A WIDAR Correlator for the Expansion Very Large Array (EVLA):

Technical, Functional, and Performance Discussion Document

MCCC Software

Generating Baseline Board Configuration Based on the Configuration of Station Boards, a Proposal

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ABSTRACT

This document is a prelude to the detailed design of the MCCC software system for the EVLA correlator. The purpose of the document is to present an analysis of the correlator hardware architecture, and to use this analysis to develop a rules-based approach for controlling the configuration of the hardware in the simplest way possible. The implemented functionality will be in more detail described in the RFS document.

Table of Contents

List of Figures

List of Tables

Acronyms

BB	Baseband
BLB	Baseline Board
CCC	Correlator Chip Cell, a minimum unit that can be assigned to an X/Y pair of data streams. CCC has 128 complex lags that can produce 64 spectral channels. The EVLA Correlator Chip has 16 CCCs.
CCQ	Correlator Chip Quad, consists of four CCCs.
CMIB	Correlator Monitor and Control Interface Board. Embedded processor, a PC104+ module, installed as a mezzanine board onto each board in the correlator (Station Board, Baseline Board, Phasing Board and Time Generator Board).
DS	Data Stream
EMCS	EVLA Monitor & Control System. This refers to one or more layers of software residing on computers outside of the correlator, that communicates with the correlator via VCI.
MCCC	Master Correlator Control Computer. Off-the-shelf computer system that coordinates correlator components (boards). During normal operations, the MCCC provides a single point of access for controlling and monitoring the correlator.
SB	Subband
STB	Station Board
VCI	Virtual Correlator Interface. Interface between the correlator (the MCCC) and the EMCS.

1 Introduction

This document is a prelude to the detailed design of the MCCC software system for the EVLA correlator. The purpose of the document is to present an analysis of the correlator hardware architecture, and to use this analysis to develop a rules-based approach for controlling the configuration of the hardware in the simplest way possible.

Access to the software system will be via commands sent across the Virtual Correlator Interface (VCI). This part of the VCI will be the "face of the correlator" as seen by the EVLA Monitor and Control System (EMCS). The software itself will reside on the Master Correlator Control Computer (the MCCC), and will be known as the MCCC software (sometimes the MCCC, for short).

The document begins by describing "rules and limitations" imposed by the hardware design. It then presents the hardware design from a programmer's perspective. The balance of the document proceeds with the analysis and justification of the rules and limitations. Included is a series of key examples, which are used to illustrate the "coverage" of the proposed command set. At this stage the commands cannot be described in detail, nor can all the parameters be listed exhaustively.

The proposed design relies upon well-known design principles to maximize functionality and simplicity. These principles include knowing the state of the system at all times and developing a command set that covers as many configurations as possible without resorting to a list of "arbitrary modes". The result is a system that can carry out all of the required correlator functions and can support several simultaneous "users".

The following design "philosophy" is used to configure the correlator:

1) The EMCS (the "user") specifies which antennas will be used for a particular sub-array and the configuration of the station boards associated with those antennas in the subarray.

2) The EMCS will also specify the required correlator output products for those antennas in the subarray.

3) Based on the above input, the MCCC software derives the Baseline Board configurations needed to provide the requested output. In other words, it allocates Baseline Board resources to that subarray. There are a few additional parameters needed to govern the allocation of resources, the most important of which is whether recirculation can be used.

4) The EMCS can also directly specify the use of particular correlator resources in cases where this is needed, if those resources are available. It is envisaged that this capability will typically be used for testing.

5) The EMCS can allocate and deallocate correlator resources indefinitely. The MCCC software will track the use of resources at all times, and can provide this information to the EMCS at any time.

6) The MCCC software provides consistency and resource checking to determine whether configuration commands can be implemented, and returns error messages appropriately.

A complete compendium of rules and limitations of the system is contained in Section 2.2.

1.1 Purpose

This is an interim document, intended to obtain comments and suggestions; implemented functionality will be described in the MCCC Requirements and Functionality Specification [3]and VCI Protocol Specification [1] and, eventually, in the MCCC User Manual.

1.2 Scope

The functionality described here does not include all the parameters that will be implemented for the Station Board (basebands / subbands); only the "core" parameters, used to determine requirements for Baseline Board resources, are considered in this document.

Content of the Station Board Configuration message is defined in the document "VCI Protocol Specification" [1].

1.3 Terminology

The following terminology is used when defining rules and requirements:

"*Must*" is used when failure to follow the rule would result in rejection of the configuration request and/or that output products will not be generated (e.g. a baseline may be disabled).

"*Should*" is used when describing expected and recommended behavior. It implies that the correlator is able to handle requests that do not follow the specified recommendation or rule. When referring to received configuration request messages, "*should*" implies that a configuration request is accepted even if a configuration does not follow a rule, but the originally specified parameters may be modified to fall within the set of rules. An error or warning is generated to notify the originator when the configuration has been modified.

2 Overview

This document discusses correlator configuration parameters that have impact on the Baseline Board configuration.

In EVLA correlator, configuration of Baseline Boards is not specified directly, it is derived from the Station Board configuration and from the requirements for output products[1].

It is a requirement that a configuration can be activated on each Station Board separately.

However, since four Station Boards, that may or may not be connected to the same antenna, share the same set of Baseline Board resources (Correlator Chips and associated hardware), it is obvious that the EMCS, when specifying a configuration for a single Station Board, must take into consideration the configuration of other boards that belong to the same Station Quad.

It is recommended that a configuration change *should* be activated on all Station Boards in a Station Quad at the same time.

In the case when a configuration is activated on each Station Board separately, it is the responsibility of the EMCS to ensure that required Baseline Board resources are not already used by other Station Boards; otherwise the request will be rejected. In order to re-allocate Baseline Board resources (Correlator Chip CCQs), the EMCS *must* re-configure Station Boards that use those resources. For example, in order to add additional basebands, the EMCS might need to increase the recirculation factor on previously configured basebands.

In either case, in order to avoid runtime conflicts, the EMCS must, to a certain extent, be aware of the correlator internal architecture.

Section 2.2 below contains a list of rules and limitations that should be followed when specifying correlator configuration.

2.1 Activation Trigger

It is a requirement that the EVLA correlator must be able to receive a configuration request in advance and activate the configuration at specified time.

Typically, the correlator will receive a group (or sequence) of Configuration Request messages followed by a trigger that instructs the correlator (the MCCC) to act upon all received messages with the same Configuration Identifier. The Activation Trigger specifies when the new configuration should be activated (the activation time).

In the case when received messages contain a Station Board configuration, the Baseline Board configuration is generated only after the Activation Trigger has been received.

[1] Requirements for the output products are specified for each subband of each baseband.

It is recommended that the configuration for all Station Boards that belong to the same Subarray *should* be transmitted first, and then the trigger message that instructs the correlator to act upon received messages.

However, Stations and Station Boards can be added to a Subarray at any time. When an activation trigger for a single Station Board Configuration Request is received, the MCCC re-considers each baseline that receives input from the Station Quad affected by the configuration change. For each baseline, the MCCC considers whether there are enough available resources (CCQs) to accommodate the new request. If at least one baseline may be configured as requested, configuration is accepted. An appropriate error/warning messages are generated when request cannot be configured as specified.

2.2 Summary of Rules And Limitations

The following rules apply for the configuration of the EVLA correlator:

1. All Station Boards in a Station Quad *must* belong to the same Subarray.
2. Each Station Board in a Station Quad may belong to a different station (i.e. may receive input from a different antenna).
3. Each Station Board Configuration Request specifies complete configuration for a Station Board. Newly received Station Board Configuration Request completely replaces previous Station Board configuration.
4. A different Hardware Integration Time may be specified for each subband of each baseband (each STB Filter[2] output). However, subband Hardware Integration Time must be harmonically related to one of the four DUMPTRIG signals generated by Station Boards in the same Quad. (DUMPTRIG signal is generated based on the Minimum Hardware Integration Time, which is configurable parameter of the Station Board.)
5. For each subband, LTA Integration Time and Backend Integration Time are harmonically related to Hardware Integration Time.
6. Basebands on the same Station Board:
    a) *must* belong to the same subarray,
    b) *must* belong to the same station.
    c) *must* have different Baseband IDs.
7. Output of each STB Filter *must* be assigned unique set of Station/Baseband/Subband Identifiers.
8. The following rules apply for Station, Baseband and Subband Identifiers:

[2] In older EVLA documents STB (Station Board) Filter was referred to as FIR (Finite Impulse Response) Filter.

a) At any given time, there *must* be only one station with the specific Station ID in the correlator. This implies that stations cannot have the same Station ID even if they belong to different Subarrays.

b) For a single station, each baseband *must* have a different Baseband ID.

c) For a single Station Board Data Path, output of each STB Filter *must* be assigned a different Subband ID.

9. The following applies for a pair of data streams where correlation is required:

   a) The data streams *should* have the same bandwidth.

   b) The data streams *should* have the same central frequency.

   c) The Hardware Integration time *should* be the same for both data streams. If the H/W Integration Time is not the same, the shorter Integration Time will be used.

   a) Required number of spectral channels *should* be the same. If the number of spectral channels is not the same for both data streams, the MCCC will use the smaller of the two specified values.

   b) Recirculation:

      1. Recirculation factor *should* be the same. If not, lower recirculation factor is used (unless higher number is already in use for the column/row).

      2. If recirculation is optional (zero) for one data stream, but not for the other, the specified (non-zero) value is used for both.

   c) The parameter "Sensitivity loss allowed" *should* be set in the same way for both data streams. If sensitivity loss is allowed for one, and not for the other data stream, it is assumed that sensitivity loss is allowed for both.

   d) Required number of products should be the same for both data streams. If it is not the same for both data streams, the correlator (MCCC) will use the smaller of the two specified values.

10. Data streams that are configured as a polarization pair *should* have the same bandwidth and central frequency, and different polarization.

11. Cross-products may be required only for the data streams that are configured as polarized pairs.

12. If 4 products are required for one data stream in a polarization pair it *must* be required for the other. Otherwise the configuration is rejected.

13. Unless additional recirculation memory (R2) is available, the following limitation applies for data streams in a Baseline Board Input:

    a. in 4-bit correlation mode, two out of four data stream pairs may use recirculation

b. in 7-bit correlation mode, one out of four data stream pairs may use recirculation.

14. The following applies for the data streams in the same Baseline Board Input (i.e. data streams that are correlated on the Correlator Chips in the same column/row):

    a. All data streams that use recirculation *must* have the same bandwidth. If two data streams that require recirculation have different bandwidth, recirculation will be configured for the first data stream only. The second data stream will be configured without recirculation (probably resulting in less spectral channels than originally required). A warning message will be generated.

    b. All data streams that use recirculation *must* use the same recirculation factor. If different recirculation factor is specified for data streams in the same Baseline Board Input, required products will be obtained only for the first pair of data streams that requires recirculation. Data streams that require a different recirculation factor on the Correlator Chips in the same column/row will be ignored (i.e. correlation for such data streams will be disabled).

Chapters 3 and 4 provide an overview of the correlator architecture and describe how the MCCC implements this rules to generate Baseline Board configuration based on the received Station Board configuration.

2.3 Error Handling

Received VCI Configuration Requests will be checked for syntactic and semantic errors. Messages that violate the rules (mostly specified by XML Schema) will be rejected by the correlator, which means:

a) the configuration change request in the message will not be performed, and

b) an appropriate error message will be sent to the originator.

The correlator will also check if the received configuration is correctly and consistently specified for entities for which configuration is defined by two or more VCI Configuration Request messages:

a) Station,

b) Station Board Quad,

c) Baseline and

d) Subarray.

An inconsistent or erroneous configuration may have the following consequences:

a) Output products cannot be obtained as requested (due to physical limitations of the correlator).

b) Generated output products are meaningless.

c) Backend cannot accept the configuration.

The correlator will provide a tunable error handling mechanism, as follows:

1. An error level indicator will be assigned to each error/consistency check.

2. The level at which the correlator VCI rejects the configuration will a configurable parameter.

Example: The correlator VCI software will check if all the baselines in a subarray are configured in the same way (i.e. if all the stations in a subarray have the same number of basebands and subbands, and if the same number of products is required for all). If that is not the case, the originator of the request will be warned using the reply message, however, whether or not the configuration will be rejected, will depend on the current setting of the “configuration reject level” parameter.

3 Hardware Configuration

This chapter gives a brief overview of the Station Board and Baseline Board hardware configuration. The diagrams show only elements that are discussed later in the document. The numbering scheme used in this document is defined in the "EVLA Correlator System Numbering Plan" [2].

As shown in **Figure 1**, Station Board has two identical Data Paths. A Station Board input stream may consist of up to two basebands. Any of the two basebands can be forwarded to any of the two Station Board Data Paths. The output of each Station Board (STB) Filter can be forwarded to any of the 18 Station Board Outputs. Data Stream Identifiers (Station ID, Baseband ID and Subband ID) are inserted in the output data stream before the output cross bar switch.

Figure 1 Station Board

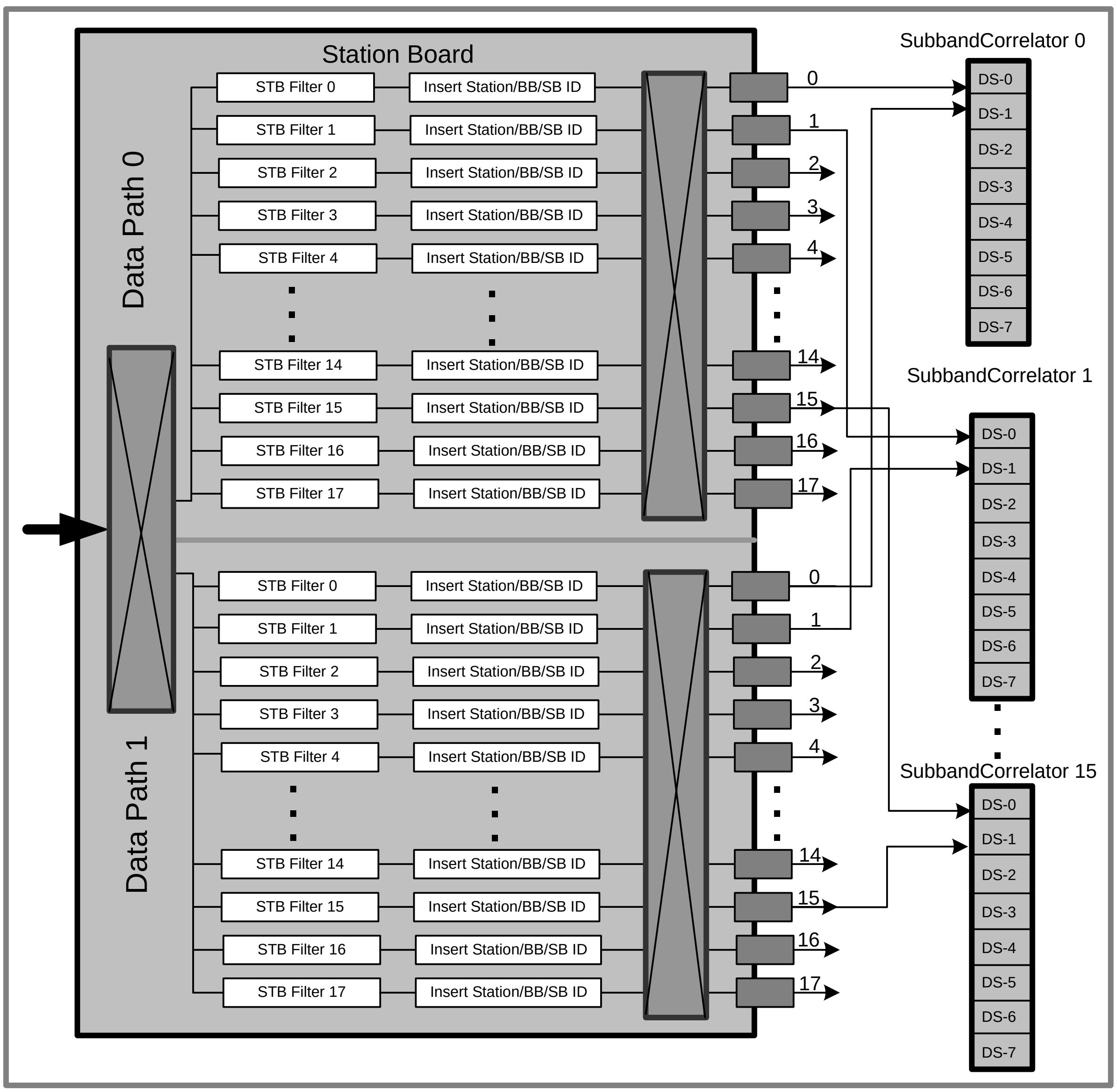


Figure 2 is a simplified diagram of the Baseline Board.

- A Baseline Board has 8 X and 8 Y inputs.
- Each input consists of 8 Data Streams.
- Input Switches are used to re-arrange data streams in Baseline Board Input when needed (details shown in **Figure 4**).
- All Correlator Chips in the same row/column receive the same input.

