER HERA2 /WIDTH wide
!

```



```

backend /clear
BACKEND FTS 1          /RECEIVER HERA1
BACKEND FTS 2          /RECEIVER HERA2
!
!
!! HERA narrow bandwidth with FTS fine resolution
!
receiver /clear
RECEIVER HERA1 /WIDTH narrow
RECEIVER HERA2 /WIDTH narrow
!
backend /clear
BACKEND FTS 1  /FINE   /RECEIVER HERA1
BACKEND FTS 2  /FINE   /RECEIVER HERA2
!

```

### 7.3 CALIBRATE

CALIBRATE (no parameters)

Specify a calibration measurement with the heterodyne receivers,  
normally with subscans "SAC": Sky -- Ambient temperature load -- Cold load

NOTE: CALIBRATE is always and automatically done with switching mode "total  
and the time per phase is adjusted to be in the range 0.1 to 0.5 [sec]

```

/SKY xOffsetC yOffsetC
or
/SKY NO                      ! do not do sky calibration

```

Do a calibration subscan on sky.

```

Real      :: xOffsetC      ! x-offset
Real      :: yOffsetC      ! y-offset

```

NOTES: with the usage /SKY xOffsetC yOffsetC, both parameters are required,  
but you can replace either parameter with \* to leave it unchanged.  
The system for the offsets is selected through the option /SYSTEM.

#### 7.3.1 CALIBRATE /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.

**7.3.2 CALIBRATE /AMBIENT**

/AMBIENT [yes|no]

Do a calibration subscan on the ambient temperature load.

Logical    :: doAmbient               ! default: true

**7.3.3 CALIBRATE /COLD**

/COLD [yes|no]

Do a calibration subscan on the cold temperature load.

Logical    :: doCold                 ! default: true

**7.3.4 CALIBRATE /GAINIMAGE**

--> NOTE: OBSOLETE WITH CHANGE TO EMIR

**7.3.5 CALIBRATE /GRID**

/GRID [yes|no]

NOT YET AVAILABLE FOR EMIR

Do a calibration subscan on a grid. This is a special calibration option for polarization observations.

Logical    :: doGrid                 ! default: true

IMPORTANT NOTE:

remember to turn this option off again for normal calibrations:  
e.g., CALIBRATE /GRID NO or CALIBRATE /DEFAULT.

**7.3.6 CALIBRATE /SKY**

/SKY xOffsetC yOffsetC

or

/SKY NO                               ! do not do sky calibration

Do a calibration subscan on sky.

Real        :: xOffsetC               ! x-offset

Real        :: yOffsetC               ! y-offset

NOTES: with the usage /SKY xOffsetC yOffsetC, both parameters are required, but you can replace either parameter with \* to leave it unchanged. The system for the offsets is selected through the option /SYSTEM.

### 7.3.7 CALIBRATE /SYSTEM

/SYSTEM systemName

Name of system for offsets.

Character :: systemName           ! name of system, one of:  
                                   ! PROJECTION  
                                   ! TRUEHORIZON  
                                   ! NASMYTH

<<TBD:                           ! DESCRIPTIVE>>  
 <<TBD:                           ! BASIS>>  
 <<TBD:                           ! EQUATORIAL>>  
 <<TBD:                           ! HADECL>>  
 <<TBD:                           ! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).  
 If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

IMPORTANT NOTE: OFFSETS    /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako, the values xOffset yOffset are used during the observations. (this includes the case that they are explicitly set to 0.0). It is up to the observer to make sure that they are "correct". (in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified

(cleared), for the MAMBO bolometer, Nasmyth offsets are used automatically according to the selected bolometer channel (pixel).

### 7.3.8 CALIBRATE /TCALIBRATE

/TCALIBRATE tCalibrate

Time per CALIBRATE subscan.

Real            :: tCalibrate            ! time

## 7.4 CATALOG

CATALOG [SOURCE|LINE] fileName

Select a source or line catalog.

Character :: kind                      ! SOURCE or LINE

Character :: fileName                ! file name

Selects a file with name fileName as source or line catalog.

Source Catalog:

The format of a line in the source catalog is the same as that of the parameters of the SOURCE command, without the keyword "SOURCE" and without any options (see HELP SOURCE). Example:

W30H EQ 2000 02:27:03.8812 +61:52:24.572 LSR -45.0 [FLUX 3.73 1.00]

IMPORTANT NOTE:

sourceName is limited to 12 characters.

Line Catalog:

The format of a line in the line catalog is same as that of the 2nd, 3rd, and 4th parameter of the RECEIVER command:

lineName            frequency            SB

with frequency in unit [GHz] (see HELP RECEIVER).

Example:

12CO(1-0)            115.271204            UI            (for EMIR)

12CO(2-1)	230.537990	LI	(for EMIR)
12CO(2-1)	230.537990	LSB	(for HERA)

**IMPORTANT NOTE:**

lineName is limited to 12 characters.

NB: Don't use / & < > in names of sources, lines, projects, PI, observer, operator, etc. Don't use ()/ in source names.

**7.4.1 CATALOG SOURCE**

Source Catalog:

The format of a line in the source catalog is the same as that of the parameters of the SOURCE command, without the keyword "SOURCE" and without any options (see HELP SOURCE). Example:

W3OH EQ 2000 02:27:03.8812 +61:52:24.572 LSR -45.0 [FLUX 3.73 1.00]

**IMPORTANT NOTE:**

sourceName is limited to 12 characters.

**7.4.2 CATALOG LINE**

Line Catalog:

The format of a line in the line catalog is same as that of the 2nd, 3rd, and 4th parameter of the RECEIVER command:

lineName	frequency	SB
----------	-----------	----

with frequency in unit [GHz] (see HELP RECEIVER).

Example:

12CO(1-0)	115.271204	UI	(for EMIR)
12CO(2-1)	230.537990	LI	(for EMIR)
12CO(2-1)	230.537990	LSB	(for HERA)

**IMPORTANT NOTE:**

lineName is limited to 12 characters.

**7.5 DISPLAY**

DISPLAY REDO

Redo (refresh) the text in the display window.

## 7.6 DIYLIST

DIYLIST

User-defined list of subscans and segments for observing mode "DIY";  
to define subscans, see `HELP SUBSCAN`.

NB: this is a protected command (needs privilege).

DIYLIST without any parameters or options:

- lists defined subscans and segments in the pako window  
(this requires `SET LEVEL 2` or lower)
- in the `pakoDisplay` shows conditions, e.g., maximum possible elevation
- plots defined subscans and segments (depending on `SET plotStyle`)

### 7.6.1 DIYLIST /CLEAR

`/CLEAR [yes|no]`

Completely clear the user-defined list of subscans and segments DIY.

### 7.6.2 DIYLIST /PURPOSE

`/PURPOSE purpose`

Set a purpose for a scan, i.e., an intended use of the data.  
This applies in particular to `DIYLIST`.

Character :: purpose !

NOTE: `/PURPOSE` by itself or  
`/DIY` clears the purpose.

NOTE: at this time (2012-11-08) this is only for information,  
and included in the XML, but it has no practical effect.

**7.7 FOCUS**

FOCUS lengthFocus

Specify a focus measurement.

Real        :: lengthFocus        ! length [mm] of focus scan

The sequence of focus subscans is determined by  
lengthFocus /nSubscans /otfFocus:

```
lengthFocus      ! total length [mm] of the focus scan
/nSubscans       ! number of focus subscans
<< TD:/otfFocus      ! not yet implemented>>
```

```
focus subscan 1 is at offset  0.0
focus subscan 2 is at offset  lengthFocus/2
in case /nSubscans 3:
focus subscan 3 is at offset -lengthFocus/2
in case /nSubscans >3:
focus subscan 3 is at offset  lengthFocus/2
focus subscan 4 is at offset -lengthFocus/2
focus subscan 5 is at offset -lengthFocus/2
focus subscan 6 is at offset  0.0
(etc.)
```

**7.7.1 FOCUS /DEFAULTS**

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

**7.7.2 FOCUS /NSUBSCANS**

/NSUBSCANS nSubscans

Integer    :: nSubscans        ! number of subscans

**7.7.3 FOCUS /TSUBSCAN**

/TSUBSCAN tSubscan

time per subscan

Real        :: tSubscan        ! time

**7.7.4 FOCUS /TUNE**

```

/TUNE xOffsetT yOffsetT
or
/TUNE NO                ! no tune subscan

```

Tune subscan at the specified offsets, before any other subscans.

```

Real      :: xOffsetT      ! x-offset for tune subscan
Real      :: yOffsetT      ! y-offset for tune subscan

```

NOTE: with the usage /TUNE xOffsetT yOffsetT, both parameters are required, but you can replace either parameter with \* to leave it unchanged.

For FOCUS, the offsets for the tune subscan are in the "trueHorizontal" system.

**7.7.5 FOCUS /TTUNE**

```

/TTUNE tTune

time per TUNE subscan

Real      :: tTune          ! time

```

**7.7.6 FOCUS EXAMPLES**

```

!
! Id: demo-focus.pako
!   FOCUS EXAMPLE,v 1.1.1 2009-05-08 Hans Ungerechts
!
SWBEAM                                ! to select beam switching
!
FOCUS      2.0                        - ! length [mm]
  /NSUBSCANS 6                        - ! number of subscans
  /TSUBSCAN 12                        ! time per subscan
!
PAUSE "FOCUS OK to start? [c/q]"      ! a chance to check
!
START                                           ! start
!
!! Comments:
!! We assume here that a pointing measurement has been done
!! immediately before the FOCUS (strongly recommended!),
!! see: demo-pointing, and therefore
!! we assume here that source, receivers, and backends
!! already have been selected and set up.
!! If you want the intensity of the Focus data to be
!! calibrated, you have to do a Calibrate with the same
!! receivers and (continuum) backends before.

```



## 7.8 LISSAJOUS

```
LISSAJOUS    xAmplitude  yAmplitude
/CENTER      xCenter     yCenter
/FREQUENCY   frequencyX  frequencyY
/PHASES      phiX        phiY
/TOTF        t0tf
/SYSTEM      system
```

additionally for NIKA:

```
/FOCUS       f1 f2 [... f18] [direction]
/POINTING    [yes|no]
/TUNE        xOffsetT    yOffsetT
/TTUNE       tTune
```

Specify an On-The-Fly (OTF) map with a Lissajous curve in 1 subscan.  
LISSAJOUS is at this time (2014-11-10) supported only for GISMO and NIKA

```
Real        :: xAmplitude      ! amplitude for x-offsets
Real        :: yAmplitude      ! amplitude for y-offsets
Real        :: xCenter         ! center x-offset
Real        :: yCenter         ! center y-offset
Real        :: frequencyX      ! frequency [Hz] for x
Real        :: frequencyY      ! frequency [Hz] for y
Real        :: phiX            ! phase offset [rad] for x
Real        :: phiY            ! phase offset [rad] for y

Real        :: t0tf            ! time [s]
Character    :: systemName     ! name of system, one of:
                                ! PROJECTION
                                ! TRUEHORIZON

Real        :: f1 f2 [... f18] ! focus offset [mm] during each Lissajous cur
Character    :: direction      ! direction of focus offsets, one of:
                                ! X
                                ! Y
                                ! Z

Real        :: xOffsetT        ! x-offset for tune subscan
Real        :: yOffsetT        ! y-offset for tune subscan
Real        :: tTune           ! time [s] for tune subscan
```

During a Lissajous OTF segment, the position offsets  
x and y as a function of time t are:

```
x = xCenter + xAmplitude * SIN(2 Pi frequencyX t + phiX)
y = yCenter + yAmplitude * SIN(2 Pi frequencyY t + phiY)
```

SIN is the usual sine function, Pi is the number Pi.

xAmplitude yAmplitude xCenter yCenter are in angle units ([arc sec])  
 frequencyX frequencyY are in [Hz]  
 phiX phiY are in [rad]

Note that the possible frequencies are very low,  
 typically 0.01 to 0.15 Hz.

At the start of a Lissajous subscan, paKo will insert a "ramp" along a straight line, i.e., a linear OTF segment, increasing the count of segments by 2. This ramp up starts with speed 0 relative to the source and joins smoothly with the start position and velocity of the Lissajous segment. The purpose is to avoid a sudden acceleration at the start of the Lissajous segment. The inserted ramp up segment and the Lissajous segment become part of the same subscan.

Lissajous curves with large amplitudes or frequencies can reach the antenna's speed and acceleration limits for tracking. Lissajous curves can be executed only for elevations less than a maximum, which depends on the Lissajous parameters. For information, this elevation condition is shown by pako. Even below the limits, during very fast Lissajous curves the tracking errors will be higher, several arc sec, than during most other observations.

DO NOT TRY TO OBSERVE LISSAJOUS ABOVE THIS MAXIMUM ELEVATION.

### 7.8.1 LISSAJOUS /CENTER

/CENTER xCenter yCenter

position of center

Real :: xCenter ! center x-offset  
 Real :: yCenter ! center y-offset

### 7.8.2 LISSAJOUS /FREQUENCY

/FREQUENCY frequencyX frequencyY

Real :: frequencyX ! frequency [Hz] for x  
 Real :: frequencyY ! frequency [Hz] for y

### 7.8.3 LISSAJOUS /PHASES

/PHASES phiX phiY

Real :: phiX ! phase offset [rad] for x  
 Real :: phiY ! phase offset [rad] for y

### 7.8.4 LISSAJOUS /SYSTEM

/SYSTEM systemName

Name of system for offsets.

