A SUMMARY OF *AIPS* CONTINUUM UV-DATA CALIBRATION

From VLA Archive Tape to a UV FITS Tape
AIPS Memo No. 76 Updated

Glen Langston

A.1 Basic calibration

The Gentle User enters the Computer room with a VLA archive tape containing a scientific breakthrough. The user's sources are named SOURCE1 and SOURCE2. The interferometer phase is calibrated by observations of CAL1 and CAL2. The flux density scale is calibrated by observing 3C48 (=0137+331) and polarization is calibrated with observations of 3C286 and/or 3C138. Mount the tape on drive number n, log in and start *AIPS*. Example input: AIPS NEW. Mount the tape: INTAPE=n; DENS=6250; MOUNT.

PRTTP Find out what is on the tape, get project number and bands. TASK='PRTTP'; PRTLEV=-2; NFILES=0; INP; GO; WAIT; REWIND.

FILLM Load your data from tape. Select only one band at a time to process. TASK='FILLM'; VLAOBS='?'; BAND=' '; NFILES=?; INP; GO. (Replace all ?'s with appropriate values.) FILLM will load your visibilities (uv-data) into a large file for each band and create 6 *AIPS* tables each. The tables have two letter names described below.

- HI Human readable history of things done to your data. Use PRTHI to read it.
- AN Antenna location and polarization tables. Antenna polarization calibration is placed here.
- NX Index into visibility file based source name and observation time. Not modified by calibration.
- SU Source table contains the list of sources observed and indexes into the frequency table. The flux densities of the calibration sources are entered into this table.
- FQ Frequencies of observation and bandwidth with index into visibility data. Not modified.
- CL Calibration table describing the antenna based gains. Version 1 should never be modified. The CL table contains entries at regular time intervals (*i.e.*, 2 minutes) for each antenna. **The ultimate goal of calibration is to create a good CL version 2.** Use PRTAB to read tables.

PRTAN Print out the antenna locations. TASK='PRTAN'; PRTLEV=0; INP; GO. Choose a good *Reference* antenna (called R) near the center of the array (REFANT=R). Check the VLA operator log to make sure the antenna was OK during the entire observation.

QUACK Flag the bad points at the beginning of each scan, even the ones with good amplitudes could have bad phases. Creates a Flag Table (FG). You want to use FG table version 1 for all tasks. TASK='QUACK'; FLAGV=1; OPCOD=' '; APARM=0; SOUR=' '; INP; GO deletes the first six seconds of each scan, which may not be enough.

- FG A flag table marks bad data. FG tables contain an index into the UV data based on time range, antenna number, frequency and IF number.

LISTR Lists your UV data in a variety of ways. Make a list of your observations. TASK='LISTR'; OPTYP='SCAN'; DOCRT=-1; SOUR=' '; CALC='*'; TIMER=0; INP; GO. NOTE: IF you have observed in a such a way as to create more than one FREQID, you must run through the entire calibration once for EACH FREQID. For new users, it is better to use UVCOP to copy each FREQID into separate files and calibrate each file separately. This is required if you are doing polarization calibration.

UVCOP Skip this step if your data consists of only one FREQID. Copy different FREQIDs into separate files. TASK='UVCOP'; FREQID=?; CLRON; OUTDI=INDI; INP; GO. The result will be a ??.UVCOP file.

SETJY Sets the flux of your flux calibration source in the SU table. TASK='SETJY'; SOUR='3C48',' '; OPTYP='CALC'; FREQID=1; INP; GO. Adjust flux density for partial resolution following the rules in the VLA Calibration Source Manual or the *AIPS CookBook*.

TASAV As insurance, make a copy of all your tables. TASK='TASAV'; CLRON; OUTDI=INDI; INP; GO.

CALIB CALIB is the heart of the *AIPS* calibration package. RUN VLAPROCS, an *AIPS runfile*, to create procedures VLACALIB, VLACLCAL and VLARESET. The procedure VLACALIB runs CALIB. Set the UV and Antenna limits for 3C48. For L, C and X band 5% and 5 degree errors are OK; for other bands the limits are higher. CALIB places antenna amplitude and phase corrections into an SN table for the time of observation of phase calibration sources.

SN Solution table contains antenna based amplitude and phase corrections for the time of observations of the calibration sources. These SN table results are latter interpolated for all times of observation and placed in a CL table. Only the CL table corrections will be applied to the program sources.

TASK='VLACAL'; CALS='3C48',' '; CALCODE='*'; REFANT=*R*; UVRA=?; SNVER=1; DOCALIB=-1 MINAMP=10; MINPH=10; INP; VLACAL. The task CALIB lists antenna pairs which deviate significantly from the solution. If you have lots of errors, then carefully examine your data using TVFLG or LISTR. (See *AIPS CookBook* for a lengthy discussion on flagging.) If one antenna is bad over a limited time range, use UVFLG to flag that antenna for the time from just after the previous good CAL observation to before the next good CAL observation.

