

## The Optimized Connectivity Scheme: Baseline Board Configuration

*NRC-EVLA Memo# 029*

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### ABSTRACT

Memo 28 in this series describes an optimized connectivity scheme for the 32-station EVLA correlator: the Baseline Boards are arranged as pairs; each pair performs correlations for one subband of one Baseband (I/F) pair for all the stations. Memo 28 provides examples of the correlator modes and indicates that, for 32 stations, a Baseline Board pair can perform all cross-correlations, but only half of auto-correlations.

This memo shows how the number of products, especially auto-correlation products, that can be obtained depends on the number of stations and subarrays.

For 4-bit correlation, a Baseline Board pair can perform all cross-correlations for one subband of one Baseband (I/F) pair for 32 stations and auto-correlations for 16 stations (out of 32). The full set of products (cross and auto correlations) can be obtained for up to 26 stations.

For 7-bit correlation, a Baseline Board pair can perform all cross-correlations for up to 16 stations and auto-correlations for all 7-bit input streams (for 16 stations there are 32 input streams, two for each station).

The diagrams provide examples of the Baseline Board and Correlator Chip configuration for 4-bit and 7-bit correlation.

### Introduction

One of the issues discussed at the review of the optimized connectivity scheme for the 32-station EVLA correlator, is the fact that the optimized correlator cannot provide the full set of cross-correlation and auto-correlation products for 32 stations. This memo shows how, when the number of stations is less than 32, unused rows and columns on the Baseline Board can be used to obtain additional auto-correlation products.

All examples in this memo assume the maximum number of subbands, so that a single Baseline Board pair is available for each subband.



Memo 28 shows that, when the number of subbands is smaller, the unused correlator quadrant(s) may be used to obtain more spectral channels. Unused quadrants could also be used to obtain more auto-correlation products, but since such configuration is both straightforward and inefficient, it is not considered in this document.

## Baseline Board Connections

In order to understand the limitations on the number of products that can be obtained for a given number of stations (antennas) user has to understand some aspects of the WIDAR architecture. This section provides a high-level overview of the baseline rack and Baseline Board hardware. The diagrams show only elements relevant to the issue addressed in the further text, i.e. the number of correlation products that can be obtained. A comprehensive description of the new connection scheme can be found in Memo 28 [1].

**Figure 1** is a conceptual diagram of the baseline rack. As shown in the diagram, Baseline Boards are arranged as pairs; input received by the first board is forwarded to the second board.

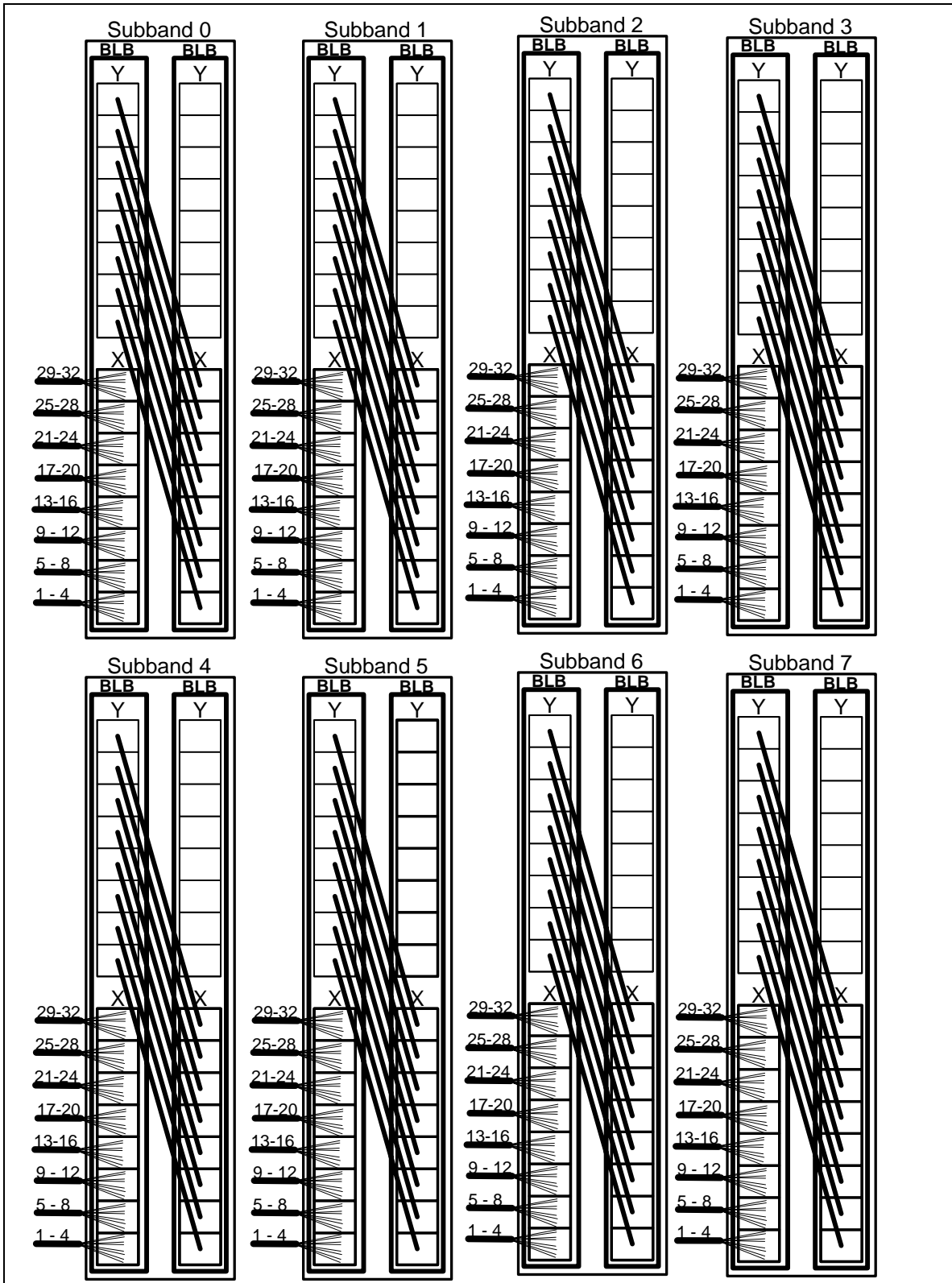
Baseline Board input comes from the station racks. Connections will be arranged so that each Baseline Board receives one subband of one Baseband pair for up to 32 stations. Software controlled crossbar switches on the Station Board and in the station rack provide full flexibility, so that any subband can be forwarded to any Baseline Board.

**Figure 2** shows the main elements of the Baseline Board. Two FPGAs in the Baseline Board input implement the full crossbar switch, which is used to arrange 64 input data streams as 8 groups of 8 data streams. The input crossbar switch can forward any input stream to any output stream.

