

SID



سرویس های ویژه



سرویس ترجمه تخصصی



کارگاه های آموزشی



بلاگ مرکز اطلاعات علمی



عضویت در خبرنامه



فیلم های آموزشی

کارگاه های آموزشی مرکز اطلاعات علمی جهاد دانشگاهی



کارگاه آنلاین آشنایی با پایگاه های اطلاعات علمی بین المللی و ترند های جستجو



مباحث پیشرفته یادگیری عمیق؛ شبکه های توجه گرافی (Graph Attention Networks)



کارگاه آنلاین مقاله نویسی IEEE و ISI ویژه فنی و مهندسی

High frequency electromagnetic interference reduction on the squid attached in pulse tube cryocooler

M. J. Eshraghi^{1,*}, M. Cho.¹, J. Mok Kim², I. Sasada¹

¹ Department of Applied Science for Electronics and Materials, Kyushu University, Kyushu, Japan

² Korea Research Institute of Standards and Science, Seoul, Korea

Received: 8 May 2009/Accepted: 10 September 2009/ Published: 20 September 2009

Abstract

Measurements of the high frequency electromagnetic interference (EMI) of a pulse tube cryocooler are made in a typical laboratory environment using laboratory-made current transformers. The inverter makes high frequency EMI which could cause severe interference with SQUID operation inside the Pulse Tube cryocooler. By covering the power lines, which include a neutral line, of the valve motor with a copper mesh cover, as a ground line, one order decrease in the magnitude of the EMI noise is successfully obtained. This paper describes one example to show how to observe and reduce conducted high frequency noise currents in a precision experimental system.

PACs: 85.25.Dq; 87.19.le; 84.37.+q

Keywords: Electromagnetic interference, PT cryocooler, SQUIDS, Noise measurement.

1. Introduction

Superconducting quantum interference devices (SQUIDS) have been applied to diagnose heart diseases and brain functions as detecting magnetocardiogram (MCG) and magnetoencephalogram (MEG) fields [1, 2]. Instead of using liquid helium to keep low temperature for operating the SQUID system, a refrigerator such as Gifford-McMahon cooler or pulse tube cryocooler may be used. In the GM cooler, the cooling process is performed by reciprocal motion of a displacer which contains heat regenerative material. On the other hand the pulse tube cryocooler uses pressure vibration in the pulse tube instead of using a displacer, so there is no moving part in cold stage. Therefore, pulse tube cryocooler is more stable than GM cooler with regard to physical vibration [3].

Helium gas is used in operating the pulse tube cryocooler and the gas is repeatedly being pushed into the pulse tube and exhausted with 1.8 Hz frequency by a valve motor. Since one single turn of the valve motor makes two switching of the gas flow, the valve motor is controlled by a three-phase inverter. The inverter acts with 10 kHz switching frequency and its harmonics surprisingly reach up to around 20 MHz. Even though the three stainless steel flexible hoses, which are used to connect the valve motor to the pulse tube cryocooler are connected to the valve motor via insulating ceramic connectors, the high frequency harmonics are conducted into the pulse tube cryocooler. As a result, the conducted switching noise current causes a critical interference with the operation of the

SQUID sensor which is installed in 4 K stage of the pulse tube cryocooler.

In order to solve this problem, paths of the high frequency noise currents are analyzed with laboratory-made current transformer sensors which have good high frequency characteristic. Furthermore, an appropriate solution is proposed to suppress the noise currents by modifying the noise paths.

2. Current Transformers

Each current transformer sensor consists of a frame which have inside diameter of 5 cm, 30 layers of Metglas 2714A amorphous ribbon which is 5 cm in width and 20 μm in thickness, and 72 turns of detection coil. Induced current is detected as a voltage by adding a 2.2 k Ω resistor to the secondary. Six current sensors are made for detecting switching noise currents in several points at the same moment.

First of all, induced voltage responses on all the sensors are measured in a range from 100 kHz up to 15 MHz. Excitation test current provided by a 5 volts peak-to-peak voltage from an oscillator passes through the center of each sensor. By comparing the output voltage temporal shapes of sensors, the sensor reproducibility is confirmed.

On the other hand, the current to voltage transfer functions of the current sensors are not evaluated yet, but some investigations are performed to assure that their frequency and amplitude characteristics are well matched among six sensors. Therefore, the value on the vertical axis in each figure is used for comparison with the values which have been gathered from other sensors in other points. At this experiment level, these values could not be used to evaluate the exact values

*Corresponding author: Mohammad Javad Eshraghi;

E-mail: javad4@asem.kyushu-u.ac.jp

Tel: (+81) 92 583-7799

Fax: (+81) 92 583-7799

of the conducted noise currents, but they are meaningful to show and compare the temporal shapes of the output voltage and hence the harmonic components of the conducted noise.

