Inter-scan Overheads for Sequences of Drifts with ALFA

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This note is a complement to our previous memo on the use of the "Fixed Azimuth Drift" observing mode using ALFA (*http://alfa.naic.edu/memos/memo041206.pdf*) and is intended to be helpful for other ALFA observers, especially those using ALFA in drift mode. A concise summary of geometric issues associated with tracking sources, particularly those which transit near the zenith, with an alt-az telescope is presented in the GBT Memo written by Frank Ghigo (*http://www.gb.nrao.edu/GBT/memos/memo52.ps*). Frank's memo contains useful formulae and diagrams of the variation of the azimuth tracking rate with zenith angle as well as the rate of change of parallactic angle as a function of hour angle.

The A1963 project objective is to map very deeply an area of sky 2° in R.A. by 1° in Dec. The target galaxy, NGC 2903, lies at Dec. +21° and is itself a strong HI line emitter as well as an extended radio continuum source. That it transits close to the Arecibo zenith is of particular note. The adopted mapping strategy is to conduct drifts 8^{min} in length at 12 different Decs, giving a final sampling in Dec. of $\sim 1'$. Maps from many days but constructed separately according to azimuth will be CLEANed and the data regridded and accumulated. On a given night, 12 separate drifts are obtained over a range of azimuths at ZA $< 14°$. Thus after 12 nights, 12 complete maps of the field will be available, each one constructed by combining the 12 Dec. drifts obtained at approximately the same azimuth. At each azimuth, ALFA is rotated so that the beam tracks are equally separately in Dec., but that spacing is not the same for all azimuths, growing from $\sim$1.8′ at large HA to $\sim$2.1′ at transit. To allow correction of the 12 separate azimuth maps for the beam pattern particular to that Az,ZA combination, the precursor program A1963 will also construct beam maps covering $\sim$40′ in Dec. at the same range of azimuths as the spectral line observations. A first sequence of continuum drifts was successfully obtained on 04Dec06, consisting of 23 separate 240 sec drifts spanning the same range of Az,ZA as covered by the spectral line observations. Schedules and logs are available at the A1963 website: *http://www.naic.edu/∼ngc2903*. Further observations are scheduled.

In the course of planning and executing this first A1963 run, we needed to understand in some detail issues related to CIMA command communications, telescope slew motions and ALFA rotation. The time required between drifts was larger than we had anticipated, and considerable effort went into understanding overheads and to devising an efficient observing strategy. Here are several points which may be helpful to others planning observations with similar precise scheduling demands.

- **Telescope Slew Times**: The nominal values of telescope slew rates are 0.4°/sec in Az and 0.04°/sec in ZA. However, those occur after the arm/dome have achieved constant speed. Overheads are also associated with acceleration ($\sim$4 sec), deceleration ($\sim$10 sec), and settle ($\sim$3 sec). The slew speed seems a bit slower than nominal in ZA when the ZA is large. The rate of change of telescope position δAz and δZA are functions of hour angle. The amount of change in each will of course depend on the drift length, but the overheads will not differ much. As should be obvious, the largest changes in δZA occur at large ZA while the largest changes in δAz occur at small ZA, and the rates vary significantly between sources at different Decs.
- **ALFA Rotation Times**: The ALFA motor is currently set at 500 rpm. The corresponding ALFA rotation speed has been estimated by timing a rotation of 100° to be $\sim$56 sec. However, timing of smaller rotations implies an overhead of a few seconds, presumably related to acceleration, deceleration and settle. In addition, because the communication between CIMA and the ALFA motor only occurs every 10 seconds, an additional delay of up to that amount is possible.
- **Calibration mode overheads**: E-ALFA programs other than *ALFALFA* elect the commonly-applied synchronous calibration mode that executes a Cal ON/OFF sequence at the beginning or end of the drift, available as the options *LOOPSTART* and *LOOPEND* in the CIMA Spectral Line Observing Mode widget. Although the Cal ON and Cal OFF may each last only 1 sec, it takes 5 to 8 seconds to complete the sequence. Thus a nominal drift of N seconds actually takes from N+5 to N+8 seconds. If *LOOPSTART* is selected, the start of the drift can be predicted only with similar uncertainty for that

reason. Because of the delay, Cal ON/OFF sequences obtained when the telescope is not tracking may be affected by varying sky contributions to the total power between the ON and OFF.

- **Rotation/slew sequence**: At the moment, once "*OBSERVE*" is hit in the special CIMA *Fixed Azimuth Drift Map* widget that we used (a special version provided by Mikael Lerner and sourced separately), the rotation of ALFA executes first, and only after the array is rotated to the requested angle does the telescope slew begin.

In devising a schedule such as those used for the A1946 observations, we also had to keep track of hardware limitations associated with the dome position and ALFA rotation. Several additional points are hence worth noting.

- **Transit "zone of avoidance"**: For drift observations, there is no "zone of avoidance" arising from the rate of change of parallactic angle (see the discussion in Frank Ghigo's GBT memo), but the Gregorian dome cannot be moved to ZA $< 1.1^\circ$. Hence, observations of sources which transit within a couple of degrees of Arecibo zenith need to be conducted at significant HA. Obviously, the exact size of the "zone of avoidance" depends on the Dec. of the map center and its extent.
- **ALFA rotation angle hardware limits**: The rotation of ALFA is restricted to the range from -99° (counterclockwise) to +100.4° (clockwise). The beam orientation required to produce beams on the sky equally spaced in declination tracks the parallactic angle of the source but with an offset which varies systematically as the source moves across the sky. This offset is $\sim +19^\circ$ for a source on the meridian. For sources which transit near zenith, the range of rotation angle required to produce a single beam configuration exceeds these rotation limits during a full track across the sky, so that observers must consider alternative strategies.
- **Zenith angle dependence of the telescope gain, beam pattern, etc.**: The variation of spectral parameters with zenith angle is discussed in the various system performance memos presented on the AO ALFA web site *http://alfa.naic.edu/performance/*. A1963 has elected to restrict observations to ZA $< 14^\circ$ in order to minimize the impact of the degradation of system performance at high ZA. Even so, proper consideration of changing parameters should be incorporated to deliver robust and well–calibrated datasets.

Please note that these observations relate to the experience of the A1963 observing team during their run 28Nov-06Dec 2004 and may not apply equally to observers using other versions of CIMA widgets or after future changes are implemented.