MoF1
AN IMPROVED SENSOR FOR THE NIST CRYOGENIC THERMAL TRANSFER STANDARD

Thomas E. Lipe*, Carl D. Reintsema†, and Joseph R. Kinard*
Electronics and Electrical Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-8111

Abstract

We are developing a new primary standard of ac-dc difference, based on a resistive superconducting transition-edge sensor. We describe the performance limitations of the present device, and present a new sensor design which will improve the operating environment, and hence the performance, of the standard.

Introduction

The first prototypes of a new primary standard for ac-dc difference, the Cryogenic Thermal Transfer Standard (CTTS) have been described previously [1,2]. This standard uses a resistive superconducting transition-edge sensor (TES) and feedback circuit to monitor ac and dc signals applied in a timed sequence to a heater structure. The CTTS operates at about 6 K, where contributions to the ac-dc difference from Thomson and Peltier effects are predicted to be small. The reduction of these thermoelectric effects, coupled with the great sensitivity inherent in a TES, is expected to result in a primary standard of ac-dc difference with uncertainties of less than 1×10^{-7}.

Magnetic Fields

The most recent measurements on the CTTS are reported in [1]. Large ac-dc differences at frequencies of 10 kHz and above are due to reactance effects in the transmission line carrying the unknown signal through the cryostat to the measurement platform. Although the high-temperature superconducting transmission line [3] used in the CTTS has reduced the high-frequency ac-dc differences over previous, non-superconducting transmission lines, a short length of non-superconducting line remains, and is the primary source of error in this frequency regime.

The ac-dc differences at audio frequency exhibit a strong square-law dependence on the input signal level. This input-level dependence is consistent with the suppression of the critical temperature (T_c) of the TES caused by the coupling of the magnetic fields from the signal and trim heaters into the TES.

New TES Chip

A new detector chip has been designed to reduce the magnetic fields coupling into the TES from the heater structures. The new chip, shown in Figure 1, incorporates superconducting niobium (Nb) ground planes beneath the heaters and TES, for increased shielding, and Nb wiring to all structures to reduce substitution and measurement errors. In addition, the heaters on the new chip are arranged in either a planar bifilar pattern with the leads extremely close to each other, or in a micro-stripline geometry incorporating the Nb groundplane as the current return path.

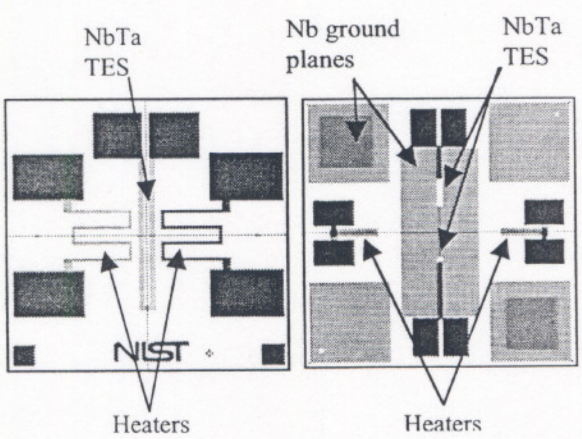

Figure 1. The original sensor chip (left) and the new sensor chip (right), showing the design modifications.

---

* Electricity Division, Gaithersburg, MD
† Electromagnetic Technology Division, Boulder, CO
NIST is part of the Technology Administration, U.S. Department of Commerce.

Models of both new heater designs indicate that the magnetic fields coupling into the TES are reduced by about two orders of magnitude solely as a result of the change in chip geometry. The calculated magnetic field profile resulting from the new chip geometry, exclusive of the shielding, is contrasted with that of the original chip in Figure 2. Taking into account the shielding, the fields at the TES are negligible. This should significantly reduce the ac-dc differences of the CTTS at audio frequency, and increase the stability of the measurements.

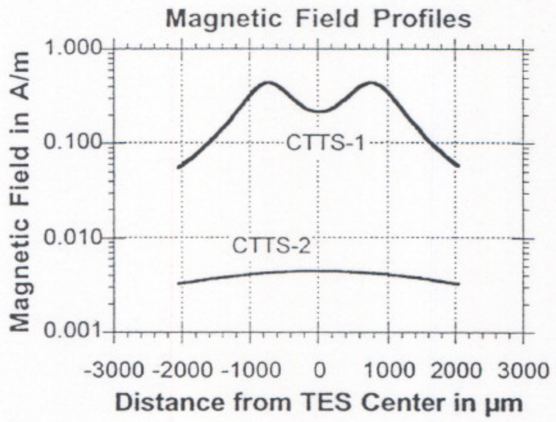

Figure 2. Calculated magnetic fields resulting from the heater currents for the original sensor chip (CTTS-1) and the new, shielded chip (CTTS-2), shown as a function of position on the TES chip.

Conclusions

We have described data that indicate that the primary contribution to the ac-dc difference of the CTTS at audio frequencies is the suppression of the T_c of the sensor by the coupling of magnetic fields from the heaters to the TES. A new sensor chip featuring superconducting shielding and improved field cancellation has been designed and fabricated. Models of the magnetic fields on the new chip indicate a reduction of about two orders of magnitude in the fields coupling to the TES. It is expected that this new design will substantially improve the performance of the CTTS at these frequencies.

References

[1] C.D. Reintsema, J. R. Kinard, T. E. Lipe, J. A. Koch, and E. N. Grossman, "Thermal Transfer Measurements at Microwatt Power Levels," in *CPEM '98 Conference Digest*, pp. 171-172, Washington, DC, USA, July 6-10, 1998.

[2] T. E. Lipe, J. R. Kinard, and C. D. Reintsema, "Improvements in the NIST Cryogenic Thermal Transfer Standard," *IEEE Trans. Instrum. Meas.* Vol. 50, no. 2, pp. 326-329, April, 2001.

[3] C.D. Reintsema, J.R. Kinard, and T.E. Lipe, "A High-Temperature Superconducting Transmission Line for Cryogenic Electrical Metrology Applications," in *CPEM 2000 Conference Digest*, pp. 488-489, Sydney, NSW, Australia, May 14-19, 2000.