COMPARISON OF IONOSPHERIC DELAYS OBTAINED FROM S-X VLBI EXPERIMENTS AND GPS OBSERVATIONS

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ABSTRACT

GPS observations gathered during S-X VLBI experiments have been analyzed to extract the ionospheric delay along the signal path of the VLBI observations. These GPS-based delays have been compared with those obtained from S-X VLBI observations, with the rms of the differences less than 0.1 nanoseconds. In order to check the use of dual GPS data for the ionospheric calibration of single frequency VLBI observations, the baseline lengths estimated using dual VLBI data have been compared with those estimated from single band VLBI data calibrated with the GPS-based ionospheric delays. The differences between both results for European baselines were in the order of 3-5 parts per 10^9.

1. INTRODUCTION

Radio signals crossing the ionosphere suffer a delay that is proportional to the ionospheric Total Electron Content (TEC) along the path and to the inverse of the frequency squared. Being frequency dependent, this delay can be calibrated using dual frequency observations. This is the standard procedure in geodetic Very Long Baseline Interferometry (VLBI) and Global Positioning System (GPS).

However, there are applications in which the use of two frequencies is not possible due to the type of observation or to the available equipment, as in some astrometric VLBI experiments. In this case external ionospheric information is needed for the calibration of the observations.

Some techniques that can be used for ionospheric calibration are the Faraday rotation of geostationary satellite signals, ionospheric models based on ionosonde data, etc. In general, the information provided by these methods is limited in their spatial distribution or their precision is insufficient.

Dual frequency GPS observations can also be used to extract ionospheric delays. This has the advantage that the frequencies used are closer to those used in VLBI. Moreover, they can provide more precise ionospheric calibrations and better spatial coverage.

In this paper we present ionospheric delays for geodetic VLBI observations computed using GPS data and we compare them with the ionospheric delays obtained from dual VLBI data calibrations. For these comparisons, we have analyzed dual GPS data gathered at three European VLBI stations during S-X geodetic VLBI experiments.

2. ESTIMATION OF THE TEC

The main source of error in the estimation of the TEC using dual frequency observations is produced by frequency dependent instrumental delays in the GPS satellites and receiving systems. In the case of the VLBI, the receiver instrumental delay for each station is not distinguishable from a clock bias, so it is neglected in the geodetic analysis. The GPS case is more complicated because we should also consider one term for each satellite.

In the estimation of the TEC from GPS data we have used phase and pseudorange observations. We have estimated, with a method based on Kalman filtering, the instrumental differential biases for each GPS receiver and satellite, assumed constant during each experiment (Sardón and Wanninger, 1993). Once these biases have been removed, we obtain for each observation time, the TEC corresponding to the different GPS observation paths. For more details see (Sardón 1993).

3. EXPERIMENTS

We have analyzed dual GPS data gathered at the European VLBI stations of Madrid (Spain), Onsala (Sweden) and Wettzell (Germany) during five NASA Crustal Dynamics Project VLBI experiments (24 hours each) that appear on table I. All stations were equipped with ROGUE GPS receivers (Onsala from May 1991) located few hundred meters apart from the VLBI antennas.

GPS observations below 10 degrees elevation were neglected to reduce the effect of multipath errors and to avoid the mismodeling of the function that maps the vertical TEC to slant TEC at low elevations.

DATE	VLBI EXPERIMENT	GPS DATA
September 5/6, 1990	90 EUROPE 2	Madrid Onsala Wettzell
December 20/21, 1990	90 EUROPE 3	Madrid Onsala Wettzell
January 6/7, 1991	91 EUROPE 1	Madrid Onsala
December 1/2, 1991	91 EUROPE 3	Madrid Onsala Wettzell
January 14/15, 1992	92 EUROPE 1	Madrid Onsala Wettzell

TABLE I: Geodetic VLBI experiments.