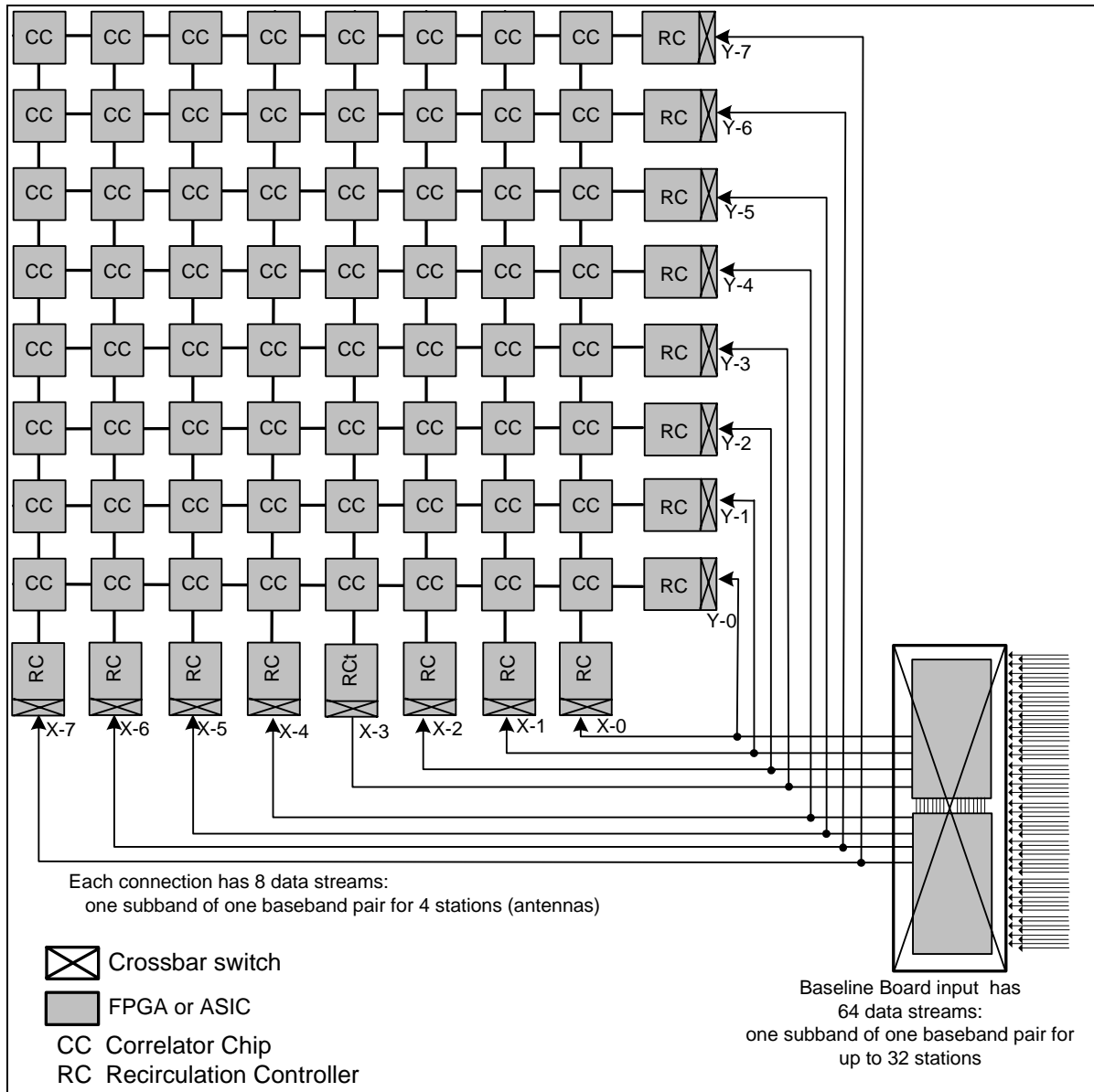
Each group of 8 data streams is forwarded to X and Y Recirculation Controller with the same ID (e.g. X-0 and Y-0). Recirculation Controller also implements a full crossbar switch that can be used to rearrange data streams. In the Recirculation Controller the data streams are rearranged before recirculation is performed.

Output of a Recirculation Controller becomes input for 8 Correlator Chips in the same column or row. All the Correlator Chips in the same column/row on the Baseline Board receive identical input.

Figure 1 Baseline Rack



**Figure 2 Baseline Board**



## 4-Bit Correlation

The diagrams in this chapter provide examples of the Baseline Board configuration for a single subarray that consists of 32, 28 and 26 stations. **Figure 3**, **Figure 4** and **Figure 5** each show Correlator Chips on two Baseline Boards connected with the patch panel, as shown in **Figure 1**. Each square in the diagrams represents a Correlator Chip. A Baseline Board has 64 Correlator Chips arranged in 8 columns and 8 rows. The numbers along upper and left border of the Correlator Chip matrix are Station IDs. Two input data streams are used to carry one subband of one Baseband pair, which means that the Correlator Chip can receive input from up to 4 stations. To maximize the number of products that can be obtained, data streams in X and Y input are arranged in different order. This is achieved using the crossbar switch in the Recirculation Controller.

The configuration in **Figure 3**, **Figure 4** and **Figure 5** applies for all the 3IQ/4RQ (3-bit initial quantization, 4-bit re-quantization) modes specified in the Memo 28. It also applies to 3IQ/7RQ (3-bit initial quantization, 7-bit re-quantization) mode, only, as specified in Memo 28, in that case a Baseline Board pair would produce only 1 of the 4 cross-products required to produce the final result.

Baseline Boards in **Figure 3** are configured to obtain all the cross-correlation products for 32 stations. As the diagram shows, two Baseline Boards can perform all the cross-correlations for a subarray that consists of 32 stations. Auto-correlation can be performed for a half of the stations (16).

For a subarray that consists of 28 stations, two Baseline Boards can produce all cross-correlation products and auto-correlation products for up to 22 stations. The Baseline Board configuration for a 28 station subarray is shown in **Figure 4**.

For a subarray that consists of 27 stations, auto correlation can be performed for 24 stations.

A complete set of products (cross-correlation and auto-correlation) can be obtained for up to 26 stations. **Figure 5** is an example of two Baseline Boards configured to produce all the cross and auto-correlation products for 26 stations.

In the case when only a subset of auto correlation products can be produced, the order of the data streams in the Correlator Chip input determines a subset of the auto-correlation products. The setup of the Baseline Board input crossbar switch and the crossbar switches in the Recirculation Controllers will be determined by the correlator software (Configuration Mapper) based on the number of stations.

*If needed, user might be allowed to specify the list of antennas (stations) for which auto-correlation products should be obtained. Obviously, such requirement would increase complexity of the Configuration Mapper software.*

