Japan Aerospace Exploration Agency		ISR.35-GNL.11

Test Plan for Magnetic Shielding of Polarization Modulator

approved by	reviewed by	authors Yuki Sakurai Tomotake Matsumura data: Dec. 21 2016

1 Purpose

In this document we report on our reply to the action item ISR.35-GNL.11, which is identified with following information:
ID: ISR.35-GNL.11
ITEM: Set a test plan to check if magnetic shielding is sufficient.
SOURCE (REPORT): DEAD LINE: Aug. 2016
SECTION IN PHASE-A1 PLAN DOCUMENT: Aug. 2016,
WBS ID: WBS A1.02.06.03.08
EXPECTED OUTPUTS: Establish test plan for Magnetic Shielding of Polarization Modulator.

2 Introduction

The detector of the LiteBIRD is a transition edge sensor (TES), and it is read out by a SQUID. Therefore, an external magnetic field can be a problem in general. The requirements to the external magnetic field are less than 2 Gauss for long-term stability and less than 5×10^{-5} Gauss/$\sqrt{(\mathrm{Hz})}$ for short-term fluctuation. Since these are tentative values, an experiment is in preparation in order to justify them. Sources of the external magnetic field are a motor of a satellite bus system, environmental magnetic field in a L2 orbit and so on. One of the main sources is a polarization modulator unit (PMU). The PMU employs a superconducting magnetic bearing (SMB) in the rotational mechanism, which is a contactless bearing.In the SMB, a relatively large permanent magnet formed in ring shape is used as a rotor. The inner diameter of the rotor magnet is 400 mm and 200 mm for the Low Frequency Telescope (LFT) and the High Frequency Telescope, respectively. The half-wave plate is mounted inside of the rotor magnet. Figure 1 shows the position of the PMU and the detector with their distance. Thus, a magnetic shield for the PMU must be designed and evaluated if necessary. In this document, we report a test plan for the magnetic shield of the polarization modulator following the action item from the International Science Review.

3 Description

There are mainly three test plan for the PMU magnetic shield.

1. Justifications of TES requirements
2. Magnetic field simulations, design of the magnetic shield
3. Test of designed magnetic shield

3.1 Justifications of TES requirements

blah, blah, blah ...

3.2 Magnetic field simulations, design of the magnetic shield

The evaluation of the magnetic shield due to the PMU magnet is carried out by a electromagnetic field simulation. The software package is a finite element method (FEM) based simulation called ”JMAG”. The JMAG has an advantage of a high-speed computation and containing numerous application packages of

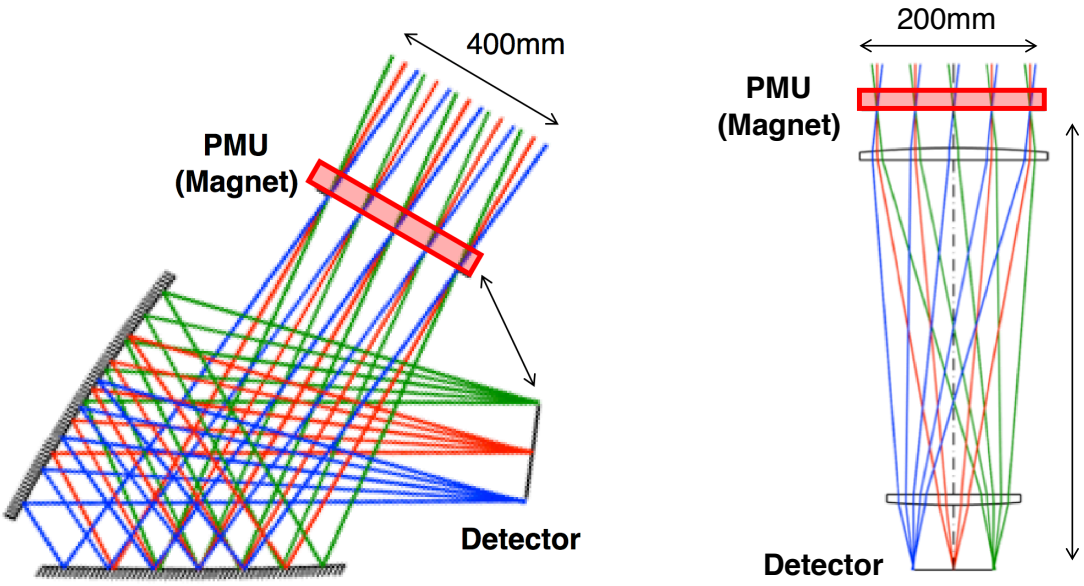

Figure 1:

the electromagnetic field analysis. The magnetic shielding is also included in the packages. It has several achievements such as a design of a magnetically shielded room and so on. In order to cross check the simulation result, we also apply the electromagnetic field simulation by a COMSOL software. The COMSOL is multi-physics simulation software based on the FEM. It also has several achievements of the magnetic field analysis.

