Setting pc_phases_x/y for collocated antennas

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1. Introduction

For the same observation, the *fourfit* results for collocated antennas to a common other antenna should obtain the same dTEC. When this is not the case, a likely cause is inconsistent phase offsets introduced as pc_phases_x/y for the two polarizations. This memo provides a procedure for setting the pc_phases_x/y of one antenna to values that will provide the same dTEC as the other antenna.

2. The problem

When the session vt9189 (19JUL08VG) was correlated at Haystack, this was the first VGOS data received from ONSA13SW (Ow). The pc_phases_x/y that were initially chosen for Ow gave a dTEC to GGAO12M (Gs) that was different from the ONSA13NE (Oe) to Gs dTEC value by ~7 TECU. The values of dTEC obtained from *fourfit* should have agreed within 1 TECU since the two Onsala antennas are separated by only about 1 km and effectively see the same path through the ionosphere.

In order to assess which of the two values, Gs-Ow or Gs-Oe, might be more correct, values of TEC at the time, azimuth, and elevation of one observation were obtained from the Madrigal database of GPS/GNSS-derived TEC.

Comparison of the dTECs found with *fourfit* and the dTEC found as the difference of TECs from Madrigal (GPS) for the GGAO12M (Gs) to Onsala baseline showed that Madrigal dTEC agreed with Gs-Oe to 0.3 TECU and differed from Gs-Ow by -7.1 TECU. Thus, the choice was to make the Ow dTEC value agree with that of Oe since it appeared that Gs-Oe gave the more accurate value.

The problem was to find values of the pc_phases_x/y for Ow that gave dTEC for Gs-Ow approximately equal to Gs-Oe.

3. Procedure

The following initials are used: G = GGAO12M; S = ONSA13NE; T = ONSA13SW.

The pc_phases_x/y must be determined separately for each polarization, but the procedure is the same for both and will be described for only Y-pol.

Since it is not possible to determine the pc_phases_x/y for all antennas without an external reference for at least one antenna, historically the phases for GGAO12M X-pol have been used as the reference values.

A high (>100) SNR is desirable. Usually this means that the parallactic angle difference (dPA) between the remote antenna and the collocated antennas should be near (+ or -) 45°. For the example given here the dPA was near 90°, giving a much higher SNR in XY compared to XX. In fact, the SNR for the XX polarization was only about 10. Thus this example describes the procedure for Y-pol for the collocated antennas.

Designate the control file for which the pc_phases_x/y give the unequal dTEC values as the ‘inconsistent’ control file.

Steps:

1. Run *fourfit* for GS using the ‘inconsistent’ control file with polarization ‘–PXY’ to obtain the value of dTEC to be reproduced for GT.

   For example: `fourfit -pt -m1 -b GS -PXY -c  cf_quicktest  190-1220/0059+581.0QSGBL`

2. Create a duplicate of the ‘inconsistent’ control file, named, for example, ‘quicktest_modified’.
3. In the duplicated control file, e.g. quicktest_modified, modify the ionosphere lines to not estimate the ionosphere:

```
* Set: ion_npts to 1:
    ion_npts  1
* For station G: set ionosphere to the negative of the dTEC value found for GS above:
    if station G
        * Reverse the sign of ion TEC for the first station:
        * ion TEC for the GS baseline obtained in step1:  -5.451
        ionosphere  5.451
```

4. Set all values of pc_phases_y for station T to 0.0.

```
* For station T: set ionosphere to 0.0
    if station T
        ionosphere  0.0
```

5. Run *fourfit* with the modified control file:

```
fourfit -pt -m1 -b GT -PXY -c  cf_quicktest_modified  190-1220/0059+581.0QSGBL
```

6. Put the negative of the resulting channel phases into the original ‘inconsistent’ control file as pc_phases_y for T and call it ‘quicktest_corrected’.
7. Run *fourfit* for baseline GT using the corrected pc_phases_y:

```
fourfit -pt -m1 -b GT -PXY -c  cf_quicktest_corrected  190-1220/0059+581.0QSGBL
```

The value of dTEC should be the same (within 0.1 TECU) as for the reference baseline (GS in this case).

The process should be repeated for the XX polarization for a high-SNR observation. In principal it can be a different scan if an observation with dPA around 45° cannot be found.

