Internet VLBI system and 1 Gbps VLBI system based on the VSI

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Abstract

Recent technological developments at the Communications Research Laboratory are mainly aiming for improvements of the sensitivity by expanding the observation frequency bandwidth and establish real-time capabilities of the VLBI observations and data processing. For these purposes, Giga-bit VLBI system and the IP-based real-time VLBI system are currently under developments. Among of these research and developments, recent achievements and future plans will be reported.

1. Introduction

As the technology development center of the International VLBI Service for Geodesy and Astrometry, Communications Research Laboratory (CRL) has been developing and performing researches in various fields of VLBI, including technological developments of data acquisition and data processing systems. The recently established Key Stone Project (KSP) VLBI network is an integration of the researches and developments at CRL. For the KSP VLBI Network system, a lot of technological challenges were made and realized. Among of all, the real-time VLBI system was realized by using high speed data transmission system over the Asynchronous Transfer Mode network which connects the four observation sites at Kashima, Koganei, Miura, and Tateyama. The observation and data processing systems were also fully automated. As the results, frequent VLBI experiments became possible and the results of an experiment became available immediately after each observation session. The usefulness and the power of the automated real-time VLBI system was clearly demonstrated by the dense measurements during the dramatic crustal deformation event associated with volcanic activities of the Miyake-jima volcano started in June 2000. Figure 1 shows the horizontal site coordinates of the Tateyama site measured by the KSP VLBI network. As clearly seen in the figure, the north-eastward motion of the site starting the end of June 2000 was observed. The motion continued for a few months and the accumulated motion reached about 5cm. Similar large site motions were observed at other sites by VLBI and GPS techniques as shown in the Figure 2. These site motions can be explained with the theoretical model assuming a combination of a strike slip fault and a dyke as illustrated in the Figure 3. Such a irregular site motions were first studied by the VLBI technique and it was made possible by the real-time and automated features of the KSP VLBI Network.

This real-time VLBI technique is also used to connect a 64-m antenna at Usuda Deep Space Center of the Institute of Space and Astronautical Science (ISAS) and a 34-m antenna at Kashima Space Research Center of CRL to realize a real-time VLBI baseline of a length of 208 km under the collaboration of CRL, ISAS, National Astronomical Observatory (NAO), and Nippon Telegraph and Telephone Corporation (NTT). Test observations were successfully carried out in December 1998 at the data rate of 256 Mbps and this project was named GALAXY since then. The observation sessions of the GALAXY project have been performed once every several months. After

