VLBA Correlator Memo No. 108

FITS Format for Interferometry Data Interchange

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Abstract

The interface between the VLBA Correlator and the AIPS post-processing software is specified in the form of a FITS format definition. The format uses the "BINTABLE" extension to ~~FITS, rather than~~ the older Random Groups extension. Although the design is motivated by the need to satisfy the requirements of the VLBA, the format has been made sufficiently general that it is capable of being used as an interchange and archiving format for all radio interferometers.

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1 Introduction

This document is intended to define a new FITS format for the interchange of interferometry data. The principal motivation behind this initiative is the advent of the VLBA correlator The NRAO needed to define a distribution and archive format for the data produced by the VLBA correlator, so we thought it appropriate to design an interchange format which would be useful to all interferometers and one that could be written in almost real-time at a correlator or an observatory.

1.1 Why a new FITS format?

The random groups FITS format (Greisen and Harten, 1981) used for the interchange of interferometry data has several deficiencies:

- It is not convenient to use it in 'real-time' systems because the system has to know how big the data file is before writing it to the distribution medium. If an observation is terminated early the file must be padded with zeroes in order not to violate the FITS standards and therefore confuse FITS readers.

- The data are normally written in one huge file which is followed by tables essential for the correct interpretation of the data. This means that a media error anywhere in the file results in the loss of the whole file. Also there is the potential for the loss of the associated tables, due to reaching end-of-medium while writing, or again due to a medium error. This will result in essentially useless data. With the ability of present-day interferometers to write very large volumes of data in a relatively short time this can be a serious problem.

- It is very difficult to write such a format onto multi-volume media. With the expectation that data files are growing rapidly in size this is a serious deficiency. This deficiency may however be overtaken by technological advances since large capacity distribution media are now becoming available (but are they large enough?).

1.2 What should the new FITS format be?

We suggest that interferometry data be written in the form of FITS binary tables (see Cotton and Tody, 1991), using the conventions adopted by the Single Dish FITS agreement of November 1989.

The uv-data itself will be written in the form of a binary table (defined below), with a large database being broken up into smaller, more manageable, time quanta (the VLBA correlator group have chosen $\approx$ 300Mbyte as their quantum). Each of these *uv* binary tables will be accompanied by the associated calibration, flagging, etc. tables for the same timerange. At the beginning of a tape or an observation (and possibly at random points throughout the tape) will be written various time invariant tables (e.g. array geometry, source tables, etc.). Since the tables to be written are, in the language of FITS, extension tables they must be preceeded by a dummy FITS file. We recognize this is a somewhat clumsy construct but we feel that we must abide by the rules of FITS. A FITS reader will recognize this type of file since the NAXIS keyword will have a value of 0, and the EXTEND keyword will be true, indicating the presence of extension files. Our suggestion is that the associated calibration tables are written before the *uv* binary table, this would mean that a logical grouping of associated tables would always end with the *uv* binary table, a construct that can be easily recognized by FITS readers. So the structure of the tape file could look like that shown in Table 1, a dummy (header and history information) random groups FITS file followed by a series of binary tables. Note that in the example structure there is no Flagging table 2. This scenario demonstrates that not all tables need be written with each group, only tables valid for a particular time range need be written. The groups of tables need not be written in chronological order although for practical FITS readers such an order would be preferred. In section 2.8 we discuss under what conditions certain tables **MUST** be present.

An example of a dummy random groups FITS header is (the first two lines of numbers are only present to show character positions and are not part of the table header):

```
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234
SIMPLE  =                    T /
BITPIX  =                    8 /
NAXIS   =                    0 /
EXTEND  =                    T /
BLOCKED =                    T /Tape may be blocked
OBJECT  = 'BINARYTB'
TELESCOP= 'VLBA    '
OBSERVER= 'VB001   '
DATE-OBS= '04/01/94'
DATE-MAP= '25/01/94'
GROUPS  =                    T /
GCOUNT  =                    0 / dummy random group file, zero size
PCOUNT  =                    0 /
```

The advantage of this scheme is that if a media errors occur then only the table in which the error occurred will be lost. The reading program should be able to read through the tape after

Dummy random groups FITS file, header only, defines data file of size zero (see example below). Also contains history information.
Array geometry table
Frequency table
Source table
Flagging table 1
Calibration table 1
Antenna table 1
UV table 1
Calibration table 2
Antenna table 2
UV table 2
Calibration table 3
Antenna table 3
Flagging table 3
UV table 3

Table 1: Structure of the interferometry data file

the error and find the beginning of the next table and resume reading the rest of the data. In section 4 we shall define a protocol for dealing with end-of-media and databases which span more than one volume of a medium.

2 The *uv* binary table

The *uv* binary table contains the raw correlated data and associated random parameters. To correctly interpret the data several tables may also be associated with a *uv* binary table.

There exist a minimum set of random parameters which should always be associated with a visibility point. These are time, baseline number, u, v and w. In addition other random parameters may be present; the random parameters used most often are frequency ID, source ID, data integration time and data weight (if not part of the data matrix). Other random parameters not forseen may also be added, FITS readers must be able to cope with them.

Examination of the *uv* binary table header below shows that the table types for u, v and w have a projection code associated with them. A three character code should normally be associated with the u, v and w table types. The most common codes are shown in Table 32, see Appendix A.

In the sections that follow the "code" column is element_count + basic type code, where basic type codes are

D	$\Rightarrow$	Double precision
E	$\Rightarrow$	single precision
A	$\Rightarrow$	character
J	$\Rightarrow$	long integer
L	$\Rightarrow$	logical
I	$\Rightarrow$	short integer
X	$\Rightarrow$	bit array

If the values of any columns are unavailable then the column should be defined to have zero size in the header information, see Section 3.4.1 for an example.

2.1 Data Weights

When writing the *uv* data there are, in principal, two ways in which the associated weights may be written. First, if the visibility spectrum has a constant weight for all BANDS (see section 2.5 for the definition of a BAND) it can be stored as a single random parameter. However it is more general to assume that at a very minimum the weight will vary from band to band and from polarization to polarization. Therefore the preferred method of storing the weight will be to have one value per polarization and/or band. Therefore the weight random parameter must be a vector of length: number of Stokes parameters $\times$ number of bands. The order in which the values are present in the vector depends on the order in which STOKES and BAND are present in the table header. If STOKES is first then the weights for each STOKES will be stored for BAND 1, followed by the weights for each STOKES for BAND 2 etc.

The second more general method of storing the weights is to associate a weight with each spectral point. In this case the weights should be stored as an additional dimension in the data matrix itself. FITS readers should be able to cope with both situations.

2.2 The table definition

The definition we propose for the *uv* binary table header is given below. These tables will use a restricted subset of the Single Dish conventions. The principle restriction is that the Axis Descriptor columns *must* be virtual. Effectively this means that the structure of the data cube must be constant inside a given table (i.e. same number of frequency channels, polarizations etc.). According to the Single Dish conventions this means that the Axis Descriptors `CTYPE`n, `CRVAL`n, `CRDELT`n, `CRPIX`n and `CRROT`n become header keywords rather than actual entries in the table. Another rule that must be followed is that the COMPLEX axis is the first in the data matrix, other axes can follow in arbitrary order.

