Vol. 36 No. 148 *Journal of the Communications Research Laboratory* *July 1989*
Printed in Tokyo, Japan *pp. 107–124*

A HIGHLY STABLE CRYSTAL OSCILLATOR APPLIED TO GEODETIC VLBI

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(Received on February 3, 1989)

ABSTRACT

Instead of a hydrogen maser, a carefully selected Crystal oscillator which is phase locked to a Cesium (Cs) frequency standard for time ranges of more than 100 seconds is adopted to the time and frequency standard of a geodetic VLBI experiment. The domestic VLBI experiment with 55 km baseline using the Crystal oscillator at one end was made in Japan and the obtained error of the baseline vector components were 4 cm, and that of the baseline length was 3 cm. This system may be operated after only 2 hours warm up. These results coincide with those of conventional geodetic Laser ranging and VLBI using a hydrogen maser within the formal error. A VLBI experiment with over 1000 km baseline was carried out successfully in October 1988.

1. Introduction

Very Long Baseline Interferometry (VLBI)(1)–(7) is one of the most accurate modern positioning techniques. Although it was initially developed by astronomers as a tool to improve the angular resolution of radio telescopes, it was realized that it would also be an ideal geodetic instrument. Signals from a cosmic or celestial radio source, usually the random noise signals of a quasar or other compact extragalactic object, are received at the antennas of two or more radio telescopes. These signals are amplified and down-converted to a low frequency band, keeping coherence by using a local oscillator which is phase locked to a hydrogen maser frequency standard. The converted signals are then digitized, time-tagged, and recorded on wide bandwidth magnetic tapes. Subsequently the recorded signals are played back at a central processing site. The processor cross correlates the data from the tapes sent from both stations under computer control. The output of the processor is a sampled cross correlation function, which is the fringe of the interferometer. One of the important points of this technique is the use of independent frequency standard in every station (Fig. 1). Progress in atomic frequency standards and also high precision time synchronization technology has made it possible to conduct VLBI experiments with baselines of longer than 10,000 km.

In usual VLBI experiments made for geodetic purposes, each antenna receives signals from a radio source for a hundred seconds or more in one observation. This observation is repeated changing between dozen or more radio sources during a nominal 24-hour session. A single experiment therefore consists of a hundred or more observations. The frequency standard of VLBI must be stable over a long time range (more than 100 sec) as well as a short time range (less than 100 sec). Short time range stability is essential for maintaining

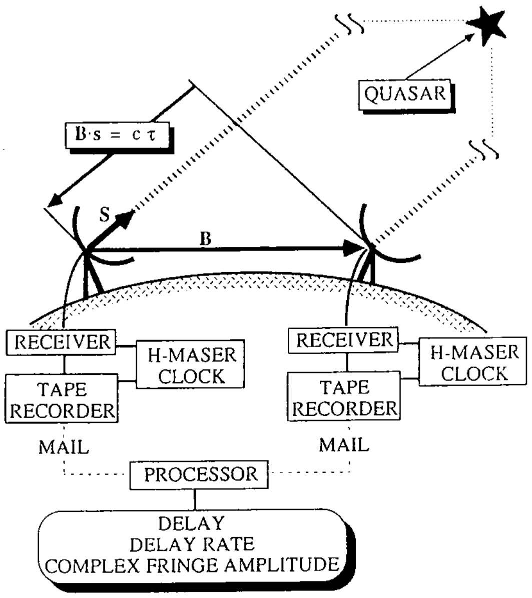


Fig. 1 VLBI basic geometry

the coherence and long time stability is necessary for regulating the time of observations. The hydrogen maser oscillator satisfies these requirements and this is a reason for its use for VLBI. However, resent technology has improve the stability of Crystal oscillator (AT-cut resonator of the BVA style(8),(9)). The possibillity of Crystal oscillator as a frequency standard of VLBI will now be discussed. A hydrogen maser frequency standard with stability better than 10^{-14} has been playing an important role in the VLBI experiments. Maintaining the coherence of the receiving signal of each station is one of the most important factors in VLBI data acquisition, while the stability of the atmosphere which causes phase scintillation, is about 10^{-13} as measured by VLBI. The atmospheric scintillation degrades the coherence of the VLBI data, which is independent of the phase fluctuation of hydrogen maser. Research work in the Crystal oscillators has made remarkable progress in recent years, and the stability of selected Crystal oscillators reaches σ_y (τ ⟨100 sec) = 3×10^{-13}, a value comparable to the stability of the atmosphere. Therefore the potential for obtaining a good fringe by using the Crystal oscillator instead of the hydrogen maser exists. The main purpose of the new frequency reference system development was to contract a highly transportable time and frequency standard for VLBI, and in our case we adopted a Crystal oscillator for VLBI frequency reference. The Crystal oscillator has advantages for space technology application (Space VLBI etc.), and transportable VLBI because it satisfies the requirements of small size, light weight, and aseismatic structure.

A new frequency system which constructed a Crystal oscillator whose phase is locked to that of a Cesium (Cs) frequency standard (Crystal-Cesium system) has been developed for time ranges of over 100 seconds, as the stability of Cesium frequency standard is better than that of a Crystal oscillator for long term ranges. First of all, zero and short baseline interferometer experiments(10),(11) were carried out to assess the performance of the Crystal-Cesium system and to find the optimum data analysis method for using the Crystal-Cesium system. Secondly, the 55 km baseline (a reference baseline in Japan, which has been measured 5 times by VLBI and other methods) VLBI experiment was made in order to provide a comparison with conventional results and to determine optimum integration time for this system. As a result of these experiments, the baseline vector was obtained with an error of 4.3 cm on each component, and 3.4 cm on its length.