At first, we must study the necessity of the PMU magnetic shield. Figure 2 shows the decision tree for the PMU magnetic shield. The magnetic shield for the detector and its readout (detector magnetic shield) is to be installed by default. However, it does not take into account the magnetic field from the PMU magnet. The first decision point is whether the detector magnetic shield is sufficient or not. We estimate the magnetic field due to the PMU magnet at the detector position by the JMAG simulation. In this simulation, the PMU magnet is formed into a ring shape with ϕ=400 mm and magnetized in the axial direction. The detector magnetic shield, whose specifications (a shape and a material) are already designed, are given to the simulation. From the simulation result, we determine the first decision point. If it is sufficient, there is no necessity of the PMU magnetic shield.

Then, we investigate the magnetic circuit of the PMU magnet. The magnetic circuit is a combination of the magnetization and the yoke. It has a possibility to reduce the magnetic field leakage due to the PMU magnet. Figure 3 shows the magnet with axial magnetization and an alternative magnetic circuit. The alternative one has a magnet with radial magnetization and two iron yokes on both inner and outer side. It improves not only the magnetic shielding but also the performance of the SMB. We perform the same simulation as above with this magnetic circuit. Then, we decide to the necessity of the PMU magnetic shield.

If the two decision points are passed, the PMU magnetic field must be constructed. In order to design it, we must determine mainly three design parameters as following,

- Position: PMU side or detector side

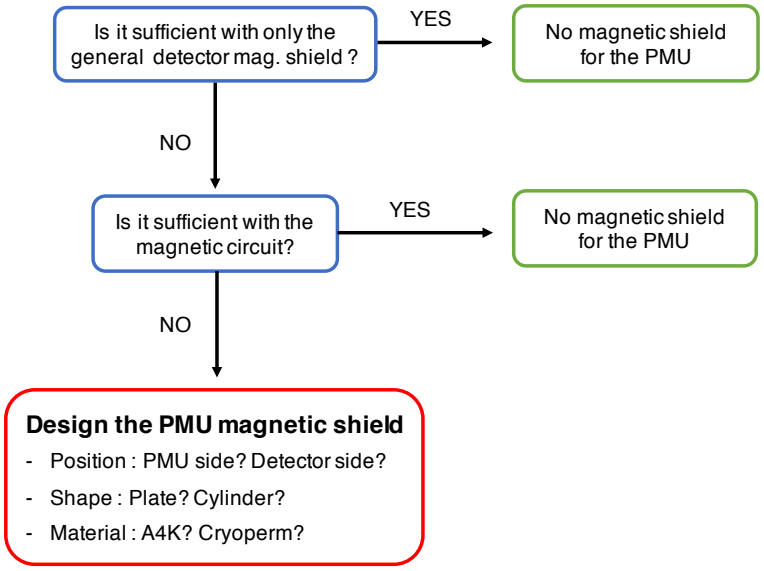

Figure 2: Decision tree and design items for the PMU magnetic shield.

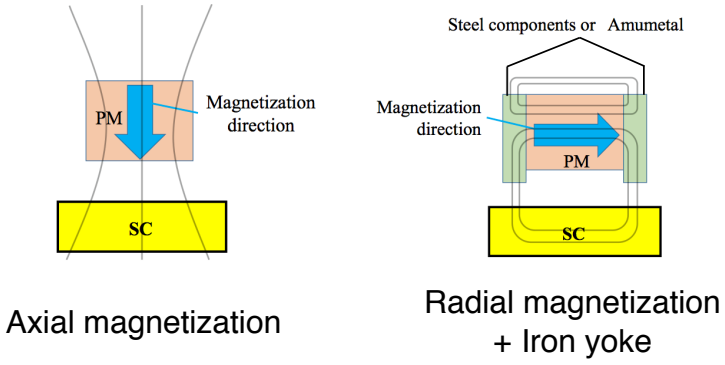

Figure 3:

- Shape: plate or cylinder or cylinder + bottom plate
- Material: A4K, Amunickel, Cryoperm10, e.t.c.

There is a trade-off between a shielding power and a weight. We perform the simulation with their all combinations in order to select the best configuration. The final design of the PMU magnetic shield must be determined with including an interface with other equipments.

3.3 Test of the magnetic shield

Simultaneously designing the magnetic shield by the simulation, we test the magnetic shield by an actual measurement. At first, we measure material propeties of the magnetic shield. The JMAG software does not include properties of magnetic shield materials for cryogenic temperature. Thus, it is necessary to input properties from material specifications and to adjust with a measurement. The measurement is performed in room temperature and cryogenic temperature using cryostat.

TES (100 mK cryostat) meets SMB (4 K cryostat) @IPMU

4 Summary

We describe the test plan for the magnetic field for the PMU. The JMAG electromagnetic simulation is employed to design and evaluate it. At first, the necessity of the magnetic shield is investigated with considering the detector magnetic shield and the magnetic circuit of the PMU magnet. Then, we design the magnetic shield by the simulation with several combinations of design parameters. The final design is determined by a trade-off study between the shielding power and the weight of the magnetic shield. Simultaneously, the comparison between a simulation and a measurement is performed using a small PMU prototype in order to test the designed magnetic shield.

Comments from Reviewers