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12th January 2007

GBT SOFTWARE PROJECT NOTE 8.6

GBT GO FITS File Specification

HTML version Available¹

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Abstract

The FITS format structure is presented for the GBT GO (Observer's User Interface) scan data files. The scan data FITS files are permanently archived after each observation, and will usually be input to the aips++ filler, which has the task of combining all scan data FITS files into an aips++ Measurement Set. This data may then either be processed further in aips++, or written out in an aips++ supported FITS format (one of which is single dish FITS).

The contents of the GO FITS file are intended to be indicative of the observer's intent when performing an observation comprised of a sequence of scans. They are not intended to provide detailed data processing information; this should be obtained from the other FITS files associated with each scan.

¹<http://www.gb.nrao.edu/GBT/MC/doc/dataproc/gbtGOFits/gbtGOFits/gbtGOFits.html>

History

8th November 2001 Penultimate definition of FITSVER 1.1; released for general comment (Richard Prestage).

16th November 2001 Final version agreed for implementation of FITSVER 1.1. Added history. Subsequent changes to the content of this document should increment the document version number (Richard Prestage).

28th November 2001 Removed SlewTo and Peak from the list of possible PROCNAME values. Changed unknown to Unknown in the possible PROCNAME values. In the example for the FITS Keywords for positional information changed COORDSYS to have a legal value. Put in the correct glish shell function used to determine the value of DATEBLD.

7th March 2002 Add PSWITCH as possible value for SWSTATE keyword. Also added description for each possible SWSTATE value and changed list to be an itemized list. Remove SWWCAL and SWNOCAL as possible values for SWCHSIG. Add FSW01, FSW12, FSW0102, BEAMSW, POLSW, FSW01NOCAL, FSW12NOCAL, FSW0102NOCAL, BEAMSWNOCAL and POLSWNOCAL as possible values for SWCHSIG. Change references for switching signals documentation from note by Ron Maddalena to the GO Design Document and the GO Switching Signals Implementation document. Change to FITSVER 1.2.

21st March 2002 Add TPWCALSP to SWCHSIG values.

17th October 2002 Add nod to list of possible procedures.

12th January 2007 Fix bug so that all RA positions are written in degrees. Change to FITSVER 2.6. Change will appear in M&C version 7.1.

2nd May 2007 Reworded frequency related section to refer to LO1 FITS documentation. FITSVER was not changed.

14th May 2010 Change to FITSVER 2.7. Added RESTFRQn keywords to record all user-supplied rest frequencies as keyword=value pairs. They have been available in the HISTORY for some time.

1 Introduction

All GBT scan data GO FITS files should conform to the standards specified in the GBT Software Project Note 4.0, “Device and Log FITS Files for the GBT.” In version 1.1 the GO FITS files consist simply of ASCII header records, with no associated data, and no extensions. The information in the header records can be split into five main categories, as follows:

- GBT standard primary header keywords,
- additional “housekeeping” related keywords
- Observing procedure related keywords,
- Target positional information, and
- Target frequency related information.

These are described in detail in the following sections.

The GO FITS files are slightly unusual in that they are produced by calls to a glish procedure and corresponding glish client, rather than a C++ device manager. However, apart from some subtleties in the GBT standard header keywords, this has no other impact on the structure or content of the files.

NOTE: At the time of production of FITSVER 1.2 GO FITS files, the file can only be expected to be complete if the observer configures the system and executes scans using GBT supplied glish procedures and observing tables. Although it is entirely legitimate for an observer to configure the system using their own private procedures, we have not yet devised a mechanism to reliably ensure that these will write all the required information to the GO FITS file.

2 GBT standard primary header keywords

The Primary Header of all GBT FITS files starts with a number of required keywords, and finishes with the keyword END as shown in the example below:

```
SIMPLE = T / file does conform to FITS standard
BITPIX = 8 / number of bits per data pixel
NAXIS = 0 / number of data axes
EXTEND = T / FITS dataset may contain extensions
ORIGIN = 'NRAO Green Bank' /
INSTRUME= 'GO' / File was created by GBT Observer's Interface
GBTMCVER= '3.3.2' / telescope control software release
FITSVER = '1.2' / FITS definition version for this device
DATEBLD = 'Thu Jun 21 18:46:25 GMT 2001' / time program was linked
SIMULATE= 0 / Is the instrument in simulate mode
DATE-OBS= '2001-10-27T02:56:30' / Manager parameter startTime
TIMESYS = 'UTC' / time scale specification for DATE-OBS
TELESCOP= 'NRAO_GBT' / Green Bank Telescope (Robert C. Byrd 100m)
OBJECT = 'ugc11891' / Manager parameter source
PROJID = 'tigerTeam_05' / Manager parameter projectId
OBSID = 'test' / Manager parameter scanId
SCAN = 17 / integer scan identifier
:
:
```