UVFLG Flag bad UV-data. TASK='UVFLG'; ANTEN=?,0; BASELI=?,0; TIMER=?; FLAGV=1; SOUR=' '; OPCOD=' '; INP; GO. If in doubt about any data, FLAG THEM! If you have flagged the primary calibrator, return to CALIB above and try again.

CALIB Now calibrate the antenna gain based on the rest of the cal sources. Look in the Calibrator manual for UV limits; if there are limits, VLACAL must be run separately for these sources. TGET VLACAL; CALS='CAL1','CAL2',' '; ANTEN=0; BASELI=0; UVRANGE=?,?; INP; VLACAL. Flag bad antennas listed. Each execution of CALIB replaces previous corrections in the SN table or appends new corrections. If unsatisfied with a VLACAL execution, all effects of it are removed by running VLACAL again for the same sources (but different ADVERBS or after flagging bad data).

GETJY Sets the flux of phase calibration sources in the SU table. TASK 'GETJY'; SOUR='CAL1,'CAL2',' '; CALS='3C48',' '; BIF=0; EIF=0; INP; GO. GETJY over-writes existing SU table entries, and is not affected by previous executions.

TASAV Good time to save your tables. TGET TASAV; INP; GO.

CLCAL Read the antenna amplitude and phase corrections from the SN table and interpolate the corrections into a new CL table. CLCAL applies calibration source corrections to the program sources. Each execution of CLCAL adds to output CL table version 2. CLCAL is run using the procedure VLACLCAL. TASK='VLACLC'; SOUR='SOURCE1','CAL1',' '; CALS='CAL1',' '; OPCODE='CALI'; TIMER=0; INTERP='2PT'; INP; VLACLC. Run CLCAL for the second source using the second calibrator. TGET VLACLC; SOUR='SOURCE2','CAL2',' '; CALS='CAL2',' '; INP; VLACLC. Move the SN table corrections for 3C48 into the CL table.

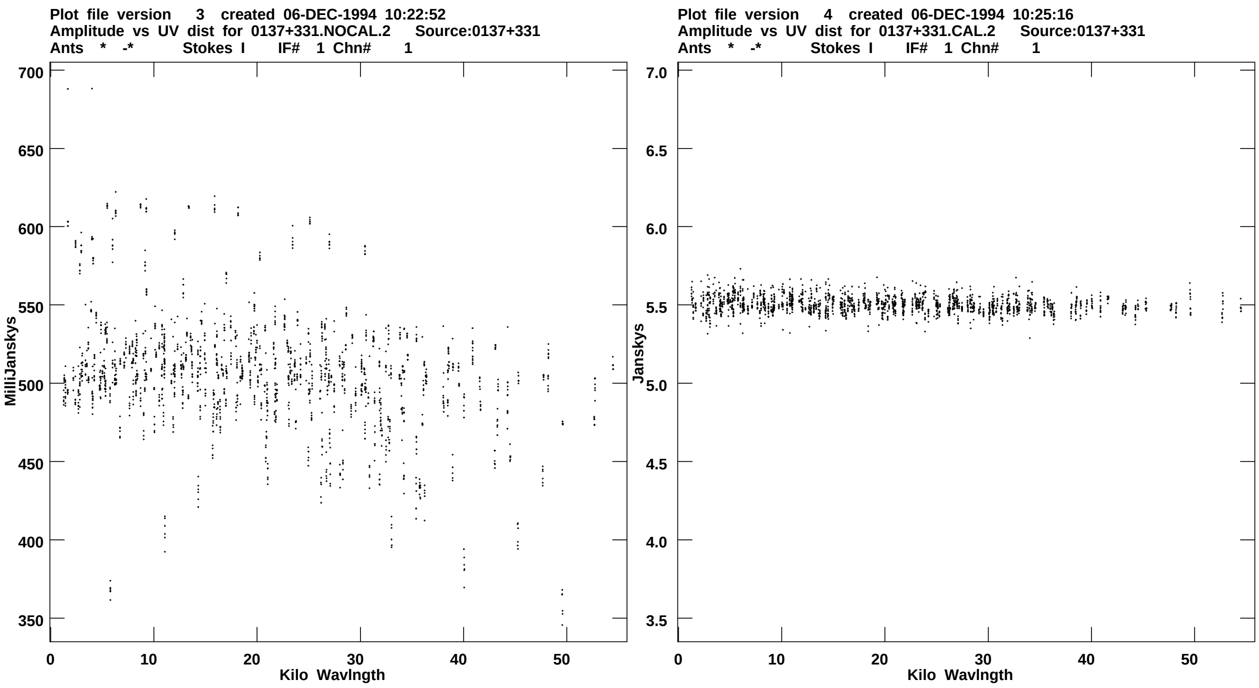

Figure A.1: *(left)* Un-calibrated *uv*-data and *(right)* calibrated *uv*-data from a C-band snapshot of 3C48. Default VLA gains are a tenth of the actual gains and can show significant scatter. Only wild *uv* points ∼50% greater than the average can be detected before calibration.

