



Introduction

Normally Pico Veleta data is recorded for GMVA as PV (DBBC2) data in 8 band x 64 MHz per polarization setup. However, during the October 2019 (C192) GMVA session this data was recorded with wrong polarization setup for most of the session (during C192A, C192B and the first quarter of C192C parts both polarization channels recorded RCP and LCP was completely lost), due to an undetermined technical problem. Luckily Pico Veleta was also recording data with the other backend for testing purposes, DBBC3 in 16 band x 32 Mhz per polarization setup. To avoid the loss of the data the main production correlation was performed using this P3 data (for C192A and C192C also a correlation with PV was done to be used at PIs discretion).

Unfortunately, because DBBC3 is still in the commissioning stage, phase instability and small amplitude inconsistencies for different boards were found due to hardware problems. To compensate for this, additional per band delay corrections were applied during the correlation, which are described below.

.vex and .v2d channel setup of P3

The frequency setup for P3 in the \$FREQ section of ,vex files was done as follows:

```
def 86044.00MHz32x32MHz;
* mode = 1      stations =P3
    sample_rate =      64.000 Ms/sec;    * (2bits/sample)
    chan_def = : 86044.00 MHz : U :  32.00 MHz : &CH01 : &BBC01 :
&NoCal; *Lcp
    chan_def = : 86044.00 MHz : L :  32.00 MHz : &CH02 : &BBC01 :
&NoCal; *Lcp
    chan_def = : 86108.00 MHz : U :  32.00 MHz : &CH03 : &BBC02 :
&NoCal; *Lcp
    chan_def = : 86108.00 MHz : L :  32.00 MHz : &CH04 : &BBC02 :
&NoCal; *Lcp
    chan_def = : 86172.00 MHz : U :  32.00 MHz : &CH05 : &BBC03 :
&NoCal; *Lcp
    chan_def = : 86172.00 MHz : L :  32.00 MHz : &CH06 : &BBC03 :
&NoCal; *Lcp
    chan_def = : 86236.00 MHz : U :  32.00 MHz : &CH07 : &BBC04 :
&NoCal; *Lcp
    chan_def = : 86236.00 MHz : L :  32.00 MHz : &CH08 : &BBC04 :
&NoCal; *Lcp
    chan_def = : 86300.00 MHz : U :  32.00 MHz : &CH09 : &BBC05 :
&NoCal; *Lcp
    chan_def = : 86300.00 MHz : L :  32.00 MHz : &CH10 : &BBC05 :
&NoCal; *Lcp
    chan_def = : 86364.00 MHz : U :  32.00 MHz : &CH11 : &BBC06 :
&NoCal; *Lcp
    chan_def = : 86364.00 MHz : L :  32.00 MHz : &CH12 : &BBC06 :
&NoCal; *Lcp
    chan_def = : 86428.00 MHz : U :  32.00 MHz : &CH13 : &BBC07 :
&NoCal; *Lcp
    chan_def = : 86428.00 MHz : L :  32.00 MHz : &CH14 : &BBC07 :
&NoCal; *Lcp
```

Special processing of P3 (Pico Veleta DBBC3) data in C192 session

```

chan_def = : 86492.00 MHz : U : 32.00 MHz : &CH15 : &BBC08 :
&NoCal; *Lcp
chan_def = : 86492.00 MHz : L : 32.00 MHz : &CH16 : &BBC08 :
&NoCal; *Lcp
chan_def = : 86044.00 MHz : U : 32.00 MHz : &CH17 : &BBC09 :
&NoCal; *Rcp
chan_def = : 86044.00 MHz : L : 32.00 MHz : &CH18 : &BBC09 :
&NoCal; *Rcp
chan_def = : 86108.00 MHz : U : 32.00 MHz : &CH19 : &BBC10 :
&NoCal; *Rcp
chan_def = : 86108.00 MHz : L : 32.00 MHz : &CH20 : &BBC10 :
&NoCal; *Rcp
chan_def = : 86172.00 MHz : U : 32.00 MHz : &CH21 : &BBC11 :
&NoCal; *Rcp
chan_def = : 86172.00 MHz : L : 32.00 MHz : &CH22 : &BBC11 :
&NoCal; *Rcp
chan_def = : 86236.00 MHz : U : 32.00 MHz : &CH23 : &BBC12 :
&NoCal; *Rcp
chan_def = : 86236.00 MHz : L : 32.00 MHz : &CH24 : &BBC12 :
&NoCal; *Rcp
chan_def = : 86300.00 MHz : U : 32.00 MHz : &CH25 : &BBC13 :
&NoCal; *Rcp
chan_def = : 86300.00 MHz : L : 32.00 MHz : &CH26 : &BBC13 :
&NoCal; *Rcp
chan_def = : 86364.00 MHz : U : 32.00 MHz : &CH27 : &BBC14 :
&NoCal; *Rcp
chan_def = : 86364.00 MHz : L : 32.00 MHz : &CH28 : &BBC14 :
&NoCal; *Rcp
chan_def = : 86428.00 MHz : U : 32.00 MHz : &CH29 : &BBC15 :
&NoCal; *Rcp
chan_def = : 86428.00 MHz : L : 32.00 MHz : &CH30 : &BBC15 :
&NoCal; *Rcp
chan_def = : 86492.00 MHz : U : 32.00 MHz : &CH31 : &BBC16 :
&NoCal; *Rcp
chan_def = : 86492.00 MHz : L : 32.00 MHz : &CH32 : &BBC16 :
&NoCal; *Rcp
#endif;
*
```

