

The Swarm Absolute Scalar Magnetometer

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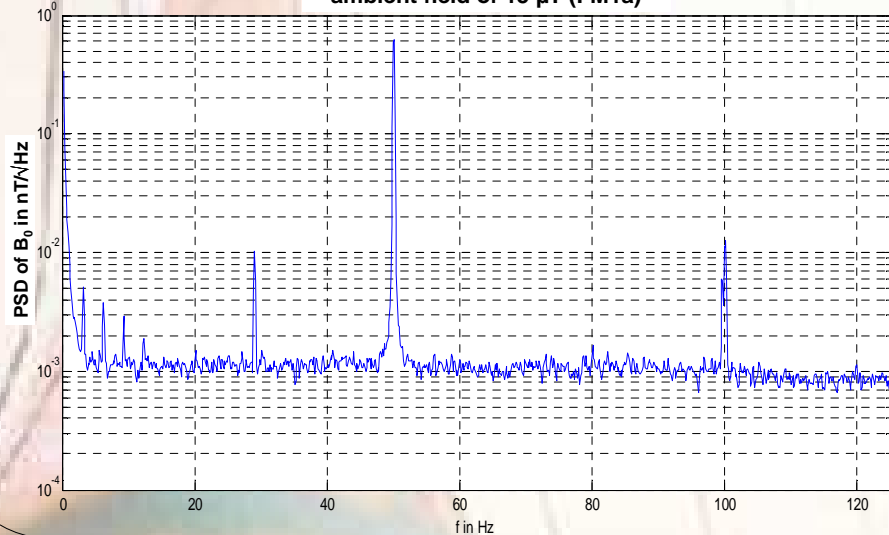


ASM MAIN MISSION

As the magnetic reference of the ESA Swarm mission, ASM shall provide **absolute measurements of the Earth's magnetic field strength**, with **unequaled performances**, independent of the field modulus, the spatial position and orientation :

- Measurement range: [15 μ T - 65 μ T],
- Scalar bandwidth / sampling rate :
 - Standard mode: [0 - 0,4 Hz] / 1 Hz
 - Burst mode : [0 - 100 Hz] / 250 Hz
 - for ambient noise level measurement
 - may also have a scientific interest ?
- Scalar resolution / precision :
 - **Resolution < 1 pT/ $\sqrt{\text{Hz}}$** [DC-100 Hz] demonstrated over the [15 μ T - 65 μ T] range
 - **Precision < 1 pT** ($F_s = 1 \text{ Hz}$, $BW = 0,4 \text{ Hz} \Rightarrow \sigma = R * \sqrt{BW} < 1 \text{ pT}$)
- Scalar accuracy :
 - The internal ASM accuracy error sources have been accurately characterized
 - Maximum accuracy error after correction : **$\sigma_{\text{max}} : 65 \text{ pT}$**
- Stability :
 - Better than 25 pT over 15 days, demonstrated at Chambon-La-Forêt (IPGP)

PSD of B_0 in the [0-125 Hz] band,
ambient field of 15 μ T (FM1a)



ASM SIDE MISSION

On an **experimental basis**, ASM shall provide **absolute measurements of the Earth's magnetic field direction**, the nominal Swarm vector data being delivered by the VFM.

→ **unique instrument in providing simultaneous absolute scalar & vector measurements at the same point**

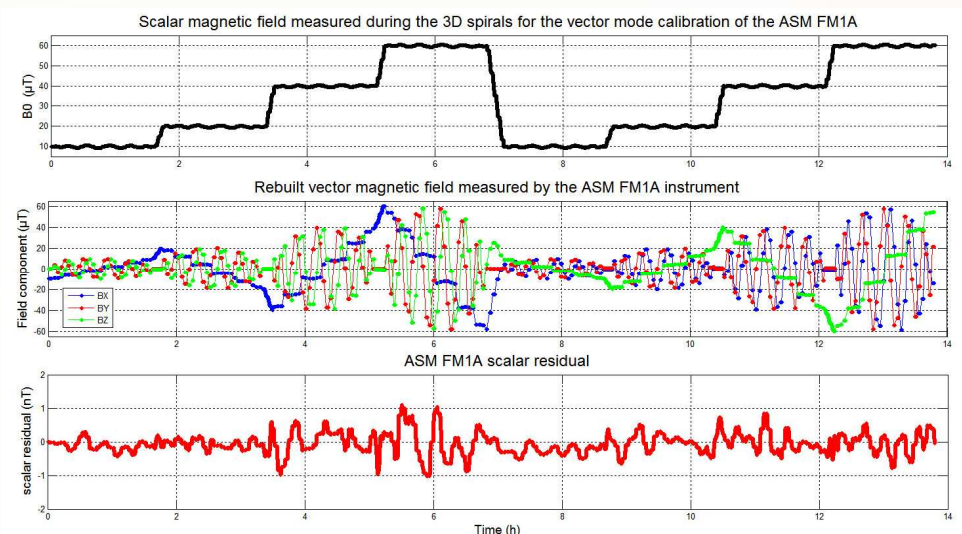
→ **auto calibration, permanent quality assessment, stability, no offsets nor drifts**

