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Room-Temperature Readout Electronics for the ECHo-100k Experiment

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Recent advances in the development of cryogenic particle detectors, such as the magnetic microcalorimeter (MMC), allow the fabrication of sensor arrays with an increasing number of pixels, enabling measurements with unprecedented energy resolution. Since these detectors must be operated at the lowest temperatures, the readout of large detector arrays is still quite challenging due to strict limits regarding the number of signal lines interfacing the cryostat and the maximum readout power. This is especially true for the ECHo experiment, which aims to simultaneously run 6,000 two-pixel detectors to further narrow down the upper limit of the electron neutrino mass. The system has 400 two-pixel detectors connected to a common readout line via a microwave SQUID multiplexer (μMUX). For the operation of the cold electronics and to perform online data elaboration, we developed a room-temperature readout system using a software-defined radio (SDR) scheme. The SDR readout electronics follow a modular approach with three distinct hardware units: a digital data processing board using a Xilinx ZynqUS+ MPSoC; a converter board featuring DACs and ADCs with a coherent clock distribution network; and a radio frequency front-end board to translate the signals between the baseband and the microwave domains. In this contribution, we present the overall system architecture as well as the individual stages of the data processing chain. Subsequently, we show the performance and characterization results of the full-scale SDR system. The generated frequency comb for driving the μMUX resonators was evaluated regarding signal-to-noise ratio (SNR) and spurious free dynamic range (SFDR). Additionally, the crosstalk and amplitude noise of each individual channel, after frequency demultiplexing, were investigated by operating the SDR in direct loopback mode. Overall, the performance of the full-scale SDR system showcased its capability to reliably read and process the massively parallel detector array data.

Poster prize

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