Submillimeter Array Technical Memorandum

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Correlator Back Plane Switching

I. Introduction

This document will examine the wiring which resides between the station units and the correlator boards. Specifically, the goal is to develop a mapping arrangement for the backplanes which meets the present and future needs of the SMA.

The signals from the station units must be driven to several different correlator boards to implement the necessary baseline calculations. This paper will consider which paths are needed and if any modes require changes to the station unit to correlator board mapping. The correlator boards provide a great deal of electronic switches. What additional switching resources are needed in excess of the correlator board crosspoint switching? Before discussing the proposed solution, it is necessary to frame the issue by stating some of the relevant assumptions. The next section will attempt to introduce these issues.

II. Correlator Sizes

For this discussion, a variation of the correlator system must be considered. The standard configuration is the 6 chassis machine which is under development at this time by Haystack. This machine is being constructed for the 6 antenna SMA with the option for joint operation with the JCMT and CSO. The variation of the correlator which must be considered here is the possible expansion of the present unit by a factor of 2. This double-sized correlator will be have a total of 12 chassis and is intended for the expanded 8 antenna SMA which is under consideration. I should make it clear that the double-sized correlator is not a funded project. However, as will be shown by this document, a very nominal amount of planning at this time will facilitate a painless expansion.

III. Desirable Modes

This section will only discuss the modes which affect the backplane switching. Naturally, there are lots of resolution modes, but they can be implemented using the correlator board switching options. What is important for this discusssion are modes that require changing the signals entering the correlator boards.

III.A. 6 Chassis Modes

III.A.1. 6 Station Cross Correlation Mode - Full BW with Cross-polarization possible

This is the "regular" mode of operation with each board able to process 8 chunks per antenna (4 per receiver) with full cross polarization capabilities and *no* autocorrelations. This mode must be able to calculate all 15 baselines for the 6 element interferometer antennas using the available 6 chassis in the correlator. The full 2 GHz of bandwidth from both receivers is processed and cross-polarization between receivers is possible.

III.A.2. 8 Station Cross Correlation Mode - Half BW with *no* Cross-polarization

This is the mode intended for operation of the 6 element SMA in junction with the CSO and JCMT. Given the incompatibility of the receivers, implementation of the full cross polarization capabilities is unnecessary. This mode will be implemented by switching the IF from the JCMT (and CSO) into one of the IF inputs intended for an SMA antenna. This switch is performed in the analog hardware. From the perspective of the correlator board, half the chunks from a given antenna will appear as data from the additional antennas. This mode can process the full 2 GHz but from only one receiver channel.

III.A.3. Sub-Arrays

In the simplest form, this mode takes a single antenna out of the SMA and views it as a single dish telescope. This mode will be useful for servicing a problematic antenna or possibly for certain observation techniques. This mode is easily implemented, but as an added constraint, it would be useful to avoid the complexity of forcing a correlator board to perform auto and cross correlations processing, simultaneously. Thus, it would be preferable to have the board(s) which perform autocorrelations be removed from the system without impacting the remaining 10 baselines of the 5 antenna interferometer sub-array. Naturally, sub-arrays of less than 5 antennas would be useful. As it turns out, the 1-5 mode, which was just described, is the only mildly difficult sub-array and the other combinations come out naturally. This includes the degenerate case of 6 separate single dish antennas.

III.B. 12 Chassis Correlator - The Double Correlator

III.B.1. 8 Station Cross Correlation Mode - Full BW with Cross-polarization

This is the "regular" mode of operation for an 8 antenna SMA. It is identical to the 6 antenna version with full polarization on the full bandwidth and 2 receivers per antenna. However, the correlator must now calculate 28 baselines worth of data instead of 15.

III.B.2. 10 Station Cross Correlation Mode - Half BW with *no* Cross-polarization

When the 8 antenna SMA is operational, it’s likely that the JCMT and CSO will again be called upon to increase baselines coverage. With the addition of these two antennas, the SMA would have 10 stations. As in the original JCMT/CSO mode, the correlator will be forced to sacrifice half the bandwidth (1 receiver) to perform the additional baseline measurements. With 10 stations the correlator must handle 45 baselines, which is well within the capabilities of the expanded correlator.

