National Aeronautics and
Space Administration

International VLBI Service for Geodesy and Astrometry

Annual Report 2010

Edited by
D. Behrend and K.D. Baver

IVS Coordinating Center
May 2011

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Front cover: *The year 2010 marks the beginning of construction of the IVS next generation VLBI network. The network will consist of fast slewing 12-meter class antennas with signal electronics that have been completely revised to process four bands each independently settable to any frequency in the full 2-14 GHz range. The new broadband system was designed to achieve extremely precise delays at modest SNR and to have the frequency flexibility to avoid RFI. The network is expected to grow over the next several years. The use of four frequency bands within the 2-14 GHz range to determine the phase delay is likely to require correction for the structure of the radio sources as part of the VLBI2010 observations and data analysis. This volume contains several reports from components that describe advances in VBLI2010 technology and network evolution.*

NASA/TP—2011–215880

International VLBI Service for Geodesy and Astrometry 2010 Annual Report

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Preface

This volume of reports is the 2010 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 2010 Annual Report documents the work of the IVS components for the calendar year 2010, our twelfth 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 contents of this Annual Report also appear on the IVS Web site at

`http://ivscc.gsfc.nasa.gov/publications/ar2010`

This book and the Web site are organized as follows:

- The first section contains general information about IVS, a map showing the location of the components, information about the Directing Board members, and the annual report of the IVS Chair.
- The next seven sections hold the reports from the Coordinators and the reports from the IVS Permanent Components: Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers.
- The next section contains a compilation of publications in the field of geodetic and astrometric VLBI during 2010.
- The last section includes reference information about IVS: the Terms of Reference, the lists of Member and Affiliated organizations, the IVS Associate Member list, a complete list of IVS components, the list of institutions that contributed to this report, and a list of acronyms.

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About IVS

About IVS

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

- 27 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,
- 26 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.

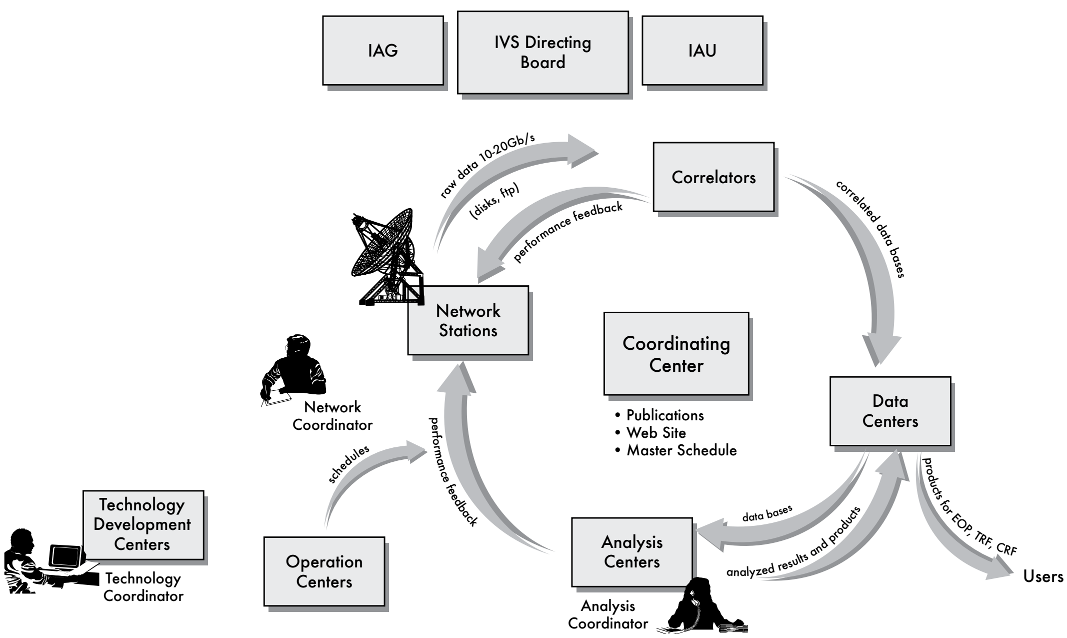
Altogether

- 79 Permanent Components, representing 41 institutions in 19 countries,
- ~280 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
CSIRO	Australia
Vienna University of Technology	Austria
Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Geodetic Survey Division, Natural Resources Canada	Canada
Dominion Radio Astrophysical Observatory	Canada
Universidad de 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
Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
Forschungseinrichtung Satellitengeodäsie, TU-Munich	Germany
Max-Planck-Institut für Radioastronomie	Germany
Istituto di Radioastronomia INAF	Italy
Agenzia Spaziale Italiana	Italy
Politecnico di Milano DIIAR	Italy
Geographical Survey Institute	Japan
National Institute of Information and Communications Technology	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Auckland University of Technology	New Zealand
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Institute of Applied Astronomy	Russia
Pulkovo Observatory	Russia
Sternberg Astronomical Institute of Moscow State University	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Korea Astronomy and Space Science Institute	South Korea
Instituto Geográfico Nacional	Spain
Chalmers University of Technology	Sweden
Karadeniz Technical University	Turkey
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
FÖMI Satellite Geodetic Observatory	Hungary
Joint Institute for VLBI in Europe (JIVE)	Netherlands
Westerbork Observatory	Netherlands
National Radio Astronomy Observatory	USA

Products

The VLBI technique contributes uniquely to

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

Further significant products are

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

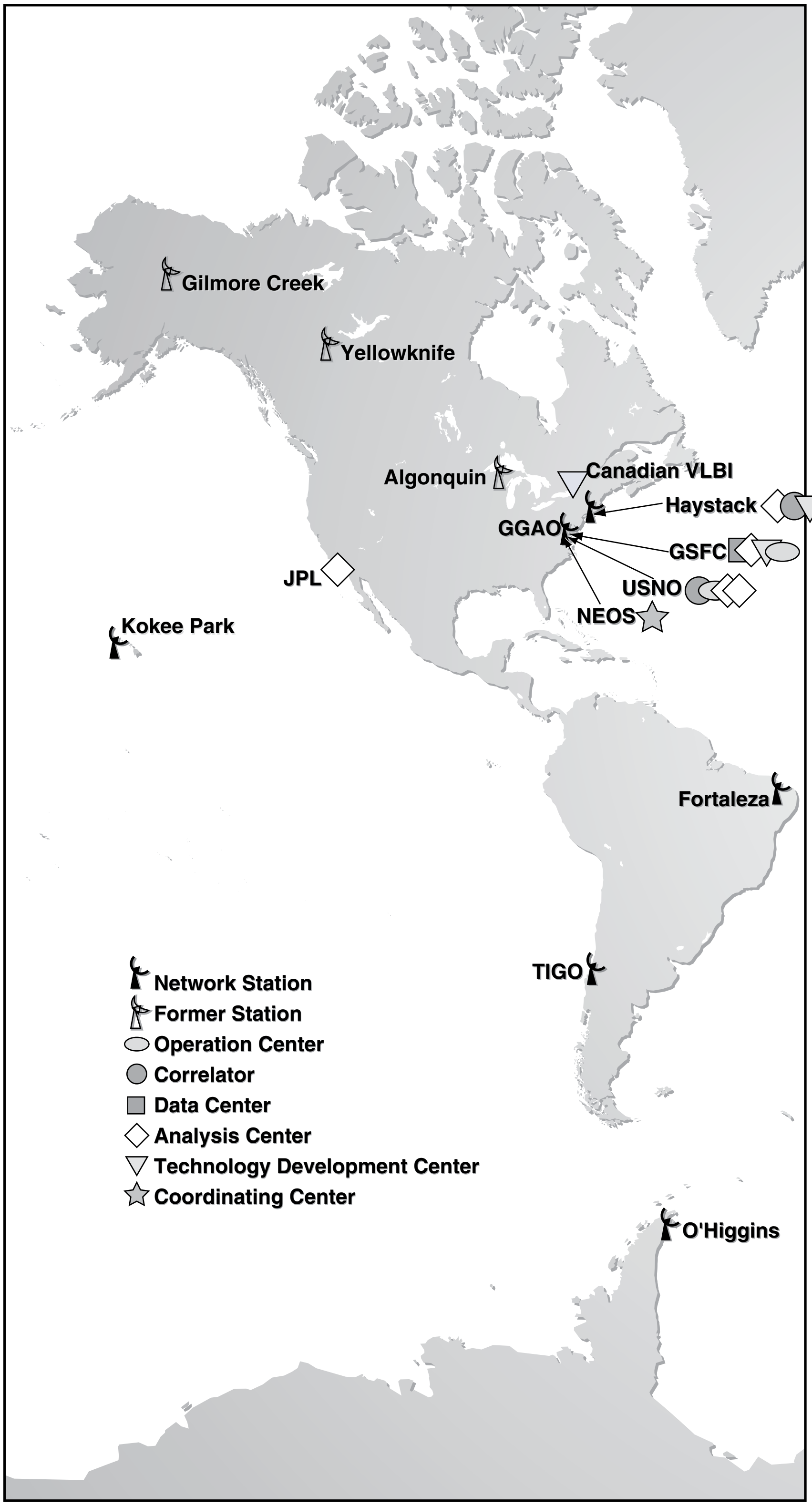
All VLBI data and results in appropriate formats are archived in data centers and publicly available for research in related areas of geodesy, geophysics and astrometry.

IVS Component Map

IVS Components by Country

Country	Qty.
Australia	3
Austria	1
Brazil	1
Canada	1
Chile	1
China	3
France	3
Germany	8
Italy	8
Japan	12
Norway	4
Russia	9
South Africa	1
South Korea	1
Spain	1
Sweden	3
Turkey	1
Ukraine	2
USA	16
Total	**79**

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




Ny Ålesund
NMA
FFI
Onsala
Svetloe
IAA
PUL
AIStPbU
SAI
IGGB
BKG
MAO
FGS(BKG,IGGB)
DGFI
Wettzell
Paris
TU Vienna
Zelenchukskaya
Bordeaux
INAF
Medicina
Simeiz
Yebes
PMD
Matera
KTU
Noto
Badary
Nanshan
Mizusawa
Tsukuba
Kashima34
Seshan
KASI
NICT
Shanghai
Kashima 11
Koganei
Hartebeesthoek
Parkes
GA
Hobart
Syowa

IVS Directing Board

NAME: Harald Schuh

AFFILIATION: Vienna University of Technology, Austria

POSITION: Chair and IAG Representative

TERM: ex officio

NAME: Dirk Behrend

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

POSITION: Coordinating Center Director

TERM: ex officio

NAME: Rüdiger Haas

AFFILIATION: Chalmers University of Technology, Sweden

POSITION: Technology Development Centers Representative

TERM: Feb 2009 to Feb 2013

NAME: Patrick Charlot

AFFILIATION: Bordeaux Observatory, France

POSITION: IAU Representative

TERM: ex officio

NAME: Hayo Hase

AFFILIATION: Bundesamt für Kartographie und Geodäsie/TIGO, Germany/Chile

POSITION: Networks Representative

TERM: Feb 2007 to Feb 2011

NAME: Andrey Finkelstein

AFFILIATION: Institute of Applied Astronomy, Russia

POSITION: At Large Member

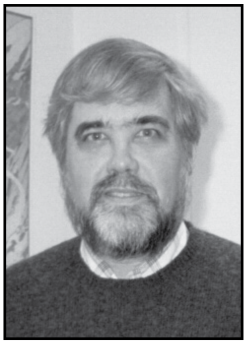
TERM: Feb 2009 to Feb 2011

NAME: Ed Himwich

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

POSITION: Network Coordinator

TERM: permanent



NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

TERM: Feb 2007 to Feb 2011

NAME: Oleg Titov

AFFILIATION: Geoscience Australia, Australia

POSITION: Analysis and Data Centers Representative

TERM: Feb 2009 to Feb 2013

NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative

TERM: ex officio

NAME: Gino Tuccari

AFFILIATION: Istituto di Radioastronomia, Italy

POSITION: Networks Representative

TERM: Feb 2009 to Feb 2013

NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent

NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

TERM: permanent

NAME: Kazuhiro Takashima

AFFILIATION: Geographical Survey Institute, Japan

POSITION: At Large Member

TERM: Feb 2009 to (Feb 2011)

NAME: Xiuzhong Zhang

AFFILIATION: Shanghai Astronomical Observatory, China

POSITION: At Large Member

TERM: Feb 2009 to Feb 2011

Harald Schuh

Institute of Geodesy and Geophysics, Vienna University of Technology

With the 2010 Annual Report the IVS components report about their progress and activities which were conducted during the service's twelfth year of existence. I would like to thank all IVS Associate Members for their contributions over the course of the year, in particular for providing their reports in time. Timely appearance of the Annual Report is always an ambitious goal and is highly appreciated for maintaining this volume as a real information exchange tool for the community and related groups. I thank the editors for the timely release.

In 2010 IVS observing activities were slightly reduced with respect to previous years, mostly because of major station repair work at Wettzell and Fortaleza. Nonetheless, the remainder of the observing activities remained at the same high level as in previous years, testament to the optimized coordination by the Coordinating Center and strong support from all components despite the limited resources and failures at a few aging radio telescopes. I would like to thank the staff of the Coordinating Center who bear much responsibility and carry a heavy burden for the entire service activities. Day-to-day work is done continuously by the Network Stations, the Correlators, the Data Centers, and the Analysis Centers and is the basis for the regular provision of precise and reliable IVS products. Here I would like to emphasize those activities performed in 2010 that go beyond the normal work load.

IVS Contribution to the Global Geodetic Observing System (GGOS)

In 2005 the intergovernmental Group on Earth Observations (GEO) was formed. This group initiated the creation of a Global Earth Observing System of Systems (GEOSS) for monitoring and understanding global change. The International Association of Geodesy (IAG) contributes to this multi-national and multi-institutional effort with the Global Geodetic Observing System (GGOS). GGOS will provide the most precise terrestrial and celestial reference frames based on the well-established, international space-geodetic services.

Integration and combination in the framework of GGOS is the main challenge for the international geodesy in the new decade. GGOS goes beyond the integration of the geometric techniques (VLBI, SLR, GNSS, DORIS) as it includes also techniques measuring terrestrial gravity, the global Earth gravity field, sea level, and also the magnetic field. Eventually a consistent combination of all geometric and physical techniques will be required. GGOS plays an essential role in helping to solve environmental and societal problems. Many tasks such as establishing a unified global height system or open questions related to global change, sea level rise, or the prevention of natural hazards need precise reference frames and exact geodetic measurements. VLBI can give a critical contribution to GGOS by its relation to a quasi-inertial celestial reference frame and its unique ability to measure long-term UT1-UTC and precession/nutation. One of the IVS main tasks in 2010 was to continue its contribution as an efficient partner within GGOS. Several GGOS events were attended in 2010 with presentations about the IVS and its next generation VLBI2010 system; the IVS is well represented in the GGOS Steering Committee.

VLBI2010 and the VLBI2010 Committee (V2C)

In recent years the IVS has developed the concept and specifications of a next generation VLBI system called VLBI2010. The goals of the new system are to achieve (on scales up to the size of the Earth):

- 1 mm position accuracy,
- 0.1 mm/yr velocity accuracy,
- continuous observations, and
- results available in near real-time.

The VLBI2010 Committee (V2C), chaired by Bill Petrachenko, was established in 2005. It is tasked with promoting the goals set by the VLBI2010 Report released by the IVS Working Group 3 "VLBI2010: Current and Future Requirements for Geodetic VLBI Systems." All results have been summarized in the excellent VLBI2010 Progress Report with recommendations that can be used as benchmark for new VLBI systems. Since the VLBI2010 Progress Report was finalized in spring 2009 and put on the IVS Web site (ftp://ivscc.gsfc.nasa.gov/pub/misc/V2C/TM-2009-214180.pdf) the V2C activities have continued with a lot of further simulations and technical studies. I would like to thank all members of the V2C for taking over the responsible leading role in the realization of the VLBI2010 visions.

VLBI2010 is supposed to provide not only the visions but also very detailed specifications for future VLBI systems. Right now several countries have already decided to develop or purchase new VLBI systems. We highly appreciate that Geoscience Australia (GA), Australia; Auckland University of Technology (AUT), New Zealand; Korea Astronomy & Space Science Institute (KASI) and National Geographic Information Institute (NGII), Korea; the NASA Goddard Space Flight Center (GSFC), USA;

the Norwegian Mapping Agency (NMA); the Bundesamt für Kartographie und Geodäsie (BKG), Germany; Instituto Geográfico Nacional (IGN), Spain together with the Regional Government of the Azores, Portugal; and the National Astronomy and Ionosphere Center (NAIC), operated by Cornell University at Arecibo, Puerto Rico, started or continued their activities to implement new telescopes of the VLBI2010 type. I would like to congratulate them on the ambitious projects and wish them success for the realization in the next years. Thus, already now twelve VLBI2010 antennas have been approved with more proposals under consideration or even in review in countries like Russia, Finland, France, Saudi Arabia, and Sweden. With new antennas and the expected re-opening of the Fairbanks radio telescope, the global coverage of geodetic VLBI is getting better, but it is still far from being optimal, in particular more VLBI sites in the southern hemisphere would be more than welcome.

After providing the detailed description of the VLBI2010 concept the current task for the IVS is its realization. To support the implementation of VLBI2010 and to actively contact governmental entities and funding organizations the VLBI2010 Project Executive Group (V2PEG) under the leadership of Hayo Hase, which was established in March 2009, continued its activities in 2010. Several letters of support were sent to government bodies and funding agencies all over the world and a so-called station survey was sent to the IVS network stations in December 2010. Based on this questionnaire very useful information was obtained about the status of the planning process concerning the transition to VLBI2010 at the various observing stations.

IVS Working Group 4 on "VLBI Data Structures"

The IVS Working Group on "VLBI Data Structures" established in September 2007 is a response to the strong need of new, common VLBI data structures. This Working Group examines the data structure currently used in VLBI data processing and investigates what data structure is likely to be needed in the future. It designs a data structure that meets current and anticipated future requirements including a cataloging, archiving, and distribution system. Further, it prepares the transition capability through conversion of the current data structure as well as cataloging and archiving softwares to the new VLBI2010 system. The chair of Working Group 4, John Gipson, gave a presentation about the new format, which is based on the Network Common Data Format (NetCDF), at the IVS General Meeting in Hobart. The final release of the new format is scheduled for 2011.

IVS Working Group 5 on "Space Science Applications"

The current mandate of the WG5, chaired by Leonid Gurvits, comprises the following tasks:

1. To investigate synergies in scientific and technological areas between the IVS core activities and VLBI experiments in application to planetary and space science missions.
2. To determine areas of VLBI support of planetary and space science missions where experiments conducted by the IVS (possibly together with other VLBI networks) can be mutually beneficial.
3. To investigate desirability and feasibility of establishing a mission-specific liaison between IVS and appropriate space agencies and organizations involved in planetary and space science missions.

IVS Working Group 6 on "VLBI Education and Training"

The IVS Directing Board established at its meeting in Bordeaux in March 2009 the Working Group 6 on "Education and Training" chaired by Rüdiger Haas. The general aim of IVS WG6 is to support education and training in the field of geodetic and astrometric VLBI, in order to pass on and maintain expertise in this field for the next generations.

The Terms of Reference of IVS WG6 are:

1. To establish contacts to education institutions in geodesy and geosciences worldwide with the aim to raise interest in geodetic VLBI among students.
2. To develop ideas for education material that can be distributed to education institutions.
3. To seek funding to organize training in form of, for instance, IVS summer schools for Master and PhD students.

Events in 2010

In February 2010, we held our sixth General Meeting in Hobart, Tasmania, Australia. In conjunction with the General Meeting, an IVS Analysis Workshop, a V2C meeting, and the 23rd Directing Board Meeting were organized. The Proceedings of the 6th IVS General Meeting have been printed already on almost 500 pages with Dirk Behrend and Karen D. Baver as editors, demonstrating that the IVS is a fast and efficient organization. I would like to thank the Local Organizing Committee, whose members were John Dickey, Karen Bradford, Jim Lovell, Richard Coleman, Christopher Watson, Simon Ellingsen, Gary Johnston, Oleg Titov, and Sergei Gulyaev for the excellent organization. I thank also the session conveners and all other individuals who contributed to the great success of the meeting. The University of Tasmania is deeply acknowledged for providing the meeting facilities and for the great hospitality we received from the Australian colleagues. A special highlight was certainly the official dedication ceremony of the 12-m AuScope antenna held at Hobart station. The memorable inauguration done by the Governor of Tasmania, His Excellency, The Honourable Sir Peter Underwood, was attended by almost 200 people, VLBI specialists as well as members of the University of Tasmania and other local representatives.
On 23 October 2010, the 24th Directing Board Meeting was held in Shanghai, in connection with the Joint GGOS/IAU Workshop on Observing and Understanding Earth Rotation. I take this opportunity to thank our dear colleague and member of the Directing Board, Prof. Xiuzhong Zhang, Shanghai Astronomical Observatory, for the excellent organization and making the stay a very pleasant one.
One new IVS Operational Analysis Center (Geospatial Information Authority of Japan) and two new IVS Associate Analysis Centers were approved in 2010 (Norwegian Mapping Agency, Norway and Politecnico di Milano, Italy); one new 'Special Analysis Center for Specific Observing Sessions' SAC-SOS (Institute of Geodesy and Geophysics, Vienna, Austria), and one Observing Station (Parkes CSIRO Radio Telescope, Australia) were also accepted as new IVS components.

Summary information about all IVS events and activities is available on the IVS homepage http://ivscc.gsfc.nasa.gov and in the IVS Newsletters 26, 27, and 28. The Newsletter is an excellent means to transfer information to everybody. The editor team, Dirk Behrend, Hayo Hase, and Heidi Johnson, presented interesting and up-to-date information. They once again did an excellent job, which is highly appreciated.

The Directing Board in 2010

In 2010 the Directing Board member Kazuhiro Takashima, GSI, Japan, withdrew for personal reasons and was replaced by Shinobu Kurihara (GSI). The elections of new Directing Board members for the term 2011 to 2015 were held in December 2010. The elected representatives are:
- Networks representative: Hayo Hase, TIGO Concepción (Chile)
- Correlators and Operations Centers representative: Alessandra Bertarini, Bonn Correlator (Germany)

For the at-large positions (term 2011 to 2013), Shinobu Kurihara, Geospatial Information Authority of Japan; Fengchun Shu, Shanghai Astronomical Observatory, China; and Jesús Gómez-González, National Geographical Institute of Spain were chosen to complement the Directing Board. I am very pleased that the IVS Directing Board is well balanced in its composition with respect to global coverage, with respect to component representation, and with respect to a good mixture of experienced and young members.

IVS Highlights in the Coming Year 2011

In the week from March 28, 2011 the 20th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting will be held in Bonn (Germany) organized by Max-Planck-Institute for Radio Astronomy (MPIfR) together with the VLBI group at the Institute of Geodesy and Geoinformation (IGG) of Bonn University. It will be a great pleasure to return to the location where the first European VLBI meeting took place more than 30 years ago under the leadership of James Campbell. James will also attend the event in Bonn and tell us about the history of European VLBI.

Finally, I would like to mention the next continuous VLBI session (CONT11) that will take place in the second half of September 2011 and is anticipated to be observed on a network of 16 stations. As the CONT sessions have always shown the best possible performance of international VLBI and provided the most interesting and valuable results we expect another bunch of extremely useful VLBI data. It should also be mentioned here that a special issue of Journal of Geodesy about the scientific usage of CONT08 data is in preparation and will be published soon.

IVS Coordination

IVS Coordination

Coordinating Center Report

Dirk Behrend

Abstract

This report summarizes the activities of the IVS Coordinating Center during the year 2010 and forecasts activities planned for the year 2011.

1. Coordinating Center Operation

The IVS Coordinating Center is based at the 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 the 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 2010

During the period from January through December 2010, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated, with local committees, two IVS Directing Board meetings, in Hobart, Tasmania, Australia (February 2010) and Shanghai, China (October 2010). Notes from each meeting were published on the IVS Web site.
- Communications support: Maintained the Web pages, e-mail lists, and Web-based mail archive files. Included analysis reports on the 24-hour session Web pages. Maintained Intensive session Web pages.
- Publications: Published the 2009 Annual Report in summer 2010. Published three editions of the IVS Newsletter in April, August, and December, 2010. All publications are available electronically as well as in print form.
- Observing Program Committee (OPC): Coordinated meetings of the OPC to monitor the observing program, review problems and issues, and discuss changes.
- 2010 Master Schedule: Generated and maintained the master observing schedule for 2010. Coordinated VLBI resources for observing time, correlator usage, and disk modules. Coordinated the usage of Mark 5 systems at IVS stations and efficient deployment of disk modules.
- 2011 Master Schedule: Generated the proposed master schedule for 2011 and received approval from the Observing Program Committee.
- VLBI2010: Supported the activities of the VLBI2010 Committee (V2C) and the VLBI2010 Project Executive Group (V2PEG). Coordinated the program of the VLBI2010 Developers and Analysis meeting in Hobart.

- Meetings: Coordinated, with the Local Committee, the sixth IVS General Meeting, held in Hobart, Tasmania, Australia in February 2010. Chaired the Program Committee for the meeting.

Figure 1. Inauguration event of the Hobart 12-m antenna during the sixth IVS General Meeting.

Assisted with the organization of the workshop “VLBI and GNSS: New Zealand and Australian Perspectives” held in Auckland, New Zealand. Served on the Scientific Organizing Committee of the workshop.

Figure 2. Participants of the workshop “VLBI and GNSS: New Zealand and Australian Perspectives” at Auckland University of Technology.

3. Staff

The staff of the Coordinating Center is drawn from individuals who work at Goddard. The staff and their responsibilities are listed in Table 1.

Table 1. IVS Coordinating Center staff.

Name	Title	Responsibilities
Dirk Behrend	Director	Web site and e-mail system maintenance, Directing Board support, meetings, publications, session Web page monitoring
Cynthia Thomas	Operation Manager	Master schedules (current year), resource management and monitoring, meeting and travel support, special sessions
Frank Gomez	Web Manager	Web server administration, mail system maintenance, Data Center support, session processing scripts, mirror site liaison
Karen Baver	General Programmer and Editor	Publication processing programs, LaTeX support and editing, session Web page support and scripts

4. Plans for 2011

The Coordinating Center plans for 2011 include the following:

- Maintain IVS Web site and e-mail system.
- Publish the 2010 Annual Report (this volume).
- Coordinate, with the local committee, the sixth IVS Technical Operations Workshop to be held at MIT Haystack Observatory in May 2011.
- Support Directing Board meetings in 2011.
- Coordinate the 2011 master observing schedules and IVS resources.
- Publish Newsletter issues in April, August, and December.
- Support the VLBI2010 activities of the V2C and the V2PEG.

Analysis Coordinator Report

A. Nothnagel, S. Tesmer née Böckmann, T. Artz

Abstract

IVS 2010 analysis coordination issues that may also cause noticeable impacts for the future are reported here. Routine Earth orientation parameter combinations on the basis of datum-free normal equations were transfered to the IVS Combination Center at BKG, Frankfurt a.M., Germany.

1. General Issues

The "Eleventh IVS Analysis Workshop" was hosted by the University of Tasmania, School of Mathematics and Physics, Hobart, Australia, on February 11, 2010, in connection with the Sixth IVS General Meeting. The coordination of IVS routine data analysis was discussed as well as developments for improving geodetic and astrometric data analysis in general.

The timeliness of the submission of the SINEX files from the operational IVS Analysis Centers to the IVS Data Centers has remained an issue of constant annoyance. The reason is that the combination process has to wait until at least four centers have submitted their results. The irregular composition of contributions generates an additional component of noise to the combined products. At the same time, the IERS Earth Orientation Product Center and the IERS Rapid Service and Prediction Center are delayed in including the VLBI results in their combinations as well. This leads to a constant downweighting of the IVS products in the IERS combinations.

During the Analysis Workshop, it was shown that the treatment of the subdaily tidal Earth rotation parameter variations and the introduction of harmonic site position variations may generate alias effects in the daily EOP time series. Especially the pole rates and the nutation components are affected by model differences by up to 100 μas/d and 50 μas, respectively. The Analysis Coordinator emphasized that the Analysis Centers should strictly follow the IERS Conventions including Tab. 5.1 in their routine EOP determinations.

A number of tests have been carried out to support endeavors to achieve suitability of analysis packages and their results for the combination. Furthermore, the implementations of the Vienna Mapping Function 1 (VMF1) in Calc/Solve by GSFC and BKG have been tested and compared.

2. IVS Operational Data Analysis and Combination

From October 1, 2009, the operational combination has been taken over by the IVS Combination Center at the German Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt a.M. (see separate report by BKG/DGFI). The input to these combinations are datum-free (constraint-free) normal equation systems in SINEX format (Solution Independent Exchange format). The transition from the nutation representation in the ecliptic system through nutation in longitude $\mathrm{d}\psi$ and obliquity $\mathrm{d}\varepsilon$ to the nutation representation in the IAU2000 paradigm, $\mathrm{d}X$ and $\mathrm{d}Y$, has been realized successfully in most of the analysis software packages. Therefore, the combination is now solely based on this new representation. For users of the old system, a separate table is generated through a transformation.

The next steps of combination, in particular with respect to future computations of the International Terrestrial Reference Frame (ITRF), are planned to also include the elements for the radio source positions in the normal equation systems. All software developers have been informed by the Analysis Coordinator that this step is imminent.

3. UT1 Intensive Sessions

At present, the results of the 1h UT1-UTC Intensive sessions are reported by the analysis centers in the IVS EOP exchange format (for more details see IVS Analysis Coordinator's Web page). Due to a lack of resources, a combination of the Intensive results is not foreseen in the near future. However, the individual results are still very valuable since they have been used by various agencies for further processing. In order to make optimal use of these results, it is necessary to also report the polar motion a prioris in the result files (eopi files). All analysts dealing with the analysis of Intensive sessions are kindly asked to also report their polar motion a prioris in the respective files.

In the not too distant future, all of the Intensive observing sessions will be operated in an e-VLBI mode for the transmission of the raw data. This is already the case for the INT2 and INT3 sessions. With this in place, the latency between observations and data analysis will be as short as a few hours only. At this time, some of the necessary auxiliary data like polar motion or mapping functions from numerical weather models, like VMF1, will not yet be available and will have to be replaced by predictions. Therefore, the initial results can only be considered as being preliminary, and a mechanism of UT1 products with staggered latencies and accuracies will have to be introduced. For the purpose of developing a plan for a properly organized setup, a 'Task Force on Intensives' was established under the lead of Rüdiger Haas.

4. Thermal Expansion of Radio Telescopes

Further details of radio telecopes have been collected in the antenna-info file under the url http://vlbi.geod.uni-bonn.de/IVS-AC/Conventions. The background of the thermal expansion models is described in [1].

5. Personnel

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

Axel Nothnagel	+49-228-733574	nothnagel@uni-bonn.de
Thomas Artz	+49-228-733563	thomas.artz@uni-bonn.de
Sarah Tesmer née Böckmann	+49-228-733563	boeckmann@uni-bonn.de (until Dec. 15, 2010)

References

[1] Nothnagel A. (2009) Conventions on thermal expansion modelling of radio telescopes for geodetic and astrometric VLBI. J. Geod 83(8):787–792, doi:10.1007/s00190-008-0284-z

Network Coordinator Report

Ed Himwich

Abstract

A brief report on network performance is presented. Most of network operations went well. Some positive developments are identified. There were a few significant problems, mostly with antennas. New antennas have been or are being built by Australia, New Zealand, and the USA. There are prospects for Korea, India, and Saudi Arabia to start contributing to IVS.

1. Network Performance

The overall network performance was for the most part good. This year's report does not include the usual detailed assessment of overall network performance. However, the usual average single station loss of 10-20% probably occurred again this year.

One of several positive developments this year was the increased usage of e-transfer. This speeds data transfer and reduces shipping costs. Another positive development was that Mark 5B recorders were installed at several stations. This will improve correlator efficiency. A third development is that digital back-ends are starting to be used for operations. The DBBC developed by the EVN is being used at Hobart in Australia (which in another positive development has just started observing) and will be used at Katherine and Yarragadee as well and in New Zealand. The Haystack/NRAO developed RDBE is nearing readiness for observations and is expected to start being used in 2011.

Overall, while the network operated well for the most part, there are a few notable issues (in alphabetical order):

- Fortaleza was down with antenna problems the whole year. They are expected to begin observing again in spring 2011.
- Kokee Park is operating on a single (damaged) azimuth gearbox while the other one is repaired. The repair is expected to be completed in 2011, and then the other azimuth gearbox will be repaired.
- The HartRAO 26-m antenna started observing again in August after being off-line almost two years due to a bearing problem.
- Matera had a warm X-band receiver all year. It is expected to be repaired in spring 2011.
- The receiver at Medicina warmed up in November. It is not clear when it will be repaired.
- Noto suffered a bearing failure and was unable to observe from April onward. Repair is expected to be completed no sooner than fall 2011.
- Ny-Ålesund has had higher than normal SEFDs since about May 2011. The cause of this is being investigated.
- The O'Higgins burst had to be canceled due to illness.
- TIGO had been having a significant number of quality factor zero scans. This was traced to a source modeling problem on baselines involving TIGO in the scheduling process, and the problem was corrected. TIGO has for several years had higher than normal SEFDs. There has been no success in resolving this issue.

- Svetloe has antenna problems dating from the previous year but began observing again in July.
- The Tsukuba antenna was damaged by a lightning strike and missed observing from approximately August through September.
- Wettzell required antenna repairs, and they were out of operation from September through November. They also had a reduced observing load for the months of April through August while waiting for the repairs.

2. New Stations

There are prospects for new stations on several fronts. These include (in approximate order of how soon they will start regular observations):

- In Australia, the new 12-m antenna at Hobart has been completed and started initial observations. New antennas at Katherine and Yarragadee are under construction. It is expected that all three of these antennas will be contributing to IVS in 2011.
- In New Zealand, the station at Warkworth has its antenna in place. It is expected that this antenna will start observing for IVS in 2011.
- At GSFC in the USA, a new 12-m antenna has been erected and is undergoing testing. While this antenna is primarily for use in the development of the VLBI2010 systems, it is expected that it will eventually join the network for regular observing.
- At Arecibo in Puerto Rico a new 12-m antenna has been erected and is expected to be used for geodetic observing.
- At Wettzell in Germany, construction of the new Twin Telescope Wettzell (TTW) for VLBI2010 is underway.
- In Spain/Portugal, the RAEGE (Atlantic Network of Geodynamical and Space Stations) project aims to establish a network of four fundamental geodetic stations including radio telescopes that will fulfill the VLBI2010 specifications: Yebes (1), Canary Islands (1), and Azores (2).
- In Norway, the Norwegian Mapping Authority (NMA) has applied for a project to establish a fundamental station at Ny-Ålesund, which will include a twin telescope of the Wettzell type.
- Onsala is also applying for funds for a twin telescope system.
- In Russia, an effort is underway to get 12-m VLBI2010 antennas at some of the QUASAR network sites.
- Korea is planning to build one antenna primarily for geodesy (Korea VLBI system for Geodesy, KVG) at Sejong with construction to be completed in 2011. There is also interest in geodetic use of the Korean VLBI Network (KVN), which will consist of three stations intended primarily for astronomy.
- There is interest in India in building a network of four telescopes that would be useful for geodesy.

- Saudi Arabia is investigating having a combined geodetic observatory, which would presumably include a VLBI antenna.
- Colombia is investigating having a combined geodetic observatory, which would presumably include a VLBI antenna.

Many of these antennas may become available for use in the next few years. Efforts are being made to ensure that these antennas will be compatible with VLBI2010.

IVS Technology Coordinator Report

Alan Whitney

Abstract

The efforts of the Technology Coordinator in 2010 include the following areas: 1) support of work to implement the new VLBI2010 system, 2) e-VLBI development, 3) continuing development of global VLBI standards, and 4) DiFX software correlator for geodetic VLBI. We will briefly describe each of these activities.

1. VLBI2010 Progress

Progress continues towards the goal of a next-generation VLBI2010 system. Much more detailed information about VLBI2010 development is presented elsewhere in this report; here we briefly report some of the highlights:

1.1. Development of the VLBI2010 Broadband System

The VLBI2010 system continues to develop at several locations:

1. Completion and demonstration at Haystack of an RDBE personality for geodetic VLBI observations: The current working version accepts two 512mHz IFs, channelizes each into fifteen adjacent 32mHz-wide channels using polyphase filter band (PFB) technology; the user can choose any 16 of these channels to be sent to a 10GigE data link at an aggregate rate of 2 Gbps, which is then recorded on a Mark 5C data system in Mark 5B+ data format. A version of this RDBE supporting the VDIF output format is currently under development, as well as an RDBE version capable of supporting up to four 512mHz IFs. Support for Tsys calibration is also being added to the RDBE firmware.
2. Mark 5C VLBI data system: Mark 5C is now used routinely at 2 Gbps to a single 8-disk module. Mark 5C has been successfully tested at 4 Gbps to dual 8-disk modules, and operational support software for this mode will be released in early 2011. A new SATA-module PCB backplane is being developed by Conduant that will allow 4 Gbps to be recorded to a single 8-disk module; this module will have a different module connector and will not be compatible with the current Mark 5 systems.
3. Development of firmware for the FILA10G board for the dBBC continues at MPIfR. This board is installed in the dBBC developed by Gino Tuccari to support 10GigE output to Mark 5C or other similar VLBI data recording systems.
4. The new ‘Eleven’ broadband feed for VLBI2010 developed at Chalmers University in Sweden has been successfully tested between the 18-m antenna at Westford Observatory and the 5-m antenna at NASA/GSFC. Another broadband feed concept, developed at Caltech and called ‘QRFH’, has recently been tested and is being considered.
5. A new 12-m antenna from Patriot Antenna Systems has been installed at NASA/GSFC in Maryland and will be commissioned in early 2011. Installation of two new 13-m VLBI2010 antennas is underway at Wettzell.

6. A number of VLBI2010 data-taking sessions between Westford and NASA/GSFC were undertaken during 2010. Most were recorded onto four Mark 5B+ units at each station using older DBE1 backend units as data sources, at an aggregate data rate of 8 Gbps/station. Late in 2010, a successful experiment using a prototype RDBE and Mark 5C was conducted. Most data were processed on the Mark IV correlator at Haystack Observatory, though successful correlations have also been performed on the DiFX software correlator at Haystack Observatory.

2. e-VLBI Development

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

MPIfR continues regular e-VLBI transfers of data for which the Bonn correlator is the correlation target. This includes data from Japan, Onsala, Ny-Ålesund, and Wettzell. All data recorded on K5 systems at Tsukuba and Kashima are transferred either to MPIfR or Haystack depending on the target correlator. Syowa K5 data are physically shipped to Japan and electronically transferred to Haystack or MPIfR. UT1 Intensive data from Wettzell, Japan, and Ny-Ålesund are transferred to either MPIfR or the Washington correlator. Welcome news! After a long and tortured process, the Kokee station was finally connected to the world at 100 Mbps. This connection is helping to lower the processing latency for time-critical UT1 data from days to hours. Efforts are underway to significantly increase the data-rate capability to support higher-bandwidth observations and still lower latencies.

2.2. 9th International e-VLBI Workshop Held at Perth, Australia

The 9th International e-VLBI Workshop was held 18-20 October 2010 in Perth, Australia, hosted by the International Centre for Radio Astronomy Research (ICRAR) and Curtin University. The workshop was attended by more than 50 participants from 10 countries.

The focus of the meeting was "e-VLBI and the Path to the Square Kilometre Array." Within this context, e-VLBI has a lot to offer as a pathfinder technology for the proposed SKA telescope, and the presentations from both the e-VLBI and the SKA communities made for a particularly interesting forum. The workshop was three days in duration, with the first two days dedicated to scientific and technical presentations. The third day was a networking forum for representatives of networking organizations and scientists to discuss current and future trends in high-speed data transport and relevance to e-VLBI and the SKA.

Many presentations from the Perth workshop are available on-line at

http://cira.ivec.org/dokuwiki/doku.php/events/evlbi2010/start

The 10th International e-VLBI Workshop will be held in South Africa in Q3 2011.

3. Global VLBI Standards

3.1. VLBI Standards Web site Established

http://www.vlbi.org has been established as a one-stop shop for access to global VLBI standards. These include VEX, VSI-H, VSI-S, VDIF, and standardized VLBI file-naming conventions. As new standards emerge, they will also be included in this Web site.

Figure 1. Attendees at the 9th International e-VLBI Workshop held in Perth, Australia.

3.2. VDIF Data Format

Adoption of the VLBI Data Interchange Format (VDIF), ratified in 2008 at the Madrid e-VLBI workshop, continues to accelerate. The VLBI2010 project has adopted VDIF as the standard data format, and work is proceeding to fully implement it. Several other data systems now in development have also embraced the VDIF format, and VDIF is now moving strongly into the astronomical world as well. Broad adoption of VDIF across various VLBI disciplines will allow for more standardization and inter-operational capabilities that will benefit all of VLBI.

The VDIF specification is available at *http://www.vlbi.org*. A VTP Task Force, led by Chris Phillips of ATNF, has been appointed to lead the development of the second half of this standardization effort, which is now on-going. The members of the VTP Task Force are Richard Hughes-Jones, Mark Kettenis, Chris Phillips (chair), Mamoru Sekido, and Alan Whitney.

3.3. VEX2 Task Force Continues Work

The VEX file format is a standardized method to prescribe a complete description of a VLBI experiment, including setup, scheduling, data-taking and correlation, independent of any particular VLBI data-acquisition system or correlator. VEX has gained broad acceptance and is used to support a large fraction of global VLBI observations, but needs updating as new technologies and equipment become available. The VEX2 Task Force was created in late 2009 to undertake this job. The members of the VEX2 Task Force are Walter Brisken (NRAO, chair), Ed Himwich (NASA/GSFC), Mark Kettenis (JIVE), Cormac Reynolds (Curtin University), and Alan Whitney (MIT Haystack). This group continues working to craft the needed VEX updates and to incorporate them into several VLBI-support software packages.

4. DiFX Software Correlator for Geodetic VLBI

The so-called DiFX software correlator was originally developed at Swinburne University in Australia by Adam Deller, primarily for astronomical VLBI use. The development of an economical and powerful software correlator, a dream less than a decade ago, has been made possible by the relentless march of Moore's Law to provide powerful inexpensive clustered PCs with high-speed data interconnections that can distribute and correlate VLBI data in an efficient manner. Since the original DiFX development several years ago, the use of the DiFX correlator has spread, and a global DiFX user group has been formed to coordinate continued improvements and additions. Several institutions that support geodetic VLBI correlation processing now have DiFX correlators (MPIfR, USNO, Haystack Observatory) and have been working to augment the core DiFX software to meet the needs of geodetic VLBI. This includes the integration of much of the Mark IV correlator software involving data management, output data formats, fringe finding and delay estimates, and editing/quality-assurance software. In addition, a substantial amount of work has been done to integrate accurate multi-tone phase-calibration processing into the DiFX correlator, a task that is often not important for astronomical VLBI. Progress towards developing the necessary additions and improvements to DiFX for geodetic VLBI has been rapid, allowing the DiFX correlator to take over the job of current hardware correlators. MPIfR closed its Mark IV hardware correlator at the end of CY2010. Haystack Observatory is planning to phase out its Mark IV correlator by the end of 2011, with USNO likely to follow soon thereafter.

Network Stations

Network Stations

Fortaleza Station: 2010 Status and Antenna Repair

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

Abstract

This is a brief report about the activities carried out at the Fortaleza geodetic VLBI station (ROEN: Rádio Observatório Espacial do Nordeste), located in Eusébio, CE, Brazil, during the period from January 2010 until January 2011. The main activities concentrated on the repair of the antenna azimuth bearing and are described in detail in this report. They were successfully finalized on January 29, 2011. Regular GPS observations and new tests of the high speed network for e-transfers for e-VLBI were also performed in the period.

1. General Information

The Rádio Observatório Espacial do Nordeste, ROEN, located at INPE facilities in Eusébio, nearly 30 km east of Fortaleza, Ceará State, Brazil, began operations in 1993. Geodetic VLBI and GPS observations are carried out regularly, as contributions to international programs and networks. ROEN is part of the Brazilian space geodesy program, which was initially conducted by CRAAE (a consortium of the Brazilian institutions Mackenzie, INPE, USP, and UNICAMP) in the early 1990s. The program began with erecting antenna and instrumental facilities, with activities sponsored by the U.S. agency NOAA and the Brazilian Ministry of Science and Technology's FINEP agency. ROEN is currently coordinated by CRAAM, Center of Radio Astronomy and Astrophysics, Engineering School, Mackenzie Presbyterian University, São Paulo, in agreement with the Brazilian National Space Research Institute, INPE. The activities are currently carried out under an Agreement of Cooperation signed between NASA—representing research interests of NOAA and USNO—and the Brazilian Space Agency, AEB. Under the auspices of the NASA-AEB Agreement, a contract was signed between NASA and CRAAM, Mackenzie Presbyterian Institute and University to partially support the activities at ROEN. The contract was extended until 2014. The counterpart of the operational costs, staff, and support of infrastructure are provided by INPE and by Mackenzie.

2. Main Instruments

The largest instrument at ROEN is the 14.2-m radio telescope, on an alt-azimuth positioner. It is operated at S- and X-bands, using cryogenic radiometers. The system is controlled by the Field System, Version 9.9.2. Observations are recorded with a Mark 5 system. One Sigma-Tau hydrogen maser clock standard is operated at ROEN. GPS monitoring is performed within a cooperative program with NOAA (USA). There is a Leica System 1200 installed at the station that operates continuously. The collected data are provided to the NOAA/IGS center and to the Brazilian IBGE center. ROEN has all basic infrastructures for mechanical, electrical, and electronic maintenance of the facilities.

3. Staff

The Brazilian space geodesy program is coordinated by one of the authors (PK), who is Brazil's AEB representative in the NASA-AEB Agreement. The coordination receives support from the

São Paulo office at CRAAM/Instituto and Universidade Presbiteriana Mackenzie, with administrative support from Valdomiro S. Pereira and Lucíola Russo. e-VLBI connectivity tests have been conducted with the assistance of Dr. C. Guillermo Gimenez de Castro, of Mackenzie. The Fortaleza Station facilities and geodetic VLBI and GPS operations are managed on site by Dr. A. M. P. de Lucena (CRAAE/INPE), assisted by Eng. Adeildo Sombra da Silva (CRAAE/Mackenzie), and the technicians Avicena Filho (CRAAE/INPE) and Carlos Fabiano B. Moreira (CRAAE/Mackenzie).

4. Current Status and Activities

4.1. Operational and Maintenance Activities

The summary of activities performed in the period is listed below:

1) Contracting and supervising services for the update of the cryogenic system;

2) Operation and maintenance of geodetic GPS (NOAA within the scope of NASA contract);

3) Review and update of all technical documentation of the observatory (electrical designs, tables, lists of components, etc.);

4) Realization of high speed connectivity performance tests, connection improvements, national and international, to allow e-VLBI experiments;

5) Operation and maintenance of power supply equipment at the observatory (main and diesel driven standby);

6) Procurement and technical discussion with companies and consultants to evaluate and repair the antenna azimuth bearings;

7) Contracting and supervising services for the antenna azimuth bearing repair (See Figures 1-6);

8) Planning and preparation of documentation needed for electrical cabling disassembly required for the azimuth drives removal;

9) Repair and maintenance of antenna brakes and antenna motor fans;

10) Hiring and supervision of the antenna painting service;

11) Refurbishment of receiver box;

12) Maintenance of the Web site (http://www.roen.inpe.br) and the local server computer.

Figure 1. Antenna ready to be lifted up from the azimuth base for bearing replacement.

Figure 2. Antenna after being moved to the side of the pedestal.

4.2. Repair of the Antenna Azimuth Bearing

When searching for companies to provide the repair services, we received proposals from four companies, each offering a different solution. The repair job was awarded to the Brazilian company Robrasa and their installation company partner Peyrani, who had presented the best and most technically consistent bid for the job. Their offer exhibited the best solution in terms of risk, cost, and benefit. The repair consisted of the fabrication of a new bearing, which was performed at the Robrasa factory in Diadema, near São Paulo, and accomplished in six months, and of the new bearing shipment to Eusébio site (the Fortaleza VLBI facility), followed by the replacement. For this, the antenna was lifted up and displaced, the old bearing was removed, the new bearing was put into place, the antenna was relocated, and checks, tests, and azimuth movements were done for final acceptance. The installation was performed over a period of twelve days. All phases were performed successfully and on schedule. A pictorial of the work steps can be found at http://200.129.55.1. A rather unique methodology was used by Robrasa. The entire antenna structure, without removal of any pieces, was separated from the tower using hydraulic jacks running on rails, leaving the azimuth area free for the work. Figures 1–6 illustrate the procedure.

Figure 3. Old bearing being removed.

Figure 4. Detail of the new bearing installed.

Figure 5. Antenna being moved back.

Figure 6. Antenna resting on its base again.

5. Future Plans

For the immediate future, plans are to reassemble the receiver antenna at the focus, redo the electrical connections, and complete the testing and necessary adjustments in order to resume geodetic VLBI observations in a time scale of 4–6 weeks.

Acknowledgements

We acknowledge the advice on the azimuth repair job received from Prof. Antonio G. de Mello, head of the Mechanics Dep. of Mackenzie's Engineering School. These activities have received partial support from NASA, within an agreement with the Brazilian Space Agency (AEB) and a contract with Mackenzie, as part of an agreement between Mackenzie and INPE.

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Irv Diegel

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 report year. The outlook lists the outstanding tasks to improve the performance of GGAO.

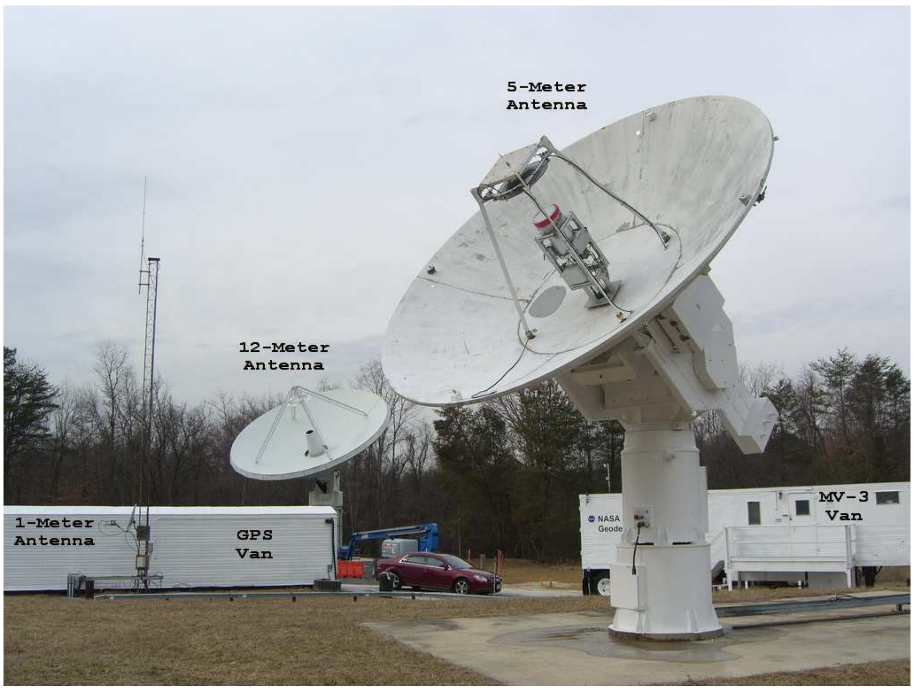


Figure 1. Goddard Geophysical and Astronomical Observatory.

1. GGAO at Goddard

The Goddard Geophysical and Astronomical Observatory (GGAO) consists of a 5-meter radio telescope for VLBI, a new 12-meter radio telescope for VLBI2010 development, a 1-meter reference antenna for microwave holography development, an SLR site that includes MOBLAS-7, the NGSLR development system, and a 48″ telescope for developmental two-color Satellite Laser Ranging, a GPS timing and development lab, a DORIS system, meteorological sensors, and a hydrogen maser. In addition, we are a fiducial IGS site with several IGS/IGSX receivers.

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

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://cddisa.gsfc.nasa.gov/ggao/vlbi.html	

2. Technical Parameters of the VLBI Radio Telescopes at GGAO

The 5-meter radio telescope for VLBI at GGAO (MV3) was originally built as a mobile or transportable station; however, it was moved to GGAO in 1991 and has been used as a fixed station since that time. In the winter of 2002 the antenna was taken off its trailer and permanently installed at GGAO.

In October of 2010, construction of the new 12-meter VLBI2010 developmental antenna was completed. This antenna features all electric drives and a Cassegrain feed system. Integration of the broadband receiver and the associated sub-systems is underway as a joint effort between HTSI and the MIT Haystack Observatory.

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

Table 2. Technical parameters of the radio telescopes at GGAO.

Parameter	5-meter	12-meter
Owner and operating agency	NASA	NASA
Year of construction	1982	2010
Diameter of main reflector d	$5m$	$12m$
Azimuth range	$+/-270°$	$+/-270°$
Azimuth velocity	$3°/s$	$5°/s$
Azimuth acceleration	$1°/s^2$	$1°/s^2$
Elevation range	$+/-90°$	$5-88°$
Elevation velocity	$3°/s$	$1.25°/s(Avg.)$
Elevation acceleration	$1°/s^2$	$1°/s^2$
Receiver System		
Focus	Cassegrain	Cassegrain
Receive Frequency	$2-14GHz$	$2-14GHz$
T_{sys}	$100\,K$	$50\,K(Theoretical)$
Bandwidth	$512MHz$, 4 bands	$512MHz$, 4 bands
G/T	$26\,dB/K$	$43\,dB/K$
VLBI terminal type	VLBI2010	VLBI2010
Recording media	Mark 5B	Mark 5B
Field System version	9.10.3	9.10.3

3. Technical Staff of the VLBI Facility at GGAO

GGAO is a NASA R&D and data collection facility, operated under contract by Honeywell Technology Solutions Incorporated (HTSI). Table 3 lists the HTSI staff that are involved in VLBI operations and development at GGAO.

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

Name	Background	Dedication	Agency
Jay Redmond	Engineering technician	100%	HTSI
Irv Diegel	Electrical Engineer	50%	HTSI
Skip Gordon	Engineering technician	20%	HTSI
Paul Christopoulos	Engineering technician	20%	HTSI

4. Status of MV3 at GGAO

Having ceased VLBI operations in May 2007, MV3 continues on a full time basis to be a major component in the program to demonstrate the feasibility of the VLBI2010 broadband delay concept. Working under the guidance of the MIT Haystack Observatory, MV3 has played a critical role in the advancement of the VLBI2010 project.

Although MV3 is still outfitted with the prototype VLBI2010 equipment installed in 2009, most of the activities at GGAO have been focused on the construction of the new VLBI2010 12-meter antenna. However, there were some other activities worth noting:

- Continuation of wideband system testing and characterization of the 5-meter antenna.
- Upgrade of the ethernet infrastructure at MV3.
- Installation of a new Field System computer.
- Installation of a thermal shutdown system to protect the backend equipment from HVAC failure.
- Procurement of new test equipment for characterization of the wideband RF hardware.
- Re-packaging of the Broadband Phase Cal unit into a temperature-controlled RF-tight enclosure with additional monitor and control capabilities.
- Support for a Small Business Innovation Research (SBIR) project to investigate and develop the use of GPS to measure large radio telescope properties. This was an effort led by NVI, Inc. with support from HTSI.
- Support for the development and implementation of a holographic imaging capability based on the VLBI2010 receiving hardware.

The holographic imaging capability is being developed by the MIT Haystack Observatory, with support from HTSI, in order to understand antenna deformations that could potentially dilute the accuracy of the VLBI2010 system. Initial holographic data collections were performed using the 5-meter dish as the antenna to be tested and a 1-meter satellite reeiving dish as the phase reference.

Preliminary results show that the imaging technique was able to faithfully reconstruct deformations in the aperture of the primary reflector. These deformations included GPS antennas mounted on the rim of the dish, an RF absorbing block, the offset feed cover, and the subreflector in the center of the primary as shown in Figure 2.

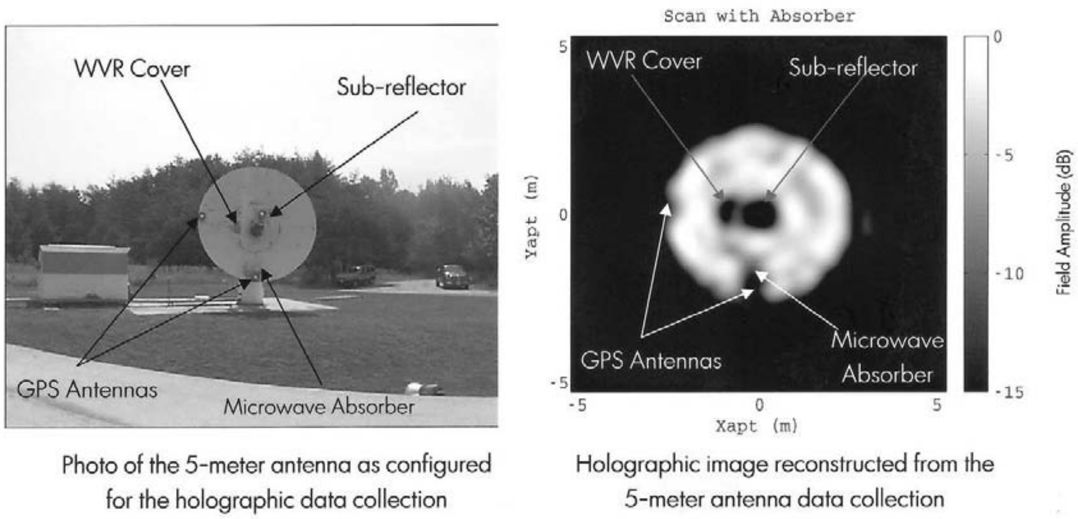


Figure 2. Holographic imaging of the 5-m antenna.

5. Outlook

GGAO will continue to support VLBI2010, e-VLBI, and other developmental activities during the upcoming year. Tentative plans for 2011 include:

- Installation of the new VLBI2010 broadband receiver system onto the 12-meter antenna.
- Short baseline ties between the 5 and 12-meter antennas.
- Continued testing of the new broadband phase calibrator for the VLBI2010 system.
- Installation of the new RDBE and Mark 5C, enabling data recording at 4 Gbps.
- Installation of a new Sigma Tau maser in the MV3 trailer.
- Continue holographic imaging of the 5 and 12-meter antennas.
- Continue broadband observations and testing of the VLBI2010 system.

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck, Michael Gaylard, Jonathan Quick, Marisa Nickola

Abstract

HartRAO provides the only fiducial geodetic site in Africa, and it participates in global networks for VLBI, GNSS, SLR, and DORIS (located at the adjoining Satellite Application Centre). This report provides an overview of the resumption of geodetic VLBI activities on the 11th of August 2010 after the repair of the 26-m radio telescope.

1. Geodetic VLBI at HartRAO

Hartebeesthoek is located 65 kilometers northwest of Johannesburg, just inside the provincial boundary of Gauteng, South Africa. The nearest town, Krugersdorp, is 32 km distant. The telescope is situated in an isolated valley which affords protection from terrestrial radio frequency interference. HartRAO uses a 26-meter equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The telescope was part of the NASA deep space tracking network until 1974 when the facility was converted to an astronomical observatory. The telescope is co-located with an ILRS SLR station (MOBLAS-6), an IGS GNSS station (HRAO), and an IDS DORIS station (HBMB) at the adjoining Satellite Application Centre (SAC) site.

Figure 1. The 26-m drives again: on the 20th of July 2010 at 10h35 SAST the HartRAO 26-m telescope was driven for the first time since the 3rd of October 2008's breakdown due to the failure of the south polar bearing.

2. Technical Parameters of the 26-m Telescope of HartRAO

Table 1 contains the technical parameters of the HartRAO radio telescope and the Karoo Array Telescope (KAT) prototype, XDM (eXperimental Development Model), while Table 2 contains technical parameters of the HartRAO 26-m radio telescope's receivers. The data acquisition system consists of a Mark IV terminal and a Mark 5A recorder.

Table 1. Antenna parameters.

Parameter	**HartRAO-26 m**	**KAT 15-m XDM**
Owner and operating agency	HartRAO	HartRAO
Year of construction	1961	2007
Radio telescope mount	Offset equatorial	Az-El
Receiving feed	Cassegrain	Prime focus
Diameter of main reflector d	$25.914\,m$	$15\,m$
Focal length f	$10.886\,m$	$7.5\,m$
Focal ratio f/d	0.424	0.5
Surface error of reflector	$0.5\,mm$	$\sim 2.5\,mm$
Short wavelength limit	$1.3\,cm$	$2\,cm$
Pointing resolution	0.001°	0.001°
Pointing repeatability	0.004°	not tested
Slew rate on each axis	HA: $0.5^\circ\ s^{-1}$	Az: $2^\circ\ s^{-1}$
	Dec: $0.5^\circ\ s^{-1}$	El: $1^\circ\ s^{-1}$

Table 2. 26-m receiver parameters with dichroic reflector (DR), used for simultaneous S-X VLBI, off or on.

