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Design, Calibration and Testing of Precise Magnetometers

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Abstract

The requirements for precise global mapping of the Earth's vector magnetic field from a LEO satellite are discussed.

Introduction

The Earth's magnetic field has been precisely mapped from space, first by NASA's Magsat Mission in 1979-1980 [1] and 20 years later, as part of the IAGA International Decade of Geopotential Field Research [2], by the Danish Ørsted Mission (1999 -) [3], the German CHAMP Geopotentials Mission (2000 -) [4] and by Ørsted-2, the Danish MMP (Magnetic Mapping Payload) onboard the Argentine-US SAC-C Earth observation satellite (2000 -) [5]. Several missions are under study for continuing the International Decade of Geopotential Field Research; such as ESA's SWARM Mission and others.

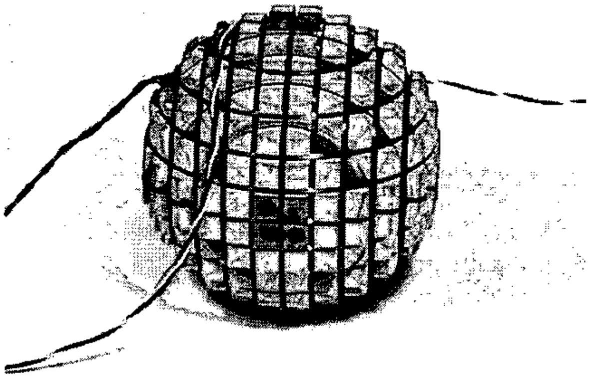

Figure 1. The Oersted·DTU/DSRI CSC Compact Spherical Coil tri-axial vector feedback sensor.

Precise Magnetic Vector Field Measurements from Space

Magnetic field determination in space requires a combination of vector data, attitude, position and time. Three instruments provide this: a high-precision vector magnetometer, an absolute attitude determination system in term of a star camera and a GPS receiver. In addition, a precision attitude transfer system between the star camera and the vector magnetometer must be provided, and an absolute scalar magnetometer is needed for in-flight calibration of the vector magnetometer offsets, scale values, etc. The Danish CSC tri-axial vector-feedback magnetometer [6] (see Fig. 1) has performed the magnetic vector-field mapping task on the recent missions together with the Danish Advanced Stellar Compass system.

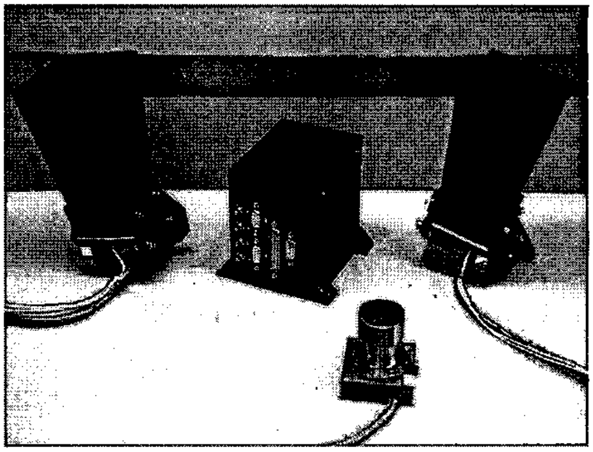

Figure 2. The Oersted·DTU µ-ASC Micro Advanced Stellar Compass system.

The Oersted·DTU Micro Advanced Stellar Compass [7] (see Fig. 2) successfully provides absolute arc sec inertial attitude on eight missions and will fly on ten more in near future. For in-orbit vector magnetometer

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calibration, a scalar field data rate of only about one per minute or less is required [8], and of all the nuclear and electron spin resonance magnetometers the omni-directional toroid-sensor Proton Free Precession magnetometer [9] (see Fig. 3) is the simplest, the closest to being absolute and the most resource effective at low data rates. The local satellite magnetic environment is equally important as a high quality of the instruments. A well-designed field-mapping mission requires careful compromises between the sensors' boom deployment length, spacecraft ac/dc magnetic cleanliness and arc sec-level stability of the mechanical attitude transfer between the star camera and the vector magnetometer sensor. Pre-flight (and in-flight) instrument calibrations and inter-calibrations [10] need to be carefully planned and performed, and the accuracy of the overall absolute timing and the relative timing between the instruments is of equally vital importance for the success of the data analysis.

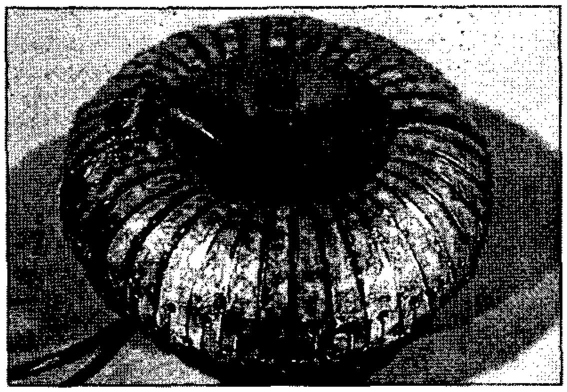

Figure 3. The Oersted-DTU/DSRI Toroidal omni-directional Proton Free Precession scalar sensor.

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