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Overview of the 17th TDC Meeting

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The 17th meeting of the IVS Technology Development Center at Communications Research Laboratory was held on September 26, 2000 at the Kashima Space Research Center of the Communications Research Laboratory. Meeting rooms at the Kashima Space Research Center and Headquarters of the Communications Research Laboratory were connected by a TV conference relay and a part of the attendants participated in the meeting from the meeting room at the Headquarters.

Attendance

CRL members

Takao Morikawa, Taizoh Yoshino, Michito Imae, Mizuhiko Hosokawa, Noriyuki Kurihara, Jun Amagai, Hitoshi Kiuchi, Yuko Hanado, Mizuhiko Hosokawa, Fujinobu Takahashi, Hiroshi Kumagai (KSRC: Kashima Space Research Center), Tetsuro Kondo (KSRC), Junichi Nakajima (KSRC), Ryuichi Ichikawa (KSRC), Eiji Kawai (KSRC), Mamoru Sekido (KSRC), Tomonari Suzuyama (KSRC), Hiroshi Okubo (KSRC), and Yasuhiro Koyama (KSRC)

Special members

Noriyuki Kawaguchi (National Astronomical Observatory), Kosuke Heki (National Astronomical Observatory), Yoshihiro Fukuzaki (Geographical Survey Institute), Takahiro Iwata (NASDA), Arata Sengoku (Hydrographic Department, Japan Coast Guard) and Sotetsu Iwamura (substitute for Hisao Uose, NTT Information Sharing Platform Laboratories)

The following special members could not attend: Hideyuki Kobayashi (National Astronomical Observatory), and Kazuo Shibuya (National Institute of Polar Research)

Minutes

1. Opening Greeting

Takao Morikawa, the director of the IVS Technology Development Center at Communications Research Laboratory (CRL), made opening greetings as following to the meeting attendants.

CRL will change from a government research institute to a so called an independent administrative institution on 1 April 2001. It will be a drastic change for the laboratory and all of the research projects in the laboratory are now requested to establish their own middle term (5 years) research plans. We are expecting to have fruitful discussions today to brush up our future plan.

The 17th meeting of the IVS Technology Development Center at Communications Research Laboratory was held on September 26, 2000 at the Kashima Space Research Center of the Communications Research Laboratory.

2. Reports of the 4th IVS Directing Board Meeting (*Tetsuro Kondo*)

The 4th meeting of the IVS Directing Board was held in the Paris Observatory on September 17, 2000. Tetsuro Kondo (CRL) and Shigeru Matsuzaka (Geographical Survey Institute: GSI) participated as the Directing Board members from Japan. At the meeting, it was introduced that the organization of IVS was formally recognized by the International Astronomical Union in its general assembly in August. Alan Whitney (Haystack Observatory) reported that the first official version of the hardware specifications of the VLBI Standard Interface (VSI) has been fixed and agreed by the VSI committee members. He also noted that the establishment of the VSI hardware specification has been achieved by long and frequent discussions among the concerned individuals including VSI committee members through e-mail, tele-conferences, and face-to-face meetings. Tetsuro Kondo made a presentation about the developments of the internet protocol VLBI (IP-VLBI) technique in the IVS Directing Board meeting and in the Journées 2000 symposium which was held after the IVS Directing Board meeting. The presentation seemed to draw great interests from many attendants. The current plan of the dates and the venue for the 2nd General Meeting of the IVS to be held in Japan was proposed by Shigeru Matsuzaka and Tetsuro Kondo. The plan was acknowledged by the IVS Directing Board. We are planning to hold the General Meeting from February 4 to 6, 2002 at Tsukuba International Congress Center. In addition, we will consider an option to hold another international workshop after the General Meeting.

Q: Are there any plans in IVS to promote the concepts of VSI to the entire VLBI community?

A: There was no specific discussions during the Directing Board meeting. I think it is very important for our group to develop new systems based on the VSI hardware specifications as soon as possible.

C: It will be the most effective promotion for the VSI specification if we can develop an actual system based on the concept. It will become a good demonstration of the concept of the VSI if we succeed to achieve compatibility between the VERA system of the National Astronomical Observatory (NAO) and our Giga-bit VLBI system.

C: Alan Whitney also mentioned that his group at Haystack Observatory will apply VSI specifications to their next generation systems.

C: I would like to suggest CRL to lead the realization of the VSI systems and discussions of the software part of the VSI specifications.

3. Technology Development Center Activity Reports

3.1 Site position displacements due to the seismic and volcanic activities in the area of Izu islands detected by the KSP VLBI Network (*Yasuhiro Koyama*)

The extraordinary site displacements of the Tateyama and Miura VLBI stations observed by the Key Stone Project (KSP) VLBI observations were reported. If the position of the Kashima VLBI station is fixed, the total site displacements of the Tateyama and Miura stations during three months from the end of June became 5 cm and 3 cm toward north-west direction, respectively. These displacements can be well explained by a combination model with a dyke and strike slip fault under the sea floor east of Kozushima Island. The time when the unusual displacements began was estimated by using baseline length data between the Tateyama and Kashima stations. The estimated results was consistent with the time when the swarm earthquake and volcanic activities began which was June 26, 2000. It was also estimated that the crustal deformation became quiet after sometime around August 18, 2000.

Q: How large was the dyke estimated?

A: In our model based on the model proposed by a group in Nagoya University, the dyke is 5 m thick, 12 km wide, and locates 3 km to 15 km under the sea floor.

Q: Is the dyke above the plate boundary between Philippine Sea Plate and North-America plate?

A: The plate boundary is located much deeper than the assumed dyke.
C: There is a new geophysical hypothesis which assumes a new subduction of the Philippine Sea Plate in the southeast part of the Izu peninsula. In this hypothesis, the new plate boundary is considered to cross the region where the dyke is considered. The direction of the dyke is in good agreement with the direction of the new subduction, and it is parallel with the maximum compression axis expected from a surrounding stress distribution.
Q: How long was the total displacement at Tateyama?
A: It was about 5 cm.
C: It is very interesting to see how this phenomenon evolves. It is also interesting to investigate whether there is any differences between GPS and VLBI.
A: In principle, the results from VLBI and GPS are consistent within their uncertainties.

3.2 Extraordinary crustal deformation at Tokyo area and the Keystone project (*Taizoh Yoshino*)

Unusual change of the baseline length between Kashima and Tateyama stations was noticed in the middle of July 2000 from the results obtained by the automated data analysis of the Key Stone Project (KSP) VLBI experiments. Immediately after it was noticed, the frequency of the VLBI experiments were doubled from every other days to everyday basis. The unusual change continued at least until September. Although the VLBI experiments including the Miura station are less frequent (once every 6 days) because the high speed ATM network to the station became unavailable from May 1999, a similar site position displacement of the Miura station became apparent from the tape-based KSP VLBI results.

Originally, two stations at Miura and Tateyama were scheduled to terminate operations by the end of 2000. It was also planned that the antennas and VLBI facilities at Miura and Tateyama would be transported to the Hokkaido University and the Gifu University, respectively. However, after the crustal deformation began, the importance of the VLBI data obtained with both stations was recognized. In particular, the VLBI monitoring of the site position of the Tateyama station is considered very important. Supporting letters and requests to continue VLBI observations with these stations were received from organizations and individual researchers. Gerhard Beutler, the vice-chairperson of the International Association of Geodesy, and Wolfgang Schlueter, the chairman of the IVS Directing Board sent us letters to encourage the continuation of the KSP VLBI observations. Responding to these encouragements and requests, we started to negotiate with related institutions. We are expecting we can extend the VLBI observations at least at the Tateyama station for one year. (*Editorial supplement: Recently we decided to extend the term of the Keystone observation for one year with three stations, Koganei, Kashima and Tateyama. See page 27 for details.*)
C: Detection of the on-going crustal deformation by the VLBI technique is the result of the technical developments achieved by CRL, i.e., by the real-time VLBI technique and the improvements in measurement accuracy. This is a very good opportunity to expand real-time VLBI observation network to much larger network.
A: We would like to emphasize about the technical development achievements when we publicize these remarkable results.
C: I would like to encourage CRL to take this

opportunity to enhance the research and development activities related to VLBI. It is also an epoch making event for the real-time VLBI technique to demonstrate its advantage.
C: The timeliness is not the only advantage of the real-time VLBI technique. The continuous VLBI observations of the KSP would not be possible if it is done with the conventional tape-based VLBI method.
Q: How long does it take to obtain a result from VLBI observations.
A: Each session consist of about 24 hours of VLBI observations. All data obtained in the session are analyzed immediately after the session completes, and a result becomes available about 30 minutes after the last observation in the session.
C: It should be possible to update the latest result by using the Kalman filtering method even during the session. I think such technical developments are also important.

3.3 Comparison of ionospheric delay obtained by GPS and VLBI (*Mamoru Sekido*)

Ionospheric delay values obtained by the VLBI observations with the KSP VLBI network were compared with the ionospheric total electron content (TEC) map constructed from the GPS technique. For the comparison, the TEC map produced by the GPS observations at KSP sites and the map produced by the Bern University using the IGS sites were used. From these comparisons, the GPS based TEC map can be used for the ionospheric delay correction in the geodetic VLBI data analysis with a sufficient accuracy.
C: If there is no correlation between uncertainties of global ionosphere map and total electron contents, accuracy of the ionospheric delay correction will be further improved by using both of data.
Q: Are there any 3-dimensional ionosphere models available at present?
A: As far as I know, only 2-dimensional ionosphere maps are available from IGS analysis centers of IGS at present.
C: It will be good to investigate the correlation with the geomagnetic turbulence index. I would also like to suggest you to use longer VLBI baselines for comparisons. KSP VLBI baselines are too short to investigate the ionospheric differential delays.
Q: Although it turned out that there was a good correlation between the GPS based ionospheric correction and the VLBI data, what is the cause of the offset between the two results?

A: In the VLBI results, cable length difference and internal delay difference between X-band and S-band receiving systems are contained.