In the following example *uv* table header the first two lines of numbers are only present to show character positions and are not part of the table header.

```
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234
XTENSION= 'BINTABLE'           / Visibility data  table
BITPIX  =                    8 / binary data
NAXIS   =                    2 / table is a matrix
NAXIS1  =                16532 / width of table in bytes
NAXIS2  =                  449 / number of entries in table
PCOUNT  =                    0 / random parameter count
GCOUNT  =                    1 / group count
TFIELDS =                   12 / number of columns in each row
EXTNAME = 'UV_DATA'            / Name of table
EXTVER  =                    1 / version number of table
          / Following are the global keywords
NMATRIX = 1                    / No. matrices following UV header
DATE-OBS= '04/01/94'           / observing date as 'dd/mm/yy'
TELESCOP= 'VLBA    '           / telescope used
OBSERVER= 'VB001   '           /
          / The following defines the data matrix columns
MAXIS   = 6                    / no. axes in data matrix.
MAXIS1  = 2                    / dimension of axis 1
CTYPE1  = 'COMPLEX '           / Complex axis
CDELT1  = 1.0                  / complex increment
CRPIX1  = 1.0                  / reference pixel
CRVAL1  = 1.0
MAXIS2  = 4                    / dimension of axis 2
CTYPE2  = 'STOKES  '           / Polarization axis
CDELT2  = -1.0                 / Polarization increment
CRPIX2  = 1.0                  / Polarization reference pixel
CRVAL2  = -1.0                 / RR correlations
MAXIS3  = 128                  / dimension of axis 3
CTYPE3  = 'FREQ    '           / frequency axis
CDELT3  = 1.0E3                / frequency increment
CRPIX3  = 1.0                  / frequency reference pixel
CRVAL3  = 1.4095678E9          / reference frequency of first BAND (Hz)
MAXIS4  = 4                    / dimension of axis 4
CTYPE4  = 'BAND    '           / BAND axis
CDELT4  = 1.0                  / BAND increment
CRPIX4  = 1.0                  / BAND reference pixel
CRVAL4  = 1.0                  / first BAND number
          / For historical reasons axes of dimension 1 are needed to
          / define the position of the source.
MAXIS5  = 1                    /
CTYPE5  = 'RA                  /
CDELT5  = 0.0                  /
CRPIX5  = 1.0                  /
CRVAL5  = 0.0                  /
MAXIS6  = 1                    /
```

```
CTYPE6  = 'DEC     '            /
CDELT6  = 0.0                   /
CRPIX6  = 1.0                   /
CRVAL6  = 0.0                   /
        / The following defines the random parameters
TFORM1  = '1E      '            / u in seconds
TTYPE1  = 'UU-L    '
TUNIT1  = 'SECONDS '
TFORM2  = '1E      '            / v in seconds
TTYPE2  = 'VV-L    '
TUNIT2  = 'SECONDS '
TFORM3  = '1E      '            / w in seconds
TTYPE3  = 'WW-L    '
TUINT3  = 'SECONDS '
TFORM4  = '1D      '            / Julian date at 0h of current
TTYPE4  = 'DATE    '            / day in observation
TUNIT4  = 'DAYS    '
TFORM5  = '1D      '            / UTC time from 0h of current day
TTYPE5  = 'TIME    '            / in observation
TUNIT5  = 'DAYS    '
TFORM6  = '1J      '            / Baseline
TTYPE6  = 'BASELINE'            / Ant1*256 + Ant2
TFORM7  = '1I      '            /
TTYPE7  = 'ARRAY   '            / Array number
TFORM8  = '1I      '            / Source number
TTYPE8  = 'SOURCE_ID  '            / Referenced to SU table
TFORM9  = '1I      '            / Frequency Identifier
TTYPE9  = 'FREQID  '            / Referenced to FQ table
TFORM10 = '1E      '
TTYPE10 = 'INTTIM  '            / Time span of datum (seconds)
TFORM11 = '16E     '            / weights of STOKES and BANDS
TTYPE11 = 'WEIGHT  '            /
        / The following defines the data matrix itself
TFORM12 = '4096E   '            / The data matrix in Jy.
TTYPE12 = 'FLUX    '
TUNIT12 = 'JY      '
TMATX12 = T                     / This is a standard data matrix
        / The following is an optional scaling keyword. If not set it
        / will be assumed to be 1.0
VIS_SCAL=   1.026700000000E-01 / Normalization scaling
        / The following are the global keywords, see Table~\ref{ckwt}
OBSCODE = 'VB001'
NO_STKD =          4
STK_1   =         -1
NO_BAND =          4
NO_CHAN =        128
REF_FREQ=  1.40956780000000000D+09
```

```
CHAN_BW =  1.0E+03
REF_PIXL=  1.0E+00
TABREV  =          1
SORT    = 'TB      '
END                            / blank fill rest of 2880 record
```

Following this are records containing the binary data. In this example the rows will have a structure as follows (data type and count for each item is given in parentheses): u (1E), v (1E), w (1E), date (1D), time (1D), baseline (1J), array (1I), source number (1I), frequency id number (1I), data time span (1E), weight (16E), interferometer data (4096E). Data for one visibility record immediately follows the previous record and may span 2880 byte FITS logical blocks.

The binary table is defined in this way in an attempt to follow closely the bit structure that is typical of random group FITS files, i.e. for continuum data from a single BAND with 4 correlation products the data would look like:

random parameters											RR		LL		RL		LR	
u	v	w	d	t	b	a	s	f	i	wt(4)	R1	I1	R2	I2	R3	I3	R4	I4

2.3 Units

In the example given above the units of the matrix are 'JY', this of course is only valid for calibrated data. This field in the header can in principal be any character string, however we suggest that the units for the output data from an interferometer or correlator be labelled 'UNCALIB'. For data in other wavebands this string should of course contain the appropriate unit.

2.4 Time

The time labels associated with interferometry data are traditionally UTC or IAT times. In order for the FITS reader to determine the time system associated with the data a character string TIMSYS is encoded in the array geometry table as a keyword (Table 6). Several other keywords relating to the time system and polar motion are also recorded in this table. We chose the array geometry table because our rules insist that this table must always be present or the data are regarded as illegal.

2.5 Frequencies and associated parameters

The true frequency of the observations is given by the signed sum of the reference frequency in the *uv* binary table, the BAND frequency offset stored in the frequency table (if present), the peculiar source frequency offset stored in the source table (if present), and the time variable frequency offset stored in the interferometer model table (if present).

There are many occasions in which interferometer data consist of multiple sets of frequency channels. The spacing in frequency in each of the sets may be constant but the frequency

"Stokes" parameter	Value
I	1
Q	2
U	3
V	4
RR[a]	-1
LL	-2
RL	-3
LR	-4
XX[b]	-5
YY	-6
XY	-7
YX	-8

[a]using IEEE circular polarization definition
[b]using X horizontal, Y vertical

Table 2: Stokes-Parameter Type Codes

spacing between the sets may be arbitrary, we shall refer to these sets of frequencies as BANDS. All polarization measurements made using the equally spaced set of frequencies are part of the same BAND. The reference frequency of each of these BANDs is stored in the frequency table as an offset from the "reference frequency" of the whole dataset. The reference frequency of the whole dataset is the reference frequency of the first BAND in the first data record. Examples of BANDS are the A-C and B-D IFs of the VLA and the output of independent video converters in VLBI recorders.

In addition to multiple BANDS, provision is made to allow multiple sets of frequencies and/or bandwidths in the same file. This is by means of the "FREQID" random parameter which indicates which entry in the frequency table applies to that visibility. The structure of all visibilities in a given table (number of spectral channels, BANDs, polarizations etc.) must be the same. The FREQID random parameter allows different sets of "labels", i.e. frequency and bandwidth inside the same table.

2.6 Polarization

A convention must be adopted to describe the Stokes, or polarization, axes. The logical convention which we suggest is tabulated in Table 2.

2.7 Subarrays

It is common, especially in VLBI observations, for a subset of antennas to be observing a different source (or at a different frequency) than other antennas in the same array. This often occurs when observing low declination sources and the source of interest is below the horizon for antennas at the extreme eastern and/or western ends of the array. In this case we define those antennas to be in a different subarray.

We define a subarray to be a subset of a given set of antennas which are observing a different source, or a different frequency, than the principal set. The subarray distinction will not be explicitly carried within the data structure, if a group of antennas are pointing at a different source from the main group, or are observing with a different frequency, then their source id or frequency id numbers will be different from those of the main group of antennas and post-processing software should explicitly recognize this as the presence of a new subarray.

2.8 When should tables be associated with a *uv* table?

In principal a *uv* binary file need only have an array geometry and an antenna characteristics table associated with it; *i.e.* they must always be present. However in practice there will be several different types of table associated with a file. There are certain rules which must be followed when determining what tables should be present:

- if a `SOURCE_ID` random parameter exists then a source table must be present.
- if there is more than one `BAND` in the data matrix then a frequency table must be present.
- if a `FREQID` random parameter exists then a frequency table must be present.

These rules tell a programmer when certain tables *must* be present, however in most cases the *uv* binary tables will be accompanied by a variety of tables which contain important auxiliary information. These are described below. If a table has zero entries then the writing task should not write it, however FITS readers must be able to deal with such cases.

2.9 Irregularly gridded data

There may well be cases in which data from an instrument is not gridded onto a regularly spaced grid; e.g. data from an AOS. In such cases the Single Dish FITS agreement was that such data would be regridded into a regularly spaced frequency grid.

