MIRA Manual - v. 2.3

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Author: Helmut Wiesemeyer (email: wiesemey@iram.fr)
Contributors: A. Sievers, H. Ungerechts, C. Thum, K. Schuster, G. Paubert, W. Brunswig, J. Pety, P. Hily-Blant, the MBFITS working group
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Description - about this document:
This manual describes MIRA, a **M**ultichannel **I**maging and Calibration Software for **R**eceiver **A**rrays. MIRA succeeds OTFCAL for the calibration of the new IMBFITS raw data at the 30m telescope.

Related documents:
http://www.iram.fr/IRAMFR/GILDAS/

1 Preface

MIRA as in the current version is still under development. Parts of its capabilities depend on the work done for other program libraries (CLASS90, TELCAL, PAKO). Comments and suggestions from users are welcome, and will be a valuable tool to further improve MIRA.

MIRA in its current version is exclusively used to reduce data written in the new IMBFITS raw data format. For old raw data, the old data processing software (OTFCAL) will be kept and maintained.

As soon as MIRA is fully integrated into as the standard heterodyne data processing software for the new control system, it will further evolve to provide tools for imaging with heterodyne receiver arrays.

This is a summary of recent changes in MIRA:

Version 1.1

- For online data processing, a prototypical procedure `mira_pro:reduce.mira` has been commited to the CVS.
- New default for `MIRA\CAL`: the calibration parameters of *all* frontend-backend combinations are computed.
- Output message formats for `MIRA\SCAN` changed.
- Calibration parameters are already computed and issued when a chopper-wheel calibration is loaded. For spectrometers with several basebands, mean values are given (for basebands belonging to the same spectrum).
- Command syntax for `MIRA\VIEW` changed to
  `MIRA\VIEW [ifb] [/CAL] [/GAINS] [/PHASES] [/SIGNAL] [/MAP]`
  Useful defaults are provided.
- Command syntax for `MIRA\SOLVE [pointing|focus] [ifb]` changed to `MIRA\SOLVE [ifb]`. Whether a pointing is to be solved or a focus is automatically determined from the observing procedure of the current scan.
- MIRA commands using the SIC macros in `mira_pro:p_plot_*.mira` can now be retrieved from SIC's command stack (concerns `MIRA\SOLVE` and `MIRA\VIEW`).
- `MIRA\SOLVE`: for pointings, the execution can be halted after the subscan fits with QUIT.
- MIRA command FIND has a new option `FIND /NEW` (for online data processing). Only new data are put into the index list. If no new data are found, the index list remains unchanged.
- Lists of MIRA commands FIND and LIST: by default, a "short" list is provided (without frontend names and spectral lines). The previous "long" list can be retrieved with the new option `LIST /LONG`. The telescope name is suppressed in any case. Note that the scan number is now listed in the first column, and the observation number in the last one.
- The information is the current index list can now be retrieved from the new SIC structure list (type `\MIRA\VARIABLE LIST r`).

- Support of old raw data abandoned.

Version 1.2

- Default for MIRA command CAL is now the first frontend-backend combination. If all frontend-backend combinations are to be calibrated, the argument ALL has to be specified, i.e. CAL ALL [/...options].
- The option /OFF of MIRA command CAL now offers several modi for the subtraction of the reference signal in OTF maps with total-power mode. The reference signal is either a mean of all off-measurements (option NONE, the default), an unweighted mean of the reference measurements taken before and after the on-measurement, and weighted means (weighting by total power or elapsed time). See the MIRA language internal help for more details.
- MIRA command WRITE, option /FEBE has a new argument: `MIRA\WRITE` *number* `/FEBE ALL` writes all frontend-backend combinations into the CLASS output file, starting with the observation identification *number* (if specified, otherwise successively increased by default).

Version 1.3

- MIRA stability is improved. If, for a given scan, the imbFits file of one of the backends is faulty, this backend will be ignored in the index list (and a warning message is issued).
- The new imbFits keywords `XOFFSET`i and `YOFFSET`i (with $i = 1$ to n_{offsets}, where n_{offsets} is the number of offsets from the catalogue position) are accomodated in MIRA's `SCAN%DATA` section.The resulting offset is in `SCAN%HEADER`.
- The SIC macro `reduce.mira` now becomes `reduceCont.mira` and `reduceSpec.mira`. See section 2.1 for details.
- New option `/ZOOM` for command `MIRA\VIEW`. First the data is fully shown, and the interactive cursor is called to define a rectangle to be zoomed in. The axis labels are correspondingly updated.
- `MIRA\VIEW /MAP /ZOOM` can be used to plot a subset of data. In the subset display, the range of `ON` positions covered by the subscan(s) is indicated.
- `MIRA\CAL`, option `/OFF`: the default weight mode for on-the-fly maps is now `AVER` (taking an average of all available off-source subscans). Option `NONE` does not remove any off-source signal, but concatenates the spectral basebands.
- MIRA's SIC variable `ARRAYi\%DATAj\%ISWITCH` (with `i` frontend-backend number, `j` baseband number) now becomes an array of character strings (instead of integer flags). See section 5 for details.

Version 1.4

- The header information provided by MIRA's command VIEW has been extended.
- `MIRA\CAL`: if the setup of the backends used for an observation is not strictly the same as for the previous (or, for offline data processing, the subsequent) calibration, MIRA complained about an inconsistent calibration. In version 1.4, MIRA looks whether a calibration is available for exactly the same spectral charactersistics. If so, the calibration is applied, even if the number of the backend part has changed. If no calibration with the same spectral characteristics is available, MIRA issues a warning, and flags those data as uncalibrated.
- Ambigeous scan numbers: it may happen that a raw data directory contains data from different observing dates, but with the same scan numbers. Until now, the only way out was to preselect the data in the index list, using `FIND /OBSERVED`. Otherwise, MIRA entered into a state of confusion and crashed when such a scan was read with `MIRA\SCAN`. In version 1.4, this is not so anymore: in case of ambigous scan numbers, the user is asked to enter the desired observing date (if nothing is entered, `MIRA\SCAN` returns to the command prompt, allowing to opt for the solution using `FIND /OBSERVED`.
- The pause between pointing solutions by subscans and coadded subscans, respectively, makes automatic online data processing impossible, since MIRA waits for the use to type `continue`. So, the pause was switched off in version 1.3. In version 1.4, it can be activated using MIRA's logical flag `doPause` (yes or .true. for interactive offline MIRA sessions, if the user wants to have a close look at the pointing subscans).
- Sometimes there are still spikes in the pointings (although usually lower than or comparable to the signal). MIRA's despiking routine works best after calibration, and the spikes get attributed a blanking value. Therefore, the `MIRA\SOLVE` command has been upgraded to correctly handle blanked values for either backend counts or equivalent temperature scales.
- slight syntax change for `MIRA\VIEW /PHASE idPhase irec`. `idPhase` can be one of the character strings `ON, OFF, LOAD, SKY, HOT, COLD, FLO, FHI`. The specified phase is averaged across the whole scan, unless a special record is specified with `irec`.
- If a backend part is disconnected, keeping the others, MIRA will work even if there will be a "hole" in the associated frontend-backend numbers (e.g. using VESPA parts 1, 3 and 4). Not yet tested for more than one backend part lacking.

Version 1.5

- The procedure for online data processing is now called onlineDataProcessing.mira. It can be called by
  `mira.exe @onlineDataProcessing projId scan obsDate calScan obsDateCal`
  where `projId` is the Pico Veleta project id (e.g. 203-04), `scan` the scan number to be reduced, `obsDate` the corresponding observing date (format yyymmdd), `calScan` the scan number of the calibration scan (may be 0 if no calibration is to be done), and `obsDateCal` the observing date of the calibration scan (can be different from `obsDate`). The MIRA SIC procedures `reduceSpec.mira` and `reduceCont.mira` are obsolete.

- `MIRA\SCAN` has a new option `/TRACKING trackingError`. If specified, all backend data with azimuth or elevation tracking errors larger than `trackingError` are flagged, i.e. attributed the blanking value for raw data.

- In VESPA polarimetry mode, the fourth subscan of the paKo command `CAL /GRID` is plotted in blue.

Version 1.6

- MIRA commands `VIEW`, `CAL` and `WRITE` have new options for HERA pixels. See online help for details.

- MIRA command `FIND` is too slow for online data processing if used for large data archives. There are two solutions: either use `SCAN` without a previous `FIND`, or at least one of the following options: `FIND /OBSERVED yyyy-mm-dd`, `/SCAN`, `/BACKEND` (`FIND /SCAN` is fastest).

- You *do not need* to use `FIND` to load a scan ! MIRA command `SCAN` loads a scan, even if no index list exists. In case the scan number is ambigeous, MIRA takes by default the last observing date found (otherwise you have to use `FIND /OBSERVED`). See the online help for details.

- There is a new utility procedure, `odp.mira`. It essentially does the same job as the online data processing triggered by the NCS coordinator, but is more interactive. Use: `@ odp iRef idScan`, where `iRef` is the frontend-backend combination to be used for pointings and focus solutions, and `idScan` is the scan to be reduced. The output CLASS file is called spectra.30m, in order to avoid confusion with spectraOdp.30m (produced by the coordinator).

- Large data sets with too short a dump time (e.g. frequency switched on-the-fly maps) can be compressed within MIRA with the new option `/COMPRESS` for command `SCAN` (see MIRA language help).

- For calibration measurements without sky counts, MIRA now issues the receiver temperature(s).

Version 1.7

- After extensive testing with the G95 compiler, all memory leaks within MIRA have been removed.
- Under certain weather conditions, TelCal is not very tolerant regarding inaccurate calibration parameters (e.g. forward efficiency, cold load temperature). The new command `MIRA\OVERRIDE` allows to manually set the load temperatures and beam and forward efficiencies to values different from the entries in the imbFits raw data file. For details, please read the MIRA language internal help.
- The cookbook section now contains a subsection on OTF and HERA data reduction, and another on the reduction of polarisation data.
- Pointing fits now also display the fitted width and peak flux of the Gaussian. Pointing corrections: both the previous and new corrections are displayed.
- Thanks to recent developments in the telcal library (pety@iram.fr), double beam fits for pointings using the wobbler are now supported.
- Baselines for pointing drifts are now fitted simultaneously with the Gaussian. The baseline determined by MIRA (using dumps without the source signal) is used as an initial guess.
- CLASS output files get the default extension `.30m`
- For pointing drifts, all subscans are now written to the CLASS output file (i.e. option `WRITE /SUBSCAN` is not needed anymore). See the MIRA language internal help, comand `MIRA\WRITE`, for details.
- For XPOL observations (VESPA in polarimetry mode), MIRA can calibrate phases. The XPOL widgets for CLASS know whether MIRA has done a phase calibration (CLASS header variable `CMODE = 10`) or not (`CMODE = 0`). See the MIRA language internal help, command `MIRA\CAL`, for details.
- Command `MIRA\VIEW` gets a new option `/XPOL` for viewing the amplitude and phase of the cross correlation of orthogonally polarized receivers (for VESPA data in XPOL mode).
- The SIC structure `LIST` has been simplified: the structure `LIST%ATTRIBUTE1` becomes `LIST1`, `LIST%ATTRIBUTE2` becomes `LIST2` etc. For details see section 5.2.11.
- There is now one MONITOR section per frontend-backend combination, allowing to accomodate monitor data points that are specific for a given frontend. For details, see section 5.2.6.
- `VIEW /CAL` now also issues the calibration and weather parameters on the GREG display (so they become visible even if MIRA is used in automatic mode in the background). For HERA data, these parameters are only displayed if option `VIEW /CAL /PIXEL` is used (otherwise the plots are overcharged).

Version 1.8

- Removed a bug: now more than 9 simultaneous frontend-backend combinations allowd.
- Command `FIND /NEW` now behaves differently: if new data are found, they are appended to the index list (if existing). This allos to load scans that are not in the index list, but whose data files are already written to disk (i.e. avoids a new FIND command in order to get those data).
- New option `/SHOW` for MIRA command `FILE`: `FILE /SHOW` displays the names of the current input and output files (if openend, otherwise a warning message is issued).
- Calibrations of the sideband ratio are now automatically evaluated when MIRA reads in a corresponding scan. The resulting gain image may then be used for further calibration by using the new keyword `GAIN[IMAGE]` for MIRA command `OVERRIDE`.
- On-offs with the continuum backend, when displayed with `VIEW /PHASE`, yield the flux and its error. A baseline linearly depending on elapsed time is automatically fitted by MIRA at the on-off subtraction of `MIRA\CAL`.
- MIRA now solves skydips.
- Format of backend data becomes dynamic: integer, single or double precision floating point count rates, according to the TFORM3 keyword in the imbFits backend HDU.
- New options `/PROJECT` and `/STAT` for command `MIRA\FIND`, for selecting data from one or several projects, and for writing the total integration time of the observtions of the current index list into a hidden file .stat. Mainly for observing pool administration. `LIST /PROJECT` includes the project number into the index list.
- Calibrations with less then 3 subscans (i.e. from `PAKO\CAL /SKY NO` are also plotted, and relevant calibration parameters are indicated on MIRA's graphical display.
- For image gain calibrations of continuum backends, the data are plotted by subscan. For spectrometers, the image gain vs. frequency is shown.
- Command `LIST /REDUCE` write a procedure for off-line data reduction, instead of listing the data. For details see the MIRA language documentation.
- Option `/MASK` for command `CAL /OFF` also uses the OTF dumps as reference (masking the source). Works with OTF maps sufficiently exceeding the emission region.
- New option `/TAU` for command `SCAN`. For calibration scans only. Allows to keep the opacity fixed and calculates the corresponding atmospheric model (instead of computing that corresponding to the measured sky emission temperature). Mainly used for skydips (see next item).
- Skydips are now solved by a two-step procedure: First, fit `totalPower = a.[1-exp(-tauZenith.airMass)]+b` with fit parameters `a` and `tauZenith`. Then calibrate the skydip with the atmospheric model corresponding to the measured zenith opacity, and derive the forward efficiency from the fit parameters `a` and `b`.
- New option `/TRACES` for command `VIEW` for visualizing the antenna speed, fast and slow traces. For identifying bad antenna data.