```
Character :: systemName      ! name of system, one of:
                             ! PROJECTION
                             ! TRUEHORIZON
                             ! NASMYTH

<<TBD:                       ! DESCRIPTIVE>>
<<TBD:                       ! BASIS>>
<<TBD:                       ! EQUATORIAL>>
<<TBD:                       ! HADECL>>
<<TBD:                       ! HORIZONTAL>>
```

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

```
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM projection,
OFFSETS ... /SYSTEM projection is ignored (not used).
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM trueHorizon,
OFFSETS ... /SYSTEM trueHorizon is ignored (not used).
```

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

```
If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako,
the values xOffset yOffset are used during the observations.
(this includes the case that they are explicitly set to 0.0).
It is up to the observer to make sure that they are "correct".
(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)
```

```
If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified
(cleared), for the MAMBO bolometer, Nasmyth offsets are used
automatically according to the selected bolometer channel (pixel).
```

### 7.8.5 LISSAJOUS /TOTF

```
/TOTF tOtf
```

time per OTF subscan or segment

Real           :: tOtf                   ! time

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

### 7.8.6 LISSAJOUS /FOCUS

/FOCUS f1 f2 [... f18] [direction]  
or  
/FOCUS NO

[For Lissajous] designate the purpose of the scan to be "Focus", i.e., to determine focus corrections. A subscan with a Lissajous curve will be executed for each focus offset specified.

Real           :: f1 f2 [... f18]       ! focus offsets [mm]  
   ! (at least 2, at most 18 values)  
Character :: direction               ! direction of focus offsets, one of:  
   ! X  
   ! Y  
   ! Z

/FOCUS NO clears the option /FOCUS.

### 7.8.7 LISSAJOUS /POINTING

/POINTING [YES|NO]

Logical       :: doPointing           ! default: no

[For Lissajous] designate the purpose of the scan to be "Pointing", i.e., to determine pointing corrections.

/POINTING NO clears the option /POINTING.

### 7.8.8 LISSAJOUS /TUNE

/TUNE xOffsetT yOffsetT  
or  
/TUNE NO                               ! no tune subscan

Tune subscan at the specified offsets, before any other subscans.

Real           :: xOffsetT           ! x-offset for tune subscan  
Real           :: yOffsetT           ! y-offset for tune subscan

NOTE: with the usage /TUNE xOffsetT yOffsetT, both parameters are required, but you can replace either parameter with \* to leave it unchanged.

The offsets for the tune subscan are in the system selected with /SYSTEM.

### 7.8.9 LISSAJOUS /TTUNE

/TTUNE tTune

time per TUNE subscan

Real           :: tTune           ! time

## 7.9 OFFSETS

OFFSETS xOffset yOffset

Specify source offsets.

Real           :: xOffset           ! x-offset

Real           :: yOffset           ! y-offset

IMPORTANT NOTE: one should be careful with the OFFSETS command, which is only used and only needed in a few special situations, e.g., with Wobbler-switching ONOFF and to set NASMYTH offsets for focal-plane-array receivers. The function of OFFSETS is explained in the paKo user's manual, Section "A Guide to the Perplexed" and, in more detail, in the Section "NCS Explained", Subsection "Coordinate Systems, Projections, and Offsets."

For many observations all "offsets" are specified as parameters or options of the command for the observing mode.

/SYSTEM systemName

Name of system for offsets.

Character :: systemName           ! name of system, one of:  
                                  ! PROJECTION  
                                  ! TRUEHORIZON  
                                  ! NASMYTH

<<TBD:                           ! DESCRIPTIVE>>  
<<TBD:                           ! BASIS>>  
<<TBD:                           ! EQUATORIAL>>  
<<TBD:                           ! HADECL>>  
<<TBD:                           ! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).  
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako, the values xOffset yOffset are used during the observations. (this includes the case that they are explicitly set to 0.0). It is up to the observer to make sure that they are "correct". (in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified (cleared), for the MAMBO bolometer, Nasmyth offsets are used automatically according to the selected bolometer channel (pixel).

### 7.9.1 OFFSETS /DEFAULTS

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

### 7.9.2 OFFSETS /CLEAR

/CLEAR [yes|no]

Completely clear a list of connected hardware, e.g., receivers, backends, or parameters of the associated command.

### 7.9.3 OFFSETS /SYSTEM

/SYSTEM systemName

Name of system for offsets.

```

Character :: systemName      ! name of system, one of:
                             ! PROJECTION
                             ! TRUEHORIZON
                             ! NASMYTH

<<TBD:                      ! DESCRIPTIVE>>
<<TBD:                      ! BASIS>>
<<TBD:                      ! EQUATORIAL>>
<<TBD:                      ! HADECL>>
<<TBD:                      ! HORIZONTAL>>

```

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

```

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM projection,
OFFSETS ... /SYSTEM projection is ignored (not used).
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM trueHorizon,
OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

```

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

```

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako,
the values xOffset yOffset are used during the observations.
(this includes the case that they are explicitly set to 0.0).
It is up to the observer to make sure that they are "correct".
(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

```

```

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified
(cleared), for the MAMBO bolometer, Nasmyth offsets are used
automatically according to the selected bolometer channel (pixel).

```

## 7.10 ONOFF

```
ONOFF xOffset yOffset
```

Specify on-off measurement, a.k.a. "position switching".

```
Real      :: xOffset      ! x-offset of "on-source" position
Real      :: yOffset      ! y-offset of "on-source" position

Character :: sourceName    ! name of "on-source" position
```

NOTE: if SWWOBBLER is the selected switching mode, the special option /SWWOBBLER YES (TRUE) is implied even without specifying it, and the on-off parameters appropriate for on-off Wobbler switching are set.

If SWWOBBLER and ONOFF are combined in the standard way, we effectively take data at 3 positions:

1. the source position
2. the source position + throw (offset in the "true-angle" horizontal system)
3. the source position - throw (offset in the "true-angle" horizontal system)

with throw = ABS(wOffset2-wOffset1).

Data from 1. are treated as source signal, data from 2 and 3 as off-source reference signal. Note that in the astronomical coordinates, positions 2 and 3 will rotate around the source position (1). Therefore one must normally be sure that the extent of the source is less than throw-beamWidth (/2).

```
/REFERENCE xOffsetR yOffsetR [systemNameRef]
or
/REFERENCE NO                ! no reference
```

position of off-source reference subsamples

```
Real      :: xOffsetR      ! x-offset
Real      :: yOffsetR      ! y-offset
Character :: systemNameRef ! name of system
                        ! see /SYSTEM for choices
```

NOTE: with the usage /REFERENCE xOffsetR yOffsetR, both parameters are required but you can replace either parameter with \* to leave it unchanged.

```
/SYSTEM systemName
```

Name of system for offsets.

```
Character :: systemName    ! name of system, one of:
                        ! PROJECTION
                        ! TRUEHORIZON
                        ! NASMYTH
```

```
<<TBD:                ! DESCRIPTIVE>>
<<TBD:                ! BASIS>>
```



```
<<TBD:                ! EQUATORIAL>>
<<TBD:                ! HADECL>>
<<TBD:                ! HORIZONTAL>>
```

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

```
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM projection,
OFFSETS ... /SYSTEM projection is ignored (not used).
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM trueHorizon,
OFFSETS ... /SYSTEM trueHorizon is ignored (not used).
```

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

```
If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako,
the values xOffset yOffset are used during the observations.
(this includes the case that they are explicitly set to 0.0).
It is up to the observer to make sure that they are "correct".
(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)
```

```
If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified
(cleared), for the MAMBO bolometer, Nasmyth offsets are used
automatically according to the selected bolometer channel (pixel).
```

### 7.10.1 ONOFF /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.

### 7.10.2 ONOFF /NSUBSCANS

```
/NSUBSCANS nSubscans
```

```
Integer    :: nSubscans      ! number of subscans
```

**7.10.3 ONOFF /REFERENCE**

```

/REFERENCE xOffsetR yOffsetR [systemNameRef]
or
/REFERENCE NO                ! no reference

```

position of off-source reference subscans

```

Real      :: xOffsetR      ! x-offset
Real      :: yOffsetR      ! y-offset
Character :: systemNameRef ! name of system
                        ! see /SYSTEM for choices

```

NOTE: with the usage /REFERENCE xOffsetR yOffsetR, both parameters are required but you can replace either parameter with \* to leave it unchanged.

**7.10.4 ONOFF /SWWOBBLER**

```

/SWWOBBLER [yes|no]

```

(option of command ONOFF)

set parameters appropriate for on-off Wobbler switching

```

Logical    :: doSwWobbler

```

If switching mode SWWOBBLER has been selected, the following parameters of ONOFF are set according to wOffset1 and wOffset2:

```

ONOFF
  xOffset  is set to: -wOffset1
  yOffset  is set to:  0.0

/REFERENCE      is set to:  Yes
  xOffsetR      is set to: -wOffset2
  yOffsetR      is set to:  0.0
  systemNameRef is set to:  TRUEHORIZON

/SYSTEM
  systemName     is set to:  TRUEHORIZON

```

NOTE: in this case the values selected by /SWWOBBLER overrule the corresponding values specified directly in the command.

NOTE: To do ONOFF with Wobbler switching and other (unconventional) values for the parameters listed above, simply specify the values using command ONOFF with option /SWWOBBLER NO (not recommended).

NOTE: If the selected switching mode is SWWOBBLER and if the option /SWWOBBLER is not explicitly given, it will be assumed to be .True. (Yes), If the selected switching mode is not SWWOBBLER and if the option /SWWOBBLER is not explicitly given, it will be assumed to be .False. (No),

**7.10.5 ONOFF /SYMMETRIC**

/SYMMETRIC [yes|no]

Logical :: doSymmetric ! default: no

(For ONOFF) select a subscan sequence that is "symmetric" in time.  
This requires that the number of subscans is a multiple of 4.

Example for ONOFF with	/SYMMETRIC no	/SYMMETRIC yes
1st subscan:	OFF	OFF
2nd "	ON	ON
3rd "	OFF	ON
4th "	ON	OFF
(and so on)		

NOTE that this does not in anyway change the positions  
of the ON-source and OFF-source subscans!

**7.10.6 ONOFF /SYSTEM**

/SYSTEM systemName

Name of system for offsets.

Character :: systemName ! name of system, one of:  
! PROJECTION  
! TRUEHORIZON  
! NASMYTH

<<TBD: ! DESCRIPTIVE>>  
<<TBD: ! BASIS>>  
<<TBD: ! EQUATORIAL>>  
<<TBD: ! HADECL>>  
<<TBD: ! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection  
offsets in the chosen coordinate system. This is normally the  
astronomical system of offsets in which point-by-point (TRACK, ONOFF)  
or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$   
applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a  
focal-plane array receiver (bolometer, HERA) to the commanded  
astronomical position, e.g., to use an off-center pixel for pointing,  
focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)  
is in /SYSTEM projection,

```

OFFSETS ... /SYSTEM projection is ignored (not used).
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM trueHorizon,
OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

```

IMPORTANT NOTE: OFFSETS    /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako,  
the values xOffset yOffset are used during the observations.  
(this includes the case that they are explicitly set to 0.0).  
It is up to the observer to make sure that they are "correct".  
(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified  
(cleared), for the MAMBO bolometer, Nasmyth offsets are used  
automatically according to the selected bolometer channel (pixel).

### 7.10.7 ONOFF /TSUBSCAN

/TSUBSCAN tSubscan

time per subscan

Real            :: tSubscan            ! time

### 7.10.8 ONOFF EXAMPLES

```

!
! Id: demo-onoff.pako
!   ONOFF SWTOTAL EXAMPLE,v 1.1.1 2009-05-05 Hans Ungerechts
!   "POSITION SWITCHING"
!
@ demo-rx-spectrometers           ! demo setup of receivers
!                                 ! and spectrometers
!                                 ! REPLACE WITH YOUR SETUP!
!
SET ANGLE arcsec                  !
!
SWTOTAL                           - ! select total power
  /TPHASE          0.5             ! time per phase (data sample)
!
CALIBRATE                         - !
  /AMBIENT          - ! ambient load
  /COLD             - ! cold   load
  /SKY              -600.0  0.0    - ! sky at offsets -600.0 0.0
  /SYSTEM           projection    - ! system for SKY offsets
  /TCALIBRATE       5.0          ! time per calibration subscan
!
PAUSE "CALIBRATE OK to start? [c/q]" ! a chance to check
!

```

```

START                                ! start
!
ONOFF      40.0   -30.0               - ! offsets of on position
  /NSUBSCANS 12                      - ! number of subscans
  /REFERENCE -600.0   0.0  projection - ! offsets of off-source referen
  /SYSTEM     projection              - ! system for offsets
  /SYMMETRIC                          - ! "symmetric" subscan sequence
  /TSUBSCAN   30                      ! time per subscan
!
PAUSE "ONOFF SWTOTAL OK to start? [c/q]" ! a chance to check
!
START                                ! start
!
!! Comments:
!! we assume here that the source already has been selected,
!! see: demo-source

!
! Id: demo-onoff-swwobbler.pako
!   ONOFF SWWOBBLER EXAMPLE,v 1.1.6 2011-07-31 Hans Ungerechts
!   "WOBBLER SWITCHING"
!
@ demo-rx-spectrometers              ! demo setup of receivers
!                                    ! and spectrometers
!                                    ! REPLACE WITH YOUR SETUP!
!
SET ANGLE arcsec                     !
!
!                                    ! select wobbler switching
SWWOBBLER  -120.0  120.0             - ! wobbler +/- 120 arc sec
  /TPHASE    1.0                      ! 1 seconds per phase
!
CALIBRATE                                - !
  /AMBIENT                                - ! ambient load
  /COLD                                  - ! cold   load
  /SKY      -600.0   0.0              - ! sky at offsets -600.0 0.0
  /SYSTEM     projection              - ! system for SKY offsets
  /TCALIBRATE 5.0                      ! time per calibration subscan
!
PAUSE "CALIBRATE OK to start? [c/q]" ! a chance to check
!
START                                ! start
!
!!                                    ! OPTIONAL:
!! OFFSETS  20 30                    - ! mapping offsets in
!! /SYSTEM projection                ! system projection
!
ONOFF  /SWWOBBLER                    - ! ONOFF for Wobbler switching
  /NSUBSCANS 12                      - ! number of subscans
  /SYMMETRIC                          - ! "symmetric" subscan sequence
  /TSUBSCAN   30                      ! time per subscan
!
PAUSE "ONOFF SWWOBBLER OK to start? [c/q]" ! a chance to check
!

```