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

3. Staff Members Involved in VLBI

Table 3 lists the HartRAO station staff who are involved in geodetic VLBI. Jonathan Quick (VLBI friend) provides technical support for the Field System as well as for hardware problems.

Table 3. Staff supporting geodetic VLBI at HartRAO.

Name	Function	Program
Ludwig Combrinck	Program Leader	Geodesy
Jonathan Quick	Hardware/Software	Astronomy
Jacques Grobler	Operator	Technical
Lerato Masongwa	Operator	Technical
Marisa Nickola	Logistics/Operations	Geodesy
Pieter Stronkhorst	Operator	Technical

4. Current Status

On the 3rd of October 2008 the HartRAO 26-m radio telescope suffered a critical failure of its south polar shaft bearing, bringing all observing to a halt and thereby any further participation in geodetic VLBI sessions.

The bearing is located on the main polar drive shaft, which carries the 26-m's 200-tonne moving structure. General Dynamics was contracted to replace the failed bearing. An A-frame jacking support had to be constructed to hold up the telescope structure above the polar shaft in order to replace the bearing. On the 23rd of March 2010 groundbreaking for the erection of the A-frame took place, and on the 30th of June the telescope structure was lifted to remove the polar shaft's south end cap. The bearing's inner race had failed, and fragments of it were still being removed over the following week. On the 15th of July the new bearing was in place, and the next day the end cap was back on and the A-frame came down.

On the 20th of July the 26-m drove again for the first time in over 21 months. The first post-repair geodetic session was the ICRF experiment, CRF60, on the 11th of August 2010. Appropriately, HartRAO's 26-m was joined again by the Hobart 26-m, the same telescope which partenered us in our last pre-repair geodetic session, the Deep South experiment, CRDS49, on the 16th of September 2008. During 2010 HartRAO participated in 18 experiments (Table 4).

Table 4. Geodetic VLBI experiments HartRAO participated in during 2010.

Experiment	Number of Sessions
R1	12
RDV	4
CRF	1
T2	1
Total	18

During the breakdown the 26-m's receivers were serviced and updated. Conversion of the 15-m XDM KAT prototype to be able to do geodetic VLBI to supplement the 26-m continued. A coaxial S/X (2.3+8.4GHz) cryogenic receiver needs to be fitted to the antenna. Prototyping has been followed by construction of the operational S/X feeds.

The first wide-band e-VLBIs linking Africa with Europe (at 1024 Mbps) and Australia (at 512 Mbps) were carried out during the latter part of 2010.

Figure 2. The new bearing is in place. (Credit: M. Gaylard)

Figure 3. Test assembly of the XDM's S/X feeds and receiver.

Figure 4. The old fragmented bearing on display in the foyer.

Figure 5. GNSS installation at Hamburg. (Credit: L. Combrinck)

5. Future Plans

With the prospect of 15 days' continuous observing during the CONT11 campaign in September 2011, the 26-m will be tested to the limit again. Conversion of the 15-m XDM (KAT prototype) for use in geodetic VLBI experiments will continue during 2011. We are looking forward to the acquisition of a Mark 5B+ recorder early in 2011.

During April 2010, a Global Navigation Satellite System (GNSS) was installed for troposphere calibration at Hamburg in the Eastern Cape. Similar GNSS installations are planned for Willowmore, also in the Eastern Cape, as well as Klerefontein in the Northern Cape during 2011. The construction of a Lunar Laser Ranger (LLR) housing is planned for early 2011.

The Space Geodesy Programme is an integrated program, combining VLBI, SLR, and GNSS, and it is active in several collaborative projects with GSFC, JPL, and GFZ (Potsdam) as well as numerous local institutes. Collaboration also includes CNES/GRGS/OCA and the ILRS community in a Lunar Laser Ranger (LLR) project with local support from the University of Pretoria and the National Laser Centre (CSIR), among others. General information as well as news and progress on Geodesy and related activities can be found at `http://geodesy.hartrao.ac.za/`.

Hobart, Mt. Pleasant Station and AuScope VLBI Project Report

Jim Lovell, John M. Dickey, Brett Reid, Simon Ellingsen, Jamie McCallum

Abstract

This is a brief report on the activities carried out at the Mt. Pleasant Radio Astronomy Observatory at Hobart, Tasmania and for the AuScope VLBI Project. During 2010, the Hobart 26-m antenna continued to make a significant contribution to IVS through participation in 70 observing sessions. The new Hobart 12-m AuScope antenna was officially opened in February and commenced operations later in the year, with 16 IVS observations. Construction of the AuScope Katherine and Yarragadee antennas was completed and fringes successfully obtained between Katherine and Hobart.

1. Introduction

The Mt. Pleasant Observatory is located about 15 km north-east of Hobart at longitude 147.5 degrees East and latitude 43 degrees South. Hobart is the capital city of Tasmania, the island state of Australia located to the south of the mainland. The station is operated by the School of Mathematics and Physics at the University of Tasmania. The station has a co-located GPS receiver and a site which is used for absolute gravity measurements.

2. Brief Description of Hobart 26-m VLBI Facilities

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

3. Staff

Staff at the observatory consist of academics, Prof. John Dickey (director), Dr. Simon Ellingsen, and Prof. Peter McCulloch who has a large input into the receiver design and implementation. Dr. Jim Lovell is Project Manager for the AuScope VLBI project. Dr. Jamie McCallum is a post-doctoral fellow and has had input into the development and implementation of AuScope-related hardware at the observatory. Mr. Tim Hoban is employed as a computer programmer for the AuScope project. Mr. Brett Reid is the Observatory Manager whose position is funded by the university. In addition we have two electronics technical officers, Mr. Eric Baynes and Mr. Brenton Jones. For operation of the observatory during geodetic observations we rely heavily on support from astronomy PhD and post graduate students.

4. Geodetic VLBI Observations

The Hobart 26-m antenna participated in 70 geodetic VLBI experiments during 2010. These were divided between the APSG (1), CRF (1), OHIG (2), R1 (38), R4 (21), RDV (2), and T2 (2), programs plus four additional TQAK observations of 3-h duration each to examine post-seismic movement at TIGO following the Chilean megaquake. All experiments were recorded using Mark 5A. During 2011 the new Hobart 12-m antenna will take up the majority of the geodetic observing with the 26-m participating in one observation per month to ensure continuity of the Hobart timeseries.

Figure 1. The three AuScope VLBI sites as of December 2010 (photos by Jim Lovell and Vince Noyes).

5. The AuScope VLBI Project

AuScope is part of the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS). It encompasses NCRIS Capability 5.13: "Structure and Evolution of the Australian Continent". An important part of this is the acquisition of three new radio telescopes and a data processing facility for geodesy. AuScope aims to provide a fundamental reference frame in Australia to 1-mm accuracy based on the locations of three radio telescopes as established by VLBI observations. Each site will also host a permanent GPS receiver to tie the telescope reference frame to a denser GPS frame of ~100 antennas across the continent. The construction and operation of the array is being managed by the University of Tasmania with data correlation supported by Curtin University of Technology.

Three 12-m diameter antennas have been supplied by Patriot Products division of Cobham Satcom. The antennas have surface accuracies of 0.3 mm RMS and slew rates of 5 deg/s in azimuth and 1.25 deg/s in elevation. Each antenna is being equipped with room temperature dual-polarization S/X receiver systems (SEFD is 3500 Jy in all bands), Vremya-ch Hydrogen maser standards, HAT-Lab DBBC samplers, and Conduant Mark 5B+ recorders. Construction of all three antennas at Hobart, Katherine (Northern Territory), and Yarragadee (Western Australia) has been completed. The Hobart 12-m antenna was officially opened on February 9, during the

Sixth IVS General Meeting, hosted by the University of Tasmania. The Hobart 12-m commenced IVS observations later in the year and participated in 16 sessions: APSG (2), CRF (1), R1 (7), and R4 (6). Installation of receiver, recording, and control equipment was completed at Katherine and first fringes detected to Hobart in December. Final installation work is scheduled for Katherine in early 2011, to be followed by Yarragadee, and both sites are expected to commence IVS observing in the first half of 2011.

Kashima 34-m Radio Telescope

Ryuichi Ichikawa, Eiji Kawai, Mamoru Sekido

Abstract

The Kashima 34-m radio telescope has been continuously operated and maintained by the National Institute of Information and Communications Technology (NICT) as a facility of the Kashima Space Research Center (KSRC) in Japan. This brief report summarizes the status of this telescope, the staff, and activities during 2010.

1. General Information

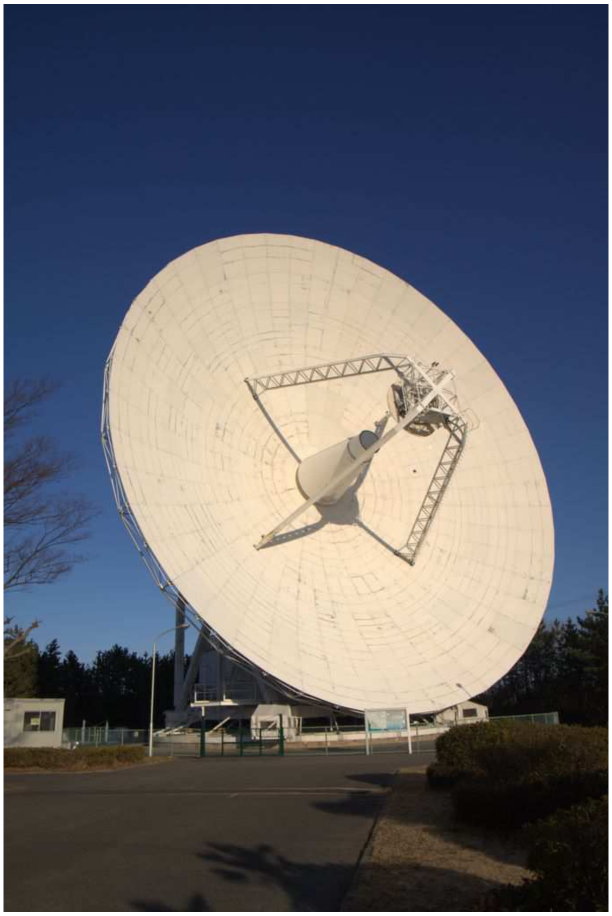
The Kashima 34-m radio telescope (Figure 1, left) was constructed as a main station of the "Western Pacific VLBI Network Project" in 1988. After that project's termination, the telescope has been used not only for geodetic experiments but also for astronomy and other purposes [1]. The station is located about 100 km east of Tokyo, Japan and is co-located with the 11-m radio telescope and the International GNSS Service station (KSMV) (Figure 1, right). The station is maintained within the Space-Time Measurement Project of the Space-Time Standards Group, NICT.

2. Component Description

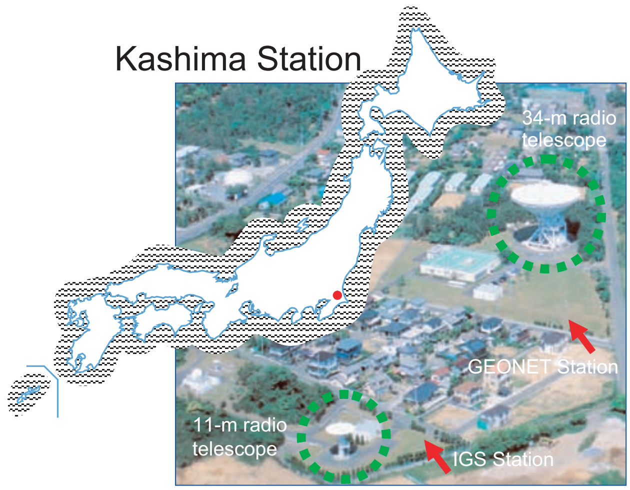
The receiver equipment of the Kashima 34-m radio telescope is summarized in Table 1 and Table 2. In particular the S-band receiver is equipped with a high-temperature superconductor (HTS) band-pass filter for RFI mitigation [2]. We also installed a band-pass filter on July 15, 2008 to cut out signals between 1405 MHz and 1435 MHz for L-band RFI mitigation.

Table 1. Main specifications of the 34-m radio telescope.

Main reflector aperture	34.073 m
Latitude	N 35° 57' 21.78"
Longitude	E 140° 39' 36.32"
Height of AZ/EL intersection above sea level	43.4 m
Height of azimuth rail above sea level	26.6 m
Antenna design	Modified Cassegrain
Mount type	AZ-EL mount
Drive range azimuth	North ±270°
Drive range elevation	7°-90°
Maximum speed azimuth	0.8°/sec
Maximum speed elevation	0.64°/sec
Maximum operation wind speed	13 m/s
Panel surface accuracy r.m.s.	0.17 mm



The Kashima 34-m radio telescope.



Facilities at Kashima.

Figure 1. The Kashima Station.

Table 2. The receiver specifications of the 34-m radio telescope.

Band	frequency (MHz)	Trx (K)	Tsys (K)	Efficiency	SEFD (Jy)	Polarization
L	1350-1750⋆	18	45	0.68	200	L/R
S	2193-2350	19	72	0.65	340	L/R
C	4600-5100	100	127	0.70	550	L(R)
X-n	8180-9080∗	41	48	0.68	210	L/R
X-wL	8180-9080#	41	67	0.68	300	L/R
X-wH	7860-8360#	-	67	0.68	300	L/R
K	22000-24000	105	141	0.5	850	L(R)
Ka	31700-33700	85	150	0.4	1100	R(L)
Q	42300-44900	180	350	0.3	3500	L(R)

∗ : 8GHz LNA narrow band use. # : 8GHz LNA wide band use.
⋆ : Narrow bandwidth filter, 1405 - 1435 MHz, is used generally to mitigate RFI.

3. Staff

The engineering and technical staff of the Kashima 34-m radio telescope are listed in Table 3. Dr. Kondo has returned to KSRC in March 2010 and is continuing the development of the K5 system. On the other hand, Dr. Sekido has temporarily moved to a government office.

Table 3. The engineering and technical staff of the Kashima 34-m radio telescope.

Name	Main Responsibilities
Eiji Kawai	responsible for operations and maintenance
Mamoru Sekido	software and reference signals
Kazuhiro Takefuji	mechanical and RF related parts
Shingo Hasegawa	K5 operation and data transfer
Ryuichi Ichikawa	responsible for the project
Yasuhiro Koyama	international e-VLBI
Tetsuro Kondo	software correlator development and e-VLBI

4. Current Status and Activities

The 34-m radio telescope is an active facility for both geodetic and radio astronomical purposes. In addition, experimental VLBI measurements for spacecraft tracking and precise time transfer have been performed over the recent years. Figure 2 shows a pie chart of the annual operation time for each purpose. The total operation time during 2010 was 1543 hours, which increased as compared to the previous year's total of 1246.5 hours. The increase of operation time of the 34-m Kashima antenna was caused mainly by filling in for the 32-m Tsukuba antenna of Geospatial Information Authority of Japan (GSI) during a necessary repair caused by a lightning damage. During this time we performed more than twenty IVS sessions including 1-hour "Intensive" dUT1 sessions.

We repaired and maintained several parts of the antenna (i.e., rustproof painting of reflector structure) between the end of May and July of 2010 in order to keep all components working.

5. Future Plans

As more than two decades have passed, the Kashima 34-m radio telescope requires continuous repairs. We are now preparing some countermeasures to maintain the antenna performance in anticipation of the new project for the next five years. Fortunately NICT headquarters supports the replacement of the AZ/EL drive units. We are going to install them in the next fiscal year.

References

[1] Kawai, E., M. Sekido, R. Ichikawa, Kashima 34-m Radio Telescope, International VLBI Service for Geodesy and Astrometry 2008 Annual Report, NASA/TP–2009-214183, D. Behrend and K. D. Baver (eds.), pp. 114–117, 2008.

[2] Kawai, E., J. Nakajima, H. Takeuchi, H. Kuboki, T. Kondo, M. Suzuki, K. Saito, RFI mitigation at a

2 GHz band by using a wide-band high-temperature superconductor filter, J. Geod. Soc. Jpn., Vol. 54, No. 1, pp. 31–37, 2008.

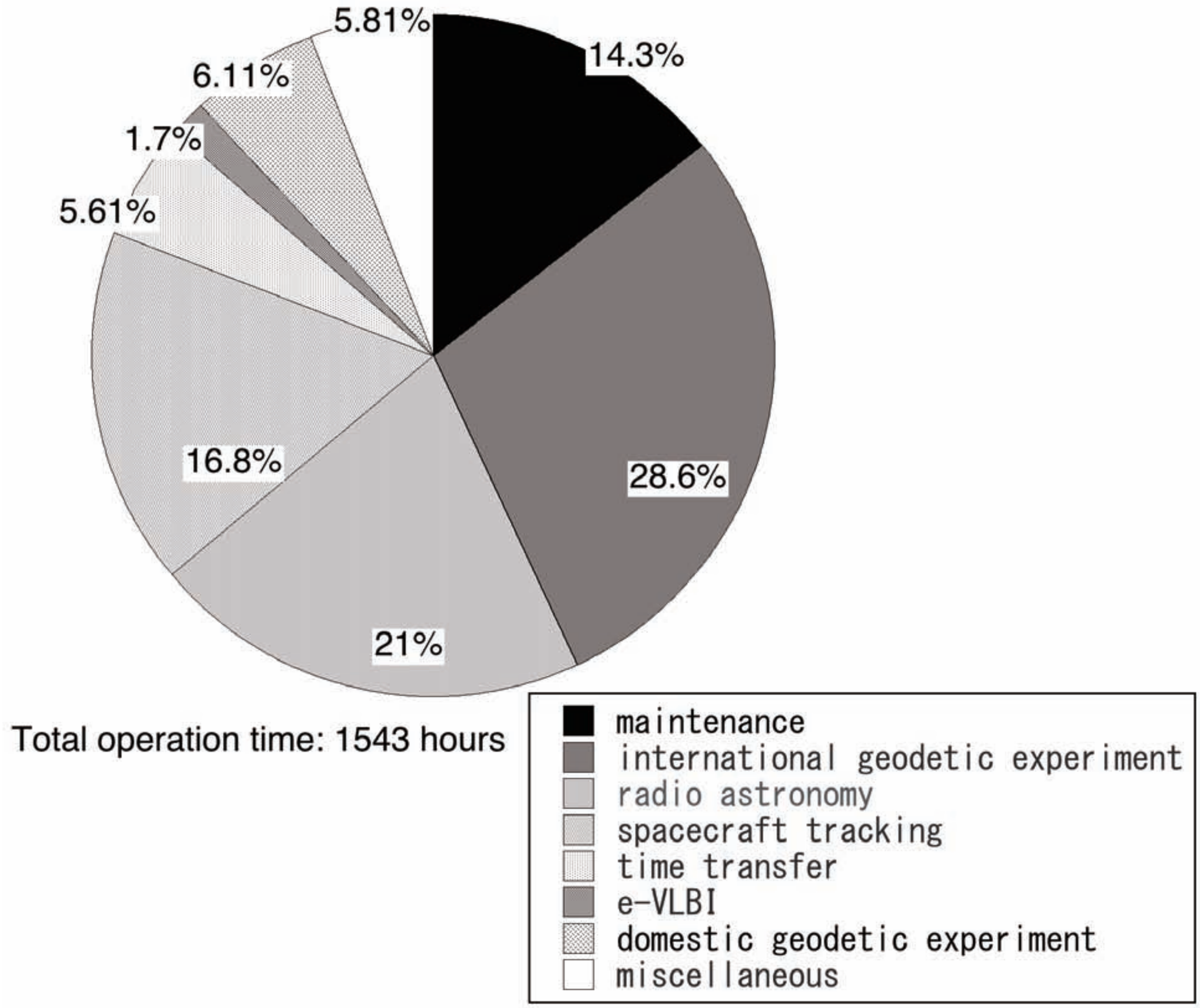


Figure 2. Statistical chart of the telescope operation time according to purpose.

Kashima and Koganei 11-m VLBI Stations

Hiroshi Takiguchi, Ryuichi Ichikawa

Abstract

Two 11-m VLBI antennas at Kashima and Koganei are continuously operated and maintained by the National Institute of Information and Communications Technology (NICT). This brief report summarizes the status of these antennas, the staff, and the activities during 2010.

1. Introduction

Figure 1. 11-m VLBI antennas at Kashima (left) and Koganei (right).

Two 11-m VLBI antennas at Kashima and Koganei (Figure 1) used to be stations of the Key Stone Project (KSP) VLBI Network. The network consisted of four VLBI stations at Kashima, Koganei, Miura, and Tateyama (Figure 2). These 11-m antennas 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 are remaining as IVS Network Stations. The KSP was a research and development project of the National Institute of Information and Communications Technology (NICT, formerly Communications Research Laboratory) [1]. After the regular VLBI sessions with the KSP VLBI Network terminated in 2001, the 11-m VLBI stations at Kashima and Koganei have mainly been used for the purposes of technical developments and miscellaneous observations.

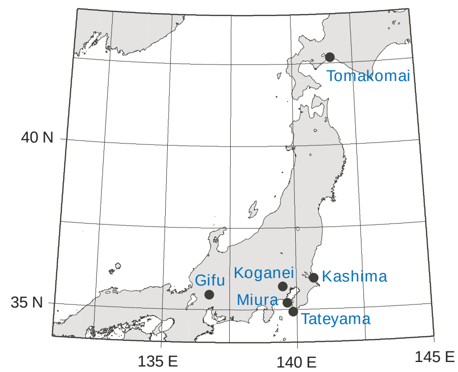


Figure 2. Geographic locations of four KSP VLBI stations and two stations at Tomakomai and Gifu.

2. Current Status

The main specifications of the antennas are summarized in Table 1. Both antennas can observe S and X-band. Originally, the specifications of these antennas were the same. However, the specifications were changed due to improvement and breakdown of equipment.

Table 1. The specifications of the KSP 11-m antennas.

		Kashima	Koganei
Antenna Type		Cassegrain type	
Diameter of the Main Reflector		11 m	
Mount Style		Az El mount	
Latitude		N 35° 57’ 20.13”	N 35° 42’ 38.01”
Longitude		E 140° 39’ 26.90”	E 139° 29’ 17.10”
Height of Az/El intersection above sea level		62.4 m	125.4 m
Input Frequency (MHz)	S band	2212 ∼ 2360	2212 ∼ 2360
	X Low band	7700 ∼ 8200	7700 ∼ 8200
	X High band	8180 ∼ 8680	8180 ∼ 8600
Local Frequency (MHz)	S band	3000	3000
	X Low band	7200	7200
	X High band	7680	7600

In 2009, we installed the radio frequency (RF) distribution system using optical fibers at Koganei to transmit the reference signal to the VLBI back end which is coherent with Universal Time, Coordinated (NICT). Therefore, the reference signal (10MHz/1PPS) at Koganei station is coherent with UTC(NICT) [2]. In November 2009, we observed the all-sky Tsys of Kashima and Koganei antennas to research the influence of radio frequency interference (RFI) signal. In X-band, we did not see the RFI signal. However, in S-band, we detected interference from the RFI signal at each station. At Kashima, we introduced a more narrow band-pass filter to reject the RFI signal in early 2010. In April 2010, we introduced another band-pass filter (2212 ∼ 2360

MHz) at both stations. Figure 3 shows the intermediate frequency (IF) spectrum at S-band (left: Kashima 11m, right: Koganei 11m). In the last annual report, we described that we changed the phase calibration (P-cal) unit from 5-MHz to 1-MHz signal. However, we changed back the P-cal unit to 5-MHz signal at both stations, because the 1-MHz P-cal unit was found out to be unstable. Additionally, we set up a precise temperature control room at the Kashima 11m observation room.

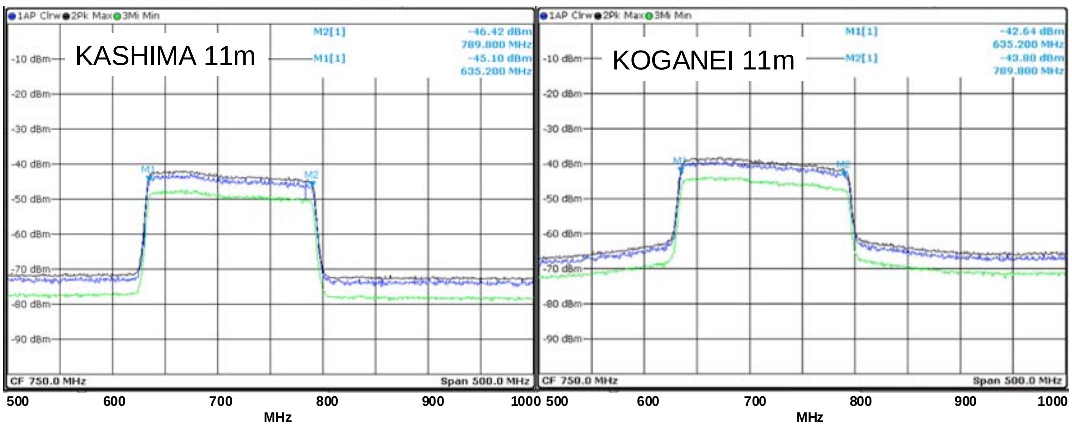


Figure 3. The IF spectrum in S-band (left: Kashima 11m, right: Koganei 11m).

3. Activities in 2010

Since 2007, we have been performing special purpose geodetic VLBI experiments between the Kashima (11-m or 34-m) and Koganei (11-m) stations to evaluate the capability of geodetic VLBI for precise time and frequency transfer. In 2010 we carried out two inter-comparison experiments (August and October) on the Kashima 11m - Koganei 11m baseline. Thereby we compared results from VLBI, GPS, TWSTFT with a DPN code and time comparison equipment (TCE) on the satellite ETS-8. For both experiments, we used two types of sampling systems named K5/VSSP32 and K5/VSI (ADS1000 and ADS3000+). About the results of these experiments, please see the NICT "Analysis Center" and "Technology Development Center" reports in this volume.

In order to verify our technical developments, experiments on Kashima-Koganei baselines have also been conducted for several purposes. These experiments include e-VLBI observations, geodetic observations using MARBLE (Multiple Antenna Radio-interferometry of Baseline Length Evaluation) system, and many others. In particular, we carried out dedicated experiments such as "RF direct sampling", "crystal clock tests for T&F", and "feeding multiple samplers (K5/VSSP32) to one PC".

Apart from the VLBI sessions, the Space Environment Group of NICT started to use the 11-m antenna at Koganei to download data from the STEREO spacecraft. Two STEREO spacecraft were launched by NASA in October 2006 to investigate the solar terrestrial environment and to provide 3D images of the Sun and solar storms. The Koganei 11-m antenna is therefore operated for this purpose when no VLBI sessions are scheduled.

4. Staff Members

The 11-m antenna stations at Kashima and Koganei are operated and maintained by the Space-Time Standards Group at Kashima Space Research Center, NICT. The staff members of the group are listed in Table 2. The operation and maintenance of the 11-m VLBI station at Koganei is also greatly supported by Space-Time Standards Group, Space Environment Group, and Space Communications Group at Koganei Headquarters of NICT. We are especially thankful to Jun Amagai and Tadahiro Gotoh for their support.

Table 2. Staff members of Space-Time Standards Group, KSRC, NICT.

Name	Main Responsibilities
KAWAI Eiji	Antenna Systems
ICHIKAWA Ryuichi	Meteorological Sensors, IGS Receivers
AMAGAI Jun	Antenna System and Timing Systems at Koganei 11m station
SEKIDO Mamoru	Field System, Calibration and Frequency Standard Systems
HASEGAWA Shingo	System Engineer

5. Future Plans

In 2011, we plan to continue precise time transfer VLBI experiments and e-VLBI developments. In addition to the VLBI observations and developments, the data downlink from the two STEREO spacecraft will be continued. Additionally, we are planning to set up the following things to improve the antenna's condition for precise time and frequency transfer VLBI experiments:

- overhaul the Hydrogen maser
- adjust the phase calibration (P-cal) unit
- develop the digital phase calibration unit

References

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

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Kokee Park Geophysical Observatory

Ron Curtis

Abstract

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

1. KPGO

The Kokee Park Geophysical Observatory (KPGO) is located in the Kokee State Park on the island of Kauai in Hawaii at an elevation of 1,100 meters near the Waimea Canyon, often referred to as the Grand Canyon of the Pacific.

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. We presently employ a Mark 5A recorder for all of our data recording.

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. Staff of the VLBI System at KPGO

The staff at Kokee Park during calendar year 2010 consisted of five people employed by Honeywell Technology Solutions, Inc. under contract to NASA for the operation and maintenance of the observatory. Matt Harms, Chris Coughlin, and Ron Curtis conducted VLBI operations and maintenance. Ben Domingo was responsible for antenna maintenance, with Amorita Apilado providing administrative, logistical, and numerous other support functions. Kelly Kim of Caelum Research Corporation also supported VLBI operations and maintenance during 24-hour experiments and as backup support.

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-Mark 5
Field System version	9.7.6

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, starting in year 2002 and continuing into 2010.

Kokee Park also hosts other systems, including a 7-m PEACESAT command and receive antenna, a DORIS beacon, a QZSS monitoring station, a TWSTFT relay station, and a Turbo-Rogue GPS receiver. Kokee Park is an IGS station.

In October of 2007, Japanese interests, along with representatives from NASA, USNO, and the

State Department, held a meeting at KPGO to explore the possible installation of a project called Quasi-Zenith Satellite System (QZSS). In 2008, further investigation continued towards making the QZSS project a part of KPGO. NASA sent an engineering team to investigate the support requirements that would be needed to implement the QZSS project here, and an engineering team from Japan surveyed the site for the hardware that would be installed. The aging KPGO infrastructure was upgraded in stages as the project progressed. In October of 2009, the power at KPGO was upgraded to support the QZSS and Two-Way Satellite Time and Frequency Transfer (TWSTFT) requirements. In March of 2010 the construction of the antenna base for the project was completed, and all components were installed and tested. In July of 2010 the TWSTFT for the project was operationally configured by USNO and NICT.

In June of 2010, the remote control capability for the DORIS beacon was installed at KPGO.

In October of 2010, two members of the Ny-Ålesund VLBI team visited KPGO for the sharing of processes and procedures on operations and maintenance.

Also, in 2008, advances were made for making real-time VLBI data from KPGO a reality. The agencies that will be responsible for the wideband pipes leading from the site entered into a service agreement late in 2008. The coordination with the parties involved in the communication infrastructure upgrades continued through 2010. While work continues towards implementing the final architecture an interim configuration has permitted some successful testing. Initially, the daily Intensive experiments are being targeted so correlation back at the Washington Correlator can happen days earlier than it previously did. 24-hour experiment data flow will hopefully follow when the final architecture is implemented. The testing of the new communication infrastructure is expected to continue in 2011.

5. Outlook

Now that we have started flowing real-time data for the daily USNO Intensive experiments in 2010, we hope to build on that start and support 24-hour experiments in (almost) real time as well in 2011. If the sustained data rate requirements cannot be met, we will need to set up a buffering system of some sort with the Mark 5 recorder.

In late 2010 work began on running fiber cable up the mountainside so the data rate needs can be fully met. The local Navy plans to provide the fiber cable when the run is completed and tested in 2011.

Plans are in progress to upgrade KPGO to Mark 5B mode in 2011.

Figure 1. KPGO VLBI 20-m antenna (right) with the old NASA USB 9-m antenna in the background.

Figure 2. QZSS antenna.

Figure 3. DORIS remote control (left foreground) and beacon (right foreground).

Figure 4. QZSS/TWSTFT equipment racks.

Matera CGS VLBI Station

Giuseppe Bianco, Giuseppe Colucci, Francesco Schiavone

Abstract

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

1. General

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

The Matera VLBI station is located at the Italian Space Agency’s ‘Centro di Geodesia Spaziale G. Colombo’ (CGS) near Matera, a small town in the south of Italy. The CGS came into operation in 1983 when the Satellite Laser Ranging SAO-1 System was installed at CGS. Fully integrated into the worldwide network, SAO-1 was in continuous operation from 1983 up to 2000, providing high precision ranging observations of several satellites. The new Matera Laser Ranging Observatory (MLRO), one of the most advanced Satellite and Lunar Laser Ranging facilities in the world, was installed in 2002 and replaced the old SLR system. CGS also hosted 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 radio telescope. Since then, Matera has performed in 869 sessions up through December 2010.

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

In 2000 we started activities with an Absolute Gravimeter (FG5-Micro-G Solutions). The gravimeter operates routinely at CGS, and it is available for external campaigns on request.

Figure 2. MLRO in action, photo courtesy of Francesco Ambrico.

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

2. Technical/Scientific Overview

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

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

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

In October 2010, the Mark 5A was replaced by a new Mark 5B+. The VSI Sampler kit was installed in place of the old Mark IV formatter.

Table 1. Matera VLBI Antenna Technical Specifications.

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

3. Staff

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

Table 2. Matera VLBI staff members.

Name	Agency	Activity	E-Mail
Dr. Giuseppe Bianco	ASI	Space Geodesy Manager	giuseppe.bianco@asi.it
Francesco Schiavone	e-geos	Operations Manager	francesco.schiavone@e-geos.it
Giuseppe Colucci	e-geos	VLBI contact	giuseppe.colucci@e-geos.it

4. Status

In 2010, 56 sessions were acquired. Figure 3 shows a summary of the total acquisitions per year, starting in 1990.

In 2004, in order to fix the existing rail problems, a complete rail replacement had been planned. In 2005, due to financial difficulties, it was instead decided that only the concrete pedestal under the existing rail would be repaired. From then on, no rail movements have been noted [1]-[3].

In April 2008, due to cracks on the surface, the AZI-1 wheel was replaced by a newly built one. In April 2009, a second wheel was replaced due to the same kind of problem.

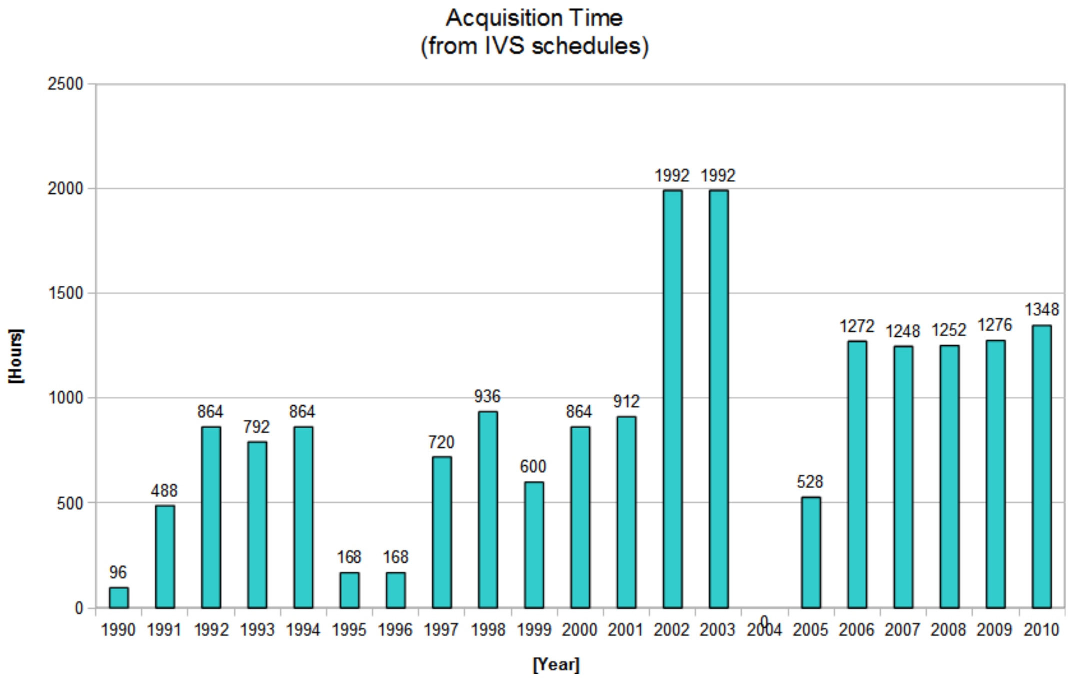

Figure 3. Acquisitions per year.

5. Outlook

In order to plan the eventual building of a VLBI2010 system, the fund raising investigation process has been started. At this moment it is not clear when the budget for starting the project will be ready.

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

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The Medicina Station Status Report

Alessandro Orfei, Andrea Orlati, Giuseppe Maccaferri, Franco Mantovani

Abstract

General information about the Medicina Radio Astronomy Station, the 32-m antenna status, and the staff in charge of VLBI observations are provided. In 2010 the data from geodetic VLBI observations were acquired using the Mark 5A recording system with good results. Updates of the hardware have been performed and are briefly described.

1. The Medicina 32-m Antenna and General Information

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

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

2. Antenna Description

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

The receivers are cooled with cryogenic techniques to improve the system sensitivity. The antenna's operative receiver is easily changed; only a few minutes are needed to change the observing frequency. A recent picture of the antenna is shown in Figure 1.

3. The Staff

Many scientists and technicians take care of the observations. However, a limited number are dedicated to maintaining and improving the reliability of the antenna during the observations: Alessandro Orfei is the Chief Engineer, expert in microwave receivers; Andrea Orlati, Software Engineer, takes care of the observing schedules and regularly implements SKED, DRUDG, and the Field System. At the end of 2010 Giuseppe Maccaferri took a one-year sabbatical period. Marco Bartolini and Simona Righini have been temporarily included in the staff helping Andrea Orlati for the VLBI preparation and observation.

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

4. Current Status and Activities

The operating system was updated to Debian Etch and kernel 2.6.18. The sdk 8.3 and StreamStorm driver version 9.20 were also installed. Switching between e-VLBI and vlbi on disk is now straightforward.

The Mark 5 has been equipped with a new 10-Gbit network card. Our disk pool for geodetic sessions is still 33 TB. No other purchases are planned by now.

As regards the receivers, the 22-GHz multifeed receiver will be no longer available in Medicina by spring 2011, when it will be sent to the SRT site. We have under construction a dual feed system as its substitute.

The S/X receiver cooling system, including the helium pipeline, needs a complete refurbishment. We are preparing the maintenance and substitution of the S/X cooling system; in the meantime the receiver will be used uncooled. INAF has procured enough money to make heavy maintenance on the 32-m antenna. It will be a long work, and we foresee we will repair the elevation wheel, paint the antenna structure, and change the subreflector drives.

The upgrade to 10 Gb/s is still work in progress, as is the creation of a 10 Gb/s POP center at Bologna Headquarters. The needed devices have been bought but not installed yet. Negotiations with a local network consortium are still the main issue. Data from EUROPE experiments have been transferred to the Bonn Correlator through the network on a regular basis since 2009.

5. Geodetic VLBI Observations

In 2010 Medicina took part in 24 (24-hour) routine geodetic sessions (namely two IVS-T2, eighteen IVS-R4, one IVS-R1, two EUROPE, and one R&D experiments).

VERA Geodetic Activities

Takaaki Jike, Seiji Manabe, Yoshiaki Tamura, Makoto Shizugami, VERA group

Abstract

Geodetic activities of VERA in the year 2010 are briefly described. The regular geodetic observations are carried out both in K- and S/X-bands. The frequency of regular observations are three times a month—twice for the VERA internal observations in K-band and once in S/X-band. The networks of the S/X sessions are JADE of GSI and IVS-T2. The raw data of the T2 sessions are electronically transferred to the Bonn and Haystack correlators via Internet by using the Tsunami protocol.

Gravimetric observations are carried out at the VERA stations. The superconducting gravimeter previously installed at Esashi Earth Tides Station was moved to Mizusawa and placed in the vicinity of the VERA antenna in order to monitor vertical displacement at the end of 2008, and the observation continued throughout the year.

1. General Description

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

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

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

2. Technical Parameters

Parameters of the antennas and front- and back-ends are summarized in Tables 2 and 3 respectively. Two observing modes are used in geodetic observations. One is the VERA internal observation in K-band with the recording rate of 1 Gbps. The other is the conventional S/X-

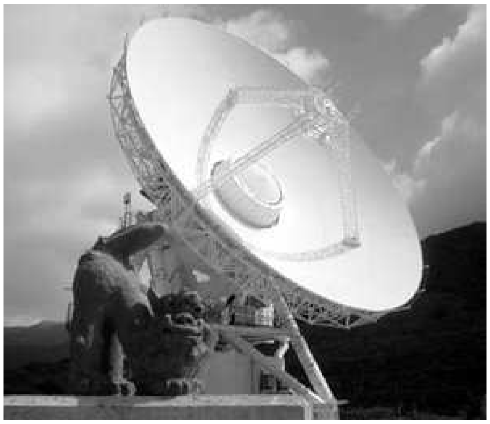

Figure 1. VERA Ishigakijima antenna.

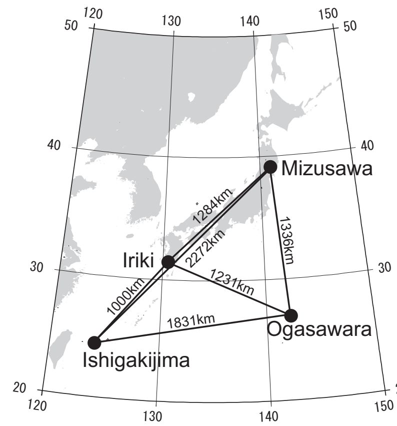

Figure 2. Location of the VERA stations.

Table 1. General information.

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

band observation with K5-VSSP. JADE, which is GSI's domestic observation project, and IVS-T2 sessions belong to this class. Only Mizusawa and Ishigakijima participated in these sessions.

Table 2. Antenna parameters.

Diameter	20m	Slew	Azimuth	Elevation
Mount	Az-El	range	-90° – 450°	5° – 85°
Surface accuracy	0.2mm(rms)	speed	2.1°/sec	2.1°/sec
Pointing accuracy	<12"(rms)	acceleration	2.1°/sec^2	2.1°/sec^2

	S	X	K
HPBW	1550"	400"	150"
Aperture efficiency	0.25	0.4	0.47

3. Organizational Change and Staff Members

Mizusawa VERA Observatory of NAOJ was reorganized to Mizusawa VLBI Observatory in April 2009. VERA and VSOP-2 were integrated into a unified project. Noriyuki Kawaguchi was inaugurated as Director in April 2010. The geodesy group consists of S. Manabe (chief, scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician).

Table 3. Front-end and back-end parameters.

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

4. Current Status and Activities

4.1. VLBI

VERA observes seven days a week except for the maintenance period in the summer. The nominal frequency of geodetic observations is three days a month. Among these three, VERA internal geodetic observations in K-band are performed twice a month and Mizusawa and Ishigakijima participate in JADE by GSI or IVS-T2 sessions in S/X-band on a once-a-month basis. The main purpose of the VERA internal geodetic observations is to determine relative positions of the VERA antennas accurate enough for astrometric requirements. The purpose the S/X sessions is to make the VERA coordinates refer to the IVS reference frame. The reason for the shift of the observing frequency band from S/X-band to K-band is to avoid the strong radio interference by cellular phone in S-band, particularly at Mizusawa. Interfering signal which has line spectra is filtered out. However, this filtering considerably degrades the system noise temperature. It is likely that the S-band observation will become impossible in the near future. On the other hand, VERA has the highest sensitivity in K-band as shown in Table 3. Thanks to the high sensitivity in this band the maximum number of scans in K-band is 800/station/24-hours, while that in S/X-band is 500 at most. It has been confirmed that the K-band observations are far more precise, although the ionospheric delay is not corrected for. In fact, standard deviations of the individual determinations of the antenna positions in K-band are less than half of those in S/X-band.

The error ellipsoid is fairly elongated in the vertical direction due to the insufficient network size for separating the vertical displacement from the zenith atmospheric delay variation. There seems no significant systematic difference in the estimated coordinates between S/X- and K-bands. This means that the majority of the ionospheric effect can be eliminated in the course of estimating the tropospheric delay, at least for the VERA network whose typical size is around 2300 km. However, the number of observations are not enough to derive a definite conclusion.

In order to link the VERA network to the international reference frame, VERA started participation in the IVS-T2 sessions by using Mizusawa and Ishigakijima stations in 2009. The observations at Ishigakijima were conducted by GSI. In September 2009, we successfully made a test observation and electronic data transfer to the Haystack correlator via Tsunami protocol. In 2010, we participated in six T2 sessions and in three JADE sessions. VERA internal geodetic observations were carried out 28 times. The final estimation of the geodetic parameters are derived by using the software developed by VERA team.

4.2. Other Activities

Continuous GPS observations were carried out at each VERA station throughout the year. The observation of gravity tide with a LaCoste-Romberg gravimeter at Ogasawara was completed, and that at Ishigakijima is underway. The provisional result shows that there is no large discrepancy in the tidal amplitude and phase between the observations and those predicted by ocean models.

The superconducting gravimeter (SCG) was moved from the Esashi Earth Tides Station to Mizusawa in order to accurately monitor gravity change for the purpose of monitoring height change at VERA Mizusawa station. Four water table gauges surrounding the SCG were used for monitoring the water table height. The preliminary results show that gravity variation due to the variation of the water table can be corrected as accurately as the 1μgal level.

5. Future Plans

The internal K-band VLBI and the participation in the IVS-T2 sessions will be continued. Continuous GPS and gravimetric observations will also be carried out. Reconfirmation of local ties between GPS and VLBI has become an urgent task. The possibility of optical fiber links between Mitaka and the VERA stations is being pursued. Widening of the receiving and recording bandwidth is planned.

Noto Station Status Report

G. Tuccari

Abstract

Noto station was not operational for a large part of 2010 due to a structural damage in the radio telescope. An expensive maintenance is needed, and INAF found the resources to repair the structure at the end of the year. The activity at the station is reported.

1. Antenna Status, Receivers, Networks

Noto antenna suffered from very serious damage to the axis of a driving azimuth wheel (see Figures 1 and 2). This event necessitated stopping all operations and placing the antenna in a safe state. As the azimuth track grout needs to be remade, new wheels and a new track have been planned. The entire repair operation has been financed (about 850,000 Euro) by INAF (Istituto Nazionale di Astrofisica). In the first months of 2011 the selection of the company able to renew the structure will be made, and then a period of around six months is planned for fully recovering the antenna functionality. The whole work (wheel replacement, grout and track removal, new track installation and its anchorage with innovative techniques and telescope alignment) should be completed by the end of summer 2011.

The maintenance of the receivers (C,Q,K) is currently underway. The SXL receiver developed in the last years will be renewed in order to reduce its weight, allowing its placement in the primary focus in a safe way. All the bands will also be converted in a digital implementation to be transfered with 10G Ethernet optical network technology to the control station and the DBBC environment.

A fiber optics link for e-VLBI activities has been financed by GARR (Italian Academic and Research Network) and is in the commissioning phase. It is planned to start with the installation in June 2011.

2. DBBC Backend

The DBBC backend is now regularly used at some stations after a gradual introduction in the station activities. Here, in summary, we list the main news.

Two operational modes are possible at present—the Digital Down Converter configuration and the Multichannel Equispaced configuration.

The Digital Down Converter configuration generates 16 x 1-16 MHz wide tunable bands. The implementation emulates an analog VLBI down-converter system, with independent channels in bandwidth and tuning base. Each Core2 board is able to produce four BBCs.

The Multichannel Equispaced configuration generates 16 x 32 MHz wide bands. The implementation is realized adopting the intrinsic capability of a highly efficient DFT processor to down-convert in base band contiguous slices of band. As the single DFT operation shows poor frequency rejection between adjacent channels, a preliminary filter is adopted to greatly improve the separation performance.

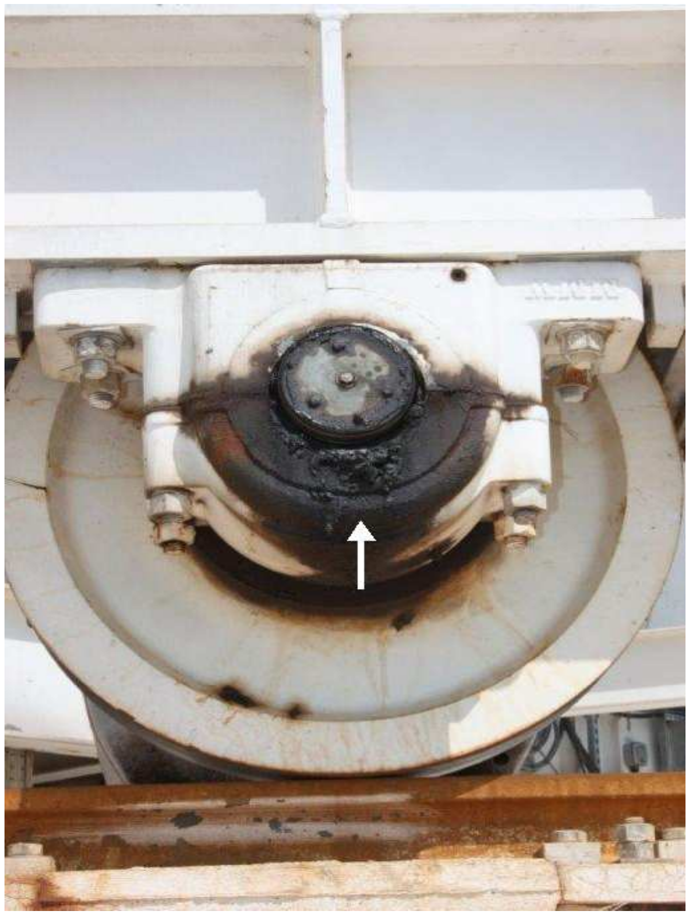

Figure 1. The damaged Noto azimuth wheel. The arrow points towards the damaged area.

Figure 2. The damaged axis in detail; the wheel is off-axis.

2.1. Hardware

In the VLBI backend implementation two observing types are mainly required: tunable configuration and fixed contiguous bands. The first is adopted to emulate the present Mark IV terminal and is required for both geodetic and astronomical observing modes. The second is devoted to astronomical millimeter observations and the coming VLBI2010 geodetic modes. Both modes are required in the same terminal to be used depending on the observation to be performed; so some efforts have been made to accomplish these modes in a unique hardware architecture.

The ADB1 board operates with a 1024 MHz sampling clock, for converting an input signal in the range 10—2200 MHz, while the ADB2 is operated at 2048 MHz with an input signal of up to 3500 MHz. The ADB2 is able to operate in ADB1 mode and moreover can adopt as piggyback a FILA10G board, to transfer pure sampled data using optical fibers with a 10G Ethernet connection. The ADB2 board was widely tested and is available to be inserted in the standard DBBC2 stack.

The processing unit Core2 board is also fully operative and represents the element adopted to generate the down-converted channels in both modes: tunable and fixed tuning. The board is compatible with ADB1 and ADB2 and supports a minimal equivalent of four Core1 functionality. One Core2 board is able to emulate the complete functionality of four analog BBCs, or to generate a fixed tuning version of fifteen 32-MHz-wide baseband channels, covering an input receiver band of 512 MHz.

The new CaT2 board (Clock and Timing) is able to generate a highly flexible number of synthesized sampling clock (e.g., 2048 MHz, 1024 MHz) values, phase locked with an external 10 MHz. Low phase-noise and very small sensitivity to temperature are the main features. The board is also producing 1PPS synchronization signals for all the ADB boards and the entire digital chain. Frequency selection is performed with the use of the DBBC2 internal PC Set.

The FiLa10G can be used as piggy-back board with any ADB2 sampler, giving the possibility to transmit and receive at the same time a high data rate of 20 Gbps + 20 Gbps. The bi-directional functionality could be required, for instance, when an RFI mitigation is needed to be realized in a remote location with respect to the sampling and processing site. With the typical sampling frequency of 2.048 MHz and the full 10-bit data representation, a double optical fiber set meets the full data handling requirement. The Fila10G is the interface between the DBBC and Mark 5C recorder.

2.2. Firmware

The DBBC2 VHDL firmware was completely rewritten in a platform-independent fashion. This was accomplished with a great simplification that produced a very compact and efficient code. Performance improvement guarantees a bit-by-bit identical output from a set of BBCs belonging to the same Core2 board, having of course the same tuning settings and input data. Some debugging is still underway to check the entire new code.

The fixed tuned (PFB) configuration firmware is also available; it produces a set of 16 (15 usable) contiguous 32 MHz bands from a 512 MHz input range, in any of the Nyquist zones available from the ADB1/2 boards. This configuration is available for the VLBI2010 mode or for the millimeter VLBI network.

Firmware under development is covering the following tasks: a) fully tunable 1 GHz input bandwidth, b) 1 GHz PFB with 31 channels 32 MHz bandwidth, c) 65K points spectrometer.

2.3. New Hardware Development

New hardware parts to be integrated in the system are under development. This covers the interfacing, input bandwidth, and processing capability.

The FILA10G board is the interface between the system and the Mark 5C recorder or the network. Main connections are two optical fibers operating each at a maximum rate of 10 Gbps. In VLBI standard this is limited by 8.192 Gbps/fiber, and for the present recording capability the limitation is 4 Gbps. The data rate is fully bi-directional and compliant with the standard Ethernet networks, under UDP protocol. At present the development status sees the hardware defined and available with some prototypes, and the firmware development completed for Mark 5B mode while VDIF modes are underway.

The 10G network FILA10G board is adopting optical fibers. In order to be connected with one or two Mark 5C recorders, that adopt the copper CX4 standard, it needs to be interfaced with a commercial 10G switch having both types of ports. As an alternative, a bi-directional interface that can be used for this purpose was developed. It is named GLAPPER to recall its functionality to be a transition between GLAss and coPPER.

A kit to expand the backend functionalities to the VLBI2010 has been defined as upgrade element for a standard DBBC terminal. In such an implementation eight IFs are implemented.

2.4. HAT-Lab

HAT-Lab is a spin-off company supported by INAF for the DBBC production. The company has agreements with IRA-Noto, where laboratories are placed for a part of the production, and MPI in Bonn where other phases of the production are realized. A certain number of operations are realized by external specialized companies to simplify and optimize the production of the complex boards. Assembly and testing is fully realized at HAT-Lab, IRA, and MPI.

At present eight systems have been deployed by IRA, and in 2010 HAT-Lab has delivered eight additional systems. Production time is today close to six months while the first batch of production took a longer time, around nine months, due to the initial settings of the production lines.

2.5. Fringe Test

Regular observations are underway in the geodetic network. More fringe test observations have also been performed with the down-converter configuration. A reduction in the fringe amplitude has initially been seen, around 80%. This has been found due to an additional noise in the timing communication between ADB1 and Core2 boards. An extensive laboratory testing has been realized, and the best conditions have been determined making use of a phase calibration.

3. Geodetic Observations in 2010

During 2010, the Noto station participated in three geodetic experiments: EUR103, EUR104, and T2062.

Ny-Ålesund 20-meter Antenna

Carl Petter Nielsen

Abstract

In the year 2010, the 20-meter VLBI antenna at the Geodetic Observatory, Ny-Ålesund, participated in VLBI experiments, observing 91 of 91 scheduled 24-hour experiments and 116 of 118 scheduled Intensives. The reason for the lost experiments was the repair of the cooling system. Several experiments during November had to be run with a warm receiver due to a failure of the cold-head. In 2010, Ny-Ålesund was manned by four employees dividing three positions between them: Carl Petter Nielsen as base commander and Geir Mathiassen, Moritz Sieber, and Lars Karvonen as engineers, all working 75%. In connection with the application for two new antennas, the Norwegian Mapping Authority (NMA) carried out an extensive Enviromental Impact Assessment (EIA) and will continue towards its completion in summer 2011. During spring some holes were drilled to establish the quality of the ground and to find the best location for the new antennas. In the autumn Geir Mathiassen and Carl Petter Nielsen visited Kokee Park to learn more about antenna maintenance.

1. General Information

The Geodetic Observatory of the NMA is situated at 78.9° N and 11.87° W in Ny-Ålesund, in Kings Bay, at the west side of the island of Spitsbergen. This is the biggest island in the Svalbard archipelago. In 2010, Ny-Ålesund was scheduled for 91 24-hour VLBI experiments, including R1, R4, EURO, RD, T2, and RDV sessions, and 118 Intensives within the Int1/Int3 program, making a total of 209 experiments. Two Intensives had to be cancelled because of station problems, in both cases, connected to the cooling system. Of the 207 completed experiments 71 1-hour and four 24-hour experiments were added during the year because of downtime/problems at other stations. This is an increase of 72.5% since 2009 (measured in number of experiments).

In addition to the 20-meter VLBI antenna, the Geodetic Observatory has two GPS antennas in the IGS system and a Superconducting Gravimeter in the Global Geodynamics Project (GGP) installed at the site. There is also a CHAMP GPS and a SATREF (dGPS) installation at the station. At the French research station in Ny-Ålesund, there is a DORIS station. In October 2004, a GISTM (GPS Ionospheric Scintillation and TEC Monitor) receiver was installed at the Mapping Authority structure in the frame of ISACCO, an Italian research project on ionospheric scintillation observations, led by Giorgiana De Franceschi of the Italian Institute of Volcanology and Geophysics (INGV).

2. Component Description

The antenna is intended for geodetic use and is designed for receiving in S-band and X-band. Ny-Ålesund is a Mark 5A station. The station configuration file can be found on the IVS Web site: ftp://ivscc.gsfc.nasa.gov/pub/config/ns/nyales.config. Ny-Ålesund is located so far north that the sun is below the horizon from the 23rd of October until the 22nd of February, and the station has midnight sun from the 20th of April to the 27th of August. The station is situated under the auroral circle during daytime giving some extra disturbance in the ionosphere, but generally the polar atmosphere is calmer than the atmosphere closer to the equator.

3. Staff

Carl Petter Nielsen has a two year contract as base commander, ending 2011.12.31. Geir Mathiassen, Moritz Sieber, and Lars Karvonen all have two year contracts as engineers ending 2012.09.01, 2011.09.01, and 2012.02.01, respectively. Everybody works 75%, which means that three full-time positions are covered. When Carl Petter Nielsen is off, one of the others steps in as base commander.

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

Hønefoss:	Section manager:	Line Langkaas
	Station responsible at Hønefoss:	Line Langkaas
Ny-Ålesund:	Station commander:	Carl Petter Nielsen
	Engineer	Geir Mathiassen
	Engineer	Moritz Sieber
	Engineer	Lars Karvonen since 2010.02.01

Figure 1. Ny-Ålesund antenna.

4. Current Status and Activities

Ny-Ålesund participated in the scheduled VLBI experiments. During 2010 e-VLBI was extended to the transfer of R4 and Int1 sessions from Ny-Ålesund to the Washington Correlator in addition to transferring R1 and Int3 measurements to the Bonn Correlator. The Ministry of Education granted funding for a fiber cable between Longyearbyen and Ny-Ålesund. The new cable will enable us to take part in real time correlation as opposed to our present radiolink, which is 100 Mbit/s.

The Superconducting Gravimeter (SCG) placed on the same foundation as IGS-GPS NYA1 has been running without problems. The yearly service on the system was performed by the staff in September. There were some problems in transporting the liquid helium (LHe) to Ny-Ålesund. Due to the 2–3 weeks it takes to transport the LHe to Ny-Ålesund, most of it might turn into gas on the journey, especially if the ship experiences bad weather. Therefore we had to have an extra tank of LHe, but still we only had just enough LHe to last until the first boat in April 2011. National Astronomical Observatory of Japan, Mizusawa VERA Observatory, which owns the SCG, lent this equipment to NMA starting 2007.04.01, to continue the scientific measurement series.

NMA plans to take part in VLBI2010 and has applied to the Norwegian government for funding of two new VLBI antennas and an SLR system. In order to establish the optimal site, some ground drilling has been done, and on this background a site has been chosen. Ny-Ålesund is an Arctic research village, and the scientific community (organized in Ny-SMAC) would like to keep Ny-Ålesund and the surroundings as pristine and unaffected by human activity as possible. Therefore NMA has initiated an extensive Enviromental Impact Assessment (EIA) involving the different interested parties.

In the autumn Geir Mathiassen and Carl Petter Nielsen visited Kokee Park to learn more about antenna maintenance. This was a very useful exercise for the staff at Ny-Ålesund, who all are fairly new to VLBI.

5. Future Plans

Ny-Ålesund will continue to participate in the 119 regular and 43 Intensive experiments as well as the CONT11 in September. The station is currently trying to replace the Mark IV with a Mark 5 formatter. Hopefully we will succeed despite some problems at the moment. In order to save energy, three heat pumps will be installed, and the plan to insulate the ceiling will finally be carried out. Rüdiger Haas and Sten Bergstrand will measure the movement of the surrounding terrain in late February before the solar heating starts.

If our application for funding is successful, building of the roads and the foundations of the new antennas will start in 2011.

The SCG has to be refilled with liquid helium each year, and the lift has to be re-certified every year. A new car will be bought. Depending on the availability of cable ships, the new fiber cable between Longyearbyen and Ny-Ålesund will be laid down during summer 2011 or 2012.

German Antarctic Receiving Station (GARS) O'Higgins

Christian Plötz, Reiner Wojdziak, Alexander Neidhardt

Abstract

In 2010 the German Antarctic Receiving Station (GARS) O'Higgins contributed to the IVS observing program with four observation sessions. The remote control tests with the software developed at Wettzell were continued for VLBI sessions. The antenna of the Global Navigation Satellite Systems (GNSS) reference point "OHI3" was replaced by a calibrated one for GALILEO satellites.