8. Results for this example

	GS	GT (‘inconsistent’)	GT (corrected)
dTEC	-5.451	-12.721	-5.525
SNR	98.0	104.4	104.4

ph/seg (lower left corner of *fourfit* plot)

RMS	1.5	1.9	1.9
Theo	1.4	1.3	1.3

The main point of this table is that the dTEC for GT after deriving the pc_phase_y values agrees with the GS value, as expected. Other than that there is no difference between the use of the uncorrected and corrected pc_phases_y.

9. Caveats

- This procedure only sets the pc_phases_y for the second site in order to produce an estimated dTEC that is equal to the first site.
- It does not say anything about the accuracy of the common dTEC value.
- I adjusted the Gs-Ow value for dTEC to the previously used Gs-Oe value for dTEC because the Gs-Oe dTEC was much more consistent with the externally determined value from the Madrigal GPS data.

10. Comments

Another (perhaps simpler) approach to obtaining the pc_phases_y (or _x) would be to calculate the dispersive phases at the frequencies of the 32 channels using the difference of the XY and XX dTECs, obtained with the 'inconsistent' control file, then use these phase values to correct the pc_phases_y (or _x) for the second station that were used in the 'inconsistent' file.

In principle, values for the pc_phases_x/y could be obtained for arbitrary pairs of antennas if the values for one of the antennas were known and the line-of-sight TEC values for both antennas were obtained with an accuracy of better than perhaps a few tenths of TECU. However, at this time no global service provides TEC along the VLBI line of site with that accuracy. It would be necessary to make use of local GPS/GNSS observations.

Appendix

Here are the original slides from which this memo was developed.

Setting pc_phases_x/y to give the same dTEC for collocated antennas

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Problem

- The original vt9189 (19JUL08VG) pc_phases_x/y for Ow gave dTEC to GGAO12M different from Oe by ~7 TECU. They should be the same since collocated.
- Comparison with dTECs from Madrigal (GPS) for the GGAO12M (Gs) to Onsala baseline showed Madrigal agreed with Gs-Oe to 0.3 TECU and differed from Gs-Ow by -7.1 TECU.
- Problem: find pc_phases_x/y for Ow that gives dTEC for Gs-Ow approximately equal to Gs-Oe.

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Procedure(0)

- G = GGAO12M S = ONSA13NE T = ONSA13SW
- Find pc_phases_x/y for Ow that give dTEC (ion TEC) approximately equal to Oe
- Do remote station X-pol (-PXX) and Y-pol (-PXY) separately
  - Use G X-pol as reference (this is the default for ffres2pcp.py)
  - Desirable to use an observation with parallactic angle difference (dPA) close to 45° so XX and XY will both be strong
  - This example is for XY only since the sample scan has dPA near 90°. You need to repeat separately for XX on an observation with high SNR in XX.

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Procedure(1)

- Run *fourfit* for GS using the 'inconsistent' control file and –PXY to get the value of dTEC to be reproduced for GT
  fourfit -pt -m1 -b GS -PXY -c cf_quicktest 190-1220/0059+581.0QSGBL
- Create a duplicate control file from the 'inconsistent' cf
- Change pc_phases_y for T to 0.0

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Procedure(2)

- Modify ionosphere lines
  - Set: ion_npt 1
  - For station G: set ionosphere to negative of dTEC value found for GS above
  - For station T: set ionosphere to 0.0

```
ion_npts  1
* set ionosphere for G to GS value
if station G
* Reverse sign of ion TEC for first station
* ion TEC for GS baseline: -5.451
   ionosphere  5.451
if station T
   ionosphere  0.0
```

- Run *fourfit*
- Put the negative of the resulting channel phases as pc_phases_y for T in the original 'inconsistent' control file
- Run *fourfit* with the corrected pc_phases_y for T

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Results

	GS	GT ('inconsistent')	GT (corrected)
dTEC	-5.451	-12.721	-5.525
SNR	98.0	104.4	104.4
		ph/seg	
RMS	1.5	1.9	1.9
Theo	1.4	1.3	1.3

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Caveats

- This procedure only sets the dTEC values for the two collocated sites equal.
- It does not say anything about the accuracy of the common dTEC value.
- I adjusted the Gs-Ow value for dTEC to the previously used Gs-Oe value for dTEC because the Gs-Oe dTEC was much more consistent with the externally determined value from the Madrigal GPS data.

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Questions?

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