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Optical Linked VLBI in Japan

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1. Introduction

Optical linked VLBI is the key technology to change historical VLBI style in this decade. It will not only achieve high sensitivity by the fast data transfer beyond magnetic tapes, but other features are also attractive for the VLBI operation. The optical linked data transfer without the media transport and its real-time correlation capability enables the quick look of observations. This means our global VLBI network will serve as a connected interferometer. Dynamic scheduling and real-time fringe checks eliminate independent fringe tests before observation and after standby. These features of optical linked VLBI minimize observation failure usually known long after observation and maximize telescope resources. Currently operated optical VLBI network KSP (Key Stone Project), GALAXY (Giga-bit Astronomical Large Array Xross-connect) and other experimental based optical VLBI in Japan are briefly summarized in this report.

2. Currently Operated Optical Linked VLBI in Japan

2.1. Key Stone Network

One of the long operated optical linked VLBI for geodetic data production is the KSP-VLBI around the Tokyo metropolitan area. The 256 Mbps VLBI data is transmitted via ATM (Asynchronous Transfer Mode). The retrieved data from four telescopes are adjusted for their data epoch at buffers in front of the Koganei correlator. The highly reliable KSP VLBI is operated every other day and additional R&D observations are scheduled between the geodetic regular schedule [Kiuchi *et al.* 1999].

2.2. GALAXY

In 1998 the geodetic KSP network and astronomical VSOP/OLIVE network were mutually connected. The GALAXY (Giga-bit Large Array Xross-connect) appears under three different institutes. The network consists of Usuda 64 m (ISAS), Nobeyama 45 m (NRO), Kashima 34 m (CRL) and four 11m in Kashima, Koganei, Miura, and Tateyama [Kiuchi *et al.* 1999]. Correlation capability is four station maximum at the Koganei correlator and there is additional limitation in telescope combinations. Possible observation frequencies are listed in Table 1. The GALAXY network performed dynamical change of schedule when they found the HR1099 flare up stars

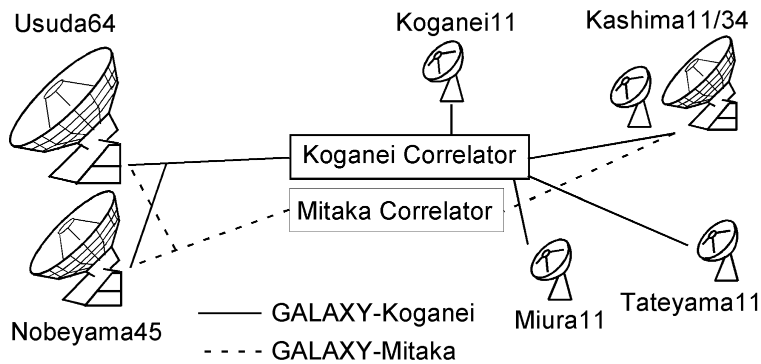

Figure 1. Optical Connection of KSP and GALAXY domestic optical VLBI.

variability during the observations. Mitaka VSOP-FX correlator is planned to share the processing.

Table 1. Two currently operated optical VLBI networks in Japan.

	KSP real time VLBI	GALAXY real time VLBI
Telescopes	4 x 11 m (KSP)	Usuda 64 m, Nobeyama 45 m, Kashima 34 m, 4 x 11 m (KSP)
Receiver Frequency	2/8 GHz	1.6/2/5/8/22 GHz
Correlator (Terminal)	Koganei (K4)	Koganei (K4), Mitaka (VSOP-FX)
Baseline Maximum Length	134 km	208 km
Scheduling	Automatic, static schedule	Operator control, dynamic schedule

3. Optical Linked VLBI with Experimental Results

3.1. Giga-bit ftp-VLBI

CRL has been developing the Giga-bit VLBI system which has a capability to perform 1024 Mbps VLBI observations. In this system, we realized ftp based data transfer which enables us to perform a fringe check during observation sessions. Using large memory 1024 Mbit (=128 MByte) the unit freezes the stream data at the assigned epoch. Besides the continuous tape recording, a connected PC starts ftp transfer from one station to the other. After the ftp, immediately software correlation starts and shows the result. The software correlator has an advantage in its flexibility to extended lag windows. Although the delay resolution is less than 1 ns at 1024 Mbps/1-bit/ch system, we are able to know the precise clock offset before tape correlation. Except for small telescope combinations, one second of the Giga-bit observations is enough to detect fringes from strong sources. The amount of ftp data is reduced when large telescopes are used. Figure 2 shows the ftp-VLBI 3C279 fringe between Nobeyama 45 m and Kashima 34 m from 12.8 MByte (0.1 sec) data. The processed lag window is expanded to about 50000 in this case. Starting from ftp, it takes about 10 to 15 minutes to see the fringes when the observation is normal.

