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Overview of the Eighth TDC Meeting

The Eighth meeting of the Technical Development Center was held on March 8, 1996 at the conference room of Kashima Space Research Center of Communications Research Laboratory.

Attendance

CRL members

Fujinobu Takahashi, Taizoh Yoshino, Michito Imae, Hiroo Kunimori, Shin'ichi Hama, Chihiro Miki, Jun Amagai, Akihiro Kaneko, Toshimichi Otsubo, Hideyuki Nojiri, Mizuhiko Hosokawa, Hitoshi Kiuchi, Kohichi Sebata, Yuko Hanado, Shingo Ohmori (KSRC: Kashima Space Research Center), Yukio Takahashi (KSRC), Takahiro Iwata (KSRC), Noriyuki Kurihara (KSRC), Ryuichi Ichikawa (KSRC), Yasuhiro Koyama (KSRC), Mamoru Sekido (KSRC), Junichi Nakajima (KSRC), Tadahiro Gotoh (KSRC), Tetsuro Kondo (KSRC)

Special members

Kosuke Heki (National Astronomical Observatory), Takashi Saito (Geographical Survey Institute), Teruo Kanazawa(Hydrographic Department, Maritime Safety Agency), Kazuo Shibuya (National Institute of Polar Research), Yoshimitsu Okada(National Research Institute for Science and Disaster Prevention), Teruyuki Kato (Earthquake Research Institute, University of Tokyo),

Following special members could not attend: Nobuyuki Kawano (National Astronomical Observatory), Noriyuki Kawaguchi (National Astronomical Observatory), Hisashi Hirabayashi (Institute of Space and Astronautical Science),

Agenda

1. Opening address by Fujinobu Takahashi, director of the Standards and Measurements Division, CRL
2. Reorganization of the IERS VLBI
3. Activity reports by the special members
4. Antarctica VLBI and Asia Pasific VLBI
5. Data publication format and coordinate system
6. Technical reports

6.1 Keystone project

6.2 Other technical development activities

7. Closing address by Shingo Ohmori, director of the Kashima Space Research Center, CRL

A cheerful mascot character of deer "Anton-kun" and a huge soccer ball were painted on the surface of main reflector of 34 m antenna at Kashima. The painting is a part of bidding activities for 2002 World Cup Football Games. Kashima Soccer Stadium, located near the Kashima Space Research Center, may become a venue of the World Cup games in 2002.

GSI Activity

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VLBI

GSI participated in 11 international VLBI observations in FY1995. Kashima 26m-antenna, that has been used for international VLBI observation, had been fixed last year. GSI's transportable VLBI system (3.8m antenna and transportable container for observation) has been transported to Korea for Japan - Korea VLBI observation, under the cooperation with NGI (National Geography Institute, Korea). We conducted 24-hour observation 4 times, and got the baseline between Kashima-26m and Suwon site in Korea. Domestic VLBI observations for Kashima-Mizusawa and Kashima-Tsukuba baselines were conducted. New VLBI observation sites, Chichijima and Aira, are under construction. They will have a 10m-class telescope, S/X receiver and K-4 VLBI equipment. Another VLBI site with a 25m-30m class antenna will be established in GSI Headquarters' field at Tsukuba. These new facilities will be available in 1997 - 1998, and operated by GSI for geodesy and Earth sciences.

GPS

GPS permanent networks, that have two hundred GPS permanent sites, have been operated by GSI for more than one year. These network has detected crustal deformation concerned with some big earthquakes such as Hyogo-ken Nanbu EQ (Kobe EQ), Hokkaido Toho-oki EQ, Sanriku-Haruka-oki EQ. The network are added more than 400 sites in FY1995. Furthermore, two or three hundred sites are going to be established in FY1996. The data from this observation network will be available in the near future for researchers and surveyors who wish to use them.

Organization

A new department Geodetic Observation Center is established in this year. It operates the continuous observation networks; GPS, tide gauges, tiltmeters and extensometers.

Reorganization of the IERS VLBI

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The International Earth Rotation Service (IERS) was established in 1988. In October, 1990 at Virginia Beach (USA), the Directing Board of the IERS approved the designation of two technical development centers of VLBI, which are the Haystack Observatory and the Communications Research Laboratory (CRL). The IERS strategy was discussed within the Directing Board held on 11th July 1995 at Boulder during the XXI IUGG General Assembly (See the Report on the IERS Directing Board Meeting No.16) . One of the most important actions decided to be taken was to distribute the CALL FOR PROPOSALS to the VLBI community to reorganize the structure of the IERS. The meaning of this action was explained. In January of 1996, CRL proposed to continue to work as a VLBI technical development center. It is said that the discussion on the selection of the proposal will be held in October, 1996.

Format of the VLBI Data Publication

Kosuke Heki

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There are variety of users who might be interested in geodetic VLBI data outputs and the data should be handed over to them in appropriate formats. They are to be classified as follows;

(1) VLBI researchers

Those who need a VLBI database to perform their own parameter estimation. Conventional Mark-3 type database will do.

(2) Geodesists

Those who want to tie their GPS results to VLBI coordinates/velocities. Solution (technique) Independent Exchange (SINEX) format, which is usable for both VLBI and GPS, might be pertinent for this purpose.

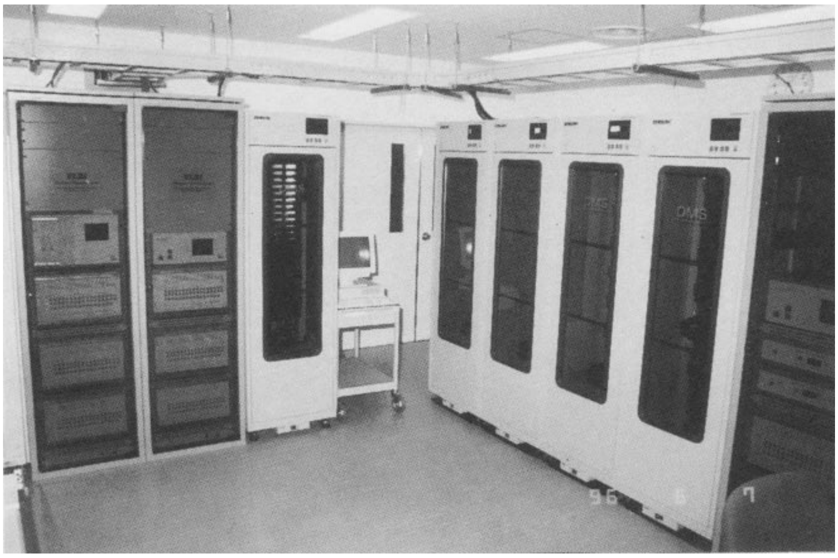
(3) Seismologists (earthquake prediction researcher)

Those who want to monitor time series of daily baseline vectors for possible earthquake precursors (the detection could be retrospective). Time series should be given in local coordinates as well as geocentric coordinates.

(4) Geophysicists, Geologists

Those interested in site velocities and their tectonic implications. Changing rates of the baseline vectors or site velocities directly estimated by connecting multiple VLBI databases would satisfy the requirements.

Keystone project data are mainly used for the category 3 purposes but CRL should be prepared for every kind of requirments considering potential future users.



*Correlators for the Key Stone Project located in the correlation center at Koganei central station. (Left) Real-time correlators. (Right) Tape-based correlators and automatic tape-exchanger units for each station.**(see Page 17)*

Data Format of the Key Stone Project VLBI Analysis Results

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1. Introduction

Observed data of the daily VLBI experiment of the Key Stone Project are analyzed every day automatically. The latest results of the daily analysis are available to the public in various ways. Any researchers interested in the Key Stone Project data can access the results over the Internet. At present, following three methods are available to access the results.

- e-mail
- anonymous FTP
- World Wide Web

2. e-mail

Baseline lengths and site position displacements from the arbitrarily determined reference position are formatted in a text file and sent to the e-mail addresses registered beforehand. The displacements are expressed in the east-west, north-south, and vertical up-down directions. Reference positions have been determined by an analysis based on the ITRF93 coordinate system upon an experiment performed on January 19, 1995, when two KSP stations (Kashima and Koganei) and 34m antenna station at Kashima participated in the same VLBI experiment. Although this method is only used internally at present, the e-mail address of a responsible researcher in Japan Meteorological Agency (JMA) will be added to the distribution list. JMA will use this information as one of many data related with the earthquake research around Tokyo.

3. anonymous FTP

Either ASCII data files of Postscript graphics files are accessible in the anonymous FTP area of the data analysis computer. One can access all these files at kouma.crl.go.jp by giving 'anonymous' for the username and e-mail address for the password. Following sections describe the data file format of the ASCII data files accessible by means of anonymous FTP.

3.1 Miscellaneous information about each experiment

Miscellaneous information for each experiment can be obtained in the file `exp.inf`. The time and date of the first and last observations in each experiment, along with the data and time when the latest analysis was done, are given in the file. The other file, `stat.dat`, gives statistical information, such as root-mean-square delay residual in the data analysis, number of data used for the analysis and number of data excluded from the analysis. Information on all baselines is stored in a single file.

3.2 Baseline length data

Estimated baseline lengths from every experiments are stored in the file, `baseline.dat`. All the baselines are stored in a single file. Standard deviation of the estimated baseline lengths are given in the last column.

3.3 Site coordinate data

Site coordinates in either global geocentric rectangular coordinate system (XYZ) or the locally defined coordinate system (ENU) are stored in multiple files. There are two files each for all four stations. In case when the site coordinates were fixed as *a-priori* information for reference station, the errors in the data files are denoted as 0.00 mm. Otherwise, the errors are given from the one standard deviation obtained through least-square parameter adjustment estimation. Correlation factors between each coordinate component are also given. Each line represent the results from a single experiment.

