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International VLBI Service for Geodesy and Astrometry

2006 Annual Report

Edited by
D. Behrend and K.D. Baver

IVS Coordinating Center
April 2007

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Preface

This volume of reports is the 2006 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the permanent components of IVS.

The IVS 2006 Annual Report documents the work of the IVS components for the calendar year 2006, our eighth year of existence. The reports describe changes, activities, and progress of the IVS. Many thanks to all IVS components who contributed to this Annual Report.

With the exception of the first section (described below), the contents of this Annual Report also appear on the IVS web site at

`http://ivscc.gsfc.nasa.gov/publications/ar2006`

This book and the web site are organized as follows:

- The first section contains general information about IVS, a map showing the location of the components, information about the Directing Board members, and the annual report of the IVS Chair.
- The next seven sections hold the reports from the Coordinators and the reports from the IVS Permanent Components: Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers.
- The next section contains a compilation of publications in the field of geodetic and astrometric VLBI during 2006.
- The last section includes reference information about IVS: the Terms of Reference, the lists of Member and Affiliated organizations, the IVS Associate Member list, a complete list of IVS components, the list of institutions that contributed to this report, and a list of acronyms.

Table of Contents

About IVS

IVS Organization

Objectives

IVS is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. The goals are:

1. To provide a service to support geodetic,
2. geophysical and astrometric research and operational activities.
3. To promote research and development activities in all aspects of the geodetic and astrometric VLBI technique.
4. To interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system.

The IVS
- Interacts closely with the IERS, which is tasked by IAU and IUGG with maintaining the international celestial and terrestrial reference frames (ICRF and ITRF),
- coordinates VLBI observing programs,
- sets performance standards for the observing stations,
- establishes conventions for data formats and products,
- issues recommendations for analysis software,
- sets standards for analysis documentation,
- institutes appropriate product delivery methods in order to insure suitable product quality and timeliness.

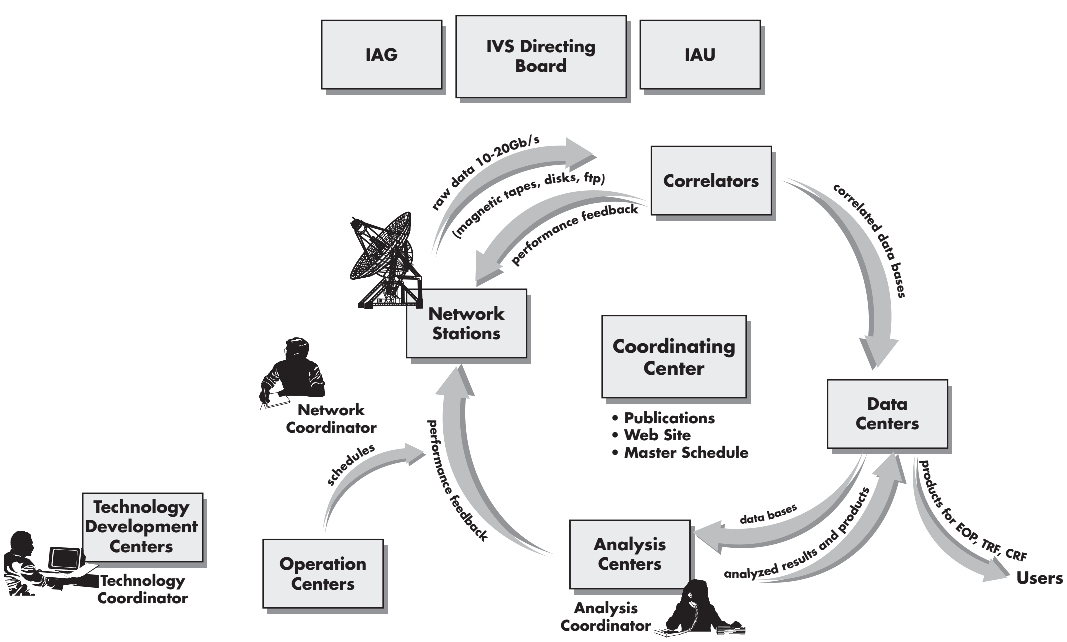
Realization And Status Of IVS

IVS consists of
- 30 Network Stations, acquiring high performance VLBI data,
- 3 Operation Centers, coordinating the activities of a network of Network Stations,
- 6 Correlators, processing the acquired data, providing feedback to the stations and providing processed data to analysts,
- 6 Data Centers, distributing products to users, providing storage and archiving functions,
- 21 Analysis Centers, analyzing the data and producing the results and products,
- 7 Technology Development Centers, developing new VLBI technology,
- 1 Coordinating Center, coordinating daily and long term activities.

Altogether
- 74 Permanent Components, representing 37 institutions in 17 countries,
- ~280 Associate Members.

In addition the IVS has:
- Directing Board, determining policies, standards and goals; the board is composed of 16 members (elected and ex officio), including
- Coordinators for the network, analysis and technology.

ORGANIZATION OF INTERNATIONAL VLBI SERVICE



IVS Member Organizations

The following organizations contribute to IVS by supporting one or more IVS components. They are considered IVS Members. Listed alphabetically by country.

Organization	Country
Geoscience Australia	Australia
University of Tasmania	Australia
Vienna University of Technology	Austria
Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Space Geodynamics Laboratory	Canada
Geodetic Survey Division, Natural Resources Canada	Canada
Dominion Radio Astrophysical Observatory	Canada
Canadian Space Agency	Canada
Universidad de Concepción	Chile
Universidad del Bío Bío	Chile
Instituto Geográphico Militar of Chile	Chile
Chinese Academy of Sciences	China
Observatoire de Paris	France
Observatoire de Bordeaux	France
Deutsches Geodätisches Forschungsinstitut	Germany
Bundesamt für Kartographie und Geodäsie	Germany
Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
Forschungseinrichtung Satellitengeodäsie, TU-Munich	Germany
Istituto di Radioastronomia INAF	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
National Institute of Information and Communications Technology	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Institute of Applied Astronomy	Russia
Pulkovo Observatory	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Instituto Geografico Nacional	Spain
Chalmers University of Technology	Sweden
Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
NASA Goddard Space Flight Center	USA
U. S. Naval Observatory	USA
Jet Propulsion Laboratory	USA

IVS Affiliated Organizations

The following organizations cooperate with IVS on issues of common interest, but do not support an IVS component. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Listed alphabetically by country.

Organization	Country
Australian National University	Australia
University of New Brunswick	Canada
Max-Planck-Institut für Radioastronomie	Germany
FÖMI Satellite Geodetic Observatory	Hungary
Korea Astronomy Observatory	Korea
Joint Institute for VLBI in Europe (JIVE)	Netherlands
Westerbork Observatory	Netherlands
Auckland University of Technology	New Zealand
National Radio Astronomy Observatory	USA

Products

The VLBI technique contributes uniquely to

- Definition and realization of the International Celestial Reference Frame (ICRF)
- Monitoring of Universal Time (UT1) and length of day (LOD)
- Monitoring the coordinates of the celestial pole (nutation and precession)

Further significant products are

- All components of Earth Orientation Parameters at regular intervals
- Station coordinates and velocity vectors for the realization and maintenance of the International Terrestrial Reference Frame (ITRF)

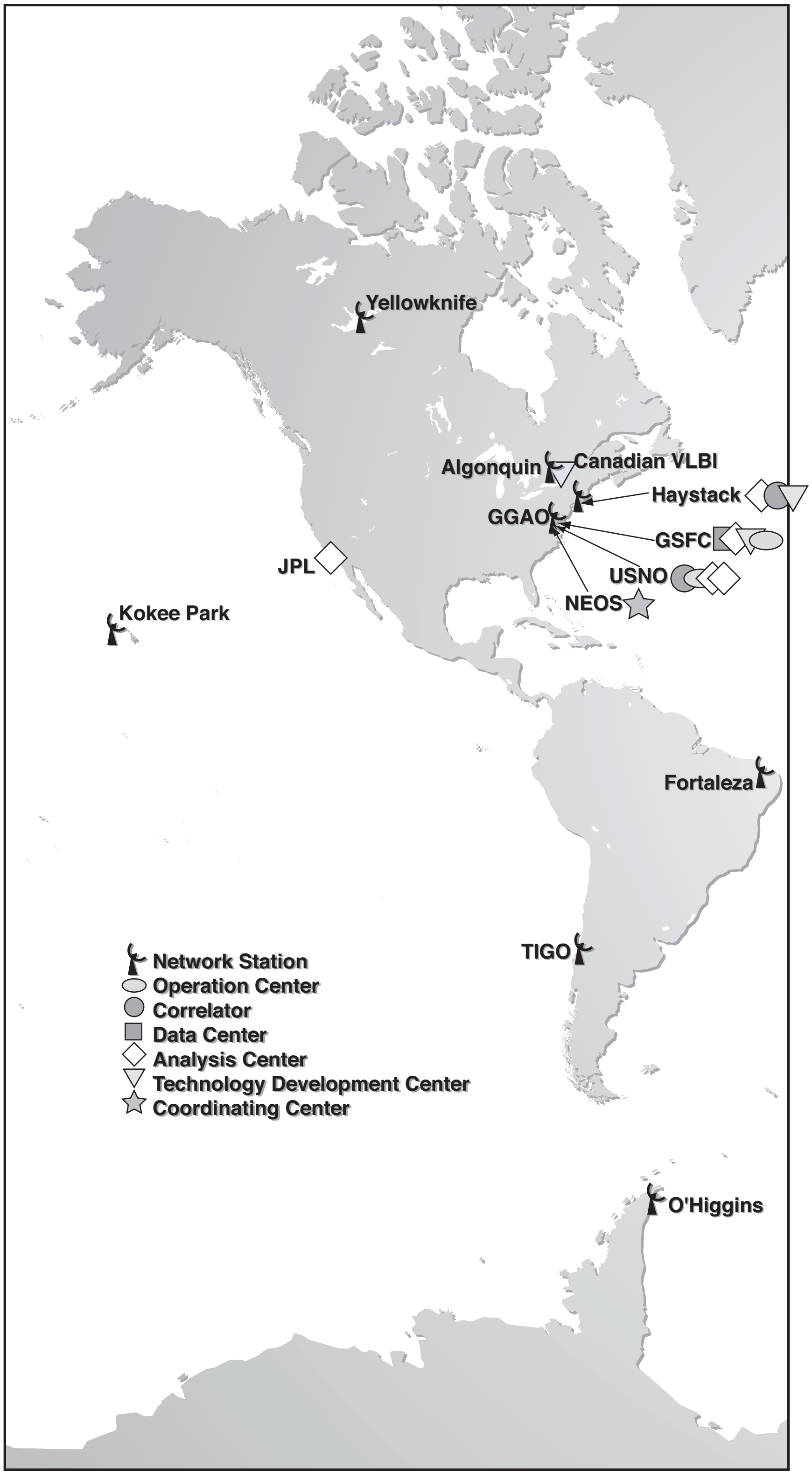
All VLBI data and results in appropriate formats are archived in data centers and publicly available for research in related areas of geodesy, geophysics and astrometry.

IVS Component Map

IVS Components by Country

Country	Qty.
Australia	2
Austria	1
Brazil	1
Canada	3
Chile	1
China	3
France	3
Germany	8
Italy	7
Japan	12
Norway	3
Russia	7
South Africa	1
Spain	1
Sweden	3
Ukraine	2
USA	16
Total	**74**

A complete list of IVS Permanent Components is in the IVS Information section of this volume.




Ny Ålesund
Onsala
FFI
Svetloe
IAA
AIStPbU
GIUB
BKG
FGS(BKG,GIUB)
DGFI
MAO
Wettzell
Paris
TU Vienna
Zelenchukskaya
Bordeaux
Medicina
Simeiz
CNR
Yebes
Matera
Noto
Nanshan
Mizusawa
Tsukuba
Kashima34
Seshan
CRL
Shanghai
Kashima 11
Koganei
Hartebeesthoek
GA
Hobart
Syowa

IVS Directing Board

NAME: Wolfgang Schlüter

AFFILIATION: Bundesamt für Kartographie und Geodäsie, Germany

POSITION: Chair and Networks Representative

TERM: Feb 2003 to Feb 2007

NAME: Ed Himwich

AFFILIATION: NVI, Inc./Goddard Space Flight Center, USA

POSITION: Network Coordinator

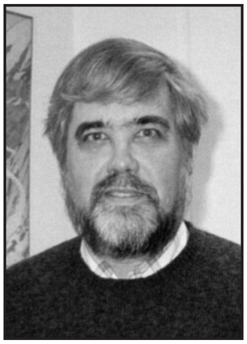
TERM: permanent

NAME: Dirk Behrend

AFFILIATION: NVI, Inc./Goddard Space Flight Center, USA

POSITION: Coordinating Center Director

TERM: ex officio



NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

TERM: Feb 2003 to Feb 2007

NAME: Roy Booth

AFFILIATION: Hartebeesthoek Radio Astronomy Observatory, South Africa, and part-time Onsala Space Observatory, Sweden

POSITION: FAGS Representative

TERM: ex officio

NAME: Yasuhiro Koyama

AFFILIATION: National Institute of Information and Communications Technology, Japan

POSITION: At Large Member

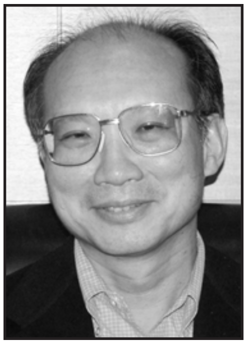
TERM: Feb 2005 to Feb 2007

NAME: Patrick Charlot

AFFILIATION: Bordeaux Observatory, France

POSITION: IAU Representative

TERM: ex officio



NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative

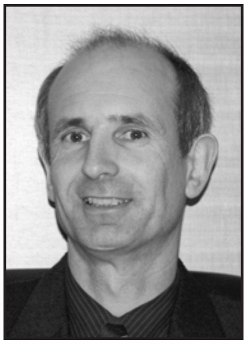
TERM: ex officio

NAME: Zinovy Malkin

AFFILIATION: Institute of Applied Astronomy, Russia

POSITION: At Large Member

TERM: Sept 2005 to Feb 2007



NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent

NAME: Franco Mantovani

AFFILIATION: INAF Bologna, Italy

POSITION: At Large Member

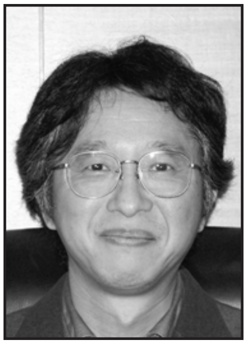
TERM: Sept 2005 to Feb 2007

NAME: William Petrachenko

AFFILIATION: National Resources Canada, Canada

POSITION: Technology Development Centers Representative

TERM: Feb 2005 to Feb 2009



NAME: Shigeru Matsuzaka

AFFILIATION: Geographical Survey Institute, Japan

POSITION: Networks Representative

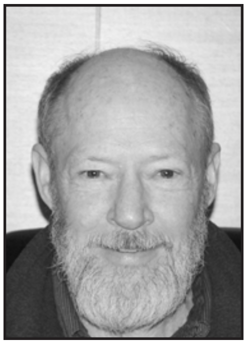
TERM: Feb 2003 to Feb 2007

NAME: Harald Schuh

AFFILIATION: Vienna University of Technology, Austria

POSITION: IAG Representative

TERM: ex officio



NAME: Arthur Niell

AFFILIATION: Haystack Observatory, USA

POSITION: Analysis and Data Centers Representative

TERM: Feb 2005 to Feb 2009

NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

TERM: permanent

IVS Chair's Report

Wolfgang Schlüter,
Bundesamt für Kartographie und Geodäsie

With the 2006 Annual Report the IVS components report about their progress and activities which were conducted during the service's eighth year of existence. I would like to thank the IVS Associate Members for their contributions over the course of the year, in particular for providing their reports in time. Timely appearance of the Annual Report is always an ambitious goal and is highly appreciated for maintaining this volume as a real information exchange tool for the community and related groups. I thank the editors for the timely release.

Extraordinary Events in 2006

In 2006, IVS had to face two events that had an impact on the service products. First, Gilmore Creek discontinued its VLBI observations in January 2006 and the telescope, located in Fairbanks, Alaska, was mothballed for an undefined period of time. The second event was the cessation of the Canadian VLBI operations by NRCan in October 2006. The VLBI network today is not robust enough to compensate for such events without degradation of the final products. Various reasons, in particular the costs for required upgrades of the worn out network stations, have contributed to the termination of the observations at these stations. Due to their location on the North American continent, these stations have been of extreme importance to the IVS and, accordingly, their contribution to the IVS observing program was strong. Nevertheless, the Coordinating Center and the Observing Program Committee had to accept the facts and were able to minimize the influence on the product quality. Thanks to the fact that other network stations, in particular the new Russian network station Zelenchukskaya, compensated for the loss by providing more observation time, the products could be kept at an appropriate quality. We regret the withdrawals, but we have to respect the decisions and express our gratitude that the stations supported the IVS observing program for so many years. We strongly encourage the responsible agencies to consider replacement antennas within our new program VLBI2010 within the next years.

I was very pleased to see the solidarity to the IVS from the IAG, from its companion services IERS, ILRS, IGS, and IDS, and from several VLBI friends, who all sent letters of concern and raised their voice of protest against the cessation of the VLBI operations by NRCan. Unfortunately, we could not change the decision. I feel very sorry for the colleagues, who had to leave our community due to the termination of the VLBI activities. I take this opportunity to express my gratitude to the colleagues from Gilmore Creek, Algonquin Park and Yellowknife for all what they have done for IVS.

It has to be stressed that VLBI currently plays a unique and fundamental role in the realization of the global reference frames, in particular of the Celestial Reference Frame, and in the provision of the complete set of Earth Orientation Parameters. VLBI uniquely provides DUT1, a parameter required for the transformation between ITRF and ICRF. Its knowledge is a prerequisite for all space missions. IVS has been given the responsibility, but it has to rely on the contributions from the agencies and institutions that form the basis of IVS. Today there is no other institution capable to provide these particular parameters other than IVS. We, as the IVS Associated Members, are aware of the responsibility to society and we should never become tired of explaining the importance of our technique, even if (or especially because) the facts are not obvious to everybody outside of our community.

One has to highly appreciate that Geoscience Australia (GA), Australia; Auckland University of Technology (AUT), New Zealand; Korea Astronomy & Space Science Institute (KASI) and National Geographic Information Institute (NGII), Korea; and the Bundesamt für Kartographie und Geodäsie (BKG), Germany started activities to implement new telescopes to support the vision of VLBI2010. I would like to congratulate them on the ambitious projects and wish them success for the realization in the next years.

In January 2006, we held our fourth General Meeting in Concepción, Chile. In conjunction with the General Meeting, an Analysis Workshop and the 15th Directing Board Meeting were organized. The Proceedings have been published, demonstrating the success of the meeting. I would like to thank Dirk Behrend and the Local Organizing Committee, whose members were Hayo Hase, Oscar Cifuentes and Jenny Neumann, for the excellent organization. I thank Rector Professor Lavanchy of the University of Concepción for providing the meeting facilities and for the hospitality we received from the Chilean authorities and people.

In September 2006, an e-VLBI Workshop, a face-to-face meeting of the VLBI2010 Committee and the 16th Directing Board Meeting were held at the Haystack Observatory.

Thanks to Arthur Niell, Alan Whitney and Heidi Johnson, who were responsible for the organization, we had a very successful meeting. I express my thanks for hosting the meeting and for the received hospitality.

Summary information about all IVS events and activities is available in the Newsletters 14, 15, and 16. The Newsletter is an excellent means to transfer information to everybody. The editor team, Dirk Behrend, Hayo Hase, and Heidi Johnson, presented interesting and up-to-date information. They once again did an excellent job, which is highly appreciated.

Changes in the Directing Board in 2006

The International Astronomical Union (IAU) nominated its representative for a three-year term. Patrick Wallace, UK, whose term was from 2004 to 2006, was replaced by Patrick Charlot, France. The elections of the two Networks Representatives as well as of the Correlators and Operations Centers Representative for the term 2007 to 2011 were held in December 2006. The elections were carried out by the Election Committee consisting of Alan Whitney (chair), Dirk Behrend, and Harald Schuh. Prior to the elections, the list of Associate Members, who have the right to vote, was updated by the Coordinating Center in order to have an up-to-date member list. The terms for the two Networks Representatives Wolfgang Schlüter, Germany and Shigeru Matsuzaka, Japan ended in February 2007; their re-election was not possible following the Terms of Reference. The term for Kerry Kingham also expired in February 2007, but he was eligible for re-election. Hayo Hase, BKG-Germany (currently with TIGO in Chile) and Yoshihiro Fukuzaki, Japan were elected as the new Representatives for the Networks, and Kerry Kingham, USA was elected as the Representative for the Correlators and Operation Centers. The terms of the At Large members Yasuhiro Koyama, Japan; Franco Mantovani, Italy; and Zinovy Malkin, Russia ended as well; Koyama-san was not eligible for re-election. For the at large positions (term 2007 to 2009), Andrey Finkelstein, Russia; Oleg Titov, Australia; and Xiuzhong Zhang, China were elected by the Directing Board in January 2007.

I would like to express my gratitude to Shigeru Matsuzaka, Yasuhiro Koyama, Franco Mantovani, and Zinovy Malkin for their important support and contributions. It was a pleasure to work with them. I congratulate Hayo Hase, Yoshihiro Fukuzaki, Kerry Kingham, Andrey Finkelstein, Oleg Titov, and Xiuzhong Zhang for being elected and wish them success for their work on the IVS Directing Board. I would like to express my thanks to the Associate Members for voting and to the Election Committee for conducting the elections. I am very pleased that the IVS Directing Board is well balanced in its composition with respect to global coverage, with respect to component representation, and with respect to a good mixture of experienced and young members.

At the 17th Directing Board Meeting, held on February 24, 2007, my term as IVS Chair came to an end. I served two four-year terms spanning the eight years of the existence of the IVS. I would like to take this opportunity to express my sincere gratitude to all of you, who supported VLBI and IVS.

It was a real honor for me to serve as chair and it was very pleasant to collaborate with all of you. I am very grateful that I had the good fortune of collaborating with so many unique people, excellent scientists, engineers and technicians. I would also like to express my sincere gratitude to all the institutions and agencies that support IVS components providing the reliable basis for all our work. During my term as chair I got generous support form the BKG. Without the backing from the BKG and its strong support, I would not have been able to serve IVS as I was able to do. For this support, I thank Dietmar Grünreich, President of BKG. Finally, I congratulate Harald Schuh as the new chair and wish him all the best for a continuous success of the IVS. With Harald Schuh, who has thorough knowledge and experience in VLBI, as chair IVS is in an excellent position to face future challenges.

IVS Coordination

Coordinating Center Report

Dirk Behrend

Abstract

This report summarizes the activities of the IVS Coordinating Center during the year 2006, and forecasts activities planned for the year 2007.

1. Coordinating Center Operation

The IVS Coordinating Center is based at Goddard Space Flight Center and is operated by NEOS (National Earth Orientation Service), a joint effort for VLBI by the U.S. Naval Observatory and NASA Goddard Space Flight Center.

The mission of the Coordinating Center is to provide communications and information for the IVS community and the greater scientific community and to coordinate the day-to-day and long-term activities of IVS.

The web server for the Coordinating Center is provided by Goddard. The address is

`http://ivscc.gsfc.nasa.gov`

2. Activities during 2006

During the period from January through December 2006, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated, with local committees, two IVS Directing Board meetings, in Concepción, Chile (January 2006) and Haystack, MA, USA (September 2006). Notes from each meeting were published on the IVS web site.
- Communications support: Maintained the web pages, e-mail lists, and web-based mail archive files.
- Publications: Published the 2005 Annual Report in spring 2006. Published three editions of the IVS Newsletter in April, August, and December, 2006. Published the Proceedings of the fourth IVS General Meeting in summer 2006. All publications are available electronically as well as in print form.
- 2006 Master Schedule: Generated and maintained the master observing schedule for 2006. Coordinated VLBI resources for observing time, correlator usage, tapes and disk modules. Coordinated the usage of Mark 5 systems at IVS stations and efficient deployment of disk modules.
- 2006 Master Schedule: Generated the proposed master schedule for 2007 and received approval from the Observing Program Committee.
- Meetings: Coordinated, with the Local Committee, the fourth IVS General Meeting, held in Concepción, Chile in January 2006. Chaired the Program Committee for the meeting.
- Observing Program Committee (OPC): Coordinated meetings of the OPC to monitor the observing program, review problems and issues, and discuss changes.

Figure 1. Impression from the opening ceremony of the fourth IVS General Meeting in Concepción, Chile.

3. Staff

The staff of the Coordinating Center is drawn from individuals who work at Goddard. The staff and their responsibilities are:

Name	Title	Responsibilities
Dirk Behrend	Director	Web site and e-mail system maintenance, Directing Board support, meetings, publications, session web pages monitoring
Cynthia Thomas	Operation Manager	Master schedule (current year), resource management and monitoring, meetings and travel support, special sessions
Frank Gomez	Web Manager	Web server administration, mail system maintenance, data center support, session processing scripts, mirror site liaison
Karen Baver	Publication Programmer and Editor	Publication processing programs, Latex support and editorial assistance

4. Plans for 2007

The Coordinating Center plans for 2007 include the following:

- Maintain IVS web site and e-mail system; implement new station pages.
- Publish the 2006 Annual Report (this volume).
- Coordinate, with the local committee, the fourth IVS Technical Operations Workshop to be held at Haystack Observatory, USA in April/May 2007.
- Support Directing Board meetings in 2007.
- Coordinate the 2007 master observing schedule and IVS resources.
- Publish Newsletter issues in April, August, and December.

Analysis Coordinator Report

A. Nothnagel, S. Böckmann, M. Vennebusch

Abstract

IVS analysis coordination issues in 2006 are reported here.

1. General Issues

The "Seventh IVS Analysis Workshop" was held at the Universidad de Concepción in Concepción, Chile, on January 12, 2006, in connection with the IVS 2006 General Meeting. Detailed information on presentations and discussions can be found in [2].

The institute hosting the office of the IVS Analysis Coordinator has been reorganized and was named Institute for Geodesy and Geoinformation of the University of Bonn (IGGB) on October 1, 2006. The relationship between the institute and the IVS is not affected.

2. IVS Operational Data Analysis and Combination

2.1. Terrestrial Reference Frame

A large portion of the work in the year 2006 was devoted to the generation of the IVS input to ITRF2005. For the ITRF2005, the International Earth Rotation and Reference Systems Service (IERS) invited the services of the International Association for Geodesy (IAG), i.e. the International VLBI Service for Geodesy and Astrometry (IVS), the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), and the International DORIS Service (IDS), to submit one consolidated set of input data for their technique. The official contribution of the IVS has been computed by the IVS Analysis Coordinator's office.

In the case of IVS, the IERS asked for individual data sets for each VLBI observing session of 24 hours duration in *Solution INdependent EXchange* (SINEX) format. SINEX files permit the transmission of the full variance/covariance information to interpret the quality of the solution to its full extent or to further combine the results with other solutions. This can be realized through reporting either the full variance/covariance matrix or the normal equation matrix of a solution setup (see latest definition under http://www.iers.org/documents/ac/sinex/sinex_v202.pdf. The latter option is mainly meant for further combinations but, if required, variance/covariance information can easily be extracted through an inversion procedure which may have to include a datum definition if necessary. In order to facilitate combination steps through a procedure which may be completely free of any datum definition, the IVS had decided that IVS Analysis Centers report datum-free normal equation matrices in their SINEX files to the IVS Analysis Coordinator. Consequently, the IVS input to ITRF2005 was also based on datum-free normal equations.

Quite a lot of effort had to be spent on eliminating problems originating from peculiarities of certain sessions which inhibited a combination in a straight forward way. Noteworthy is the fact that the Japanese regional network is linked to the global network of ITRF sites only insufficiently. This situation should be addressed by our Japanese colleagues in future session plannings. Several sites with only very few observing days of the past (1980ies) were eliminated from the station list for ITRF2005.

The final IVS data set was combined from data of Deutsches Geodätisches Forschungsinstitut (DGFI), of Bundesamt für Kartographie und Geodäsie (BKG), of NASA Goddard Space Flight Center (GSFC), of Shanghai Astronomical Observatory (SHAO), and of U.S. Naval Observatory (USNO). Unfortunately, the data of Geoscience Australia (GA) and of Kiev Main Astronomical Observatory (MAO) could not be used due to incompatibility of the data sets. For the next realization of the ITRS, however, we are confident that these difficulties will be overcome. For more details of the generation of the IVS input files to ITRF2005 see [3].

Within the inter-technique combination (VLBI, SLR, GPS and DORIS) extensive discussions on the definition of the scale of ITRF2005 were necessary and are still going on. Owing to its high quality and its long-term stability, only the VLBI input series has finally been used for the determination of the global scale of ITRF2005. ITRF2005 files are available under http://itrf.ensg.ign.fr/ITRF_solutions/2005/ITRF2005.php.

2.2. IVS EOP Series

In parallel to the ITRF2005 investigations, a new combination strategy for the two IVS EOP series (rapid and quarterly solutions) has also been developed. Preparations were made for a change from a combination of EOP on the basis of results to a combination on the basis of datum-free normal equations in SINEX format. The advantage of the new combination strategy is that one common terrestrial reference frame (ITRF2005) is applied after the combined datum-free normal matrix is generated. This helps to avoid that systematic differences caused by different TRF used in the individual contributions enter the combination. Due to the complicated dependency on several observatories participating in the sessions in a variety of configurations, the TRF effect is almost impossible to eliminate from EOP-only solutions afterwards. For testing purposes, the application of an identical TRF to all contributions also allows a better investigation in remaining systematics. The weighted RMS differences between the individual IVS Analysis Centers and the combined products have been reduced from roughly 80 – 100 μas to 50 – 60 μas in all components.

Since January 1st 2007, the new procedure is used for the generation of the official combined IVS EOP series. However, until March 1st 2007, the old IVS EOP series based on EOP time series combinations will be maintained. As for the present IVS combined EOP series based on EOP results, a rapid solution (ivs07r1e.eops) and a quarterly solution (ivs07q1e.eops) is generated also for the new IVS EOP series. SINEX files of five IVS Analysis Centers (BKG, DGFI, GSFC, SHAO and USNO) are used as input data. The rapid solution contains only R1- and R4-sessions and new data points are added twice a week as soon as the SINEX files of the five IVS Analysis Centers are available. The SINEX file submissions should not be later than 36 hours after the correlation is completed. A web page is automatically updated which states the timeliness of the latest submissions of the R1- and R4-sessions. For the quarterly solution, updated every three months, all available data from 1984 onwards are used.

On the IVS Analysis Coordinator's web page additional information about the series, the residuals of the individual contributions w.r.t. the combined solution as well as comparisons with IGS and IERS EOP results are provided.

3. IVS Pilot Project "Baseline Lengths"

In late 2006, the VLBI group of Agenzia Spaziale Italiana at Matera, Italy, joined the project and has contributed data to the series since then. In September 2006 at its 16th board meeting, the IVS Directing Board decided to turn the Pilot Project into a full product line. Baseline length results are now often used for public relations activities. Especially astronomers and telescope operators like to use the graphs for explaining what else can be done with radio telescopes. For more details see [1].

4. Personnel

Table 1. Personnel at the IVS Analysis Coordinator's office

Sarah Böckmann	++49-228-732623	boeckmann@uni-bonn.de
Axel Nothnagel	++49-228-733574	nothnagel@uni-bonn.de
Markus Vennebusch	++49-228-733565	vennebusch@uni-bonn.de

References

[1] IGGB, Bonn (2006): IVS Product "Baseline Lengths", Results available online at http://vlbi.geod.uni-bonn.de/baseline-project/index.php

[2] Nothnagel A. (2006) *Summary of the 7th IVS Analysis Workshop*; International VLBI Service for Geodesy and Astrometry; General Meeting Proceedings 2006, D. Behrend and K.D. Baver (eds.), NASA/CP-2006-214140, Greenbelt MD, p. 373 - 376

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Network Coordinator Report

Ed Himwich

Abstract

This report includes an assessment of the network performance in terms lost observing time for the 2006 calendar year. Overall, the observing time loss was about 13.6%. A table of relative incidence of problems with various subsystems is presented. The most significant causes of loss were receiver problems (accounting for about 20.8%), antenna reliability (19.0%), miscellaneous problems (18.0%), rack problems (16.3%), and RFI (11.6%). The Canadian participation in IVS observing ended in 2006. There are prospects for Korea, India, and New Zealand to start contributing to IVS. New antennas are being purchased by Australia and New Zealand. The current situation for the handling of correlator clock adjustments by the correlators is reviewed. The situation is found generally to have greatly improved compared to previous years. The handling of these adjustments directly impact the UT1-UTC estimates from VLBI data.

1. Network Performance

The network performance report is based on correlator reports for experiments in calendar year 2006. This report includes the 145 24-hour experiments that had detailed correlator reports available as of February 23, 2007. Results for 42 experiments were omitted because either they were correlated at the VLBA, have not been correlated yet, or correlation reports were not available on the IVS data centers. Experiments processed at the VLBA correlator were omitted because the information provided is not as detailed as from Mark IV correlators. The experiments that have not been correlated yet include mostly RD, JD, and T2 experiments from the second half of the year, as well as some OHIG experiments. The experiments without reports on the IVS data centers include mostly E3 experiments processed by the Penticton correlator. In summary, roughly 80% of the scheduled experiments for 2006 are included in this report.

An important point to understand is that in this report the network performance is expressed in terms of lost observing time. This is straightforward in cases where the loss occurred because operations were interrupted or missed. However, in other cases, it is more complicated to calculate. To handle this, a non-observing time loss is typically converted into an equivalent lost observing time by expressing it as an approximate equivalent number of recorded bits lost. As an example, a warm receiver will greatly reduce the sensitivity of a telescope. The resulting performance will be in some sense equivalent to the station having a cold receiver but observing for (typically) only one-third of the nominal time and therefore only recording one-third of the expected bits. In a similar fashion, poor pointing can be converted into an equivalent lost sensitivity and then equivalent lost bits. Poor recordings can be simply expressed as the fraction of total recorded bits lost.

Using correlator reports, an attempt was made to determine how much observing time was lost at each station and why. This was not always straightforward to do. Sometimes the correlator notes do not indicate that a station had a particular problem while the quality code summary indicates a significant loss. Reconstructing which station or stations had problems and why in these circumstances, does not always yield accurate results. Another problem was that it is hard to determine how much RFI affected the data unless one or more channels were removed and that eliminated the problem. For individual station days, the results should probably not be assumed to be accurate at better than the 5% level.

The results here should not be viewed as an absolute evaluation for the quality of each station's performance. As mentioned above the results themselves are only approximate. In addition, some problems are beyond the control of the station, such as weather and power failures. Instead the results should be viewed in aggregate as an overall evaluation of how much of the data the network is collecting as a whole. Development of the overall result is organized around individual station performance, but the results for individual stations do not necessarily reflect the quality of operations at that station.

Since stations typically observe with more than one other station at a time, the average lost observing time per station is not equal to the overall average loss of VLBI data. Under some simplifying assumptions, the average loss of VLBI data is roughly about twice the average loss of observing time. This approximation is described in the Network Coordinator's section of the 2001 IVS Annual Report.

For the 145 experiments from 2005 examined here, there are 935 station days or about 6.4 stations per experiment on average. Of these experiment days about 13.6% (or about 127 days) of the observing time was lost. For comparison to earlier years, see Table 1.

Table 1. Lost Observing Time

Year	**Percentage**
1999-2000*	11.8
2001	11.6
2002	12.2
2003	14.4
2004	12.5
2005	14.4
2006	13.6

* The percentage applies to a subset of the 1999-2000 experiments.

The lost observing time for 2006 was slightly less than for 2005. It is not clear whether the year-to-year variations in lost observing time reflect real changes in the performance level or simply variations due to inaccuracies in the analysis method. It does seem, however, that despite the approximations in the analysis method, the calculated observing time loss has been running fairly consistently at the 12-14% level for several years. It should be noted that the CONT05 experiments in 2005, where a special effort was made to achieve high reliability at some of the most reliable stations in the network, an observing time loss of only 4.0% was achieved. If these observing time losses are converted into VLBI data yield losses, then 2006 had about 27% VLBI data loss, 2005 about 29% VLBI data loss, 2004 about 25%, and 2003 about 29%.

An assessment of each station's performance is not provided in this report. While this was done in some previous years, this practice seems to be counter-productive. Although many caveats were provided to discourage people from assigning too much significance to the results, there was feedback that suggested that the results were being over-interpreted. Some stations reported that their funding could be placed in jeopardy if their performance appeared bad even if it was for reasons beyond their control. Last and least, there seemed to be some interest in attempting to "game" the system to improve the individual results. Consequently, only summary results are presented here.

For the purposes of this report, the stations were divided into two categories: (A) those that were included in 16 or more network experiments among those analyzed here, and (B) those in 9 or fewer. Half of the stations in the former category had been included in more than 50 experiments. The distinction between these two groups was made on the assumption that the results would be more meaningful for the stations with more experiments.

There are 16 stations in the 20-or-more experiment category. Of these, six successfully collected data for approximately 90% of their expected observing time. Five more stations collected 80% or more. Four more stations collected 65% or more. One station in this group collected only slightly more than 50% of its schedule data. These statistics are somewhat worse than last year. They are balanced by the fact that the stations with fewer experiments were more successful in collecting data this year. The average data loss from both groups this year were about equal, rather than the station with more experiments being significantly more successful.

There are 20 stations in the 9-or-fewer experiment category. The range of lost observing time for stations in this category was 0%-35%. The median success rate was about 6.5%. Overall the stations in this category lost about 13% of the 80 station days (about 9% of the total analyzed) that fall in this category. It is notable that the performance for the stations that were in the fewest experiments was better than last year (41%).

Although the results are not being reported for individual stations, a few stations deserve special recognition for how much their data collection improved from the previous year. Four stations improved the percentage of data they collected by more than 5%. These stations are TIGO, Zelenchukskaya, Svetloe, and Medicina.

The losses were also analyzed by sub-system for each station. Individual stations can contact the network coordinator (weh@ivscc.gsfc.nasa.gov) for the break-down for their individual station. A summary of the losses by sub-system (category) for the entire network is presented in Table 2. This table includes four years of data sorted by descreasing loss in 2006.

Table 2. Percentage Data Lost by Sub-system

Sub-System	**2006**	**2005**	**2004**	**2003**
Receiver	20.8	24.2	18.0	25.2
Antenna	19.0	24.4	32.9	17.8
Miscellaneous	18.0	8.0	8.0	6.0
Rack	16.3	5.1	6.8	5.0
RFI	11.6	6.2	5.0	9.3
Clock	4.9	14.5	0.5	3.4
Unknown	4.0	3.3	10.1	12.6
Recorder	3.3	8.9	11.1	10.9
Operations	2.0	4.7	6.1	3.6
Software	0.1	0.5	0.1	0.1
Shipping	0.0	0.2	1.4	6.1

The categories in Table 2 are rather broad and require some explanation, which is given below.

Antenna This category includes all antenna problems including mis-pointing, antenna control computer failures, and mechanical break-downs of the antenna.

Clock This category includes situations where correlation was impossible because either the clock offset was not provided or was wrong leading to no fringes. Maser and coherence problems that could be attributed to the maser were also included in this category. Phase instabilities reported for Kokee were included in this category.

Miscellaneous This category includes several small problems that do not fit into other categories, mostly problems beyond the control of the stations such as power, weather, and errors in the observing schedule provided by the Operation Centers. As of the 2006 report, this category also includes errors due to tape operations at the stations that were forced to use tape because either they didn't have a disk recording system or did not have enough media. This category is dominated by power and weather issues.

Operations This category includes all operational errors, such as DRUDG-ing the wrong schedule, starting late because of shift problems, operator (as opposed to equipment) problems changing recording media and others.

Rack This category includes all failures that could be attributed to the rack (DAS) including the formatter and BBCs.

Receiver This category includes all problems related to the receiver including out-right failure, loss of sensitivity because the cryogenics failed, design problems that impact the sensitivity, and loss of coherence that was due to LO problems. In addition, for lack of a clearly more accurate choice, loss of sensitivity due to upper X band Tsys and roll-off problems were assigned to this category.

Recorder This category includes problems associated with disk recording systems and network transfer of data. As of the 2006 report, no problems associated with tape operations are included in this category.

RFI This category includes all losses directly attributable to interference including all cases or amplitude variations in individual channels, particularly at S-band.

Shipping This category includes data that could not be correlated because the media were either lost in shipping or held up in customs long enough that it could not be correlated with the rest of the experiment data. There were no such instances this year.

Software This category includes all instances of software problems causing data to be lost. This includes crashes of the Field System, crashes of the local station software, and errors in files generated by DRUDG.

Unknown This category is a special category for cases where the correlator did not state the cause of the loss and it was not possible to determine the cause with a reasonable amount of effort.

From the results it can be seen that antenna and receiver together account for almost 40% of the losses. This is down slightly from previous years. For 2006 the stations with significant antenna problems include Zelenchukskaya, Svetloe, Algonquin, and Westford. In particular, the antenna problems at Algonquin were so severe that the need for expensive repairs appears to have helped precipitate the decision by the Canadian government to terminate their country's VLBI operations.

Stations with significant receiver problems include Matera, Zelenchukskaya, Ny-Ålesund, Fortaleza, and Medicina. Most of these problems are in the category of reliability problems with the cryogenics, power supplies, and amplifiers. Losses due to receiver cryogenic problems were significantly reduced this year compared to previous years. For some stations, Fortaleza in particular, the most significant issue is the roll-off in the X-band bandpass, which has been included in this category.

The "Miscellaneous" category is significantly larger than for previous years. This is primarily due to power outages, primarily at Algonquin, weather problems, at HartRAO and Hobart primarily, and a security issue at Tsukuba. There was also a bureaucratic problem that prevented Matera from observing for the first few weeks of the year.

The "Rack" category was larger this year primarily due to the fact that Seshan observed with only eight BBCs. However, there were some Mark IV formatter failures, as well as a lack of availability of the correct filters for R1s at Fortaleza.

The "RFI" category is larger this year than last, possibly due to more uniformity in attributing amplitude fluctuations to this cause as well as the fact that Matera, the station with the most severe RFI problems, was able to observe more this year because their antenna was working more reliably.

The "Clock" category represents less loss than last year. This is primarily because the long term failures of the Masers that occurred in 2005 were not repeated. However, loss of coherence at other stations (Kokee in particular) were included in this category and contributed to the increase over 2003 and 2004.

The "Recorder" category is down significantly from previous years primarily because almost all recording is done on disk and the problems with the few tape recordings that were made are reported now in the "Miscellaneous" category. The decrease in data loss due to recorder operations of about 11% to about 3% probably represents the "disk dividend" we have been hoping to get as tape use is curtailed.

2. Closure of Canadian Stations

The Canadian government stopped all VLBI operations. This was apparently a cost-cutting move. This appears to have been precipitated by the need for a costly repair to the antenna at Algonquin.

3. New Stations

The station at Badary, Russia should start observing in 2007. There are prospects for new stations on several fronts. Both Australia and New Zealand are in the process of obtaining new antennas, two and one, respectively. Korea is planning to build one antenna primarily for geodesy. There is also interest in using the Korean VLBI Network (KVN), which will consist of three stations intended primarily for astronomy, for geodesy. There is interest in India in building a network of four telescopes that would be useful for geodesy. Many of these antennas may become available for use in the next few years. Efforts are being made so that these antennas will be compatible with VLBI2010.

4. Clock Offsets

As noted in the Network Coordinator's reports for the last few years, it is important to develop consistent procedures for handling the clock offsets during the correlation process. Stations measure the offset between their formatter and the UTC time provided by GPS. The correlators typically apply a small, few μseconds or less, adjustment to the measured offsets in order to align the data to get fringes. If the adjustments are not applied in a consistent fashion by all correlators, a corresponding error will be made in the UT1-UTC parameter adjustments. This will affect the quality of IVS UT1-UTC products at the level of the inconsistency in the adjustments. This could be corrected during the data analysis, but currently no analysis package does this. It would require a significant amount of bookkeeping to add this feature now.

The Network Coordinator's report for 2002 recommended that the correlators develop a consistent table of adjustments for correcting the local measurements of the formatter offsets relative to GPS. This would remove a source of correlator-to-correlator and experiment-to-experiment variability in the UT1-UTC results. It was suggested that in developing this table the applied correction for Kokee should be artificially set to zero (when Kokee uses the VLBA formatter; when they use a Mark IV, the correction should be increased to about 0.4 μseconds). Although not strictly correct, it is a simple approach and will maintain a level of consistency with old data, much of which was processed by WACO with a correction of zero for Kokee. However, the "true" adjustment will have to be compensated for when an effort is made to align the ICRF and ITRF at this level. It was also recommended in the report from 2002 that a reference for the clock rate should be established at the same time.

Significant progress was made in 2005 in implementing these recommendations. The calendar year 2006 is the first one in which this approach was applied to all experiments. The offset adjustment for Wettzell in 2006 is shown in Figure 1. The scatter of these measurements is greatly improved for Mark IV correlators (Bonn, Haystack, and WACO). Generally the variation is at the 0.1 μsecond level, but there are few larger outliers for the Bonn correlator. It is not known if these outliers are due to typographic errors or if the adjustments for these experiments were larger than expected. They should be investigated. In any event, the results are greatly improved compared to previous years where the adjustments were scattered over a range at least 10 times as large.

It is interesting to note that the adjustments used by the GSI (K-5) correlator are biased by about 1 μsecond compared to those used by the Mark IV correlators. If this is correct, it would bias UT1-UTC estimates from GSI correlated experiments compared to Mark IV correlated experiments. As it happens, the GSI correlator is currently used only for "K" type Intensives and domestic Japanese 24-hour experiments. The UT1-UTC precision of these experiments is much less than that of the 24-hour international experiments, around 10-20 μseconds for the "K" type Intensives compared to a few μseconds for R1 and R4 experiments. Consequently, this bias does not significantly impact the results. It has recently been realized that the K-5 correlator does not include the effect of the clock offset and rate in its calculation of the time-tags and delays that it produces [Y. Koyama (NICT), personal communication]. Thus the quality of the correlator clock model is not currently impacting the UT1 results for the K-5 correlator. This will be corrected in the future.

A further issue is how stable the UT1 rate measurements are. This depends on the accuracy of the correlator models for the Maser (and associated station electronics) rates for the observing stations. The desired accuracy of the IVS Working Group 2 report was for 0.3-0.5 μseconds/day.

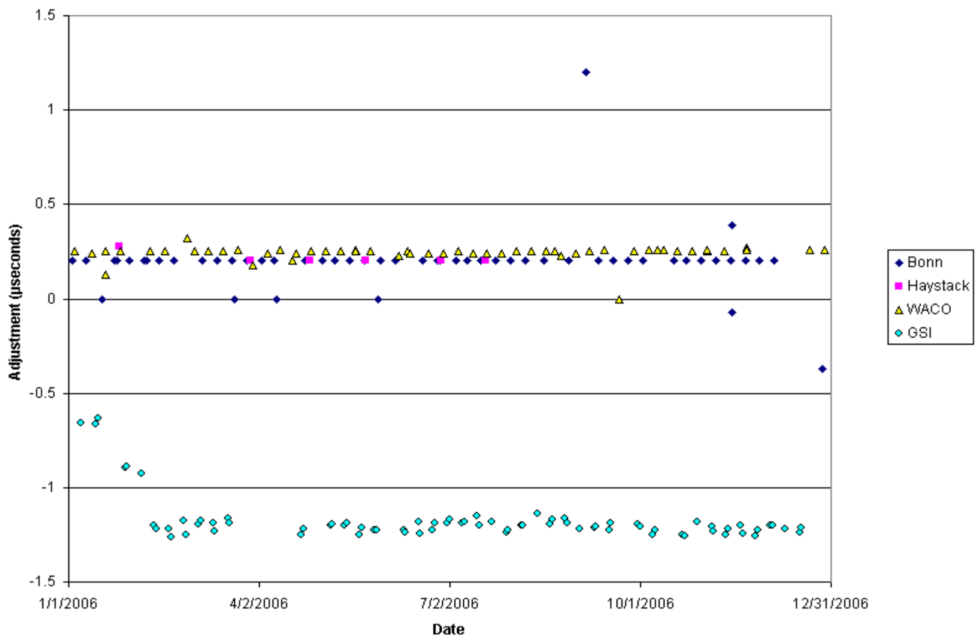


Figure 1. Wettzell Correlator UTC Clock Adjustments

This translates into a clock rate of about 3.5e-12 to 5.8e-12. It would be desirable to have the correlator clock models consistent at a level 10% of that, 3e-13, or better. It turns out that it is possible to determine the station rates at about the level required from the formatter offset values recorded during 24-hour experiments.

A plot of the Correlator Clock Rate Model for Wettzell for 2006 using this approach is shown in Figure 2. It is difficult to see on the scale of the plot, but the clock rates used by the Mark IV correlators (Bonn, Haystack, and WACO) vary at about the desired level, about 2.5e-13 (5e-13 peak-to-peak, i.e., simplifying by saying the peak-to-peak is about twice the RMS). This is about good enough and is an improvement of a factor two over last year. The rates for Wettzell used by the GSI correlator vary by about 1.4e-11 (peak-to-peak). These exceed the desired level by a factor of about 30. As with UT1-UTC estimates for GSI, this is probably not an issue given the lower precision of the experiments processed by this correlator. However, this should probably be improved. The reason for the scatter in the rates used by the GSI correlator is that they are determined from the clock offsets measured during the short span of data collected in the K Intensives [Y. Koyama (NICT), personal communication]. This explains the larger range of the values. The origin of the systematic nature of the rates is not clear, but presumably is related to some systematic effect that is being sampled by the clock offset measurements. As mentioned previously the correlator clock model is not being taken into account in the results of the K-5 correlator. But this is planned for the future.

Another area of concern is that different recording systems may require different adjustments. There is a difference between Mark IV and VLBA formatters of about 0.4 μseconds [K. Kingham (USNO), private communication]. This was accounted for when Kokee changed from using VLBA to Mark IV formatters. A value of 0.26 μseconds was measured between the K-5 and the Mark IV formatters, K5 later than Mark IV [Y. Koyama *et al.*, Timing Offset of the K5/VSSP System,

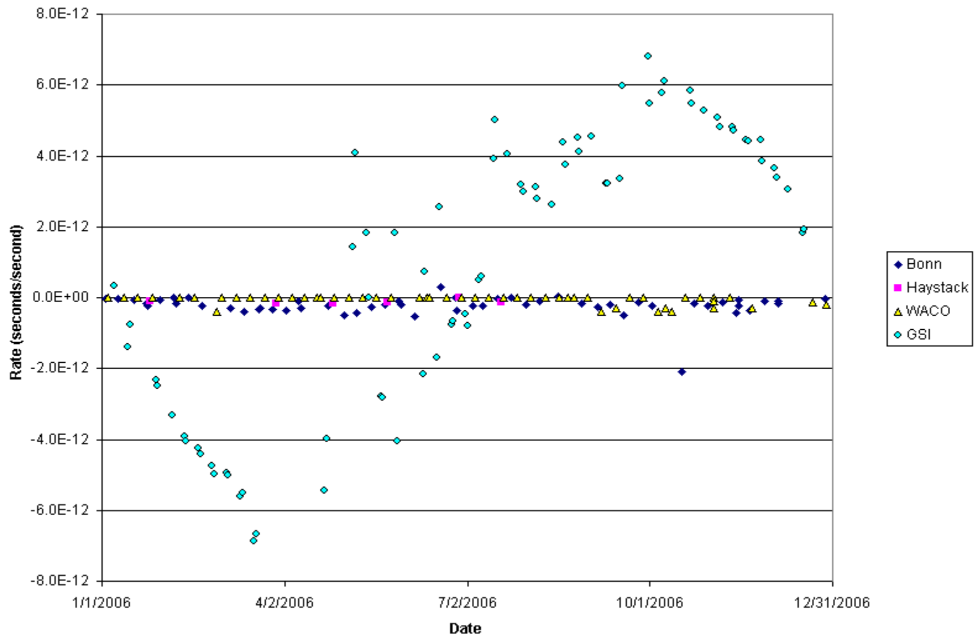


Figure 2. Wettzell Correlator Clock Rate Model

IVS NICT TDC News No. 26, p. 6-8]. This should be compared to the value that has been empirically determined from processing of K-5 data at Mark IV correlators [K. Kingham (USNO), private communication]. Unfortunately, while in the past there was a need to consider how S2 recorders (and correlator) would be integrated into this scheme, due to the cessation of Canadian VLBI operations, this is no longer an issue.

It is also important to consider whether there are offsets between different recording rates within a given recording system. It was recently discovered that there appears to be a 8 μsecond offset for the Mark IV formatter when the tape data rate is 18 MHz as compared to other lower data rates [D. Smythe, Timing Offset of the Mark IV Formatter, Haystack Observatory Mark 5 Memo #047]. This offset essentially affects only 1024 Mb/s recordings. Otherwise the Mark IV formatter is known to not have an offset between different data rates [D. Smythe (Haystack Observatory), private communication].

The difference between correlators must also be considered. The VLBA correlator has moved to the same relative offset used by the Mark IV correlators, i.e. Kokee with a VLBA formatter is 0 μseconds [C. Walker (NRAO), private communication]. However, we don't know if the VLBA correlator has an offset relative to the Mark IV correlators. We must also consider that an offset of the K5 correlator relative to the Mark IV. This will have to be investigated before experiments that yield more precise estimates of UT1, typically 24-hour with long baselines, are processed with the K5 correlator.

IVS Technology Coordinator Report

Alan Whitney

Abstract

The efforts of the Technology Coordinator in 2006 were primarily in the following areas: 1) beginning coordination work to implement a new geodetic VLBI system as outlined in the IVS Working Group 3 'VLBI2010' study, 2) continued development and deployment of e-VLBI, and 3) support of the 5th annual e-VLBI Workshop held at MIT Haystack Observatory. We will briefly describe each of these activities.

1. VLBI2010 Progress

A VLBI2010 workshop was held at MIT Haystack Observatory on 15 September 2006. The purpose of the workshop was to build on the conclusions of the September 2005 IVS Working Group 3 report and set the stage to begin actual development of a new geodetic VLBI system. A number of broad conclusions and decisions were reached during the meeting, including:

1. A goal of 4 psec precision for the group-delay observable for each baseline-observation appears to be a good match to the 1 mm geodetic measurement accuracy goal of VLBI2010.
2. A 12 m diameter antenna with Tsys ~50K with ~60% efficiency and the ability to move between any two locations in the sky within ~ 30 sec appears to be a reasonable choice.
3. The system should cover a continuous ~2-15 GHz band; this choice has several clear advantages:
   - Maintains backwards compatibility with current S/X system
   - Extends the current spanned bandwidth by almost a factor of two.
   - Allows for growth for observing up to ~13 GHz of bandwidth when the data transmission and correlation technology allows, though the new broadband system may require the use of dual-linear polarization.
4. A 'burst mode' type of operation appears to be highly desirable, which would have roughly the following characteristics:
   - Capture on-source data into high-speed RAM for ~5 sec at a data rate of perhaps 32 Gbps, covering 4 dual-polarization bands of 1 GHz each across the 2-15 GHz receiver bandwidth.
   - Transfer data to a recording system or data-transmission system for ~20 sec at a rate of ~8 Gbps while the antennas move to the next source.
   - Repeat this cycle continuously over 24 hours to collect ~2800 observations, many more than are collected today. Besides rapid sky coverage, this mode of operation will quickly sample the atmosphere in all directions to allow better determination of changing atmospheric parameters.
5. Hydrogen-maser technology is almost certainly sufficient for the requirements of VLBI2010 – uncertainties in atmosphere are expected to dominate H-maser uncertainties most of the time.

6. A study needs to be made of the benefits and problems associated with placing multiple antennas at a single site. A preliminary study indicates that placing multiple smaller, faster antennas at a single site is better than a single larger antenna, even if the single large antenna is fast. The best use of multiple antennas is to have them pointing at different areas of the sky since the effect of clock errors can be minimized or eliminated. However, with a single very fast antenna, the need for multiple antennas at a site is greatly diminished.

There are many challenges to implementing the proposed system, including:

1. cost of a fast-moving 12 m antenna
2. feed technology to cover the 2-15 GHz RF band
3. system calibration – a system of injection of short 10-30 ps pulses into the feed has been suggested
4. recording and/or data-transmission technology to absorb the vast amount of data generated by such a system (~60 TB/day at each station!)
5. how to correlate this large amount of data

Progress is being made towards implementing a system suitable to meet VLBI2010 goals, including:

1. identification of potential antenna vendors, though costs for motions at the desired speeds are not yet known.
2. identification of a couple of candidate dual-linear-polarization feeds to approximately span the 2-15 GHz broadband goal.
3. demonstration of broadband digital back-end technology in Japan, Europe and the U.S. that will form the basis of back-end channelization for VLBI2010 systems.
4. demonstration VLBI experiments with 4 Gbps recording capability conducted in Japan and U.S.

A VLBI demonstration of the convergence of these technologies is planned for summer 2007 which will outfit two existing antennas (Westford and GSFC/GGAO) with broadband systems recording at 8 Gbps. Not only will such a system demonstrate a large step toward the required technology, it should substantially increase observation SNRs to uncover systematic error sources which have heretofore been masked.

2. E-VLBI Development

e-VLBI development is continuing on a number of fronts, which we will briefly describe here:

2.1. Ny-Ålesund Connected

During the last year a number of e-VLBI tests and experiments have been conducted with the Ny-Ålesund station, one of the most remote stations in the VLBI network. Courtesy of arrangements between NASA and Norway, which jointly own an undersea fiber-optic cable from Svalbard to the mainland, these tests have allowed a significant amount of data to be transferred from Ny-Ålesund to Haystack Observatory, where they are recorded on Mark 5 disk modules and shipped to the target correlator. The current speed of the connection is limited to less than 100

Mbps, but plans are being discussed to increase the speed to ~300 Mbps, which would be suitable to transferring essentially all data from Ny-Ålesund via e-VLBI. Since Ny-Ålesund media have traditionally been among the most difficult to transport rapidly and reliably, the new e-VLBI connection promises a real step forward.

2.2. MPI Correlator Connected

The Mark IV VLBI correlator at MPI Bonn has recently been connected at 1 Gbps. This connection will allow data to be transferred directly from remote stations to the MPI correlator. Tests of this new link are currently underway and production use of the connection is expected in early 2007.

2.3. Continuing Expansion and Development of Routine e-VLBI Data Transfers

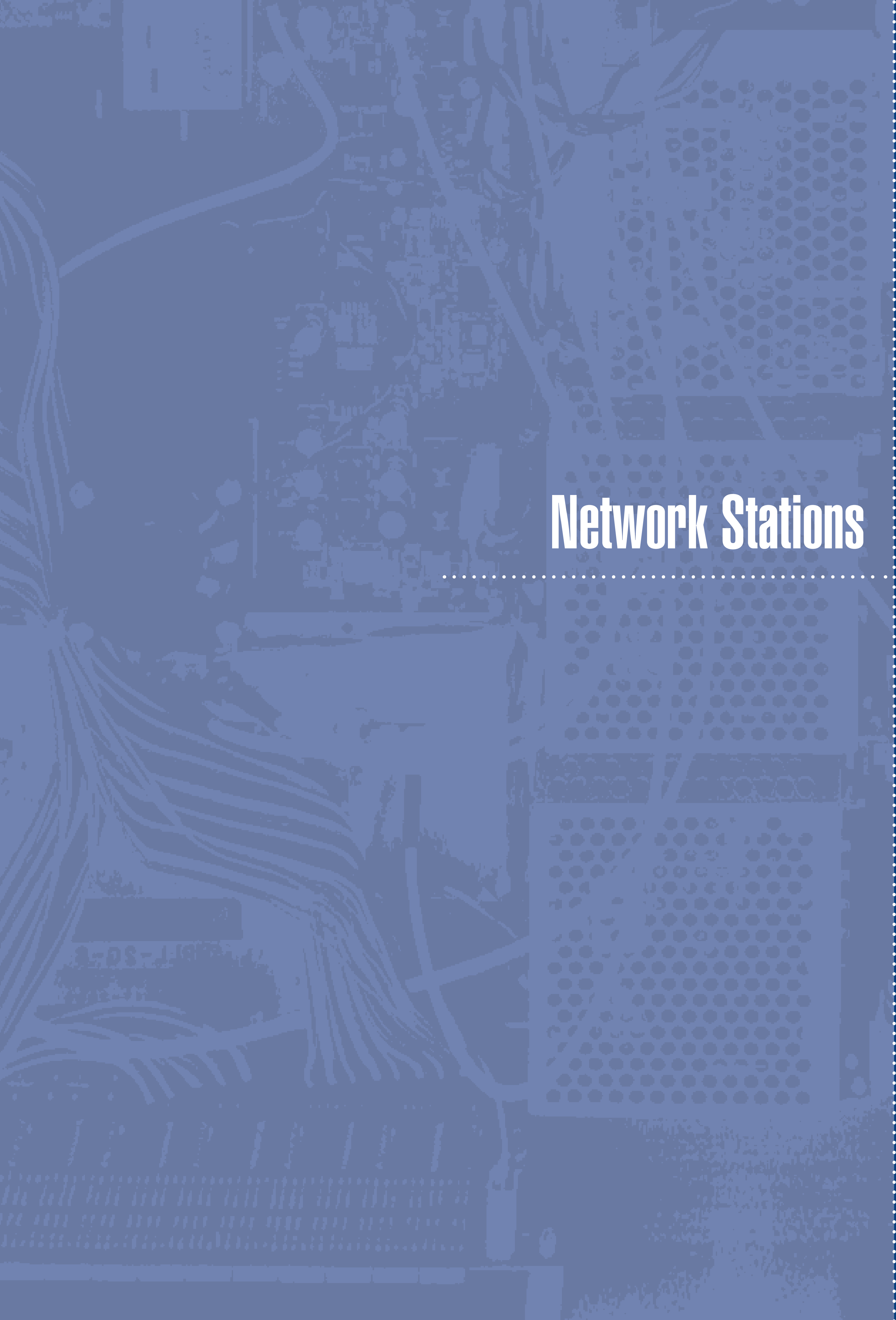
Routine use of e-VLBI continues to grow. All data recorded on K5 systems at Tsukuba and Kashima are currently transferred via e-VLBI to Haystack Observatory, where it is transferred to Mark 5 disk modules and sent to target correlators at Haystack, USNO, or MPI. Syowa (Antarctica) data are now being transferred to Haystack from Japan, after the Syowa K5 disk media have been physically shipped to Japan. Daily UT1 Intensive data from Wettzell are transferred via e-VLBI to a site near USNO in Washington, D.C., where it is picked up and taken to USNO for correlation. Additionally, monthly UT1 Intensive data are transferred from Tsukuba to MPI for correlation. Regular e-VLBI data transfers from Ny-Ålesund are expected to begin within the next few months. The biggest impediment to rapid e-VLBI expansion continues to be station connectivity to high-speed networks, but the situation is improving. Tsukuba, Kashima, Onsala, Westford, Onsala, and Medicina are now connected with 1 Gbps links, though some issues remain in actually using some of the links at full speed. Wettzell is connected at ~30 Mbps, with plans to upgrade to ~600 Mbps in Spring 2007. TIGO is in the process of upgrading its connection to ~30 Mbps. Projects are underway to connect Hobart, Fortaleza, and Svetloe in 2007.

2.4. VSI-E Beta Testing

VSI-E beta testing continues, though progress has been somewhat slower than desired. A reference implementation of the proposed VSI-E specification has been developed and is undergoing testing. The primary purpose of VSI-E is to provide a standardized specification for e-VLBI data formats and protocols that is compatible between both homogeneous and heterogeneous VLBI data systems. The VSI-E framework provides signaling, control, framing, and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility for users to choose the transport protocol that best suits their networking environment (e.g. UDP, TCP, or other variants). The first live testing of VSI-E is currently ongoing using Kashima, Ny-Ålesund, and Haystack. The Kashima site is a unique testbed since data are collected on the K5 at Kashima, while Haystack uses Mark 5A systems, enabling testing on heterogeneous systems. Once the reference implementation is fully checked out, attention can be turned to optimizing the code for high-speed operation, followed by broader deployment.

3. 5th International e-VLBI Workshop Held at MIT Haystack Observatory

The 5th International e-VLBI Workshop was held 17-20 September 2006 at MIT Haystack Observatory in Westford, MA. The return of the workshop to Haystack, where the first e-VLBI workshop was held in 2002, followed the cycle of these annual workshops from U.S. to Europe to Japan to Australia and back again to Haystack. The workshop was attended by more than 60 participants from 15 countries. The workshop was expanded to four days (from the usual two) by the addition of two days of tutorial lectures and demonstrations before the main body of the workshop itself. These tutorial sessions were designed to help attendees deepen their knowledge about some of the various complex aspects of networking and e-VLBI, including detailed discussion of transmission protocols, the problems and pitfalls of tuning a network for optimum speed, a primer on network security for e-VLBI, and an in-depth look at VSI-E. The workshop presented an opportunity to share the experiences of progress and developments in e-VLBI around the world and to explore possibilities for coordination and cooperation. The standard of presentations was again very high, and many new results and plans were presented. e-VLBI is set for rapid progress around the world in the next few years. All presentations from the workshop are available online at *http://www.haystack.edu/geo/vlbi_td/abstract.html*. The workshop series will continue its rotation around the world with the next e-VLBI workshop to be hosted in Europe at MPI. We all look forward to another stimulating and valuable meeting.



Network Stations

Algonquin Radio Observatory

Mario Bérubé, Anthony Searle

Abstract

The Algonquin Radio Observatory (ARO) is situated in Algonquin provincial park, about 250 km north of Ottawa and is operated by the Geodetic Survey Division (GSD) of Natural Resources Canada as a primary site for the Canadian Spatial Reference System.

The antenna is involved in a large number of international geodetic VLBI sessions each year and is a key site in the ongoing Canadian S2 developments. The ARO antenna is the most sensitive IVS Network Dish.

This report summarizes recent activities at the Algonquin Radio Observatory.

Figure 1. Algonquin Radio Observatory rests in its final position after 40 years of use.

1. Overview

The ARO 46-meter antenna was used in the first successful VLBI experiment in 1967 and was involved as early as 1968 in geodesy, when the baseline length between the ARO and a telescope in Prince Albert, Saskatchewan was measured to be 2143 km (sigma=20m).

GSD also maintains a permanent GPS monitoring station at Algonquin (ALGO) which is used by all IGS Analysis Centers as a fiducial reference. The site acts as a primary location for the Canadian Spatial Reference System (CSRS), and ensures global consistency for reference frame users in Canada. Absolute gravity observations are available for the site which is located on the stable Precambrian Canadian Shield. A Satellite Laser Ranging observation campaign was conducted in 1993. Local site stability has been monitored regularly using a high-precision network.

2. Site Improvements

In March, extensive brush clearing of the power line path was completed. Though not impervious to power failures, the cleared line was more robust against outages due to minor storms.