2. Potential of the Crystal Oscillator as the VLBI Frequency Standard

The stability of frequency standard in a short time period is an important factor in maintaining the coherence of received signals in VLBI experiments. However VLBI observation from the ground always suffer from the atmospheric scintillation effect, resulting in a loss of coherence. Therefore the stability of the atmosphere determine the limit of require-

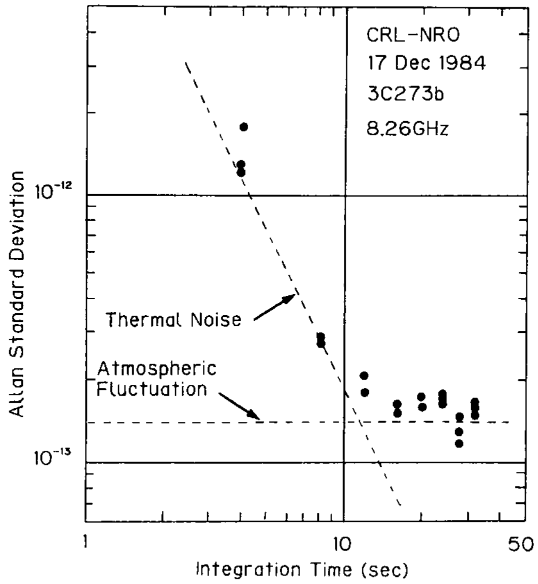
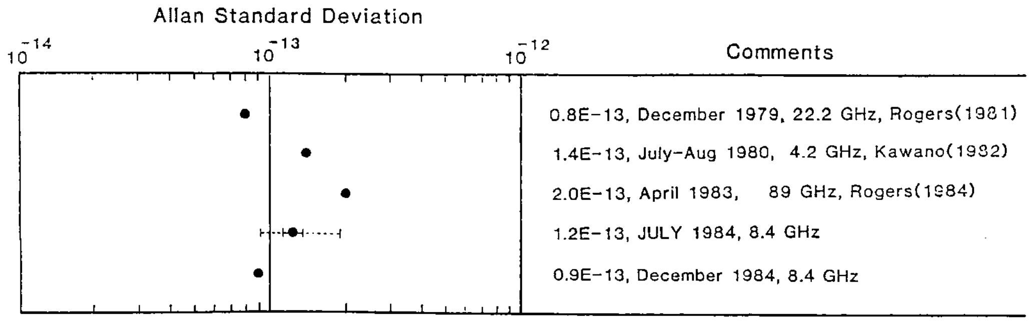


Fig. 2 Atmospheric fluctuation in Allan standard deviation
This is the result of the domestic VLBI between CRL-NRO (Nobeyama Radio Observatory) in Dec. 1984. X-axis shows the integration time and Y-axis shows the stability in Allan variance.

Table 1 Atomospheric fluctuation in Allan standard deviation



Comments
0.8E-13, December 1979, 22.2 GHz, Rogers(1981)
1.4E-13, July-Aug 1980, 4.2 GHz, Kawano(1982)
2.0E-13, April 1983, 89 GHz, Rogers(1984)
1.2E-13, JULY 1984, 8.4 GHz
0.9E-13, December 1984, 8.4 GHz

ment for that of frequency standard in a short time range. The stability of atmosphere was measured to about 1×10^{-13} at 100 sec by domestic VLBI (Fig. 2), this result being almost same as those of Rogers(12), Kawano(13) and our measurements (Table 1). The stability of hydrogen maser is 1×10^{-14} at 100 sec and it is stable enough compared with the atmosphere, while recent technology progress has provided a stability of 3×10^{-13} for Crystal oscillators, which is almost the same as the atmosphere's stability. A Crystal oscillator is strongly proposed as a frequency standard for VLBI in a short time range.

The requirements for the VLBI frequency standard are as follows;

(1) To keep the signal coherence during integration time.

(2) Phase variance of the clock instability should be better than accuracy of the measurement.

The coherence loss L_c due to the instability of frequency standard in 100 sec integration time is estimated by Eq. 1(14),(15).

$$L_c = \omega_0^2\ (\alpha_p/6 + \alpha_f/12*T + \sigma_y^2/57*T^2) \qquad \text{(1)}$$

where

L_c: loss of coherence

ω_0: angular frequency of local oscillator (8080 MHz in X band) [rad/sec]

α_p: Allan variance of white phase noise at 1 sec
$(1\times10^{-13})^2$: hydrogen maser

α_f: Allan variance of white frequency noise at 1 sec
$(7\times10^{-14})^2$: hydrogen maser

σ_y^2: Constant Allan variance of flicker frequency noise
$(5.5\times10^{-15})^2$: hydrogen maser
$(3\times10^{-13})^2$: Crystal

T: Integration time [sec]

The stability of the hydrogen maser(16) at Kashima is shown in Fig. 3. According to Eq. 1, the calculated losses for hydrogen maser and Crystal oscillator at an integration time of 100 sec are 1.23×10^{-4} and 0.041 respectively, and compared with the loss due to 1 bit sampling (Loss = 0.36) at data acquisition they are small enough to be ignored. Long term stability of the frequency standard is necessary for regulating the results of each observation when analyzing them. Though the long term stability of the Crystal oscillator is not acceptable for VLBI, the high performance Cesium frequency standard has a superior stability in a long term ($\sigma_y(\tau > 100) \leq 3\times10^{-13}$). But if only Cesium is used in VLBI experiments, it is impossible to keep the coherence of the X band signal, as the stability of Cesium is worse than 10^{-12} in the short term during signal integration. Hence a frequency standard, which has the stability of the Crystal in a short time range and that of Cesium in a long time range, is needed to satisfy the requirements of VLBI and can be realized by using a Crystal oscillator with its phase locked to the Cesium frequency standard in a long time range.

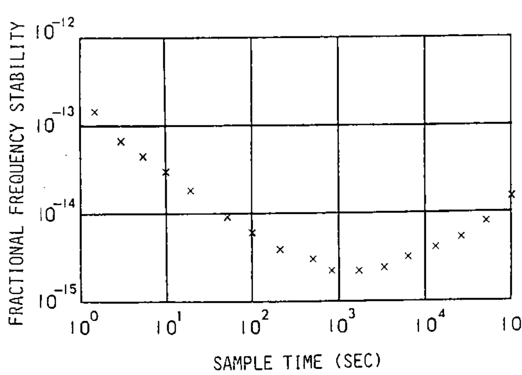


Fig. 3 Stability of the hydrogen maser in Kashima station

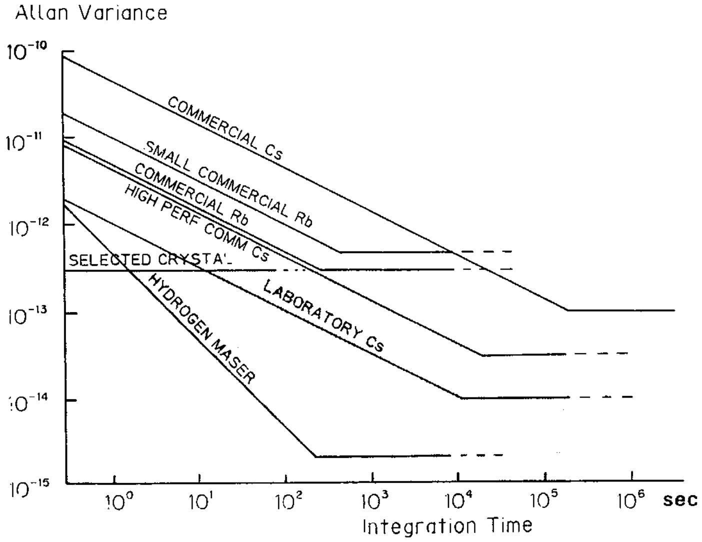


Fig. 4 Required stability

The required stability of this equipment is the shaded area in Fig. 4. Stability measurements with Zero Baseline Interferometry and the short baseline VLBI experiment were made.

