# *Summary of AIPS UV-data Calibration*

*From VLA Archive Tape to a UV FITS Tape*

*91 April 04*

The Gentle User enters the Computer room with their VLA archive tape containing a scientific breakthrough. For the sake of demonstration, let's call the user's sources SOURCE1 and SOURCE2. The interferometer phase is calibrated by observations of the calibration sources CAL1 and CAL2. The flux density scale is calibrated by observing 3C286 . Mount your tape on drive number $n$, log in and start *AIPS* . Example user input: AIPS NEW. Mount the tape: INTAP $n$; 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. TASK='FILLM'; VLAOBS='?'; BAND="; DOALL=1; NFILES=$m$; INP;GO. FILLM will load your visibilities (UV data) into a large file and create 6 *AIPS* tables. The tables have two letter names:

- 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. Ultimate goal of calibration is to create a good version 2. Use PRTAB to read tables.

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

**LISTR** Lists your UV data in a variety of ways. Make a list of your observations: TASK='LISTR'; OPTYP='SCAN'; DOCRT=-1; CALCODE="; SOUR="; 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 procedure which follows *ONCE FOR EACH* FREQID. For new users, it is better at this point to use UVCOP to copy each FREQID into separate files and then calibrate each file separately.

**UVCOP** Skip this step if your data consists of only one FREQID. Copies different FREQIDs into separate files. TAST='UVCOP'; FREQID=?; OUTNAME='?'; 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='3C286',"; OPTYP='CALC'; INP;GO.

**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. Execute VLAPROCS, an *AIPS* "runfile", to create procedures VLACALIB, VLACLCAL and VLARESET (RUN VLAPROCS). The procedure VLACALIB runs CALIB. Set the UV and Antenna limits for 3C286. For L, C and X band, 10% and 10 degree errors are OK; for other bands the limits are higher.

SN Solution table contain antenna based gains corrections. These SN table results are latter placed in a CL table by task CLCAL.

TASK='VLACAL'; CALS='3C286',"; CALCODE='*'; REFANT=?; UVRA=0; MINAMP=10; MINPH=10; INP; VLACAL. The task CALIB lists antenna pairs which deviate significantly from the solution.

**TVFLG** If you have lots of errors, then carefully examine your data using TVFLG. (See *AIPS* Cookbook) If only a few antenna pairs are 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 and then run VLACAL again.

**UVFLG** Flags bad UV-data. Skip this step if you have no bad data. TASK='UVFLG'; ANTEN=?,0; BASELI=0; TIMER=?; FLAGV=1; SOUR="; OPCOD="; INP;GO. If in doubt about any *uv*-data , FLAG THEM! This will create a Flag Table (FG). You want to use FG table version 1 for all tasks.

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.

**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 (i.e. enter TGET VLACAL; CALS='?',"; ANTEN=?; BASELI=0; INP; VLACAL for CAL1 and then again for CAL2). Otherwise: TGET VLACAL; CALS='CAL1','CAL2',"; ANTENN=0; BASELI=0; INP; VLACAL. Flag bad baselines listed. Continue if only a few are listed, otherwise run VLACAL again.

**GETJY** Sets the flux of phase calibration sources in the SU table. TASK 'GETJY'; SOUR='CAL1','CAL2',"; CALS='3C286',"; BIF=0; EIF=0; INP;GO.

**TASAV** Good time to save your tables: TGET='TASAV'; OUTDI=INDI; CLRON; INP;GO.

**CLCAL** Calibrate the antenna gain and interpolates it into a new CL table. 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. Next, self-calibrate the flux calibrator: TGET VLACLC; SOUR='3C286',"; CALS='3C286',"; INP; VLACLC.