Figure 2 Baseline Board

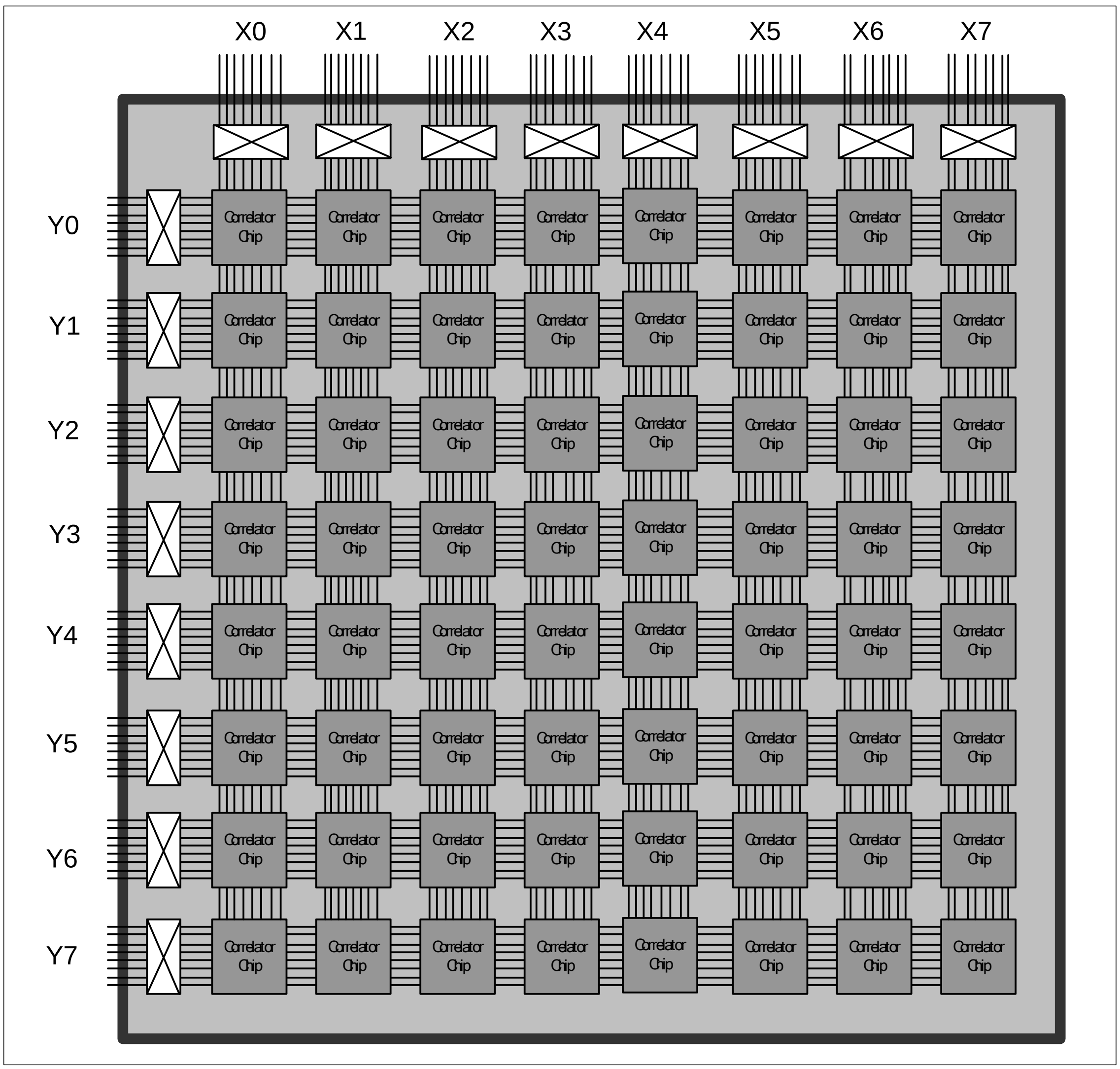


Figure 3 shows a single Correlator Chip, two Station Quads and Baseline Board Input hardware (X Input and Y Input). The switches in the X and Y inputs can be used to re-arrange data streams in Baseline Board Input before they are forwarded to the Correlator Chip. The switch in the CCQ input allows any of the two input data streams to be forwarded to any CCC.

Figure 3 Correlator Chip and Station Boards

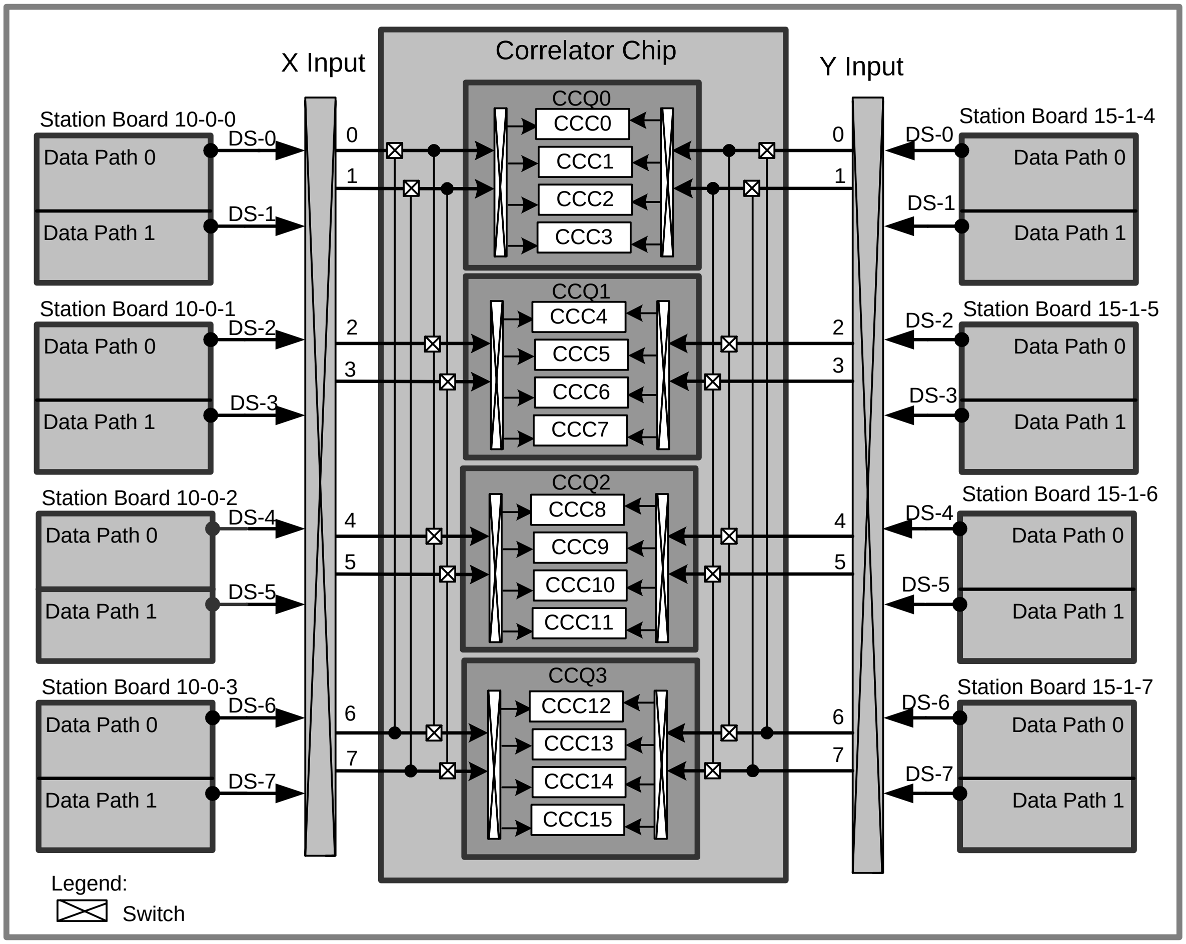
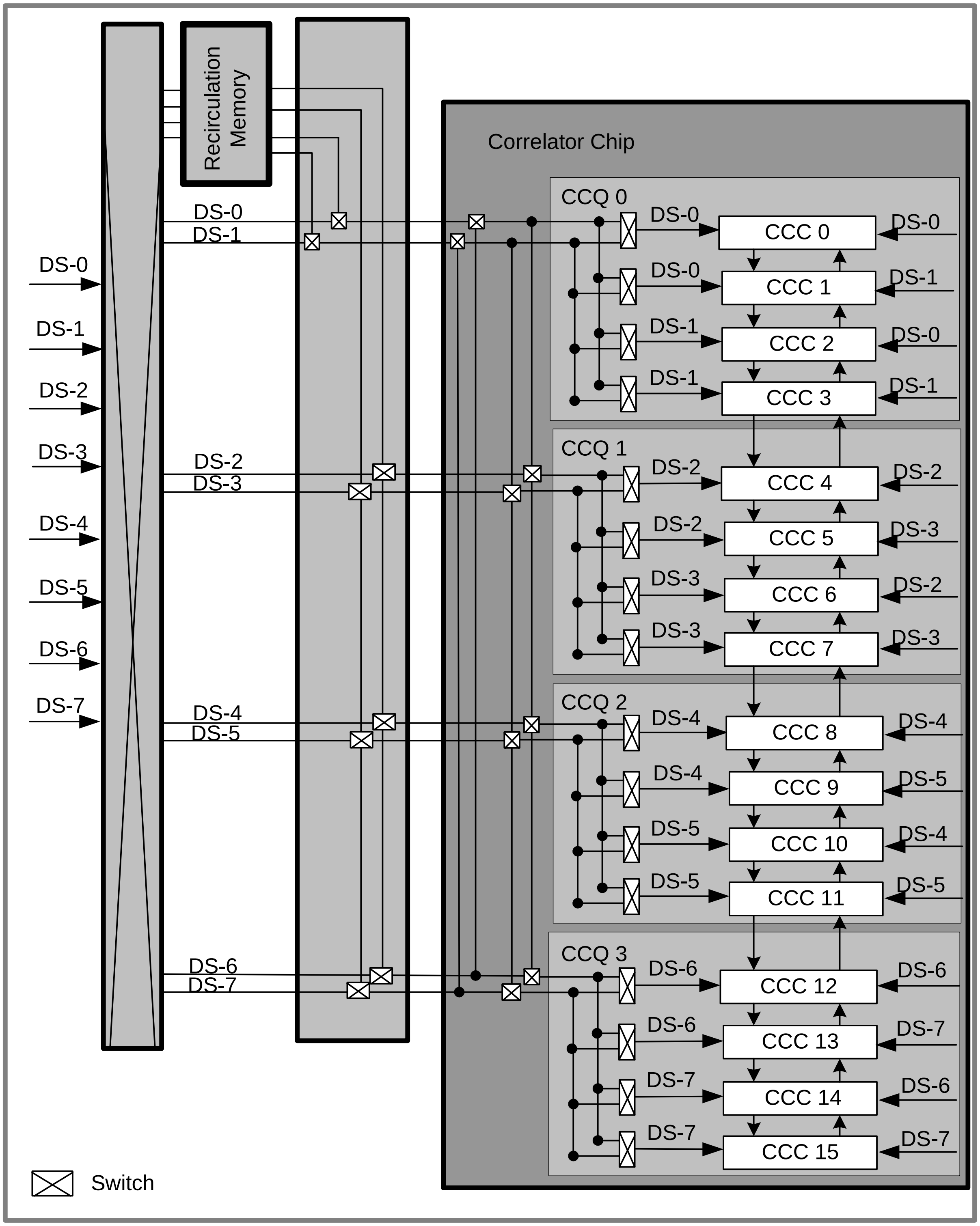


Figure 4 shows input switches for a single Baseline Board Input. The Input Crossbar Switch allows any of 8 Baseline Board Input Data Streams to be connected to any Correlator Chip Input Data Stream or to recirculation memory. Recirculation memory can handle two data stream pairs at the same time.

- Each Correlator Chip Input consists of 8 data streams, which may be considered as four pairs.
- A Correlator Chip has four Correlator Chip Quads (CCQs).
- A Correlator Chip Quad (CCQ) has 4 Correlator Chip Cells (CCCs).
- A Correlator Chip Cell (CCC) has 128 complex lags.

Figure 4 Baseline Board Input and Correlator Chip



In 4-bit correlation mode:

- A Baseline Board Input Data Stream can be forwarded to the Correlator Chip without changes (if recirculation is not used).
- At least one CCC is needed to obtain a correlation product.
- Without recirculation a CCC can produce 64 spectral channels for a single polarization product.

In 7-bit correlation mode:

- Recirculation memory is used to convert a 7-bit Data Stream into two 4-bit Data Streams that are input for the Correlator Chip.
- Four Baseline Board Input Data Streams may be processed in the recirculation memory.
- At least one CCQ is needed to obtain a single 7-bit correlation product.
- Without recirculation, a CCQ (4 CCCs) can produce 64 spectral channels for a single polarization product.

Regardless of the correlation mode, the smallest unit that can be assigned to a pair of Data Streams is CCQ (four CCCs). Nominally, one CCQ is assigned to each pair of Correlator Chip Input Data Streams. If, in 4-bit mode, a polarization pair does not use all four CCCs, remaining CCCs in the same CCQ cannot be assigned to another pair of inputs. This restriction is imposed by hardware design.

If output products for one or more input pairs are *not* required, the corresponding CCQ(s) may be assigned to another pair. Baseline Board Input Crossbar switch and/or Correlator Chip internal switches may be used to forward the same data stream to additional CCQs.

In the EVLA correlator, a Correlator Chip is connected to the same Station Board output on each Station Board Data Path (baseband) in a Station Quad.

Note: Station Board Identifiers (rack-crate-slot) shown in **Figure 3** are just examples and are added to emphasize the fact that four Station Boards belong to the same Station Quad.

3.1 Configuration Discovery

Connections between Station Boards and Baseline Boards are detected by placing correlator in a special “configuration discovery” mode. When the physical configuration of the correlator changes (e.g. when new Station Boards and/or Baseline Boards are added), the “configuration table” on the MCCC must be updated, either manually or by placing the correlator in the “configuration discovery” mode.

Details of the configuration discovery will be described in the MCCC Design Document.

In the EVLA configuration, there will be 16 Subband Correlators, and each Subband Correlator will have one Correlator Chip for each pair of inputs (i.e. for each baseband). However, the MCCC software must not assume that this will always be the case; it must be able to handle any number of Subband Correlators that is physically possible (i.e. between 0 and 18 Subband Correlators). The number of Correlator Chips per baseline is detected during the Configuration Discovery. The MCCC must be able to handle configurations where the number of Correlator Chips is not the same for all baselines.

4 Subarray Configuration

A subarray consists of a group of stations (antennas). In the EVLA correlator, a station consists of up to four Station Boards that belong to the same Station Quad. A configuration where each Station Board belongs to a different station is allowed.

A subarray configuration is specified as a collection of Station Board Configuration Requests with the same Subarray ID.

All stations (antennas) that have the same Subarray ID belong to the same subarray.

Unless otherwise specified, the MCCC assumes that correlation is required for all the baselines that receive input from stations that belong to the same subarray.

When a new station or a Station Board is added to a subarray, baselines for the newly added station are enabled (unless explicitly disabled).

The EMCS may choose:

1. to activate the configuration for all Station Boards (stations) that belong to a subarray at the same time, or

2. to activate the configuration for each station independently.

The **Configuration ID** and **Subarray ID** have no the same significance:

- **Configuration ID** is used to indicate which Configuration Request messages should be activated at the same time. The components affected by the Configuration Request messages with the same Configuration ID are not necessarily part of the same subarray.

- **Subarray ID** indicates which Station Boards (stations) belong to the same subarray. Subarray ID is used to indicate basebands where correlation is required.

Therefore, the **Subarray ID** and **Configuration ID** may be assigned independently of each other, as follows:

- Stations / Station Boards that belong to the same subarray are not necessarily configured and activated at the same time and may have different Configuration IDs.

- Stations / Station Boards that belong to different subarrays may use the same Configuration ID. For example: If only a part of a previously defined subarray is used for the new configuration, and the rest should be de-configured (to stop generating output products that are not required any more); a group of Station Board Configuration Request messages that have the same Configuration ID and will be activated at the same time, may include Station Boards that belong to two (or more) different subarrays.

4.1 Activation Trigger

A subarray configuration may be specified as a sequence of Station Board Configuration Request messages followed by a trigger message. An activation trigger instructs the correlator to act upon all previously received configuration request messages with the specified Configuration ID.

For a Station Board configuration that means:

- For each Station Board Configuration Request, verify that Station Board configuration is correct.
- Verify that Station Quad configuration is correct.
- Assign Subband Correlator(s) to each output Data Stream.
- Starting from the first Station Quad, find all baselines that belong to a subarray, derive configuration for each Correlator Chip (and associated hardware) that belongs to a subarray.
- Activate Station Board and Baseline Board configuration at specified time.

Network does not guarantee that messages will be received in the same order as they are transmitted. For example, the trigger message may be received before some of the configuration messages, it is supposed to activate, are received.

To avoid configuration failure, the EMCS *should* wait for all the configuration messages to be acknowledged before transmitting an activation trigger. The exact order in which configuration request messages are received does not matter, as long as they are all received before the trigger.

4.2 De-configure Acknowledged Configuration

The correlator must provide a mechanism for the EMCS to:

- Discard all messages that are waiting for a trigger message (i.e. flush the wait queue).
- Discard configuration messages with the specified Configuration ID.
- Remove from the activation queue and discard all messages and associated configurations that are waiting to be activated (i.e. flush the activation queue).
- Remove from the activation queue a configuration that is scheduled to be activated at specified time.

Details are to be defined.

When a request is received to remove from the activation queue and discard a previously specified configuration, the MCCC have to find and re-consider all configurations with the activation time after the discarded configuration. The most simple and safe approach is to re-calculate Baseline Board configuration for all configurations to be activated after the configuration that was removed from the queue.

4.3 Station Board Configuration Message

A newly received Station Board configuration completely replaces the previous Station Board configuration, i.e. even if the EMCS wants to change only one parameter of a single data stream (baseband / subband) the configuration for the whole board must be specified.

Discussion: Other approach would be to allow the EMCS to add / modify one baseband / subband at a time, or to modify a single parameter of baseband or subband. If that was the case, the MCCC would be required to manage hundreds of messages waiting to be activated at different times. A change of a single Station Board parameter may affect baseline configuration. For every configuration change, the MCCC have to calculate the Baseline Board configuration for all the baselines and store the generated configuration model until it is activated. Handling and keeping hundreds of models may have prohibitive processing and memory requirements.

A received Station Board Configuration Request is processed as follows:

1. Immediately upon receipt, the MCCC verifies that all mandatory parameters have been specified and that all specified parameters are within supported range. At this time, a Station Board is considered as an isolated entity, not as a part of a Station Quad or a Subarray. If all checks are successfully completed, the Acknowledgement message is sent to the originator and the message is added to the queue of messages that are waiting for a trigger.