3.4 Geodetic VLBI experiments using giga-bit VLBI system (*Yasuhiro Koyama*)

The results from recent geodetic VLBI experiments with the giga-bit VLBI system are reported. In the past year, several problems were solved and the site coordinate errors have been improved. The current level of system accuracy as a whole is comparable to the KSP VLBI system performed at the total data rate of 256 Mbps. Further efforts are continuing to improve the accuracy.

3.5 Future VLBI observation system developments (*Junichi Nakajima*)

In order to realize equipments based on the hardware specifications of VSI, developments of a new correlation processing system and modifications of the existing gigabit VLBI system are planned. The details of these system were reported.
Q: What kind of data recorder is the GBR-1080?
A: GBR-1000 was originally developed to record high definition TV signals and it has both digital and analog recording capabilities. GBR-1080 is the new data recorder developed by Toshiba Corporation as a digital data recorder. It is also designed so that it can be used as an external storage system of computer systems.
Q: How about to develop a new recorder interface system using digital filters?
A: We are not considering to use digital filters in the new system.

3.6 Development of VSI-based S2-K4 copying system and data sampler (*Mamoru Sekido*)

Features and specifications of a copying system which converts S2 data tapes to K4 data tapes being developed were reported. The system is designed based on the VSI hardware specifications. A data sampler unit which meats the VSI hardware specifications is also planned to be developed. By using these systems, the K4 input interface system, DFC2100, can be replaced and the K4 system can meat the VSI concepts.
C: It will be important to design the copying system so that it can be operated without an aid of a computer system.
A: We are planning to design the system so that it can be used stand-alone.

3.7 Status report of the IP-VLBI development (*Tetsuro Kondo*)

Current status of the real-time VLBI observation and data processing system based on the Internet protocol (IP) was reported. The system is designed for geodetic VLBI and it is designed based on a multi-channel concept. One channel unit with a data sampling and formatting board and a PC has been completed. A test observation at 4 MHz of data rate with the 34m and the 26m VLBI stations at Kashima Space Research Center was performed. The observed data were processed off-line, and a fringe has been successfully detected. At present, developments of data transfer and processing softwares are performed. We are planning to perform a test observation again and the real-time data correlation at the date rate of 40kHz will be tried.
Q: Is it difficult to achieve the clock speed of 4 MHz for the PCI bus?
A: It does not seem to be so difficult under the current technology.
C: If the Internet VLBI becomes possible, it will become possible to use many PCs in parallel like the current data analysis for SETI.

3.8 High speed IP data transmission system for VLBI (*Sotetsu Iwamura, NTT*)

A concept and design of a high speed IP data transmission system to be developed for the VLBI application was reported. The system will transfer ID1 format data by using multiple PC systems in parallel. Each PC system will convert the input data into IEEE1394 data stream and then to IP datagrams. The received data on the other side are then sorted to reconstruct the input data stream. Although the size of the data packet can be adjusted, it will become about 1 Mbyte. The data rates of the ID1 data at 16, 32, 64, 128, and 256 Mbps will be considered. UDP/IP protocol will be used and the forward error correction will be performed. We would like to achieve 64Mbps of total data rate for the initial target. Manufacturing of the newly designed boards are continuing and the first test is expected to be performed from the end of October, 2000.
Q: Will not become the IEEE1394 a bottleneck?
A: IEEE1394 is considered to be fast enough because multiple PC systems will be used in parallel.
Q: How do you realize the error correction?
C: The Reed Solomon code error correction requires about 150% of an overhead, but the increase of the data amount will not be a problem if the number of PC systems are increased accordingly.
Q: Isn't it possible to process the data in parallel if you can separate the data stream into individual channels?
A: The system is designed to be as transparent as possible, and it will be difficult to separate the data channel from the ID1 data stream.

3.9 Installation of a GPS observation system at Marcus Island (*Ryuichi Ichikawa*)

After the 10m VLBI antenna terminated observations, a GPS observation system has been installed at the same point. There are many points that the GPS observations at Marcus Island is considered to be favorable. First of all, weather data are continuously obtained and the satellite observation data such as TRMM are easily available. In order to acquire GPS observation data continuously at Marcus Island and to collect data remotely, a remote GPS data acquisition system using a satellite mobile telephone and a solar battery has been installed.

4. Reports and Suggestions from Special Members

Kosuke Heki (National Astronomical Observatory)

Apparent periodic changes with a period of one year are often found in the baselines data of the continuous GPS observation network operated by GSI in the northeast block of the main island of Japan. The periodic change is large if the baseline is in a direction perpendicular to the mountain ridge of the region. On the other hand, the change is small if the baseline is in parallel with the mountain ridge. In addition, it turned out that the phase of the change is opposite between the east part and the west part of the block which is separated by the mountain ridge. Although such a phenomenon suggests that a certain torque is working to the mountain ridge, the actual torque expected from the meteorological data is too small to cause the change. It is an interesting phenomenon although the clear conclusion has not yet been obtained. It should be also noted that the similar periodic change is found in the VLBI data for the Kashima-Kauai baseline length, while the change is not apparent in the Fairbanks-Kauai baseline length.
Q: There are similar periodic changes in the KSP VLBI baseline length. We are considering the water vapor above the rice fields near Kashima station. Are there similar change in the GPS data in the Kanto district?
A: In the GPS data, such periodic changes in the Kanto region are not noticeable. Similar periodic changes can be found in the southwest region of Japan and in Taiwan.
Q: How about in Hokkaido region?
A: Yes. There are similar changes in the region.
C: There was a paper in the Journal of Geophysical Research which reported a possibility that the atmospheric torque is causing earthquakes.

Fukuzaki Yoshihiro (Geographical Survey Institute)

In GSI, a correlator system same as the KSP correlator at Koganei has been installed from three years ago. However, when the data recording rate is changed to 128Mbps from 64Mbps, it tends to fail the correlation processing frequently. Because of this problem, it took as long as three months to process a domestic VLBI experiment with four stations. A few software bugs were discovered and the softwares were corrected, but it did not solve the problem completely. I would like to have comments from CRL to solve the situation.

GSI is very interested in the developments of real-time IP-VLBI system, and we would like to introduce the system in the future.
C: There isn't a similar problem in the Mitaka correlation system of NAO.
A: DFC2200 is used for the data output interface in GSI. It seems that the DFC2200 are causing the problem.

Noriyuki Kawaguchi (National Astronomical Observatory)

For the VERA project, new observation systems including an 8Gbps sampler, 1Gbps recorders, and digital filter units which operates at 1Gbps are being currently developed. We are also planning to carry out radiation-proof tests of super-high-speed LSI chips for the preparations of the future VSOP-2 mission. In the near future, 32m antenna system for satellite communication at Yamaguchi will be transferred to NAO. NAO will refurbish the antenna so that it can be used for astronomical VLBI observations. The efficiency of the antenna is estimated as 63% (57-70%) at 8GHz and 21% (10-45%) at 22GHz. I would like to ask cooperations for these future plans.
Q: How large are the size and the expense of the digital filter system?
A: The size of the system is similar to the size of the near real-time correlator system for the VSOP. Although the initial development cost of the LSI chips is large, the production cost per chip will become very cheap. If the number of taps of the digital filter is reduced like the analog filters, the size will become similar to the DFC2100 system.

5. Greeting of Closing

Hiroshi Kumagai, the vice-director of the IVS TDC at CRL, greeted the closing.

Site position displacements due to the seismic and volcanic activities in the area of Izu islands detected by the KSP VLBI Network

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1. Introduction

Site positions of the three VLBI stations at Koganei, Miura, and Tateyama are estimated with respect to the site position of the Kashima VLBI station by performing geodetic VLBI experiments regularly under the Keystone Project. Until recently, steady motions of the three stations were observed with respect to the Kashima station, and these motions were well explained by the effects of the relative motions of the Pacific Plate and the Philippine Sea Plate with respect to the North American Plate. However, a remarkable change of the Tateyama site position was noticed in the middle of July 2000. Immediately after the unusual motion of the Tateyama station was recognized, the frequency of the real-time VLBI experiments with three stations at Kashima, Koganei, and Tateyama were doubled to the every day basis from the regular frequency of once every two days. Since the high speed ATM (asynchronous transfer mode) digital network to the Miura station became unavailable from the beginning of May 1999, the VLBI experiments including the Miura station is now performed only by the conventional tape-based VLBI observations, and the frequency of the all four sites are performed once every six days. Because the frequency of the VLBI experiments with the Miura station is very low, it took a while to obtain convincible results but the unusual site displacement is also apparent at Miura station. Figure 1 and Figure 2 show the baseline lengths of the KASHIMA-TATEYAMA and the KASHIMA-MIURA baselines, respectively.

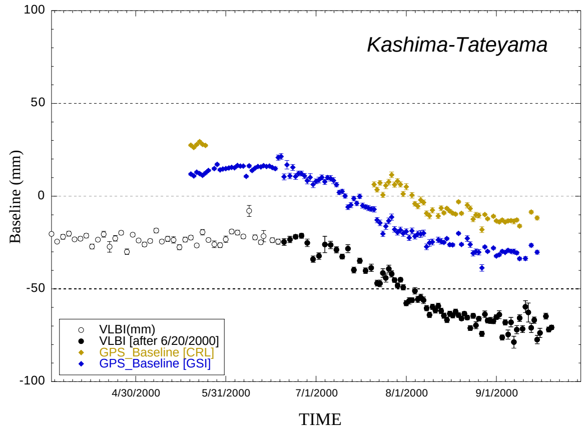

Figure 1. Baseline length between Kashima and Tateyama stations estimated from the regular geodetic VLBI sessions with the Keystone VLBI network. The results from GPS observations performed under the Keystone Project and by the Geographical Survey Institute are also shown.