3. The Stability Measurement with Zero Baseline Interferometry

Stability was measured with Zero Baseline Interferometry (ZBI)(10) (Fig. 5). This method used the K-3 VLBI system which was developed at CRL. System noise of this method is very low and this measurement is a realistic method for VLBI experiments, because the performance of the oscillator is measured in the same configuration. In VLBI, the geodetic reference point is the intersection point of the axes of Azimuth (Az) and that of Elevation (El), and is a stationary point. In ZBI method, both receiving systems are mounted on a same antenna. In this case, the baseline length is zero, because the geodetic reference point is common for both systems.

The common noise generated by a Noise Diode is injected into both X band feeder

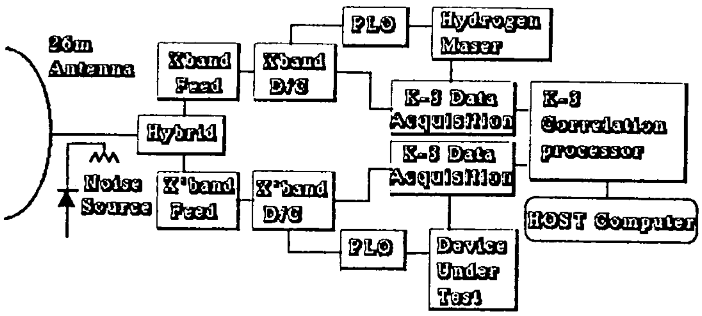


Fig. 5 Block diagram of the stability measurement system

systems. The reference signal is supplied to one system by a hydrogen maser and to the other by the test frequency system (DUT: Device Under Test). A cross correlation was made between the two systems in real time by using the K-3 VLBI correlation processor. Then the resulting stability was equivalent to both referencies. In this case, the DUT's are a Cesium, a Crystal and a Crystal-Cesium system. This method is a modified DMTD (Double Mixer Time Difference) method. The results are shown in Fig. 6, which shows the detected fringe phase in the X band. It is possible to find out the long term characteristics in stability of the frequency standard. The result of using Crystal oscillator (Fig. 6a) shows random walk over the long term caused by the external temperature change. When using Cesium frequency standard (Fig. 6b), the fringe phase is stable in the long term. And in the case of using a Crystal-Cesium system frequency standard (Fig. 6c), the fringe phase is as stable as when using only a Cesium frequency standard. Fig. 7 shows the observed delay in X band. This detected fringe phase is the respective instrumental delay of two systems. It is possible to find out the capability for keeping coherence. When using a Crystal oscillator (Fig. 7a), it is possible to get a good fringe, and the determined delay is stable. When a Cesium frequency standard is used (Fig. 7b), the determined delay changed as much as 100 nsec, and thus it is impossible to keep the coherence in the X band. This means the Cesium frequency standard is not suitable for the frequency standard of VLBI in the X band. The results from the Crystal-Cesium system have the same characteristics as those from when only the Crystal oscillator was used.

Fig. 8 shows that the coherence depends on integration time, and it is calculated directly from the correlated data. It is possible to tell coherence from this Figure.

Fig. 9 shows the stability of the Crystal-Cesium system, which is measured by the detected fringe.

These results show that the Crystal oscillator has a good short term stability but it is inferior to the Cesium frequency standard in the long term, while a Cesium standard has a excellent long term stability but it is unusable for X band VLBI experiments. The Crystal-Cesium system is very close to meeting requirements.

