4-Gsps 2-bit FX Correlator with 262144-point FFT

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ABSTRACT

We developed a 4-Gsps 2-bit test FX Correlator with 262144-point FFT for the pre-prototype of the high-dispersion ALMA correlator. This test FX correlator has a 15.625-kHz frequency resolution and 131072 channels over the 2-GHz bandwidth.

INTRODUCTION

Toward the ultimate synthesis radio telescope at submillimeter and millimeter wavelengths, the design and development phase of Atacama large submillimeter/millimeter Array (ALMA) is now underway as a collaboration between Europe and North America, and Japan will join in this effort. The ALMA correlator with highest spectral resolution of 5 kHz and maximum bandwidth of 2 GHz bandwidth per one IF band is recommended by the ALMA Scientific Advisory Committee (ASAC). We, thus, propose a high-performance FX correlator system which always realizes both super-high spectral-resolution (<0.1 km/s at 40 GHz) and wideband (> 700 km/s at 850 GHz) observations simultaneously up to 850 GHz for each 2-GHz baseband (IF) of the ALMA system [1]. The realization of the Fourier-transform circuits with the frequency resolving points of 524288 (= 512 x 1024) over 2-GHz bandwidth is necessary for our proposed FX correlator.

We developed a 4-Gsps 2-bit test FX Correlator with 262144 points FFT for the pre-prototype of the high-dispersion ALMA correlator. In this paper, we present the key features of test FX correlator.

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A 4-Gsps 2-bit test FX Correlator developed for the high-dispersion ALMA correlator is shown in Fig.1. It consists of two F-parts and one X-part, and calculates one cross-correlation spectrum or one auto-correlation spectrum of 131072 (= 128 x 1024) frequency channels.

The input to the test FX correlator is 2 bit 64 parallel ECL data at 64 MHz clock, and the signal is processed as follows (Fig.2). (1) First, the input data are put into the delay compensation buffer up to 19 km. We are able to control it in both the usual delay tracking and wave-front clock modes. (2) The data after delay tracking is expanded to 9 bit in the 262144(= 256 x 1024)-point FFT part in which the calculation is made with fixed point 18-bit expression (real part 9 bits and imaginary part 9 bits including a sign bit). In addition, the bit expansion function has memory to suppress the strong spurious and DC bias. (3) Following the FFT, 90-degree phase demodulation, delta W correction and re-quantization are proceeded for 16 sets of the spectral data. The number of bits of the complex data is reduced from 9 bits to 3, 4 or 5 bits with re-quantization. Then, the data are sent to the X-part and the complex correlation is calculated with 3, 4 or 5 bits. To study the performance of re-quantization, we can select the re-quantized and correlated number of bits, 3-, 4- or 5-bit complex. (4) Finally, 180-degree phase demodulation is performed, and the data are integrated to 0.512-67.1 sec.

Using the test FX Correlator, we can investigate quantization and re-quantization issues beleaguered in digital signal processing, and confirm a performance of inverse convolution correction to avoid the over-flow in FFT operation with finite-bit length by the strong spurious and DC bias. Moreover, we can measure the

sampling jitter of 4-Gsps 2-bit Analog-to-Digital Converter [2] for the estimation of coherence loss due to the Flicker-frequency noise. Also, the astronomical high performance and results of the test FX Correlator have been reported in [3].

