Astrophysical Phenomena Revealed by Space VLBI
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Very Long Baseline Connected Interferometry via the 2.4-Gbps ATM Network

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Abstract

The Communications Research Laboratory (CRL), the National Astronomical Observatory (NAO), the Institute of Space and Astronautical Science (ISAS), and the Telecommunication Network Laboratory Group of Nippon Telegraph and Telephone Corporation (NTT) have developed a very long baseline connected interferometry 6-station array with a maximum baseline length of 208 km, using a high-speed asynchronous transfer mode (ATM) network with an AAL1 that corresponds to the constant bit-rate protocol. The VLBI observed data (256 Mbps/station) is transmitted through a 2.488-Gbps [STM-16/OC-48] ATM network instead of being recorded onto magnetic tape. By combining antennas via a high-speed ATM network, a highly-sensitive connected interferometry system has been realized. The system was composed of two real-time VLBI networks: the Key-Stone Project (KSP) network of CRL (which is used for measuring crustal deformation in the Tokyo metropolitan area), and the OLIVE (Optically LInked VLBI Experiment) network of NAO and ISAS which is used for astronomy (space VLBI). These networks operated in cooperation with NTT. In order to realize connected interferometry, the acquired VLBI data (256 Mbps/station) were corrected via the ATM networks and were synthesized using the VLBI technique. The cross-correlation processing and data observation were done simultaneously.

1 Real-Time VLBI System

CRL developed an automated real-time VLBI system using an ATM network called the KSP network in 1996. The KSP project, which began in 1994, was developed in order to measure crustal deformation in the Tokyo metropolitan area (Kondo et al. 1998; Koyama et al. 1998). In regular geodetic KSP, VLBI experiments run every other day for 24 hours. It was found that a horizontal position uncertainty of about 2 mm and a vertical position uncertainty of about 10 mm were achieved (Koyama et al. 1998). The system was designed to operate automatically throughout the entire process; the results obtained are available to the public via the Internet (http://ksp.crl.go.jp). NAO and ISAS also developed the OLIVE real-time VLBI network in 1997 for astronomy. The network was used for monitoring the space-VLBI (VSOP: VLBI Space Observatory Programme) signals. These networks were operated in cooperation with NTT. In both systems, STM-16/OC-48 [SDH: synchronous digital hierarchy/SONET: synchronous optical network] ATM networks (Sato et al. 1990) are used. The large-size (208 km) highly-sensitive array (very long baseline connected interferometry array) was established by high-speed digital optical data links composed of both the KSP and the OLIVE networks. Four of the seven antennas; Usuda (64 m), Nobeyama (45 m), Koganei (KSP-11m), Kashima34 (34 m) / Kashima11 (KSP-11m), Miura (KSP-11m), and Tateyama (KSP-11m) were selected by the ATM cross-connect switch. The virtual telescope (the connected real-time VLBI array) was realized to observe weak radio sources.

2 VLBI Data Acquisition and Correlation System

Radio-signals received from astronomical radio sources at the VLBI site were converted to digital signals by the VLBI data-acquisition system — a high-end version of the K-4 system (Kiuchi et al. 1997). The data rate of the ATM transmission was selected from five possible rates (ranging from 16 to 256 Mbps). The six-baseline real-time KSP correlation system is usually operated as the very long baseline connected interferometry array. The KSP correlation processor is an XF type using field-programmable gate arrays (FPGAs) on a VME board. The correlation processor has a 512-Mbps data processing speed capability and 512 complex lags in total.

3 System Evaluation

The real-time VLBI system (very long baseline connected interferometry) was operated from September 1998. The very long baseline connected interferometry experiments were carried out with a 256-Mbps data rate at each station. The selection of Kashima34 (34 m) and Kashima11 (KSP-11m) was alternated. All of the radio telescopes were Az-El type antennas. The KSP system is a dual-frequency system (8 GHz-band and 2 GHz-band) for compensating ionospheric delay. The Usuda64 antenna has receivers ranging from 1.5 to 22 GHz. Nobeyama45 has receivers ranging from 22 to 110 GHz, and Kashima34 has receivers from 1.5 to 43 GHz. The VLBI observation equipment at each site includes an ATM transmitter. The Kashima34 station was the only station that transmitted its IF (intermediate frequency) analog signal – to the Kashima11 VLBI site about 600 m away. The IF analog signal is sent using commercially available fiber-optic links modulated in the radio-frequency range. The fiber-optic links were the Ortel 10341A laser diode and the Ortel 10455A photo detector. The IF signal is converted to digital signal by the KSP VLBI data-acquisition system (high-end version of the K-4). The 16-ch digital filtering was done after sampling in the VLBI data-acquisition system, the bandwidth of each channel was 8 MHz. The cross-correlation processing using the KSP six-baseline real-time correlation processor and observation were done simultaneously. Weak radio star observations were carried out, including the source HR1099. The HR1099 binary system, the radio emission of which is considered to be non-thermal in nature, is a non-eclipsing system. It is probably related to and consistent with a magnetic activity scenario. The radio behavior of HR1099 is quite characteristic: two rather different phases, quiescent and active, appear to alternate. The observation was carried out in a dual-frequency (X-band and S-band) using Usuda, Kashima34, Koganei, and Miura. The active phase of HR1099 (flare-up of X-band signal) was detected. The correlated amplitude of the quiescent phase was 3.14×10^{-5} in X-band (4.16×10^{-5} in S-band) and that of active phase was 2.61×10^{-4} in X-band (1.77×10^{-5} in S-band). The period of the quiescent phase is far longer than that of the active phase and the active phase detection was done between Usuda64 and KSP antennas. Unfortunately, it was not possible to operate the Kashima34 because of a gale during the flare-up detection epoch.

4 Conclusion

A real-time VLBI system that corresponds to the constant bit-rate protocol using the STM-16/OC-48 ATM networks with AAL1 was developed. The system was demonstrated its function successfully. This system is a significant advance in VLBI and should provide more precise information about radio astronomy.

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