3 The associated tables

We shall now describe the set of general tables that can accompany a UV binary table; in sections that follow we shall describe the suggested format of each table in more detail. The basic set of tables described in the following sections are all that are needed to define a data set from any given array. However some interferometers or correlators will need additional tables, for instance the VLBA requires a table to store the actual CALC model used to generate the interferometer model polynomials. Any interferometer specific tables will be described in appendices.

Keyword	Type	Description
OBSCODE	A	A character string defining an observing code.
NO_STKD	I	The number of polarizations in the data. Must be the same as MAXIS*n*, where n refers to the STOKES axis number in the *uv* binary table.
STK_1	I	The code to describe the first Stokes parameter in the data (Table 2), Must be the same as CRVAL*n*, where *n* refers to the STOKES axis number in the *uv* binary table.
NO_BAND	I	The number of BANDs in the data. Must be the same as MAXIS*n*, where *n* refers to the BAND axis number in the *uv* binary table.
NO_CHAN	I	The number of spectral channels in each BAND. Must be the same as MAXIS*n*, where *n* refers to the FREQ axis number in the *uv* binary table.
REF_FREQ	D	The reference frequency of the *uv* data in Hz. Must be the same as CRVAL*n* in the *uv* binary table. CRVAL*n* is the axis describing the frequency of the data.
CHAN_BW	R	The bandwidth of an individual spectral channel of BAND 1 in Hz. Must be the same as CDELT*n* in the *uv* binary table. CDELT*n* is the axis describing the frequency of the data.
REF_PIXL	R	The pixel (spectral channel) to which the reference frequency refers. Must be the same as CRPIX*n* in the *uv* binary table. CRPIX*n* is the axis describing the frequency of the data.
TABREV	I	The revision number of the table. This will be used in the software to track changes to the table. All tables will start life with a revision number of 1.

Table 3: Standard keywords for all tables

3.1 Keywords common to all associated tables

We require a method by which associated tables can be easily and unambiguously associated with the *uv* binary table. We suggest that this be done by incorporating in each table a standard set of keywords, all of which must be the same for associated tables. The standard keywords are tabulated in Table 3.

3.2 Time invariant tables.

Accompanying each complete observation there may be a set of time-invariant tables which describe various parameters that are constant throughout the observation. The tables that fall into this class are listed in Table 4.

Table name	Description
`Array Geometry table`	contains information such as antenna coordinates
`Frequency table`	contains frequency-like information
`Source table`	contains various types of information about the sources observed.
`Gain curve table`	contains tabulated gain curves for antennas.

Table 4: Time-invariant tables

3.3 Time variant tables

There may also be a set of tables which contain information on various time-variable parameters; tables in this class are listed in Table 5. In addition other tables may be present, such as a table containing the parameters used in the generating the VLBA interferometer model. These tables may well be present on the distribution tape for archival purposes but readers may ignore them if desired.

In all of the time variable tables that follow the first column in the tables is always TIME. This variable refers to the centre of the time interval (units: days) referred to 0^h on the reference day in the appropriate time system (see section 2.4). In this case the reference day is defined as the value of DATE-OBS in the *uv* binary table with which the table is associated for array number 1. It is possible that other "arrays" have different reference days (for example multi-configuration VLA observations), these should be encoded (as the keyword `RDATE`) in the array geometry table header appropriate for each array (see Section 3.4.1).

3.4 Detailed table descriptions

In this, and subsequent sections we shall define the contents of the tables. The structure described will be the logical structure of the tables, for two of them (one time-invariant, the other time-variant) we shall describe in detail the FITS header so programmers can see how the logical structure translates to the interchange format.

Table name	Description
`Interferometer model`	information on the model used to form the interferometer, will vary as a function of time, antenna. May also contain data that varies as a function of time, antenna, BAND, polarization, freq. id.
`Antenna characteristics`	various polarization properties can vary as a function of time or frequency.
`Phase-cal`	A table used to record phase-calibration information.
T_{sys}	A table containing the T_{sys} and T_{ant} measurements.
`Flagging`	generalized flagging information.
`Calibration`	quantities needed to produce calibrated data from the raw *uv* data.
`Weather`	Various weather related parameters.
`Bandpass`	Antenna-based complex bandpass functions.
`Baseline corrections`	Multiplicative or additive corrections to be applied on a baseline-by-baseline basis.
`CALC`	a VLBA specific table, it describes the inputs to CALC that are then used to generated the CALC model table (see Appendix B).
`CALC model`	a VLBA specific table, it describes the CALC model components used to generate the interferometer model (see Appendix C).

Table 5: Time-variant tables

3.4.1 Array Geometry Table

Logical records consist of the information for a single antenna. In the case of an orbiting antenna the elements of the orbit are given. For orbiting antennas the orbital elements are given by ORBPARM.

The FITS EXTNAME will be 'ARRAY_GEOMETRY'. Other keywords in the table header are given in Table 6, and the column labels are specified in Table 7.

Each array should have its own array geometry table, the number of the array should be denoted by the version number (EXTVER) of the table.

The structure of the header record in the FITS binary table would be as follows:

```
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234
XTENSION= 'BINTABLE'           / Extension type
BITPIX  =                    8 / Binary data
NAXIS   =                    2 / Table is a matrix
NAXIS1  =                   64 / Width of table in bytes
NAXIS2  =                    5 / Number of antennas in table
PCOUNT  =                    0 / Random parameter count
GCOUNT  =                    1 / Group count
TFIELDS =                    7 / Number of fields in each row
EXTNAME = 'ARRAY GEOMETRY'     / Table name
EXTVER  =                    1 / Version number of table
TFORM1  = '8A      '           / FORTRAN format of field  1
TTYPE1  = 'ANNAME          '   / Type (heading) of field  1
TUNIT1  = '        '           / Physical units of field  1
TFORM2  = '3D      '           / FORTRAN format of field  2
TTYPE2  = 'STABXYZ         '   / Type (heading) of field  2
TUNIT2  = 'METERS  '           / Physical units of field  2
TFORM3  = '3E      '           / FORTRAN format of field  3
TTYPE3  = 'DERXYZ          '   / Type (heading) of field  3
TUNIT3  = 'METERS/SEC      '   / Physical units of field  3
TFORM4  = '0D      '           / FORTRAN format of field  4
TTYPE4  = 'ORBPARM         '   / Type (heading) of field  4
TUNIT4  = '        '           / Physical units of field  4
TFORM5  = '1I      '           / FORTRAN format of field  5
TTYPE5  = 'NOSTA           '   / Type (heading) of field  5
TUNIT5  = '        '           / Physical units of field  5
TFORM6  = '1I      '           / FORTRAN format of field  6
TTYPE6  = 'MNTSTA          '   / Type (heading) of field  6
TUNIT6  = '        '           / Physical units of field  6
TFORM7  = '1E      '           / FORTRAN format of field  7
TTYPE7  = 'STAXOF          '   / Type (heading) of field  7
TUNIT7  = 'METERS  '           / Physical units of field  7
ARRAYX  =    0.00000000000000000D+00
```

Keyword	Type	Description
ARRAYX	D	Array centre X coord. (meters, earth centre)
ARRAYY	D	Array centre Y coord.
ARRAYZ	D	Array centre Z coord.
ARRNAM	A	Array name
NUMORB	I	Number of orbital parameters
RDATE	A	Reference date for array as 'DD/MM/YY'[a]
FREQ	D	Reference freq. for array (Hz)[b]
FRAME	A	Coordinate frame of reference system (e.g. 'Geocentric')
TIMSYS	A	Time system, 'IAT' or 'UTC'
GSTIA0	D	GST at time[c]=0 (degrees) on ref. date
DEGPDY	D	Earth rotation rate (deg/day)
POLARX	E	Polar position X (meters) on ref. date
POLARY	E	Polar position Y (meters) on ref. date
UT1UTC	E	UT1-UTC (time sec.) on ref. date
IATUTC	E	IAT-UTC (time sec.) on ref. date
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

[a]For array 1 RDATE is the same as DATE-OBS in the *uv* binary table

[b]For array 1, the reference frequency stored in the array geometry table will be the same as the FREQ value in the *uv* binary table.

[c]the time referred to will be either IAT or UTC depending on the value of TIMSYS.

