NCCS Input Files for Single-Dish Observing

M J Gaylard, B Woermann, J L Jonas, J Quick 2001/02/12

This document describes the keywords and their associated parameters that are used in input (source) files and catalogues for all single-dish observing with the NCCS. Typical real-world examples are provided. Written in SGML, this document is viewable from the NCCS documentation index at /usr/local/src/nccs/doc/index.html using Netscape, and can be converted to other formats, e.g. latex, postscript, plain-text etc. using SGML-tools.

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1 Introduction

On the HP1000 every observing program has a unique source or input file format and its own parser for interpeting the parameters from these files. The input files are extremely cryptic, not easily understandable by a human, and usually require programs to be written that will create them in the correct format.

Yet it is entirely possible to standardise on one routine to read all input files, by using a standard file format, differing only in the information needed to define fully each type of observation.

I suggest that keywords followed by parameters are used, in a format analogous to that of the header in FITS format files. Some of the keywords and parameters entered in this way could end up unchanged in the files output by the observing program. As an example, an input or source file for doing continuum radiometry by drift and active scans might look like this:

```
SETUP                           / start setup of common parameters
OBSERVER= M.J. GAYLARD          / observer's name
PROJECT = Continuum tests
PROPOSAL= 1999/001
RESTFREQ= 1650.0E6              / centre frequency in Hz, defines receiver
INSTRUME= NA                    / connect to noise-adding radiometers
SCANTYPE= DRIFT                 / or STEP or SCAN or ...
CATALOG = calibrators.cat       / info on source positions as stored in a catalog
ENDSETUP                        / end common parameters setup

OBJECT  = HYDRA A               / object for first scan, a calibrator
SCANLENG= 1.5                   / length of drift scan, in degrees
OUTFILE = mghydra               / output file name

OBJECT  = TAU A                 / object for second scan
COORDTYP= EQUATORIAL            / optional
EQUINOX = 1950.0                / mandatory for equatorial coords
RA      = 93.231                / decimal degrees alternative to hms
DEC     = 20.413                / decimal degrees alternative to d'"
SCANLENG= 1.7                   / length of drift scan, in degrees
OUTFILE = mgtau

OBJECT  = Sgr A latitude scan   / object for third scan
COORDTYP= GALACTIC              / not strictly needed - GLON, GLAT unique
PROJTYPE= NONE                  / #JJ# trivial projection
GLON    = 0                     / "origin" or "special point" of scan
GLAT    = 0                     / "origin" or "special point" of scan
SCANTYPE= SCAN                  / active scan in galactic coordinates
```

```
STARTX   = 0                    / scan start offset in longitude
STARTY   = -5                   / scan start offset in latitude
STOPX    = 0                    / scan end offset in longitude
STOPY    = +5                   / scan end offset in latitude
SCANTIME= 100                   / scan rates in longitude, latitude
OUTFILE = mgsgra
```

Note that the "=" copied from the FITS style is not essential. The input files can be made more "free format" for example the start of the above file could be written as:

```
setup                           / start setup of common parameters
observer M.J. Gaylard           / observer's name
project Continuum tests
proposal 1999/001
restfreq 1650.0E6               / centre frequency in Hz, defines receiver
instrume   narad                / connect to noise-adding radiometers
scantype Drift                  / or STEP or SCAN or ...
endsetup                        / end common parameters setup
```

where spaces could also be ascii "tab" characters, and upper and lower case characters are used interchangeably, except in the observer's name.

Currently abbreviations that are unambiguous for some key words cannot be used. It is hoped that this will be implemented in a future version.

What are the advantages of this type of input file? It is:

- understandable by humans
- easily created or edited by any text editor
- easily created by an interactive front end, if desired
- unambiguously understood by one standard command interpreter (parser).

All that changes for specific types of observation are the relevant keywords needed to define it correctly. Implementing such commonality will greatly aid the development of a command parser and an observing scheduler.

The objective of this document is to specify all the keywords and their associated parameter types that will be needed for single-dish observing using the NCCS.

For other approaches to this see:

For the GBT this was the specification:

Observer Monitor and Control Requirements for the GBT, from `http://www.gb.nrao.edu/GBT/memos/memo81.txt`

which was implemented in this way for input files:

GBT observing tables (= input or command files), at `http://www.gb.nrao.edu/~rfisher/Glish/shorthand.html`

Writing GBT observing procedures in Glish, at `http://www.gb.nrao.edu/~rfisher/Glish/glish\_procs.html`

Advanced GBT procedure writing in Glish, at `http://www.gb.nrao.edu/~rfisher/Glish/gbt\_procedures.html`

For HET:

HET scheduler local copy from `http://rhea.as.utexas.edu/HET\_documentation/phase2.ps`

2 Single-dish Observing Methods

Single-dish observing methods used on the HP1000 that require replicating and extensions proposed for the NCCS are:

- Continuum radiometry, which employs two methods, scanning and stepping:
  - scanning, which, from the point of view of the observer, includes multiple types for which increasing numbers of parameters need to be specified:
    - passive (drift) scans, where the telescope is parked at an earlier RA than the target and Earth rotation produces the scan
    - scan in one coordinate while tracking in the other:
      - RA scan, track (park) in Dec
      - Dec scan, track RA (or park in HA)
    - active scanning in the coordinate systems:
      - Equatorial
      - Galactic
      - Ecliptic
      - Horizon (Altazimuth)
      - Topocentric (Telescope)
      - other Longitude + Latitude
    - Maps are constructed from sets of scans:
      - maps made from scans observed individually, at any suitable time
      - maps made from uninterrupted sets of scans that must be set up as one entity.
  - stepping, i.e. tracking in RA at positions stepped around a beam pattern at
    - second or first null in RA and Dec,
    - half power points in RA and Dec,
    - beam centre in RA and Dec,
    - zero-crossing point of dual beam receivers.
- Spectrometry, which employs two methods, a third being possible:
  - tracking the target position and switching in frequency between the two halves of the scan;
  - tracking the target position for half the scan and a reference position a specified distance away for the other half;
  - a technique used elsewhere is to take a single reference off-source spectrum and use it with many on-source spectra of different targets.

  Doppler tracking of the changing Vlsr correction or comet velocity is used, by controlling a local oscillator frequency.
- Pulsar timing, in which the pulsar is tracked and its signal is recorded synchronous with the predicted doppler-shifted pulse period.

3 Input Files and Scheduling

A model of scheduling of observing is implicit in the construction of input files using the keywords defined below.

On the HP1000, scheduling information was setup in a separate database called SHDATA, and a "master observing program" was set up which was interrupted by the scheduler. SHDATA could be changed after setup by running SHPRM.

In the scheduling model implicit here, scheduling information is no longer separated from the input or source file, but is integral with it. All observing would be scheduled in the same way, by one scheduler with one input file parser. The parser will verify that the commands given in the input file can be executed by the observing program, for example that the frequency chosen can actually be observed by the frontend + backend.

To set up observing, the scheduler is simply given a list of the input files to use. This would be a "live" list, where input file names could be added or removed in real time, and the input files themselves could be edited in real time if needed. Any editor could be used for this, as all the information is in plain text.

In the NCCS several levels of priority are defined in the scheduler:

- priority 0: VLBI
- priority 1: override
- priority 2: foreground
- priority 3: background

Hence it may be necessary to use PRIORITY as a keyword, to enforce this prioritization in the scheduler, rather than have it implicit. If PRIORITY is unspecified it will default to the lowest level.

4 Definition of Keywords and their Parameters

Keywords have been defined to match those used by FITS as far as possible, as this is to be the standard output file format, and to maximise consistency through the system.

As noted above, rigorously following the FITS format for each keyword line is not desirable, i.e. that the ninth character must be an = sign, that the tenth character is left blank for legibility, and that the (optional) parameters taken by the keyword start at the eleventh character in the line.

Characters are ASCII. The examples shown are generally in uppercase, matching the FITS standard, but the command parser must be insensitive to case for the key words, but not for some parameters, such as personal or file names, where the case must be preserved.

The following has not yet been implemented, but will be in a future version if still desirable. Optionally, a '/' character denotes the end of the parameter characters and the start of a comment (except for filenames where '/' defines directories). Possible extension: a '\' at the end of a line could be used to denote that the next line is a continuation of the current line.

Any given keyword may be needed by one or more components of the NCCS, and has been classified by JQ in this way:

- P - used by parser
- S - used by scheduler

- C - coordinate information used by scheduler
- Oc - common to general observing programs
- O - used only by a specific observing program
- E - requires JPL solar system ephemeris
- C - minor body parameter needed for two-body ephemeris generator

4.1 Generally Applicable Keywords

SETUP (P)

Optional. Defines a section for setting parameters common to a set of scans. It takes no parameters. There would normally be a SETUP section at the start of each input file. Only one per input file is allowed and if present should precede all other sections. Parameters for an individual scan which conflict with what is in the SETUP would be discarded after that scan, as the parameters in SETUP are reapplied at the start of every scan in the file. Parameters that would typically be placed in this section would be OBSERVER, RESTFREQ, CONF + ENDCONF + DEFCONF, SCANTYPE, CATALOG.

ENDSETUP (P)

Optional, as SETUP is automatically terminated by the first occurence of OBJECT, but not by CONF... ENDCONF. Used to denote the end of the SETUP section containing globally applicable keywords.

CONF (P)

Optional. Define a group of keywords to be used repeatedly in the subsequent observations. The parameter taken is a character string that uniquely "name"s this configuration. The "name" is then given as a parameter to a later USECONF command to indicate that this configuration is to be used in the observation of a particular object. The text between CONF and ENDCONF is pasted in wherever USECONF "name" is found later.

An example of its usage would be:

```
CONF    = 18NA                   / receiver name, reference for later use
RESTFREQ= 1660E6                 / define the front end to use
INSTRUME= NA                     / define the instrument to use
ENDCONF                          / end of this configuration block
...

OBJECT   Hydra A                 / observe calibrator
USECONF  18NA                    / paste in text from CONF 18NA
SCANTYPE STEP                    / use standard stepping scan
```

ENDCONF (P)

Optional. Marks the end of a CONF block of commands. If ENDCONF is not explicitly present at the end of a CONF block, the block will be terminated automatically by the next occurrence of ENDSETUP, CONF, DEFCONF or OBJECT.