Figure 3 One Subarray, 32 Stations, 4-Bit Correlation

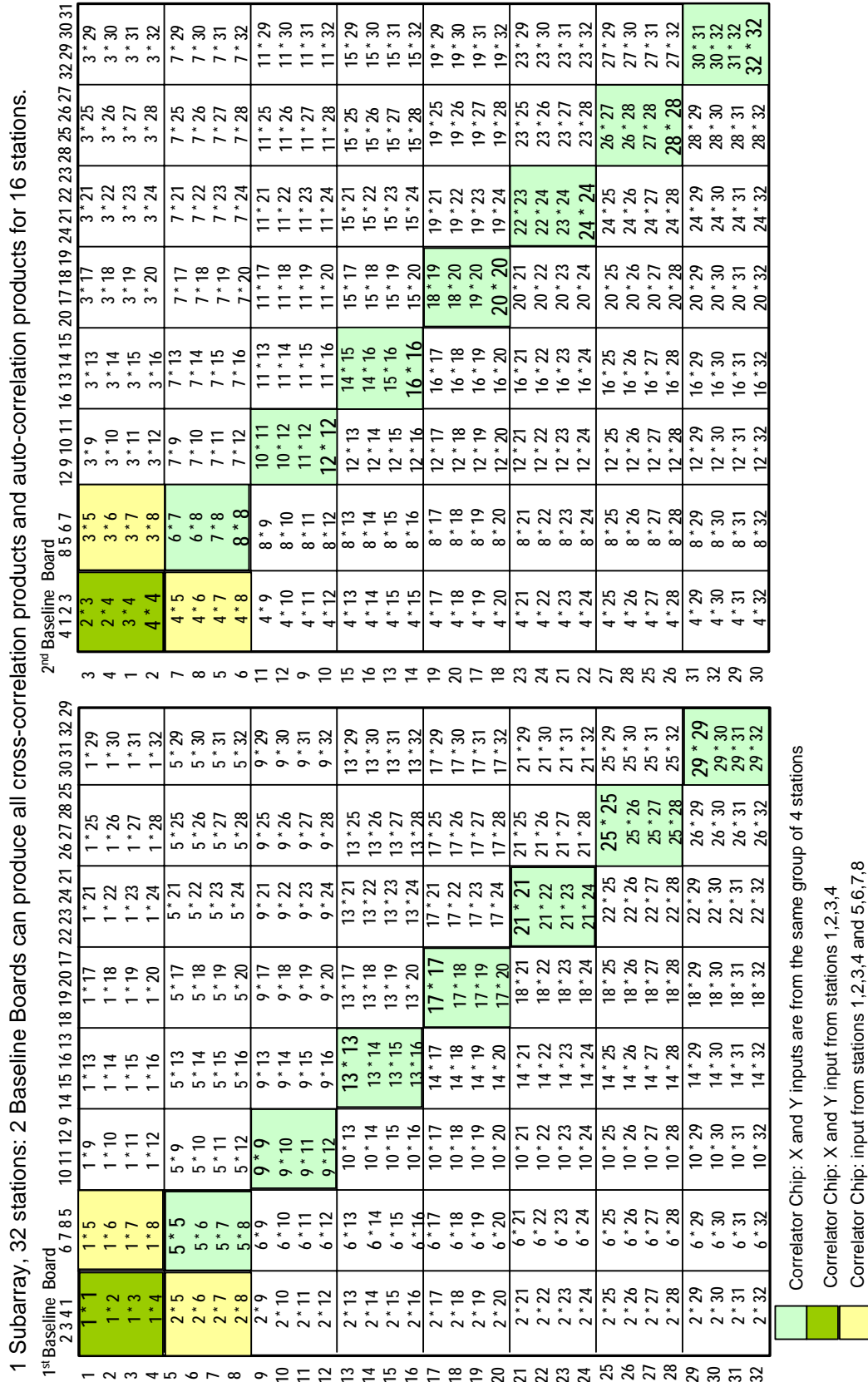


Figure 4 1 Subarray, 28 Stations, 4-Bit Correlation

1 Subarray, 28 stations: 2 Baseline Boards can produce all cross-correlation products and auto-correlation products for 22 stations.