4. World Wide Web (WWW)

By using one of many browser applications for the World Wide Web, one can view and download all the files accessible by means of anonymous FTP. In addition to the data accessible by the anonymous FTP method, one can display plots of these

Table 1. [exp.inf]

94/08/29 04:54 -- 94/08/30 05:27	94AUG29XX.out	11-Aug-95	17:09:20
94/12/20 01:00 -- 94/12/21 01:01	94DEC21XX.out	6-Sep-95	11:14:01
95/01/17 08:07 -- 95/01/18 06:04	95JAN17XX.out	16-Feb-96	23:17:45
95/01/19 00:00 -- 95/01/20 00:03	95JAN19XX.out	6-Sep-95	11:14:03
95/01/31 00:00 -- 95/01/31 04:17	95JAN31XX.out	6-Sep-95	11:14:06
95/02/01 00:00 -- 95/02/01 04:18	95FEB01XX.out	6-Sep-95	11:14:06
95/02/02 00:16 -- 95/02/02 04:24	95FEB02XX.out	6-Sep-95	11:14:07
95/02/03 00:00 -- 95/02/03 04:24	95FEB03XX.out	6-Sep-95	11:14:08
95/02/06 00:00 -- 95/02/06 04:17	95FEB06XX.out	6-Sep-95	11:14:08
95/02/07 00:00 -- 95/02/07 04:14	95FEB07XX.out	6-Sep-95	11:14:09
⋮			
96/04/07 15:00 -- 96/04/07 20:13	96APR07XX.out	10-Apr-96	14:45:19
96/04/08 15:00 -- 96/04/08 20:17	96APR08XX.out	10-Apr-96	15:14:27
96/04/09 15:00 -- 96/04/09 20:15	96APR09XX.out	11-Apr-96	15:01:04

Table 2. [stat.dat]

Exp Code	Duration (Start-End)	Baseline	RMS delay (ns)	# of Obs. good(bad)
94AUG29XX	94/08/29 04:54 -- 94/08/30 05:27	KASHIM11-KOGANEI	.060	122(131)
94DEC21XX	94/12/20 01:00 -- 94/12/21 01:01	KOGANEI -KASHIM11	.047	139(54)
95JAN19XX	95/01/19 00:00 -- 95/01/20 00:03	KASHIM11-KOGANEI	.069	151(40)
95JAN31XX	95/01/31 00:00 -- 95/01/31 04:17	KASHIM11-KOGANEI	.031	40(2)
95FEB01XX	95/02/01 00:00 -- 95/02/01 04:18	KASHIM11-KOGANEI	.034	37(5)
95FEB02XX	95/02/02 00:16 -- 95/02/02 04:24	KASHIM11-KOGANEI	.042	36(5)
95FEB03XX	95/02/03 00:00 -- 95/02/03 04:24	KASHIM11-KOGANEI	.046	36(6)
95FEB06XX	95/02/06 00:00 -- 95/02/06 04:17	KASHIM11-KOGANEI	.048	33(9)
95FEB07XX	95/02/07 00:00 -- 95/02/07 04:14	KASHIM11-KOGANEI	.059	33(6)
		⋮		
96APR07XX	96/04/07 15:00 -- 96/04/07 20:13	KASHIM11-KOGANEI	.024	86(3)
96APR08XX	96/04/08 15:00 -- 96/04/08 20:17	KASHIM11-KOGANEI	.021	32(58)
96APR09XX	96/04/09 15:00 -- 96/04/09 20:15	KOGANEI -MIURA	.027	89(4)

data graphically and browse detailed output of parameter estimation software **VLBEST** for each experiment. To achieve these capabilities, HTML (Hyper Text Makeup Language) files are automatically produced according to the available data set. The WWW homepage is accessible at the URL http://kouma.crl.go.jp (for Japanese language homepage, use http://kouma.crl.go.jp/index-J.html instead). Figure 1 shows what the homepage of the Key Stone Project looks like.

In the detailed output of **VLBEST**, one can access all the adjusted values estimated in the analysis. Usually, the hydrostatic atmospheric delay in the zenith direction at interval of three hours, clock offsets and their rates (clock parameters) at interval of three hours, site coordinates of all stations except for a reference station are the parameters to be adjusted. Theoretical models used in the analysis are also described in the **VLBEST** output.

5. In the Future

At present, the SINEX data format is being considered to be adopted to release detailed analysis results to the public. The SINEX format is widely used as a standard by the GPS community, and therefore the format will be preferable to exchange data with other organizations. Under the

Table 3. [baseline.dat]

	MJD	Baseline	BL Length (mm)	Error (mm)
94AUG29XX	49593.204	KASHIM11-KOGANEI	109099666.40	7.20
94DEC21XX	49706.042	KASHIM11-KOGANEI	109099655.70	5.40
95JAN19XX	49736.000	KASHIM11-KOGANEI	109099660.10	4.00
95JAN31XX	49748.000	KASHIM11-KOGANEI	109099677.20	8.50
95FEB01XX	49749.000	KASHIM11-KOGANEI	109099682.50	11.50
95FEB02XX	49750.011	KASHIM11-KOGANEI	109099676.60	11.60
95FEB03XX	49751.000	KASHIM11-KOGANEI	109099662.90	12.70
95FEB06XX	49754.000	KASHIM11-KOGANEI	109099653.60	19.60
95FEB07XX	49755.000	KASHIM11-KOGANEI	109099681.50	19.50
		⋮		
96APR07XX	50180.625	KASHIM11-KOGANEI	109099659.50	2.90
96APR08XX	50181.625	KASHIM11-KOGANEI	109099677.70	13.70
96APR09XX	50182.625	KOGANEI -MIURA	57734581.10	4.30

Table 4. [koganei.xyz]

	MJD	X (mm)	X err	Y (mm)	Y err	Z (mm)	Z err	Cxy	Cxz	Cyz
94AUG29XX	49593.204	-3941937455.20	24.85	3368150904.60	18.28	3702235290.20	21.41	-.8925	-.9177	.8722
94DEC21XX	49706.042	-3941937470.60	17.33	3368150901.40	11.06	3702235300.70	15.56	-.9001	-.9520	.8660
95JAN19XX	49736.000	-3941937480.80	6.28	3368150915.60	5.99	3702235307.90	5.63	-.8243	-.8347	.8064
95JAN31XX	49748.000	-3941937479.40	26.66	3368150937.80	18.29	3702235322.50	26.22	-.8978	-.9659	.8617
95FEB01XX	49749.000	-3941937413.90	34.19	3368150885.60	26.07	3702235245.30	32.69	-.8837	-.9634	.8325
95FEB02XX	49750.011	-3941937526.30	39.74	3368150968.90	25.32	3702235336.60	40.70	-.9345	-.9379	.8661
95FEB03XX	49751.000	-3941937479.30	39.95	3368150914.00	26.94	3702235295.30	40.62	-.9059	-.9666	.8655
95FEB06XX	49754.000	-3941937436.00	61.20	3368150869.00	44.65	3702235264.30	57.06	-.8925	-.9679	.8483
95FEB07XX	49755.000	-3941937466.00	62.33	3368150924.60	40.80	3702235280.60	62.51	-.9124	-.9725	.8755
					⋮					
96APR07XX	50180.625	-3941937481.10	10.40	3368150910.70	8.19	3702235289.70	8.06	-.9034	-.9389	.8903
96APR08XX	50181.625	-3941937410.10	124.12	3368150879.40	86.05	3702235248.70	100.38	-.9942	-.9953	.9953
96APR09XX	50182.625	-3941937480.80	.00	3368150916.60	.00	3702235307.90	.00	.0000	.0000	.0000

Table 5. [koganei.enu]

	MJD	E (mm)	E err	N (mm)	N err	U (mm)	U err	Cen	Ceu	Cnu
94AUG29XX	49593.204	-7.54	7.30	1.54	6.80	-32.51	36.20	.0410	.3630	-.0800
94DEC21XX	49706.042	4.90	5.20	4.44	4.20	-18.57	24.90	.3570	.6240	.1930
95JAN19XX	49736.000	.73	2.60	.38	2.50	-.58	9.70	.0890	-.1350	-.1930
95JAN31XX	49748.000	-17.06	7.80	4.44	6.90	18.79	40.30	.6020	.5340	.3890
95FEB01XX	49749.000	-19.92	10.40	-9.39	9.20	-94.24	52.20	.6340	.3500	.1860
95FEB02XX	49750.011	-10.24	10.40	-16.72	13.00	72.38	60.00	.4760	.6990	.4310
95FEB03XX	49751.000	.97	11.40	-8.58	11.00	-9.70	61.00	.6430	.5750	.4760
95FEB06XX	49754.000	7.05	18.00	2.52	15.00	-78.26	91.90	.6140	.4330	.1760
95FEB07XX	49755.000	-15.73	17.60	-18.63	16.00	-20.90	94.30	.6800	.6280	.4960
					⋮					
96APR07XX	50180.625	4.65	2.90	-12.68	2.60	-13.60	15.00	.0530	.2410	-.4370
96APR08XX	50181.625	-17.68	17.10	-2.59	9.20	-97.87	180.30	-.6710	.8920	-.6710
96APR09XX	50182.625	-.03	.00	.00	.00	-.05	.00	.0000	.0000	.0000

