

Real-time Gigabit VLBI System and Internet VLBI System

Tetsuro Kondo ¹, Yasuhiro Koyama ¹, Junichi Nakajima ¹, Mamoru Sekido ¹,
Ryuichi Ichikawa ¹, Eiji Kawai ¹, Hiroshi Okubo ¹, Hiro Osaki ¹, Moritaka Kimura ¹,
Yuichi Ichikawa ², GALAXY Team ³

¹) *Kashima Space Research Center, Communications Research Laboratory*

²) *Nihon Tsushinki Co.Ltd.*

³) *CRL, NAOJ, ISAS, and NTT joint project team*

Contact author: Tetsuro Kondo, e-mail: kondo@crl.go.jp

Abstract

The development of a gigabit VLBI system and an Internet VLBI system at CRL is carried out as one of the subjects to promote “research on key technologies to establish the space-time infrastructure in the space”, a new project started two years ago. First we have developed a tape-based gigabit VLBI system. Some geodetic VLBI experiments were performed using this system. In parallel with the development of the tape-based system, a real-time gigabit VLBI system has been developed in collaboration with National Astronomical Observatory Japan (NAOJ), Institute of Space and Astronautical Science (ISAS) and Nippon Telegraph and Telephone Corp.(NTT). In the real-time system, VLBI data are transmitted through the high speed ATM network to a correlator. We successfully carried out the first real-time 1 Gbps VLBI experiment using Kashima 34m antenna and Usuda 64m antenna on June 23, 2001, and first real-time fringes were successfully detected. In addition to the success in 1 Gbps real-time VLBI, we also succeeded in 2 Gbps tape-based VLBI on December 12, 2001.

On the other hand a new real-time VLBI system using IP (Internet protocol) technology called “IP-VLBI” or “Internet VLBI” has been developed since 1999 to reduce network cost and to expand connection sites. We have been developing the IP-VLBI system as a PC-based system consisting of a PCI-bus sampler board and PC software to make real-time data transmission, reception and correlation.

1. Introduction

“Research on key technologies to establish the space-time infrastructure in the space” is a project started in FY2000, and shares research subjects with Time and Frequency Measurements Group, Atomic Frequency Standards Group, and Radio Astronomy Applications Group (VLBI group) at Communications Research Laboratory.

With the advent of GPS known as a “Car-Navi: car navigation system”, wherever we might be on the earth, we could know our position correctly. The space version of this positioning system is a “Space-Navi: space navigation system” which offers precise time and position information to spacecrafts in space. “Research on key technologies to establish the space-time infrastructure in the space” is the project to investigate key technologies to realize the Space-Navi. A system assumed at present is schematically depicted in Fig.1. This project consists of four research subjects, that is, (1) highly stable space-borne Hydrogen maser frequency standard, (2) time keeping of satellite group, (3) establishment of a space-time standard coordinate system, and (4) research on spacecraft positioning technology. VLBI group takes charge of the subjects (3) and (4). “Establishment of a space-time standard coordinate system” is subdivided into real-time precise measurement of the earth orientation parameters (EOP) and precise positioning of a space-time fiducial point (space lighthouse) in space. To achieve real-time and high-time resolution EOP monitoring (Fig.2), we

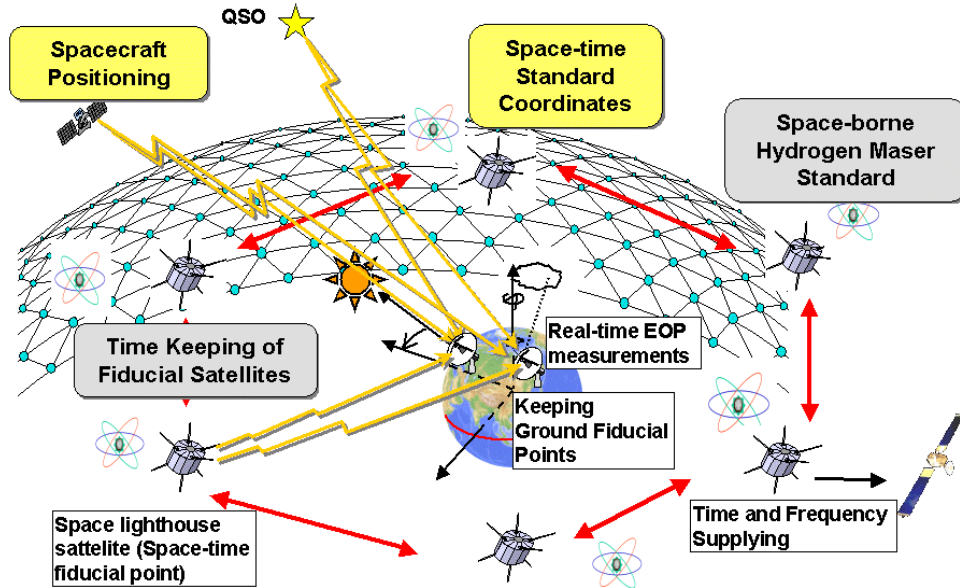


Figure 1. Research on key technologies to establish the space-time infrastructure in the space.

