GBT Spectral Processor FITS File Specification

Abstract

The FITS format structure is presented for the GBT SpectralProcessor 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 scan data FITS files contain both 1) a complete description of the spectral processor setup for the observation and 2) measurement data with a FITS keyword description of the data organization. The STATE and PORT tables describe the setup and the DATA table contains measured values.

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1http://www.gb.nrao.edu/GBT/MC/doc/dataproc/ghtSPFits/ghtSPFits.html
1 **Background**

All GBT scan data FITS files should conform to the standards specified in the GBT Software Project Note 4.0, “Device and Log FITS Files for the GBT.” The SpectralProcessor consists of two identical Banks (A and B) which are setup in tandem and whose output are combined into a single FITS file. Three GBT SpectralProcessor binary table extensions will be produced: PORT, STATEand DATA, and these tables will be placed in a single scan data FITS file for each scan.

2 **Primary HDU keywords**

The SpectralProcessor FITS keywords for the primary HDU conforms to the definition for common FITS headers. Only the keyword MODE is added to identify the overall state. Possible values are:

- DedispTimeSamples
- TimeSyncSpectra
- SigAvgDedisp
- SpectraBurst
- FreqTimeAvg
- VoltageTimeSamples
- StdSpectLine
- PowerTimeSamples
- PulsePhaseSpectra
- SyncFreqTime

The primary header keywords are as follows:

```
SIMPLE   = T / file does conform to FITS standard
BITPIX   = 8 / number of bits per pixel
NAXIS    = 0 / number of data axes
EXTEND   = T / FITS dataset may contain extensions
ORIGIN   = 'NRAO Green Bank' /
DATE-OBS = '2000-10-25T13:57:17' / Scan Coordinator parameter startTime
TIMESYS  = 'UTC' / time scale specification for DATE-OBS
INSTRUME = 'SpectralProcessor' / device or program of origin
GBTMCVER = '3.3.0' / telescope control software release
FITSVR   = '1.1' / FITS definition version for this device
DATEBLD  = 'Thu Jun 7 20:15:13 GMT 2001' / time program was linked
SIMULATE = 0 / Is the instrument in simulate mode?
TELESCOP = 'NRAO_GBT' / Green Bank Telescope (Robert C. Byrd 100m)
OBJECT   = '0013+1527' / Scan Coordinator parameter source
PROJECT  = 'RMP_DCR' / Scan Coordinator parameter projectId
OBSID    = 'test' / Scan Coordinator parameter scanId
SCAN     = 3 / Scan Coordinator parameter scanNumber
MODE     = 'StdSpectLine' / Set of quadrants and associated input ports
END
```
As for all GBT scan data FITS files, the DATE-OBS keyword takes the value of the Manager parameter startTime. This is the scheduled start time for the scan as a whole. The actual time at which integrations are taken is recorded in the DATA table; it is possible that there may be some delay between the start of the scan (as recorded in DATE-OBS) and the actual time of the first integration.

3 PORT Binary Table Extension

The PORT table describes the SpectralProcessor set up and which IF inputs (samplers) have been used. An example header, plus ascii listing of typical table data, is given below:

