NICT Technology Development Center 2015+2016 Biennial Report

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Abstract The National Institute of Information and Communications Technology (NICT) is developing and testing VLBI technologies and conducts observations with this new equipment. This report gives an overview of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1 NICT as IVS-TDC and Staff Members

The National Institute of Information and Communications Technology (NICT) publishes the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" at least once a year in order to inform about the development of VLBI related technology as an IVS Technology Development Center. The newsletter is available at the following URL `http://www2.nict.go.jp/sts/stmg/ivstdc/news-index.html`. Table 1 lists the staff members at NICT who are contributing to the Technology Development Center.

Table 1 Staff members of NICT TDC as of January 2017 (listed alphabetically).

HASEGAWA, Shingo	KAWAI, Eiji
KONDO, Tetsuro	KOYAMA, Yasuhiro
MIYAUCHI, Yuka	SEKIDO, Mamoru
TAKEFUJI, Kazuhiro	TSUTSUMI, Masanori
UJIHARA, Hideki	

2 General Information

We have not only been developing a broadband VLBI system called GALA-V, which has to meet the VGOS (VLBI Global Observing System) requirements, but also upgrading Cassegrain optics antennas such as our 34-m radio telescope and compact telescopes for the project of Time and Frequency transfer. The distinguishing features of GALA-V are that we apply a direct sampler called K6/GALAS and broadband feed horns called IGUANA and NINJA.

Until now, we have installed two compact antennas (MARBLE1 and MARBLE2) at the National Metrology Institute of Japan (NMIJ) in Tsukuba, Ibaraki and the NICT headquarters in Koganei, Tokyo for the purpose of time and frequency (T&F) comparison between NICT and NMIJ. Both NICT and NMIJ keep the national time standard UTC(NICT) and UTC(NMIJ). We observed several VLBI sessions with the broadband system for the time and frequency comparison. Moreover, broadband sessions with other institutes, GSI and Tasmania University, were observed in 2015 and 2016.

3 Direct Sampler K6/GALAS

The specifications of the direct sampler K6/GALAS [1] are shown in Table 2 (see [1] for the evaluation). With deployment of the K6/GALAS, the front and backend systems have become quite simple. Firstly, an RF signal is divided into a lower 8-GHz range and an

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upper 8-GHz range, which will cover the whole frequency allocation of VGOS. Because the RF signal is directly digitized without analog frequency conversion, the phase differences between the output channels are fixed at the sampling stage. Thus, highly precise delays can be derived after broadband bandwidth synthesis.

Table 2 Specifications of the direct sampler K6/GALAS.

Frequency range	0.01 to 24 GHz
Number of analog inputs	2
Sampling rate	16384 or 12800 MHz
Quantization	3 bit
DBBC	1GHz bandwidth, 2 bit, 4 streams
10GbE protocol	VDIF / VTP/ UDP / IP

4 Development of Wideband Feeds

New wideband feeds developed at NICT were installed at the Kashima 34-m antenna and the MARBLE VLBI station at Koganei, Tokyo as shown in Figures 1 and 2. These feeds were named NINJA because of their beam widths' flexible designs. The beam widths are 17 degrees for the 34-m, from the center of the sub-reflector to the edge, and 26 degrees for the new optics of the MARBLE 2.4-m. MARBLE was upgraded to a 2.4-m dish with Cassegrain optics to improve its sensitivity.

The NINJA feed has a sensitivity from 3.2 to 14.4 GHz in frequency with newly developed OMT. The project GALA-V uses 3.2–4.8 GHz, 4.8–6.4 GHz, 9.6–11.2 GHz, and 12.8–14.4 GHz simultaneously for our time and frequency transfer project. Moreover, a simultaneous astronomical observation of 6.7 GHz and 12.2 GHz methanol maser and other wide-band applications are possible.

The measured modified system temperature (Tsys) and aperture efficiency for each antenna are shown in Figures 3 and 4.

5 Wideband Bandwidth Synthesis

An algorithm for wideband bandwidth synthesis (WBWS) exceeding a bandwidth of 10 GHz has been developed [3]. The estimation of the differential total electron content (TEC) in the ionosphere is also included in the algorithm. The new algorithm was implemented in our bandwidth synthesizing software package KOMB [2] and successfully applied to 24-hour wideband observations of the Kashima–Ishioka baseline (Figure 5). The baseline length of about 50 km is considered to be a bit too short to detect the differential TEC; however, we could detect it successfully.

