to the B_x field. A near-DC response of the magnetometer is still proportional to B_y. In a proof demonstrating this capability, the first and second modulations were applied at different frequencies at the same time. It was found that the magnetometer successfully measured simultaneously all 3 components of the magnetic field with just a single detector using appropriate frequency-dependent signal resolution.

Using this capability a 3-D map of all 3 components of the magnetic field with femtotesla sensitivity and a spatial resolution of several mm is obtained. In this way it is believed that the imaging capabilities of the human MEG magnetometer can approach that of magnetic resonance imaging (MRI).

Example 9

Spatial Resolution of Magnetic Field Sources

The accuracy of source localization was modeled using a simple current dipole source. It was supposed that a current dipole to be measured in human MEG is located 2 cm below the surface of the head and that the edge of sensing cell begins 1 cm above the surface and is centered directly over the current dipole. A current dipole that produces a maximum field of 100 fT 1 cm above the surface of the head was employed. It was assumed that component of the magnetic field normal to the head is measured on a cubic 3-D array with 8 to 32 points on each side with an r.m.s. error of 1 fT. FIG. **13** shows the r.m.s. uncertainty in the position of the current dipole determined from a non-linear fit as a function of the number of measurement points and the grid spacing. As expected, for a larger number of measurement points the optimal grid spacing is predicted to be smaller. Diffusion limits the spatial resolution inside the magnetometer to about 0.2 cm. This spacing between adjacent channels gives near-optimal resolution of 0.02 mm for 16^3 measurement points.

For comparison, the same simulation for a typical SQUID arrangement was carried out, using about 250 magnetometers arranged around the surface of the head with inter-channel spacing of 2 cm. Assuming magnetic field noise of 5 fT rms, typical for commercial SQUID systems, localization resolution of 2 mm was obtained, in agreement with other similar simulations. Thus, an atomic magnetometer of the present invention provides a predicted improvement by a factor of 100 in localization accuracy over SQUID magnetometers, due both to the higher sensitivity and to the 3-dimentional arrangement of sensor points with small inter-channel spacing provided by the instant magnetometer.

Example 10

A Multiple Sensing Cell Magnetometer Useful in Human MEG

A magnetometer useful in human diagnostic MEG is constructed having a plurality of sensing cells disposed at different locations about subject. This arrangement contributes to localizing sources of magnetic fields whose position within the subject is not known.

Testing of the Magnetometer

The magnetometer is initially tested with non-biological field sources. All magnetometer channels is individually calibrated using known external fields. The spatial localization performance of the magnetometer is first investigated using a small current loop that generates an easily calculable magnetic dipolar field. An MEG phantom using a saline-filled sphere is also constructed to simulate a current-dipole source in the brain. Various gradiometer configurations and non-linear fitting methods are to be tested to improve localization accuracy. After the localization performance has been established with non-biological sources, experiments with human volunteers will be performed.

First the somatosensory cortex will be mapped, where highly organized and well-localized sources of neural activity can be accurately and reliably activated under well-controlled experimental conditions. A non-magnetic tactile stimulator is constructed using a Braille cell. Stimulus triggering is synchronized with data acquisition and pump beam scanning across the cell.

A subject is initially examined with functional magnetic resonance imaging to determine the regions of their brain that become active under particular type of stimulation. For MEG imaging the measurement cell is positioned directly above the active brain regions. The exact orientation of a subject's head is measured using small calibration coils attached to their head.

Many parameters of the magnetometer are flexible and can be modified by a skilled artisan from measurements on human subjects. Parameters that are routinely examined include, by way of nonlimiting example, orientation of the lasers relative to the head, the size of the probe beam pixels, the size of the pump beam, the pumping rate, and the like. It is expected that this instrument will exceed in performance commercial MEG systems currently known in the field.

We claim:

1. A high sensitivity atomic magnetometer comprising

a) a sensing cell containing a mixture comprising an alkali metal vapor and a buffer gas, wherein the sensing cell is exposed to a background magnetic field lower than a first predetermined value;

b) means for increasing the magnetic polarization of the alkali metal vapor thereby increasing the sensitivity of the alkali metal vapor to a low intensity magnetic field;

c) magnetizing means for imposing a magnetic field on a volume of space comprising the sensing cell;

d) means for probing the magnetic polarization of the alkali metal vapor, the probing means providing an output from the alkali metal vapor, the output comprising characteristics related to the low intensity magnetic field; and

e) measuring means wherein the measuring means receives the output, determines the characteristics of the low intensity magnetic field, and provides a representation of the low intensity magnetic field, wherein the measuring means comprises a plurality of output detecting means.

2. The atomic magnetometer described in claim **1** further comprising magnetic shielding enclosing a region of space comprising the magnetizing means and the sensing cell.

3. The atomic magnetometer described in claim **1** wherein the first predetermined value is about 10^{-8} tesla.

4. The atomic magnetometer described in claim **1** wherein the limit of detectability of the atomic magnetometer is less than 10 femtotesla $(Hz)^{-1/2}$.

5. The atomic magnetometer described in claim **1** wherein the density of the alkali metal in the vapor is about 10^{11} cm^{-3} or greater.

6. The atomic magnetometer described in claim **1** wherein the alkali metal is chosen from the group consisting of sodium, potassium, rubidium and cesium.

7. The atomic magnetometer described in claim **1** wherein the alkali metal is potassium.