TGET VLACLC; SOUR='3C48',' ';CALS='3C48',' '; INP; VLACLC. (3C48 could also be calibrated with CAL1 or CAL2.)

LISTR Make a matrix listing of the Amplitude and RMS of calibration sources with calibration applied. Look for wild points. TASK='LISTR'; OPTYP='MATX'; SOUR='CAL1','CAL2',' '; DOCAL=1; DOCRT=-1; DPARM=3,1,0; UVRA=0; ANTEN=0; BASELI=0; BIF=1; INP; GO. If only a few points are bad, flag them and continue. If too many are bad, delete CL table 2 and the SN tables using VLARESET. Then return to the first CALIB step. If the data look good, run LISTR again for IF two. TGET LISTR; BIF=2; INP; GO

UVPLT Plot the *uv*-data in a variety of ways. Make a Flux versus Time plot first. Choose XINC so the plot will have no more than 1000 points. TASK='UVPLT'; SOUR='SOURCE1',' '; XINC=10; BPARM(1)=11; DOCAL=1; BIF=1; INP; GO. Look at the plot with LWPLA, TKPL, TVPL or TXPL. Plot other IF . Flag wild points. Plot Flux versus baseline. TGET UVPLT; BPARM=0; INP; GO.

Calibration is now complete for continuum, un-polarized observations. Write the calibrated data to tape with FITTP if you don't want to calibrate the polarization. To create images from the *uv*-data use SPLIT to calibrate the multi-source data and create a single source *uv*-data set. (FITTP and SPLIT are described at the end of the polarization calibration process.)

A.2 Polarization calibration

For polarization observations, the following steps are required. For 21cm or longer wavelength observations, ionospheric Faraday rotation corrections may be needed. See FARAD in the *AIPS CookBook*, but don't expect much help anymore.

TASAV As added insurance, save your tables again. TGET TASAV; INP; GO.

LISTR Print the parallactic angles of the calibration sources. TGET LISTR; SOUR=' '; CALC='*'; OPTYP='GAIN'; DPARM=9,0; INP; GO

PCAL Intrinsic antenna polarization calculation. PCAL will be successful only if cal. sources are observed at several parallactic angles. PCAL will modify the AN and SU tables. TASK='PCAL'; CALS='CAL1','CAL2',' '; BIF=1; EIF=2; DOCAL=1; REFANT=*R*; INP; GO

LISTR Now determine the absolute linear polarization angle. Make a matrix listing of the angle of 3C286. TGET LISTR; SOUR='3C286',' '; DOCAL=1; BIF=1; DOPOL=1; GAINUSE=2; OPTYP='MATX'; DPARM=1,0; STOKES='POLC'; INP; GO. Record the matrix average angle, ϕ_1, for IF 1. The observed angles are different for each frequency and IF . Record the matrix average angle, ϕ_2, for IF 2 (BIF=2; INP; GO).

CLCOR Now apply the angle corrections to CL table 2. The relative phase of Left and Right circular polarization produces the linear polarization angle and the phase correction is applied to L. The phase difference (twice the angle of linear polarization) for 3C286 is 66^o and for 3C138, $\phi = -18^o$ at L band, perhaps -24^o at higher frequencies. TASK='CLCOR'; STOKES='L'; SOUR=' '; OPCOD='POLR'; BIF=1; EIF=2; CLCORPRM=66-ϕ_1,66-ϕ_2,0; GAINVER=2; INP; GO. Run LISTR again to check the phases. TGET LISTR; INP; GO. If the phases are wrong, return to PCAL and LISTR, then do another CLCOR.

A.3 Backup and imaging

FITTP Writes the output *uv*-data to tape. DISMOUNT your archive; MOUNT your output tape. TASK='FITTP'; DOEOT=1; OUTTAP=INTAP; INP; GO. Use DOEOT=-1 when at the beginning of a new tape.

SPLIT The *AIPS* calibration process only modifies the tables associated with the multi-source *uv*-data set. SPLIT selects individual sources, reads the CL table and multiplies the visibilities by the corrections to produce a calibrated single-source *uv*-data set. TASK='SPLIT'; SOUR=' '; CALC=' '; UVRA=0; TIMER=0; DOCAL=1; FLAGVER=1; GAINUSE=2; DOPOL=1; DOBAN=-1; BIF=0; EIF=0; STOKES=' '; BLVER=-1; APARM=0; DOUVCOM=1; CHANSEL=0; INP; GO

Mapping Use your favorite Fourier Transform task (*e.g.*, UVMAP, HORUS, MX, WFCLN or IMAGR) to produce images from the calibrated data. A set of *AIPS* procedures (called MAPIT) has been developed to automatically Fourier Transform, deconvolve and self-calibrate the *uv*-data. See *AIPS* Memo No. 72.