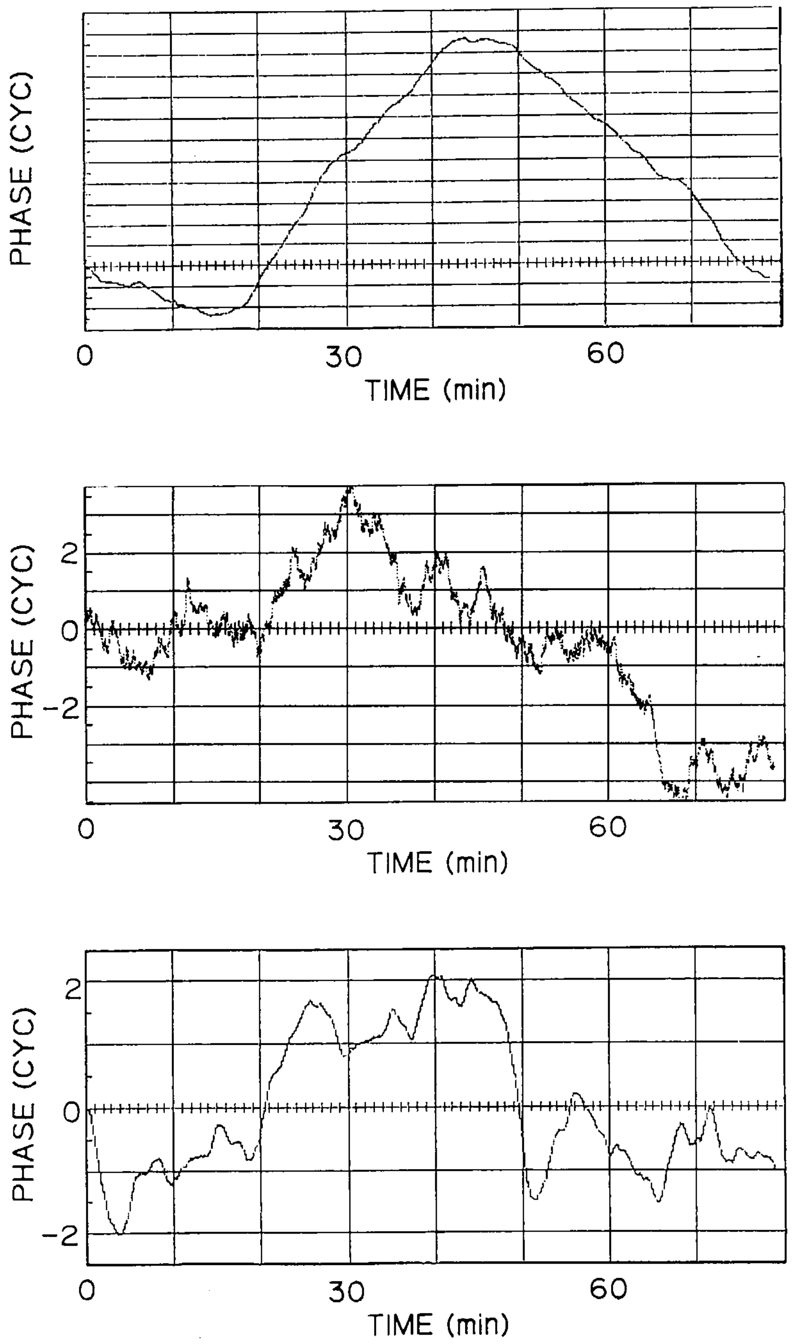


Fig. 6 Variation of the correlated phase
(in regular order)
(a) the result of using a Crystal oscillator only
(b) the result of using a Cesium standard only
(c) the result of using a Crystal-Cesium system

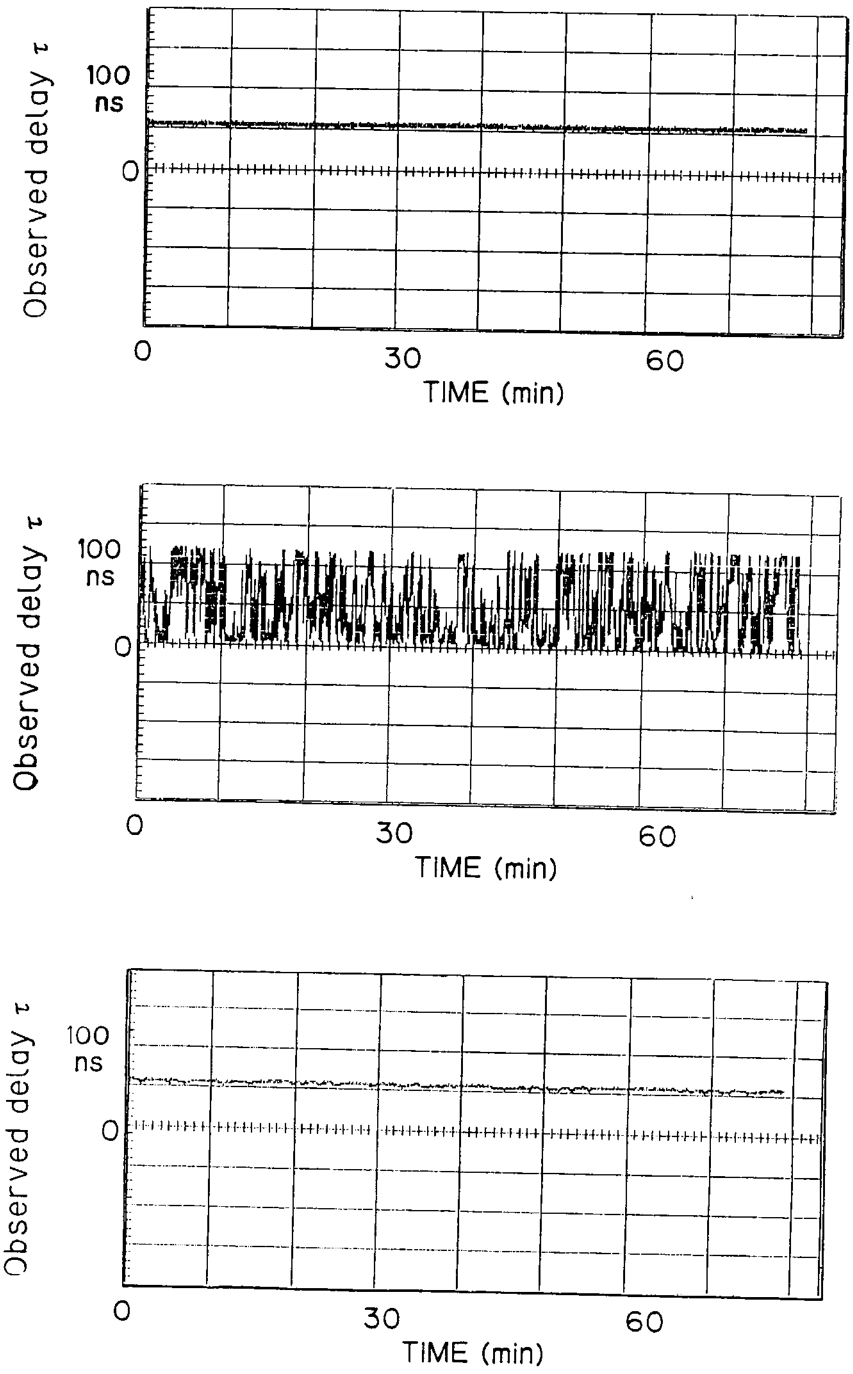


Fig. 7 Variation of the determined delay τ (in regular order)

(a) the result of using a Crystal oscillator only
(b) the result of using a Cesium standard only
(c) the result of using a Crystal-Cesium system

