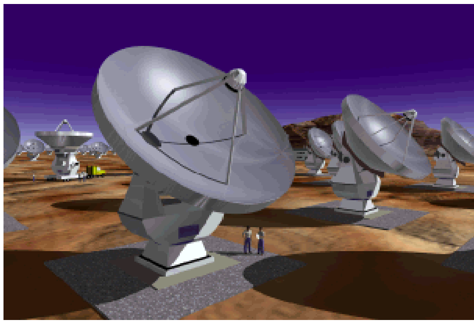

Atacama Large Millimeter Array	ALMA-SW-0015 Revision:1 2001-08-13 *Interface Description* Robert Lucas

ALMA Test Interferometer Raw Data Format

Interface Description

Robert Lucas and Brian Glendenning

Keywords: Data Format, FITS, Test Interferometer

Author Signature: Robert Lucas	Date: 2001-08-13
Approved by: B. Glendenning, K.-Y. Morita, G. Raffi Institute: NRAO, NRO, ESO	Signature: Date:
Released by: Institute:	Signature: Date:

Change Record

Revision	Date	Author	Section/ Page affected	Remarks
1	2001-04-24	Both	All	Initial Version
1	2001-08-13	Both	All	Reviewed Version

`$Id: AlmaTIFormat.tex,v 1.25 2001/08/16 08:04:57 lucas Exp lucas $`

Contents

Abstract

This document describes the FITS raw data format for the ALMA Test Interferometer.

1 Introduction

The goal of this document is to define the raw data format for the ALMA Test Interferometer. This is nevertheless done while keeping in mind that the format might be later extended to be a candidate for the ALMA raw data format.

Another consideration was that the raw data will be converted to be input to Plateau de Bure Calibration software (CLIC, CLASS) to be reused for the Test Interferometer.

2 Some definitions

Extracted from the ALMA Software Glossary:

dump The smallest interval of time for which a set of correlated data can be accumulated and output from the correlator.

integration A set of dumps, all identical in configuration (except for the antenna motion and some others), that is accumulated and forms the basic recorded unit.

observation A set of integrations while the antennas complete an elemental pattern across the source, possibly while frequency switching, nutator switching, etc.

scan A set of observations with a common goal, for example, a pointing scan, a focus scan, or an atmospheric amplitude calibration scan, or a correlation scan on a continuum source or a line source.

For instance in the case of holography measurements an observation would be a drift across the transmitter or a bore-sight measurement, while a scan could be the whole set of observations needed to acquire a beam map. Or a scan could be a pointing scan with two observations (an azimuth drift and an elevation drift across the pointing calibrator) or an atmospheric calibration scan with three observations (autocorrelations on the sky, and two loads at different temperatures, ...).

A scan can be as simple as a short integration on a celestial source while total power and/or correlator output are recorded; or it could be a set of pointed observations that are used together to form a map of an extended celestial source.

3 FITS ALMA-TI File Structure

A FITS ALMA-TI File will include a set of scans recorded during an observing session executed to perform a specific test of the antennas. The file shall contain:

1. One primary header that will identify the file as being of the ALMA-TI file format. The nature of the test can be summarized in comments inserted in the primary header.
2. For each observation, a set of binary tables containing all the observation data and all the header information necessary to describe that data:
   (a) One binary table for data associated parameters `DATAPAR-ALMATI`. This table will contain parameters that vary with time during the data set (except the data itself, contained in `AUTODATA-ALMATI` and/or `CORRDATA-ALMATI`, `HOLODATA-ALMATI` tables). A new `DATAPAR-ALMATI` table is written for each observation. The header contains, as FITS keywords, header parameters that do not depend on time or on antenna.
   (b) One binary table for various monitored parameters `MONITOR-ALMATI`, as described below.
   (c) One binary table for antenna and receiver calibration parameters: `CALIBR-ALMATI`. This table contains calibration parameters that are constant in time during the observation. There is one table row for each antenna.
   (d) Zero or more binary tables for correlation data values: `CORRDATA-ALMATI`. There is at least one such table for each baseband of the correlator. There may be two, e.g. if channel averages of

Table 1: List of ALMATI Binary Tables

EXTNAME	Description	Rows
DATAPAR-ALMATI	Data associated parameters	Time
CALIBR-ALMATI	Antenna parameters	Antenna number
CORRDATA-ALMATI	Correlation Data	Time
AUTODATA-ALMATI	Autocorrelation Data	Time
HOLODATA-ALMATI	Single Dish Holography Data	Time
MONITOR-ALMATI	Monitor Data	Time

the correlations for this baseband are kept separately, with a shorter integration time. Each table row corresponds to an integration point and a particular interferometer baseline.

(e) Zero or more binary tables for autocorrelation data values: `AUTODATA-ALMATI`. There is at least one such table for each baseband of the correlator. There may be two, as for `CORRDATA-ALMATI`. Each table row corresponds to an integration point and a particular antenna of the array.

(f) Zero or mode binary tables for single dish holography data values : `HOLODATA-ALMATI`

The use of binary tables introduces some flexibility by allowing columns to contain arrays. We make use of the "Multidimensional Array" convention in Appendix B of Cotton et al (1995).

All tables have an `TABLEREL` keyword so that table format changes may be recognized by software.

The tables shall preferably be written in the following order: `DATAPAR-ALMATI`, `CALIBR-ALMATI`, `CORRDATA-ALMATI`, `AUTODATA-ALMATI`, `HOLODATA-ALMATI`, `MONITOR-ALMATI`.

The general header and the table headers shall include all keywords needed to conform the the FITS standards; for clarity reasons not all of them are listed here.

All table headers contain the FITS keywords `OBS-NUM` and `SCAN-NUM` and `DATE-OBS`. All tables describing a particular observation have the same `OBS-NUM` and `DATE-OBS` values. All tables describing a particular scan have the same `SCAN-NUM` value.

Header keywords that depend on baseband numbers appear as FITS keywords in the DATA tables. Antenna based parameters that depend on baseband (e.g. due to frequency dependence) should be arrays in the `CALIBR-ALMATI` table (there are no explicit examples here).

4 The Primary header

a

Keyword	Type	Value	Description
NAXIS	I	0	
SIMPLE	L	T	
BITPIX	I	32	
EXTEND	L	T	
TELESCOP	13A	'VTXEIE-ALMATI'	Telescope Name
	13A	'VTX-ALMATI'	Optionnally Added here for
	13A	'EIE-ALMATI'	clarity only ...
	13A	'MSB-ALMATI'	...
ORIGIN	A	'ALMA'	Organisation or Institution
CREATOR	A	'TICSv0.0'	Software (including version)
COMMENT	A	'Generated sample data'	

Notes:

1. `CREATOR` contains the name and version of the software that produced the FITS file.

5 The DATAPAR-ALMATI Binary Table

The DATAPAR-ALMATI binary table contains most header information. Parameters that are valid for the whole observation appear as header keywords, while parameters or arrays that change with time (every data integration) are in table columns. There is a new DATAPAR-ALMATI binary table for each observation. The table has one line per integration point. Each integration point in an observation is referred to by a unique number INTEGNUM which appears in the DATAPAR-ALMATI table and in the data tables.

