The Need for Ionospheric Corrections at 5 GHz
VLBA Test Memo No. 68

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Abstract

This memo discusses the need to make global ionospheric corrections on VLBA observations at 5-GHz frequency. For phase-referencing observations near solar maximum, as at the current epoch, it is shown that corrections using global ionosphere models and the AIPS task **TECOR** can be of significant benefit. These global corrections may permit successful phase-referencing that is not possible otherwise. However, even the global ionospheric corrections probably are not adequate for calibrator-source separations larger than 2°–3°.

1 Ionospheric Corrections to VLBA Data

Ionospheric corrections to the phase of VLBA data have been found to be important at 1.7 and 2.3 GHz, particularly near the time of solar maximum. These corrections can be used to increase coherence time, which may enable fringes to be found on a fairly weak source or else may enable successful phase-connection to take place. A variety of means have been explored to perform calibration of the ionospheric phase effects, and are described in VLBA Scientific Memos 22 and 23. This test memo describes the results of making similar ionospheric calibrations at an observing frequency of 5 GHz.

2 Description of Observations

A test of ionospheric corrections at 5 GHz was carried out using a 3.5-hour observation by Schmitt et al. (observation code BS104H), on 26 September 2001 from 1051 to 1421 UT. The observation was a pure phase-referencing program at 5 GHz. The phase-reference source was J0607+4739, while the target source was the galaxy MCG 8-11-11, about 3° away, with coordinate name J0554+4626. The observations were carried out near transit for most of the VLBA, with elevations typically above 60° for all stations except Mauna Kea. (There were no data available from Saint Croix because the tape from the station was lost in transit to the correlator.) The phase-referencing cycle used 50 seconds on the calibrator, followed by 250 seconds on the galaxy, and another 50 seconds on the calibrator. Thus, the total phase-referencing cycle time was just under 6 minutes.

3 Calibration and Analysis

Data were calibrated in the usual way, with amplitude calibration and pulse-calibration applied based on *a-priori* gains as well as measurements made during the observations. Following this calibration, a global run of the AIPS task **FRING** was made on the source J0607+4739, with one solution per 50-second integration. The phase solutions (SN table) for IF 1 are shown in the left-hand panel of Figure 1; results for the other IFs are similar. In this figure, note that there are periods when the phases for Brewster, Hancock, North Liberty, and Owens Valley, relative to the reference antenna at Los Alamos, cycle through a complete 360° cycle in about 30 minutes. At Mauna Kea, the phases were fairly benign until about 1200, when they began moving quite rapidly, going through a full cycle in roughly 15 minutes or less. Indeed, from inspection of the left-hand panel of Figure 1, it is not entirely clear which 2π ambiguity to choose to connect the phase, which can lead to incorrect calibration of the phase on the target source.

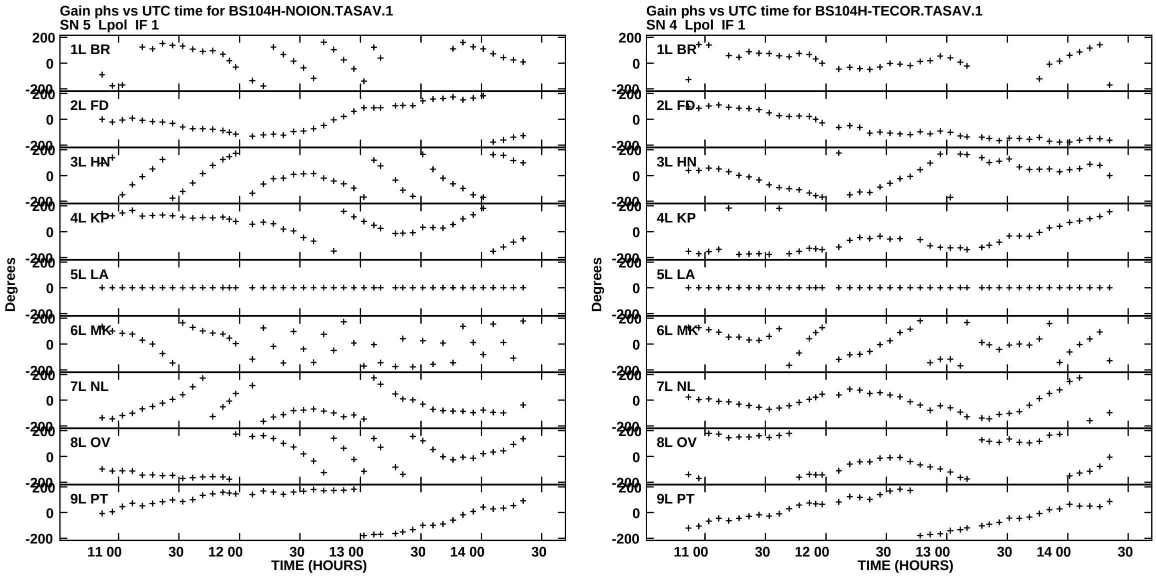

Figure 1: Phases vs. time on baselines to Los Alamos. The left-hand panel shows results with no *a-priori* ionospheric correction applied, while the right-hand panel shows the improved results after using the AIPS task **TECOR**.

The systematic changes in phase, and the fact that they are seen on all the long baselines to the reference antenna, seem more reminiscent of the ionosphere than the troposphere. Since all antennas are effectively looking through different sections of the troposphere, their phase variations should be uncorrelated, and the general structure of the phase seen in Figure 1 should be relatively independent of baseline length. However, since the ionospheric effects occur at a much higher elevation (several hundred kilometers above the Earth's surface) and have larger scale sizes, one might expect the fluctuations to depend on baseline length, as seen in the data.

The discussion above leads to the question of whether ionospheric data can be used to calibrate the relative phase drifts of the VLBA antennas. In AIPS, such calibration is made using the task **TECOR**, which applies global ionospheric models that are reported on a regular grid in space and time. The available models currently use grids with spacings of 5° in longitude, 2.5° in latitude, and 2 hours in time. **TECOR** uses the azimuth and elevation to which each antenna is pointed in order to find the ionospheric "pierce point," then interpolates to estimate the ionospheric corrections. As mentioned previously, some discussion of global ionospheric models and of how **TECOR** works can be found in VLBA Scientific Memos 22 and 23, as well as in the **TECOR** "explain" file.[1]

The right-hand panel of Figure 1 shows the results of a fringe-fit that was run under the same conditions as the left-hand panel, except that a global ionospheric calibration was applied first using **TECOR**. Inspection of this figure shows clearly that the phase wraps have been reduced significantly on the long baselines, supporting the hypothesis that the ionosphere is a major contributor to the phase drifts even at 5 GHz. (The **TECOR** input file indicates that the total electron content along some lines of sight was greater than 10^{18} electrons per square meter.) After application of **TECOR**, the phase connection for Mauna Kea appears to be straightforward. However, it is important to note that a remaining limitation on the proper phase calibration is the distance between target source and calibrator. Recent experience with other segments of BS104 has shown that separations of 5° between the reference source and the target often are too large to permit useful phase calibration, and that separations $\leq 2^\circ$–3° are required, even at 5 GHz.

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[1] Note that **TECOR** recently has been upgraded by Amy Mioduszewski to accept multiple models spanning multiple UT dates. This eliminates a previous requirement for the observer to concatenate and hand-edit files covering multiple dates. In addition, a mistake has been corrected in the explain file; the dispersive delay correction switch APARM(1) should be turned **ON** to get a useful result.