Technology Development Center at NICT

Kazuhiro Takefuji, Hideki Ujihara

Abstract

The National Institute of Information and Communications Technology (NICT) has led a development of the VLBI technique and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1. NICT as an IVS-TDC and Staff Members

The National Institute of Information and Communications Technology (NICT) has published a newsletter, "IVS NICT-TDC News (former IVS CRL-TDC News)", at least once a year in order to inform readers about NICT's development of VLBI-related technology as an IVS Technology Development Center. The newsletter is available at the following URL: **http://www2.nict.go.jp/w/w114/stmg/ivstdc/news-index.html**. Table 1 lists the staff members at NICT who are involved in the VLBI Technology Development Center at NICT.

Table 1. Staff Members of NICT TDC as of January 2012 (alphabetical).

AMAGAI, Jun	HASEGAWA, Shingo	HOBIGER, Thomas	ICHIKAWA, Ryuichi
KAWAI, Eiji	KONDO, Tetsuro	KOYAMA, Yasuhiro	MIYAUCHI, Yuka
SEKIDO, Mamoru	TAKEFUJI, Kazuhiro	TSUTSUMI, Masanori	UJIHARA, Hideki

2. Current Status and Activities

2.1. RF Direct Sampling System for Geodetic VLBI

We have carried out a test VLBI experiment by using a so-called "RF direct sampling" technique. In a conventional VLBI system, RF signals are converted to IF band signals, then converted to baseband signals using an analog baseband converter, then sampled and converted to digital signals. IF signals travel a few hundred meters down a coaxial cable or an optical cable; so temperature variations will affect the cable and change the internal group delay. Phase calibration, which inserts 1 or 5 MHz step comb signals in frequency before a low noise amplifier, will compensate for this group delay. However, if RF signals are sampled just after the low noise amplifier, a phase calibration system is not necessary. Recently it became possible to sample IF signals directly due to progress of the sampling device, and then a digital baseband converter, like ADS3000+ [1], was developed. Now some sampling devices have a wider input frequency bandwidth – more than 10 GHz. If RF signals such as 8 GHz band signals can be sampled directly, an IF converter is omissible from the receiving system. This will reduce the cost of the system associated with the converter and will increase the reliability of the system. ADX-831, developed by the ELECS INDUSTRY CO. LTD., is a sampler that has an input band width of 10 GHz.

We have carried out a test VLBI observation with ADX-831 to evaluate the feasibility of the RF direct sampling VLBI. The RF direct sampling system was installed at the Tsukuba 32-m and Kashima 11-m antennas. Figure 1 shows a system block diagram. The RF direct sampling has sampling modes of 2bit-1024Msps. According to the Nyquist theorem, it needs 18 GHz speed to record X-band (9 GHz) signal. However since the X-band bandwidth is around 1 GHz, a 1024 MHz sampling speed (under sampling of digital technique) was almost enough. The signal after 1024 MHz sampling (0 to 512 MHz) is exactly the same as the band-filtered signal (8192 to 8704 MHz). It acts like a "digital" base band converter. High order sampling is mainly used for filtered band; then the sampled band can be reconstructed to the original. But an anti-alias filter was not inserted before the sampler in this case, so other folded signals from out of band ($\leq$ 8192 MHz and $\geq$ 8704 MHz) will overlap. The overlapped signal will make noise (system temperature) increase, reducing the fringe amplitude. But we could detect fringes of overlapped signals with difference of fringe rotation (Figure 2). So we think that the reduced fringe amplitude will be canceled after bandwidth synthesis. This technique is named "DSAMS" (Direct Sampling Applied for Mixed Signals). DSAMS was also adopted to S/X band which were connected after LNA in RF frequency. Figure 3 shows synthesized S and X-band and their fringes [2].

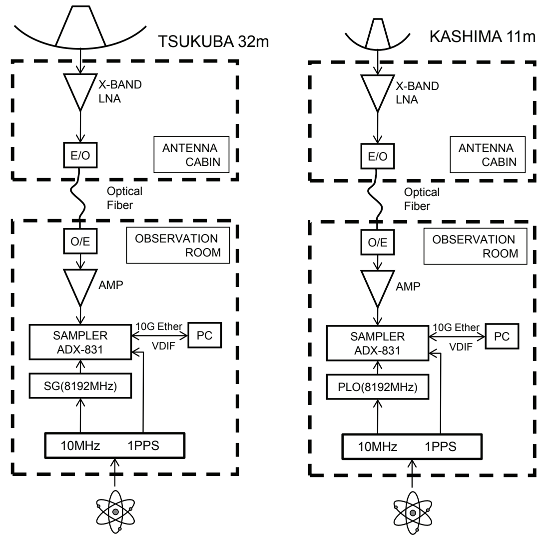


Figure 1. A system block diagram. RF direct sampling was operated at Kashima 11-m and Tsukuba 32-m.

