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Real-time Signal Processing and Data Acquisition for the Electric Field Detector (EFD-02) on the CSES-02 satellite

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The Electric Field Detector (EFD-02) on board of the second China Seismo-Electromagnetic Satellite (CSES-02) will measure the ionospheric electric field components at a Low Earth Orbit (LEO) over a wide frequency band (DC - 3.75 MHz) and with less than 1 \muV/m/\sqrt{Hz} sensitivity. EFD-02 will measure the voltage differences between pairs of probes installed at the tips of four booms deployed from the satellite. In this work we describe the digital hardware section based on a Zynq SoC device in charge of signal processing and data acquisition and we show the instrument overall performances.

Summary (500 words)

The China Seismo-Electromagnetic Satellite (CSES) program is meant to monitor dynamic perturbations of top-side electromagnetic field, plasma and particles of the Earth's ionosphere to study their possible correlations with the occurrence of seismic events. Another major goal of the mission is the investigation of the interaction between the solar wind and magnetosphere-ionosphere system. The CSES-02 mission foresees the launch of a second satellite, scheduled by the end of 2023, with an expected lifetime of 6 years.
Aboard of CSES-02 there will be the Electric Field Detector (EFD), that measures the differences in electric potential (with respect to the spacecraft potential) between different pairs of probes mounted at the tips of 4 booms deployed at 4.5 m from the satellite. Electric field components are obtained as the difference between two probes voltages divided by their relative distance (8.3 m on average).
Regarding the instrument specifications, EFD-02 band range will cover from DC to 3.5 MHz, with a typical resolution ≤1 \muV/m (DC-16 Hz). Signal acquisition is realized in five bands defined as follows: ULF band in the range from 0 to 100 Hz, with dynamic range of 144 dB; ELF band up to 2 kHz with a dynamic range of 120 dB; VLF band up to 30 kHz with a dynamic range of 96 dB; VLFe up to 100 kHz with a dynamic range of 96 dB; HF in the range of 21 kHz to 3.75 MHz with a dynamic range of 72 dB. There are 4 different ULF channels, each one deriving from the 4 probes, while there are 3 channels for ELF, VLF, VLFe and HF bands, deriving from 3 analog signal differences between programmable pairs of the 4 probes. The measured sensitivity of the instrument is less than 0.1 \muV/m/\sqrt{Hz}.
The instrument is composed of several parts, such as the Electric Field Probes, that are 4 identical sensors housing a spherical shell placed at the end of the satellite boom; the Low Voltage Power Supply and Control, that manages power supply, housekeeping and TM/TC interface towards the satellite; the Splitter, that controls the switching of signals and power supply lines of the probes between the hot and cold electronics; the Analog Processing Unit, that makes the analog-to-digital conversion and pre-filtering of the signals; the Digital Processing Unit (DPU) that performs digital processing and data handling. The architecture of the DPU will be described, in particular the Programmable Logic part implemented in a Zynq SoC device, that is in charge of signal filtering, frequency band division, Fourier transform, statistical functions calculation and, finally, data scheduling and formatting according to the 82 Gbit/day payload requirement.
Regarding the statistical functions, we perform real-time calculation of average, standard deviation and kurtosis of spectral data on VLF, VLFe and HF bands with a streaming pipelined architecture, implemented both

in fixed point and in floating point arithmetics. The results and comparison of these two implementations will be shown.

Authors: PARMENTIER, Alexandra (Tor Vergata University of Rome); RUSSI, Andrea (INAF-IAPS); DE SANTIS, Cristian (Universita degli Studi di Roma Tor Vergata (IT)); BADONI, Davide (INFN Sezione di Roma Tor Vergata); ALUNNO CAMELIA, Elio (NEAT SRL); FIORENZA, Emiliano (INAF-IAPS); DE ANGELIS, Fabrizio (INAF-IAPS); NUCCILLI, Fabrizio (INAF-IAPS); REBUSTINI, GIammaria (INFN Roma Tor Vergata); MASCIANTONIO, Giuseppe (INFN Roma Tor Vergata); BERTELLI, Igor (INAF-IAPS); VERTOLLI, Nello (INAF-IAPS); PICOZZA, Piergiorgio (INFN and University of Rome Tor Vergata); CIPOLLONE, Piero (INFN Roma Tor Vergata); DIEGO, Piero (INAF-IAPS); UBERTINI, Pietro; SPARVOLI, Roberta; AMMENDOLA, Roberto (INFN e Universita Roma Tor Vergata (IT))

Presenters: REBUSTINI, GIammaria (INFN Roma Tor Vergata); REBUSTINI, Gianmaria (INFN Rome "Tor Vergata")

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