3. General Specifications

- Latitude : N 45° 57' 19.812"
- Longitude : E 281° 55' 37.055"
- Elevation : 260.42m
- Reflector : 46m diameter with first 36.6m made of 0.634cm steel plates surrounded by 4.6m of steel mesh.
- Foci : S and X band at prime focus. Gregorian capability with 3m elliptical subreflector.
- Focal length : 18.3m (prime focus)
- Focal ratio : f/D = 0.4 for full surface and 0.5 for solid surface.
- Surface accuracy : 0.32cm for solid portion and 0.64 for mesh.
- Beamwidth : 3.0 arcmin at 3cm wavelength (10GHz)
- Azimuth speed : 20 degrees per minute
- Elevation speed : 5 degrees per minute
- Receiver : S and X cryogenic receiver.
- VLBI equipment : VLBA4 with thin tape drive and Mark 5 Disk recorder. S2 DAS and RT.
- PCFS version : 9.7.7
- Time standard : NR Maser
- GPS receiver : BenchMark
- Timing receiver : CNS clock

4. Algonquin Operations

In August, ARO suffered a major malfunction of the bearing assembly for the azimuth drive. Plans to repair the antenna were not undertaken.

Algonquin Radio Observatory was involved in several International VLBI networks in 2006. Geodetic VLBI activities are summarized below.

4.1. Sessions Performed January 1, 2006 - December 31, 2006

Session Type	Number of Sessions
R4	27
E3	6
R&D	4
T2	2
RVD	1
Total	40

On September 25, the Canadian government announced the cessation of Very Long Base Interferometry activities in Canada. Algonquin Park VLBI operations ceased.

Fortaleza Station Report for 2006

Pierre Kaufmann, A. Macílio Pereira de Lucena, Adeildo Sombra da Silva, Claudio E. Tateyama

Abstract

This is a brief report about the activities carried out at Fortaleza geodetic VLBI Station (ROEN: Rádio Observatório Espacial do Nordeste), located in Eusébio, CE, Brazil, in 2006. The observing activities consisted of 72 VLBI sessions and continuous GPS monitoring recordings.

1. General Information

The Rádio Observatório Espacial do Nordeste, ROEN, located at INPE facilities in Eusébio, nearly 30 km east of Fortaleza, Ceará State, Brazil, began operations in 1993. Geodetic VLBI and GPS observations are carried out regularly, as contributions to international programs and networks. ROEN is part of the Brazilian space geodesy program which was initially conducted by CRAAE (a consortium of the Brazilian institutions Mackenzie, INPE, USP, and UNICAMP) in the early 1990s. During that time the antenna and instrumental facilities were erected, and it was the beginning of the activities sponsored by U.S. agency NOAA, Brazilian Ministry of Science, and Technology's FINEP agency. ROEN is currently coordinated by CRAAM, Center of Radio Astronomy and Astrophysics, Mackenzie Presbyterian University, São Paulo, in agreement with the Brazilian National Space Research Institute, INPE. A new contract was signed in May 2004 between NASA and CRAAM, Mackenzie Presbyterian Institute and University to partially support the activities at ROEN until 2009. This contract is a consequence of the Agreement of Cooperation signed between NASA – representing research interests of NOAA and USNO – and the Brazilian Space Agency, AEB, in 2002. The counter-part of the operational costs, staff, and support of infrastructure are provided by INPE and by Mackenzie.

2. Component Description

The largest instrument of ROEN is the 14.2 m radio telescope, an alt-azimuth positioner. It is operated at S- and X-bands, using cryogenic radiometers. The system is controlled by Field System, Version 9.9.2 program. Observations are recorded with a Mark 5 system. One Sigma-Tau hydrogen maser clock standard is operated at ROEN.

GPS monitoring is performed in a cooperation program with NOAA, USA. There is a Leica System 1200 installed at the station that operates continuously. The collected data are provided to the NOAA/IGS center and to Brazilian IBGE center. ROEN has all basic infrastructures for mechanical, electrical and electronic maintenance of the facilities.

3. Staff

The Brazilian space geodesy program is coordinated by Prof. Pierre Kaufmann, from São Paulo main office at CRAAM (CRAAE)/Instituto and Universidade Presbiteriana Mackenzie, receiving scientific assistance from Dr. Claudio E. Tateyama, and partial administrative support from Val-

Figure 1. Fortaleza's 14.2 m antenna.

domiro S. Pereira and Neide Gea Escolano. Partial technical assistance is given by Itapetinga Radio Observatory staff, near São Paulo, also operated by INPE/Mackenzie.

The Fortaleza Station facilities and geodetic VLBI and GPS operations are managed on site by Dr. A. M. P. de Lucena (CRAAE/INPE), assisted by Eng. Adeildo Sombra da Silva (CRAAE/Mackenzie), the technicians Avicena Filho (CRAAE/INPE) and Carlos Fabiano B. Moreira (CRAAE/Mackenzie).

Figure 2. Fortaleza's station team

4. Current Status and Activities

4.1. VLBI Observations

Fortaleza participated in the following geodetic VLBI experiments, as detailed in the table below for the year 2006.

Fortaleza also participated in tracking of the European sonde SMART-01 before its impact on

Table 1. 2006 session participation.

Experiment	Number of Sessions
IVS-R1	13
IVS-R4	46
IVS-T2	05
IVS-CRF	03
IVS-OHIG	05

the lunar surface.

4.2. Development and Maintenance Activities in 2006

Considerable attention was given to technical maintenance problems, specially to the following ones:

1. Repair of the cryogenic system.
2. Replacement of Mark 5 recorder power supply.
3. Repairs of the following circuits, modules or systems: Mark III video converters, Mark III power supplies, Mark III IF Distributor module.
4. Repair in UPS system.
5. Maintenance of web site (http://www.roen.inpe.br) and the local server computer.
6. Updating Field System to version 9.9.2.

4.3. GPS Operation

The IGS network GPS receiver operated regularly at all times during 2006. Data were collected and uploaded to IGS/NOAA computer.

5. Agreement

An Agreement between Mackenzie and Ceara State University (UECE), Fortaleza, has been implemented, intended to explore GPS and VLBI meteorology in connection with the regional weather and climate in the North-East of Brazil.

6. Future Plans

In 2007, it will be completed the high speed optical network that will allow ROEN to participate in e-VLBI experiments. The updating of Mark III system will be also completed with the installation of Mark IV video converters during this year. Antenna painting was contracted in 2006 and will be concluded by April, 2007.

7. Acknowledgements

These activities have received partial supports from NASA, within a contract with Mackenzie, from Mackenzie and from INPE.

8. Publications

Diniz, S.I.F., Tateyama, C.E., "Precessão de Jato de BL Lac", Annual Meeting of the Brazilian Astronomical Society, 30 July - 3 de August 2006, Atibaia, SP, Boletim da SAB, vol. 26, n. 1,p. 150, 2006.

Kaufmann, P., "Radio Astronomy and VLBI in Brazil". 4th IVS General Meeting, January 9-11, 2006, Concepción, Chile. IVS 2006 General Meeting Proceedings, edited by D. Behrend and K. D. Baver, NASA/CP-2006-214140, p.137-141, 2006.

Namba, C.Y., Tateyama, C.E. "Precessão de Jato de 3C273" Annual Meeting of the Brazilian Astronomical Society, 30 July - 3 de August 2006, Atibaia, SP, Boletim da SAB, vol. 26, n. 1,p. 156, 2006.

Steimberg, D., Tateyama, C.E., "Precessão de jato de OJ287", XXXIIa. Annual Meeting of the Brazilian Astronomical Society, 30 July - 3 de August 2006, Atibaia, SP. Boletim da SAB, vol. 26, no 1, 167, 2006.

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Mark Evangelista

Abstract

This report summarizes the technical parameters and the technical staff of the VLBI system at the fundamental station GGAO. It also gives an overview about the VLBI activities during the previous year. The outlook lists the outstanding tasks to improve the performance of GGAO.

1. GGAO at Goddard

The Goddard Geophysical and Astronomical Observatory (GGAO) consists of a radio telescope for VLBI, SLR site to include MOBLAS-7, SLR-2000 (development system), a 48" telescope for developmental two color Satellite Ranging, a GPS timing and development lab, meteorological sensors and a H-maser. In addition, we are a fiducial IGS site with several IGS / IGSX receivers.

Figure 1. Old semi-permanent MV3 VLBI antenna.

Figure 2. New permanent MV3 antenna.

GGAO is located on the east coast of the United States in Maryland. It is about 15 miles NNE of Washington D.C. in Greenbelt, Maryland (Table 1).

2. Technical Parameters of the VLBI Antenna at GGAO

The radio telescope for VLBI at GGAO (MV3) was originally built as a mobile or transportable station. It was previously known as Orion and was part of the original CDP. It is now being used as a fixed site having been moved to Goddard and semi-permanently installed here since the spring of 1991 as shown in Figure 1. In the winter of 2002 the antenna was taken off its trailer and permanently installed at GGAO as shown in Figure 2. The design criteria were

- transportability on two tractor trailers utilizing a 5 meter dish size to maximize receive and mobility considerations,
- setup of the radio telescope within eight hours (although it has been used as a fixed site since the spring of 1991)

Table 1. Location and addresses of GGAO at Goddard.

Longitude	76.4935° W
Latitude	39.0118° N
MV3 Code 299.0 Goddard Space Flight Center, (GSFC) Greenbelt, Maryland 20771	
http://www.gsfc.nasa.gov	

The technical parameters of the radio telescope are summarized in Table 2.

Table 2. Technical parameters of the radio telescope of GGAO for geodetic VLBI.

Parameter	GGAO-VLBI
owner and operating agency	NASA
year of construction	1982
diameter of main reflector d	$5m$
azimuth range	$0 \ldots 540°$
azimuth velocity	$3°/s$
azimuth acceleration	$1°/s^2$
elevation range	$0 \ldots 90°$
elevation velocity	$3°/s$
elevation acceleration	$1°/s^2$
X-band	$8.18 - 8.98\,GHz$
receiving feed	Cassegrain focus
T_{sys}	$24\,K$
Bandwidth	$800MHz, -2dB$
G/T	$32.1\,dB/K$
S-band	$2.21 - 2.45GHz$
receiving feed	primary focus
T_{sys}	$19\,K$
Bandwidth	$240MHz, -2dB$
G/T	$21.2\,dB/K$
VLBI terminal type	Mark IV
recording media	thin-tape, Mark 5
Field System version	9.8.2

3. Technical Staff of the VLBI Facility at GGAO

The GGAO VLBI facility gains from the experiences of the staff from the Research and Development VLBI support staff. GGAO is a NASA R&D and data collection facility, operated under contract by Honeywell Technology Solutions Incorporated (HTSI). Table 3 lists the GGAO station staff that are involved in VLBI operations.

Table 3. Staff working at the MV3 VLBI station at GGAO.

Name	Background	Dedication	Agency
Jay Redmond	engineering technician	100%	HTSI
Skip Gordon	engineering technician	20%	HTSI

4. Status of MV3 at GGAO

GGAO participated in several VLBI experiments which are listed in Table 4. In addition to the scheduled experiments listed in Table 4, MV3 has participated in several unscheduled experiments for VLBI developmental purposes and various other developmental activities.

Table 4. Participation of GGAO in VLBI Experiments from February 1, 2006 to December 5, 2006.

Date	Experiment
2006-02-01	RDV55
2006-02-07	T2043
2006-04-25	RDV59
2006-05-23	T2044
2006-06-27	T2045
2006-08-01	T2046
2006-10-28	T2047
2006-12-05	T2048

After 30 years of dedication and support of the VLBI program, Charles Kodak has decided to retire. GGAO and Honeywell wish him well and thank him for his years of service to the VLBI family.

5. Outlook

GGAO will continue to support both scheduled experiments and developmental activities. The plan for 2007 consists of:

1. Continue testing of pre-release versions of PC-FS and new Linux kernel releases.
2. Continue with support of Mark 5 and Digital Back End (DBE) hardware development.
3. Continually striving to improve the performance of the entire Mark 5 data collection and station specific equipment.
4. MV3 has installed Mark 5 and e-VLBI hardware and continues to test real-time VLBI from GGAO to Haystack. On January 26, 2007, MV-3 recorded two 480MHz bands that covered

all of the X-band IF, with two-bit sampling, for an aggregate data rate of ~4Gb/s. Two VSI data streams (each ~2Gb/s) were recorded on two Mark 5B's and the data were transferred to the Haystack correlator via high-speed internet connections. It was also demonstrated, by comparing to simultaneously recorded Mark IV data, that there appears to be no major sources of signal loss in the DBE system.

5. GGAO will continue to support the development and testing of VLBI2010 hardware and software.

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck, Marisa Nickola

Abstract

HartRAO, the only fiducial geodetic site in Africa, participates in VLBI, GPS and SLR global networks. This report provides an overview of our geodetic VLBI activities during 2006. New VLBI research is reported. In order to meet future requirements of geodetic VLBI, we have initiated the first steps towards founding a new space geodetic station which will cater to new developments and challenges as addressed by VLBI2010 and future requirements of GPS and SLR/LLR.

1. Geodetic VLBI at HartRAO

Hartebeesthoek is located 65 kilometers north-west of Johannesburg within the World Heritage Site known as the Cradle of Humankind, just inside the provincial boundary of Gauteng, South Africa. The nearest town, Krugersdorp, is 32 km distant. The telescope is situated in an isolated valley which affords protection from terrestrial interference. HartRAO uses a 26-metre equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The telescope was part of the NASA deep space tracking network until 1975 when the facility was converted to an astronomical observatory. The telescope is co-located with an SLR station (MOBLAS-6) and an IGS GPS station (HRAO). HartRAO joined the EVN as an associate member during 2001. Astronomical and geodetic VLBI have been allocated equal shares (15% each) of telescope time. The allocation for geodetic VLBI has been increased for 2007.

Figure 1. Our new director, Prof. Roy Booth.

Figure 2. The dish - sunset and clouds from an approaching cold front.

2. Technical Parameters of the VLBI Telescope of HartRAO

The feed horns used for 13 cm and 3.5 cm are dual circularly polarised conical feeds. The RF amplifiers are cryogenically cooled HEMTS. Tables 1, 2 and 3 contain the technical parameters of the HartRAO radio telescope, its receivers and recording systems. The Jan/Feb OHIGs were recorded to tape. Hours before the RDV was due to start on the 25th of April 2006, the Mark IV tape drive failed, forcing the Mark 5 to take over the reins. On the 23rd of May, Cynthia Thomas's e-mail made this official - "[from now on] HartRAO will be on the schedule with disk only".

Table 1. Antenna parameters.

Parameter	**HartRAO-VLBI**
Owner and operating agency	HartRAO
Year of construction	1961
Radio telescope mount	Offset equatorial
Receiving feed	Cassegrain
Diameter of main reflector d	$25.914\,m$
Focal length f	$10.886\,m$
Focal ratio f/d	0.424
Surface error of reflector	$< 0.5\,mm$
Wavelength limit	$< 1.0\,cm$
Pointing resolution	0.001°
Pointing repeatability	0.020°

Table 2. Receiver parameters with dichroic reflector (DR), used for simultaneous S-X VLBI, off or on.

Parameter	**X-band**	**S-band**
T_{sys} (DR off) (K)	60	44
T_{sys} (DR on) (K)	70	50
S_{SEFD} (DR off) (Jy)	684	422
S_{SEFD} (DR on) (Jy)	1330	1350
Point source sensitivity (DR off) (Jy/K)	11.4	9.6
Point source sensitivity (DR on) (Jy/K)	19	27
3 dB beamwidth (°)	0.092	0.332

Table 3. VLBI recording systems.

Parameter	**HartRAO-VLBI**
VLBI terminal	Mark IV
VLBI recorder	Mark 5A, Mark IV, S2

3. Staff Members Involved in VLBI

Dr Roy Booth has taken over as Director from the 1st of July 2006. Table 4 lists the HartRAO station staff who are involved in geodetic VLBI. Jonathan Quick (VLBI friend) has continued to provide technical support for the Field System as well as for hardware problems.

Table 4. Staff supporting geodetic VLBI at HartRAO.

Name	**Function**	**Programme**
Ludwig Combrinck	Programme Leader	Geodesy
Jonathan Quick	Hardware/Software	Astronomy
Sarah Buchner	Training	Astronomy
Marisa Nickola	Logistics/Operations	Geodesy
Pieter Stronkhorst	Operator	Technical
Gert Agenbag	Operator	Geodesy - student
Joel Ondego Botai	VLBI research	Geodesy - student
Roelf Botha	Operator	Geodesy - student
Attie Combrink	Operator	Geodesy - post doctoral researcher
Sakia Madiseng	Operator	Geodesy - student
Mojalefa Moeketsi	Operator	Geodesy - student
Vasyl Suberlak	Operator	Geodesy - post doctoral researcher

4. Current Status

During 2006 HartRAO participated in 52 experiments (Table 5), which utilised the telescope time allocated to geodetic VLBI to its fullest extent.

Table 5. Geodetic VLBI experiments HartRAO participated in during 2006.

Experiment	**Number of Sessions**
R1	28
CRDS	10
OHIG	6
CRF	3
T2	3
RDV	2
Total	52

In 2006, our two Ph.D. students, Joel Ondego Botai and Attie Combrink, in collaboration with the SA Weather Service, started to analyse VLBI-derived precipitable water vapour (PWV) estimates. Comparisons were made with PWV estimates from GPS, radiosondes and two water vapour radiometers (WVR) on loan from BKG (Germany) and ETHZ (Switzerland). Ongoing **research** will include attempts to improve VLBI baseline repeatabilities using WVR-derived troposheric signal path delays. One of the WVRs is being returned to ETHZ and we would like to thank them for making the instrument available to us for more than a year.

Microwave holography is to be used to obtain the best overall surface shape after the **antenna surface upgrade**. The holographic system is finally phase stable after replacing the original system with a small reference dish on the main antenna and using a common local oscillator. HF low loss cables for the holography dish are being replaced with a much cheaper cylindrical waveguide built with standard A1 pipes.

Figure 3. Holography on the edge - Ben Klein showing off his reference antenna.

Figure 4. XDM - pedestal and mould.

5. Future Plans

The eXperimental Development Model (XDM) is a 15-m diameter radio telescope being built at Hartebeesthoek as a prototype for the Karoo Array Telescope (KAT), which will be used to test technology leading up to development of the Square Kilometer Array (SKA). Once the XDM has been tested and its frequency range determined, geodetic VLBI might prove to be a suitable application.

We have taken initial steps towards the development of a new integrated Space Geodesy Facility which will support SLR, LLR, VLBI and GPS as well as host other earth science instrumentation. This will mean the construction of a new site, development and implementation of new state of the art equipment and will place the southern hemisphere and especially Africa securely in the space geodesy arena for the next several decades. Matjiesfontein in the arid Karoo region of the Western Cape province has been identified as a potential site. Initial geological site surveys have already been conducted and a Working Group on the future of Space Geodesy in South Africa has been established. We would like to invite possible participants in this venture to contact us. The Geodesy Programme is an integrated programme, supporting VLBI, SLR and GPS and is active in several collaborative projects with GSFC, JPL, GFZ (Potsdam) and local institutes.

Hobart, Mt. Pleasant, Station Report for 2006

Brett Reid, John M. Dickey

Abstract

This is a brief report on the activities carried out at the Mt. Pleasant Radio Astronomy Observatory at Hobart, Tasmania. During 2006, the Observatory participated in 44 VLBI observing sessions with IVS, 24 hours each.

1. Introduction

The Mt. Pleasant Observatory is located about 15 km north east of Hobart at longitude 147.5 degrees East and latitude 43 degrees South. Hobart is the capital city of Tasmania, the island state of Australia located to the south of the mainland. The station is operated by the School of Mathematics and Physics at the University of Tasmania with financial support from the University and with the aid of an Australian Research Council (ARC) Linkage grant in conjunction with Geoscience Australia. The station has participated in geodetic VLBI programs since 1988 but only joined IVS in 2002 when we were able to secure funding support for geodetic observations for a five year period. The station has a co-located GPS receiver and a site which is used for absolute gravity measurements.

2. Brief Description of VLBI Facilities

The antenna is a 26m prime focus instrument with an X-Y mount. The focus cabin has been upgraded to include a feed translator with provision for four different receiver packages which enables rapid change over between geodetic and astronomical requirements. Standard receiver packages provide for operation at L band, S, C, X and K bands. There is also the dual frequency S/X geodetic receiver. All of these receivers are cryogenically cooled. The antenna has a maximum slew rate of 40 degrees per minute about each axis. The station is equipped with a Mark IV electronics rack and a Mark 5 VLBI recording system as well as S2 recorder. There is also another disk based recording system as used by other Australian VLBI antennas.

3. Staff

Staff at the observatory consisted of academics, Prof. John Dickey (director), Dr. Simon Ellingsen, Dr. Melanie Johnston-Hollitt and Prof. Peter McCulloch who has had a large input into the receiver design and implementation. Dr Giuseppe Cimó and Dr Jamie Stevens are research fellows and have had input into the Linux systems at the observatory. Jamie is also working on the fiber optic link to Mount Pleasant which is now due for commisioning by March 2007. Mr. Brett Reid is the Observatory Manager whose position is funded by the university. In addition we have an electronics technical officer, Mr. Eric Baynes, and a half time mechanical technical officer, Mr Geoff Tonta. For operation of the observatory during geodetic observations we rely heavily on support from astronomy PhD and post-graduate students.

Figure 1. The Mt. Pleasant 26m antenna.

4. Geodetic VLBI Observations

Hobart participated in 44 geodetic VLBI experiments during 2006. These were divided between the R1, CRDS, OHIG, RDV, T2, CRF, R4 and APSG programs. All experiments were recorded using Mark 5A. The antenna was down for a month during May for a scheduled upgrade of the drive motors and controllers. The SCR DC drives were changed for AC vector drives. The antenna drives have proven far more reliable since the upgrade. The motors and controllers were bought using an equipment grant from University of Tasmania in 2005. The observatory staff performed the installation and commissioning of the new drives.

5. Future Plans

In 2007, Hobart is increasing its support to IVS by participating in 60 24-hour experiments, an increase of 36% above those performed in 2006.

The ARC LEIF (Large Equipment and Infrastructure Funding) funded 10 Gb/s fibre optic link between the Mt. Pleasant VLBI site and the university campus is expected to be complete by March 2007.

The 2006 equipment money from the university was used to purchase vacuum/cryogenic parts to enable vacuuming of the cryogenic dewars remotely, decreasing downtime for the antenna. We hope to install the remote vacuum system in the first half of 2007.

In 2006 the Australian geodetic community made a strong case for expanding the VLBI research infrastructure available for IVS. The recently announced National Cooperative Research Infrastructure Scheme includes funds for building three new 12m telescopes, to be dedicated to IVS observations for approximately 50% of the time. This five year project will vastly improve the capabilities of the IVS in the southern hemisphere. Funding from the Australian Department of Education, Science, and Training is expected starting later in 2007.

Kashima 34-m Radio Telescope

Eiji Kawai, Hiromitsu Kuboki

Abstract

National Institute of Information and Communications Technology (NICT) operates Kashima 34-m radio telescope continuously as a facility of the Kashima Space Research Center in Japan. This is the network station report mainly focused on the telescope facilities.

1. Introduction

The Kashima 34-m telescope (Figure 1) was constructed by National Institute of Information and Communications Technology (NICT) in 1988. The telescope is located about 100 km east of Tokyo, Japan. During 18 years of operation, the telescope has been kept in a fairly good condition and the antenna has participated in various VLBI and single-dish observations. The 34-m telescope is operated by the Space-Time Applications Project (formerly the Radio Astronomy Applications Group) of the Space-Time Standards Group of Kashima Space Research Center (KSRC), NICT.

Figure 1. The Kashima 34-m radio telescope.

2. Telescope Status

2.1. Receiver Systems

The receivers currently available at the Kashima 34-m telescope can observe L, C, K, Ka, Q, S, and X-bands. The measured performance of the receivers are summarized in Table 2. If the polarization of the receiver is switchable to both RHCP and LHCP polarizations, it is indicated as

Table 1. Main specifications of the 34-m Radio Telescope.

Main reflector aperture	34.073 m
Latitude	N 35° 57' 50.76"
Longitude	E 140° 39' 36.16"
Height of AZ/EL intersection above sea level	43.6 m
Height of azimuth rail above sea level	26.3 m
Antenna design	Modified Cassegrain
Mount type	AZ-EL mount
Drive range azimuth	North ±270°
Drive range elevation	7°-90°
Maximum speed azimuth	0.8°/sec
Maximum speed elevation	0.64°/sec
Maximum operation wind speed	13 m/s
Panel surface accuracy r.m.s.	0.17 mm

Table 2. Receiver Specification of the 34-m Radio Telescope.

Band	frequency (MHz)	Trx (K)	Tsys (K)	Efficiency	SEFD (Jy)	Polarization
L	1350-1750	18	43	0.68	190	R/L
S	2193-2350	19	83	0.65	390	R/L
C	4600-5100	100	127	0.70	550	L(R)
X	8180-9080*	41	52	0.68	230	R/L
K	21800-23800	75	160	0.5	970	L(R)
Ka	31700-33700	85	150	0.4	1100	R(L)
Q	42300-44900	180	300	0.3	3000	L

*: X-band receiving frequency is a result of preliminary expansion of the receiving frequency range. See section 2.2 in this report for details.

R/L. If the polarization cannot be switched, but it is still possible to change the polarization by changing the wave guide configuration, it is indicated as R(L) or L(R). Ka-band efficiency in Table 2 is a provisional value. All receivers, except for the C-band receiver, are using cooled HEMT LNA which are kept around 12 K physical temperature. The C-band LNA is using an ambient FET LNA. The low noise amplifiers of the Ka and K-band receivers are placed inside a dual-band dewar. The low noise amplifiers of S and X-band receivers are also placed inside a cooled dewar. Only L and Q-band LNAs are placed in a dedicated cooled dewar for each band.

To mitigate Radio Frequency Interference (RFI), additional filters were installed in the L and S-band receivers. For the S-band receiver, a High Temperature Superconductor (HTS) filter is used [1]. A coaxial bandpass filter with 11 sections was employed for 1350-1450 MHz in the L-band to avoid the influence of RFI.

The IF (intermediate frequency) signals of the receivers are transmitted from the telescope to the observation room via optical fibers. Higher frequency band receivers (K, Ka, and Q) use frequency range of 5-7 GHz as the IF signals. IF signals are then converted to base band signals or other IF signals in the observation room.

Table 3. X-band nominal receiving frequency range of Kashima 34-m antenna before and after the preliminary expansion.

Receiver	Frequency Coverage (MHz)		
	Before Sept. 2005	From Sept. 2005 to May 2006	After May 2006
X-n	8180-8600	—(*)	8180-8600
X-wL	7860-8360	8580-9080	8580-9080
X-wH	8180-8600	8180-8600	8180-8600

*: To use local oscillator signal for X-wL subsystem, X-n subsystem was temporally unavailable.

2.2. On the Change of the X-band Receiver Configuration

The original nominal frequency coverage of the X-band receiver of the Kashima 34-m antenna was from 7860 MHz to 8600 MHz. This frequency coverage was chosen to cover a wide frequency range to improve the time delay measurements in domestic geodetic VLBI experiments. However, after the 34-m antenna was constructed, international wide band geodetic VLBI experiments began to be performed by expanding the X-band receiving frequency to the upper frequencies up to 9080 MHz. Therefore, we decided to try to expand the frequency range of the X-band receiver of the 34-m antenna up to 9080 MHz so that it can participate in the international wide band geodetic VLBI experiments. At first, we replaced the RF bandpass filter of the X-wL subsystem from its original filter (7860-8360 MHz) to the new filter (8580-9080 MHz) as shown in Table 3 in August 2005 during annual maintenance. To convert the new frequency range of the X-wL subsystem, the local frequency signal (8080 MHz) for the X-n subsystem was temporally removed and connected to the mixer of the X-wL subsystem. Detailed measurements are described in Ref. [2], [3].

After May 2006, the X-n subsystem became available for observations (Table 3). Then simultaneous dual polarization (RHCP/LHCP) observation became possible for frequency range 8180 - 8600 MHz. Figure 2 shows the block diagram of the S/X-band receiver system after change in May 2006.

2.3. Mechanical System

In September and October 2006, the backup structure of the main reflector was repaired by removing the rust and by welding reinforcement plates. In 2007 we plan to have a large-scale repair of the backup structure of the main reflector from August until mid-October 2007.

3. Technical Staffs of the Kashima 34-m Radio Telescope

Engineering and technical staffs of the Kashima 34-m telescope are Eiji Kawai (responsible for operations and maintenance), Mamoru Sekido (software and reference signals), Hiroshi Takeuchi (software and hardware) until February 2006, Hiromitsu Kuboki (mechanical and RF related parts), Yasuhiro Koyama (international e-VLBI), and Tetsuro Kondo (software correlator developments and e-VLBI).

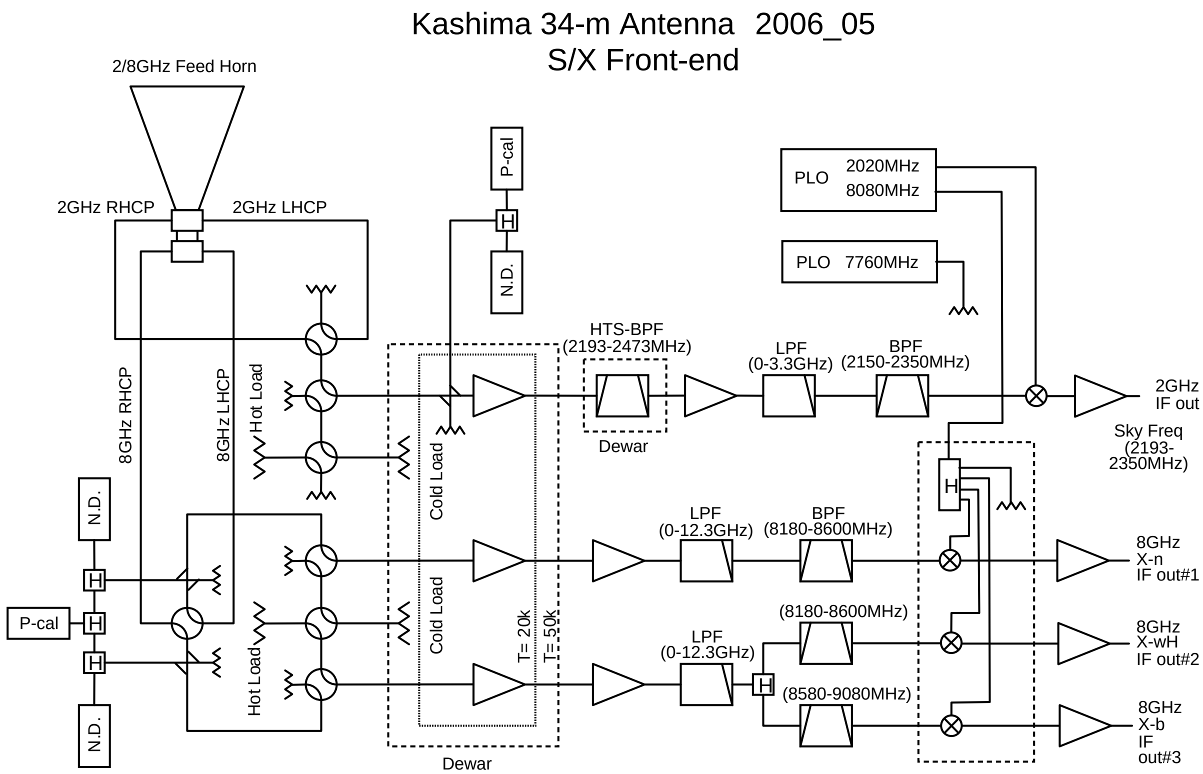


Figure 2. Block diagram of the Kashima 34-m antenna S/X receiver after May 2006.

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Kashima and Koganei 11-m VLBI Stations

Yasuhiro Koyama

Abstract

Two 11-m VLBI stations at Kashima and Koganei used to be a part of the Key Stone Project VLBI Network. The network consisted of four VLBI stations at Kashima, Koganei, Miura, and Tateyama. Since Miura and Tateyama stations have been transported to Tomakomai and Gifu, Kashima and Koganei 11-m stations are remaining as IVS Network Stations. After the regular VLBI sessions with the Key Stone Project VLBI Network terminated in 2001, these stations are mainly used for the purposes of technical developments and miscellaneous observations. In 2006, a geodetic VLBI test experiment using the multi-channel 2 Giga-bits AD sampler unit ADS2000 was performed between Kashima and Koganei 11m VLBI stations. Efforts to determine the precise orbit of spacecrafts were continued by using Geotail spacecraft and two KSP VLBI stations. In addition, a series of experiments were carried out for the development of e-VLBI by using the high-speed network connection between the sites and the two 11-m antennas.

1. Introduction

The Key Stone Project (KSP) was a research and development project of the National Institute of Information and Communications Technology (NICT, formerly Communications Research Laboratory) [1]. Four space geodetic sites around Tokyo were established with VLBI, SLR, and GPS observation facilities at each site. The locations of the four sites were chosen to surround Tokyo Metropolitan Area to regularly monitor the unusual deformation in the area (Figure 1).

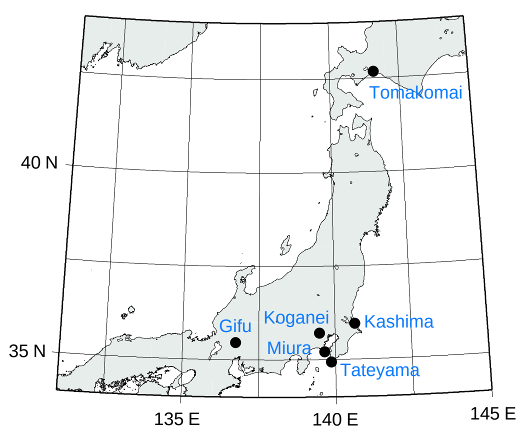

Figure 1. Geographic locations of four KSP VLBI stations and two stations at Tomakomai and Gifu.

Therefore, the primary objective of the KSP VLBI system was to determine precise site positions of the VLBI stations as frequently and fast as possible. To realize this objective, various new technical advancements were attempted and achieved. By automating the entire process from the observations to the data analysis and by developing the real-time VLBI system using the high-speed digital communication links, unattended continuous VLBI operations were made possible.

Daily continuous VLBI observations without human operations were actually demonstrated and the results of data analysis were made available to the public users immediately after each VLBI session. Improvements in the measurement accuracies were also accomplished by utilising fast slewing antennas and by developing higher data rate VLBI systems operating at 256 Mbps.

11-m antenna and other VLBI facilities at Miura and Tateyama stations have been transported to Tomakomai Experimental Forest of the Hokkaido University and to the campus of Gifu University, respectively. As a consequence, two 11-m stations at Kashima and Koganei (Figure 2) are remaining as IVS Network Stations. After the regular VLBI sessions with the Key Stone Project VLBI Network terminated in 2001, 11-m VLBI stations at Kashima and Koganei are mainly used for the purposes of technical developments and miscellaneous observations.


Figure 2. 11-m VLBI antennas at Kashima (left) and Koganei (right).

2. Activities in 2006

For technical developments, the baseline between Kashima and Koganei is now used as a test bed for real-time VLBI observations based on the Internet Protocol (IP). The two stations used to be connected by high-speed Asynchronous Transfer Mode (ATM) network in collaboration with the NTT Laboratories until July 2003. In April 2004, NICT started to operate the high-speed research test-bed network called JGNII and both the Kashima and Koganei stations are connected to the JGNII backbone with OC-192 (10 Gbps) connection. JGNII is a follow-on project of the JGN (Japan Gigabit Network) which was operated by the Telecommunications Advancement Organization of Japan (TAO) for 5 years from 1999. When TAO was merged with Communications Research Laboratory to establish NICT as a new institute, JGNII succeeded the JGN project. Whereas the JGN project was operated based on the ATM architecture, the new JGNII network mainly uses IP. One GbE (Gigabit Ethernet) interface is installed at Koganei station and two GbE interfaces are connected at Kashima station. This environment provides an ideal opportunity for e-VLBI research and developments.

In the year 2006, a geodetic VLBI test experiment was performed on March 17 and 18 for about 10 hours by using the newly developed multi-channel Giga-bit sampler units called ADS2000 [1]. By using the ADS2000 and the K5/VSI system, the 16 channels of data (10 for X-band and 6 for S-band) were recorded to the hard disks in the K5 system at the total data rate of 2048 Mbps. Each channel was sampled at the sampling rate of 64 Msps and the digitization level of 2 bits/sample. The observed data were processed by the K5 software correlator and then analysed with the CALC/SOLVE software. From this experiment, the baseline length was estimated with an RMS uncertainty of 1.3 mm and the performance of the system was confirmed.

Efforts to determine precise orbit of spacecrafts by means of differential VLBI observations were also continued from previous years. The S-band telemetry signal from the Geotail spacecraft was used to demonstrate precise orbit determination by means of differential VLBI observations. These efforts were initiated in 2003 with the requirements for precise orbit determination of spacecraft Nozomi and Hayabusa. Such efforts are still continuing with the hope of improving the technique for future space missions.

In 2006, the operating system for the Koganei KSP station was replaced with the fs9 software running on a Linux PC server. Since the operating system for the Kashima KSP station was also replaced with the fs9 software in 2004, both stations are now operated by using the fs9 software.

3. Staff Members

The 11-m antenna stations at Kashima and Koganei are operated and maintained by the Radio Astronomy Applications Group at Kashima Space Research Center, NICT. The staff members of the group are listed in Table 1. The operations and maintenance of the 11-m VLBI station at Koganei is also greatly supported by Space-Time Standards Group and Space Communications Group at Koganei Headquarters of NICT. We are especially thankful to Jun Amagai and Tadahiro Gotoh for their supports.

Table 1. Staff members of Space-Time Standards Group, KSRC, NICT.

Name	Main Responsibilities
Yasuhiro KOYAMA	Administration
Eiji KAWAI	Antenna System
Hiromitsu KUBOKI	Antenna System
Mamoru SEKIDO	Field System, Calibration and Frequency Standard Systems
Ryuichi ICHIKAWA	Meteorological Sensors, IGS Receivers
Masanori TSUTSUMI	System Engineer

4. Future Plans

In 2007, we plan to continue e-VLBI developments and differential VLBI observations to the spacecraft Geotail for the precise determination of its orbit. In addition to the VLBI observations and developments, there is a plan to use the 11-m antenna at Koganei to receive the downlink data from STEREO satellite.

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Kokee Park Geophysical Observatory

Kelly Kim

Abstract

This report summarizes the technical parameters and the staff of the VLBI system at Kokee Park on the Island of Kauai.

1. KPGO

Kokee Park Geophysical Observatory (KPGO) is located on the Island of Kauai in Hawaii and is located in Kokee State Park, hence its name. It is located at an elevation of 1100 meters near the Waimea Canyon, which is often referred to as the Grand Canyon of the Pacific.

Kokee Park Geophysical Observatory first participated in VLBI operations as part of the GAPE experiments in 1984. At that time the station was part of NASA's STDN (Satellite Tracking Data Network). The 9-m system was modified by installing a focal point receiver, hydrogen maser, data acquisition terminal, tape drive and computer system. This was operational for the summer of 1984. The system was removed after the GAPE '84 experiments and reinstalled again for the summer of 1985. It was not until 1986 that we became a continuous participant in VLBI operations.

In October 1989 NASA phased out the STDN operation on Kauai and the station was transferred to the Crustal Dynamics Project at the Goddard Space Flight Center. The station started weekly operation for the U.S. Naval Observatory as part of the NAVNET network.

Early in 1992 construction of USNO's present 20-meter antenna was started. The foundation work was completed in August 1992 and the structure was started in September just as Hurricane Iniki struck on September 11, 1992. Installation was completed in 1993 and first light was in June 1993. Later in 1993 the use of the 9-meter system was discontinued.

Starting in July 2000 Kokee Park began daily (Monday through Friday) participation in the Intensive schedule for USNO.

S2 recorder system was installed in 2000. Mark IV system was installed during 2001.

In May of 2002 Mario Bérubé and Bill Petrachenko arrived on site for installation and testing of an S2 DAS. We have since that time supported the E3 series of experiments on a monthly basis.

In May of 2002 Kokee Park received a Mark 5 system that was first run in parallel with the tape drive during the daily Intensive sessions (three times a week). Correlation was first done at Haystack; after several weeks of comparison we then started to ship the disk to USNO. During CONT02 the Mark 5 was used in stand alone mode. Switching between Intensive sessions and other experiments then became much simplified.

During November 2002 a survey team was on station to verify our antenna footprint and to survey the new (replacement) Doris beacon antenna.

A new MET package (MET3) was installed in February 2003.

In mid 2004 we started having problems with our Azimuth Gear Reducers. One was removed and shipped back to the manufacturer for refurbishment (this was found to be too expensive) so an additional unit was procured. The new Gear Reducer was finally received and installed in time for CONT05.

A new F.S. Computer was installed in 2005.

In 2006, use of the tape recorder ceased and we now use the Mark 5 for all VLBI supports with the exception of the Australian S2 supports, which run on their own system using VHS tapes.

Canadian S2 support ended late in 2006 due to Canadian government budget cuts leading to the demise of their program. Also this year, PRARE support ended when the equipment became no longer supportable due to lack of spares. We will miss both of these projects and wish those we have met working on these programs the very best in the future.

Late in 2006, we had problems with our primary (Sigma Tau) maser and have been using our backup (NASA NR-1) maser as our primary while awaiting parts to be procured for the Sigma Tau repair.

Figure 1. Kokee Park Geophysical Observatory 9m & 20m antennas.

Table 1. Location and Addresses of Kokee Park Geophysical Observatory.

Longitude	159.665° W
Latitude	22.126° N
Kokee Park Geophysical Observatory P.O. Box 538 Waimea, Hawaii 96796 USA	

2. Technical Parameters of the VLBI System at KPGO

The receiver is of NRAO (Green Bank) design (dual polarization feed using cooled 15 K HEMT amplifiers). The DAR rack and tape drive were supplied through Green Bank. The antenna is of the same design and manufacture as those used at Green Bank and Ny-Ålesund.

The technical parameters of the radio telescope are summarized in Table 2.

Timing and frequency is provided by a Sigma Tau Maser with a NASA NR Maser providing backup. Monitoring of the station frequency standard performance is provided by a CNS (GPS) Receiver/Computer system. The Sigma Tau performance is also monitored via the IGS Network.

Table 2. Technical parameters of the radio telescope at KPGO.

Parameter	Kokee Park
owner and operating agency	USNO-NASA
year of construction	1993
radio telescope system	Az-El
receiving feed	primary focus
diameter of main reflector d	$20m$
focal length f	$8.58m$
f/d	0.43
surface contour of reflector	$0.020 inches rms$
azimuth range	$0\ldots540^{\circ}$
azimuth velocity	$2^{\circ}/s$
azimuth acceleration	$1^{\circ}/s^2$
elevation range	$0\ldots90^{\circ}$
elevation velocity	$2^{\circ}/s$
elevation acceleration	$1^{\circ}/s^2$
X-band (reference $\nu = 8.4GHz, \lambda = 0.0357m$)	$8.1 - 8.9\,GHz$
T_{sys}	$40\,K$
$S_{SEFD}(CASA)$	$900\,Jy$
G/T	$45.05\,dB/K$
η	0.406
S-band (reference $\nu = 2.3GHz, \lambda = 0.1304m$)	$2.2 - 2.4GHz$
T_{sys}	$40\,K$
$S_{SEFD}(CASA)$	$665\,Jy$
G/T	$35.15\,dB/K$
η	0.539
VLBI terminal type	VLBA/VLBA4-Mark 5
Field System version	9.7.6

3. Staff of the VLBI System at KPGO

The staff at Kokee Park during calendar year 2006 consisted of five people who are employed by Honeywell International under contract to NASA for the operations and maintenance of the Observatory. Staffing was reduced in 2006 due to budget reductions. VLBI operations was conducted by Matt Harms and Kelly Kim. Ben Domingo does antenna maintenance with Amorita Apilado providing admin, logistical and numerous other support functions.

4. Status of KPGO

Kokee Park has participated in many VLBI experiments since 1984. We started observing with GAPE, continued with NEOS and CORE, and are now in IVS R4 and R1. We also participate in the RDV experiments.

We averaged 1.5 experiments per week during calendar year 2000 and increased to an average of 2 experiments of 24 hours each week with daily Intensive experiments during year 2002 and into 2006.

Kokee Park also hosts other geodetic measurement systems, including PRARE, a DORIS beacon, and a Turbo-Rogue GPS receiver. Kokee Park is an IGS station.

5. Outlook

We are looking at real time e-VLBI testing in early 2007 to see if our "last mile" connectivity issue can be resolved.

2007 will also be a year of rebuilding for the crew of KPGO as long time site manager Clyde Cox retired. We will be filling the staff vacancy and look forward to adding to the history of operational competency this site has provided in past years.

Figure 2. Kokee Park also hosts other systems; DORIS Beacon, PRARE, and IGS (GPS).

Matera CGS VLBI Station

Giuseppe Bianco, Giuseppe Colucci, Francesco Schiavone

Abstract

This report describes the status of the Matera VLBI station. Also an overview of the station, some technical characteristics of the system and staff addresses are given.

1. General

The Matera VLBI station is located at the Italian Space Agency's 'Centro di Geodesia Spaziale G. Colombo' (CGS) near Matera, a small town in the South of Italy. The CGS came into operation

Figure 1. The Matera "Centro di Geodesia Spaziale" (CGS).

in 1983 when a Satellite Laser Ranging SAO-1 System was installed at CGS. Fully integrated in the worldwide network, SAO-1 was in continuous operation from 1983 up to 2000, providing high precision ranging observations of several satellites. The new Matera Laser Ranging Observatory (MLRO), one of the most advanced Satellite and Lunar Laser Ranging facilities in the world, has been installed in 2002 and replaced the old SLR system. CGS hosted also mobile SLR systems MTLRS (Holland/Germany) and TLRS-1 (NASA).

In May 1990 the CGS extended its capabilities to Very Long Baseline Interferometry (VLBI) installing a 20-m radiotelescope. Since then, Matera performed 709 sessions up to December 2006.

In 1991 we started GPS activities, participating in the GIG 91 experiment installing in Matera a permanent GPS Rogue receiver. In 1994 six TurboRogue SNR 8100 receivers were purchased in order to create the Italian Space Agency GPS fiducial network (IGFN). At the moment 12 stations are part of the IGFN and all data from these stations, together with 24 other stations in Italy, are archived and made available by the CGS WWW server GeoDAF (http://geodaf.mt.asi.it).

Thanks to the co-location of all precise positioning space based techniques (VLBI, SLR, LLR and GPS), CGS is one of the few "fundamental" stations in the world. With the objective of exploiting the maximum integration in the field of Earth observations, in the late 1980s ASI extended CGS involvement also to remote sensing activities for present and future missions (ERS-1, ERS-2, X-SAR/SIR-C, SRTM, ENVISAT, COSMO-SkyMed).

2. Technical/Scientific Overview

The Matera VLBI antenna is a 20-meter dish with a Cassegrain configuration and AZ-EL mount. The AZ axis has ±270 degrees of available motion. The slewing velocity is 2 deg/sec for both AZ/EL axis.

The technical parameters of the Matera VLBI antenna are summarized in Table 1.

The Matera time and frequency system consists of three frequency sources (two Cesium beam and one H-maser standard) and three independent clock chains. The EFOS-8 H-maser from Oscilloquartz is used as a frequency source for VLBI.

The control computer is a SWT Pentium/233 PC running Linux and FS version 9.9.2.

Table 1. Matera VLBI Antenna Technical Specifications.

Input frequencies	S/X	2210−2450 MHz / 8180−8980 MHz
Noise temperature at dewar flange	S/X	<20 K
IF output frequencies	S/X	190−430 MHz / 100−900 MHz
IF Output Power (300 K at inp. flange)	S/X	0.0 dBm to +8.0 dBm
Gain compression	S/X	<1 dB at +8 dBm output level
Image rejection	S/X	>45 dB within the IF passband
Inter modulation products	S/X	At least 30 dB below each of 2 carriers at an IF output level of 0 dBm per carrier
T_{sys}	S/X	55/65 K
SEFD	S/X	800/900 Jy

3. Staff

The list of the VLBI staff members of Matera VLBI station is provided in Table 2.

Table 2. Matera VLBI staff members.

Name	Agency	Activity	E-Mail
Dr. Giuseppe Bianco	ASI	VLBI Manager	giuseppe.bianco@asi.it
Francesco Schiavone	Telespazio	Operations Manager	francesco.schiavone@telespazio.com
Giuseppe Colucci	Telespazio	VLBI contact	giuseppe.colucci@telespazio.com

4. Status

Due to unexpected difficulties in renewing the service contract between ASI and Telespazio, operations for 2006 started on February 1.

In 2006, 53 sessions were acquired. All sessions were acquired using Mark 5 only. Fig. 2 shows the total Acquisitions Summary per year, starting in 1990.

In 2004, in order to fix all the rail problems, a complete rail replacement was planned. In 2005, due to financial difficulties, it was instead decided to repair the concrete pedestal under the

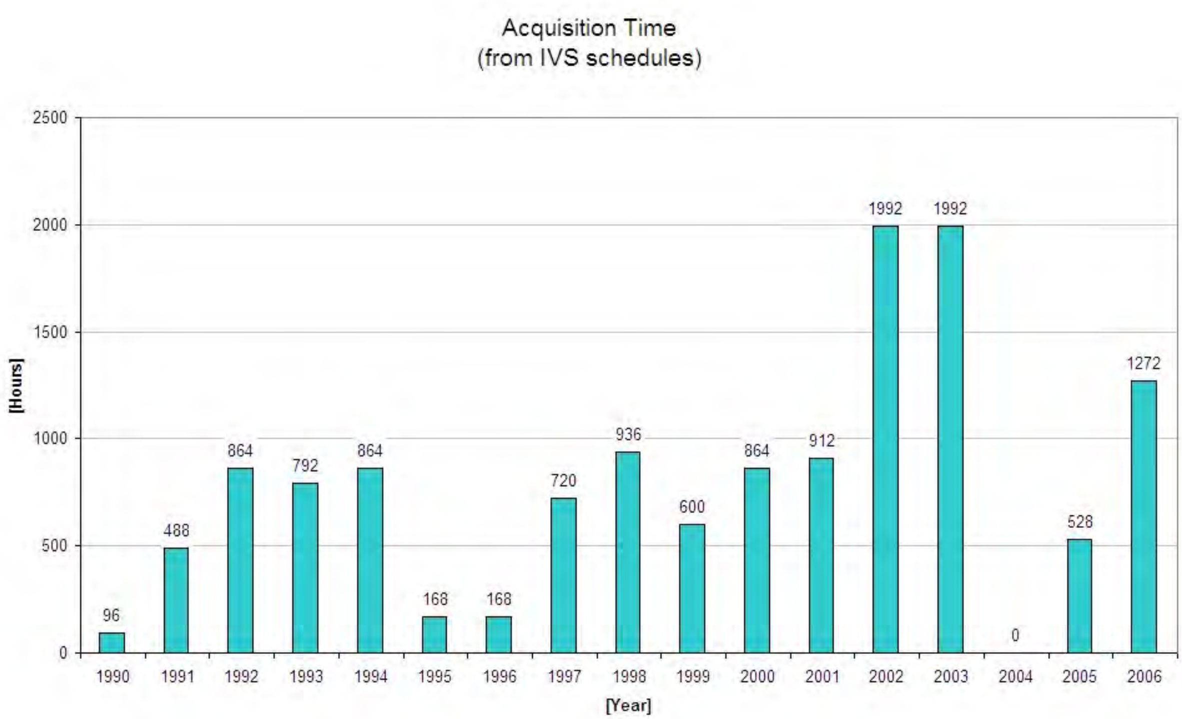

Figure 2. Acquisitions per year.

existing rail only. From then on, no rail movements have been noted [1]-[3].

5. Outlook

The plan is to continue to work on the rail. The goal is to replace it with a newly designed one and to replace at least 1 of the 4 azimuth wheels because of cracks on the surface.

Another goal is to replace the Antenna Control Unit and both Azimuth and Elevation encoders, because it is not possible to find spare parts for these components anymore.

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The Medicina Station Status Report

Alessandro Orfei, Andrea Orlati, Giuseppe Maccaferri, Franco Mantovani

Abstract

General information about the Medicina Radio Astronomy Station, the 32 m antenna status and the staff in charge for VLBI observations, are provided. In 2006 the data from geodetic VLBI observations were acquired using the Mark 5A recording system with good results. Updates of the hardware have been performed and are briefly described.

1. The Medicina 32 m Antenna. General Information

The Medicina 32 m antenna is located at the Medicina Radio Astronomy Station. The Station is run by the Istituto di Radioastronomia and is located about 33 km east of Bologna. The Consiglio Nazionale delle Ricerche (CNR) was the funding agency of the Istituto di Radioastronomia till the end of 2004. Since January 1st, 2005 the funding agency is the Istituto Nazionale di Astrofisica (INAF).

The antenna, inaugurated in 1983, regularly takes part in IVS observations since 1985 and is an element of the European VLBI network. A permanent GPS station, which is part of the IGS network, is installed in the vicinity. Another GPS system is installed close to the VLBI telescope (MSEL) and is part of the EUREF network.

2. Antenna Description

The Medicina antenna has Cassegrain optics, consisting of a primary mirror of 32 m in diameter, and a secondary mirror, called subreflector, of convex shape and about 3 m in diameter. The subreflector, mounted on a quadrupode, is placed opposite the primary mirror, and focuses the radio waves at its centre, where the receiver system is located. For some observing frequencies, a simplified optical system is enough. The subreflector is therefore shifted from its normal position, and the receiving system is placed at the primary focus: this is the case of the S/X observations. The antenna can operate in the range between 327 MHz and 22 GHz.

The receivers are cooled with cryogenic techniques to improve the system sensitivity. The antenna is flexible in changing the operative receiver: only few minutes are needed to change the observing frequency. A recent picture of the antenna is shown in Figure 1.

3. The Staff

Many scientists and technicians are taking care of the observations. However, there is a limited number of people that is dedicated to maintain and improve the reliability of the antenna during the observations: Alessandro Orfei is the Chief Engineer, expert in micro-wave receivers; Giuseppe Maccaferri is the Technician in charge of the telescope's backend; Andrea Orlati is the Software Engineer who takes care of the observing schedules and regularly implements SKED&DRUDG and the Field System.

Figure 1. View of the Medicina 32 m dish taken during geodetic VLBI observations. Note that the subreflector is shifted to allow the use of the S/X receiver located in the primary focus of the radio telescope.

4. Current Status and Activities

During 2006 the Field System version 9.9.0 was installed. The Mark 5A recording system works fine. Almost all observations are made by using hard disks. New disk frames for a storage capacity of 22.5 TB are available for geodetic observations.

4.1. Optic Fiber Link

The Institute of Radioastronomy, the Emilia-Romagna Regional Government and GARR (Italian Academic and Research Network) have signed an agreement under which the Regional Government provides a fiber optical link at 1 Gb/s between the Medicina Station and the GARR backbone in Bologna. The connection is now available. In 2006 Medicina participated to many e-VLBI tests and experiments. At the moment, the whole link is not supporting the maximum rate, mainly due to the long connection to Bologna. EVN will perform many tests to routinely transfer observations using this data link. When a direct connection Bologna-Medicina will be available much more than 256Mb/s will be reliably supported.

5. Geodetic VLBI Observations

During 2006, the Medicina 32 m dish took part in 24 geodetic VLBI sessions, namely 1 IVS-T2, 13 IVS-R4 and 6 EUROPE, 3 VLBA and 1 R&D experiments.

VERA Geodetic Activities

Seiji Manabe, Takaaki Jike, Yoshiaki Tamura, VERA group

Abstract

A general description of VERA is given from the standpoint of geodetic interest. Geodetic observations with VERA started in late 2002 and have been done routinely since late 2004. The frequency of regular observations are three times a month, that is, twice for VERA internal observations and once for participation in JADE of GSI. In 2006, alternating observations in S/X- and K-bands started in order to investigate the feasibility of observations in K-band. The results in 2006 show that precision of observations in K-band is twice as good as those of the S/X-band observations and there is no significant discrepancy between the S/X- and K-band observations when comparing day-to-day fluctuations. However, more observations are necessary to arrive at a final conclusion, such as the replacement of the S/X-band observations by the K-band observations. Future plans for 2007 are also described.

1. General Description

VERA is a Japanese domestic VLBI network consisting of Mizusawa, Iriki, Ogasawara and Ishigakijima stations. Each station is equipped with a 20m radio telescope and a VLBI backend. The Mizusawa antenna is shown in Figure 1. The VERA array is controlled from the Array Operation Center at Mizusawa via Internet.

The primary scientific goal of VERA is to reveal structure and dynamics of our Galaxy by determinig 3-dimensional force field and mass distribution. Galactic maser sources are used as dynamical probes, positions and velocities of which can be precisely determined by phase referenced VLBI relative to extragalactic radio sources. The distance is measured as a classical annual trigonometric parallax. Observing frequency bands of VERA are S and X, K (22 GHz) and Q (43 GHz). Geodetic observations are made in S/X- and K-bands; Q-band is currently not used. Only a single beam is used (even in K-band) in geodetic observations, although VERA can observe two closely separated ($0.2^\circ <$ separation angle $< 2.2^\circ$) radio sources simultaneously by using the dual beam platforms.

General information about the VERA stations is summarized in Table 1 and the geographic locations are shown in Figure 2. Lengths of baselines range from 1000 km to 2272 km. The skyline at Ogasawara station ranges from 7° to 18°, because it is located at the bottom of an old volcanic crater. The north-east sky at Ishigakijima station is blocked by a near-by high mountain. However, most part of the skyline is below 9°. The skylines at Mizusawa and Iriki are low enough to observe sources with low elevation. Since Ogasawara and Ishigakijima are small islands in the open sea and their climate is subtropical, the humidity in summer is very high. This brings about high system temperature in summer, in particular in K and Q bands. These stations as well as Iriki station are frequently attacked by strong typhoons. The wind speed sometimes reaches 60–70 m/s.

2. Technical Parameters

Parameters of the antennas and front- and back-ends are summarized in Tables 2 and 3, respectively. The helical array antenna on one of the dual-beam platforms is shown in Figure 3. Two observation modes are used for geodetic observations. One is the VERA internal observation. The observing frequency bands are S/X and K and the recording rate is 1 Gbps. The other is the

Figure 1. Mizusawa VERA antenna (foreground)

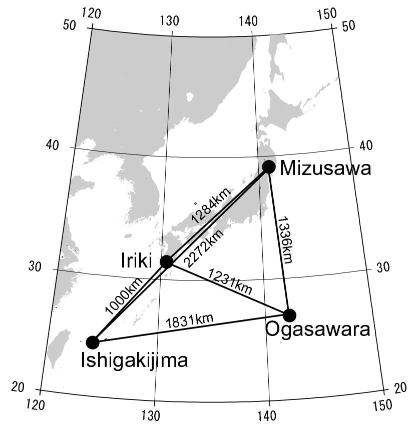

Figure 2. Location of VERA stations

Table 1. General information

Sponsoring agency	Mizusawa VERA Observatory, National Astronomical Observatory of Japan	
Contributing type	Network observing station	
Location	Mizusawa	141° 07' 57".199E, 39° 08' 00".726N, 75.7m(a.s.l.)
	Iriki	130° 26' 23".593E, 31° 44' 52".437N, 541.6m(a.s.l.)
	Ogasawara	142° 12' 59".809E, 27° 05' 30".487N, 223.0m(a.s.l.)
	Ishigakijima	124° 10' 15".578E, 24° 24' 43".834N, 38.5m(a.s.l.)

joint observation with the Geographic Survey Institute (GSI) by Mizusawa's participation in GSI's domestic observation sessions called JADE. Its frequency band is S/X and the recording rate is 128 Mbps. A K5-VSSP data aquisition terminal is used.

3. Staff Members

The VERA team of NAOJ is led by Hideyuki Kobayashi and consists of 9 scientists, 10 technicians and 4 post-docs. Among them the members of the geodesy group are S. Manabe (chief, scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician). The AOC is operated by VERA members independent of geodetic or astronomical staffing.

4. Current Status

VERA observes 6 days a week, except for a maintenance period in summer. Geodetic observations have been regularly scheduled 3 days a month since late 2004. VERA internal geodetic observations are performed twice a month and the monthly participation of Mizusawa in JADE with GSI is done on a once per month basis. The purpose of the JADE participation is to obtain VERA's coordinates in the terrestrial reference frame realized by the IVS. S/X- and K-band observations are alternately made within a framework of the VERA internal observations. The reason for the K-band observation is to avoid the strong radio interference by cellular phone in S-band,

Table 2. Antenna parameters

Diameter	20m		
Mount	Azimuth–Elevation		
Surface accuracy	0.2mm(rms)		
Pointing acccuracy	<12h(rms)		
	S	X	K
HPBW	1550"	400"	150"
Aperture efficiency	0.25	0.4	0.47
Slew	Azimuth	Elevation	
range	-90°–450°	5°–85°	
speed	2°.1/sec	2°.1/sec^2	
acceleration	2°.1/sec^2	2°.1/sec^2	

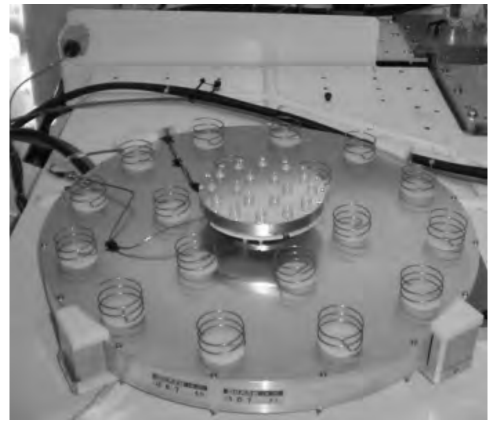

Figure 3. Helical array
Large and small disks are for S- and X-bands, respectively.

Table 3. Front-end and back-end parameters

Front-end					
Frequency band	Frequency range(GHz)	Receiver temperature	Polarization	Receiver type	Feed
S	2.18–2.36	100°K	RHC	HEMT	Helical array
X	8.18–8.60	100°K	RHC	HEMT	Helical array
K	21.5–24.5	39±8°K	LHC	HEMT(cooled)	Horn
Back-end					
Type	channels	BW/channel	Filter	Recorder	Deployed station
VERA	16	16MHz	Digital	DIR2000	4 VERA
K5-VSSP	16	4MHz	VC	HDD	Miuzsawa

particularly at Mizusawa. An interfering signal, which has line spectra, is filtered out. However, this filtering considerably degrades the system noise temperature. It is likely that the S-band observing becomes impossible in the near future. Experimental K-band observations are made in order to clarify how accuracy is improved by taking advantage of relatively high sensitivity and no interference in K-band. However, since the K-band observation uses only a single frequency band, there is the possibility that the effect of the ionosphere is considerably large even for a small network such as VERA. Besides this possibility, there might be unknown systematic differences between the conventional S/X-band and K-band observations.

The number of scans in S/X-bands is typically 500/station/24hours, while that in K-band is 800 thanks to the high sensitivity in this band. The precision of the site topocentric coordinates in the S/X-bands are 1–2 mm and 7–9 mm for the horizontal and vertical components, respectively. Those of the K-band observations are <1mm and 5mm. The error ellipsoid is strongly elongated in the vertical direction due to the insufficient network size for separating the vertical displacement from the atmospheric zenith delay variation. There seems to be no significant systematic difference in the estimated coordinates between S/X and K-bands. This means that the most part of the ionospheric effect can be eliminated in the course of estimating the tropospheric delay, at least for the VERA network whose typical size is around 2000 km. However, the number of observations is not enough to derive a definite conclusion.

VERA has a fifth DIR2000 besides the four at the VERA stations for recording purposes at Mitaka correlation center. This recorder is used to record data sent from Tsukuba 32m antenna linked to the Mitaka correlation center via optical fiber network. There were a few experiments where Tsukuba was treated as if it were the fifth VERA station. The experiments were successful. However, final comparison with JADE is not yet complete.

The raw data are correlated by Mitaka FX Correlator that has 5-station capability. Final results for the geodetic parameters are derived by using the software developed by VERA team.

A LaCoste-Romberg gravimeter was installed at Ishigakijima station in spring of 2006 in order to precisely determine the tidal characteristics of Ishigakijima station. The provisional result seems to indicate that there is no large discrepancy in the tidal amplitude and phase between the observation and the model calculation based on the latest ocean tide model, NAO.99Jb (Matsumoto et al., 2000 [1]).

5. Plans for 2007

Regular geodetic observations will be continued with the same frequencies as those in 2006. The S/X- and K-band observations will be alternately made until it becomes clear whether the K-band can replace the S/X-band or not. The participation in JADE will also be continued. Joint observations with the 11m telescope of Gifu University is planned to start in the spring. The Gifu telescope was formerly equipped with an S/X-band receiver. Last year the S/X-receiver was replaced by a K-band receiver. The telescope is linked to Mitaka via optical fiber and it is possible to record Gifu data by using a DIR2000 1Gbps recorder at Mitaka. Gifu is expected to join regularly the VERA internal observations in K-band and will be able to be regarded as the fifth station of VERA at least for geodetic purposes. Experimental observations with Tsukuba in the same mode will also be made. However, since VERA can only record 5-station data simultaneously, it is not possible to have both stations participate at the same time.

Gravimetric observations by LaCoste-Romberg gravimeter will continue at Ishigakijima in order to clarify tidal characteristics there. Three more LaCoste-Romberg gravimeters will be deployed in Iriki, Ogasawara and Mizusawa.

Plans other than observations are improvement of software, such as model update and GUI, and improvement and automization of data analyses.

References

[1] Matsumoto, K., Takanezawa, T. and Ooe, M.:2000, Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: a global model and a regional model around Japan, Journal of Oceanography, 56,567-581.

Noto Station Status Report

G. Tuccari

Abstract

The observing activity in Noto is again fully operational after a serious failure in the antenna drive system. Fringes have been found in all the testing experiments, proving the normal status. This brief report summarizes the main activities in 2006.

1. Activity Plan

An organization chart was established with a new structure of the Noto Section personnel. It includes a revised organization in all the activities including operations, logistics and ordinary maintenance, in particular operations like the introduction of new receivers, the renewing of the antenna driving software, the implementation of new software dedicated to single dish measurements. As soon as funds will be available the remaking of the grout and azimuth rail will be realized. Better performance is expected in terms of tracking and pointing precision.

2. Receivers and Microwave Technology

The new SX receiver has not been installed yet and a revision is considered in order to decrease the weight and to simplify the operations of receiver changes in the primary focus of the antenna. A further variation could come from the digitization of the received bands with the sampling stage realized in the receiver area. This digital receiver would produce a digital stream to be transferred through optical fibres to the backend. The date of installation is not yet decided.

3. Acquisition Terminal and Digital Technology

A large number of disk packs was acquired in 2006 with a total amount of 100 TB for both astronomy and geodesy. The Mark 5B interface to upgrade the recorder from the Mark 5A is available and it will be installed as soon as this will be supported on the correlation side.

