SMA Technical Memorandum

Title VLBI operation for the SMA
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Summary

The SMA has made provision for VLBI operation in its design, but the VLBI-specific hardware and software are not included in the initial construction plan. This memo describes the provisions made, and the hardware needed for VLBI operation. The principal hardware items are: Hydrogen maser, VLBI recording unit, IF splitter and processing unit, circular polarizer for frequencies other than 345 GHz.

Introduction

The SMA will almost certainly take part in VLBI experiments at some stage. When it does, it is highly desirable that the 8 antennas be phased together to increase the effective collecting area by a factor of 8. To do this effectively, the regular interferometer should operate simultaneously with VLBI to permit continuous monitoring of the phase difference between the different antennas. The phase differences between the signals can then be set to zero by using the phase rotators in the 1st local oscillators. It is also desirable to make a local correlation between the combined signal and the signal from one antenna to test the accuracy of the phasing.

There are four major systems in the SMA which would need to be changed to permit VLBI operation, the LO system, the IF output, the on-line control system and the receiver polarization. In each instance, the possibility of VLBI operation has been considered, and provision made for VLBI operation if needed, although extra equipment will be required for VLBI.

LO System

LO Distribution The phase stability requirements for VLBI operation are much higher than for local interferometry, since many slow phase drifts in the phase reference (e.g. 60 Hz phase noise) cancel out in local connected-element interferometry, since they affect all antennas, and do not change the phase differences. We have designed the LO system for maximum phase stability to minimise all these phase drifts and give the best VLBI performance. (However, we have also used equal cable lengths in the distribution system to cancel common-mode phase noise in local interferometry.)

Frequency Reference There is also provision for using a maser as the fundamental frequency reference, instead of the crystal or GPS signal used for local work. One consequence of this is that we must allow for incoherence between our GPS-based timing clock and our frequency reference. This could have been done by some kind of software calibration equation for the time difference, but we chose to allow for the difference in the correlator timing unit. Our basic 10 millisecond clock and all longer term timing are derived from the GPS system, while all high frequency references are derived from a crystal or maser. In the correlator timing unit, each 10 millisecond integration period is set as an exact number of 52 MHz clock pulses, but the number of pulses is allowed to change from one 10 millisecond period to the next, to absorb the incoherence between the clocks. The integration period is always the same number of clock pulses, so the blanking interval may vary slightly between periods.

The maser is not included in the construction budget.

IF System and VLBI recording unit

To obtain a VLBI output signal, it is necessary to add together the IF signals coherently before passing them to the recording unit. Since our delay is digital, the digital signals must be added and then

converted back to analog form, after passing through the delay lines. In the original scheme, the cables between the delay unit and the correlator racks would have been split to extract the delayed digital signals. Now that the delay lines are embedded in the correlator rack, the processing box must include extra delay lines. Since the VLBI bandwidths are small, only a few chunks need to be processed for VLBI.

Splitters Splitters must be inserted in the lines from the A/D system and the correlator racks, to extract copies of the digitized signals for processing. For a small number of chunks, some outputs are already available on the receiver boards because of the provision for expanded frequency resolution.

Signal Processor The IF signals from the splitters must go into a processor which applies the delay, undoes the Walsh function phase modulation (see also software below), remultiplexes the signals to a 208 MHz data stream, adds the signals from the antennas, and passes them through an A/D converter to obtain an analog signal for the VLBI recording unit. Some frequency conversion may also be required to match the VLBI input band. The 180 degree functions are easily removed digitally, but the 90 degree functions will be harder if they are not turned off for the experiment.

Phasing Test There should be a provision in the Processor box to correlate (analog) the phased signal with the signal from one of the antennas to give a local test of the phasing.

The splitter and processor are not included in the construction budget, nor is the VLBI recording unit.

Optics

Polarization VLBI is performed with circular polarization. The SMA already has provision for a circular polarizer at 345 GHz, but polarizers would have to be added to the optical path for operation at other frequencies.

The other polarizers are not included in the construction budget.

Software

Phase Control The phase control of the array also allows the phase and delay reference positions to be chosen arbitrarily. The lobe rotators and delay lines correct all signals to the reference position, which then becomes the effective location of the VLBI signal from the SMA. With the ability to choose the reference position freely, the apparent location of the SMA will be unaffected by the physical locations of the antennas. The frequency used for the phase rotator computations will also be selectable, to allow us to turn off the 3rd LO phase rotators, and set the 1st LO phase rotators for the selected VLBI sideband.

Walsh Functions There should be provision for operating the SMA without Walsh functions. They should be removable in the IF processor box, but it may be convenient to operate without the 90 and or 180 degree functions for test purposes. If the phase rotators are used to select only one sideband, then the 90 degree switching is not needed for sideband separation.

Schedule Interface A perl script or something similar is required to convert VLBI schedules to SMARTS control scripts. SMARTS has already been designed with timing control to operate schedules at exact UT times, although this is not the normal mode for local interferometry.

Phasing Up A convenient method should be provided for monitoring and adjusting the phases to zero on all baselines. This should be possible with the normal interferometer control software.