5.1 DATAPAR-ALMATI Binary Table Header Keywords

name	Type	Units	Value	Description
EXTNAME	A		'DATAPAR-ALMATI'	
TABLEREV	J			Table format revision number
TELESCOP	13A	-	'VTXEIE-ALMATI'	Telescope Name
	13A	-	'VTX-ALMATI'	
	13A	-	'EIE-ALMATI'	
	13A	-	'MSB-ALMATI'	
SCAN-NUM	J	-		Scan number
OBS-NUM	J	-		Observation number
DATE-OBS	A	-		observing date (ISO format) in TIMESYS system
TIMESYS	A	-		time system (TT, TAI, UTC ...)
LST	D	s		Sidereal time (start)
OBSMODE	4A	-		Scan type
PROJID	4A	-		Project ID
AZIMUTH	D	deg		Azimuth at start of observation
ELEVATIO	D	deg		Elevation at start of observation
LATSYS	8A	-		type of latitude-like offsets
LONGSYS	8A	-		type of longitude-like offsets
EXPOSURE	E	s		Total integration time
NO_ANT	J	-	N_{A}	number of antennas
NO_BAND	J	-	N_{BD}	number of base-bands
NO_CHAN	J	-	N_{CH}	Total number of spectral channels
NO_FEED	J		N_{FE}	number of polar. feeds (1/2)
NO_POL	J		N_{PO}	number of polar. products (1/2/4)
NO_SIDE	J		N_{SB}	number of sidebands
NO_PHCOR	J		N_{PHC}	number of different averaging results
NO_CORR	J		N_{CO}	number of correlation tables per baseband
NO_AUTO	J		N_{AU}	number of auto correlation tables per baseband
NO_HOLO	J			number of SingleDish Holography tables (0/1)
VFRAME	D	m/s		radial vel. correction
OBS-LONG	D	deg		observatory longitude
OBS-LAT	D	deg		observatory latitude
OBS-ELEV	E	m		observatory elevation
SOURCE	12A	-		Source name
CALCODE	4A	-		Calibrator Code
RA	1D	deg		Right Ascension at mean Equinox
DEC	1D	deg		Declination at mean Equinox
PMRA	1D	deg		Proper motion in RA
PMDEC	1D	deg		Proper motion in DEC
EQUINOX	1E	y		Equinox
GLON	1D	deg		Galactic Longitude

name	Type	Units	Value	Description
GLAT	1D	deg		Galactic Latitude
ELON	1D	deg		Ecliptic Longitude
ELAT	1D	deg		Ecliptic Latitude
AZIM-FIX	1D	deg		Fixed Azimuth
ELEV-FIX	1D	deg		Fixed Elevation
DISTANCE	1D	AU		Geocentric Distance
CALMODE	12A	-		Calibration mode
UT1UTC	D	s		UT1-UTC
IATUTC	D	s		IAT-UTC
POLARX	D	deg		x coordinate of North Pole
POLARY	D	deg		y coordinate of North Pole
NO_SWITCH	J			num. of switch phases in a switch cycle
FRONTEND	J			Front end number

Notes:

1. LATSYS and LONGSYS describe the meaning of the LATOFF and LONGOFF columns in the table. They take values like 'RA—SIN', 'DEC–SIN', 'AZIM-SIN', 'ELEV-SIN' (we have the goal of following the World Coordinate System (WCS) convention).
2. VFRAME radial projection of $V_{\mathrm{FRAME}} - V_{\mathrm{OBS}}$
3. The source direction is described by *either*:
   - RA, DEC, EQUINOX, PMRA, PMDEC for equatorial system of coordinates.
   - GLON, GLAT, for Galactic (II) coordinates.
   - AZIM-FIX, ELEV-FIX, for coordinates in the local Azimuth, Elevation system (like the holography transmitter).
   - ELON, ELAT, for Ecliptic coordinates

   For moving objects RA and DEC, or ELON and ELAT, shall be listed in optional columns to describe the source motion as used by the control system.
4. Foreseen OBSMODE values:

POIN	Pointing measurement
FOCU	Focus measurement
CALI	Autocorrelation on load
AUTO	Autocorrelation on sky
CORR	Correlation on sky
SKYD	Skydip
HOLO	Holography
ONOF	Total power ON-OFF
FSWI	Frequency switch
...	...

   e.g. for a holography map, the boresight observations have OBSMODE="CORR", while the scanning observations have OBSMODE="HOLO".
5. OBS-LONG, OBS-LAT and OBS-ELEV give the array center coordinates in the geocentric system. They define the origin of the antenna-based baseline vectors for each antenna (STABXYZ in the CALIBR-ALMATI table), of the UUVVWW vectors for each antenna.
6. NO_CHAN is the total number of spectral line channels in all basebands. It is included here, since DATAPAR-ALMATI is the first binary table, as a convenience for FITS reading programs. The number of channels in each data table is specified by the keyword CHANNELS.

7. NO_FEED is the number of polarization feeds used (1 or 2) while NO_POL is the number of polarization products in the correlator data.
8. NO_PHCOR is the number of different averaging results. If 2, then correlation data is averaged with and without applying real-time phase correction prior to averaging; the two results are described by the 4th axis in the CORRELATION-ALMATI table data columns (phase correction is not available with the Test Interferometer).

5.2 DATAPAR-ALMATI Binary Table Columns

name	Type	Units	Description
INTEGNUM	1J	-	Integration point number
INTEGTIM	1E	s	Integration time
MJD	D	day	Observing date/time (Modified Julian Date)
UUVVWW	D(3,$N_{\rm A}$)	s	u,v,w antenna coord. projected on source vector.
AZELERR	E(2,$N_{\rm A}$)	deg	Az,El pointing errors
SOURDIR	D(3,$N_{\rm A}$)	-	Source direction cosines
DELAYGEO	D($N_{\rm A}$)	s	Geometrical Delay
DELAYOFF	D($N_{\rm BD}, N_{\rm A}$)	s	Delay offset
PHASEGEO	D($N_{\rm A}$)	rad	Geometrical Phase
PHASEOFF	D($N_{\rm BD}, N_{\rm A}$)	rad	Phase Offset
RATEGEO	D($N_{\rm A}$)	rad/s	Geometrical Phase Rate
RATEOFF	D($N_{\rm BD}, N_{\rm A}$)	rad/s	Phase Rate Offset
FOCUSOFF	E($N_{\rm A}$)	m	Focus offset
LATOFF	E($N_{\rm A}$)	deg	lat.-like offset
LONGOFF	E($N_{\rm A}$)	deg	long.-like offset
TOTPOWER	E($N_{\rm BD}, N_{\rm A}$)	adu	Total Power in each baseband
WINDSPEE	1E	m/s	Wind speed
WINDDIRE	1E	deg.	Wind direction (E from N)
FLAG	J($N_{\rm PO}, N_{\rm BD}, N_{\rm A}$)	-	Flag words
ISWITCH	4A		ID of phase in switch cycle
WSWITCH	1E		weight of phase in switch cycle
AUTO	L($N_{\rm AU}$)		Integration present in AUTODATA-ALMATI Tables
CORR	L($N_{\rm CO}$)		Integration present in CORRDATA-ALMATI Tables
HOLO	1L		Integration present in HOLODATA-ALMATI Table

Notes:

1. INTEGNUM refers to corresponding integration periods in the data tables.
2. SCAN-NUM and OBS-NUM uniquely identify a given DATAPAR-ALMATI table in the file. OBS-NUM is needed to identify separate observations within a scan; by convention OBS-NUM starts with 1 at the beginning of the data file, and continually increases (it is not reset to 1 at the beginning of each scan). SCAN-NUM sequentially increases with time but may be recycled (e.g. *modulo* 10000 for compatibility with the CLIC reduction program). These two numbers are repeated in the data table headers to avoid confusion.
3. All table columns refer to integration midpoint.
4. LATOFF and LONGOFF give the antenna pointing direction relative to the source direction as defined in the DATAPAR-ALMATI table.
5. SOURDIR gives the phase tracking center direction in the geocentric system of rectangular coordinates (the one used to define the baseline coordinates).