The DBBC (digital baseband converter) development group was fully operative and complete units have been produced. Three units are under construction for the geodetic stations of Wettzell, Tigo and O'Higgins. Using this digital backend, tuning configurations are possible, allowing for multi-channel solutions the geodetic community is poised to use. At present, the main functionality of a 64 channel system is ready to be used for testing in the radiotelescopes, and observations have been regularly performed between Noto and Medicina. A small hardware version has been used in the so-called 'EVN Aspiring Stations' (Evpatoria in Ukraine and Irbene in Latvia) for testing the antenna and VLBI equipment performance. The Field System support to the DBBC is simplified by commands already defined in FS style. A complete EVN-PC has been kindly sent to Noto by the Metsahovi group for testing functionalities with the VSI interfaces. The maximum DBBC data rate with 2 VSI connectors is 4.096 Gbps for up to 64 tunable channels of 32-16-8-4-2-1-0.5 MHz bandwidth. For bandwidths of 64, 128, 256, 512 MHz, the maximum data rate is 8.192 Gbps. Four input analog bands are in the range 1-512, 512-1024,1024-1536,1536-2048 MHz. An upgraded version of DBBC is under development that will feature additional input bands up to 3.5 GHz and a bidirectional 10 Gbps connection.

4. Geodetic Experiments in Noto during 2006

In 2006 the Noto radiotelescope participated in the following scheduled geodetic experiments: EUROPE-85, T2049, EUROPE-86, CRF44, EUROPE-87, EUROPE-88, CRF46, EUROPE-89, and EUROPE-90.

Ny-Ålesund 20 Metre Antenna

Helge Digre

Abstract

For the year 2006, the 20-meter VLBI antenna at the Geodetic Observatory, Ny-Ålesund has participated in VLBI experiments at the scheduled level. Ny-Ålesund also participated in a test of e-VLBI, transferring experiment data from Ny-Ålesund to Haystack. In December, Ny-Ålesund also participated in 3 e-VLBI Intensives. In 2006, Ny-Ålesund felt the consequences of the reduction in maintenance and the lack of operator presence, both caused by the reduction in staff that came as a result of the general reduction in the Norwegian Mapping Authority's (NMA) budgets. For 2006, Ny-Ålesund was a one-person-only station until July 2006. In July 2006 a second operator, Jan-Ivar Tangen, was employed and started his training. Sick-leave from mid-September to the end of November again forced the observatory to operate as a one-manned station. Maintenance and repair have been done at a minimum level, given the personnel situation. No alarms are signed for and no errors are corrected during unmanned operation.

1. General Information

The Geodetic Observatory of the Norwegian Mapping Authority (NMA) at 78.9 N and 11.87 W is located in Ny-Ålesund, in Kings Bay at the west side of the island of Spitsbergen, the biggest island in the Svalbard archipelago. In 2006, Ny-Ålesund was scheduled for 67 VLBI experiments within R1, EURO, RD and RDV. In addition, R4212, R5251, I06354, I06355 and I06356 were done as extras. For 2006, Ny-Ålesund was moved from running weekly R4s to weekly R1s. Nine experiments were cancelled because of systems being down. For the same reason, one experiment ran only 13 hours. Four experiments lost up to 15 hours observing time due to alarms during unmanned operation. Two experiments were ended early and up to 6 hours observing time was lost because of installation of e-VLBI equipment. Some 360 ° turns caused loss of observations because the Ny-Ålesund config-file was not updated after testing and repairing the azimuth hardware end-switches before CONT05. Most of this lost observation time was caused by lack of maintenance and reduction of personnel. In addition to the 20-meter VLBI antenna, the Geodetic Observatory has two GPS antennas in the IGS system and a Super Conducting Gravimeter in the Global Geodynamics Project (GGP) installed on the site. There is also a CHAMP GPS and a SATREF (dGPS) installation at the station. In October 2004 a GISTM (GPS Ionospheric Scintillation and TEC Monitor) receiver was installed at the Statens Kartverk structure in the context of ISACCO, an Italian research project on ionospheric scintillation observations, led by Giorgiana De Franceschi of the Italian Institute of Volcanology and Geophysics (INGV).

2. Component Description

The antenna is intended for geodetic use, and is designed for receiving in S- and X- band. The equipment is Mark 5. The station configuration file can be found on the IVS web site: ftp://ivscc.gsfc.nasa.gov/pub/config/ns/nyales.config. Ny-Ålesund is located so far north that it has daytime aurora in winter and midnight sun from 20th of April to 27th of August. The location of the antenna enables signal reception over the North Pole. In 1998, Ny-Ålesund was the only antenna that could receive signals from the Mars Global Surveyor for 24 hours.

3. Staff

Table 1. Staff related to VLBI operations at Ny-Ålesund.

Hønefoss:	Section manager:	Rune I. Hanssen
	Station responsible at Hønefoss:	Svein Rekkedal
Ny-Ålesund:	Station commander:	Leif Morten Tangen[1] / Helge Digre
	Engineer	Jan-Ivar Tangen (since July 3)

There has been no participation at VLBI meetings by any of the staff in Ny-Ålesund.

4. Current Status and Activities

Ny-Ålesund has tried to participate in VLBI experiments at the scheduled level, and has done so, mostly as a tag-along station. Ny-Ålesund is a Mark 5A only station. Both the FS and Mark 5 were upgraded to the latest software versions. Two new FS computers were bought last year. Still some modifications and testing have to be done before they can be used permanently for experiments. Two new communication cards have recently been ordered. A direct high-speed data link from Ny-Ålesund Geodetic Observatory to MIT Haystack has been tested from January to August. The high-speed data link was supposed to be able to transfer 100 Mbps. Technical problems for the supplier on Svalbard for the link from Ny-Ålesund to Longyearbyen has reduced the maximum capacity to 85 Mbps in the test period. The Ny-Ålesund high-speed data-link project is a cooperative effort between UNINETT, NORDUnet, NASA Goddard Space Flight Center, MIT Haystack Observatory and NMA. The responsible person at NMA is Rune I. Hanssen.

The Super Conducting Gravimeter (SCG) (placed on the same fundament as IGS-GPS NYA1), has been running without problems. The yearly service on the system was performed by Professor Tadahiro Sato and Dr. Yoshiaki Tamura in the middle of August. National Astronomical Observatory of Japan, Mizusawa VERA Observatory, who owns the SCG, will lend this equipment to NMA from 2007.04.01, to keep the recording of the data going. The Geodetic Observatory, Ny-Ålesund, operated as a one-manned, Mark 5 only, station in the first half of 2006. The second half of 2006 was meant to be a two-manned station, but because of sick leave from mid-September to the end of November, it was operated by only one man.

5. Future Plans

Ny-Ålesund will continue to participate in the experiments the antenna is scheduled for, and will try to do as many experiments as possible, given the maintenance and personnel situation at the station.

NMA will hire a third person for Ny-Ålesund in 2007, and we hope to have 3 persons early in 2007. Until then, the experiments will continue to run unmanned during nights.

The tests with e-VLBI will continue, most likely with main interest on Intensives. The new Field

[1] Leif Morten Tangen is on leave of absence from 2006.11.01 until 2008.03.01.

System computers will hopefully be set to permanent use early next year. National Astronomical Observatory of Japan—Mizusawa VERA Observatory—will lend Norwegian Mapping Authority their superconducting gravimeter (already installed at Ny-Ålesund) from 01.04.2007 onward, so the scientific measuring series will continue.

German Antarctic Receiving Station (GARS) O'Higgins

Wolfgang Schlüter, Christian Plötz, Reiner Wojdziak, Andreas Reinhold

Abstract

In 2006 the German Antarctic Receiving Station (GARS) in O'Higgins contributed to the IVS observing program with 8 observation sessions. Mark 5A systems replaced the tape drive systems. Control software and hardware was improved towards observing remotely. A local survey was carried out to determine the local ties and the telescope axes. A radar tide gauge was set up for testing.

1. General Information

The German Antarctic Receiving Station (GARS) is jointly operated by the Federal Agency of Cartography and Geodesy (BKG) and the German Aerospace Center (DLR). The Institute for Antarctic Research Chile (INACH) coordinated the preparatory activities and logistics prior to a campaign. The 9m radiotelescope at O'Higgins is used for geodetic VLBI and for downloading remote sensing images from satellites. The access to the station is organized campaignwise during the Antarctic spring and summer. In 2006 the station was occupied from January to March and from October to December. DLR and BKG jointly sent engineers and operators for the campaigns together with a team which maintained the infrastructure such as the provision of power etc.

Over the last years, special flights with "Hercules"-aircrafts and small TwinOtters-aircrafts were organized by INACH in close collaboration with the Chilean Army, Navy and Airforce in order to transport the staff, the technical material and also the food for the entire campaign from Punta Arenas via station Frei on King George Island to the station O'Higgins on the Antarctic Peninsula. Only a few times, the staff and material were transported by ship to O'Higgins. Due to the fact that the conditions for landing on the glacier became unpredictable, requiring a lot of security precautions, the employment of ships for transportation to O'Higgins became more and more important. As a consequence of the global warming, the glacier was melting. During the summer period, landing with TwinOtters airplanes became impossible. Arrival time and departure time was strongly dependent on the weather conditions and on the general logistics. Today more time to travel from Punta Arenas to O'Higgins has to be considered.

After the long Antarctic winter usually the equipment at the station has to be initialized; damages, which result from the strong winter period, have to be identified and repaired. Shipment of spare parts or material for upgrades from Germany needs careful preparation in advance.

In co-location with the 9m radiotelescope for VLBI

- two GPS receivers are operated in the frame of IGS all over the year, an Alan Osborn ACT (OHI2), which has a long and stable history and a JAVAD receiver (OHI3) for GPS and GLONASS tracking.
- a tide gauge is installed, which has been operating for several years with some interruptions caused by destroyed cables from the scratching ice on the rocks.
- a meteorological station providing pressure, temperature and humidity and wind information, as long as the extreme conditions outside did not disturb the sensors.

- an H-Maser, an atomic Cs-clock, a GPS time receiver and a Total Accurate Clock (TAC) are employed for the provision of the time and frequency.

The 9m radiotelescope is designed for dual purpose: for performing geodetic VLBI and for receiving the remote sensing data from ERS 2, JERS and ENVISAT and in future from TerraSAR-X. Different antenna tracking modes and different receivers have to be activated depending on the application.

Figure 1. View to GARS O'Higgins

2. Technical Staff

The staff members for operating, maintaining and improving the GARS VLBI component and the geodetic devices are summarized in Table 1.

Table 1. Staff – members

Name	Affiliation	Function	Working for
Christian Plötz	BKG/FESG	electronic engineer	O'Higgins (responsible), RTW
Reiner Wojdiak	BKG	software engineer	O'Higgins, IVS Data Center Leipzig
Andreas Reinhold	BKG	geodesist	O'Higgins, BKG-Leipzig

3. Observations in 2006

During the Antarctic summer campaign (January-March 2006) and during the Antarctic spring campaign (October-December 2006) GARS participated in the following sessions of the IVS observing program:

- 4 sessions during the period January - February (OHIG42, T2043, OHIG43, OHIG44)
- 4 sessions during the period October- December (OHIG45, OHIG46, OHIG47, T2047)

The observations were recorded on disks with Mark 5A. The data were shipped from O'Higgins to Punta Arenas with the earliest possibility after they were recorded. From Punta Arenas, the disks were shipped by regular air transports to the correlator.

4. Maintenance

The extreme conditions in the Antarctic require special maintenance and repair of the GARS telescope and of the infrastructure. The effect of corrosion, problems with connectors and capacitors need to be detected; the H-Maser has to be set up into its operation mode as soon as the operators arrive. The antenna, S/X-band receiver and the data acquisition system has to be activated properly. Those components, which were damaged during the previous campaign, usually were replaced. Work to maintain the containers had been started in 2005 and was finalized in 2006. This concerned the installation of a new roof and new windows, as well as the extension of the air conditioning system.

5. Technical Improvements

At the beginning of the campaign 2006 the rack with the tape drive was removed. As the Mark 5 system was implemented in 2005, the complete tape drive rack became obsolete. As already reported, in 2005 the Antenna Control Unit (ACU) was replaced by a complete new system built by VERTEX. Due to some inconsistencies in the operations, it was decided to employ the old ACU for the observations in order to avoid failures during the VLBI experiments. Final testing of the new ACU is planned for the first campaign in 2007. At the beginning of the campaign in 2006, the fieldsystem was upgraded to Version 9.7.7.

6. Miscellaneous

A new local survey was carried out during the first campaign in the period from January to March 2006 in order to control the local ties and to confirm the intersection of the antenna axes. A radar tide gauge was tested to investigate features for a permanent installation. The radar tide gauge will be imployed for the calibration of the exisitng tide gauge.

7. Upgrade Plans for 2007

For 2007 it is planned to expand the observing capabilities, in particular by extending the period of observations by employing the remote control facilities. Such an upgrade will become possible in close collaboration with DLR. The Internet capabilities will be improved at least by a factor of two (256kbps), but with respect to the upcoming remote sensing missions 30Mbps links might become reality. The upgrade to Mark 5B is also planned for 2007.

The IVS Network Station Onsala Space Observatory

Rüdiger Haas, Gunnar Elgered

Abstract

This report shortly summarizes the status of the Onsala Space Observatory in its function as an IVS Network Station. We describe the activities during the year 2006, the current status, and future plans.

1. Staff Associated with the IVS Network Station at Onsala

The staff associated with the IVS Network Station at Onsala remained mainly the same as reported in the IVS Annual Report 2005 [1]. However, two Ph.D. students left the observatory during the year.

Table 1. Staff associated with the IVS Network Station at Onsala. The complete telephone numbers start with the prefix +46-31-772.

Function	Name	e-mail	telephone
Responsible P.I.s	Rüdiger Haas	rudiger.haas@chalmers.se	5530
	Gunnar Elgered	kge@oso.chalmers.se	5565
Observatory director	Hans Olofsson	hans.olofsson@chalmers.se	5520
Ph.D. students involved in VLBI observation	Sten Bergstrand (until 2006.02.28)	sten@oso.chalmers.se	5566
	Camilla Granström (until 2006.05.31)	camilla@oso.chalmers.se	5566
	Martin Lidberg	lidberg@oso.chalmers.se	5578
	Tobias Nilsson	tobias@oso.chalmers.se	5575
Field system responsibles	Biörn Nilsson	biorn@oso.chalmers.se	5557
	Michael Lindqvist	michael@oso.chalmers.se	5508
VLBI equipment responsibles	Karl-Åke Johansson	kaj@oso.chalmers.se	5571
	Leif Helldner	helldner@oso.chalmers.se	5576
VLBI operators	Roger Hammargren	roger@oso.chalmers.se	5551
	Fredrik Blomqvist	blomqvist@oso.chalmers.se	5552
Telescope scientists	Lars EB Johansson	leb@oso.chalmers.se	5564
	Lars Lundahl	lundahl@oso.chalmers.se	5559

2. Geodetic VLBI Observations during 2006

In 2006 the observatory was involved in the five VLBI-experiment series EUROPE, R1, T2, RDV, and RD06. Initially, 26 experiments were planned for 2006. The first two experiments in 2006 were lost due to problems with the telescope drives. We therefore agreed to compensate for this by observing two additional experiments. One other experiment in the summer was lost again due to telescope problems. In the summer of 2006, the Onsala Program Committee agreed to a request by IVS to observe 10 additional R1-experiments during the autumn of 2006 as a replacement for the closed Gilcreek station. In total, Onsala participated successfully in 35 geodetic VLBI experiments during 2006 (see Table 2). All experiments were recorded on Mark 5 disc modules, and some of the data were transferred via optical fiber to the Bonn correlator.

Table 2. Geodetic VLBI experiments at the Onsala Space Observatory during 2006.

Exper.	Date	Remarks (problems)	Exper.	Date	Remarks (problems)
EURO-79	01.24	lost, telescope problems	EURO-83	09.04	o.k.
RD06-01	01.25	lost, telescope problems	R1-241	09.11	5 scans lost
T2-043	02.07	o.k., 2 scans lost	R1-242	09.18	o.k.
R1-211	02.13	o.k., ca 5 scans lost	RD06-07	09.19	no corr. rep. yet
R1-216	03.20	o.k., 4 scans lost	R1-243	09.25	5 scans lost
EURO-80	03.21	o.k., 3 scans lost	R1-244	10.02	1 scan lost
RD06-02	03.29	o.k., 10 scans lost	RD06-08	10.04	no corr. rep. yet
R1-218	04.03	o.k., 40 scans lost	R1-245	10.09	warm RX, cooling during exp.
RDV-56	04.25	o.k., 3 scans lost	R1-247	10.23	2 scans lost
RD06-03	04.26	o.k., 7 scans lost	R1-249	11.06	o.k.
EURO-81	05.29	o.k., 1 scan lost	R1-250	11.13	o.k.
RD06-04	06.28	o.k., 3 scans lost	EURO-84	11.14	o.k., 1 scan lost, e-VLBI to Bonn
EURO-82	07.03	o.k., 40% of scans lost	RD06-09	11.15	no corr. rep. yet
R1-233	07.17	ca 15 scans lost	R1-253	12.04	o.k.
RD06-05	07.19	9 scans lost	T2-048	12-05	2 scans lost, no corr. rep. yet
R1-235	07.31	16 scans lost	RDV-60	12.06	o.k.
R1-236	08.07	16 scans lost	R1-254	12.11	1 scan lost
RD06-06	08.23	lost, telescope problems	RD06-10	12.12	no corr. rep. yet
RDV-58	08.30	15 scans lost	R1-255	12.18	o.k., 2.5 hours lost, e-VLBI to Bonn

The previously reported problems with the azimuth encoders [1], [2] continued unfortunately also partly during 2006. Three experiments were completely lost due to telescope problems, and during most experiments between 1-15 scans were lost, see Table 2. Communication problems between the field system and the telescope computer caused data loss of about 2.5 hours in the R1-255 experiment.

The new antenna control system was finalized in 2006 and installed in the second half of the year. The new system appears to reduce the number of lost scans and the ongoing fine-tuning of the system is expected to avoid telescope problems in the future.

Also in 2006 radio interference in S-band, due to UMTS mobile telephone signals was a disturbing factor.

3. Geodetic e-VLBI Activities during 2006

In the second half of 2006 we started with network connection tests to the Bonn correlator.

A first e-VLBI data transfer to Bonn was performed in November with the EURO-84 data. The EGAE software [3] was used and 30 minute average values of the achieved data rates are shown in the left graph in Figure 1. Since the EGAE software does read first from the Mark 5 module to the system hard-disk and then transfers the data with bbftp [4], the shown average values are significantly lower than the actually achieved data rates for the transfer Onsala to Bonn. Data rates of up to 100 Mbit/s were achieved in this test.

In December we did a first test to use our PCEVN-computer [5] for the data transfer of geodetic

VLBI experiments. Parts of the R1-255 experiment were recorded on the PCEVN-computer that was daisy-chained to the Mark 5 computer. After the R1-255 experiment the data were transferred with the tsunami-protocol [6] to the Bonn correlator. Data rates of more than 600 Mbit/s were achieved, see right graph in Figure 1.

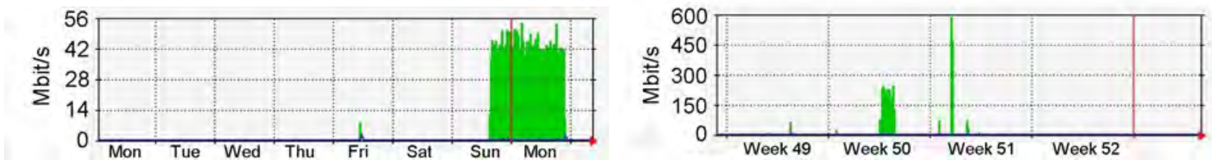

Figure 1. Left: EURO-84 e-VLBI data transfer from Onsala to Bonn using the EGAE software. Shown are 30 minute average values. The actually achieved data rates were on the order of 100 Mbit/s. Right: R1-255 e-VLBI data transfer (week 51) from Onsala to Bonn using the PCEVN and the tsunami-protocol. Shown are 2 hour average values and the achieved data rates were on the order of 600 Mbit/s. (The data transfer in week 50 was a regular real-time e-VLBI experiment with the EVN.)

4. Monitoring Activities

We continued also in 2006 to monitor the vertical height changes of the telescope tower with the invar monitoring system [7], [8]. Figure 2 shows mean temperature (left) and vertical height variation (right) of the telescope tower since 1996. Mean temperature and vertical height change are highly correlated and the annual vertical height variation is roughly 3 mm peak-to-peak.

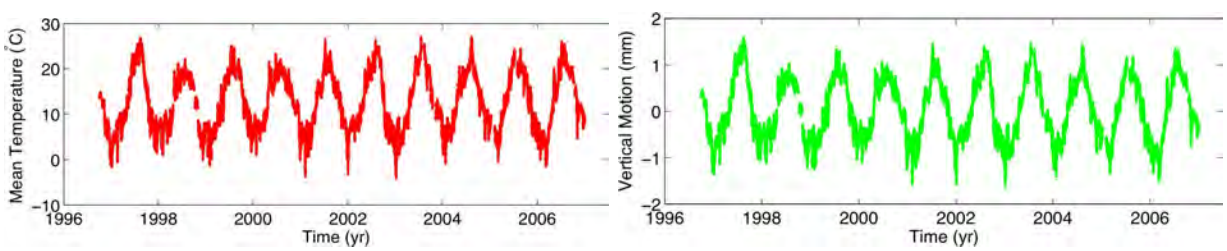

Figure 2. Left: time series of mean temperature of the telescope tower. Right: time series of relative vertical height of the telescope tower measured with the invar monitoring system.

The calibration campaign for the Onsala pressure sensor has continued [7]. We do parallel manually recordings with a Vaisala barometer that we borrow from the Swedish Meteorological and Hydrological Institute (SMHI), and the Onsala barometer (Setra Systems) that is used for VLBI. The SMHI barometer is calibrated every year at the SMHI headquarters.

Figure 3 shows the time series of pressure differences (a) and the corresponding amplitude spectrum (b). The amplitude spectrum reveals a clear annual signal with an amplitude of almost 0.18 hPa. We suspect that it is related to temperature influences on one or both pressure sensors.

A microwave radiometer is operated at the observatory to monitor the atmospheric water vapor content. However, during 2006 the instrument was in maintenance for large parts of the year.

The observatory hosts a gravimeter platform, which is used for repeated absolute gravity mea-

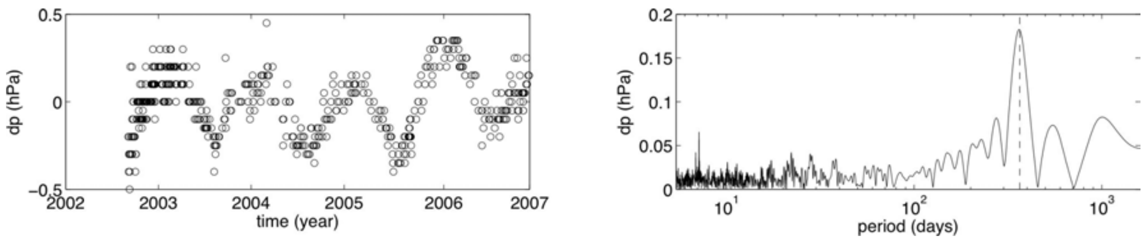

Figure 3. Left: time series of pressure differences Vaisala - Setra. Right: corresponding amplitude spectrum of the pressure differences. The annual period is indicated with a vertical dotted line.

surements for several years. The University for Environment and Life Sciences at Ås, Norway, visited the observatory during their Absolute Gravimetry campaign between October 6 and 8, and the Institut für Erdmessung, University of Hannover, Germany, between October 7 and 10.

5. Outlook and Future Plans

The Onsala Space Observatory will continue to be an IVS Network Station and to participate in the IVS observation series. For the year 2007 a total of 27 experiments in the series EUROPE, R1, T2, RDV, and RD06 are planned. We aim at an increased and regular use of e-VLBI data transfer, e.g. with the PCEVN.

During 2007 the network connection of Onsala will be upgraded from 1 Gbit/s to 10 Gbit/s.

We will continue to monitor the relevant VLBI system parameters to be able to detect possible error sources as early as possible and to achieve and maintain high quality of the observational data. This monitoring activity includes the stability of the telescope, the local tie, the pressure sensor calibration and the operation of a microwave radiometer.

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Sheshan VLBI Station Report for 2006

Xiaoyu Hong, Qingyuan Fan, Tao An

Abstract

This report summarizes the current status, recent activities, updates in equipments, and the personnel at the Sheshan VLBI station, located in sheshan county about 30km away from Shanghai. Observing activities in 2006 included seventeen 24-hour VLBI sessions organized by the IVS and fifteen experiments organized by the EVN, respectively. A new set of S/X receivers with cryogenic amplifiers were installed at the telescope in April 2006. They worked well in VLBI experiments, and the performance is briefly displayed in the main text. Severe deformations in the antenna track were found at the end of July 2006. The observing activities had to stop for repairing the track. The repairing project took four months and was accomplished at the end of the year. After one week's testing, the telescope resumed VLBI experiments.

1. General Information

The Sheshan VLBI Station (also named SESHAN25 in Geodetic community) is located at Sheshan, 30 km west of Shanghai. A 25-meter radio telescope, since 1987, has been one of the major astronomical facilities of the Chinese National Astronomical Observatories. The telescope is operated by the Shanghai Astronomical Observatory, CAS. The Sheshan VLBI Station is a member of the IVS, EVN and APT, taking part in astrometric, geodetic and astrophysical VLBI experiments. In recent years, it has also been involved in tracking man-made satellites. A 5-station correlator center is running at the host institute, Shanghai Astronomical Observatory (SHAO).

2. Observations in 2006 and Current Status of the Telescope

During the period January to August 2006, SESHAN25 successfully participated in seventeen 24-hour IVS geodetic sessions along with fifteen EVN experiments. As one of the VLBI ground stations tracking the Chinese Chang'E satellite, the telescope was involved in a variety of testing experiments in the first half of the year. We are grateful for the kind help and support from the VLBI experts among the IVS and other groups in all processes of the project. A 5-station data processing center at SHAO started to play a full role in early 2006. Several real-time experiments among the Chinese VLBI Network consisting of four stations at Shanghai, Beijing, Kunming and Urumqi, were carried out successfully. The achieved data rate of the fiber link network was about 16 Mbps. The delay, delay rate, and the angular positions (RA and DEC) could be derived in 10 minutes.

Since August 2006, the telescope had to stop operations due to severe track deformations. Figure 1 (left panel) shows one of the largest deformations. The compression between two sections of the rail was so great in some places that it caused dislocations or resulted in a large separation with a maximum gap of 20mm. The whole track and concrete under the rail was overhauled and replaced. The repairing work lasted four months till the end of the year. The right panel in Figure 1 exhibits a section of the reconstructed rail. After one to two weeks' testing and pointing checks, the telescope restarted operations in January 2007.

A new S/X cryogenic receiver (Figure 2) started working in VLBI experiments since April 2006, replacing the old one whose amplifiers had worked at ambient temperature. Table 1 lists parameters of the new cryogenic S/X receivers. The SEFDs given in column (5) were measured on 9 Feb 2007 after the track repair; they agree with the values of 800 Jy (S band) and 820 Jy (X band) which were measured before the track repair in August 2006. For the parameters at other bands of the telescope the reader is referred to the 2005 report.

The FS software is kept up-to-date with the latest version. Currently version 9.9.2 is used. Some local station programs were updated to improve the clock and weather data acquisition and to facilitate monitoring. The power equipments in the observing dome were reconstructed to guarantee safe and smooth operation during VLBI experiments.

Table 1. S/X receivers of the SESHAN25 antenna

Band	RF (MHz)	LO(MHz)	Type	SEFD(Jy)	Tsys(K)	Pol.
13 cm	2150–2450	1600	Cryogenic	790	63	right circ. pol.
3.6 cm	8200–9000	9100	Cryogenic	880	57	right circ. pol.

Figure 1. Left: deformation in the rail of the Sheshan 25m telescope (photo taken on 8 August 2006). Right: reconstructed tracks (photo taken on 25 December 2006).

3. The Staff of the Sheshan VLBI Station

Table 2 lists the group members of the Sheshan VLBI Station. The staff involved in the VLBI program at the station has various responsibilities. Prof. Wei Wenren retired in December 2006. Zhao Rongbing joined our group at the beginning of the year. He works on software development for antenna control and maintains the VLBI terminal equipment.

4. Outlook

The Sheshan VLBI Station will participate in sixteen 24-hour IVS geodetic sessions and a number of EVN experiments. The telescope will be involved in Chinese Chang'E Campaign in the next year.

Table 2. The staff at the Sheshan VLBI Station.

Name	Background	Position & Duty	Contact
Xiaoyu Hong	astrophysics	Director of station, Professor	xhong@shao.ac.cn
Qingyuan Fan	ant. control	Chief Engineer, Professor	qyfan@shao.ac.cn
Wenren Wei	electronics	Professor, VLBI terminal	wwr@shao.ac.cn
Zhuhe Xue	software	Professor, VLBI terminal, FS	zhxue@shao.ac.cn
Quanbao Ling	electronics	Senior Engineer,VLBI terminal	qling@shao.ac.cn
Weihua Wang	astrophysics	Associated Professor	whwang@shao.ac.cn
Tao An	astrophysics	VLBI friend	antao@shao.ac.cn
Bin Li	microwave	Engineer,receiver	bing@shao.ac.cn
Jinqing Wang	electronics	Engineer,VLBI terminal	jqwang@shao.ac.cn
Huihua Li	electronics	Engineer	hhlee@shao.ac.cn
Lingling Wang	software	Engineer,FS	llwang@shao.ac.cn
Bo Xia	electronics	Operator	bxia@shao.ac.cn
Wei Gou	electronics	Operator	gouwei@shao.ac.cn
Hong Yu	ant control	Post doctor,antenna control	yuhong@shao.ac.cn
Rongbing Zhao	software	Engineer,VLBI terminal,FS	rbzhao@shao.ac.cn

Figure 2. The new S/X receivers at the Sheshan station.

Simeiz 22-m VLBI Station

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Abstract

We summarize briefly the status of the 22-m radio telescope as an IVS Network Station. We also present estimates of the annual irregularity of the plate motion.

1. Current Status and Activities

Figure 1. Simeiz VLBI station.

The 22-m radio telescope RT-22 of the Radio Astronomy Laboratory is located at the foot of mount Koshka ("The Cat") at the shore of Black Sea about 20 kilometers west from the city of Yalta (Figure 1). Radio astronomical station Simeiz was founded in 1965. First single dish observation was made in 1966. First VLBI observation was made in 1969. Radioastronomical station Simeiz was included to the International VLBI Network in 1980. The Laboratory provides observing facilities for astronomers from the international community and for its own staff.

Parameters of the 22 meters radio telescope are presented in Table 1.

Table 1. The antenna parameters of the Simeiz station.

Diameter D, m	22
Surface tolerance, mm (root mean square)	0.25
Wavelength limit, mm	2
Feed System	Cassegrain system or primary focus
Focal length F, m	9.525
Focal ratio F/D	0.43
Effective focal length for Cassegrain system, m	134.5
Mounting	Azimuth-Elevation
Pointing accuracy, arc sec.	10
Maximum rotation rate, degree/sec	1.5
Maximum tracking rate, arcsec/sec	150
Working range in Azimuth, degrees (0 to South)	-270 $\pm$ 270
in Elevation, degrees	0 - 85

The current projects:

1. Very Long Baseline Interferometry.

Facilities for VLBI observations at frequencies 612 MHz, 1.6, 2.3, 5.0, 8.4 and 22 GHz are available. RT-22 has participated in VLBI investigations since 1969. The highest resolution was achieved in the experiments in collaboration with USA antennas. The velocities of wind in the southern and northern hemispheres of Venus were measured in the course of the VEGA-project. Geodynamical VLBI program started at RT-22 in 1994 (Clark, et al., 1995). The position of the Simeiz station was determined with an accuracy of several millimeters.

Estimates of the horizontal velocity of the station Simeiz were calculated using VLBI observations carried out under geodynamics programs during the years 1994-2004. The complete set of 3 million VLBI observations has been analyzed and it was found that the station moves with respect to the Eurasian tectonic plate considered as a rigid with a rate 2.8 $\pm$ 0.9 mm/yr in a North-North-East direction (Petrov et al., 2001; Volvach et. al., 2004).

Several hundreds of radio sources were studied during the past years. It was found that they had similar structure of core-jet type and movements of the components in jets occurring with relativistic velocities. The obtained VLBI maps are compared with the data on mm variability of radio sources. We suggest that the mm burst is unlikely to produce a detectable new VLBI component. An earlier detection of radio bursts and, consequently, the associated sources in the cores requires single-dish observations, for example, in the millimeter band.

2. Multi-wavelength monitoring of Active Galactic Nuclei.

Millimeter wave observations of extragalactic radio sources were started at the 22-m Crimean Astrophysical Observatory radio telescope in 1973. 3.8 cm–1.1 mm variability of several dozens of AGNs was monitoring at the Crimean observatory together with the Metsahovi Radio Station (Finland). Since 1973, over 20000 observations of some 200 sources have been obtained. Data for several dozens of sources of extensive monitoring were combined with the other observations to derive separate quiescent and flare component spectra, which are crucial to gain an understanding of structure and evolution of compact radio sources. The simple shape and the overall evolution of the flares agree in far greater detail with the shock–in–jet model. As extended monitoring programs have demonstrated, there are unpredictable outbursts, quiescent periods, minimum flux levels and secular trends. It follows from the analysis that the flare evolution can be divided into 3 phases: the rapid flux increase; the plateau, where the flux is relatively constant; and the slow intensity decrease. The variations of mm radiation of more than 30 extragalactic radio sources were studied as well as the data on their burst maximum and burst amplitudes were obtained (Volvach, et al., 2006).

3. Multi-frequency molecular line observations.

Study of the star-forming regions in molecular lines has been started in 1978. Two main types of observation are carried out at the radio telescope: 1) observations of maser sources (hydroxyl masers, water masers, SiO masers) at the frequencies of 1.6 GHz, 4.8 GHz, 22 GHz and 86 GHz. 2) observations of millimeter molecular emission at the frequency range from 85 GHz to 115 GHz. The radio telescope is equipped with high-sensitive cryogenic receivers with noise temperatures of: 1) 30 K at 22 GHz, 2) 39 K at 4,8 GHz, and 3) 70 K at frequencies from 85 GHz to 115 GHz. Characteristics of the antenna for 3 mm range: beam width 40 arcsec, effective aperture area 100 m^2. Spectrum analyzers for line observations: 1) 128 channels filter bank spectrum analyzer with frequency band 12 MHz; 2) digital spectrum analyzer for maser observations with the frequency band 4 MHz and frequency resolution of 8 kHz; 3) 64 channels filter bank spectrum analyzer with frequency band 64 MHz.

4. VLBI radar method.

The sounding of investigated objects by radio signals of powerful radar and the receiving of reflected echo-signals with array of radio telescopes in VLBI mode and differential VLBI mode. Scientific goals: Study of short-periodic variation of proper rotation for the Earth group planets, precise determination of their trajectories in Radio Reference Frame coordinate system; Researching the asteroids, crossing the Earth orbit (NEA), improving their trajectory knowledge; Investigation of space debris population at geostationary and high-elliptic orbits (including statistical measurements of cm-sized objects). VLBI radar experiments to research the Earth group planets, the near-Earth asteroids and space debris objects were arranged: the echo-signals were detected, the main period of rotation and the size estimations for 25 space debris objects, Venus and Mars planets were obtained. The RT-22 was equipped with specialized NearRealTimeVlbi Terminal. This allows to transfer the radar echoes through Internet from the radio telescopes to the near real-time correlator in Noto. A near real-time system can provide quickly the results of radar observations.

2. The Estimate of Annual Irregularity of Motion of the Lithospheric Plates

The fundamental geodynamics area “Simeiz-Katsively” is situated on the coast of the Black Sea near the village of Simeiz 20 km west of the city of Yalta in Ukraine. It consists of two satellite laser ranging stations, a permanent GPS receiver, a tide gauge and the radiotelescope RT-22. All these components are located within 3 km.

The positions of the points in the Simeiz geodynamics test area have been determined by special Third GPS survey campaign by Main Astronomical Observatory.

Absolute offsets of reduction points of the radio telescope RT-22 and two satellite laser ranging stations from 1994 to 2004. Results are presented in Table 2.

The catalog of the National Earthquake Information Center, U.S. Geological Survey for 1964-1990 was used for analysis of more than 130 thousand worldwide earthquakes with magnitude $M \geq$ 3.0 (VX DAT,1928-1990). An annual period with a high statistical probability was revealed for

Table 2. Offsets for 10 years of the coordinates of points in the Simeiz area.

Station	dX	dY	dZ
RT22G	-0.216	0.126	0.077
KATS-SLR	-0.200	0.137	0.032
SIMI-SLR	-0.230	0.134	0.069

number of earthquakes with $M < 5.0$ (Gorkavyi et al., 2000). The annual period was more clearly detected in medium latitudes ($\varphi \sim 38° - 61°$) for both the northern and southern hemispheres, but phase oscillations in the North and South are almost opposite. Maximum of number of earthquakes fall on a local spring season. Average amplitude of oscillation is $\approx 15\%$ from annual seismic activity averaged for 27 years. It was shown that the annual period in seismicity has a clear link to the seasonal periodicity of angular momentum of atmosphere (impulse of wind) (Gorkavyi et al., 2005). These seasonal variations of atmospheric pressure can interact with Earth's crust and oceanic flows and can generate variations in speed of tectonic plates and in number of earthquakes. Annual variations of speed of a tectonic plate were estimated to be $\triangle V \approx \pm(0.5 - 0.6) cm/yr$ (Gorkavyi et al., 2005). Phase and value of estimated variation of a plate's speed agree with annual variation of lithospheric parameters from direct measurements by VLBI, GPS and satellite laser ranging (Titov et. al., 2003).

3. Future Plans

The activities in 2007 at "Simeiz-Katsively" area will consist of: (1) carrying out modernization of site's VLBI (Mark 5B system), SLR-1 and SLR-2 with the purpose to increase their level of equipment according to the international standards; (2) realization of observations on site's VLBI and SLR for maintenance in territory of Crimea the International Terrestrial Reference Frame (ITRF) and high-precision connection (at a level of several millimeters) to permanent GPS stations of the network to ITRF; (3) creation of a prototype of a system to monitor geodynamic phenomena of mountain region of Crimea and geotectonics of the Black Sea basin.

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Svetloe Radio Astronomical Observatory

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Abstract

This report summarizes information on recent activities at the Svetloe Radio Astronomical Observatory (SvRAO). During the previous year a number of changes were carried out at the observatory to improve some technical parameters and upgrade some units to required status. The report provides also an overview of current geodetic VLBI activities and gives an outlook for the next year.

1. Introduction

Svetloe Radio Astronomical Observatory (SvRAO) was founded by the Institute of Applied Astronomy (IAA) as the first station of the Russian VLBI network QUASAR. VLBI network QUASAR was described in [1].

Sponsoring organization of the project is the Russian Academy of Sciences. SvRAO is located at the Karelian Neck, near Svetloe village, about 100 km north of St. Petersburg. The basic instruments of the observatory are the 32-m radio telescope RT-32 and technical systems provided for the realization of VLBI observations.

During last year, Svetloe observatory participated regularly in various radio astronomical programs including VLBI and single dish observations of quasars and planets.

2. Participation in IVS Observational Programs

Table 1 summarizes the sessions performed during 2006.

Table 1. The list of IVS sessions observed at SvRAO in 2006.

	IVS-R4	IVS-EURO	IVS-T2	IVS-E3	IVS-R& D	IVS-VLBA	IVS-Int
January	3	1		1			2
February	2						2
March	4	1					2
April	3						2
May	1						
June							
July							
August	4		1	2	1		2
September	4	1		2		1	2
October	4						2
November	5	1	1				2
December	2		1				2
Total	32	4	3	5	1	1	18

3. Radio Telescope

In 2006 at SvRAO the following problems were solved:

1. Large equipment cabin was dismantled. Refrigerators were remounted into the new small cabin on the azimuthal antenna platform. Electric drives were removed from the cabel loop cabin under the azimuthal antenna platform.
2. The antenna rail was reconstructed by adding a steel supporting construction and rebuilding the concrete under it.
3. Electronic part of the angle data unit was improved by using modern components.

Figure 1. Former view of RT.

Figure 2. Current view of RT without large equipment cabin.

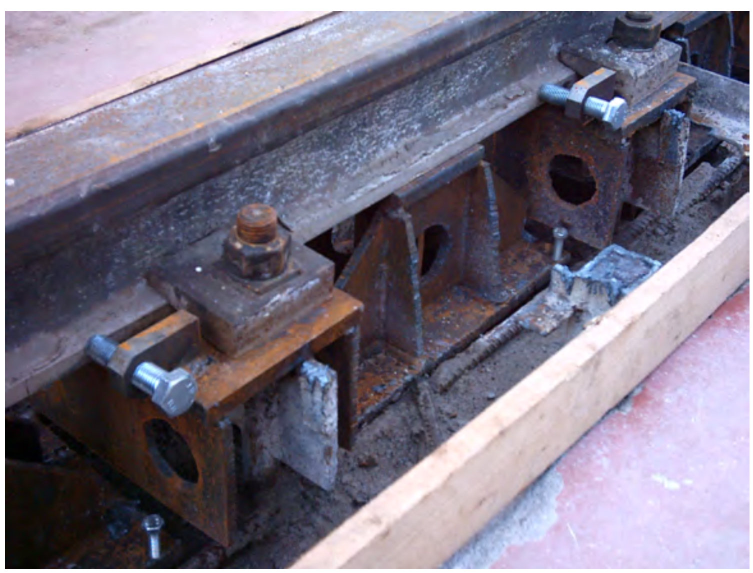

Figure 3. Steel supporting construction under the rail.

4. Outlook

Our plans for the coming year are the following:

- To participate in IVS R4, T2, EURO and RVD observational sessions.
- To participate in domestic observational programs for obtaining Earth orientation parameters.
- To continue geodetic control of the antenna parameters.

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JARE Syowa Station 11-m Antenna, Antarctica

Koichiro Doi, Kazuo Shibuya

Abstract

The operation of the 11 m S/X-band antenna at Syowa Station (69.0°S, 39.6°E) by the Japanese Antarctic Research Expeditions (JAREs) started from February 1998 and continues till today (March 2007). The number of quasi-regular geodetic VLBI experiments attained 72 at the end of 2006.

Data of all OHIG sessions and CRD sessions in 2006 were recorded on hard disks through the K5 terminal. The K5 hard disks were brought back from Syowa Station to Japan. From the NICT server the data were electronically transferred to MIT Haystack Observatory, where they were converted to the Mark 5 format. And the Mark 5 data were then sent to the destination Mark 5 Correlator for the final correlation.

Syowa Station will participate in four OHIG sessions in 2007. The antenna time drastically decreased as receiving activity of remote sensing satellites became very low. We like to increase, with the help of the observing program committee, the OHIG sessions than those planned in the 2007 year schedule.

1. Overview

Syowa Station has become one of the key observatories in the southern hemisphere geodetic network, as reported in [1]. As for VLBI, Syowa antenna is registered 66006S004 as the IERS Domes Number, and 7342 as the CDP Number. Basic configuration of the Syowa VLBI front-end system did not change from the description in [2].

K5 recording system was introduced to Syowa Station in September 2004 and some tests were carried out to confirm normal data recording. Syowa's recording terminal K4 was fully replaced by K5 simultaneously with the termination of SYW session at the end of 2004. Syowa participates in the OHIG sessions. VLBI data transfer through Intelsat link became possible following the introduction of the K5 system and it may accelerate the correlation process; the transfer rate, however, from Syowa Station to NIPR is not faster than 0.5 – 1 Mbps.

2. Notes on System Maintenance

There is no significant problem in the "mechanical system". The hydrogen maser set (Anritsu RH401A; 1001C), which was in good condition until 2003 was brought back to Japan for overhaul (H2 ran out). The 1002C was used for the observations done in the years 2004 to 2006. JARE-48 will install 1001C again at Syowa Station (planned for March 2007). The tube in the Cs frequency comparator has to be changed, and the video-converter/local oscillator has to be replaced with a new one in the near future.

3. Session Status

Table 1 summarizes the status of processing as of January 2007 for the sessions after 2003. The SYW session consisted of Syowa (Sy), Hobart (Ho) and HartRAO (Hh). The OHIG sessions involved Fortaleza (Ft), O'Higgins (Oh) and Kokee Park (Kk) with TIGO Concepcion (Tc) from November 2002, together with the 3 SYW antennas. In 2005, Syowa joined the CRD sessions instead of SYW sessions. Syowa participated in six OHIG sessions in 2006.

Until 2004, OHIG sessions' data on K4 tapes from Syowa Station were copied to Mark IV tapes at GSI and the Mark IV tapes were sent to the Mark IV Correlator for final correlation. After introducing the K5 system, K5 hard disk data brought back from Syowa Station were ftp transferred to MIT Haystack Observatory through NICT server and converted to the Mark 5 format data there.

Figure 1. Syowa VLBI staff for JARE-47 (Feb. 2006 - Jan. 2007).

4. Staff of the JARE Syowa Station 11-m Antenna

- Kazuo Shibuya, Project coordinator at NIPR.
- Koichiro Doi, Liaison officer at NIPR.
- Kuniko Egawa (from Japan Hydrographic Association), Chief operator for JARE-46 (Feb.

2005 - Jan. 2006).

- Isao Okabayashi (from NEC), Antenna engineer for JARE-46.
- Takanobu Sawagaki (from Hokkaido University), Chief operator for JARE-47 (Feb. 2006 - Jan. 2007). (right in Figure 1)
- Hiroshi Ishii (from NEC), Antenna engineer for JARE-47. (left in Figure 1)

Table 1. Status of SYW and OHIG experiments as of January 2007

Code	Date	Station	Hour	Correlation	Solution	Notes
SYW026	2003/Apr/10	Ho, Hh	24 h	Yes	Yes	(J44)
SYW027	2003/Aug/06	Ho, Hh	24 h	Yes	Yes	
OHIG27	2003/Nov/19	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
SYW028	2003/Nov/26	Ho, Hh	24 h	Not yet	Not yet	
OHIG28	2003/Dec/03	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
SYW029	2004/Jan/07	Ho, Hh	24 h	Yes	Yes	
OHIG29	2004/Feb/10	Ho, Hh, Ft, Oh, Tc	24 h	Yes	Yes	(J45)
SYW030	2004/Apr/07	Ho, Hh	24 h	Yes	Yes	
SYW031	2004/Aug/18	Ho, Hh	24 h	Yes	Yes	
OHIG32	2004/Oct/26	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG33	2004/Nov/09	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG34	2004/Nov/30	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG35	2004/Dec/08	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
SYW032	2004/Dec/13	Ho, Hh	24 h	Yes	Yes	
OHIG36	2005/Jan/26	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG37	2005/Feb/02	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	(J46)
OHIG38	2005/Feb/15	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
CRDS18	2005/Apr/11	Ho, Hh	24 h	Not yet	Not yet	
CRDS19	2005/May/10	45, Hh	24 h	Yes	Not yet	
OHIG39	2005/Nov/08	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG40	2005/Nov/09	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG41	2005/Nov/16	Ho, Hh, Ft, Oh, Kk	24 h	Not yet	Not yet	
OHIG42	2006/Jan/31	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	(J47)
OHIG43	2006/Feb/08	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG44	2006/Feb/14	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG45	2006/Nov/07	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG46	2006/Nov/14	Ho, Hh, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG47	2006/Nov/29	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	

(1) 45: DSS45
(J44) JARE-44: op H. Ikeda eng. K. Soeda (J45) JARE-45: op K. Doi eng K. Fukuhara
(J46) JARE-46: op K. Egawa eng I. Okabayashi (J47) JARE-47: op T. Sawagaki eng H. Ishii

5. Analysis Results

At the end of 2006, 47 sessions from May 1999 through November 2005 have been analyzed with the software CALC/SOLVE developed by NASA/GSFC. The data of 4 sessions by JARE-47 (4 OHIG) are not returned yet.

The length of the Syowa-Hobart baseline is increasing with a rate of 54.0 $\pm$ 0.6 mm/yr. The Syowa-HartRAO baseline shows slight increase with a rate of 11.5 $\pm$ 0.5 mm/yr. These results agree approximately with those of GPS. We do not detect obvious change in the Syowa-O'Higgins baseline. Detailed results from the data until the end of 2003 as well as comparisons with the results from other space geodetic techniques are reported in [3].

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Geodetic Observatory TIGO in Concepción

Sergio Sobarzo, Cristobal Jara, Eric Oñate, Cristian Herrera, Carlos Verdugo, Hayo Hase, Armin Böer, Bernd Sierk

Abstract

During 2006 TIGO performed 111 24-hour observations and one 4-hour student experiment. In January, TIGO was the host of the Fourth IVS General Meeting and the Seventh IVS Analysis Workshop. In September, TIGO observed the SMART-1 crash on the moon. Also, this year was the beginning of eVLBI transfers at TIGO.

1. General Information

The operation of TIGO is based on an agreement between Chile and Germany in which

- Universidad de Concepción
- Universidad del Bío Bío
- Instituto Geográfico Militar
- Bundesamt für Kartographie und Geodäsie

are committed until the end of 2007. A prolongation of the cooperation for the period 2008 through 2011 is under discussion. TIGO is located near the Universidad de Concepción, at longitude 73.025 degrees West and latitude 36.843 degrees South, 500 kilometers south of Santiago, Chile's capital.

2. Component Description

The IVS network station TIGOCONC is the VLBI part of the Geodetic Observatory TIGO, which was designed to be a fundamental station for geodesy. Hence the VLBI radiotelescope is co-located with an SLR telescope (ILRS site), a GPS/Glonass permanent receiver (IGS site) and other instruments like water vapour radiometer, seismometer, superconducting gravimeter and absolute gravity meter.

The atomic clock ensemble of TIGO consists of two hydrogen masers, three cesium clocks and three GPS time receivers realizing the Chilean contribution to the Universal Time scale (Circular T, BIPM).

The technical parameters of the TIGO radiotelescope as published in [1] have not been changed.

In 2006 Mark IV tape recording was completely replaced by Mark 5 disk recording. S2 cassette recording of TIGO terminated with the close down of Canadian VLBI operation.

3. Staff

During 2006 Gonzalo Remedi terminated his work at TIGO and was replaced by electronic engineer Eric Oñate. Roberto Aedo joined the TIGO SLR team and was replaced by Cristian Herrera, informatic engineer, whose support will improve the eVLBI development. In 2006, TIGO's VLBI group consisted of the persons listed in Table 1.

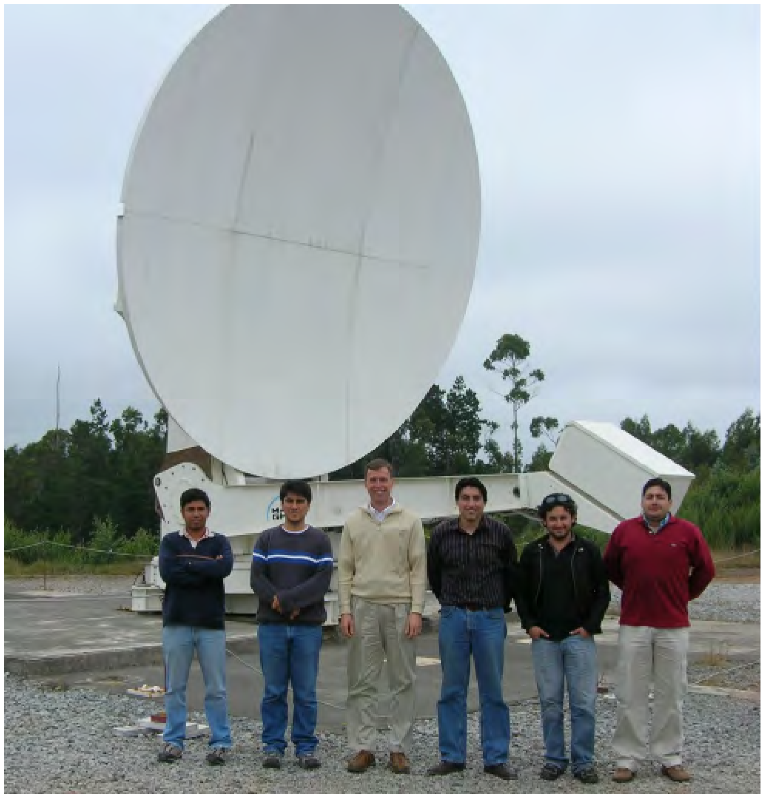


Figure 1. Current VLBI staff (Jara, Sobarzo, Hase, Herrera, Verdugo and Oñate).

Table 1. TIGO VLBI support staff in 2006.

Staff	Function	Email
Hayo Hase	head	hayo.hase@tigo.cl
Sergio Sobarzo	chief engineer	sergio.sobarzo@tigo.cl
Cristobal Jara	electronic engineer	cristobal.jara@tigo.cl
Eric Oñate	electronic engineer	eric.onate@tigo.cl
Cristian Herrera	informatic engineer	cristian.herrera@tigo.cl
Carlos Verdugo	mechanical engineer	carlos.verdugo@tigo.cl
any VLBI operator	on duty	vlbi@tigo.cl
all VLBI operators		vlbistaff@tigo.cl

4. Current Status and Activities

During 2006 TIGO was scheduled to participate in 112 IVS experiments and one 4-hour experiment with students of the Technical University of Vienna (see Table 2).

In January 2006 both the Fourth IVS General Meeting and the Seventh IVS Analysis Workshop were held in Concepción. During 6 days the VLBI and Earth science communities discussed about applications and research fields of VLBI, as well as the future of this geodetic technique.

Table 2. TIGO's IVS observation statistics for 2006.

Name	# of exp.	ok	failed
R1xxx	48	48	0
T20xx	2	2	0
E30xx	9	8	1
R4xxx	44	44	0
RDVxx	3	3	0
OHIGxx	6	6	0
Total IVS	112	111	1
VIExx	1	1	0

Also during this year TIGO joined the EXPReS project, which aims at connecting 21 VLBI radiotelescopes in 6 continents using high-speed networks allowing real time VLBI. In this frame, numerous tests have been conducted in order to evaluate and improve the Internet connection of the TIGO observatory, which is the only South American participant in EXPReS.

A first evaluation of the TIGO Internet connection was made on July 2nd where a 2 Mbps limit was found. However using parallel streams it is possible to increase the speed up to a theoretical ceiling of 5 Mbps, the contractual limit, as is shown in Figure 2.

The support of the Chilean Academic Network REUNA, GEANT and RedCLARA increased the available TIGO bandwidth to 90 Mbps. On January 5th, 2007 a test was made where a top speed near 55 Mbps was reached, as is shown in Figure 3.

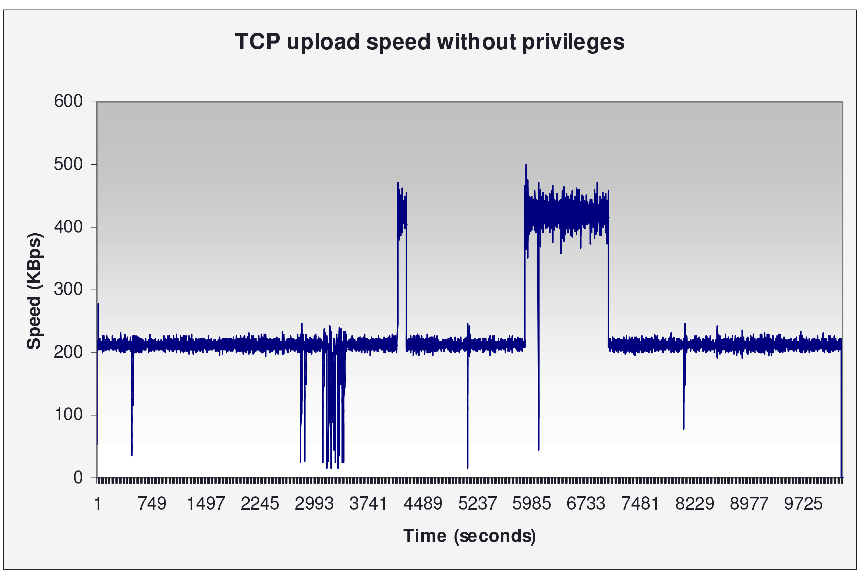


Figure 2. Speed evolution of a file transfer without privileges.

On September 3rd, the first European lunar mission with the satellite SMART-1 terminated with its crash into the moon. TIGO observed together with Hobart and ATCA the last signals

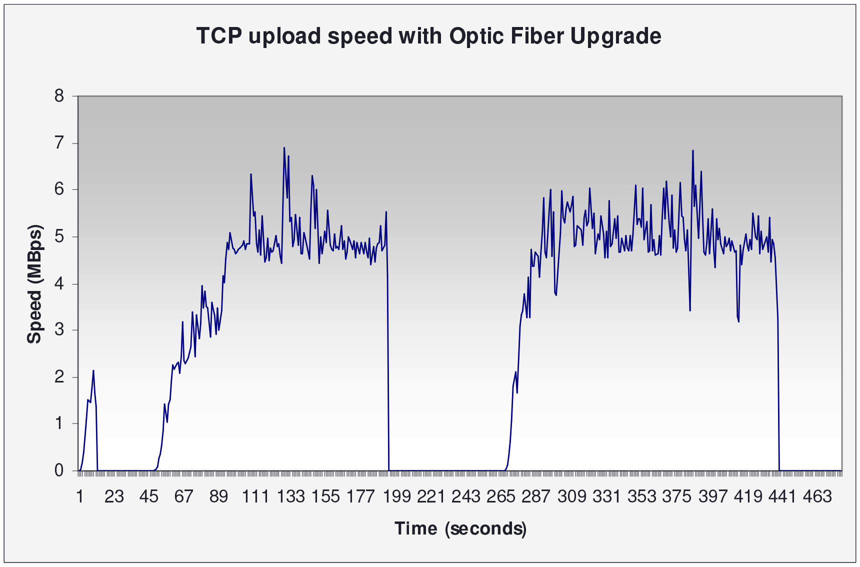


Figure 3. Speed evolution of a file transfer with privileges.

of SMART-1 using VLBI. The signal was recorded on 8-packs and was also visually monitored to determine the precise time of impact. As a result, SMART-1 was declared dead at 05:42:22.394076 ±0.000010 s UT on 03 September 2006. Due to the high temporal resolution by VLBI it was possible to determine the place of the impact with an error of only ±2 cm, a fantastic geodetic achievement.

5. Future Plans

The VLBI activities in 2007 will focus on

- execution of the IVS observation program for 2007,
- investigations on the realization of VLBI2010 in Concepción,
- investigations related to eVLBI and EXPReS,
- fund allocation for eVLBI to get more bandwidth,
- experimental satellite trackings,
- repetition of the local survey.

References

[1] Vandenberg, N.R.: International VLBI Service for Geodesy and Astrometry 2000 Annual Report, NASA/TP–1999-209243, 1999

Tsukuba 32-m VLBI Station

Kensuke Kokado, Junichi Fujisaku, Kazuhiro Takashima

Abstract

The Tsukuba 32-m radio telescope is operated by Geographical Survey Institute (GSI) VLBI group. This report summarizes the observation activities and status of Tsukuba 32-m VLBI station. In 2006, we performed a total of about 140 domestic/international VLBI sessions. All of the observations were performed using the K5 system and we transferred the data of the international sessions to the correlator via high capacity global network. The VERA Ishigakijima (VERAISGK) station of the National Astronomical Observatory of Japan (NAOJ) participated in our geodetic sessions since February 2006.

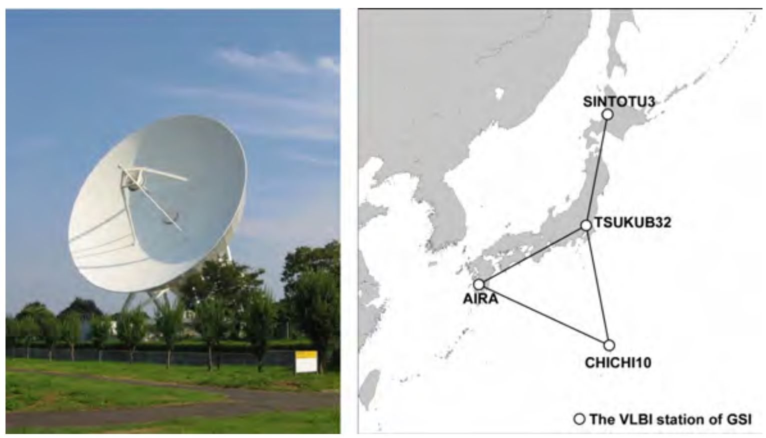


Figure 1. Tsukuba 32-m VLBI station and GARNET (GSI VLBI network)

1. General Information

The Tsukuba 32-m VLBI station (TSUKUB32) is located at GSI in Tsukuba Science City about 50 km to the northeast of the capital Tokyo and hosts a lot of public and private scientific research institutes. GSI started VLBI experiments with a 5-m mobile station in 1981. In its experiment history, GSI had also operated a 3.8m-mobile station and Kashima-26 m station. TSUKUB32 was constructed in 1998. This was a turning point, as GSI shifted its aim of experiments from the existing mobile stations to fixed regular ones. Since then, GSI has been performing various domestic/international VLBI sessions with TSUKUB32 as main dish together with three other permanent VLBI stations, AIRA, CHICHI10 and SINTOTU3. These four stations, owned and operated by GSI, form GSI's domestic VLBI network named GARNET (GSI Advanced Radio telescope NET work). We have performed our domestic VLBI observations using GARNET. A series of the observations is named JADE (JApanese Dynamic Earth observation by VLBI). The main purposes of JADE observation are to define the reference frame for Japan and to monitor the plate motions for the advanced study of crustal deformations. For this reason the GARNET stations, centered around TSUKUB32, are placed to surround the Japanese mainland.

2. Component Description

Table 1 shows TSUKUB32's current configuration. In 2006, we performed all domestic/international sessions using the K5 system and the automatic observation system, with the K5 system directly recording Linux files using control utilities from FS9 (version.FS-9.9.0) and checking the raw observation data. In 2005, we added hot-ejectable Serial ATA disks so that observation data can be shipped to a correlator during an observing session. But disk failures often occurred due to frequent disk swapping; sometimes we failed to observe a session. Therefore we changed to transferring the data to the correlator over the network without using hot-ejection.

Table 1. Configuration of Tsukuba 32m antenna

Site 8-letter code	TSUKUB32	2-letter	Ts
IERS DOMES number	21730S007	CDP number	7345
Site Position	ITRF2005	S band SEFD (Jy)	360
X(m)	-3957408.779	X band SEFD (Jy)	320
Y(m)	3310229.403	K band SEFD (Jy)	not measured
Z(m)	3737494.800	S band Tsys (K)	75 (Zenith)
S-band w/BPF	2215-2369 MHz	X band Tsys (K)	50 (Zenith)
X1-band	7780-8280 MHz	K band Tsys (K)	75(Zenith)
X2-band	8180-8680 MHz	Az slew 3.0 deg/sec	Range 10.0 - 710.0
X3-band	8580-8980 MHz	El slew 3.0 deg/sec	Range 5.0 - 88.0
K-band	20.5-25.5 GHz		

3. Staff

Table 2 shows the regular operating staff of GSI VLBI group. Masayoshi Ishimoto (former network chief) left our group and Etsurou Iwata and Hiromi Shigematsu joined in April 2006. Yoshihiro Fukuzaki is in charge of the analysis of SYOWA experiments and elected member of the IVS Directing Board (Networks Representative).

Table 2. Staff list of the GSI VLBI group

Name	Position	Jobs
Kazuhiro TAKASHIMA	Leader of VLBI group	Management
Etsurou IWATA	Network chief	Network
Morito MACHIDA	Analysis chief	Correlation
Hiromi SHIGEMATSU	Correlation chief	Correlation
Junichi FUJISAKU	Operation chief	Experiments coordination, Operation
Kensuke KOKADO	Operator	Baseline Analysis, Operation
Daisuke TANIMOTO	Operator	Operation, Field System
Yoshihiri FUKUZAKI	Researcher	IVS DB, SYOWA Station

4. Current Status and Activities

As for the regular sessions listed in Table 3, TSUKUB32 performed a total of 143 domestic/international VLBI sessions in 2006. We have added 5 sessions, which were for IVS-R sessions and IVS-INT2 sessions with K5 system, as compared with 2005.

Table 3. The regular sessions at Tsukuba 32-m VLBI station in 2006

Sessions	Code	Number
IVS-R	R1207,R1209 ... R1254,R1255	31
IVS-T	T2043,T2044	2
IVS-R&D	RD0606	1
VLBA	RDV58,RDV60	2
APSG	APSG18,19	2
JADE	JD0601-0612	12
IVS-INT2	K06007,K06014 ... K06350,K06351	92
S-JADE	S06174	1
Total		143

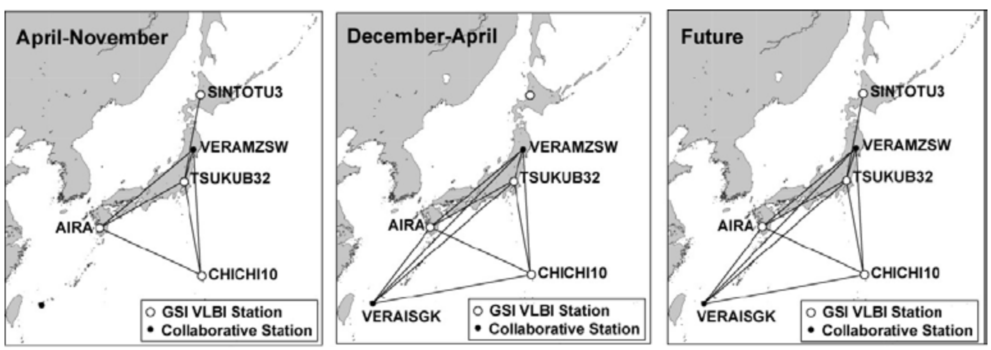


Figure 2. The core network of JADE sessions

We performed JADE sessions every month. A number of Japanese VLBI stations, such as VERAMZSW, MIZNAO10 of NAOJ and GIFU11 of the Gifu University participated in JADE sessions. The VERAISGK station of NAOJ on Ishigakijima island participated in several JADE sessions (JD0602, JD0603, JD0604 and JD0612) in 2006. The purpose was to improve the precision of the terrestrial reference frame of the southwest island of Japan. There was no K5 system in VERAISGK, so we moved the K5 system of SINTOTU3 and performed the observation during winter, because SINTOTU3 cannot perform the observation due to heavy snow. All results of these sessions are available on GSI VLBI Web site (http://vldb.gsi.go.jp/sokuchi/vlbi/sess/index.html).

We also performed S06174 session, a special domestic VLBI session in which USUDA VLBI station of Japan Aerospace Exploration Agency (JAXA) and four stations of GSI participated.

In addition to the sessions listed in Table 3, we performed several other observations. Optical-connected real-time VLBI observations were performed in cooperation with universities and research institutes in Japan including the Gifu University and the NAOJ. The data were transferred via a dedicated high-speed optical fiber network (2.4 Gbps) called “Super-SINET”.