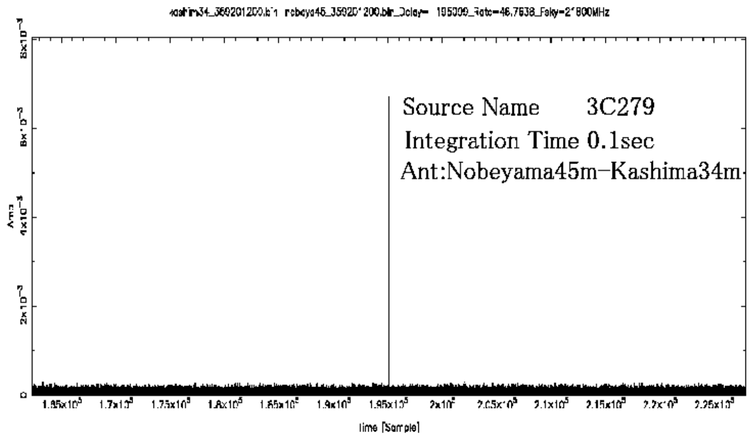

Figure 2. Gigabit ftp-VLBI fringe between Kashima 34m and Nobeyama 45m.

3.2. Giga-bit SDI-based Optical System

There are several approaches to establish over Giga-bit VLBI data transmission. One method is the high speed ATM and IP enhancement. The standardized transfer protocol promises commercial based extension in future. On the other hand, the interface employed in high speed consumer instruments are focused for local usage. In this case, the technology is concentrated into key devices and much cheaper than the ATM under its strict definition. SDI (Serial Data Interface) used in HDTV (High Definition TV) instrument connection supports optical data transmission up to 1.5 Gbps and 20 km distance without an optical repeater. We have developed the interface 1024 Mbps VLBI data and attribution data transfer shown in Figure 3 [Nakajima *et al.* 1999]. Large digital delay is occurring at parallel to serial data transfer. To compensate for this delay the concept of VSI (VLBI standard Interface, [Whitney, in this volume]) plays an important role. In the idea, 1 PPS tick label the data at DAS (Data Acquisition System). This will eliminate all digital delays introduced at later digital/analog component and only the clock offset between the telescopes remains in processing. There is no need to use a cable counter when the DAS is located near the receiver and the digital optical transmission is installed. We confirmed fringes and 1024 Mbps transmission performance by experimentally installing the unit in the correlation system as in Figure 4. Short distance interferometry experiments between Kashima 34m and Kashima 26m are planned.

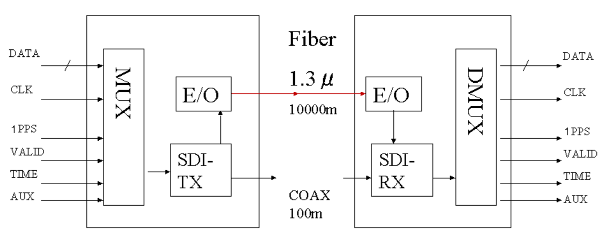

Figure 3. SDI Gigabit optical transmission system.

Figure 4. Giga-bit optical transmitter SPO1152TX/RX test in VLBI correlation

3.3. Other Optical-based VLBI Experiments in Progress

The other optical based VLBI projects are as follows. A 155 Mbps STM-1 ATM transmitter is completed to provide real-time VLBI. The unit will support VLBI via an international optical link or a satellite link [Kiuchi, personal communication]. Recently, the National Astronomical Observatory carried out a 2048 Mbps VLBI data transmission test which will fully utilize 2.5 Mbps ATM performance. They succeeded in send-back more than hundreds km [Kawaguchi, personal communication]. The GALAXY network is expected to enhance the performance up to 1024 Mbps in future. NTT (Nippon Telegram and Telecom) is developing a high speed "IP over ATM" interface which will adapt the KSP system for future expansion. CRL is also developing an IP-based VLBI system less than 1 Mbps. The variable rate IP-VLBI is realized by PC computer based technology. Experimenting with a simple frequency standard, the system will provide the possibility of preliminary VLBI experiment at many dishes never used for VLBI. This will give experience and opportunity to join the VLBI network to new groups. In the future, when we can afford to use broadband optical links between remote places this will bring us standard bandwidth VLBI observations. All real-time VLBI progress brought about direct results never obtained by tape based VLBI. But it should be noted that the fringe finding method and observation procedure is more difficult than tape based VLBI. Since most of the current VLBI systems were designed under a tape based concept, the future system should be improved to adapt automatic optical linked VLBI operations.

References

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