6. DELAYGEO, PHASEGEO, RATEGEO are the geometrical delays, phases, and phase rates computed from astronomy and applied in hardware or software, during the integration period. Note that RATEGEO is physically the same thing as a frequency offset; it adds up to the nominal LO frequencies as specified in the baseband data tables.
7. DELAYOFF, PHASEOFF, RATEOFF are the delay offsets, phase offsets, and phase rate offsets applied in addition to the geometrical values. Note that RATEOFF is physically the same thing as a frequency offset; it adds up to the nominal LO frequencies as specified in the baseband data tables.
8. FLAG is an array of flag 32-bit words, one for each combination: antenna, baseband, polarization product. Each bit is assigned a different meaning (the data is bad when the bit is set to 1):
   - 32: DATA (reserved for data reduction)
   - 31: POINTING (tracking errors too large)
   - 30: TSYS (system noise too high)
   - 29: LOCK (phase-lock loop open)
   - 28: SHADOW (antenna was shadowed)
   - 27: SATURATION (too much signal on detectors)
   - 26: TIME (was wrong)
   - 21-25: free to be assigned if needed.
   - 1-20: reserved
9. AUTO values are set to true if there are corresponding rows in the AUTODATA-ALMATI tables; if there are no such rows, AUTO contain false. For instance, one may have a single baseband, and three AUTODATA-ALMATI tables, one with channel-averaged data, kept every second, the other with the full channel data, with only one integration for the whole observation (60 seconds), the third one with the same 60-second integration time and channel averaged data. In that case there will be 61 rows in DATAPAR-ALMATI:
   - 60 rows corresponding to the 1-second intervals, with the first AUTO value equal to true and the second and third ones to false;
   - 1 row corresponding to the 60 second integration, with the first AUTO value value equal to false and the second and third ones to true.

   The first AUTODATA-ALMATI table (channel averages) will have 60 rows, one for each 1 second interval; the second and third ones will have only 1 row corresponding to the whole observation.
10. CORR values behave exactly in the same way but refer to the CORRDATA-ALMATI tables.
11. HOLO value behaves exactly in the same way but refer to the HOLODATA-ALMATI table (it's foreseen to have only one).
12. CALMODE specifies the atmospheric calibration mode that has been applied in quasi real time (if any). Under different modes, some parameters are actually measured, others are determined from them, e.g. using a model atmosphere. The atmospheric calibration modes for ALMATI and ALMA are TBD.
13. For switched observations using e.g. the nutating subreflector, there are, for each integration period, as many rows (NO_SWITCH) as there are different switch phases in one cycle. All the parameters in each row (including the integration time) refer to the time average of that corresponding phase in all the switch cycles of the integration period. The phase is identified by a number (in column ISWITCH) and by a weight (in column WSWITCH). These columns need not be present is there is no such switching.

6 The MONITOR-ALMATI Binary Table

The MONITOR-ALMATI binary table contains monitor data (sensor readings) measured by the control system. In general monitor data are sampled at rates independent of the integration time, however it is more convenient for data analysis if the monitor points are resampled to be at the same time as the data integrations.

For integer, floating point, and complex monitor points the samples written are linearly interpolated between data measurements available during the observation (if any), and linearly extrapolated after the last available data measurement (in order to avoid any latency in the writing process of up to 5 minutes for the less frequent monitor values).

Logical, character, and bit-pattern data are merely a copy of the latest previously sampled value. Note that a bit-pattern is stored as byte(s), with the unused bits being zero-padded in the most significant byte.

Monitor data which could not be sampled or is otherwise unavailable uses NaN (not a number) for floating point and complex values, and uses the `TNULL` convention for byte or integral values. Missing character string monitor points are represented as ASCII NULL. If this scheme is unsuitable in practice (for example if NaN turns out to be a meaningful value for some sensors) then in a later revision of this document we will introduce a scheme where each monitor column is accompanied by a "validity" column.

The name of the column is the name of the monitor point in the control system, and the type similarly reflects the type of the control point. Monitor points can in principle be scalars as well as (1-dimensional) arrays.

As with the other `-ALMATI` tables, a new monitor table is produced for every observation. Note that the monitor points available can in principle vary from table to table (for example, if equipment is added or removed).

Besides the keywords related to defining the columns of monitor points, the following keywords will also be supplied.

6.1 `MONITOR-ALMATI` Table Header Keywords

name	Type	Units	Value	Description
`EXTNAME`	A		'MONITOR-ALMATI'	
`TABLEREV`	J			Table format revision number
`SCAN-NUM`	J	-		Scan number
`OBS-NUM`	J	-		Observation number
`DATE-OBS`	A	-		observing date (ISO format)

6.2 `MONITOR-ALMATI` Binary Table Columns

name	Type	Units	Description
`INTEGNUM`	1J	-	Integration point number
Monitor Point 1	any	any	First monitor point
...			
Monitor Point n	any	any	Last monitor point

Approximately 1000 monitor points are expected for the full test interferometer, thus the total length of the file may be dominated by monitor data.

7 The `CALIBR-ALMATI` Binary Table

There is one `CALIBR-ALMATI` binary table for every observation. It includes the calibration parameters used / to be used for amplitude calibration of the data in that observation.

7.1 `CALIBR-ALMATI` Binary Table Header Keywords

name	Type	Units	Value	Description
EXTNAME	A		'CALIBR-ALMATI'	
TABLEREV	J			Table format revision number
SCAN-NUM	J	-		Scan number
OBS-NUM	J	-		Observation number
DATE-OBS	A	-		observing date (ISO format)
NO_BAND	J		$N_{\rm BD}$	number of base-bands
NO_FEED	J		$N_{\rm FE}$	number of feeds (1/2)
NO_POL	J		$N_{\rm PO}$	number of pols. products
NO_SIDE	J		$N_{\rm SB}$	number of sidebands
FREQUSRD	E	Hz		[PHC] radiometer signal frequency
FREQUIRD	E	Hz		[PHC] radiometer image frequency

7.2 CALIBR-ALMATI Binary Table Columns

name	Type	Units	Description
ANTENNID	1J	-	Antenna number ID
STATIOID	1J	-	Station number ID
ANTENAME	12A	-	Antenna name
STATNAME	12A	-	Station name
STABXYZ	3D	m	Coordinates
STAXOF	1E	m	Axis offset
POLTY	1A($N_{\rm FE}$)	-	Feed type (X, Y, L, R)
POLA	E($N_{\rm FE}$)	deg	Feed orientation
APEREFF	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Aperture efficiency
BEAMEFF	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Beam efficiency
ETAFSS	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Forward efficiency
ANTGAIN	E($N_{\rm FE}$,$N_{\rm BD}$)	K/Jy	Antenna Gain
HUMIDITY	E	-	rel humidity (0.-1.)
TAMBIENT	E	K	Ambient temperature
PRESSURE	E	Pa	Ambient pressure
THOT	1E($N_{\rm FE}$,$N_{\rm BD}$)	K	Chopper temperature
TCOLD	1E($N_{\rm FE}$,$N_{\rm BD}$)	K	Cold Load temperature
PHOT	E($N_{\rm FE}$,$N_{\rm BD}$)	adu	Total power on Chopper
PCOLD	E($N_{\rm FE}$,$N_{\rm BD}$)	adu	Total power on Cold Load
PSKY	E($N_{\rm FE}$,$N_{\rm BD}$)	adu	Total power on Sky
GAINIMAG	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Gain ratio image/signal
TRX	E($N_{\rm FE}$,$N_{\rm BD}$)	K	Receiver temperature
TSYS	E($N_{\rm FE}$,$N_{\rm BD}$)	K	System temperature
TSYSIMAG	E($N_{\rm FE}$,$N_{\rm BD}$)	K	System temperature (Image)
TAU	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Opacity
TAUIMAG	E($N_{\rm FE}$,$N_{\rm BD}$)	-	Opacity (Image)
TCABIN	1E	K	Receiver Cabin temp.
TDEWAR	1E	K	Receiver Dewar temp.
IA	1E	deg	Pointing Coefficient
CA	1E	deg	Pointing Coefficient
NPAE	1E	deg	Pointing Coefficient
AN	1E	deg	Pointing Coefficient
AW	1E	deg	Pointing Coefficient
IE	1E	deg	Pointing Coefficient
ECEC	1E	deg	Pointing Coefficient