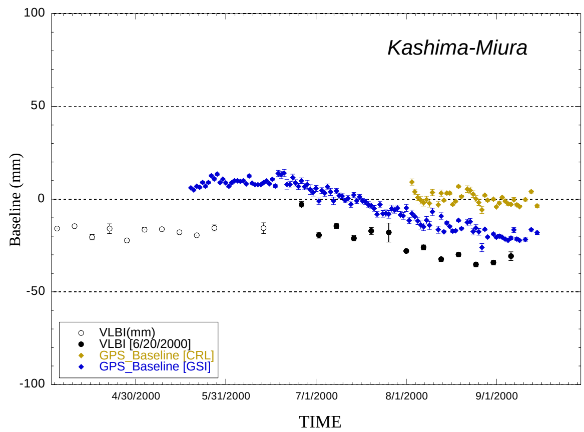

Figure 2. Baseline length between Kashima and Miura stations estimated from the regular geodetic VLBI sessions with the Keystone VLBI network. The results from GPS observations performed under the Keystone Project and by the Geographical Survey Institute are also shown.

2. Geophysical Interpretation

It is apparent that the unusual change of the baseline lengths began at some time between the end of June and the beginning of July. Similarly, large displacements of the GPS observation sites in the area near the Izu islands have been found in the results of the continuous GPS monitoring network operated by the Geographical Survey Institute. These results indicate that a wide area crustal deformation occurred in the area. Almost at the same time when the deformation began, seismic activities in the area of the Izu Islands and volcanic activities at Miyakejima Island began. The epicenter of the earthquake swarm moved from the west side of the Miyakejima Island to the area east of the Kozushima Island. The volcanic activities at the Miyakejima Island started on 26 June 2000 and have been continued until present. A few eruptions occurred during the period and emissions of the volcanic gases are still continuing. On the other hand, the earthquake swarm continued for about two months and it became quiet. The cause of the earthquake swarm is explained by an intrusion of a dyke in the area. By considering a dyke model, both the earthquake swarm and the crustal deformation can be explained. The motion of the epicenter from the Miyakejima Island to the eastern off of the Kozushima Island is explained by a model which assumes that a huge amount of magma under the Miyakejima Volcano moved to the east of the Kozushima Island. The model is consistent with the actual phenomena of the collapse of the summit of the Oyama Mountain which is the volcano of the Miyakejima Island. Tateyama and Miura are located about 50 km northeast of the epicenter of the earthquake swarm and the motions of these site provide useful condition to constrain various parameters of the dyke model. Figure 3 shows the site velocities of the Keystone VLBI sites observed before the unusual crustal deformation began while Figure 4 shows the site displacements observed during the period between the end of June 2000 and the middle of September 2000. Figure 5 shows the deformation pattern expected from a combination model with a dyke and a strike strip fault. The model was constructed from the distribution of the epicenter of the earthquake swarm and the crustal deformation observed by the GPS and VLBI measurements. The dyke is assumed to be 5m thick with a depth of 3km and dimensions of 20km (horizontal) and 12km (vertical). The fault is assumed to have a slip of 4m with a depth of 3km and dimensions of 5.9km (horizontal) and 10km (vertical).

As shown in Figure 5, the model used in the figure well explains the 5cm and 3cm site displacements at Tateyama and Miura stations. The dis-

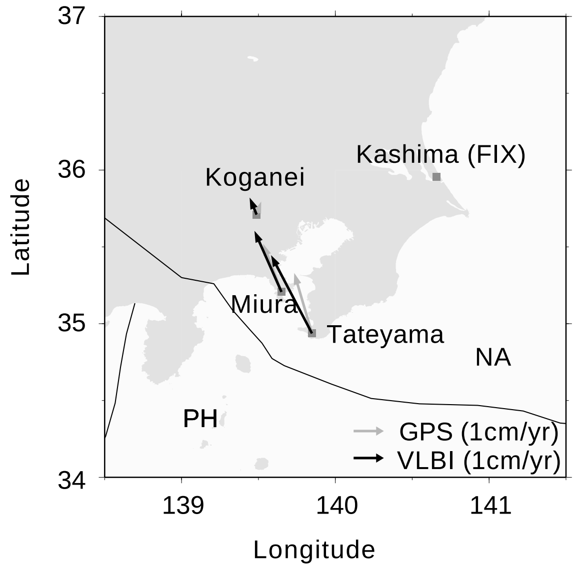

Figure 3. Site velocities of three VLBI stations of the KSP VLBI Network at Koganei, Miura, and Tateyama with respect to Kashima station observed before the unusual crustal deformation began.

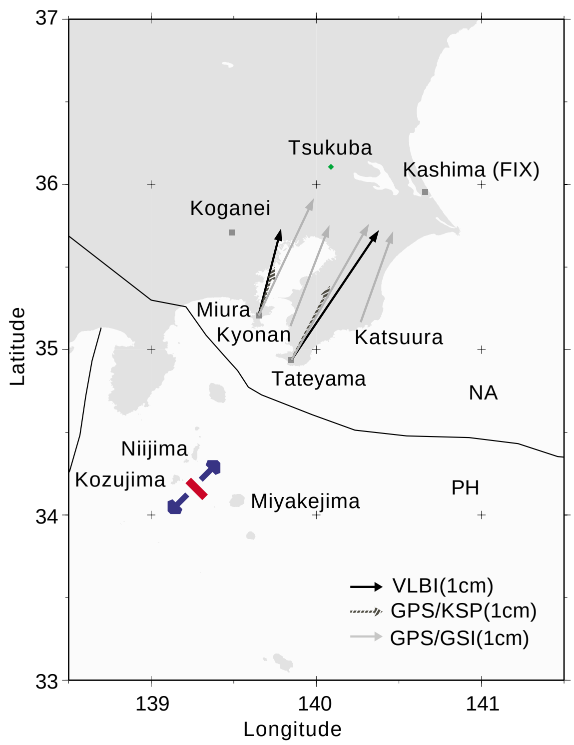

Figure 4. Site displacements at Tateyama and Miura sites observed during the three months from the end of June 2000 detected by the KSP VLBI network and a model which can explain the observed crustal deformation are shown.

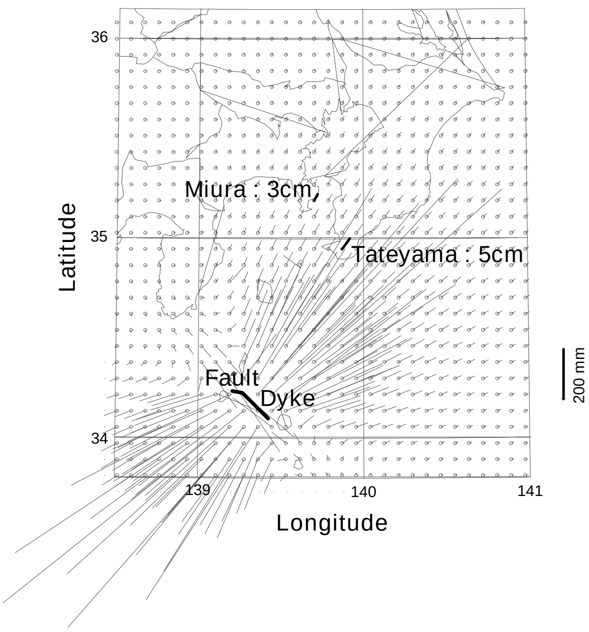

Figure 5. A geophysical model with a dyke and a strike slip fault which can explain the observed crustal deformation. The dyke is assumed to be 5m thick with a depth of 3km and dimensions of 20km (horizontal) and 12km (vertical). The fault is assumed to have a slip of 4m with a depth of 3km and dimensions of 5.9km (horizontal) and 10km (vertical). The model parameters were taken from a model proposed by the group of Nagoya University. The displacements were calculated by the software MICAP-G developped by the Meteorological Research Institute.

tances from the area where the earthquake swarm concentlate to Tateyama and Miura stations are about 100km and 120km, respectively. The fact that the effect of the crustal deformation extended to such long distances indicates that the depth of the dyke is quite deep. This way, the precise site displacements measured by the geodetic VLBI measurements at Tateyama and Miura provide crucial information which constrain the parameters of the geophysical model.

One of the important points to understand the event is to evaluate the time when the crustal deformation began. To estimate the beginning time, a time series of baseline length between Kashima and Tateyama stations was taken from January 2000 up to the end of July 2000. A simple model is assumed that the rates of change are constant before and after the beginning of the event. The root mean squared (rms) of the residuals is evaluated by changing the date when the event began. The results are shown in Figure 6. The minimum of the rms residual in the figure is not steep but it coincides with the date when the earthquake swarm began, i.e. 26 June 2000. The results suggest that the site displacements at Tateyama and Miura stations were caused by the formation of the dyke.

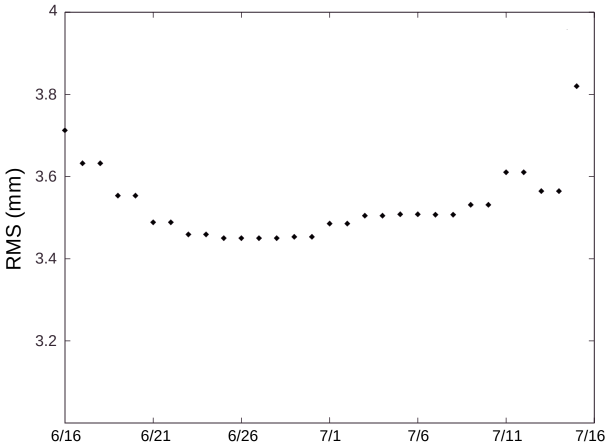

Figure 6. The rms residual of the baseline length between Kashima and Tateyama stations calculated by changing the date when the event began.

3. Future Plan

Although it was planned to terminate the operations of Tateyama and Miura stations by the end of the year 2000, many efforts have been paid to continue the operation at least at Tateyama station. It is expected to continue real-time VLBI operations with three stations at Kashima, Koganei, and Tateyama will continue for about a year. We are planning to take this opportunity to further improve the accuracy and precision of the measurements.

Extraordinary crustal deformation at Tokyo area and the Keystone project

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Communications Research Laboratory (CRL) has been contributing to the seismic study around the Tokyo area by the precise geodetic measurement from the Keystone network since 1996. The Keystone VLBI data is routinely provided to the Meteorological Agency in Japan (JMA) immediately after the data analysis which is automatized. The Keystone VLBI data has been reported to the Coordinating Committee for Earthquake Prediction every three months.