GSI made a joint-research agreement with Tsukuba University for installing the K-band receiver in TSUKUB32 antenna. We installed and adjusted the receiver for actual operation.

Figure 3. The K-band receiver of TSUKUB32

5. Future Plans

Since 2005, TSUKUB32 has performed observations using the K5 system (K5/VSSP). In 2006, TSUKUB32 continued the installation and adjustment of the new K5 system (K5/VSSP32), which enables us to record in 32 Msps mode, but it is not completed. Therefore we will set it up completely and perform all domestic/international sessions using the new K5 system. The current K5 system of TSUKUB32 is scheduled to be moved to VERAISGK station and we will include VERAISGK in all domestic sessions. Table 4 shows the K5 system specifications. We will set up the K-band receiver system completely in collaboration with Tsukuba University and will then perform tests with optical-connected real-time VLBI observations for astrometry using this receiver.

Table 4. The specifications of the K5 system

	K5/VSSP	K5/VSSP32
# of CH per unit	4	4
Max sampling rate	16 Msps/ch	32 Msps/ch
# of AD bit	1,2,3,4	1,2,3,4
Max data rate per unit	64 Mbps	256 Mbps
Output I/F	PCI-bus	USB 2.0

References

[1] J. Fujisaku, S. Kurihara, K. Takashima: Tsukuba 32m VLBI station, IVS 2004 Annual Report, February 2004

[2] J. Fujisaku, K. Kokado, K. Takashima: Tsukuba 32m VLBI station, IVS 2005 Annual Report, February 2005

Nanshan VLBI Station Report for 2006

Aili Yusup, Na Wang

Abstract

The Nanshan 25-meter radio telescope is operated by Urumqi Observatory. This report describes the activities and status of Nanshan VLBI station as an IVS network station in 2006.

1. Introduction

The station is located 70 km south of Urumqi, the capital city of Xinjiang Uygur Autonomous Region of China. The station is affiliated to Urumqi Observatory of National Astronomical Observatories, CAS. We contribute to IVS in geodetic VLBI observations. Urumqi also participated in domestic VLBI experiments between Urumqi and Shanghai, and successfully completed several test e-VLBI observations with Shanghai and Kashima, respectively. Urumqi Observatory will continue the collaberation in international e-VLBI activities.

2. Telescope Status

2.1. Antenna

- Diameter: 25 meter
- Antenna type: Cassegrain beam wave-guide
- Seat-rack type: Azimuth-pitching ring
- Main surface precision: 0.40 mm (rms)
- Pointing precision: 15" (rms)
- Rolling range: Azimuth: -270° to 270°; Elevation: 5° to 88°
- Maximum rolling speed: Azimuth: 1.0°/sec; Elevation: 0.5°/sec

2.2. Receiver

The basic specifications of the receivers are given in Table 1.

2.3. Recording System

Mark IV, Mark 5 and Mark II recording systems are available at Nanshan VLBI station. The performance of the observing system has been improved over the last year. New FS computer is in use at Nanshan and the Field System has been upgraded to version 9.9.0 and it works well. The p-cal control system has been updated and the parameters of S/X band receivers are sampled from the FS software.

Table 1. Specifications of receivers

		Parameters		Freq. Range
1.3 cm	LCP	Tsys=190K	DPFU=0.057	22100–24000
3.6 cm	RCP	Tsys=110K	DPFU=0.093	8100–8900
6 cm	dual	Tsys=22K	DPFU=0.105	4700–5110
13 cm	RCP	Tsys=75K	DPFU=0.096	2150–2320
18 cm	dual	Tsys=21K	DPFU=0.088	1400–1720
30 cm	LCP	Tsys=160K	DPFU=0.06	800–1200

2.4. Time and Frequency System

A new time and frequency system was established at Nanshan station and it works well. We also upgraded the GPS time receiver.

3. Personnel

Table 2. The main staff at Nanshan VLBI Station

Name	Position	Working area	e-mail
Wang Na	Professor	Station chief	na.wang@ms.xjb.ac.cn
Aili Yusup	Professor	Chief engineer	aliyu@ms.xjb.ac.cn
Sun ZhengWen	Senior engineer	Microwave, Receiver	sunzw@ms.xjb.ac.cn
Liu Xiang	VLBI scientist	VLBI friend	liux@ms.xjb.ac.cn
Aili Esamdin	Scientist	Astronomy	aliyi@ms.xjb.ac.cn
Jarken Yesembek	Scientist	Astronomy	jerken@ms.xjb.ac.cn
Dong YouSuo	Senior engineer	Antenna control	dongys@ms.xjb.ac.cn
Chen Maozheng	Senior engineer	Microwave, Receiver	mzchen@ms.xjb.ac.cn
Wang Weixia	Senior engineer	Microwave, Receiver	wangwx@ms.xjb.ac.cn
Shao Minghui	Senior engineer	Time and Freq., Terminal	shaomh@ms.xjb.ac.cn
Yang Wenjun	Engineer	Terminal	yangwj@ms.xjb.ac.cn
Wang Shiqiang	Engineer	Antenna	Wangshq@ms.xjb.ac.cn
Zhang Hua	Engineer	Terminal, Time and Freq.	zhangh@ms.xjb.ac.cn
Li Guanghui	Engineer	Network, Computer	ligh@ms.xjb.ac.cn
Ma Jun	Engineer	Microwave, Receiver	majun@ms.xjb.ac.cn
Chen Chenyu	Engineer	Antenna	chency@ms.xjb.ac.cn

4. Nanshan VLBI Observations during 2006

Table 3. Geodetic VLBI experiments observed by Urumqi Observatory during 2006.

Experiment	Date	Remarks (problems)
T2043	02.08	ok
T2044	05.24	ok
T2045	06.28	ok
T2046	08.02	ok
APSG18	09.13	ok
APSG19	10.11	ok
QUAK06	11.09	ok
T2047	11.29	ok
T2048	12.06	ok

5. Future Plan

A new 1.3-cm dual polarization cryogenic receiver will be built in 2007. A band for both 92 cm and 49 cm receiver systems will be built in April of 2007.

Westford Antenna

Mike Poirier

Abstract

Technical information is provided about the antenna and VLBI equipment at the Westford site of Haystack Observatory, and about changes to the systems since the 2005 IVS Annual Report.

1. Westford Antenna at Haystack Observatory

Since 1981 the Westford antenna has been one of the primary geodetic VLBI sites in the world. Located ~70 km northwest of Boston, Massachusetts, the antenna is part of the MIT Haystack Observatory complex.

Figure 1. The radome of the Westford antenna.

The Westford antenna was constructed in 1961 as part of the Lincoln Laboratory Project West Ford that demonstrated the feasibility of long-distance communication by bouncing radio signals off a spacecraft-deployed belt of copper dipoles at an altitude of 3600 km. In 1981 the antenna was converted to geodetic use as one of the first two VLBI stations in the National Geodetic Survey Project POLARIS. Westford has continued to perform geodetic VLBI observations on a regular basis since 1981. Westford has also served as a test bed in the development of new equipment and techniques now employed in geodetic VLBI worldwide. Primary funding for geodetic VLBI at Westford is provided by the NASA Space Geodesy Program.

Table 1. Location and addresses of Westford antenna.

Longitude	71.49° W
Latitude	42.61° N
Height above m.s.l.	116 m
MIT Haystack Observatory Off Route 40 Westford, MA 01886-1299 U.S.A.	
http://www.haystack.mit.edu	

2. Technical Parameters of the Westford Antenna and Equipment

The technical parameters of the Westford antenna, which is shown in Figure 2, are summarized in Table 2.

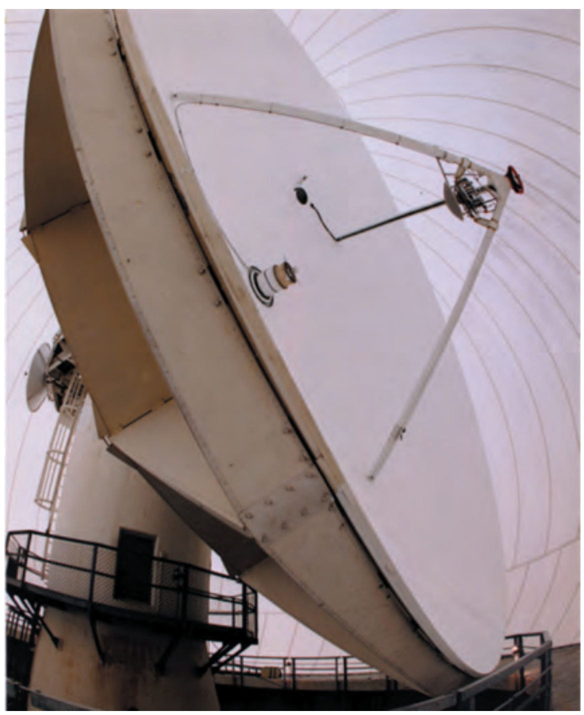


Figure 2. Wide-angle view of Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

The antenna is enclosed in a 28-meter-diameter, air-inflated radome made of 1.2-mm-thick, Teflon-coated fiberglass – see Figure 1. When the radome is wet, system temperatures increase by

Table 2. Technical parameters of the Westford antenna for geodetic VLBI.

Parameter	*Westford*	
primary reflector shape	symmetric paraboloid	
primary reflector diameter	18.3 meters	
primary reflector material	aluminum honeycomb	
S/X feed location	primary focus	
focal length	5.5 meters	
antenna mount	elevation over azimuth	
antenna drives	electric (DC) motors	
azimuth range	$90° - 470°$	
elevation range	$4° - 87°$	
azimuth slew speed	$3°\ s^{-1}$	
elevation slew speed	$2°\ s^{-1}$	
	X-band system	*S-band system*
frequency range	8180-8980 MHz	2210-2450 MHz
T_{sys} at zenith	50–55 K	70–75 K
aperture efficiency	0.40	0.55
SEFD at zenith	1400 Jy	1400 Jy

10–20 K at X-band and by a smaller amount at S-band. The major components of the VLBI data acquisition system are a Mark IV electronics rack, a Mark 5A recording system, and a Pentium-class PC running PC Field System version 9.9.2. The primary frequency and time standard is the NR-4 hydrogen maser. A CNS Clock GPS receiver system provides independent timing information and comparisons between GPS and the maser. Westford also hosts the WES2 GPS site of the IGS network. A Dorne-Margolin chokering antenna is located on top of a tower ~60 meters from the VLBI antenna, and a Turbo Rogue receiver acquires the GPS data. A meteorology package provided by the NOAA Forecast Systems Laboratory continually logs meteorological data, which are downloaded daily and are available from the IGS and cignet archives.

3. Westford Staff

The personnel associated with the VLBI program at Westford and their primary responsibilities are:

Joe Carter	antenna controls
Brian Corey	VLBI technical support
Kevin Dudevoir	pointing system software
Dave Fields	technician, observer
Glenn Millson	observer
Michael Poirier	site manager
Alan Whitney	site director

4. Status of the Westford Antenna

During the period 2006 January 1 through 2006 December 31, Westford participated in 62 24-hour geodetic sessions. Westford regularly participated in the IVS-R1, IVS-R&D and RD-VLBA series of geodetic sessions as well as various fringe tests and e-VLBI experiments.

Some minor losses of data were caused by equipment failures compounded by our normal mode of unattended operations. A major loss of data occurred in December, when multiple components in the antenna servo control system failed, and Westford was unable to observe the six sessions scheduled for that month. The component failures along with the unavailability of replacement parts forced us to upgrade and re-engineer the antenna servo control system. The Westford team replaced the digital servo, main servo amplifiers, and main motor generator and control circuitry in both the azimuth and elevation axes. These systems were replaced with a new digital servo and with solid-state motor controllers in both axes. These upgrades and the associated software work were completed in just over one month after the failure.

Use of the Westford antenna is shared with the Terrestrial Air Link (TAL) Program operated by the MIT Lincoln Laboratory. In this project Westford serves as the receiving end on a 42-km-long terrestrial air link designed to study atmospheric effects on the propagation of wideband communications signals at 20 GHz.

5. E-VLBI Development at Westford

Westford continues to play a key role in the development of e-VLBI. In 2006, Westford served as a test bed for:

- continued high-speed e-VLBI development over both a dedicated 10 Gbps link to Haystack Observatory and a 2.5 Gbps (OC48) link to the rest of the world, and
- integration and testing of the e-VLBI technology with the new Mark 5B system.

As an additional, operational test of the Mark 5B system, the Westford data from four IVS-R&D sessions in the second half of 2006 were recorded on a Mark 5B system, in parallel with the Mark 5A.

6. Outlook

At Westford we anticipate being able to participate in 68 24-hour geodetic sessions in 2007 and to support occasional e-VLBI experiments and fringe tests.

Fundamentalstation Wettzell - 20m Radiotelescope

Richard Kilger, Wolfgang Schlüter

Abstract

2006 was a very successful year for the 20m-Radiotelescope in Wettzell/Germany contributing strongly to the IVS observing program. Technical changes, improvements and upgrades were done to increase the reliability of the entire VLBI observing system.

1. General Information

The 20m-Radiotelescope in Wettzell (RTW) was designed in the years 1980/81 as a project of the former “Sonderforschungsbereich 78 Satellitengeodäsie”. RTW is an essential component of the Fundamentalstation Wettzell (FSW) and is jointly operated by Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie (FESG) of Technical University Munich. At the FSW the following geodetic space technique systems are co-located:

- WLRS (Wettzell Laser Ranging System), a laser ranging system designed for Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) contributing to the ILRS; presently a new laser Satellite Observing System (SOS-W) for low orbiting satellites is under construction.
- GPS receivers, involved in global network IGS, in the European network EUREF, and in the national network GREF as well as in time transfer experiments,
- “G”, a ringlaser dedicated for monitoring daily variations of Earth rotation with a relative accuracy of better than 10^{-8},
- RTW, integrated into the geodetic observing programs of the IVS.

A time and frequency system (T&F) has been established for the generation of the timescale (UTC(IfAG)) and for the provision of very precise frequencies needed for VLBI, SLR/LLR and GPS observations, employing Cs-clocks, H-Masers and GPS time receivers. The time scale UTC(IfAG) is published in the monthly Bulletin T of BIPM. Additional in situ observations are carried out, such as gravity observations with a super conducting gravity meter, recording of earthquakes with a seismometer, meteorological observations to monitor pressure, temperature and humidity as well as wind speed, wind direction and rain fall, water vapour observations with radiometer(s), conventional geodetic control measurements to tie the reference points of the space geodetic systems RTW, WLRS, GPS and “G” to the local terrestrial coordinate system and to investigate the local stability.

2. Staff

The staff of the Fundamentalstation Wettzell consists in total of 35 members for operations, maintenance and repair, for improvement of all devices and for developement of new systems. Within the responsibility of the Fundamentalstation Wettzell are also the

- TIGO systems (see special report in this volume), operated in Concepción/Chile jointly with a Chilean partner consortium, with 3 experts from Wettzell and

Figure 1. Fundamental Station Wettzell

- O'Higgins station (see special report in this volume) in the Antarctica jointly operated by the German Space Center (DLR) and the Institute for Antarctic Research Chile (INACH).

The staff operating RTW is summarized in Table 1.

Table 1. Staff - members of RTW

Name	Affiliation	Function	Working for
Wolfgang Schlüter	BKG	head of the FSW	RTW, TIGO, O'Higgins, T&F,...
Richard Kilger	FESG	group leader RTW	RTW
Erhard Bauernfeind	FESG	mechanical engineer	RTW
Ewald Bielmaier	FESG	technician	RTW
Gerhard Kronschnabl	BKG	electronic engineer	RTW, TIGO and O'Higgins (partly)
Christian Plötz	BKG/FESG	electronic engineer	O'Higgins, RTW (partly)
Raimund Schatz	FESG	software engineer	RTW
Walter Schwarz	BKG	electronic engineer	RTW, O'Higgins and WVR (partly)
Reinhard Zeitlhöfler	FESG	electronic engineer	RTW
Daniel Helmbrecht	FESG/BKG	student	RTW
Christian Hupf	FESG/BKG	student	RTW

3. Observations in 2006

The 20m-RT-Wettzell is engaged in geodetic VLBI operation since the end of 1983 –now for 24 years. Table 2 shows the amount of scheduled and successfully observed sessions in the year 2006. According to the 2006 Master Schedule of IVS, RTW has run most 24h geodetic VLBI sessions compared to any other telescope in our community. This did not change over the last 7 years. Since April 1984, RTW participates daily to the one-hour, one-baseline INTENSIVE sessions–additional to the 24h-sessions–in order to determine UT1-UTC. At the beginning of 1984 it was observed together with Westford, since 1995 with Greenbank and since 1999 with Kokee Park in Hawai. These sessions are called INT1 and are performed every weekday. The correlation is done at WACO. On Saturday and Sunday, Wettzell is engaged in INT2 together with Tsukuba/Japan, filling the weekend gap with data. INT2, correlated at the VLBI correlator in Tsukuba, provides UT1-UTC with shortest latency. The VLBI correlator in Tsukuba has a fast Internet connection and obtains the data from the observing stations via e-VLBI. There is a continuous effort going on to shorten the latency, which is caused mostly by the data transfer between the stations and the correlator. RTW will improve its Internet connection in 2007 from 34 Mbit/sec to 622 Mbit/sec and will extend the data transfer to all correlators which already have fast Internet connection (Bonn, Tsukuba and Haystack).

Table 2. RTW observations in 2006

program	**number of 24h-sessions**
IVS R1	52
IVS R4	52
IVS T2	6
IVS R&D	10
RDV/VLBA	6
EUROPE	6
VIE	1
in total	**133 [d]**

program	**number of 1h-sessions**
INT1(Kokee-RTW)	237
INT2(Tsukuba-RTW)	78
in total	**315**

4. Technical Improvements and Maintenance

VLBI observations require high reliability of all participating stations. Therefore careful service of all components is essential to ensure successfully performing VLBI measurements over the year(s). Additionally, the 20m-RTW has to be kept on a high technical standard and has to be upgraded according to technological advancement.

In 2006 the following actions were carried out

- to maintain the antenna hardware:
  - change of 3 Azimuth motors that were worn out by continuous load of observations,
  - replacement of tachos at Az-motors; replacement of broken coupling,
  - repair of servo failure at M9 (power surge),
  - careful adjustment of servos and drive system to split the power for all motors as exactly as possible,
  - replacement of the keys for all azimuth and elevation motors,
  - service of ventilators of all Az+El-motors ,
  - change of lubrication oil and grease of Az+El-gearings.
- to improve the receiver:
  - integration of a new X-band amplifier from Sandy Weinreb into the dewar, thus improving Tsys(X)
  - integration of special HF-cables in the dewar in this context,
  - realisation of a dewar testing facility, thus testing and measuring a dewar on ground,
  - installing a more accurate pressure gauge built by Hastings at the dewar of the antenna,

- investigating issues concerning the 5V power-supply.

- to maintain the data acquisition system
  - investigations to locate spurious signals in VC01, 02 and 03; working hard finding reasons for it,
  - shielding of cables,
  - repairing formatter #116.
- to implement the Mark 5 recording system
  - installation of an additional Mark 5 unit (Mk5-684) as back-up (in practice already needed),
  - repair of a special power supply pack of Mk5-02, to avoid unexpected system shut-downs,
  - testing before Giga-Bit-recordings (R&D-sessions),
  - repair of 8-packs; interchange of fixed discs in BKG-units.
- to improve the software
  - on October 23, 2007 upgrade from FS 9.7.7 to FS 9.9.0,
  - on November 23, 2007 upgrade from FS 9.9.0 to FS 9.9.2,
  - reinstallation of the invar height measuring system.
- to support TIGO and O'Higgins
  - repair of phasecal unit for O'Higgins in Wettzell,
  - order and supply spare parts for TIGO and O'Higgins.
- and to contribute to VLBI 2010
  - prepare specifications for a new VLBI 2010 compatible telescope (TWIN-Telescope Wettzell) for the planned requests of bids from companies,
  - design the TWIN Telescope Wettzell, considering a broadband-feed capable to receive a frequency-band from 1 to 18 GHz.

5. Plans for 2007

During 2007, RTW plans are to keep up its standard in observing quality and quantity. Some dedicated items will be:

- upgrade the 34 Mbit/s Internet connection to 622 Mbit/s,
- integrate digital baseband converters (DBBC),
- integrate Mark 5B units
- design in detail the VLBI 2010 TWIN Telescope.

Observatorio Astronómico Nacional – Yebes

Francisco Colomer

Abstract

This report updates the description of the OAN facilities as an IVS network station. Most of the ongoing projects have already been described in detail in the IVS Annual Report for 2005. The most important news is that the construction of the new 40-meter radiotelescope is complete, and the antenna is now being commissioned.

1. General Information: the OAN Facilities

The Observatorio Astronómico Nacional (OAN) of Spain, which is a department of the Instituto Geográfico Nacional (IGN, Ministerio de Fomento), operates a 14 meter radiotelescope at Yebes (Guadalajara, Spain). This facility has been a network station of the IVS until 2003, and has participated regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe, Earth rotation, and polar motion.

The construction of a new 40 meter radiotelescope is completed, and its commissioning has started. First-light receiver is a dual polarization cryogenic HEMT for the 21-24 GHz band. The new S/X receiver is under construction with some delay, and will be installed as soon as possible (but not before early 2008).

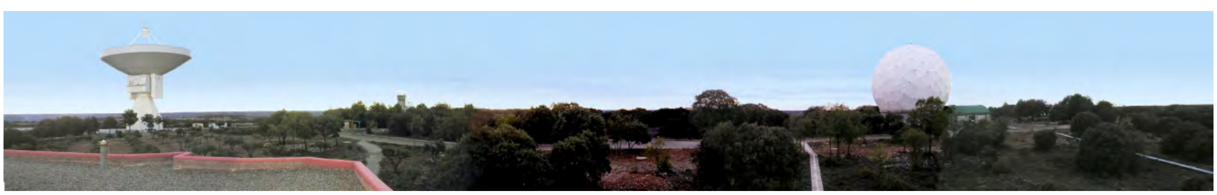


Figure 1. Panoramic view of the Yebes observatory, including the new 40-m (left) and the old 14-m (right, radome enclosed) radiotelescopes for geodetic and astronomical VLBI, and the antenna of the IGS station (on the roof of the building, left foreground).

2. OAN Staff Working in VLBI Projects

Table 1 lists the OAN staff who are involved in VLBI studies, some of which can be found at the telescope (CAY) address. The VLBI activities are also supported by other staff like receiver engineers, computer managers, secretaries and students.

3. Status of the Geodetic VLBI Activities at OAN

The main changes since the IVS Annual Report for 2005 are the completion of the construction of the 40-m radiotelescope, and the relocation of the VLBI and auxiliary equipment (GPS and H-maser) to the new premises.

Table 1. Staff in the OAN VLBI group (Email: **vlbitech@oan.es**).

Name	Background	Role	Address
Francisco Colomer	Astronomer	VLBI Project coordinator	OAN
Jesús Gómez–González	Astronomer	General Subdirector for Astronomy, Geodesy and Geophysics	IGN
Maria Rioja	Astronomer	Scientist (Astrometry)	OAN
Pablo de Vicente	Astronomer	VLBI Technical coordinator	CAY

4. Future Plans

The construction of a new building for the installation of permanent equipment for constant gravity monitoring is delayed and expected in 2007. Also the construction of a network of concrete pillars around the 40-m radiotelescope to measure the reference point of the instrument and the local tie to the old 14-m radiotelescope is planned for 2007.

References

[1] Cordobés, D., López-Pérez, J.A. "Estudio de la estabilidad en frecuencia de sistemas de transmisión de la señal del máser de Hidrógeno por fibra óptica y cable coaxial". Informe Técnico OAN 2006-10. (see `http://www1.oan.es/informes/archivos/IT-OAN-2006-10.pdf`).

[2] Azuaga, M., Serna, J.M., Miguel, A. "Medidas de los componentes del módulo de FI del RX banda X del RT de 40m del CAY". Informe Técnico OAN 2006-13. (see `http://www1.oan.es/informes/archivos/IT-OAN-2006-13.pdf`).

[3] Cordobés, D., de Vicente, P., Fernández, J., Almendros, C., Yagüe, J.M. "Traslado de los equipos de VLBI al radiotelescopio de 40m". Informe Técnico OAN 2007-1. (see `http://www1.oan.es/informes/archivos/IT-OAN-2007-1.pdf`).

Yellowknife Observatory

Mario Bérubé, Anthony Searle

Abstract

The Yellowknife VLBI antenna is a 9-meter diameter antenna which was formerly the "MV-1" mobile antenna. The MV-1 was a proof-of-concept for mobile VLBI and in 1991 NASA and NOAA offered the system for use at Yellowknife.

The antenna is located at the Yellowknife Geophysical Observatory and is operated by the Geodetic Survey Division, Natural Resources Canada as part of the active control of the Canadian Spatial Reference System. This report gives an update on recent activities.

Figure 1. Dismantling the Yellowknife 9m antenna.

1. Overview

Formerly the "MV-1" mobile antenna, the Yellowknife antenna was used as a proof-of-concept for mobile VLBI under the ARIES (Astronomical Radio Interferometric Earth Surveying) program.

Following the successful proof-of-concept, the MV-2 and MV-3 mobile antennas were built and used extensively during NASA's Crustal Dynamics project. The MV-1 antenna was then stationed at Vandenberg Air Force Base. In 1991 NASA and NOAA offered the system to Energy, Mines and Resources, Canada, for use at Yellowknife. With support of the Crustal Dynamics Project the Yellowknife VLBI observatory saw first light in Yellowknife in the summer of 1991.

The antenna is located at the Yellowknife Geophysical Observatory and is the responsibility of the Geodetic Survey Division, Natural Resources Canada. The Yellowknife Geophysical Observatory is operated by the Geological Survey of Canada, Pacific Division, Natural Resources Canada. It served as a second VLBI point for the Canadian Spatial Reference System (CSRS) in Canada.

2. General Specifications

- Latitude : 62.48 North
- Longitude : 114.48 West
- Elevation : 181.0 m
- Reflector : 9m
- Receiver : S and X cryogenic
- Azimuth speed : 40 degrees per minute
- Elevation speed : 40 degrees per minute
- PCFS version : 9.7.6
- VLBI equipment : Mark III and thick tape drive. S2 data acquisition and recording terminal.
- Time standard : NR Maser
- GPS receiver : BenchMark

3. Antenna Improvements

Since being installed in Yellowknife, the MV-1 has not required any major upgrades. The antenna is parked every winter because the antenna is unable to operate in low temperatures (November through March). Once spring arrives, the Yellowknife team prepares the antenna for the upcoming season.

Mechanical maintenance was performed in 1998 and the antenna has performed reasonably reliably since that time. An upgrade to the Mark III recorder was made prior to the 2006 observing season.

4. Antenna Survey

The Yellowknife antenna is surrounded by a high precision survey network which has been measured three times since 1990. This network has been precisely measured to obtain the geodetic tie between the VLBI, the GPS and the DORIS reference points with a precision of a few mm.

5. Operations January 2006 - December 2006

The E3 network was rescheduled in 2006 to provide more observations for the Yellowknife antenna. Though other stations in the network experienced some outages during this time, the Yellowknife Observatory had one of its most sucessful seasons.

In 2006, Yellowknife was involved in 3 IVS–T2 (Terrestrial Reference Frame sessions) and 8 IVS–E3 sessions.

On September 25, the Canadian government announced the cessation of Very Long Base Interferometry activities in Canada. Yellowknife VLBI operations ceased.

Zelenchukskaya Radio Astronomical Observatory

Andrei Dyakov, Sergey Smolentsev

Abstract

This report shortly sumarizes the observations activities at the Zelenchukskaya 32-m VLBI station during the year 2006.

1. General Information

Zelenchukskaya Radio Astronomical Observatory was founded by Institute of Applied Astronomy (IAA) as one of three stations of the Russian VLBI network QUASAR. Sponsoring organization of the project is the Russian Academy of Sciences (RAS). The Zelenchukskaya Radio Astronomical Observatory is situated in Republic Karachaevo-Cherkessiya (Northern Caucasia) about 70 km south of Cherkessk, near Zelenchukskaya (not far from Radiotelescope RATAN-600). The geographic locations of Observatory are shown on web site of IAA RAS (http://www.ipa.nw.ru/PAGE/koi8-r/DEPOBSERV/rus_zel.htm). The basic instruments of the observatory are a 32-m radio telescope and technical systems for doing VLBI observations.

Figure 1. Zelenchukskaya Observatory.

Table 1. Zelenchukskaya Observatory location and address.

Longitude	41°34′
Latitude	43°47′
Zelenchukskaya Observatory	
Republic Karachaevo-Cherkessia	
357140, Russia	
ipazel@mail.svkchr.ru	

2. Technical and Scientific Information

The technical parameters of Radiotelescope RT-32 and Zelenchukskaya station equipment were presented in the 2005 Annual Report [1].

It is necessary to inform that optical fiber lines took part in operation.

GPS observations:

A new, improved GPS receiver ASHTECHZ-X113 with ASH 700936D_M antenna Dorne-Margolin/ChokeRing was installed at observatory in exchange for receiver AOA SNR-8000ACT. Observational data are sent to BKG and IGS every hour.

3. Participation in the IVS Observing Program

Table 2 summarizes the sessions performed during 2006.

Table 2. The list of IVS sessions observed at "Zelenchukskaya" in 2006.

	IVS-R1	IVS-R4	IVS-EURO	IVS-T2	IVS-VLBA
January	2	2	1		
February		2			
March	1	3	1		
April	3	3			1
May	1	3	1	1	
June	4	3		1	
July	2	3	1		
August	1	2		1	1
September	2	2	1		
October	2	2			
November	3	3	1	1	
December	2	1			
Total	23	29	6	4	2

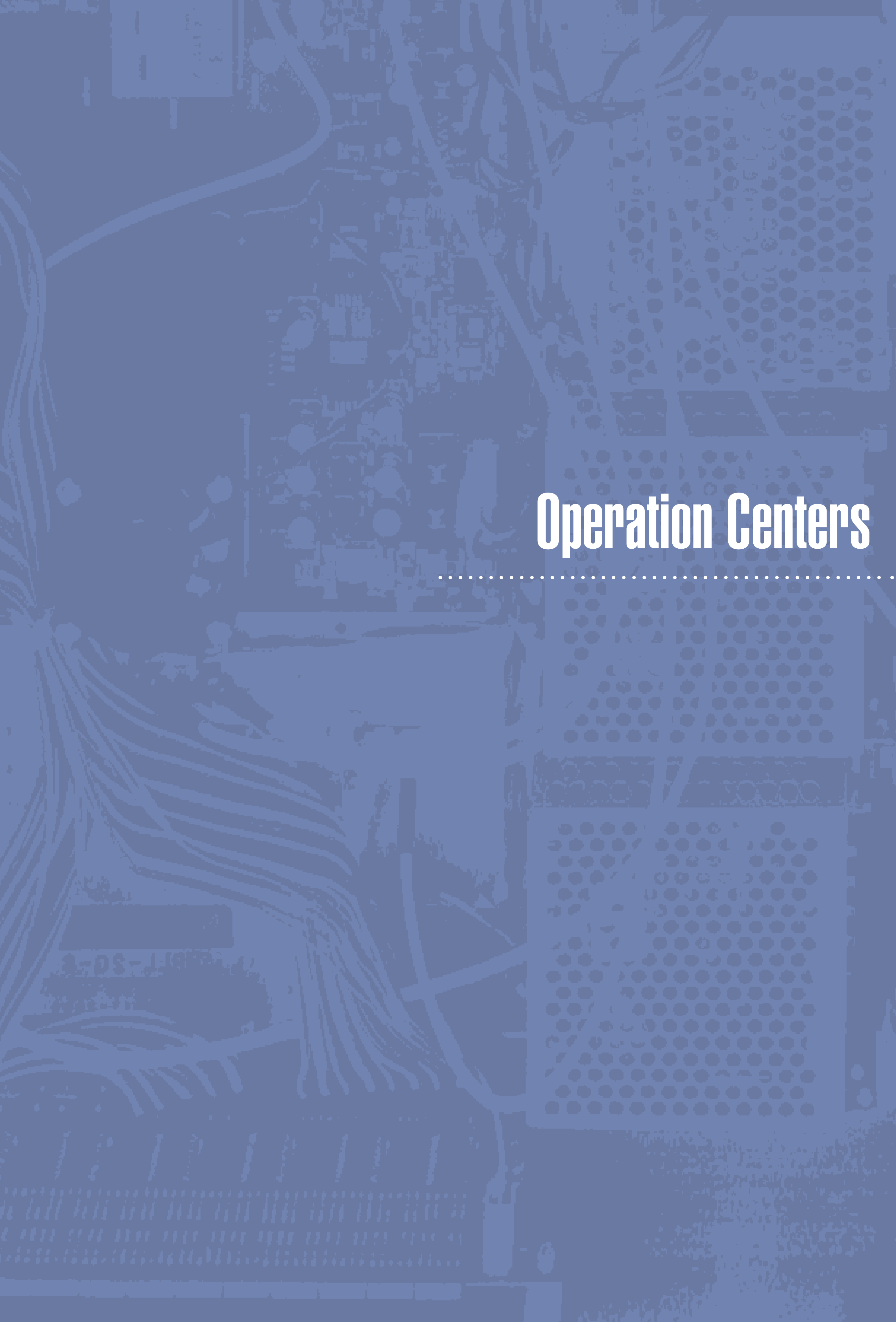
4. Outlook

Our plans for the coming year are the following:

- Participation in IVS R1, R4, T2, EURO and RDV observing sessions.
- Upgrade of rail by means of replacement of the concrete under it.
- To put into operation the cable lengths control system ("ground unit").

References

[1] International VLBI Service for Geodesy and Astrometry 2005 Annual Report, NASA/TR-2006-214136, 154–157.



Operation Centers

The Bonn Geodetic VLBI Operation Center

A. Nothnagel, A. Müskens

Abstract

In 2006, the name of the GIUB Operation Center has been changed to IGGB Operation Center. It has continued to carry out similar tasks of organizing and scheduling various observing series as in 2005.

1. Center Activities

The IGGB VLBI Operation Center is located at the Institute for Geodesy und Geoinformation (formerly Geodetic Institute) of the University of Bonn, Nussallee 17, D-53115 Bonn, Germany. It has been organizing and scheduling VLBI observing sessions for more than twenty years. The observing series organized and scheduled in 2006 are the same as in 2005 except that the scheduling for the INT2 series (Wettzell - Tsukuba) had been handed over to BKG in Leipzig.

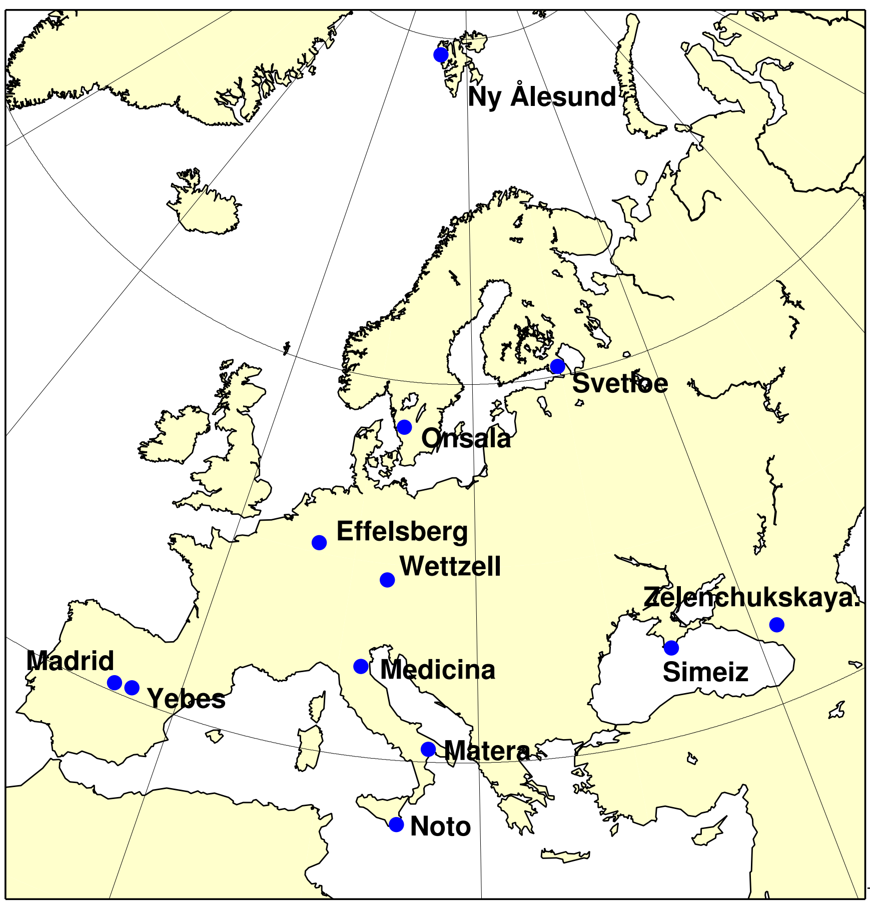


Figure 1. Observatories participating in the Europe sessions

- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE)**
  In Europe, a series of special sessions has been scheduled for the determination of precise station coordinates and for long term stability tests. This year, six sessions with Ny-Ålesund, Onsala, Metsahovi, Svetloe, Zelenchukskaya, Effelsberg, Wettzell, Simeiz, Madrid (DSS65A), Medicina, Matera, and Noto were scheduled employing a new frequency setup for the recording with 16 instead of 14 channels and 4 MHz instead of 2 MHz bandwidth in fan-out mode (identical to the setup of the IVS-T2 sessions). The new Yebes 40 m telecope is in the process of being completed and will be included in the Europe sessions as soon as possible.

- **IVS-T2 series**
  This series has been observed roughly every second month (6 sessions in 2006) primarily for maintenance and stabilisation of the VLBI terrestrial reference frame as well as for Earth rotation monitoring as a by-product. Each station of the global geodetic VLBI network is planned to participate several times per year in the T2 sessions. In view of the limitations in station days, priority was given to stronger and more robust networks with many sites over more observing sessions. Therefore, 12 to 16 stations have been scheduled in each session requiring multiple passes on the IVS correlators. The scheduling of these sessions has to take into account that a sufficient number of observations is planned for each baseline of these global networks. In summer 2006, the recording frequency setup was changed from 14 to 16 channels and from 2 MHz to 4 MHz channel bandwidth.

- **Southern Hemisphere and Antarctica Series (OHIG):**
  Six sessions of the Southern Hemisphere and Antarctica Series with the Antarctic stations Syowa (Japanese) and O'Higgins (German) plus Fortaleza, Hobart, Kokee, HartRAO and DSS45 have been organized for maintenance of the VLBI TRF and Earth rotation monitoring. These sessions are clustered in time at periods when O'Higgins is manned depending on logistical circumstances and manpower available. Since late 2006 these sessions are also recorded with the same new frequency setup as in the IVS-T2 and Europe sessions.

2. Staff

Table 1. Personnel at IGGB Operation Center

Arno Müskens	++49-228-525264	mueskens@mpifr-bonn.mpg.de
Axel Nothnagel	++49-228-733574	nothnagel@uni-bonn.de

CORE Operation Center Report

Cynthia C. Thomas, Daniel MacMillan

Abstract

This report gives a synopsis of the activities of the CORE Operation Center from January 2006 to December 2006. The report forecasts activities planned for the year 2007.

1. Changes to the CORE Operation Center's Program

The Earth orientation parameter goal of the IVS program is to attain precision at least as good as 3.5 μs for UT1 and 100 μas in pole position.

The IVS program which started in 2002, used the Mark IV recording mode for each session. The IVS program began using the Mark 5 recording mode in mid 2003. By the end of 2006, all stations with the exception of two have been upgraded to Mark 5. Due to the efficient Mark 5 correlator, the program continues to be station time and media dependent—as it has been for the past two years. The following are the network configurations for the sessions for which the CORE Operation Center was responsible:

IVS-R1: 52 sessions, scheduled weekly and mainly on Mondays, six to eight station networks

RDV: 6 sessions, scheduled evenly throughout the year, 16 to 20 station networks

IVS-R&D: 10 sessions, scheduled monthly, five to seven station networks

2. IVS Sessions January 2006 to December 2006

This section displays the purpose of the IVS sessions for which the CORE Operations Center is responsible.

- IVS-R1: In 2006, the IVS-R1s were scheduled weekly with six to eight station networks. Ny-Ålesund, Westford, and Wettzell participated in most of the IVS-R1 sessions. Fortaleza participated in several IVS-R1 sessions using 4 MHz bandwidth while the other stations used 8 MHz. Seshan participated in the IVS-R1 sessions with only 8 BBC during 2006. Both Ny-Ålesund and Zelenchuckskaya were tagged along to all IVS-R1 sessions in which the two stations participated.

  The purpose of the IVS-R1 sessions is to provide weekly EOP results on a timely basis. These sessions provide continuity with the previous CORE series. The "R" stands for rapid turnaround because the stations, correlators, and analysts have a commitment to make the the time delay from the end of recording to results as short as possible. The time delay goal is a maximum of 15 days. Participating stations are requested to ship discs to the correlator as rapidly as possible. The "1" indicates that the sessions are mainly on Mondays.

- RDV: There are six bi-monthly coordinated astrometric/geodetic experiments each year that use the full 10-station VLBA plus up to 10 geodetic stations.

  These sessions are being coordinated by the geodetic VLBI programs of three agencies: 1. USNO will perform repeated imaging and correction for source structure; 2. NASA will analyze this data to determine a high accuracy terrestrial reference frame; and 3. NRAO will use these sessions to provide a service to users who require high quality positions for a small number of sources. NASA (the CORE Operation Center) prepares the schedules for the RDV sessions.

- R&D: The purpose of the 10 R&D sessions in 2006, as decided by the IVS Observing Program Committee, was to record at 1 Gbit/s data rate to evaluate the geodetic results. Those experiments also tested the entire data flow from scheduling through analysis for the higher data rate. There were six regular stations that participated in the R&D sessions during 2006 until July when Algonquin stopped observing permanently.

3. Current Analysis of the CORE Operation Center's IVS Sessions

Table 1 gives the average formal errors for the R1, R4, RDV, R&D, and T2 sessions from 2006. The R1 sessions have somewhat better formal uncertainties in 2006 compared with 2005, where poorer uncertainties in 2005 were mostly due to problems with Gilcreek. RDV uncertainties are somewhat better in 2006 than 2005 apparently reversing the trend of the previous 2-3 years, which was caused by a decrease in the number of sites in the RDV network and in the number of observations. The differences between R&D mean formal uncertainties from 2005 and 2006 is due to a generally smaller observing network for the 2006 sessions.

Table 2 provides the EOP differences with respect to IGS for the different VLBI series. The level of WRMS agreement for the R1 sessions is better in 2006 than in 2005, which is consistent with better formal uncertainties in 2006. On the other hand, the agreement of R4 sessions with IGS was worse in 2006, consistent with poorer formal uncertainties. To understand the cause of this requires further investigation of the R4 networks used in 2005 and 2006. No statistically significant conclusions can be drawn from the WRMS differences for the RDV and T2 sessions since there are too few sessions available.

Table 1. Average EOP Formal Uncertainties for 2006

Session Type	Num	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (μas)	DEPS (μas)
R1	49	54(62)	52(59)	2.5(2.3)	111(132)	45(53)
R4	49	73(62)	72(59)	3.2(2.3)	166(132)	67(53)
RD	8	73(59)	57(51)	2.0(1.8)	146(120)	58(49)
T2	3	54(62)	55(61)	2.5(2.5)	126(148)	48(60)
RDV	5	40(43)	41(48)	1.9(2.6)	74(84)	31(34)

Values for 2005 are shown in parenthesis

4. The CORE Operations Staff

Table 3 lists the key technical personnel and their responsibilities so that everyone reading this report will know whom to contact about their particular question.

Table 2. Offset and WRMS Differences (2006) Relative to the IGS Combined Series

Session Type	Num	X-pole Offset (μas)	X-pole WRMS (μas)	Y-pole Offset (μas)	Y-pole WRMS (μas)	LOD Offset (μs/d)	LOD WRMS (μs/d)
R1	49	-78(-56)	79(90)	-185(-162)	79(88)	-5(-2)	18(17)
R4	49	-122(-138)	97(92)	-181(-212)	136(105)	-2(1)	21(19)
RD	8	-30(-146)	164(134)	-199(-178)	180(111)	1(-1)	17(17)
T2	3	-180(-35)	106(153)	-197(-254)	86(83)	-4(2)	9(19)
RDV	5	-47(-70)	10(29)	-150(-138)	81(43)	-2(3)	11(20)

Values for 2005 are shown in parenthesis

Table 3. Key Technical Staff of the CORE Operations Center

Name	Responsibility	Agency
Dirk Behrend	Organizer of CORE program	NVI, Inc./GSFC
Brian Corey	Analysis	Haystack
Irv Diegel	Maser maintenance	Honeywell
John Gipson	SKED program support and development	NVI, Inc./GSFC
Frank Gomez	Software engineer for the Web site	Raytheon/GSFC
David Gordon	Analysis	Raytheon/GSFC
Ed Himwich	Network Coordinator	NVI, Inc./GSFC
Chuck Kodak	Receiver maintenance	Honeywell
Dan MacMillan	Analysis	NVI, Inc./GSFC
Leonid Petrov	Analysis	NVI, Inc./GSFC
David Rubincam	Procurement of materials necessary for CORE operations	GSFC/NASA
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordinate master observing schedule and prepare observing schedules	NVI, Inc./GSFC

5. Planned Activities during 2007

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2007.

- The IVS-R1 sessions will be observed weekly and recorded in a Mark 5 mode.
- The IVS-R&D sessions will be observed 10 times during the year. The purpose of the R&D sessions in 2007 as determined by the IVS Observing Program Committee is to continue the series of Gb/s tests and to check new stations in Gigabit mode.
- The RDV sessions will be observed 6 times during the year.

NEOS Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 2006. The Operation Center schedules IVS-R4 and the INT1 Intensive experiments.

1. VLBI Operations

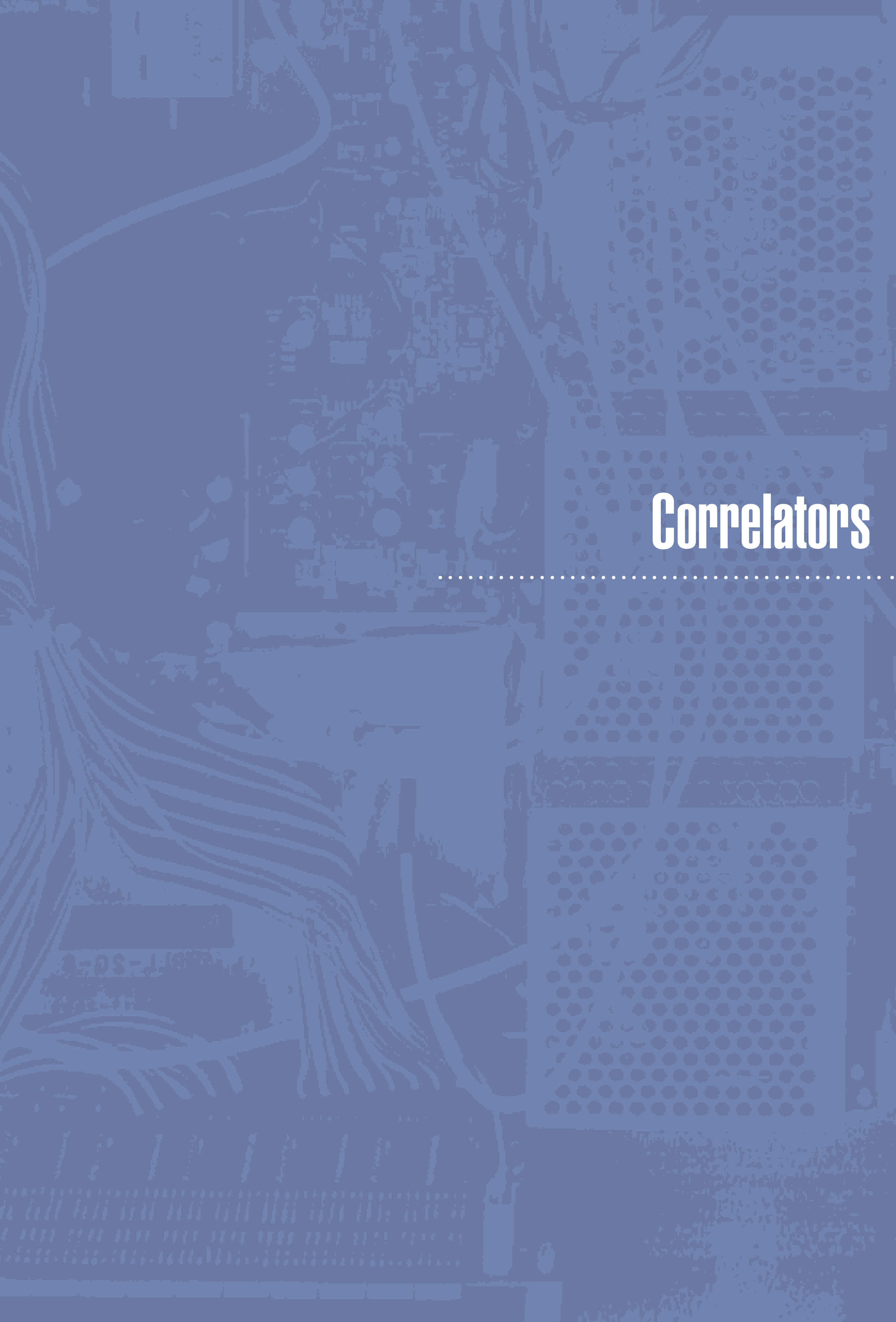
NEOS operations in the period covered consisted, each week, of one 24-hour duration IVS-R4 observing session, on Thursday-Friday, for Earth Orientation, together with five daily one-hour duration "intensives" for UT1 determination, Monday through Friday. The operational IVS-R4 network has included VLBI stations at Kokee Park (Hawaii), Wettzell (Germany), Fortaleza (Brazil), Ny-Ålesund (Norway), Algonquin Park (Canada), TIGO (Chile), Svetloe and Zelenchukskaya (Russia), Hobart (Australia), Onsala (Sweden), and Matera and Medicina (Italy). A typical R4 consisted of 7 to 8 stations.

The regular stations for the weekday IVS Intensives were Kokee Park and Wettzell. During the second half of the year a set of sessions including Kokee Park, Wettzell and Svetloe was observed twice per month in order to characterize the Kokee Park – Svetloe baseline so that Svetloe can be used as an alternate for Wettzell should it be needed.

All sessions are correlated at the Washington Correlator, which is located at USNO and is run by NEOS.

2. Staff

K. A. Kingham and M. S. Carter are the only staff members of the NEOS Operation Center. Kingham is responsible for the overall managment and Carter makes the schedules. M. S. Carter is located at the USNO Flagstaff Station (NOFS).



Correlators

The Bonn Astro/Geo Mark IV Correlator

Alessandra Bertarini, Arno Müskens, Walter Alef

Abstract

The Bonn Mark IV VLBI correlator is operated jointly by the MPIfR and the IGGB in Bonn and the BKG in Frankfurt. In 2006 besides routine correlation, the first eVLBI transfer from some geodetic stations to Bonn correlator were made. A prototype software correlator was also installed at MPIfR.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR)[1] Bonn, Germany. It is operated jointly by the MPIfR and by the Bundesamt für Kartographie und Geodäsie (BKG)[2] in cooperation with the Institut für Geodäsie und Geoinformation der Universität Bonn (IGGB) [3]. It is a major correlator for geodetic observations and MPIfR's astronomical projects, for instance those involving millimetre wavelengths and astrometry.

2. Present Status and Capabilities

Figure 1. Left-most rack contains the two correlator crates. Rack second from left contains two station units with two rack-mounted Mark 5A playback units. Rack second from right contains from top to bottom three Mark 5B units and the eVLBI-dedicated linux computer. Right-most rack contains two Mark 5B units.

The Bonn correlator (Fig 1) is one of the four Mark IV VLBI data processors in the world. It has been operational since 2000. A summary of the Bonn correlator capabilities is presented in Table 1.

[1]http://www.mpifr-bonn.mpg.de/div/vlbicor/
[2]http://www.bkg.bund.de/
[3]http://www.gib.uni-bonn.de

Table 1. Correlator Capabilities

Playback Units	
Number available:	7 Mark IV tape drives, 8 Mark 5A systems (interchangeable)
Tape types:	Thick, thin
Playback speeds:	80 ips, 160 ips (thin tapes); 135 ips, 270 ips (thick tapes) up to 1024 Mbit/s (Mark 5A)
Formats:	Mark III/Mark IV/VLBA (Mark IV/VLBA w/wo barrel roll, data demod.)
Sampling:	One bit; two bit
Fan-out:	1:1 1:2 1:4
Fan-in:	Not supported
No. channels:	$\leq$ 16 USB and/or LSB
Bandwidth/channel:	(2, 4, 8, 16) MHz
Signal:	Mono, dual frequency; dual polarization
Modes:	128-16-1 128-16-2 128-8-1 128-8-2 128-4-1 128-4-2 128-2-2 256-16-1 256-16-2 256-8-1 256-8-2 256-4-2 512-16-2 512-8-2 1024-16-2
Correlation	
Geometric Model:	CALC 8
Number of boards:	16
Phase cal:	Single tone extraction at selectable frequency
Pre-average times:	0.2 s to 5 s
Lags per channel:	32 minimum, 2048 maximum; 1024 tested and used
Maximum output:	9 stations: 36 baselines, 16 channels, 32 lags with autocorrelation function (ACF) parallel-hand polarizations only; 8 stations: 28 baselines, 16 channels, 32 lags with ACF full pol.
Fringe-fit:	Off-line FOURFIT run
Export:	Database, MK4IN to AIPS

The correlator is controlled from a dedicated workstation. Correlation setup, data inspection, fringe-fitting and data export are done with a separate workstation. Per year about 300 to 400 Gbytes of correlated data are generated. The total disk space available for data handling at the correlator is more than 1000 Gbytes. Data security is guaranteed by using a file system with redundancy (RAID level 5) and by daily back-up of the data on a 120 Gbyte disk of a low-end Linux PC.

3. Staff

The people in the geodetic group at the Bonn correlator are

- Arno Müskens: group leader, overall experiment supervision, scheduling of T2, OHIG, EURO series and eVLBI coordinator.
- Alessandra Bertarini: experiment setup and evaluation of correlated data, software correlator development, eVLBI commissioning tests and media shipping.
- Alexandra Höfer: experiment setup and evaluation of correlated data and media shipping.
- Christian Dulfer: eVLBI software support.
- 5 student operators for the night shifts and the weekends.

MPIfR staff supports IVS correlation with

- Walter Alef: correlator department head, correlator software maintenance and upgrades, software correlator development, eVLBI commissioning and computer system administration.
- David Graham: technical development, consultant and software correlator development.
- Alan Roy: deputy department head, water vapour radiometer (WVR), technical assistance.
- Heinz Fuchs: correlator operator, responsible for the correlator operator schedule, daily operations, and media shipping.
- Hermann Sturm: correlator operator, correlator support software, media shipping.
- Michael Wunderlich: engineer maintaining correlator, playback drives, Mark 5 and development of the digital baseband converter.
- Rolf Märtens: technician maintaining playback drives and Mark 5.

4. Status

- Experiment Status:
  In 2006 the Bonn group correlated 44 R1, six EURO, two T2, eight OHIG, which cleared the OHIG backlog from 2005, and about 20 astronomical projects. One K-band fringe test was correlated to measure the station coordinates of the Australian LBA antennas.
- CONT05:
  After a trial re-fringe-fitting carried out at Bonn in 2005, all the CONT05 sessions were re-fringe-fitted with one *fourfit* control file. The aim of the re-fringe fitting was to reduce the number of clock breaks between the sessions due to differences in the *fourfit* control files and to ease the comparison between the VLBI-CONT05 data and measurements with other geodetic techniques. This operation took place in 2006 at the Bonn correlator with support of Brian Corey (MIT Haystack Observatory).
- Software Correlator:
  In September 2006, Adam Deller (Swinburne University, Melbourne, Australia) visited the Bonn correlator and installed his C++ software correlator. The use of a software correlator has become possible recently due to the rapid increase of computing power in low-cost PCs. A couple of hours from an R1 were recorrelated using the software correlator and need now to be imported into AIPS for validation.

- eVLBI:
  In the second half of 2006, the Bonn group started to conduct tests to establish and test the network link to Bonn and to get familiar with the various TCP- and UDP-based protocols. Some tests were conducted with Onsala and an entire geodetic session (EURO84, ~700 GB) was transferred from Onsala to Bonn using the big-block FTP-based (EGAE) software from Haystack. In addition the Tsunami (UDP-based) protocol was tested with Metsahovi and Onsala and a sustained data rate of about 800 Mbit/s was obtained.
- Correlator Status:
  Two tape drives were decommissioned to make space for the Mark 5B racks, so the number of usable tape drives reduced to seven units in 2006.

5. Outlook for 2007

- Correlator:
  The tape drives and station units (SU) will still be mantained in 2007 since a couple of antennas are still recording on tape. There will be a gradual change toward Mark 5B, which will further simplify the correlation process since the SUs will no longer be needed. The HP correlator control computer and the HP used for the correlation setup, data inspection and data export will be decommissioned and substituted by a linux file server with a RAID disk array with 10 TByte capacity and two high-end linux workstations.
- Software Correlator:
  The software correlator output will be compared in detail with the hardware correlator output. A linux cluster is partly funded, more funds will be acquired in 2007 and 2008, provided tests are positive.
- eVLBI:
  The eVLBI project will continue with more antennas and with some of them real-time transfers will be tested. The immediate aim is routine data transfer from the more remote stations.
- Digital Baseband Converter (dBBC):
  The Bonn group is involved in the development of a digital baseband converter (dBBC) for the European VLBI Network (EVN). This unit is designed as a full replacement for the existing analog BBCs. Version I is already in production and a version II with broader bandwidth and lower cost is under developement. Version II will be fully compatible with version I.

Haystack Observatory VLBI Correlator

Mike Titus, Roger Cappallo, Brian Corey, Arthur Niell, Alan Whitney

Abstract

The Haystack Correlator continued to be used for a wide variety of operational, testing and developmental projects. Mark 5B was developed to the level of routine production use. Several repair and maintenance issues were addressed at all the Mark IV correlators. Migration of correlator software to a linux platform continues. Raw correlator output for all experiments dating back to late 2002 was exported to Goddard. Non-real-time e-VLBI transfers continue. Activities are increasingly focused on R&D rather than routine production.

Figure 1. Partial view of the Haystack Mark IV correlator, showing 3 racks containing 7 Mark 5A correlator playback units, 2 Mark 5B DOM correlator playback units with associated correlator interface board units, 1 Mark 5A e-VLBI transfer unit, decoder, the correlator rack, 3 tape drives, and 1 rack containing 4 Station Units. In the foreground is the new linux-based correlator control computer display.

1. Introduction

The Mark IV VLBI correlator of the MIT Haystack Observatory, located in Westford, Massachusetts, is supported by the NASA Space Geodesy Program and by the National Science Foundation. The available correlator time is dedicated mainly to the pursuits of the IVS, with a small portion of time allocated to processing radio astronomy observations for the Ultra High Sensitivity VLBI (u-VLBI) project. The Haystack Correlator serves as a development system for testing new correlation modes, for e-VLBI, for hardware improvements such as the Mark 5B system, and for diagnosing correlator problems encountered at Haystack or at one of the identical correlators at the U.S. Naval Observatory and the Max Planck Institute for Radioastronomy. This flexibility is made possible by the presence on-site of the team that designed the correlator hardware and software. Additionally, some production correlator time is dedicated to processing geodetic VLBI observations for the IVS.

2. Summary of Activities

Mark 5B is now in use for routine production. Three R&D experiments with data recorded in parallel in both Mark 5A and Mark 5B format at Westford have been processed, and another has been processed with only Mark 5B data from Westford. Many Mark 5B related development and verification tests, as well as a wide variety of other tests, were performed throughout the year. These tests were related to various software and hardware components, some examples being testing DOMs and CIBs, modifications to the messaging system, suman/domino software changes, data conversions between Mark 5A and Mark 5B, and testing for digital back end development. Testing of Mark 5A software revisions and new operating systems continues, with the intention of releasing a new version of the Mark 5A code using Conduant's latest SDK release and a contemporary O/S. Efforts to migrate the correlator software to a linux platform continue, along with the addition of a new computer dedicated to the project. Many maintenance issues have been addressed, both locally and at the Bonn and WACO correlators. Local examples include diagnosis and repair of two separate incidents of failed amplifiers in the TSPM splitter box, and repair and testing of failed input and control boards from all correlators. Bonn and WACO maintenance includes provision of replacements for failed input boards and SU parts, diagnosis of a tape library corruption problem at Bonn, and consultation with WACO on various problems. Leonid Petrov's corel_export program, which allows for the export of raw correlator output data to Goddard, was installed and used to export all experiments processed at Haystack since (and including) CONT02 in late 2002. Real-time e-VLBI testing has taken a hiatus this year due to the temporary loss of our use of a high speed link out of Lincoln Laboratory, but non-real-time transfers continue, with 63 experiments from four stations transferred this year. These non-real-time transfers included data from Kashima and Tsukuba, Japan; Ny-Ålesund, Norway; and Syowa, Antarctica.

3. Experiments Done

In 2006, 33 geodetic-VLBI experiments were processed at the Haystack correlator, consisting of 11 R&Ds, 3 T2s, and 19 test experiments. The test experiments cover a wide assortment of projects, some of which were touched on in the summary above. There was also a large number of smaller tests not included in the above count because they were too small to warrant individual experiment numbers.

4. Current/Future Hardware and Capabilities

Currently, functional hardware installed on the system includes 3 tape units, 7 Mark 5A units, 7 station units, 2 Mark 5B units (DOMs) with their associated correlator interface boards (CIBs), 16 operational correlator boards, 2 crates, and miscellaneous other support hardware. Another minor rearrangement of correlator hardware took place this year, with tape drive 5 removed to make room for a new rack containing the two Mark 5Bs and their associated CIB units. Also, a new linux based PC was procured to act as the new correlator control computer, and is in use (see Figure 1). In order to reduce noise and save electricity, only one tape drive is kept powered up, though it has rarely been used in the past year. We have the capacity to process all baselines for 9 stations simultaneously in the standard geodetic modes, provided the aggregate recordings match the above hardware matrix. In 2007, expansion of the Mark 5B units may allow for the retirement of Station Units and an increase in available playback units.

5. Staff

John Ball, long time software team member and Mark 5A guru, retired in June 2006, but is still able to assist us on Mark 5 issues on a part-time basis. Staff who participated in aspects of Mark IV, Mark 5, and e-VLBI development and operations include:

5.1. Software Development Team

- John Ball - operator interface; playback; Mark 5A/5B; e-VLBI
- Roger Cappallo - correlation software leader; system integration; post processing; Mark 5B; linux conversion
- Kevin Dudevoir - correlation; maintenance/support; Mark 5A/5B; e-VLBI; linux conversion
- Chester Ruszczyk - e-VLBI
- Jason SooHoo - e-VLBI
- Alan Whitney - system architecture; Mark 5A/5B; e-VLBI

5.2. Operations Team

- Peter Bolis - correlator maintenance
- Brian Corey - experiment correlation oversight; station evaluation; technique development
- Dave Fields - playback drive maintenance; Mark 5 installation and maintenance; general technical support
- Glenn Millson - correlator operator
- Arthur Niell - technique development
- Don Sousa - correlator operator; experiment setup; tape library and shipping
- Mike Titus - correlator operations oversight; experiment setup; computer services; software & hardware testing
- Ken Wilson - correlator maintenance; playback drive maintenance; general technical support

6. Conclusion/Outlook

The increased use of Mark 5B will improve capability, as each Mark 5B that is integrated will allow either the retirement of a station unit or an increase in the number of stations that can be simultaneously correlated. Retirement of station units should increase efficiency and throughput due to several factors: reduction in the need for reprocessing, routine use of a 32 MHz playback clock, and the smaller setup time required by Mark 5B. Upgrade of other correlators and stations to Mark 5B will follow. e-VLBI tests and experiments will hopefully resume, include more stations, and be more extensive. Non-real-time e-VLBI transfers will continue, possibly including more stations. Correlator operations have been focusing more on R&D and development work than on routine production, and this mode of operation will continue. The effort to move operational correlator production tasks to more modern Linux-based systems over the next year will continue, possibly including the correlator run-time software. Development in support of VLBI2010 is anticipated to increase next year. All the above work should result in a greatly improved data processing system as well as provide greater capability and a higher quality end-product to the IVS community.

IAA Correlator Center

Igor Surkis, Andrey Bogdanov, Alexey Melnikov, Violet Shantyr, Vladimir Zimovsky

Abstract

In 2006 regular three-station observations were started on the Russian national VLBI network Quasar. A 4-board MicroPARSEC correlator with S2-PT terminal was used to process it. High accuracy group delays were calculated. The EOP were determined by the IAA Data Analysis Center. A more powerful 12-board MicroPARSEC correlator is about to be put into operation.

1. Introduction

The IAA Correlator Center is located and staffed by the Institute of Applied Astronomy in St.-Petersburg, Russia. It is sponsored and funded by the Russian Academy of Sciences, by the Russian Foundation of Basic Research and by the Russian Ministry of Science and Eduction. The IAA Correlator Center is devoted to processing geodetic, astrometric, and astrophysical observations made by the Russian national VLBI network Quasar.

2. Summary of Activities

The MicroPARSEC correlation unit (Figure 1) has beeen developed in the last few years. It is based on the Altera FPGA technology. MicroPARSEC was developed using a standard PCI board, which is inserted into a personal computer. MicroPARSEC is directly connected to the S2-PT. One MicroPARSEC board can correlate 2 frequency channels of one base with maximum bandwidth of 16 MHz and 1-bit or 2-bit sampling. Input data format is VSI.

In 2003–2004, a correlator with a single MicroPARSEC board and a single S2-PT device was developed, which became the main correlator of the IAA Correlator Center in 2005.

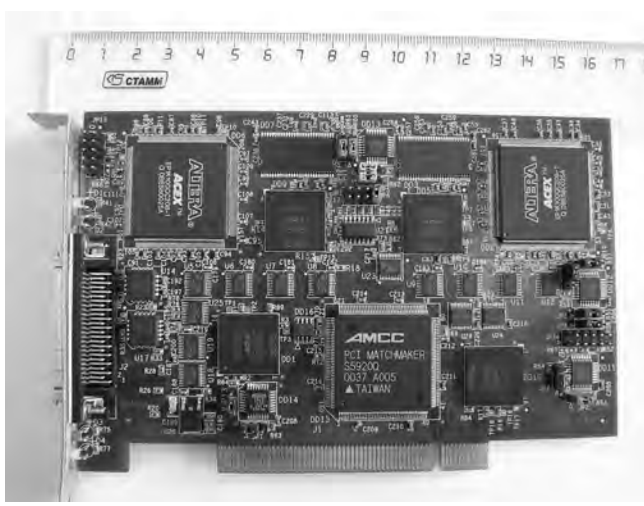


Figure 1. The MicroPARSEC board.