Version 1.9

- `OVERRIDE` now allows to set the calibration parameters once for a whole MIRA session, until `OVERRIDE /RESET`. After reset, a new calibration has to be read.
- `VIEW /TRACES` now also shows the antenna mount drive dumps between the subscans (the previous versions only showed those data actually used for interpolation to the backend record times). To this end, a new structure has been created that can be examined and visualized via its SIC copy in `ANTENNA%ENCODER_AZ_EL` (encoder values for azimuth, elevation and their timestamp) and `ANTENNA%TRACKING_AZ_EL` (tracking errors).
- New parameter `calCheck` (logical SIC variable) can be used to switch off the consistency check for an observation and its associated calibration measurement (default: `.true.`). Use `let calCheck .false.` if you connect more than one part of the same backend to the same receiver, with identical spectral setup. With `let calCheck = .true.\`, MIRA tries to find for an observation the corresponding spectral backend part in the calibration data, even if its number has changed (e.g. because a backend part was dropped between the calibration and observation).
- In this context, `CAL ifb /FEBECAL jfb` allows the user to calibrate the frontend-backend unit ifb with the channel gains and calibration temperature of frontend-backend unit jfb (for particular circumstances only, e.g. inconsistent calibrations).
- For pointings, `SOLVE ifb jfb` computes the alignment of frontend `jfb` with respect to frontend `ifb`, and writes the results into an ASCII file *alignment.dat* (or appends them to it, if existing). The receiver alignment is computed from fits to the difference signal (rather from the differences between fit signals). The results are plotted for a Nasmyth focus cabin.
- Calibrations with switch mode `FREQUENCY` are supported, but still experimental. Please contact the author for further enquiries.
- New command `FLAG` allows to flag selected basebands, channels, HERA pixels, records or subscans (e.g. to solve pointings with a bad subscan) .
- New option `LIST /FLUX` prepares an ASCII table with pointing fluxes in the current index list (calibrated in Ta* if the index list contains calibrations).
- Calibration parameters can be stored in an XML file if `writeXML` is set: `let writeXML yes`.

From version 1.93 to 1.95:

- fix atmospheric water vapour content for calibration: `scan /pwv value`. Preparations for EMIR nomenclature.
- Observing mode DIY (OTF along Lissajous figures) now allowed. Plot figures with VIEW /OTF.
- Plot limits for tracking errors (command VIEW /TRACES) are variable. This is to suppress visualization of data with too large tracking errors (e.g. while telescope is slewing).
- Skyslews can be read by MIRA and plotted. Fitting opacity and forward efficiency still needs to be developed.

- Doppler correction sign changed on 2008-10-29, to $d = -v_{\rm obs}/c$ where d is the Doppler correction (CLASS variable `DOPPLER` in the spectroscopy section, and $v_{\rm obs}$ the observatory velocity with respect to the local standard of rest (> 0 if the observator recedes from the LSR).

- Command `list /flux argument` produces an ASCII output file with continuum fluxes (where argument is the backend name, e.g. 1MHz). `list /flux` deduces pointing fluxes, using the continuum backends, as before.

- Command `cal /off /mask` now also works with option `/off time`. Syntax for `/mask d1 [d2 d3 d4 ...]` has changed: if only argument d1 is given, this is the number of OTF dumps at the start and end of each OTF subscan used as atmospheric refernce. If (d1,d2), (d3,d4), etc. are given pairwise this is to indicate the respective first and last OTF dump framing the source (up to 5 masks allowed, i.e. 10 arguments).

Version 2.0

- Support for the new EMIR receiver.

- It is now possible to write calibrated total power data to CLASS. Please use:
`cal all /gains /off none /tcal`

- It is possible to concatenate spectral subbands for plotting. Command syntax: `VIEW ifb1 ifb2` for concatenating subbands `ifb1, ifb2`, or `VIEW ifb1 to ifb2` for concatenating all subbands between `ifb1` and `ifb2`.

- The following parameter can now be set in interactive mode: `badLevel`, this is the level with respect to median total power at which spectral channels are blanked, default: factor 20 above or below median).

- For continuum observations, the behaviour of `view ifb /phase iphase` now is the following: `iphase = 1, 2,...` shows only total power phase `iphase`. For one of `iphase = on, off` (for continuum on-offs) or `iphase = sky, load` (for beam-switched scans) `iphase` is the leading phase in the signal difference.

- `MIRA\override` now also allows us to change the weather data (e.g. if the weather stations fails and if wrong weather data are written into the imbfits files). Use: `override tamb[_p_humid] Tamb Pamb` where `Tamb` and `Pamb` are the values for the ambient outside temperature and pressure (° C and hPa, respectively) e.g. measured by hand or `*` to remain unchanged).

- From 2009-06-17 11:00 UTC onwards, all CLASS spectra written with Mira versions under gildas installations `gag_dev` and `gag_may09` at the 30m telescope are written with the following convention: `doppler = -vSource(Obs)/clight`, where `vSource(Obs)` is the source velocity in the observatory frame, in the same sign convention as in Astro (vSource(Obs) ¡ 0 for source approaching observatory).

Version 2.1

- The parameter `flagBSwSpikes` allows to automatically blank spikes with abnormally short integration times (shorter than actual values, hence normalization wrong, resulting in spikes). Default: .false. (works both for old and EMIR data).

- In the SIC variable section RAW, subsection ANTENNA, the new variables `dateObs` and `dateEnd` are the start and end times of a given subscan, as written into the imbfits raw data (i.e., unlike `subScanStart` and `subScanEnd`, not filtered by the safeguards in Mira's subroutine syncData).
- If `CAL /off NONE` was specified, `MIRA\WRITE` writes both on-source and reference spectra to the output CLASS file.
- New parameter `timingCheck` (logical flag, default: yes). Allows to switch off the automatic avoidance of hazardous extrapolation of antenna trace data). For details see section 5.1.

Version 2.2

- Full support of 64bit processors. Tested with g95 and ifort compilers on Debian v. 5.0.3.
- Support of data reduction of incomplete imbfits files (i.e., by subscan), except for focus and skydip scans. NB: Currently WILMA and VESPA data are written to imbfits output only at scan end.
- New parameter `traceExtrapolation` (logical flag, default: yes). Only for `timingCheck = no`. Enables extrapolation of fast and slow traces before or after scan start, respectively end, and points in time that still contain valid backend data. For details see section 5.1.

Version 2.3

- Data reduction by subscan (pointings, on-off measurements, on-the-fly maps) is now fully supported (for backends whose raw data are written subscanwise).
- New option `/BACKEND` for `MIRA\SCAN` select backends from index list for reading and further processing (default: all backends). `/DROP` drops the selected backends from the list of data to be read and processed.

2 MIRA online use

This section previously contained first thoughts how MIRA can be integrated in an online data processing scheme for visualizing and writing calibrated data. MIRA now has a procedure `onlineDataProcessing.mira`, which is called by the NCS coordinator (via a Python script) in the following way:

```
mira.exe @onlineDataProcessing projId scan obsDate calScan obsDateCal
```

where `projId` is the Pico Veleta project id (e.g. 203-04), `scan` the scan number to be reduced, `obsDate` the corresponding observing date (format yyymmdd), `calScan` the scan number of the calibration scan, and `obsDateCal` the observing date of the calibration scan (can be different from `obsDate`). MIRA now allows to use two global SIC variables, `ncsData` and `visData`, in order to specify where the raw data are located, and where the plots, XML result files and CLASS spectra should be put. The procedure `onlineDataProcessing.mira` sets these variables to

```
ncsData = /ncsServer/mrt/ncs/data
visData = /vis/203-04
```

The raw data are searched in `$ncsData/yyyymmdd/scans/` (where yyyymmdd is the observing date), the calibrated CLASS file (spectra.30m) for the project is in `$visData/mira`, the plots are in `$visData/mira/plots`, and the XML result files (for the time being only for pointing and focus) are in `$visData/results`. The conventions for the names of plots and result files are described in the document `http://mrt-lx1/mainWiki/NCSFileStructure`

There is also a new utility procedure, `odp.mira`. It essentially does the same job as the online data processing triggered by the NCS coordinator, but is more interactive. Use:

```
@ odp iRef idScan
```

where `iRef` is the frontend-backend combination to be used for pointings and focus solutions, and `idScan` is the scan to be reduced. The output CLASS file is called spectra.30m, in order to avoid confusion with spectraOdp.30m (produced by the coordinator). The results (XML and CLASS files) are in `$HOME/miraOdp`, the plots in `$HOME/miraOdp/plots`. If the respective directories do not exist, `odp.mira` makes them.

An interactive way to generate a CLASS file from a long list of observations is

```
list /reduce [reductionScript] [classFile]
```

which creates a macro 'reductionScript' (default: reduce.mira) whose execution within your MIRA session (@ reduce) calibrates the data in the current index list (previously specified with `MIRA\FIND`) and writes them to 'classFile' (default: mira.30m).

3 A typical (offline) data reduction session

3.1 Single-pointing observations

For the sake of a cookbook recipe, here is an example of a MIRA session.

`file in "/ncsServer/mrt/ncs/data/2005-04-06"`	opens the input directory for reading
`file out spectra.30m new`	opens output file for calibrated data (CLASS format by default)
`find /observed 2005-09-06 /scan 5 15`	only puts scans 5 to 15 from September 6 into the index list.

... and yields the following list (with column 1 - scan number, column 2 - object, column 3 - observing procedure, column 4 switch mode, column 5 - backend name, column 6 - date of observation, column 7 - observation number) :

```
  5 VENUS      calibrat     beamSwitching     CONTI   2005-09-06    1
  6 VENUS      pointing     beamSwitching     CONTI   2005-09-06    2
  9 VENUS      focus        beamSwitching     CONTI   2005-09-06    3
 12 IRC+10216  calibrat     beamSwitching     4MHZ    2005-09-06    4
 13 IRC+10216  onOff        beamSwitching     4MHZ    2005-09-06    5
 14 IRC+10216  calibrat     beamSwitching     4MHZ    2005-09-06    6
 15 IRC+10216  onTheFly     totalPower        4MHZ    2005-09-06    7
```

The same list can be displayed with MIRA command LIST, which also allows to write it to an output file and not to the screen (option /OUTPUT), and to issue information on the frontends connected and spectral lines observed (option /LONG).

Tip: If you search with FIND in a large data archive, the search procedure becomes slow, since it has to open each individual fits file. Note that FIND is *not* a prerequesite for MIRA command SCAN (see below). You can also accelerate the search by using at least one of the options /BACKEND, /OBSERVED or /SCAN (SCAN will be fastest).

A typical data reduction session looks like this:

`scan 5` loads scan 5 (calibration), computes the calibration paramters, and issues the following information:

```
FeBe Number              Frontend                  Backend

     1                     A100                     CONTI
     2                     B100                     CONTI
     3                     A230                     CONTI
     4                     B230                     CONTI


idFe THotLoad TColdLoad idBe  Pix  recTemp sysTemp calTemp tauZenith pwv
     ---- [Kelvin] ----            ------ [Kelvin] -------  [Neper]  [mm]
-------------------------------------------------------------------------
A100  295.199    86.000 CONTI  1     78.60  480.33  228.15    7.29   10.1
B100  295.199    88.000 CONTI  1     39.91  404.02  216.94    7.31   11.9
A230  295.199    86.000 CONTI  1    289.67 1515.64  350.22    0.39    5.6
B230  295.199    86.000 CONTI  1     91.00  800.64  305.18    0.43    6.2
```

`scan 6` loads scan 6 (a pointing on Venus)

Note: It may happen that your index list contains observations from different days, but with the same scan number. By default, MIRA loads the last observation found. If you want to load another observation, you have to use option `/OBSERVED` of command `FIND`.