6 Wideband Bandwidth VLBI

We observed a broadband VLBI session with the Ishioka station and the Hobart station in 2016. Figure 6 shows the cross-spectrum on the baseline of Ishioka and MARBLE2. The flat phase on the figure indicates that every bandwidth was corrected successfully by WBWS processing with four 1 GHz bandwidths (5.4, 6.5, 8.2, and 10.1 GHz). After WBWS processing, the delay error of the synthesized band was improved, 14 times better than that of the single band of 5.4 GHz.

The first trans-Pacific broadband VLBI (multiple 1 GHz bandwidths) observations were made with the Hobart 12-m antenna in Tasmania, Australia and with the Ishioka 13-m and Kashima 34-m antennas in Ibaraki, Japan on August 9, 2016. The main goal of the session was to get the first fringes and obtain an ionosphere effect in a broadband result. Figure 7 shows the WBWS result without TEC correction, and the quadratic curvature in the cross-spectrum phase shows the ionosphere effect. Under the condition that a baseline is a few hundreds of kilometers long, it is difficult to obtain a TEC effect; however, with the longer baseline shown, the TEC effect appears clearly.

References

1. K.Takefuji, "Performance of Direct Sampler K6/GALAS", IVS NICT-TDC News 36, pp.20-22, 2016, `http://www2.nict.go.jp/sts/stmg/ivstdc/news_36/pdf/tdcnews_36.pdf`
2. T. Kondo, M. Sekido, and H. Kiuchi, KSP bandwidth synthesizing software, *J. Commun. Res. Lab., Vol.46*, pp.67–76, 1999.
3. T. Kondo and K. Takefuji, An algorithm of wideband bandwidth synthesis for geodetic VLBI, *Radio Sci., Vol. 51*, doi:10.1002/2016RS006070, 2016.

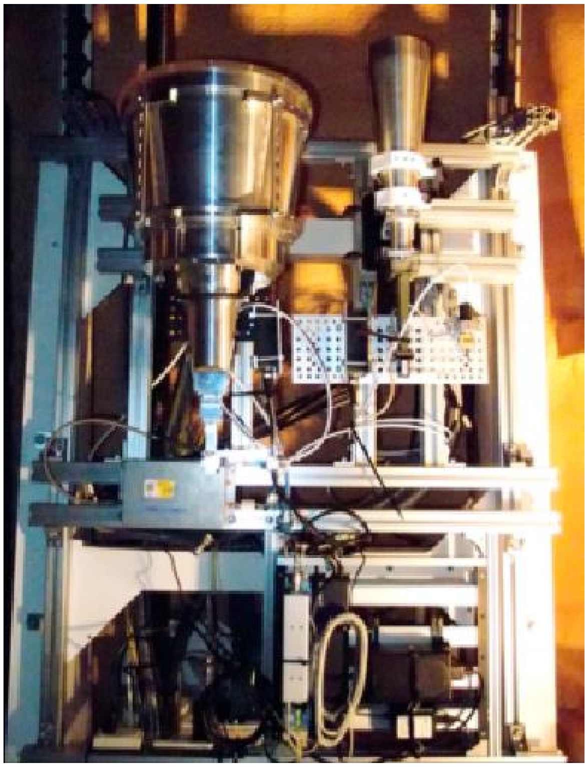

Fig. 1 NINJA feed (left) and IGUANA feed (right) in the feed cone of the Kashima 34-m antenna.

Fig. 2 Renewed MARBLE with 2.4-m dish and the NINJA feed.

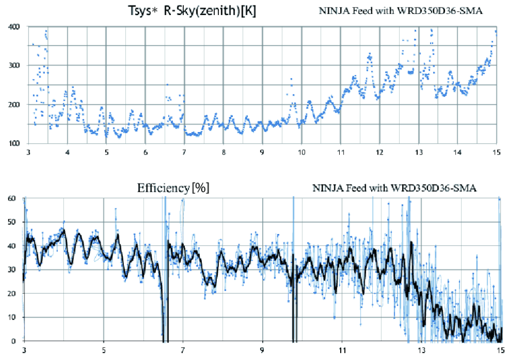

Fig. 3 Measurement of the modified system temperature and the aperture efficiency of the Kashima 34-m antenna with the NINJA feed.