1 <sup>st</sup> Baseline Board														2 <sup>nd</sup> Baseline Board																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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1	1*1	1*5	1*9	1*13	1*17	1*21	1*25	1*29	1*33	1*37	1*41	1*45	1*49	1*53	1*57	1*61	1*65	1*69	1*73	1*77	1*81	1*85	1*89	1*93	1*97	1*101	1*105	1*109	1*113	1*117	1*121	1*125	1*129	1*133	1*137	1*141	1*145	1*149	1*153	1*157	1*161	1*165	1*169	1*173	1*177	1*181	1*185	1*189	1*193	1*197	1*201	1*205	1*209	1*213	1*217	1*221	1*225	1*229	1*233	1*237	1*241	1*245	1*249	1*253	1*257	1*261	1*265	1*269	1*273	1*277	1*281	1*285	1*289	1*293	1*297	1*301	1*305	1*309	1*313	1*317	1*321	1*325	1*329	1*333	1*337	1*341	1*345	1*349	1*353	1*357	1*361	1*365	1*369	1*373	1*377	1*381	1*385	1*389	1*393	1*397	1*401	1*405	1*409	1*413	1*417	1*421	1*425	1*429	1*433	1*437	1*441	1*445	1*449	1*453	1*457	1*461	1*465	1*469	1*473	1*477	1*481	1*485	1*489	1*493	1*497	1*501	1*505	1*509	1*513	1*517	1*521	1*525	1*529	1*533	1*537	1*541	1*545	1*549	1*553	1*557	1*561	1*565	1*569	1*573	1*577	1*581	1*585	1*589	1*593	1*597	1*601	1*605	1*609	1*613	1*617	1*621	1*625	1*629	1*633	1*637	1*641	1*645	1*649	1*653	1*657	1*661	1*665	1*669	1*673	1*677	1*681	1*685	1*689	1*693	1*697	1*701	1*705	1*709	1*713	1*717	1*721	1*725	1*729	1*733	1*737	1*741	1*745	1*749	1*753	1*757	1*761	1*765	1*769	1*773	1*777	1*781	1*785	1*789	1*793	1*797	1*801	1*805	1*809	1*813	1*817	1*821	1*825	1*829	1*833	1*837	1*841	1*845	1*849	1*853	1*857	1*861	1*865	1*869	1*873	1*877	1*881	1*885	1*889	1*893	1*897	1*901	1*905	1*909	1*913	1*917	1*921	1*925	1*929	1*933	1*937	1*941	1*945	1*949	1*953	1*957	1*961	1*965	1*969	1*973	1*977	1*981	1*985	1*989	1*993	1*997	1*1001	1*1005	1*1009	1*1013	1*1017	1*1021	1*1025	1*1029	1*1033	1*1037	1*1041	1*1045	1*1049	1*1053	1*1057	1*1061	1*1065	1*1069	1*1073	1*1077	1*1081	1*1085	1*1089	1*1093	1*1097	1*1101	1*1105	1*1109	1*1113	1*1117	1*1121	1*1125	1*1129	1*1133	1*1137	1*1141	1*1145	1*1149	1*1153	1*1157	1*1161	1*1165	1*1169	1*1173	1*1177	1*1181	1*1185	1*1189	1*1193	1*1197	1*1201	1*1205	1*1209	1*1213	1*1217	1*1221	1*1225	1*1229	1*1233	1*1237	1*1241	1*1245	1*1249	1*1253	1*1257	1*1261	1*1265	1*1269	1*1273	1*1277	1*1281	1*1285	1*1289	1*1293	1*1297	1*1301	1*1305	1*1309	1*1313	1*1317	1*1321	1*1325	1*1329	1*1333	1*1337	1*1341	1*1345	1*1349	1*1353	1*1357	1*1361	1*1365	1*1369	1*1373	1*1377	1*1381	1*1385	1*1389	1*1393	1*1397	1*1401	1*1405	1*1409	1*1413	1*1417	1*1421	1*1425	1*1429	1*1433	1*1437	1*1441	1*1445	1*1449	1*1453	1*1457	1*1461	1*1465	1*1469	1*1473	1*1477	1*1481	1*1485	1*1489	1*1493	1*1497	1*1501	1*1505	1*1509	1*1513	1*1517	1*1521	1*1525	1*1529	1*1533	1*1537	1*1541	1*1545	1*1549	1*1553	1*1557	1*1561	1*1565	1*1569	1*1573	1*1577	1*1581	1*1585	1*1589	1*1593	1*1597	1*1601	1*1605	1*1609	1*1613	1*1617	1*1621	1*1625	1*1629	1*1633	1*1637	1*1641	1*1645	1*1649	1*1653	1*1657	1*1661	1*1665	1*1669	1*1673	1*1677	1*1681	1*1685	1*1689	1*1693	1*1697	1*1701	1*1705	1*1709	1*1713	1*1717	1*1721	1*1725	1*1729	1*1733	1*1737	1*1741	1*1745	1*1749	1*1753	1*1757	1*1761	1*1765	1*1769	1*1773	1*1777	1*1781	1*1785	1*1789	1*1793	1*1797	1*1801	1*1805	1*1809	1*1813	1*1817	1*1821	1*1825	1*1829	1*1833	1*1837	1*1841	1*1845	1*1849	1*1853	1*1857	1*1861	1*1865	1*1869	1*1873	1*1877	1*1881	1*1885	1*1889	1*1893	1*1897	1*1901	1*1905	1*1909	1*1913	1*1917	1*1921	1*1925	1*1929	1*1933	1*1937	1*1941	1*1945	1*1949	1*1953	1*1957	1*1961	1*1965	1*1969	1*1973	1*1977	1*1981	1*1985	1*1989	1*1993	1*1997	1*2001	1*2005	1*2009	1*2013	1*2017	1*2021	1*2025	1*2029	1*2033	1*2037	1*2041	1*2045	1*2049	1*2053	1*2057	1*2061	1*2065	1*2069	1*2073	1*2077	1*2081	1*2085	1*2089	1*2093	1*2097	1*2101	1*2105	1*2109	1*2113	1*2117	1*2121	1*2125	1*2129	1*2133	1*2137	1*2141	1*2145	1*2149	1*2153	1*2157	1*2161	1*2165	1*2169	1*2173	1*2177	1*2181	1*2185	1*2189	1*2193	1*2197	1*2201	1*2205	1*2209	1*2213	1*2217	1*2221	1*2225	1*2229	1*2233	1*2237	1*2241	1*2245	1*2249	1*2253	1*2257	1*2261	1*2265	1*2269	1*2273	1*2277	1*2281	1*2285	1*2289	1*2293	1*2297	1*2301	1*2305	1*2309	1*2313	1*2317	1*2321	1*2325	1*2329	1*2333	1*2337	1*2341	1*2345	1*2349	1*2353	1*2357	1*2361	1*2365	1*2369	1*2373	1*2377	1*2381	1*2385	1*2389	1*2393	1*2397	1*2401	1*2405	1*2409	1*2413	1*2417	1*2421	1*2425	1*2429	1*2433	1*2437	1*2441	1*2445	1*2449	1*2453	1*2457	1*2461	1*2465	1*2469	1*2473	1*2477	1*2481	1*2485	1*2489	1*2493	1*2497	1*2501	1*2505	1*2509	1*2513	1*2517	1*2521	1*2525	1*2529	1*2533	1*2537	1*2541	1*2545	1*2549	1*2553	1*2557	1*2561	1*2565	1*2569	1*2573	1*2577	1*2581	1*2585	1*2589	1*2593	1*2597	1*2601	1*2605	1*2609	1*2613	1*2617	1*2621	1*2625	1*2629	1*2633	1*2637	1*2641	1*2645	1*2649	1*2653	1*2657	1*2661	1*2665	1*2669	1*2673	1*2677	1*2681	1*2685	1*2689	1*2693	1*2697	1*2701	1*2705	1*2709	1*2713	1*2717	1*2721	1*2725	1*2729	1*2733	1*2737	1*2741	1*2745	1*2749	1*2753	1*2757	1*2761	1*2765	1*2769	1*2773	1*2777	1*2781	1*2785	1*2789	1*2793	1*2797	1*2801	1*2805	1*2809	1*2813	1*2817	1*2821	1*2825	1*2829	1*2833	1*2837	1*2841	1*2845	1*2849	1*2853	1*2857	1*2861	1*2865	1*2869	1*2873	1*2877	1*2881	1*2885	1*2889	1*2893	1*2897	1*2901	1*2905	1*2909	1*2913	1*2917	1*2921	1*2925	1*2929	1*2933	1*2937	1*2941	1*2945	1*2949	1*2953	1*2957	1*2961	1*2965	1*2969	1*2973	1*2977	1*2981	1*2985	1*2989	1*2993	1*2997	1*3001	1*3005	1*3009	1*3013	1*3017	1*3021	1*3025	1*3029	1*3033	1*3037	1*3041	1*3045	1*3049	1*3053	1*3057	1*3061	1*3065	1*3069	1*3073	1*3077	1*3081	1*3085	1*3089	1*3093	1*3097	1*3101	1*3105	1*3109	1*3113	1*3117	1*3121	1*3125	1*3129	1*3133	1*3137	1*3141	1*3145	1*3149	1*3153	1*3157	1*3161	1*3165	1*3169	1*3173	1*3177	1*3181	1*3185	1*3189	1*3193	1*3197	1*3201	1*3205	1*3209	1*3213	1*3217	1*3221	1*3225	1*3229	1*3233	1*3237	1*3241	1*3245	1*3249	1*3253	1*3257	1*3261	1*3265	1*3269	1*3273	1*3277	1*3281	1*3285	1*3289	1*3293	1*3297	1*3301	1*3305	1*3309	1*3313	1*3317	1*3321	1*3325	1*3329	1*3333	1*3337	1*3341	1*3345	1*3349	1*3353	1*3357	1*3361	1*3365	1*3369	1*3373	1*3377	1*3381	1*3385	1*3389	1*3393	1*3397	1*3401	1*3405	1*3409	1*3413	1*3417	1*3421	1*3425	1*3429	1*3433	1*3437	1*3441	1*3445	1*3449	1*3453	1*3457	1*3461	1*3465	1*3469	1*3473	1*3477	1*3481	1*3485	1*3489	1*3493	1*3497	1*3501	1*3505	1*3509	1*3513	1*3517	1*3521	1*3525	1*3529	1*3533	1*3537	1*3541	1*3545	1*3549	1*3553	1*3557	1*3561	1*3565	1*3569	1*3573	1*3577	1*3581	1*3585	1*3589	1*3593	1*3597	1*3601	1*3605	1*3609	1*3613	1*3617	1*3621	1*3625	1*3629	1*3633	1*3637	1*3641	1*3645	1*3649	1*3653	1*3657	1*3661	1*3665	1*3669	1*3673	1*3677	1*3681	1*3685	1*3689	1*3693	1*3697	1*3701	1*3705	1*3709	1*3713	1*3717	1*3721	1*3725	1*3729	1*3733	1*3737	1*3741	1*3745	1*3749	1*3753	1*3757	1*3761	1*3765	1*3769	1*3773	1*3777	1*3781	1*3785	1*3789	1*3793	1*3797	1*3801	1*3805	1*3809	1*3813	1*3817	1*3821	1*3825	1*3829	1*3833	1*3837	1*3841	1*3845	1*3849	1*3853	1*3857	1*3861	1*3865	1*3869	1*3873	1*3877	1*3881	1*3885	1*3889	1*3893	1*3897	1*3901	1*3905	1*3909	1*3913	1*3917	1*3921	1*3925	1*3929	1*3933	1*3937	1*3941	1*3945	1*3949	1*3953	1*3957	1*3961	1*3965	1*3969	1*3973	1*3977	1*3981	1*3985	1*3989	1*3993	1*3997	1*4001	1*4005	1*4009	1*4013	1*4017	1*4021	1*4025	1*4029	1*4033	1*4037	1*4041	1*4045	1*4049	1*4053	1*4057	1*4061	1*4065	1*4069	1*4073	1*4077	1*4081	1*4085	1*4089	1*4093	1*4097	1*4101	1*4105	1*4109	1*4113	1*4117	1*4121	1*4125	1*4129	1*4133	1*4137	1*4141	1*4145	1*4149	1*4153	1*4157	1*4161	1*4165	1*4169	1*4173	1*4177	1*4181	1*4185	1*4189	1*4193	1*4197	1*4201	1*4205	1*4209	1*4213	1*4217	1*4221	1*4225	1*4229	1*4233	1*4237	1*4241	1*4245	1*4249	1*4253	1*4257	1*4261	1*4265	1*4269	1*4273	1*4277	1*4281	1*4285	1*4289	1*4293	1*4297	1*4301	1*4305	1*4309	1*4313	1*4317	1*4321	1*4325	1*4329	1*4333	1*4337	1*4341	1*4345	1*4349	1*4353	1*4357	1*4361	1*4365	1*4369	1*4373	1*4377	1*4381	1*4385	1*4389	1*4393	1*4397	1*4401	1*4405	1*4409	1*4413	1*4417

