

ERIS 2013 VLBI Tutorial

The Very Long Baseline Interferometry (VLBI) technique provides a way to map the radio emission in the source at the milliarcsecond-scale level (sub-mas or 10 mas scales, depending on the observing frequency and the baseline length). The European VLBI Network (EVN) is one of the most sensitive VLBI networks. VLBI is very useful to probe very high brightness temperatures that is typically observed in compact, non-thermal sources. The EVN is particularly suited (among other things) to map structures on 10-mas scales in weak objects. We however need nearby compact and bright calibrators, and use the so called phase-referencing technique (quick switching between calibrator and target) to calibrate data on faint sources. In this tutorial we will reduce a simple continuum, phase-referencing EVN data set. The following files will be needed, the raw data in IDI FITS format:

rf006b_1_1.IDI1
rf006b_1_1.IDI2
rf006b_1_1.IDI3
rf006b_1_1.IDI4

Those who are doing only the general VLBI tutorial will need at least the first file. Those who will participate in the second VLBI tutorial will have to download all files from the ERIS webpage. Besides the raw data, we will need the EVN pipeline calibration tables, as well as the pipeline calibrated data of the phase-reference source and the calibrator:

rf006b.tasav.FITS
J1217+3007.UVDATA.FITS
J121839.7.UVDATA.FITS

The files belong to an EVN user project (RF006) that are now publicly available from the EVN Data Archive as well. All EVN projects are calibrated by a pipeline and the results are stored in the archive as well. This provides a good starting point to the users, and makes EVN data processing much easier and quicker. We are now ready to start the calibration of the data set. In the following we will (loosely) follow the data reduction steps described in the EVN Data Analysis Guide (http://www.evbi.org/user_guide/guide/userguide.html).

DATA PROCESSING

Before starting AIPS (13DEC11 or later version), define an environment variable for the directory where your data are. In c-shell you do it like this:

```
setenv MYDATA <directory>
```

Start AIPS with the default printer, and pick a user number (>1). To load the data we use the task FITLD.

```
FITLD
>task 'FITLD'           {always start a task like this}
>datain 'MYDATA:rf006b_1_1.IDI1' {no closing apostrophe, otherwise AIPS will
                               assume all CAPITAL characters in the filename}

>outdisk 1
>douvcomp -1; digicor -1
>ncount 1
>outman 'rf006b'
>inp                       {to double check input adverbs;
                               most adverbs should stay the default}

>go                       {always run a task with 'go'}
```

Those who will participate the second VLBI tutorial please instead use the following adverbs to read in and concatenate all the files to a single dataset:

```
FITLD
>task 'FITLD'
>default
>datain 'MYDATA:rf006b_1_1.IDI' {no number at the end, AIPS will find it out!}
>outdisk 1
>douvcomp -1; digicor -1
>ncount 4                       {to read in 4 files}
>doconcat 1                     {to create a single file in AIPS}
>outnam 'rf006b'
>inp
>go
```

TIP: after 'go', the task input adverbs are preserved. To read in the inputs from the last 'go' for a task, type 'tget <task name>'.