PORT Binary Tables Extension: Header

<table>
<thead>
<tr>
<th>XTENSION= 'BINTABLE'</th>
<th>/ binary table extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>BITPIX = 8</td>
<td>/ 8-bit bytes</td>
</tr>
<tr>
<td>NAXIS = 2</td>
<td>/ 2-dimensional binary table</td>
</tr>
<tr>
<td>NAXIS1 = 118</td>
<td>/ width of table in bytes</td>
</tr>
<tr>
<td>NAXIS2 = 2</td>
<td>/ number of rows in table</td>
</tr>
<tr>
<td>PCOUNT = 0</td>
<td>/ size of special data area</td>
</tr>
<tr>
<td>GCOUNT = 1</td>
<td>/ one data group (required keyword)</td>
</tr>
<tr>
<td>TFIELDS = 5</td>
<td>/ number of fields in each row</td>
</tr>
<tr>
<td>TTYPE1 = 'BANK_A'</td>
<td>/ label for field 1</td>
</tr>
<tr>
<td>TFORM1 = '1A'</td>
<td>/ data format of field: 1-byte CHAR</td>
</tr>
<tr>
<td>TUNIT1 = 'none'</td>
<td>/ physical unit of field</td>
</tr>
<tr>
<td>TTYPE2 = 'PORT_A'</td>
<td>/ label for field 1</td>
</tr>
<tr>
<td>TFORM2 = '1I'</td>
<td>/ data format of field: 2-byte INTEGER</td>
</tr>
<tr>
<td>TUNIT2 = 'INDEX'</td>
<td>/ physical unit of field</td>
</tr>
<tr>
<td>TTYPE3 = 'BANK_B'</td>
<td>/ label for field 1</td>
</tr>
<tr>
<td>TFORM3 = '1A'</td>
<td>/ data format of field: 1-byte CHAR</td>
</tr>
<tr>
<td>TUNIT3 = 'none'</td>
<td>/ physical unit of field</td>
</tr>
<tr>
<td>TTYPE4 = 'PORT_B'</td>
<td>/ label for field 2</td>
</tr>
<tr>
<td>TFORM4 = '1I'</td>
<td>/ data format of field: 2-byte INTEGER</td>
</tr>
<tr>
<td>TUNIT4 = 'INDEX'</td>
<td>/ physical unit of field</td>
</tr>
<tr>
<td>TTYPE5 = 'TAPER'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT5 = 'none'</td>
<td>/ physical unit of field</td>
</tr>
<tr>
<td>TTYPE6 = 'FREQRES'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT6 = 'HZ'</td>
<td>/</td>
</tr>
<tr>
<td>TFORM6 = '1D'</td>
<td>/</td>
</tr>
<tr>
<td>TTYPE7 = 'BANDWDTH'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT7 = 'HZ'</td>
<td>/</td>
</tr>
<tr>
<td>TFORM7 = '1E'</td>
<td>/</td>
</tr>
<tr>
<td>TTYPE8 = 'ATTENUAT'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT8 = 'dBm'</td>
<td>/</td>
</tr>
<tr>
<td>TTYPE9 = 'FASTTIME'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT9 = 'SECONDS'</td>
<td>/</td>
</tr>
<tr>
<td>TFORM9 = '1E'</td>
<td>/</td>
</tr>
<tr>
<td>TTYPE10 = 'SLOWTIME'</td>
<td>/</td>
</tr>
<tr>
<td>TUNIT10 = 'none'</td>
<td>/</td>
</tr>
<tr>
<td>TFORM10 = '1E'</td>
<td>/</td>
</tr>
<tr>
<td>TTYPE11 = 'CLIP'</td>
<td>/</td>
</tr>
</tbody>
</table>
Each row of the PORT table describes one complex spectrum produced by the SpectralProcessor. The total number of rows therefore defines the size of the third dimension (CYTPE3 = ‘PORT’) of the seventh column (TTYPE7 = ‘DATA’) of the DATA table described below, and the row number provides the index into this dimension.

Each row contains the value of two ports which are identified by BANK and PORT (BANK_A, PORT_A, BANK_B, and PORT_B). For non-cross multiplier mode, i.e., Square, the A and B ports are the same. For example, using two samplers per rack yields:

<table>
<thead>
<tr>
<th>BANK_A</th>
<th>PORT_A</th>
<th>BANK_B</th>
<th>PORT_B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>A</td>
<td>2</td>
</tr>
</tbody>
</table>