III.B.3. Sub-Arrays

This mode is analogous to the original Sub-Array discussion, except 8 autocorrelations are needed instead of 6. Once again, it would be desirable to form sub-arrays without requiring correlator boards to perform both autocorrelation and cross-correlations.

IV. Constraints

Now that the goals are stated, it’s necessary to consider the constraints to meeting these goals. The flexibility of the crossbar switches which exist on the correlator boards give a great deal of options of implementing the required modes. However, there are some subtle constraints that must be considered.

IV.A. Correlator Input Channel"C’

Each correlator board has three input channels called : "A,B and C". Figure #5, which was taken from the correlator board specification produced by Haystack, gives a graphical representation of the distribution of these channels. In normal operation, one input channel would carry 8 chunks from a single antenna (4 chunks per receiver). In this mode, there is really no difference between A, B or C because the board can perform any combination of two channel (i.e. AxB & AxC or AxB & BxC or AxC & BxC). However, there is a subtle limitation to the "C" channel in nonstandard modes. For example, the "C" input channel cannot be used for data which is to be autocorrelated because the correlator chip is designed to allow feedback from the "X" input. Also, it is not possible to perform cross-correlation within a channel, i.e. C[a]xC[b] (Note - this does not mean autocorrelation. This refers to the ability to perform cross correlation on two different chunks, a and b, from the same input channel). This flexibility is important for the JCMT/CSO modes because the 8 chunks are split into two antennas with 4 chunks each. Therefore, it is desirable to cross correlate half of an input channel with the other half of the same input channel.

IV.B. Backplane wiring.

One of the practical constraints is to avoid excess wiring delays and loads. With the high clock rate (52 MHz), it would be desirable to avoid unnecessary permutation of the various antenna signals which will complicate the layout of the backplane. For this reason, the receiver board will have direct connections to the correlator board through only 4 connectors M1, M3,M5 and M7. The other input will be derived from neighboring connectors.

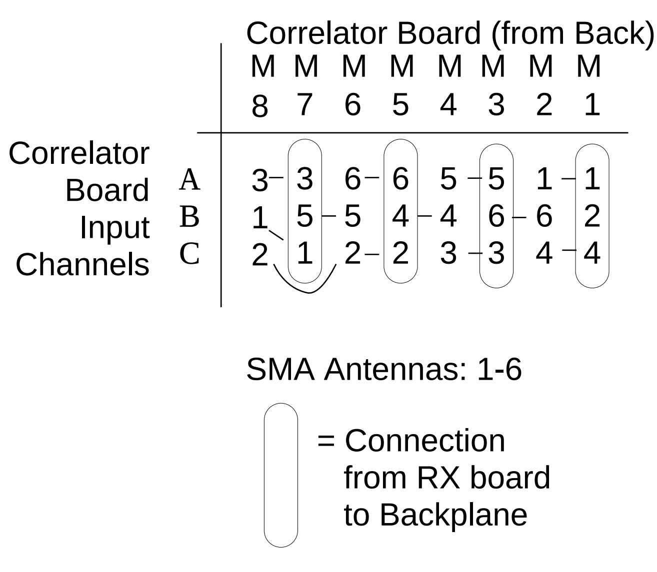


Figure #1 - Proposed Backplane Mapping

V. Solution

Given these constraints and goals, I will describe one possible solution to this mapping. This configuration is not the only possible solution and was not derived with any fundamental knowledge. The proposed solution was found by trial-and-error and is undoubtedly sub-optimal. Nonetheless, it seems to meet the criteria and should be easily implemented.