1. General Information

The German Antarctic Receiving Station (GARS) is jointly operated by the Federal Agency for Cartography and Geodesy (BKG; as part of the duties of the Geodetic Observatory Wettzell, GOW) and the German Aerospace Center (DLR). The Institute for Antarctic Research Chile (INACH) coordinates the activities and logistics. The 9-m radio telescope at O'Higgins is used for geodetic VLBI and for downloading of remote sensing images from satellites such as ERS-2 and the TanDEM-X as well as for commanding and monitoring spacecraft telemetry. In 2010 the station was manned in January and February from BKG and the colleagues of DLR. DLR and BKG jointly sent engineers and operators for the campaigns together with a team for the infrastructure (e.g., power generator). In 2010 the DLR kept the station operational during the year.

Over the last years, special flights with "Hercules C-130" aircrafts and small "Twin Otter DHC-6" aircrafts were organized by INACH in close collaboration with the Chilean Army, Navy, and Airforce and with the Brazilian and Uruguayan Airforce in order to transport the staff, the technical material, and also the food for the entire campaign from Punta Arenas via Base Frei on King George Island to O'Higgins on the Antarctic Peninsula. Another route uses transportation by ship to and from O'Higgins. Due to the fact that the conditions for landing on the glacier are absolutely weather dependent and require a lot of security precautions, the usage of a ship for transportation to O'Higgins becomes more and more important. In general, transport of personnel and cargo is quite challenging. Arrival time and departure time depend strongly on the weather conditions and on the general logistics.

After the long Antarctic winter usually the equipment at the station has to be initialized. Damages, which result from the winter period or strong storms, have to be identified and repaired. Shipment of spare parts or material for upgrades from Germany has to be carefully prepared in advance.

The 9-m radio telescope for VLBI is co-located with other equipment:

- an H-Maser, an atomic Cs-clock, a GPS time receiver, and a Total Accurate Clock (TAC) offer time and frequency.
- two GNSS receivers were operational, while the permanent site "OHI3" was used in the frame of IGS all over the year. The receivers worked without failure in 2010.
- a meteorological station provided pressure, temperature, and humidity and wind information, as long as the temporarily extreme conditions outside did not disturb the sensors.

- the installation of a new radar tide gauge was shifted to 2011. The radar sensor itself will be position-calibrated by a GPS antenna mounted on top of the radar sensor unit.
- defective underwater sea level gauge will be replaced for permanent monitoring of temperature, tide pressure, and salinity of the sea water.

The 9-m radio telescope is designed for dual purpose:

- performing geodetic VLBI and
- receiving the remote sensing data from LEO satellites, mainly from ERS-2 and TanDEM-X.

Figure 1. Photo of GARS O'Higgins taken during transport from the landing zone to the station (on the right side is the rope bridge which connects the peninsula to O'Higgins).

Figure 2. Sunset behind the penguin colony.

2. Technical Staff

The staff members for operation, maintenance and upgrade of the GARS VLBI components and the geodetic devices are summarized in Table 1.

Table 1. Staff members.

Name	Affiliation	Function	Working for
Johannes Ihde Ullrich Schreiber	BKG BKG	interim head of the GOW (until September 2010) head of the GOW (since October 2010)	GOW GOW
Christian Plötz	BKG	electronic engineer	O'Higgins (responsible), RTW
Reiner Wojdziak	BKG	software engineer	O'Higgins, IVS Data Center Leipzig
Thomas Klügel	BKG	geologist	administration for O'Higgins (mainly laser gyro and local systems Wettzell)
Rudolf Stoeger	BKG	geodesist	logistics for O'Higgins
Alexander Neidhardt	FESG	head of the RTW group and VLBI station chief	RTW, TTW (partly O'Higgins, laser ranging)
Gerhard Kronschnabl	BKG	electronic engineer	RTW, TTW (partly TIGO and O'Higgins)

3. Observations in 2010

GARS participated in the following sessions of the IVS observing program during the Antarctic summer campaign (January-February 2010)

- IVS-T2067 February 02-03, 2010
- IVS-OHIG67 February 03-04, 2010
- IVS-OHIG68 February 09-10, 2010
- IVS-OHIG69 February 10-11, 2010

The observations were recorded with Mark 5A. The related data modules were carried from O'Higgins to Punta Arenas by the staff when they returned home. From Punta Arenas, the disk units were shipped by regular air transport back to Wettzell and then to the correlator in Bonn, Germany.

Figure 3. Mostly used for transportation to and from O'Higgins is the FACH "Twin Otter DHC-6".

4. Maintenance

The extreme environmental conditions in the Antarctic require special attention to the GARS telescope and to the infrastructure. Corrosion frequently results in problems with connectors and capacitors. Therefore defective equipment needs to be detected. The antenna, the S/X-band receiver, the cooling system, and the data acquisition system have to be activated properly. In 2010 a replacement dewar was planned in Wettzell, but the unit will have to be finished in 2011 in order to replace the original O'Higgins dewar. The current dewar has to be pumped permanently by a turbo molecular pump to maintain the required vacuum due to air leakage at the chamber.

Those components, which were damaged during the previous campaign or because of the extreme conditions, were replaced. The meteorological station failed partly during the Antarctic winter. Therefore a new system will be installed to fulfill again the reliability requirements for collecting weather data. The intermediate frequency distributor module "ifdcd" failed in February due to problems on the Monitor and Control Bus (MCB) board, which realizes the communication to the NASA Field System. The module was transported to Wettzell, repaired, and sent back to the O'Higgins station. Nevertheless, it is very difficult to maintain and repair this kind of equipment. Some components as well as technical information are close to unavailable.

5. Technical Improvements

Remote control of complete VLBI sessions was extended. With the newly developed software from Wettzell, the O'Higgins Field System can be controlled over a secure Internet connection from Wettzell. This is a key feature for extended operation periods at GARS O'Higgins.

O'Higgins is represented in the GNSS network with the reference point "OHI3". With the GALILEO capability upgrade of the GNSS system, the station participates in the COoperative Network for GIOVE Observation (CONGO) network, by establishing a GALILEO reference station at O'Higgins.

6. Upgrade Plans for 2011

It is planned to install the radar tide gauge directly on shore. A sea level tide gauge is planned to be re-installed. Additionally a new communication antenna setup, capable of up to 8 Mbit/s, is going to extend bandwidth for data transmission as peer-to-peer connection between O'Higgins and Oberpfaffenhofen, Germany. The GARS station will be manned by DLR continuously in 2011 for a planned period of three years, because of the TanDEM-X-Mission. This may lead to an extended operation period of IVS VLBI measurements. A new S/X-band dewar will replace the original dewar of the O'Higgins VLBI system. Furthermore it is planned to realize a second gravimeter measurement. The first one took place in 1997.

Onsala Space Observatory – IVS Network Station

Rüdiger Haas, Gunnar Elgered, Johan Löfgren, Tong Ning, Hans-Georg Scherneck

Abstract

During 2010 the Onsala Space Observatory contributed as an IVS Network Station to 27 VLBI sessions organized by the IVS. We used the majority of these sessions to do ultra-rapid dUT1 observations together with our colleagues in Tsukuba. Furthermore, we observed several additional one-baseline ultra-rapid dUT1 sessions. This report briefly summarizes the activities during the year 2010.

1. General Information

The Onsala Space Observatory has a more than 40-year history in VLBI. Onsala was the first European observatory to be involved in geodetic/astrometric VLBI observations, and the first trans-atlantic VLBI observations were performed together with Haystack Observatory already in April 1968. Today Onsala is a fundamental geodetic station with equipment for geodetic VLBI, GNSS, a superconducting gravimeter, and several radiometers for atmospheric measurements. Figure 1 shows a recent aerial photo of the area around the 20-m telescope.

Figure 1. Aerial photo taken in December 2010. Shown are: (1) the radome enclosing the 20-m radio telescope used for geodetic/astrometric VLBI, (2) the IGS antenna, (3) the water vapor radiometer Astrid, (4) the old gravimeter house, (5) the new gravimeter house, and additional office and laboratory buildings.

2. Staff Associated with the IVS Network Station at Onsala

The staff associated with the IVS Network Station at Onsala remained the same as reported in last year's annual report. Contact information is found on the observatory Web page `http://www.chalmers.se/rss/oso-en/`.

3. Geodetic VLBI Observations for the IVS during 2010

In 2010 the Onsala observatory was involved in four IVS observing series: EUROPE, R1, T2, and RD10. In total, Onsala participated and acquired useful observations in 27 experiments, see Table 1. All experiments were recorded on Mark 5 modules. Most of the experiments whose data were correlated at the Bonn correlator were additionally recorded in parallel on the PCEVN-computer that is daisy-chained to the Mark 5 computer. The observed data of these experiments were then e-transferred using the Tsunami protocol, and no Mark 5 modules were actually sent to Bonn. Radio interference due to UMTS mobile telephone signals continued to be a disturbing factor for the S-band observations.

Table 1. Geodetic VLBI experiments at the Onsala Space Observatory during 2010.

Exper.	Date	Remarks	Correlated
R1-413	JAN.11	E-transfer to Bonn	o.k, but 30 min lost due to Mark 5 module failure
EUR-103	JAN.18	E-transfer to Bonn	o.k.
R1-415	JAN.25	E-transfer to Bonn	o.k.
R1-417	FEB.08	E-transfer to Bonn	o.k.
RD-10.02	FEB.17	module shipment to Haystack	o.k.
R1-420	MAR.01	E-transfer to Bonn	o.k.
EUR-104	MAR.02	E-transfer to Bonn	o.k., but some scans lost due to power failure
R1-425	APR.06	E-transfer to Bonn	o.k.
RD-10.03	APR.07	module shipment to Haystack	o.k.
R1-426	APR.12	E-transfer to Bonn	o.k.
R1-427	APR.19	E-transfer to Bonn	o.k.
R1-428	APR.26	E-transfer to Bonn	o.k., but some problems with phase-cal
RD-10.04	MAY.04	module shipment to Haystack	o.k.
R1-437	JUN.28	E-transfer to Bonn	o.k, but 40 min missed due to power failure
RD-1005	JUN.29	module shipment to Haystack	o.k.
EUR-106	JUL.05	E-transfer to Bonn	o.k.
R1-438	JUL.06	E-transfer to Bonn	o.k.
R1-440	JUL.19	E-transfer to Bonn	o.k.
R1-445	AUG.23	E-transfer to Bonn	o.k.
R1-446	AUG.30	E-transfer to Bonn	o.k.
R1-449	SEP.20	E-transfer to Bonn	o.k.
T2-071	SEP.21	module shipment to Haystack	o.k.
R1-450	SEP.27	E-transfer to Bonn	o.k.
T2-072	OCT.05	module shipment to Haystack	o.k.
R1-457	NOV.15	E-transfer to Bonn	o.k, but 6 scans missed due to Mark 5 problems
R1-461	DEC.13	E-transfer to Bonn	o.k.
R1-462	DEC.20	E-transfer to Bonn	o.k.

4. Fennoscandian-Japanese Ultra-rapid dUT1 Measurements

During 2010 we continued our involvement in the successful Fennoscandian-Japanese ultra-rapid dUT1 project. We used a number of standard 24-hour IVS sessions where both Onsala and Tsukuba (or Kashima) were involved to continuously determine dUT1 results during the ongoing VLBI observations. In total, 15 R1 sessions, three RD sessions, and two T2 sessions were used as ultra-rapid dUT1 sessions. Even one European session, EUR.104, was performed as an ultra-rapid experiment. In this case, both Onsala and Metsähovi sent their data in real-time to the Tsukuba correlator, where the data were correlated and analyzed. However, the dUT1 results were of low quality, mainly due to the short baseline Onsala-Metsähovi. Additionally, we performed a few dedicated one-baseline ultra-rapid dUT1 sessions. These sessions were observed for several hours during the European night hours after standard IVS sessions. In both cases the dUT1 results were determined already during the ongoing VLBI observations using a 'sliding window' approach with approximately 35 scans. Table 2 gives an overview of these additional one-baseline ultra-rapid dUT1 sessions.

Table 2. Dedicated Fennoscandian-Japanese ultra-rapid dUT1 experiments in 2010.

Exper.	Date	Duration	Baseline	Mbps	Transfer	Correlation	Analysis
UR0.271	SEP.28	8 h	Onsa-Kash	256	real-time	real-time	automated
UR0.279	OCT.06	8 h	Onsa-Tsuk	256	real-time	real-time	automated
UR0.348	NOV.16	12.5 h	Onsa-Tsuk	256	real-time	real-time	automated
UR0.355	DEC.21	12.5 h	Onsa-Tsuk	256	real-time	real-time	automated

5. Monitoring Activities in 2010

Monitoring activities were continued as described in previous annual reports.

Calibration of pressure sensor. We continued to calibrate the Onsala pressure sensor using a Vaisala barometer borrowed from the Swedish Meteorological and Hydrological Institute (SMHI). This Vaisala instrument was installed at Onsala in late 2002 and has been calibrated at SMHI main facility in Norrköping every 1–2 years since then. The agreement between the Onsala pressure sensor and the SMHI pressure sensor is on the level of ±0.1 hPa.

Vertical height changes of the telescope tower. We continued to monitor the vertical height changes of the telescope tower using the invar rod system at the 20-m telescope. New temperature sensors were installed and the measurements made available via Internet, see `http://wx.oso.chalmers.se/pisa/`.

Microwave radiometry. The water vapor radiometer Astrid was in operation continuously during 2010, mainly observing in a so-called sky-mapping mode. The second water vapor radiometer Konrad is still being upgraded in the electronic lab at the observatory.

Sea-level monitoring. We operated the GNSS-based tide gauge during several months at the coastline close to the observatory to monitor the local sea-level. The tidal analysis of the sea-level variations clearly shows the dominant ocean tides in the Kattegatt.

Superconducting gravimetry. The superconducting gravimeter (SCG) operated continuously during 2010. It produced a highly precise record of gravity variations, and it recorded earthquakes and free oscillations of the earth. Further information on the SCG can be found on the Web page `http://froste.oso.chalmers.se/hgs/SCG/`. Auxilliary sensors for bedrock temperature and rock deformation below the gravimeter house were installed in the spring of 2010. The measurements are available on a Web page, see `http://wx.oso.chalmers.se/gravimeter/`.

Seismological observations. A three-axis seismometer has been operated at the observatory since May 2010. Since the current operating site is slightly disturbed by man-made vibrations, the instrument has to be moved to a better site within the observatory premises. The actual location has not yet been identified.

Monitoring of the RFI environment. During 2010 a system to monitor the radio frequency interference (RFI) environment was developed as part of a master's thesis. The instrument will be installed permanently at the Onsala site in 2011.

6. New Contract with the Swedish Research Council

In connection with the international evaluation of the observatory carried out in 2009 by the Swedish Research Council (VR), a new contract between Chalmers University of Technology, the host university for the observatory, and VR was signed in late 2010. This contract states that the observatory has the role as a Swedish national infrastructure for radio astronomy as well as geodesy.

7. Outlook

The Onsala Space Observatory will continue to operate as an IVS Network Station and to participate in the IVS observation series. For 2011 a total of 41 experiments is planned, including the 15-day-long CONT11 campaign. We aim to use e-transfer of as many of the experiments as possible. We will also continue the Fennoscandian-Japanese ultra-rapid dUT1 project and focus on 24-h ultra-rapid dUT1 sessions, and additional one-baseline ultra-rapid sessions during the European night hours.

During 2011 we plan to carry out the following hardware improvements:

- Replacement of the analog VLBI backend by a digital one.
- Installation of the GNSS-based tide gauge at a new location for continuous observations. As a reference we will add a traditional tide gauge based on pressure sensors.
- A more permanent installation of the seismometer at a place at the observatory with fewer man-made vibrations.
- Monitoring of the RFI environment.

Encouraged by the positive evaluation of the observatory in 2009, and the new contract with the Swedish Research Council in 2010, we will start a discussion on a transition of Onsala to become fully VLBI2010-compliant.

Parkes 2010 IVS Report

John Reynolds, Tasso Tzioumis

Abstract

This report describes the 2010 activities and future plans of the IVS Network Station at Parkes, Australia.

1. New Status

In February 2010 the Parkes Observatory officially became a network station of IVS, having participated actively for many years as an “ex officio” member.

2. 2010 Observing

In 2010 Parkes participated in just two IVS sessions (R1416 and CRF61). Planned participation in several more sessions fell through due to cancellations coming from the delays in commissioning of the AUSTRAL network. It is hoped the level of participation in 2011 will resume to its typical levels of six to eight sessions per year.

In addition to these two IVS sessions, Parkes during 2010 also participated in several hybrid astronomy/geodesy observations in a program led by Leonid Petrov of ADNET Systems/GSFC. This program has the dual aims of identifying additional calibrator sources in the Southern Hemisphere and refining the locations of several southern hemisphere radio astronomy stations that are equipped neither with dual S/X receiving systems nor IVS-compatible recording systems.

3. Maintenance

The Parkes station is equipped with a Mark 5B+ recorder and Mark 5 D/A rack, which replaced the long-serving Mark IIIA recorder in late 2007. (The rack code is MARPOINT, for those interested in such history). In mid-2010 the Observatory purchased 14 new disk modules with 8TB capacity for use with both IVS and other sessions. Use of these SATA modules required an upgrade to the Mark 5B+ to Debian Etch and SDK 8, thereby exposing an unusual fault with the Streamstor card, which was unable to read back SATA modules. The board was returned to Conduant who promptly replaced two termination resistors, the values of which had been optimized since the manufacture of the board. No further problems were experienced.

4. Future Plans

The dual S/X receiver at Parkes currently has limited bandwidth that precludes the use of the IF3 module. An upgrade to the receiver is planned in 2011 to allow wider bandwidths to be recorded using an IF3 module or equivalent.

Figure 1. Parkes 64-meter antenna, with the movable 60-foot antenna (now decommissioned) in the distance. (Credit: John Sarkissian, CSIRO.)

Figure 2. Parkes antenna, with geodetic monument and dual-frequency GPS antenna in the foreground. (Credit: John Sarkissian, CSIRO.)

Figure 3. Parkes antenna at night. (Credit: John Sarkissian, CSIRO.)

Sheshan VLBI Station Report for 2010

Xiaoyu Hong, Qingyuan Fan, Bo Xia, Tao An

Abstract

This report summarizes the observing activities at the Sheshan station (SESHAN25) in 2010. The SESHAN25 radio telescope participated in sixteen 24-hour VLBI sessions organized by the IVS and two VLBI sessions organized by the EVN, as well as in a number of e-VLBI sessions and formatter tests by the EVN. In October and November 2010, SESHAN25 was involved in the VLBI tracking of the Chinese Chang'E-2 Lunar satellite. We also report on updates and development of the facilities at the station.

1. General Information

The Sheshan VLBI station (also named SESHAN25 in the geodetic community) is located at Sheshan, about 30 km west of Shanghai. A 25-meter radio telescope is in operation at 1.3, 3.6/13, 5, 6, and 18-cm wavelengths. The Sheshan VLBI station is a member of the IVS and EVN. The SESHAN25 telescope takes part in international VLBI experiments for astrometric, geodetic, and astrophysical research. Apart from its international VLBI activities, the telescope spent a large amount of time on the Chinese Lunar Project, including the testing before the launch of the Chang'E-2 satellite and the tracking campaign after the launch of Chang'E-2.

2. VLBI Observations in 2010

In 2010, SESHAN25 participated in 16 IVS sessions. SESHAN25 also participated in the EVN sessions in February and June. There were no known problems during the observations. A new 6.7-GHz receiver with dual-circular polarization has been available since spring 2010. We found fringes in the EVN February session. Soon it witnessed the first methanol spectral lines from a massive star-forming region observed with the new receiver. Methanol maser line studies were started both in single-dish and in VLBI modes after that. In order to participate in the Chinese Chang'E-2 Lunar Project, SESHAN25 prepared for Chang'E-2 tracking in mid-September, and it did real-time VLBI tracking after its launch on 1st October. Since December 2010, SESHAN25 has observed the Chang'E-2 satellite with a long term routine VLBI tracking model for two or three days per week.

3. Development and Maintenance of Sheshan Telescope in 2010

We have upgraded the Mark 5A Firmware Version to 12.06 (API 10.07, SDK 8.2), in order to use SATA modules. We also performed routine maintenance of our antenna in the middle of 2010.

4. The Staff of the Sheshan VLBI Station

Table 1 lists the group members of the Sheshan VLBI Station. The staff are involved in the VLBI program at the station with various responsibilities.

Table 1. The staff of the Sheshan VLBI Station.

Name	**Background**	**Position and Duty**	**Contact**
Xiaoyu HONG	Astrophysics	Director, Astrophysics	xhong@shao.ac.cn
Qingyuan FAN	Ant. control	Chief Engineer, Antenna	qyfan@shao.ac.cn
Zhiqiang SHEN	Astrophysics	Head of VLBI Division	zshen@shao.ac.cn
Zhuhe XUE	Software	Professor, FS	zhxue@shao.ac.cn
Quanbao LING	Electronics	Senior Engineer,VLBI terminal	qling@shao.ac.cn
Bin LI	Microwave	Technical friend, receiver	bing@shao.ac.cn
Tao AN	Astrophysics	Astrophysics	antao@shao.ac.cn
Bo XIA	Electronics	VLBI friend,VLBI terminal	bxia@shao.ac.cn
Hong YU	Ant. control	Associated Professor, Antenna	yuhong@shao.ac.cn
Li FU	Ant. mechanics	Engineer, Antenna	fuli@shao.ac.cn
Jinqing WANG	Electronics	Engineer, Antenna	jqwang@shao.ac.cn
Lingling WANG	Software	Engineer, VLBI terminal	llwang@shao.ac.cn
Rongbing ZHAO	Software	Engineer, VLBI terminal	rbzhao@shao.ac.cn
Weiye ZHONG	Microwave	Engineer, receiver	wyzhong@shao.ac.cn
Wei GOU	Electronics	Operator	gouwei@shao.ac.cn
Linfeng YU	Electronics	Operator	lfyu@shao.ac.cn
Yongbin JIANG	Electronics	Operator	jyb@shao.ac.cn

5. Outlook

In 2011 the Sheshan radio telescope will take part in 23 IVS sessions and three EVN sessions. The telescope will regularly monitor the Chang'E-2 satellite in its lunar orbit for 2–3 days per week in 2011.

A new telescope with a diameter of 65-m will be built about 6 km west of the current site of the Sheshan 25-m radio telescope. It is planned to be available for C, L, and S/X bands in 2012.

Stations of Space Geodesy and Geodynamics of CrAO: Simeiz VLBI, Simeiz-1873 SLR, CrAO-GPS

A.E. Volvach, A.I. Dmitrotsa, V. Andreatta

Abstract

This report gives an overview about the geodetic VLBI, SLR and GPS activities at CrAO stations. We summarize briefly the status of the 22-m radio as IVS Radio Network Station Telescope, the laser Simeiz-1873, and the GPS-CrAO stations.

1. General Information

The fundamental geodynamics area "Simeiz-Katsively" is situated on the coast of the Black Sea near the village of Simeiz about 20 km west of the city of Yalta in the Ukraine. It consists of two satellite laser ranging stations, a permanent GPS receiver, a sea level gauge, and the radio telescope RT-22. All these components are located within 3 km (Figure 1).

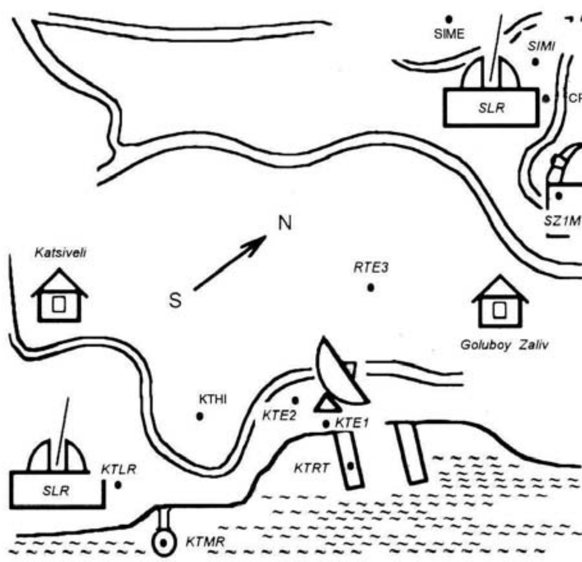

Figure 1. The geodynamics area "Simeiz-Katsively".

The positions of the points in the geodynamics test area "Simeiz-Katsively" have been determined by a special GPS survey campaign. Results are presented in Table 1.

1.1. "Simeiz" (Crimea) VLBI Station

The radio telescope RT-22 has a steering parabolic mirror with diameter 22 m and focal length 9 525 mm (Figure 2). The surface has a root mean square accuracy of 0.25 mm and an effective area of 210 m^2 which does not depend on elevation angle at geodetic frequencies 2.3 and 8.4 GHz. The antenna has an azimuth-elevation mounting with an axis offset of -1.8 ± 0.2 mm. The working range in azimuth is [-210°, 210°] (zero is to the south) and in elevation is [-1°, 85°]. The maximum

Table 1. Final solution for coordinates of points in the area “Simeiz-Katsively”.

Station	X, m	RMS, m	Y, m	RMS, m	Z, m	RMS, m
KTHI	3785378.6041	0.0004	2551165.3915	0.0003	4439717.4172	0.0004
KTLR	3785923.9017	0.0005	2550781.8054	0.0003	4439471.6117	0.0004
KTRT	3785160.8761	0.0004	2551262.2573	0.0002	4439789.8357	0.0004
SIME	3783746.4067	0.0000	2551362.7445	0.0000	4441445.1801	0.0000
CRAO	3783897.2187	0.0006	2551404.3953	0.0004	4441264.2859	0.0006
SIMI	3783887.4552	0.0004	2551403.5454	0.0003	4441266.8603	0.0005
KTE2	3785236.0690	0.0477	2551188.5462	0.0308	4439784.2244	0.0531
KTE1	3785206.0519	0.0345	2551216.1368	0.0240	4439790.8836	0.0426

slewing rate is 1.5°/sec. The control system of the telescope provides accuracy of pointing at the level of 10″.

The foundation pit of the telescope is 9 meters deep, and it has three meters of crushed stones and then six meters of concrete. The height of the elevation axis above the foundation is 14.998 meters. The telescope is located 80 meters from the edge of the Black Sea.

The reference point of the radio telescope has IERS name “CRIMEA”, ITRF name “Simeis”, IERS DOMES number 12337S008, and CDP number 7332.

The reference point of the antenna is the point of projection of the azimuthal axis on the elevation axis. The coordinates of this point are determined in analysis of the observations. However, this point may move with respect to the local area where the radio telescope is located.

RT-22 was equipped with modern Mark 5A and Mark 5B+ VLBI recording systems and a new H-maser. That gives the possibility to continue astrophysical and fundamental geodetic VLBI observations.

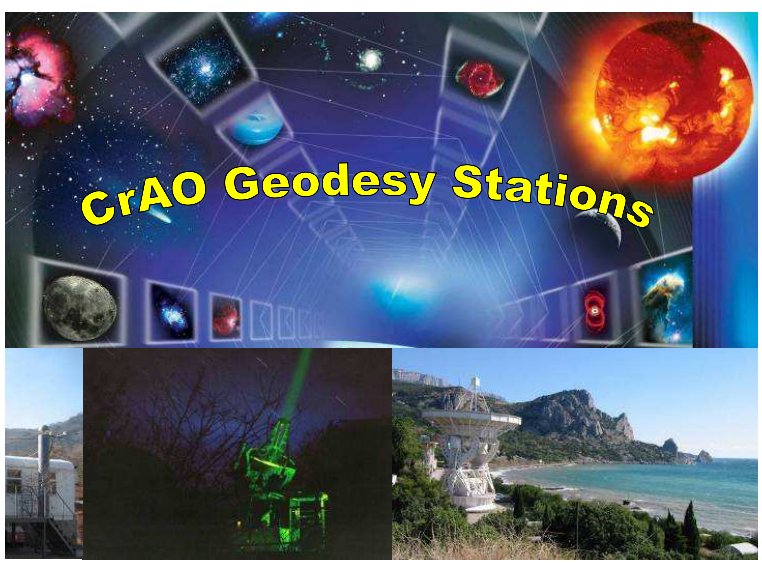

Figure 2. CrAO-GPS, Simeiz-1873 SLR, and Simeiz VLBI stations.

1.2. Satellite Ranging Station SLR "Simeiz-1873"

Regular satellite laser ranging started in our observatory in 1976 as an INTERKOSMOS station. In 1988 CrAO installed a new station (near the old station) with name Simeiz-1873 (Figure 2): Network: ILRS and EUROLAS, Name: Simeiz, Code: SIMI, Plate: Europe, CDP: 1873, IERS DOMES: 12337S003, Laser SOD: 12337S003. The coordinates of station are presented in Table 2.

Table 2. Coordinates to 01.01.2010 by ITRF2005 of the Simeiz-1873 station.

Latitude	44° 24′ 47.31″
Longitude	33° 59′ 27.44″
Height	364.24 m
X	3783902.127 m
Y	2551405.097 m
Z	4441257.417 m

1.3. GPS Station "GPS-CrAO"

The GPS-CrAO station (Figure 2) was upgraded in 2008. The GPS system includes a receiver and an antenna. The computer system and Meteorological Survey Equipment were supplied by NASA/Science Division/UNAVCO (Figure 3).

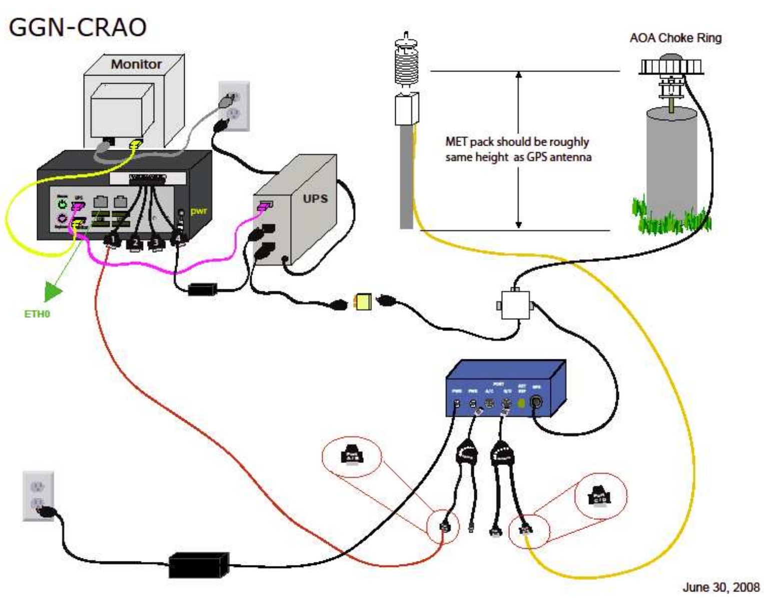

Figure 3. GGN-CrAO.

2. Current Status and Activities

In 2010 the Space Geodesy and Geodynamics stations regularly participated in the International Network programs of IVS, the International GNSS Service (IGS), and the International Laser Ranging Service (ILRS).

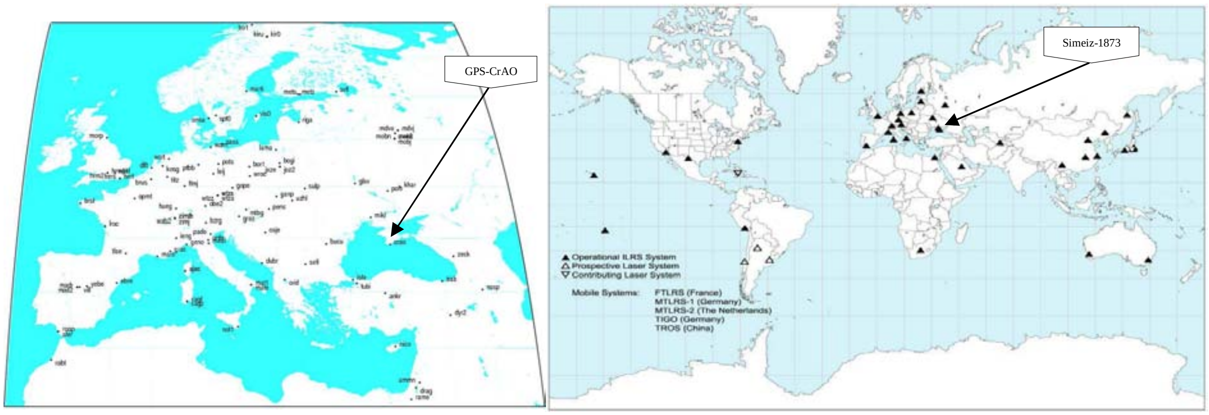

Figure 4. “GPS-CrAO” and “Simeiz-1873” stations of International Network - IGS and ILRS.

From January 1 through December 31, Simeiz VLBI station participated in twelve 24-hour geodetic sessions. Simeiz regularly participated in the EUROPE and T2 series of geodetic sessions.

Use of the Simeiz antenna is shared with the “Radioastron” program. The Research program provides for work with highly sensitive radiometers at frequencies of 22 GHz and 36 GHz. The catalog of sources for flight program “Radioastron” observations of a sample of sources from the preliminary “Radioastron” catalog were obtained at 22.2 and 36.8 GHz on the RT-22 radio telescope of the Crimean Astrophysical Observatory [1]. This makes it possible to obtain spectral characteristics of the sources near 22 GHz the fundamental frequency of the experiment “RadioAstron”. To implement the project prepared by the scientific program, a substantial part of which is the study of compact structures in extragalactic sources, we conducted ground-based VLBI test experiments.

3. Future Plans

Our plans for the coming year are the following: put into operation the VLBI Data Acquisition System DBBC, upgrade the laser of SLR Simeiz-1873 station, and set up new GPS station near Simeiz VLBI station.

References

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JARE Syowa Station 11-m Antenna, Antarctica

Koichiro Doi, Kazuo Shibuya, Yuichi Aoyama

Abstract

The operation of the 11-m S/X-band antenna at Syowa Station (69.0°S, 39.6°E) by the Japanese Antarctic Research Expeditions (JAREs) started in February 1998 and continues until today (December 2010). A cumulative total of 91 quasi-regular geodetic VLBI experiments were observed by the end of 2010. Syowa Station will participate in six OHIG sessions in 2011.

The data from three OHIG sessions in 2010 were recorded on hard disks through the K5 terminal. They will be brought back from Syowa Station to Japan in April 2011. The data from the OHIG62 through the OHIG69 sessions observed by JARE48 and JARE49 have been transferred to the Bonn Correlator directly by way of one of NICT's servers. Analysis results calculated by the GSFC IVS Analysis Center from the data until the OHIG69 session indicate that the length of the Syowa-Hobart baseline is increasing with a rate of 55.3 ± 0.9 mm/yr and that the length of the Syowa-HartRAO baseline is increasing with a rate of 10.9 ± 0.8 mm/yr. The length of the Syowa-O'Higgins baseline is slightly increasing with a rate of 2.5 ± 1.5 mm/yr.

1. Overview

Syowa Station has become one of the key observatories in the Southern Hemisphere's geodetic network, as reported in [1]. For VLBI, the Syowa antenna is registered as IERS Domes Number 66006S004 and as CDP Number 7342. The basic configuration of the Syowa VLBI front-end system has not changed from the description in [2].

A K5 recording system was introduced at Syowa Station in September 2004. Syowa's K4 recording terminal was fully replaced by K5 simultaneously with the termination of the SYW session at the end of 2004. Syowa has participated in the OHIG sessions in the austral summer season since 1999. Data transfer through an Intelsat satellite link from Syowa Station to NIPR became possible with the introduction of the K5 system, but huge VLBI data transfers are not realistic because of the low transfer speed.

2. Notes on System Maintenance

There is no significant problem in the "mechanical system". After the hydrogen maser set (Anritsu RH401A; 1002C) had been used for observations from 2004 to 2010, it was turned off at the end of 2010, because of problems in the 10 MHz output. A backup hydrogen maser set (Anritsu RH401A; 1001C) replaced the 1002C, and it is operating normally. The hydrogen maser 1002C will be back to Japan in April 2011. It will be overhauled and will be deployed in Syowa in January 2012 again. The tube in the Cs frequency comparator and local oscillator will have to be replaced with a new one in the near future.

3. Session Status

Table 1 summarizes the status of processing as of December 2010 for the sessions after 2004. The OHIG sessions involved Fortaleza (Ft), O'Higgins (Oh), Kokee Park (Kk), Parkes (Pa), TIGO Concepción (Tc), Syowa (Sy), Hobart (Ho), and HartRAO (Hh). In 2005, Syowa joined the CRD sessions, but after 2006, Syowa participated only in OHIG sessions. Syowa participated in three

OHIG sessions in 2010.

Until 2004, K4 tapes containing the OHIG sessions' data from Syowa Station were copied to Mark IV tapes at GSI, and the Mark IV tapes were sent to the Mark IV Correlator for final correlation. Since the introduction of the K5 system, K5 hard disk data brought back from Syowa Station have been transferred by ftp to the MIT Haystack Observatory or the Bonn Correlator through a NICT server and converted to the Mark 5 format data there.

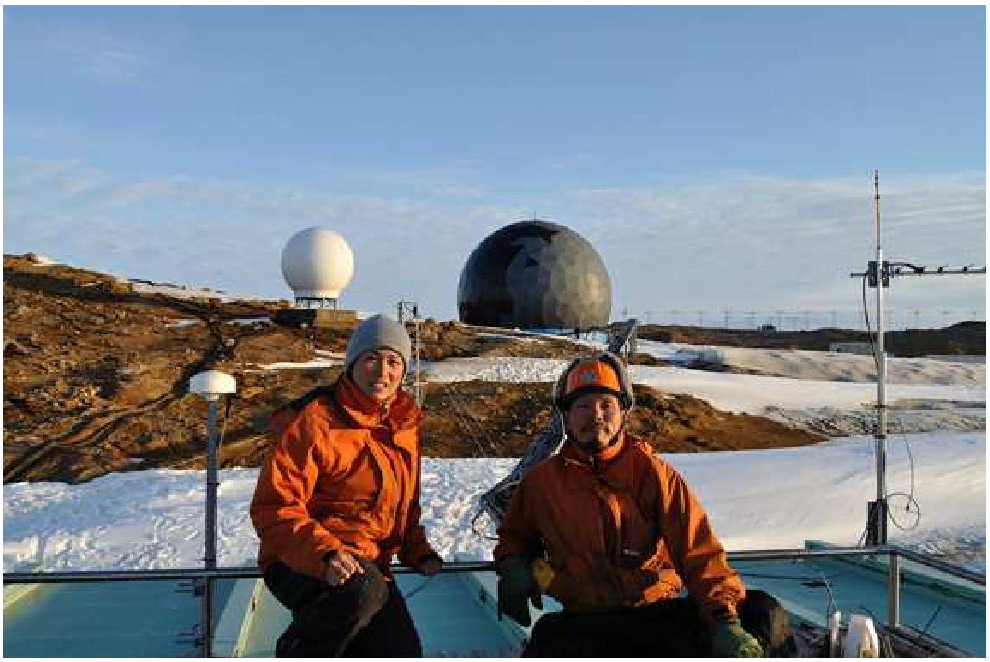


Figure 1. Syowa VLBI staff for JARE-51 (February 2010 — January 2011).

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

- Kazuo Shibuya, Project coordinator at NIPR.
- Koichiro Doi, Yuichi Aoyama, Liaison officer at NIPR.
- Yuichi Aoyama (from National Institute of Polar Research), Chief operator for JARE-49 (February 2008 — January 2009).
- Hideaki Kumagai (from NEC), Antenna engineer for JARE-49.
- Yusuke Murakami (from University of Tokyo), Chief operator for JARE-50 (February 2009 — January 2010).
- Yuji Yamaguchi (from NEC), Antenna engineer for JARE-50.
- Iuko Tsuwa (from University of Tokyo), Chief operator for JARE-51 (February 2010 — January 2011) (left in Figure 1).
- Yoshinao Kinjyo (from NEC), Antenna engineer for JARE-51 (right in Figure 1).

Table 1. Status of OHIG and CRDS sessions as of December 2010.

Code	Date	Station	Hour	Correlation	Solution	Notes
OHIG37	2005/Feb/02	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	J46
OHIG38	2005/Feb/15	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
CRDS18	2005/Apr/11	Ho, Hh	24 h	Yes	Yes	
CRDS19	2005/May/10	45, Hh	24 h	Yes	Yes	
OHIG39	2005/Nov/08	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG40	2005/Nov/09	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG41	2005/Nov/16	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG42	2006/Jan/31	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG43	2006/Feb/08	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	J47
OHIG44	2006/Feb/14	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG45	2006/Nov/07	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG46	2006/Nov/14	Ho, Hh, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG47	2006/Nov/29	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG49	2007/Feb/13	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	J48
OHIG51	2007/Nov/06	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG52	2007/Nov/07	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG53	2007/Nov/13	Ho, Hh, Ft, Oh, Kk, Pa, Tc	24 h	Yes	Yes	
OHIG54	2007/Nov/14	Ho, Hh, Ft, Oh, Kk, Pa, Tc	24 h	Yes	Yes	
OHIG55	2008/Feb/06	Hh, Oh, Kk, Tc	24 h	Yes	Yes	J49
OHIG56	2008/Feb/12	Hh, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG57	2008/Feb/13	Hh, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG59	2008/Nov/12	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG60	2008/Nov/18	Ho, Ft, Oh, Kk, Pa, Tc, Ts	24 h	Yes	Yes	
OHIG61	2008/Nov/19	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG62	2009/Feb/04	Ft, Ho, Kk, Oh, Tc	24 h	Yes	Yes	J50
OHIG63	2009/Feb/10	Ft, Ho, Kk, Oh, Tc	24 h	Yes	Yes	
OHIG64	2009/Feb/11	Ft, Ho, Kk, Oh, Tc	24 h	Yes	Yes	
OHIG65	2009/Nov/10	Ho, Kk, Oh, Tc	24 h	Yes	Yes	
OHIG66	2009/Nov/11	Ho, Kk, Oh, Tc	24 h	Yes	Yes	
OHIG67	2010/Feb/03	Ft, Kk, Oh, Tc	24 h	Yes	Yes	J51
OHIG68	2010/Feb/09	Ft, Ho, Kk, Oh, Tc, Hb	24 h	Yes	Yes	
OHIG69	2010/Feb/10	Ft, Ho, Kk, Oh, Tc, Hb	24 h	Yes	Yes	

45: DSS45, Ts: Tsukuba32
J46: JARE-46, op K. Egawa eng I. Okabayashi J47: JARE-47, op T. Sawagaki eng H. Ishii
J48: JARE-48, op N. Arai eng H. Sugawara J49: JARE-49, op Y. Aoyama eng H. Kumagai
J50: JARE-50, op Y. Murakami eng Y. Yamaguchi J51: JARE-51, op I. Tsuwa eng Y. Kinjyo

5. Analysis Results

As of the end of December 2010, 75 sessions from May 1999 through February 2010 have been analyzed with the software CALC/SOLVE developed by NASA/GSFC.

According to the result analyzed by the GSFC IVS Analysis Center, the length of the Syowa-Hobart baseline is increasing with a rate of 55.3 $\pm$ 0.9 mm/yr. The Syowa-HartRAO baseline shows a slight increase with a rate of 10.9 $\pm$ 0.8 mm/yr. These results agree approximately with those of GPS. The Syowa-O'Higgins baseline also shows slight increase, although the rate is only 2.5 $\pm$ 1.5 mm/yr. Detailed results from the data until the end of 2003 as well as comparisons with the results from other space geodetic techniques are reported in [3].

References

[1] Shibuya, K., Doi, K., and Aoki, S. (2003): Ten years' progress of Syowa Station, Antarctica, as a global geodesy network site. Polar Geoscience, 16, 29-52.

[2] Shibuya, K., Doi, K., and Aoki, S. (2002): JARE Syowa Station 11-m Antenna, Antarctica, in International VLBI Service for Geodesy and Astrometry 2002 Annual Report, 149-152, NASA/TP-2003-211619, ed. by N. R. Vandenberg and K. D. Baver.

[3] Fukuzaki, Y., Shibuya, K. Doi, K., Ozawa, T., Nothnagel, A., Jike, T., Iwano, S., Jauncey, D.L., Nicolson, G.D., and McCulloch, P.M. (2005): Results of the VLBI experiments conducted with Syowa Station, Antarctica. J. Geod., 79, 379-388.

Geodetic Observatory TIGO in Concepción

Sergio Sobarzo, Eric Oñate, Cristian Herrera, Pedro Zaror, Felipe Pedreros, Octavio Zapata, Hayo Hase

Abstract

In 2010, 119 successful VLBI observations were carried out at TIGO. The present report reviews the 2010 activities, and the forthcoming 2011 tasks are also given.

1. General Information

The operation of TIGO is based on an agreement between the Republic of Chile and the Federal Republic of Germany. The operation relies on three institutions:

- Universidad de Concepción (Chile),
- Instituto Geográfico Militar (Chile), and
- Bundesamt für Kartographie und Geodäsie (Germany).

TIGO is located on terrain of the Universidad de Concepción (long. 73.025 degrees West, lat. 36.843 degrees South), in Concepción, Chile.

2. Component Description

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

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

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

3. Staff

The VLBI staff changed in two positions: Miguel Soto and Cristian Duguet left TIGO at the beginning of the year and were replaced by Felipe Pedreros and Octavio Zapata. The 2010 TIGO VLBI group consisted of the persons listed in Table 1.

4. Current Status and Activities

During 2010 TIGO was scheduled to participate in 119 IVS experiments (see Table 2) and four 24-hour experiments framed of the TANAMI project [2]. Five additional experiments (TQUAK) had been initiated as soon as TIGOCONC became operational again after the M8.8 earthquake in Concepción on February 27, 2010.

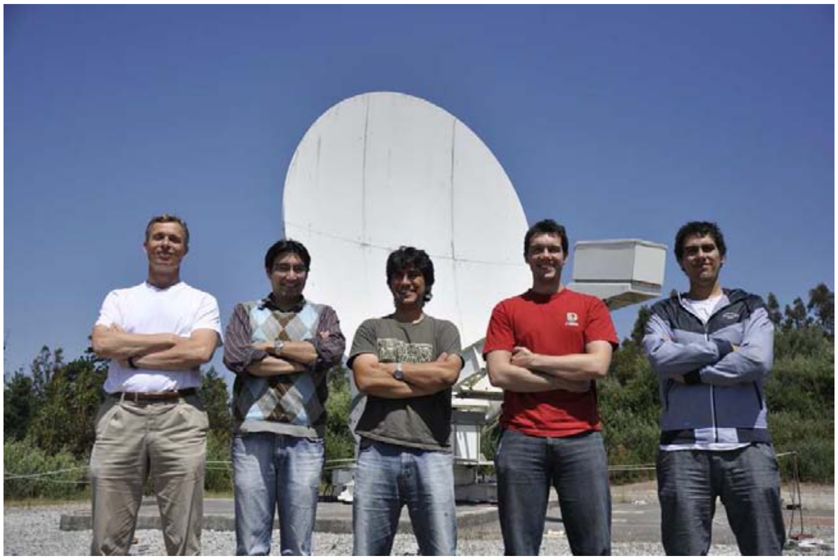


Figure 1. Current VLBI Staff: Hase, Herrera, Sobarzo, Zaror, and Zapata. Oñate and Pedreros were absent.

Table 1. TIGO-VLBI support staff in 2010.

Staff	Function	Email
Hayo Hase	Head	hayo.hase@tigo.cl
Sergio Sobarzo	Chief Engineer	sergio.sobarzo@tigo.cl
Eric Oñate	Electronic Engineer	eric.onate@tigo.cl
Cristian Herrera	Informatic Engineer	cristian.herrera@tigo.cl
Pedro Zaror	Mechanical Engineer	pedro.zaror@tigo.cl
Felipe Pedreros	Telecommunications Engineer	felipe.pedreros@tigo.cl
Octavio Zapata	Telecommunications Engineer	octavio.zapata@tigo.cl
any VLBI-operator	on duty	vlbi@tigo.cl
all VLBI-operators		vlbistaff@tigo.cl

Table 2. TIGO's IVS observation statistics for 2010.

Name	# of Exp.	OK	Failed
R1xxx	47	41	6
R4xxx	50	46	4
R&D	4	4	0
OHIGxx	6	6	0
T20xx	7	7	0
TQAKXX	5	5	0
Tanami	4	4	0
Total IVS	119	109	10

4.1. Post-earthquake Recovery

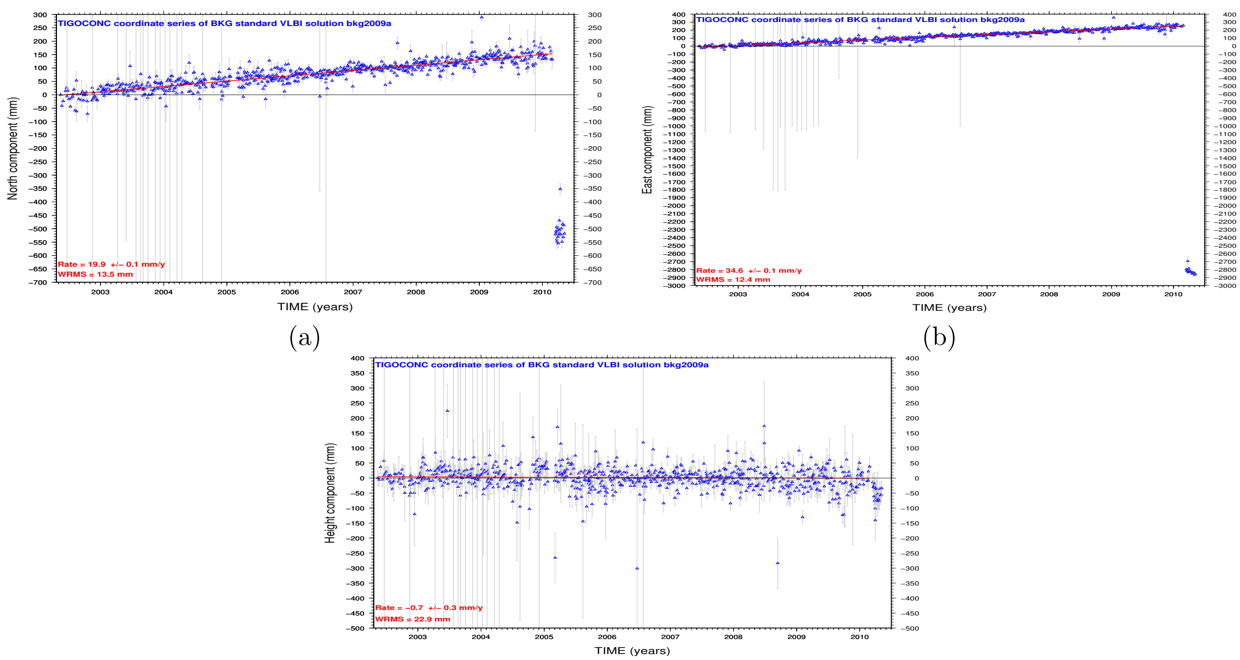
The M8.8 earthquake destroyed or damaged several instruments and infrastructure of TIGO. All TIGO containers had been shaken heavily and changed their positions. A horizontal displacement of more than 3 meters of the TIGO site was measured by GPS/GLONASS and later on confirmed by independent VLBI and SLR measurements (Fig. 2).

The recovery consisted of a diagnosis plan and damage analysis of the equipment to bring them back to operation as soon as possible. The TIGO team made tests of all components of the VLBI systems including racks, wiring, inclinometers, computers, and the radio telescope.

The mechanical functionality was carefully checked to detect possible damages in the cables chain, motors, and gears, among others by conducting manual movements in azimuth and elevation to avoid problems later on during real measurements.

Thanks to these successful tests, TIGO was able to participate already two weeks after the major event from the R1422 experiment onwards—covering still the period of strong post-seismic motion.

VLBI measurements are shown in Fig. 2 where the earthquake displacement and subsequent behavior can be appreciated.



(a) (b) (c)

Figure 2. TIGOCONC coordinate time series showing earthquake displacement. a) North component b) East component c) Height component.

4.2. Mark 5 Upgrade

In September and October 2010, an upgrade of the Data Acquisition System was performed. This consisted of a complete change of hardware and software of one of the two recording systems, namely from Mark 5A to Mark 5B, and the replacement of one VSI card in the formatter. For the development of this project, the MIT Haystack Observatory facilitated a Mark IV formatter as backup while the necessary tests and adjustments were performed for the implementation of the new system.

5. Future Plans

The VLBI activities in 2011 will be focused on:

- execution of the IVS observation program for 2011
- continuation of investigations related to e-VLBI
- repetition of the local survey.

(a) (b) (c)

Figure 3. Earthquake damage, photos taken in Concepción a few days after the quake.

References

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

[2] M. Kadler, R. Ojha, S. Tingay and J. Lovell, *The TANAMI Program: Southern-Hemisphere VLBI Monitoring of Relativistic Jets in Active Galaxies*, American Astronomical Society, AAS Meeting #211, #04.13; Bulletin of the American Astronomical Society, Vol. 39, p.732.

Tsukuba 32-m VLBI Station

Shinobu Kurihara, Kensuke Kokado, Ryoji Kawabata, Jiro Kuroda, Misao Ishihara, Daisuke Tanimoto, Yasuko Mukai

Abstract

The Tsukuba 32-m VLBI station is operated by the Geospatial Information Authority of Japan (GSI). This report summarizes the current status and the future plans of the Tsukuba 32-m VLBI station and related facilities. Over 200 sessions were observed with Tsukuba 32-m, Kashima 34-m, and other GSI antennas in accordance with the IVS Master Schedule. Lightning struck the Tsukuba facility in July, and the antenna and some devices were damaged. Some IVS sessions planned at Tsukuba were canceled, and Kashima 34-m antenna filled in for Tsukuba 32-m antenna during two months. In addition, several ultra-rapid dUT1 experiments and compact VLBI system experiments were conducted.

1. General Information

The Tsukuba 32-m VLBI station (TSUKUB32) is located at GSI in Tsukuba Science City which is about 50 km to the northeast of the capital Tokyo. GSI has three regional stations besides TSUKUB32: SINTOTU3, CHICHI10, and AIRA, which form the Geodetic VLBI network in Japan covering the whole country (Figure 2). GSI carried out the domestic VLBI session series called "JADE (JApanese Dynamic Earth observation by VLBI)". The main purposes of the JADE series are to define the reference frame of Japan and to monitor the plate motions for the advanced study of crustal deformations. Additionally, Mizusawa (VERAMZSW) and Ishigakijima (VERAISGK), which are part of the VERA network of the National Astronomical Observatory of Japan (NAOJ), also participated in the JADE sessions.

Figure 1. Tsukuba 32-m VLBI station and VLBI team.

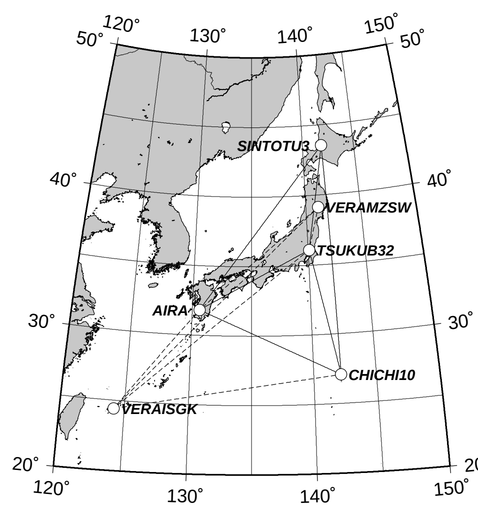


Figure 2. Geodetic VLBI network in Japan.

2. Component Description

The specifications of the Tsukuba 32-m antenna are summarized in Table 1.

Table 1. Tsukuba 32-m antenna specifications.

Owner and operating agency	Geospatial Information Authority of Japan
Year of construction	1998
Radio telescope system	Az-El
Receiving feed	Cassegrain
Diameter of main reflector	32 m
Azimuth range	10 – 710°
Elevation range	5 – 88°
Az/El drive velocity	3°/sec
Tsys (X/S)	50 K / 75 K
SEFD (X/S)	320 Jy / 360 Jy
RF range (X1)	7780 – 8280 MHz
RF range (X2)	8180 – 8680 MHz
RF range (X3)	8580 – 8980 MHz
RF range (S with BPF)	2215 – 2369 MHz
Recording terminal	K5/VSSP32, ADS3000+ with DBBC

In 2010, a hydrogen maser frequency standard (Anritsu Corp., SA0D05A) and the next generation gigabit sampler (Cosmo Research Corp., ADS3000+) were installed at Tsukuba 32-m station. And as the Field System PC, having been used since 2002, became dated, we replaced it with a new rack mount type PC.

3. Staff

Table 2 lists the regular operating staff belonging to the GSI VLBI observation group. The former head of the Space Geodesy Division, Shigeru Matsuzaka, transferred to the Planning Department as the Assistant Director for International Observation, and Misao Ishihara took over the division head position in April. Ryoji Kawabata newly joined our group as a technical official in April. Yoshihiro Fukuzaki and Yuji Miura moved to another division in June, and Jiro Kuroda became the deputy head of our division. Kensuke Kokado had been visiting the Haystack Observatory in the United States as a visiting researcher until January 6, but after that, he came back to our group. Kazuhiro Takashima had been an IVS Directing Board at-large member, but he left the post for health reasons. Shinobu Kurihara succeeded to the post in October. Routine operations were mainly performed under contract with Advanced Engineering Service Co., Ltd. (AES).

4. Current Status and Activities

4.1. Geodetic VLBI Observations

The regular sessions in the IVS Master Schedule are shown in Table 3. TSUKUB32 participated in 61 domestic and international 24-hr VLBI sessions and 118 Intensive 1-hr sessions this year. SINTOTU3, CHICHI10, and AIRA participated not only in domestic sessions but also in some international sessions.

Table 2. Staff list of the GSI VLBI group.

Name	Position/Company	Function
Misao ISHIHARA	Head of Space Geodesy Div.	Supervisor
Jiro KURODA	Deputy head of Space Geodesy Div.	Management, Collocation
Shinobu KURIHARA	VLBI operation chief	Responsible official, IVS DB member
Kensuke KOKADO	Analysis chief	Correlation, Analysis, Data transfer
Ryoji KAWABATA	Technical official	VLBI operation, miscellaneous work
Kazuhiro TAKASHIMA	Senior researcher	Research
Daisuke TANIMOTO	AES, Co., Ltd.	Observation
Yasuko MUKAI	AES, Co., Ltd.	Observation and Correlation
Toshio NAKAJIMA	I-JUSE	System engineer

Table 3. The number of regular sessions in 2010.

Sessions	TSUKUB32	KASHIM34	SINTOTU3	CHICHI10	AIRA
IVS-R1	38	6	–	–	–
IVS-T2	6	1	–	7	7
APSG	2	–	2	2	2
VLBA	4	1	–	–	–
IVS-R&D	5	–	–	–	–
JADE	6	2	7	4	4
IVS-INT2	80	12	–	–	–
IVS-INT3	38	7	–	–	–
Total	179	29	9	13	13

4.2. Lightning Strike at Tsukuba 32-m Antenna

On July 25, Tsukuba 32-m antenna was damaged by a lightning strike. The air conditioner in the observation room stopped, and the interface port of the ACU and the encoders for the Az drive & reflector in the waveguide were broken. Since it was expected to require a long time to restore the antenna, colleagues at NICT KSRC (National Institute of Information and Communications Technology, Kashima Space Research Center) kindly let us use Kashima 34-m antenna during repair period. We could operate totally 29 sessions using Kashima 34-m antenna in August and September as shown in Table 3. The session numbers in the KASHIM34 column only reflect sessions that were operated by GSI during the period of the Tsukuba 32-m repair. With the IVS-INT2 on October 2, Tsukuba 32-m resumed operation.

4.3. Ultra-rapid dUT1 Experiments

The ultra-rapid dUT1 experiment is a joint project of Japan (GSI & NICT) and Fennoscandia (Onsala & Metsähovi). This year again, we tried to transfer the regular IVS 24-hr data from the Fennoscandian station to the Tsukuba correlator and to carry out automatic data conversion, correlation, and data analysis. The experiment was conducted in 22 IVS 24-hr sessions and seven special schedules. For IVS-R1417 on February 8, we demonstrated the ultra-rapid experiment by near real-time Internet broadcasting of antenna image, correlation fringe image, and dUT1 time series plot at the 6th IVS General Meeting. The details of the analysis are reported in the Tsukuba Analysis Center report.

4.4. Developing a Compact VLBI System (MARBLE)

GSI and NICT are developing a compact VLBI system with a 1.5-m diameter aperture dish (MARBLE: Multiple Antenna Radio-interferometry of Baseline Length Evaluation) in order to provide reference baseline lengths for GPS and EDM calibration. In the report year, eight geodetic experimental observations were carried out between two MARBLEs and two large antennas (TSUKUB32 or KASHIM34). In particular, the last two experiments were implemented using ADS3000+ for data acquisition, and we succeeded in IF data sampling and obtaining geodetic solutions.