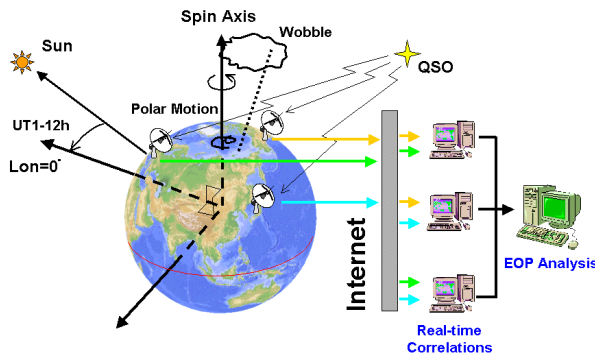


Figure 2. Real-time EOP monitoring system.

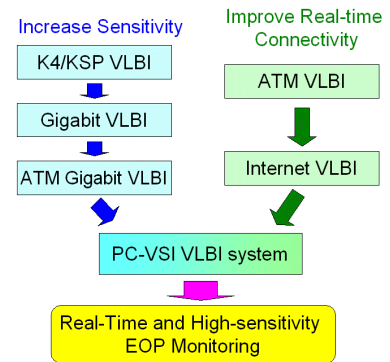


Figure 3. A plan of system development.

started the development of a gigabit and Internet VLBI system. A plan of our development is shown in Fig.3. Current status of the development of the system will be reported here.

2. Gigabit VLBI system

In order to increase time resolution of EOP measurement, it becomes important how many sources (quasars) can be observed in a short time period. Thus it is required to shorten observation time per one source, i.e., increasing system sensitivity is essential. Two approaches can be considered to realize this requirement. One is to use a larger antenna; the other is to make the receiving bandwidth larger. Generally, since drive speed becomes slow for a larger antenna, a source change comes to take time, and it is disadvantageous for the increase in the number of observation per unit time. We hence take an approach of receiving bandwidth expansion, i.e., we

started the development of a gigabit VLBI system.



Figure 4. A gigabit VSI recorder.

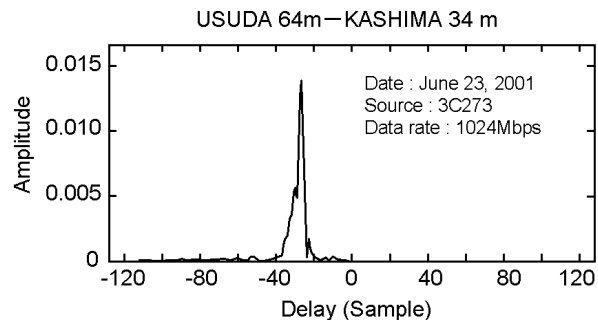


Figure 5. First real-time 1 Gbps VLBI fringes observed on June 23, 2001 on Kashima-Usuda baseline.

First system was developed as a tape-based system. Now the system evolution is continued as a VSI compliant system (Fig. 4) [1], and real-time capability has been taken into the system. Since we already have ATM real-time VLBI technique developed under the Key Stone Project (e.g., see [2]), a real-time gigabit VLBI experiment became possible soon in collaboration with the Institute of Space and Astronautical Science (ISAS), National Astronomical Observatory (NAO), and Nippon Telegraph and Telephone Corporation (NTT). Challenge to get real-time fringes using gigabit VLBI system was carried out between Usuda 64-m antenna and Kashima 34-m antenna on June 23, 2001, and first real-time fringes with a data rate of 1 Gbps were successfully detected (Fig.5). Now it is possible to carry out 1 Gbps real-time VLBI stably.

In addition to the success in 1 Gbps real-time VLBI, we also succeeded in 2 Gbps VLBI using ADS-1000 on December 12, 2001 but in tape-based VLBI (not real-time VLBI). Two 1 Gbps recorders were used at each station. Sampling frequency was 1 GHz and we adopted 2 bit Analog to Digital conversion, so the data rate became 2 Gbps. We could confirm the increase of signal to noise ratio corresponding to the theoretical expectation compared with the case of 1 bit A/D conversion.

3. Internet VLBI system

Regarding the real-time VLBI system, we have already developed real-time VLBI system using the ATM high speed network. However connection site is still limited and network cost is still expensive. In order to reduce network cost and to improve interconnectivity with other sites, we have been developing new real-time VLBI system using IP (Internet protocol) technology that has already spread widely. We call this system “IP-VLBI”. Two kinds of IP-VLBI system are under development by NTT and CRL.