`cal all` corrects all observations in the current scan for gains, applies the Ta* scale and subtracts off signals. N.B. CAL is NOT a prerequisite for solving pointings or foci.

`solve 4` solves the pointing measurement, using the receiver B230, plots the results (Fig.1, 2), and writes an XML file for the control system.

Tip: Occasionally, spikes appear in the raw data. If they are stronger than the total power level, they can be removed from the raw data with MIRA's command DESPIKE. If they are comparable to the total power level, you should first calibrate the pointing, then despike, and then solve the pointing fit.

Tip: By default, MIRA's pointing procedure halts for a while after the subscan plots, and then displays the results of the coadded azimuth respectively elevation subscans. This is for online data processing. For offline data processing, you may want to have a close look at the subscans. In that case, please enter **LET doPause yes**.

`scan 9`	loads scan 9
`solve 1`	solve and plot the focus for receiver B230 (Fig.3), and writes an XML file for the control system.
`scan 12`	loads scan 12 (a calibration for the 4MHz filterbank), and issues

```
FeBe Number              Frontend                  Backend

     1                     A230                     4MHZ
     2                     B230                     4MHZ


idFe THotLoad TColdLoad idBe  Pix  recTemp sysTemp calTemp tauZenith pwv
     ---- [Kelvin] ----            ------ [Kelvin] -------  [Neper]  [mm]
-------------------------------------------------------------------------
A230  295.199    86.000 4MHZ   1    362.19 3018.86  240.79    0.40    5.8
B230  295.199    86.000 4MHZ   1    127.34 1658.64  213.17    0.42    6.0
```

`scan 13`	loads scan 13 (an on-off on IRC+10216)
`view [1 /phases ON]`	plots the uncalibrated spectrum of the A230 receiver. The text in brackets is the default for `\view` (uncalibrated data).
`view 1 /phases OFF`	You may want to look e.g. at the off-phase, too.
`cal all`	calibrates the spectra of both the A230 and B230 receivers.
`view [1 /signal]`	plots the calibrated spectrum for the A230 receiver (Fig.4). The text in brackets is the default for `\view` (calibrated data).
`write /febe ALL`	writes the calibrated spectra into the output file for CLASS (starting with observing number 1)

MIRA offers possibilities to plot calibration counts, gainarrays of spectrometers, raw data (individual phases of the switch cycle), calibrated data (as spectra or pseudo-maps for OTF). For details, please have a look at section 4.

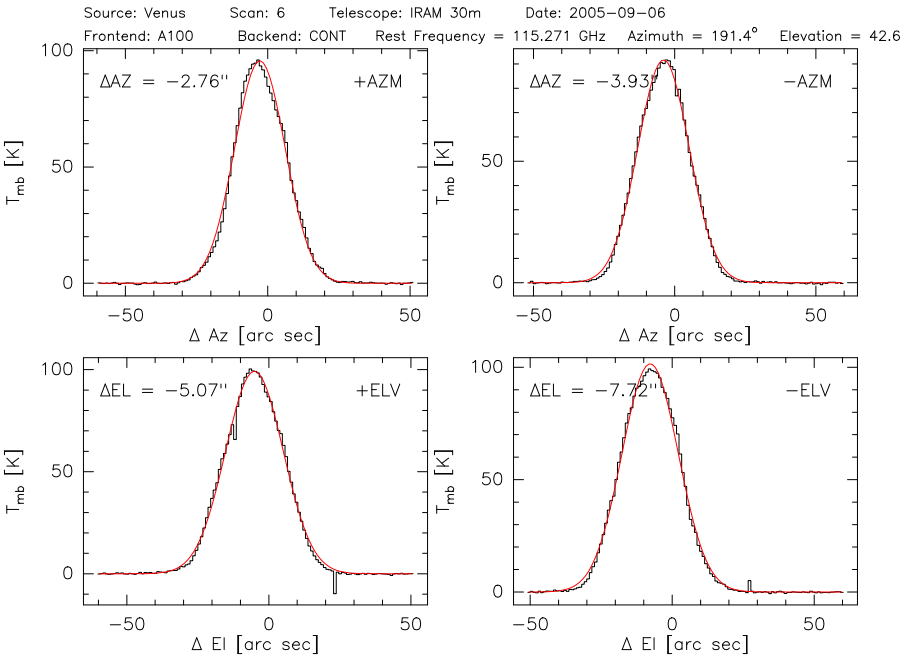


Figure 1: Example for a pointing solution (first step).

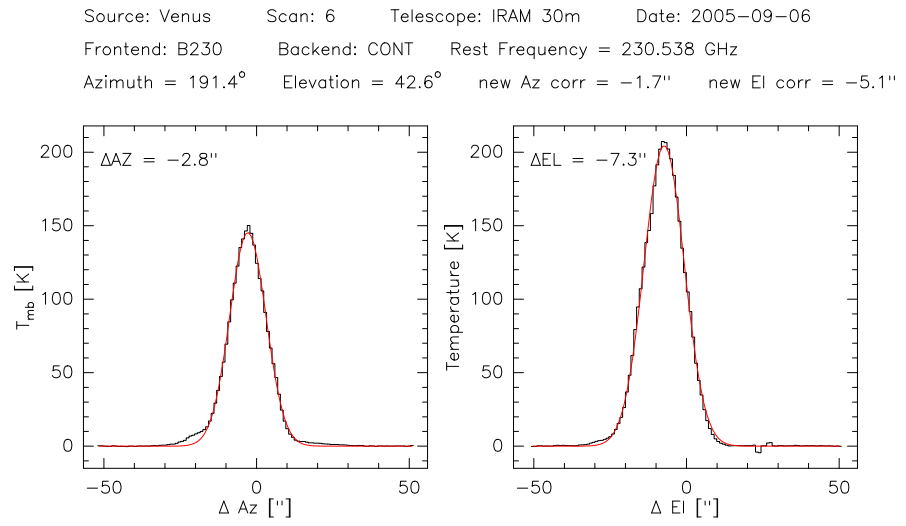


Figure 2: Example for a pointing solution (subscans coadded).

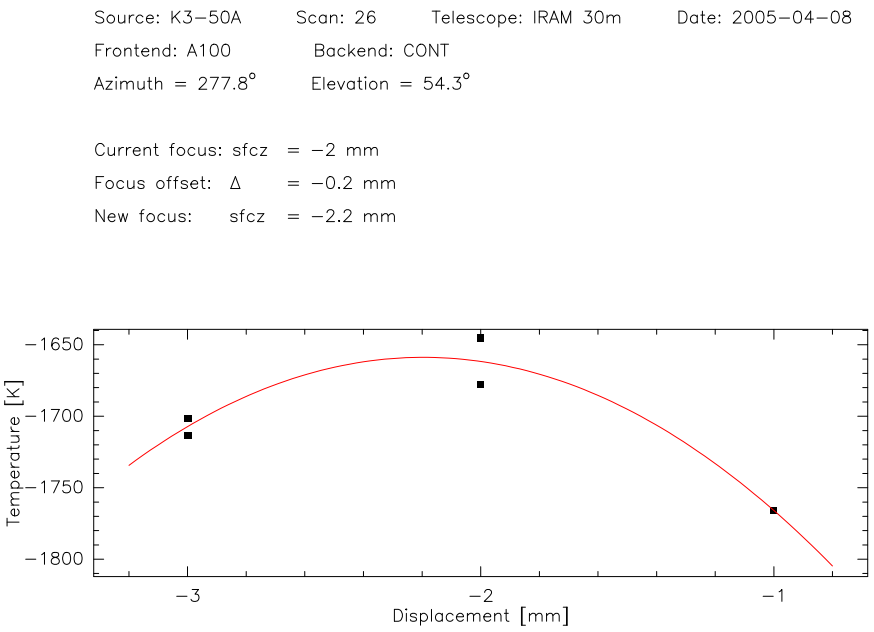


Figure 3: Example for a focus solution.

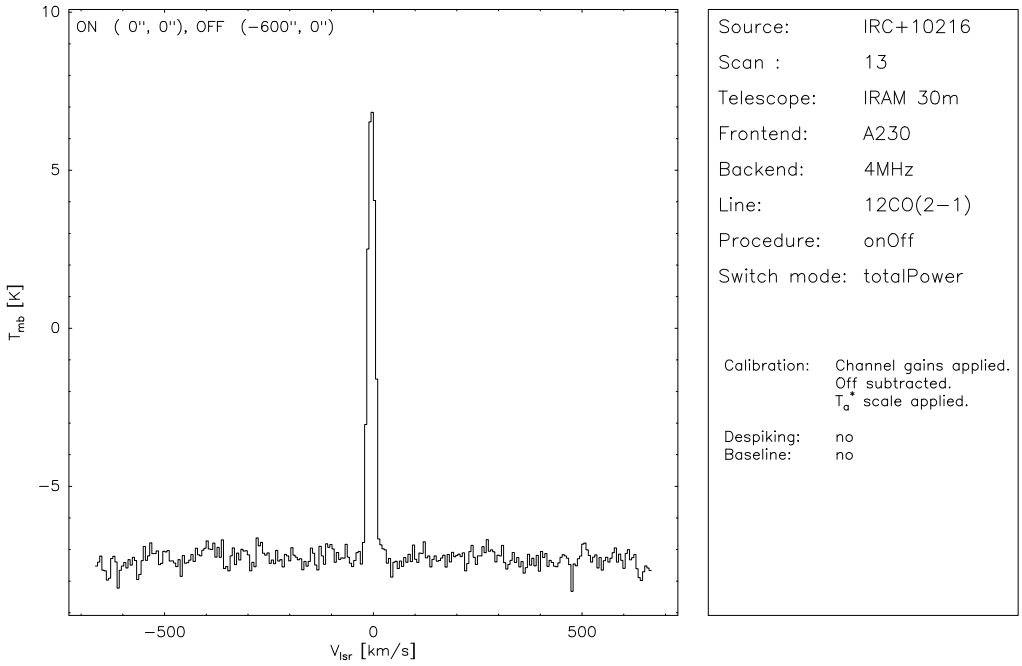


Figure 4: Example of a calibrated spectrum.

3.2 OTF maps

In principle, data reduction for OTF maps is the same as described in the previous section. However, for switch mode "totalPower", there are different modes to weight the off-source reference measurement. This is to get the best estimate of the atmospheric total power contribution during an OTF subscan. The modes are specified as arguments for option `/OFF` of command `MIRA\CAL` (see the MIRA language internal help for the command syntax). This command subtracts the atmospheric total power, and concatenates spectral basebands if necessary.

- Mode NONE: No atmospheric reference signal is subtracted, but spectral basebands are concatenated.
- Mode AVER: Uses the unweighted average of *all* available off-source reference measurements.
- Mode EQUAL: As mode AVER, but only the reference measurements done immediately before and after the OTF subscan are used.
- Mode TIME: Uses as reference signal a weighted mean of the off-measurements taken before respectively after the on-subscan. The first reference has a weight decreasing with the time elapsed between the on-the-fly record and the first reference measurement (and the weight of the second reference increases correspondingly).
- Mode TOTAL: as mode TIME, but uses the total power rather than the elapsed time as weighting criterion, such that the total power of the on-the-fly record equals the weighted sum of the total power of the reference measurements. A spectral line contributing significantly to the total power may be masked (see the MIRA language internal help for the command syntax).

The default (also used by the automatic online data processing) is mode AVER. Depending on weather conditions, you may get flatter and lower baselines using one of the other options.

Tip: For large OTF maps, or HERA OTF maps, the amount of data shown makes it impossible to show fine features in an appropriate way. In that case, the command `VIEW /ZOOM` allows the user to show a subset of the data: it calls the interactive cursor, which is used to define two diagonally opposite corners with two single mouse clicks). The plot is then re-displayed, with new ordinate and abscissa scales. For HERA data, this option works for a single pixel only (command syntax for pixel `ipix`: `VIEW /PIXEL ipix /ZOOM`).

Tip: For OTF maps observed with frequency switching, the amount of data may become large for short switch cycles, and the calibration may be painfully slow. It can be accelerated by averaging dumps before calibration. Please use `SCAN /COMPRESS dumpTime` (if the argument `dumpTime` is not an integer multiple of the uncompressed dump time, the compression factor is rounded to the next integer).

Tip: If there are no (or not enough) data from the reference position, it is possible to use the data from the OTF subscans themselves to get a reference spectrum (syntax: `CAL all /GAINS /TCAL /OFF /MASK n1 n2 [n3 n4 ...]\` where n1 and n2 respectively n3 and n4 etc. are the first and last OTF dumps on the source). This works only if the OTF map is large enough to contain emission-free positions. For weak sources, one has to work iteratively.

For HERA data, command `VIEW` displays the pixel offsets (in PaKo's projection system, with respect to the reference pixel) in the plot's boxes, and (schematically) in the plot header. The pixel offsets are also given in the box labels, together with the offsets (pixel offsets plus scan offsets) of the ON position (and/or the OFF position, depending on the plot produced).