name	Type	Units	Description
IA-R	1E	deg	Pointing Coefficient (receiver)
CA-R	1E	deg	Pointing Coefficient (receiver)
IE-R	1E	deg	Pointing Coefficient (receiver)
ECEC-R	1E	deg	Pointing Coefficient (receiver)
A-OBS	1E	deg	Pointing correction
E-OBS	1E	deg	Pointing correction
REFRACTIO	1E	deg	Refraction correction (current)
PREWATER	E(N_{FE},N_{BD})	m	Precipitable water vapor (meter!)
PREWATRD	1E	m	[PHC] Prec. water vapor from radiometer
ETAFSRD	1E	m	[PHC] Forward efficiency of radiometer
THOTRD	1E	K	[PHC] Chopper temperature of radiometer
TCOLDRD	1E	K	[PHC] Cold Load temperature of radiometer
PHOTRD	1E	adu	[PHC] radiometer power on Chopper
PCOLDRD	1E	adu	[PHC] radiometer power on Cold Load
PSKYRD	1E	adu	[PHC] radiometer power on Sky
TSYSRD	1E	K	[PHC] radiometer system temperature
TRXRD	1E	K	[PHC] radiometer receiver temperature
GAINIMRD	1E	-	[PHC] radiometer Gain ratio image/signal
PATHRD	1E	m	[PHC] water vapor pathlength at (obs. freq)
DPATHRD	1E	m	[PHC] increment per K of radiometric emission
VALIDRD	1L	-	[PHC] validity of radiometric correction

Notes:

1. There is one table row per antenna.
2. Some or all of the parameters (like the system and/or receiver temperatures) vary with frequency across the band. How to take this into account (insert the whole spectrum here, or in each data table?) is still TBD.
3. The pointing coefficients are taken from Mangum (2001, draft)
4. The STABXYZ vectors have their origin at the array center; the direction of Z is parallel to Earth axis towards the North Pole, while X is parallel to the the intersection of the local meridian plane with Earth equatorial plane, oriented away from Earth center, and Y towards East (Thomson et al. “Interferometry and Synthesis in Radio Astronomy”, fig. 4.6, p. 87)
5. Keywords and columns marked [PHC] are referring only to phase correction and are not used for the Test Interferometer.

8 The CORRDATA-ALMATI Binary Table

There is one CORRDATA-ALMATI table for each baseband. As a difference with FITS-IDI, the base-bands have different number of channels.

8.1 CORRDATA-ALMATI Table Header Keywords

name	Type	Units	Value	Description
EXTNAME	A		'CORRDATA-ALMATI'	
TABLEREV	J			Table format revision number
SCAN-NUM	J	-		Scan number
OBS-NUM	J	-		Observation number
DATE-OBS	A	-		observing date (ISO format)

name	Type	Units	Value	Description
NO_POL	J		N_{PO}	number of pol. products
NO_SIDE	J		N_{SB}	number of sidebands
NO_LO	J			number of LOs
BASEBAND	J	-		Baseband number
TABLEID	J	-		Baseband table number
FREQLO1	D	Hz		LO1 Frequency
SIDEBLO1	J	-		side band LO1
FREQLO2	D	Hz		LO2 Frequency
SIDEBLO2	J	-		side band LO2
...	...	...		(as needed)
INTERFRE	D	Hz		Intermediate frequency at ref. channel
FREQRES	R	Hz		Frequency resolution
IFLUX	1E	Jy		I flux
QFLUX	1E	Jy		Q flux
UFLUX	1E	Jy		U flux
VFLUX	1E	Jy		V flux
RESTFRQA	1D	m/s		Rest frequency A
TRANSITA	12A	-		line identifier for A
RESTFRQB	1D	m/s		Rest frequency B
TRANSITB	12A	-		line identifier for B
1CTYP4	8A		'COMPLEX '	Complex axis for col.4 (USB1)
1CRPX4	1E	-	1.0	Ref. pixel
1CRVL4	1E	-	1.0	Value at ref. pixel
11CD4	1E	-	1.0	Increment per pixel
2CTYP4	8A	-	'FREQ-FRQ'	Frequency axis for col.4 (USB1)
2CRPX4	1E	Hz		Ref. channel
2CRVL4	1D	Hz		Observed frequency
22CD4	1E	Hz		Channel Separation
2CUNI4	1E	-	'Hz'	Unit
2CTYP4A	8A	-	'VRAD-FRQ'	Velocity axis for col.4 (USB1)
2CRPX4A	1E	m/s		Ref. channel
2CRVL4A	1D	m/s		Velocity at ref. channel
22CD4A	1E	m/s		Velocity Channel Separation
2CUNI4A	1E	-	'm/s'	Unit
2VSOU4A	1E	m/s		Source Velocity
2SPEC4A	1E	m/s	'LSRK-TOP'	Velocity System
3CTYP4	8A	-	'STOKES'	Stokes axis for col.4 (USB1)
3CRPX4	1E	-	1.0	Ref. pixel
3CRVL4	1E	-	-5.0	Value at ref. pixel
33CD4	1E	-	1.0	Increment per pixel
4CTYP4	8A	-	'PHASCORR'	Phase Corr.axis for col.4 (USB1)
4CRPX4	1E	-	1.0	Ref. pixel
4CRVL4	1E	-	0.0	Value at ref. pixel
44CD4	1E	-	1.0	Increment per pixel
1CTYP5	8A	-	'COMPLEX '	Complex axis for col.5 (LSB1)
1CRPX5	1E	-	1.0	Ref. pixel
1CRVL5	1E	-	1.0	Value at ref. pixel
11CD5	1E	-	1.0	Increment per pixel
2CTYP5	8A	-	'FREQ-FRQ'	Frequency axis for col.5 (LSB1)
2CRPX5	1E	Hz		Ref. channel
2CRVL5	1D	Hz		Observed frequency

name	Type	Units	Value	Description
22CD5	1E	Hz		Channel Separation
2CUNI5	1E	-	'Hz'	Unit
2CTYP5B	8A	-	'VRAD-FRQ'	Velocity axis for col.5 (LSB1)
2CRPX5B	1E	m/s		Ref. channel
2CRVL5B	1D	m/s		Velocity at ref. channel
22CD5B	1E	m/s		Velocity Channel Separation
2CUNI5B	1E	-	'm/s'	Unit
2VSOU5B	1E	m/s		Source Velocity
2SPEC5B	1E	m/s	'LSRK-TOP'	Velocity System
3CTYP5	8A	-	'STOKES'	Stokes axis for col.5 (LSB1)
3CRPX5	1E	-	1.0	Ref. pixel
3CRVL5	1E	-	-5.0	Value at ref. pixel
33CD5	1E	-	-1.0	Increment per pixel
4CTYP5	8A	-	'PHASCORR'	Phase Corr.axis for col.5 (LSB1)
4CRPX5	1E	-	1.0	Ref. pixel
4CRVL5	1E	-	0.0	Value at ref. pixel
44CD5	1E	-	1.0	Increment per pixel

Notes:

1. FREQLO1, FREQLO2, ..., only include the 'constant' part of the LO frequencies, not the 'variable' part that is produced as a result of fringe rotation applied on those LOs by programmable phase rotators. These variable parts are described by columns RATEGEO, RATEOFF in the DATAPAR-ALMATI table.
2. N_{SB} is 2 when phase switching is used to separate sidebands from the same baseband; in all other cases, N_{SB} is 1.
3. SIDEBLO1 identifies which LO1 sideband is present when the other one is rejected with the frequency offset method ($N_{\text{SB}} = 1$).
4. The velocity axes are optional, as well as the corresponding restfrequency/line identifiers couples (RESTFRQA,TRANSITA).
5. IFLUX, QFLUX, UFLUX, VFLUX are optional. They are intended to be present whenever they are used by data reduction programs (e.g. for calibrators).

