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LOW MAGENTIC FIELD MEASUREMENT BY NMR USING POLARIZED FLOWING WATER

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I. INTRODUCTION

The nuclear magnetic resonance (NMR) using flowing water has been previously employed for the measurement of an average field over an extended path where the twe RF coils were separated [1]. The water polarized in a strong field flows into the region in which the field is to be measured. Using this method an average field of 1.8 mT was measured over 60 cm length by the signal from a detector coil in a strong field. In present work, an NMR experiment was performed with RF and detection coils in the field to be measured [2]. The low magnetic fields in the range of 0.1 mT were measured over a few cm region by this system.

II. PROCEDURE

The schematic diagram of the NMR measurement system is shown in Fig.1. Flowing water enters the apparatus through the tube of 4 mm inner diameter and passes through a baffled chamber which is placed in 0.26 T. The flow rate and the volume of the chamber are arranged so that the flowing water spends a time comparable to the spin-lattice relaxation time (about 3 s for water) in polarizing field.

The polarized water flows into the 2 cm diameter sphere at the center of solenoid which is located in an earth's field compensated environment. The uniformity of solenoid field is about 5 ppm/cm obtained by using three auxiliary currents in addition to a main current [3]. The average field is taken over the volume of the sphere by the turbulent flowing of water. Just before flowing into the sphere an RF coil of 0.33 mm length and 20 turns supplies a cw field oscillating at the Larmor frequency for protons in the field to be measured. The RF field is fed from a synthesizer (hp 3325) and the amplitude of this field is adjusted so that each proton passing through sees a $\pi/2$ pulse where the induced transition probability is maximum. A detector coil surrounding the sphere is orthogonal to both the RF field and the measuring field. The signal induced in the coil is detected by lock-in amplifier (EG & G Par 5210). The detector coils have 800, 1600 and 3500 turns for the measurements of 1.0, 0.5 and 0.1 mT ranges respectively, and their signal-to-noise ratios are improved by tuning the coil at the Larmor frequency of measuring field.

III. RESULTS AND DISCUSSIONS

The NMR line width plays a decisive role in the uncertainty of field measurement, which depends on the field uniformity, the water flow rate and the RF field amplitude. The optimized water flow rate and the RF field amplitude are 20 cc/s and 0.5 μT respectively. Under these conditions magnitude of NMR signal is 60 μV in 1 mT field, which is about 100 times bigger than that by induction for a stationary water sample.

The Fig.2 (a)-(c) show the NMR signals measured at the fields of 1.0, 0.51 and 0.12 mT respectively. The pronounced signal is demonstrated even in the field of 0.1 mT range where the range of lock-in amplifier is downed to 3 μV in comparison with 1 mV range in 1.0 and 0.51 mT. The line width of the signal is 1.0 Hz where the natural line width for water is ten times narrower. In conclusion the NMR signal with a good signal-to-noise ratio is obtained by using polarized flowing water in a 0.1 mT range, and the field can be determined by the signal within the uncertainty of a few tens ppm.

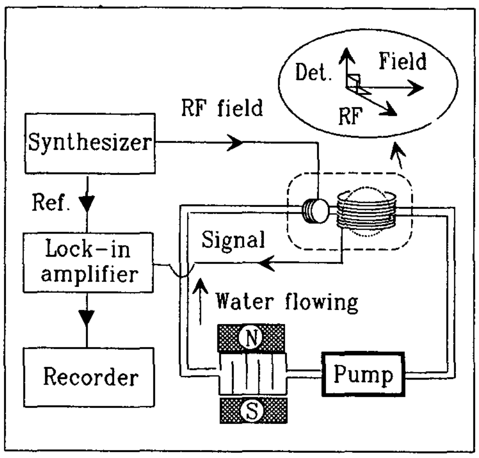

Fig.1 Schematic diagram for NMR measurement using polarized flowing water.

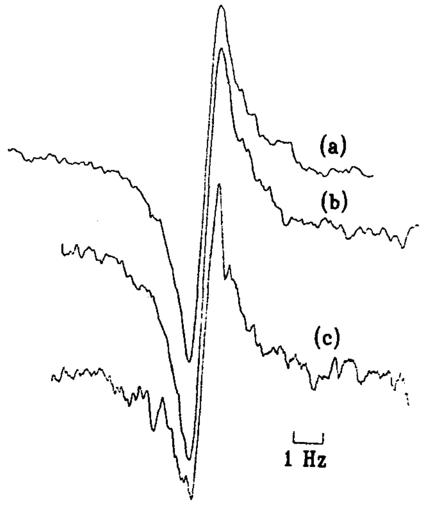

Fig.2 NMR signals measured at (a) 1.0 (b) 0.51 (c) 0.12 mT ranges.

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