Other keywords as described in this document

```

:
:
END

```

The meaning of these parameters are as described in GBT/SPN/004, with the following exceptions:

- DATEBLD refers to the date on which the glish directory corresponding to GBTCMCVER was last modified (i.e., the output of `ls -l --full-time /home/gbtversions/n.m.l/glish | head -2 | tail 1`) where `n.m.l` corresponds to GBTCMCVER.
- SIMULATE = T means that the User Interface itself was running in simulate mode.
- OBJECT, PROJID and OBSID are the string values that were sent to the Scan co-ordinator parameters source, projectId and scanId respectively.

3 Housekeeping related keywords

For FITSVER 1.2, there is only one additional piece of housekeeping information; the name of the observer:

```
OBSERVER= 'Commissars' / Name of observer
```

4 Observing procedure related keywords

The following FITS keywords provide information to the aips++ filler to allow it and subsequent aips++ data processing stages to reduce the data appropriately:

```

PROCNAME= 'OffOn' / Name of observing procedure
PROCTYPE= 'SIMPLE' / Observing procedure class
PROCSEQN= 2 / Scan sequence number
PROCSIZE= 2 / Number of scans in procedure
OBSTYPE = 'LINE' / Type of Observation
SWSTATE = 'NONE' / Type of switching
SWCHSIG= 'SWWCAL' / Switching Signals Mode?
LASTON = 0 / Last On for pos switching
LASTOFF = 0 / Last Off for pos switching

```

PROCNAME is the name of the GO observing procedure used for the scan described in this FITS file. Possible values for version 1.1 are: Track, MajorPoint, MinorPoint, Cross, CrossAzEl, CrossUpdate, RALongMap, DecLatMap, RALongOTF, DecLatOTF, PointMap, Tipping, OffOnOff, OffOn, OnOff, Fivepoint, FocusSubreflector, FocusPrime, Rotateprime, Circle, Nod, Unknown.

A PROCNAME value of “unknown” indicates that the GO system has attempted to provide a value for PROCNAME, but the observing procedure is unrecognized. In this case, additional comments may appear in the GO FITS file.

PROCTYPE Describes the category of procedure used for the observation. Possible values for 1.1 are: POINTING, POLARIZATION, CALIBRATION, SIMPLE, MAP, UNKNOWN (with the meaning of UNKNOWN as for PROCTYPE).

PROCSEQN is the scan sequence number of the observation within the possible range of scans for the procedure used.

PROCSIZE is the total number of scan in a given procedure.

OBSTYPE provides information as to the type of observing that was performed. Possible values are: CONTINUUM, LINE, PTIMING, PSEARCH, PDEDISP, PVSAMPLING, PMONITOR, UNKNOWN

SWSTATE Broadly describes the type of switching used during the observation. Possible values are:

- PSWITCHON - position switching ON scan
- PSWITCHOFF - position switching OFF scan
- PSWITCHONOFF - positions switching with ON and OFF in same scan
- FSWITCH - frequency switching
- BSWITCH - beam switching
- PSWITCH - polarization switching
- NONE - non-switching mode or unknown state

SWTCHSIG indicates the possible switching signal scheme used, while SWSTATE describes the type of switching (e.g. position or frequency) SWTCHSIG indicates how that particular switching scheme was configured. Note that the selection of switching signals can be bypassed so this keyword is not guaranteed to be absolutely correct. Current allowed values are:

- USERDEF - user defined
- TPWCAL - total power with calibration
- TPNOCAL - total power without calibration
- TPWCALSP - total power with cal. for spectral processor using doppler tracking, not yet implemented
- FSW01 - frequency switching, online and offline pair, with calibration
- FSW12 - frequency switching, symmetric about line, with calibration
- FSW0102 - frequency switching, symmetric offsets, with calibration
- BEAMSW - beam switching, with calibration
- POLSW - polarization switching, with calibration
- FSW01NOCAL - frequency switching, online and offline pair, without calibration, not yet implemented
- FSW12NOCAL - frequency switching, symmetric about line, without calibration, not yet implemented
- FSW0102NOCAL - frequency switching, symmetric offsets, without calibration, not yet implemented
- BEAMSWNOCAL - beam switching, without calibration, not yet implemented
- POLSWNOCAL - polarization switching, without calibration, not yet implemented

These are described in more detail in GBT Software Project Note 18² and GBT Software Project Note 19³

LASTON Provides the scan number of the last known valid ON scan for position switching observations.

