Recipe for calibrating a VLBA data set

Hands-on Session, MWSchool, July 2nd, 2009

Eduardo Ros & Matthias Kadler

For the hands-on session we use archival data from the VLBA, corresponding to the 5 GHz part of the multi-band observations of the AGN CTA102, observed on June 8th, 2006, experiment code BR122B. Those can be downloaded from the NRAO VLBA archive at
ftp://ftp.aoc.nrao.edu/e2earchive/VLBA_BR122B_LPOL8IF8MHZ16CH_4.9605GHZ04.uvfits
and read into AIPS with `fitld`.

```
>imheader
AIPS 1: Image=MULTI     (UV)         Filename=BR122B      .FQ-4  .   1
AIPS 1: Telescope=VLBA               Receiver=VLBA
AIPS 1: Observer=BR122               User #= 1000
AIPS 1: Observ. date=08-JUN-2006     Map date=29-JUN-2009
AIPS 1: # visibilities     79742     Sort order  TB
AIPS 1: Rand axes: UU-L-SIN  VV-L-SIN  WW-L-SIN  TIME1  BASELINE
AIPS 1:            SOURCE  FREQSEL  INTTIM  GATEID  CORR-ID  WEIGHT
AIPS 1:            SCALE
AIPS 1: ----------------------------------------------------------------
AIPS 1: Type    Pixels   Coord value     at Pixel     Coord incr   Rotat
AIPS 1: COMPLEX      1   1.0000000E+00       1.00  1.0000000E+00    0.00
AIPS 1: STOKES       1  -2.0000000E+00       1.00 -1.0000000E+00    0.00
AIPS 1: FREQ        16   4.9604900E+09       0.53  5.0000000E+05    0.00
AIPS 1: IF           8   1.0000000E+00       1.00  1.0000000E+00    0.00
AIPS 1: RA           1    00 00 00.000       1.00       3600.000    0.00
AIPS 1: DEC          1    00 00 00.000       1.00       3600.000    0.00
AIPS 1: ----------------------------------------------------------------
AIPS 1: Coordinate equinox 2000.00
AIPS 1: Maximum version number of extension files of type HI is   1
AIPS 1: Maximum version number of extension files of type FQ is   1
AIPS 1: Maximum version number of extension files of type AT is   1
AIPS 1: Maximum version number of extension files of type CT is   1
AIPS 1: Maximum version number of extension files of type OB is   1
AIPS 1: Maximum version number of extension files of type AN is   1
AIPS 1: Maximum version number of extension files of type CL is   1
AIPS 1: Maximum version number of extension files of type CQ is   1
AIPS 1: Maximum version number of extension files of type GC is   1
AIPS 1: Maximum version number of extension files of type IM is   1
AIPS 1: Maximum version number of extension files of type MC is   1
AIPS 1: Maximum version number of extension files of type PC is   1
AIPS 1: Maximum version number of extension files of type SU is   1
AIPS 1: Maximum version number of extension files of type TY is   1
AIPS 1: Maximum version number of extension files of type WX is   1
AIPS 1: Maximum version number of extension files of type NX is   1
AIPS 1: Keyword = 'OLDRFQ  '  value =  4.31854900D+10
```

Looks good. You have a 5 GHz data set, with 79472 visibilities.

If you want to check what is in the data type:

```
> task 'listr'
> optype 'scan'
> docrt 72
> go
```

This produces a listing with a series of scans and frequencies:

```
File = BR122B      .FQ-4  .   1 Vol = 1  Userid = 1000
Freq =  4.960490000 GHz   Ncor =  1   No. vis =     79742
Scan summary listing

Scan      Source      Qual  Calcode Sub         Timerange          FrqID   START
```

```
   1 3C345          : 0000  V       1  0/09:48:14 -   0/09:52:05     1       1
   2 CTA102         : 0000  V       1  0/10:29:27 -   0/10:37:16     1    5216
   3 CTA102         : 0000  V       1  0/11:17:39 -   0/11:25:28     1   17443
   4 CTA102         : 0000  V       1  0/12:03:51 -   0/12:11:45     1   25450
   5 3C454.3        : 0000  V       1  0/12:34:24 -   0/12:38:17     1   35466
   6 CTA102         : 0000  V       1  0/13:12:55 -   0/13:20:47     1   40290
   7 CTA102         : 0000  V       1  0/14:01:07 -   0/14:08:59     1   51710
   8 CTA102         : 0000  V       1  0/14:47:21 -   0/14:55:13     1   63293
   9 CTA102         : 0000  V       1  0/15:24:39 -   0/15:29:31     1   73246

Source summary
Velocity type = 'GEOCENTR'    Definition = 'OPTICAL '

  ID Source           Qual  Calcode RA(2000.0)     Dec(2000.0)  No. vis
   1 3C345          : 0000   V     16:42:58.8100  39:48:36.994    5215
   2 CTA102         : 0000   V     22:32:36.4089  11:43:50.904   69703
   3 3C454.3        : 0000   V     22:53:57.7479  16:08:53.561    4824

  ID Source            Freq(GHz) Velocity(Km/s) Rest freq (GHz)
   1 3C345                4.9605         0.0000         43.1855
     IF(  2)              4.9685         0.0000         43.1855
     IF(  3)              4.9765         0.0000         43.1855
     IF(  4)              4.9845         0.0000         43.1855
     IF(  5)              4.9925         0.0000         43.1855
     IF(  6)              5.0005         0.0000         43.1855
     IF(  7)              5.0085         0.0000         43.1855
     IF(  8)              5.0165         0.0000         43.1855
   2 CTA102               4.9605         0.0000          2.2545
     IF(  2)              4.9685         0.0000          2.2545
     IF(  3)              4.9765         0.0000          2.2545
     IF(  4)              4.9845         0.0000          2.2545
     IF(  5)              4.9925         0.0000          2.2545
     IF(  6)              5.0005         0.0000          2.2545
     IF(  7)              5.0085         0.0000          2.2545
     IF(  8)              5.0165         0.0000          2.2545
   3 3C454.3              4.9605         0.0000         43.1855
     IF(  2)              4.9685         0.0000         43.1855
     IF(  3)              4.9765         0.0000         43.1855
     IF(  4)              4.9845         0.0000         43.1855
     IF(  5)              4.9925         0.0000         43.1855
     IF(  6)              5.0005         0.0000         43.1855
     IF(  7)              5.0085         0.0000         43.1855
     IF(  8)              5.0165         0.0000         43.1855

Frequency Table summary
FQID IF#      Freq(GHz)      BW(kHz)   Ch.Sep(kHz)  Sideband
   1   1      4.96049000    8000.0005    500.0000      1
       2      4.96849000    8000.0005    500.0000      1
       3      4.97649000    8000.0005    500.0000      1
       4      4.98449000    8000.0005    500.0000      1
       5      4.99249000    8000.0005    500.0000      1
       6      5.00049000    8000.0005    500.0000      1
       7      5.00849000    8000.0005    500.0000      1
       8      5.01649000    8000.0005    500.0000      1
```