At the beginning of 2006, a new 4-board correlator MicroPARSEC (Figure 2) was completed. It consists of 4 MicroPARSEC units, one S2-PT, a special commutation device, and one personal computer. This correlator can process up to 8 frequency channels on 1 base. It takes 144 hours to process a three-station, 24-hour session of the Quasar VLBI network using this correlator.

In March 2006 this correlator became the main correlator of the IAA Correlator Center.

Figure 2. 4-board MicroPARSEC correlator.

At present, we are completing a 12-board MicroPARSEC correlator (Figure 3). It consists of 12 MicroPARSEC units placed into a special industrial computer, two S2-PTs and a special commutation device. This correlator can process up to 24 frequency channels simultaneously, i.e. 3 bases with 8 frequency channels each, so it will take 48 hours to process a standard Quasar VLBI session.

In December 2006, we started testing the 12-board MicroPARSEC correlator, and we are planning to put it into use in March 2007.

The postprocessing software was also modified to obtain high accuracy group delays and to prepare the IAA Correlator Center to process geodetic observations.

At present, the MicroPARSEC correlator is equipped with only S2-PT devices. In spite of the MicroPARSEC capabilities, we are currently limited by S2-PT characteristic allowing only observations of 2 MHz bandwidth with 1-bit sampling. We are planning to use Mark 5B terminals in the future.

3. Experiments Done

At the end of 2005, the first EOP determination experiments were performed on the three-station Russian national VLBI network Quasar. The data were processed with the single board MicroPARSEC correlator in January-February 2006.

Due to the configuration of Badary station equipment at that time the observations were only performed on X-band with 4 frequency channels. The ionospheric delays were calculated using GPS TEC (total electron content) maps, then NGS files were produced. The first national VLBI EOP were obtained in the IAA Data Analysis Center.

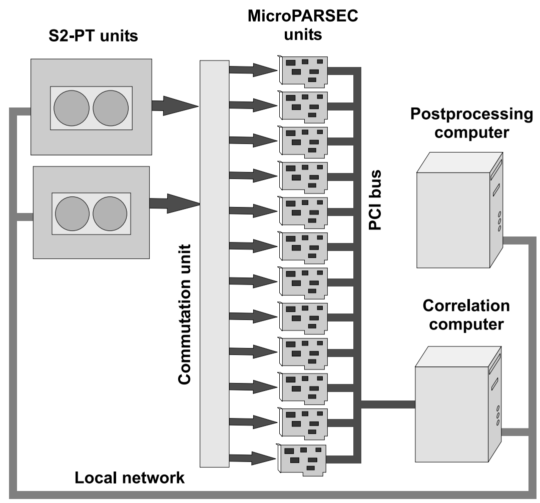


Figure 3. 12-board MicroPARSEC correlator.

In August 2006, the regular national VLBI observations on the Quasar VLBI network with full set of 14 frequency channels were started by the IAA RAS, which included three observational programs:

- EOP determination program, which lasts 24 hours using 3 stations and is run twice a month.
- UT1-UTC determination program, which lasts 8 hours using 2 stations and is run twice a month.
- Time synchronization program, which lasts 8 hours using 2 stations and is run twice a month.

All observational data were processed using the 4-board MicroPARSEC correlator.

The accuracies of the calculated group delays and ionospheric delays are within 50-100 picoseconds.

The accuracies of the EOP parameters calculated by the IAA Data Analysis Center are within about 1 mas for pole coordinates and 50 microseconds for UT1-UTC.

The scheduling of the Quasar observation series was done by the IAA RAS using the SKED software (Linux version).

4. Staff

- Andrey Bogdanov — software developer, correlator operator
- Alexey Melnikov — software developer, correlator operator
- Violet Shantyr — software developer, post processing
- Igor Surkis — leading investigator, system integrator, software developer
- Vladimir Zimovsky — hardware developer, system integrator, correlator operator

5. Conclusion

Russian regular geodynamic observations with the Quasar VLBI network have started. The data obtained have been processed using MicroPARSEC correlator at the IAA Correlator Center. The new 12-board MicroPARSEC correlator of higher efficiency is about to be implemented.

VLBI Correlators in Kashima

Mamoru Sekido, Tetsuro Kondo, Yasuhiro Koyama, Moritaka Kimura

Abstract

Correlators at Kashima have been developed for data processing of experimental VLBI observations for geodesy, spacecraft navigation and astronomy. A new PC-based VLBI sampler K5/VSSP32 is under development. Real-time data processing with software correlator was demonstrated with intercontinental baseline (Kashima – Westford) at JGN2 symposium in January 2007. Construction of software correlator as backup correlator for VERA project has been in progress as a contract with NAOJ.

1. General Information

The VLBI group of Kashima Space Research Center (KSRC) of National Institute of Information and Communications Technology (NICT) has been contributing to the VLBI community by development of VLBI technologies. In April 2006, the name of our group was changed from "Radio Astronomy Applications Section" to "Space-Time Application Project".

The hardware correlator developed for the Key Stone Project [1] is still available at KSRC, though it was not used in 2006. Instead, software correlator running on personal computers (PC) is mainly used for data processing of geodetic and spacecraft VLBI observations. Figure 1 shows a view of the observation room of the 34m station. The cluster of PCs are used for both VLBI data acquisition and correlation processing. VLBI data obtained at other stations are transferred to Kashima through the network or by sending hard disk drives (HDD) via usual mail. The cluster of PCs is used for correlation processing by sharing the data via Local Area Network (LAN). For the practical use of the software correlator, we have a contract with National Astronomical Observatory of Japan (NAOJ) to build a correlator system by using software correlator as a backup system for the VERA project [2].

A demonstration of real-time correlation processing of intercontinental baseline was successfully performed in the JGN2 symposium held in Hiroshima, Japan in January 2007. That success was achieved by strong support from staff of Haystack Observatory and Network people of JGN2 [3], Internet2 [4] and Dragon project [5].

Figure 1. A view of the observation room of Kashima 34m antenna. K5 system located in this room is used for observation and also for correlation processing.

2. Component Description

2.1. Data Processing for Geodesy

New version of PC-based sampling system K5/VSSP32 [6] is under development by Nitsuki Co Ltd under supervision of T.Kondo. The new observation and correlation software compatible with

K5/VSSP32 sampler is being prepared by T.Kondo.

A project named "Caravan" to build a prototype of a small VLBI antenna system with wide-band data acquisition system [7] is in progress. A 2.4m diameter antenna equipped with a gigabit recording system was tested with geodetic VLBI experiments between the 2.4 m station and Tsukuba 32m diameter telescope. The first test observation was 16 MHz sampling 8 channel only for X-band by using the K5/VSSP data acquisition system. Correlation was performed with software correlator. Further test experiments are planned for February 2007.

2.2. Data Processing of Spacecraft Observation

A series of VLBI observations of spacecraft HAYABUSA were organized in November 2005; at that time HAYABUSA made touch down to the asteroid ITOKAWA. A limit in precision of delay measurement was caused by spacecraft signal, since Japanese space missions have not been designed to transmit multi-tone signals with large frequency separation for VLBI spacecraft navigation. The phase delay observable has the potential for much higher precision of delay measurement, though absolute delay measurements are difficult due to phase ambiguity. The occasion of HAYABUSA's approach to ITOKAWA was a good chance to evaluate the calibration precision of Delta-VLBI technique with phase delay. Because the orbit of Itokawa is given with enough precision by other techniques (radar and optical measurement), it is possible to use phase delay observable assuming zero ambiguity by using Itokawa's orbit as a priori position of HAYABUSA. In this case, the purpose of the measurement is not orbit determination, but evaluation of the Delta-VLBI calibration technique. For this purpose, correlation processing to extract phase delay was performed with software correlator developed by M.Sekido. The excess delay correction with Delta-VLBI was confirmed to be successful in the order of 0.1 nanoseconds.

In 2007, the Japanese and Chinese space agencies will launch a lunar mission, which will use the VLBI technique extensively for measuring the lunar gravity field. China operates four VLBI stations for this lunar mission. As a test experiment, Japanese spacecraft GEOTAIL was observed jointly with Japanese and Chinese VLBI stations in December 2006. The data were recorded with Mark 5 system in China and with K5 system in Japan. Data conversion is in progress for data exchange and correlation processing in both countries. The ease of data conversion between different data acquisition systems is a benefit of PC-based recording systems. Realization of VSI-E will completely remove the troubles of data conversion between different VLBI systems in the near future.

2.3. E-VLBI Demonstrations

NICT is a unique institute which has specialists both in network research and in VLBI research. We are collaborating with Network Architecture Group and JGN2 group within NICT. The JGN2 is a high-speed network test-bed for encouraging the network research funded by Ministry of Internal Affairs and Communications. We are participating in JGN2 as a user and have performed e-VLBI demonstrations in conferences. The international conference of "Super Computing 2006" was held in Tampa in Florida in November 2006. Since a high-speed network connection to the Haystack Observatory was not available at the time, we performed pseudo VLBI data transfer to Kashima from a server placed in Chicago. Then the correlation results were output to a display in Tampa. The data transfer rate was 512 Mbps. At the JGN2 symposium held in Hiroshima in January 2007, we demonstrated real-time VLBI data processing with distributed software correlators. Thanks to support from people of the Haystack Observatory, we could use Westford 18m diameter radio telescope as a counter part. Since a high speed dedicated network connection through GROWNET and BOSSNET was not ready at that time, we used a shared network for the connection from Haystack to Chicago. The stable network performance with TCP/IP was unfortunately less than 64 Mbps; hence we wrote a program to extract one channel of the 16 Mbps 2bit data stream from 16MHz × 32 bit parallel data stream provided by VSI-H standard interface. Then the single channel of data was transferred to software correlators in Tokyo. The software correlator is composed of three PCs located at Akihabara, Otemachi, and Koganei, which are interconnected by an optically linked network. The fringe of 3C84 was successfully detected with real-time correlation processing with software correlator, and the result was transferred to Hiroshima for display. The successful achievement of these demonstrations was due to support from staff of Haystack, JGN2, Internet2 DRAGON project, and network group of NICT.

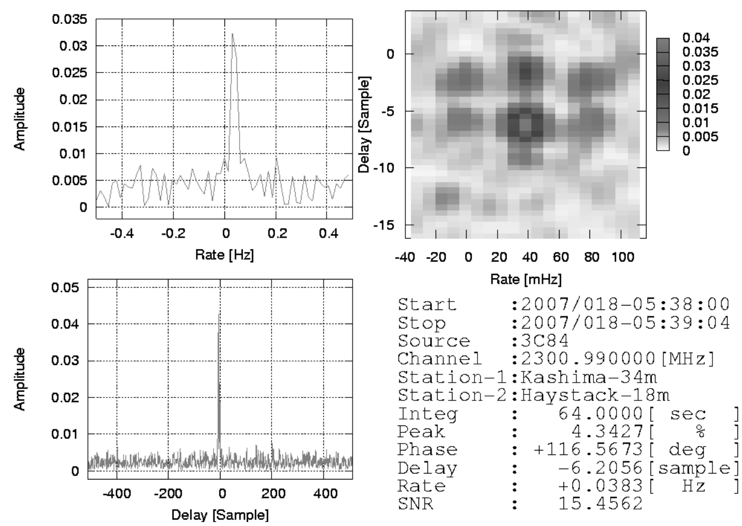


Figure 2. Fringe for 3C84 detected in real-time software correlation on Westford (18m)–Kashima (34m) baseline

2.4. Construction of Software Correlator for VERA Project

Our group has a contract with NAOJ to build a software correlator for the VERA project [2]. The VERA project already operates an FX-correlator, which was originally developed for VSOP project [8]. The software correlator system is being prepared [9] for replacement or as a backup of the current correlator. The specifications of the software correlator are given in Table 1. This system is going to be complete in 2007.

Table 1. Picture and specifications of software correlator for VERA Project

Specification parameters of the Software Correlator	
Stations	5
Baselines	10
Processing Rate	512 - 1024 Mbps/station
Lags Number	64 - 64000 points
Output	10 cross and 5 auto correlations
Output rate	1 - 100Hz
Output format	CODA, FITS

3. Staff

- Tetsuro Kondo is working on the development and maintenance of the software correlator for K5/VSSP [10]. Data format converter between Mark 5 and K5 is included in his package. Also he is in charge of new version of PC-based VLBI sampler K5/VSSP32 [6].
- Yasuhiro Koyama is project leader of "Space-Time Application Project" and is in charge of overall activity in our group.
- Mamoru Sekido is in charge of the e-VLBI activity and writing software for data transfer over the network. He is also working on VLBI applications for spacecraft navigation [11, 12].
- Moritaka Kimura is working on the development of a high speed Gigabit software correlator. He is in charge of development of software correlators for VERA project of NAOJ.
- Masanori Tsutsumi is working as system engineer for maintenance of PCs.

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Tsukuba VLBI Correlator

Morito Machida, Kazuhiro Takashima, Hiromi Shigematsu, Etsuro Iwata

Abstract

This is a report of the activities at the Tsukuba VLBI Correlator in 2006.

1. General Information

The Tsukuba VLBI Correlator is situated at the Geographical Survey Institute (GSI) in Tsukuba, Ibaraki Pref., Japan. It is a part of VLBI components operated by GSI, together with the Tsukuba 32-m VLBI station (TSUKUB32). The K5/VSSP correlator system has been in operational use since April 2005. In addition to the daily work, the Tsukuba VLBI Correlator also served as a K5/VSSP correlator system for development purposes in August 2006. Intensive sessions (IVS-INT2) performed on Saturday and Sunday on the TSUKUB32–WETTZELL baseline for monitoring UT1-UTC have been correlated at the Tsukuba VLBI Correlator. Processing of JADE series (geodetic sessions with domestic VLBI network of GSI, run for 24-hour) is also a major task for the Tsukuba VLBI Correlator.

2. Component Description

2.1. Correlation Systems

Software correlation processing at the Tsukuba VLBI Correlator has been done on K5/VSSP. It is based on the K5/VSSP technology that has been developed at NICT (National Institute of Information and Communications Technology, Japan). There are two K5/VSSP correlators at the Tsukuba VLBI Correlator. The first K5/VSSP correlation system, which is now abbreviated "system 1", has been operational since April 2005 as described above. The installation of a second K5/VSSP correlation system, abbreviated "system 2", was completed in August 2006. "system 2" has continued operation, dedicated mainly to processing Intensive sessions so far, while processing of JADE series is usually subject to "system 1".

The equipment for the K5/VSSP software correlation "system 1" has not changed with respect to the component description given in the 2005 report. The equipment for the K5/VSSP software correlation "system 2" currently consists of eight Linux computers with 3.4GHz Intel Pentium 4 as the data servers—each of which can share a couple of disk cartridges at once through a drive unit with 16 drive slots, eight rack mount Linux computers with 3.4GHz Intel Xeon dual CPUs as the correlation servers, and one Linux computer for file handling and multi-task control as the management computer. Each data servers can perform distributed computing as well as function as correlation servers.

The K5/VSSP acquisition system puts raw data from every four channels per scan into Linux files that could amount to, for example, 250 to 300 Gbytes in total during a 24-hour session. These files are stored as formatted binary files on four or eight 250 Gbytes removable disk cartridges, then transported to the correlator. Each disk cartridge from stations is connected to a data server in an external mounting mode.

2.2. File Sharing Logic

It is assumed that each data server should share auxiliary and raw data files with the management computer and correlation servers when distributed computing is going to be performed on the system. Each data server (host name:serv??) has directories /disk/serv??/sd1 and /disk/serv??/sd2 where two removable disk cartridges are mounted as /dev/sda1 and /dev/sdb1 of local disk partitions respectively. As NFS (network file system) server, a setup for /etc/exports on each data server allows these directories to be shared with the management computer and correlation servers. Meanwhile, the management computer should have directory /home/vlbi/ipvlbi where auxiliary files such as schedule, session log and a priori delay&rate calculation are copied to. Setting up NFS server on the management computer allows auxiliary files to be accessible with data and correlation servers. Instead of NFS client setup, there is automounting setup for /etc/auto.master and /etc/auto.misc, allowing servers to mount disk partitions on a remote server. Setting up NFS and automounting appropriately makes ready for control of distributed computing.

2.3. K5/VSSP Correlation Package and Aid Application

To make software correlation from raw data within the cluster of servers, the most essential elements are four kernel programs: "apri_calc", "cor", "sdelay" and "komb". They have been originally designed and developed by NICT. Based on an agreement of research cooperation between GSI and NICT, the Tsukuba VLBI Correlator is allowed to take advantage of these products which are licensed under NICT. "apri_calc" calculates a priori delay&rate for each scan per single baseline. "cor" executes software correlation. "sdelay" makes coarse fringe directly from correlator output. "komb" is a bandwidth synthesis program to obtain multi-band delay. The kernel programs have the ability to process only one scan data of single baseline.

These four kernel programs alone were supposed to do the software correlation, but they could not keep up with the demands for processing many scans for multi-baselines. Besides, our preliminary way of distributed computing sometimes did not work properly. There might be a conflict between correlation servers to get a task because of lacking access control to a list of tasks waiting to be correlated. As a solution, we developed an aid application software, "PARNASSUS" (Processing Application in Reference to NICT's Advanced Set of Softwares Usuable for Synchronization), to handle multi-baseline sessions. This application serves the operator as a tool, providing a graphical user interface and facilitating multi-task control.

There were some steps toward a full combination of "PARNASSUS". The latest version PARNASSUS 1.3, released March 2006, covers a priori delay&rate calculation, correlation execution, bandwidth synthesis and creating Mark III database. The application succeeds in optimizing operator's input into kernel program and comprehensively handling distributed computing of software correlation.

2.4. Primary Solution

CALC/SOLVE developed by NASA/GSFC is installed on an HP workstation to produce primary solution.

2.5. Machinery Room

Many computers are together in a machinery room now. The operator's room was set up in a different room to avoid subjection to a continuously low frequency audio noise, which might affect the operators working in close proximity.

Following are some issues with running K5/VSSP correlation systems in daily work:

- It consumes a lot of electric power in total. Most of the power supply cables are busy.
- Some correlation servers went down due to overload of cooling CPU fan. Our solution was a CPU fan (9200 rpm) replacement.

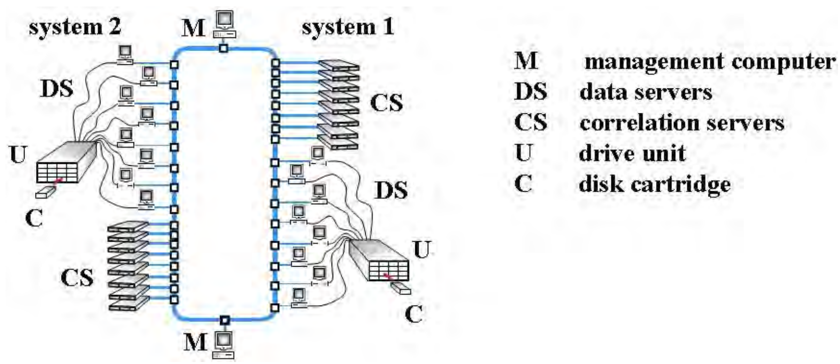


Figure 1. Simplified figure of the K5/VSSP correlation system.

3. Staff

List of the staff at the Tsukuba VLBI Correlator in 2006 is as follows. Staff in the observation domain are listed in the report of the Tsukuba 32-m VLBI station in the Network Stations section of this volume. M. Ishimoto, technical expert of the Tsukuba VLBI Correlator for three years, has left for a new career in April. In his stead, E. Iwata and H. Shigematsu took over the responsibility of maintaining and upgrading the correlation system. S. Fujiwara has left for a new career in August. Routine operations were mainly performed under contract with Advanced Engineering Services Co., Ltd (AES) over 200 days in the 2006 fiscal year (April 2006 through March 2007). AES was asked for 24 additional days of routine operations which were funded by National Astronomical Observatory of Japan. T. Nakajima from the Institute of Japanese Union of Scientists & Engineers worked for us. In particular, many addition in development of "system 2" should profit from his capacity as a system engineer and network administrator.

- S. Matsuzaka : Supervisor, Head of Space Geodesy Division (GSI)
- K. Takashima : Operations manager (GSI)
- E. Iwata : technical staff (GSI), system development and consultant
- H. Shigematsu : technical staff (GSI), correlation chief, media library and shipping
- M. Machida : technical staff (GSI), data evaluation, primary analysis

- K. Nozawa : main operator in routine correlation processing (Advanced Engineering Services Co., Ltd)
- K. Takano : sub-operator in routine correlation processing, software engineer for "PARNASSUS 1.3" (Advanced Engineering Services Co., Ltd)

4. Current Status and Activities

During 2006, 84 Intensive sessions (IVS-INT2) on TSUKUB32-WETTZELL single baseline for UT1, 12 geodetic sessions of domestic network for 24-hour (JADE series) were processed at the Tsukuba VLBI Correlator. One geodetic session for 24-hour (S06174 session) was processed using K5/VSSP correlator.

Most of the former K4 correlator equipment was removed in March 2006. After shifting correlation from K4 to K5/VSSP, one of our plans was due to add some more servers to the existing K5/VSSP correlation system ("system 1") as expansion. Eight rackmount-type Linux computers and eight Linux computers were available for this work. However, the development turned to preparing another correlation system, "system 2". This was triggered by "GSI internship 2006", which was a short-term stay program by GSI's Policy Board for the purpose of self-advertisement. Its goal was that students should learn GSI's activities through this program. This was an opportunity, as one program item, "VLBI Data Processing", required the use of a correlator, and the Tsukuba VLBI Correlator needed another correlation system. In particular, installing "system 2" brought us capacity building for running and maintaining the K5/VSSP correlator system on a regular basis.

S06174 session, conducted under GSI's initiative, aimed at the improvement of the USUDA64 (Ud) site position. USUDA64 of 64 m in diameter is mainly a navigation antenna for deep space missions belonging to JAXA (Japan Aerospace Exploration Agency). Excluding two good sessions in 1990 and 2003, some geodetic sessions in the past have not met accurate solutions for USUDA64's position so far. Processing of S06174 was funded by JAXA.

5. Plan for 2007

- It is planned to continue to process the TSUKUB32/WETTZELL Intensive sessions (IVS-INT2) with the K5 system. The sessions are to be performed on both Saturday and Sunday with K5 (TSUKUB32) and Mark 5 (WETTZELL) systems. The Tsukuba VLBI Correlator is also expected to be responsible for processing 12 geodetic sessions (JADE) of the domestic VLBI network of GSI.
- One of our aims to speed up the processing is to work on an expansion of our K5 correlation system. We will add some more correlation servers and data servers to the existing K5/VSSP correlation systems.
- Some implementation plans for the next version of "PARNASSUS" will be discussed in the advisory team of VLBI correlation domain.
- The previously described plan for estimating antenna thermal deformation using finite element method was initiated in 2006. Body temperature measurements will be continued at 11 points of the antenna mounting frame every minute.

Washington Correlator

Kerry A. Kingham, Brian J. Luzum, David M. Hall

Abstract

This report summarizes the activities of the Washington Correlator for the year 2006. The Washington Correlator provides up to 80 hours of processing per week, primarily supporting Earth Orientation and astrometric observations. In 2006 the major programs supported include the IVS-R4, IVS-INT, IVS-R1, IVS-T, and CRF and CRFD experiments.

1. Introduction

The Washington Correlator (WACO) is located at and staffed by the U. S. Naval Observatory (USNO) in Washington, DC, USA. The correlator is sponsored and funded by the National Earth Orientation Service (NEOS) which is a joint effort of the USNO and NASA. Dedicated to processing geodetic and astrometric VLBI observations, the facility spent 100 percent of its time on these experiments. All of the weekly IVS-R4 sessions, all of the daily Intensives, and several IVS-R1 sessions were processed at WACO. The remaining time was spent on terrestrial reference frame and astrometry sessions. The facility houses a Mark IV Correlator.

Figure 1. The right half of WACO showing 4 Mark 5A units (far right), legacy tape drives, the operator's console, and the central processor (left).

2. Correlator Operations

The Washington Correlator continues to operate 80 hours per week with an operator on duty. This year, the correlator has functioned well unattended, allowing another 24 hours per week, on average, of extra processing. This has also decreased the time it takes to process an R4 or R1 by one day.

The correlator staff has been trained in the testing and repair of Mark 5 modules. Not only were failed disks replaced, but some modules were upgraded by the replacement of small disks with larger ones.

The Intensive observations from Wettzell continue to be electronically transferred to the Washington area and transported to the correlator. This operation saves 1 to 2 days in shipping time.

Table 1 lists the experiments processed during 2006.

Table 1. Experiments processed during 2006

52	IVS-R4 experiments + 2 CONT days as Rapids
10	CRF (Celestial Reference Frame)
7	IVS-R1
3	APSG (Asia Pacific)
2	IVS-T (Terrestrial Reference Frame)
223	Intensives
16	Kk-Sv-Wz Intensives

3. Staff

The Washington Correlator is under the management and scientific direction of the Earth Orientation Department of the U.S. Naval Observatory. USNO personnel continue to be responsible for overseeing the scheduling and processing. During the period covered by this report, a private contractor, NVI, Inc., supplied a contract manager and correlator operators. An addition to the staffing this year is David Hall who is filling the post last held by Jim Martin. Unfortunately, long time correlator operator Joe Granderson had to retire due to health issues. Brian Luzum is spending most of his time working on the Earth Orientation combinations due to staff shortages in the Earth Orientation Department. He is still available to help with post–processing analysis when necessary.

Figure 2. Kenneth Potts, Firew Waktole and Bruce Thornton keep an eye on a prepass.

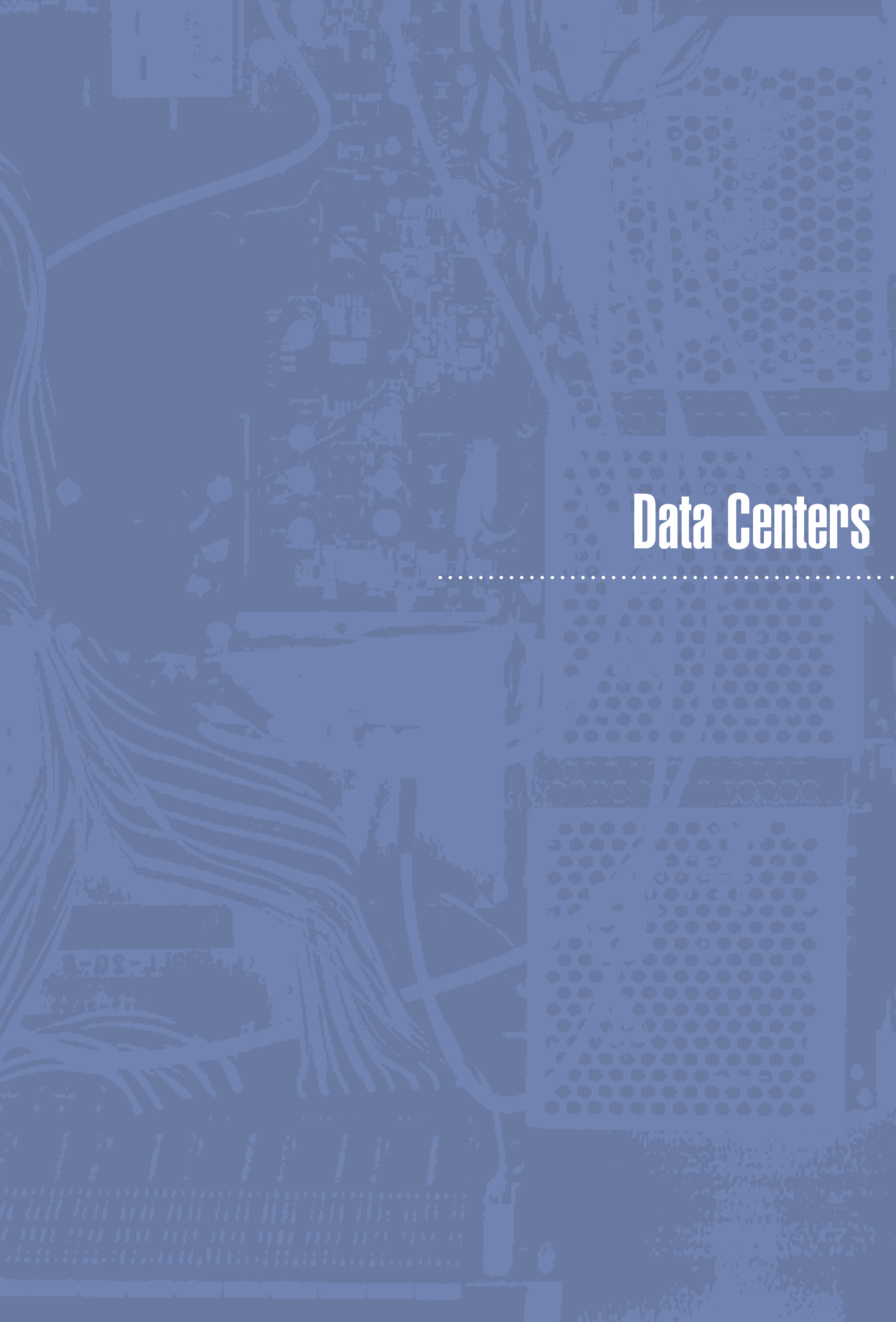
Table 2 lists staff and their duties.

Table 2. Staff

Staff	**Duties**
Dr. Kerry Kingham (USNO)	VLBI Correlator Project Scientist
David Hall (USNO)	VLBI Correlator Project Manager
Dr. Brian Luzum (USNO)	VLBI Correlator Scientist (part time)
Bruce Thornton (NVI)	Operations Manager
Harvis Macon (NVI)	Lead Correlator operator
Roxanne Inniss (NVI)	Media Librarian
Kenneth Potts (NVI)	Correlator Operator
Firew Waktole (NVI)	Correlator Operator

4. Outlook

The Washington Correlator plans to upgrade the Mark 5A playbacks to Mark 5B coordinated with the installation of Mark 5Bs at the Network Stations, and upgrade to a new correlator control computer. It is expected that the number of playbacks available will increase to 10 with the addition of 2 Mark 5B units.



Data Centers

BKG Data Center

Volkmar Thorandt, Reiner Wojdziak

Abstract

This report summarizes the activities and background information of the IVS Data Center for the year 2006. Included are information about functions, structure, technical equipment and staff members of the BKG Data Center.

1. BKG Data Center Functions

The BKG (Federal Agency for Cartography and Geodesy) Data Center is one of the three IVS Primary Data Centers. It archives all VLBI related data of IVS components and provides public access for the community. The BKG Data Center is connected to the OPAR and CDDIS Data Centers by mirroring the OPAR and the CDDIS file stocks several times per day. The following sketch shows the principle of mirroring:

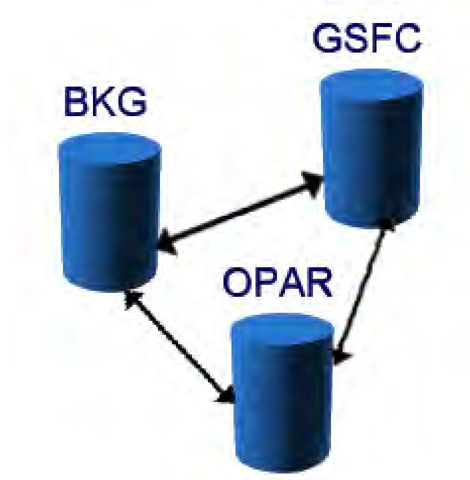


Figure 1. Principle of mirroring

IVS components can choose one of these Data Centers to put their data into the IVS network by using its incoming area which each of them has at its disposal. The BKG incoming area is protected and users need to obtain username and password to get access (please contact the Data Center staff).

An incoming script is watching the incoming area and checking the syntax of the files sent by IVS components. If it is o.k. the script moves the files into the data center directories; otherwise the files will be sent to a badfile area. Furthermore the incoming script informs the responsible staff at Data Center by sending e-mails about its activities. The incoming script is a part of the technological unit which is responsible for managing the IVS and the Operational Data Center and to carry out first analysis steps in an automatic manner. All activities are monitored to guarantee data consistency and to control all analysis steps from data incoming to delivering of analysis products to IVS.

Public access to the BKG Data Center is available through FTP and HTTP:

```
FTP:             ftp://ivs.leipzig.ifag.de/pub/vlbi/

HTTP:            http://www.leipzig.ifag.de/VLBI
```

Structure of BKG IVS Data Center:

```
vlbi/           : root directory
ivs-iers/       : VLBI products for IERS
ivs-pilot2000/  : directory for special investigations
ivs-pilot2001/  : directory for special investigations
ivs-pilotbl/    : directory for baseline time series
ivs-pilottro/   : directory for tropospheric time series
ivs-special/    : special CRF investigations
ivscontrol/     : controlfiles for the data center
ivsdata/        : VLBI observation files
ivsdocuments/   : IVS documents
ivsproducts/    : analysis products
                  (earth orientation, terrestrial and celestial frames,
                   troposphere, daily sinex files)
raw/            : raw files
```

2. Technical Equipment

DELL Server (SUSE Linux Enterprise 9.5 operating system)
disk space: 140 GBytes (Raid system)
internet rate: 34 MBit/sec
backup: automatic tape library

3. Staff Members

Volkmar Thorandt (coordination, data analysis, data center, volkmar.thorandt@bkg.bund.de)
Reiner Wojdziak (data center, web design, reiner.wojdziak@bkg.bund.de)
Dieter Ullrich (data analysis, data center, dieter.ullrich@bkg.bund.de)
Gerald Engelhardt (data analysis, gerald.engelhardt@bkg.bund.de)

CDDIS Data Center Summary for the 2006 IVS Annual Report

Carey Noll

Abstract

This report summarizes activities during the year 2006 and future plans of the Crustal Dynamics Data Information System (CDDIS) with respect to the International VLBI Service for Geodesy and Astrometry (IVS). Included in this report are background information about the CDDIS, the computer architecture, staffing supporting the system, archive contents, and future plans for the CDDIS within the IVS.

1. Introduction

The Crustal Dynamics Data Information System (CDDIS) has supported the archive and distribution of Very Long Baseline Interferometry (VLBI) data since its inception in 1982. The CDDIS is a central facility providing users access to raw and analyzed data to facilitate scientific investigation. The CDDIS archive of GNSS (GPS and GLONASS), laser ranging, VLBI, and DORIS data are stored on-line for remote access. Information about the system is available via the Web at the URL http://cddis.gsfc.nasa.gov. The current and future plans for the system's support of the IVS are discussed below.

2. System Description

The CDDIS archive of VLBI data and products are accessible to the public via anonymous ftp access.

2.1. Computer Architecture

The CDDIS is operational on a dedicated server, cddis.gsfc.nasa.gov. The system has over 3.5 Tbytes of on-line magnetic disk storage; approximately 900 Gbytes are devoted to VLBI activities. A dedicated DLT tape system is utilized for system backups. The CDDIS is located at NASA GSFC and is accessible to users 24 hours per day, seven days per week.

2.2. Staffing

Currently, a staff consisting of one NASA civil service employee and two contractor employees supports all CDDIS activities (see Table 1 below).

Table 1. CDDIS Staff

Name	Position
Ms. Carey Noll	CDDIS Manager
Dr. Maurice Dube	Head, CDDIS contractor staff and senior programmer
Ms. Ruth Labelle	Programmer

3. Archive Content

The CDDIS has supported GSFC VLBI coordination and analysis activities for the past several years through an on-line archive of schedule files, experiment logs, and data bases in several formats. This archive has been expanded for the IVS archiving requirements.

The IVS data center content and structure is shown in Table 2 below (a figure illustrating the flow of information, data, and products between the various IVS components was presented in the CDDIS submission for the 2000 IVS Annual Report). In brief, an incoming data area has been established on the CDDIS host computer, cddis.gsfc.nasa.gov. Operations and analysis centers deposit data files and analyzed results using specified file names to appropriate directories within this filesystem. Automated archiving routines, developed by GSFC VLBI staff, peruse the directories and migrate any new data to the appropriate public disk area. These routines migrate the data based on the file name to the appropriate directory as described in Table 2. Index files in the main subdirectories under ftp://cddis.gsfc.nasa.gov/pub/vlbi are updated to reflect data archived in the filesystem. Furthermore, mirroring software has been installed on the CDDIS host computer, as well as all other IVS data centers, to facilitate equalization of data and product holdings among these data centers. At this time, mirroring is performed between the IVS data centers located at the CDDIS, the Bundesamt für Kartographie und Geodäsie in Leipzig, and the Observatoire de Paris.

The public filesystem in Table 2 on the CDDIS computer, accessible via anonymous ftp, consists of a data area, which includes auxiliary files (e.g., experiment schedule information, session logs, etc.) and VLBI data (in both data base and NGS card image formats). A products disk area has also been established to house analysis products from the individual IVS analysis centers as well as the official combined IVS products. A documents disk area contains format, software, and other descriptive files.

4. Data Access

During 2006, over 150 user organizations accessed the CDDIS on a regular basis to retrieve VLBI related files. Nearly 25,000 VLBI-related files were downloaded per month from the archive.

5. Future Plans

The CDDIS staff will continue to work closely with the IVS Coordinating Center staff to ensure that our system is an active and successful participant in the IVS archiving effort. We also hope to procure new computer hardware to increase on-line disk storage capacity, ensure system redundancy, and better serve our user community.

Table 2. IVS Data and Product Directory Structure

Directory	Description
Data Directories	
vlbi/ivsdata/db/*yyyy*	VLBI data base files for year *yyyy*
vlbi/ivsdata/ngs/*yyyy*	VLBI data files in NGS card image format for year *yyyy*
vlbi/ivsdata/aux/*yyyy*/*ssssss*	Auxillary files for year *yyyy* and session *ssssss*; these files include: log files, wx files, cable files, schedule files, correlator notes
vlbi/raw	VLBI raw data
Product Directories	
vlbi/ivsproducts/crf	CRF solutions
vlbi/ivsproducts/eopi	EOP-I solutions
vlbi/ivsproducts/eops	EOP-S solutions
vlbi/ivsproducts/daily_sinex	Daily solutions
vlbi/ivsproducts/trf	TRF solutions
vlbi/ivsproducts/trop	Troposphere solutions
Project Directories	
vlbi/ivs-iers	IVS contributions to the IERS
vlbi/ivs-pilot2000	IVS Analysis Center pilot project (2000)
vlbi/ivs-pilot2001	IVS Analysis Center pilot project (2001)
vlbi/ivs-pilotbl	IVS Analysis Center pilot project (baseline)
vlbi/ivs-pilottro	IVS Analysis Center pilot project (troposphere)
vlbi/ivs-special	IVS special analysis solutions
Other Directories	
vlbi/ivscontrol	IVS control files (master schedule, etc.)
vlbi/ivsdocuments	IVS document files (solution descriptions, etc.)
vlbi/dserver	dserver software and incoming files

Italy INAF Data Center Report

M. Negusini, P. Sarti, S. Montaguti

Abstract

This report summarizes the activities of the Italian INAF VLBI Data Center. Our Data Center is located in Bologna, Italy, and belongs to the Institute of Radioastronomy, which is part of the National Institute of Astrophysics. We also report about some changes in the hardware facilities devoted to IVS activities.

1. Introduction

The main analysis activity and storage is concentrated in Bologna, where we store and analyze single databases, using CALC/SOLVE software.

The IRA started to store geodetic VLBI databases in 1989, but the databases archived in Bologna mostly contain data including European antennas from 1987 onward. In particular, most of the databases available here have VLBI data with at least three European stations. However we also store all the databases with the Ny-Ålesund antenna observations. In 2002 we decided to store the complete set of databases available on the IVS data centers; although, we limited the time span to the observations performed from 1999 onwards. All the databases have been processed and saved with the best selection of parameters for the final arc solutions. In order to perform global solutions, we have computed and stored the superfiles for all the databases.

In some cases we have introduced GPS-derived wet delays into the European databases (for the time being, we did this for 1998 and 1999 EUROPE experiments), as if they were produced by a WVR. These databases are available and stored with a different code from the original databases. In order to produce these databases, we have modified DBCAL and this new version is now available to external users.

2. Computer Availability and Routing Access

To date, the main computer is an HP 785/B2600 workstation. The Internet address of this computer is boira3.ira.inaf.it and the databases are stored in different directories and on different disks as well. The complete list of directories where databases are stored follows:

1 = /data1/mk3/data1
2 = /data1/mk3/data2
4 = /data6/dbase6
6 = /data5/dbase5
5 = /data4/dbase4
7 = /data7/dbase7
8 = /data8/dbase8
9 = /data9/dbase9
10= /geo/data
11= /geo/1999
12= /geo/2000

The username for accessing the database at the moment is geo. The password can be requested by sending an e-mail to negusini@ira.inaf.it.

The main computer, which was formerly located in Matera and was moved to Bologna, is an HP282 computer with Internet address hp-j.ira.inaf.it. The databases are stored in the following directories:

7 = /data8/dbase8
8 = /data10/dbase10

The superfiles are stored in different directories:

/data2/super
/data10/super10
/data9/super9
/data8/super8

The list of superfiles is stored in the file /data6/solve_files/SUPCAT. The area for data storage has a capacity up to 366 gigabytes with the installation of an external server. The data can be accessed using the username geo, and the password can be requested by writing to negusini@ira.inaf.it.

In the last months a new Linux workstation has been installed, with the aim to migrate all the VLBI analysis to Calc/Solve Version 10. The Internet address of this computer is sarip.ira.inaf.it. At present, a subset of the databases is stored in the following directory:

1 = /data2/dbase2

The superfiles are stored in:

/data1/super

During 2007 a new server with a storage capacity of 1 TB will be available and, therefore, all experiments performed in the previous years will be downloaded and analyzed, thus completing the catalogue. The username for accessing the databases, when the workstation will be properly working, will be geo. The password may be requested by sending an e-mail to negusini@ira.inaf.it.

Data Center at NICT

Yasuhiro Koyama

Abstract

The Data Center at National Institute of Information and Communications Technology (NICT) archives and releases the databases and analysis results processed at the Correlation Center and the Analysis Center at NICT. Regular VLBI sessions with the Key Stone Project VLBI Network were the primary objects of the Data Center. These regular sessions continued until the end of November 2001. In addition to the Key Stone Project VLBI sessions, NICT has been conducting geodetic VLBI sessions for various purposes and these data are also archived and released by the Data Center.

1. Introduction

In April 2004, the Communications Research Laboratory was integrated with the Telecommunications Advanced Organisation of Japan (TAO) to establish the National Institute of Information and Communications Technology (NICT) as a new institute. The IVS Data Center at NICT archives and releases the databases and analysis results processed by the Correlation Center and Analysis Center at NICT. Major parts of the data are from the Key Stone Project (KSP) VLBI sessions [1] but other regional and international VLBI sessions conducted by NICT are also archived and released. Since routine observations of the KSP network terminated at the end of November 2001, there were no additional data for the KSP regular sessions since 2002. In 2006, for example, five geodetic VLBI sessions were carried out. The analysis results in the SINEX (Solution Independent Exchange) file format as well as other formats are available on the WWW server. Database files generated with the Mark III database file format are available upon request and will be sent to the users on DDS tape cartridges. Database files of non-KSP sessions, i.e. other domestic and international geodetic VLBI sessions, are also available on the WWW server. Table 1 lists the WWW server locations maintained by the Data Center at NICT. In the past, an FTP server was used to provide data files, but it was decided to terminate the FTP service because of security risks of maintaining an anonymous FTP server. Instead, www3.nict.go.jp WWW server was prepared to place large size data files.

Table 1. URL of the WWW server systems.

Service	URL
KSP WWW pages	`http://ksp.nict.go.jp/`
IVS WWW mirror pages	`http://ivs.nict.go.jp/mirror/`
Data server	Currently not available

The maintenance of these server machines was moved from the VLBI research group of NICT to the common division for the institutional network service of the laboratory in 2001 to improve the network security of these systems.

2. Data Products

2.1. KSP VLBI Sessions

The KSP VLBI sessions were performed with four KSP IVS Network Stations at Kashima, Koganei, Miura, and Tateyama on a daily or bi-daily (once every two days) basis until May 1999. The duration of each session was about 23.5 hours. Within that period, daily observations were performed from March 1 to April 1, 1999 to obtain continuous VLBI data series for various investigations such as studies about the atmospheric delay models and for the improvements of the data analysis technique. The high-speed ATM (Asynchronous Transfer Mode) network line to the Miura station became unavailable in May 1999 and the real-time VLBI observations with the Miura station became impossible. Thereafter, the real-time VLBI sessions were performed with three stations only— Kashima, Koganei, and Tateyama. Once every six days (every third session), the observed data were recorded to the K4 data recorders at three stations and the Miura station participated in the sessions with the tape-based VLBI technique. In this case, the observed data at three stations (without Miura station) were processed in real-time and the analysis results were released promptly after the observations completed. A day later, the observed tapes were transported from Kashima, Miura, and Tateyama stations to Koganei station for tape-based correlation processing of the full six baselines. After the tape-based correlation processing was completed, the data set produced with the real-time VLBI data processing was replaced by the new data set.

In July 2000, unusual site motion of the Tateyama station was detected from the KSP VLBI data series, and the frequency of the sessions was increased from bi-daily to daily since July 22, 2000. The daily sessions were continued until November 11, 2000, and the site motion of the Tateyama and Miura stations were monitored in detail. During the period, it was found that Tateyama station moved about 5 cm to the northeast direction. Miura station also moved about 3 cm to the north. The unusual site motions of these two stations gradually settled and the current site velocities seem to be almost the same as the site velocities before June 2000. By investigating the time series of the site positions, the unusual site motion started sometime between the end of June 2000 and the beginning of July 2000. At the same time, volcanic and seismic activities near the Miyakejima and Kozushima Islands began. These activities are believed to have caused the regional crustal deformation in the area, explaining the unusual site motions at Tateyama and Miura.

2.2. Other VLBI Sessions

In addition to the KSP regular VLBI sessions, domestic and international geodetic VLBI sessions were conducted by NICT in cooperation with Geographical Survey Institute (GSI) and other organisations. These sessions are listed in Table 2. The observed data of these sessions were correlated by using the K-4 correlator and the K5 software correlator at NICT either at Koganei or at Kashima.

In 2006, six geodetic VLBI sessions were performed in total. The GEX14 session was carried out with the baseline between 11m VLBI stations at Kashima and at Koganei for about 9 hours from 03:00 UT on March 17, 2006. The purpose of this session was to demonstrate the capability of the newly developed multi-channel Giga-bit A/D sampler unit ADS2000 [2]. At both stations, the ADS2000 sampler unit was used to sample 10 X-band channels and 6 S-band channels at the

Table 2. Geodetic VLBI sessions conducted by NICT (since 2003)

Year	exp. names	sessions
2003	CUTE	CUTE04
	K5 Test	U03031, JD0306
	e-VLBI	evlbi4, tsev6
	Nozomi	34 sessions
	Hayabusa	10 sessions
2004	e-VLBI	tsev7, tsev8
	Geodetic	U04306
	Hayabusa	5 sessions
	Huygens	2 sessions
2005	Geodetic	c0505 (CONT05, partial participation), GEX13
	Hayabusa	14 sessions
2006	Geodetic	GEX14, viepr2, CARAVAN (3 sessions)
	Spacecraft	Geotail : 1 session
	Pulsar	1 session

sampling data rate of 64Msps for each channel and the digitising level of 2 bits/sample. The data observed at Koganei site were transfered to Kashima over the high speed network, and processed with the K5 software correlator. As the results from the session, the baseline length between two sites was estimated with an RMS uncertainty of 1.2 mm, and the performance of the ADS2000 sampler unit was demonstrated. Another geodetic VLBI session, viepr2, was performed for 3 hours from 13:00 UT on December 4, 2006. This session was organised in cooperation with Vienna University of Technology to educate students at the university. Three stations at Kashima (34-m), Wettzell, and TIGO participated in the session. The observed data have been transferred to Kashima and all the data were processed with the K5 software correlator.

The remaining three sessions were performed with the small aperture (2.4-m) station at Kashima and the 34-m station at Kashima. The 2.4-m antenna is called as CARAVAN-2400. The antenna has been developed to realize standard length traceable to the frequency standard provided by Hydrogen masers. The final purpose is to develop one pair of 1.5-m level small aperture stations and the baseline length between these small stations will be used as the reference baseline for the calibration of geodetic GPS receivers.

Figure 1 shows the number of geodetic VLBI sessions and number of valid observed delays used in the data analysis for each year up to the year 2006.

3. Staff Members

The data center at NICT is operated and maintained by the Space-Time Standards Group at Kashima Space Research Center, NICT. The staff members are listed in Table 3.

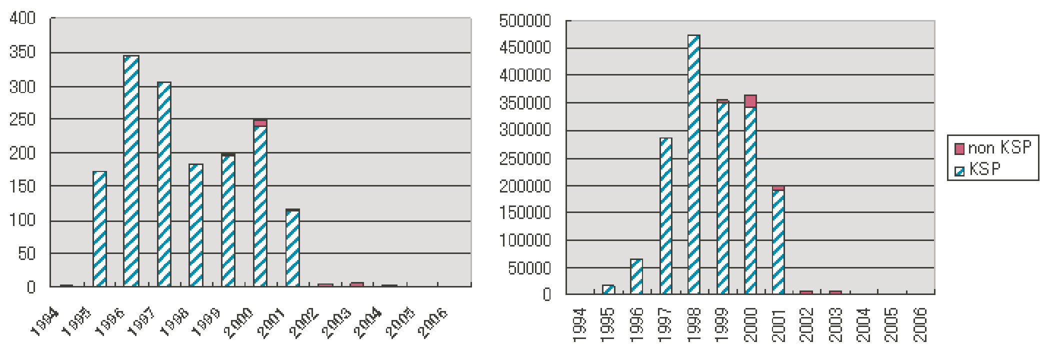


Figure 1. Number of sessions (left) and observed delays (right) used in the data analysis.

Table 3. Staff members of Space-Time Standards Group, KSRC, NICT

Name	Main Responsibilities
KOYAMA Yasuhiro	Administration of Servers, Generation and Archival of Databases
TSUTSUMI Masanori	System Engineer

4. Future Plans

Although the regular VLBI sessions with the KSP VLBI network finished in 2001, the IVS Data Center at NICT will continue its service and will archive and release the analysis results accumulated by the Correlation Center and Analysis Center at NICT. In addition, a number of VLBI sessions will be conducted for the purposes of various technology developments.

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Paris Observatory (OPAR) Data Center

Christophe Barache

Abstract

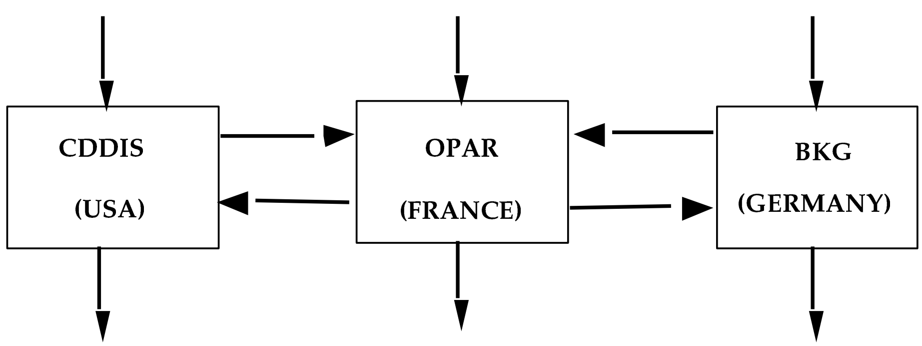
This report summarizes the OPAR Data Center activities in 2006. Included is information about functions, architecture, status, future plans and staff members of OPAR Data Center.

1. OPAR Data Center Functions

The Paris Observatory (OPAR) has provided a Data Center for the International VLBI Service for Geodesy and Astrometry (IVS) since 1999. The OPAR as well as CDDIS and BKG is one of the three IVS Primary Data Centers. Their activities are done in close collaboration for collecting files (data and analysis files), and making them available to the community as soon as they are submitted.

The three data centers have a common protocol and each of them:

- has the same directory structure (with the same control file),
- has the same script,
- is able to receive all IVS files (auxilliary, database, products, documents),
- mirrors the other ones every three hours,
- gives free FTP access to the files.



This protocol gives the IVS community a transparent access to a data center through the same directory, and a permanent access to files in case of a data center breakdown.

2. Architecture

To be able to put a file in a Data Center, operational and analysis centers have to be registered by the IVS Coordinating Center. The file names have to conform to the name conventions. A script checks the file and puts it in the right directory. The script undergoes permanent improvement and takes into account the IVS components' requests.

The structure of IVS Data Centers has not changed with respect to 2005:

```
ivscontrol/       : provides the control files needed by the data center
                    (session code, station code, solution code...)
ivscontrol_new/   : temporary test directory
ivscontrol_old/   : temporary test directory
ivsdocuments/     : provides documents and descriptions about IVS products
ivsdata/          : provides files related to the observations:
   aux/           :   auxilliary files (schedule, log...)
   db/            :   observation files in data-base CALC format
   ngs/           :   observation files in NGS format
   sinex/         :   observation files in SINEX format
ivsproducts/      : provides results from Analysis Center:
  eopi/           :   Earth Orientation Parameters, intensive sessions
  eops/           :   Earth Orientation Parameters, sessions of 24h
  crf/            :   Celestial Reference Frame
  trf/            :   Terrestrial Reference Frame
  daily_sinex/    :   Time series solutions in SINEX format of Earth
                      orientation and site positions
  trop/           :   Tropospheric time series (starting july 2003)
ivs-iers/         : provides products for IERS Annual Report
ivs-pilot2000/    : provides products of 2000 for special investigations
ivs-pilot2001/    : provides products of 2001 for special investigations
ivs-pilottro/     : provides tropospheric time series for Pilot Project
                       (until june 2003)
ivs-pilotbl/      : provides baselines files
ivs-special/      : specific studies
raw/              : original data (not writable actually at OPAR Data Center)
```

3. Current Status

The OPAR data center is operated actually on a new PC Server (PowerEdge 2800 - Xeron 3.0 GHz) located at Paris Observatory, and running the Fedora Linux operating system. To make all IVS products available on-line, the disk storage capacity was significantly increased and the server is equipped now with RAID 600 GB disk extensible up to 4.7 TB.

The OPAR server is accessible 24 hours per day, seven days per week through Internet connection with 2Mbit/s rate. Users can get the IVS products by using the FTP protocol. Access to this server is free for users.

FTP access:

ivsopar.obspm.fr
username : anonymous
password : your e-mail
cd vlbi (IVS directory)

4. Future Plans

The OPAR staff will continue to work with the IVS community and in close collaboration with the two others Primary Data Centers in order to provide public access to all VLBI related data. To ensure better access and make available raw data also in the OPAR Data Center, we have ordered new disks to get 3 TB for data storage.

5. Staff Members

Staff members who are contributing to OPAR Data Center and Analysis Center for IVS are listed below :

- Christophe Barache, Data Center manager and Data Analysis.
- Anne-Marie Gontier, responsible for GLORIA Analysis Software.
- Sébastien Lambert, scientific developments.
- Martine Feissel, scientific developments.
- Daniel Gambis, interface with IERS activities.

To obtain information about the OPAR Data Center please contact: ivs.opa@obspm.fr

Analysis Centers

Analysis Center of Saint-Petersburg University

Maria Kudryashova, Veniamin Vityazev

Abstract

The contribution of the Analysis Center of Saint Petersburg University for IVS consists in routine estimations of EOP time series and UT1-UTC values. Information about activities, staff members and background information is included in this report.

1. Introduction

Sobolev Astronomical Institute is located in Petrodvorets, near St. Petersburg. It is a research institute of the Saint Petersburg State University. The IVS Analysis Center of Saint Petersburg University was established in the Institute in 1998. The main activity of the AC SPU consists of routine processing of 24-hour and 1-hour observational sessions for obtaining Earth Orientation Parameters (EOP) and rapid UT1-UTC values, respectively. During 2006, the activities of AC SPU were supported by the Ministry of Education and Science of the Russian Federation (in frame of grant RNP.2.1.1.5077 "Astronomical and Geophysical Research based on VLBI and GPS/GLONASS observations").

2. Staff

The staff members who are involved in the activities of the Analisys Center are listed below:

- Veniamin Vityazev – Director of Astronomical Institute of Saint-Petersburg University, PhD., Prof. General coordination and support of activity at the Astronomical Institute.
- Maria Kudryashova – Research assistant of Astronomical Institute of Saint-Petersburg University. Processing of VLBI data.

3. Activities in 2006

- As in the previous years we continued to provide the series of five EOPs (spu0003i.eops) and rapid estimations of UT1-UTC (spu00002.eopi) values on a regular basis. Detailed description of the solution strategies have been given in our previous reports (see for instance [1], [2]).
- A new version of the OCCAM software package (version 6.2) was released [3]. Our center took part in testing this version and in the near future we are planning to change our current version to the new one. A preliminary comparison of the EOP series obtained by old and new versions of the software revealed that 1) the scatter of the post fit residuals (represented by weighted rms) was decreased when applying the new version; 2) formal errors of the parameters under estimation were more realistic in comparison with results of previous versions of the package due to more realistic estimation of χ^2 values.
- During the year 2006 we continued our investigations of sub-diurnal variations of EOP. Several individual time series of sub-diurnal EOP obtained from the CONT02 VLBI campaign

were compared. Two of these series were kindly provided by Dr. S. Bolotin (Main Astronomical Observatory of National Academy of Science of Ukraine) and by Dr. D. MacMillan (Goddard Space Flight Center). Analysis of the results is in progress. We also studied the covariance function of Earth orientation parameters which is needed for the least-squares collocation estimation of these parameters.

4. Future Plans

In the coming year we are planning to update our EOP solutions as well as to continue the investigations of sub-diurnal variations of Earth orientation parameters and their correlations with geophysics.

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Geoscience Australia Analysis Center

Oleg Titov

Abstract

This report gives an overview about the activities of the Geoscience Australia IVS Analysis Center during the year 2006.

1. General Information

The Geoscience Australia (GA) IVS Analysis Center is located in Canberra. The Geodesy group is operated as a part of the Geospatial and Earth Monitoring Division (GEMD).

2. Component Description

Currently the GA IVS Analysis Center contributes nutation offsets, three EOPs and their rates on regular basis for IVS-R1 and IVS-R4 networks and their predeccesors (IRIS-A, NEOS-A). The EOP time series from 1983 to 2006 are available. Also the CRF catalogues using a global set of VLBI data since 1979 are regularly submitted.

3. Staff

- Dr. Oleg Titov - project manager

4. Current Status and Activities

The last global solution has been done using the new features of the OCCAM 6.2 software. VLBI data comprising 3415 daily sessions from 25-Nov-1979 till 07-Sep-2006 have been used to compute the global solution aus2006b. This includes 3,638,913 observational delays from 1559 radiosources observed by 60 VLBI stations. Weighted root-mean-square of the solution is about 0.53 cm (about 16 picosec).

The aus2006b solution strategy used radiosources as close as possible to the ICRF [1]. Coordinates of 212 defining sources [1] were treated as global and imposed by the NNR constraints. 102 'other' sources were treated as local and their positions were estimated for each VLBI session. The rest of the 1245 sources were treated as global parameters without NNR constraints.

Station coordinates were also estimated using NNR and NNT constraints. The long-term time series of the station coordinates have been established to estimate the corresponding velocities for each station. Due to a limited amount of observations the velocities have been estimated for 55 stations only. Velocities of five stations (DSS65A, MARKUS, METSAHOV, VLBA85-3 and ZELENCHK) were not estimated. The tectonic motion for Gilcreek after the Denali earthquake is modelled using an exponential function [3].

The adjustment has been done by least squares collocation method [4], which considers the clock offsets, wet troposphere delays and troposphere gradients as stochastic parameters with apriori covariance functions. The gradient covariance functions were estimated from the GPS hourly values [2].

5. Geodetic Activity of the Australian Radiotelescopes

During 2006 two Australian radiotelescopes (Hobart and Parkes) were involved in geodetic VLBI observations. The geodesy group promoted the observations in different ways.

The operations of the Hobart telescope for geodetic VLBI is supported through an Australian Research Council (ARC) grant awarded jointly to the University of Tasmania (UTAS) and GA.

The Parkes 64-meter telescope participated in five geodetic VLBI sessions in 2006. Six sessions are planned for 2007. This program is promoted in cooperation with the Australian Telescope National Facility (ATNF).

6. New Geodetic VLBI Network

In November 2006 the geospatial bid within the National Collaborative Research Infrastructure Strategy (NCRIS) capability "Structure and Evolution of the Australian Continent" was approved. The VLBI part of this bid includes three new modern VLBI sites to be built in different parts of the Australian continent. The proposed design includes a small size dish (12 m) with fast slewing rate (5 degrees/second) equipped with Mark 5B recorder. All sites will eventually be linked with optical fiber to transmit the recorded data with high speed to the correlator facility which is being established at Australia's Swinburne University under supervision of Prof Steven Tingay.

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Bordeaux Observatory Analysis Center Report

Patrick Charlot, Antoine Bellanger, Géraldine Bourda, Arnaud Collioud, Alain Baudry

Abstract

This report summarizes the activities of the Bordeaux Observatory Analysis Center in 2006. During this period, our group has been strengthened by the arrival of a new staff member, allowing us to further develop the VLBI imaging activity initiated in 2005. A total of 548 VLBI maps have been produced by full imaging of three RDV sessions. Another highlight was the analysis of a complete year of data with the newly-developed GINS software and the estimation of the Earth Orientation Parameters. Other activities focus on regular processing of the IVS-R1 and IVS-R4 sessions and calculation of additional structure indices to refine our source categorization based on this criterion. Plans for 2007 follow the same analysis and research lines and include participation in the recently-created IAU/IVS/IERS working group on the second realization of the International Celestial Reference Frame.

1. General Information

The Bordeaux Observatory is located in Floirac, near the city of Bordeaux, in the southwest of France. It is funded by the University of Bordeaux and the CNRS (National Center for Scientific Research). VLBI analysis and research activities are primarily developed within the M2A group ("Métrologie de l'espace, Astrodynamique, Astrophysique") led by P. Charlot.

The contribution of Bordeaux Observatory to IVS is mostly concerned with the maintenance, extension, and improvement of the International Celestial Reference Frame (ICRF). This includes regular VLBI imaging of the ICRF sources and evaluation of their astrometric suitability, as well as the monitoring of the temporal evolution of their astrometric coordinates. The group also develops observing programs aimed at extending the ICRF and is in charge of the VLBI aspects in the multi-technique GINS software which combines VLBI and space geodetic data at the observation level.

2. Description of Analysis Center

The Bordeaux Observatory Analysis Center routinely analyzes the weekly IVS-R1 and IVS-R4 sessions. This analysis, conducted with the JPL VLBI estimation software MODEST [1], is primarily targeted at estimating monthly radio source coordinates. We expect in the near future to implement an operational solution in order to quickly report source position instabilities.

Another activity is focused on producing VLBI maps of the ICRF sources by analysis of data from the RDV sessions. This analysis is conducted with the AIPS and DIFMAP calibration and imaging software. The aim of such regular imaging is to compare source structural evolution and positional instabilities. The maps are also used to derive "structure indices" in order to characterize the astrometric suitability of the sources. Such a categorization will be important in the framework of the newly-created IAU/IVS/IERS working group on the next realization of the ICRF.

In addition, we develop experimental VLBI analysis with the GINS multi-technique software [2], as part of a project aimed at combining all VLBI and space geodetic data (SLR, GPS, DORIS) at the observation level. In this collaborative effort, the VLBI data are analyzed in Bordeaux, while the satellite geodetic data are processed either at the GRGS ("Groupe de Recherches de Géodésie Spatiale") in Toulouse (for GPS and DORIS) or at the OCA ("Observatoire de la Côte d'Azur") in Grasse (for SLR), with the final multi-technique combination produced at Paris Observatory.

3. Scientific Staff

The IVS group in Bordeaux comprises the following five individuals who are involved either part time or full time in VLBI analysis and research activities, as described below:

- Patrick Charlot (50%): overall responsibility for Analysis Center work and data processing. His major research interests include the densification and extension of the ICRF and studies of source structure effects in astrometric VLBI data.
- Antoine Bellanger (100%): engineer with background in statistics and computer science. His main role is to conduct initial VLBI data processing with MODEST and develop analysis tools as needed. He is also the web master for the M2A group.
- Géraldine Bourda (25%): postdoc fellow funded by the French space agency (CNES). She is in charge of implementing and validating routine VLBI analysis with the GINS software for multi-technique data combination at the observation level.
- Arnaud Collioud (75%): engineer with background in astronomy and interferometry. He was recruited as a new staff member on 1 April 2006. His task is to process the RDV sessions with AIPS and DIFMAP in order to image the sources observed in these sessions.
- Alain Baudry (10%): radioastronomy expert with specific interest in radio source imaging and astrometric VLBI.

4. Analysis and Research Activities during 2006

During 2006, our level of activity has significantly increased thanks to the arrival of Arnaud Collioud in our group. His arrival has allowed us to take our share in the processing of the RDV sessions, as part of a collaboration involving USNO, Whittier College (USA), and the Max Planck Institute for Radioastronomy in Bonn. Initial work consisted in establishing and testing appropriate procedures for calibration, edition, and automatic imaging of all the sources observed in these sessions. After validation of the procedures, three such sessions (RDV20, RDV42 and RDV51) have been fully processed and a total of 548 VLBI images at either X or S band for 162 different sources have been produced. See Fig. 1 for a sample of images derived from the RDV42 data. In addition, we have pursued our collaboration with Julio Camargo (Observatorio do Valongo, Brazil) to process the RDV36 session in a similar way. We expect to place all of our images along with the corresponding structure correction maps on our web site in the near future.

In parallel with this work, we have also continued our calculation of structure indices in order to improve the source categorization based on intrinsic VLBI structures. The aim is to densify our series of structure indices, taking advantage of newly-available maps, in order to identify the sources that remain astrometrically suitable (i.e. with a structure index value of either 1 or 2) at any epoch [3]. Our current calculation indicates that there are 221 such ICRF sources (out of the 560 sources for which a structure index value is available for at least one epoch). These sources are potential candidates to serve as defining sources in the next realization of the ICRF.

