RESULTS OF THE JAPAN-US JOINT VLBI SYSTEM-LEVEL EXPERIMENTS

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Summary

The Japan-US VLBI system-level experiments were carried out in January and February, 1984. These experiments showed the Japanese. Very Long Baseline Interferometry(VLBI) system had the expected performances, and the baseline length between Kashima in Japan and Mojave in USA was determined with a precision of 3cm.

Introduction

VLBI has a potential of cm accuracy in a long distance measurement, for example, in several thousands km. A precise Very Long Baseline Interferometer, called K-3 system was completed at Radio Research Laboratories(RRL) in September, 1983. The K-3 system is designed to be compatible with the Mark-III system of USA for the use of global VLBI experiments. After the fringe test with Mojave in USA(1), the Japan-US system-level experiments were carried out to confirm the overall performance of the K-3 system and to measure the baseline length with cm precision in a global VLBI network. In succession to the experiments, global experiments started in July,1984 to detect plate motions and to measure the earth rotation in cooperation with NASA. These experiments will continue at least through 1989(2).

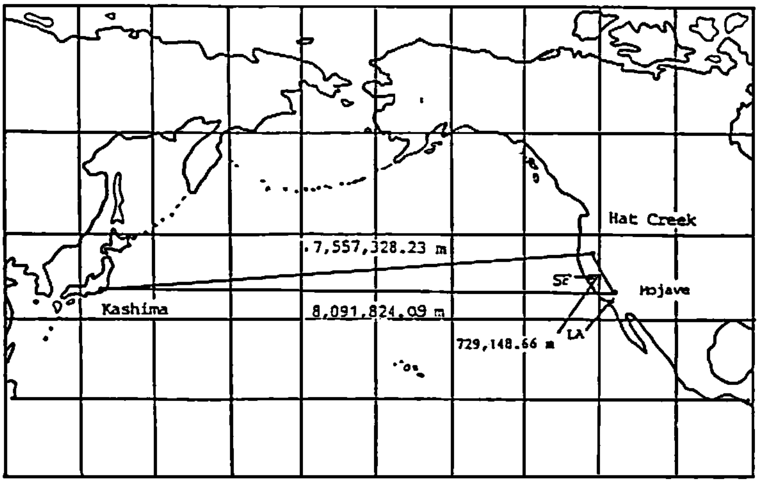
In this report, the Japan-US joint VLBI system-level experiments, the determinations of the baseline length and Kashima position(X,Y,Z) referred to Mojave position together with their errors were mainly discussed.

Experiment

The experiments were carried out two times to confirm the repeatability of the estimation of the baseline length. Kashima (Japan;RRL) with K-3 system and Mojave(USA;NASA) with Mark-III system participated in the first experiment. The second were made among three stations, Kashima, Mojave and Hat Creek(USA;Univ. of Calif.) with Mark-III system. The observations were made according to the same schedule as that for the coming global experiments, taking into consideration of the purpose of the system-level experiment. In both experiments, 13 radio sources (most of these sources are quasi-stellar objects) were alternately observed for about 24 hours. The total delay time and delay rate data in each experiment reached to about 200. The baseline length and other parameters can be estimated from these delay time data.

Fig. 1 shows the configuration of baselines in the experiments. The length of the inter-continental baseline(Kashima-Mojave) is about eight thousands km. The baselines from Kashima to the two stations in USA are in almost East-West direction, so that it is difficult to estimate earth orientation parameters (EOP). For this reason, we adopted the parameters obtained by the optical observations(IPMS; International Polar Motion Servicee) and the other (BIH;Bureau International de l'Heure) for use in our analyses.

Fig. 1. Configuration of the baselines



Results

The data processing and the analysis were performed independently by two institutes, RRL and Haystack Observatory in the data processing, RRL and Goddard Space Flight Center(GSFC) in the data analysis, which used the different software in some parts(3,4) from each other. The standard deviation of delay residuals processed in RRL was roughly equal to that in Haystack Observatory. However, the two results of the estimated Kashima position(X,Y,Z) and the baseline length have distinct difference in the first experiment. This difference would be caused by physical models used. Fig. 2 shows the residual delays for observed stars(A,B,..) after the parameter estimation. The standard deviation is about two or three times larger than that of the measured delay time. This discrepancy between them means the existence of some systematic errors. Furthermore, we had to employ the EOP's by IPMS and BIH because of the flat configuration of baselines mentioned above. We also compared the results derived from two EOP's. The discrepancy could be found in Kashima position. It is one of the purposes of these experiments to derive discrepancies due to different software and EOP's. Table 1. shows the baseline length and adjusted values of Kashima position (X,Y,Z) from the "a priori" one in the VLBI coordinate system. The "a priori" Kashima position was calculated from (X,Y,Z) in Bessellian coordinate system released by Geographical Survey Institute of Japan(GSI). It is worthy of note that the position of Kashima (X,Y,Z) should be corrected by several meters. The correction of Kashima position and, therefore, the correction of the reference position of Japan will be more precisely estimated by the coming global VLBI experiments.