Look at the message server to see how it proceeds (AIPS_MSGSRV window).

```

jop86 > FITLD1: Task FITLD (release of 31DEC11) begins
jop86 > FITLD1: Create RF006B .UVDATA. 1 (UV) on disk 1 cno 3
jop86 > FITLD1: FRINI: 'BB_CHAN' COLUMN NOT FOUND
jop86 > FITLD1: Sky frequencies (MHz) before re-ordering occurs:
jop86 > FITLD1: Incoming FREQID # 1
jop86 > FITLD1: 1626.99 1634.49 1642.99 1650.49
jop86 > FITLD1: 1658.99 1666.49 1674.99 1682.49
jop86 > FITLD1: ATINI: 'POLCALA' COLUMN NOT FOUND
jop86 > FITLD1: ATINI: 'POLCALB' COLUMN NOT FOUND
jop86 > FITLD1: TABHDR: column 10 type FLUX TDIM ignored
jop86 > FITLD1: CL table interval set at 1.00 minutes
jop86 > FITLD1: Current file has 313149 visibilities
jop86 > FITLD1: File ref. freq: 1626.99 MHz
jop86 > FITLD1: Found 1156+295 at 0/19:50:41 src # 12
jop86 > FITLD1: fqid # 1
jop86 > FITLD1: 10000 vis. written
jop86 > FITLD1: 20000 vis. written
jop86 > FITLD1: Found J1217+3007 at 0/20:05:41 src # 13
jop86 > FITLD1: 30000 vis. written
jop86 > FITLD1: Found J121839.7 at 0/20:09:40 src # 3
jop86 > FITLD1: 40000 vis. written
...
jop86 > FITLD1: Telescope=EVN Receiver=VLBA
jop86 > FITLD1: Observer=RF006B User#=1220
jop86 > FITLD1: Observ. date=21-APR-2009 Map date=28-AUG-2013
jop86 > FITLD1: # visibilities 973236 Sort order TB
jop86 > FITLD1: Rand axes: UU-L-SIN VV-L-SIN WW-L-SIN TIME1 BASELINE
jop86 > FITLD1: FREQSEL SOURCE INTTIM CORR-ID
jop86 > FITLD1: -----
jop86 > FITLD1: Type Pixels Coord value at Pixel Coord incr Rotat
jop86 > FITLD1: COMPLEX 3 0.0000000E+00 1.00 1.0000000E+00 0.00
jop86 > FITLD1: STOKES 4 -1.0000000E+00 1.00 -1.0000000E+00 0.00
jop86 > FITLD1: FREQ 16 1.6269900E+09 1.00 5.0000000E+05 0.00
jop86 > FITLD1: IF 8 1.0000000E+00 1.00 1.0000000E+00 0.00
jop86 > FITLD1: RA 1 01 33 29.289 1.00 3600.000 0.00
jop86 > FITLD1: DEC 1 30 45 37.493 1.00 3600.000 0.00
jop86 > FITLD1: -----
jop86 > FITLD1: Coordinate equinox 2000.00
jop86 > FITLD1: Maximum version number of extension files of type HI is 1
jop86 > FITLD1: Maximum version number of extension files of type AT is 1
jop86 > FITLD1: Maximum version number of extension files of type NX is 1
jop86 > FITLD1: Maximum version number of extension files of type CL is 1
jop86 > FITLD1: Maximum version number of extension files of type CT is 1
jop86 > FITLD1: Maximum version number of extension files of type FQ is 1
jop86 > FITLD1: Maximum version number of extension files of type AN is 1
jop86 > FITLD1: Maximum version number of extension files of type SU is 1
jop86 > FITLD1: ----- FILE 4 LOADED -----
jop86 > FITLD1: Appears to have ended successfully
jop86 > FITLD1: jop86 31DEC11 TST: Cpu= 32.0 Real= 116 IO= 57

```

Load the (gunzipped) pipeline calibration tables as a dummy dataset:

```
FITLD
>tget fitld
>datain 'MYDATA:rf006b.tasav.FITS
>outclass 'tasav'
>go
```

To see your file(s), type

```
>clrn; indi 1; cata          {etc.}

>cata
AIPS 1: Catalog on disk 1
AIPS 1:  Cat Usid Mapname      Class  Seq  Pt      Last access  Sta
AIPS 1:   1 1220 RF006B        .UVDATA.    1  UV 28-AUG-2013 17:16:08
AIPS 1:   2 1220 RF006B        .TASAV .    1  UV 28-AUG-2013 17:16:05
```

To see calibration tables attached to a uv file:

```
>getn <AIPS catalog number>; imhead
```

Shall we have a look at the FITS header of the data we have just loaded in:

```

>getn 1
AIPS 1: Got(1) disk= 1 user=1220 type=UV RF006B.UVDATA.1
>imhead
AIPS 1: Image=MULTI (UV) Filename=RF006B .UVDATA. 1
AIPS 1: Telescope=EVN Receiver=VLBA
AIPS 1: Observer=RF006B User #= 1220
AIPS 1: Observ. date=21-APR-2009 Map date=28-AUG-2013
AIPS 1: # visibilities 973236 Sort order TB
AIPS 1: Rand axes: UU-L-SIN VV-L-SIN WW-L-SIN TIME1 BASELINE
AIPS 1: FREQSEL SOURCE INTTIM CORR-ID
AIPS 1: -----
AIPS 1: Type Pixels Coord value at Pixel Coord incr Rotat
AIPS 1: COMPLEX 3 0.0000000E+00 1.00 1.0000000E+00 0.00
AIPS 1: STOKES 4 -1.0000000E+00 1.00 -1.0000000E+00 0.00
AIPS 1: FREQ 16 1.6269900E+09 1.00 5.0000000E+05 0.00
AIPS 1: IF 8 1.0000000E+00 1.00 1.0000000E+00 0.00
AIPS 1: RA 1 01 33 29.289 1.00 3600.000 0.00
AIPS 1: DEC 1 30 45 37.493 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 FG 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 NX 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 CT 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 AN is 1
AIPS 1: Maximum version number of extension files of type SU is 1
AIPS 1: Keyword = 'OLDRFQ ' value = 1.62699000D+09

