Vol. 46 No. 1 Journal of the Communications Research Laboratory March 1999
Printed in Tokyo, Japan pp. 219–220

9. FUTURE PLANS

By
Taizoh YOSHINO

ABSTRACT

Advanced technologies are exploited in the Key Stone Project (KSP) to measure the crustal deformation around Tokyo with a precision within several millimeters. This paper discusses the contributions which the KSP project could make to future space geodesy.

Keywords: VLBI, SLR, GPS, Collocation, Real-time VLBI

1. Introduction

Since the Great Kanto Earthquake hit the South Kanto area in 1923, there has not been a big earthquake in Tokyo. Although we are still far from being able to predict an earthquake shortly before it occurs, there is desire in achieving this goal. Since the study of crustal deformation is fundamental to seismology, we are working on developing a precise geodetic measurement system to monitor the preseismic and postseismic activity. Hence, the Key Stone Project uses advanced VLBI (Very Long Baseline Interferometry) and SLR (Satellite Laser Ranging) technologies to monitor the crustal deformation of Tokyo. We confirmed that the developed system showed the performance we had expected. The system is used on a regular basis to monitor the crustal movement around the Tokyo area. The feature of the system is, however, inherently double-sided from the beginning because we introduced the state-of-the-art technology in the system design. One is a precise geodetic monitoring system and the other is a test site for research on using new technologies of the KSP system.

The CRL began developing a domestic VLBI system in the mid-1970's. In the early 1980's, a VLBI system, called the K-3 system, for an intercontinental experiment was developed at CRL with technical assistance from NASA. After the detection of the Pacific plate motion in 1985 by the VLBI technique using the K-3 and the MarkIII system developed at NASA, VLBI became widely known as a powerful tool for making geodetic and geodynamics measurements. The CRL continued to improve the VLBI system for the measurement in even higher precision in geodesy and astrometry. The VLBI system is used not only for the measurement of plate motion and crustal deformation, but also for the Earth's rotation monitoring and radio astronomical observations. The CRL also began SLR observations in 1990 as an independent space geodetic technique. The CRL develops the hardware and software for SLR observations, which help to determine the precise orbit of geodetic satellites and remote sensing satellites, as well as the precise position of the station. Thus, this new technology has greatly contributed to Earth science and related fields.

2. The Key Stone System as an Incubator

The primary purpose of the project is to monitor crustal deformation in the Tokyo area so that the results of observations can be used for earthquake study. We reached the precision of the baseline length measurement between the Key Stone stations to within a few millimeters. This technology has been transferred to the Geographical Survey Institute in Japan for geodetic measurements in a domestic network. Along with the KSP, the nationwide GPS array is deployed throughout Japan for seismology study. Hence, it is expected that the KSP will provide a fiducial point to improve reference coordinates and that it will serve as a test bed for space geodesy using an integrated system.

One of the unique techniques developed in this project is real-time VLBI. The VLBI data sent from four stations via optical fiber network at a rate of 256 Mbps is processed in real-time and regularly used for routine observation. Although this network is regional, it could serve as a model for international networks in the future. Once an international broadband network is developed, the real-time VLBI technique could be used to monitor the Earth's rotation, providing quick service for space navigation and other applications. Hence, it is demonstrated to solve UT1 and pole positions quickly from the KSP VLBI data. System development using commercial communication network has also begun[1]. Real-time VLBI is also useful in terms of reducing the manpower needed in the operation. Innovations in modern communication technology could have a significant impact on VLBI technology. From the point of view of system compatibility, it is easier to handle the problem because we can be free from the recording on the magnetic tape. The data flow format in the real-time VLBI must be discussed in the international VLBI community. On the other hand, innovations could lead to the development of high-speed data recording, which would be useful given that a broadband network will not always be available everywhere in the future. In terms of radio astronomy, the wider the available bandwidth is, the more sensitive the system is. Hence, greater bandwidth could be of benefit to the small aperture telescope used in VLBI observations. In particular, a broadband network will help providing quick feedback to control systems, such as those in space navigation.

The automated operation system developed in the KSP is also important for a future use. In the data recording system, an automatic tape-changer reduces the manpower needed for an operation. The computer network that connects the four stations helps the automated operation and remote control. Hence, VLBI operation is unmanned at all stations except the central station. An automatic system would also be of great help for SLR observation. In the SLR system in the KSP, remote operation has been instituted as the first step toward full automation.

The KSP system consists of VLBI, SLR, and GPS facilities. At each site, above system is installed closely so that the reference point of each system can be easily linked. Because the influence of ground motion and/or atmospheric conditions is common to each system at the collocation site, system error can be caught by comparing the data from the collocated stations. Hence, such information is useful for improving each system. In this meaning, KSP system is ideally collocated. Such a kind of collocation is firstly realized in Japan by the KSP. The number of collocated station is still small even in the world. A local survey to tie the reference points of each observing system is important for a combination of technique. It also helps improving the global reference frame. Combination and integration of techniques can be superior to a single technique if they are complementary. In the case of VLBI, SLR and GPS combination, it is an excellent combination since geometrical references, frequency band, and atmospheric delay due to the wet component are different.

3. Future Aspects

Technologies developed for KSP is naturally applicable for a regular use of the geodetic measurements and also for Earth's rotation monitoring. Besides the regular uses and technical transfers, the technologies developed in the KSP can be used in other fields. Space development is one of the fields we can apply our technologies. In the future space development, a precise coordinate system and modern communication techniques are important for space activities such as positioning, navigation, and study of planets. Both radio and optical communication will be used to link ground and space geometrically. Since quick service is essential in guiding space vehicles, Earth's rotation monitoring using international real-time VLBI will be useful for a basis of GPS service. The SLR observations will help determination of the precise satellite orbit. The motion of the Moon is currently observed optically using the retroreflectors placed on the Moon, which is called LLR (Lunar Laser Ranging). Since the lunar probe plan started also in Japan, the breakthrough in the scientific study of the Moon can be performed through the precise positioning by placing new scientific missions. A combination of radio techniques and optical techniques may be used for such space development. In the future, the precise geodetic network will be extended to the space. The space geodetic techniques will be used fully for this purpose.

4. Concluding Remarks

Modern technology helped a great success in space geodesy. The KSP uses both VLBI and SLR technology. The KSP uses new technologies in radio and optical techniques as well as in communication technology and software. Thus, the KSP system is useful not only for monitoring crustal deformation, but also for serving as an ideal test site for research. The space techniques for geodesy will be used also in space navigation. In the lunar probe project planned in Japan, extension of geodetic network to the space is discussed. Although the KSP project is of limited duration, it proves quite a few possibilities to be used in the future space geodesy.

References

(1) Y. Takahashi, H. Kiuchi, A. Kaneko, S. Hama, T. Yoshino, and N. Kurihara, "International real-time VLBI using worldwide communication network," Proceedings of Real-time VLBI Forum, Westford, May, 1998.

Taizoh YOSHINO
Keystone Project Team
Space geodesy and technical development
E-mail: yosh@crl.go.jp