compared with the normal PV \$FREQ setup:

```

def 86076.00MHz16x64MHz;
* mode = 1      stations =Pv
sample_rate = 128.000 Ms/sec; * (2bits/sample)
chan_def = : 86076.00 MHz : U : 64.00 MHz : &CH01 : &BBC01 :
&NoCal; *Rcp *
chan_def = : 86204.00 MHz : U : 64.00 MHz : &CH02 : &BBC02 :
&NoCal; *Rcp *
chan_def = : 86332.00 MHz : U : 64.00 MHz : &CH03 : &BBC03 :
```

```

&NoCal; *Rcp *
    chan_def = : 86460.00 MHz : U : 64.00 MHz : &CH04 : &BBC04 :
&NoCal; *Rcp *
    chan_def = : 86076.00 MHz : U : 64.00 MHz : &CH05 : &BBC05 :
&NoCal; *Lcp
    chan_def = : 86204.00 MHz : U : 64.00 MHz : &CH06 : &BBC06 :
&NoCal; *Lcp
    chan_def = : 86332.00 MHz : U : 64.00 MHz : &CH07 : &BBC07 :
&NoCal; *Lcp
    chan_def = : 86460.00 MHz : U : 64.00 MHz : &CH08 : &BBC08 :
&NoCal; *Lcp
    chan_def = : 86076.00 MHz : L : 64.00 MHz : &CH09 : &BBC01 :
&NoCal; *Rcp *
    chan_def = : 86204.00 MHz : L : 64.00 MHz : &CH10 : &BBC02 :
&NoCal; *Rcp *
    chan_def = : 86332.00 MHz : L : 64.00 MHz : &CH11 : &BBC03 :
&NoCal; *Rcp *
    chan_def = : 86460.00 MHz : L : 64.00 MHz : &CH12 : &BBC04 :
&NoCal; *Rcp *
    chan_def = : 86076.00 MHz : L : 64.00 MHz : &CH13 : &BBC05 :
&NoCal; *Lcp
    chan_def = : 86204.00 MHz : L : 64.00 MHz : &CH14 : &BBC06 :
&NoCal; *Lcp
    chan_def = : 86332.00 MHz : L : 64.00 MHz : &CH15 : &BBC07 :
&NoCal; *Lcp
    chan_def = : 86460.00 MHz : L : 64.00 MHz : &CH16 : &BBC08 :
&NoCal; *Lcp
endif;

```

Since LCP and RCP were recorded at two different Mk6 modules, two data streams were defined at the .v2d files:

```

ANTENNA P3 {
    datastreams = P3L, P3R
    zoom = 32mhz
}

DATASTREAM P3L {
    filelist = filelist.P3.LCP
    format=VDIF_8224-2048-16-2
}

DATASTREAM P3R {
    filelist = filelist.P3.RCP2
    format=VDIF_8224-2048-16-2
}

```

In addition, to correlate all stations in 16 x 32 MHz mode zoom bands were defined:

```

ZOOM 32mhz {
addZoomFreq = freq@86012/bw@32.0
addZoomFreq = freq@86044/bw@32.0
addZoomFreq = freq@86076/bw@32.0
addZoomFreq = freq@86108/bw@32.0
addZoomFreq = freq@86140/bw@32.0
addZoomFreq = freq@86172/bw@32.0
addZoomFreq = freq@86204/bw@32.0
addZoomFreq = freq@86236/bw@32.0
addZoomFreq = freq@86268/bw@32.0
addZoomFreq = freq@86300/bw@32.0
addZoomFreq = freq@86332/bw@32.0
addZoomFreq = freq@86364/bw@32.0
addZoomFreq = freq@86396/bw@32.0
addZoomFreq = freq@86428/bw@32.0
addZoomFreq = freq@86460/bw@32.0
addZoomFreq = freq@86492/bw@32.0
}

```

Determination and application of per band delay corrections

First, a few scans with good strong Ef - P3 fringes were selected based on initial correlations. In fact just one scan is enough, but a few in the beginning, middle and end of each experiment were processed to make sure that the solutions are stable. It turned out that apart from a small general clock correction in the .vex file for each experiment to compensate for the normal clock drift due to imperfect delay rate determination, exactly the same delay solutions work for the whole session, confirming that they are due to constant hardware peculiarities and not some other variable factors.