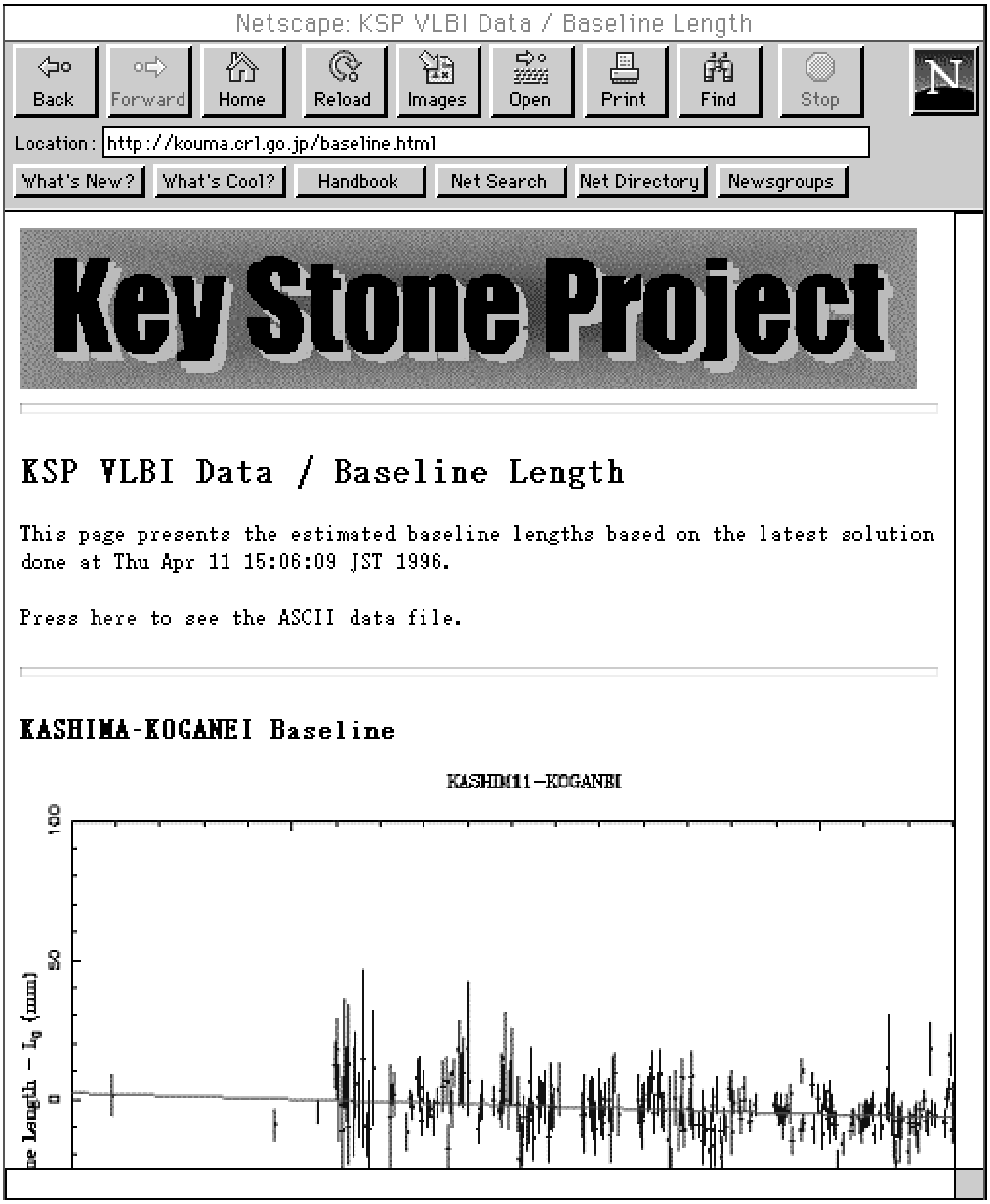

Figure 1. Homepage of the Key Stone Project (URL http://kouma.crl.go.jp).

Key Stone Project, SLR and GPS data will be observed too. These data set will also be analyzed and released along with the VLBI data.

Current Status of the Key Stone Project (KSP)

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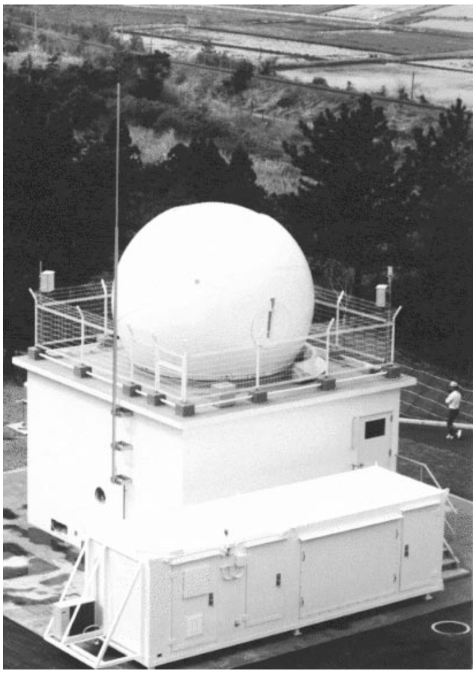
Development of the KSP, which monitors crustal deformation around the Tokyo metropolitan area with a space geodetic technique (VLBI, SLR and GPS), started in FY1993. Three of four VLBI stations, Kashima, Koganei and Miura, have been completed construction and have been carrying out daily observations. Last station (Tateyama) is just about ready to start observations. Four SLR stations also have been constructed by the end of FY 1995.

Kashima VLBI station

Miura VLBI station



Kashima SLR station

Tateyama VLBI station

VLBI Data Analysis System for the Key Stone Project

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1. Introduction

The data analysis software package of the Key Stone Project, which was nicknamed "Takemikazuchi"[1], is characterized by its highly automated design and its operator friendly Graphical User Interface. The software runs on a UNIX workstation (Figure 1) at Koganei Central Station located in the headquarters of the Communications Research Laboratory.

The software utilizes CALC (Version 8.1) and Mark-III Database Handler software developed by Goddard Space Flight Center of National Aeronautics and Space Administration (NASA). Since all the processed data from a Key Stone VLBI experiments are stored in a Mark-III database, the results can be exchanged with other institutes participating geodetic VLBI activities worldwide. Figure 2 illustrates the data flow of the data analysis software.

As soon as the bandwidth synthesis processing (**KOMB**) is finished on all the observations taken in a daily VLBI session, '**KOMB**' output files are organized and two databases (X-band and S-band) are created from these files. S-band database is only used for correlated amplitude monitoring purposes, and on the other hand, X-band database is used for data analysis in the following steps. The X-band database is prepared for data analysis by the program **DBUPDATE**. **DBUPDATE** stores various *a-priori* information in the database. Next, (**CALC**) is executed on the X-band database to calculate theoretical delay and delay rates and their covariance matrices. At this point, the X-band database becomes ready to be analyzed by the least-square parameter adjustment program **VLBEST**. At first, **VLBEST** runs with only clock offsets and their rates of change at all stations except for a reference station. Kashima station is always chosen as the reference station whenever the station participated the session. From the results, **REMAMB** resolves delay ambiguities.

[1] "Takemikazuchi" is the name of a mythological god who is symbolized by thunderbolt. Kashima Shrine located near the Kashima Space Research Center is the home of this god, and the gigantic 'Key Stone' was put on the head of a huge catfish by him long time ago to prevent hazardous earthquakes which had been caused by the catfish, so it was told.

Figure 1. HP9000 model 715/100 workstation used for the Keystone VLBI data analysis.

Table 6. List of experiments used for the comparison.

Date of Experiments	(# of data actually used in the analysis) / (# of data correlated) (1) KSP Automatic Analysis	(2) KSP Manual Analysis	(3) K-3 Correlator + SOLVE
1995.12.3	58/86	78/86	97/101
1995.12.4	61/82	74/82	97/101
1995.12.5	79/89	80/89	94/100
1995.12.6	78/84	80/84	95/98
1995.12.8	71/77	72/77	94/99

Next, **VLBEST** runs again with the same sets of estimate parameters on the ambiguity-resolved data. From the results, **MRKOBS** flags out bad data points which have large residuals. Finally, **VLBEST** runs again and the full set of estimation parameters are adjusted. These parameters are: clock offsets and their rates of change at all stations except for the reference station, wet component of tropospheric delay (three hour intervals) at all stations, and site coordinates of all stations except for the reference station. Unless the root-mean-square of the residual delays exceeds a certain threshold (100 psec), the estimated results are soon released in a variety of data types and formats. If the RMS residual exceeds the threshold value, an e-mail message is sent to a responsible operator to notify the problem. The operator investigates the data closely and tries to resolve the problem. **Takemikazuchi** provides Graphical User Interface to support these tasks for the operator. The operator can remove or recover any data point, insert epoch points for tropospheric delay and clock parameters, and change the estimation strategy very easily.

In addition to the normal data analysis procedure just described above, results are revised automatically upon receipt of the weekly and monthly bulletins of the International Earth Rotation Service (IERS), i.e. Bulletins A and B respectively. This is necessary since Earth Orientation Parameters (EOP) available at the time of the first data analysis are, in fact, predicted values based on the data in past. The predictions have large uncertainties, especially the last Bulletin A is almost one week old. The uncertainties of the predictions are estimated as 3.8 mas for terrestrial pole positions and 1.5 msec for UT1$-$UTC at prediction length of 10 days (IERS, 1995). These uncertainties correspond to the site position estimation error of 2.0 mm and 12.0 mm respectively for the baselines with distance of 110 km, which is roughly the distance between Kashima and Koganei stations. All the e-mail messages received by the Takemikazuchi system are analyzed and the EOP data file is updated according to the Bulletin data if the e-mail was either Bulletin A or Bulletin B. Whenever the EOP data file is updated, all the affected databases are also updated and processed for data analysis. As such, the same database is repeatedly analyzed with updated EOP values at least four times (two times with Bulletin A values and two times with Bulletin B values).