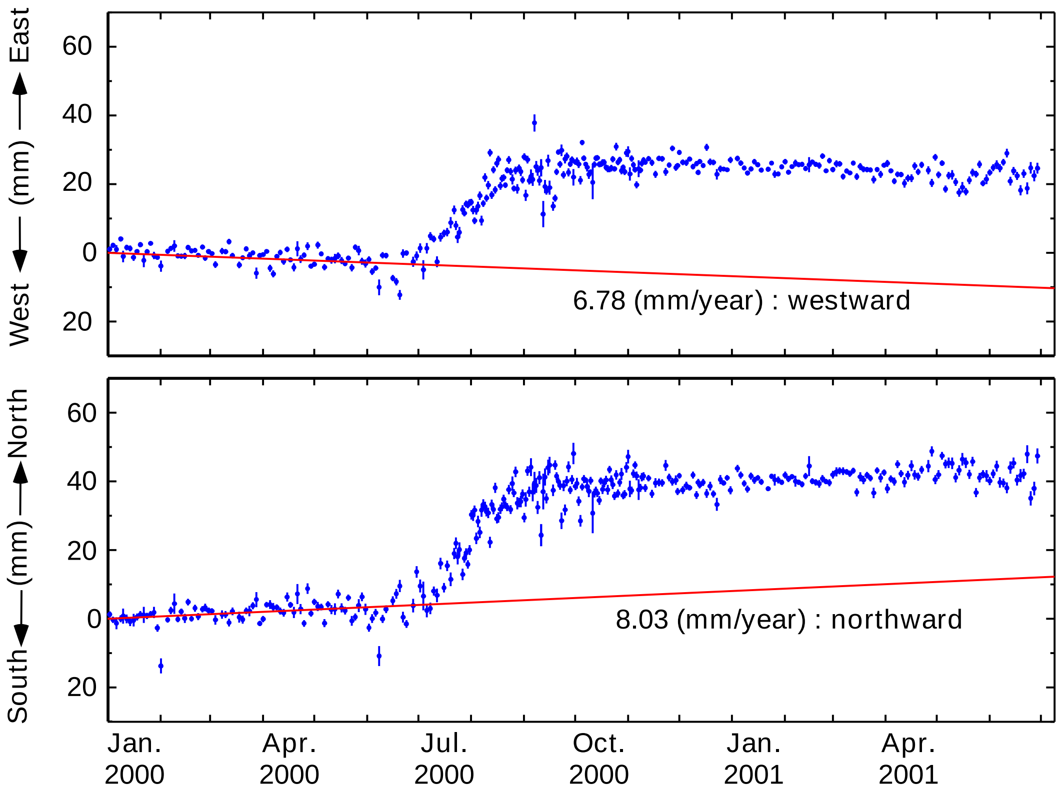

Figure 1. Horizontal site coordinates of Tateyama determined from KSP VLBI observations. Error bars are the estimated one-sigma formal error uncertainties of the coordinates. In each plot, a least square fit for the data before June 2000 is shown by a slanted line.

