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INTERNATIONAL VLBI SERVICE FOR GEODESY AND ASTROMETRY

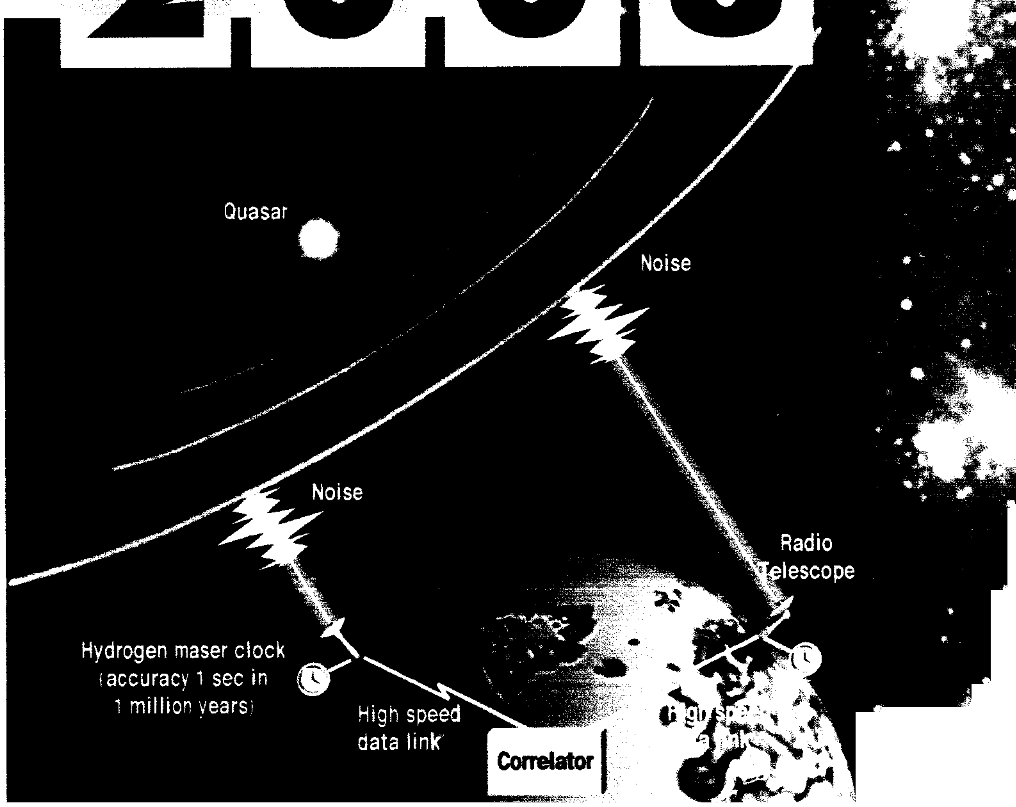
ANNUAL REPORT

Edited by
N.R. Vandenberg
and K.D. Baver

IVS Coordinating Center

February 2004

2003



The cover image depicts the VLBI concept of the near future: broad-spectrum white noise from quasars is recorded at radio telescopes and transmitted via high speed data links to a correlator.

Preface

This volume of reports is the 2003 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 2003 Annual Report documents the work of the IVS components for the calendar year 2003, our fifth 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.

The entire contents of this Annual Report also appear on the IVS web site at

`http://ivscc.gsfc.nasa.gov/publications/ar2003`

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 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 contributing 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, geophysical and astrometric research and operational activities.
2. To promote research and development activities in all aspects of the geodetic and astrometric VLBI technique.
3. 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

- 29 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.

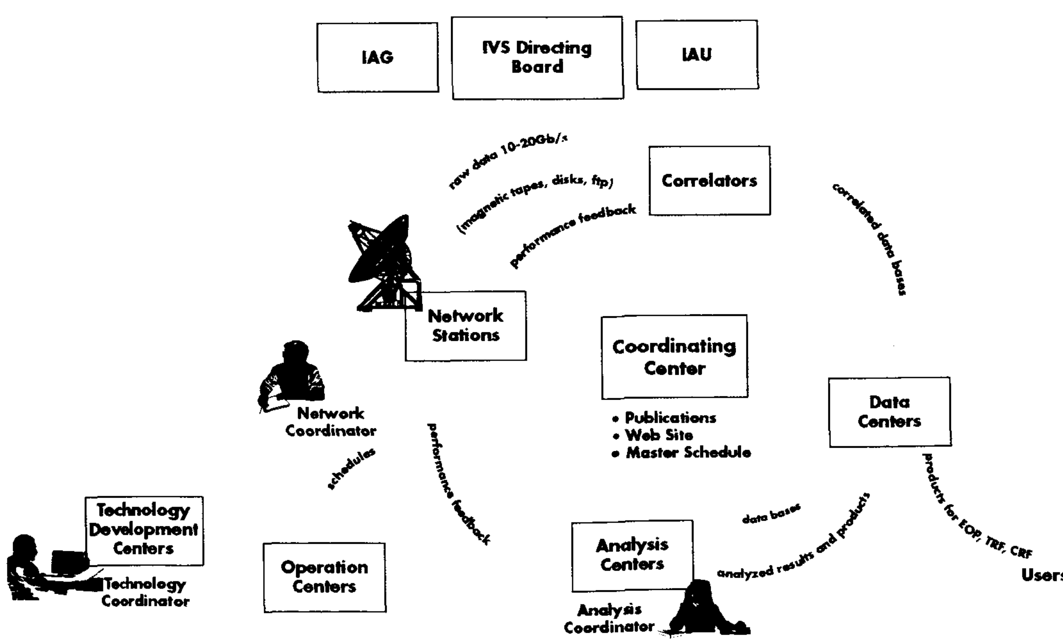
Altogether

- 73 Permanent Components, representing 37 institutions in 17 countries,
- ~250 Associate Members.

In addition the IVS has:

- Directing Board, determining policies, standards and goals; the board is composed of 15 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
Universidad Catolica de la Santísima Concepción	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
Geodetic Institute of the University of Bonn	Germany
Forschungseinrichtung Satellitengeodesie, TU-Munich	Germany
Istituto di Radioastronomia CNR	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
Communications Research Laboratory	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
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
Central (Pulkovo) Astronomical Observatory	Russia
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.

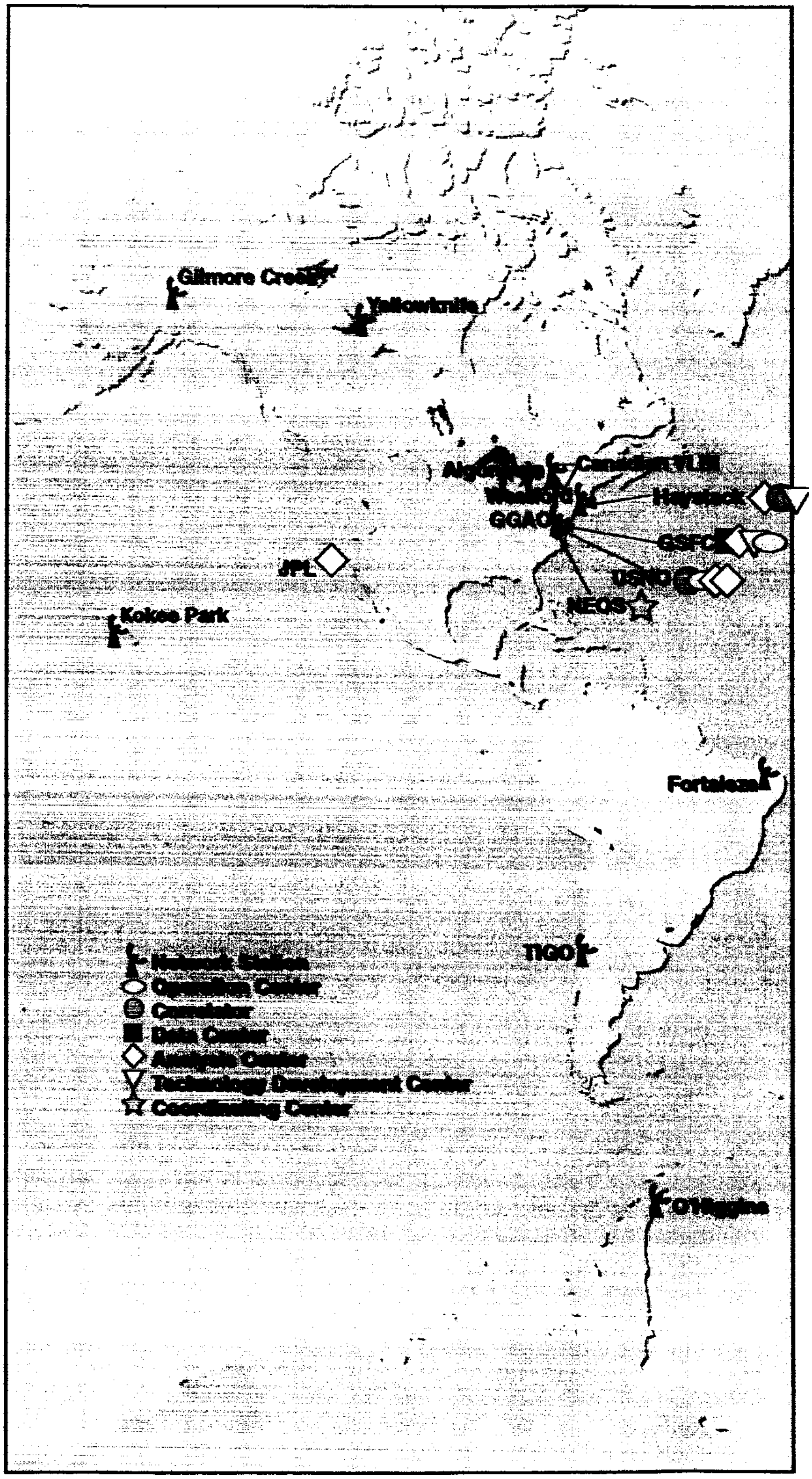
http://ivscc.gsfc.nasa.gov

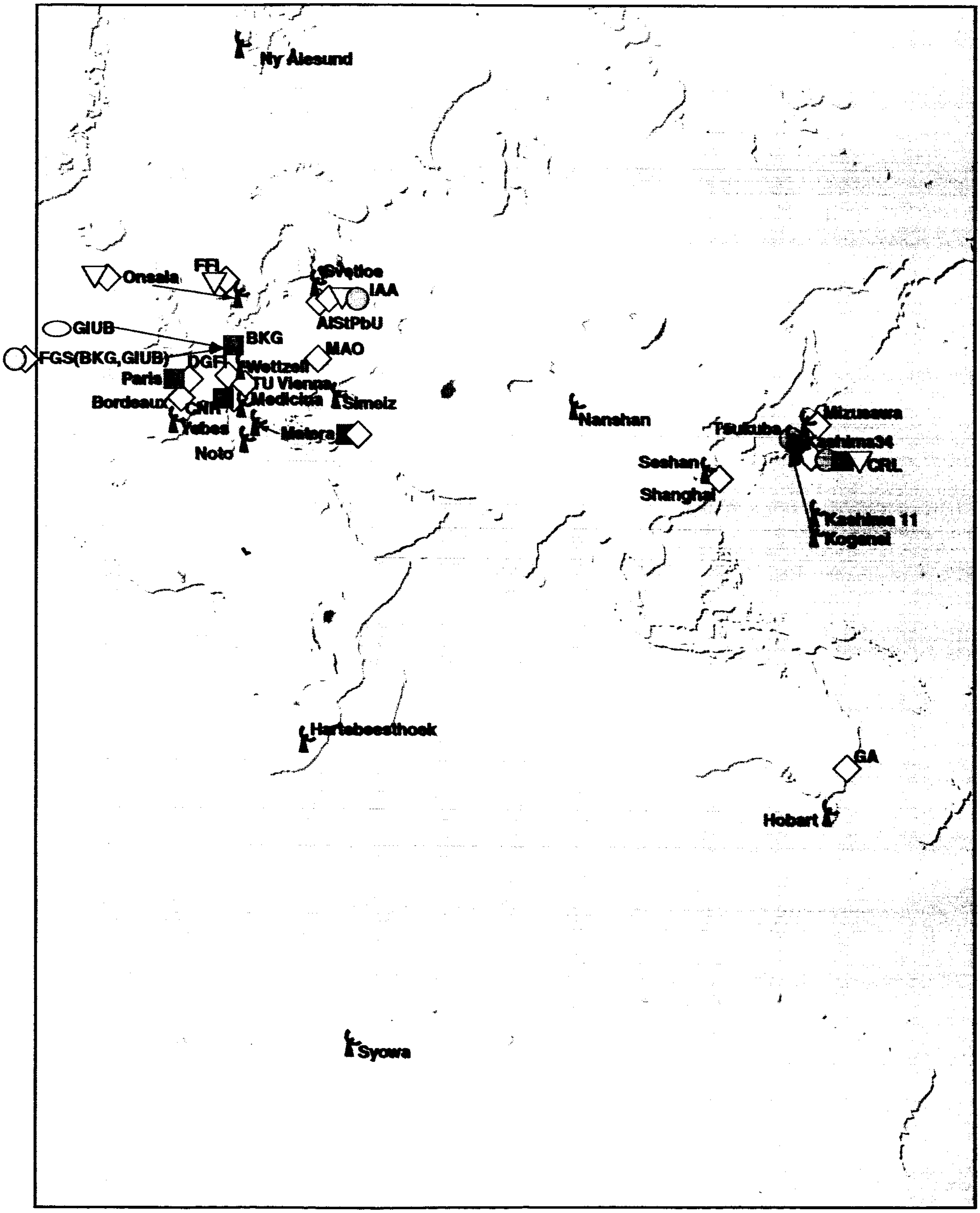
IVS COMPONENT MAP

IVS COMPONENTS BY COUNTRY

Australia	2
Austria	1
Brazil	1
Canada	3
Chile	1
China	3
France	3
Germany	8
Italy	7
Japan	12
Norway	3
Russia	5
South Africa	1
Spain	1
Sweden	3
Ukraine	2
USA	17
Total	73

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

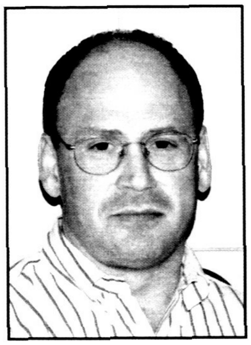
IVS DIRECTING BOARD

NAME: Wolfgang Schlüter

AFFILIATION: Bundesamt für Kartographie und Geodäsie, Germany

POSITION: Chair and Networks Representative

TERM: Feb 2003 to Feb 2007

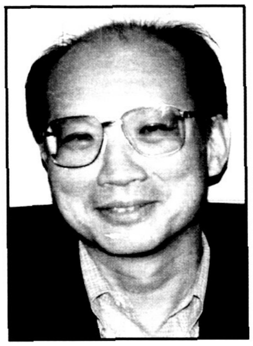


NAME: Ed Himwich

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

POSITION: Network Coordinator

TERM: permanent

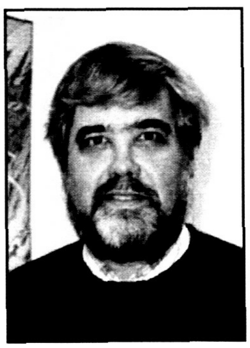


NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative

TERM: ex officio

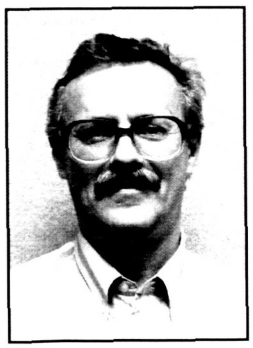


NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

TERM: Feb 2003 to Feb 2007



NAME: Zinovy Malkin

AFFILIATION: Institute of Applied Astronomy, Russia

POSITION: Analysis and Data Centers Representative

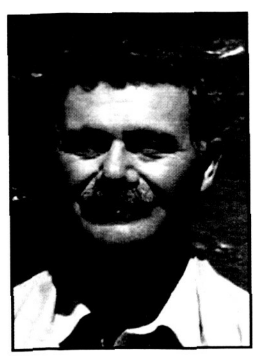
TERM: Sept 2003 to Feb 2005

NAME: Yasuhiro Koyama

AFFILIATION: Communications Research Laboratory, Japan

POSITION: At Large Member

TERM: Feb 2001 to Feb 2005



NAME: Franco Mantovani

AFFILIATION: CNR Bologna, Italy

POSITION: At Large Member

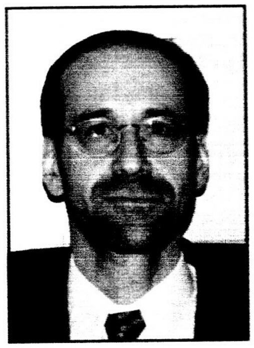
TERM: Sept 2003 to Feb 2005

NAME: Shigeru Matsuzaka

AFFILIATION: Geographical Survey Institute, Japan

POSITION: Networks Representative

TERM: Feb 2003 to Feb 2007

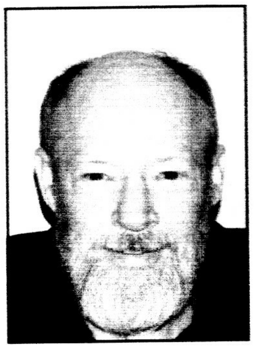


NAME: Harald Schuh

AFFILIATION: Vienna University of Technology, Austria

POSITION: IAG Representative

TERM: ex officio



NAME: Arthur Niell

AFFILIATION: Haystack Observatory, USA

POSITION: Techology Development Centers Representative

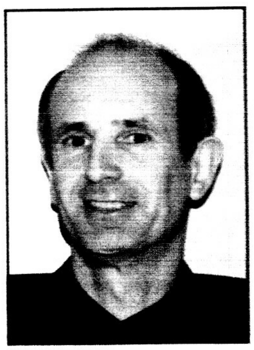
TERM: Feb 2001 to Feb 2005

NAME: Nancy Vandenberg

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

POSITION: Coordinating Center Director

TERM: ex officio

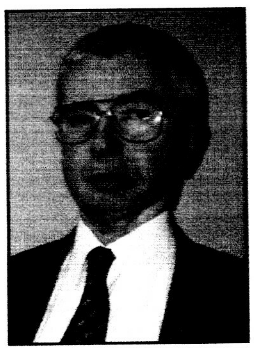


NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent



NAME: Patrick Wallace

AFFILIATION: Rutherford Appleton Laboratory, UK

POSITION: IAU Representative

TERM: ex officio

NAME: William Petrachenko

AFFILIATION: National Resources Canada, Canada

POSITION: At Large Member

TERM: Feb 2003 to Feb 2005

NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

TERM: permanent

IVS CHAIR'S REPORT

Wolfgang Schlüter
Bundesamt für Kartographie und Geodäsie, Germany

Reviewing the last years, it is notable that the International VLBI Service for Geodesy and Astrometry (IVS) is now fulfilling its role as a service within the IAG by providing important products for the maintenance of global reference frames (ITRF, ICRF and EOP's). IVS is providing time series that are timely and precise and it has established observing programs and procedures to meet the current requirements as best as the resources allow. IVS uniquely provides the parameters for the CRF, a complete set of the Earth rotation parameter and in particular the DUT1 parameter. Those products can be regarded as a basic infrastructure and are essential for research in fields related to the Earth and to space as well as for applications such as navigation and geodesy which make use of global reference frames. IVS is dependent on the contributions of its members and member institutions which proposed their support by their responses to the original call for participation. IVS is coordinating and optimizing the available resources as much as possible aiming to increase the efficiency and the quality of the products.

With great respect I appreciate the effort and the contributions from all IVS Permanent Components – from the Network Stations, the Operation Centers, the Correlators, the Analysis Centers, the Data Centers, the Technology Development Centers and last but not least from the Coordinating Center. I express my sincere thanks to all members and member institutions for the strong support during 2003. In particular I thank the IVS Coordinators Axel Nothnagel, Ed Himwich, and Alan Whitney for their strong engagement as well as Nancy Vandenberg as Director of the Coordinating Center and as chair of the Observing Program Committee.

Considering that financial resources throughout our community have been reduced, I feel the responsibility to express my concern. I would like to emphasize that the most effective generation of the IVS products could only be done through international collaboration. This is the way all the IAG services are working – namely all collaborating agencies contribute according to their resources, and in return all benefit from the results and products, which never could be achieved by a single institution. I'm aware that this kind of organization is very sensitive to any reduction from collaborating partners but to keep these highly qualified products at low cost, it requires the long term continuous support which is in the responsibility of all members and member institutions.

Progress in 2003

The most significant progress in 2003 came from employment of the disk-based digital data recording systems Mark 5 and K5, which allow us to handle the large amount of VLBI raw data at lower cost and with more reliability. The digital data recorders are the basis for the development of e-VLBI. It also has to be pointed out that the work at the correlator has improved significantly and the correlation procedure, in particular the recorrelation, can now be done faster. The transition from Mark 4 to Mark 5A is being performed smoothly, and most of the observing stations and the correlators are now equipped with disk-based digital recorders.

Further developments have been carried out for the VLBI Standard Interface (VSI). Hardware has been built and the VSI software interface was released, which is very important for the combination of the different recording techniques. The Mark 5B recording systems are being developed, which will result in a step forward, as formatters will become obsolete, the problems with the Mark 4 correlator station units will be overcome, and compatibility of the technology will be supported by the integration of VSI.

The Pilot Project "Tropospheric Parameters", led by the University of Vienna was carried out successfully and was turned over to a regular service product. The tropospheric parameters were accepted as an official IVS product at the 9th Directing Board Meeting.

A new Pilot Project, led by the Analysis Coordinator Axel Nothnagel, "Time Series of Station Coordinates and Baseline Lengths", has been set up, which is a first step in the provision of regular baseline lengths. Such a time series will be useful for many investigations of periodic and aperiodic variations caused by geophysical phenomena.

The board established its third Working Group, chaired by Alan Whitney and Arthur Niell, which is tasked to develop a vision for VLBI in 2010. It has to be considered that many components have been used in VLBI for some decades and urgently need an upgrade or even replacement. A lot of technical improvements will have to be integrated into a new VLBI generation and some upcoming problems, such as the interference in S-band, need a solution. A report from the VLBI2010 Working Group should be made available in 2004 which will become a guideline for the establishment of the next VLBI generation and will support the establishment of joint developments, in order to decrease development costs.

Key events in 2003

In 2003 we had some IVS technical meetings: the 4th Analysis Workshop at Paris Observatory held April 4-5, 2003, the 16th European VLBI Meeting in Leipzip, in May, 2004, and the Technical Operations Workshop (TOW) held at Haystack in September, 2004. An e-VLBI workshop was held in Dwingeloo jointly with the EVN. These meetings are of importance to promote progress and to support the exchange of experiences. I highly appreciate the good documentation of these meetings e.g. through the publication of proceedings and their fast appearance after the meetings. Thanks to the editors but also to the agencies which cover the costs.

It was a great surprise for me when Harald Schuh informed us with an e-mail that a team of European scientists coordinated by Prof. Dr. Veronique Dehant was one of two winners of the Decartes Prize 2003 for the project titled "Nutation". The Decartes Prize is the highest award for science in Europe. The IVS community can be proud of this event as VLBI provides the important measurements and products which are precise enough for the improvement and the control of the nutation model. With great respect for the group I express my appreciation and I congratulate them for such a wonderful success.

Changes in the Directing Board

At the beginning of 2003 the first four-year terms ended for the elected board members Kerry Kingham from the U.S. Naval Observatory representing the Correlators and Operation Centers, Shigeru Matsuzaka from Geographical Survey Institute/Japan and myself representing the Network Stations, and also the terms ended for the at large members Wayne Cannon, Space Geodetic Laboratory/Canada and Paolo Tomasi, CNR Bologna/Italy. The election for the next four-year term resulted in the re-election of Kerry Kingham, Shigeru Matsuzaka, and myself. The board elected William Petrachenko, National Resources Canada and Zinovy Malkin, Institute for Applied Astromomy, St. Petersburg/Russia as new at large members – following the ToR – for two-year terms.

For Nicole Capitaine, Paris Observatory/France her term as IAU representative ended and Patrick Wallace, Rutherford Appleton Laboratory/Chilton-UK was appointed by IAU to take over her position.

At its 9th meeting the board elected the new chair. It is a great honor for me being elected for the second time and I would like to express my thanks to the Associate Members and to the board members for their demonstration of confidence. With pleasure I want to congratulate the re-elected, the elected and the nominated board members. I'm convinced that the new board will continue the work with fairness, balance, and enthusiasm, and will meet all the challenges of the future for IVS.

I thank Nicole Capitaine, Wayne Cannon and Paolo Tomasi for their important contributions, for their support and strong engagement during the first four years.

At the 10th Directing Board Meeting James Campbell, University of Bonn/Germany withdrew as representative of the IAG and Harald Schuh, University of Vienna/Austria was appointed by IAG as its representative. The board decided to appoint Zinovy Malkin to replace Harald as Analysis and Data Centers representative and then elected Franco Mantovani, CNR Bologna/Italy for the open at large position.

I thank James Campbell, one of the pioneers in VLBI, for his contributions to the VLBI community, as chair of the CSTG Commission that helped to shape the IVS, and of course for his work as chair of the Steering Committee that formed the IVS. My congratulations to Franco Mantovani on his election. He represents not only a major contributing institution but also gives a voice for the related group of radio astronomers.

It has to be mentioned that Harald Schuh became a member of the newly established IAG Executive Committee. He was elected as one of the three service representatives. Chopo Ma, Goddard Space Flight Center/Greenbelt-USA was elected as one of the three service representatives in IAG Commission 1 (Reference Frames). Chopo Ma and I have been nominated as members of the Planning Group for IGGOS (Integrated Global Geodetic Observing System) – the IAG pilot project. It is of importance for IVS to have representatives on all these IAG committees. My congratulations to Harald Schuh and to Chopo Ma and my best wishes for successful and effective service on the committees.

Thanks

Again we can state that in 2003 IVS members have been very active and as result we had a successful year. I thank all members for their important contributions and for carrying out the additional work load in working groups, committees, for the preparation of presentations at various conferences, for writing reports etc. I would also express my gratitude to the member agencies for their important and strong support of IVS, which finally allows the members to make IVS into a living service.

IVS COORDINATION

Coordinating Center Report

Nancy R. Vandenberg

Abstract

This report summarizes the activities of the IVS Coordinating Center during the year 2003, and forecasts activities planned for the year 2004.

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 2003

During the period from January through December 2003, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated two IVS Directing Board meetings, at Paris Observatory, France, (April 2003) and at Haystack Observatory, USA (October 2003). Notes from each meeting were published on the IVS web site.
- Communications support: Maintained the IVS web site, e-mail lists, and web-based mail archive files. Set up a new e-mail system using the Mailman facility, which eliminated the spread of spam on the IVS mail lists. Coordinated the team that developed a new structure and design for the web site (see next section).
- Publications: Published the 2002 Annual Report in spring 2003. Published three editions of the IVS Newsletter in April, August, and December, 2003. All publications are available electronically as well as in print form.
- 2003 Master Schedule: Generated and maintained the master observing schedule for 2003. Coordinated VLBI resources for observing time, correlator usage, tapes and disk modules. Coordinated the introduction and usage of Mark 5 systems at IVS stations.
- 2004 Master Schedule: Generated the proposed master schedule for 2004 and received approval from the Observing Program Committee.
- Meetings: Coordinated, with the NRCan Local Committee, the third IVS General Meeting, held in Ottawa, Canada in February 2004. 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.

3. Web Site Update

During 2003 the IVS web site design was updated. Construction of the new site will be accomplished in early 2004.

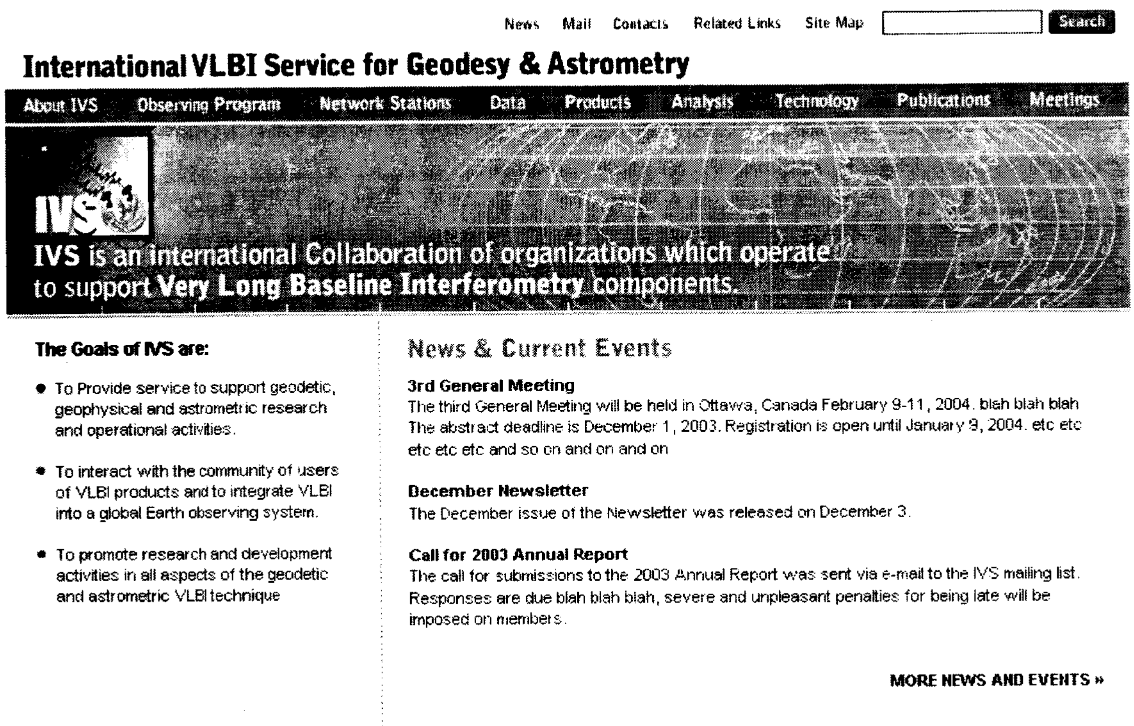


Figure 1. **New IVS home page.** This image shows the design of the new IVS home page. Major topics are shown in the bar at the top of the image, useful links such as mail and search are at the top of the page. The content of the home page gives the main mission of IVS for new visitors to the site, as well as current news and events for regular visitors.

The web site covers three main topics for IVS: activities, organization, and products. The site works to serve three main purposes:

- To provide a location on the web for IVS members and members of the scientific community to find data, products and general information provided by IVS.
- To act as a hub of information for IVS members. Since participants in the program are spread all over the world, the web site can act as a good resource to keep members informed of IVS activities.

- To promote IVS and to educate the scientific community and other interested parties in the work IVS is doing.

The new site has a clean design, improved navigation, and a revised structure that better reflects the needs of users. The structure was developed via discussions with a team consisting of Hayo Hase, BKG, Germany and Chile; Yasuhiro Koyama, CRL Kashima, Japan; Zinovy Malkin, Institute of Applied Astronomy, Russia; Dan Smythe, MIT Haystack Observatory, USA; Christoph Steinforth, University of Bonn, Germany; and Nancy Vandenberg, Coordinating Center Director. The design and construction of the new site was implemented by Doug League, RS Information Systems, of the NASA GSFC Technical Information Services Branch.

4. Staff

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

Name	Title	Responsibilities	Allocation
Nancy Vandenberg	Director	Web design and content, Directing Board support, meetings, publications	50%
Cynthia Thomas	Operation Manager	Master schedule (current year), resource management, meetings and travel support, special sessions	50%
Frank Gomez	Web Manager	Web server administration, mail system maintenance, data center support, session processing scripts, mirror site liaison	50%
Karen Baver	Publication Programmer and Editor	Publication processing programs, Latex support and editorial assistance	10%
Debra Gonzalez	Data Technician	Master schedules, resource monitoring, session web pages monitoring	30%

5. Plans for 2004

The Coordinating Center plans for 2004 include the following:

- Support the new IVS web site and implement new station pages.
- Publish the 2003 Annual Report (this volume).
- Publish Proceedings of the third IVS General Meeting.
- Support Directing Board meetings in 2004.
- Coordinate the 2004 master observing schedule and IVS resources.
- Publish Newsletter issues in April, August, and December.
- Publish an IVS color brochure.

Analysis Coordinator Report

A. Nothnagel, C. Steinforth

Abstract

IVS analysis coordination issues in 2003 are reported here.

1. General Issues

The "Fourth IVS Analysis Workshop" was held at Observatoire de Paris in Paris, France, April 3 - 4, 2003. Detailed information on the presentations and discussions can be found under http://giub.geod.uni-bonn.de/vlbi/IVS-AC.

2. IVS Operational Data Analysis and Combination

2.1. Terrestrial Reference Frame

In late 2002 it became evident that the ITRF2000 coordinates and velocities [1] of some of the VLBI stations regularly used in IVS-R1 and -R4 observing sessions did not match VLBI observations accumulated up to late 2002 [2]. Consequently the use of ITRF2000 as a fixed terrestrial reference frame (TRF) lead to significant distortions in some of the EOP series submitted by IVS Analysis Centers and in the combined IVS EOP series. In addition the site of GILCREEK (Fairbanks) was affected by an earthquake in October 2002. For these reasons a conventional VLBI terrestrial reference frame (VTRF2003) was developed with its axis and geocenter definition closely aligned to ITRF2000 but with modifications of some of the station coordinates and velocities (Nothnagel, 2003).

2.2. IVS EOP Series

Early in 2003 routine analysis and combination of the earth orientation parameters (EOP) series submitted by the six IVS Analysis Centers has seen a change with respect to the underlying terrestrial reference frame. Until the end of 2002 the combined EOP series were closely linked to the ITRF2000. Owing to the deficiencies of ITRF2000 listed above, VTRF2003 was used as the TRF for a consistent alignment of the TRF and the IVS EOP series.

Since the end of 2003 a seventh series provided by Sergei Bolotin from the Main Astronomical Observatory Kiev, Ukraine, is regularly submitted to the IVS Data Centers. First comparisons with the combined series have been carried out.

On January 1, 2003, the IAU2000 resolutions were planned to take effect. However, some of the numerical constants of the IAU2000 precession, nutation and non-rotating origin models had not been finalized early enough. Therefore, modifications in the VLBI analysis software packages for the IAU2000 resolutions had not yet been completed for a timely start of producing the new type of EOP. In order to provide celestial pole offsets in the new paradigm (X, Y) a conversion program was developed on the basis of software kindly provided by Christian Bizouard, Observatoire de Paris. Consequently, the rapid service EOP series (e. g. ivs03r1e.eops) as well as the complete (since 1979) IVS series are routinely complemented by the files ivs03r1X.eops and ivs03q1X.eops which contain celestial pole offsets (X, Y) instead of the classical nutation offset $d\psi$, $d\varepsilon$ w.r.t. to IAU1980. More details can be found in the proceedings of the Third IVS General Meeting, Ottawa, Canada, February 9 - 11, 2004.

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Network Coordinator Report

Ed Himwich

Abstract

This report includes an assessment of the network performance in terms of the yield of usable data over a 12 month period. A table of relative incidence of problems with various subsystems is presented. The current situation for the handlng of correlator clock adjustments by the correlators is reviewed.

1. Network Performance

The network performance report is based on correlator reports for sessions in calendar year 2003. As of the date this report was generated, 188 sessions had been processed. There are another 24 sessions from the calendar year that had not been processed yet, or the correlator results were not available. Most of the missing sessions are from the latter part of the year and/or are waiting for tapes from Antarctica before they can be processed. Roughly 85%-90% of the scheduled station days are accounted for.

An important point to understand is that in this report the data loss is expressed in terms of lost observing time. This is straightforward in cases where operations were interrupted or missed. However in other cases, it can be more difficult to calculate. To do this a non-observing time loss is typically converted into an equivalent lost observing time. 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. In a similar fashion, poor pointing is converted into an equivalent lost sensitivity. Poor playback is expressed as the fraction of total recorded bits lost.

From the correlator reports, an attempt is made to determine how much observing time was lost at each station. This is not always straightforward to do. Sometimes the correlator notes do not indicate that a station had a particular problem while the quality code summary will indicate a significant loss. Reconstructing which station or stations had problems and why in these circumstances does not always yield accurate results. Another problem is that it is hard to determine how much RFI affected the data unless one or more channels were removed and that eliminated the problem. Similar problems occur for intermittent poor playback. 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 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 are noisy.

Since stations typically observe with more than one other station at a time, the lost observing time per station is not equal to the overall loss of VLBI data. Under some simplifying assumptions, the loss of VLBI data is roughly about twice the loss of observing time. The argument that supports this has been described in previous years' versions of this report.

For the 188 sessions with results available from 2003, there are 1040 station days or almost 6 stations per session on average. Of these session days about 14.2% (or about 148 days) of the observing time was lost. For comparison, the results for 2002 were about 12.2%, for 2001 about 11.6%, and for a subset of 1999-2000 the results were about 11.8%.

The observing time lost for 2003 is somewhat worse than previous years which were more typically around 12%. If these observing time losses are converted into VLBI data yield losses, then 2003 had about 28% VLBI data loss and previous years about 24%. Whether these results reflect a significant decline in performance is not clear. There were several significant problems that contributed large data losses to 2003's results. Typically these were receivers that either failed or had their cryogenics fail or antenna failures. Without more information about the long term performance of the network, these problems might be considered anomalous.

In previous years an assessment of each station's performance was given in this report. That practice has been discontinued. 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, this year only summary results are presented.

For the purposes of this report, the stations were divided into two categories: (A) those that were included in 14 or more network sessions, and (B) those in nine or fewer. Some of the stations in the former category had been included in as many as 100 sessions. The distinction between these two groups was made on the assumption that the results would be more meaningful for the stations participating in more sessions.

There are 15 stations in the 14 or more session category. Of these 10 successfully collected data for approximately 90% of their expected observing time. Four more stations collected 70% or more. One station in this group collected about 60%. The vast majority of the commonly used stations are in the 90% or more category.

There are 22 stations in the nine or fewer session category. This category included several stations that had previously not been included IVS sessions, including several domestic Japanese stations. The range of successful observing time for stations in this category was 35%-100%. The median success rate was 87%. Overall the stations in this category observed successfully about 78% of the time.

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 Fortaleza, HartRAO, Ny-Ålesund, and Onsala. Given the high level of reliability of these stations it will be impossible for most of them to improve by this much again this year.

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 for the entire network is presented in Table 1.

The categories in Table 1 are rather broad and require some explanation. The "Receiver" category includes all problems related to the receiver including out-right failure, loss of sensitivity because the cryogenics failed, and design problems that impact the sensitivity. The "Antenna" category includes all antenna problems including mis-pointing, antenna control computer failures, and mechanical break-downs of the antenna. The "Unknown" category is a special category for

Table 1. Data Lost by Sub-system

Sub-System	Percentage lost
Receiver	25.2
Antenna	17.8
Unknown	12.6
Recorder	10.9
RFI	9.3
Shipping	6.1
Miscellaneous	6.0
Rack	5.0
Operations	3.6
Clock	3.4
Software	0.1
Total	100.0

cases where the correlator did not state or was unable to determine a cause of the loss, but also includes the upper X-band IF problem at TIGO which has yet to be understood. The "Recorder" category includes all electrical and mechanical problems related to the recorder system (tape or disk). This includes passes that are unrecoverable because of overwriting. The "RFI" category includes all losses directly attributable to interference. The "Shipping" category includes data that could not be correlated because the media was either lost in shipping or held up in customs long enough that it could not be correlated with the rest of the session data. The "Miscellaneous" category includes several small problems that do not fit into other categories, including errors in the observing schedule provided by the Operation Centers. However, by far the largest contributor to this category is power failures. In retrospect power failures should have had their own category. The "Rack" category includes all failures that could be attributed to the rack (DAS) including the formatter and BBCs. The "Operations" category includes all operation errors, such as DRUDG-ing the wrong schedule, starting late because of shift problems, problems changing tapes and others. The "Clock" category includes situations where correlation was impossible because either the clock offset was not provided or was wrong leading to no fringes. It is difficult to be sure in some of these cases that the clock offset was the culprit, but in some it was clear. The "Software" 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 operating system problems. This category could also include errors in files generated by the DRUDG program, but none of these were noted for 2003.

From the results it can be seen that receiver, antenna, and recorder account for more than 50% of the losses. In fact for 2003 there were several unusual receiver and antenna problems. If these are not repeated in 2004, the data yield should be better. Additionally, the data losses associated with the recorder should go down significantly as more stations switch to using disk drives for media. The disk systems are much more reliable than tape recorders.

2. Clock Offsets

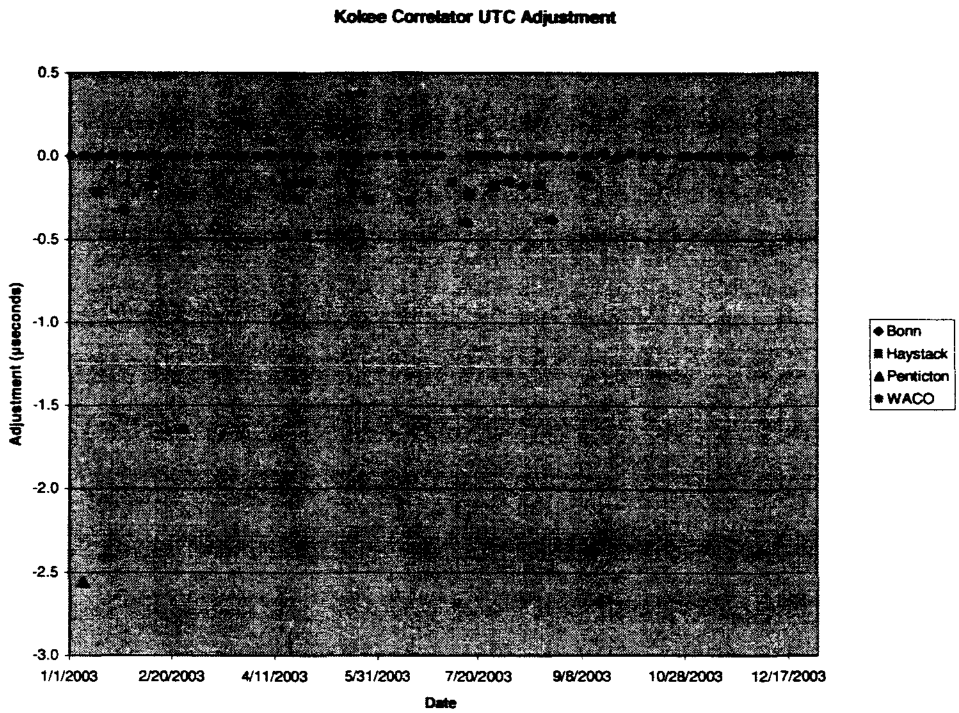

Figure 1. **Kokee UTC Correlator Adjustment**

As noted in the previous year's report, 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, a 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 products at the level of the inconsistency in the adjustments applied for correlation. This could be corrected during the data analysis, but currently no analysis packages do this. It would require a significant amount of bookkeeping to add this feature now.

Last year's report recommended that the correlators develop a consistent table of adjustments to correct the local measurements of the formatter relative to GPS. This would remove a source of correlator-to-correlator and session-to-session 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.

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 an offset 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 last year's report that a reference for the clock rate should be established at the same time. Although this is not as critical as the offset, it can easily be handled at the same time. Of course a good candidate station for the clock rate reference has to be found. As of last year's report, it seemed that Kokee's small rate relative to GPS, 1e-14 or better, would make it a good candidate. This would be a convenient choice for consistency's sake since again WACO has assumed that Kokee had a zero rate for much of the old data. This discussion is carried on in more detail in last year's report.

At the IVS Directing Board meeting in September 2004, the Correlator Representative to the Directing Board had offered to develop a consistent set of adjustments for the correlators to use. Currently this set of adjustments is under development [K. Kingham, USNO, private communication]. Consequently it would be premature to expect the offsets to be consistent for 2003. As a sample of the situation in 2003, the adjustments for Kokee are shown by correlator in Figure 1. In this figure it can be seen that the UTC adjustment applied by WACO is zero. Both Bonn and Haystack variable but small non-zero adjustments. The results for UT1-UTC will be affected at the level that the adjustments vary, less than 0.5 μsecond. However the offsets applied by Penticton have considerably more variation. Since there were no sessions involving Kokee processed by the GSI correlator, we have no information about the adjustments for this station and correlator combination.

It is not only important that the UTC adjustments applied by the correlators are all consistent, but also the final clock value must be applied in the generation of the time-tags for the observations. It is known that this is done at the three Haystack Observatory developed correlators: Bonn, Haystack, and WACO. However it is not known what the Penticton and GSI correlators do in this regard. Requests have been made to B. Petrachenko and K. Takashima, respectively, to find out more about how these correlators handle the offsets. (We also have no information about clock offsets are handled by the Miytaka correlator. However, the IVS geodetic sessions that Miytaka processes are not primarily intended to measure UT1-UTC.) If the final clock value is not applied in the generation of the time tags, the session-to-session variation in the locally measured formatter to GPS will be included in the UT1-UTC parameter estimates.

Another area of concern is that different recording systems may require different adjustments. A particular example is that the CRF22 session was correlated at WACO using data from two different systems: K3 formatter recorded to tape and a K5 recorder using disks. WACO found a 3.3 μsecond clock offset between the two systems. This difference corresponds to almost a kilometer of cable difference. This does not seem realistic. If no cause for this is found, and probably even if it is, it will be necessary to calibrate the differences between different systems. This might be undertaken by recording the same data with two or more systems and then comparing the final clock offsets that are needed to correlate them.

IVS Technology Coordinator Report

Alan Whitney

Abstract

The efforts of the Technology Coordinator in 2003 were primarily in the following areas: 1) creation of IVS Working Group 3 for VLBI2010, 2) continued development of the VSI-E specification for e-VLBI, 3) support of the 2nd annual e-VLBI Workshop held at JIVE. We will describe each of these briefly.

1. IVS Working Group 3 - VLBI2010

At the September 2003 IVS Directing Board meeting, the IVS Working Group 3 was formally created. The VLBI2010 Working Group will examine current and future requirements for VLBI geodetic systems, including all components from antennas to analysis, and produce a report with recommendations for a new generation of systems that meet the following criteria:

- Highest-precision geodetic and astrometric results
- Low cost of construction
- Low cost of operation
- Fast turnaround of final results

Among the issues to be explored are:

- Modernization of VLBI data-acquisition systems for higher stability and reliability, wider bandwidth, lower cost
- Small, low-cost, fast-moving antennas
- New observing strategies
- Optimum and practical observing frequencies
- Fully automated observations; remote monitoring
- Transmission of data via high-speed network (e-VLBI)
- Possible correlator upgrades
- Fast turnaround of results by full pipelining of data from antennas to correlator to final analysis

Among the factors encouraging the VLBI2010 initiative:

- Continuing RFI problems at many sites
- DSN moving to X/Ka (32 GHz) band observations. Advantage: eliminates S-band RFI
- Aging antennas
- Technology advances in disks and e-VLBI
- Concerns in the US:

  - Retirement of current practitioners
  - Reduced support for VLBI technology development by sponsoring agencies

Goals of VLBI2010:

- Unattended observing
- Global coverage
- Electronic data transfer, near real-time correlation.
- Smaller antennas? (~12m for expected to be available for ~$150k)
- Spanned bandwidth 4 GHz

We will draw on the resources of both the astronomy and geodesy VLBI communities in these investigations, as well as other relevant expertise (such as SKA and ATA, for example).

The VLBI2010 Working Group is composed of 16 members drawn broadly from the geodetic VLBI community:

- Brian Corey - antennas, RF/IF systems, calibration
- Hayo Hase - antenna systems
- Ed Himwich- control, data management
- Hans Hinteregger - digital backend systems, correlators
- Tetsuro Kondo - data systems, data transport, real-time
- Yasuhiro Koyama - data systems, data transport
- Chopo Ma - post-correlation analysis; data management
- Zinovy Malkin - post-correlation analysis
- Arthur Niell - atmospheric calibration, analysis
- Bill Petrachenko - antenna arrays, multi-beam VLBI, frequency standards
- Wolfgang Schlueter - antennas, observing strategies, frequency standards
- Harald Schuh - post-correlation analysis, cross-technique use
- Dave Shaffer - observing strategies, systems, analysis
- Gino Tuccari - digital backend systems
- Nancy Vandenberg - scheduling, observing strategies
- Alan Whitney - data systems, data transport, correlators

The Working Group is co-chaired by Alan Whitney and Arthur Niell. A draft report is expected to be available in spring 2004, with a final report approximately 3 months later.

2. VLBI Standard Interface - e-VLBI (VSI-E)

Work continues on the development of the VSI-E specification for a standardized data format for e-VLBI interchange. At the 2003 e-VLBI Workshop in JIVE, many of the members of the VSI-E committee met to discuss the choice of an underlying protocol for VSI-E. There was general consensus that the well-known and well-developed Internet Real-Time Protocol (RTP) would best serve as a base for the development of VSI-E. RTP has the following advantages:

- Developed for real-time transmission of digitally-sampled analog data
- Well developed, supported, and widely used
- Built-in monitoring and network and end-system performance
- Adaption to varying network capability and performance
- Built-in multi-cast and multi-streaming support

On the other hand, RTP, as currently defined, is not entirely suitable for the wide range of e-VLBI operational conditions, ranging from disk-buffered at both station and correlator to full real-time operation. Much effort has been expended to extend the current RTP protocol to handle the full range of operational space that e-VLBI demands. Furthermore, these extensions are being developed as generally as possible so that the extended RTP standard that encompasses e-VLBI will have a good chance of being accepted as an Internet standard protocol by the Internet Engineering Task Force. Acceptance by the IETF would lend worldwide credibility to the extended RTP standard and help encourage its use and support. To this end, the draft VSI-E standard is being subjected to minute scrutiny by non-VLBI network experts as well as VLBI network experts. We expect a final draft for ratification to be ready in early/mid 2004.

The members of the VSI-E committee are:

- Wayne Cannon; York University, Canada
- Brent Carlson; DRAO, Canada
- Dick Ferris; ATNF, Australia
- Dave Graham; MPI, Germany
- Ed Himwich; NASA/GSFC, U.S.
- Richard Hughes-Jones; Manchester Univ, England
- Nori Kawaguchi; NAO, Japan
- Tetsuro Kondo; CRL, Japan
- David Lapsley; Haystack, U.S.
- Sergey Likhachev; ASC, Russia
- Ari Mujunen; Metsahovi, Finland
- Sergei Pogrebenko; JIVE, Netherlands
- Jon Romney; NRAO, U.S.
- Ralph Spencer; Jodrell, England
- Harro Verhouter; JIVE, Netherlands
- Alan Whitney; Haystack, U.S.

3. Second International e-VLBI Workshop Held at JIVE

Approximately 80 attendees representing 15 institutions worldwide participated in a 2-day workshop held at JIVE on 15-16 May 2003. The purpose of this workshop was to continue the work of the 2002 e-VLBI workshop at Haystack Observatory to explor the current state of high-speed VLBI data transmission. Among the topics discussed were:

- Reports on e-VLBI tests and demonstrations
- Plans for ongoing e-VLBI development
- Status of interaction with network providers and developers
- International networking facilities - now and future
- Standards and protocols for e-VLBI data transfer.
- Hardware and software interfaces to telescope back-ends and correlators

Progress in e-VLBI continues to be rapid, particularly with the rapid spread of global high-speed networks, the adoption of e-VLBI compatible data systems (Mark 5, K5, PC-EVN), and the rapid drop in prices for high-speed network equipment. Over the last year, international e-VLBI demonstrations have reached as much as 700 Mbps (Japan to U.S.). In addition to e-VLBI data transmission, we heard about the development of new software correlators in Japan and Europe, as well as plans for continued e-VLBI development in several countries. The program committee consisted of Yasuhiro Koyama of CRL, Steve Parsley of JIVE, Jon Romney of NRAO and Alan Whitney of Haystack Observatory. Presentations from the workshop are available on-line at *http://www.jive.nl/evlbi_ws/meeting*.

NETWORK STATIONS

Algonquin Radio Observatory

Mario Bérubé, Calvin Klatt, 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 in partnership with the Space Geodynamics Laboratory, CRESTech.

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 is the most sensitive IVS Network Station.

This report summarizes recent activities at the Algonquin Radio Observatory.

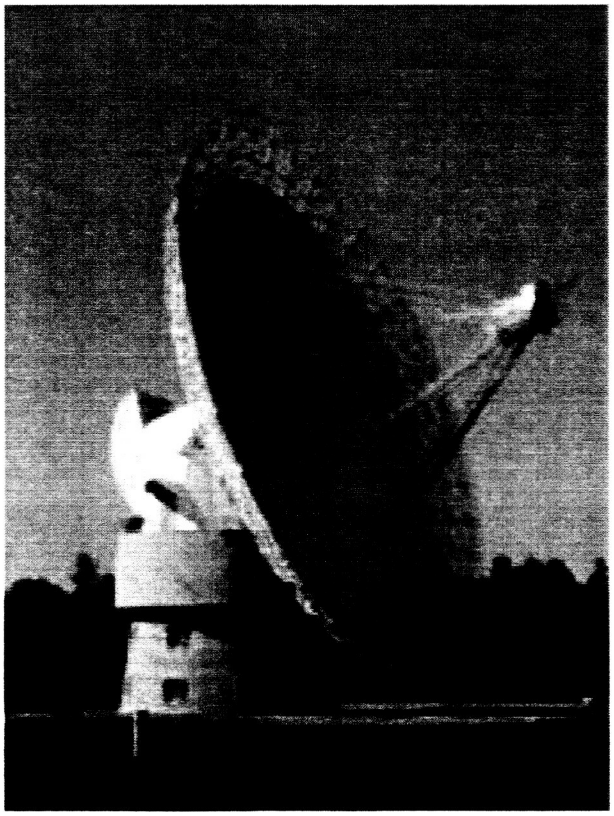

Figure 1. Algonquin Radio Observatory 46m Antenna

1. Overview

The ARO 46 m 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).

The GSD also maintains a permanent GPS monitoring station at Algonquin which is used by all IGS Analysis Centers as a fiducial reference. Satellite laser ranging and absolute gravity observations are also available for the site which is located on the stable pre-cambrian Canadian Shield. Local site stability has been monitored regularly using a high-precision network.

2. Site Improvements

In order to improve the operational performance of Algonquin, GSD undertook a major upgrade of the antenna control system which was completed in 1997.

This antenna control system still uses the original azimuth and elevation encoders to determine antenna position. We have made some progress in the effort to upgrade these and efforts continue in a manner that will not affect scheduled operations.

Figure 2. Visiting neighbour

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 : 24 degrees per minutes.
- Elevation speed : 5 degrees per minutes.
- Receiver : S and X cryogenic receiver.
- VLBI equipment : VLBA4 with thin tape drive. S2 DAS and RT.
- PCFS version : 9.5.3
- Time standard : NR Maser
- GPS receiver : BenchMark
- Timing receiver : CNS clock

4. Antenna Survey

The antenna is surrounded by a high stability network made of thirteen concrete piers. This network has been precisely measured five times to obtain the geodetic tie between the VLBI, the GPS, and the SLR reference points with a precision of a few mm. The VLBI antenna itself requires a special indirect survey since the reference point cannot be accessed directly.

5. Algonquin Operations

Algonquin Radio Observatory is involved in several international VLBI networks. Geodetic VLBI activities are summarized below.

ARO participated in the VLBI observation of Nozomi for precise orbit determination in collaboration with the Institute of Space and Astronomical Science (ISAS), Communication Research Laboratory (CRL) Japan, the Canadian Space Agency (CSA) and SGL, CRESTech.

ARO has participated in testing of bi-static radar observations of satellites in collaboration with SGL.

5.1. Sessions Performed January 1, 2003 - December 31, 2003

Session Type	Number of Sessions
R4	50
E3	10
R&D	10
T2	2
Total	72

Fortaleza Station Report for 2003

Pierre Kaufmann, A. Macílio Pereira de Lucena, Claudio E. Tateyama

Abstract

This is a brief report on the activities carried on at Fortaleza geodetic VLBI Station (ROEN: Rádio Observatório Espacial do Nordeste), Eusébio, CE, Brazil, in 2003, consisting mainly of 66 VLBI observing sessions and continuous GPS monitoring recordings.

1. Introduction

The Rádio Observatório Espacial do Nordeste, ROEN, located at INPE facilities in Eusébio, nearly 30 km east from 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 carried out by CRAAE, the Center for Radio Astronomy and Space Applications (a consortium between Brazilian institutions Mackenzie, INPE, USP and UNICAMP). During the year of 2003 the operational staff and part of infrastructure were maintained within an agreement between the Instituto Nacional de Pesquisas Espaciais, INPE and Instituto Presbiteriano Mackenzie through its Universidade Presbiteriana Mackenzie, Centro de Rádio-Astronomia e Astrofísica Mackenzie, CRAAM. Part of operation costs and technical maintenance, support of infrastructure, are sponsored by US agencies NASA, USNO and NOAA, with Agreements with Mackenzies CRAAM, under the Brazilian Program for Space Geodesy.

Figure 1. Fortaleza staff in front of antenna

2. Brief Description of ROEN Facilities

The largest instrument of ROEN is the 14.2 m radio telescope, on one alt-azimuth positioner. It is operated at S- and X-bands, using cryogenic radiometers. The system is controlled by Field

System, Version 9.6.2 program. Observations are recorded with a Mark III data acquisition system. One Sigma-Tau hydrogen maser clock standard is operated at ROEN.

GPS monitoring is performed by one dual frequency GPS Rogue receiver operated continuously. The collected data are provided to the IGS center, as well to Brazilian IBGE center. ROEN has all basic infrastructure for mechanical, electrical and electronic maintenance of the facilities.

3. Space Geodesy Team

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 Valdomiro S. Pereira and Neide Gea. 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 in site by Eng. A. M. P. de Lucena (CRAAE/INPE), assisted by Eng. Adeildo Sombra da Silva (CRAAE/Mackenzie), and technician Avicena Filho (CRAAE/INPE). Local administrative support was given by Dadimar Dias Nobre.

4. Geodetic VLBI Observation

Fortaleza participated in following geodetic VLBI experiments, as detailed in the table below for the year 2003.

Experiment	Number of Sessions
IVS-R4	50
IVS-T2	07
IVS-CRF	03
IVS-OHIG	06

5. Development and Maintenance Activities in 2003

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

1. Tests and electrical alignment of the DC motors in both axis.
2. Up-dating and tests for new versions of Field System.
3. Repair on cryogenic system with replacement of cold head.
4. Repairs on the following circuits, modules, or systems: Mark III video converters, Mark III power supplies and Mark III IF3 module.
5. Maintenance of web site (http://www.roen.inpe.br).

6. GPS Operation

The IGS network GPS receiver operated regularly at all times during 2003. Data were collected and uploaded to IGS/NOAA computer.

7. Students Activities

The following students have participated in the program during 2003:

1. Carlos Fabiano Barros Moreira(CEFET/CE), ROEN;
2. Jose Ronnylson Santos dos Anjos(CEFET/CE), ROEN;
3. Danilo Morales Teixeira(FBCEE/UPM), CRAAM-SP.

8. Scientific Paper

TATEYAMA, C.E.; KINGHAM, K.A.; "Structure of OJ 287 from Geodetic VLBA Data", in press, Astrophys.J., 2003.

9. Visitors

In 2003 we received at ROEN the visits from Mr. William T. Wildes, the program manager at GSFC/NASA and Mr. Charles Kodak, from Honeywell, for technical inspections and discussions.

10. ROEN Participation in TOW

Engineer Adeildo Sombra da Silva, from ROEN, has participated in the IVS Technical Operations Workshop (TOW), held by IVS, at Haystack Observatory, MIT, Massachusets, USA, September 21-25 2003.

11. Future Plans

The Mark IV formatter was purchased and received in 2003. It is planned to complete the Mark III updating during 2004.

Gilmore Creek Geophysical Observatory

Kyle Eberhart

Abstract

The following report provides a general technical description and operational overview of the Gilmore Creek Geophysical Observatory located near Fairbanks, Alaska.

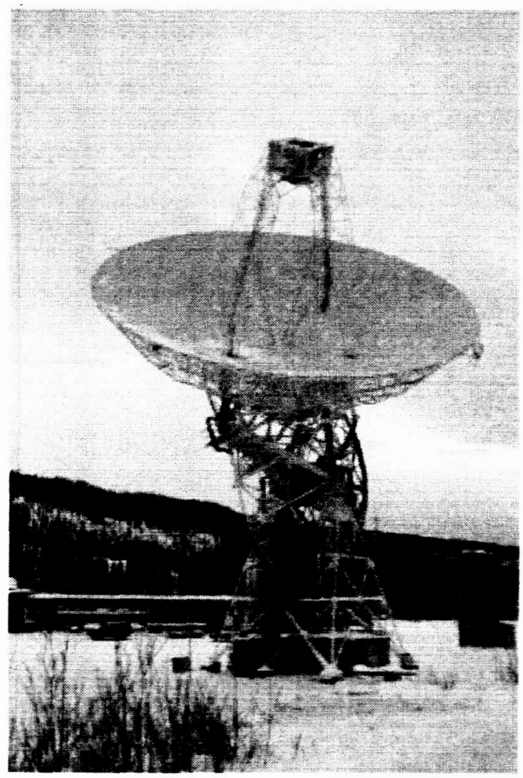

Figure 1. Gilmore Creek Geophysical Observatory's telescope and building, Fairbanks, Alaska.

1. GCGO at Fairbanks

Gilmore Creek Geophysical Observatory (GCGO) is located 22 km northeast of Fairbanks, Alaska. The observatory is co-located with the NOAA weather satellite command and data acquisition station. The station sits on an 8,500 acre reservation that is mostly undeveloped wilderness. Ten antennas are in operation. GCGO was instrumented by NASA's Crustal Dynamics Project in the mid 80's for the Alaskan mobile VLBI campaign and used as the base station for those geodetic measurements. The GCGO is part of the NASA Space Geodesy program in cooperation with the U.S. Naval Observatory.

2. Technical Parameters of GCGO

The 26 meter telescope, monument number 4047, X-East Y-North, latitude N 64° 58' 43.81288" and longitude E 147° 29' 42.18552" height 306.418 meters is hydraulic-operated and controlled by a Modcomp computer system (see table 2). The DAT rack is a VLBA terminal and recorder (thin tape). The X/S band microwave receiver has a cryogenic low noise front end. VLBI Field System version 9.5.7 is used with a PC. Hydrogen Maser NR 5 is the time standard with an HP Cesium for the telescope computer. A CNS (TAC) receiver is monitored by the TAC32 software for GPS offset measurements. The JPL GPS scintillation project is observed using an Ashtech and 8100 Rogue GPS receiver.The Institut Geographique National in France operates a DORIS beacon located near the NOAA VHF transmitter building. Nortel Data Network Systems operates the PRARE (Precise Range and Range Rate Equipment) for the German Space Agency. CLS from France operates the ARGOS and ARGOS-NEXT beacon. The ARGOS-NEXT platform is located next to the NOAA 26 meter antenna.

Table 1. Address of GCGO near Fairbanks.

Gilmore Creek Geophysical Observatory
NOAA/NESDIS FCDAS
1300 Eisele Road
Fairbanks, AK 99712
`http://www.fcdas.noaa.gov`

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

Parameter	GCGO
owner and operating agency	NOAA/NASA
year of construction	1962
receiving feed	primary focus
diameter of main reflector	26 meters
focal length	10.9728 meters
surface accuracy of reflector	889 mm rms
X Y mount	1 degree per second
S-band	$2.2 - 2.4, GHz$
T_{sys}	$62\,K$
$SEFD(CASA)$	$650\,Jy$
G/T	$35.3\,dB/K$
X-band	$8.1 - 8.9, GHz$
T_{sys}	$58\,K$
$SEFD(CASA)$	$550\,Jy$
G/T	$44.5\,dB/K$

3. Staff of the Gilmore Creek Facility, Fairbanks, Alaska

GCGO is co-located with the NOAA Fairbanks command and data acquisition facility. The NOAA Manager is Lance Seman. The site is operated by Space Mark International with Janine Jarvis as Project Manager and Roger Kermes as the Operations Manager. S. Caskey and K. Eberhart are assigned as GCGO technical staff with T. Knuutila, Z. Padilla, and others assisting. The telescope's hydraulic system is maintained by M. Meindl, A. Sanders and F. Holan. Day by day scheduling is done by NVI, Cindy Thomas and VLBI technical directives/contract modifications by NASA/GSFC, Bill Wildes.

4. Status of Gilmore Creek Geophysical Observatory

In 2003 GCGO was scheduled with 105 sessions and missed three. In early 2003 GCGO observed several sessions warm due to problems with our helium lines. We also replaced our recorder's capstan motor in April, the Dewar in June, a servo valve on our antenna in September and the head in our recoder in October. Our visitors included Senator Ted Stevens, NASA Administrator Sean O'Keefe, Bill Wildes GSFC/NASA, and Ed Himwich/NVI.

5. Outlook

A Mark 5 installation and Mark 4 formatter are expected early in 2004.

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Charles Kodak

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 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.

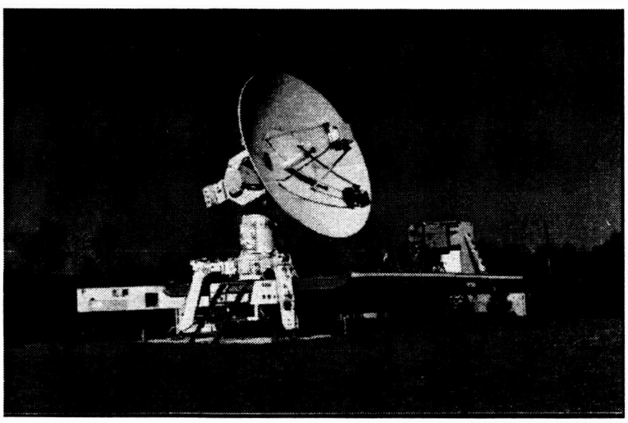

Figure 1. Old semi permanent MV-3 VLBI antenna.

Figure 2. New permanent MV-3 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	MK4
recording media	thin-tape only
Field System version	9.6.9 (9.5 BETA)

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
TBD	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 March 12, 2003 to October 10, 2003.