3. Experimental Analysis

3.1. Problem

Fig. 1 shows the schematic diagram of the separate valve motor type 4 K pulse tube cryocooler system and the experimental configuration of EMI noise measurement. The high frequency noise current generated by the inverter causes a problem by being conducted into the PT-Dewar via the ceramic connectors which are used at the valve motor side of the flexible hoses as electric insulators.

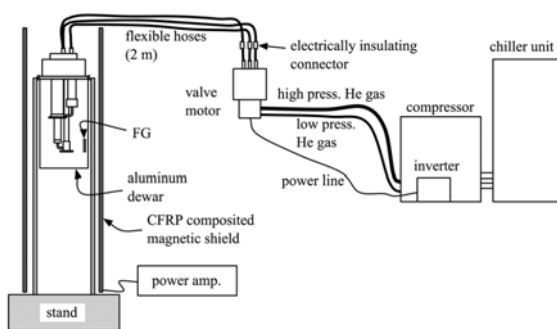


Fig. 1. Schematic diagram of the separate valve motor type 4 K pulse tube cryocooler system.

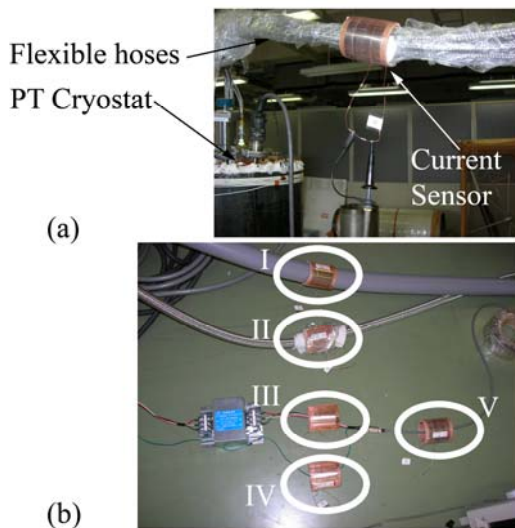


Fig. 2. Points for measuring the conducted noise currents : (a) Three flexible hoses between the valve motor and the PT-Dewar, (b) High pressure flexible hose(I), Low pressure flexible hose(II), Power lines (III), Three phase lines(IV), Neutral line(V) (between the inverter and the valve motor).

In order to diagnose this high frequency noise problem, the high frequency noise current conducted through the three flexible hoses between the valve

motor and the PT-Dewar is measured with the aid of the current sensor, as shown in Fig. 2(a). The measurement result proves the existence of the high frequency noise current conducted into the PT-Dewar, as shown in Fig. 3. The frequency of the noise current comes up to around 20 MHz and can make the noise current pass through the ceramic connectors.

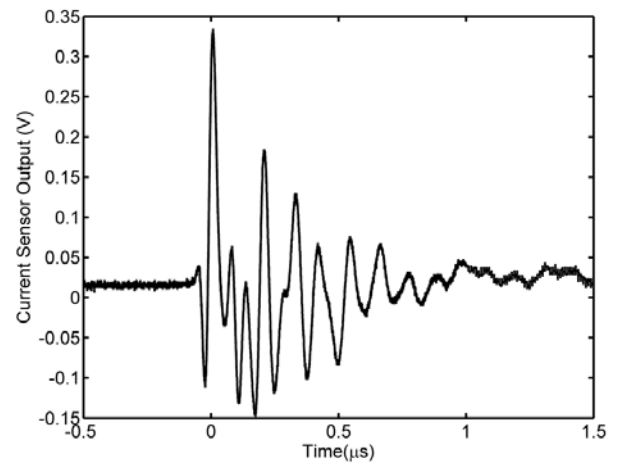


Fig. 3. High frequency noise current conducted into the PT-Dewar.