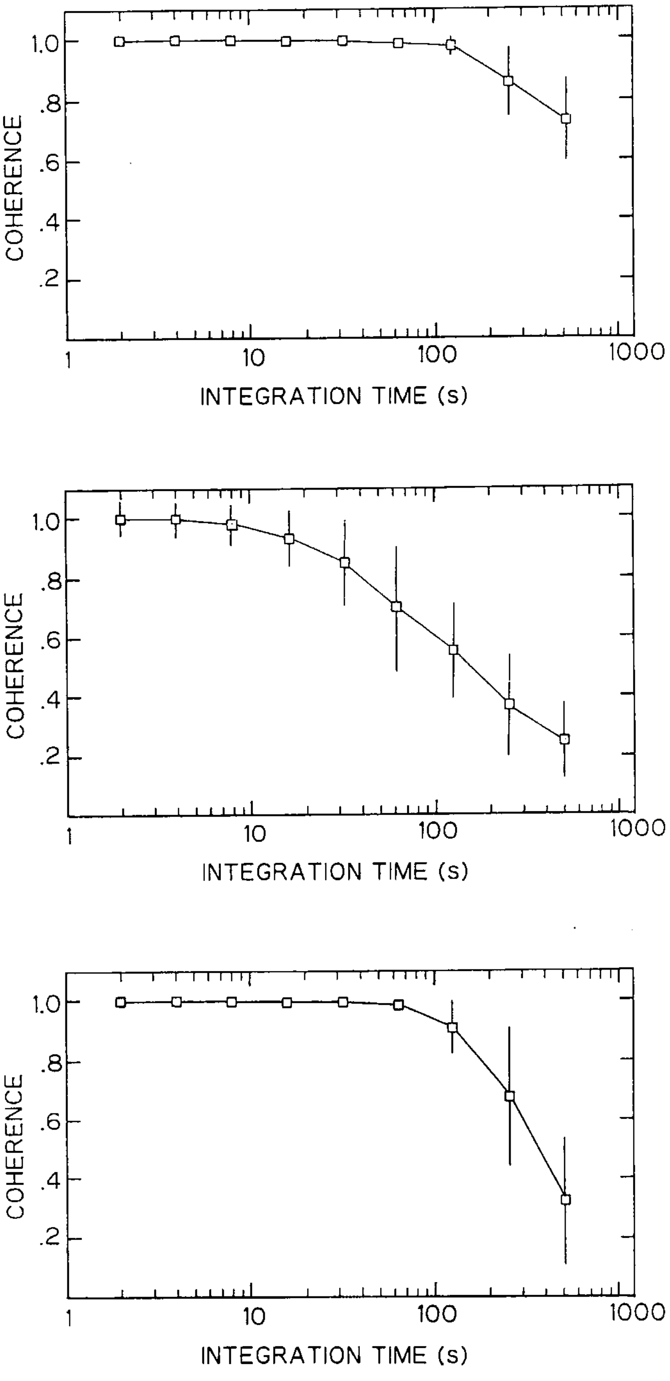


Fig. 8 Coherence
(in regular order)
(a) the result of using a Crystal oscillator only
(b) the result of using a Cesium standard only
(c) the result of using a Crystal-Cesium system

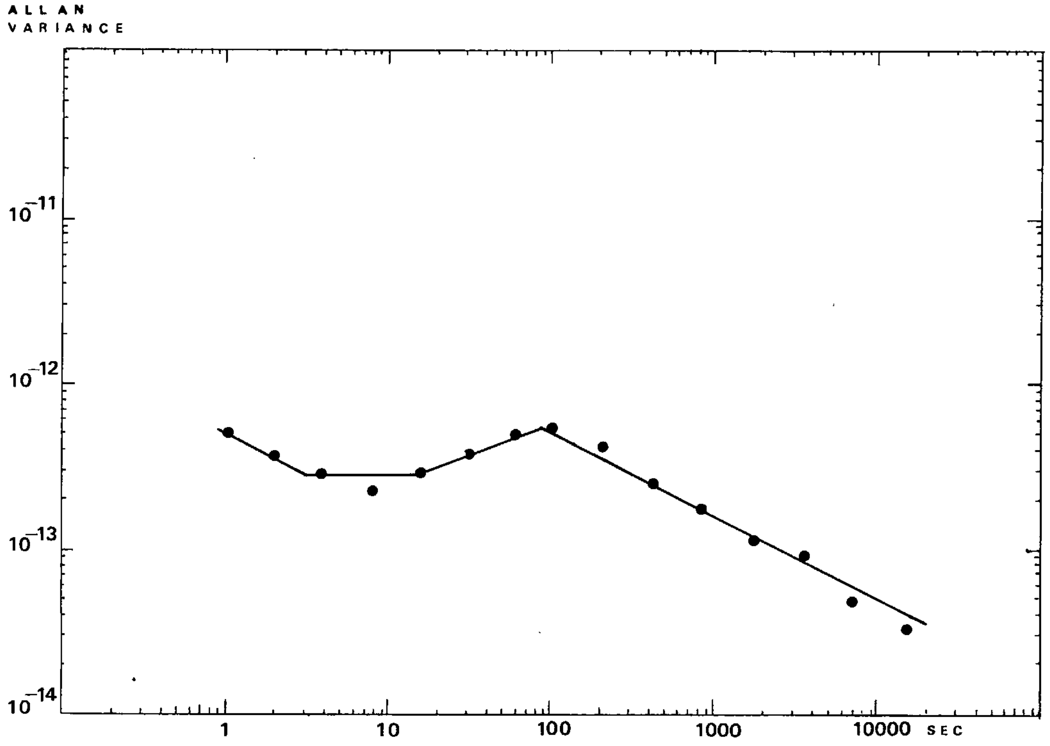


Fig. 9 Stability of the Crystal-Cesium system

4. Estimation of the Optimum Integration Time for the Crystal-Cesium System

The SNR of VLBI is calculated by Eq. 2.

$$\begin{aligned} SNR = {} & [\pi * Sc/8k] * [D1 * D2 * SQRT(\eta 1 * \eta 2)/SQRT(Ts1 * Ts2)] \\ & * SQRT(2BT) * \rho \qquad (2) \end{aligned}$$

where

Sc: correlated flux of source

D: diameter of the antenna

Ts: system temperature

T: integration time

k: Boltzman constant

η: antenna efficiency

B: band width

$$\rho = \underbrace{(2/\pi)}_{\text{1 bit sampling loss}} * \underbrace{0.6}_{\text{Scintillation loss}} * \underbrace{SQRT(3/4)}_{\text{Fringe stopping loss}}$$

The coherence loss is expressed by Eq. 1. There is an optimum integration time which gives the maximum SNR*coherence, and an estimate of this suitable integration time is shown in Fig. 10. Fig. 10 (a) shows the estimated SNR*coherence were a fixed Cesium stability ($\sigma_y(1) = 3\times10^{-12}$) and variable Crystal stability are used. Fig. 10 (b) shows the opposite situation (fixed Crystal stability and variable Cesium stability), where fixed Crystal stability is $\sigma_y(1) = 4\times10^{-13}$. The optimum integration time depends on the stability of the

Stability of Crystal oscillator $\sigma_y(\tau=1)$	Maximum SNR point in Integration Time
3×10^{-13}	190 [sec]
4×10^{-13}	184
5×10^{-13}	177
6×10^{-13}	169