Date	Experiment
2003-03-12	RDV37
2003-03-18	T2015
2003-04-08	T2016
2003-05-07	RDV38
2003-06-18	RDV39
2003-07-09	RDV40
2003-09-16	T2021
2003-10-14	T2022

5. Outlook

GGAO will continue to support both scheduled experiments and developmental activities. The plan for 2004 consists of:

1. Continue testing of pre-release versions of PC-FS and new Linux kernel releases.
2. Continue with research on Mark 5 hardware development.
3. Continually striving to improve the performance of the entire MK4 data collection and station specific equipment.
4. MV-3 has installed the Mark 5 and e-VLBI hardware and has begun testing real-time from GGAO to Haystack. Correlation with the Westford data on the Mark 4 correlator was successful. (Oct 24, 2002).
5. The MV-3 antenna at GGAO has been permanently fix to the ground and has been resurveyed. (Oct. 2003)

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck

Abstract

HartRAO is the only fiducial geodetic site in Africa and participates in VLBI, GPS and SLR global networks. This report provides an overview of our geodetic VLBI activities during 2003. The status of the 26m radio telescope surface upgrade is reported. Future plans include automating the dichroic system which allows duel frequency operation. 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.

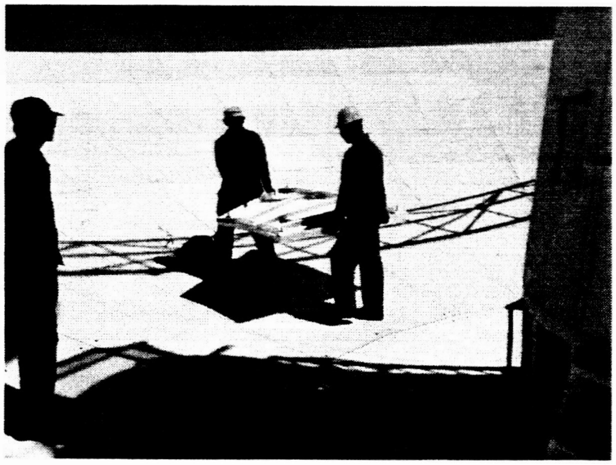

Figure 1. The last panel of the 26 metre radio telescope surface upgrade being installed by Simon Morake and Andrew Masiteng.

1. Geodetic VLBI at HartRAO

HartRAO is located north of Krugersdorp (close to Johannesburg), South Africa, in a valley of the foothills of the Witwaters mountain range. 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 (Deep Space Instrumentation Facility (DSIF) 51) until 1975 when the facility was converted to an astronomical observatory. The telescope is colocated 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.

2. Technical Parameters of the VLBI Telescope of HartRAO

The feed horns used for 13 cm and 3.5 cm are single polarised conical feeds. Both S and X bands have right hand circular polarisation. The RF amplifiers are cryogenically cooled HEMTS.

Table 1 contains the technical parameters of the HartRAO radio telescope [1]. Upgrade to a Mark 5 recording unit has taken place during late 2003 and has been installed successfully.

Table 1. Technical parameters of the radio telescope of HartRAO for geodetic VLBI, [1].

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	$25.914m$
focal length f	$10.886m$
f/d	0.424
surface contour of reflector	$\pm 2.0mm$
wavelength limit	2.5 cm
pointing resolution	0.001°
pointing repeatability	0.004°
X-band (standard $\nu = 8.580GHz, \lambda = 0.0349m$)	$8.180 - 8.980\,GHz$
T_{sys}	$65\,K$
S_{SEFD}	$1500\,Jy$
Point source	$17.1\,Jy/K$
3 dB beamwidth	0.092°
S-band (standard $\nu = 2.280GHz, \lambda = 0.1316$)	$2.210 - 2.344GHz$
T_{sys}	$40\,K$
S_{SEFD}	$1500\,Jy$
Point source	$9.7\,Jy/K$
3 dB beamwidth	0.332°
VLBI terminal type	MKIV
recording media	thin-tape only
Field System version	9.4.18
attended VLBI observations	24h, mode C

3. Staff Members Involved in VLBI

Table 2 lists the HartRAO station staff who are involved in geodetic VLBI. Marisa Nickola has been responsible for downloading of schedules, preparing SNAP files and related documentation. Several of the SLR operators have participated in geodetic VLBI shifts. Jonathan Quick (VLBI friend) has continued to provide technical support for the Field System as well as for hardware problems.

Table 2. Staff supporting geodetic VLBI at HartRAO.

Name	Background	Dedication	Function	Programme
Ludwig Combrinck	Geodesy	10%	Programme Leader	Geodesy
Jonathan Quick	Astronomy	5%	Hardware/Software	Astronomy
Marisa Nickola	Technical	50%	Logistics/Operations	Geodesy
William Moralo	Technical	5%	Operator	Geodesy
Pieter Stronkhorst	Technical	5%	Operator	Geodesy
Attie Combrink	Geodesy	5%	Operator	Geodesy

4. Current Status

During 2003 HartRAO participated in 58 (63 the previous year) experiments (Table 3), which utilised the telescope time allocated to geodetic VLBI to its fullest extent. The antenna surface upgrade is continuing and the last panel was installed at the end of 2003 (see Figure 1) and (Figure 2). It is planned to use holography to determine the overall shape of the dish during 2004. Based on the results of the holography, individual panels will be adjusted to obtain the best overall surface shape. Automation of the dichroic, which will include the construction of a new and more efficient dichroic, will commence once the surface upgrade has been completed.

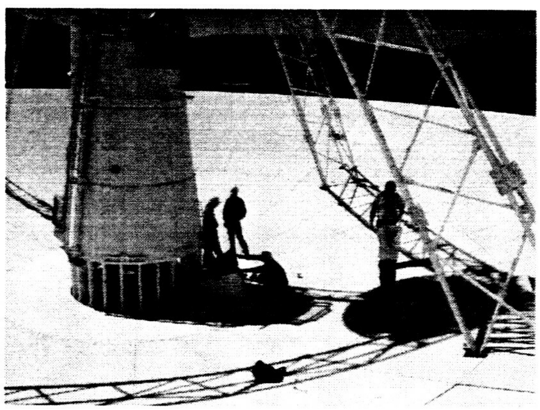

Figure 2. The final panel has been installed and we are all milling around in confusion or relief.

5. Future Plans

During 2003 we acquired a Mark 5 upgrade. Several parallel experiments using tapes and Mark 5 have been completed with no technical problems and we will phase out the tapes as soon as it is appropriate.

We have started initial steps towards the development of a new integrated Space Geodesy Facility which will support SLR, LLR, VLBI and GPS as well as host a multitude of 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

Table 3. Geodetic VLBI experiments HartRAO participated in during 2002.

Experiment	**Number of Sessions**
SUR	3
CRF	5
OHIG	6
R1	35
SYOWA	4
T2	5
Total	58

securely in the space geodesy arena for the next several decades. 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 colloborative projects with GSFC, JPL, GFZ (Potsdam) and local institutes.

References

[1] Combrinck, L., Hartebeesthoek Radio Astronomy Observatory (HartRAO), In: International VLBI Service for Geodesy and Astrometry 2000 Annual Report, NASA/TP-2001-209979, N. R. Vandenberg and K. D. Baver (eds.), 84-87, 2001.

Hobart, Mt. Pleasant, Station Report for 2003

Brett Reid, Simon Ellingsen

Abstract

This is a brief report on the activities carried out at the Mt. Pleasant Radio Astronomy Observatory at Hobart, Tasmania. During 2003 the Observatory participated in 38 geodetic VLBI observing sessions. The recording system was upgraded from Mark III to Mark 5.

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. 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 has been used again during 2003 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 recently been upgraded to include a feed translator with provision for four different receiver packages which enables rapid change over between geodetic and astronomical requirements. An upgrade completed during 2003 allows standard receiver packages to provide for operation at L band, S, C, X and K bands as well as 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 now equipped with a Mark 4 electronics rack and a Mark 5 VLBI recording system as well as S2 recorder.

3. Staff

Staff at the observatory consisted of two academics, Professor Peter McCulloch and Dr. Simon Ellingsen as well as the Observatory Manager, Mr. Brett Reid, funded by the University. In addition we have an electronics technical officer, Mr. Eric Baynes funded through the ARC grant and a half time mechanical technical officer, Mr Barry Wilson. For operation of the observatory during geodetic observations we rely heavily on support from astronomy post-graduate students.

At Peter McCulloch's retirement dinner, Peter was awarded the honour of Professor Emeritus by the University of Tasmania in recognition of his contributions in the field of radio astronomy.

4. Geodetic VLBI Observations

Hobart participated in 38 geodetic VLBI experiments during 2003. These were divided between the R1, OHIG, SYOWA, CRF, SUR, and APSG programs. With the upgrade to Mark 5 during

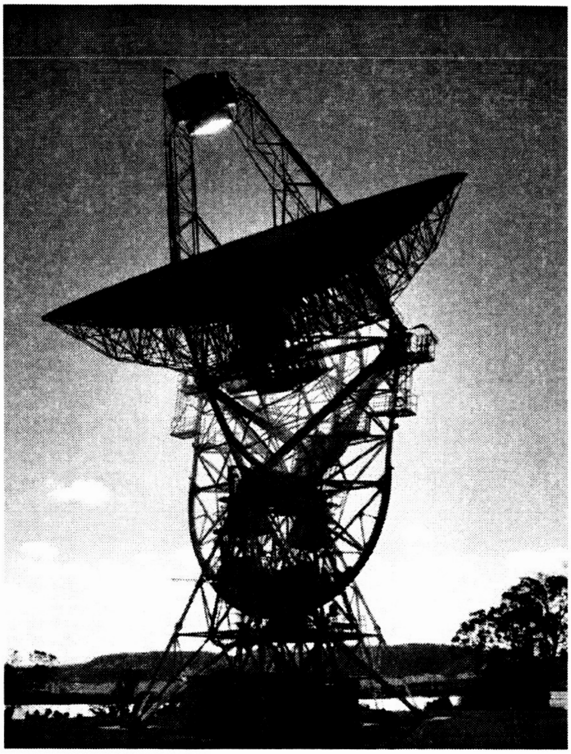

Figure 1. The Mt Pleasant 26m antenna

2003, Hobart was the first station to switch from reel to reel tapes to using Mark 5 recording media only for geodetic experiments correlated at Bonn, Washington and Haystack. Syowa experiments, correlated at Mitaka, are recorded using S2 media. During 2003 the station's Hi-Ranger elevated work platform tower had its 10 year major overhaul done to enable continued safe work at heights.

5. Future Plans

We will have two new academic staff members commencing in 2004. Also, as a part of the (ARC) linkage funding, we plan to have a PhD student in geodetic VLBI commencing. The stations existing humidity, temperature and pressure sensors will be replaced in early 2004 by a more accurate MET3 sensor funded by NAOJ.

Kashima 34m Radio Telescope

Junichi Nakajima, Eiji Kawai, Hitoshi Takeuchi, Hiroo Osaki, Hiromitsu Kuboki

Abstract

In April 2004, Communications Research Laboratory (CRL) will be re-organized into National Institute of Information and Communications Technology (NICT, Figure 1). From a policy to promote communication technology and related science, NICT will double its scale in number of staff and research budget. In NICT, VLBI is getting more important application to handle huge amount data transfer as well as its scientific results. There is no change in Kashima Space Research Center under the NICT. This network station report is mainly focused to telescope related projects in 2003.

1. Introduction

Communications Research Laboratory (CRL) constructed the Kashima 34m telescope in 1988 (Figure 2). The telescope is located 100 km east of Tokyo. During 15 years operation, the telescope is kept in good condition and joined VLBI and single-dish observations. The 34m telescope is operated by Radio Astronomy Applications Group.

NiCT National Institute of Information and Communications Technology

Figure 1. NICT, new institute logo reorganized from CRL.

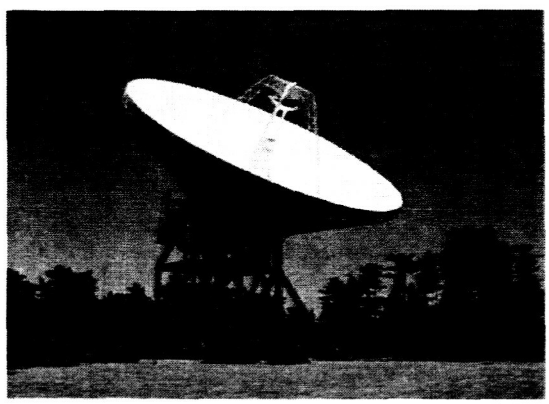

Figure 2. The Kashima 34m radio telescope.

2. Telescope Status

2.1. Conventional Back-end System and Field System

As a role of VLBI technology development center, TDC, Kashima 34m is particular site with functions where all kind of back-ends are gathered. Currently, G-bit (1024Mbps), K-4 (256Mbps), K3-A (MarkIIIA compatible), VSOP, and S-2 VLBI magnetic tape systems are available. K4, VLBA and S2 are controlled from the Field System (FS-9) together as well as 34m telescope. The FS-9 functional enhancement are done by the Kashima group. Weather monitoring logging system was renewed. As for single dish observation, there are two AOS systems in operation. One is the Pulsar AOS timing measurement system. The another is multi purpose AOS spectrometer. Please see the AOS details in previous Annual Reports. Latter AOS system will be moved to digital spectrometer using K5/PC-VSI. New weather monitoring and logging system were installed.

2.2. New VLBI Back-end, Unified K5-series

New PC-based VLBI system become popular to support VLBI observations. Two PC-based VLBI system had been developed at CRL. These are system up to 256 Mbps and 2048 Mbps. In 2003, both system are unified under name of K5 (Figure 3).

We have developed K5/PC-VSSP narrow band multi-channel system to substitute system up to 256 Mbps. The K5/PC-VSSP is unique since each unit is integrated with on board 4-channel AD converters. Four 4-channel K5/PC-VSSP units are equivalent to conventional 16-channel 256 Mbps VLBI system. With the matured 256-Mbps data rate, the K5/PC-VSSP system was used in Nozomi spacecraft positioning, geodetic and ERP observations. Different from magnetic tape recorders, the PC-based K5/PC-VSSP can also perform data correlation. K5 correlation software packages are completed and distributed to sites. In this view, K5/PC-VSSP is hardware and software in a single body. K5 correlation software is used at JIVE correlator. Speed of these software is increasing and GRID cluster PC system under development enables real-time VLBI experiment. Results from K5 correlation software is directly connected to analysis software and provide reliable results.

Another new VLBI back-end is K5/PC-VSI system for high speed VLBI acquisition. Two high-speed AD samplers ADS-1000 (1ch, 1024 M-Sps, 2048 Mbps) and ADS-2000 (16ch, 64 M-Sps, 2048 Mbps) are prepared for K5/PC-VSI. Essential of K5/PC-VSI is that the components are using VSI interface which is internationally specified. Successive K5/PC-VSI recording system can capture the high-speed interface data up to Gbps to normal Linux file system. With this K5/PC-VSI system acquired G-bps data can be transmitted via network or processed simultaneously. These multi task features during recording are achieve by well designed PCI-X interface board (PC-VSI2000DIM, digitallink co. ltd.) and newly invented Linux device driver ability. To handle huge amount of Gbps data stored to T-Byte disk-array, high speed software correlation core is developed separately. By recent CPUs Intel Xeon series, the core reached performance of 100 Mbps processing. This means multiple CPU and small number of cluster PCs will reach real-time processing of G-bps data.

name	hardware	software
K5/ PC-VSSP geodesy	IP-VLBI board 4ch on board AD 64-256Mbps	proofed K5 package vlbi@home
K5/ PC-VSI astronomy	PC-VSI board 1ch-wide /16ch AD 512-2048Mbps	high-speed *gico3* soft GRID corr.

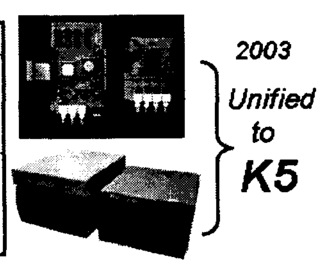

Figure 3. K5 unified character descended from two PC based e-VLBI system.

3. Telescope Status

3.1. Receiver Systems

Receivers in Kashima 34m telescope are L, C, K, Ka, Q and S/X band. The Ka and K receivers are integrated to a dual-band dewar. These receiver performances are summarized in Table 1. Efficiency of Ka receiver is still provisional. Please see receivers details in previous Annual Report.

Table 1. Receiver Specification of the 34m Radio Telescope.

Band	frequency(Hz)	Trx(K)	Tsys(K)	Efficiency	Polarization
L	1350-1750	18	43	0.68	R/L
S	2210-2350	19	83	0.65	R/L
C	4600-5100	25	108	0.70	L(R)
X	7860-8680	41	52	0.68	R/L
K	21800-23800	75	160	0.5	L(R)
Ka	31700-33700	85	150	0.4	R(L)
Q	42300-44900	180	300	0.3	L

3.2. RFI Mitigation (Interference)

IMT-2000, mobile phone base stations, in S-band once saturated the receiver system in Kashima 34m telescope. To avoid interference from transmitters, we have developed cooled HTS (High Temperature Super-conductor) filters. The sharp cutoff filter skirt of -30dB/MHz enabled us to receive lower S-band adjacent to IMT-2000 allocation. The filter is integrated into maintenance free refrigerator cryogenics. See details in TDC Newsletters from CRL.

3.3. Mechanical System

Continuous effort was put into telescope up-grading. Part of feed control was replaced to Ether basis. Extra EL and AZ motors were purchased. Encoder electrical units under heating environment were newly produced. MTBF of telescope components are carefully checked, inspected and they are replaced before failure. Key components are ready to change immediately in trouble. Accurate sub-reflector re-alignment tools are developed for annual maintenance. Usually position sub-reflector parameters are affected after mechanical overhaul. This year, positioning accuracy less than 0.1 mm is realized by the caliper like alignment tool. As a result parameter adjustment observation before start up mm-wave observation was reduced to a few days after maintenance.

Table 2. Mechanical Specification of the 34m Radio Telescope.

Maximum Speed Azimuth(deg/sec)	0.8
Maximum Speed Elevation(deg/sec)	0.64
Drive Range Azimuth(deg)	+-270
Drive Range Elevation(deg)	7-90
Operation Wind Speed (m/s)	13
Panel Surface Accuracy r.m.s.(mm)	0.17

4. On-going Projects and Major Results of 2003

e-VLBI (Domestic K5 experiment series) Sessions to verify K5 VLBI system were completed. In 2003, comparison between K4 and K5 proved K5 data quality and output validity. The K5 results well agreed with K4 and they increased sensitivity. Koganei 11m and Kashima 11m telescope remotely operated sites were in the experiment too. K5 1024 Mbps observation are carried out at the same time. Universities telescopes related observations are increased too. New telescope Yamaguchi 32m and Tomakomai 11m are operated by small university groups. CRL had been technically supporting these groups and carried out e-VLBI experiment series with these stations.

e-VLBI (International K5 experiment series) Monthly IVS-T and IVS-CRF sessions are scheduled at Kashima 34m. Though these observation are recorded to tapes, K5 system captured the observations too. Part of the observation data was transferred to Haystack and Washington correlator via the Internet. The VLBI data is processed as well as the tape data. This is a step to regular e-VLBI without tape shipping. Another successful international observation has been carried out with Finland. K5 2-Gbps observations were carried out with Metsahovi observatory. Software correlations are running at both site. Distributed correlation architecture utilize network bandwidth between the stations.

NOZOMI observation Satellite positioning by relative VLBI technique has become a strong demand to VLBI group in this decade. Positioning software and hardware package development is one of main mission in Kashima Radio Astronomy Applications group. In year 2003, series of experimental observations are carried out targeting NOZOMI spacecraft to Mars and initial VLBI positioning results were produced. Usuda 64m, Kashima 34m, Tsukuba 32m, universities telescopes and Algonquin joined these sessions. CRL group processed the data rapidly and ISAS NOZOMI operation group referred the results. The spacecraft finally completed its swing-by maneuver. After the NOZOMI, HAYABUSA spacecraft toward a minor planet needs same VLBI positioning technique. Accuracy and performance of this satellite positioning VLBI system is improving. Here the PC-based e-VLBI realized flexible numerical processing and data correlation too.

Pulsar, J-Net, VERA and other projects Long-term periodical observation of pulsars revealed the stability nature in Allan variance. Japanese domestic astronomical VLBI observation, J-Net increased ability with National Astronomical Observatory's VERA stations. Kashima 34m and Nobeyama 45m are requested to join their observations to boost sensitivity. Kagoshima university group carried out spectral observation at 22 GHz and 43 GHz.

5. Outlook and Technical Staff

As a VLBI station in network era, Internet bandwidth will become important infrastructure in advanced experiment. 10-Gbps access network to back-bone node is planned to be installed at Kashima Space Research Center. Engineering and Technical staff who take charge of Kashima 34m telescope are Eiji Kawai (leader of all operations and maintenance), Hiroshi Takeuchi (scientific engineer), Hiroo Osaki (software engineer), Hiromitsu Kuboki (RF and mechanical technician), and Yuki Watanabe, Yujiro Hirose (Contracter Rikei Corp., Vertex TIW). Tetsuro Kondo (kondo@crl.go.jp) is the supervisor of all Kashima 34m project.

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 various observations. In the year 2003, three geodetic VLBI sessions were performed to evaluate the performance of the K5 and Gigabit VLBI systems. Many observations were also performed to determine precise orbit of the Nozomi and Hayabusa spacecraft.

1. Introduction

The Key Stone Project (KSP) was a research and development project of the 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). 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 all of the process from the observations to the data analysis and by developing the real-time VLBI system using 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 public users immediately after each VLBI session. Improvements in the measurement accuracies were also accomplished by utilizing fast slewing antennas and by developing higher data rate VLBI systems operating at 256 Mbps.

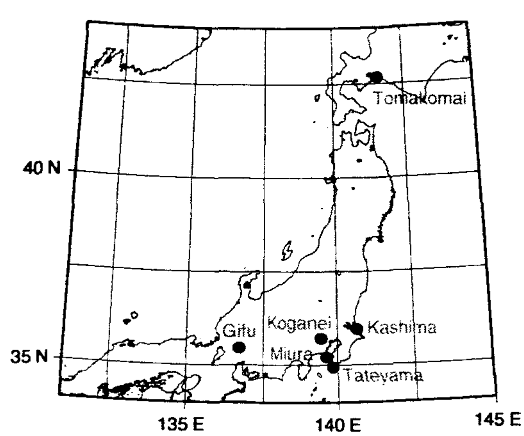

Figure 1. Geographic locations of four KSP VLBI stations and two stations at Tomakomai and Gifu.

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 various observations.

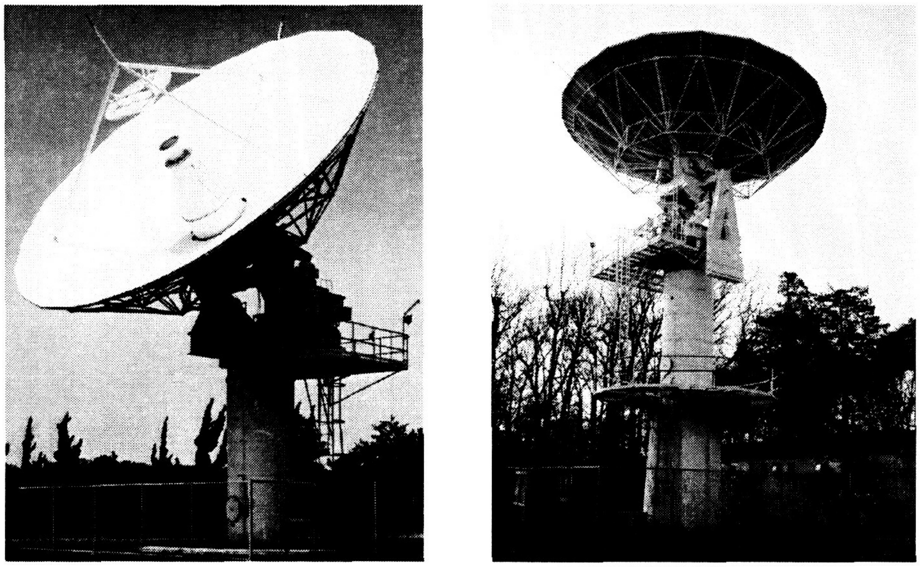

Figure 2. 11-m VLBI antennas at Kashima (Left) and Koganei (Right).

2. Activities in 2003

For technical developments, the baseline between Kashima and Koganei is now used as a test bed for IP-based real-time VLBI observations. The two stations used to be connected by high speed ATM (Asynchronous Transfer Mode) network with a collaboration with the NTT Laboratories until July 2003. The ATM connection was temporarily terminated and the two stations are currently connected at a maximum speed of 100 Mbps. The network is shared by the usual traffic of the Communications Research Laboratory and is an ideal technical test-bed for e-VLBI under the shared network environment which will be inevitable in connecting most VLBI sites in the world.

Regarding conventional geodetic VLBI experiments, four sessions listed in Table 1 were performed in 2003. The CUTE04 session was performed as a series of geodetic VLBI experiments to determine precise positions of the Tomakomai and Gifu VLBI stations. CUTE is the acronym of the CRL and University Telescopes Experiment. The observations were made with the K4 VLBI system at a data rate of 256 Mbps. GEX011 session was performed to evaluate the Gigabit VLBI system and observations were conducted for only six hours with Kashima 11-m and Tomakomai 11-m stations. The other two VLBI experiments were performed by using three different VLBI systems. In the U03031 session, the K5 VLBI system and the Gigabit VLBI system were used at Kashima and Koganei 11-m VLBI stations in addition to the K4 VLBI system. The JD0306 session is one of the routine domestic VLBI sessions conducted by Geographical Survey Institute

(GSI). 11-m VLBI stations at Kashima, Tomakomai, Gifu and 32-m VLBI station at Yamaguchi participated in the session in addition to the three GSI VLBI stations at Tsukuba, Chichijima, and Aira. The K5 VLBI system was used at five stations, i.e. Kashima, Tsukuba, Tomakomai, Gifu, and Yamaguchi in addition to the K4 VLBI system except for the Yamaguchi station where only the K5 VLBI system was used. At Kashima and Tomakomai stations, the Giga-bit VLBI system was also used in parallel. The results from these two sessions were compared between different systems and the expected performance of the K5 VLBI system and the Giga-bit VLBI system were confirmed [2].

Table 1. Geodetic VLBI sessions conducted in 2003.

Session	Date	Participating stations
U03031	January 31	Kashima (11-m and 34-m), Koganei (11-m), Usuda (64-m), Gifu (11-m), Tsukuba (32-m)
CUTE04	March 12	Kashima (11-m), Tomakomai (11-m), Gifu (11-m)
GEX011	July 15	Kashima (11-m), Tomakomai (11-m)
JD0306	July 16	Kashima (11-m), Tomakomai (11-m), Yamaguchi (32-m) , Gifu (11-m), Tsukuba (32-m), Aira (11-m), Chichijima (11-m)

The two 11-m stations at Kashima and Koganei were also used for VLBI observations of the spacecraft Nozomi and Hayabusa in 2003. Nozomi is the spacecraft of Japan Aerospace Exploration Agency (JAXA) launched in 1998 to explore the planet Mars, whereas Hayabusa is the spacecraft of JAXA launched in 2003 to explore the asteroid Itokawa. Since precise orbit determination of the spacecraft Nozomi was required before the final Earth swing-by in June 2003, VLBI observations of the spacecraft Nozomi were carried out. Many VLBI stations in Japan including the 11-m VLBI stations at Kashima and Koganei, and the VLBI station at Algonquin participated in the observations. In total, 34 VLBI sessions were performed in 2003. The spacecraft Hayabusa is expected to arrive at the asteroid Itokawa in 2005 and precise orbit determination of the spacecraft will be essential to make the mission successful. In 2003, several observations were made mainly to survey adequate celestial radio sources for differential VLBI observations to be used in the critical observations which will be performed in 2004 and 2005.

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, Communications Research Laboratory. The staff members of the group are listed in Table 2. The operations and maintenance of the 11-m VLBI station at Koganei is also greatly supported by the Optical Space Communications Group at Koganei Headquarters of CRL. We are especially thankful to Dr. Hitoshi Kiuchi and Dr. Yoshinori Arimoto for their support.

4. Future Plans

The current network connection between Kashima and Koganei is limited to a maximum speed of 100 Mbps, but the speed will be upgraded to 10 Gbps in April 2004. The connection from

Table 2. Staff members of Radio Astronomy Applications Group, KSRC, CRL

Name	Main Responsibilities
Tetsuto KONDO	Group Leader
Eiji KAWAI	Antenna System
Yasuhiro KOYAMA	International e-VLBI
Ryuichi ICHIKAWA	Spacecraft Orbit Determination
Junichi NAKAJIMA	High Data Rate VLBI System
Mamoru SEKIDO	Spacecraft Orbit Determination
Hiro OSAKI	International e-VLBI
Hiroshi TAKEUCHI	Antenna System
Moritaka KIMURA	High Data Rate VLBI System
Hiromitsu KUBOKI	Antenna System

Koganei to the TransPAC was upgraded to 1 Gbps in 2003. We are planning to perform e-VLBI observations under collaboration with Haystack Observatory by using the improved network connections.

The S/X receivers of the 11-m antenna at Tomakomai was removed to install the new 22 GHz receiver to the antenna system. As a result, CUTE sessions will only be performed with three VLBI stations at Kashima, Koganei, and Gifu. Instead, 22 GHz VLBI observations will be made with Kashima 34-m VLBI station and the Tomakomai 11-m VLBI station after the new 22 GHz receiver is installed on the Tomakomai station.

In 2004, we are planning to continue VLBI observations toward the spacecraft Hayabusa for its precise orbit determination. The use of phase delay measurements will be investigated to improve the accuracy and precision of the determination of the orbit.

Currently, the antenna system and the VLBI facilities are controlled by the automated VLBI observation system developed for the Key Stone Project. The system is running on the relatively old Unix operating system and we are planning to use FS9 in the future. As of January 2004, we have succeeded to control the antenna system from the FS9 software and we expect we can use the FS9 software for VLBI sessions at two 11-m VLBI stations at Kashima and Koganei in the future.

In April 2004, Communications Research Laboratory will be integrated with the Telecommunications Advanced Organization of Japan (TAO) and the new institute will be established. The name of the institute will be National Institute of Information and Communications Technology and the VLBI activities in the CRL will be continued under the new institute.

References

[1] Special issue for the Key Stone Project, J. Commun. Res. Lab., Vol. 46, No. 1, March 1999

[2] Koyama, Y., T. Kondo, H. Osaki, K. Takashima, K. Sorai, H. Takaba, and K. Fujisawa, IVS CRL TDC News, No. 23, Nov. 2003, pp. 26-30

Kokee Park Geophysical Observatory

Clyde A. Cox

Abstract

This report summarizes the technical parameters and the technical staff of the VLBI system at Kokee Park on the Island of Kauai. Included is an overview of the VLBI activities for the year 2003.

1. KPGO

Kokee Park Geophysical Observatory is located on the Island of Kauai in the Hawaiian Islands; Kauai is the most northwestern (inhabited) Island. The site is in a State Park (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.

S-2 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 a S-2 DAS. We have since that time supported the E-3 series of experiments on a monthly basis.

In May of 2002 Kokee Park received a Mark 5 system which 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 became a pleasure.

During November 2002 the 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.

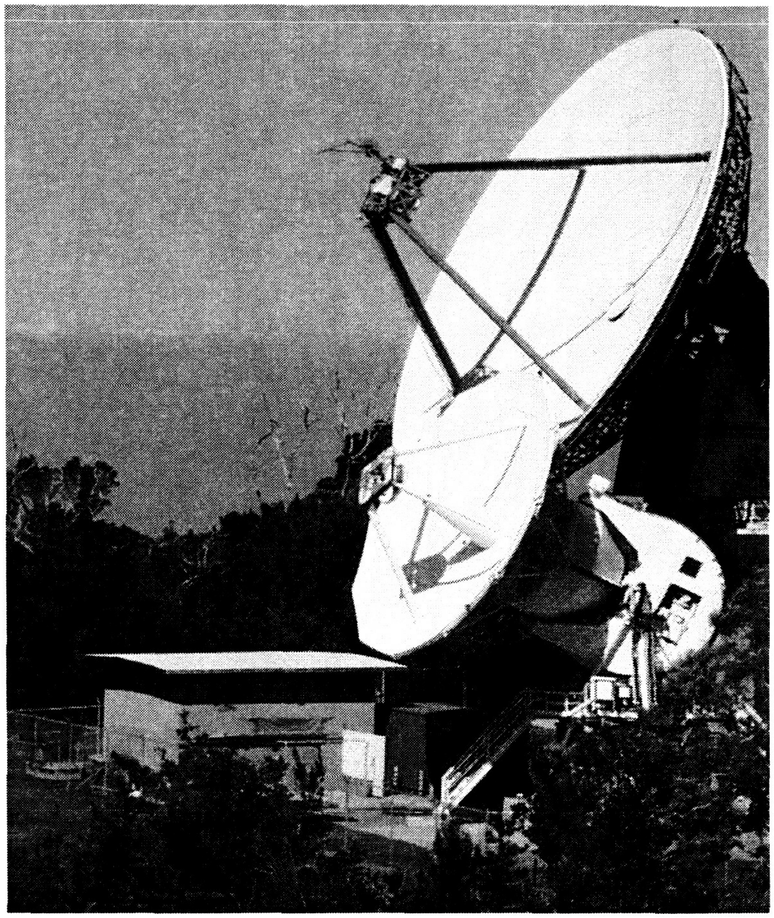

Figure 1. Kokee Park Geophysical Observatory 9m & 20m antennas.

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.

3. Technical Staff of the VLBI System at KPGO

The staff at Kokee Park consists of six people who are employed by Honeywell under contract to NASA for the operations and maintenance of the Observatory. VLBI operations are conducted by Kelly Kim, Matt Harms, and Kawika Fujita.

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 2003.

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

e-VLBI was expected to make its debut during the first part of 2003. However, we are delayed due to the common "last Mile" problem. Now with the year starting we are seeing light at the end of the tunnel, tests are starting to show a transfer rate of up to 85 Mbps (using UDP) to Haystack.

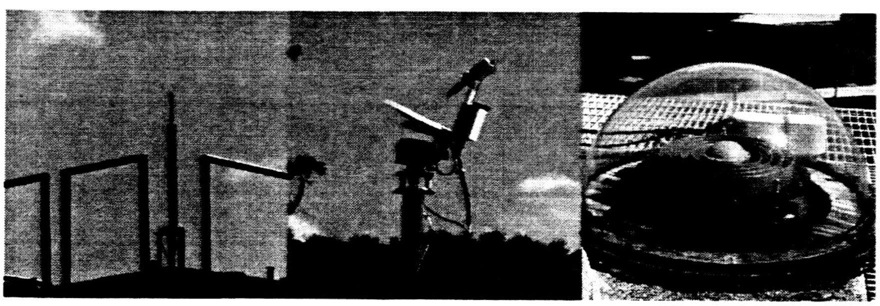

Figure 2. Kokee Park also hosts other systems; DORIS Beacon, PRARE, and IGS (GPS).

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	$0 \ldots 540°$
azimuth velocity	$2°/s$
azimuth acceleration	$1°/s^2$
elevation range	$0 \ldots 90°$
elevation velocity	$2°/s$
elevation acceleration	$1°/s^2$
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-MARK5
recording media	thin-tape only
Field System version	9.6.9

Matera CGS VLBI Station

Giuseppe Colucci, Domenico Del Rosso, Luciano Garramone

Abstract

This report summarises the VLBI activities performed at the Matera VLBI station[1]. Also an overview of the technical characteristics of the system and some staff addresses will be given.

1. General

The Matera VLBI station is located at the Italian Space Agency "Centro di Geodesia Spaziale" (CGS) near Matera, a small town in the South of Italy. The CGS came into operation in 1983 when

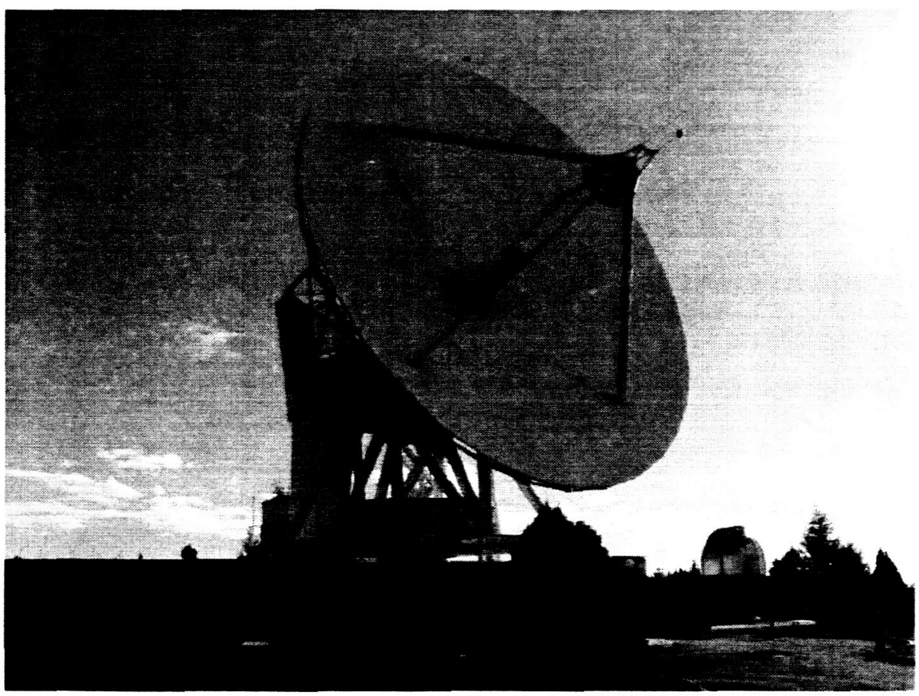

Figure 1. The Matera "Centro di Geodesia Spaziale" (CGS)

a Satellite Laser Ranging SAO-1 System was installed at CGS. Fully integrated in the worldwide network, SAO-1 has been in continuous operation from 1983 up to 2000, providing high precision ranging observations of several satellites. The new Matera Laser Ranging Observatory (MLRO), the most advanced Satellite and Lunar Laser Ranging facility in the world, has been installed in 2002 and has 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 634 sessions up to December 2003. In 1996 the receiver was upgraded to standard wideband and at the end of 1999 a Mark IV formatter and decoder were installed by MIT Haystack.

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 15 other stations in Italy, are archived and made available by the CGS WWW server GeoDAF (http://geodaf.mt.asi.it).

Thanks to the colocation of all precise positioning space based techniques (VLBI, SLR, LLR, GPS and PRARE), 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 in remote sensing activities for present and future missions (ERS-1, ERS-2, X-SAR/SIR-C, SRTM, ENVISAT).

2. Technical/Scientific

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 summarised in Table 1.

The Matera time and frequency system is composed 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 9.6.9.

Table 1. Matera VLBI Antenna Technical Specifications

Input frequencies	S/X	2210 MHz to 2450 MHz / 8180 MHz to 8980 MHz
Noise temperature at dewar flange	S/X	<20 K
IF output frequencies	S/X	190 MHz to 430 MHz / 100 MHz to 900 MHz
IF Output Power with 300 K at the input 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
Ing. Luciano Garramone	ASI	VLBI Manager	luciano.garramone@asi.it
Domenico Del Rosso	Telespazio	Operations Manager	domenico_delrosso@telespazio.it
Giuseppe Colucci	Telespazio	VLBI contact	giuseppe.colucci@asi.it

4. Status

Table 3 summarizes the sessions performed during 2003. Figure 2 shows the summary of acquisition up to December 2003 in terms of hours of acquisition. During this year, mainly 2 problems afflicted the VLBI acquisition at Matera.

- Up to February 3 (R1056), no fringes were found on Matera tapes. Cause was traced to a problem with the GPS receiver used to measure the formatter time. After the problem was identified, R1055 session (January 27) was included in the correlation and fringes were found.

- In Semptember and October, Matera did not observe due to a severe problem discovered on the antenna rail. Acquisition restarted after a temporary fix.

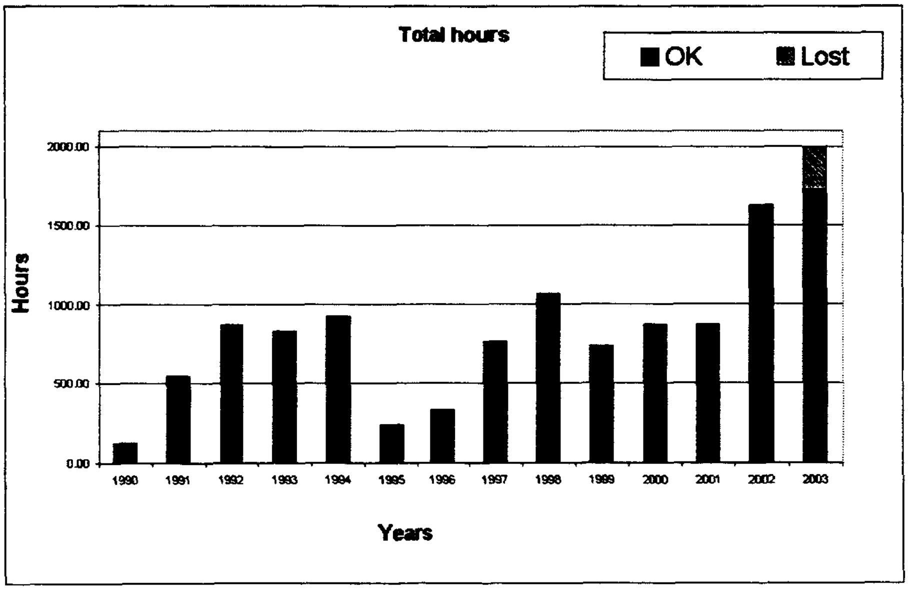

Figure 2. Summary of acquisition from May 1990 to December 2003

5. Outlook

In first months of 2004, Mark 5 recorder will be installed. Seven disks pack modules have been purchased to be included in the IVS pool.

Heavy work on the antenna rail will be planned to definitively fix the rail problem.

Table 3. Summary of sessions

Month	IVS-R1	IVS-R4	UVS-T2	RDV	EUROPE	TOTAL
January	3 (2-lost)	2 (2-lost)				5
Februar	3 (1-lost)	2				5
March	5	4	1	1	1	12
April	3	3	1			7
May	4	2		1	1	8
June	4	4		1		9
July	4	2		1		7
August	4	2				6
September	3 (1-lost)	2 (1-lost)		1 (1-lost)	1 (1-lost)	7
October	2	1				3
November	4	2				6
December	5 (2-lost)	1		1	1	8
TOTAL	**44**	**27**	**2**	**6**	**4**	**83**

References

[1] G.Colucci, D.Del Rosso, E.Lunalbi, M.Paradiso: "Matera VLBI Station Report on the Operational and Performance Evaluation Activities from January to December 2003", available soon at this address: http://geodaf.mt.asi.it/html/surv_rep.html

The Medicina Station Status Report

Alessandro Orfei, Franco Mantovani, Pierguido Sarti

Abstract

The activities done at the Medicina radio astronomy station are briefly summarized. Those activities were mainly related to the geodetic VLBI observations and to the upgrading of the 32-m dish.

1. Main Activities at the Medicina Station

The activities at the Medicina Station were mainly addressed to improve the data acquisition quality. Most of the upgrading work was done in the electronic hardware and to improve the efficiency of the 32-m dish. Great care was also taken to increase the reliability of the station during VLBI sessions.

1.1. The Upgrade of the 32-m Dish

The Medicina 32-m dish has been heavily upgraded during Summer 2003. A new antenna servo system has been installed. This uses modern components and digital electronics. A higher degree of reliability and less maintenance interventions are expected. The software developed for pointing and traching of the antenna has been adapted to the new system.

All the cables routing on the antenna were changed after over 20 years of the antenna observing activities. Together with usual metallic wires, high quality coaxial cables were installed together to several fiber optics links.

The vertex cabin was fully renewed. A completely new mechanical structure was installed to allow the allocation of many receivers at the same time as part of a long term plan to achieve full frequency agility of the telescope. This is the second step of that plan, which is related to the secondary focus of the antenna. In the first step, a robotic system was implemented to shift the secondary mirror of the telescope under computer control. The same system also allowed the shift of the primary focus receiver box which hosts the 22 GHz, S/X and 1.6 GHz receivers. Moreover, a new control hardware was installed in order to check housekeeping data coming from the receivers and allowing the switching among receivers hosted in the secondary focus receiver cabin.

1.2. The Mark 5 recording system

The prototype version of the new Mark 5 system, delivered in 2002 from Haystack, was upgraded to Mark 5A. The present status of the Mark 5 system looks fine. Many tests were done with good results. One of the tests implied the transferring of data from the Bologna gate of the backbone to the JIVE Correlator in Dwingeloo, via the high data rate GARR/GEANT network.

Disks and disks enclosures were acquired. Four (4) modules are available now with 8×120 GB disks each and 4 modules with 8×250 GB disks are going to be assembled. Twenty more empty modules are available at the station ready to be filled with disks.

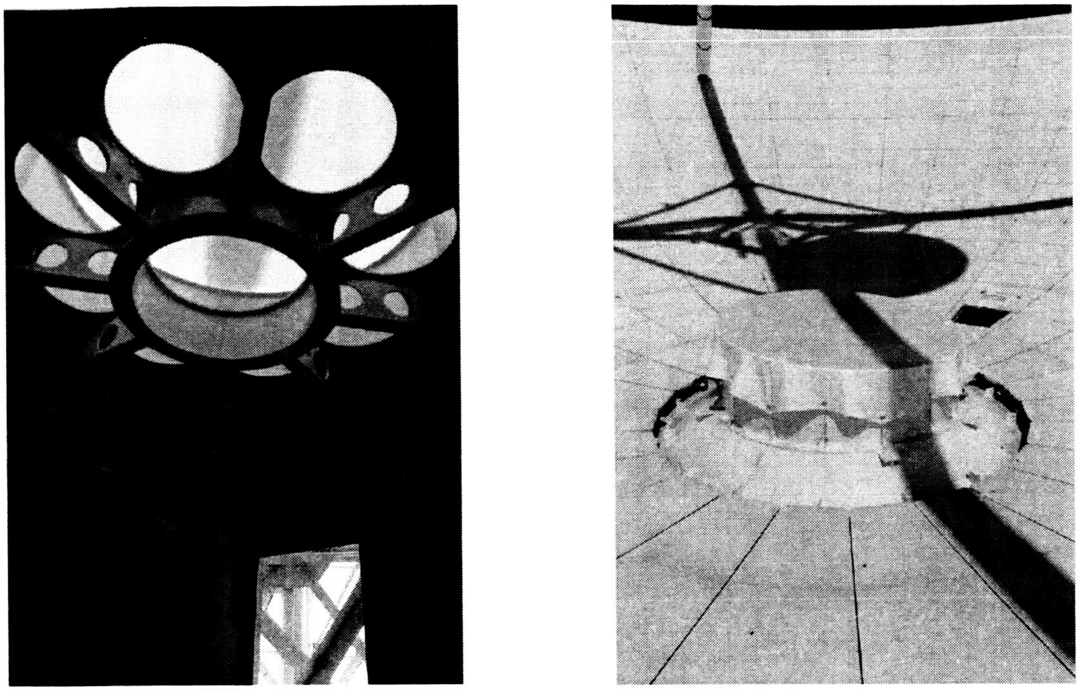

Figure 1 – *Left*: View of the cover of the vertex room. Eight receivers can be permanently mounted, one for each of the external holes. The hole on-axis will host receivers under test. *Right*: View of the top of the vertex room.

1.3. Development of Control Software

In-house codes have been written to keep under control the status of the Mark 5 operations. The new software is under test at the moment.

On request of the European VLBI Network Technical Operation Group, a dedicated software is under development to keep under control the recording tracks of the Mark 4/Mark 5 systems. As soon as the software is ready, it will be made available to the EVN stations and to any interested IVS station on request. A beta version is available and under test.

1.4. Geodetic Activities

a) VLBI Observations

During 2003, the Medicina 32-m dish has taken part in 10 geodetic VLBI observations namely IVS–T, RDV and EUROPE projects. Due to delays in the upgrading, the antenna could not observed during three sessions in September 2003 as originally scheduled. One more project was skipped by the IVS Coordinating Center in December.

b) Local Survey

In September 2003 the VLBI Reference Point (RP) in Medicina has been surveyed for the fourth time. It has also been the third determination of the IGS-GPS RP and consequently of the GPS-VLBI eccentricity. A method based on Classical Geodesy measurements for determining eccentricities between co-located space geodesy techniques has been developed and tested on the data acquired during the three surveys (Sarti et al. 2004). In Table 1 eccentricity values for the three surveys expressed in a local frame are shown. The variability of the yearly estimated

Table 1. Local tie

Eccentricity	2001	2002	2003
XVLBI(m)	45.5356±0.0003	45.5360±0.0002	45.5348±0.0001
YVLBI(m)	21.5805±0.0004	21.5825±0.0003	21.5764±0.0001
ZVLBI(m)	17.6995±0.0008	17.7024±0.0006	17.7003±0.0003
XGPS (m)	29.9692±0.0010	29.9692±0.0008	29.9840±0.0003
YGPS (m)	79.9215±0.0011	79.9268±0.0006	79.9209±0.0003
ZGPS (m)	0.5699±0.0008	0.5701±0.0005	0.5684±0.0003

coordinates of both endpoints of the eccentricity vector suggests an instability of the pillars used to define the local frame. This latter is defined fixing its planimetric origin on pillar P3 (recently assigned IERS DOMES number: 12711M006) while its altimetric origin is fixed on pillar G7. Only two other pillars (P1 and P2 with IERS DOMES numbers 12711M004 and 12711M005, respectively) establish the local ground control network. In Table 2 coordinates of markers P1, P3 and G7 obtained adjusting terrestrial observations acquired during 2001, 2002 and 2003 surveys are shown.

Table 2. Survey

Coordinates	2001	2002	2003
XP1(m) (fixed)	0.0	0.0	0.0
YP1(m)	42.6586±0.0002	42.6628±0.0002	42.6636±0.0002
ZP1(m)	2.0772±0.0003	2.0783±0.0003	2.0772±0.0002
XP3(m) (fixed)	0.0	0.0	0.0
YP3(m) (fixed)	0.0	0.0	0.0
ZP3(m)	2.0195±0.0003	2.0177±0.0003	2.0154±0.0003
XG7(m)	6.1261±0.0005	6.1309±0.0002	6.1386±0.0003
YG7(m)	72.7897±0.0006	72.7924±0.0002	72.7907±0.0003
ZG7(m) (fixed)	0.0	0.0	0.0

It is therefore urgent to enlarge the local ground control network adding properly positioned pillars so as to ensure a high stability of the local frame. This activity has been planned for spring

2004 when at least three new triplets of pillars will be added to the local network. A detailed geological survey is also scheduled in order to complete the relevant set of information regarding the stability at the observatory and distinguish between local scale and large scale movements. Considerations on local soil characteristics suggest the use of triplets of 22 meters long micro pillars so as to ensure a reliable three-dimensional framing of the eccentricity.

References

[1] Sarti P., Sillard P., Vittuari L., 2004. Surveying co-located Space Geodesy techniques for ITRF computation. Journal of Geodesy, in press.

Noto Station Activity

G. Tuccari, C. Stanghellini, S. Buttaccio

Abstract

The most important achivements at the Noto station are presented and a status is shown about developments and future plans.

1. Station Activity and Upgrade

1.1. Antenna

The new driving system is now fully operative and a few firmware problems shown by the system have been fixed. A replacement of the antenna control software is now in a testing stage, it will operate within the Field System PC, taking advantage of the finer control now possible with the new ACU.

A correction algorithm acting on the primary mirror active surface has been introduced, to correct the deformations present in the secondary mirror. This correction improves the efficiency for the highest available bands: 22, 43 and 86 GHz.

1.2. Receivers and Microwave Technology

The cooled multifeed SXL receiver, even if completed, suffered for a complex vacuum problem, that delayed its use. Indeed, the large vacuum box chamber, about 800 mm wide on each side, presented a long term leakage due to microscopic fractures on the surface. The problem was solved making use of a particular covering material. Now the receiver is going to be reassembled and hopefully, it will be in use before the summer.

A 86 GHz receiver was kindly given to the Noto station on permanent loan by MPI Bonn. This primary focus receiver has been adapted to be placed in the antenna with a full remotely controlled positioning system. In the first months of 2004, the active surface will be adapted to optimize the efficiency at this 3 mm band.

A new 5 cm receiver is available for VLBI and single dish observations.

A new VHF-UHF receiver has been built, covering the range 250 - 600 MHz, and 600 - 1200 MHz. It will be used primarily in EVN observations.

1.3. Acquisition Terminal and Digital Technology

The Mark 5A recorder has been installed and tested at 256, 512, 1024 Mbit/s; four packs with 8 disks are already available and the acquisition of further packs is expected during the year, in order to switch as soon as possible to disk only recording.

A digital base-band converter prototype with wide and narrow band channels is under development. The full project, financed by the EVN, is expected to provide in two years, a fully digital system to be used with Mark 5 recorder or e-net connection through VSI interface. The first experimental tests will be performed during 2004.

2. Geodetic Experiments in Noto during 2003

During 2003 the Noto radiotelescope participated to the following geodetic experiments: EURO67 (25 MAR), EURO68 (06 MAY), CRF18 (13MAY), T2021 (16 SEP), T2022 (14 OCT), CRF24 (8DEC), EURO70 (16DEC). Noto participated also in EURO69 experiment (23SEP) but data did not show fringes during correlation.

NYAL Ny-Ålesund 20 Metre Antenna

Helge Geir Digre

Abstract

For the year 2003, the 20-meter VLBI antenna at the Geodetic Observatory, Ny-Ålesund has participated in VLBI experiments at the scheduled level, except for the period 12th of June to 19th of June, when the Observatory was closed to avoid possible SARS contamination. Maintenance and repair have been done. There have been temporary changes in staff. Ny-Ålesund's status as an EU Large Scale Facility site has not been renewed by EU.

1. General Information

The Geodetic Observatory of the Norwegian Mapping Authority at 78.9 N and 11.87 W is located in Ny-Ålesund, in Kings Bay at the west side of the island Spitsbergen, the biggest island in the Svalbard archipelago. In 2003, Ny-Ålesund was scheduled for 69 VLBI experiments within R4, R1, EURO, VLBA/RDV, RD, T2 and ICRF. In addition to the 20-meter VLBI antenna, the observatory has two GPS antennas in the IGS system and a Super Conducting Gravimeter is installed on the site. On the site, there is also a CHAMP GPS and a PRARE installation. The LaCoste-Romberg has been removed from Ny-Ålesund. The place Ny-Ålesund was an EU Large Scale Facility from 1997 to 2002. EU did not renew the LSF status for 2003. Ny-Ålesund Geodetic Observatory was closed down from 12th of June to 19th of June. The director of Kings Bay had invited Chinese visitors from Beijing, who arrived in Ny-Ålesund before the 10 days incubation period for SARS was through. There has been a change of director in Kings Bay this summer, so it is very unlikely that something like this happens again under the new director.

2. Component Description

The antenna is intended for geodetic use, and is designed for receiving in S- and X- band. The equipment was all Mark 4 until late in the autumn, when it was upgraded with a Mark 5A unit. Station configuration file: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 this location of the antenna makes it possible to receive 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

The head of the division needed Vidar Eggimann at the main office in Hønefoss for the rotation period from July until November. As replacement, Kari Buset and Tom Pettersen worked about one month each on the Observatory during this 4-month rotation period. David Holland went on sick leave at the end of his first period and is still on sick leave. To be able to do the scheduled experiments in the rotation period starting the 1st of November, Leif Morten Tangen stayed a bit longer in November, and Svein Rekkedal came up for a week in mid-December.

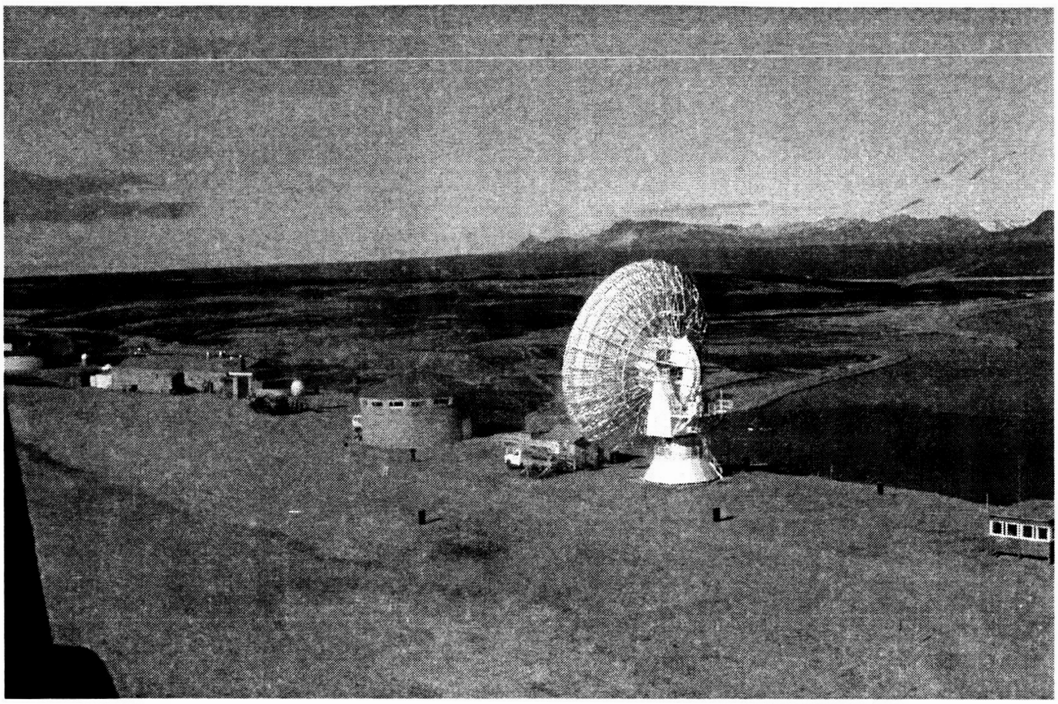

Figure 1. **Ny-Ålesund 20 meter antenna**

Table 1. Staff related to the operation of the VLBI in Ny-Ålesund.

Hønefoss:	Section manager:	Rune I. Hanssen	
	Station responsible, Hønefoss:	Svein Rekkedal	
Ny-Ålesund:	Station commander:	Leif Morten Tangen / Helge Digre	
	Engineers:	Vidar Eggimann / David Holland	
	Engineer:	Sune Elshaug	
	Rotation group:	Kari Buset	(07.2003)
		Tom Pettersen	(09.2003)

4. Current Status and Activities

Ny-Ålesund has participated in VLBI experiments at the scheduled level, except for the period 12th of June to 19th of June, when the Observatory was closed to avoid possible SARS contamination. Because of this, Ny-Ålesund did not participate in 4 experiments, while the 5th was moved until later in the year. There have been some problems with inert gases, causing the cold head failure. The transport time for the replacement cold head has caused that experiments have been run with warm receiver. Ny-Ålesund's status as an EU Large Scale Facility site has not been renewed by EU, so there have been no LSF funded scientists visiting the site in 2003. The temporary installed (1996) LaCoste-Romberg gravimeter has been removed from the bunker where it was mounted, and has been returned to the main office in Hnefoss. The Super Conducting Gravimeter placed on the same fundament as IGS-GPS NYA1, has been running without any problems. This year, PRARE has been more and more unstable and work consuming. From this spring, weekly re-booting has been necessary to keep it running. At the end of the year, it would not run at all any more. The back up from Germany has been very limited since this summer. The "cherry-picker" has got new hydraulic hoses all over, so hopefully, it can be re-certified next year. Its hydraulic pump is electrically driven. In winter, it is much quicker to use then the diesel driven alternative.

Ny-Ålesund has bought and installed Mark 5A. After successfully running one experiment recording on tape and using Mark 5 in "piggyback-mode", Ny-Ålesund is running Mark 5A on all experiments except the ones correlated at Socorro. The Mark 5 system has been fully tested and is proved able to record with the highest possible data rate.

The 5-year contract for lease of ground and community services with Kings Bay AS has been renewed. The Ministry of Environment funds the Norwegian Mapping Authority (NMA). For 2004, there will be cutbacks again. As a part of the process of reducing costs, one of the suggestions from NMA was to temporary close down the Geodetic Observatory for an undecided period of time, something NMA meant should be easy to do because all employees are on time limited contracts. The Ministry of Environment did not accept any close down, so as far as known today, the Geodetic Observatory in Ny-Ålesund will be running in 2004.

5. Future Plans

Ny-Ålesund will continue to participate in the experiments the antenna is scheduled for, and will try to make it possible to increase the number of yearly experiments. The SCG has to be refilled with liquid Helium each year, and the lift has to be re-certified every year. Hopefully it will be possible to have the "cherry-picker" re-certified. The Maser is up for the bi-annual service check in 2004. Also, it is 2 years since the inner and outer reference systems were checked, so this should also be done again in 2004.

Ny-Ålesund reduced the number of experiments from 2002 to 2003. The main reason for this was all the problems and the consequences of the problems in 2002. From the middle of November to the end of January, Ny-Ålesund has the Polar Night and is without any daylight. In 2002, January was one of the months that year with most experiments. With trouble during the Polar Night, everybody became really aware of the fact that the Observatory is located at almost 79°N. What was learned the hard way then was that breakdowns in winter ought to be avoided, as it is difficult to do repair work outdoors during the Polar Night.

This resulted in the following conclusions: Continue the work on improving the maintenance and repair procedures, aiming for achieving only planned downtime. Try to get or build "Module-based" replacement "bottle-neck" sections to reduce downtime. On the location there ought to be spare modules containing known critical parts, so the whole module could be taken out for repair, while the spare is mounted. Then the module with the defective part should be repaired, serviced and tuned indoors in the workshop while the antenna is up and ready again after a short stop because the spare module is installed. Critical spare parts should be located in Ny-Ålesund to avoid downtime and extra repair time caused by transportation time.

German Antarctic Receiving Station (GARS) O'Higgins

Wolfgang Schlüter, Christian Plötz, Walter Schwarz, Reiner Wojdziak

Abstract

In 2003 the German Antarctic Receiving Station (GARS) in O'Higgins contributed to the IVS observing program by dedicated obervation sessions. Mark 5 system has been integrated. Steps have been undertaken to conduct remote control operations in the next future.

1. General Information

The German Antarctic Receiving Station is jointly operated by the Federal Office of Cartography and Geodesy (BKG), the German Aerospace Center (DLR) and the Institute for Antarctic Research Chile (INACH).

The 9m radiotelescope at O'Higgins is used for geodetic VLBI and for remote sensing purposes. Access to the station is organized only campaign-wise during the Antarctic spring and summer from November to March. DLR and BKG jointly send engineers and operators for the campaign together with a team which maintains the infrastructure such as the provision of power etc: Special flights with small Twin Otter 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 Island Frey to the station O'Higgins on the Antarctic Pensinsula. Conditions and time schedule are unpredictable and require a lot of security precautions. Arrival time and departure time is strongly dependent on the weather conditions and the general logistics.

After the long Antarctic winter usually the equipment has to be initialised and damages have to be identified and repaired. Shipping of spare parts or upgrade material from Germany needs careful preparation in advance, but nevertheless the arrival of material in O'Higgins is mostly delayed. The station is ready for operation usually just at the last minute before a session is planned to start. This requires flexibility not only from the staff but also from those colleagues who prepare the schedule and from the staff of the collaborating stations.

Beside the 9m radiotelescope for VLBI, the site has:

- two GPS receivers, a TURBO Rogue (OHIG), which has a long and stable history and one Ashtech Z18 receiver, capable for GPS and GLONASS tracking. The Ashtech will be replaced by a JAVAD receiver during the summer campaign 2004.
- a PRARE station for the ERS2 tracking, which unfortunately failed due to lack of spare parts, in particular due to cable problems. The cable could not be repaired successfully nor replaced during the October-December campaign 2003.
- a tide gauge, which has operated several years with some interruptions caused by destroyed cables from ice scratching 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.

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

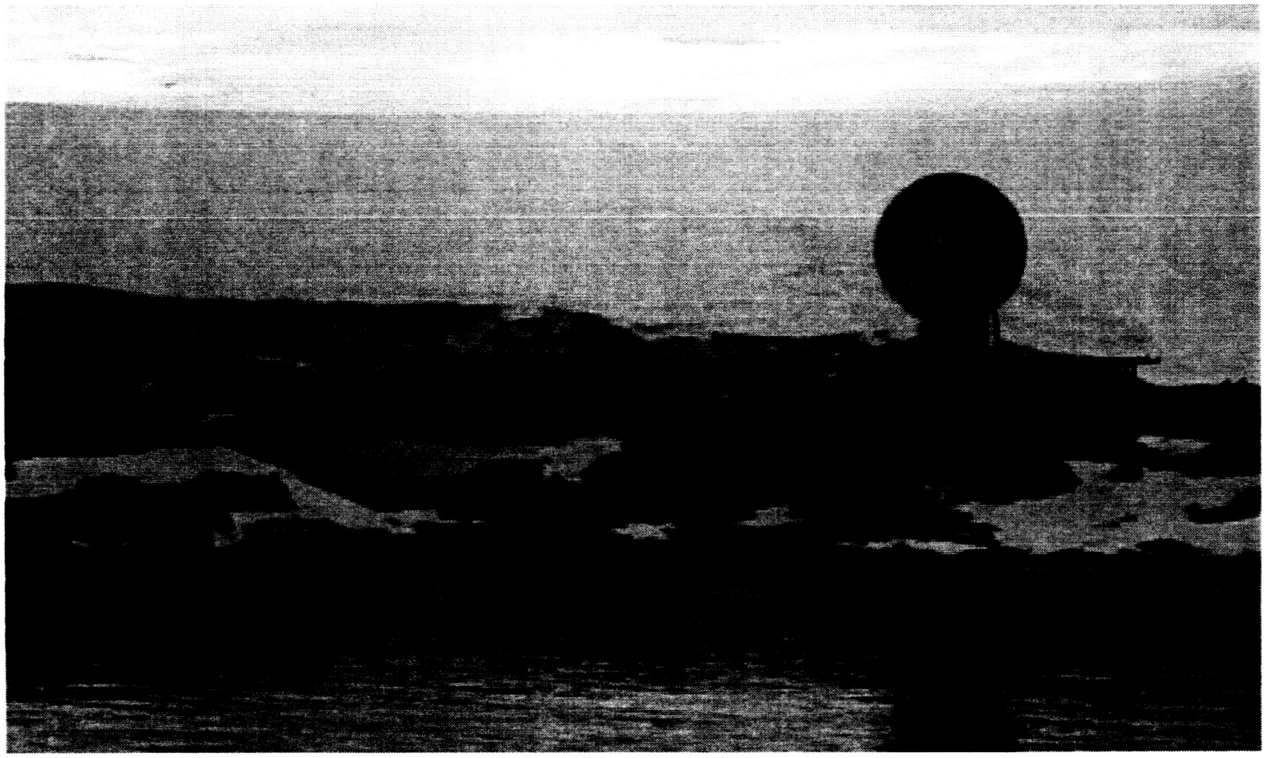

Figure 1. GARS O'Higgins

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

2. Technical Staff

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

3. Observations in 2003

During the Antarctic summer campaign (January/February 2003) and during the Antarctic spring campaign (November-December 2003) GARS participated in the following sessions of the IVS observing program:

- 5 sessions during the period January - February (OHIG 23, OHIG24, OHIG25, T2013 and T2014)
- 5 sessions during the period November- December (OHIG26, OHIG27, O'HIG 28, T2023 and T2024),
- the Vienna Students Project, which was carried out November 27, 2003.