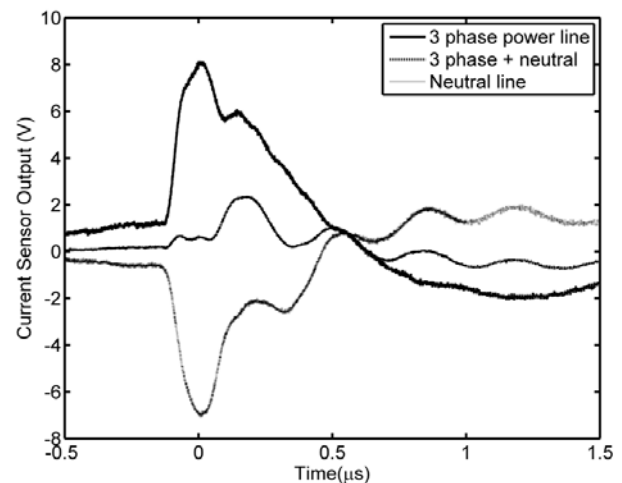


Fig. 4. Temporal shapes of the conducted noise currents through the power lines (three phase lines and neutral line together), the three phase lines, and the neutral line.

3.2. Noise path analysis

Helium gas flows in and out of the compressor and the valve motor via a high pressure and a low pressure hose. The valve motor receives the power from the inverter via the power lines. The power lines include three phase lines and one neutral line.

Reduction of the conducted noise current to the PT-Dewar is essential for the proper operation of the SQUID sensor inside the PT-Dewar. In order to analyze the noise paths and to find a way to reduce switching current noises, they are measured on the power lines and the high and the low pressure flexible

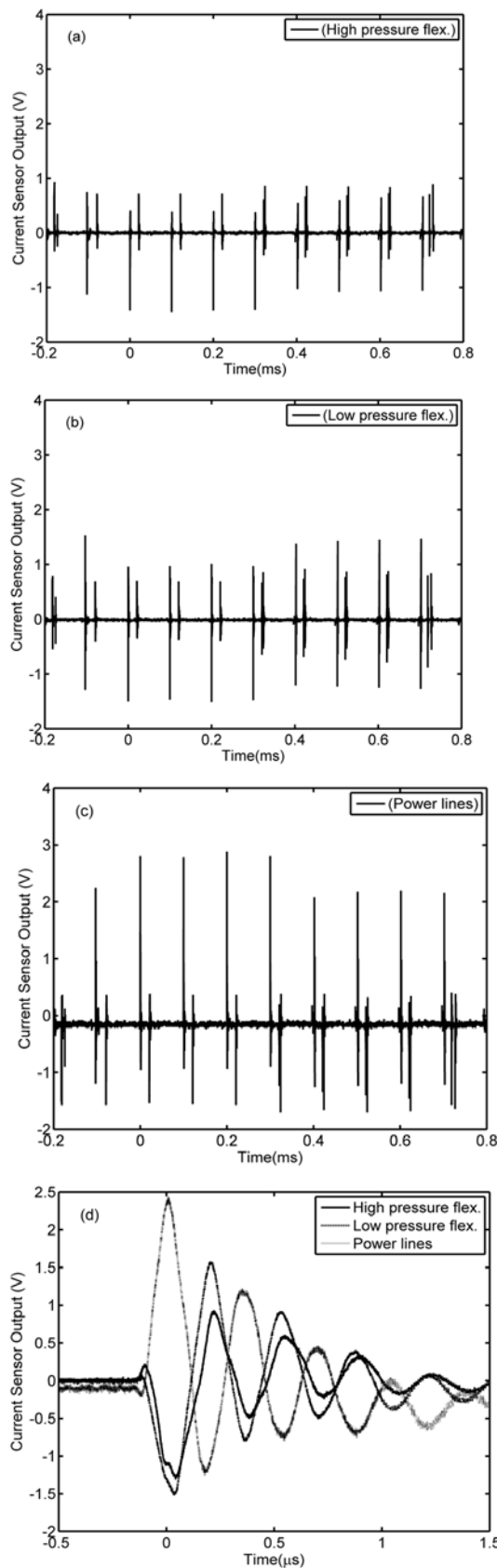


Fig. 5. Measurement results of the noise currents: (a) Power lines (three phase lines and neutral line together), (b) High pressure flexible hose, (c) Low pressure flexible hose, (d) Comparison of the noise shapes in a shorter time span.

hoses between the compressor and the valve motor, as shown in Fig. 2(b).

Fig. 4 shows the temporal shapes of the conducted noise currents through the power lines (three phase lines and neutral line together), the three phase lines, and the neutral line separately. Although the conducted noise through the neutral line is in the opposite polarity with the summed noise currents through the three phase lines, they are not exactly mirrored waveforms. So there is some unbalanced current in the system which is indicated by “3 phase + neutral” in the figure.

