Paper ID: 10307
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EARTH OBSERVATION SYMPOSIUM (B1)
Earth Observation Sensors and Technology (3)

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SPACEBORN SCALAR MAGNETOMETERS FOR EARTH'S FIELD STUDIES

Abstract

Although the evolution of the Earth's magnetic field has been recorded for decades or even centuries in ground-based observatories, these measurements are very sparsely and unevenly distributed on the globe's surface. As a consequence, these data sets are not sufficient to establish accurate global field models. To mitigate that problem, they have been completed by numerous additional snapshot surveys accumulated over the years, carried out either on aircrafts or ships. The situation has however radically evolved with the emergence in the late 1950's of satellites, which offer the possibility to obtain a global coverage in a relatively short period. While the first magnetometer was flown on Sputnik 3 in 1958, high resolution vector measurements were obtained only with Magsat in 1980. Since then, the standard payload of Earth magnetic mapping satellites combines both scalar and vector magnetometers: the scalar sensor provides the absolute reference to calibrate the vector instrument in flight, which is then basically operated as a variometer. In this paper we present two generations of scalar magnetometers developed by LETI in collaboration with CNES for Earth observation space missions: first the Overhauser magnetometers based on Nuclear Magnetic Resonance, flown with success respectively on the Oersted (operating since 1999) and Champ (2000-2010) satellites, and second the helium magnetometer integrated on the three Swarm ESA satellites to be launched in 2012. Their respective design constraints and main characteristics are analyzed in view of the scalar performances requirements, which directly derive from the missions scientific objectives. A focus is made on their heading errors since the spatial anisotropy directly affects the instruments' accuracy, and the issues related to the long term stability, which is mandatory for the magnetic field's secular variation studies, are also reviewed in detail. Apart from enhanced metrological performances, the helium magnetometer also implements a dedicated architecture thanks to which continuous vector measurements are derived. This intrinsically scalar instrument hence delivers simultaneously absolute measurements of both the intensity and the direction of the ambient magnetic field. The operation principles are presented and results of its calibration process and the subsequent performances in terms of vector precision and accuracy are analyzed. Finally, mid term outlooks are described: they essentially consist in the miniaturization of the helium magnetometer and evolutions of the sensor mode of operation to allow its exploitation at very low fields, making it suitable for future planetary exploration missions.