Ultra-sensitive magnetic field sensor for space applications

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PhD may follow: Yes

Summary :

Magnetic sensors for space flight are highly sensitive inductive sensors but they are cumbersome and heavy (150g/axis) which impacts the launching cost. Since many years, research has been performed in order to reduce the sensor size and mass. However no further progress is expected on this line without a definite change of paradigm. The solution could be spintronic devices provided they could present the proper sensitivity. Our aim is therefore to develop a magnetic sensor which will combine an innovative architecture with a low-noise magnetoresistive element based on a phenomenon we recently discovered. The experimental work will be : i)the microfabrication of the device; ii) measurement of the electrical noise. The device composition will be optimized depending on the obtained results.

Full description :

The aim of this project is to manufacture a magnetic sensor that could be a serious competitor, in term of sensitivity, to those currently shipped onboard the space missions, with a weight reduction of at least two orders of magnitude. Up to now, magnetic field sensor used for space missions are inductive magnetic sensors that have a very high sensitivity, up to few tenths of fT. Nevertheless, this very good sensitivity is achieved at the cost of large size and mass (150g per axis), markedly increasing the launching cost. Solutions to reduce the sensor mass has been systematically tested for years but no further improvement can now be obtained without a change of paradigm. Using nano-devices from spin electronics integrated on silicon would allow a significant progress in the size and mass reduction of vectorial magnetic sensors provided they could have the required sensitivity.

Our aim is to develop an ultra-sensitive magnetic sensor that combines an innovative architecture and a low noise magnetoresistive element. It will include a magnetic circuit, a biasing coil and a tunnel junction, made with thin film technology, an electronic circuit in ASIC technology and a feed back coil made with a micro winding process, the latter responsible for the sensor high performance in terms of linearity and stability. The sensor high sensitivity is obtained by a strong amplification (>300) of the measured magnetic field thanks to a magnetic circuit acting as a flux concentrator, and by using magnetic tunnel junctions with high magnetoresistive ratio.

The originality of the proposed sensor lies in a differential and heterodyne detection combined with a feed-back.

In fact, none of the nano-devices sensitive to the magnetic field (from the Hall sensors to the magneto-resistances or magneto-impedances) exhibits today the expected sensitivity, due to a large 1/f noise that spreads up to 100kHz. Therefore the magnetic field to be measured is modulated by an ac biasing field, so that the measurement is translated in the vicinity of the biasing frequency where the noise is low.

The innovative and ambitious features of the proposed solution should allow to develop a sensor able to detect
magnetic fields as low as 100fT/Hz1/2 in the frequency range below 10kHz, which corresponds to a sensitivity three orders of magnitude larger than the best magnetoresistive sensors currently available. Furthermore, a large reduction in size increases the sensor spatial resolution which extends the scope of applications towards the medical sector, biotechnologies or non destructive control for example.

Requested skills :

solid state physics