2. When an activation trigger is received, all the configuration messages with the specified Configuration ID are processed again. A Station Board is considered as an element of a Station Quad. A Station Board configuration may be rejected at this point if quad configuration is not correct.

3. A list of baselines, which are affected by the configuration changes for Station Quads from step 2, is created and a new configuration is generated for each baseline.

4. The new Station Board and Baseline Board configuration is stored in the activation queue. For the boards where there are no other configurations waiting to be activated before this configuration, new configuration is immediately sent to CMIBs.

   Note: Each CMIB has two configuration banks that hold:

   - the current (active) board configuration and
   - the next or previous board configuration.

   The MCCC may handle several future configurations for each board in the system.

4.3.1 Initial Station Board Configuration Verification

A received Station Board Configuration Request is handled as follows:

1. Message is screened for the semantic and syntactic errors (see the next list).
2. If an error is detected, Reject message is sent to the originator that includes reason for rejection. All detected problems are listed in the message.
3. If no major problems are detected, the received message is placed in the queue of messages that wait for the activation trigger.
4. An Acknowledgement is sent to the originator of the message. If minor inconsistencies, which can be corrected by the MCCC, have been detected in the received message, they are listed as warning messages in the Acknowledgement message.

When a Station Board Configuration Request is received the MCCC performs the following checks:

2. All parameters *must* be within acceptable range.
3. Basebands on the same Station Board:
    a) *must* belong to the same subarray,
    b) *must* belong to the same station.
    c) *must* have different Baseband IDs.

4.3.2 Station Board Input and Output

For EVLA antennas organization of Station Board Input Stream data is defined by the number of bits in the input stream.

For Station Board Input Stream the following values are supported:

- 3-bits: Station Board Input Stream may carry data for up to two basebands. Any of the two Station Board Data Paths may be used to process any of the two basebands; both Data Paths may be configured to process the same baseband.
- 8-bits: Station Board Input Stream contains only one baseband. Both Data Paths may be used to process the same baseband.

Organization of the Station Board Output Data Stream is defined as number of bits to correlate, i.e. correlation mode. The following values are supported:

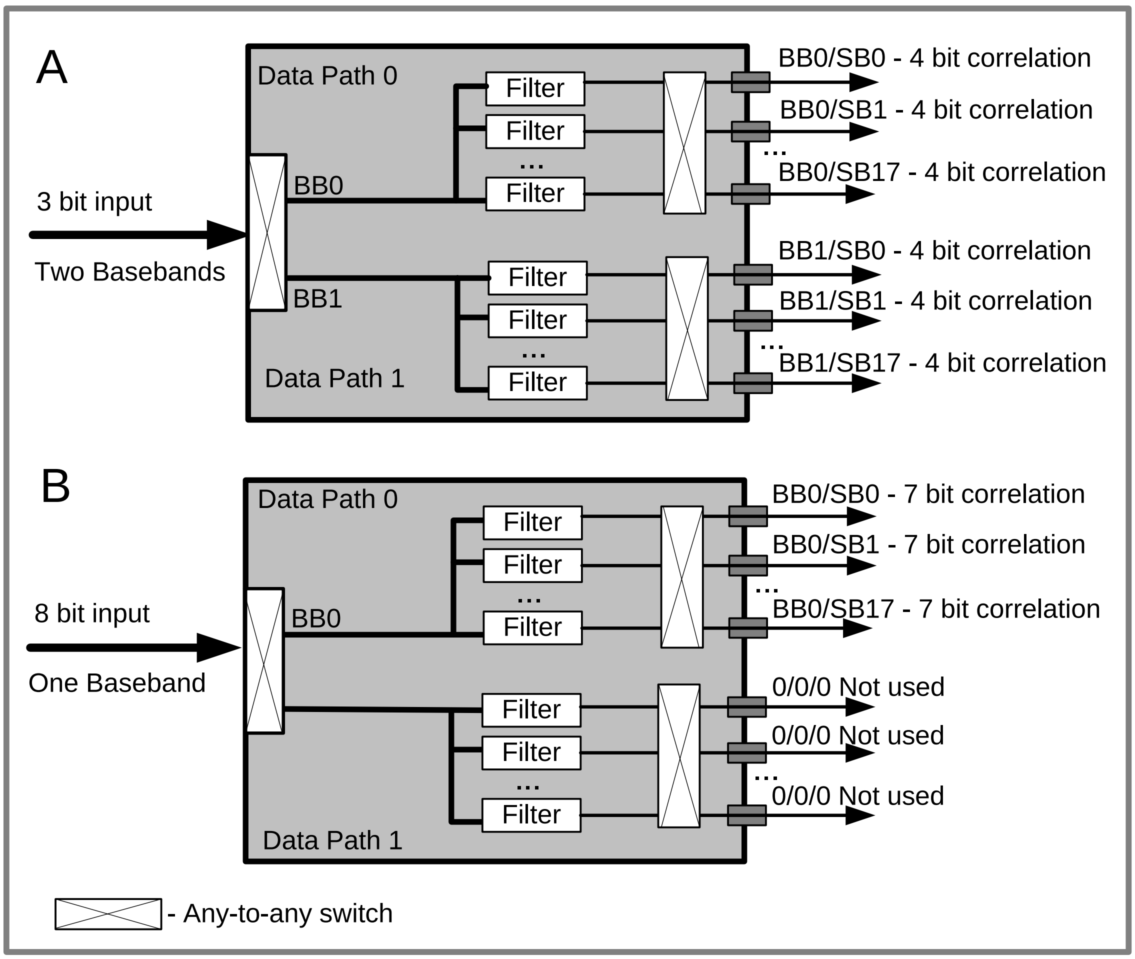
- 4-bit correlation mode
- 7-bit correlation mode

Figure 5 shows two typical configurations of Station Board input and output. However, the correlator does not impose limitations, any combination of input and output organization is acceptable.

Figure 5 Configuration A: 3-bit Input Stream may carry up to two basebands. Station Board in the diagram generates 4-bit output data streams. Each Station Board Output Data Stream carries one subband of one baseband.

Figure 5 Configuration B: 8-bit Input Data Stream may carry only one baseband. Station Board in the diagram is configured to generate 7-bit output data streams. In the diagram, the first Station Board Data Path is used to generate subbands; the other Data Path is not used. A configuration where both Data Paths generate subbands for the same baseband is also supported, in that case a Station Board may generate up to 32 (36) subbands for the same baseband.

Figure 5 Station Board Input and Output Data Streams –Typical Configurations



4.4 Station Quad

In EVLA correlator, a Station Quad consists of four Station Boards that are located in the same crate, in slots 0 to 3 or slots 4 to 7. The same Station Board Output on all Station Board Data Paths in a Quad is connected to the same set of Correlator Chips (Baseline Board Inputs).

The following applies for the Station Boards that belong to the same Station Quad:

- All Station Boards in a Quad *must* belong to the same subarray (have the same Subarray ID)[3].

  A configuration that specifies different Subarray IDs for Station Boards that belong to the same Quad is rejected.

- Output of each Station Board Filter in a Station Quad *should* be assigned unique set of data stream identifiers (Station/Baseband/Subband IDs).

  Note, however, that output of a single Station Board Filter can be forwarded to more than one Station Board output. Station Board output data streams *should* have the same identifiers *only* if they carry the same astronomical data.

  A configuration that does not comply with this requirement is not rejected, a warning is sent to the originator but the configuration is activated as requested.

- Each Station Board in a Quad *may* belong to a different station (i.e. may receive astronomical data from a different antenna or station).

4.5 Station Quad Configuration

When a Configuration Activation Trigger has been received, the MCCC finds all the Station Board Configuration Requests with the specified Configuration ID in the "waiting queue". The messages are sorted according to the board identifier (rack-crate-slot) and each quad is considered independently.

- In the case when a new configuration is received for all four Station Boards in a Quad, the previous Quad configuration is completely overridden by the new configuration and does not need to be taken into account.

  If all the requirements for output products cannot be accommodated, precedence is given to basebands on Station Boards with lower Slot IDs.

- In the case when a new configuration partially replaces the previous Station Quad configuration (e.g. two of four Station Boards are re-configured) and there are no enough resources to accommodate the new configuration, precedence is given to the previously configured basebands/subbands; the newly received configuration request is rejected. The

[3] All Station Boards in the quad must have the same Minimum Hardware Dump Time.

previously specified and accepted configuration (which may or may not be currently active) is not affected.

In order to re-assign resources reserved for the previously specified configuration, the EMCS must explicitly free the resources by transmitting a new configuration for the Station Board that uses the resources.

For example, in the case when the EMCS wants to re-arrange existing configuration in order to accommodate additional basebands (e.g. by increasing recirculation factor) Configuration Requests for the previously configured basebands should be re-transmitted with different parameters.

4.5.1 Polarization Pair

4.5.1.1 Basebands

Any two basebands that belong to the same station may be configured as a polarization pair.

The following baseband parameters are used to define polarization pairs:

- Baseband ID of the other baseband in a pair (polarization pair “mate”).
- Polarization identifier: Right or Left. If polarization is not explicitly specified, Baseband with the smaller Baseband ID is assumed to be right polarized, and the baseband with the greater Baseband ID is assumed to be left polarized.

Basebands that are configured as a polarized pair, *should* have:

1. the same bandwidth
2. the same LO, and
3. different polarization.

Warning is generated if the basebands that form a polarization pair have different bandwidth and/or LO, or if they have the same polarization, but the correlator proceeds with configuration.

4.5.1.2 Data Streams

Corresponding subbands of the basebands that belong to a polarization pair may be considered as a polarized data stream pair.

“Corresponding subbands” are subbands with the same Subband ID.

Cross-products can be obtained only for the data streams that are configured as polarization pairs. In other words, the “polarization pair mate” *must* be specified for a baseband where 4 products are required for at least one of the subbands. If 4 products are required for a data stream, for which “a polarization mate” is not specified, the Configuration Request is rejected.

Cross-products can be obtained only if both data streams are forwarded to the same Subband Correlator (Correlator Chip). Configuration where members of a polarized pair where cross-product are required are forwarded to different Subband Correlators is rejected.

4.5.1.3 3-bit Input Stream, 4-bit Correlation Mode

Figure 6 shows a typical configuration for 3-bit Station Board Input Stream and 4-bit correlation mode:

- eight basebands are configured as four polarization pairs; polarization pairs are configured as listed in **Table 4-1**.
- four polarization products (RR, RL, LR and LL) are generated for each pair of data streams. Output products are listed in **Table 4-2**.

N.B. **Table 4-1** and **Figure 6** show a typical configuration, however, any combination of baseband pairs and polarizations is allowed.

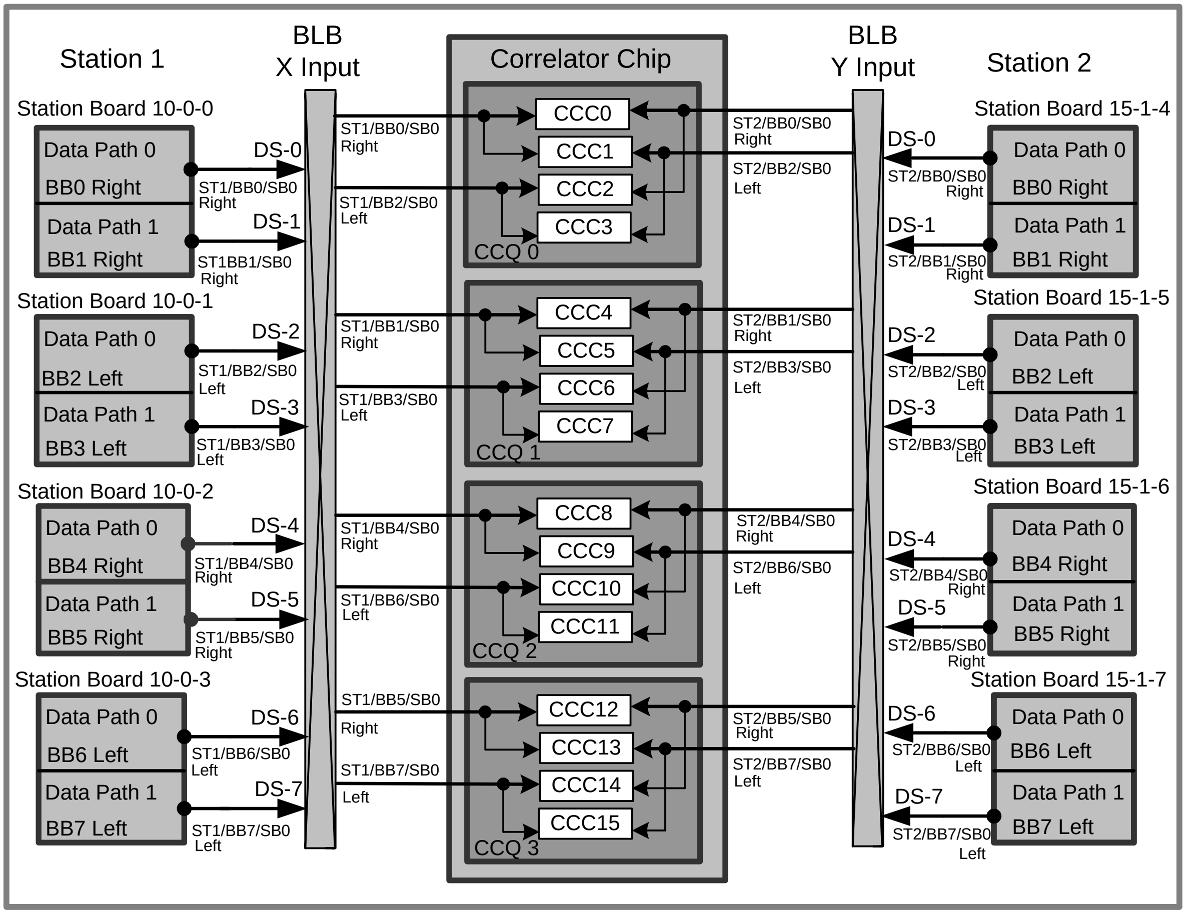
Table 4-1 Polarization Pair Configuration for Basebands in Figure 6

	1st Baseband	**2nd Baseband**
1st pair	1st BB on the 1st Station Board - Right	1st BB on the 2nd Station Board - Left
2nd pair	2nd BB on the 1st Station Board - Right	2nd BB on the 2nd Station Board - Left
3rd pair	1st BB on the 3rd Station Board - Right	1st BB on the 4th Station Board - Left
4th pair	2nd BB on the 3rd Station Board - Right	2nd BB on the 4th Station Board - Left

Table 4-2 Output Products for Configuration in Figure 6

	Right * Right (RR)	**Right * Left (RL)**	**Left * Right (LR)**	**Left * Left (LL)**
CCQ0	ST1/BB0/SB0 * ST2/BB0/SB0	ST1/BB0/SB0 * ST2/BB2/SB0	ST1/BB2/SB0 * ST2/BB0/SB0	ST1/BB2/SB0 * ST2/BB2/SB0
CCQ1	ST1/BB1/SB0 * ST2/BB1/SB0	ST1/BB1/SB0 * ST2/BB3/SB0	ST1/BB3/SB0 * ST2/BB1/SB0	ST1/BB3/SB0 * ST2/BB3/SB0
CCQ2	CST1/BB4/SB0 * ST2/BB4/SB0	ST1/BB4/SB0 * ST2/BB6/SB0	ST1/BB6/SB0 * ST2/BB4/SB0	ST1/BB6/SB0 * ST2/BB6/SB0
CCQ3	ST1/BB5/SB0 * ST2/BB5/SB0	ST1/BB5/SB0 * ST2/BB7/SB0	ST1/BB7/SB0 * ST2/BB5/SB0	ST1/BB7/SB0 * ST2/BB7/SB0

Figure 6 Typical Configuration for 3-bit Input, 4-bit Correlation Mode, 8 Basebands



4.5.1.4 8-bit Input Stream, 7-bit Correlation Mode

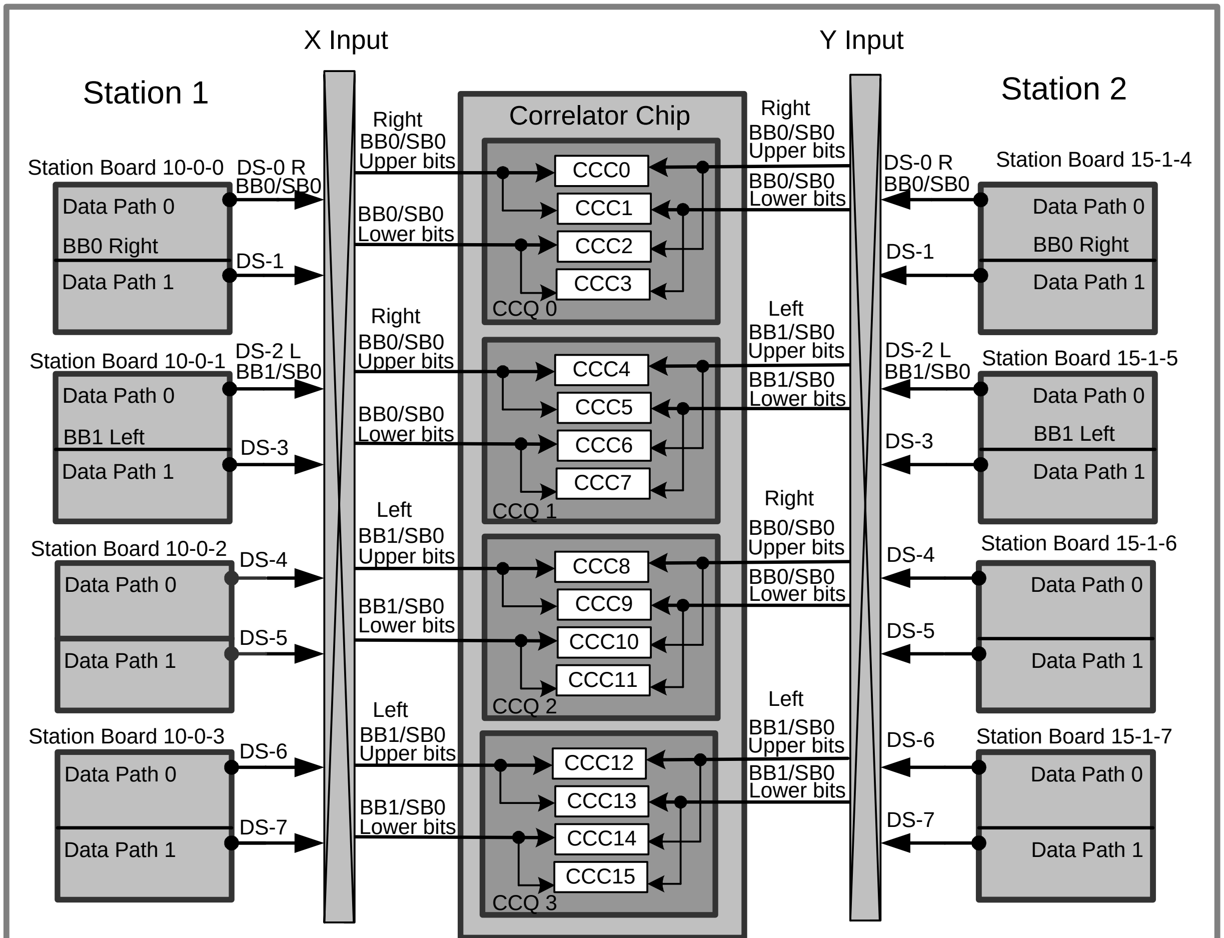
Figure 7 and **Figure 8** below are examples of a Station Quad configuration for 8-bit input stream and 7-bit correlation mode. Both diagrams show two Station Quads and a single Correlator Chip.