Error sources

There are various kinds of errors in the estimation of baseline length. These are, (1) random-like errors added to delay time data such as phase noises inversely proportional to the signal-to-nise-ratio(SNR) and instability of the hydrogen-maser, (2) systematic errors added to delay time data such as measurement errors of propagation delay and instrumental delay, (3) errors due to imperfect physical models used in an analysis software and (4) errors due to the position of a radio star and its fine structure. Table 2. shows these errors in the Japan-US system-level experiments.

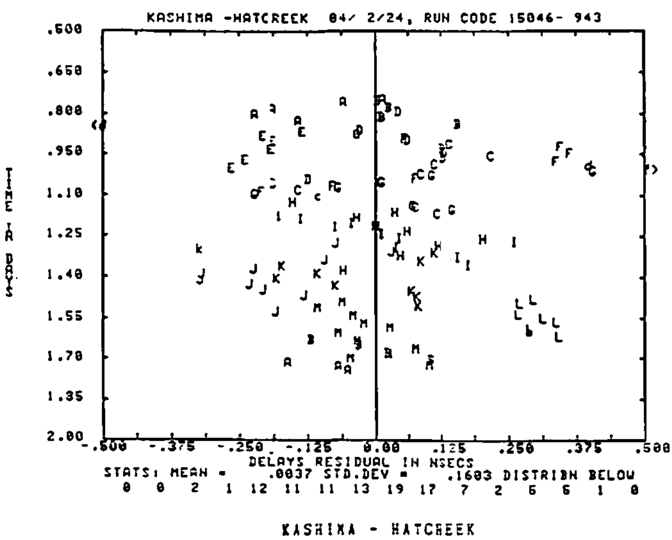
Although an imperfect physical model used in an analysis software cause the largest error, It is not so much a problem as a purpose of

Table 1. Estimated baseline length and correction of Kashima position.

	Correction of (X,Y,Z) X(m) (error)	Y(m)	Z(m)	Baseline length (m) (error)
The first experiments				
Haystack processing GSFC analysis	3.88 (0.04)	0.13 (0.04)	3.62 (0.04)	8091824.11 (0.04)
Haystack processing RRL analysis	3.69 (0.03)	0.04 (0.03)	3.54 (0.03)	8091824.06 (0.03)
The second experiments				
Haystack processing GSFC analysis	4.60	0.26	3.59	8091824.09
Haystack processing RRL analysis	4.59 (0.03)	0.24 (0.02)	3.68 (0.03)	8091824.08 (0.02)
	*4.34	*0.19	*4.07	*8091824.08
RRL processing RRL analysis	4.55 (0.03)	0.25 (0.03)	3.75 (0.03)	8091824.09 (0.03)

* By use of EOP by IPMS (in other cases EOP by BIH were used)

Fig. 2. Residual delay after the parameter estimation.



VLBI. It is supposed that the remained error in the physical models of the K-3 analysis software is about 12 cm for a inter-continental baseline. We can improve the physical models by analyses of many global VLBI data. This consideration is also true to the error source (4). Errors of (1) do not make a severe influence because a large amount of delay time data are usually obtained in a series of observations. The measurement errors of propagation delay due to the dry air and instrumental delay are rather small compared with the other errors. On the other hand,a measurement error of propagation delay due to water vapor makes a severe influence in the estimation of baseline length. Finally, this error limits the accuracy in VLBI.

Table 2. Various kinds of errors in the estimation of baseline length.

Error sources	Error(cm)	Comments
Random error		
SNR	1.6	Kashima-OVRO
Instability of H-maser	1-2	Frequency stability of 1×10^{-14}
Fine structure of a star	3	7cm at maximum (in worst case)
Systematic error		
Propagation delay(dry air)	0.1	With a pressure gage
Propagation delay(w.v.)	3	With a W.V.R.
Instrumental delay	0.1	With delay calibrator
Physical model	1-5	In these experiments
EOP	2	Difference between BIH and IPMS
Star position	1-3	(JPL 1983-5) - (BLOCK-Q)

Discussion

Earth orientation parameters which gave rotation of coordinates were not determined in these experiments because of the flat configuration of baselines, so that the estimated Kashima position (X,Y,Z) probably includes errors of several tens cm. The estimated baseline length, however, is reliable with several cm precision. The follow-on experiments with global networks which were composed of Japan, North America, Hawaii, Micronesia, Europe etc. were initiated in 1984. The precise position of Kashima will be determined in the near future.

In the application of VLBI to geodesy, a nuisance is the measurement error of propagation delay due to water vapor in the atmosphere. This error is larger than any delay time measured with a VLBI system. The research on the propagation delay is most desired in VLBI.

Acknowledgement

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