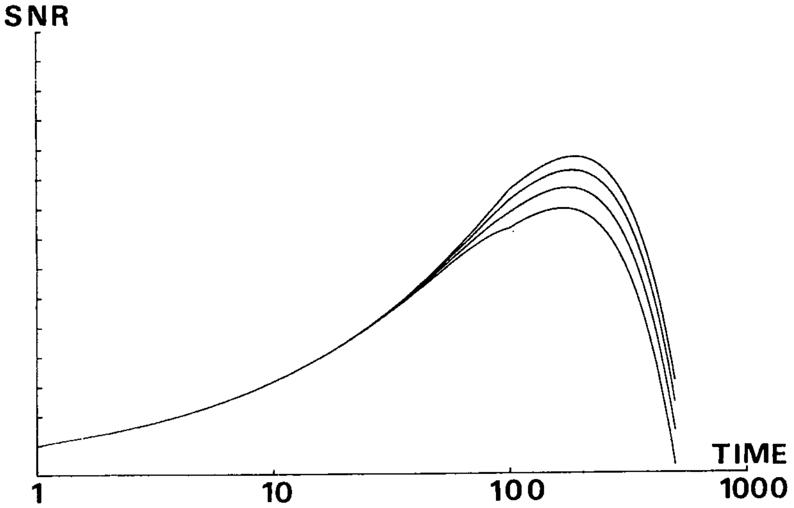


Fig. 10 (a) Estimated SNR*coherence (fixed Cesium stability)

Stability of Cesium Frequency Standard in $\sigma_y(\tau=1)$	Maximum SNR point in Integration Time
3×10^{-12}	184 [sec]
4×10^{-12}	118
5×10^{-12}	100

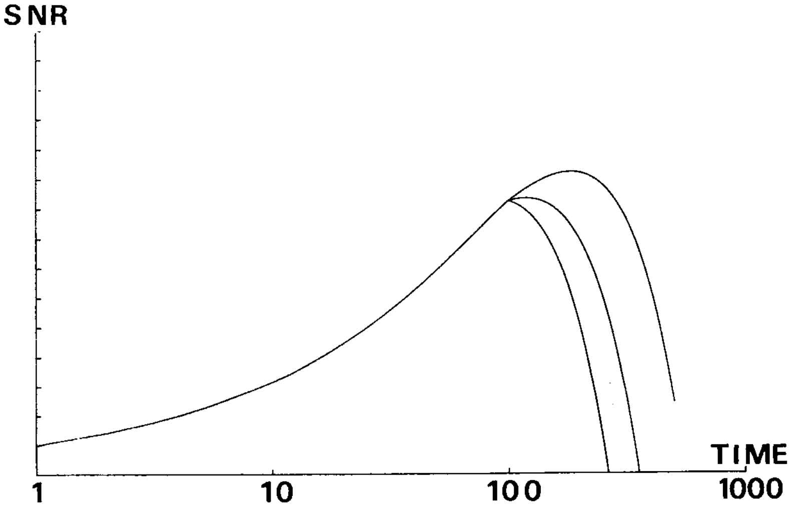


Fig. 10 (b) Estimated SNR*coherence (fixed Crystal stability)

Crystal oscillator and that of the Cesium frequency standard. When using high performance commercial Cesium, the SNR*coherence has a maximum value at about 120 sec integration time. As in this case the clock error is less than 0.05 nsec, it can be said that the optimum integration time is 120 sec for this system.

It is possible to use the data with SNR better than 7 for VLBI data analysis. In other words, the Crystal-Cesium system, which can get SNR of better than 7 in 120 sec integration time can be used with the VLBI antenna pair.

5. Test Experiment Using a Crystal Oscillator with Short Baseline

A short baseline experiment of only 80 m was made at Kashima, the purpose of the experiment being to find a suitable analysis method to apply to the Crystal-Cesium system in VLBI experiments. The clock parameters between both systems are measured easily by conventional methods. The 26 m Az-El type radio telescope and the portable VLBI system(11) were used. The 26 m Radio telescope is equipped with the K-3 VLBI system which is compatible with the Mk-III VLBI system developed in the USA. The portable VLBI station consists of a 3 m antenna, an antenna control unit and the K-3 VLBI system. In the experiment, the reference frequency standards on each station are independent. A hydrogen maser is used as the reference frequency standard of the 26 m antenna system which is our main system. The Crystal-Cesium system works as the reference frequency standard of the portable VLBI station. Fig. 11 shows a block diagram of this experiment. The experiment was carried out over 24 hours, the cross correlation being made in real time.

Fig. 12 (a) shows the result of the residual rate which is the difference between the observed and the calculateed fringe rates one according to an a priori baseline vector and clock rate. The horizontal axis shows the residual rate in pico-sec/sec and vertical axis shows time in days. The accuracy of the delay rate is extremely sensitive if the hydrogen maser is used. But in case of the Crystal-Cesium system, the obtained residual rate itself is not enough for baseline analysis, but is useful for solving the ambiguity. The contribution between the residual delay to baseline analysis and the residual rate is as follows;

(the weight of the residual delay) / (The weight of the residual rate)

$$= \left\{ \langle | \tau_{g\,max} \cos \omega t | \rangle / \sigma_D \right\} \; / \; \left\{ \langle | \tau_{g\,max} \sin \omega t | \rangle / \sigma_R \right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