Board		8	7	6	5	4	3	2	1
Inputs	A	3	3	6(8)	6(8)	5(7)	5(7)	1	1
	B	1	5(7)	5(7)	4	4	6(8)	6(8)	2
	C	2	1	2	2	3	3	4	4
6 Ant. Mode		3x1	5x3	5x2	6x2	4x5	6x5	1x6	2x1
		3x2	5x1	---	6x4	4x3	6x3	1x4	2x4
Sub Array		3	5		6	4		1	2
8 Ant. Mode		3x1	5x3	5x2	6x2	4x4	6x5	1x6	2x1
		3x2	5x1	7x2	6x4	4x3	6x3	1x4	2x4
		---	5x7	6x7	6x8	3x7	5x8	4x8	--
		---	1x7	7x8	2x8	4x7	3x8	1x8	--

	1	2	3	4	5	6	7
1							
2	1						
3	8	8					
4	2	1	4				
5	7	6	7	4			
6	2	5	3	7	3		
7	7	6	4	4	7	6	
8	2	5	3	2	3	5	6

(x) - indicates 4 chunk switch implemented in IF

Figure #2 - Operational Modes for 6 Chassis Correlator (and lower half of 12 Chassis Corr.)

V.A. Solution applied to 6 Chassis correlator

Figure #1 gives a sketch of the proposed backplane mapping.. Each antenna is assigned a number, SMA antennas are 1-6 (the JCMT and CSO will be 7 and 8). The signals from the station unit are accepted by the receiver board and driven to the correlator board via the inputs indicated. This scheme should allows every signal to be driven using the 4 connector receiver-to-backplane scheme proposed by Jim Levine. The inter-board connectors are indicated with the circular shapes. The other correlator signals are all derived on the backplane using wiring from a neighboring connector from the receiver board (or nearby signal in the case of the antenna #2 path). In the worse case, a driver must source 3 correlator boards, and only in once place: signal #2 on boards 5,6,8. In all other cases, the maximum load is 2.

Figure # 2 presents a sketch the of the various modes implemented with this interconnection scheme. The 6 antenna modes shows the boards which will perform the 15 baseline calculations for the "standard" SMA 6 antenna interferometer.

The sub-array entry indicates which boards can be dropped from the system to calculate the autocorrelation for a given antenna. The goal was to allow a board to be removed from the interferometer calculations without impacting the the remaining 5 antenna sub-array. Thus, the specified autocorrelation board for a given antenna must only contain baselines for that antenna and not a crossproduct from the other two input channels which enter the board. This was also constrained by the C channel’s inability to perform autocorrelations.

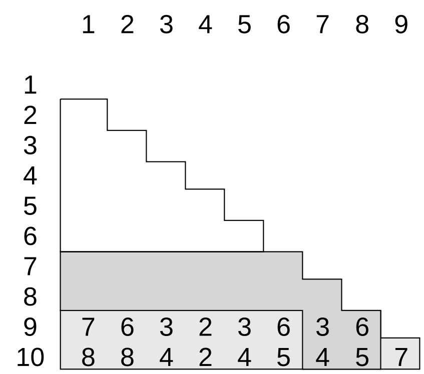
This organization of 2 baselines per correlator board ensures that smaller sub-arrays can be implemented without any problems. If two antennas are removed to perform autocorrelations, then the remaining 4 element interferometer is not disturbed. This process can continue all the way to a mode with 6 independent single dishes.

The final entry describes the JCMT-CSO linkup. By injecting one of the extra antenna’s IF into SMA antenna 5’s IF and the other extra IF into the unused receiver channel for 6th SMA antenna,, the necessary 28 baselines can be performed. The implementation of the necessary signal path chang-

Board		8	7	6	5	4	3	2	1
Inputs	A	3	3	6(8)	6(8)	5(7)	5(7)	1	1
	B	1	5	5	4	4	6	6	2
	C	2	1	2	2	3	3	4	4

Swap

Board		8	7	6	5	4	3	2	1
Inputs	A	10	10	6(8)	6(8)	5(7)	5(7)	10	10
	B	1	9	9	10	10	9	9	2
	C	2	1	2	2	3	3	4	4
6 Ant. Mode		10x1	9x10	9x6	10x6	10x5	9x5	9x4	---
		10x2	9x1	9x2	--	10x3	9x3	10x4	--
Sub Array		10	9						
8 Ant. Mode		10x1	9x10	9x6	10x6	10x5	9x5	9x4	---
		10x2	9x1	9x2	--	10x3	9x3	10x4	--
6 -> 6/8		--	--	9x8	10x8	10x7	7x9	--	--
5 -> 5/7		--	--	--	--	--	--	--	--