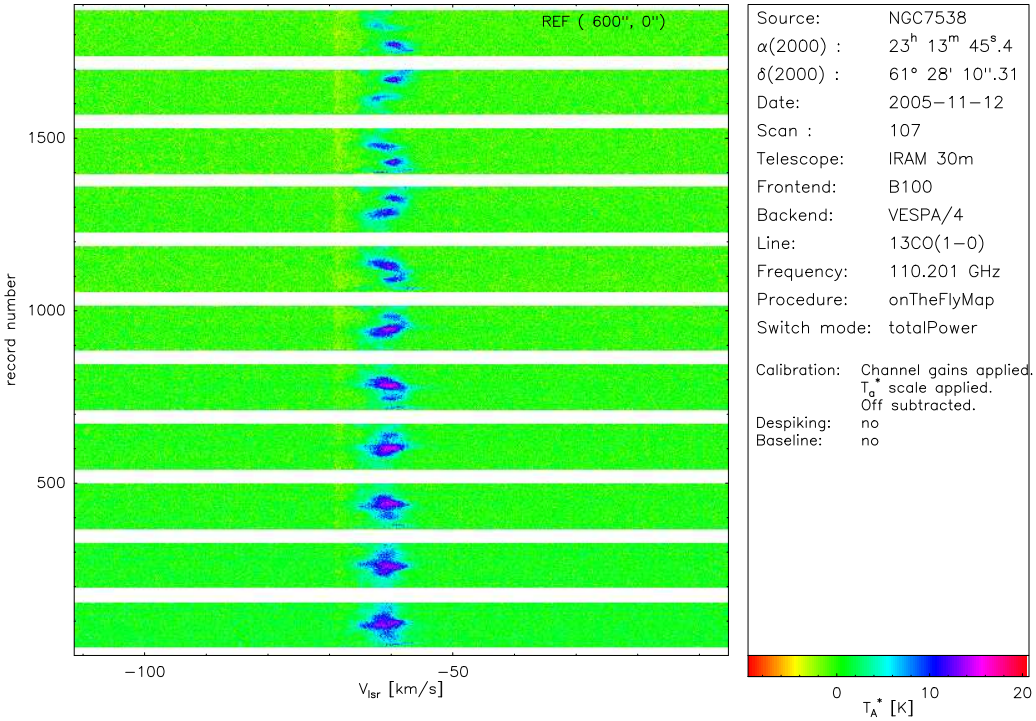
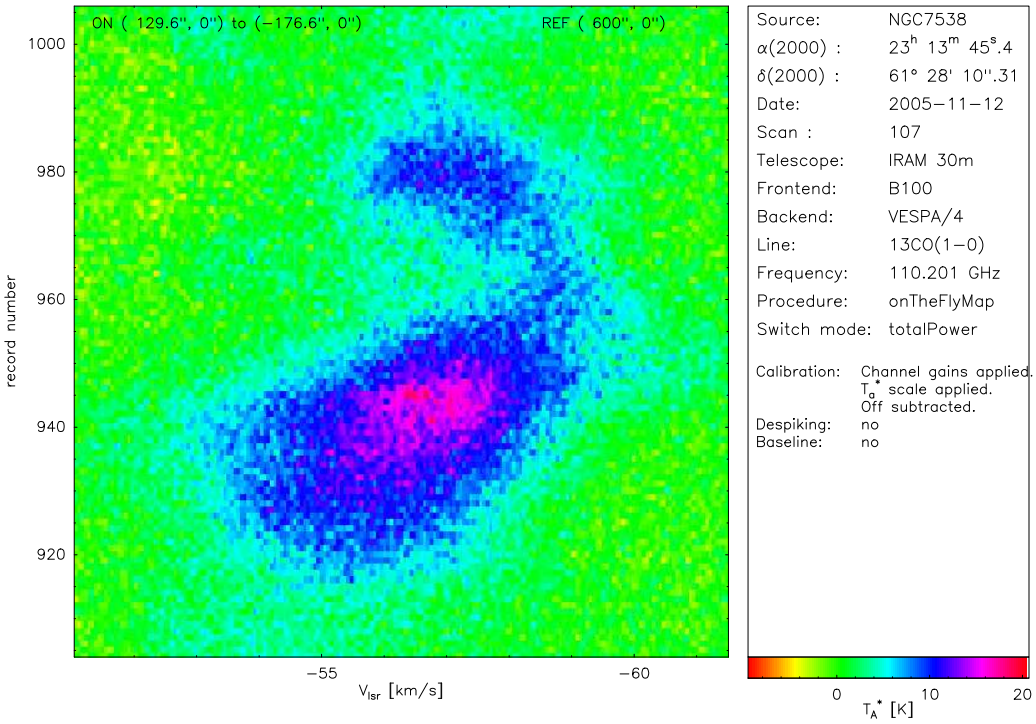


Figure 5: Example of a calibrated, large OTF map, as displayed by MIRA. The records masked by a blanking value correspond to the off-source reference measurements. The offset position of the reference measurement is displayed.



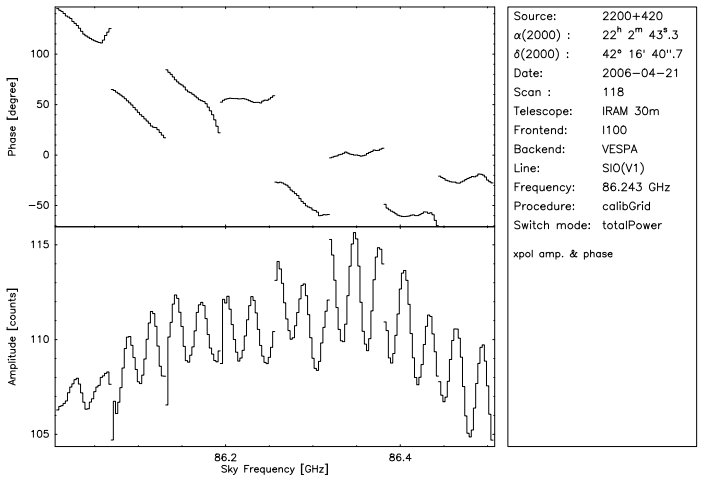


Figure 7: Example of the phase (top) and amplitude (bottom) of a VESPA phase calibration measurement towards a polarizer.

3.3 Polarization measurements

The VESPA backend at the 30m telescope can simultaneously measure the four Stokes parameters, by computing the cross-correlation of an orthogonally polarized receiver pair. However, the phase difference between the signals from both receivers has to be calibrated, in order to attribute the real and imaginary part of the complex cross correlation to the Stokes U and V parameters. This phase difference is measured by a dedicated observation (a calibration with an additional subscan towards the cold load, equipped with a polarizer). If VESPA is in its polarimetry mode, this calibration is the default. MIRA then calculates the amplitude and phase (step 1) and applies the corrections to the astronomical observations (step 2).

`SCAN calScan`	Reads a calibration including a polarizer measurement in scan *calScan*. The spectra are (for each backend part) in order H, V, R, I (for horizontal, vertical, real part, imaginary part).
`CAL all [/GAINS /TCAL /PHASE]`	Determines, for all backend parts, the relative phase of the orthogonally polarized receiver pair, and the amplitude loss of the cross correlation due to phase noise. The options `/GAINS /TCAL /PHASE` do not need to be specified, they are the default for polarisation calibrations.
`VIEW iPart /XPOL`	Plots the phase and amplitude of the complex cross correlation of the polarizer measurement (Fig. 7) for an assessment the validity of the calibration. *iPart* is the number of the VESPA part to be plotted.
`SCAN obsScan`	Reads the astronomical observation.
`CAL all [/GAINS /TCAL /OFF /PHASE]`	Calibrates this observation, and applies the phase calibration previously determined.

Then the calibrated Stokes spectra can be written out to a CLASS file. The data can then be further reduced using CLASS enhanced by the XPOL macros.

4 MIRA language internal help

4.1 CAL

```
MIRA\CAL [ALL|ifb] [/GAINS [/TCAL]] [/PHASE]
   [/OFF  [NONE]  [AVER]  [EQUAL]  [TIME] [TOTAL vMin vMax] /MASK d1
[d2]]
   [/FEBECAL jfb]
```

CAL calibrates the raw data of the observations loaded with MIRA\SCAN. By default, the first frontend-backend combination is calibrated, otherwise the frontend-backend combination number ifb, or all frontend-backend combinations if ALL is specified instead. If no option is specified, all three calibration stages are performed (i.e. normalization by channel gains, conversion from backend counts to a temperature scale, subtraction of the off-signal with concatenation of autocorrelator basebands.

CAL /GAINS normalizes the spectral band by the gainarray.

CAL /TCAL Converts from backend counts to temperature (forward beam brightness temperature if beam efficiciency set to forward efficiency, otherwise main beam brightness temperature), using the TCal scale automatically determined when a "chopper wheel" calibration is loaded.

CAL /PHASE Applies the phase calibration for XPOL measurements (i.e. VESPA in polarimetry mode). The imaginary part of the cross correlation between orthogonally polarized receivers thus becomes the Stokes V parameter (circular polarization). In order to have a valid phase calibration, a calibGrid measurement with an identical spectral setup has to be previously calibrated.

CAL /OFF subtracts the atmospheric emission as measured on the OFF position, and concatenates spectral basebands. For frequency-switched observations, the subtraction of the reference signal has to be done in CLASS with command FOLD.

For on-offs with continuum backends, a baseline linearly varying with elapsed time is subtracted before further processing the data. The resulting fluxes and errors can be displayed with VIEW /PHASE.

For on-the-fly data in total power mode, CAL /OFF has the following options:

CAL /OFF NONE does not subtract the reference signal, only concatenates spectral basebands. Both the reference spectra and on-source spectra are written to the CLASS file (see command MIRA\WRITE).

CAL /OFF AVER uses as reference signal for off subtraction the unweighted mean of all available reference measurements. This is the default.

CAL /OFF EQUAL uses as reference signal an unweighted mean of the off-measurements taken before respectively after the on-subscan.

CAL /OFF TIME uses as reference signal a weighted mean of the off-measurements taken before respectively after the on-subscan. The first reference has a weight decreasing with the time elapsed between the on-the-fly record and the first reference measurement (and the weight of the second reference increases correspondingly).

CAL /OFF TOTAL vMin vMax uses as reference signal a weighted mean value of the off-measurements taken before respectively after the on-subscan. The weighting is done in a way to ensure that the total power of the on-the-fly record equals the total power of the reference signal. A spectral line contributing significantly to the total power can be masked with the arguments vMin and vMax.

CAL /MASK d1 [d2 [d3 d4 ...]] uses the OTF subscans themselves as atmospheric reference, masking the source, which appears between dumps d1 and d2 (and d3 and d4 etc). If only one argument d1 is given, this is the number of dumps used as reference at the start and end of each OTF subscan.

CAL ifb /FEBECAL jfb calibrates the frontend-backend combination ifb with the calibration measurement of frontend-backend combination jfb.

4.2 DESPIKE

```
MIRA\DESPIKE [ifb] [/PIXEL [ipix]] [/ITERATE niter]
                [/WINDOW vMin vMax] [/THRESHOLD value]
```

DESPIKE removes spikes from spectra, OTF data, and continuum drifts, respectively. If the frontend-backend identification number ifb is not specified, the first frontend-backend combination of the current scan is despiked.

DESPIKE /PIXEL [ipix]
Allows to specify the pixel number ipix for array observations. Default is pixel 1 (for HERA1 and HERA2: pixel 5, the central one).

DESPIKE /ITERATE niter

```
Allows to remove up to niter spikes (default is niter = 10).

DESPIKE /WINDOW vMin vMax
Spectral  channels with velocities between vMin and vMax are not consid-
ered in the search for spikes. Used to avoid confusion between e.g. nar-
row spectral lines and spikes.

DESPIKE /THRESHOLD value
By  default,  the  threshold  for searching for spikes is 5 sigma (rms),
i.e.  records where the difference between the data value and the median
of  the  spectrum or the time series is higher than 5 sigma are despiked
(i.e. attributed  the  blanking  value).  With  option  /THRESHOLD,  the
threshold can be set to another value.
```

4.3 FILE

```
    MIRA\FILE IN|OUT name [NEW] [/CLASS] [/MBFITS] [/SHOW]

Selects the input directory and output files.
FILE IN name         defines the input directory
FILE OUT name [NEW]  defined the output file;
                     initializes a file if NEW is given.

FILE /CLASS Opens a CLASS type file for output (default). If the output
            filename has no extension, defaults to .30m

FILE /MBITS Converts IMBFITS raw data to MBFITS raw data.
            Not yet implemented.

FILE /SHOW  Displays the names of the current input and output files
            (if opened, otherwise a warning message is issued).
```

4.4 FIND

```
    MIRA\FIND [/BACKEND] [/FRONTEND] [/LINE] [/OBSERVED] [/PROCEDURE]
           [/SCAN] [/SOURCE] [/TELESCOPE] [/NEW] [/SWITCHMODE] [/SILENT]
           [/WHAT] [/PROJECT] [/STAT]

FIND performs a search in the input directory to build a new index,
according to selection criteria defined by one or more of the following
options. The index list (as desribed in the help for command MIRA\LIST).
Each option accepts more than one argument.
```

NEW: FIND is not anymore a prerequisite for the MIRA\SCAN command. In case o ambiguous scan numbers, MIRA\SCAN will implicitely take the last scan found (i.e. the most recent one).