A specific study was also targeted at examining the astrometric suitability of the sources with bright optical counterparts (QSOs) that are potential candidates for the link with the future GAIA frame [4]. This study showed that there are only 67 sources that have excellent or good astrometric suitability in the ICRF, hence indicating the need to identify additional radio sources to establish

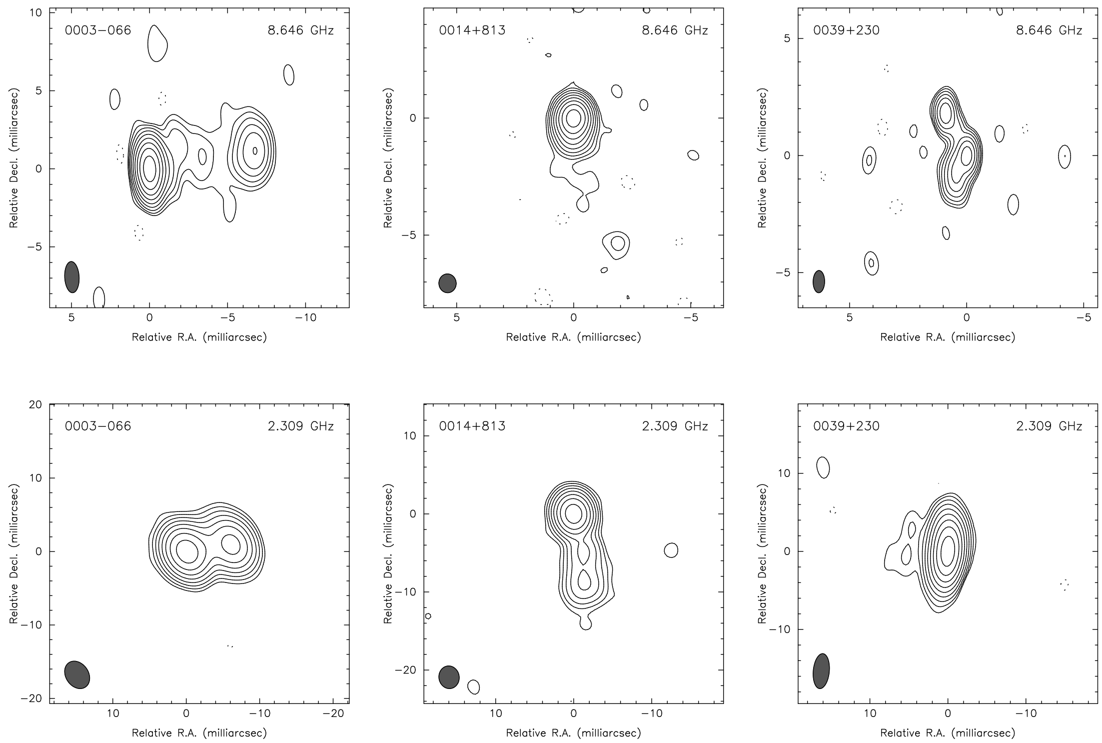

Figure 1. VLBI images at X band (upper panel) and S band (lower panel) for three ICRF sources (0003−066, 0014+813, and 0039+230) as derived from the data of the RDV42 session conducted on 2003 December 17. The three sources were selected randomly according to increasing right ascension starting at RA=00h.

the GAIA link. Interestingly, it was also found that the brightest QSOs tend to have less accurate ICRF positions, most probably because they possess more extended structures.

Another major achievement during the past year was the realization of the first large-scale VLBI analysis (i.e. including all IVS-R1 and IVS-R4 sessions from 2005) estimating Earth Orientation Parameters (EOP) with the GINS software. The results for polar motion and nutation offsets derived from this analysis are plotted in Fig. 2 and compared with the corresponding estimates in the IVS combined series. This comparison shows agreement between the two EOP series at the 0.2 mas level. Additional testing continues by carefully comparing the calculated VLBI delays in GINS with those from MODEST in order to guarantee millimeter accuracy in modeling. In the future, GINS may eventually replace the MODEST software for our routine IVS analysis.

5. Outlook

For the year 2007, our plans include the following:

- Keep on analyzing the new IVS-R1 and IVS-R4 sessions as they become available and implement an operational monthly "arc solution" to quickly report the temporal evolution of the source positions.

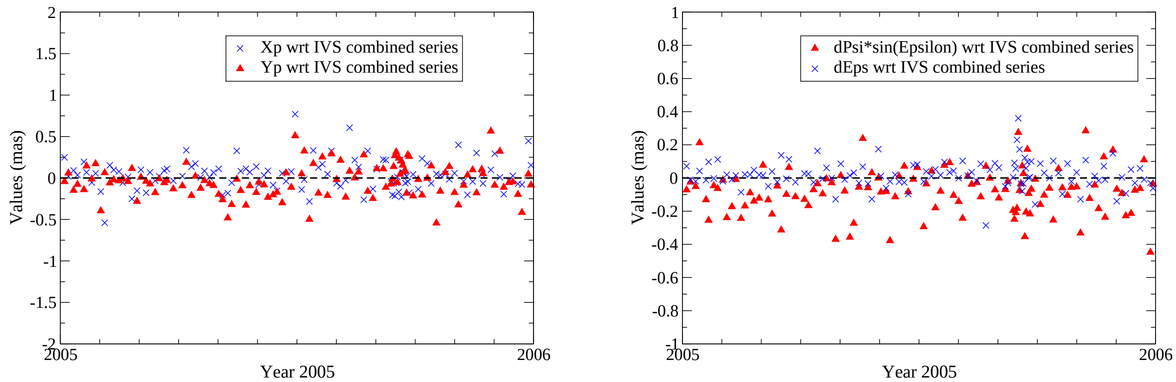

Figure 2. Polar motion (X_p, Y_p) and nutation offsets ($d\epsilon$, $d\psi \sin \epsilon$) derived from analysis of the 2005 IVS-R1 and IVS-R4 sessions with the GINS software. The results are reported with respect to the corresponding values in the IVS combined series.

- Pursue further the testing of the GINS software and develop operational procedures for VLBI analysis as part of the effort to integrate VLBI, GPS, DORIS and SLR data in a multi-technique combination at the observation level.
- Continue the processing of the RDV sessions to monitor the X- and S-band structural variability of the ICRF sources in cooperation with the other groups that contribute to the imaging of these sessions.
- Continue to evaluate the astrometric suitability of the ICRF sources as new maps become available and categorize the sources according to our structure index criterion.
- Participate in the work of the newly-created IAU/IVS/IERS working group on the realization of the next ICRF, in particular by contributing to the selection of defining sources and the identification of unstable sources.
- Implement an online database to make our source maps, structure correction maps and structure indices publicly available through the web.

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Matera CGS VLBI Analysis Center

Roberto Lanotte, Giuseppe Bianco, Cinzia Luceri

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS) at Matera from January 2006 through December 2006 and the contributions that the CGS intends to provide for the future as an IVS Data Analysis Center.

1. General Information

The Matera VLBI station became operational at the Space Geodesy Center (CGS) of the Italian Space Agency (ASI) in May 1990. Since then it is active in the framework of the most important international programs. VLBI data analysis activities are performed at CGS for a better understanding of the tectonic motions with specific regards to the European area. The CGS, operated by Telespazio on behalf of ASI, provides full scientific and operational support using the main space geodetic techniques: VLBI, SLR and GPS.

2. Staff at CGS contributing to the IVS Analysis Center

- Dr. Giuseppe Bianco, Responsible for CGS, ASI (primary scientific/technical contact).
- Dr. Cinzia Luceri, Responsible for scientific activities, e-GEOS.
- Dr. Roberto Lanotte, Geodynamics data analyst, Telespazio.

3. Current Status and Activities

3.1. Global VLBI Solution cgs2006a

The main VLBI data analysis activities at the CGS in the year 2006 were directed towards the computation of a global VLBI solution, named cgs2006a, using the CALC/SOLVE software (developed at the GSFC). The cgs2006a is available on the IVS products ftp sites and its main characteristics are:

- Data span:
  1979.08.03 - 2006.07.27 (3213 sessions)
- Estimated Parameters:
  - Celestial Frame:
    right ascension and declination as global parameters for 625 sources and as local parameters for 1854 sources.
  - Terrestrial Frame:
    Coordinates and velocities for 83 stations as global parameters and as local parameters for 29 stations.
  - Earth Orientation:
    Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi and deps.

3.2. IVS Tropospheric Products

Regular submission of tropospheric parameters (wet and total zenith path delays, east and north horizontal gradients) for all VLBI stations observing in the IVS R1 and R4 sessions was continued during 2006. At present 387 sessions have been analysed and submitted covering the period from 2002 to 2006.

3.3. IVS Pilot Project "Time Series of Baseline Lengths"

Regular submission of station coordinate estimates, in SINEX files, was continued during 2006 for the IVS pilot project "Time Series of Baseline Lengths". Moreover the series has been completed with the sessions prior to 2000 and now it is composed of 3124 sessions, from 1979 to 2006. At the present, an analysis of the differences between the CGS series and those provided by other analysis centers participating in this project is under investigation.

4. Future Plans

- Continue and improve the realization of global VLBI analysis.
- Continue to participate in IVS analysis projects.

DGFI Analysis Center Annual Report 2006

Volker Tesmer, Hermann Drewes, Manuela Krügel

Abstract

This report summarizes the activities of the DGFI Analysis Center in 2006 and outlines the planned activities for the year 2007.

1. General Information

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institution located in Munich. It is run by the German Geodetic Commission (Deutsche Geodätische Kommission, DGK) at the Bavarian Academy of Sciences. The research covers all fields of geodesy and includes the participation in national and international projects as well as functions in international bodies (see also http://www.dgfi.badw.de).

2. Activities in 2006

1. Effect of various analysis options on estimated TRF and station position parameters

   Geodetic computations offer a variety of analysis options, which are subject of general conventions, like the IERS Conventions, or technique dependent conventions proposed by the technique services. But, neither can all options be objectively judged as right or wrong, nor are the effects of all options on geodetic parameters known in detail.

   For example, VLBI results significantly depend on the chosen tropospheric mapping function (MF), which may cause systematic effects. As illustrated in Figure 1, the station height components of a TRF solution computed from 20 years of data differ by up to 13 mm between solutions computed with the VMF1 (Vienna Mapping Function 1) and the NMF (Niell Mapping Function). Discrepancies between station height time series reveal annual periodical signals with amplitudes up to 5 mm (Figure 2). In terms of station position repeatability, VMF1 is clearly superior: Using VMF1 the overall WRMS of the heights is between 5% and 7% better, for stations between 30° and 50° latitude even by up to 23% than with NMF.
   Using constant a priori ZD (zenith delay) instead of a ZD derived from surface meteorological data may change the station heights of an estimated TRF tremendously, as estimated ZD and station heights are correlated. With the approaches usually used, e.g. in GPS data analysis, the station heights change less than 1 cm. Furthermore, periodic and annual signals in differences of such height position time series can be found up to 4 mm (Figure 3).

   These results and other tested analysis options are described in Tesmer et al. (2006).

2. Effect of various analysis options on VLBI-determined CRF

   The next VLBI-determined realization of the International Celestial Reference System (ICRS) is prepared thoroughly. It will presumably serve as an important link between Earth-oriented and space-oriented sciences via other celestial reference frames (e.g. GAIA) to be created in the next decade. Such satellite-based celestial reference frames are planned to be

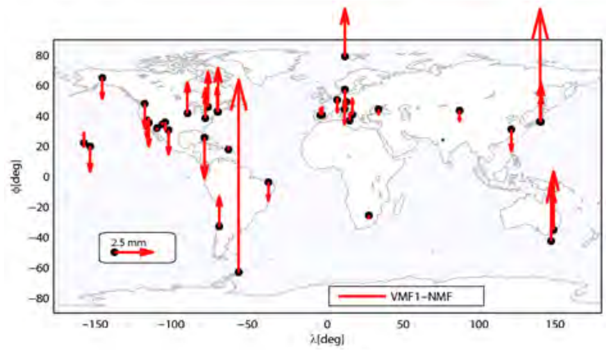

Figure 1. TRF height differences: Comparing solutions with VMF1 and NMF.

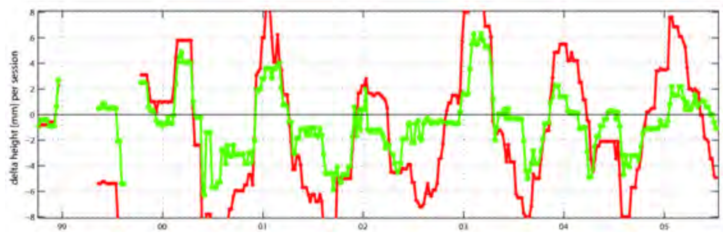

Figure 2. Time series of height differences in Tsukuba (Japan): Solutions VMF1 vs. NMF (dark) and GMF (light), displayed are moving medians computed every 7 days for values of 70 days each.

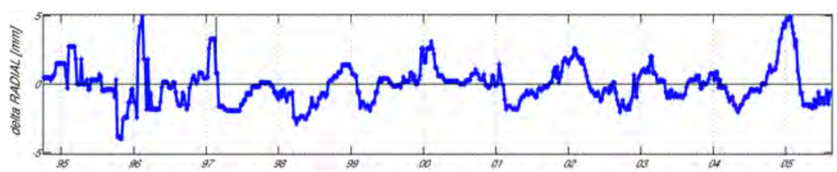

Figure 3. Time series of height differences in Ny-Ålesund (Spitsbergen, Norway): Solution using ZD from surface met data vs. solution using constant apriori ZD. Displayed are moving medians computed every 7 days for values of 70 days each.

of even higher precision than it can be achieved with VLBI observing at the Earth's surface. This connection will be realized by the very stable VLBI station network referred to the International Terrestrial Reference Frame (ITRF). In this context, the effects of various analysis options on VLBI-determined CRF (celestial reference frames) were investigated:

- different troposphere mapping functions and gradient models,
- impact of elevation-dependent weighting (refined stochastic model),
- choice of data set (neglecting 534 sessions before 1990 and 21 astrometric sessions),
- handling of sources that may not be assumed to have time-invariant positions,
- handling of the station network (estimate the station positions per session, as positions and velocities over 20 years, or fix them to a priori values).

The biggest systematic effects in the estimated source positions of up to 0.5 mas were found to be due to different gradient models (see e.g. Figure 4, grey stars indicate the differences between the declination estimates of the all sources in the solution, solid red lines are median values computed each 0.5° for all values inside a ±12.5° band). The choice of the data set does generally not have a significant influence. This holds also (with exceptions) for different options how to treat sources which are assumed to have time-invariant positions (Figure 5).

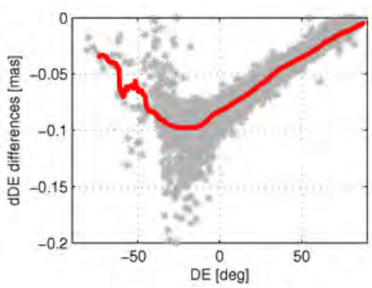

Figure 4. Differences between 2769 declination estimates of two CRF solutions: using constant a priori gradient values (mean of 1990-1995) - using 0 a priori values.

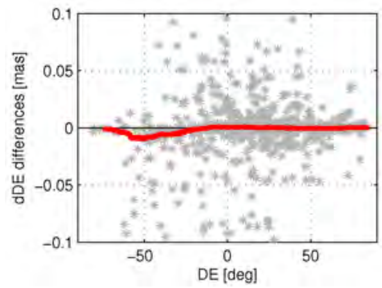

Figure 5. Differences between 669 declination estimates of two CRF solutions: without using the 21 sessions of the VCS (VLBA Calibrator Survey) - with using the VCS sessions.

3. IVS VLBI contribution to the ITRF2005

   The release of the ITRF2005 in October 2006 is a major step towards more consistent IERS products. The DGFI IVS Analysis Center contributed to this effort in two different ways:

   Firstly, SINEX files for 2666 daily sessions between 1984 and 2005 were submitted to the IVS, containing the EOP (Earth orientation parameters) and station positions for each 24-hour session as unconstrained normal equations. As the IVS moved to generate its operational products using a comparable procedure (not combining results but datum free normal equations) at the beginning of 2006, DGFI continues to submit these files as operational analysis center, which is the only non CALC/SOLVE contribution to this IVS product.

   Secondly, the two independent solutions of the ITRF2005, computed by DGFI and the IGN (Institut Geographique National, France) were validated. This enabled to compare geodetic results computed with OCCAM (EOP, station position time series) using the two indenpendent ITRF2005 solutions as a reference. It turned out that the VLBI parts of both ITRF2005 solutions were well adapted to VLBI-only results and did not differ significantly.

4. IVS Working Group on a new realization of the ICRS

   DGFI actively takes part in the corresponding IAU and IVS Working Groups by contributing solutions, as well as doing research, especially to better understand expected systematic differences and to optimize the homogeneity of the celestial and the terrestrial reference frames under the umbrella of the IERS (see also 2.2 of this report).

5. IVS OCCAM Working Group

   The VLBI software OCCAM is the central tool for DGFI′s work in IVS. It is maintained, refined and adapted to the current requirements in close collaboration within the IVS OCCAM Working Group, chaired by Oleg Titov, Geoscience Australia (Canberra, Australia). Leading members are scientists from the Vienna University of Technology, Austria, the St.

Petersburg University and the Institute of Applied Astronomy, Russia, and DGFI. During the last year, the code solving the equation systems with the least squares approach was updated in many parts, in very close cooperation with the Vienna University of Technology.

3. Staff

In 2006, members of the DGFI IVS Analysis Center were Volker Tesmer, Manuela Krügel and Hermann Drewes.

4. Plans for 2007

- Further improve the VLBI software OCCAM,
- support IVS TRF and CRF preparation activities, including submission of appropriate solutions computed at DGFI as well as analysis of different contributions,
- submit SINEX files for all 24-h sessions to the IVS on an operational basis,
- intensify the work related to a combined estimation of geodetic target parameters from VLBI and observations of other space geodetic techniques.

5. Selected Publications

Krügel, M., D. Thaller, V. Tesmer, M. Rothacher, D. Angermann, R. Schmid: Tropospheric Parameters: Combination studies based on homogeneous VLBI and GPS data. In: Schuh, H., A. Nothnagel, C. Ma (Eds.): VLBI issue. J. of Geod., DOI 10.1007/s00190-006-0127-8, 2006

Steigenberger, P., V. Tesmer, M. Krügel, D. Thaller, R. Schmid, S. Vey, M. Rothacher: Comparisons of homogeneously reprocessed GPS and VLBI long time series of troposphere zenith delays and gradients. In: Schuh, H., A. Nothnagel, C. Ma (Eds.): VLBI issue. J. of Geod., DOI 10.1007/s00190-006-1024-y, 2006

Tesmer, V.: Konsistente Realisierung von Referenzrahmen mit dem Verfahren VLBI. DGFI-Report No. 78, 2006

Tesmer, V., J. Boehm, R. Heinkelmann, H. Schuh: Impact of Analysis Options on the TRF, CRF and Position Time Series Estimated from VLBI. In: Behrend, D., K. Baver (Eds.): IVS 2006 GM Proceedings. NASA/CP-2006-214140, 243-251, 2006

Tesmer, V., J. Boehm, R. Heinkelmann, H. Schuh: Effect of different tropospheric mapping functions on the TRF, CRF and position time series estimated from VLBI. In: Schuh, H., A. Nothnagel, C. Ma (Eds.): VLBI issue. J. of Geod., DOI 10.1007/s00190-006-0126-9, 2006

Thaller, D., M. Krügel, M. Rothacher, V. Tesmer, R. Schmid, D. Angermann: Combined Earth orientation Parameters based on homogeneous and continuous VLBI and GPS data. In: Schuh, H., A. Nothnagel, C. Ma (Eds.): VLBI issue. J. of Geod., DOI 10.1007/s00190-006-0115-z, 2006

FFI Analysis Center

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an analysis center focuses primarily on a combined analysis at the observation level of data from VLBI, GPS and SLR using the GEOSAT software. This report shortly summarises the current status of analyses performed with the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. Introduction

A number of co-located stations with more than one observation technique have been established. In principle, all instruments at a given co-located station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each co-located site. In addition, a constant eccentricity vector from the reference point of the co-located station to each of the individual phase centers of the co-located antennas is estimated using constraints in accordance with a priori information given by the ground surveys. One set of Earth orientation parameters (EOP) and geocenter coordinates can be estimated from all involved data types. The present dominating error source of VLBI is the water content of the atmosphere which must be estimated. The introduction of GPS data with a common VLBI and GPS parameterization of the zenith wet delay and atmospheric gradients will strengthen the solution for the atmospheric parameters. The inclusion of SLR data, which is independent of water vapour, gives new information which will help in the de-correlation of atmospheric and other solve-for parameters and lead to more accurate parameter estimates. These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully accounted for with the GEOSAT software developed by FFI during the last 24 years.

2. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

3. Combination of VLBI, GPS, and SLR Observations at the Observation Level

The GEOSAT software was recently upgraded to use numerical weather models (ECMWF) and 3D raytracing for the calculation of signal delays due to the troposphere. Twelve years of VLBI data have been analyzed with this feature and the improvment of the results is remarkable. It seems that the ECMWF model needs to be slightly scaled by 1-3 estimated parameters in the VLBI analyses per co-located station. The raytracing procedure can also be used to detect periods with rapidly changing atmospheric conditions which cannot be modelled with sufficient accuracy. This information can be used to identify and neglect such data leading to more stable values for the atmospheric scaling parameters. This strategy is expected to be especially valuable for the analysis of GPS and future Galileo tracking data due to the great redundancy of datasets provided by the two satellite systems.

Results from analyses of CONT-series data show best-case repeatabilities around 1 mm in the horizontal plane and 2 mm in the vertical direction.

The GEOSAT software is presently undergoing extensive developments. Some of these are explained elsewhere in this publication in a short report by the FFI TDC.

The BKG/GIUB VLBI Analysis Center

Volkmar Thorandt, Axel Nothnagel, Gerald Engelhardt, Markus Vennebusch, Thomas Artz, Sarah Böckmann, Dieter Ullrich

Abstract

In 2006, the Geodetic Institute of the University of Bonn (GIUB) was renamed Institute for Geodesy and Geoinformation of the University of Bonn (IGGB). The activities at the BKG/IGGB VLBI Analysis Center, as in previous years, consisted of routine computations of Earth orientation parameter (EOP) time series and a number of research topics in geodetic VLBI. The VLBI group at BKG continued its regular submissions of time series of tropospheric parameters and the generation of daily SINEX (Solution INdependent EXchange format) files. Quarterly updated solutions were computed to produce terrestrial reference frame (TRF) and celestial reference frame (CRF) realizations. Routine computations of the UT1 - UTC Intensive observations include all sessions of the Kokee – Wettzell and Tsukuba – Wettzell baselines. At IGGB the emphasis was placed on individual research topics.

1. General Information

In 2006, the Geodetic Institute of the University of Bonn (GIUB) was renamed Institute for Geodesy and Geoinformation of the University of Bonn (IGGB). The jointly operated IVS Analysis Center of the Federal Agency for Cartography and Geodesy (BKG), Leipzig, and of the Institute for Geodesy and Geoinformation of the University of Bonn will, thus, continue to exist as BKG/IGGB VLBI Analysis Center. The relationship with IVS is not affected by this change of name.

Both institutions maintain their own analysis groups in Leipzig and Bonn but cooperate intensively in the field of geodetic VLBI. The responsibilities include data analysis for generating IVS products as well as special investigations with the goal of increasing accuracy and reliability. BKG is responsible for the computation of time series of EOP and tropospheric parameters, the generation of daily SINEX files, and quarterly updated global solutions for TRF and CRF realizations. Besides data analysis the BKG group is also responsible for the scheduling of the Tsukuba - Wettzell INT2 UT1 - UTC observing sessions. IGGB continues to host the office of the IVS Analysis Coordinator and carries out special investigations in the technique of geodetic and astrometric VLBI. Details of the research topics of BKG and IGGB are listed in Section 3.

2. Data Analysis

At BKG the Mark 5 VLBI data analysis software system Calc/Solve, release of March 18, 2004 (ref. [1]), was used for VLBI data processing until Dec. 31, 2006. It was running under Fortran 90 on an HP workstation with an HP-UX11.00 operating system.

Independently of this, the Linux version of Calc/Solve, release 2006.07.19, revision 2006.09.26 (ref. [2]) was installed on another machine with an operating system GNU/Linux 2.6.5-7.97-smp for tests in parallel to the routine data analysis. The main difference between the two Calc/Solve versions is the new Calc 10 implementation in the Linux version for complying with the IAU 2000 Resolutions and the IERS Conventions 2003. In addition, an independent technological software environment for the Calc/Solve software is available. The latter is used for linking up the Data Center management with the pre- and post-interactive part of the EOP series production and to monitor all Analysis and Data Center activities (Data Center topics are described in the BKG Data Center report in this issue).

- **Processing of correlator output**
  The BKG group continued the generation of calibrated databases for the sessions correlated at the MPIfR/BKG Mark 5 Astro/Geo Correlator at Bonn (e.g. EURO, OHIG, T2) and submitted them to the IVS Data Centers.

- **Scheduling**
  BKG continued scheduling the INT2 Intensive sessions on the baseline TSUKUBA-WETTZELL. Altogether 94 schedule files were created in 2006.

- **IVS EOP time series**
  The generation of the BKG EOP time series bkg00007 was continued. Every time after the preprocessing of any new VLBI session (correlator output database version 1), a new global solution with 24 hour VLBI sessions since 1984 was computed and the EOP time series bkg00007 was extracted for the IVS combination. Altogether 3379 sessions were processed. The main parameter types in this solution are globally estimated station coordinates and velocities together with radio source positions. Minimal constraints for the datum definition were applied to achieve no-net-rotation and no-net-translation for 26 selected station positions and velocities with respect to the VTRF2003 (ref. [4]) and no-net-rotation for 212 defining sources with respect to ICRF-Ext.1 (ref. [3]). The station coordinates of the stations CTVASTJ (Canada), DSS65A (Spain), METSAHOV (Finland), SVETLOE (Russia), ZELENCHK (Russia) were estimated as local parameters in each session.

  The UT1 time series bkgint04 was also continued. The observations of both baselines KOKEE-WETTZELL and TSUKUBA-WETTZELL, each with a duration of about 1-hour, were processed regularly. Series bkgint04 was generated with fixed TRF (VTRF2003) and fixed CRF derived from the global BKG solution for EOP determination. The estimated parameter types were only UT1, station clock, and zenith troposphere. A total of 2028 UT1 Intensive sessions were analyzed for the period between 1999.01.01 and 2007.01.07.

- **Quarterly updated solutions for submission to IVS**
  Also in 2006 quarterly updated solutions were computed for the IVS products TRF and CRF. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00007. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is available in SINEX format, version 2.1 and includes station coordinates, velocities, and radio source coordinates together with the covariance matrix, information about constraints, and the decomposed normal matrix and vector.

- **Tropospheric parameters**
  The VLBI group of BKG continued regular submissions of long time series of tropospheric parameters to the IVS (wet and total zenith delays, horizontal gradients) for all VLBI sessions since 1984. The tropospheric parameters are directly extracted and transformed into SINEX for tropospheric estimates from the results of the standard global solution for the EOP time series bkg00007.

- **Daily SINEX files**
  The VLBI group of BKG also continued the regular submissions of daily SINEX files for all available 24 hours sessions as base solutions for the IVS time series of baseline lengths

and for combination techniques. In addition to the global solutions independent session solutions were computed for the parameter types station coordinates, EOP, and nutation parameters. The a priori datum for TRF is defined by the VTRF2003 and the fixed CRF derived from the global complete BKG solution for EOP determination is used for the a priori CRF information.

3. Research Topics

- **Singular Value Decomposition**
  It is well known that the VLBI technique is very sensitive to variations in both the network geometry and the observation geometry. As mentioned in the 'IVS-WG3 Report on Data Analysis' improved analysis strategies together with observation scheduling should be developed in order to reduce the effect of single observations on the results. One way of assessing the sensitivity of an adjustment problem is to analyse the design matrix of the corresponding least-squares problem by algebraic tools. At IGGB an objective and automatic analysis tool (or regression diagnostics tool) has been developed which helps to analyse the design matrix of a VLBI adjustment by so-called singular value decomposition. In order to find (groups of) important and less important (and thus negligible) observations, so-called cluster analysis methods are used. The results will be published in a Ph.D. thesis in 2007.
- **ITRF2005 Input Generation**
  For IVS' contribution to the ITRF2005 the IVS Analysis Coordinator's office at IGGB performed the intra-technique combination of more than 4100 sessions (data span: 1979 through 2005). For each session the data of up to five IVS Analysis Centers have been combined on the normal equation level and have been submitted to ITRF combination centres. Before the final combination, both internal and external comparisons with either the combined solution or with IGS- or C04-EOP-series have been performed. More details and results can be found in [5].
- **Analysis of water vapour radiometer data**
  Investigations of water vapour radiometer data have concentrated on the analysis of raw brightness temperature measurements from the broadband radiometer at Effelsberg.
- **Variance component estimation of IVS normal equation combination**
  In order to account for the different qualities of the individual contributions, i.e. individual normal equations, to the IVS normal equation combination, weighting factors have been determined. One way of determining weighting factors is to use variance component estimation. The basic idea of the variance component estimation is to compute individual variance factors for each group of observations instead of one common a posteriori variance factor. Here, a group of observations consists of an individual normal equation system for one session. The estimated variance factors can then be used for re-weighting each contribution.
- **Analysis of sub-daily ERP variations**
  First steps have been taken to generate time series of sub-daily ERP from VLBI observations on the basis of CONT05 sessions using Calc/Solve. This investigation uses a temporal resolution between 15 and 60 minutes. The main objective of the initial investigation is to find out how different parameterizations in the estimation process affect the target parameters in order to find an optimal setup for estimation of sub-daily ERP.

4. Personnel

Table 1. Personnel at BKG/IGGB Analysis Center

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[2] GSFC, NASA (2006): Release of Mark 5 VLBI Analysis Software Calc/Solve from July 19, 2006 (web reference: http://vlbi.gsfc.nasa.gov/solve).

[3] ICRF-Ext.1 (http://hpiers.obspm.fr/webiers/results/Icrf)

[4] Nothnagel A. (2003): VTRF2003: A Conventional VLBI Terrestrial Reference Frame, In: Proceedings of the 16th Working Meeting on European VLBI for Geodesy and Astrometry, held at Leipzig, May 09 10, 2003, edited by W. Schwegmann and V. Thorandt, Bundesamt für Kartographie und Geodäsie, Frankfurt/Leipzig, 2003, p. 195 205 Jun. 30, 2003.

[5] Vennebusch M., S. Böckmann, A. Nothnagel (2006): The contribution of Very Long Baseline Interferometry to ITRF2005, Journal of Geodesy, DOI:10.1007/s00190-006-0117-x

GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Dan MacMillan, Leonid Petrov, John Gipson, Karen Baver

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2006. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development aimed at improving the VLBI technique.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. It is part of a larger VLBI group which also includes the IVS Coordinating Center, the Core Operation Center, a Technology Development Center, and a Network Station. The Analysis Center participates in all phases of geodetic and astrometric VLBI analysis, software development, and research aimed at improving the VLBI technique.

2. Activities

2.1. Analysis Activities

The GSFC analysis group routinely analyzes all IVS sessions using the Calc/Solve system, and performs the AIPS fringe fitting and Calc/Solve analysis of the VLBA-correlated RDV sessions. The group submits the analyzed databases to IVS for all R1, RDV, R&D, APSG, and NEOS Intensive INT01 sessions. During 2006, the group processed and analyzed 196 24-hr (50 R1, 53 R4, 14 CONT05B, 6 RDV, 1 VLBA/Quake, 7 old VLBA, 8 R&D, 5 T2, 8 CRF, 8 CRDS, 1 CRFS, 6 EURO, 13 OHIG, 3 APSG, 8 E3, and 5 JADE) sessions and 307 1-hr UT1 (223 NEOS INT01 and 84 INT02) sessions. We also submitted updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately following analysis. The group also generated and submitted two TRF solutions to the IVS Data Centers using all suitable VLBI sessions. A special effort was also made to process six old VLBA sessions from the CONT96 campaign. Inadequate software had prevented their processing when originally released. They were successfully fringed using the NRAO AIPS program, analyzed using Calc/Solve and submitted to IVS. The GSFC Analysis Center maintains a web site at http://lupus.gsfc.nasa.gov/, where the latest solutions and velocity plots can be found.

2.2. Support Activities

The GSFC VLBI Analysis Center has provided a source position service as part of the RDV program since 1997. Observations of 17 requested sources were made in 2006 for members of the astronomy/astrometry community, and precise positions were obtained where possible. The Analysis Center also continued its support of the Gravity Probe B mission by generating VLBA astrometric databases of the guide star for CFA researchers and by observing the phase referencing calibrator in several RDV sessions.

2.3. Research Activities

The GSFC Analysis Center performs research aimed at improving the VLBI technique. The primary research activities undertaken during 2006 include the following:

- Unstable Sources: The source position time-series for many of the frequently observed radio sources in the NASA geodetic VLBI program show systematic, non-linear as well as linear variations of as much as 0.5-1.0 mas, due mainly to source structure changes. If these apparent source position variations are not modeled, they produce corresponding systematic variations in estimated Earth orientation parameters (EOP's) at the level of 0.02-0.04 mas in nutation and 0.01-0.02 mas in polar motion. We examined the stability of position time-series of the 107 radio sources in the current NASA geodetic source catalog. We looked at different ways of handling source instabilities where the positions of unstable sources are either estimated for each session, or spline parameters are estimated for them. We found that some of these strategies improve EOP accuracy by reducing the biases and WRMS differences between EOP measurements from the independent but simultaneous CORE-A and NEOS-A VLBI networks from 1997 to 2000. These results are discussed in a paper accepted for the Journal of Geodesy special issue for VLBI. [MacMillan, D.S. and Ma C., 'Radio Source Instability in VLBI Analysis', J. Geod, 2007, in press.]
- CONT Campaigns: Relative to tidal models, high frequency EOP residuals from the various CONT campaigns all have WRMS's of 0.18 to 0.20 mas, compared with formal uncertainties ranging from about 0.20 mas for CONT94 to 0.12 mas for CONT05. We investigated whether or not there is any signal in these residuals. We found evidence of a possible terdiurnal signal in the VLBI polar motion hourly series for CONT02, but it was not present in CONT05. However, it is not clear what the source of such a signal may be. AAM is a possible source, but the size of the signal from the polar motion residuals was at least 2 orders of magnitude larger than what is expected from AAM. It is likely that the terdiurnal signal, as well as other spurious peaks at other multiples of 1 cpd, are artifacts of analysis, but further investigation will be required to resolve this.
- Simulations: We developed procedures for simulating the performance of a network of VLBI antennas. The procedure consists of generating a simulation database from an observing schedule for the network and then performing a Monte Carlo simulation by running a SOLVE solution over a large number of repetions of the database. In each repetition, observed delay residuals are generated as random clock and atmosphere noise. Repeatability of parameter estimates (e.g., baseline lengths or station positions) from the solution gives a measure of parameter precision. We have used this simulation tool to analyze different options for the VLBI2010 design.
- Source Monitoring: We continued the source monitoring program which began on February 1, 2004. Its goals are to observe all geodetic catalog sources at least 12 times and all non-geodetic catalog sources at least twice in every 2 month period. This is done by including the sources which have not met their targets in either the weekly R1's or the bi-monthly RDV's. The maximum number of monitored sources is restricted to no more than 10 in the R1's, and 30 in the RDV's. Overall, the observing goals were met with only a few exceptions. Only 1 geodetic source (0530-727) did not meet its target in 2006. And only 10 non-geodetic sources were not observed in 2006, all being weak sources with fluxes less than 0.1 Jy in either S or

X-band. Another 22 non-geodetic sources were observed only once. These were also weak sources, but not quite as weak, typically 0.15-0.20 Jy.

- Correlated Noise: A key assumption of VLBI parameter estimation is that observations on different baselines are independent. If this assumption is false, then the parameter estimates will be incorrect and the formal errors too small. One simple alternate assumption is that at each epoch, all observations involving a common station are correlated due to station dependent noise. This effect can be accounted for by modeling the normal equations by introducing station-dependent correlations between the observations in a given scan. The functional form of the correlation depends on its source. For example, correlation due to atmosphere mis-modeling increases at lower elevations. We looked at the effect of including unmodeled correlated errors on two datasets: 1) the R1 and R4 sessions during 2005 (an example of good operational stations over a prolonged period of time), and 2) the CONT05 sessions (an example of a very-good VLBI network over a short period of time). We found that incorporating different kinds of atmosphere mis-modeling improved both data sets in the sense that 1) baseline scatter was reduced and 2) agreement with external EOP was improved. For example, in our tests using the CONT05 data set we found that the scatter in 48 out of 55 baselines was improved with an average reduction of 10%.
- Quake VLBA Session: The GSFC Analysis Center obtained VLBA time for a special session on November 8 to measure any possible displacements resulting at the Mauna Kea VLBA site resulting from an October 15 earthquake on the island of Hawaii. Results will be published in 2007.
- Higher Frequency CRF: Members of the analysis group continued working with associates at JPL, USNO, NRAO and Bordeaux Observatory to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (~24 and ~43 GHz). The primary goals are to build up a reference frame for use in planetary spacecraft navigation at Ka band (~33 GHz), and to build a reference frame less affected by source structure and apparent proper motion and potentially more precise than the current X/S frame. One K band session was observed and analyzed in 2006, concentrating on weaker sources and ecliptic sources. To date, the group has conducted 9 VLBA sessions and developed a catalog of 267 sources at K-band and 132 sources at Q-band, with sub-mas positions. Future work will concentrate on observing weaker sources, and densifying the catalog along the ecliptic and in the regions needed for several upcoming Mars missions.

2.4. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Several updates were released during 2006. Specifically, Calc version 10.0 and the Linux/HP-UX compatible version of Calc/Solve were released in Spring 2006. Calc 10 complies with the IAU 2000 Resolutions and the IERS Conventions (2003), and uses the non-rotating origin system. The GSFC Analysis Center now does all of its database processing and analysis on Linux PC machines. Near the end of 2006, program Dbedit was also converted to allow writing Mark IV databases on Linux PC (Little Endian) machines, a feature that will allow the correlators to phase out their HP systems.

3. Staff

Members of the analysis group and their areas of activity include: Dr. Chopo Ma (CRF, TRF, EOP, K/Q reference frame development, IVS representative to the IERS, and current chairman of the IERS directing board), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, apparent proper motion, and post-seismic studies), Dr. David Gordon (database analysis, RDV processing and analysis, K/Q reference frame development, VLBA calibrator surveys, Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis, VLBA calibrator surveys, Calc/Solve development, Linux migration, GEODYN development), Dr. John Gipson (source monitoring and improved parameter estimation), and Ms. Karen Baver (R4 and Intensives analysis, software development, Linux migration, web site development and maintenance).

4. Future Plans

Plans for the next year include: participation in development of the next VLBI ICRF, participation in additional K/Q observations and reference frame development, participation in VLBI2010 development efforts, and performing further research aimed at improving the VLBI technique.

MIT Haystack Observatory Analysis Center

Arthur Niell

Abstract

The contributions of Haystack Observatory to the analysis of geodetic VLBI data focus on improvement in the accuracy of the estimation of atmospheric delays and on the reduction of instrumental errors through analysis. In 2006 most of the effort was related to evaluating error sources for the proposed VLBI2010 system, including the impact of phase errors due to source structure.

1. Geodetic Research at the Haystack Observatory

The MIT Haystack Observatory is located approximately 50 km northwest of Boston, Massachusetts. Geodetic analysis activities are directed primarily towards improving the accuracy of geodetic VLBI results, especially through the reduction of errors due to the atmosphere and to instrumentation. This work, along with operation of the geodetic VLBI correlator and with support of operations at the Westford, GGAO, Fortaleza, and Kokee Park VLBI sites, is supported by NASA through a contract from the Goddard Space Flight Center.

2. Evaluation of Source Structure Phase Across a Wide Spanned Bandwidth

Since the anticipated observable for the next generation geodetic VLBI system is the phase delay, variations in phase due to changes in structure of the observed radio sources across the observed frequency range could be significant.

In order to investigate the magnitude of the problem, spectra were constructed for the Gaussian components of several sources based on the S-band and X-band models derived by Fey and Charlot [1].

Sources of varying complexity were selected in order to span the range of variation that might be encountered and to see how the variation depends on the Structure Index (SI) as derived by Charlot [2]. The modeled sources and their structure indices at S and X band are listed in the following table.

Table 1. Structure Indices (SI) for selected sources.

Source	**Structure Index**	
	S-band	X-band
0014+813	1	1
0113-118	2	3
0149+218	2	2
0202+149	2	2
0248+430	2	4

The complex visibilities are easily calculated for Gaussian component models. The phases as a function of frequency are shown in the figures for a baseline length of one Earth radius for observations at several orientations relative to the projected baseline. The sources 0149+218 (Figure 1a) and 0202+149 (Figure 1b), even though having SI of 2 at both S and X, would not add significant errors to the phase delay for an observation at any orientation relative to the projected baseline. On the other hand the sources 0113-118 (Figure 2a) and 0248+430 (Figure 2b) would make phase connection across the band impossible without apriori structure information. For the source 0014+813, with SI of 1 at both S and X, the maximum phase is approximately 0.25 radians near 2.5 GHz. While this is not significant for the connection of phase, the error would be correlated with the effect of the ionosphere, which is another source of error that must be assessed.

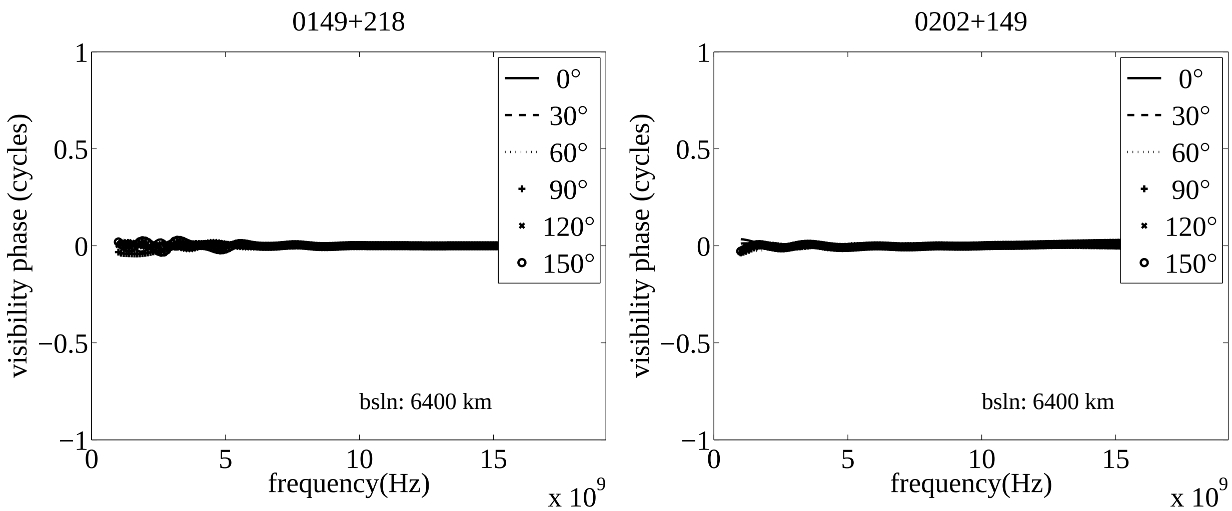

Figure 1. The source structure phase as a function of frequency and at six orientations relative to a baseline with length 6400 km for a) 0149+218 and b) 0202+149.

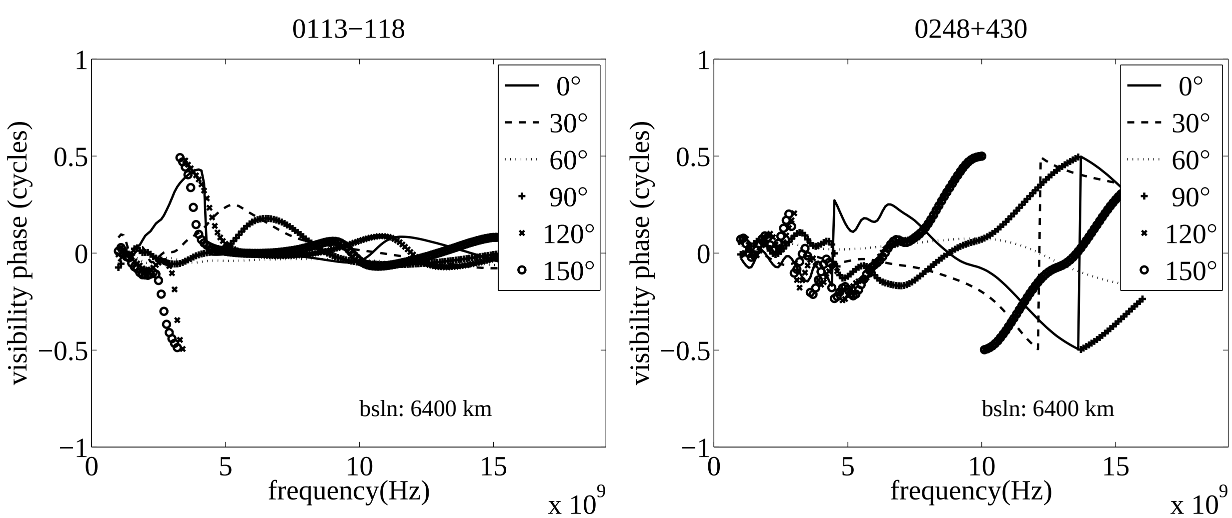

Figure 2. The source structure phase as a function of frequency and at six orientations relative to a baseline with length 6400 km for a) 0113-118 and b) 0248+430.

To the extent that these simplified models and this small sample represent the distribution of actual source structures, it appears that SI classes 1 and 2 may not produce large phase variations with frequency. Thus these sources may be acceptable for the geodetic observations. Of course a larger study is needed to see if the conclusion is supported when better statistics are established.

3. Outlook

In the upcoming year we will continue investigation of the potential improvements that can be obtained in the geodetic results by incorporating atmospheric effects as calculated from the MM5 Numerical Weather Model with a small horizontal grid spacing, as well as continuing the VLBI2010 simulations.

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IAA VLBI Analysis Center Report 2006

Elena Skurikhina, Sergey Kurdubov, Vadim Gubanov

Abstract

This report presents an overview of IAA VLBI Analysis Center activities during 2006 and the plans for the coming year. The activities of the IAA VLBI Analysis Center developed in two directions: first, routine computations of Earth orientation parameters (EOP), baseline lengths, tropospheric parameters from 24-h sessions and UT1-UTC from IVS Intensive sessions with OCCAM/GROSS software and submission of the results to IVS, and secondly, QUASAR software development with the aim to use one software for generation of our contribution to all kinds of IVS products in 2007.

1. General Information

The IAA IVS Analysis Center (IAA AC) is located at the Institute of Applied Astronomy of the Russian Academy of Sciences in St. Petersburg, Russia. IAA AC contributes to IVS products, such as rapid and long-term series of EOP, station position, tropospheric parameters.

2. Component Description

IAA AC performs routine VLBI data processing using OCCAM/GROSS software. EOPs, EOPi, baseline length, tropospheric parameters are submitted to the IVS on a regular basis. QUASAR software was further developed to conform with IERS Conventions (2003) and to add the possibility to output Daily SINEX files. Global solution was calculated with QUASAR package and was submitted to IVS after Analysis Coordinator approval. IVS NGS-files are generated regularly in automatic mode.

3. Staff

– Vadim Gubanov, Prof.: development of the QUASAR software, development of the methods of stochastic parameter estimation.

– Sergey Kurdubov, scientific reseacher: development of the QUASAR software, global solution and DSNX-file calculation.

– Elena Skurikhina, Dr., VLBI data processing, OCCAM/GROSS software development.

– George Krasinsky, Prof., development of new Precession-Nutation Theory based on numerical integration of refined differential equations of the Earth rotation.

– Zinovy Malkin, Dr. (until August), data transmission automatization, EOP-Intensive data processing, OCCAM/GROSS software development, empirical nutation model development.

– Yulia Sokolova, scientific researcher (until March), CRF realization comparison and combination.

4. Current Status and Activities

- **Routine analysis**
  During 2006 the routine data processing was performed with OCCAM/GROSS software

using Kalman Filter. IAA AC provided the operational processing of the "24h" and Intensive VLBI sessions. Submitting the results to the IERS and IVS was performed on a regular basis. Processing of the Intensive sessions is fully automated. The EOP series iaa2005a.eops and iaa2005a.eopi, iaa2005a.bl and troposphere parameters iaa2005a.trl were continued. At the moment, the EOPS series contains 3333 estimates of pole coordinates, UT1, and celestial pole offsets, and the EOPI series contains 5472 estimates of UT1. New long-time series of station coordinates, baseline lengths, and tropospheric parameters (ZTD, gradients) were computed with the station position catalog ITRF2005. Analysis of the results is in progress. New series iaa2007a.eops, iaa2007a.eopi, iaa2007a.bl, iaa2007a.tro and iaa2007a.trl calculated with ITRF2005 station position catalog and new model of station position correction due to oceanic loading will be presented in the near future.

- **Software development for VLBI processing**

  Development of the OCCAM/GROSS software was continued to provide intraday EOP variations.

  QUASAR software [2, 4] was made compatible with the IERS Conventions (2003), and the possibility to output Daily SINEX files was added in 2006. The QUASAR software was developed to provide contributions to IVS products. The software is able to calculate all types of IVS products. After Analysis Coordinator approval, Daily SINEX files will be submitted to IVS on a regular basis and for quarterly solution [3].

- **Global solution**

  In 2006, a global solution [1] using the QUASAR software was obtained and tested for submission to IVS. All available data for 1979–2006 were processed. Stochastic signals were estimated by means of the least-squares collocation technique. The radio source coordinates, station coordinates and velocities were estimated as global parameters. EOP, WZD (linear trend plus stochastic signal), troposphere gradients, station clocks (quadratic trend plus stochastic signal) were estimated as arc parameters for each session.

  3791 24-hours sessions, 4823609 delays have been processed. 2522 global parameters have been estimated: 745 radio-source positions, positions and velocities of 132 VLBI stations (14 with discontinuities).

  Transformation parameters (47 stations were used for calculations) vs. VTRF2005 are listed in Table 1, residuals amount to 6 mm for 1997.0 and 8 mm for 2005.0.

Table 1. Transformation parameters between VTRF2005 and obtained catalogue for two epoch

EPOCH	T1,mm	T2,mm	T3,mm	D, 10^{-9}	R1,mas	R2,mas	R3,mas
2005.0	4.6	-5.3	8.5	-1.9	.027	-.010	.004
1997.0	4.7	-5.3	5.0	-1.6	-.062	-.090	-.005

Fixing the frame was performed by the minimal set of no-net-rotation/translation constraints.

- CRF: no-net-rotation w.r.t. ICRF-Ext.2, using 212 defining sources of ICRF
- TRF: no-net-rotation/translation w.r.t. VTRF2003 using 12 stations of VTRF2003

The mean formal errors of source catalogue were in right ascension 0.15 mas, and in declination 0.12 mas. WRMS differences vs. ICRF.Ext2 was 0.2 mas in right ascension and declination (for statistic on differences used common sources observed more than 3 sessions more 20 times, total 574 sources).

- **Station position estimation**

The station positions of Zelenchukskaya and Badary (Table 2) were calculated in the ITRF2005 reference frame. A-priori values for the velocity components were used from GSP data analysis in both cases. The station position of Zelenchukskaya was calculated from the treatment of 57 IVS 24-hour sessions. These values were used for station Badary coordinate estimation.

Table 2. Station positions and velocities for Zelenchukskaya and Badary, epoch 2000.0, in ITRF2005

Station	Station Position, m			Velocity, mm/year		
	X	Y	Z	V_x	V_y	V_z
Badary	-838200.732 ± 0.006	3865751.582 ± 0.016	4987670.962 ± 0.026	-.0253	0.0002	-.0037
Zelenchukskaya	3451207.819 ± 0.011	3060375.220 ± 0.008	4391914.937 ± 0.014	-.0220	.0156	.0082

The station position of Badary was calculated from processing 8 24-hour observational sessions from August through December 2006 with VLBI network Svetloe-Zelenchukskaya-Badary using the S2 registration system. Correlation was performed on MicroParsec correlator of IAA. Figure 1 shows the time series of station positions for Badary station.

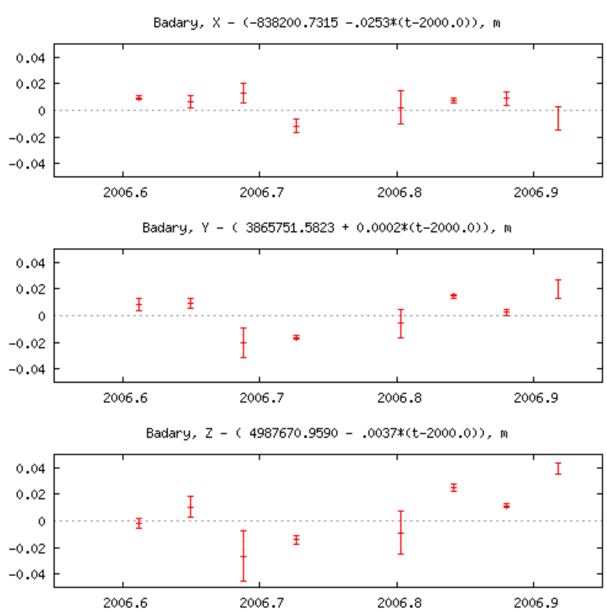

Figure 1. Badary station position time series.

- **Subdaily EOP parameter calculation**
  Earth Rotation Parameters with high resolution were calculated from CONT05 VLBI observing campaign data processing using two different approaches: (1) one 15-day session and (2) global solution for 15 24-hour sessions using Kalman Filter and Least Squares Collocation Methods for Parameter estimation [5, 6].

- **IVS NGS card generation**
  Operational computation of the NGS cards was continued. NGS cards are computed in automated mode. To reduce the delay in delivering NGS cards to the users, IVS data archive is now checked for new files every 6 hours.

  IAA archive of VLBI observations and products was supported. At present, all available X and S databases and NGS cards are stored.

5. Future Plans

- Provide contribution to all types of IVS products (EOP-S, EOP-I, TRF, CRF, Daily Solution Files, Tropospheric Parameters, Time Series of Baseline Lengths) with new QUASAR software.
- Continue regular computation of operational and long-time EOP, station coordinates, and troposphere parameters series with OCCAM software (at least to March 2007).
- Continue investigations of VLBI estimation of EOP, station coordinates, and troposphere parameters, and comparison with satellite techniques.
- Calculation and study of intraday EOP variation.
- Further improvement of algorithms and software for processing the VLBI observations.
- Continue to compute and provide to IVS the NGS cards, every 1-hour for Intensive sessions.

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Vienna IGG Special Analysis Center Annual Report 2006

Harald Schuh, Johannes Boehm, Robert Heinkelmann, Thomas Hobiger, Paulo Jorge Mendes Cerveira, Andrea Pany, Emine Tanir, Kamil Teke, Sonya Todorova, Joerg Wresnik

Abstract

Among other studies in 2006, the Institute of Geodesy and Geophysics (IGG) at the Vienna University of Technology has carried out Monte-Carlo simulations to assist the development of a new geodetic VLBI system (VLBI2010). These investigations are critical for the definition of the observing strategy and network configuration, and it has been shown that the troposphere is the limiting factor for the precision and accuracy of the new system.

1. General Information

The Institute of Geodesy and Geophysics (IGG) is part of the Faculty of Mathematics and Geoinformation of the Vienna University of Technology. It is divided into three research units, one of them focusing on advanced geodesy (mathematical and physical geodesy, space geodesy). Within this research unit, one group (out of four) is dealing with geodetic VLBI.

Figure 1. Members of the IVS AC at IGG, Vienna, who took part at the IVS General Meeting 2006 in Chile. From left: Joerg Wresnik, Harald Schuh, Robert Heinkelmann, and Johannes Boehm.

2. Staff

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of IGG, member of IVS Directing Board), and nine scientific staff members. Their main research fields are summarized in Table 1. Since October 2006, Thomas Hobiger has been working at the NICT in Kashima, Japan.

Table 1. Staff members and focus of research

Johannes Boehm	VLBI2010, troposphere, OCCAM
Robert Heinkelmann	troposphere, celestial and terrestrial reference frame
Thomas Hobiger	ionosphere, software correlator
Paulo Jorge Mendes Cerveira	Earth orientation, datum definition, OCCAM
Andrea Pany	troposphere, clocks
Emine Tanir	combination
Kamil Teke	troposphere
Sonya Todorova	ionosphere
Joerg Wresnik	VLBI2010

3. Current Status and Activities

- **Modification of the VLBI software package OCCAM**
  Together with Oleg Titov (Geoscience Australia), chairman of the 'OCCAM Group', and Volker Tesmer (Deutsches Geodätisches Forschungsinstitut, Germany), IGG is involved in the development of the OCCAM software (Titov et al., 2004 [3]). In 2006 the application of hydrostatic and wet a priori gradients from numerical weather models was implemented.

- **VLBI2010**
  Within VLBI2010 simulation studies have been carried out to identify the best observing strategies for the new geodetic VLBI system (see Figure 2).

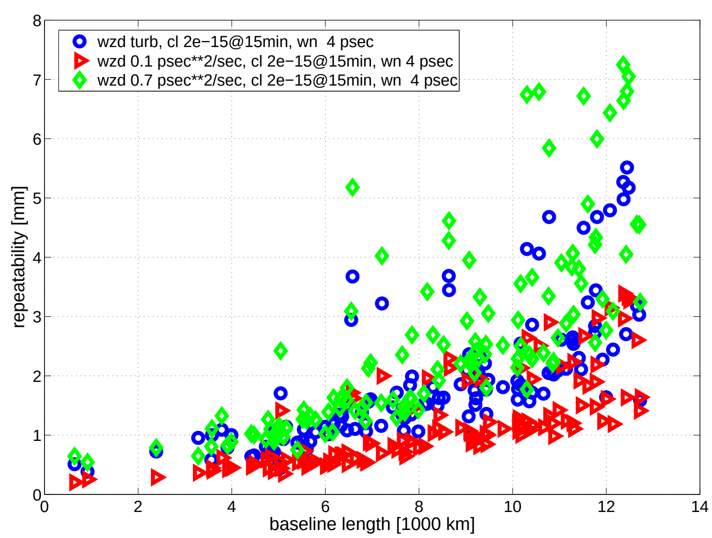

Figure 2. Baseline length repeatabilities for three different simulations of the wet zenith delays: 0.1 and 0.7 $psec^2/sec$ power spectral density for all stations and wet zenith delays from a turbulence model provided by the group at Onsala Space Observatory. In all cases, the Allan Standard Deviation of the clocks was set to $2 \cdot 10^{-15}$, and a white noise of 4 $psec$ was added at the antennas.

- **IVS Troposphere Combination and Long Time Series**
  The combination of IVS-R1 and IVS-R4 troposphere estimates within the 'IVS Pilot Project - Troposphere' has been modified: ZELENCHK, the new network station at Zelenchuskaya, Russia, has been added and GILCREEK, Fairbanks, Alaska, was removed from the combination. In April a recombination of all available R1 and R4 sessions was performed (see http://mars.hg.tuwien.ac.at/∼ivstrop). The long time series of tropospheric parameters of eight IVS ACs have been analysed, compared and combined, and the series of wet and total zenith delay estimates are available from the IVS Data Centers. Preliminary results were presented (Heinkelmann et al. 2006a [1]), and a paper about the combination procedure as well as results of the comparisons with products of the IGS and ECMWF will appear soon.

- **Vienna Terrestrial and Celestial Reference Frames: Vie-TRF and Vie-CRF**
  At the 4th IVS General Meeting in Concepcion, Chile, the first global solution of the IVS Special Analysis Center IGG, IGG05R01, was presented. IGG05R01 includes consistent estimates of TRF, EOP, and CRF (Heinkelmann et al., 2006b [2]) using the OCCAM (Titov et al. 2004 [3]) and DOGS-CS software packages. Atmospheric pressure loading and antenna thermal deformation models were added and, in particular, effects of meteorological input data on the reference frames were studied. Additionally, the influence of several datum definitions was tested using the updated version of IGG05R01 for their effects on celestial and terrestrial reference frames.

- **Thermal deformation of VLBI antennas**
  The investigations on thermal deformation for the antenna Onsala and Wettzel have been summarized by Wresnik et al. 2006 ([4]).

- **Combination of VLBI normal equations**
  Investigations were done on the optimum intra-technique combination for VLBI Analysis Center solutions by applying variance component estimation. The goal is to obtain the relative weighting factor and a Tikhonov-type regularization method to stabilize the combined solution.

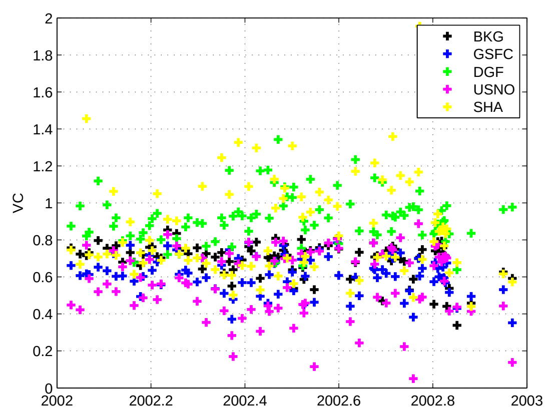

Figure 3. Variance components as a measure of how much the individual solutions from five Analysis Centers (BKG, GSFC, DGFI, SHA, USNO) differ from the combined solution.

- **Derivation of high-frequency polar motion and universal time variations**
  High-frequency (semi-hourly) polar motion and universal time variations were estimated for the CONT02 and CONT05 time periods, using the most recent a-priori reduction models with two software packages, OCCAM61E and CALC/SOLVE (provided by the Institute for Geodesy and Geoinformation of the University of Bonn).
- **Impact of datum definition on space geodetic parameters**
  Another field of investigation was the impact of the datum definition on space geodetic parameters. Three methods were studied: by using minimum conditions, minimum pseudo-observations, and finally singular value decomposition. A rigorous deformation analysis was applied to station coordinates and quasar positions. The three methodologies converge to acceptable solutions, only if stable station coordinates and quasar positions are used for the datum definition.
- **Ionosphere, software correlator, phase delay connection**
  Thomas Hobiger and Tetsuro Kondo (at the IGG from March 1 to August 31) were carrying out investigations on the ionosphere, software correlators and the phase delay connection for delta VLBI observations.

4. Future Plans

For the year 2007 the plans of the IVS Special Analysis Center at IGG include:

- Further simulation studies for VLBI2010, e.g. with the application of turbulence models
- Explore the capabilities of the Kalman Filter in OCCAM
- Derivation of high-frequency Earth rotation parameters

5. Acknowledgements

We are very grateful to the Austrian Science Fund (FWF) for supporting our work by research projects P16136-N06 ('VLBIONOS'), P16992-N10 ('VLBI for climate studies'), and P18404-N10 ('VLBI2010').

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Italy INAF Analysis Center Report

M. Negusini, P. Sarti, S. Montaguti, C. Abbondanza

Abstract

This report summarizes the activity of the Italian INAF VLBI Analysis Center. Our Analysis Center is located in Bologna, Italy, and belongs to the Institute of Radioastronomy which is part of the National Institute of Astrophysics. IRA runs the observatories of Medicina and Noto, where two 32m VLBI AZ-EL telescopes are situated. We illustrate the AC VLBI data analysis activity as well as other activities related to the local surveys performed at Medicina and Noto observatories.

1. Current Status and Activity

During summer 2006, we carried out GPS-based ties at both Noto and Medicina observatories. The Noto GPS tie was performed at the end of June and beginning of July 2006, while the Medicina survey was performed in mid-July 2006. Both surveys were carried out for testing a rapid static GPS-based indirect approach to eccentricity vector computation. The approach is based on the method that has been developed by our AC for local ties computation using terrestrial observations [4]. The surveys required a careful planning of the movements of the telescopes so as to ensure a good redundancy of points that are used for determining the elevation and azimuth circles and, finally, the telescope's reference point. The total duration of the procedure that has been implemented for driving the antennas during the surveys exceeds 72 hours. There are four complete azimuth circles, with 12 different positions and 8 elevation circles with 12 positions. The steps separating each position during the rotations were 30 and 10 deg respectively for azimuth and elevation movements. We were induced to investigate the possibility of computing GPS-based ties following the positive experience that was performed through the analysis of the 2002 Medicina GPS survey [1].

The 2006 GPS tie has been compared with all the other ties computed since 2001 in Medicina. Results have been summarized in a paper that has been presented in October at GRF meeting in Munich and that has been submitted in December for publication on the related IAG Symposium proceedings [2]. The GPS data acquired in Noto in 2006 are going to be processed in the near future and they will be compared to the results that have been obtained through the GPS survey carried out in 2003. GPS based ties and indirect methodologies are being investigated within a Ph.D. project realized by Claudio Abbondanza, in cooperation with the University of Bologna. Another Ph.D. activity is currently being developed by Simonetta Montaguti. It is also based on a cooperation with the University of Bologna and is related to gravitational deformation of VLBI telescopes. During 2006, a terrestrial survey of the position of the S/X receiver placed on the telescope's quadrupode in Medicina has been performed. Data are currently being processed and are going to integrate the information collected through the 2005 survey of the dish. It was performed for determining the deformation of the primary mirror using laser scanning [3] and for determining its position as the antenna rotates in elevation, so as to detect the existence and the entity of a possible gravitational sag.

2. Data Analysis and Results

The IRA started to analyze VLBI geodetic databases in 1989, using a CALC/SOLVE package on the HP1000 at the Medicina station. In the following years the same software was installed on an HP360 workstation and later on an HP715/50 workstation. We usually analyze databases with at least three European baselines. We are also storing all the databases which contain observations performed using the Ny-Ålesund antenna. All hardware resources are now located at Bologna headquarters. These are two HP785/B2600 workstations and one HP282 workstation. In the last months a new Linux workstation has been installed, with the aim to migrate all the VLBI analysis to Calc/Solve Version 10. During 2006, we have stored all the 1999-2006 databases available on the IVS data centers. All the databases have been processed and saved with the best selection of parameters for the final arc solutions.

Our AC has been participating in the IVS TROP Project on Tropospheric Parameters since its inception. Submission of tropospheric parameters (wet and total zenith delay, horizontal gradients) of all IVS-R1 and IVS-R4 24hr VLBI sessions was regularly performed in form of SINEX files. In the last year, due to several problems, we did not regularly submit results, but we tried to answer to a certain number of high priority requests. Long time series of troposphere parameters have been computed using all VLBI sessions available in our holdings, in order to estimate the variations in time of the content of water vapour in the atmosphere. We submitted a new solution for long time series of tropospheric parameters to IVS TROP Project.

3. Outlook

For the time being, our catalogue contains all experiments that involve European stations and all sessions performed after 1998. In 2007, together with the new Linux workstation and the up-to-date Calc/Solve Version 10 software, a new server with a storage capacity of 1 TB will be available. Therefore, all experiments performed in the previous years will be downloaded and analyzed, thus completing the catalogue. The regular submission of INAF tropospheric parameters to IVS data center will be resumed as soon as possible.

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IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine

Sergei Bolotin, Yaroslav Yatskiv, Svitlana Lytvyn

Abstract

This report summarizes the activities of VLBI Analysis Center at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine in 2006.

1. Introduction

The VLBI Analysis Center was established in 1994 by the Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine (NASU) as a working group of the Department of Space Geodynamics of the MAO. In 1998 the group started its IVS membership as an IVS Analysis Center. The AC MAO is located in the Central building of the observatory in Kiev.

2. Technical Description

VLBI data analysis at the center is performed on two computers: a Pentium-4 1.9GHz box with 256 MB RAM and a 160 GB HDD, and a recently purchased Pentium-4 3.4GHz box with 1 GB RAM and two 200 GB HDD. Both computers are running under the Linux/GNU Operating System.

