THE ROLE OF JAPAN IN THE NEW INTERNATIONAL EARTH ROTATION SERVICE (EXPECTED CONTRIBUTION OF THE PLANNED JAPANESE VLBI SYSTEM VERA)

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ABSTRACT. The outline of the planned Japanese VLBI system for the Earth rotation study and astrometry (VERA) is described. As a result of simulation study, it is concluded that precision and accuracy of the VLBI estimates of astronomical and geophysical parameters are remarkably improved when VERA participates in the present IRIS network.

1. INTRODUCTION

In the course of the history of the Earth rotation study, Japan has constantly contributed to the international cooperations for monitoring Earth rotation since last century. In order to further contribute to the activities of the new International Earth Rotation Service (IERS) which relys upon high-precision space techniques, several Japanese institutes have strived to figure out future observational systems which will fulfill the precision requirement of the IERS.

Recognizing importance of the VLBI technique for the Earth rotation study and also technical development of the K-3 system achieved by the Radio Research Laboratory (RRL), Japanese scientists agreed to design a VLBI system to be mainly dedicated to regular monitoring of Earth rotation. This system is called VERA (VLBI for the Earth Rotation study and Astrometry) and is composed of one baseline, namely, two stations.

In this paper, we give a short description of the results of simulation for estimating various astronomical and geophysical parameters using VERA in combination with the present four IRIS regular stations. Planned participation of Japanese institutes is also described.

2. PLANNED PARTICIPATION OF JAPAN IN THE IERS

Table I gives the Japanese institutes which are expected to participate in the activities of the IERS. NIA in Table I stands for a new national institute for astronomy which will be established in the near future in combination with the TAO and ILOM. The geodetic works which have been conducted at the two institutes will be continued at the NIA. Hence the Japanese VLBI system VERA will also be operated at the NIA.

In order that Japanese VLBI techniques can contribute to the present IRIS activities before completion of the planned VERA system, the

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TABLE I Planned Participation of Japan in the IERS

Techniques and Functions		IERS (1988)	IERS (1991-1992)
SLR	Observation	JHD, NIA	JHD, NIA
	Analysis		JHD
VLBI	Observation	RRL Kashima (26m)	VERA, NIPR RRL Kashima
	Analysis	ILOM	NIA
	Operation	ILOM	NIA

JHD : Japan Hydrographic Department,
TAO : Tokyo Astronomical Observatory,
ILOM: International Latitude Observatory of Mizusawa,
NIPR: National Institute for Polar Research,
NIA : New Institute for Astronomy (ILOM + TAO).

ILOM and RRL have searched for a possibility to use the Kashima's 26m antenna for the Earth rotation purposes. Even though expected frequency of observations may be not more than once every month, arrangement is ongoing to make it operational in the IRIS network in 1987.

The NIPR will start building a 11m antenna in Showa Base of the Antarctica in 1987 and hopes to use it for the VLBI purposes in 1991.

In accordance with the launching of the Japanese Geodetic Satellite (EGS) in August 1986, the JHD set up a computing center for orbit determination of the EGS. The computing center is expected to have capability to analyse SLR data.

3. VLBI FOR THE EARTH ROTATION STUDY AND ASTROMETRY: VERA

The objective of VERA for the Earth rotation study is twofold. One is to join international VLBI networks on regular basis, and the other is to carry out intensive one-baseline observations for pursuing specific purposes of contemporary interest. The outline of essential features of VERA is summarized in Table II.

4. METHOD OF SIMULATION

4.1. Evaluation of Precision and Accuracy

Precision and accuracy of observation are evaluated from, a) dispersions of single observations, b) standard deviations of estimated parameters, and c) systematic errors. Among them, a) and b) can be determined straightforwardly through the method of least squares. As regards c), it is the objectives of the analysis of actual data to identify the causes of systematic errors and to estimate them. On the other hand, the main objective of our simulations is to test robustness of the system against

TABLE II The Outline of the Planned Japanese VLBI System VERA

Antennas	35 m main antenna: near Mizusawa (Northern Japan)
	15 m sub-antenna: one of the south-west islands
Baseline Length	2,300 km
Recording System	K-3 system (Mark-III compatible)
Frequency Bands	S, X and K (K band to observe water maser sources)
Correlator	Multi-station correlator in the ILOM

various systematic errors. For example, in case of estimating EOPs under the given values of station positions, it is necessary to examine the effects of errors in the given station positions on the estimated EOPs. The smaller the effects are, the more robust the system is against the systematic error like station position errors.