```

START                                ! start
!
!! Comments:
!! we assume here that the source already has been selected,
!! see: demo-source
!!
!! IMPORTANT NOTE: ONOFF with SWWOBBLER (wobbler switching on-off)
!! requires that the subscans are offset relative to the source
!! in the trueHorizon system by -1 * the Wobbler elongations (offsets).
!! With the commands above, paKo recognizes this and automatically
!! sets the correct values.
!! In this case, OFFSETS can be used to set additional mapping
!! offsets in the "projection" of the astronomical coordinate
!! system. These mapping offsets in the projection apply
!! to all ONOFF subscans.

```

## 7.11 OTFMAP

OTFMAP xStart yStart xEnd yEnd

Specify an On-The-Fly (OTF) map with linear OTF subscans.

Real	:: xStart	! x-offset of start of first OTF	subscan
Real	:: yStart	! y-offset of start of first OTF	subscan
Real	:: xEnd	! x-offset of end of first OTF	subscan
Real	:: yEnd	! y-offset of end of first OTF	subscan

The sequence of subscans is determined by:

/croLoop /nOtf /reference /step /zigzag

/croLoop	sequence of:
	R off-source Reference
	O on-source OTF
/nOtf	number of OTF subscans
/reference	off-source reference position
/step	step in x and y between OTF subscans
	= translation of one OTF subscans to the next
/zigzag	option to scan back-and-forth

The scan analysis loops through the letter codes in croLoop until nOtf OTF subscans have been generated, starting with first letter in the croLoop.

IF THE CROCODE LETTER IS "R" AND /REFERENCE IS TRUE:

1 subscan tracking the fixed off-source reference position  
is generated

IF THE CROCODE LETTER IS "O":

1 linear OTF subscan is generated.

- The start and end positions of the first OTF subscan are:  
parameters xStart yStart xEnd yEnd of the OTFMAP command
- For the second and all following OTF subscans:  
xStart yStart xEnd yEnd of the previous OTF subscan are  
incremented by parameters dx and dy of option /step.  
If /zigzag is true, xStart yStart and xEnd yEnd are  
interchanged.

Then the next letter code in the croLoop is considered  
in the same way.

If /reference is true, a croCode ending in "R" will ensure that an  
off-source reference subscan follows the last OTF subscan.

/CROLOOP croLoop

sequence of R = off-source Reference  
0 = On-source subscans

Character :: croLoop

Example:  
/croLoop R00R

/NOTF nOtf

Integer :: nOtf ! number of OTF (on-the-fly) subscans

/REFERENCE xOffsetR yOffsetR [systemNameRef]  
or  
/REFERENCE NO ! no reference

position of off-source reference subscans

Real :: xOffsetR ! x-offset  
Real :: yOffsetR ! y-offset  
Character :: systemNameRef ! name of system  
! see /SYSTEM for choices

NOTE: with the usage /REFERENCE xOffsetR yOffsetR, both parameters are requi  
but you can replace either parameter with \* to leave it unchanged.

/STEP dx dy

Step (shift or translation) between lines in a map.

Real :: dx ! shift in x-offsets  
Real :: dy ! shift in y-offsets

/SYSTEM systemName

Name of system for offsets.

Character :: systemName ! name of system, one of:

```

                                ! PROJECTION
                                ! TRUEHORIZON
                                ! NASMYTH

<<TBD:                        ! DESCRIPTIVE>>
<<TBD:                        ! BASIS>>
<<TBD:                        ! EQUATORIAL>>
<<TBD:                        ! HADECL>>
<<TBD:                        ! HORIZONTAL>>

```

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

```

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM projection,
OFFSETS ... /SYSTEM projection is ignored (not used).
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...)
is in /SYSTEM trueHorizon,
OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

```

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

```

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako,
the values xOffset yOffset are used during the observations.
(this includes the case that they are explicitly set to 0.0).
It is up to the observer to make sure that they are "correct".
(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

```

```

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified
(cleared), for the MAMBO bolometer, Nasmyth offsets are used
automatically according to the selected bolometer channel (pixel).

```

### 7.11.1 OTFMAP /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.



**7.11.2 OTFMAP /CROLOOP**

/CROLOOP croLoop

sequence of R = off-source Reference  
 0 = On-source subscans

Character :: croLoop

Example:

/croLoop R00R

**7.11.3 OTFMAP /NOTF**

/NOTF nOtf

Integer :: nOtf ! number of OTF (on-the-fly) subscans

**7.11.4 OTFMAP /REFERENCE**

/REFERENCE xOffsetR yOffsetR [systemNameRef]

or

/REFERENCE NO ! no reference

position of off-source reference subscans

Real :: xOffsetR ! x-offset

Real :: yOffsetR ! y-offset

Character :: systemNameRef ! name of system

! see /SYSTEM for choices

NOTE: with the usage /REFERENCE xOffsetR yOffsetR, both parameters are required but you can replace either parameter with \* to leave it unchanged.

**7.11.5 OTFMAP /STEP**

/STEP dx dy

Step (shift or translation) between lines in a map.

Real :: dx ! shift in x-offsets

Real :: dy ! shift in y-offsets

**7.11.6 OTFMAP /SPEED**

/SPEED speed1 [speed2]

speed of OTF subscans

Real :: speed1 ! speed at start

Real :: speed2 ! speed at end

For OTFMAP speed2 = speed1.

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

### 7.11.7 OTFMAP /SYSTEM

/SYSTEM systemName

Name of system for offsets.

Character :: systemName           ! name of system, one of:  
                                      ! PROJECTION  
                                      ! TRUEHORIZON  
                                      ! NASMYTH

<<TBD:                               ! DESCRIPTIVE>>  
 <<TBD:                               ! BASIS>>  
 <<TBD:                               ! EQUATORIAL>>  
 <<TBD:                               ! HADECL>>  
 <<TBD:                               ! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).  
 If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

IMPORTANT NOTE: OFFSETS    /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako, the values xOffset yOffset are used during the observations. (this includes the case that they are explicitly set to 0.0). It is up to the observer to make sure that they are "correct".

(in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified (cleared), for the MAMBO bolometer, Nasmyth offsets are used automatically according to the selected bolometer channel (pixel).

### 7.11.8 OTFMAP /TOTF

/TOTF tOtf

time per OTF subscan or segment

Real        :: tOtf                    ! time

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

### 7.11.9 OTFMAP /TREFERENCE

/TREFERENCE tReference

time per off-source reference

Real        :: tReference            ! time

### 7.11.10 OTFMAP /ZIGZAG

/ZIGZAG [yes|no]

alternate direction between lines in a map

Logical     :: doZigzag

### 7.11.11 OTFMAP /TUNE

/TUNE xOffsetT yOffsetT

or

/TUNE NO                            ! no tune subscan

Tune subscan at the specified offsets, before any other subscans.

Real        :: xOffsetT              ! x-offset for tune subscan

Real        :: yOffsetT              ! y-offset for tune subscan

NOTE: with the usage /TUNE xOffsetT yOffsetT, both parameters are required, but you can replace either parameter with \* to leave it unchanged.

The offsets for the tune subscan are in the system selected with /SYSTEM.

## 7.11.12 OTFMAP /TTUNE

```
/TTUNE tTune
```

```
time per TUNE subscan
```

```
Real      :: tTune      ! time
```

## 7.11.13 OTFMAP EXAMPLES

```
!
! Id: demo-otfmap.pako
!   OTFMAP SWTOTAL EXAMPLE,v 1.1.6 2011-07-21 Hans Ungerechts
!
! demo-rx-spectrometers      ! demo setup of receivers
!                             ! and spectrometers
!                             ! REPLACE WITH YOUR SETUP!
!
SET ANGLE arcsec              !
!
SWTOTAL                       - ! to select total power
/TPHASE      0.5              ! time per phase (data sample)
!
CALIBRATE                     - !
/AMBIENT                     - ! ambient load
/COLD                         - ! cold load
/SKY      -500.0 -400.0      - ! sky at offsets -500.0 -400.0
/SYSTEM      projection      - ! system for SKY offset
/TCALIBRATE  5.0             ! time per calibration subscan
!
PAUSE "CALIBRATE OK to start? [c/q]" ! a chance to check
!
START                          ! start
!
OTFMAP      -300  -15  300  -15 - ! offsets at start and end of f
/CROLOOP      ROR                - ! subscans: reference-OTF-refer
/NOTF      4                    - ! number of on-the-fly subscans
/REFERENCE  -500 -400 projection - ! offsets of off-source referen
/STEP      0  10                - ! step (shift) between OTF subs
/SYSTEM      projection          - ! system for offsets
/TOTF      120.0                - ! time per on-the-fly subscan
/TREFERENCE  20.0                - ! time per off-source reference
/ZIGZAG                                ! go back and forth
!
PAUSE "OTFMAP SWTOTAL OK to start? [c/q]" ! a chance to check
!
START                          ! start
!
!! Comments:
!! we assume here that the source already has been selected,
!! see: demo-source
!!
```

```

!! /CROLOOP      ROR means that there will be an
!!               off-source reference subscan (R)
!!               before and after each OTF suscan (0).
!!               Therefore with /NOTF 4 on-the-fly subscans the complete
!!               subscan sequence will be:
!!               R OTF#1 R   R OTF#2 R   R OTF#3 R   R OTF#4 R
!!               with
!! /CROLOOP      ROOROR it would be:
!!               R OTF#1      OTF#2   R   OTF#3      OTF#4 R
!
!
! Id: demo-otfmap-swfrequency.pako
!   OTFMAP SWFREQUENCY EXAMPLE,v 1.1.11 2011-11-25 Hans Ungerechts
!
@ demo-rx                      ! demo setup of receivers
!
BACKEND /CLEAR                  ! clear previous backends
BACKEND VESPA 1 0.040 40.0 0.0 E090 hor LI ! high spectral resolution
BACKEND VESPA 2 0.040 40.0 0.0 E090 ver LI ! with VESPA
BACKEND VESPA 3 0.080 80.0 0.0 E230 hor LI
BACKEND VESPA 4 0.080 80.0 0.0 E230 ver LI
!                                ! REPLACE WITH YOUR SETUP!
!
SET ANGLE arcsec               !
!
!                                ! setup frequency switching
SWFREQUENCY  -3.9      3.9 /receiver E090 ! for EMIR band E090
SWFREQUENCY  -11.7     11.7 /receiver E230 ! for EMIR band E230
SWFREQUENCY                      /tphase 0.20 ! same for all receivers/bands
!
CALIBRATE                      - !
  /AMBIENT                      - ! ambient load
  /COLD                         - ! cold   load
  /SKY      -600.0   0.0        - ! sky at offsets -600.0 0.0
  /SYSTEM      projection        - ! system for offset
  /TCALIBRATE  5.0              ! time per calibration subscan
!
PAUSE "CALIBRATE OK to start? [c/q]" ! a chance to check
!
START                            ! start
!
OTFMAP      -300  -300  300 -300    - ! offsets at start and end of f
  /CROLOOP      0                    - ! only OTF subscans
  /NOTF         4                    - ! number of on-the-fly subscans
  /REFERENCE    no                   - ! no off-source reference subsc
  /STEP         0    10              - ! step (shift) between OTF subs
  /SYSTEM      projection            - ! system for offset
  /TOTF        120.0                 - ! time per on-the-fly subscan
  /ZIGZAG                          ! go back and forth
!
PAUSE "OTFMAP SWFREQUENCY OK to start? [c/q]" ! a chance to check
!
START                            ! start
!

```

```
!! Comments:
!! we assume here that the source already has been selected,
!! see: demo-source
```

## 7.12 POINTING

POINTING length

Specify a pointing measurement with linear OTF subscans in the "true-angle" horizontal system, along azimuth and elevation, all centered on the source.

```
Real      :: length          ! length (angle) of each subscan
```

The first subscan is incrementing in azimuth. If the number of OTF subscans, nOtf, is 2, the second subscan is incrementing in elevation. If nOtf > 2, the subscan sequence is: incrementing azimuth, decrementing azimuth, incrementing elevation, and if nOtf > 3: decrementing elevation, etc.

### 7.12.1 POINTING /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.

### 7.12.2 POINTING /DOUBLEBEAM

```
/DOUBLEBEAM [yes|no]
```

Pointing: do a "double-beam" pointing

```
Logical    :: doDoubleBeam
```

This is valid only for pointing with Wobbler switching (SWWOBBLER).

This option has an effect only if SET 2nRotation 0.0

### 7.12.3 POINTING /NOTF

```
/NOTF nOtf
```

```
Integer    :: nOtf          ! number of OTF (on-the-fly) subscans
```

#### 7.12.4 POINTING /TOTF

/TOTF t0tf

time per OTF subscan or segment

$$\text{Real} \quad :: \quad \text{t0tf} \quad ! \quad \text{time}$$

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

### 7.12.5 POINTING /TUNE

```
/TUNE xOffsetT yOffsetT
```

or

```

/TUNE NO                                ! no tune subscan

```

Tune subscan at the specified offsets, before any other subscans.