You have three sources, one scan for 3C345 and 3C454.3, and seven scans for the target source in the observations, CTA102. The data are divided in frequency into 8 sub-band channels (IF) of 8 MHz width.

To check the array used and the antenna numbers, type:

```
> task 'prtan'
> go
```

```
Array= VLBA         Freq=  4960.490000 MHz     Ref.date= 08-JUN-2006

Array reference position in meters (Earth centered)
Array BX=         0.00000    BY=         0.00000    BZ=         0.00000
Polar X =   0.12309 Polar Y =   0.32700 arcsec
Earth rotation rate =  360.9856449733 degrees / IAT day
GST at UT=0 =  256.2391070699 degrees
UT1-UTC=      0.1999170   Data time(UTC     )-UTC=      0.0000000 seconds
Solutions not yet determined for a particular FREQID
```

```
Ant   1 = BR       BX= -2112065.1044 BY=  3705356.5080 BZ=  4726813.7087
Mount=ALAZ  Axis offset=  2.1320 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   2 = FD       BX= -1324009.2361 BY=  5332181.9626 BZ=  3231962.4114
Mount=ALAZ  Axis offset=  2.1325 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   3 = HN       BX=  1446374.9789 BY=  4447939.6642 BZ=  4322306.1422
Mount=ALAZ  Axis offset=  2.1307 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   4 = KP       BX= -1995678.7462 BY=  5037317.7076 BZ=  3357328.0531
Mount=ALAZ  Axis offset=  2.1328 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   5 = LA       BX= -1449752.4835 BY=  4975298.5809 BZ=  3709123.8635
Mount=ALAZ  Axis offset=  2.1329 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   6 = MK       BX= -5464075.0892 BY=  2495248.5290 BZ=  2148297.1295
Mount=ALAZ  Axis offset=  2.1407 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   7 = NL       BX=  -130872.3897 BY=  4762317.1035 BZ=  4226851.0035
Mount=ALAZ  Axis offset=  2.1299 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   8 = OV       BX= -2409150.2774 BY=  4478573.1649 BZ=  3838617.3478
Mount=ALAZ  Axis offset=  2.1319 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   9 = PT       BX= -1640953.8418 BY=  5014816.0264 BZ=  3575411.8027
Mount=ALAZ  Axis offset=  2.1374 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  10 = SC       BX=  2607848.5989 BY=  5488069.5924 BZ=  1932739.6344
Mount=ALAZ  Axis offset=  2.1365 meters    IFA               IFB
Feed polarization type =                    R                 L
```

All 10 VLBA antennas participated in the experiment. Have a look at the NRAO web directory for this experiment, containing logs, observing files and plots (typing BR122B into Google works to find the way!):

http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/

And then from those files, choose:
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122blog.vlba

The file looks like that:

```
VERY LONG BASELINE ARRAY OBSERVING LOG
--------------------------------------
Project:        BR122B
Observer:       Ros, E.
Project type:   VLBA
Obs filename:   br122bcrd.*
Date/Day:       2006JUN08/159
Ants Scheduled: SC HN NL FD LA PT KP OV BR MK

=UT-Time===Comment=========================================MF#===%AD==AMD=
           Operator is Anthony Sowinski.
           UT1-UTC correct, vclock and gps delta okay.
     0935  Begin file.
0935-1536 *SC 7mm receiver 15K stage likely still warm.         18279   16   57
           Had cooled down to 54K earlier this evening but now   18339
           reads -7.8K.
     0935 *HN and KP rotation positions affected by motor        18315
           work done to both FRMs. HN probably only only good    18316
           at lower frequencies but KP much better off and may
           be good at all bands.
     0935 %Recent rain at SC,HN,LA.
```

```
0935-0936 *SC Mark5 unhappy with originally active module and    OTHER  100    1
           switched to module in bank B.
0948-0951 *SC FRM Rotation drive fault.                          FRM    100    3
     0953 *Raining at HN.
     1010 *Raining at LA.
1055-1309 *HN Loss of commercial power, stopping observing.      COM    100  134
     1224  FD WEA: Site tech reports clear skies, dry.
1321-1325 *SC FRM focus drive fault.                             FRM    100    4
     1327  SC WEA: Site tech reports light scattered low
           clouds, dry.
     1339  LA WEA: Site tech reports scattered clouds.
     1342  Operator is Sonja Mendoza.
     1352 *PT WEA: Light precipitation.
1355-1401 *SC site tech has parked antenna in order to           OTHER  100    6
           replace the Vertex Room telephone on its hook.
1402-1404 *SC Antenna autostowed, probable power glitch.         COM    100    2
     1419  BR WEA: Site tech reports low scattered clouds,
           dry.
1421-1430 *PT Antenna autostowed, probable power glitch.         COM    100    9
     1451  KP WEA: Site tech reports clear skies, dry.
1455-1504 *PT Antenna autostowed, probable power glitch.         COM    100    9
     1508  OV WEA: Site tech reports clear skies, dry.
1525-1530 *PT Antenna autostowed, probable power glitch.         COM    100    5
     1536  End.


Downtime Summary:
       Total downtime : 230 min
       Percentage downtime of observing: 6.4%
       Average downtime per hour : 3.8 min

    Total scheduled observing time (# Antennas): 3610 min (10)

Notes:
    * = Entries where data was affected.
    % = Entries where data may have been affected.
    & = Entries where the site tech was called out.
  WEA = Weather entries.
  MF# = Maintenance form or major downtime category associated with a problem.
  %AD = The percentage of an antenna affected by a problem.
  AMD = Total antenna-minutes downtime for a problem.
 Tsys = System Temperature (TP/SP x Tcal/2)
  ACU = Antenna Control Unit
  FRM = Focus/Rotation Mount
  RFI = Radio Frequency Interference
  VME = Site control computer
   CB = Circuit Breaker
 vclock = Program that compares site clock time to a standard.
```

There are a lot of details, but you should just check what concerns your wavelength, 6 cm: nothing, except for some autostow times in some of the antennas which will already be flagged from the data.