Empty Slot

Figure #3 - Operational Modes for upper half of 12 Chassis Correlator

es can be achieved with the cross-bar switches that already reside on the correlator boards. Thus, backplane switches are *not* necessary to implement the required modes for the 6 antenna SMA.

The signal switching is performed by changing the correlator board crossbar switches. The switching can take an input channel (for example A) and produce cross-correlations between chunks within this antenna channel. Thus, when the JCMT-CSO mode is used the 8 chunks of antenna #6 will be split into 4 chunks for antenna #6 and 4 chunks for the JCMT. The JCMT signals can be correlated with the other input antennas on the board AND with the signals from #6 as long as they do not enter on the correlator board through input C. (See the constraints description)

This meets the requirements, however it should be noted that full sub-array flexibility is not possible with the JCMT-CSO linkup. Also, some provision for switching the IF into the #5 and #6 antenna must be made. The IF switching is specific, the JCMT/CSO must use the 5th and 6th IF; any old IF will not necessarily work due to the Channel "C’ constraint.

V.B. Solution applied to 12 Chassis correlator

The proposed solution seems to meet the necessary criteria of a 6 antenna SMA, it is now necessary to consider the ramifications of a double sized correlator to handle the 8 antenna SMA expansion. The most obvious problem from the perspective of a correlator backplane is the need to drive each station unit signal into additional correlator boards to calculate the new baseline pairs. Ideally, the expansion from 15 baseline pairs to 28 should be performed with minimal disturbance to the existing 6 chassis correlator (which we will assume is operational before the expansion occurs).

Therefore, the goal would be to avoid any changes to the backplane wiring and minimal disturbance to the wiring matrix. Another useful advantage would be to re-use the same backplane boards in the expanded system.

Although, this is not necessarily the proper venue for discussing the matter, the extra baseline pairs mean each station unit should be prepared to drive two backplanes, not one as required for the original correlator.

A solution that implements the necessary modes and meets the goals of easy expansion plus reusable backplanes is suggested in Figure #3. The new antennas are called 9 and 10 to keep consistent with the previous discussion (the JCMT and COS will remain as 7 and 8). Naturally, this numbering scheme is a bit cumbersome but is simply a temporary abstraction for this discussion.

Figure #3 represents the calculations performed by only the *new* half of the correlator. The original 6 chassis correlator will perform identical processing on the original 15 baselines. No wiring changes to the original correlator are necessary. The 13 new baselines which are engendered by the extra antennas are handled in the expansion chassis. This is not particularly symmetric, but does meet the goal for minimizing the disturbance to the existing correlator. One positive consequence of this asymmetric arrangement is the reduction of one board per chassis. Thus, the the expanded correlator will require only 42 correlator boards to populate the 6 new chassis. Correlator Slot 1 can be left empy and still accomplish all the necessary modes.

A single backplane/receiver design to implement the mapping for both variations (Figure 2 and 3) does not require any crossbar switching chips. The path swap indicated in figure #3 can be static and therefore performed with jumpers. Once a board is setup for the upper or lower 6 chassis group, it would never required reconfiguration. The mode swap for the JCMT-CSO operation is performed using the correlator board crossbar switches. Thus, the receiver-backplane does not require ANY electronic switches.

Figure #4 shows one possible implementation of this static switching for one signal path. The receiver board requires a total of 40 such jumpers. The receiver board will need inputs for 8 antennas with a full set of 8 chunks per antenna. However, in the initial 6 chassis system the upper two receivers circuits can be left unstuffed.