USECONF (P)

Optional. Paste in the block of commands specified previously by CONF = name... ENDCONF. If USECONF is specified with multiple parameters, the CONF blocks are pasted in and used sequentially in the given order.

DEFCONF (P)

Optional. Paste in, by default (unless a blank USECONF appears in the object), a block of commands specified previously by one or more CONF ... ENDCONF blocks. e.g. DEFCONF conf1 conf2 conf3 DEFCONF must appear in the SETUP section, if present.

OBJECT (Oc)

Mandatory for actual observing. Identification of the object in some form, such as a name (e.g. Hydra A or 0915-11). If the object's coordinates are to be obtained from a catalogue, the name must be recognisable, i.e. the characters must match the name or its alternatives as given in the catalogue.

The keyword OBJECT is used to signify the start of the definition of the parameters needed for a new scan, or set of scans using different receivers, on this object. When used in a catalogue, alternative names are to be comma-delimited as they may naturally contain spaces, eg "Hydra A".

ENDOBJ (P)

Optional. Can be used to specify the end of a set of parameters for the scan(s) of an object. This is normally terminated anyway by the next OBJECT keyword or end of intput file.

COMMENT

Optional. Comment line, ignored by parser, as are blank lines. Currently a comment stretching over multiple lines must have each line beginning with COMMENT.

OBSERVER (Oc)

Mandatory. Name of the principal investigator.

OBSLOCAL (Oc)

Optional. Name of on-site person responsible for the observing if the OBSERVER is not on site.

PROJECT (Oc)

Mandatory. Short name for the observing project, taken from the observing proposal. Specified in section 6.10 of the "NCCS Requirements and Specifications".

PROPOSAL (Oc)

Mandatory. Number of the observing proposal, allocated on acceptance of the observing proposal. Specified in section 6.10 of the "NCCS Requirements and Specifications". Following the GBT model, it is used to create the directory into which the output data files will be placed. Suggested format: year/3-digit number, eg 1999/012

SCANTYPE (Oc S)

Mandatory. Defines the type of scan (observation) and hence the parameters that are required to define it fully. In essence, the SCANTYPE defines the observing program or algorithm that will be called by the scheduler to execute the scan.

Options are:

- POSITION: slew to a specified coordinate and park.
- DRIFT: carry out continuum radiometry during a drift scan of a given length centred on a specified coordinate, with a calibration cycle at the start of scan.
- TRACK: track a specified coordinate at siderial rate, optionally for a specified duration.
- SCAN: carry out continuum radiometry while driving from specified start coordinate at specified rates in orthogonal coordinates, with a calibration cycle at the start (and end?) of each scan.

- SCANPNT: carry out continuum radiometry on a point source by carrying out two orthogonal scans centred on the specified coordinates, first in HA while parked in Dec, the second in Dec while tracking in RA. This is a special case of SCAN, and uses scan parameters optimised for each receiver, derived from information in SYPARM.
- SCANCIRC: carry out a circular scan around the specified point. This is another special case of SCAN. The scan radius can be be set using data in SYPARM, such as at the halfpower radius of the beam.
- STEP: carry out continuum radiometry while carrying out a sequence of TRACKs at user selectable or default points around the beam. The data defining these points for each receiver system are found in SYPARM.
- MAP: carry out continuum radiometry while carrying out a set of uninterrupted scans fully sampling an area around a specified object.
- SPECTRUM: take a spectrum pair while tracking specified coordinates, with total power calibration.
- PULSAR: time arrival of pulses from a pulsar while tracking specified coordinates, with optional calibration.

RESTFREQ (Oc P)

Common observing program parameter. Mandatory for real observing. Standard or centre frequency to be used. Unambiguously defines the receiver system to be used. The specified frequency is checked against the upper and lower frequency limits each receiver within the observing method specific part of the parser (i.e. the implementation of this is the responsibility of the author of the observing programme). If the receiver is tunable, it will be set to the specified frequency. If not tunable, it will operate at the standard frequency defined in SYPARM.

RESTFREQ can be used within the SETUP section only within a CONF ... ENDCONF block. Within an object each occurrence of RESTFREQ gives a separate scan on this object.

Units of frequency are Hertz (FITS standard). Multiple RESTFREQ + INSTRUMEs can be defined within a CONF ... ENDCONF block, and there can be multiple instruments connected to a receiver.

Receivers are defined to be dual, providing opposite senses of polarization, normally left and right circular. Hence if it is possible to set the rest frequency independently for the two channels, then we will need to use the form (currently not yet implemented):

```
RESTFREQ LEFT 123.456e6
RESTFREQ RIGHT 123.654e6
```

If RESTFREQ = 0 then no receiver is specified; the telescope can POSITION and TRACK, without pointing corrections or beam offsets added, but no data can be acquired. This option allows the telescope to be parked at or track any desired position, e.g. zenith or a position to drain off water, before setting up observing.

If observing is wanted with more than one receiver operating simultaneously, this will need to be specified, perhaps by giving more than one rest frequency, where the first specified defines the primary system, and the other(s) the secondary receivers (not yet implemented in the parser). The beam offsets applicable to the first receiver specified in this way would be used. Except in the case of the dual-SX system, the secondary receivers would point at different positions in the sky to the primary receiver. More than one receiver operating simultaneously is envisaged as a requirement for continuum mapping.

INSTRUME (O)

Common observing program parameter. Mandatory if RESTFREQ is not zero and SCANTYPE is not SPECTRUM or PULSAR, ie the scan is continuum radiometry of some form, as three types of continuum radiometer are defined. Specifies the instrument to be attached to the receiver operating at RESTFREQ. The name INSTRUME is used rather than BACKEND for consistency with the FITS standard.

Defined INSTRUMEnts are:

- NA - noise-adding radiometer providing gain stabilisation, usable when a modulatable high-level noise diode is installed
- TP - total power radiometer
- DICKE - Dicke-switching radiometer, usable with dual-beam receivers only
- PULSARTIMER - currently the Mark I pulsar timer from the HP1000 (default if scantype is PULSAR)
- SPECTROMETER - the Australian Multibeam correlator (default if scantype is SPECTRUM).

The first letter of the INSTRUMEnt is sufficient to identify it uniquely, though more are likely wanted for clarity, at least for human parsers. As noted above, the last two types are strictly redundant.

There are two of each type of radiometer, one per polarization, so they are used in pairs. The type of radiometer selected also defines how the receiver will be configured, as this must match the instrument configuration.

Defining SCANTYP = SPECTRUM automatically implies INSTRUME = SPECTROMETER, that secondary backends, total power radiometers, will also be connected in order to calibrate the signal amplitude, and that the receiver will be in single feed, total power mode i.e. dual feed receivers will be locked to a single feed and that any noise diodes used for noise-adding gain stabilisation will be switched off. In addition, the narrowband intermediate frequency (IF) system will be used, together with the tuneable local oscillator (LO) system.

Likewise, defining SCANTYP = PULSAR automatically implies INSTRUME = PULSARTIMER, and the receiver is in single feed, total power mode, and total power radiometers are attched for calibration.

SOURCE (Oc P)

Optional. Defines a source number for the object. Should be unique within the input file, or misidentification can occur. Parameter is integer or integer mixed with letters. Can be used, for example, to define where to start observations in an input file, e.g. "start at source 25" or "start at source 11B", the alternative being "start at object HYDRA A". From start of file would normally be numbered 1, 2, 3..., but not necessarily so. Particularly useful when an object name is used repeatedly in a file, thus becoming ambiguous as a start pointer.

CATALOG (P)

Optional. Defines the name of a catalogue (including its absolute directory path) in which some or all of the necessary information about the object is to be found. Catalogues must have standard formats, to be defined. I suggest that we use the input file format, using keywords with parameters. This permits full interchangeability, in the sense of cut and paste, between the information in input files and in catalogues. Comments may not be permissable with this keyword owing to possible confusion of the prefatory '/' with the '/' use for directory paths.

OBJFLUX (O)

Optional for calibrators. Parameters are the coefficients used to calculate the flux density of the object at the observing frequency.

CALRANGE (O)

Optional for calibrators. Parameters are the lower and upper frequencies in Hz between which the flux computed from OBJFLUX parameters is valid.

REFERENC (O)

Optional. Reference or source of information. (standard FITS)

OUTFILE (Oc)

Used by all observing programs. Optional. Name of the output file to which data are to be written. Output files are always appended to, never overwritten. If no output file name is specified, a unique name is generated, for instance from the date and time, e.g. 19990504t122308.fits (not yet implemented). If OUTFILE is defined in the SETUP section then all the data will be recorded in files with the basename OUTFILE and date/time suffix. At the GBT data files are placed in directories named for the observing proposal number. This seems an appropriate model to follow here. Comments may not be permissable with this keyword owing to possible confusion of the prefatory '/' with the '/' use for directory paths.

4.2 Keywords specific to coordinates

JJ: The coordinates of the "special point" defined below are not necessarily given in terms of an equatorial coordinate, hence the scheduler may have to do some coordinate projection and transformation. This rather undesirable duplication of the coordinate code in Steer may be avoided if we introduce some new functionality into Steer and its associated server. What is probably needed is an RPC in the Steer server that returns the current ST and the current HA, DEC, AZ and ALT of a given command position, but won't do any driving or radiometer sampling.

MG: One could generalise this further by asking that the predicted Vlsr also be returned, for spectroscopy or pulsar timing.

COORDSYS (C P S)

Optional. Defines the coordinate system. For more information on coordinate types see *Representations of celestial coordinates in FITS*, of 1996/09/09, by E W Greisen and M Calabretta, in `/usr/local/src/fits/wcs.all.ps` and printed copy.

