The New Bonn Mk IV – AIPS Data Export Path

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Abstract. We have written an interface program for exporting raw Mk IV correlator data into AIPS. This program – called `Mk4IN` – is realized within AIPS and uses the Haystack Mk IV data routines to access the correlated data. Together with the Haystack Observatory Post-processing System (HOPS) and a modified AIPS task for estimating antenna based residuals from the baseline-based fringe fit results from HOPS, a complete export path is now in place. It is optimized for mm-VLBI and astrometry, but it also simplifies the reduction of continuum VLBI data in AIPS: data can be mapped without any further fringe fitting in AIPS.

1. Introduction

When the Mk IV VLBI correlator was installed in Bonn in December 1999[1], it was clear from the beginning that in order to use its full potential for astronomy, astrometry and mm-VLBI in particular an interface to NRAO's image processing software AIPS was essential. This lesson had been learnt in the era of the Mk III correlators, where for several years only a rudimentary export path to AIPS existed. Only the introduction of the AIPS task `MK3IN` made it possible to map radio sources with Mk III VLBI observations with a dynamic range close to what could be expected from theory.

2. Requirements

All Mk IV correlators are lag based, which implies that the correlated data are complex numbers in delay-space. AIPS expects data in the cross-spectral domain, so that any export path from Mk IV to AIPS has to include a Fourier transformation.

As it is standard practice at the Mk IV correlators of the Haystack type to do multi-pass correlation, a method to select a unique data-set without duplicates has to be a part of an export procedure.

Data bit rates of 512 MBits/s and more which are recorded with more than 32 tracks per pass have to be correlated in two passes, as the playback units are only equipped with one reproduce head (=32 tracks). In each pass one half of the total recorded bandwidth is correlated. AIPS task `VBGLU` can be used to combine the two correlations, provided a number of properties of the two data sets match.

Phase calibration signals (phase-cal) are extracted at the Mk IV correlators of the Haystack type. These calibration signals can be used to remove the a priori unknown inter-IF phase differences thus making fringe searches at the highest frequencies much more reliable. Even for standard continuum VLBI the alignment of IF phases as well as the relative phases of two circularly polarised channels can be calibrated automatically when the measured phase-cal signals are used.

A requirement for astrometric observations is that the correlator model is carried along with the data, so that total observables can be determined.

The residuals determined with the fringe-fitting program – `fourfit` – of the HOPS[2] package should be exported to AIPS, as `fourfit` gives a more precise estimate of the detection threshold than its AIPS equivalent. This is essential for VLBI observations at the highest frequencies where the coherence time is short, the sensitivity is low and where the fringe fit results have to be inspected scan by scan in order to determine whether the fringes are detected.

3. Realization Of The Export Path

For realizing the interface program we had two choices: either create a FITS writer or a direct interface program to AIPS. The FITS writer would have been more general, but more difficult to debug, as the correctness of the created FITS file could only have been checked by reading it into AIPS. In addition to debugging the FITS writer we might have been forced to debug and adapt `FITLD` – the AIPS FITS reader – to Mk IV data. So it was decided to write a direct Mk IV to AIPS interface: `MK4IN`.

Data selection software for forming a unique data set was already available in HOPS so that no further software was necessary. We expected to use AIPS task `BLAPP` which uses the same method as described in Alef & Porcas (1986) to derive antenna-based fringe-fit residuals from the baseline-based `fourfit` results.

The structure of `MK4IN` could be kept fairly simple as the HOPS program `fourfit` could be enhanced by Colin Lonsdale (Haystack Observatory) to write the raw data in the cross-spectral domain, which serves `MK4IN` as input. This data has all phase and amplitude corrections and data editing applied; `fourfit` does this transform in a routine way to add both sidebands together. The cor-

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[1] For an overview of the system see Alef et al. (2000)

[2] http://web.haystack.mit.edu/vlbi/hops.html

rections include measured and manual phase-cal, upper-sideband/lower-sideband (USB/LSB) phase-offsets, state-count corrections, bit-shift corrections etc. All correlator flags are honored and are used to edit the data.

MK4IN uses the HOPS data I/O routines to read the cross-spectral output produced by `fourfit`. Thus the final program consists of four layers: On top the MK4IN code written in FORTRAN, the standard AIPS libraries, then the MK4IN code written in C which interfaces to the HOPS I/O routines. The disadvantage of this approach is that MK4IN cannot be a proper AIPS task, but can only be a local program where both AIPS and the relevant sections of the Haystack correlator software are installed.