Due to logistic requirements the observers were forced to leave O'Higgins one week earlier in December than planned, right after the last VLBI session. The tapes were packed in a container which should be shipped from O'Higgins to Punta Arenas immediately after they left. Unfortunately problems to load the container onto a Navy ship caused a delay of shipping the tapes from O'Higgins to Punta Arenas, from where they usually were sent via courier to Wettzell.

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, Data Center Leipzig
Walter Schwarz	BKG	electronic engineer	RTW, O'Higgins
Gerhard Kronschnabl	BKG	electronic engineer	RTW, O'Higgins (partly)

4. Maintenance

The extreme conditions in the Antarctic requires maintenance and repair of the GARS telescope and of the infrastructure. We have to consider the effect of corrosion; problems with connectors and capacitors need to be detected; H-Maser has to set up into operation mode; antenna, S/X-band receiver and the data acquisition system has to set up properly. Conditions outside the containers are sometimes very extreme due to the temperature and in particular the speed of wind, which reached 160 km/h in December 2003. Up to 250 km/h has been observed during previous campaigns.

Those components which were damaged during the previous campaign usually have to be replaced. During this period the device to measure the speed of wind was completely replaced.

5. Technical Improvements

The transition from the Mark IV to the Mark 5A has been successfully performed. Two Mark 5A system were available. Both have been prepared for use in Antarctica ahead of time at the Fundamentalstation Wettzell, in order not to be faced with severe problems in O'Higgins. One system has been shipped to GARS and is already installed. The second system still remains in Wettzell for further development.

A new computer has been prepared and modified to implement the new Field System version. Due to interface problems with a board the Field System and the new PC could not be finally integrated in GARS. The problem will be solved by a replacement of the board during the campaign at the beginning of 2004.

For the planned remote control of GARS, more power and a more reliable power system is required. A new power generator including UPS is on the way to O'Higgins. The system will arrive in O'Higgins in February 2004 and will be set up also in the first campaign 2004.

All computers for operating the geodetic devices and all servers need a replacement with the new PC generation, as they were worn out and caused failures. An Internet link via satellite to Santiago with 128 kbps has been established. The link allows regular data transfers and telephone communication. The link will be the basis for the remote control.

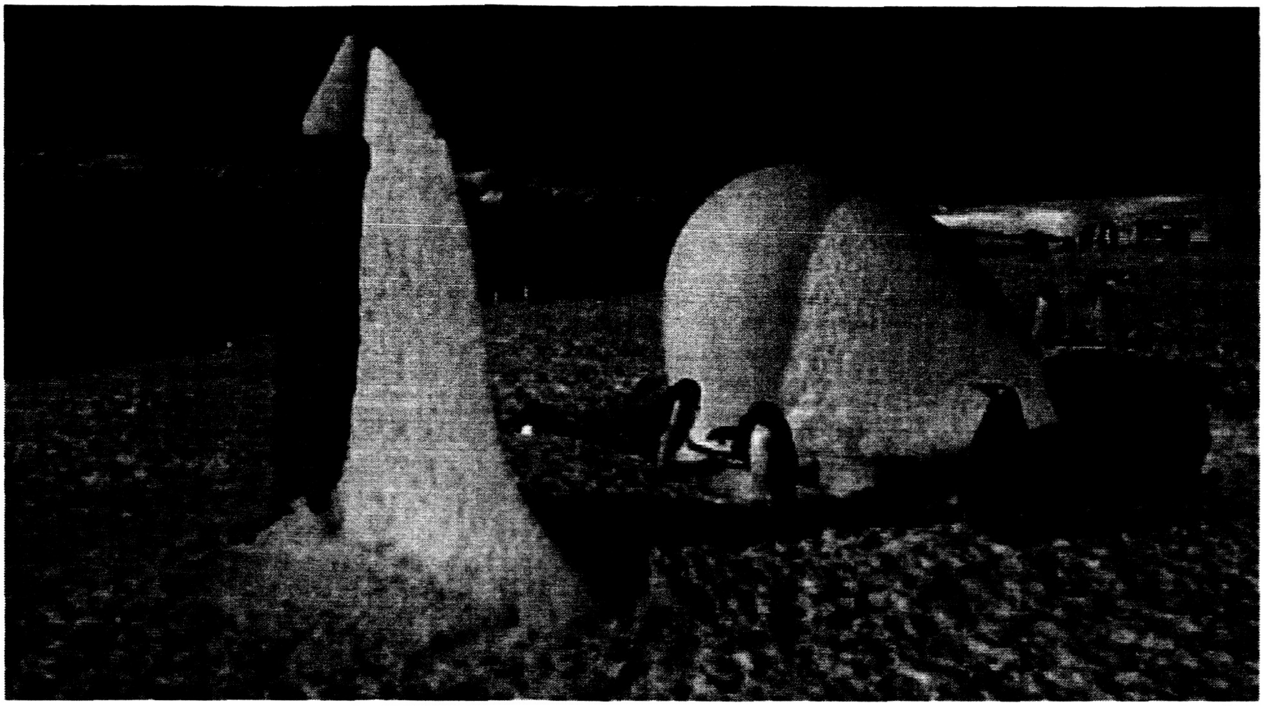

Figure 2. View from the telescope to the Ashtech GPS antenna and to the radome for the Turbo Rogue antenna.

6. Upgrade Plans for 2004

During 2004 it is planned to replace the Field System computer, to test the Mark 5, to replace the worn out power station by a stronger one which will be capable to provide enough power during unmanned periods. All these steps are required for the establishment of remote control capabilities, which will be prepared and tested for geodetic VLBI as well as for the acquisition of remote sensing data in 2004.

Some restoration work will be done, in order to maintain the antenna as corrosion has to be prevented.

The IVS Network Station Onsala Space Observatory

Rüdiger Haas, and Gunnar Elgered

Abstract

We summarize briefly the status of the Onsala Space Observatory in its function as an IVS Network Station. The activities during the year 2003, the current status, and future plans are described.

1. Overview

The IVS Network Station at the Onsala Space Observatory (OSO) has been described in earlier IVS annual reports, e.g. [1], [2] [3] [4].

During 2003 a number of maintenance and upgrade activities were performed at Onsala. The Russian Kvarz maser was serviced, amplifiers of the telescope azimuth encoders were exchanged, the VLBI system was upgraded to Mark 5A, and the observatory was connected by a 1 Gbit/s optical fibre link to the Swedish Internet backbone.

2. 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 earlier, e.g. in [1]. However, Lubomir Gradinarsky finished his Ph.D. and left the observatory, while two new Ph.D. students, Camilla Granström and Tobias Nilsson, started to work at the observatory during 2003.

Table 1. Staff associated with the IVS Network Station at Onsala. All e-mail addresses end with @oso.chalmers.se, the complete telephone numbers start with the prefix +46-31-772.

Function	Name	e-mail prefix	telephone extension
Responsible P.I.s	Gunnar Elgered	kge	5565
	Rüdiger Haas	haas	5530
Ph.D. students involved in VLBI observations	Sten Bergstrand	sten	5566
	Camilla Granström	camilla	5566
	Martin Lidberg	lidberg	5578
	Tobias Nilsson	tobias	5575
	Borys Stoew	boris	5575
Field system responsibles	Biörn Nilsson	biorn	5557
	Michael Lindqvist	michael	5508
VLBI equipment responsibles	Karl-Åke Johansson	kaj	5571
	Leif Helldner	helldner	5576
VLBI operator	Roger Hammargren	roger	5551
Telescope scientists	Per Bergman	bergman	5552
	Lars Lundahl	lundahl	5559

3. Geodetic VLBI Observations During 2003

During 2003 the observatory has been involved in the four regular VLBI-experiment series EUROPE, IVS-R1, IVS-T2, and RDV. In total OSO was scheduled to participate in 18 geodetic VLBI experiments during 2003 (see Table 2).

Table 2. Geodetic VLBI experiments at the Onsala Space Observatory during 2003.

Exper.	Date	Remarks (problems)	Exper.	Date	Remarks (problems)
RDV-37	03.12	o.k., S-band RFI	T2-020	08.12	o.k.
R4-062	03.13	o.k.	R4-084	08.14	o.k.
EURO-67	03.25	o.k.	T2-021	09.16	o.k.
EURO-68	05.06	o.k., encoder problems	RDV-41	09.17	o.k., RFI in Channel 4 X-band
RDV-38	05.07	o.k., S-band RFI	EURO-69	09.23	o.k., first Mark 5A experiment!
RDV-39	06.18	o.k., S-band RFI	T2-022	10.14	o.k., second Mark 5A experiment
RDV-40	07.09	o.k., S-band RFI	R4-093	10.16	o.k., encoder problems
R4-082	07.31	o.k.	EURO-70	12.16	not correlated yet
R4-083	08.07	o.k.	RDV-42	12.17	not correlated yet, encoder problems

Most of the experiments were observed without problems. However, during some of them we unfortunately had technical problems with the telescope's azimuth encoders that caused loss of observational data. In EURO-68 we lost the first 9 scans and later during the experiment nearly 2 hours. During R4-093 about 45 minutes of observations were lost, and during RDV42 two hours of observations were lost due to the encoder problems.

Radio interference in S-band due to UMTS mobile telephone signals was a disturbing factor in 2003 causing disturbing peaks in the band-pass. Many correlation reports mentioned explicitely the radio interference. Also radio interference in X-band was reported for RDV-41.

The two first experiments recorded with the new Mark 5A system at Onsala were EURO-69 and T2-022. Both experiments were correlated successfully.

4. Maintenance and Upgrade of the Onsala VLBI System

During 2003 the VLBI equipment at Onsala was maintained and upgraded, see Table 3 for an overview. The highlights are the installation of a Mark 5A unit and the connection to the Swedish Internet backbone by an optical fibre link with 1 Gbit/s capacity.

The Mark 5A unit was installed at the observatory in August. After thorough testing of the equipment the first VLBI experiment with Mark 5A was EURO-69 recorded on September 23. The data were correlated succesfully at the Bonn correlator. In December 2003 five Mark 5A units were assembled at the observatory and are now dedicated to the IVS disk pool. These Mark 5A units are equipped with 8 disks of 160 Gigabyte each.

In November the Mark 5A unit was connected to the Swedish internet backbone with an optical fibre link of a capacity of up to 1 Gbit/s. The Mark 5A unit had to be upgraded to be able to handle this data rate. First tests sending data have been perfomed.

The calibration of the Onsala pressure sensor using a reference barometer provided on a long term loan by the Swedish Meteorological and Hydrological Institute (SMHI) was continued throughout the year 2003. The largest offset observed between the two sensors was 0.5 hPa

[5].

Table 3. Maintenance and upgrade work of the Onsala VLBI system during 2003.

February	Maintenance of Onsala's Kvarz maser and exchange of the disociator.
April	Installation of a new temperature and humidity sensor at the NASA weather station and installation of new cables.
August	Installation and tests of Mark 5A equipment.
November	Installation of two new amplifiers for the telescope's azimuth encoders.
November	Connection of the Mark5 unit to the Swedish internet backbone with an optical fibre link of up to 1 Gbit/s capacity.
December	Maintenance of all video converter filter cards and checks of offset levels and gains.

5. Telescope Stability, Reference Point Determination, and Local Tie

We continued to monitor the vertical changes of the telescope tower by an invar monitoring system [6], see Figure 1. We fitted a simple model to express the relative vertical height changes measured with the invar rod as a function of the mean value of the temperatures measured with 16 temperature sensors located at 4 different levels and 4 different directions in the concrete foundation of the telescope. The empirically determined expansion coefficient for the concrete foundation of the telescope is $9.6 \cdot 10^{-6} \pm 0.2 \cdot 10^{-6}$ (1/°C). Here we corrected for an expansion of the invar rod using the theoretical expansion coefficient of invar which is $1.5 \cdot 10^{-6}$ (1/°C). The rms of the model fit is 0.056 mm. The empirically determined expansion coefficient is slightly smaller than the theoretical one for dry concrete which is $12 \cdot 10^{-6}$. One reason might be that the mean value calculated from all temperature sensors does not provide the effective temperature of the concrete.

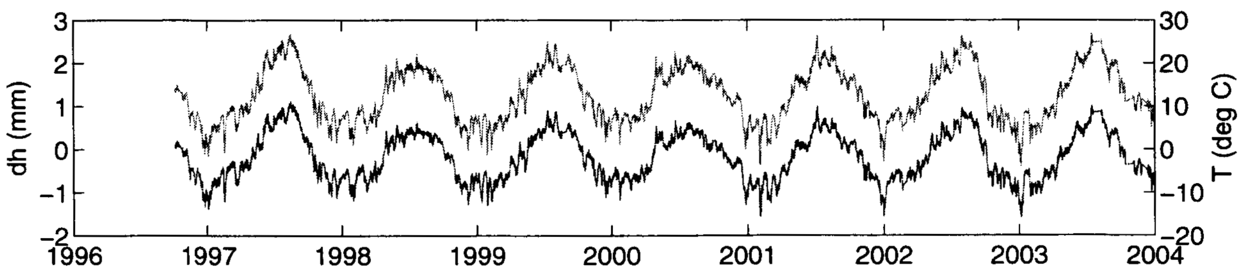

Figure 1. Lower blue curve, left scale: relative vertical height dh in (mm) of the OSO telescope tower. Upper red curve, right scale: mean temperature T in (°) C of the concrete foundation of the telescope.

The campaign based GPS measurements using an antenna mounted on top of the VLBI telescope [7] have also been continued.

The classical geodetic measurements performed in the spring and the early summer 2002 at the observatory were further analysed [8]. Several geometric properties of the telescope were determined: The divergence of the telescope's azimuth axis with respect to the local vertical was found to be to 13" ± 6". A non-orthogonality of the telescope's azimuth and elevation axis on the order of 40" ± 8 " was detected. Furthermore, an axis offset of 6 mm ± 0.4 mm was determined.

The local tie between the IVS and the IGS reference points at the observatory was determined in the local network. Additional GPS observations performed in the local network at the observatory allowed us to transform this local tie also into a global reference system. The new local tie information was submitted together with its complete covariance information to the International Earth Rotation Service (IERS). This information is also available from us on request.

6. Outlook

The Onsala Space Observatory will continue to be an IVS Network Station and to participate in the IVS observation series. For the year 2004 a total of 22 experiments in the series EUROPE, RDV, IVS-R and IVS-T are planned.

The Onsala Mark 5A system is now connected to the Swedish Internet backbone by a 1 Gbit/s optical fibre link and we plan to participate in international e-VLBI activities.

The monitoring of the relevant system parameters will be continued in order to detect possible error sources as early as possible and to maintain a high quality of the observation data. The stability of the telescope, its vertical height changes and the local tie to other monuments will be monitored also in the future.

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Sheshan VLBI Station Report for 2003

Xiaoyu Hong, Wenren Wei, Shiguang Liang, Xinyong Huang

Abstract

The Sheshan 25-meter radio telescope is an alt-az antenna run by Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). It is one of the five main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, IVS, and APT. Sheshan station also participated in a large mount VSOP survey observation in the period from 1997 to 2003. We give a short report the current status and future plans of Sheshan VLBI station of Shanghai Astronomical Observatory as an IVS Network Station.

1. Introduction

The telescope is located about 30 km west of Shanghai. Station is located at longitude: 121^o 11' 59" E, latitude: 31^o 05' 57" N, and height 5 meters above the sea level (ground).

The radio telescope started its operation in 1987. It is one of the five main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, APT and IVS. There is a two-station Mark IV data processor and an analysis center of IERS of various space geodetic observations in Shanghai Astronomical Observatory.

Sheshan station participates into the EVN session for astrophysics, IVS session for the geodetic purpose, and VSOP survey program.

2. Facilities

2.1. Antenna

Diameter : 25 meters
Antenna type: Kashegelun beam wave-guide
Seat-rack type: Azimuth-pitching ring
Main surface precision: 0.65 mm (rms)
Point precision: 20"(rms)
Rolling range: Azimuth : -86^o – 425^o; Elevation: 5^o – 88^o
Maximum rolling speed: Azimuth : 0.55^o/sec; Elevation: 0.28^o/sec

The quick frequency changing system has been built. Since the L band feed is located at main focus while the other feeds are located in second focus, the switch frequency system does not include L band. We can change the observed frequency among 3.6/13 cm, 6 cm and 1.3 cm in 5 minutes. We still need 30 minutes from L band to the others.

The antenna surface adjustment has been done before September of 2003. The efficiencies at short wavelengths have been improved.

The efficiency at 22 GHz has not been measured carefully yet. We do not have the parameters at this moment.

2.2. Receiver

Five bands for VLBI observations are available at Sheshan VLBI station: L band (18 cm), C band (6 cm), K band (1.3 cm), and S/X band (13/3.6 cm). The parameters of the receivers are listed in Table 1. Column 1 gives the observation band. The frequency range is listed in column 2, followed by the efficiency of each band in column 3. The receiver type, system temperature, and polarization model are listed in columns 4, 5 and 6, respectively.

The L, C, and K bands are used for astrophysics and S/X double frequencies are used for geodesy. X band is also used for astrophysical observations sometimes.

A new C-band receiver with double polarization will be available in the second half of 2004.

Table 1. VLBI Receivers of Seshan Satation

Band (cm) (1)	**Bandwidth** (MHz) (2)	**Efficiency** (%) (3)	**Type** (4)	T_{system} (K) (5)	Polarization (6)
18	1620-1680	40	Room Temperature	~ 100	LCP & RCP
13	2150-2350	45	Room Temperature	~ 100	RCP
6	4700-5100	58	Cryogenic	45-50	LCP
3.6	8200-9000	50	Cryogenic	~ 50	RCP
1.3	22100-22600	~20	Cryogenic	~110	RCP & LCP

2.3. Recording System

VLBA, Mark IV and S2 recording systems are available now at Sheshan VLBI station. Mark IV upgrade of Sheshan station has completed in 2000. Two head stacks recording system has been tested successfully and good fringes have been found to Sheshan station, both head-stacks successfully. The performance of the observing system of Shanghai station has been more advanced over the last few years.

The Field System has been upgraded to 9.5.17 version and it works well for Sheshan station in the second half of 2002. The Mark IV recording system works well for EVN and IVS observations, and S2 recording system work well for VSOP observation. Two head stacks recording system has been tested successfully and good fringes have been found to Sheshan station.

We are purchasing a Mark 5A system for Sheshan station. It will be delivered to Shanghai at the beginning of 2004.

3. Personnel

There are some changes of the staff at Sheshan station. The main staff members at Sheshan VLBI Station are listed in following Table 2.

Prof. Liang Shiguang retired in the Nov. 2003. He is still employed to work for our station after he retired.

Table 2 - The main staff in Sheshan VLBI Station

Name	Position	Working area	email address
Xiaoyu Hong	Professor	Head of station	xhong@shao.ac.cn
Wenren Wei	Professor	Chief Engineer	wwr@shao.ac.cn
Shi-guang Liang	Professor	Microware	sgliang@shao.ac.cn
Xinyong Huang	Senior Engineer	VLBI friend	xhuang@shao.ac.cn
Zhuhe Xue	Senior Engineer	Terminal software	zhxue@shao.ac.cn
Qing-yuan Fan	Senior Engineer	Antenna control	qyfan@shao.ac.cn
Song-lin Chen	Engineer	Microware	slchen@shao.ac.cn
Bin Li	Engineer	Microware	bing@shao.ac.cn
Jinqing Wang	Engineer	Observation et al	jqwang@shao.ac.cn
Huihua Li	Engineer	Observation et al	hhlee@shao.ac.cn
Lingling Wang	Engineer	Observation et al	llwang@shao.ac.cn
Ruiming Tu	Engineer	Observation et al	trmshao@shao.ac.cn
Ming Zhang	Associate Research	Astrophysics	zhangm@shao.ac.cn
Weihua Wang	Associate Research	Astrophysics	whwang@shao.ac.cn

4. Current Status & Activities and Future Plans

A new Hydrogen Maser Clock has been ordered from Datum for Sheshan VLBI station. The export license has been approved by USA. We expect to have it in 2004.

Since the antenna control system is not quite stable now, we plan to upgrade it in 2004.

"Simeiz-Katsively" Geodynamic Area: Results of the Geodetic VLBI Observing Program and Variability of the Black Sea Level

A. Volvach, Ju. Sokolova, O. Shabalina

Abstract

This report gives an overview about the geodetic VLBI activities at the Simeiz station. It also summarizes the seasonal and long-term variability of the Black Sea level near Yalta and Katsively.

1. Measurements of Motion of Simeiz Station Using VLBI

The different analysis groups use different VLBI software for their investigations. Estimates of the horizontal velocity of the radioastronomical station Simeiz were obtained using VLBI observations carried out under geodynamics programs during the years 1994-2000 using CALC/SOLVE for data analysis (Petrov et al., 2001).

We continue it and the estimations of the horizontal and the vertical velocity of Simeiz station were obtained during the years 1994-2002. To analyse the time series of positions of the Simeiz VLBI site 3 million measurements of group delay from 1983 to 2003 have been processed using the Occam5_1 software at Saint-Petersburg IVS Analysis Center. The station rates have been estimated by weighted least squares (LSQ) method using a linear model. Figures 1, 2, 3 show the time series of topocentric coordinates of Simeiz.

2. The Black Sea Level

The 22-m radiotelescope RT-22 is located 80 m from the edge of the Black Sea. The geodynamics areas "Simeiz-Katsively" consists of two satellite laser ranging stations, a permanent GPS receiver, a sea level gauge and the radiotelscope RT-22 (Nesterov & Volvach, 2002). All these components are located within 3 km. Yalta level gauge is located near Yalta 20 km east of RT-22. Measurement of Yalta and Katsively level of Black Sea are plotted in Figure 4.

Height of a level is given in centimeters concerning uniform zero for posts of the Black Sea, which is located 500 cm below the zero Kronshtadt tide-gauge. High factor of correlation 0.964 testifies to synchronous change of levels. The level varies insignificantly from January till March. Then it begins prompt growth till May. Then the growth is slowed down and in June there comes a maximum. After July there is a fast fall up to the minimal size observable in October. From October till November the seasonal level varies little. In the period from November till December there is fast growth which is slowed down in the period December - January. The long-term variability of average annual value of sea level for Yalta and Katsively is shown in Figure 5.

Until 1999 the growth in change of sea level was observed. Then in 2000 the growth was slowed down and the recession began.

3. Future Plans

The VLBI activities in 2004 at "Simeiz-Katsively" area will consist of: (1) carrying out modernization of sites VLBI (Mark5B system), SLR-1 and SLR-2 with the purpose to increase their

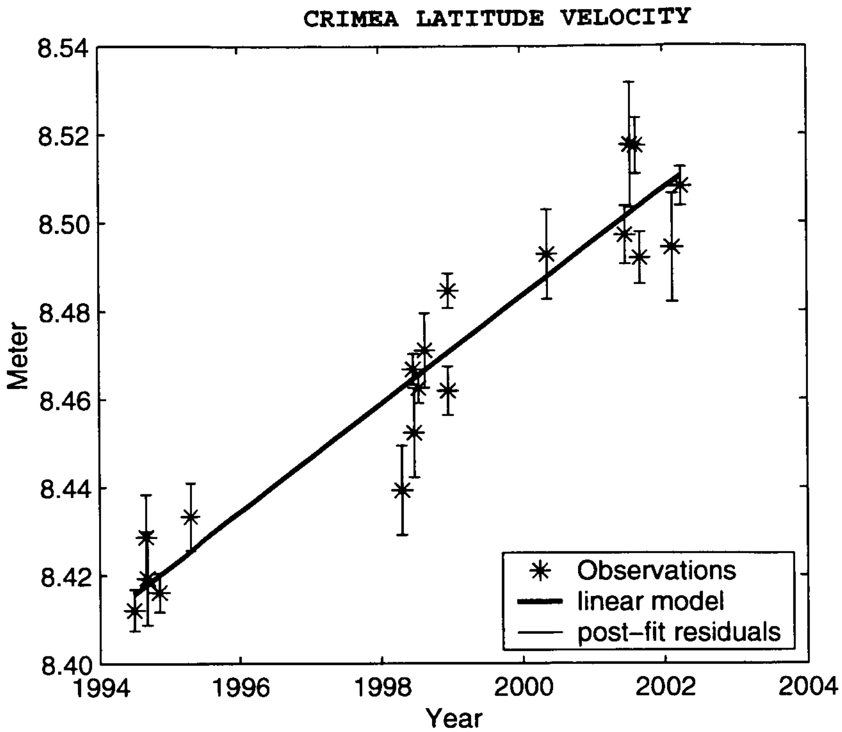

Figure 1. Crimea latitude velocity.

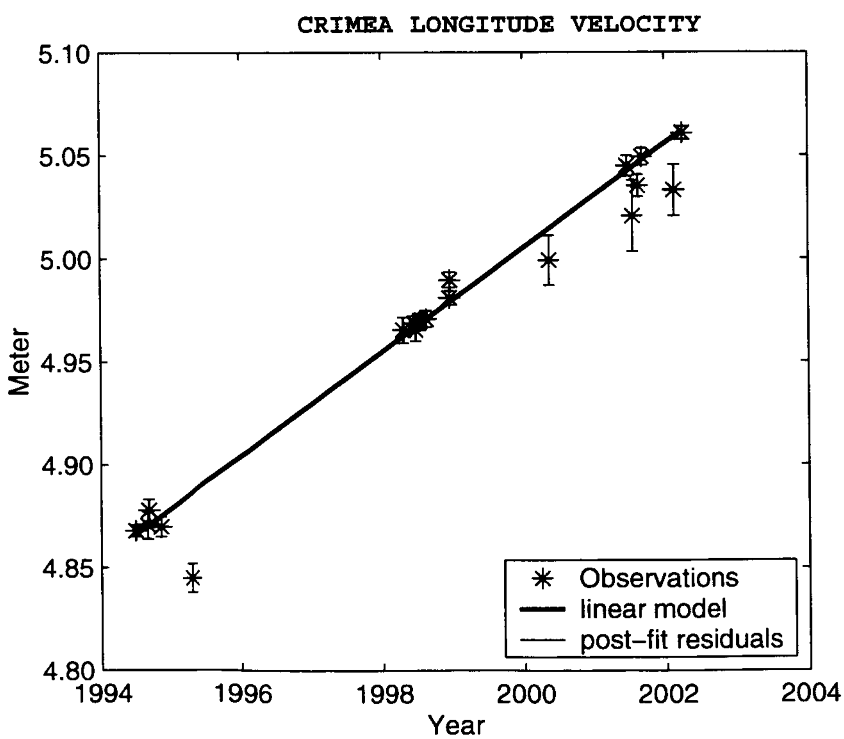

Figure 2. Crimea longitude velocity.

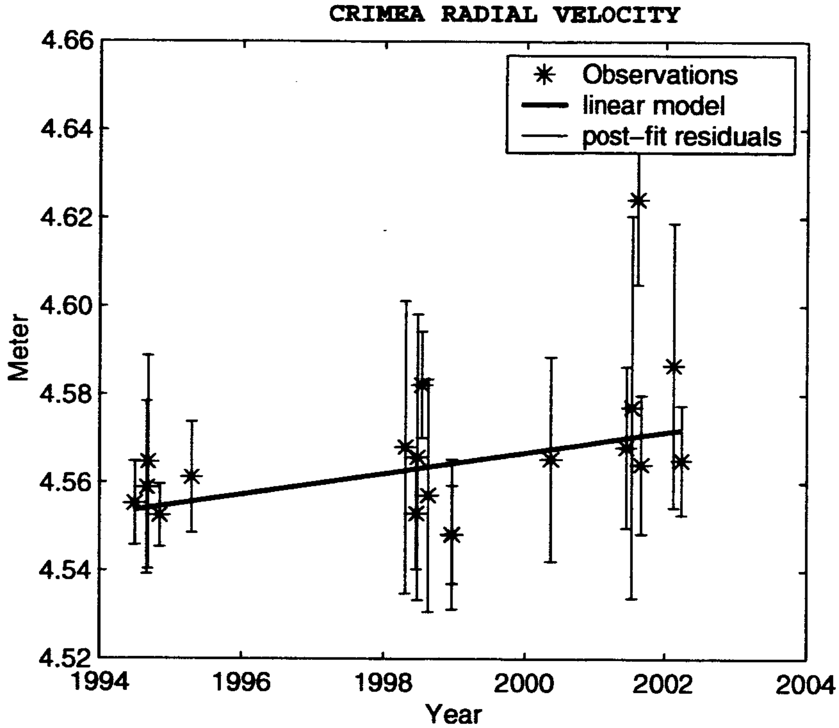

Figure 3. Crimea radial velocity.

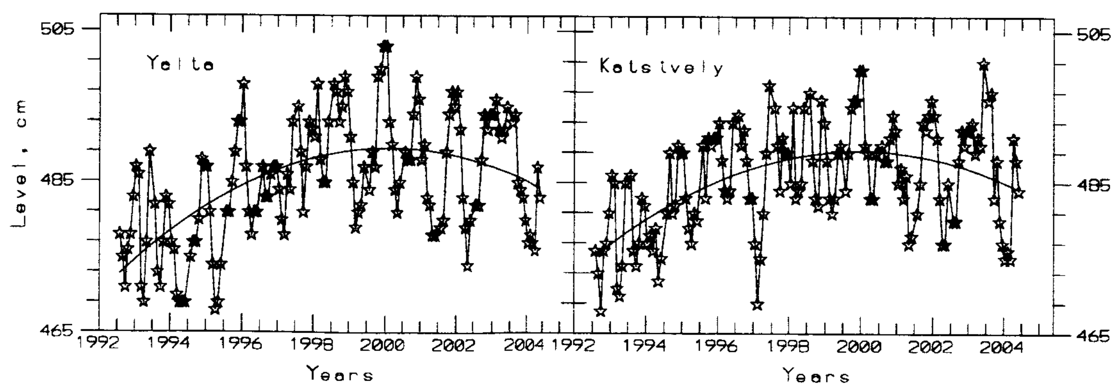

Figure 4. The Black Sea level near Yalta and Katsively.

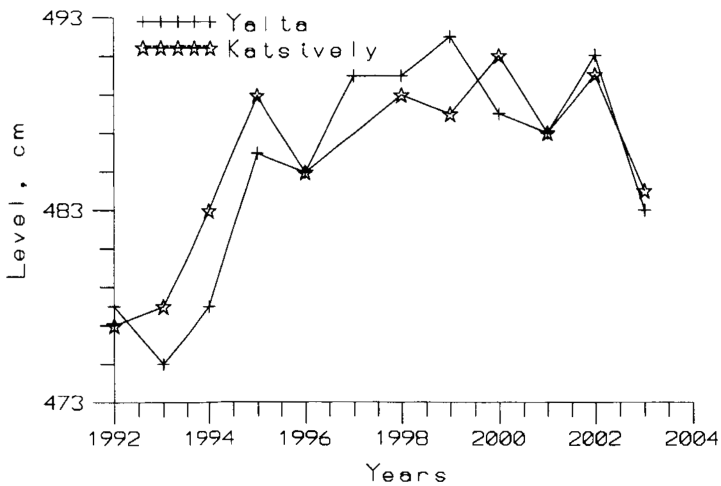

Figure 5. The long-term variability of Black Sea near Yalta and Katsively.

level of equipment according to the international standards; (2) realization of observations on sites 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) permanent GPS stations of the network to ITRF; (3) creation of the prototype of a system of monitoring of geodynamic phenomena of mountain region of Crimea and geotectonics of the Black Sea basin.

4. Acknowledgment

VLBI is possible only as a result of the coordinated efforts of many people. Authors would like to thank I. Srepka and N. Srepka for maintenance of the receivers at the station, P. Nikitin, A. Shevchenko and P. Koseko for their efforts in observations as well as the personnel at other VLBI stations and correlators.

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Svetloe Radio Astronomical Observatory

Sergey Smolentsev, Ismail Rachimov

Abstract

This report provides information about changes in the Svetloe Radio Astronomy Observatory (SvRAO) status in period spanning after the last IVS report. The activities during 2003, the current status, and future plans are described. In 2003, after successful installation of a Mark 3A terminal in cooperation with NASA, SvRAO started participation in IVS observing program, which is our main achievement during last year, and a major milestone for the QUASAR project.

1. Introduction

Svetloe Radio Astronomical Observatory (SvRAO) was founded by the Institute of Applied Astronomy (IAA) as the first station of Russian VLBI network QUASAR. Sponsoring organization of the project is Russian Academy of Sciences. The site is located at the Karelian Neck near Svetloe village about 100 km north from St. Petersburg. The basic instruments of the observatory are 32-m radio telescope RTF-32 and technical systems provided realization of VLBI observations.

During last years Svetloe observatory regularly participated in various radio astronomy programs including VLBI and RL VLBI observations of quasars, Sun, planets, asteroids using recording terminal S2-RT. In particular, several observing sessions were performed on the baseline Svetloe–Zelenchukskaya.

In 2003, after successful installation of a Mark 3A terminal in cooperation with NASA, on Mar 6, 2003 SvRAO started participation in IVS observing program, which is our main achievement during last year, and a major milestone for the QUASAR project [1].

2. Participation in IVS Observing Programs

During 2003 Svetloe IVS station participated in 21 R4, T2 and EURO sessions (Table 1).

Table 1. List of IVS sessions observed at SvRAO in 2003.

Month	R4	T2	EURO
March	2	1	
April	2	1	
May	1	1	1
June	1		
July	2		
August	2		
September	2		1
October	3		
November	1		
Total	16	3	2

Four R4 sessions were not correlated in time because of delay in tape delivering due to customs problems. Four scheduled experiments were not observed due to BBC upgrade at Signatron (USA), one experiment was not observed due to planned repair of radio telescope, and one experiment was cancelled. Totally 16 sessions were correlated and are available for scientific analysis.

An analysis of the observations performed at the IAA by means of OCCAM software allowed us to determine SVETLOE coordinates at the millimeter level of accuracy. It was also shown that including Svetloe observatory in the IVS network yields essential improvement of the accuracy of determination of the EOP. We processed the same observations using all participating stations and excluding SVETLOE from the network. The results of comparison showed a decrease both in EOP uncertainty and postfit wrms [2].

3. Radio Telescope

Geodetic control measurements at the radio telescope dish surface were fulfilled (Fig 1). The antenna was painted in August 2003.

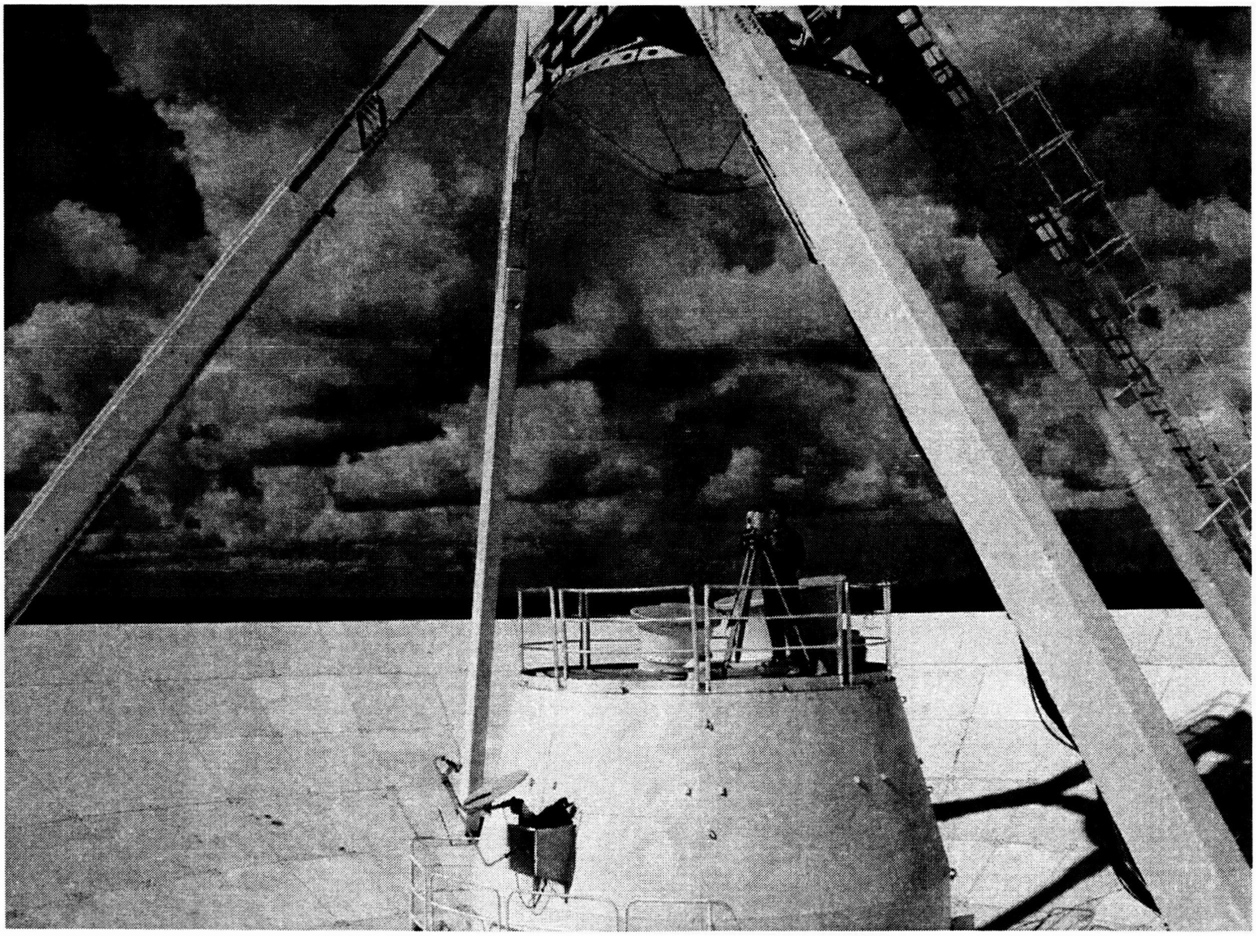

Figure 1. Geodetic control of the radio telescope surface.

The radio telescope is equipped with 5 low-noise cooled receivers with HEMT amplifiers for wavelengths 1.35, 3.5, 6.0, 13 and 18/21 cm for observations in the left and right circular polarizations. The parameters of the LCP X band receiver were improved. The latest results of measurements of radio telescope parameters carried out in 2003 are presented in Table 2.

Table 2. Parameters of the radio telescope RTF-32 at SvRAO.

Band	Pol	Frequency range, MHz	T_{rec}, K	T_{sys}, K	SEFD
X	R	8180–8880	15	40	250
	L	8180–8680	13	38	240
S	R	2150–2500	42	80	600

4. Collocation with GPS

A permanent GPS receiver was installed at Svetloe in 1996. Svetloe observatory participated in several regional and global geodetic GPS projects, and is an EPN station from 1996, and an IGS station from 2003.

The local geodetic network (LGN) was established at SvRAO in 1994 (see IVS 2000 Annual Report). In 1995–1998 several local surveys were performed at Svetloe. In result, GPS marker is tied to the LGN with the accuracy about 2 mm. However, we still cannot provide an accurate survey involving the VLBI radio antenna. In December 2003 a leveling sessions was carried out to check LGN markers stability.

5. Outlook

Our plans for the coming year are the following.

- Recording terminal Mark 5A will be put into operation.
- Installation of Canadian S2 DAS in cooperation with NRCan and start in the IVS E3 observing program.
- Participation in 39 IVS R4, T2, EURO and E3 observing sessions.
- Geodetic survey for accurate tie between the radio telescope and the SVTL GPS marker.

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Geodetic Observatory TIGO in Concepción

Hayo Hase, Armin Böer, Stefan Riepl, Sergio Sobarzo, Cristobal Jara, Roberto Aedo, Gonzalo Remedi, Marcus Moreno, Matias Sanchez, Gonzalo Hermosilla

Abstract

During TIGO's second year of operation in Concepción, TIGO performed 106 24h VLBI observations and is hence one of the most scheduled IVS sites. The operational load is carried out by a relatively young team of Chilean students. Activities of the VLBI group at TIGO during 2003 and an outlook for 2004 are given.

1. General Information

One year after the arrival of TIGO in Chile in 2002, on January 15, 2003, the Geodetic Observatory TIGO was officially inaugurated with speeches by

- Intendente Jaime Toha (Representative of the President of Chile in the Eighth Region),
- Rector Sergio Lavanchy (Universidad de Concepción),
- Henning Rosen (Representative of German Minister of Interior),
- Prof. Dietmar Grünreich (President of Bundesamt für Kartographie und Geodsie)

in the presence of the rectors of the two other partner universities, Hilario Hernandez of Universidad del Bío Bío and Fernando Jimenez of Universidad Católica de la Santísima Concepción, and the Commander in Chief of the Chilean Army, General Cheyre with the director of the Instituto Geografico Militar, General Pablo Gran and more than 180 invited guests.

During 2003 the existing committments of TIGO towards the international services like IVS, ILRS, IGS and UT at BIPM had been kept by lots of data from Concepción.

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 collocated with a SLR telescope (ILRS site), a GPS/Glonass permanent receiver (IGS site) and other instruments like water vapour radiometer, superconducting gravity meter, seismometer.

The atomic clock ensemble of TIGO consists of 2 hydrogen masers, 2 cesium clocks and 3 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 November 2003 the first Mark 5 observations had been performed. Since then TIGO supports Mark 4 thintape, Mark 5 fixdisk and S2 VHS tape recordings.

TIGO's spare Mark 4 formatter was given on loan to Hobart, University of Tasmania, in order to improve the observation possibilities in the southern hemisphere within the IVS.

3. Staff

In 2003 chief engineer Eduardo Carvacho terminated his work at TIGO. As a replacement UdeC hired 2 doctorate students of the electrical department of the engineering faculty, Sergio

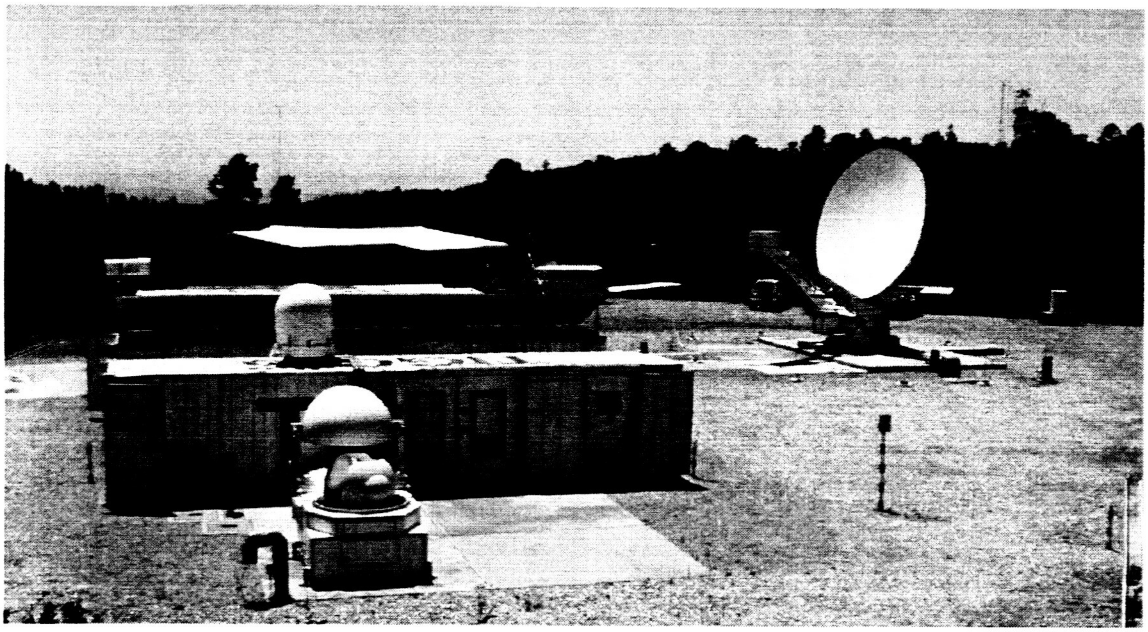

Figure 1. **Geodetic Observatory TIGO:** Instruments from left to right: water vapour radiometer, SLR Radar, SLR telescope, meteorological sensors, VLBI radiotelescope, local survey monument.

Sobarzo and Cristobal Jara. Both of them together with Hayo Hase participated in the IVS-TOW 2003. The actual TIGO-VLBI group consists of the persons listed in table 1.

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
Roberto Aedo	electronic engineer	roberto.aedo@tigo.cl
Gonzalo Remedi	programmer	gonzalo.remedi@tigo.cl
Marcos Moreno	geologist	marcos.moreno@tigo.cl
Matias Sanchez	geologist	matias.sanchez@tigo.cl
Gonzalo Hermosilla	geologist	gonzalo.hermosilla@tigo.cl
any VLBI-operator	on duty	vlbi@tigo.cl
all VLBI-operators		vlbistaff@tigo.cl

Table 1. TIGO-VLBI support staff in 2003.

4. Current Status and Activities

During 2003 TIGO was participating in 106 VLBI experiments (24h) and one 3h experiment within a students project of the Technical University of Vienna. The operation of the latter one at TIGOCONC was broadcasted via webcams and the internet based video conference system VRVS (http://www.vrvs.org) to the classroom at Vienna, from where the students participated. Table 2 gives an overview about the observed experiment series.

Name	# of exp.	ok	failed
R10xx	51	49	2
T20xx	2	2	-
E30xx	11	9	2
R40xx	26	25	1
RDVxx	5	5	-
RDxxx	10	10	-
OHIGxx	6	6	-
Total IVS	106	101	5
VIExx	1	1	-

Table 2. TIGO's IVS observation statistic.

Besides ongoing VLBI observations a local site survey was executed in March/April 2003 by Rudolf Zernecke (TUM Wettzell), and Rodrigo Miranda (UdeC). This survey tied the VLBI radiotelescope reference points to those of the ILRS site and the IGS site at TIGO. In addition a precision levelling was executed to tie TIGO to the Chilean vertical reference system.

In April 2003 three borehole tiltmeters had been installed at each of the three international service platforms: at the radiotelesope fundament, at the laser telescope fundament and inside the GPS/GLONASS monument in order to monitor longterm inclinations [2], [3].

5. Future Plans

The VLBI-activities in 2004 will focus on

- execution of the IVS observation program for 2004,
- participation in the IVS-VLBI2010 working group,
- testing the spare Mark 5 unit,
- investigations related to eVLBI,
- development of a VLBI operators certification program,
- the installation of an upgrade for the antenna control unit and programming the Field System antenna interface (September/October 2004),
- repetition of the local survey.

In early 2004 a complementary regional GPS network will be installed with four permanent GPS receivers, Ashtec Z12, for the regional monitoring of the TIGO site stability. The selected sites are Dichato, Quellon, Santa Juana, Faro Hualpen and distances to TIGO range from 20-50km. At the coastal site of Dichato the GPS monument will be collocated with a tidegauge in order to connect TIGO to the mean sealevel. This regional GPS network will allow complementary studies of the local ionospheric and water vapour conditions.

Figure 2. **Logo of TIGO** symbolizes a reference point. It consists of a symbolic reference cross indicating the classical perpendicular orientation directions as it is used to indicate north-south and east-west. The *millimetric* reference point is located at the intersection of the four directions. The four letters "TIGO" are arranged in a circle, which allows the association with a sextant or a telescope tube with counter weights. This association is intended – connecting TIGO's actual mission to the historical achievements of geodesy. The used colours are taken from the German and Chilean flags, symbolizing the cooperation within this bilateral project.

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Tsukuba 32-m VLBI Station

Kozin Wada, Shinobu Kurihara, Kazuhiro Takashima

Abstract

This report summarizes the improvement of devices and observation activities at Tsukuba 32 m station. We had 31 international, 11 domestic and 32 Intensive UT1 sessions during this year. We have installed the disk-based K-5 recording system connected to the Internet. Also we have started some preliminary experiments with a high-speed network, Super-SINET, for realtime observation and mass data transfer. For the first stage of future e-VLBI, we plan to use these systems for regular domestic experiments in 2004.

1. General Information

The Tsukuba 32 m VLBI station (TSUKUB32) is located at "Geographical Survey Institute" (GSI) in Tsukuba Science City, a core area of public and private scientific research institutes, about 50 km northeast of the capital Tokyo. GSI started VLBI experiments in 1981 with a 5 m-mobile station. Through the history of experiments, GSI had also operated a 3.8 m-mobile station and the Kashima-26 m station. TSUKUB32 has been in operation since 1998. Since then GSI has shifted

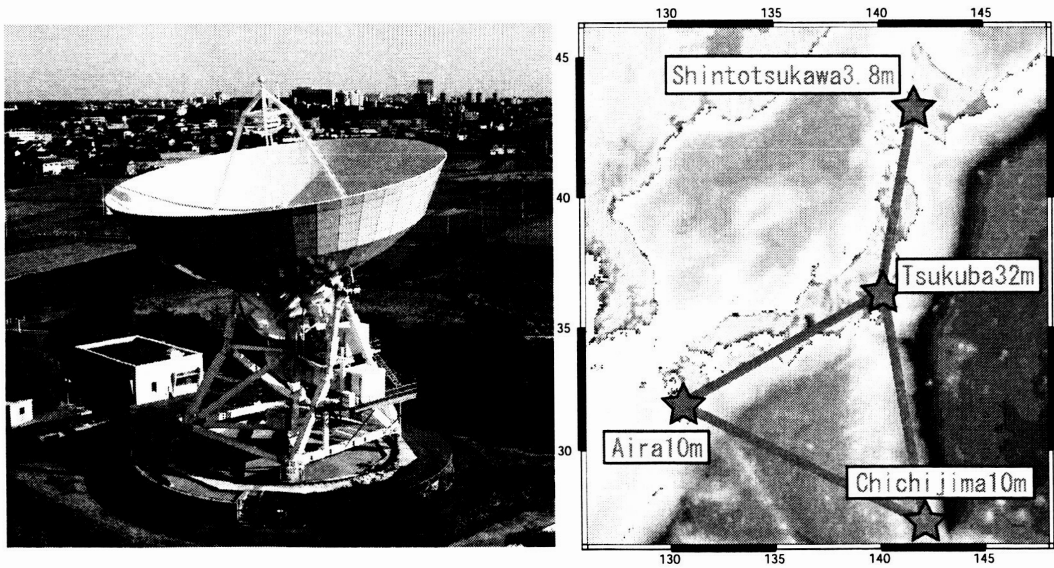

Figure 1. Tskuba 32 m VLBI station and GARNET (GSI VLBI network)

its aim of experiments from mobile observations toward fixed regular ones. TSUKUB32 has been operational as a main dish of GSI with three other permanent stations, Aira, Shintotsukawa and Chichijima, performing geodetic VLBI experiments on a regular basis in a variety of international, domestic and other scientific experiments (Table 4). The network of the GSI VLBI stations is named GARNET (GSI Advanced Radiotelescope Network). The main purposes of this network are to define the framework of Japan and to monitor the plate motions for the advanced study of crustal deformations. For this reason the four fixed stations including TSUKUB32 are placed to surround the Japanese mainland (Figure 1).

Table 1. Location and address of Tsukuba 32m VLBI station

Latitude (deg)	36.1031 N
Longitude (deg)	140.0887 E
Altitude	44.7 m
Address	Geographical Survey Institute(Kitasato 1 Tsukuba Ibaraki 305-0811 JAPAN)
Web	http://vldb.gsi.go.jp/sokuchi/vlbi/english/

2. Component Description

The current configuration of TSUKUB32 is shown in Table 2. In 2003 we have installed the K-5 sampling/recording system in parallel with the K-4 and Mark IV (VLBA). The backend K-series systems have been developed at Communication Research Laboratory (CRL). In addition, we have already realized the remote-controlled system with K-4 and used it within GARNET. The remote-controlled system is also applied to the K-5 system easily. The combination of the remote-controlled system with K-5 will provide the increase of the number of experiments. Some preliminary experiments for the K-5 system were held with CRL and GIFU University.

Table 2. Configuration of Tsukuba 32m antenna

Site 8-letter code	TSUKUB32	2-letter	Ts
IERS DOMES number	21730S007	CDP number	7345
Site Position (ITRF2000) X (m) Y (m) Z (m)	before Apr. 1999 -3957408.752 3310229.367 3737494.789	Site Position (+43.7 mm UP) X (m) Y (m) Z (m)	after Apr. 1999 -3957408.779 3310299.390 3737494.815
X band SEFD (Jy)	320	S band SEFD (Jy)	360
X band Tsys (K)	50 (Zenith)	S band Tsys (K)	75 (Zenith)
Az slew 3.0 deg/sec	Range 10.0 - 710.0	El slew 3.0 deg/sec	Range 5.0 - 88.0
S-band w/BPF	2215-2369 MHz	X1-band	7780-8280 MHz
X2-band	8180-8680 MHz	X3-band	8580-8980 MHz

3. Staff

Table 3 shows the regular operating staff of VLBI group at GSI. Four new staff members have joined this year because both regular observations and correlation works have been increased. Shigeru Matsuzaka is a member of IVS Directing Board (Networks Representative). Hiromichi Tsuji is the supervisor of VLBI group. Yoshihiro Fukusaki is in charge of the analysis of SYOWA experiments, although he is not an regular member. Kouhei Miyagawa, former chief of analysis, moved from our group in April 2003.

Table 3. Staff working at GSI VLBI group

Name	Position	Jobs
Kazuhiro TAKASHIMA	Leader of VLBI group	Management
Takashi TSUTSUMI	Collocation chief	Collocation, Operation
Morito MACHIDA	Analysis chief	Correlation, Operation
Masayoshi ISHIMOTO	Network chief	Network, e-VLBI, Operation
Kozin WADA	Operation chief	Experiments coordination, Operation
Shinobu KURIHARA	Operator	Analysis, Operation

4. Current Status and Activities

Table 4. The regular experiments at Tsukuba 32 m VLBI station in 2003

Experiment	Code	Number
IVS-R	R1054,56,60,61,62,66,67,70,73,74,76,77,79,85,86,87,90,100,R4073	19
IVS-T	T2013,2014,2015,2022	4
VLBA	RDV37,38,39,40,41,42	6
APSG	APSG12,13	2
JADE	JD0301-0311	11
UT1	K03102-K03354	32
Total		74

As for the regular experiments listed in Table 4, we have added 17 experiments, which were for UT1 and JADE experiments with the K-4 system, compared with last year. The number of other regular experiments with the Mark IV (VLBA) system has been constant over the past few years.

In 2003, domestic experiments using GARNET were carried out totally 11 times. A series of the experiments is named JADE (Japanese Dynamic Earth observation by VLBI). The main purpose of JADE experiment is to monitor the plate motions around Japan periodically once a month. One of the most remarkable results was detection of Tokachioki Earthquake event which occurred on September 26th (Fig 2). The JADE experiments are opened to any VLBI stations with the K-4 recording system. As a result, many Japanese VLBI stations, such as GIFU11, TOMAKO11, KASHIM11, KASHIM34, MIZNAO10 and VERAMIZSW have participated in JADE experiments. All these results are available on GSI VLBI Web site (http://vldb.gsi.go.jp/sokuchi/vlbi/sess/index.html).

Totally 32 Intensive UT1 sessions were carried out with the TSUKUB32-WETTZELL baseline every Saturday using the K-4 system. The sessions are scheduled as the complement to the KOKEE-WETTZELL baseline. Since UT1 session is still vacant on Sunday and Thursday, we will try to fill up all days through a week.

The TSUKUB32 station has been connected to very-high speed optical fiber network (2.4Gbps) named Super-SINET managed by National Institute of Informatics (NII). The network is used for realtime observation and mass data transfer in VLBI. Though the network is still under construc-

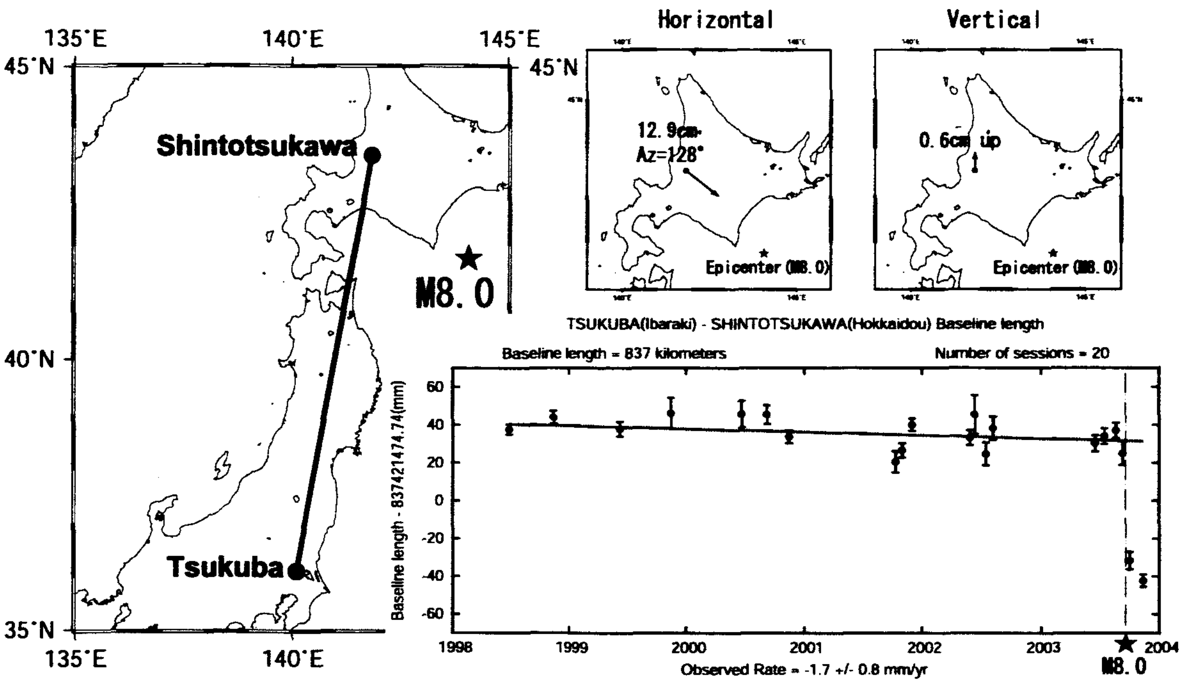

Figure 2. Tokachioki Earthquake and the result of JADE experiment

tion, it has already started to carry out some experiments. Practical scientific experiments had been held with the TSUKUB32-USUDA64 (JAXA) baseline for the realtime celestial object survey, planned by National Astronomical Observatory of Japan (NAOJ), from January to March. Also the real time fringe test had been done successfully with the TSUKUB32-GIFU11 baseline on November 11th.

5. Future Plans

At the beginning of 2004, we are ready to install K-5 systems to other GARNET stations. This means that it is the transition period from tape-based to hard disk-based recording system. Basically we plan to replace K-4 systems with K-5 to use for regular basis in domestic experiments until 2005. In addition, we plan to install software correlator for the K-5 system in Tsukuba with the high-speed network. We are also developing the compatibility of Mark 5 and K-5 in cooperation with CRL. With this advanced technique, K-5 system can be used in international regular experiments in the near future.

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[2] K. Takashima, S. Kurihara, M. Ishihara, K. Nemoto, M. Iwata, K. Shiba, M. Onogaki, and K. Kobayashi: Status and Results of GSI Domestic VLBI Networks, Bull. Geograph. Surv. Inst., Vol. 46, pp.1–9, March 2000

Westford Antenna

Michael 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 2002 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.

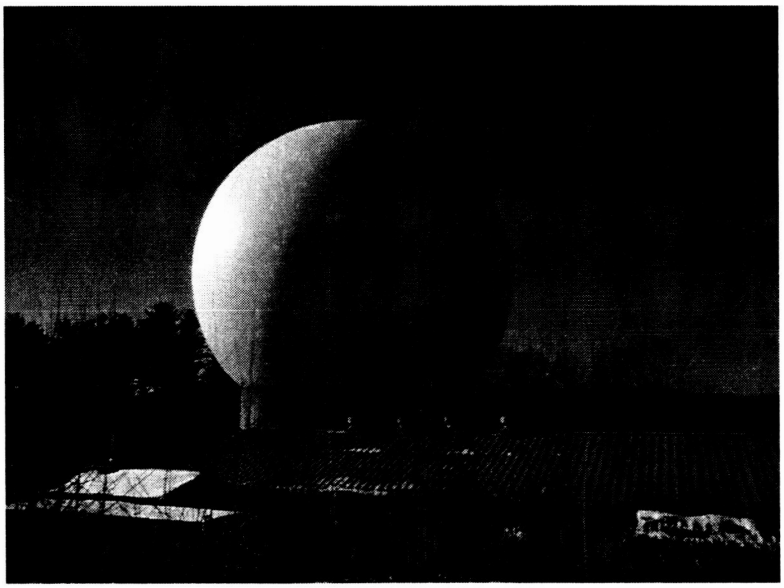

Figure 1. The radome of the Westford antenna.

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.

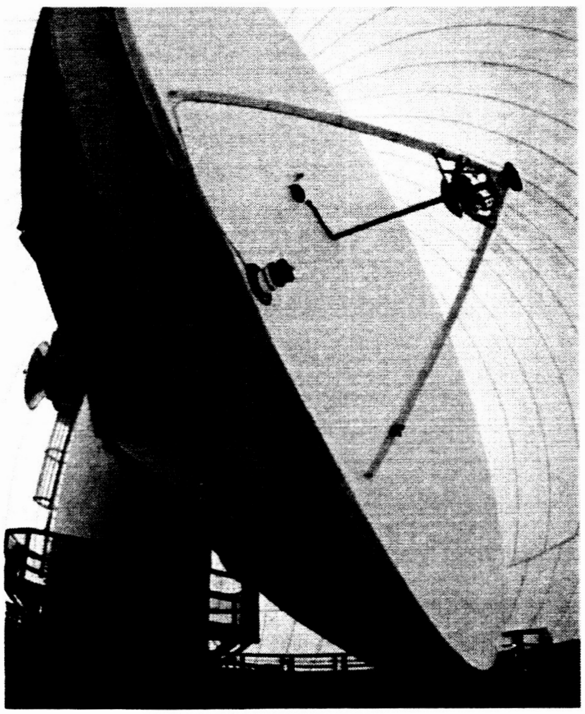

Figure 2. Wide-angle view of Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

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 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 4 electronics rack, a Mark 4 tape drive, which is used for recording thin tapes only, a Mark 5A recording system, and a Pentium-class PC running PC Field System

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	$90^\circ - 470^\circ$	
elevation range	$4^\circ - 87^\circ$	
azimuth slew speed	3° s^{-1}	
elevation slew speed	2° s^{-1}	
	X-band system	*S-band system*
frequency range	8180-8980 GHz	2210-2450 GHz
T_{sys} at zenith	50–55 K	70–75 K
aperture efficiency	0.40	0.55
SEFD at zenith	1400 Jy	1400 Jy

version 9.6.9. 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 GPS 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:

John Ball	pointing system software
Joe Carter	antenna controls
Ellen Cellini	observer
Brian Corey	VLBI technical support
Glenn Millson	observer
Michael Poirier	site manager; chief observer
Alan Whitney	site director

4. Status of the Westford Antenna

During the period 2003 January 1 - 2003 December 31, Westford participated in a total of 71 24-hour geodetic experiments. Westford participated regularly in the IVS-R1, IVS-R&D, and RD-VLBA series of geodetic experiments, as well as four IVS-T2 sessions and various fringe tests and e-VLBI experiments.

A Mark 5A recorder was installed at Westford in June 2003, as a replacement for the Mark 5P prototype used over the preceding year in occasional engineering tests and e-VLBI experiments. The Mark 5A has been used to record all geodetic sessions since June, with the exception of the RD-VLBA experiments, which are still recorded on tape.

There have been no significant equipment failures during this operational period.

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 2003, a number of e-VLBI demonstration experiments were carried out. Among them was a Kashima (Japan) to Westford UT1 experiment where data were recorded at Kashima and Westford on the K5 system, as well as on the Mark 5A system at Westford. Data were transferred via e-VLBI in both directions, with the necessary format conversion from K5 to Mark 5A format done via software. Correlation was done both on a software correlator in Japan and the Mark 4 correlator at Haystack. Data from the Haystack correlator were transferred to NASA/GSFC for analysis of the UT1 results. All of this was done in less than 22 hours, from data collection to final results!

6. Outlook

We anticipate Westford will be able to participate in the 72 24-hour geodetic experiments that are scheduled for Westford in 2004. More e-VLBI experiments are also planned for 2004.

Fundamentalstation Wettzell - 20m Radiotelescope

Wolfgang Schlüter, Richard Kilger

Abstract

In 2003 the radiotelescope in Wettzell contributed strongly to the IVS observing program. The transition to the Mark 5A system has been completed for routine operation, a 34 Mbps Internet link has been installed for first e-VLBI activities. Technical upgrades have been done.