4.2. Method of Computation

The software used for the simulations is essentially the same as the one used for analysing actual IRIS VLBI data provided by the NGS and it can reproduce the IRIS results with the coincidence better than a few tenths of mas.

The adopted procedures of the computation are as follows.
a) Observational schedules: Since precisions of the estimated parameters essentially depend upon the observing schedule adopted, it is important to make an optimum schedule. However, we have so far had no general method to determine an optimum observing schedule. In this computation, we define 'optimum' as minimizing the weighted sum of the dispersions in estimating the parameters by the method of least squares.
b) Computation of partial derivatives: The software for computing partial derivatives is an improved version of KAPRI of the K-3 system, and it can reproduce the theoretical values of partial derivatives of the Mark III.
c) Parameter estimation: Among several possible methods of analysis, we adopt the method of least squares. In carrying out the simulations, we adopt as the dispersions of single observations for delay and delay rate the following values which reproduce the average formal errors of the IRIS EOPs. They are 0.105 ns for delay, and 0.04 ps/s for delay rate.
d) Constraints: The constraints to be imposed are dependent upon combinations of the parameters to be estimated.
d-1) Clock parameters: Usually one station is constrained. Depending upon the schedule, some other stations are necessary to be constrained.
d-2) Station positions: In case of one-baseline observations, the position of one station is fixed. In case the positions of three or more stations are estimated, net translation is assumed to be zero. Depending upon the schedule adopted, this constraint may be required for each of the sub-networks.
d-3) Simultaneous determination of EOPs and station positions: Net rotation is assumed to be zero.
d-4) Biases: When biases are necessary to be introduced into some

parameters, it is convenient to treat them as the estimates in the first step, and then to fix them to the biased values using constraints.

5. SIMULATED VERA SINGLE BASELINE OBSERVATIONS

5.1. Conditions for the Simulations

The simulations are made under the following conditions.
a) Schedule: 24-hour observation with 7-minute interval.
b) Optimized parameters: Station position parameters of the sub-antenna.
c) Stars: IRIS 14 stars.
d) The position of the main antenna is assumed to be given.

5.2. Results of the Simulations

Table III gives the results of the simulations for various desired parameters to be determined by the VERA single baseline observations.

TABLE III Simulated VERA Single Baseline Observations

Baseline vector determination:	length	longitude	latitude
Standard deviation (SD)	1.7 cm	2.5 mas	0.6 mas
Star position determination:	right ascension		declination
SD (14 stars)	0.19 - 0.43 ms		1.7 - 4.5 mas
SD (1 star)	0.12 - 0.37 ms		0.9 - 2.2 mas
Effects of position errors of the sub-antenna	0.06 ms/cm		0.5 mas/cm
UT1 determination (SD 0.06 ms):			
Effects of polar motion errors	x-component 0.080ms/mas		y-component 0.074 ms/mas
Effects of position errors of the sub-antenna	vertical 0.001ms/cm	NS 0.087 ms/cm	EW 0.075ms/cm
Effects of star position errors	right ascension		declination
(declination = 1 degree)	0.17 ms/ms		0.015 ms/mas
(declination = 69 degrees)	0.01 ms/ms		0.001 ms/mas
Nutation:	longitude		obliquity
SD	1.0 mas		0.5 mas
Effects of star position errors	-		-
Clock comparison:	timing		rate
SD	100 ps		3×10^{-16} s/s

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6. COMPARISON OF INTERNATIONAL VLBI NETWORKS INCLUDING VERA

The simulations are made for three cases of the international VLBI networks.

