Technology Development Center at NICT

Kazuhiro Takefuji, Hideki Ujihara

Abstract

National Institute of Information and Communications Technology (NICT) has led the development of 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. TDC at NICT

National Institute of Information and Communications Technology (NICT) has published the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" at least once a year in order to inform the development of VLBI related technology as an IVS technology development center. The newsletter is available through the Internet at following URL **http://www2.nict.go.jp/w/w114/stmg/ivstdc/news-index.html**.

2. Staff Members of NICT TDC

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).

Name	Works
AMAGAI, Jun	QZS[1], GPS analysis, TWSTFT[2]
HASEGAWA, Shingo	K5/VSSP32, K5/VSI
HOBIGER, Thomas	QZS, VLBI,eVLBI, GPS, GNSS analysis
ICHIKAWA, Ryuichi	MARBLE[3] system, VLBI analysis
KAWAI, Eiji	34m and 11m antenna system
KONDO, Tetsuro	K5/VSSP32, Software correlator
KOYAMA, Yasuhiro	e-VLBI, VLBI analysis
MIYAUCHI, Yuka	Software engineer
SEKIDO, Mamoru	e-VLBI, Delta-VLBI, VLBI analysis
TAKEFUJI, Kazuhiro	ADS3000+ system, Direct sampling system
TSUTSUMI, Masanori	K5 system, ADS3000+ system
Ujihara, Hideki	Designer of Broad band feed

[1] QZS: Quasi-Zenith Satellites
[2] TWSTFT: Two-Way Satellite Time and Frequency Transfer
[3] MARBLE: Multiple Antenna Radio-interferometry of Baseline Length Evaluation

3. Current Status and Activities

3.1. RF Direct Sampling system for geodetic VLBI

We have successfully 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 connect a few hundred meter with coaxial cable or optical cable, so that group delay will easily change by temperature variation. Phase calibration which inserts 1 or 5MHz step comb signals in frequency before low noise amplifire will compensate this group delay. However, if RF signals are sampled just after low noise amplifire, phase calibration system is not necessaly. Recently it becomes available to sample IF signals directly due to the progress of the performance of a sampling device, and then a digital baseband converter, like ADS3000+[1], has been developed. Now some sampling devices have a wide input frequency band width 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 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 RF direct sampling VLBI. RF direct sampling system was installed both Tsukuba 32-m and Kashima 11-m antennas. Figure 1 shows a system block diagram. RF direct sampling with sampling modes of 2bit-1024Msps. According to Nyquist theorem, it need 18GHz to record X-band (9GHz) signal. But band width of X-band is around 1GHz, 1024MHz sampling speed(under sampling of digital technique) was applied. The sampled signal (DC to 512MHz) is same with RF signal(8192 to 8704MHz). it is like a “digital” base band converter. An under sampling is mainly used for filterd band, then sampled band can be reconstracted the original. In this case anti-aliace filter did not insert before sampler, so that aliaced, folded signal from out of band ($\leq$ 8192MHz and $\geq$ 8704MHz) will be overlapped. The overlapped signal will increse noise, in other word fringe amplitude will reduce. However, fringes of overlappled signals could be detected with difference of fringe rotation (Fig.2). Then, reduced fringe amplitude will cancel after bandwidth synthesis. The DSAMS was also adopted to S/X band geodetic VLBI. S and X-band connected after LNA in RF frequency. Figure 3 shows synthesized S and X-band and thier fringes.

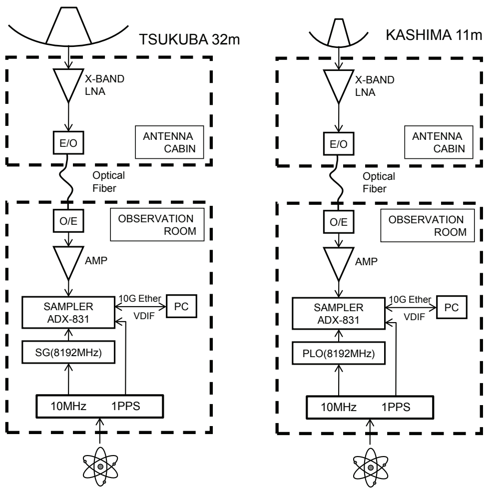


Figure 1. A system block diagram. RF direct sampling was operated at Kashima 11m and Tsukuba 32m.