```

The data have various tables attached to them. These contain information e.g. on the telescopes used and what is their antenna numbers AIPS is using internally (AN: antenna table). We will print this information *** on screen*** with PRTAB.

```

PRTAB
>inext 'an'
>doctr 1
> go

```

We would like to plot some data for baselines to one of the telescopes (e.g. Medicina, antenna 2 in this data set), phase and amplitude versus frequency. First, we will have to look for a short data segment ('scan') where a compact and very bright calibrator ('fringe-finder source') was observed. We use LISTR for that.

```
LISTR
>optype 'scan'
>docrt 1 {docrt >0 for printing on screen!}
>go
```

```
jop86 LISTR(31DEC11) 1220 28-AUG-2013 17:19:21 Page 1
File = RF006B .UVDATA. 1 Vol = 3 Userid = 1220
Freq = 1.626990000 GHz Ncor = 4 No. vis = 973236
Scan summary listing
```

Scan	Source	Qual	Calcode	Sub	Timerange	FrqID	START VIS	END VIS
1	1156+295	:0001		1	0/19:50:41 - 0/20:03:39	1 1	28008	
2	J1217+3007	:0001		1	0/20:05:41 - 0/20:09:38	1	28009	36576
3	J121839.7	:0001		1	0/20:09:41 - 0/20:13:09	1	36577	44064
4	J1217+3007	:0001		1	0/20:13:11 - 0/20:14:28	1	44065	46248
5	J121839.7	:0001		1	0/20:14:32 - 0/20:17:59	1	46249	53736
6	J1217+3007	:0001		1	0/20:18:41 - 0/20:19:38	1	53737	55824
7	J121839.7	:0001		1	0/20:19:41 - 0/20:23:09	1	55825	63312
8	J1217+3007	:0001		1	0/20:23:12 - 0/20:24:29	1	63313	65496
9	J121839.7	:0001		1	0/20:24:31 - 0/20:27:59	1	65497	72984
10	J1217+3007	:0001		1	0/20:28:42 - 0/20:29:39	1	72985	75072
11	J121839.7	:0001		1	0/20:29:42 - 0/20:33:08	1	75073	82560
12	J1217+3007	:0001		1	0/20:33:11 - 0/20:34:28	1	82561	84744
13	J121839.7	:0001		1	0/20:34:31 - 0/20:37:58	1	84745	92232
14	J1217+3007	:0001		1	0/20:38:42 - 0/20:39:38	1	92233	94320
15	J121839.7	:0001		1	0/20:39:41 - 0/20:43:09	1	94321	101808
16	J1217+3007	:0001		1	0/20:43:12 - 0/20:44:29	1	101809	103992
17	J121839.7	:0001		1	0/20:44:31 - 0/20:47:59	1	103993	111480
18	J1217+3007	:0001		1	0/20:48:41 - 0/20:49:38	1	111481	113568
19	J121839.7	:0001		1	0/20:49:41 - 0/20:53:09	1	113569	121056
20	J1217+3007	:0001		1	0/20:53:12 - 0/20:54:29	1	121057	123240

...

First scan on 1156+295 is a very bright and compact fringe-finder. We select just a brief two minutes of data from that scan; for a bright fringe-finder it gives sufficient signal-to-noise ratio, and the two minutes is shorter than the coherence time at the observing frequency of 1.6 GHz.

```

POSSM
>task `possm`
>docal -1
>timer 0 19 52 0 0 19 54 0
>antennas 2 0
>baseline 0
>dotv 1
                                     {for plotting on TV server}
>aparm 0
>aparm(9) = 1
>nplots 4
>go