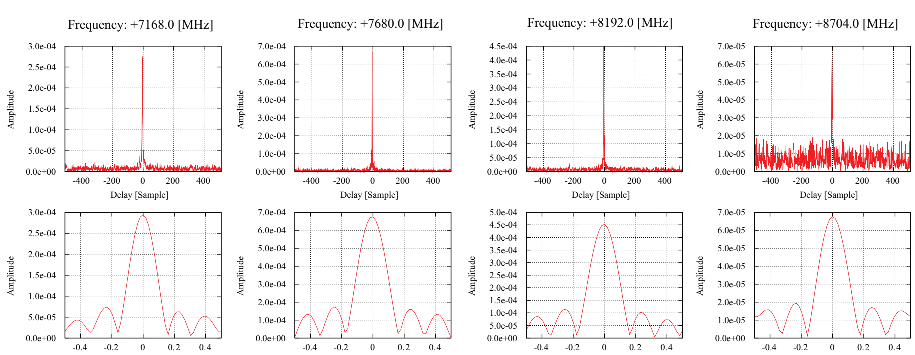


Figure 2. First fringes for DSAMS (Direct Sampling Applied for Mixed Signals) applied for X-band VLBI. The sampling mode of ADX-831 is 2bit-1024Msps. All four X-band fringes were simultaneously obtained with just one sampler.

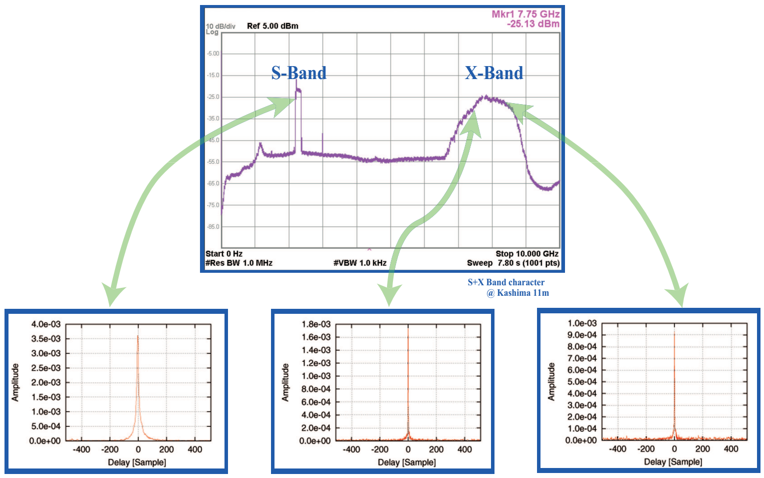


Figure 3. First fringe of DSAMS (Direct sampling applied for mixed signals) applied for geodetic VLBI. The sampling mode of ADX-831 is 2bit-1024Msps. Fringes of S-band and X-band were simultaneously obtained with only one sampler.

3. Development of Wide Band Feeds

Wideband feeds are being developed at NICT, NAOJ, and other Japanese universities for VLBI2010, SKA, and MARBLE. SKA is an international radio astronomy project for constructing the Square Kilometer Array. MARBLE is a small portable VLBI station developed by NICT and GSI in Japan. They all need wideband feed with a 1:10 or more frequency ratio.

We are now studying Arrayed Travel Wave Antennas (Arrayed TWA) with dual linear polarization for them, which is shown in Figure 4. Several elemental feeds were tested, and their beam patterns were measured at MET-LAB at Kyoto University in 2011. Grading robes are clearly seen [Figure 5], because of the lack of a central feed element, which was not yet placed properly. Also, numerical simulations were carried out with COMSOL for the feed elements [Figure 6]. The element size is $(L = 280mm) \times (W = 120mm) \times (t = 1mm)$, and the relative permitivity of the dielectric substrate is tested on $\epsilon_r = 1, 2.2, 4, 10$. We are now planning to assemble the elements into an Arrayed TWA for evaluation of beam shaping before installing it on the MARBLE.