Performances (inversely proportional to the field modulus) :

- Measurement range : $\pm 65 \mu\text{T}$
- Sampling rate : 1 Hz
- Bandwidth : [DC- 0,4 Hz]
- Resolution : **< 1 nT/√Hz at 40 μ T**
- Absolute accuracy **$\leq 1 \text{ nT}$ (2 σ) at 40 μ T**

Proven concept on ground, performance to be validated in flight (will depend on the background noise). Swarm will offer a unique opportunity to validate the ASM vector data in orbit by comparing them with the VFM's, thus opening the way for a **potential in-space cross calibration**.

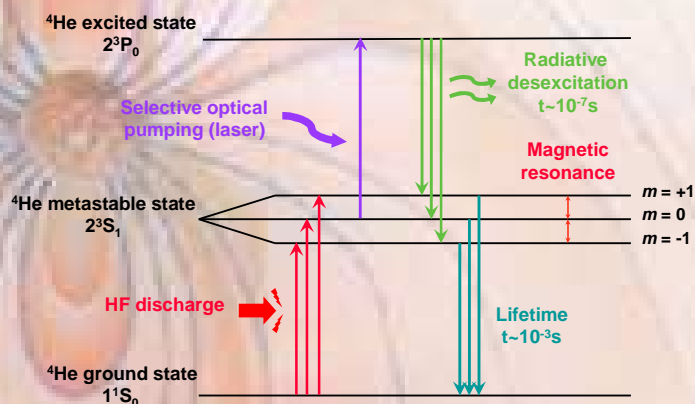
Vector calibration process and results



PHYSICAL PRINCIPLE (SCALAR MEASUREMENT)

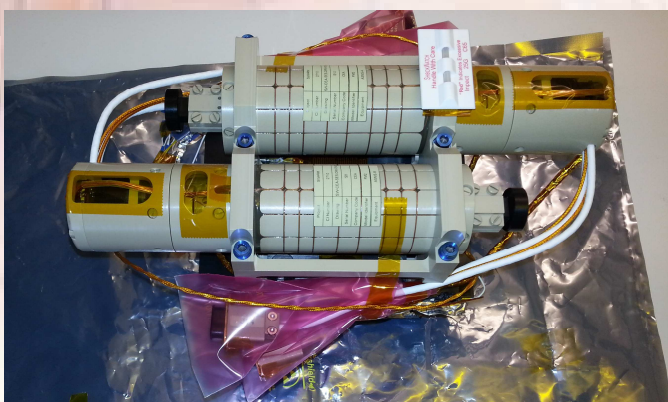
ASM is a **magnetic field to frequency converter** based on atomic spectroscopy of the ^4He in its metastable level 2^3S_1 . The magnetic field modulus B_0 is directly proportional to the magnetometer's resonance frequency F (Zeeman effect) :

$$B_0 = F / \gamma^4\text{He}, \text{ with } \gamma^4\text{He} / 2\pi \approx 28 \text{ GHz} / \text{T}$$



SENSOR'S ISOTROPIC DESIGN

A non magnetic sensor including the ^4He cell, based on an isotropic design with a static and a rotating part, optimal resonance conditions controlled by a piezoelectric motor : no dead zones.



PHYSICAL PRINCIPLE (VECTOR MEASUREMENT)

Innovative concept based on the scalar architecture using 3 orthogonal coils: **superposition of 3 AC low frequency modulations** (amplitude $\sim 50 \text{ nT}$) on the static field B_0 , along 3 orthogonal directions. A real time analysis of the resulting scalar measurement, with simple deconvolution operations, provide then simultaneously a direct estimation of the magnetic field projections on the three modulation directions in addition to the static field determination.

$$\|\vec{B}_{\text{tot}}\| = \left\| \vec{B}_0 + \sum_{i=x,y,z} \vec{b}_{mi} \cos(\Omega_i t) \right\|$$

STATUS

6 ASM instruments are integrated on the 3 Swarm satellites (full cold redundancy), which are **ready for shipment to the launch site**.

The launch from Plessetsk with a Rockot launcher is due by the end of 2013.

ASM level 1B products will be validated during the first months following the launch, in close partnership between CNES, CEA-Leti and IPGP.

Want to learn more ?
<http://swarm-mission.cnes.fr>