Table 6: Keywords for Array Geometry Table

```
ARRAYY  =   0.00000000000000000D+00
ARRAYZ  =   0.00000000000000000D+00
ARRNAM  = 'VLBA    '
NUMORB  =                  0
RDATE   = '04/01/94'
FREQ    =   1.40956780000000000D+09
FRAME   = 'GEOCENTRIC'
TIMSYS  = 'UTC'
GSTIAO  =   1.25600000000000000D+02
DEGPDY  =   3.60985644973500000D+02
POLARX  =   1.2E+01
POLARY  =   9.4E-01
UT1UTC  =  -2.35E-02
IATUTC  =   2.6E+01
OBSCODE = 'VB001'
NO_STKD =                  4
STK_1   =                 -1
NO_BAND =                  4
NO_CHAN =                128
REF_FREQ=  1.40956780000000000D+09
CHAN_BW =  1.0E+03
REF_PIXL=  1.0E+00
TABREV  =                  1
END
```

The rest of the header block is blank filled. The binary data starts after the next logical record block boundary. The last record of the table data is zero filled past the end of the valid data.

Title	Units	Code	Description
ANNAME		8A	Station name
STABXYZ	meters	3D	X,Y,Z offset from array centre
DERXYZ	meter/s	3E	first-order derivatives of antenna coordinates with respect to the array centre.
ORBPARM		*D	Orbital parameters, an array whose dimension is given by the header keyword NUMORB
NOSTA		1I	Station number
MNTSTA		1I	Mount type: 0 $\Rightarrow$ alt-az 1 $\Rightarrow$ equatorial 2 $\Rightarrow$ "X-Y" 3 $\Rightarrow$ orbiting 4 $\Rightarrow$ bizarre
STAXOF	meters	3E	Axis offset (x, y, z)

Table 7: Column Labels for Array Geometry Table

3.4.2 Frequency Table

The Frequency extension table for a *uv* data set contains relevant information about the BANDs and FREQIDs in the raw *uv* data file. If a Frequency table is present it is possible for a *uv* data file to contain multiple frequency and multiple bandwidth data. The *uv* data can carry a FREQID random parameter, this points to a row in the Frequency table which contains the information needed to define the frequency-like parameters associated with a particular FREQID number. In this particular case the CDELT*n* associated with the frequency axis should be the bandwidth of the spectral channel of the first BAND of the first visibility record.

The FITS EXTNAME will be 'FREQUENCY'. Other keywords in the table header are specified in Table 8, and the column labels are specified in Table 9.

The logical records (table rows) consist of all the frequency-like information for all the BANDs associated with a given FREQID number. There are as many table rows as there are FREQID numbers in the data.

Keyword	Type	Description
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 8: Keywords for frequency table

Title	Units	Code	Description
FREQID		1I	The FREQID number in the *uv* data
BANDFREQ	Hz	*D[a]	Frequency offset from ref. freq. defined in UV binary table: $True = Ref + Offset$
CH_WIDTH	Hz	*R	The bandwidth of an individual frequency (spectral) channel
TOTAL_BANDWIDTH	Hz	*R	The total bandwidth of a BAND, usually is $CHWIDTH \times \#channels$
SIDEBAND		*I	Sideband of each BAND: -1 $\Rightarrow$ 0-baseband-frequency is high frequency end; i.e. frequency decreases with increasing channel number. 1 $\Rightarrow$ 0-baseband-frequency is low frequency end; i.e. frequency increases with increasing channel number

[a] BANDFREQ, CH_WIDTH, TOTAL_BANDWIDTH and SIDEBAND are arrays whose dimensions are given by the header keyword NO_BAND.

Table 9: Column labels for frequency table

Keyword	Type	Description
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 10: Keywords for source table

3.4.3 Source table

Each logical record consists of the position and other information about a source in the raw *uv* data file. Sources are distinguished in the data file by a source ID number (see Section 2.1).

The FITS `EXTNAME` will be `'SOURCE'`. Other keywords in the table header are specified in Table 10, and the column labels are specified in Table 11.

For moving sources the apparent position is for 0^h on the reference day, and in the time system (section 2.4) defined in the array Antenna Geometry file. The motion from this position is given by PMRA and PMDEC.

Note that a source can have the same number, name, qualifier etc., but be present several times in the table each time with a different FREQID. This is to accomodate variables such a IFLUX, SYSVEL etc. which may vary as a function of the FREQID. The FREQID information is not stored as another dimension (c.f. the BAND axis) because one does not normally know the maximum number of FREQIDs in a database before writing the tables. So the file creation program should create another row in the source table whenever it reads a source with a FREQID that it has not read before.

Title	Units	Code	Description
SOURCE_ID		1I	The source identification number.
SOURCE		16A	Name of the source (16 Char).
QUAL		1I	Source qualifier
CALCODE		4A	Calibrator code (4 char)
FREQID		1I	Frequency ID number
IFLUX	Jy	*E[a]	Flux density at reference frequency of this FREQID (Ipol)
QFLUX	Jy	*E	Flux density at reference frequency of this FREQID (Qpol)
UFLUX	Jy	*E	Flux density at reference frequency of this FREQID (Upol)
VFLUX	Jy	*E	Flux density at reference frequency of this FREQID (Vpol)
ALPHA		*E	Spectral index of source per BAND, defined as: $S = S_0\nu^{-\alpha}$
FREQOFF	Hz	*D	Frequency offset from reference + frequency table offset per BAND.
RAEPO	degrees	1D	Right Ascension at standard mean equinox
DECEPO	degrees	1D	Declination at standard mean equinox
EQUINOX		8A	Standard equinox: '1950.0B' 'J2000'
RAAPP	degrees	1D	apparent Right ascension at 0^h IAT on reference day in *uv* file header.
DECAPP	degrees	1D	apparent declination at 0^h IAT on reference day in *uv* file header.
SYSVEL	meter/sec	*D	Systemic velocity at the reference pixel (channel) of each BAND; reference pixel is defined by CRPIX*n* in *uv* binary table.
VELTYP		8A	Velocity type: 'LSR' 'BARYCENT' 'GEOCENTR' 'TOPOCENT'
VELDEF		8A	Velocity definition: 'RADIO' 'OPTICAL'
RESTFREQ	Hz	*D	Line rest frequency
PMRA	deg/day	1D	Proper motion in RA
PMDEC	deg/day	1D	Proper motion in Dec
PARALLAX	arcsec	1E	Parallax of source (if measurable)

[a] All entries with dimensions marked "*" are arrays whose dimension is given by the header keyword NO_BAND.

Table 11: Column labels for source table

Keyword	Type	Description
NO_POL	I	The number of polarizations (R or L) in the table.
NO_TABS	I	The maximum number of tabulated values for an antenna
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 12: Keywords for Gain Curve Table

3.4.4 Gain Curve Table

This table contains tabulated gain curves for antennas. Logical records consist of information for a single antenna.

The FITS `EXTNAME` will be `'GAIN_CURVE'`. Other keywords in the table header are given in Table 12, and the column labels are specified in Table 13.

Title	Units	Code	Description
ANTENNA_NO		1I	Antenna number
ARRAY		1I	Array number
FREQID		1I	Frequency ID number
TYPE_1		*I[a]	Gain curve type: 1 ⇒ tabulated values 2 ⇒ polynomial 3 ⇒ spherical harmonic
NTERM_1		*I[b]	Number of terms or entries in the gain curve array.
X_TYP_1		*I[c]	Gain curve X-absicssa code type: 0 ⇒ none 1 ⇒ elevation (degrees) 2 ⇒ zenith angle (degrees) 3 ⇒ hour angle (degrees) 4 ⇒ declination (degrees) 5 ⇒ 90 - declination (degrees)
Y_TYP_1		*I[d]	Gain curve Y-absicssa code type: 0 ⇒ none 1 ⇒ elevation (degrees) 2 ⇒ zenith angle (degrees) 3 ⇒ hour angle (degrees) 4 ⇒ declination (degrees) 5 ⇒ 90 - declination (degrees)
X_VAL_1		*E[e]	Value of the X abscissa.
Y_VAL_1		*E[f]	Value of the Y abscissa.
GAIN_1		*E[g]	Corresponding values of relative gain (if tabulated); or coefficients of approximating function. Use depends upon the value of TYPE_em n.
SENS_1	K/JY	*E[h]	The point source sensitivity.
Polarization column labels:[i]			
TYPE_2		*I	Gain curve type.
NTERM_2		*I	Number of terms or entries in the gain curve array.
X_TYP_2		*I	Gain curve X-absicssa code type.
Y_TYP_2		*I	Gain curve Y-absicssa code type.
X_VAL_2		*E	Value of the X abscissa.
Y_VAL_2		*E	Value of the Y abscissa.
GAIN_2		*E	Equivalent to GAIN_1.
SENS_2	K/JY	*E	The point source sensitivity.