5. VLBI2010

GSI started the consideration of VLBI2010 by setting up the VLBI2010 Exploratory internal Committee in the Geodetic Department in January. So far, eight meetings have been convened, and the committee decided their policy to construct a new VLBI2010 antenna. After the decision, GSI included an expense for VLBI2010 in the budget requests for the next fiscal year starting in April 2011. The expense request is for RFI environment and underground condition surveys. In the government draft budget for the fiscal year 2011, the request was approved. The budget will be formally approved, when the bill is passed by the Diet.

6. Future Plans

The gigabit digital sampler “ADS3000+” will be used in routine operation. The anti-aliasing filters necessary for “ADS3000+” will be delivered by the end of March 2011. First we will try “ADS3000+” in a JADE session.

7. Other Topics

On December 24, Mr. Hyun-Hee Joo commenced a six-month visit to Japan from NGII (National Geographic Information Institute) of the Republic of Korea. He will stay at GSI until the middle of June 2011 to acquire VLBI-related technique and management skills necessary to succeed in their KVG (Korean VLBI for Geodesy) project.

Nanshan VLBI Station Report for 2010

Aili Yusup, Xiang Liu

Abstract

The Nanshan 25-meter radio telescope is operated by Urumqi Observatory. This report describes the activities and the status of Nanshan VLBI station as an IVS network station in 2010.

1. Introduction

The Nanshan VLBI station is located 70 km south of Urumqi, the capital city of the Xinjiang Uygur Autonomous Region of China. The station is affiliated with the Urumqi Observatory of the National Astronomical Observatories of CAS. In 2010, we participated in a total of 153 domestic and international VLBI sessions and contributed to IVS in geodetic VLBI observations. Nanshan VLBI station has participated in domestic VLBI experiments as one of the VLBI ground stations tracking the Chinese Chang'E satellite. In addition, a GPS station, as a part of the IGS network, is located near the VLBI telescope.

Figure 1. Urumqi Observatory of the National Astronomical Observatories of CAS is located at the foothills of the Tianshan mountain range. Within the IVS the site is also known as Nanshan VLBI Station.

2. Telescope Status

2.1. Antenna

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

Figure 2. The 25-m, modified Cassegrain radio telescope of Urumqi Observatory was built in 1993.

2.2. Receivers

The basic specifications of the receivers and the antenna sensitivity are given in Table 1. In 2010, the S/X-band feed horn was replaced with a new one.

Table 1. Specifications of receivers.

Parameters				Freq. Range (MHz)
1.3 cm	dual	under construction		22100–24000
3.6 cm	RCP	Tsys= 50K	DPFU=0.093	8100–8900
6 cm	dual	Tsys= 22K	DPFU=0.11	4700–5110
13 cm	RCP	Tsys= 70K	DPFU=0.096	2150–2450
18 cm	dual	Tsys= 24K	DPFU=0.088	1400–1720
30 cm	LCP	Tsys=160K	DPFU=0.06	800–1200
49 cm	dual	under construction		560–660
92 cm	dual	under construction		305–345

2.3. Recording System

The recording systems available at the Nanshan VLBI station are Mark 5B, Mark IV, Mark II, and K5. The performance of the observing system was improved in the report year. A new FS computer was installed, the Field System was upgraded to version 9.10.4, and it works well. The DBBC System, which was built at Shanghai Observatory (SHAO), was installed at Urumqi for domestic VLBI observations with the Mark 5B recorder. The analog BBC system is still being used for international VLBI observations together with the Mark 5B recorder.

2.4. Time and Frequency System

There are three H-masers at Nanshan Station: an MHM2010 imported from Symmetricom company of the U. S. plus the No. 13 and No. 90 H-masers made in Shanghai. The time and frequency comparison system operates continuously.

3. IVS Observations in 2010

Nine IVS sessions were scheduled for Nanshan VLBI station in 2010. We participated in six of these sessions and had to cancel three sessions due to a conflict with tracking the Chinese Chang'E-2 satellite from September to November 2010; the details for five of these sessions are listed in Table 2. There is a pretty strong but narrow 3G cellphone signal at S-band, which led to a total loss of signal in SR2U as documented in the IVS session reports.

Table 2. IVS sessions of Nanshan VLBI station in 2010.

Experiment	Date	Remarks (problems)
T2067	02.02	Observed, no signal in SR2U
T2068	04.13	Observed, no signal in SR2U
T2069	05.18	Observed, no signal in SR2U
T2070	07.20	Observed, no signal in SR2U
APSG27	12.15	Observed, no known problems

4. Personnel

The main staff of Nanshan VLBI Station is compiled in Table 3.

Table 3. The main staff of Nanshan VLBI Station.

Name	Position	Working area	e-mail
Na Wang	Professor	Station chief	na.wang@uao.ac.cn
Aili Yusup	Professor	Chief engineer	aliyu@uao.ac.cn
Xiang Liu	Professor	VLBI friend	liux@uao.ac.cn
Maozheng Chen	Senior engineer	Receiver	mzchen@uao.ac.cn
Minghui Shao	Senior engineer	Time and Freq., Terminal	shaomh@uao.ac.cn
Wenjun Yang	Engineer	Terminal	yangwj@uao.ac.cn
Shiqiang Wang	Engineer	Antenna	Wangshq@uao.ac.cn
Hua Zhang	Engineer	Terminal, Time and Freq.	zhangh@uao.ac.cn
Guanghui Li	Engineer	Network, Computer	ligh@uao.ac.cn
Jun Ma	Engineer	Receiver	majun@uao.ac.cn
Chenyu Chen	Engineer	Antenna	chency@uao.ac.cn
Jun Nie	Scientist	Network, Computer	niejun@uao.ac.cn
Ming Zhang	Scientist	Astronomy	zhangming@uao.ac.cn

Warkworth 12-m VLBI Station: WARK12M

Sergei Gulyaev, Tim Natusch, Stuart Weston, Neville Palmer, David Collett

Abstract

This report summarizes the geodetic VLBI activities in New Zealand in 2010. It provides geographical and technical details of WARK12M—the new IVS network station operated by the Institute for Radio Astronomy and Space Research (IRASR) of Auckland University of Technology (AUT). The details of the VLBI system installed in the station are outlined along with those of the co-located GNSS station. We report on the status of broadband connectivity and on the results of testing data transfer protocols; we investigate UDP protocols such as 'tsunami' and UDT and demonstrate that the UDT protocol is more efficient than 'tsunami' and 'ftp'. Overall, the station is fully equipped, connected, and ready to start participating in regular IVS observational sessions from the beginning of 2011.

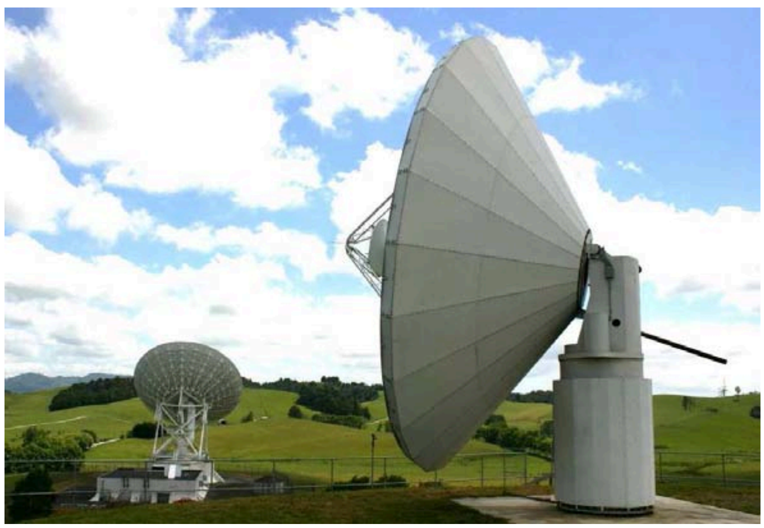


Figure 1. Warkworth 12-m (right) and Warkworth 30-m (left) antennas. Photo: Jordan Alexander

1. Introduction

The New Zealand 12-m radio telescope is located some 60 km north of the city of Auckland, near the township of Warkworth (see Figure 1). It was manufactured by Patriot Antenna Systems (now Cobham Antenna Systems), USA. The antenna specifications are provided in Table 1. The radio telescope is designed to operate at S and X bands and supplied with an S/X dual-band dual-polarization feed. The antenna is equipped with a digital base band converter (DBBC) developed by the Italian Institute of Radio Astronomy, a Symmetricom Active Hydrogen Maser MHM-2010 (75001-114), and a Mark 5B+ data recorder developed at MIT Haystack Observatory.

The support foundation for the antenna is a reinforced concrete pad that is 1.22 m thick by 6.7×6.7 meters square. The ground that the foundation is laid on consists of weathered sandstone/mudstone, i.e. of sedimentary origin, laid down in the Miocene period some 20 million years ago. The pedestal is essentially a steel cylinder of 2.5 m diameter. It supports the antenna elevation axis which is at a height of approximately 7.1 m above ground level. Apart from the pedestal,

Table 1. Specifications of the Warkworth 12-m antenna.

Antenna type	Dual-shaped Cassegrain
Manufacturer	Cobham/Patriot, USA
Main dish Diam.	12.1 m
Secondary refl. Diam.	1.8 m
Focal length	4.538 m
Surface accuracy	0.35 mm
Pointing accuracy	18″
Frequency range	1.4—43 GHz
Mount	alt-azimuth
Azimuth axis range	$90^\circ \pm 270^\circ$
Elevation axis range	4.5° to 88°
Azimuth axis max speed	5°/s
Elevation axis max speed	1°/s
Main dish F/D ratio:	0.375

all other components of the antenna (the reflector and feed support structure) are constructed of aluminium. The radio telescope is directly connected to the regional network KAREN (Kiwi Advanced Research and Education Network) [1].

In November 2010 Telecom New Zealand handed over to Auckland University of Technology its 30-meter Cassegrain wheel-and-track beam-waveguide antenna. It was manufactured in 1984 by Nippon Electric Corp., and since then it was used by Telecom NZ for communication between New Zealand and various Pacific Islands. The antenna is just 200 meters north of WARK12M (Figure 1). According to expert opinion, the antenna is in good state, and after conversion to a radio telescope, it has the potential to contribute to both astronomical and geodetic VLBI.

2. Antenna Position Survey

The reference point of a VLBI site is defined as the intersection of the azimuth and elevation axes of the telescope. A preliminary survey has been conducted in collaboration with the New Zealand Institute of Geological and Nuclear Sciences (GNS Science) and Land Information New Zealand (LINZ) to determine an initial estimate of the reference point of the VLBI site WARK12M (see details in [2]). A real-time kinematic (RTK) GPS method was used to derive the position with respect to the co-located GPS station WARK.

A co-located GPS station WARK was established in November 2008 at the radio telescope site and is one of 39 PositioNZ network stations in New Zealand [3]. All data received from the PositioNZ stations are processed to produce daily positions for each station in terms of ITRF2000. The RTK reference receiver was set up in an arbitrary location with clear sky view and was configured to record raw observations in addition to transmitting real-time corrections. The RTK station was later post-processed with respect to WARK, and all RTK rover-surveyed positions were subsequently adjusted relative to the updated reference position.

Several points on the rim of the main reflector were identified, and each point was measured several times with the RTK rover while the telescope was repositioned in elevation and azimuth between each measurement. The rover GPS antenna was mounted on a 0.5 m survey pole and was hand held for each measurement. For determination of the horizontal axis, the telescope azimuth axis was held fixed at $Az = 0°$. A point near the highest edge of the reflector was identified and measured with the telescope in four positions of elevation. This was repeated with a point on the edge of the reflector to one side of the telescope. Five positions of elevation were measured at this point. For determination of the vertical axis, the telescope elevation axis was held fixed at $El = 80°$. Three points around the edge of the reflector were identified, and three measurements of each identified point with the fixed telescope elevation and varying azimuths were conducted. The resulting points from these measurements describe two vertical circles of rotation which define the movable elevation axis and three horizontal circles of rotation which define the movable azimuthal axis. The coordinates for all subsequent calculations were retained as geocentric Cartesian coordinates to avoid any possibility of errors related to transformation of projection.

To determine the axes and their intersection point, the equation of a circle from three points was used to calculate all possible combinations of three observed points which define a circle of rotation. Mean values were taken for all horizontal axis definitions and all vertical axis definitions. The midpoint of the closest point of approach of each axis with the other was used as the final estimate of the point of intersection. The distance between the axes was calculated to be 24 mm. Based on the variation of results for different combinations of survey points, we estimate that the accuracy of the determined intersection point is within 0.1 m.

In summary, the following coordinates of the intersection of the azimuth and elevation axes for WARK12M were derived in terms of ITRF2000 at the epoch of the survey (March 2010):

$$
\begin{array}{lcrcl}
\mathrm{X} & = & -5115324.5 & \pm & 0.1 \mathrm{~m} \\
\mathrm{Y} & = & 477843.3 & \pm & 0.1 \mathrm{~m} \\
\mathrm{Z} & = & -3767193.0 & \pm & 0.1 \mathrm{~m}
\end{array}
$$

The radio telescope reference point coordinates will subsequently be re-determined to a higher accuracy with the use of a variety of terrestrial and GNSS survey techniques (e.g. [4]) and a more rigorous least squares analysis of the observations. Four geodetic survey monuments have been built within 15–20 m from the antenna pedestal for this purpose.

3. Network Connectivity and Data Transfer Protocols

In April 2010, the regional advanced network KAREN established a GigaPoP at the Warkworth Radio Astronomical Observatory, which provides a 1 Gbps international connectivity for the WARK12M radio telescope. Soon after the connection of WARK12M to KAREN, connectivity was achieved with a number of VLBI partners and correlation centers, including Bonn (Germany), CSIRO (Australia), JIVE (Netherlands), and Metsähovi (Finland).

Various network protocols were tested, such as 'ftp', 'tsunami' [5] and UDT [6]. The results of data transfer tests between the IRASR and the data processing center in Bonn are presented in Table 2. They were obtained by transferring an actual 16-bit VLBI file produced in observations with the 12-m radio telescope. It was transferred from IRASR's IBM Blade server via the KAREN network using the default settings for each protocol with no tuning. Columns 1 and 2 show the protocol used and the amount of data sent in bytes, and columns 3 and 4 give the time it took to transfer the data and an average throughput rate (each test was repeated 5–10 times).

Table 2. Data transfer statistics: IRASR to Bonn.

Protocol	Bytes	Time (s)	Throughput (Mbps)
Ftp	65 G	8016	65
Tsunami	65 G	3466	151
UDT	65 G	1920	273

Table 2 clearly demonstrates the advantage of the UDT protocol over ‘tsunami’ and ‘ftp’. UDT is about two times faster than ‘tsunami’ and more than four times faster than the standard ‘ftp’ protocol. Tests were conducted repeatedly over several days and at different times resulting in slightly different average rates without changing the main conclusion that the UDT protocol is superior to ‘ftp’ and ‘tsunami’. In addition, UDT has an application programming interface (API) allowing easy integration with existing or future applications. Also, UDT is a better citizen on the network leaving bandwidth for TCP and other UDP protocols, a capability which is very important on a shared network such as KAREN.

A traceroute command from the AUT Blade server to the IP address in Bonn gave a route of 14 hops. Re-issuing this command repeatedly over several months showed that the route appears stable, without any changes. A high number of hops on the route (14) demonstrates the complexity of the path and explains why data transfers via protocols such as ‘ftp’ are not efficient.

In June 2010 file transfer tests to the correlator site at Curtin University, Perth were conducted. Using ‘tsunami’, a rate of 300 Mbps was achieved, while UDT was superior at 400 Mbps sustained throughput. In December 2010 the first e-VLBI tests from the Mark 5B recorder at the Warkworth Observatory to a server at CSIRO, Australia using UDP were conducted. The required data rate of 512 Mbps was achieved sustainably.

It is worth mentioning data transfer sessions conducted between Warkworth and Metsähovi in 2010. In August WARK12M participated in observations of the ESA’s Mars Express (MEX). First, data (86 GB) was transmitted to Metsähovi using ‘tsunami’; the next set of data (187 Gbytes) was sent to Metsähovi using UDT. Average rates sustained were 250 and 300 Mbps respectively.

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Westford Antenna

Mike Poirier

Abstract

Technical information is provided about the antenna and VLBI equipment at the Westford site of the Haystack Observatory and about changes to the systems since the IVS 2009 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.

Table 1. Location and addresses of the 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`	

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. Funding for geodetic VLBI at Westford is provided by the NASA Space Geodesy Program.

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.

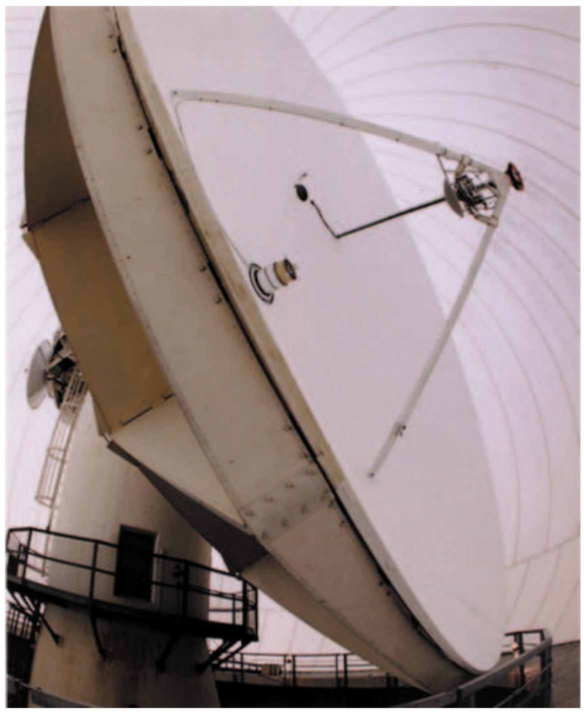

Figure 2. Wide-angle view of the Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

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 IV electronics rack, a Mark 5B recording system, and a Pentium-class PC running PC Field System version 9.10.2. The primary frequency and time standard is the NR-4 hydrogen maser. A CNS Clock GPS receiver system provides independent timing information and comparisons between GPS and the maser. Westford also hosts the WES2 GPS site of the IGS network. A Dorne-Margolin chokering antenna is located on top of a tower ∼60 meters from the VLBI antenna, and a LEICA GRX1200 Reference Station receiver acquires the GPS data.

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

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

3. Westford Staff

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

Chris Beaudoin	broadband development
Joe Carter	antenna controls
Brian Corey	VLBI technical support
Kevin Dudevoir	pointing system software
Dave Fields	technician, observer
Glenn Millson	observer
Arthur Niell	principal investigator
Michael Poirier	site manager
Alan Whitney	site director

4. Status of the Westford Antenna

From January 1, 2010 through December 31, 2010, Westford participated in 61 standard 24-hour and 31 Intensive geodetic sessions. Westford regularly participated in the IVS-R1, IVS-R4, IVS-R&D, RD-VLBA, TQAK, and Intensive sessions along with fringe tests, e-VLBI sessions, and VLBI2010 broadband development testing.

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

Westford did not participate in any e-VLBI sessions during 2010 due to network limitations to the outside world from Haystack. 2011 expects to see this role change with network upgrades already scheduled and in progress. e-VLBI participation was replaced by the evaluation of the new Roach Digital Backend (RDBE) and Mark 5C units, a joint program with NRAO. Successful geodetic trials of the systems between Westford and the 5 meter at GGAO were achieved.

6. VLBI2010

In April 2010, Westford participated in a broadband VLBI experiment with MV3 at GGAO in which the source 4C39.25 was observed through transit. This experiment provided data to aid in the development of polarimetric analysis of the geodetic observables.

7. Outlook

Westford is expected to participate in 80 24-hour sessions in 2011. We also plan to have the flexibility to support occasional fringe tests, e-VLBI experiments, and the continuing VLBI2010 broadband development testing.

Geodetic Observatory Wettzell: 20-m Radio Telescope and Twin Telescope

Alexander Neidhardt, Gerhard Kronschnabl, Raimund Schatz

Abstract

In the year 2010 the 20-m radio telescope at the Geodetic Observatory Wettzell, Germany contributed again very successfully to the IVS observing program. But because of a problem with the elevation bearing the workload had to be reduced, and a three-month maintenance shutdown from September to November was necessary. Aside from this, technical changes, developments, improvements, and upgrades have been done to increase the reliability of the entire VLBI observing system. In parallel the construction of the new Twin radio telescope (TTW) has continued.

1. General Information

The 20-m Radio Telescope Wettzell (RTW) is an essential component of the Geodetic Observatory Wettzell (GOW) and is jointly operated by Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie (FESG) of the Technical University Munich. In addition to the RTW also an ILRS laser ranging system, several IGS GPS permanent stations, a large laser gyroscope G (ringlaser), and complementary local techniques such as time and frequency, meteorology, and superconducting gravity meter are operated. Currently also the first fully VLBI2010 compliant Twin telescope is built up on location of the GOW. It should extend the observation possibilities according to the technical suggestions of the International VLBI Service for Geodesy and Astrometry (IVS) Working Group 3 (WG3) and VLBI2010 Committee.

Within the responsibility of the GOW are also the TIGO system in Concepción, Chile, operated mainly together with the Universidad de Concepción (see separate report about TIGO), and the German Antarctic Receiving Station (GARS) O'Higgins in Antarctica, operated together with the German Space Center (DLR) and the Institute for Antarctic Research Chile (INACH) (see separate report about O'Higgins).

2. Staff

The staff of the GOW consists in total of 32 members (excluding students) for operations, maintenance, repair issues, and improvement and development of the systems. The staff operating RTW is summarized in Table 1. One additional engineer is on a position which is funded by the "Novel EXploration Pushing Robust e-VLBI Services" (NEXPReS) project in cooperation with the Max-Planck-Institute for Radioastronomy (MPIfR), Bonn. It was also possible to support student operators to work within development projects and internships.

3. Observations in 2010

The 20-m RTW has supported the geodetic VLBI activities of the IVS and other partners, such as the EVN, for over 25 years. All successfully observed sessions in the year 2010 are summarized in Table 2. Because of a severe problem with the elevation bearing, the observation workload had to be reduced to less than 50% of the normal from March to August. In consultation with the IVS

Table 1. Staff members of RTW.

Name	**Affiliation**	**Function**	**Working for**
Johannes Ihde	BKG	interim head of the GOW (until September 2010)	GOW
Ullrich Schreiber	BKG	head of the GOW (since October 2010)	GOW
Alexander Neidhardt	FESG	head of the RTW group and VLBI station chief	RTW, TTW (partly O'Higgins, laser ranging)
Erhard Bauernfeind	FESG	mechanical engineer	RTW
Ewald Bielmeier	FESG	technician	RTW
Gerhard Kronschnabl	BKG	electronic engineer	RTW, TTW (partly TIGO and O'Higgins)
Christian Plötz	BKG	electronic engineer	O'Higgins, RTW
Raimund Schatz	FESG	software engineer	RTW
Walter Schwarz	BKG	electronic engineer	RTW (partly O'Higgins and WVR)
Reinhard Zeitlhöfler	FESG	electronic engineer	RTW
Martin Ettl	FESG/MPIfR	IT and computer scientist (since August 2010)	NEXPReS
Alexander Bauer	FESG/BKG	student (January to May 2010)	RTW
Thomas Guggeis	FESG/BKG	student (January to December 2010)	RTW, project work
Martin Riederer	FESG/BKG	student (March to December 2010)	RTW, project work
Johannes Vogl	FESG/BKG	student (March to December 2010)	RTW, project work

Table 2. RTW observations in 2010.

program	**number of 24h-sessions**
IVS R1	29
IVS R4	28
IVS T2	1
IVS R&D	5
RDV/VLBA	1
EUROPE	2
total	**66**
total (in hours)	**1584**

program	**number of 1h-sessions**
INT1(Kokee-RTW)	175
INT2/K(Tsukuba-RTW)	68
INT3/K(Tsukuba-RTW-NyAl)	33
total (in hours)	**276**

special program	**in hours**
VENUS (4 obs.)/MARS Express (1 obs.)	5
DBBC tests	1
total (in hours)	**8**

Coordinating Center, the IVS 2010 Master Schedule was adjusted to optimize the combination of R1 and R4 with minimal influence on the time series. The main priority was to participate in all daily one-hour INTENSIVE sessions (INT) in order to determine UT1-UTC. For these sessions the complete data transfer is done with e-VLBI techniques. RTW routinely uses the increased Internet connection capacities of 1 Gbit/sec for the e-transfers to Bonn, Tsukuba, and Haystack. According to the implementation of a Field System extension for remote control, weekend INTENSIVEs were done in the new observation modes by remote attendance, remote control from students at the laser ranging system, or completely unattended (these new modes were suspended in the time of the bearing problems).

In addition to the standard sessions, RTW was also active for Digital Baseband Converter (DBBC) tests and for spacecraft tracking. Within these additional one-hour observations the ESA Venus Express and the Mars express spacecraft were observed at X-band with the Wettzell radio telescope, using a framework of the assessment study for possible contributions in the European VLBI network to the upcoming ESA deep space missions. The first goal of these observations was to develop and test the scheduling, data capture, transfer, processing, and analysis pipeline.

The high dynamic range of the detections allowed achievement of a milliHz level of the spectral resolution accuracy and extraction of the phase of the spacecraft signal carrier line. Apart from other important results, the measured phase fluctuations of the carrier line at different time scales can be used to determine the influence of the Solar wind plasma density fluctuations on the accuracy of the astrometric VLBI observations.

4. Technical Improvements and Maintenance

VLBI observations require high reliability of all participating stations. Therefore careful maintenance of all components is essential to ensure successfully performed VLBI measurements through the year. Within the maintenance work, the repair of the bearing was one of the big events of the year. The radio telescope team became aware of emerging elevation bearing problems about a year ago. In early spring the problem increased, when squeaking noises forced the operators to stop observing sessions. In March a special inspection done by the Wettzell group and a team from Vertex Antennentechnik GmbH brought to light that the elevation bearings were severely damaged. The right side of the elevation axis was lowered by 2 mm and the left side by 0.5 mm in comparison to the original state. In consultation with the Coordinating Center, Wettzell's observing load was reduced while technical solutions were investigated. In order to change the defective bearings, a disassembly of the antenna was unavoidable. Luckily a sufficient amount of money was put aside by FESG over the past several years so that the repair could be funded by the FESG. Then the repair itself was scheduled for September to November. A 400-ton crane lifted the 40-ton main reflector and the counterweights (each 35 tons) off the pedestal. After inspection the gear wheels and the new elevation bearings were installed a few days later. Following a couple of photogrammetric surveys the dish surface could be re-adjusted to 0.15 mm RMS. Almost as planned, the 20-m radio telescope went back into operation on 29 November 2010. Within the whole maintenance the RTW team, the administration of the TUM (especially FESG), and, of course, the whole team of Vertex Antennentechnik GmbH did an excellent job.

Figure 1. Repair of the bearings of the 20-m radio telescope.

The Twin Telescope Wettzell (TTW) project has been planned for the period 2008-2011. As the construction of the tower foundations was finished at the end of 2009, where the main driver was the high stability requirement of the reflector for several load scenarios (with snow, ice, and wind), the structures of the main reflectors were assembled from their single parts at the beginning of 2010. The elevation cabins (40-ton-per-piece steel construction) had to be trucked from Italy to Wettzell on a heavy load transport. As the 400-ton crane was already ordered for the repair of the 20-m telescope, it was cost-effective to also use it for the mounting of the "Twins". On 19 October 2010 the lift of the reflectors became a media event with television and reporter teams on location. The installation worked flawlessly and after the last of the 280 screws at each reflector was tightened, the silhouettes of the new instruments were visible for the first time. First functionality tests of the new radio telescopes are scheduled for 2011. Together with the existing 20-m antenna, the Twin Telescope offers many new possibilities for satisfying future geodetic needs.

Figure 2. The new "skyline" of the observatory with the Twin telescopes in the background.

In July the NEXPReS project started. Wettzell participates in Task 3 of Work Package 5 mainly together with MPIfR. The goal is to support the identification and repair of failures of the systems during e-VLBI correlations in near real-time. Therefore the software implementations for a remotely controllable extension to the NASA Field System (FS) will be continued. An appropriate authentication, a dedicated role management for different user types, different remote access states to shared telescopes, and sophisticated graphical user interfaces should be developed. In 2010 the project started with the engagement of Martin Ettl as project engineer and with first preparations to release the existing software for future FS packages.

Additionally, the 20-m RTW has to be kept on a high technical standard and has to be improved according to technological advancement. In 2010 the following additional developments and maintenance tasks have been done:

- Test setup of the new Digital Baseband Converter (DBBC), including observations with test schedules to record data for system evaluations, maintain parts of the controlling code to run the DBBC via Ethernet.
- Regular tasks and maintenance days (obtaining replacements for the hardware, 8-pack repairs, gear maintenance, FS updates, cryo-system maintenance, servo replacements, improvements by using EVN-PCs for e-VLBI issues).

5. Plans for 2011

For 2011, dedicated plans are:

- Usage of the digital baseband converters (DBBC)
- Continuing NEXPReS
- Continuing construction of and first tests with the Twin telescopes
- Investigations on VLBI2010-conforming radar systems for laser ranging.

Instituto Geográfico Nacional of Spain

Francisco Colomer, Jesús Gómez–González, José Antonio López–Fernández, Susana García–Espada, Pablo de Vicente

Abstract

This report updates the description of the Yebes Observatory facilities as an IVS Network Station. The Yebes 40-m radio telescope has performed geodetic VLBI observations regularly since September 2008. In addition to this, the project to establish an Atlantic Network of Geodynamical and Space Stations (RAEGE) is progressing well, and the construction of the first three antennas of VLBI2010 specifications has been contracted.

1. General Information: the IGN Facilities at Yebes

The radio telescopes (the new 40-m and the old 14-m which was an IVS Network Station since 2003) are located at the Observatory of Yebes, a department of the Instituto Geográfico Nacional (IGN, Ministerio de Fomento).

Yebes Observatory is also the reference station for the Spanish GNSS network and holds permanent facilities for gravimetry. The RAEGE project will provide a new VLBI2010-type antenna in Yebes in 2012. An SLR system in a new control building will also be built in the near future.

2. IGN Staff Working on VLBI Projects

Table 1 lists the IGN staff who are involved in geodetic VLBI studies and operations. The VLBI activities are also supported by other staff such as receiver engineers, computer managers, secretaries, and students. The process of hiring dedicated telescope operators has suffered delays, not being yet available; this limits the amount of observing time that Yebes can offer to the IVS.

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

Name	Background	Role	Address*
Francisco Colomer	Astronomer	VLBI Project coordinator	ROM, IGN
Pablo de Vicente	Astronomer	VLBI Technical coordinator	CAY
Susana García–Espada	Engineer	geoVLBI expert	CAY
Jesús Gómez–González	Astronomer	Deputy Director for Astronomy, Geodesy and Geophysics	IGN
José Antonio López–Fdez	Engineer	Yebes site manager	CAY
Javier López–Ramasco	Geodesist	Geodesist	CAY
Alvaro Santamaría	Geodesist	Geodesist	CAY

Addresses:

ROM: Real Observatorio de Madrid. Calle Alfonso XII, 3. E–28014 Madrid, Spain.
CAY: Centro Astronómico de Yebes. Apartado 148, E–19080 Guadalajara, Spain.
IGN: Instituto Geográfico Nacional. Calle General Ibañez de Ibero 3, E–28003 Madrid, Spain.

Table 2. Characteristics of the Yebes 40-m geodetic VLBI station.

Parameter	Value	DAR	VLBA5 (14) + VSI-C
Diameter	40 meter	Recorder	Mark 5B
Receivers	2 - 115 GHz	H-maser	T4-Science iMaser 3000
S/X T_{sys}	190/50 K	GPS	TrueTime XL-DC
S/X SEFD	1400/210 Jy	Weather station	SEAC-EMC

3. Status of Geodetic VLBI Activities at IGN

The 40-m radio telescope has participated in 18 sessions, of the EURO, R4, and T2 types. One was lost (R4425, bad disk reported).

Yebes has been connected to GÉANT at 1 Gbps since April 2009. Ways to increase the capacity are under consideration.

A new Hydrogen maser has been purchased, to replace the Russian KVART-73 maser which failed in 2009 after 13 years of successful operation.

An absolute gravimeter is now permanently placed at the new building in Yebes. A GWR superconducting gravimeter was installed in May 2010 (see Fig. 1).

Figure 1. GWR superconducting gravimeter installed in a dedicated building in Yebes.

Cooperation with the geodesy group at Onsala Space Observatory in Sweden continued by modeling the tropospheric effect caused by neutral atmosphere using the HIRLAM 3D-VAR numerical weather prediction model, where a direct improved mapping function is calculated using raytracing. First results were presented at the IVS 2010 General Meeting in Hobart (Australia).

4. Project RAEGE

IGN has started the construction in Spain and Portugal of a network of four new Fundamental Geodynamical and Space Stations. The project, named *RAEGE* (after "**R**ed **A**tlántica de **E**staciones **G**eodinámicas y **E**spaciales"), consists of the erection in Yebes (1), Canary Islands (1), and Azores Islands (2), of one radio telescope of VLBI2010 class (i.e. of 13.2-m diameter, high slew rate, capable of operating in the 2-14 GHz bands but also up to 90 GHz), a permanent GNSS receiver, a gravimeter, and (at least in Yebes) an SLR station.

Radio frequency interference (RFI) has been monitored at the Yebes station and the chosen sites at the Santa María (see Fig. 2) and Flores Island of the Azores, demonstrating that in the latter cases the spectrum in the band of interest is very clean.

The construction of three antennas, to be installed in Yebes, Azores (Santa María), and Canary Islands, has been contracted to MT Mechatronics (Germany). The first antenna (see Fig. 3) will be erected in Yebes in 2012, shortly followed by the antenna in Santa María.

A cooperation with the Institute of Seismology (IoS) of the Chinese Academy of Sciences will allow the loan of a mobile SLR system to Yebes in 2011. This system will operate until the fixed SLR station is built.

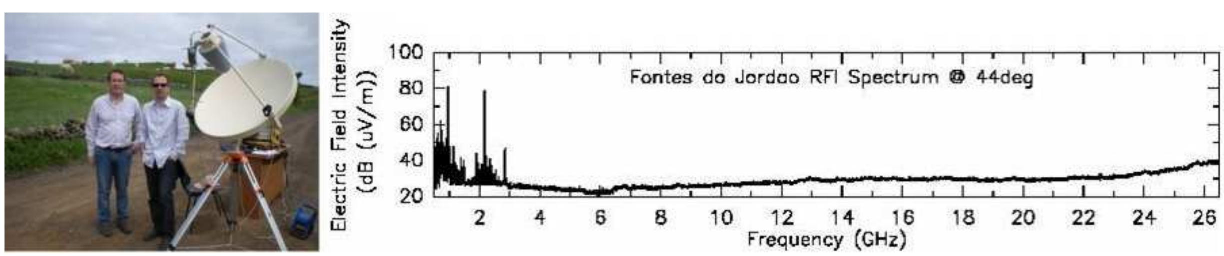

Figure 2. RFI measurement at the RAEGE station in Santa María, Azores Islands.

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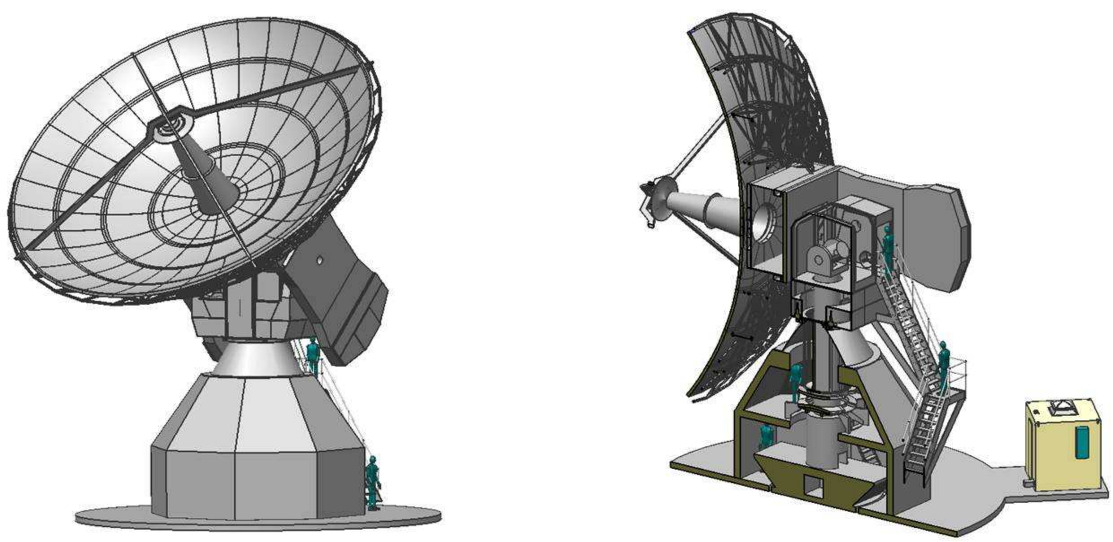

Figure 3. Design of the VLBI2010 antennas for RAEGE.

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Operation Centers

Operation Centers

The Bonn Geodetic VLBI Operation Center

A. Nothnagel, A. Müskens

Abstract

The IGGB Operation Center has continued to organize and schedule the IVS-T2, IVS-OHIG, IVS-INT3, and EUROPE sessions.

1. Center Activities

The IGGB VLBI Operation Center is located at the Institute of Geodesy und Geoinformation of the University of Bonn, Nussallee 17, D-53115 Bonn, Germany. It has been organizing and scheduling VLBI observing sessions for more than twenty years. The observing series organized and scheduled in 2010 are the same as in 2009.

- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE)**
  In Europe, a series of special sessions has been scheduled for the determination of precise station coordinates and for long term stability tests. This year, six sessions with Ny-Ålesund, Onsala, Metsahovi, Svetloe, Zelenchukskaya, Badary, Effelsberg, Wettzell, Simeiz, Madrid (DSS65A), Medicina, Matera, Noto, and Yebes (YEBES40M) were scheduled employing the frequency setup of 16 channels and 4 MHz bandwidth in fan-out mode (identical to the setup of the IVS-T2 sessions).

- **IVS-T2 series**
  This series has been observed roughly every second month (7 sessions in 2010) primarily for maintenance and stabilization of the VLBI terrestrial reference frame as well as for Earth rotation monitoring as a by-product. Each station of the global geodetic VLBI network is planned to participate at least once per year in the T2 sessions. In view of the limitations in station days, priority was given to stronger and more robust networks with many sites over more observing sessions. Therefore, 12 to 15 stations have been scheduled in each session, requiring multiple passes on the IVS correlators. The scheduling of these sessions has to take into account that a sufficient number of observations is planned for each baseline of these global networks. The recording frequency setup is 16 channels and 4 MHz channel bandwidth.

- **Southern Hemisphere and Antarctica Series (OHIG):**
  In February 2010, only three sessions of the Southern Hemisphere and Antarctica Series with the Antarctic stations Syowa (Japanese) and O'Higgins (German) plus Fortaleza, Hobart, Kokee, and DSS45 were organized. The (southern) winter O'Higgins burst was canceled for various reasons. The purpose of these sessions is the maintenance of the VLBI TRF and monitoring of Earth rotation as a by-product. The recording frequency setup is 16 channels and 4 MHz channel bandwidth. Due to the fact that Syowa is not able to deliver the recorded data for nearly one year after the observations, the correlation and the generation of the databases will be delayed considerably.

- **UT1 determination with near-real-time e-VLBI (INT3):**
  The so-called INT3 sessions included the telescopes of Ny-Ålesund, Tsukuba, and Wettzell for weekly UT1 determinations with rapid processing time. Since August 2007, these sessions have been scheduled to start every Monday morning at 7:00 a.m. UT.

  The operations of the INT3 series are directly linked to data transmission and correlation since the raw VLBI observation data of the three sites is directly transferred to the Bonn Correlator by Internet connections to speed up delivery of the results. The transmission rate is about 100 Mb/s for Ny-Ålesund (limited due to the use of a radio link for the first part of the distance) and 400 Mb/s from Tsukuba and Wettzell.

  Since December, the correlation has been solely carried out with the new DiFX software correlator because the Mark IV hardware correlator died in mid-December as a result of a control crash. Although the development of the full data correlation and export process was not yet complete at that time, the sessions have been processed with a reasonable latency. At present, several small processing steps still require manual interaction and iterations, causing small delays to persist.

  Since the beginning of 2010, 46 sessions have been observed and transmitted successfully. 90% of the sessions have been correlated and have had their databases delivered within the first 8 hours after the end of the observations. A further 5% have been completed within 10 hours. The rest took between 10 and 24 hours due to difficulties with networking hardware.

2. Staff

Table 1. Personnel at IGGB Operation Center.

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

CORE Operation Center Report

Cynthia C. Thomas, Daniel MacMillan

Abstract

This report gives a synopsis of the activities of the CORE Operation Center from January 2010 to December 2010. The report forecasts activities planned for the year 2011.

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 for pole position.

The IVS program, which started in 2002, used the Mark IV recording mode for each session. The IVS program began using the Mark 5 recording mode in mid-2003. By the end of 2007, all stations were upgraded to Mark 5. Due to the efficient Mark 5 correlator, the program continues to be dependent on station time and media. The following are the network configurations for the sessions for which the CORE Operation Center was responsible in 2010:

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

RDV: 6 sessions, scheduled evenly throughout the year, 13 to 16 station networks

IVS-R&D: 5 sessions, scheduled monthly, six to eight station networks

2. IVS Sessions from January 2010 to December 2010

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

- IVS-R1: In 2010, the IVS-R1s were scheduled weekly with five to nine station networks. During the year, 17 different stations participated in the IVS-R1 network, but there were only seven stations that participated in at least half of the scheduled sessions—Ny-Ålesund (47), Westford (48), Tigo (41), Tsukuba (38), Hobart-26m (34), Kokee (33), and Wettzell (29). After being down for almost two years, HartRAO started participating in the IVS-R1s again in mid-August. Also the new Hobart-12m antenna was tagged along to several sessions during 2010.

  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 the results as short as possible. The time delay goal is a maximum of 15 days. Participating stations are requested to ship discs to the correlator as rapidly as possible. The "1" indicates that the sessions are mainly on Mondays.

- RDV: There are six bi-monthly coordinated astrometric/geodetic experiments each year that use the full 10-station VLBA plus up to 8 geodetic stations.

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

- R&D: The purpose of the five R&D sessions in 2010, as decided by the IVS Observing Program Committee, was to improve the scheduling technique of the Intensive sessions.

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

Table 1 gives the average formal errors for the R1, R4, RDV, and T2 sessions from 2010. The R1 sessions' formal uncertainties are generally at the level of the 2008-2009 averages, but somewhat better than in 2009. The R4 X-pole uncertainty for 2010 sessions is clearly worse than for 2008-2009. This must be caused by poorer network geometry due to the loss of several stations during the year. For example, Fortaleza was down and not available to participate during 2010. In addition, Svetloe's and Wettzell's participation was cut by 50 percent when compared to the two stations' participation during 2009. The other EOP parameter uncertainties are at the level of the 2008-2009 average. The R4 uncertainties are clearly significantly worse than the R1 uncertainties, because the global geometry of the R1s is better. RDV uncertainties are not significantly different in 2010 than in the preceding two years. Clearly the RDV formal errors are significantly better than any of the other experiment series. This must be due to the larger number of RDV stations as well as better global geometry.

Table 2 shows the EOP differences with respect to IGS for the R1, R4, T2, and RDV series. The WRMS differences were computed after removing a bias, but estimating rates does not affect the residual WRMS significantly. Of all the series, the RDV series has the best WRMS agreement of X-pole and Y-pole with IGS in 2010 as well as for all sessions since 2000. Both the R1 and R4 series show worse WRMS agreement of X-pole for 2010 than for the R1 and R4 series since 2000, but not much difference for Y-pole. This is consistent with the formal error trend for the R4s. It is not clear why the agreement is worse for the R1s. For all session types, LOD WRMS agreement with IGS for 2010 is somewhat better than the agreement for each full series since 2000. There are some significant biases greater than 100 mas between the VLBI and GPS series that should be investigated. Formal uncertainties of the bias estimates are not shown, but the polar motion biases are all several sigma.

Table 1. Average EOP Formal Uncertainties for 2010

Session Type	Num	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (μas)	DEPS (μas)
R1	51/52	60(61,57)	59(63,52)	2.3(2.4,2.5)	117(129,114)	47(52,44)
R4	51/52	98(73,80)	88(79,90)	3.3(2.9,3.5)	178(192,194)	73(73,79)
RDV	5/6	41(40,43)	45(42,45)	1.9(1.7,2.2)	69(70,79)	29(28,31)
T2	3/7	75(79,56)	72(91,66)	4.3(4.1,2.9)	158(171,139)	65(69,58)

Values in parentheses are for 2009 and then 2008. For the number of sessions in 2010, both the number of processed sessions as of the end of January 2011 and the number of sessions observed are given.

Table 2. Offset and WRMS Differences (2010) Relative to the IGS Combined Series.

Session Type	Num	X-pole Offset (μas)	X-pole WRMS (μas)	Y-pole Offset (μas)	Y-pole WRMS (μas)	LOD Offset (μs/d)	LOD WRMS (μs/d)
R1	51(459)	-54(-1)	132(98)	166(121)	96(95)	1.9(0.3)	15(17)
R4	51(458)	-35(-42)	132(112)	183(120)	117(114)	4.0(1.9)	16(19)
RDV	5(65)	10(45)	77(81)	160(154)	44(90)	6.6(0.3)	14(15)
T2	3(69)	-203(-6)	192(145)	423(98)	151(146)	23.8(0.9)	11(20)

Values in parentheses are for the entire series (since 2000) for each session type

4. The CORE Operations Staff

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

Table 3. Key Technical Staff of the CORE Operations Center

Name	Responsibility	Agency
Dirk Behrend	Organizer of CORE program	NVI, Inc./GSFC
Brian Corey	Analysis	Haystack
Irv Diegel	Maser maintenance	Honeywell
Mark Evangelista	Receiver 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	NVI, Inc./GSFC
Ed Himwich	Network Coordinator	NVI, Inc./GSFC
Dan MacMillan	Analysis	NVI, Inc./GSFC
David Rubincam	Procurement of materials necessary for CORE operations	GSFC/NASA
Braulio Sanchez	Procurement of materials necessary for CORE operations	GSFC/NASA
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordination of master observing schedule and preparation of observing schedules	NVI, Inc./GSFC

5. Planned Activities during 2011

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2011.

- The IVS-R1 sessions will be observed weekly and recorded in a Mark 5 mode.
- The IVS-R&D sessions will be observed ten times during the year.
- The RDV sessions will be observed six times during the year.

NEOS Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 2010. The Operation Center schedules IVS-R4 and the INT1 Intensive experiments.

1. VLBI Operations

NEOS operations in the period covered consisted, each week, of one 24-hour duration IVS-R4 observing session, on Thursday-Friday, for Earth Orientation, together with five daily one-hour duration “Intensives” for UT1 determination, Monday through Friday. In 2010, the operational IVS-R4 network included VLBI stations at Kokee Park (Hawaii), Wettzell (Germany), Ny-Ålesund (Norway), TIGO (Chile), Svetloe, Badary and Zelenchukskaya (Russia), Hobart (Australia), Yebes (Spain), and Matera and Medicina (Italy). A typical R4 consisted of five to eight stations.

The regular stations for the weekday IVS Intensives were Kokee Park and Wettzell. Intensives including Kokee Park, Wettzell, and Svetloe were observed twice per month in order to characterize the Kokee Park — Svetloe baseline so that Svetloe can be used as an alternate for Wettzell should it be needed. This year, Wettzell underwent a major overhaul and Kokee Park — Ny-Ålesund Intensives were scheduled during the period Wettzell was unavailable.

The Operation Center updated the version of sked as updates became available.

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

Table 1. Experiments Scheduled during 2010.

52	IVS-R4 experiments
220	Intensives (Kk–Wz or Kk–Ny)
2	Kk-Sv-Wz Intensives
3	Kk-Sv-Ny Intensives

2. Staff

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

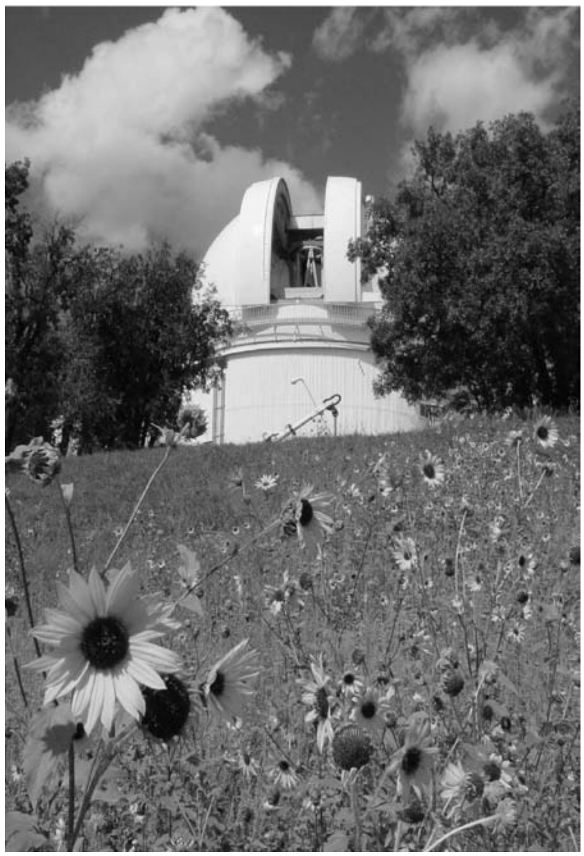

Figure 1. U. S. Naval Observatory Flagstaff Station, location of half of the Operation Center.

Correlators

Correlators

The Bonn Astro/Geo Correlator

Simone Bernhart, Alessandra Bertarini, Arno Müskens, Walter Alef

Abstract

The Bonn VLBI correlator is operated jointly by the MPIfR and the IGG in Bonn and the BKG in Frankfurt. The hardware Mark IV processor system was switched off in early December 2010 after a severe hardware failure, and subsequently geodetic correlation was moved over to the DiFX software correlator. Astronomical production correlation has been done exclusively with the DiFX correlator since autumn 2009.

1. Introduction

The Bonn correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR)[1] Bonn, Germany. It is operated jointly by the MPIfR and the Bundesamt für Kartographie und Geodäsie (BKG)[2] in cooperation with the Institut für Geodäsie und Geoinformation der Universität Bonn (IGG)[3]. It is a major correlator for geodetic observations and MPIfR's astronomical projects, for instance those involving millimeter wavelengths and astrometry. Astronomical experiments have been correlated with the DiFX software correlator since autumn 2009 while geodetic correlation was still ongoing on the Mark IV until December 3rd, 2010. The decommissioning of the hardware correlator, initially scheduled for the end of 2010, was preponed due to a severe hardware failure which could not be repaired with an acceptable effort.

2. Present Correlator Capabilities

In 2010, the Mark IV and DiFX correlators were operated in parallel in Bonn. The DiFX correlator was mainly used for the correlation of astronomical experiments, while the geodetic use was initially restricted to testing such as the feasibility of geodetic correlation and the implementation of the phase-cal signal extraction in the correlator software. The geodesists had to change over to the DiFX correlator earlier than planned due to an unexpected Mark IV hardware failure in early December.

2.1. Mark IV Correlator

The Bonn hardware correlator was one of the four Mark IV VLBI data processors in the world. It was operational from 2000 until early December 2010. It consisted of a standard Mark IV correlator rack, seven Mark 5A units, four Mark 5B units, and one additional unit dedicated to e-VLBI. The hardware Mark IV processor system and capabilities have not been changed since the last report and can be found at `http://ivscc.gsfc.nasa.gov/publications/ar2009/cobonn/`.

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

2.2. DiFX Correlator

DiFX (Distributed FX correlator) was developed at Swinburne University in Melbourne, Australia by Adam Deller (and collaborators), and adapted to the VLBA operational environment by Walter Brisken and NRAO staff.

Key parameters of the software correlator cluster are:

- 60 nodes with 8 compute cores each (480 cores total)
- 4 TFlops (floating point operations) in the Linpack benchmark test
- Infiniband 20 Gb interconnect
- two times 1 Gb Ethernet interconnect
- two 20 TB raid systems
- FXmanager control computer which is the control node for the correlator
- Frontend control computer for users who use the cluster for other tasks than correlation
- Appliance control computer for installing and monitoring the cluster
- closed loop rack cooling
- Correlation is done with the pre-release of DiFX version 2.0[4] (DiFX-trunk)
- 14 Mark 5 units are connected to the software correlator. VLBI data can be played into the cluster from the Mark 5 recorders via 1 Gb Ethernet. If more than 14 playback units are required and in the case of e-VLBI, data are copied to the raid systems (presently five) prior to correlation.
- All Mark 5s can play back all kinds of Mark 5 data (A/B/C).
- The fuse-based access to Mark 5 modules on all Mark 5s was changed to the native mode (implemented by Walter Brisken) making the Mark 5s part of the software cluster.
- The Mark 5A and Domino programs on the Mark 5s have been replaced by NRAO's mk5daemon. It enables reading the module directories, i.e., the start and stop time of each scan; resetting the streamstor card; rebooting the Mark 5s, and module conditioning.

The capabilities of the DiFX software correlator can be found at `http://www.mpifr-bonn.mpg.de/div/vlbicor/correlator\_e.html`. Some important features are:

- Phase-cal extraction of all tones in a sub-band simultaneously
- Interface to Mk IV data format which enables the use of geodetic analysis software and Haystack fringe fitting program.

[4] astro-ph/-72141: DiFX: A software correlator for very long baseline interferometry using multi-processor computing environments

3. Staff

The people in the geodetic group at the Bonn correlator are:
Arno Müskens - group leader, scheduling of T2, OHIG, EURO, INT3.
Alessandra Bertarini - experiment setup and evaluation of correlated data, software correlator development. Digital baseband converter (DBBC) testing. Finished PhD at IGG Bonn in June 2010, subject of the thesis: Effects on the geodetic-VLBI measurables due to polarization leakage in the receivers.
Simone Bernhart - e-VLBI supervision and operations, experiment setup and evaluation of correlated data, media shipping. Finished PhD at the MPIfR in March 2010, subject of the thesis: Flux Density and Kinematic Measurements of the IDV Source 0917+624.
Laura La Porta - experiment setup and evaluation of correlated data, DBBC testing.
Rene Böckelmann - setup and trial correlation of INT3.
Frédéric Jaron - phasecal extraction for software correlator, software support, and Web page maintenance.
Six student operators for the night shifts and the weekends.

The people in the astronomy group of MPIfR at the Bonn correlator who support IVS correlation are:
Walter Alef - head of the VLBI technical department, correlator software maintenance and upgrades, computer system and cluster administration. Friend of the correlator.
David Graham - technical development, consultant, DBBC development and testing - retired in July 2010.
Alan Roy - deputy group leader, instrument scientist (water vapor radiometer, technical assistance, development of FPGA firmware for linear to circular polarization conversion, project manager for equipping APEX for millimeter VLBI).
Helge Rottmann - software correlator development and operation, cluster administration.
Heinz Fuchs - correlator operator, responsible for the correlator operator schedule, daily operations and media shipping.
Hermann Sturm - correlator operator, correlator support software, media shipping and Web page development.
Michael Wunderlich - engineer, technical VLBI developments, (Mark IV correlator and) Mark 5 maintenance.
Rolf Märtens - technician maintaining correlator hardware and Mark 5 playbacks.
Gino Tuccari - guest scientist from INAF, DBBC development, DBBC project leader.

4. Status

Experiments: In 2010 the Bonn group correlated 51 R1, seven EURO, six T2, eight OHIG, 44 INT3, and about 27 astronomical experiments (including tests and mm observations).
e-VLBI: e-transfers to Bonn are performed on a regular basis from Tsukuba, Ny-Ålesund, Onsala, Metsähovi, Wettzell, Kashima (including data of the Antarctic Syowa station), Aira, Chichijima, Japanese VERA stations Ishigakijima (all from Tsukuba) and Mizusawa (from Mitaka), Medicina, Yebes, and Hobart (since autumn 2010). Furthermore, successful tests have been performed between New Zealand and Bonn and between Fortaleza and Bonn. E-transfer reduces the time between observation and correlation since no shipment is required. The achieved data rates range

from 100 Mb/s with Ny-Ålesund (limited by radio link) to 600 Mb/s with peaks up to 800 Mb/s (with Metsähovi). The transfers are done using the UDP-based Tsunami protocol. The total disk space available for e-VLBI data storage at the correlator is currently about 46 Tbyte. A Web page has been developed (`http://www.mpifr-bonn.mpg.de/cgi-bin/showtransfers.cgi`) which shows currently active (Tsunami) e-transfers. This is not intended as a scheduling tool for upcoming e-transfers but should rather help to coordinate transfer times and rates on a first come-first served basis.

Hardware correlator: Six Mark 5A and five Mark 5B units were available for the hardware correlator. One additional Mark 5 unit was dedicated to e-VLBI. The Mark IV correlator was shut down at the beginning of December due to a broken control board. A repair would have taken longer than the initially scheduled replacement by the DiFX correlator at the end of 2010.

DiFX software correlator: The implementation of the phase-cal signal extraction into the DiFX correlator software was finished and verified for geodetic experiments; the first R1 was correlated without phase-cal extraction in May. Since September, further R1s and one EURO experiment were correlated on both the Mark IV and the DiFX correlator, and the results were compared concerning their compatibility. The abrupt changeover to the DiFX correlator in early December, however, made it necessary to iron out a few bugs in the conversion software from DiFX to Mark IV format causing delays in the submission of the experiment databases. Nevertheless, the use of geodetic analysis software and the Haystack fringe fitting program is now working, which enables the delivery of the databases back on schedule. For the DiFX correlator, no station units are required anymore. Hence, they have been removed from the Mark 5 racks, and the units are only used for data playback.

DBBC: The Bonn group is involved in the development of a DBBC for the European VLBI Network (EVN) and geodesy. The DBBC is designed as a full replacement for the existing analog BBCs. The following stations have already bought one or more DBBCs: Wettzell (3), Latvia, Yebes, and AuScope (Australia), and the functionality of these DBBCs is currently being tested. Hobart12, one of the AuScope stations, already uses it in their regular observations.

5. Outlook for 2011

DiFX Correlator: There are still some minor bugs in the conversion software from DiFX to Mark IV format which need to be fixed. Attempts are currently being made to iron out some minor issues in the export software as well. Furthermore a graphical user interface will be installed on the DiFX control computer in the near future to simplify the use of the software correlator.

e-VLBI: Stream correlation using e-VLBI transfer will continue, and e-VLBI tests with other antennas are planned/ongoing. An additional 70 TB data raid will be installed at the cluster in mid-February to increase the storage capacity for correlated geodetic data and future e-transfers, especially with regard to the envisaged higher observing rate of 512 Mbps in the course of VLBI2010. In order to meet the requirements of the higher observing rate, there are still plans to upgrade our Internet connection from 1Gbps to 2Gbps. However, the funding and technical implementation prove to be more than difficult.

DBBC: There is ongoing testing among several EVN stations in order to deploy a fully functional DBBC and replace the analog BBCs in the field.

Haystack Observatory VLBI Correlator

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

Abstract

This report summarizes the activities of the Haystack Correlator during 2010. Highlights include processing of the very large astrometry session IYA2009, more VLBI2010 experiments, a new tarball release, DiFX software correlator development, RDBE and Mark 5C testing, and more u-VLBI SgrA* observations. Non-real-time e-VLBI transfers and engineering support of other correlators continued.

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 the National Science Foundation. The available correlator time is dedicated mainly to the pursuits of the IVS, with a smaller fraction of time allocated to processing radio astronomy observations for the Ultra High Sensitivity VLBI (u-VLBI) project. The Haystack Correlator serves as a development system for testing new correlation modes, for e-VLBI, for hardware improvements such as the Mark 5C system, and for diagnosing correlator problems encountered at Haystack, at the identical correlator at the U.S. Naval Observatory, and, until late 2010, also at 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

2.1. IYA2009 Session

IYA2009 production processing dominated the entire first half of the year, essentially until June when the final data set was exported to Goddard. In total, twenty-two passes were needed to process all baselines of the thirty-three stations which participated, and roughly 560 hours of correlator time were used. This experiment tested all aspects of the processing chain. Many limitations of the real-time system, other supporting software, and the HOPS software suite were found and fixed. Examples include total number of files, total number of stations in the real-time software, and plotting limits within the aedit post-processing software. All these limits were raised in order to shepherd the experiment through to export.

2.2. Broadband Delay Experiments

Four broadband-delay development experiments using prototype VLBI2010 systems were conducted and correlated in a variety of configurations, including different frequency placements of the RF bands and different LO frequency offsets. These experiments were designed to explore the capabilities and potential limitations of the evolving VLBI2010 hardware. All were interferometric observations between the Westford 18-m and the GGAO 5-m antennas, with the post-receiver hardware at each site including four digital back ends (DBEs) and Mark 5B+ units. Although there were fewer broadband experiments this year, each was conducted more effectively due to lessons learned from previous years' work. All were re-observations of previous experiment types such as one overlapping bands test, a 3C273B/3C279 source swapping test, and a 4C39.25 transit. These tests were facilitated by changes to the post-processing software to allow a fit of 64 channels across four bands, extracting phase cal information from all tones within the bands, and by correcting the phases for ionospheric effects.