```

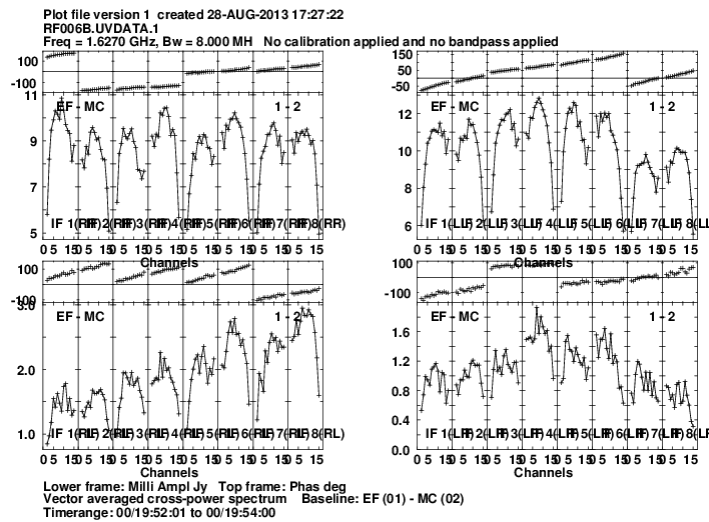


Fig. 1 Plot of raw data on the fringe-finder 1156+295. Four polarizations are shown: RR (top left), LL (top right), RL (bottom left), LR (bottom right) for the baseline Medicina-Effelsberg. There is a residual delay in the data, visible in the frequency dependence of phase (on top of each panel). There is sometimes a phase jump between subbands, which will have to be corrected for. The amplitudes are not calibrated yet, and the bandpass shape of each subband is clearly visible.

Copy flag and calibration tables over to the data file using TACOP:

```

TACOP
>task `tacop`
>getn 2
AIPS 1: Got(1)   disk= 1   user=1219   type=UV   RF006B.TASAV.1
>geto 1
AIPS 1: Got(0)   disk= 1   user=1219   type=UV   RF006B.UVDATA.1

```

```

>inext 'fg'
>inver 1
>go

>inext 'cl'
>inver 2
>ncount 1
>go

```

Plot the data again, but now applying CL.2

POSSM

```
>tget possm
```

```
>aparm 0, 1, 0, 2, 0, 0, 0, 0, 1, 0
```

{for setting an amplitude range to show}

```
>docal 1
```

```
>gainuse 2
```

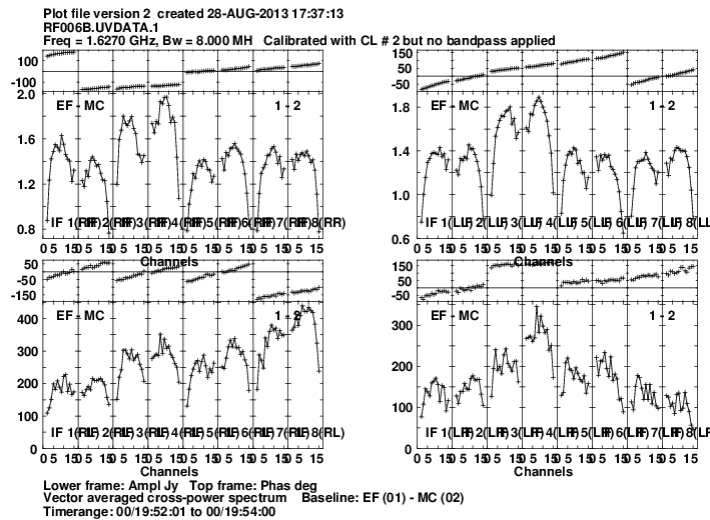


Fig. 2 The same data as Fig. 1, but the pipeline a-priori amplitude calibration applied (calibration table CL.2). The amplitudes are in units of Jansky (Jy). Subbands IF3 and IF4 have slightly higher amplitudes. This can be corrected for at a later stage during imaging and self-calibration. The cross-hand polarization amplitudes are lower than the parallel hand ones, as expected; these are partly caused by polarization leakage in the receivers, and partly due to source polarization. We will not focus on polarization calibration in this tutorial, we are only interested in the total intensity ($I = (RR+LL)/2$).

Manual phasecal: remove delay/phase difference between subbands. Will use the plotted 2 minutes of data on 1156+295, because it looks good quality. To fit for residual phases, delays and rates, we use the AIPS task FRING. During manual phasecal we are not interested in the rates, they will be zeroed.

```
FRING
>task `fring`
>timer 0 19 52 0 0 19 54 0
>calsour '1156+295' ''
>docal 1; gainuse 2
>doband -1; flagver 1
>antennas 0
>weightit 1 {changes data weights; optional, usually good for EVN data}
>refant 1 {in this data set antenna 1 is Effelsberg}
>solint 2
>aparm 3, 0, 0, 0, 0, 3, 5 {dparm(5)=0 is to find independent delay & phase solutions
                             for all IFs}
>dparm 1, 200, 50, 1, 0, 0, 0, 1 {dparm(8) = 1 to zero rate solutions}
>snver 0 {create new table}
>go
```

```
...
jop86 > FRING1: Ant(02): Phas= 9.6 rate= -0.33 delay= -17.33 SNR= 299.7
jop86 > FRING1: Ant(03): Phas= -34.3 rate= 0.07 delay= -2.48 SNR= 345.1
jop86 > FRING1: Ant(04): Phas= -72.1 rate= 0.33 delay= -3.83 SNR= 380.7
jop86 > FRING1: Ant(05): Phas= -95.3 rate= -0.04 delay= -6.93 SNR= 522.9
jop86 > FRING1: Ant(08): Phas= 98.4 rate= 0.20 delay= -10.03 SNR= 197.0
jop86 > FRING1: Standard RMS errors (deg, mHz, nsec):
jop86 > FRING1: Ant(02): Phas= 0.19 rate= 0.007 delay= 0.125
jop86 > FRING1: Ant(03): Phas= 0.17 rate= 0.006 delay= 0.108
jop86 > FRING1: Ant(04): Phas= 0.15 rate= 0.006 delay= 0.098
jop86 > FRING1: Ant(05): Phas= 0.11 rate= 0.004 delay= 0.071
jop86 > FRING1: Ant(08): Phas= 0.29 rate= 0.017 delay= 0.130
jop86 > FRING1: Found 102 good solutions
jop86 > FRING1: Failed on 26 solutions
jop86 > FRING1: Adjusting solutions to a common reference antenna
jop86 > FRING1: Appears to have ended successfully
jop86 > FRING1: jop86 31DEC11 TST: Cpu= 0.4 Real= 1 IO= 229
```