2. Comparison of Results with Conventional Systems

To validate the results obtained by the Key Stone Project VLBI data analysis system, the estimated site position of the Koganei VLBI station was compared with the results obtained by other conventional methods. Table 1 gives the list of experiments with the number of correlated observations and actually used data for analysis. In the table, (1) and (2) are the results obtained using the KSP correlator, whereas (3) are the results obtained using the K-3 correlator. For the least-squares parameter adjustment, **VLBEST** was used in (1) and in (2), whereas **SOLVE** was used in (3). Differences between (1) and (2) are due to whether bad data are removed (1) automatically by the program **MRKOBS** or (2) interactively by using the Graphical User Interface.

The number of correlated observations in columns (1) and (2) are same since they are based on the same databases. These numbers are always less than the numbers in column (3) because there were still miscellaneous problems during the automatic correlation processing. The numbers of data actually used in the analysis in the column (1) are always less than those in column (2). This is, perhaps, because the threshold of delay residuals in the program **MRKOBS** is too small, and hence some valid data are also removed from the later analysis. Figure 3 shows the estimated site positions of Koganei VLBI station for five experiments

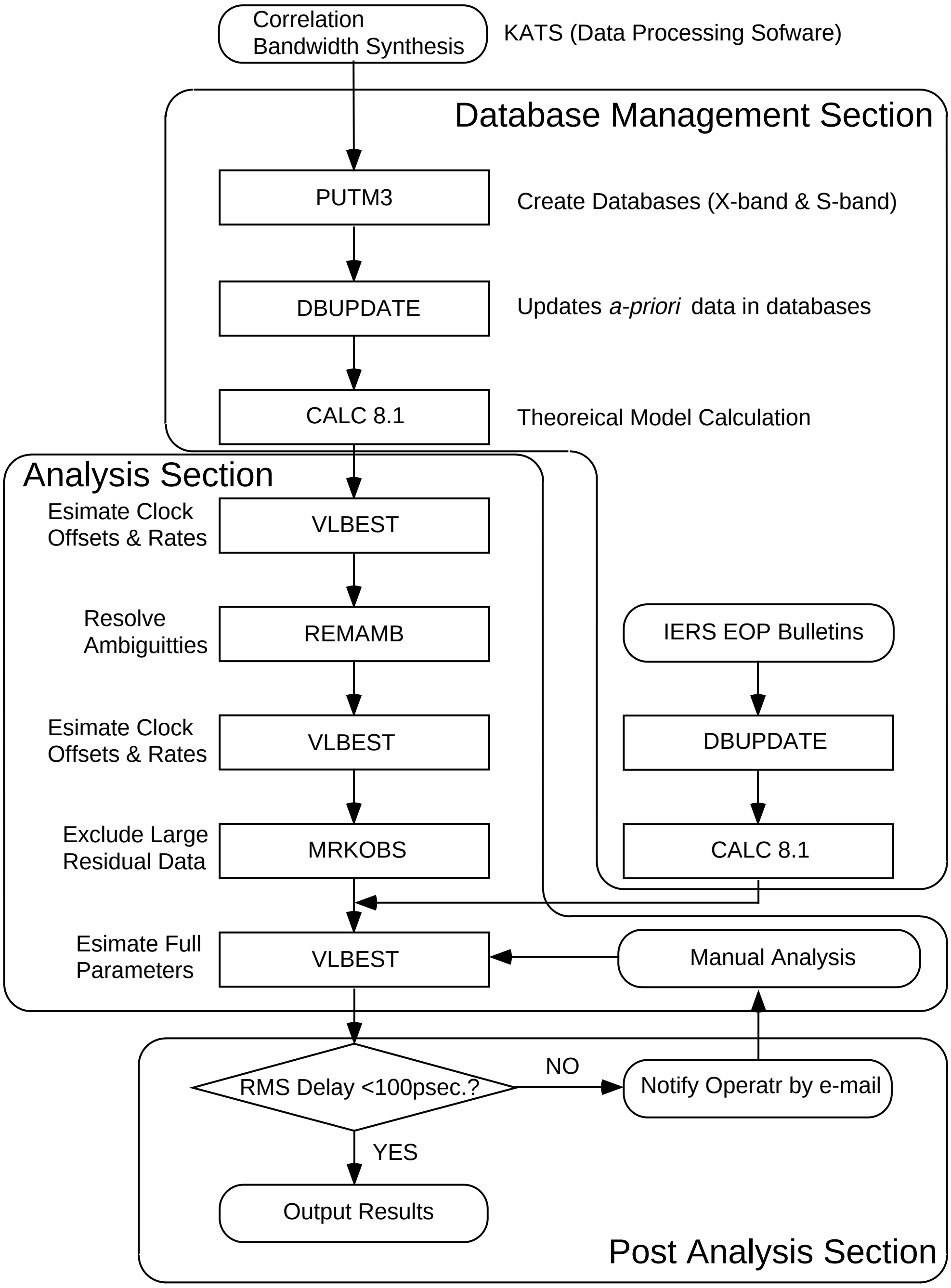

Figure 2. Flow chart of the Key Stone Project VLBI data analysis.

in the horizontal plane. Uncertainties are expressed as one-sigma standard deviation error ellipses. Figure 4 shows the similar comparison for the vertical axis. These comparisons do not indicate statistically significant differences between the different approaches of data analysis, as expected.

3. Effects of EOP Prediction Uncertainties

To evaluate the effects of prediction uncertainties of EOP values, the results were compared with different IERS bulletins. The experiment done on November 7, 1995 was chosen for the comparison. The experiment was first analysed on November 8, 1995 by using EOP predictions released in the Bulletin A issued on November 2, 1995. The EOP values are revised three times, first by Bulletin A issued on November 9, 1995, and hen two Bulletin B issued on December 8, 1995 and on January 3, 1996. Figure 5 shows the difference of EOP values according to the final value in the Bulletin B issued on January 3, 1996.

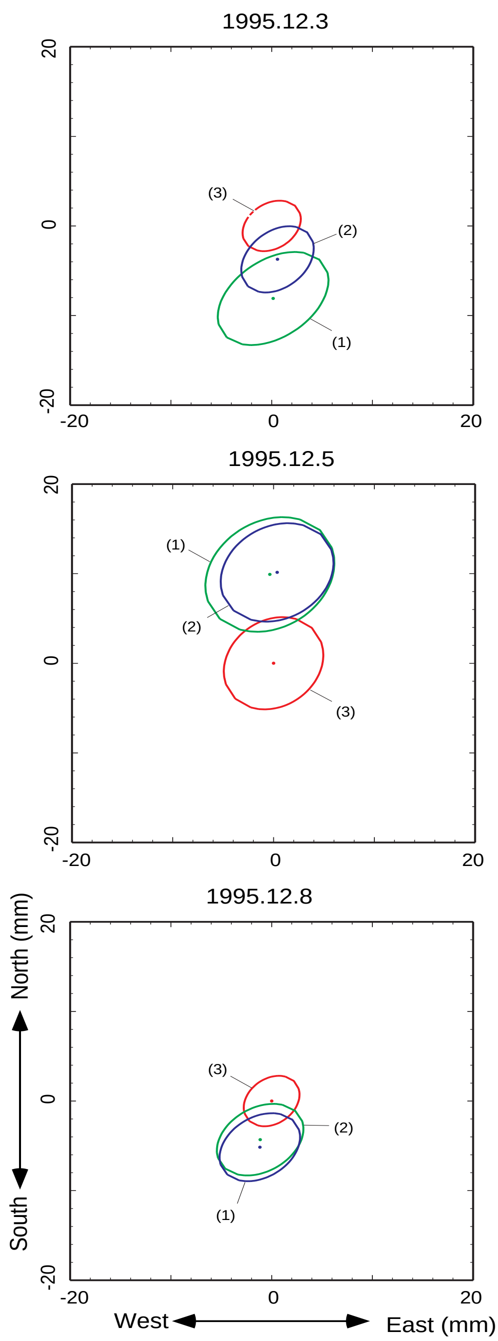

Figure 3. Estimated site position of Koganei VLBI station compared in the horizontal plane.

As seen in the figure 5, the differences between predicted and revised values increase, as the prediction is made for many days in the future. As the EOP values are revised in the following IERS bulletins, the values converge toward the final values. Figure 6 shows the four different site position estimates of Koganei VLBI station compared in the horizontal plane. Each ellipse represents a one-sigma standard deviation uncertainty estimated using different EOP data sets. Figure 7 compares the same results on the vertical axis.