8.2 CORRDATA-ALMATI Binary Table Columns

name	Type	Units	Description
INTEGNUM	I	-	Integration point number
STARTANT	I	-	Start Antenna
ENDANTEN	I	-	End Antenna
DATAUSB1	E	-	Data for USB of LO1
DATALSB1	E	-	Data for LSB of LO1

Notes:

1. INTEGNUM refers to corresponding integration period in the data parameter table.
2. DATAUSB1 and DATALSB1 columns are both present when phase switching is used to separate sidebands from the same baseband.
3. TDIM for the DATA-USB1 and DATA-LSB1 columns is '(2,N_{CH},N_{PO})'
   (a) The complex axis (dummy coordinate)
   (b) The frequency axis: this is the actual observing frequency (not taking into account fringe rates).

(c) The Stokes axis with the convention:

Value	1	2	3	4	-1	-2	-3	-4	-5	-6	-7	-8
Parameter	I	Q	U	V	RR	LL	RL	LR	XX	YY	XY	YX

(d) An optional fourth axis is described here as an extension to describe data corrected (1.0) and uncorrected (0.0) data using a real-time phase correction system (based on water vapour radiometry. This is not used for the Test Interferometer.

4. The axes for the data arrays are described using the WCS proposal [3].
5. A sample `CORRDATA` header is given in Appendix.
6. Units should be relative correlation (1=100% correlated)

9 The `AUTODATA-ALMATI` Binary Table

There is one `AUTODATA-ALMATI` table for each baseband. The base-bands may have different number of channels (there is only one baseband for the test interferometer).

9.1 `AUTODATA-ALMATI` Binary Table Header Keywords

Name	Type	Units	Value	Description
`EXTNAME`	A		'AUTODATA-ALMATI'	
`TABLEREV`	J			Table format revision number
`NO_POL`	J		N_{PO}	number of pol. products
`SCAN-NUM`	J	-		Scan number
`OBS-NUM`	J	-		Observation number
`DATE-OBS`	A	-		observing date (ISO format)
`BASEBAND`	J	-		Baseband number
`TABLEID`	J	-		Baseband table number
`FREQLO1`	D	Hz		LO1 Frequency
`SIDEBLO1`	J	-		side band LO1
`FREQLO2`	D	Hz		LO2 Frequency
`SIDEBLO2`	J	-		side band LO2
...	...	...		(as needed)
`IF_VAL`	D	-		IF frequency of ref. channels
`FREQRES`	R	-		Frequency resolution
`RESTFRQA`	1D	m/s		Rest frequency A
`TRANSITA`	12A	-		line identifier for A
`RESTFRQB`	1D	m/s		Rest frequency B
`TRANSITB`	12A	-		line identifier for B
`IFLUX`	1E	Jy		I flux
`QFLUX`	1E	Jy		Q flux
`UFLUX`	1E	Jy		U flux
`VFLUX`	1E	Jy		V flux
`1CTYP3`	8A		'FREQ-FRQ'	Frequency axis for col.3
`1CRPX3`	1E	Hz		Ref. channel
`1CRVL3`	1D	Hz		Observed frequency
`11CD3`	1E	Hz		Channel Separation
`1CUNI3`	1E		'Hz'	Unit
`1CTYP3A`	8A		'VRAD-FRQ'	Velocity axis for col.3
`1CRPX3A`	1E	m/s		Ref. channel
`1CRVL3A`	1D	m/s		Velocity at ref. channel

Name	Type	Units	Value	Description
11CD3A	1E	m/s		Velocity Channel Separation
1CUNI3A	1E		'm/s'	Unit
1VSOU3A	1E	m/s		Source Velocity
1SPEC3A	1E	m/s	'LSRK-TOP'	Velocity System
2CTYP3	8A		'STOKES'	Stokes axis for col.3
2CRPX3	1E	-	1.0	Ref. pixel
2CRVL3	1E	-	-5.0	Value at ref. pixel
22CD3	1E	-	-1.0	Increment per pixel

9.2 AUTODATA-ALMATI Binary Table Columns

Name	Type	Units	Description
INTEGNUM	I	-	Integration point number
ANTENNA	I	-	Antenna
DATA	E	-	Data

Notes:

1. INTEGNUM refers to corresponding integration period in the data parameter table.
2. TDIM for the DATA column is '(N_{PO},N_{CH})'
   (a) The frequency axis: this is the actual observing frequency (not taking into account fringe rates).
   (b) The Stokes axis with the convention:

Value	1	2	3	4	-1	-2	-3	-4	-5	-6	-7	-8
Parameter	I	Q	U	V	RR	LL	RL	LR	XX	YY	XY	YX

3. Units: fraction of system temperature

10 The HOLODATA-ALMATI Binary Table

There is one HOLODATA table for each baseband. The base-bands may have different number of channels (there is only one baseband for the test interferometer).

10.1 HOLODATA-ALMATI Binary Table Header Keywords

Name	Type	Units	Value	Description
EXTNAME	A	-	'HOLODATA-ALMATI'	
TABLEREV	J			Table format revision number
SCAN-NUM	J	-		Scan number
OBS-NUM	J	-		Observation number
DATE-OBS	A	-		observing date (ISO format)
BASEBAND	J	-	1	Baseband number
TRANDIST	E	m		transmitter distance
TRANFREQ	D	Hz		transmitter frequency
TRANFOCU	D	m		offset from prime focus

Notes:

1. The DATAPAR-ALMATI table in the same observation shall have NO_ANT=1 and the CALIBR-ALMATI table shall contain the identification of the antenna that is being measured.

10.2 HOLODATA-ALMATI Binary Table Columns

Name	Type	Units	Description
INTEGNUM	I	-	Integration point number
HOLOSS	E	-	Data S*S
HOLORR	E	-	Data R*R
HOLOQQ	E	-	Data Q*Q
HOLOSR	E	-	Data S*R
HOLOSQ	E	-	Data S*Q
HOLOQR	E	-	Data Q*R

Notes:

1. INTEGNUM refers to corresponding integration period in the data parameter table.

A Sample primary header

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                    0 / length of data axis 1
NAXIS2  =                    0 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format defined in Astronomy and
COMMENT   Astrophysics Supplement Series v44/p363, v44/p371, v73/p359, v73/p365.
COMMENT   Contact the NASA Science Office of Standards and Technology for the
COMMENT   FITS Definition document #100 and other FITS information.
COMMENT This file conforms to the ALMA-TestInterferometer standard
COMMENT v1.0, 2001-07-03 see Lucas and Glendenning, 2001
COMMENT http://www.alma.nrao.edu/development/computing/docs/memos/
ORIGIN  = 'ALMA    '           / Organization or Institution
CREATOR = 'CLIC    '           / Program name and version
TELESCOP= '(simulated)'        / Telescope name
END

        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

B Sample DATAPAR-ALMATI table header

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  651 / width of table in bytes
NAXIS2  =                    6 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   20 / number of fields in each row
TTYPE1  = 'INTEGNUM'           / label for field   1
TFORM1  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE2  = 'INTEGTIM'           / label for field   2
TFORM2  = '1E      '           / data format of field: 4-byte REAL
TUNIT2  = 's       '           / physical unit of field
TTYPE3  = 'MJD     '           / label for field   3
TFORM3  = '1D      '           / data format of field: 8-byte DOUBLE
TUNIT3  = 'day     '           / physical unit of field
TTYPE4  = 'UUVVWW  '           / label for field   4
TFORM4  = '12D     '           / data format of field: 8-byte DOUBLE
TUNIT4  = 's       '           / physical unit of field
TTYPE5  = 'AZELERR '           / label for field   5
```