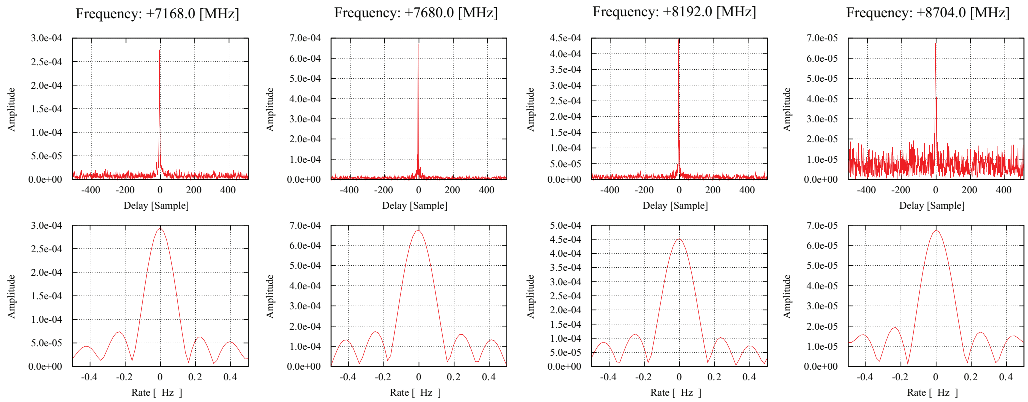


Figure 2. First fringe for DSAMS (Direct Sampling Applied for Mixed Signals) applied for X-band VLBI. The sampling mode of ADX-831 is 2bit-1024Msps. Each Fringes of four X-band were simultaneously obtained with “single” sampler.

Frequency [MHz]	7168	7680	8192	8704
Delay [sample]	-5.534	-5.114	-4.195	-2.917
Rate [mHz]	-1.367	-5.515	-3.163	1.171
SNR	39.417	85.858	58.584	9.321

Table 2. Specification of four X-band fringes with single sampler of Fig.2

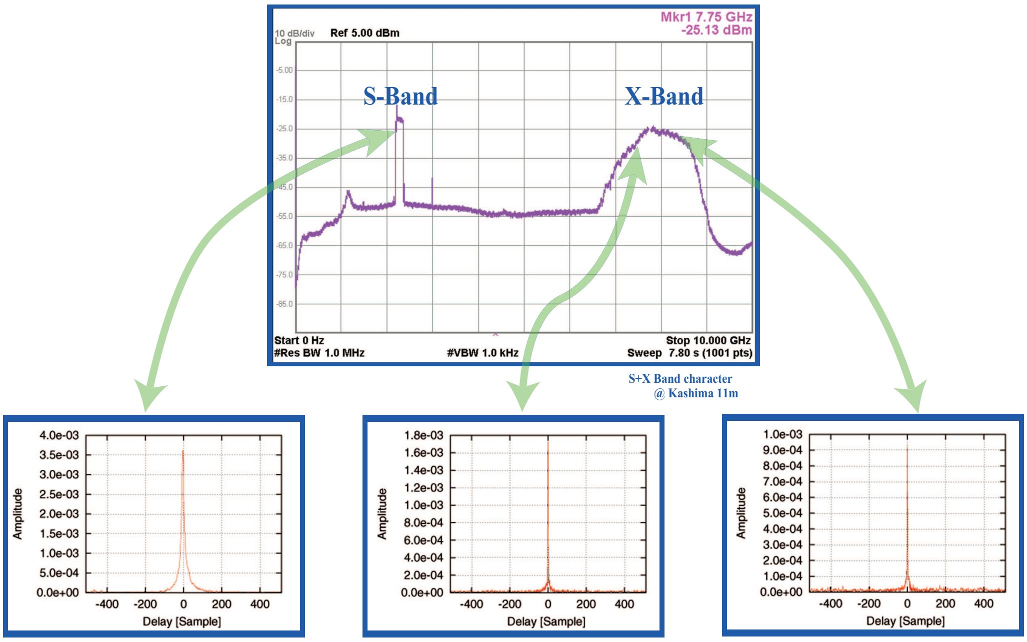


Figure 3. First fringe of DSAMS (Direct sampling applied for mixed signals) applied for geodetic VLBI. The sampling mode of ADX-831 is 2bit-1024Msps. Fringes of S-band and X-band were simultaneously obtained with the only one sampler.

4. Development of Wide Band Feeds

Wide Band feeds are developing in NICT, NAOJ and other universities in japan for VLBI2010, SKA and MARBLE. SKA is an international radio astronomy project for constructing Square Kilometer Array. MARBLE is small portable VLBI station developed in NICT and GSI in Japan. They are all needing wideband feed with 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 fig4 This year, several elemental feeds are tested and measured their beam patterns at METLAB in Kyoto University[Fig.5]. Grading robes are clearly seen, because of lack of central feed element which was not yet placed properly. Also, numerical simulations were carried out with COMSOL for the feed elements[Fig.6]. The element size is $L = 280mm \times W = 120mm \times t = 1mm$ and 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 testing on the MARBLE.

