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Development of a Spaceborne Hydrogen Maser

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1. Introduction

Japan has started a research and development project of Quasi-Zenith Satellite System (QZSS) in 2003, as explained elsewhere. The project will provide a regional satellite positioning service as well as communication and broadcasting services. QZSS is composed of three satellites, and will complement and augment GPS and carry Rb and/or Cs SV clock for satellite positioning service. The first satellite, which is planned to be launched in 2008, will also carry an active hydrogen maser to demonstrate the technology of Spaceborne H-Maser (SHM). The QZSS project is carried on by government and private sectors. Among the national institutions participating in the project, Communications Research Laboratory (CRL) is developing the SHM as well as the time transfer link between the satellite and master control station on the earth.

2. Development of SHM at CRL

In 1997 CRL has started the basic research on SHM. In early period of the research, we rigorously solved the Maxwell equation for the electromagnetic field in a sapphire loaded cavity. Based on the analysis, the design principle of a sapphire loaded cavity was established and a basic model of SHM was developed using the sapphire loaded cavity, which is shown in Fig.1. The magnetic sensitivity of the model is less than $2x10^{-14}$/Gauss, and the temperature sensitivity is $3x10^{-14}$/℃. Fig.2 shows the measured frequency stability.

When QZSS project started in 2003, CRL had the following engineering problems of SHM.

(1) Longer lifetime and higher reliability
(2) Better performance in space
(3) Further reduction in weight and size
(4) Higher proof against mechanical shock at launching

In order to overcome these problems, a Bread Board Model has been developed, of which structure is shown in Fig.3.

For longer lifetime, Non Evaporable

Fig.1 Basic Model of SHM

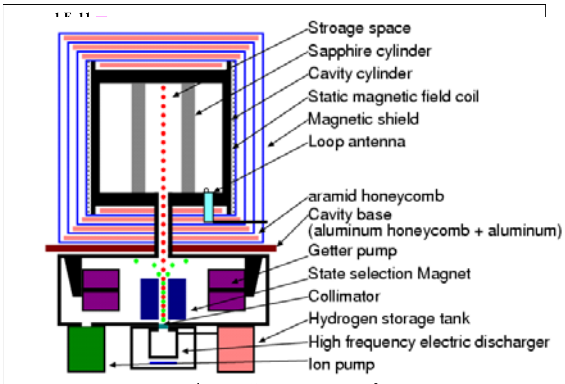

Fig.3 Structure of BBM

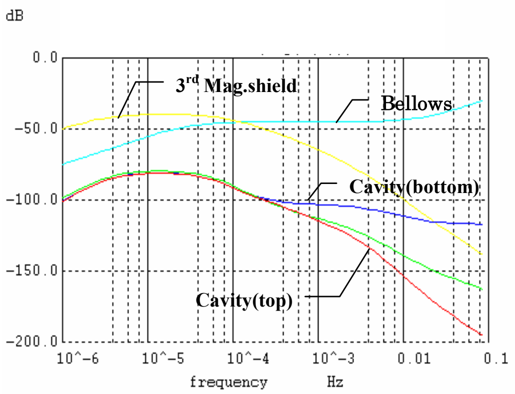

Fig.4 Suppression of ambient temperature change

Getter (NEG) Pump has been developed and the accelerated lifetime test has shown that 1kg NEG has the pumping capacity of hydrogen for ten years operation. NEG pump works without power and is highly reliable, but its surface can be saturated at room temperature by residual gas such as CO, N_2, O_2, and H_2O.Thus, for longer period operation, the residual gas other than H_2 must be minimized.

For better thermal insulation and mechanical strength, aramid honeycomb spacing plates are used between magnetic shields. MLI thermal blanket with low emissivity are also used to reduce the thermal radiation between magnetic shields. Fig.4 shows the results of a thermal simulation that the change in ambient temperature can be suppressed by 80db at the microwave cavity, which is better by one order magnitude than the performance of Basic Model.

Four coaxial magnetic shields give the shielding factor of 167,000. By using thin magnetic shields, the weight of physics package is greatly reduced. They are made of 0.5mm thick permalloy plates except the innermost shield which is 1mm thick. For further weight reduction, the microwave cavity which also serves as the vacuum envelope is adopted and a conventional vacuum bell-jar is not used. The current total weight of BBM is less than 50kg.

3. Future Schedule

Based on the results of BBM, engineering models will be developed and extensive qualification tests will be made such as vibration test, thermal vacuum tests, and EMI tests in 2004 and 2005. In 2006 and 2007, the flight model will be developed and integrated with the satellite. The flight model will be launched in 2008.