Project Of Absolute Three-Component Vector Magnetometer Based On Quantum Scalar Sensor

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The new method of the fast precision measurement of three Earth magnetic field (EMF) vector components using optically pumped M_x-magnetometer placed in symmetrical magnetic coils system is proposed and mathematically proved. The method provides very high absolute accuracy (of order of 0.1 nT at 0.1 sec sampling rate). Absoluteness here implies that the process of measurement changes measured parameter, i.e. field component value, no more than by the value determined by sensitivity of scalar sensor. The short-term resolution of the method is determined by the M_x-magnetometer sensitivity.

It is well known that any component of magnetic field can be measured by measuring of the field scalar value – provided that two orthogonal components are compensated down to zero with a special magnetic coils system. This method does not require high compensation accuracy, since according to vector addition rules the contribution of small residual orthogonal component is to high extent suppressed in a presence of a big non-compensated component.

However it is not easy to build a real three-component device based on this method because the compensation of any field component requires relatively strong compensating magnetic field; therefore procedures of measuring of three field components by this method must be separated in space or in time. Besides, a very fast scalar magnetometer is needed in order to follow field jumps arising when switching from one component measurement to another.

The main point of the method proposed here lies in creation a system of compensating fields around the sensor, harmonically changing in such a way that total field vector in the sensor would rotate (keeping its length) around the initial field direction and during each rotation cycle would pass through three different points, two components of the field in each compensated with high accuracy and third component not compensated at all so it can be measured.

As a scalar device we propose Cesium or Potassium optically pumped magnetometer registering oscillating signal of transverse magnetization of the atoms in the cell – so-called M_x-magnetometer, characterized with high accuracy and speed.

The suggested method is applicable to wide field range, though its application for precise measuring of EMF components is most obvious – because of EMF high homogeneity and relatively small variations.

The mathematical model of the magnetometer based on these principles was built and the device behavior was modeled numerically. A program was written for this purpose based on scalar M_x-magnetometer model. Numerical modeling shows that using standard Cs sensor with 20nT resonance linewidth one can achieve about 0.015nT r.m.s. sensitivity in each field component at 0.1 sec sampling rate, accompanying by 0.1nT absolute accuracy – provided that coil constants do not vary more than by 100 ppm and coil axes directions do not vary more than by 0.6".