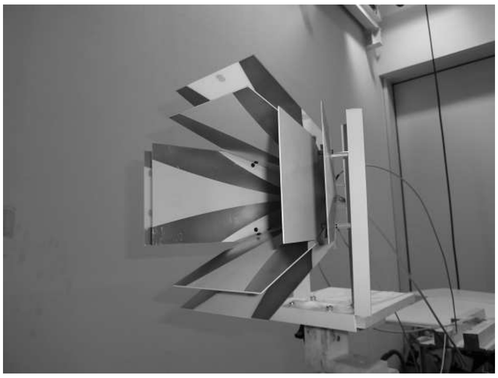
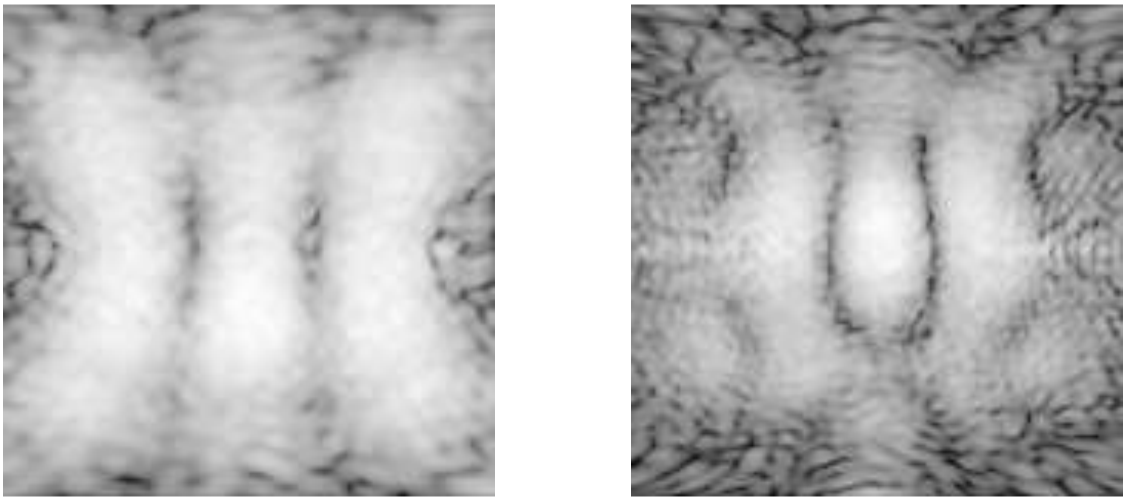


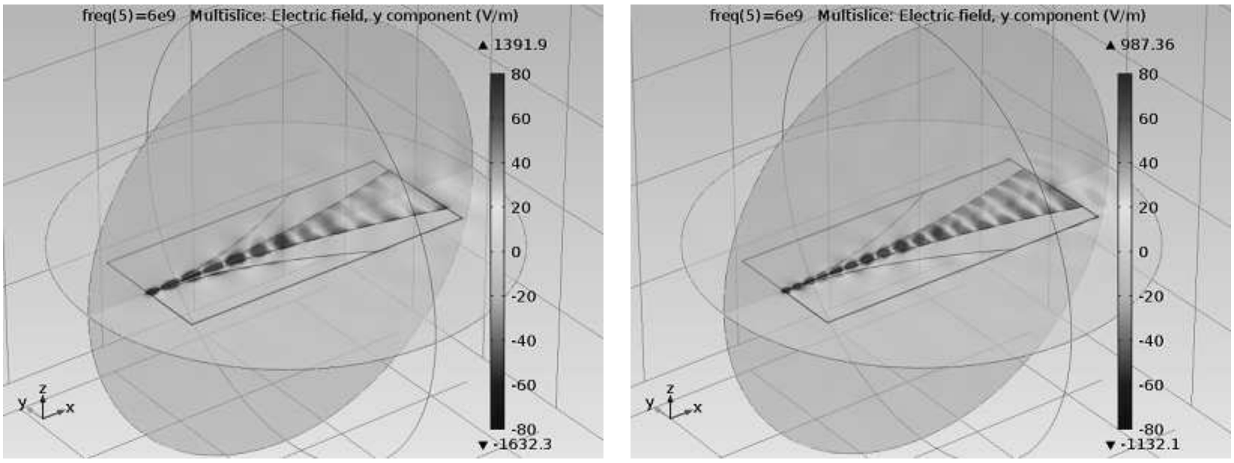
Figure 4. Experimental elements for wideband feeds.



Farfield pattern of the feed elements at 3GHz

Farfield pattern of the feed elements at 4GHz

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



Ey field on the element at 6GHz $\epsilon_r = 2.2$ | Ey field on the element at 6GHz $\epsilon_r = 10$

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

5. Future Plans

- Feasibility experiment of internatinal baseline ($\geq$ 1000 km) with RF direct sampling system
- To assemble the elements into an Arrayed TWA for evaluation of beam shaping before testing on the MARBLE.

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.