All the results except for the first one estimated using the predicted EOP values agree with each other. The agreement is so good that the error ellipses in the horizontal plane and error bars in the vertical axis are hardly distinguishable. On the other hand, the first results differ from the other three by about 12 mm. Since the final target of the Key Stone Project is an accuracy of 2 mm for horizontal plane and 5 mm for vertical axis, the difference of 12 mm is quite serious. Therefore, it is important to note that the site coordinates estimated right after the experiment is finished may have large systematic error due to the insufficient

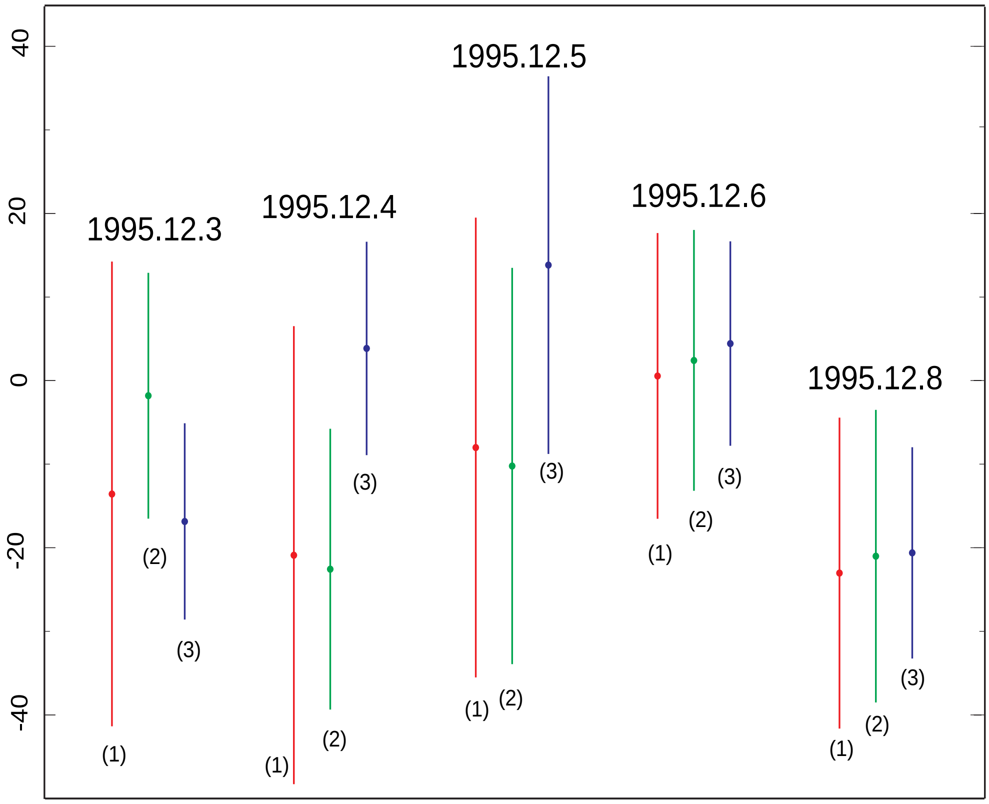

Figure 4. Estimated site position of Koganei VLBI station compared in the vertical axis.

prediction accuracy. In the first analysis, baseline results should be used mainly. Three dimensional site coordinates are reliable from the second analysis results. It is also important to note that the results of the second analysis are in fact good enough, and such results can be obtained within a week.

4. Summary

Daily VLBI observations with three stations, i.e. Kashima, Koganei, and Miura stations, started on December 1, 1995. As a result of automation-oriented system design, the data processing and analysis are almost automatically done without much effort. Daily observations begin at 1:00 UT and end at 6:30 UT. The recorded data tapes at Kashima and Miura stations are transported to Koganei Central station at 8:00 UT, and arrive the next morning. Correlation processing finishes for all the observations by 6:00 UT, and the analysis results become available by 6:30 UT. Thus, all the process tasks are finished within 24 hours from the time of the last observation.

The comparison of the results with other conventional results showed no significant differences. From this result, the data analysis system of the Key Stone Project is confirmed in its functionality. To prevent unnecessarily removal of valid data, the algorithm of **MRKOBS** should be improved.

The effects of prediction uncertainties of Earth Orientation Parameters were also examined. The results indicated that the three dimensional site coordinates estimated in the first data analysis needs to be used cautiously. When high accuracy and reliability of the results are required, as in the case of the Key Stone Project, only the baseline lengths after the initial analysis, or the complete results after the second analysis should be used.

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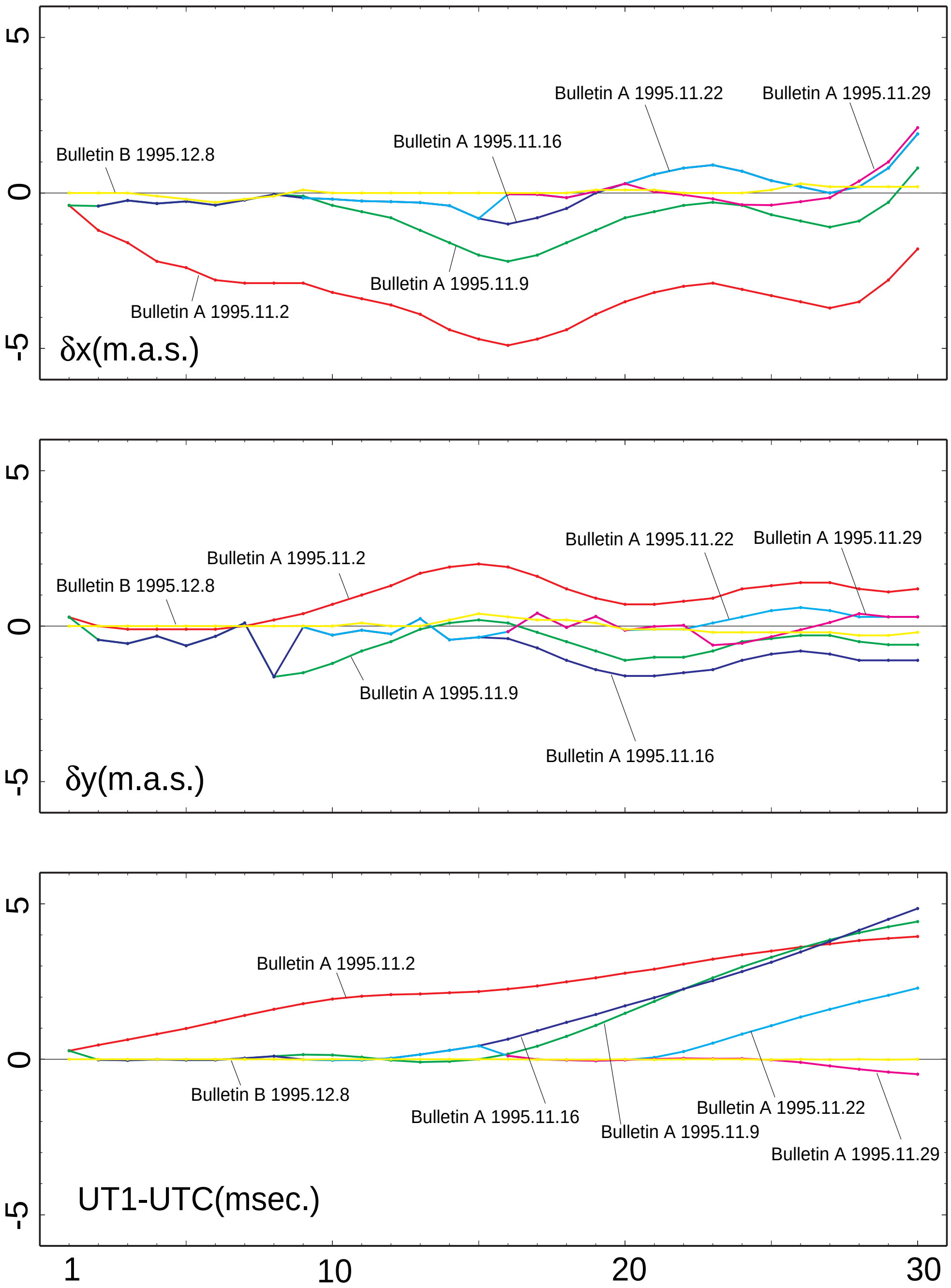

Figure 5. Comparizon of Earth Orientation Parameters (wobble of Earth's rotation pole and UT1−UTC) in the different IERS bulletins.

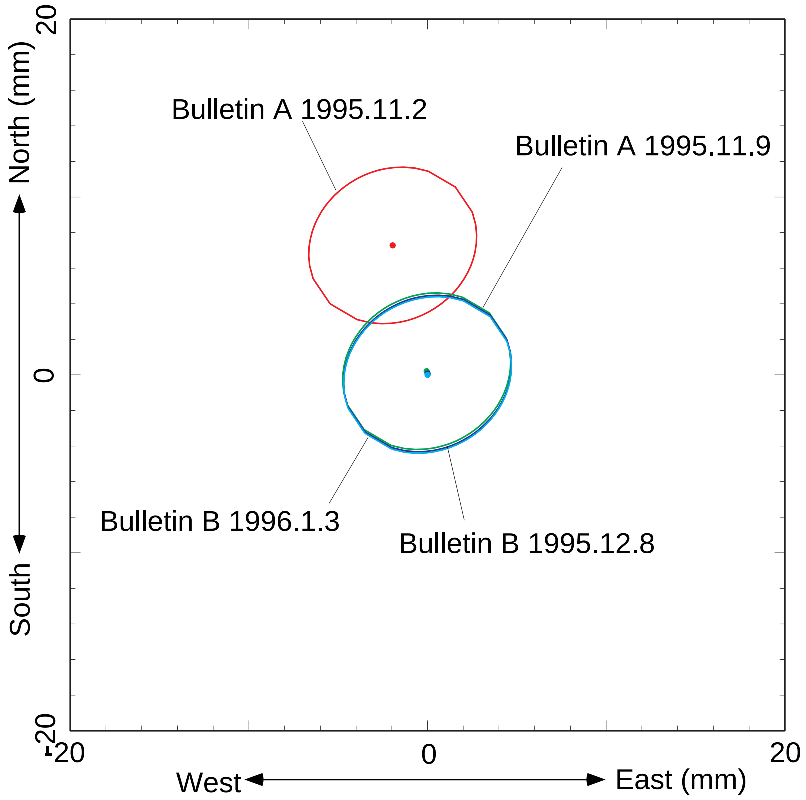

Figure 6. Estimated site position of Koganei VLBI station compared in the horizontal plane.