In **Figure 7,** two basebands are configured as a polarization pair.

In 7-bit correlation mode the whole Correlator Chip (four CCQs) is needed to obtain 4 polarization products (RR, RL, LR and LL) for a pair of Data Streams.

Note that the Baseline Board Input Data Stream carries 7-bits for each baseband/subband. In the Baseline Board Input, the 7-bit input data stream is converted into two 4-bit data streams that carry upper and lower bits. Four CCCs are needed to obtain one product in 7-bit mode.

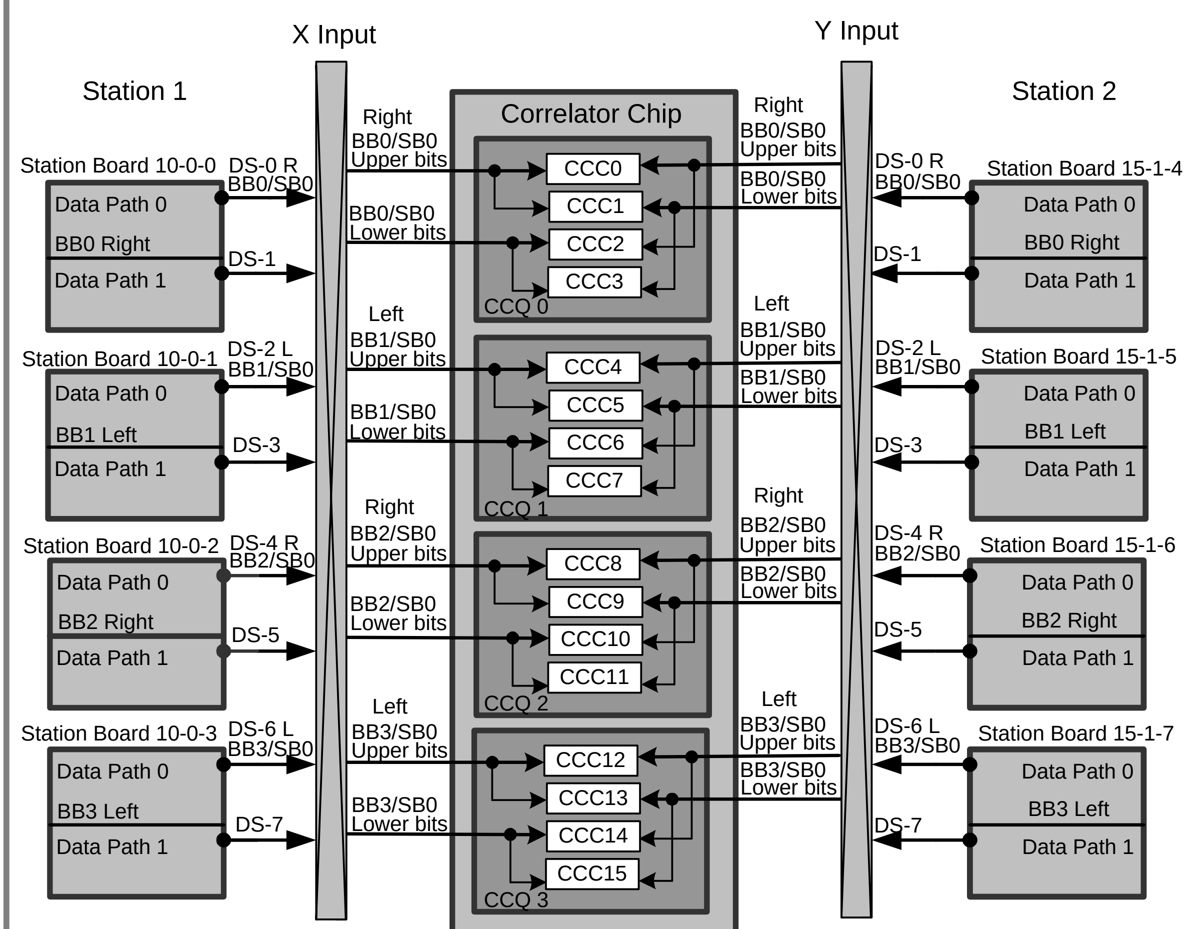
Figure 7 Typical Configuration for 8-bit Input, 7-bit Correlation Mode, 2 Basebands




```
Output products:
CCQ0: Station1 BB0(Right) * Station2 BB0(Right)
CCQ1: Station1 BB0(Right) * Station2 BB1(Left)
CCQ2: Station1 BB1(Left)  * Station2 BB0(Right)
CCQ3: Station1 BB1(Left)  * Station2 BB1(Left)
```

Figure 8 shows the configuration where four 8-bit basebands are configured for each Station Quad. The Correlator Chip is configured to obtain one product for each X/Y Data Stream pair (cross-products are not required).

Figure 8 Typical Configuration for 8-bit Input, 7-bit Correlation Mode, 4 Basebands




```
Output products:
CCQ0: Station1 BB0(Right)* Station2 BB0 (Right)
CCQ1: Station1 BB1(Left) * Station2 BB1 (Left)
CCQ2: Station1 BB2(Right)* Station2 BB2 (Right)
CCQ3: Station1 BB3(Left) * Station2 BB3 (Left)
```

4.5.2 Number of Polarization Products

In the Configuration Request the number of required products is specified for each subband of each baseband (data stream).

Acceptable values for the number of polarization products are: 0, 1 and 4.

Table 4-3 shows the valid configurations for a polarized pair of data streams. The last row in the table for each configuration lists polarization products that are obtained.

4 products (cross-products RL and LR) can be required only for the data streams that belong to a polarized pair. If 4 products are required for a data stream that does not belong to a polarized pair, configuration is rejected.

The following applies for a polarization pair where 4 products (cross-products) are required:

a) Subband bandwidth *should* be the same for both data streams.

b) Central frequency should be the same for both data streams.

c) Basebands *should* have different polarization.

d) Hardware Integration Time *should* be the same. If H/W Integration Time is not the same, shorter Integration Time will be used.

e) Required number of spectral channels *should* be the same. If not, the smaller of the number of spectral channels is obtained.

f) Recirculation:

    i. Recirculation factor *should* be the same. If not, lower recirculation factor is used.

    ii. If recirculation is optional (zero) for one input data stream, but not for the other, the specified (non-zero) value is used for both.

g) If sensitivity loss is allowed for one, and not allowed for the other input data stream, it is assumed that sensitivity loss is allowed for both.[4]

---

[4] Sensitivity loss occurs when the recirculation factor is greater than the bandwidth reduction. The configuration parameter “sensitivity loss allowed” is relevant only when recirculation is specified as optional and, given the number of resources, recirculation should be used to obtain the required number of products/spectral channels.

If sensitivity loss is specified as “not allowed”, the recirculation factor must be lower or equal than the bandwidth reduction factor, i.e. the following must be true

$$(\text{subband bandwidth} * \text{recirculation factor}) <= 128 \text{ MHz}$$

,where 128 MHz is the maximum supported subband bandwidth. If sensitivity loss is allowed, this restriction does not apply.

h) Four polarization products *must* be specified for both data streams in a pair. If 4 products are required for one and not for the other data stream in a pair, the maximum of two products will be obtained (no cross-products).

Error/warning messages are generated and sent to the originator when an error or inconsistency is found in the specified configuration.

Table 4-3 Number of Required Products – Valid Configurations

	Number of polarization products				
	Configuration a.	Configuration b.	Configuration c.	Configuration d.	Configuration e.
1st Data Stream (Right)	0	1	0	1	4
2nd Data Stream (Left)	0	0	1	1	4
Total number of output products for the Data Stream pair	0	1	1	2	4
Polarization Products	-	RR	LL	RR LL	RR RL LR RR

4.6 Recirculation

Depending on the hardware configuration, Baseline Board might be able to handle recirculation for all input data streams for each Correlator Chip. A system wide parameter R2 will be used to specify whether enhanced recirculation memory is available or not.

R2 will be set to "On" if two instances of recirculation memory are available per Baseline Board Input. If that is the case, four input data streams can be forwarded to each recirculation memory. If R2 is On recirculation can be applied for all eight input data streams, with restrictions that are specified below.

For a Baseband Board where only basic recirculation memory is available (R2 is Off):

- In 4-bit correlation mode, recirculation can be performed for two data stream pairs. Recirculation factor must be the same for both pairs where recirculation is required. If that is not the case, recirculation factor specified for the first pair that requires recirculation is assigned to the other pair that requires recirculation.

- For 7-bit correlation mode, recirculation can be performed for only one data stream pair.

If number of pairs that require recirculation is greater than supported, recirculation will be enabled on the first come first served basis, starting from the data stream pair that is processed first (usually that is the 1st data stream in the Baseline Board Input). For remaining pairs on the same Correlator Chip will be disabled (no output product will be obtained).

All Correlator Chips in the same column/row on a Baseline Board receive identical input, i.e. if one Correlator Chip requires recirculation for a pair of data streams, all Correlator Chips in the same row/column receive the data stream with the same recirculation factor.

All data streams in a single Baseline Board Input that use recirculation *must* have the same bandwidth.

In the Station Board Configuration Request, recirculation may be specified as optional.

The following rules are applied when recirculation is specified as optional:

1. If another pair in the same Baseline Board Input (the same row/column of Correlator Chips) uses recirculation, use the same recirculation factor.

2. For the first pair that uses recirculation, recirculation factor is calculated so that the minimum number of physical resources (CCQs/CCCs) is used.

3. If the calculated recirculation factor is higher than 256 (the maximum supported), use the recirculation factor of 256.

4.7 Using Recirculation Memory for Distributed Lag Chain

In the EVLA correlator, more than one Correlator Chip may be available per baseline:

- When more than one Correlator Chip per baseline is available in a single Subband Correlator.

- When more than one Subband Correlator is used for a single subband.

The number of Correlator Chips per baseline is detected during the "configuration discovery", as described in Section 3.1.

If more than one Correlator Chip is available for a data stream pair, Correlator Chips may be configured as follows:

- each Correlator Chip may be used to obtain a different polarization product(s), or

- a single lag chain may be distributed across two or more Correlator Chips.

If a single lag chain is distributed across several Correlator Chips, recirculation memory is used to emulate delay caused by the lags obtained on other Correlator Chip. Restrictions, specified in Chapter 4.6., also apply for data stream pairs that use recirculation memory to emulate delay.

4.8 Subband Correlators

For each subband, a choice of the Station Board Output defines which Subband Correlator is used to obtain output products.

For each subband, a Station Board Configuration Request *may* specify:

a) Subband Correlator ID(s) (which is the same as the Station Board Output ID) and/or

b) The number of Subband Correlators to be used for the data stream (pair).

If the Subband Correlator ID is not specified in the Station Board Configuration Request, the MCCC assigns Subband Correlators.

Subband Correlator IDs *must* be specified either for all subbands that belong to the same baseband, or for none[5]. In other words: Allocation of Subband Correlators is either entirely controlled by the originator of the message or entirely controlled by the MCCC.

In this document, it is assumed that the Subband Correlator ID is identical to the Station Board Output ID, i.e. Subband Correlator 0 means: Subband Correlator that is connected to the Station Board Output 0.

In the EVLA correlator, output N (where N=0..15) on each Station Board Data Path will be connected to the same group of Baseline Boards (i.e. the same Subband Correlator).

4.8.1 Subband Correlators Allocated by the Originator

The following rules apply for the Station Board Configuration Request that explicitly assigns Subband Correlators:

a) If Subband Correlator is specified for one subband, it *must* be specified for all the subbands that belong to the same baseband.

b) More than one Subband Correlator can be assigned to a single data stream (subband).

c) On a single baseband, a particular Subband Correlator can be assigned to only one subband.

[5] This should apply for a Subarray: if choice of Subband Correlators is not the same for all stations (antennas) in a Subarray, the correlator will not be able to obtain required output or the output products will not make sense since correlation will be performed among different subbands.

If statements a) and/or c) are not true, the Station Board Configuration Request is rejected.

When Subband Correlators are specified in the Station Board Configuration Request, the MCCC uses *only* Subband Correlators specified in the message. If, for a particular baseband, there are more Subband Correlators in the system than used by the received configuration, the MCCC will not use additional resources. This allows the EMCS to have full control of resource allocation. (For example: The originator may want to leave some of the Subband Correlators idle; so that they can later be used for additional basebands.)

4.8.2 Subband Correlators Allocated by the MCCC

If the Subband Correlator IDs are not specified in the Station Board Configuration Request, the MCCC assigns Subband Correlators.

Starting from the 1st data stream pair in the Station Quad, the MCCC calculates required resources (CCQs) and allocates Subband Correlators.

If there are fewer subbands defined for a baseband than Subband Correlators in the system, more than one Subband Correlator may be assigned to a single subband.

When cross products are required, the same subband on both basebands in a pair must use the same Subband Correlator.

4.9 Station Board Filters

Station Board (STB) Filters are assigned in the same manner as Station Board Outputs (Subband Correlators), i.e. they are either specified in the Station Board Configuration Request or assigned by the MCCC.

If not explicitly specified in the received Configuration Request message, STB Filters are assigned by the MCCC. When possible, the MCCC assigns the STB Filter with the same identifier as Subband ID.

Since output of an STB Filter may be forwarded to more than one Station Board Output, there is no need to use multiple STB Filters if a subband is forwarded to more than one Subband Correlator.

Note: STB Filter IDs have only local significance; changes in the assignment of STB Filters usually do not require re-configuration of Baseline Board resources.

4.10 Product Parameterization

The following parameters define requirements for the output products:

1. Number of basebands
2. Number of subbands
3. Number of polarization products
4. Number of spectral channels per product
5. Recirculation factor
6. Sensitivity loss allowed

In the Station Board Configuration Request, the parameters for output product may be specified as follows:

1. All the parameters may be explicitly specified.
2. All the parameters except for the *recirculation factor* explicitly specified. If recirculation is specified as optional, parameter "sensitivity loss allowed" must be considered, as follows:
    a. If sensitivity loss is allowed, the MCCC calculates the recirculation factor so that the minimum number of hardware resources (CCQs/CCCs) is used to obtain the specified number of spectral channels.
    b. If sensitivity loss is *not* allowed, the MCCC first calculates the maximum recirculation factor that can be used without sensitivity loss and than calculates the number of resources (CCCs/CCQs) required to obtain the specified number of spectral channels.
3. The EMCS may ask the MCCC to obtain the maximum number of spectral channels for the specified number of basebands, subbands and products. In this case, the MCCC uses all available resources and the maximum allowed recirculation factor, as follows:
    a. If the recirculation factor is specified, the MCCC uses all available resources to maximize the number of spectral channels per product.
    b. If recirculation is optional and sensitivity loss is allowed, the MCCC uses the maximum allowed recirculation factor (256 or the factor already used on the same Correlator Chip) and all available resources to obtain the maximum number of spectral channels.
    c. If recirculation is optional and sensitivity loss is not allowed, the MCCC calculates the maximum recirculation factor that can be used without loss of

sensitivity and uses all available resources to maximize the number of spectral channels per product.

In the case when some data streams on the Correlator Chip have a fixed configuration and some not, the MCCC first assigns resources for the data streams with the fixed configuration. After that, remaining resources are assigned to the data streams where the number of spectral channels and/or recirculation factor is not specified.

4.11 Allocation of Baseline Board Resources

Based on the Station Board configuration, for each data stream pair in a Baseline Board Input, the MCCC calculates required Baseline Board resources.

The following parameters may or may not be explicitly specified by the originator of the Station Board Configuration Request:

- Subband Correlator allocation,
- Number of spectral channels per product and
- Recirculation factor.

When some of the parameters listed above are not explicitly specified, it is up to the MCCC to determine the optimum configuration. The subsequent sections describe the algorithm used to determine baseline configuration for the supported combinations of predetermined and optimizing parameters.