```
TFORM5  = '8E      '           / data format of field: 4-byte REAL
TUNIT5  = 'deg     '           / physical unit of field
TTYPE6  = 'SOURDIR '           / label for field   6
TFORM6  = '12D     '           / data format of field: 8-byte DOUBLE
TTYPE7  = 'DELAYGEO'           / label for field   7
TFORM7  = '4D      '           / data format of field: 8-byte DOUBLE
TUNIT7  = 's       '           / physical unit of field
TTYPE8  = 'DELAYOFF'           / label for field   8
TFORM8  = '8D      '           / data format of field: 8-byte DOUBLE
TUNIT8  = 's       '           / physical unit of field
TTYPE9  = 'PHASEGEO'           / label for field   9
TFORM9  = '4D      '           / data format of field: 8-byte DOUBLE
TUNIT9  = 'rad     '           / physical unit of field
TTYPE10 = 'PHASEOFF'           / label for field  10
TFORM10 = '8D      '           / data format of field: 8-byte DOUBLE
TUNIT10 = 'rad     '           / physical unit of field
TTYPE11 = 'RATEGEO '           / label for field  11
TFORM11 = '4D      '           / data format of field: 8-byte DOUBLE
TUNIT11 = 'rad/s   '           / physical unit of field
TTYPE12 = 'RATEOFF '           / label for field  12
TFORM12 = '8D      '           / data format of field: 8-byte DOUBLE
TUNIT12 = 'rad/s   '           / physical unit of field
TTYPE13 = 'FOCUSOFF'           / label for field  13
TFORM13 = '4E      '           / data format of field: 4-byte REAL
TUNIT13 = 'm       '           / physical unit of field
TTYPE14 = 'LATOFF  '           / label for field  14
TFORM14 = '4E      '           / data format of field: 4-byte REAL
TUNIT14 = 'deg     '           / physical unit of field
TTYPE15 = 'LONGOFF '           / label for field  15
TFORM15 = '4E      '           / data format of field: 4-byte REAL
TUNIT15 = 'deg     '           / physical unit of field
TTYPE16 = 'TOTPOWER'           / label for field  16
TFORM16 = '8E      '           / data format of field: 4-byte REAL
TUNIT16 = 'adu     '           / physical unit of field
TTYPE17 = 'WINDSPEE'           / label for field  17
TFORM17 = '1E      '           / data format of field: 4-byte REAL
TUNIT17 = 'm/s     '           / physical unit of field
TTYPE18 = 'WINDDIRE'           / label for field  18
TFORM18 = '1E      '           / data format of field: 4-byte REAL
TUNIT18 = 'deg     '           / physical unit of field
TTYPE19 = 'FLAG    '           / label for field  19
TFORM19 = '8J      '           / data format of field: 4-byte INTEGER
TTYPE20 = 'AUTO    '           / label for field  20
TFORM20 = '3L      '           / data format of field: 1-byte LOGICAL
EXTNAME = 'DATAPAR-ALMATI'     / name of this binary table extension
TDIM4   = '(3,4)   '           / size of the multidimensional array
TDIM6   = '(3,4)   '           / size of the multidimensional array
TDIM5   = '(2,4)   '           / size of the multidimensional array
TDIM8   = '(2,4)   '           / size of the multidimensional array
TDIM10  = '(2,4)   '           / size of the multidimensional array
TDIM12  = '(2,4)   '           / size of the multidimensional array
TDIM16  = '(2,4)   '           / size of the multidimensional array
```

```
TDIM19  = '(1,2,4) '           / size of the multidimensional array
TABLEREV= 'v1.0 2001-07-03'    / DATAPAR-ALMATI   release
TELESCOP= '(simulated)'        / Telescope name
SCAN-NUM=                 2380 / Scan number
OBS-NUM =                 1315 / Observation number
DATE-OBS= '1999-12-02T11:03:07.499' / Date
TIMESYS = 'UTC     '           / Time system
LST     =  5.8203903775313E+04 / Sidereal time (start)
OBSMODE = 'CALI    '           / Scan type
PROJID  = 'JA56    '           / Project ID
AZIMUTH = -1.0945473084575E+02 / Azimuth (degrees)
ELEVATIO=  4.2869955533152E+01 / Elevation (degrees)
LATSYS  = 'ELON-SIN'           / type of latitude-like offsets
LONGSYS = 'ELAT-SIN'           / type of longitude-like offsets
EXPOSURE=       5.00000000E+00 / Total integration time (s)
NO_ANT  =                    4 / Number of antennas
NO_BAND =                    2 / Number of basebands
NO_CHAN =                  128 / Total number of channels
NO_POL  =                    1 / Number of pols.
NO_FEED =                    1 / Number of feeds.
NO_SIDE =                    2 / Number of side bands
VFRAME  =  2.8960006181090E+04 / radial vel. corr. (m/s)
NO_PHCOR=                    0 / Number of phase corr. data
NO_CORR =                    0 / Number of CORRDATA Tables per baseband
NO_AUTO =                    3 / Number of AUTODATA Tables per baseband
NO_HOLO =                    0 / Number of HOLODATA Tables per baseband
OBS-LAT =  4.4633890000000E+01 / Observatory Latitude (degrees)
OBS-LONG=  5.9079167000000E+00 / Observatory Latitude (degrees)
OBS-ELEV=       2.56000000E+03 / Observatory Elevation (m)
SOURCE  = 'MWC349  '           / Source Name
CALCODE = 'PHAS    '           / Calibrator code
RADESYS = 'FK4     '           / Equatorial Coordinate system
RA      =  3.0773687500000E+02 / RA at mean equinox (deg.)
DEC     =  4.0488972222222E+01 / DEC at mean equinox (deg.)
PMRA    =  0.0000000000000E+00 / RA P.motion at mean equinox (deg.)
PMDEC   =  0.0000000000000E+00 / DEC P.motion at mean equinox (deg.)
EQUINOX =       1.95000000E+03 / Mean Equinox
VELTYP  = 'VELO-EAR'           / Velocity type
UT1UTC  =  0.0000000000000E+00 / UT1-UTC
IATUTC  =  0.0000000000000E+00 / IAT-UTC
POLARX  =  0.0000000000000E+00 / x coordinate of North Pole
POLARY  =  0.0000000000000E+00 / x coordinate of North Pole
END