The AIPS file header as well as the AN, SU and FQ tables are constructed from the observe VEX file, which is also used to control the correlation. This avoids problems with multi-pass correlations and `VBGLU` in particular. The `fourfit` solutions are written to a BS table. The correlator model is extracted from the antenna files (type 3 files) and is stored as the coefficients of a third order polynomial for each entry (time) in the CL table together with the first two terms of the clock.
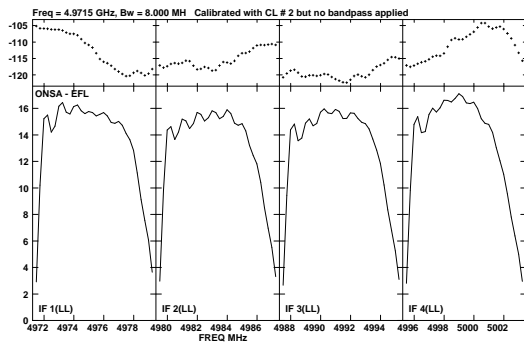

Fig. 1. Example spectrum of a 5 GHz EVN observation, calibrated with `fourfit` solutions.
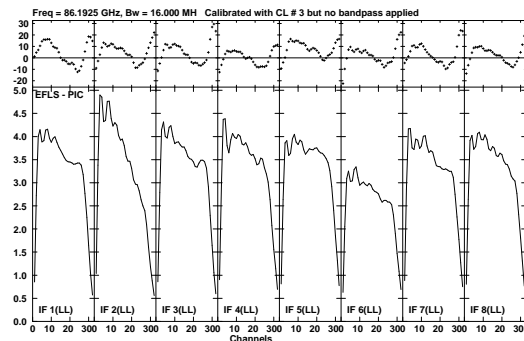

Fig. 2. Example spectrum of a `VBGLU`ed 512-Mbits observation at 86 GHz, calibrated with single IF `FRNGE` solutions.

MK4IN and the whole export path have been tested with an EVN continuum data set (see Fig 1), a 512-Mbit observation at 86 GHz (see Fig 2) , and a spectral line observation at 129 GHz. Tests with an astrometric data set are underway and will be reported in this conference.

4. How To Export Data

– The correlated data has to be fringe-fitted with `fourfit`. Manual phase-cal, USB/LSB phase-offsets etc. can be introduced. The cross-spectra are written to disc as part of the type 2 files (see Alef et al., 2000).
– A unique data-set can be selected with the HOPS tasks `aedit` and `linkdata`. A more sophisticated selection can be done with a script written at the MPIfR.
– MK4IN reads the `ovex`-file, sets up the AIPS header, and creates the AN, SU, and FQ tables. The cross-spectra, the `fourfit` solutions, and the correlator model are read, reformatted and written to the UV-file, the BS table, and the CL table respectively. The input parameters to MK4IN are the number of correlated lags, weight threshold, CL time interval etc.
– The AIPS UV-file has to be sorted.
– An index (NX) table has to be created.
– Antenna based residuals are derived and a first solution table is created from the BS table with a slightly modified version of `BLAPP`.

5. Summary

With the design chosen for the Mk IV to AIPS interface a straightforward, fairly easy to implement and robust solution was found. Some restrictions exist: all data must be correlated with the same number of lags, the number of lags may be limited by `fourfit`, and one baseline/scan can only come from one run of `fourfit`. Advantages of the new software are:

– MK4IN is especially designed for multi-pass correlation and merging of data with `VBGLU`.
– All phase-corrections like phase-cal etc. are applied (Measured phase-cals make combining data with `VBGLU` easier).
– Full polarization capability.
– Full spectral line capability, but limited by permissible lags in `fourfit`.
– The correlator model is passed in the CL-table.
– The `fourfit` results are passed in a BS-table. No fringe-fitting in AIPS is needed except if `VBGLU` is used, but for highest dynamic range maps single-IF fringe-fits are superior.
– The number of IFs is halved for double-sideband modes.
– Little editing is needed as correlated data is only produced for good scans.

In order to implement all features desired by the mm-VLBI observers an AIPS task for plotting, editing and interpolating BS-tables will be written in the near future.

References

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