Base coordinate systems are:

- EQUATORIAL, taking Right Ascension and Declination of EQUINOX
- GALACTIC, taking Galactic Longitude and Latitude
- ECLIPTIC, taking apparent (?) Ecliptic Longitude and Latitude
- HORIZON, taking Altitude and Azimuth
- TOPOCENTRIC, taking Hour Angle and Declination

Note that STEER as currently implemented does not use EQUATORIAL as a coordinate type, but instead implies it by using the EQUINOX (see below) as the coordinate types APPARENT, MEAN, B1950 and J2000. See Steer.h.

Technically COORDSYS may be redundant, as it is implied by the key words used to specify the "special point", but may improve human readability. The celestial position specified by these coordinates is mapped into the origin (PROJTYPE=CAR) or pole (PROJTYPE=SIN or TAN) of the "native coordinate system", as defined in the WCS/CCS documentation.

Coordinates for bodies in the solar system, such as the Sun, moon, planets, comets etc. must be calculated in real time or obtained from the output of a program such as MICA (DOS) or the JPL solar system ephemeris. Parameters for real-time calculations using the Astronomical Almanac are defined below for completeness, but the JPL solar system ephemeris is now part of the NCCS software library.

The JPL solar system ephemeris, at `http://www.gb.nrao.edu/~rfisher/Ephemerides/ephem\_descr.html` describes how to obtain and use this software for computing the positions of solar system objects.

Now derived from JPL ephemeris:

Based on the HP programs SUN7 and MAPR3, the following keywords and parameters were needed from the Astronomical Almanac to compute the Sun's position, for which the coordinate type ECLIPTIC is used. The Sun's position at the time of observation is obtained by linear interpolation between the two ecliptic longitudes. On the HP1000 the equivalent parameter file (catalogue) always preceded the parameters with the day number and year, so that one file (catalogue) could contain the parameters for more than one day, without creating ambiguity, and it seems reasonable to follow this precedent. However it should be modified to have year month day as the first three parameters, to match the format of the Astronomical Almanac.

- **ELON**, the Sun's ecliptic longitude at 0 h TDT (Dynamical Time), tabulated for each day in the Astronomical Almanac, section C. The parameters are the year month day and the ecliptic longitude in degrees, minutes, seconds. Values must be given for the day of observation and for the following day, to permit interpolation.
- **TAI-UTC**, which is TAI - UTC from the Astronomical Almanac, Page K9, in seconds. To match the Astronomical ephemeris format, the first three parameters are the year month day from which it becomes valid, followed by TAI-UTC. (In the software, one also has to remember the fixed offset TDT = TAI + 32.184 seconds (Almanac, p L2), see MAPR3)

Now derived from JPL ephemeris:

Based on the HP programs MOON and MAPR3, the following keywords and parameters were needed for computing the Moon's position. The parameters are obtained from the table of Daily Polynomial Coefficients, section D, Astronomical Almanac. The coordinate type used for the Moon is EQUATORIAL, and the EQUINOX is NOW. On the HP1000 the equivalent parameter file (catalogue) always preceded the parameters with the year and day number, so that one file (catalogue) can contain the parameters for more than one day, without creating ambiguity, and it seems reasonable to follow this precedent. However it could be modified to have year month day as the first three parameters, to match the format of the Astronomical Almanac.

- **MOONARA**, the coefficients for the Moon's apparent Right Ascension at 0 h TDT, in degrees. The parameters are the year month day and six coefficients A0 to A5.
- **MOONADEC**, the coefficients for the Moon's apparent Declination at 0 h TDT, in degrees. The parameters are the year month day and the six coefficients B0 to B5.
- **MOONPLX**, the coefficients for the Moon's horizontal parallax at 0 h TDT, in degrees. The parameters are the year month day and five coefficients P0 to P4.

Now derived from JPL ephemeris:

For planets, the following keywords and parameters were needed, from the tables for each planet in section E of the Astronomical Almanac. The position at the time of observation is obtained by linear interpolation between the apparent position at 0h on the day of observation, and 0h on the following day. The coordinate type used for planets is EQUATORIAL, and the EQUINOX is NOW. Again, to prevent ambiguity, the parameters need to be preceded by the date, and for the same reason each planet will need a separate catalogue.

- **RA**, the apparent Right Ascension at 0 h TDT for the day of observation. The parameters are the year month day and RA in hours, minutes, seconds.
- **DEC**, the apparent Declination at 0 h TDT for the day of observation. The parameters are the year month day and DEC in degrees, minutes, seconds.

For comet or other minor body positions, TBCEG, the "Two-body comet ephemeris generator" fortran program from JPL is available. This was modified to ACEPH which gives a prediction for a specific time. For more information see *nccs/doc/spectroscopy/comets.txt*. In brief, the following parameters are required, known as the six osculating elements of the comet's orbit:

- **PHJD**, Julian date of perihelion passage (ET)
- **PHDIST**, perihelion distance (a.u.)
- **ECCENT**, eccentricity
- **PHARG**, argument of perihelion (degrees)
- **ASCNLONG**, longitude of ascending node (degrees)
- **INCLIN**, inclination (degrees), and in addition,
- **ETMUTC**, the difference between Ephemeris Time (ET) and Universal Time Coordinated (UTC), in seconds

EQUINOX (C P S)

Used by parser, scheduler, observing program. Mandatory if keywords RA, DEC are used (COORDSYS= EQUATORIAL). Defines the equinox (previously known as the EPOCH in FITS) for equatorial coordinates. Following the FITS standard, the keyword takes the parameters:

- 1950.0 for B1950 (default RADECSYS = FK4)
- 2000.0 for J2000 (default RADECSYS = FK5)
- MEAN for mean of current date in IAU 1984 system
- APPARENT for apparent of current date in IAU 1984 system

Only 1950.0 and 2000.0 are allowed in catalogues.

RA (C)

Mandatory for COORDSYS= EQUATORIAL; longitude-like coordinate of a "special point" (see CRVAL1 in WCS/CCS documentation). Defines the right ascension of the object. If three numerical values are given, they are assumed to be hours minutes and seconds, e.g. 09 15 23.54. Can also be written with postfix notation as 09h15m23.54s. If one numerical value is given, it is assumed to be in decimal degrees, e.g. 93.231 or 93.231d in postfix notation. If RA, DEC are specified then COORDSYS= EQUATORIAL is implied if it was not specified, but EQUINOX is mandatory.

HA (C)

Mandatory for COORDSYS= TOPOCENTRIC; longitude-like coordinate of a "special point" (see CRVAL1 in WCS/CCS documentation). Defines the hour angle of the start of a scan. Parameter handling by parser: Units are decimal degrees if a single value is given with no postfix symbol, e.g. 123.456. Can be specified in decimal hours using postfix notation as 3.15h. Can be specified in hours, minutes, seconds only by using postfix notation with no spaces e.g. 3h or 3h17m or 3h17m10s. If HA, DEC are specified then COORDSYS= TOPOCENTRIC is implied if it was not specified.

DEC (C)

Used by scheduler and observing program. Mandatory for COORDSYS= EQUATORIAL or TOPOCENTRIC; latitude-like coordinate of a "special point" (see CRVAL2 in WCS/CCS documentation). Defines the declination of the object. Parameter handling by parser: If one numerical value is given, it is assumed to be in decimal degrees, e.g. 13.231 or 13.231d in postfix notation. If three numerical values are given, they are assumed to be degrees minutes and seconds, e.g. -11 01 20.7. Postfix notation can be used, e.g -11d01'20.7". For negative declinations, a minus sign must be present. Care must be taken with declinations between 0 and -1 degrees. Handling of negative angles entered as 360 - Dec?

GLON (C)

Mandatory for COORDSYS= GALACTIC; longitude-like coordinate of a "special point" (see CRVAL1 in WCS/CCS documentation). Defines the galactic longitude of the object. If GLON, GLAT are specified then COORDSYS= GALACTIC is implied if it was not specified. Parameter handling by parser as per DEC.

GLAT (C)

Mandatory for COORDSYS= GALACTIC; latitude-like coordinate of a "special point" (see CRVAL2 in WCS/CCS documentation). Defines the galactic latitude of the object. Parameter handling by parser as per DEC.

ELON (C)

Mandatory for COORDSYS= ECLIPTIC; longitude-like coordinate of a "special point" (see CRVAL1 in WCS/CCS documentation). Defines the ecliptic longitude of the object. If ELON, ELAT are specified then COORDSYS= ECLIPTIC is implied if it was not specified. Parameter handling by parser as per DEC.

ELAT (C)

Mandatory for COORDSYS= ECLIPTIC; latitude-like coordinate of a "special point" (see CRVAL2 in WCS/CCS documentation). Defines the ecliptic latitude of the object. Parameter handling by parser as per DEC.

AZIMUTH (C)

Mandatory for COORDSYS= HORIZON; longitude-like coordinate of a "special point" (see CRVAL1 in WCS/CCS documentation). Defines the azimuth measured in degrees clockwise from north (does this match the STEER definition?). If AZIMUTH, ALTITUDE are specified then COORDSYS= HORIZON is implied if it was not specified. Parameter handling by parser as per DEC.

ALTITUDE (C)

Mandatory for COORDSYS= HORIZON; latitude-like coordinate of a "special point" (see CRVAL2 in WCS/CCS documentation). Defines the altitude measured from the horizontal. Parameter handling by parser as per DEC.

LONGPOLE (Oc)

Longitude of the celestial pole in the "native coordinate system", as defined in the WCS/CCS documentation. The function of this parameter is to rotate the observation field about the "special point". This would normal only be used with the azimuthal projections ("SIN" and "TAN") and is specified in degrees. Parameter handling by parser as per DEC.

PROJTYPE (Oc)

Used by scanning program. Projection type.