4. VLBI AND GPS IONOSPHERIC DELAYS

Using the TEC obtained from GPS observations, we have predicted the TEC in the direction of the VLBI observations. The ionospheric delay assigned to each VLBI baseline was computed as the difference between the ionospheric delay corresponding to each station in the baseline. The GPS ionospheric delays are compared with the VLBI ionospheric delays obtained for each baseline from the S and X band observations.

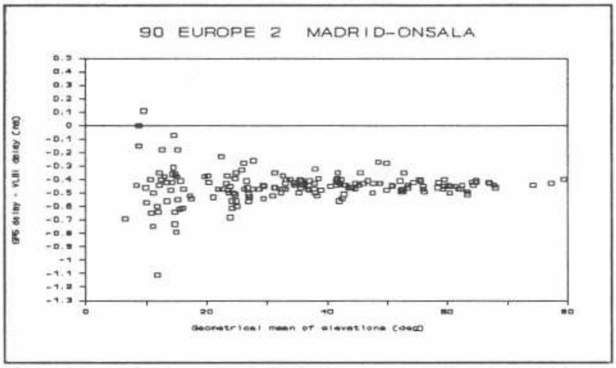

Figure 1: GPS minus VLBI ionospheric delays versus the geometrical mean of the source elevations at both VLBI stations.

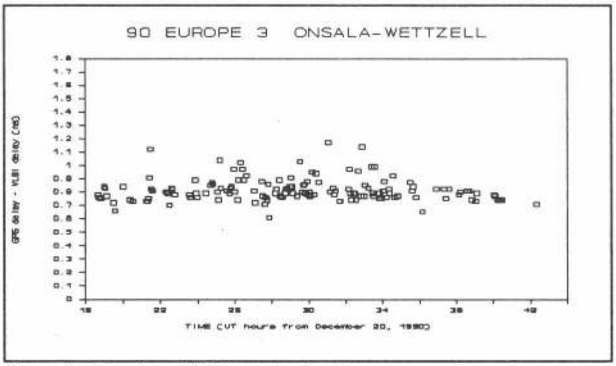

Figure 2: GPS minus VLBI ionospheric delays versus time.

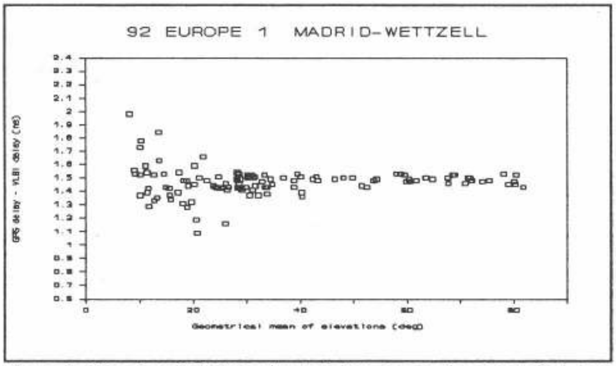

Figure 3: GPS minus VLBI ionospheric delays versus the geometrical mean of the source elevations at both VLBI stations.

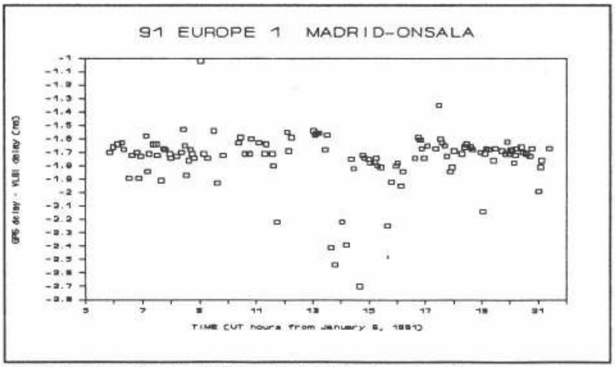

Figure 4: GPS minus VLBI ionospheric delays versus time.

Figures 1 to 4 show some examples of the differences (in nanoseconds) between the VLBI ionospheric delays and the GPS ionospheric delays, as a function of time and as a function of the geometrical mean of the elevations at both VLBI stations in the baseline.

