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Magnetic Gradiometer Using Optically Pumped Cesium Magnetometer

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1. Introduction

The atom magnetic resonance (AMR) technique based on the optical pumping polarization of gaseous samples provides higher sensitivity and accuracy than nuclear magnetic resonance (NMR) of liquid. Generally optical pumping polarization of atom is a million times bigger than nuclear spin polarization by thermal relaxation. Also its resonance frequency is a few hundred times higher than NMR frequency. AMR signal is independent of the amplitude of magnetic field, while NMR amplitude signal decreases along with the decrease of the magnetic field.

Optical pumping method employing two or more sensors is a more effective way of measuring the earth's magnetic field (EMF) gradient. It allows getting the sensitivity up to 100 times in detecting the magnetized object at EMF background. With optically pumped gradiometer (OPG), we can measure the magnetized objects in motion, without drift.

EMF variations are quite uniform at the earth surface and have the gradient level about 0.01-0.05 nT/km depending on the points of observation. It means the EMF magnetic field variations are the same at distance about 100 m within 0.001-0005 nT (1-5 pT) difference. For instance, when measuring the magnetic field difference at two points using two ideal (free from the instrumentation noise) identical magnetometers having the base (distance) of 100 m between the sensors, we can get the stable output signal without any variations within 1-5 pT. This instrument is the magnetic gradiometer. When a magnetized object is within the range of the sensor, the balance of two sensors change and the difference is detected.

2. Experimental Apparatus

Fig.1 represents the block-diagram of the Cesium-gradiometer. The sensors of two Cesium self-oscillating magnetometers were placed on the linear base at 7 m distance from one another. Frequencies of the AMR signals from the magnetometers, which are proportional to the magnetic field, were compared at the phase detector. The frequency difference was converted to current and compensated the magnetic field difference inside the Cesium sensor 1 to maintain the equal phases (or frequencies) on the inputs of the phase detector. So the voltage across the standard resistor, which is located in the feedback coil circuit, represents the magnetic field difference between the two sensors.

The car, as an example of the magnetized object, was used for the determination of its space distribution of magnetic field projection on the EMF direction, effective magnetic moment, and the maximum distance for detection.

3. Calculation and Results

The magnetic field distribution of the dipole magnetization of an object is determined by formula:

$$H = \frac{M}{4\pi} \cdot \frac{2x^2 - y^2}{R^5}$$

where H-magnetic field strength(A/m), M-magnetic moment($A.m^2$), R- distance from the object to the point of the measurement(m), x,y - axial and perpendicular coordinates of the measuring point.

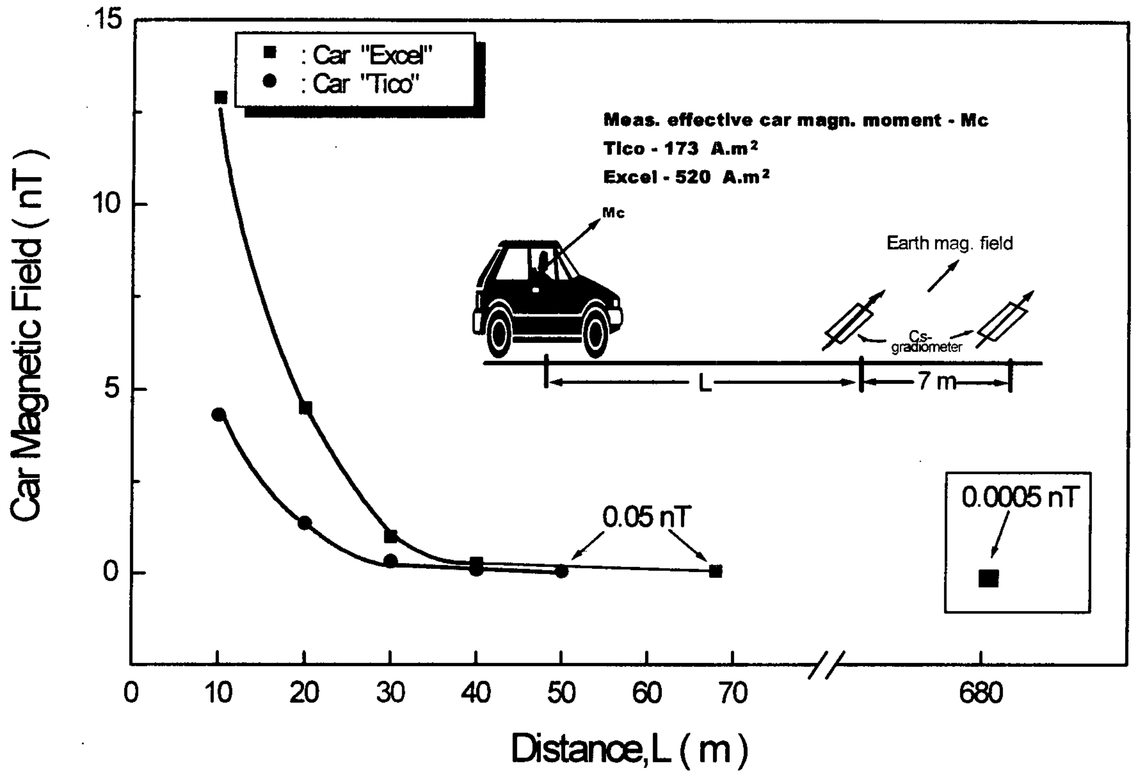

Fig. 1. Block diagram and measurement result of Cesium magnetic field gradiometer

Fig.1 shows the result of these measurements. The noise of magnetometers is about 0.05 nT (standard deviation). And, the maximum distance to find out the mini-car Tico and the ordinary size car Excel was 50 m and 68 m respectively.

In order to demonstrate the effectiveness of the scanning of an object, the Cesium AMR gradiometer was designed using the ordinary commercial magnetometers.

4. References

[1] Private Report by V. Ya. Shifrin.

[2] V. Ya. Shifrin, V. N. Khorev and P. G. Park, Metrologia, 36(3), pp. 171-177(1999).

[3] V.Ya. Shifrin, P. G. Park, V. N. Khorev, C. H. Cho, and C. S. Kim, IEEE. Trans. Meas. Instrum. 47(3), pp. 638-643(1998).

[4] T. R. Carver, "Optical Pumping", Science, 141(3581), pp.599-608(1963).

[5] V.Ya. Shifrin, Po Gyu Park, Cheol Gi Kim, V.N. Khorev and Chang Ho Choi, IEEE. Trans. Meas. Instrum. 46, 97(1997).