CARMA Memorandum Series #14 [1]

Stability of BIMA antenna position solutions

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ABSTRACT

We review the stability of the BIMA antenna position solutions for two recent array con£gurations. Antenna position changes of more than $\sim$ 1mm have been observed at some stations.

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[1]This document is also BIMA Memo # 97

1. Introduction

The stability of BIMA baseline solutions has been an issue since the beginning of the array. Changes in antenna positions of several millimeters have been measured which cannot be accounted for by timing or other errors. While much effort has been expended in an attempt to isolate the antenna stations from environmental effects, including changes in water content and frost heave in the surrounding soil and rocks, instability is still observed - particularly during large seasonal temperature changes. This memo describes the data collection and analysis procedure, and gives some examples of observed instability.

Baseline calibration is done by observing a collection of strong QSOs. An error in the assumed antenna position produces a 24 hour period sinusoid in the measured phase of each QSO. The amplitude of the sinusoid and the HA of the zero crossing gives the direction and magnitude of the error in the equatorial components (B1 and B2 - the local meridian direction and its E-W orthognal). The error in the polar component (B3) is given by the absolute value of the phase, which is proportional to sin(Dec). Since the antenna-based phases vary slowly with time due to thermal effects, the QSOs are observed in a semi-random sequence in order to allow smooth time-varying instrumental drifts to be distinguished from the HA & Dec sinusoidal dependence caused by baseline errors.

A typical baseline observation runs for 6-8 hours and includes 10-15 QSOs with a wide range of RAs and Decs. The antenna positions are derived from a least squares solution to the antenna-based phases relative to one of the antennas. Usually four parameters are £t: three geocentric position vectors (B1, B2, B3) and an instrumental phase. Only the instrumental phase is allowed to vary with time. The uncertainty in the least-squares £t depends on the sampling in HA and Dec and on the quality of the data. At BIMA we routinely achieve an accuracy of 0.2-0.3mm at 3.4 mm wavelength for a 6 hour run in good weather. This is suf£cient to keep phase error in degrees less than about half the sky separation in degrees between source and calibrator.

2. Observations

2.1. D-array 21 May, 2003

The most recent array move was to D-array on 21 May, 2003. Figure 1 shows the physical layout of the antennas. In this array £ve antennas are on meadow stations, which are anchored to large concrete blocks embedded in soil. Two antennas are on normal stations, which have independent concrete piers tying the station to bedrock. These stations are located on the concrete Tee but are isolated from it by paper separaters. Three antennas are on ”skin” stations, which means they are bolted directly on the concrete runway without any other foundation.

The £rst set of baseline data was obtained on 23 May. A second data set was obtained on 28 August, near the end of the spring and summer sessions and before the start of the fall schedule. The difference between the antenna positions obtained from the 23 May data and the 28 August data are given in mm next to each antenna in Fig 1. The largest position changes were less than 1mm and occurred for the four southern-most antennas on the Tee (ants 5,7,8 and 10). All of these except ant 10 are on skin stations. Their movement was mainly toward the west, and all showed an elevation drop of about 0.5mm relative to ant 1.

he baseline data obtained for the initial measurement in May was somewhat marginal due to weather. The data obtained in August was rather better. Fig 2 attempts to demonstrate that the apparent position changes found between these two measurements is real, and not an artifact of the sampling or data quality. It shows the antenna-based phases measured for antennas 2, 5, 7 and 10 at both epochs. Each point represents the averaged phase over a 5-minute scan on a QSO. Antenna 2 has the smallest position change observed relative to ant 1, and ants 5 and 10 have the largest. Ant 7 has a smaller change, corresponding to a change in elevation without any lateral shift on the ground.

The top and bottom rows in Fig 2 show the QSO phases corrected for the best-£tting antenna position solution for that epoch. The two middle rows show the QSO phases adjusted to the solution from the other epoch. For columns where the middle rows have larger phase scatter than the outer rows, the antenna's position derived from the data taken at the other epoch is inconsistent with the data taken at that epoch. For ant 5 the inconsistency is clear. For ant 2, which showed no signi£cant position change, good consistency is apparent. For ants 7 and 10, for which signi£cant changes are measured, the situation is less clear owing mainly to low s/n in the 23May data.

2.2. C-array, Spring 2001

These apparent changes would be more convincing if the antenna positions were monitored at regular intervals during the change. If the changes are due to the antennas physically moving, the positions would be expected to vary systematically over time. Suf£cient sampling of the antenna positions is available to show this for the spring 2001 C-array, which started in late February and ended in early June. Early in the array it became apparent that the position of antenna 10 on skin station 125E was changing. Four baseline datasets were obtained in order to keep track of the changes. In addition to those measurements, ¤ux calibration data was used to supplement the baseline data. The ¤ux measurements were taken in varying conditions for shorter lengths of time, and do not use a psuedo-random sequence. However they generally give results consistent with the baseline data, though with a larger uncertainty.

