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저온전류비교기를 이용한 극저 잡음 전류 비교기

(Ultralow noise current comparator based on a cryogenic current comparator)

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I. Introduction

A Cryogenic Current Comparator (CCC) proposed and first realized by Harvey[1] is the most accurate device to compare two currents. The CCC is generally used for calibration of standards resistors versus the quantum Hall resistance.[2] In addition, the extremely low winding ratio errors of the CCC, $< 10^{-9}$, is very useful to realize an amplifier with a highly accurate gain.[3]

Here we describe the development and a test of a CCC designed for a amplification of very low current. In particular, the influence of external noise including earth magnetic field on the resolution of the CCC will be discussed.

II. Experimental setup

The CCC is of the overlapped type as described, e. g., in Ref. 2. The 17 windings, made of 63 μm-thick-insulated copper-clad $Nb_{48}Ti_{52}$ wire, have number of turns 1, 1, 1, 2, 4, 8, 16, 17, 32, 64, 128, 128, 256, 512, 1024, 1024 and 2048. The coil is covered by a toroidal 0.2 mm-thick lead foil overlapped at the ends. The shield has 2.5 turns of overlap and the overlapped layers are insulated by Kapton tape. The magnetic flux generated by the superconducting lead foil is sensed by a 7 turns (diameter of 30 mm) of superconducting pickup coil with 1.7 μH inductance. The pickup coil is connected to a commercial thin film dc SQUID sensor (Quantum Design). The comparator, pickup coil and the SQUID are shielded by two superconducting cans made of lead foils with a thickness of 0.3 mm. The noise power spectral density of the SQUID sensor with a pickup coil and the CCC is obtained using Dynamic Signal Analyzer, Agilent 35670A, within frequency range up to 800 Hz, respectively.

III. Results and Discussion

Figure 1a reveals the noise power spectral density of the intrinsic dc-SQUID noise measured without connecting the pickup coil. The dc-SQUID with the pickup coil shielded by Nb can shows a slightly increased noise level by about one order, 3×10^{-5} V/Sqrt(Hz) (Fig. 1c). A reduce in the earth's field by about 100 dB through the external shielding cabinet slightly reduces noise level down to 1×10^{-5} V/Sqrt(Hz) (Fig. 1b). But, an additional shielding by a superconducting lead foil leads to an increase in noise level (Fig. 1d). Furthermore, the noise power spectral density of the CCC is slightly increased with the second lead foil. Thus, the overall noise level of the CCC is about $7 \sim 8 \times 10^{-5}$ V/Sqrt(Hz) (Fig. 1e). It should be mentioned that the increasing noise level with the number of the shielding cans is due to the trapped magnetic flux and flicker noise caused by vortices displacement in the lead cans. Nevertheless, the rms noise level of the SQUID with the pickup coil was measured to be about 1.14×10^{-4} Φ_0/Sqrt(Hz), where the Φ_0 is the flux quantum h/2e, obtained from the data sheet of Quantum Design and measured transfer function. In addition, the overall sensitivity of the CCC is 7 μAturn/Φ_0.

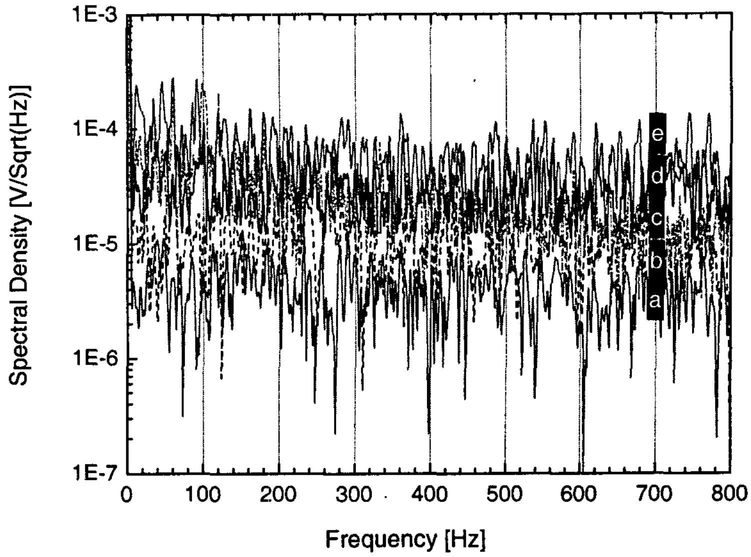

Fig. 1. (a) Noise power spectral density of the dc-SQUID intrinsic noise measured without connecting the pickup coil. Noise power spectral density of the dc-SQUID with the pickup coil shielded by Nb can and with (b) and without an external shielding cabinet (c). Noise power spectral density of the CCC with one (d) and two superconducting lead cans(e).

The ratio accuracy of the CCC was tested directly by a binary bild-up technique. By measuring the SQUID output of two windings with an equal number of turns connected in anti-series configuration, the error of the 1:1 ratio can be determined. So that a nearly canceling current in the CCC produces magnetic flux, which is induced by the shielding current on the torus. No winding errors were detectable within experimental accuracy at the level of 10^{-9}. In addition, current resolution of the CCC was estimated to be 7 x 10^{-10} Aturn.

IV. Summary

A high-precision current comparator has been built to amplify very low current in the range of 10^{-10} Aturn. This result opens a possibility of magnifying the low current delivered by a SET pump in the near future.

Acknowledgment

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References

[1] I. K. Harvey, Rev. Sci. Instrum. **43**, 1626 (1972).
[2] B. Jeckelmann and B. Jeanneret, Rep. Prog. Phys. **64**, 1603 (2001).
[3] G. Rietveld, E. Bartolomé, J. Sesé, P. de la Court, J. Flokstra, C. Rillo, and A. Camón, IEEE Trans. Instrum. Meas. **52**, 621 (2003).