\textbf{EXTNAME} = ‘PORT’ / name of this binary table extension

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\textbf{TUNIT11} = ‘none’ / \textbf{TFORM11} = ‘1E’ /
\textbf{TTYPE12} = ‘THRESH’ / \textbf{TUNIT12} = ‘SECONDS’ /
\textbf{TFORM12} = ‘1E’ /
\textbf{TTYPE13} = ‘SYNTHL’ / \textbf{TUNIT13} = ‘CODE’ /
\textbf{TFORM13} = ‘1B’ /
\textbf{TTYPE14} = ‘OVERL’ / \textbf{TFORM14} = ‘1B’ /
\textbf{TTYPE15} = ‘IMODF’ / \textbf{TUNIT15} = ‘CODE’ /
\textbf{TFORM15} = ‘1B’ /
\textbf{TTYPE16} = ‘IFSYNTH’ / \textbf{TUNIT16} = ‘CODE’ /
\textbf{TFORM16} = ‘1B’ /
\textbf{TTYPE17} = ‘TAPEROFF’ / \textbf{TUNIT17} = ‘CODE’ /
\textbf{TFORM17} = ‘1B’ /
\textbf{TTYPE18} = ‘RFIEXEC’ / \textbf{TFORM18} = ‘1B’ /
\textbf{TTYPE19} = ‘CLKSRC’ / \textbf{TUNIT19} = ‘CODE’ /
\textbf{TFORM19} = ‘1B’ /
\textbf{TTYPE20} = ‘IFLO’ / \textbf{TFORM20} = ‘1B’ /
\textbf{TUNIT20} = ‘CODE’ /
\textbf{TFORM20} = ‘1B’ /
\textbf{TTYPE21} = ‘IFSIDE’ / \textbf{TUNIT21} = ‘CODE’ /
\textbf{TFORM21} = ‘1B’ /
\textbf{MULTMODE} = ‘SqrCross’ / Square, Cross, or SqrCross

(This will have to wait until we have actual data!!)
For cross multiplier modes, i.e., Cross and SqrCross, the ports will have all combinations. For example, using one sampler per rack yields:

<table>
<thead>
<tr>
<th>BANK_A</th>
<th>PORT_A</th>
<th>BANK_B</th>
<th>PORT_B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>A</td>
<td>1</td>
</tr>
</tbody>
</table>

The MULTMODE keyword specifies whether the scan was intended to be cross and/or squared.

The definitions of the columns in the binary table are as follows:

**BANK_A** Identifier for the first bank containing the A/D sampler for the spectrum.

**PORT_A** Index to the A/D sampler in BANK_A for the spectrum.

**BANK_B** Identifier for the second bank containing the A/D sampler for the spectrum. This will be identical to **BANK_A** in Square mode.

**PORT_B** Index to the A/D sampler in BANK_B for the spectrum. This will be identical to **PORT_A** in Square mode.

**TAPER** Describes the weighting function used on the A/D amplitude-vs-time series before its transformation. Possible values are Box, Halfbox, and Cosine.

**FREQRES** Specifies the frequency resolution, i.e., Hz per channel.

**BANDWIDTH** Specifies the port bandwidth.

**ATTENUAT** Specifies the port attenuator setting.

**FASTTIME** Specifies the response time of the total power pulsed RFI threshold detector.

**SLOWTIME** Specifies the response time of the baseline comparison level for the total power pulsed RFI threshold detector.

**CLIP** Specifies the maximum instantaneously level applied to the slow baseline integrator. It is specified in fraction of the total IF power plus noise peak level with the given bandwidth.

**THRESH** Specifies the level difference between the outputs of the fast and slow integrators that will flag an RFI pulse. Specified in fraction of total IF peak noise excursions from the average DC detected level with the given bandwidth.