Figure 5 1 Subarray, 26 stations, 4-Bit Correlation

1 Subarray, 26 stations: 2 Baseline Boards can produce all cross-correlation products and all auto-correlation products.

1 <sup>st</sup> Baseline Board													2 <sup>nd</sup> Baseline Board												
2 3 4 1	6 7 8 5	10 11 12 9	14 15 16 13	18 19 20 17	22 23 24 21	26 25 2 3	6 7 10 11	2 3	4 1 2 3	8 5 6 7	12 9 10 11	16 13 14 15	20 17 18 19	24 21 22 23	26 25 14 15	18 19 22 23									
1	1*1	1*5	1*9	1*13	1*17	1*21	1*25	2*3	2*4	3*5	3*9	3*13	3*17	3*21	3*25										
2	1*2	1*6	1*10	1*14	1*18	1*22	1*26	2*4	3*4	3*6	3*10	3*14	3*18	3*22	3*26										
3	1*3	1*7	1*11	1*15	1*19	1*23		3*4	3*5	3*7	3*11	3*15	3*19	3*23											
4	1*4	1*8	1*12	1*16	1*20	1*24		4*4	4*4	3*8	3*12	3*16	3*20	3*24											
5	2*5	5*5	5*9	5*13	5*17	5*21	5*25	4*5	4*6	6*7	7*9	7*13	7*17	7*21	7*25										
6	2*6	5*6	5*10	5*14	5*18	5*22	5*26	4*6	4*7	6*8	7*10	7*14	7*18	7*22	7*26										
7	2*7	5*7	5*11	5*15	5*19	5*23		4*7	4*8	7*8	7*11	7*15	7*19	7*23											
8	2*8	5*8	5*12	5*16	5*20	5*24		4*8		8*8	7*12	7*16	7*20	7*24											
9	2*9	6*9	9*9	9*13	9*17	9*21	9*25	4*9	4*9	8*9	10*11	11*13	11*17	11*21	11*25										
10	2*10	6*10	9*10	9*14	9*18	9*22	9*26	4*10	4*10	8*10	10*12	11*14	11*18	11*22	11*26										
11	2*11	6*11	9*11	9*15	9*19	9*23		4*11	4*11	8*11	11*12	11*15	11*19	11*23											
12	2*12	6*12	9*12	9*16	9*20	9*24		4*12	4*12	8*12	12*12	11*16	11*20	11*24											
13	2*13	6*13	10*13	13*13	13*17	13*21	13*25	4*13	4*13	8*13	12*13	14*15	15*17	15*21	15*25										
14	2*14	6*14	10*14	13*14	13*18	13*22	13*26	4*14	4*14	8*14	12*14	14*16	15*18	15*22	15*26										
15	2*15	6*15	10*15	13*15	13*19	13*23		4*15	4*15	8*15	12*15	15*16	15*19	15*23											
16	2*16	6*16	10*16	13*16	13*20	13*24		4*16	4*16	8*16	12*16	16*16	15*20	15*24											
17	2*17	6*17	10*17	14*17	17*17	17*21	17*25	4*17	4*17	8*17	12*17	16*17	18*19	19*21	19*25										
18	2*18	6*18	10*18	14*18	17*18	17*22	17*26	4*18	4*18	8*18	12*18	16*18	18*20	19*22	19*26										
19	2*19	6*19	10*19	14*19	17*19	17*23		4*19	4*19	8*19	12*19	16*19	19*20	19*23											
20	2*20	6*20	10*20	14*20	17*20	17*24		4*20	4*20	8*20	12*20	16*20	20*20	19*24											
21	2*21	6*21	10*21	14*21	18*21	21*21	21*25	4*21	4*21	8*21	12*21	16*21	20*21	22*23	23*25										
22	2*22	6*22	10*22	14*22	18*22	21*22	21*26	4*22	4*22	8*22	12*22	16*22	20*22	22*24	23*26										
23	2*23	6*23	10*23	14*23	18*23	21*23		4*23	4*23	8*23	12*23	16*23	20*23	23*24											
24	2*24	6*24	10*24	14*24	18*24	21*24		4*24	4*24	8*24	12*24	16*24	20*24	24*24											
25	2*25	6*25	10*25	14*25	18*25	22*25	25*25	4*25	4*25	8*25	12*25	16*25	20*25	24*25	26*26										
26	2*26	6*26	10*26	14*26	18*26	22*26	25*26	4*26	4*26	8*26	12*26	16*26	20*26	24*26	26*26										
2							2*2								14*14										
3							3*3								15*15										
6							6*6								18*18										
7							7*7								19*19										
10							10*10								22*22										
11							11*11								23*23										

Correlator Chip: X and Y inputs are from the same group of 4 stations

## Correlator Chip Configuration

**Figure 6** shows the detailed configuration for two Correlator Chips on the Baseline Board diagonal (the Correlator Chips shown in the diagram are located in column 0, row 0). As shown in the diagram, they receive X and Y input from the same group of 4 stations.

In **Figure 6**, Recirculation Controllers are used to arrange input data streams so that the 1<sup>st</sup> data stream pair is different in each input. This arrangement provides for relatively simple and straightforward configuration of the Correlator Chips that perform cross-correlations (i.e. that are not on the diagonal).

**Figure 7** shows an alternative configuration where the same Correlator Chips are configured to obtain a single auto-correlation product for each station. The configuration in **Figure 7** would produce auto-correlation products for the following data streams: 1R, 2L, 3R and 4L.

If perceived as useful, user might be allowed to select between the two subsets of auto-correlation products:

1. Perform auto-correlation for both polarizations (data streams) for a subset of stations (as shown in **Figure 6**). As already described, all auto-correlation products can be obtained for a single subarray of up to 26 antennas. For a subarray that consists of more than 26 antennas user could specify the subset of antennas.
2. Perform auto-correlation for one polarization per station, for all stations (as shown in **Figure 7**). If acceptable, it should be left to the Configuration Mapper to decide which polarization to auto-correlate for which station.



Figure 6 Baseline Board diagonal, auto-correlation products for 2 out of 4 stations, 4-bit correlation