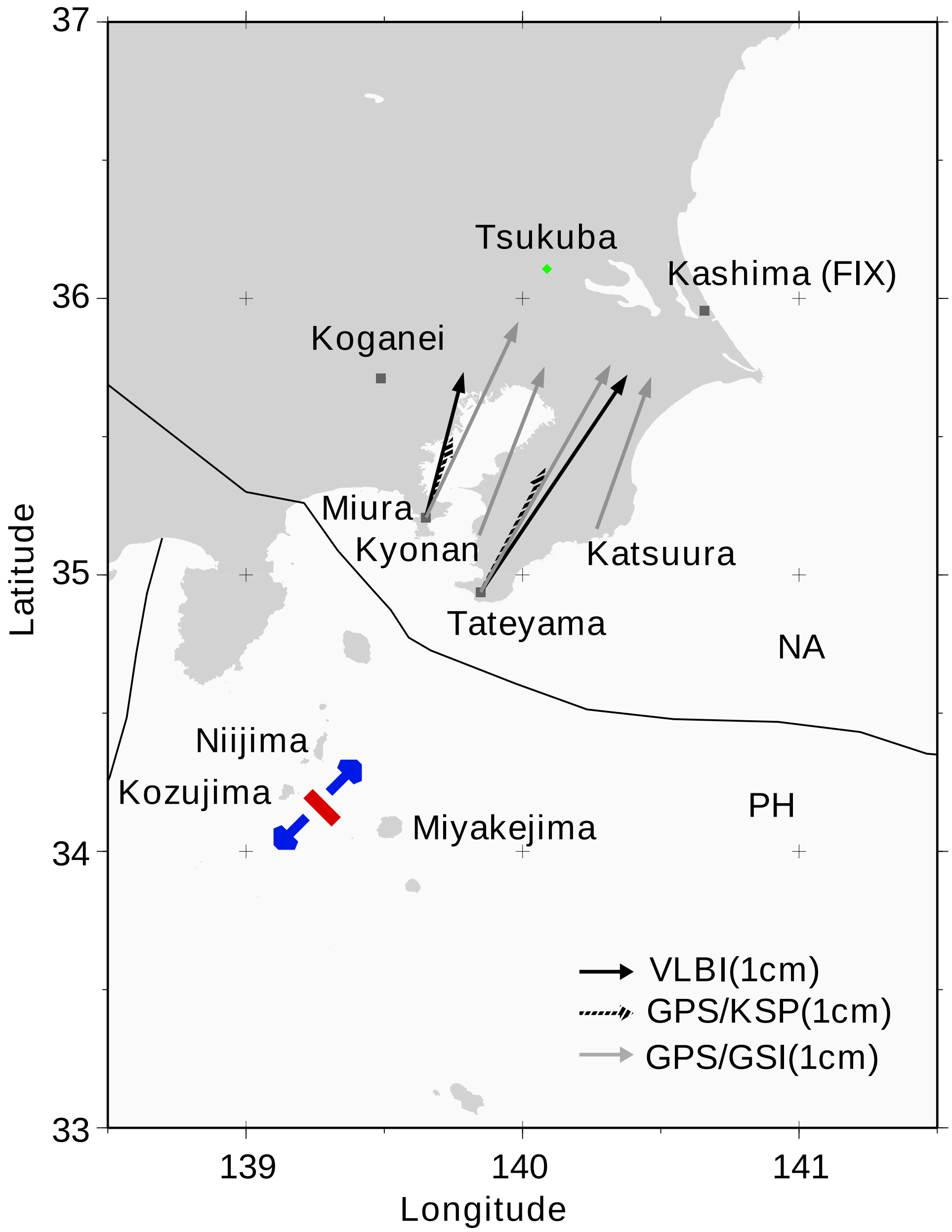

Figure 2. Horizontal site motions detected at south-Kanto area observed by VLBI and GPS techniques.

