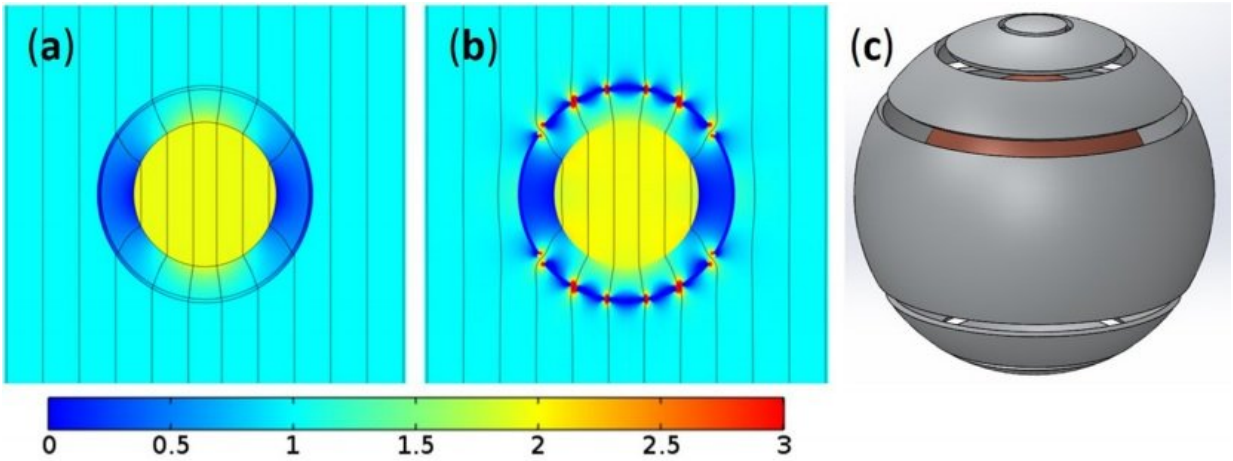
Invisible magnetic sensors measure magnetic fields without disturbing them

April 25 2018, by Lisa Zyga



Simulation of a spherical shell that cancels the distortions caused by a ferromagnetic sphere, making the sphere invisible (magnetically undetectable) from the outside. Credit: Mach-Batlle et al. ©2018 American Institute of Physics

Currently, most of the magnetic sensors used in today's computers, airplanes, cars, and other systems distort the magnetic fields that they are measuring. These distortions can cause major problems for some applications, in particular biomedical techniques, that require highly accurate measurements, and can also cause cross-talk in sensor arrays.

In a new study, researchers have designed "invisible" magnetic sensors—sensors that are magnetically invisible so that they can still

detect but do not distort the surrounding magnetic fields. The researchers, Rosa Mach-Batlle, Carles Navau, and Alvaro Sanchez at the Autonomous University of Barcelona, have published a paper on the invisible magnetic sensors in a recent issue of *Applied Physics Letters*.

"This is the first proposal to render a magnetic sensor invisible," Mach-Batlle told *Phys.org*. "The invisibility can even be made exact in some cases, something never achieved before, to our knowledge."

Many magnetic sensors are made of ferromagnetic materials, which have the advantage of enhanced sensor detectability compared to other materials. However, the downside of ferromagnetic materials is that they attract magnetic fields, causing distortions in the same magnetic fields that the sensors are detecting.

The challenging part of making invisible magnetic sensors is to simultaneously cancel these distortions while still allowing the sensors to detect the magnetic fields. Previously, researchers have designed magnetic cloaks for cloaking magnetic objects that make it impossible to magnetically detect them from the outside. However, these cloaks work both ways, so that the cloaked magnetic objects are completely isolated from and unable to detect any external magnetic fields. So a cloaked sensor could no longer function as a sensor.

In the new study, the researchers have proposed a method for making a sensor magnetically invisible while maintaining its ability to sense. Their strategy uses a spherical magnetic shell that cancels out the leading term of the distortion that the sensor creates in response to external magnetic fields. The shell is also designed with tiny "air gaps" that allow a fraction of the external magnetic field to arrive at the sensor. Theoretically, the invisibility can be made perfect under certain conditions—specifically, when the sensor is spherical and the magnetic field is uniform.

According to the researchers' model, the proposed spherical shell must be made of a material with certain properties (in particular, a precise diamagnetic permeability) that do not exist in nature. Nevertheless, the researchers expect that these properties can be emulated with metamaterials made of high-temperature superconductors. In the future, the researchers plan to further explore these possibilities as well as variations on magnetic cloaking.

"We are developing ideas such as exploring cloaking properties for AC fields or incorporating the intriguing concept of negative static permeability for creating novel shapes of magnetic fields," Sanchez said.

More information: Rosa Mach-Batlle, Carles Navau, and Alvaro Sanchez. "Invisible magnetic sensors." *Applied Physics Letters*. DOI: 10.1063/1.5023565

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