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Design and evaluation of multi-bit-input single-flux-quantum autocorrelator system for astronomical data analysis

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In radio astronomy, a superconductor-insulator-superconductor (SIS) mixer are used to detect millimeter and sub-millimeter waves from the universe. For efficient observation, increasing in the viewing angle by integration of multiple SIS mixers into one refrigerator is important. However, because the amplifier that is placed in the low temperature stage and transmits signal to room-temperature electronics is required for each mixer, total power consumption increases. Therefore, the number of SIS mixers integrated into one refrigerator is limited. To solve this problem, integration of a single-flux-quantum (SFQ) analog-to-digital converter (ADC) and an autocorrelator into the low-temperature stage is promising. Because the SFQ ADC has high-sensitivity, the low-temperature amplifiers could be removed. Moreover, total power consumption of the system can be drastically reduced by employing the SFQ ADC and the SFQ autocorrelator that can operate at several GHz with ultra-low power consumption. In this study, as a prototype of the system, we designed and evaluated the performances of the SFQ ADC that converts the SIS output signal to 2-bit digital data, the SFQ autocorrelator that supports 2-bit signal inputs, and the SFQ binary counter that can be used as an integrator. All circuit components were designed and implemented using the AIST 10 kA/cm^2 Nb advanced process 2 (ADP2). The autocorrelator was designed using many exclusive-OR gates, the implementation cost of which is small compared to that of the CMOS circuit. The number of the Josephson junction of the autocorrelator, and the counter are 1322, and 169, respectively. The experimental results of the designed circuits will be presented.

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