Note some telescopes have missing IFs in this data. We have solutions in all Ifs where it is expected.

Some AIPS tasks, like FRING create solution tables, that can be incrementally added to the existing calibration tables. To apply SN.1 solutions to CL.2 and write CL.3, we use the task CLCAL.

```

CLCAL (SN.1 + CL.2 => CL.3)
>task 'clcal'
>timer 0
>opcode 'cali'
>calsour '1156+295' ' '
>gainver 2
>gainuse 3
>snver 1
>refant 1
>go

```

```

POSSM
>tget possm
>gainuse 3
>tvini
>go

```

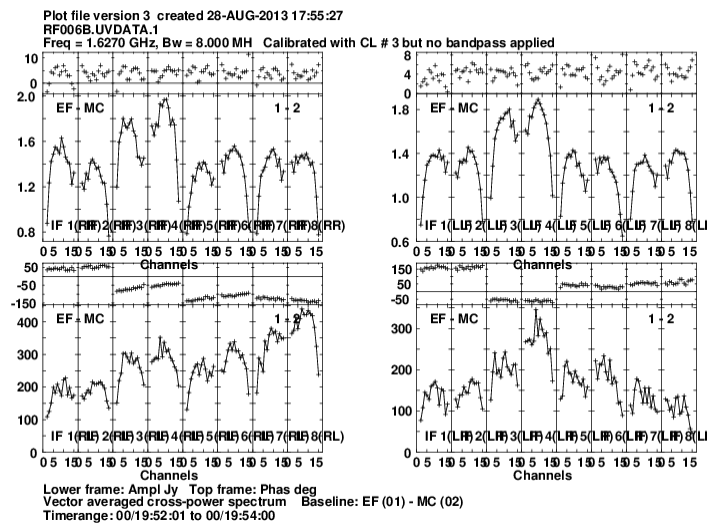


Fig. 3 After the manual phase calibration of the subbands, the phases become contiguous and close to zero (notice the phase scale difference compared to previous figures), as expected for a point source in the phase centre. The best fringe-finders are bright, and dominated by a mostly unresolved component. The residual phases are due to partly source structure and partly due to residual errors in the calibration (to be improved further in self-calibration and imaging).

Let's look at the phase-reference source data later in time. One may run LISTR again to find a time range for J1217+3007. We just randomly pick a scan.

```

POSSM
>tget  possm
>timer  0 21 48 50 0 21 49 30
>aparm  0
>aparm(9) = 1
>go