**SYNTHL** Designates whether the IF’s synthesizer is out of lock, i.e., 1 if out of lock.

**OVERL** Designates whether the total power is overloaded, i.e., 1 if overloaded.

**IMODF** Designates whether the InterMode filter is on, i.e., 1 if in.

**IFSYNTH** Designates whether synthesizer doubler is on, i.e., 1 if doubling.

**TAPEROFF** Designates whether synthesizer taper offset between racks is on.

**RFIEXC** Designates whether RFI excision is on.

**CLKSRC** Designates whether clock source is external, i.e., 1 if external.

**IFLO** Designates whether the IF’s LO is external, i.e., 1 if external.

**IFSIDE** Designates whether the IF’s sideband selection is upper or lower, i.e., 1 if lower.
4 STATE Binary Table Extension

The SpectralProcessor FITS keywords for the STATE table conforms to the definition for common FITS headers as described in GBT Software Project Note 4.0 “Device and Log FITS Files for the GBT.” The row number provides the index into the STATE dimension of the seventh column (DATA) in the DATA table. The order of the states in this table is that of the STATE dimension in the DATA cube.

Note that the SpectralProcessor cannot act as a slave to switching signals generated from an external source, i.e., it must be the master. An example STATE header, plus ASCII listing of typical table data, is given below:

STATE Binary Tables Extension: Header
-------------------------------------------------------------------------------
this will wait for actual data
-------------------------------------------------------------------------------

STATE Binary Tables Extension: Data (complete)
-------------------------------------------------------------------------------
wait for real data
-------------------------------------------------------------------------------

Note that this table describes the SpectralProcessor’s internal configuration of switching signals, it is name STATE in accordance with common M&C usage and convention in the other GBT backend FITS files.

5 DATA Binary Table Extension

The DATA table contains a (large) DATA column containing counts from both banks of the Spectral Processor.

An example extension header, and a subset of the data is given below:

DATA Binary Tables Extension: Header
-------------------------------------------------------------------------------
XTENSION = 'BINTABLE' / FITS binary table.
BITPIX = 8 / Binary data.
NAXIS = 2 / Table is a Matrix.
NAXIS1 = 32792 / Width of table in bytes.
NAXIS2 = 1 / Number of entries (rows) in Table.
PCOUNT = 0 / Pointer Count
GCOUNT = 1 / Only one group.
TFIELDS = 7 / Number of fields in each row.
TTYPE1 = 'DMJD ' /
TFORM1 = '1D ' /
TUNIT1 = 's ' /
TTYPE2 = 'UTDTSTRT' /
TUNIT2 = 'MJD ' /
TFORM2 = '1J ' /
TTYPE3 = 'UTCSTRT ' /
TUNIT3 = 'SECONDS ' /
TFORM3 = '1D ' /
TTYPE4 = 'PSRPER ' /
TUNIT4 = 'PULSAR PERIOD' /
TFORM4 = '1D ' /
TTYPE5 = 'FFTS ' /
-------------------------------------------------------------------------------
The **DATA** table contains rows describing each integration obtained during the scan.

The **DMJD** column specifies the center of the integration, as does **UTDSTRT** and **UTCSTRT** (but more accurately to nail down pulsar work). The **PSRPER** gives the actual integration time which can vary from integration to integration in pulsar mode. The **FFTS** and **DELETED** columns contain the number of Fourier transforms used and the number deleted as the result of RFI excision. They are three-dimensional entries with variable size axes between scans, but constant within a scan, i.e., **STATE***PORT*. The structure of these 3 dimensional elements are specified by the keywords **TDIM5** and **TDIM6**. The first dimension always has only one element. The structure of the 3 dimensional element **DATA** is specified by the keyword **TDIM7**. Its dimensions are defined by the keywords:

**CTYPE1** Type of data along the first axis of the **DATA**'s 3 dimensional table element. Normally this FITS keyword entry has the form **CTYPE1** = 'FREQUENCY'.

**CTYPE2** Type of data along the second axis of the 3 dimensional table element. Normally this FITS keyword entry has the form **CTYPE2** = 'STATE'.

**CTYPE3** Type of data along the third axis of the 3 dimensional table element. Normally this FITS keyword entry has the form **CTYPE3** = 'PORT'.

6 SUMMARY

The definition of FITS file keywords and table columns conforms to the standard for the GBT project as a whole.
A  Example FITS file

Examples from each of the three Spectral Processor modes.