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 a 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.

2 General Information

We have been developing a broadband VLBI system called GALA-V, which has not only to meet the VGOS (VLBI2010 Global Observing System) requirements, but also upgrading cassegrain optics antenna such as our 34 m ratio telescope and compact telescopes for the project of Time and Frequency transfer. Distinguishing features of GALA-V, we apply a direct sampler called K6/GALAS and broadband feed horns called IGUANA, and NINJA.

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Table 1 Staff Members of NICT TDC as of January, 2017 (alphabetical).

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

Until now, we have installed two compact antennas (MARBLE1 and MARBLE2) in National Metrology Institute of Japan (NMIJ) in Tsukuba, Ibaraki and NICT headquarter in Koganei, Tokyo for a 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 made several VLBI sessions with the broadband system for the time and frequency comparison. Moreover, the broadband session with other institutes GSI and Tasmania university were carried out in 2015 and 2016.

3 Direct sampler K6/GALAS

The specification of the direct sampler K6/GALAS[1] is shown in table 3 (see [1] for the evaluation). With deploying the K6/GALAS, the front and back-end system has become quite simple. Firstly, RF signal is divides to lower 8 GHz range and upper 8 GHz range, which will covers the whole frequency allocation of VGOS. Because RF signal is directly digitized without analog frequency conversion, the phase differences between the output channels are fixed at sampling stage. Thus, highly precise delay can be derived after broadband bandwidth synthesis.

Frequency range	0.01 to 24 GHz
Number of analog input	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 in NICT were installed Kashima 34 m antenna and MARBLE VLBI station placed in Koganei, Tokyo is shown in figures 1, 2. These feeds were named NINJA because of their flexible designs of their beam width. The beam width for the 34 m is 17 degrees, 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 2.4 m dish of cassegrain optics to improve its sensitivity.

NINJA feed has a sensitivity from 3.2 to 14.4 GHz in frequency with newly developed OMT. The project GALA-V uses 3.2-4.8GHz, 4.8-6.4GHz, 9.6GHz-11.2GHz and 12.8GHz-14.4GHz 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.

Measured modified system temperature (Tsys*) and aperture efficiency for each antennas are shown in figures, 3 and 4.

5 Widband Bandwidth Synthesis

An algorithm for wideband bandwidth synthesis (WBWS) exceeding a band width 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 implemeted in our bandwidth synthesizing software package KOMB[2] and successfully applied to 24-hour wideband observation carried out on the Kashima-Ishioka baseline (Fig.5). The baseline length of about 50 km is considered to be a bit short to detect the differential TEC, however we could detect it successufully.

6 Widband Bandwidth VLBI

We carried out a broad band VLBI toward Ishioka station and Hobart station in 2016. Figure 6 shows the cross-spectrum on the baseline of Ishioka and MARBLE2. The flat phase on the figure indicates every bandwidth were corrected successfully in WBWS processing with four 1 GHz bandwidth (5.4, 6.5, 8.2 and 10.1 GHz). After WBWS, the delay error of 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 bandwidth) was carried out VLBI observations on the Hobart 12 m antenna in Tasmania, Australia, with the Ishioka13 m and Kashima 34 m antennas in Ibaraki, Japan on 9 August, 2016. The main goal of the session was to get a first fringe and obtain an ionosphere effect in broadband result. Figure 7 shows the WBWS result without TEC correction and the quadratic curvature on cross-spectrum phase shows the ionosphere effect. On the condition that within a few hundred of kilometer, it is difficult to obtain TEC effect, however on the longer baseline the TEC effect appeared 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.

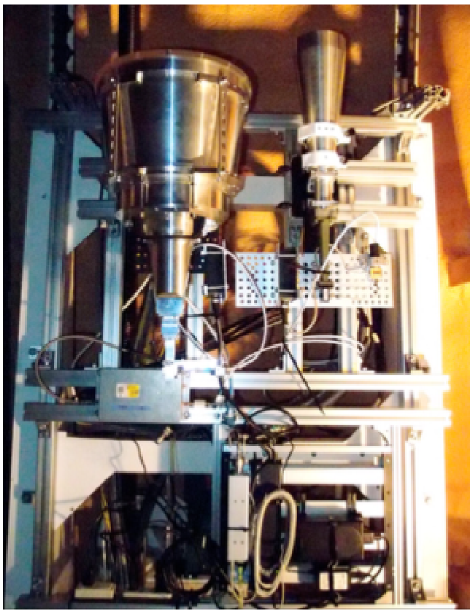

Fig. 1 NINJA Feed(left) and IGUANA feed(right) in the feed cone of Kashima 34m antenna