**LISTR** Make a matrix listing of the Amplitude and RMS of calibration sources with calibration applied: 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. Look for antenna pairs with wild RMSs and flag them with UVFLG. If only a few are bad, continue, else delete CL table 2 and the SN table using VLARESET. Then return to the first CALIB step. If the data look good, run LISTR again for the remaining IF (s). TGET LISTR; BIF=2; INP;GO

**UVPLT** Plots the *uv*-data in a variety of ways. Make at Flux versus Time plot first. Choose XINC so the plot will have approximately 1000 points (divide the number of visibilities by 1000 and choose the closest prime number to that). Set ANTEN=0; BASELI=0; TIMER=0. Then: TASK='UVPLT'; SOUR='SOURCE1',","; XINC=13; BPARM(1)=11; DOCAL=1; BIF=1; INP;GO. Repeat UVPLT with your calibrators also. Look at the plots with QMSPL, TVPL or TXPL (for plotting on the

QMS, the TV, or the terminal, respectively). Plot other IF (s). Flag wild points using UVFND and either UVFLG or CLIP. Plot Flux versus baseline: TGET UVPLT; BPARM=0; INP;GO.

If the calibration failed because of a bad reference antenna or too much noisy data, you may reset the parameters with: INP VLARESET; VLARESET This will bring you back to the first CALIB step above.

Calibration is now complete for continuum, un-polarized observations. Skip down to FITTP. 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.

*a)* *b)*

**Figure:** *a)* Uncalibrated *uv*-data and *b)* calibrated *uv*-data from an X-band snapshot of 3C286. Default VLA gains are a tenth of the actual gains and show significant scatter. Only wild *uv*-data points ~50 % greater than the average can be detected before calibration.

## POLARIZATION CALIBRATION

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

**LISTR** Examine the parallactic angles of your calibrator observations: TASK='LISTR'; ANTEN=0; SOUR="; CALCOD='*'; OPTYPE='GAIN'; DPARM=9,0; INP; GO.

**PCAL** Intrinsic antenna polarization calculation. This step is only possible if you have observed calibration sources at many parallactic angles. PCAL will only modify the AN table. TASK='PCAL'; CALS='CAL1','CAL2',"; BIF=1; EIF=2; REFANT=?; INP;GO

**TACOP** Make a copy of the last CL table; In case the CLOCR fails, the original CL table will be preserved. TASK='TACOP'; OUTDI=INDI ; INEXT='CL'; INVER=2; NCOUNT=1; OUTVER=3; INP; GO. Use CL table version 3 for all following steps.

**LISTR** Now determine the absolute linear polarization angle. Make a matrix listing of the angle of 3C286 . The observed angles are different for each frequency and IF . TASK='LISTR'; SOUR='3C286',"; DOCAL=1; GAINUSE=3; BIF=1; DOPOL=1; OPTYP='MATX'; INP; GO. Record the matrix average angle, $\phi_1$, for IF 1. Run LISTR again for IF 2. TASK='LISTR'; BIF=2; INP; GO. Record the matrix average angle, $\phi_2$, for IF 2.

**CLCOR** Now apply the angle correction to CL table 3. CLCOR needs only to be run once, unless you make a mistake. The phase correction is applied to the Left circularly polarized signal. (The relative phase of L and R produces the linear polarization angle) The angle of linear polarization for 3C286 is $66^o$. (For 3C138 , $\phi = -24^o$.) TASK='CLCOR'; STOKES='L'; SOUR="; OPCOD='POLR'; BIF=1; EIF=2; GAINVER=3; CLCORPA=66-$\phi_1$,66-$\phi_2$,0; INP; GO. Run LISTR again to check the phases. TGET LISTR; DOPOL=1; INP; GO. Check the phases, if they are wrong run CLCOR again. TGET CLCOR; OPCOD='PHAS'; CLCORPA=66-$\phi'_1$,66-$\phi'_2$,0; INP;GO

**FITTP** Writes the output *uv*-data to tape. DISMOUNT your archive; MOUNT your output tape. TASK='FITTP'; DOEOT=-1;BLOCK=10; OUTTAP=INTAP; INP;GO.

**Mapping** See *AIPS* cookbook for instructions on using TASK='SPLIT' to create a single source data set. Next use your favorite Fourier Transform task (i.e. MX or HORUS). Automatic imaging and self-calibration is now possible using the *AIPS* procedure MAPIT. See the *AIPS* MAPIT memo for more details.

Please send comments to Glen Langston or Dean Schlemmer, NRAO-Charlottesville. E-mail addresses: glangsto@nrao.edu, dschlemm@nrao.edu