1. General Information

The radiotelescope in Wettzell (RTW) is jointly operated by the Bundesamt für Kartographie und Geodäsie (BKG) and the Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (FESG) within the frame of the Forschungsgruppe Satellitengeodäsie (FGS).

At the Fundamentalstation Wettzell (FSW) the 20m Radiotelescope (RTW) for VLBI is collocated with three more geodetic space technique systems:

- the Laser ranging system WLRS (Wettzell Laser Ranging System) designed for SLR and LLR,
- several GPS receivers, integrated in the global IGS, the European GPS, and in the national GPS network, and for time transfer experiments,
- a DORIS station on loan from CNES/France.

At the Wettzell observatory, the first ringlaser, "G" dedicated to the monitoring of the variations in Earth rotation has been developed in close cooperation with the University of Canterbury-New Zealand. The system was established in 1998 to 2001 and is operating since fall 2001. "G" is sensitive to monitoring daily variations better than 10^{-8} relative accuracy.

Additional in situ observations were carried out such as:

- gravity observations, employing a super conducting gravity meter
- earth quake observations with a seismometer
- meteorological observations to monitor pressure, temperature and humidity, rain fall, wind speed, wind direction and also
- water vapour observations with a radiometer.

A Time and Frequency system (T&F) is established for the generation of timescales (UTC(IfAG)) and for the provision of very precise frequencies needed for VLBI, SLR/LLR and GPS observations, employing Cs-clocks and H-Masers and GPS time receivers. The timescale UTC(IfAG) is published in the monthly Bulletin T of the BIPM.

The 20m radiotelscope (RTW) has been established during the period 1980 to 1983. First observations were performed in 1983, routine operation started 1984. Since that time the telescope contributed strongly and continuously to many geodetic VLBI measurements.

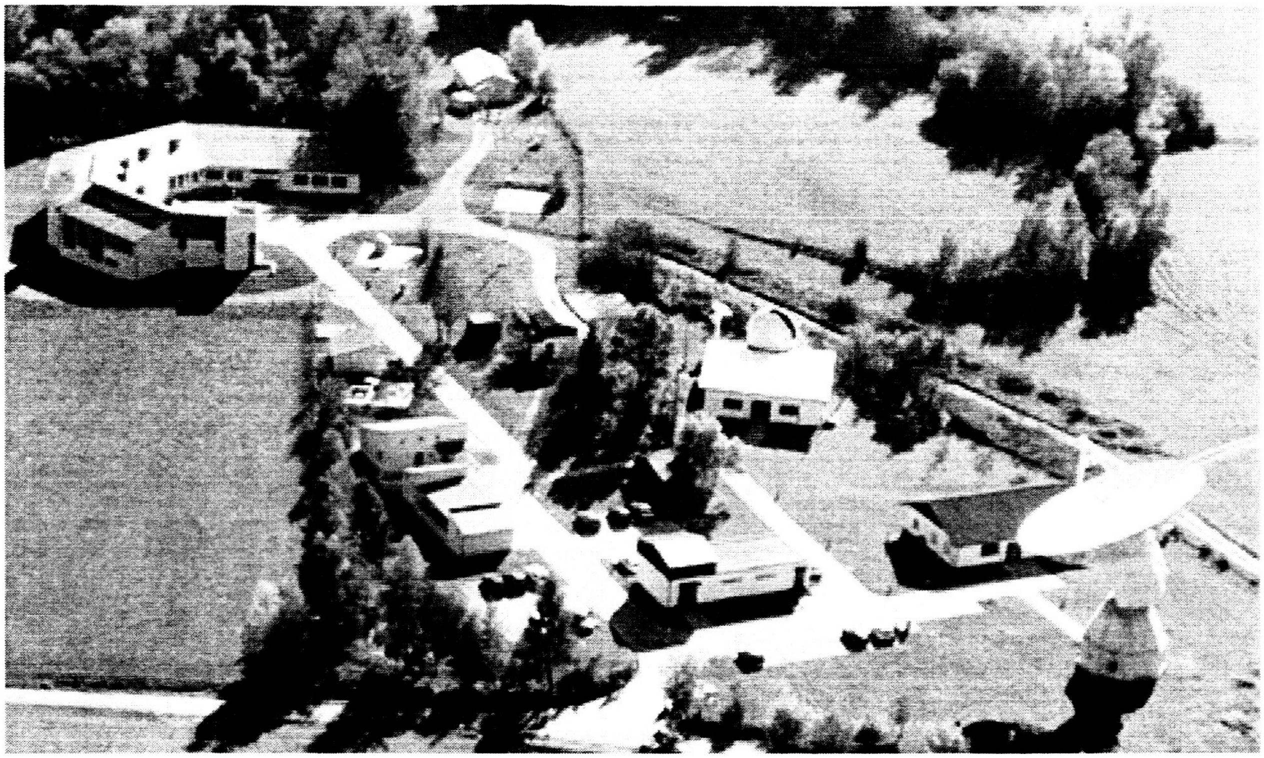

Figure 1. View of the FundamentalStation Wettzell

2. Staff

The staff of the Fundamentalstation Wettzell consists in total of 35 members for operating, maintaining and improving all the devices, and developing new systems. Within the responsibility of the Fundamentalstation Wettzell are the TIGO systems, operated in Concepcion-Chile jointly with a Chilean partner consortium with 3 experts from Wettzell, and the O'Higgins station, jointly operated with the German Space Center (DLR) and the Institute for Antarctic Research Chile (INACH). The staff operating the 20m radiotelcope in Wettzell (RTW) is summarized in the table 1.

3. Observations in 2003

The RTW was schedule in 2003 in total for 122 24 hr experiments of the IVS observing program. In addition it was scheduled four days per week in the INTENSIVE observations with Kokee Park. On many Saturdays the Intensive observations with Tsukuba, employing K4 recording technique were performed for about one hour. In comparison with the IVS telescopes, the RTW observed most of all. The table 2 summarizes the participation of RTW in the 24 hr observation sessions.

It has to be mentioned that during the VLBI sessions the DORIS is switched off in order to avoid interference.

Table 1. Staff - members

Name	Affiliation	Function	Working for
Wolfgang Schlüter	BKG	Head of the FSW	RTW, TIGO, O'Higgins
Richard Kilger	FESG	Group leader RTW	RTW
Eberhard Bauernfeind	FESG	mechanical engineer	RTW
Ewald Bielmaier	FESG	technician	operator RTW
Gerhard Kronschnabl	BKG	electronic engineer	RTW, TIGO (partly), O'Higgins (partly)
Christian Plötz	BKG/FESG	electronic engineer	O'Higgins, RTW
Raimund Schatz	FESG	software engineer	RTW
Walter Schwarz	BKG	electronic engineer	RTW, O'Higgins
Reinhard Zeitlhöfler	FESG	electronic engineer	RTW
Rudolf Zernecke	FESG	survey engineer	RTW, TIGO (partly)

Table 2. RTW participation in the IVS 24 hr observing program

program	number of sessions
IVS R1	50
IVS R4	49
IVS R&D	10
IVS T2	3
VLBA	6
EUROPE	4
VIE	1
in total	122

4. Maintenance

The intensive use of RTW requires maintenance in particular to avoid failures during the observations. Many problems have been caused by failures of the receiver cooling system, which mostly occur during hot summer periods. A lot of effort has been made to repair and to improve the cooling system. The antenna control unit (ACU) fails randomly, the reasons are unknown. If the ACU fails a restart is usually required. Azimuth motors had to be replaced and worn out couplings between the motor and the transmission had to be replaced. Random failures occurred also due to the shared memory of the FieldSystem with specific RTW software. This problem was solved and no further failures were observed due to that problem.

5. Technical Improvements

The transition from the Mark 4 to the Mark 5A via Mark 5P has been successfully completed. Two Mark 5A systems were integrated, one of the units is modified for the Intensive observations as Intensives only require one hard disk per experiment and not a complete 8-pack. The second unit is used as a spare and also to test and to develop e-VLBI procedures. The tapes drives still are available.

First tests for e-VLBI were performed in order to investigate the problems which occur on the national and intercontinental links. A 34 Mbps Internet connection is installed, for which the support is affordable. The link can be extended to 155 Mbps, as soon as it is affordable. The 34 Mbps links allow the transmission of Intensive data to the correlator. Still a lot of work and coordination is needed.

The last FieldSystem version was implemented.

6. Upgrade Plans for 2004

During 2004 it is planned to replace the ACU in order to overcome the random failures which could not be explained. The e-VLBI procedure for Intensive observations should be set up and an upgrade of the Mark 5A to Mark 5B is foreseen.

Observatorio Astronómico Nacional – Yebes

Francisco Colomer

Abstract

This report updates the description and details of the OAN facilities as an IVS network station. The 14 meter radiotelescope at Yebes participates regularly in the geodetic VLBI campaigns (EUROPE and CORE), as well as astronomical VLBI experiments as part of the European VLBI Network (EVN). The new 40 meter radiotelescope will start operation in Yebes during 2004, being available as soon as possible for geodetic VLBI. The institute staff is involved in technical developments, and scientific research in geodesy, astrometry and astrophysics.

Figure 1. Status of construction of the new 40 meter radiotelescope of OAN at Yebes (Guadalajara, Spain), as of December 4^{th} 2003.

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 is a network station of the IVS, and participates regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe (project EUROPE), Earth rotation, and pole motion (project CORE).

The 14 meter radio telescope, built in 1976, and nowadays used for VLBI, has been described in the 1999 IVS Annual Report. A photograph is included there, and a map of the Yebes site is in the report for year 2000.

The VLBI equipment has been constantly upgraded. A Mark 5A unit was purchased from Conduant, and is now installed and operational. Due to the old control system, there is no direct interface between the Field System computer and the telescope. This fact has forced the development of several tools which, to date, allow automatic operation.

On the other hand, studies are being conducted to connect the Yebes site to GEANT (the high speed transeuropean data network). Finally, we succeeded in obtaining protection against radio interference at Yebes in and out of the radioastronomy bands. The full text of this law is available at:

`http://www.oan.es/instalaciones/cay/A21789-21790.pdf`

The institute is currently involved in the construction of a new 40 meter radiotelescope (see Fig. 1) which is expected to be available for geodetic VLBI observations in mid 2005. Progress can be followed at the web address:

`http://www.oan.es/instalaciones/telescopios/40m/40m.shtml`

2. OAN Staff Working in VLBI projects

Table 1 lists the OAN staff which are involved in VLBI studies, some of which can be found at the telescope (CAY) address. The associated members of IVS are indicated with an asterisk. Contact information is provided at the URL:

`http://www.oan.es/investigacion/astronomia/vlbi.shtml`

The VLBI activities are also supported by other staff like receiver engineers, computer managers, secretaries and students.

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

Name	Background	Role	Dedication	Address
Francisco Colomer*	Astronomer	VLBI Project coordinator	30%	OAN
Pablo de Vicente*	Astronomer	VLBI Technical coordinator	30%	CAY
Isaac López-Fernández	Engineer	Technical support	20%	CAY
Maria Rioja*	Astronomer	Scientist	20%	OAN
Alberto Barcia	Engineer	Chief engineer	10%	CAY
Rebeca Soria	PhD student	Support	10%	OAN
Jean-Francois Desmurs	Astronomer	Associated scientist	10%	OAN
Jesús Gómez-González*	Astronomer	IGN General Subdirector for Geodesy and Geophysics	10%	IGN
Rafael Bachiller	Astronomer	Director of OAN	10%	OAN

3. Status of the Geodetic VLBI Activities at OAN

The main contribution of OAN to IVS is the realization of geodetic VLBI observations in the EUROPE and CORE projects: the OAN radio telescope at Yebes has participated in two EUROPE and three CORE experiments in 2003, failing to participate in two other EUROPE and one CORE due to technical problems with the old antenna control system and receiver. The institute also participates in the European VLBI Network (EVN) for astronomy (two sessions at X band in 2003), taking part in its logistics and carrying out technical developments.

4. Future Plans

The OAN 14-m radio telescope at Yebes goes on participating regularly in the campaigns for the EUROPE and CORE projects.

The construction of the new 40 meter radiotelescope at Yebes is progressing well. The erection is expected to finish in May 2004. This telescope is expected to be operational at S/X bands in mid 2005. Other frequencies of operation will be 4-7 GHz, 10-15 GHz, 21-24 GHz (first light receiver), 30-32 GHz, 40-50 GHz, and 72-116 GHz.

Finally, studies are being conducted to connect the Yebes site to GEANT (the high speed transeuropean data network).

References

[1] R. Bolaño, P. de Vicente, C. Albo, C. Almendros: "Monitorizacin de los errores de posicionamiento de la antena de 14M para su uso sincronizado con el terminal VLBI", Informe Técnico OAN 2003-6

Yellowknife Observatory

Mario Bérubé, Calvin Klatt, 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. This report gives an update on recent activities.

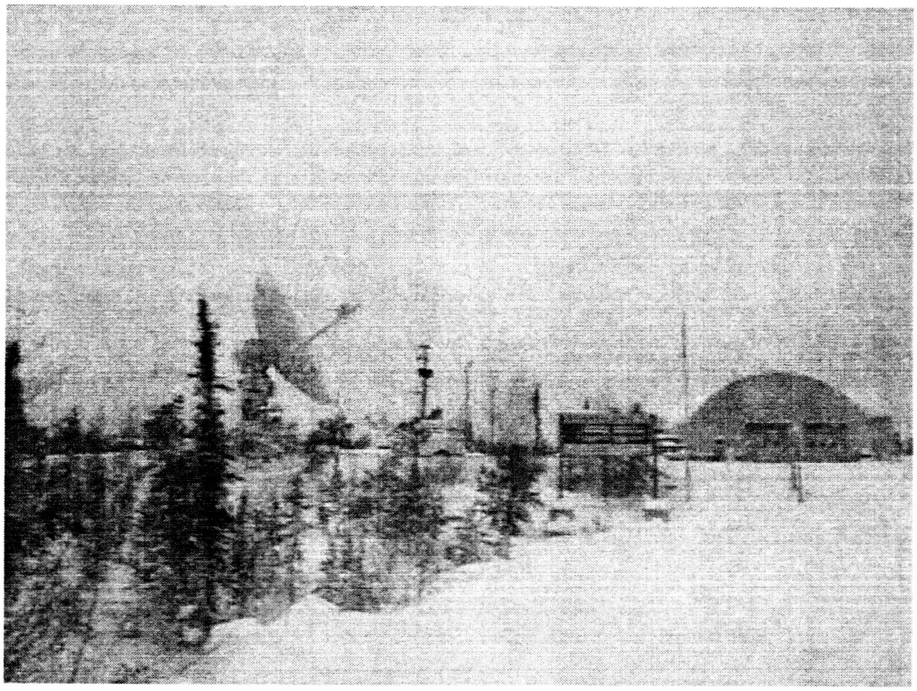

Figure 1. A snowy Yellowknife Geophysical Observatory 9m antenna.

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 came on the air in the summer of 1991.

The antenna is located at the Yellowknife Geophysical Observatory and is operated by the Geodetic Survey Division, Natural Resources Canada. The Yellowknife Geophysical Observatory is operated by the Geological Survey of Canada, Pacific Division, Natural Resources Canada.

2. General Specifications

- Latitude : 62.48 North
- Longitude : 114.48 West
- Reflector : 9m
- Receiver : S and X cryogenic
- Azimuth speed : 40 degrees per minutes
- Elevation speed : 40 degress per minutes
- PCFS version : 9.5.3
- VLBI equipment : Mk 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 (December till 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. The antenna control unit was replaced with one similar to that at Algonquin. Last year, antenna reliability was improved by upgrading antenna drives.

Maintenance of NR maser was done as scheduled with power supply upgrade.

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 2003 - December 2003

In 2003 Yellowknife was involved in 4 IVS–T2 (Terrestrial Reference Frame sessions), and in 5 IVS–E3 sessions.

OPERATION CENTERS

The Bonn Geodetic VLBI Operation Center

A. Nothnagel, D. Fischer, A. Müskens

Abstract

In 2003 the GIUB Operation Center has continued to carry out similar tasks of organizing and scheduling various observing series as in 2002.

1. Center Activities

The GIUB VLBI Operation Center is located at the 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 are the same as in 2002:

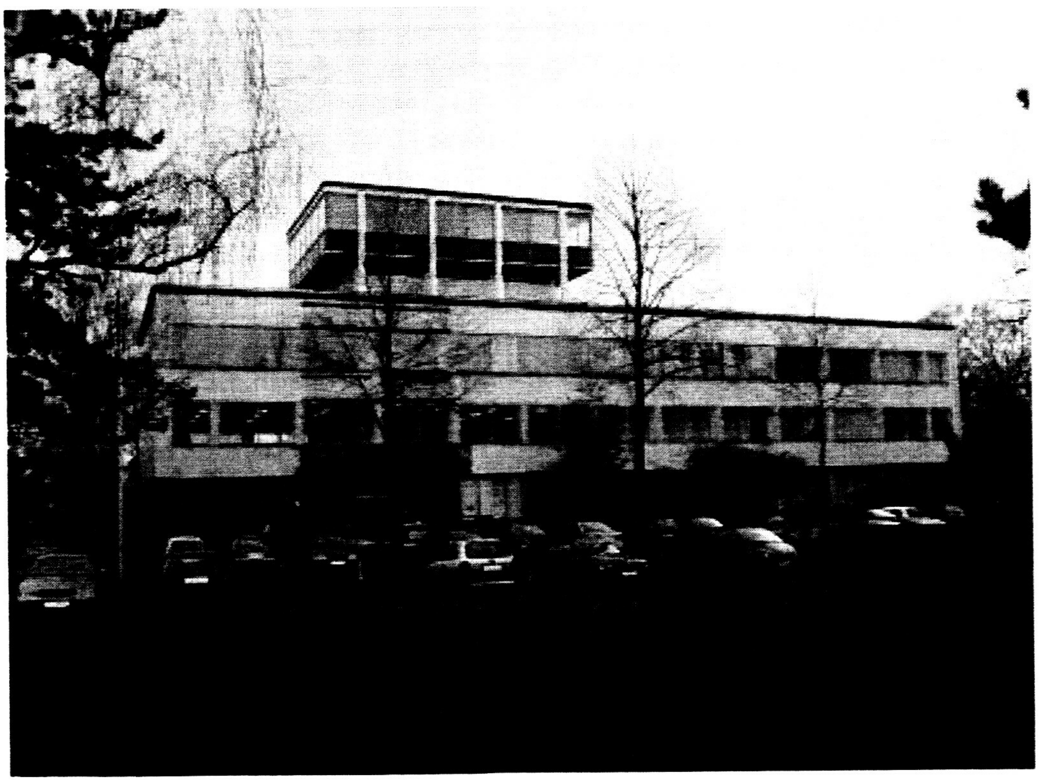

Figure 1. Building of the Geodetic Institute

- **Tsukuba - Wettzell UT1-UTC K4 Intensive Series**
  The Tsukuba - Wettzell Intensive series for monitoring UT1-UTC has been continued as a joint project of the Bundesamt für Kartographie und Geodäsie (BKG, Germany), the Geographic Survey Institute (GSI, Japan) and the Geodetic Institute of the University of Bonn (GIUB, Germany).

31 single baseline sessions of about 90 minute duration were scheduled between April 12th and December 31th, 2003. Each one was carried out between 7.30 and 9.00 UT and was composed of 20 scans. Taking advantage of unattended observing at Tsukuba the sessions could be scheduled on Saturdays filling the weekend gaps of other series. The K4 system was employed for recording the data. In the scheduling of the individual sessions special emphasis was given to the use of equatorial sources and to the inclusion of sources spanning a wide range of elevations.

BKG and GSI contribute observing time at the Wettzell and Tsukuba radio telescopes. GSI is responsible for the K4 correlation at Tsukuba and GIUB carries out the operation control, scheduling and analysis of the sessions.

- **IVS-T2 series**
  This series is observed roughly once per month (10 sessions in 2003) primarily for maintenance and stabilisation of the VLBI terrestrial reference frame as well as for Earth rotation monitoring as a by-product. This series is the follow-on of the International Radio Interferometric Surveying - South (IRIS-S) campaign with varying network configurations.
- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE)**
  Four sessions with Ny-Ålesund, Onsala, Wettzell, Simeiz, Madrid (DSS65), Yebes, Medicina, Matera, Noto, Svetloe, and Effelsberg (participated once) have been scheduled for precise station coordinate determination and long term stability tests.
- **Southern Hemisphere and Antarctica Series (OHIG):**
  Four sessions 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.

2. Staff

Table 1. Personnel at GIUB Operation Center

Dorothee Fischer	++49-228-732623	dorothee.fischer@uni-bonn.de
Arno Müskens	++49-228-525264	mueskens@mpifr-bonn.mpg.de
Axel Nothnagel	++49-228-733574	nothnagel@uni-bonn.de

Arno Müskens took care of the T2 and the OHIG sessions, Dorothee Fischer organized the Tsukuba - Wettzell series while Axel Nothnagel was responsible for the EUROPE project.

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 2003 to December 2003. The report forecasts activities planned for the year 2004.

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 was started in 2002 and used the Mark IV recording mode for each session. The IVS program began using the Mark 5 recording mode in mid 2003. The following are the network configurations for the sessions for which the CORE Operation Center was responsible:

IVS-R1: 52 sessions, scheduled weekly on Mondays, seven station network

RDV: 6 sessions, scheduled evenly throughout the year, 18 to 20 station network

IVS-R&D: 10 sessions, scheduled monthly, seven station network

2. IVS Sessions January 2003 to December 2003

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

- IVS-R1: In 2003, the IVS-R1s were scheduled weekly with a seven station network. There was a core network for each day plus two or three other stations. Hobart started observing in May 2003 when the station was upgraded to Mark 5. Hobart was the only "Mark 5 only" station during 2003. Wettzell, Westford, Kokee, and HartRAO were the only other stations that recorded on Mark 5 during this period.

  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 tapes to the correlator as rapidly as possible. The "1" indicates that the sessions are 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 small numbers of sources. NASA (the CORE Oeration Center) prepares the schedules for the RDV sessions.

- R&D: The purpose of the 10 R&D sessions in 2003, as decided by the IVS Program Committee, was to provide additional information to understand possible differences between the IVS-R1 and the IVS-R4 sessions. In 2002, the IVS-R4 sessions appeared to be achieving better earth orientation results with a lower data rate (56 Mbps vs. 256 Mbps). The R&D sessions were scheduled with a network similar to the IVS-R4 network but using the IVS-R1 observing mode. The R&D experiments used a 7-station Northern-hemisphere geodetic network and were scheduled monthly, adjacent to IVS-R4 sessions with the same stations except one. Westford participated in the R&D replacing Fortaleza since Fortaleza has not been upgraded to Mark IV.

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

Table 1 lists the average formal errors for X-pole, Y-pole, UT1, and nutation parameters estimated from the R1, R4, R&D, T2, and RDV sessions that took place during 2003. The R1 EOP parameters agree better with C04 than those from R4, T2, and R&D sessions although this may be due in part to the better formal uncertainties of the R1s and the weighting scheme employed in generating C04. Clearly X-pole and DPSI are not determined as precisely with R4 compared to R1. Formally, the R&D EOP precision is not significantly different from R4 precision (except somewhat in X-pole) but there are some significant differences in the comparison with C04. But with only 10 sessions, we may not be able to make statistically significant conclusions. For example, removing one session reduces the wrms difference relative to C04 for UT1 to 2.7 us.

Table 1. Table 1. Average EOP Formal Uncertainties

Session Type	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (mus)	DEPS (mus)
R1	52	50	1.9	114	47
R4	81	69	2.9	163	65
T2	157	157	6.0	335	145
R&D	65	70	2.4	143	60
RDV	33	37	1.8	72	28

Table 2. Table 2. WRMS Differences Relative to C04

Session Type	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (mus)	DEPS (mus)
R1	61	71	2.9	113	56
R4	97	66	3.3	165	77
T2	158	99	6.2	164	81
R&D	94	103	9.2	122	36
RDV	44	32	2.5	79	28

4. The CORE Family

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 3. Key Technical Staff of the CORE Operations Center

Name	Responsibility	Agency
Tom Buretta	Recorder and electronics maintenance	Haystack
Brian Corey	Analysis	Haystack
Irv Deigel	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
Cindy Villiard	Analysis	Raytheon/GSFC
Dan MacMillan	Analysis	NVI, Inc./GSFC
Leonid Petrov	Analysis	NVI, Inc./GSFC
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordinate master observing schedule and prepare observing schedules	NVI, Inc./GSFC
Nancy Vandenberg	Organizer of CORE program	NVI, Inc./GSFC
William Wildes	Procurement of materials necessary for CORE operations	GSFC/NASA

5. Planned Activities during 2004

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2004.

- The IVS-R1 sessions will be observed weekly and recorded in a Mark IV mode. We will increase the number of stations using Mark 5 recorders as determined by the Coordinating Center.
- The IVS-R&D sessions will be observed 10 times during the year. The purpose of the R&D sessions in 2004 as determined by the IVS Observing Program Committee is to study how to use Gb/s data rate for geodesy. Phase delay will be attempted and the SNRs will be set high.
- The RDV sessions will be observed 6 times during the year.

U.S. Naval Observatory Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 2003. The Operation Center schedules IVS-R4 and the 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 four daily one-hour duration "intensives" for UT1 determination. The operational IVS-R4 network has included VLBI stations at Gilmore Creek (Alaska), Kokee Park (Hawaii), Wettzell (Germany), Fortaleza (Brazil), Ny-Ålesund (Norway), Algonquin Park (Canada), TIGO (Chile), Svetloe (Russia), Hobart (Australia), Onsala (Sweden), and Matera (Italy). A typical R4 consists of 7 stations. The stations for the IVS-Intensives were Kokee Park and Wettzell.

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

2. Staff

M. S. Carter continues as the only staff member of the NEOS Operation Center.

CORRELATORS

The Bonn Astro/Geo Mark IV Correlator

Arno Müskens, Walter Alef

Abstract

The Bonn Mark IV VLBI correlator is operated jointly by the MPIfR (Bonn), the GIUB (Bonn) and the BKG (Frankfurt). In the course of 2003 eight Mark 5A systems have been installed. The amount of data recorded with Mark 5A has reached 40%.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (*MPIfR*)[1], Bonn, Germany. It is jointly operated by the MPIfR and by the *BKG*[2] in cooperation with the *GIUB*[3]. It is a major correlator for geodetic observations, and MPIfR's astronomical projects.

2. Present Status and Capabilities

The correlator in Bonn is one of four world-wide Mark IV VLBI data processors. It has been operational since 2000. It consists of the standard 16 station capable correlator unit and nine Honeywell/Metrum 96 tape drives, each of which is connected to the correlator via a standard Mark IV station unit and high speed data links.

The tape units are all equipped with digitally-switched equalizer boards developed in Bonn which allow playback of thin (and thick) tapes recorded at normal (80/135 ips) and double speed (160/270 ips).

In the course of 2003 eight Mark 5 disc-recorder units were added to the data processor. The tape drives were re-arranged to make space for a rack which can hold seven Mark 5 units (see Fig 1). The Mark 5 units are connected to the station units in parallel to the tape drives. Data from the tape units is fed into input for head one and data from Mark 5 into input for head two. As the tape drives are equipped with only one playback head the second input is otherwise unused. Playback from tape or disc can be selected via a simple software switch. With this setup all 32-track modes can be correlated from both tapes and discs. 64-track modes can be correlated with modest re-cabling with either one or two correlation passes depending on the details of the experiment.

The supported formats on tape and disc are Mark IIIA, Mark IV and VLBA, both Mark IV and VLBA with 1- or 2-bit sampling and barrel-rolling. Fan-in modes are not supported while all the fan-out modes 1:1 and 1:2 and 1:4 are possible. Up to 16 frequency channels can be used, both upper and lower sidebands. Channel bandwidths of 2, 4, 8 and 16 MHz are available. Observing modes with 512 and 1024 Mbits/s have been correlated successfully without major problems, where 1024 Mbits/s can only be realized with Mark 5 systems.

The correlation is done in a scan-based way; the overhead for each scan is about 2 to 3 minutes for tapes and 1 minute for the disc recordings. It takes less than about 5 seconds to synchronize

[1] http://www.mpifr-bonn.mpg.de/div/vlbicor/index_e.html

[2] Bundesamt für Kartographie und Geodäsie, Frankfurt, Germany, http://www.ifag.de/Geodaesie/gf_e.htm

[3] Geodetic Institute, University of Bonn, Germany, http://giub.geod.uni-bonn.de/vlbi

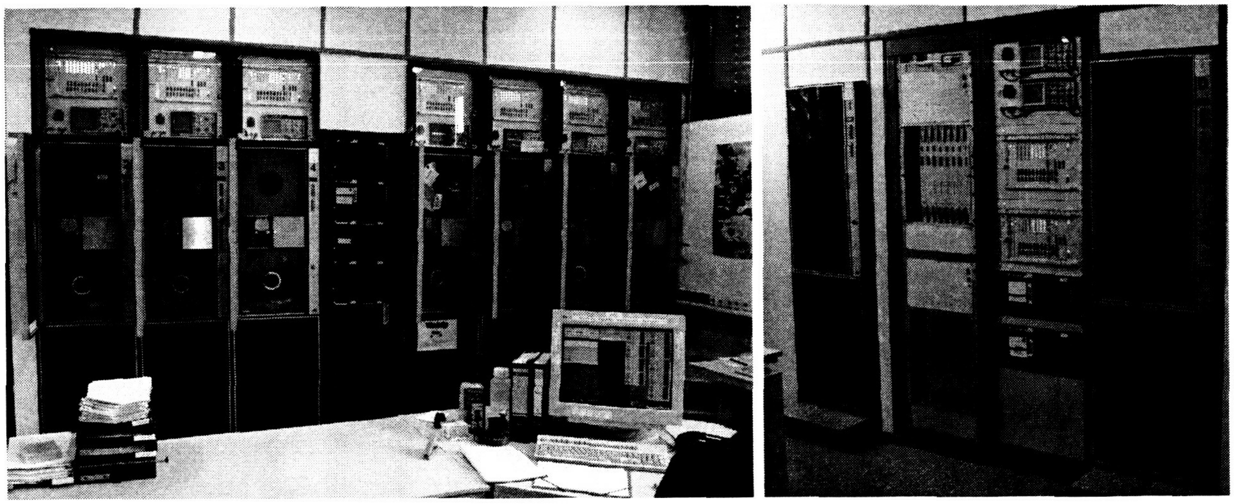

Figure 1. Tape drives with stations units on top, Mark 5 units in a rack, and the correlator surrounded by two more tape drives, Mark 5 units, and station units. The correlator control console is visible on the desk in the center.

the tapes while the synchronization of Mark 5 systems is instantaneous. Up to two of the phase-cal tones can be extracted, but only one is used by the fringe-fitting software to align different frequency channels. The geometric correlator model is CALC 8. The pre-averaging time is flexible from 1 to 5 seconds. Shorter pre-averaging times are possible, but can only be sustained by correlating fewer stations simultaneously.

The installed computer power is sufficient to handle all nine tape units in a correlator mode with 32 lags, auto-correlations and 1 s pre-averaging. Full polarization correlation is possible with 8 stations simultaneously. For improved spectral line resolution, correlator modes with up to 1024 complex lags have been used. Correlation setup, data inspection, fringe-fitting, and data export is 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 380 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 GB disk of a low-end Linux PC.

The correlator software has become fairly stable in the last two years, and the only major changes provided by Haystack addressed the handling of Mark 5 data. The track-finding software for the tape drives was modified in Bonn to avoid accidental correlation with one head-pitch offset.

The software of the Mark 5 systems is still under constant development and has to be upgraded regularly, but the reliability of the disk systems is already higher than that of the tape drives.

An up-to-date list of correlator capabilities can be found on the Internet under http://www.mpifr-bonn.mpg.de/EVN/MK4CORstatus.

3. Correlator Operations and Statistics

The people in the geodetic group at the Bonn correlator are

- Arno Müskens : group leader, overall experiment supervision, scheduling of T2 and OHIG series

- Izabela Rottmann : experiment supervision (part time; left in 2003)
- Alessandra Roy : experiment supervision (part time)
- Alexandra Höfer : experiment supervision (started in late 2003)
- 10 student operators for the night shifts and the weekends (60 hrs / week)
- Alan Roy : measurement and correction of tropospheric path length variations

Experiment supervision includes the preparation of correlator control files, fringe searching, supervision of the correlation process, preparation of the re-correlation, the correlator report, database generation, archiving, and the supervision of tape shipments.

MPIfR supports IVS correlation with

- Walter Alef : correlator manager, correlator software maintenance and upgrades, and computer system administration
- David Graham : technical development, consultant
- Heinz Fuchs : correlator operator, responsible for correlator operator scheduling, daily operations, and tape shipping.
- Hermann Sturm : correlator operator, correlator support software, tape shipping
- Michael Wunderlich : engineer, correlator and playback drive maintenance, Mark 5 support
- Arno Freihold : engineer, correlator maintenance, digital BBC development
- Rolf Märtens : technician, playback drive maintenance, Mark 5 support

The Bonn group correlated in 2003:

- T2 experiments : 8
- R1 experiments : 30
- EURO experiments : 5
- CONT02 experiments : 1
- OHIG experiments : 3

Experience with IVS-R and other 24 hour observations shows it has been possible to reduce the processing factor (correlation time/observe time) by about 20 to 30% (see Fig 2), and the amount of re-processing by almost 75%. This is mostly due to reduced setup time and less operator interaction now that up to four stations record on Mark 5 systems, to more stable station unit software, and improved track-finding software.

The geodetic backlog from 2002 vanished towards the end of 2003 with the help of the improved throughput and less geodetic observing and correlation. The overall usage of the correlator in 2003 for geodetic correlation was 57% compared to 70% in 2002.

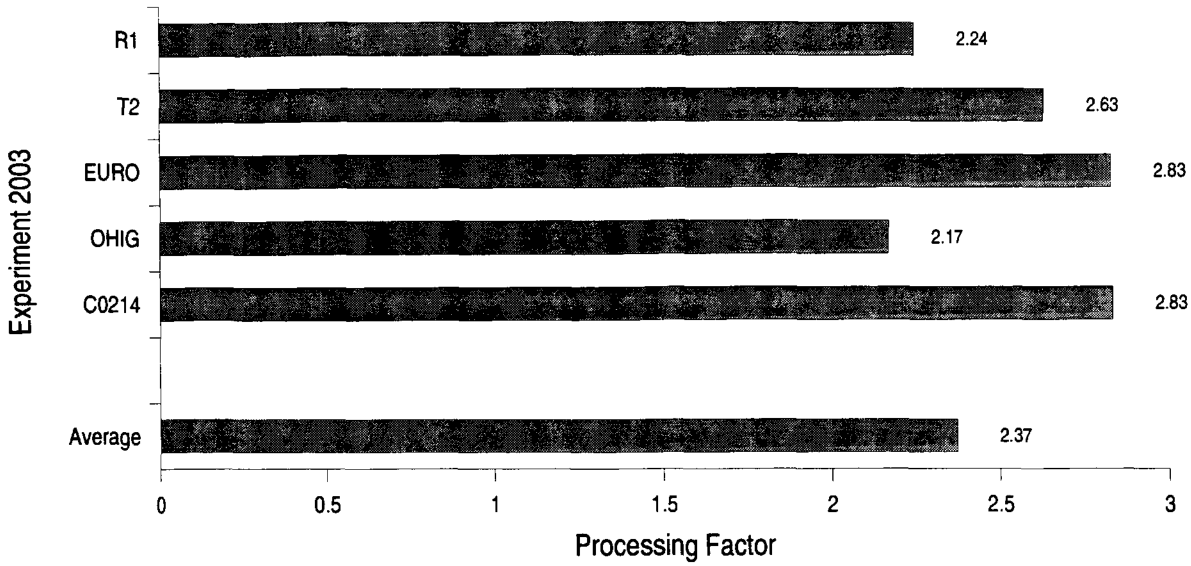

Figure 2. The processing factor could be reduced by about 20 to 30% compared to 2002. This is mostly due to the conversion of 2 to 4 stations to Mark 5 recording system.

4. Outlook

It is expected that in the course of 2004 all geodetic and EVN observations will be done exclusively with Mark 5. The tape drives will still be maintained because of joint 3mm-observations with the VLBA which does not yet have funding for Mark 5.

MPIfR will support the development of the Mark 5B system by re-designing the serial high-speed data links between the correlator and the planned station unit part of the Mark 5B units. It is also planned to fully upgrade the correlator to Mark 5B systems in 2004/2005.

The development of fully digital base-band converters (dBBCs) is also supported at MPIfR. This project lead by Gino Tuccari from Noto will eventually allow replacing the aged analog BBCs with new hardware. Improved bandpass characteristics as well as higher data-rates will help to increase the precision of the geodetic observables.

Haystack Observatory VLBI Correlator

Mike Titus, Roger Capppallo, Brian Corey, Arthur Niell

Abstract

This report presents the status of the Haystack Correlator, focusing on its activities, its current and future hardware capabilities, and its staff.

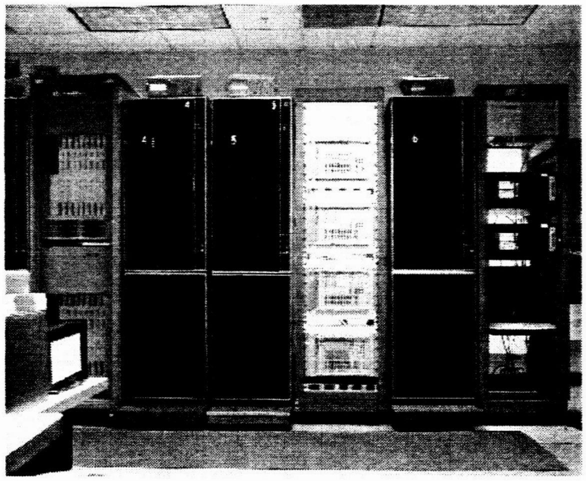

Figure 1. Partial view of Haystack Mark IV correlator, showing correlator rack, 3 tape units, 1 rack containing 4 SUs, and 1 rack containing 2 Mark 5A units and a decoder.

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 divided approximately equally between processing geodetic VLBI observations for IVS and processing millimeter-wave radio astronomy observations for the Coordinated Millimeter VLBI Array. In addition to its role as an operational processor, the Haystack Correlator also serves as a development system for testing new correlation modes and hardware improvements 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.

2. Summary of Activities

Integration and testing of Mark 5 on the correlator has continued throughout the year. The two initial Mark 5P units have been replaced with Mark 5As, and two more have been added. Production use of Mark 5 has steadily increased, resulting in frequent upgrades with enhanced software on the Mark 5s and correlator in order to improve the smoothness of operation. The increased use of Mark 5 recordings and the effects of other improvements in software, such as the elimination of "forks" and byte slips, have resulted in improved efficiency. For R1 experiments the efficiency factors are now routinely below 2.0 - typically 1.8 or so - whereas previously they were typically between 2 and 2.5. This is reflected in the improved efficiency of all the Mark IV correlators, which have significantly reduced or completely eliminated their backlogs over the last year.

Another area of continued focus has been e-VLBI. Several e-VLBI test experiments, and the use of e-VLBI for quick feedback fringe tests, have demonstrated the value of e-VLBI in an operational sense. One particular accomplishment worthy of note is the turnaround of a Kashima-Westford Intensive session within 24 hours (27 June 03). More recently, the focus has been on automating the transfer process and the transfer of entire 24-hour sessions (particularly Kashima data from the CRF series).

In addition to these developments, other improvements and fixes continue to be implemented on a time available or as needed basis. These are intended to improve operations or data quality, or to correct problems. It should be noted that some fixes and improvements come as a byproduct of Mark 5 or e-VLBI related development, showing that new technology development and improvements of a more general nature are often coupled.

3. Experiments Done

Since January 2003, 40 experiments have been processed at the Haystack correlator. This total subdivides into 19 R1s, 8 R&Ds, 3 CONTs and 10 test experiments. The test experiments cover an assortment of e-VLBI, Mark 5, correlator software, and station/equipment tests. The increase in 24-hour production experiments over last year (+4), reflects the better throughput due to improved efficiency.

4. Current/Future Hardware and Capabilities

Currently functional hardware installed on the system consists of 7 tape units, 4 Mark 5 units, 7 station units, 16 operational correlator boards, 2 crates, and miscellaneous other support hardware, with the ability to process all baselines for 7 stations simultaneously in the standard geodetic modes. By late 2004, development of the Mark 5B might allow the correlation of more than 7 stations, due to the ability to add Mark 5 units without the need for an accompanying station unit. We expect to remove tape drives from the system as more stations move to exclusively recording on Mark 5.

5. Staff

Staff who participate in aspects of Mark IV development and operations include:

5.1. Software Development Team:

- John Ball - operator interface; playback; Mark 5/e-VLBI development
- Roger Cappallo - leader; system integration

- Kevin Dudevoir - correlation; maintenance/support; e-VLBI development
- David Lapsley - e-VLBI development
- Colin Lonsdale - post processing
- Alan Whitney - system architecture; Mark 5/e-VLBI development

5.2. Operations Team:

- Peter Bolis - correlator maintenance
- Tom Buretta - playback drive maintenance
- Brian Corey - experiment correlation oversight; station evaluation; technique development
- Dave Fields - playback drive maintenance; Mark 5 installation/maintenance
- Ellen Cellini - correlator operator
- 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

6. Conclusion/Outlook

Continued integration and expansion of Mark 5 units into the correlator will be a major effort in the next year. Mark 5B development might make possible an increase in the number of stations that can be processed simultaneously. Another major priority will be development of e-VLBI. Efforts to improve operations and efficiency will continue, and all of the above tasks should result in further improved data quality and increased data throughput for the Mark 4 correlators in the coming year.

IAA Correlator Center

Valery Gratchev

Abstract

In 2003 the IAA S2 correlator TISS-1M processed six sessions for radio source structure investigation. Also, some revisions and updates were made for control and post processing programs. The Institute of Applied Astronomy is developing Altera FPGA-based scalable correlator PARSEC with Mark4 specification. We have developed the prototype correlator MicroPARSEC. PCI-bus correlator board MicroPARSEC has standard office PC board format.

1. General Information

The S2/Mark3 correlator (Figure 1), new correlator MicroPARSEC and PARSEC are located at and staffed by the Institute of Applied Astronomy in Saint-Petersburg, Russia. The correlators are sponsored and funded by the Russian Academy of Sciences, by the Russian Foundations of Basic Research and by the Russian Ministry of Sciences and Technologies. Dedicated to processing geodetic, astrometric and astrophysical VLBI observations, the general role of the correlators is as an operational processor for VLBI observation in Russia.

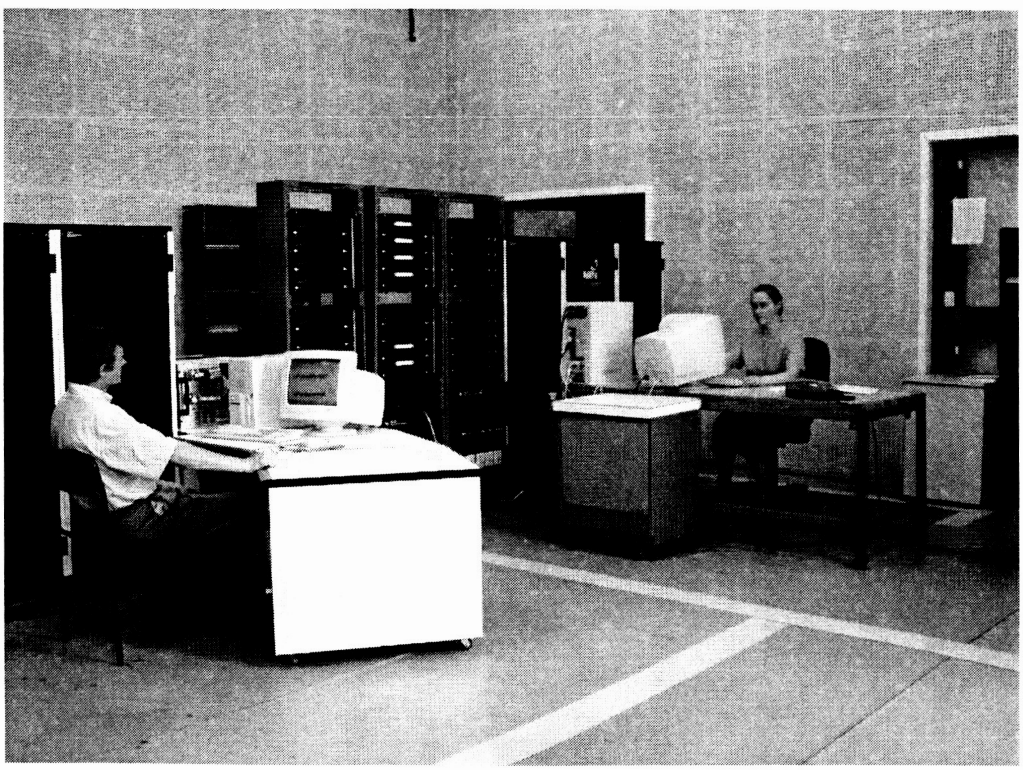

Figure 1. **S2 correlator TISS-1M at the IAA correlator center in Saint-Petersburg.**

There are three racks with S2-PT terminals at the center of the back plane and six racks for correlator devices on the left and right from play back terminals. On the right of front plane, there is a table with control computer with correlation software and post processing program PrOut.

2. Correlation Processing

In 2003, we processed the following S/X experiments at Svetloe-Zelenchukskaja baseline for radio source mapping by using of amplitude method.

04-06 February and 28 February 2003,

04-05 March 08-16 March 2003,

20-28 April 2003, 22-25 May 2003,

09-12 August 2003,

14-17 September 2003.

Also, we made some fringe tests to investigate the antenna pointing accuracy at Svetloe and Zelenchukskaija.

3. New Correlators

The Institute of Applied Astronomy is developing Altera FPGA-based scalable correlator PARSEC with Mark4 specification. The correlator unit uses PCI-bus correlator boards, standard CompactPCI hardware with single board Intel Pentium control computer and standard Linux operating system (Figure 2). We have estimated that it is possible to provide 4-station and 16-channel 1- or 2-bit data processing by using single correlator unit with Mark5 VSI compatible playback system for VLBI and e-VLBI.

We have developed the prototype correlator MicroPARSEC. PCI-bus correlator board MicroPARSEC (Figure 3) has the following features: standard office PC board format, single board supports 2 cross-correlation channel for one baseline, operation at input data rate to 64 Msamples/sec/channel, 1 or 2 bit sampling, integrated input data rate to 512 Mbit/s, the board can be connected directly to Canadian S2-RT or S2-PT.

The features of the IAA correlators are summarized in Table 1.

We have produced and tested four MicroPARSEC correlator boards, which also may be used as scalable spectrum analyzer for station phase cal extraction and other different system diagnostic and/or spectral line real time observation data processing in single dish mode on our radio telescopes in Svetloe, Zelenchukskaya and Badary. We are going to start volume production in order of the correlator board MicroPARSEC for standard office PC with standard Windows 98/2000/XP operating system and special control and monitor program developed in IAA.

4. Updating the Control and Post Processing Programs

One of the major updates was made to the control correlator program for serial processing data of geodetic S2 VLBI observation at Russian stations. The program is installed in IBM PC Pentium III under Windows 98. For the calculation of model for delay tracking and fringe stopping the program package ERA developed at the IAA is used.

The post processing program PrOut was updated to extract the observables from serial raw correlator output data. The PrOut in Visual C++ v.6.0 is installed on IBM PC Pentium IV computer under Windows XP operating system.

Table 1. Comparison of the correlators at the IAA

	TISS-1M	MicroPARSEC	PARSEC
Year of production	1993	2003	2004
Data input format	Mark3	S2/VSI	S2/VSI
Number of channels	30	2	16
Number of lags	8	64	64
Processing rate/ch	4 Mbps	64 Mbps	64 Mbps
Sample bit	1 bit	1 or 2 bit	1 or 2 bit
Phase resolution in fringe rotation	32 bit	32 bir	32 bit
Phase cal detect	1 Hz ÷ 1 MHz	1 Hz ÷ 4 MHz	1 Hz ÷ 4 MHz
Accumulation counter	24 it	30 bit	30 bit
Parameter period	5ms ÷ 1s	50ms ÷ 50s	50ms ÷ 50s
Pulsar gate	No	Yes	Yes
Main logic	Standard logic 1C	FPGA	FPGA
Data transfer	S2	S2/Mark5B	S2/Mark5B
Baselines	3	1	6

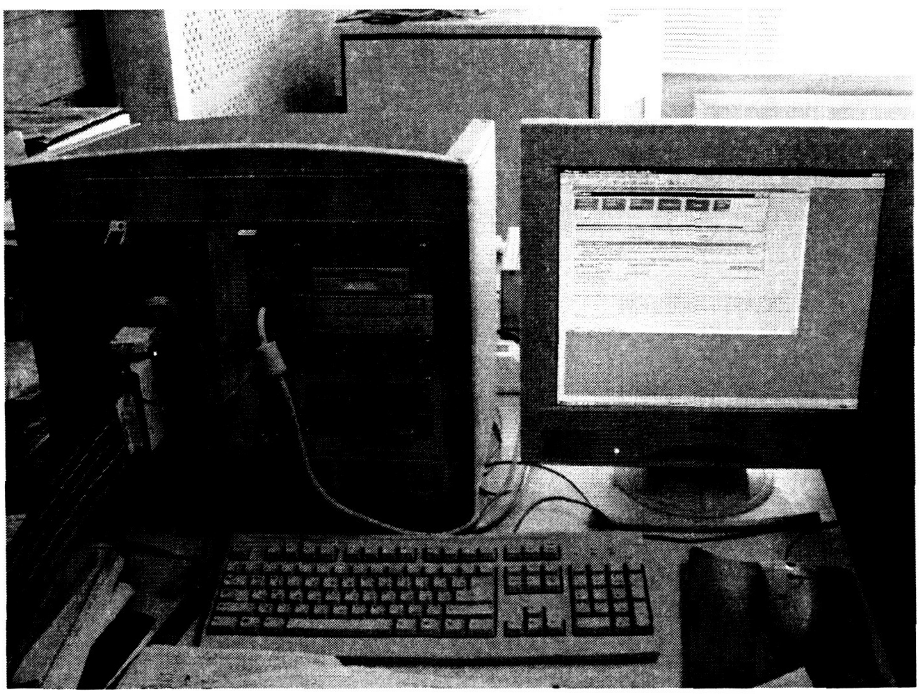

Figure 2. **The prototype of Altera FPGA-based scalable correlator PARSEC with Mark4 specification.**

5. Conclusion/Outlook

Full construction of PARSEC correlator will be a major effort in 2004. The development, integration and expansion of Mark5 VSI compatible units will also be a priority.

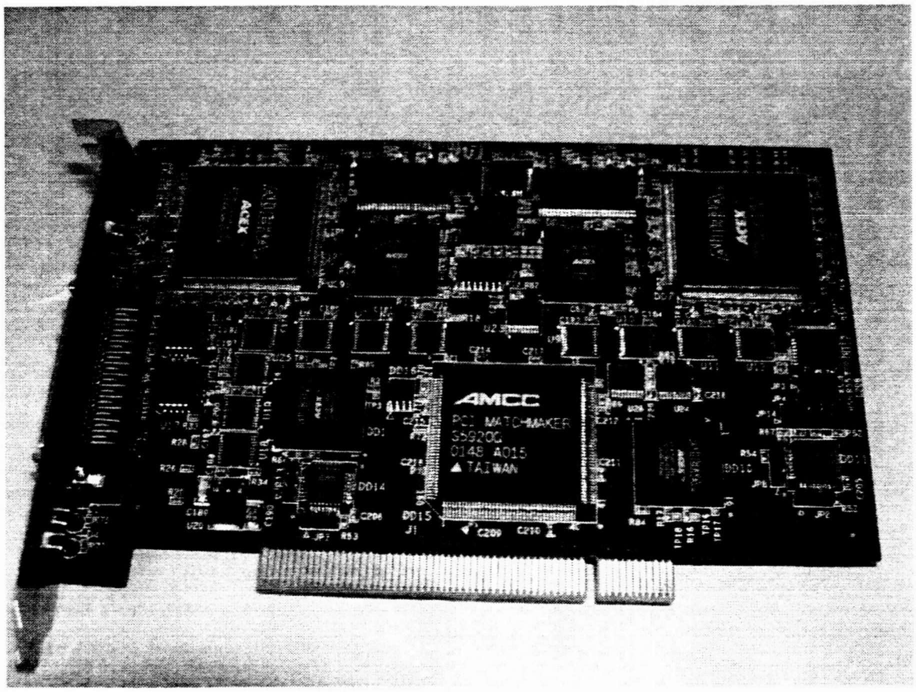

Figure 3. **PCI-bus correlator board MicroPARSEC.**

Kashima VLBI Correlators

Mamoru Sekido, Yasuhiro Koyama

Abstract

Tape-based correlation system of KSP has been used for processing of domestic VLBI experiments and Antarctica VLBI experiments. Except for KSP VLBI correlation system, overall activity in Kasihma/CRL related with VLBI correlator is introduced. Development of software correlators and status of giga-bit VLBI system are also described.

1. General Information

This component used to be titled "KSP-VLBI Correlation Center" until the previous issue. However the "Key Stone Project" had already closed and the correlators are now operated by VLBI group of Kashima Space Research Center. Thus the title was changed to Kashima VLBI Correlators. Corresponding to the change of title, the view of description was expanded from KSP correlation system to overall correlator related activity at Kashima/CRL.

The KSP correlation system (Kiuchi[a], 1999) is capable to process 4 stations 6 baselines tape-based VLBI data simultaneously. The data rate per station is 64 Mbps, 128 Mbps, or 256 Mbps with 16 channels 1 bit sampled data. We have other 6 one-baseline correlator units for real-time VLBI of the KSP (Kiuchi[b] et al., 1999), although it was not used after the shutdown of KSP. Then, for upgrading processing capability of correlation system at Geographical Survey Institute (GSI) from 3 baselines to 6 baselines, 3 correlation units and one recorder interface units were loaned to GSI.

2. Experiments Processed by KSP System

Figure 1 shows the view of operation room of KSP correlation system.

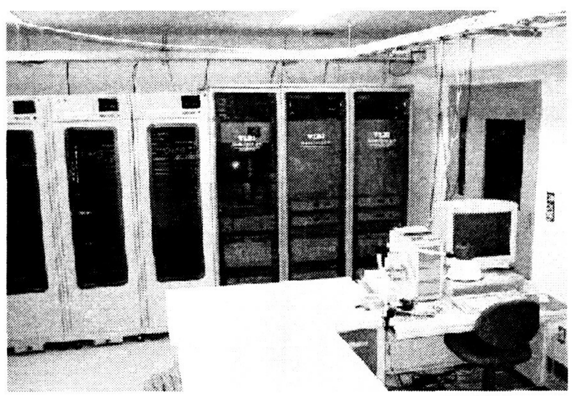

Figure 1. Operation room of KSP correlation system

The names of experiments processed by the KSP correlator in 2003 are as follows:

JADE series: Geographical Survey Institute (GSI) has been organizing domestic geodetic VLBI experiments with its own stations. Additionally GSI accepts any stations to join the experiments in omnibus style. This type of experiments are named JADE series and it is useful for Universities to determine their antenna coordinates in the ITRF and to perform geodetic study with single antenna. One of the cases is 11m antenna in Gifu University. However, correlation processing facility is limited at GSI and CRL. Then correlation processing between Gifu and other stations were performed with KSP correlator at Kashima.

SYOWA series: National Institute of Polar Research (NIPR), GSI, and National Astronomical Observatory (NAOJ) have been organizing a series of VLBI experiments to measure the Antarctica plate motion. Hobart, HartRAO, and Japanese Syowa VLBI stations were joined. The data observed at Hobart and HartRAO were originally recorded by S2 recorder, then the data are copied to K4 tapes at Mitaka. And several sessions of this series of experiments were processed by KSP correlator in Kashima.

3. Giga-bit Correlators GICO-I and GICO-II

Correlation processor with 1 giga-bps system (Nakajima et al. 2001) was developed in combination with 1 Gbps VLBI data recorder GBR-1000. And the next upgraded giga-bit correlator GICO-II (Nakajima[a] et al., 2000), which has 2 correlator chip sets accepting 2 Gbps data stream, was developed and it has been used for the first real-time giga-bit VLBI system on GALAXY network three years before (Nakajima[b] et al., 2000). These giga-bit VLBI system was used for verification of capability for geodetic VLBI application in 2003 (Takeuchi et al., 2003). Giga-bit VLBI system is displayed in Figure 2.

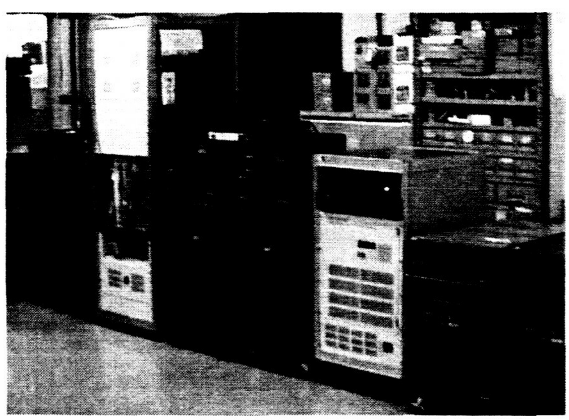

Figure 2. The Giga-bit VLBI system. The system in the left tall rack is GICO-I and that in the right short rack is GICO-II.

4. Software Correlators

PC-based data VLBI system named "K5 system" has been developed (Kondo et al., 2003). The data compatibility between K5 and Mark 5 has been confirmed in some recording modes and intercontinental e-vlbi experiment for UT1 measurement has been performed on Kashima-Haystack baseline (Koyama et al., 2003; Whitney and Koyama 2003). The K5 VLBI system is composed of 4 PCs with each IP-VLBI sampler board. One IP-VLBI sampler board has 4 channels with various sampling modes. The IP-VLBI board has also been used for VLBI experiments for spacecraft navigation (Ichikawa et al.,2003). The detail of the spacecraft observation will be discussed in the IVS General Meeting in 2004. Giga-bit sampler with VSI interface is also under development and corresponding high speed FX type software correlator has been also developed for the GIGA bit sampling data (Kimura and Nakajima. 2002, Kimura et al., 2003). This software correlator has flexibility to choose any lag number and is optimized to perform any number of baselines of Giga-bit data within a constant time interval, when the same number of PCs with observation stations are used for processing. Another activity in software correlator is "VLBI@HOME" project (Figure 3), which performs correlation processing with screen saver mode. It is a kind of approach for distributed correlation processing like a SETI@HOME. VLBI data might be processed on many office PCs in the darkness of midnight in near future.

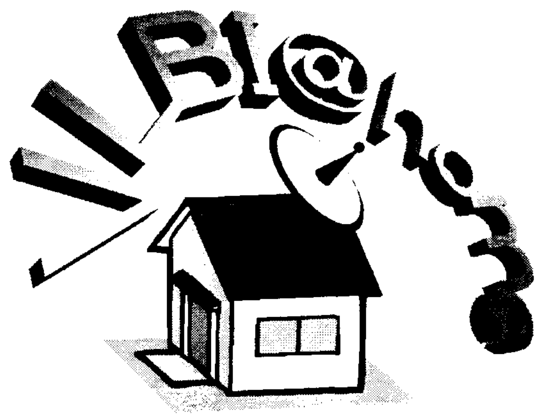

Figure 3. Logo mark of VLBI@home.

5. Staff

- Tetsuro Kondo is responsible for overall operations and performance, and he is developing software correlator for geodetic purpose.
- Yasuhiro Koyama is in charge of correlation processing system and working for e-VLBI on intercontinental baseline.
- Junichi Nakajima is in charge of giga-bit VLBI system.
- Mamoru Sekido is in charge of KSP correlation system and working for VLBI application for spacecraft navigation.
- Shinobu Arimura is in charge of routine correlation processing operation with KSP correlators.
- Moritaka Kimura is working for development of hardware giga-bit correlator and a high speed giga bit software correlator.
- Hiroshi Takeuchi is working for development of VLBI correlation system in screen saver mode.

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Tsukuba VLBI Correlator

Morito Machida, Masayoshi Ishimoto, Shinobu Kurihara, Kazuhiro Takashima

Abstract

This is a report of activities at the Tsukuba VLBI Correlator in 2003.

1. General Information

The Tsukuba VLBI Correlator is located at Geographical Survey Institute(GSI) in Tsukuba, Ibaraki, Japan. The facility holds the K-4 (KSP) correlation system for processing geodetic VLBI experiments. It consists of three correlator units, three tape drive units housed in auto tape changers and a HP workstation to control the system and run Interactive CALC/SOLVE (NASA/GSFC). The workstation also provides a working area for executing correlation software, Oxtail Version 2.0, which was updated in March 2003 as described in the previous Annual Report.

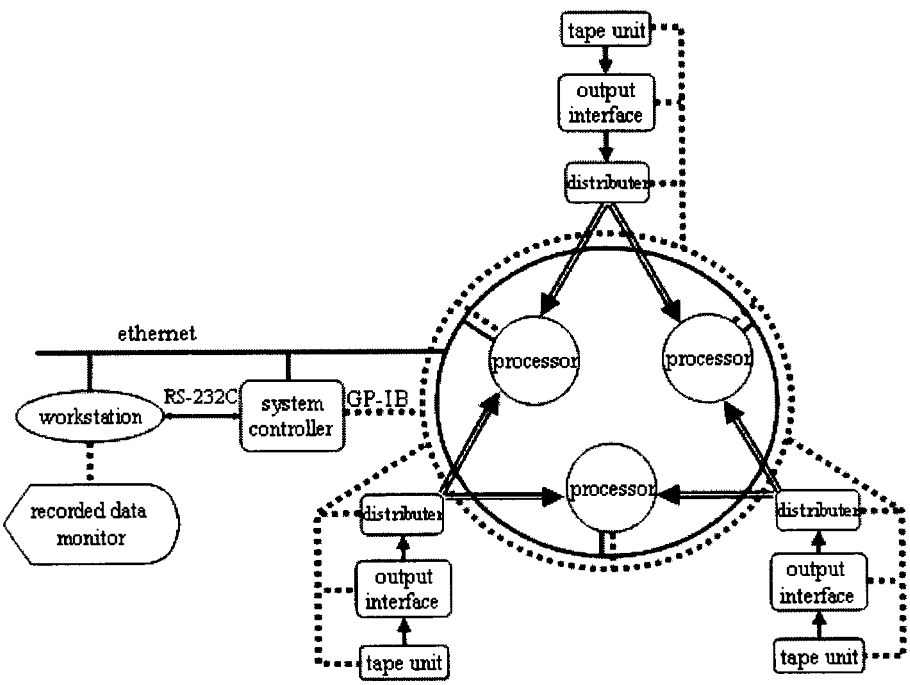

Figure 1. Diagram of K-4 (KSP) correlation system at the Tsukuba VLBI Correlator.

2. Correlation Processing

We extended the operational time due to the increased demand for geodetic correlation. During 2003, 11 domestic experiments, 28 intensive sessions and some fringe tests have been processed at the Tsukuba VLBI Correlator. The JADE (Japanese Dynamic Earth observation by VLBI) series are set monthly by GSI for monitoring plate motions and maintaining the International

Terrestrial Reference Frame in Japan. GSI's original VLBI network (GARNET or GSI Advanced Radiotelescope Network) stations regularly take part in the JADE experiments, and other stations with K-4 recording system can join JADE to determine their antenna positions. Due to that the capacity is not enough to process the data from all participating stations at once, we correlated only the data from the GARNET stations and the Mizusawa station at the Tsukuba VLBI Correlator, and the data from other participating stations were correlated by Gifu University or CRL at the KSP-VLBI Correlation Center of Kashima Space Research Center under an agreement between CRL and GSI. In 2003, it took several months to get all data put together into Mark III databases with several non-GARNET stations joined in JADE, and we handled as follows. As preliminary stage, we processed the GARNET and Mizusawa station's data and made databases to check the quality of the results. After these databases were submitted to IVS, we re-processed all baselines by adding the data of the other stations that were sent later from the KSP-VLBI Correlator at Kashima. We resubmitted it informing the re-processing to IVS analysts, because correlators normally submit databases to IVS only once.

Intensive sessions for determining UT1 were observed by the single baseline between TSUKUB32 and WETTZELL nearly weekly from April through December, 2003. At each session, we took 5-7 days to receive the data from WETTZELL and 1 day to complete the correlation processing and the primary solution. After the database was submitted to IVS, the final analysis were done at University of Bonn. We were confident that UT1 was determined with consistency by comparing our results to the WETTZELL-KOKEE baseline. The WETTZELL-KOKEE baseline is orthogonal to TSUKUB32-WETTZELL baseline and the intensive sessions of the WETTZELL-KOKEE single baseline is being carried out 4 times a week with Mark 5 recording systems. The results of these two baselines generally agreed each other in each experiment even though two different recording systems were used.

In the JADE experiments, no fringe had been detected on the baselines to SINTOTU3 in the GSI VLBI network since August, 2002. We tried to get to the reason for it in various ways and found that there was about -5 msec of gross time deviation on the local time system, which was caused by unlocking 1 pps signal in the GPS timing receiver. We tried to do fringe test with setting the stations's clock offset -5.165 msec and finally succeed in fringe detection. Some of previous JADE experiments such as JADE-0206 were re-processed with the offset and new databases were re-submitted to IVS.

In the intensive sessions, because of equipment failures, we lost the data of several sessions, which were not taken into account of 28 sessions.

3. Global Solution

The set of coordinates of GSI VLBI stations is to be a basis for defining the framework in the geodetic datum of Japan. However, the GSI VLBI stations except TSUKUB32 are not members in the major IVS network stations that the positions and velocities have been determined on a worldwide scale with global solutions using the CALC/SOLVE etc. The JADE experiments that these GSI VLBI local stations take an active role do not have the advantage of estimating EOP, because the baselines are not intercontinental. Consequently, the weights of these stations are set too low on the conventional global solutions on a regular basis such as for EOP. In this circumstances, we have approached to determine these local station position/velocity with few mm precision in our research activities in 2003. Preliminary results (Table 1) can be reviewed on the web (http://vldb.gsi.go.jp/sokuchi/vlbi/solutions/).