```
Real      :: xOffsetT      ! x-offset for tune subscan
```

```
Real      :: yOffsetT      ! y-offset for tune subscan
```

NOTE: with the usage /TUNE xOffsetT yOffsetT, both parameters are required, but you can replace either parameter with \* to leave it unchanged.

For POINTING, the offsets for the tune subscan are in the "trueHorizontal" system.

### 7.12.6 POINTING /TTUNE

```
/TTUNE  tTune
```

time per TUNE subscan

```
Real      :: tTune      ! time
```

### 7.12.7 POINTING EXAMPLES

```

!
! Id: demo-pointing.pako
!   POINTING EXAMPLE,v 1.1.11 2011-11-25 Hans Ungerechts
!
SOURCE    Mars
OFFSETS /CLEAR
!
! clear previously set offsets
!
@ demo-rx
!
! demo setup of EMIR
!
! REPLACE WITH YOUR SETUP!
!
BACKEND /CLEAR
!
! clear previous backend setup
!

```

```

BACKEND BBC          /Default          ! connect 1 part to each
!                                     ! EMIR subband selected
!
SET ANGLEUNIT arcsec          ! make sure angle unit is arc s
!
SWBEAM                  ! to select beam switching
!
POINTING /DEFAULT          ! reset all options
!
POINTING      120          - ! pointing with subscan length
    /NOTF      4          - ! 4 OTF subscans
    /TOTF      30.0       ! 30 seconds per OTF subscan
!
PAUSE "POINTING OK to start? [c/q]"    ! a chance to check
!
START                                ! start
!
RETURN
!
!!
!! NOTE:
!! if you use NASMYTH offsets for an off-center pixel
!! of a mutlibeam receiver don't use OFFSETS/ CLEAR.
!! If you want the intensity of the Pointing data to be
!! calibrated, you have to do a Calibrate with the same
!! receivers and (continuum) backends before the pointing.
!!

```

### 7.13 RECEIVER

RECEIVER	receiverBand	lineName [frequency SB]
RECEIVER BOLOMETER	bolometerName	[pixel]

Specify selection and setup for receivers.

The first form is for heterodyne receivers,  
the second form for bolometers.

Heterodyne:  
=====

[illegible]



! choices for EMIR: LO LI UI UO

Choices for receiverBand are:

E090 E150 E230 E330 HERA1 HERA2

lineName is limited to 12 characters.

NB: Don't use / & < > in names of sources, lines, projects,  
PI, observer, operator, etc. Don't use ()/ in source names.

E090 E150 E230 E330 are the 4 EMIR (Eight MIXer Receiver) bands,  
HERA1 and HERA2 are the 2 parts of HERA (HEterodyne Receiver Array).

If only receiverBand and lineName are specified, we try to read the  
frequency and sideband/subband from the line catalog specified with:  
CATALOG LINE fileName.

The local oscillator for the receiverBand will be set so that the  
frequency (corrected for the Doppler shift) will be in the requested  
sideband/subband SB. See receiver documentation for the exact values  
of the IF.

NOTE: EMIR subbands, IF cables, and Backends

The output signals from EMIR are transmitted to the spectrometers and  
NBC through 8 IF cables. Each IF cable carries one subband of bandwidth  
4 GHz. This subbands are LO, LI, UI, or UO.

NBC, 4MHz, WILMA, and VESPA can only(!) be connected to IF cables 1 to 4.  
FTS parts 1 to 4 can also be connected to IF cables 1 to 4.

The command options RECEIVER /HORIZONTAL and RECEIVER /VERTICAL allow  
to select up to 4 EMIR subbands that will be transmitted through IF  
cables 1 to 4 (compare HELP RECEIVER /HORIZONTAL and the EMIR user  
documentation). This selection can include Outer subbands.

In addition, the IF cables 5 to 8 carry the 4 Outer subbands  
corresponding to the subbands selected for IF cables 1 to 4. E.g., if  
we select for IF 1 to 4:

E230 ver UO	E090 ver UI	E230 hor UI	E090 hor UI
-------------	-------------	-------------	-------------

then the IF cables 5 to 8 will transmit:

E230 ver UO	E090 ver UO	E230 hor UO	E090 hor UO.
-------------	-------------	-------------	--------------

Only FTS parts 5 to 8 can be connected to IF cables 5 to 8.

BACKEND NBC|WILMA|FTS /DEFAULT will automatically set the maximum  
number of backend parts for all available subbands.

BACKEND BBC is completely independant of the sub band selections for  
the IF cables.

Bolometer:

=====

```
RECEIVER BOLOMETER    bolometerName    [pixel]
RECEIVER BOLOMETER    GISMO
RECEIVER BOLOMETER    NIKA              [pixel]
```

```
Character :: bolometerName    ! name of bolometer
Integer   :: pixel            ! number of NIKA pixel
```

Choices for bolometerName are:  
GISMO NIKA

If the pixel number is specified with RECEIVER BOLOMETER NIKA, pako will try to find and use the Nasmyth offsets for this pixel in a corresponding configuration file.

However, if Nasmyth offsets are explicitly specified with OFFSETS /SYSTEM Nasmyth, the values from OFFSETS take precedence over any values found for a NIKA pixel.

### 7.13.1 RECEIVER /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.

### 7.13.2 RECEIVER /CLEAR

```
/CLEAR [yes|no]
```

Completely clear a list of connected hardware, e.g., receivers, backends, or parameters of the associated command.

### 7.13.3 RECEIVER /CONNECT

```
/CONNECT [yes|no]
```

connect (or disconnect) the specified hardware, e.g., backend or backend part.

--> DEPRECATED. PROTECTED (needs SET userLevel)

### 7.13.4 RECEIVER /DEROTATOR

```
/DEROTATOR angle system
```

Specify derotator angle for HERA

```
Real      :: angle          ! in units [deg] (!)
Character :: system         !
```

Choices for system:

```
"Nasmyth"
"horizon"
"equatorial"
"frame"      ! same as Nasmyth
"sky"        ! same as equatorial
```

NOTES: The last 2 are for consistency with old control system and HERA convey  
This option works only for RECEIVER HERA1 or RECEIVER HERA2 (of course it's  
same angle for HERA1 and HERA2).

### 7.13.5 RECEIVER /DISCONNECT

/DISCONNECT

disconnect the specified hardware, e.g.,  
backend or backend part.

--> DEPRECATED. PROTECTED (needs SET userLevel)

### 7.13.6 RECEIVER /DOPPLER

/DOPPLER doppler

```
Character :: doppler      ! apply doppler correction?
                        ! choices: DOPPLER|FIXED
```

### 7.13.7 RECEIVER /EFFICIENCY

/EFFICIENCY forwardEfficiency beamEfficiency

specify forward and beam efficiencies

```
Real      :: forwardEfficiency !
Real      :: beamEfficiency    !
```

### 7.13.8 RECEIVER /GAINIMAGE

/GAINIMAGE gainImage [dB]

Specify the gain ratio of image to signal sidebands.

Real        :: gainImage        !

If "dB" is added after the value, the ratio is assumed to be in dB, otherwise a decimal fraction.

--> A standard value for EMIR is -13 db, for HERA -10 db.

### 7.13.9 RECEIVER /HORIZONTAL

/HORIZONTAL [sb1 [sb2]]  
/HORIZONTAL n[one]

EMIR subbands for Horizontal polarization.

This option applies only to EMIR.

Character    :: sb1, sb2    ! for EMIR: LO|LI|UI|UO

This option selects which EMIR subband(s) of this polarization will be transmitted through IF cables 1 to 4. Note that some backends, NBC, 4MHz, WILMA, VESPA, can only be connected to IF cables 1 to 4, i.e., only to the EMIR subbands selected with the RECEIVER command.

For each EMIR band and polarization, at most 2 subbands can be transmitted through IF cables 1 to 4. Which combinations of EMIR bands, polarizations, and subbands are possible is determined by the hardware of the EMIR IF switching box. See the EMIR documentation for details.

If no subband is explicitly specified with this option, paKo will assume that for this polarization the same single subband SB is requested as specified for the main parameters (frequency, tuning) of the RECEIVER command for this EMIR band.

/HORIZONTAL n[one] means that from this polarization no subband will be transported through IF cables 1 to 4.

### 7.13.10 RECEIVER /SCALE

/SCALE scale

Select the calibration intensity scale.

Character :: scale        ! choices: ANTENNA|BEAM

If scale is "ANTENNA", the scale is antenna temperature.  
If scale is "BEAM", the scale is (main) beam temperature.

**7.13.11 RECEIVER /TEMPLOAD**

```

/TEMPLOAD tempColdLoad tempAmbientLoad
/TEMPLOAD L[OOKUP]      L[OOKUP]
/TEMPLOAD *              ...

```

Set effective temperatures for the calibration loads at cold and ambient temperature.

```

Real      :: tempColdLoad      !
Real      :: tempAmbientLoad   !

```

NEW LOGIC FOR SINGLE-PIXEL SIS RECEIVERS (FROM SUMMER 2007, paKo v1.0.7)

If a numerical value is entered for tempColdLoad or tempAmbientLoad, that value is used for calibration calculations.

Instead of specifying a value one may enter the string L(OOKUP) for tempColdLoad and/or tempAmbientLoad. This is shown in the pakoDisplay by the letter "L" instead of a number.

In this case, during the execution of the observations, the NCS will use measured values for the corresponding load temperature(s).

A \* can be substituted for tempColdLoad, which means to leave the value for tempColdLoad unchanged from the previous RECEIVER command.

NOTE: FOR HERA

measured values are always used during the execution of the observations. This is the same logic as in older versions of paKo/NCS.

**7.13.12 RECEIVER /VERTICAL**

```

/VERTICAL [sb1 [sb2]]
/VERTICAL n[one]

```

EMIR subbands for Vertical polarization

This option applies only to EMIR.

```

Character  :: sb1, sb2      ! for EMIR: L0|LI|UI|U0

```

This option selects which EMIR subband(s) of this polarization will be transmitted through IF cables 1 to 4. Note that some backends, NBC,

4MHz, WILMA, VESPA, can only be connected to IF cables 1 to 4, i.e., only to the EMIR subbands selected with the RECEIVER command.

For each EMIR band and polarization, at most 2 subbands can be transmitted through IF cables 1 to 4. Which combinations of EMIR bands, polarizations, and subbands are possible is determined by the hardware of the EMIR IF switching box. See the EMIR documentation for details.

If no subband is explicitly specified with this option, paKo will assume that for this polarization the same single subband SB is requested as specified for the main parameters (frequency, tuning) of the RECEIVER command for this EMIR band.

/VERTICAL n[one] means that from this polarization no subband will be transported through IF cables 1 to 4.

### 7.13.13 RECEIVER /WIDTH

/WIDTH width

Select receiver setup for WIDE or NARROW bandwidth mode.

Character :: width ! width. choices: WIDE|NARROW

NOTE: Option /WIDTH NARROW changes the (local oscillator) setup of receivers HERA1 HERA2 in such a way that a line in the center of the receiver bandwidth appears in the center of the bands of VESPA.

Spectrometers with 1GHz or more bandwidth normally require /WIDTH WIDE.

--> NOTE: THIS OPTION DOES NOT APPLY TO EMIR!

### 7.13.14 RECEIVER BOLOMETER

```
RECEIVER BOLOMETER    bolometerName    [pixel]
RECEIVER BOLOMETER    GISMO
RECEIVER BOLOMETER    NIKA              [pixel]
```

Character :: bolometerName ! name of bolometer  
Integer :: pixel ! number of NIKA pixel

Choices for bolometerName are:  
GISMO NIKA

If the pixel number is specified with RECEIVER BOLOMETER NIKA, paKo will try to find and use the Nasmyth offsets for this pixel in a

coresponding configuration file.

However, if Nasmyth offsets are explicitly specified with  
OFFSETS /SYSTEM Nasmyth, the values from OFFSETS take precedence over  
any values found for a NIKA pixel.

### 7.13.15 RECEIVER EXAMPLES

```

!
! Id: demo-receiver.pako
!      basic RECEIVER EXAMPLES,v 1.1.15 2013-10-14 Hans Ungerechts
!
CATALOG line    demo-EMIR.lin      ! specify line catalog
!
RECEIVER /CLEAR                      ! clear all receivers previously set
!
say                                " !    --> E090 band from catalog
receiver /clear
RECEIVER E090   12C0(1-0)           - ! line (frequency, subband U0 from catalo
                  /Horizontal        - ! subband from catalog
                  /Vertical          ! subband from catalog
say                                " ! NOTE: E090 band from catalog
pause
!
say                                " !    --> E090 band USB Outer subband
receiver /clear
REC E090 12C0(1-0) 115.271204 U0 - ! line frequency and subband explicit
                  /Horizontal U0    - ! USB Outer subband explicit
                  /Vertical   U0     ! USB Outer subband explicit
say                                " ! NOTE: E090 H&V   U0   4 GHz BW
pause
!
!
say                                " !    --> E090+E150 bands LSB dual polariz.
receiver /clear
RECEIVER E090   HCN(1-0)           - !
                  /Hor              LI - ! LSB Inner subband
                  /Ver              LI  ! LSB Inner subband
RECEIVER E150   CS(3-2)            - !
                  /H                LI - ! LSB Inner subband
                  /V                LI  ! LSB Inner subband
say                                " ! NOTE: E090 H+V LI      4 GHz BW
say                                " !           E150 H+V LI      4 GHz BW
say                                " !    ++  E090 H+V L0      4 GHz BW for FTS
say                                " !    ++  E150 H+V L0      4 GHz BW for FTS
pause
!
!
say                                " !    --> E090+E230 bands LSB dual polariz.
receiver /clear
RECEIVER E090   HCN(1-0)           - !
                  /Horizontal LI    - !
                  /Vertical   LI     !

```

```

RECEIVER E230 12C0(2-1) - !
                  /Horizontal LI - !
                  /Vertical LI !
say              " ! NOTE: E090 H+V LI      4 GHz BW
say              " !      E230 H+V LI      4 GHz BW
say              " ! ++ E090 H+V L0      4 GHz BW for FTS
say              " ! ++ E230 H+V L0      4 GHz BW for FTS
pause
!
!
say              " ! --> E150+E330 bands LSB dual polariz.
receiver /clear
RECEIVER E150 CS(3-2) - !
                  /H LI - !
                  /V LI !
RECEIVER E330 13C0(3-2) - !
                  /H LI - !
                  /V LI !
say              " ! NOTE: E150 H+V LI      4 GHz BW
say              " !      E330 H+V LI      4 GHz BW
say              " ! ++ E150 H+V L0      4 GHz BW for FTS
say              " ! ++ E330 H+V L0      4 GHz BW for FTS
pause
!
!!!!
!
RECEIVER /clear
say              " ! --> HERA1+HERA2 LSB
RECEIVER HERA1 12C0(2-1) 230.537990 LSB
RECEIVER HERA2 12C0(2-1) 230.537990 LSB
say              " ! NOTE: HERA1+HERA2 LSB
pause
!

```

## 7.14 SAVE

```

SAVE [commandToSave]
SAVE ALL [CORRECTIONS]
SAVE SET [CORRECTIONS]
SAVE SWITCHING

```

Save parameters and options of a command in the form of a valid .pako script.

Character :: commandToSave ! command to save

If commandToSave is not specified, the last selected observing mode is saved.

SAVE ALL saves (nearly) all current setup parameters, as well as the



current switching and observing modes, to file all.pako, or to a different file specified with /FILE.

NOTE: SAVE ALL and SAVE SET save the pointing and focus corrections only if they are used in the form

SAVE ALL C[ORRECTIONS]

SAVE SET C[ORRECTIONS]

(Normally SAVE ALL and SAVE SET are meant to generate paKo scripts that can be used to re-produce the setup at a later time, when one probably wants to use different corrections. On the other hand the idiomatic usage: SAVE ALL C /FILE LAST allows to save "really everything" in order to recover it with @ LAST)

SAVE SWITCHING saves the currently selected switching mode (total power, beam, frequency, wobblers), to file switching.pako, or to a different file specified with /FILE.

NOTE: the parameters of "unused" (unselected) hardware, switching modes, and observing modes are never saved.

#### 7.14.1 SAVE /APPEND

/APPEND [yes|no]

Append to existing file, do not create a new one.

Logical :: doAppend ! default: false

#### 7.14.2 SAVE /FILE

/FILE fileName

Specify file name.

Character :: fileName !

#### 7.14.3 SAVE EXAMPLES

```
!
! SAVE EXAMPLES v1.0.0 2005-12-19 Hans Ungerechts
!
SOURCE ...
SWFREQUENCY ...
SWTOTAL ...
ONOFF ...
OTFMAP ...
SAVE          ! saves OTFMAP          to file otfmap.pako
SAVE ALL      ! saves "everything" to file all.pako
SAVE ONOFF    ! saves ONOFF           to file onoff.pako
```

```

SAVE SOURCE      ! saves SOURCE      to file source.pako
SAVE SWITCHING   ! saves SWTOTAL     to file switching.pako
SAVE SWFREQUENCY ! saves SWFREQUENCY to file swfrequency.pako
!
```

## 7.15 SET

```
SET keyword  value [value* ...]
```

Set values for some general parameters.