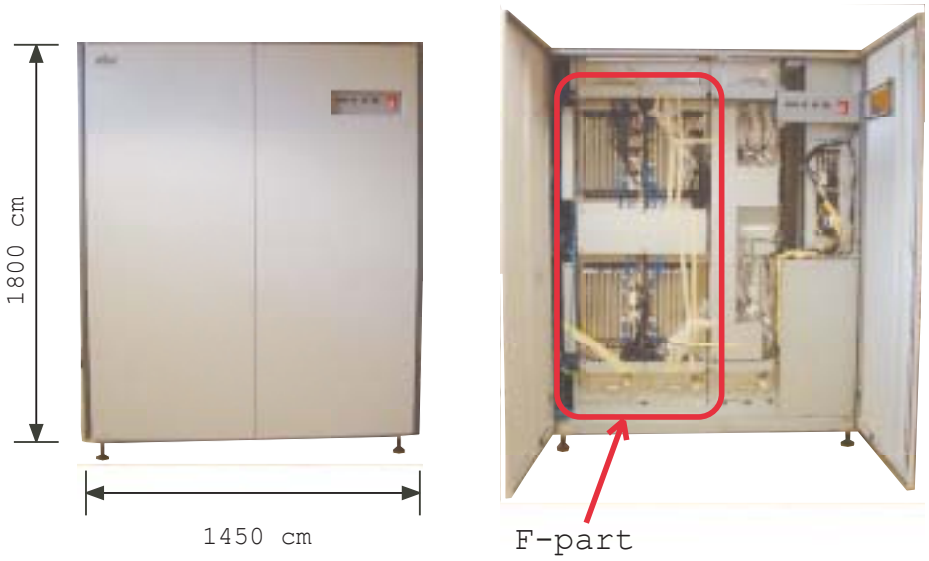

Figure 1: 4-Gsps 2-bit FX Correlator with 262144-point FFT

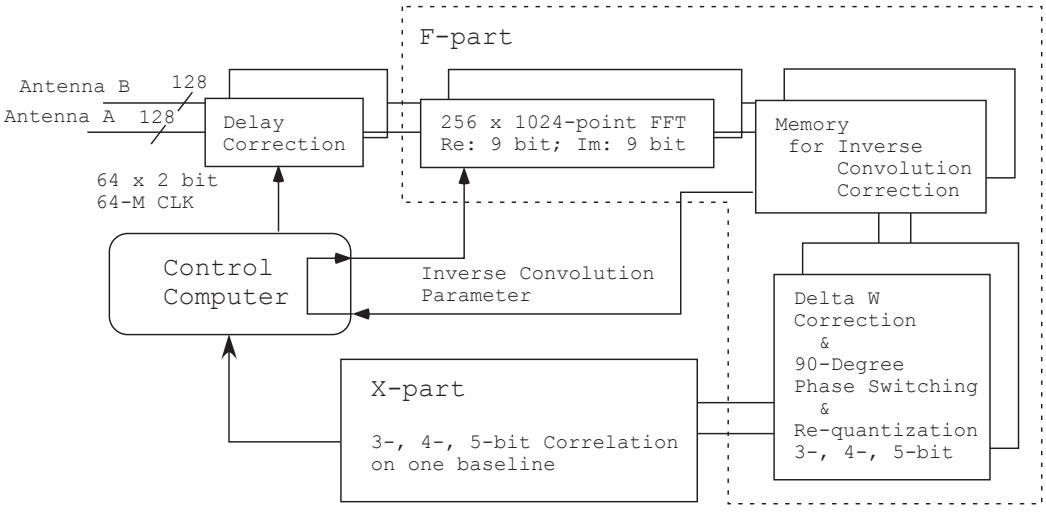

Figure 2: Test FX Correlator Architecture

262144-point FFT

The key feature for FX-type correlator is F-part. The 262144-point FFT is divided into two sets of 512x512-point FFT and the multiplication of 512 x 512 twiddle factors (Fig.3). The 64-parallel input data are converted to 32 sets of input data for Radix-2 512-point FFT, and 262144-point FFT is performed with parallel processing.

Fig.3 shows that the FFT LSI has the bit length of 12 bits, while its input and output are 9 bits, and more, the twiddle factors are represented by 9 bit.

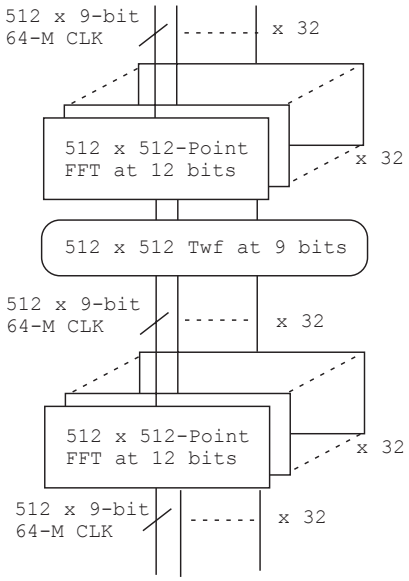

Figure 3: 262144-point FFT Architecture

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