The Main Astronomical Observatory has a 256 kbps main Internet channel and a 256 kbps backup.

For data analysis we are using the software SteelBreeze which is being developed at the MAO NASU. The SteelBreeze software is written in the C++ programming language and uses Qt widget library. SteelBreeze makes Least Squares estimation of different geodynamical parameters with the Square Root Information Filter (SRIF) algorithm (see [1]).

The software analyzes VLBI data (time delay) of single and multiple sets of sessions. The time delay is modeled according to the IERS Conventions (2003) [2], plus additional models (tectonic plate motion, nutation models, wet and hydrostatic zenith delays, mapping functions, etc). The software makes estimations of the following parameters: Earth orientation parameters, coordinates and velocities of a selected set of stations, coordinates of a selected set of radio sources, clock function and wet zenith delay.

3. Staff

The VLBI Analysis Center at Main Astronomical Observatory consists of three members:

Prof. Yaroslav Yatskiv: Head of the Department of Space Geodynamics, performs general coordination and support of activity of the Center.

Sergei Bolotin, Ph.D.: Senior research scientist of the Department of Space Geodynamics, responsible for the software development and data processing.

Svitlana Lytvyn: A Ph.D. student who is involved in the activities of the AC. Her Ph.D. thesis concerns the stability of VLBI-derived celestial and terrestrial systems.

4. Current Status and Activities in 2006

In 2006 we performed regular VLBI data analysis to determine Earth orientation parameters. "Operational" solutions were produced and submitted to the IVS on a weekly basis. The IERS Conventions (2003) [2] models have been applied in the analysis. In the solution, coordinates of stations and Earth orientation parameters are estimated.

Also, this year our participation in the IVS Tropospheric Parameters project was continued. Estimated wet and total zenith delays for each station were submitted to IVS. The analysis procedure was similar to the one used for the operational solutions.

5. Plans for 2007

MAO Analysis Center will continue to take part in operational EOP determination as well as updating the solutions of TRF and CRF from VLBI analysis of full dataset of observations.

The development of the software SteelBreeze will also be continued next year.

Acknowledgments

The work of our Analysis Center would be impossible without activities of other components of IVS. We are grateful to all contributors of the Service.

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Analysis Center at National Institute of Information and Communications Technology

Ryuichi Ichikawa, Mamoru Sekido, Thomas Hobiger, Tetsuro Kondo, Yasuhiro Koyama

Abstract

This report summarizes the activities of the Analysis Center at National Institute of Information and Communications Technology (NICT) for the year 2006.

1. General Information

The NICT analysis center is located in Kashima, Ibaraki, Japan. It is operated by the Radio Astronomy Applications Group, Kashima Space Research Center of NICT. Analyses of VLBI experiments and related study fields at NICT are mainly concentrated on experimental campaigns for developing new techniques such as e-VLBI for the real-time EOP determination and compact VLBI system, ionospheric and atmospheric path delay study, and differential VLBI (DVLBI) for spacecraft orbit determination. In addition we carried out monthly IVS-T2 sessions.

2. Staff

The staff members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order):

- HOBIGER Thomas, Postdoctoral fellowship researcher of the Japan Society for the Promotion of Science (JSPS)/Ionospheric and atmospheric research using VLBI and GPS
- ICHIKAWA Ryuichi, Compact VLBI system development and Atmospheric Modeling
- KONDO Tetsuro, Software Correlator
- KOYAMA Yasuhiro, International e-VLBI
- SEKIDO Mamoru, International e-VLBI and VLBI for spacecraft navigation

3. Current Status and Activities

3.1. CARAVAN2400

The CARAVAN (Compact Antenna of Radio Astronomy VLBI Adapted for Network) is part of a small radio telescope system that is dedicated to mobile e-VLBI measurements. We are now developing a compact geodetic VLBI facility with a 2.4 m diameter dish antenna at Kashima (see Figure 1), which is named CARAVAN2400. A first geodetic VLBI experiment between the CARAVAN2400 and Tsukuba 32m antenna of the Geographical Survey Institute (GSI) was carried out on September 21, 2006. The result of the experiment is summarized in Table 1.

3.2. TID Experiment

Five VLBI experiments dedicated to the detection of traveling ionospheric disturbance (TID) were carried out on Kashima 34 m - Gifu 11 m baseline from March to July of 2006 in cooperation

Table 1. CARAVAN2400 positions derived from first geodetic VLBI experiment.

	X(mm)	**Y(mm)**	**Z(mm)**
position	$-3997490991.30 \pm 10.445$	3276829292.16 ± 10.334	3724308240.31 ± 10.394

Figure 1. CARAVAN2400

with the Gifu University. In this experiment, one strong source (e.g. 3C273B) was continuously observed for 1-2 hours split into 5 minute scans. Though a characteristic TID signal could not be detected during the experiments, the acceptable gap length between each scan was assessed in order to obtain phase change during the experiment. In addition, phase change due to the atmospheric disturbance was also investigated.

3.3. Differential VLBI for Spacecraft Tracking

We performed an international differential VLBI experiment in cooperation with China for tracking GEOTAIL spacecraft on December 20, 2006. In this experiment, Kashima, Tsukuba and Aira of GSI, Usuda and Uchinoura of ISAS/JAXA, Mizusawa of NAOJ, Urumqi and Kunming of the Chinese VLBI Network (CVN) of the National Astronomical Observatories of China (NAOC) participated. One of the purposes of the experiment is to evaluate an accuracy of phase delay measurement for tracking.

The bandwidth of the spacecraft's signal is too narrow to achieve enough precision using group delay observables. Thus phase delay is considered as alternative choice to get higher delay resolution, also the ambiguity of phase is an issue to be solved. Phase delay observables are extracted with a special correlation software using the signal around transmitting frequency. In addition, a relativistic delay model for Earth-based VLBI observation of sources at finite distances[1] was implemented in the correlation and processing analysis software.

3.4. Atmospheric Path Delay Study

3.4.1. WVR Observation during CONT05

We compared estimated ZWD time series derived from an independent analysis of simultaneous radiosonde, WVR, GPS and VLBI observations at Tsukuba over the CONT05 period. The measured ZWDs at Tsukuba are shown in Figure 2. The mean and standard deviation values of the differences between the different techniques such as WVR, GPS, and VLBI (with 10° minimum elevation angle cutoff) are summarized in Table 2. (See Ichikawa et al. [2]). WVR data sets and the related documents are archived on our Web site [3].

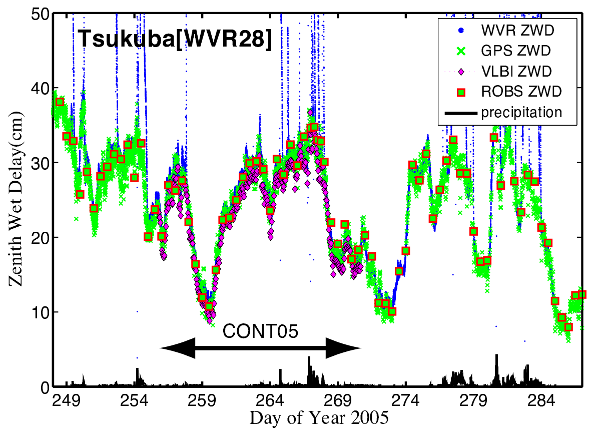

Figure 2. Time series of ZWD derived from the co-located techniques VLBI, WVR, GPS and radiosondes at Tsukuba during September 6 – October 12, 2005. The arrows indicate the period of the CONT05 campaign for which VLBI data were compared.

Table 2. Mean and scatter (standard deviation) values in millimeter between ZWDs derived from different techniques at Tsukuba.

	GPS	VLBI
WVR26	12.3 ± 16.5	23.6 ± 13.5
WVR28	6.5 ± 15.2	17.2 ± 12.1
VLBI	-12.1 ± 12.6	—

3.4.2. Atmospheric Path Delay Estimation using a Recent High Resolution Numerical Weather Model

Japan Meteorological Agency (JMA) provides a meso-scale analysis model over Japan and Eastern Eurasia with about 10 kilometer horizontal resolution (see Figure 3). We are now modifying a ray tracing tool for estimating atmospheric slant delay through the recent numerical weather model of JMA. This tool will enable to evaluate horizontal and vertical positioning errors associated with horizontal water vapor inhomogeneity.

4. Future Plans

For the year 2007 the plans of the Analysis Center at NICT include:

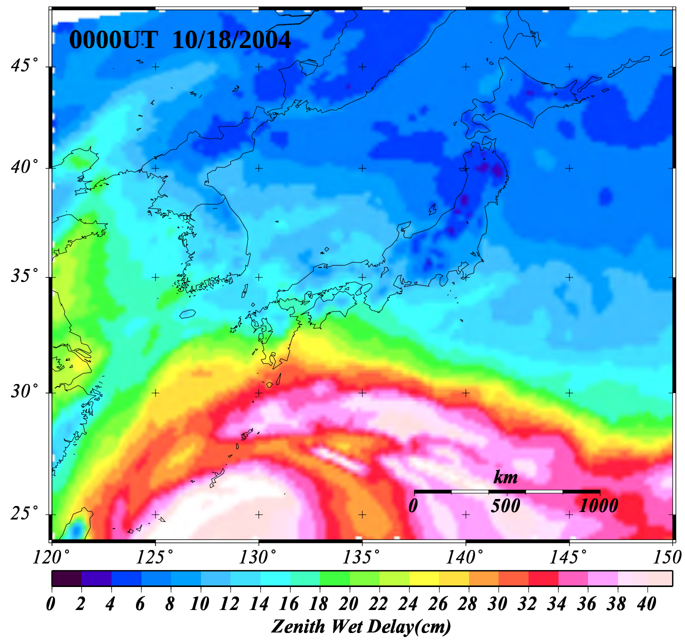

Figure 3. Zenith wet delay retrieved by the JMA meso-scale analysis model at 00:00 UT October 18, 2004.

- Several international and domestic VLBI experiments for real-time EOP determination using e-VLBI and the K5 system (both VSSP system and PC/VSI system)
- Differential VLBI experiments for spacecraft tracking and its analysis
- Development of the analysis software for spacecraft positioning using phase delay observables
- Improvement of processing speed and efficiency for the VLBI data correlation using multi-processor and high speed network
- Evaluation of simulated positioning errors due to tropospheric parameters (VLBI, GPS, WVR and the numerical weather prediction model)

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[2] Ichikawa, R., H. Kuboki, M. Tsutsumi, and Y. Koyama, Zenith wet delay comparisons at Tsukuba and Kashima VLBI stations during the CONT05 VLBI campaign, *IVS NICT-TDC News*, **No.27**, pp. 19-22.

[3] *http://www2.nict.go.jp/w/w114/stsi/CONT05_WVR/*

Paris Observatory Analysis Center OPAR: Report on Activities, January - December 2006

A.-M. Gontier, S. Lambert, C. Barache

Abstract

The OPAR Analysis Center, its organisation and technical means are briefly presented. Its general scientific and operational aims are summarized. The current state of the operational determination of EOP and coordinate time series are described.

1. The OPAR Analysis Center

1.1. The Team

The analysis center is now run by the following team: A.-M. Gontier is the head of the group, C. Barache is in charge of all the technical, database and computer aspects, S. Lambert is participating in the scientific developments and in operational analysis. There are two associated members, M. Bougeard and D. Gambis.

1.2. Characteristics of the Analyses

During 2006 the Linux version of Calc 10 and Solve 2006.06.08 software was installed on our computer and used to analyze VLBI observations. The French geodetic VLBI analysis software package GLORIA is undergoing some developments and testing and will be operational in the near future.

1.3. Main Objectives of the Analysis Center

The following activities are done operationally:

- quarterly (long term) and weekly solutions for the Earth's orientation,
- time series of radio source and station coordinates.

Activities under investigations:

- different scheme to obtain time series of radio sources and station coordinates,
- software development and documentation,
- studies of celestial reference frame.

2. Determination of EOP

First, a long term EOP solution was computed. About 1500 sessions of VLBI data from January 1994 until December 2006 were used. Together with the EOP, clocks, axis offsets, atmospheric and gradients parameters were estimated. The station coordinates and velocities were adjusted as global parameters. A no-net-rotation condition with respect to ITRF 2000 was applied on 33 station positions and velocities. The source coordinates were adjusted as global parameters, except for few of them estimated as local (poorly observed sources). The orientation of the celestial frame was defined by a no-net-rotation with respect to ICRF-Ext.2 tie to the Feissel-Vernier et al. (2006) 247 stable sources. The global postfit rms delay was 21 ps.

A rapid EOP solution is run weekly when the databases of the latest sessions are made available and gives estimates for each sessions, of polar motion, UT1 and corresponding rates, and precession-nutation. The same analysis as for the long term solution is applied, except for the terrestrial and celestial frames. The station coordinates and velocities and the source coordinates are fixed to the values obtained in the long term solution.

The long term and operational solutions will be submitted to the IVS in early 2007.

3. Time Series of Radio Source and Station Coordinates

The production and analysis of time series of radiocenter positions is a key action to select the best subset of radio sources to define a stable, non-rotating celestial reference frame. It was shown that VLBI results based on Feissel-Vernier (2003) source selection scheme are more consistent than those obtained in the conventional ICRF manner (Gontier & Feissel-Vernier 2006, Arias & Bouquillon 2004, Feissel-Vernier et al. 2005).

In order to contribute to the ICRF revision, we compute time series of radio source positions per session. Four analyses are conducted, in order to keep at least one third of the 247 sources of 'definition' as globals (thus, the NNR is applied to this third) and to get local estimates for all the other sources. Polar motion and rate and UT1 are fixed to the latest IERS Bulletin A values (only UT1 rate is estimated). However, station coordinates are estimated as local parameters. As for the long term EOP solution, the analysis currently starts in 1994. Figure 1 shows an example of time series for the source 2145+067.

4. Current Developments

The results of the current analyses are available on the OPAR web site (http://ivsopar.obspm.fr) and the operational series will be submitted regularly to the IVS in the near future.

It has been recently shown that the network geometry is a key problem in VLBI and some network inconsistencies are showing up in the Earth Orientation Parameters, thus producing 'fake' EOP values (Lambert & Gontier 2006). Studies are currently conducted to find out whether the use of GNSS derived station coordinates could improve the VLBI determination of EOP.

Time series of radio source and stations coordinates will be extended to all the observations since 1984 when new computer and disk will be available. We will then investigate those longer time series by using and developping the Feissel-Vernier selection scheme and compare to the previous list of stable sources.

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Figure 1. Time series from 1994 to 2006 for the source 2145+067. Average values of the right ascension and the declination over the observational time span have been removed. For the top plot right ascension (red solid circle) and declination (green solid triangle) have been shifted by +1 and -1 mas, respectively. Bottom plot shows normal points at 0.5 year intervals for the same source.

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The IVS Analysis Center at the Onsala Space Observatory

Rüdiger Haas, Hans-Georg Scherneck, Tobias Nilsson

Abstract

This report briefly summarizes the activities of the IVS Analysis Center at the Onsala Space Observatory during 2006. Some examples of achieved results and ongoing analyses are presented.

1. Introduction

The IVS Analysis Center at the Onsala Space Observatory focusses on a number of research topics that are relevant for space geodesy and geosciences. We address these research topics in connection to data observed with geodetic VLBI and complementing techniques. In the year 2006 the main focus was on high-frequency Earth orientation, GPS-VLBI ties, loading phenomena, and atmospheric water vapor. Some results are briefly presented in the following.

2. hfEOP from VLBI CONT Campaigns

We analyzed the CONT94, CONT02 and CONT05 VLBI data and derived polar motion and UT1 values with a temporal resolution of 1 hour. The resulting time series show periodic behavior with mainly diurnal and semi-diurnal periods. Most of this periodic behavior can be explained by a model for high-frequent polar motion and UT1 variations due to ocean tidal influences [1], [2]. However, the three CONT campaigns reveal significantly different residuals with respect to this model, in particular for polar motion. Figure 1 shows wavelet scalograms of retrograde and prograde residual polar motion after subtracting the theoretical model. Results have been presented at the IVS General Meeting 2006 [3] and work is continuing to understand the differences of the results from the three CONT campaigns.

3. GPS-VLBI Ties at Onsala and Ny-Ålesund

We analyzed all available GPS data recorded with GPS antennas mounted on top of the VLBI telescopes at Onsala and Ny-Ålesund. These antennas had been mounted in order to monitor the local ties between the radio telescopes and the GPS monuments at these two space geodetic sites [4], [5]. Time series of residuals with respect to mean value of the topocentric local ties at Onsala and Ny-Ålesund are shown in Fig. 2 and Fig. 3, respectively. The current level of accuracy of the performed measurements does not allow to monitor local-ties with sub-mm accuracy [6].

4. Ocean Tide and Atmospheric Loading

The service provided by the automatic ocean tide loading provider [7] has been maintained and in late 2006 a transition of the program to a new computer has started. We expect an improvement of the processing speed by a factor of ten compared to the old computer.

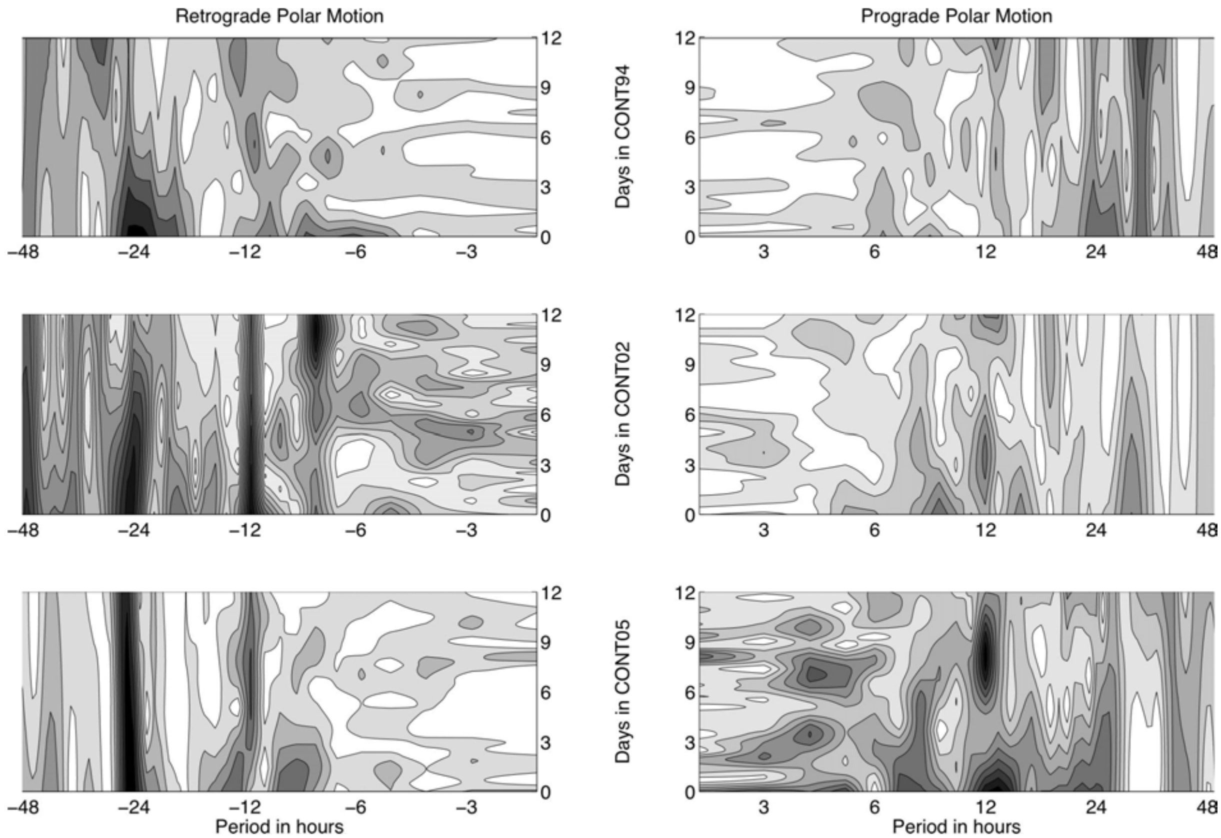

Figure 1. Wavelet scalograms of retrograde (left) and prograde (right) residual polar motion from CONT94 (top), CONT02 (middle) and CONT05 (bottom) after subtracting predictions based on the extended Ray model [1], [2]. Normalized wavelet energy is shown in grey-scale, where dark colours mean high energy.

5. Contribution to the IVS TROP Project

Also during 2006 we continued to submit on a regular basis tropospheric parameters for the VLBI stations observing in the IVS R1 and R4 networks [8].

6. Simulations of Equivalent Zenith Wet Delay for VLBI2010

We contributed to the VLBI2010 simulation efforts with simulations of equivalent zenith wet delays for all stations in the VLBI2010 simulation network. These simulations were done based on a turbulence model [9] together with wind data from a numerical weather model [10].

7. Outlook

The IVS Analysis Center at the Onsala Space Observatory will continue its work on specific topics relevant for space geodesy and geosciences.

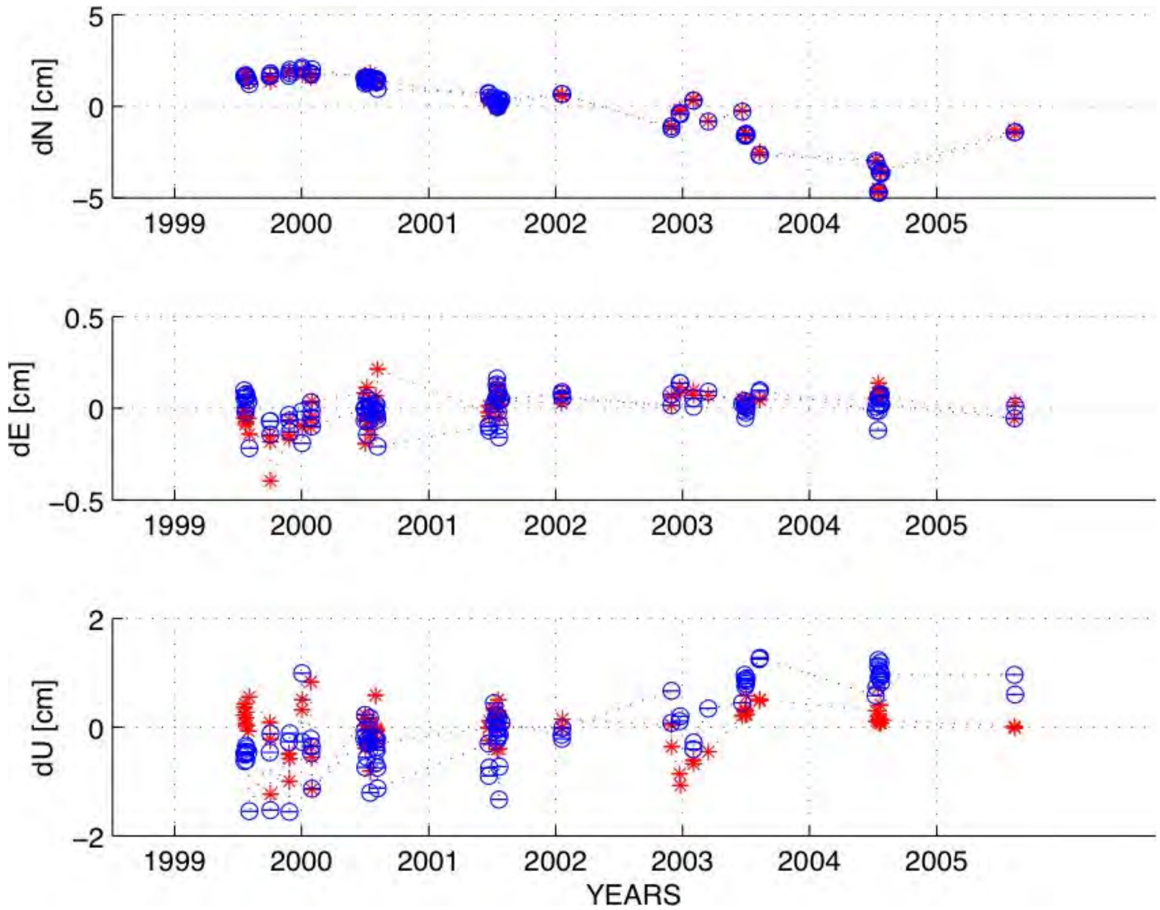

Figure 2. Time series of residuals with respect to a mean value of the topocentric local tie between the GPS monument and a GPS antenna mounted on top of the VLBI telescope at Onsala. Stars (red) correspond to L1-solutions, circles (blue) to L2-solutions in the GPS analyses.

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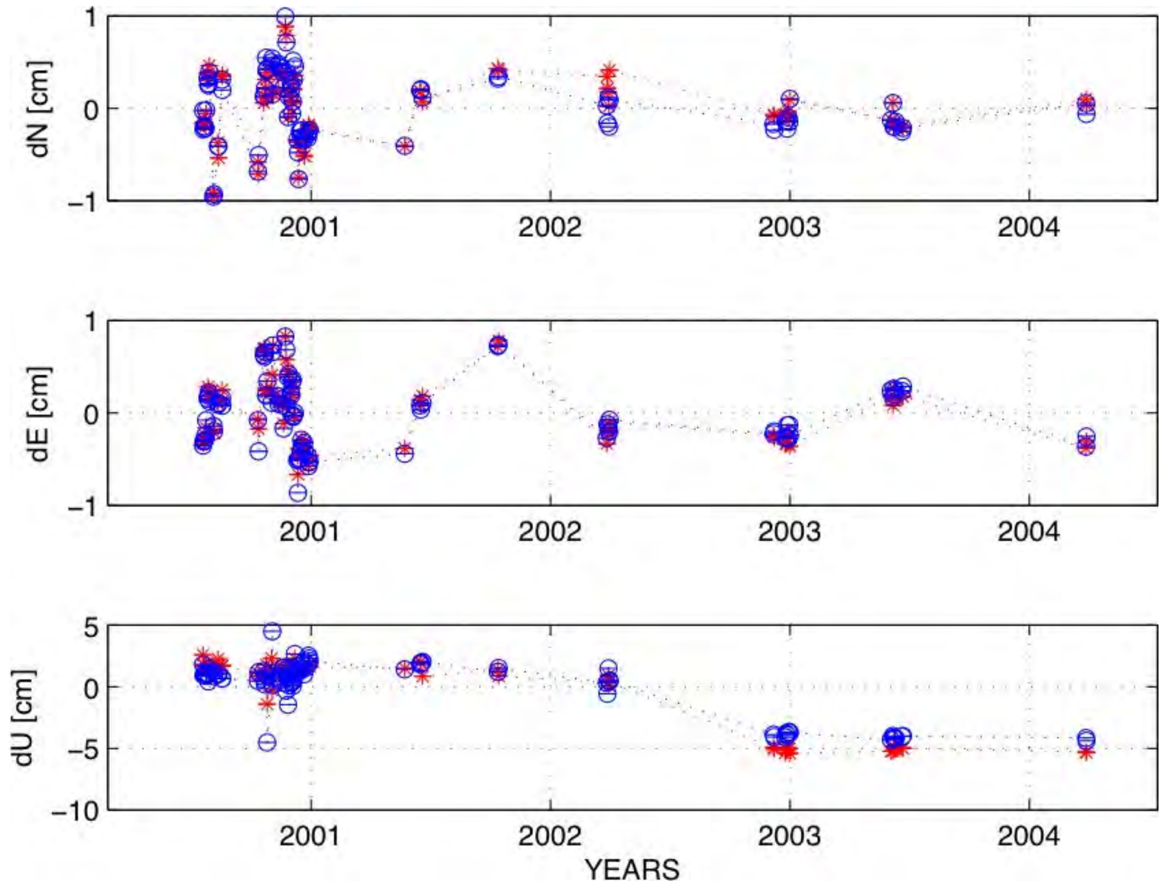

Figure 3. Time series of residuals with respect to a mean value of the topocentric local tie between the GPS monument and a GPS antenna mounted on top of the VLBI telescope at Ny-Ålesund. Stars (red) correspond to L1-solutions, circles (blue) to L2-solutions in the GPS analyses.

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PUL IVS Analysis Center Report 2006

Zinovy Malkin, Julia Sokolova, Anisa Bajkova

Abstract

This report briefly presents the PUL IVS Analysis Center activities during 2006 and plans for the coming year. The main topics of investigations in 2006 were improvement of celestial reference frame ICRF, modelling of the Free Core Nutation and software development. Other projects, such as regular contribution to the IVS products and radio source mapping, are underway.

1. General Information

The PUL IVS Analysis Center is located at the Central (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences, widely known as Pulkovo Observatory. It was established in September 2006. Its main activities are:

- Improvement of the International Celestial Reference Frame (ICRF), including investigations of radio source catalogues, construction of combined catalogues, investigation of the ICRF stability, and investigation of radio source structure and its variability.
- Computation and investigation of EOP, station position, and baseline length time series.
- Comparison of VLBI products with other space geodesy techniques.

The analysis center supports a web page at `http://www.gao.spb.ru/english/as/ac_vlbi/`.

2. Scientific Staff

The PUL team consists of three scientists:

1. Zinovy Malkin (90%) — team coordinator, computation and analysis of EOP, station coordinates and baseline length, development of algorithms and software for data processing;
2. Julia Sokolova (100%) — global data analysis for deriving radio source catalogues and source position time series, comparison and combination of radio source catalogues, development of algorithms and software for CRF studies;
3. Anisa Bajkova (10%) — image processing and analysis, development of algorithms and software for image processing.

3. Analysis Activities

The activities of the PUL IVS Analysis Center during 2006 included:

- Investigations in the framework of the IVS Pilot Project "Next ICRF" (now IERS/IVS Working Group on the Second Realization of the ICRF) were started. Main emphasis in this activity was on the computation of radio source catalogues, their comparison and combination:
  - The impact of radio source instability on celestial pole offset estimates was investigated [1]. No significant effect was found.

- The first version of the radio source catalogue and source position time series from a global analysis of the VLBI data with the OCCAM 6.2 software was completed. An investigation of the results is underway.
- Four methods of representation of the systematic part of the position differences in radio source catalogues were examined [2]. These were simple rotation, rotation plus deformation (used at the IERS ICRS Product Center since 1995), and expansion in orthogonal functions (Legendre-Fourier polynomials and spherical functions). Using Legendre-Fourier functions proved to be the most accurate method. The method of comparison of radio source catalogues used by the IERS evidently does not provide adequate representation of the systematic differences in the modern VLBI catalogues.
- Initial versions of two combined radio source catalogues were constructed [2]. The first of them provides an improvement of the current realization of the ICRF in terms of random errors, and the second one allows us to account for possible ICRF systematic errors. A comparison of celestial pole offsets obtained from processing of VLBI observations using ITRF and the second combined catalog showed that even using this initial version improves the results by about 5%. Further improvement is expected after refining our combination procedures.

- A regular computation of two refined Free Core Nutation (FCN) time series was started in the end of 2006. The first series makes use of an empirical model with variable amplitude and phase [3, 4]. This model is provided for the period from 1984.0 to two years before the current date to obtain geophysically meaningful data without edge effect. The IVS combined EOP series is used for the computation of the differences between observations and the IAU2000A nutation model. The model is aimed primarily at users who are interested in the geophysical interpretation of the observations.

  The second FCN series is computed by smoothing the IVS combined EOP series, and includes a forward and backward prediction covering the period from 1976 to two years beyond the current date. It is aimed primarily at users who need maximum accuracy for the CRF↔TRF transformation, including real-time applications, without bothering about theoretical background and geophysical meaning.
- Development of software for data processing was continued.
- PUL archive of VLBI observations and products was originated. At present, all available databases and X-band NGS cards have been stored.
- PUL staff members participated in the activities of various IVS projects, Working Groups and Committees.

4. Outlook

Plans for the coming year include:

- Further improvement of algorithms and software for processing of VLBI observations.
- Start of regular processing of VLBI data.
- Continuation of the investigations listed above.
- Support of the PUL archive for data and products.

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SHAO Analysis Center 2006 Annual Report

Jinling Li

Abstract

Our research activities in 2006 were mainly focused on the reduction of tracking data of satellite by VLBI, ranging and Doppler, which will be continued for the first half of the next year. In 2007 we will do some data analysis and experiments on the application of differential VLBI and phase-referencing VLBI. We will do a local survey at Sheshan.

1. General Information

As one of the research groups of Shanghai Astronomical Observatory (SHAO), we focus our activities on the studies of Radio Astrometry and Celestial Reference Frames. We use CALC/SOLVE system in the routine VLBI data analysis. We are now developing softwares coded in FORTRAN to deal with the tracking data of satellite by VLBI, ranging and Doppler. The members involved in the IVS/IERS activities are Jinling Li, Guangli Wang, Bo Zhang, Li Guo, Jing Wang and Zhihan Qian.

2. Activities in 2006

We participated in some IERS/IVS campaigns aimed at comparisons of reference frames and/or Earth Rotation Parameters (EOP). Now we have the ability to do the VLBI solutions on a regular base.

Differential VLBI plays an important role in the deep space exploration. However, the application of this technique is restricted due to the prerequisite that the angular distance between the target and the reference objects should be very small in order to maintain a high precision. A strategic design of the implementation of differential VLBI is developed by using observations of several reference sources spread out in a specially selected circular band and interpolating the non-geometric delay to the target object. Real data analysis of astrometric and geodetic VLBI experiments shows that by using our design a precision of about $1ns$ in the correction of the non-geometric delay could be obtained at S-band. We will check the performance of the design by experiments using the four Chinese antennas.

The dominant error source in VLBI phase-referencing is the model error of atmospheric delay during correlation. The most common approach to correct this error is measuring directly the vertical atmospheric delay by geodetic-like VLBI observations before, during and after the phase-referencing. However, this approach is limited by the fluctuation of dynamic atmospheric delay at each antenna. Atmospheric delay is dominated by the troposphere at frequencies higher than 5GHz. The comparison between atmospheric delay derived by GPS and VLBI observations at sites with co-located VLBI and GPS systems shows that the standard deviation of the difference is about several millimeters after a systematic bias is removed. This suggests that GPS could be used to monitor the large scale fluctuation of dynamic tropospheric delay and to increase the precision of correction of the atmospheric delay model error. Model and software development and application of experiments are continuing.

We take part in the Chinese lunar project Chang'E. We are developing softwares to process VLBI, range and Doppler satellite tracking data. We have examined the software by tracking data in the modes of real-time and post-stage processing both for geo-satellite and lunar satellite (SMART1). At present the software is very near to the status of being applicable to the mission. The next step is to do the synthesis reduction of VLBI observations of satellite and quasars.

3. Plans for 2007

We will continue to focus our efforts on the application studies of VLBI to satellite positioning and orbit determination. We will try to be closely involved in IERS/IVS analysis activities. We will do some data analysis and experiments on VLBI phase-referencing and differential VLBI. We will do the local survey at Sheshan observation site to connect the reference markers of SLR, VLBI and GPS.

U.S. Naval Observatory VLBI Analysis Center

David A. Boboltz, Alan L. Fey, David M. Hall, Kerry A. Kingham

Abstract

This report summarizes the activities of the VLBI Analysis Center at the United States Naval Observatory for calendar year 2006. Over the course of the year, Analysis Center personnel analyzed biweekly diurnal experiments with designations IVS-R1 and IVS-R4 for use in-house and continued timely submission of IVS-R4 databases for distribution to the IVS. During the 2006 calendar year, the USNO Analysis Center produced three periodic global Terrestrial Reference Frame (TRF) solutions with designations usn2006a, usn2006b, and usn2006c. Earth orientation parameters based on these solutions, updated by the diurnal (IVS-R1 and IVS-R4) experiments, were submitted to the IVS. A significant milestone was the conversion of all USNO database to CALC 10 and the transition to global solutions based on these databases.

Other activities in the 2006 calendar year included the continued generation of files in the SINEX format based on new 24-hr experiments and submission to the IVS. With regards to the Celestial Reference Frame (CRF), Analysis Center personnel continued a program designed to increase the sky density of ICRF sources especially in the southern hemisphere. Activities included scheduling, analyzing and submitting databases for IVS-CRF experiments and the production of global CRF solutions designated crf2006a, crf2006b, and crf2006c. This report also describes activities planned for the 2007 calendar year.

1. Introduction

The USNO VLBI Analysis Center is supported and operated by the United States Naval Observatory (USNO) in Washington, DC. The primary services provided by the Analysis Center are the analysis of diurnal experiments, the production of periodic global Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF) solutions, and the submission to the IVS of intensive (EOP-I) and session-based (EOP-S) Earth orientation parameters based on USNO global TRF solutions. Analysis Center personnel maintain the necessary software required to continue these services to the IVS including periodic updates of the GSFC CALC/SOLVE software package. In addition to operational VLBI analysis, USNO personnel engage in research aimed at developing the next generation ICRF. Information on USNO VLBI analysis activities may be obtained at:

`http://rorf.usno.navy.mil/vlbi/`.

2. Current Analysis Center Activities

2.1. Experiment Analysis and Database Submission

During the 2006 calendar year, personnel at the USNO VLBI Analysis Center continued processing of diurnal (IVS-R1 and IVS-R4) experiments for use in internal USNO global TRF and CRF solutions. USNO is also responsible for the timely analysis of the IVS-R4, and the resulting databases are submitted within 24 hours of correlation for dissemination by the IVS. In addition, Analysis Center personnel continue to be responsible for the analysis and database submission for the periodic IVS-CRF experiments. The primary goal of these experiments is the densification of ICRF sources in the southern hemisphere. In 2006, USNO scheduled and analyzed 19 CRF experiments including IVS-CRF37 through IVS-CRF42, CRF-S8, and IVS-CRDS25 through IVS-CRDS33. The analyzed databases were submitted to the IVS. In the 2006 calendar year, Analysis

Center personnel also continued analyzing IVS intensive experiments for use in a USNO EOP-I time series.

2.2. Global TRF Solutions, EOP and SINEX Submission

USNO VLBI Analysis Center personnel continued to produce periodic global EOP/TRF solutions (usn2006a, usn2006b and usn2006c) over the course of the 2006 calendar year. A significant milestone was achieved with the conversion of all USNO databases and the transition to global solutions based on the CALC 10 software. This occurred in June 2006 beginning with the usn2006b/crf2006b solutions. All USNO global EOP/TRF solutions including the most recent solution may be found at:

`http://rorf.usno.navy.mil/solutions/`.

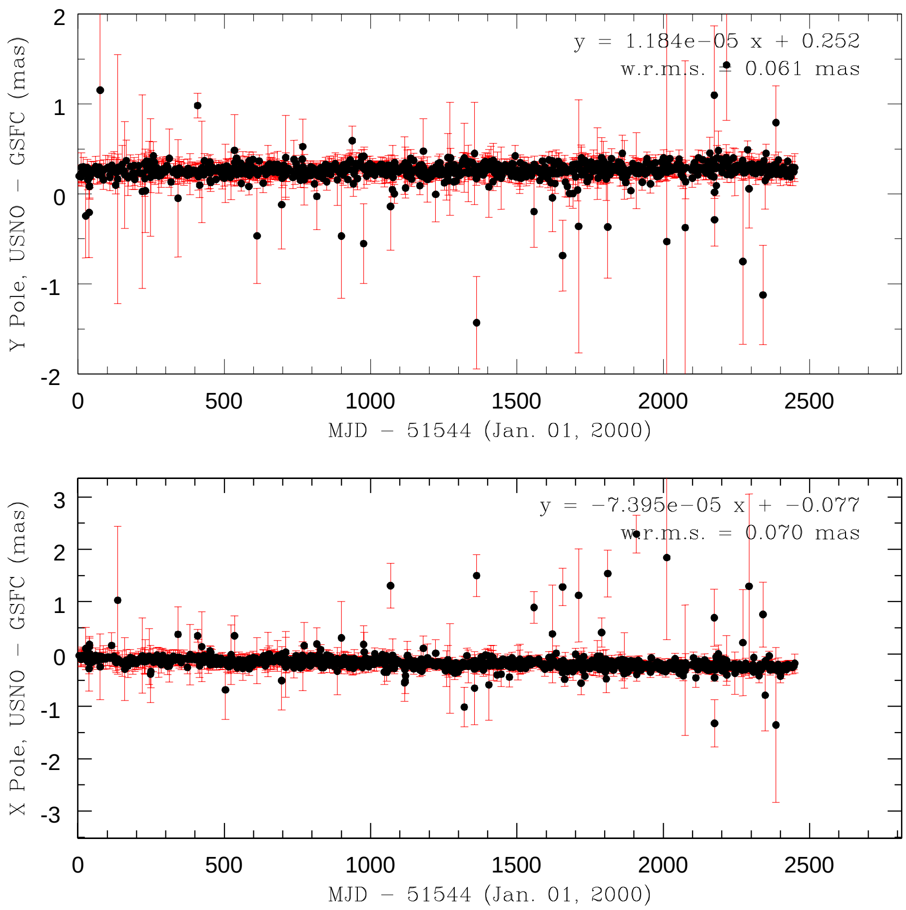

Figure 1. Differences between pole positions estimated from the usn2006c TRF solution and the IERS-C04 time series from January 2000 through October 2006. A weighted least squares linear fit to the data and the weighted RMS are shown in the upper right corner of each plot.

Session-based Earth orientation parameters derived from these TRF solutions were compared to those derived from GSFC periodic TRF solutions and with the IERS-C04 time series prior to submission to the IVS. Figure 1 shows an example of the comparison information available at the web site mentioned above. In this figure, differences in pole position estimates derived from the usn2006c solution and the IERS-C04 time series are plotted.

Analysis Center personnel continued to produce an EOP-S series based on the global TRF solutions and continuously updated by new data from the IVS-R1/R4 experiments since the most recent global solution. This updated EOP-S series is submitted to the IVS twice weekly within 24 hours of experiment correlation and is included in the IERS Bulletin A. Analysis Center personnel also continued to produce suitable SINEX format files based on new 24-hr experiments and the resulting files submitted to the IVS.

In addition to EOP-S and SINEX series, USNO Analysis Center personnel continued to produce and submit to the IVS an EOP-I series based on the IVS intensive experiments.

2.3. Celestial Reference Frame

During the 2006 calendar year, Analysis Center personnel continued work on the production of global CRF solutions for dissemination by the IVS including crf2006a, crf2006b, and crf2006c. These solutions are routinely compared to the current ICRF and are available through the previously mentioned web site: `http://rorf.usno.navy.mil/solutions/`. Figure 2 shows the more than 2000 sources available in the geodetic/astrometric database. Analysis center personnel are currently exploring the benefits of adding the sources from the VLBA Calibrator Survey (VCS) many of which were observed in only one experiment and are shown as asterisks in Figure 2.

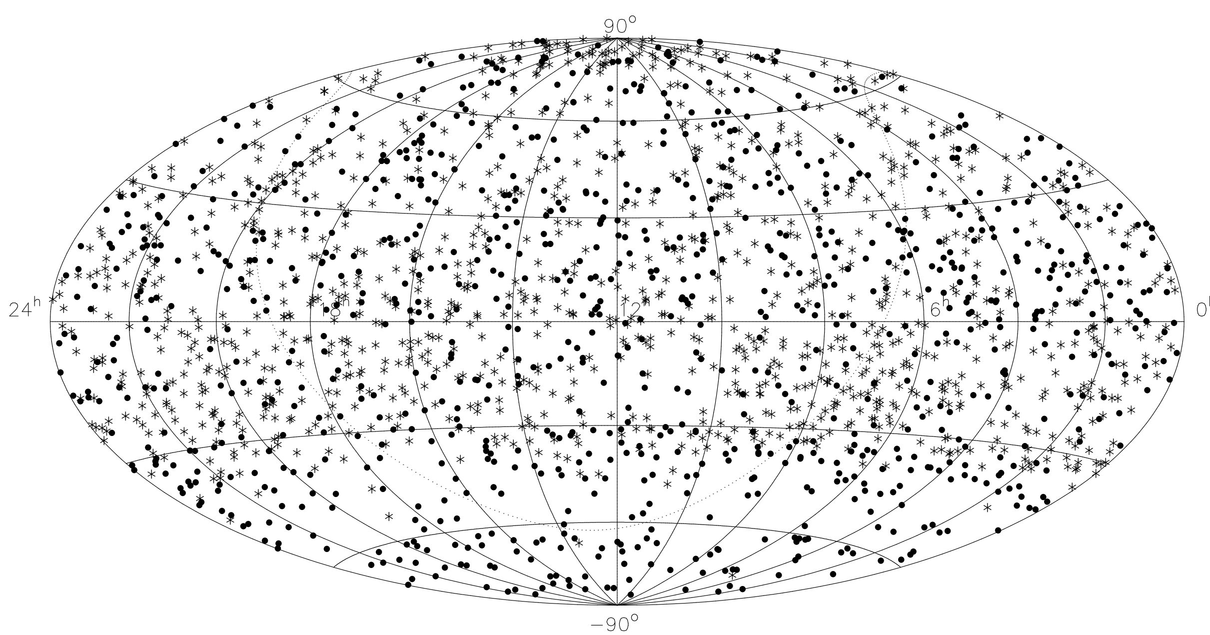

Figure 2. The 2000+ sources in the geodetic/astrometric database with the inclusion of the VLBA Calibrator Survey (VCS). The asterisks represent those sources observed in only one experiment and are mostly VCS sources.

During 2006, Analysis Center personnel also continued research into the densification of the ICRF in the southern hemisphere through IVS-CRF and ATNF/USNO observations. Astrometric positions of 34 southern hemisphere extragalactic sources south of $\delta = 20°$ were published by Fey, et al. (2006, AJ, 132, 1944). These positions have average formal uncertainties of 0.23 mas in $\alpha \cos \delta$ and 0.35 mas in δ.

3. Staff

The staff of the VLBI Analysis Center is drawn from individuals who work at the USNO. The staff and their responsibilities are:

Name	Responsibilities
David A. Boboltz	Periodic global TRF solutions and comparisons, Sinex generation and submission, web page administration, VLBI data analysis.
Alan L. Fey	Periodic global CRF solutions and comparisons, CRF densification research, web page administration, VLBI data analysis.
David M. Hall	VLBI data analysis and database submission, IVS EOP-S and EOP-I submission.
Kerry A. Kingham	Correlator interface, VLBI data analysis

4. Future Activities

For the upcoming year January–December 2007, USNO VLBI Analysis Center personnel plan to accomplish the following activities:

- Continue the processing of biweekly IVS-R1/R4 experiments for use in internal TRF and CRF global solutions and continue submission of IVS-R4 databases for dissemination by the IVS.
- Continue the production of periodic global TRF solutions and the submission of EOP-S estimates to the IVS updated by the IVS-R1/R4 experiments.
- Submit a series of SINEX format files retroactive to 1979 based on all available USNO (CALC 10) databases.
- Continue the analysis of intensive experiments and submission of EOP-I estimates to the IVS.
- Continue the scheduling, analysis and database submission for all IVS-CRF experiments.
- Continue ATNF/USNO astrometric observations and research regarding the densification of the ICRF in the southern hemisphere.
- Continue the production of periodic global CRF solutions.
- Begin research into the development of the second realiztion of the ICRF (ICRF-2).

USNO Analysis Center for Source Structure Report

Alan L. Fey, David A. Boboltz, Roopesh Ojha, Ralph A. Gaume, Kerry A. Kingham

Abstract

This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure for calendar year 2006. VLBA RDV experiments RDV57 and RDV59 were calibrated and imaged. VLBA high frequency experiment BL122C was calibrated and imaged. Images from these three experiments, together with images from RDV16 and RDV23 were added to the USNO Radio Reference Frame Image Database. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Activities planned for the year 2007 include continued imaging of ICRF sources at standard and higher frequencies and continued analysis of source structure and its variation.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of ICRF sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The web server for the Analysis Center is hosted by the USNO and can be accessed by pointing your browser to

`http://rorf.usno.navy.mil/ivs_saac/`

The primary service of the analysis center is the Radio Reference Frame Image Database (RRFID), a web accessible database of radio frequency images of ICRF sources. The RRFID contains 4164 Very Long Baseline Array (VLBA) images (a 20% increase over the previous year) of 517 sources (a 4% increase over the previous year) at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 1154 images (a 18% increase over the previous year) of 270 sources (a 6% increase over the previous year) at frequencies of 24 GHz and 43 GHz. The RRFID can be accessed from the Analysis Center web page or directly at

`http://www.usno.navy.mil/rrfid.shtml`

A recent addition to the RRFID are 74 Australian Long Baseline Array (LBA) images of 69 southern hemisphere ICRF sources at a radio frequency of 8.4 GHz.

Shown in Figure 1 is the distribution on the sky of the sources which have been imaged at 2.3 GHz and 8.4 GHz.

2. Current Activities

2.1. RDV Imaging

VLBA experiment RDV59 (2006SEP13) was calibrated and imaged, adding 184 (92 S-band; 92 X-band) images to the RRFID including images of 7 sources (0220-349, 1244-255, 1308+328, 1640-231, 1758+388, 1805-214 and 2005-489) not previously imaged.

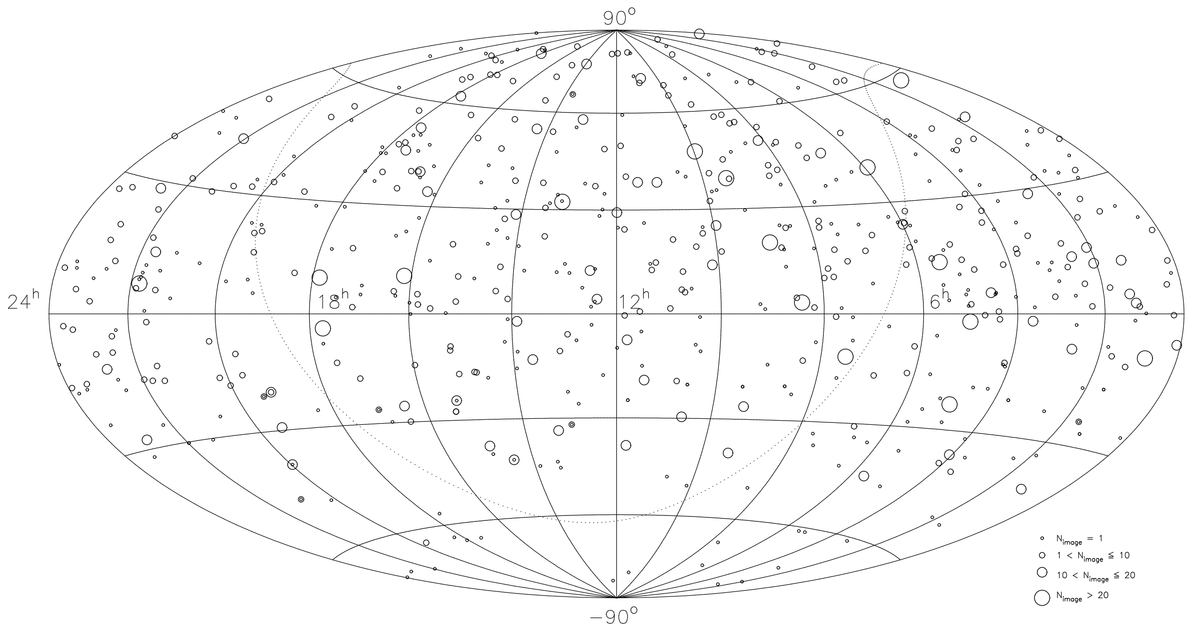

Figure 1. Distribution of the sources which have been imaged at 2.3 GHz and 8.4 GHz shown on an Aitoff equal area projection of the celestial sphere. The size of the open circles indicates roughly the number of times each source has been imaged as indicated by the key.

VLBA experiment RDV57 (2006JUL11) was calibrated and imaged, adding 160 (80 S-band; 80 X-band) images to the RRFID including images of 4 sources (0151+474, 0629-418, 0834-201 and 1032-199) not previously imaged.

VLBA experiment RDV23 (2000OCT23) was calibrated and imaged, adding 188 (94 S-band; 94 X-band) images to the RRFID including images of 4 sources (0118-272, 0925-203, 1451-400 and 0836+182) not previously imaged. These results were contributed by Glenn Piner and Corey Nichols of Whitier College who calibrated, edited and imaged the data.

VLBA experiment RDV16 (1999JUN21) was calibrated and imaged, adding 182 (91 S-band; 91 X-band) images to the RRFID including images of 5 sources (0135-247, 0338-214, 0610+260, 1734+363 and 1806+456) not previously imaged. These results were contributed by Glenn Piner and Corey Nichols of Whitier College who calibrated, edited and imaged the data.

Collaborations continue with Glenn Piner at Whitier College and Patrick Charlot of Bordeaux Observatory to calibrate and image several of the RDV experiments.

2.2. VLBA High Frequency Imaging

VLBA observations to extend the ICRF to 24 and 43 GHz continued in 2006. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO) and Bordeaux Observatory. During the calender year 2006 one VLBA high frequency experiment, BL122C, was calibrated and imaged adding 178 (K-band only) images to the RRFID including images of 15 sources not previously imaged.

2.3. ICRF Maintenance in the Southern Hemisphere

The USNO and the Australia Telescope National Facility (ATNF) continue a collaborative program of VLBI research on Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the Southern Hemisphere by a) increasing the reference source density with additional bandwidth-synthesis astrometric VLBI observations, and b) VLBI imaging at 8.4 GHz of ICRF sources south of $\delta = -20°$.

3. Staff

The staff of the Analysis Center is drawn from individuals who work at the USNO. The staff are: Alan L. Fey, David A. Boboltz, Roopesh Ojha, Ralph A. Gaume and Kerry A. Kingham.

4. Future Activities

The Analysis Center currently has a program of active research investigating the effects of intrinsic source structure on astrometric position determination. Results of this program are published in the scientific literature.

The following activities for 2007 are planned:

- Continue imaging and analysis of VLBA 2.3/8.4/24/43 GHz experiments;
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners;
- Fey et al. (2004, AAS, 205, 9112) developed an algorithm to use images from the RRFID to classify sources in terms of their suitability for astrometric use based on their spatial compactness. Initially applied to the high frequency (24/43 GHz) data, the method will be applied to the study of ICRF sources at the standard frequencies (2.3/8.4 GHz).

Technology Development Centers

Canadian VLBI Technology Development Center

Bill Petrachenko, Mario Bérubé, Anthony Searle

Abstract

The Canadian Technology Development Center has developed an "end-to-end" geodetic VLBI system built on S2 equipment. The development of this system has led to an operational IVS network. Development work continues to streamline operations and improve S2 instrumentation. The Technology Development Center is actively preparing to engage in the development of the VLBI2010 systems.

1. Introduction

The Canadian VLBI Technology Development Center is a collaborative effort of the National partners interested in the advancement of VLBI technology, namely the Geodetic Survey Division of Natural Resources Canada (GSD/NRCan) and the Dominion Radio Astrophysical Observatory (DRAO) of the Herzberg Institute for Astrophysics of the National Research Council of Canada, (DRAO/HIA/NRC).

2. S2 VLBI Geodesy

The S2 VLBI observation program continued in 2006 as the operational "E3" IVS observing network. The "E3" Network consists of Algonquin, Yellowknife, the Canadian Transportable VLBI Antenna (CTVA), Kokee Observatory, Svetloe Observatory, and the Transportable Integrated Geodetic Observatory (TIGO) located in Concepcion, Chile.

3. S2 VLBI System

The S2-DAS is designed to accommodate up to four VLBA/Mark IV type single sideband baseband converters (BBCs), each with a local oscillator (LO) independently frequency switchable under computer control. The recording system uses 8 modified super–VHS recorders.

The Canadian Correlator is a six station correlator (expandable to ten stations) using S2 playback terminals and is designed to handle S2 frequency–switched bandwidth synthesis data.

4. Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6m radio telescope acquired to facilitate densification of the VLBI measurements of the Canadian Spatial Reference System (CSRS). The antenna will be co-located with GPS elements of the Canadian Active Control System (CACS), part of the CSRS, to provide fiducial station positions. The Canadian Technology Development Center is responsible for CTVA system development.

At the end of 2005 the CTVA in Saint John's was disabled by a nearby satellite radio ground transmitter. In 2006, the CTVA system was packaged into a standard shipping container and returned to Ottawa.

On September 25, the Canadian government announced the cessation of Very Long Base Interferometry activities in Canada. Operations of the S2 correlator, CTVA, and the E3 network program were stopped.

Figure 1. CTVA being prepared to be packaged in shipping container

5. S2 Geodetic Experiment Scheduling, Operations and Analysis

The "E3" network continued to contribute to the IVS observing program with several EOP sessions using 6 stations. Several sessions were rescheduled this year to maximise the observations at Yellowknife. The loss of the Gilmore Creek antenna to the network impacted the decision.

Several of the sessions conducted outside of the IVS using the S2 and the Canadian stations were added to the IVS master schedule and the data added to the IVS collections. Though these sessions are only 2 and 3 stations, they should provide an improved VLBI position for the PENTICTN site.

6. VLBI2010

Active contributions in a number of areas continued toward VLBI2010.

Simulations were performed to demonstrate that the broadband delay concept could be used successfully to produce high precision delay measurements even at comparatively low SNR. Together with Arthur Niell, a study was undertaken to investigate the corrupting effect of source structure on the broadband delay process. A further study, including Patrick Charlot, has been proposed to investigate the effectiveness of using source structure corrections to mitigate degradation in cases where source structure is known to be a problem.

A study was undertaken into alternate scheduling algorithms to increase the number of observation per day and to improve uv coverage for the purpose of using the geodetic/astrometric data directly to produce source structure corrections.

A study was undertaken into the pros and cons of having multiple antennas at a site.

7. Dominion Radio Astrophysical Observatory (DRAO)

There are currently two projects under way at DRAO with potential relevance to VLBI2010.

A 32-station correlator is being developed for the eVLA project. The correlator, which handles up to 64 Gbps per station (assuming standard 2-bit VLBI sampling), can efficiently be scaled back to handle lower bit rates, e.g. the 8 Gbps anticipated for VLBI2010. VSI interfaces have been incorporated into the design, and the correlator is fully VLBI capable. The design phase of the project is now complete and prototypes of all major components have been produced. Prototype testing is well under way.

A capability is being developed to produce low-cost light-weight composite radio antennas for astronomy and geodesy. If properly designed, composites have very low coefficient of thermal expansion and are typically characterized by a high degree of stiffness per unit weight. These properties translate into structures that experience both low thermal and gravitational deformation. In addition, the light weight of the reflector (~15% of a metal antenna) greatly eases the design and cost of a high slew rate drive system, an important requirement of the VLBI2010 antenna spec. To date, materials and processes have been studied in depth. It is expected that a proof-of-concept 10 m dish will be fabricated before the end of 2007.

FFI Technology Development Center - Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center focuses primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS and SLR. This report shortly summarises the latest improvements of the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. The GEOSAT Software

The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in Andersen ([1]). The models of GEOSAT are listed in Andersen ([2]). The most important changes implemented in 2006 are described in the following.

The GEOSAT software is presently undergoing extensive development. The IERS-2003 Conventions have been implemented including all extensions/corrections up to 20 Jan 2007. Also included is pressure loading corrections produced by Petrov and Boy. The validation of GEOSAT with VLBI and SLR tracking data is completed with very promissing results. Right now the GNSS part of GEOSAT is in the validation phase.

Regarding SLR: The use of a detector-dependent center of mass corrections, correction for the non-linearity of the Stanford counter, 3D raytracing, and taking into account a signal strength dependent range bias for some stations, lead to a slight change in the value of GM as determined from SLR data. The use of multicolor laser data has been implemented and gives excellent post-fit residuals. The results indicate that for some periods station biases at the level of 5 mm still exist.

Also the GNSS part of GEOSAT has undergone extensive changes, e.g. with the inclusion of a second and third order ionospheric correction, absolute phase center corrections for all antennas etc.

A new software component for the generation of a Geophysical Events file has been included in GEOSAT. This file contains information about earthquakes, the magnitude, and distance to stations included in the ITRF. Based on this information we plan to develop an estimation strategy where noise, dependent on the distance to the epicenter, is added to the station reference point motion for stations affected by earthquakes.

Instrumental Events files for VLBI, GPS, and SLR have also been included in GEOSAT. These files give the epochs of changes in software or hardware of the instrument and the type of change. Every time an instrumental event occur noise will be added to the relevant estimated eccentricity vector.

The new version of GEOSAT is expected to be ready for routine processing within 1 year. The new version of GEOSAT will have two additional very usefull features: 1) It can simultaneously combine data from virtually any number of VLBI, SLR, and GPS instruments at a co-located site either observing simultaneously or in different time windows. All information will contribute to the estimation of the migration of an automatically selected master reference point at each station. 2) The station-related solve-for model parameters in a combined processing of the VLBI + SLR + GNSS can either be instrument-dependent, technique-dependent, microwave-dependent, optical-dependent, site-dependent, satellite/spacecraft-dependent, or radio source-dependent. The switching between the different types is extremely simple. A typical application would be to, in a first run, treat the zenith wet delay parameters as instrument-dependent parameters. This means that e.g. a station with two GPS receivers and one VLBI instrument will have three estimates of these parameters. If the results look consistent, all these parameters can be estimated as one single parameter represented by a microwave-dependent parameter in a second run. The same can be tested for clock parameters for co-located clocks etc. Since the raytracing starts at the position of the phase center for each instrument/antenna, the effect of different antenna heights will automatically be accounted for to the level of accuracy of the numerical weather model rescaled by the in-situ observed pressure values from the surfmet data.

2. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

[2] Andersen, P. H. High-precision station positioning and satellite orbit determination. PhD Thesis, NDRE/Publication 95/01094.

GSFC Technology Development Center Report

Ed Himwich, John Gipson

Abstract

This report summarizes the activities of the GSFC Technology Development Center (TDC) for 2006, and forecasts planned activities for 2006. The GSFC TDC develops station software including the Field System, scheduling software (SKED), hardware including tools for station timing and meteorology, scheduling algorithms, operational procedures, and provides a pool of individuals to assist with station implementation, check-out, upgrades, and training.

1. Technology Center Activities

The GSFC IVS Technology Development Center (TDC) develops hardware, software, algorithms, and operational procedures. It provides manpower for station visits for training and upgrades. Other technology development areas at GSFC are covered by other IVS components such as the GSFC Analysis Center.

The current staff of the GSFC TDC consists of John Gipson and Ed Himwich, employed by NVI, Inc.

The remainder of this report covers the status of the main areas of development that are currently being pursued.

2. Field System

The GSFC TDC center is responsible for development, maintenance, and documentation of the Field System (FS) software package. The FS provides equipment control at VLBI stations. It interprets the .snp schedule and .prc procedure file (both, as prepared by DRUDG from the .skd schedule). The FS controls the antenna, data acquisition hardware, and related ancillary equipment needed for making VLBI measurements. All major VLBI data acquisition backends are supported. The FS is customizable to allow it to control station specific equipment. It is used at all the IVS network stations (over 30) and also at many stations that do VLBI only for astronomical observations. The only major observatories not using it are the VLBA and VERA.

During this period some of the new features that were released in FS version 9.9 were:

- "autoftp" feature for near-realtime fringe tests implemented
- Pointing model expanded to 30 parameters
- Arbitrary length (up 512 character) SNAP procedure arguments supported
- numerous small bug fixes and improvements were added

In the next year, several other improvements are expected, among these are: (1) Support for Mark 5B recorders, (2) Support for DBBC and DBE racks, (3) a complete update to the documentation and in a more modern format that will be easier to use; (4) conversion of the FORTRAN source to use the g77 compiler, this will enable use of the source level debugger, *gdb* for development and field debugging; (5) use of *fsvue* or Real VNC for network operation; (6) *chekr* support for Mark 5A and 5B systems; (7) use of the Mark IV Decoder for phase-cal extraction in the field; and (8) support for periodic firing of the noise diode during observations.

3. SKED and DRUDG

The GSFC TDC is responsible for the development, maintenance, and documentation of SKED and DRUDG. These two programs are very closely related, and operate as a pair for the preparation of the detailed observing schedule for a VLBI session, and its proper execution in the field. In the normal data flow for geodetic schedules, first SKED is run at the Operation Centers to generate the .skd file that contains the full network observing schedule. Then stations use the .skd as input to DRUDG for making the control files and procedures for their station. Catalogs are used to define the equipment, stations, sources, and observing modes which are selected when writing a schedule with SKED. During 2006 many changes were made to the catalogs, SKED, and DRUDG.

3.1. Catalog Changes

Changes were made to the Catalog system in 2006 following suggestions received at the IVS General Meeting in Chile and at other times. Specifically, changes were made to:

- Allow simpler experiment setup in the case that there are more BBCs at a station then are used. This is the case for the RDVs which use only 8 BBCs. Previously the unused BBCs had to be set “by-hand” to a frequency that will not cause spurious signals.
- Allow simpler processing of experiments where different stations have different number of BBCs. This is done by assigning the same frequency to the same channels at all stations. Previously the frequencies were assigned to the first N-channels. This caused the correlators to have to “re-map” the channels prior to correlation.

As a result of the above changes, standard recording modes for the R1s, R4s, T2s and other sessions needed to be modified. In addition special recording modes were added for special tests.

USNO decided to begin recording in 16 channels for the R4s and the Intensives in January 2007. New catalog modes were added to support this change.

3.2. SKED

Many bug-fixes and upgrades to SKED were made this year. Some of the more notable ones include:

- Modifying tag-along mode to use snr_margin. This means that an observation is flagged as good if the SNR at the maximum allowable duration is within snr_margin of the target. This makes tag-along mode consistent with normal scheduling, and results in more observations in tag-along mode.
- Removed a bug in Mark 5 schedules that caused extra time between observations. This was because SKED does not keep track of tape footage for Mark 5 schedules. Part of the code which looked at the tape footage assumed that each observation was at the start of a pass (since the footage was 0), and scheduled extra time.
- SKED used two different arrays to store the latitude and the longitude of stations. Further the arrays differed in the sense of the longitude. This led to much confusion. One of the arrays was removed.
- Many changes were made to reading and writing VEX files. This was done when it was discovered that sometimes SKED could not read in a VEX file it had written!

- The downtime command was enhanced so that you can have many downtimes at a station.
- Simultaneous visibility plot. SKED was modified to plot a graph showing which sources are simultaneously visible by a set of stations.
- Time format made much more flexible. Previously SKED only accepted time-tags in the form YYDDDHHMMSS, e.g., 06345170000. Although this contains all the information, it is a little hard to read. SKED was modified to ignore "/", ":" and "-" while parsing time strings. Hence the above time might be written as 06/345/17:00:00.

In addition we assisted many institutions in installing the Linux version of SKED which is becoming the new standard.

3.3. DRUDG

Many modifications were made to support changing hardware specifications.

Haystack Observatory Technology Development Center

Alan Whitney

Abstract

Work at MIT Haystack Observatory is currently focusing on four areas:

1. Mark 5B/Mark 5B+ VLBI data systems
2. e-VLBI
3. Digital Backend
4. VLBI2010 Progress

We will describe each of these areas.

1. Mark 5B VLBI Data System

The Mark 5B VLBI data system is now being deployed to stations and correlators. The Mark 5B is based on the same physical platform, uses the same disk-modules, and supports the same maximum data rate of 1024 Mbps as the Mark 5A. However, the Mark 5B incorporates a VSI standard interface that can operate at an input-clock rate up to 64 MHz.

