CALIBRATION OF BDA SOLAR OBSERVATIONS WITH GPS SATELLITES AS CALIBRATOR SOURCES

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ABSTRACT

A new technique for the calibration of BDA complex visibilities is proposed, making use of satellites of the Global Positioning System (GPS) as calibrator sources. The technique is based on the properties of the GPS signals, namely the strong flux, higher than that of the Quiet Sun at 1575 MHz, and the source dimensions which imply that the satellites can be regarded as point sources for the BDA. The present status of development of the technique is presented, as well as the results of its application to solar observations using the prototype of the Brazilian Decimetric Array (PBDA), during the period from May to September, 2007. The results indicate that the GPS signals are adequate for calibration of solar observations with the BDA.

Key-words: calibration, solar observations

INTRODUCTION

The solar observations made with interferometers are usually not completely calibrated due to the low brightness (~ 1 – 20 Jy) of most of the celestial calibrators. It is also impossible to observe these standard calibrators with the prototype of the Brazilian Decimetric Array (BDA – Sawant et al., 2007), due to their low brightness and the small number of antennas (5) of the array that implies very low sensitivity. These facts imply that the calibration of BDA solar data requires the use of very strong calibrators, and very few are available in the present catalogs.

A different calibration approach is the suggestion to use satellites of the Global Positioning System (GPS) as calibrator sources (Zhiwei et al., 2007). The GPS signal power on Earth's surface is well known, around -160 dBW at the frequency of the L1 carrier at 1.575 GHz (Rizos, 1999), that is inside the operation band of the PBDA, optimized to 1.6 GHz. Given the satellite orbits, at an approximate height of 20,000 km, it is also possible to consider them as point sources in the far field of the BDA synthesized beam. These properties led to the suggestion that GPS satellites might be appropriate as calibrators for solar observations with interferometers, motivating tests with the BDA.

A method was developed to test this hypothesis that is outlined as follows:

(i) Determine the variation of the position of the satellite in the sky, based on the TLE (two line elements) estimate, in a spherical coordinate system attached to the EW baseline.

(ii) Obtain a set of theoretical phases from the variation of the satellite's position as determined in (i).

(iii) Obtain the phase dispersion of the measured visibilities with respect to the model by subtracting the theoretical phases from the data set.
(iv) Obtain a set of antenna-based calibration solutions from the phase dispersion of the measured visibilities.
(v) Determine the baseline-based amplitude gains through normalization of the observed amplitudes according to the known flux of the satellite signal.
(vi) Determine the phase gains for each baseline, combining the antenna-based gains.
(vii) Apply the calibration solutions to the solar data, interpolating the solutions obtained.

OBSERVATIONS AND RESULTS

The test observations were done with the Prototype of the Brazilian Decimetric Array (PBDA) from May to September 2007. Shown in Figure 1 is a comparison between the theoretical synthesized beam of the PBDA in the EW direction and the one dimensional brightness profile of the GPS satellite after the calibration was applied to the data.

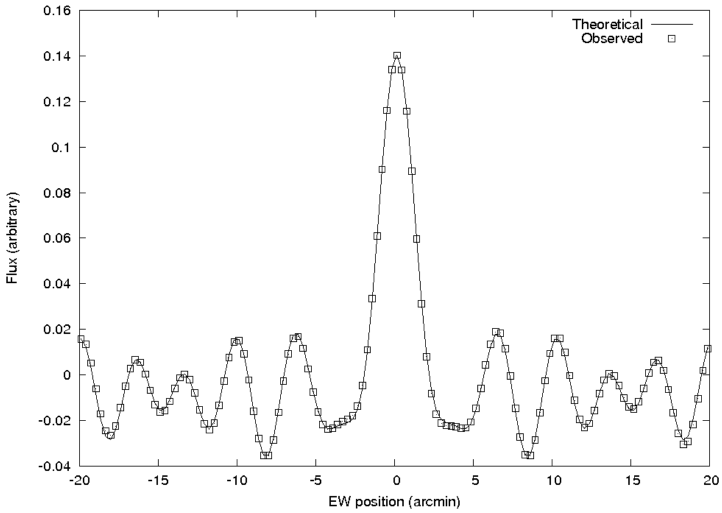

Fig. 1 – Comparison between the theoretical synthesized beam of the PBDA and the one dimensional profile of the GPS satellite GPS BIIA-22 (PRN 05) as observed on test observations on 07/13/2007.

The solar observations were carried out from 24 to 29 September 2007. Each scan on the Sun was preceded and succeeded by scans on a GPS satellite, so that the calibration solutions for the solar data could be obtained by interpolating the calibration solutions for the satellites. The map obtained on 27 September 2007 is shown in Figure 2, where a map of the Sun in EUV on the same day is shown for comparison.

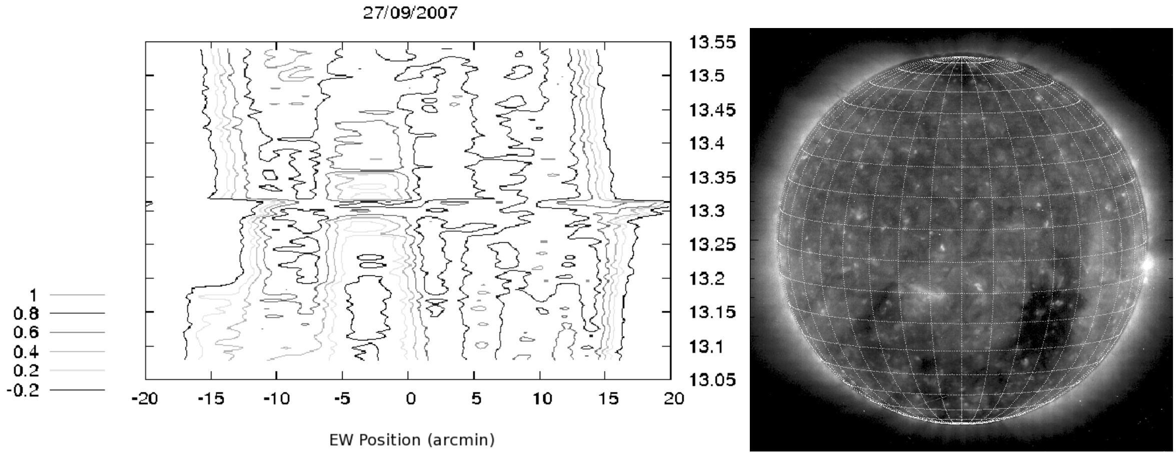

Fig. 2 – One dimensional brightness profile of the Sun obtained with the PBDA on 27 September 2007 (left), and map of the Sun at 195 A obtained with the Extreme Ultra-Violet Imaging Telescope (EIT/SoHO) on the same date. Note that a depression in brightness is seen in both maps, but it appears shifted eastward on the PBDA map with respect to the EIT map.

CONCLUSIONS

The results indicate that very high phase accuracy can be obtained on interferometric observations of GPS satellites, and that these sources are indeed adequate for the calibration of interferometric observations of strong sources like the Sun, particularly for solar observations with the BDA. However, the results also indicate that more tests and further technique development are required to ensure the reliability of the method.

At the present status, the implementation of this method still demands the inclusion of antenna-based calibration for amplitudes, as well as an absolute flux scale, based on the GPS signal power. Also, further solar observations with the BDA have to be carried out, specially after the installation of more antennas, aiming at improving the accuracy of the antenna-based solutions, which implies better calibration and better maps.

Finally, tests of calibration of solar observations with GPS signals should be done with other interferometers to allow the complete verification of the method proposed in this work.

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