[a]TYPE_*n* are arrays whose dimensions are given by the header keyword NO_BAND.
[b]NTERM_*n* are arrays whose dimensions are given by the header keyword NO_BAND.
[c]X_TYP_*n* are arrays whose dimensions are given by the header keyword NO_BAND.
[d]Y_TYP_*n* are arrays whose dimensions are given by the header keyword NO_BAND.
[e]X_VAL_*n* are arrays whose dimensions are given by the header keywords NO_BAND.
[f]Y_VAL_*n* are 2-dimensional arrays whose dimensions are given by the header keywords NO_BAND and NO_TABS, the latter number varies more rapidly.

Keyword	Type	Description
NO_POL	I	The number of polarizations (R or L) in the table
NPOLY	I	The order of the polynomials used to form the correlator model, this is the maximum value of the polynomial order. For example, orbiting stations may need more terms than ground stations, programmers must take care to ensure that unused coefficients for stations are set to zero.
REVISION	E	Revision number of software used to generate the correlator model.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 14: Keywords for interferometer model table

3.4.5 Interferometer Model Table

This table contains information about the interferometer model. It will hold the geometric portion of the model as used by the correlators, as well as any dispersive components. The aim is that this table will hold the total geometric observables. In normal astronomical applications the total model is not applied to the data, the residual corrections (held in the calibration table) are the values to be applied to the data.

The FITS `EXTNAME` will be `'INTERFEROMETER_MODEL'`. Other keywords in the table header are specified in Table 14, and the column labels are specified in Table 15. Logical records in this table consist of the information for a single antenna, source, time interval, `FREQID` value and array.

The structure of the header record in the FITS binary table would be as follows:

```
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234
XTENSION= 'BINTABLE'           / FITS Binary Table Extension
BITPIX  =                    8 /
NAXIS   =                    2 /
NAXIS1  =                  336 /
NAXIS2  =                   30 /
PCOUNT  =                    0 /
```

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in the appropriate time system (section 2.4) for this array number.
TIME_INTERVAL	Days	1E	Interval over which polynomials are valid
SOURCE_ID		1J	Identification number of the source used.
ANTENNA_NO		1J	Antenna number.
ARRAY		1J	Array number
FREQID		1J	Freq Id number
I.FAR.ROT	Rad/m**2	1E	Ionospheric Faraday Rotation
FREQ.VAR	Hz	*E[a]	Time variable freq. offset
PDELAY 1	Seconds	*D[b]	The total phase delay at the reference time
GDELAY 1	Seconds	*D[c]	The total group delay at the reference time
PRATE 1	Hz	*D	The phase delay rate, i.e. the time derivative of the phase delay.
GRATE 1	Sec/sec	*D	The group delay rate
DISP 1	Seconds	1E	Dispersive delay for polarization 1. This is the delay in seconds at a wavelength of 1 meter, it scales to other frequencies as the wavelength squared.
DDISP 1	Sec/sec	1E	Dispersive delay rate for polarization 1.'
Column labels for polarization columns:[d]			
PDELAY 2	Seconds	*D	The total phase delay at the reference time
GDELAY 2	Seconds	*D	The total group delay at the reference time
PRATE 2	Hz	*D	The phase delay rate, i.e. the time derivative of the phase delay.
GRATE 2	Sec/sec	*D	The group delay rate
DISP 2	Seconds	1E	Dispersive delay for polarization 2. This is the delay in seconds at a wavelength of 1 meter, it scales to other frequencies as the wavelength squared.
DDISP 2	Sec/sec	1E	Dispersive delay rate for polarization 2.

[a] FREQ.VAR is an array whose dimension is given by the header keyword NO_BAND.

[b] PDELAY*n* and PRATE*n* are polynomials of order NPOLY, there is one polynomial for each band. Therefore the coefficients are stored as arrays whose dimensions are given by the products of the header keywords NO_BAND and NPOLY, within the array the polynomial coefficient number varies most quickly, i.e.TDIMnn = (NPOLY,NO_BAND).

[c] GDELAY*n* and GRATE*n* are polynomials of order NPOLY, the coefficients of which are stored as arrays whose dimensions are given by the header keyword NPOLY.

[d] These columns are present only if NO_POL = 2.

Table 15: Column labels for interferometer model table

```
GCOUNT  =                    1 /
TFIELDS =                   14 /
EXTNAME = 'INTERFEROMETER_MODEL' /
EXTVER  =                    1 /
TTYPE1  = 'TIME    '           / time of centre of model interval
TFORM1  = '1D      '           /
TUNIT1  = 'DAYS    '           /
TTYPE2  = 'TIME_INTERVAL'      / model interval
TFORM2  = '1E      '           /
TUNIT2  = 'DAYS    '           /
TTYPE3  = 'SOURCE_ID'          / source id from sources table
TFORM3  = '1J      '           /
TTYPE4  = 'ANTENNA_NO'         / antenna number from antennas table
TFORM4  = '1J      '           /
TTYPE5  = 'ARRAY   '           / array id number
TFORM5  = '1J      '           /
TTYPE6  = 'FREQID  '           / frequency id number from frequency table
TFORM6  = '1J      '           /
TTYPE7  = 'I.FAR.ROT'          / ionospheric faraday rotation
TFORM7  = '1E      '           /
TUNIT7  = 'RAD/METER**2'       /
TTYPE8  = 'FREQ.VAR'           / time variable freq. offset
TFORM8  = '2E      '           /
TUNIT8  = 'HZ      '           /
TTYPE9  = 'PDELAY_1'           / total phase delay at ref time
TFORM9  = '12D     '           /
TUNIT9  = 'TURNS   '           /
TTYPE10 = 'GDELAY_1'           / total group delay at ref time
TFORM10 = '6D      '           /
TUNIT10 = 'SECONDS '           /
TTYPE11 = 'PRATE_1 '           / phase delay rate
TFORM11 = '12D     '           /
TUNIT11 = 'HZ      '           /
TTYPE12 = 'GRATE_1 '           / group delay rate
TFORM12 = '6D      '           /
TUNIT12 = 'SEC/SEC '           /
TTYPE13 = 'DISP_1  '           / dispersive delay for polar.1
TFORM13 = '1E      '           /
TUNIT13 = 'SECONDS '           /
TTYPE14 = 'DDISP_1 '           / dispersive delay rate for polar. 1
TFORM14 = '1E      '           /
TUNIT14 = 'SEC/SEC '           /
OBSCODE = 'TF007   '           /
RDATE   = '28/12/95'           /
NO_STKD =                    1 /
STK_1   =                   -1 /
NO_BAND =                    2 /
```

```
NO_CHAN =                  256 /
REF_FREQ=   1.66114000000000000E+09 /
CHAN_BW =   3.12500000000000000E+04 /
REF_PIXL=   1.00000000000000000E+00 /
TABREV  =                    2 /
NO_ANT  =                    6 /
NO_POL  =                    1 /
CDATE   = '28/12/95'           /
NPOLY   =                    6 /
REVISION=   1.00000000000000000E+00 /
END
```

Keyword	Type	Description
NOPCAL	I	Number of polarization calibration constants.
POLTYPE	A	Feed polarization parameterization, only if the feed parameters have been entered: 'APPROX ' ⇒ linear approximation 'ORI-ELP ' ⇒ orientation ellipticity 'X-Y LIN ' ⇒ linear approximation for linearly polarized (X-Y) data.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 16: Keywords for antenna characteristics table

3.4.6 Antenna characteristics table

This table contains information about the time or frequency variable polarization characteristics of the antennas.

The FITS EXTNAME will be 'ANTENNA'. Logical records consist of the information for a single antenna and FREQID number over a specified time interval.