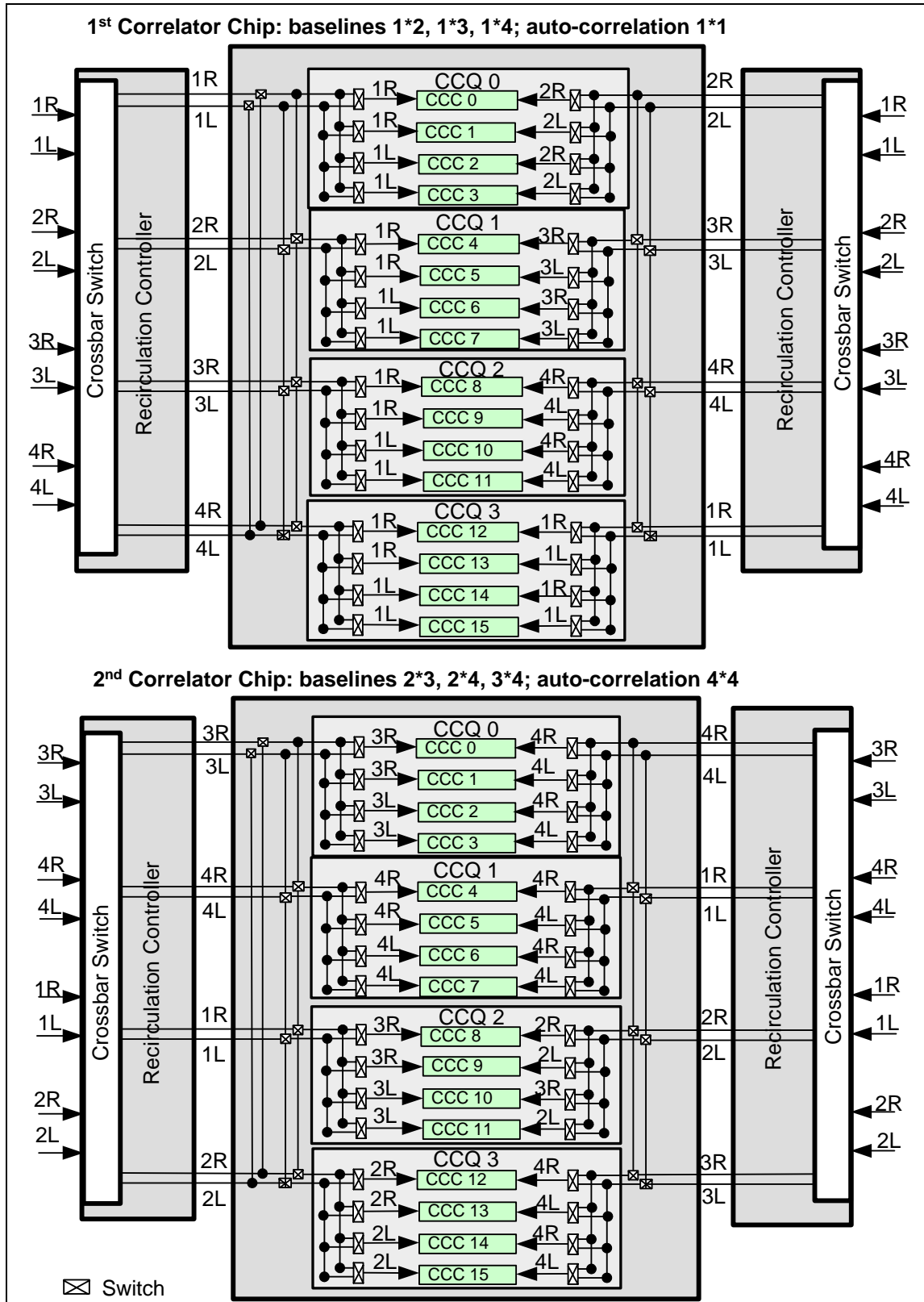
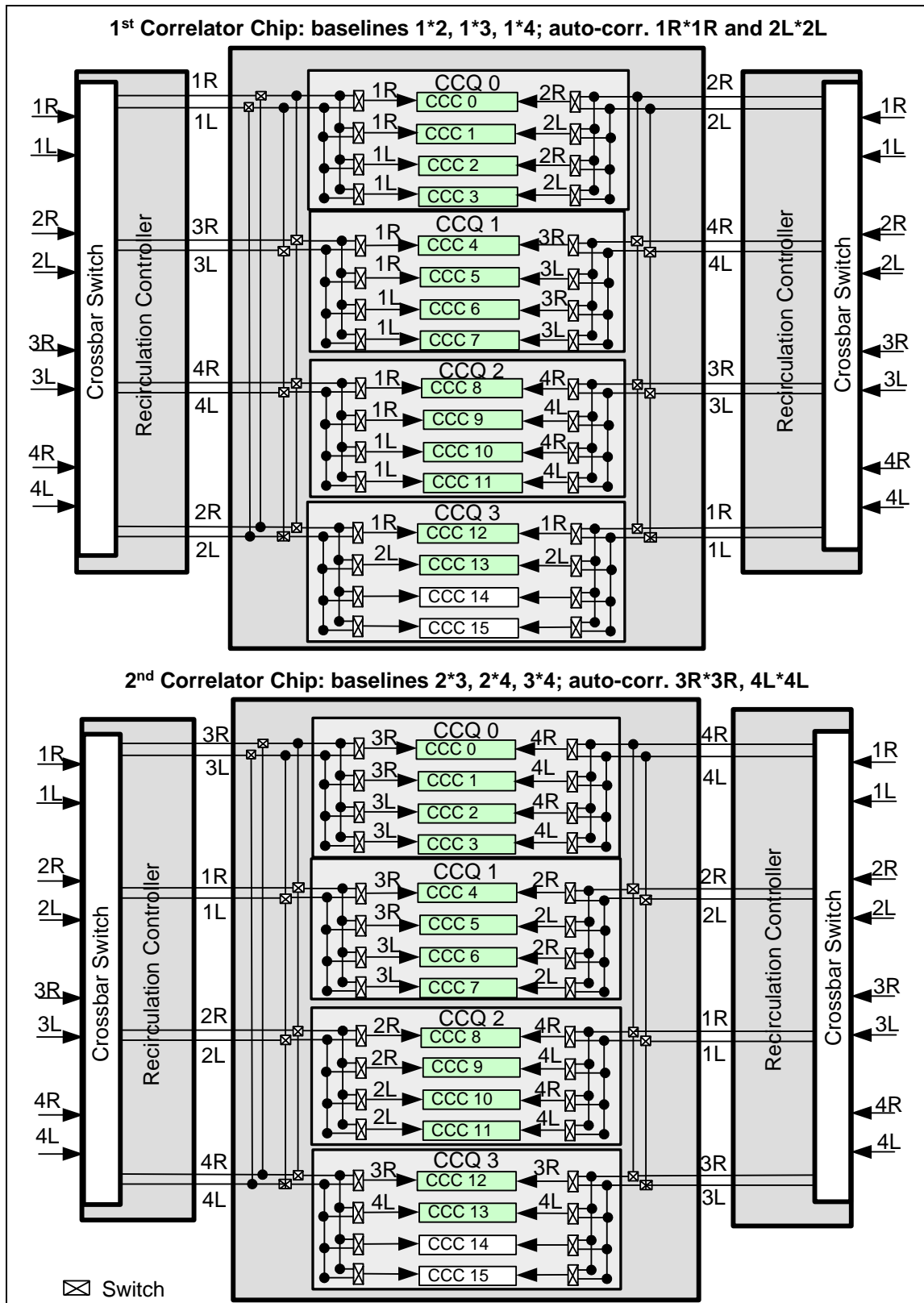


Figure 7 Baseline Board diagonal, 1 auto-correlation product per station, 4-bit correlation



## 7-Bit Correlation

Examples in this section apply for all the 8IQ/7RQ (8-bit initial quantization, 7-bit re-quantization) modes specified in Memo 28[1].

**Figure 8** shows detailed configuration of the upper left corner of two Baseline Boards that perform 7-bit correlation. The diagram shows only 4 Correlator Chips on each board; remaining six rows and six columns are configured in the same fashion.

Two Baseline Board data streams are used to carry higher (H) and lower (L) nibble of each 7-bit data stream<sup>1</sup>. 4 input data streams are used for one subband of one Baseband pair. The X and Y input of the Correlator Chip each have 8 data streams, therefore, in 7-bit mode, a Correlator Chip can receive data from up to 4 stations.

As shown in **Figure 8**, 4 Correlator Chips that receive input data from the same group of 4 stations perform all cross-correlations.

**Figure 9** is an example of a pair of Baseline Boards that are configured for 7-bit correlation. The diagram shows that two Baseline Boards can perform all cross-correlations for up to 16 stations. In addition, auto-correlation can be performed for each 7-bit input data stream.

**Figure 10** shows the configuration for two Correlator Chips on the diagonal that receive input from stations 1 and 2. These two Correlator Chips can be configured to obtain all the sub-products fro baseline 1\*2 and auto-correlation products for each 7-bit input stream, as follows:

$$1R*1R, 1L*1L, 2R*2R \text{ and } 2L*2L$$

If a subarray consists of less than 16 stations, unused rows and columns may be used to get more products (e.g.  $nR * nL$ , where n is the Station ID).

One  $CCQ^2$  is needed to obtain all sub-products for 7-bit correlation. **Figure 10** shows how the data streams are arranged in order to obtain all the products. For those who need a thorough understanding of the correlator architecture **Figure 11** shows detailed Correlator Chip configuration for the same inputs.

<sup>1</sup> There are 8 bits in 2 Baseline Board data streams; 7-bits are used for data, while the 8<sup>th</sup> bit is used to indicate whether or not input data is valid.