2.3. New Tarball Release

A new tarball was released after extensive development and testing. This involved significant revision to the run-time software system which now incorporates techniques like compilation from source code on each individual platform in order to improve stability and to maintain compliance with the growing number of operating systems involved in the hardware correlator system. This tarball was installed in Bonn and is pending installation at WACO.

2.4. DiFX Software Correlator Development

Extensive DiFX correlator testing is underway, with the intent of transitioning to the new system by mid-2011. The *difx2mark4* application was developed in order to convert the output of the DiFX correlator into Mark IV format for reading into the HOPS package for post-processing. Extensive effort was expended on getting the DiFX correlator to handle phase cal tones properly. In December 2010 the Bonn correlator switched to DiFX for production, a transition made possible by these developments.

2.5. Independent HOPS Package

An independent HOPS release package was developed so that this package can be made generally available to the geodesy and astronomy communities. Thus, recipients of raw correlator output can do their own post-correlation analysis.

2.6. Digital Backend Testing

Testing was done on some next generation digital backend systems such as the RDBE and recording systems such as the Mark 5C. The Conduant SDK9 software package was also tested on two Mark 5B DOMs.

2.7. WACO Support

In addition to the usual support work, a significant amount of correlator time was used for testing equipment, such as four Mark 5Bs and several CIBs, prior to their shipment to WACO. There was also testing of a suspect control board when WACO was having top-crate syncing problems.

2.8. Bonn Support

Help was provided in converting K5 e-VLBI-transferred data to Mark 5B format; this was an augmentation of the ability to convert K5 to Mark 5A format. Various disk and correlator software related processing problems were addressed. Additionally, Haystack re-established the programmer for FIFO chips in order to replenish stock and provide spares to Bonn and WACO.

2.9. Galactic Center Polarization Project

Another u-VLBI project involving observations of the galactic center (SgrA*) was conducted, this time with dual polarization. This also was an engineering test of a phased-array processor system to combine the collecting area of interferometer elements on Mauna Kea. This system will increase the sensitivity of the u-VLBI array and will be adopted at other sites once fully operational.

2.10. Frequency Standard Test

There was an experiment to compare the stability and performance of a crystal sapphire oscillator to a hydrogen maser and rubidium clock as a frequency standard for the u-VLBI project.

2.11. e-VLBI

Non-real-time transfers have continued. Data from ten experiments were transferred to Haystack this year from six stations, all in Japan: Kashima, Tsukuba, Chichijima, Ishigakijima, Aira, and Mizusawa. In addition, this year the Westford station participated in twenty-six Intensive sessions which were e-transferred to the GSI correlator.

2.12. Experiments Correlated

In 2010, twenty-seven geodetic VLBI experiments were processed at the Haystack Correlator, consisting of the previously mentioned IYA2009, two R&Ds, four T2s, and twenty test experiments. The test experiments included broadband development and a wide assortment of other projects, some of which were touched on in the summary above. As usual, there was also a large number of smaller tests that are not included in the above count because they were too small to warrant individual experiment numbers.

2.13. Current/Future Hardware and Capabilities

As of the end of 2010, functioning hardware installed at the correlator included two tape units, seven Mark 5A units, seven station units, seven Mark 5B units (DOMs) with their associated correlator interface boards (CIBs), sixteen operational correlator boards, two crates, and miscellaneous other support hardware. We have the capacity to process all baselines for eleven stations simultaneously in the standard geodetic modes, provided the aggregate recordings match the above hardware matrix. This configuration reflects the addition of three new 5B units, for a grand total of fourteen playback units on the Mark IV correlator. This gives us the capability to run larger experiments in one pass.

In mid-2011, we hope to transition to the software correlator, only keeping the hardware correlator alive in support of USNO until their transition, expected in 2012.

3. Staff

Staff who participated in aspects of Mark IV, DiFX, Mark 5, and e-VLBI development and operations include:

3.1. Software Development Team

- John Ball - Mark 5A/5B; e-VLBI
- Roger Cappallo - real-time correlator software and troubleshooting; system integration; post-processing; Mark 5B/5C; Linux conversion; e-VLBI; DiFX correlator development
- Geoff Crew - DiFX correlator development, post-processing software
- Kevin Dudevoir - correlation; maintenance/support; Mark 5A/5B/5C; e-VLBI; Linux conversion; correlator software and build system development; computer system support/development
- Jason SooHoo - e-VLBI; Mark 5A/5B/5C
- Chester Ruszczyk - e-VLBI; Mark 5A/5B/5C
- Alan Whitney - system architecture; Mark 5A/5B/5C; e-VLBI

3.2. Operations Team:

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

4. Conclusion/Outlook

A full transition to the DiFX software correlator is expected by mid-2011. Testing of a complete VLBI2010 system is expected to start in early 2011. Testing and implementation of new digital back end and recording systems will continue.

IAA Correlator Center

Igor Surkis, Voitsekh Ken, Alexey Melnikov, Vladimir Mishin, Violet Shantyr, Vladimir Zimovsky

Abstract

The activities of the 6-station IAA RAS correlator includes regular processing of domestic geodetic VLBI programs Ru-E and Ru-U. Since 2009, the Ru-U sessions have been transferred in e-VLBI mode for correlation at the IAA Correlator Center.

1. Introduction

The IAA Correlator Center is located and hosted by the Institute of Applied Astronomy in St.-Petersburg, Russia. The IAA Correlator Center is devoted to processing geodetic, astrometric, and astrophysical observations made with the Russian domestic VLBI network Quasar.

2. Summary of Activities

The IAA RAS correlator has the following features:

- 6-station and 15-baselines,
- maximal data range of 1 Gbps from each station,
- 1- or 2-bit quantized input VLBI signals,
- VSI-H input signals format,
- 16 frequency channels per baseline (240 frequency channels in total),
- maximal clock frequency of 32 MHz,
- Mark 5B playback terminals.

The correlator hardware is based on FPGA technology. Data processing and data transfer boards are placed in the Compact PCI 6U crates. All of the correlator hardware is mounted in four racks as shown in Figure 1.

The correlator equipment is connected through a local network and consists of crates, playback terminals, and a control personal computer. The correlator operates using GNU/Linux. Special software for controlling correlator works on crates and control computer and has a user-friendly GUI.

3. Experiments in 2010

In 2010 the IAA Correlator Center processed the domestic 2- and 3-station sessions and 4-station sessions with international participation. 22 Ru-E and 52 Ru-U domestic sessions were observed and processed.

The 24-hour 3-station Ru-E VLBI sessions are intended for EOP estimation. Signal sampling is 1-bit, frequency channel bandwidth is 16 MHz, and the total bit rate is 512 Mbps using standard wide geodetic frequency setup.

Figure 1. The 6-station IAA RAS correlator.

The 1-hour 2-station Ru-U VLBI sessions are intended for UT1-UTC estimation. Signal sampling is 1-bit, frequency channel bandwidth is 8 MHz, and the total bit rate is 256 Mbps using standard wide geodetic frequency setup. All of the 1-hour Ru-U sessions were processed in e-VLBI mode; about 40 GB of data from each station were transferred to the correlator. The first several scans of the Ru-E sessions were processed in e-VLBI mode for verification of station equipment. Several test VLBI experiments have been carried out with Shanghai Observatory in China.

4. Staff

- Artemy Fateev — software developer;
- Voitsekh Ken — hardware developer;
- Alexey Melnikov — software developer, scheduler;
- Vladimir Mishin — software developer, post processing;
- Violet Shantyr — software developer, post processing;
- Igor Surkis — leading investigator, software developer;
- Vladimir Zimovsky — hardware developer.

VLBI Correlators in Kashima

Ryuichi Ichikawa, Moritaka Kimura, Mamoru Sekido

Abstract

K5 VLBI data acquisition and processing systems developed at the Kashima Space Research Center have been used for data processing of R&D VLBI experiments. Two major correlation tasks processed in 2010 were the MARBLE project, which aimed at establishing a reference baseline for length calibration, and a project for time and frequency transfer. The high speed software correlation system for K5/VSI called "GICO3" has been extended to be used for geodetic VLBI measurements.

1. General Information

The VLBI group of the Kashima Space Research Center (KSRC) of the National Institute of Information and Communications Technology (NICT: Fig.1) has been contributing to the VLBI community by developing the K5 VLBI data acquisition system (DAS) and correlation systems.

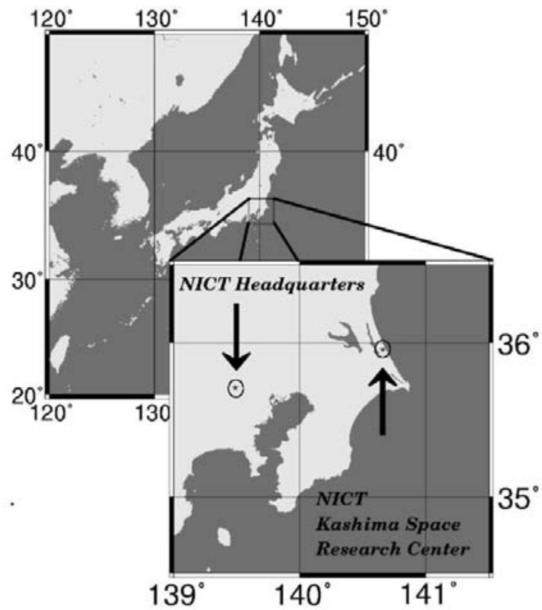

Figure 1. Location of NICT/KSRC.

The multi-channel DAS named K5/VSSP32 [1] has been used for geodetic and radio science observations. A corresponding software correlation package for the K5/VSSP32 has been developed and maintained by Dr. T. Kondo. Another DAS system named K5/VSI [2], which captures the data stream from a VSI-H interface [4], utilizes a different software correlator called "GICO3" [3].

The former K5/VSSP32 system is a multi-channel data acquisition system with four channel inputs per unit. One unit has the sampling capability in the range of 40 kHz to 64 MHz, with quantization bits 1, 2, 4, and 8 and the limit for the output data rate of up to 256 Mbps. A geodetic K5 DAS system is composed of four K5/VSSP32 units. This system has been widely used for geodesy operationally. e-VLBI experiments for rapid UT1 measurements have been performed using this system in collaboration with the Onsala, Metsähovi, Tsukuba, and Kashima stations.

Another K5 system (K5/VSI) was originally developed with the feature of a high sampling rate for astronomy. Since the K5/VSI DAS is a recording system, it can be used in combination with any sampler systems with the VSI-H interface. For instance, this system has been regularly used in a combination with Mark 5B sampler (VSI-H output) in ultra-rapid UT1 measurements on the Wettzell—Tsukuba baseline.

2. Staff

The names of the staff members who contribute to the Correlation Center at NICT/Kashima and their tasks are listed below in alphabetical order.

- HASEGAWA Shingo: maintenance and troubleshooting of K5 system computers, operation of the 34-m antenna for IVS sessions.
- HOBIGER Thomas: developer of a new VLBI database system that uses NetCDF, research on atmospheric delay calibration with the ray tracing technique, development of software receiver for GNSS.
- ICHIKAWA Ryuichi: VLBI Project Manager at Kashima, research on the MARBLE project, atmospheric delay with ray tracing.
- KAWAI Eiji: maintenance of the 34-m telescope, operation of the telescope for IVS sessions.
- KIMURA Moritaka: developer of the high speed Gigabit software correlator "GICO3" and the K5/VSI DAS.
- KONDO Tetsuro: development and maintenance of the software correlator package of the K5/VSSP32.
- KOYAMA Yasuhiro: Group Leader of "Space-Time Application Group".
- SEKIDO Mamoru: e-VLBI development and observations, maintenance of the 34-m station.
- TSUTSUMI Masanori: maintenance of K5 system computers.

3. Component Description

In 2010 VLBI experiments have been performed for the MARBLE project [5] and for technology development of the time and frequency transfer between distant pairs of atomic time standards [6]. Table 1 shows a brief summary of the experiments.

Table 1. Major correlation tasks processed in 2010.

Project	Exp code	Date	Stations	baseline x scans	Data rate (Mbps)
MARBLE	m10223	11 Aug.	Ks34, Mb1, Mb2	3x239	256
MARBLE	m10259	16 Sep.	Ks34, Mb1, Mb2	3x242	256
MARBLE	m10266	23 Sep.	Ks34, Mb1, Mb2	3x234	256
MARBLE	m10280	7–9 Oct.	Ks34, Mb1, Mb2	3x721	256
MARBLE	m10316	11 Nov.	Ts32, Mb1, Mb2	2x295	2048
MARBLE	m10356	22 Dec.	Ts32, Mb1, Mb2	2x318	2048
Time Comp.	k10116	26 Apr.	Ks34, Ks11 ,Kg11	3x987	256
Time Comp.	k10130	10 May.	Ks34, Ks11 ,Kg11	3x701	256
Time Comp.	k10148	28 May.	Ks11, Kg11	1x627	256
Time Comp.	k10160	9–14 Jun.	Ks11, Kg11	1x2968	256
Time Comp.	k10189	8–10 Jul.	Ks11, Kg11	1x2204	256,2048
Time Comp.	k10212	31 Jul.–01 Aug.	Ks11, Kg11	1x1388	256
Time Comp.	k10216	8 Aug.	Ks11, Kg11	1x490	256,2048
Time Comp.	k10274	1 Oct.	Ks11, Kg11	1x1773	256,2048

Ts32:Tsukuba-32m, Ks34:Kashima-34m, Ks11:Kashima-11m, Kg11:Koganei-11m, Mb1:Marble-1, Mb2:Marble-2

Ultra-rapid UT1 observations with e-VLBI technology have been performed by the Geospatial Information Authority of Japan (GSI) on the Onsala—Tsukuba baseline. In addition, the GSI has started the operational dUT1 observations (i.e., "Intensive" observations) in 2010. We have supported these e-VLBI experiments, although actual correlation has been performed by GSI.

4. Development and Future Plans

4.1. e-VLBI Development

The high speed sampler ADS3000+, which has the function of a digital base band converter (DBBC) and sports a VSI-H interface, has been developed together with the K5/VSI DAS. Digital filtering via FPGA circuit has been tested, and multi-channel observations for geodetic VLBI applications have been performed for evaluation. Software tools for the data conversion from the GICO3 high speed software correlation output to conventional Mark3DB have been developed, and the analysis scheme with the CALC/SOLVE package is being established. This new scheme of VLBI observation and data processing (ADS3000+ and K5/VSI → GICO3 software correlation → Mark3DB → CALC/SOLVE) has been used for the MARBLE and the time and frequency transfer experiments (Table 1).

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Tsukuba VLBI Correlator

Kensuke Kokado, Shinobu Kurihara, Ryoji Kawabata, Kentaro Nozawa

Abstract

This report briefly summarizes the activities at the Tsukuba VLBI Correlator in 2010. The Tsukuba VLBI Correlator processed 96 IVS-INT2 sessions and eight JADE sessions with the K5/VSSP correlation system, which includes the K5/VSSP kernel software. The software correlation system and high-speed data transfer network enabled us to correlate the data of the IVS-INT2 sessions during observation. We correlated all of the data of the INT2 sessions with the real-time correlation system in 2010.

Figure 1. Tsukuba VLBI Correlator

1. Introduction

The Tsukuba VLBI Correlator is part of the VLBI facilities operated by the Geospatial Information Authority of Japan (GSI) as is the Tsukuba 32-m VLBI station (TSUKUB32). A principal component of our correlation system is the K5/VSSP correlation software package developed by the National Institute of Communications and Technology (NICT). We can install the software on commercially-based computers operated by Linux operating system (OS). We processed several IVS-INT2 sessions and domestic VLBI sessions (JADE sessions) with a number of computers which had the K5/VSSP software package installed. The sessions we processed in 2010 are described in Section 4.

2. Component Description

The system components of the Tsukuba VLBI correlator are described in Table 1. We have two systems to process the observed data of international sessions or domestic sessions. System 1 is for JADE sessions and other domestic sessions, which make use of the VLBI stations of Japan Aerospace Exploration Agency (JAXA) or the compact VLBI system (MARBLE) developed in a collaboration between GSI and NICT. The system is operated by the management application "PARNASSUS" (Processing Application in Reference to NICT's Advanced Set of Software Usable for Synchronization) designed for distributed correlation processing.

System 2 is for INT2 sessions. We introduced the management application "Cor_mgr" in the system. The application is developed with the Perl programing package. We are able to correlate the VLBI data automatically using "Cor_mgr" and other utility programs. MK3TOOLS is the program that creates the Mark III database from the output files of the K5/VSSP bandwidth synthesis program.

The entire hardware is based on commercial products. Although the operating systems of some data or correlation servers were Redhat Linux release 9, we replaced it with CentOS version 5.4 or 5.5 in 2010. Now, all of the servers work well.

For the INT2 sessions, we have been transferring the data observed at Wettzell or Westford station via high-speed network. The Tsukuba VLBI Correlator is connected to the high-speed network "SINET3 (Science Information NETwork3)" operated by the National Institute of Informatics (NII). The network enables us to do real-time data transfer from Wettzell to Tsukuba.

3. Staff

The technical and engineering staff of the Tsukuba VLBI Correlator are as follows. Yuji Miura, who was a technical staff member in 2009, moved to another department in June 2010. Most of our staff are subcontracted engineers from either of two private companies: Advanced Engineering Service Co., Ltd (AES) or The Institute of Japanese Union of Scientists and Engineers (I-JUSE).

Kensuke Kokado: Technical official (GSI)
Correlation Chief, Management of overall activity of Tsukuba VLBI correlator
Maintenance/support of K5 software correlation system and e-VLBI network system

Kentaro Nozawa: Technical Operator (AES)
Main operator of the correlation work
Maintenance of the real-time correlation system (System 2)

Yasuko Mukai: Technical Operator (AES)
Sub-operator of the correlation work
Routine correlation processing, Management of media shipping

Toshio Nakajima: System Engineer (I-JUSE)
System Engineer for maintenance of computers and e-VLBI network system

Table 1. Specifications of the K5/VSSP correlation system components

<table>
<tr><th></th><th>System 1</th><th>System 2</th></tr>
<tr><td>Management Server
(CPU)</td><td>1 server
(Intel Pentium 4, 3.0GHz)</td><td>1 server
(Intel Xeon 3.4GHz dual CPU)</td></tr>
<tr><td>Correlation Servers
(CPU)</td><td>24 servers
(Intel Xeon 3.06GHz dual CPU)</td><td rowspan="2">8 servers
(Intel Xeon 3.4GHz dual CPU)</td></tr>
<tr><td>Data Servers
(CPU)</td><td>24 servers
(Intel Pentium 4, 3.0GHz)</td></tr>
<tr><td>Data Format</td><td colspan="2">K5/VSSP or K5/VSSP32</td></tr>
<tr><td>HDD type</td><td colspan="2">Serial ATA Disk</td></tr>
<tr><td>K5/VSSP Archive Version</td><td colspan="2">ipvlbi_cor_20100723
komb20100811</td></tr>
<tr><td>Main application</td><td>PARNASSUS 1.3
MK3TOOLS</td><td>Cor_mgr
MK3TOOLS</td></tr>
<tr><td>Operating System</td><td colspan="2">CentOS version 5.4, version 5.5</td></tr>
<tr><td>Processing Session</td><td>JADE
Additional domestic session</td><td>IVS-INT2 session
etc.</td></tr>
</table>

4. Current Status and Activities

4.1. Processing of JADE Sessions

JADE is a domestic 24-hour VLBI session type scheduled by GSI. The participating stations are four GSI stations (TSUKUB32, SINTOTU3, CHICHI10, and AIRA) and two VERA stations (VERAMZSW and VERAISGK) of the National Astronomical Observatory of Japan (NAOJ). TSUKUB32 and VERAISGK stations are connected to broad-band network, so we can transfer the data via network. However, the other stations' transfer rates are too slow to transfer the data to the correlator. Therefore, we have to send the data by shipment of the hard disks. These disks sent by shipment are injected into the disk array of the correlation system. We have more than 100 hard disks for the shipment, because we need more than four disks per station for each JADE session.

The JADE sessions and the other domestic sessions processed at the Tsukuba correlator in 2010 are described in Table 2. Additional domestic sessions have been observed for the determination of the positions of USUDA64 and UCHINOUR stations operated by JAXA. GSI commenced the additional domestic sessions with JAXA in 2006. The participating stations are GSI's four stations and USUDA64 or UCHINOUR stations. The session has not been registered yet with the IVS, so we have not submitted the database.

The processing factor of each JADE session is described in the rightmost column of Table 2. They depend on the number or performance of the correlation servers. We could reduce the processing time if we had a lot of high-performance servers. The processing factors per baseline of JADE1009, JADE1010, and JADE1011 were more than 1.00. The cause for the delay was that we had some trouble with the hard disks or the network file system.

Table 2. JADE sessions processed in 2010 (Ts:TSUKUB32, Ai:AIRA, S3:SINTOTU3, Cc:CHICHI10, Vm:VERAMZSW, Vs:VERAISGK, Uc:UCHINOUR, Kb:KASHIM34).

Session	Stations	Processed Baseline #	Processing Factor
JADE-1001	TsAiCcS3VmVs	11	3.94
JADE-1003	TsAiCcVm	6	2.82
U10073	TsAiCcUc	6	2.38
JADE-1005	TsS3	1	0.43
JADE-1006	TsAiCcS3	6	3.41
JADE-1008	KbAiCcS3Vm	10	8.32
JADE-1009	KbS3	1	1.72
JADE-1010	TsS3	1	1.45
JADE-1011	TsS3	1	1.12

4.2. Processing of IVS-INT2 Session

As the method of data transfer has been improved with the development of the e-VLBI system, we introduced a real-time data transfer system developed by NICT in 2010. The transfer system enables us to convert the Mark 5 format data to K5 format data at the same time as the data transfer. We have adopted the real-time data transfer system on the Ts-Wz baseline only. On the other baselines, the data is transferred using the UDP-based protocol “TSUNAMI” after the observing sessions. The data transfer rate reached up to 300 Mbps between Tsukuba and Wettzell. As the data of the INT2 sessions are processed in real-time, the processing factor of the session is about 1.00. If we process all of the data with PARNASSUS or Cor_mgr after the observing session, the processing factor will be under 0.4.

Table 3. IVS-INT2 sessions processed in 2010

Session	Stations	Processed session #
IVS-INT2(K)	Ts-Wz	64
IVS-INT2(H)	Ts-Wf	16
IVS-INT2(D)	Kb-Wz	4
IVS-INT2(F)	Kb-Wf	9
Ts:TSUKUB32, Kb:KASHIM34, Wz:WETTZELL, Wf:WESTFORD		

5. Plans for 2011

We plan to register the domestic sessions with the JAXA VLBI stations as IVS sessions and will then submit the databases to the IVS Data Center. The Tsukuba VLBI correlator will process eight JADE sessions, 101 IVS-INT2 sessions, and two IVS-INT3 sessions. All of the INT2 and the INT3 sessions will be processed with the real-time correlation system.

Washington Correlator

Kerry A. Kingham, David M. Hall

Abstract

This report summarizes the activities of the Washington Correlator for the year 2010. The Washington Correlator provides up to 80 hours of attended processing per week plus up to 40 hours of unattended operation, primarily supporting Earth Orientation and astrometric observations. In 2010 the major programs supported include the IVS-R4, IVS-INT, APSG, and CRF observing sessions.

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 sessions. All of the weekly IVS-R4 sessions, all of the IVS-INT01 Intensives, and the APSG and CRF sessions were processed at WACO. The facility houses a Mark IV Correlator.

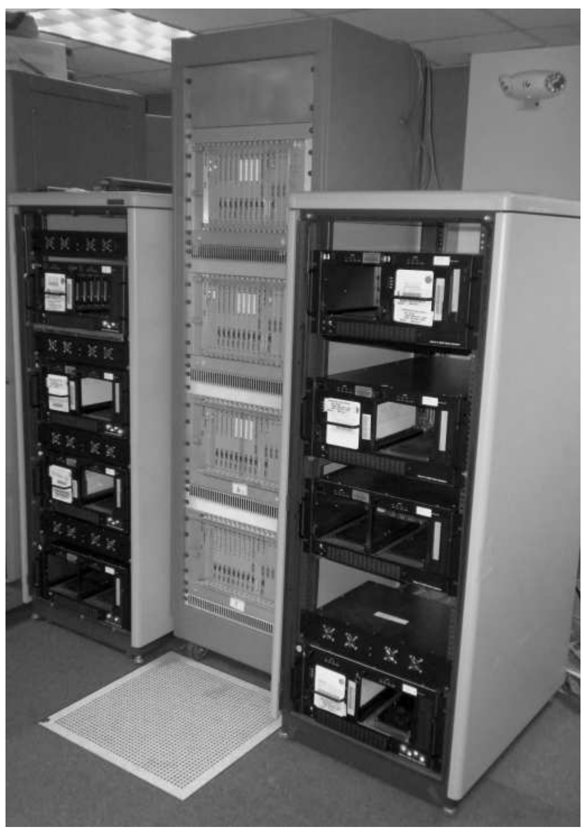

Figure 1. Conversion to Mark 5Bs: five Mark 5Bs (left rack and right bottom) share space with three Mark 5As (upper right) on the right side of the correlator. All of these will be Mark 5B by next year.

2. Correlator Operations

- The Washington Correlator continues to operate 80 hours per week with an operator on duty. The correlator has continued to function well unattended, allowing another 40 hours per week, on average, of extra processing. This has also decreased the time it takes to process an R4 or other 24-hour sessions by one day.
- The correlator staff continues the testing and repair of Mark 5 modules. Not only were failed disks replaced, but some modules were upgraded by the replacement of lower capacity disks with higher capacity disks.
- Prior to April 2010, Intensive observations from Kokee Park Geophysical Observatory (KPGO) were shipped via FedEx to the Washington area. This required station personnel to travel down the road to the local town to meet the FedEx pickup. The shipping to the correlator typically took two days. After April 2010, observations from KPGO were sent directly to the correlator over an Internet 2 connection. This operation saved the two days of shipping time and allowed processing within 24 hours of the observation.
- A Mark 5B playback unit was added to the correlator complement of Mark 5s, which now brings the correlator complement to eight Mark 5As and four Mark 5Bs. An additional Mark 5B+ is used for transfers.
- Intensive observations from Kokee Park, Wettzell, and Ny-Ålesund were routinely transferred via e-VLBI during 2010. 24-hour sessions from both Hobart antennas, Ny-Ålesund, Tsukuba, Aira, Kashima, Chichijima, and Sintotu were also transferred by high-speed networks.
- Correlator time was also spent processing test observations connected with the commissioning of the Hobart 12-m antenna.
- Table 1 lists the experiments processed during 2010.

Table 1. Experiments processed during 2010.

51	IVS-R4 sessions
1	IVS-R1 session
4	CRF (Celestial Reference Frame)
4	R&D sessions
211	Intensives
2	Kk-Sv-Wz Intensives
3	Kk-Sv-Ny Intensives
5	TQUAKE (Tigo Earthquake)

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 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 2. Staff.

Staff	**Duties**
Dr. Kerry Kingham (USNO)	Chief VLBI Operations Division and Correlator Project Scientist
David Hall (USNO)	VLBI Correlator Project Manager
Bruce Thornton (NVI)	Operations Manager
Harvis Macon (NVI)	Lead Correlator Operator
Roxanne Inniss (NVI)	Media Librarian
Kenneth Potts (NVI)	Correlator Operator

4. Outlook

The Washington Correlator plans to upgrade the Mark 5A playbacks to Mark 5B, in coordination with the installation of Mark 5Bs at the Network Stations. e-VLBI operations are expected to expand, and additional transfer capability and disk space will be added. Intensive processing is expected to transfer to a software correlator by the end of 2011.

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 2010. 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 GSFC CDDIS Data Centers by mirroring the OPAR and the CDDIS file stocks several times per day. The following sketch shows the principle of mirroring:

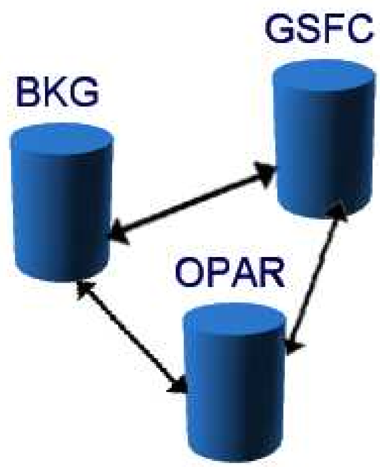

Figure 1. Principle of mirroring

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

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

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

```
FTP:             ftp://ivs.bkg.bund.de/pub/vlbi/
```

```
HTTP:            http://ivs.bkg.bund.de/vlbi/
```

Structure of BKG IVS Data Center:

```
vlbi/           : root directory
ivs-special/    : special CRF investigations
ivscontrol/     : controlfiles for the data center
ivsdata/        : VLBI observation files
ivsdocuments/   : IVS documents
ivs-iers/       : old IERS solutions
ivsproducts/    : analysis products
    crf/        : celestial frames
    trf/        : terrestrial frames
    eops/       : earth orientation (24h sessions)
    eopi/       : earth orientation (Intensive sessions)
    daily_sinex/ : daily sinex files (24h sessions)
    int_sinex/  : daily sinex files (Intensive sessions)
    trop/       : troposphere
```

2. Technical Equipment

DELL Server (SUSE Linux operating system)
disk space: 500 GBytes (Raid system)
backup: automatic tape library

3. Staff Members

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

CDDIS Data Center Summary for the IVS 2010 Annual Report

Carey Noll

Abstract

This report summarizes activities during the year 2010 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, staff 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 archiving and distribution of Very Long Baseline Interferometry (VLBI) data since its inception in 1982. The CDDIS is a central facility providing users access to data and derived products to facilitate scientific investigation. The CDDIS archive of GNSS (GPS and GLONASS), laser ranging, VLBI, and DORIS data are stored on-line for remote access. Information about the system is available via the Web at the URL http://cddis.gsfc.nasa.gov. In addition to the IVS, the CDDIS actively supports other IAG services including the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), the International DORIS Service (IDS), the International Earth Rotation and Reference Frame Service (IERS), and the Global Geodetic Observing System (GGOS) of the IAG. 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 is accessible to the public through anonymous ftp.

2.1. Computer Architecture

The CDDIS is operational on a dedicated server, cddis.gsfc.nasa.gov. The system has over 8 Tbytes of on-line disk storage; at this time, over 100 Gbytes are devoted to VLBI activities. (The over 1 Tbyte archive of raw correlator output files were moved offline from the CDDIS archive in 2010.) 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 five (one full-time, four part-time) contractor employees supports all CDDIS activities (see Table 1).

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.

Table 1. CDDIS Staff

Name	Position
Ms. Carey Noll	CDDIS Manager
Dr. Maurice Dube	Head, CDDIS contractor staff and senior programmer
Ms. Ruth Labelle	Programmer (part-time)
Mr. Scott Fenton	Programmer (part-time)
Ms. Lisa Lee	Web developer (part-time)
Ms. Lori Tyahla	Programmer (part-time)

This archive has been expanded for the IVS archiving requirements.

The IVS Data Center content and structure is shown in Table 2. (A figure illustrating the flow of information, data, and products between the various IVS components was presented in the CDDIS submission to the IVS 2000 Annual Report.) In brief, an incoming data area has been established on the CDDIS host computer, cddis.gsfc.nasa.gov. Using specified file names, operation and analysis centers deposit data files and analyzed results to appropriate directories within this filesystem. Automated archiving routines, developed by GSFC VLBI staff, peruse the directories and move 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 sub-directories under ftp://cddis.gsfc.nasa.gov/pub/vlbi are updated to reflect data archived in the filesystem. Furthermore, mirroring software has been installed on the CDDIS host computer, as well as all other IVS primary data centers, to facilitate equalization of data and product holdings among these data centers. At this time, mirroring is performed between the IVS data centers located at the CDDIS, the Bundesamt für Kartographie und Geodäsie in Leipzig, and the Observatoire de Paris.

The public filesystem in Table 2 on the CDDIS computer, accessible via anonymous ftp, consists of a data area, which includes auxiliary files (e.g., experiment schedule information, session logs) and VLBI data (in both database 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

In June 2010 the CDDIS transitioned operations to a new distributed server environment. Users continued to access the CDDIS as before; however, suppliers of data and product files were required to use a new server dedicated to incoming file processing. The structure of the VLBI data and product archive remained unchanged in this new system configuration.

During 2010, over 550 distinct hosts accessed the CDDIS on a regular basis to retrieve VLBI related files. These users successfully downloaded over 65 Gbytes of data and products (350,000 files) from the CDDIS VLBI archive last year.

Table 2. IVS Data and Product Directory Structure

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

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.

Italy INAF Data Center Report

M. Negusini, P. Sarti, C. Abbondanza

Abstract

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

1. Introduction

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

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

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

2. Computer Availability and Routing Access

To date, the main computer is a Linux workstation, on which Mark 5 Calc/Solve version 10 was installed and to which all VLBI data analysis was migrated. The Internet address of this computer is sarip.ira.inaf.it. Since 2007 a new server with a storage capacity of 1 TB has been available, and, therefore, all experiments performed in the previous years were downloaded and archived, thus completing the catalog. The older experiments will be analyzed in order to perform global long term analysis. At present, the databases are stored in the following directories:

1 = /data2/dbase2
2 = /geo1/dbase1
3 = /geo1/dbase
4 = /geo1/dbase3

The superfiles are stored in:
/data1/super1

The list of superfiles is stored in the file /data2/mk5/save_files/SUPCAT. The username for accessing the databases is geo. The password may be requested by sending an e-mail to negusini@ira.inaf.it.

Data Center at NICT

Ryuichi Ichikawa, Hiroshi Takiguchi, Mamoru Sekido, Yasuhiro Koyama

Abstract

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

1. Introduction

The IVS Data Center at National Institute of Information and Communications Technology (NICT) archives and releases the databases and analysis results processed by the Correlation Center and the Analysis Center at NICT. Major parts of the data are from the Key Stone Project (KSP) VLBI sessions [1], but other regional and international VLBI sessions conducted by NICT are also archived and released. Since routine observations of the KSP network terminated at the end of November 2001, there have been no additional data from the KSP regular sessions since 2002. In 2009, a series of geodetic VLBI sessions were carried out by using the Kashima 34-m, Kashima 11-m, and Koganei 11-m stations to demonstrate precise time comparison. Another series of astronomical VLBI sessions were carried out between the Kashima 34-m and Koganei 11-m stations to monitor the flux densities of radio variable stars using real-time e-VLBI data transfer and processing. In addition, seven geodetic experiments using the two compact VLBI systems with a 1.6-m antenna were also carried out [2]. The analysis results in SINEX (Solution INdependent EXchange) format as well as in other formats are available on the Web server. Database files of non-KSP sessions, i.e., other domestic and international geodetic VLBI sessions, are also available on the Web server. Table 1 lists the Web server locations maintained by the NICT Data Center. In the past, an FTP server was used to provide data files, but it was decided to terminate the FTP service because of the security risks of maintaining an anonymous FTP server. Instead, the `www3.nict.go.jp` Web server was prepared to provide large size data files.

Table 1. URL of the Web server systems.

Service	URL
KSP Web pages	`http://ksp.nict.go.jp/`
IVS Web mirror pages	`http://ivs.nict.go.jp/mirror/`
Database files	`http://www3.nict.go.jp/w/w114/stsi/database/`
e-VLBI Sessions	`http://www.nict.go.jp/w/w114/stsi/research/e-VLBI/UT1/`
Hayabusa Sessions	`http://www.nict.go.jp/w/w114/stsi/research/Navi/HAYABUSA/`

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

2. Data Products

2.1. KSP VLBI Sessions

The KSP VLBI sessions were performed with four KSP IVS Network Stations at Kashima, Koganei, Miura, and Tateyama daily or bi-daily (every two days) until May 1999. 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. Thereafter, the real-time VLBI sessions were performed with the three other stations. 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 the three stations other than 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 the Kashima, Miura, and Tateyama stations to the Koganei station for tape-based correlation processing with all six baselines. After the tape-based correlation processing was completed, the data set produced with the real-time VLBI data processing was replaced by the new data set.

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

2.2. Other VLBI Sessions

In addition to the KSP regular VLBI sessions, domestic and international geodetic and astronomical VLBI sessions were conducted by NICT in cooperation with the Geospatial Information Authority of Japan (GSI), the National Astronomical Observatory (NAO), and other organizations. These sessions are listed in Table 2. The recent observed data of these sessions were mainly processed by using the K5 software correlator at NICT either at Koganei or at Kashima or by using a real-time hardware correlator developed by NAO.

In 2010, 38 IVS geodetic VLBI sessions (442 hours in total) including 1 hour "Intensive" dUT1 sessions were carried out as shown in Table 2. The increase of IVS sessions is mainly due to the temporary replacement of the 32-m Tsukuba antenna operated by the GSI by the 34-m Kashima antenna during the repair of the lightning damage. Seven MARBLE experiments using the compact VLBI system were also performed together with the GSI Tsukuba 32-m antenna. In addition, nine time transfer sessions were performed. The purpose of the sessions is to evaluate the capability of geodetic VLBI experiments for precise and accurate time transfer between Time and Frequency laboratories located worldwide.

Table 2. Geodetic VLBI sessions conducted by NICT (since 2005).

Year	exp. names	sessions
2005	Geodetic	c0505 (CONT05, partial participation), GEX13
	Hayabusa	14 sessions
2006	Geodetic	GEX14, viepr2, CARAVAN (3 sessions)
	Spacecraft	Geotail: 1 session
	Pulsar	1 session
2007	Ultra Rapid e-VLBI	15 times, 29 sessions
	Time Transfer	4 sessions, 12 days in total
	Cs-Gas-Cell	1 session
	Spacecraft	Hayabusa: 1 session
2008	Ultra Rapid e-VLBI	8 times, 33 sessions
	Time Transfer	26 sessions
	Variable Star e-VLBI	31 sessions
2009	e-VLBI	15 sessions, 90.5 hours in total
	IVS	12 sessions, 332 hours in total
	Time Transfer	9 sessions, 72 hours in total
	VERA	16 sessions, 149 hours in total
	Survey	26 sessions, 276 hours in total
2010	IVS	38 sessions, 442 hours in total
	Radio astronomy	34 sessions, 324 hours in total
	Spacecraft (IKAROS, UNITEC-1, QZSS)	33 sessions, 259 hours in total
	domestic geodetic	13 sessions, 94 hours in total
	Time Transfer	9 sessions, 86 hours in total
	e-VLBI	9 sessions, 27 hours in total

3. Staff Members

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

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

Name	Main Responsibilities
KOYAMA Yasuhiro	Administration of Data Servers
ICHIKAWA Ryuichi	Development of compact VLBI system
SEKIDO Mamoru	Responsible for e-VLBI sessions
TAKIGUCHI Hiroshi	Time Transfer
HASEGAWA Shingo	System Engineer

4. Future Plans

The IVS Data Center at NICT will continue its service and will archive and release the analysis results accumulated by the Correlation Center and the Analysis Center at NICT. In addition, a number of VLBI sessions will be conducted for the purposes of various technology developments.

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[3] Koyama, Y., T. Kondo, M. Kimura, and H. Takeuchi, IVS NICT TDC News, No. 26, Sep. 2005, pp. 9-12.

Paris Observatory (OPAR) Data Center

Christophe Barache, Sébastien B. Lambert

Abstract

This report summarizes the OPAR Data Center activities in 2010. Included is information about functions, architecture, status, and future plans of OPAR Data Center.

1. OPAR Data Center Functions

The Paris Observatory (OPAR) has provided a Data Center for the International VLBI Service for Geodesy and Astrometry (IVS) since 1999. The OPAR is one of the three IVS Primary Data Centers together with CDDIS and BKG. 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 (auxiliary, database, products, documents),
- mirrors the other ones every three hours,
- gives free FTP access to the files.

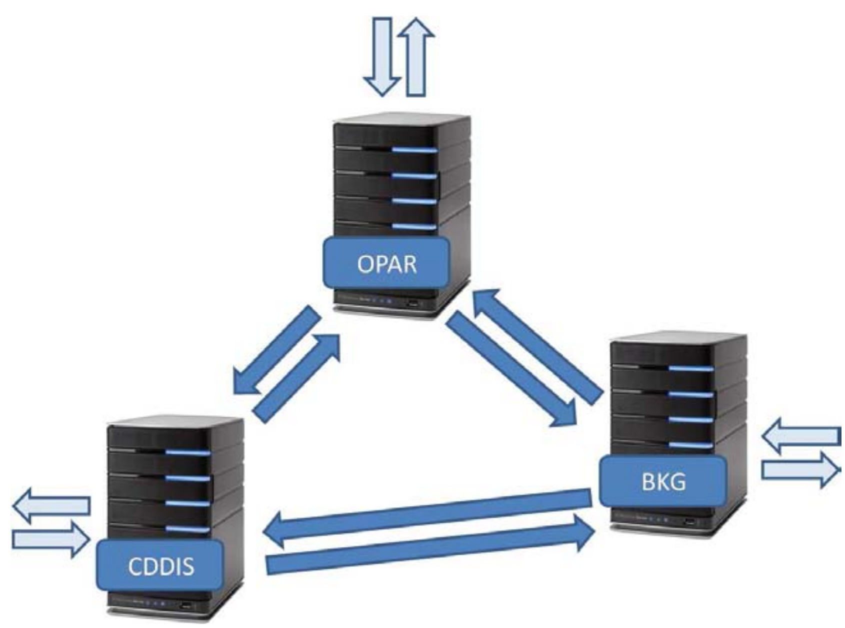


Figure 1. Mirroring among the primary Data Centers.

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

2. Architecture

To be able to put a file in a Data Center, Operation 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 is:

```
ivscontrol/       : provides the control files needed by the data center
                    (session code, station code, solution code...)
ivscontrol_new/   : temporary test directory
ivscontrol_old/   : temporary test directory
ivsdocuments/     : provides documents and descriptions about IVS products
ivsdata/          : provides files related to the observations:
   aux/           :   auxiliary 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 Centers:
  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
  int_sinex/      :   Daily Intensive solutions in SINEX format, mainly
                      designed for combination
  trop/           :   Tropospheric time series (starting July 2003)
ivs-iers/         : provides products for IERS Annual Report
ivs-pilot2000/    : provides products of 2000 for special investigations
ivs-pilot2001/    : provides products of 2001 for special investigations
ivs-pilottro/     : provides tropospheric time series for Pilot Project
                       (until June 2003)
ivs-pilotbl/      : provides baselines files
ivs-special/      : specific studies
raw/              : original data (not writable at OPAR Data Center)
```

3. Current Status

The OPAR Data Center is operated on a PC Server (PowerEdge 2800 - Xeron 3.0 GHz) at Paris Observatory running the Fedora Linux operating system.

To make all IVS products available on-line, the disk storage capacity was significantly increased, and the server is equipped now with a RAID 3 TB disk extensible up to 4.7 TB.

The OPAR server is accessible 24 hours per day, seven days per week through Internet connection with 2 Mbit/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)

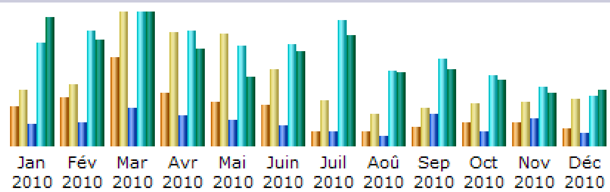
This year, 25 distinct users regularly put/got data on/from the FTP OPAR ivsincoming. There were also 3273 distinct users of the Web OPAR server. We provide more statistical information about the OPAR Data Center access in Figure 2.

4. Future Plans

The OPAR staff will continue to work with the IVS community and in close collaboration with the two other Primary Data Centers in order to provide public access to all VLBI related data.

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

WEB OPAR **Historique mensuel**



Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2010	311	435	1110	5351	299.69 Mo
Fév 2010	371	482	1186	6000	247.57 Mo
Mar 2010	687	1037	1993	6973	312.42 Mo
Avr 2010	404	879	1585	6043	226.56 Mo
Mai 2010	344	870	1348	5216	163.00 Mo
Juin 2010	313	589	1032	5317	219.27 Mo
Juil 2010	110	350	752	6538	258.78 Mo
Aoû 2010	106	251	514	3944	171.31 Mo
Sep 2010	144	290	1662	4557	177.12 Mo
Oct 2010	177	330	700	3673	154.47 Mo
Nov 2010	179	342	1415	3065	124.26 Mo
Déc 2010	127	364	692	2564	130.20 Mo
Total	3273	6219	13989	59241	2.43 Go

Figure 2. Monthly access of the Data Center during 2010. For each month in column 1, columns 2 through 6 show, in order, the number of different visitors, the total number of visits, the number of pages viewed, the number of accesses of the Web site, and the downloaded bandwidth in megabytes (Mo) or gigabytes (Go).

Analysis Centers

Analysis Center of Saint Petersburg University

Dmitriy Trofimov, Veniamin Vityazev

Abstract

This report briefly summarizes the activities of the Analysis Center of Saint Petersburg University during 2010. Changes which happened as well as our future plans are described.

1. Introduction

The Analysis Center of Saint Petersburg University (SPU AC) was established in the Sobolev Astronomical Institute of the SPb University in 1998. The main activity of the SPU AC for the International VLBI Service before 2007 consisted of routine processing of 24-hour and 1-hour observational sessions for obtaining Earth Orientation Parameters (EOP) and rapid UT1-UTC values, respectively. Due to staff changes in 2007 we had a gap in our submissions for IVS. In 2008 we resumed submitting results of 24-hour session processing. During 2010 the activities of the SPU AC continued unchanged.

2. Staff

The lecturer in astronomy of Saint Petersburg University, Dmitriy Trofimov, was in charge of the routine processing of the VLBI observations. General coordination and support for the activities of the SPU AC at the Astronomical Institute was performed by Prof. Veniamin Vityazev.

3. Activities in 2010

- In 2010 we continued the work resumed in 2008. The routine estimation of the five Earth Orientation Parameters was performed. The OCCAM package software (version 6_2) was used for current processing of VLBI data [1]. The time series is named spu00004.eops. It includes data obtained by the IRIS-A, NEOS-A, R1, and R4 observing programs, and it covers 23 years of observations (from January 2, 1989 until the end of 2010). The total number of processed experiments is about 1640, of which 100 VLBI sessions were processed in 2010. Our experience and the equipment of the Analysis Center was used for giving lectures and practical work on the basics of radio interferometry for the university students. In 2010, the work of the SPU AC was supported by the project "Kinematic and Dynamic Astronomy" (a grant of the President of the Russian Federation for leading scientific schools) as well as by the project "Acquisition and analysis of time-series in astronomy and the study of astronomical catalogs" (an SPU grant for fundamental research).
- All parameters have been adjusted using the Kalman filter technique. For all stations (except the reference station), the wet delay, clock offsets, clock rates, and troposphere gradients were estimated. Troposphere wet delay and clock offsets were modeled as a stochastic process such as a random walk. The clock rates and the troposphere gradients were considered to be the constant parameters.

- The main details of the preparation of the EOP time series spu00004.eops are summarized below:
  - Data span: 1989.01–2010.12
  - CRF: fixed to ICRF-Ext.2
  - TRF: VTRF2005 was used as an a priori TRF
  - Estimated parameters:
    1. EOP: $x, y, UT1 - UTC, d\psi, d\varepsilon$;
    2. troposphere: troposphere gradients were estimated as constant parameters, and wet troposphere delays were modeled as a random walk process;
    3. station clocks were treated as follows: offset as a random walk process, rate as a constant.
  - nutation model: IAU 1980
  - mapping function: VMF1
  - technique: Kalman filter
  - software: OCCAM v.6_2

4. Future Plans

In 2011 we are going to continue our regular processing of the results of the VLBI sessions as well as giving lectures and the practical work for the students within a special course on radio astrometry which is included in the systematic curriculum of astronomical education at SPb University.

References

[1] O. Titov, V. Tesmer, J. Boehm, OCCAM v. 6. 0 Software for VLBI Data Analysis, In International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings, N. R. Vandenberg and K. D. Baver (eds.), NASA/CP-2004-212255, pp.267-271, 2004.

Geoscience Australia Analysis Center

Oleg Titov

Abstract

This report gives an overview about the activities of the Geoscience Australia IVS Analysis Center during 2010.

1. General Information

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

2. Component Description

Currently the GA IVS Analysis Center contributes nutation offsets, EOP, and EOP rates on a regular basis for IVS-R1 and IVS-R4 networks and their predecessors (IRIS-A and NEOS-A). The EOP time series are available for 1983 to 2010. The CRF catalogs using a global set of VLBI data since 1979 are regularly submitted.

3. Staff

- Dr. Oleg Titov - project manager

4. Current Status and Activities

Several CRF solutions have been prepared using the OCCAM 6.2 software. The last solution has been uploaded in January 2011. VLBI data comprising 4,005 daily sessions from 25-Nov-1979 to 02-Oct-2010 have been used to compute several global solutions with different sets of reference radio sources. This includes 5,017,615 observational delays from 2,848 radio sources observed by 60 VLBI stations. [1].

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. The tectonic motion for the Gilcreek VLBI site after the Denali earthquake was modeled using an exponential function [2]. The tectonic motion of the TIGOCONC VLBI site after a strong earthquake on 27 February 2010 is under study (Figure 1).

The adjustment has been done by least squares collocation [3], which considers the clock offsets, wet troposphere delays, and troposphere gradients as stochastic parameters with a priori covariance functions. The gradient covariance functions were estimated from GPS hourly values [4].

5. Geodetic Activity of the Australian Radio Telescopes

During 2010 three Australian radio telescopes – Hobart26, Hobart12 operated by the University of Tasmania (UTAS), and Parkes operated by the Australia Telescope National Facility (ATNF), – were involved in geodetic VLBI observations. GA's Geodesy Group supported the observations

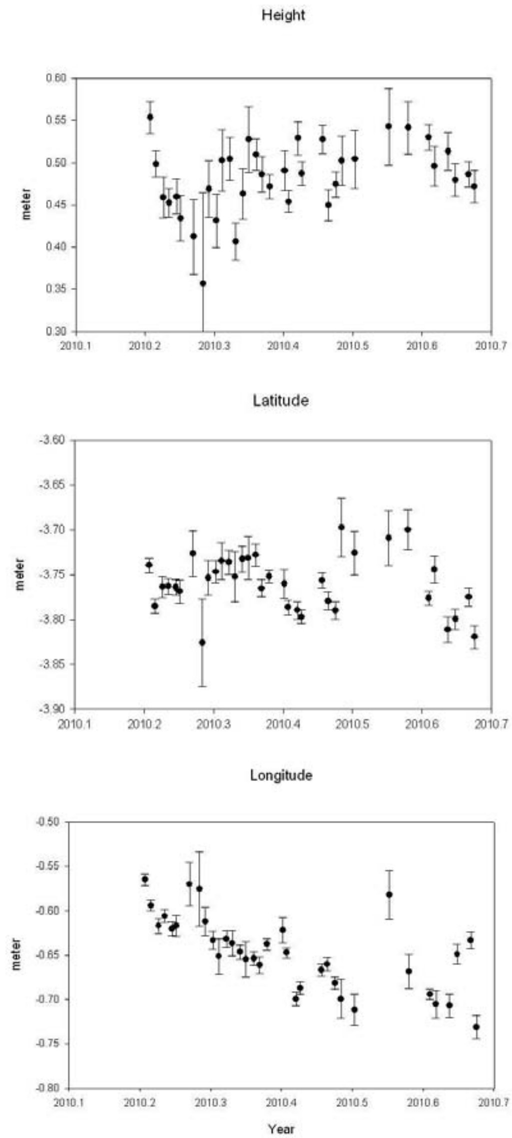


Figure 1. Height, latitude, and longitude variations of the TIGOCONC geodetic positions in 2010 following the 27 February 2010 earthquake.

in different ways including assistance with campaign scheduling.

The Parkes 64-meter telescope participated in two geodetic VLBI sessions in 2009 (R1416 and CRF-61) for improvement of the ITRF and the ICRF in the Southern Hemisphere. This program is undertaken in cooperation with ATNF and UTAS.

In August 2010 a group of scientists from Australia and Germany undertook a run of spectroscopic observations of the reference radio sources. They used the New Technology Telescope (NTT) optical facility (3.58-meter telescope in La Silla, Chile) operated by the European Southern Observatory (ESO). The goal of this work is to identify the radio sources regularly observed for the geodetic and astrometric VLBI programs. New red shifts of 31 radio sources in the southern hemisphere have been found. Five radio sources (1659-621, 1758-651, 1815-553, 2236-572, and 2344-514) belong to the list of the ICRF2 defining sources. Two observers (Oleg Titov and David Jauncey (ATNF)) were supported by a travel grant of the Access to Major Research Facilities Program (AMRFP) to travel to La Silla. A paper reporting the results is under preparation. Figure 2 shows a sky field around the 1758-651 source made at NTT. Two stellar objects are close to each other; therefore the slit of the spectrograph was directed to cover both objects. Figure 3 shows the dirty spectrum of the two objects. While the brighter object does not show any features, the fainter companion has two strong emission lines. The clean spectrum after processing shown in Figure 4 reveals two strong emission lines identified as CIII] and MgII. A set of less prominent lines was also found.

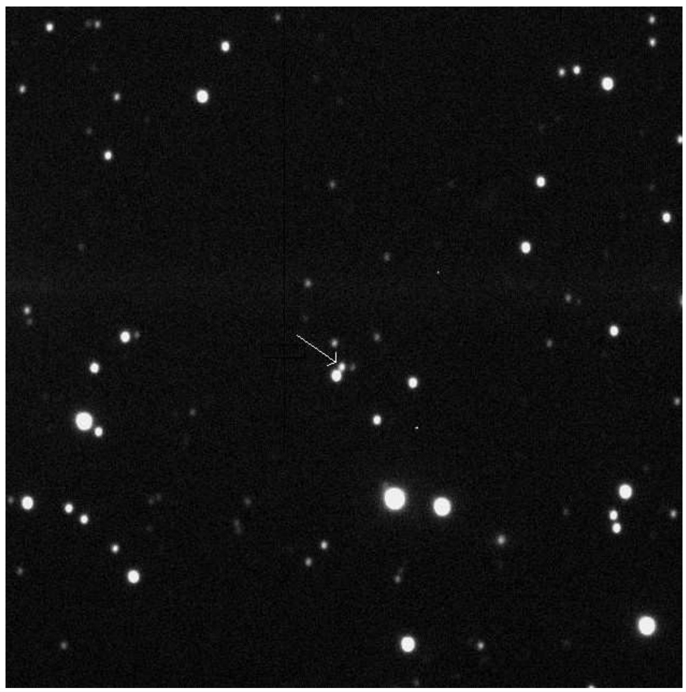


Figure 2. The NTT image of the sky field around the quasar 1758-651 (shown by arrow). Closeness of the quasar to the bright star probably caused an identification failure in the past.

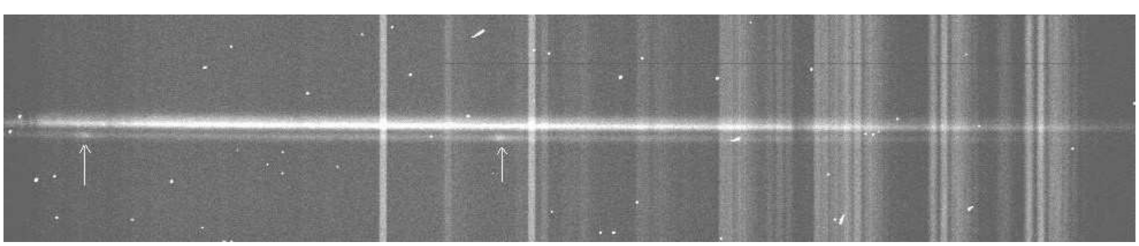


Figure 3. The spectra of the two optical objects of Figure 2. The spectrum of the star has no features while the less powerful spectrum of 1758-651 highlights two emission lines shown by arrows.

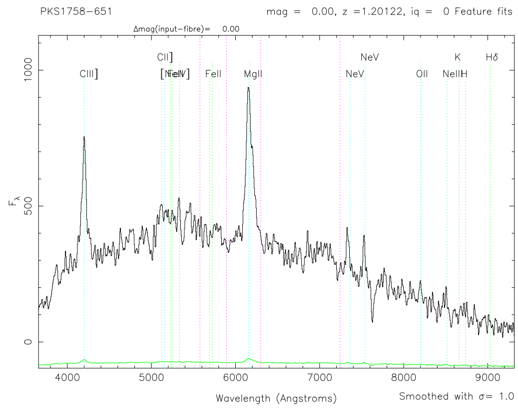


Figure 4. The clean spectrum of 1758-651 after processing. Two main lines CIII] and Mg II are followed by a set of less prominent lines. The red shift was estimated as equal to 1.2.

6. New Geodetic VLBI Network

Geoscience Australia supported the installation work of the new Australian geodetic VLBI network during 2010. Antenna Hobart12 started operations in October 2010. Two other antennas, Katherine and Yarragadee, will start operations in 2011.

Acknowledgements

This report has been published with permission of the Geoscience Australia CEO.

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Report for 2010 from the Bordeaux IVS Analysis Center

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

Abstract

This report summarizes the activities of the Bordeaux IVS Analysis Center during the year 2010. The work was focused on (i) regular analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package; (ii) systematic VLBI imaging of the RDV sessions and calculation of the corresponding source structure index and compactness values; (iii) testing of a pipeline to model-fit VLBI structures in an automatic way; and (iv) continuation of our VLBI observational program to identify optically-bright radio sources suitable for the link with the future Gaia frame. Also of importance is the implementation of the *IVS Live* Web site which allows one to monitor IVS sessions in real time and to view source images.

1. General Information

The "Laboratoire d'Astrophysique de Bordeaux" (LAB), formerly Bordeaux Observatory, is located in Floirac, near Bordeaux, in the southwest of France. It is funded by the University of Bordeaux and the CNRS ("Centre National de la Recherche Scientifique"). VLBI activities are primarily developed within the M2A team ("Métrologie de l'espace, Astrodynamique, Astrophysique").

The contribution of the Bordeaux group to the IVS has been mostly concerned with the maintenance, extension, and improvement of the International Celestial Reference Frame (ICRF). This includes regular imaging of the ICRF sources and evaluation of their astrometric suitability, as well as developing specific VLBI observing programs for enhancing the celestial reference frame.

In addition, the group is in charge of the VLBI component in the multi-technique GINS software package [1] as part of a collaborative effort within the French "Groupe de Recherches de Géodésie Spatiale" (GRGS) to combine VLBI and space geodetic data (SLR, GPS, DORIS) at the observation level. This effort also involves space geodesy groups in Toulouse, Grasse, and Paris.

2. Description of Analysis Center

The Bordeaux IVS group routinely analyzes the weekly IVS-R1 and IVS-R4 sessions with the GINS software package. During the past year, weekly normal equations for all such sessions in 2009 and 2010 (with 6-hour EOP resolution) have been produced and integrated in the multi-technique solutions derived by the GRGS within the framework of the "Combination at the Observation Level" (COL) Working Group. Additional work was dedicated to implementing operational procedures for automating the data processing with GINS and for assisting in evaluating the results.

The group is also focused on imaging the ICRF sources on a regular basis by systematic analysis of the data from the RDV sessions which are conducted six times a year. This analysis is carried out with the AIPS and DIFMAP software packages. The aim of such regular imaging is to characterize the astrometric suitability of the sources based on the so-called "structure index", and to compare source structural evolution and positional instabilities. Such studies are essential for identifying sources of high astrometric quality as for the ICRF2 [2] or the future Gaia link.

3. Scientific Staff

During the past year, several changes occurred with IVS staff. The most significant event is that Géraldine Bourda obtained a permanent position at the LAB, starting on 1 September 2010; this position comprises research, teaching duties, and IVS service activity. With two researchers and two engineers on permanent positions, the IVS group can now build on solid ground. Also Ming Zhang's CNRS post-doctoral fellowship ended on 30 September 2010; he then went back to China and obtained a permanent position at Urumqi Astronomical Observatory. Yet another change is Alain Baudry's retirement on 1 September 2010; now with a part-time ESO contract to accomplish ALMA duties, he still spends time at the LAB and keeps contact with VLBI and IVS. In all, six individuals contributed to IVS analysis and research activities during 2010. A description of what each person worked on, along with the time spent on these activities, is given below.

- Patrick Charlot (20%): overall responsibility for Analysis Center work and data processing. His research interests include the ICRF densification, extension, and link to the Gaia frame, studies of source structure effects in astrometric VLBI data, and astrophysical interpretation.
- Antoine Bellanger (80%): engineer with background in statistics and computer science. His tasks are to process VLBI data with GINS and to develop procedures and analysis tools to automate such processing. He is also the Web master for the M2A group.
- Géraldine Bourda (50%): now with a permanent position at the LAB. She is tasked with developing the VLBI part of GINS and is responsible for the analysis results derived from GINS. She also leads a VLBI observational program for linking the ICRF and the future Gaia frame.
- Arnaud Collioud (100%): engineer with background in astronomy and interferometry. His tasks are to process the RDV sessions with AIPS and DIFMAP to image the sources, to maintain the Bordeaux VLBI Image Database (BVID), and to develop VLBI2010 simulations.
- Ming Zhang (50%): post-doc fellow funded by the CNRS (until 30 September 2010). His work has been targeted towards finding automatic ways to model-fit VLBI structures and extract physical information with the aim of studying the evolution of the sources from the BVID.
- Alain Baudry (10%): radioastronomy expert with specific interest in radio source imaging and astrometric VLBI. Retired since 1 September 2010.