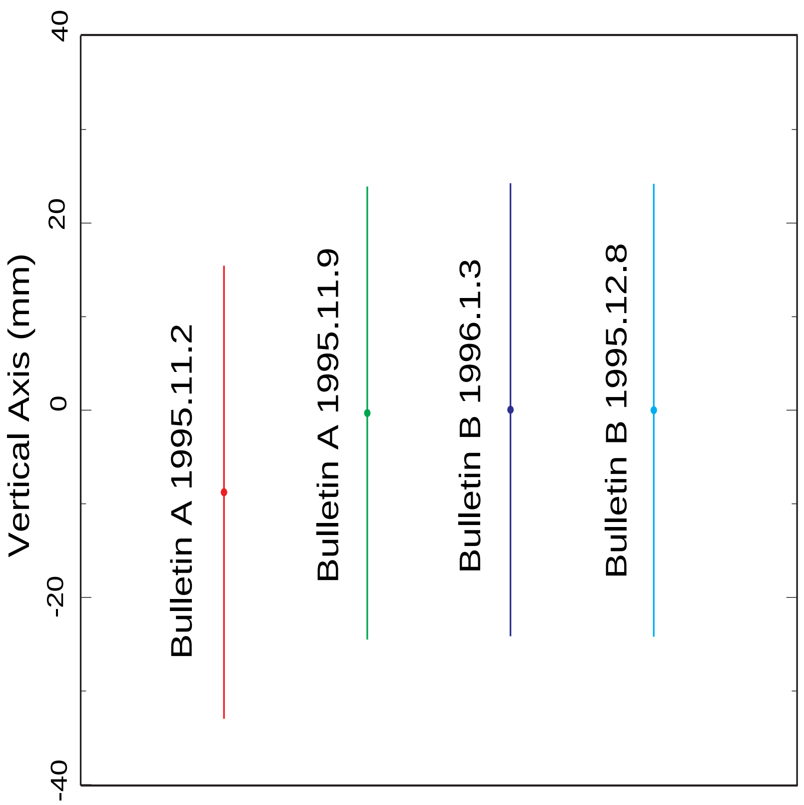

Figure 7. Estimated site position of Koganei VLBI station compared in the vertical axis.

Correlation Processing System for the Key-Stone Project

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Abstracts

We have developed an XF type VLBI correlation processor by making use of Field Programmable Gate Arrays. This correlator was specially designed for the Key-Stone Project, which is concerned with measuring crustal deformation in the Metropolitan area. The outline of the correlator is (1) Automatic bit synchronization during multi-baseline processing, (2) Network Filing System for storing correlated data, (3) maximum data rate is 512 Mbps, (4) 2-bit and higher sampled data processing capability, (5) 16ch high speed (32 Mbps/channel) processing, (6) Compact and light-weight, (7) Signal provided by VME back plane. Using this new correlator, we can improve the precision of the geodetic VLBI and also contribute to radio astronomy VLBI.

1. Correlation Processing System

The periodicity of the time code is not required for spectrum analysis. Only the sampled data are needed. The K-4 recorder has helical data tracks, two longitudinal annotation tracks and a control track (Fig. 1). The Track Set ID numbers are recorded on the control track, and can be read at any tape speed even during fast forward or rewind. The output interface unit can control the synchronous replay of several Data Recorders, convert the Track set ID for the data clock, and send data to a correlator. There is an obvious relationship between the Track Set ID (which is a head control signal written on the control track) and the time code block. It is possible to manage the time code using the Track set ID and Time code block. For a few seconds the time code data is over written on the data train in a pre-observation header block. After the time code block, data timing is checked by the Track Set ID, which means that the output data is only digitized raw data during an observation.

In the multi-baseline correlation processing, all the output interface units are daisy-chain connected via GPIB and a timing control line. A block diagram of the correlation system is shown in Fig. 2. Therefore, the tape position data and the status data of all the data recorders can be exchanged via the output-interface units. The replayed data from the data recorder is written into a buffer memory. The measured phase difference between the replayed and the external 1 PPS signal sent from the Main Replay system is monitored by the clock. The measured data is then sent to the main replay system, and used for the bit synchronization (fine synchronization) between the main and sub replay systems. The main replay system (the main output interface unit and the data recorder) and the sub replay system (the sub output interface unit and the data recorder) can be synchronized in one-bit steps. The delay adjustment is done by controlling the track set ID position control and subsequent programmable memory. The signal (raw data) is unformatted instead of in the Mark-III format. We are developing an XF type VLBI correlation processor for the K-4 system by making use of Field Programmable Gate Arrays. The outline of the correlator is:

(1) Automatic bit synchronization during multi-baseline processing,
(2) Network (Ethernet) Filing System for storing correlated data,
(3) 2-bit or higher sampled data processing capability,
(4) 16 ch high speed (32 Mbps/channel) processing,
(5) Compact and light-weight,
(6) Signal provided by VME back plane.

And specifications are;

(1) Fringe phase resolution 32 bit (at K=1),
(2) 28 bit integrator (integration time from 1 sec to 16 sec),
(3) maximum clock rate 32 MHz,
(4) Phase calibration signal detector (Pcal detection frequency from 10 kHz to 9990 kHz),
(5) 256 kbit delay tracker,
(6) A priori calculation is done each correlator,
(7) 32 complex lags in each channel,
(8) 16 ch XF type correlator,
(9) fringe search mode (512 lags).

This correlator was specially designed for the Key-Stone Project, which is concerned with measuring crustal deformation in the Metropolitan area. The detected fringes are shown in Fig. 3, and geodetic results are reported in this issue. The project utilizes 4 stations in the Metropolitan area, and each station has a new K-4 system and an 11-m antenna. Using this new correlator, we can improve the precision of the geodetic VLBI and also contribute to radio astronomy VLBI. The multi-baseline correlation processor (4-station) is shown