Comparatively large noise currents exist on both high and low pressure flexible hoses. This phenomenon originates from the large unbalanced current due to the unbalanced three phase loads (Fig. 4). Large part of the unbalanced noise current flows in the neutral line, however, a part of the current leaks out into the flexible hoses. In order to describe this phenomenon more clearly, Fig. 5 shows the amounts of the switching noise currents in the power lines and the flexible hoses. Fig. 5(a) shows the temporal shape of the total noise current that passes through the power lines. The 10 kHz noise from the inverter is clearly visible in this figure and also in the temporal shapes of the measured noise currents that pass through the high and low pressure flexible hoses, as shown in Figs. 5(b) and 5(c). Fig. 5(d) shows the current noise shapes of the power lines and the flexible hoses around the moment of the switching timing of the inverter. In other words, this figure is the temporal evolution of the large peaks of in Fig. 5(a) to 5(c). It is apparent that the conducted noise in the power lines is in opposite polarity with the conducted noise in the flexible hoses, as a result they make a closed loop with regard to the noise return paths, which consist of neutral line of the power lines, high pressure flexible hose, and low pressure flexible hose.

4. Discussion-Noise reduction

By observing the noise paths, it can be concluded that the impedance of the neutral line is somehow high for carrying the whole noise return, so the noise finds some other low impedance return paths, one of these ways are the high and low pressure flexible hoses, and the other way is the capacitive coupling to the PT-Dewar [4]. So by decreasing the impedance of the neutral line, it should be possible to force the some part of the unbalanced current to flow into the neutral line and to reduce the amount of the conducted noise current to the PT-Dewar.

After covering the three phase lines and the neutral line with a copper mesh cover coaxially and connecting both ends of the copper mesh cover to the neutral points at both ends [5], the conducted noise currents are measured in the high and low pressure flexible hoses and the power lines (Fig. 6). By comparing the

peak-to-peak values of the measured noise currents in the power lines and the flexible hoses with (Fig. 6) and without (Fig. 5(d)) the copper mesh cover, it is proved that there is approximately six times reduction in the conducted noise from the compressor and the inverter to the valve motor.

Conducted noise current between the valve motor and the PT-Dewar is also measured (Fig. 7). By comparing the peak-to-peak values of the conducted noise currents with (Fig. 7) and without (Fig. 3) the copper mesh cover, it can be seen clearly that the conducted noise current level has been reduced up to 5 times. The copper mesh cover has conducted some part of the high frequency noise current and it results in lower noise level in the PT-Dewar. Finally, the SQUID operates normally as drawing an ideal demonstration, as shown in Fig. 8.

5. Conclusion

Conducted noise currents through the stainless steel flexible hoses and the power lines of the pulse tube cryocooler are measured with the aid of the laboratory-made current sensors in order to analyze the noise paths. By covering the power lines with a copper mesh cover coaxially as a ground line, the impedance of the neutral line decreases, and as a result, the conducted noise to the PT-Dewar shows five times reduction. This experiment describes an example to show the importance of observation of conducted noise currents in solving the high frequency noise current interference problems.

Acknowledgment

The early stage of this work was supported by the Grants-in-Aid for Scientific Research (A) 15206048.

References

- [1] H. Nowak, "Biomagnetic instrumentation Magnetism in Medicine," W. Andre, H. Nowak, Eds. Berlin: Wiley-VCH, 88 (1998).
- [2] J. M. Kim, Y. H. Lee, K. Kim, H. Kwon, Y. Park, I. Sasada, IEEE Trans. Appl. Supercond., **15**, 644 (2005).
- [3] R. N. Richardson, B. E. Evans, Int. J. Refrig., **20**, 367 (1997).
- [4] D. M. Hockanson, J. L. Drewniak, T. H. Hubing, T. P. Van Doren, F. Sha, M. J. Wilhelm, IEEE Trans. EMC, **38**, 557 (1996).
- [5] H. W. Ott, "Noise Reduction Techniques in Electronic Systems," John Wiley & Sons Inc., 105 (1988).

SID



سرویس های ویژه



سرویس ترجمه تخصصی



کارگاه های آموزشی



بلاگ مرکز اطلاعات علمی



عضویت در خبرنامه



فیلم های آموزشی

کارگاه های آموزشی مرکز اطلاعات علمی جهاد دانشگاهی



کارگاه آنلاین آشنایی با پایگاه های اطلاعات علمی بین المللی و ترند های جستجو



مباحث پیشرفته یادگیری عمیق؛ شبکه های توجه گرافی (Graph Attention Networks)



کارگاه آنلاین مقاله نویسی IEEE و ISI ویژه فنی و مهندسی