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Development of a Compact VLBI System for Providing over 10-km Baseline Calibration

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Abstract. We are developing a compact VLBI system with 1.6 m diameter aperture antenna in order to provide reference baseline lengths for calibration. The reference baselines are used to validate surveying instruments such as GPS and EDM and maintained by the Geographical Survey Institute (GSI). The VLBI system is designed to be assembled with muscle power simply in order to perform short-term (about one week) measurements at several reference baselines in Japan islands. We have evaluated a front-end system with a wide-band quad-ridged horn antenna by installing it on the 2.4 m diameter antenna at Kashima. On Dec. 5, 2007 we have successfully detected fringes of the 3C84 signal for S/X band. In addition, a geodetic VLBI experiment using a LD-pumped cesium gas-cell atomic frequency standard was successful.

1. Introduction

National Institute of Information and Communication Technology (NICT) are developing a compact VLBI system with 1.6 m diameter aperture antenna in collaboration with GSI. GSI has the responsibility to calibrate and validate survey instruments such as GPS receivers and Electro-Optical Distance Meters (EDM). The validation work is operationally carried out at a 10 km reference baseline maintained by GSI, which is located about 5 km east of GSI headquarters, Tsukuba, Japan (Fig. 1).

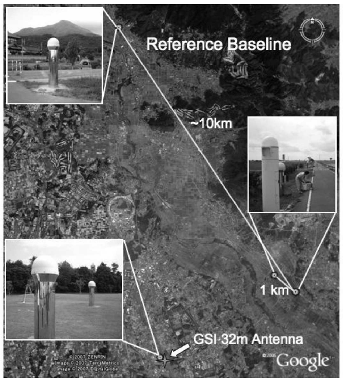


Figure 1. GSI reference baseline

Along the baseline, pillar monuments made of stainless steel are installed. To guarantee the quality of validation, the baseline length has to be evaluated routinely. In addition, GSI compares an operational EDM equipment and a iodine-stabilized He-Ne laser wavelength standard in order to keep its traceability for length to a national standard maintained by the National Institute of Advanced Industrial Science and Technology (AIST).

However, since it is too long to get a line of sight from the end to the other end by EDM at the actual reference baseline, calibration works at present are only performed at the shorter baseline in stead of a measurement of the entire 10 km length.

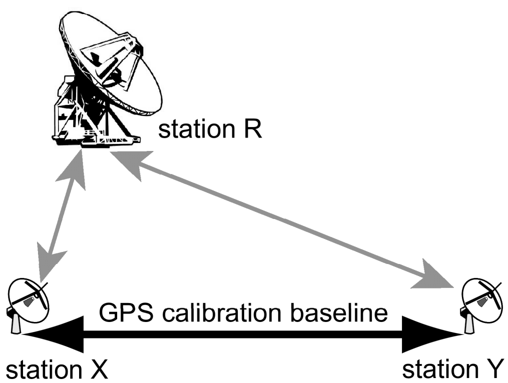


Figure 2. MARBLE concept

On the other hand, the geodetic VLBI technique can give an independent measurement to examine the baseline with a few millimeter accuracy using the hydrogen-maser. Moreover, the hydrogen-maser frequency standard can be considered as the traceable technique to the national standard. Thus, we started to develop a compact VLBI system with 1.6 m diameter aperture antenna in order to measure the accurate length of the reference baseline.

In this short article, we describe the technical requirements, system concept, and feasibility study of the VLBI system dedicated to 10 km measurement.

2. Development

2.1. MARBLE System

The compact VLBI system will be installed at both ends of the reference baseline in order to perform baseline calibration. However, it is too insensitive to detect fringes between both stations using such compact antenna. Thus, we have designed a new observation concept which includes one large antenna station into the baseline observation. The schematic image of the new concept is shown in Fig. 2.

We can detect two group delays between each compact antenna and the large one based on conventional VLBI measurements. A group delay between the two compact antennas, ΔXY, can be indirectly calculated using the simple equation

$$\Delta XY = \Delta RY - \Delta RX, \tag{1}$$

where ΔRX and ΔRY are two group delays obtained conventionally (Fig. 2). We named the idea Multiple Antenna Radio-interferometry of Baseline Length Evaluation (MARBLE).

2.2. Compact VLBI System

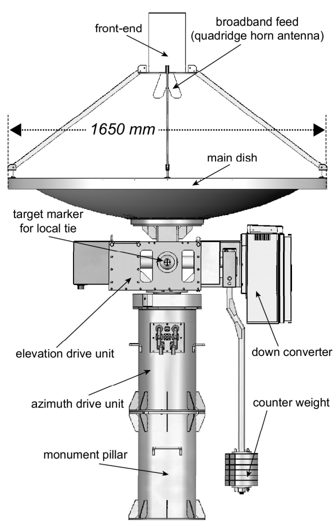


Figure 3. Schematic image of the MARBLE compact VLBI system

The core equipment of the MARBLE system is the compact VLBI system as described so far. To perform short-term (about one week) measurements at several reference baselines in Japan islands, the most important idea in developing the VLBI system is transportability.