4. Analysis and Research Activities during 2010

As noted above, a major activity of the Bordeaux group consists in imaging the sources observed during the RDV sessions on a systematic basis. During 2010, two such sessions were processed (RDV76 and RDV78), resulting in 370 VLBI images at either X or S band for 156 different sources. The imaging work load has been shared between the USNO and Bordeaux groups since 2007 (starting with RDV61): the USNO group processes the odd-numbered RDV sessions while the Bordeaux group processes the even-numbered ones. The VLBI images are used in a second stage to derive structure correction maps and visibility maps along with values for structure indices and source compactness (see [3, 4] for a definition of these quantities) in order to assess astrometric source quality. All such information is made available through the Bordeaux VLBI Image Database (BVID)[1]. At present, the BVID comprises a total of 2108 VLBI images (with links to an additional

[1]The BVID may be accessed at http://www.obs.u-bordeaux1.fr/BVID

7124 VLBI images from the Radio Reference Frame Image Database of the USNO at either S, X, K, or Q band) along with 9232 structure correction maps and as many visibility maps.

Plans to take advantage of this wealth of VLBI images for astrophysics have also been initiated. For this purpose, a pipeline that automatically fits Gaussian components to the observed VLBI structures and subsequently estimates jet proper motions and flux density variability has been developed [5]. Comparison with results obtained manually for a few sources shows excellent agreement in the case of structures with strong and well-separated VLBI components, whereas results sometimes disagree for structures that comprise weak and/or blended VLBI components. A comparison for a large data set (50 to 100 sources) is now underway to assess the potential use of this pipeline to study source structural variability in a systematic way from the BVID data.

The other major activity in the group is an observational program to identify and characterize appropriate radio sources to align the ICRF and the future Gaia optical frame. To this end, dedicated VLBI observations of a sample of 398 optically-bright radio sources have been undertaken [6]. From this sample, an initial 105 sources have already been imaged, half of which show the required properties in terms of astrometric suitability [7]. During the past year, a total of 106 hours of observing time was allocated to image an additional 215 sources. These observations were carried out in March and November 2010 with a 15-station network combining the European VLBI Network and the Very Long Baseline Array. Observations of the remaining sources are planned for March 2011 to complete the imaging work. Next will come dedicated astrometric observations of the most compact sources identified though such imaging to accurately measure their positions.

5. Dissemination and Outreach

As reported in [5], the Bordeaux group set up a dynamic Web site displaying VLBI images of the observed radio sources in real time for the particular IVS session dedicated to the International Year of Astronomy 2009 (IYA2009) which took place on 18 November 2009. Following this event – which drew quite a lot of interest – the IVS Directing Board suggested that the IYA09 Web site be extended in order to make it run for every IVS session. The work was carried out during 2010, and a final product, *IVS Live*, was presented for approval to the IVS Directing Board in October 2010. The *IVS Live* Web site may be reached from the IVS home page or directly at the following address:

http://ivslive.obs.u-bordeaux1.fr/

IVS Live is meant both as an outreach and a scientific tool. The main reason for its existence is to monitor IVS sessions in real time and to view source images (Fig. 1). But it can also be used to navigate through IVS sessions and to search for specific information about sources and stations. It will be regularly updated and extended in order to increase its value to the IVS community. The most recent enhancement is a display of the projected source direction on the terrestrial map.

6. Outlook

Our plans for the coming year are focused on moving towards operational analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package. We will also continue imaging the RDV sessions in cooperation with USNO as well as evaluating the source astrometric suitability based on structure index and source compactness indicators. In addition, we expect to develop astrophysical interpretation of the BVID data by using the pipeline that we have developed to

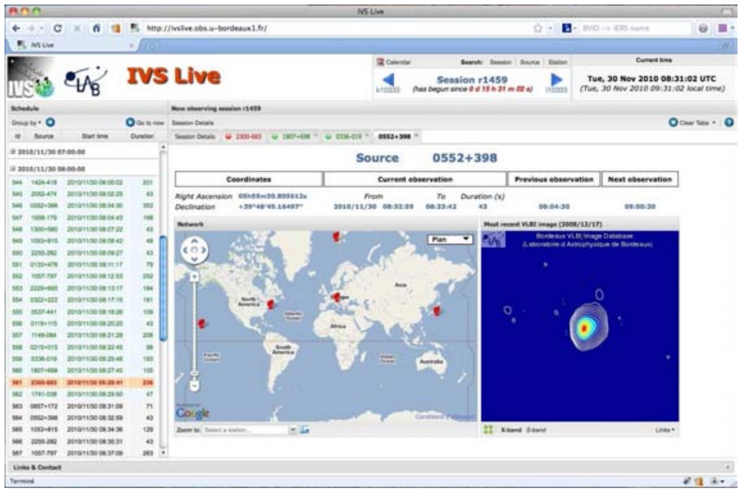

Figure 1. A snapshot of the *IVS Live* Web site while observing the source 0552+398 in the course of the IVS session R1459 on 30 November 2010. See the December 2010 IVS newsletter for details on the functionalities.

model-fit VLBI structures in an automatic way. Regarding the Gaia link, our goal is to complete the VLBI imaging of the 398 optically-bright radio sources selected for this purpose, to assess their astrometric suitability, and to engage in astrometric observations on the most compact of these sources. Simulations of the VLBI2010 system's imaging capabilities will also be started again with focus on the assessment of the accuracy of the structural corrections derived from such images.

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BKG/DGFI Combination Center Annual Report 2010

Sabine Bachmann, Robert Heinkelmann, Michael Gerstl

Abstract

This report summarizes the activities of the BKG/DGFI Combination Center in 2010 and outlines the planned activities for the year 2011. The main goal in 2010 was to perform the operational combination of the IVS Rapid EOP series (R1 and R4 sessions). Since October 1, 2009 these combinations have been performed at the BKG/DGFI Combination Center. In 2011 the responsibility for the operation of the IVS quarterly solutions should also be taken over from the IVS Analysis Coordinator.

1. General Information

The BKG/DGFI Combination Center was established in October 2008 as a joint effort of the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) and the German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI). The participating institutions, as well as the tasks and the structure of the IVS Combination Center, have been described in [5]. The tasks comprise quality control and a timely combination of the session-based intermediate results of the IVS Analysis Centers into a final combination product (e.g., Earth Orientation Parameters (EOP)). In coordination with the IVS Analysis Coordinator, the combination results will be released as official IVS products. The Combination Center is also expected to contribute to the generation of the official IVS input to any ITRF activities. These tasks should be performed on an operational basis.

2. Component Description

The BKG/DGFI Combination Center performs a combination of session-based results of the IVS Analysis Centers on an operational basis. The strategy for the combination has been adopted from the combination process developed and performed by the IVS Analysis Coordinator (cf. [3], [4]). In 2009 the responsibility for the combination of the two IVS EOP series (rapid and quarterly solutions) on the basis of datum-free normal equations in SINEX format was taken over by the Combination Center.

At BKG Combination Center (BKG CC) the following tasks are performed:

- Ensuring quality control of the Analysis Center results: Checking the format of the results and their suitability for combination, performing identification and reduction of outliers, comparing the Analysis Centers' results with each other, and comparing the results w.r.t. external time series, e.g. from IERS or IGS.
- Providing feedback to the Analysis Centers: Quality control results will be available at the BKG/DGFI IVS Combination Center Web page [6]. If requested by the Analysis Centers, the results will be provided by e-mail, too.
- Creating high quality combination products and performing timely archiving and distribution: Combination products will be created using the DGFI DOGS software package [7].
- Submitting official IVS combination products to the IERS: The produced official IVS combination products will be submitted to the responsible IERS components as requested by the IERS. This will be supported by the staff of the IERS Central Bureau at BKG.

- Placing final results in IVS Data Centers: Final results will be placed in the BKG Data Center. This will be assisted by the staff of the BKG Data Center in Leipzig.
- Generating official IVS input to the ITRF: Official IVS input to the ITRF will be created as combined weekly solutions in SINEX format.

DGFI is in charge of the following Combination Center functions:

- Developing state-of-the-art combination procedures: State-of-the-art combination procedures will be developed mainly at DGFI. This work, as well as the following item, is also related to DGFI's efforts within the IERS WG on the Combination on Observation Level (COL).
- Performing software development and documentation: At DGFI the DOGS software package will be continuously updated by implementing the developed state-of-the-art combination procedures.
- Adhering to IERS Conventions: The DGFI DOGS software package is continuously updated to be in accordance with the IERS Conventions.

3. Staff

At the end of March 2010 Wolfgang Schwegmann, responsible for the BKG CC, left BKG and thus the Combination Center after several years of collaboration with the IVS. At BKG, without interruption, Sabine Bachmann took over the combination procedure. The list of the staff members of the BKG/DGFI Combination Center in 2010 is given in Table 1.

Table 1. Staff members of the BKG/DGFI Combination Center.

Name	Affiliation	Function	E-Mail
Michael Gerstl	DGFI	Software maintenance	gerstl@dgfi.badw.de
Robert Heinkelmann	DGFI	Combination strategies	heinkelmann@dgfi.badw.de
Sabine Bachmann	BKG	Combination	sabine.bachmann@bkg.bund.de
Alexander Lothhammer	BKG	Hardware maintenance	alexander.lothhammer@bkg.bund.de

4. Current Status and Activities

The combination of the IVS Rapid EOP series (R1 and R4 sessions), started in 2009 at BKG, has been continued routinely in 2010. In 2010, six IVS Analysis Centers (BKG, DGFI, GSFC, IAA, OPA, and USNO) contributed to the IVS combined product (see [4]). The rapid solutions contain only R1 and R4 sessions, and new data points are added twice a week as soon as the SINEX files of at least four IVS Analysis Centers are available. The results of the combination process are placed in the BKG Data Center in Leipzig. The combined rapid EOP series, as well as the results of the quality control of the Analysis Center results, are also available at the BKG/DGFI

Combination Center Web page [6]. The main update of the combination procedure was the change of the nutation parameter from $d\psi$ and $d\epsilon$ (referring to the IAU2000A precession-nutation model) to dX and dY (referring to the IAU2006 precession-nutation model), the latter being used by four out of the six Analysis Centers.

The completion of the IVS quarterly solution has been intensively continued. Within the quarterly combination, every three months all available sessions from 1979 up to the present are combined. Presently several tests have been performed with good intra-technique results. Comparisons with external time series from IERS and IGS are under way.

5. Plans for 2011

The inter-technique combinations for IVS activities are currently performed by accumulating either normal equations or solution equations. Since the observations analyzed by the various Analysis Centers are initially identical, combinations on the observation equation level are pointless. Compared to the combination of solution equations, the normal equation level is advantageous because it still enables correlations among the parameters and allows the addition of a unique set of datum (condition) equations. The functional models of the inter-technique combination methods for normal equations and solutions are trivial, while the stochastic models are not. The current algorithm applied for routine combinations on the normal equation level includes individual scaling of the Analysis Centers' contributions through variance component estimation. The scaling is in particular valuable, because different parameter estimation techniques (e.g. least-squares adjustment, Kalman filter, Square Root Information Filter (SRIF), or least squares collocation) may be applied. Besides the scaling among the Analysis Centers the combination algorithm should consider the fact that the same original observations are used by the Analysis Centers. The 're-application of observations' requires the stochastic model to contain off-diagonal elements. The framework of a combination theory considering this fact was introduced by [2] and labeled the Operator Software Impact (OSI). As a first step for improving the IVS combination strategy, the OSI model has been applied to the combination of troposphere parameters during CONT08 [1]. In 2011 it is planned to test the OSI model on the normal equation level and to make it available for IVS routine combinations.

In 2011 the work of the BKG/DGFI Combination Center will focus on the following:

- Performing the IVS quarterly solution combination on an operational basis.
- Performing quality control of improved Analysis Center solutions and using these solutions in the routine combination.
- Including two new Analysis Center solutions: one based on the GEOSAT software and provided by Halfdan Pascal Kierulf from the Geodetic Institute, Norwegian Mapping Authority (NMA), Hønefoss, Norway, and the other based on the OCCAM software and provided by Oleg Titov from Geoscience Australia (AUS), Canberra, Australia.
- Entire transition of the combination software to the actual nutation parameter dX and dY as soon as every AC contributes these parameters in their SINEX files.
- Extending the combination analysis by including source parameters.

- Maintaining and extending available information on the combination procedure and combination results available at the Combination Center Web page [6].

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Matera CGS VLBI Analysis Center

Roberto Lanotte

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS), Matera, from January 2010 through December 2010 and the contributions that the CGS intends to provide for the future as an IVS Analysis Center.

1. General Information

The Matera VLBI station became operational at the Space Geodesy Center (CGS) of the Italian Space Agency (ASI) in May 1990. Since then, it has been active in the framework of the most important international programs. The CGS, operated by e-geos (a Telespazio/ASI company) on behalf of ASI, provides full scientific and operational support using the main space geodetic techniques: VLBI, SLR, and GPS.

2. Staff at CGS contributing to the IVS Analysis Center

- Dr. Giuseppe Bianco, responsible for CGS/ASI (primary scientific/technical contact).
- Dr. Rosa Pacione, responsible for scientific activities, e-geos.
- Dr. Roberto Lanotte, geodynamics data analyst, e-geos.

3. Current Status and Activities

3.1. Global VLBI Solution cgs2009a

The main VLBI data analysis activities at the CGS in the year 2010 were directed towards the realization of a global VLBI solution, named cgs2009a, using the CALC/SOLVE software (developed at GSFC). The solution activities, started at the end of 2009, ended in March 2010, when the solution sections (CRF, TRF, and EOP) were published in the IVS archives. The main, final characteristics of this solution are:

- Data span:
  1979.08.03 - 2009.12.22 (3680 sessions)
- Estimated Parameters:
  - Celestial Frame:
    Right ascension and declination as global parameters for 1678 sources
  - Terrestrial Frame:
    Coordinates and velocities for 88 stations as global parameters
  - Earth Orientation:
    Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi, and deps.

3.2. IVS Tropospheric Products

Regular submission of tropospheric parameters (wet and total zenith path delays, and east and north horizontal gradients) for all VLBI stations observing in the IVS R1 and R4 sessions continued during 2010. At present 957 sessions have been analyzed and submitted, covering the period from 2002 to 2010. The results are available at the IVS Data Centers.

3.3. IVS Product "Time Series of Baseline Lengths"

Regular submission of station coordinate estimates, in SINEX files, continued during 2010 for the IVS product "Time Series of Baseline Lengths". This is composed of 4306 sessions, from 1979 to 2010.

3.4. CGS Contribution to IERS EOP Operational Series

Since 2008, CGS has been delivering IERS R1 and R4 session EOP estimates as a regular contribution to the IERS EOP operational series. The whole cgs2007a solution, available when the contribution started, has been delivered to IERS as a reference series updated by periodic EOP solution submissions.

4. Future Plans

- Continue and improve the realization of our global VLBI solution, providing its regular update on time.
- Continue to participate in IVS analysis projects, providing datum-free normal equations.

DGFI Analysis Center Annual Report 2010

Robert Heinkelmann, Manuela Seitz, Michael Gerstl, Hermann Drewes

Abstract

This report summarizes the activities of the DGFI Analysis Center in 2010 and outlines the planned activities for 2011.

1. General Information and Component Description

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institute hosted at the Bavarian Academy of Sciences (BADW) located in Munich. It is run by the Free State of Bavaria, and it is evaluated every four years by a scientific advisory board consisting of four international experts nominated by the International Association of Geodesy (IAG) and of three professors working at German universities nominated by the German Geodetic Commission (Deutsche Geodätische Kommission, DGK). The research covers all fields of geodesy and includes the participation in national and international projects as well as functions in international bodies (see also http://www.dgfi.badw.de).

In November 2010 the research activities of DGFI were reviewed by the scientific advisory board for the first time. In their expertise the scientific board pointed out positively the proposed work in the context of IVS enabling the IVS AC at DGFI to carry on its work for another four-year period (2011-2014). On the 28th of October 2010 the scientific geodetic institutions in Munich and Bavaria—namely the Institute of Astronomical and Physical Geodesy (IAPG) and the Forschungseinrichtung Satellitengeodäsie (FESG) including the personnel at the Geodetic Observatory Wettzell (both at Technical University Munich (TUM)), the Bayerische Kommission für die internationale Erdmessung and the Deutsches Geodätisches Forschungsinsitut of the Deutsche Geodätische Kommission (both at the Bavarian Academy of Sciences)—have signed a cooperation agreement to establish the Center for Geodetic Earth system Research (Centrum für Geodätische Erdsystemforschung), CGE[1]. The CGE's mission is the research of global change through the measurement of changes in the solid Earth, the oceans, the ice caps, and the atmosphere, as well as the analysis of these changes with regards to the triggering physical processes.

2. Staff

The DGFI IVS AC[2] is operated by Robert Heinkelmann and Manuela Seitz. The recent developments and numerical optimizations of our VLBI analysis software were almost completely carried out by Michael Gerstl. Our activities are managed by Hermann Drewes, who retired at the end of 2010. We regret to lose Hermann's expertise; but, nevertheless, we wish Hermann a joyful retirement.

3. Current Status and Activities

- IVS Operational Analysis Center at DGFI

[1] http://www.badw.de/aktuell/pressemitteilungen/archiv/2010/PM_28_2010/index.html
[2] http://www.dgfi.badw.de/index.php?id=126&L=2

DGFI routinely processes the standard IVS sessions (currently the two IVS rapid turnaround networks IVS-R1 and IVS-R4) and additional sessions of the geodetic and astrometric program run by IVS and delivers datum free normal equations in SINEX format. The duty to process and submit sessions within 24 hours after the availability of the database (DB) version 4 (or higher) demands the full automation of the analysis. A small but important step towards decreasing the product latency could be achieved with the help of the Institute of Applied Astronomy (IAA), St. Petersburg, that provided a routine enabling the output of correlator information from DB in ASCII format. In this context, we want to thank Igor Surkis and colleagues from IAA for the preparation of FORTRAN routines.

- Automation of the VLBI analysis

  The main task during 2010 was the automation of VLBI analysis at the 'post-post-processing' level, i.e., starting with DB version 4 (or higher). IVS folders containing DB files are routinely checked for new files. In case of a new file, the highest DB version available is downloaded onto a local Linux PC and transformed to NGS format. Applying the routines provided by IAA an ASCII text file is then created in addition to the transformation from DB to NGS format. The ASCII text file contains the correlator comments including those on real clock breaks. The clock breaks mentioned by the correlator are then automatically detected and removed by an algorithm developed at DGFI. After a first least-squares adjustment, clock breaks and offsets are considered, and a second robust adjustment is performed, eliminating possible outliers. The outlier-free group delays corrected for clock breaks and for offsets are then transformed into normal equations and written to SINEX format via the DOGS-CS software.

- Re-arrangement of the VLBI software used and developed at DGFI

  The VLBI software used at DGFI got completely rearranged and is now part of the DGFI Orbit and Geodetic Parameter Estimation Software DOGS (Gerstl et al., 2000; Heinkelmann and Gerstl, 2010).

  - The new code enables running on 32bit and 64bit operating systems.
  - The explicit declaration of all variables increases the reliability.
  - '8byte real' instead of 'DOUBLE PRECISION' types of variables allow machine independence.
  - 'COMMON' blocks are replaced by modules, increasing the reliability.
  - Arrays are allocated dynamically, saving memory space.
  - Avoidance of 'EQUIVALENCE' statements allows optimization.
  - Binary files were shortened or completely removed.

  The program body is modular, and thus modules which are in common in VLBI and SLR analyses are now identical for both techniques. The software migration thus increases the consistency between the VLBI and SLR solutions provided by DGFI and reduces the time and effort for maintenance. The program language is FORTRAN2003, compatible with FORTRAN95.

4. Future Plans

At DGFI IVS AC we want to continue and deepen our investigations concerning the atmosphere, i.e., the neutral atmosphere and the ionosphere. Besides, the inclusion of the DOGS VLBI software into routine processes will be one of our main goals in 2011. For the operational VLBI analysis we want to further automate the analysis procedure and to extend our product portfolio. The Linux PC, which currently runs the automated procedures, is located at the Institute of Geodesy and Geophysics, TU Vienna, Austria so far. In 2011 we want to migrate those processes to a PC maintained at our institute.

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FFI Analysis Center

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an Analysis Center focuses primarily on a combined analysis at the observation level of data from VLBI, GPS (ground-based and LEO), SLR, altimetry and gradiometry using the GEOSAT software. This report briefly summarizes the current status of analyses performed with the GEOSAT software. FFI is currently an Analysis Center for IVS and ILRS and a Technology Development Center for IVS.

1. Introduction

A number of co-located stations with more than one observation technique have been established. In principle, all instruments at a given co-located station move with the same velocity, and it should be possible to determine one set of coordinates and velocities for each co-located site. In addition, a constant eccentricity vector from the reference point of the co-located station to each of the individual phase centers of the co-located antennas is estimated using constraints in accordance with a priori information given by 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 nearly independent of water vapor, gives new information which will help in the de-correlation of atmospheric and other solve-for parameters and lead to more accurate parameter estimates. These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully provided by the GEOSAT software developed by FFI.

2. The GEOSAT Software and Analysis Activities in 2010

The analysis activities in 2010 have been concentrated on testing and validating the newly implemented modules for accelerometry and altimetry. The GEOSAT orbit model has been validated against external LEO orbit. The RMS difference between JPL GRACE orbits and internal GEOSAT orbits is typically 4 mm in each cartesian direction. The corresponding RMS difference between external GOCE orbits (ESA official, approximately 250 km altitude) and internal GEOSAT orbits is typically 11 mm.

The Norwegian Mapping Authority (NMA) and FFI have started a close cooperation in analysis of space geodetic data using the GEOSAT software. NMA has recently been given the status of an Associate Analysis Center of IVS. The GEOSAT software is to be used in the analysis of VLBI data. We are right now trying to get our GEOSAT-generated SINEX files accepted by the IVS combination software. There are options in GEOSAT so that the VLBI model is in compliance with the other analysis software packages.

3. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI).

The BKG/IGGB VLBI Analysis Center

Volkmar Thorandt, Axel Nothnagel, Gerald Engelhardt, Dieter Ullrich, Thomas Artz, S. Tesmer née Böckmann, Judith Pietzner

Abstract

In 2010, the activities of the BKG/IGGB VLBI Analysis Center, as in previous years, consisted of routine computations of Earth orientation parameter (EOP) time series and of a number of research topics in geodetic VLBI. The VLBI group at BKG continued its regular submissions of time series of tropospheric parameters and the generation of daily SINEX (Solution INdependent EXchange format) files. Quarterly updated solutions have been computed to produce terrestrial reference frame (TRF) and celestial reference frame (CRF) realizations. Routine computations of the UT1–UTC Intensive observations include all sessions of the Kokee–Wettzell and Tsukuba–Wettzell baselines and the networks Kokee–Svetloe–Wettzell and Ny-Ålesund–Tsukuba–Wettzell. At IGGB, the emphasis has been placed on individual research topics.

1. General Information

The BKG/IGGB VLBI Analysis Center has been established jointly by the analysis groups of the Federal Agency for Cartography and Geodesy (BKG), Leipzig, and the Institute of Geodesy and Geoinformation of the University of Bonn (IGGB). Both institutions cooperate intensely in the field of geodetic VLBI. The responsibilities include both data analysis for generating IVS products and special investigations with the goal of increasing accuracy and reliability. BKG is responsible for the computation of time series of EOP and tropospheric parameters, for the generation of SINEX files for 24-hour VLBI sessions and 1-hour Intensive sessions, and for the generation of quarterly updated global solutions for TRF and CRF realizations. Besides data analysis, the BKG group is also responsible for writing schedules for the Tsukuba-Wettzell INT2 UT1-UTC observing sessions. IGGB continues to host the office of the IVS Analysis Coordinator and carries out special investigations within the technique of geodetic and astrometric VLBI. Details of the research topics of IGGB are listed in Section 3.

2. Data Analysis at BKG

At BKG, the Mark 5 VLBI data analysis software system Calc/Solve, release 2010.05.21 [1], has been used for VLBI data processing. It is running on a Linux operating system. The software is now able to use the IAU2006 Nutation/Precession model. As in the previous releases the Vienna Mapping Function (VMF1) has been implemented in a separate Solve version. This modified version was used for all data analysis. The VMF1 data were downloaded daily from the server of the Vienna University of Technology. Additionally, the technological software environment for Calc/Solve has been refined to link the Data Center management with the pre- and post-interactive parts of the EOP series production and to monitor all Analysis and Data Center activities.

- **Processing of correlator output**
  The BKG group continued the generation of calibrated databases for the sessions correlated at the MPIfR/BKG Mark 5 Astro/Geo Correlator at Bonn (e.g., EURO, OHIG, and T2) and submitted them to the IVS Data Centers.

- **Scheduling**
  BKG continued scheduling the INT2 Intensive sessions, which are observed on the baselines TSUKUBA-WETTZELL, KASHIMA-WETTZELL, KASHIMA-WESTFORD, and TSUKUBA-WESTFORD. Altogether 92 schedule files were created in 2010.

- **BKG EOP time series**
  The old BKG EOP time series bkg00012 was replaced by the new bkg00013. One main difference to the former solution is the new a priori set of coordinates of the second realization of the International Celestial Reference Frame (ICRF2) [2]. Further the estimation of the nutation parameters in this series is based on partial derivatives of X,Y-nutation components with respect to IAU2000A/2006 precession and nutation models. Because of a big earthquake in the region of the VLBI station TIGOCONC in Chile with station displacements of about 3 meters, the modeling of this station was changed from globally estimated station coordinates to locally estimated coordinates in all post-quake sessions.

  Each time after the preprocessing of any new VLBI session (correlator output database version 1), a new global solution with 24-hour sessions since 1984 was computed, and the EOP time series bkg00013 was extracted. Altogether 4097 sessions were processed. The main parameter types in this solution are globally estimated station coordinates and velocities together with radio source positions. The datum definition was realized by applying no-net-rotation and no-net-translation conditions for 26 selected station positions and velocities with respect to VTRF2008a and a no-net-rotation condition for 295 defining sources with respect to ICRF2. The station coordinates of the telescopes AIRA (Japan), CHICHI10 (Japan), CTVASTJ (Canada), DSS13 (USA), HOBART12 (Australia), PT_REYES (USA), SEST (Chile), SINTOTU3 (Japan), TIGOCONC (Chile), WIDE85_3 (USA), VERAISGK (Japan), VERAMZSW (Japan), and YEBES40M (Spain) were estimated as local parameters in each session.

  The UT1-UTC Intensive time series bkgint08 was replaced by bkgint09. The series bkgint09 was generated with fixed TRF (VTRF2008a) and fixed ICRF2. The estimated parameter types were only UT1-TAI, station clock, and zenith troposphere. Observations of the two baselines KOKEE-WETTZELL and TSUKUBA-WETTZELL and also of the networks KOKEE-SVETLOE-WETTZELL and NYALES20-TSUKUBA-WETTZELL were processed regularly. The analysis of the e-VLBI experiments each week on Mondays could be finished almost always on the same day. Delays of maximal one day appeared because of problems in data transfer. The lack of observations due to maintenance and repair work at WETTZELL could be compensated by observations with WESTFORD and Ny-Ålesund. A total of 3476 UT1 Intensive sessions were analyzed for the period from 1999.01.01 to 2010.12.31.

- **Quarterly updated solutions for submission to IVS**
  In 2010, one quarterly updated solution was computed for the IVS products TRF and CRF. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00013. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is available in SINEX format, version 2.1, and includes station coordinates, station velocities, and radio source coordinates together with the covariance matrix, information about constraints, and the decomposed normal matrix and vector.

- **Tropospheric parameters**

The VLBI group of BKG continued regular submissions of long time series of tropospheric parameters to the IVS (wet and total zenith delays and horizontal gradients) for all VLBI sessions since 1984. The tropospheric parameters were extracted from the standard global solution bkg00013 and transformed into SINEX format.

- **Daily SINEX files**
  The VLBI group of BKG also continued regular submissions of daily SINEX files for all available 24-hour sessions for the IVS combined products and for the IVS time series of baseline lengths. In addition to the global solutions, independent session solutions with the new models mentioned above were computed for the station coordinates, radio source coordinates, and EOP parameters including the X,Y-nutation parameters. The a priori datum for TRF is defined by the VTRF2008a, and ICRF2 is used for the a priori CRF information.

- **SINEX files for Intensive sessions**
  The parameter types are station coordinates, pole coordinates and their rates, and UT1-TAI and its rate. But only the normal equations stored in the SINEX files are important for further combination with other space geodetic techniques.

3. Research Topics at IGGB

- **Correlations within the IVS combination process**
  As the contributions of each Analysis Center (AC) to the official IVS combined products are derived from virtually the same set of original observations, correlations between the contributions are expected. So far, this topic has been completely neglected in any intra-technique combination approach. In a study [3], the observation equations of two ACs (BKG and IGGB) have been used directly for the combination (in contrast to using normal equation systems, NEQs). With this approach, the level of correlations has been determined, and the influence of neglecting the correlations on the estimated combined parameters as well as their formal errors have been investigated. Based on CONT02 observations, it turned out that a realistic level of correlations between the two contributions lies between 0.5 and 0.7, which is much less than expected.

- **Determination of sub-daily tidal ERP models**
  The IERS model for tidal Earth Rotation Parameter (ERP) variations with periods around one day and below as given in the IERS Conventions [4] does not describe all effects that are measured by VLBI. An empirical model has been estimated from VLBI observations applying a new approach based on the transformation of NEQs [5]. Furthermore, the general reliability and stability of VLBI-derived sub-daily ERP has been investigated [6].

  Furthermore, the approach of estimating a sub-daily tidal ERP model applying the transformation of NEQs has been used to determine a combined model based on homogeneously reprocessed GPS and VLBI NEQs. This combination also allows to determine long term time series of hourly spaced ERPs. It turned out that the combined time series can be estimated almost without any constraints as geometric instabilities of the techniques are cross-wise compensated and the stochastic noise is reduced which is the very purpose of combinations.

- **Gravitational deformation of the Effelsberg radio telescope**
  Radio telescopes are subject to varying gravitational effects when tilted in different ele-

vation angles for observations of extra-terrestrial objects. The Effelsberg radio telescope's paraboloid was subject to a novel type of survey being carried out with a total station. It was mounted head-down close to the sub-reflector of the telescope to determine the paraboloid deformations through coordination of discrete points on the surface. The main reflector of the telescope is subject to displacements of individual points of up to 54 mm, while the focal length changes by about 13 mm when the telescope is tilted from 90° to 7° pointing elevation.

4. Personnel

Table 1. Personnel at BKG/IGGB Analysis Center

Thomas Artz	IGGB	+49-228-733563	thomas.artz@uni-bonn.de
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GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Dan MacMillan, John Gipson, Karen Baver, Sergei Bolotin, Karine Le Bail

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2010. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development aimed at improving the VLBI technique.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. It is part of a larger VLBI group which also includes the IVS Coordinating Center, the CORE Operation Center, a Technology Development Center, and a Network Station. The Analysis Center participates in all phases of geodetic and astrometric VLBI analysis, software development, and research. We maintain a Web site at http://lupus.gsfc.nasa.gov.

2. Activities

2.1. Analysis Activities

The GSFC Analysis Center analyzes all IVS sessions, using the *Calc/Solve* system, and performs the *AIPS* fringe fitting and *Calc/Solve* analysis of the VLBA-correlated RDV sessions. The group submits the analyzed databases to IVS for all R1, RDV, R&D, APSG, INT01, and INT03 sessions. During 2010, GSFC analyzed 149 24-hour (53 R1, 53 R4, 5 RDV, 6 R&D, 5 EURO, 7 T2, 1 APSG, 8 OHIG, 4 CRF, and 7 JADE) sessions, five 3-hour (TQuak) sessions, and 366 1-hour UT1 (229 INT01, 92 INT02, and 45 INT03) sessions, and we submitted updated EOP and daily Sinex files to IVS immediately following analysis. As part of the RDV program, we also observed 51 requested sources for the astronomy community and determined precise positions for most.

2.2. Research Activities

- R&D Intensives: We continued studying an alternative scheduling strategy for the INT01 Intensives, begun in 2009, by running 5 additional R&D Intensive sessions. In these sessions, Kokee and Wettzell observed a series of 1-hour pseudo-Intensives that alternated between the current strategy (using a small list of strong sources) and an alternative strategy (using all mutually visible geodetic sources). As a result of preliminary analysis, the USNO began using the alternative strategy on alternating days beginnning in July 2010.
- IYA2009 Session: For the celebration of the International Year of Astronomy in 2009, GSFC scheduled the largest astrometric VLBI session ever attempted. This involved 34 globally distributed stations and used 243 of the 295 ICRF2 defining sources. Correlation was done at Haystack in 2010. Thirty-two stations performed adequately and were made into X and S databases. We analyzed these using a test version of *Solve* which was updated to handle 32 stations, and the analyzed databases were submitted to IVS.

- ITRF2008: GSFC participated in studying and evaluating the two versions of ITRF2008, provided by IGN (France) and DGFI (Germany). The IGN TRF shows a scale difference of -0.39 ppb compared to a GSFC *Calc/Solve* solution. This is due to a scale difference of -1.05 between SLR and VLBI solutions. Removing rotation and translation differences, the WRMS position and velocity differences between the IGN or DGFI solutions and a GSFC solution were 2-3 mm and 0.3-0.4 mm/yr for the 40 most frequently used stations. When the TRF was fixed to the IGN or DGFI TRF's, the resulting X-pole and Y-pole estimates were not significantly different from a standard *Calc/Solve* solution in which positions and velocities were estimated. We also studied the Allan variances of the EOPs differenced from IGS EOPs. The two ITRF2008 solutions and the GSFC solution show the same level and type of noise, with no significant differences. Our results were reported at the IAG Symposium "Reference Frames for Applications in Geosciences".
- High Frequency EOP: We generated a new empirical high frequency EOP tidal model. Comparisons with other empirical models derived from VLBI and GPS data show good agreement. We also compared the new model and other HF-EOP empirical models against models derived using satellite altimetry data and found small but significant differences.
- Comparisons of Wet Zenith Delays: We compared tropospheric parameters derived from three independent radio techniques (VLBI, GPS and WVR) for the CONT05 campaign. These comparisons showed very good agreement, with path length WRMS residual differences at the level of 5-10 mm.
- VLBA HW/SW Correlator Comparison: A detailed comparison was made of the RDV77 session, as correlated on both the VLBA hardware correlator and the new VLBA-DiFX software correlator. Group delay differences agreed at an average WRMS of 4.2 psec, with a noise floor of ~2.5 psec on the shortest baselines. These results compare well to other correlator comparisons and essentially validate the VLBA-DiFX correlator for geodetic processing.
- Chilean Earthquake: We studied the motion of the VLBI station TIGOCONC in Concepción, Chile, near the epicenter of the 8.8 magnitude earthquake of February 27, 2010. We found coseismic offsets of -45, -3040, and -678 mm in the Up, East, and North directions. Also, post-seismic transient motion was seen in the East component during the months following, but after 10 months, the East rate has nearly returned to its previous value. We presented our results at the Fall AGU Meeting.
- VLBI2010 Simulations: We investigated the geodetic performance of the future VLBI2010 network, focusing on expected accuracy and possible systematic effects. We performed simulations of several different error contributions: 1) troposphere mapping function error, 2) antenna gravitational deformation, 3) site pressure error, and 4) latitude-dependent tropospheric turbulence. Biases at the 1-2 mm level in site positions can result from the first three error sources. Vertical uncertainty due to tropospheric turbulence has latitude dependence, but no significant bias. These results were reported at the Fall AGU Meeting.
- ICRF2 Effects: A study was made of the effects of the switchover to ICRF2. Only small differences are seen in the TRF, CRF, and EOPs from VLBI solutions. The most obvious effect is an $\sim$40 μasec rotation of the CRF, mostly about the Y-axis. This is primarily a result of the small overlap of the ICRF and ICRF2 defining sources and the subsequent

difficulty of aligning them. We compared EOPs from an ICRF and an ICRF2 solution to IGS EOPs, using Allan variances, and found no significant differences.

- Source Monitoring: We continued our successful source monitoring program using the R1 and RDV sessions. In May we switched over from monitoring the ICRF defining sources to the ICRF2 defining sources. In July USNO joined this program with the R4 sessions.
- Astronomical Source Catalog: An astronomical source catalog in the ICRF2 frame was compiled. This catalog contains positions of 3658 total sources, of which 3468 are X/S global sources, 39 are X/S arc sources, 125 are X/GPS-ionosphere sources, and 26 are X-only sources. It is available at http://lupus.gsfc.nasa.gov/dataresults_main.htm.
- Source Position Time Series Studies: We continued our analysis of source position time series. We analyzed and compared the VLBI data from the last 20 years (1989.5–2009.5) and from the last 10 years (1999.5–2009.5). Data over the last 10 years shows greater stability, pointing to network improvements. The selection of a set of stable sources is not unique: compared with an OPA solution, the overlap is at 85% of the sources. The analysis of various sources showed that the time series noise is not a stationary process. We compared time series of ten different analysis centers using five different software packages, for data through mid-2008. We found that the correlation in source stabilities depends somewhat on the analysis strategy and the software package used.
- Regularization of VLBI Time Series: VLBI sessions are typically not spaced at regular intervals, making analysis difficult with basic statistical tools. We developed a tool to construct a regular data span using Singular Spectrum Analysis (SSA). For source time series, prediction using this tool has been studied and has shown efficiency in the short-term (one to two years). The SSA method has permitted us to decompose the UT1-TAI time series into tendencies, periodic signals, and white noise.
- Geodetic Catalog: We analyzed the sources in the geodetic catalog, and some show different behavior over the last ten years than over the entire VLBI period. A signal can be detected easily for such sources as an apparent proper motion (local drift, jump, and/or periodic signal). The sources identified have since been removed from the geodetic catalog.
- Meteorological Data: We have looked for discrepancies in the meteorological data in CONT08 and all 2008 R1 and R4 sessions. Station pressures in the databases can differ by up to 10 hPa from ECMWF data, which can produce vertical differences of up to 1 mm. Also, some stations have no met data, requiring *Calc/Solve* to use constant default values. Replacing these constant values with ECMWF values resulted in better performance. However, a consequence of the use of ECMWF values is loss of the diurnal variations of the met signals (due to the 6-hr smoothing), which can increase the RMS of fit.

2.3. Software Development

The GSFC VLBI Analysis Center develops and maintains the *Calc/Solve* analysis system, a package of approximately 120 programs and 1.2 million lines of code. A new version of *Calc/Solve* was released in May 2010. Among other changes, it uses X/Y nutation partials and allows the use of the 2006 IAU nutation model as an á priori. We also continued work on a new software system. A replacement for the interactive part of *Calc/Solve*, *νSolve*, is being developed using C++. We expect first public release of this software in 2011.

3. Staff

The Analysis Center staff consists of one GSFC civil servant, Dr. Chopo Ma, and six NVI, Inc. employees who work under contract to GSFC. Dr. Ma oversees the GSFC VLBI project for GSFC and is also the IVS representative to the IERS and the current chair of the IERS Directing Board. Dr. John Gipson is the GSFC VLBI Project Manager and also the chair of IVS Working Group 4 on VLBI Data Structures. Table 1 lists the seven staff members and their main areas of activity.

Table 1. Staff members and their main areas of activity.

Ms. Karen Baver	Intensive analysis, monitoring, and improvement; software development; Web site development.
Dr. Sergei Bolotin	Database analysis, next generation software development.
Dr. John Gipson	Source monitoring, high frequency EOP, parameter estimation, new data structure, station dependent noise.
Dr. David Gordon	Database analysis, RDV analysis, ICRF2 and astronomical catalogs, K/Q reference frame, *Calc* development, quarterly updates.
Dr. Karine Le Bail	Time series statistical analysis (EOPs, source positions), database meteorological data analysis.
Dr. Chopo Ma	ICRF2, CRF/TRF/EOP, K/Q reference frame.
Dr. Daniel MacMillan	CRF/TRF/EOP, mass loading, antenna deformation, apparent proper motion, VLBI2010 simulations, VLBI+SLR combination.

4. Future Plans

Plans for the next year include: ICRF2 maintenance, astronomical catalog expansion, participation in VLBI2010 development, continued development of the new VLBI data structure and the new analysis software, K/Q observations and high frequency reference frame development, further analysis of the meteorological data and replacement of missing and bad data, continued study of various VLBI time series (such as LOD) with the SSA and other statistical tools, and further research aimed at improving the VLBI technique.

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Haystack Observatory Analysis Center

Arthur Niell

Abstract

Analysis activities at Haystack Observatory are directed at improving the accuracy of geodetic measurements, whether from VLBI, GNSS, SLR, or any other technique. In this article the analysis done in 2010 that contributes to technique improvement as a result of improved geophysical measurements, modeling, and analysis is reported. The focus was on reduction of the error produced by inaccurate correction of atmosphere effects. Analysis activities that were related to technology development are reported elsewhere in this volume.

1. Introduction

The research at Haystack Observatory that directly affects geophysical and geodetic results has historically been related to atmosphere effects, and that was the case in 2010. The thrust of that activity during the past year was to define a framework for meteorological data systems that will enable access to more accurate meteorological data for the individual geodetic techniques and will, at the same time, facilitate common meteorological calibration of the techniques.

While this framework, as currently conceived, is not dependent on significant new technology development, it will rely on implementation of the Monitor and Control Infrastructure that is an integral part of the VLBI2010 system.

2. The Role of the Meteorological Data System

The Earth's atmosphere affects geodetic results both through integrated effects, such as the additional delay due to water vapor, and by in situ effects, such as the response to temperature changes of the VLBI, SLR, or GNSS supporting structure. In addition to the importance of using the most accurate meteorological data for determining these effects for each geodetic technique, the accuracy of the overall geodetic system, as constituted in the GGOS project, will be enhanced by the use of consistent meteorological data. In the simplest case, for example for closely located systems, the same well-calibrated pressure sensor would be used for all of VLBI, SLR, and GNSS. In other cases, where different sensors must be used, for example when the temperature needed is inside a radome for one technique but outside for another co-located system, the relative calibration should be readily verifiable by easy access to both sets of measurements. Yet another requirement is for the measurements to be taken continuously in order to be available for performance monitoring and for calibrating effects that might have significant latency, such as structural deformation which may have a time lag of hours.

At the center of this framework is adoption of the concept that the meteorological data are observables with the same value as the delay observations themselves and with the same requirements for understanding the uncertainties and calibration.

In order to facilitate these objectives, the data from each meteorological ("met") sensor must be available remotely along with the position of the sensor in global coordinates. The data should include time, value, and sufficient information to assign an uncertainty that can be related to the uncertainties of the geodetic observables.

3. Model for the Met Sensor Data System

Because there may be several sensors of each meteorological quantity at a site, the data from each sensor should be accessible individually. One way to do this is to have the information for each sensor stored in a file with a descriptive name. One possibility is 'station_sensortype_index.txt'. The index would allow for multiple sensors at a site. An example would be westford_pressure_1.txt.

An example of the need for multiple sensors of the same type is the situation at VLBI sites with a radome. One (or more) temperatures inside the radome or embedded in the antenna support structure is needed for thermal deformation, while an outside temperature is needed for deformation of a co-located GPS structure. In the analysis process the appropriate sensor for each technique would be selected (and could be easily changed if necessary) by specifying it in a wrapper.

The data in the file might be:

First line:

```
% Name yr mm dd hh mm value sig cal_corrn uncert X Y Z
```

Then for each measurement:

```
w_p1 2009 12 11 23 05 1004.5 0.2 9.9 0.5 6378000 4577000 1200000
```

By providing the location of the sensor in geocentric coordinates each technique can make the correction to its antenna/telescope location since that is also well known in geocentric coordinates. Although this particular format would be highly redundant and inefficient in having quantities such as position and calibration repeated for each measurement, it serves to visualize the minimum information needed.

The data files should be stored both locally (at least for some period of time) and on a globally accessible server, such as cddis. Local access during and between observing sessions is necessary for station health and safety, such as remote monitoring of wind speed or temperature for unattended operation, while global longterm availability is needed for the data analysis.

4. Implementation

As an example of the value of complementary data sources, a comparison was made in 2005 of the meterological data at Westford obtained using the GSOS sensors, the Suominet met data, and a third set of instruments, called yoda, which were located 1.2 km away at the Haystack antenna. The GSOS instruments were the primary met sensors for the Westford site at the time. After adjusting the Suominet and yoda data to the height of the GSOS pressure sensor, it was clear that the GSOS data time tags were off by -1.5 hours. After correction the GSOS and Suominet data agreed to 0.1 hPa in mean with an RMS difference of 0.2 hPa. The results are shown in Figure 1.

Currently two sets of met sensors are operating at Westford: the Suominet sensors are still recording data from the site less than 1 km from the Westford antenna, and recently a new set of met sensors was installed near the Westford GPS and VLBI antennas. The Suominet data from the site designated SA01 are available almost continuously from 2001doy200 to the present. The Met3 data sequence began only last year but is continuous. The metadata for each site are not complete in the current data records since calibration and sensor position information are not included, but such information can be added after-the-fact.

As is true for many sites, Westford has a poor record of maintaining met sensors. Fortunately the availability of the Suominet data may help overcome that shortcoming at Westford. The use of alternative sources of met data is being implemented by the Goddard analysis group using only a simple height difference correction for the pressure. Hopefully the new way of storing and applying met data proposed here will become more widespread.

5. Outlook

Westford and the new VLBI2010 site at the Goddard Space Flight Center should serve as testbeds for the meteorological data system. In the next year the goal is to fill out the data fields for calibration and location and to develop, in cooperation with the analysts of all techniques, a better format.

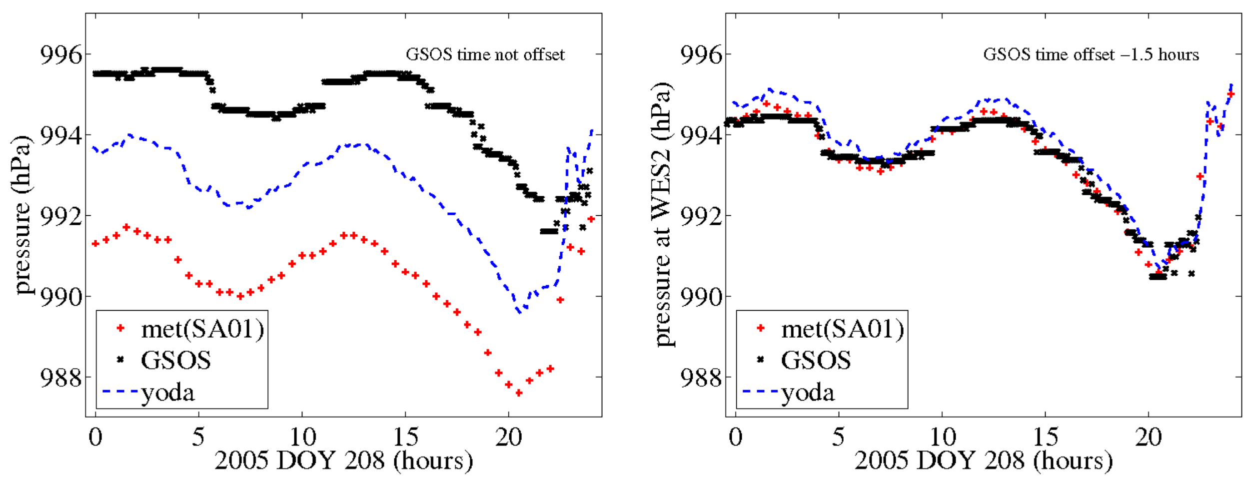

Figure 1. Data from three pressure sensors near the Westford antenna: a) before correction for height difference and for a time offset of 1.5 hours in the GSOS data and b) after correction.

IAA VLBI Analysis Center Report 2010

Elena Skurikhina, Sergey Kurdubov, Vadim Gubanov

Abstract

This report presents an overview of IAA VLBI Analysis Center activities during 2010 and the plans for the coming year.

1. General Information

The IAA IVS Analysis Center (IAA AC) is located at the Institute of Applied Astronomy of the Russian Academy of Sciences in St. Petersburg, Russia. IAA AC contributes to IVS products, such as daily SINEX files, TRF, CRF, rapid and long-term series of EOP, baseline length, and tropospheric parameters. EOP, UT1, and station positions were estimated from domestic observation programs Ru-E and Ru-U. The IAA AC generates NGS files.

2. Component Description

The IAA AC performs data processing of all kinds of VLBI observation sessions. For VLBI data analysis we use the QUASAR and the OCCAM/GROSS software packages. All reductions are performed in agreement with IERS Conventions (2003). Both packages use NGS files as input data.

The IAA AC submits to the IVS Data Center all kinds of products: daily SINEX files for EOP and EOP-rates and station position estimates, TRF, CRF, baseline length, and tropospheric parameters.

The QUASAR and the OCCAM/GROSS software packages are supported and developed.

IVS NGS files are generated in automatic mode on a regular basis.

3. Staff

– Vadim Gubanov, Prof.: development of the QUASAR software and development of the methods of stochastic parameter estimation.

– Sergey Kurdubov, scientific researcher: development of the QUASAR software, global solution, and DSNX files calculation.

– Elena Skurikhina, Dr.: team coordinator, VLBI data processing, and OCCAM/GROSS software development.

4. Current Status and Activities

- **Software development for VLBI processing**

  The QUASAR software is being developed to provide contributions to IVS products. The software is capable of calculating all types of IVS products. A scale problem was fixed in the QUASAR software in 2009.

- **Routine analysis**

During 2010 the IAA AC continued to submit daily SINEX files for the IVS-R1 and IVS-R4 sessions as rapid solution (iaa2010a.snx) and SINEX files based on all 24-hour experiments for the Quarterly Solution.

The routine data processing was performed with the OCCAM/GROSS software using a Kalman Filter. IAA AC operationally processed the "24h" and Intensive VLBI sessions and submitted the results to the IERS and IVS on a regular basis. Processing of the Intensive sessions is fully automated. The EOP series iaa2007a.eops and iaa2005a.eopi, baseline lengths iaa2007a.bl, and troposphere parameters iaa2007a.trl were continued. Long-time series of station coordinates, baseline lengths, and tropospheric parameters (ZTD, gradients) were computed with the station position catalog ITRF2005.

- **EOP parameter calculation from domestic QUASAR network observations**

  The regular determinations of Earth's orientation parameters with the QUASAR VLBI Network Svetloe-Zelenchukskaya-Badary and single baseline 1-hour observations for UT1 with e-VLBI transfer were performed weekly. Correlation is performed at the IAA correlator. For 2010 the mean RMS EOP deviations from the IERS 05C04 series in the Ru-E program were 1.1 mas for Pole position, 35 s for UT1-UTC, and 0.37 mas for Celestial Pole position for 20 sessions. The RMS deviation of the Universal Time values from the IERS C04 series for 49 sessions of the Ru-U program was 59 μs. Station positions were specified in the ITRF2008 reference frames for both domestic and IVS observations.

- **Antenna Axis Offset Estimation from VLBI observations**

  We performed a study of the stability of the axis offset value after repairs [1] and estimated how its value affects EOP estimations. The antenna axis offsets were estimated from global solutions and single sessions. We have built a set of global solutions from R1 and R4 sessions from the sets of sessions before and after the SVETLOE repair. We compared our estimates with local survey data for the stations of the QUASAR network. The Svetloe station axis offset values have changed in the repairs. For non-global networks, the axis offset value of a single station can significantly affect the EOP estimations. The main task of this study is to check the stablility of the axis offset after repairs. The axis offset estimations from single sessions are very unstable; therefore we used global solutions over several time intervals. For the estimation of the SVETLOE axis offset we used the R1 and R4 sessions divided into four intervals:

  - 2003.03.06-2005.05.26: 55 sessions, from start of operation until test rail repair
  - 2005.07.21-2006.05.04: 40 sessions, from test rail repair until full rail repair and removing of large equipment cabin
  - 2006.08.03-2007.06.21: 55 sessions, from full rail repair until repair of the bearings
  - 2007.08.30-2009.06.25: 141 sessions, from bearings repair until now

  We performed three on-site measurements of the SVETLOE axis offset: in 2005 and 2006 by Igor Shahnabiev and in 2009 by "Yustas Ltd". A comparison between our estimated values (designated as "VLBI") and on-site Local Geodetic Surveying measurements (designated as "On-site") are presented in Table 1.

Table 1. Values of SVETLOE axis offset from VLBI and on-site measurements (in mm).

	2003.03.06-2005.05.26	2005.07.21-2006.05.04	2006.08.03-2007.06.21	2007.08.30-2009.06.25
VLBI	-15.5 ± 3.2	-15.9 ± 3.6	-10.0 ± 2.8	$+1 \pm 2$
On-site	$-12.5\pm??$		-7.5 ± 0.5	-3.0 ± 1.5

In order to determine how the difference in axis offset can affect our EOP estimations from local network observations, we have processed 41 sessions of our domestic Ru-E [1] program. These are 24-hour sessions with the network "Quasar" [1] consisting of three observatories Svetloe, Zelenchukskaya, and Badary and scheduled for the EOP estimation. The biases and RMS (after removing bias) between obtained EOP and IERS 05C04 series are presented in Tables 2 and 3. For the results presented in Table 2 a single axis offset value for SVETLOE was used for all sessions. For the results in Table 3 the estimated and measured values were taken in their corresponding time intervals.

Table 2. Biases and RMS w.r.t. IERS EOP 05 C04 in EOP estimates with a single SVETLOE offset value.

offset value	-75mm		-3mm		-125mm	
EOP	bias	rms	bias	rms	bias	rms
Xp, mas	-0.114 ± 0.165	0.952	-0.109 ± 0.166	0.959	-0.101 ± 0.157	0.908
Yp, mas	0.588 ± 0.212	1.225	0.790 ± 0.211	1.221	0.342 ± 0.210	1.216
UT, ms	0.009 ± 0.008	0.046	0.005 ± 0.008	0.046	0.012 ± 0.008	0.046
Xc, mas	-0.608 ± 0.120	0.695	-0.596 ± 0.118	0.684	-0.619 ± 0.118	0.679
Yc, mas	-0.093 ± 0.114	0.660	-0.094 ± 0.113	0.652	-0.104 ± 0.109	0.631

One can see from the comparison of the bias values of Table 2 that a difference of 1 cm in the axis offset can result in a difference of up to 0.5 mas in the Y-pole coordinate for our network configuration. The differences in axis offset did not have much impact on the RMS, but it can introduce systematic biases in the EOP.

Table 3. Biases and RMS w.r.t. IERS EOP 05 C04 in EOP estimates using estimated (SVETLOE offsets = -16 mm, -10 mm, 1 mm) and measured (SVETLOE offsets = -12.5 mm, -7.5 mm, -3 mm) values for the corresponding intervals.

offset value	estimated		measured	
EOP	bias	rms	bias	rms
Xp, mas	-0.111±0.161	0.956	-0.090 ± 0.161	0.932
Yp, mas	0.690 ±0.210	1.213	0.590 ± 0.210	1.210
UT, ms	0.006±0.008	0.046	0.008 ± 0.008	0.046
Xc, mas	-0.615±0.116	0.667	-0.602 ± 0.120	0.693
Yc, mas	-0.087±0.111	0.641	-0.110 ± 0.115	0.644

The value of the antenna axis offset can significantly affect the parameters estimated from VLBI data. Offsets can change through repair work at the stations. In order to improve the accuracy of VLBI results it is necessary to estimate the axis offset after the repair at the the stations by on-site measurement or from reprocessing of observations. The differences between estimated and measured values need to be investigated.

5. Future Plans

- We plan to continue to submit all types of IVS product contributions.
- Continue investigations of VLBI estimation of EOP, station coordinates, and troposphere parameters, and comparison with satellite techniques.
- Further improvement of algorithms and software for processing VLBI observations.

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Vienna IGG Special Analysis Center Annual Report 2010

Harald Schuh, Johannes Böhm, Sigrid Böhm, Vahab Nafisi, Tobias Nilsson, Andrea Pany, Lucia Plank, Hana Spicakova, Jing Sun, Kamil Teke, Claudia Tierno Ros

Abstract

The main activities of the VLBI group at the Institute of Geodesy and Geophysics (IGG) of the Vienna University of Technology in 2010 were related to the development of the Vienna VLBI Software VieVS (http://vievs.hg.tuwien.ac.at/). In particular, tools for the simulation of VLBI observations and for VLBI global solutions were added to the latest release, and investigations on scheduling and spacecraft tracking have been started. Furthermore, studies on VLBI2010 simulations, Earth rotation, and geodynamical parameters from VLBI have been continued. One highlight was the first VieVS User Workshop held at our institute in September 2010.

1. General Information

The Institute of Geodesy and Geophysics (IGG) is part of the Faculty of Mathematics and Geoinformation of the Vienna University of Technology. It is divided into three research units, one of them focusing on advanced geodesy (mathematical and physical geodesy, space geodesy). Within this research unit, one group (out of three) is dealing with geodetic VLBI.

Figure 1. Members of the VLBI group and participants at the first VieVS User Workshop from 7-9 September 2010. Dudy Wijaya, Minttu Uunila, Nataliya Zubko, Emine Tanir, Tobias Nilsson, Jing Sun, Kamil Teke, Lucia Plank, Veikko Saaranen, Sigrid Böhm, Hana Spicakova, Andrea Pany, Johannes Böhm, Harald Schuh, Vincenza Tornatore, Matthias Madzak, Joel Botai, Vahab Nafisi.

2. Staff

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of IGG, Chair of the IVS Directing Board), and nine scientific staff members. Their main research fields are summarized in Table 1.

Table 1. Staff members ordered by the main focus of research.

Johannes Böhm	VLBI2010, Vienna VLBI Software (VieVS)
Andrea Pany	VLBI2010, troposphere, turbulence theory
Jing Sun (from 04/2010)	VLBI2010, scheduling
Sigrid Böhm	Earth orientation, tidal influences
Tobias Nilsson	VieVS, turbulence, Earth orientation
Lucia Plank	VieVS, spacecraft tracking
Hana Spicakova	VieVS, global solution
Kamil Teke	VieVS, least squares adjustment
Vahab Nafisi	troposphere, ray-tracing
Claudia Tierno Ros (from 10/2010)	ionosphere

3. Current Status and Activities

- **Vienna VLBI Software VieVS**
  Most of the activities were related to the development of the Vienna VLBI Software VieVS (http://vievs.hg.tuwien.ac.at/). In particular, tools for the simulation of VLBI observations and for VLBI global solutions were added to the latest release (Version 1c), and investigations on scheduling and spacecraft tracking have been started. Furthermore, studies on VLBI2010 simulations, Earth rotation, and geodynamical parameters from VLBI have been continued. One highlight was the first VieVS User Workshop held at our institute in September 2010.

- **Universal Time from IVS Intensive Sessions**
  We investigated the impact of tropospheric gradients on Universal Time (UT1) estimated from Intensive sessions. Due to the small number of observations, gradients are normally not estimated in the analysis of Intensive sessions. Thus the presence of gradients may lead to errors in the estimated UT1. We did these investigations using both the actual Intensive sessions (Böhm et al., 2011, [1]) as well as simulated Intensives created by extracting single-baseline observations from the CONT08 data set (Nilsson et al., 2011, [2]). The results show that gradients can be a significant error source for the Intensive sessions, especially for the INT2 and INT3 sessions. We also showed that the results can be improved if gradients are estimated in the analysis of the Intensive data.

- **Global Solutions with VieVS**
  The module *vie_glob* is the part of VieVS which enables the estimation of reference frames in global adjustments. It was tested by using artificial observation files (created with *vie_sim*) following the schedule of IVS R1 and R4 sessions from the years 2002-2010. For example, we investigated the impact of a priori horizontal gradients on declination of the sources.

- **Earth Orientation Parameters from VieVS**
  A re-processing of all geodetic VLBI sessions from 1984 to 2010, suitable for EOP determination, was conducted with VieVS. In a first step a database with special processing options for individual (problematic) sessions was created or completed, respectively. Based on this information several EOP time series for different purposes were calculated:
  - A dUT1 time series with 6-hour resolution was computed in order to investigate zonal tidal signals with periods from 5 to 35 days and to estimate the so-called zonal response coefficient κ defined by Agnew and Farrell (1978, [3]).
  - A series of daily celestial pole offsets was generated for re-introduction in further Earth rotation parameter (ERP) computations.
  - High resolution (hourly) ERP, i.e. polar motion and dUT1, were derived for the whole time span. The high frequency variations of the ERP were examined for tidal excitation, and a set of diurnal and semi-diurnal tidal constituents was estimated and compared to previous estimates from the Occam software and to the terms of the IERS conventional model (Petit and Luzum, 2010, [4]). Figure 2 displays the resulting amplitudes from VLBI (Occam, VieVS) for polar motion with respect to the amplitudes of the IERS model for ERP variations due to ocean tides. The “zero terms” reflect the noise level of the time series, as the amplitudes are estimated for periods where no tidal signal is expected.

