The Generic Instrument: V Design of Cross-calibration

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1 Introduction

A previous memo described calibration and imaging for the generic Interferometer (Cornwell and Wieringa, 1996) using the measurement equation developed by Hamaker, Bregman and Sault (1995) (see also Noordam, 1995). Most attention has been paid to self-calibration whereby the derived calibration information need only be applied to the source from which it was derived. The more general case is to derive calibration on one source or set of sources, and then apply it to another source. The purpose of this memo is to sketch the form of the design for this form of calibration, that we will call *cross-calibration*. This is a sketch only and, in keeping with AIPS++ philosophy, the reader is referred to the AIPS++ header files for more information.

We assume that the reader is familiar with the terminology, notation and results from the above mentioned references.

2 Goals

The goals for the design of the calibration and imaging capabilities were described by Cornwell and Wieringa (1996). Here we describe the additional goals for cross-calibration:

- Describe calibration information in the form of `MeasurementComponents`,
- Allow very general selection of data for calibration determination (e.g. "All 6cm observations where wind velocity$\leq$3 m/s"),
- Allow direct manipulation of calibration tables,
- Allow iterative calibration,
- Allow incremental calibration,
- Allow construction of `MeasurementComponents` from externally-derived data or from calibration solutions,
- Allow specification of source structure via SkyModels,
- Keep all data in one place.

3 Some comments on capabilities available inside AIPS++

Tables All data, original and calibration, is placed in the Table system, where it is accessible and modifiable by a number of "free-form" mechanisms, the principle being glish and the tablebrowser.

The MeasurementSet is of the form one main Table, plus many subsiduary Tables (e.g. ANTENNA, FEED, ARRAY). The main table contains data, coordinate information such as time and uvw, and keys into the sub-Tables (see Wieringa and Cornwell, 1996).

keys ANTENNA1, ANTENNA2, ARRAY_ID, CORRELATOR_ID, FEED1, FEED2, FIELD_ID, OBSERVATION_ID, PULSAR_ID, SOURCE_ID, SPECTRAL_WINDOW_ID

coordinates SCAN_NUMBER, UVW, TIME, EXPOSURE, INTERVAL, PULSAR_BIN

data DATA, SIGMA, WEIGHT, WEIGHT_SPECTRUM, FLAG, FLAG_ROW

Selection of data from a MS leads to another reference MS with little overhead. The selection can be by one or more of:

- data (e.g. "all amplitudes $\geq$ 5 Jy"),
- coordinates (e.g. "all times in the following range"),
- keys (e.g. "SPECTRAL_WINDOW_ID=1 or 4"),

- properties determined by lookup in a subtable (e.g. "wind velocity ≤ 3 m/s"),

The `MeasurementEquation` is the fundamental mechanism used to describe calibration and imaging in terms of `MeasurementComponents`. These describe some aspect of the measurement process, such as antenna-based gain, while not prescribing how the calculation of actual values is to be performed, for instance in the case of antenna phases via a table calculated from a priori values or via a phase-screen model.

4 An approach to cross-calibration

Our preferred approach to calibration uses the reference table or MS concept to keep both the original data together in one MS and to provide calibrated views of that data via reference tables.

- The `MeasurementSet` M is subject to some selection, S_{cal}, to produce a logical subset MS $M(S_{cal})$, the calibrator MS. The selection used is of interest in two ways: first to ensure that the correction is applied to the relevant data (e.g. 6cm to 6cm observations), and second as information to the user (e.g. "wind-velocity ≤ 3 m/s").
- For each such calibrator MS, a SkyModel is used to predict the corresponding coherences.
- For each such calibrator MS, one will want to perform a solution for one or more `MeasurementComponents` (e.g. `GJones` and `DJones`).
- Each `MeasurementComponent` is then stored as a Table in the calibrator MS.
- The `MeasurementSet` M is subject to some selection, S_{source}, to produce a logical subset MS $M(S_{source})$, the source MS.
- `MeasurementComponents` are then explicitly copied from calibrator to source MS, either by the user or by some simple program.
- After copying, a `MeasurementComponent` can be subject to a number of operations:
  - Re-interpolation in some coordinate such as time or some derived quantity such as antenna elevation or airmass,
  - Editing by hand or by algorithm,
  - Boot-strapping of some form (e.g. determination of the flux of some sources from a primary calibrater),

- Recasting to another form (e.g. antenna-based phases to position-based phase screen).

All of these are probably best thought of as construction of a new `MeasurementComponent` that replaces the initial one.

The net result is that one main MS and a number of reference MSes pointing to it and containing the relevant `MeasurementComponents`. This scheme has a number of advantages:

1. (Relative) simplicity. We consider this to be very important,
2. The `MeasurementComponents` in the source MSes exist independently of the calibrator MSes and can be edited or munged as one chooses,
3. Self-calibration is easily accomodated by simply updating the `MeasurementComponents` in the source MSes.

An alternate but more complicated approach is to defer the connection between sources and calibrators until the correction of data is actually performed. In this scheme, each reference MS is assigned a unique integer, CG, and an MS column "CALIBRATION_GROUP" is set to that integer. The links between calibrator and source are then made via this index. The data for which these corrections are to be applied are selected via a selection S_{source} to form a target MS, $M(S_{source})$. The column CALIBRATION_GROUP of this MS, is set to CG. We discarded this type of deferred selection of `MeasurementComponents` as being overly complex, and not allowing the user to munge the `MeasurementComponents` "by hand".

References

Cornwell, T.J., 1995, AIPS++ Implementation Note 183.
Cornwell, T.J. and Wieringa, M.H., 1996, AIPS++ Implementation Note 189.
Hamaker, J.P., Bregman, J.D., and Sault, R.J., 1995, *Understanding radio polarimetry: I Mathematical foundations*, submitted to A&A.
Noordam, J., 1995, AIPS++ Implementation Note 185.
Wieringa, M.H., and Cornwell, T.J., 1996, AIPS++ Implementation Note 191.