NOTE: if you use MIRA\FIND together with a large data archive, you can accelerate the search by either not using FIND at all or by specifying at le

/BACKEND name	Searches for data from backend name.
/FRONTEND receiver	Searches for data from a given receiver.
/LINE transition	Search for data of spectral line transition.
/OBSERVED startDate [endDate]	Searches for data observed between startDate and endDate. If endDate is not specied, looks only for data observed the day of startDate. Date format is YYYY-MM-DD (e.g. 2005-09-29).
/PROCEDURE procedure	Searches for data of a given observing procedure (e.g. pointing, focus, onOff, calibration,...).
/SCAN i1 [i2]	Searches for data from scans i1 to i2 (or only scan i1 if i2 not specified).
/SOURCE object	Searches for data from source object.
/TELESCOPE antenna	Searches for data from telescope antenna.
/NEW	Searches for new data written to the input directory and appends them to the existing index list. If no new data are found, the current index list remains unchanged. For online data processing at the telescope.
/SWITCHMOD switch	Searches for observations done with switchmode switch (e.g. wobbler, beamSwitching).
/SILENT	Loads the observations corresponding to the se criteria into the index list, without issuing list output.
/WHAT	List the selection currently used.
/PROJECT xxx-yy	Selects only data from project xxx-yy.
/STAT	Writes the total integration time of all observations in the current index list into output file .stat (mainly for observing pool administration).

4.5 FLAG

MIRA\FLAG [all|ifb] [/BASEBAND] [/CHANNEL] [/PIXEL] [/RECORD] [/SUBSCAN]

FLAG allows to ignore selected data for further reduction by attributing the the blanking value, for frontend-backend unit ifb (or for all units using th

```
corresponding keyword). If only one item is specified (e.g. baseband), the
corresponding baseband(s) are flagged for all pixels and records, unless
options /PIXEL and /RECORD are specified, too. Multiple arguments are possib
To reset the flags, the scan has to be read again.
```

4.6 LIST

```
    MIRA\LIST [/OUTPUT listfile] [/LONG] [/PROJECT] [/REDUCE] [/FLUX [backen

LIST writes the current index list to the screen:
column 1 :      scan number
column 2 :      source name
column 3 :      observing procedure
column 4 :      switch mode
column 5 :      backend name
column 6 :      observing date (format YYYY-MM-DD)
column 7 :      running index

LIST /OUTPUT listfile   Writes the index list into output file listfile,
                        instead of writing to the screen. No default
                        provided (LIST /OUTPUT has the same action as LIST).
                        Default extension is .lis

LIST /LONG              Provides a more complete listing. Each frontend-
                        backend combination is listed. Information which is
                        the same for all frontend-backend combinations is
                        only written once per scan (all columns except for
                        the spectral line name and the frontend name).
column 1:               scan number
column 2:               source name
column 3:               spectral line name
column 4:               observing procedure
column 5:               switch mode
column 6:               frontend name
column 7:               backend name
column 8:               observing date
column 9:               running index

LIST /PROJECT           Includes the project number into the current index
                        list. LIST /LONG and LIST /PROJECT are mutually
                        exclusive. The listing gets the following format:
column 1 :      scan number
column 2 :      source name
column 3 :      observing procedure
column 4 :      switch mode
```

```
column 5 :      backend name
column 6 :      observing date (format YYYY-MM-DD)
column 7 :      project number (format XXX-YY)
column 8 :      running index
```

LIST /REDUCE [macro] [classFile] Instead of listing the data in the current index, prepares a procedure for off-line data reduction (default: reduce.mir of all observations in the current index. The class output file defaults to mira.30m

LIST /FLUX writes an ASCII-table pointd-mmm-yyyy.dat with pointing corrections and fluxes for all pointings in the index list. The flux unit is antenna temperature [K] if the index list contains the corresponding calibra measurements, otherwise backend counts. The executions halts after subscans scans if doPause = yes (then type c to continue or q to quit). If a backend name is specified as argument, fluxes from on-offs with the corresponding backend are written instead.

LIST /FORMAT [shortByScan] [longByScan] [shortBySubscan] [longBySubscan] Options for the output format of the pointing flux list: "short" means the essential information, "long" yields some extra information appended to extr columns extending the output file, "ByScan" means that only solutions for subscan averages (of azimuth respectively elevation subscans) are written, whereas "BySubscan" contains the solution for individual subscans.

LIST /FLAG ifb isub1 isub2 isub3 ...
Only used together with option /FLUX. Flags frontend-backend unit ifb in subscan(s) isub1, isub2, isub3 etc. , for all pointing scans in the current If you only want to flag a single scan iscan, use FIND /SCAN iscan prior to calling LIST /FLUX.

4.7 OVERRIDE

```
MIRA\OVERRIDE TEM[PLOAD] | EFF[ICIENCY] | GAIN[IMAGE] value1 value2 |
          TAMB[PID] value1 value2 [/FEBE ifb|all] [/RESET]
```

OVERRIDE allows to change parameters relevant for calibration. By default, the parameters for frontend-backend combination 1 are changed (see below for option /FEBE). Instead of value1 and value2, asterisks may be used to leave the parameter unchanged (see below). The parameters changed are displayed on the screen. If the scan loaded is a calibration (i.e. sky, hot load, cold load), the calibration parameters are automatically re-calculated, using the new values for the load temperatures and/or efficiencies. The calibration parameters in the raw data are replaced by tho set with OVERRIDE until reset by OVERRIDE /RESET

```
Keyword TEM[PLOAD]:     changes the temperatures of the cold load (value1)
                        and of the hot load (value2).

Keyword EFF[ICIENCY]:   changes the forward efficiency (value1) and the
                        beam efficiency (value2).

Keyword GAIN[IMAGE]:    changes the the suppression of the image band
                        (value1).

OVERRIDE /FEBE ifb|all  This is to specify the frontend-backend combination
                        (ifb) for which the calibration parameters are to
                        be changed. Keyword "all" changes the parameters
                        for all frontend-backend combinations in the
                        current scan.

OVERRIDE /RESET         Resets all calibration parameters to default (raw da
                        values). A new calibration has to be read in order t
                        activate the change.

EXAMPLES:
OVERRIDE TEMPLOAD * 300 /FEBE all  Changes the hot load temperature for all
                                   frontends to 300 K. All cold load
                                   temperatures are left unchanged.

OVERRIDE EFFICIENCY 0.95           Changes the forward efficiency of
                                   frontend 1 to 0.95. All beam
                                   efficiencies are unchanged.

OVERRIDE GAINIMAGE 0.1 /FEBE 1     Changes the sideband suppression for the
                                   receiver in frontend-backend combination
                                   number 1 to 0.1.

OVERRIDE TAMBPID -7.5 712     Changes ambient outside temperature and
                                   pressure to -7.5 deg C and 712 hPa.
```

4.8 SCAN

```
MIRA\SCAN scan [/TRACKING trackingError] [/COMPRESS integTim]
            [/TAU tau1 [tau2 ...]] [/PWV h2omm]
            [/SUBSCAN first last] [/BACKEND backend1 backend2 ...]
            [/DROP ignoreBackend1 ignoreBackend2 ...]
```

Loads a scan from the current index list. ALL frontend-backend combinations used are loaded. A list of identification numbers for the frontend-backend combinations is issued. For calibrations, MIRA\SCAN also computes the

calibrations parameters, and writes them to the screen. The calibration parameters for VESPA basebands are individually computed; however, the screen output is for mean values across all basebands corresponding to one spectrum.

NOTE: (1) MIRA\FIND is not anymore a prerequisite for command MIRA\SCAN (see for FIND).
(2) After commands OVERRIDE (for calibrationts) or changing the value logical flag timingCheck the scan needs to be read again in order to v new settings.

SCAN /TRACKING trackingError Backend dumps with azimuth- or elevation tracki errors larger than trackingError (in degree) are flagged (i.e. attributed the blanking value for raw data).

SCAN /COMPRESS dumpTime Allows to compress large data sets (e.g. with too short a dump time). If the new dump time is not an integer multiple of the uncompressed dump time, command SCAN rounds the compression factor to the next integer.

SCAN /TAU tau1 tau2 ... For calibration scans. Keeps the opacity fixed at values tau1 tau2 ... for frontend-backend numbers 1,2,..., and calculates the corresponding calibration.

SCAN /PWV h2omm For calibration scans. Keeps the atmospheric water vapour fixed at value h2omm and calculate the corresponding calibration for all connected frontend-backend units.

SCAN /SUBSCAN first last Only reads in subscans "first" to "last".

SCAN /BACKEND backend1 backend2 ... Only reads in backend1, backend2, e

SCAN /DROP ignoreBackend1 ignoreBackend2 ... Ignores listed backend for read

4.9 SOLVE

MIRA\SOLVE [ifb [jfb]] [/PIXEL ipix] [/BINNING nbin]

SOLVE retrieves the pointing respectively focus corrections or a solution to a skydip from the observing procedure loaded with MIRA\SCAN. By default, the first frontend connected to the continuum backend is used, otherwise

number ifb. The pointing and focus results are written to the output device, and to output files miraResultsPointing.xml respectively miraResultsFocus.xm for further use by the telescope's control system. If two receiver numbers i and jfb are entered, the receiver alignment in the Nasmyth focus is fitted a plotted (together with the other results in file alignment.dat created by MI

SOLVE /PIXEL ipix	For observations with HERA. Allows to specify another pixel than the reference pixel for pointing, focus or skydip. For skydips, enter SOLVE /PIXEL 0 to plot all pixels.
SOLVE /BINNING nbin	For pointing measurements, allows to smooth the azimuth and elevations drifts (for weak pointing sources). nbin is the number of dumps averaged (simple box window smoothing).

4.10 VARIABLE

MIRA\VARIABLE section|* read|write

Generates a SIC copy of one of the following MIRA data sections (wildcard permitted, activates all sections), for read (default) ow write access. For further documentation on MIRA's data structure, please consult section 5 of the MIRA manual. The section MON consists of SIC structures MON%HEADER and MON%DATA. Each frontend-backend combination has its own GAINS and REDUCE section (e.g. GAINS1, REDUCE3, etc.). The sections SCAN, FEBE, and DATA consist of header and data structures for each frontend-backend combination, e.g. SCAN1%HEADER, SCAN1%DATA, FEBE2%HEADER, FEBE3%DATA, and so on. The DATA and HEADER structures of section ARRAY are written for each baseband, e.g. ARRAY1%HEADER1, ARRAY2%DATA3, etc.

VARIABLE PRIM	Retrieves the IMBFITS primary header.
VARIABLE SCAN	Same for the scan header and table sections.
VARIABLE FEBE	Information related to the frontend-backend combination.
VARIABLE ARRAY	Raw data headers and data sections.
VARIABLE DATA	For calibrated raw data, and monitor points interpolated at the backend timestamps.
VARIABLE MON	Monitoring headers and table sections.
VARIABLE GAINS	Calibration parameter for each frontend-backend combination.
VARIABLE CHOICE	Search options for MIRA's command FIND.
VARIABLE REDUCE	MIRA internal flags for calibration history.
VARIABLE LIST	Entries of the current index list.

4.11 VIEW

```
MIRA\VIEW [ifb] [/CAL] [/GAINS] [/PHASES [phaseId] [irec]] [/SIGNAL [idu
          [/MAP] [/PIXEL ipix] [/TRACES [trackLimits]] [/XPOL ipart]
          [/ZOOM] [/DEROTATOR [frameAngle]] [/OTF]
```

VIEW is MIRA's command for plotting the data of frontend-backend combination number ifb (default is 1). Alternatively, VIEW ifb1 ifb2 concatenates bands ifb1 and ifb2 for plotting (for option /SIGNAL only), and VIEW ifb1 TO ifb2 concatenates all bands from ifb1 to ifb2.

The item to be plotted is specified
by one of the following options. Otherwise, the following defaults are provided: VIEW /CAL for chopper-wheel calibrations, VIEW /PHASES for all uncalibrated data, VIEW /SIGNAL for calibrated data (at least off subtracted) from a single position, respectively VIEW /MAP for OTF maps.

VIEW /CAL
For calibrations only. Plots the counts from the loads (sky, ambient, cold, respectively) versus time (for continuum backends. For spectral line backends, plots the subscan average of the dumps from the corresponding loads versus frequency. Calibration and weather parameters are also displaye (for HERA data only if option /PIXEL is used).

VIEW /GAINS
Plots the gainarray currently in use. For spectrometers only.

VIEW /MAP
Plots a pseudo-map (data values versus velocity and record number) for calibrated OTF data.