Table 1. Station position with global solution by GSI

station	X [m]/sigma	Y [m]/sigma	Z [m]/sigma	session
TSUKUB32	-3957408.777	3310229.389	3737494.810	159
	0.001	0.001	0.001	
SINTOTU3	-3642142.083	2861496.672	4370361.833	25
	0.004	0.003	0.004	
AIRA	-3530219.321	4118797.578	3344015.867	30
	0.003	0.003	0.003	
CHICHI10	-4490618.487	3483908.175	2884899.137	32
	0.003	0.003	0.003	
TOMAKO11	-3680586.461	2917515.862	4300987.820	4
	0.012	0.012	0.011	
KASHIM11	-3997505.669	3276878.395	3724240.692	9
	0.001	0.001	0.001	
MIZNAO10	-3857236.104	3108803.215	4003883.080	15
	0.004	0.003	0.004	
VERAMZSW	-3857241.871	3108784.809	4003900.612	4
	0.007	0.005	0.007	
GIFU11	-3787123.441	3564181.761	3680275.133	9
	0.032	0.029	0.031	
GIFU3	-3787518.273	3564247.177	3679797.254	5
	0.022	0.020	0.021	

4. Related Topics

In the process of correlation and primary solution, we often found our station's problems affected the quality of results such as clock breaks and unstable thermal environments. To improve the quality of data obtained from the stations, we checked the data each time after experiments and fed back the information to the stations each time when a defect occurred (Figure 2).

We upgraded the management system of D1 tape, which was introduced in July 2002, with a handy barcode reader to reduce tape librarian's burden.

The geodetic department of GSI will be reorganized from April 2004. The GSI VLBI group will belong to a newly established space geodetic division.

5. Staff

- K. Takashima : Operation manager (GSI).
- M. Machida : technical staff (GSI).
- M. Ishimoto : technical staff, intensive setups (GSI).

- S. Kurihara : technical staff, global solution analyst (GSI).
- K. Sakamoto : operator in charge of routine correlation processing (Space Engineering Development Co., Ltd).
- T. Nishino : operator in charge of routine correlation processing (Space Engineering Development Co., Ltd).

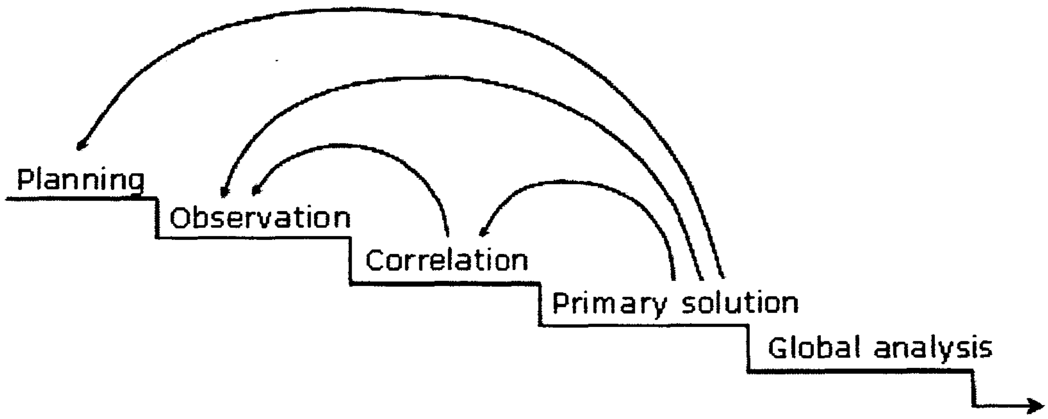

Figure 2. Water-fall model for VLBI operations at GSI

6. Plan for 2004

From April 2004 to March 2005, GSI is planning 12 JADE experiments. Because GSI is shifting the recording system of GSI network stations toward the disk-based K-5 recording system in early 2004, we will need a K-5 compatible correlation system to deal with the K-5 data at Tsukuba. We are considering to increase the number of UT1 intensive sessions in 2004. The sessions on Saturday will be observed with the K-4 recording system as usual. The weekday's sessions are expected to be run by Mark 5/K-5. It seems that introducing the K-5 system to the Tsukuba VLBI Correlator would be useful in land surveying as well as in navigations with on-line data transfers. The current tape based correlator has the ability to process 3 baselines for 3 stations simultaneously. It could be still usable for JADE experiments to confirm the data by the K-5 system. We are planning to expand it to process 6 baselines for 4 stations simultaneously for more efficient correlating processing.

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Washington Correlator

Kerry A. Kingham

Abstract

This report summarizes the activities of the Washington Correlator for the year 2003. The Washington Correlator provides 136 hours of processing per week, primarily supporting Earth Orientation and astrometric observations. In 2003 the major programs supported includes the IVS-R4, IVS-INT, IVS-R1, IVS-T and CRF. Four Mark 5 playbacks were added.

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 reference frame and astrometry sessions. The facility houses a Mark 4 Correlator.

2. Correlator Operations

The two Washington Correlator Mark 5P (prototype) units were upgraded to Mark 5As in April. Four additional Mark 5A playbacks were added in October. At the end of the year, the Washington Correlator had 6 Mark 5A playbacks on-line. The Correlator Facility also conditioned 68 "A" 8-packs.

During the year, the main theme was the increase in Mark 5 operational experience. By November, up to 4 stations in IVS experiments were recording with the Mark 5s using 8-packs of various sizes. The Intensives continued to use single disks and celebrated the first full year of Mark 5 Intensives in November. The increase in the use of Mark 5 for recordings had a direct impact on the processing factors. Due to the "perfect" playback, lack of tape positioning, and the need for less operator intervention, the average processing factor dropped from 3.9 to 1.5. Unfortunately, this will not allow more experiments to be processed by the correlator because staff shortages will prohibit setup and review.

The correlator facility operates 136 hours per week, and is fully loaded at this level.

Table 1 lists the experiments processed during 2003.

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. Table 2 lists staff and their duties.

Table 1. Experiments processed during 2003

52	IVS-R4 experiments
1	CONT
14	CRF (Celestial Reference Frame)
6	IVS-R1
3	APSG (Asia Pacific)
3	OHIGGINS
3	R&D
3	SURVEY
5	IVS-T (Terrestrial Reference Frame)
200	Intensives

Table 2. Staff

Staff	Duties
Dr. Kerry Kingham (USNO)	VLBI Correlator Project Scientist, responsible for the scientific integrity of correlated data, hardware and software maintenance and upgrades, and computer system administration. Also responsible for process scheduling and evaluation of correlated data. Oversees session setups and prepasses and evaluates station performance.
Bruce Thornton (NVI)	Operations Manager, responsible for correlator operator scheduling, daily operations, and tape shipping. Intensive processing and review.
Harvis Macon (NVI)	Lead Correlator operator, NEOS-A and Intensive setups.
Roxanne Watkins (NVI)	Tape Librarian
Dwayne Sneed (NVI)	Correlator Operator
Joseph Granderson (NVI)	Correlator Operator
Kenneth Potts (NVI)	Correlator Operator
Steven Springer (NVI)	Part-time Correlator Operator
Lawrence Dorsey (NVI)	Part-time Correlator Operator
Valerie Bockarie (NVI)	Part-time Correlator Operator

4. Outlook

The Washington Correlator expects to add more Mark 5 playback units to the correlator in the next year. The increased use of Mark 5 should increase the efficiency and and quality of the processing.

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 2003. 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:

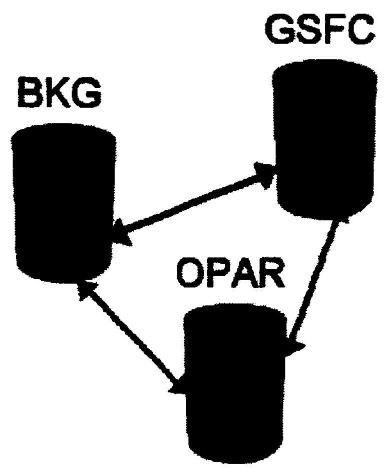

Figure 1. **Principle of mirroring**

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 the users need to obtain username and password to get access (please contact the Data Center staff).

An incoming script is watching this 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 part of a 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:

```
ftp.leipzig.ifag.de
uid: anonymous
pw: e-mail address
cd vlbi
```

respectively

```
WWW:              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
ivscontrol/      : controlfiles for the data center
ivsdata/         : VLBI observation files
ivsdocuments/    : IVS documents
ivsproducts/     : analysis products
                   (earth orientation, terrestrial and celestial frames,
                    troposphere)
```

2. Technical Equipment

HP Workstation (HP UX 10.20 operating system) and Linux Server
disk space: 190 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)

Data Center at Communications Research Laboratory

Yasuhiro Koyama

Abstract

The Data Center at Communications Research Laboratory archives and releases the databases and analysis results processed at the Correlation Center and the Analysis Center at Communications Research Laboratory. 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, Communications Research Laboratory has been conducting geodetic VLBI sessions for various purposes and these data are also archived and released by the Data Center.

1. Introduction

The IVS Data Center at the Communications Research Laboratory (CRL) archives and releases the databases and analysis results processed by the Correlation Center and Analysis Center at CRL. Major parts of the data are from the Key Stone Project (KSP) VLBI sessions [1] but other regional and international VLBI sessions conducted by CRL are also archived and released. Since routine observations of the KSP network terminated in the end of November 2001, there were no additional data for the KSP regular sessions since 2002. In 2003, three geodetic VLBI sessions were carried out and processed. The analysis results in the SINEX (Solution Independent Exchange) file format and other form of data formats are available from the WWW and FTP servers. Database files generated with the Mark III database file format are available upon request and will be sent to the users in DDS tape cartridges. Database files of non-KSP sessions, i.e. other domestic and international geodetic VLBI sessions, are also available from the FTP server. Table 1 shows the list of WWW and FTP server systems maintained by the Data Center at CRL.

Table 1. URL of the WWW and FTP server systems.

Service	URL
KSP WWW pages	`http://ksp.crl.go.jp/`
IVS WWW mirror pages	`http://ivs.crl.go.jp/mirror/`
FTP	`ftp://ftp.crl.go.jp/pub/dk/ivs/`

The maintenance of these server machines has been moved from the VLBI research group of the CRL 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 the period, daily observations were performed from March 1 until 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 real-time VLBI observations with the Miura station became impossible. After this time, the real-time VLBI sessions were performed with three stations at 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 except for the 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-base correlation processing of the full six baselines. After the tape-base correlation processing 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 seems 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 from 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 near the area, and the unusual site motions at Tateyama and Miura are explained by the event.

2.2. Other VLBI sessions

In addition to the KSP regular VLBI sessions, domestic and international geodetic VLBI sessions have been conducted by CRL in cooperation with Geographical Survey Institute (GSI) and other organizations. These sessions are listed in Table 2. The observed tapes of these sessions were correlated by using the K-4 correlator and the software correlation programs (K-5 correlator) at CRL either at Koganei or at Kashima.

In 2003, two e-VLBI sessions (evlbi4 and tsev6) were performed for two hours each with Kashima 34m and Westford stations with cooperation with Haystack Observatory. The purpose of these experiments were to demonstrate rapid turnaround processing of the international VLBI observations by using e-VLBI technique. Especially, we have demonstrated that the UT1-UTC can be estimated within one day from the observations from the session tsev6 performed on June 27, 2003 [2]. Two K5 test session, i.e. U03031 and JD0306, were performed to evaluate the performance of the newly developed K5 VLBI system and Gigabit VLBI system. In the U03031 session, the K5 VLBI system and the Gigabit VLBI system were used in parallel with the K4 VLBI system at Kashima 11-m and Koganei 11-m stations. On the other hand, the JD0306 is one of the routine domestic VLBI sessions coordinated by the Geographical Survey Institute. Kashima 11-m, Tomakomai 11-m, Gifu 11-m, and Yamaguchi 32-m stations participated in the JD0306 session in

Table 2. Geodetic VLBI sessions conducted by CRL

Year	exp. names	sessions
1999	K4 Tie	K4TIE1, K4TIE2
2000	Japan Tie	JPNTI2, JPNTI3, JPNTI4, JPNTI5, JPNTI6
	GIFT	GIFT01, GIFT02
2001	Japan Tie	JPNTI7
	HOKT	HOKT01
2002	HOKT	HOKT02
	CUTE	CUTE01, CUTE02, CUTE03
	Usuda	USUDA1
2003	CUTE	CUTE04
	K5 Test	U03031, JD0306
	e-VLBI	evlbi4, tsev6
	Nozomi	34 sessions
	Hayabusa	10 sessions

addition to the regular GSI VLBI sites at Tsukuba 32-m, Chichijima 11-m, and Aira 11-m. K5 VLBI system was used at five stations and Gigabit VLBI system was used at two stations. Results from different VLBI systems were compared and it was confirmed that the K5 VLBI system and Gigabit VLBI system have expected performance [3].

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

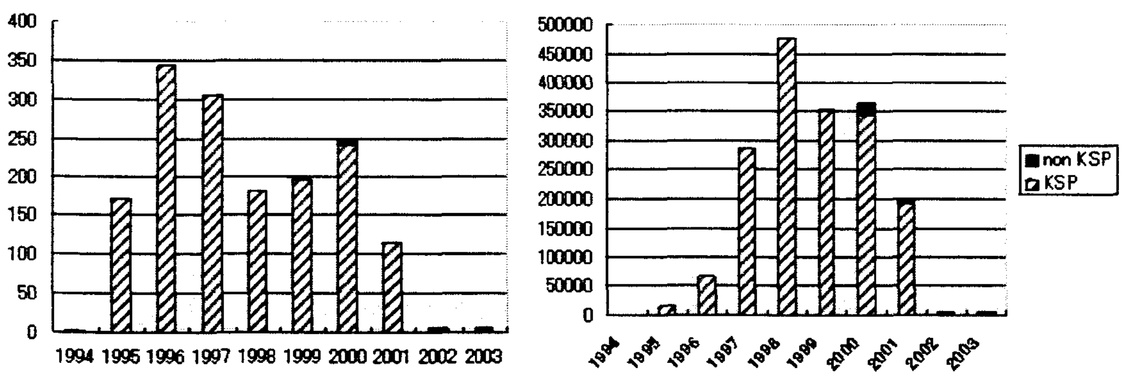

Figure 1. Number of sessions (left) and observed delays (right) used in the data analysis for each year up to the year 2003.

3. Future Plans

Although the regular VLBI sessions with the KSP VLBI network finished in 2001, the IVS Data Center at CRL will continue its service and will archive and release the analysis results accumulated by the Correlation Center and Analysis Center at CRL. In addition, a number of VLBI sessions are planned to be conducted in the year 2004 and these data will be archived and released to the public users.

In April 2004, Communications Research Laboratory will be integrated with the Telecommunications Advanced Organization of Japan (TAO) and the new institute will be established. The name of the institute will be National Institute of Information and Communications Technology and the VLBI activities in the CRL will be continued under the new institute.

References

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CDDIS Data Center Summary for the 2003 IVS Annual Report

Carey Noll

Abstract

This report summarizes activities during the year 2003 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. A large portion of the CDDIS holdings of GPS, 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://cddisa.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 UNIX server which has over 540 Gbytes of on-line magnetic disk storage (470 Gbytes in RAID storage); approximately 25 Gbytes are devoted to VLBI activities. 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 2.5 contractor employees supports all CDDIS activities (see Table 1 below).

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

Table 1. CDDIS Staff

Name	Position
Ms. Carey Noll	CDDIS Manager
Dr. Maurice Dube	Head, CDDIS contractor staff and senior programmer
Ms. Ruth Kennard	Request coordinator
Ms. Laurie Batchelor	Data technician (part-time)

been established on the CDDIS host computer, cddisa.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://cddisa.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 fr Kartographie und Geodsie 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 2003, over 100 user organizations accessed the CDDIS on a regular basis to retrieve VLBI related files. Nearly 17K 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. A new Linux server was procured in 2002; additional RAID disks and a dedicated DLT tape backup system were also purchased. The CDDIS staff plans to make this new system operational by the end of 2003.

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 se ssion *ssssss*; these files include: log files, wx files, cable files, schedule files, correlator notes
Product Directories	
vlbi/ivsproducts/crf	CRF solutions
vlbi/ivsproducts/eopi	EOP-I solutions
vlbi/ivsproducts/eops	EOP-S solutions
vlbi/ivsproducts/trf	TRF solutions
vlbi/ivsproducts/trop	Troposphere solutions
vlbi/ivsproducts/ivs-iers	IVS contributions to the IERS
vlbi/ivsproducts/ivs-pilot2000	IVS Analysis Center pilot project (2000)
vlbi/ivsproducts/ivs-pilot2001	IVS Analysis Center pilot project (2001)
vlbi/ivsproducts/ivs-pilotbl	IVS Analysis Center pilot project (baseline)
vlbi/ivsproducts/ivs-pilottro	IVS Analysis Center pilot project (troposphere)
Other Directories	
vlbi/ivscontrol	IVS control files (master schedule, etc.)
vlbi/ivsdocuments	IVS document files (solution descriptions, etc.)

Italy CNR Data Center Report

M. Negusini

Abstract

This report summarizes the situation of the Italy CNR VLBI data center. It will give fundamental information about the structure of the center, its locations, and its activities.

1. Introduction

The Italy CNR VLBI data center is the joint effort of:

a) the Istituto di Radioastronomia (Institute of Radio Astronomy IRA) of the Consiglio Nazionale delle Ricerche (CNR) located in Bologna, where the research activity is carried out, both in radio astronomy and geodesy, and the two VLBI antennas in Medicina (near Bologna) and Noto (in Sicily) are managed,

b) and in its section located in Matera at the Center of Spatial Geodesy (of the Italian Space Agency), where the main research activity in geodesy is carried out, and a VLBI antenna, a laser ranging telescope, a permanent GPS receiver and a PRARE antenna are located.

At the moment, the main analysis activity and storage is concentrated in Matera, where we store and analyze single databases, using CALC/SOLVE software. We are using f-solve regularly updated. The IRA has started to store VLBI geodetic databases from 1989, but the databases archived in Bologna mostly contain data including European antennas, starting from 1987. In particular most of the databases present here have VLBI data with at least three European antennas. However we are also storing all the databases with the Ny-Ålesund antenna data. During 2002 and 2003, we have stored in Matera all the 2000-2003 databases available on the IVS data centers. All the databases have been processed and saved with the best selection of the parameters for the final arc solutions.

In some cases we have introduced the wet delay coming from GPS into the European databases (at present only for EUROPE experiments for the years 1998 and 1999), as if it was produced by a WVR. Also these databases are available and stored with a different code from the original databases. For this we have produced a modified version of DBCAL, available to external users.

In Matera we have stored part of the databases and all the superfiles and we are performing there global solutions, too.

2. Computer Availability and Routing Access

In Bologna the main computer is a HP 785/B2600 workstation. The internet address of this computer is boira3.ira.cnr.it and the databases are stored in different directories and in different disks as well. The complete list of directories where databases are stored is the following:

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 tomasi@ira.cnr.it.

In Matera the main computer is an HP282 computer with internet name hp-j.itis.mt.cnr.it. The databases are stored in different directories and the full list follows:

1 = /data1/mk3/data1
2 = /data1/mk3/data2
6 = /data5/dbase5
5 = /data4/dbase4
7 = /data8/dbase8
8 = /data10/dbase10
9 = /data13/dbase13
10 = /data14/dbase14

The super files 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 been enlarged to 250 gigabytes with the installation of a new server. The data can be accessed using the username geo, and the password can be requested from tomasi@ira.cnr.it.

Paris Observatory (OPAR) Data Center

Najat Essaïfi

Abstract

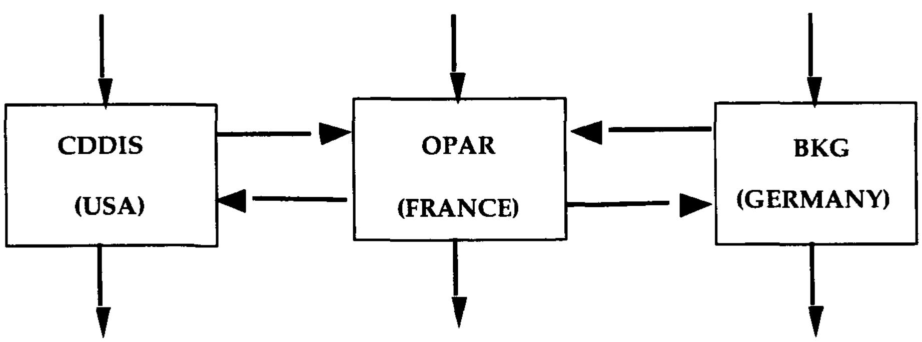
This report summarizes the OPAR Data Center activities over 2003. Included are informations about functions, architecture, status, future plans and staff members of OPAR Data Center.

1. OPAR Data Center Functions

The Paris Observatory (OPAR) has provided since 1999 a Data Center for the International VLBI Service for Geodesy and Astrometry (IVS). The OPAR as well as CDDISA 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 evolved since 2002, one primary directory has been added:

```
ivscontrol/       : provides the control files needed by the data center
                    (session code, station code, solution code...)
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
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
ivs-pilotbl/      : provides baselines files
```

3. Current Status

The OPAR data center is operated actually on a PC located at Paris Observatory, and running the Linux red hat 8.0 operating system. To make all IVS products available on-line, the disk storage capacity was significantly increased and the server is equipped now with a 120 Gb disc storage for VLBI activities.

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 to the OPAR Data Center the staff is studying some computer system enhancements, including a RAID disk system.

5. Staff Members

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

- Najat Essaïfi, Data Base manager.
- Anne-Marie Gontier, responsible for GLORIA analysis software.
- Martine Feissel, scientific developments.
- Daniel Gambis, interface with IERS activities.

6. Contact Information

To obtain informations about the OPAR data center please contact :

Najat Essaïfi
Observatoire de PARIS
61, Avenue de l'Observatoire
75014 Paris - FRANCE
Phone : 33 1 40 51 22 33
Fax : 33 1 40 51 22 91
E-mail : essaifi@hpvlbi.obspm.fr

ANALYSIS CENTERS

Analysis Center of Saint-Petersburg University

Maria Kudryashova

Abstract

This report briefly summarized the activity of the Analysis Center of Saint Petersburg University during 2003. Changes which happened in our solution and staff are described.

1. Introduction

Analysis Center of Saint Petersburg University is involved in processing of intensive sessions from 1998. Since 2000 it also derives Earth Orientation Parameters (x,y coordinates of pole, UT1-UTC, nutation offsets) by processing NEOS-A, R1, R4 sessions. OCCAM software is used in the Analysis center in order to obtain our solutions. Unfortunately, this year our solution have not be included in combined IVS solution due to some problems which we had with Terrestrial Reference Frame.

2. Staff

This year a new member was involved in the process of data handling.

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.

Julia Sokolova - Student of Saint-Petersburg University. Processing of VLBI data.

3. Description of Solutions

Currently we continue to contribute UT1-UTC values obtained by processing Int1 observational program. Our time series (spu00002.eopi) contains 1161 estimates since Sept. 1, 1997. All estimated parameters (UT1-UTC, offset for wet delay, offsets and rates of station clocks) have been adjusted using least square technique. Troposphere gradients were not estimated in this solution. The MBH2000 nutation model is used as a priori one.

Also, we continued processing of 24-hour session in order to compute five EOP. In March, 2003 name of our solution spu00002.eops which contained all 24-hour VLBI sessions since 1994 have been changed to spu0002i.eops. This change has been done in order to distinguish this time series from our new solution spu0002m.eops. The only difference between this time series is an a priory nutation model. To compute spu0002m.eops we applied MBH 2000 model. As for spu0002i.eops time series, IAU 1980 nutation model have been used. Detailed description of analysis strategy and estimated parameters is given in [1]. OCCAM software v.5.0 have been used for obtaining these solutions.

The EOP time series spu0002i.eops was replaced by series spu0003i.eops in Aug, 2003. There are few differences between the solutions. In order to obtain spu0003i.eops new version of OCCAM package v.5.1 is used. This version of the software allows us to estimate corrections for station coordinates under NNR and NNT conditions. Some stations (for instance, Tigoconc) have unstable coordinates so we estimate their location for every session in which this station takes part. Also, new Terrestrial Reference Frame (VTRF 2003, see [2]) was implemented for computation spu0003i.eops. 915 NEOS-A, R1 and R4 sessions with about 24-hour measurements duration were analyzed in order to calculate spu0003i.eops. This series covers time span between Jan. 1, 1989 and 31 Dec., 2003.

All parameters have been adjusted using Kalman filter technique. Troposphere gradients are treated as a constant parameters. Main differences between this two series are summarized in the table 1 for clarity.

Table 1. Differences between spu0002i.eops and spu0003i.eops

	spu0002i.eops	spu0003i.eops
OCCAM version	5.0	5.1
TRF	fixed to ITRF2000	not fixed. VTRF2003 is used as a priory TRF
time span	Jan., 1994 - Aug., 2003	Jan., 1989 -now
number of sessin	545	915
trop.grad	estimated as stoch.param.	estimated as constant param.

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Geoscience Australia Analysis Center

Oleg Titov, Ramesh Govind, Clement Ogaja

Abstract

This report gives an overview about activity of the Geoscience Australia IVS Analysis Center during the 2003 year.

1. General Information

The Geoscience Australia IVS Analysis Center is located in Canberra. In 2003 the Center physically moved to new location in Symonston building. At the new structure the Space Geodesy Analysis Center became a part of Minerals and Geohazard Division.

2. Component Description

Currently the GA IVS Analysis Center contributes five EOPs for IVS-R1 and IVS-R4 networks. The EOP time series from 1983 to 2003 are available. Also the CRF catalogues using a global set of VLBI data from 1980 to 2003 are regularly submitted.

3. Staff

- Dr. Ramesh Govind - Director of the Space Geodesy Analysis Center
- Dr. Oleg Titov - project officer
- Dr. Clement Ogaja - project officer

4. Current Status and Activities

Global homogeneous solution has been done using the new facilities of OCCAM. VLBI data comprising 2985 daily sessions from 12-Apr-1980 till 13-Oct-2003 have been used to compute the global solution AUS2003b. This includes 2,707,712 observational delays from 645 radiosources observed by 58 VLBI stations. Weighted root-mean-square of the solution is about 0.645 cm (about 21 picosec).

Using the NNR approach all radiosource coordinates were estimated as global parameters without separation into stable and unstable ones. 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 52 stations only.

New version of the OCCAM (v6.0) software is being prepared in collaboration with scientists from Vienna (Technical University of Vienna), Munich (DGFI) and Saint-Petersburg (IAA). It will include updated system of reductions, three adjustment methods, latest advanced mapping functions, etc.

Also the GA Analysis Center continues the regular submission of EOPs to the IVS/IERS and works on the development of long-term time series for the EOP, station coordinates and comparison of techniques (VLBI, SLR, GPS) for EOP and ITRF adjustment.

Long-term comparison of results from co-located VLBI, GPS and SLR stations contributing to the IVS, IGS, ILRS have been carried out to assess the consistency between the techniques. Seasonal variations of baseline lengths as well as individual site radial components were considered over long time periods. Spectral analysis of the baseline time series revealed the existence of both annual and semiannual terms. The estimates of the signal amplitudes and phases as well as relative rates were computed for 19 independent co-located baselines and cross-validated (Fig.1).

A subsequent estimation was done to determine the seasonal effects at the individual sites. For instance, the annual terms indicated that the northern hemisphere sites rise in the first part of the year and lower in the second part (Fig.2). Similarly, it was shown that sites in the southern hemisphere are lowered in the first part of the year (Fig.3).

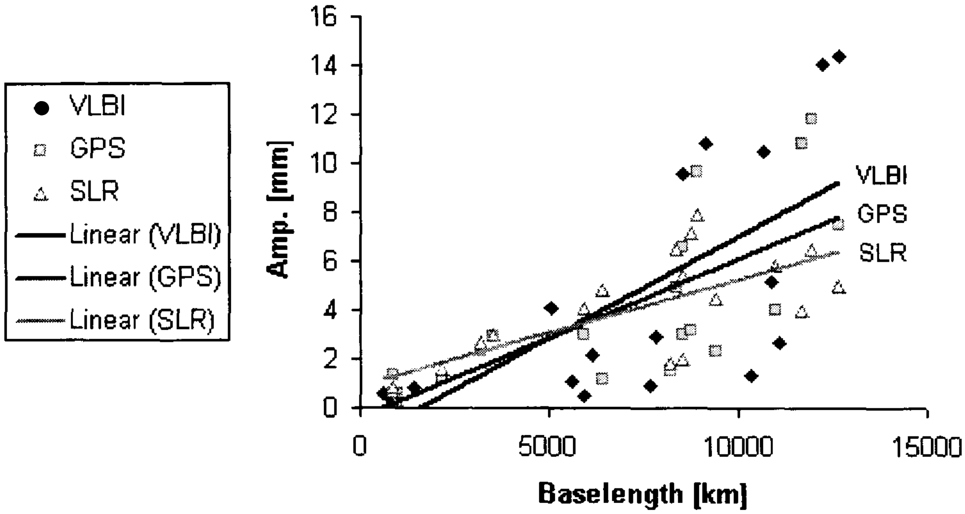

Figure 1. Amplitude vs baseline length of annual signature for 19 baselines from co-located sites.

5. Future Plans

- comparison of the individual ICRF solutions available through the IVS website
- combined estimation of the EOPs using VLBI, SLR and GPS data
- cooperation with the Australian National University (ANU), Australian National Telescope Facility (ANTF) and University of Tasmania on development of VLBI for the southern hemisphere

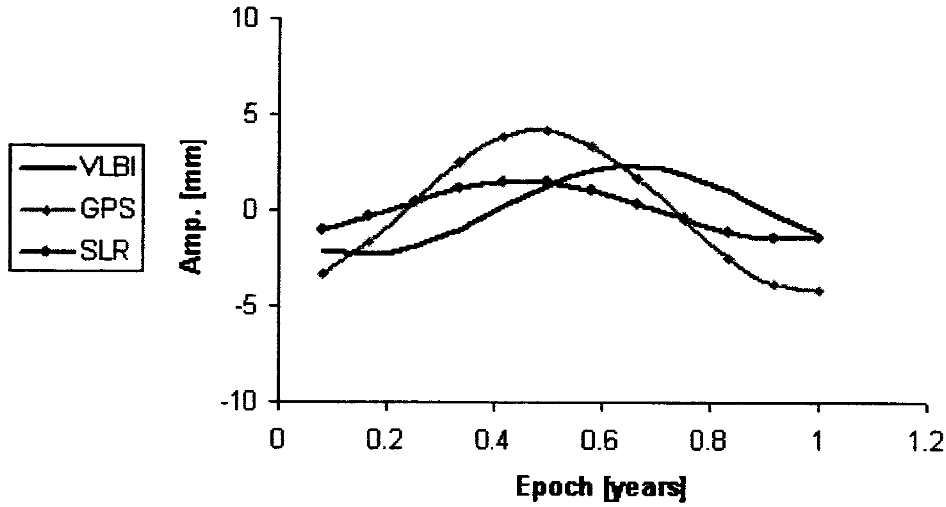

Figure 2. Annual signatures from co-located sites at Matera.

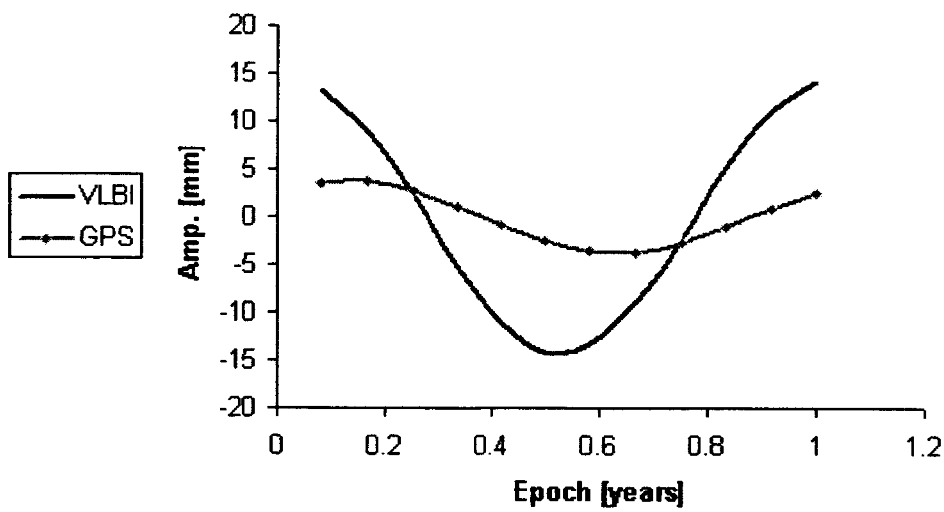

Figure 3. Annual signatures from co-located sites at Hobart.

Bordeaux Observatory Analysis Center Report

Patrick Charlot, Antoine Bellanger, Alain Baudry

Abstract

This report summarizes the activities of the Bordeaux Observatory Analysis Center during the year 2003. On the analysis side, we have completed processing of five years of NEOS-A/IVS-R4 data (1999–2003) and obtained preliminary results for the temporal evolution of the source positions over this period. On the research side, our major achievements include the organisation and scheduling of a third experiment as part of our ICRF densification project in the northern sky, and evaluation of astrometric suitability for additional sources at S, X, K and Q bands. Plans for the year 2004 follow the same analysis and research lines.

1. General Information

The Bordeaux Observatory Analysis Center 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).

Our work is focused on the maintenance, extension, and improvement of the celestial reference frame. In particular, we lead an observing program on the European VLBI Network (EVN) to densify the International Celestial Reference Frame (ICRF) [1] and conduct research related to the effect of source structure in geodetic VLBI data [2]. Additionally, we develop routine analyses of IVS data with the aim of studying the ICRF source position stability and the physical phenomena that can affect this stability.

VLBI analyses are conducted with the MODEST software, developed and maintained by the Jet Propulsion Laboratory [3]. It is installed on a Compaq DS20 workstation along with the AIPS and DIFMAP imaging software.

As a result of reorganisation of the University network, the Observatory www address and all email adresses for people at the Observatory changed in June 2003. These are now:

`name@obs.u-bordeaux1.fr`
`http://www.obs.u-bordeaux1.fr`

2. Scientific Staff

Our group is composed of the following three individuals, who are involved part or full time in IVS analysis and research activities, as described below:

- Patrick Charlot (50%): overall responsibility for Analysis Center work and data processing. He is the PI of the ICRF densification project on the EVN. He is also involved in radio source imaging and has a major interest in studying source structure effects in geodetic VLBI data.
- Antoine Bellanger (100%): engineer with background in statistics and computer science. His main role is to conduct initial data processing and develop analysis tools as needed. In the future, he will also maintain a web site dedicated to our analysis activities.
- Alain Baudry (10%): radioastronomy expert. He is involved in the ICRF densification project and has interest in radio source imaging.

3. Analysis and Research Activities during 2003

During the past year, our level of activity has been stable. On the analysis side, we have completed initial processing of all NEOS-A and IVS-R4 sessions conducted between 1999 and 2003 and have started to analyze the 2003 IVS-R1 sessions. Additionally, we have derived preliminary time series of source positions based on this data set. Figure 1 shows an example of such "arc" positions (monthly estimates) for the source 0229+131. These results will be refined in the future while we keep on analyzing new sessions as they become available.

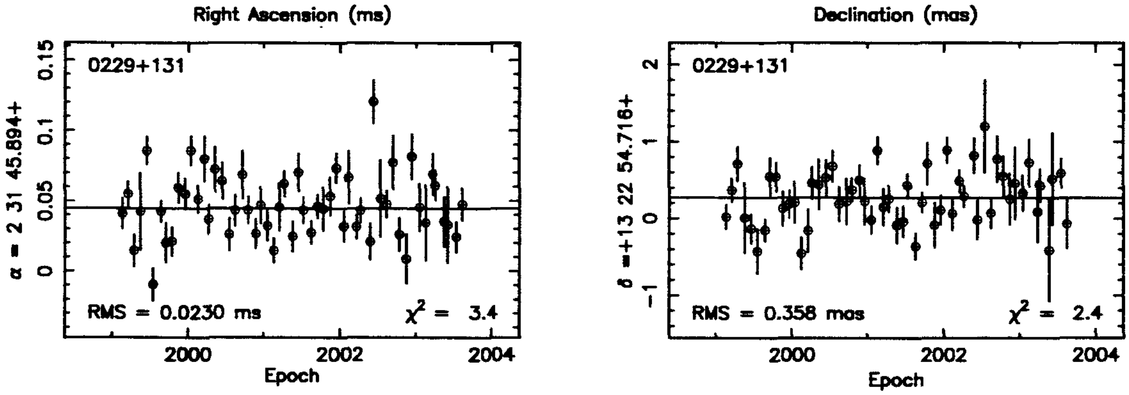

Figure 1. Estimated monthly coordinates for the source 0229+131 between 1999 and 2003.

On the research side, we have pursued further our observing program for densifying the ICRF in the northern sky. As described in [1], the aim of this project is to add 150 new sources at carefully selected sky locations to fill the "empty" regions of the frame and improve the overall source distribution. Following our initial two experiments in 2000 and 2002 (each observing 50 new sources) [4, 5], an additional third experiment was carried out on October 27, 2003, to complete this project. The network used for the latter comprised seven telescopes from the European VLBI Network (EVN) along with three external non-EVN geodetic stations that agreed to join this project. The participating telescopes are listed in Table 1. The data from this experiment have just been correlated with the Bonn Mark IV correlator. Final fringe-fitting, data export, and astrometric analysis should be conducted shortly.

Table 1. Network used in third ICRF densification experiment.

EVN telescopes	Non-EVN telescopes
Effelsberg	Algonquin Park
Medicina	Goldstone (DSS 13)
Noto	Ny Alesund
Onsala	
Hartebeestoek	
Urumqi	
Shanghai	

Another achievement is the evaluation of astrometric suitability for an additional 60 ICRF sources based on newly-available X- and S-band maps in the Radio Reference Frame Image Database. Structure indices were derived according to the average structural delay effects for these sources following our standard scheme [6]. Overall, structure indices are now available for 450 ICRF sources, about 75% of the total number of ICRF sources [7]. Analysis of the structure index distribution shows that 57% of the sources in this sample have a structure index value of either 1 or 2 at X band, indicating compact or very compact structure. At S band, structural effects are less significant (89% of the sources have a structure index value of either 1 or 2), a consequence of the fact that the S-band structure corrections are scaled down as a result of the dual-frequency group-delay calibration applied to eliminate propagation effects in the ionosphere.

Additionally, we have also evaluated the astrometric suitability of 108 ICRF sources at K band (24 GHz) and Q band (43 GHz) based on data acquired by the VLBA K-Q Survey collaboration [8] in May, August and December 2002. The major goals of this project are to extend the ICRF in the 24–43 GHz range and to enhance VLBI phase-referencing at high frequency by increasing the number of calibrators available at these frequencies. As reported in [7], comparison of the structure index distribution at K and Q bands with that at the standard X band frequency is striking, indicating a larger portion of structure index values of 1 as observing frequency increases (32% at 8 GHz, 56% at 24 GHz, and 71% at 43 GHz). Hence, these initial results already suggest that the astrometric suitability of the sources is significantly better at 24 GHz and 43 GHz than at the standard 8 GHz geodetic observing frequency.

4. Outlook

During the year 2004, our plans include the following:

- Refine our "arc position" analysis of the 1999–2003 NEOS-A and IVS-R4 sessions to monitor the temporal evolution of the source coordinates, and keep on analyzing the new IVS 2004 sessions as they become available.
- Finish up post-processing and analysis for all three ICRF densification experiments, and compare the derived astrometric positions with those from the VLBA Calibrator Survey.
- Continue to evaluate the astrometric suitability of the ICRF sources as new maps become available at S, X, K and Q bands, and make the corresponding structure indices and structure correction images available through our web page.
- Assess more precisely the impact of massive source structure modeling in astrometric data analysis by repeating our previous test on the RDV data [9] after identification of the most appropriate structural reference feature for each source.
- Start processing RDV experiments in cooperation with the USNO team to monitor the X- and S-band structural evolution of the ICRF sources and extend the time basis of the current image data base.
- Re-design our web page[1] to make multi-epoch and multi-frequency structure indices and false color structure correction images publicly available, along with results of source position stability, for possible use by IVS operation and analysis centers.

[1] http://www.obs.u-bordeaux1.fr/public/radio/PCharlot/structure.html

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Matera CGS VLBI Analysis Center

Roberto Lanotte, Giuseppe Bianco

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS) at Matera from January 2003 through December 2004 and the contributions that the CGS intends to provide for the future as an IVS Data Analysis Center.

1. Introduction

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, LLR and GPS.

2. Analysis Activities in 2003

The VLBI data analysis activities at the CGS in the year 2003 were directed towards the realization of a global VLBI analysis, named cgs2004a, using the CALC/SOLVE software (developed at the GSFC). The cgs2004a will be included in the IVS solutions "pool" and its main characteristics are:

- Data span:
  1980.04.11 - 2003.10.30
- Estimated Parameters:
  - Celestial Frame:
    right ascension and declination as global parameters for 554 sources and as local parameters for 17 sources.
  - Terrestrial Frame:
    Coordinates and velocities for 44 stations as global parameters and as local parameters for 66 stations.
  - Earth Orientation:
    Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi and deps.

The CGS is contributing to the IVS project "Tropospheric Parameters".

3. Future Plans

- Participate in the IVS pilot project "Time series of baseline lengths"
- Continue and improve the realization of global VLBI analysis.
- Continue to participate in IVS analysis projects.

4. Staff at CGS contributing to the IVS Analysis Center

- Dr. Giuseppe Bianco, Responsible for CGS, ASI (primary scientific/technical contact).
- Dr. Cecilia Sciarretta, Responsible for scientific activities, Telespazio.
- Dr. Roberto Lanotte, Geodynamics data analyst, Telespazio.

Analysis Center at Communications Research Laboratory

Ryuichi Ichikawa, Mamoru Sekido, Hiroo Ohsaki, Yasuhiro Koyama, Tetsuro Kondo

Abstract

This report summarizes the activities of the Analysis Center at the Communications Research Laboratory (CRL) for the year 2003. By using the newly developed PC-based data acquisition and data processing system (K5 VLBI system), we performed the international e-VLBI sessions twice and we demonstrated a rapid estimation of UT1-UTC less than one day after the observations on June 27, 2003. We also performed more than 30 VLBI experiments for the two Japanese spacecraft, NOZOMI and HAYABUSA from September 2002 until November 2003. These VLBI experiments are aimed to establish positioning technology for interplanetary spacecrafts in realtime.

1. General Information

The CRL analysis center is located in Kashima, Ibaraki Japan. It is operated by the Radio Astronomy Applications Group, Kashima Space Research Center of CRL. VLBI analyses at CRL are being mainly concentrated on experimental campaigns for developing new techniques such as differential VLBI (DVLBI) for spacecraft orbit determination and e-VLBI measurements for real-time EOP determination. In addition we are now preparing to perform a feasibility experiment of GPS and VLBI data transmission using a satellite communication link through the TCP/IP protocol from the South Pacific to Japan. We are also conducting a water vapor radiometer (WVR) observation in Kashima and a numerical simulation of atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) estimated by ray-tracing through the non-hydrostatic numerical weather prediction model (NHM).

2. Staff

The staff members who are contributing to the Analysis Center at the CRL are listed below:

- Kondo Tetsuro, Responsible for overall operations and performance.
- Koyama Yasuhiro, Development of data analysis software for geodetic experiments.
- Sekido Mamoru, Development of data analysis software for DVLBI.
- Ohsaki Hiro, Development of data analysis software for DVLBI.
- Ichikawa Ryuichi, Development of data analysis software for DVLBI and atmospheric modeling.

3. Current Status and Activities

3.1. Geodetic VLBI Experiments

Two geodetic VLBI sessions were carried out to evaluate the performance and functions of the K5 VLBI system [Koyama et al.,(2003a)[1]]. The first session was performed for about 24 hours from January 31, 2003 using Kashima34-Koganei baseline. The second experiment was performed for about 24 hours from July 14, 2003 using five VLBI stations at Kashima (34m), Tsukuba (32m), Tomakomai (11m), Gifu (11m), and Yamaguchi (32m). The example of the results are shown in Table 1. The comparison of the RMS residuals of delay and delay rates suggests the performance of the K5 systems is better than the K4 systems.

Table 1. Comparison of Kashima 11 - Koganei 11 baseline lengths estimated from the data obtained with K4 and K5 systems on Jan. 31, 2003.

	No. of valid data	Baseline Length (mm)	RMS Residual Delay(psec)	RMS Residual Rate(fsec/sec)
K4	112	109099657.0±6.7	76	136
K5	159	109099641.2±3.2	33	92

3.2. Real-time EOP Measurements

We performed a test e-VLBI session for two hours from 16:00 UT on March 25, 2003 with the Kashima-Westford baseline [Koyama et al.,(2003b)[2]]. The 34-m antenna VLBI station at Kashima and the 18-m antenna station at Westford were used for the observations. This was the fourth test in the series of e-VLBI test observations. During the previous tests, successful detections of the fringes from the e-VLBI observations were demonstrated and the software developments have been continued with the data sets obtained. The estimated UT1-UTC value is shown in the Table 2 as well as the values published in the IERS Bulletin B.

Table 2. Estimated value of UT1-UTC from the Kashima-Westford e-VLBI session and reported values from IERS Bulletin B 183, May 2, 2003.

	Epoch (UT)	UT1-UTC(μsec)
e-VLBI	20:00 on Mar. 25	-338727.0±23.9
IERS	00:00 on Mar. 25	-337951
IERS	00:00 on Mar. 26	-338610

The next e-VLBI session was performed for two hours beginning at 13:00 UT on June 27, 2003. The observation mode, configuration of the observing systems, and the baseline were identical to the previous e-VLBI session performed in March, 2003. The purpose of the session was to demonstrate how fast the UT1-UTC can actually be estimated from the international e-VLBI session.

Table 3 shows the actual time sequence of the observations, file transfers, and data processing during the e-VLBI session. As shown in Table 3, the UT1-UTC was estimated within 21 hours and 20 minutes after the session finished. Thus the rapid estimation of EOP in less than one day was successfully demonstrated by the international e-VLBI observations and data analysis.

3.3. Differential VLBI

Precise spacecraft positions (5-10 nrad) can be obtained with differential spacecraft-quasar VLBI (DVLBI) observations that directly measure the angular position of the spacecraft relative

Table 3. Time sequence from the observations to the data analysis. Time is in Japanese Standard Time and start from 22:00 on June 27, 2003

TIME(UT)	Event
Time	Event
22:00	Observations Start
00:00	Observations End
~04:20	File extraction and transmission
	From Kashima to Westford:
	107Mbps (41.54GByte in 51m 35s)
	From Westford to Kashima:
	44.6Mbps (41.54GByte in 2hr 04m 02s)
~08:10	File Conversion (Mark5 to K5)
~20:30	Software Correlation
~21:20	Bandwidth Synthesis Processing, Database Generation, Data Analysis

to nearby quasars. We performed more than 30 VLBI experiments for the two Japanese spacecraft, NOZOMI ("Hope") and HAYABUSA ("Falcon") from September 2002 until November 2003 [see Ichikawa et al., 2003[3] and Sekido et al., 2003[4] in detail]. These VLBI experiments are aimed to establish positioning technology for interplanetary spacecraft in realtime.

The final products obtained from the NOZOMI VLBI experiments were available with approximately 30 hours latency as shown in Figure 1. On the other hand, the removable data hard disks at other stations (Tomakomai, Tsukuba, Yamaguchi, and Algonquin) were mailed to Kashima. Thus, the latency to product the group delays using these station data were up to several days.

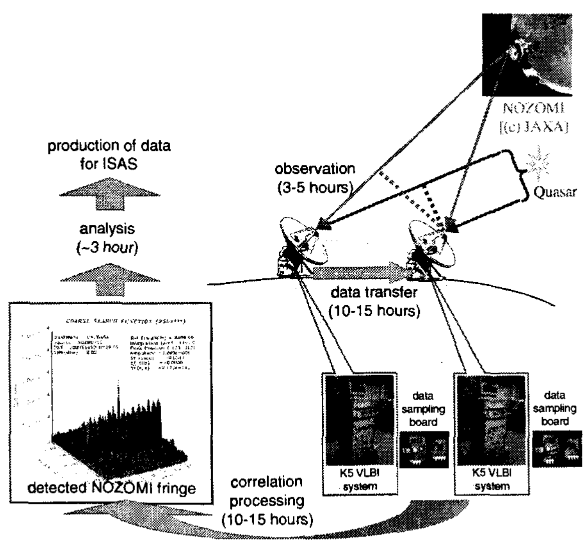

Figure 1. Schematic image showing NOZOMI VLBI data flow and analysis

Preliminary results demonstrate that the VLBI delay residuals are consistent with R&RR observables. However, the rms scatter between them is relatively large up to several tens of nanoseconds. We are now evaluating our VLBI group delays by comparing with the R&RR results more deeply.

We are now preparing to perform another VLBI experiment. One of the candidate targets is HAYABUSA, which was developed to investigate asteroids. HAYABUSA was launched on May 9, 2003 [JAXA, 2003][5]. The first HAYABUSA VLBI experiment was successfully carried out November 26, 2003. We are now evaluating the obtained HAYABUSA group delays by comparing with the R&RR results.

3.4. Evaluation of Atmospheric Model

Observations of atmospheric slant delay using water vapor radiometer (WVR) nearby the Kashima 11-m antenna are carried out for detecting and characterizing water vapor variations. We are also evaluating atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) and positioning errors derived from slant path delays obtained by ray-tracing through the non-hydrostatic numerical weather prediction model (NHM) with 1.5 km horizontal resolution.

4. Future Plans

During the year 2004 the plans of the Analysis Center at CRL include:

- Several international and domestic VLBI experiments for real-time EOP determinations using the e-VLBI and K5 systems (both IP-VLBI system and PC/VSI system).
- Development of analysis software for spacecrafts positioning using phase delay observables
- Improvement of processing speed and efficiency for VLBI data correlation using multiprocessor and high speed network
- Comparisons of the tropospheric parameters derived from VLBI, GPS, WVR and non-hydrostatic numerical weather prediction data.

In addition KSP data sets are still available at the URL http://ksp.crl.go.jp/index.html. General information about VLBI activities at the CRL is provided at http://www2.crl.go.jp/ka/radioastro/index.html.

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DGFI Analysis Center Annual Report 2003

Volker Tesmer, Hansjörg Kutterer, Hermann Drewes

Abstract

This report summarizes the activities of the DGFI Analysis Center in 2003 and outlines the planned activities for the year 2004.

1. DGFI Analysis Center Operation

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institution located in Munich. It is supervised 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 research projects as well as functions in international bodies.

The long-term research programme of DGFI is based on the general theme "Fundamentals of Geodetic Reference Systems". The definition of geodetic reference systems is studied and methods for their realisation with modern space geodetic techniques are developed. Geodetic observations are analysed, approaches for the data processing are set up, tested and exemplarily applied (see DGFI web server `http://www.dgfi.badw.de`).

DGFI contributes to the International VLBI Service (IVS) as an Analysis Center to improve the space-geodetic observation technique Very Long Baseline Interferometry (VLBI) and the analysis of its observations, respectively, by participating in pilot projects and by research projects which are mainly concerned with the modelling of VLBI observations.

2. Activities in 2003

1. Refinement of the stochastic model of VLBI observations

   Up to now, improvements of modelling the observations of "Very Long Baseline Interferometry (VLBI)" are mainly achieved by refining the functional representation of the geometrical-physical properties of the observations. Further progress in this field requires big efforts and is not possible with any precision. In contrast, the stochastic properties of the observations (which comprise functionally not representable influences) have not been handled thoroughly.

   The refinement of the stochastic VLBI model considered here is based on two principal ideas: (1) Discrepancies between the functional model and the observations can be understood at least approximately as variances of the observations. (2) Deficits of the functional model which affect several observations more or less systematically might be interpreted as covariances (correlations) between observations. For this reason, the deficits of the stochastic model of VLBI observations were studied in order to set up a more adequate structure of the variance-covariance matrix of the observations. The associated unknown variance and covariance components were estimated according to the MINQUE principle.

   The most significant improvements of the conventional stochastic VLBI model were found to be related to the observing stations (site-specific effects) and the elevation angles (tropospheric effects) (see Tesmer, 2003). Although standard VLBI solutions can be improved by the refined stochastic model for the observations, its potential is not yet exhausted.

2. Parameter constraints in VLBI data analysis

   It is common practice in VLBI parameter estimation to model two types of parameters. On the one hand there are classical target parameters such as station coordinates and Earth orientation parameters. On the other hand there are additional parameters like, e.g., the coefficients of the piecewise linear functions for the troposphere and the clocks as well as the offsets of the horizontal tropospheric gradients per station. In order to stabilize the estimation, prior information on the additional parameters is added by means of pseudo-observations (soft constraints). For assessing the impact of these constraints on the VLBI results, several aspects were studied such as the bias of the parameters, the respective contribution of the constraints to the estimation, and the consistency of observed data and prior information. Numerical results were derived from the NEOS-A sessions of 2000 and 2001 using the VLBI software OCCAM 5.0 (Least Squares Method).

   Typically, the induced parameter bias is visible in the results but it is not significant. However, in sessions with extended gaps of observation data the results can be strongly influenced. The contribution of the constraints to the estimated parameters (in terms of partial redundancies calculated for the constraints) is rather moderate in the standard case but becomes dominant in case of increased weights, in particular for the gradient offsets. This is underlined by results for the statistical consistency of the constraints and the observed data. Particular care must be taken in case of weakly configured networks, which can be due to temporary losses of observations on single VLBI sites. For details see Kutterer (2003).

3. CONT02 VLBI normal equations for a rigorous combination with GPS

   From 16th to 31st of October 2002, the CONT02 VLBI observation campaign, which was initiated by the IVS, was carried out. This campaign is especially suitable for the combination of VLBI observations with those of other space-geodetic techniques.

   In order to provide the optimum conditions for combining VLBI and GPS as rigorously as possible, much care was taken to set up VLBI normal equations with models and estimated parameters which are adapted to those of the used GPS normal equations. The following models or parameter representations had to be verified or modified, respectively, in the VLBI software OCCAM: solid Earth tides, pole tide, ocean loading, tropospheric delay, subdaily EOP variations, daily a-priori EOP values and their interpolation as well as the nutation model. The VLBI observation data were additionally reformatted from 24h blocks, beginning at 18 h UTC to blocks beginning at 0 h UTC in order to avoid a potential error source. The normal equations were supplied in the SINEX 1.0 format. First CONT02 combination results of VLBI and GPS data are for example reported in Thaller et al. (2003).

4. IVS OCCAM working group

   The software OCCAM which is used at DGFI to analyse VLBI observations is continually improved by a group of scientists from Geoscience Australia (Canberra, Australia), the Vienna University of Technology (Vienna, Austria), the St. Petersburg University, the Institute of Applied Astronomy (both St. Petersburg, Russia) and DGFI. As the groups concentrate on different research fields, an official version (currently 6.0) of the source code is kept which reflects the common interest. This version is updated if needed. The group met twice on the occasion of international scientific meetings (4th IVS Analysis meeting in Paris, France; Les Journées 2003, St. Petersburg, Russia) in order to define and to partially elaborate the source code changes. DGFI's most important contributions to the new version of OCCAM are an advanced outlier rejection routine (Kutterer et al., 2003) and a first version of a refined stochastic model for VLBI observations (see Tesmer, 2003). There is also a new interface for the conversion of OCCAM internal normal equations into a DOGS-CS readable format.

3. Staff

The personnel of DGFI involved in the IVS Analysis Center during 2003 did not change w.r.t. 2002, notably Hermann Drewes, Hansjörg Kutterer and Volker Tesmer. Volker Tesmer was funded externally by the German research association 'Deutsche Forschungsgemeinschaft (DFG)' under the contract DR 143/11-1.

4. Plans for 2004

The primary contributions will be to participate in further Pilot Projects of IVS. Additionally, DGFI will take part in the IVS VLBI2010 Working Group. In the medium term, DGFI aims to become an operational IVS Analysis Center, which would imply a commitment to regularly contribute to the official IVS products. Other research goals will be:

- Further improvement of the VLBI software OCCAM
- Simultaneous and consistent determination of a TRF, a CRF and the EOP in one solution using minimum datum constraints
- Combined estimation and comparative analysis of geodetic target parameters from VLBI and GPS observations

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FFI Analysis Center

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an analysis center will focus 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

Recently, a number of colocated stations with more than one observation technique have been established. In principle, all instruments at a given colocated station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each colocated site. In addition, a constant eccentricity vector from the reference point of the colocated station to each of the individual phase center of the colocated 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, give 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 17 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

Only test analyses performed in 2003.

The GEOSAT software is presently undergoing extensive development. Some of the changes are explained in our technical development report.

The GIUB/BKG VLBI Analysis Center

Axel Nothnagel, Gerald Engelhardt, Volkmar Thorandt, Markus Vennebusch, Dorothee Fischer

Abstract

The activities at the GIUB/BKG VLBI Analysis Center for the year 2003 consist of routine computations of Earth orientation parameter (EOP) time series and a number of research topics in geodetic VLBI. At BKG the new interactive graphic tool REPA [1] was developed for the VLBI Analysis Software Calc/Solve [2]. In 2003 the VLBI group at BKG has started regular submissions of tropospheric parameters for the IVS-R1 and IVS-R4 sessions, and generating of daily SINEX (Solution INdependent EXchange format) files for IVS. Quarterly updated solutions were computed for the IVS products Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF). At GIUB analysis activities concentrated on investigations concerning the Wettzell - Tsukuba K4 UT1 Intensive series and on combinations of VLBI data using SINEX files.

1. General Information

The GIUB/BKG VLBI Analysis Center has been established jointly by the Bundesamt für Kartographie und Geodäsie (BKG), Leipzig, and the Geodetic Institute of the University of Bonn (GIUB). Both institutions closely cooperate in the field of geodetic VLBI maintaining their own analysis groups in Leipzig and Bonn. The responsibilities include data analysis and software development. BKG is responsible for the computation of EOP time series and tropospheric parameters of the IVS-R1 and IVS-R4 sessions, the generating of daily SINEX files, and quarterly updated global solutions for the TRF and the CRF.

On May 9-10, 2003 the 16th Working Meeting on European VLBI for Geodesy and Astrometry was organized by the BKG and took place at the BKG branch at Leipzig [3].

2. Data Analysis

At BKG the Mark 5 VLBI data analysis software system Calc/Solve, release of September 25, 2003 [2], is currently used for VLBI data processing. In addition, the older Mark 4 version, release of May 15, 2003 and an independent program environment for the Calc/Solve software are available. The latter is used for the pre- and post-interactive part of the EOP series determination. The Mark 4 Calc/Solve software under Fortran77 is installed on a HP9000/280/1 workstation with an HP-UX10.20 operating system and the Mark 5 software under Fortran90 on another HP workstation with an HP-UX11.00 operating system.

- **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. R1, T2, OHIG, EURO) and submitted them to the IVS Data Centers for distribution.

- **IVS EOP time series**
  The EOP time series bkg00003, bkg00004, and bkg00005 computed from 24 hour VLBI sessions were replaced by the series bkg00006 with all 24 hour sessions since 1984 suitable for EOP determination. The main differences to the older series are the use of a new a priori TRF

called VTRF2003 [4] estimating TRF and CRF parameters in the global solution together with the EOP. From the beginning of 1984 to the end of 2003 altogether 2894 sessions of 24-hour observing time were processed.

The EOP time series bkgint02 computed from the UT1 intensive sessions was replaced by the series bkgint03. The new one is generated with fixed TRF (VTRF2003) and fixed CRF derived from the global BKG solution for EOP determination. 1074 UT1 intensive sessions with about 1 hour measurement duration were analysed for the period between Jan. 1, 1999 to Dec. 31, 2003.

- **Quarterly updated solutions for submission to IVS**
  For the IVS products TRF and CRF quarterly updated solutions were computed. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00006. 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, with station coordinates, velocities, and covariance matrix.

3. Research Topics

- **Development of a new graphic tool for the Calc/Solve software**
  The new interactive graphic tool REPA [1] has been implemented into the latest Calc/Solve releases. Both Fortran77 and Fortran90 versions are available. So it will be possible to transfer the program to LINUX. REPA allows the user to manage all necessary manipulations on VLBI observations and can create various plots of the baselines in the data base. The program can solve ambiguities for all baselines of a database in one step automatically. As of now the program is useful only for the data type "Group Delay and Rate".
- **IVS Product - Tropospheric Parameters**
  After the completion of the IVS Pilot Project - Tropospheric Parameters the VLBI group of BKG has started regular submissions of tropospheric parameters to IVS (wet and total zenith delays, horizontal gradients) for all IVS-R1 and IVS-R4 sessions since Jan. 1, 2002. The tropospheric parameters are directly extracted and transformed into SINEX for tropospheric estimates from the results of the solution for the EOP time series bkg00006. It is planned to submit long time series of tropospheric parameters from 1984 on.
- **Daily SINEX files**
  The BKG VLBI group has started the regular submissions of daily SINEX files as base solutions for the planned IVS time series of baseline lengths and for combination techniques. In addition to the global solutions independent session solutions are computed for the parameter types station coordinates, EOP, and nutation parameters.
- **Investigations of Solve SINEX Output for Combination**
  Currently the IVS Analysis Centers at BKG and at GSFC regularly produce datum-free normal equation matrices of VLBI sessions while the USNO Analysis Center is testing its output. Thus, for selected epochs three different SINEX files (V. 2.0) are available which are used for extensive testing of the combination procedures on the basis of the DGFI DOCS-CS software. First efforts concentrate on the combination of earth orientation parameters (EOP) only. In a second step it is intended to combine TRFs as well. More details can be found in the proceedings of the Third IVS General Meeting, Ottawa, Canada, February 9 - 11, 2004.

- **Correlations between estimated parameters**
  The investigations of correlations between estimated parameters have been continued now concentrating on a detailed analysis of the observation equations by singular–value decomposition.
- **Analysis of Tsukuba–Wettzell K4 UT1-UTC Intensive Observations**
  In 2003 thirty-one 1-hour sessions were observed in the Tsukuba–Wettzell K4 Intensive UT1–UTC Project. At Bonn the sessions have been analyzed in great detail. The main task is a consistent integration of the results in other series like the Wettzell–Kokee Park MK5 UT1–UTC series. Figure 3 depicts the series based on differences w.r.t. the IERS C04 series together with the Wettzell - Kokee Park results using identical analysis strategies.

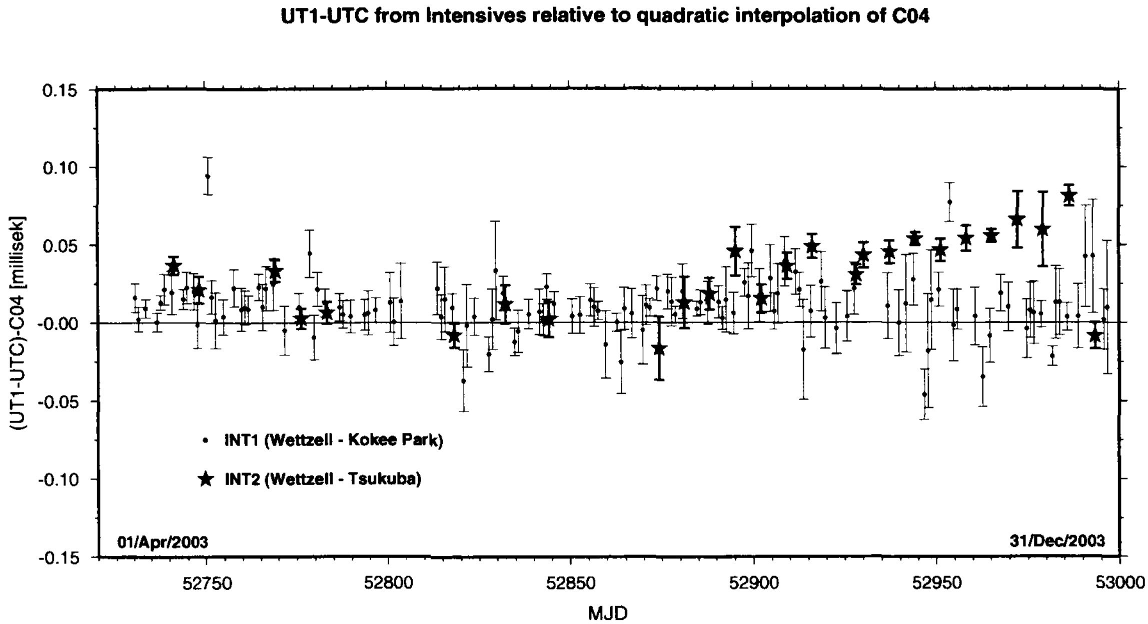

Figure 1. Residuals of Tsukuba - Wettzell and Kokee Park - Wettzell UT1-UTC Intensive Series w.r.t. IERS C04

Questions on reference frames and analysis strategies have been investigated in view of a consistent integration of this series in other UT1 observing series. Apriori polar motion series and nutation modeling play an important role in the analysis. More details can be found in the proceedings of the Third IVS General Meeting, Ottawa, Canada, February 9 - 11, 2004.

4. Personnel

Table 1. Personnel at GIUB/BKG Analysis Center

Gerald Engelhardt	BKG	++49-341-5634438	gerald.engelhardt@bkg.bund.de
Dorothee Fischer	GIUB	++49-228-732623	dorothee.fischer@uni-bonn.de
Axel Nothnagel	GIUB	++49-228-733574	nothnagel@uni-bonn.de
Christoph Steinforth	GIUB	++49-228-732623	steinforth@uni-bonn.de
Volkmar Thorandt	BKG	++49-341-5634285	volkmar.thorandt@bkg.bund.de
Dieter Ullrich	BKG	++49-341-5634328	dieter.ullrich@bkg.bund.de
Markus Vennebusch	GIUB	++49-228-733570	vennebusch@uni-bonn.de
Reiner Wojdziak	BKG	++49-341-5634286	reiner.wojdziak@bkg.bund.de

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GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Dan MacMillan, Leonid Petrov, Karen Baver

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2003. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development activities 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 Mark 4 IVS sessions using the Calc/Solve system, and performs the AIPS post correlation analysis (phase calibration and fringe fitting) and the Calc/Solve analysis of the VLBA-correlated RDV sessions. It submits updated session EOP files and daily Sinex solutions for all IVS sessions to the IVS data centers immediately after analysis. Timeliness goals are 3 working hours after correlator release for Intensive submissions, and 1 working day for 24-hr Mark 4 submissions. The group submits analyzed databases to IVS for all INT01 NEOS Intensive, R1, RDV, CONT02, R&D, and APSG sessions. During 2003, the group processed and analyzed 168 24-hr sessions (49 R1, 53 R4, 6 RDV, 5 CONT02, 13 T2, 12 CRF, 6 OHIG, 12 R&D, 5 EURO, 4 APSG, and 3 SURVEY sessions), 179 1-hr INT01 NEOS Intensive sessions, and 29 INT02 Intensive sessions. The group also generates and submits quarterly updated TRF and CRF solutions to the IVS data centers using all suitable VLBI sessions.