<sup>2</sup> Correlator Chip Quad consists of 4 Correlator Chip Cells (CCCs)

**Figure 8 Baseline Board: 7-bit correlation mode (detail)**

1<sup>st</sup> Baseline Board

	1HL 1LL	2HR 2LR 2HL 2LL	1HR 1LL	3HL 3LL	4HR 4LR 4HL 4LL	3HR 3LL
1HR 1LR	1L * 1L			1R * 3L		
2HL 2LL	1L * 2L			1R * 3R		
2HR 2LR	1L * 2R			1R * 4R		
1HL 1LL	1R * 1R			1R * 4L		
3HR 3LR	1L * 3R			3L * 3L		
4HL 4LL	1L * 3L			4L * 3L		
4HR 4LR	1L * 4R			4R * 3L		
3HL 3LL	1L * 4L			3R * 3R		

2<sup>nd</sup> Baseline Board

	2HL 2LL	1HR 1LR 1HL 1LL	2HR 2LL	4HL 4LL	3HR 3LR 3HL 3LL	4HR 4LL
2HR 2LR	2L * 2L			2R * 3L		
1HL 1LL	1R * 2R			2R * 3R		
1HR 1LR	1R * 2L			2R * 4R		
2HL 2LL	2R * 2R			2R * 4L		
4HR 4LR	2L * 3R			4L * 4L		
3HL 3LL	2L * 3L			3R * 4R		
3HR 3LR	2L * 4R			3R * 4L		
4HL 4LL	2L * 4L			4R * 4R		

Figure 9 1 Subarray, 16 Stations, 7-bit correlation

1 Subarray, 16 stations, 7-bit correlation: All cross-correlation products and auto-correlation for each 7-bit input.

1 <sup>st</sup> Baseline Board				2 <sup>nd</sup> Baseline Board			
1	2	3	4	1	2	3	4
1	1L*1L 1L*2R 1L*4R 1R*1R	1R*3R 1R*3L 1R*4R 1R*4L	3L*3L 3L*4R 3L*6R 3R*3R	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
2	1L*2R 1L*4R 1R*1R	1R*3L 1R*4R 1R*4L	3L*4R 3L*6R 3R*3R	1R*5L 1R*6R 1R*6L	3R*5L 3R*6R 3R*6L	5L*6R 5L*6L 5R*5R	5R*7L 5R*8R 5R*8L
3	1L*3R 1L*4L 1L*6L	3L*3L 3L*4R 3L*6R 3R*3R	3L*3L 3L*4R 3L*6R 3R*3R	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
4	1L*4R 1R*1R 1R*4L	1R*3R 1R*3L 1R*4R 1R*4L	3L*3R 3L*4R 3L*6R 3R*3R	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
5	1L*5R 1L*6R 1L*6L	3L*5R 3L*6R 3L*6L	3L*5R 3L*6R 3L*6L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
6	1L*6R 1L*6L	3L*6R 3L*6L	3L*6R 3L*6L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
7	1L*7R 1L*8R 1L*8L	3L*7R 3L*8R 3L*8L	3L*7R 3L*8R 3L*8L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
8	1L*8R 1L*8L	3L*8R 3L*8L	3L*8R 3L*8L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
9	1L*9R 1L*10R 1L*10R	3L*9R 3L*10R 3L*10R	3L*9R 3L*10R 3L*10R	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
10	1L*10R 1L*10R	3L*10R 3L*10R	3L*10R 3L*10R	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
11	1L*11R 1L*12R 1L*12L	3L*11R 3L*12R 3L*12L	3L*11R 3L*12R 3L*12L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
12	1L*12R 1L*12L	3L*12R 3L*12L	3L*12R 3L*12L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
13	1L*13R 1L*14R 1L*14L	3L*13R 3L*14R 3L*14L	3L*13R 3L*14R 3L*14L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
14	1L*14R 1L*14L	3L*14R 3L*14L	3L*14R 3L*14L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
15	1L*15R 1L*16R 1L*16L	3L*15R 3L*16R 3L*16L	3L*15R 3L*16R 3L*16L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L
16	1L*16R 1L*16L	3L*16R 3L*16L	3L*16R 3L*16L	1R*5R 1R*5L 1R*6R 1R*6L	3R*5R 3R*5L 3R*6R 3R*6L	5L*5L 5L*6R 5L*6L 5R*5R	5R*7R 5R*7L 5R*8R 5R*8L

Correlator Chip: X and Y inputs are from the same stations  
 Correlator Chip: input from stations 1,2,3 and 4



Figure 10 Baseline Board diagonal, 7-bit correlation

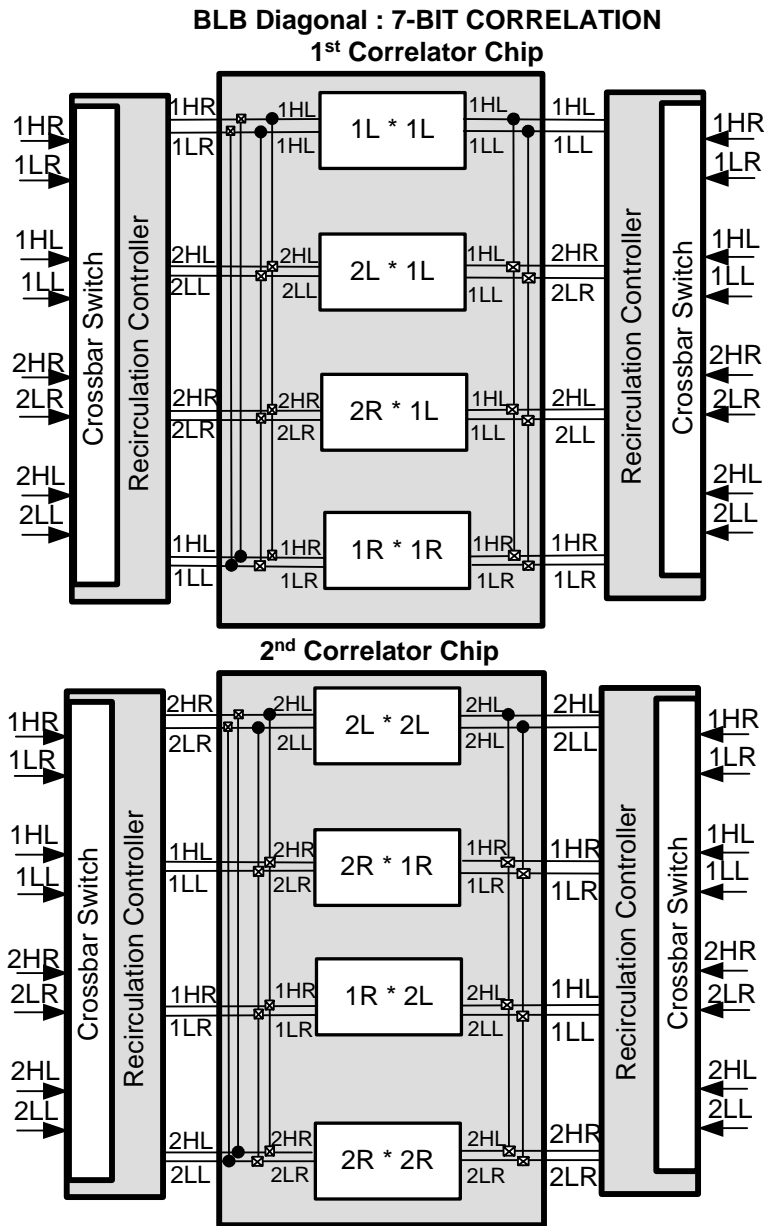
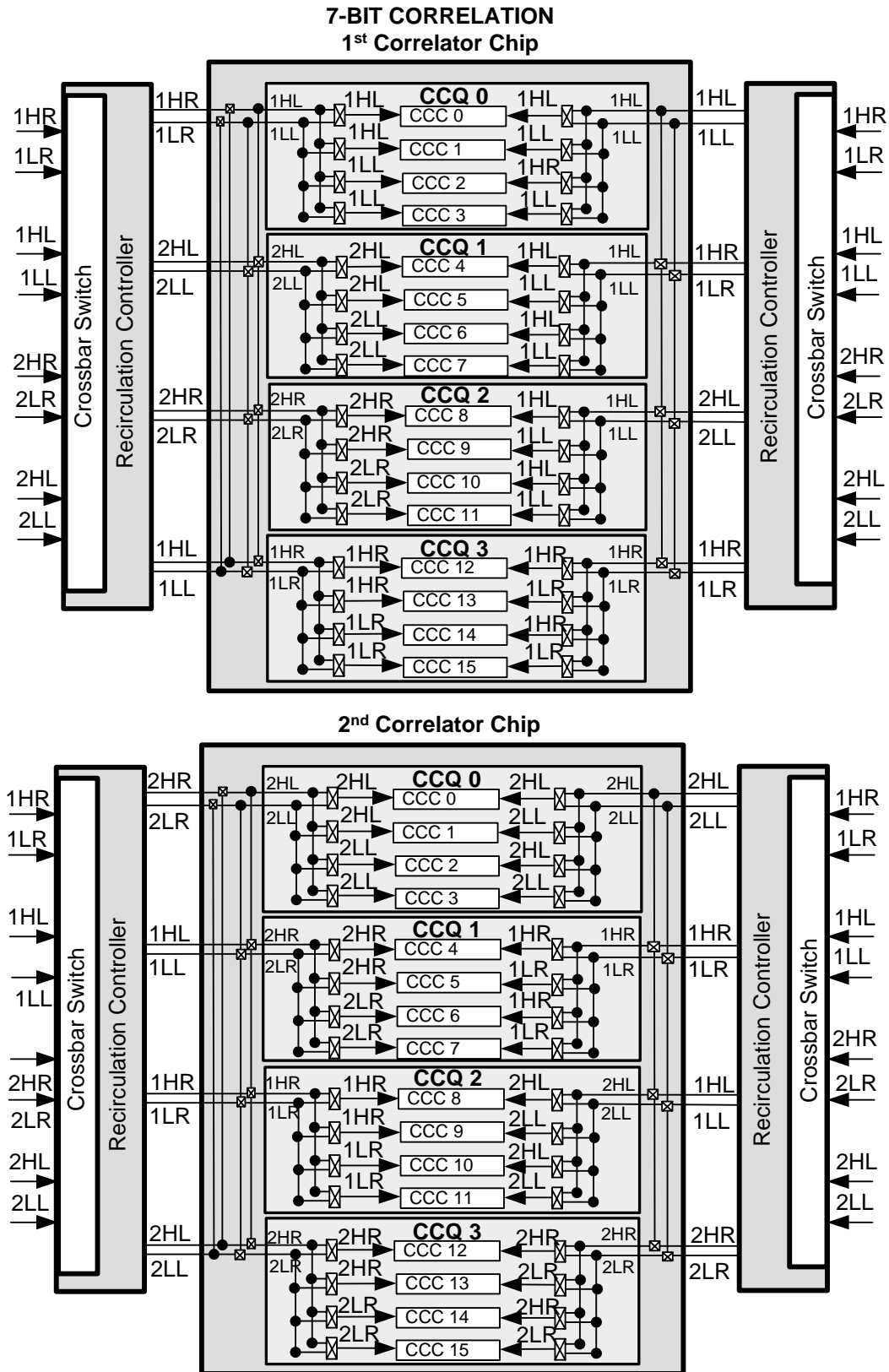