Please keep in mind tha the antennas MK and SC are located at the edges of the array (Hawaii and Virgin Island, respectively), and that the central ones, suitable for being taken as a reference, are PT, LA (both in New Mexico), KP (Arizona), and FD (Texas). A map is to be found at http://www.vlba.nrao.edu/sites/

From here on, you could just run all the pipeline scripts defined in the Appendix C of the AIPS cookbook (vlbautils), see http://www.aips.nrao.edu/cook.html. However, it is better to be careful and not to rush, here, just check step-by-step what you do, in the case something is not standard—then you should do things by hand.

To have a reference file outside of aips, listing source scans, antennas, etc., you get a summary of the observations with `vlbasumm` (this is just `listr` and `prtan` again) as follows:

```
> restore 0
> run vlbautil
> getn N
> docrt -1
> outfile 'MYAREA:br122a_vlbasumm       ! Notice that we don't close the quote (lower case!)
```

```
> vlbasumm
```

For later, it is good to check if there are data for all antennas in every scan . You get this information using `listr` with `optype 'matx'`.

```
> task 'listr'
> opty 'matx'
> go
```

You will see something like this, for each scan in the experiment:

```
Freq=  4.960490000 GHz   Ncor=  1   No. vis=     79742
Stokes = LL   Subarray =   1


Time =   0/09:48:14 to   0/09:52:05   Source = 3C345           : 0000
Flux =  0.0000 Jy, Calcode = V   , Freq =  4.960490000 GHz
Amplitudes, 1000 =   0.100 Jy, averaging type = Vector
LCP in upper right

Ant -- 1-- 2-- 3-- 4-- 5-- 6-- 7-- 8-- 9--10
  1|      63  20  94  84   5  62 131  94  26
  2|         100 129 131  35 147  87 143  39
  3|              77  91  24 130  46  98  54
  4|                 141  29 138 116 158  10
  5|                      30 150 106 158  24
  6|                          35  21  32  24
  7|                              99 158  43
  8|                                 121  14
  9|                                      19
 10|
LCP|
Ampscalar average of matrix    = 7.854E-03(7.422E-04) sigma = 4.923E-03
Vector    average of upper data= 1.021E-03            sigma = 7.122E-03
```

If you list all the scans, you will see that the antenna 3 (HN) is missing for some of them. So, we don't want to have this as a reference one. Also 10 (SC) is missing for one scan. We will take LA (5) as reference. From now on, we write `refant 5` in the tasks we apply.

Now we want to calibrate the amplitudes in the data with the a-priori information recorded by the telescope sites, and included in the archival data set as tables, namely, the TY (system temperatures), PC (pulse tones), and GC (gain curves). To consolidate these tables and to avoid duplications or bugs, we run `vlbamcal` for this.

```
> restore 0
> run vlbautil
> getn N                     ! The catalog number of your file
> vlbamcal
```

Look at the message server window. It will tell you what is happening (tables are being copied and duplicates are being removed).

You can have a look at the system temperatures in the NRAO data archive:

http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.BR.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.FD.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.HN.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.KP.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.LA.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.MK.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.NL.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.OV.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.PT.ps.gz
http://www.vlba.nrao.edu/astro/VOBS/astronomy/jun06/br122b/br122btsm.SC.ps.gz

That looks a bit messy. BR122B was a multi-frequency observing run, and all points are plotted together. You can see the values of T_{sys} in the TY table (see Illustration 1):

```
> task 'snplt'
> inext 'cl'
> optype 'ty'
> dotv 1
```

Well, it seems that there are some points at the beginning of each scan that are too high. Probably the antenna was slewing, or wrong values from another frequency were written into this table. You should edit out these points as follows:

```
> task 'snedt'
> inext 'ty'
> bif 1
> eif 8
> dotv 1
```

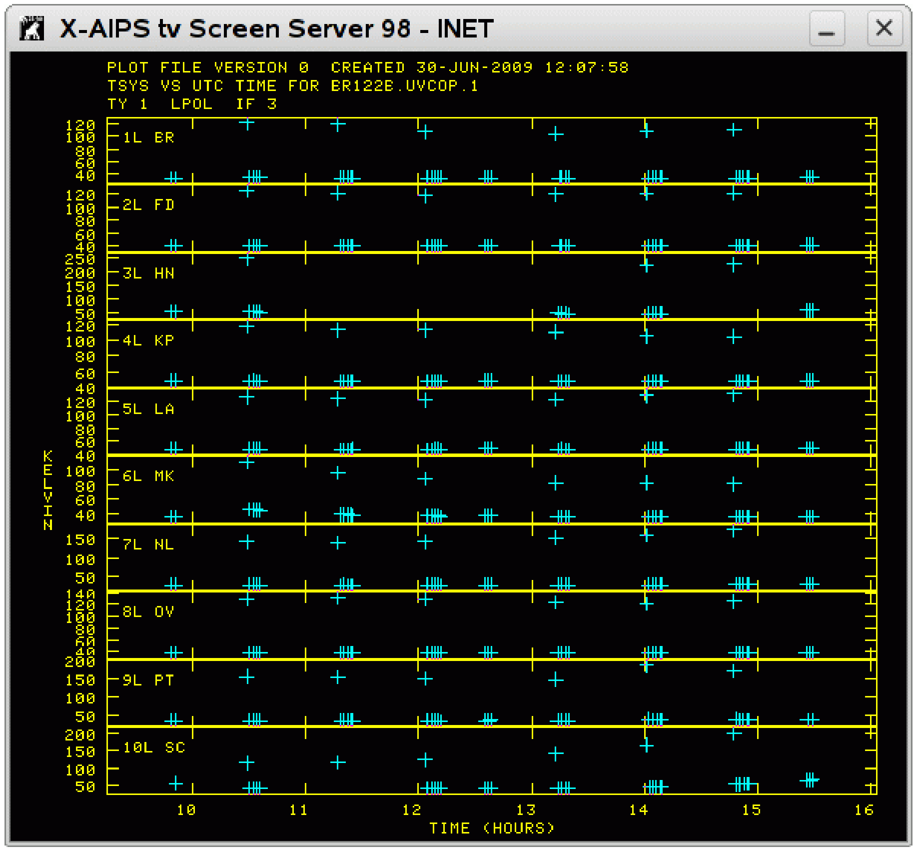

Illustration 1: Pre-edited Tsys table (SNPLT)