2.2. Research Activities

The GSFC analysis group performs research aimed at improving VLBI analysis and modeling techniques, improving tropospheric and other geophysical modeling, improving the measurement and understanding of Earth orientation, maintaining and refining the celestial and terrestrial reference frames, and other related scientific investigations. The primary research activities undertaken during 2003 include the following:

- Mass loading: Observed VLBI site position variations have significant contributions at seasonal frequencies. To explain these variations, staff investigated the effect of various mass loading signals on crustal displacements measured by VLBI. Specifically, the effects of hydrological loading, atmospheric pressure loading, and non-tidal ocean loading were considered. Applying loading models for these three effects reduced annual vertical site amplitudes for

~70% of the most frequently used VLBI sites by up to 2-3 mm, where the total observed amplitudes were generally 3-6 mm. Use of these models also improves baseline length repeatabilities except for some northern latitude sites where it is suspected that the snow component of the hydrologic model is not correct.

- Atmospheric pressure loading: Detailed investigations of atmospheric pressure loading were carried out. A rigorous procedure for computing atmospheric pressure loading was developed. A model for atmospheric tides was included. For all VLBI and SLR stations, the 3-D displacements due to atmospheric pressure loading were computed using the 6-hr surface pressure fields from the National Centers for Environmental Prediction (NCEP). The error budget of the pressure loading time series was quantitatively estimated and the errors were found to be below 15%. The loading series were validated by comparing them with a dataset of 3.5 million VLBI observations for the period of 1980–2003. It was shown that, on average, only 5% of the amount of power present in the loading time series was not also present in the VLBI data. For the first time, horizontal displacements caused by atmospheric loading have been detected. Correction for atmospheric loading in VLBI produces a significant improvement in baseline length repeatability, except for the annual component. A paper on pressure loading was presented at the GPS meeting in Luxembourg in April 2003 (see Petrov and Boy, http://arXiv.org/abs/physics/0401117), and a refereed paper (see Petrov and Boy, http://arXiv.org/abs/physics/0311096) was submitted to and accepted by JGR, to appear in 2004. On 18 March 2003, an atmospheric pressure loading service for VLBI and SLR was established. Series of 3-D displacements due to atmospheric pressure loading for all VLBI and SLR stations are updated daily. They are available at http://gemini.gsfc.nasa.gov/aplo.
- IMF: The impact of using an isobaric mapping function on VLBI analysis was investigated. The use of the NCEP Numerical Weather Model (NWM) to provide in situ atmosphere information for atmosphere delay mapping functions was evaluated using VLBI data spanning 11 years. Parameters required by the IMF mapping functions were calculated from the NWM and incorporated into Calc/Solve. Compared with the NMF mapping functions, the application of IMF in global solutions demonstrates that the hydrostatic IMF mapping function, IMFh, provides both significant improvement in baseline length repeatability and noticeable reduction in the amplitude of the residual harmonic site position variations at semidiurnal to long-period bands. For baseline length repeatability, the reduction in the observed mean square deviations achieves 80% of the maximum expected for the change from NMF to IMF. On the other hand, the wet IMF mapping function, IMFw, as implemented using the NCEP data, results in a slight degradation of baseline length repeatability, probably due to the large grid spacing used by the NWM. A paper on this subject was presented at the GPS meeting in Luxembourg in April 2003 (see Niell and Petrov, http://arXiv.org/abs/physics/0401118).
- Antenna thermal deformation: Antenna thermal expansion and contraction can contribute significantly to a site's annual vertical variations, with amplitudes as large as 3-4 mm. A simple model based on antenna dimensions and material expansion coefficients was applied in the VLBI analysis, along with the mass loading models. For many sites, the thermal expansion correction helps to reduce the annual vertical amplitudes.
- Quasar proper motions: When proper motions are estimated in the VLBI standard solutions, about 100 quasars are found with position uncertainties less than 50 μas/yr and apparent proper motions greater than 50 μas/yr. The weighted RMS of apparent proper motion is

about 30 μas/yr in both right ascension and declination, which is significant compared to the ICRF noise floor given that the observed proper motions are from 1-2 decades of observing. For many sources, structure effects are certainly responsible for much of the observed apparent proper motion, and structure corrections are desirable. Based on analysis of the coherence of the pattern of observed proper motion over the sky, attempts are being made to estimate the galactic rotation rate. A presentation on this topic was made at the VLBA Tenth Anniversary Meeting, in Socorro, New Mexico, in June 2003 (see http://arXiv.org/abs/astro-ph/0309826).

- Gilcreek post-seismic behavior: Analysis of the time series of VLBI horizontal positions at Fairbanks shows that, over the year following the Denali fault earthquake of November 2002, the site velocity averaged ~20 and ~8 mm/yr faster to the South and East, respectively, in comparison to the long-term rate prior to the earthquake. The position variation roughly follows an exponential transient decay with a time constant of 2-3 months. Another year of data may be needed to determine whether the horizontal rates have returned to their pre-earthquake values.
- CONT02 analysis: Analysis of the CONT02 sessions showed that the baseline length precision is at the level of the best VLBI sessions and polar motion offset and rate estimates agree with those from GPS at the level of their formal uncertainties. The variance of subdaily EOP residuals (160-200 μas for X, Y, and UT1) to tidal models are not significant compared to the formal uncertainties of the subdaily estimates. This variance is similar to that for previous CONT campaigns. However, the subdaily EOP residuals do show modulated diurnal, semi-diurnal, and 2-day variations.
- Antenna fixed axis tilt analysis: A Solve user-partial was used to estimate the tilts of all antennas with axis offsets in the RDV sessions. This study confirmed the tilt of the Pietown antenna, as first determined by NRAO using the pointing data. The pointing data shows a slowly increasing tilt, starting around 1991, and amounting to ~3.75 arc-minutes at 206 degrees azimuth, as of May 2003. Solve gives a tilt of ~2.6 arc-minutes at 202 degrees azimuth, at an averaged epoch of ~2000.0. Factoring in the difference in epochs, this is excellent agreement. The motion determined for Pietown is anomalous, showing an excess velocity of some 2 - 2.5 mm/yr to the SW, compared to Fort Davis, Los Alamos, and Kitt Peak, and cannot be explained by the geology of the region. Pietown's increasing tilt, of ~.3 arc-min/yr, translates into ~1.5 mm/year of motion to the SSW, if due to settling at the base of the antenna, and more if the settling/tilting is occuring deeper under the antenna. Thus, Pietown's anomalous motion may be entirely due to local settling effects.
- High frequency CRF: Members of the analysis group are working with JPL, USNO, NRAO, and others, to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (~24 and ~43 GHz). The primary goal is to build up a reference frame for use in planetary spacecraft navigation at Ka band (~33 GHz). Three sessions were analyzed during the year, a K-band survey and two K/Q sessions, using AIPS and Calc/Solve. Combined with two K/Q sessions from the previous year, the CRF determined shows declination dependent offsets from the X/S CRF, indicative of ionospheric effects. Though non-simultaneous, the K and Q observations were interpolated to obtain ionosphere corrections. Though these corrections add considerable noise to the solutions, they also appear to reduce the declination dependent errors.

2.3. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Updates were released approximately bimonthly in 2003. Work in 2003 concentrated on the development of a Linux compatible version of Calc/Solve. Extensive upgrading of Calc for compliance with the IERS Conventions (2003) was begun and will be finished in 2004.

3. Staff

Members of the analysis group (and their areas of activity) include: Dr. Chopo Ma (CRF, TRF, EOP, and K/Q CRF analysis; IERS representative), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, proper motion, and post-seismic studies), Dr. David Gordon (database analysis; RDV and K/Q CRF analysis; Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis; Calc/Solve development), Ms. Karen Baver (R4 and Intensives analysis, software development), and Ms. Cindy Villiard (data processing).

4. Future Plans

Plans for the next year include: Finishing the update of Calc for compliance with the IERS Conventions (2003); finishing and releasing the first Linux version of Calc/Solve; participation in a third set of VLBA calibrator survey sessions; participation in additional K/Q observations and reference frame development; and further research aimed at improving the VLBI technique.

5. Publications

Fomalont, E. B., L. Petrov, D. S. MacMillan, D. Gordon, C. Ma, "The Second VLBA Calibrator Survey: VCS2", Astronomical Journal, **126**, 2562–2566, 2003.

Petrov, L., C. Ma, "Study of Harmonic Site Position Variations Determined by VLBI", J. Geophys. Res., **108**, No. B4, 2190, 2003.

MIT Haystack Observatory Analysis Center Report

Arthur Niell

Abstract

The data from twenty years of the NCEP numerical weather model have been used to calculate the IMF hydrostatic mapping function for several sites distributed in latitude from $-66°$ to $+78°$. Comparison of heights estimated with the NMF hydrostatic mapping function demonstrates that using NMFh results in height errors at annual and semi-annual periods with amplitudes as large as approximately 8 mm and 4 mm, respectively, when data down to 5° are included. The errors are smallest at the equator and increase towards the poles.

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 to improving the accuracy of the estimation of atmosphere delay and thus reducing errors in the geodetic analysis. This work, along with operating the geodetic VLBI correlator and with supporting operations at the Westford, GGAO, Gilmore Creek, and Kokee Park geodetic sites, is supported by NASA through a contract with the Goddard Space Flight Center.

2. Periodic Errors in Atmosphere Models

New atmosphere mapping functions have been developed at MIT Haystack Observatory [4] and at Vienna University of Technology [2] that are based on Numerical Weather Models which provide *in situ* values for the atmosphere state variables of temperature, humidity, and pressure. These more accurate mapping functions then allow evaluation of the errors in previous generations of mapping functions.

The NMF hydrostatic mapping function [3] depends only on day of year, latitude, and height above sea level. The time dependence is simply an annual sinusoid with a fixed phase for all sites. Thus, if the phase or amplitude is wrong, or if there are higher order harmonics in the true mapping function, estimates of the local height and zenith atmosphere delay made using NMFh will have errors at those periods.

The IMF hydrostatic mapping function [4] has as the primary input parameter the 200 hPa geopotential height (hereafter referred to as *z200*) above the VLBI site. Values of this parameter from the National Center for Environmental Prediction (NCEP) on a global 2.5° by 2.0° grid for 0, 6, 12, and 18 UT of each day from 1980 through the present are stored at the Goddard Space Flight Center. The values of *z200* have been interpolated to the location of eight VLBI sites and three other locations in order to provide a comparison with NMFh. The surface pressure at each site was also obtained in order to calculate the atmosphere hydrostatic delay at 5°.

In order to convert the path delay at 5° into a height error, a simulation was used to obtain the scaling error of path delay change to height change. This simulation used a twenty-four hour GPS observing schedule, which may not give exactly the same results as current VLBI sessions, but is consistent (within 25 percent) with similar previous evaluations for VLBI data.

The predicted height error for the Fairbanks site is shown in Figure 1. The sum of the annual and semi-annual terms of the series, as calculated by a Fourier transform, is superimposed. The error is minimum in the winter and maximum in the late summer. This is consistent with the other sites in the northern hemisphere included in this evaluation. The error has the opposite sign in the southern hemisphere.

The amplitudes of the annual and semi-annual errors for the eleven sites are shown in Figure 2.

A significant implication of this result is that using the more accurate mapping functions will reduce the annual height change (and baseline length change) that is characteristic of the degree-1 deformations recently studied by [1].

3. Outlook

Preliminary results of using IMF for analysis of the ensemble of VLBI data from 1980 through late 2002 confirm the expected reduction of periodic variation in baseline lengths [5]. The necessary parameters for [2] have been extracted from the ECMWF by Johannes Boehm and can be similarly tested.

Possible improvement could be obtained by raytracing the profiles of the NWMs, but this may require more computing capability than is currently available in the geodetic VLBI community. In the meantime, both IMF and VMF provide atmosphere parameterization that is more accurate than some other error sources for daily solutions.

Future work will address the form of the wet mapping function as determined from much higher resolution numerical weather models.

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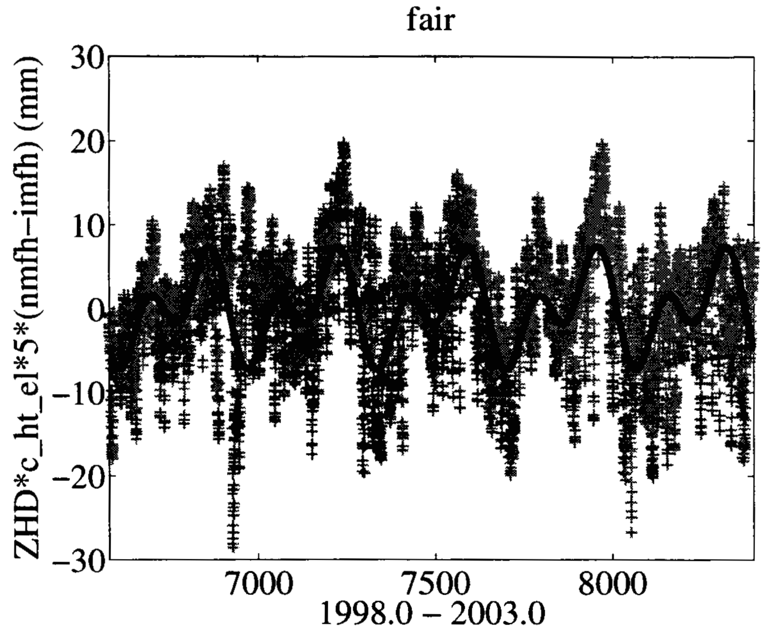

Figure 1. Height error for Fairbanks for 1998.0 - 2003.0 due to using NMFh, by comparison with IMFh, for 5° minimum elevation.

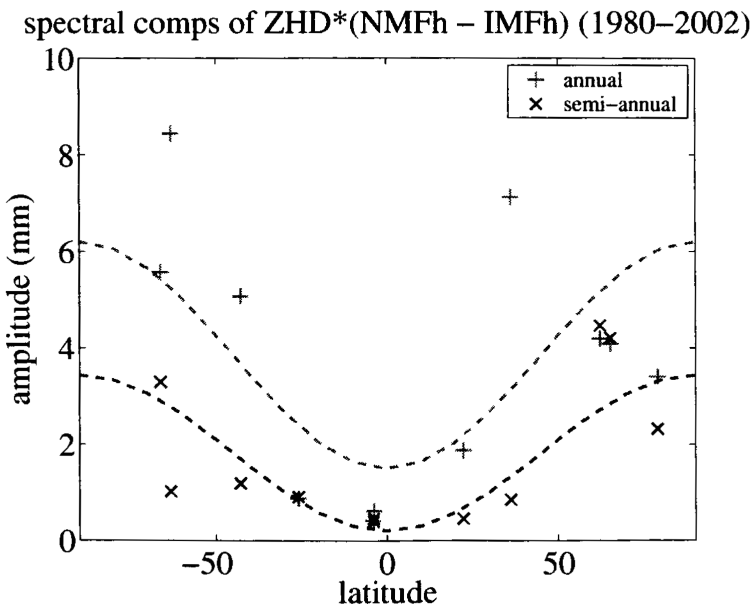

Figure 2. Amplitudes of the annual and semi-annual terms of the height error resulting from using NMFh compared to IMFh for 5° minimum elevation.

IAA VLBI Analysis Center Report 2003

Zinovy Malkin, Elena Skurikhina, Vadim Gubanov, Yuriy Rusinov, George Krasinsky, Nadia Shuygina

Abstract

The report contains a brief overview of IAA activity as IVS Analysis Center in 2003 and the plans for nearest future.

1. General Information

The IAA Analysis Center (IAA AC) is located at the Institute of Applied Astronomy of the Russian Academy of Sciences in St. Petersburg, Russia. The main fields of the activity include EOP service, computation of station and radio source coordinates, geodynamical investigations, comparison and combination of EOP, TRF and CRF realizations, development and comparison of models and software for processing VLBI observations. The IAA AC web page `http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/ac_vlbi/` is supported.

Three groups at the IAA contribute to IAA AC activity:

1. Lab of Space Geodesy and Earth Rotation (LSGER group, contact *malkin@quasar.ipa.nw.ru*): Dr. Zinovy Malkin (Head, 30%), Elena Skurikhina (100%). The main tasks of this group are determination of long-time EOP series, station and radio source coordinates, comparison and combination of space geodesy products. The group also maintains EOP service, space geodesy observations and various data bases. The group explores OCCAM and GROSS software.

2. Group of processing of VLBI observations with the QUASAR software (former Lab of New Methods in Astrometry and Geodynamics, QUASAR group, contact *gubanov@quasar.ipa.nw.ru*): Prof. Vadim Gubanov (Head, 100%), Iraida Vereshagina (Kozlova) (100%, left IAA in October 2003), Yuriy Rusinov (50%). The main task of this group is determination of EOP, station and source coordinates and other astrometric and geophysical parameters using QUASAR software with emphasis on investigation of stochastic parameters (EOP, troposphere, clocks).

3. Lab of Ephemeris Astronomy (LEA group, contact *nvf@quasar.ipa.nw.ru*): Prof. George Krasinsky (Head, 10%), Nadia Shuygina (20%). The main IVS related activity of this group is the investigations in Earth sciences and dynamical astronomy based on processing VLBI observations, and combining VLBI, satellite, radar and optical observations at the observational level, using ERA software.

2. Analysis Activities

2.1. LSGER Group

The activities of the LSGER group in 2003 included:

- Development of the OCCAM and GROSS software used for processing of the VLBI observations. Main improvements made during the period are implementation of a new atmospheric loading model (data provided by GSFC is used), new TRF realization VTRF2003 with updates for stations SVETLOE and GGAO, new FCN model. Many other changes with no significant systematic effect were made.

- Continued operational processing of the "24h" and intensive VLBI sessions, submitting the results to the IERS and IVS. Processing of the intensive sessions is fully automated. New EOP series iaao0307.eops and iaai0307.eopi were started. At the moment, the eops series contains 2792 estimates of pole coordinates, UT1 and nutation, and the eopi series contains 4618 estimates of UT1.
- 24-year session station coordinates, baseline lengths, and tropospheric parameters (ZTD, gradients) time series are obtained. Analysis of the results is in progress. In particular, ZTD series (one value for each session) is analyzed. Long time ZDT behavior can be described as combination of seasonal term and linear drift. Some results are presented in Table 1. The comparison with meteodata series is also made [4].

Table 1. Parameters of WZD time series.

Station	Nobs	Time span	Bias, mm	Drift, mm/year	Ann. amp., mm
ALGOPARK	429	1992.4–2003.8	84.8±2.5	-1.4±0.8	60.9±0.9
FORTLEZA	622	1993.3–2003.8	250.6±1.7	-1.0±0.6	56.4±2.4
GILCREEK	929	1984.5–2003.8	52.0±1.1	0.7±0.2	42.3±1.3
HARTRAO	459	1986.0–2003.8	95.3±3.2	2.1±0.5	58.3±3.3
HRAS 085	480	1980.5–1990.8	84.3±5.2	2.1±1.8	5.2±4.1
KAUAI	345	1987.5–1994.2	80.7±3.1	2.3±1.7	27.3±2.8
KOKEE	859	1993.4–2003.8	89.8±1.2	0.3±0.4	19.1±1.7
MATERA	382	1990.7–2003.8	99.3±2.4	-0.2±0.6	42.3±2.7
MOJAVE12	447	1983.4–1992.6	54.0±3.5	0.7±1.3	13.3±3.3
NRAO20	173	1995.1–2000.4	72.9±4.5	-2.9±4.3	33.2±4.9
NRAO85 3	374	1989.2–1996.6	92.9±2.7	2.5±1.4	44.4±4.2
NYALES20	328	1994.7–2003.7	40.0±1.2	1.9±0.4	28.3±1.5
RICHMOND	646	1984.0–1992.6	201.1±3.9	5.5±1.5	46.5±4.0
WESTFORD	830	1981.3–2003.8	83.9±2.8	1.7±0.5	18.0±3.2
WETTZELL	1584	1984.0–2003.8	81.5±1.2	-0.1±0.2	27.4±1.4

- 24-year session station coordinates time series in the SINEX format is prepared for the IVS Baseline Length Pilot Project.
- Investigation of nutation series available in the IVS data base was continued. Corrections to the IAU2000 precession in longitude and obliquity have been estimated, and a new FCN model is proposed [2].
- Comparison of European baseline length variations derived from VLBI and GPS observations was continued [3].
- Support of IAA data base of VLBI observations and products. At the moment more than 8500 X band NGS files and more than 10,000 X and S databases are stored.

2.2. QUASAR Group

In 2003 software QUASAR was prepared for processing all observations made during 1979–2003 to improve terrestrial and celestial reference systems and EOP [1]. New database of observations in the QUASAR format was created. The special features of this database are:

1. Using special graphic system of QUASAR, the diurnal trends of clock for all stations were reduced to general quadratic model.

2. The series, containing more than 2000 observations (e.g. VLBA, BB023), were shared in several subseries, each containing less than 2000 observations. This allows us to process observations with limited computing resources.

All observations had preliminary processing, new evaluations of autocovariance functions of stochastic signals such as WTD fluctuation, clock instability, and UT1 variation were obtained. It was proved that the Least Squares Collocation (LSC) method gives estimates of signals that are stable with respect to uncertainty of their a priori covariance functions. The efficiency of database correction is demonstrated in Figure 1. One can see that two subseries of CONT94 program give very close LSC-estimates of WTD coinciding with the direct WVR measurements.

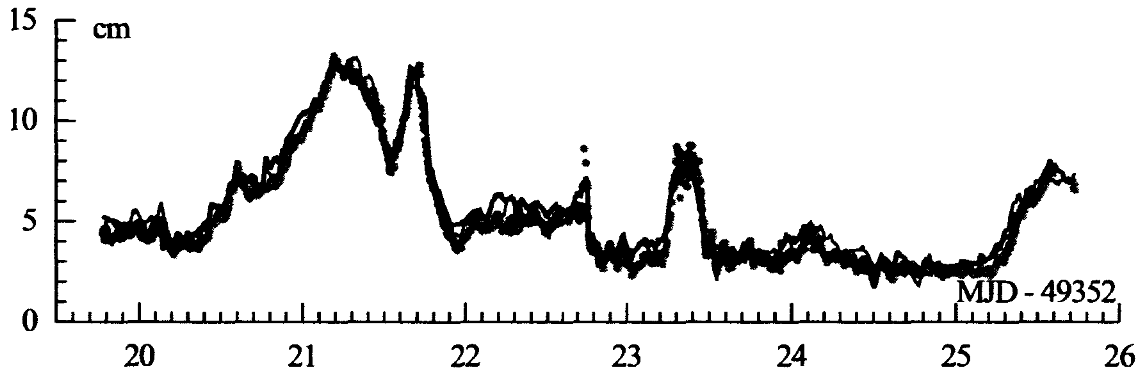

Figure 1. LSC-estimation of WTD at Onsala with comparison of two subseries (thick and thin lines) and WVR-measurements (bullets).

During January–September 2003 estimates of total tropospheric path delay were submitted to the IVS Troposphere Pilot Project.

2.3. LEA Group

A combined analysis of VLBI and SLR measurements at the observation level is carried out for improving the accuracy and time resolution of EOP. Both SLR and VLBI observations are processed by the same software ERA, using the same astronomical constants and models for different kinds of measurements.

At the first stage condition equations for VLBI and SLR observations are obtained from independent processing of each technique. For VLBI measurements zenith component of troposphere delay and its gradients are adjusted as stochastic signals for each day of observation. Both coordinates of quasars and site coordinates are not improved in this solution. For SLR data we used laser ranges to geodetic satellites LAGEOS (L1), LAGEOS 2 (L2), and Etalon 1&2 (E). The short arc technique with the arc length of 7 days is applied to all the SLR measurements to adjust orbital parameters along with radiation pressure coefficient, and along track acceleration, which are considered as non-stochastic.

At the second stage the SLR and VLBI condition equations are mixed to determine corrections to parameters mentioned above along with five Earth rotation parameters. Kalman filtering procedure is used to solve the system of condition equations. Combining SLR and VLBI measurements on one day arcs makes it possible to improve the standard deviations of pole coordinates in comparison with those obtained by each technique separately. Table 2 illustrates corrections to the Earth orientation parameters w.r.t. the EOP(IERS)C04 and their formal uncertainties obtained from different sets of observations for daily intervals. Applying Kalman filtering method also allows us to derive EOP variations with subdiurnal periods.

Table 2. Corrections to EOP(C04) and formal uncertainties obtained from different sets of observations.

Parameter	VLBI	L1+L2+E	VLBI+L1	VLBI+L1+L2	VLBI+L1+L2+E
Xp, mas	-0.276	-0.035	-0.551	0.189	0.188
	110	36	19	18	18
Yp, mas	-0.114	-0.556	-0.348	0.841	0.839
	98	37	29	24	24
UT1-UTC, ms	0.004		0.011	-0.005	-0.005
	6		5	6	6
Dpsi, mas	-0.189		-0.115	-0.342	-0.336
	180		197	250	224
Deps, mas	0.513		0.553	0.512	0.120
	86		95	120	119

3. Outlook

Plans for the coming year include:

- Improvement of algorithms and software for processing of VLBI observations. In particular, implement the IMF and/or VMF mapping function(s).
- Continue regular computation of EOP series, station coordinates, and troposphere parameters with OCCAM software. Submit the results to IVS and IERS.
- Obtain a preliminary results of global analysis of the VLBI data with QUASAR software.
- Continue investigations of VLBI EOP, station coordinates, and troposphere delays series.
- Continue to support data base of VLBI observations and products.

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Italy CNR Analysis Center Report

M. Negusini

Abstract

This report summarizes the work of the Italy CNR VLBI Analysis Center. It will give fundamental information about the structure of the center, its locations, and its activities.

1. Introduction

The Italy CNR VLBI data center is the joint effort of:

a) the Istituto di Radioastronomia (Institute of Radio Astronomy IRA) of the Consiglio Nazionale delle Ricerche (CNR) located in Bologna, where the research activity is carried out, both in radio astronomy and geodesy, and the two VLBI antennas in Medicina (near Bologna) and Noto (in Sicily) are managed;

b) and in its section located in Matera at the Center of Spatial Geodesy (of the Italian Space Agency), where its main research activity in geodesy is carried out, and a VLBI antenna, a laser ranging telescope, a permanent GPS receiver and a PRARE antenna are located.

The IRA has started to analyze VLBI geodetic databases from 1989, using a CALC/SOLVE package on the HP1000 at the Medicina station. In the following years that software was installed on an HP360 workstation and later on an HP715/50 workstation. We have analyzed here mostly databases with some European baselines, generally at least three. Most of the databases have been reprocessed in Bologna (using CALC and SOLVE). We are now using CALC9.1 and f-solve for data analysis. However, we are also storing all the databases with the Ny-Ålesund antenna data. During 2002 and 2003, we have stored in Matera all the 2000-2003 databases available on the IVS data centers. All the databases have been processed and saved with the best selection of the parameters for the final arc solutions. At present, the main analysis activity and storage is concentrated in Matera, where we store and analyze single databases, using CALC/SOLVE software. We are using F-solve regularly updated.

2. Data Analysis and Results

The main computer in Bologna is HP 785/B2600 workstation and its internet address is boira3.ira.cnr.it. At present we have installed and tested on this machine the Mark-5 VLBI Analysis Software Calc/Solve under Fortran90 compiler. In Matera the main computer is an HP282 workstation with internet name hp-j.itis.mt.cnr.it. Here, we have installed f-solve (with a center name of ITISCNR) and we are using it for the analysis of single experiments and also for global solutions in order to compute the positions and velocities of European stations.

Until June 2003, we continued to participate in the IVS Pilot Project -Tropospheric Parameters, dedicated to test and evaluate future provision of additional operational products by IVS. Regular submissions of tropospheric parameters (wet and total zenith delays, horizontal gradients) of all IVS-R1 and IVS-R4 24hr VLBI sessions were solicited. Starting with July 2003 the combined tropospheric estimates are regular IVS products within the TROP Project and our Analysis Center continued the submission of the estimated tropospheric parameters on a regular basis. In order to fulfill the request of the project, we modified the CALC/SOLVE software, so that it is able to produce the Sinex files containing the tropospheric parameters in the suitable format.

Moreover, we imported and analyzed all the other 2000-2003 databases available on the IVS data centers, in order to compute the tropospheric parameters. We are carrying out a comparison between the VLBI tropospheric estimates and the GPS-derived troposphere for the co-located sites.

We are continuing to work using external tropospheric zenith path delays in order to improve the repeatability of the VLBI geodetic results. We are inserting the wet zenith path delays in the VLBI databases as if this information had been derived using a water vapor radiometer. These data have been inserted into the VLBI databases using an updated version of DBCAL. We are testing the results on the IVS-R1 and IVS-R4 databases.

Vienna IGG Special Analysis Center Annual Report 2003

Harald Schuh, Johannes Boehm, Thomas Hobiger

Abstract

Since July 2003 the combined tropospheric parameters determined at IGG (Schuh and Boehm, 2003 [4]) are regular IVS products provided by the IVS Data Centers one month after the availability of each new session database. Additionally, a forthcoming project within IVS-TROP has been initialized that is dealing with the combination of long time series of tropospheric parameters derived from VLBI for climate studies. The IGG has continued its research on the determination of ionospheric parameters from VLBI data.

1. General Information

The IVS Special Analysis Center at the Department of Advanced Geodesy of the Institute of Geodesy and Geophysics (IGG) is part of the University of Technology, Vienna. It is mainly engaged in atmospheric research (troposphere and ionosphere) and the development of the VLBI software package OCCAM.

Figure 1. **Members of the IVS AC at IGG, Vienna** (from left G. Estermann, S. Todorova, H. Schuh, J. Boehm, and T. Hobiger). The picture was taken at the Working Meeting on European VLBI in Leipzig, Germany.

2. Staff

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of Department of Advanced Geodesy, Member of IVS Directing Board) and the research assistants Johannes Boehm and Thomas Hobiger. While Johannes Boehm is mainly concentrating on tropospheric resarches, Thomas Hobiger focuses on the ionosphere. They are supported by several student assistants.

3. Current Status and Activities

- **Modification of the VLBI software package OCCAM**
  Together with Oleg Titov (Geoscience Australia), chairman of the 'OCCAM Group', and several other scientists from various countries, IGG is involved in the development of the OCCAM software. In particular, it is in charge of the classical least-squares approach using the Gauss-Markov model. In 2003, new tropospheric mapping functions based on data from numerical weather models have been implemented (Isobaric Mapping Functions IMF (Niell, 2001 [3]) with a priori hydrostatic gradients, and the Vienna Mapping Functions VMF (Boehm and Schuh, 2004 [1])).

- **IVS Tropospheric Parameters: IVS-TROP**
  Since July 2003 the combined tropospheric parameters determined at IGG (Schuh and Boehm, 2003 [4]) are regular IVS products provided by the IVS Data Centers one month after the availability of each new session database. The combination is done with submissions rev-ceived from seven IVS Analysis Centers and it includes a detailed statistical analysis. Additionally, a forthcoming project within IVS-TROP was initialized that is dealing with the combination of long time series of tropospheric parameters for climate studies. More information about IVS-TROP can be found at the webpage `http://www.hg.tuwien.ac.at/~ivstrop`.

- **Vienna Mapping Functions VMF**

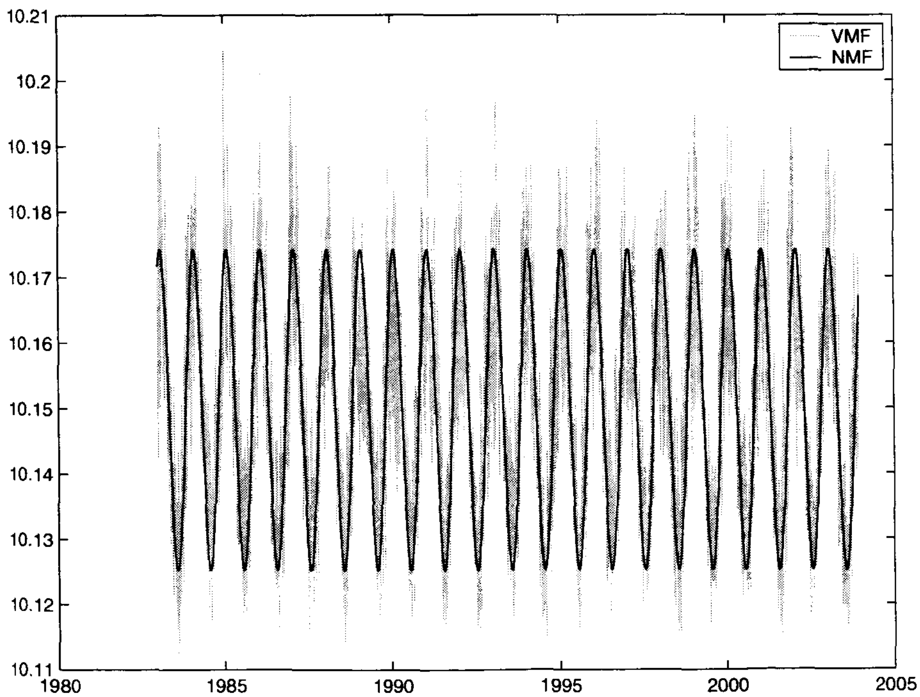

Figure 2. **Hydrostatic mapping functions from NMF and VMF** for an elevation angle of 5 degrees at Wettzell since 1984.

In 2003, much effort was put into the development of new tropospheric mapping functions based on data from numerical weather models. On the one hand data from the ECMWF (European Centre for Medium-Range Weather Forecasts) was used to determine the parameters of the Isobaric Mapping Functions IMF (Niell, 2001 [3]), on the other hand the Vienna Mapping Functions VMF (Boehm and Schuh, 2004 [1]) were developed at IGG. Figure 2 shows the comparison of the VMF with the NMF (Niell, 1996 [2]) at station Wettzell, Germany since 1984. More information about the mapping functions based on data from the ECMWF can be found at `http://www.hg.tuwien.ac.at/~ecmwf` .

- **Determination of ionospheric parameters - Vienna TEC Model (VTM)**
  In March 2003 a project entitled "VLBIonos", funded by the Austrian Science Fund (FWF) was launched. The project aims at the determination of ionospheric parameters by VLBI and comparsion with other techniques like GPS or Topex/Poseiden.
  It is a well known fact that in geodetic VLBI the observations are performed at two distinct frequencies (2.3 and 8.4 GHz) in order to determine ionospheric delay corrections. This allows us to gain information from VLBI observables about the sum of electrons (total electron content - TEC) along the ray path through the ionosphere. Because VLBI is a differential technique only the differences in the behavior of the propagation media over the stations determine the leading signs and the absolute values of the observed ionospheric delays. However, there is an instrumental delay offset per baseline that shifts the measurements by a constant value. This offset is thought to be independent of the azimuth and elevation in which the antennas point and this allows us to separate the ionospheric parameters for each station from the ionospheric offsets per baseline in a least-squares adjustment process. First tests using Fourier coefficients up to 4th order plus a constant value and a linear trend representing the vertical TEC (VTEC) were already made by Kondo (1991, [5]). Slant TEC (STEC) values are converted into VTEC values by a mapping function. The disadvantage of this approach is the assumption that these values are assigned to the station coordinates but not to the geographical coordinates of the intersection point of the ray path and the infinite thin ionospheric layer. Some problems may occur due to the apparent negative TEC values corresponding to the trigonometric approach. This effect can be avoided by a second approach developed at IGG using piecewise-linear functions having only positive values. This functional model was improved further to an adaptive piecewise-linear approach which fits the length of each time interval to the density of the observations. Figure 3 shows a comparison between the results obtained by VLBI and by different GPS analysis centers for 24 hours at Fortaleza, Brasil. In addition to the functional model a stochastical model was developed, that takes the elevation angle of each observation into account. The precision of the estimated values is about 2-3 TEC units (TECU). These results agree within 3-10 TECU with other techniques like GPS (Hobiger, 2003 [6]).

4. Future Plans

For the year 2004 the plans of the IVS Special Analysis Center at IGG include:

- Further development of OCCAM, e.g. the estimation of radio source coordinates,
- Research on new tropospheric gradient models that are based on numerical weather data,
- Participation in the new IVS Pilot Project - Baseline Lengths,

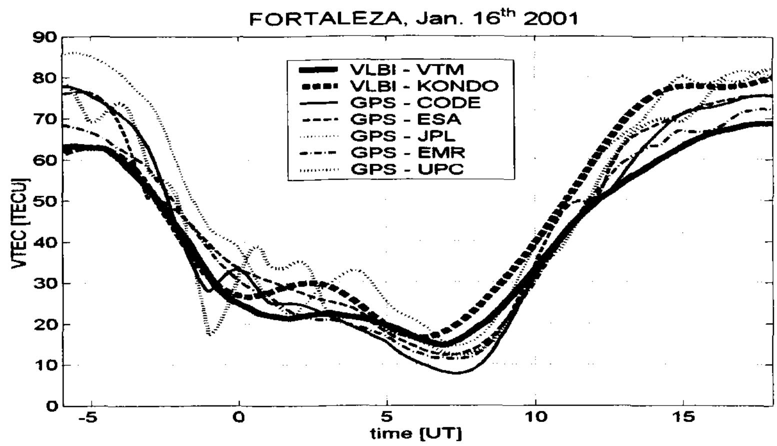

Figure 3. VTEC over the station Fortaleza, Brasil, comparison between VLBI (Vienna TEC Model - thick line; Kondo approach - thick dotted line) and individual GPS solutions (from IGS).

- Combination and analysis of long time series of tropospheric parameters with respect to climate variations,
- Determination of total electron content (TEC) maps from VLBI.

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JPL VLBI Analysis Center IVS Annual Report for 2003

Chris Jacobs

Abstract

This report describes the activities of the JPL VLBI Analysis Center for the year 2003. We continue to do celestial reference frame, terrestrial reference frame, and spacecraft navigation work using the VLBI technique. Tracking the two Mars Exploration Rover spacecraft was the highlight for the year. We continued improvements in the first sub-milliarcsecond global celestial reference frames at K-band (24 GHz) and Q-band (43 GHz). The K-band catalog more than doubled in size from 108 to 230 sources.

1. General Information

The Jet Propulsion Laboratory (JPL) analysis center is located in Pasadena, California. Like the rest of JPL, it is operated by the California Institute of Technology under contract to NASA. JPL has had a VLBI analysis group since about 1970. Our work is focussed on supporting spacecraft navigation. This includes several components:

1. Radio Reference Frame (RRF) and Terrestrial Reference Frame (TRF) are efforts which provide infrastructure to support spacecraft navigation and Earth orientation measurements.
2. Time and Earth Motion Precision Observations (TEMPO) measures Earth orientation parameters based on single baseline semi-monthly measurements. These VLBI measurements are then combined with daily GPS measurements as well as other sources of Earth orientation information. The combined product is used to provide Earth orientation for spacecraft navigation use.
3. Delta differenced One-Way Range (ΔDOR) is a differential VLBI technique which measures the angle between a spacecraft and an angularly nearby extragalactic radio source. This technique thus complements the radial information from spacecraft doppler and range measurements by providing plane-of-sky information for the spacecraft trajectory.

2. Technical Capabilities

The JPL Analysis Center acquires its own data and supplements it with data from other centers. The data we acquire is taken using NASA's Deep Space Network (DSN).

1. Antennas: Most of our work uses 34m antennas located near Goldstone California, Madrid Spain, and Tidbinbilla Australia. These include the following Deep Space Stations (DSS): the 'High Efficiency' subnet comprised of DSS 15, DSS 45, and DSS 65 (see fig. 1) which has been the most often used set of antennas for VLBI. More recently, we have been using the DSN's beam waveguide antennas: DSS 13, DSS 24, DSS 25, DSS 26, DSS 34, DSS 54 and DSS 55. DSS 26 and DSS 55 were used for VLBI for the first time in 2003. Less frequent use is made of the DSN's 70m network (DSS 14, DSS 43, DSS 63). Typical system temperatures are 35K. Antenna efficiencies are typically well above 50% at X-band.

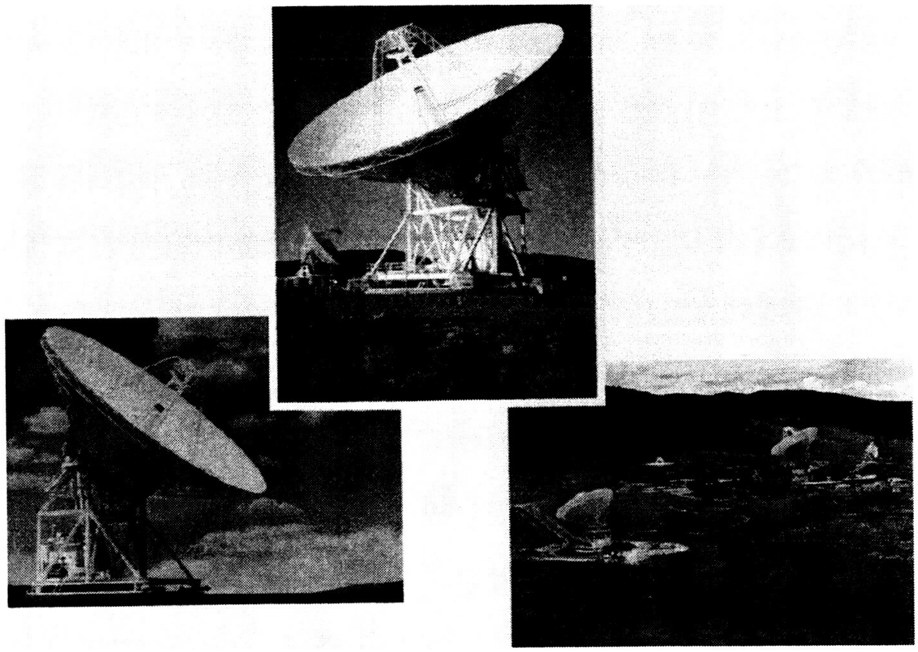

Figure 1. This figure shows the three high-efficiency antennas in the subnet: Goldstone is in the center; Robledo, Spain is in the lower left; Tidbinbilla, Australia is on the lower right. These antennas were designed to have an optimum efficiency at X-band (8.4 GHz), which was to become the standard downlink frequency for solar-system exploration. An important secondary objective was to have a reasonable efficiency at Ka-band (32 GHz) thereby allowing for possible future use at the next highest band allocated for deep space communications. The subnet was completed in 1986 in time for the Voyager encounter with Uranus.

2. Data acquisition: The DSN sites have standard MkIV VLBI data acquisition systems. In addition we have a JPL-unique system called the VLBI Science Recorder (VSR) which has digital "video converters" and records directly to hard disk. The data is later transferred via network to JPL for correlation processing. We have purchased Mark 5 recorders and expect to install them within the coming year.

3. Correlators: The JPL Block II VLBI correlator handles the TEMPO and RRF correlations of Mark IIIA format tapes. The ΔDOR data from the VSR systems are correlated using the SOFTC software correlator running on UNIX or VMS workstations.

4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10°$) differential solutions. The TEMPO solutions typically have a highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. The RRF solves for a full TRF and CRF which is later used by TEMPO and ΔDOR. Experimental CRF work this year has focussed on modelling source structure.

3. Staff

Our staff are listed below with a brief indication of areas of concentration within the VLBI effort at JPL. Note that not all of the staff listed work on VLBI exclusively as our group is involved in a number of projects in addition to our VLBI work.

- Jim Border: ΔDOR
- Sid Dains: Field support of VLBI experiments at Goldstone.
- Chris Jacobs: RRF and TRF
- Peter Kroger: ΔDOR
- Gabor Lanyi: ΔDOR, WVR, RRF, and TRF
- Steve Lowe: Software correlator, fringe fitting software
- Walid Majid: ΔDOR
- Sumita Nandi: ΔDOR
- Chuck Naudet: WVR, Mark IV support, and RRF
- Jean Patterson: ΔDOR
- Ojars Sovers: RRF and TRF. Maintains MODEST analysis code.
- Alan Steppe: TEMPO and TRF.
- L.D. Zhang: RRF

4. Current Status and Activities

This year's highlight was the support of navigation for the two Mars Exploration Rovers. The Mars atmosphere entry point was hit to within a few hundred meters. In preparation for the 2005 Mars mission, JPL is leading a collaboration with Goddard Space Flight center, the U.S. Naval Observatory, National Radio Astronomical Observatory, and the Bordeaux Observatory to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) (*e.g.* Jacobs *et al*, 2004). Figure 2 shows the current K-band CRF which has more than tripled from 65 to 230 sources since last year's report.

A-WVR: The advanced Water Vapor Radiometer (A-WVR) developed for the Cassini gravitational wave experiment, continues to be used in research applications. This device can calibrate water vapor induced delays with fractional stability of roughly a few parts in 10^{15} over time scales of 2,000 to 10,000 seconds.

5. Future Plans

We are also in the planning stage for developing a Ka-band (32 GHz) realization of the ICRF. All this work is motivated by the anticipation that spacecraft navigation will require a 32 GHz reference frame within a few years.

Mark 5 recorders: In 2003 we acquired Mark 5 hard disk recording systems which we hope to integrate into the Deep Space Network over the next year as we continue to move away from tape based recording.

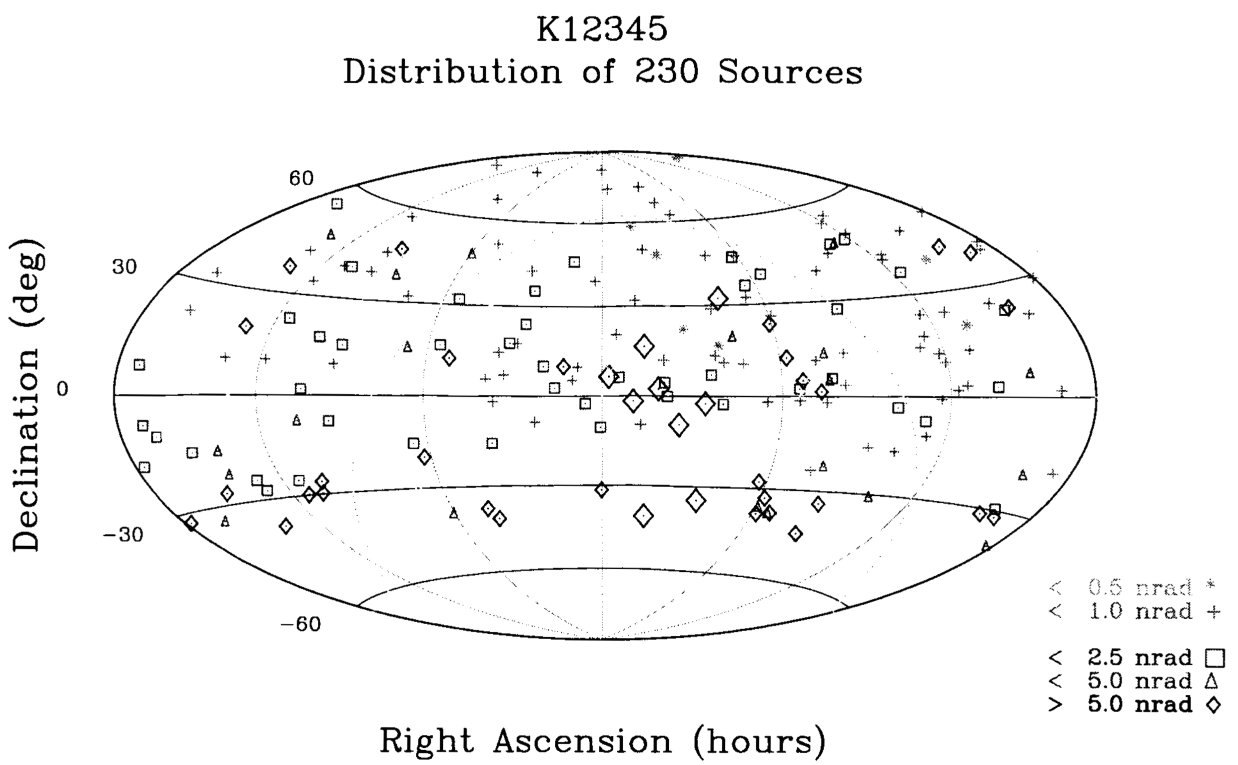

Figure 2. Celestial Reference Frame at K-band (24 GHz). There are 230 sources spread over the sky north of −30 deg declination. The label K12345 indicates that the frame is based on data from the 5 sessions of an ongoing program of observations. The shading and symbols in the legend indicate the formal declination precision. Note the highest precision is toward the north with precision lessening towards the south by as much as a factor of ≈two. This is a result of using the VLBA which is a northern array. The dotted line indicates the ecliptic plane. The central solid curved line indicates the galactic plane.

6. Acknowledgements

The research described in this paper was in part performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine

Sergei Bolotin, Yaroslav Yatskiv

Abstract

This report summarizes the activities of VLBI Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine in 2003.

1. Introduction

The VLBI Analysis Center was established in 1994 by Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine as a working group of the Department of Space Geodynamics of MAO. In 1998 it started its IVS membership as an IVS Analysis Center. The AC MAO is located in Central building of the observatory in Kiev.

The primary goal of the activity of the Center is the development of the VLBI data processing software SteelBreeze. From 2003 we started submissions of VLBI data analysis results to IVS.

2. Technical Description

The computer of the Analysis Center is a Pentium-4 1.9 GHz CPU box with 256M RAM and a 160 Gb HDD. It is running under Linux/GNU Operating System and is used for software development and VLBI data processing.

Main Astronomical Observatory has a 56 kbps link for Internet connection.

The SteelBreeze software is written in the $C++$ programming language and uses Qt widget library. SteelBreeze makes Least Square 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 now consists of two members:

Prof. Yaroslav Yatskiv: Head of the Department of Space Geodynamics, performs general coordination and support of activity of the Center.

Ph.D. Sergei Bolotin: Senior research scientist of the Department of Space Geodynamics, responsible for the software development and data processing.

4. Current Status and Activities in 2003

This year production of two types of solutions has been started. The first type of solution, "global", is based on the all available VLBI data which are suitable for determination of TRF, CRF and EOP and consists of estimated coordinates and velocities of stations, coordinates of radio sources and a series of Earth rotation parameters. In the second one, "operational", only sessions from latest several years are used and Earth rotation parameters estimated in VLBI data analysis.

The "global" solution was obtained in the end of 2003 and submitted to IVS. Almost all suitable VLBI observations conducted since 1979 till September 2003 were analyzed. The IERS Conventions (2003) [2] models have been applied in the analysis. In additional, atmospheric pressure loading ephemerides [3] have been used to model site displacements. Obtained TRF consists of coordinates of 106 and velocities of 67 stations of observations. The CRF consists of coordinates of 1571 radio sources. In the analysis 2654 estimates of EOP have been obtained.

The "operational" solution is produced and submitted to IVS on a weekly basis since November. It is based on VLBI observations conducted since 2000 and analysis procedure is similar to the "global" one (except applying atmospheric pressure loading). In this solution only coordinates of stations and Earth rotating parameters are estimated.

5. Plans for 2004

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 be continued next year also.

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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Paris Observatory Analysis Center–OPAR: Report on Activities, January - December 2003

A.-M. Gontier, M. Feissel-Vernier

Abstract

In 2003 the OPAR Analysis Center activities focused, on the one hand, on the compliance of GLORIA software with the IAU 2000 resolutions. Various tests were performed to compare different ways of implementing the classical expression of the transformation from a geocentric frame to a celestial one. On the other hand, we analyse the impact of the celestial frame stability on the monitoring of the EOP.

1. Implementation of IAU 2000 Resolutions in VLBI Analysis

The analysis of an Earth based observation of celestial objects requires an astrometric model to express the transformation from a geocentric terrestrial frame to a geocentric celestial one. One of the resolutions adopted by the XXIV General Assembly of the IAU (Manchester, August 2000) recommends the use of a new approach referring to the non-rotating origin on the equator of date, proposed by Guinot in 1979 [10], and using the celestial coordinates of the CIP [3], instead of the classical transformation which refers to the equinox of date and uses classical precession and nutation quantities. In GLORIA software the update of the new paradigm and the classical one, based on the IAU 2000 A model for precession-nutation was made and compare together last year [7], [8]. Different ways of implementing the classical transformation have been investigated and tested with GLORIA this year.

Based on Chapter 5 of IERS Conventions 2003 [11], we have implemented two different ways of computing the Greenwich Sideral Time GST:

- version *a*: implementation of the numerical relation between GST and the Earth rotation angle θ referred to the Celestial Ephemeris Origin ([11] chapter 5, equation 35) which includes an update of the "equation of the equinoxes".
- version *b*: modification of the current relationship between Greenwich Mean Sideral Time (GMST) and UT1 [1] to include dGMST ([11] chapter 5, equation 37 with a constant term of 14600μas) due to the correction in the precession rate, together with an update of the "equation of the equinoxes" ([11] chapter 5, second line of equation 35).

In order to study the impact of the frame bias at J2000 (especially the equinox offset $d\alpha_0$), we have also implemented a so-called VLBI version. It includes the usual precession parameter ([11] chapter 5, equation 31), Herring's routine for nutation "IAU2000A.f" [11] and the computation of GST using version b together with equation 47 of [4].

Various tests have been performed to verify the level of agreement between those three classical versions using the 1999 NEOS sessions. The analyses showed differences less than 0.5μas on polar motion, 0.1μs on UT1 with a slope of 3μs/century between the a version and the others. For $d\psi \sin\epsilon$, $d\epsilon$ the differences are less than 0.5μas between a and b version but could reach 3.5μas between a and the VLBI version. For the EOP the mean value of the standard errors is about 53μas.

2. Improved EOP Determination

The study of long time series of radio source coordinates gives the possibility to detect unstable sources that are not suitable for the maintenance of the frame. Statistical schemes to select a subset of objects that would be used for the maintenance of the ICRF and the monitoring of the Earth's rotation have been studied in the Feissel-Vernier [6] paper. The impact of such selection on various applications of the celestial reference frame is described in Gontier et *al.* [8] and Gontier and Feissel-Vernier [9]. The investigation of the use of the stable sources in the determination of EOP is presented hereafter.

The stability of time series of EOP of various origins can be compared by the Allan variance. The Allan variance of a time series x_i with N items and sampling time τ is defined as:

$$\sigma_A^2(\tau) = \frac{1}{2N}\sum_i(x_{i+1} - x_i)^2$$

The Allan variance analysis allows one to characterize the power spectrum of the variability in time series, for sampling times ranging from the initial interval of the series to 1/4 to 1/3 of the data span, in our case one year through four years. This method allows one to identify white noise (spectral density S independent of frequency f), flicker noise (S proportional to f^{-1}), and random walk (S proportional to f^{-2}). Note that one can simulate flicker noise in a time series by introducing steps of random amplitudes at random dates. When several series of measurements of the same phenomenon are available, it is possible not only to derive the level of measurement noise, but also its spectrum by the three-corner-hat method [2], assuming that their measurement errors are independent. The slope of the graph giving the Allan variance as a function of sampling time, both in logarithmic scale, points to white noise (slope = -1), flicker noise (slope = 0), or random walk noise (slope = +1).

Figure 1 shows measurement stability graphs for polar motion and universal time determinations over 1990-2002 based on either all sources or on the stable sources only. The results shown here involve both GPS and VLBI for polar motion, and only VLBI solutions for universal time. The set of VLBI solutions considered are based on seven different source selections, considering various sources characteristics, e.g. defining, stable, unstable, etc [12].

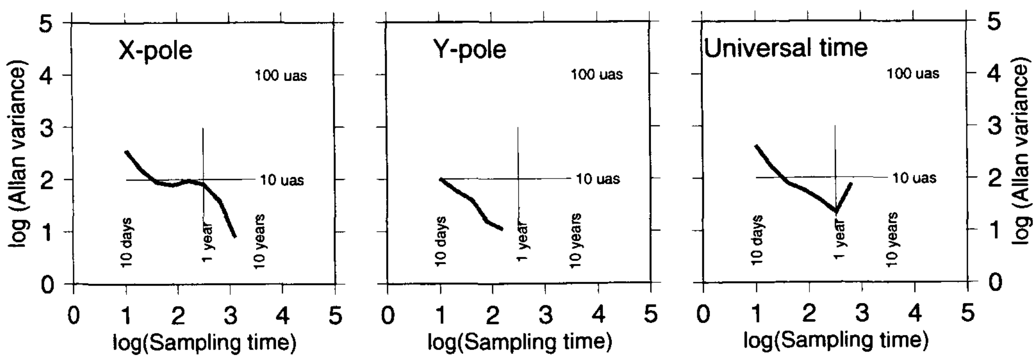

Figure 1. Stability of pole coordinates and universal time over 1990-2002 according to source selection. All sources: green(light); stable sources only: blue (dark).

In addition to the fact that the Allan variance is always lower when using the stable sources only, a striking feature for x-pole is that the use of the stable sources cancels the random walk noise appearing beyond one-year sampling time when using all sources. The reference to the stable sources ensures or strengthens white noise in the long term for the measurement of polar motion. The measurement of universal time involves the stability of both the terrestrial and the celestial reference frames. The possible influence of the terrestrial frame on the remaining random walk signature beyond one year should be investigated.

Nutation is the motion of the Earth's axis in space in response to the torque exerted by the Moon, Sun and planets. The state of the art model recommended by the IAU in 2000 [13], is based on *i*) the modelling of the astronomical external torque at the 0.1 μas accuracy level [14] [15], *ii*) the modelling of the response of the non rigid Earth to this external torque, and *iii*) the VLBI observations relative to extragalactic directions materialized by the quasars. When observed at the current level of precision (a fraction of a milliarcsecond), no object is really point-like. Apparent motions, if existing, may be related to the existence of jets originating in the sources. Such motions may give rise to time varying inhomogeneities in the celestial reference frame that, in turn, could mimic nutation signals.

Studying the influence on nutation of the variable torque exerted by the atmosphere and the ocean, Dehant et al. [5] showed that apparent variability in the celestial frame can lead to changes in estimates of precession or long period nutation coefficients at a level comparable to that of the variable nutation excited by the Earth's fluid layers (a few tens of μas).

Figure 2 shows the celestial frame effect on precession and obliquity rate and on the 18.6 year nutation term. The precession and obliquity rates changed by 20 μas/year and the 18.6 year prograde component by 30 μas.

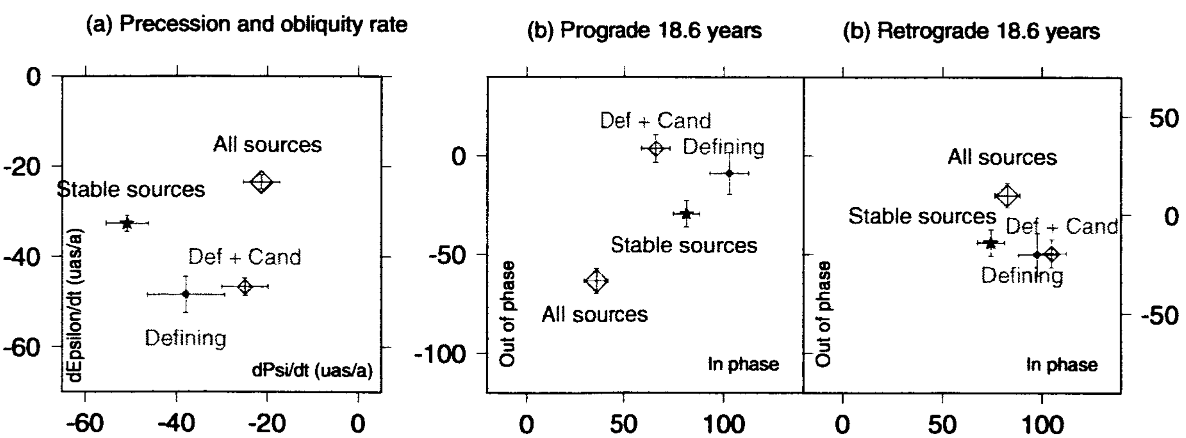

Figure 2. Precession and obliquity rate corrections (left graph) and prograde and retrograde corrections to the 18.6 year nutation term in μas (right graph).

3. Summary

The update of the GLORIA software to comply with the IAU 2000 resolutions was made. The comparisons between the different implementations of the classical transformation showed an agreement better than 4μas on estimated EOP.

M. Feissel-Vernier [6] proposed a source selection scheme based on time series analysis of source coordinates that gives the possibility to detect unstable sources. The consideration of the stable sources strengthens white noise in the long term for the measurements of polar motion. The impact on UT1 is less sensible as the measurement involves also the stability of the terrestrial frame. The improved stability and internal consistency of the frame impacts positively the determination of Earth orientation parameters.

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The IVS Analysis Center at the Onsala Space Observatory

Rüdiger Haas, and Hans-Georg Scherneck

Abstract

We give a brief overview of the activities of the IVS Analysis Center at the Onsala Space Observatory during 2003. Some examples of achieved results and ongoing analyses related to earth rotation, loading phenomena, and atmospheric research are presented.

1. Introduction

The IVS Analysis Center at the Onsala Space Observatory (OSO) is active in research concentrating on a number of particular topics that are relevant to space geodesy and geosciences. These research topics are important for geodetic VLBI and are investigated using VLBI observations and corresponding analysis programs. In the following we will briefly address some of these topics and present some examples of performed and ongoing analyses. For the future we plan to continue VLBI related research along those lines, concentrating on particular research topics. There are no plans at OSO for a routine analysis of global VLBI data in a service sense.

2. Earth Rotation Variations and ENSO

We analysed the combined IVS time series of earth orientation parameters [1] to study El-Niño/Southern Oscillation (ENSO). The IVS UT1 values were processed similar to the description in [2] and using the effective atmospheric angular momentum functions as calculated from NCEP/NCAR reanalyses [3]. The resulting excess length-of-day (dLOD) values are shown in Figure 1 together with the Multivariate ENSO Index (MEI) [4]. There is a clear correlation between the two time series and both clearly show the ENSO events during the last 23 years.

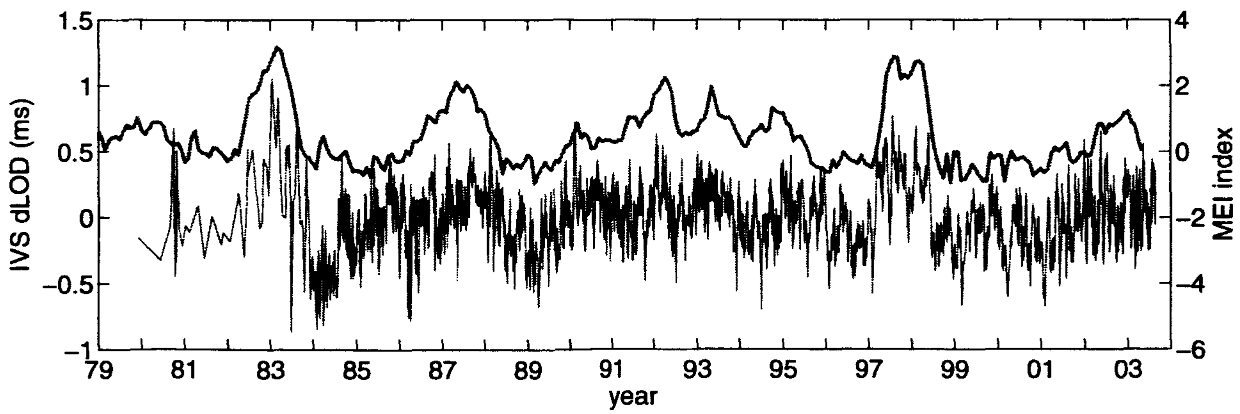

Figure 1. Lower blue curve, left scale: Excess in length of day (dLOD) in ms derived from combined IVS EOP values [1]. Top red curve, right scale: Multivariate ENSO index (MEI) [4]. Both time series clearly show the ENSO events during the last 23 years.

3. High-frequency EOP During CONT02

We analysed the CONT02 VLBI observations and determined polar motion and UT1 values with a time resolution of 1 hour. Figure 2 displays the time series and their corresponding spectra. Variations with 12 hour and 24 hour periodicity are detectable both in polar motion and UT1. A variation with an 8 hour period is detected marginally above the significance limit in Yp. Further investigations are ongoing.

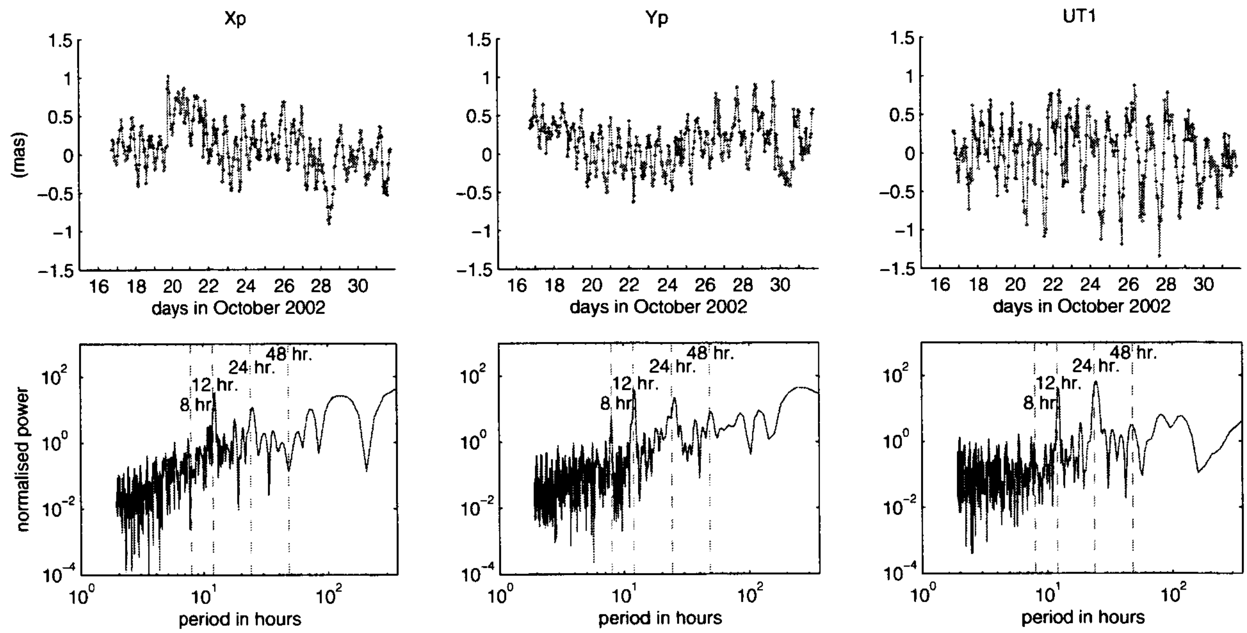

Figure 2. Polar motion and UT1 for CONT02. Upper plots in red: time series of Xp (left column), Yp (middle column) and UT1 (right column) with a time resolution of 1 hour. Lower plots in blue: spectra of the above time series. Periods of 8, 12, 24, and 48 hours are indicated with red vertical lines.

