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MEMS-based gradiometer for the complete characterization of Martian magnetic environment

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The in-situ determination of the Martian magnetic field is one of the most important and ambitious objectives in Mars exploration, because its implications in paleomagnetism, tectonics and mineral determination.

To place sensors on Mars is a complicated task, due to the extreme conditions of the planet surface and also because of the relative low budget devoted to this kind of instrument: low power, mass, volume and the need to operate in a magnetically noise environment.

A complete and accurate measurement of the magnetic environment includes the determination of both magnitude and gradient of the magnetic field (B). There are many developments of magnetometers with the characteristics mentioned before [2], but the question about gradient is not that well solved and most gradient sensors are based on a couple of magnetometers separated a certain distance [2, 3].

The aim of this abstract is to introduce a new MEMS based robust gradiometer for the point measurement of the field gradient with the ultimate goal to perform in situ measurement on Mars and shed some light in the magnetic anomalies explanation of the Red Planet.

Since in some conditions$\nabla \times \bar{\mathrm{B}} = 0$, we assume knowing six of the nine components is sufficient to reconstruct entirely the magnetic field gradient. The device proposed consists of a set of six cantilevers to measure these six components (with resolution in the order of 1 nT/mm) combined either with another miniaturized and more accurate magnetometer (with resolution below the nT) for the measurement of the field vector.

Every component system consists of a cantilever with an appropriate geometry, an excitation coil and a mechanism to generate a field gradient. The cantilevers are made of piezoelectric material (bimorph, with two piezoelectric layers) covered by a soft ferromagnetic material (of Iron-Nickel base). Is explained below the working principle for one component.

When the excitation system generates an alternating magnetic field (enough to saturate) along the width of the cantilever, the ferromagnetic material is alternatively saturated in both directions along the cantilever's width.

Under the presence of a magnetic field gradient in the normal direction to the plane of the cantilever, the ferromagnetic material experiments a force, making the cantilever vibrate. This vibration generates an electric signal, given that when the cantilever vibrates, the piezoelectric layers stretches and contracts, so it sets a voltage difference.

The current system with dimensions in the order of mm is run at its resonant frequency. In the presence of an external magnetic field gradient, the vibration frequency changes. The external gradient can be easily measured by means of the measurement of the frequency shift.

References:

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