VIEW /PHASES [phaseId] [irec]
Plots the uncalibrated data against time (for continuum backends) respectively frequency and record number (for spectrometers), using phase phaseId (according to the observing procedure viewed, it defaults to 0 SKY, or FHI). By default, the scan average of all phases iphase in shown, otherwise record number irec.

For on-offs with continuum backends, the mean flux and its estimated error a displayed (for HERA data please select a pixel). For continuum data taken with the beam switch, phase1-phase2 is plotted, where the leading phase1 is given by phaseId. For one of phaseId = 1, 2, ..., nphases, only the total power for the corresponding phase is shown.

VIEW /PIXEL ipix
By default, VIEW shows data for all HERA pixels. If you want to visualize only one pixel (e.g. together with option /ZOOM, see below), please use this option.

VIEW /DEROTATOR [frameAngle]
Plots HERA's derotator angle for the Nasmyth reference system, for the last scan read in. If frameAngle is not specified, the current position angle of HERa is used.

VIEW /SIGNAL [idump]
Plots calibrated data, as time series (for continuum drifts) respectively spectra (for spectrometers). For OTF maps, record number idump can be specified to plot a single spectrum.

VIEW /TRACES [trackLimits]
A tool to visualize the antenna speed and fast trace values. The plot distinguishes between the trace values, and their interpolation at the backend record time (used for further data processing). Optionally, parameter trackLimits [arc sec] can be used to narrow the plot limits for th tracking errors.

VIEW [ipart] /XPOL
Allows to plot the amplitude and phase of the cross correlation of orthogonally polarized receivers, as measured by a calibGrid procedure (only for VESPA data in XPOL mode). If the Stokes parameters of several spectral lines are simulteaneously measured, ipart sets the VESPA part (defaults to 1). In order to retrieve the amplitude and phase, please perform first a calibration.

VIEW /ZOOM
Plots and calls the interactive cursor to define a region for a zoom. Use the cursor to define the lower left and upper right corner (order does not matter).

VIEW /OTF
Displays a layout of points on the sky sampled by the OTF maps in the curren index list generated with FIND (latitude offset vs. longitude offset).

4.12 WRITE

MIRA\WRITE [/FEBE ALL|ifb] [/PIXEL ALL|ipix] [/SUBSCANS isub]

```
Writes calibrated data to a CLASS file (respectively raw data to a
MBFITS file, not yet implemented, see help for MIRA\FILE). The number of
the spectrum (or continuum drift) is successively increased.

WRITE  /FEBE ALL|ifb
Specifies the frontend-backend combination to be written (here: ifb). Defaul
is 1. Argument ALL: writes CLASS spectra for all frontend-backend combinatio
in current index.

WRITE /PIXEL ALL|ipix
For HERA data: spectra from pixel ipix are written (default pixel 1). To
write out all pixels: WRITE /PIXEL ALL

WRITE /SUBSCAN isub
By default, all subscans are written to the CLASS output file (for OTF maps
one CLASS spectrum per records, for pointing one CLASS drift per subscan).
With the /SUBSCAN option, only a given subscan of an OTF map or a pointing
is written to the output file (defaults to subscan 1 if isub is not specifie
```

5 MIRA / SIC variables

Most of the variables in the internal MIRA structure can be copied to and examine (e.g. plotted with GREG) as SIC variables. MIRA provides the following commands for defining and initialising these variables. For an explanation of the sections and their contents, I also refer to the document "Multi-Beam FITS Raw Data Format", revision 1.4. Variables derived from WCS (= *world coordinate system*) FITS keywords have their leading number appended to the end of the keywords' names, for the sake for compatibility with FORTRAN (e.g. `CRVL4_1` instead of `1CRVL4`).

5.1 Global SIC default variables

By default, i.e. without reading any data, MIRA defines the following SIC variables:

```
doPause                         ! Logical GLOBAL
```

which can be set to `.true.` or `.false.` with

```
let doPause yes
```

respectively

```
let doPause no
```

It is used to halt the execution of `MIRA\SOLVE` until the user types `continue`.

```
writeXML                    ! Logical GLOBAL
```

is used to write (`let writeXML yes`) XML files with pointing, focus, and calibration solutions applied to the data (respectively to suppress this via `let writeXML no`). The files are named `iram30-pointing-20071022s99.xml` for pointings, and `iram30m-focus-...` and `iram30m-calibration-...` for focus solutions and calibration parameters, respectively.

The following variables are used by the automatic online data processing (see section 2), and specify, for the 30m file system, the paths to the imbFits raw data location (ncsData) and to the MIRA data products (visData), respectively:

```
ncsData                     ! Character*  256 GLOBAL
visData                     ! Character*  256 GLOBAL
```

Global SIC variables for calibration purposes:

```
calByChannel                ! Logical GLOBAL
```

By default, one separate calibration temperature is applied for each spectral baseband. If you want to use a different calibration temperature for each spectral channel, use `let calByChannel yes`) before reading a calibration scan. This feature is to be used e.g. if the image gain is not neglectable (e.g. DSB tuning) and varies significantly across the spectral bandpass.

```
calCheck                    ! Logical GLOBAL
```

The SIC logical variable `calCheck` (default: `.true.`) allows to check the consistency of an observation and its calibration measurement. If only part of the backend units are calibrated, then MIRA tries to identify backend units that can be calibrated. Use `let calCheck = no` when you connect two or more parts of the same backend to the same receiver, with identical spectral setup (otherwise the assignment of the calibration parameters will not be unique anymore).

```
ignoreTraceflag             ! Logical GLOBAL
```

The `TRACEFLAG` parameter in the raw data indicates whether the antenna was in a defined state (e.g. tracking or scanning) or not. The latter may happen in the data if synthesizer data are taken while the antenna is in stow position (thus simulating astronomical observations). The default is `let ignoreTraceflag no`. For data taken while the antenna is in stow position please set it to `yes`.

```
badLevel                    ! Real GLOBAL
```

The `badLevel` parameter allows to automatically flag bad spectral channels. Default: if in the calibration the total power of a spectral channel is more than a factor 20 above or below the median total power across the baseband under consideration, this raw data point will be flagged (and the calibrated spectral channel too).

```
flagBSwSpikes                ! Logical GLOBAL
```

A recent analysis has shown that some dumps in beam switched pointings have abnormally short integration times (5 msec and more below the nomincal value). However, the actual integration times are longer. The wrong normalization (from counts to count rates) thus results in spikes. With `let flagBSwSpikes .true.` this data are automatically flagged (default: no flagging).

```
timingCheck                  ! Logical GLOBAL
```

By default (`timingCheck = yes`) MIRA checks that each backend data point is framed in time by data point from the other data streams (subreflector, antenna, fast and slow traces). If this is not the case although the data point is between the nominal subscan start and end time, the latter are modified accordingly in order to avoid hazardous extrapolations. This automatic correction can be switched off by setting `let timingCheck no` (after a change of the `timingCheck` flag, the scan needs to be read again in order to validate the new settings.

```
traceExtrapolation           ! Logical GLOBAL
```

Only for `timingCheck = no`. Allows for extrapolation of antenna trace data (fast and slow) for backend data at scan start without a trace data point before, or for backend data at scan end without a trace data point after.

5.2 SIC variable corresponding to MIRA's data structure

`var prim r [w]`	retrieves primary header as SIC variables for reading (default) or writing.
`var scan r [w]`	same for the scan header and table sections
`var febe r [w]`	frontend-backend header and table sections
`var array r [w]`	arraydata headers and table sections
`var data r [w]`	data headers and table sections
`var mon r [w]`	monitoring headers and table sections
`var gains r [w]`	MIRA variables
`var choice r [w]`	search options for MIRA command `find`
`var reduce r [w]`	MIRA internal flags for calibration history

Here is a listing of the corresponding SIC variables. The array dimensions are specified by the following parameters:

$n_{\rm fb}$	number of frontend-backend combinations
$n_{\rm pix}$	number of pixels
$n_{\rm bd}$	number of basebands
$n_{\rm cpb}$	number of spectral channels per baseband
$n_{\rm chan}$	number of spectral channels (concatenated basebands)
$n_{\rm off}$	number of off positions from catalogue position
$n_{\rm rec}$	number of records (= backend data)
$n_{\rm ph}$	number of phases (e.g. 2 = on, off)
$n_{\rm subsc}$	number of subscans
$n_{\rm subr}$	number of subreflector monitor points
$n_{\rm slow}$	number of antenna monitor points (slow rate)
$n_{\rm fast}$	number of antenna monitor points (fast rate)

Variable types are denoted as S (structure), I (integer), R (real, single precision), D (real, double precision), C (character string) and L (logical).

Caveats: (1) Neither the MIRA data structures nor the corresponding SIC structures are exactly mapped from the MBFITS V1.54 file definition. However, I tried to keep them as close as possible. (2) Not all of the following items are already copied from the IMBFITS file to SIC variables (even if the SIC variable is declared).

5.2.1 PRIMARY section

PRIM	S	
PRIM%HEADER	S	
PRIM%HEADER%MBFTSVER	C*11	MBFITS version
PRIM%HEADER%CREATOR	C*32	Softwrae (including version)
PRIM%HEADER%ORIGIN	C*32	Organisation or Institution
PRIM%HEADER%TELESCOP	C*13	Telescope Name
PRIM%HEADER%EXTEND	L	
PRIM%HEADER%BITPIX	I	
PRIM%HEADER%SIMPLE	L	
PRIM%HEADER%NAXIS	I	

5.2.2 SCAN section

General scan information.

SCAN	S		
SCAN%HEADER	S		
SCAN%HEADER%ZFLX	R	deg	Pointing coefficient (Flexure)
SCAN%HEADER%ECEC	R	deg	Pointing coefficient (P8)
SCAN%HEADER%IE	R	deg	Pointing coefficient (P7)
SCAN%HEADER%AW	R	deg	Pointing coefficient (-P4)
SCAN%HEADER%AN	R	deg	Pointing coefficient (P5)
SCAN%HEADER%NPAE	R	deg	Pointing coefficient (P3)
SCAN%HEADER%CA	R	deg	Pointing coefficient (P2)
SCAN%HEADER%IA	R	deg	Pointing coefficient (P1)
SCAN%HEADER%NFEBE	I		number of frontend-backend combinations
SCAN%HEADER%WOBMODE	C*20		wobbler mode (SQUARE/TRIANGULAR)
SCAN%HEADER%WOBCYCLE	R	sec	wobbler period
SCAN%HEADER%WOBDIR	C*4		wobbler throw direction
SCAN%HEADER%WOBTHROW	D	deg	wobbler throw (can also be used for beam switching)
SCAN%HEADER%WOBUSED	L		Wobbler used ?
SCAN%HEADER%TRANFOCU	I	m	(optional, HOLO) transmitter offset from prime focus
SCAN%HEADER%TRANFREQ	I	Hz	(optional, HOLO) transmitter frequency
SCAN%HEADER%TRANDIST	I	m	(optional, HOLO) transmitter distance
SCAN%HEADER%ZIGZAG	L		(optional, OTF/RASTER) Scan in zigzag ?
SCAN%HEADER%CROCYCLE	C*20		CAL/REF/ON loop string
SCAN%HEADER%SCANPAR1	D		(optional) spare scan parameter
SCAN%HEADER%SCANPAR2	D		(optional) spare scan parameter
SCAN%HEADER%SCANSKEW	D	user def.	(optional, OTF/RASTER) offset in scan direction between lines