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

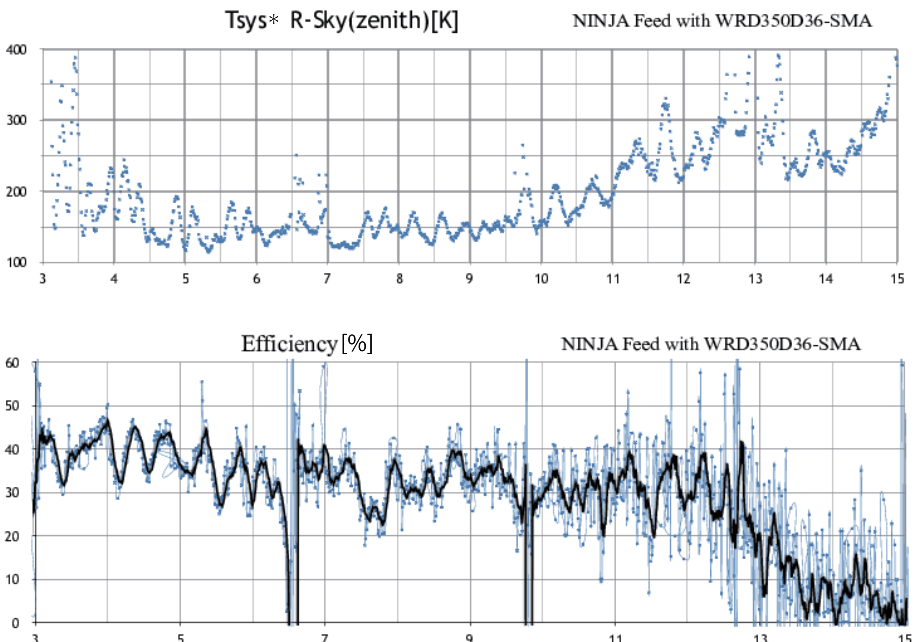

Fig. 3 Measurement of the modified system temperature and the aperture efficiency of Kashima 34m antenna with the NINJA feed

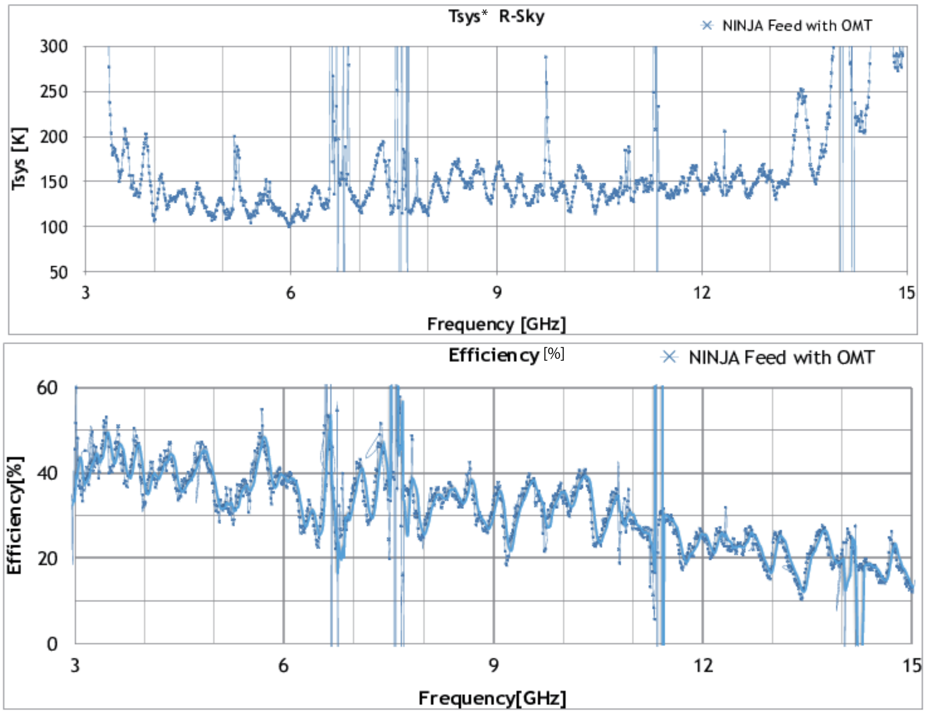

Fig. 4 Measurement of the modified system temperature and the aperture efficiency of renewed MARBLE2 with the NINJA feed