```

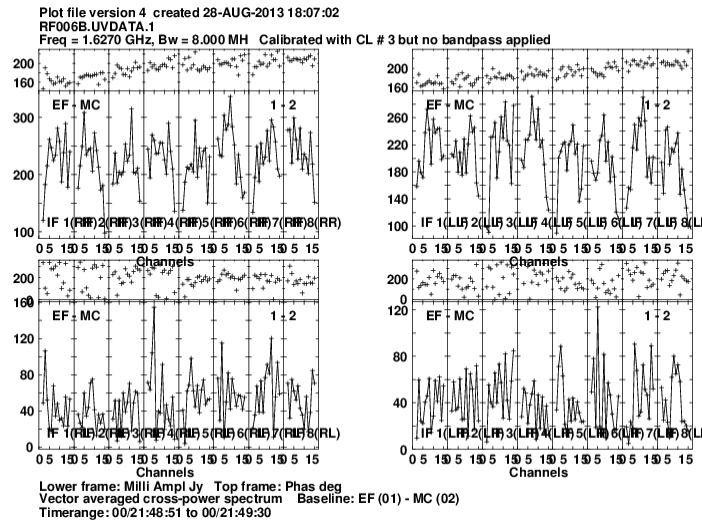


Fig. 4 As can be seen the phase-reference source is somewhat fainter. But it should be also compact with phases close to zero and no delay. So far we have only corrected for delay & phase errors for one particular time, when the fringe-finder was observed. We will have to repeat this process for the whole dataset. The phases nicely line up between the IFs because our earlier FRING run is still effective in that sense: IF to IF phase difference should normally stay constant during an observation (but it is not always that case, check carefully!). Our advantage compared to the pipeline FRING solutions is that it solves for the delay, rate and phase residuals independently in each IF, while we, after doing the manual phasecal, may combine all IFs to obtain higher signal to noise ratio solutions.

```

FRING
>tget  fring
>timer  0                                {all timerange}
>gainuse  3
>calsour  '1156+295' 'J1217+3007' ' '    {calibrators}
>aparm(5) = 1                             {combine IF for higher SNR}
>aparm(9) = 1                             {a trick to force FRING to really make an effort...}
>dparm(8) = 0                             {do not zero rates this time!}
>search  1, 5, 4                          {...if Ef fails, Wb and Tr may serve as reference antenna}
>go

```

```

...
jop86 > FRING1: IF( 1) RMS residual= 0.86291
jop86 > FRING1: IF number = 1 Poln. = 2
jop86 > FRING1: Fitted phases, rates, delays and SNR: [ P = phase(deg),
jop86 > FRING1: R = rate(mHz), D = Single-Band Delay(nsec), S = SNR ]
jop86 > FRING1: Ant(02): Phas= 155.2 rate= -0.71 delay= -10.44 SNR= 129.9
jop86 > FRING1: Ant(03): Phas= 23.5 rate= 0.80 delay= -0.93 SNR= 162.4
jop86 > FRING1: Ant(04): Phas=-100.4 rate= 1.16 delay= -0.90 SNR= 119.0
jop86 > FRING1: Ant(05): Phas= 142.0 rate= -0.36 delay= -0.76 SNR= 151.3
jop86 > FRING1: Ant(07): Phas=-117.7 rate= -0.32 delay= 2.65 SNR= 49.0
jop86 > FRING1: Ant(08): Phas= 14.0 rate= -0.16 delay= -0.03 SNR= 282.0
jop86 > FRING1: Ant(09): Phas= 182.3 rate= -0.29 delay= 1.85 SNR= 41.4
jop86 > FRING1: Standard RMS errors (deg, mHz, nsec):
jop86 > FRING1: Ant(02): Phas= 0.44 rate= 0.040 delay= 0.035
jop86 > FRING1: Ant(03): Phas= 0.35 rate= 0.029 delay= 0.027
jop86 > FRING1: Ant(04): Phas= 0.48 rate= 0.035 delay= 0.035
jop86 > FRING1: Ant(05): Phas= 0.38 rate= 0.028 delay= 0.027
jop86 > FRING1: Ant(07): Phas= 1.17 rate= 0.089 delay= 0.385
jop86 > FRING1: Ant(08): Phas= 0.20 rate= 0.017 delay= 0.015
jop86 > FRING1: Ant(09): Phas= 1.38 rate= 0.103 delay= 0.451
jop86 > FRING1: Found 11552 good solutions
jop86 > FRING1: Failed on 48 solutions
jop86 > FRING1: Adjusting solutions to a common reference antenna
jop86 > FRING1: Appears to have ended successfully
jop86 > FRING1: jop86 31DEC11 TST: Cpu= 26.1 Real= 27 IO= 8202

```

Signal to noise ratios are very good, as can be seen in the messages. An extremely low ratio of failed solutions, FRING has done a great job! SNPLT can be used to plot delay, phase and rate solutions, but for now we trust these solutions and will apply them to the so far highest version of the CL table, CL.3. CLCAL will run twice. First we use the 1156+295 solutions and apply them only for that source. Then, we will take solutions for the phase-reference source, and apply them to both J1217+3007, the reference source itself, and to the target data, J121839.7 as well.

```

CLCAL (SN.2 + CL.3 => CL.4)
>tget clcal
>timer 0
>opcode 'cali'
>calsour '1156+295' ' '
>sources '1156+295' ' '
>gainver 3
>gainuse 4
>snver 2
>refant 1
>go

```

```

CLCAL (SN.2 + CL.3 => CL.4; updating it for other sources)
>calsour 'J1217+3007' ' '
>sources 'J1217+3007' ' J121839.7' ' '
>interpol 'ambg' {to resolve phase ambiguities using the rate solutions}
>opcode 'cali'
>go

```

In the second CLCAL run we applied J1217+3007 solutions to both the phase-reference source and the target. CLCAL interpolated J1217+3007 solutions to the J121839.7 scans. This is phase-referencing.