You remove the outliers in the AIPS TV window, and then you get what is shown on Illustration 2. The T_{sys} values are now in a narrow range of some tens of degrees Kelvin.
Having done this, one can proceed further.

If you want to perform some special analysis implying phase referencing or polarisation calibration, you need to remove the ionospheric dispersive delay, fix the earth orientation parameters in the data, and correct for the parallactic angle. This is not needed for most purposes in continuum imaging at this wavelength. Anyway, let's get into that.

To correct the ionosphere, you need to apply `tecor`, you get this with the utility `vlbatecr`.

In case you find a problem with the utility, you should download this file:

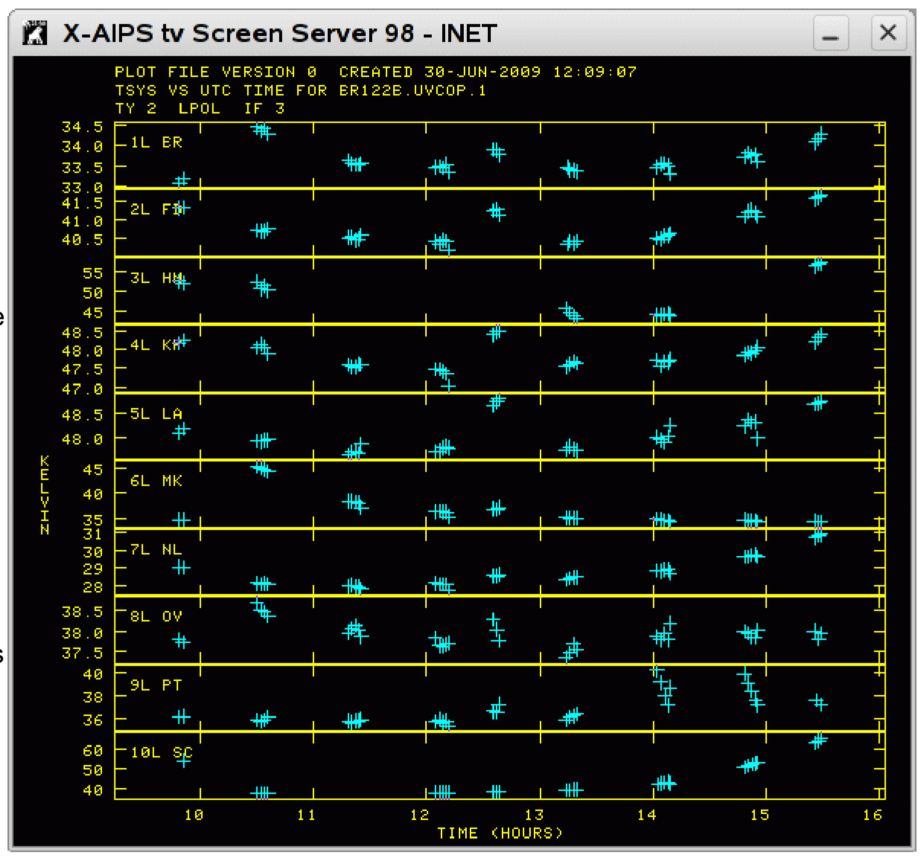

Illustration 2: Tsys table after editing

ftp://cddis.gsfc.nasa.gov/gps/products/ionex/2006/159/jplg1590.06i.Z into your area. Uncompress it, and read it with tecor, which will modify CL table, as follows:

```
> task 'tecr'
> infile
'MYAREA:jlpg1590.06i
> aparm 1 0
> go
```

So you produce a new CL table, #2, including the ionosphere correction. You can inspect the data before and after this (Illustration 3) to see the changes:

```
> task 'vplot'
> bparm 0 2
> aparm 0
> docal 1
> antennas 5
> grchan 1
> gainuse 1
> go
> grchan 2
> gainuse 2
> go
```