- NONE Do not do any coordinate rotation or projection. Needed for drift scans and backward compatibility. Default for drift scans.
- CAR normal plate carree (cartesian) cylindrical projection. Default for "long scan" maps.
- SIN orthographic zenithal projection (no slant). Default for "small area" maps.
- TAN gnomonic zenithal projection (no distortion). Default for "tracking and stepping" observations.
- ZEN native zenithal projection. This points the pole of the native system at the special point and would alleviate the need for the DEC-90 calculation. The euler angles would be set to theta = 0, phi = 90 - latitude, psi = longitude. See example: continuum radiometry: a circular scan at the beam halfpower point.

Until Steer is modified we will have to stick to "PROJTYPE=CAR".

The three angles (RA et al, DEC et al, and LONGPOLE) are used to construct the "EULER" angles currently used by Steer. The construction depends on the "PROJTYPE":

- PROJTYPE=NONE: theta = 0, phi = 0, psi = 0
- PROJTYPE=CAR: theta = 0 (LONGPOLE not used), phi = -CRVAL2, psi = + CRVAL1
- PROJTYPE=SIN,TAN: theta = +LONGPOLE, phi = 90 -CRVAL2, psi = +CRVAL1

JJ envisages that, in time, we (JJ!) will change the Steer server to accept the parameters "CRVAL1", "CRVAL2" and "LONGPOLE" rather than the greek entities.

X

x offset from special point (deg) for pointing or stepping observations. Regarded as deleted by JQ for unspecified reasons, but see section: keywords specific to scanning. Parameter handling by parser as per DEC.

Y

y offset from special point (deg) for pointing or stepping observations. X and Y are specified in the projected coordinate frame. Format for (x,y) type coordinates should probably always be given in degrees, unless a postfix notation is developed (e.g. 1h5m22s, 23', 7d5'22"). Regarded as deleted by JQ for unspecified reasons, but see section: keywords specific to scanning. Parameter handling by parser as per DEC.

If PROJTYPE=NONE then X and Y are simply added to the coordinate of the "special point":

- Celestial Long = RA et al + X
- Celestial Lat = DEC et al + Y

4.3 Keywords specific to observing scheduling

These keywords define scheduling constraints and some simple repeat options. These should be sufficient to replicate the type of scheduling previously carried out on the HP1000.

More complex control structures can be defined if necessary.

ORDER (S)

Used by scheduler. Optional. Specify the order in which the objects in a file are to be observed. Possibilities are:

- SEQUENTIAL - follow the sequence in the file exactly
- OPTIMISE - observe in sequence such that the soonest object to set will be observed first
- RANDOM - randomise the objects in (RA, DEC) for example for checking encoders or error maps
- LINKED - linked sequence of scans.

Other possibilities may be developed. Default if unspecified: OPTIMISE

PRIORITY (S)

Used by scheduler. Optional.

- priority 0: VLBI
- priority 1: override
- priority 2: foreground

- priority 3: background

Default: priority 3.

STARTAT (P)

Used by parser. Optional. Specifies the object or source no. with which observing must start. Subsequent observations continue sequentially. Must match either the object name or the corresponding source identifier if specified.

STRTDATE (S)

Used by scheduler. Mandatory. Start date or epoch for observations. The start date can be written in various formats:

- Julian days (MJD) (1 parameter)
- Year, Day of Year (2 parameters)
- Year, Month, Day (3 parameters)

When coupled with INCREMNT, this permits observations to be scheduled weekly, for example. A more complex example is given by any object which is to be observed only when certain behaviour is predicted to occur - this would not be synchronised to UT, but to the ephemeris of the behaviour. Circinus X-1 is one such case, for which the Julian date option would be used in order to specify the flare epoch as accurately as possible.

INCREMNT (S)

Used by scheduler. Optional. Units are days. For weekly monitoring, a single value of 7 is sufficient. For objects such as Cir X-1, the period of the behaviour is used, with STRTDATE and ENDDATE bracketing the monitoring period if it is longer than one day. For Cir X-1, to observe from 2 days before the flare epoch to 4 days after, the parameters would be:

- STRTDATE "give predicted Julian date for 2 days before flare epoch"
- ENDDATE "give predicted Julian date for 4 days after flare epoch"
- INCREMNT 16.605793

where 16.605793 is the flare period.

STARTST (S)

Optional. Siderial start time. Parser handling of parameters as per RA.

STRTTIME (S)

Optional. Specifies the Universal Time at which the observations are to start. Its use can be tied in to STRTDATE to specify a start date other than the current date. If STRTTIME is not specified, and the YEAR, DAY-OF-YEAR or YEAR, MONTH, DAY format is used, the start time will be 0h UT on the start date.

Can also be specified as "SUNSET" or "SUNRISE". Whether this usage is applicable may depend on the receiver in use, so it should be defined when the receiver is defined by RESTFREQ + INSTRUME usually in a CONF ... ENDCONF block. If it is defined elsewhere in the input file, where it is not logically associated with a specific receiver, then it will be applied to all receivers. The default value is for no day/night constraint. Requires JPL solar system ephemeris.

ENDDATE (S)

Used by scheduler. Mandatory. Specifies a date at which these observations are to end. The format is the same as for STRTDATE.

ENDTIME (S)

Used by scheduler. Optional. Specifies the Universal Time at which the observations are to end. Parameters are decimal hours or hours and minutes. Its use can be tied in to ENDDATE to specify an end date and time other than on the current date. If ENDTIME is not specified, and the YEAR, DAY-OF-YEAR or YEAR, MONTH, DAY format is used, the end time will be 0h UT on the end date.

Can also be specified as "SUNSET" or "SUNRISE". Whether this usage is applicable may depend on the receiver in use, so it should be defined when the receiver is defined by RESTFREQ + INSTRUME usually in a CONF ... ENDCONF block. If it is defined elsewhere in the input file, where it is not logically associated with a specific receiver, then it will be applied to all receivers. The default value is for no day/night constraint. Requires JPL solar system ephemeris.

REPEATS (S)

Used by scheduler. Optional. The associated parameter specifies the number of times the scan or set of scans at different frequencies is to be repeated in order to get data with the wanted signal-to-noise ratio. For example, eight spectra, each of 15 minutes duration, may be needed for a particular object; REPEAT would then be = 8. If omitted, REPEATS defaults to 1.

RESTART (S)

Used by scheduler. Optional. Implies that observing can restart from the beginning of the file. Often used in spectroscopy and other input files to indicate that the inputfile wraps around and can be restarted if it reaches the end. This keyword is normally placed at the end of the file. If inserted before the end, objects after this keyword will not be observed.

STOP (P)

Optional. Implies that there is no further observing from this input file. It is redundant at the end of a file if RESTART is not specified, but if inserted before the end of an input file, it terminates observing from the file, and objects after the STOP will not be observed. The parameter ZENITH could be used optionally to park the telescope at zenith when the STOP is encountered (not yet implemented).

HALIST (S)

Used by scheduler. Optional. List of hour angles at which scans on this object should be carried out. If not specified, then any hour angle at which it is visible, or within HALIMIT if specified, is acceptable. The HALIST option is normally used for a source file containing a single object that is to be monitored more than once per day. Parameter handling by parser as per HA. An object that has an HALIST may not be linked (using ORDER) to a previous object, but an object with an HALIST may have subsequent objects linked (using ORDER) to it.

HALIMIT (S)

Used by scheduler. Optional. Absolute value of hour angle within which valid observations can be made. Object is not to be observed outside this hour angle range. Parameter handling by parser as per HA. Alternative forms could be defined if necessary, e.g. ALTLIMIT providing an altitude limit. The default value is the STEER limit.

SUNDIST (S)

Used by scheduler. Requires JPL solar system ephemeris. Optional. Angular distance from the Sun beyond which observations can be made. Units are degrees. If the angular separation is less than specified by SUNDIST, the object is not observed. Usable angular separations depend on the receiver system in use, so this parameter can take different values for each defined receiver, and should be defined when the receiver is defined by RESTFREQ + INSTRUME. If it is defined elsewhere in the input file, where it is not logically associated with a specific receiver, then it will be applied to all receivers. The default value is zero. Parameter handling by parser as per DEC.

MOONDIST (S)

Used by scheduler. Requires JPL solar system ephemeris. Optional. Angular distance from the Moon beyond which observations can be made. Units are degrees. If the angular separation is less than specified by MOONDIST, the object is not observed. Usable angular separations depend on the receiver system in use, so this parameter can take different values for each defined receiver, and should be defined when the receiver is defined by RESTFREQ + INSTRUME. If it is defined elsewhere in the input file, where it is not logically associated with a specific receiver, then it will be applied to all receivers. The default value is zero. Parameter handling by parser as per DEC.

WEATHER (S)

Optional. Worst allowable weather condition which will permit useful data to be obtained. The three possibilities are CLEAR, CLOUD and RAIN. The application of this keyword assumes that there are methods for determining the weather state. The default case is to run in any of the three weather conditions.

4.4 Keywords specific to Scanning

These now follow JJ's prescription, with the addition of radius for a circular scan.

STARTX (Oc)

x offset from special point of scan start. Parameter handling by parser as per DEC.

STARTY (Oc)

y offset from special point of scan start. Parameter handling by parser as per DEC.

STOPX (Oc)

x offset from special point of scan end. Parameter handling by parser as per DEC.

STOPY (Oc)

y offset from special point of scan end. Parameter handling by parser as per DEC.

SCANTIME (Oc)

Length of scan in seconds.

SCANDIST (Oc)

Optional keyword for drift scan. The single parameter for a drift scan is the scan length in right ascension of date. Units are degrees. Parameter handling by parser as per DEC. For a drift scan, if the distance is not specified, the default is the beamwidth to first nulls (from SYPARM or calculated) + 20 percent. This default depends on the receiver in use, as the beamwidth is frequency-dependent. Hence SCANDIST is tied to a particular receiver, so if multiple receivers are specified and the default scan length is not wanted, SCANDIST must be specified after each RECEIVER + INSTRUME definition.

RADIUS (Oc)

Optional keyword for circular scan. The single parameter defines the radius of the circle, in degrees. Parameter handling by parser as per DEC. Alternatively, frequency-dependent values from SYPARM can be used, such as HP, FN, SN. If not specified, the RADIUS would be set to HP, the halfpower point of the beam.