Figure 3 shows the 2001 C-array layout with the total change in position measured between February and June indicated for each antenna. Position changes between 0.2mm (about 2 sigma) and 3mm were observed, with four antennas registering changes greater than 1mm. Antenna 2 at normal station 100W was used as the reference antenna for this array.

Fig 4 plots the solutions obtained at each epoch for which usable data was obtained from either baseline or ¤ux calibration observations. While the antenna positions were updated on-line regularly to keep the phase transfer errors small, the solutions plotted are relative to the original antenna positions in order to show the total change clearly. The times at which baseline updates were applied on-line are indicated on the plot. The changes plotted in Fig 4 are in geocentric coordinates. The equatorial and polar components are shown individually, together with the total change in nanoseconds. The same data are plotted in Fig 5, but transformed to local coordinate changes (North, East and Elevation) in millimeters.

In the EW direction the motion observed is westerly relative to antenna 2 for all antennas except 6. These changes are mostly less than 1mm, apart from ant 10 which moved west by 3mm in three months. To the extent that the same change is seen in all antennas, the actual change is most likely in the reference antenna. In the NS direction changes up to 1.8 mm occurred for several antennas. Most antennas moved south, with the exception of antenns 1 (1.5mm north) and 9 (0.3mm north). The two northern-most antennas 1 and 8, both of which are on normal stations, moved in opposite directions NS giving a total relative movement of 3mm. In all cases for which signi£cant elevation changes occurred they went lower. Ant 10 reached a peak elevation change of -1mm in mid-May and then began to rise again. Ant 6 was relatively stable until mid-May, at which time it began to drop by about 1mm over the next several weeks.

3. Conclusion

Taken together the antenna motions do not show a clear pattern indicating a general change like expansion or contraction on the scale of the array, except for the general westerly trend. Instead the motions suggest that antenna position changes are dominated by local processes. While the antenna with the largest change (10) was located on a skin station, the two with the next largest changes (1 and 8) were located on normal stations. There is some suggestion based on this and the previous example that the meadow stations may be more stable than stations located on the Tee. In any case the changes are de£nitely real and apparently unpredictable, and must be monitored regularly in order to avoid excess phase transfer errors.