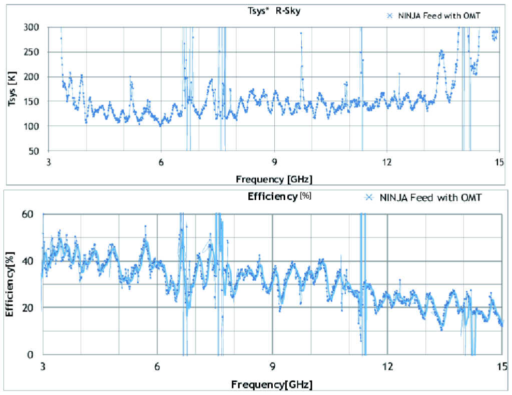

Fig. 4 Measurement of the modified system temperature and the aperture efficiency of the renewed MARBLE2 with the NINJA feed.

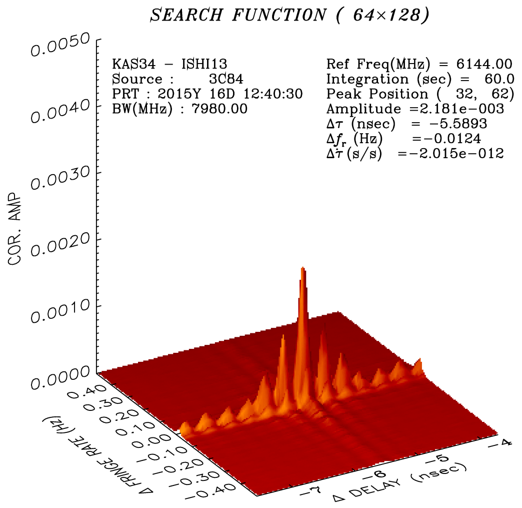

Fig. 5 An example of the fringe search function (source: 3C84, date: Jan.16, 2015).

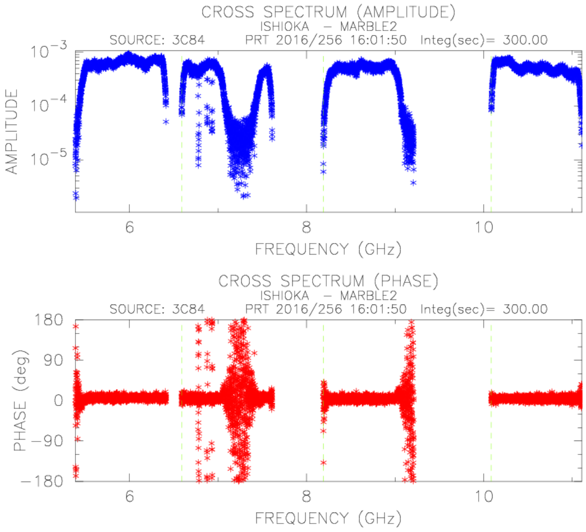

Fig. 6 Wide bandwidth synthesis was performed on the baseline between Ishioka and MARBLE2.

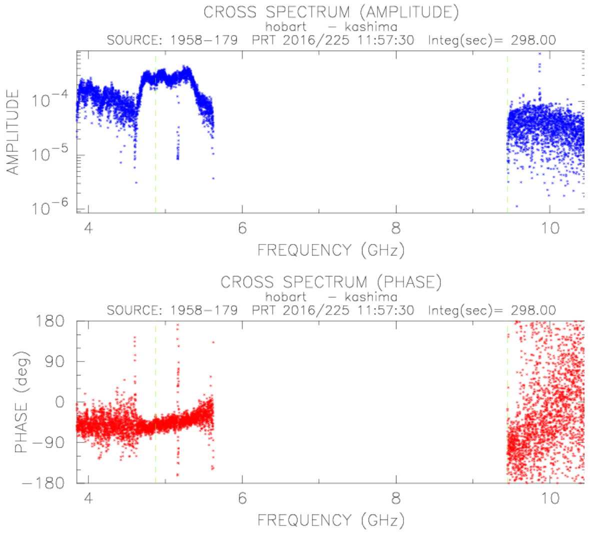

Fig. 7 The contribution of the ionosperic effect appears on the cross-spectrum of the Hobart12–Kashim34 baseline.