```

Character      :: keyword
Character|Integer|Real :: value*
```

Keywords	Type of Value(s)	
=====	=====	
Level	Integer [Integer]	! mininum value(s) for warning and error mess
Project	Character(len=24)	! project ID
PI	Character(len=24)	! PI. Don't use & < >
Observer	Character(len=24)	! Observer(s). Don't use & < >
Operator	Character(len=24)	! Telescope operator(s). Don't use & < >
Pointing	Real Real	! Pointing corrections [arc sec]
Focus	Real	! Focus correction [mm]
Topology	Character(len=24)	! Topology for the overlapping azimuth range
2ndRotation	Real	! Rotation angle for Secondary and Wobbler
Comment	Character(len=128)	! Purpose. Don't use & < >
Purpose	Character(len=24)	! Purpose. Don't use & < >
EMIRcheck	Character	! "strict" "relaxed" "loose"
doSubmit	Logical	! turn submission of jobs to queue on or off

NB: Don't use / & < > in names of sources, lines, projects, PI, observer, operator, etc. Don't use ()/ in source names.

In order to include blank characters in a value of type Character, the complete value should be included in " ", see example: SET Observer below.

Only a few of these parameters are shown in the Display. Use command SHOW to list (nearly) all of them.

### 7.15.1 SET COMMENT

```
SET COMMENT comment
SET COMMENT ""
```

Comment      Character(len=128) ! Comment. Don't use & < >

Set comment for an observation. The value of "comment" is displayed in the monSDH display during the execution of each scan, and logged in the iram30m-scan-\*.xml files.

```
SET COMMENT ""
clears the comment.
```

NOTE: SET COMMENT can use values of variables, e.g.,  
if 'ii' = 11 and 'imax' = 33 are variables in a loop:  
PAKO> set comment " loop "'ii'" of "'imax'" executing "  
I-SET, Comment has been set to: loop 11 of 33 executing  
PAKO> start

Then "loop 11 of 33 executing" will be shown in the monSDH when the scan is executed.

### 7.15.2 SET DOSUBMIT

```
SET DOSUBMIT YES|NO
```

Logical :: doSubmit

Turn submission of jobs to observing queue on or off. (compare command START).

IMPORTANT NOTE: to avoid any possible confusion, in each project account at the 30-m telescope, only 1 running instance of Pako should have SET DOSUBMIT YES!

### 7.15.3 SET FOCUS

```
SET FOCUS focus
```

Real :: focus                      ! focus correction [mm]

Set focus correction in [mm]

### 7.15.4 SET LEVEL

```
SET LEVEL minimalForStandardOut [ minimalForFile ]
```

```
Integer :: minimalForStandardOut ! in range 0 to 9
```

```
Integer :: minimalForFile        ! in range 0 to 9
```

Set minimal "level" for paKo "messages" to be written

1: interactively to the standard output, i.e., the terminal window

2: to the message log file pako.mes.

All paKo "messages" have an associated severity number. With SET LEVEL we can select that only messages with severity higher than minimalForStandardOut (minimalForFile) are written. Very serious messages with severity 9 and higher can NOT be turned off.

The severity number for messages of kind:

```
I   is 1 or 2           Informational message
```

```
W   is 3 or 4           Warning      message
```

```
E   is 5 or 6           Error        message
```

```
F   is 7 or higher      Fatal Error  message
```

Example: SET LEVEL 5 3

Has the effect that "I" messages are not shown at all, and only "E" and "F" messages are shown in the terminal window.

### 7.15.5 SET POINTING

```
SET POINTING azimuthCorrection [elevationCorrection]
```

```
Real :: azimuthCorrection ! [arc sec]
```

```
Real :: elevationCorrection ! [arc sec]
```

Set pointing corrections in units of [arc sec]

\* in place of a number: leave the value unchanged

Example:

```
SET POINTING 1.1 2.2
```

### 7.15.6 SET PURPOSE

```
SET PURPOSE purpose
```

```
SET PURPOSE ""
```

Purpose Character(len=24) ! Purpose. Don't use & < >

Choices for purpose are:

```
CALIBRATE FOCUS MAP POINTING TIP
```

Set purpose for an observation. The value of "purpose" is displayed in the monSDH display during the execution of each scan, and logged in the iram30m-scan-\*.xml files. It may also be used elsewhere, e.g., in data handling software.

```
SET PURPOSE ""
clears the purpose.
```

### 7.15.7 SET 2NDROTATION

```
SET 2ndRotation rotation
```

```
Real :: rotation          ! rotation angle [deg]
```

Set rotation angle for the secondary mirror and Wobbler mechanism [deg].

The angle is limited to be between -50 and +50 [deg].

NOTE: Its sense is opposite to the mathematical convention!  
(this will be changed in a future release of the NCS.)

The rotation angle is relative to the horizontal system. A value of 0.0 corresponds to the Wobbler switching purely in Azimuth, i.e., "normal" Wobbler switching.

Observers must inform the operator if they want to use this feature.

A non-zero values is up to know only meaningful and supported for bolometer observations with Wobbler switching and the observing modes: POINTING, FOCUS, and OTFMAP. The OTF map must be set to be in the (true-angle) horizontal system and the direction of the OTF subscans must agree with that of the 2ndRotation. (There is a special pako script available in the bolometer pool to do this).

To avoid un-intentional errors, this feature can only be used by "privileged users": ask the AOD or the NCS team.

### 7.15.8 SET TOPOLOGY

```
SET TOPOLOGY topology
```

```
topology    Character(len=24) ! Topology for the overlapping azimuth range
```

Choices for topology are:  
LOW HIGH

Select a "topology" for sources in the overlapping azimuth range  
60 to 100 degrees = 420 to 460 degrees.

The 30m antenna has azimuth limits of 60 and 460 degrees. Azimuth 360

degrees is due North. Therefore there is an overlap range approximately toward East-Northeast, which the antenna can reach at a low azimuth 60 to 100 (from the South) or at a high azimuth 420 to 460 (from the North).

SET TOPOLOGY LOW selects to use the azimuth range 60 to 420 degrees  
SET TOPOLOGY HIGH selects to use the azimuth range 100 to 460 degrees

Note: this is shown in a figure in paKo's manual,  
Section "NCS Explained: Azimuth Topology".

### 7.15.9 SET EMIRCHECK

SET EMIRcheck emirCheck

emirCheck Character !

Choices for emirCheck are:

"strict"|"relaxed"|"loose"

Make the checking of frequency limits less than strict. This allows to command frequencies that are completely outside the designed and tested range of the receiver bands.

The standard and recommended limit checking corresponds to "strict".

THIS MUST BE USED CAREFULLY AND ONLY IN CONSULTATION WITH STAFF  
ASTRONOMERS OR ENGINEERS.

### 7.15.10 SET LIMITCHECK

SET LIMITCHECK limitCheck

limitCheck Character(len=24) !

Choices for limitCheck are:

"strict"|"relaxed"|"loose"

Make the checking of some limits less than strict.

The standard and recommended limit checking corresponds to "strict".

THIS MUST BE USED CAREFULLY AND ONLY IN CONSULTATION WITH STAFF  
ASTRONOMERS OR ENGINEERS.

NB: this is a protected command (needs privilege).

### 7.15.11 SET USERLEVEL

SET USERLEVEL userLevel

userLevel Character(len=24) !

Choices for userLevel are:

"beginner"|"normal"|"experienced"

Sets level of user's experience with paKo and the NCS. Some features, that require special care, are only available if userLevel is set to a higher level.

### 7.15.12 SET EXAMPLES

```
!
! Id: demo-set.pako
!   basic SET EXAMPLES, v 1.1.1 2009-05-18 Hans Ungerechts
!
SIC PRIORITY 1 PAKO                ! PAKO commands get precedence
!                                ! over similar GREG commans!
!
SET Project    111-22                ! project ID (project number)
SET PI         "Dr. Lilo D. Doe"      ! principal investigator
SET Observer   "John Doe"            !
SET Operator   Pako                  !
SET Topology    low                  ! topology for azimuth
!
SET Level      3 3                   ! suppress informational message
!                                ! ("I-messages") from paKo
!
DEVICE image w                       ! for plots
!
SHOW                                           ! show the values set with set
!
!! NOTE: don't use special characters like <, >, &, accents in the names!
!!
!
! Id: demo-set2.pako
!   additional SET EXAMPLES, v 1.1.1 2009-05-08 Hans Ungerechts
!
!! SET doSubmit   YES                ! to allow submission to Queue
!
SET Pointing     -1.1 2.2            ! pointing corrections
SET Focus        -2.3                ! focus correction      [mm]
```

```

!
SHOW                                     ! show the values set with set
!

```

## 7.16 SHOW

SHOW

List all parameters that can be set with command SET,  
as well as their current values.

## 7.17 SOURCE

```

SOURCE sourceName
    [[systemName epoch] lambda beta
    [referenceFrame velocity    ] ]
SOURCE Body sourceName
    perihelionEpoch ascendingNode      argumentOfPerihelion
    inclination      perihelionDistance eccentricity

```

Select a source from the source catalog or specify source parameters  
directly on command the line.

```

Character*12  :: sourceName      ! don't use: & < > ( ) /
Character     :: systemName      !
[C]Real       :: epoch           ! in units [years]
                                   ! NOTE: epoch should be J2000.0
Coordinate    :: lambda          ! longitude
Coordinate    :: beta           ! latitude
Character     :: referenceFrame  ! reference system for velocity
Real          :: velocity        ! in units [km/s]

```

IMPORTANT NOTES:

sourceName is limited to 12 characters.

So far only Equatorial J2000.0 coordinates are well tested.

<<TBD:

Observations of the Sun and near the Sun are not yet supported.

>>

NB: Don't use / & < > in names of sources, lines, projects,  
PI, observer, operator, etc. Don't use ()/ in source names.

IMPORTANT NOTE ON VELOCITY:



One should not use very large Doppler velocities (thousands of kilometers) to achieve red-shift corrections of frequencies. Instead one should enter the red-shifted frequencies in the line catalog (or with the RECEIVER command) and use Doppler velocity of 0.0.

The alternative approach (with very large Doppler velocities) needs special methods and attention in the data processing, which are *"not"* implemented in CLASS because it is better to observe in such a way that minimum modification to the data is done later on" (J. Pety). For a full discussion of this question see: Gordon et al. 1992, A&A, 264, 337 in Sect. 6

The second form accepts 6 Real arguments to specify the orbital elements of a solar system body:

```
Body                ! special keyword -- exactly like this!
Real      :: perihelionEpoch      ! Julian Date [d]
Real      :: ascendingNode        ! [deg]
Real      :: argumentOfPerihelion ! [deg]
Real      :: inclination          ! [deg]
Real      :: perihelionDistance   ! [deg]
Real      :: eccentricity         !
```

If only sourceName is specified, we try to read the other parameters from the source catalog specified with CATALOG SOURCE fileName. The sourceName in the command must match a source name in the source catalog with all characters (no minimum match), but the case is ignored for the matching. Example: SOURCE w3oh matches W3OH in the source catalog, but SOURCE w3o does not!

The option: /VELOCITY systemVelocity velocity overrides the values in the catalog.

Epoch can optionally start with a 1-character code "J" or "B" to distinguish between "J" and "B" epochs/ equatorial coordinates. (If this code letter is not present, "J" is implied!).

The coordinates are specified in astronomical sexagesimal format: with : as field separator, i.e.:

```
hh:mm:ss.ss
ddd:':":'."
```

Examples:

```
12:34:56.78 for 12 hours, 34 minutes, 56.78 seconds
123:45:67.89 for 123 degrees, 45 arc minutes, 67.89 arc seconds
```

For systemName: equatorial and haDec, the longitude, lambda, is assumed to be in hours; for all other systems it is assumed to be in degrees. Latitude, beta, is always in degrees.

Choices for systemName:  
"equatorial"

"horizontal"

```
<<TBD: not yet supported:  >>
<<TBD: "galactic"          >>
<<TBD: "apparentEquatorial" >>
<<TBD: "ecliptic"          >>
<<TBD: "apparentEcliptic"  >>
<<TBD: "haDec "            >>
```

Choices for referenceFrame:

"LSR"  
"barycentric"  
"heliocentric"

```
<<TBD: not yet supported:  >>
<<TBD: "3K"                 >>
<<TBD: "galactocentric"     >>
<<TBD: "body"               >>
<<TBD: "geocentric"         >>
<<TBD: "topocentric"        >>
<<TBD: "null"               >>
```

Planets' names are accepted as a special case, if sourceName is one of:

"Mercury"  
"Venus"  
"Mars"  
"Jupiter"  
"Saturn"  
"Uranus"  
"Neptune"  
"Pluto"

Satellites' (moons') names are accepted, if sourceName is one of:

"Phobos"  
"Deimos"  
"Io"  
"Europa"  
"Ganymede"  
"Callisto"  
"Mimas"  
"Enceladus"  
"Tethys"  
"Dione"  
"Rhea"  
"Titan"  
"Hyperion"  
"Iapetus"  
"Miranda"  
"Ariel"  
"Umbriel"  
"Titania"  
"Oberon"  
"Gabriel"  
"Moon"

### 7.17.1 SOURCE /CATALOG

```
/CATALOG catalogName
/CATALOG *
```

Character :: catalogName

Allows to specify that the search (for a source) should be done in the catalog file "catalogName", instead of the catalog specified with command CATALOG. The default file extension is .sou