Table 4-4 Supported combinations of predefined and optimizing parameters

	All product parameters are explicitly specified	Recirculation is optional	The maximum number of spectral channels is required	The maximum number of spectral channels is required, recirculation is optional
The originator (EMCS) allocates Subband Correlators	Section 4.11.2	Section 4.11.4	Section 4.11.6	Section 4.11.8
The MCCC allocates Subband Correlators	Section 4.11.3	Section 4.11.5	Section 4.11.7	Section 4.11.9

4.11.1 Nomenclature

The following nomenclature is used in the subsequent sections:

- The 1st Station Board in a Station Quad is the board with the lowest Slot ID.
- The 1st baseband in a Station Board Quad is the baseband defined on the Data Path 0 of the 1st Station Board in a Quad.
- For a particular baseband, the 1st subband is a subband with the lowest Subband ID.
- The 1st data stream pair in a Station Board Quad is a pair that includes the 1st subband of the 1st baseband in a Station Quad.

Allocation of Baseline Board resources starts from the 1st data stream pair in a Station Quad.

4.11.2 Originator Allocates SB Correlators / All Parameters Explicitly Specified

The Station Board Configuration Request messages specify:

- Station Board Output ID (Subband Correlator) for each subband.
- All parameters for required output product are defined, including number of spectral channels and recirculation factor.

In the Station Board Configuration Request message, the Station Board Output is explicitly specified for each data stream. Starting from the 1st data stream pair, the MCCC calculates and allocates required number of resources (CCQs/CCCs). The MCCC uses only Subband Correlators specified in the received Configuration Request.

Resources (CCQs/CCCs) are allocated on the first-come-first-served basis.

If there are no enough resources to obtain all required products for all basebands, precedence is given to the 1st pair of baseband in a Station Quad.

The Configuration Accepted message generated as a response for the activation trigger specifies:

a) the configuration that will be activated,

b) an error or warning message for every modified or ignored parameter.

4.11.3 MCCC Allocates SB Correlators / All Parameters Explicitly Specified

In this case, the Station Board Configuration Request messages:

- Subband Correlators are not assigned by the originator. The MCCC allocates Subband Correlators for all the subbands.
- All other parameters for required output products, including the number of spectral channels and recirculation factor are explicitly specified.

Beginning from the 1st data stream pair, for each pair of data streams, the MCCC calculates how many CCQs/CCCs are needed to obtain all required products. Starting from the Subband Correlator 0 (Station Board Output 0), the MCCC finds the first Subband Correlator that has enough resources to obtain all required products. If such Subband Correlator does not exist, the MCCC allocates resources on two or more Subband Correlators. If cross products are required, data streams that belong to the same polarization pair must be forwarded to the same Subband Correlator (i.e. they must use the same Station Board Output ID).

Subband Correlator are assigned for all the subbands of the 1st pair of data streams, than for the 2nd, 3rd and 4th.

4.11.3.1 Example: Total Bandwidth For 8 Basebands

In this example, correlation is performed for total bandwidth for all eight basebands.

Required Configuration:

1st baseband pair: SB0-SB15: 4 products; 64 spec. channels; no recirculation

2nd baseband pair: SB0-SB15: 4 products; 64 spec. channels; no recirculation

3rd baseband pair: SB0-SB15: 4 products, 64 spec. channels, no recirculation

4th baseband pair: SB0-SB15: 4 products; 64 spec. channels; no recirculation

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

For the above-specified configuration, one CCQ is needed to obtain all required products for a polarization pair. The MCCC assigns one CCQ per sub-band correlator to each polarization pair for each subband.

For each baseband, **Table 4-5** shows which subband (SB) is assigned to which Station Board Output / Subband Correlator.

Number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband.

Table 4-5 Subband Correlator Configuration for Example 4.11.3.1

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (1)		SB0 (1)		SB0 (1)		SB0 (1)		4
1	SB1 (1)		SB1 (1)		SB1 (1)		SB1 (1)		4
2	SB2 (1)		SB2 (1)		SB2 (1)		SB2 (1)		4
3	SB3 (1)		SB3 (1)		SB3 (1)		SB3 (1)		4
4	SB4 (1)		SB4 (1)		SB4 (1)		SB4 (1)		4
5	SB5 (1)		SB5 (1)		SB5 (1)		SB5 (1)		4
6	SB6 (1)		SB6 (1)		SB6 (1)		SB6 (1)		4
7	SB7 (1)		SB7 (1)		SB7 (1)		SB7 (1)		4
8	SB8 (1)		SB8 (1)		SB8 (1)		SB8 (1)		4
9	SB9 (1)		SB9 (1)		SB9 (1)		SB9 (1)		4
10	SB10 (1)		SB10 (1)		SB10 (1)		SB10 (1)		4
11	SB11 (1)		SB11 (1)		SB11 (1)		SB11 (1)		4
12	SB12 (1)		SB12 (1)		SB12 (1)		SB12 (1)		4
13	SB13 (1)		SB13 (1)		SB13 (1)		SB13 (1)		4
14	SB14 (1)		SB14 (1)		SB14 (1)		SB14 (1)		4
15	SB15 (1)		SB15 (1)		SB15 (1)		SB15 (1)		4

4.11.3.2 Example: 7-bit Correlation Mode

In this example 7-bit correlation is required for total bandwidth for a single pair of basebands.

Required Configuration:

1st baseband pair: SB0-SB15: 4 products; 64 spec. channels; no recirculation

- Station Board Input Stream: 8-bits for all boards.

  For 8-bit input stream baseband pair is configured as follows:

  - 1st Station Board, Data Path 0
  - 2nd Station Board, Data Path 0

- 7-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

As shown in Table 4-6, Data Paths 0 on the 1st and 2nd Station Board are considered as a polarization pair.

In 7-bit mode, a CCQ is needed for one polarization product. Four CCQs (a Correlator Chip) is needed to obtain four polarization products for a single pair of basebands.

Table 4-6 Subband Correlator Configuration for Example 4.11.3.2

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (4)								4
1	SB1 (4)								4
2	SB2 (4)								4
3	SB3 (4)								4
4	SB4 (4)								4
5	SB5 (4)								4
6	SB6 (4)								4
7	SB7 (4)								4
8	SB8 (4)								4
9	SB9 (4)								4
10	SB10 (4)								4
11	SB11 (4)								4
12	SB12 (4)								4
13	SB13 (4)								4
14	SB14 (4)								4
15	SB15 (4)								4

4.11.3.3 Example: Multiple Subband Correlators Per DS Pair

Required Configuration:

1st baseband pair: SB0-SB1: 4 products; 512 spec. channels; no recirculation

2nd baseband pair: SB0-SB1: 4 products; 512 spec. channels; no recirculation

3rd baseband pair: SB0-SB1: 4 products, 512 spec. channels, no recirculation

4th baseband pair: SB0-SB1: 4 products; 512 spec. channels; no recirculation

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

For 4-bit correlation mode, 512 spectral channels, two CCQs are needed per product. Since four products are required per data stream pair, two Correlator Chips are required for each pair of data streams. The MCCC assigns two Subband Correlators to a single Data Stream pair.

Table 4-7 shows Subband Correlator configuration. Number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband.

Table 4-7 Subband Correlator Configuration for Example 4.11.3.3

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (4)								4
1	SB0 (4)								4
2	SB1 (4)								4
3	SB1 (4)								4
4			SB0 (4)						4
5			SB0 (4)						4
6			SB1 (4)						4
7			SB1 (4)						4
8					SB0 (4)				4
9					SB0 (4)				4
10					SB1 (4)				4
11					SB1 (4)				4
12							SB0 (4)		4
13							SB0 (4)		4
14							SB1 (4)		4
15							SB1 (4)		4

4.11.3.4 Example: Each Data Stream Pair Has Different Configuration

This is an example of a Station Quad where 1st, 2nd and 3rd pair of basebands each have different configuration.

Required Configuration:

1st baseband pair: SB0-SB3: 4 products; 512 spec. channels; no recirculation

2nd baseband pair: SB0-SB7: 4 products; 64 spec. channels; no recirculation

3rd baseband pair: SB0-SB1: 4 products, 128 spec. channels, no recirculation

4th baseband pair: SB0-SB3 :1 product; 256 spec. channels; no recirculation

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators.
- Each Subband Correlator has one Correlator Chip per baseline.

For each baseband, Table 4-8 shows which subband (SB) is assigned to which Station Board Output / Subband Correlator.

Number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband.

Table 4-8 Subband Correlator Configuration for Example 4.11.3.4

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (4)								4
1	SB0 (4)								4
2	SB1 (4)								4
3	SB1 (4)								4
4	SB2 (4)								4
5	SB2 (4)								4
6	SB3 (4)								4
7	SB3 (4)								4
8			SB0 (1)		SB0 (2)		SB0 (1)		4
9			SB1 (1)		SB1 (2)		SB1 (1)		4
10			SB2 (1)		SB2 (2)		SB2 (1)		4
11			SB3 (1)		SB3 (2)		SB3 (1)		4
12			SB4 (1)						1
13			SB5 (1)						1
14			SB6 (1)						1
15			SB7 (1)						1

4.11.3.5 Example: Each Data Stream Has A Different Configuration (a)

This is an example of a Station Quad where requirements are different for each pair of basebands. In addition, requirements are different for the basebands BB0 and BB1 that belong to the 1st baseband pair.

The Station Boards belong to two different stations, which allows the EMCS to re-use Baseband IDs within the same Station Quad.

Required Configuration:

Station 1:

1st Station Board, Data Path 0: BB0: SB0-SB7: 1 product; 256 spec. channels; no recirculation

1st Station Board, Data Path 1:BB1: SB0-SB7: 1 product; 128 spec. channels; no recirculation

2nd Station Board, Data Path 0:BB2: SB0-SB7: 1 product; 64 spec. channels; no recirculation

2nd Station Board, Data Path 1:BB3: SB0-SB3: 1 product; 64 spec. channels; no recirculation

Station 2:

3rd Station Board, Data Path 0:BB0: SB0-SB5: 1 product; 64 spec. channels; no recirculation

3rd Station Board, Data Path 1:BB1: SB0-SB5: 1 product; 64 spec. channels; no recirculation

BB2 and BB3 are configured as polarization pair:

4th Station Board, Data Path 0:BB2: SB0-SB7: 4 products; 64 spec. channels; no recirculation

4th Station Board, Data Path 1:BB3: SB0-SB7: 4 products; 64 spec. channels; no recirculation

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

For each baseband, Table 4-9 shows which subband (SB) is assigned to which Station Board Output / Subband Correlator. The number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband.

Table 4-9 Subband Correlator Configuration for Example 4.11.3.5

STB Output / Sub-band Correlator	1st Station Board		2nd Station Board		3rd Station Board		4th Station Board		Used CCQs
	Data Path 0	Data Path 1	Data Path 0	Data Path 1	Data Path 0	Data Path 1	Data Path 0	Data Path 1	
	BB 0	BB 1	BB 2	BB 3	BB 0	BB 1	BB 2	BB 3	
0	SB0 (1)	SB0 (1[6])	SB0 (1)		SB0 (1)				4
1	SB1 (1)	SB1 (1)	SB1 (1)		SB1 (1)				4
2	SB2 (1)	SB2 (1)	SB2 (1)		SB2 (1)				4
3	SB3 (1)	SB3 (1)	SB3 (1)		SB3 (1)				4
4	SB4 (1)	SB4 (1)	SB4 (1[7])		SB4 (1)				4
5	SB5 (1)	SB5 (1)	SB5 (1)		SB5 (1)				4
6	SB6 (1)	SB6 (1)	SB6 (1)				SB0 (1)		4
7	SB7 (1)	SB7 (1)	SB7 (1)				SB1 (1)		4
8							SB2 (1)		1
9							SB3 (1)		1
10							SB4 (1)		1
11							SB5 (1)		1
12							SB6 (1)		1
13							SB7 (1)		1
14									0
15									0

[6] Only 2 CCCs are used, however, a CCQ is the minimum unit that can be assigned to a data stream or to a data stream pair.

[7] Only one CCC is used, however a CCQ is the minimum unit that can be assigned to a data stream.

4.11.3.6 Example: Each Data Stream Has A Different Configuration (b)

This example shows the configuration where data streams that belong to the same pair are correlated on different Subband Correlators.

For the Subbands 0 to 3, Baseband 0 and Baseband 1 require 4 CCQs for each product; i.e. each data stream needs a complete Correlator Chip.

Required Configuration:

Station 1:

BB0 and BB1 are configured as a polarization pair.

1st Station Board, Data Path 0:BB0: SB0-SB3: 1 product; 1024 spec. channels; no recirculation

SB4-SB7: 4 products; 64 spec. channels, no recirculation

1st Station Board, Data Path 0:BB1: SB0-SB3: 1 product; 1024 spec. channels; no recirculation

SB4-SB7: 4 products; 64 spec. channels, no recirculation

2nd Station Board, Data Path 0:BB2: SB0-SB3: 1 product; 64 spec. channels; no recirculation

2nd Station Board, Data Path 0:BB3: SB0-SB3: 1 product; 64 spec. channels; no recirculation

Station 2:

BB2 and BB3 are configured as a polarization pair.

3rd Station Board, Data Path 0:BB0: SB0-SB5: 1 product; 64 spec. channels; no recirculation

3rd Station Board, Data Path 0:BB1: SB0-SB5: 1 product; 64 spec. channels; no recirculation

4th Station Board, Data Path 0:BB2: SB0-SB7: 4 products; 64 spec. channels; no recirculation

4th Station Board, Data Path 0:BB3: SB0-SB7: 4 products; 64 spec. channels; no recirculation

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Station Board outputs are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

For each baseband, Table 4-10 shows which subband (SB) is assigned to which Station Board Output / Subband Correlator. Number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband.

Table 4-10 Subband Correlator Configuration for Example 4.11.3.6

Sub-band Correlator	1st Station Board		2nd Station Board		3rd Station Board		4th Station Board		Used CCQs
	Data Path 0	Data Path 1	Data Path 0	Data Path 1	Data Path 0	Data Path 1	Data Path 0	Data Path 1	
	BB 0	BB 1	BB 2	BB 3	BB 0	BB 1	BB 2	BB 3	
0	SB0 (4)								4
1		SB0 (4)							4
2	SB1 (4)								4
3		SB1 (4)							4
4	SB2 (4)								4
5		SB2 (4)							4
6	SB3 (4)								4
7		SB3 (4)							4
8	SB4 (1)		SB0(1)		SB0(1)		SB0(1)		4
9	SB5 (1)		SB1(1)		SB1(1)		SB1(1)		4
10	SB6 (1)		SB2(1)		SB2(1)		SB2(1)		4
11	SB7 (1)		SB3(1)		SB3(1)		SB3(1)		4
12					SB4 (1)		SB4 (1)		2
13					SB5 (1)		SB5 (1)		2
14					SB6 (1)		SB6 (1)		2
15					SB7 (1)		SB7 (1)		2

4.11.4 Originator Allocates SB Correlators / Recirculation is Optional

The Station Board Configuration Request messages specify:

- Station Board Output ID (Subband Correlator) for each specified sub-band.
- All parameters for the required output, except the recirculation factor.

Subband Correlators are assigned by the originator; it is up to the MCCC to distribute the assigned resources (Correlator Chips / CCQs / CCCs) among the data streams and to calculate the recirculation factor.

For each data stream pair, the MCCC calculates and allocates the minimum number of the CCQs/CCCs needed to obtain required products.

- If four products per pair are required:
  - For 4-bit correlation mode, one CCQ is assigned to each data stream pair.
  - For 7-bit correlation mode, four CCQs are assigned to each data stream pair.
- If less than four products per pair are required, one CCQ is assigned to each data stream pair in either correlation mode.

The MCCC then calculates the recirculation factor that should be used to obtain the required number of products with the minimum number of resources. Due to restrictions that apply for use of recirculation, the MCCC may find that additional CCQs are needed. If that is the case, the MCCC should try to re-arrange resources so that adjacent CCQs on the same Correlator Chip are assigned to each data stream pair.

A mixed configuration, where some data stream pairs in a Station Quad have all product parameters pre-defined and some not, is allowed. For the Station Quads with mixed configuration, the MCCC first allocates CCQs for the data stream pairs with fixed configuration. Remaining resources are then distributed among the pairs where recirculation is optional.

Note: This document describes the overall approach. The actual algorithm used to assign resources and calculate recirculation factor will take into consideration all the limitations imposed by hardware.

4.11.4.1 Example: 4-bit Correlation

Required Configuration:

1st baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

2nd baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

3rd baseband pair: SB0-SB7: 4 products, 256 spec. channels, recirculation optional

4th baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Sensitivity loss is allowed on all data streams.
- Station Board Outputs are specified so that each data stream is assigned two Subband Correlators, as follows:
    1. All data streams for Subband 0 are assigned Subband Correlator 0 and 1
    2. All data streams for Subband 1 are assigned Subband Correlator 0 and 1
    3. All data streams for Subband 2 are assigned Subband Correlator 2 and 3
    4. All data streams for Subband 3 are assigned Subband Correlator 2 and 3
    5. All data streams for Subband 4 are assigned Subband Correlator 4 and 5
    6. All data streams for Subband 5 are assigned Subband Correlator 4 and 5
    7. All data streams for Subband 6 are assigned Subband Correlator 6 and 7
    8. All data streams for Subband 7 are assigned Subband Correlator 6 and 7

System configuration:

- o There are 16 Subband Correlators
- o Each Subband Correlator has one Correlator Chip per baseline.

Starting with the Subband 0 of the 1st data stream pair, the MCCC assigns CCQs and calculates the recirculation factor. Product parameterization is the same for all required Subbands; here is how resources are assigned for Subband 0:

Subband 0 of the 1st baseband pair:

- Minimum number of CCCs needed to obtain 4 products for 4-bit correlation is 4, i.e. at least one CCQ is needed per data stream pair.
- Recirculation factor of 4 is needed to obtain 256 spectral channels per product, for 4 products.
- The MCCC assigns one CCQ in Subband Correlator 0 and sets recirculation factor of 4.

Subband 0 of the 2nd baseband pair:

- Requirements are the same as for the 1st DS pair.
- The MCCC assigns one CCQ in Subband Correlator 0 and sets recirculation factor to 4.