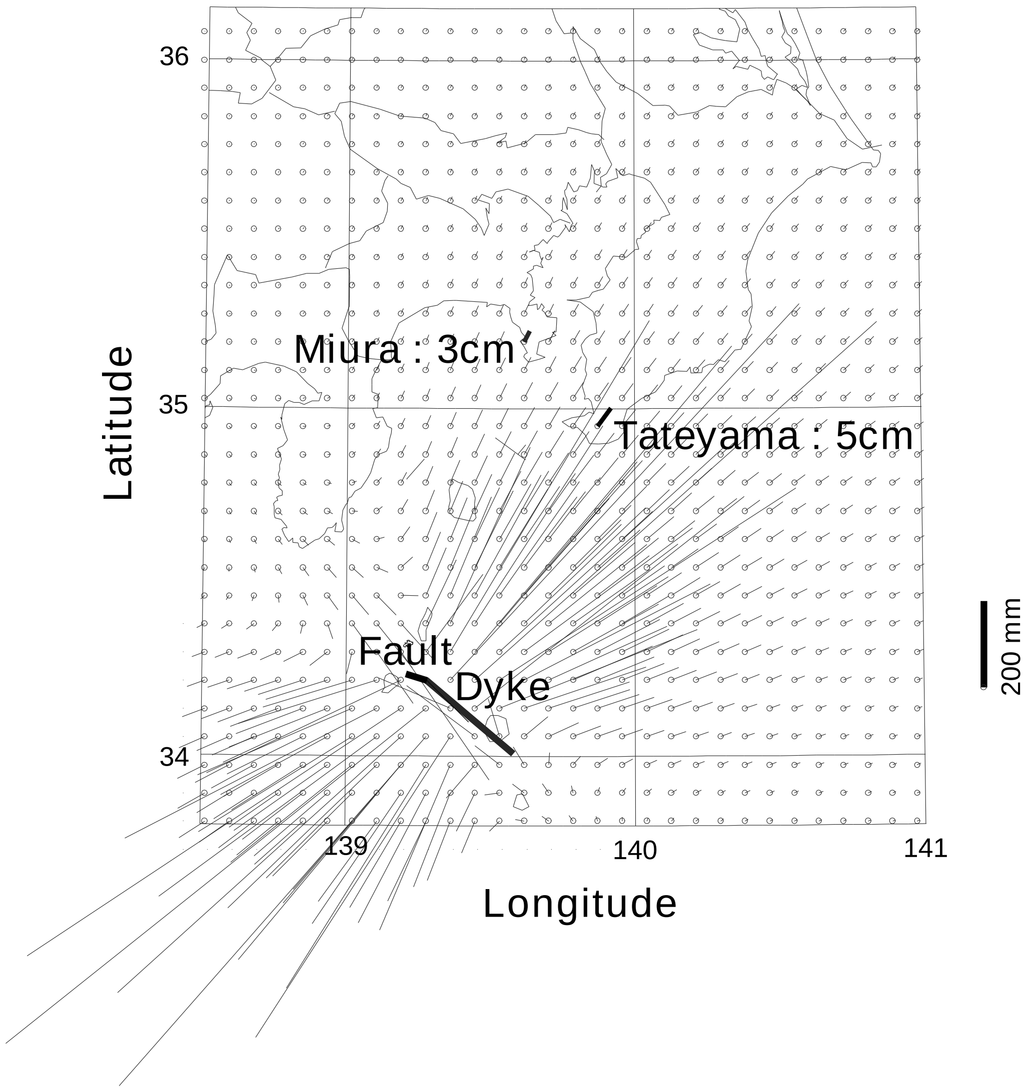

Figure 3. Proposed theoretical model which explains the crustal deformation observed in the south-Kanto area. A combination model with a strike slip fault and a dyke is assumed and the resulting horizontal deformation pattern by using the assumption is shown in the figure.

developing Giga-bit VLBI systems and ATM network interfaces, test observations were carried out at the date rate of 1024 Mbps on June 23, 2001. The test observations were successful and the improved sensitivity of the observations with the extended bandwidth was demonstrated. Efforts are continuing to make it possible to use most of the network speed of 2.4 Gbps by realizing 2048 Mbps real-time VLBI observations. We are expecting to perform test observations at the data rate of 2048 Mbps in early 2002.

After the realization of the KSP VLBI systems, CRL has been concentrating its efforts in two major directions. One of the directions is to realize real-time VLBI system over the Internet by using IP protocol. The other direction is to enhance the sensitivity of the VLBI system by increasing the data rate of the data acquisition system. The current status of these developments will be described in this report.

2. Giga-bit VLBI System

The developments of the giga-bit VLBI system began in 1996 and the first successful observations were performed on October 19, 1999. The system is consisted by a sampler system, a data recording system, and a data correlation system. The sampler system was initially developed by modifying a commercially available digital oscilloscope unit so that the observed data are sampled at the data rate of 1024 Msps and only one bit data stream out of 4 sampling bits is extracted. The data recording system was developed by modifying commercially available high definition broadcasting recorder system so that it can record at the data rate of 1024 Mbps. The correlator system was initially developed as the real-time correlator for the Nobeyama Millimeter Array of NAO. These systems constitute the initial version of the Giga-bit VLBI system and were used in a series of geodetic and astronomical VLBI sessions since the year 1999.

The developments of the second generation Giga-bit VLBI system have began to adapt the hardware specifications of the VLBI Standard Interface (VSI) of which the first version was agreed in August 2000. All the systems were re-designed to meet the specifications. The Figure 5 shows the new data recorder unit which is capable to record digital data stream at the data rate of 1024 Mbps. Multiple data recorder units can be synchronized so that multiple channels can be recorded simultaneously by using two or more units. The Figure 4 shows the new sampler unit which uses high speed digital sampling chip and it is capable to sample 1 channel data at 1024 Mbps 1 bit/sample.

The new data correlator unit is capable to correlate two data streams at the data rate of 1024 Mbps. The unit can be used to correlate two data channels for single baseline or one data channel for two baselines simultaneously by synchronizing the data recorder units. All these new systems are interfaced with each other based on the VSI specifications. Therefore, these systems can be connected with other VLBI systems as far as the other systems are also based on the VSI specifications.

