

# Space VLBI Experiments Using ETS-VI

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**Abstract.** We report our project of the space VLBI experiments using ETS-VI which will be launched in 1994. Transmissions of the frequency standard signals which are synchronized by a hydrogen maser will be made with the feeder link station at Kashima Space Research Center (KSRC). The frequency monitor signal is returned from ETS-VI to the ground station, and the Doppler shift of its frequency are measured to control the up-link frequency. Experiments for the real time fringe monitor using a wavefront clock will be made with an imitated radio source signal emitted from the S-band imitated satellite station at KSRC.

## 1. Introduction

Space VLBI is a radio astronomical interferometer of the highest spacial resolution using the baseline which is longer than the Earth diameter provided by antennas on satellites and on the ground. The first experiment of space VLBI was made using TDRSS, the Tracking and Data Relay Satellite System, in 1988, and the first fringes with the baseline in the space were obtained (LEVY *et al.*, 1989; LINFIELD *et al.*, 1989). The regular astronomical observations of space VLBI will be made using VSOP, the VLBI Space observatory Programme (NISHIMURA, 1991; HIRABAYASHI *et al.*, 1992), which will be started by Japan's Institute for Space and Astronautical Science in 1996, and Radioastron which will be made by the Russian group. These astronomical programs having very high spacial resolutions of ~0.1 milli arc-sec will shed new lights on astrometry, astrophysics, and geodynamics. Properties of the satellite stations for these space VLBI experiments are summarized in Table 1.

In advance of the regular observations of space VLBI, Communications Research Laboratory (CRL) is planning to make experiments of new technologies for data and frequency standard signal transmissions using ETS-VI (IWATA *et al.*, 1993), Japan's Engineering Test Satellite VI (NAKAMARU and KITAHARA, 1989). In this project experiments of communication link with frequency standard signals provided by hydrogen masers will be made. It is necessary to control the frequency

of the transmitted frequency standard signals for the fixed frequency conversion on the satellite to remove the large Doppler shift values in space VLBI experiments. In our experiments, up-link frequency control of the frequency standard signals is made frequency of the communication link as described in Section 3.

Table 1. Properties of the satellite stations for space VLBI experiments.

satellite	launch	$h$ ( $10^3$ km)	$D$ ( $m\phi$ )	$f$ (GHz)
TDRSS	1985	36	2 4.9	2.3 15
ETS-VI	1994	36	$0.34 \times 19^a$	2.3
VSOP	1996	20 - 1	10	1.7, 5, 22
Radioastron	not fixed	75 - 9	10	22

<sup>a</sup>Phased array antenna.

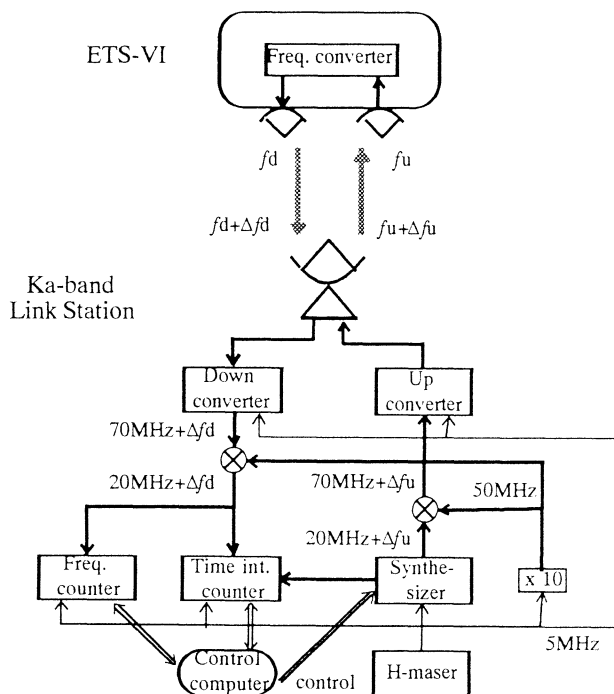


Fig. 1. A block diagram of the up-link frequency control system in the Space VLBI Experiments using ETS-VI.