The VLBI system consists of a 1.6 m diameter aperture antenna with a broadband feed, an azimuth drive unit, an elevation drive unit, an IF downconverter unit, an antenna control unit (ACU), a counterweight, and a monument pillar (Fig. 3). Each drive unit is equipped with a zero-backlash harmonic drive gearing component. These are designed to be assembled with muscle power simply.

3. Experiments

3.1. Geodetic VLBI Experiment using LD-pumped Cesium Gas-cell Atomic Frequency Standard

A portable and stable frequency standard is desirable to carry out the field VLBI measurements using the MARBLE compact VLBI system. In addition, it is also important that such frequency standard is easy to handle under a rough temperature control. To prepare a hydrogen-maser frequency standard and a thermostatic chamber at both ends of the reference baseline is not practical. One of the possibilities to resolve this problem is to use an LD-pumped cesium gas-cell atomic frequency standard (hereafter, we call this "CS gas-cell standard") made by Anritsu [1].

Figure 4. LD-pumped cesium gas-cell atomic frequency standard

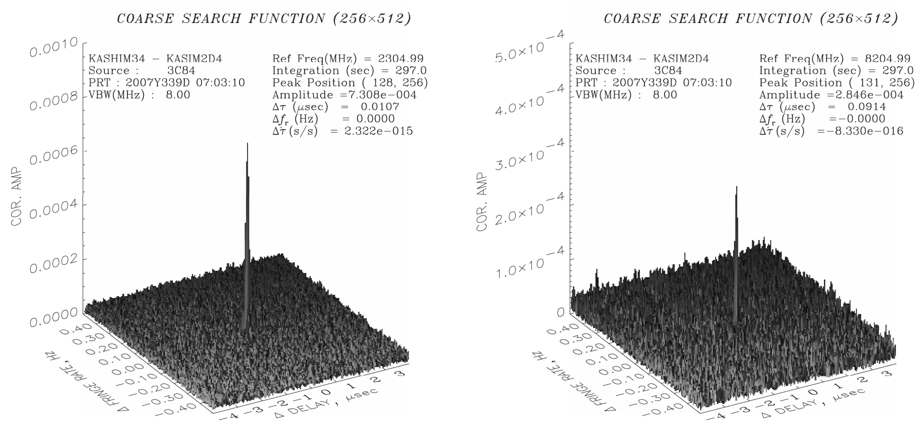
We carried out a VLBI experiment between Kashima 34 m and Koganei 11 m on Jul. 19, 2007 in order to evaluate the CS gas-cell standard in the geodetic VLBI measurements. At Koganei we used a hydrogen-maser frequency standard. On the other hand, at Kashima we installed the CS gas-cell standard in place of the hydrogen-maser one. The analyzed baseline length is well consistent with those obtained by previous VLBI measurements using the conventional way (Tabl. 1).

Table 1. Results of experiments. In the first column of the table, 'H' and 'Cs' denote the use of a hydrogen-maser frequency standard and a CS gas-cell standard, respectively

date	WRMS residual, ps	baseline vector, mm	sigma, mm		
			length	horizontal	vertical
2007.06.15 (H)	32	109337424.10 ± 1.17	1.17	0.76	4.82
2007.06.17 (H)	29	109337422.26 ± 1.00	1.00	0.67	4.09
2007.06.20 (H)	37	109337421.45 ± 0.76	0.76	0.51	3.12
2007.07.19 (Cs)	39	109337422.58 ± 1.26	1.26	0.92	5.14

3.2. First Fringe Test using Broadband Feed

We developed a new front-end system for the MARBLE compact VLBI system. For geodetic purposes, the S/X dual-band frequency receiver is indispensable in order to calibrate ionospheric path delay error. We use a broadband dual-polarized quad-ridge horn antenna (type 3164-05 ranging 2 GHz–18 GHz [2]) made by ETS-Lindgren within the present front-end system. We installed the new front-end system on the 2.4 m diameter antenna at Kashima and we have successfully detected fringes of the 3C84 signal for both S and X bands on Dec. 5, 2007 (Fig. 5).



S-band X-band

Figure 5. Detected first fringes using broadband feed

4. Concluding Remarks

We are developing a compact VLBI system with 1.6 m diameter aperture antenna in order to provide reference baseline lengths for GPS and EDM calibration maintained by GSI. We successfully detected fringes of the 3C84 signal for both S and X bands using the new front-end system with a wide-band quad-ridged horn antenna by installing it on the 2.4 m diameter antenna at Kashima. In addition, a geodetic VLBI experiment using an LD-pumped cesium gas-cell atomic frequency standard provided a consistent baseline length with the previous results obtained using a hydrogen maser frequency standard.

References

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[2] Lindgren, ETS-Lindgren, The Model 3164-05 Open Boundary Quadridge Horn, Data Sheet, 2005.