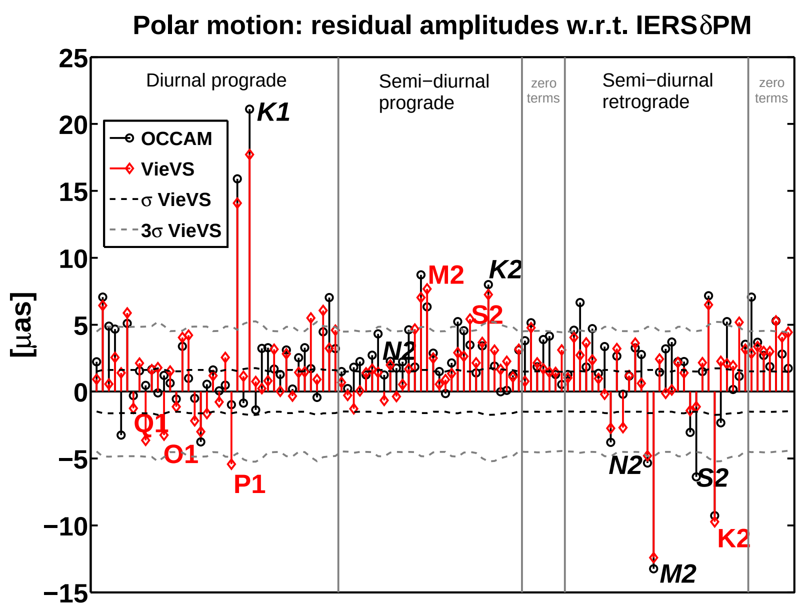

Figure 2. Hourly ERP: Amplitudes from VLBI (Occam, VieVS) for polar motion with respect to the amplitudes of the IERS model for ERP variations due to ocean tides. The “zero terms” reflect the noise level of the time series, as the amplitudes are estimated for periods where no tidal signal is expected.

- **Space VLBI with VieVS**
  VieVS was prepared to enable the processing of space VLBI data. Actual work has been done for two mission scenarios so far: on the one hand differential VLBI (D-VLBI) data from the two sub-satellites of the Japanese lunar mission Selene were processed, and on the other hand VLBI observations of GNSS satellites were modelled in VieVS. Main parts of research in this topic are the treatment of fast moving targets in VieVS, the implementation of a delay model for radio emitters at finite distances, and the adequate mathematical model and adjustment of the particular unknowns.
- **IVS Comparison Campaign**
  The IVS Comparison Campaign was started with the goal to compare different VLBI analysis software packages on the basis of the computed delay and its partial derivatives. First contributions of theoretical delays by six analysis groups indicate that presently an accuracy of 1 ps agreement cannot be achieved consistently when applying various correction models during analysis (Plank et al., 2010, [5]).

4. Future Plans

In 2011 we will continue the development of the Vienna VLBI Software VieVS, with special focus on spacecraft tracking and scheduling. Additionally, we will contribute to the ongoing activities within VLBI2010, and Earth orientation and reference system studies will be carried out. Other goals are to become an operational IVS Analysis Center, to organize a second VieVS User Workshop, to use external ray-traced delays, and to equip VieVS with a Kalman filter solution.

Acknowledgements

We are very grateful to the Austrian Science Fund (FWF) for supporting our work by the research projects P21049-N14 ('SCHED2010') and P23143-N21 ('Integrated VLBI'). We also acknowledge the Austrian Academy of Sciences for funding project 22353 and the German Research foundation (DFG) for funding project SPEED2 (SCHU 1103/3-2).

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Italy INAF Analysis Center Report

M. Negusini, P. Sarti, C. Abbondanza

Abstract

This report summarizes the activity of the Italian INAF VLBI Analysis Center. Our Analysis Center is located in Bologna, Italy and belongs to the Institute of Radioastronomy, which is part of the National Institute of Astrophysics. IRA runs the observatories of Medicina and Noto, where two 32-m VLBI AZ-EL telescopes are situated. This report contains the AC's VLBI data analysis activities and briefly outlines the investigations carried out at Medicina and Noto concerning gravitational deformations of the VLBI telescopes.

1. Current Status and Activity

Investigations on VLBI local tie surveying and antenna deformations continued in 2010. The deformation patterns of the structure were determined in previous years, and a complete signal path variation (SPV) model could be defined for the Medicina telescope [1, 2]. The same procedure adopted for Medicina was applied successfully to Noto. Particular attention was paid to accurate computation of the coefficients of the linear combinations that determine the SPVs [3]. The two models were used to correct the VLBI delay in routine geodetic VLBI data analysis. Results clearly show that the reference point height depends on elevation-dependent signal path variations, these latter being induced by gravitational deformations [4]. The height shift of the antenna reference point in Medicina is 8.9 mm, and it is 6.7 mm at Noto, much larger than the VLBI formal errors on positions. This bias cannot be determined by relying on VLBI data alone as its effect propagates directly into the estimated station height and antenna axis offset [4].

2. Data Analysis and Results

The IRA started to analyze VLBI geodetic databases in 1989, using a CALC/SOLVE package on the HP1000 at the Medicina station. In subsequent years, the same software was installed first on an HP360 workstation and later on an HP715/50 workstation. In more recent years, two HP785/B2600 workstations and an HP282 workstation were used. In 2007, a new Linux workstation was set up for the migration of all the VLBI data analysis, and Mark 5 Calc/Solve was installed. During 2010, we stored all the 1999-2010 databases available on the IVS Data Centers. All the databases were processed and saved with the best selection of parameters for the final arc solutions. The most recent IRA solution for crustal deformation comprises all the Europe sessions analyzed at IRA from 1987 to 2009, and the estimated horizontal and vertical velocities are presented in [5].

Our Analysis Center has participated in the IVS TROP Project on Tropospheric Parameters since the beginning of the activities. Tropospheric parameters (wet and total zenith delay and horizontal gradients) of all IVS-R1 and IVS-R4 24-hour VLBI sessions were regularly submitted in the form of SINEX files. In 2010 we regularly submitted our results to IVS. We have also computed and submitted a long time series of troposphere parameters using all VLBI sessions available in our catalog in order to estimate the variations over time of the content of water vapor in the atmosphere.

3. Outlook

For the time being, our catalog finally contains all available experiments. In 2011, using our new Linux workstation and the up-to-date Mark 5 Calc/Solve software, we plan to analyze all available databases, thus completing the catalog. We will continue with the regular submission of INAF tropospheric parameters to the IVS data centers, also studying the impact of the Vienna Mapping Function on the geodetic results.

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JPL VLBI Analysis Center Report for 2010

Chris Jacobs

Abstract

This report describes the activities of the JPL VLBI Analysis Center for the year 2010. We continue to do celestial reference frame, terrestrial reference frame, earth orientation, and spacecraft navigation work using the VLBI technique. In 2010 we doubled our default reference frame data rate to 448 Mbps. Our international collaboration to build celestial frames at K- (24 GHz) and Q-bands (43 GHz) matured to roughly part-per-billion (ppb) accuracy. Our in-house work to build a reference at X/Ka-bands (8.4/32 GHz) is also close to ppb accuracy. We supported several missions with VLBI navigation measurements. We continue to study ways to improve spacecraft tracking using VLBI techniques.

1. General Information

The Jet Propulsion Laboratory (JPL) Analysis Center is in Pasadena, California. Like the rest of JPL, the center is operated by the California Institute of Technology under contract to NASA. JPL has done VLBI analysis since about 1970. We focus on spacecraft navigation, including:

1. Celestial Reference Frame (CRF) 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 provides Earth orientation for spacecraft navigation.
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.
4. ΔVLBI phase referencing uses the VLBA to measure spacecraft positions.

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 34-m antennas located near Goldstone (California, USA), 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 Figure 1) which has been the most often used set of antennas for VLBI. More recently, we have been using the DSN's beam waveguide (BWG) antennas: DSS 13, DSS 24, DSS 25, DSS 26, DSS 34, DSS 54, and DSS 55. Less frequent use is made of the DSN's 70-m network (DSS 14,

DSS 43, and DSS 63). Typical X-band system temperatures are 35K on the HEF antennas. The 70-m and BWGs are about 20K. Antenna efficiencies are typically well above 50% at X-band.

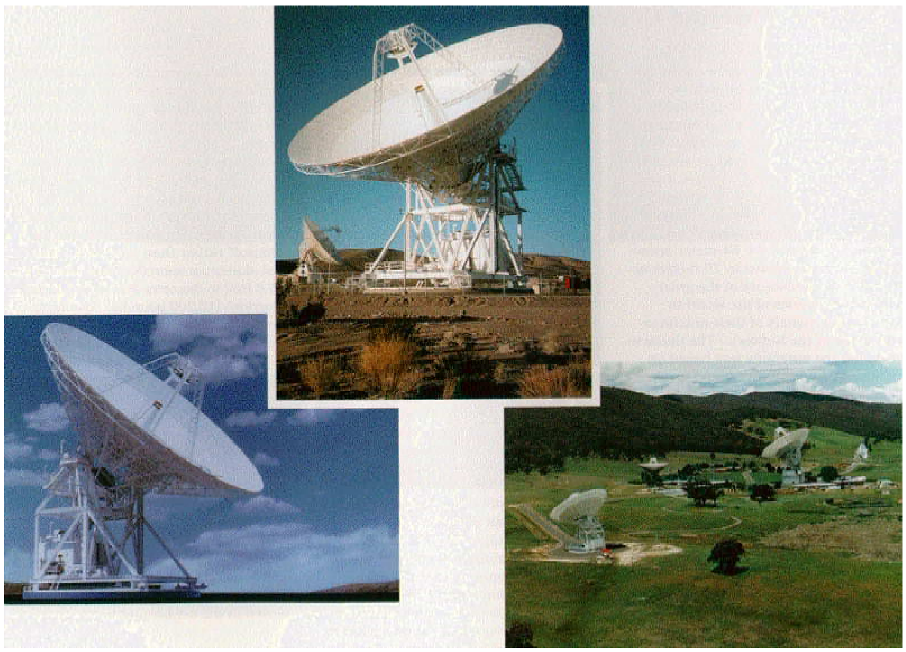

Figure 1. The three 'high-efficiency' DSN antennas: Goldstone (center); Robledo, Spain (lower left); and Tidbinbilla, Australia (lower right). These antennas have an optimum efficiency at X-band (8.4 GHz)—the standard frequency for solar-system exploration. These antennas were completed before 1986 for the Voyager Uranus encounter. In the 1990s, Ka-band (32 GHz) BWG antennas (not shown) were added.

2. Data acquisition: We use the Mark 5A VLBI data acquisition systems. In addition, we have JPL-unique systems called the VLBI Science Recorder (VSR) and the Wideband VSRs (WVSR) which have digital baseband converters and record directly to hard disk. The data is later transferred via network to JPL for processing with our software correlator.
3. Correlators: The JPL VLBI Correlator has been exclusively based on the SOFTC software which handles the ΔDOR, TEMPO, and CRF correlations. The software correlator has also been used for connected element interferometry tests of antenna arraying.
4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10^\circ$) differential solutions. The TEMPO solutions typically have a highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. These reference frames are produced from global solutions which then provide the framework needed for use by TEMPO and ΔDOR.

3. Staff

Our staff are listed below along with areas of concentration. 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 VLBI.

- Durgadas Bagri: VLBI instrumental calibrations and TEMPO.
- Jim Border: ΔDOR spacecraft tracking.
- Mike Heflin: ΔDOR, CRF and TRF. Maintains MODEST analysis code.
- Chris Jacobs: S/X, K, Q, X/Ka CRFs, and TRF.
- Peter Kroger: ΔDOR spacecraft tracking.
- Gabor Lanyi: VLBA phase referencing, ΔDOR, WVR, K-Q CRF, and TRF.
- Steve Lowe: Software correlator, fringe fitting software, ΔDOR.
- Walid Majid: ΔDOR, VLBA phase referencing.
- Chuck Naudet: WVR, Mark 5A support, and K-Q CRF.
- Lyle Skjerve: Field support of VLBI experiments at Goldstone.
- Ojars Sovers: S/X, K, Q, and X/Ka CRFs and TRF. Maintains MODEST analysis code.
- Alan Steppe: TEMPO and TRF.

4. Current Status and Activities

In order to support the DSN's move to Ka-band (32 GHz), JPL is leading a collaboration (Lanyi et al., Charlot et al.) with Goddard, the U.S.N.O., NRAO, and the Bordeaux Observatory to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz).

JPL's X/Ka-band (8.4/32 GHz) CRF was presented in two papers by Jacobs et al. The X/Ka to Gaia optical frame tie potential was discussed by Bourda, Charlot, and Jacobs.

During 2010 our default Mark 5A rate was increased to 448 Mbps yielding a very high sensitivity VLBI system when combined with the DSN's large apertures and low system temperatures.

VLBI spacecraft tracking continues to provide measurements of angular position in support of mission navigation and planetary ephemeris development (Border, 2009). Jones et al. report on work done with Cassini to improve the Saturn ephemeris. Measurements of Mars Reconnaissance Orbiter and Odyssey were obtained to improve the Mars ephemeris, while ESA provided measurements of Venus Express to improve the Venus ephemeris. Measurements were taken during interplanetary cruise to support navigation for Messenger, New Horizons, Deep Impact, Dawn, and Akatsuki. Finally, measurements were obtained of Hayabusa during its return trip to Earth to ensure successful targeting for landing the sample capsule in central Australia.

5. Future Plans

In 2011, we hope to improve TEMPO and reference frame VLBI by increasing data rates to 896 Mbps. Operational Ka-band phase calibrators have been built and are planned for deployment in 2011. Work on the Digital Back End (DBE) continues. Our next generation fringe fitting program is also expected to come online. We anticipate refereed publications on our X/Ka celestial reference frame work. On the spacecraft front, we plan to continue supporting a number of operational missions while further improving techniques for using VLBI for spacecraft tracking.

Acknowledgements

The work described here 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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KASI Combination Center Report

Younghee Kwak, Jungho Cho

Abstract

This report introduces the activities of the Korea Astronomy and Space Science Institute (KASI) as an IVS Combination Center and shows the current status of the combination work. It also outlines the intended tasks for 2011.

1. General Information

KASI was accepted as an IVS Combination Center on October 21, 2008. The KASI Headquarters is located in the Daeduk Research and Development Complex, Daejeon. Currently, the KASI Space Geodesy Research Group mainly works on the application and the combination of space geodetic techniques.

2. Component Description

The mission of the KASI Combination Center is:

- to create high quality combination products
- to control the quality of the Analysis Centers' results
- to provide feedback to the Analysis Centers
- to adhere to the IERS Conventions

3. Staff

Table 1. Personnel at the KASI Combination Center.

Jungho Cho	+82-42-865-3234	jojh@kasi.re.kr
Younghee Kwak	+82-42-865-2031	bgirl02@kasi.re.kr

4. Current Status and Activities

(1) The Bernese S/W for IVS combination:

For combination analysis, we use the Bernese S/W 5.0 which is a GPS data processing program. The Bernese S/W provides the functions of stacking normal equations and estimating parameters. The input to the Bernese S/W is the Normal Equation (N.E.) Matrix and the N.E. vector from the daily SINEX files of the individual ACs, which is the same input that the BKG/DGFI Combination Center uses. The output are daily SINEX files with combined station coordinates and

Earth Orientation Parameters (EOP).

(2) Validation of Bernese S/W:

We presented the preliminary combination results at the IVS General Meeting. While TRF accuracy was within general IVS accuracy [1], some of the EOP looked biased [2]. The Analysis Coordinator advised us to reanalyze the individual solutions to validate the S/W. We reanalyzed the CONT08 solutions of BKG, GSFC, and OPA for X-pole, Y-pole, UT1-UTC, and their rates. Since the EOP series were not provided from USNO for this period, USNO was excluded. IAA and DGFI were also excluded, because their SINEX format file could not be processed in Bernese S/W. Figure 1 shows the reanalyzed BKG EOP minus the original EOP from BKG, the original EOP from BKG minus the three AC combined EOP, and the reanalyzed BKG EOP minus the three AC combined EOP, respectively. Figure 2 shows the differences between each AC's solution and the combined solution.

5. Future Plans

After completing verification of the Bernese S/W, we will produce NQ0 format files (input format files Bernese S/W handles) for DGFI and IAA to combine all of the ACs' products. We will also establish the automated combination processing with the Bernese Processing Engine (BPE). This automated processing will produce an IVS combination solution for the whole period (1984 to present) easily and rapidly.

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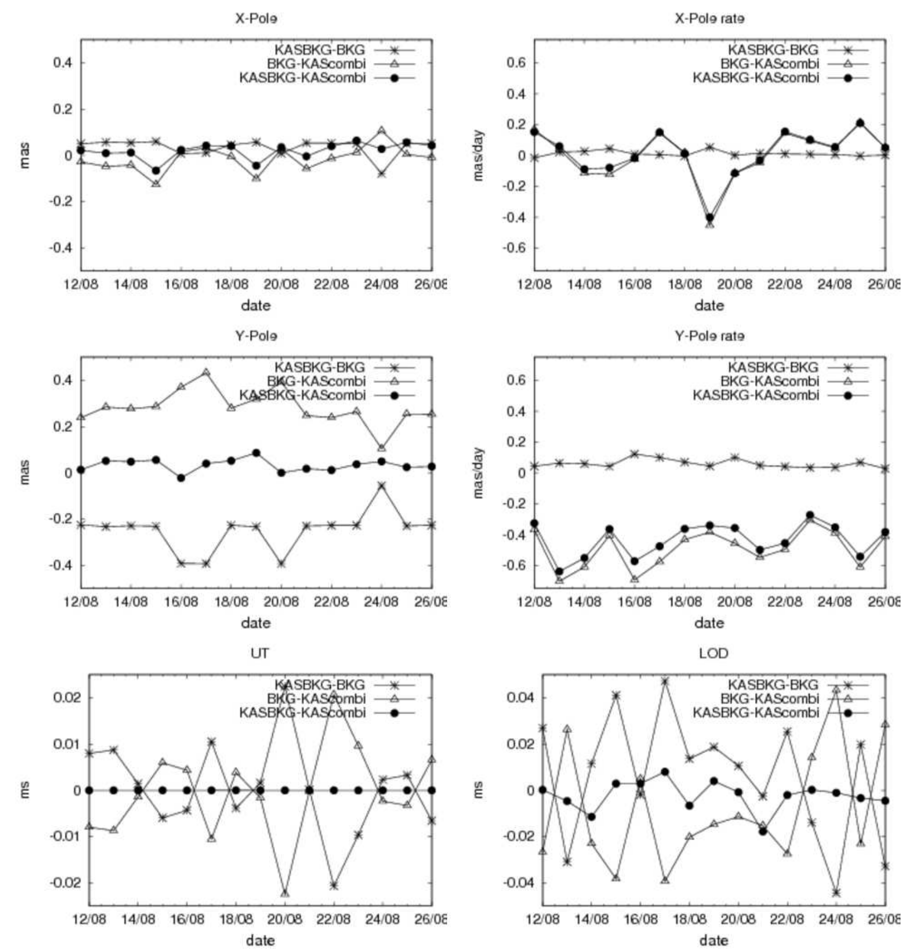

Figure 1. The differences between the reanalyzed BKG EOP (KASBKG) and the original EOP from BKG (BKG), the differences between the original EOP from BKG (BKG) and the three AC combined EOP (KAScombi), and the differences between the reanalyzed BKG EOP (KASBKG) and the three AC combined EOP (KAScombi).

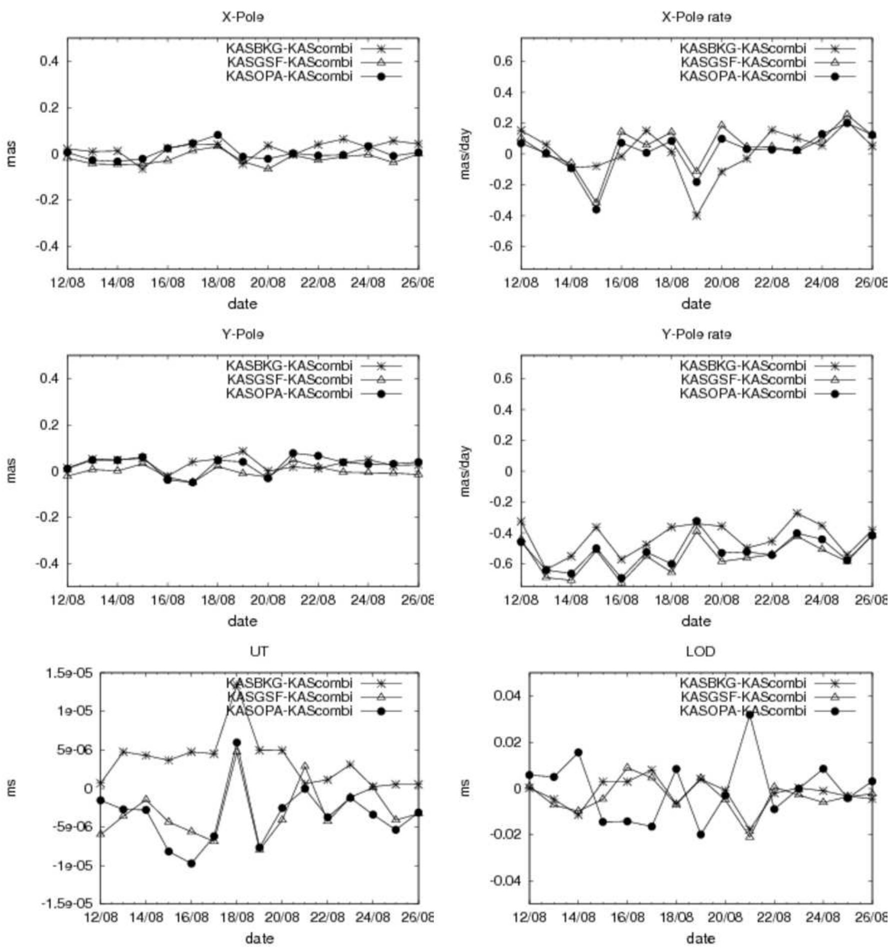

Figure 2. The residuals of each AC's reanlyzed EOP solution with respect to the three AC combined EOP (KAScombi). Here, KASBKG, KASGSF, and KASOPA mean the reanalyzed BKG EOP, GSF EOP, and OPA EOP, respectively.

KTU-GEOD IVS Analysis Center Annual Report 2010

Emine Tanır, Kamil Teke

Abstract

This report summarizes the activities of the KTU-GEOD IVS Analysis Center (AC) in 2010 and outlines the planned activities for the year 2011. Analysis of the IVS EUROPE sessions is one of our specific interests.

1. General Information

KTU-GEOD IVS Analysis Center (AC) is located at the Department of Geomatics Engineering, Karadeniz Technical Univesity, Trabzon, Turkey.

2. Staff

Members who have contributed to the research work at the KTU-GEOD IVS Analysis Center (AC) from the establishment of the AC up to the present are listed in Table 1.

Figure 1. Members of the KTU-GEOD IVS Analysis Center (AC) at the 15^{th} General Assembly of WEGENER, which was held in Istanbul. From right: Emine Tanır and Kamil Teke.

3. Current Status and Activities

Since 23^{rd} of June 1989 every year several (6-12) IVS EUROPE sessions have been carried out. The last complete solution of IVS EUROPE sessions was done about 10 years ago [1]. In 2010 we analyzed the IVS EUROPE sessions from 1990 to 2010. We determined horizontal and vertical crustal motion in Europe. We compared our results with the previous findings derived from VLBI and GNSS data analyses. We considered six VLBI stations: Matera and Medicina

Table 1. Staff of the KTU-GEOD Analysis Center.

Name	Working Location	Main Focus of Research
Emine Tanır	Karadeniz Technical University, Department of Geomatics Engineering, Trabzon, Turkey.	Responsible for KTU-GEOD IVS AC and data processing.
Kamil Teke	[1] Vienna University of Technology, Institute of Geodesy and Geophysics, Vienna, Austria.	Least-squares adjustment.
	[2] Hacettepe University, Department of Geodesy and Photogrammetry Engineering, Ankara, Turkey.	Data processing.

in Italy; Wettzell in Germany; Svetloe in Russia; Onsala in Sweden; and Ny-Ålesund in Norway. We analyzed the IVS EUROPE sessions with VieVS (Vienna VLBI Software) developed at the Institute of Geodesy and Geophysics (IGG), Vienna University of Technology (TU Wien). We estimated horizontal and vertical velocities for each VLBI station by fitting a linear function to the coordinate time series. We compared these velocities with those of ITRF2005, VTRF2008, and a EUREF GNSS solution (see Table 2). According to our results, the VLBI sites of Onsala and Ny-Ålesund are rising at rates of 4 mm/year and 8 mm/year, respectively (see Table 2).

Table 2. Velocity vectors (cm/year) in north, east, and radial directions from the analysis of IVS EUROPE sessions, from ITRF2005 and VTRF2008 TRF solutions, and from the analysis of EUREF GNSS sessions (all velocities are at epoch 2000.0).

Stations	IVS EUROPE			ITRF 2005			VTRF 2008			EUREF GNSS		
	v_n	v_e	v_r	v_n	v_e	v_r	v_n	v_e	v_r	v_n	v_e	v_r
MATERA (MATE)	1.9	2.4	0.0	1.9	2.4	0.0	1.9	2.3	0.1	2.0	2.3	0.2
MEDICINA (MEDI)	1.8	2.2	-0.2	1.8	2.2	-0.2	1.8	2.2	-0.2	2.1	2.2	-0.1
WETTZELL (WTZR)	1.5	2.0	0.0	1.6	2.0	0.0	1.6	2.0	0.0	1.7	2.0	0.1
ONSALA60 (ONSA)	1.5	1.7	0.4	1.5	1.7	0.3	1.5	1.7	0.4	1.6	1.7	0.3
SVETLOE	1.3	2.1	0.0	1.6	1.9	0.2	1.1	2.1	0.4	-	-	-
NYALES20	1.4	1.0	0.8	1.4	1.1	0.8	1.4	1.0	0.8	-	-	-

Figure 2 shows the radial velocities of the GNSS sites of which coordinate time series are available approximately longer than four years without any gap. Although the other European VLBI sites show uplift, the Medicina VLBI site is subsiding about 2 mm/year. The IVS EUROPE radial velocities estimated by VieVS are in good agreement with the EUREF GNSS solution at co-located sites in direction and in reasonable agreement in magnitude [2, 3]. The horizontal and radial velocity estimates of IVS and EUREF solutions agree at co-located sites within a few mm/year. In general the radial components of the antenna positions do not agree as well as the horizontal components. For the case of our study, i.e. analyzing IVS EUROPE VLBI data, estimating EOP or fixing to a priori models did not cause significant differences in the horizontal velocity estimates, contrary to radial velocities. After de-trending the coordinate time series, at some VLBI sites (e.g., Wettzell) clear annual spectra were detected [3].

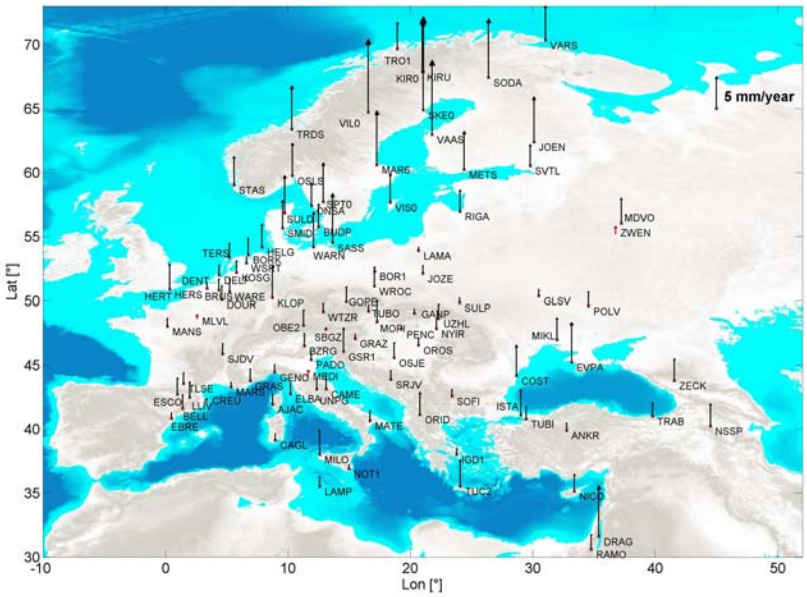

Figure 2. Radial velocity vectors from the EUREF GNSS solution.

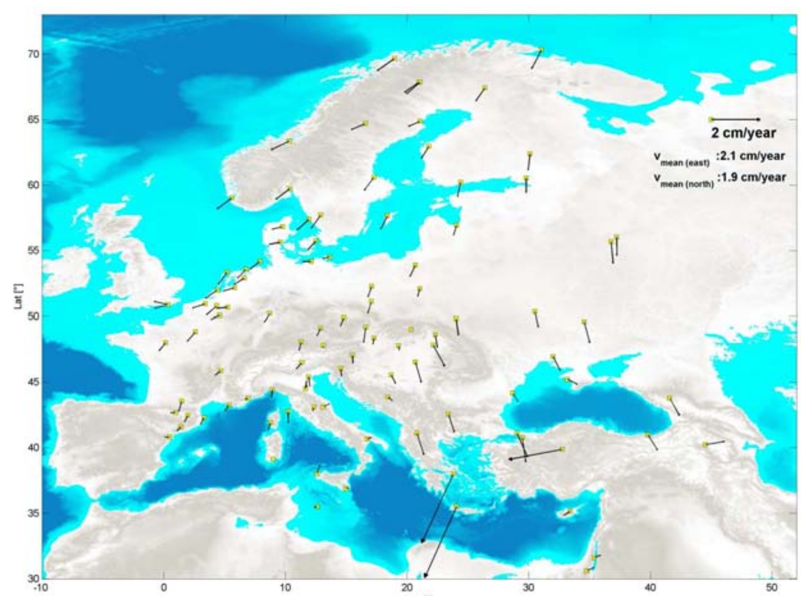

Figure 3. Relative horizontal velocity vectors from the EUREF GNSS solution when the European plate is fixed (Europe intra-plate motions).

4. Future Plans

We will continue to analyze VLBI sessions with different parameterizations, focusing on the IVS EUROPE series by using VieVS. In 2011, we plan to study different stochastic models in the analysis of VLBI sessions.

Acknowledgements

We are thankful to IVS and to the members of the VLBI group at the Institute of Geodesy and Geophysics (IGG), Vienna University of Technology (TU Wien). We are grateful to Karadeniz Technical University for its financial support to KTU-GEOD IVS AC research activities.

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IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine

Svitlana Lytvyn, Yaroslav Yatskiv

Abstract

This report summarizes the activities of the VLBI Analysis Center at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine in 2010.

1. Introduction

The VLBI Analysis Center was established in 1994 by the Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine (NASU) as a working group of the Department of Space Geodynamics of the MAO. In 1998 the group started its IVS membership as an IVS Analysis Center. The MAO AC is located at the office building of the observatory in Kiev.

2. Technical Description

VLBI data analysis at the center is performed on two computers: an Intel Core 2 Duo 3.1 GHz box with 4 Gb RAM and a 1 TB HDD, and a Pentium-4 3.4 GHz box with 1 GB RAM and two 200 GB HDDs. Both computers are running under the Linux/GNU Operating System.

For data analysis we use the SteelBreeze software which was developed at the MAO NASU. The SteelBreeze software is written in the C++ programming language and uses the Qt 2.x widget library. SteelBreeze makes Least Squares estimation of different geodynamical parameters with the Square Root Information Filter (SRIF) algorithm (see [1]).

During 2010 we ported SteelBreeze to use the Qt3 library. Now there is no need to compile. Qt2 library and SteelBreeze can be linked with the Qt3 library which is provided with any Linux distribution.

The software analyzes VLBI data (time delays) of a single session or a set of multiple sessions. The time delay is modeled according to the IERS Conventions (2003) [2], as well as by using additional models (tectonic plate motion, nutation models, wet and hydrostatic zenith delays, mapping functions, etc.). The following parameters are estimated: Earth orientation parameters, coordinates and velocities of a selected set of stations, coordinates of a selected set of radio sources, clock function, and wet zenith delay.

3. Staff

The VLBI Analysis Center at Main Astronomical Observatory consists of three members:

Yaroslav Yatskiv: Head of the Department of Space Geodynamics; general coordination and support of activity of the Center.

Svitlana Lytvyn: Junior research scientist of the Department of Space Geodynamics; investigates the stability of VLBI-derived celestial and terrestrial systems.

Sergei Bolotin: Scientific consultant on VLBI software development.

4. Current Status and Activities in 2010

In 2010 we performed regular VLBI data analysis to determine Earth orientation parameters. “Operational” solutions were produced and submitted to the IVS on a weekly basis. The IERS Conventions (2003) [2] models were applied in the analysis. In the solutions, station coordinates and Earth orientation parameters were estimated.

Also, this year we continued to participate in the IVS Tropospheric Parameters project. Estimated wet and total zenith delays for each station were submitted to IVS. The analysis procedure was similar to the one used for the operational solutions.

5. Plans for 2011

The MAO Analysis Center will continue to participate in operational EOP determination, as well as in updating the TRF and CRF solutions from VLBI analysis of the full data set of observations. We also plan to port SteelBreeze to use the Qt4 widgets library.

Acknowledgements

The work of our Analysis Center would be impossible without the activities of other components of IVS. We are grateful to all contributors from the Service.

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Analysis Center at National Institute of Information and Communications Technology

Thomas Hobiger, Hiroshi Takiguchi, Ryuichi Ichikawa, Mamoru Sekido, Yasuhiro Koyama, Tetsuro Kondo

Abstract

This report summarizes the activities of the Analysis Center at National Institute of Information and Communications Technology (NICT) for the year 2010.

1. General Information

The NICT Analysis Center is operated by the space-time standards group of NICT and is located in Kashima, Ibaraki, Japan as well as at the headquarters in Koganei, Tokyo. Analysis of VLBI experiments and related study fields at NICT are mainly concentrated on experimental campaigns for developing new techniques such as time and frequency transfer, e-VLBI for real-time EOP determination, prototyping of a compact VLBI system, analysis software development, and atmospheric path delay studies.

2. Staff

Members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order, working locations in parentheses):

- HOBIGER Thomas (Koganei, Tokyo), Atmospheric research, analysis software development
- ICHIKAWA Ryuichi (Kashima), Compact VLBI system and atmospheric modeling
- KONDO Tetsuro (Kashima), Software correlator
- KOYAMA Yasuhiro (Koganei, Tokyo), e-VLBI
- SEKIDO Mamoru (Kashima), International e-VLBI and VLBI for spacecraft navigation
- TAKIGUCHI Hiroshi (Kashima), Time-transfer experiments, e-VLBI and loading effects

3. Current Status and Activities

3.1. Ultra-rapid UT1 Experiments

In cooperation with Geospatial Information Authority of Japan (GSI), Onsala Space Observatory, and Metsähovi Radio Observatory it has become possible [6] to obtain UT1 estimates—which have been proven to be as accurate as the IERS Bulletin-A results—a few minutes after the last observation has been made. This operation mode, called ultra-rapid UT1 determination, has been developed further and extended by a fully automated analysis procedure based on c5++ (Section 3.3). Additionally, results from these low-latency experiments were used by the IERS for test purposes to check the impact of such near-real-time information for their EOP products.

3.2. Time and Frequency Transfer via VLBI

As a new frequency transfer technique which enables the comparison of highly stable frequency standards, we proposed the geodetic VLBI technique using our MARBLE system. NICT is currently developing several T&F transfer techniques besides VLBI such as GPS and two-way satellite time and frequency transfer (TWSTFT). In 2010 we carried out two intercomparison experiments (August and October) on the Kashima 11 m to Koganei 11 m baseline. Thereby we compared results from VLBI, GPS, TWSTFT with a DPN code [7], and time comparison equipment (TCE) on the satellite ETS-8 [8]. Figure 1 shows the result of the August experiment. The October experiment, which aimed at checking if these techniques are able to measure the correct time difference, was conducted by introducing an artificial delay using a coaxial phase shifter which was inserted into the path of the reference signal from the Hydrogen maser to the Kashima 11-m antenna. We are analyzing data in detail now.

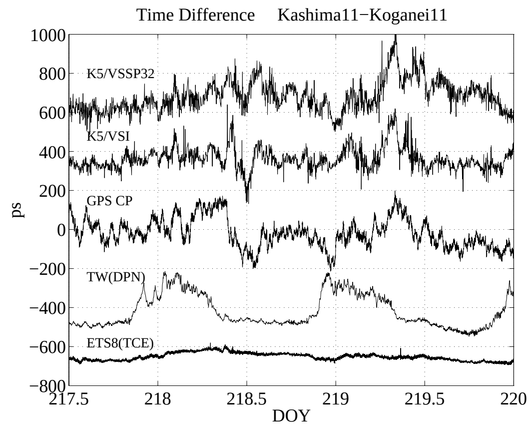

Figure 1. T&F by VLBI using two sampling modes K5/VSSP32 (S/X multi channel) and K5/VSI (S/X broadband) (see TDC report in this issue).

3.3. Development of a Multi-technique Space-geodetic Analysis Software Package

Otsubo et al. (1994, [4]) have developed an analysis software package based on Java named CONCERTO4 which enables the user to consistently process SLR, GPS, and other satellite tracking data. Driven by the need to update the software and to replace the existing Java code, VLBI was added as an additional module to this analysis package, and it was renamed c5++. The software provides state-of-the-art modules for a variety of geodetic, mathematical, and geophysical tasks that can be combined into a stand-alone VLBI application. Although many of these modules can be used for any of the space geodetic techniques, a couple of technique-specific solutions (like relativity, antenna deformation) had to be coded exclusively for VLBI. Thanks to the efforts of the Vienna VLBI group we were able to validate (see Figure 1) our software within the “Comparison Campaign of VLBI Data Analysis Software” [5] before using it for analysis purposes. As our software has the capability to carry out unattended ambiguity resolution of single baseline experiments, the automated analysis procedure of the real-time UT1 experiments has been realized with c5++ [2]. The software is currently under revision to be in agreement with the IERS Conventions 2010 and to become a complete package for multi-baseline experiments. Moreover, further applications including time and frequency transfer and space-craft navigation are being implemented in order to support the research activities of NICT’s VLBI project.

3.4. MARBLE

We have developed two prototypes of a compact VLBI system with a 1.6 m diameter aperture dish in order to provide reference baseline lengths for calibration purposes. The reference

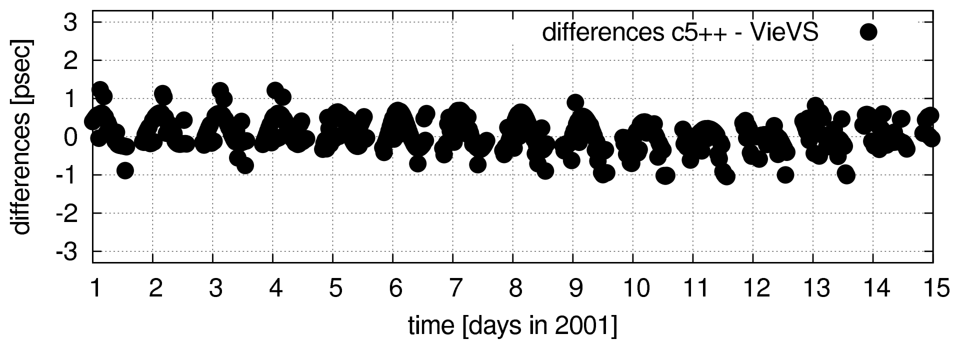

Figure 2. Differences of total theoretical delay for the baseline Westford-Wettzell between c5++ and VieVS as obtained within the "Comparison Campaign of VLBI Data Analysis Software" [5].

baseline is maintained by GSI. We named the system "Multiple Antenna Radio-interferometry for Baseline Length Evaluation (MARBLE)" [3]. We have carried out six geodetic VLBI experiments between Kashima and Tsukuba (about 54 km) during the fiscal year of 2010. The baseline length repeatability is 2.4 mm.

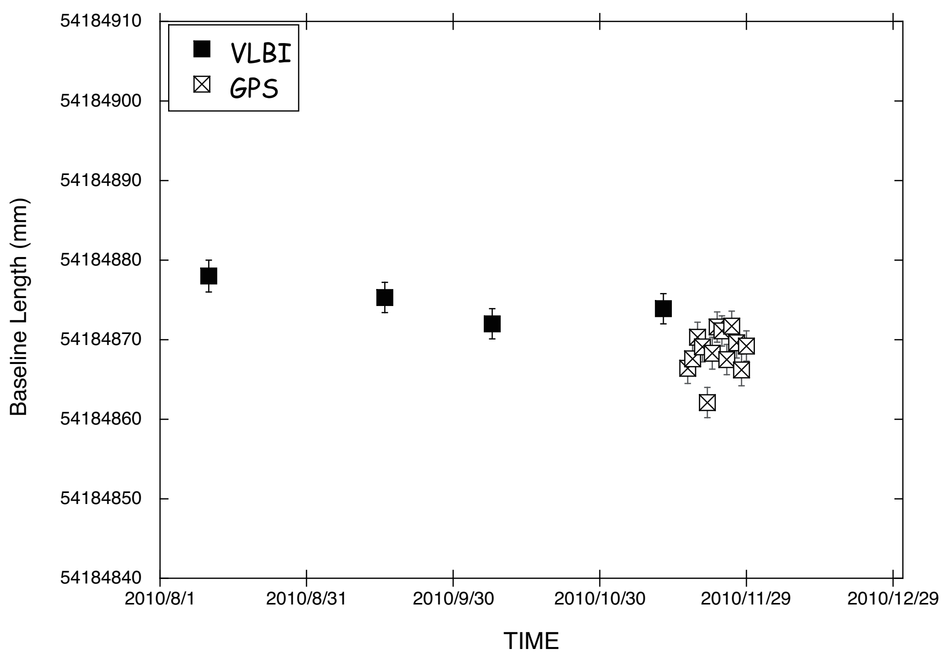

Figure 3. Baseline lengths between Kashima and Tsukuba as obtained by MARBLE and GPS.

3.5. Ray-traced Troposphere Slant Delay Correction for Space Geodesy

A software package, called Kashima Ray-tracing Tools (KARAT), has been developed which is capable of transforming numerical weather model data sets to geodetic reference frames, computing fast and accurate ray-traced slant delays, and correcting geodetic data on the observation level.

Besides other space-geodetic techniques like GPS or InSAR, the impact of such corrections on UT1 estimates from VLBI has been investigated by Böhm et al. [1]. A thorough comparison of ray-traced troposphere delays with results from other space-geodetic techniques during CONT08 has been made by Teke et al. (2011, [9]). Moreover, the usage of such corrections for other VLBI applications is currently under investigation.

4. Future Plans

For the year 2011 the plans of the Analysis Center at NICT include:

- Time and frequency transfer experiments by VLBI
- Further improvement of the multi-technique space-geodetic analysis software c5++
- Extension of the concept of ultra-rapid UT1 experiments to a multi-baseline network which allows the determination of all three EOPs
- Improvement of processing speed and efficiency for the VLBI data correlation using multi-processors/multi-cores and high-speed networks
- VLBI experiments for spacecraft tracking and its analysis

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NMA Analysis Center

Halfdan Pascal Kierulf

Abstract

This report summarizes the activities of the NMA Analysis Center in 2010 and outlines the planned activities for 2011. The NMA had in 2010 two main goals. The first goal was to adapt the multi-technique geodetic software GEOSAT to deliver to the IVS Combination Center unconstrained SINEX solutions compatible with the solutions from the other IVS Analysis Centers. The other was to be accepted as an IVS Associate Analysis Center. NMA was accepted as an IVS Associate Analysis Center on 28 October 2010. NMA has performed lots of activity during 2010 to modify the software to be as compatible as possible with the other VLBI software used to deliver results to the IVS. The overall agreement between the GEOSAT solution and results from the other IVS Analysis Centers are satisfactory. However, some discrepancies still exist and have to be adressed.

1. Introduction

During recent years the Norwegian Mapping Authority (NMA) has started a close collaboration with Forsvarets forskningsinstitutt (FFI, Norwegian Defense Research Establishment) to use and further develop the geodetic multi-technique software GEOSAT ([1, 2]). One of the main goals of this project has been to use the VLBI module of GEOSAT to establish NMA as an IVS Analysis Center and to deliver unconstrained Solution Independent Exchange format (SINEX) solutions for the IVS combined solutions ([3]).

To produce VLBI solutions for IVS is the first part of a larger strategic plan from NMA. The next step is to include other geometric geodetic techniques (GNSS and SLR) in a common solution, in which the different techniques are combined at the observation level. The long term goal of this large effort is to also include data from the gravity satellites GRACE and GOCE and from satellite altimetry.

2. NMA Analysis Activities in 2010

The NMA has in collaboration with FFI made a large effort to make the GEOSAT software compatible with other VLBI analysis software.

One of the first challenges that had to be solved was how to extract an unconstrained SINEX solution from the Square-Root Information Filter (SRIF) matrix given by GEOSAT. A first test solution was sent to the IVS Combination Center in autumn 2009. During 2010 several solutions covering all VLBI sessions with at least four stations from 1994 to present were submitted to the IVS Combination Center. The first solution was presented at the 6th IVS General Meeting, Hobart, Australia [5]. The overall agreement between the NMA-GEOSAT solution and the solutions from the other ACs is satisfactory for this first comparison. However, some discrepancies have been found (see [5] for details). This revealed some issues that have to be investigated. The NMA is in an iterative process with the IVS Combination Center to sort out these issues.

The discrepancies between results from GEOSAT and results from other IVS Analysis Centers may have several reasons. Differences in the underlying models are one possible explanation. For a short description of the main features of the software, see Section 4. The use of 3D-raytracing instead of VMF1 ([4]) is likely to produce some systematic differences. GEOSAT was therefore extended with the option to use the VMF1 mapping function. The first results using VMF1 have been compared to the other solutions. This has reduced the discrepancies. During the iterative process with the IVS Combination Center some other discrepancies in the software were also revealed, and the software was updated. To what extent the use of a Kalman filter approach instead of a Least Square Adjustment may introduce differences is unknown, but it is not likely that it would give long-term systematic differences.

3. NMA Planned Analysis Activities in 2011

The NMA will in 2011 continue the iterative process with the IVS Combination Center to make the GEOSAT solution as compatible as possible with the other software. As soon as the GEOSAT solution is in satisfactory agreement with the other solutions, NMA will start to deliver unconstrained normal equations in SINEX format to the IVS-EOP combination on a routine basis. Tests of different models are also planned, for instance a comparison of results using VMF1 and 3D-raytracing.

4. The GEOSAT Software

During the last 28 years FFI has developed a software package called GEOSAT for the combined analysis of VLBI, GNSS (GPS, Galileo, GLONASS), SLR and other types of satellite tracking data (DORIS, PRARE, altimetry, gravity, radar, direction, Deep Space Network, etc.) The observations are combined at the observation level with a consistent analysis strategy and consistent models. With this procedure, the time-evolution of the common multi-technique parameters (for example EOP, geocenter, troposphere, or clock parameters) is treated consistently across the techniques.

GEOSAT is based on an upper diagonal factorized Kalman filter which allows the estimation of time variable parameters, such as the troposphere and clocks, as stochastic parameters. The tropospheric delays in various directions are mapped to tropospheric zenith delay using ray-tracing. Meteorological data from ECMWF with a resolution of six hours is used to perform this ray-tracing. The ray-tracing depends both on elevation and azimuth angle. Atmospheric pressure corrections are applied ([7]). Other models are following the IERS and IVS conventions [6].

5. Staff

Dr. Halfdan Pascal Kierulf - Research geodesist of Norwegian Mapping Authority (NMA)
Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI and NMA).

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Paris Observatory Analysis Center OPAR: Report on Activities, January—December 2010

Sébastien B. Lambert, Christophe Barache

Abstract

We report on activities of the Paris Observatory VLBI Analysis Center (OPAR) for calendar year 2010 concerning the development of operational tasks and our Web site.

1. Operational Status

1.1. Reanalyses

Four reanalyses of diurnal sessions were done (2010a, b, c, and d), and the resulting EOP series and radio source catalogs were sent to the IVS. The latest solution processed 5,070 sessions since 1979. Each of these solutions estimated EOP and rates as session parameters, station coordinates and velocities as global parameters, and ∼1,400 sources' coordinates as global parameters, while the remaining sources' coordinates (about 1,000) were treated as session parameters. Troposphere and clock parameters were estimated every 20 minutes and 60 minutes, respectively, and gradients were estimated every six hours except for a list of 110 stations. Axis offsets were estimated as global parameters for a list of 66 stations. We used up-to-date geophysical and astronomical modeling to compute the theoretical delay and partials, including the IAU 2006 nutation and precession, the Vienna mapping functions 1, the FES 2004 ocean loading model, and the antenna thermal deformations as provided by A. Nothnagel (2009, J. Geod., 83, 787). We used the latest version of the Calc/Solve geodetic VLBI analysis software package. More details can be found on the Analysis Center Web site at `http://ivsopar.obspm.fr/earth/glo`.

1.2. Coordinate Time Series

Station and radio source coordinate time series were also produced and updated regularly (approximately every three months). Figures 1 and 2 show the Web pages relevant to the radio source coordinate time series. For each source, a page displays plots of original and smoothed time series and provides links to source information at various external databases (e.g., the French Virtual Observatory software package Aladin that permits to get the optical counterpart of the VLBI quasars, or the Bordeaux VLBI Image Database that gives the VLBI structure).

1.3. Operational Solutions

OPAR personnel have routinely analyzed diurnal sessions since 1979. The solution is aligned to the 2010c global solutions. All session types were analyzed, but only unconstrained normal equations relevant to the IVS rapid turn-around sessions (R1 and R4) were sent to the IVS in SINEX format for combination in the framework of the IVS Analysis Coordinator's task.

The operational solution 2010i analyzing Intensive sessions after 2006 was also submitted to the IVS together with corresponding SINEX files.

An important step was the automation of the treatment of diurnal and Intensive sessions, in order to match the IERS requirements in terms of latency. We built up homemade scripts, based

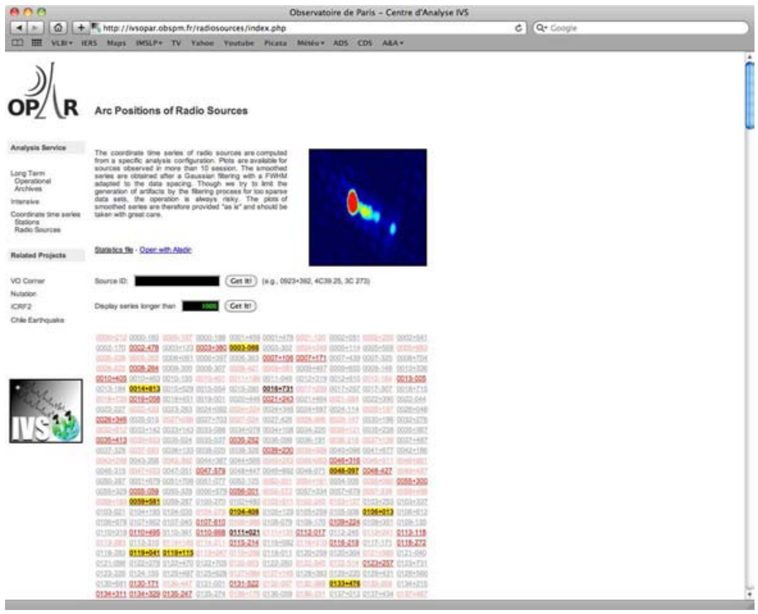

Figure 1. The Web page listing the sources for which coordinate time series are available. The color code indicates the number of observations: highlighted source names stand for sources having the longest observational history.

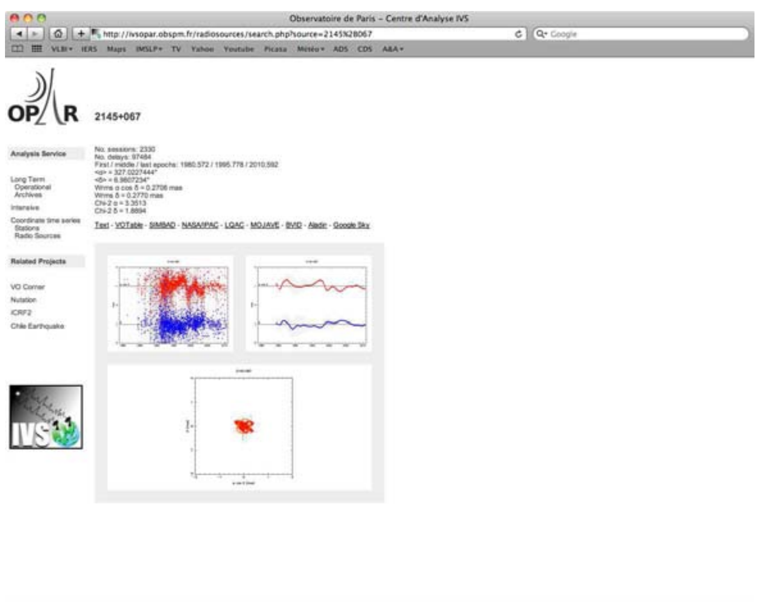

Figure 2. The Web page relevant to 2145+067 with the time series plots and the links to external databases.

on the UNIX cron command, to regularly check the local OPAR Data Center within 30 minutes after the mirroring between the three primary IVS Data Centers. If new sessions are available, a bash script launches the solutions and sends the SINEX and EOP files back to the Data Center as IVS products. The main numerical results of the analysis are sent out by e-mail to the analyst so that he/she can check whether the solution is acceptable or needs special care. The Web site is also updated automatically by a crontab file located on a different machine. We therefore guarantee that newly arrived IVS databases are processed within less than 24 hours after submission.

Operational analysis of both diurnal and Intensive sessions will be continued in 2011. All the above products, except SINEX files, were also published on the OPAR Web site. SINEX files were only sent to the Data Centers.

2. Follow-up of Various Phenomena

2.1. Free Core Nutation

The free core nutation (FCN) is a free oscillation of the Earth's figure axis in space due to the presence of a liquid core rotation inside the viscoelastic mantle. Its period is close to 430 days and is retrograde. Understanding the excitation of the FCN and its amplitude and phase variations is still an open question, although the community generally believes that the key resides in improved atmospheric and oceanic circulation modeling at diurnal and subdiurnal frequencies. At OPAR, we maintain a FCN model directly fitted to routinely estimated nutation offsets (Fig. 3). More explanations and material can be found at `http://ivsopar.obspm.fr/earth/geo`.

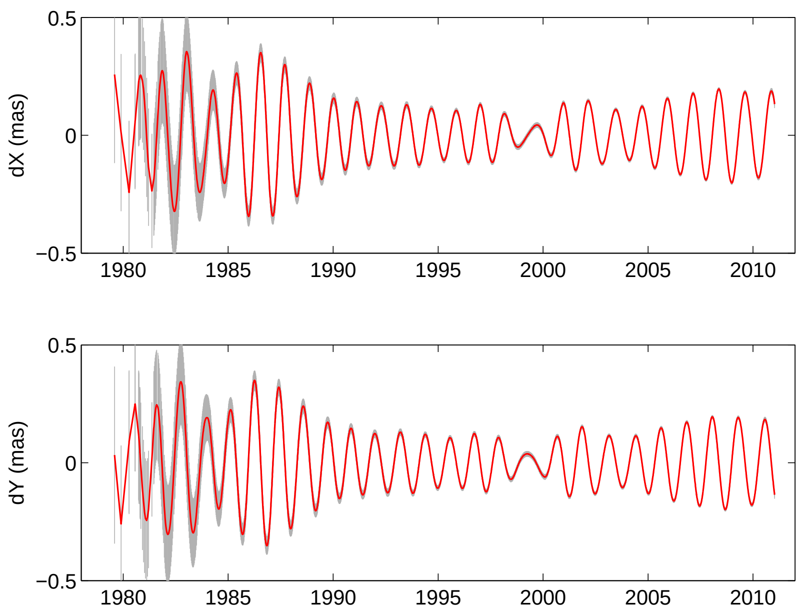

Figure 3. The free core nutation fitted to opa2010d nutation offsets with respect to the IAU 2006 nutation and precession models.

2.2. Displacement of TIGO at Concepción

Still using the routinely analyzed diurnal sessions, we monitored the displacement of the station of TIGO at Concepción after the 27 February 2010 (2010.15) earthquake. Figure 4 displays the UEN coordinates of TIGO with respect to the mean position estimated in the 2010d solution. The monitoring is continued at `http://ivsopar.obspm.fr/earth/tigo`.

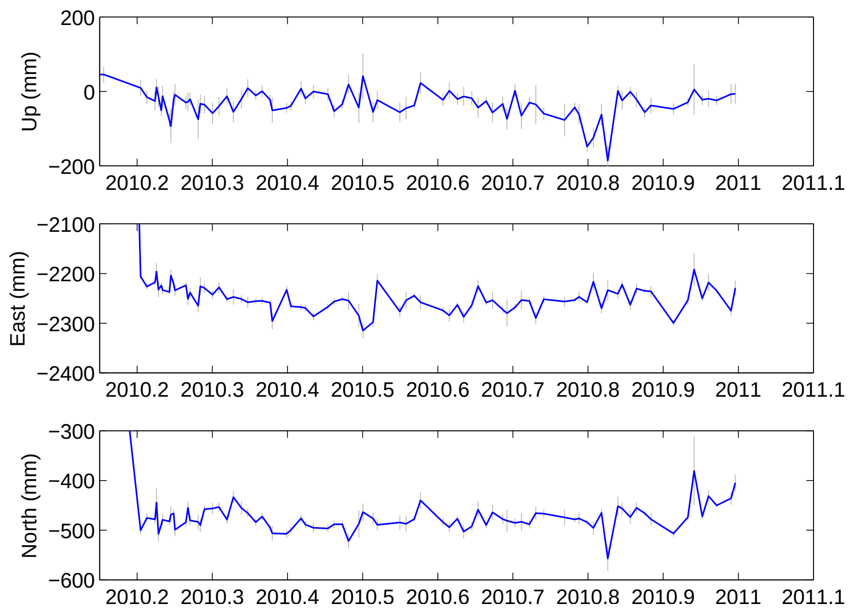

Figure 4. The UEN coordinates of TIGO with respect to the mean position estimated in the 2010d solution.

3. Staff Members

Staff members who contributed to the OPAR Analysis and Data Centers in 2010 are listed below:

- Sébastien Lambert, Analysis Center manager, responsible for data analysis, development of GLORIA analysis software,
- Christophe Barache, Data Center manager, data analysis,
- Daniel Gambis, responsible for the IERS Earth Orientation Center, interface with IERS activities,
- Anne-Marie Gontier, who headed OPAR since its inception in 1998, passed away on September 24th 2010.

Onsala Space Observatory – IVS Analysis Center

Rüdiger Haas, Hans-Georg Scherneck

Abstract

We briefly summarize the activities of the IVS Analysis Center at the Onsala Space Observatory during 2010 and give examples of results of ongoing work.

1. Introduction

We concentrate on a number of research topics that are relevant for space geodesy and geosciences. These research topics are addressed in connection to data observed with geodetic VLBI and complementing techniques.

2. Calibration of VLBI Atmospheric Delays with External Information

We used the CONT05 campaign to study whether VLBI atmospheric delays can be calibrated using external information. As external information we used atmospheric parameters derived from GPS data analysis and water vapor radiometers (WVR).

All eleven stations that participated in CONT05 are equipped with GPS. The GPS data were analyzed by the precise point positioning (PPP) technique [1] with the Gipsy-Oasis software [2], and zenith wet delays (ZWD) and atmospheric gradients were estimated with five minute temporal resolution. Six of the CONT05 stations also had at least one WVR operating during the campaign. For three of these stations, Kokee, HartRAO and Wettzell, both ZWD and gradients could be derived from the WVR, while for the remaining three stations, Algopark, Onsala and Tsukuba, only ZWD could be derived from the WVR observations. The temporal resolution was 30 minutes.

In a first step, the time series of ZWD and gradients from GPS and WVR were compared to those that result from the analysis of the CONT05 VLBI data. The VLBI results were derived with the Calc/Solve software [3] with a temporal resolution of 1 hour for ZWD and 6 hours for gradients.

As an example, Figure 1 shows the time series of ZWD and gradients for Wettzell and Algopark. Wettzell turns out to be an extreme case in the sense that the east gradient (EGR) bias between VLBI and WVR is as large as 2.5 mm. In general the gradient biases are smaller than 0.3 mm. The gradient RMS is in general on the order of 1–1.5 mm, with the exception of Kokee which is an extreme case with a value of 10 mm for the comparison of VLBI and WVR derived north gradient (NGR). The biases for ZWD are in general on the order of 2–4 mm but can reach in extreme cases up to 20 mm for the comparison of Algopark and Tsukuba VLBI and WVR results. The ZWD RMS are in general on the order of 6–10 mm but can reach in extreme cases up to 20 mm for the comparison of Algopark VLBI and WVR results.