They are:

Case A: Present IRIS network composed of 3 US stations and Wettzell.

Case B: Group delay and delay rate data acquired by the VERA independent one-baseline observations are simply merged in the IRIS network data in solving global solutions. The observing schedule of the IRIS is IRIS243.

Case C: Four IRIS stations and two VERA stations are divided into three sub-networks. Simulated observations are made by switching the sub-networks every ten minutes so that the total number of observations become almost the same as in Case B. Observing stars are selected from the IRIS 14 stars and the observing schedule is made to optimize the EOP determination.

Results of the simulations are given in the following figures.

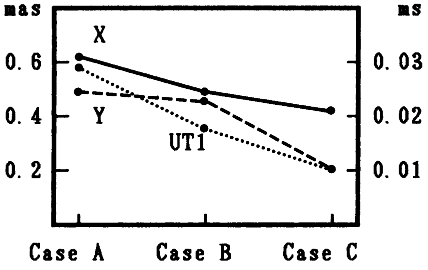

Figure 1. Standard deviations in polar motion and UT1 determination.

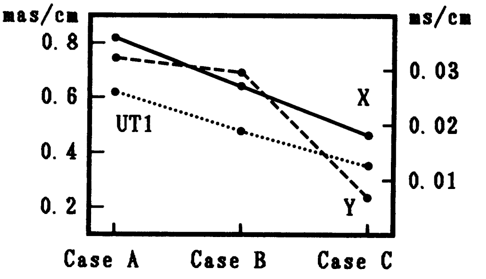

Figure 2. Maximum biases in polar motion and UT1 due to station position errors. (Station positions not estimated)

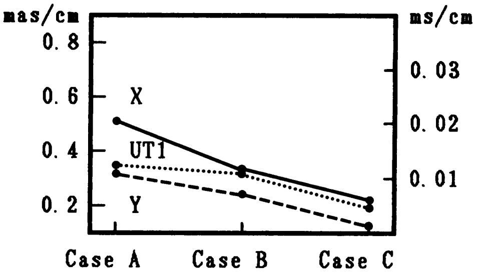

Figure 3. Maximum biases in polar motion and UT1 due to station position errors. (Station positions estimated)

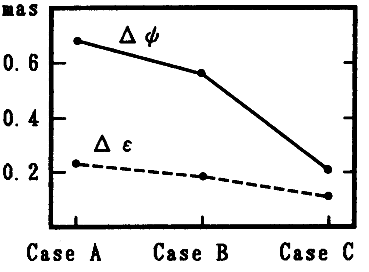

Figure 4. Standard deviations of nutation determination.

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7. SUMMARY

7.1. Simulated VERA One-Baseline Observations

a) Precision in the determination of relative positions of the two stations is about ± 3 cm. Latitude is better determined than longitude.
b) Star positions are determined with about ± 1 mas through 24-hour observations when station positions are known with the precision better than ± 1 cm.
c) Standard deviation of UT1 is about three times larger than that of the present IRIS observations. Effects of errors of the given station positions are not negligibly small. While those of the errors of star positions are trivial.
d) Nutation can be determined almost free from star position errors. Frequent observations may bring about the precision comparable to the present IRIS results.
e) Precision of clock comparison is about ± 100 ps.

7.2. Comparison of the International VLBI Networks

a) By simply merging group delay and delay rate data acquired by the VERA single baseline observations in the present IRIS data, polar motion, nutation and in particular UT1 determinations are expected to be remarkably improved. This means that independent single VLBI baselines can contribute to improving EOPs, even when their observing schedules are independent of internationally arranged one.
b) When the observing schedule of the IRIS and VERA networks is internationally well arranged, improvement of EOPs is excellent.
c) Effects of station position errors on the estimated global parameters considerably diminish, when VERA participates in the international network in a well arranged way. This means that the global network becomes more stable.

Thus in conclusion, the Japanese VLBI system VERA is expected to considerably contribute to improving precision and accuracy of EOPs by participating in the well coordinated international VLBI network.