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys, for this array number.
TIME_INTERVAL	Days	1E	Interval over which polarization constants apply
ANNAME		8A	Station name
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
FREQID		1I	FREQID for which parameters are determined
NO_LEVELS		1I	NO_LEVELS specifies the number of digitizer levels used in the digitizer, for the VLBA this will be either 2 or 4, for MkII and MKIII terminals this is 2.
POLTYA		1A	Feed A feed poln. Type codes are: 'R' 'L' 'X' 'Y'
POLAA	degrees	*E	Feed A feed position angle.[a]
POLCALA		*E	Feed A poln. cal parameter.[b]
POLTYB		1A	Feed B feed poln. Type codes are: 'R' 'L' 'X' 'Y'
POLAB	degrees	*E	Feed B feed position angle.
POLCALB		*E	Feed B poln. cal parameters.

[a]POLAA and POLAB are arrays whose dimension is given by the header keyword NO_BAND.

[b]POLCALA and POLCALB are arrays whose dimension is given by the header keywords NO_BAND and NOPCAL, with NO_BAND being the most slowly varying element.

Table 17: Column labels for antenna characteristics table

Keyword	Type	Description
NO_POL	I	The number of polarizations (R or L) in the table
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 18: Keywords for system temperature table

3.4.7 System Temperature table

This table contains the measured T_{sys} and/or T_{ant} values for the antennas.

The FITS **EXTNAME** will be **'SYSTEM TEMPERATURE'**. Logical records consist of the information for a single antenna, time interval and FREQID number.

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys, for this array number.
TIME_INTERVAL	Days	1E	Interval over which temperature measurements apply
SOURCE_ID		1I	Identification number of the source used.
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
FREQID		1I	FREQID for which parameters are determined
TSYS_1	Kelvins	*E[a]	On-source system temperature of polarization 1.
TANT_1	Kelvins	*E	On-source antenna temperature of polarization 1.
Polarization column labels:[b]			
TSYS_2	Kelvins	*E	On-source system temperature of polarization 2.
TANT_2	Kelvins	*E	On-source antenna temperature of polarization 2.

[a]TSYS_n and TANT_n are arrays whose dimensions are given by the header keyword NO_BAND.
[b]These columns are present only if NO_POL = 2.

Table 19: Column labels for system temperature table

3.4.8 Calibration table

This table contains information necessary to translate the raw data (in its spectral format) to a calibrated spectrum.

The FITS EXTNAME will be 'CALIBRATION'. Logical records consist of the information for a single antenna, time interval and FREQID number.

Keyword	Type	Description
NO_ANT	I	The number of antennas for which there is information
NO_POL	I	The number of polarizations (R or L) in the table
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 20: Keywords for calibration table

3.4.9 Phase-Cal Table

This table contains information derived from the phase-calibration system attached to an antenna. This information is used to provide calibration between different baseband converters and polarizations.

The FITS EXTNAME will be 'PHASE-CAL'. Logical records consist of the information for a single antenna and time interval. The keywords are shown in Table 22 and the column labels in Table 23

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys, for this array number.
TIME_INTERVAL	Days	1E	Interval over which calibration constants apply
SOURCE_ID		1I	Identification number of the source used.
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
FREQID		1I	FREQID for which parameters are determined
TSYS_1	Kelvins	*E[a]	On-source system temperature of polarization 1.[b]
TANT_1	Kelvins	*E	On-source antenna temperature of polarization 1.
SENSITIVITY_1	K/Jy	*E	Sensitivity of polarization 1.
PHASE_1	Radians	*E	Phase part of complex antenna gain for polarization 1.
RATE_1	Sec/sec	*E	Residual rate of polarization 1
DELAY_1	Seconds	*E	Residual delay of polarization 1. DELAY*n* and RATE*n* are the residual values by which the data are to be corrected during calibration.
REAL_1		*E	Real part of the gain calibration factor[c]
IMAG_1		*E	Imaginary part of the gain calibration.
WEIGHT_1		*E	Weight of polarization 1.
REFANT_1		I	Reference antenna used for solution.
Polarization column labels:[d]			
TSYS_2	Kelvins	*E	On-source system temperature of polarization 2.
TANT_2	Kelvins	*E	On-source antenna temperature of polarization 2.
SENSITIVITY_2	K/Jy	*E	Sensitivity of polarization 2.
PHASE_2	Radians	*E	Phase part of complex antenna gain for polarization 2.
RATE_2	Sec/sec	*E	Residual rate of polarization 2.
DELAY_2	Seconds	*E	Residual delay of polarization 2.
REAL_2		*E	Real part of the gain calibration factor
IMAG_2		*E	Imaginary part of the gain calibration.
WEIGHT_2		*E	Weight of polarization 2.
REFANT_2		I	Reference antenna used for solution.

[a]TSYS_n, TANT_n, SENSITIVITY_n, PHASE_n, RATE_n and DELAY_n, are arrays whose dimensions are given by the header keyword NO_BAND.

[b]This is probably the most general way in which the antenna calibration can be represented. The complex gain calibration factor has been broken up into an easily recognizable phase part and an amplitude portion which is recorded in terms of directly measurable quantities rather than derived quantities. The amplitude portion of the antenna gain calibration factors can be calculated by:

- for those antennas that cannot measure antenna temperature (for the k-th antenna):
  $GA_k = TSYS_k/SENSITIVITY_k$
- for antennas with a measured antenna temperature:
  $GA_k = TSYS_k FLUX/TANT_k$

The visibility functions are then converted into correlated flux densities (jk baseline):
$VIS_{jk,cal} = \sqrt{GA_j GA_k} VIS_{jk,raw}$ This simple formulation ignores such things as correlator b-factors.

[c]The real and imaginary components of the complex gain are carried along in this table for efficiency reasons. These are the values that should normally be applied to the visibilities. At all times these values should be consistent with the values in the TSYSn, SENSITIVITYn, TANTn and PHASEn columns.

[d]These columns are present only if NO_POL = 2.

Keyword	Type	Description
NO_POL	I	The number of polarizations (R or L) in the table
NO_TONES	I	The maximum number of phase-cal tones per band
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 22: Keywords for phase-calibration table

3.4.10 Weather Table

This table contains information on the ambient weather conditions at an antenna. The contents of the weather table should be, if at all possible, measured quantities. However this is probably impossible for some quantities such as the column density of water as derived from Water Vapour Radiometer data, in this case the value in the table should be the desired quantity.

The FITS **EXTNAME** will be **'WEATHER'**. Logical records consist of the information for a single antenna, time interval and source, since some quantities need to be measured in the source direction. The keywords are shown in Table 24 and the column labels in Table 25.

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys, for this array number.
TIME_INTERVAL	Days	1E	Interval over which phase-cal information applies
SOURCE_ID		1I	Identification number of the source used.
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
FREQID		1I	FREQID for which parameters are determined
CABLE_CAL	Seconds	1E	Cable cal.
STATE_1		*E[a]	The four values of the state count, i.e. the percentage of time in the digitizer spends in its lowest, med-low, med-high and highest states respectively.
PC_FREQ 1	Hz	*D[b]	The frequency at which the phase-cal tone was recorded.
PC_REAL 1		*E	Real part of the phase-cal measurement.
PC_IMAG 1		*E	Imaginary part of the phase-cal measurement.
PC_RATE 1	Sec/sec	*E	Phase-cal rate.
Polarization column labels:[c]			
STATE_2		*E	The state count.
PC_FREQ 2	Hz	*D	The frequency at which the phase-cal tone was recorded.
PC_REAL 2		*E	Real part of the phase-cal measurement.
PC_IMAG 2		*E	Imaginary part of the phase-cal measurement.
PC_RATE 2	Sec/sec	*E	Phase-cal rate.

[a]STATE_*n* are 2-dimensional arrays dimensioned by the keyword NO_BAND and the constant 4. The latter number varies more frequently.

[b]PCFREQ*n*, PCREAL*n*, PCIMAG*n*, PCRATE*n* are 2–D arrays dimensioned by the keywords NO_BAND and NO_TONES. The tone number varies more rapidly, i.e. TDIMnn = (NO_TONES, NO_BAND).

[c]These columns are present only if NO_POL = 2.

