Development of the Receiving System for VSOP-2 Mission

Hiroshi NAGAI[1],
e-mail:nagai@hotaka.mtk.nao.ac.jp
Takashi KASUGA[2],
e-mail:kasuga_t@k.hosei.ac.jp
Masato TSUBOI[3],
e-mail:tsuboi@nro.nao.ac.jp
Yasuhiro MURATA[4],
e-mail:murata@vsop.isas.jaxa.jp
and VSOP-2 working group

1. Department of Astronomical Science, The Graduate University for Advanced Studies
Osawa 2-21-1, Mitaka, Tokyo 181-8588
2. The Department of System and Control Engineering, Hosei University
Kajino-cho 3-7-2, Koganei, Tokyo 184-8584
3. Nobeyama Radio Observatory, National Astronomical Observatory,
Minamimaki, Minamisaku, Nagano 384-1305, Japan
4. Japan Aerospace Exploration Agency/The Institute of Space and Astronautical Science
Yoshinodai 3-1-1, Sagamihara, Kanagawa 229-8510

1 Introduction

Very Long Baseline Interferometry (VLBI) is the powerful technique for imaging astronomical sources with high angular resolution. In VLBI observation, widely separated radio telescopes observe astronomical radio sources simultaneously, and the radio signals are recorded to the magnetic tapes at each telescope station. Then the recorded data is combined at a correlator. Using this technique, the angular resolution is attainable λ/D where λ is wavelength and D is the maximum baseline length between two radio telescopes. Hence a VLBI array with one telescope on the earth-orbiting space craft can break through the maximum attainable resolution on the ground VLBI array, this is called 'Space VLBI'.
The first space VLBI experiment has been demonstrated with a Tracking and Data Relay Satellite System (TDRSS) communication satellite. The feasibility of space VLBI technique has confirmed by series of experiments using 2-3 ground telescopes and 4.9 m antenna of TDRSS satellite at 2.3 and 15 GHz between 1986-1988 (e.g., Linfield et al. 1988, 1989).
In 1997, the first space VLBI mission VSOP (Hirabayshi et al. 1998, 2000), based on the HALCA satellite launched by ISAS/JAXA, demonstrated the technical capability for imaging astronomical radio sources with interferometric technique using space-ground baselines at 1.6 and 5 GHz. VSOP has aimed high angular resolution imaging of Active Galactic Nuclei (AGN), and has been providing various new aspects.
Following the success of VSOP, the second-generation space VLBI mission 'VSOP-2' is planned to be launched in 2011 (Hirabayashi et al. 2001, 2004a, 2004b).

2 Overview of VSOP-2

Figure 1 shows the current design of VSOP-2 satellite. Radio signal from the source is reflected by the 9-m offset cassegrain type antenna, 1.1-m sub-reflector, and then lead into the main body, which contains on-board radio astronomy observing system. The signal is amplified and down converted, then digitized, and finally transmitted to the ground link antenna. The detail description of satellite design is presented in related paper Hirabayashi et al. and Edwards et al. (session J).

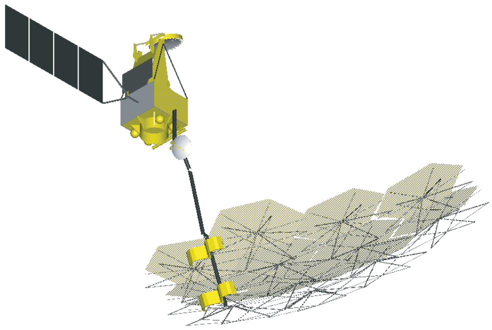

Figure 1: A schematic view of VSOP-2 satellite.

Table 1 shows the comparison of the capability between HALCA and VSOP-2 satellite. VSOP-2 increases its resolution and sensitivity to detect radio sources 10 times larger than those of VSOP, and make it possible to investigate the polarized emission structure of radio sources.
The scientific objectives are investigating the acceleration mechanism and collimation mechanism of AGN jets, accretion mechanism onto the super massive black hole in the center of AGN, magnetosphere of young stellar objects, and so on. The detail description of scientific objectives is presented in related paper Kameno et al. (session J).

	HALCA	VSOP-2
maximum resolution	0.45 m arcsec	38 μ arcsec
sensitivity	300 mJy/beam	11 mJy/beam
frequency	1.6, 5 GHz	8, 22, 43 GHz
downlink rate	128 Mbps	1 Gbps
polarization	LHCP	LHCP&RHCP
antenna diameter	8 m	9 m
perigee	21400 km	25000 km
apogee	560 km	1000 km

Table 1: Characteristics of HALCA and VSOP-2 satellite

3 The Design of VSOP-2 Receiving System

3.1 Overview of Receiving System

Figure 2(a) shows the schematic view of the receiving system. At 22 and 43 GHz, the radio signal led from the horn is converted to right and left hand circular polarization (RHCP/LHCP) using orthogonal mode transducer (OMT) and circular polarizer. Each polarization signal is amplified by low noise amplifier (LNA) separately, and then down converted to the intermediate frequency. On the other hand, 8 GHz signal is divided to two orthogonal linear polarizations, each polarization signal is amplified, and then combined RHCP and LHCP. As we describe later in next subsection, 8 GHz receivers will not be cooled. Hence the additional noise at 8 GHz is more significant than that at 22 and 43 GHz. However this configuration is free from the polarizer, we can reduce the additional noise about 20%.