At this point you can fix the Earth Orientation Parameters:

```
> vlbaeops
```

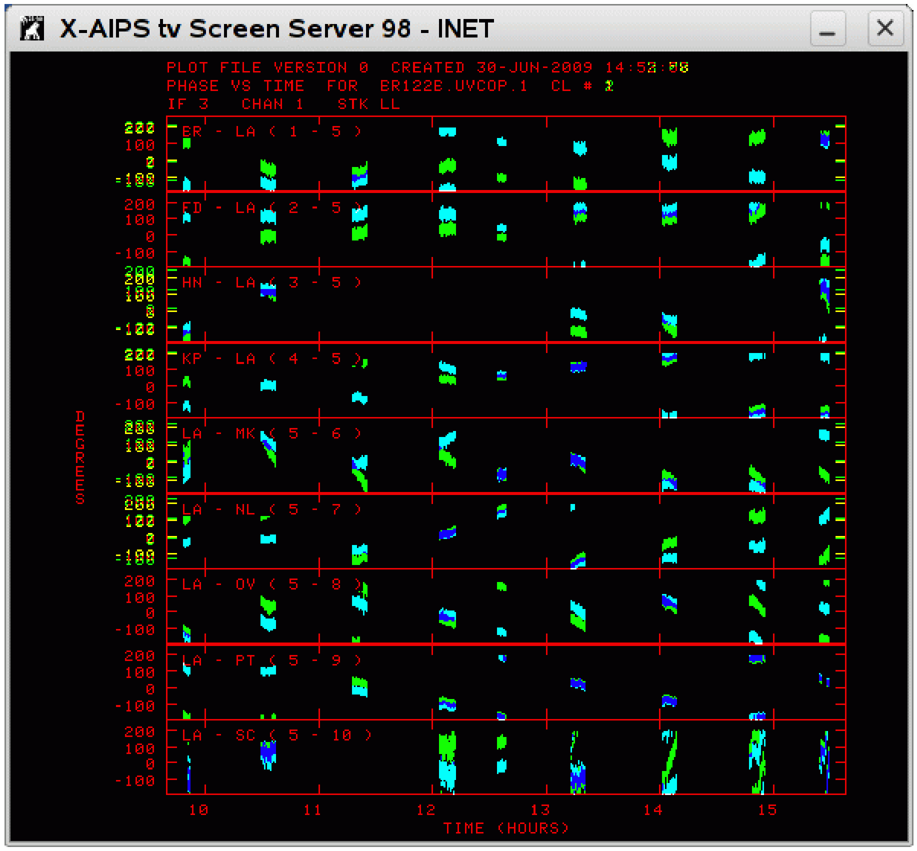

Illustration 3: Phases before and after ionospheric correction

It will create a new CL version, #3, by application of this file to the data: http://gemini.gsfc.nasa.gov/solve_save/usno_finals.erp

Again, you can check what was done to the data with snplt. Some corrections of picoseconds have been applied to the delay values, and of microhertz to the rate values.

It is time to correct for the digital sampling bias with accor, and to determine the gain factors (which convert correlation coefficients into flux density values, given in Jy). This is computed using measured system temperatures and gain curves by the task apcal. The results are written to SN tables and applied to CL tables. The utility vlbacala performs together accor, snsmo, clcal, apcal, and clcal:

```
> restore 0
> run vlbautil
> getn N
> refant 5
> vlbacala
```

This will create a SN#1 from accor, which will be smoothed by snsmo, copied back into SN#1 by tacop, and then applied to CL #3 to get CL #4. apcal will take TY#2 and GC#1 and create SN#2, which is applied to CL#4 to get CL#5. Take a deep breath, drink some water, and go further.

In summary:

SN#1 contains sampler corrections (factors should be around 1)
SN#2 contains gain corrections (factors should be around 15-20 for the VLBA at this frequency)
CL#4 adds sampler corrections

```
CL#5 adds gain corrections
```

The resulting calibration, written in CL#5, should be checked again with `snplt.` Bad points should be edited out, if appearing. CL#5 (plotting all IFs together with `opcode 'alif')` should look similar to Illustration 4.

It is time to calibrate the delay, rate, and phase. At this stage, one should save the tables, to be able to come back here if things get wrong or important CL tables are removed by accident. To save your tables, use `tasav:`

```
> task 'tasav'
> outcla 'tasav'
> go
```

To check now the structure of your data for a given time as a function of frequency, you can use `possm` (`vlbacrpl` is the short version of that). The goal now is to get a zero residual phase to be able to average the data in frequency.

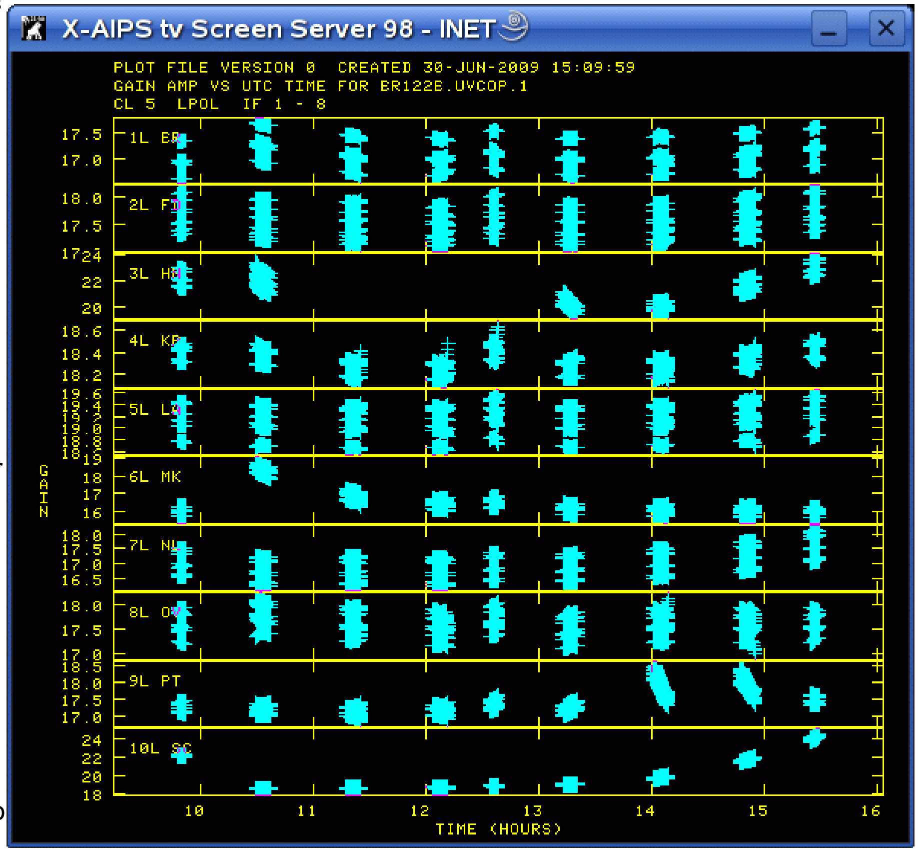

Illustration 4.: CL table after applying sampler and amplitude corrections.

The first, simple correction, is the parallactic angle (angle between receivers and the sky meridian). This correction is performed with `vlbapang` (fixing the CL table with the task `clcor`). This creates CL#6.

You can checkthe phases before and after running the parallactic angle correction with `snplt`,

There are some instrumental delay offsets which have to be removed from the data. For this, the VLBA measures pulse-cal values, written in the PC table. You should inspect the PC table with `snplt.` There are some values taken every few minutes for each antenna. You will notice as well that not all scans have measured values. You need a time period of one-to-two minutes where all antennas have measured PC tones. You should consult again the output of `listr` using the `'matx'` option to see where all antennas were present in a scan. This is the case, e.g., for 0/13:15:00-0/13:17:00 (CTA102). The `timerang` adverb in `snplt` can show that.