COORDOUT (Oc)

Optional. Specify output coordinate system if different from projected. Keywords as per COORDSYS, plus EQUINOX if COORDSYS = EQUATORIAL.

4.5 Keywords specific to Stepping

STEPSEQ (Oc)

Optional keyword for STEPing observations. Its parameters define the sequence of tracks to be taken, and are aliases for beam-dependent numerical (x,y) offsets. Defined positions in SYPARM are:

- SNN, SNS, SNE, SNW: second null North, South, East, West
- FNN, FNS, FNE, FNW: first null N, S, E, W
- HPN, HPS, HPE, HPW: half-power points N, S, E, W
- ON: beam centre
- ZC: zero-crossing point between dual beams (was known as CE), useful for HA pointing if there is no inflection between the beams
- A, B: defines A (with calibration diode) or B beam for dual beam systems. Can be specified for single beam systems, but is redundant.
- CAL: specifies the track on which to calibrate. It would normally be done at the start of the pattern, as a system check.

The step sequences used on the HP in the programs TNFPC, TNSTP and TNFQS, in this notation, were:

- TNFPC, dual beam: does pointing in Dec using HP points for both beams, uses zero-crossing for hour angle pointing:

  `FNNACAL, HPNA, ONA, HPSA, FNSA, ZC, FNNB, HPNB, ONB, HPSB, FNSB`

- TNFPC, single beam: does pointing in Dec only:

  `FNNCAL, HPN, ON, HPS, FNS`

- TNSTP, dual beam: does pointing in both Dec and HA using HP points, with zero-crossing as last point, but otherwise does not use the second beam:

  `FNNACAL, HPNA, ONA, HPSA, FNSA, FNEA, HPEA, ONA, HPWA, FNWA, ZC`

- TNSTP, single beam: does pointing in both Dec and HA using HP points:

  `FNNCAL, HPN, ON, HPS, FNS, FNE, HPE, ON, HPW, FNW`

- TNFQS, dual and single beams, does no pointing:

  `FNNACAL, ONA, FNSA`

Default scan patterns need to be decided upon, but any useful step pattern can be implemented using the STEPSEQ command.

4.6 Keywords specific to Uninterruptible Maps

These are maps observed as a single entity, like a step sequence. The small map keywords are based on the inputs used by MAPR3 on the HP1000. Scans are defined to be "vertical" ie in latitude at a fixed longitude.

COORDSYS (as defined previously) and corresponding keywords are used to define the coordinates of the map centre, and is mandatory. COORDSYS also defines the orientation of the map, eg if RA, DEC, scans will be in RA, DEC; if in Ecliptic longitude and latitude, the scans will be in ecliptic coordinates.

Note that for mapping the Sun and the Moon, the input signal level to the instrument must be computer controllable to avoid saturation. The first step in mapping the Sun or Moon (and perhaps all objects) is to track the centre of the object and measure the signal level, adjusting it to prevent saturation. This was done manually with the HP1000, but this is not acceptable for the NCCS.

Keywords specific to small maps are defined below.

Some tight linkage between the scheduler, the mapping procedure and Steer will be needed to implement the "SCANST" keyword, but perhaps this functionality is not needed in the scheduler. After some considerable thought and many changes of heart, JJ has come to the conclusion that time-critical observing, such as Skymap-like procedures, should be treated as a single observation by the scheduler, i.e. will hog the antenna. There does not seem to be any reason to include extremely specific functions into the scheduler that will only be used by a single observing process. In addition, there is no need for the scheduler to be involved in scheduling individual scans which cannot be interrupted anyway. JJ knows that this appears to moves away from the concept of "orthogonal coding", but the time-critical mapping JJ has in mind (the south pole region) is quite complex and specialized.

MG asks: Do all our readers agree with this? Scheduler shutdown just for JJ's maps?

SIZELONG (Oc)

Optional for small map. Map height in terms of projected coordinates (e.g. longitude, declination etc.) in degrees.

SIZELAT (Oc)

Optional for small map. Map width in terms of projected coordinates (e.g. latitude, right ascension etc.) in degrees. At least one of SIZELAT or SIZELONG must be set. If only one is set, the map is made square.

SPACLONG (Oc)

Optional for small map. Spacing of scans in longitude, in terms of projected coordinates in degrees. If not set, a default will be used based on the beamwidth at the frequency in use.

SPACLAT (Oc)

Optional for small map. Bin size in latitude, in terms of projected coordinates in degrees. If not set, a default will be used based on the beamwidth at the frequency in use.

SCANMODE (Oc)

Specify scanning in longitude or in latitude? Parameters?

SCANDIR (Oc)

Optional for small map. Specifies direction(s) of scans. Parameters?

A SCANTIME (as defined previously) can be specified, as for any active scan. If not specified, a default value is used based on the beamwidth at the frequency in use, in order to get a suitable number of samples per beamwidth.

4.7 Keywords specific to Spectroscopy

SPVLSR (Oc)

Mandatory for spectra of galactic objects (double). Parameter is the velocity with respect to the local standard of rest at which the spectrum is to be centred. Units are km/s. An alternative parameter will be used for solar system objects such as comets.

SPBW (Oc)

Mandatory for spectra (double). The single parameter defines the spectrometer bandwidth that is to be used. Units are Hz, following the FITS standard for frequency.

SPCHAN (Oc)

Mandatory for spectra (int). The single parameter specifies the number of correlator channels per input signal channel that the correlator must be configured for.

SPCONF (Oc)

Optional for spectra (string). Defines the correlator configuration, ie left+right circular polarization (default), left only, right only, Stokes parameters IQUV from left+right circular polarization).

SPFS (Oc)

Optional for spectra (double). The single parameter defines the frequency-switching offset that is to be applied to the second of the pair of spectra. Units are Hz, following the FITS standard for frequency. If SPFS is not specified, then SPPS must be non-zero. It might be useful to define a default parameter value for SPFS, namely if SPFS is given without a parameter, it defaults to half of the bandwidth specified by SPBW.

SPPS (Oc)

Optional for spectra (double). Two parameters define the offsets in position that are to be applied to the second of the pair of spectra. The meaning of the parameters depends on the coordinate type that has been specified. If coordinates are galactic, offsets will be longitude, latitude, whereas if coordinates are equatorial, offsets will be RA, Dec. Units are decimal degrees. If SPPS is not specified, then SPFS must be non-zero.

SPTIME (Oc)

Mandatory for spectra (double). Total duration of the scan, which comprises a pair of frequency- or position-switched spectra of duration SPTIME/2. Units are minutes rather than seconds, to be human-friendly?? Used to set correlator parameters. Note that the MB correlator produces a new spectrum every five seconds, and up to 20 of these are normally averaged to produce the average spectrum written to file, so SPTIMES that are multiples of 100 seconds are what may be implemented.

SPPOINT (Oc)

Optional for spectra (int, TRUE=non-zero / FALSE=zero passed to observing program by parser). Used by observing program to construct a set of 3 or 5 scans. Takes no parameters. If this keyword is present, obtain spectra of duration SPTIME at the half-power points of the beam. For spectra using frequency-switching, the first spectrum of the pair is offset to the north, the second to the south. Total duration is then 3 x SPTIME. For position-switched spectra, four spectrum pairs are observed, at the north, south, east and west half-power points. Total duration is then 5 x SPTIME. The half-power beamwidth is obtained from SYPARM, or can be computed from the observing frequency, knowing the size of the telescope (HPBW/deg = 67 * wavelength[metres] / diameter[metres]).

4.8 Keywords specific to Pulsar Timing

PLPERIOD (Oc)

Mandatory for pulsars. The pulsar period in seconds.

PLPDRV1 (Oc)

Mandatory for pulsars. The pulsar period derivative in s/s^1. Also known as "pdot".

PLPDRV2 (Oc)

Mandatory for pulsars. The pulsar period second derivative in s/s^2 Also known as "pdotdot".

PLDM (Oc)

Mandatory for pulsars. The dispersion measure in units of pc/cm^3. Needed for glitch checking (?)

PLDMDRV (Oc)

Mandatory for pulsars. The rate of change of the dispersion measure with time in units of pc/cm^3/s^1 (?) Needed for glitch checking (?)

PLEPOCH (Oc)

Mandatory for pulsars. The epoch in Julian days applicable to PLPERIOD, PLPDRV1, PLPDRV2, PLDM and PLDMDRV.

PLPOL (Oc)

Optional for pulsars. Parameter is a numerical factor to do with polarization, does what? If PLPOL is omitted, the default value is unity.

PLPHASE (Oc)

Mandatory for pulsars. The phase offset from current ephemeris at the time of the most recent observation, in milliperiods, also known as the "drift". When glitch detection is on, this is updated in this or another disk file by the observing program. The concept of doing this must be considered - do we want observing programs modifying their own source files? A separate file dedicated to maintaining the latest phase seems a safer idea. Is it frequency-dependent?

PLTCONST (Oc)

Mandatory for pulsars. The time constant to be set for the post-detection filter, in microseconds.

PLPINT (Oc)

Mandatory for pulsars. The number of periods to integrate at each frequency band. An implication of this is that it must accompany a frequency definition as a second parameter. PLPINT x PLPERIOD defines the scan time, needed for the scheduler.

PLGLITCH (Oc)

Optional for pulsars. Defines the glitch detection status. If the keyword is not present, glitch detection is OFF. The parameters are:

- OFF: turn off glitch detection
- ON: turn on glitch detection. Sound alarm if glitch detected, update ephemeris offset in pulsar ephemeris file.

PLCAL (Oc)

Optional for pulsars. Defines whether to calibrate using the noise diode or not. If the keyword is not present, its status is ON. The parameters are:

- OFF: turn off calibration
- ON: turn on calibration.

For pulsars such as Vela and 1641-45, only the first observation is calibrated, the repeats using the same calibration to save time.

4.9 Keywords in Catalogues

A catalogue must not contain scheduling-specific keywords.