SCAN%HEADER%SCANYSPC	D	user def.	(optional, OTF/RASTER) step between scan/raster lines
SCAN%HEADER%SCANXSPC	D	user def.	(optional, OTF/RASTER) step along line between samples
SCAN%HEADER%SCANTIME	D	user def.	(optional, OTF) time for one line
SCAN%HEADER%SCANXVEL	D	user def.	(optional, OTF) tracking rate along line
SCAN%HEADER%SCANLEN	D	user def.	(optional, OTF/RASTER) line length
SCAN%HEADER%SCANRPTS	I		(optional) number of repeats of each scan line. Default 1.
SCAN%HEADER%SCANLINE	I		(optional) number of lines in a scan. Default 1.
SCAN%HEADER%SCANDIR	C*4		(optional) scan direction
SCAN%HEADER%SCANGEOM	C*20		Scan geometry
SCAN%HEADER%SCANMODE	C*20		Mapping mode
SCAN%HEADER%SCANTYPE	C*20		Scan astronomical type
SCAN%HEADER%DISTANCE	D	AU	geocentric distance
SCAN%HEADER%ORBEQUNX	D		Elements equinox: J2000.0 or B1950.0
SCAN%HEADER%ORBEPOCH	D	Julian days	EPOCH, Epoch of orbital elements
SCAN%HEADER%ECCENTR	D		EC, Eccentricity
SCAN%HEADER%INCLINAT	D		IN, Inclination
SCAN%HEADER%OMEGA	D		W, Angle from ascending node to perihelion
SCAN%HEADER%LONGASC	D		OM, Longitude of ascending node (in degrees)
SCAN%HEADER%PERIDIST	D	AU	QR, perihelion distance
SCAN%HEADER%PERIDATE	D	Julian days	TP, Full Julian date of perihelion passage
SCAN%HEADER%MOVEFRAM	L		True if tracking a moving frame. If true, the above orbital elements are stored.
SCAN%HEADER%CALCODE	C*4		Calibrator code
SCAN%HEADER%LATOBJ	D	deg	Source latitude in native frame.
SCAN%HEADER%LONGOBJ	D	deg	Source longitude in native frame.
SCAN%HEADER%LONGOFF	D	deg	Longitude offset from catalogue position.
SCAN%HEADER%LATOFF	D	deg	Latitude offset from catalogue position.
SCAN%HEADER%OBJECT	C*10		Source name.
SCAN%HEADER%LATPOLE	D	deg	Basis latitude of native pole.
SCAN%HEADER%LONPOLE	D	deg	Native longitude of celestial pole.
SCAN%HEADER%CRVAL1	D	deg	Native frame zero in basis system (long.)
SCAN%HEADER%CRVAL2	D	deg	Native frame zero in basis system (lat.)
SCAN%HEADER%EQUINOX	R	Julian years	Equinox
SCAN%HEADER%RADECSYS	C*32		additional system definition for ecliptic/ equatorial coordinates
SCAN%HEADER%CTYPE1	C*8		Basis system (longitude) XLON-SFL
SCAN%HEADER%CTYPE2	C*8		Basis system (latitude) XLAT-SFL
SCAN%HEADER%ETUTC	D	s	Ephemeris Time - UTC time translation
SCAN%HEADER%GPSTAI	D	s	GPS time - TAI translation
SCAN%HEADER%TAIUTC	D	s	TAI-UTC time translation
SCAN%HEADER%UT1UTC	D	s	UT1-UTC time translation
SCAN%HEADER%NOBS	I		Number of observations in this scan
SCAN%HEADER%NOBSTOTAL	I		Number of subscans upon correct completion
SCAN%HEADER%LST	D	s	Local apparent sidereal time (scan start)
SCAN%HEADER%MJD	D	day	Scan start time (modified Julian date) in TIMESYS system
SCAN%HEADER%DATE_OBS	C*23		Scan date/time (in TIMESYS system)
SCAN%HEADER%SCANNUM	I		Scan number
SCAN%HEADER%OBSID	C*12		Observer and Operator initials
SCAN%HEADER%PROJID	C*12		Project ID
SCAN%HEADER%SITEELEV	R	m	Observatory elevation

SCAN%HEADER%SITELONG	D	deg	Observatory longitude
SCAN%HEADER%SITELAT	D	deg	Observatory latitude
SCAN%HEADER%TELESCOP	C*13		Telescope name
SCAN%DATA	S		
SCAN%DATA%LONGOFF	$n_{\rm off}$ D	deg	longitude offset from catalogue position
SCAN%DATA%LATOFF	$n_{\rm off}$D	deg	latitude offset from catalogue position
SCAN%DATA%FE	$n_{\rm fb}$ I		frontend ID of each frontend-backend combination 0 = unknown 1 = A100 2 = B100 3 = C150 4 = D150 5 = A230 6 = B230 7 = C270 8 = D270 9 = HERA 10 = HERB
SCAN%DATA%BE	$n_{\rm fb}$ I		backend ID of each frontend-backend combination 0 = unknown 1 = continuum 4 = VESPA 5 = WILMA 7 = 4MHz

5.2.3 FEBE section

There is one FEBE (=frontend-backend description) section per frontend-backend combination. The following list is for frontend-backend combination 1 (the corresponding items for combination 2 were FEBE2%HEADER and FEBE2%DATA, and so on).

FEBE1	S		
FEBE1%HEADER	S		
FEBE1%HEADER%ZFLXRX	R	deg	Pointing Coefficient (receiver), adds to ZFLX
FEBE1%HEADER%ECECRX	R	deg	Pointing Coefficient (receiver), adds to ECEC (P8)
FEBE1%HEADER%IERX	R	deg	Pointing Coefficient (receiver), adds to IE (P7)
FEBE1%HEADER%CARX	R	deg	Pointing Coefficient (receiver), adds to CA (P2)
FEBE1%HEADER%IARX	R	deg	Pointing Coefficient (receiver), adds to
FEBE1%HEADER%FRQTHROW	R	Hz	Frequency switching throw
FEBE1%HEADER%NPHASES	I		number of switch phases in a switch cycle
FEBE1%HEADER%SWTCHMOD	C*20		Switch mode
FEBE1%HEADER%NUSEFEED	I		number fo feeds in use.
FEBE1%HEADER%FEBEFEED	I		total number of feeds.
FEBE1%HEADER%FEBEBAND	I		total number of basebands for this frontend-backend combination
FEBE1%HEADER%DEWANG	R	deg	dewar angle
FEBE1%HEADER%DEWRTMOD	C*5		dewar tracking system
FEBE1%HEADER%DATE_OBS	C*23		observing date (Y2K format with time) in TIMESYS system (scan start)
FEBE1%HEADER%SCANNUM	I		scan number
FEBE1%HEADER%FEBE	C*17		frontend-backend combination identification

FEBE1%DATA		S		
FEBE1%DATA%GAINELE1	$n_{\rm bd}$	R	deg	Gain-elevation correction parameter 1 (see MBFITS manual)
FEBE1%DATA%GAINELE2	$n_{\rm bd}$	R	deg	Gain-elevation correction parameter 2 (see MBFITS manual)
FEBE1%DATA%GAINIMAG	$n_{\rm pix} \times n_{\rm bd}$	R		Gain ratio image/signal sideband
FEBE1%DATA%FLATFIEL	$n_{\rm pix} \times n_{\rm bd}$	R		receiver array flat field (relative gains)
FEBE1%DATA%BOLCALFC	$n_{\rm pix}$	R	Jy/counts	bolometer calibration factor
FEBE1%DATA%ANTGAIN	$n_{\rm pix} \times n_{\rm bd}$	R	K/Jy	Antenna gain
FEBE1%DATA%HPBW	$n_{\rm pix} \times n_{\rm bd}$	R	deg	Half-power beam width
FEBE1%DATA%ETAFSS	$n_{\rm pix} \times n_{\rm bd}$	R		forward efficiency
FEBE1%DATA%BEAMEFF	$n_{\rm pix} \times n_{\rm bd}$	R		beam efficiency
FEBE1%DATA%APEREFF	$n_{\rm pix} \times n_{\rm bd}$	R		aperture efficiency
FEBE1%DATA%POLA	$n_{\rm pix}$	R	deg	feed orientation
FEBE1%DATA%POLTY		C*1		feed type (X, Y, L, R)
FEBE1%DATA%REFFEED		I		feed number of reference feed
FEBE1%DATA%FEEDOFFX	$n_{\rm pix}$	D	deg	feed x offset
FEBE1%DATA%FEEDOFFY	$n_{\rm pix}$	D	deg	feed y offset
FEBE1%DATA%DATA%FEEDTYPE	$n_{\rm pix}$	C*1		feed type (see MBFITS manual)
FEBE1%DATA%USEFEED	$n_{\rm pix}$	I		list of feeds which are in use

5.2.4 ARRAY section

There is one ARRAY (= receiver array description) section per frontend-backend combination and per baseband. The following list is for frontend-backend combination 1 and baseband 1 (the corresponding structure names for frontend-backend combination 2 were FEBE2%HEADER1 and FEBE2%DATA1, respectively FEBE2%HEADER2 and FEBE2%DATA2 for baseband 2, and so on).

ARRAY1	S		
ARRAY1%HEADER1	S		
ARRAY1%HEADER1%VSYS4R_2	R	km/s	observer velocity in rest frame
ARRAY1%HEADER1%VSOU4R_2	R	km/s	source velocity in rest frame
ARRAY1%HEADER1%SOBS4R_2	C*8	'TOPOCENT'	observing frame
ARRAY1%HEADER1%SPEC4R_2	C*8	e.g. 'LSRK'	standard of rest frame for velocities
ARRAY1%HEADER1%CD4R_21	D	km/s	velocity channel separation
ARRAY1%HEADER1%CUNI4R_2	C*8	'km/s'	Unit
ARRAY1%HEADER1%CRVL4R_2	D	km/s	velocity at reference channel
ARRAY1%HEADER1%CRPX4R_2	R		reference channel
ARRAY1%HEADER1%CTYP4R_2	C*8	e.g. 'VARD-FRQ'	velocity axis for col.3
ARRAY1%HEADER1%WCSNM4R	C*8	e.g. 'LsrkVRad'	axis name
ARRAY1%HEADER1%SOBS4F_2	C*8	'TOPOCENT'	observing frame
ARRAY1%HEADER1%SPEC4F_2	C*8	e.g. 'LSRK'	standard of rest for frequencies
ARRAY1%HEADER1%CD4F_21	D	Hz	channel separation
ARRAY1%HEADER1%CUNI4F_2	C*8	'Hz'	Unit

ARRAY1%HEADER1%CRVL4F_2	D	Hz	frequency at reference channel in rest frame
ARRAY1%HEADER1%CRPX4F_2	R	Hz	reference channel.
ARRAY1%HEADER1%CTYP4F_2	C*8	'FREQ-FRQ'	frequency axis for col. 3
ARRAY1%HEADER1%WCSNM4F	C*8	e.g. 'LsrkFreq'	axis name
ARRAY1%HEADER1%CD3A_11	I		pixel index separation = 1
ARRAY1%HEADER1%CRVL4_1	I		pixel index value at this position = 1
ARRAY1%HEADER1%CRPX4_1	I		ref. position = 1
ARRAY1%HEADER1%CTYP4_1	C*8	'PIX-INDX'	Pixel/feed index in USEPIX array
ARRAY1%HEADER1%SBSEP	D	Hz	sideband separation
ARRAY1%HEADER1%SIDEBAND	C*3		main sideband (USB or LSB)
ARRAY1%HEADER1%RESTFREQ	D	Hz	rest frequency of line (optional)
ARRAY1%HEADER1%TRANSITI	C*20		main line transition (optional)
ARRAY1%HEADER1%MOLECULE	C*20		main line molecule (optional)
ARRAY1%HEADER1%BANDWID	D	Hz	bandwidth for this band
ARRAY1%HEADER1%FREQRES	D	Hz	frequency resolution
ARRAY1%HEADER1%CHANNELS	I		number of channels for this baseband
ARRAY1%HEADER1%DATE_OBS	C*23		observation start in TIMESYS system
ARRAY1%HEADER1%OBSNUM	I		observation number
ARRAY1%HEADER1%SCANNUM	I		scan number
ARRAY1%HEADER1%BASEBAND	I		baseband number
ARRAY1%HEADER1%FEBE	C*17		frontend-backend combination ID

ARRAY1%DATA1%ISWITCH		$n_{\rm rec}$	C*4		integration type NONE ON OFF LOAD SKY HOT COLD FHI FLO
ARRAY1%DATA1%MJD		$n_{\rm rec}.n_{\rm ph}$	D	day	MJD at integration midpoint in TIMESYS system
ARRAY1%DATA1%DATA	$n_{\rm pix} \times n_{\rm cpb} \times n_{\rm rec} \times n_{\rm ph}$		R		backend data

5.2.5 DATA section

There is one DATA section per frontend-backend combination. The following list is for frontend-backend combination 1 (the corresponding structure names for combination 2 were DATA2%HEADER and DATA2%DATA, and so on). Data associated parameters are interpolated from the monitor data (next section) at the MIDTIME timestamp of the backend data.