For the selected time, the amplitude and phase as a function of frequency are plotted as follows:

```
> run vlbautil
> timer 0 13 15 0 0 13 17 0
> refant 5
```

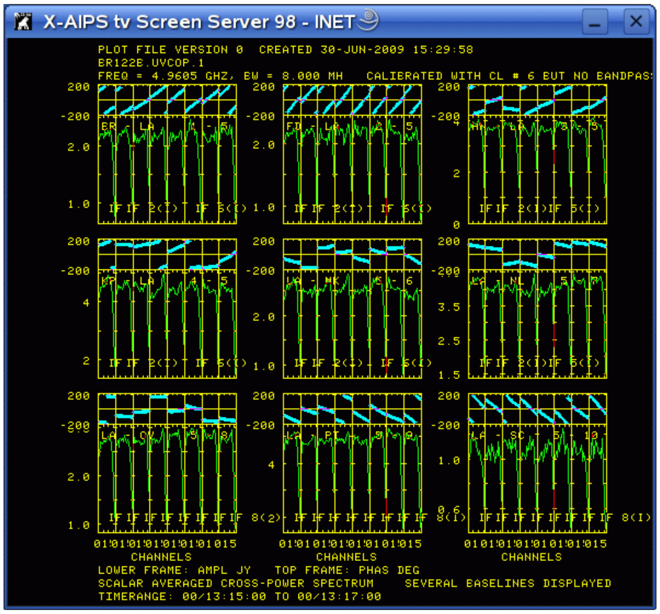

Illustration 5.: POSSM output before pulse cal correction, with LA as reference antenna.

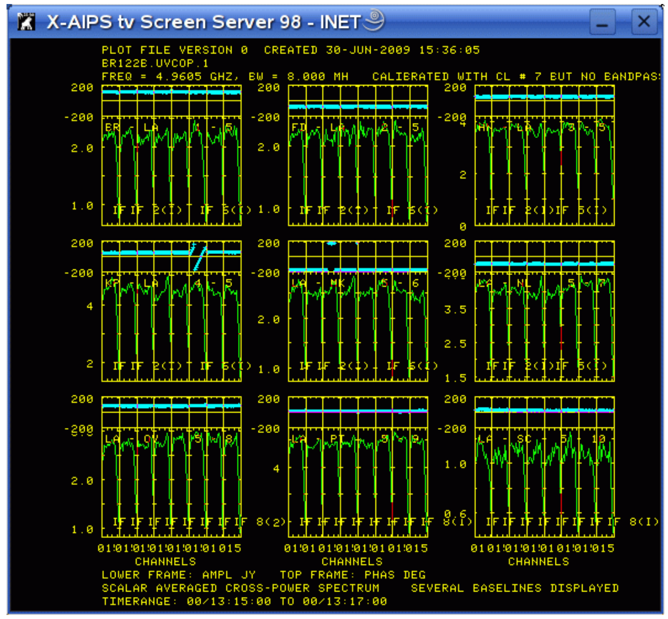

Illustration 6.: POSSM after the first attempt to get the phase-cal correction. Notice that the IF#6 in KP (middle, left panel) has a wrong correction.

```
> gainuse 6
> dotv 1
> vlbacrpl
```

That produces the plot shown in Illustration 5. To get correct offsets between the phases at different IFs right, and their slopes, we will apply `pcor (vlbapcor)`, as follows:

```
> run vlbautil
> timer 0 13 15 0 0 13 17 0
> refant 5
> calsour 'cta102' ''
> opcode ''
> gainuse 6
```

This creates SN#3 with the phase-cal instrumental corrections, and applies it to CL#6 to produce CL#7. We obtain the corrected phases, as shown in Illustration 5. Notice, however, that the IF6 phases for KP is wrong! We don't know why, but it is easier to choose an alternative time period instead of investigating the cause of this. We check another time range where all phase-cal values are present again, with `snplt`. We erase SN#3 and CL#7 with `extdest` (carefully!) before proceeding.

```
> inp extdest
> inext 'sn'
> invers 3
> extdest
> inext 'cl'
> invers 7
> extdest
```

We find an alternative time range at 0/13:19:45-0/13:20:45. Applying `vlbapcor` again, we get a good pulse-cal correction. The phases before and after correction are shown together in Illustration 9 (`possm` with two different `grchan` values to overlap them).

Now that we have no phase offsets between IFs and no slopes in the phase as a function of frequency over the full bandwidth, we can proceed with the delay and rate calibration for the whole experiment. We want to remove global frequency- and time-dependent phase errors for the complete time range. This is done with the task

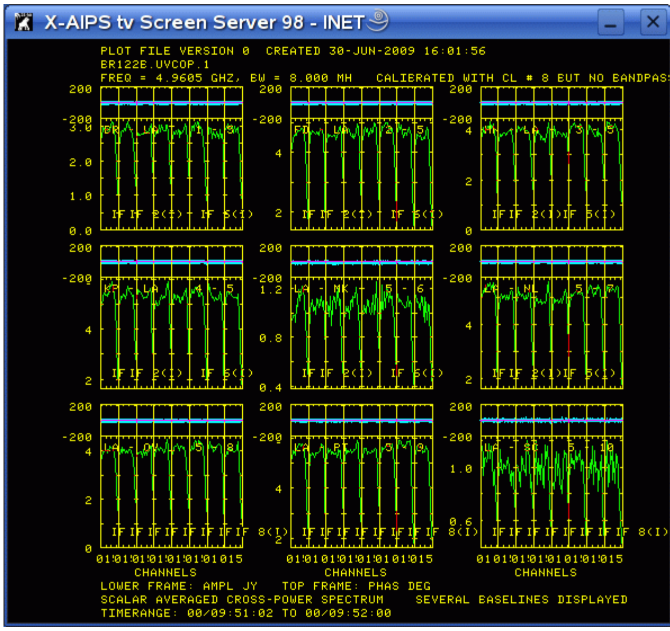

Illustration 7.: POSSM plot after fringe fitting for a given time and reference antenna.