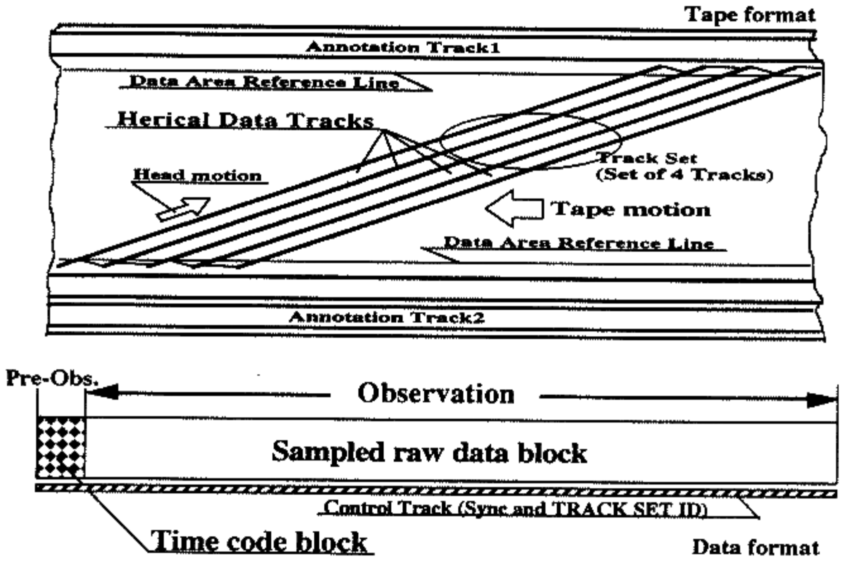

Figure 1. Tape format and data format

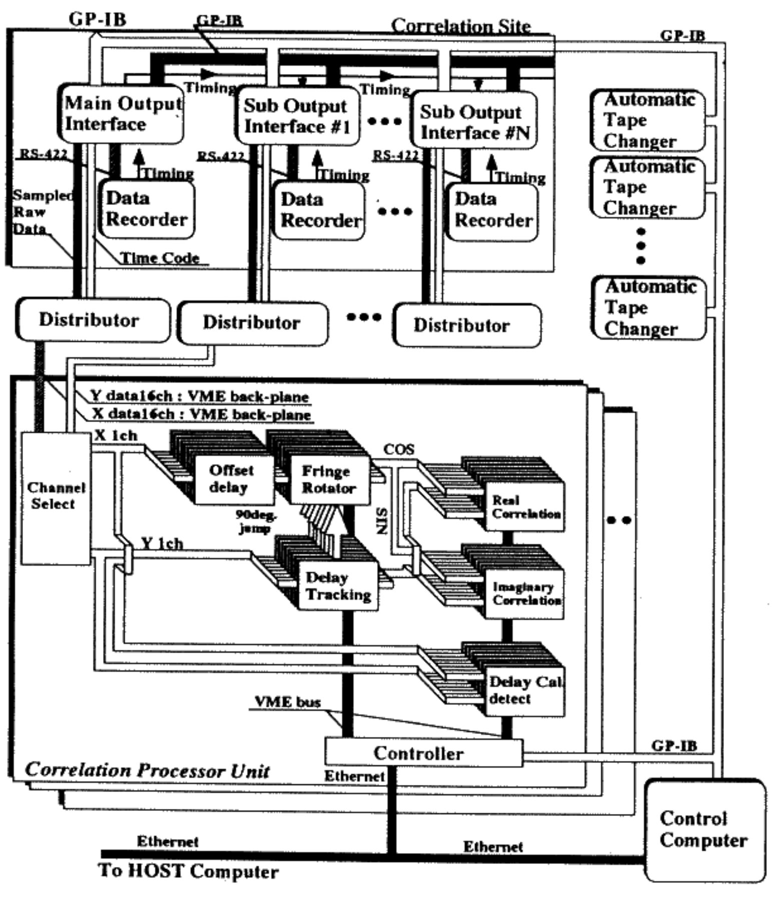

Figure 2. Block diagram of correlation processing system

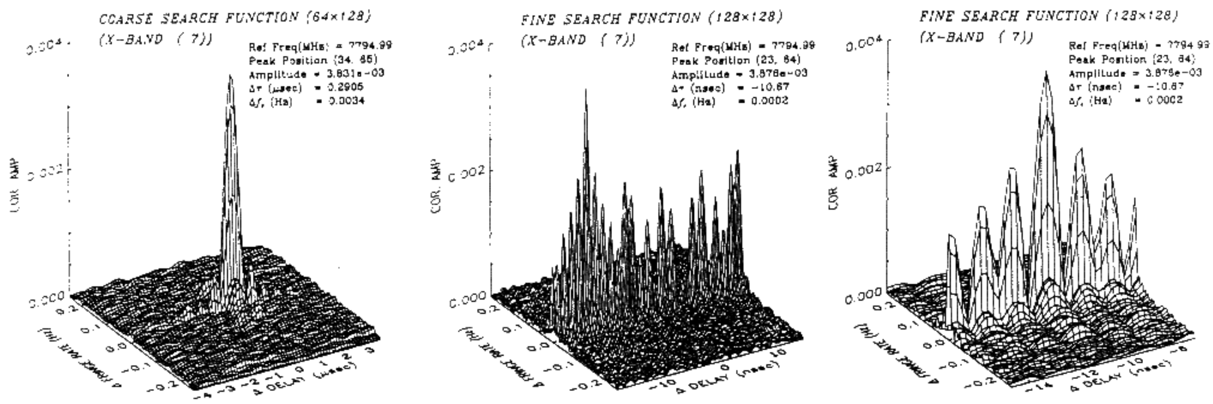

Figure 3. Detected fringes

in Fig. 4. It is also possible to use this correlator for real-time VLBI.

2. Conclusion

The KSP (new K-4) data acquisition mode includes VLBA and VSOP data modes. Multi-baseline correlation processors using Field Programmable Gate Array has been developed.

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Figure 4. Developed multi-baseline correlation processing system. From left : 4 DMS (Digital Mass-strage System: automatic tape changer)

Pulsar VLBI Experiment with Kashima (Japan) - Kalyazin (Russia) Baseline

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1. Introduction

Interferometric measurement of a pulsar is one of the most effective techniques to measure accurate source positions. Precise measurement of a pulsar position will give us information concerning proper motion and parallax. Interferometric measurements on pulsars have been carried out, but the number of pulsars whose positions were measured is still smaller than the total number of known pulsars because newly discovered pulsars are rapidly increasing due to recent intensive systematic surveys. We have started measuring their positions by using VLBI between Kashima and Kalyazin. This report shows the results of the first experiment.

2. Observations

This Pulsar VLBI observation program is based on collaboration between the Communications Research Laboratory (CRL) and the Lebedev Physical Institute. Our first VLBI observation was performed on 14 March 1995. We used a 34m antenna at Kashima and 64m antenna at Kalyazin, which is about 150 km north of Moscow. The baseline length is about 7000 km and minimum fringe spacing is 7 mas at 1.4 GHz. The system temperature and efficiency of the 34m antenna and the 64m antenna are about 40 K and 0.6 respectively for both antennas. The employed VLBI data acquisition system is Japanese K4 system which is compatible with the Mark -III mode C.

3. Correlation and Analysis

Correlation processing was performed by a K3 correlator, which was developed by CRL. A gating function was available on the correlator, but we couldn't use it due to some problems in data processing of gated data. After ordinal cross correlation processing, the result was stored in the Mk-III database and analyzed with software *SOLVE*. The *SOLVE* is a program developed by NASA for baseline and source position analysis with group delay. The estimated position of PSR0329+54 is

$$\mathrm{PSR0329+54}: \begin{array}{ll} \alpha: & 3^h32^m59^s.369 \pm 0.01 \\ \delta: & 54^\circ 34' 43''.627 \pm 0.08 \end{array}$$

Now we are developing a new correlator with gating function to improve the signal to noise ratio. Our observations will be continued for a few years to detect the proper motion.

Acknowledgements

We thank the staff of Kalyazin 64m antenna operation team, especially V. A. Agafonov, A. N. Fatiev, and M. A. Dolgov. Also V. V. Oreshko, V. Sternenko, and A. V. Serov, who helped us with the receiver and atomic standard. Many thanks to members of CRL Radio astronomy applications section for their support of this experiment.

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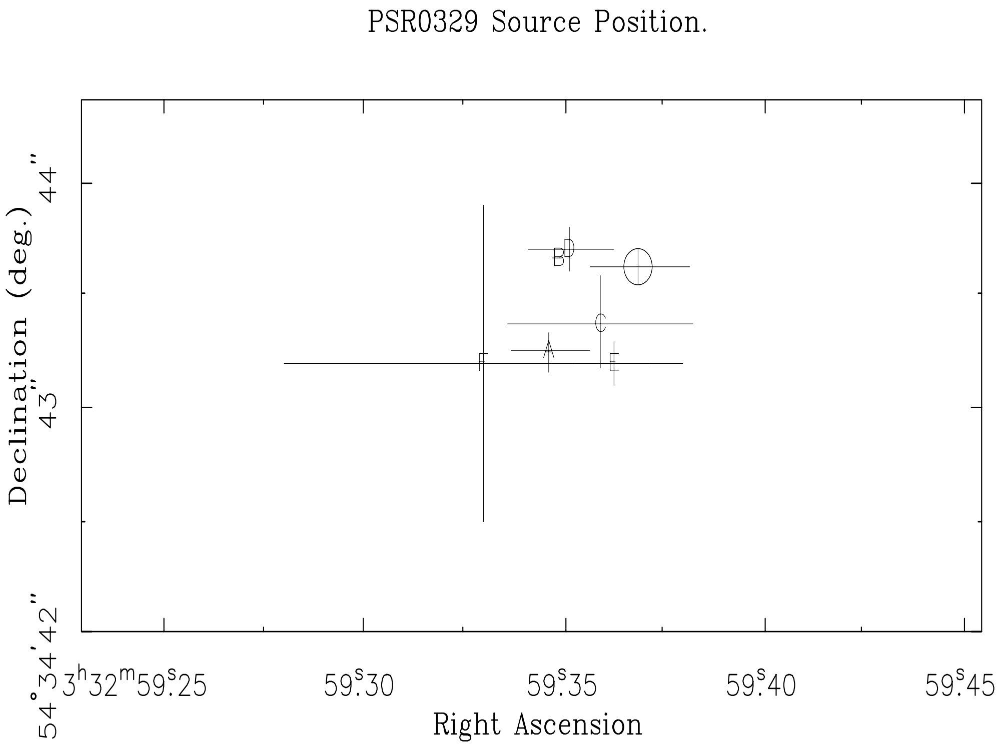

Figure 1. Estimated position of PSR0329+54. Our result is ◯ and others are as follows: A: Taylor et al.(1993), B: VLBI by Bartel et al. (1985), C: 35 km-Interferometer by Backer and Sramek (1981), D: VLA by Formalont et al. (1984), E: Pulse-Time-of-Arrival (PTA) measurement by Downs and Reichely(1983), F: PTA measurement by Helfand et al.(1980). Transformation between the deferent coordinate system is not applied in this figure.

The Examination of Selenodesy and Planetodesy Using VLBI and Counter VLBI

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Recently, the plan of Selenodesy by use of VLBI (RISE: Radio Interferometry for Selenodesy) is proceeding. In this plan, as the VLBI radio sources both that on the Moon surface and on board of satellites around the moon are considered. As a next step to the selenodesy, we (Hosokawa and Imae at CRL and Kawano and Hanada at NAO) began to examine the planetodesy using counter VLBI technique. The first target of the planetodesy is the planet Mars.

With the progress of these projects, a study group on the mechanics of spacecraft and VLBI has been organized in last fall. Hosokawa is appointed as the contact person of the group in CRL. For the realization of these plans, many new technical developments and analysis methods on VLBI technology will be needed. Let us summarize the technical topics and problems of these plans.

There are two important characteristics in these plans. These are, the radio sources are artificial ones, and they are at the finite distances. Because of the former property we will be able to set the intensity and the frequency characteristics of the sources somewhat freely. The latter demands a new analysis method where the parallactic corrections and the motion of the sources should be taken into account. The sensitivity to the motion of the source will provide a new route to the real time positioning of the space crafts.

In the case of counter VLBI, the former property will be fully applied to the planetodesy plan. In our examination, all radio sources on Mars are equipped with atomic clocks, so that all the signals from these sources should be synchronized. This synchronization would be done by two-way satellite time transfer via the Mars-stationary satellite. As the radio sources, we can choose the carriers or the spectrum diffused ones according to the purpose and possible system of the plan. Then, we will be able to measure the differences among propagation times of the radio signals from the sources on Mars to the observatory on the Earth. On the other hand, interplanetary radio propagation would be affected by many relativistic effects that are caused by the complicated motion of the sources and by the gravitational field by the massive bodies in the Solar system. Hence, we have to make the corrections for these effects.