A catalogue must at minimum define:

- OBJECT, the object name, with alternatives if necessary, with which to associate the following keywords. ENDOBJ can be used, optionally, knowing that the next OBJECT automatically ends the previous OBJECT description.

All observation types require source coordinates:

- COORDSYS, the coordinate type e.g. equatorial, galactic etc.
- EQUINOX, the epoch, if coordinates are equatorial
- RA / DEC or coordinates as defined previously, or parameters used to define the coordinates, e.g. for comets or other solar system objects.

For calibrator sources, coefficients defining the flux density are optional:

- OBJFLUX, coefficients defining the flux vs frequency
- CALRANGE, upper and lower frequencies for which flux is valid
- REFERENC, source of the information

For spectra, the catalogue can optionally contain:

- SPVLSR, the Vlsr for galactic objects or positions, in km/s.
- SPBW, the spectrometer bandwidth, in MHz
- SPFS, the optional frequency-switching offset, in MHz
- SPPS, the optional position offset, in degrees
- SPTIME, the duration of the spectrum, in seconds
- SPPOINT, optional, obtain spectra offset for pointing correction

Other parameters are needed for comet observations, as defined previously.

For pulsars, the catalogue also contains ephemeris and other information:

- PLPERIOD, the pulsar period in seconds
- PLPDRV1, the pulsar period derivative in s/s^1
- PLPDRV2, the pulsar period second derivative in s/s^2
- PLDM, the pulsar dispersion measure
- PLDMDRV, the dispersion measure derivative
- PLEPOCH, the pulsar epehemris epoch
- PLPOL, polarization factor?

- PLPHASE, the phase offset from current ephemeris at the time of the most recent observation, in milliperiods
- PLTCONST, the time constant of the post-detection filter to be set, in microseconds
- PLPINT, the number of periods to integrate, at a specified frequency
- PLGLITCH, defines the glitch detection status, ON or OFF
- PLCAL, calibration on or off.

5 Parser Logic

5.1 Introduction

The logical structure of the HartRAO parser should meet the following design constraints (in rough order of importance):

- Any conceivable observation must be able to be specified in an input file ie. any assumptions made by the parser must not preclude any possible combination of keywords that would otherwise be useful.
- The input file structure must be as self-evident as possible, avoiding indirect implication which could be misconstrued or misread. The file structure should be explicit enough that any syntactical error can easily be detected and isolated.
- Repetition of information should be avoided ie. the parser must allow constructs to compact configuration duplications. This will need to be carefully balanced against the first constraint.
- The logical structure should be the simplest possible to make coding and maintenance of the parser easier.

The generalised format of the input file is defined to be:

```
SETUP
...             "global" or "common" keywords applicable to all objects

CONF    name1
...             named block of keywords to be inserted at USECONF name1
ENDCONF
CONF    name2
...             named block of keywords to be inserted at USECONF name2
ENDCONF
CONF    name3
...             named block of keywords to be inserted at USECONF name3
ENDCONF
DEFCONF name1 name2     default configs to be used for an object where
                        no USECONF is specified
ENDSETUP        end of global or common area

OBJECT  name    first object for observation
...             no USECONF so uses DEFCONF
[ENDOBJ]        optional end-of-object statement
```

```
OBJECT          next object for observation
USECONF name3   only CONF name3 is used for this object

OBJECT          next object for observation
RESTFREQ XXX    define scan specific to this object
USECONF         no parameter so do not paste in DEFCONFs
...
```

This format is discussed in more detail below.

5.2 The SETUP section

Keywords appearing before the first object are regarded as GLOBAL, i.e. to pasted in at the top of each scan definition. They must be enclosed by by SETUP... ENDSETUP, e.g.

```
SETUP
OBSERVER= J.L. JONAS
OBSLOCAL= G.D. NICOLSON
PROJECT = galactic plane map at 3.5cm
PROPOSAL= 1999/003
...
ENDSETUP
```

There is one and only one global SETUP per input file, and this appears at the start of the input file. Where multiple SETUPs appear to be needed, the possibility of error or ambiguity in parsing the commands is so great that another input file must be created.

All keywords are categorised in terms of whether thay may appear within the "SETUP" section or an "OBJECT" block or both. For example, the SETUP block therefore cannot validly contain RESTFREQ other than within a CONF... ENDCONF block.

Being globally defined, keywords in SETUP will be used for all scans unless they are replaced by the local definition of a keyword after OBJECT or RESTFREQ or from a pasted in CONF block.

5.3 CONF blocks

Within the setup section, re-useable combinations of keywords may be explicitly defined in a "CONF name"... "ENDCONF" blocks. Each config block would consist of any combination of keywords from those applicable to an "OBJECT" block with one exception, namely that when a "RESTFREQ" keyword is included, it must be the first keyword in the block (such that all the other keywords will always be associated with the "RESTFREQ" when the "CONFIG" is used.)

These "CONFIG" blocks may be inserted into an "OBJECT" block at any point using the "USECONF" keyword such that the "OBJECT" block is only interpreted once all such substitutions have occurred.

5.4 DEFault CONFiguration

A "DEFCONF" keyword with the names of one or more CONF blocks as parameters in the "SETUP" section defines which "CONFIG" blocks will be included automatically just before the (explicit or implicit) "ENDOBJ" when no explicit "USECONF" was given.

DEFCONF can only appear in the SETUP section.

"USECONF" with no argument is used to cancel the implicit inclusion of DEFCONF.

5.5 OBJECTs

After encountering OBJECT, global keywords from SETUP are pasted in. Then if a catalog has been defined the parameters for the object in the catalog are pasted in. If USECONF NAME follows immediately after OBJECT, the SETUP keywords and keywords in a catalog (if the object is in the catalog and a catalog name has been given in the SETUP section) are pasted in before the CONF NAME keywords.

As in SETUP, all keywords common to the scans on the OBJECT must occur before a USECONF block or the RESTFREQ keyword (which may be standalone within an OBJECT but not standalone outside a CONF block within SETUP).

If no USECONF appears explicitly after OBJECT or via a pasted in CONF block, DEFCONF will be pasted in at the end of the keywords for the object.

If no RESTFREQ appears at all in the list of keywords for an object after pasting in SETUP and either named CONF or DEFCONF, no scans will be done.

After the SETUP keywords and the CONF NAME or DEFCONF keywords have been pasted in as text in the appropriate places after OBJECT, the sequence of keywords from OBJECT to the next OBJECT can be parsed to create scans for the scheduler and observing programs.

In parsing the sequence of keywords from OBJECT on, a new SCAN construct is started when RESTFREQ is encountered after OBJECT. Subsequent RESTFREQs after the same OBJECT imply consecutive SCANs to be created as structures and later executed. The keywords between each RESTFREQ are specific to each SCAN thus defined.

Keywords that are repeated within a SCAN constructed in this way are handled such that the parameters associated with the last instance of the repeated keyword replace the earlier parameters.

5.6 Parse example

```
SETUP                           / global SETUP block
OBSERVER= G.D. NICOLSON
PROJECT = flux calibration
PROPOSAL= 1999.001
CATALOG = calibrators.cat
OUTFILE = calibrator.data
                                / above are implicit at start of all OBJECTs

CONFIG=   18NA                  / Start of explicit CONF block
RESTFREQ= 1650E6                / ( must be first line of block )
INSTRUME= NA
WEATHER = Cloud
ENDCONF                         / end of explicit CONF block

CONFIG=   13NA                  / Start of explicit CONF block
#RESTFREQ= 2300E6               / ( commented out - not available )
#INSTRUME= NA                   / (currently not implemented )
#WEATHER = Cloud
ENDCONF                         / end of explicit CONF block
```

```
CONFIG=   6D                    / Start of explicit CONF block
RESTFREQ= 5000E6
INSTRUME= DICKE
WEATHER = Clear
ENDCONF                         / end of explicit CONF block

CONFIG=   3D                    / Start of explicit CONF block
RESTFREQ= 8400E6
INSTRUME= DICKE
WEATHER = Clear
ENDCONF                         / end of explicit CONF block

CONFIG  = STEP                  / Start of explicit CONF block
                                / - no restfreq in this block
SCANTYPE= STEP                  / stepping type observation
STEPSEQ = FNNCAL, HPN, ON, HPS, FNS, FNE, HPE, ON, HPW, FNW
ENDCONF                         / end of explicit CONF block

CONFIG  = SCAN                  / Start of explicit CONF block
                                / - no restfreq in this block
SCANTYPE= SCANPNT               / crossed scans type observation
ENDCONF                         / end of explicit CONF block

DEFCONF = STEP 6D 3D 13NA 18NA  / Default setup is stepping at 4 frequencies
                                / - though 13cm is temporarily unavailable
                                / implicit at the end of those OBJECTs where
                                / nothing was explicitly specified.

ENDSETUP                        / end of global SETUP


OBJECT  = 0915-11               / calibrator - get coords etc from catalog
                                / SETUP values implicitly pasted in here
HALIST  = 0H                    / start at meridian transit (HA = 0 hour)
                                / default CONF list pasted in here.
                                / expands to step scans at all 4 frequencies
ENDOBJ

OBJECT  = 1228+02               / start new object, also calibrator
                                / SETUP values implicitly pasted in here
HALIST  = 1h                    / start at HA = 1 hour
USECONF = STEP                  / set default observation type to stepping

RESTFREQ= 12178E6               / Only this source is strong enough at 2.5cm
INSTRUME= TP
WEATHER = Clear
USECONF = SCAN                  / - use crossed scans as source is extended

USECONF = 3D SCAN               / - use crossed scans at 3.5cm also
```

```
USECONF = 6D 13NA 18NA          / but step scan at the other 3 frequencies
                                / default CONF list not applicable
ENDOBJ

OBJECT  = 1648+05               / start new object, also calibrator
                                / SETUP values implicitly pasted in here
HALIST  = -3h 3h                / start scans at HA = -3  and +3 hours
USECONF = STEP 13NA 18NA        / don't bother with 3.5 and 6cm
                                / default CONF list not applicable
ENDOBJ
```

6 Examples of Input Files and Catalogues

6.1 Continuum Radiometry: Multi-Wavelength Scans of a Calibrator

This is a source file to carry out continuum radiometry using the stepping and scanning techniques for comparison, on a flux calibrator at four frequencies as it crosses the zenith meridian. The catalogue that it refers to follows it. This type of file would typically be scheduled in to calibrate other observing.