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

C Sample CALIBR-ALMATI table header

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                  234 / width of table in bytes
NAXIS2  =                    4 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                   40 / number of fields in each row
TTYPE1  = 'ANTENNID'           / label for field   1
TFORM1  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE2  = 'STATIOID'           / label for field   2
TFORM2  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE3  = 'STABXYZ '           / label for field   3
TFORM3  = '3D      '           / data format of field: 8-byte DOUBLE
TUNIT3  = 'm       '           / physical unit of field
TTYPE4  = 'STAXOF  '           / label for field   4
TFORM4  = '1E      '           / data format of field: 4-byte REAL
TUNIT4  = 'm       '           / physical unit of field
TTYPE5  = 'POLTY   '           / label for field   5
TFORM5  = '1A      '           / data format of field: ASCII Character
TTYPE6  = 'POLA    '           / label for field   6
TFORM6  = '1E      '           / data format of field: 4-byte REAL
TUNIT6  = 'degr.   '           / physical unit of field
TTYPE7  = 'APEREFF '           / label for field   7
TFORM7  = '2E      '           / data format of field: 4-byte REAL
TTYPE8  = 'BEAMEFF '           / label for field   8
TFORM8  = '2E      '           / data format of field: 4-byte REAL
TTYPE9  = 'ETAFSS  '           / label for field   9
TFORM9  = '2E      '           / data format of field: 4-byte REAL
TTYPE10 = 'ANTGAIN '           / label for field  10
TFORM10 = '2E      '           / data format of field: 4-byte REAL
TUNIT10 = 'K/Jy    '           / physical unit of field
TTYPE11 = 'HUMIDITY'           / label for field  11
TFORM11 = '1E      '           / data format of field: 4-byte REAL
TTYPE12 = 'TAMBIENT'           / label for field  12
TFORM12 = '1E      '           / data format of field: 4-byte REAL
TUNIT12 = 'K       '           / physical unit of field
TTYPE13 = 'PRESSURE'           / label for field  13
TFORM13 = '1E      '           / data format of field: 4-byte REAL
TUNIT13 = 'hPa     '           / physical unit of field
TTYPE14 = 'THOT    '           / label for field  14
TFORM14 = '2E      '           / data format of field: 4-byte REAL
TUNIT14 = 'L       '           / physical unit of field
TTYPE15 = 'TCOLD   '           / label for field  15
TFORM15 = '2E      '           / data format of field: 4-byte REAL
TUNIT15 = 'K       '           / physical unit of field
TTYPE16 = 'PHOT    '           / label for field  16
TFORM16 = '2E      '           / data format of field: 4-byte REAL
TUNIT16 = 'adu     '           / physical unit of field
TTYPE17 = 'PCOLD   '           / label for field  17
TFORM17 = '2E      '           / data format of field: 4-byte REAL
```

```
TUNIT17 = 'adu     '           / physical unit of field
TTYPE18 = 'PSKY    '           / label for field  18
TFORM18 = '2E      '           / data format of field: 4-byte REAL
TUNIT18 = 'adu     '           / physical unit of field
TTYPE19 = 'GAINIMAG'           / label for field  19
TFORM19 = '2E      '           / data format of field: 4-byte REAL
TTYPE20 = 'TRX     '           / label for field  20
TFORM20 = '2E      '           / data format of field: 4-byte REAL
TUNIT20 = 'K       '           / physical unit of field
TTYPE21 = 'TSYS    '           / label for field  21
TFORM21 = '2E      '           / data format of field: 4-byte REAL
TUNIT21 = 'K       '           / physical unit of field
TTYPE22 = 'TSYSIMAG'           / label for field  22
TFORM22 = '2E      '           / data format of field: 4-byte REAL
TUNIT22 = 'K       '           / physical unit of field
TTYPE23 = 'TAU     '           / label for field  23
TFORM23 = '2E      '           / data format of field: 4-byte REAL
TTYPE24 = 'TAUIMAG '           / label for field  24
TFORM24 = '2E      '           / data format of field: 4-byte REAL
TTYPE25 = 'TCABIN  '           / label for field  25
TFORM25 = '1E      '           / data format of field: 4-byte REAL
TUNIT25 = 'K       '           / physical unit of field
TTYPE26 = 'TDEWAR  '           / label for field  26
TFORM26 = '1E      '           / data format of field: 4-byte REAL
TUNIT26 = 'K       '           / physical unit of field
TTYPE27 = 'PREWATER'           / label for field  27
TFORM27 = '1E      '           / data format of field: 4-byte REAL
TUNIT27 = 'm       '           / physical unit of field
TTYPE28 = 'PREWATRD'           / label for field  28
TFORM28 = '1E      '           / data format of field: 4-byte REAL
TUNIT28 = 'm       '           / physical unit of field
TTYPE29 = 'ETAFSRD '           / label for field  29
TFORM29 = '1E      '           / data format of field: 4-byte REAL
TTYPE30 = 'THOTRD  '           / label for field  30
TFORM30 = '1E      '           / data format of field: 4-byte REAL
TUNIT30 = 'K       '           / physical unit of field
TTYPE31 = 'TCOLDRD '           / label for field  31
TFORM31 = '1E      '           / data format of field: 4-byte REAL
TUNIT31 = 'K       '           / physical unit of field
TTYPE32 = 'PHOTRD  '           / label for field  32
TFORM32 = '1E      '           / data format of field: 4-byte REAL
TUNIT32 = 'adu     '           / physical unit of field
TTYPE33 = 'PCOLDRD '           / label for field  33
TFORM33 = '1E      '           / data format of field: 4-byte REAL
TUNIT33 = 'adu     '           / physical unit of field
TTYPE34 = 'PSKYRD  '           / label for field  34
TFORM34 = '1E      '           / data format of field: 4-byte REAL
TUNIT34 = 'adu     '           / physical unit of field
TTYPE35 = 'TSYSRD  '           / label for field  35
TFORM35 = '1E      '           / data format of field: 4-byte REAL
TUNIT35 = 'K       '           / physical unit of field
TTYPE36 = 'TRXRD   '           / label for field  36
```

```
TFORM36 = '1E      '            / data format of field: 4-byte REAL
TUNIT36 = 'K       '            / physical unit of field
TTYPE37 = 'GAINIMRD'            / label for field  37
TFORM37 = '1E      '            / data format of field: 4-byte REAL
TTYPE38 = 'PATHRD  '            / label for field  38
TFORM38 = '1E      '            / data format of field: 4-byte REAL
TUNIT38 = 'm       '            / physical unit of field
TTYPE39 = 'DPATHRD '            / label for field  39
TFORM39 = '1E      '            / data format of field: 4-byte REAL
TUNIT39 = 'm       '            / physical unit of field
TTYPE40 = 'VALIDRD '            / label for field  40
TFORM40 = '1L      '            / data format of field: 1-byte LOGICAL
EXTNAME = 'CALIBR-ALMATI'       / name of this binary table extension
TDIM7   = '(1,2)   '            / size of the multidimensional array
TDIM8   = '(1,2)   '            / size of the multidimensional array
TDIM9   = '(1,2)   '            / size of the multidimensional array
TDIM10  = '(1,2)   '            / size of the multidimensional array
TDIM14  = '(1,2)   '            / size of the multidimensional array
TDIM15  = '(1,2)   '            / size of the multidimensional array
TDIM16  = '(1,2)   '            / size of the multidimensional array
TDIM17  = '(1,2)   '            / size of the multidimensional array
TDIM18  = '(1,2)   '            / size of the multidimensional array
TDIM19  = '(1,2)   '            / size of the multidimensional array
TDIM20  = '(1,2)   '            / size of the multidimensional array
TDIM21  = '(1,2)   '            / size of the multidimensional array
TDIM22  = '(1,2)   '            / size of the multidimensional array
TDIM23  = '(1,2)   '            / size of the multidimensional array
TDIM24  = '(1,2)   '            / size of the multidimensional array
TABLEREV= 'v1.0 2001-07-03'     / CALIBR-ALMATI    release
NO_ANT  =                    4 / Number of Antennas
SCAN-NUM=                 2380 / Scan number
OBS-NUM =                 1315 / Observation number
DATE-OBS= '1999-12-02T11:03:07.499' / Date
NO_BAND =                    2 / Number of basebands
NO_POL  =                    1 / Number of polar. products
NO_FEED =                    1 / Number of feeds.
FREQUSRD=       2.14884467E+11 / Radiometer Signal Frequency
FREQUSRI=       2.17976226E+11 / Radiometer Image  Frequency
END

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

D Sample CORRDATA-ALMATI table header

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

XTENSION= 'BINTABLE'            / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
```

