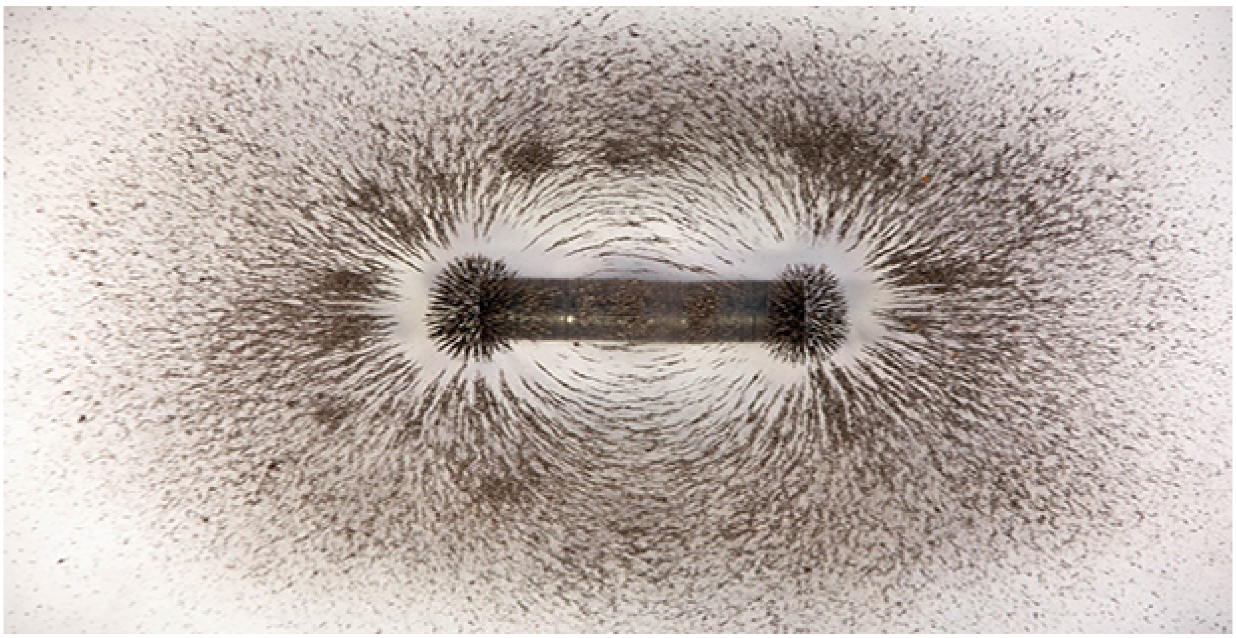
Boosting the ability to detect superweak magnetic fields

March 21 2017



An iconic visualization of otherwise invisible magnetic field lines associated with a bar magnet hints of the far weaker biology-based magnetic fields from hearts and brains that DARPA's new AMBIIENT program aims to measure with unprecedented ease. Credit: DARPA

Each beat of your heart or burst of brain activity relies on tiny electrophysiological currents that generate minuscule ripples in the surrounding magnetic field. These field variations provide the basis for a range of research tools and diagnostic techniques with mouthful names like magnetoencephalography (MEG) and magnetocardiography (MCG). But tapping into biology's faint magnetic fields requires heroic and costly measures, including high-tech shields to block the larger, potentially confounding magnetic forces all around us and boutique magnetic field sensors that require expensive and cumbersome liquid helium cooling.

DARPA's new Atomic Magnetometer for Biological Imaging In Earth's Native Terrain (AMBIIENT) program is all about ushering magnetic field sensing into a new era in which MEGs, MCGs, and an assortment of other wish-list magnetic field sensing techniques become practical realities for a wide range of applications. Potentially on the horizon, for example, are sensor systems for detecting spinal signals, diagnosing concussions, and brain-machine interfaces (BMIs) for such uses as controlling prosthetic limbs and external machines via the subtle magnetic signals associated with thought.

A few elephants in the room have been preventing biomagnetic field sensing from extending beyond its current limitations. Planet Earth has been the biggest buzz kill. Its average magnetic field is 50 millionths of a Tesla, a unit of magnetic field strength named after the mid-19th and early-20th century inventor Nikola Tesla. This means that Earth's magnetic field is a million to a billion times stronger than the 10 picoTesla (10^{-11} Tesla) to 10 femtoTesla (10^{-14} Tesla) magnetic fields emanating from human bodies. On top of that, even today's leading-edge magnetic field sensors—based, for example, on Superconducting Quantum Interference Devices (SQUIDs)—suffer from a limited dynamic range, which means they are unable to respond reliably in the presence of magnetic field strengths that span many orders of magnitude, as is the case when biological magnetic fields superimpose upon Earth's own magnetism. Without intense shielding, those magnetic whispers from biology would be lost amidst the blaring din of Earth's magnetism, even with the best available sensors in play.

"Traditionally, measuring small magnetic signals in ambient environments has relied on pairs of high-performance sensors separated by a baseline distance and then measuring the small field-strength differences between the two sensors," said Robert Lutwak, AMBIIENT's program manager in DARPA's Microsystems Technology Office. "This gradiometric technique has worked well for applications in geophysical surveying and unexploded ordnance detection," Lutwak added, "but due to the combination of the sensors' limited dynamic range and the natural spatial variation of the background signals, this approach falls several orders of magnitude short of being able to detect biological magnetic signals."

The AMBIIENT program is challenging the research community to devise new types of magnetic gradiometers that can detect picoTesla- and femtoTesla magnetic signatures out in the open, without shielding and with whatever the ambient magnetic field environment might be. To do so will require researchers to, in Lutwak's words, "exploit novel atomic physics techniques and architectures to directly measure extremely tiny gradients in magnetic fields without having to compare the difference between absolute field measurements from two sensors separated along a baseline." One physics-based approach AMBIIENT performers are likely to pursue is to monitor changes in the polarization or other measureable features of a small laser beam as it passes through vapor cells hosting atoms that respond in laser-beam-altering ways to even femtoTesla magnetic fields. Monitoring changes in the laser light's features would thereby open a novel and practical window on magnetic fields that were previously unmeasurable under ambient conditions. This opens up scenarios in which, say, a medic on a battlefield would be able to wield a wandlike sensor to quickly screen a warfighter for signs of concussion or other head trauma written in the brain's subtle magnetic fields

"High sensitivity magnetic sensing and imaging will offer a powerful new tool for medical research and clinical diagnosis of neurological and cardiac activity," said Lutwak. "DARPA's goal is to end up with the capability of high-sensitivity magnetic sensing in a low-cost device that can operate in common environments." He also envisions some uncommon extensions of magnetic field sensing, including magnetic navigation (MagNav) as a backup, alternative, or supplement to GPS-based navigation. Equipped with the sort of sensors that could emerge from the AMBIIENT program, for example, an aircraft coasting at airliner altitudes might be able to keep track of the naturally varying and well-mapped magnetic field variations at the Earth's surface for determining its over-ground location within about 250 meters.

Provided by DARPA

Citation: Boosting the ability to detect superweak magnetic fields (2017, March 21) retrieved 3 July 2024 from https://phys.org/news/2017-03-boosting-ability-superweak-magnetic-fields.html