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ESTABLISHEMENT OF THE MAGNETIC FLUX DENSITY STANDARD IN THE RANGE 100 µT to 1000 µT

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Abstract

The magnetic flux density standard in the range 100 µT to 1000 µT has been established using a standard Helmholtz coil. The ambient magnetic field including earth's magnetic field components inside the room and other noises has been compensated to a level of the order of 100 nT. A circular triaxial Helmholtz coil pair of size nearly 800 mm has been used for compensating the ambient magnetic field. The standard Helmholtz coil of size 300 mm has been placed in the geometrical centre of the triaxial Helmholtz coil pair. The magnetic flux density has been measured using triaxial and single axis fluxgate magnetometers. The coil constant of the standard Helmholtz coil has been found to be 850.6808± 0.0036804 µT/A, which is in good agreement with the manufacture's specification viz, 850 µT/A, with an uncertainty of < ± 0.5 %.

Introduction

Magnetic flux density standards were realized in the past as physical artifacts, i.e., accurately designed solenoids or Helmholtz coil pairs which were traceable to the SI units of length, resistance and voltage. Today the system consists of a standard field source with a nuclear or atomic resonance magnetometer plus the auxiliary unit necessary for compensation and stabilization of the magnetic field generated by the standard field source. The quantum magnetometer or the resonance device is an intrinsic standard, realizing traceability to the SI unit of time via the resonance equation $\omega_0 = \gamma_n \mathbf{B}$, where ω_0 is the resonance frequency or more precisely the Larmor precession frequency of the species involved, γ_n is the gyromagnetic ratio and B is the absolute magnetic field to be measured. Several NMIs maintain the physical standards for magnetic units with stated uncertainty to the base SI units and has been disseminated to measurement and testing laboratories [1-2]. In the present case the magnetic flux density standard has been realized using a standard Helmholtz coil kept in the geometrical centre of triaxial Helmholtz coil pair geometry. The field range intended is from 100 µT-1000 µT. The coil constant determined for a field value of 1000 µT is in good agreement with the manufacturer's specification.

Experimental Details

The magnetic flux density standard in the range from 100 µT to 1000 µT has been established using a traixial Helmholtz coil pair of size ~800 mm for field compensation and a standard Helmholtz coil of size ~300 mm as the field source. The coils were energized by programmable current sources (Keithley 2430 and 6221). The ambient field compensation has been done in a passive way in which the magnetic field in three directions were measured with two triaxial fluxgate sensors positioned in the E-W direction and passing through the axial direction of the standard Helmholtz coil, and the data recorded continuously at an interval of 10 s using Spectramag-6(Bartington Instruments). The standard field at the geometrical centre of the standard coil has been measured using a single axis fluxgate magnetometer (Mag-01H). The analog output from the Mag-01H was fed to a precision multimeter (HP3458A) and twenty acquisitions were made with in a time five seconds. A LabVIEW programme has been made for data acquisition and automatic compensation of the ambient magnetic field. Though the ambient magnetic field in the E-W direction has been compensated to a level of 100 nT, the residual field has been recorded before and after the standard Helmholtz coil was energized and has been deducted from the measured field for the standard Helmholtz coil. Using the measured value of B an I the coil constant, B/I for for the standard Helmholtz coil has been measured and uncertainty has been estimated.

Results and Discussion

The total experimental set up is shown in the photograph (Figure.1). Before installing the whole set-up we have measured the ambient magnetic field existing on the site, in order to determine the value and the noise characteristics. The results of the measurements are given in Figue.2. The Z-direction of the triaxail fluxgate sensors coincides with the E-W direction, which is the axial direction for the standard Helmholtz coil. Beacause the experimental set-up is in inside the lab (presently not isolated from

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the main lab building) we have observed a lot of noise in all the directions. The average value of the ambient

