that in some cases, the EPR signal may be strong enough to be detectable even in the absence of prepolarization.

This work was done by Inseob Hahn, Peter Day, Konstantin Penanen, and Byeong Ho Eom of Caltech and Mark Cohen of UCLA Center for Cognitive Neuroscience for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-44656, volume and number of this NASA Tech Briefs *issue, and the page number.*

Reducing Field Distortion in Magnetic Resonance Imaging

An unconventional magnetic-field configuration would be used in SQUID MRI.

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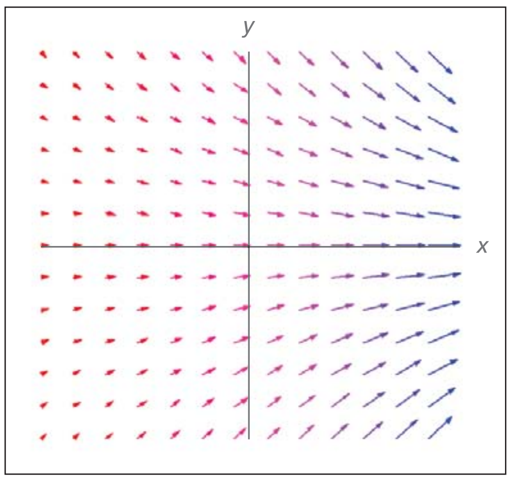
A concept for a magnetic resonance imaging (MRI) system that would utilize a relatively weak magnetic field provides for several design features that differ significantly from the corresponding features of conventional MRI systems. Notable among these features are a magnetic-field configuration that reduces (relative to the conventional configuration) distortion and blurring of the image, the use of a superconducting quantum interference device (SQUID) magnetometer as the detector, and an imaging procedure suited for the unconventional field configuration and sensor.

In a typical application of MRI, a radio-frequency pulse is used to excite precession of the magnetic moments of protons in an applied magnetic field, and the decaying precession is detected for a short time following the pulse. The precession occurs at a resonance frequency proportional to the strengths of the magnetic field and the proton magnetic moment. The magnetic field is configured to vary with position in a known way; hence, by virtue of the aforesaid proportionality, the resonance frequency varies with position in a known way. In other words, position is encoded as resonance frequency.

MRI using magnetic fields weaker than those of conventional MRI offers several advantages, including cheaper and smaller equipment, greater compatibility with metallic objects, and higher image quality because of low susceptibility distortion and enhanced spin-lattice-relaxation-time contrast. SQUID MRI is being developed into a practical MRI method for applied magnetic flux densities of the order of only 100 μT.

In conventional MRI, it is required that all of the magnetic moments precess around the same axis defined by an applied static, homogeneous magnetic field. One of the problems in developing low-magnetic-field-strength MRI arises from the relationship among image resolution, image-acquisition time, and the gradient of the magnetic field. In general, the resolution (that is, the reciprocal of the smallest size of an image feature that can be resolved) is proportional to the strength of the magnetic-field gradient and the image-acquisition time. Because of fundamental properties of a magnetic field, an image-position-encoding gradient necessarily entails undesired concomitant field components proportional to the image-position-encoding gradient. These components are undesired because they cause distortion or blurring of the image. The distortion can be reduced by weakening the gradient so that the total field variation in the magnetic field is a small fraction of the static homogeneous field. However, in weakening the gradient, one must either accept lower resolution or else increase image-acquisition time to retain resolution.



Field Configuration is shown in *x,y* plane.

According to the present concept, it should be possible to reduce distortion to a very low (in principle, negligible) level while using a low-strength magnetic field, without sacrificing resolution and without need for excessively long image-acquisition time. There would be no applied static, homogeneous field because in MRI, it is not required that all the magnetic moments precess about the same axis. The encoding magnetic field, **B**, would be configured to lie in the *x,y* plane of *x,y,z* Cartesian coordinate system: the field would be given by

$$\mathbf{B} = B_0 e^{x/a}[\hat{x}\cos(y/a) - \hat{y}\sin(y/a)]$$

where $\hat{x}$ and $\hat{y}$ are unit vectors along the *x* and *y* axes and B_0 and a are arbitrary constants to be chosen by design (see figure). Inasmuch as the strength of this field is given by $|\mathbf{B}| = B_0 e^{x/a}$, this field would encode position along the *x* axis as a function of resonance frequency. Although *x* would be a nonlinear (specifically, a logarithmic) function of resonance frequency, it would be possible, through suitable choice of the arbitrary constants, to reduce the deviation from linearity and the concomitant spatial variation of resolution over the image region to tolerable levels.

A close approximation of the magnetic field described above could be generated by electric currents flowing axially on a *z*-oriented circular cylinder having a length much greater than its radius. The current density (K) needed to generate the magnetic field is a known continuous function of the azimuthal angle (θ). In practice, the required continuous current density $K(\theta)$ would be approximated by use of multiple discrete wires positioned at suitable angular intervals and driven by suitable currents. To encode position along an axis at an angle α with respect to the *x* axis in the *x,y* plane so that back projection reconstruction could be used, one would shift the current-density pattern by electronically changing the pattern of drive currents to make it approximate $K(\theta + \alpha)$.

In SQUID MRI, the magnetic moments are prepolarized in a strong magnetic field separate from the encoding field. In a system according to the present concept, the prepolarizing magnetic field would be oriented along the z axis. The prepolarizing magnetic would then be turned off so rapidly that immediately afterward, the magnetic moments would remain polarized and would start to precess about the x,y-oriented encoding magnetic field. The sensing loop of the SQUID magnetometer would be placed to detect the z component of magnetization.

This work was done by Byeong Ho Eom, Konstantin Penanen, and Inseob Hahn of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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