Subband 0 of the 3rd baseband pair:

- Requirements are the same as for the 1st and 2nd DS pair.
- The MCCC finds that two DS pairs on the Correlator Chip in Subband Correlator 0 already use recirculation. R2 is not used; the MCCC cannot add another pair that requires recirculation. Another Correlator Chip must be used for this pair.
- Two Subband Correlators are available for this Subband; the MCCC assigns a CCQ in Subband Correlator 8 and sets recirculation factor to 4.

Subband 0 of the 4th baseband pair:

- Requirements are the same as for other DS Pairs.
- The MCCC finds that additional pair that uses recirculation cannot be added to Correlator Chip on Subband Correlator 0, a CCQ on Subband Correlator 8 is assigned and recirculation factor of 4 is set for this pair.

Table 4-12 shows allocation of the Subband Correlators for this example.

Number in the parenthesis beside Subband ID indicates how many CCQs are assigned to a subband. An acronym “rf” stands for the recirculation factor.

Table 4-11 Subband Correlator Configuration for Example 4.11.4.1

Subband Correlator	1st Baseband Pair		2nd Baseband Pair		3rd Baseband Pair		4th Baseband Pair		Used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (1) rf=4		SB0 (1) rf=4						2
1					SB0 (1) rf=4		SB0 (1) rf=4		2
2	SB1 (1) rf=4		SB1 (1) rf=4						2
3					SB1 (1) rf=4		SB1 (1) rf=4		2
4	SB2 (1) rf=4		SB2 (1) rf=4						2
5					SB2 (1) rf=4		SB2 (1) rf=4		2
6	SB3 (1) rf=4		SB3 (1) rf=4						2
7					SB3 (1) rf=4		SB3 (1) rf=4		2
8	SB4 (1) rf=4		SB4 (1) rf=4						2
9					SB4 (1) rf=4		SB4 (1) rf=4		2
10	SB5 (1) rf=4		SB5 (1) rf=4						2
11					SB5 (1) rf=4		SB5 (1) rf=4		2
12	SB6 (1) rf=4		SB6 (1) rf=4						2
13					SB6 (1) rf=4		SB6 (1) rf=4		2
14	SB7 (1) rf=4		SB7 (1) rf=4						2
15					SB7 (1) rf=4		SB7 (1) rf=4		2

4.11.5 MCCC Allocates SB Correlators / Recirculation is Optional

For the configuration where Subband Correlators are not allocated and recirculation is specified as optional, the MCCC must:

- Calculate the recirculation factor so that the minimum number of h/w resources (Correlator Chips / CCQs) is used.
- Assign Subband Correlator(s) to each data stream.

Starting form the 1st pair of data streams (1st subband of the first baseband pair), the MCCC:

- Finds how many CCQs needed to obtain all required products.
- Calculates the recirculation factor needed to obtain required number of spectral channels with the minimum number of CCQs.
- Finds the first Subband Correlator that has available resources assigns CCQs and sets the recirculation factor and input switches as required.

Resources are first assigned to all the subbands of the 1st baseband pair, than to all the subbands of the 2nd baseband pair, and so on.

4.11.5.1 Example: 4-bit Correlation, Sensitivity Loss Not Allowed

This example shows configuration similar to configuration in Section 4.11.4.1 where Subband Correlators are assigned by the originator of the Configuration Request.

In this example, when calculating the recirculation factor, the MCCC must take into account that loss of sensitivity is not allowed.

Sensitivity loss occurs when recirculation factor is greater than the bandwidth reduction.

If sensitivity loss is not allowed, recirculation factor must be lower or equal than the bandwidth reduction factor, i.e. the following must be true:

*(subband bandwidth * recirculation factor) <= 128 MHz*

, where 128 MHz is the maximum supported subband bandwidth.

Required Configuration:

1st baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

2nd baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

3rd baseband pair: SB0-SB7: 4 products, 256 spec. channels, recirculation optional

4th baseband pair: SB0-SB7: 4 products; 256 spec. channels; recirculation optional

- All subbands: bandwidth is 32MHz and sensitivity loss is not allowed.
- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Correlator must assign Subband Correlators so that the minimum number of h/w resources is used to obtain the specified number of products and spectral channels.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

Starting with the Subband 0 of the 1st baseband pair, the MCCC assigns CCQs and calculates the recirculation factor. Product parameterization is the same for all required Subbands; here is how resources are assigned for Subband 0:

1 Baseband Pair:

a) Minimum number of CCCs needed to obtain 4 products for 4-bit correlation is 4, i.e. at least one CCQ is needed per data stream pair.

b) Using one CCQ, the recirculation factor of 4 is needed to obtain 256 spectral channels per product, for 4 products.

c) For the recirculation factor of 4, sensitivity loss would occur, since:

$$64\text{MHz} * 4 > 128\text{MHz}$$

d) The maximum recirculation factor that can be used is:

$$128\text{MHz} / 64\text{MHz} = 2$$

e) To obtain the required number of spectral channels with the recirculation factor of 2, two CCQs are needed.

f) The MCCC assigns two CCQs in Subband Correlator 0 and sets the recirculation factor 2 for this data stream pair.

In this example, the same parameters are specified for all eight subbands; for Subband 1 two CCQs are allocated on Subband Correlator 1, for Subband 2, two CCQ are allocated on Subband Correlator 2, and so on.

2nd Baseband Pair:

a) Requirements are the same as for the 1st pair.

b) The MCCC assigns two CCQ per subband, on Subband Correlator 0 to 7.

3rd Baseband Pair:

a) Requirements are the same as for the 1st and 2nd pair.

b) The MCCC finds that two CCQs are needed for each subband. Since all four CCQs are already used on the Subband Correlator 0, the MCCC finds the first Subband Correlator that has free resources – Subband Correlator 8, and assigns two CCQs to Subband 0. Subband 9 is used for Subband 1, etc.

4th Baseband Pair:

a) Requirements are the same as for other DS Pairs.

b) CCQ on Subband Correlators 8 to 15 are assigned to subbands of this baseband pair.

Table 4-12 shows allocation of resources (Subband Correlators) for this example.

Number in the parenthesis beside the Subband ID indicates how many CCQs are assigned to a subband. An acronym “rf” stands for the recirculation factor.

Table 4-12 Subband Correlator Configuration for Example 4.11.5.1

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (2) rf=2		SB0 (2) rf=2						4
1	SB1 (2) rf=2		SB1 (2) rf=2						4
2	SB2 (2) rf=2		SB2 (2) rf=2						4
3	SB3 (2) rf=2		SB3 (2) rf=2						4
4	SB4 (2) rf=2		SB4 (2) rf=2						4
5	SB5 (2) rf=2		SB5 (2) rf=2						4
6	SB6 (2) rf=2		SB6 (2) rf=2						4
7	SB7 (2) rf=2		SB7 (2) rf=2						4
8					SB0 (2) rf=2		SB0 (2) rf=2		4
9					SB1 (2) rf=2		SB1 (2) rf=2		4
10					SB2 (2) rf=2		SB2 (2) rf=2		4
11					SB3 (2) rf=2		SB3 (2) rf=2		4
12					SB4 (2) rf=2		SB4 (2) rf=2		4
13					SB5 (2) rf=2		SB5 (2) rf=2		4
14					SB6 (2) rf=2		SB6 (2) rf=2		4
15					SB7 (2) rf=2		SB7 (2) rf=2		4

4.11.5.2 Example: 4-bit Correlation Mode, Sensitivity Loss Allowed

Table 4-13 shows Subband Correlator allocation for the same configuration as 4.11.5.1 when sensitivity loss is allowed. One CCQ is used to obtain 4 products per each data stream pair. Recirculation factor of 4 is used to obtain 256 spectral channels per product. Only two data stream pairs per Correlator Chip may use recirculation, therefore only two CCQs per Correlator Chip are used in this configuration.

Table 4-13 Subband Correlator Configuration for Example 4.11.5.2

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (1) rf=4		SB0 (1) rf=4						2
1	SB1 (1) rf=4		SB1 (1) rf=4						2
2	SB2 (1) rf=4		SB2 (1) rf=4						2
3	SB3 (1) rf=4		SB3 (1) rf=4						2
4	SB4 (1) rf=4		SB4 (1) rf=4						2
5	SB5 (1) rf=4		SB5 (1) rf=4						2
6	SB6 (1) rf=4		SB6 (1) rf=4						2
7	SB7 (1) rf=4		SB7 (1) rf=4						2
8					SB0 (1) rf=4		SB0 (1) rf=4		2
9					SB1 (1) rf=4		SB1 (1) rf=4		2
10					SB2 (1) rf=4		SB2 (1) rf=4		2
11					SB3 (1) rf=4		SB3 (1) rf=4		2
12					SB4 (1) rf=4		SB4 (1) rf=4		2
13					SB5 (1) rf=4		SB5 (1) rf=4		2
14					SB6 (1) rf=4		SB6 (1) rf=4		2
15					SB7 (1) rf=4		SB7 (1) rf=4		2

4.11.5.3 7-bit Correlation

This is an example of the configuration where 7-bit correlation is required for 8 subbands for a single pair of basebands.

Required Configuration:

1st baseband pair: SB0-SB7: 4 products; 1024 spec. channels; recirculation optional, sensitivity loss is allowed

- Station Board Input Stream: 8-bits for all boards.
- 7-bit correlation mode is required for all data streams.
- Subband Correlators are not specified.

System configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

For the 7-bit correlation mode, at least one Correlator Chip is required to obtain four products for two data streams.

With one Correlator Chip per polarized pair, 1024 spectral channels per product can be obtained with the recirculation factor of 16.

Sensitivity loss is allowed; the subband bandwidth is not taken in consideration.

The MCCC assigns one Correlator Chip per subband and sets the recirculation factor of 16 for the first two data stream pairs.

As shown in Table 4-14 only eight Subband Correlators are used.

Two unused Station Boards in the same Quad could be used to obtain the same number of subbands, products and spectral channels for an additional pair of basebands.

Table 4-14 Subband Correlator Configuration for Example 4.11.5.3

Subband Correlator	1st DS Pair		2nd DS Pair		3rd DS Pair		4th DS Pair		Total number of used CCQs
	BB0 1st STB Data Path 0	BB2 2nd STB Data Path 0	BB1 1st STB Data Path 1	BB3 2nd STB Data Path 1	BB4 3rd STB Data Path 0	BB6 4th STB Data Path 0	BB5 3rd STB Data Path 1	BB7 4th STB Data Path 1	
0	SB0 (4) rf=16								4
1	SB1 (4) rf=16								4
2	SB2 (4) rf=16								4
3	SB3 (4) rf=16								4
4	SB4 (4) rf=16								4
5	SB5 (4) rf=16								4
6	SB6 (4) rf=16								4
7	SB7 (4) rf=16								4
8									
9									
10									
11									
12									
13									
14									
15									

4.11.6 Originator Allocates SB Correlators / Maximize Number of Spectral Channels

In this case, the MCCC has to distribute CCQs among data streams that share the same Subband Correlator. The required number of spectral channels per product is not specified, the MCCC will maximize use of assigned Subband Correlator in order to obtain the maximum number of spectral channels that can be obtained with the specified recirculation factor.

Number of spectral channels is calculated as follows:

*(Number of lags / 2) * Recirculation Factor*

4.11.7 MCCC Assigns SB Correlators / Maximize Number of Spectral Channels

In this case, the correlator should use all the available resources in order to obtain the maximum number of spectral channels.

The MCCC finds the minimum number of CCQs needed to obtain all required products and assigns available Subband Correlators so that each required data stream gets at least the minimum. If there are more resources available, the MCCC, again starting from the first data stream pair, adds more CCQs (CCCs) to each pair.

Once the number of CCQs per data stream pair is determined, the MCCC calculates the number of spectral channels that can be obtained.

4.11.8 Originator Allocates SB Correlators / Maximize Number of Spectral Channels / Recirculation is Optional

In this case:

1. The MCCC distributes Subband Correlator resources (CCQs) among data streams that are assigned to the same Subband Correlator.

2. The MCCC determines the recirculation factor that can be used, as follows:

   a. If two data stream pairs on the same Correlator Chip already use recirculation, recirculation cannot be used.

   b. If one data stream pair (or one data stream) on the same Correlator Chip already uses recirculation, the same recirculation factor must be used.

   c. If sensitivity loss is allowed, the maximum supported recirculation factor (256) can be used.

d. If sensitivity loss is not allowed, the MCCC calculates the maximum allowed recirculation factor, as follows:

Recirculation Factor = 128 MHz / Subband Bandwidth

4.11.9 MCCC Assigns SB Correlators / Maximize Number of Spectral Channels / Recirculation is Optional

In this case, the MCCC distributes available resources among all specified data streams. The MCCC should maximize use of available h/w resources and at the same time should arrange resources so that all data streams can use recirculation in order to maximize the number of spectral channels.

When resources are distributed among the data streams, the MCCC calculates the recirculation factor as in 4.11.8.

4.11.9.1 Example: 10 Subbands Per Baseband

This example illustrates that, when the number of subbands is not sub-multiple of the number of Subband Correlators and the MCCC is allowed to maximize the number of spectral channels, the number of spectral channels may be different for each baseband pair and/or each subband.

Required Configuration:

- 1^{st} baseband pair: SB0-SB9: 1 product; max. spec. channels; recirculation optional
- 2^{nd} baseband pair: SB0-SB9: 1 product; max. spec. channels; recirculation optional
- 3^{rd} baseband pair: SB0-SB9: 1 product, max. spec. channels, recirculation optional
- 4^{th} baseband pair: SB0-SB9: 1 product; max. spec. channels; recirculation optional
- Station Board Input Stream: 3-bits for all boards.
- 4-bit correlation mode is required for all data streams.
- Subband Correlator not specified
- Sensitivity loss is allowed for all data streams.

System (hardware) configuration:

- There are 16 Subband Correlators
- Each Subband Correlator has one Correlator Chip per baseline.

The minimum unit that can be used to obtain one product is one CCC; however, a CCQ is the minimum unit that can be assigned to a pair of data streams.

Starting from the 1st subband of the 1st baseband pair, the MCCC assigns one CCQ to each data stream pair.

1st pair of basebands: one CCQ on Subband Correlators 0 to 9 are assigned to Subbands 0 to 9.

2nd pair of basebands: one CCQ on Subband Correlators 0 to 9 are assigned to Subbands 0 to 9.

3rd pair of basebands: the MCCC finds that on the Correlator Chip in the Subband Correlator 0 only two CCQs are used, but two data stream pairs already use recirculation. The MCCC checks if there is a Subband Correlator with an unused CCQ where recirculation can be used and finds it in the Subband Correlator 10. In the same fashion, Subband 1 to 5 are assigned CCQs in Subband Correlators 11 to 15. For Subband 6 there is no Subband Correlator with a Correlator Chip where recirculation can be used. A CCQ in Subband Correlator 0 is assigned to Subband 6, recirculation cannot be used. The same applies for Subbands 7, 8, and 9.

4th pair of basebands: configuration is the same as for the 3rd pair.

Sensitivity loss is allowed; the maximum recirculation factor (256) will be used on all data streams where recirculation is allowed.

The following number of spectral channels would be obtained:

1st baseband pair:

Subbands 0 to 3:

64 spec. chan. per CCQ * 4 (CCQs) * 256 = 65536 spectral channels

Subbands 4 to 9:

One CCQ is assigned per baseband pair; however there are two unused CCQs. The MCCC may consider adding an additional CCQ to each data stream pair. If that is the case the number of spectral channels would be:

64 spec. chan. per CCQ * 4 (CCQs) * 2 * 256 = 131072 spectral channels

2nd baseband pair: Configuration is the same as for the 1st baseband pair

3rd baseband pair:

Subbands 0 to 5:

One CCQ is assigned per baseband pair; however there are two unused CCQs. The MCCC may consider adding an additional CCQ to each data stream pair. If that were the case the number of spectral channels would be:

64 spec. chan per CCQ * 4 (CCQs) * 2 * 256 = 131072 spectral channels[8]

Subbands 6 to 9:

One CCQ is assigned to each data stream pair and recirculation is not allowed, number of spectral channels is as follows:

64 spec. chan per CCQ * 4 (CCQs) * 1 = 256 spectral channels

4th baseband pair: Configuration is the same as for the 3rd pair.

In Table 4-15, the black number in parenthesis is the number of CCQs that are initially assigned; the number in gray is the number of used CCQs used if the MCCC is programmed to maximize use of resources for each Subband Correlator.

Table 4-15 Subband Correlator Configuration for Example 4.11.9.1

Subband Correlator	1st DS Pair	2nd DS Pair	3rd DS Pair	4th DS Pair	Used CCQs
0	SB0 (1) rf=256	SB0 (1) rf=256	SB6 (1) rf=1	SB6 (1) rf=1	4
1	SB1 (1) rf=256	SB1 (1) rf=256	SB7 (1) rf=1	SB7 (1) rf=1	4
2	SB2 (1) rf=256	SB2 (1) rf=256	SB8 (1) rf=1	SB8 (1) rf=1	4
3	SB3 (1) (2) rf=256	SB3 (1) (2) rf=256	SB9 (1) rf=1	SB9 (1) rf=1	4
4	SB4 (1) (2) rf=256	SB4 (1) (2) rf=256			2 (4)
5	SB5 (1) (2) rf=256	SB5 (1) (2) rf=256			2 (4)
6	SB6 (1) (2) rf=256	SB6 (1) (2) rf=256			2 (4)
7	SB7 (1) (2) rf=256	SB7 (1) (2) rf=256			2 (4)
8	SB8 (1) (2) rf=256	SB8 (1) (2) rf=256			2 (4)
9	SB9 (1) (2) rf=256	SB9 (1) (2) rf=256			2 (4)
10			SB0 (1) (2) rf=256	SB0 (1) (2) rf=256	2 (4)
11			SB1 (1) (2) rf=256	SB1 (1) (2) rf=256	2 (4)
12			SB2 (1) (2) rf=256	SB2 (1) (2) rf=256	2 (4)
13			SB3 (1) (2) rf=256	SB3 (1) (2) rf=256	2 (4)
14			SB4 (1) (2) rf=256	SB4 (1) (2) rf=256	2 (4)
15			SB5 (1) (2) rf=256	SB5 (1) (2) rf=256	2 (4)

[8] Additional CCQ are marked in gray in Table 4-15.