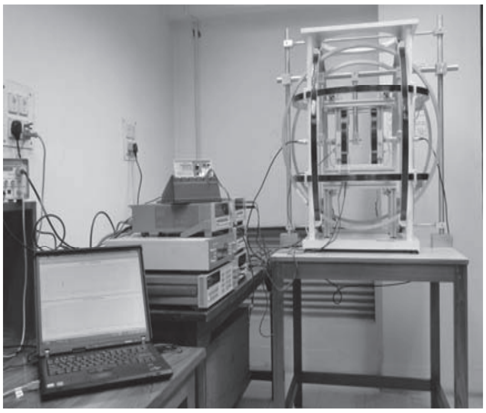

Figure.1 Photograph of the magnetic flux density Standard

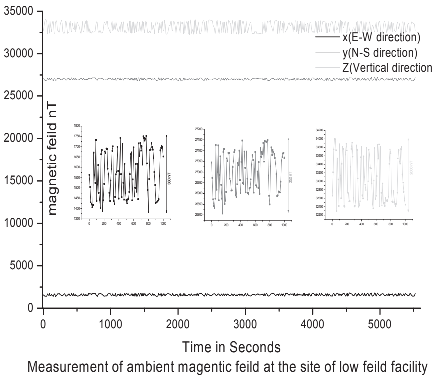

Figure.2 The ambient magnetic field in the three directions with traixial fluxgate sensors

magnetic field values in the three directions were fed as the input to the current sources so that the amount of current drawn from the source and flown through the triaxial coils will compensate for the ambient field. In the Z direction (E-W direction) we have done an active compensation by which the actual field has been measured and fed as the input to the current source (Keithley-6221). In this way we could achieve compensation as low as 100 nT. The fluctuations in the other directions were left as such. The magnetic field value measured after the compensation is shown in the Figure.3. The coil constant of the Helmholtz coil has been determined by taking the ratio between B and I, where B is the magnetic field value measured from the single axis fluxgate magnetometer, and I is the current measured using the source-meter, 2430. Because the measurements have been taken with in span of 10 s, the effect the temperature on the coil constant has been ignored. The uncertainty budget is given in

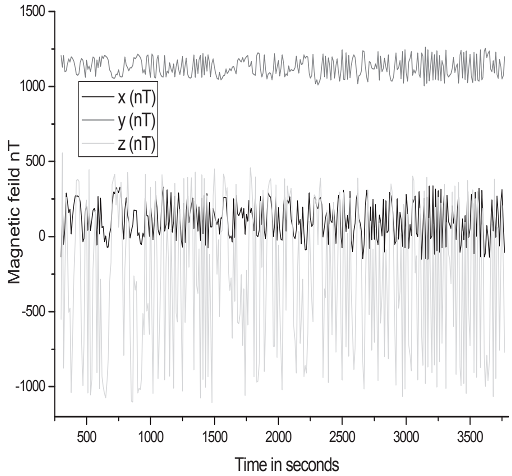

Figure.3 Measured magnetic field after compensation

Source of uncertainty	Distribution function	Divisor	Relative uncertainty	Sensitivity coefficient	Degrees of freedom
Magnetic field reading	Rectangular	√3	2.5952 x 10^{-3}	1	∞
Current Reading	Rectangular	√3	1.0838 x 10^{-3}	1	∞
Repeatability	Normal	1	6.1480 x 10^{-7}	1	19
Combined Realtive Standard Uncertainty			3.6804 x 10^{-3}	-	-
Expanded Uncertainty(95% confidence level)			7.3608 x 10^{-3}	-	Coverage factor, k=2

Table.1 Uncertainty budget for the Standard Helmholtz coil for the field of 1000 µT

Table.1 .The main source of uncertainty is from the magnetic field reading, which comprises of different components viz, the spatial inhomogenity of the field produced, measurement of magnetic field through the fluxgate magnetometer with a calibrated uncertainty of 0.2%, and the uncertainty in the voltmeter reading. The coil constant has been found to be 850.6808± 0.0036804 µT/A for the set field of 1000.773 µT.

References

[1] Intercomparison of magnetic flux density by means of field coil transfer standard, EUROMET Project No.446, Final Report, 2001

[2] A.E. Drake, "Traceable magnetic measurements," J . Magn. Magn. Mater., vol. 133, pp. 371-376, 1994