To summarize, there are many interesting and challenging subjects on VLBI technology in the plans of Selenodesy and the planetodesy. Therefore it would be worth paying attention to these plans for us, the VLBI technical development center.

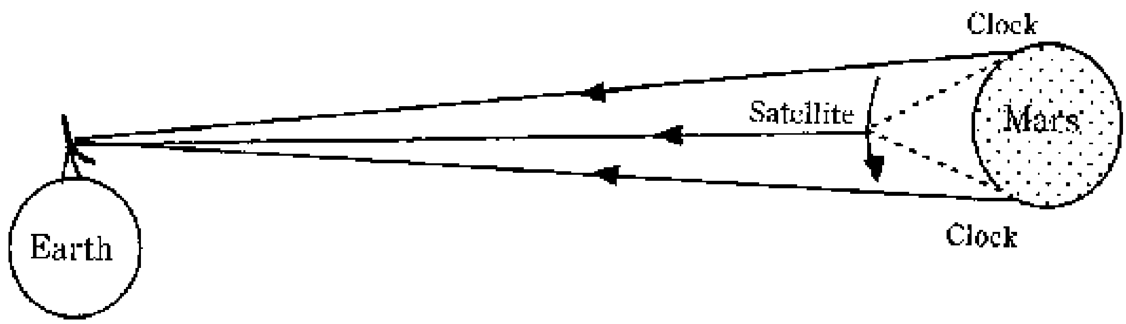

Figure 1. Figure on Counter VLBI.

A Plan of Interferometric Observations of Jovian Radio Wave Emissions at Low Frequencies (25 - 35 MHz)

Tetsuro Kondo

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Jupiter radiates very intense burst-like radio waves in the decametric range of wavelengths. These bursts are the most intense received on Earth, except for emissions from the disturbed sun. Many investigators have observed Jovian decametric radio emissions (JDR) from the ground, and later in space since the first discovery of JDR about 40 years ago, and have studied its various characteristics.

The source regions are thought to be located at Jovian northern and southern auroral regions and/or at the foot of the Io flux tube from evidence based on a wave generation mechanism and the occurrence characteristics of JDR. However so far no direct observation of source location was made because of large refraction caused by the terrestrial ionosphere at such a low frequency. It is difficult to identify absolute source position when the signal is propagated through the ionosphere.

Usually scintillation of ionosphere effects have a time scale of several seconds and longer. If JDR switches its source location between southern and northern hemispheres within sufficiently short time scale compared with that of ionospheric scintillation, we could detect relative source motion. Motivated by this idea, we are planning to carry out interferometric observations of JDR using two antennas located at Kashima and Hiraiso (both are branches of Communications Research Laboratory) spanning about 50 km in north-south direction. Figure 1 shows an antenna newly constructed at Kashima for this study. It is a spatially-crossed 13-element log-periodic antenna with a nominal frequency coverage of 25-70 MHz installed on a 15 m tower as an azimuth-elevation mount.

Presently the Galileo spacecraft's orbiter is orbiting Jupiter, and will measure the Jupiter system and its magnetosphere for at least two years. Therefore it provides a good opportunity to make a direct comparison between observations from the ground and those in situ.

Figure 1. Antenna for detection of decametric radio waves at Kashima.

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Letter of Thanks from National Institute of Polar Research

The director of TDC/CRL received a "letter of thanks" in November, 1995 from Dr. Shibuya of National Institute of Polar Research for the support of TDC at CRL to successful aquirement of the Antarctic VLBI Project budget. (*T.K.*)

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November 1, 1995

Dr. Fujinobu Takahashi
Director for IERS VLBI
Technical Development Center
Communications Research Laboratory
4-2-1 Nukui-kita, Koganei, Tokyo 184

Dear Dr. Takahashi:

As the coordinator of space geodesy programs in the National Institute of Polar Research (NIPR), I am very much pleased to tell you that financial endorsement to install VLBI system at Syowa Station was obtained within the framework of the Japanese 1995 Fiscal Year.

I am not forgetting "Resolution for Promoting VLBI at Syowa Station in Antarctica", issued as the IERS VLBI Technical Development Center Resolution in 28 February 1992, which supported this endorsement greatly.

Please circulate my sincere thanks to all the members who joined in this resolution, and I heartily expect all members' continuing collaboration with tho Japanese Antarctic Research Expedition.

Sincerely yours,

Kazuo Shibuya

Kazuo Shibuya
Professor of Geophysics
Center for Antarctic
Environment Monitoring (CAEM)
National Institute of
Polar Research (NIPR)
Kaga 1-9-10, Itabashi-ku
Tokyo 173

cc: T. Hirasawa (Director General of NIPR)

Letter of thanks from NIPR.

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First Step Toward Geodetic Real-Time VLBI — Successful Detection of Fringes on the Baseline Between Kashima and Koganei Connected by ATM Networks —

Communications Research Laboratory (CRL) is developing a real-time VLBI technique for geodetic use in cooperation with Telecommunication Network Laboratory Group of Nippon Telegraph and Telephone Corpolation (NTT). The real-time VLBI means that correlation processing is made in real time like a connected element interferometer. In May,1996 the first fringes were successfully detected on Kashima-Koganei baseline (about 100 km) (Fig.1). In real-time VLBI digitized data of radio signals from quasers are directly transmitted to a central station where a correlator is located using ATM (Asyncronous Transfer Mode with a speed of 256 Mbps) networks consisting of optical fiber link instead of recording on a magnetic tape. (*T.K.*)

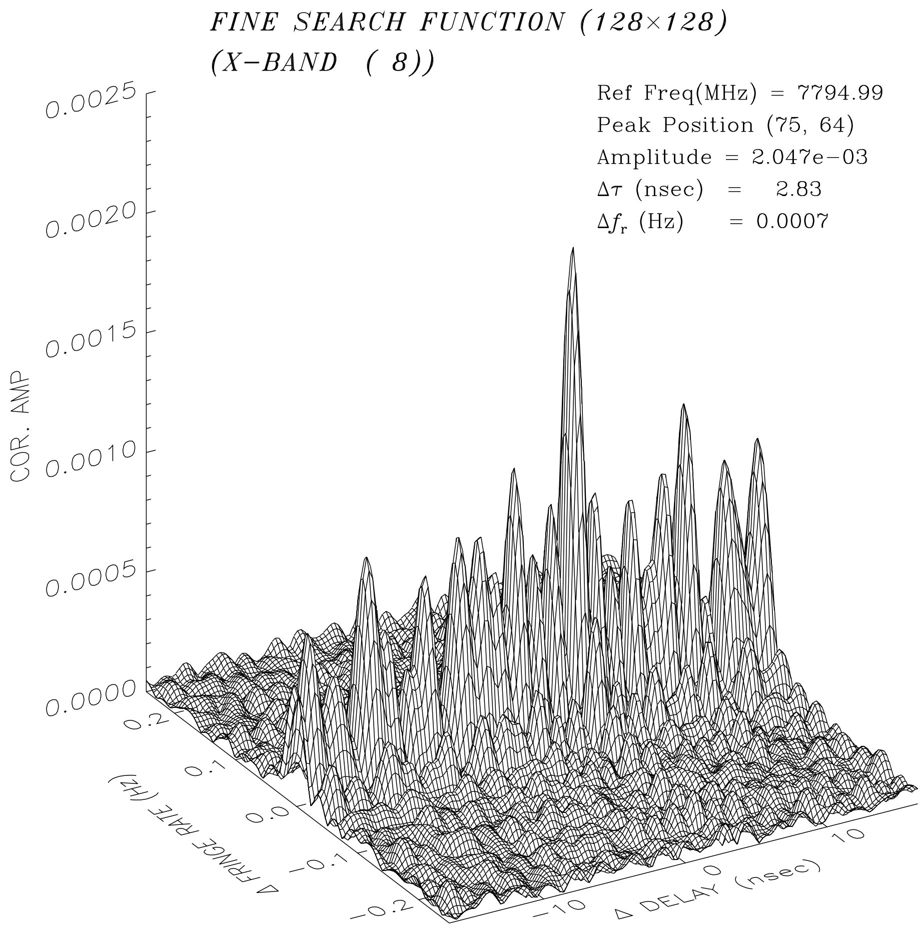

Figure 1. First real-time VLBI fringes after bandwidth synthesis of 8 channels in 8 GHz band for 4C39.25 on the Kashima-Koganei baseline.

Technical Development Center (TDC) at the Communications Research Laboratory (CRL) is supposed to do

1) the development of new observation techniques and new systems for advanced Earth's rotation observations by VLBI and other space techniques,

2) the promotion of research in Earth rotation by advanced methods in VLBI,

3) the distribution of new VLBI technology.

The TDC meeting, attended by the ordinary members from inside the CRL and the special members from the outside, is held twice a year. The special members advise the committee, concerning the plan of technical developments. The TDC newsletter is published biannually by CRL to inform the IERS community its current activities.

This news was edited by Tetsuro Kondo and Yasuhiro Koyama, Kashima Space Research Center, who are editorial staff members of TDC at the Communications Research Laboratory, Japan. The editors wish to thank Dr. O. J. Sovers for his kind help in the correction of the news translated from Japanese to English.

Inquires on this issue should be addressed to:

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Summaries of VLBI and related activities at the Communications Research Laboratory are available from the home page of the Radio Astronomy Applications Section of the Kashima Space Research Center on the World Wide Web (WWW). The URL to view the home page is : *http://apollo.crl.go.jp/*

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