4.12 Baseline Configuration

When the Subband Correlators are allocated for all the Station Quads affected by the configuration change, the MCCC, starting from the first Station Quad, generates baseline configuration.

All Correlator Chips in the same row/column on a Baseline Board receive the same input that consists of eight data streams.

There are two switches in the Baseline Board Input that can be used to re-arrange input data streams. The configuration of the switches in the Baseline Board Input is determined when the first Correlator Chip in the column/row is configured. Other Correlator Chips in the same column/row have to use the same configuration. If previously configured Correlator Chips do not use all the data stream pairs, it may be possible to make some adjustments.

Corresponding data streams in the X and Y input of a Correlator Chip create a baseline.

A number of checks are performed for each X/Y pair of data streams in order to determine whether the correlation should and can be performed (i.e. whether the configuration parameters match). I so, the MCCC allocates CCQs and CCCs to be used and sets the CCQ and CCC switches.

4.12.1 X/Y Pair

The following tests are performed for each X/Y pair of data streams:

1. X and Y station *must* belong to the same subarray. Correlation is disabled for the data streams that belong to different subarrays.

2. Number of bits to correlate (correlation mode) *must* be the same, if not, correlation is disabled.

3. Subband bandwidth *should* be the same. If bandwidth is not the same generate warning and proceed.

4. Hardware integration time *should* be the same. If hardware integration time is not the same for both, use shorter integration time.

5. Recirculation factor *should* be the same for both. If that is not the case, configure the recirculation factor as follows:

    - If this is the first Correlator Chip that is being configured in the column and row, and the recirculation factor is non-null for both X and Y data streams, but not the same, force the lower recirculation factor.

    - If this is the first Correlator Chip that is being configured in the column and row, if the recirculation is optional (zero) for one, but not for the other data stream, apply the specified (non-zero) value for both.

- If the recirculation factor is already configured for column or row, use that recirculation factor if possible. Otherwise disable the baseline.

- If the recirculation factor is already configured for both column and row, but not the same, disable baseline.

6. Required number of spectral channels *should* be the same. If the required number of spectral channels is not the same for X and Y data stream, configure for the smaller number of spectral channels.

7. The parameter "sensitivity loss allowed" *should* be set in the same way for both data streams. If sensitivity loss is allowed for one, and not allowed for the other data stream, assume that sensitivity loss is allowed.

8. The number of products *should* be the same for both data streams. If the required number of products is not the same, configure for the smaller number of products.

An appropriate warning/error message will be generated each time when a parameter specified in the Configuration Request has to be modified.

4.12.2 Polarization Pair

Table 4-16 shows the valid configurations for the parameter "number of products" for a pair of data streams. The last row in the table lists the products that would be obtained for each configuration.

Table 4-16 Number of Required Products - Valid Configuration for X/Y pair

Case	Valid configuration of the parameter: Number of polarization products				Total number products	Products
	Input X		Input Y			
	1st DS (Right polarized)	2nd DS (Left polarized)	1st DS (Right polarized)	2nd DS (Left polarized)		
a.	0	0	0	0	0	-
b.	1	1	0	0	1	RR
c.	0	0	1	1	1	LL
d.	1	1	1	1	2	RR, LL
e.	4	4	4	4	4	RR, RL, LR, LL

4.12.3 Lag Chain

When more than one CCC is used for a single output product, adjacent CCCs should be used whenever possible, in order to minimize use of Recirculation Memory

The following Sections show the typical lag chain for 4-bit and 7-bit correlation mode.

4.12.3.1 Lag Chain for 4-bit Correlation Mode

Figure 9 shows a Correlator Chip for the following configuration:

- Four data stream pairs
- Four products per pair
- Correlation mode: 4-bits

One CCC per product is used for this configuration, each CCC receives a different combination of X and Y data streams. There is no chaining of CCCs.

Figure 10 shows a Correlator Chip for the following configuration:

- Four data stream pairs
- Two products per pair (RR, LL)
- Correlation mode: 4-bits

Two CCC per product are used for this configuration, adjacent CCCs are used so that output of one CCC can be forwarded to the next. There is no need to use recirculation memory to emulate lag delay.

Figure 11 shows a Correlator Chip for the following configuration:

- Four data stream pairs
- One product per pair (RR)
- Correlation mode: 4-bits

Four CCCs are used for each product. CCCs are chained; there is no need to use recirculation memory.

Figure 9 Correlator Chip: 4 DS Pairs, 4 Products per Pair, 4-bit Correlation Mode

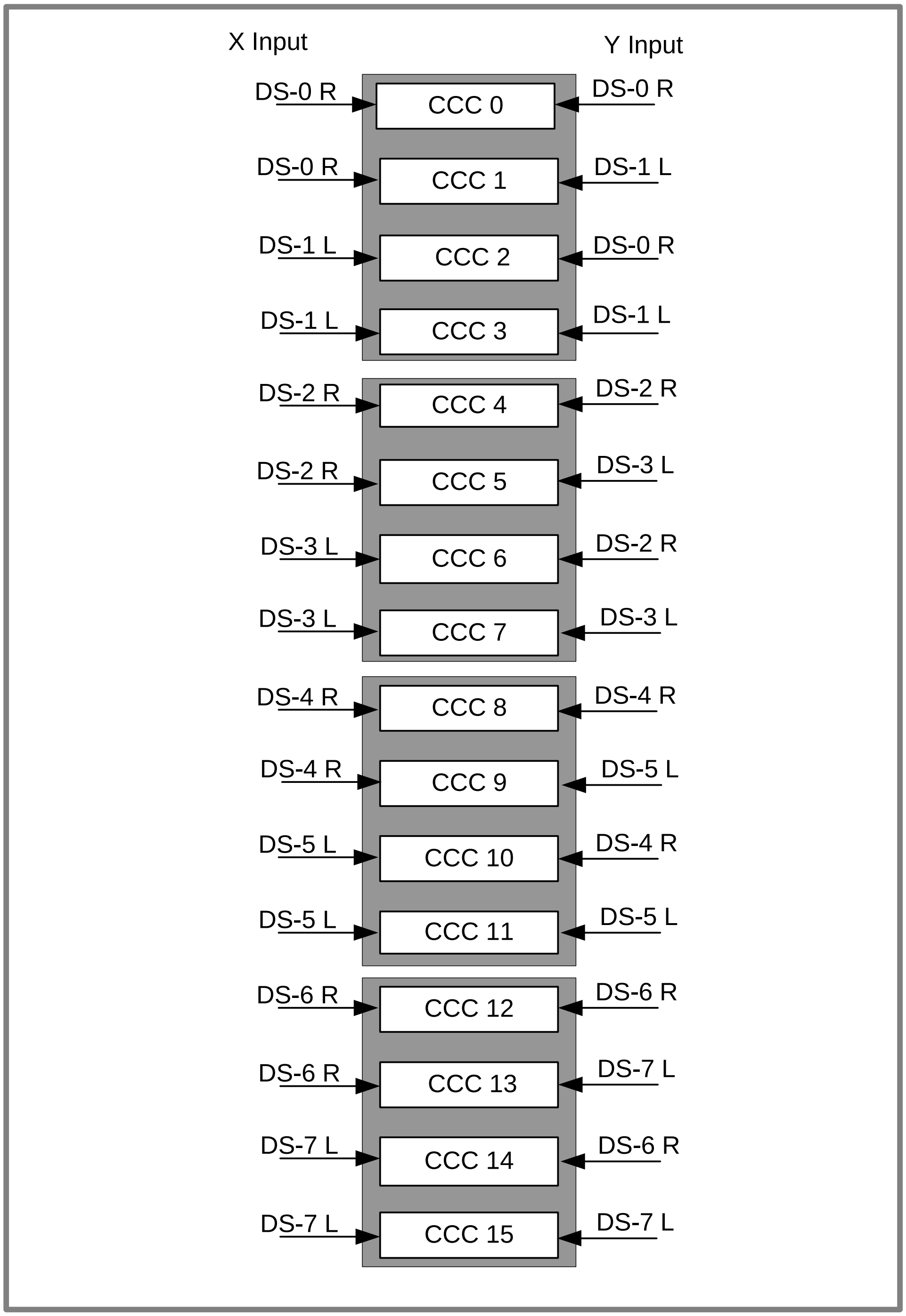


Figure 10 Correlator Chip: 4 DS Pairs, 2 Products per Pair, 4-bit Correlation Mode

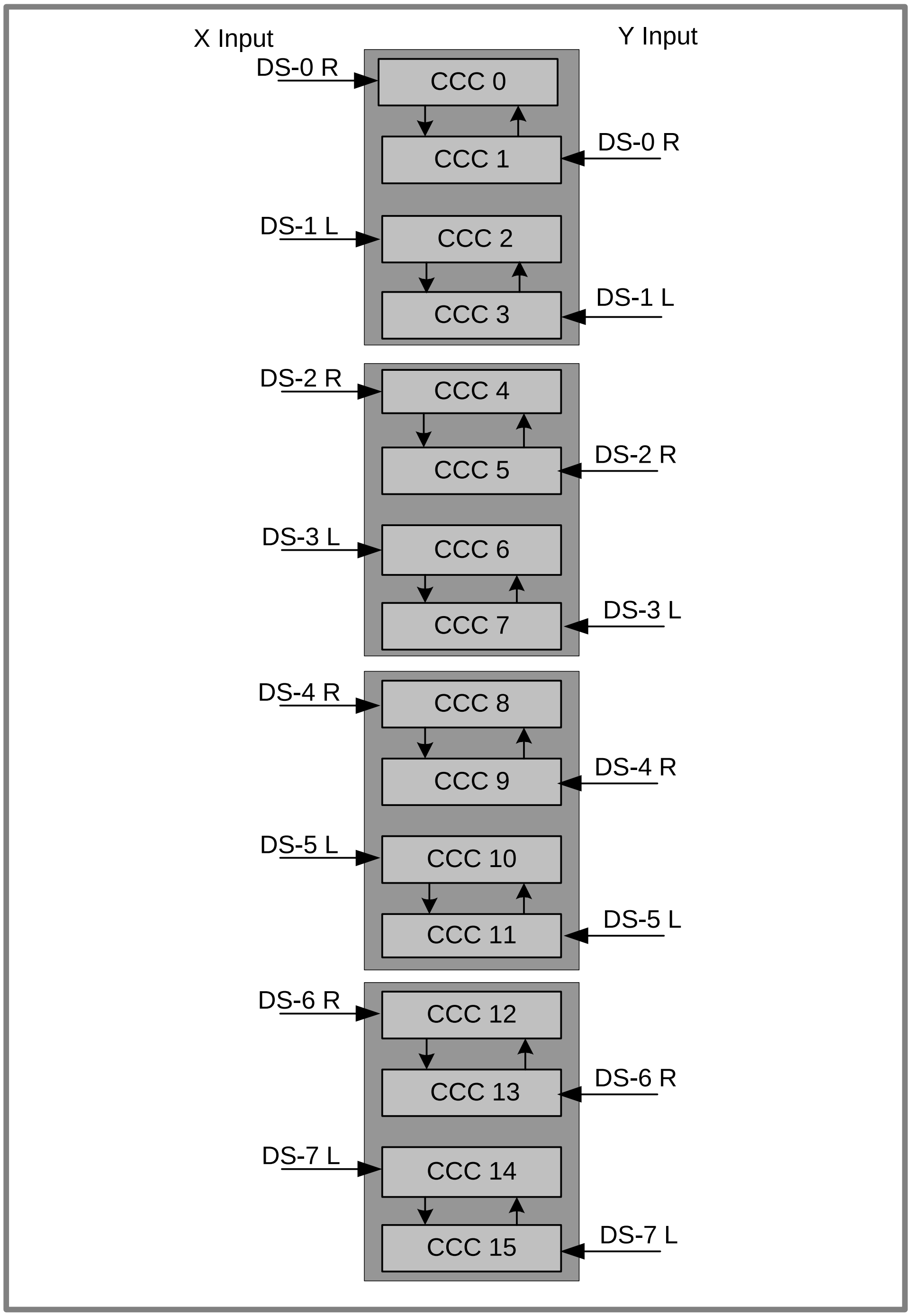


Figure 11 Correlator Chip: 4 DS Pairs, 1 Product per Pair (RR), 4-bit Correlation Mode

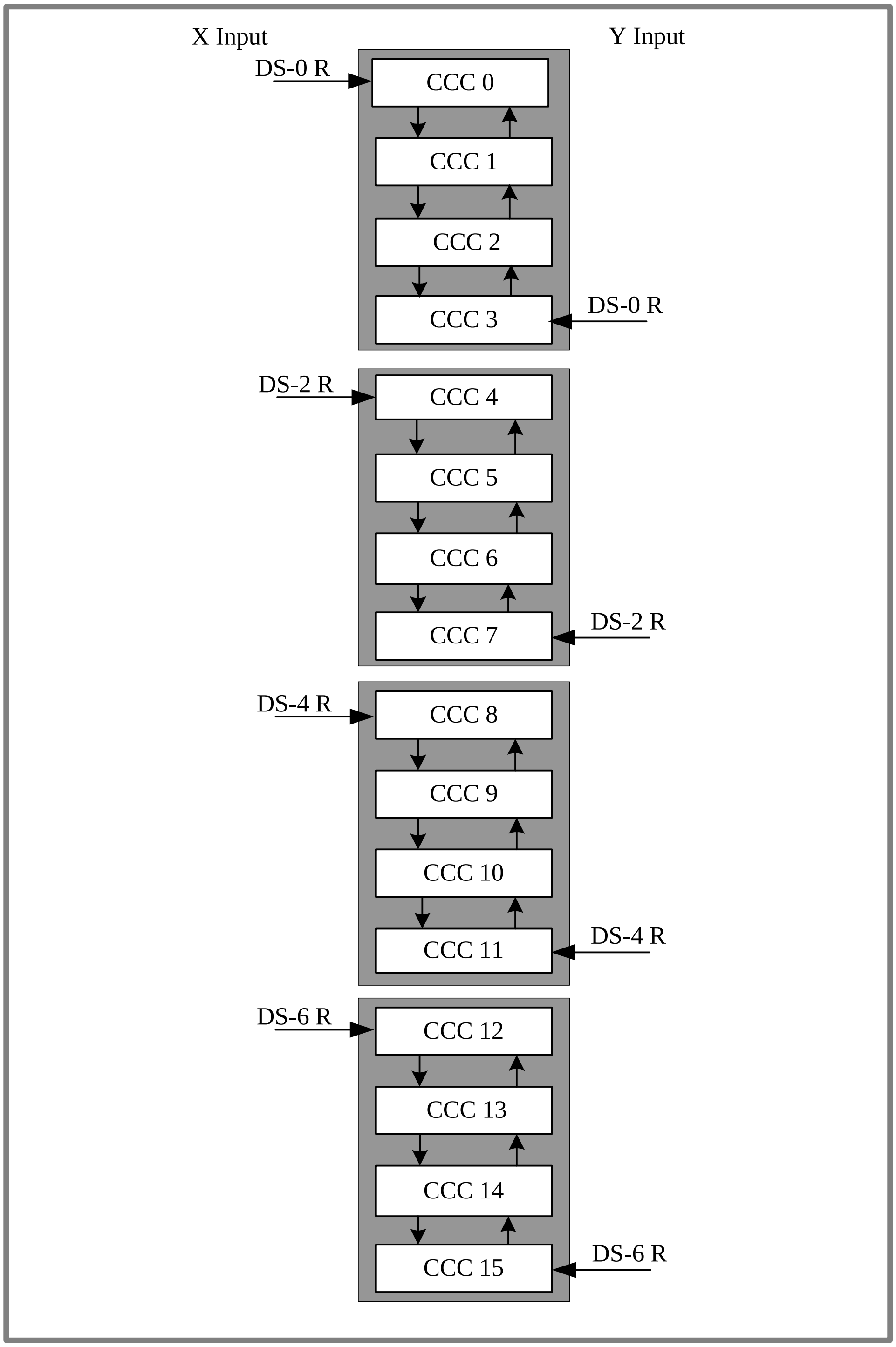
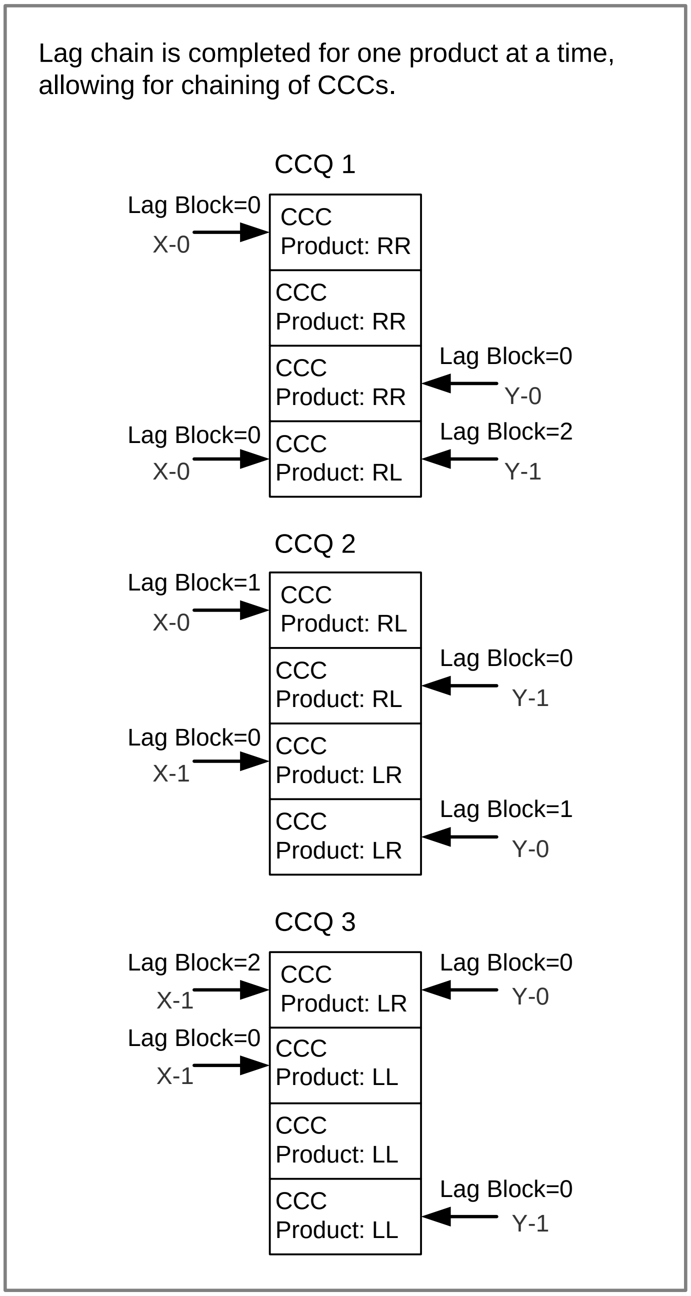


Figure 12 illustrates lag chain distribution for the configuration where 3 CCQs are available and four products are required. CCQs are not located on the same Correlator Chip. Data streams X-0 and Y-0 are right polarized, while X-1 and Y-1 are left polarized. The diagram shows configuration for the 4-bit correlation mode.