Just Ef and P3 stations were correlated for these scans and difx2mark4 conversion was done. Then fourfit fringe finding was run for each band, each time modifying the configuration file.

In fourfit syntax the 16 bands are:

```
freqs a b c d e f g h i j k l m n o p
```

First solution for *freqs b* (**note: b rather than a!**) was run and only LL single-band delay (SBD) was recorded. Since the first per band delay in .v2d file must be 0, this correction is applied to all bands by modifying the clock section of the .vex file in the usual way. Then the scan should be recorellated. If the correction was applied rightly, the new SBD for *freqs b* LL should be exactly 0. Now we can proceed with the other delays. Changing *freqs* parameter for each letter in sequence, we record SBD for both RR and LL. Then they should be applied in the following way:

```

ANTENNA P3 {
  datastreams = P3L, P3R
  zoom = 32mhz
  freqClockOffs= bL, aL, dL, cL, fL, eL, hL, gL, jL, iL, lL, kL, nL,
mL, pL, oL,
                bR, aR, dR, cR, fR, eR, hR, gR, jR, iR, lR, kR, nR,

```

```
mR, pR, oR
}
```

Here bL stands for delay correction determined from freqs b LL, aL - freqs a LL, bR - freqs b RR etc. bL must be 0, otherwise vex2difx will stop with an error. There will be a warning if bR is non-zero, but this one can safely be ignored.

The order of delay corrections in the .v2d file is somewhat counterintuitive, this has to do with the definitions of upper and lower sidebands in the .vex file. For each channel first goes the upper sideband, and then the lower sideband. Since in frequency the lower sideband is lower than the upper one, in terms of fourfit channels this corresponds to b, and then a. For the next channel d, and then c, and so on. Also, since LCP is defined in the first part of frequency setup, and then RCP in the second part, the first 16 delays are for LCP, and the final 16 delays are for RCP, also in the same b, a, d, c, f, e etc. order.

```
ANTENNA P3 {
  datastreams = P3L, P3R
  zoom = 32mhz
  must be zero!
  freqClockOffs=0,0.0037,-0.0062,-0.0031,-0.0052,-0.0069,-0.0044,-0.0054,-0.0014,-0.0145,0.0024,0.0006,0.001,0.0026,0.0045,0.0062,
  0.018,0.0225,0.0134,0.0136,0.0102,0.0113,0.0122,0.0129,0.0112,0.0119,0.0111,0.0092,0.0099,0.0116,0.015,0.0158
}
```

Unlike the clock section of the .vex file, the sign of the correction must be the OPPOSITE to what is determined by fourfit for EfP3 baseline. E. g. if for freqs b RR fourfit determines SBD -0.018 microseconds, we write 0.018 into the corresponding position of *freqClockOffs*.

After all the 32 corrections are determined and included into the .v2d file, vex2difx and then the correlation should be rerun. If all is done correctly, looking for fringe solutions in every channel must give us now SBD values very close to zero.

Fringe solution with manually corrected phase differences (manual phase cal)

Now we can run the fringe solutions for all channels together. To see how this improved the phase stability, in addition it is a good idea to run fourfit in message level 1 mode, i. e. with *-m1* flag.

Then during the fringe solution one of the status messages will give us the average phase values for each frequency band. These values can be added into the fourfit configuration file in the following manner:

```
if station i
  pc_phases_l abcdefghijklmnop -356.9 -182.9 -148.6 29.7 24.3
210.0 334.9 158.9 342.4 177.0 173.4 2.0 133.4 321.0 236.4
60.4
  pc_phases_r abcdefghijklmnop -141.5 -292.4 -237.3 -15.6 -33.0
189.6 341.8 205.7 196.4 57.1 237.8 98.4 91.9 317.9 81.8
289.9
```

Running fourfit again with this modified configuration file should provide us with a solution with stable phases. One of the indications that everything worked out correctly is that now the peak of multiple-band delay solution must be very close to the single-band delay solution peak.

Plots

TBD