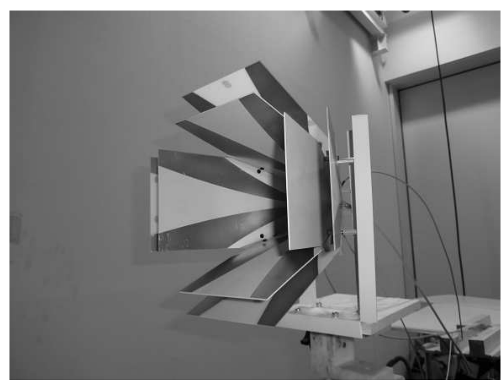
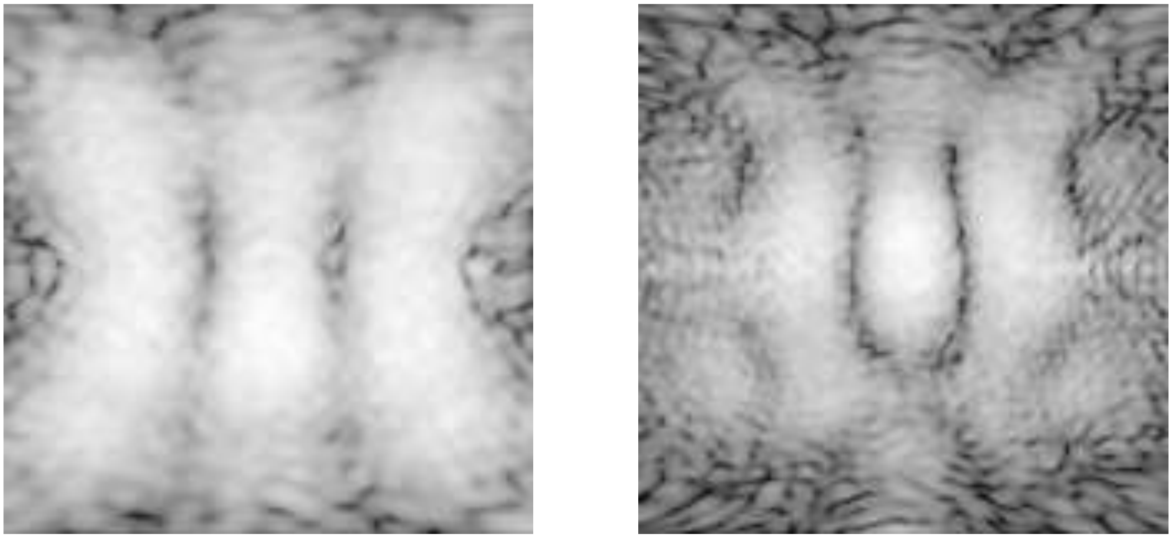


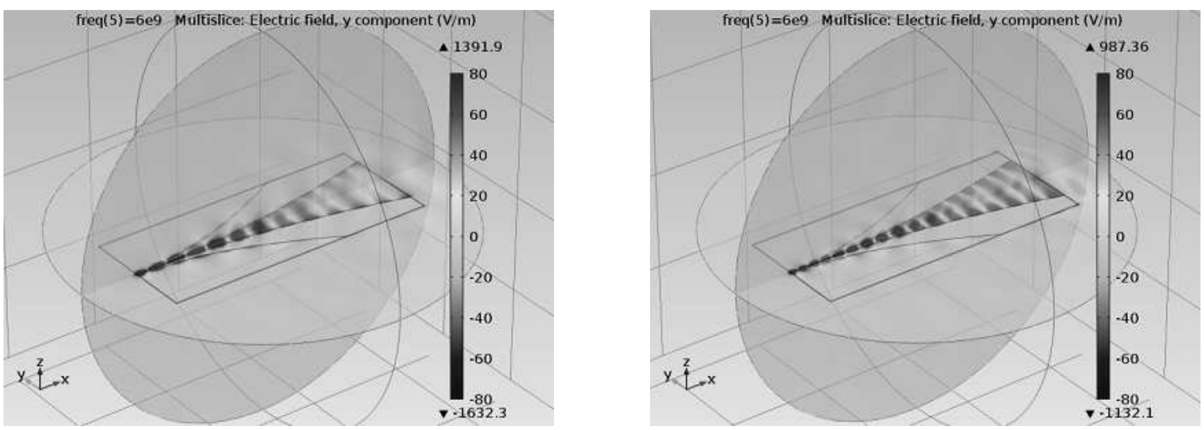
Figure 4. Experimental elements for wideband feeds.



Farfield pattern of the feed elements at 3 GHz

Farfield pattern of the feed elements at 4 GHz

Figure 5. Farfield patterns of experimental elements for the wideband feed [Figure 4].



Ey field on the element at 6 GHz $\epsilon_r = 2.2$

Ey field on the element at 6 GHz $\epsilon_r = 10$

Figure 6. Simulated E field component parallel to the substrate of feed element [Figure 4].

References

[1] Takefuji K., Koyama Y., Takeuchi H., First Fringe Detection with Next-Generation A/D Sampler ADS3000+, IVS TDC News, No. 30, pp.17-21, 2009.

[2] Takefuji K., Kondo T., Sekido M., RF direct sampling applied for geodetic VLBI, 2012, in preparation.