JJ: Note that the RA and DEC keywords in the catalogue will be used to define a source-centred coordinate system. Because "SCANTYPE=STEP" the "PROJTYPE" defaults to "TAN", i.e. no need to worry about "Cos Dec" corrections in steps. Until Steer is modified the TAN coordinate projection will be approximated by CAR.

```
SETUP
OBSERVER= G.D. NICOLSON
PROJECT = flux calibration
PROPOSAL= 1999.001
CATALOG = calibrators.cat
OUTFILE = calibrator.data       / output file for all scans
CONF    = 1666NA
RESTFREQ= 1666E6                / use 18cm receiver at 1666MHz
INSTRUME= NA                    / use noise-adding radiometer pair
WEATHER = cloud
ENDCONF =
CONF    = 2300NA
RESTFREQ= 2300E6                / use 13cm receiver
INSTRUME= NA                    / use noise-adding radiometer pair
WEATHER = cloud
ENDCONF =
CONF    = 5000DI
RESTFREQ= 5000E6                / use 6cm receiver
INSTRUME= DICKE                 / use dicke radiometer, beam-switching mode
WEATHER = clear
ENDCONF =
CONF    = 8500DI
RESTFREQ= 8500E6                / use 3.5cm receiver
INSTRUME= DICKE                 / use dicke radiometer, beam-switching mode
WEATHER = clear
ENDCONF =
```

```
DEFCONF = 1666NA 2300NA 5000DI 8500DI  / use all 4 conf blocks as default
ENDSETUP

OBJECT  = 0915-11               / use the definitive flux calibrator
SOURCE  = 1
SCANTYPE= STEP                  / first we step at all frequencies
STEPSEQ = FNNCAL, HPN, ON, HPS, FNS, FNE, HPE, ON, HPW, FNW
HALIST  = 0h00m                 / starting at HA = 0 hour JJ notation

OBJECT  = 0915-11
SOURCE  = 2                     / same object name so add a SOURCE ident.
SCANTYPE= SCANPNT               / now we do cross-scans at all frequencies
HALIST  = 1h00m                 / starting at HA = 1 hour in postfix notation
```

The continuum calibrator catalogue `calibrator.cat`, would have multiple entries like this:

```
COMMENT = fluxes of these calibrators are computed using:
COMMENT = Log(S/Jy) = C1 + C2*log(F/MHz) + C3*(log(F/MHz))**2
REFERENC= Ott et al. (1994) AA 284, 331.
OBJECT  = 0915-11, 3C218, Hydra A, HydA
COORDSYS= EQUATORIAL
EQUINOX = 1950.0
RA      = 09 15 41
DEC     = -11 53 06

OBJFLUX = 4.729 -1.025 +0.0130  / coefficients C1, C2, C3 for flux calc
CALRANGE= 1408E6 10550E6        / valid frequency range for computing flux
COMMENT = galaxy, size 47" * 15"
```

With appropriate programming, using the information in the catalogue the calibrator flux density at each frequency used can be written to the output file for use in calibrating the day's observing, together with the observational data.

6.2 Continuum Radiometry: Routine monitoring of Cir X-1

This demonstrates the use of some of the scheduling options. Note that the interval between binned samples for the output is adaptively set to match the beamsize, with say 12 points per halfpower beamwidth, by the standard drift scan software (or SYPARM), so is not specified. Parameters used in the example are "inspired" by those found in HP/OBCIR.

This input file would set up three drift scans per day at 3.5cm, starting one day before the expected transition date through two days after the transition date. The transition dates are calculated from the STRTDATE and first INCREMNT parameter.

All post-observing data processing such as subtracting off a background, fitting a polynomial to the baseline, measuring peak heights by Gaussian fitting are done by standard analysis programs using the data recorded in the disk file. These processes could be done by a LINES command file, for example.

JJ: Because "SCANTYPE=DRIFT" the default "PROJTYPE" is "NONE" and "X" and "Y" are preset to "RA" and "DEC".

```
SETUP
OBSERVER= G.D. NICOLSON
PROJECT = monitor flux of flaring binary star Circinus X-1
PROPOSAL= 1999/002
COMMENT define all receivers of interest for Cir X-1 in setup,
COMMENT 'useconf' specifies those wanted for each object
COMMENT non-flaring currently so only use most sensitive receiver, 3.5cm

CONF    = 13                    / configuration block name
RESTFREQ= 2300E6                / use 13cm receiver
INSTRUME= NA                    / use noise-adding radiometer pair
SCANDIST= 1.85d                 / scan length at 13cm, in degrees
STRTTIME= SUNSET                / JJ alternative to NIGHTOBS
ENDTIME = SUNRISE               / JJ
ENDCONF                         / end of configuration block

CONF    = 6                     / new configuration block name
RESTFREQ= 5000E6                / use 6cm receiver
INSTRUME= DICKE                 / use dicke radiometer, beam-switching mode
SCANDIST= 1.85                  / scan length at 6cm   OR
SUNDIST = 45                    / observe at 6cm if > 45 deg from Sun
                                / implicit ENDCONF as new CONF follows

CONF    = 3.5                   / new configuration block name
RESTFREQ= 8500E6                / use 3.5cm receiver
INSTRUME= DICKE                 / use dicke radiometer, beam-switching mode
SCANDIST= 1.082d                / scan length at 3.5cm
SUNDIST = 30d                   / observe at 3.5cm if > 30 deg from Sun
RCVNAME = 3.5                   / implicit ENDCONF as ENDSETUP or OBJECT follows
ENDSETUP
                                / blank line to be pretty
OBJECT  = CIR X-1               / start of scan definition
COORDSYS= EQUATORIAL            / just so
EQUINOX = 1950.0                / B1950 coordinate equinox
RA      = 229.201               / RA in decimal degrees
DEC     = 303.013               / Dec in decimal degrees
SCANTYPE= DRIFT                 / drift scan
STRTDATE= 2443075.87            / 1976 d 299.37; JD avoids leapyear problems
                                / one day before flare epoch
ENDDATE = 2443078.87            / two days after flare epoch, giving 3 days of
                                / observations
INCREMNT= 16.5768               / period (ignore Pdot)
OUTFILE = cirx1                 / output file name for all scans
HALIST  = -3h30m 0h +3h30m      / scans at three hour angles
USECONF = 3.5                   / only use config named 3.5
REPEATS = 2                     / do two scans for comparison
WEATHER = clear                 / observe only in clear weather
ENDOBJ                          / (redundant) end of object scan definition
```

6.3 Continuum Radiometry: Scans for a large map

This is how we would probably implement Sarah's mapping technique, not to be confused with Skymap. Notice that there is no mention of an ST or RA, so the scheduler will have to deal with galactic coordinates. Each scan is written to a separate file to aid data editing.

```
SETUP
OBSERVER= J.L. JONAS
OBSLOCAL= G.D. NICOLSON
PROJECT = galactic plane map at 3.5cm
PROPOSAL= 1999/003
COORDSYS= GALACTIC              / ###JJ###
                                / ###JJ### no need for EQUINOX
CONF    = 8000NA
RESTFREQ= 8000E6                / 3.6cm map ###JJ###
INSTRUME= NA                    / use noise-adding radiometer pair
                                / ###JJ### presumably this will set up
                                / "Beam A" feed offsets???  JQ ?
ENDCONF

SCANTYPE= SCAN
PROJTYPE= TAN                   / ###JJ### default would be "CAR", but
                                /   we want to compare with optical image
GLON    = 270d                  / Galactic coordinated of map centre
GLAT    = +20d                  /
LONGPOLE= 0.0                   / ###JJ### this is the default field
                                / rotation, so not strictly needed
HALIMIT = 3h0m                  / ###JJ### no need for constant HA start,
                                /       only reasonable elevation
                                / ###JJ### no generic OUTFILE
WEATHER = clear                 / observe only in clear weather

DEFCONF = 8000NA
ENDSETUP

                                / ###JJ### new scan definitions
OBJECT  = SCAN001X
OUTFILE = mapjj.x.1.fits        / individual output file
STARTX  = -5d                   / new way of specifying scan start/stop
STARTY  = -5d                   /   relative to special point (map centre)
STOPX   = -5d                   / default would be STARTX
STOPY   = +5d
SCANTIME= 100                   / scan at (5+5)/100 = 0.1 deg/sec
                                / DEFCONF automatically pasted in

OBJECT  = SCAN002X
OUTFILE = mapjj.x.2.fits        / individual output file
STARTX  = -4.9d                 / new way of specifying scan start/stop
STARTY  = +5d                   /   relative to special point (map centre)
STOPX   = -4.9d                 / default would be STARTX
STOPY   = -5d
```

```
                                / scan spacing is 0.1 degree
SCANTIME= 100                   / scan at 10/100 = 0.1 deg/sec
                                / DEFCONF automatically pasted in

etc

OBJECT  = SCAN001Y
OUTFILE = mapjj.y.1.fits        / individual output file
STARTX  = -5d                   / new way of specifying scan start/stop
STARTY  = -5d                   /   relative to special point (map centre)
STOPX   = +5d
STOPY   = -5d                   / default would be STARTY
SCANTIME= 100                   / scan at 10/100 = 0.1 deg/sec
                                / DEFCONF automatically pasted in
etc
```

6.4 Continuum radiometry: a scan at constant elevation

This is part of an input file to show the coordinate specification for a doing a scan at constant elevation, from JJ.

#JJ#: This example (and your drift scan example) show up an interesting problem: how do you scan through a target specified in a celestial coordinate system using geocentric coordinates to specify the scan. In the above example I have made no attempt to scan through a target, rather assumed the required criterion was to scan at a given elevation with no real regards to the celestial coordinate requirements.