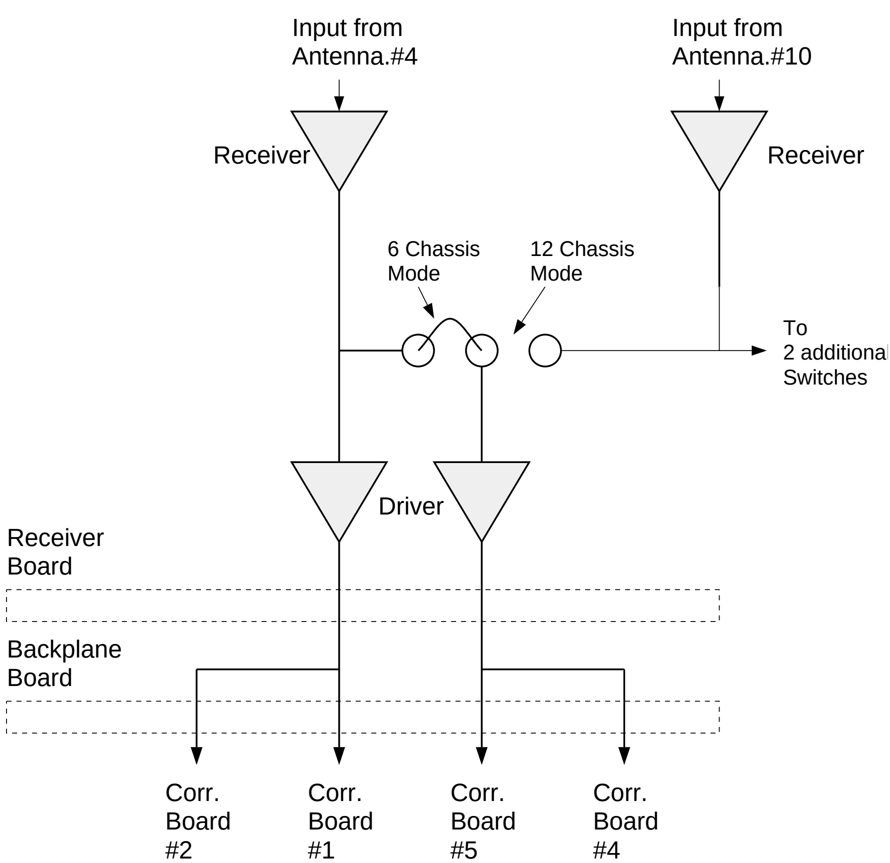


Figure #4 - Jumpers to implement 12 chassis mode

VI. Recommendations

If all of the following recommendations are met, the 6 modes described in section III will be achieved. Also, these recommendations will smooth the transition to a 12 chassis correlator.

1. The *Station Unit Boards* should have the ability to drive two (2) independent cables to the correlator hardware. This second channel is only needed for the expanded (12 Chassis) correlator and therefore could be left unstuffed for the initial implementation.

2. The proposed correlator backplane/receiver combination requires only 4 interconnections as suggested by Haystack This reduction will not limit the necessary SMA modes, that is, if the data paths conform to the other suggestions of this document.

3. The wiring from the receiver input to the correlator boards shall be as indicated in Figures 2,3 and 4. The two variations are implemented on the same board using jumpers. The jumpers are static and will be set at assembly time. No active control of backplane configuration is necessary.

4. The receiver board shall contain connections for 8 antennas x 8 chunks. The original Haystack proposal only specified inputs for 6 antennas x 8 chunks and 2 antennas with 4 chunks. In the present implementation, the two extra antenna channels will be unused and can be left unstuffed.

5. Implementation of the JCMT-CSO modes will be performed by IF switching into the 5th and 6th SMA antenna. This requires manipulation of the crossbar switches that exist on the correlator boards. This method also requires the flexibility to handle cross-correlations within an input group (example "A").

6. The correlator shall have the ability to run with correlator boards missing. Therefore,the signal drivers should be able to operate with less than a full loads. This is useful to allow the reduction of one correlator board as suggested for the expanded system. However, this capability is also useful for normal maintenance tests. Naturally, some type of blank panel may be needed to ensure the integrity of the air plenum.