Following the magma intrusion event at Izu Islands about 150km south of Tokyo at the end of June 2000, extraordinary crustal deformation over 2 cm/month was observed by the VLBI network in the Kashima-Tateyama baseline (Figure 1). Since we have never observed such a large deformation, both hardware and software system was checked first. Then, we changed the frequency of experiment from every two days to every day.

We got request to report the data also to the Headquarters for Earthquake Research Promotion under the Science and Technology Agency in Japan. The Keystone results were used to understand how far the crust deformed and the status of seismic activities. Naturally, we exchanged information with many seismologists and geodesists. Actually the Keystone data was used with the dense GPS network data to estimate the volcanic model at Izu islands. Since this is the most significant crustal deformation detected by the VLBI network moreover with GPS, the event was announced internationally via NASA sggmail on August 18. We received many responses with excitement. The observed data was introduced also in the TV news and newspapers.

Although it was planned to terminate the project at the end of next March since the project is time limited, the discussion started if we should continue the observation because we received requests from IAG (International Association of Geodesy), IVS (International VLBI Service for Geodesy and Astrometry), Liason committee of geodesy under the Science Council of Japan, JMA and GSI (Geographical Surveying Institute) to continue the observation at least one year. Most people understood the importance of the observation also to monitor the after-effect. We hope we can announce the one-year extension of the project soon.

(*Editorial supplement: Recently we decided to extend the term of the Keystone observation for one year with three stations, Koganei, Kashima and Tateyama. See page 27 for details.*)

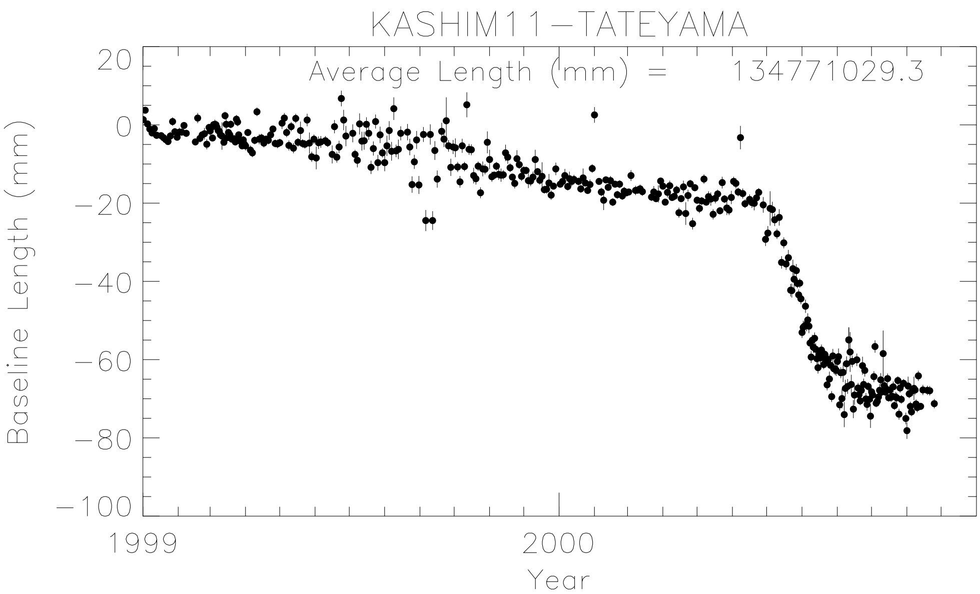

Figure 1. Kashima-Tateyama baseline length change. Extraordinary crustal deformation over 2 cm/month was observed during July-August 2000.

Comparison of ionospheric delay obtained by GPS and VLBI

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1. Introduction

High accuracy geodetic measurements and absolute astrometry are performed by dual band VLBI observations. But several kind of sources such as pulsars cannot be observed with S and X dual frequency because of their spectral characteristics. Ionospheric delay is the most significant error source in those VLBI observation at below a few Giga Hertz. Ionospheric delay correction to VLBI observation by GPS derived TEC is one of approaches to the problem. Not only pulsar VLBI observation, but also geodetic VLBI observation will have benefit if single band VLBI achieves comparative accuracy with conventional dual band VLBI observation. Single band VLBI enable to reduce the cost of dual band receiver system and to use all data channel of VLBI data acquisition system for X-band.

For evaluation of feasibility of GPS-based ionospheric delay correction to single band VLBI observation, we compared GPS-based ionospheric TEC (Total Electron Content) measurement and TEC measured by dual band VLBI.

2. Ionospheric TEC measurement by VLBI

VLBI observation system of Key Stone Project (KSP) [*Yoshino*, 1999] has been operated routinely every two days for 24 hours geodetic VLBI observation. Ionospheric delay data in the VLBI observation were extracted from geodetic VLBI experiment database on Kashima-Koganei baseline. The accuracy of the TEC data evaluated from the signal to noise ratio (SNR) was about 0.4 TEC unit (TECU=10^{16} electrons/m^2).

3. GPS-based TEC measurement

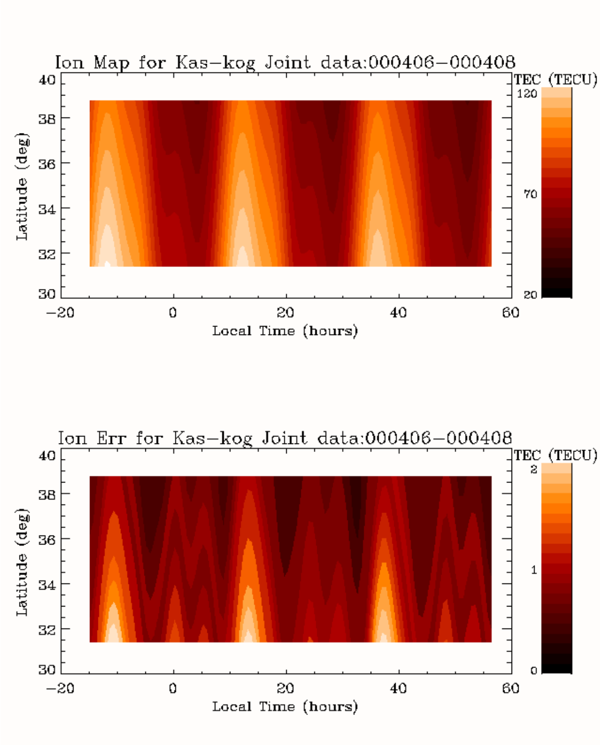

Figure 1. Local TEC map above Kashima and Koganei station estimated from TEC measurements by locally installed two sets of TECMETERs. Upper panel indicates local TEC map and lower one is error of the estimation. Horizontal axis means both time direction and longitude direction of space coordinates.

Two ways of GPS-based TEC measurements were compared with VLBI derived TEC. In one case, TECMETER, which is special GPS receiver for TEC measurement was used. In the second case, global ionosphere maps (GIM) generated by Bern University were used.

TEC distribution estimation with TECMETER

TECMETER measures arrival time difference of P-code in the L1 and L2 GPS signals. Since the observed group delay contains satellite code bias (SCB) and receiver bias (RB) [*Sardón E. et al.,* 1994], the delay can be converted to TEC in line of sight after calibration of those biases. The TECMETER observation data were calibrated with SCB data provided from the DLR [*Sardón E. et al.,* 1994] and the RB data derived from observed data. Two sets of TECMETER was placed at Kashima and Koganei VLBI station and local TEC map above the stations was estimated after the delay calibration. The TEC distribution modeling was as follows: Earth ionosphere was approximated with thin spherical shell and the height of

Table 1. Statistical comparison between VLBI TEC measurements and GPS-based TEC measurements. In case I, two TEC maps were generated from TECMETER observation data at each VLBI stations. In case II, the TECMETER data from two stations were combined and a single TEC map was generated. In case III, the global ionosphere map model produced by the CODE was used. VLBI derived TEC, which is difference of the TEC along the line of sight from each VLBI stations, were compared with the corresponding difference in the three cases of GPS-based TEC measurements. The root mean square of the difference, correlation coefficient, proportional coefficient and offset are computed.

	Date	4/7	4/9	4/11	4/13	4/15	4/17
Case I	RMS (TECU)	5.6	5.6	7.4	5.0	8.2	9.7
(TECMETER)	Correlation	0.39	0.0	0.12	0.35	0.15	0.0
	offset (TECU)	5.0	-3.6	-1.5	2.0	-0.66	19.8
	proportional coefficient	1.35	-0.2	0.56	1.1	0.88	-0.1
Case II	RMS (TECU)	1.2	1.2	1.3	1.2	1.3	1.0
(TECMETER)	Correlation	0.79	0.75	0.78	0.80	0.76	0.84
	offset (TECU)	2.32	2.59	2.90	2.0	2.38	2.93
	proportional coefficient	0.88	0.87	0.98	0.86	1.08	1.01
Case III	RMS (TECU)	0.70	0.89	0.75	0.73	0.82	0.69
(GIM/CODE)	Correlation	0.92	0.88	0.91	0.92	1.00	0.92
	offset (TECU)	2.3	2.9	2.32	2.40	2.68	2.48
	proportional coefficient	0.83	1.07	1.01	0.95	1.11	1.02

ionosphere was assumed constantly 300 km. TEC distribution on the shell was expressed by products a latitude function of linear trend plus offset and longitude function of linear trend plus 4th order of trigonometric function [*Sekido et al.,* 2000]. An example of obtained TEC map is shown in Figure 1.

Global Ionosphere Map produced by the CODE

Center for Orbit Determination in Europe (CODE) in Bern University is one of the IGS analysis center and is generating global ionosphere maps from GPS data of world IGS network [*Schaer, Beutler, and Rothacher,* 1998; *Schaer,* 1999]. The data is expressed with 149 coefficients of spherical harmonics expansion. The daily ionosphere map data without any interruption since January 1995 are open to public through the Internet (http://www.aiub.unibe.ch/ionosphere.html).