3. Internet VLBI System

In the KSP real-time VLBI system, data are transmitted through the high-speed ATM network. However, the cost of the ATM network is still expensive and connection sites are extremely limited, and hence the ATM-VLBI is not yet well generalized. Therefore, We started developments of the new real-time VLBI system using IP (Internet protocol) technology expecting we can reduce the

Figure 4. The VSI based Giga-bit data recorder unit.

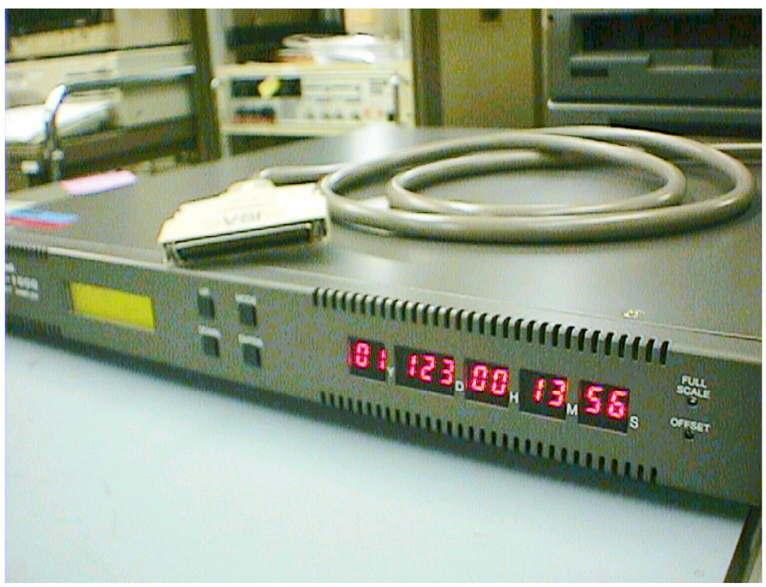

Figure 5. The VSI based Giga-bit data sampler unit.

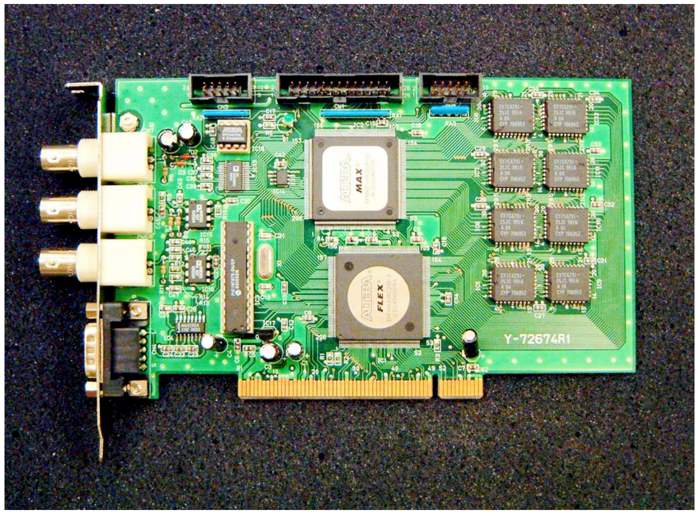

Figure 6. The sampler board for the Internet VLBI. The board has three BNC connectors to receive observed data, 10 MHz reference signal, and 1 PPS (pulse-per-second) signal. The board is expandable to sample four input data channels.

cost of the network and to expand connected sites for the real-time VLBI observations. We call this system Internet VLBI system, and started the development in late 1999. We have been developing the PC-based Internet VLBI system consisting of a PCI-bus sampler board (Figure 6) and softwares to make real-time data transmission and reception. We also intend to carry out the real-time correlation on a PC system. One sampler board can have four video signal inputs and is designed to be able to sample analog signal with a frequency of up to 16 MHz for one bit sampling level. The sampler board has been evaluated by using actual signals from radio sources. Real-time characteristics have been evaluated by using the Local Area Network at Kashima Space Research Center. So far, we confirmed the sufficient performance of coherent sampling up to 16 MHz sampling. Regarding the real-time correlation processing by using a PC system, we can process 4 MHz sampling data in real-time at present. Improvements on the software algorithm to make correlation processing faster are in progress.

