Wideband High Resolution Autocorrelator

Configurations Using WIDAR Correlator Components

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ABSTRACT

The WIDAR correlator being developed for the EVLA and e-MERLIN telescopes consists of hardware elements that could be used in other telescope or signal processing applications. One such application is wideband autocorrelation with very high spectral resolution. With relatively little hardware it is possible to build a very high resolution autocorrelator which optimally uses correlator hardware, yielding a maximum of 512k spectral channels per sub-band spectrum. Multiple sub-band spectra can be obtained with replication of modules for each sub-band, and/or correlator resources can be dynamically allocated to sub-bands. The FIR filter on the Station Board, if it turns out to be feasible in an FPGA, can be re-configured to allow for sub-band overlap and elimination of aliasing at sub-band boundaries, at the expense of some dynamic range. In this case, it would be possible to obtain the seamless wideband autocorrelation spectrum across the wideband input. If one Station Board is used this means up to 16.5 million channels can be obtained across 4 GHz, yielding a 250 Hz resolution bandwidth.

Introduction

This memo will illustrate how WIDAR correlator components can be used to implement a very powerful, and relatively low cost wideband, high resolution autocorrelator system with potential applications in single-dish radio telescopes and perhaps commercial wideband spectrum analysis systems.

Baseline Board Autocorrelation Configuration

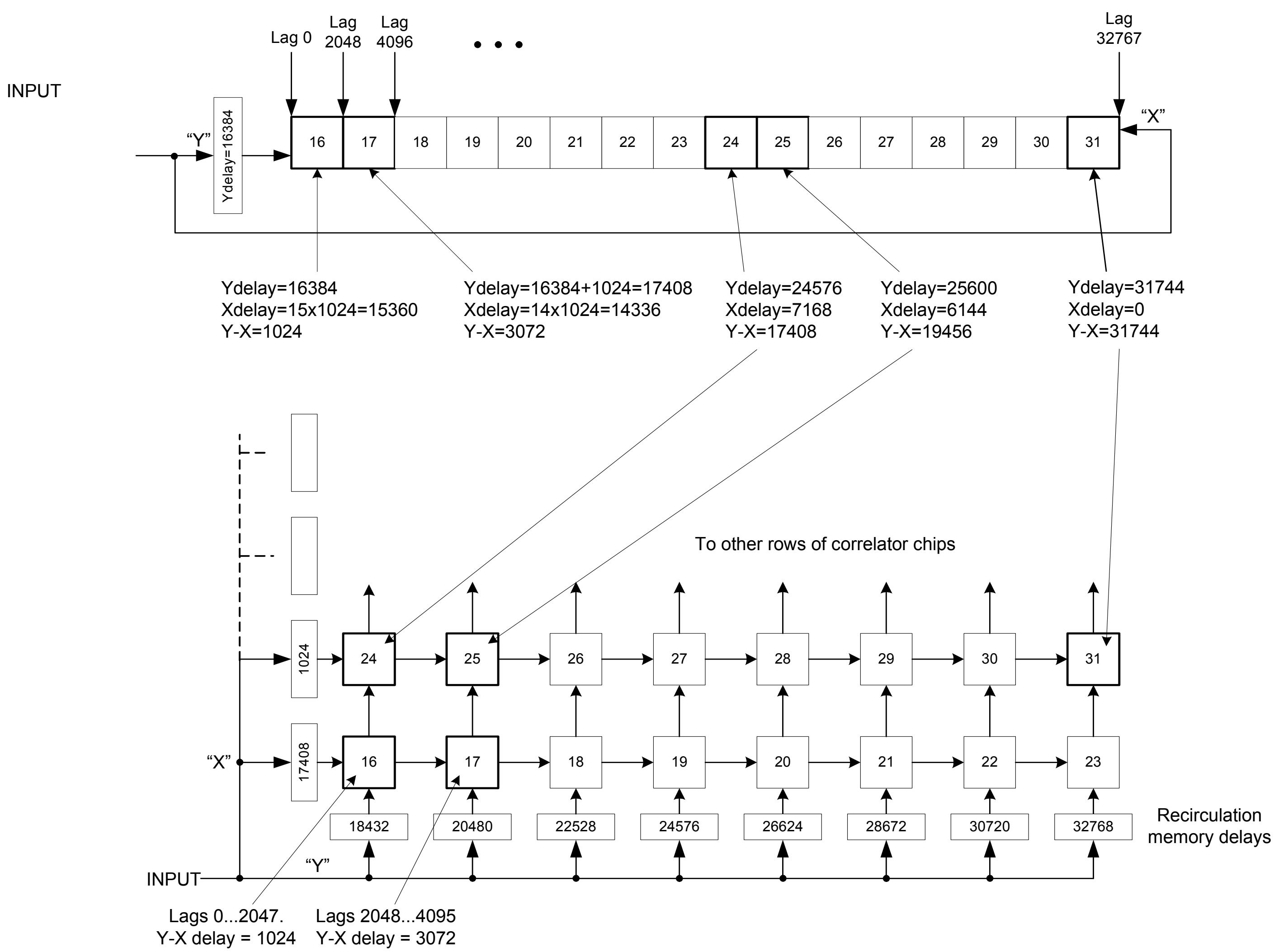
The Baseline Board can be configured to perform up to 4 autocorrelations, optimally utilizing all of the lags on all of the correlator chips on the board. There is a limit of 4 autocorrelations since each sampled data stream needs to experience delay using the Recirculation Controller's delay memory in "static delay mode", only 4 streams can be delayed, and each of those streams experiences the same delay.