4. Ocean Tide Loading and Atmospheric Loading

The automatic ocean tide loading provider [5] has been maintained during 2003. On the website http://www.oso.chalmers.se/~loading users can chose between 11 different ocean tide models that are available to calculate ocean tide loading parameters for site positions that can be specified interactively. The parameters are provided in several formats, and are sent to the user via e-mail.

Time series of atmospheric loading predictions that are based on global convolution of atmopheric pressure fields are available for most of the VLBI databases since 1990 on the website http://www.oso.chalmers.se/~hgs/apload/apload.html.

5. European Crustal Motion

The analysis of the purely European geodetic VLBI observations has continued and results for crustal motion have been published in 2003 [6].

6. Atmospheric Parameters at Onsala During CONT02

Additionally to the CONT02 VLBI observations we performed simultaneous observations with the Onsala IGS permanent GPS equipment, two water vapor radiometers (WVR), and a rain radar (RR) at the observatory. The water vapor radiometer Astrid was operated in sky mapping mode, while the water vapor radiometer Konrad followed the VLBI observation schedule and was perfoming tip-curve measurements during slewing times of the VLBI telescope. Figure 3 shows preliminary results for the zenith wet delay (ZWD) derived from observations with the four collocated techniques. These prelimiary results show a reasonably good agreement between the ZWD derived from the different techniques and have been communicated the EGS-AGU-EUG Joint Assembly 2003 [7] and the 16th Working Meeting on European VLBI for Geodesy and Astrometry [8]. However, the rain radar measurements indicate that there are still some WVR-data that were influenced by rain and should be removed from the time series. Furthermore, there are still some unexplained biases and thus the investigations are continuing.

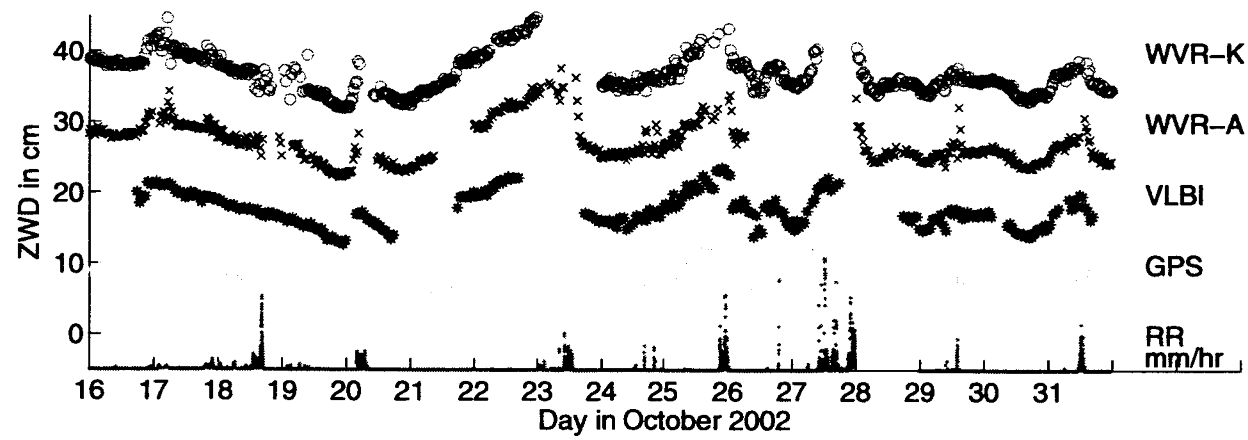

Figure 3. Equivalent zenith wet delays in cm and rain rate in mm/hr at Onsala during CONT02. Top to bottom the time series are: radiometer Konrad (red, offset by +30 cm), radiometer Astrid (blue, offset by +20 cm), VLBI (black, offset by +10 cm), GPS (green, no offset), rain radar (magenta, offset by -5 mm/hr).

7. Trends in Tropospheric Water Vapor at Onsala

We investigated trends in the tropospheric water vapor content based on ZWD data determined from observations with the three collocated techniques VLBI, GPS, and WVR at Onsala and radiosondes (RS) at Landvetter airport 37 km away from the observatory. Data for more than 23 years are available from VLBI, WVR and RS, while GPS data are available since 1993. Each of the techniques has specific advantages and disadvantages in terms of stability and time resolution. Therefore, a combination of the results of the individual techniques appears to be a promising approach. We developed strategies to assess trends in tropospheric water vapor and to combine the results of the four independent techniques in order to determine robust results that can be useful for climate related research [9].

8. Activity in the IVS Pilot Project – Tropospheric Parameters

We continued our activity in the IVS Pilot Project – Tropospheric Parameters. Tropospheric parameters for all VLBI stations observing in the IVS R1 and R4 networks were submitted to the IVS. Figure 4 shows histograms of the ZWD for four stations that are located in different climate zones: Ny-Ålesund – polar, Wettzell – temperate, Hartrao – dry, Fortaleza – tropical. A dependence of the amount of water vapor on the climate zone is obvious.

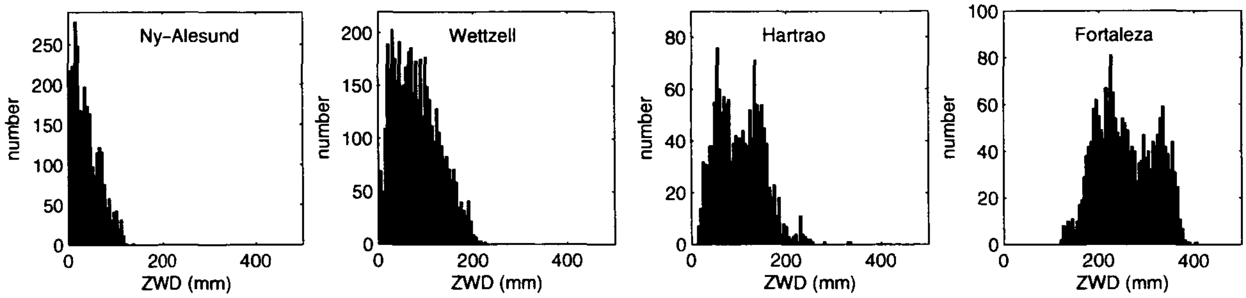

Figure 4. Histograms of zenith wet delay (ZWD) values for four stations located in four different climate regions. The histograms include results from the IVS R1 and R4 experiments during 2002 and 2003.

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Shanghai Astronomical Observatory Analysis Center Report

Jinling Li

Abstract

Our activities in the calender year 2003 are involved in the coordination of the VLBI observations for the Asia-Pacific Space Geodynamics (APSG) program, data archives and reduction and application studies. Our plans for the calender year 2004 will be mainly focused on the application of VLBI to the positioning of spacecraft.

1. General Information

As one of the research groups of the Center for Astrogeodynamics Research, Shanghai Astronomical Observatory (SHAO), we focus our activities on studies of Radio Astrometry and Celestial Reference Frames. Facilities for us to analyze the astrometric and geodetic VLBI observations are the HP C180 Workstation, several sets of personal computers with advanced technical specifications, as well as several sets of SUN Workstations in the computer division of SHAO. We use CALC/SOLVE system in the routine VLBI data reduction. The members involved in the IVS activities are Jinling Li, Guangli Wang, Bo Zhang, Li Guo, Nianchuan Jian, Ming Zhao and Zhihan Qian.

2. Current Activities

2.1. Observation Coordination and Data Reduction

Our group continue the coordination of the VLBI experiments as well as the observation archives and reduction for the Asia-Pacific Space Geodynamics (APSG) program. In October of 2003 two 24h VLBI sessions were carried out. We also participated in some IERS/IVS campaigns aimed at comparisons of reference frames and/or Earth Rotation Parameters. We contributed to IERS several sets of global solutions from VLBI data reduction.

2.2. Modelling the Residual Clock Behavior in VLBI Data Reduction

Based on the observations and simulated data, the feasibility of the periodic function modelling (P-model) of the residual clock behavior in the routine VLBI data reduction was discussed. Two global solutions of 1,567 VLBI sessions from 1990 to 2001 were performed corresponding to the continuous piecewise linear modelling (N-model) and the P-model of the residual clock behavior. It is shown that compared with the N-model the number of unknowns in the solution could be evidently decreased and so the degree of freedom increased when the P-model was used. Though the formal errors of the coordinates of stations and sources as well as the Earth Orientation Parameter are on the same level, it is slightly better to model the residual clock behavior by the P-model than the N-model. The formal errors of coordinates could be decreased for more than 80% of the stations and 70% of the radio sources (Figure 1 and Figure 2).

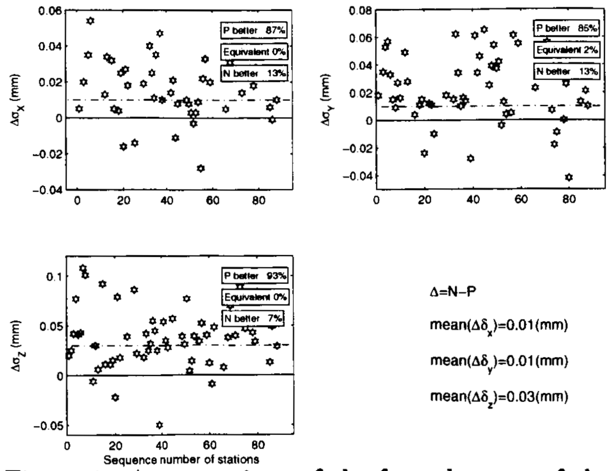

Figure 1. A comparison of the formal errors of the station coordinates between the P- and N-model of the residual clock behavior

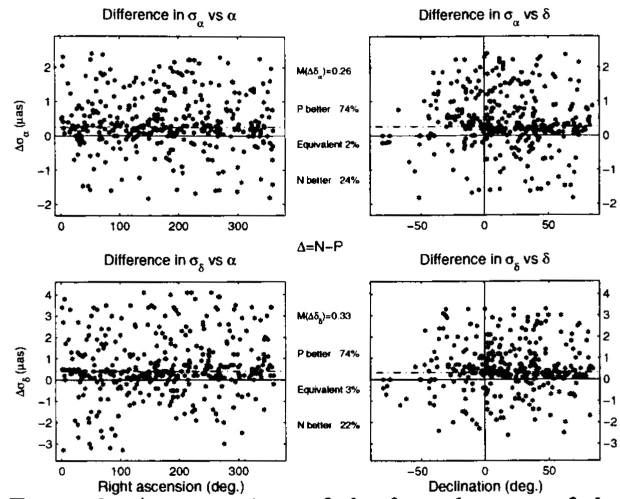

Figure 2. A comparison of the formal errors of the radio source coordinates between the P- and N-model of the residual clock behavior

2.3. Solutions and Analysis of EOP High Frequency Variation

To get the solutions of the EOP high frequency variation in a piecewise manner, we could use piecewise continuous linear modelling with constraints on the change of the rate between connected pieces. By doing so the solutions to the rates could be strongly correlated with each other and the real change in the rate may be concealed. We have tried to solve for the means of EOP within every piece without any constraints. Comparisons show that if the data points are sufficient the constraints are not necessary. Figure 3 shows our solutions to the high frequency variation of EOP and its wavelet analysis.

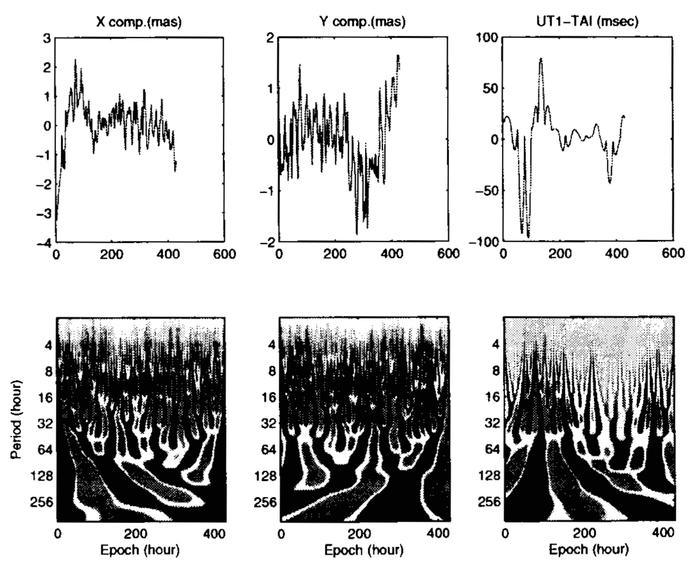

Figure 3. An example of the solutions and analysis of the high frequency variation of EOP

2.4. Some Other Activities Related with the Chinese CHANGE Project

The angular resolution in spacecraft positioning by the intended Chinese VLBI network was analyzed in order to provide some quantitative reference specifications to the feasibility demonstration and the program design of the Chinese CHANGE project.

Table 1 lists the angular resolution estimations by shifting the spacecraft geocentric distance, the constraint of range, the configuration of station network and the type of observations. The spherical coordinates of the spacecraft are $\alpha = 105°$ and $\delta = 35°$. In Table 1, the site code from 1 through 7 represent respectively the VLBI stations of SHANGHAI, URUMQI, KUNMING, BEIJING, KASHIMA, SVETLOE and HARTEBEESTHOEK, σ_α and σ_δ represent respectively the angular resolution in the right ascension and declination, "Corr" is the correlation coefficient between the two estimations. From Table 1 it could be concluded that (1) either τ or $\dot{\tau}$ could be used independently in the spacecraft positioning, if τ and $\dot{\tau}$ observations are used in combination in the positioning the precision of the resulting angular resolution is better than only using one of the two types observations; (2) if only $\dot{\tau}$ observations are used without the range constraint, the angular resolution in right ascension and declination are strongly correlated with each other and so result in a low precision of estimation; (3) in the combination use of τ and $\dot{\tau}$ observations the latter contributes to a very limited extent to the improvement of the precision; (4) the range constraint obviously improves the angular resolution; (5) the intended Chinese VLBI network is longer in east-west baseline than in north-south, the corresponding longitudinal angular resolution is better than the latitudinal; (6) if the Chinese network is supplemented with some international stations when tracking the spacecraft, the angular resolution could be improved significantly.

Taking into consideration the inclination angles among the lunar orbit, equatorial and ecliptic planes, Figure 4 and Figure 5 demonstrate the estimation of angular resolutions for the intended Chinese network only and for the Chinese network supplemented by some international stations. The target distance is $380,000km$, only delay observations are used with $1km$ range constraint and $\sigma_\tau = 1ns$. The comparison of the two figures shows that with the supplement of international stations the sky coverage with high resolution is extended and the resolution is improved significantly.

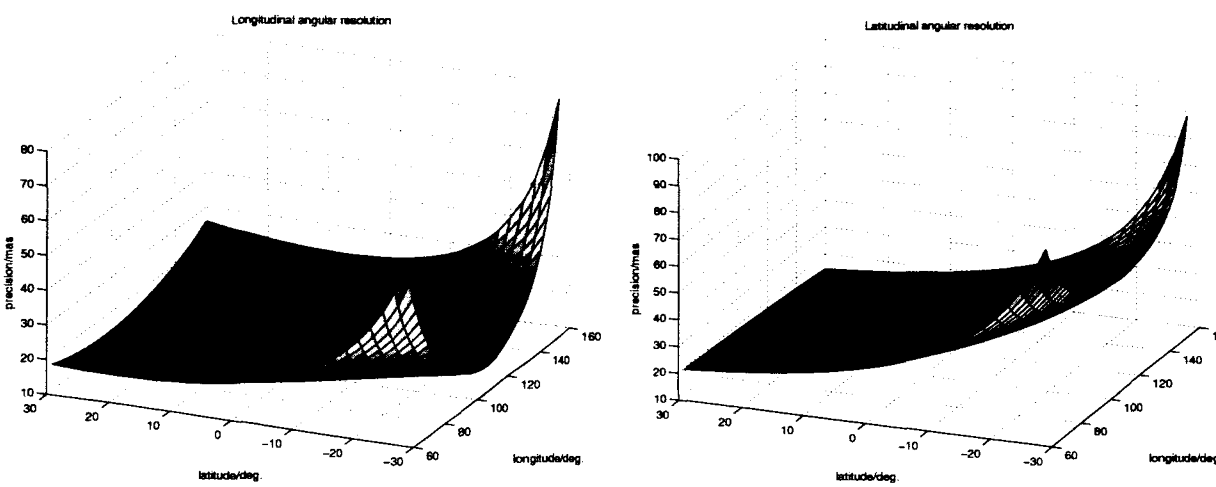

Figure 4. Angular resolution estimation with $1ns$ delay observation $380,000km$ target $1km$ range constraint and four (1 to 4) tracking stations

Table 1. Angular resolution estimation from VLBI observables

$r = 180,000km$		Without constraint			$1km$ range constraint		
Site code	Data type	Angular resolution(mas)			Angular resolution(mas)		
		σ_α	σ_δ	Corr	σ_α	σ_δ	Corr
1 to 4	τ	18.0	21.1	0.16	17.2	19.2	0.33
	$\dot{\tau}$	4290.8	21556.2	−0.99	533.7	413.4	-0.34
	$\tau, \dot{\tau}$	17.2	19.1	0.33	17.2	19.1	0.33
1 to 7	τ	6.5	4.4	-0.09	6.3	4.4	-0.10
	$\dot{\tau}$	134.1	485.3	-0.46	129.2	274.6	-0.44
	$\tau, \dot{\tau}$	5.3	4.4	-0.09	5.2	4.4	-0.09
$r = 380,000km$		Without constraint			$1km$ range constraint		
Site code	Data type	Angular resolution(mas)			Angular resolution(mas)		
		σ_α	σ_δ	Corr	σ_α	σ_δ	Corr
1 to 4	τ	18.4	21.5	0.16	17.5	19.5	0.34
	$\dot{\tau}$	5119.4	19386.1	-0.99	539.7	347.3	-0.36
	$\tau, \dot{\tau}$	17.6	19.6	0.32	17.5	19.5	0.34
1 to 7	τ	6.7	4.4	-0.08	5.0	4.4	-0.12
	$\dot{\tau}$	128.0	379.9	-0.42	125.4	124.7	-0.71
	$\tau, \dot{\tau}$	5.9	4.4	-0.08	4.9	4.4	-0.12

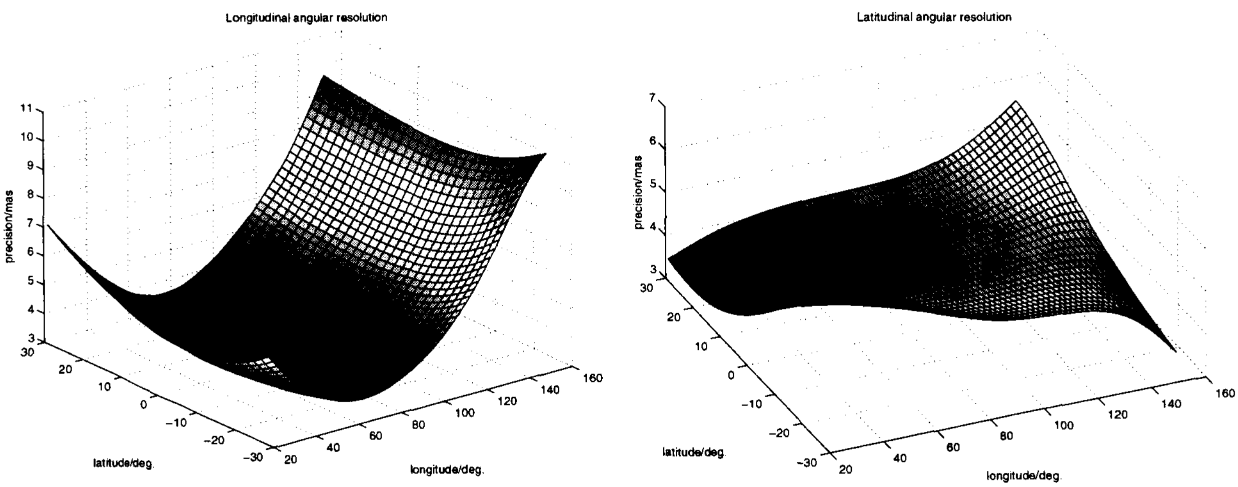

Figure 5. Angular resolution estimation with $1ns$ delay observation $380,000km$ target $1km$ range constraint and seven (1 to 7) tracking stations

3. Plans for the Calendar Year 2004

We will continue to deliver our efforts on the coordination of the APSG program as well as on the response to various IERS and IVS campaigns of regional and global VLBI data analysis. We will focus most of our efforts on the application of VLBI to the positioning of spacecraft.

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 2003. 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. In addition, Analysis Center personnel analyzed and submitted databases for Celestial Reference Frame (CRF) experiments: CRF-17 through CRF-24, CRF-MS7, and CRF-DS5 through CRF-DS9. During the 2003 calendar year, the USNO Analysis Center produced two periodic global Terrestrial Reference Frame (TRF) solutions with designations usn2003a and usn2003b. Earth orientation parameters based on these solutions, updated by the diurnal (IVS-R1 and IVS-R4) experiments, were submitted to the IVS. The VLBI Analysis Center personnel at USNO completed ICRF Extension 2, and produced global CRF solutions designated crf2003a and crf2003b. This report also describes activities planned for the 2004 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 session-based Earth orientation parameters (EOP-S) 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 2003 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 2003, USNO scheduled and analyzed 14 CRF experiments including CRF-17 through CRF-24, CRF-MS7, and CRF-DS5 through CRF-DS9. The analyzed databases were submitted to the IVS for dissemination to the community.

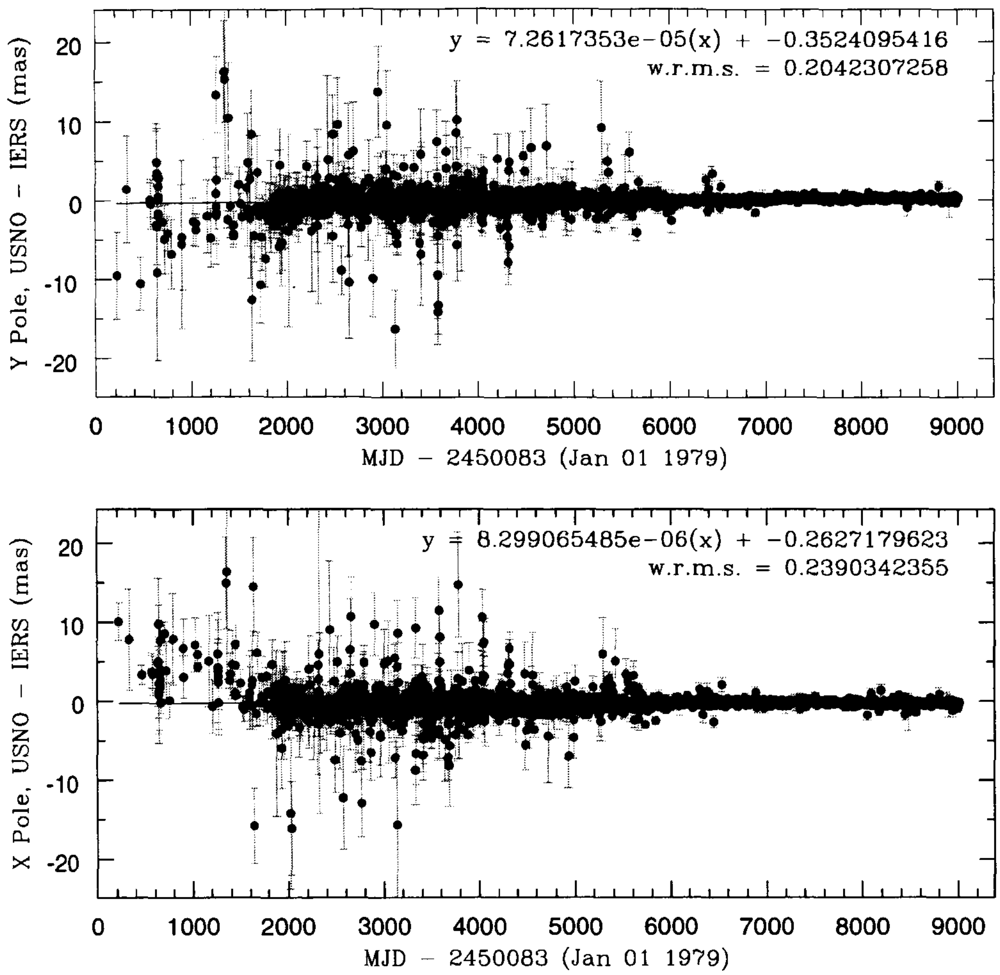

Figure 1. Differences between pole positions estimated from the usn2003b TRF solution and the IERS-C04 time series. A weighted least squares linear fit to the data and the weighted RMS are shown in the upper right corner of each plot.

2.2. Global TRF Solutions and EOP Submission

USNO VLBI Analysis Center personnel continued to produce periodic global TRF solutions (usn2003a and usn2003b) over the course of the 2003 calendar year. All USNO global TRF solutions including the most recent solution may be found at:

`http://rorf.usno.navy.mil/solutions/.`

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 usn2003b solution and the IERS-C04 time series are plotted.

EOP-S based on the global TRF solutions were continuously updated with new data from the IVS-R1/R4 experiments prior to the introducition of the next global solution. These updated EOP-S files were submitted to the IVS twice weekly within 24 hours of the experiment correlation. Analysis Center personnel also worked to produce suitable SINEX format files based on the 24-hr experiments for the IVS Pilot Program to produce a combination for a Time Series of Baseline Lengths by the group at UBonn.

2.3. Global CRF Solutions and ICRF-Ext.2

During the calendar year 2003, personnel at the USNO VLBI Analysis Center completed work on Extension 2 of the ICRF, and a paper reporting the results has been submitted. The primary objective of ICRF-Ext.2, is to provide positions for extragalactic radio sources observed since the definition of the ICRF (July 1995) and its first extension (April 1999) and to refine the positions of candidate and other sources using additional observations. The data added to the ICRF in ICRF-Ext.2 spanned May 1999 through May 2002 and was obtained from both geodetic and astrometric observing programs coordinated through the IVS. Approximately 1.2 million new observations from approximately 400 sessions were added along with 50 new sources. For the first time, data from the Very Long Baseline Array (VLBA) experiments with the designation RDV were included. The 30 station RDV experiments added over 652,000 delay observations (~20% of the total number of delays) to the solution.

During 2003, Analysis Center personnel continued work on global CRF solutions including crf2003a and crf2003b. These solutions were compared to the current ICRF. As an example, Figure 2 shows the differences between USNO CRF2003b source positions and the corresponding ICRF-Ext.2 positions.

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	Quarterly global TRF solutions, solution comparisons, web page design and administration, VLBI data analysis.
Alan L. Fey	Quarterly global CRF solutions, solution comparisons, web page design and administration, VLBI data analysis.
David M. Hall	VLBI data analysis and database submission, IVS EOP submission.
Kerry A. Kingham	Correlator interface, VLBI data analysis

4. Future Activities

For the upcoming year January 2004–December 2004, 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

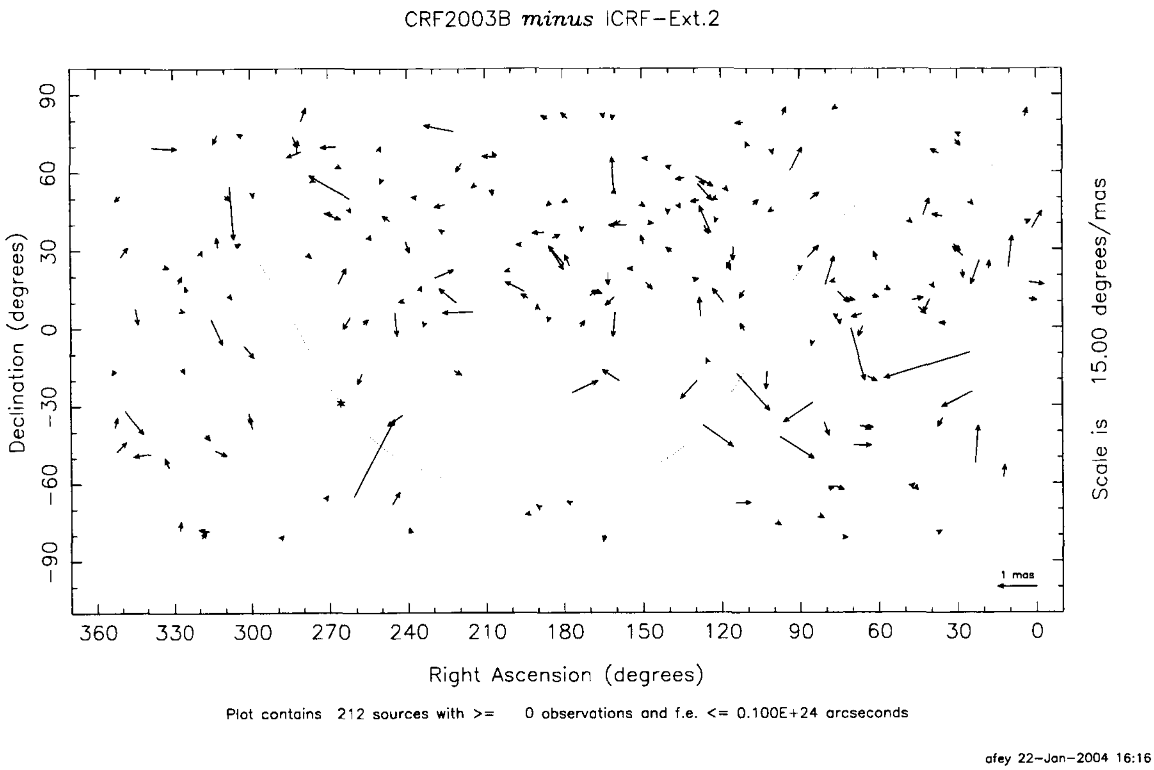

Figure 2. Differences in the source positions as derived from the USNO CRF2003b solution and the ICRF-Ext.2 solution. Plotted are all 212 defining sources of the ICRF. The dotted line represents the galactic equator. The differences are due primarily to the fact that the ICRF defining source positions have not changed since the definition of the ICRF.

CRF global solutions.

- Continue the submission of databases for IVS-R4 experiments for dissemination by the IVS.
- Continue the analysis and database submission for all IVS-CRF experiments.
- 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.
- Begin the submission of Sinex format files based on USNO databases for dissemination by the IVS.
- Begin the submission of EOP-I estimates based on the intensive experiments to the IVS.
- Begin the analysis of intensive experiments for use in USNO internal EOP-I time series estimates.
- Continue the production of periodic global CRF solutions.
- Make additional astrometric observations in the Southern Hemisphere in collaboration with ATNF partners.

USNO Analysis Center for Source Structure Report

Alan L. Fey, David A. Boboltz, 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 2003. International Celestial Reference Frame (ICRF) sources were observed using the Very Long Baseline Array (VLBA) at 24 GHz and 43 GHz as part of a program to extend the ICRF to higher radio frequencies. Experiments BR079C and BL115A were calibrated and imaged. A program to measure apparent jet velocities from the motions of source components using 8.4 GHz VLBA images continued. A total of 60 sources have been analyzed to date. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Imaging of 69 southern hemisphere ICRF sources at 8.4 GHz was completed. Activities planned for the year 2004 include continued model fitting and imaging of ICRF sources at standard and higher frequencies as well as continued research into the effects of intrinsic source structure on astrometry.

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 most ICRF sources with declination greater than about −30 degrees. Source structure information is provided in the form of synthesis images and source models suitable for evaluating sources for astrometric and/or geodetic use and for long-term monitoring of sources. The RRFID contains 3060 Very Long Baseline Array (VLBA) images of 452 sources at radio frequencies of 2.3 GHz and 8.4 GHz. The RRFID can be accessed from the Analysis Center web page or directly at

`http://www.usno.navy.mil/RRFID/`

A recent addition to the RRFID are VLBA images of ICRF sources at radio frequencies of 24 GHz and 43 GHz. The RRFID contains 578 images of 230 sources at these frequencies.

2. Current Activities

2.1. VLBA High Frequency Imaging

VLBA observations to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) continued in 2003. 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

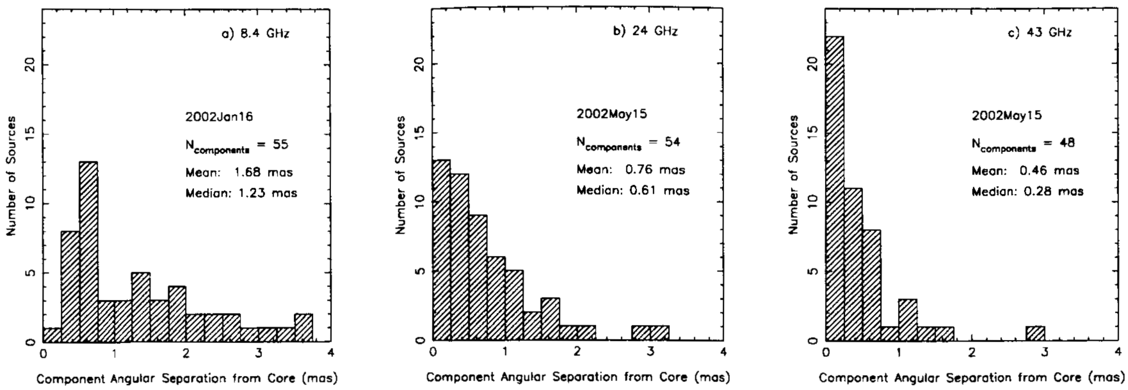

Figure 1. Distribution of Gaussian component angular separation from the assumed core component for the 28 common sources observed on 2002 Jan 16 and 2002 May 15 at a) 8.4 GHz, b) 24 GHz and c) 43 GHz. The core is defined as the model component fitted to the image having the smallest angular size.

Observatory. The long term goals of this program are to 1) develop higher frequency reference frames for improved deep space navigation, 2) extend the VLBA calibrator catalog at K/Q-band, 3) provide the benefit of the ICRF catalog to new applications at these higher frequencies, and 4) study source structure variation at K/Q-band in order to improve the astrometric accuracy. During the calender year 2003, two VLBA high frequency experiments (BR079C and BL115A) were calibrated and imaged.

Gaussian component models fitted to selected images show that the sources are generally more compact as one goes from the ICRF frequency of 8.4 GHz to 24 GHz. This result, shown in Figure 1, suggests that reference frames defined at higher radio frequencies will be less susceptible to the effects of intrinsic structure than the ICRF.

The distribution of "Structure Index" calculated from the first epoch of K/Q-band images (Charlot 2002, private communication) is shown in Figure 2. Also shown are values for the 28 sources observed in RDV31 at X-band which overlap with these sources. Note the shift toward lower values as the frequency of observation increases.

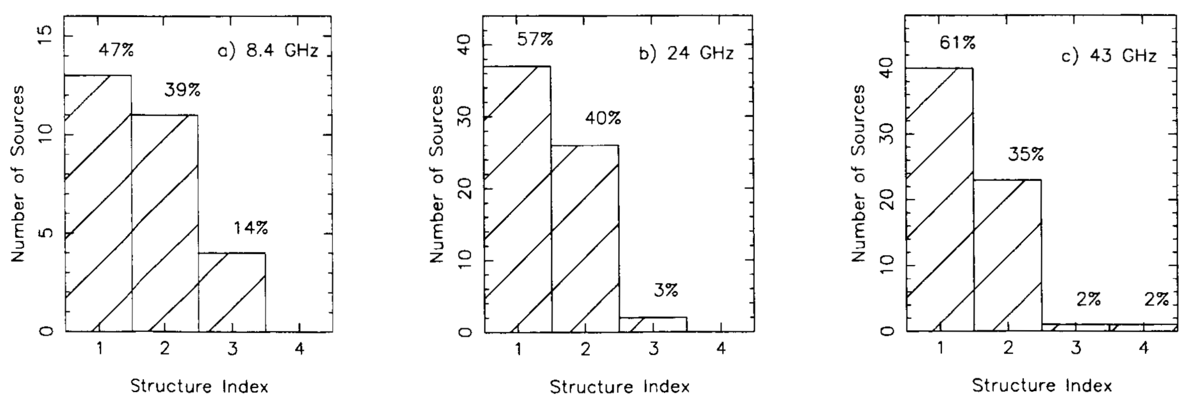

Figure 2. Distribution of "Structure Index" for sources at a) 8.4 GHz, b) 24 GHz, and c) 43 GHz. A total of 65 sources were observed at 24 and 43 GHz on 2002 May 15 (BR079A). Also shown are the values for the 28 overlap sources observed at 8.4 GHz on 2002 Jan 16 (RDV31).

The BL115A experiment was conducted as a 24 GHz survey in order to obtain a better idea of the number of ICRF sources detectable at this frequency. Of the 249 sources observed, there were sufficient data to image a total of 184 sources. As an estimate of the compactness of the sources a core fraction, defined as the ratio of core flux density to total flux density, was calculated. Core flux density is defined as the CLEAN-ed flux density in an image contained within one synthesized beam. The total flux density is defined as the total CLEAN-ed flux density (i.e., the sum of all CLEAN model components). The distribution of source core fraction versus source total flux density is shown in Figure 3. As can be seen in this figure, the weaker sources appear to be more compact (but this may just be a selection effect).

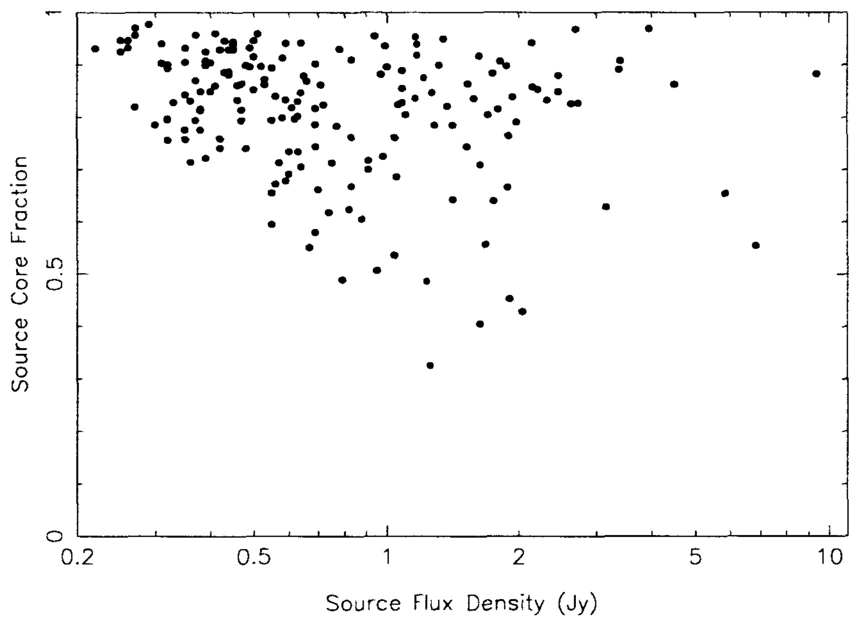

Figure 3. The distribution of source core fraction (ratio of core flux density to total flux density) versus source total flux density. Core flux density is defined as the CLEAN-ed flux density in an image contained within one synthesized beam. The total flux density is defined as the total CLEAN-ed flux density (i.e., the sum of all CLEAN model components).

2.2. Motions of Source Components

VLBA observations for maintenance of the celestial and terrestrial reference frames have been carried out since about 1994. Since 1997, these VLBA RDV observations have been part of a joint program between the USNO, Goddard Space Flight Center (GSFC) and the NRAO. Images produced from VLBA RDV observations are made available through the RRFID.

A joint program between Whitier College and the USNO to measure apparent jet velocities from the motions of source components using RRFID data at 8.4 GHz was initiated by Piner et al (2002, AAS, 200, 4501). To date, a total of 60 sources have been analyzed (Piner et al. 2003, AAS, 203, 9207). Results show that the distribution of apparent component speeds peaks at low values (near 1c, where c is the speed of light) but extends to values as high as 30c. The average apparent speed for all components is 4.8c.

2.3. ICRF Maintenance in the Southern Hemisphere

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a continuing VLBI research program in 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. Plans include strengthening the ICRF in the Southern Hemisphere by a) increasing the reference source density with additional S/X-band bandwidth-synthesis astrometric VLBI observations, and b) VLBI imaging at 8.4 GHz of ICRF sources south of $\delta = -20°$.

VLBI images for a total of 69 Southern Hemisphere ICRF sources were made at a frequency of 8.4 GHz using the Australian Long Baseline Array (Ojha, et al. 2004, in preparation). The images were used to calculate a core fraction, i.e., the ratio of core flux density to total flux density, for all observed sources. The resulting distribution, with a mean value of 0.83, suggests that most sources are relatively compact. However, just over half the observed sources show significant extended emission in the form of multiple compact components. These sources are probably poorly suited for high accuracy reference frame use unless intrinsic structure can be taken into account. Many of the observed sources have never been previously imaged at milliarcsecond resolution.

3. Staff

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

Name	Responsibilities
Alan L. Fey	Primary scientific contact, Web and data base design and content, Webmaster, Web server administration, VLBA data analysis (imaging), structure analysis
David A. Boboltz	VLBA data analysis (imaging), structure analysis
Ralph A. Gaume	Liaison to the ICRF Product Center of the IERS
Kerry A. Kingham	Web and data base design and content, Webmaster, Web server administration, geodetic data analysis (imaging), Mark 4 interface to imaging software, structure analysis

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 2004 are planned:

- Continue imaging and analysis of VLBA 2.3/8.4 GHz experiments
- Continue imaging and analysis of VLBA 24/43 GHz experiments
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners

TECHNOLOGY DEVELOPMENT CENTERS

Canadian VLBI Technology Development Center

Anthony Searle, Calvin Klatt, Mario Bérubé

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.

1. Introduction

The Canadian VLBI Technology Development Center is a collaborative effort of the Space Geodynamics Laboratory (SGL), 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 2003 as the operational "E3" IVS observing network. The "E3" Network consists of Algonquin, Yellowknife, the Canadian Transportable VLBI Antenna (CTVA), Kokee observatory, and the Transportable Integrated Geodetic Observatory (TIGO) located in Concepcion Chile. Yellowknife and Kokee were not scheduled to observe in all twelve sessions, but split the year to ensure a four–station network for all sessions. The small network size limited the contribution to EOP determination.

3. S2 VLBI Data Acquisition System (S2-DAS)

The S2 VLBI data acquisition system is being jointly developed by SGL and GSD. 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 objective of the development of the S2-DAS is to enable high sensitivity group delay measurements without appealing to a more costly parallel IF/baseband sub-system.

A sixth network DAS has been prepared for use at the Svetloe antenna, and is expected to be in place in the spring of 2004.

The DAS Operating System (DASOS) has seen extensive development in the past few years. Further software development continues to improve robustness and efficiency. New algorithms for automatic gain control and status monitoring are currently being tested and will be included in the next official release. Due to reduced personnel at SGL, hardware support for the S2–DAS was moved to the laboratories at GSD.

4. S2 VLBI Correlator

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.

Recent activity has focussed on the development of visualization and statistical analysis software to enhance system performance monitoring.

Maintenance of the playback terminals was completed in early 2003. A large backlog of VSOP observations was given priority as the HALCA mission came to an end. Correlator staff was cut to one person as a result of the end of HALCA operations. It is expected that the S2 correlator will apply to become an IVS Correlator in 2004.

5. Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6m radio telescope acquired to facilitate densification of the terrestrial reference frame in remote regions. The antenna will be collocated with GPS elements of the Canadian Active Control System (CACS) to provide fiducial station positions. The GSD is responsible for CTVA system development.

Figure 1. CTVA positioned in St. John's, Newfoundland.

The CTVA spent all of 2003 in St. John's, Newfoundland. During the spring of 2003, the Kvarz CH1-75 maser received a new crystal oscillator, as a short term replacement the CTVA was able to produce results using a passive maser. CTVA uses a group of local university and college students for all observing operations.

As an operational antenna in an IVS network, the CTVA will apply to become an IVS Network Station in 2004.

6. S2 Geodetic Experiment Scheduling, Operations and Analysis

Due to the small size of the E3 network contributions to EOP determination were limited. Results of the few 5–station E3 sessions were presented at the April 2003, IVS Analysis workshop in Paris. With the larger network, E3 results were shown to be comparable to the R4 network. This work included simulations that indicated a 5–station S2 network that included Svetloe could produce EOP uncertainties that are at the level of the IVS R4 network. These results have lead to the inclusion of Svetloe in the E3 Network in 2004.

The analysis component of the Canadian Technology Development Center will apply to become an IVS Analysis Center in 2004.

Technology Development Center at CRL

Tetsuro Kondo

Abstract

Communications Research Laboratory (CRL) has led the development of VLBI technique in Japan and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at CRL and summarizes recent activities.

1. TDC at CRL

Communications Research Laboratory (CRL) has published the newsletter "IVS CRL-TDC News" twice a year in order to inform the world about the development of VLBI related technology in Japan as an IVS Technology Development Center. The newsletter has been published twice a year. One of them is published as proceedings of the symposium held at the Kashima Space Research Center every autumn. The newsletter is available through the Internet at following URL **http://www.crl.go.jp/ka/radioastro/tdc/index.html**.

2. Staff Members of CRL TDC

Table 1 lists the staff members at CRL who are involved in the VLBI technology development center at CRL.

Table 1. Staff Members of CRL TDC as of December, 2003 (alphabetical).

Name (Last, First)	Works
Ichikawa, Ryuichi	Delta VLBI
Kawai, Eiji	Antenna system
Kimura, Moritaka	Giga-bit e-VLBI
Kondo, Tetsuro	e-VLBI
Koyama, Yasuhiro	e-VLBI, analysis softwares
Kuboki, Hiromitsu	Antenna system
Nakajima, Junichi	Giga-bit e-VLBI
Osaki, Hiro	FS9, e-VLBI
Sekido, Mamoru	Delta VLBI
Takeuchi, Hiroshi	Antenna system, and e-VLBI

3. Recent Activities

3.1. Geodetic VLBI using K5/VSSP system[1]

The first 24-hour geodetic observation using the K5/VSSP (IP-VLBI) system was carried out on the Kashima-Koganei baseline on January 31, 2003. Observations were also carried out by using the K4 system and the gigabit VLBI system in parallel with the K5 system for system verification

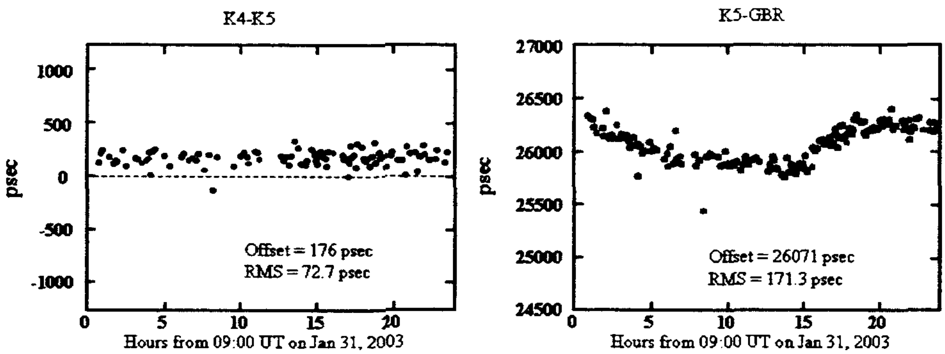

Figure 1. Differences of group delays obtained from K4, K5, and gigabit VLBI systems.

by comparing each result. Fig. 1 shows results of differences of group delays observed by each system. An offset seen in the comparison result between K4 and K5/VSSP denotes the difference of the instrumental delay of each system. The standard deviation of data variation is consistent with that predicted from signal to noise ratio. It is therefore concluded that the K5/VSSP has no fatal defect. Long term variations of the scale of several hours or more seen in the results between K5 and gigabit system (GBR) are considered as the characteristics of the gigabit system against the change of ambient temperature. The K4 and the K5/VSSP systems are multi-channel (i.e., band splitting) systems while the gigabit system is a single channel (i.e., full band) system. In the case of multi-channel system, phase calibration signals injected in each channel cancels out delay variations commonly appearing in the both systems such as the effect of temperature variations. Long term variations are usually treated as a clock behavior in a baseline analysis, so that it does not affect positioning accuracy seriously.

3.2. US-Japan e-VLBI for a Rapid UT1 Measurement[2]

We attained the shortest record of time to obtain UT1 in collaboration with MIT Haystack Observatory team. We succeeded in UT1 measurement in less than 24 hours from the observation start by means of e-VLBI conducted on the Kashima (K5)-Westford (Mark 5) baseline on June 25, 2003. Times required for observations, data transfer, format conversion, correlation processing, and UT1 analysis (including bandwidth synthesis) were 2 hours, 4 hours, 4 hours, 12 hours, and 1 hour, respectively.

3.3. Delta e-VLBI for Spacecraft Positioning[3][4][5][6]

We carried out a series of delta VLBI observations of "NOZOMI", a Japanese spacecraft exploring Mars, under cooperation with the VLBI community in Japan using the K5/VSSP system during the period just before the last earth swing-by (June 19, 2003) to cruise to Mars. Measurements of group delay were carried out and it was confirmed by a closure test that an accuracy of nanosecond order was achieved. Although the baseline lengths are not long (a few hundreds kilometers) the accuracy of spacecraft positioning of 300 mas was attained in spite of the use of low intensity and narrow-band (< 1MHz) signals. To improve this accuracy ten times or more, we are developing a technique to observe phase delay and to connect it between observation scans.

Technology development of e-VLBI for spacecraft positioning is continued using the "HAYABUSA (falcon)" that is a Japanese spacecraft launched in May, 2003 and aims at the sample return from an asteroid.

3.4. K5/PC-VSI Gigabit VLBI System[7]

Using a VSI interface board (PC-VSI 2000DIM) developed in the last fiscal year, we succeeded in direct acquisition of 1 Gbps data with the Linux file system. Data acquisition of 2 Gbps rate is possible with this interface board. As the K5/PC-VSI system adopts a general-purpose PC and file system, it shows a remarkable affinity for the Internet compared with the Mark 5 system. A series of e-VLBI experiment (ftp data transfer after an observation) with the Metsähovi Radio Observatory (MRO), Finland was conducted as in the last fiscal year. Observations with 2 Gbps were carried out in June, 2003 and fringes were successfully detected by using a software correlator (Fig. 2).

Development of a 16-ch sampler (ADS2000) (Fig. 3) that substitutes for DFC2000 goes well and is almost finished.

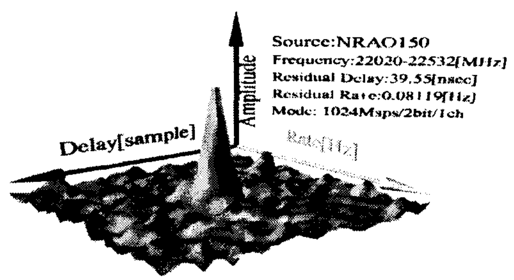

Figure 2. 2 Gbps fringes observed on Kashima - Metsähovi baselline using K5/PC-VSI system.

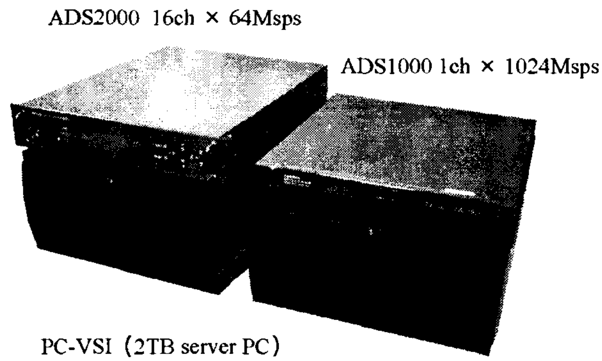

Figure 3. K5/PC-VLBI system: PCs with PC-VSI board (2TB server), a giga-bit A/D sampler (ADS1000), and a 16ch × 64Msps sampler (ADS2000).

3.5. Practical Use of Software Correlator[8][9]

Two types of software correlator have been developed at CRL. One is a software correlator dedicated to geodetic VLBI data processing. Real-time processing of 10 Mbps data is possible now by a PC. It was already used practically for the processing of "Nozomi" VLBI observation data and of 24-hour geodetic VLBI session data.

The other type of software correlator is dedicated to the processing of gigabit VLBI data. Real-time processing of 100 Msps (mega-samples per sec) is possible now. Network distributed processing system aiming at the real-time processing of 1 Gsps data is under development.

Figure 4. Logomark of NICT.

4. Coming Reorganization from CRL to NICT

Under the "Reorganization and Rationalization Plan of Special Public Institutions" adopted at a Japanese Cabinet meeting held in December 2001, CRL and the Telecommunications Advancement Organization of JAPAN (TAO) will be reorganized as the National Institute of Information and Communications Technology (NICT) on April 1, 2004. Fig. 4 shows the new logomark of NICT.

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FFI Technology Development Center - Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center will focus 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 improvments 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 2003 are described in the following.

A new major software component of GEOSAT has been developed for 3D raytracing through the atmosphere. A complete 3D atmospheric model provided daily by ECMWF is input to the software. Based on the available tracking (VLBI, GPS, or SLR) for that specific date a set of tables for each active station is automatically generated with information about the time delay in the different elevation and azimuth directions. Also statistical information concerning the variability of relevant parameters are extracted from the ECMWF data. This information is used in the estimation filter as time-dependent parameter constraints. No mapping functions are used anymore. Different interpolation schemes are under testing. A new model/parameterization for the atmospheric delay is under consideration in GEOSAT. The status is that some individual VLBI-only sessions have been analyzed. A clear reduction in a posteriori residuals is observed. The Grueger model is default for the MW refractive index and the Ciddor model is default for the optical or near optical wavelengths. The Ciddor model has been tested against Ciddor's own software.

The pressure loading tables provided by Leonid Petrov is used by GEOSAT. For stations not included in this table a simple pressure scaling model is used where the load scale parameter is automatically estimated in the analysis. A grid of reference pressure values has been derived by averaging the surface pressure levels provided by NCEP during the last 20 years.

A model for thermal deformation of the VLBI antenna construction has been included. Thermal coefficients and thermal time delays can be estimated.

The station eccentricity file has been checked in great detail and updated with all the most current log files of VLBI, GPS, and SLR. The eccentricity information is treated as a new observation type in GEOSAT in addition to the VLBI, GPS, and SLR observation types.

The GEOSAT software calculates one set of station coordinates and velocities for a reference marker at a colocated station in addition to the eccentricity vector to each different antenna reference point. The software has been extended so that observations from several active VLBI systems, GPS receivers and SLR systems all will contribute to the estimation of the parameters for the station reference marker. The instruments could be operating either simultaneously or in different time windows.

The IERS 2003 Conventions has been fully implemented including the new EOP parameterization.

The absolute GPS satellite antenna phase center table published by Rothacher recently has been implemented as an a priori model. The parameters will be estimated during the analysis.

All relevant partial derivatives has been verified against numerical partial derivatives.

In the global processing of several years of data the stable sources listed by Feissel et al. are automatically estimated as constants while the others are estimated as random walk parameters or session parameters. A set of defining stations satifying certain criteria is automatically estimated as constants where the other stations are estimated as constants during a certain interval (between one day and one month).

2. Future Plans

We plan to implement an orbital overlap scheme for automatic evaluation of the orbit quality (GPS, LAGEOS). Observations from the GALILEO navigation system wil be applied when available. Only minor changes in GEOSAT are required for this extension.

3. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

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GSFC Technology Development Center Report

Ed Himwich, John Gipson, Raymond Gonzalez, Nancy Vandenberg

Abstract

This report summarizes the activities of the GSFC Technology Development Center for 2003. The report forecasts activities planned for the year 2004. The GSFC Technology Development Center (TDC) develops station software including the Field System (FS), 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. There are other technology development areas at GSFC covered by other IVS components such as the GSFC Analysis Center.

The current staff of the GSFC TDC consists of Nancy Vandenberg, Ed Himwich, Chuck Kodak, Raymond Gonzalez, John Gipson, and Willam Wildes.

The remainder of this report covers the status of the main areas of development that are currently being pursued.

2. Field System

During this period some new features were released in FS version 9.6:

1. support for Mark 5A recorders
2. support for the ATNF LBA DAS (provided by J. Quick, HartRAO)
3. support for MET3 meteorological sensors with stand-alone logging independent of the FS available
4. improved TAC support with stand-alone logging independent of the FS available
5. numerous improvements in the new system temperature scheme including improved robustness
6. numerous small bug fixes and improvements were added

The new FS Linux Distributon 5 was released. This was developed with the assistance of J. Quick (HartRAO). This new distribution is based on the Debian "woody" distribution and includes up to date versions of various packages and, most importantly, current security patches.

A new PC configuration for FS operations was defined. The most significant change in the configuration is that now three IDE hard disks are used instead of two SCSI disks. The change to IDE was possible because performance of the kernel IDE driver has improved significantly. Because of the cost savings in the change to using IDE drives, it is now feasible to have three disks. This allows a more robust "rotating" back-up scheme to be used.

In the next year, several other improvements are expected, among these are: (1) integrated support for Mark 5A recorders including support for schedules written for Mark 5A systems, (2) integration of S2 DAS support (to be provided by M. Bérubé, NRCanada), (3) fsvue will become the primary user interface for the FS (this will allow simultaneous use of remote and local FS consoles), (4) support for station specific detectors in the new ONOFF program, and (5) an ANTTAB file generation script will be included.

3. SKED and DRUDG

The GSFC Technology Development Center is responsible for development, maintenance, and documentation of the SKED and DRUDG programs. These two programs operate as a pair for preparation of the detailed observing schedule for a VLBI session and its proper execution in the field. In the normal data flow for geodetic scheduling, first SKED is run at Operation Centers to make the .skd file that contains the full network observing schedule. Then the stations use the .skd file as input to DRUDG for making the control files and procedures for their station. During 2003 many changes were made to both SKED and DRUDG.

SKED had the following features added to it:

1. SRCFLR. This allows a user to specify a target number of observations for the first N sources in the source list. For example, you could specify that you wanted the first 10 sources to each have at least 1.5% of the total number of observations. This option is useful if you have some sources in a session that you want to observe. For example, the RDV experiments have a set of core sources, and a set of sources that are scheduled periodically. It is important that when the later sources are scheduled that they be observed.
2. SRCDIST. This option imposes soft constraints on the number of observations per source. There are four modes: NONE, UPTIME, EVEN, SQRT.
   (a) NONE imposes no constraint.
   (b) UPTIME tries to have the number of observation per source be proportional to the total uptime of the source. This will emphasize sources that are visible by most of the network.
   (c) EVEN tries to make the number of observations per source be the same for all sources.
   (d) SQRT tries to make the number of observations per source be proportional to the square root of the uptime. This smooths out the distribution of observations.
3. FILL IN MODE. In a given scan typically some of the antennas will stop observing before others. If FILL IN MODE is turned on, SKED monitors the idle time to see if it can squeeze in additional observations during this idle time.
4. BEST N. Sked was modified to choose the BEST-N sources based on observing strength and station geometry for a given experiment. This obviates the need for a scheduler to choose these sources by hand.

Another option that was partially implemented during the latter part of 2003 was the implementation of an automatic source-monitoring program. There are several goals to this program:

1. Observe all sources frequently enough to monitor their flux density.

2. Increase the number of sources used in scheduling geodetic experiments.
3. Make the selection of the sources automatic.

We developed a database containing a list of all the sources observed by the various member institutions of IVS since the inception of geodetic VLBI in 1979. For each experiment and each source this database contains information on the number of observations scheduled, the number of observations correlated, and the number of good observations. This database can be queried by SKED to select sources that have not been observed recently.

Several changes were made to DRUDG to support the increasing use of Mark 5 recorders. These included the addition of two new modes:

1. Mark 5A piggy back mode allows stations to record simultaneously on tapes and Mark 5A recorders. The tape recorder is attached to the first output of the formatter, and the Mark 5A modules are attached to the second output.
2. Mark 5A mode allows stations to record using the Mark 5A modules as the primary recorder. The Mark 5A modules are attached to both outputs of the formatter.
3. Mark 5A pig-wire mode allows stations to record using the Mark 5A recorders as the primary recorder when these are attached to the second output of the formatter (same as for piggyback mode).

In all of the above modes the schedules are first generated by SKED as if the experiments were going to be recorded on tape. Then the recorder type is changed in DRUDG. This is necessary because SKED is not yet Mark 5 aware. Another reason for doing it this way is that number of Mark 5A units increased over the course of the year. Scheduling the experiments to use tape seemed to be prudent. You could always change the schedule to use disk at the stations. The converse operation is more problematic, because SKED allocates time for tape change. If the experiments were scheduled to use Mark 5A recorders this time would not be allocated.

One of the primary goals for next year include making SKED Mark 5 aware.

Haystack Observatory Technology Development Center

Alan Whitney, David Lapsley

Abstract

VLBI technology development at Haystack Observatory continues to focus on VLBI data recording and transport. With the completion of the Mark 5A disk-based data-recording system and its subsequent widespread deployment (~80 units now in operation), engineering efforts are now focused on developing the Mark 5B, which uses the same platform and media as Mark 5A, but which will comply with the VSI specification. Additionally, a major program continues to focus on e-VLBI development, including the development of VSI-E, new protocols and algorithms, performance testing and monitoring, and the beginnings of routine e-VLBI transfers.

1. Mark 5B VLBI Data System

The Mark 5B VLBI data system is now being developed at MIT Haystack Observatory. It is based on the same physical platform, uses the same disk-modules as the Mark 5A, and supports the same maximum data rate of 1024 Mbps. However, the Mark 5B will incorporate a VSI standard interface and command set. The Mark 5B system may be used with a Mark 4 or VLBA data-acquisition rack with the use of simple interface electronics connecting directly to the Mark 4 or VLBA samplers, eliminating the need for an external formatter. For existing VLBA systems using VLBA formatters, the current recording limit is 512 Mbps due to formatter limitations; the use of a Mark 5B connected to the sampler outputs will allow the recording of 1024 Mbps. For existing Mark 4 systems, the Mark 5B will allow connection of all 14 BBCs to two Mark 5Bs for a total aggregate data rate of 1792 Mbps. A backwards compatibility path will be provided to allow disks recorded on the Mark 5B system to be replayed on a Mark 5A system with the output in VLBA tape-track format. This will allow existing Mark 4 correlators to process Mark 5B data. An upgrade to existing Mark 5A systems will be made to implement this compatibility path.

In addition, the Mark 5B is being designed to emulate all critical functionality of the Mark 4 Station Unit, so that the Mark 5B may be directly connected to a Mark 4 correlator through a simple interface without the use of a Mark 4 Station Unit. This will allow existing Mark 4 correlators to inexpensively expand the number of stations they support. Prototype Mark 5B systems are expected to be available in late 2004.

2. e-VLBI Development

Haystack Observatory continues to develop the e-VLBI technique with a broad spectrum of efforts, including:

- VSI-E draft: After many months of fine tuning, the first VSI-E draft specification was distributed for discussion within the community. After a general consensus at the VLBI workshop in Dwingeloo that the RTP based framework would provide many advantages to the VLBI community, networking and astronomy researchers have been working to come up with a strawman solution that will be acceptable to both communities: meeting the requirements of the application while doing so in a manner that is efficient and network "friendly". The framework provides signaling, control, framing and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility in that it allows users to choose the transport protocol that most suits their networking environment (e.g. UDP, TCP or other variants).

- New connections to Wettzell and Kokee: Wettzell has recently installed a new E3 (34 Mbps) link to the University of Regensberg, which connects to the German Federal Network (DFN) and then the pan-European GEANT research network. Researchers at Wettzell, Hawaii and Haystack have been actively involved in testing this link and are looking forward to being able to utilize it to support Intensive experiments using e-VLBI. In Hawaii, a new OC3 link has been installed on Kauai between PMRF and Kokee Park. This has increased the bottleneck bandwidth from $\sim$ 5 Mbps to $\sim$ 80 Mbps. A series of experiments are planned that will use this bandwidth for the support of Intensive experiments.
- Regular data transfer from Kashima: Starting in October 2003, data from all of the sessions at the Kashima 34 m antenna have been recorded in K5 format and transferred to Westford via e-VLBI. The data were converted to Mark 5 format and then stored on Mark 5 disk pack before being sent for correlation on Mark 4 correlators. Thanks to the efforts of many people at CRL, USNO and Haystack the data were transferred successfully and fringes were detected for two of the experiments transferred so far. Sessions CRF22, CRF23 and T2023 were all transferred using e-VLBI. The data were transferred from Kashima to Westford using BBFTP and special software to automate the transfer to a performance server at Haystack and then to a Mark 5 8-pack. The main purpose of this transfer was to verify the feasibility and automation software. The data rates for the sessions were relatively low, as the path they were traversing was bandwidth limited. It is expected that in the near future the path bandwidth will be significantly increased as part of a network upgrade. Session CRF22 involved the transfer of 442 GB of data at 11.02 Mbps using 4 parallel TCP streams. Session CRF23 involved the transfer of 489 GB of data at 11.8 Mbps using 4 parallel TCP streams. Session T2023 involved the transfer of 543 GB of data at 33.6 Mbps using 8 parallel TCP streams.
- Automated data transfers: 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. This effort has resulted in tools that allow users to efficiently transfer large volumes of data between Mark 5 units and PCs across LANs as well as MANs.
- DRAGON: Researchers at Haystack have recently started a new project, the Dynamic Resource Allocation through GMPLS over Optical Networks (DRAGON) in collaboration with the University of Maryland Mid-Atlantic Crossroads (MAX), Univ. of S. California Information Sciences Institute, George Mason Univ., NASA/GSFC and USNO, and industry partner Movaz Networks. This project features e-VLBI as one of its premier applications and will provide advanced optical switching infrastructure for supporting e-VLBI experiments.
- Performance and testing: Haystack has been working in close collaboration with Internet2 on the development of an automated performance tool, BGPerf. Ali Lotia and Charles Yun from Internet2 have developed a tool that automates the secure initiation and tear-down of "iperf" flows ("iperf" is a widely used network bandwidth measurement and estimation tool). Network performance tests with BGPerf are ongoing. BGPerf automates logging and timestamping of results, secure initiation of connections between clients and servers and

resource usage limitation. It will soon include support for a database back end, multiple performance tools and parsing of output files to extract higher order performance results. Haystack has also developed a performance site for monitoring qualitative performance using existing tools such as MRTG, Smokeping, etc.