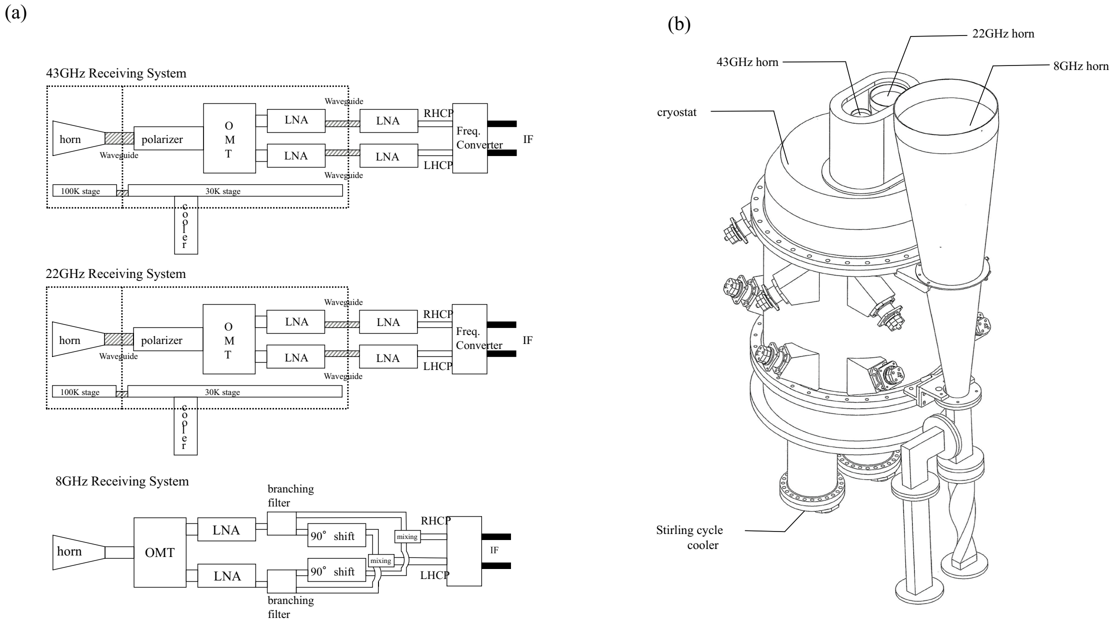

Figure 2: (a) The design of receiving system of VSOP-2 satellite. (b)A outside view of cryostat and the location of receiving system at each frequency

3.2 Cooler

While the receiving system of HALCA is not operated in cooled condition, that of VSOP-2 satellite is planned to be cooled to reduce the noise temperature for 22 and 43 GHz bands. It is one of the key developments how we cool the receiving system with the weight limit on satellite, power supply from the satellite system, and severe thermal condition on the orbit. Our goal of the total system noise temperature is 60, 30, and 40 K at 8, 22, and 43 GHz, respectively.
At 22 and 43 GHz, feed horns are cryogenically cooled about 100 K, and polarizers and LNAs are cooled to about 30 K by two Stirling cycle cryogenic coolers, which are developed for Astro-F mission (Infrared astronomy) in JAXA (see Figure 2(b)). Taking into account of the heat generation of LNAs, heat inflow from the outside, and radiation from the sun, we confirmed that feed horns can be cooled to about 110 K and polarizers and LNAs to below 30 K by the simulation. Because of the capability of cooler arise from the limitation of power supply and weight on the satellite, 8 GHz receiver will not be cooled.

3.3 LNA

The high electron mobility transistor (HEMT) amplifiers are planed to be used for the LNAs. We developed a 43 GHz GaAs MMIC cooled receiver using commercial MMIC LSI (Figure 3). The noise temperature of this LNA achieves about 40 K at 30 K physical temperature. With this LNA, we prospect the total system noise temperature of 70 K at 43 GHz. We are also developing the InP HEMT amplifiers to aim lower noise and lower power consumption.

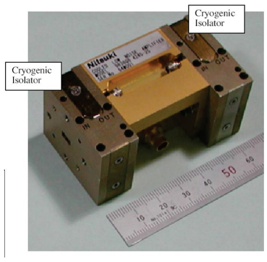

Figure 3: A GaAs MMIC cooled receiver developed for 43 GH.

3.4 Low Heat Conductance Wave Guide

Because the receiving systems at 22 and 43 GHz are operated in cooled condition, waveguides (shown by shaded parts in Figure 2) have to be insulated to keep out the heat. We are developing the circular waveguides made of glass fiber reinforced polymer (GFRP), whose inner side is coated by thin gold layer (Figure 4). The mechanical and electrical characteristics and heat conductance are now being measured in cooled condition.

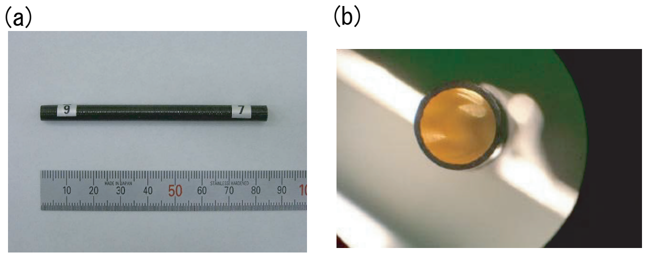

Figure 4: (a)A outside view and (b) inner view of a prototype of low heat conductance waveguide.

4 Summary

We are now developing the receiving system of VSOP-2 satellite, which is second generation space VLBI mission. VSOP-2 satellite will upgrade to (1) cooled receiving system, (2) higher frequency (43 GHz) observation, (3) dual polarization observation, and so on. Although these items are technically challenging, we are progressing to solve them and realize this mission.

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