4. Conclusions and Future Perspectives

The researches and developments of the Giga-bit VLBI system and Internet VLBI system were described. Both systems are in developments and we are expecting to complete these systems in 2002. The Giga-bit VLBI system will enable us to perform sensitive VLBI observations at 1024 Mbps, or much faster data rates if we use multiple data recording system. The Internet VLBI system, on the other hand, will enable us to perform real-time VLBI observations with more sites other than the currently connected sites. In the future, our vision is to establish variety of the VLBI data acquisition systems based on the VSI specifications so that users can select the system according to the necessity of the observations. Real-time VLBI observation capability between inter-continental baselines, we will be able to improve the timeliness of the VLBI observation results.

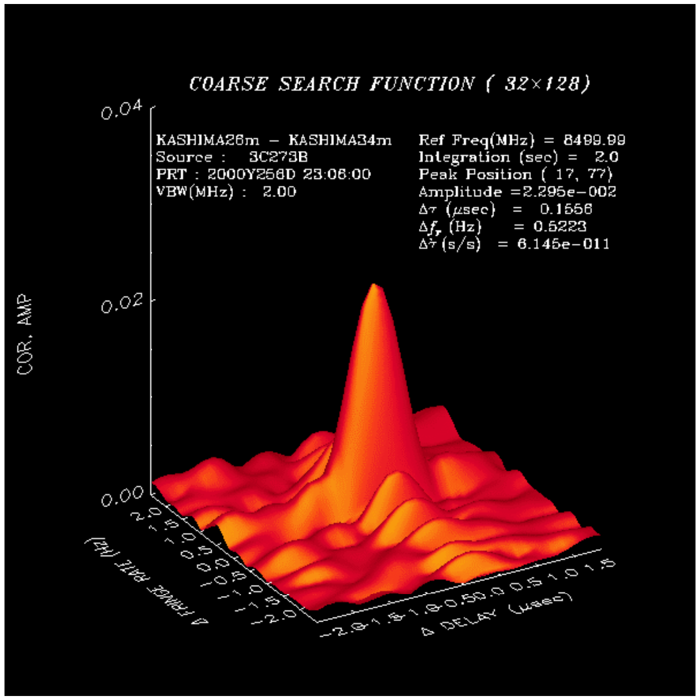

Figure 7. The coarse search function which indicate successful detection of a fringe for the baseline between 26-m antenna and 34-m antenna at Kashima Space Research Center. The correlation processing was performed on a PC system after the sampled data were locally stored on a disk and then transfered to a PC for correlation processing.

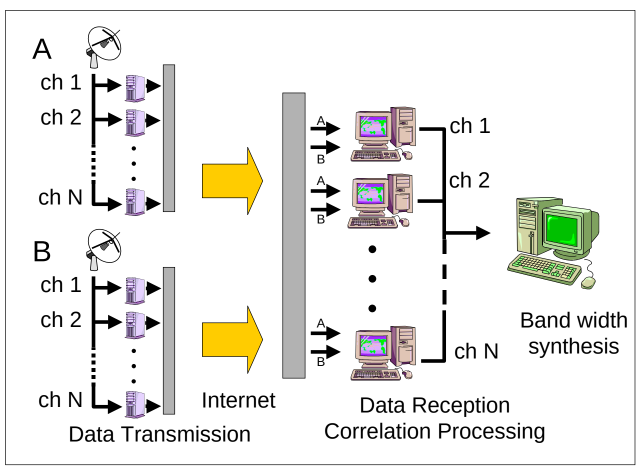

Figure 8. A concept of multiple channel observations and real-time correlation processing for geodetic VLBI observations.