## 2. System

ETS-VI is a geostationary satellite on the orbit of  $\sim 36,000$  km height, which will be launched by National Space Development Agency of Japan in 1994. The system of the satellite station is composed of the S-band Intersatellite Communication payload (SIC) system and the Feeder Link Communications Equipment (FLCE). The system of the ground stations is composed of the Ka-band feeder-link station and the space VLBI observation system at Kashima Space Research Center of CRL. Figures 1 and 2 show the block diagrams of the system for the up-link frequency control and the real time fringe monitor in the space VLBI experiments, respectively. VLBI observations on the satellite are made with the SIC antenna of 19-element 34 cm diameter phased array which forms a beam size of  $\sim 5^\circ$  at S-band. The SIC antenna is fixed toward the center of the Earth, and the tracking of the beam is done by the

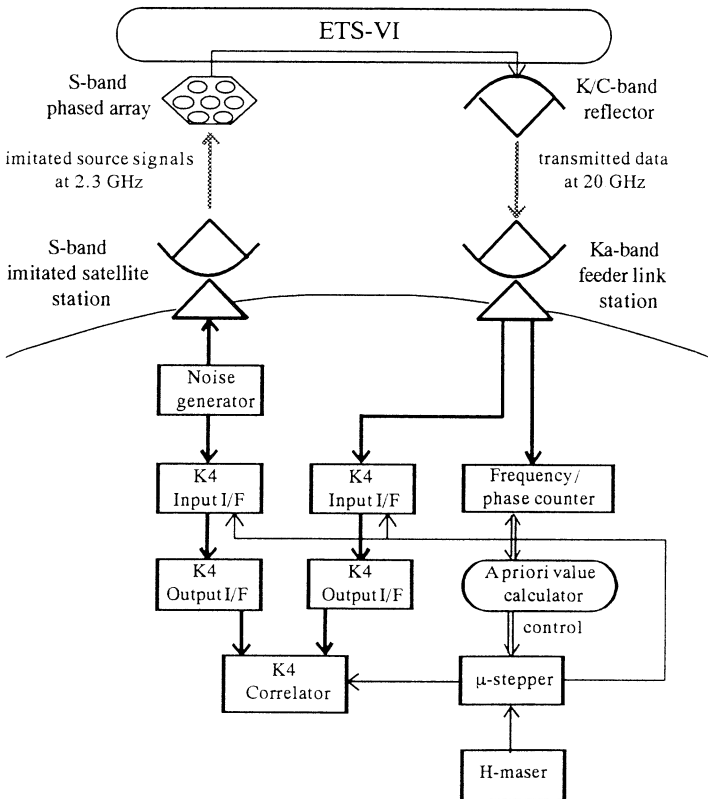


Fig. 2. A block diagram of the real time fringe monitoring system in the Space VLBI Experiments using ETS-VI.

phase scanning in the range of less than  $\sim 15^\circ$ . The center frequency of the VLBI observation is 2.2875 GHz and the band width of that is 4 MHz. The S-band receiver system has an antenna gain of 27.3 dB and G/T of  $-4.4$  dB/K as nominal values, an aperture efficiency of 43 of 0 deg and a system noise temperature to be  $\sim 1500$  K. The communication link on the satellite is made using 2.5 m diameter K/C-band reflector of FLCE for the up-link and 3.5 m diameter K/S-band reflector of FLCE for the down-link.

Transmissions of VLBI data, frequency standard signals, and frequency monitor signals on the ground are made with the 5 m diameter antenna of the Ka-band feeder link station. The frequency standard signals are transmitted in the pilot link system at the up-link frequency of 29.96325 GHz. The frequency monitor signals are transmitted in the FLCE return link system at the up-link frequency of 29.772 GHz and at the down link frequency of 19.938 GHz. The VLBI data are transmitted in the SIC return link system at the down-link frequency of 20.2455 GHz with the frequency band width of 4 MHz. The VLBI data are recorded by the K-4 type data acquisition systems developed by CRL (KIUCHI *et al.*, 1991a; HAMA and KIUCHI, 1991).

### 3. Experiments

The frequency standard signals are generated by a synthesizer which is synchronized by the 5 MHz signal provided by a hydrogen maser. Figure 1 shows the block diagram of the communication link. The frequency standard signals is up-converted into 70 MHz IF and divided into frequency standard signal and frequency monitor signal. Both the signals are transferred to the feeder link station and coherently up-converted into 30 GHz-band through 1.7 GHz IF-band using the 5 MHz signal of the hydrogen maser (Fig. 1). They are emitted from the Ka-band antenna of the feeder link station to the K/C-band reflector on ETS-VI. The frequency conversions on ETS-VI are also coherently made using the frequency standard signal. The VLBI data received at the SIC antenna and the frequency monitor signal are up-converted into 20 GHz-band and returned from ETS-VI to the feeder link station. They are down-converted into 1.7 GHz IF-band, the frequency monitor signal is again down-converted into 70 MHz IF-band.