```
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                  360 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    5 / number of fields in each row
TTYPE1  = 'INTEGNUM'           / label for field   1
TFORM1  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE2  = 'STARTANT'           / label for field   2
TFORM2  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE3  = 'ENDANT  '           / label for field   3
TFORM3  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE4  = 'DATAUSB1'           / label for field   4
TFORM4  = '2E      '           / data format of field: 4-byte REAL
TTYPE5  = 'DATALSB1'           / label for field   5
TFORM5  = '2E      '           / data format of field: 4-byte REAL
EXTNAME = 'CORRDATA-ALMATI'    / name of this binary table extension
TDIM4   = '(2,1,1) '           / size of the multidimensional array
TDIM5   = '(2,1,1) '           / size of the multidimensional array
TABLEREV= 'v1.0 2001-07-03'    / CORRDATA-ALMATI  release
SCAN-NUM=                 2384 / Scan number
OBS-NUM =                 1325 / Observation number
DATE-OBS= '1999-12-02T11:07:32.000' / Date
NO_POL  =                    1 / Number of pols.
NO_SIDE =                    2 / Number of side bands
NO_LO   =                    2 / Number of LO's
NO_PHCOR=                    2 / Number of phase corr. data
CHANNELS=                    1 / number of channels in baseband
BASEBAND=                    1 / Baseband number
TABLEID =                    1 / Baseband table number
TRANSITA= 'CO(1-0) '           / Line Transition A
RESTFREA=  1.0743390000000E+11 / Rest  Freq. A (Hz) at reference channel
TRANSITB= 'CO(1-0) '           / Line Transition B
RESTFREB=  1.0743390000000E+11 / Rest  Freq. B (Hz) at reference channel
INTERFRE=  2.8000000000000E+08 / Intermediate Freq. (Hz) at reference channel
FREQLO1 =  1.0593748708538E+11 / Local Oscillator 1
SIDEBLO1=                    1 / Side Band LO 1
FREQLO2 =  1.8567962909567E+09 / Local Oscillator 2
SIDEBLO2=                   -1 / Side Band LO 2
IFLUX   =       8.97073328E-01 / Flux in I (Jy)
1CTYP4  = 'COMPLEX '           / Complex axis
1CRPX4  =       1.00000000E+00
1CRVL4  =       1.00000000E+00
11CD4   =       1.00000000E+00
2CTYP4  = 'FREQ-FRQ'           / Observed Frequency axis
2CRPX4  =       1.00000000E+00 / reference pixel
2CRVL4  =  1.0751428337633E+11 / Observed Freq.(Hz) at ref. pixel in Hz
22CD4   =      -1.52000000E+08 / Channel separation in Hz
3CTYP4  = 'STOKES  '           / Stokes axis
3CRPX4  =       1.00000000E+00
3CRVL4  =      -5.00000000E+00
33CD4   =      -1.00000000E+00
1CTYP5  = 'COMPLEX '           / Complex axis
```

```
1CRPX5  =       1.00000000E+00
1CRVL5  =       1.00000000E+00
11CD5   =       1.00000000E+00
2CTYP5  = 'FREQ-FRQ'           / Observed Frequency axis
2CRPX5  =       1.00000000E+00 / reference pixel
2CRVL5  =  1.0436069079442E+11 / Observed Freq.(Hz) at ref. pixel in Hz
22CD5   =       1.52000000E+08 / Channel separation in Hz
3CTYP5  = 'STOKES  '           / Stokes axis
3CRPX5  =       1.00000000E+00
3CRVL5  =      -5.00000000E+00
33CD5   =      -1.00000000E+00
END

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

E Sample AUTODATA-ALMATI table header

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   12 / width of table in bytes
NAXIS2  =                   20 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    3 / number of fields in each row
TTYPE1  = 'INTEGNUM'           / label for field   1
TFORM1  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE2  = 'ANTENNA '           / label for field   2
TFORM2  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE3  = 'DATA    '           / label for field   3
TFORM3  = '1E      '           / data format of field: 4-byte REAL
EXTNAME = 'AUTODATA-ALMATI'    / name of this binary table extension
TDIM3   = '(1,1)   '           / size of the multidimensional array
TABLEREV= 'v1.0 2001-07-03'    / AUTODATA-ALMATI  release
SCAN-NUM=                 2380 / Scan number
OBS-NUM =                 1315 / Observation number
DATE-OBS= '1999-12-02T11:03:07.499' / Date
NO_POL  =                    1 / Number of pols.
NO_SIDE =                    2 / Number of side bands
NO_LO   =                    2 / Number of LO's
NO_PHCOR=                    0 / Number of phase corr. data
CHANNELS=                    1 / number of channels in baseband
BASEBAND=                    1 / Baseband number
TABLEID =                    1 / Baseband table number
TRANSITA= 'CO(1-0) '           / Line Transition A
RESTFREA=  1.0743390000000E+11 / Rest  Freq. A (Hz) at reference channel
TRANSITB= 'CO(1-0) '           / Line Transition B
RESTFREB=  1.0743390000000E+11 / Rest  Freq. B (Hz) at reference channel
INTERFRE=  2.8000000000000E+08 / Intermediate Freq. (Hz) at reference channel
FREQLO1 =  1.0593748708538E+11 / Local Oscillator 1
SIDEBLO1=                    1 / Side Band LO 1
FREQLO2 =  1.8567962909567E+09 / Local Oscillator 2
SIDEBLO2=                   -1 / Side Band LO 2
IFLUX   =       1.00000000E+00 / Flux in I (Jy)
1CTYP3  = 'FREQ-FRQ'           / Observed Frequency axis
1CRPX3  =       1.00000000E+00 / reference pixel
1CRVL3  =  1.0751428337633E+11 / Observed Freq.(Hz) at ref. pixel in Hz
11CD3   =      -1.52000000E+08 / Channel separation in Hz
2CTYP3  = 'STOKES  '           / Stokes axis
2CRPX3  =       1.00000000E+00
2CRVL3  =      -5.00000000E+00
22CD3   =      -1.00000000E+00
END
```

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

F Sample HOLODATA-ALMATI table header

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   28 / width of table in bytes
NAXIS2  =                   32 / number of rows in table
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    7 / number of fields in each row
TTYPE1  = 'INTEGNUM'           / label for field   1
TFORM1  = '1J      '           / data format of field: 4-byte INTEGER
TTYPE2  = 'HOLOSS  '           / label for field   2
TFORM2  = '1E      '           / data format of field: 4-byte REAL
TTYPE3  = 'HOLORR  '           / label for field   3
TFORM3  = '1E      '           / data format of field: 4-byte REAL
TTYPE4  = 'HOLOQQ  '           / label for field   4
TFORM4  = '1E      '           / data format of field: 4-byte REAL
TTYPE5  = 'HOLOSR  '           / label for field   5
TFORM5  = '1E      '           / data format of field: 4-byte REAL
TTYPE6  = 'HOLOSQ  '           / label for field   6
TFORM6  = '1E      '           / data format of field: 4-byte REAL
TTYPE7  = 'HOLOQR  '           / label for field   7
TFORM7  = '1E      '           / data format of field: 4-byte REAL
EXTNAME = 'HOLODATA-ALMATI'    / name of this binary table extension
TABLEREV= 'v1.0 2001-07-03'    / HOLODATA-ALMATI  release
SCAN-NUM=                 8713 / Scan number
OBS-NUM =                   93 / Observation number
DATE-OBS= '2000-06-23T22:49:31.999' / Date
NO_POL  =                    1 / Number of pols.
CHANNELS=                    1 / number of channels in baseband
BASEBAND=                    1 / Baseband number
TABLEID =                    1 / Baseband table number
TRANDIST=       3.00000000E+02 / Transmitter Distance (m)
TRANFREQ=  8.6243000000000E+10 / Transmitter Frequency (Hz)
TRANFOCU=       1.01230003E-01 / Focus Offset (m)
END

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

G References

References

[1] "Definition of the Flexible Image Transport System (FITS)", NOST 100-2.0, 1999.

[2] Cotton W.D., Tody, D.B., and Pence, W.D., 1995, "Binary Table Extensions to FITS", *Astron. Astrophys. Suppl.*, **113**, 156-166

[3] "Representation of World Coordinates in Fits", 2000 (`http://www.nrao.edu/~egreisen/`).