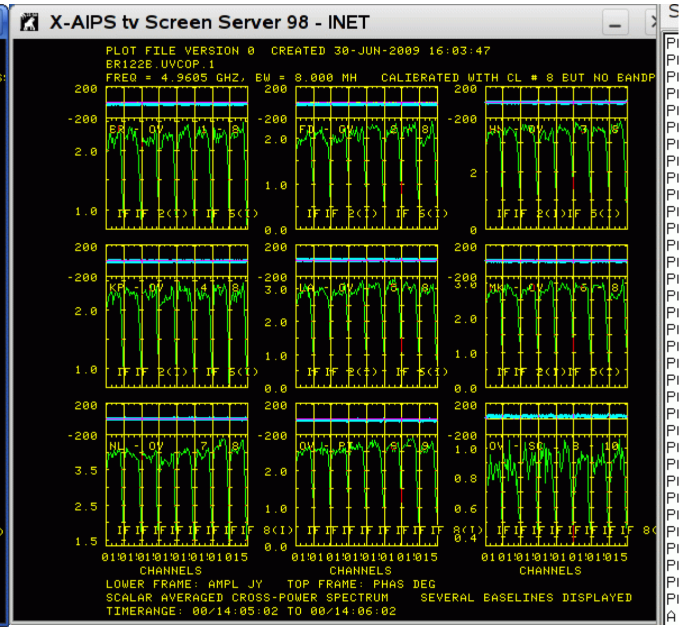

Illustration 8.: POSSM plot after fringe fitting for a different time and reference antenna.

`fring` and is the heart of the VLBI data analysis. The pipeline version of this is, e.g., `vlbafrng`.

```
> restore 0
> run vlbautil
> getn N
> refant 5
> interpol '2pt'          ! interpolation option for the CL table
> sources ''
> solint 2                ! 2min solution
```

This produces 2248 good solutions. There are no failures running the programme (the sources are bright)! The results will be written in SN#4 and applied to CL#7, producing CL#8. Now we should check again the solutions with `snplt` and `possm`. Wrong solutions or outliers should be edited out. In our case, this is not necessary. Two `possm` plots showing different scans with two different reference antennas are presented in Illustration 7 and 8.

We have now finished the amplitude- and phase-calibration! For imaging purposes, we can now average the data in frequency and time, and export them outside of the great world of `aips`.

Export your data into single-source files with `split`.

```
> task 'split'
> gainuse 8
> aparm 2 0               ! to get all channels averaged in IF, keeping IF separated
> docalib 2
```

And so you have single-source files like this, which can be imaged:

```
>imh
AIPS 1: Image=CTA102     (UV)         Filename=CTA102      .SPLIT .   1
AIPS 1: Telescope=VLBA                Receiver=VLBA
AIPS 1: Observer=BR122                User #= 1000
AIPS 1: Observ. date=08-JUN-2006      Map date=30-JUN-2009
AIPS 1: # visibilities     56069      Sort order  TB
AIPS 1: Rand axes: UU-L-SIN  VV-L-SIN  WW-L-SIN  TIME1  BASELINE
AIPS 1:            INTTIM  GATEID  CORR-ID  WEIGHT  SCALE
AIPS 1: ----------------------------------------------------------------
```

```
AIPS 1: Type     Pixels   Coord value      at Pixel      Coord incr    Rotat
AIPS 1: COMPLEX       1   1.0000000E+00        1.00   1.0000000E+00    0.00
AIPS 1: STOKES        1  -2.0000000E+00        1.00  -1.0000000E+00    0.00
AIPS 1: FREQ         16   4.9604900E+09        0.53   5.0000000E+05    0.00
AIPS 1: IF            8   1.0000000E+00        1.00   1.0000000E+00    0.00
AIPS 1: RA            1    22 32 36.409        1.00        3600.000    0.00
AIPS 1: DEC           1    11 43 50.904        1.00        3600.000    0.00
AIPS 1: ------------------------------------------------------------------
AIPS 1: Coordinate equinox 2000.00
AIPS 1: Rest freq   2254.490          Vel type: OPTICAL wrt YOU
AIPS 1: Alt ref. value  0.00000E+00  wrt pixel     1.00
AIPS 1: Maximum version number of extension files of type FQ is   1
AIPS 1: Maximum version number of extension files of type HI is   1
AIPS 1: Maximum version number of extension files of type OB is   1
AIPS 1: Maximum version number of extension files of type AN is   1
AIPS 1: Maximum version number of extension files of type WX is   1
```

`fittp` will write it out from `aips`.

You find an overall summary of the used `aips` tasks and tables in Illustration 10, and including the `vlbarun` utilities, in Illustration 11.

Congratulations and good luck with `difmap`!

Illustration 9.: Phase and amplitude vs frequency before and after successful phase-cal correction.