DATA1%HEADER	S		
DATA1%HEADER%CHANNELS	I		number of channels (for concatenated basebands)
DATA1%HEADER%OBSTATUS	C*10		Observation o.k. ? (OK/ABORT)
DATA1%HEADER%DPBLOCK	L		Data blocking ?
DATA1%HEADER%OBSTYPE	C*1		observation type (CAL, REF, ON, HOT, COLD, SKY)
DATA1%HEADER%LST	D	s	Local apparent sidereal time (obs. start)
DATA1%HEADER%DATE_OBS	C*23		observation start in TIMESYS system
DATA1%HEADER%OBSNUM	I		observation number
DATA1%HEADER%SCANNUM	I		scan number
DATA1%HEADER%FEBE	C*17		frontend-backend identification
DATA1%DATA%AZIMUTH	$n_{\rm rec}$ D	deg	azimuth inc. wobbler offsets
DATA1%DATA%BASLONG	$n_{\rm rec}$ D	deg	actual long. in astronomical basis frame, inc. wobbler offsets
DATA1%DATA%BASLAT	$n_{\rm rec}$ D	deg	actual lat. in astronomical basis frame, inc. wobbler offsets
DATA1%DATA%CBASLONG	$n_{\rm rec}$D	deg	commanded long. in astr. basis frame, inc. wobbler offsets
DATA1%DATA%CBASLAT	$n_{\rm rec}$D	deg	commanded lat. in astr. basis frame, inc. wobbler offsets
DATA1%DATA%ELEVATIO	$n_{\rm rec}$D	deg	elevation inc. wobbler offsets
DATA1%DATA%DFOCUS_X_Y_Z	$n_{\rm rec} \times 3$ D	mm	(opt.) focus offsets X, Y, Z (subrefl. position)
DATA1%DATA%FOCUS_X_Y_Z	$n_{\rm rec} \times 3$ D	mm	focus (subreflector position) X, Y, Z
DATA1%DATA%INTEGTIM	$n_{\rm rec}$ D	s	integration time
DATA1%DATA%INTEGNUM	$n_{\rm rec}$ I		integration point number
DATA1%DATA%LST	$n_{\rm rec}$ D	s	local apparent sidereal time
DATA1%DATA%LONGOFF	$n_{\rm rec}$ D	deg	long. offset from source in user native frame
DATA1%DATA%LATOFF	$n_{\rm rec}$ D	deg	lat. offset from source in user native frame
DATA1%DATA%MLONPOLE	$n_{\rm rec}$ D	deg	(opt.) longitude of basis celestial pole in body system
DATA1%DATA%MLATPOLE	$n_{\rm rec}$ D	deg	(opt.) basis latitude of body frame pole
DATA1%DATA%MCRVAL1	$n_{\rm rec}$ D	deg	(opt.) body apparent long. in basis system
DATA1%DATA%MCRVAL2	$n_{\rm rec}$ D	deg	(opt.) body apparent lat. in basis system
DATA1%DATA%MIDTIME	$n_{\rm rec}$ D	day	MJD at integration midpoint in TIMESYS system
DATA1%DATA%MJD	$n_{\rm rec}$ D	day	MJD at integration endpoint in TIMESYS system
DATA1%DATA%NINTS	$n_{\rm rec}$ I		integrations in block

DATA1%DATA%PHI_X_Y_Z	$n_{\rm rec}$	D	deg	Phi (subreflector rotation) X, Y, Z (see MBFITS manual)
DATA1%DATA%PC_11		D		matrix elements of transformation from pixel coordinates to intermediate pixel coordinates (projection of user frame)
DATA1%DATA%PC_12		D		
DATA1%DATA%PC_21		D		
DATA1%DATA%PC_22		D		
DATA1%DATA%PARANGLE	$n_{\rm rec}$	D	deg	parallactic angle
DATA1%DATA%SUBSCAN	$n_{\rm rec}$	I		subscan number of data point
DATA1%DATA%OTFDATA	$n_{\rm pix} \times n_{\rm chan} \times n_{\rm rec}$	R	counts, $T_{\rm A}^*$ [K]	OTF data with basebands concatenated and off subtracted
DATA1%DATA%RDATA	$n_{\rm pix} \times n_{\rm ch}$	R	counts, $T_{\rm A}^*$ [K]	single pointing data, basebands concatenated and off subtracted

5.2.6 MONITOR section

The MONITOR section describes all parameters associated with the data. MONITOR data are recorded independently from the backend data (DATA section). The interpolation of data associated parameters at the backend timestamps is written into the data substructure of the DATA section (see above).

Each frontend-backend combination has its own MONITOR section, i.e. MON1%HEADER and MON1%DATA for frontend-backend combination 1, MON2%HEADER and MON2%DATA for frontend-backend combination 2, etc.

Weather data and load temperatures are expected to be monitored several times per scan. For the time being, there is only one entry per imbFits file (except for HERA cold load temperatures).

MON1	S		
MON1%HEADER	S		
MON1%HEADER%DATE_OBS	C*23		observing date in TIMESYS system
MON1%HEADER%FOCOBS_X_Y_Z	3 D	mm	X,Y,Z focus correction
MON%HEADER%IAOBS_CAOBS_IEOBS	3 D	arcsec	Pointing corrections, to be added to IA (P1), CA (P2) and IE (P7). In old 30m control system terms: IAOBS = NULA, CAOBS = COL*, IEOBS = NULE
MON1%HEADER%OBSNUM	I		observation number
MON1%HEADER%SCANNUM	I		scan number

MON1%DATA		S		
MON1%DATA%REFRACTIO		D	arcsec	refraction correction
MON1%DATA%THOTCOLD	1×2	D	K	hot & cold load temperature
MON1%DATA%TAMB_P_HUMID	1×3	D	C, hPa, %	ambient temperature, pressure and rel. humidity
MON1%DATA%ANTENNA_AZ_EL	2	D	deg	SAZM & SELV from old control system
MON1%DATA%LONGOFF	n_{slow}	D	deg	long. offset from source in user native frame
MON1%DATA%LATOFF	n_{slow}	D	deg	lat. offset from source in user native frame
MON1%DATA%BASLONG	n_{slow}	D	deg	actual long. in astronomical basis frame, inc. wobbler offsets
MON1%DATA%BASLAT	n_{slow}	D	deg	actual lat. in astronomical basis frame, inc. wobbler offsets
MON1%DATA%PARANGLE	n_{slow}	D	deg	parallactic angle
MON%DATA%PHI_X_Y_Z	$n_{\mathrm{subr}} \times 3$	D	deg	Phi (subrefl. rotation) X, Y, Z (see MBFITS manual)
MON1%DATA%FOCUS_X_Y_Z	$n_{\mathrm{subr}} \times 4$	D		focus offsets and timestamp:
			mm	X subreflector position
			mm	Y subreflector position
			mm	Z subreflector position
			day	MJD timestamp in IMBF–subreflector binary table
MON1%DATA%DFOCUS_X_Y_Z	$n_{\mathrm{subr}} \times 3$	D	mm	focus (subreflector position) offsets X, Y, Z
MON1%DATA%TRACKING_AZ_EL	$n_{\mathrm{fast}} \times 2$	D	deg	antenna tracking errors in azimuth and elevation
MON1%DATA%ENCODER_AZ_EL	$n_{\mathrm{fast}} \times 3$	D		encoder azimuth & elevation and timestamp
			deg	encoder azimuth
			deg	encoder elevation
			day	MJD time of IMBF–antenna binary table (fast track)
MON1%DATA%MJD	n_{slow}	D	day	MJD time of IMBF–antenna binary table (slow track)

The `MON` structure only contains data that are used for interpolation. Daten taken e.g. between subsequent subscans, before scan start or after scan end do not have a SIC copy, except for the encoder values and tracking errors, written into structure `ANTENNA`. This structure is activated together with the `MON` structure (i.e. upon `MIRA\VARIABLE mon`), and contains (with $n_{\mathrm{allFast}} \geq n_{\mathrm{fast}}$):

ANTENNA%TRACKING_AZ_EL	$n_{\mathrm{allFast}} \times 2$	D	deg	antenna tracking errors in azimuth and elevation
ANTENNA%ENCODER_AZ_EL	$n_{\mathrm{allFast}} \times 3$	D		encoder azimuth & elevation and timestamp
			deg	encoder azimuth
			deg	encoder elevation
			day	MJD timestamp

5.2.7 GAINS section

The GAINS section is not a part of the MBFITS raw-data format, and contains information relevant to data calibration (together with the weather data, that are written to the MONITOR section). There is a separate GAINS section for each frontend-backend combination (i.e. GAINS1, GAINS2 etc.).

GAINS1%PCOLD	$n_{\rm bd} \times n_{\rm pix} \times n_{\rm cpb}$ D		backend count rate of cold load
GAINS1%PHOT	$n_{\rm bd} \times n_{\rm pix} \times n_{\rm cpb}$ D		backend count rate on ambient load
GAINS1%PSKY	$n_{\rm bd} \times n_{\rm pix} \times n_{\rm cpb}$ D		backend count rate on sky
GAINS1%LCALOF	D	deg	longitude offset for sky measurement
GAINS1%BCALOF	D	deg	latitude offset for sky measurement
GAINS1%TAUZEN	$n_{\rm bd} \times n_{\rm pix}$D	Np	zenith opacity
GAINS1%TAUZENIMAGE	$n_{\rm bd} \times n_{\rm pix}$ D	Np	zenith opacity in image band
GAINS1%TATMS	$n_{\rm bd} \times n_{\rm pix}$D	K	atmospheric emission temperature
GAINS1%TATMI	$n_{\rm bd} \times n_{\rm pix}$D	K	atmospheric emission temperature (image band)
GAINS1%TSYS	$n_{\rm bd} \times n_{\rm pix}$D	K	system temperature
GAINS1%TRX	$n_{\rm bd} \times n_{\rm pix}$ D	K	receiver temperature
GAINS1%H2OMM	$n_{\rm bd} \times n_{\rm pix}$D	mm	precipitable water vapour
GAINS1%GAINARRAY	$n_{\rm bd} \times n_{\rm pix} \times n_{\rm cpb}$ D		gain array (= PHOT−PSKY)
GAINS1%FEBE	C*17		frontend-backend identification

5.2.8 CHOICE section

The CHOICE section is not a part of the MBFITS raw-data format, and describes the selection criteria for MIRA's find command.

CHOICE	S	
CHOICE%TELESCOPE	C*13	
CHOICE%OBJECT	C*20	
CHOICE%SCAN1	C*4	first scan of selected scan range
CHOICE%SCAN2	C*4	last scan of selected scan range
CHOICE%PROCEDURE	C*8	observing procedure
CHOICE%DATE_OBS1	C*23	starting date for selection
CHOICE%DATE_OBS2	C*23	end date for selection
CHOICE%TRANSITION	C*20	spectral line name
CHOICE%FRONTEND	C*8	frontend selection
CHOICE%BACKEND	C*8	backend selection

5.2.9 REDUCE section

The REDUCE section is not a part of the MBFITS raw-data format, and contains MIRA-internal flags describing the calibration history. There is one REDUCE section per frontend-backend combination, i.e. REDUCE1, REDUCE2, etc.

REDUCE1	S	
REDUCE1%DESPIKE_DONE	L	Data despiked (yes/no) ?
REDUCE1%BASE_DONE	L	Baseline subtracted (yes/no) ?
REDUCE1%CALIBRATION_DONE	4 I	Calibration done ? (1) Normalized by gainarray (yes /no) ? (2) Backend count rates (no) or temp. scale (yes) ? (3) Off signal subtracted (yes /no) ? (4) Cross correlation phases calibrated (yes /no) ? (for polarimetry only)

5.2.10 RAW section

The RAW section is not part of the MBFITS raw-data format, and contains time stamps for subscan start and end in the IMBF raw-data. There is *one* RAW section per subscan (i.e. RAW1, RAW2,...).

RAW1	S		
RAW1%ANTENNA	S		structure for antenna monitoring data
RAW1%ANTENNA%SUBSCANTYPE	C*40		subscan type
RAW1%ANTENNA%SUBSCANSTART	D	day	subscan start (MJD in TIMESYS system)
RAW1%ANTENNA%SUBSCANEND	D	day	subscan end (MJD in TIMESYS system)
RAW1%ANTENNA%dateObs	D	day	subscan start (as written to imbfits file)
RAW1%ANTENNA%dateEnd	D	day	subscan end (as written to imbfits file)
RAW1%ANTENNA%SEGMENTXSTART	D	deg	offset at subscan start on abscissa in user native system
RAW1%ANTENNA%SEGMENTXEND	D	deg	offset on abscissa at subscan end
RAW1%ANTENNA%SEGMENTYSTART	D	deg	offset at subscan start on ordinate in user native system
RAW1%ANTENNA%SEGMENTYEND	D	deg	offset on ordinate at subscan end
RAW1%SUBREF	S		structure for subreflector monitoring data
RAW1%SUBREF%SUBSCANSTART	D	day	subscan start (MJD in TIMESYS system)
RAW1%SUBREF%SUBSCANEND	D	day	subscan end (MJD in TIMESYS system)
RAW1%SUBREF%SEGMENTXSTART	D	deg	offset at subscan start on abscissa in user native system
RAW1%SUBREF%SEGMENTXEND	D	deg	offset on abscissa at subscan end
RAW1%SUBREF%SEGMENTYSTART	D	deg	offset at subscan start on ordinate in user native system
RAW1%SUBREF%SEGMENTYEND	D	deg	offset on ordinate at subscan end
RAW1%BACKEND	S		structure for backend data
RAW1%BACKEND%SUBSCANSTART	D	day	subscan start (MJD in TIMESYS system)

5.2.11 LIST section

The LIST section is not part of the MBFITS raw-data format, and contains the information in the current index list. LIST consists of LISTof observations found), and – for each observation – LIST1, LIST2,... etc.

LIST	S	
	S	
LIST%FOUND	I	number of observations in the current index list
LIST1	S	
LIST1%NCFE	I	number of connected frontends
LIST1%DATEOBS	C*23	scan start (yyyy-mm-ddThh:mm:ss.sss)
LIST1%BACKEND	C*8	backend name
LIST1%SWITCHMODE	C*20	switching mode
LIST1%PROCEDURE	C*8	observing procedure
LIST1%TELESCOPE	C*13	observatory /telescope name
LIST1%OBJECT	C*20	source name
LIST1%SCAN	I	scan number
LIST1%INDX	I	observation number

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