One is the substitution of protocol from ATM to IP. In this system, serial high-speed data stream is directly sent by using IP instead of ATM. Although the data consist of several physical channels of data, no channel distinction is made in the transmission process. However, not only VLBI data but also any kind of data stream can be transmitted by this system. NTT has been

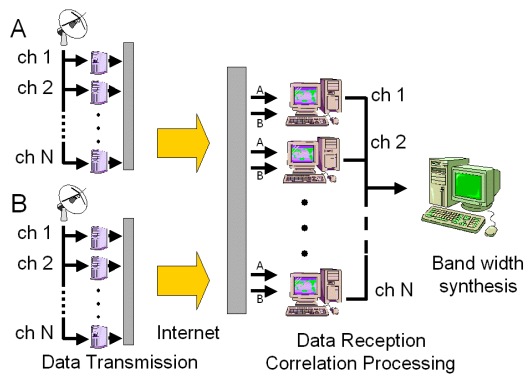


Figure 6. Internet VLBI system for geodetic use.

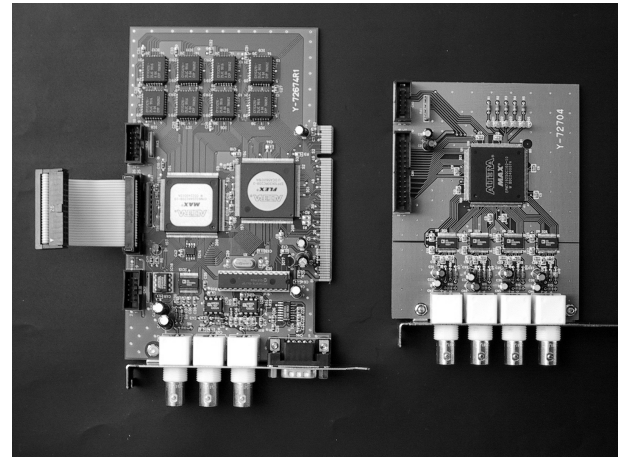


Figure 7. A PCI sampler board for the IP-VLBI system (left) and an auxiliary board for 4ch inputs (right).

developing this type.

The other kind of system is on the basis of channel data. A geodetic VLBI system usually receives 14 to 16 frequency channels at S and X bands. Each channel's data are transmitted independently by using the IP. We refer to this system as “Multi-channel IP-VLBI”, because only establishing the system for one channel, we can easily expand it to the multi-channel system (Fig.6). Only the network speed limits the number of channels and sampling frequency. CRL has been developing this type to take over current geodetic VLBI system. We have been developing a PC-based IP-VLBI system consisting of a PCI-bus sampler board (Fig.7) and PC software to make real-time data transmission and reception. We also intend to carry out the real-time correlation by PC software. One sampler board can have 4 video signal inputs by adopting an auxiliary board and is designed to be able to sample each signal with a sampling frequency of up to 16 MHz with an A/D conversion resolution of from 1 bit to 8 bits. The sampler board has been evaluated and confirms sufficient performance of both “coherent sampling” and “real-time transmission” with a sampling frequency of up to 16 MHz.

Regarding real-time software correlation processing, we can process 8 MHz sampling data in real-time at present time. An improvement in the algorithm to make correlation processing faster is in progress [3]. It is under consideration also about distributed correlation processing.

4. Conclusion

We are developing the gigabit VLBI system and the Internet VLBI system to give a proof of the possibility of the real-time precise EOP-measurement system. At present the development of both systems is proceeding independently, but both will be unified to a PC-VSI system in the near future. PC-VSI is a personal computer based VSI and we just start the development of PC-VSI.

5. Acknowledgements

The gigabit VLBI system has been developed under a cooperative effort by Communications Research Laboratory, NAOJ, Tokyo University, and Nippon Telegraph and Telephone Corp. We would like to express deep appreciations to colleagues in these organizations.

References

- [1] Nakajima, J., Y. Koyama, M. Sekido, R. Ichikawa, and T. Kondo, Approved upgrade of the Gbit VLBI system expansion, *Technical Development Center News CRL*, No.17, 25, 2000.
- [2] Koyama, Y., N. Kurihara, T. Kondo, M. Sekido, Y. Takahashi, H. Kiuchi, and K. Heki, Automated geodetic Very Long Baseline Interferometry observation and data analysis system, *Earth, Planets and Space*, 50, 709-722, 1998.
- [3] Kondo, T, Y. Koyama, M. Sekido, J. Nakajima, H. Okubo, H. Osaki, S. Nakagawa, and Y. Ichikawa, Development of the new real-time VLBI technique using the Internet Protocol, *Technical Development Center News CRL*, No.17, 22-24, 2000.