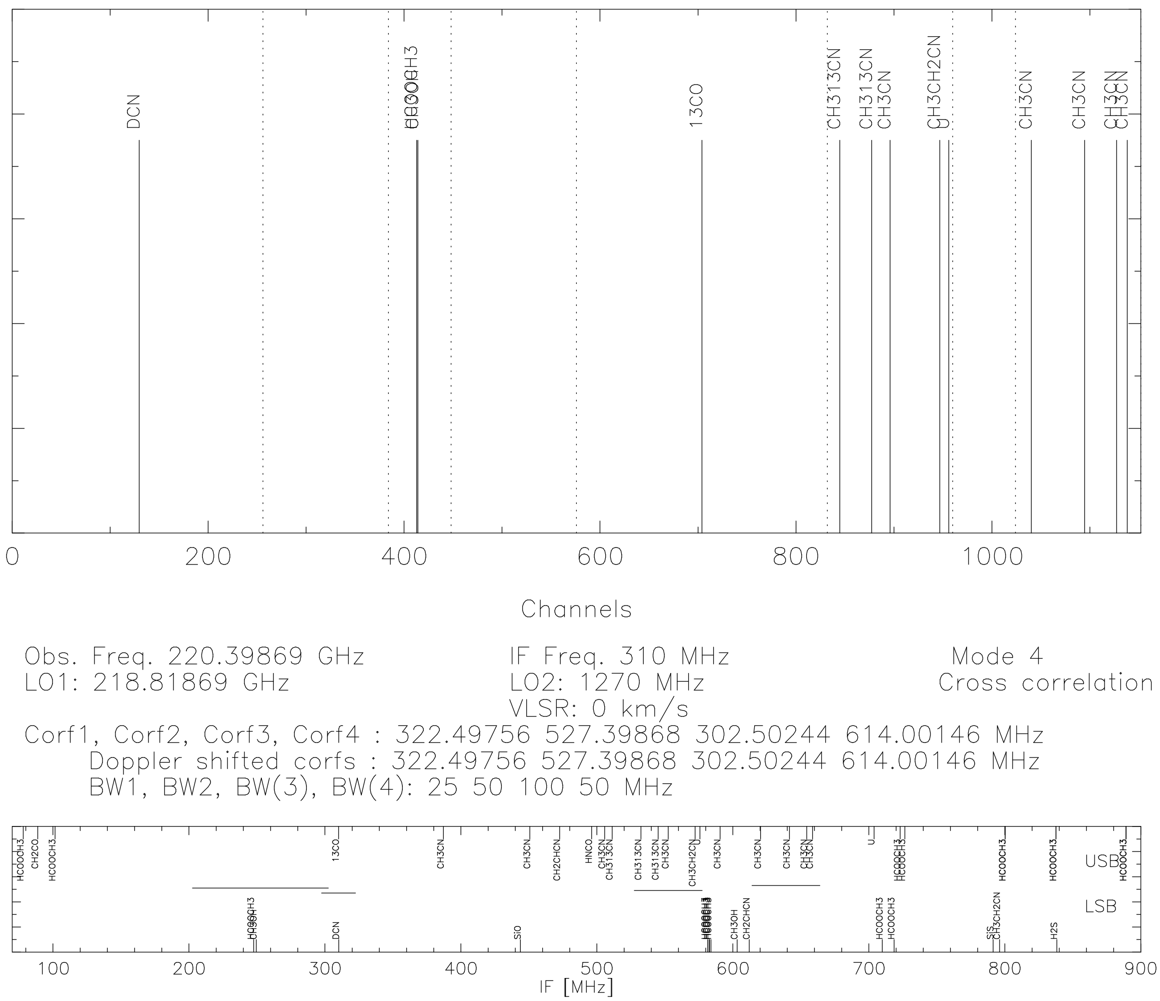

Fig. 1.— BIMA correlator in mode 4 showing spectral lines in 4 LSB and 4 USB spectral windows with bandwidths 25, 50, 100, 50 MHz.

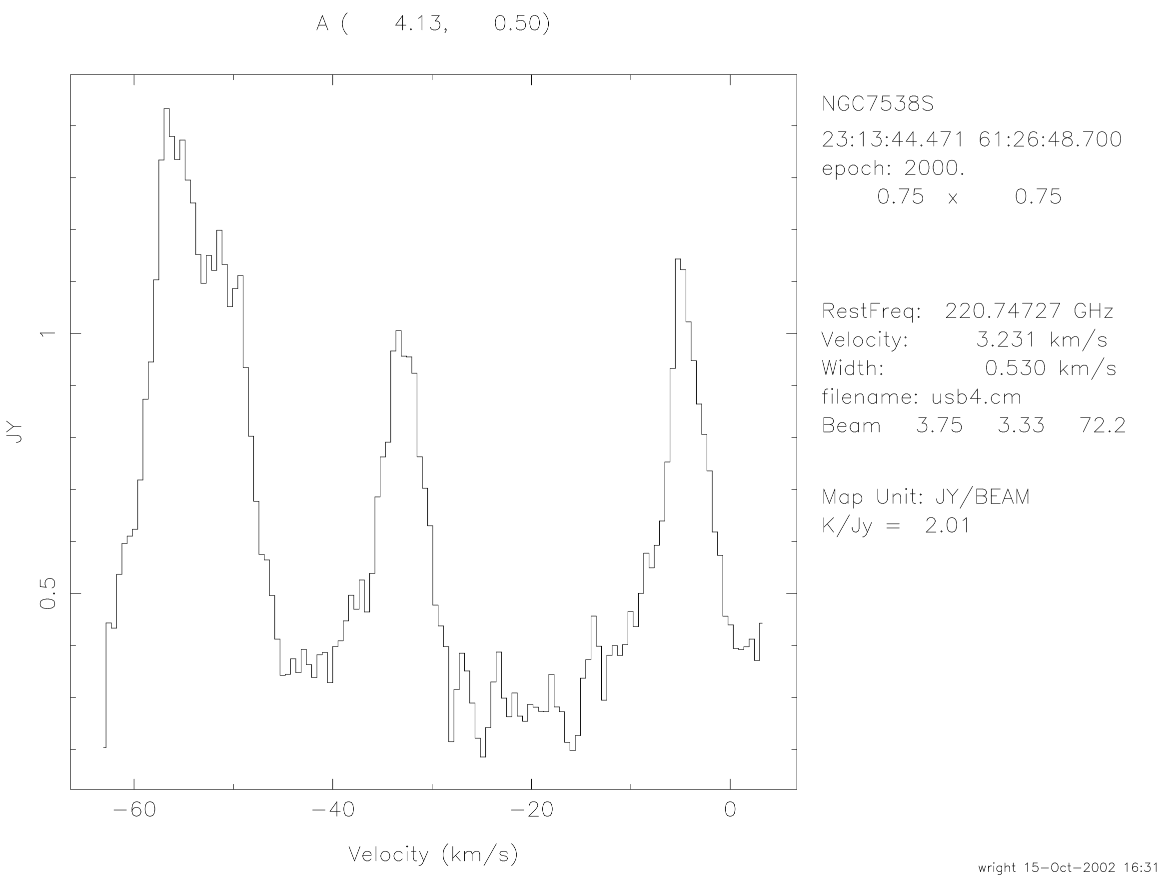

Fig. 2.— Spectra of CH_3CN emission in one spectral window