The frequency of the returned frequency monitor signal which is shifted by Doppler effect caused from the drift motion of the satellite is measured by a frequency counter and compared with the frequency of the up-link signal of 70 MHz IF-band (Fig. 1). A frequency control computer controls the up-link frequency of synthesizer to be  $20 \text{ MHz} + \Delta f$ , where  $\Delta f$  is given for the frequency received on ETS-VI to be fixed. The phase shift of frequency monitor signal caused by the atmospheric fluctuation is measured by a phase detector. It is recorded into the magnetic tape with the VLBI data, and the phase calibration is made in the correlation process.

The detected phase shift is also used in the experiment of the real time fringe monitor using the S-band imitated satellite signals (Fig. 2). The correlation process of the real time fringe monitor is made by a real time VLBI correlator using the generated signals of two ways; the signal emitted from the ground station and

observed with the SIC antenna, and the signal directly transmitted from a generator through a programmable delay. The fringe rotation is derived with the wavefront clock method developed by CRL (KIUCHI *et al.*, 1991b), which controls the standard frequency and converts the data as receiving in the same wavefront. This method is effective in space VLBI because the large coherence loss caused from the large geometrical delay and the large Doppler shift can be avoided in correlation processes. The establishment of the real time fringe monitor makes it possible to check the status of communication link system simultaneously with the observations which promotes efficiency in the VLBI observations.

#### 4. Summary

In the space VLBI experiments using ETS-VI, frequency standard signals provided by a hydrogen maser will be transmitted to the satellite to make coherent frequency conversions. Experiments for the communication link with the first case of the up-link frequency control in the space VLBI will be made using the measured frequency shift by Doppler effect of the returned frequency monitor signal on the ground station. Experiments for the real time fringe monitor using a wavefront clock will be made using the measured phase shift of the returned signal. These experiments of new technologies for frequency standard signal transmissions will take the initiative in future space VLBI observations.

**Acknowledgements.** The authors are grateful to Noriyuki Kurihara, Yukio Takahashi and Fujinobu Takahashi who gave us helpful comments and supports.

#### REFERENCES

- HAMA, S. and KIUCHI, H., 1991, *J. Commun. Res. Lab.*, **38**, 459.
- HIRABAYASHI, H., NISHIMURA, T., HIROSAWA, H., KOBAYASHI, H., MORIMOTO, M., INOUE, M., CHIKADA, Y., and KAWAGUCHI, N., 1992, *Proc. 18th Int. Symp. on Space Technology and Science*, 1813.
- IWATA, T., IMAE, M., HAMA, S., KIUCHI, H., KURIHARA, N., SEKIDO, M., and TAKAHASHI, Y., 1993, Space VLBI Experiments using ETS-VI, *Proc. Int. Workshop for Reference Frame Establishment and Technical Development in Space Geodesy*, iRiS '93 Tokyo, 107–112.
- KIUCHI, H., HAMA, S., AMAGAI, J., ABE, Y., SUGIMOTO, Y., and KAWAGUCHI, N., 1991a, *J. Commun. Res. Lab.*, **38**, 435.
- KIUCHI, H., KONDO, T., and POPELAR, J., 1991b, *J. Commun. Res. Lab.*, **38**, 577.
- LEVY, G. S. *et al.*, 1989, *Astrophys. J.*, **336**, 1098.
- LINFIELD, R. P., LEVY, G. S., ULVESTAD, J. S., EDWARDS, C. D., DINARDO, S. J., STAVERY, L. R., OTTENHOFF, C. H., WHITNEY, A. R., CAPPALLO, R. J., ROGERS, A. E. E., HIRABAYASHI, H., MORIMOTO, M., INOUE, M., JAUNCEY, D. L., and NISHIMURA, T., 1989, *Astrophys. J.*, **336**, 1105.
- NAKAMARU, K. and KITAHARA, H., 1989, *Denshi Tokyo*, **28**, 66.
- NISHIMURA, T., 1991, *Frontiers of VLBI*, eds. Hirabayashi, H., Inoue, M. and Kobayashi, H., Tokyo University Academy Press, Tokyo, 3.