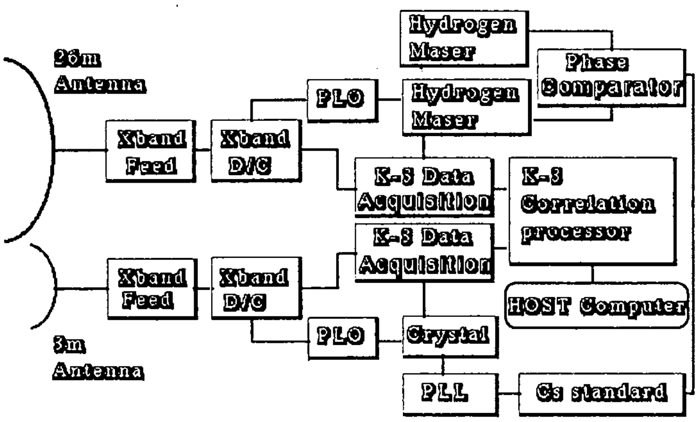


Fig. 11 Block diagram of the SBI

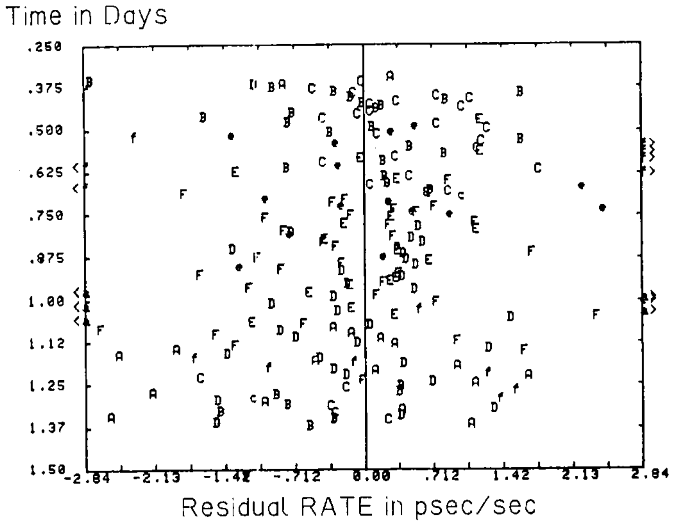
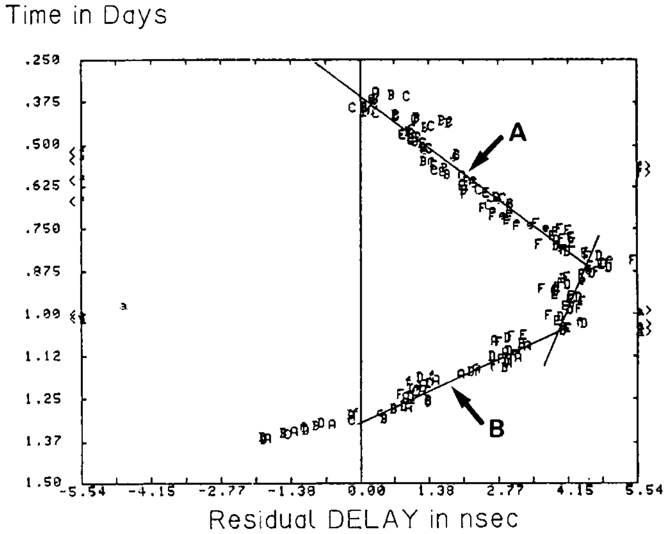


Fig. 12 (a) Residual rates of the SBI experiment



RATE(VLBI)

A 1.07×10^{-13}

B -1.56×10^{-13}

Fig. 12 (b) Residual delay of the SBI experiment

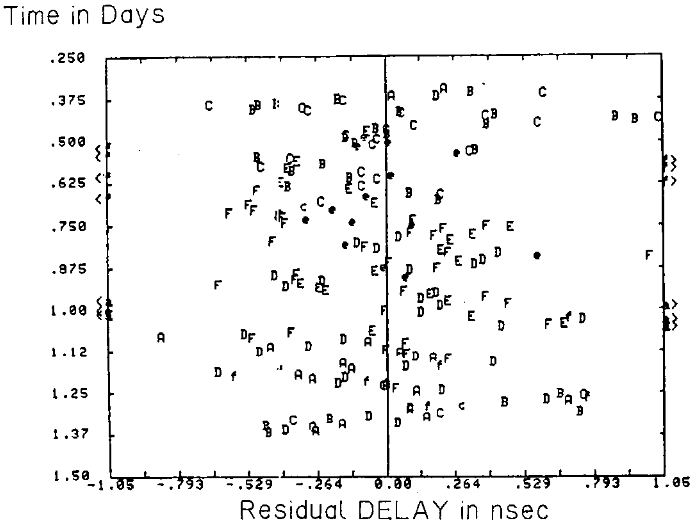


Fig. 12 (c) Residual delay after removing the clock rate change where

$\tau_{g\,max}$: maximum geometrical delay

σ_D : standard deviation of the residual delay

σ_R : standard deviation of the residual rate

ω: angular frequency of the earth rotation

$\langle \quad \rangle$: average

The values of the σ_D and σ_R in most of VLBI, are 0.1 nsec and 0.1 psec/sec, respectively. Eq. 3 becomes 1/0.07 in this case.

The one day experiment consists of over one hundred of observations. If the number of observations is N, the weight of estimated error (Eq. 3) caused by eliminating the residual rate is as follows;

$$\left\{ 1/\mathrm{SQRT}(N+0.07N) \right\} \;/\; \left\{ 1/\mathrm{SQRT}(N) \right\} = 1/\mathrm{SQRT}(1.07) = 0.97 \qquad \ldots\ldots\ldots\ldots (4)$$

Hence the contribution of the residual rate for accuracy is only 3%.

It is possible to analyse the baseline vector without the residual rate data. A baseline analysis using only the residual delay data was made. Fig. 12 (b) shows the residual delay which is the difference between the observed fringe delay and a calculated one from an a priori baseline vector and clock offset. It is clear that there are two bends which are caused by clock. When frequency monitoring, using two hydrogen masers and a Cesium is carried out, it becomes clear that the frequency change is caused by the hydrogen maser which is the reference of the main station. The frequency change rate by other conventional phase comparison methods is 2.77×10^{-13}, this is in close agreement with the change of the observed residual delay in VLBI of 2.63×10^{-13} (B-A in Fig. 12 b). Therefore we made an analysis of the baseline setting the epoch at the bends and it was shown that the Crystal-Cesium system has a good long term stability.

Fig. 12 (c) shows the final results after the reduction of the clock rate change. Using this

Table 2 Observed baseline components in SBI experiment

	X	σ_x	Y	σ_y	Z	σ_z	B	σ_B
Laser	-47.065	0.010	-19.503	0.008	-61.976	0.010	80.228	0.010
Common Ref.	-47.059	0.008	-19.531	0.007	-61.970	0.011	80.226	0.008
Crystal	-47.049	0.028	-19.511	0.029	-61.986	0.041	80.229	0.030

* in [m]

Laser : Conventional Laser ranging.

Common Ref. : Connected element interferometry using common Hydrogen maser.

Crystal : VLBI using crystal phase locked Cesium frequency standard.

residual delay, we analysed the baseline vector and compared it with the results of previous ground surveys using Laser ranging.

The results of the analysis are shown in Table 2.

The error of each baseline vector component was 4 cm, and that of the baseline length was 3 cm.

The capability of the Crystal-Cesium system, the optimum integration time and analysis method have been discussed. In the next section, the suitability of this system for long baseline experiments is discussed.