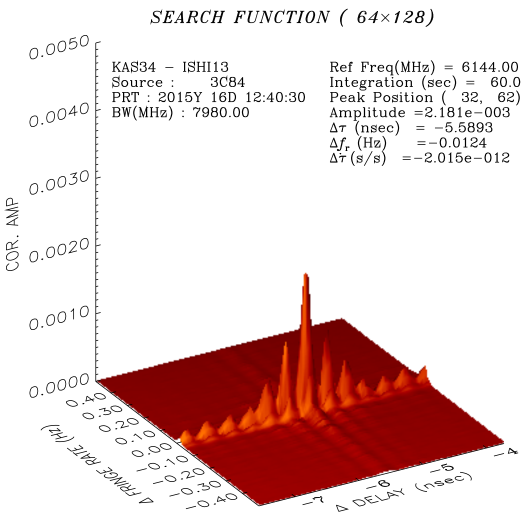

Fig. 5 An example of the fringe search function (source: 3C84, date: Jan.16, 2015)

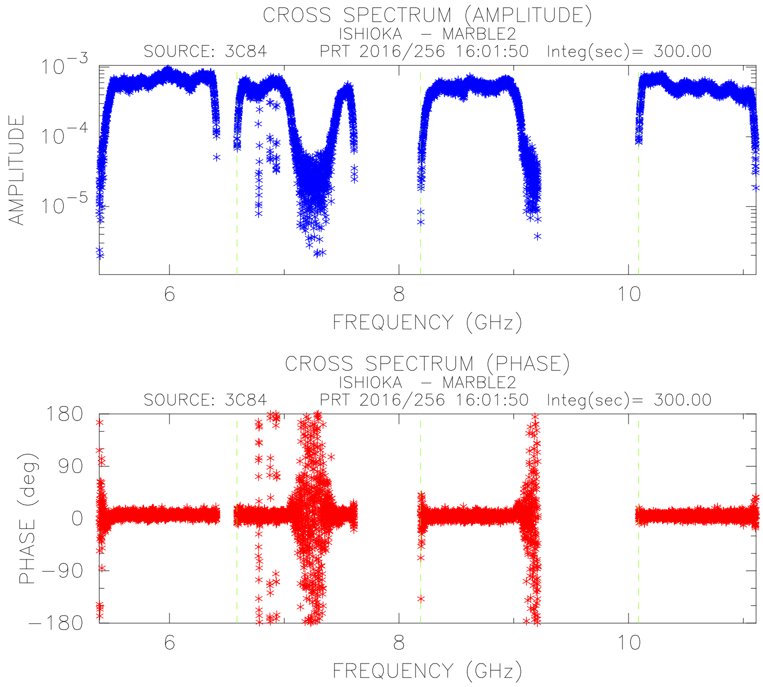

Fig. 6 Wide bandwidth synthesis was performed on the baseline of Ishioka and MARBLE2

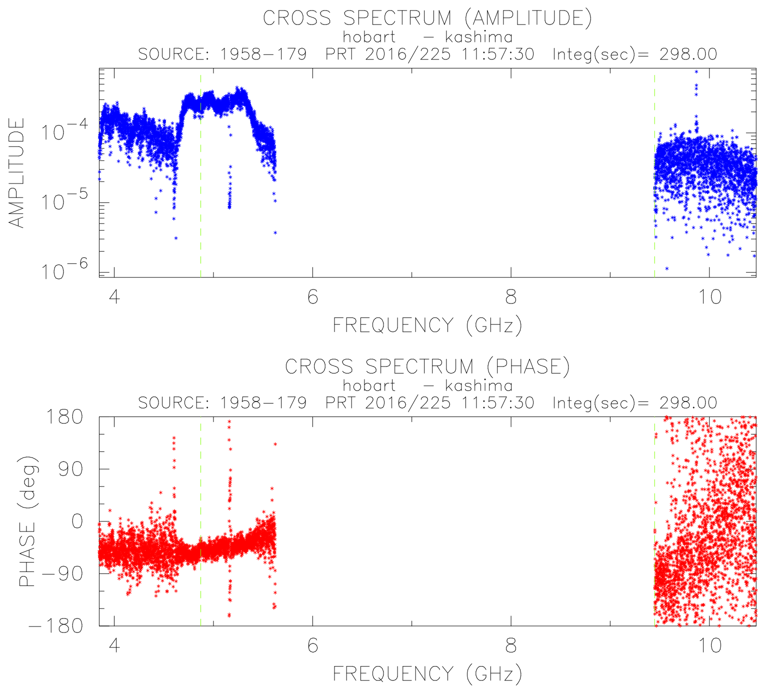

Fig. 7 The contribution of ionosperic effect is appeared on the cross-spectrum on Hobart12 and Kashim34 baseline