4. Comparison of TEC measurement between VLBI and GPS

GPS derived TEC has compared with VLBI derived TEC after converting to the slant TEC in line of sight of the VLBI observation. The period of the comparison was from 7 April to 17 April in 2000. Three cases of comparison was performed. In case I, TEC distribution maps were estimated from each data sets of TECMETER at each VLBI sites. In case II, single TEC map was estimated from joint data of the two TECMETER data sets. In case III, global ionosphere map (GIM) generated by the CODE was used. In each cases, slant TECs in line of sight from each VLBI observation sites were calculate with TEC maps and the difference of them were compared with VLBI derived TECs (ionospheric delay). The results of the comparison is summarised in Table 1.

It is obvious that independently derived TEC maps by each TECMETER data sets (case I) are difficult to use calibration of ionospheric delay in VLBI. Common TEC map derived multiple TECMETER data sets (case II) showed remarkable improvement than case I. The correlation with VLBI data was about 80 % and rms difference was about 1.2 TECU. The best model in this comparison was GIM by the CODE. The correlation with VLBI data was more than 90 % and rms difference was about 0.7 TECU. Since error of VLBI derived TEC is about 0.4 TECU, the errors of GPS derived TEC (difference) are estimated as 1.1 TECU in case II and 0.6 TECU in case III. They correspond to 23 ps and 12 ps of ionospheric delay at 8GHz in case II and case III, respectively. Since these errors are comparable or less than latest geodetic VLBI analysis residuals, we could conclude that single VLBI observation with ionospheric delay correction by GPS is now at level of practical use.

5. Conclusions

Evaluation of TEC estimation accuracy among TEC derived locally installed GPS receivers, global TEC maps derived from world IGS network were performed by comparison with VLBI data. Following conclusions was obtained. TEC maps derived independently from single TECMETER data set is difficult to use ionospheric delay correction in VLBI, but common TEC map derived from joint data sets of multiple TECMETER has much improvement and will help single band VLBI data calibration. The best model in this comparison was GIM by the CODE and it would has comparative accuracy with dual band VLBI observation.

Dual band VLBI was thought economically infeasible at the very beginning of geodetic VLBI system development [*Whitney et al,* 1976]. Now the same idea of single band VLBI is becoming available with help of GPS system, which is competitor of geodetic VLBI. Single band VLBI will enable lower cost mobile VLBI station and expansion of band width of X-band without any investment. And it will improve the accuracy of single band VLBI astrometry for such as pulsars.

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Geodetic VLBI experiments using giga-bit VLBI system

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1. Introduction

The developments of the giga-bit VLBI system at the Communications Research Laboratory started in 1996. The system consists of the A/D sampler unit (TDS580D/TDS784A), the recorder system (GBR1000), the correlator (GICO), sampler interface unit, the timing control unit (DRA1000), and the data buffer unit (DRA2000). The GBR1000 recorder unit has been developed based on the high-definition TV recorder. The original recorder unit can record digital data up to 950 Mbps, and the modified GBR1000 unit can record VLBI data at the rate of 1024 Mbps. The A/D sampler unit has been developed from the digital signal oscilloscope which has the 4-bit resolution at 1024 Mbps of data rate. A subset of the sampled data are demultiplexed to 32 data lines which can be recorded by the recorder unit. The time control unit controls the timing of the recorded data and the information is recorded in the observation data in the auxiliary data channel. Figure 1 shows a picture of the whole system.

Preliminary results from geodetic VLBI experiments were reported in the previous issue of the CRL IVS TDC news [Koyama *et al.*, 2000]. In this report, recent improvements and progress are described.

2. Experiments

Four geodetic VLBI experiments have been performed using the giga-bit VLBI system. Table 1 lists these experiments. In each experiment, observations were performed with K-4 VLBI system in parallel to compare the results.

Fringes were detected from all of the four experiments and geodetic solutions were successfully obtained. A few software problems were solved by using the actual observation data and the data quality has been gradually improved. For example, there was a timing offset of 42 msec between the correlation parameter calculations and the actual correlated data. After these problems were solved, it became clear that the frequency stability of the 25.6 MHz CW signal provided to the TDS580D/784A data sampler unit was important. In the three experiments performed before the last experiment, a signal generator with a poor frequency stability was used at one station to produce the 25.6 MHz CW signal. Therefore, the signal generator was replaced with another signal generator which has a better frequency stability in the

Figure 1. A picture of the whole system of the giga-bit VLBI system.

Table 1. A list of four geodetic VLBI experiments performed using the giga-bit VLBI system.

Date	Duration	Baseline
19 Oct. 1999	6 hours	Kashima(11m)-Koganei(11m) : 109.1km
18 Jan. 2000	26 hours	Kashima(34m)-Gifu(3m) : 358.9km
29 Feb. 2000	26 hours	Kashima(34m)-Gifu(3m) : 358.9km
20 Jun. 2000	24 hours	Kashima(11m)-Koganei(11m) : 109.1km

Table 2. Comparison of results from the last experiment on June 20 2000 obtained by the K-4 VLBI system and by the giga-bit VLBI system.

	RMS delay residual (psec)	Baseline length (mm)
K-4 VLBI system	55	109099665.7 ± 2.0
giga-bit VLBI system		
no correction	88	109099668.1 ± 2.8
with 500 MHz phase correction	68	109099664.1 ± 2.3

last experiment. As the results, the RMS residual delay was improved from the previous three experiments and the value became comparable to the results obtained with the K-4 VLBI system. However, by investigating the phase difference of the 500 MHz CW signals in the recorded data, it became evident that there is a correlation between the phase difference and the delay measurement. Figure 2 compares the difference of delay between giga-bit VLBI system and K-4 VLBI system and the phase difference of the 500 MHz CW signals.

The 500 MHz CW signals generated by signal generators were used at each of two observation stations to convert the IF signals from 500 MHz to 1000 MHz to baseband signals. As the figure clearly shows, there is a high correlation between these two quantities. It suggests that the sampling timing of the data sampler unit is not stable and the instability of the sampling timing is affecting the delay measurements. If the frequency stabilities of the 500 MHz CW signals are good enough, it should be possible to improve the solution by correcting the delay data with the phase difference of the 500 MHz CW signals. As tabulated in Table 2, the results were slightly improved.

3. Conclusions

As described in the previous section, data quality and the estimation errors from the geodetic VLBI using the giga-bit VLBI system has been improved to the level comparable to the K-4 VLBI system. Considering the fact that the equivalent frequency bandwidth from the K-4 system is larger than the one with the giga-bit VLBI system, the recent results are in fact satisfactory. The single channel architecture of the giga-bit VLBI system has a disadvantage in the effective frequency bandwidth compared with the multi-channel VLBI system where the bandwidth synthesis technique is available. However the giga-bit VLBI system has an advantage in its superior sensitivity. If the observation schedule is optimized for the giga-bit VLBI system, number of observations in an experiment can be increased, and the estimation error will be further reduced. On the other hand, there is a plan to develop a new sampler unit based on the VSI hardware specifications, and the stability of the sampling timing should be improved with the new sampler unit. Although the current giga-bit VLBI system is considered to be an experimental system, but the new system will be called as K-5 VLBI system if the overall performance supersedes the current K-4 system in accuracy and data quality.

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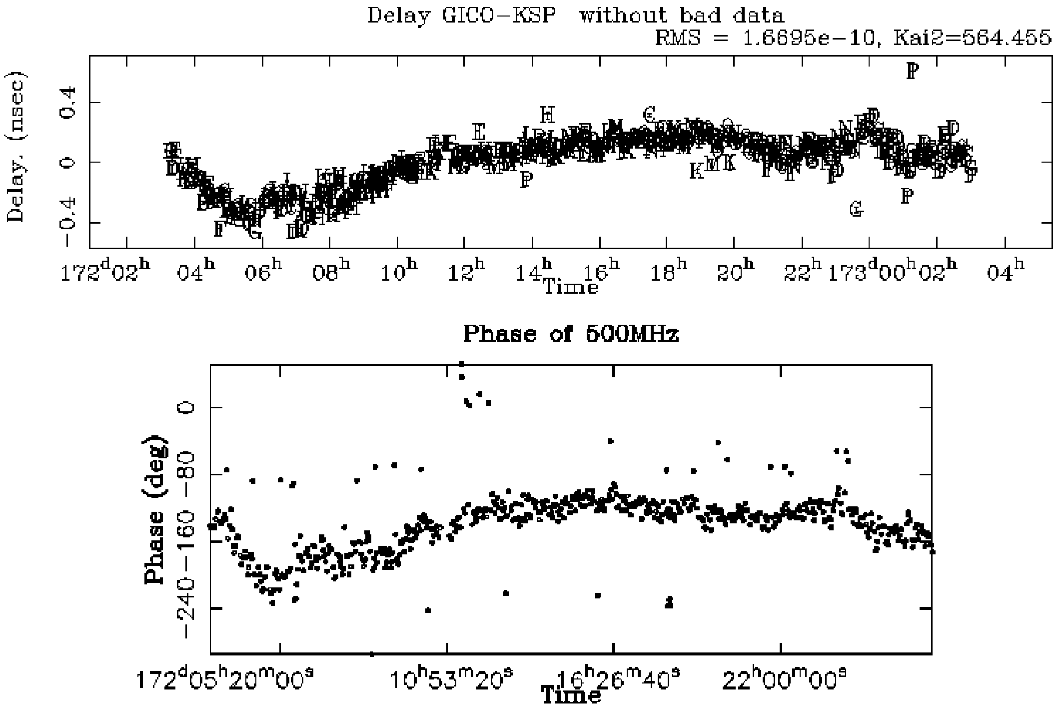

Figure 2. Comparison between the difference of delay between giga-bit VLBI system and K-4 system (below) and the phase difference of the 500 MHz CW signals (above) obtained form the data analysis of the last experiment on 20 June 2000.