- Measurement and protocol testing: Network performance characterization and protocol testing between various e-VLBI sites around the world continues. Tests within the United States, Japan, South America and Europe are ongoing. Recent results have demonstrated 360 Mbps disk-to-disk throughput using advanced transfer protocols and servers located in Tokyo, Japan and at Haystack.

- EGAE: Researchers at Haystack continue to work on the Experiment Guided Adaptive Endpoint (EGAE). This protocol will provide the interface between a VSI data acquisition system and the network. It will implement the RTP-based VSI-E protocol. Current experiments include looking at the suitability of various transport protocols (e.g. TCP, High speed TCP, SABUL, TSUNAMI, etc.) for use within this framework and how best to integrate these protocols into the EGAE.

Figure 1. e-VLBI display at Internet2 meeting in Indianapolis, October 2002.

- Internet2 e-VLBI demonstration: An e-VLBI demonstration was given at the Internet2 Fall members meeting in October 2003 in Indianapolis. The demonstration was highly successful in raising awareness of VLBI and e-VLBI. In the demonstration area, a large display was constructed which described VLBI, e-VLBI, participants in VLBI and the application of VLBI to astronomical and geodetic applications. Two Mark 5 units were located in the demonstration area, both connected via optical fiber into a dedicated 1 Gbps stream that was connected into Abilene via a shared 10 Gbps trunk. Three laptop computers were used to display animations obtained from VLBI observations, video footage of the Westford telescope taken during a geodetic observing session and a real-time display of the application transport statistics. A demonstration was given of the transfer of VLBI data between the US and another International site using prototype RTP software. A demonstration was also given of the transfer of VLBI data between two Mark 5 systems located in the US. A maximum throughput of 207 Mbps was achieved. Demonstrators were also able to test memory to memory transfers between various sites and achieve a maximum TCP throughput of 460 Mbps using FAST TCP, 180 Mbps using TCP Reno and 400 Mbps using High Speed TCP. Sincere thanks go to the following institutions for their help and participation in this demonstration:

- Arecibo Observatory, National Astronomy and Ionosphere Center of Cornell University, Puerto Rico
- Australia Telescope National Facility, Commonwealth Scientific and Industrial Research Organisation, Sydney, Australia
- Communications Research Laboratory, Kashima, Japan
- Goddard Geophysical and Astronomical Observatory, Goddard Space Flight Center, NASA, Greenbelt, MD
- Joint Institute for VLBI in Europe, The Netherlands
- MIT Haystack Observatory, Westford, MA
- Smithsonian Astrophysical Observatory (Submillimeter Array), Mauna Kea, HI

Institute of Applied Astronomy Technology Development Center

Alexander Ipatov, Nikolay Koltsov, Andrey Mikhailov, Sergey Smolentsev

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.

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 telescope in Svetloe is participating in international VLBI network observations and in domestic radioastronomical and VLBI observations. Radio telescope in Zelenchukskaya is participating in domestic radioastronomical and VLBI observations. At the Badary radio telescope the construction work is finished, the installation of the hardware and putting the telescope into operation will be done.

2. Technical/Scientific

2.1. Timekeeping and Frequency

The creation of the new phase calibrator "antenna unit" was finished in 2003. This devise has two pulses out for S and X bands receivers. Step-recovery diode is used for producing short pulses.

Pulse performance: Duration $\approx$ 50 ps, Amplitude = 1.2 V.

Demultiplexer is similar to the original version documented in Mark III manual, but special HYBRID was used here.

Electronic module of the phase calibrator is installed into 54°C thermostat. The complex testing of the phase calibrator will be fulfilled in 2004.

2.2. VLBI Data Acquisition System

In 2003 the IAA Technology Development Center finished construction of the data acquisition system (DAS) for the S2-RT recording terminal.

This DAS includes main module and up to 3 added modules. Each of modules contains distributor for 2 input IF signals (100–1000 MHz), 2 base band converters (BBCs), control unit and power-supply unit. So DAS may include from 2 up to 8 BBC's, each of them contains video channels for upper and lower side bands and output 2-bit samplers. The digital signals levels meter controls levels of input IF signals and video signals. There are filters for selection of the harmonic phase calibration signals. DAS contains the 32 MHz clock and 1 PPS synchronizer for S2-RT. Computer with RS-232 interface controls DAS.

Parameters of this DAS are showed in table 1.

First module of new DAS produced in 2002 was tested in the Svetloe and Zelenchukskaya observatories. In 2003 DAS of 4 modules (8 BBCs) for the S2-RT recording terminal was produced

Table 1. Parameters of the new DAS

Intermediate frequency range	100–1000 MHz
Number of IF inputs	2
Number of modules	from 1 up to 4
Number of base band converters	from 2 up to 8
Connection of base band converters to IF inputs	electronic switch
Sidebands	upper and lower
Image rejection	more then 26 dB
Bandwidths	0.25; 2; 8 and 16 MHz
Number of digitizer bits	2
IF attenuator's range on distributor inputs	0–18 dB
IF attenuator's range on base band converter's input	0–15 dB
Attenuation step	1 dB
Error of signal level measure	0.1%
Phase noise of local oscillator	less then 1.2 degree rms
Clock Frequency for signal's record	32 MHz
Number of two-bits output streams	up to 16
Max Total Output Data Rate	1 Gbit/s
Module Dimension	300 × 445 × 465 mm

(Fig. 1). Now it is being tuned and tested by IAA TDC. We are planning to install new DAS at the Badary observatory in summer or in autumn 2004.

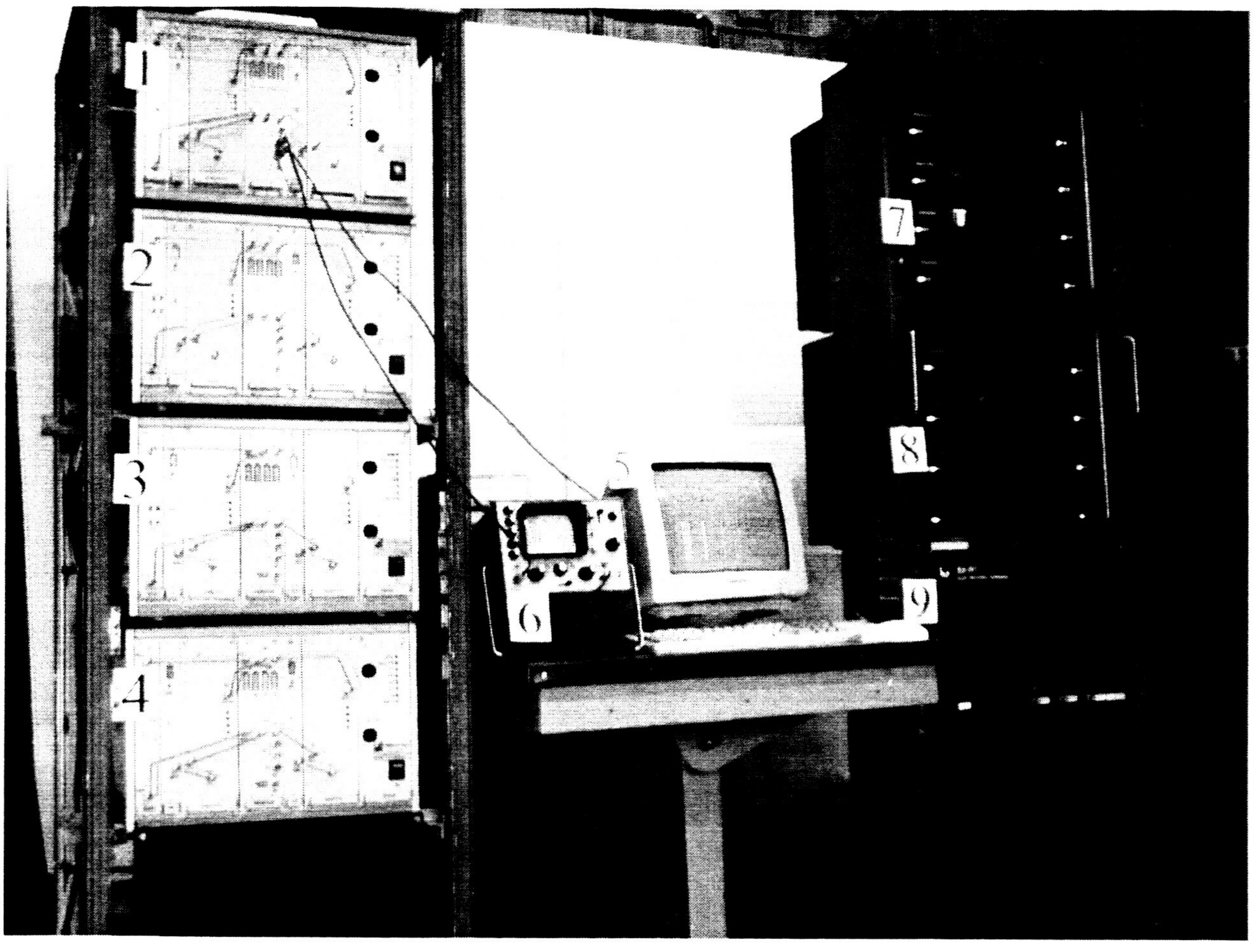
2.3. The Software

The investigations were made to improve the pointing accuracy of the antenna in Svetloe. The periodic nonlinearity errors of antenna position encoders were found previously during antenna calibration procedures. The amplitude of these errors is about 20–25 arcseconds, i.e. approximately 10% of half power beam width on X-band. It may affect the results of observations on X-band and certainly prevents the quality observations on the shorter antenna wavelength 1.35 cm. After testing of encoders we came to conclusion that this problem is the result of a deficiency in the encoder's design and elimination of nonlinearity is impossible.

The special method of measurement of such errors was developed to solve the problem. The method doesn't use any other equipment except the encoder itself and the antenna control system. The nonlinearity errors of encoders were measured in full range of antenna position angles. These results are used in antenna control software for correction of the errors.

The software was updated for this purpose. The testing of antenna pointing with the correction of nonlinearity errors indicates that the accuracy became significantly better and is within few arcseconds.

The important result of the pointing accuracy improvement is better antenna performance on the 1.35 cm band. First session of automatic pointing measurement was successfully carried out in this band using Field System software.



1, 2, 3, 4 — DAS modules; **5** — control PC; **6** — oscilloscope for phase calibration signal monitorng; **7, 8, 9** — S2-RT modules.

Figure 1. 8-channel DAS with S2-RT recording terminal

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 2. Technical Staff

Prof. Alexander Stotsky	Main Scientific Researcher	Radio Physics Radio holography	+7-812-235-3216	stotskii@ipa.rssi.ru
Prof. Nikolay Koltsov	Chief the Laboratory Signals Conversion Registration	VLBI and radiometric registration system	+7-812-235-3316	nec@ipa.rssi.ru
Dr. Sergey Smolentsev	Vice Director	Time keeping Frequency standard	+7-812-275-4415	smolen@ipa.rssi.ru
Dr. Alexander Salnikov	Chief the Laboratory Communication and Computer Systems	Network Communication Computers	+7-812-230-8361	ais@ipa.rssi.ru
Dr. Edward Korkin	Main Scientific Researcher	Dish metal constructions	+7-812-230-7415	korkin@ipa.rssi.ru
Dr. Irina Ipatova	Senior Scientific Researcher	Receivers Antenna performance	+7-812-230-6496	ipatova@ipa.rssi.ru
Dr. Vyacheslav Mardyshkin	Chief the Receivers Laboratory	Receivers Refrigerators Antenna performance	+7-812-230-6496	vvm@iaa.nw.ru
Mr. Andrey Mikhailov	Scientific Researcher	FS software Radio telescope control system	+7-812-230-6496	agm@ipa.nw.ru
Dr. Dmitry Ivanov	Chief the Laboratory Time and Frequency	Time keeping Frequency standart	+7-812-230-7416	labtf@ipa.rssi.ru
Dr. Leonid Fedotov	Senior Scientific Researcher	BBC channels	+7-812-235-3316	fedotov@ipa.rssi.ru

4. Outlook

In the new IVS year we are planning:

- to include the VLBI site Svetloe into routine geodetic VLBI observations using Mark 5 facilities,
- to include the VLBI site Zelenchukskaya into routine geodetic VLBI observations using VLBA4 — Mark 5 facilities.

The IVS Technology Development Center at the Onsala Space Observatory

Gunnar Elgered

Abstract

The main activity during the year 2003 has been to assess the stability of the Water Vapor Radiometers (WVRs) usually operating at the Onsala Space Observatory. The method of calculating the Allan variance has been applied to data acquired before and after an upgrade of the Astrid WVR. We find the exercise meaningful and plan for repeated measurements optimized for monitoring of the WVR performance in terms of noise characteristics.

1. Introduction

In our Technology Development Center Report for the year 2002 we presented a summary describing a new control and data acquisition system for the Astrid WVR [1]. We started to operate the upgraded instrument in early 2003. After a few weeks of tuning of critical timing parameters and correcting software the instrument was acquiring data continuously with a reasonable degree of reliability from March 2003.

Ideally the instrument characterization shall be carried out with the antenna beam pointing at a stable object in terms of emission comparable to typical sky brightness temperatures. Since such data are not available and especially not from the past, we decided to investigate if WVR observations made during stable atmospheric conditions could be used.

This work has been carried out by Alejandro Alvarado and Parisa Pakniat within the frame of a Master Thesis project [2]. They have studied many WVR data sets obtained during different atmospheric conditions using different data acquisition schedules. I will here just highlight some interesting results.

2. Preliminary Results

The normal data acquisition sequence used by the WVRs at Onsala is to scan the whole sky through continuous azimuth and elevation scans. This type of data are not ideal to use in order to assess instrument stability over short time scales, simply because the atmospheric variability—comparing observations in different directions—is too large. Since it is the instrument stability that we want to study it is important to minimize the influence of the atmospheric signal. Therefore, we decided to focus on data taken in the zenith direction during clear days.

An example from one of the most stable time series acquired in 2003, and the corresponding Allan variances, are shown in Figure 1 for the 21.0 GHz channel. The results for the 31.4 GHz channel are presented in Figure 2. The concept of Allan variance was developed for the characterization of frequency standards [3] but has also been used to evaluate radiometer stability [4].

In general the minimum Allan variance has been reduced when comparing the data acquired in 2003 compared to those from the year 2000. The optimum integration times have also been reduced. The sky brightness temperatures observed in the year 2000 data are however significantly higher, especially at 21.0 GHz. It is likely that also atmospheric variability is contributing to the

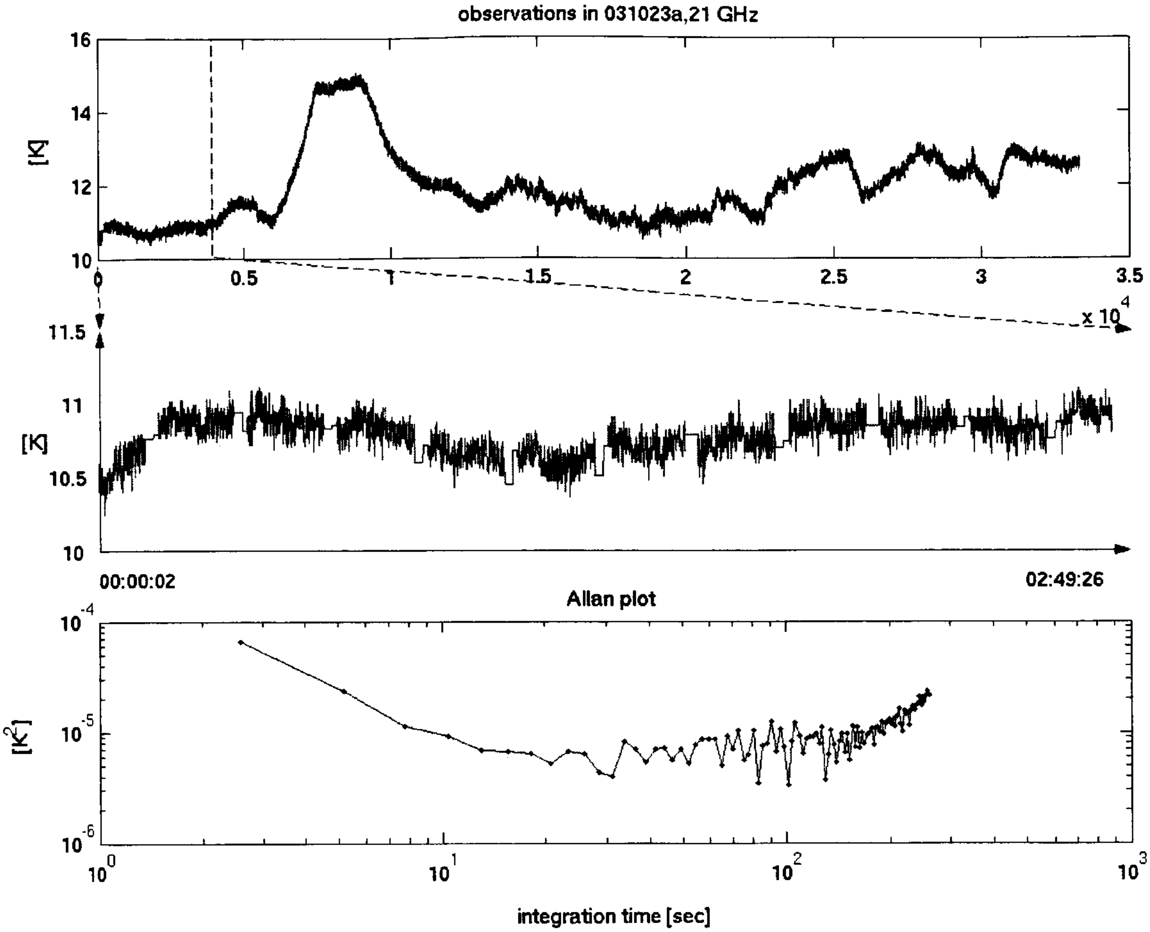


Figure 1. Time series of zenith measurements of the sky brightness temperature at 21.0 GHz (top plot). The Allan variance curve (bottom plot) is calculated from the first few hours (middle plot) showing a rather stable sky brightness temperature (from [2]).

Allan variance for the short time scales and the comparison between the two years is of course also then affected by the different atmospheres. In any case, the results obtained indicate that the new data acquisition system of the Astrid WVR is working well. In addition to the stable time series presented here we have also note that a certain type of spurious data (outliers), seen in the 31.4 GHz time series from year 2000, do not appear in the 2003 data.

3. Future

We are investigating if some special type of measurements, perhaps only of the internal reference loads, should be scheduled regularly in the future for the monitoring of the quality of the instrument. In fact it may even be worthwhile to make a similar type of analysis of our X/S-band receiver output during selected time periods between our geodetic VLBI experiments.

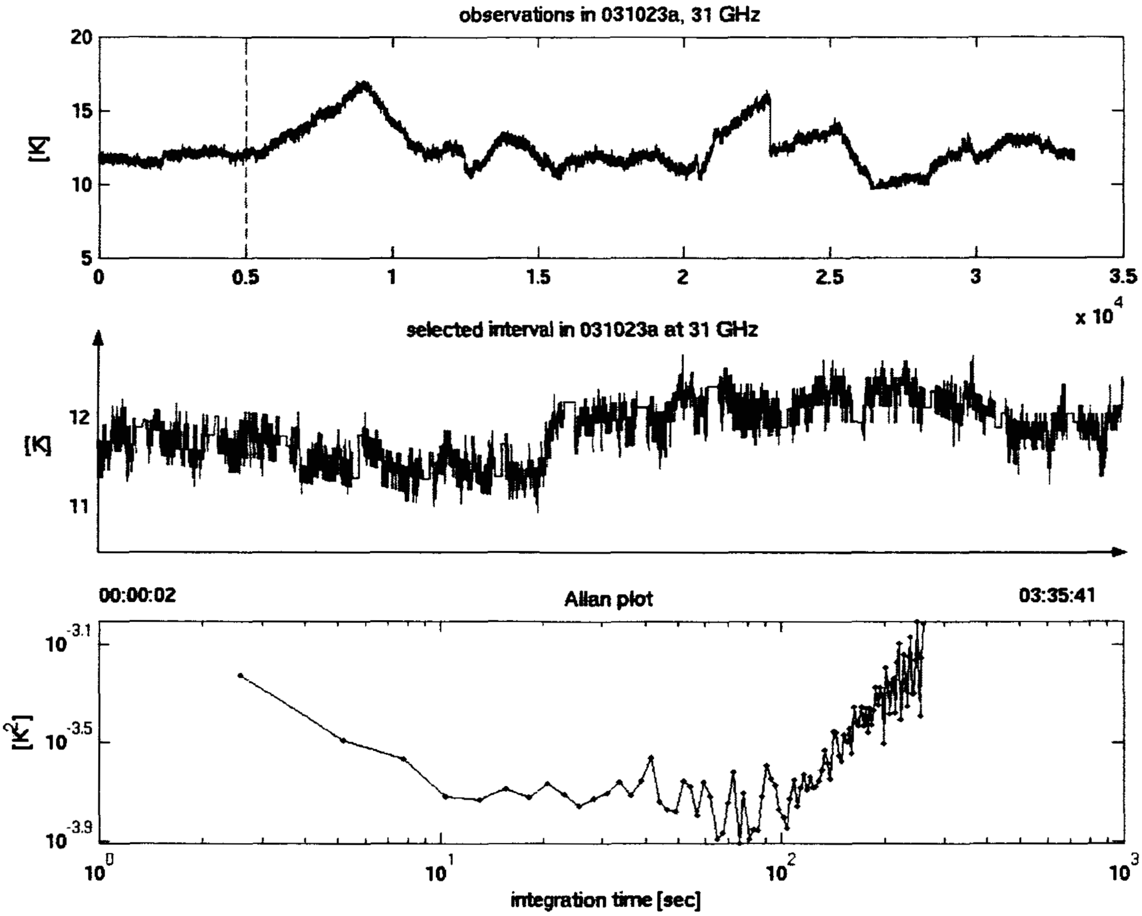


Figure 2. Time series of zenith measurements of the sky brightness temperature at 31.4 GHz (top plot). The Allan variance curve (bottom plot) is calculated from the first few hours (middle plot) showing a rather stable sky brightness temperature (from [2]).

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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, 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
- 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: 15

The four appointed members are considered ex officio and are not subject to institutional restrictions.

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: 15 February, 2001

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
Universidad Católica de la Santísima Concepción	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
Geodetic Institute of the University of Bonn	Germany
Istituto di Radioastronomia CNR	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
Communications Research Laboratory	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
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

(listed alphabetically by country)

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

IVS Associate Members

Name	Institution	Country	E-mail
Aedo, Roberto	Universidad del Bío Bío/Project TIGO	Chile	roberto.aedo@tigo.cl
Amagai, Jun	Communications Research Laboratory	Japan	amagai@crl.go.jp
Andersen, Per Helge	Norwegian Defence Research Establishment	Norway	per-helge.andersen@ffi.no
Arias, Felicitas	Bureau International des Poids et Mesures	France	farias@si.bipm.fr
Baudry, Alain	Observatoire de Bordeaux	France	baudry@observ.u-bordeaux.fr
Bauernfiend, Erhard	Fundamentalstation Wettzell	Germany	erhard.bauernfeind@bkg.bund.de
Baver, Karen	Raytheon/GSFC	USA	kdb@leo.gsfc.nasa.gov
Beck, Norman	Natural Resources Canada	Canada	beck@nrcan.gc.ca
Bergman, Per	Onsala Space Observatory	Sweden	bergman@oso.chalmers.se
Bérubé, Mario	Natural Resources Canada	Canada	mario@geod.nrcan.gc.ca
Bianco, Giuseppe	Agenzia Spaziale Italiana	Italy	bianco@asi.it
Bielmeier, Ewald	Fundamentalstation Wettzell	Germany	ewald.bielmeier@bkg.bund.de
Boboltz, David	U. S. Naval Observatory	USA	dboboltz@usno.navy.mil
Böhm, Johannes	Intitute of Geodesy and Geophysics	Austria	johannes.boehm@tuwien.ac.at
Bolotin, Sergei	Main Astronomical Observatory	Ukraine	bolotin@mao.kiev.ua
Booth, Roy	Onsala Space Observatory	Sweden	roy@oso.chalmers.se
Bougeard, Mireille	Observatoire de Paris	France	mireille.bougeard@obspm.fr
Boyer, William	NASA Goddard Space Flight Center	USA	wboyer@gemini.gsfc.nasa.gov
Brazeau, Sylvain	Natural Resources Canada	Canada	brazeau@geod.nrcan.gc.ca
Buretta, Tom	MIT Haystack Observatory	USA	tburetta@haystack.mit.edu
Buttaccio, Salvo	Istituto di Radioastronomia CNR	Italy	s.buttaccio@ira.cnr.it
Campbell, James	Geodetic Institute of the University of Bonn	Germany	campbell@sn_geod_1.geod.uni-bonn.de
Cannon, Wayne	Space Geodynamics Laboratory	Canada	wayne@sgl.crestech.ca
Cappallo, Roger	MIT Haystack Observatory	USA	rcappallo@haystack.mit.edu
Carlson, Brent	Dominion Radio Astrophysical Observatory	Canada	bcarlson@drao.nrc.ca
Carter, Merri Sue	U. S. Naval Observatory	USA	msc@maia.usno.navy.mil

Name	Institution	Country	E-mail
Caskey, Steve	GCGO VLBI	USA	oper@blizzard.gcgo.nasa.gov
Chao, Benjamin	NASA Goddard Space Flight Center	USA	chao@bowie.gsfc.nasa.gov
Charlot, Patrick	Observatoire de Bordeaux	France	charlot@observ.u-bordeaux.fr
Chen, Songlin	Shanghai Astronomical Observatory	China	slchen@center.shao.ac.cn
Colomer, Francisco	Instituto Geográfico Nacional	Spain	colomer@oan.es
Colucci, Giuseppe	Telespazio SpA	Italy	colucci@asi.it
Combrinck, Ludwig	Hartebeesthoek Radio Astronomy Observatory	South Africa	ludwig@bootes.hartrao.ac.za
Corey, Brian	MIT Haystack Observatory	USA	bcorey@haystack.mit.edu
Corneliusson, Fredrik	Onsala Space Observatory	Sweden	fredrikc@oso.chalmers.se
Cox, Clyde	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Daniels, Mike	Natural Resources Canada	Canada	mike.daniels@gdim.geod.nrcan.gc.ca
de-Vicente, Pablo	Instituto Geográfico Nacional	Spain	vicente@oan.es
Dewdney, Peter	Dominion Radio Astrophysical Observatory	Canada	ped@drao.nrc.ca
Diegel, Irv	Honeywell TSI	USA	irv.diegel@honeywell-tsi.com
Digre, Helge	Norwegian Mapping Authority	Norway	helge.digre@statkart.no
Doi, Koichiro	National Institute of Polar Research	Japan	doi@nipr.ac.jp
Dong, Yousuo	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Drewes, Hermann	Deutsches Geodätisches Forschungsinstitut	Germany	drewes@dgfi.badw-muenchen.de
Dube, Maurice	Raytheon/GSFC	USA	mdube@pop900.gsfc.nasa.gov
Eberhart, Kyle	GCGO VLBI	USA	oper@blizzard.gcgo.nasa.gov
Elgered, Gunnar	Onsala Space Observatory	Sweden	kge@oso.chalmers.se
Engelhardt, Gerald	Bundesamt für Kartographie und Geodäsie	Germany	gerald.engelhardt@bkg.bund.de
Engen, Bjorn	Norwegian Mapping Authority	Norway	bjorn.engen@statkart.no
Essaïfi, Najat	Observatoire de Paris	France	najat.essaifi@obspm.fr
Fan, Qingyuan	Shanghai Astronomical Observatory	China	qyfan@center.shao.ac.cn
Farley, Stephen	Natural Resources Canada	Canada	farley@geod.nrcan.gc.ca
Feil, Georg	Space Geodynamics Laboratory	Canada	georg@sgl.crestech.ca
Feissel, Martine	IGN/ENSG-LAREG	France	feissel@ensg.ign.fr
Fey, Alan	U. S. Naval Observatory	USA	afey@usno.navy.mil
Finkelstein, Andrey	Institute of Applied Astronomy	Russia	amf@quasar.ipa.nw.ru

Name	Institution	Country	E-mail
Fischer, Dorothee	Geodetic Institute of the University of Bonn	Germany	dorothee.fischer@uni-bonn.de
Frolov, Vladimir	Institute of Applied Astronomy	Russia	fvn@isida.ipa.rssi.ru
Gambis, Daniel	Observatoire de Paris	France	daniel.gambis@obspm.fr
Gaume, Ralph	U. S. Naval Observatory	USA	rgaume@usno.navy.mil
Gipson, John	NVI, Inc./GSFC	USA	jmg@leo.gsfc.nasa.gov
Gomez, Frank	Raytheon/GSFC	USA	fgg@gemini.gsfc.nasa.gov
Gomez-Gonzalez, Jesus	Instituto Geográfico Nacional	Spain	gomez@oan.es
Gontier, Anne-Marie	Observatoire de Paris	France	anne-marie.gontier@obspm.fr
Gonzalez, Raymond	NVI, Inc./GSFC	USA	rgonzale@gemini.gsfc.nasa.gov
Gordon, David	Raytheon/GSFC	USA	dgg@leo.gsfc.nasa.gov
Govind, Ramesh	Geoscience Australia	Australia	ramesh.govind@ga.gov.au
Grachev, Valery	Institute of Applied Astronomy	Russia	gratch@isida.ipa.rssi.ru
Gradinarsky, Lubomir	Onsala Space Observatory	Sweden	lbg@oso.chalmers.se
Gubanov, Vadim	Institute of Applied Astronomy	Russia	gubanov@quasar.ipa.nw.ru
Gueguen, Erwan	Istituto di Radioastronomia CNR	Italy	e.gueguen@ira.cnr.it
Haas, Rüdiger	Onsala Space Observatory	Sweden	haas@oso.chalmers.se
Hall, David	U. S. Naval Observatory	USA	dhall@usno.navy.mil
Hammargren, Roger	Onsala Space Observatory	Sweden	roger@oso.chalmers.se
Hanssen, Rune	Norwegian Mapping Authority	Norway	rune.hanssen@statkart.no
Harms, Matt	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Hase, Hayo	BKG/Project TIGO	Chile	hayo.hase@bkg.bund.de
Helldner, Leif	Onsala Space Observatory	Sweden	helldner@oso.chalmers.se
Himwich, Ed	NVI, Inc./GSFC	USA	weh@vega.gsfc.nasa.gov
Hinteregger, Hans	MIT Haystack Observatory	USA	hhinteregger@haystack.mit.edu
Hobiger, Thomas	Intitute of Geodesy and Geophysics	Austria	thobiger@mars.hg.tuwien.ac.at
Holland, David	Norwegian Mapping Authority	Norway	david.holland@statkart.no
Hong, Xiaoyu	Shanghai Astronomical Observatory	China	xhong@center.shao.ac.cn
Huang, Xinyong	Shanghai Astronomical Observatory	China	xhuang@center.shao.ac.cn
Ichikawa, Ryuichi	Communications Research Laboratory	Japan	richi@crl.go.jp

Name	Institution	Country	E-mail
Ipatov, Alexander	Institute of Applied Astronomy	Russia	ipatov@ipa.rssi.ru
Ipatova, Irina	Institute of Applied Astronomy	Russia	ipatova@isida.ipa.rssi.ru
Ishimoto, Masayoshi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Jacobs, Chris	Jet Propulsion Laboratory	USA	chris.jacobs@jpl.nasa.gov
Jara, Cristobal	BKG/Project TIGO	Chile	cristobal.jara@tigo.cl
Jenson, George	Natural Resources Canada	Canada	gejensen@nrcan.gc.ca
Johansson, Jan	Onsala Space Observatory	Sweden	jmj@oso.chalmers.se
Johansson, Karl-Åke	Onsala Space Observatory	Sweden	kaj@oso.chalmers.se
Johansson, Lars	Onsala Space Observatory	Sweden	leb@oso.chalmers.se
Johnson, Heidi	MIT Haystack Observatory	USA	hjohnson@haystack.mit.edu
Johnston, Kenneth	U. S. Naval Observatory	USA	kjj@astro.usno.navy.mil
Kaufmann, Pierre	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	kaufmann@usp.br
Kawai, Eiji	Communications Research Laboratory	Japan	kawa@crl.go.jp
Kawawa, Hiroshi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Kaydanovsky, Michael	Institute of Applied Astronomy	Russia	kmn@isida.ipa.rssi.ru
Kennard, Ruth	Raytheon/GSFC	USA	rkennard@pop900.gsfc.nasa.gov
Kilger, Richard	Fundamentalstation Wettzell	Germany	richard.kilger@bkg.bund.de
Kim, Kelly	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Kimura, Moritaka	Communications Research Laboratory	Japan	yosh@crl.go.jp
Kingham, Kerry	U. S. Naval Observatory	USA	kak@cygx3.usno.navy.mil
Klatt, Calvin	Natural Resources Canada	Canada	klatt@geod.emr.ca
Kodak, Charles	Honeywell TSI	USA	charles.kodak@honeywell-tsi.com
Koltsov, Nikolay	Institute of Applied Astronomy	Russia	nec@isida.ipa.rssi.ru
Kondo, Tetsuro	Communications Research Laboratory	Japan	kondo@crl.go.jp
Korkin, Edward	Institute of Applied Astronomy	Russia	korkin@isida.ipa.rssi.ru
Koyama, Yasuhiro	Communications Research Laboratory	Japan	koyama@crl.go.jp
Kozin, Wada	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Kozlova, Iraida	Institute of Applied Astronomy	Russia	via@quasar.ipa.nw.ru
Krasinsky, George	Institute of Applied Astronomy	Russia	kra@quasar.ipa.nw.ru
Kronschnabl, Gerhard	Bundesamt für Kartographie und Geodäsie	Germany	gerhard.kronschnabl@bkg.bund.de

Name	Institution	Country	E-mail
Kuboki, Hiromitsu	Communications Research Laboratory	Japan	yosh@crl.go.jp
Kudryashova, Maria	Astronomical Institute of St.-Petersburg	Russia	kudryashova@mercury.astro.spbu.ru
Kurihara, Shinobu	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Kutterer, Hansjoerg	DGFI	Germany	kutterer@dgfi.badw.de
LaFrance, Jacques	Natural Resources Canada	Canada	lafrance@geod.emr.ca
Lanotte, Roberto	Telespazio SpA	Italy	lanotte@hp835.mt.asi.it
Li, Jinling	Shanghai Astronomical Observatory	China	jll@center.shao.ac.cn
Li, Bing	Shanghai Astronomical Observatory	China	bing@center.shao.ac.cn
Li, Suqin	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Liang, Shiguang	Shanghai Astronomical Observatory	China	sgliang@center.shao.ac.cn
Liu, Xiang	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Lizin, Igor	Institute of Applied Astronomy	Russia	lizin@isida.ipa.rssi.ru
Long, Jim	Honeywell TSI	USA	jim.long@honeywell-tsi.com
Lonsdale, Colin	MIT Haystack Observatory	USA	clonsdale@haystack.mit.edu
Lucena, Antonio	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	macilio@roen.inpe.br
Ma, Chopo	NASA Goddard Space Flight Center	USA	chopo.ma-1@nasa.gov
Maccaferri, Giuseppe	Istituto di Radioastronomia CNR	Italy	g.maccaferri@ira.cnr.it
Machida, Morito	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
MacMillan, Dan	NVI, Inc./GSFC	USA	dsm@leo.gsfc.nasa.gov
Malkin, Zinovy	Institute of Applied Astronomy	Russia	malkin@quasar.ipa.nw.ru
Manabe, Seiji	National Astronomical Observatory of Japan	Japan	manabe@miz.nao.ac.jp
Mantovani, Franco	Istituto di Radioastronomia CNR	Italy	f.mantovani@ira.cnr.it
Mardyshkin, Vyacheslav	Institute of Applied Astronomy	Russia	vvm@isida.ipa.rssi.ru
Mathias, William	Natural Resources Canada	Canada	wmathias@nrcan.gc.ca
Matsuzaka, Shigeru	Geographical Survey Institute	Japan	shigeru@gsi.go.jp

Name	Institution	Country	E-mail
McCarthy, Dennis	U. S. Naval Observatory	USA	dmc@maia.usno.navy.mil
McCulloch, Peter	University of Tasmania	Tasmania	peter.mcculloch@utas.edu.au
Michailov, Andrey	Institute of Applied Astronomy	Russia	agm@isida.ipa.rssi.ru
Mitchell, Donald	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Müskens, Arno	Geodetic Institute of the University of Bonn	Germany	mueskens@mpifr-bonn.mpg.de
Nakajima, Junichi	Communications Research Laboratory	Japan	nakaji@crl.go.jp
Nanni, Mauro	Istituto di Radioastronomia CNR	Italy	m.nanni@ira.cnr.it
Negusini, Monia	Istituto di Radioastronomia CNR	Italy	m.negusini@ira.cnr.it
Newby, Paul	Space Geodynamics Laboratory	Canada	paul@sgl.crestech.ca
Nicolson, George	Hartebeesthoek Radio Astronomy Observatory	South Africa	george@bootes.hartrao.ac.za
Niell, Arthur	MIT Haystack Observatory	USA	aniell@haystack.mit.edu
Nikitin, Pavel	Laboratory of Radioastronomy of Crimean	Ukraine	nikitin@crao.crimea.ua
Nilsson, Bjorn	Onsala Space Observatory	Sweden	bin@oso.chalmers.se
Noll, Carey	NASA Goddard Space Flight Center	USA	noll@cddisa.gsfc.nasa.gov
Nothnagel, Axel	Geodetic Institute of the University of Bonn	Germany	nothnagel@uni-bonn.de
Novikov, Alexander	Space Geodynamics Laboratory	Canada	sasha@sgl.crestech.ca
Ogaja, Clement	Geoscience Australia	Australia	Clement.Ogaja@ga.gov.au
Orfei, Sandro	Istituto di Radioastronomia CNR	Italy	a.orfei@ira.cnr.it
Osaki, Hiro	Communications Research Laboratory	Japan	yosh@crl.go.jp
Outhwaite, Bill	Natural Resources Canada	Canada	wouthwai@nrcan.gc.ca
Petrachenko, William	Natural Resources Canada	Canada	billp@cass.drao.nrc.ca
Petrov, Leonid	NVI, Inc./GSFC	USA	pet@leo.gsfc.nasa.gov
Pettersson, Lars	Onsala Space Observatory	Sweden	larsp@oso.chalmers.se
Plag, Hans-Peter	Norwegian Mapping Authority	Norway	plag@statkart.no
Plötz, Christian	Fundamentalstation Wettzell	Germany	christian.ploetz@bkg.bund.de
Poirier, Michael	MIT Haystack Observatory	USA	mpoirier@haystack.mit.edu
Popelar, Josef	Natural Resources Canada	Canada	popelar@geod.emr.ca

Name	Institution	Country	E-mail
Qian, Zhihan	Shanghai Astronomical Observatory	China	qzh@center.shao.ac.cn
Quick, Jonathan	Hartebeesthoek Radio Astronomy Observatory	South Africa	jon@bootes.hartrao.ac.za
Rahimov, Ismail	Institute of Applied Astronomy	Russia	iar@ipa.rssi.ru
Redmond, Jay	Honeywell TSI	USA	jay.redmond@honeywell-tsi.com
Reid, Brett	University of Tasmania	Tasmania	Brett.Reid@utas.edu.au
Rekkedal, Svein	Norwegian Mapping Authority	Norway	svein.rekkedal@statkart.no
Remedi, Gonzalo	Universidad del Bío Bío/Project TIGO	Chile	gonzalo.remedi@tigo.cl
Rioja, Maria	Centro Astronómico de Yebes	Spain	rioja@oan.es
Rosso, Domenico	Telespazio SpA	Italy	domenico_delrosso@telespazio.it
Rottmann, Izabela	Geodetic Institute of the University of Bonn	Germany	owsianik@mpifr-bonn.mpg.de
Rusinov, Yuriy	Institute of Applied Astronomy	Russia	rusinov@quasar.ipa.nw.ru
Salnikov, Alexander	Institute of Applied Astronomy	Russia	salnikov@isida.ipa.rssi.ru
Sarti, Pierguido	Istituto di Radioastronomia CNR	Italy	p.sarti@ira.cnr.it
Schatz, Raimund	Fundamentalstation Wettzell	Germany	raimund.schatz@bkg.bund.de
Scherneck, Hans-Georg	Onsala Space Observatory	Sweden	hgs@oso.chalmers.se
Schlüter, Wolfgang	Bundesamt für Kartographie und Geodäsie	Germany	Wolfgang.Schlueter@bkg.bund.de
Schuh, Harald	Intitute of Geodesy and Geophysics	Austria	harald.schuh@tuwien.ac.at
Schupler, Bruce	Honeywell TSI	USA	bruce.schupler@honeywell-tsi.com
Schwarz, Walter	Bundesamt für Kartographie und Geodäsie	Germany	walter.schwarz@bkg.bund.de
Sciarretta, Cecilia	Telespazio SpA	Italy	cecilia@asi.it
Searle, Anthony	Geodetic Survey Division	Canada	asearle@NRCan.gc.ca
Sekido, Mamoru	Communications Research Laboratory	Japan	sekido@crl.go.jp
Shaffer, David	Radiometrics Inc.	USA	dbs@gemini.gsfc.nasa.gov
Shao, Minghui	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Shibuya, Kazuo	National Institute of Polar Research	Japan	shibuya@nipr.ac.jp
Shu, Fengchun	Shanghai Astronomical Observatory	China	sfc@center.shao.ac.cn

Name	Institution	Country	E-mail
Skurikhina, Elena	Institute of Applied Astronomy	Russia	sea@quasar.ipa.nw.ru
Smolentsev, Sergey	Institute of Applied Astronomy	Russia	smolen@isida.ipa.rssi.ru
Smythe, Dan	MIT Haystack Observatory	USA	dsmythe@haystack.mit.edu
Sobarzo, Sergio	BKG/Project TIGO	Chile	sergio.sobarzo@tigo.cl
Sousa, Don	MIT Haystack Observatory	USA	dsousa@haystack.mit.edu
Sovers, Ojars	Remote Sensing Analysis Inc.	USA	ojars@rsasys.com
Stanghellini, Carlo	Istituto di Radioastronomia CNR	Italy	c.stanghellini@ira.cnr.it
Steinforth, Christoph	Geodetic Institute of the University of Bonn	Germany	steinforth@uni-bonn.de
Steppe, Alan	Jet Propulsion Laboratory	USA	as@logos.jpl.nasa.gov
Stoew, Borys	Onsala Space Observatory	Sweden	boris@oso.chalmers.se
Stotsky, Alexander	Institute of Applied Astronomy	Russia	stotskii@isida.ipa.rssi.ru
Surkis, Igor	Institute of Applied Astronomy	Russia	surkis@quasar.ipa.nw.ru
Takashima, Kazuhiro	Geographical Survey Institute	Japan	takasima@gsi.go.jp
Takeuchi, Hiroshi	Communications Research Laboratory	Japan	yosh@crl.go.jp
Tamura, Yoshiaki	National Astronomical Observatory of Japan	Japan	tamura@miz.nao.ac.jp
Tangen, Leif Morten	Norwegian Mapping Authority	Norway	leif.morten.tangen@statkart.no
Tateyama, Claudio	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	tateyama@craam.mackenzie.br
Tesmer, Volker	DGFI	Germany	tesmer@dgfi.badw.de
Thomas, Cynthia	NVI, Inc./GSFC	USA	cct@gemini.gsfc.nasa.gov
Thorandt, Volkmar	Bundesamt für Kartographie und Geodäsie	Germany	volkmar.thorandt@bkg.bund.de
Thornton, Bruce	U. S. Naval Observatory	USA	blt@casa.usno.navy.mil
Titov, Oleg	Geoscience Australia	Australia	Oleg.Titov@ga.gov.au
Titus, Mike	MIT Haystack Observatory	USA	mtitus@haystack.mit.edu
Tomasi, Paolo	Istituto di Radioastronomia CNR	Italy	tomasi@ira.cnr.it
Torres, Miguel	Istituto di Radioastronomia CNR	Italy	m.torres@ira.cnr.it
Trigilio, Corrado	Istituto di Radioastronomia CNR	Italy	c.trigilio@ira.cnr.it
Tsuji, Hiromichi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp

Name	Institution	Country	E-mail
Tsutsumi, Takashi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Tuccari, Gino	Istituto di Radioastronomia CNR	Italy	g.tuccari@ira.cnr.it
Ullrich, Dieter	Bundesamt für Kartographie und Geodäsie	Germany	dieter.ullrich@bkg.bund.de
Vandenberg, Nancy	NVI, Inc./GSFC	USA	nrv@gemini.gsfc.nasa.gov
Vennebusch, Markus	Geodetic Institute of the University of Bonn	Germany	vennebusch@uni-bonn.de
Venturi, Tiziana	Istituto di Radioastronomia CNR	Italy	t.venturi@ira.cnr.it
Vespe, Francesco	Agenzia Spaziale Italiana	Italy	vespe@asi.it
Villiard, Cynthia	Raytheon/GSFC	USA	cav@gemini.gsfc.nasa.gov
Vityazev, Veniamin	Astronomical Institute of St.-Petersburg	Russia	vityazev@venvi.usr.pu.ru
Volvach, Alexandr	Laboratory of Radioastronomy of Crimean	Ukraine	volvach@crao.crimea.ua
Vytnov, Alexander	Institute of Applied Astronomy	Russia	vytnov@isida.ipa.rssi.ru
Wang, Guangli	Shanghai Astronomical Observatory	China	wgl@center.shao.ac.cn
Wang, Na	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Wang, Weixia	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Wei, Wenren	Shanghai Astronomical Observatory	China	wwr@center.shao.ac.cn
Whitney, Alan	MIT Haystack Observatory	USA	awhitney@haystack.mit.edu
Wildes, William	NASA Goddard Space Flight Center	USA	wtw@wildbill.gsfc.nasa.gov
Wojdziak, Reiner	Bundesamt für Kartographie und Geodäsie	Germany	reiner.wojdziak@bkg.bund.de
Xue, Zhouhe	Shanghai Astronomical Observatory	China	zhxue@center.shao.ac.cn
Yang, Zhigen	Shanghai Astronomical Observatory	China	yangz@center.shao.ac.cn
Yatskiv, Yaroslav	Main Astronomical Observatory	Ukraine	yatskiv@mao.kiev.ua
Ye, Shuhua	Shanghai Astronomical Observatory	China	ysh@center.shao.ac.cn
Yoshino, Taizoh	Communications Research Laboratory	Japan	yosh@crl.go.jp

Name	Institution	Country	E-mail
Yusup, Aili	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Zeitlhöfler, Reinhard	Fundamentalstation Wettzell	Germany	reinhard.zeitlhoefler@bkg.bund.de
Zen, Yong	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Zernecke, Rudolf	Fundamentalstation Wettzell	Germany	rudolf.zernecke@bkg.bund.de
Zhang, Ali	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Zhang, Hongbo	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Zhang, Jin	Urumqi Astronomical Observatory	China	uao@mail.wl.xj.cn
Zhou, Ruixian	Shanghai Astronomical Observatory	China	zrx@center.shao.ac.cn

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 Nordes (ROEN)	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Gilmore Creek Geophysical Observatory	National Earth Orientation Service	USA
Goddard Geophysical and Astronomical Observatory	NASA Goddard Space Flight Center	USA
Hartebeesthoek Radio Astronomy Observatory	Hartebeesthoek Radio Astronomy Observatory	South Africa
Hobart, Mt. Pleasant Radio Astronomy Observatory	Hobart, Mt. Pleasant Radio Astronomy Observatory	Australia
Kashima 34m antenna	Communications Research Laboratory	Japan
Kashima 11m antenna	Communications Research Laboratory	Japan
Koganei 11m antenna	Communications Research Laboratory	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service	USA
Matera	Agenzia Spaziale Italiana	Italy
Medicina (Italy)	Istituto di Radioastronomia CNR	Italy
Mizusawa	National Astronomical Observatory of Japan	Japan
Noto (Sicily)	Istituto di Radioastronomia CNR	Italy
Ny Ålesund Geodetic Observatory	Norwegian Mapping Authority	Norway
ERS/VLBI Station O'Higgins	Bundesamt für Kartographie und Geodäsie	Germany
Onsala Space Observatory	Chalmers University of Technology	Sweden
Seshan	Shanghai Observatory, Chinese Academy of Sciences	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy	Russia
JARE Syowa 11m antenna	National Institute of Polar Research	Japan
Transportable Integrated Geodetic Observatory (TIGO)	Bundesamt für Kartographie und Geodäsie	Germany
Tsukuba VLBI Station	Geographical Survey Institute	Japan

Nanshan VLBI Station of Urumqi Astronomical Observatory (UAO)	Shanghai Observatory, Chinese Academy of Sciences	China
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie and Forschungseinrichtung Satellitengeodäsie de Technischen Universität München	Germany
Observatório Astronómico Nacional - Yebes	Instituto Geográfico Nacional	Spain
Yellowknife Geophysical Observatory	Geodetic Survey Division, Natural Resources Canada	Canada

Operation Centers

Component Name	**Sponsoring Organization**	**Country**
Geodetic Institute Bonn	Geodätisches Institut der Universität Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service	USA

Correlators

Component Name	**Sponsoring Organization**	**Country**
Astro/Geo Correlator at the Max-Planck-Institute for Radio Astronomy	Bundesamt für Kartographie und Geodäsie and Geodätisches Institut der Universität Bonn	Germany
Kashima VLBI Correlators	Communications Research Laboratory	Japan
MIT Haystack Observatory Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy	Russia
Tsukuba VLBI Center	Geographical Survey Institute	Japan
Washington Correlator	National Earth Orientation Service	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Communications Research Laboratory	Communications Research Laboratory	Japan
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana	Italy
Italy CNR	Istituto di Radioastronomia CNR	Italy
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
GA IVS Analysis Center	Geoscience Australia	Australia
Bordeaux Observatory	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
Communications Research Laboratory	Communications Research Laboratory	Japan
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
GIUB-BKG Analysis Center	Geodätisches Institut der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy	Russia
Italy CNR	Istituto di Radioastronomia CNR	Italy
Institute of Geodesy and Geophysics (IGG)	Vienna University of Technology	Austria
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Main Astronomical Observatory	National Academy of Sciences, Kiev	Ukraine
NAOJ	National Astronomical Observatory of Japan	Japan
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden

Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
U. S. Naval Observatory	U. S. Naval Observatory	USA
USNO Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	Sponsoring Organization	Country
Canadian VLBI Technology Development Center	Space Geodynamics Laboratory, Geodetic Survey Division, Dominion Radio Astrophysical Observatory, Canadian Space Agency	Canada
Communications Research Laboratory	Communications Research Laboratory	Japan
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
MIT Haystack Observatory	National Earth Orientation Service	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy	Russia
Onsala Space Observatory	Chalmers University of Technology	Sweden

Addresses of Institutions of Authors Contributing to this Report

(listed alphabetically by country)

Geoscience Australia
PO Box 378
Canberra ACT
2601
Australia
http://ga.gov.au

Hobart, Mt. Pleasant Radio Astronomy Observatory
School of Mathematics and Physics
University of Tasmania
GPO Box 252-37
Hobart 7001
Australia

Institute of Geodesy and Geophysics/University of Technology, Vienna
Gusshausstrasse 27-29
1040 Vienna
Austria
http://www.hg.tuwien.ac.at

Centro de Rádio Astronomia e Aplicações Espaciais, CRAAE (Mackenzie, INPE, USP, UNICAMP)
CRAAE
Instituto Presbiteriano Mackenzie
Rua da Consolação 896
01302-907 São Paulo
SP
Brazil
http://www.craae.mackenzie.br

Rádio Observatório Espacial do Nordeste, ROEN
Estrada do Fio 6000
Bairro Tupuiú
61760-000 Eusébio
CE
Brazil
http://www.roen.inpe.br

Geodetic Survey Division, Geomatics Canada, Natural Resources Canada
615 Booth St.
Ottawa
Ontario
Canada K1A 0E9
http://www.geod.nrcan.gc.ca

York University and SGL/CRESTech
4850 Keele St.
Floor 1 North York
Ontario
Canada M3J 3K1
http://www.sgl.crestech.ca

Bundesamt für Kartographie und Geodäsie - TIGO
Casilla 4036
Correo 3
Concepción
Chile
http://www.tigo.cl

Universidad de Concepción - TIGO
Concepción
Chile
http://www.tigo.cl

Universidad del Bío Bío - TIGO
Concepción
Chile
http://www.tigo.cl

Shanghai Astronomical Observatory, Chinese Academy of Sciences
80 Nandan Road
Shanghai 200030
People's Republic of China
http://center.shao.ac.cn/

Observatoire de Bordeaux
BP 89
33270 Floirac
France
http://www.obs.u-bordeaux1.fr

Observatoire de Paris, SYRTE/UMR 8630
61 avenue de l'Observatoire
75014 Paris
France
http://www.obspm.fr

Bundesamt für Kartographie und Geodäsie
Karl-Rothe-Straße 10-14
04105 Leipzig
Germany
http://www.leipzig.ifag.de

Bundesamt für Kartographie und Geodäsie - Fundamentalstation Wettzell
Sackenrieder Str. 25.
D-93444 Kötzting
Germany
http://www.wettzell.ifag.de

DGFI, Deutsches Geodätisches Forschungsinstitut
Marstallplatz 8
80539 München
Germany
http://www.dgfi.badw.de

Geodätisches Institut der Universität Bonn
Nussallee 17
D-53115 Bonn
Germany
http://giub.geod.uni-bonn.de/vlbi

Max-Planck-Institute for Radioastronomy
Auf dem Hügel 69
53121 Bonn
Germany
http://www.mpifr-bonn.mpg.de

Agenzia Spaziale Italiana
Centro di Geodesia Spaziale
C.P. Aperta
Ctr.da Terlecchia
75100 Matera
Italy
http://www.asi.it

Istituto di Radioastronomia, Bologna
Via P. Gobetti 101
40129 Bologna
Italy
http://www.ira.cnr.it

Istituto di Radioastronomia, Medicina
C.P. 14
40060 Villafontana
Bologna
Italy
http://www.ira.cnr.it

Istituto di Radioastronomia del CNR, Stazione VLBI di Noto
C.P. 141
I-96017 Noto SR
Italy
http://www.ira.noto.cnr.it

Geographical Survey Institute
Kitasato 1 Tsukuba
Ibaraki
Japan
http://vldb.gsi.go.jp/sokuchi/vlbi/english/

Kashima Space Research Center, Communications Research Laboratory
893-1 Hirai
Kashima
Ibaraki 314-0012
Japan
http://www.crl.go.jp/ka/index.html

Forsvarets forskningsinstitutt (FFI) (Norwegian Defence Research Establishment)
FFI/E
Box 25
2007 Kjeller
Norway
http://www.ffi.no/

Geodetic Institute, Norwegian Mapping Authority
Kartverksveien
Hønefoss
Norway
http://www.statkart.no

The Institute of Applied Astronomy, Russian Academy of Sciences
nab. Kutuzova 10
St. Petersburg
191187
Russia
http://www.ipa.nw.ru

Sobolev Astronomical Institute of St. Petersburg University
Universitetskii pr. 28
Starii Peterhof
St. Petersburg
198504
Russia
http://www.astro.spbu.ru

HartRAO, NRF
PO Box 443
Krugersdorp
1740
South Africa
http://www.hartrao.ac.za

Observatório Astronómico Nacional
Apartado 1143
E-28800 Alcalá de Henares
Spain
http://www.oan.es/

Onsala Space Observatory (OSO)
SE-439 92
Onsala
Sweden
http://www.oso.chalmers.se

Experimental Branch of Sea Hydrophysical Institute of NAS of the Ukraine
Katsively
Yalta Crimea 98688
Ukraine

Lab of Radio Astronomy of Crimean Astrophysical Observatory
RT-22
Katsively
Yalta Crimea 98688
Ukraine
http://www.crao.crimea.ua

Main Astronomical Observatory, National Academy of Sciences of Ukraine
Main Astronomical Observatory
27 Akademika Zabolotnoho St.
Kiev
03680
Ukraine
http://www.mao.kiev.ua

Gilmore Creek Geophysical Observatory
NOAA/NESDIS CDA Station
GCGO/VLBI
1300 Eisele Rd
Fairbanks, Alaska 99712
USA
http://www.fcdas.noaa.gov

Jet Propulsion Laboratory, California Institute of Technology
Mail Stop 238-600
4800 Oak Grove Dr.
Pasadena, CA 91109
USA
http://www.jpl.nasa.gov

Kokee Park Geophysical Observatory
Kokee State Park
P.O. Box 538
Waimea, Hawaii 96796
USA

MIT Haystack Observatory
Off Route 40
Westford, MA 01886
USA
http://www.haystack.mit.edu/

NASA Goddard Space Flight Center
Code 926
Greenbelt, MD 20771
USA
http://lupus.gsfc.nasa.gov

U.S. Naval Observatory
3450 Massachusetts Ave. NW
Washington, DC 20392
USA
http://www.usno.navy.mil

List of Acronyms

AC	Analysis Center
ACU	Antenna Control Unit
AGU	American Geophysical Union
AIPS	Astronomical Image Processing System
ANU	Australian National University (Australia)
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)
CACS	Canadian Active Control System
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
CGS	Centro di Geodesia Spaziale (Italy)
CIP	Celestial Intermediate Pole
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.
CORE	Continuous Observations of the Rotation of the Earth
CRAAE	Center for Radio Astronomy and Space Applications (Brazil)
CRAAM	Centro de Rádio-Astronomia e Astrofísica Mackenzie
CRESTech	Centre for Research in Earth and Space Technology (Canada)
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory (Japan)
CSA	Canadian Space Agency (Canada)
CTVA	Canadian Transportable VLBI Antenna
CUTE	CRL and University Telescopes Experiment (Japan)
DAR	Data Acquisition Rack
DAS	Data Acquisition System
DASOS	DAS Operating System
DAT	Digital Audio Tape
DeltaDOR	Delta Differenced One-way Range
DFG	Deutsche Forschungsgemeinschaft (Germany)

DFN	Deutsches ForschungsNetz (Germany)
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DGK	Deutsche Geodätische Kommission (Germany)
DLR	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)
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
DVLBI	Differential VLBI
ECMWF	European Center for Medium Range Weather Forecasting
EGAE	Experiment Guided Adaptive Endpoint
EGS	European Geophysical Society
ENSG	L'École Nationale des Sciences Géographiques
ENSO	El-Niño/Southern Oscillation
ENVISAT	ENVIronment SATellite
EOP	Earth Orientation Parameters
ERP	Earth Rotation Parameters
EU	European Union
e-VLBI	Electronic VLBI
EVN	European VLBI Network
FCN	Free Core Nutation
FESG	Forschungseinrichtung Satellitengeodäsie (Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FGS	Forschungsgruppe Satellitengeodäsie (Germany)
FS	Field System
FTP	File Transfer Protocol
FWF	Austrian Science Fund
GA	Geoscience Australia (Australia)
GALAXY	Giga-bit Astronomical Large Array with cross connect
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)
GGAO	Goddard Geophysical and Astronomical Observatory (USA)
GCGO	Gilmore Creek Geophysical Observatory (USA)
GeoDAF	Geodetical Data Archive Facility (Italy)
GFZ	GeoForschungsZentrum (Germany)
GIUB	Geodetic Institute of the University of Bonn (Germany)
GLONASS	GLObal NAvigation Satellite System
GLORIA	GLObal Radio Interferometry Analysis
GMST	Greenwich Mean Sideral Time

GPS	Global Positioning System
GSD	Geodetic Survey Division of Natural Resources Canada (Canada)
GSFC	Goddard Space Flight Center (USA)
GSI	Geographical Survey Institute (Japan)
GST	Greenwich Sideral Time
GeoDAF	Geodetical Data Archive Facility (Italy)
HartRAO	Hartebeesthoek Radio Astronomy Observatory (South Africa)
HTSI	Honeywell Technology Solutions Incorporated (USA)
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
IDS	International DORIS Service
IERS	International Earth Rotation Service
IETF	Internet Engineering Task Force
IGFN	Italian Space Agency GPS Fiducial Network (Italy)
IGG	Institute of Geodesy and Geophysics (Austria)
IGN	Instituto Geográfico Nacional (Spain)
IGS	International GPS Service
ILRS	International Laser Ranging Service
IMF	Isobaric Mapping Function
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IRA	Istituto di RadioAstronomia (Italy)
IRIS	International Radio Interferometric Surveying
ISAS	Institute of Space and Astronautical Science (Japan)
ITIS	Istituto di Tecnologia Informatica Spaziale (Italy)
ITRF	International Terrestrial Reference Frame
ITSS	(Raytheon) Information Technology and Science Services (USA)
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)
JGR	Journal of Geophysical Research
JIVE	Joint Institute for VLBI in Europe
JPL	Jet Propulsion Laboratory (USA)
KPGO	Kokee Park Geophysical Observatory (USA)
KSP	Key Stone Project (Japan)
KSRC	Kashima Space Research Center (Japan)
LAGEOS	LAser GEOdynamic Satellite
LAREG	Laboratoire de Recherches en Géodésie (France)
LBA	Long Baseline Array (Australia)
LEA	Lab of Ephemeris Astronomy (Russia)
LLR	Lunar Laser Ranging
LOD	Length Of Day

LSF	Large Scale Facility
LSGER	Lab of Space Geodesy and Earth Rotation (Russia)
MAO	Main Astronomical Observatory (Ukraine)
MBH	Mathews/Buffett/Herring Nutation Model
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)
MRO	Metsähovi Radio Observatory (Finland)
MTLRS	Modular Transportable Laser Ranging System
NAO	National Astronomical Observatory (Japan)
NAOJ	National Astronomical Observatory of Japan (Japan)
NASA	National Aeronautics and Space Administration (USA)
NCAR	National Center for Atmospheric Research (USA)
NCEP	National Centers for Environmental Prediction (USA)
NEOS	National Earth Orientation Service (USA)
NESDIS	National Environmental Satellite, Data, and Information Service (USA)
NGS	National Geodetic Survey (USA)
NICT	National Institute of Information and Communications Technology
NIPR	National Institute of Polar Research (Japan)
NMF	Niell Mapping Function
NNR	No-Net-Rotation
NNT	No-Net-Translation
NOAA	National Oceanic and Atmospheric Administration (USA)
NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NTT	Nippon Telegraph and Telephone Corporation (Japan)
NVI	NVI, Inc. (USA)
OAN	Observatorio Astronómico Nacional (Spain)
OPAR	Paris Observatory (France)
OPC	Observing Program Committee
OSO	Onsala Space Observatory (Sweden)
POLARIS	POLar motion Analysis by Radio Interferometric Surveying
PRARE	Precision RAnge and Range-rate Experiment
RAS	Russian Academy of Sciences (Russia)
RDV	Research and Development sessions using the VLBA
REPA	REsidual Plotting and Ambiguity resolution
RFI	Radio Frequency Interference
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
RRFID	Radio Reference Frame Image Database
RTP	Real-Time Protocol
SEFD	System Equivalent Flux Density
SGL	Space Geodynamics Laboratory (Canada)

SHAO	Shanghai Astronomical Observatory (China)
SINEX	Solution INdependent EXchange format
SKA	Square Kilometer Array
SLR	Satellite Laser Ranging
SNAP	Standard Notation for Astronomical Procedures
SPbU	Saint-Petersburg University (Russia)
SRTM	Shuttle Radar Topography Mission
STDN	Satellite Tracking Data Network
SWT	SW Technology (USA)
TAC	Totally Accurate Clock
TAO	Telecommunications Advanced Organization (Japan)
TDC	Technology Development Center
TECU	Total Electron Content Units
TEMPO	Time and Earth Motion Precision Observations
TIGO	Transportable Integrated Geodetic Observatory (Germany, Chile)
TOW	Technical Operations Workshop
TRF	Terrestrial Reference Frame
TUM	Technical University of Munich
UAO	Urumqi Astronomical Observatory (China)
UDP	User Datagram Protocol
URSI	International Radio Science Union
USNO	U. S. Naval Observatory (USA)
UT1	Universal Time
UTC	Coordinated Universal Time
VCS	VLBA Calibrator Survey
VERA	VLBI Exploration of Radio Astrometry
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Functions
VSI	VLBI Standard Interface
VSOP	VLBI Space Observatory Program
VTEC	Vertical Total Electron Content
VTM	Vienna TEC (Total Electron Content) Model
VTRF	VLBI Terrestrial Reference Frame
WACO	WAshington COrrelator (USA)
WVR	Water Vapor Radiometer
WWW	World Wide Web
ZTD	Zenith Total Delay
ZWD	Zenith Wet Delay

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INTERNATIONAL VLBI SERVICE FOR GEODESY AND ASTROMETRY

IVS Coordinating Center
NASA Goddard Space Flight Center
Code 926
Greenbelt, MD 20771

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

phone: 301-614-5939
fax: 301-614-6099