Fringes from Giga-bit VLBI system

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Abstract

Expansion of observation bandwidth is one of ways to improve the sensitivity of VLBI observation. The Communications Research Laboratory and the National Astronomical Observatory of Japan have developed a new wide band VLBI system and fringes from the Giga-bit VLBI system was detected for the first time in the world. The system consists of Giga-bit sampler, high speed data recorder (GBR) and Giga-bit VLBI correlator (GICO). Introduction of the Giga-bit VLBI system and results of the first fringe test experiment is shown in this paper.

1. Introduction

VLBI systems which is currently used in the world are S2, Mark-III(VLBA), and K-4(VSOP). The Haystack in the U.S.A and ISTS in Canada is developing Mark-IV and S3 system as their Giga-bit VLBI system, respectively. Wider bandwidth observation improves signal to noise ratio (SNR) without expanding physical aperture of antenna nor observation integration time. Improvement of SNR will benefit both geodetic and astronomical VLBI by father small formal error or better quality of radio source map. Additionally it will make easier to use phase delay as observable.

The Communications Research Laboratory and the National Astronomical Observatory of Japan started development of Giga-bit VLBI recorder GBR-1000 from 1996. One baseline Giga-bit VLBI system has completed in 1998.

2. Giga-bit VLBI system

2.1. Giga-bit sampler

Giga-bit Digital sampler (Figure 1) was developed by modification of Sony Tektronix TDS-784-series Digital Oscilloscope. It has 4 channels of input with 2bit-1024Msps for each channel. One of the sampling mode, 1ch-1bit-1024Msps data stream is used for VLBI application and the data is transfered to GBR-1000 through DD-1 Giga-bit VLBI interface. This sampler is also used for Nobeyama Millimetre-Array.

Figure 1. Giga-bit sampler, which is modified from Sony Tektronix TDS-784 series Digital Oscilloscope

Figure 2. Giga-bit VLBI data recording system. Left picture shows observation system including sampler and interfaces. Right picture is the GBR-1000.

2.2. Giga-bit VLBI data recording system

The Giga-bit VLBI data recording system consists of Giga-bit recorder GBR-1000 and recorder interface DRA-1000. The GBR-1000 was modified from High Definition TV (HDTV) recorder with helical scanning head mechanism. The spinning rate of the rotary head is synchronized with 10MHz signal from Hydrogen maser and it is used as clock. The rotation of the rotary head is recorded in magnetic tape as tape counter ID number which corresponds to UT time code. Picture of the Giga-bit recording system is shown in Figure 2.

2.3. The Giga-bit correlation system

The Giga-bit COrrelator (GICO) is modified from prototype correlator for Nobeyama Millimetre Interferometer (NMI). The correlator chip UWBC (Ultra Wide Band Correlator) was developed by National Astronomical Observatory. Figure 3 shows the block diagram of the correlation system. Synchronization of data stream from two GBR-1000s is achieved under the control of DRA-1000. Geometrical delay is absorbed by DRA-2000, which has 1024 Mbit DRAM memory. The change of geometrical delay due to the Earth rotation is compensated by 4 kbit internal buffer in GICO and large buffer of DRA-2000. For the mall order of delay tracking is done by internal buffer in GICO and larger change of delay than 4 kbit is compensated by buffer in the DRA-2000. The control of this correlation procedure and receiving output data from the GICO is performed by workstation through GP-IB bus.

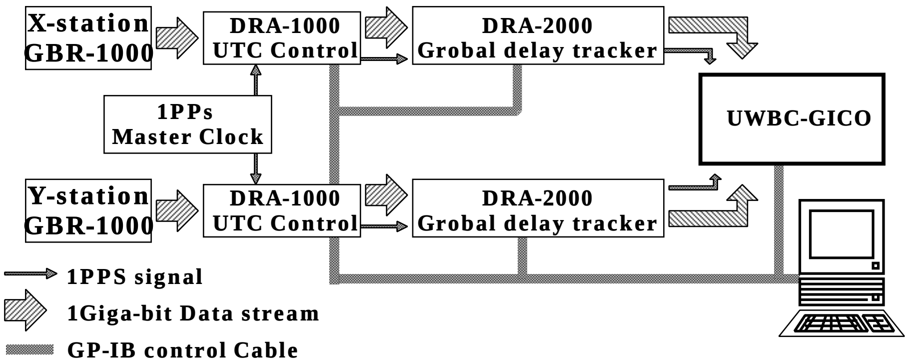

Figure 3. The Giga-bit VLBI correlation system

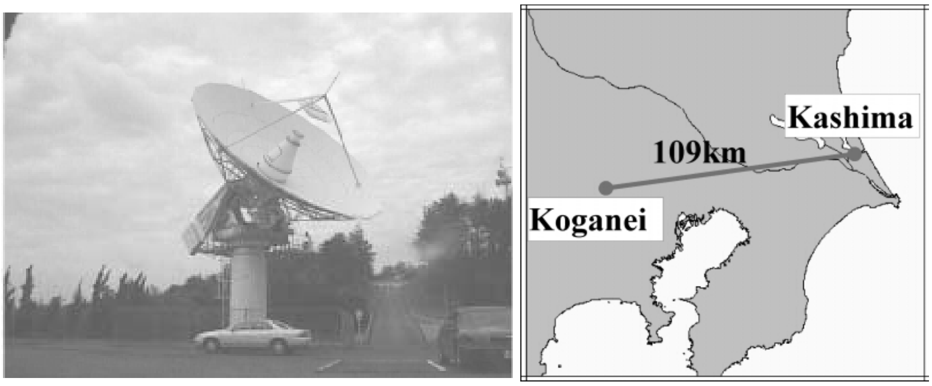

Figure 4. The 11m antenna of the KSP (left) and Kashima - Koganei baseline used for the test experiment.