Figure 11 Baseline Board diagonal, 7-bit correlation (detail)



## Subarrays

The section provides examples of the configuration with more than one subarray.

**Figure 12** and **Figure 13** show Baseline Boards configured for the same 3 subarrays:

1. Black subarray has 10 stations
2. Blue subarray has 9 stations, and
3. Red subarray has 8 stations.

Mode: 3IQ/4RQ mode (3-bit initial quantization, 4-bit re-quantization).

**Figure 12** is an example of the Baseline Board configuration for the case when dumps are harmonically related for all 3 subarrays (i.e. the minimum hardware integration time is common for all). In this case, the subarrays can share the same rows/columns on the Baseline Board.

**Figure 13** is an example of configuration in the case when dumps are not harmonically related and subarrays cannot share rows and columns of the Baseline Board.

The exact configuration and the number of auto-correlation products depend on the number of stations in each of the subarray, and will be determined for each configuration individually.

**Figure 14** shows Baseline Board configuration for 2 subarrays that have total of 27 stations. Subarrays shown in this diagram were not configured at the same time.

The “black” subarray in **Figure 14** was configured first. It has 16 stations; 4 columns and 4 rows on each Baseline Board are needed to perform all cross-correlations. Since the rest of the Baseline Board was not used at the time when configuration was received, additional row and column on each Baseline Board are used to obtain all the auto-correlation products.

The “blue” subarray was added later. As can be seen from the diagram, there are no spare rows and columns that could be used to obtain all the auto-correlation products for the second subarray.

Figure 12 Three subarrays, dumps are harmonically related, 4-bit correlation mode

3 Subarrays - all real-time, dump timing is synchronized to system timing, dumps are harmonically related  
 Black: 1 - 10 (10 stations): all cross and auto correlations  
 Blue: 11 - 19 (9 stations): all cross and auto correlations  
 Red: 20 - 27 (8 stations): all cross and auto correlations

1 <sup>st</sup> Baseline Board				2 <sup>nd</sup> Baseline Board			
2 3 4 1	6 7 8 5	10 11 12 9	14 15 16 13	18 19 20 17	22 23 24 21	26 27 25 22	2 3 6 7
1 1*1	1*5	1*9					
2 1*2	1*6	1*10					
3 1*3	1*7						
4 1*4	1*8						
5 2*5	5*5	5*9					
6 2*6	5*6	5*10					
7 2*7	5*7						
8 2*8	5*8						
9 2*9	6*9	9*9					
11 2*10	6*10	9*10					
12 2*10	6*10	10*10					
13 13*13			13*13				
14 13*14			13*14				
15 13*15			13*15				
16 13*16			13*16				
17 14*17			14*17	17*17			
18 14*18			14*18	17*18			
19 14*19			14*19	17*19			
20 18*18				18*18			
21 21*21					21*21	21*25	
22 21*22					21*22	21*26	
23 21*23					21*23	21*27	
24 21*24					21*24		
25 22*25					22*25	25*25	
26 22*26					22*26	25*26	
27 22*27					22*27	25*27	
2 22*22							2*2
3 3*3							3*3
6 6*6							6*6
7 7*7							7*7
3 2*3	3*5	3*9					
4 2*4	3*6	3*10					
1 3*4	3*7						
2 4*4	3*8						
7 4*5	6*7	7*9					
8 4*6	6*8	7*10					
5 4*7	7*8						
6 4*8	8*8						
11 4*9	8*9	11*11	11*13	11*17			
9 4*10	8*10	11*12	11*14	11*18			
10 4*10	8*10	12*12	11*15	11*19			
12 4*10	8*10		11*16				
15 12*13			14*15	15*17			
16 12*14			14*16	15*18			
13 12*15			15*16	15*19			
14 12*16			16*16				
19 12*17			16*17	18*19			
20 12*18			16*18	19*19			
17 12*19			16*19	20*20			
18 12*19							
23 20*21				20*21	22*23	23*25	
24 20*22				20*22	22*24	23*26	
21 20*23				20*23	23*24	23*27	
22 20*24				20*24	24*24		
26 20*25				20*25	24*25	26*26	
25 20*26				20*26	24*26	26*27	
23 20*27				20*27	24*27	27*27	
27 23*23							
14 14*14							14*14
15 15*15							15*15





## Conclusions

- 1) 4-bit correlation mode, 1 subarray:
  - a) full set of products (cross and auto-correlations) can be obtained for up to 26 stations,
  - b) for a subarray that has 26 to 32 stations the correlator can perform all cross-correlations and a subset of auto-correlations.
- 2) 7-bit correlation mode, 1 subarray:
  - a) for the maximum of 16 stations the correlator can perform all the cross-correlations and auto correlations for each 7-bit input stream (no  $nL * nR$  products).
- 3) For the configuration with more than one subarray, the number of auto-correlation products has to be determined for each case individually.

If needed, the observation preparation software and Configuration Mapper could allow user to specify

- 1) Whether to use additional rows and columns (if available) on the Baseline Board to perform the full set of auto-correlations,
- 2) If the full set of products cannot be obtained, the list of products.

## References

- [1] EVLA Memo 28, An Optimized Connectivity Scheme for the EVLA Correlator, Brent Carlson, DRAO, April 2007.

