The LETI / CNES Absolute Scalar Magnetometer for Swarm

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After the successful delivery of absolute scalar magnetometers relying on the Overhauser Nuclear Magnetic Resonance technology for the Earth magnetic field mapping missions Oersted and Champ, LETI has abandoned this technology by the end of the 90's to the profit of a technique based on optical pumping of helium to develop high performance magnetometers. While it also makes use of the Zeeman effect to realize a field to frequency transducer and presents many similarities to NMR sensors, helium 4 magnetometers exhibit several features that make them well suited for high resolution scalar measurements in general and for space applications in particular.

First of all, their reduced susceptibility to magnetic gradients -due to the broader resonance lines- and to radiated H fields in the low frequency range (typically between several tens of Hz up to several kHz) -Overhauser magnetometer pick-up coils act as very efficient receivers in this frequency band which also corresponds to its operating range, while the helium sensor is much more robust to such fields by design- make them much easier to operate even in standard laboratory conditions. As a consequence, instrument health checks during satellite integration and tests for instance do not systematically imply operations in a magnetically clean environment.

Now, as for the instrument performances, the main advantages are twofold: on the one hand, the magnetometer resolution is improved but of even more importance it does not depend on the magnetic field magnitude as it is the case for NMR magnetometers. This means practically that operation at low fields (for Swarm typically of the order of 20 μT) is no more a challenge. On the other hand the helium magnetometer bandwidth is also several orders of magnitude higher than for LETI's Overhauser sensors (several hundreds of Hz as compared to 0,2-0,3 Hz).

This combination of a high resolution (# 1 pT/√Hz) and high bandwidth opens the way for the implementation of an original architecture for which absolute scalar and vector measurements are continuously delivered by the same instrument: 3 low frequency AC magnetic fields are applied along mutually orthogonal directions to the helium cell. Under such conditions, the measured scalar field corresponds to the superposition of the ambient Earth field and these 3 artificial field modulations. Simple deconvolution operations of the resulting scalar measurement provide then simultaneously a direct estimation of the magnetic field projections on the three modulation directions in addition to the static field determination.

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