Submillimeter Array Technical Memorandum

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Fringe rotation constraints for 6 and 8 antennas

Summary

The analysis of fringe rotation is updated to the current down-conversion scheme. With the current phase rotators, there is plenty of margin with our planned 320 ms cycle time. There are no extra restrictions imposed by the the impending addition of two antennas, or baselines to CSO/JCMT.

Introduction

The layout of the phase rotation has now moved back closer to the system proposed in Tech memo 56, with 2 frequency conversions in the control building. In the notation of memo 56, LO2 is now nonexistant, and the phase rotators are applied at 288 instances of LO4, although it might be possible to apply them at 36 instances of LO3. In the current scheme, there are 6 frequencies of LO3 per antenna, each converting a **block** of 4 chunks.

There are two expansions of the basic interferometer which must be considered. When the Taiwanese add 2 more antennas, we will still be able to handle all phase switching with the original 32 Walsh functions. In terms of delay, we are now planning to run with unbalanced IF lines, so the total delay length must allow for this, as well as for the 1 km baselines to CSO and JCMT.

Fringe rates

From the calculations in memo 56, the residual fringe rate is the quantity which determines our maximum integration time. The maximum residual fringe rate, R_{max}, is the worst case fringe rate at any point in the IF band at the time when the fringe rate is highest., after the fringe rotators in LOs 3 and/or 4 have corrected the rate to zero at some point(s) in the band. It is given by

$$R_{max} = 0.2424\ (f_{res}/1\ \text{GHz})\ (b_{max}/\ 1\ \text{km})\ \ \text{Hz},$$

where f_{res} is the maximum frequency offset from a frequency at which the fringe rate has been corrected to zero. Since the fringe rate varies sinusoidally during a day, the average fringe rate is less than the maximum value. In the case considered in memo 56, the center of the 2 GHz IF band was corrected, giving f_{res} = 1 GHz. The corresponding maximum integration time, t_{max}, was defined as

$$t_{max} = 0.05 / R_{max} \text{ seconds,}$$

for a maximum loss of 0.4%. For f_{res} = 1 GHz, t_{max} = 0.206 sec, and with our planned integration time of 320 msec, the maximum loss would have been 1%.

Relation to Current Design and Predicted Expansions

The current design is much improved in its tolerance for integration times, since there are several phase rotators spread across the IF band, greatly reducing f_{res}. The design calls for one fringe rotator for each chunk, giving a worst case f_{res} of 52 MHz, and t_{max} of 3.96 sec for a 1 km baseline, which is very generous. Even if we were to move the fringe rotators to the 6 LO3s, f_{res} would be 182 MHz, and t_{max} would still be 1.13 sec, significantly larger than our 320 msec basic integration time.

Our integration time of 320 msec is made up of 32 periods of 10 msec, giving 32 independent Walsh functions, which allows us to handle 2 receivers on each of 8 antennas. The expansion to 8 antennas can therefore be handled with our present 32 Walsh functions, and this should take us up to the year 2000, since no more antennas have been funded beyond 8. Furthermore, expansion beyond 8 would require a rebuilding of the correlator and consequent reworking of the entire system. Therefore, we should continue with our current 32 Walsh functions and 320 msec switching cycle and defer any extension to 64 Walsh functions.

The longer integration times would, in principle, allow us to extend our basic integration time beyond 320 msec, reducing the computational load on the DSP's in the correlator. However, we will stick with the current 320 msec period, since it is highly desirable to maintain short integration times to minimize losses when we flag data or switch rapidly between sources and calibrators on short timescales (< 1minute). Such fast switching is required by observations which employ mosaicing, rapid phase calibration, or single dish spectroscopy with the chopping subreflector. However, we can keep longer integration time (perhaps multiples of 320 msec) as an emergency fallback in case we hit a severe computational bottleneck in the correlator.

Update rates and precision for lobe rotators

The LO 3/4 lobe rotators should be designed to give negligible degradation of the signal, so we place a constraint twice as tight as on the residual fringes, with the extra twist that there are two rotators involved on each baseline so the rms phase error is increased by a factor of $\sqrt{2}$, and the loss is therefore doubled. Furthermore, errors in applying the phase are incurred all the time, unlike the sample time errors described above, which vary sinusoidally during the day. There are two contributions to the phase error, one from the finite resolution of the phase rotator, and one from the fact that the updates will be made only at discrete times. In general, the rms phase error depends on the rss of these contributions, giving a loss of 0.8% x $((20/N_{update})^2 + (20/N_{resolution})^2)$, where N is the number of steps per 360° cycle. If the resolution of the rotator is

1/100 cycle, and the update rate is every 10ms (70 steps per cycle at our maximum fringe rate of 1.45 Hz for 1 km baseline and 6 GHz IF), then the loss is 0.1%, if the rotator phase remains constant during each step. This is a worst case, since we can halve the fringe rate on any one antenna by moving the phase center of the array to minimize the maximum phase rate, cutting the loss to 0.05%. Therefore it is sufficient to update the phase rotators on 10 msec boundaries, as long as the resolution is better than 3.6°.