```
/CATALOG *
```

Implies that the search will be done in the standard pointing source catalog, iram-J2000.sou.

### 7.17.2 SOURCE /GREP

```
/GREP
```

Does a "grep" search for the (partial) source name or string in the source catalog and lists any matching lines. This search ignores the case. This is only to help the user search through a source catalog. Even if the match is unique, the source found is not selected. (re-enter the SOURCE command with the full source name!)

### 7.17.3 SOURCE /VELOCITY

```
/VELOCITY referenceFrame velocity
```

Specify reference frame and source radial velocity

```
Character :: referenceFrame    ! reference system for velocity
Real      :: velocity          ! in units [km/s]
```

Choices for referenceFrame:

```
"LSR"
```

```
"barycentric"
```

```
"heliocentric"
```

```
<<TBD: not yet supported: >>
```

```
<<TBD: "3K" >>
```

```
<<TBD: "galactocentric" >>
```

```
<<TBD: "body" >>
```

```
<<TBD: "geocentric" >>
```

```
<<TBD: "topocentric" >>
```

```
<<TBD: "null" >>
```

IMPORTANT NOTE ON VELOCITY:

One should not use very large Doppler velocities (thousands of kilometers) to achieve red-shift corrections of frequencies. Instead one should enter the red-shifted frequencies in the line catalog (or with the RECEIVER command) and use Doppler velocity of 0.0.

The alternative approach (with very large Doppler velocities) needs special methods and attention in the data processing, which are *"not"* implemented in CLASS because it is better to observe in such a way that minimum modification to the data is done later on" (J. Pety). For a full discussion of this question see: Gordon et al. 1992, A&A, 264, 337 in Sect. 6

#### 7.17.4 SOURCE EXAMPLES

```

!
! Id: demo-source.pako
!   basic SOURCE EXAMPLES,v 1.1.1 2009-05-08 by Hans Ungerechts
!
CATALOG SOURCE  demo.sou           ! select source catalog
!
SOURCE  NGC7027                     ! select source from catalog
!! OFFSETS /Clear                   ! optional: clear previously set off
!
PAUSE
!
!! OTHER WAYS TO SPECIFY A SOURCE:
!
SOURCE CALORI /catalog lines-J2000  ! select source from another catalog
PAUSE
!
SOURCE OCET EQ J2000 -
    02:19:20.71 -02:58:36.17 LSR 46.800 ! command-line specification of sour
PAUSE
!
SOURCE Mars                         ! planet Mars
PAUSE
!
SOURCE Moon                         ! our Moon
PAUSE
!
SOURCE Io                           ! Jupiter's satellite "Io"
PAUSE
!
SOURCE Body Pako -                  !
    2455000.0 22.2 33.3 44.4 55.5 0.66 ! solar system body (orbital element
PAUSE
!
SOURCE w3oh                         ! will match W3OH in demo.sou
!
!! NOTES: source names must match:

```

```

!!          full source name in catalog or
!!          full name of planet or satellite
!!          the case is ignored for source name matching
!
RETURN
!
```

## 7.18 START

START

Start an observation, i.e., translate its specification to XML and submit it to the observing queue.

Observing jobs are sent to the observing queue only if the observer has SET DOSUBMIT YES in paKo (see command SET DOSUBMIT) and if the operator has selected the current project to be the "current observing queue".

IMPORTANT NOTE: to avoid any possible confusion, in each project account at the 30-m telescope, only 1 running instance of Pako should have SET DOSUBMIT YES!

Example:

```

SOURCE ...
OTFMAP ...
START          ! will start and OTF map
```

## 7.19 SUBSCAN

```

SUBSCAN xOffset    yOffset
SUBSCAN xStart     yStart      xEnd      yEnd
SUBSCAN xAmplitude yAmplitude frequencyX frequencyY xCenter yCenter phiX phi
```

NB: this is a protected command (needs privilege).

Add to user-defined list of subscans and segments for observing mode "DIY"; compare command DIY. The subscan command has the 3 main variants above, depending on the number of parameters:

```

2 --> Track subscan with fixed offsets
4 --> Linear OTF segment (subscan)
8 --> Lissajous OTF segment (subscan), IMPORTANT: SEE NOTE BELOW
```

Option /TYPE allows to enforce that the command is interpreted for one

the 3 different types, independant of the number of parameters.

Option /TUNE allows to specify that a Track subscan will be used to "tune" an instrument, e.g., NIKA.

```
Real :: xOffset      ! x offset fixed-position TRACK subscan
Real :: yOffset      ! y offset fixed-position TRACK subscan

Real :: xStart       ! x offset start   of linear OTF  segment
Real :: yStart       ! y offset start   of linear OTF  segment
Real :: xEnd         ! x offset end     of linear OTF  segment
Real :: yEnd         ! y offset end     of linear OTF  segment

Real :: xAmplitude   ! x amplitude           Lissajous OTF segment
Real :: yAmplitude   ! y amplitude           Lissajous OTF segment
Real :: frequencyX   ! frequency [Hz] for x Lissajous OTF segment
Real :: frequencyY   ! frequency [Hz] for y Lissajous OTF segment
Real :: xCenter      ! x center             Lissajous OTF segment
Real :: yCenter      ! y center             Lissajous OTF segment
Real :: phiX         ! phase offset [rad] for x Lissajous OTF segment
Real :: phiY         ! phase offset [rad] for y Lissajous OTF segment
```

If an asterisk \* appears in place of any parameter, the value will remain unchanged from the last valid SUBSCAN command.

NOTES: pako will make its best effort to "guess" the values for unspecified parameters based on the values of its internal variables after the previous valid SUBSCAN command.

Each time a SUBSCAN is accepted without error message, a subscan is added to the list; even if the command is only "SUBSCAN" by itself! Be careful that a parameter in the command line can refer to different variables depending on the type of the segment/subscan, e.g., the 1st parameter can refer to xOffset, xStart, or xAmplitude.

These features should be used with special care, e.g., to experiment with the DIYLIST and SUBSCAN commands.

It is recommended to collect all SUBSCAN commands in a paKo script and explicitly specify all parameters for each subscan!

Before START of a DIY subscanlist, you can enter DIYLIST to review pako's I-DIY messages listing the subscan currently defined (this requires SET LEVEL 2 or lower), e.g.:

```
PAKO> set level 2
PAKO> diy
I-DIY, segments #: 1 to 3
I-DIY, 1 track on at -400.0 -300.0 arcsec projection 10.0 s
I-DIY, 2 onTheFly -300.0 -200.0 to 330.0 220.0 arcsec projection 66.0 s
I-DIY, 3 track on at 440.0 330.0 arcsec projection 10.0 s
```

#### IMPORTANT: LISSAJOUS OTF

During a Lissajous OTF segment, the position offsets x and y as a function of time t are:

```

x = xCenter + xAmplitude * SIN(2 Pi frequencyX t + phiX)
y = yCenter + yAmplitude * SIN(2 Pi frequencyY t + phiY)

```

SIN is the usual sine function, Pi is the number Pi.

```

xAmplitude yAmplitude xCenter yCenter are in angle units ([arc sec])
frequencyX frequencyY                are in [Hz]
phiX      phiY                      are in [rad]

```

Note that the possible frequencies are very low, typically 0.01 to 0.15 Hz.

At the start of a Lissajous subscan, paKo will insert a "ramp" along a straight line, i.e., a linear OTF segment, increasing the count of segments by 2. This ramp up starts with speed 0 relative to the source and joins smoothly with the start position and velocity of the Lissajous segment. The purpose is to avoid a sudden acceleration at the start of the Lissajous segment. Command DIY lists this inserted OTF segment as well as the Lissajous segment. The inserted ramp up segment and the Lissajous segment become part of the same subscan.

Lissajous curves with large amplitudes or frequencies can reach the antenna's speed and acceleration limits for tracking. Lissajous curves can be executed only for elevations less than a maximum, which depends on the Lissajous parameters. For information, this elevation condition is shown by pako. Even below the limits, during very fast Lissajous curves the tracking errors will be higher, several arc sec, than during most other observations.

DO NOT TRY TO OBSERVE LISSAJOUS ABOVE THIS MAXIMUM ELEVATION.

### 7.19.1 SUBSCAN /CROFLAG

```
/CROFLAG croCode
```

```

Character :: croCode    !   R = off-source Reference
                  !   0 = On-source

```

### 7.19.2 SUBSCAN /RAMP

```

/RAMP      "None"
/RAMP      "Up"      [tRampUp]
<<TBD: /RAMP      "Down"    [tRampDown]    ! not yet implemented >>

```

```
Real      :: tRamp      ! minimal time for ramp
```

```
/RAMP Up tRamp
```

/RAMP Up must be used for Lissajous subscans.

At the start of a Lissajous subscan, paKo will insert a "ramp" along a straight line, i.e., a linear OTF segment, increasing the count of segments by 2. This ramp up starts with speed 0 relative to the source and joins smoothly with the start position and velocity of the Lissajous segment. The purpose is to avoid a sudden acceleration at the start of the Lissajous segment. Command DIY lists this inserted OTF segment as well as the Lissajous segment. The inserted ramp up segment and the Lissajous segment become part of the same subscan.

Example:

```
SUBSCAN 100 200 0.01 0.02 -10 -20 0.1 0.2 /ramp up 9
```

Lissajous subscan with a ramp up of at least 9 [sec].

### 7.19.3 SUBSCAN /SYSTEM

```
/SYSTEM systemName
```

Name of system for offsets.

```
Character :: systemName      ! name of system, one of:
                             ! PROJECTION
                             ! TRUEHORIZON
```

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset. This is the system in which OTF maps with Wobbler switching and the bolometer are normally done.

### 7.19.4 SUBSCAN /TOTF

```
/TOTF t0tf
```

time per OTF subscan or segment

```
Real      :: t0tf          ! time
```

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!



NOTE: this applies to linear and Lissajous OTF subscan segments

### 7.19.5 SUBSCAN /TSUBSCAN

/TSUBSCAN tSubscan

time per subscan

Real :: tSubscan ! time

NOTE: this applies to Track subscans

### 7.19.6 SUBSCAN /TUNE

/TUNE [yes|no]

Logical :: doTune

"Tune" an instrument, e.g., NIKA.

NOTE: this applies to Track subscans. If a valid specification of a TRACK subscan is entered without the option /TUNE, "no" is implied.

### 7.19.7 SUBSCAN /TYPE

/TYPE Type

Specify segment or subscan type.

Character :: Type ! one of:  
! TRACK  
! LINEAR  
! LISSAJOUS

## 7.20 SWBEAM

SWBEAM (no parameters)

Select beam switching, i.e., switching between 2 positions on the sky using the rotating beam-switch chopper wheel. This mode is usually only used for POINTING and FOCUS with the heterodyne receivers.

## 7.21 SWFREQUENCY

SWFREQUENCY fOffset1 [fOffset2]

Select and set up frequency switching (FS).

```
Real      :: fOffset1      ! 1st frequency offset [MHz]
Real      :: fOffset2      ! 2nd frequency offset [MHz]
```

fOffset2 should be set to be = -fOffset1 (symmetric FS).  
 This is done by default, if only fOffset1 is specified.  
 (Note that then  $\text{ABS}(f\text{Offset1}) = \text{FS amplitude} = 1/2 \text{ FS throw}$ ).  
 FS with fOffset2 not equal -fOffset1 is experimental.

/RECEIVER allows to set fOffset1 and fOffset2 for each connected receiver differently.

Parameters of other options are always the same for all receivers.

Limits for fOffset1 and fOffset2 are:

```
-9 to +9   with the 3 mm receivers /bands
-18 to +18 with the 2 mm receivers /bands
-27 to +27 with the 1 mm receivers /bands
```

#### IMPORTANT NOTES about use of Frequency Switching (FS)

Frequency Switching (FS) can be very powerful and efficient for some projects, e. g., mapping of narrow spectral lines in cold dark clouds outside the plane of the Milky Way. However, before deciding to use frequency switching one should consider some potential drawbacks:

The target lines should be narrow enough so that line signals from the 2 phases of the switching cycle are well separated.

The spectral baseline will generally be less flat than in other switching modes.

Some spectral lines are also emitted in the earth's mesosphere, e.g., the mesospheric lines from (12)CO are rather strong, typically several [K], and they will be seen in FS spectra taken toward astronomical sources with a low Doppler shift. The mesospheric lines will appear at a frequency and velocity that correspond to the rest frame of the atmosphere, i. e., to good approximation, the observatory. If, e. g., you observe using Doppler corrections for the LSR scale, the mesospheric lines will appear in the spectra at  $-1 \times$  the velocity of the Local Standard of Rest relative to the observatory.

Care must be taken that mesospheric lines are not confused with the lines from the astronomical source, which will appear in the spectrum at the velocity of the source relative to the LSR. The ASTRO software can calculate the velocity of the LSR relative to the observatory for any source and time. During observations, this velocity is also displayed on one of the NCS monitoring windows.

When observing sources near the plane of the Milky Way, line emission from clouds at other velocities than the target source, e. g., other spiral arms, can cause confusion.

In case of any doubt, there is a special report on FS that gives more advice!

### 7.21.1 SWFREQUENCY /DEFAULTS

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

### 7.21.2 SWFREQUENCY /RECEIVER

/RECEIVER receiverBand

Character :: receiverBand ! receiver / EMIR band

Choices for receiverBand are:

E090 E150 E230 E330 HERA1 HERA2

### 7.21.3 SWFREQUENCY /TPHASE

/TPHASE tPhase

time per switching PHASE

Real :: tPhase ! time

### 7.21.4 SWFREQUENCY EXAMPLES