Note: This needs a preceding SETUP section to give all mandatory keywords for this single scan.

```
OBJECT  = FRED const elevation  / object for scan
COORDSYS= HORIZON               / not strictly needed - AZ, EL  unique
AZ      = 0                     / use "native" az/el coords
EL      = 0                     /
PROJTYPE= NONE                  /
SCANTYPE= SCAN                  / active scan in galactic coordinates
STARTX  = 0                     / scan start azimuth
STOPX   = 180                   / scan end azimuth
STARTY  = 40                    / constant elevation
STOPY   = 40                    /     of 40 deg
SCANTIME= 100                   / scan time in seconds
OUTFILE = jjconel
```

6.5 Continuum radiometry: a scan in declination

Partial input file for a declination scan, from JJ.

Note: This needs a preceding SETUP section to give all mandatory keywords for this single scan.

```
OBJECT  = Sgr A declination scan/ object for scan
COORDSYS= EQUATORIAL            / not strictly needed - RA, DEC unique
EQUINOX = B1950                 / needed
PROJTYPE= NONE
```

```
RA      = 17 42 26.6            / = GLON 0.000
DEC     = -28 55 0.4            / = GLAT 0.000
SCANTYPE= SCAN                  / active scan in equatorial coordinates
STARTX  = 0                     / scan start offset in RA - ie track in RA
STOPX   = 0                     / scan end offset in RA - ie track in RA
STARTY  = -5                    / scan start offset in DEC
STOPY   = +5                    / scan end offset in DEC
SCANTIME= 100                   / scan time in seconds
OUTFILE = jjdecscan
```

6.6 Continuum radiometry: a circular scan at the beam halfpower point

This makes use of the proposed projection type called "ZEN" which is a "native zenithal projection". This would simply point the pole of the native system at the "special point" and would therefore aleviate the need for the DEC-90 calculation. The euler angles would be set to:

- theta = 0
- phi = 90 - latitude
- psi = longitude

The input file would become:

Note: This needs a preceding SETUP section to give all mandatory keywords for this single scan.

```
OBJECT  = TAU A circular scan
COORDSYS= EQUATORIAL
EQUINOX = B1950
SCANTYPE= SCAN
RA      = 82.880                / point pole of native system at source
DEC     = 21.982
PROJTYPE= ZEN                   / zenithal coordinates with no projection
STARTX  = 0                     / do full circle
STOPX   = 360                   / do full circle
STARTY  = HP                    / spec for circle at halfpower point
STOPY   = HP                    / HP got from SYPARM for this frequency
OUTFILE = taucirc
```

MG: even more user-friendly is to let the software do the obvious stuff:

```
OBJECT  = TAU A circular scan
COORDSYS= EQUATORIAL
EQUINOX = B1950
SCANTYPE= SCANCIRC
RA      = 82.880                / point pole of native system at source
DEC     = 21.982
RADIUS  = HP                    / spec for circle at halfpower point
OUTFILE = taucirc
```

6.7 Continuum radiometry: a small map of the Sun

This map is to be observed on 1999 11 11. It uses the default scanrate and binsize.

JJ: Added projection stuff. Uses the JPL solar system ephemeris.

Note: I haven't checked that this conforms with our current input format and mandatory requirements - it lacks STRTDATE, ENDDATE etc.

```
OBJECT  = SUN                   / Sun map
PROJECT = Sun map at 2.5cm
PROPOSAL= 1999/004
OBJECT  = SUN                   / use JPL solar ephemeris for position
OBSERVER= J. QUICK
COORDSYS= ECLIPTIC              / sun position specified by ecliptic long.
PROJTYPE= TAN                   / ###JJ### make a map that can be directly
                                /   compared with an optical image.
RESTFREQ= 12180E6               / 2.5cm
INSTRUME= TP                    / use total power radiometer pair
SCANTYPE= MAP                   / small map, uninterrupted
OUTFILE = sunmap
SIZELONG= 1.0                   / 1 x 1 degree map
```

6.8 Continuum radiometry: a small map of the Moon

This map is to be observed on 1999 11 03. It uses the default scanrate and binsize.

Note: I haven't checked that this conforms with our current input format and mandatory requirements - it lacks STRTDATE, ENDDATE etc.

```
OBJECT  = MOON                  / Moon map
PROJECT = Moon map at 2.5cm
PROPOSAL= 1999/005
OBJECT  = MOON                  / use JPL moon ephemeris
OBSERVER= J. QUICK
COORDSYS= EQUATORIAL            / moon position using apparent equatorial
EQUINOX = APPARENT              / ###JJ### explicit specification needed
PROJTYPE= TAN                   / ###JJ### make a map that can be directly
                                /   compared with an optical image.
RESTFREQ= 12180E6               / 2.5cm
INSTRUME= TP                    / use total power radiometer pair
SCANTYPE= MAP                   / small map, uninterrupted
OUTFILE = moonmap
SIZELONG= 1.0                   / 1 x 1 degree map
```

6.9 Spectroscopy: Monitoring a Methanol Maser

This is an extract from a typical 6.7-GHz methanol monitoring input file, set up as though the old correlator were running on the NCCS. Some keywords may change for the new correlator, and additional ones may be needed.

```
SETUP
OBSERVER= S. GOEDHART
PROJECT = 6.7-GHz methanol maser monitoring
PROPOSAL= 1999/006
CONF    = 6668SPEC
RESTFREQ= 6668.518E6            / methanol
SCANTYPE= SPECTRUM              / implies instrument = spectrometer
ENDCONF =
COORDSYS= GALACTIC              / ###JJ### not strictly needed because of
                                / GLON and GLAT below instead of LONG, LAT
OUTFILE = sgg21371
DEFCONF = 6668SPEC
ENDSETUP
                                / blank line for readability
OBJECT  = G213.71-12.60 PNT     / name change for pointing
SOURCE  = 1
GLON    = 213.710               /
GLAT    = -12.600               /
SPVLSR  = +11.0                 / km/s
SPBW    = 0.50e6                / Hz
SPFS    = 0.30e6                / Hz (freq switch by half the bandwidth)
SPTIME  = 8                     / each 8 minutes total duration
SPPOINT                         / do pointing observations NS + EW + ON
                                / ###JJ### pointing check offsets will be
                                /    independent of declination because
                                /        of projection
                                / DEFCONF automatically pasted in.

OBJECT  = G213.71-12.60         / standard name for source
SOURCE  = 2
GLON    = 213.710               /
GLAT    = -12.600               /
SPVLSR  = +11.0                 / km/s
SPBW    = 0.50e6                / Hz
SPFS    = 0.25e6                / Hz (freq switch by half the bandwidth)
SPTIME  = 8                     / each 8 minutes total duration
REPEATS = 4                     / do 4 on-souce spectra, no pointing
                                / DEFCONF automatically pasted in.


and so on for the next object.
```

6.10 Pulsar Timing: Monitoring the Vela Pulsar

Pulsar timing requires many parameters to be defined. The example below is derived from the information in the file PULSAR::16 on the HP1000, and the `Pulsar Observing Software User's Guide`.

Pulsar timing input file for regular monitoring of the Vela pulsar at two frequencies:

```
SETUP                           / common parameter definition
```

```
PROJECT = daily monitoring of the Vela pulsar
PROPOSAL= 1999/007
SCANTYPE= PULSAR                / implies INSTRUME= PULSARTIMER to parser?
OBSERVER= C.S. FLANAGAN         / principal investigator
OBSLOCAL= J. URAMA              / on-site collaborator or dogsbody
CATALOG = pulsar.cat            / pulsar catalogue
HALIST  = -5.9h -3h 0h 3h 5h    / hour angles at which obs are wanted
OUTFILE = vela.data             / all vela data to this file

CONF    = 1650
RESTFREQ= 1650E6                / observe at 18cm, standard frequency
ENDCONF

CONF    = 2300
RESTFREQ= 2300E6                / also observe at 13cm, std. freq.
ENDCONF

ENDSETUP                        / end of common parameter definition
                                / blank line added for readability

OBJECT  = PSR0833-45
PLCAL   = ON                    / calibrate for one obs only
USECONF = 1650

OBJECT  = Vela Pulsar           / alternative name used
USECONF = 1650                  / observe at 18cm, standard frequency
PLCAL   = OFF                   / no calibration
REPEATS = 4                     / do 4 obs without calibration

OBJECT  = Vela Pulsar
PLCAL   = ON                    / calibrate for one obs only
USECONF = 2300

OBJECT  = Vela Pulsar
USECONF = 2300                  / also observe at 13cm, std. freq.
PLCAL   = OFF                   / no calibration
REPEATS = 4                     / do 4 obs without calibration
```

The pulsar catalogue, `pulsar.cat`, would have multiple entries like this:

```
OBJECT  = PSR0833-45, Vela Pulsar       / comma delimited alternative names
COORDSYS= EQUATORIAL
EQUINOX = 1984.0                / = MJD 2445700.0, in PULSAR::16
RA      = 08 33 39.3120         / OR
RA      = 08h33m39.3120s        / postfix
DEC     = -45 00 10.2960        / OR
DEC     = -45d00'10.2960"       / postfix
PLPERIOD= 0.089323102747        / seconds
PLPDRV1 = 124.4496E-15          / seconds per second
PLPDRV2 = -230.0E-25            / seconds per second**2
```

```
PLDM    = 67.321                / dispersion measure pccm-3
PLDMDRV = -0.05                 / dispersion measure derivative pccm-3s-1
PLEPOCH = 2451041.21556         / pulsar ephemeris epoch in Julian days
PLPHASE = 1000                  / set to deglitch, not latest value
PLTCONST= 150                   / post-det time constant, microseconds
PLPINT  = 500 1650E6            / integrate 500 periods at 18cm/1650MHz
PLPINT  = 500 2300E6            / integrate 500 periods at 13cm/2300MHz
PLGLITCH= OFF                   / glitch det off, ephemeris has run out
```