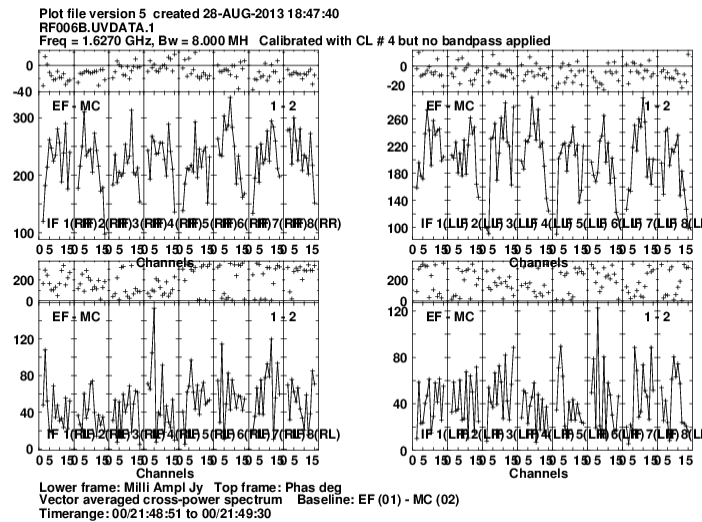


Fig. 5 The phase-reference source phases are now close to zero, at any time during the experiment. One could further improve the phase and amplitude calibration by imaging and self-calibrating the phase-reference source data, and apply those solutions to the target as well. We will not do this in this tutorial. Looking at a target scan with POSSM would show only noise because it is weak. The target should however show up later in the image, because we 'average' all data coherently (thanks to phase-referencing) in the image plane.

One may correct for the bandpass shape of the IFs, before applying the final solutions to the target. This is done with the task BPASS, and again, we need compact and bright calibrators. Here we derive a single bandpass solutions for the whole time range ('solint -1'), using all the calibrator data. BPASS must be run only when the delays have already been corrected for by FRING, because these are otherwise absorbed on the bandpass solution and will result in bad calibration.

```

BPASS
>task 'bpass'
>timer 0
>antennas 0
>calsour '1156+295' 'J1217+3007' ' '
>docal 1
>gainuse 4
>outver 1
>refant 1
>solint -1
>weightit 1
>flagver 1
>bpassprm 0
>go

```

Now we look at the bandpass solutions.

```

POSSM
>tget possm
>antennas 0
>baseline 0
>aparm(8) = 2                                {to show BP table}
>timer 0
>go

```

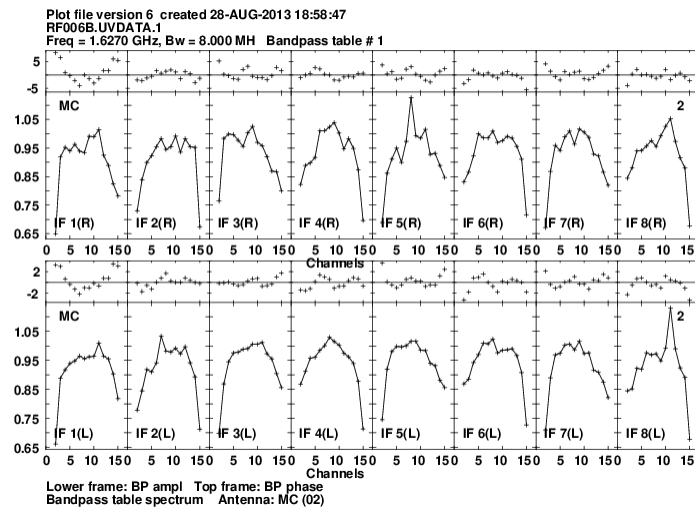


Fig. 6 Bandpass amplitude and phase solutions for Medicina, RCP (top) and LCP (bottom) polarizations.