In these figures we see that the difference between the VLBI and GPS ionospheric delays is basically a constant term, which corresponds to uncalibrated instrumental biases in the VLBI stations, plus a superimposed noise. For all the analyzed experiments, the standard deviation of the differences between both ionospheric delays was in the order of 0.1 nanoseconds. For the experiment 91 EUROPE 1, there were no GPS data from Onsala from 13:00 to 17:00 so the prediction was based on GPS data far away in time, producing the increase of noise that can be seen in figure 4. Figures 1 and 3 show that most part of the noise is produced by the low elevations used in the geodetic VLBI experiments, down to 5 degrees, where the GPS data is grossly affected by systematic errors.

5. VLBI BASELINE LENGTHS

In order to check the ionospheric delays estimated from dual GPS observations, we have introduced them in the analysis of each of the VLBI experiments. This analysis has been done with OCCAM 3.0. (Zarraoa, 1992). The differences between the VLBI baseline lengths obtained with this approach and the solutions obtained with a standard VLBI analysis are shown in table II (column 2).

WETTZELL-ONSALA 919 km	GPS IONOSPHERIC CALIBRATION	NO IONOSPHERIC CALIBRATION
Sep. 5/6, 90 (2.5)	-0.4 mm (3.7)	22.7 mm (4.2)
Dec. 20/21, 90 (3.1)	9.3 mm (4.4)	19.7 mm (4.4)
Jan. 14/15, 92 (2.0)	4.1 mm (4.5)	38.2 mm (7.0)
WETTZELL-MADRID 1655 km		
Sep. 5/6, 90 (2.7)	2.3 mm (4.6)	68.1 mm (6.1)
Dec. 20/21, 90 (4.0)	5.5 mm (6.9)	18.4 mm (6.6)
Dec. 1/2, 91 (4.6)	-0.5 mm (19.8)	93.0 mm (15.7)
Jan. 14/15, 92 (2.9)	6.5 mm (6.3)	70.6 mm (13.1)
MADRID-ONSALA 2205 km		
Sep. 5/6, 90 (3.4)	-0.7 mm (5.6)	74.1 mm (7.1)
Dec. 20/21, 90 (4.6)	13.9 mm (7.6)	29.2 mm (7.3)
Jan. 6/7, 91 (4.4)	-19.2 mm (7.7)	26.5 mm (6.9)
Jan. 14/15, 92 (3.2)	15.0 mm (7.2)	91.5 mm (14.0)

Table II: Differences (millimeters) between the VLBI baseline lengths obtained with dual VLBI data and those obtained: a) using GPS-based ionospheric delays (2nd column), b) without ionospheric calibration (3rd column).

This table also shows the differences between the standard solution and the solution obtained with no ionospheric calibration at all (column 3), with their corresponding formal errors in brackets. The first column contains the VLBI experiment and the formal errors for the standard VLBI solution.

It must be pointed out that, in general, the differences corresponding to the no ionospheric calibration are one order of magnitude larger than with GPS ionospheric calibration. In the case of the GPS ionospheric calibration, the differences are about 3-5 parts per 10^9 and most of them are within their formal errors. The formal errors from the GPS ionospheric calibration (column 2) are larger than those for the standard VLBI (column 1), due to our present limitation in modeling the ionosphere at low elevations.

6. CONCLUSIONS

In this paper we have compared the ionospheric delays obtained from dual GPS data and from S-X VLBI observations.

The differences between both ionospheric delays show a rms in the order of 0.1 nanoseconds at X band. The rms decreases significantly when no low elevation VLBI observations are used, which confirms the accuracy that can be obtained with GPS derived ionospheric calibrations for single frequency VLBI experiments.

We have also compared the baseline lengths estimated using dual VLBI data with those obtained from single band VLBI plus the GPS-based ionospheric delays. The differences between both results for European baselines were around 3-5 parts per 10^9.

We have applied our method to the calibration of geodetic VLBI experiments in order to test its performance against already calibrated data. But clearly, the use of GPS ionospheric calibrations will be more useful for other types of VLBI experiments where only one frequency is available.

ACKNOWLEDGEMENTS

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