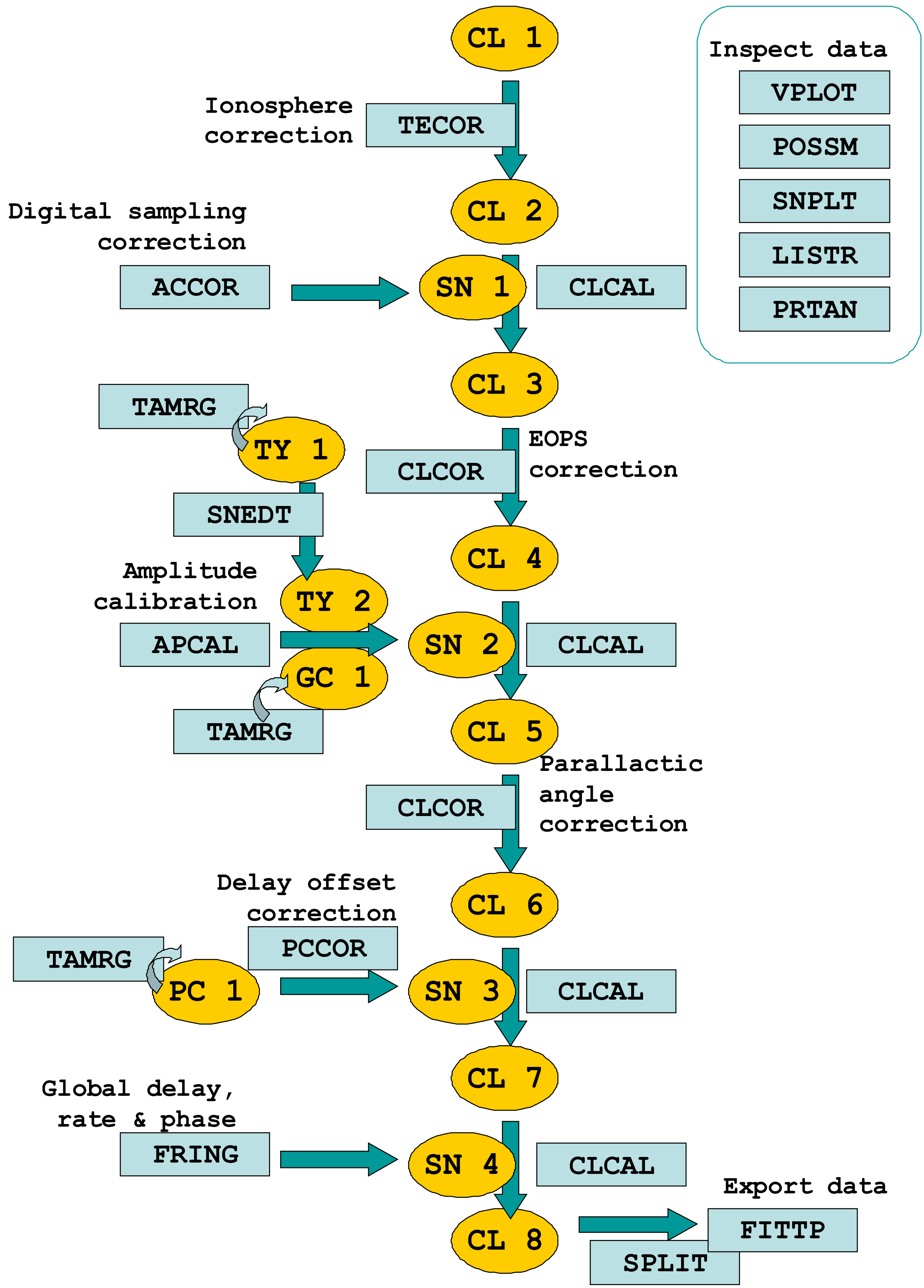

Illustration 10: Summary of AIPS tasks and files

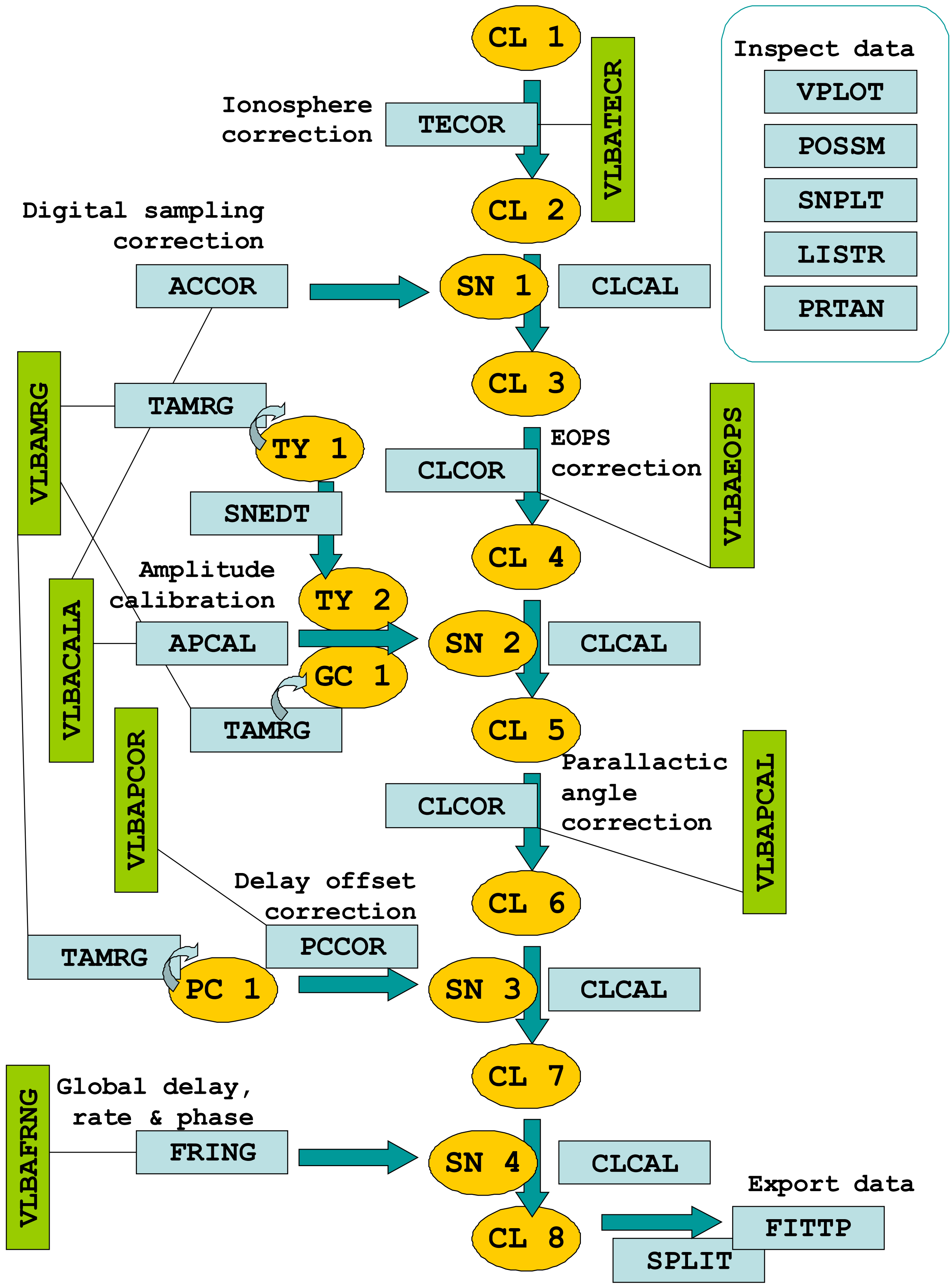

Illustration 11: Summary of AIPS VLBARUN utilities, tasks, and tables