In order to use the Mark 5B system with an existing Mark IV or VLBA data-acquisition system, the installation of an adapter is required to create a VSI output. For an existing VLBA system, a Metsahovi-designed VSI-C board is used to create a standard VSI interface; the VLBA formatter is not used. For a Mark IV system, the existing Mark IV formatter is modified to create two VSI interfaces, allowing data from all 14 BBC's to be recorded to two Mark 5B's for a total aggregate data rate of 1792 Mbps. The Mark 5B also interfaces directly to the new Haystack digital backend (DBE, see below) and the European dBBC.

An FPGA-code upgrade has been designed for the Mark 5A playback system to allow disks recorded on the Mark 5B system to be replayed on a Mark 5A system and create output data in VLBA tape-track format. This upgrade, dubbed 'Mark 5A+', along with some modest correlator-software upgrades, will allow existing Mark IV correlators with Mark 5A+ playback systems to process data recorded on Mark 5B.

In addition, the Mark 5B supports all critical functionality of the Mark IV Station Unit, so that the Mark 5B may be directly connected to a Mark IV correlator through a simple interface without the use of a Mark IV Station Unit. This capability also allows existing Mark IV correlators to inexpensively expand the number of stations connected to the correlator. The Mark 5B system is fully integrated into the Mark IV correlator system at Haystack, and will be incorporated soon at the MPI and USNO Mark IV correlators.

A 2048 Mbps version of the Mark 5B, dubbed Mark 5B+, is now also available. The Mark 5B+ differs from the Mark 5B only by the substitution of a newer StreamStor disk-interface card from Conduant Corp.

2. E-VLBI Development

Haystack Observatory continues to develop the e-VLBI technique with a broad spectrum of efforts, including:

- VSI-E testing: Haystack Observatory is working with Kashima to test the prototype VSI-E implementation. This is a particularly good testbed as Kashima uses K5 data systems and Haystack uses Mark 5 data systems, thus providing an excellent test of VSI-E between heterogeneous data platforms. Once VSI-E is fully tested and functional, attention will be turned to tuning it for higher speeds, followed by broader deployment.
- Data transfer from Ny-Ålesund: A concerted effort over the last year has resulted in e-VLBI data transfers from Ny-Ålesund, one of the most remote sites in the geodetic-VLBI network. Through an agreement with NASA and the Norwegian Mapping Authority, and with the cooperation of local authorities to use a 100km on-island microwave link to the site at Ny-Ålesund, numerous e-VLBI data transfers have been successfully executed. Currently, transfer speed is limited to ~80 Mbps, but this speed may rise significantly with the proposed installation of an upgraded microwave link. The availability of e-VLBI data transfer from Ny-Ålesund greatly helps to ensure timely delivery of data since air connections are few and sometime unreliable due to inclement weather conditions.
- Regular e-VLBI data transfers: Routine use of e-VLBI at Haystack continues to grow. All data recorded on K5 systems at Tsukuba and Kashima are currently transferred via e-VLBI to Haystack Observatory, where it is transferred to Mark 5 disk modules and sent to target correlators at Haystack, USNO or MPI. Daily UT1 Intensive data from Wettzell are transferred via e-VLBI to a site near USNO in Washington, D.C., where it is picked up and taken to USNO for correlation.
- Automated data transfers: As routine e-VLBI becomes more prevalent, it is important that the data-transfer process be automated to the fullest extent possible. As part of an ongoing effort, work is continuing on the development of toolkits for helping to automate the transfer of VLBI data across Wide Area Networks. As a result, most e-VLBI data transfers are now mostly 'hands-off', including recovery from a variety of common problems. The software tools to enable automated data transfers is now also deployed to other sites, most particularly MPI, where they have a newly installed 1Gbps connection for e-VLBI transfer to the MPI correlator.

3. Digital Back Ends

Based on an NSF-funded astronomy VLBI project, and in collaboration with the Space Science Laboratory at UC Berkeley, Haystack Observatory has designed and tested an inexpensive Digital Backend (DBE) module which can be adapted to both geodetic and radio-astronomy VLBI applications.

DBEs have a number of distinct advantages, including absolute predictability and repeatability, sharp filter cutoffs, and low cost. The complete rack of 14 analog BBCs in a current geodetic VLBI system can be replaced with a DBE at a cost of less than $15,000, compared to at least $250,000 for the inferior and obsolete analog BBCs.

A pre-production FPGA-based DBE containing a single 'iBOB' DBE board is shown in Figure 1. The unit accepts two 500 MHz bandwidth IF signals, which are sampled at 1024 Msample/sec. The samplers are followed by a polyphase filter bank which divides each 500 MHz IF into fifteen 32 MHz bandwidth channels spanning the 500 MHz IF input (the 16th channel is not useful). With 2-bit sampling, the aggregate output data rate is 4096 Mbps to two VSI-H connectors. Using two

Figure 1. Pre-production DBE under test

Mark 5B+ recorders in parallel, the entire 4096 Mbps can be recorded.

The DBE chassis is designed to accommodate two 'iBOB' boards, which allows four 500 MHz IF inputs to be processed to four VSI-H output connectors for a total output data rate of 8192 Mbps, at a cost of less than $15,000.

In January 2007 a successful test experiment using DBEs was conducted using the Westford antenna and the GGAO antenna at NASA/GSFC. One DBE chassis (Figure 1) and two Mark 5B+ units were used at each site to record data at 4096 Mbps. Correlation was done on the Mark IV correlator at Haystack Observatory.

4. VLBI2010

A one-day technical brainstorming meeting (First VLBI2010 Working Meeting) was held at Haystack Observatory in September 2006 to hammer out the initial specifications for the proposed VLBI2010 geodetic-VLBI system. Among the major decisions made were:

- A 12m diameter antenna looks to be the most suitable compromise between sensitivity, slew speed and cost. The desired slew speed would allow the antenna to move between any two points in the sky within ~30 seconds.
- Reception of the entire ~2-15 GHz RF band looks both technically feasible and highly favorable to improved results, as well as being backwards compatible with current S/X equipment.
- A 'burst-mode' type observing strategy will make best use of the system. In the proposed scenario, an observation will capture data at 16-64 Gbps to high-speed RAM for ~5 seconds, then transfer the data to a slower-speed recording or data-transmission system while the antenna moves to the next source. This cycle would be repeated every ~30 seconds to gather several thousand observations per day at each antenna, far more than can be done

today.

Haystack Observatory is planning to outfit the Westford and GGAO antennas with broad-band feeds that cover ~2-15 GHz, along with DBEs that cover 2GHz of bandwidth, and conduct test observations in 2007 that will help to evaluate the new equipment and observing strategy. These tests will help to further guide the VLBI2010 development efforts.

Institute of Applied Astronomy Technology Development Center

Leonid Fedotov, Dmitry Ivanov, Alexander Ipatov, Irina Ipatova, Alexey Lavrov, Mikhail Kosobokov, Andrey Mikhailov

Abstract

The domain of IAA TDC includes the development of software and hardware for Russian VLBI network QUASAR. This report describes IAA activities in this direction. The main result of this year is the beginning of regular VLBI observations on the three station QUASAR network.

1. General

Technology Development Center is responsible for all parts of the Russian VLBI network and consists of separate laboratories developing hardware and software for this project. Now the 32 m radio telescopes in Svetloe and Zelenchukskaya are participating in international VLBI network observations and in domestic radioastronomical and VLBI observations.

The Badary station was equipped with improved VLBI registration terminal produced at IAA. The main result of this year is the beginning of regular VLBI observations on the three station QUASAR network. The first EOP series was obtained.

2. Technical/Scientific

2.1. VLBI Data Acquisition and Recorder Equipment

New VLBI Data Acquisition System was installed at Badary observatory. The system consists of two-channel IF Distributor, new DAS R1000 with 13 VC's (currently available) and 16-channel Samplers Unit (Figure 1). This equipment was developed at IAA RAS. S2-RT terminal was used as a recorder. This VLBI equipment configuration is used in regular QUASAR network observations.

We plan to add soon the 14th VC to the DAS and to install a Mark 5B recorder with Converter from S2 interface to VSI-H which is under construction at IAA.

2.2. The Cable Length Calibration System

The Cable Length Calibration System used in VLBI observations is a standard part of Mark III/IV terminal. It consists of two separate parts: Ground Unit and Antenna Unit combined with Phase Calibration Generator. The Antenna Unit built at IAA was already installed at "Svetloe" observatory and is currently used together with standard Mark IV Ground Unit. We are developing the new Ground Unit to equip the other two antennas of the QUASAR network. The new device is compatible with the Mark IV and based on the same principle of modulation of 5 MHz reference frequency with 5 kHz signal. The prototype of this device (Figure 2) was installed at the end of the year at "Zelenchukskaya" observatory.

2.3. New Receivers Digital Control System "G3"

The new Receivers Digital Control System was developed and installed at all observatories of the QUASAR VLBI network. This is the third generation of receivers control systems at IAA and

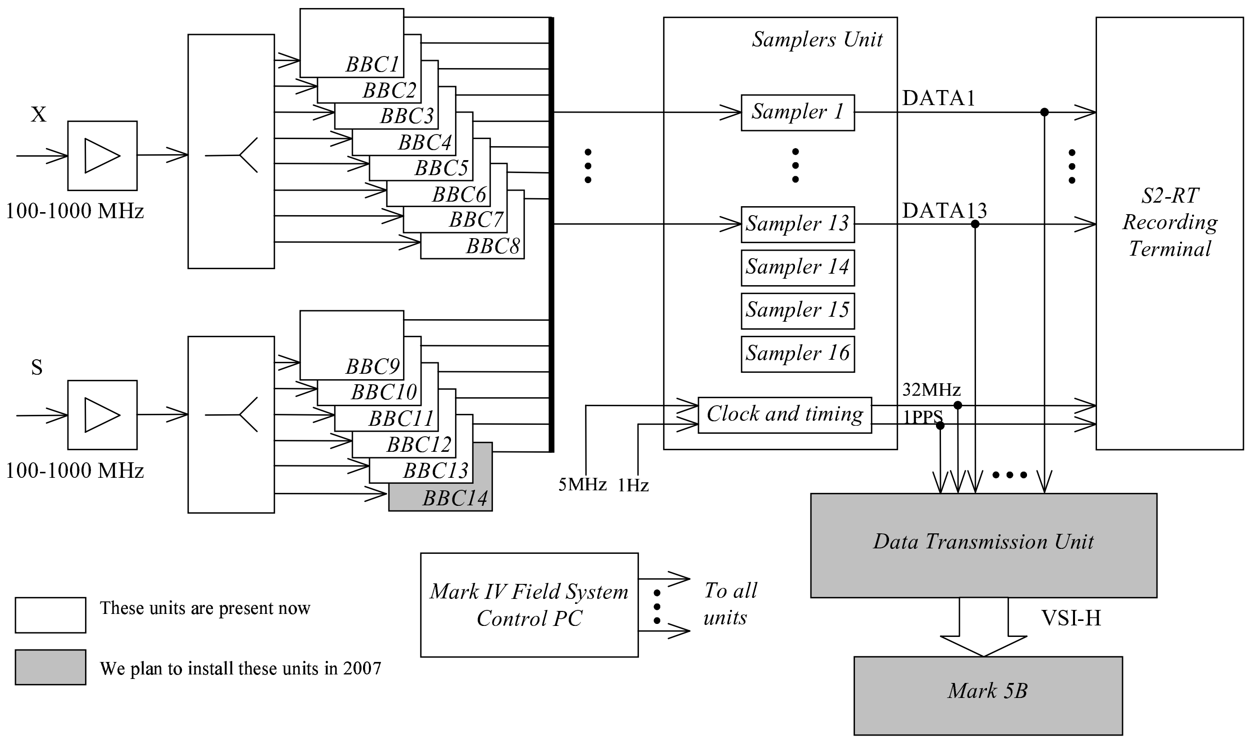

Figure 1. VLBI Data Acquisition Equipment Configuration at Badary observatory

therefore it was named "G3".

The G3 is a distributed control system based on a common data bus. Figure 3 shows location of system parts on the radio telescope. The G3 system consists of: RS232 to RS485 Transceiver, Power Control Unit (PCU), up to 16 Receiver Control Units (RCU), Distributor and up to 8 Cryogenic System Control Units (CSCU). Each control unit contains Atmel Atmega8535 Single-chip Microprocessor with integrated serial port, digital I/O ports and 10-bit analog-digital converter.

The Power Control Unit distributes the common data bus to the Receiver Control Units and to other devices in secondary focus cabin of radio telescope. It also controls the power-on commands of the Receiver Control Units.

The Transceiver, PCU and Distributor provide optical isolation up to 1000 V from long cables.

The G3 system uses its own protocol for data communication. It allows to connect up to 127

Figure 2. Prototype of the Cable Length Calibration System Ground Unit (without phase comparator)

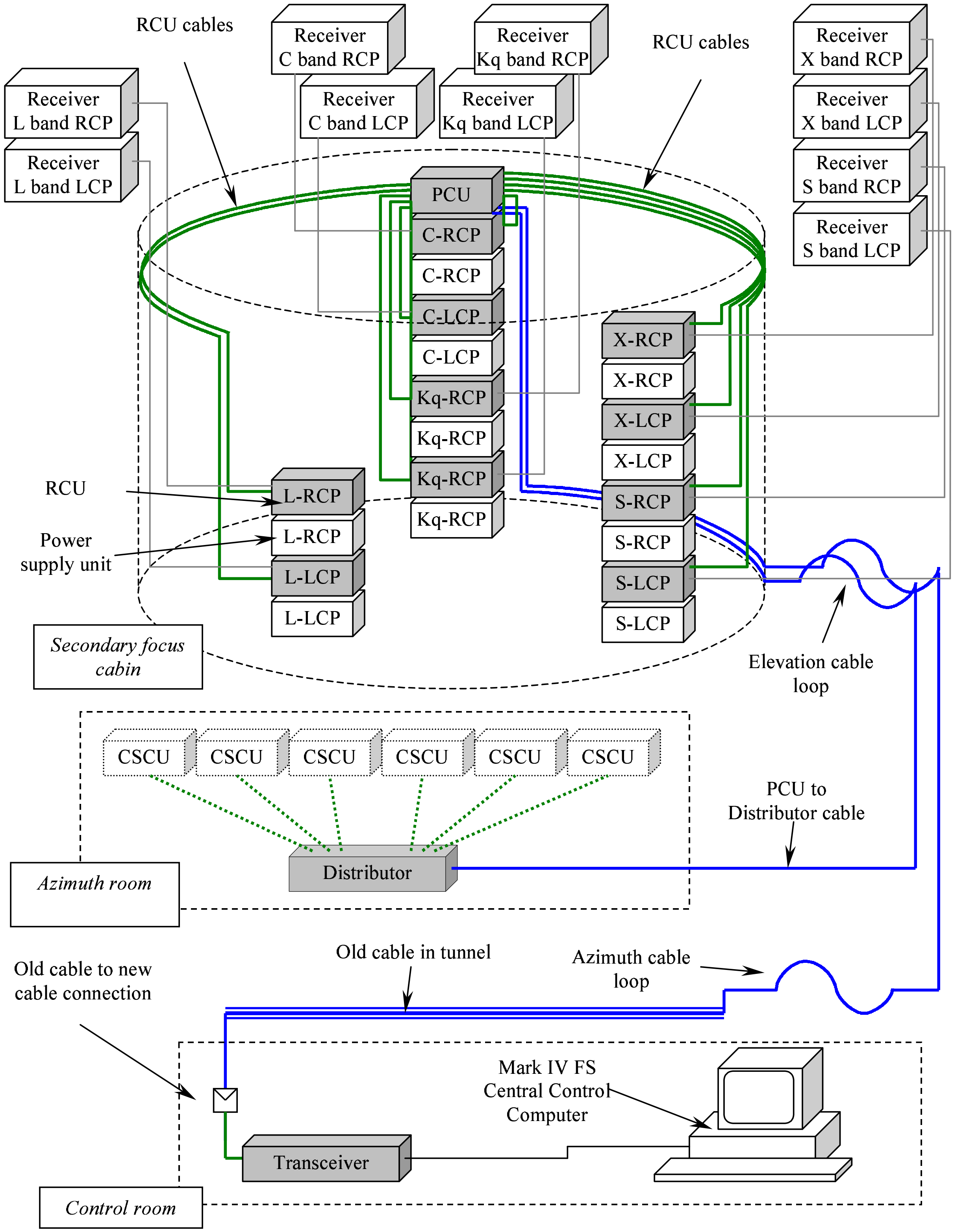

Figure 3. New Receivers Digital Control System "G3"

devices to one serial interface. The protocol is optimized for low transfer rate devices with relative simple control logic. The G3 control software is integrated into the station software on Mark IV Field System Central Control Computer.

We plan to use common bus and protocol designed for G3 as standard facility for development of control interfaces for different devices on radio telescope. Some examples of ongoing projects to be mentioned here are LO and Phase Calibration Control Unit and R1000 DAS.

2.4. New Receiver for 7 mm Band

New receiver and feed for the 7 mm band were installed on antenna at "Svetloe" observatory at the end of year. Switching to this frequency band in geodetic VLBI is now a topic for discussion within international VLBI community. The new receiver should be used for the evaluation of antenna performance on this band. We plan to use it for Solar observations as well.

Input frequency range of the receiver is 42.1–42.6 GHz, synchronized LO frequency is 42 GHz. The front-end amplifier is not cooled. Achieved system noise temperature is about 540 K.

3. Technical Staff

For all, the IAA address (8, Zhdanovskaya st., St. Petersburg, 197110, Institute of Applied Astronomy (IAA) RAS, Russia, Director Andrey Finkelstein, FAX +7-812-230-7413) is valid.

Table 1. Technical Staff

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Technology Development Center at NICT

Tetsuro Kondo, Yasuhiro Koyama, Ryuichi Ichikawa, Mamoru Sekido

Abstract

National Institute of Information and Communications Technology (NICT) has led the development of VLBI technique and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1. TDC at NICT

National Institute of Information and Communications Technology (NICT) has published the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" at least once a year in order to inform about developments of VLBI related technology as an IVS technology development center. The newsletter is available through the Internet at the URL:

http://www2.nict.go.jp/w/w114/stsi/ivstdc/news-index.html (changed in April 2006).

2. Staff Members of NICT TDC

Table 1 lists the staff members at NICT who are involved in the VLBI technology development center at NICT.

Table 1. Staff Members of NICT TDC as of December, 2006 (alphabetical).

Name	Works
HOBIGER, Thomas	VLBI analysis, Small antenna system
ICHIKAWA, Ryuichi	VLBI for spacecraft navigation, Small antenna system
ISHII, Atsutoshi	Small antenna system
KAWAI, Eiji	34m and 11m antenna system
KIMURA, Moritaka	e-VLBI, Giga-bit system, K5/VSI, Software correlator
KONDO, Tetsuro	e-VLBI, K5/VSSP32, Software correlator
KOYAMA, Yasuhiro	e-VLBI, VLBI analysis
KUBOKI, Hiromitsu	Antenna system, CARAVAN* system
SEKIDO, Mamoru	e-VLBI, VLBI for spacecraft navigation
TAKEUCHI, Hiroshi	e-VLBI, VLBI@home, ADS3000 (moved to JAXA on 3/1/2006)
TAKIGUCHI, Hiroshi	VLBI analysis
TSUTSUMI, Masanori	e-VLBI

* CARAVAN: Compact Antenna of Radio Astronomy for VLBI Adapted Network system

3. Current Status and Activities

3.1. K5 Samplers

NICT has developed two types of samplers: 1) ADS series sampler equipped with a VSI-H interface; 2) VSSP series sampler not equipped with a VSI-H but directly connectable to a host

PC. Samplers developed by NICT are summarized in Table 2.

Table 2. Specifications of the K5 samplers.

	ADS1000	ADS2000	ADS3000	K5/VSSP	K5/VSSP32
Ref. Sig.	10 MHz 1 PPS	10 MHz 1 PPS	10 MHz 1 PPS	10 MHz 1 PPS	10/5 MHz 1 PPS
# of Input Ch.	1	16	1	4	4
A/D bits	1, 2	2	8	1, 2, 4, 8	1, 2, 4, 8
Sampling Freq. (MHz)	512, 1024	2, 4, 8, 16, 32, 64	2048	0.04, 0.1, 0.2, 0.5, 1, 2, 4, 8, 16	0.04, 0.1, 0.2, 0.5, 1, 2, 4, 8, 16, 32, 64
Output Interface	VSI-H	VSI-H	VSI-H ×2	PCI-bus	USB2.0
Function	—	PCAL detection	DBBC etc.	—	digital LPF

Figure 1. ADS3000 (left) and K5/VSSP32 (right).

Figure 1 shows ADS3000 and K5/VSSP32. ADS3000 is a successor to the ADS1000. It is equipped with two VSI-H ports and is greatly improved in performance [1][2]. By use of a high-performance FPGA it is possible to output in a variety of modes with a data rate of up to 4 Gbps (Table 3). Furthermore, FPGA code is rewritable so that it can be used for multiple applications such as digital baseband converter (DBBC) for multi-channel geodetic VLBI, software demodulator for spacecraft downlink signal in spacecraft VLBI or satellite communications, or spectrometer for broadband astronomical observations.

K5/VSSP32 is a successor to the K5/VSSP. Maximum sampling frequency per channel is increased up to 64 MHz [3][4]. As a K5/VSSP32 unit has 4 channel analog inputs, 4 units can cover 16 channels which is a sufficient number of channels for geodetic VLBI. Maximum data rate is 1024 Mbps with 4 PCs. Although we have succeeded in some fringe tests using K5/VSSP32, we are improving both hardware and software to increase its reliability and performance.

3.2. K5/VSI

A VSI data capture board (VSI2000-DIM) developed by NICT can now capture data continuously with a data rate of up to 2 Gbps. Using a board with a PC equipped with a RAID disk system, we can record data with a recording rate of up to 2 Gbps. Tables 4 and 5 summarize the

Table 3. Selectable output modes of ADS3000.

Total rate	Sampling rate	# of AD bits	VSI-H clock rate	Output port
1 Gbps	128 MSps	8	32 MHz	VSI-H port1
2 Gbps	1024 MSps	2	32 MHz	VSI-H port1 + VSI-H port2
2 Gbps	512 MSps	4	32 MHz	VSI-H port1 + VSI-H port2
2 Gbps	256 MSps	8	32 MHz	VSI-H port1 + VSI-H port2
2 Gbps	256 MSps	8	64 MHz	VSI-H port1
4 Gbps	2048 MSps	2	64 MHz	VSI-H port1 + VSI-H port2
4 Gbps	1024 MSps	4	64 MHz	VSI-H port1 + VSI-H port2
4 Gbps	512 MSps	8	64 MHz	VSI-H port1 + VSI-H port2

characteristics of the K5/VSI board and recording system.

Table 4. K5/VSI data capture board

Continuous Capture Rate (Mbps)	2048 1024 512 256
Input Interface	VSI-H
PCI Interface	PCI-X (64bit/66MHz)

Table 5. K5/VSI data recording system (VSI2000-DIM + RAID).

Disk Storage Interface	Dual Fiber Channel
Max Recording Rate	2048 Mbps
HDD size	3TB
Continuous Recording Time (hours)	3 @2048 Mbps 6 @1024 Mbps 12 @512 Mbps 24 @256 Mbps

3.3. E-VLBI

We have performed e-VLBI demonstration in the international conference of "Super Computing 2006" held at Tampa, Florida, USA. Pseudo data were transferred between USA and Japan at the demonstration, and a data transfer rate of 512 Mbps was achieved (see "VLBI Correlators in Kashima" in this volume for details).

3.4. Small Antenna System

We have been developing a 2.4 m antenna VLBI system (Figure 3) named CARAVAN2400 equipped with an X band receiver [5][6]. First geodetic VLBI observations using the CARAVAN2400 were made together with Tsukuba 32 m antenna (baseline length is about 54 km) on Sept. 21-22, 2006. Eight video channel signals with 8 MHz bandwidth each on X band were sampled using K5/VSSP samplers at both stations. The position of CARAVAN2400 was successfully estimated with a standard deviation of better than 1 cm.

4. Future Plans

We will start the development of a 1-m class antenna system for geodetic VLBI observation in collaboration with GSI. This system will be dedicated to the precise measurement of a reference baseline maintained by GSI for the calibration of surveying equipment. A combination of a diplexer and a wide band feed that covers 2-18 GHz will be adopted in the 1-m class system. In order to investigate the performance of a wide band feed, it will be installed in CARAVAN2400 system first. It will contribute to examine the feasibility of VLBI2010's recommendations for next generation system.

Figure 3. 2.4 m antenna (front) and 34 m antenna (back) at Kashima during a fringe test.

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The IVS Technology Development Center at the Onsala Space Observatory

Rüdiger Haas, Magne Hagström, Tobias Nilsson, Gunnar Elgered

Abstract

During 2006 the technical development at the Onsala Space Observatory concentrated on a satellite tracking module for the VLBI field system, a new S/X-receiver for the 20 m telescope, and maintenance of the two microwave radiometers at the observatory.

1. Development of a Satellite Tracking Module for the VLBI Field System

As part of a master's thesis project a satellite tracking module for the VLBI field system (FS) was developed during 2006. The idea is to use satellites that transmit in X-band as radio sources for pointing measurements with radio telescopes. For that purpose, it should be made possible to track satellites directly with the FS and run the command 'fivepoint' during a satellite pass. The need to do such pointing measurements on X-band satellites came from the radio telescope TIGO in Chile that suffers from the low number of strong X-band radio sources in the southern hemisphere that are visible for such a small telescope (6 m diameter). A master's thesis student from Chalmers University of Technology worked on the topic and developed the module SATTRACK for the FS. Initial tests of the module were done in the summer of 2006 with the 20 m telescope at Onsala. We tracked the two earth observation satellites TERRA [1] and AQUA [2] that both use X-band to broadcast observational data to ground stations. TERRA transmits at 8212.5 MHz, while AQUA transmits at 8160.0 MHz. Both satellites are low earth orbiting satellites in polar orbit with about 700 km orbital height and orbital periods of approximately 100 minutes. Figure 1 shows an example of a spectrum observed while tracking the satellite TERRA with the Onsala 20 m telescope. The TERRA X-band signal was down-converted with the usual local oscillator frequency of 8080 MHz and is clearly visible at 132.5 MHz

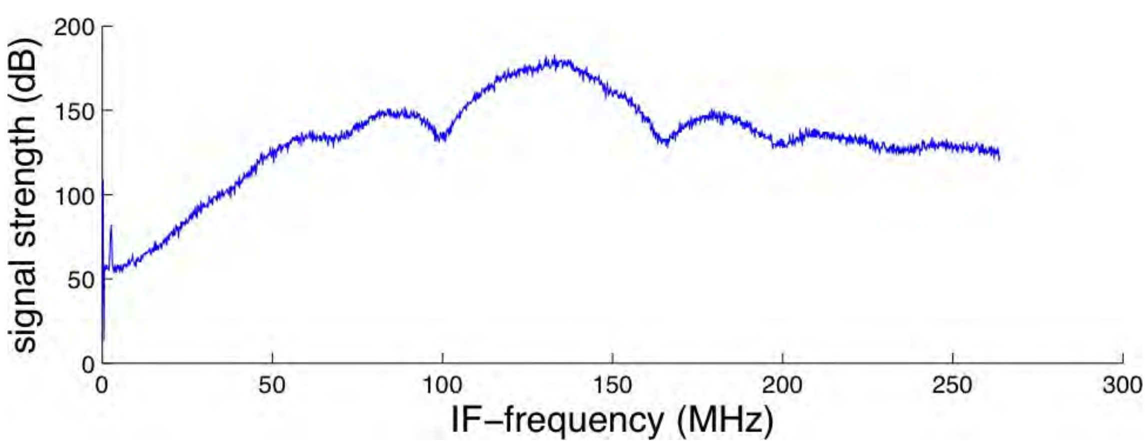

Figure 1. Spectrum of the TERRA satellite tracked and observed with the 20 m telesopce at Onsala.

2. A New S/X-band Receiver for the 20 m Telescope

During 2006 work has started to build a new S/X-receiver for the 20 m telescope, see Figure 2. This new receiver has two polarizations for X-band and one polarization for S-band. The HEMT amplifiers for X-band have noise temperatures on the order of 7–8 K. A new cooling system will be used, and the previously used LO-multipliers will be re-used. The new receiving system is expected to achieve system noise temperatures that are on the order of 15 to 20% better than those of the current system.

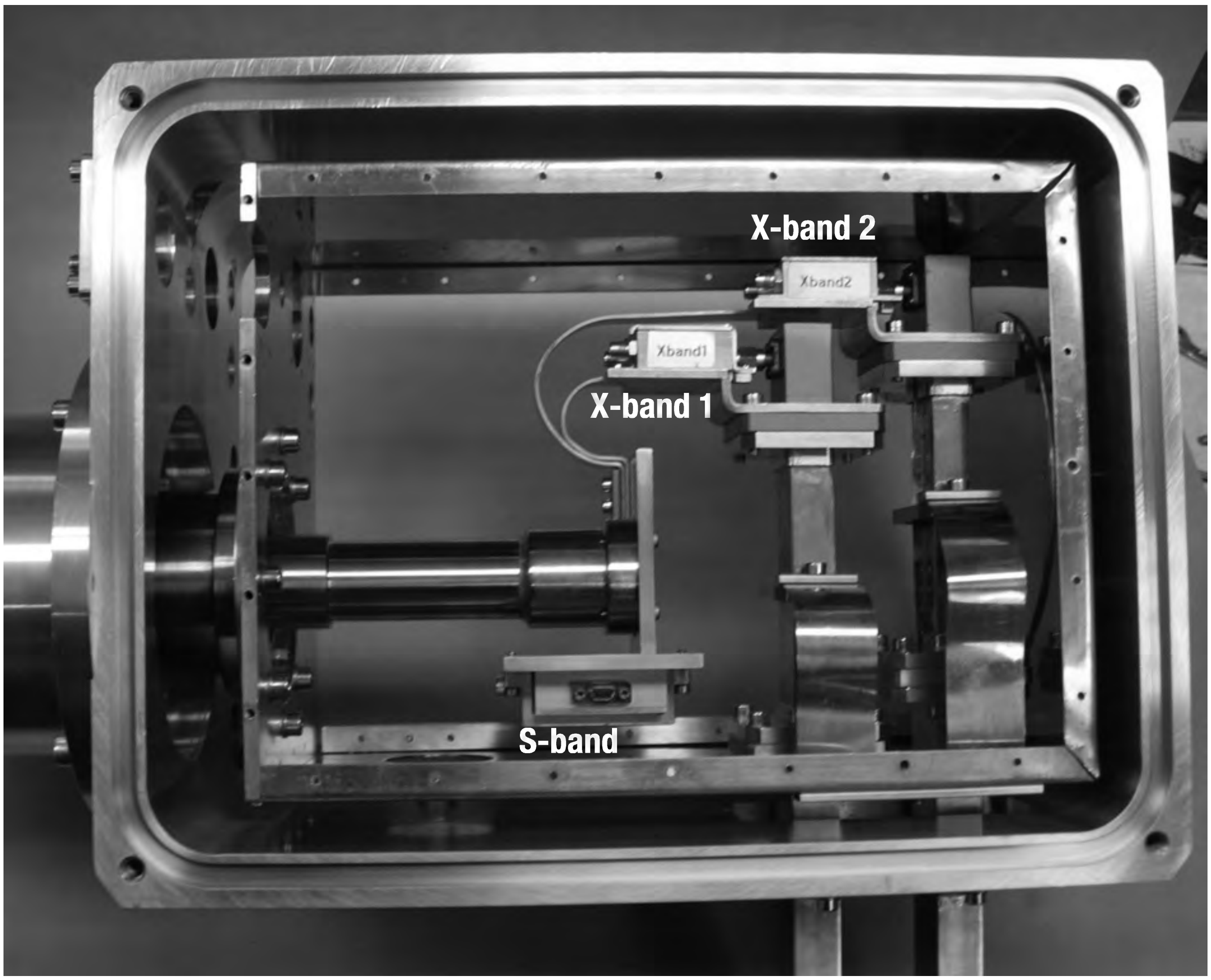

Figure 2. The new S/X-receiver for the 20 m telescope: The two HEMT-amplifiers for the two X-band polarizations are labelled as 'X-band 1' and 'X-band 2', the S-band amplifier with 'S-band'. The cooling system is attached on the left side as seen in this picture, while the two waveguides for X-band and the coaxial waveguide for S-band enter the box from the bottom as seen in this picture.

3. The Microwave Radiometers at Onsala

During 2006 the two radiometers at the observatory, Astrid [3] and Konrad [4], were subjected to maintenance work for the second half of the year. Astrid had problems with unstable power supplies and a failure of the hot load in the 31.4 GHz channel, while Konrad had problems with the azimuth and elevation drives.

4. Outlook and Future Plans

We will install and test the new S/X-receiver system for the 20 m telescope in the spring of 2007. We will continue the maintenance work of the two radiometers and expect to have them in place and running again in the spring of 2007.

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IVS Information

IVS Terms of Reference

1. Summary

1.1. Charter

The International VLBI Service for Geodesy and Astrometry (IVS) is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

IVS is an official Service of the International Association of Geodesy (IAG).

1.2. Objectives

IVS fulfills its charter through the following objectives. The primary objective of IVS is to foster VLBI programs as a joint service. This is accomplished through close coordination to provide high-quality VLBI data and products.

The second objective of IVS is to promote research and development activities in all aspects of the geodetic and astrometric VLBI technique. This objective also supports the integration of new components into IVS. The further education and training of VLBI participants is supported through workshops, reports, electronic network connections, and other means.

The third objective of IVS is to interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system. IVS interacts closely with the International Earth Rotation Service (IERS) which is tasked by the IAU and IUGG with maintaining the international celestial and terrestrial reference frames and with monitoring Earth rotation.

To meet these objectives, IVS coordinates VLBI observing programs, sets performance standards for VLBI stations, establishes conventions for VLBI data formats and data products, issues recommendations for VLBI data analysis software, sets standards for VLBI analysis documentation, and institutes appropriate VLBI product delivery methods to ensure suitable product quality and timeliness. IVS closely coordinates its activities with the astronomical community because of the dual use of many VLBI facilities and technologies for both astronomy and astrometry/geodesy.

IVS accepts observing proposals for research and operational programs that conform to the IVS objectives.

1.3. Data Products

VLBI data products contribute uniquely to these important determinations:

- definition and maintenance of the celestial reference frame
- monitoring universal time (UT1) and length of day (LOD)
- monitoring the coordinates of the celestial pole (nutation and precession)

These results are the foundation of many scientific and practical applications requiring the use of an accurate inertial reference frame, such as high-precision navigation and positioning. IVS provides, through the collaborative efforts of its components, a variety of significant VLBI data products with differing applications, timeliness, detail, and temporal resolution, such as:

- all components of Earth orientation parameters at regular intervals
- terrestrial reference frame
- VLBI data in appropriate formats
- VLBI results in appropriate formats
- local site ties to reference points
- high-accuracy station timing data
- surface meteorology, tropospheric and ionospheric measurements

All VLBI data products are archived in IVS Data Centers and are publicly available.

1.4. Research

The VLBI data products are used for research in many related areas of geodesy, geophysics, and astrometry, such as:

- UT1 and polar motion excitation (over periods of hours to decades)
- solid Earth interior research (mantle rheology, anelasticity, libration, core modes, nutation/precession)
- characterization of celestial reference frame sources and improvements to the frame
- tidal variations (solid Earth, oceanic, and atmospheric)
- improvements in the terrestrial reference frame, especially in the vertical (scale) component
- climate studies

To support these activities, there are ongoing research efforts whose purpose is to improve and extend the VLBI technique in such areas as:

- improvements in data acquisition and correlation
- refined data analysis techniques
- spacecraft tracking (Earth-orbiting and interplanetary)
- combination of VLBI data and results with other techniques

2. Permanent Components

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic, astrometric, and other results, and archives and publicizes data products. IVS accomplishes its goals through the types of permanent components described in this section. IVS will accept proposals at any time for a permanent component. Such proposals will be reviewed by the Directing Board. The seven types of IVS permanent components are:

- Network Stations
- Operation Centers
- Correlators

- Analysis Centers
- Data Centers
- Technology Development Centers
- Coordinating Center

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic and astrometric results, and archives and publicizes data products. IVS accomplishes its goals through the operational components described below.

2.1. Network Stations

The IVS observing network consists of high performance VLBI stations.

- Stations can be dedicated to geodesy or have multiple uses (including astronomical observations or satellite tracking applications).
- Stations comply with performance standards for data quality and operational reliability set up by the Directing Board.
- VLBI data acquisition sessions are conducted by groups of Network Stations that are distributed either globally or over a geographical region.

2.2. Operation Centers

The IVS Operation Centers coordinate the routine operations of one or more networks. Operation Center activities include:

- planning network observing programs,
- establishing operating plans and procedures for the stations in the network,
- supporting the network stations in improving their performance,
- making correlator time available at an IVS Correlator,
- generating the detailed observing schedules for use in data acquisition sessions by IVS Network Stations,
- posting the observing schedule to an IVS Data Center for distribution and to the Coordinating Center for archiving.

IVS Operation Centers follow guidelines from the Coordinating Center for timeliness and schedule file formats. Operation Centers cooperate with the Coordinating Center in order to define:

- the annual master observing schedule,
- the use of antenna time,
- tape availability and shipping,
- the use of other community resources.

2.3. Correlators

The IVS Correlators process raw VLBI data and station log files following a data acquisition session. Their other tasks are to:

- provide immediate feedback to the Network Stations about problems that are apparent in the data,
- jointly maintain the geodetic/astrometric community's tape pool,
- make processed data available to the Analysis Centers,
- regularly compare processing techniques, models, and outputs to ensure that data from different Correlators are identical.

2.4. Analysis Centers

The IVS coordinates VLBI data analysis to provide high-quality products for its users. The analyses are performed by Analysis Centers and by Associate Analysis Centers.

Analysis Centers are committed to produce series of Earth Orientation Parameters (EOP) or series of individual EOP components, without interruption and at a specified time lag to meet IVS requirements. In addition, Analysis Centers produce station coordinates and source positions in regular intervals.

The Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Analysis Center makes from IVS recommendations are properly documented. Analysis Centers provide timely feedback about station performance. In addition to these regular services, Analysis Centers may also perform any task of an Associate Analysis Center.

Associate Analysis Centers are committed to regularly submit specialized products using complete series or subsets of VLBI observing sessions. The analysis is performed for specific purposes as recognized by the Directing Board such as exploitation of VLBI data for new types of results, investigations of regional phenomena, reference frame maintenance, or special determinations of Earth orientation parameters. The Associate Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Associate Analysis Center makes from IVS recommendations are properly documented.

2.5. Data Centers

The IVS Data Centers are repositories for VLBI observing schedules, station log files, and data products. Data Centers may mirror other Data Centers to make the distribution and maintenance of data more efficient and reliable.

- Data Centers are the primary means of distributing VLBI products to users.
- Data Centers work closely with the Coordinating Center and with the Analysis Centers to ensure that all the information and data required by IVS components are quickly and reliably available.

Data Centers provide the following functions:

- receive and archive schedule files from Operation Centers,
- receive and archive log files and ancillary data files from the Network Stations,
- receive and archive data products from the Analysis Centers,
- provide access and public availability to IVS data products for all users.

2.6. Technology Development Centers

The IVS Technology Development Centers contribute to the development of new VLBI technology. They may be engaged in hardware and/or software technology development, or evolve new approaches that will improve the VLBI technique and enhance compatibility with different data acquisition terminals. They will:

- design new hardware,
- investigate new equipment,
- develop new software for operations, processing or analysis,
- generate new information systems,
- develop, test, and document prototypes of new equipment or software,
- assist with deployment, installation, and training for any new approved technology.
- After dissemination of the new hardware or software, the centers may continue to provide maintenance and updating functions.

2.7. Coordinating Center

The IVS Coordinating Center is responsible for coordination of both the day-to-day and the long-term activities of IVS, consistent with the directives and policies established by the Directing Board. Specifically, the Coordinating Center monitors, coordinates, and supports the activities of the Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers. The Coordinating Center works closely with the Technology Coordinator, the Network Coordinator, and the Analysis Coordinator to coordinate all IVS activities.

The primary functions of the Coordinating Center are to:

- coordinate observing programs approved by the Directing Board,
- maintain the master schedule of observing sessions, coordinating the schedule with astronomical observing programs and with IVS networks,
- foster communications among all components of the IVS,
- define the best use of community resources,
- develop standards for IVS components,
- provide training in VLBI techniques,
- organize workshops and meetings, including an annual IVS technical meeting,
- produce and publish reports of activities of IVS components,

- maintain the IVS information system and archive all documents, standards, specifications, manuals, reports, and publications,
- provide liaison with the IERS, IAG, IAU, FAGS, and other organizations,
- provide the Secretariat of the Directing Board.

3. Coordinators

Specific IVS activities for technology, network data quality, and data products are accomplished through the functions performed by three coordinators: a Network Coordinator, an Analysis Coordinator, and a Technology Coordinator.

3.1. Network Coordinator

The IVS Network Coordinator is selected by the Directing Board from responses to an open solicitation to all IVS components. The Network Coordinator represents the IVS Networks on the Directing Board and works closely with the Coordinating Center. The Network Coordinator is responsible for stimulating the maintenance of a high quality level in the station operation and data delivery. The Network Coordinator performs the following functions:

- monitors adherence to standards in the network operation,
- participates in the quality control of the data acquisition performance of the network stations,
- tracks data quality and data flow problems and suggests actions to improve the level of performance,

The Network Coordinator works closely with the geodetic and astronomical communities who are using the same network stations for observations. The Coordinator takes a leading role in ensuring the visibility and representation of the Networks.

3.2. Analysis Coordinator

The IVS Analysis Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Analysis Centers. The Analysis Coordinator is responsible for coordinating the analysis activities of IVS and for stimulating VLBI product development and delivery. The Analysis Coordinator performs the following functions:

- fosters comparisons of results from different VLBI analysis software packages and different analysis strategies,
- encourages analysis software documentation,
- participates in comparisons of results from different space geodetic techniques,
- monitors Analysis Centers' products for high quality results and for adherence to IVS standards and IERS Conventions,
- ensures that analysis products from all Analysis Centers are archived and available for the scientific community, and
- forms the official products of IVS, as decided by the IVS Directing Board, using a suitable combination of the analysis results submitted by the Analysis Centers.

The Analysis Coordinator works closely with the geodetic and astronomical communities who are using some of the same analysis methods and software. The Analysis Coordinator plays a leadership role in the development of methods for distribution of VLBI products so that the products reach the widest possible base of users in a timely manner. The coordinator promotes the use of VLBI products to the broader scientific community and interacts with the IVS Coordinating Center and with the IERS.

3.3. Technology Coordinator

The IVS Technology Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Technology Development Centers. The Technology Coordinator is responsible for coordinating the new technology activities of IVS and for stimulating advancement of the VLBI technique. The Technology Coordinator performs the following functions:

- maintains cognizance of all current VLBI technologies and ongoing development
- coordinates development of new technology among various IVS components
- helps promulgate new technologies to the geodetic/astrometric community
- strives to ensure the highest degree of global compatibility of VLBI data acquisition systems

The Technology Coordinator works closely with the astronomical community because of the many parallels between the technology development required for both groups.

4. Directing Board

4.1. Roles and Responsibilities

The Directing Board determines policies, adopts standards, and approves the scientific and operational goals for IVS. The Directing Board exercises general oversight of the activities of IVS including modifications to the organization that are deemed appropriate and necessary to maintain efficiency and reliability.

A specific function of the Board is to set scientific goals for the IVS observing program. The Board will establish procedures for external research programs and will review any proposals thus received.

The Board may determine appropriate actions to ensure the quality of the IVS products and that the IVS components maintain the adopted standards.

4.2. Membership

The Directing Board consists of appointed members who serve ex officio, members elected by the Directing Board, and members elected by the IVS components. The members are:

Appointed members ex officio:

- IAG representative
- IAU representative
- IERS representative
- FAGS representative

- Coordinating Center Director

Through a reciprocity agreement between IVS and IERS the IVS serves as the VLBI Technique Center for IERS, and as such its designated representative(s) serve on the IERS Directing Board. In turn, the IERS Directing Board designates a representative to the IVS Directing Board. This arrangement is to assure full cooperation between the two services.

Selected by Directing Board upon review of proposals from IVS Member Organizations:

- Technology, Network, and Analysis Coordinators (3 total)

Elected by Directing Board upon recommendation from the Coordinating Center (see below):

- Members at large (3)

Elected by IVS Components (see below):

- Correlators and Operation Centers representative (1)
- Analysis and Data Centers representative (1)
- Networks representatives (2)
- Technology Development Centers representative (1)

Total number: 16

The five appointed members are considered ex officio and are not subject to institutional restrictions. The FAGS representative is a non-voting member in accordance with FAGS requirements.

The five members of the Directing Board who are elected by IVS Permanent Components must each be a member of a different IVS Member Organization. All elected members serve staggered four-year terms once renewable.

At large members are intended to ensure representation on the Directing Board of each of the components of IVS and to balance representation from as many countries and institutions and IVS interests as possible. At large members serve 2-year terms once renewable.

A Board member who departs before the end of his/her term is replaced by a person selected by the Directing Board. The new member will serve for the remainder of the original term.

The three Coordinators are selected by the Directing Board on the basis of proposals from IVS Member Organizations. On a two-thirds vote the Directing Board may call for new proposals for any Coordinator when it determines that a new Coordinator is required. Coordinators are encouraged to give at least three months notice before resigning.

4.3. Elections

Election of Board members by the IVS components shall be conducted by a committee of three Directing Board members, the chair of which is appointed by the chair of the Directing Board. The committee solicits nominations for each representative from the relevant IVS components. For each position, the candidate who receives the largest number of votes from the Associate Members will be elected. In case of a tie the Directing Board will make the decision.

4.4. Chair

The chair is one of the Directing Board members and is elected by the Board for a term of four years with the possibility of reelection for one additional term. The chair is the official representative of IVS to external organizations.

4.5. Decisions

Most decisions by the Board are made by consensus or by simple majority vote of the members present. In case of a tie, the chair shall vote but otherwise does not vote. If a two-thirds quorum is not present, the vote shall be held later by electronic mail. A two-thirds vote of all Board members is required to modify the Terms of Reference, to change the chair, or to change any of the members elected by the Directing Board before the normal term expires.

4.6. Meetings

The Board meets at least annually, or more frequently if meetings are called by the chair or at the request of at least three Board members. The Board will conduct periodic reviews of the IVS organization and its mandate, functions, and components. The reviews should be done every four years.

5. Definitions

5.1. Member Organizations

Organizations that support one or more IVS components are IVS Member Organizations. Individuals associated with IVS Member Organizations may become IVS Associate Members.

5.2. Affiliated Organizations

Organizations that cooperate with IVS on issues of common interest, but do not support an IVS component, are IVS Affiliated Organizations. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Individuals affiliated with IVS Affiliated Organizations may become IVS Correspondents.

5.3. Associate Members

Individuals associated with organizations that support an IVS component may become IVS Associate Members. Associate Members are generally invited to attend non-executive sessions of the Directing Board meetings with voice but without vote. Associate Members take part in the election of the incoming members of the Directing Board representing the IVS components.

5.4. Corresponding Members

IVS Corresponding Members are individuals on a mailing list maintained by the Coordinating Center. They do not actively participate in IVS but express interest in receiving IVS publications, wish to participate in workshops or scientific meetings organized by IVS, or generally are interested in IVS activities. Ex officio corresponding members are the following:

- IAG General Secretary
- President of IAG Section II – Advanced Space Technology
- President of IAG Section V – Geodynamics
- President of IAU Division I – Fundamental Astronomy

- President of IAU Commission 19 – Rotation of the Earth
- President of IAU Commission 8 – Positional Astronomy
- President of IAU Commission 31 – Time
- President of IAU Commission 40 – Radio Astronomy
- President of URSI Commission J – Radio Astronomy

Individuals are accepted as IVS Corresponding Members upon request to the Coordinating Center.

Last modified: 12 September, 2005

IVS Member Organizations

(alphabetized by country)

Organization	Country
Geoscience Australia	Australia
University of Tasmania	Australia
Vienna University of Technology	Austria
Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Space Geodynamics Laboratory	Canada
Geodetic Survey Division, Natural Resources Canada	Canada
Dominion Radio Astrophysical Observatory	Canada
Canadian Space Agency	Canada
Universidad de Concepción	Chile
Universidad del Bío Bío	Chile
Instituto Geográfico Militar	Chile
Chinese Academy of Sciences	China
Observatoire de Paris	France
Observatoire de Bordeaux	France
Deutsches Geodätisches Forschungsinstitut	Germany
Bundesamt für Kartographie und Geodäsie	Germany
Forschungseinrichtung Satellitengeodäsie, TU-Munich	Germany
Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
Istituto di Radioastronomia INAF	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
National Institute of Information and Communications Technology	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Central (Pulkovo) Astronomical Observatory	Russia
Institute of Applied Astronomy	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Instituto Geográfico Nacional	Spain
Chalmers University of Technology	Sweden
Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
NASA Goddard Space Flight Center	USA
U. S. Naval Observatory	USA
Jet Propulsion Laboratory	USA

IVS Affiliated Organizations

Organization	Country
Australian National University	Australia
University of New Brunswick	Canada
Max-Planck-Institut für Radioastronomie	Germany
FÖMI Satellite Geodetic Observatory	Hungary
Korea Astronomy Observatory	Korea
Joint Institute for VLBI in Europe (JIVE)	Netherlands
Westerbork Observatory	Netherlands
Auckland University of Technology	New Zealand
National Radio Astronomy Observatory	USA

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IVS Permanent Components

(listed by types, within types alphabetical by component name)

Network Stations

Component Name	Sponsoring Organization	Country
Algonquin Radio Observatory	Geodetic Survey Division, Natural Resources Canada	Canada
Fortaleza, Radio Observatório Espacial do Nordeste (ROEN)	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Goddard Geophysical and Astronomical Observatory	NASA Goddard Space Flight Center	USA
Hartebeesthoek Radio Astronomy Observatory	Foundation for Research and Development	South Africa
Hobart, Mt. Pleasant Radio Observatory	University of Tasmania	Australia
Kashima 34m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Kashima 11m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Koganei 11m	National Institute of Information and Communications Technology (NICT)	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service (NEOS)	USA
Matera	Agenzia Spaziale Italiana (ASI)	Italy
Medicina	Istituto di Radioastronomia INAF	Italy
Mizusawa 10m	National Astronomical Observatory of Japan (NAOJ)	Japan
Noto (Sicily)	Istituto di Radioastronomia INAF	Italy
Ny-Ålesund Geodetic Observatory	Norwegian Mapping Authority	Norway
ERS/VLBI Station O'Higgins	Bundesamt für Kartographie und Geodäsie (BKG)	Germany
Onsala Space Observatory	Chalmers University of Technology	Sweden
Seshan	Joint Laboratory for Radio Astronomy (JLRA), CAS and Shanghai Observatory, CAS	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy RAS	Russia
JARE Syowa Station	National Institute of Polar Research	Japan

Transportable Integrated Geodetic Observatory (TIGO)	Universidad de Concepción (UdeC), Universidad del Bío Bío (UBB), Instituto Geográfico Militar (IGM), Bundesamt für Kartographie und Geodäsie (BKG)	Germany, Chile
Tsukuba VLBI Station	Geographical Survey Institute	Japan
Nanshan VLBI Station	Chinese Academy of Sciences	China
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (FESG)	Germany
Observatório Astronómico Nacional - Yebes	Instituto Geográfico Nacional	Spain
Yellowknife Geophysical Observatory	Geodetic Survey Division, Natural Resources Canada	Canada
Radioastronomical Observatory Zelenchukskaya	Institute of Applied Astronomy RAS	Russia

Operation Centers

Component Name	**Sponsoring Organization**	**Country**
Institut für Geodäsie und Geoinformation (IGGB)	Universität Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service (NEOS)	USA

Correlators

Component Name	**Sponsoring Organization**	**Country**
Astro/Geo Correlator at MPI	Bundesamt für Kartographie und Geodäsie and Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
MIT Haystack Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology (NICT)	National Institute of Information and Communications Technology (NICT)	Japan
Tsukuba VLBI Center	Geographical Survey Institute	Japan
Washington Correlator	National Earth Orientation Service (NEOS)	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana (ASI)	Italy
Italy INAF	Istituto di Radioastronomia INAF	Italy
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France

Analysis Centers

Component Name	Sponsoring Organization	Country
Astronomical Institute of St.-Petersburg University	Astronomical Institute of St.-Petersburg University	Russia
Geoscience Australia	Geoscience Australia	Australia
Observatoire de Bordeaux	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
IGGB-BKG Analysis Center	Institut für Geodäsie und Geoinformation der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy	Russia
Institute of Geodesy and Geophysics (IGG)	Institute of Geodesy and Geophysics (IGG) of the University of Technology, Vienna	Austria
Italy INAF	Istituto di Radioastronomia INAF	Italy
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Main Astronomical Observatory	Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
National Astronomical Observatory of Japan	National Astronomical Observatory of Japan	Japan

National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden
Pulkovo Observatory	Pulkovo Observatory	Russia
Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
U. S. Naval Observatory Analysis Center	U. S. Naval Observatory	USA
U. S. Naval Observatory Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	**Sponsoring Organization**	**Country**
Canadian VLBI Technology Development Center	CRESTech, NRCan, DRAO, CSA	Canada
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Onsala Space Observatory	Chalmers University of Technology	Sweden

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List of Acronyms

AAM	Atmosphere Angular Momentum
AAS	American Astronomical Society
ACF	AutoCorrelation Function
ACU	Antenna Control Unit
AD	Analog-to-Digital
AES	Advanced Engineering Services Co.,Ltd (Japan)
AGN	Active Galactic Nuclei
AIPS	Astronomical Image Processing System
ANU	Australian National University (Australia)
AOA	Allen Osborne Associates
AOC	Array Operation Center (Japan)
APSG	Asia-Pacific Space Geodynamics program
APT	Asia Pacific Telescope
ARIES	Astronomical Radio Interferometric Earth Surveying program
ARO	Algonquin Radio Observatory (Canada)
ASI	Agenzia Spaziale Italiana (Italian Space Agency) (Italy)
ATA	Allen Telescope Array
ATM	Asynchronous Transfer Mode
ATNF	Australia Telescope National Facility (Australia)
BBC	Base Band Converter
BIPM	Bureau Internacional de Poids et Mesures (France)
BKG	Bundesamt für Kartographie und Geodäsie (Germany)
BOSSNET	BOSton South NETwork
CACS	Canadian Active Control System
CARAVAN	Compact Antenna of Radio Astronomy for VLBI Adapted Network (Japan)
CAS	Chinese Academy of Sciences (P.R. China)
CAY	Centro Astronómico de Yebes (Spain)
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project
CfA	Harvard-Smithsonian Center for Astrophysics (USA)
CGS	Centro di Geodesia Spaziale (Italy)
CIB	Correlator Interface Board
CNES	Centre National d'Etudes Spatiales (France)
CNR	Consiglio Nazionale delle Ricerche (Italy)
CNRS	National Center for Scientific Research (France)
CNS	Communication, Navigation and Surveillance systems, Inc. (USA)
CODA	Correlator Output Data Analyzer
CORE	Continuous Observations of the Rotation of the Earth
CRAAE	Centro de Rádio Astronomia e Aplicações Espaciais (Brazil)
CRAAM	Centro de Rádio-Astronomia e Astrofísica Mackenzie (Brazil)
CRESTech	Centre for Research in Earth and Space Technology (Canada)
CRF	Celestial Reference Frame

CRL	Communications Research Laboratory (now NICT) (Japan)
CSA	Canadian Space Agency (Canada)
CSCU	Cryogenic System Control Unit
CSRS	Canadian Spatial Reference System
CTVA	Canadian Transportable VLBI Antenna
CUTE	CRL and University Telescopes Experiment (Japan)
CVN	Chinese VLBI Network
DAR	Data Acquisition Rack
DAS	Data Acquisition System
DAT	Digital Audio Tape
DBBC	Digital Base Band Converter
DBE	Digital BackEnd
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DISTART	Dipartimento di Ingegneria delle Strutture, dei Trasporti, delle Acque, del Rilevamento del Territorio (Italy)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DOMES	Directory Of MERIT Sites
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite
DRAGON	Dynamic Resource Allocation through GMPLS over Optical Networks
DRAO	Dominion Radio Astrophysical Observatory (Canada)
DVLBI	Differential VLBI
ECMWF	European Center for Medium Range Weather Forecasting
EGAE	Experiment Guided Adaptive Endpoint
ENVISAT	ENVIronmental SATellite
EOP	Earth Orientation Parameters
ERP	Earth Rotation Parameters
EUREF	EUropean REFerence Frame
eVLA	Expanded Very Large Array
e-VLBI	Electronic VLBI
EVN	European VLBI Network
FAGS	Federation of Astronomical and Geophysical data analysis Services
FCN	Free Core Nutation
FESG	Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FITS	Flexible Image Transport System
FS	Field System
FTP	File Transfer Protocol
FWF	Fonds zur Förderung der wissenschaftlichen Forschung (Austrian Science Fund)
GA	Geoscience Australia (Australia)
GAPE	Great Alaska and Pacific Experiment
GARNET	GSI Advanced Radiotelescope NETwork (Japan)
GARR	Gruppo per l'Armonizzazione delle Reti della Ricerca (Italy)
GARS	German Antarctic Receiving Station (Antarctica)

GEMD	Geohazard and Earth Monitoring Division (Australia)
GeoDAF	Geodetical Data Archive Facility (Italy)
GEX	Giga-bit series VLBI EXperiment
GFZ	GeoForschungsZentrum (Germany)
GGAO	Goddard Geophysical and Astronomical Observatory (USA)
GGP	Global Geodynamics Project
GISTM	GPS Ionospheric Scintillation and TEC Monitor
GIUB	Geodetic Institute of the University of Bonn (Germany)
GLONASS	GLObal NAvigation Satellite System
GMF	Global Mapping Function
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GREF	German GPS REFerence network
GRGS	Groupe de Recherches de Géodésie Spatiale (France)
GSD	Geodetic Survey Division of Natural Resources Canada (Canada)
GSFC	Goddard Space Flight Center (USA)
GSI	Geographical Survey Institute (Japan)
HF	High Frequency
HPBW	Half Power Beam Width
HTSI	Honeywell Technology Solutions Incorporated (USA)
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAU	International Astronomical Union
iBOB	Interface Break Out Board
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IDS	International DORIS Service
IERS	International Earth Rotation Service
IGFN	Italian Space Agency GPS Fiducial Network (Italy)
IGG	Institute of Geodesy and Geophysics (Austria)
IGGB	Institut für Geodäsie und Geoinformation (Germany)
IGM	Instituto Geográfico Militar (Chile)
IGN	Instituto Geográfico Nacional (Spain)
IGS	International GPS Service
ILRS	International Laser Ranging Service
INAF	Istituto Nazionale di Astrofisica (Italy)
INGV	National Institute of Geophysics and Volcanology (Italy)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IPWV	Integrated Precipitable Water Vapor
IRA	Istituto di RadioAstronomia (Italy)
IRIS	International Radio Interferometric Surveying
ISAS	Institute of Space and Astronautical Science (Japan)
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics

IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JARE	Japanese Antarctic Research Expedition (Japan)
JAXA	Japan Aerospace Exploration Agency (Japan)
JGN	Japan Gigabit Network (Japan)
JIVE	Joint Institute for VLBI in Europe
JLRA	Joint Laboratory for Radio Astronomy (China)
JMA	Japan Meteorological Agency (Japan)
JPL	Jet Propulsion Laboratory (USA)
JSPS	Japanese Society for the Promotion of Science (Japan)
KAT	Karoo Array Telescope (South Africa)
KPGO	Kokee Park Geophysical Observatory (USA)
KSP	KeyStone Project (Japan)
KSRC	Kashima Space Research Center (Japan)
KVN	Korean VLBI Network
LBA	Long Baseline Array
LEIF	Large Equipment and Infrastructure Funding
LLR	Lunar Laser Ranging
LNA	Low Noise Amplifier
LO	Local Oscillator
LOD	Length Of Day
LSB	Lower Side Band
MAO	Main Astronomical Observatory (Ukraine)
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MOBLAS	MOBile LASer
MODEST	MODel and ESTimate
MPI	Max-Planck-Institute (Germany)
MPIfR	Max-Planck-Institute for Radioastronomy (Germany)
MTLRS	Modular Transportable Laser Ranging System
NAOC	National Astronomical Observatories of China
NAOJ	National Astronomical Observatory of Japan (Japan)
NASA	National Aeronautics and Space Administration (USA)
NCRIS	National Collaborative Research Infrastructure Strategy (Australia)
NEA	Near-Earth Asteroid
NEOS	National Earth Orientation Service (USA)
NGS	National Geodetic Survey (USA)
NICT	National Institute of Information and Communications Technology (Japan)
NIPR	National Institute of Polar Research (Japan)
NMA	Norwegian Mapping Authority (Norway)
NMF	Niell Mapping Function
NNR	No-Net-Rotation
NNT	No-Net-Translation
NOAA	National Oceanic and Atmospheric Administration (USA)
NOFS	U.S. Naval Observatory Flagstaff Station (USA)

NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NSF	National Science Foundation (USA)
NTT	Nippon Telegraph and Telephone Corporation (Japan)
NVI	NVI, Inc. (USA)
OAN	Observatorio Astronómico Nacional (Spain)
OCA	Observatoire de la Côte d'Azur (France)
OPAR	Paris Observatory (France)
OPC	(IVS) Observing Program Committee
OSO	Onsala Space Observatory (Sweden)
PARNASSUS	Processing Application in Reference to NICT's Advanced Set of Softwares Usable for Synchronization
PCAL	Phase CALibration
PCU	Power Control Unit
POLARIS	POLar motion Analysis by Radio Interferometric Surveying
PRARE	Precision RAnge and Range-rate Experiment
PWV	Precipitable Water Vapour
QSO	Quasi-Stellar Object
RAS	Russian Academy of Sciences (Russia)
RCU	Receiver Control Unit
RDV	Research and Development sessions using the VLBA
RedCLARA	CLARA (Cooperación Latino Americana de Redes Avanzadas) network
REUNA	Red Universitaria Nacional (Chile)
RFI	Radio Frequency Interference
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
RRFID	Radio Reference Frame Image Database
RTP	Real-Time Protocol
SAGE	Small Advanced Geodetic e-VLBI System
SCR	Silicon Controlled Rectifier
SDK	Software Development Kit
SEFD	System Equivalent Flux Density
SGL	Space Geodynamics Laboratory (Canada)
SGT	Stinger Ghaffarian Technologies (USA)
SHAO	Shanghai Astronomical Observatory (China)
SI	Structure Index
SINEX	Solution INdependent EXchange format
SKA	Square Kilometer Array
SLR	Satellite Laser Ranging
SMART	Small Missions for Advanced Research and Technology
SNAP	Standard Notation for Astronomical Procedures
SPbU	Saint-Petersburg University (Russia)
SPU	Saint-Petersburg University (Russia)
SRTM	Shuttle Radar Topography Mission
STDN	Satellite Tracking Data Network (NASA)
STEREO	Solar TErrestrial RElations Observatory

SU	Station Unit
SWT	SW Technology (USA)
TAC	Totally Accurate Clock
TAO	Telecommunications Advanced Organization (Japan)
TDC	Technology Development Center
TEC	Total Electron Content
TerraSAR-X	Terra Synthetic Aperture Radar X-band (Germany)
TID	Traveling Ionospheric Disturbance
TIGO	Transportable Integrated Geodetic Observatory (Germany, Chile)
TLRS	Transportable Laser Ranging System
TRF	Terrestrial Reference Frame
TSPM	Test Synchronization Pulsar gating Module
TUM	Technical University of Munich
UBB	Universidad del Bío Bío (Chile)
URSI	International Union of Radio Science
USB	Upper Side Band
USNO	U. S. Naval Observatory (USA)
UT	Universal Time
UT1	Universal Time
UTAS	University of TASmania (Australia)
UTC	Coordinated Universal Time
VCS	VLBA Calibrator Survey
VEGA	Venus-Halley project (Russia)
VERA	VLBI Exploration of Radio Astrometry
VEX	VLBI EXchange format
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Functions
VSI-H	VLBI Standard Interface Hardware
VSOP	VLBI Space Observatory Program
VSSP	Versatile Scientific Sampling Processor
VTRF	VLBI Terrestrial Reference Frame
WACO	WAshington COrrelator (USA)
WG	Working Group
WVR	Water Vapor Radiometer
WWW	World Wide Web
XDM	eXperimental Development Model
ZTD	Zenith Total Delay
ZWD	Zenith Wet Delay

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14. ABSTRACT

This volume of reports is the 2006 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the components of IVS. The 2006 Annual Report documents the work of these IVS components over the period January 1, 2006 through December 31, 2006. The reports document changes, activities, and progress of the IVS. The entire contents of this Annual Report also appear on the IVS Web site at http://ivscc.gsfc.nasa.gov/publications/ar2006.

15. SUBJECT TERMS

Geodesy, astrometry, VLBI, geophysics, Earth orientation, very long baseline interferometry, interferometry, radio astronomy, geodynamics, reference frames, terrestrial reference frame, celestial reference frame, length of day, Earth system science, Earth rotation.

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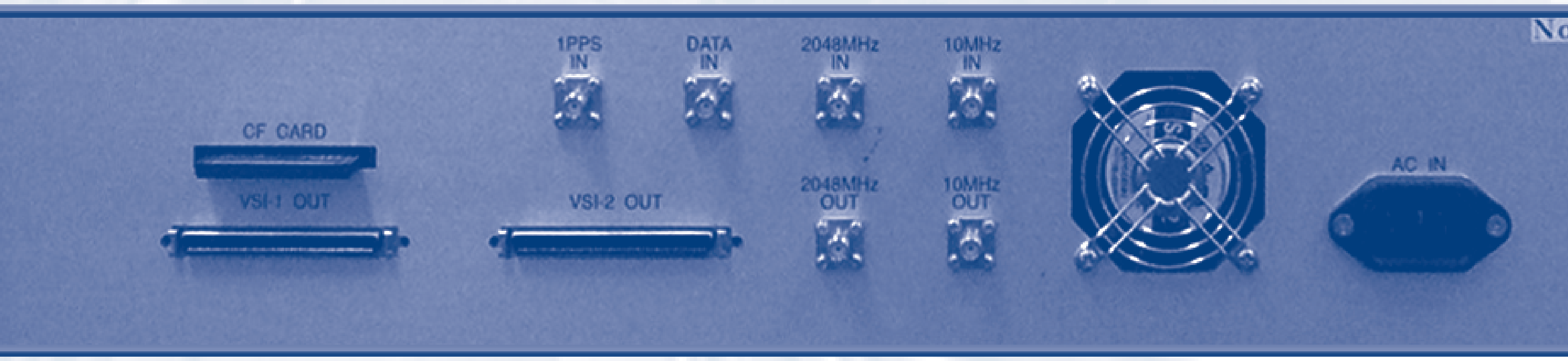

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