Let's see the result of the final calibration, by applying the latest CL table together with the bandpass table to the data:

```

POSSM
>tget  possm
>timer  0 21 48 50 0 21 49 30
>antennas  2  0
>baseline  0
>aparm  0, 1, 0, 0.4, 0, 0, 0, 0, 0, 1, 0
>doband  1
>bpver  1
>docal  1
>gainuse  4
>go

```

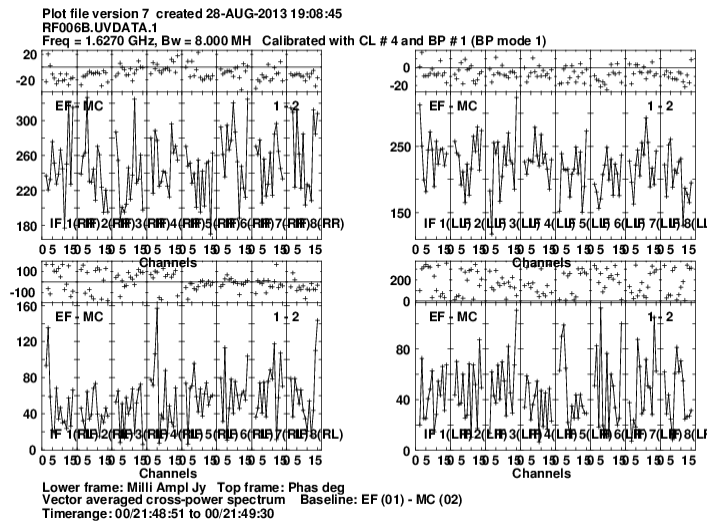


Fig. 7 The final calibration. Now ready to apply the final calibration table to all sources and average the data to some extent in frequency with SPLIT (optionally in time as well, if SPLAT is used). This way we will have a manageable size calibrated *uv*-data set. Note heavy averaging will limit the field of view of the observations, and may cause unpleasant side effects (bandwidth and time smearing, especially on long baselines).

```

SPLIT
>task 'split'
>outclass 'split'
>timer  0
>sources  ' '
>doband  1; bpver  1

```

```

>docal 1 ; gainuse 4
>flagver 1
>aparm 2 1 0 4
>go

```

Here is the list of *uv*-data files in our AIPS directory:

```
>uc
```

```
AIPS 1: Catalog on disk 1
```

```

AIPS 1: Cat Usid Mapname Class Seq Pt Last access Stat
AIPS 1: 1 1220 RF006B .UVDATA. 1 UV 28-AUG-2013 19:15:45
AIPS 1: 2 1220 RF006B .TASAV . 1 UV 28-AUG-2013 17:16:05
AIPS 1: 3 1220 J121839.7 .SPLIT . 1 UV 28-AUG-2013 19:15:40
AIPS 1: 4 1220 1156+295 .SPLIT . 1 UV 28-AUG-2013 19:15:41
AIPS 1: 5 1220 J1217+3007 .SPLIT . 1 UV 28-AUG-2013 19:15:44

```

We may proceed now with the imaging of J1217+3007 and J121839.7 (1156+295 was observed for a very short time, the *uv*-coverage is poor). The calibrated data may be imaged either in AIPS with IMAGR, or exported and imaged with your favorite imaging software. The last two figures show roughly what end result one should get.

Note that during this calibration we have made two errors. First of all, we have lost a telescope during the calibration steps. Find out which one, and find out what have we done wrong! Second, we have lost a source as well. Find out which one, and point to the calibration step where we did something wrong!

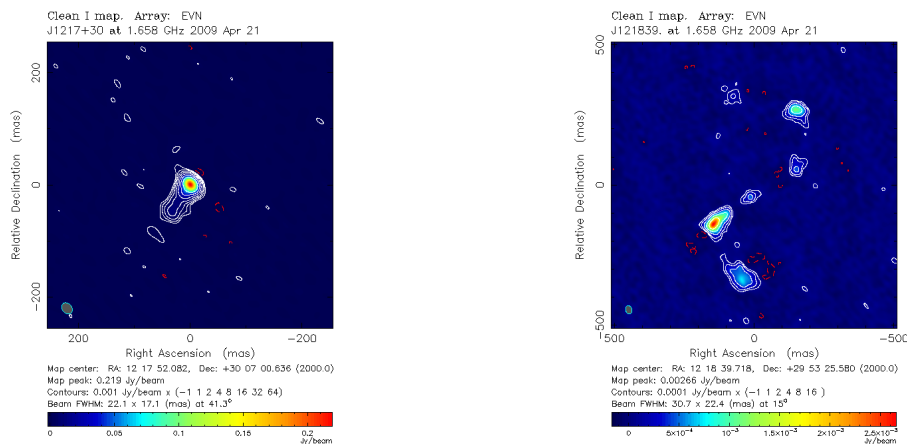


Fig. 8 Left: uniformly weighted image of the phase-reference source. Right: naturally weighted image of the target source. TIP: for imaging the target the noisy shortest baselines were flagged, and we did not use the telescope that was lost during the calibration, of course.