3. The first fringe test experiment

The first fringe test experiment was conducted on 10th July 1998 by using Kashima and Koganei 11m diameter antenna pair of KSP (Metropolitan crustal deformation monitoring project). Figure 4 shows the antenna and the baseline. Real-time VLBI system is installed in the KSP and it enables real-time system check of the observation stations. To confirm the observation systems were working normally on both stations, a parallel observation by both the KSP real-time VLBI system and the Giga-bit VLBI system was done by splitting IF signal. The clock parameter derived by correlation process of the KSP system was also useful to find a fringe with Giga-bit VLBI system. Figure 5 shows the first fringe in the world by Giga-bit VLBI system.

4. Future prospects

This Giga-bit VLBI system has very high sensitivity for continuum sources. Group delay from 512 MHz band width is derived without any additional processing like as bandwidth synthesis. Consequently phase calibration signal, which calibrate pseudo group delay introduced from using multiple video converters, is not necessary. The features of Giga-bit VLBI system will give us new observational possibilities. Here I emphasise the following two points among them.

- **High frequency Geodetic VLBI** High frequency (22GHz) geodetic VLBI experiments have been studied to take its some advantages (Takahashi et al. 1993,

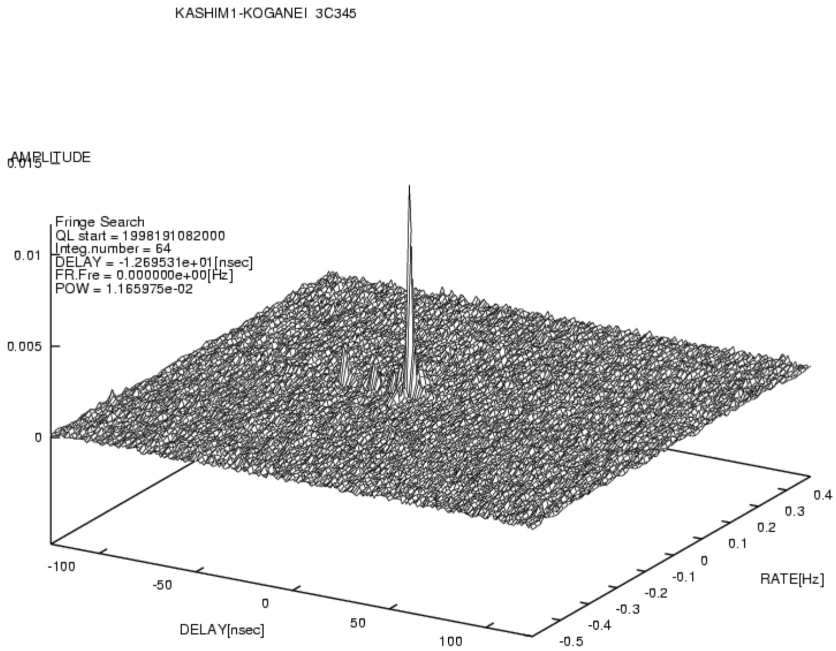

Figure 5. The first fringe detected by Giga-bit VLBI system. Observation mode was 1Gsps-1bit-1ch.

Takahashi et al. 1994). But the 22GHz geodetic VLBI has been in state of research mainly due to smaller flux density of continuum sources at high frequency. The Giga-bit VLBI system improved the sensitivity by more than 4 times the conventional 56 Mbps geodetic VLBI. And it will gives new possibility for geodetic application of 22GHz VLBI.

- **Using phase delay** Using phase delay have a potential to improve accuracy of geodetic and astrometric VLBI observation. One of the difficulties to use phase delay is to resolve ambiguity of 2π. High SNR VLBI observation by using the Giga-bit system have a potential to resolve the ambiguity of phase delay from group delay (e.g. SNR $\geq$ 60 by using Giga-bit VLBI will resolve ambiguity at RF=8GHz.). At this point of view, the Giga-bit VLBI system might have the advantage to skip bandwidth synthesis process which needs on P-cal signal. Because fluctuation or error of P-cal phase will become error sources in group delay measurement if stability of P-cal or cable delay monitoring does not achieve accuracy of the same order with one ambiguity (100 ps).

Besides of these points, Giga-bit VLBI system will be useful for astronomical observation of faint radio sources, which have never observed with VLBI. For instance, number of pulsars which can be observed with VLBI will increase and wide bandwidth observation will benefit survey of spectral line emission/absorption from high Z objects.

5. Conclusion

The first Giga-bit VLBI system has developed by Japanese VLBI group (CRL and NAO). The first VLBI observation was conducted with KSP antenna pair and the first fringe had successfully detected. The Giga-bit VLBI system will give us new observational possibilities.

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