MeasurementSet VLBI extensions

Kettenis M.M.

November, 2023

Contents

1 Introduction

The MeasurementSet (MS) defines a format in which interferometer visibilities and single-dish data are stored. It is implemented in software packages using casacore code. Version 2.0 (Note 229; Kemball and Wieringa 2000) of the MeasurementSet has been in use since 2000 in different packages and at different telescopes.

Recent developments to add VLBI capabilities to CASA revealed some gaps in the metadata provided by MS V2.0. To fill these gaps additional tables have been defined and implemented in casacore. These extension tables are filled by the code that implements the conversion from FITS-IDI to MS. This follows the existing practice established by the code that converts from ASDM to MS that is provided in CASA where several ASDM-specific tables are stored in MS form with names wit an ASDM_ prefix.

The following new tables are defined:

- **GAIN_CURVE:** Antenna gain curves
- **PHASE_CAL:** Phase calibration measurements
- **EARTH_ORIENTATION:** Earth Orientation Parameters

2 VLBI metadata tables

This section contains a description of the VLBI metadata tables. These tables are stored as subtables of the MS and like the standard subtables these are stored as keywords of the MS. All these subtables are optional.

2.1 GAIN_CURVE: Antenna gain curves

GAIN_CURVE: Antenna gain curves				
Name	Format	Units	Measure	Comments
Columns				
Keys				
ANTENNA_ID	Int			Antenna id.
FEED_ID	Int			Feed id.
SPECTRAL_WINDOW_ID	Int			Spectral window id.
TIME	Double	s	EPOCH	Interval midpoint
INTERVAL	Double	s		Time interval
Data description				
TYPE	String			Gain curve type
NUM_POLY	Int			# Series order
Data				
GAIN	Float(N_r, num_poly)			Gain
SENSITIVITY	Float(N_r)	K/Jy		Sensitivity

Notes: This sub-table contains antenna gain curves.
For further discussion of this table see casacore Issue 1029.

ANTENNA_ID Antenna identifier, as indexed by ANTENNAn from MAIN.

FEED_ID Feed identifier, as indexed from FEEDn in MAIN. A value of -1 indicates the row is valid for all feeds.

SPECTRAL_WINDOW_ID Spectral window identifier. A value of -1 indicates the row is valid for all spectral windows.

TIME Mid-point of the time interval over which the data in the row are valid. Required to use the same TIME Measure reference as in MAIN.

INTERVAL Time interval.

TYPE Gain curve type. Reserved keywords include: ("POWER(EL)" - Power as a function of elevation; "POWER(ZA)" - Power as a function of zenith angle; "VOLTAGE(EL)" - Voltage as a function of elevation; "VOLTAGE(ZA)" - Voltage as a function of zenith angle).

NUM_POLY Series order for the GAIN column (number of terms in the gain curve polynomial).

GAIN Coefficients of the polynomial that describes the (power or voltage) gain.

SENSITIVITY Sensitivity of the antenna expressed in K/Jy. This is what AIPS calls "DPFU".

2.2 PHASE_CAL: Phase calibration measurements

PHASE_CAL: Phase calibration measurements				
Name	Format	Units	Measure	Comments
Columns				
Keys				
ANTENNA_ID	Int			Antenna id.
FEED_ID	Int			Feed id.
SPECTRAL_WINDOW_ID	Int			Spectral window id.
TIME	Double	s	EPOCH	Interval midpoint
INTERVAL	Double	s		Time interval
Data description				
NUM_TONES	Int			# phase calibration tones
TONE_FREQUENCY	Double(num_tones)	Hz		Tone frequencies
Data				
PHASE_CAL	Float(N_r, num_tones)			Phase-Cal tone measurements
CABLE_CAL	Double(N_r)	s		Cable delay

Notes: This sub-table contains signal chain phase calibration measurements.
For further discussion of this table see casacore Issue 1165.

ANTENNA_ID Antenna identifier, as indexed by ANTENNAn from MAIN.

FEED_ID Feed identifier, as indexed from FEEDn in MAIN. A value of -1 indicates the row is valid for all feeds.

SPECTRAL_WINDOW_ID Spectral window identifier. A value of -1 indicates the row is valid for all spectral windows.

TIME Mid-point of the time interval over which the data in the row are valid. Required to use the same TIME Measure reference as in MAIN.

INTERVAL Time interval.

NUM_TONES Number of phase-cal tones that are measured. This number may vary by antenna, and may vary by spectral window as well, especially if spectral windows of varying widths are supported.

TONE_FREQUENCY The sky frequencies of each measured phase-cal tone.

PHASE_CAL Phase calibration measurements. These are provided as complex values that represent both the phase and amplitude for a measured phase-cal tone. Measurements are provided as a two-dimensional array such that separate measurements can be provided for each receptor of a feed (so separate values for each polarization) for each of the measured tones.

CABLE_CAL Cable calibration measurement. This is a measurement of the delay in the cable that provides the reference signal to the receiver. There should be only a single reference signal per feed (even if that feed has multiple receptors) so this is provided as a simple scalar.

2.3 EARTH_ORIENTATION: Earth orientation parameters

EARTH_ORIENTATION: Earth orientation parameters				
Name	Format	Units	Measure	Comments
Columns				
Keys				
TIME	Double	s	EPOCH	Time-stamp for values
OBSERVATION_ID	Int			Points to OBSERVATION table
Data				
UT1_UTC	Double	s		UT1 - UTC
PM	Double(2)	rad		Celestial pole position
TYPE	String			Type of EOP value

Notes: This sub-table contains the earth orientation parameters that were used to generate the correlator model. For further discussion of this table see casacore Issue 1307.

TIME Timestamp of the EOP values; this is expected to be the UTC time although some sources use TAI instead.

OBSERVATION_ID Observation identifier (see the OBSERVATION table)

UT1_UTC Difference between UT1 and UTC (UT1 - UTC) in seconds.

PM Position of celestial pole; these are provided as X and Y components (in that order) in radians.

TYPE Type of the EOP value; Reserved keywords include: ("PREDICTED" - for predicted parameter values; "PRELIMINARY" - for measured parameter values that are subject to further revision in the future; "FINAL" - for final parameter values). If the type is not know this should be an empty string.

3 References

Kemball, A.J., Wieringa, M.H., 2000, casacore Note 229.