A minor modification to the correlator chip[1] is required to allow any one of 4 input streams to use the entire correlator chip's lag resources.

[1] Implemented on October 15, 2004, as a result of this investigation.

In this configuration each autocorrelation yields 32768 lags or 32768 spectral channels. Note that with autocorrelations lags about the 0 lag are identical and so only the 32768 lags one side (say to the “right”) of lag 0 need be acquired. A diagram showing the basic lag block configuration, and associated Baseline Board recirculation delay memory configuration is shown in Figure 1. Refer to Figure 5-2 in [1] for an explanation of lag block numbering using recirculation.

Lag block configuration for 32768 lags (32768 channels)



Partial Baseline Board configuration for 32768 lags

Figure 1 Lag block configuration and partial Baseline Board configuration for 32768 lags. Four independent sampled data streams can be autocorrelated in this way, each yielding 32768 lags.

Note from Figure 1 that the maximum delay memory that is required for 32768 lags is 32768. With recirculation memory of 512k, it is thus possible to acquire a maximum of 512k lags per autocorrelation product by extending the process shown in the figure, although in this case the lags would be spread across 4 Baseline Boards. Note that each Baseline Board can correlate a total of 64x2048=131072 lags.

Figure 1 shows one INPUT (an input being up to 8 sampled data streams) fed to all 16 Recirculation Controllers. Although the Baseline Board does not have this capability, it is easily possible to do the equivalent by using one or more external fanout boards, also part of the correlator hardware developed for the EVLA and e-MERLIN. Synchronization circuitry in the Recirculation Controllers and the correlator chips ensures that all of the data is properly lined up inside the correlator chip before correlation.

With one Station Board and by using the configuration shown in Figure 1 it is possible to correlate all sub-bands on both 2 GHz basebands with 8 Baseline Boards yielding a total of 1 million spectral channels across 4 GHz. Of course, fewer Baseline Boards could be used for reduced bandwidth capability. (Fewer spectral channels can also be produced with more bandwidth, but in this case some correlator chips on the Baseline Board are not used.) Additionally, dynamic recirculation can be used on narrower sub-band bandwidths to yield a square increase in spectral resolution with decreasing bandwidth, or "wideband recirculation" can be used to increase the spectral resolution at the expense of reduced sensitivity.

Eight-bit autocorrelation, with ¼ the number of spectral channels as indicated above can be acquired by distributing correlations across correlator chips. In this case, one Baseline Board can acquire 32768 spectral channels on one 8-bit (actually 7-bit) sampled data stream.

Station Board Configuration

There is nothing unusual about the Station Board configuration for the autocorrelator except that it would be advantageous to autocorrelate sub-bands without sub-band transition band aliasing artifacts showing up in the output.

At the time of the writing of this memo, it is conceivable that the FIR filter will be implemented in an FPGA. If this does indeed turn out to be the case, then the filter could be re-configured to perform sub-band filtering with overlap, with the cost of reduced dynamic range to utilize wideband mixers in on-chip RAM [2]. In this case, the sub-bands are overlapped so that the aliasing regions can be discarded with no holes in bandwidth coverage, and only a small loss of total bandwidth.

With this change in the FIR filter configuration, it will be possible to acquire the seamless wideband autocorrelation spectrum, with the number of channels indicated in the previous section.

References

[1] Carlson, Brent, REQUIREMENTS AND FUNCTIONAL SPECIFICATION: Recirculation Controller FPGA, RFS Document: A25090N0000, Revision 2.2, September 10, 2004.

[2] Comoretto, G., A digital BBC for the ALMA interferometer, Osservatorio di Arcetri, April 26, 2000.