Another Giga-bit Sampler Prototype, Nearly Completion

– ADS-1000 development status (October, 2000) –

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Our Gbps samplers modified from Tektronix TDS784/580 DSO have advantages when they compared with former VLBI samplers. The unique function of monitoring IF signals and its FFT spectrum are quite convenient during initial Gbps observations. In addition, they have 4 channel redundancy and achieve 8 Gbps total data rate. The TDS samplers were used in all the GEX (Gbit Experiment) observations and new radio sources are detected in high-z QSOs surveys. However, they need a 2U size interface box and a massive SG (signal generator) of 25.6 MHz locked to a station's 10 MHz reference. This is a hindrance and it had been made practical Gbps VLBI system complex, especially when we carry out a VLBI campaign with remote stations.

A Design of ADS-1000 started to provide simple portable Gbps samplers. Telescope front-end mounted AD samplers will eliminate long analog transmission in near future. Although, the current AD packages weigh 50 kg and occupy 6U in the system, The ADS1000 weigh less than 10 kg and occupies 1/2U. The first prototype of the ADS-1000 under development is shown in Figure 1. In this prototype unit, an AD board and a DMUX/CPU board are separated. They are connected by coax-cables. Most of the useful functions evaluated in the former DSO samplers are implemented. Thus the bit distribution monitoring and test signal generations are possible again.

In the ADS-1000, the most important performance, is its sampling jitter. The error is expected to reduced by a high purity sampling signal which directly supplied from a PLO. As a remarkable feature, the sampler output is VSI-H compatible. According to the endorsed document VSI-H proposal [*Whitney,* 2000], we have examined LVDS devices and this is the CRL's first VSI-H instrument. In the sampler, a CPU controls VSI attribution lines as well as the other part. As defined in the VSI specification it has a RS232C port and an ether-port which enables remote control. Though the sampler is prepared for full remote controls, they still have LED and LCD display which indicate UTC and status. According to circumstances, it allows operators to direct access functions at the telescope site .

The ADS-1000 is manufactured by the DigitalLink Co.Ltd. and the Venetex corporation. They are venture companies which distinguished by the advanced digital technology.

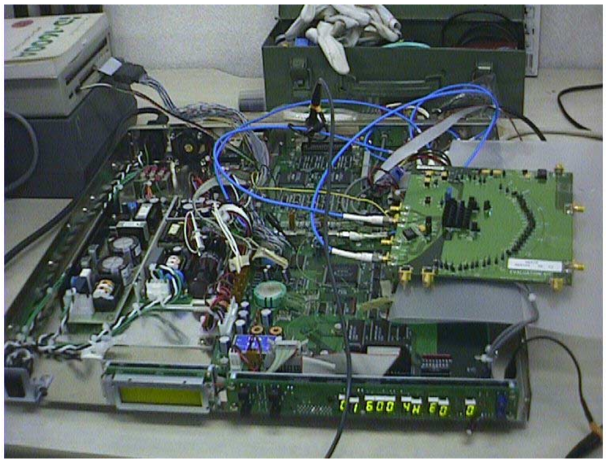

Figure 1. ADS-1000, the new compact VSI Gbps sampler under test.

Reference

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Development of VSI-based S2-K4 copying system and data sampler

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1. Introduction

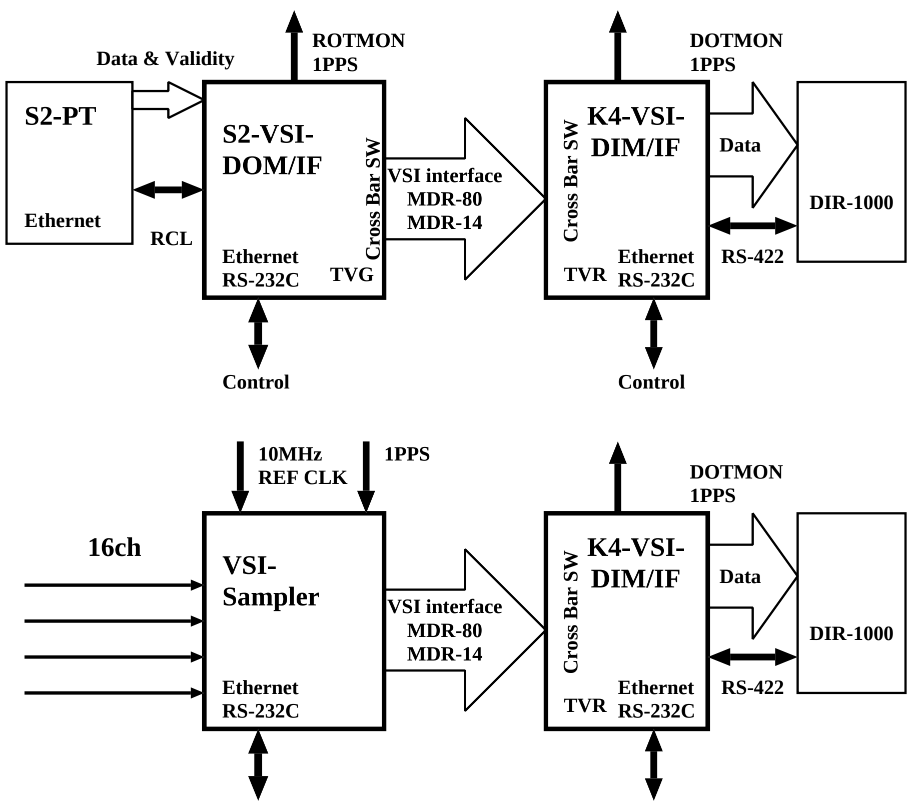
CRL VLBI group have started discussion to develop VSI-based S2-K4 copying system and VSI-based K4 data acquisition system (DAS). One of the motivations was the request of S2-K4 data copying system. Antarctica VLBI data observed in 1997-1999 [*Jike et al.,* 2000] and Pulsar VLBI observation data [*Sekido,* 2000] are recorded in S2 system. These data are desired to be correlated with K4-type (K4, KSP) correlators because of easiness of geodetic analysis. Also S2-K4 copier will expand the ability of organizing VLBI network observation. The data copier between S2 and VSOP-K4 has developed by the NAO, but its time code system is difference from conventional K4 type-1,2. Then those data cannot be correlated with K4 type correlators.

The second reason was that the VSI-H (VLBI Standard Interface Hardware Specification) was defined in August 2000 [*Whitney,* 2000] and adaption to the specification is encouraged for future developing equipment.

The third point was the production of DFC-2100 system, which is K4 data formatter, has discontinued. Then alternative K4-DAS is desired for further extension of VLBI observation network. Actually there was a proposal from the IVS to perform a part of CORE observations with K4 system.

2. Application of VSI-H to current VLBI system

As the solution of these conditions, VSI-



based

Figure 1. Plan of VSI-based S2-K4 copying system and K4-DAS. Upper drawing shows S2-K4 data copying system and lower one is VSI-based alternative K4 data acquisition system.

Table 1. K4-VSI-DIM data modes. The modes are indicated by S2 like expression.

Clock / ch	Mode
64MHz	64x4-1, 64x4-2
32MHz	32x4-1, 32x4-2, 32x8-1
16MHz	16x16-1, 16x8-1, 16x8-2, 16x4-1, 16x4-2, 16x2-1
8MHz	8x8-1, 8x8-2, 8x16-1, 8x16-2
4MHz	4x16-1, 4x16-2, 4x8-1, 4x8-2

Table 2. A proposal of VSI-S control protcol.

Command	data	Return	Comment
PLAY	–	'OK'/'NG'	Playing back the recording system.
STOP	–	'OK'/'NG'	Stopping the recording system.
REWIND	–	'OK'/'NG'	Rewinding the tape.
FF	–	'OK'/'NG'	Ejecting or unloading the tape.
POSITION_SET	Tape Position	'OK'/'NG'	Positioning tape to the specified position.
POSITION_READ	–	'OK'/'NG'	Getting the current tape Position.
STATUS	–	Status	Getting current status of the VSI equipment.
TIME_READ	–	TIME code	Getting reproduced time of DOM or current time of the DIM.
SYNC	–	'OK'/'NG'	Synchronization of the DOM to reference clock and reference 1PPS.
DELAY_SET	Delay time (μs)	'OK'/'NG'	Setting delay of reproduced 1PPS from reference 1PPS signal.
DELAY_READ	–	Delay time (μs)	Getting current setting of delay time of reproduced 1PPS from reference 1PPS signal.

K4-DAS and S2-K4 copying system was proposed. The S2-K4 copying system is composed by combination of S2-VSI-DOM (S2 VSI Data Output Module) and K-VSI-DIM (K4 VSI Data Input Module). The benefits of the application of VSI specification to those system are as follows: VSI-based S2-K4 copying system will have larger system extension capability than dedicated copying system. Alternative K4-DAS will be composed by combination of simple VSI sampler and K4-VSI-DIM. If other kind of system, such as Mk-III/VI, will adapt the VSI specification, copying capability will be expanded. And wider network observation will be available. Current plan of the VSI-based S2-K4 data copying system and K4-DAS are drown in Figure 1.

3. S2-VIS-DOM

The S2-VSI-DOM is interface to adapt the S2 output to VSI specification. The ECL logic output of S2 is converted to LVDS logic and output through 16 wires of MDR-80 connector. Time code data and recording mode will be transfered through P/Qdata line. Data validity information will be also transfered through Pvalid line. The S2-VSI-DOM is controlled through RS-232C or Ethernet as specified in VSI-H. The S2-VSI-DOM controls S2-PT (S2 Playback Terminal) with the RCL port. At present, this DOM have no function of synchronized playback among the DOMs for correlation processing.

4. K4-VIS-DIM

The K4-VSI-DIM receives VSI data and output K4 specific 8 wires data streams with time stamps. The data recording modes to be supported are listed in table 1. Several modes included in function of the DFC-2100 will be output in the same format with DFC-2100 to keep compatibility with the current K4-DAS.

5. VSI-sampler

VLBI data sampler, which output the VSI-H specified data stream, will have 16 channels of video signal inputs. Each video signal is sampled at maximum sampling rate of 64 Mbps with 2 bit quantisation. The sampler will have RS-232C and Ethernet interface for control from host computer.