Table 23: Column labels for phase-calibration table

Keyword	Type	Description
NO_ANT	I	The number of antennas for which there is information
MAPFUNC	A	The version of the mapping function (e.g. 'CFA2.2') used to map water vapour radiometry data from the zenith to the source direction, if relevent.
WVR_TYPE	A	'Z' for zenith estimate of H2O column density, 'S' for source direction estimate.
ION_TYPE	A	'Z' for zenith estimate of TEC, 'S' for source direction estimate.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 24: Keywords for weather table

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day for this array number.
TIME_INTERVAL	Days	1E	Interval over which weather information applies.
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
SOURCE_ID		1I	Identification number of the source used.
TEMPERATURE	Kelvin	1E	Ambient air temperature for an antenna.
PRESSURE	mbars	1E	Ambient atmospheric pressure (not referred to sea-level).
REL_HUMIDITY	%	1E	Ambient relative humidity.
WIND_VELOCITY	meter/sec	1E	Average wind velocity over the time interval.
WIND_DIRECTION	Degrees	1E	Average wind direction, angle increases clockwise, N-to-W
WVR_H2O	m^{-2}	1E	Average column density of water over the time interval and in either the zenith or source direction, depending on the value of WVR_TYPE.
IONOS_ELECTRON	m^{-2}	1E	Average column density of electrons over the time interval and in either the zenith or source direction, depending on the value of ION_TYPE.

Table 25: Column labels for weather table

Keyword	Type	Description
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 26: Keywords for flags table

3.4.11 Flag table

This table will contain information about which data is to be edited. The AIPS model of a flag table has proven successful and so we suggest that it be adopted. The table will contain a list of the data to be flagged.

The FITS **EXTNAME** will be **'FLAG'**. Each logical record consists of a specification of data to be flagged. These specifications are independent and may overlap. Data is to be rejected if it is specified in any flagging record that is currently selected. Any entry may be temporarily disabled by deselecting that table entry. The keywords are shown in Table 26 and the column labels in Table 27.

Title	Units	Code	Description
SOURCE_ID		1I	Source id number of the source to be flagged. 0 means all sources
ARRAY		1I	Array number, 0 means all
ANTS		2I	First element is number of the first antenna, 0 means all baselines to all antennas flagged. Second element is number of the second antenna, 0 means all baselines to ANTS(1) flagged
FREQID		I1	FREQID to be flagged, -1 means all
TIMERANG	Days	2E	Beginning and end time of flagging in the same system as the data is labeled. Both equal 0 means data flagged for all times.
BANDS		2I	Numbers of first and last BAND to be flagged.
CHANS		2I	First and last channel number in BAND.
PFLAGS		4I	Array of flags for the polarizations. 4 are kept even if fewer polarizations are present. Flags in same order as data, bit set means correlator value flagged.
REASON		24A	Reason code for flagging (24 char)
SEVERITY		1I	A severity code for the flagging information, we suggest the following convention: -1 $\Rightarrow$ no severity code set. 0 $\Rightarrow$ data totally useless, i.e. antennas not pointing, tape sync errors etc. 1 $\Rightarrow$ correlator flagged data as suspect, probably should not be used. 2 $\Rightarrow$ possible problem, data may be used.

Table 27: Column labels for flags table

Keyword	Type	Description
NO_ANT	I	The number of antennas for which there is information (actually highest antenna number).
NO_POL	I	The number of polarizations (R or L) in the table
STRT_CHN	I	First channel number present in file, relative to channel 1 of the *uv* data.
NO_BCHN	I	Number of channels in the BP table, not necessarily the same as NO_CHAN.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 28: Keywords for bandpass table

3.4.12 Bandpass table

This table contains information for bandpass calibration; this is frequency channel dependent calibration. The bandpass correction functions should be factored into antenna based components.

The FITS **EXTNAME** will be **'BANDPASS'**. Logical records consist of the information for a single antenna at a given time for all BANDs and polarizations. The keywords are shown in Table 28 and the column labels in Table 29.

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day for this array number.
TIME_INTERVAL	Days	1E	Time interval covered.
SOURCE_ID		1I	Identification number of the source used.
ARRAY		1I	Array number
ANTENNA_NO		1I	Antenna number.
BANDWIDTH	Hz	1E	Bandwidth of individual channels
FREQID		1I	Frequency group id.
BAND_FREQ	Hz	*D	Reference frequency for each BAND
REFANT_1		1I	Reference antenna
BREAL_1		*E[a]	Real part of channel gains for first polarization.
BIMAG_1		*E	Imag. part of channel gains for first polarization.
Polarization column labels:[b]			
REFANT_2		1I	Reference antenna
BREAL_2		*E	Real part of channel gains for second polarization.
BIMAG_2		*E	Imag. part of channel gains for second polarization.

[a]BREAL *n* and BIMAG *n* are arrays whose dimensions are given by the header keywords NO_BAND and NO_BCHN.
[b]These columns are present only if NO_POL = 2.

Table 29: Column labels for bandpass table

3.4.13 Baseline correction table

This table contains information for baseline dependent (antenna pair) calibration. The complex gains for each baseline necessary to correct for non–antenna based errors. These errors are assumed to consist of a multiplicative and an additive portion.

The FITS EXTNAME will be 'BASELINE_CORRECTIONS'. Logical records consist of the information for a single baseline at a given time for all BAND and polarizations. The keywords are shown in Table 30 and the column labels in Table 31.

4 Protocol for dealing with end-of-media and multi-volume media

One of the justifiable criticisms of FITS is that it is very intolerant of media errors. We hope that one of the advantages of the binary tables FITS format is that we can address this criticism by defining a method by which FITS readers can recover from such an error.

4.1 Medium error and premature end of file

A medium error should be regarded as an error condition. When an error condition is detected while reading the FITS reader should:

Keyword	Type	Description
NO_ANT	I	The number of antennas for which there is information (actually highest antenna number).
NO_POL	I	The number of polarizations (R or L) in the table
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 30: Keywords for baseline corrections table

Title	Units	Code	Description
TIME	Days	1E	Time of centre of interval since 0^h on reference day for this array number.
SOURCE_ID		1I	Identification number of the source used.
ARRAY		1I	Array number
ANTENNA_NO		2I	Antenna numbers of baseline
FREQID		1I	Frequency group id.
REAL_M		*E[a]	Real part of multiplicative factor.
IMAG_M		*E	Imag. part of multiplicative factor.
REAL_A		*E	Real part of additive correction.
IMAG_A		*E	Imag. part of additive correction.

[a] REAL_M, IMAG_M, REAL_A and IMAG_A are 2-D arrays whose dimensions are given by the header keywords NO_BAND and NO_STKD, the polarization number varies more rapidly, i.e. TDIMnn = (NO_STKD, NO_BAND).

Table 31: Column labels for baseline corrections table

- save all data read so far;
- look for the next logical record and/or the start of the next extension table by skipping logical blocks;
- if the reader has lost track of where the logical blocks start then it should perform a string search looking for either `'XTENSION= '` or `'SIMPLE ='`.

A premature end of file should also be treated as an error condition. We envision that premature end of file will be a fairly common occurrence, for instance, an observer may start a scan of length 20 minutes then decide after 5 minutes that he wishes to end that scan. The writing program should not then pad the whole table with zeroes but will end the table prematurely by padding to the end of a logical block with zeroes followed by an EOF.

We would hope that FITS writers would have the ability to change the header and modify `NAXIS2` when a file is closed prematurely. This is obviously not practical when writing to a sequential device. However most modern real-time systems have a disk between the correlator/telescope and the FITS writer and so are able to change the headers when necessary.

When a FITS writer encounters a medium error or premature end-of-file then if the associated tables are being written (i.e. all tables other than the *uv* binary table) the table in question should be written into the next file.

4.2 Multi-volume media

Due to the potentially huge size of modern databases it is probable that many databases will have to be split over several volumes of a particular transportation medium. For example, a typical DAT tape approximately 2 Gbytes, a relatively small amount in modern terms (the VLBA correlator will typically write 3 - 5 DAT tapes for a moderate spectral line observation). We must therefore define a protocol for dealing with multi-volume media.

FITS writers should, upon hitting an end of medium, back up to the end of the last logical record, write an end-of-tape mark, then call for another volume. They should then write another dummy random groups UV file, write the time invariant tables, and continue writing the table which was interrupted, after rewriting the header for that table. FITS readers should of course also be able to deal with such circumstances, they should probably deal with an end-of-volume as if it were a premature end-of-file.