If CCQs were located on the same Correlator Chip, there would be no need for use of recirculation memory; output form the last CCC on one CCQ could be forwarded to the first CCC on the next CCQ.

Figure 12 Three CCQs: 1 DS Pair, 4 Products per Pair, 4-bit Correlation Mode



4.12.3.2 Lag Chain for 7-bit Correlation Mode

In 7-bit correlation mode, two Correlator Chip Input Data Streams carry higher (H) and lower (L) bits of the same Baseline Board Input Data Stream.

Four sub-products (HH, HL, LH and LL) are needed to obtain a single polarization product (RR, RL, LR or LL) in 7-bit correlation mode.

Figure 13 shows a Correlator Chip for the following configuration:

- One data stream pair
- Four products per pair
- Correlation mode: 7-bits

In 7-bit mode, four CCCs (one CCQ) are needed for each polarization product. For this configuration, one CCQ per product is available, each CCC receives a different combination of X and Y data streams. There is no chaining of CCCs.

Figure 14 shows a Correlator Chip for the following configuration:

- One data stream pair
- One product per pair (RR)
- Correlation mode: 7-bits

In this configuration 4 CCQs are available for the required product. Adjacent CCCs are used for each sub-product so that CCCs can be chained.

Figure 13 Correlator Chip: One DS Pair, 4 Products per Pair, 7-bit Correlation Mode

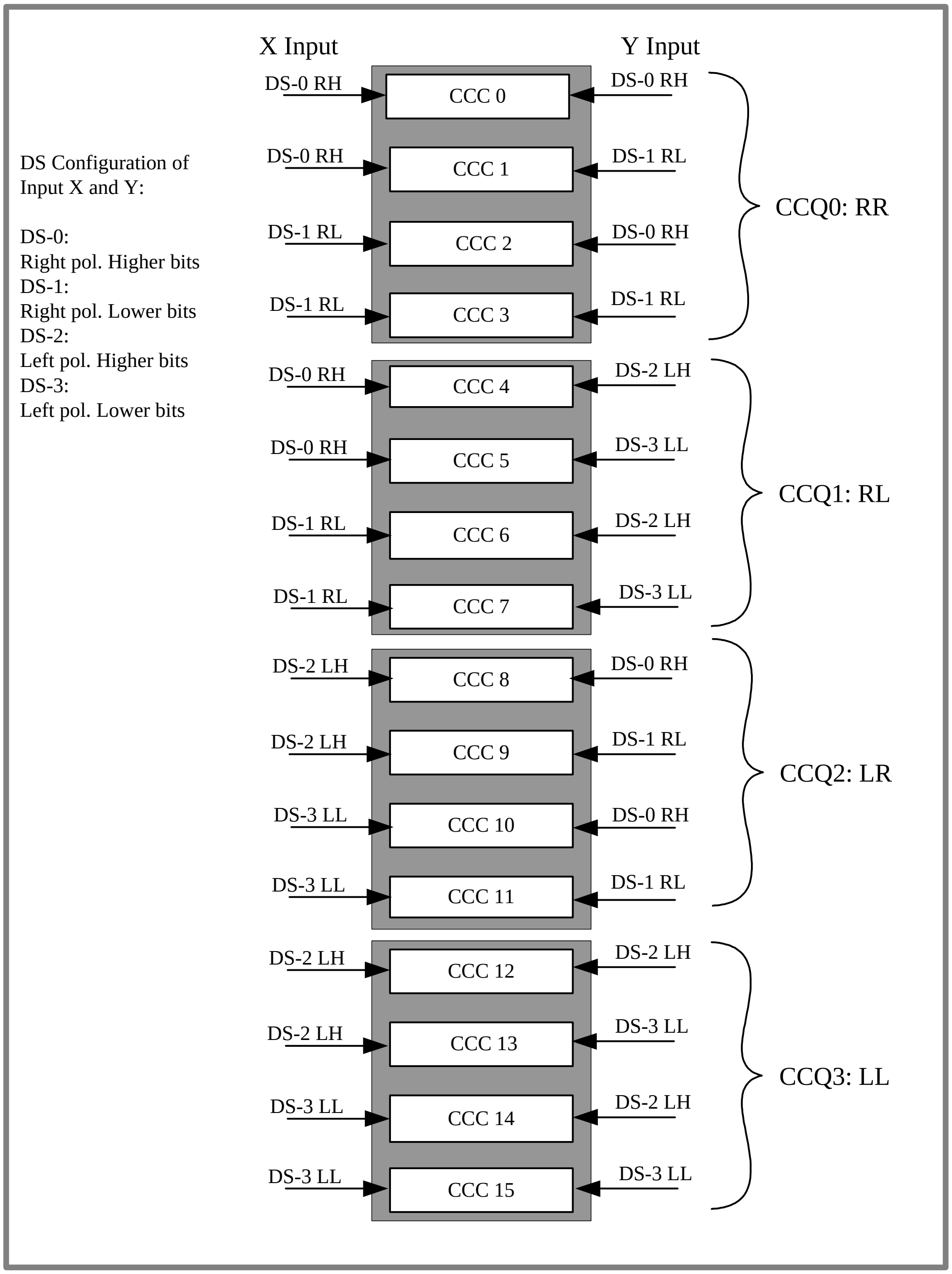
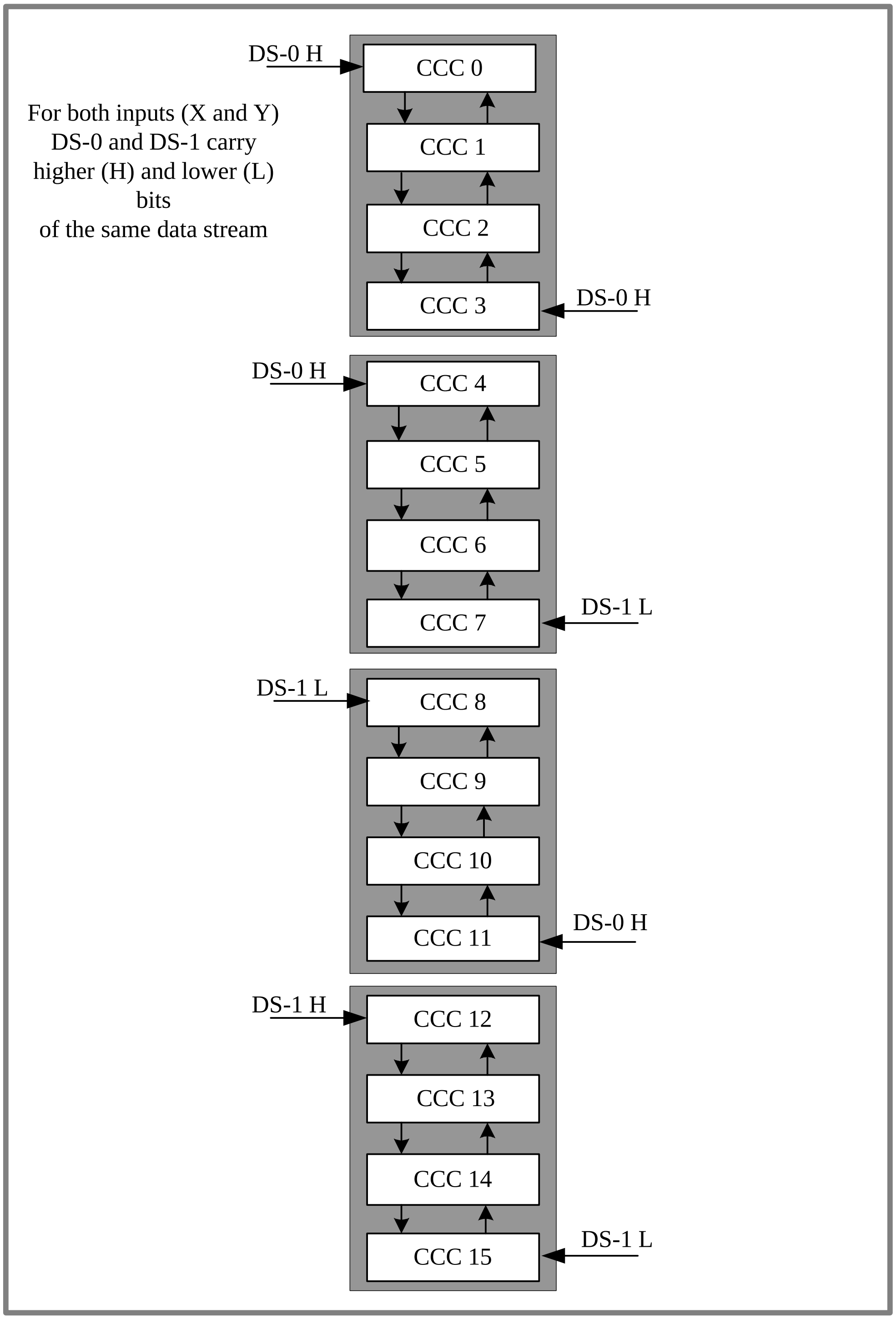


Figure 14 Correlator Chip: One Pair, 1 Product per Pair, 7-bit Correlation Mode



4.13

Baseline Board - Identical X and Y Inputs

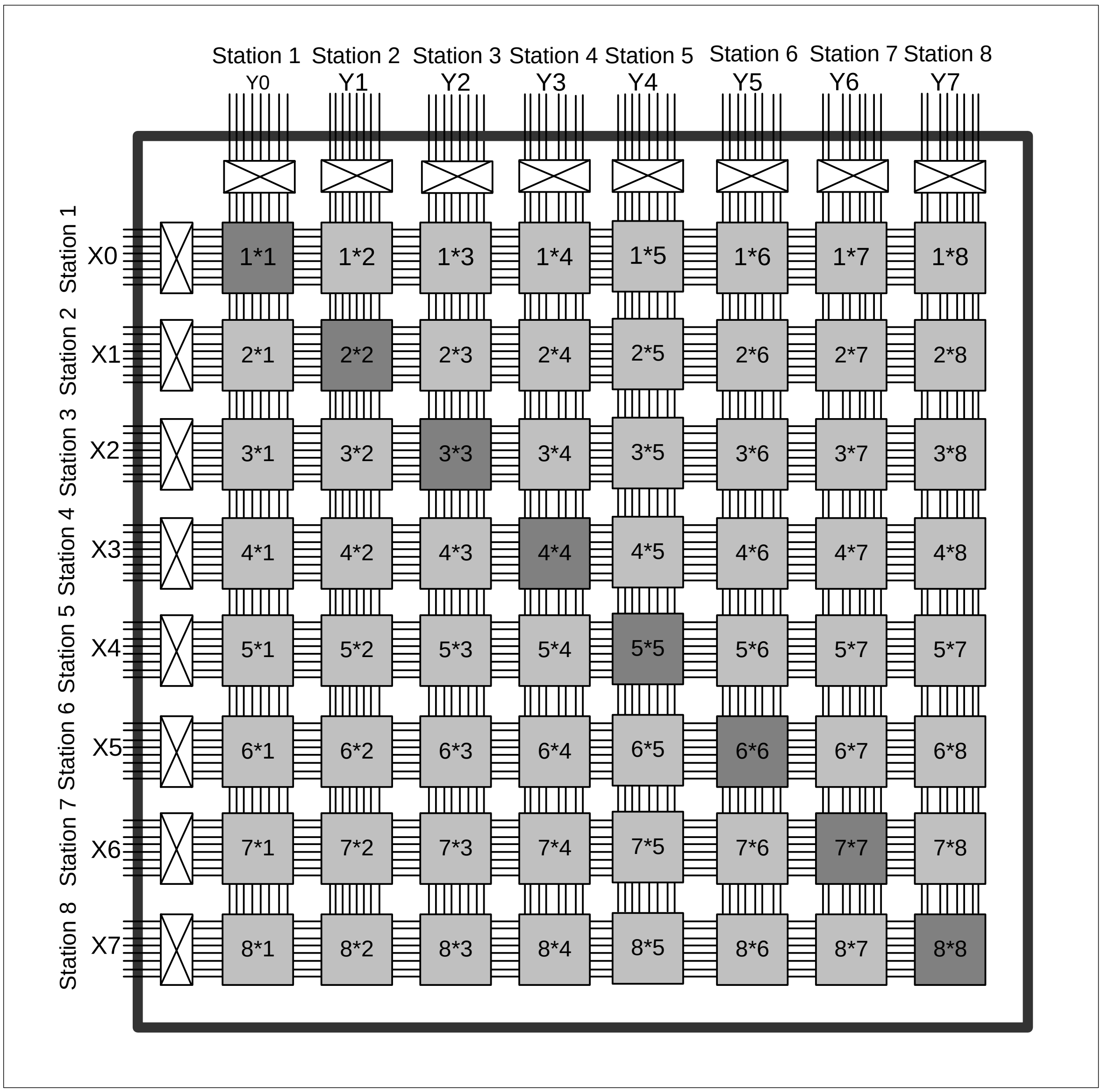
Figure 15 shows a Baseline Board where X and Y inputs are connected to the same set of eight stations (Station 1 to Station 8).

Note that in this case, there are *two* Correlator Chips for the following baselines:

Xi * Yj, i,j=0..7 and i <> j.

On the same board, there is *one* Correlator Chip for each baseline Xi*Yi, where i=0..7.

Figure 15 Baseline Board: X and Y inputs are connected to same stations



In other words, the number of lags for the baselines where auto-correlation is performed is half of what is available for other baselines. However, for auto-correlation, both inputs receive the same data; two halves of the full lag chain are symmetrical, which means that the same spectral resolution may be achieved with half of the correlator lags.

In other words, the configuration in **Figure 15** is able to provide the same spectral resolution for all the baselines.

5 References

[1] EVLA Correlator Monitoring & Control - VCI Protocol Specification, NRC, A25202, Sonja Vrcic, Latest revision,

http://www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/widar/private/Software.html

[2] EVLA Correlator System Numbering Plan, NRC, A2501, Brent Carlson, Latest revision, http://www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/widar/private/System.html

[3] EVLA Correlator: MCCC Requirements and Functionality Specification, NRC, A25202, Sonja Vrcic, Latest revision,

http://www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/widar/private/Software.html

6 Appendix

6.1 Example: Configuration Requires More Resources Than Available

The Station Board Configuration Request is received for two Station Quads (eight Station Boards), as follows:

- Eight basebands are defined for each Station Quad.
- Basebands on each Station Board are defined as a polarization pair.
- 16 subbands are defined for each baseband.
- 7-bit correlation mode is required for all data streams.
- 4 products with 64 spectral channels each are required for each pair.
- The correlator has 16 subband correlators.
- Each Subband Correlator has one Correlator Chip per baseline.

Since 16 subbands are configured, one Correlator Chip is available for each subband.

7-bit correlation requires one CCQ (4 CCCs) for each product.

4 CCQs (16 CCCs) are needed for 4 products with 64 spectral channels.

Each Correlator Chip has 16 CCCs, organized in 4 Correlator Chip Quads (CCQs).

In this example, the correlator has only one Correlator Chip per subband and *cannot* provide 4 products for 4 baseband pairs per subband.

In this situation, the MCCC can:

1. Reject the whole configuration, which means:

    a) Send a Configuration Reject message to the originator specifying the Configuration ID and the reason for rejection.

    b) Discard all the messages with the specified Configuration ID.

2. Reject the configuration for a Station Quad where configuration failed, but accept the configuration of other Station Quads. In the configuration report, which is transmitted as a response to the trigger message, the originator is notified that output data will not be delivered for the baseline A*B. The Correlator Chips that belong to the rejected baseline are set as idle at activation time.

3. Configure Correlator Chip(s) and related hardware to provide output data that can be produced with available resources and notify the originator that output data will not be delivered as requested (specify what will be delivered).

In the situation when the EVLA Monitor & Control System is not able to promptly modify and re-transmit the configuration (which may require human intervention), the third approach may be preferred; it allows the correlator to provide at least a part of the required output.

If 3. is implemented, the correlator have to decide how to assign the resources.

In this example, 16 Correlator Chips may be configured to provide a partial output, as follows:

a) 4 products for one baseband pair for 16 subbands

b) One product for 4 baseband pairs for 16 subbands

c) 4 products for 4 basebands for 4 subbands

The proposed approach is to provide all required products for all subbands of as many basebands as possible, i.e. the configuration a).

The precedence is given to the baseband on the 1st Data Path of the 1st Station Board. On the Correlator Chip shown in **Figure 3**, polarization products would be obtained for the baseband pair configured on Data Path 0 of Station Board 10-0-0 and 15-1-4.