6. Control (VSI Software specification)

Table 3. A proposal of protocol in P/Q-data

Content	Format
Time code	TIME=YYYYDDDHHMMSS;
Recording Mode	MODE=AAA; (ex. AAA=32x4-2)

Semicolon ';' will be delimiter.

The VSI-H [*Whitney,* 2000] was established and endorsed by the IVS, although software specification ,which will be VSI-S, have to be defined to make a equipment realize. We wish to propose a base of discussion on VSI-S.

- The VIS-based equipment will communicate with host computer as DTE device when RS-232C is used.
- When Ethernet is used for communication, the VSI equipment will work as server of server-client system by using socket connection. The protocol used in the connection will be UDP/IP or TCP/IP. A port number of the server-client system should be determined.
- Several basic command and status request should be defined as common over different VSI equipment. A proposal of the protocol for control is listed in table 2.
- P/Q-data will be used for information transmission from DAS to DIM, from DOM to DIM, and from DOM to DPS (Data Processing System). The information will be transmitted with ASCII code. Table 3 is a proposal of the protocol.

Comment on this proposal is welcome and we wish to encourage the discussion on VSI-S for completion of the specification of VSI.

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Development of the new real-time VLBI technique using the Internet Protocol †

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Abstract: In 1997, a real-time VLBI system for practical use was developed for the first time in the Key Stone Project (KSP). In this system VLBI data are transmitted in real-time through the high-speed Asynchronous Transfer Mode (ATM) network. As the next step, we started the development of new real-time VLBI system adopting the Internet Protocol (IP) instead of ATM. Because IP technology is already well-generalized, we can expect further spreading of the real-time VLBI technique.

1. Introduction

Communications Research Laboratory has been developing the new real-time VLBI system adopting the Internet Protocol (IP) to real-time data transmission from observation sites to correlation processing site(s). In conventional VLBI observations, signals from a radio star received at two or more antennas are recorded on magnetic tapes, then the tapes are shipped to a processing center, and correlation processing is carried out. In the Key Stone Project (KSP), which is dedicated to monitoring crustal deformation around the Tokyo metropolitan area, a real-time VLBI system for practical use was developed for the first time in the world [*Koyama, et al.,* 1998; *Kiuchi, et al.,* 2000]. Radio signals are converted to digital signals with 256 Mbps data rate and they are transmitted to a correlation center in real time through the high-speed (2.4 Gbps) Asynchronous Transfer Mode (ATM) network instead of recording them on a magnetic tape. At the correlation center a dedicated correlator connected to the ATM network processes the data in real-time. We call this real-time VLBI system "ATM-VLBI" or "VLBI over ATM".

However, network-cost is still expensive and connection sites are still limited, so that the ATM-VLBI is not yet well-generalized. Hence, it has been aimed to develop new real-time VLBI system using IP technology that has already spread widely, to reduce network-cost and to expand connection sites of network. We call this system "IP-VLBI" or "VLBI over IP".

Two kinds of system are under the consideration as a VLBI system applying IP technology for data transmission. One is the substitution of protocol from ATM to IP. In this system, serial high-speed data stream is directly sent by using IP instead of ATM (ATM may be used at the networking physical layer, but we do not care about that). We refer to the system as "High-speed IP-VLBI". Although the data are consisted from several numbers of physical channel data, no channel-distinction is made in the transmission process.

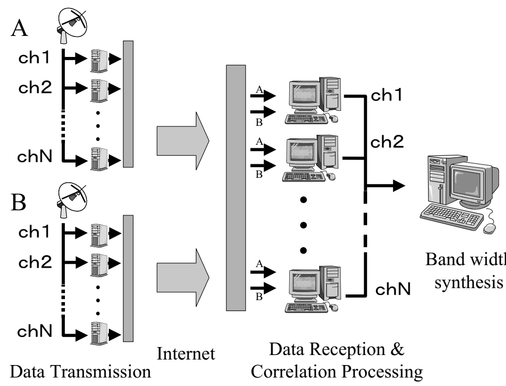

Figure 1. Concept of the multi-channel IP-VLBI system.

The other one is on the basis of channel data. A geodetic VLBI system usually receives 14 to 16 frequency channels at S and X bands. Each channel data are transmitted independently by using the IP. We refer to this system as "Multi-channel IP-VLBI" (Figure 1), because if we can establish the system for one channel, we can easily expand it to multi-channel system. Only the network speed limits the number of channels and sampling frequency. We consider that the latter system is more suitable for geodetic VLBI. In this report, we use the term "IP-VLBI" for representing the latter system. In the mean time, fringe test using data transmitted by FTP has been already realized. We call this

†This manuscript has been submitted to the proceedings of the Journées 2000.

Table 1. Specifications of PCI sampler board.

Reference signals	10MHz +10dBm, 1PPS
Number of input channels	max 4 ch
A/D resolutions	1, 2, 4, 8 bits
Sampling frequencies	40kHz, 100kHz, 200kHz, 1MHz, 2MHz, 4MHz, 8MHz, 16MHz

"FTP-VLBI" distinguished from "IP-VLBI" being developed.

A sampler board for the multi-channel IP-VLBI under the development has a maximum sampling frequency of 16MHz. Various kinds of evaluation of the sampler board have been carried out, and results are reported here.

2. A PCI Sampler Board

A sampler board under the development is a PCI-bus board (Figure 2). Table 1 summarizes specifications. The board has two reference signal inputs (10 MHz and 1 PPS signals) and is designed to have four analog signal inputs. A sampling frequency of from 40 kHz up to 16 MHz is selectable for a 1 bit A/D conversion. In the future an 8-bit A/D conversion will be possible for the general purpose. Video signals output from a VLBI backend are converted to digital signals by the sampler board then time tag generated from the reference 1 PPS signal is inserted into the data stream every second. Thereafter an IP packet is formed and sent out to the Internet. Maximum bandwidth of video frequency signals is 8 MHz because maximum sampling frequency is 16 MHz. It corresponds to the case of the KSP-VLBI system.

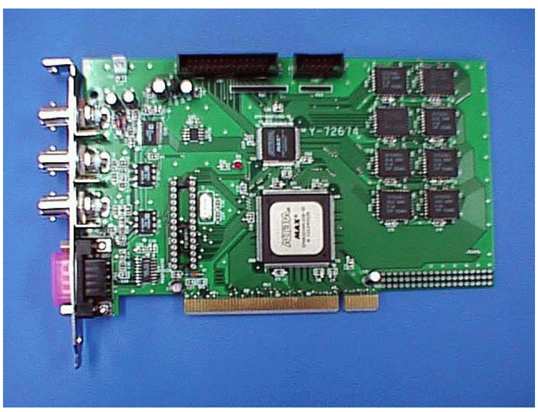

Figure 2. A PCI sampler board for the IP-VLBI system.

3. System Evaluation

To keep coherence of signals, which is an essential for VLBI, signals must be sampled using a very stable frequency standard which must be an external reference signal. Moreover to realize a real-time VLBI, sampled data must be transmitted to correlation center in real-time and must be correlated immediately. Time elapsed for correlation processing must be shorter than observation period. If observation is made for 10 seconds, correlation processing must be finished in less than 10 seconds. Thus items should be satisfied to realize a real-time VLBI system are as follows; 1) coherent sampling, 2) real-time data transmission, and 3) real-time correlation processing. In this report, we have evaluated these items independently.

The "coherent sampling" can be evaluated by cross-correlating two data stream simultaneously sampled by two PCI sampler boards. We first carried out test observations using two antennas at Kashima. Signals from a radio source received by 34 m antenna and 26 m antenna (distance is about 300 m) at Kashima Space Research Center were acquired by two personal computers (PC) equipped with a PCI sampler board (Figure 3). Common

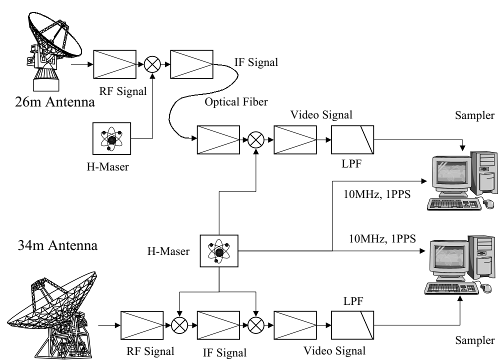

Figure 3. System configuration for a sampler board evaluation.

noise signals were also fed to both PCI boards and sampled. Sampled data were stored in the hard disk in each PC, then they were processed using an off-line program of cross-correlation. Data acquisition was carried out with changing sampling frequency from 40 kHz to 16 MHz. Up to 8 MHz sampling, we could successfully detect a good correlation (fringe) between two data stream. Figure 4 shows fringes of 3C273B detected for 40 kHz sampling data on the Kashima 34m - Kashima 26m baseline for the first time. Fringes detected at 4

MHz sampling are represented in Figure 5. As for 16 MHz sampling, we have not yet succeeded in the detection of correlation. However, we believe that the problem will be settled by improving software that acquires data from a sampler board through the PCI-bus.

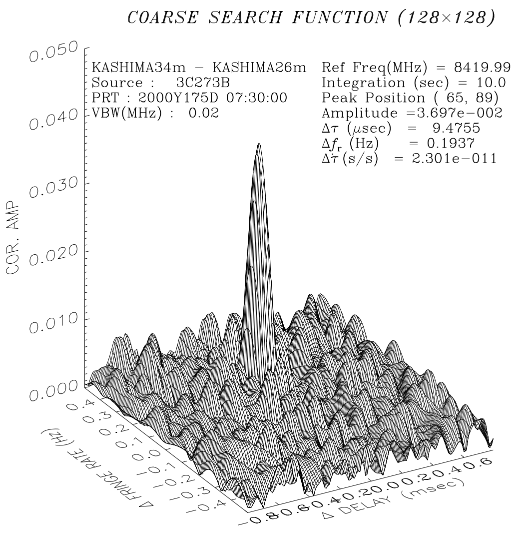

Figure 4. Detected fringes for 40 kHz sampling.