LASTOFF Provides the scan number of the last known valid OFF scan for position switching observations.

²<http://www.gb.nrao.edu/GBT/MC/doc/dataproc/GOreq/GOreq/GOreq.html>

³<http://www.gb.nrao.edu/GBT/MC/doc/dataproc/gbtGOSwitchingSignals/gbtGOSwitchingSignals/gbtGOSwitchingSignals.html>

5 Target positional information

The actual position of the antenna should in all cases be derived from the antenna FITS file. Co-ordinates provided through the GO FITS file are indicative only, and might be used, for example, to define the field center of an image.

A detailed description of GBT astronomical position handling is given in GBT/SPN/015, and so is only briefly reviewed here.

The keyword COORDSYS will be used to define the type of co-ordinate system in use. The possible values in FITS version 1.1. are “GALACTIC”, “RADEC”, “HADEC”, “AZEL”, or “OTHER”. OTHER will be used for any situation where the precise specification of the co-ordinate system has not yet been decided; for FITS versions 1.1 this includes user defined co-ordinates and solar system objects. Later versions of the FITS definition may include a representation of these co-ordinates, in which case a new value will be provided for COORDSYS.

For COORDSYS = “RADEC”, the standard (WCS) keyword RADESYS (note missing “C”) will be used to define the specific type of system in use.

Note that the standard FITS keyword EQUINOX is used to provide the epoch (i.e. instant of time) of the mean equator and equinox. Prior to version 1 of the FITS standard, the keyword EPOCH was used for this quantity; it is illegal to use the keyword EPOCH in new FITS files. For GAPPT, WCS paper II recommends use of the start time of the observation (via DATE-OBS or MJD-OBS) to provide the epoch of the equator and equinox.

The actual co-ordinate value used will be provided by the appropriate (long, lat) pair, depending on the value of COORDSYS.

The following example shows how the target positional information might appear in the GO FITS file:

```
COORDSYS= 'RADEC'      / co-ordinate system used to command telescope
RADESYS = 'FK5'        / Type of equatorial system in use
EQUINOX = 2.00000000000000E+03 / Equinox of selected coordinate reference frame
RA      = 3.30375000000000E+02 / Commanded Major Axis Value in Degrees
DEC     = 4.35000000000000E+01 / Commanded Minor Axis Value in Degrees
```

6 Target frequency related information

The content of the GO FITS file related to frequency information depends upon the value of OBSTYPE.

For OBSTYPE = “LINE”, the velocity and rest-frequency related values specified by the observer are important. These keywords, shown with typical values, are as follows:

```
VELOCITY=          42500.0 / source velocity in m/s
VELDEF = 'VRAD-LSR'      / velocity definition and reference frame
RESTFRQ =          9183000000.0 / line rest frequency in Hz
RESTFRQ1=          9183000000.0 / rest frequency 1, always matches RESTFRQ
RESTFRQ2=          9505000000.0 / rest frequency 2
RESTFRQ3=          9812000000.0 / rest frequency 3
RESTFRQ4=          8665300000.0 / rest frequency 4
```

The velocity definition and reference frame are encoded into the value of VELDEF according to the WCS paper III. See the discussion of the SOUVEL binary table in the GBT Tracking Local Oscillator FITS documentation at GBT/SPN/006 for more details on the possible values for the VELDEF keyword.

The RESTFRQn keywords were added at FITSVER 2.7. These are all of the rest frequency values that the user supplied in the order that they were supplied. The original RESTFRQ keyword is still being written and RESTFRQ1 should always match RESTFRQ. The n in RESTFRQn includes the integers 1 through 9 and the upper case letters A through Z as needed.

For OBSTYPE other than line (i.e. pulsar and continuum) the actual center frequency and bandwidth achieved at the backend should be obtained from the IF Manager FITS file. However, we provide a single keyword SKYFREQ which may be considered indicative of the planned center frequency:

$\text{SKYFREQ} = 8929391685.963282 / \text{intended sky center frequency in Hz}$