Code	Description of Projection
TAN	Tangent projection, also known as "Gnomonic", and referred to as "Standard Coordinates" in optical astrometry. This is the native projective geometry of most optical telescopes.
SIN	Sine projection, also known as "Orthographic". This is the native projective geometry of most radio aperture synthesis telescopes.
ARC	Arc projection. This is the native projective geometry of Schmidt telescopes; it is also commonly used with single-dish radio telescopes.
NCP	"North-Celestial-Pole" projection. The sky is projected onto a plane perpendicular to the North Celestial Pole and Declination is stretched. This is the native projective geometry of East-West aperture synthesis telescopes, such as the Westerbork Synthesis Radio Telescope.
STG	Stereographic projection. This is a tangent projection from the opposite side of the celestial sphere; it conserves small circles. This projection is suitable for medium-wide fields.
AIT	Aitoff-Hammer projection. This is a projection of the *entire* sphere onto an ellipse; it conserves equal areas. It is used for very large fields, generally the whole sphere.
GLS	"GLobal-Sinusoidal" projection. This is a projection of the *entire* sphere onto a "pointed" ellipse; it conserves equal areas. It is used for very large fields, generally the whole sphere.
MER	Mercator projection. This is a projection of the sphere onto a cylinder concentric with the North-South axis; it conserves rhumb lines. It is suitable for medium-wide fields.

Table 32: World-Coordinate System Axis Codes

A World-Coordinate System Axis Codes

Table 32 lists the most common coordinate projection codes used in astronomy.

B VLBA CALC Table

The model used to drive the VLBA correlator is derived from the Goddard CALC software and in order to provide full accountability the model should accompany the VLBA data. This functionality is divided into two tables: the first (this section) contains the input parameters to CALC; the second, the CALC Model Components table (Section C) contains the model components generated by CALC.

The FITS `EXTNAME` will be `'CALC'`. Other keywords in the table header are specified in Table 33, and the column labels are specified in Table 34. Logical records in this table consist of the geometric and other information as a function of time.

Keyword	Type	Description
C_VERSN	A	CALC version used.
ACCELGRV	1E	Acceleration of gravity at the earth's suface.
E-FLAT	1E	Flattening of the earth ellipsoid.
EARTHRAD	1E	The equatorial radius of the Earth (meters).
MMSEMS	1E	Mass of the moon divided by the mass of the earth.
EPHEPOC	I	Ephemeris epoch, J2000.
ETIDELAG	1E	Earth tides: lag angle.
GAUSS	1E	Gaussian gravitational constant.
GMMOON	1E	Moon mass multiplied by Newtonian gravitational constant.
GMSUN	1E	Sun mass multiplied by Newtonian gravitational constant.
LOVE_H	1E	Earth tides: global Love Number H.
LOVE_L	1E	Earth tides: global Love Number L.
PRE_DATA	1E	General precession in longitude, J2000.
REL_DATA	1E	Post newtonian expansion parameter.
TIDALUT1	I	Fortnightly terms in UT1.
TSECAU	1E	Light seconds per astronomical unit.
U-GRV-CN	1E	Newtonian gravitational constant.
VLIGHT	1E	Velocity of light in a vacuum.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 33: Keywords for CALC input table

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys), for this array number.
UT1-UTC	Seconds	1D	Difference between UT1 and UTC.
IAT-UTC	Seconds	1D	Difference between IAT and UTC.
A1-IAT	Seconds	1D	Difference between A1 and IAT.
UT1 TYPE		1A	E=extrapolated, P=preliminary, F=final.
WOBXY	Milliarcsec	2D	X, Y polar offsets.
WOB TYPE		1A	E=extrapolated, P=preliminary, F=final.
DPSI	Radians	1D	Nutation in longitude.
DDPSI	Radians/sec	1D	Derivative of DPSI.
DEPS	Radians	1D	Nutation in obliquity.
DEPS	Radians/sec	1D	Derivative of DEPS.
EARTHPOS	Meters	3D	Solar system barycentric Earth position.
EARTHVEL	Meters/sec	3D	Solar system barycentric Earth velocity.
EARTHACC	Meters/sec**2	3D	Solar system barycentric Earth acceleration.
SUNPOS	Meters	3D	Geocentric solar position, right-handed.
SUNVEL	Meters/sec	3D	Geocentric solar velocity, right-handed.
MOONPOS	Meters	3D	Geocentric lunar position, right-handed.
MOONVEL	Meters/sec	3D	Geocentric lunar position, right-handed.
CALC_FLAGS		100A	CALC + additional software runtime flags.

Table 34: Column labels for the CALC input table

Keyword	Type	Description
NO_POL	I	The number of polarizations (R or L) in the table
FFT_SIZE	I	The number of points in the FFT in the VLBA correlator.
OVERSAMP	I	The oversampling factor, 0 means no oversampling
ZERO_PAD	I	Zero padding factor(?), 0 means no zero-padding.
FFT_TWID	I	Version of FFT twiddle table used. 0 = original twiddle table, 1 = adjusted table (after adjustment no twiddle factor correction required).
TAPER_FN	A	The time series tapeing function used in the correlator. Choices in May 1996 are 'UNIFORM ' or 'HANNING '.
NPOLY	I	The order of the polynomial for GDELAY.
OBSCODE	A	Observing code (Table 3)
NO_STKD	I	Number of polarizations in the data (Table 3)
STK_1	I	The first Stokes parameter in the data (Table 3)
NO_BAND	I	The number of BANDs in the data (Table 3)
NO_CHAN	I	The number of spectral channels in the data (Table 3)
REF_FREQ	D	The reference frequency of the *uv* data (Table 3)
CHAN_BW	R	The bandwidth of an individual spectral channel (Table 3)
REF_PIXL	R	The pixel to which the reference frequency refers (Table 3)
TABREV	I	The table revision number(Table 3)

Table 35: Keywords for CALC model components table

C VLBA CALC Model Components Table

The FITS `EXTNAME` will be `'MODEL_COMPS'`. Other keywords in the table header are specified in Table 35, and the column labels are specified in Table 36. Logical records in this table consist of the information for a single antenna, source, time interval, FREQID value and array.

References

[1] Greisen and Harten, 1981, Astron.Astrophys.Suppl., 44. 371

[2] Cotton and Tody, 1991, 'Binary Table Extension to FITS'

Title	Units	Code	Description
TIME	Days	1D	Time of centre of interval since 0^h on reference day, and in appropriate time system (Section /reftimsys), for this array number.
SOURCE_ID		1I	Identification number of the source used.
ANTENNA_NO		1I	Antenna number.
ARRAY		1I	Array number
FREQID		1I	FREQID for which parameters are determined
ATMOS	Seconds	1E	The atmospheric group delay.
DATMOS	Sec/sec	1E	The atmospheric group delay rate.
GDELAY	Seconds	*D[a]	The geometric delay as produced by CALC.
CLOCK_1	Seconds	1E	The 'clock' delay, i.e. any electronically induced delay for polarization 1.
DCLOCK_1	Sec/sec	1E	The time derivative of the 'clock' delay for polarization 1.
LO_OFFSET_1	Hz	*E[b]	Station and band dependent LO offset.
DLO_OFFSET_1	Hz/sec	*E	Station and band dependent LO offset rate.
DISP 1	Seconds	1E	The dispersive delay for polarization 1. This is the delay in seconds at a wavelength of 1 meter, it scales to other frequencies as the wavelength squared.
DDISP 1	Sec/sec	1E	Dispersive delay rate for polarization 1.
Polarization column labels:[c]			
CLOCK 2	Seconds	1E	The 'clock' delay, i.e. any electonically induced delay for polarization 2.
DCLOCK 2	Sec/sec	1E	The time derivative of the 'clock' delay for polarization 2.
LO_OFFSET_2	Hz	*E	Station and band dependent LO offset.
DLO_OFFSET_2	Hz/sec	*E	Station and band dependent LO offset rate.
DISP 2	Seconds	1E	The dispersive delay for polarization 2. This is the delay in seconds at a wavelength of 1 meter, it scales to other frequencies as the wavelength squared.
DDISP 2	Sec/sec	1E	Dispersive delay rate for polarization 2.

[a] GDELAY is a polynomial array whose dimension is given by NPOLY.

[b] LO_OFFSET_*n* and DLO_OFFSET_*n* are 1-dimensional arrays whose dimensions are given by NO_BAND.

[c] These columns are present only if NO_POL = 2.

Table 36: Column labels for the CALC model table