6. The 55 km Baseline Experiment

An experiment with the 55 km baseline, which is regarded as a reference VLBI baseline in Japan, was made immediately after JEG-5 (fifth Geodetic VLBI experiment between Tsukuba GSI: Geographical Survey Institute, and Kashima CRL using hydrogen masers at both stations) and the schedule of JEG-5 was repeated, in order to avoid problems arising from the change of the propagation media error. A Crystal, a Cesium frequency standard and a PLL circuit were transported from Kashima to Tsukuba 2 hours before the start of the experiment. The 26 m Az-El type Radio telescope at CRL Kashima and the 5 m Az-El type Radio telescope at GSI Tsukuba were used. Both Radio telescopes are equipped with the K-3 VLBI system. The 26 m Radio telescope and the K-3 VLBI system was developed at Kashima and the 5 m Radio telescope was developed at Tsukuba. A hydrogen maser frequency standard is used as the reference signal at the Kashima station and the Crystal-Cesium system is used at the Tsukuba station. Other parts of the system were the same as the JEG-5 experiment. The experiment was done for 24 hours, and the cross correlation was made in Kashima. The results are shown in Table 3.

Table 3 Observed baseline components in 55 km baseline experiment

	X	σ_x	Y	σ_y	Z	σ_z	B	σ_B
JEG-5	-3957171.259	0.020	3310237.094	0.017	3737709.499	0.022	54548.556	0.007
CASE-I	-3957171.290	0.089	3310237.040	0.082	3737709.506	0.093	54548.502	0.026
CASE-II	-3957171.302	0.075	3310237.085	0.061	3737709.514	0.077	54548.522	0.021
CASE-III	-3957171.377	0.112	3310237.141	0.099	3737709.596	0.110	54548.522	0.031

* in [m]

JEG-5 : Using Hydrogen maser. integration time(80 to 300sec) is dependent on source.
CASE-I : Integration Time is same as using Hydrogen Maser(80 to 300sec).
CASE-II : Integration Time is fixed in 120sec.
CASE-III : Integration Time is fixed in 60sec.

In order to compare the accuracy dependence for the integration time, the results for the following three cases were analysed.

case I: Same integration time as JEG-5
(80 to 300 sec integration time which depends on the source flux)
case II: Integration time fixed for 120 sec.

case III: Integration time fixed for 60 sec.

The most acculate result is obtained with a 120 sec integration time (case II).

In case I, some correlated peak (fringe phase) on delay rate is detectable, and shows that the rate changed within the integration time. In case III, it is impossible to get SNR better than 7 at the weak radio sources. The difference between the result with the hydrogen maser (JEG-5) and that of the Crystal-Cesium system (case II) is less than 4.3 cm in baseline vector, and 3.4 cm in baseline length.

7. Application of the Crystal-Cesium System to the 1000 km + Baseline VLBI Experiment

The over 1000 km baseline VLBI experiment was made in October 1988 between Kashima and Wakkanai, the northernmost part of Japan. In this experiment, the highly transportable VLBI station which consists of a 3 m antenna, the antenna control unit, the K-4 VLBI system and the Crystal-Cesium system, was operated in Wakkanai. This system is the smallest VLBI data acquisition system in the world. Generally the measured accuracy of VLBI worsens as antenna size decreased, but this system has overcome the problem through the wide bandwidth receiving. The receiving bandwidth (273 MHz effective bandwidth) is twice as wide as the normal X band bandwidth (128 MHz) in CDP experiment. The K-4 VLBI system is a data aquisition system which was developed at CRL for application in transportable VLBI stations. The direction of the baseline vector was approximately North-South. Good fringes and good results were obtained from this system. The baseline vector was obtained with errors of 5.1 cm in the X, 3.8 cm in the Y, 6.2 cm in the Z components, and an error of 1.5 cm in its length on VLBI coordinate. The errors of 1.4 cm in the North-South component, 1.0 cm in the East-West component (horizontal components) and 8.7 cm in the vertical component were obtained. The results show that sensitivity in horizontal components is good, making analysis of plate motion possible, and also show the effectiveness of the Crystal-Cesium system for VLBI frequency standard even for VLBI experiments with baselines over 1000 km.

8. Discussion

The stability of the atmosphere is about 10^{-13}. This scintillation affects the coherence of the signal and it is impossible to avoid this effect even if a hydrogen maser is used. The short range stability of the Crystal oscillator reaches 3×10^{-13}, this value being almost the same as that of the atmosphere. It is shown that it is possible to get a good fringe using the Crystal oscillator instead of the hydrogen maser. But the Crystal oscillator is inferior to a Cesium frequency standard in long term stability. Our system consists of Crystal and Cesium, where the special characteristic of Crystal was utilized for the short term stability and that of Cesium was utilized for long term stability.

A Crystal oscillator whose phase is locked to a Cesium frequency standard for period over 100 seconds has been developed. A zero baseline VLBI experiment was made in order to measure the stability and coherence of the Crystal oscillator. The 55 km baseline interferometry experiment was made for comparison with the JEG-5 experiment and to check the capability of the frequency standard for practical VLBI experiments, good results being obtained in spite of a tight schedule. The Crystal-Cesium system is ready for operation after only two hours start up time. The baseline length was determined with a precision better than 3 cm and the component of baseline vector was determined with a precision better than 4 cm. Farthermore the result agrees with the results of conventional geodetic measurement within the formal error. Also it was found that unlike system using a hydrogen maser, this frequency system had a suitable schedule and analysis method.

This system can be used for VLBI frequency standard, and it has advantages for use with a transportable VLBI system, but its accuracy is worse than that of a hydrogen maser system. Although ambient temperature control was not considered, external temperature control is desirable to keep the stability of the Crystal in Flicker in using the Crystal oscillator, as it has a strong dependency on temperature.

We expect to develop the Crystal oscillator which has a stability better than 1×10^{-13} The coherence loss caused by this stability is 0.0045, which is small enough for keeping coherence.

9. Conclusion

Instead of a hydrogen maser, a Crystal-Cesium system as a transportable VLBI station frequency standard was made. The Crystal oscillator offers advantages for transportable VLBI because it is small, light in weight, aseismatic in structure and has a short in starting up time. In this paper, the capability and the optimum integration time of the Crystal-Cesium system has been discussed, and the application of this system to the long baseline interferometry has been shown. In the 55 km baseline experiment, the difference between the results with hydrogen maser and those with the Crystal-Cesium system is less than 4.3 cm in baseline vector, and 3.4 cm in baseline length. Furthermore, a VLBI experiment of over 1000 km was performed successfully, with errors of 6.2 cm in vector components, and 1.5 cm in lenght. At CRL, an Antarctic VLBI experiment is being planed for the near future. The application of this system to this experiment is our next research project.

Acknowledgement

The Crystal oscillator was specially selected by the OSCILLOQUARTZ company in Switzerland for our experiment. We would like to express our thanks to Dr. Schlueter, the director of OSCILLOQUARTZ. We are indebted to the staff members of Geographical Survey Institute in the domestic experiment.

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