```
!
! SWFREQUENCY EXAMPLES, v1.1 2009-05-11 Hans Ungerechts
!
SWFREQUENCY           /default      ! Defaults
!
SWFREQUENCY  -3.8      3.8           ! for all receiver bands
!
SWFREQUENCY  -3.9      3.9 /receiver E090 ! for EMIR band E090
SWFREQUENCY -11.7     11.7 /receiver E230 ! for EMIR band E230
SWFREQUENCY           /tphase  0.20 ! same for all receivers/bands
!
!
! setup frequency switching
SWFREQUENCY  -3.7           /receiver E090 ! fOffset2 will be +3.7
SWFREQUENCY -11.6          /receiver E230 ! fOffset2 will be +11.6
!
```

## 7.22 SWTOTAL

SWTOTAL (no parameters)

Select total power, i.e., neither beam, frequency, nor wobbler switching. Typically used with OTFMAP with off-source references or ONOFF "position switching".

### 7.22.1 SWTOTAL /DEFAULTS

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

### 7.22.2 SWTOTAL /TPHASE

/TPHASE tPhase

time per switching PHASE

Real            :: tPhase            ! time

## 7.23 SWWOBBLER

SWWOBBLER wOffset1 [wOffset2]

Select and set up wobbler switching using the wobbling secondary mirror to switch between 2 positions on the sky. This is typically used with the observing modes POINTING, FOCUS, ONOFF, or --with the bolometer-- OTFMAP.

Real            :: wOffset1            ! 1st wobbler offset (1/2 "throw")

Real            :: wOffset2            ! 2nd wobbler offset = -wOffset1

IMPORTANT NOTE: Observers must inform the operator if they want to use this feature.

There is a relation between the maximum allowed Wobbler throw and the minimum time per phase: for large throws the switching must be slow, i.e., time per phase must be large. For /timePhase 1 [sec] or longer, any wobbler throw is allowed up to the maximum of 240 ["].

Possible combinations are, e. g.:

wOffset1	throw	timePhase
-22"	44"	0.25 sec
-22"	44"	1.0 sec
-120"	240"	1.0 sec
-120"	240"	2.0 sec

Note that for OTFMAPs with Wobbler switching, special restoration algorithms are needed to recover an image of the source brightness distribution. These are available, e. g., in the MOPSIC software.

If SWWOBBLER and ONOFF are combined in the standard way, we effectively take data at 3 positions:

1. the source position
2. the source position + throw (offset in the "true-angle" horizontal system)
3. the source position - throw (offset in the "true-angle" horizontal system)

with throw = ABS(wOffset2-wOffset1).

Data from 1. are treated as source signal, data from 2 and 3 as off-source reference signal. Note that in the astronomical coordinates, positions 2 and 3 will rotate around the source position (1). Therefore one must normally be sure that the extent of the source is less than throw-beamWidth (/2).

### 7.23.1 SWWOBBLER /DEFAULTS

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

### 7.23.2 SWWOBBLER /TPHASE

/TPHASE tPhase

time per switching PHASE

Real :: tPhase ! time

## 7.24 TIP

TIP [azimuth]

Specify an antenna tipping (a.k.a., "skydip").

```
Real      :: azimuth      ! azimuth of tip
```

If azimuth is not specified, the current azimuth of the telescope is used.

NOTE:

TIP is always and automatically done with switching mode "total power" and for bolometer observations the time per phase is fixed at 0.5 [sec]

### 7.24.1 TIP /DEFAULTS

```
/DEFAULTS [yes|no]
```

Restore default values for all parameters and options.

### 7.24.2 TIP /AIRMASS

```
/AIRMASS airmassStart [TO] airmassEnd [BY] airmassStep
```

range of airmass for TIP.

```
Real      :: airmassStart  !
Real      :: airmassEnd    !
Real      :: airmassStep   !
```

NOTE 1:  $\text{elevation} = \text{ASIN}(1/\text{airmass})$

NOTE 2: for slew-tips, TIP /SLEW:

airmassStep has no effect

airmassStart > airmassEnd is allowed; this implies:

elevation (at start) < elevation (at end), i.e.,

TIP from low to high elevation.

(for "traditional" TIP with /SLEW no, airmassStart < airmassEnd, i.e., they go from high to low elevation.)

### 7.24.3 TIP /TSUBSCAN

```
/TSUBSCAN tSubscan
```

time per subscan

```
Real      :: tSubscan      ! time
```

## 7.25 TRACK

TRACK xOffset yOffset

specify tracking of a single position

Real       :: xOffset               ! x-offset of "on-source" position  
Real       :: yOffset               ! y-offset of "on-source" position

### NOTES:

TRACK is normally used for observations with frequency switching (SWFREQUENCY); also for some special observations, e.g., of pulsars. There is a built-in limit to the time per subscan, currently (2006-07) it is 3600 seconds (1 hour). If for special purposes one needs to track a source for a longer time, this can easily be done by using several subscans.

### 7.25.1 TRACK /DEFAULTS

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

### 7.25.2 TRACK /SYSTEM

/SYSTEM systemName

Name of system for offsets.

Character :: systemName           ! name of system, one of:  
                                  ! PROJECTION  
                                  ! TRUEHORIZON  
                                  ! NASMYTH

<<TBD:                           ! DESCRIPTIVE>>  
<<TBD:                           ! BASIS>>  
<<TBD:                           ! EQUATORIAL>>  
<<TBD:                           ! HADECL>>  
<<TBD:                           ! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded

astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).  
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako, the values xOffset yOffset are used during the observations. (this includes the case that they are explicitly set to 0.0). It is up to the observer to make sure that they are "correct". (in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified (cleared), for the MAMBO bolometer, Nasmyth offsets are used automatically according to the selected bolometer channel (pixel).

### 7.25.3 TRACK /NSUBSCANS

/NSUBSCANS nSubscans

Integer :: nSubscans ! number of subscans

### 7.25.4 TRACK /TSUBSCAN

/TSUBSCAN tSubscan

time per subscan

Real :: tSubscan ! time

### 7.25.5 TRACK EXAMPLES

```
!
! Id: demo-track.pako
! TRACK EXAMPLE,v 1.1.11 2011-11-25 Hans Ungerechts
!
@ demo-rx ! demo setup of receivers
!
BACKEND /CLEAR ! clear previous backends
BACKEND VESPA 1 0.040 40.0 0.0 E090 hor LI ! high spectral resolution
BACKEND VESPA 2 0.040 40.0 0.0 E090 ver LI ! with VESPA
```



```

BACKEND VESPA 3 0.080 80.0 0.0 E230 hor LI
BACKEND VESPA 4 0.080 80.0 0.0 E230 ver LI
!
!                                     ! REPLACE WITH YOUR SETUP!
!
SET ANGLE arcsec                      !
!
!                                     ! setup frequency switching
SWFREQUENCY  -3.9      3.9  /receiver E090 ! for EMIR band E090
SWFREQUENCY  -11.7     11.7 /receiver E230 ! for EMIR band E230
SWFREQUENCY                      /tphase  0.20 ! same for all receivers/bands
!
CALIBRATE                               - !
  /AMBIENT                               - ! ambient load
  /COLD                                   - ! cold    load
  /SKY      -600.0   0.0                 - ! sky at offsets -600.0 0.0
  /SYSTEM      projection                 - ! system for SKY offsets
  /TCALIBRATE   5.0                      ! time per calibration subscan
!
PAUSE "CALIBRATE OK to start? [c/q]"    ! a chance to check
!
START                                    ! start
!
TRACK      40.0   -30.0                  - ! offsets of on position
  /NSUBSCANS  5                                - ! number of subscans
  /SYSTEM      projection                 - ! system for offset
  /TSUBSCAN    60                            ! time per subscan
!
PAUSE "TRACK SWFREQUENCY OK to start? [c/q]" ! a chance to check
!
START                                    ! start
!
!! Comments:
!! we assume here that the source already has been selected,
!! see: demo-source

```

## 7.26 VLBI

VLBI

Track a single position for VLBI.

This observing mode must not be used for other (non-VLBI) observations.

Some special behaviours are associated with the observing mode VLBI:

- The scan has only one subscan on the (fixed) source position.
  - This subscan will be executed for up to 1 hour.
- In practice it is ended, when the START command is executed for the next observation, e.g., when a new VLBI scan, or a POINTING or FOCUS

is started.

- Normally, the VLBI field system sends the commands  
SOURCE ...  
VLBI  
START  
directly to paKo, which is running in a special terminal window. The  
field system sends these commands for the next scan (immediately)  
after the VLBI data recording for the current VLBI target source  
(for the currant scan) is finished.

## 7.27 OPTIONS

SUMMARY OF OPTIONS FOR PAKO\ COMMANDS:

(For help on commands say HELP PAKO\ )

For details say, e.g., HELP OPTIONS /CROLOOP  
or: HELP OP /CRO

To see if a command has a particular option, see the end of the  
HELP for this command.

### 7.27.1 OPTIONS /AIRMASS

/AIRMASS airmassStart [TO] airmassEnd [BY] airmassStep

range of airmass for TIP.

```
Real      :: airmassStart      !
Real      :: airmassEnd        !
Real      :: airmassStep       !
```

NOTE 1: elevation = ASIN(1/airmass)

NOTE 2: for slew-tips, TIP /SLEW:  
airmassStep has no effect  
airmassStart > airmassEnd is allowed; this implies:  
elevation (at start) < elevation (at end), i.e.,  
TIP from low to high elevation.

(for "traditional" TIP with /SLEW no, airmassStart < airmassEnd,  
i.e., they go from high to low elevation.)

### 7.27.2 OPTIONS /AMBIENT

/AMBIENT [yes|no]

Do a calibration subscan on the ambient temperature load.

Logical    :: doAmbient           ! default: true

### 7.27.3 OPTIONS /APPEND

/APPEND [yes|no]

Append to existing file, do not create a new one.

Logical    :: doAppend           ! default: false

### 7.27.4 OPTIONS /CLEAR

/CLEAR [yes|no]

Completely clear a list of connected hardware, e.g., receivers, backends, or parameters of the associated command.

### 7.27.5 OPTIONS /COLD

/COLD [yes|no]

Do a calibration subscan on the cold temperature load.

Logical    :: doCold           ! default: true

### 7.27.6 OPTIONS /CONNECT

/CONNECT [yes|no]

connect (or disconnect) the specified hardware, e.g., backend or backend part.

### 7.27.7 OPTIONS /CROLOOP

/CROLOOP croLoop

sequence of R = off-source Reference  
              0 = On-source subscans

Character :: croLoop

Example:

/croLoop R00R

**7.27.8 OPTIONS /DEFAULTS**

/DEFAULTS [yes|no]

Restore default values for all parameters and options.

**7.27.9 OPTIONS /DEROTATOR**

/DEROTATOR angle system

Specify derotator angle for HERA

Real       :: angle                   ! in units [deg] (!)  
Character :: system                 !

Choices for system:

"Nasmyth"

"horizon"

"equatorial"

"frame"                               ! same as Nasmyth

"sky"                                 ! same as equatorial

NOTES: The last 2 are for consistency with old control system and HERA conve  
This option works only for RECEIVER HERA1 or RECEIVER HERA2 (of course it's  
same angle for HERA1 and HERA2).

**7.27.10 OPTIONS /DISCONNECT**

/DISCONNECT

disconnect the specified hardware, e.g.,  
backend or backend part.

**7.27.11 OPTIONS /DOPPLER**

/DOPPLER doppler

Character :: doppler                 ! apply doppler correction?  
                                     ! choices: DOPPLER|FIXED

**7.27.12 OPTIONS /DOUBLEBEAM**

/DOUBLEBEAM [yes|no]

Pointing: do a "double-beam" pointing

Logical    :: doDoubleBeam

This is valid only for pointing with Wobbler switching (SWWOBBLER).

This option has an effect only if SET 2nRotation 0.0

**7.27.13 OPTIONS /EFFICIENCY**

/EFFICIENCY forwardEfficiency beamEfficiency

specify forward and beam efficiencies

Real       :: forwardEfficiency !

Real       :: beamEfficiency   !

**7.27.14 OPTIONS /FILE**

/FILE fileName

Specify file name.

Character :: fileName           !

**7.27.15 OPTIONS /FINE**

/FINE

for BACKEND FTS select the "fine" mode with a resolution of ~ 0.049 [MHz]

Note: with the option /DEFAULT or the short syntax, this allows to select the fine resolution without explicitly entering the values of resolution and bandwidth.

**7.27.16 OPTIONS /FOCUS**

/FOCUS f1 f2 [... f18] [direction]

or

/FOCUS NO

[For Lissajous] designate the purpose of the scan to be "Focus", i.e., to determine focus corrections. A subscan with a Lissajous curve will be executed for each focus offset specified.

Real       :: f1 f2 [... f18]   ! focus offsets [mm]  
                                   ! (at least 2, at most 18 values)  
 Character :: direction       ! direction of focus offsets, one of:  
                                   ! X  
                                   ! Y  
                                   ! Z

/FOCUS NO clears the option /FOCUS.

**7.27.17 OPTIONS /GAINIMAGE**

/GAINIMAGE gainImage [dB]

Specify the gain ratio of image to signal sidebands.

Real        :: gainImage        !

If "dB" is added after the value, the ratio is assumed to be in dB, otherwise a decimal fraction.

Simple standard values for these gain ratios can be found on the IRAM 30-m web pages (Telescope Summary). If you need accurate values for the single-pixel heterodyne receivers, you should measure them with:  
CALIBRATE /GAINIMAGE receiverName

**7.27.18 OPTIONS /GREG**

/GREG

Does a "grep" search for the (partial) source name or string in the source catalog and lists any matching lines. This search ignores the case. This is only to help the user search through a source catalog. Even if the match is unique, the source found is not selected. (re-enter the SOURCE command with the full source name!)

**7.27.19 OPTIONS /GRID**

/GRID [yes|no]

Do a calibration subscan on a grid in front of the cold temperature load. This is a special calibration option for polarization observations.

Logical    :: doGrid            ! default: true

IMPORTANT NOTE:

remember to turn this option off again for normal calibrations:  
e.g., CALIBRATE /GRID NO or CALIBRATE /DEFAULT.

**7.27.20 OPTIONS /HORIZONTAL**

/HORIZONTAL [sb1 [sb2]]

/HORIZONTAL n[one]

EMIR subbands for Horizontal polarization.

This option applies only to EMIR.

Character    :: sb1, sb2    ! for EMIR: LO|LI|UI|UO

This option selects which EMIR subband(s) of this polarization will be

transmitted through IF cables 1 to 4. Note that some backends, NBC, 4MHz, WILMA, VESPA, can only be connected to IF cables 1 to 4, i.e., only to the EMIR subbands selected with the RECEIVER command.

For each EMIR band and polarization, at most 2 subbands can be transmitted through IF cables 1 to 4. Which combinations of EMIR bands, polarizations, and subbands are possible is determined by the hardware of the EMIR IF switching box. See the EMIR documentation for details.

If no subband is explicitly specified with this option, paKo will assume that for this polarization the same single subband SB is requested as specified for the main parameters (frequency, tuning) of the RECEIVER command for this EMIR band.

/HORIZONTAL n[one] means that from this polarization no subband will be transported through IF cables 1 to 4.

### 7.27.21 OPTIONS /MODE

/MODE mode

Character :: mode ! backend mode

Choices for mode are:

SIMPLE	! simple (standard)
PARALLEL	! parallel mode
POLARIZATION	! polarimetry

Select special mode for VESPA.  
See VESPA user's guide for details.

For EMIR, /MODE PARALLEL or /MODE POLARIZATION connect VESPA to the same band and subband in both polarizations; they must previously have been selected with the RECEIVER command. For examples, see:  
HELP BACKEND Examples

### 7.27.22 OPTIONS /NOTF

/NOTF nOtf

Integer :: nOtf ! number of OTF (on-the-fly) subscans

### 7.27.23 OPTIONS /NSUBSCANS

/NSUBSCANS nSubscans

Integer :: nSubscans ! number of subscans

**7.27.24 OPTIONS /PERCENTAGE**

/PERCENTAGE percentage

Real :: percentage ! percentage of bandwidth to use

This is a special option for the autocorrelators, VESPA and WILMA.

For autocorrelators normally some channels at both ends of the band are blanked because they do not contain usable data, and only the central 'percentage' of the "theoretical" bandwidth is used, typically about 90%. Reasonable conservative defaults are automatically applied: in general 90%, but 82% for VESPA with bandwidth 640. This option allows the observer to adjust the percentage for special purposes.

For WILMA connected to EMIR, the useful bandwidth is 3720 MHz, and counted as 100%.

See VESPA user's guide for details.

**7.27.25 OPTIONS /POINTING**

/POINTING [YES|NO]

Logical :: doPointing ! default: no

[For Lissajous] designate the purpose of the scan to be "Pointing", i.e., to determine pointing corrections.

/POINTING NO clears the option /POINTING.

**7.27.26 OPTIONS /RECEIVER**

/RECEIVER receiverBand

Character :: receiverBand ! receiver / EMIR band

Choices for receiverBand are:

E090 E150 E230 E330 HERA1 HERA2

**7.27.27 OPTIONS /REFERENCE**

/REFERENCE xOffsetR yOffsetR [systemNameRef]

or

/REFERENCE NO ! no reference

position of off-source reference subscans

Real :: xOffsetR ! x-offset