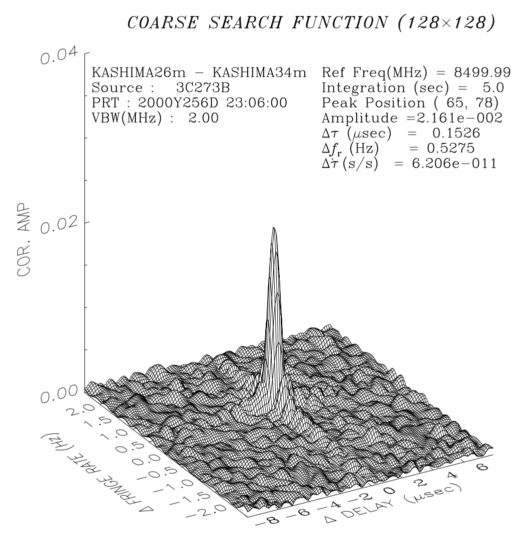

Figure 5. Detected fringes for 4 MHz sampling.

The "real-time data transmission" test through local area network (LAN) has been also carried out. So far 16 MHz sampling data seem to be successfully transmitted through the LAN. However, since sampled data are inperfect as described, we have not yet detected fringes for 16 MHz sampling data. Up to 8 MHz sampling, we have confirmed a good performance both in the "real-time data transmission" and in the "coherent sampling".

Reagrding the "real-time correlation processing", we are developing a PC program correlating two data streams without any use of dedicated hardware as long as possible. We consider that the software-correlation processing is a key technology to generalize the IP-VLBI whole over the world. The correlation program used for the evaluation of sampler board is written by using the programming language PV-WAVE. Further speedup of the correlation processing is being attempted by improving an algorithm of processing. The latest version of correlation program can process 2 MHz sampling data in real-time when it runs on the Windows 98 with the Pentium III 1GHz processor. We are confident that further speedup will become possible soon.

4. Conclusions

The PCI sampler board under the development for the IP-VLBI has been evaluated by using signals from radio sources. Real-time characteristics have been evaluated using the LAN at Kashima Space Research Center. As a result, we confirmed the sufficient performance of "coherent sampling" up to 8 MHz sampling. We could not evaluate the performance of 16 MHz sampling due to problems still remaining in the software which interfaces the board and PCI-bus. However we have a prospect to solve the problems. Regarding the "real-time correlation processing" by using PC, we can process 2 MHz sampling data in real-time at present time. An improvement on algorithm to make correlation processing faster is in progress.

Lastly, we would like to thank Y. Fukuzaki of Geographical Survey Institute for approving the use of 26m antenna at Kashima for this technical development.

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Approved upgrade of the Gbit VLBI system expansion

(News Flash: 22th, November, 2000)

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The operation results of a current Gbit VLBI system were satisfactory and reported to several papers [*Koyama et al.*, 2000; *Nakajima et al.*, 2000a] recently. Both geodetic and astronomical results are improving gradually. We were admitted to develop an enhanced Gbit VLBI system by a budget this time. Moreover, the importance of the parallel data transmission is recognized again in the VSI(VLBI Standard Interface), while IT technology promoted high-speed serial transmission by IP. All the VLBI instruments in the Gbps system will be adapted to the VSI interfaces. The application of the VSI interface to a wide scientific field was also encouraged by the laboratory.

Preliminary plan of the enhanced Gbit VLBI system is shown in Figure 1. Upgraded Gbit data recorders are introduced and new Gbit samplers, ADS-1000 [*Nakajima et al.*, 2000b], are disposed to each station. Number of the Gbit recorders are doubled and this will increase Gbps observation site. As well as former Japanese cassette system, a robot tape exchanger is being designed for automatic observation.

While the experimental correlator UWBC-GICO will continue its operation, a new multi-baseline Gbit correlator which equipped VSI-H ports will start operation. The correlator system of the CRL-TDC is promised to open the other VLBI groups and new countries. Technical supports and VSI related supplies are planned. Detailed information of the system and development status will be reported in a forthcoming CRL-TDC news.

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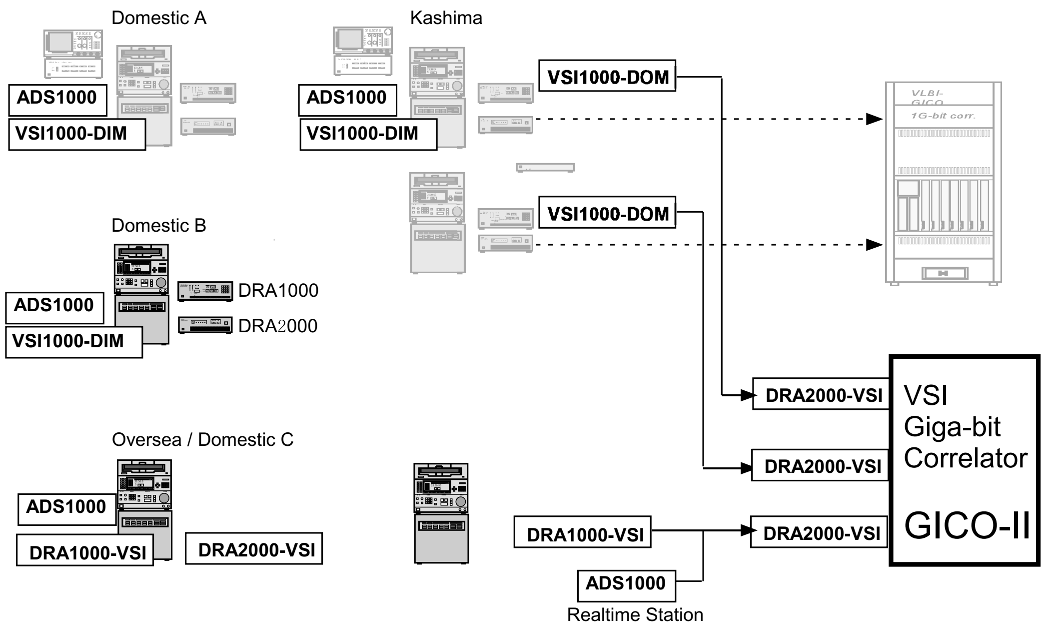

Figure 1. Proposed Gbit VLBI system enhancement for the global baseline.

- News - News - News - News -

Well-known Japanese TV heroes, Time Rangers, came to Kashima

reported by Hiro Osaki (osaki_staff@crl.go.jp)

"Freeze! Londarz get KSRC under control!"

Time is money in modern context. By managing time we can not only save our money, we can also earn that. In the future space-time may be money as well. As far as modern scientists know the order of space-time is not disturbed by any incident occurring in the future. However, if the science of space-time were to be developed amazingly, people in the future could tinker the space-time itself. What will happen then? Some villains in the future may hijack the space-time in order to make money......

It was a thrilling experience to all scientists and support staff in Kashima Space Research Center (KSRC). On the morning of Nov. 11 2000 AD a group of villains "Londarz" (named after money "launders"?) invaded KSRC and brought several facilities of KSRC under their control. They were brutal criminals came from the 30th Century with a time machine. Gate, one of the criminals, was suspected to lead the case.

Although the motive of the crime is not certain, the thugs presumably intended to use Kashima 34m parabola, an important observing facility of the Space-Time measuring project, in order to disarrange the order of space-time.

To the readers' relief Gate was arrested, shrunk, frozen, and sent back to the 30th Century by "Time Rangers"; KSRC was eventually released and space-time order was saved. The heroes were dispatched from "Time Savers program" established in 3000 AD to maintain the order of space-time.

IMPORTANT ANNOUNCEMENT

Key Stone Project will last one more year

In February this year, we made a decision to terminate the Key Stone Project at the end of March in 2001 (CRL-TDC News No.16, June, 2000).

However, extraordinary crustal deformation started since early July at the Keystone network due to the volcanic activities south of Tokyo (see Figure 1 on page 11). Then, CRL is asked to continue the observation of this event.

Finally, **we decided to extend the term of the Keystone observation for one year with three stations (Koganei, Kashima and Tateyama) to observe the specific event including the after-effect.** We hope the valuable data from the Keystone will be exploited so that the extension of the project may be meaningful. All these data is freely available. Your participation is welcome.

Inquires on this matter should be sent to ksp-master@ksp.crl.go.jp.

"IVS CRL Technology Development Center News" (IVS CRL-TDC News) published by the Communications Research Laboratory (CRL) is the continuation of "International Earth Rotation Service - VLBI Technical Development Center News" (IERS TDC News) published by CRL. In accordance with the establishment of the International VLBI Service (IVS) for Geodesy and Astrometry on March 1, 1999, the function of the IERS VLBI technical development center was taken over by that of the IVS technology development center, and the name of center was changed from "Technical Development Center" to "Technology Development Center".

VLBI Technology Development Center (TDC) at CRL is supposed

1) to develop new observation techniques and new systems for advanced Earth's rotation observations by VLBI and other space techniques,
2) to promote research in Earth rotation using VLBI,
3) to distribute new VLBI technology,
4) to contribute the standardization of VLBI interface, and
5) to deploy the real-time VLBI technique.

The CRL 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 CRL TDC newsletter (IVS CRL-TDC News) is published biannually by CRL.

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. Inquires on this issue should be addressed to T. Kondo, Kashima Space Research Center, Communications Research Laboratory, 893-1 Hirai, Kashima, Ibaraki 314-0012, Japan, TEL : +81-299-84-7137, FAX : +81-299-84-7159, e-mail : kondo@crl.go.jp.

Summaries of VLBI and related activities at the Communications Research Laboratory are on the World Wide Web (WWW). The URL to view the home page of the Radio Astronomy Applications Section of the Kashima Space Research Center is : **"http://www.crl.go.jp/ka/radioastro/"**. The URL to view the Keystone project's activity is **"http://ksp.crl.go.jp/"**.

IVS CRL TECHNOLOGY DEVELOPMENT CENTER NEWS No.17, November 2000

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