```

Real      :: yOffsetR      ! y-offset
Character :: systemNameRef  ! name of system
                        ! see /SYSTEM for choices

```

NOTE: with the usage /REFERENCE xOffsetR yOffsetR, both parameters are required but you can replace either parameter with \* to leave it unchanged.

### 7.27.28 OPTIONS /SCALE

```
/SCALE scale
```

Select the calibration intensity scale.

```
Character :: scale          ! choices: ANTENNA|BEAM
```

If scale is "ANTENNA", the scale is antenna temperature.

If scale is "BEAM", the scale is (main) beam temperature.

### 7.27.29 OPTIONS /SKY

```
/SKY xOffsetC yOffsetC
```

or

```
/SKY NO                      ! do not do sky calibration
```

Do a calibration subscan on sky.

```

Real      :: xOffsetC      ! x-offset
Real      :: yOffsetC      ! y-offset

```

NOTES: with the usage /SKY xOffsetC yOffsetC, both parameters are required, but you can replace either parameter with \* to leave it unchanged.  
The system for the offsets is selected through the option /SYSTEM.

### 7.27.30 OPTIONS /SPEED

```
/SPEED speed1 [speed2]
```

speed of OTF subscans

```

Real      :: speed1        ! speed at start
Real      :: speed2        ! speed at end

```

For OTFMAP speed2 = speed1.

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

**7.27.31 OPTIONS /STEP**

/STEP dx dy

Step (shift or translation) between lines in a map.

Real       :: dx                   ! shift in x-offsets  
Real       :: dy                   ! shift in y-offsets

**7.27.32 OPTIONS /SWWOBBLER**

/SWWOBBLER [yes|no]

(option of command ONOFF)

set parameters appropriate for on-off Wobbler switching

Logical    :: doSwWobbler

If switching mode SWWOBBLER has been selected, the following parameters of ONOFF are set according to wOffset1 and wOffset2:

```
ONOFF
    xOffset      is set to: -wOffset1
    yOffset      is set to:  0.0

/REFERENCE      is set to:  Yes
    xOffsetR     is set to: -wOffset2
    yOffsetR     is set to:  0.0
    systemNameRef is set to: TRUEHORIZON

/SYSTEM
    systemName    is set to: TRUEHORIZON
```

NOTE: in this case the values selected by /SWWOBBLER overrule the corresponding values specified directly in the command.

NOTE: To do ONOFF with Wobbler switching and other (unconventional) values for the parameters listed above, simply specify the values using command ONOFF with option /SWWOBBLER NO (not recommended).

NOTE: If the selected switching mode is SWWOBBLER and if the option /SWWOBBLER is no explicitly given, it will be assumed to be .True. (Yes), If the selected switching mode is not SWWOBBLER and if the option /SWWOBBLER is no explicitly given, it will be assumed to be .False. (No),

**7.27.33 OPTIONS /SYMMETRIC**

/SYMMETRIC [yes|no]

Logical    :: doSymmetric       ! default: no

(For ONOFF) select a subscan sequence that is "symmetric" in time.

This requires that the number of subscans is a multiple of 4.

Example for ONOFF with /SYMMETRIC no	/SYMMETRIC yes
1st subscan:	OFF OFF
2nd "	ON ON
3rd "	OFF ON
4th "	ON OFF
(and so on)	

NOTE that this does not in anyway change the positions of the ON-source and OFF-source subscans!

### 7.27.34 OPTIONS /SYSTEM

/SYSTEM systemName

Name of system for offsets.

Character :: systemName	! name of system, one of:
	! PROJECTION
	! TRUEHORIZON
	! NASMYTH

<<TBD:	! DESCRIPTIVE>>
<<TBD:	! BASIS>>
<<TBD:	! EQUATORIAL>>
<<TBD:	! HADECL>>
<<TBD:	! HORIZONTAL>>

PROJECTION for now means only the standard simple "radio" projection offsets in the chosen coordinate system. This is normally the astronomical system of offsets in which point-by-point (TRACK, ONOFF) or on-the-fly (OTFMAP) maps are made.

TRUEHORIZON means the horizontal system with a factor  $1/\cos(\text{elevation})$  applied to the azimuth offset.

NASMYTH are special offsets to point an off-center pixel of a focal-plane array receiver (bolometer, HERA) to the commanded astronomical position, e.g., to use an off-center pixel for pointing, focus, ONOFF.

IMPORTANT NOTE: projection, trueHorizon

If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM projection, OFFSETS ... /SYSTEM projection is ignored (not used).  
If the observing mode (LISSAJOUS, ONOFF, OTFMAP, ...) is in /SYSTEM trueHorizon, OFFSETS ... /SYSTEM trueHorizon is ignored (not used).

IMPORTANT NOTE: OFFSETS /SYSTEM Nasmyth

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are specified in pako, the values xOffset yOffset are used during the observations. (this includes the case that they are explicitly set to 0.0). It is up to the observer to make sure that they are "correct". (in pakoDisplay /SYS Nasmyth will be highlighted as yellow alert.)

If OFFSETS xOffset yOffset /SYSTEM Nasmyth are not specified (cleared), for the MAMBO bolometer, Nasmyth offsets are used automatically according to the selected bolometer channel (pixel).

### 7.27.35 OPTIONS /TCALIBRATE

/TCALIBRATE tCalibrate

Time per CALIBRATE subscan.

Real            :: tCalibrate            ! time

### 7.27.36 OPTIONS /TOTF

/TOTF tOtf

time per OTF subscan or segment

Real            :: tOtf                    ! time

In commands like OTFMAP that have options /SPEED and /TOTF, either option /SPEED or /TOTF can be used, the values of the other option are then implied!

### 7.27.37 OPTIONS /TPHASE

/TPHASE tPhase

time per switching PHASE

Real            :: tPhase                    ! time

### 7.27.38 OPTIONS /TREFERENCE

/TREFERENCE tReference

time per off-source reference

Real            :: tReference                ! time

### 7.27.39 OPTIONS /TSUBSCAN

/TSUBSCAN tSubscan

time per subscan

Real           :: tSubscan           ! time

#### 7.27.40 OPTIONS /TEMPLOAD

```
/TEMPLOAD tempColdLoad tempAmbientLoad
/TEMPLOAD L[OOKUP]       L[OOKUP]
/TEMPLOAD *               ...
```

Set effective temperatures for the calibration loads at cold and ambient temperature.

```
Real        :: tempColdLoad       !
Real        :: tempAmbientLoad   !
```

NEW LOGIC FOR SINGLE-PIXEL SIS RECEIVERS (FROM SUMMER 2007, paKo v1.0.7)

If a numerical value is entered for tempColdLoad or tempAmbientLoad, that value is used for calibration calculations.

Instead of specifying a value one may enter the string L(OOKUP) for tempColdLoad and/or tempAmbientLoad. This is shown in the pakoDisplay by the letter "L" instead of a number.

In this case, during the execution of the observations, the NCS will use the "best-known" values for the corresponding load temperature(s). For tempColdLoad this is based on a lookup table, for tempAmbientLoad it is derived from a measurement of the physical temperature.

The lookup table for tempColdLoad normally is valid for the standard calibration system with a closed-cycle cooling system.

A \* can be substituted for tempColdLoad, which means to leave the value for tempColdLoad unchanged from the previous RECEIVER command.

IF THE OBSERVERS HAVE ANY DOUBT ABOUT THIS, THEY SHOULD ASK A RECEIVER ENGINEER FOR THE CORRECT VALUE AND ENTER IT EXPLICITLY.

NOTE: FOR HERA The new logic is not yet available. However, for HERA "best-known" values are always used during the execution of the observations. This is the same logic as in previous versions of paKo/NCS.

#### 7.27.41 OPTIONS /TUNE

```
/TUNE xOffsetT yOffsetT
or
/TUNE NO                   ! no tune subscan
```

Tune subscan at the specified offsets, before any other subscans.

```
Real      :: xOffsetT      ! x-offset for tune subscan
Real      :: yOffsetT      ! y-offset for tune subscan
```

NOTE: with the usage /TUNE xOffsetT yOffsetT, both parameters are required, but you can replace either parameter with \* to leave it unchanged.

#### 7.27.42 OPTIONS /TTUNE

/TTUNE tTune

time per TUNE subscan

```
Real      :: tTune          ! time
```

#### 7.27.43 OPTIONS /VELOCITY

/VELOCITY referenceFrame velocity

Specify reference frame and source radial velocity

```
Character :: referenceFrame ! reference system for velocity
Real      :: velocity       ! in units [km/s]
```

Choices for referenceFrame:

"LSR"

"barycentric"

"heliocentric"

<<TBD: not yet supported: >>

<<TBD: "3K" >>

<<TBD: "galactocentric" >>

<<TBD: "body" >>

<<TBD: "geocentric" >>

<<TBD: "topocentric" >>

<<TBD: "null" >>

IMPORTANT NOTE ON VELOCITY:

One should not use very large Doppler velocities (thousands of kilometers) to achieve red-shift corrections of frequencies. Instead one should enter the red-shifted frequencies in the line catalog (or with the RECEIVER command) and use Doppler velocity of 0.0.

The alternative approach (with very large Doppler velocities) needs special methods and attention in the data processing, which are *"\*not\* implemented in CLASS because it is better to observe in such a way that minimum modification to the data is done later on"* (J. Pety). For a full discussion of this question see: Gordon et al. 1992, A&A, 264, 337 in Sect. 6

**7.27.44 OPTIONS /VERTICAL**

```
/VERTICAL [sb1 [sb2]]
/VERTICAL n[one]
```

EMIR subbands for Vertical polarization

This option applies only to EMIR.

Character    :: sb1, sb2    ! for EMIR: LO|LI|UI|UO

This option selects which EMIR subband(s) of this polarization will be transmitted through IF cables 1 to 4. Note that some backends, NBC, 4MHz, WILMA, VESPA, can only be connected to IF cables 1 to 4, i.e., only to the EMIR subbands selected with the RECEIVER command.

For each EMIR band and polarization, at most 2 subbands can be transmitted through IF cables 1 to 4. Which combinations of EMIR bands, polarizations, and subbands are possible is determined by the hardware of the EMIR IF switching box. See the EMIR documentation for details.

If no subband is explicitly specified with this option, paKo will assume that for this polarization the same single subband SB is requested as specified for the main parameters (frequency, tuning) of the RECEIVER command for this EMIR band.

/VERTICAL n[one] means that from this polarization no subband will be transported through IF cables 1 to 4.

**7.27.45 OPTIONS /WIDTH**

```
/WIDTH width
```

Select receiver setup for WIDE or NARROW bandwidth mode.

Character :: width                   ! width. choices: WIDE|NARROW

NOTE: Option /WIDTH NARROW changes the (local oscillator) setup of receivers HERA1 and HERA2 in such a way that a line in the center of the receiver bandwidth appears in the center of the bands of the Backends 1MHz (with 256 or 512 MHz bandwidth) and VESPA.

Spectrometers with 1GHz bandwidth normally require /WIDTH WIDE.

**7.27.46 OPTIONS /ZIGZAG**

/ZIGZAG [yes|no]

alternate direction between lines in a map

Logical        :: doZigzag



## 8 Postscript

*“You will certainly not doubt the necessity of studying astronomy and physics,  
if you are desirous of comprehending the relation between the world and Providence as it is in reality,  
and not according to imagination.”*

*“You must, however, not expect that everything our Sages say  
respecting astronomical matters should agree with observation.”*

*“Astronomy had, in the days of Aristotle,  
not yet developed to the height it has reached at present.”*

Moses Maimonides — Moses ben Maimun — Abu Amran Musa  
Cordoba, 1135—Cairo, 1204

From the Arabic “*Dalalat al’Haírîn*”,  
translated into Hebrew as “*Moreh Nebûkím*” (1204),  
and into Latin as “*Doctor Perplexorum*”, “*Dux Dubitantium*”.  
French translation entitled “*Guide des égarés*” (Paris, 1856-66).  
Here quoted from the English translation “*The Guide of the Perplexed*” (London, 1889).

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