In a second step, slant delays were constructed based on the GPS and WVR results for the atmospheric parameters. The NMF mapping function [4] was used to map the zenith delays into the line of sight of each observation. Also a set of slant delays was generated that was derived from the VLBI results for atmospheric parameters themselves. Then three 'calibration' solutions were produced with Solve—i.e., the three different sets of slant delays were introduced as calibrations. The parameterization was identical to the reference solution—i.e., ZWD and

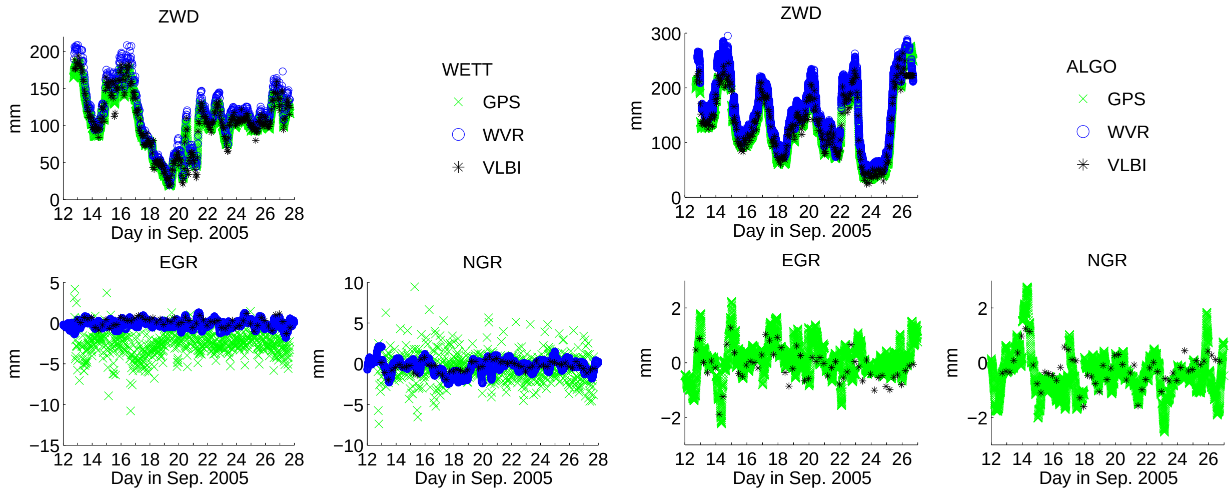

Figure 1. Time series of zenith wet delays (ZWD), east gradients (EGR), and north gradients (NGR) for Wettzell (left) and Algopark (right) during CONT05.

gradients were estimated with 1-hour and 6-hour temporal resolution, respectively. Figure 2 shows the resulting WRMS of the four solutions for all fifteen CONT05 sessions. There is no significant improvement in the WRMS when using GPS- or VLBI-calibration with respect to the uncalibrated reference solution (called NMF-solution in Figure 2). The WRMS fit even deteriorates when the WVR-based slant delays are used as calibration.

Figure 3 presents a comparison of estimated ZWD for Onsala (left), HartRAO (middle), and Tsukuba (right). The ZWD in general reduce to values near zero when slant delays are used as calibration in the analysis. This can be expected if the slant delays were really representing the true atmospheric conditions. However, there are still signatures left in the ZWD time series. At HartRAO there are signatures of up to 20 mm visible when GPS- or WVR-derived slant delays are used as calibration, and at Tsukuba the WVR-calibration even produces a bias of about 40 mm. This indicates strongly that the slant delays used for the calibration are not good enough and for some stations introduce noise and biases.

3. Raytracing through the High Resolution Numerical Weather Model HIRLAM

We used data from the High Resolution Numerical Weather Model HIRLAM to derive slant delays and apply these in the analysis of Europe VLBI data [5]. The slant delays were calculated by 1-dimensional raytracing using the *Davis-Herring-Niell raytracing software* [6]. European VLBI sessions from March 2005 to September 2007 were analyzed and the results from the HIRLAM-calibration were compared to results from a standard analysis. If ZWD are estimated from both approaches, a clear reduction in the estimated ZWD and their variation is visible when using the HIRLAM-calibration. If ZWD are not estimated in the HIRLAM-calibration approach, the baseline repeatabilities improve with respect to a standard solution only if an elevation cutoff angle of 19 degrees or larger is used. Below this value, the standard approach of estimating ZWD still gives superior baseline repeatabilities.

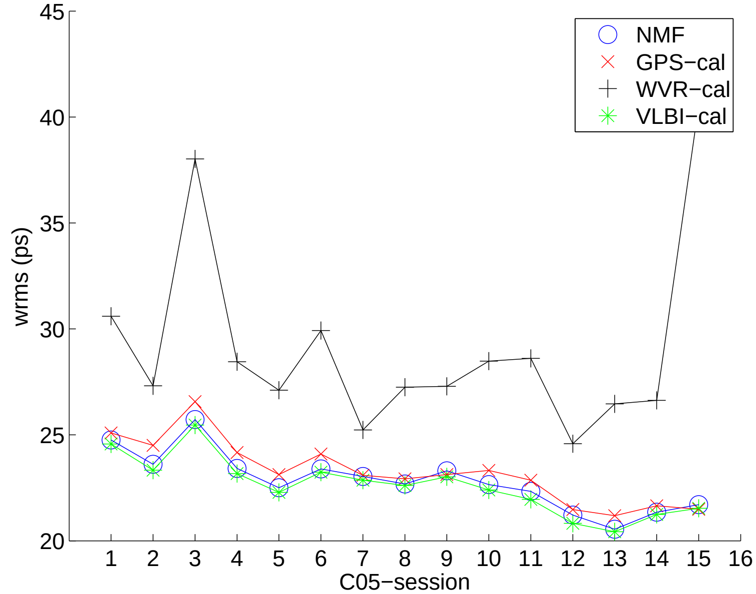

Figure 2. Resulting WRMS for four different analyses: NMF – a standard solution without calibrating atmospheric delays; GPS-cal – a solution using GPS-derived slant delays for the calibration; WVR-cal – a solution using WVR-derived slant delays for the calibration; and VLBI-cal – a solution using VLBI-derived slant delays for the calibration.

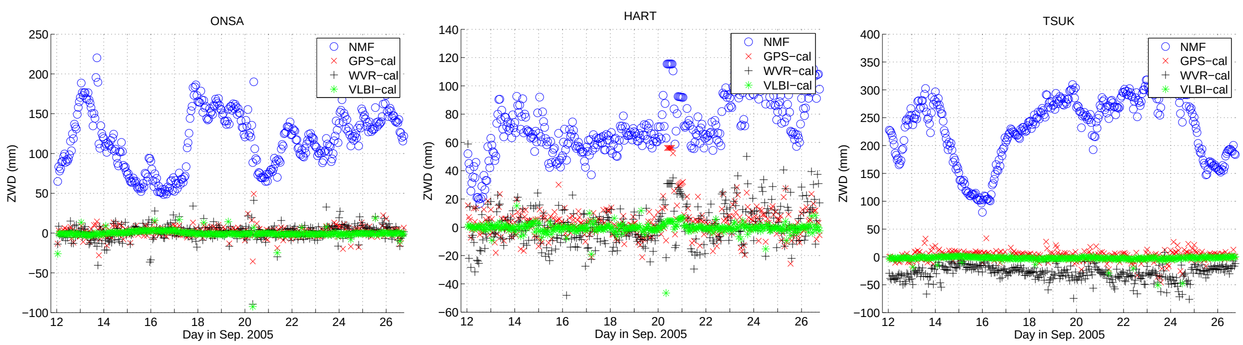

Figure 3. Estimated ZWD for Onsala (left), HartRAO (middle), and Tsukuba (right) when either no calibration is applied (NMF) or a calibration is applied based on GPS results (GPS-cal), WVR results (WVR-cal), or VLBI results (VLBI-cal).

4. Time and Frequency Transfer with VLBI and GPS

We used the CONT08 data to evaluate time and frequency transfer with VLBI and GPS [7]. Those VLBI stations that use the same H-maser for their VLBI and GPS equipment are of major interest. The Onsala-Wettzell baseline shows the best results in CONT08. The VLBI-derived frequency link stability was 1.2E-15 for one day, while the corresponding GPS-derived frequency link stability was between 1.9E-14 and 6.2E-16, depending on which GPS-receiver at Wettzell was included in the analysis. The significant relative frequency offset of about at least 5E-16 can be attributed to either technique, e.g., the absence of integer ambiguity resolution in the GPS-analysis and possible biases introduced by day-boundary problems in the VLBI solutions.

5. Ocean Tide Loading

The automatic ocean tide loading provider [8] was maintained during 2010.

6. Outlook

The IVS Analysis Center at the Onsala Space Observatory will continue its efforts to work on specific topics relevant to space geodesy and geosciences. During 2011 we plan to intensify our activities.

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New Associate Analysis Center Established at PMD

Vincenza Tornatore

Abstract

In this report a new Associate Analysis Center is presented to the scientific community: the Politecnico di Milano DIIAR (PMD) Analysis Center (AC). The IVS Directing Board approved the proposal for such a new AC at its 24^{th} meeting in Shanghai on October 23, 2010. An introduction of the group collaborating in the AC, location of PMD, its equipment, and the foreseen scientific activities are briefly presented in this report. We will make all efforts to develop the AC towards the scientific main purposes of the IVS.

1. Principal Characteristics

The proposal of DIIAR (Dipartimento di Ingegneria Idraulica, Ambientale, Infrastrutture viarie, Rilevamento) of Milano Politecnico to become an International VLBI Service for Geodesy and Astrometry Analysis Center (IVS AC) [1] was accepted at the 24^{th} Directing Board meeting, which was held in correspondence with the Joint GGOS/IAU Science Workshop "Observing and Understanding Earth Rotation", in Shanghai, China on October 25-28, 2010.

All office supplies, hardware, and personnel are supported and maintained by DIIAR, Politecnico di Milano, the host institution of the PMD AC (see Figure 1).

Figure 1. Head office of Politecnico di Milano University where PMD is hosted.

The hardware equipment consists of a server, a personal computer, a notebook, two printers (one black-and-white and one color laser jet), a fax, and a scanner. All the equipment together with the MATLAB compiler are provided by DIIAR.

The software we are going to use in the Analysis Center is VieVs (Vienna VLBI Software) [3], which is developed by the members of the VLBI group of the Institute of Geodesy and Geophysics

(IGG), Vienna University of Technology (TU Wien). VieVs uses the programming language Matlab. Matlab is a very well known tool for university students. In many courses of their curriculum the students of Politecnico di Milano use Matlab. The use of Matlab will ease the implementation of new ideas and models also in the VieVs software.

2. Group at DIIAR Contributing to the PMD IVS Analysis Center

The following personnel will support the work of the new Analysis Center:

- Dr. Vincenza Tornatore: responsible for PMD (primary scientific/technical contact).
- Dr. Letizia Cannizzaro: expert in time series evolution and GPS data processing.
- Mrs. Cinzia Vajani: with secretary's and hardware maintenance tasks.
- PhD student: with primary interest in the geodetic VLBI technique; still to be engaged.

3. Main Interests and Future Plans

The principal interests of PMD IVS AC concern the study of the European baseline evolution.

The first objective of the Analysis Center is to start to analyze all EUROPE sessions under the same modeling conditions and analogous parametrization using the VieVs software. We would like first to compare our results with those of other ACs that have similar interest in the study of EUROPE sessions and preferably use the same VieVS software in order to have some degree of validation, e.g., with the KTU-GEOD (Karadeniz Technical University, Department of Geomatics Engineering) IVS AC that has also interest in EUROPE sessions [2]. The main purpose of PMD is to estimate European site coordinates and baseline lengths with respective variance-covariance matrices and to study their temporal evolution.

Another purpose of the Analysis Center is to compare VLBI results with GPS (Global Positioning System) results obtained for stations where the two techniques are present. We would like to apply the same statistical studies to both techniques to reveal possible differences in estimated deformations of the European plate. Comparisons with geophysical models in the area should also be performed.

Since the software VieVS is fully compatible with the Windows and Linux Operating Systems and it is distributed with its open source code based on Matlab, it would be very compelling to also involve students in the implementation of particular models compatible with those from other space geodetic techniques like GPS. The presence in the same Department of expertise in studies of GPS time series evolution will represent a good opportunity for direct comparisons of VLBI results obtained under the same processing strategies.

Acknowledgements

We are thankful to the Directing Board of the IVS, to DIIAR "Politecnico di Milano", and to all colleagues collaborating for supplying the necessary means to obtain fruitful results.

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Pulkovo IVS Analysis Center (PUL) 2010 Annual Report

Zinovy Malkin

Abstract

This report briefly presents the PUL IVS Analysis Center activities during 2010 and plans for the coming year. The main topics of the investigations of PUL staff in the report period were ICRF related studies, computation and analysis of EOP series, celestial pole offset (CPO) modeling, and VLBI2010 related issues.

1. General Information

The PUL IVS Analysis Center (AC) was organized in September 2006 and is located at and sponsored by the Pulkovo Observatory of the Russian Academy of Sciences. It is a part of the Pulkovo EOP and Reference Systems Analysis Center (PERSAC) [1]. The main topics of our IVS related activities are:

- Improvement of the International Celestial Reference Frame (ICRF).
- Computation and analysis of the Earth rotation parameters (EOP).
- Modeling of the celestial pole offset (CPO) and free core nutation (FCN).
- Comparison of VLBI products with other space geodesy techniques.
- Computation and analysis of observation statistics.

The PUL AC's Web page `http://www.gao.spb.ru/english/as/ac_vlbi/` is supported. The homepage contains the following sections:

- *General Information on the PUL AC*: brief history, activity overview, staff.
- *VLBI data analysis*: CPO/FCN series, UT1 Intensives series, mean Pole coordinates. Data are updated daily.
- *Data files used in analysis*: station information adapted to the SINEX SITE/ID format, a database name/experiment code cross-reference table including the number and list of actually observed stations based on the IVS master file, average meteorological parameters for stations based on information from databases.
- *OCARS catalog*: The latest version of the catalog of optical characteristics of astrometric radio sources (OCARS) [2].
- *Approaches and occultations*: forthcoming mutual events of planets and astrometric radio sources [3, 4].
- *Publications and presentations*.
- *Links to the VLBI World*.
- *Contact information*.

2. Scientific Staff

The PUL team in 2010 included:

1. Zinovy Malkin (70%) — team coordinator, EOP and CRF computation and analysis;
2. Natalia Miller (5%) — EOP analysis;
3. Elena Popova (100%) — CPO analysis (until July).

3. Activities

The main activities of the PUL IVS Analysis Center during 2010 included:

- Regular processing of the Intensive sessions and submission of results to IVS was started in October 2010.
- ICRF related research was continued, mainly in the framework of the IAG Working Group 1.4.1 "Theoretical Aspects of the Celestial Reference System and Systematic Effects in the CRF Determination". The main directions of this activity were comparison and combination of radio source catalogs, as well as investigation of their stochastic and systematic errors.
- The work on the OCARS catalog was continued. The catalog is updated several times per year. The latest version is available at the PUL Web page.
- A catalog of the occultations of astrometric radio sources by planets through the year 2050 was computed [4].
- Investigations of CPO modeling and its impact on data processing were continued. The main results obtained in 2010 were the following:
  - PUL CPO and FCN series were computed and updated daily.
  - Comparison of CPO models was performed, and recommendations on the choice of an optimal model for VLBI data processing were developed [5].
  - The CPO prediction accuracy for different models was investigated [6], and its impact on UT1 Intensive results was studied [7].
- PUL archive of VLBI data and products was supported. At present, all available databases and NGS cards have been stored along with the main IVS and IERS products. These archives are updated daily.
- Development of algorithms and software for data processing and analysis was continued.
- PUL staff members participated in activities of several IERS, IAG, and IVS projects, committees, and working groups.

4. Outlook

Plans for the coming year include:

- Continuing VLBI related studies.
- Continuing UT1 Intensives processing.

- Continuing development of algorithms and software for data processing.
- Continuing support of the PUL archives of data and products.

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SAI VLBI Analysis Center Report 2010

Vladimir Zharov, Mark Kaufman

Abstract

This report presents an overview of the SAI VLBI Analysis Center activities during 2010 and the plans for 2011. The SAI AC analyzes all IVS sessions for computation of the Earth orientation parameters (EOP), investigates time series of source positions within the context of new realizations of the ICRF, makes submissions of data and analysis products, and performs research and software development aimed at improving the VLBI technique.

1. General Information

The SAI VLBI Analysis Center is located at Sternberg State Astronomical Institute of Lomonosov Moscow State University in Moscow, Russia. The Analysis Center participates in geodetic and astrometric VLBI analysis, software development, and research aimed at improving the VLBI technique.

2. Component Description

The SAI AC performs data processing of all kinds of VLBI observation sessions. For VLBI data analysis we use the ARIADNA software package developed at SAI. All reductions are performed in agreement with IERS Conventions (2003).

The package uses files in NGS format as input data.

The latest version is installed on the correlator of the AstroSpace Center in support of the Radioastron mission.

3. Staff

- Vladimir Zharov, Prof.: development of the ARIADNA software, development of the methods of parameter estimation
- Mark Kaufman, scientific researcher: development of the ARIADNA software, solution and analysis
- Dmitry Duev, post-graduate student: VLBI data processing, troposphere modeling
- Nikolay Voronkov, scientific researcher: global solution
- Svetlana Nosova, engineer: VLBI data processing

4. Current Status and Activities

- **Software development for VLBI processing**

  The ARIADNA software is being developed to provide contributions to IVS products. The software is used for calculating all types of IVS products.

  The latest version of software can be used for the solution of many tasks during the Radioastron mission: calculation of delay and delay rate for the space-ground interferometer, orbit determination of the space telescope by numerical integration of the differential equations of motion, and use of Doppler tracking, laser ranging, and VLBI observations for improvement of the Radioastron orbit based on the Kalman filter.

- **Routine analysis**

  During 2010 the routine data processing was performed with the ARIADNA software using the least-squares method with rigid constraints. SINEX files for both IVS 24-hour and Intensive sessions were generated. But an attempt to use these files for estimation of the EOP was unsuccessful due to the rigid constraints. In 2011 a new approach with non-rigid constraints will be developed for the generation of SINEX files.

  The SAI AC operationally processed the 24-hour and Intensive VLBI sessions. VLBI database creation and processing of all sessions is fully automated. The EOP series sai2010a.eops and sai2010a.eopi were calculated. These series were computed with the ITRF2005 catalog of station positions and velocities.

  Experimental series sai2010c.eops and sai2010c.eopi were calculated for the experimental catalog of the radio sources whose positions and velocities were estimated in 2009. Analysis of these series is being performed.

- **Global solution**

  N. Voronkov re-wrote software for the supercomputer of the Moscow State University to obtain a global solution. The radio source coordinates and velocities, and the station coordinates and velocities were estimated as global parameters. EOP, troposphere wet zenith delay (approximated as a polynomial function), troposphere gradients, and station clocks (approximated as a polynomial function) were estimated as arc parameters for each session.

- **Troposphere modeling**

  At the stations with missing meteorological data we used surface data files (temporal coverage: 4-times daily, spatial coverage: 2.5 degree latitude x 2.5 degree longitude global grid) from NCEP/NCAR Reanalyzes (http://www.cdc.noaa.gov/data/gridded/data.ncep.reanalysis.surface.html) for calculating air temperature, pressure, and relative humidity. For that purpose a program was written to interpolate these data to the given coordinates of the station at the time of observation.

5. Future Plans

- Continue investigations of VLBI estimation of EOP, station coordinates, and troposphere parameters and continue comparison with satellite techniques.
- Continue studies concerning the Third Realization of the ICRF.
- Further improve algorithms and software for processing VLBI (ground and space-ground) observations.

SHAO Analysis Center 2010 Annual Report

Guangli Wang, Jinling Li, Minghui Xu, Li Guo, Fengchun Shu, Zhihan Qian, Bo Zhang

Abstract

This report gives an introduction to the astrometric/geodetic activities of Shanghai Astronomical Observatory (SHAO) in 2010. The main activities were the the observation and processing of the VLBI experiments with the Chinese VLBI network (CVN) and the research activities towards VLBI2010.

1. General Information

We use the CALC/SOLVE system for routine VLBI data analysis. The members involved in the IVS analysis activities are Guangli Wang, Jinling Li, Minghui Xu, Bo Zhang, Li Guo, Fengchun Shu, and Zhihan Qian.

2. Activities in 2010

In 2010 we spent most of our time supporting the Chinese Lunar mission. We conducted six geodetic VLBI experiments using four domestic VLBI stations, the main purpose being to determine the station coordinates, especially of the two new stations, for the Chinese space exploration projects, as well as for the Project of Monitoring Network of the Chinese Mainland Geological Environment. We carried out three 2-hour experiments to measure UT1 using the two VLBI stations at Seshan and Urumqi, getting the UT1 solutions within half an hour after the experiment was completed.

Now we are preparing to restart our routine data analysis and submit to the IVS.

3. Plans for 2011

We will enhance the IVS analysis work, return to our normal contribution of solutions to IVS, and make more active efforts to be involved in the activities of the VLBI community.

Tsukuba VLBI Analysis Center

Kensuke Kokado, Shinobu Kurihara, Ryoji Kawabata, Kentaro Nozawa

Abstract

The Geospatial Information Authority of Japan (GSI) became an IVS operational Analysis Center on April 7th, 2010. Our role is to submit dUT1 results from the IVS-INT2 session as soon as possible after the end of the session. GSI has been developing the real-time data processing and analysis system in cooperation with NICT. This report summarizes the progress and status of the ultra-rapid dUT1 measurement system.

1. Introduction

GSI has implemented the ultra-rapid dUT1 experiment in cooperation with the National Institute of Communications and Technology (NICT), Onsala station of the Onsala Space Observatory (OSO) in Sweden, and the Metsähovi station of the Metsähovi Radio Observatory in Finland since 2007. The purpose of this experiment is to obtain dUT1 results within the shortest possible time. After some experiments in 2007, we succeeded in obtaining the dUT1 results within 3 minutes 45 seconds of the end of the observing sessions on Feb. 21, 2008, on the Tsukuba—Onsala baseline. The system of the experiments was introduced into an IVS regular session "IVS-INT2" in 2008, and we have been carrying out the ultra-rapid dUT1 experiment in all of the INT2 sessions. Additionally, we have also implemented the ultra-rapid dUT1 experiment in 24-hour IVS regular sessions, such as "IVS-R1"and "IVS-T2", in which the Tsukuba and Onsala stations participated. Although the system is almost completed, we have not completed the quality check of the dUT1 results yet. After we confirm that the results are consistent with the results of the other Analysis Centers, we will start to submit the results within a few minutes after the end of the observing session for IVS-INT2 sessions.

2. Current Analysis Center Activities

Tsukuba VLBI Analysis Center has implemented the ultra-rapid dUT1 measurement to obtain the dUT1 results within a few minutes after the observing sessions. The ultra-rapid dUT1 measurement of IVS-INT2 sessions is implemented automatically, because there is no staff in the office during the INT2 session scheduled on the weekend. The detail of the automatic data processing system is described in this section. Figure 1 shows the process of the ultra-rapid dUT1 measurement system.

2.1. Automatic Data Transfer Program

For the IVS-INT2 sessions, we must transfer data from the Wettzell or Westford station to the Tsukuba correlator as soon as possible. Therefore, we introduced a real-time data transfer system developed by NICT into the sessions. The system adopts VLBI Data Interchange Format (VDIF) and Simple UDP (SUDP) protocol in the data transfer process. As the VDIF format data is converted to K5/VSSP format at the time of recording on the receiving server (Tsukuba's transfer server), it is not necessary to convert the data after the data transfer. It enables us to reduce the latency of VLBI sessions. This system requires the K5/VSI board in the station which

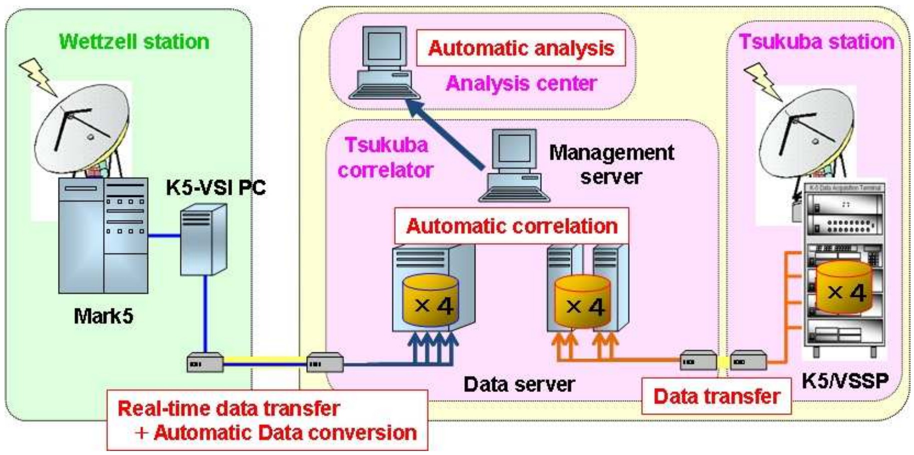

Figure 1. Ultra-rapid dUT1 measurement system

transfers the data to the correlator. NICT installed the K5/VSI board in the Wettzell station and succeeded in real-time data transfer from Wettzell to Tsukuba or Kashima station. The Onsala and Metsähovi stations have another real-time data transfer system which consists of the Tsunami protocol and PC-EVN. However, the other stations have not installed a real-time data transfer system yet, so we implemented the data transfer from the stations after the end of the session.

2.2. Automatic Data Conversion Program

For the INT2 sessions' Tsukuba—Wettzell baseline, we do not have to convert the data any more because we have adopted the real-time data transfer system. However, it is necessary to convert the data from Mark 5 format to K5 format for the INT2 sessions' Tsukuba—Westford baseline. As the data transfer is executed immediately after the Mark 5 data is put on the transfer server at Haystack, we will convert the transferred data after all data is transferred. The data conversion is also executed automatically using a perl script. It takes about 1.5 hours to convert all the data. We are considering how to reduce the delay caused by data conversion.

2.3. Automatic Correlation Program

The correlation work for the ultra-rapid dUT1 sessions is implemented by the "Cor_mgr" program developed by NICT. We created some scripts to execute the Cor_mgr automatically. The script confirms if the K5 data of both stations is ready in the data server, and it distributes the correlation to the correlation servers if the data is available. We use about eight correlation servers for the correlation work. The processing factor of the correlation system will be less than 0.30 if all of the data are already available before we start the correlation program.

2.4. Automatic Data Analysis Program

We adopt mainly two kinds of analysis software for the ultra-rapid dUT1 measurement. The software is OCCAM developed by Vienna University of Technology and C5++ developed by NICT. We can analyze the VLBI data with the software automatically. The analysis time is less than one minute. Therefore, we can obtain the dUT1 results within a few minutes if we complete the correlation work immediately after the end of the observing session.

3. Results of Our Activities

The Tsukuba Analysis Center analyzes the data of three kinds of ultra-rapid dUT1 sessions. This section shows the results of the experiments and the assignment for next one.

3.1. Ultra-rapid dUT1 Measurements in INT2 Sessions

We have analyzed the data of INT2 sessions for ultra-rapid dUT1 measurements using CALC/SOLVE, C5++, and OCCAM. The differences between solutions from pairs of analysis software are shown in Figure 2. The C5++ solution looks consistent with the CALC/SOLVE solutions. The differences are less than 40 microseconds. However, some of the OCCAM solutions have over 40 microseconds difference compared with the CALC/SOLVE solutions. We have to figure out whether the solution is right or not.

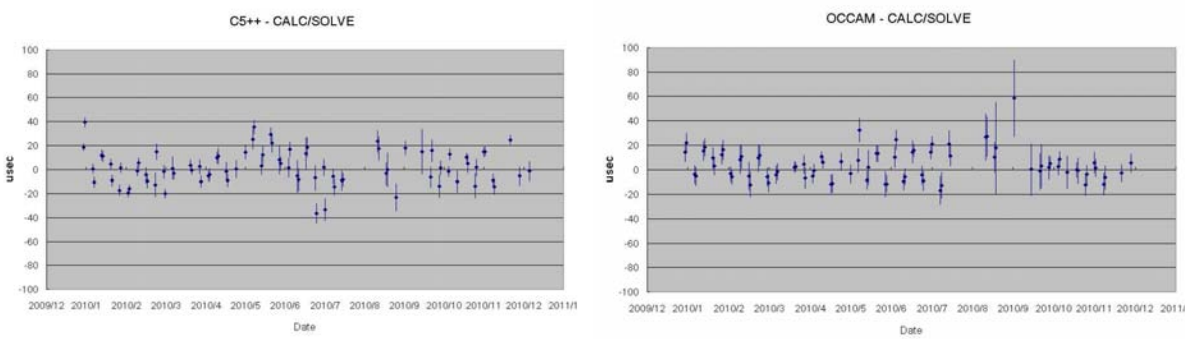

Figure 2. Comparisons of solutions estimated by each software.

3.2. Ultra-rapid dUT1 Measurements during 24-Hour VLBI Sessions

In 2010, we also implemented the ultra-rapid dUT1 measurements for 21 IVS 24-hour sessions (R1, RDV, T2 etc.) in which Tsukuba, Onsala, or Metsähovi stations participated. In the case of 24-hour sessions, we can obtain a number of dUT1 value during the observing session because the data analysis is done every 35 scans. Although we failed to transfer data of some scans due to overload of transfer server on some of the sessions, we could obtain dUT1 values at more than 80 points on each session. After IVS 24-hour sessions, Tsukuba and Onsala stations implemented an additional ultra-rapid dUT1 experiment, which is optimized for dUT1 measurement. We could observe about 430 scans in 11 hours and obtain dUT1 at more than 330 points during the observing session. Figure 3 shows the UT1-UTC values obtained by C5++ or OCCAM software on the "UR0355" session on Dec. 22, 2010. The results of the C5++ analysis fluctuates more than the OCCAM results. We have to investigate whether the results are reliable or not.

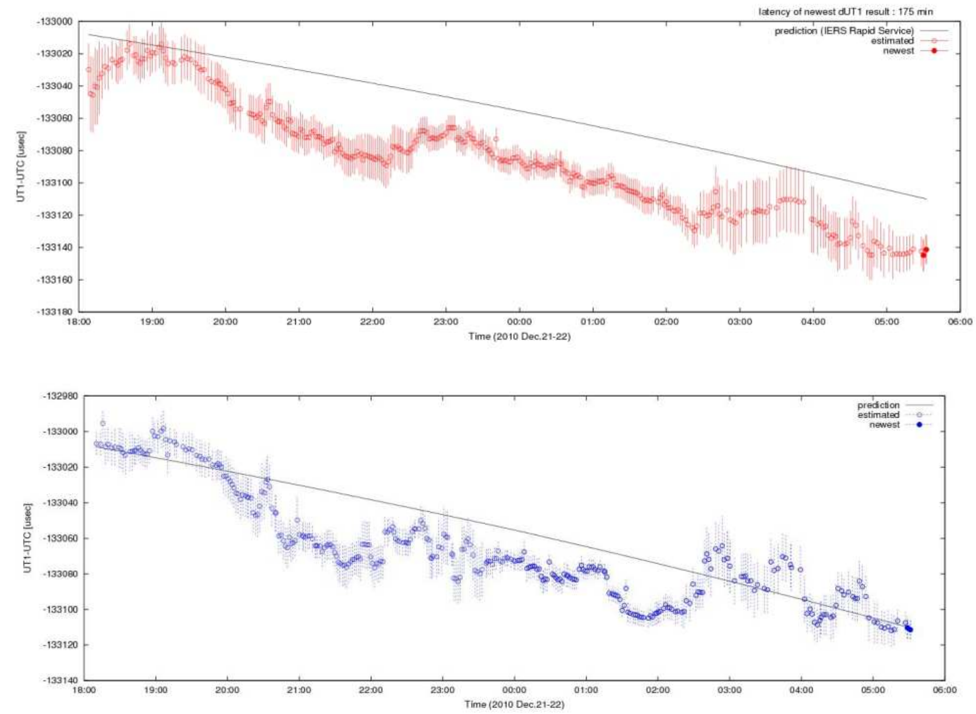

Figure 3. Top: OCCAM solutions on additional ultra-rapid dUT1 session. Bottom: C5++ solutions on additional ultra-rapid dUT1 session.

4. Staff

Kensuke Kokado: Technical Official (GSI)

Management of overall activity of Tsukuba Analysis Center.
Maintenance and support of real-time data transfer system
Maintenance/support of K5 software correlation system and e-VLBI system

Kentaro Nozawa: Technical Operator (AES)

Main operator of the analysis work
Maintenance of the real-time correlation and analysis system

Toshio Nakajima: System Engineer (I-JUSE)

System Engineer for maintenance of computers and e-VLBI network

5. Plan for 2011

Although our Analysis Center has tried ultra-rapid dUT1 measurements on INT2 sessions, we have not submitted the results officially to the IVS Data Centers yet. As we stabilize the data processing system, we will start to submit the C5++ results from the end of February 2011. We plan to implement ultra-rapid dUT1 measurements with the Auckland 12-m antenna in New Zealand (WARK12M). If we succeed for a North-South baseline, we will be able to obtain X/Y polar motion parameters immediately after the observing session. We would like to implement two baseline ultra-rapid dUT1 experiments including West-East and North-South baselines in 2011.

U.S. Naval Observatory VLBI Analysis Center

David A. Boboltz, Alan L. Fey, Nicole Geiger, Kerry A. Kingham, David M. Hall

Abstract

This report summarizes the activities of the VLBI Analysis Center at the United States Naval Observatory for calendar year 2010. Over the course of the year, Analysis Center personnel continued analysis and timely submission of IVS-R4 databases for distribution to the IVS. During the 2010 calendar year, the USNO VLBI Analysis Center produced one periodic global Terrestrial Reference Frame (TRF) solution for internal use only. Earth orientation parameters (EOP), updated by the latest diurnal (IVS-R1 and IVS-R4) experiments, were routinely submitted to the IVS. Sinex files based upon the bi-weekly 24-hour experiments were also submitted to the IVS.

During the 2010 calendar year, Analysis Center personnel focused much of their efforts on both the DiFX software correlator implementation at USNO and on establishing a program of daily Intensive experiments to measure UT1–UTC using two stations of the Very Long Baseline Array (VLBA). Analysis Center personnel also continued research into future high-frequency celestial reference frames based upon the VLBA K/Q-band experiments.

1. Introduction

The USNO VLBI Analysis Center is supported and operated by the United States Naval Observatory (USNO) in Washington, DC. The primary services provided by the Analysis Center are the analysis of diurnal experiments, the production of periodic global Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF) solutions, and the submission to the IVS of Intensive (EOP-I) and session-based (EOP-S) Earth orientation parameters based on USNO global TRF solutions. Analysis Center personnel maintain the necessary software required to continue these services to the IVS including periodic updates of the GSFC CALC/SOLVE software package. In addition to operational VLBI analysis, Analysis Center personnel are actively engaged in research related to future reference frames, the electronic transfer of VLBI data, and software correlation.

2. Current Analysis Center Activities

2.1. IVS Experiment Analysis and Database Submission

During the 2010 calendar year, personnel at the USNO VLBI Analysis Center continued to be responsible for the timely analysis of the IVS-R4 experiments, with the resulting databases submitted within 24 hours of correlation for dissemination by the IVS. Due to a decrease in staffing, the Analysis Center has suspended in-house analysis of the IVS-R1 experiments in favor of using the databases submitted by NASA-GSFC. Analysis Center personnel continue to be responsible for the analysis and database submission for the periodic IVS-CRF experiments. In 2010, USNO scheduled and analyzed four CRF related experiments including IVS-CRF58 through IVS-CRF61. The analyzed databases were submitted to the IVS. Analysis Center personnel also continued analyzing IVS Intensive experiments for use in the USN-EOPI time series.

2.2. Global TRF Solutions, EOP, and Sinex Submission

USNO VLBI Analysis Center personnel continued to produce periodic global EOP/TRF solutions over the course of the 2010 calendar year. This year a single solution (2010a) was produced and submitted to the IVS. Analysis Center personnel continued to submit the USN-EOPS series, which are now based upon the 2010a solution and are updated with new IVS-R1/R4 experiments. The updated EOPS series was submitted to the IVS twice weekly within 24 hours of experiment correlation and is included in the IERS Bulletin A. Analysis Center personnel also continued routine submission of Sinex format files based upon the 24-hour VLBI sessions. In addition to EOPS and Sinex series, USNO VLBI Analysis Center personnel continued to produce and submit an EOPI series based upon the IVS Intensive experiments.

2.3. Celestial Reference Frame (CRF)

On January 1, 2010 the Second Realization of the International Celestial Reference Frame (ICRF2) was adopted by the International Astronomical Union (IAU) as the fundamental reference frame for all astronomy. USNO VLBI Analysis Center personnel made significant contributions to the IERS Technical Note No. 35, which provides a complete description of ICRF2.

During the 2010 calendar year, Analysis Center personnel continued work on the production of global CRF solutions for dissemination by the IVS including crf2010a. The global CRF solutions produced are routinely compared to the current ICRF (now ICRF2). Also in 2010, Analysis Center personnel continued to collaborate with colleagues from Bordeaux Observatory, NASA-GSFC, NASA-HQ, NASA-JPL, and NRAO on a program of high-frequency reference frame observations made with the VLBA. This project aims to investigate the feasibility of a CRF at frequencies between 24 and 43 GHz. Recently, two articles were published summarizing the astrometric results (Lanyi et al., 2010, AJ, 139, 1695) and the imaging results (Charlot et al., 2010, 139, 1713) from the program. No new K/Q-band sessions were observed in 2010; however a previous session that was accepted but never scheduled was observed in January 2011. In addition, a proposal for new observations was submitted.

2.4. Software Correlator

Over the course of the 2010 calendar year, Analysis Center personnel were heavily involved in the implementation, testing, and evaluation of the DiFX software correlator. It is vital to the future of VLBI at USNO that a smooth transition takes place from the current Mark IV hardware correlator to the new DiFX software correlator. In late 2010 the software correlator implementation was transferred to a single 12-core machine. In addition, two Mark 5 units were purchased and connected to the correlator via a 1 Gbps ethernet switch. Geodetic data from several experiments have been successfully correlated on this latest edition of the DiFX software. Post-correlation fringe-fitting and calibration were performed within the Astronomical Image Processing System (AIPS), but testing is underway on a new difx2mark4 package that will allow the correlator output to be read into the more traditional Haystack Observatory Post-processing System (HOPS). Analysis Center personnel continue to interface with colleagues from various institutions that are collaborating on DiFX and attended the DiFX meeting in Socorro, NM in October of 2010.

2.5. VLBA Intensive Experiments

To test the feasibility of using the VLBA for the purpose of measuring UT1–UTC, two series of test observations (TB014 and TC015) were conducted in the 2009–2010 time frame. The TC015 series included five VLBA stations and was optimized for the Mauna Kea, HI to St. Croix, USVI baseline. The TB014 series included only three stations and was optimized for the shorter Mauna Kea (MK) to Pie Town, NM (PT) baseline. The data were correlated on the USNO implementation of the software correlator, were fringe-fitted within NRAO's AIPS package, and were further analyzed within the GSFC SOLVE package. Figure 1 shows the differences between the VLBA MK-PT baseline UT1–UTC results and IERS C04-05. Differences between IERS C04-05 and the USN-EOPI and USN-EOPS series are also shown.

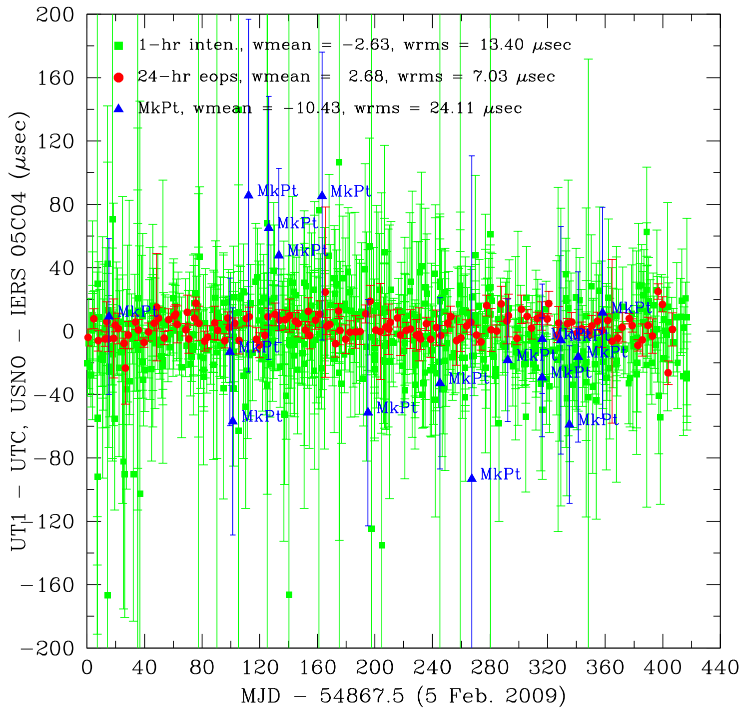

Figure 1. Differences in UT1-UTC between IERS C04-05 and data from VLBA test experiments TB014 and TC015 for the MK-PT baseline. Also shown are differences between IERS C04-05 and both the USN-EOPI and USN-EOPS standard series for comparison.

Based upon the tests conducted, the USNO signed a memorandum of understanding (MOU) with NRAO and the National Science Foundation (NSF) to begin using two stations of the VLBA to measure UT1–UTC. The plan is for a 1.5-hour daily Intensive between the MK and PT stations to be observed and for the data to be electronically transferred over high-speed network links to USNO for correlation. This new Intensive series is scheduled to begin in October 2011. To connect the two stations to the network, USNO has contracted with NRAO for the Pie Town (PT) station and with the University of Hawaii for the Mauna Kea (MK) station. These contracts will provide for 1 Gbps links to nearby 10 Gbps POPs on National Lambda Rail and Internet2 for

PT and MK, respectively. The data from this baseline will be correlated on the DiFX software correlator, fringed using FOURFIT and HOPS, analyzed within SOLVE, and submitted to the IVS for distribution to the community.

3. Staff

The staff of the VLBI Analysis Center is drawn from individuals in both the Astrometry and Earth Orientation departments at the U.S. Naval Observatory. The staff and their responsibilities are as follows:

Name	**Responsibilities**
David Boboltz	Periodic global TRF solutions and comparisons; VLBA Intensive program; software correlator implementation; VLBI data analysis.
Alan Fey	Periodic global CRF solutions and comparisons; CRF densification research; software correlator implementation; VLBI data analysis.
Nicole Geiger	Software correlator implementation; VLBI data analysis; EOP, database and Sinex submission.
Kerry Kingham	Hardware correlator interface; software correlator implementation; VLBI data analysis.
David Hall	Hardware correlator interface; software correlator implementation; VLBI data analysis.

4. Future Activities

For the upcoming year January 2011–December 2011, USNO VLBI Analysis Center personnel plan to accomplish the following activities:

- Continue testing and evaluation of the USNO implementation of the DiFX software correlator. Streamline pre- and post-correlation processing.
- Begin testing the electronic transfer of VLBI Intensive data from the MK and PT VLBA stations with regular operations beginning in October 2011.
- Continue analysis and submission of IVS-R4 experiments for dissemination by the IVS.
- Continue the production of periodic global TRF solutions and the submission of EOP-S estimates to the IVS updated by the IVS-R1/R4 experiments.
- Continue submission of Sinex format files based on the 24-hour experiments, and begin production of a Sinex series based upon the Intensive experiments.
- Continue the analysis of Intensive experiments and submission of EOP-I estimates to the IVS.
- Continue the scheduling, analysis, and database submission for all IVS-CRF experiments.
- Continue the production of periodic global CRF solutions.
- Continue research into the development of high-frequency reference frames based upon VLBA K- and Q-band sessions.

USNO Analysis Center for Source Structure Report

Alan L. Fey, David A. Boboltz, Roopesh Ojha, Ralph A. Gaume, Kerry A. Kingham

Abstract

This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure for calendar year 2010. VLBA RDV experiments RDV75, RDV77, and RDV79 were calibrated and imaged. Images from these three experiments were added to the USNO Radio Reference Frame Image Database. VLBA high frequency (K/Q-band) experiment BL151b was calibrated and imaged. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Activities planned for the year 2011 include continued imaging of ICRF sources at standard and higher frequencies and continued analysis of source structure and its variation.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of International Celestial Reference Frame (ICRF) sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The Web server for the Analysis Center is hosted by the USNO and can be accessed by pointing your browser to

`http://rorf.usno.navy.mil/ivs_saac/`

The primary service of the Analysis Center is the Radio Reference Frame Image Database (RRFID), a Web accessible database of radio frequency images of ICRF sources. The RRFID contains 7,279 Very Long Baseline Array (VLBA) images (a 7.9% increase over the previous year) of 782 sources (a 10% increase over the previous year) at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 1,706 images (a 12% percent increase over the previous year) of 282 sources (a 0.7% increase over the previous year) at frequencies of 24 GHz and 43 GHz. The RRFID can be accessed from the Analysis Center Web page or directly at

`http://rorf.usno.navy.mil/rrfid.shtml`

The RRFID also contains 74 images of 69 Southern Hemisphere ICRF sources using the Australian Long Baseline Array (LBA) at a radio frequency of 8.4 GHz.

Images of ICRF sources can also be obtained from the Bordeaux VLBI Image Database (BVID) at

`http://www.obs.u-bordeaux1.fr/m2a/BVID/`

2. Current Activities

2.1. VLBA Imaging

Very Long Baseline Array (VLBA) observations for maintenance of the celestial and terrestrial reference frames have been carried out since about 1994. Since 1997, these VLBA RDV (Research and Development with VLBA) observations have been part of a joint program between the

USNO, the Goddard Space Flight Center (GSFC), and the National Radio Astronomy Observatory (NRAO). During each 24-hour VLBA RDV session, about 100 ICRF sources are observed at S/X-band (2.3/8.4 GHz) using the VLBA together with up to 10 additional geodetic antennas. Images are produced from these observations and made available through the RRFID.

VLBA experiment RDV77 (2009OCT07) was calibrated and imaged, adding 180 (90 S-band; 90 X-band) images to the RRFID including images of 21 sources (0110-361, 0332-403, 0521-403, 0627+814, 0705-412, 0714+457, 0717-393, 0855+143, 0857-329, 1015+057, 1149-084, 1232-338, 1327+504, 1406-297, 1456+044, 1817+157, 2005+372, 2039+037, 2215+150, 2311-373, 2348-432) not previously imaged.

VLBA experiment RDV75 (2009MAY13) was calibrated and imaged, adding 179 (90 S-band; 89 X-band) images to the RRFID including images of 27 sources (0007-325, 0114-211, 0115-214, 0227-369, 0347-211, 0422-380, 0422-389, 0436-129, 0843-336, 1027-186, 1255-177, 1302-208, 1339-287, 1346-306, 1550-242, 1613-350, 1622-310, 1647+744, 1749+701, 1751+288, 1759-396, 1906-217, 2000+472, 2120-309, 2122-238, 2307+106, 2357-318) not previously imaged.

VLBA experiment RDV73 (2009JAN21) was calibrated and imaged, adding 175 (87 S-band; 88 X-band) images to the RRFID including images of 23 sources (0035-252, 0043-268, 0055-059, 0420+022, 0502-152, 0515+208, 0529+483, 0532-378, 0632-235, 0741-444, 0847-120, 0915-118, 1059-438, 1133-032, 1243-160, 1428+370, 1602-115, 1633-409, 1650-157, 1711-209, 1913-272, 2157-255, 2220-318) not previously imaged.

Collaborations continue with Glenn Piner at Whittier College and Patrick Charlot of the Laboratoire d'Astrophysique de Bordeaux to calibrate and image several of the VLBA RDV experiments.

2.2. VLBA High Frequency Imaging

A program to extend the ICRF to 24 and 43 GHz continued in 2010. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO), and the Laboratoire d'Astrophysique de Bordeaux. During the calender year 2010 two papers were published in the *Astronomical Journal:*, 1) "The Celestial Reference Frame at 24 and 43 GHz. I. Astrometry" by Lanyi et al. and 2) "The Celestial Reference Frame at 24 and 43 GHz. II. Imaging" by Charlot et al. (see § 5).

VLBA high frequency experiment BL151b (2008DEC18) was calibrated and imaged adding 187 (K-band only) images to the RRFID including two sources not previously imaged.

2.3. ICRF Maintenance in the Southern Hemisphere

The USNO and the Australia Telescope National Facility (ATNF) continue a collaborative program of VLBI research on Southern Hemisphere source imaging and astrometry using USNO, ATNF, and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the Southern Hemisphere.

A program to monitor the structure of quasars south of declination $-30°$ that are either known to be gamma-ray loud or are expected to be gamma-ray loud continued. The program, called TANAMI (Tracking Active galactic Nuclei with Australia Milliarcsecond Interferometry), is observing a sample of quasars at 8 GHz and 24 GHz bands (see § 5).

3. Staff

The staff of the Analysis Center is drawn from individuals who work at the USNO. The staff are: Alan L. Fey, David A. Boboltz, Roopesh Ojha, Ralph A. Gaume, and Kerry A. Kingham.

4. Future Activities

The Analysis Center currently has a program of active research investigating the effects of intrinsic source structure on astrometric position determination. Results of this program are published in the scientific literature.

The following activities for 2011 are planned:

- Continue imaging and analysis of VLBA 2.3/8.4/24/43 GHz experiments
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners and the TANAMI program team.

5. Relevant Publications

Publications of relevance to Analysis Center activities:

- "TANAMI: tracking active galactic nuclei with austral milliarcsecond interferometry. I. First-epoch 8.4 GHz images," Ojha, R., Kadler, M., Böck, M., Booth, R., Dutka, M. S., Edwards, P. G., Fey, A. L., Fuhrmann, L., Gaume, R. A., Hase, H., Horiuchi, S., Jauncey, D. L., Johnston, K. J., Katz, U., Lister, M., Lovell, J. E. J., Müller, C., Plötz, C., Quick, J. F. H., Ros, E., Taylor, G. B., Thompson, D. J., Tingay, S. J., Tosti, G., Tzioumis, A. K., Wilms, J. & Zensus, J. A. 2010, A&A, 519, 45
- "The Celestial Reference Frame at 24 and 43 GHz. I. Astrometry," Lanyi, G. E., Boboltz, D. A., Charlot, P., Fey, A. L., Fomalont, E. B., Geldzahler, B. J., Gordon, D., Jacobs, C. S., Ma, C., Naudet, C. J., Romney, J. D., Sovers, O. J. & Zhang, L. D. 2010, AJ, 139, 1695
- "The Celestial Reference Frame at 24 and 43 GHz. II. Imaging," Charlot, P., Boboltz, D. A., Fey, A. L., Fomalont, E. B., Geldzahler, B. J., Gordon, D., Jacobs, C. S., Lanyi, G. E., Ma, C., Naudet, C. J., Romney, J. D., Sovers, O. J. & Zhang, L. D. 2010, AJ, 139, 1713

Technology Development Centers

Technology Development Centers

Canadian VLBI Technology Development Center

Bill Petrachenko

Abstract

The Canadian VLBI Technology Development Center (TDC) is involved in activities related to the realization of VLBI2010.

1. Introduction

The Canadian TDC is a collaborative effort of the National partners interested in the advancement of VLBI technology, namely the Geodetic Survey Division of Natural Resources Canada (GSD/NRCan) and the Dominion Radio Astrophysical Observatory (DRAO) of the Herzberg Institute for Astrophysics of the National Research Council of Canada (DRAO/HIA/NRC).

2. VLBI2010 Committee (V2C)

The Canadian TDC is primarily focused on encouraging the realization of VLBI2010. This is done by Bill Petrachenko, chairman of the V2C, and Toni Searle, both of NRCan. In collaboration with others, this year's activity focused on the following areas:

- Development of algorithms for processing broadband data,
- Application of those algorithms to the processing of broadband data produced by the NASA broadband delay proof-of-concept effort,
- Development of a specification for VLBI2010 total power detection,
- Execution of studies into the nature, impact, and mitigation of Radio Frequency Interference (RFI),
- Execution of studies into the impact on the VLBI2010 broadband system of RFI generated at co-location sites that include the DORIS beacon and SLR aircraft avoidance radar,
- Participation in the VLBI2010 Project Executive Group.

3. DRAO Activities

Two prototype 10-m composite antennas that are light, stiff, and cost effective have been developed and tested. Under the leadership of Gordon Lacy, design studies for more efficient designs continue.

Under the leadership of Brent Carlson and Dave Fort, DRAO completed the production of the correlator for the EVLA project. It is one of the most ambitious radio interferometry correlators ever designed. Correlator expertise at DRAO is now being directed toward novel designs for the SKA.

FFI Technology Development Center—Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center focuses primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS (ground-based and LEO), SLR, altimetry, and gradiometry. This report shortly summarizes the latest improvements of the GEOSAT software. FFI is currently an Analysis Center for IVS and ILRS, and a Technology Development Center for IVS.

1. The GEOSAT Software and Activities in 2010

FFI's contribution to the IVS as a Technology Development Center focuses primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS (ground-based and LEO), SLR, altimetry, accelerometry, and GRACE KBR. The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in Andersen [1].

Space borne accelerometry has been implemented, and a small set of data has been tested (GOCE and GRACE). A complete production line for altimetry (Topex, ENVISAT, JASON 1 & 2) has been implemented and tested. The IERS 2010 Conventions have been implemented and tested. The GEOSAT orbit model has been validated against external LEO orbits. The RMS difference between JPL GRACE orbits and internal GEOSAT orbits is typically 4 mm in each cartesian direction. The corresponding RMS difference between external GOCE orbits (ESA official, approximately 250 km altitude) and internal GEOSAT orbits is typically 11 mm. This work will continue in 2011.

The Norwegian Mapping Authority (NMA) and FFI have started a close cooperation in analysis of space geodetic data using the GEOSAT software. NMA has recently been given the status of an Associate Analysis Center of IVS. The GEOSAT software is to be used in the analysis of VLBI data. We are right now trying to get our GEOSAT-generated SINEX files accepted by the IVS combination software. There are options in GEOSAT so that the VLBI model is in compliance with the other analysis software packages.

2. Staff

Dr. Per Helge Andersen—Research Professor of Forsvarets forskningsinstitutt (FFI). Dr. Eirik Mysen—Scientist at the Norwegian Mapping Authority (NMA). Dr. Kristian Breili—Scientist at the Norwegian Mapping Authority (NMA). Dr. Halfdan Kierulf—Scientist at the Norwegian Mapping Authority (NMA).

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

GSFC Technology Development Center Report

Ed Himwich, John Gipson

Abstract

This report summarizes the activities of the GSFC Technology Development Center (TDC) for 2010 and forecasts planned activities for 2011. The GSFC TDC develops station software including the Field System, scheduling software (SKED), hardware including tools for station timing and meteorology, scheduling algorithms, and operational procedures. It provides a pool of individuals to assist with station implementation, check-out, upgrades, and training.

1. Technology Center Activities

The GSFC IVS Technology Development Center (TDC) develops hardware, software, algorithms, and operational procedures. It provides manpower for station visits for training and upgrades. Other technology development areas at GSFC are covered by other IVS components such as the GSFC Analysis Center. The current staff of the GSFC TDC consists of John Gipson and Ed Himwich, both employed by NVI, Inc. The remainder of this report covers the status of the main areas supported by the TDC.

2. Field System

The GSFC TDC is responsible for development, maintenance, and documentation of the Field System (FS) software package. The FS provides equipment control at VLBI stations. It interprets the .snp schedule and .prc procedure files (both as prepared by DRUDG from the .skd schedule). The FS controls the antenna, data acquisition hardware, and related ancillary equipment needed for making VLBI measurements. All major VLBI data acquisition backends are supported. The FS is customizable to allow it to control station specific equipment. It is used at all the IVS network stations (i.e., more than 30) and also at many stations that do VLBI only for astronomical observations. The only major VLBI facilities not using it are the VLBA and VERA.

There were no new releases of the FS during this period. However, several development projects were started:

- Patriot 12-m Interface. A preliminary interface to Patriot 12-m antennas was developed. This was implemented using the position and velocity tracking mode in the Patriot antenna controller. All aspects of this appear to work, but final testing is delayed until next year when a receiver will be available.
- Satellite Tracking. A satellite tracking capability was developed for the FS. This will allow an antenna to be pointed at a satellite in one of three modes: (1) Ephemeris, (2) Az-El, or (3) RA-Dec. The Ephemeris tracking mode is the most flexible and precise. A one second ephemeris for several hours is built in memory, which the *antcn* antenna interface can use to guide the antenna. However, this requires special programming of the antenna interface, and some antennas may not be able to support this mode. The Az-El mode is useful for geo-synchronous or possibly slowly moving satellites, if the antenna being used supports commanding with fixed Az-El coordinates. The RA-Dec mode is the most universal since all antennas support RA-Dec pointing, but it may have limited usefulness if the satellite is not

moving at a nearly sidereal rate. It is expected that the Az-El and RA-Dec modes will be enhanced to allow periodic recommanding of the position. This may help with tracking slow moving objects. However, depending on the behavior of the antenna, this may introduce unacceptable jumps in the antenna tracking. The open source *predict* program is used to calculate the pointing angles from the orbital elements.

- Holography. A new SNAP command **holog** was developed to support holographic measurements of antennas. In it simplest form, this command will move an antenna in a boustrophedon pattern around a grid centered on either an Az-El or RA-Dec commanded position. A user-defined SNAP procedure is run to collect data at each grid point. Various options are available including specifying a "return to center" interval for recalibration, changing the order in which the grid points are visited, and allowing single "cuts" to be made on each axis.

These new capabilities will be included in FS releases next year. Several other improvements are expected in future releases, including:

- Support for DBBC and RDBE racks
- Support for Mark 5C recorders
- Use of *idl2rpc* for remote operation
- A complete update to the documentation and conversion to a more modern format that will be easier to use
- Conversion of the FORTRAN source to use the *gfortran* compiler; this will enable use of the source level debugger, *gdb*, for development and field debugging
- *Chekr* support for Mark 5A and Mark 5B systems
- Use of the Mark IV Decoder for phase-cal extraction in the field
- FS Linux 9 (based on Debian *squeeze*) distribution
- Support for periodic firing of the noise diode during observations
- Distribution of the new *gnplt*.

3. SKED and DRUDG

The GSFC TDC is responsible for the development, maintenance, and documentation of SKED and DRUDG. These two programs are very closely related, and they operate as a pair for the preparation of the detailed observing schedule for a VLBI session and its proper execution in the field. In the normal data flow for geodetic schedules, first SKED is run at the Operation Centers to generate the .skd file that contains the full network observing schedule. Then stations use the .skd file as input to DRUDG for making the control files and procedures for their station. Catalogs are used to define the equipment, stations, sources, and observing modes which are selected when writing a schedule with SKED.

Changes to SKED and DRUDG are driven by changes in equipment and by feedback from the users. The following summarizes some of the important changes to these programs in 2010 and plans for 2011.

3.1. SKED

The following changes were made to SKED:

- A station is no longer scheduled in tag-along mode if the station is “down” (not available for observing).
- **StatWt** was made its own command and given more flexibility. The user can now give independent weights to each of the stations to try to increase the number of observations that are scheduled.
- The command **SrcWt** was introduced. This is analogous to **StatWt** in that the user instructs SKED to preferentially select scans involving certain stations.
- A new command **Coverage** was introduced which calculates and reports sky coverage at the stations.
- Previously the user needed to specify the full path for use in the master command. This meant, for example, that the user had to change the directory specified in skedf.ctl in order to use this command for Intensives or if the year changed. Now all the user needs to do is specify the directory where the master-files are kept, and SKED will search all of master-files.
- Many internal references to tape were removed. The motivation was that many calculations were no longer necessary since it is no longer necessary to worry about rewinding tapes and ensuring that there is enough space left at the end of a tape. Some of these calculations actually led to incorrect schedules or resulted in increased idle time.
- All reported bugs were fixed. For the most part these occurred in unusual circumstances.
- The formatting of some error messages was improved to aid the user in understanding exactly what the problem was.

In addition we worked on updating the SKED documentation. The last time this was completely updated was in the 1990s.

Plans for the next year include: (1) releasing the updated documentation, (2) making VEX format native, and (3) modifying SKED as necessary to support VLBI2010.

3.2. DRUDG

The only changes made to DRUDG were in the calculation of BBC frequencies. In some unusual cases the printed results were incorrect because of round-off errors. This was fixed by making the intermediate calculations in double precision.

Plans for the next year include: (1) a documentation update and (2) support for VLBI2010.

Haystack Observatory Technology Development Center

Chris Beaudoin, Brian Corey, Arthur Niell, Alan Whitney

Abstract

Technology development at MIT Haystack Observatory focused on four areas in 2010:

- Digital backend recorder development
- Development of VLBI2010 receiver hardware
- RFI compatibility at GGOS stations
- Monitor and control infrastructure

1. Digital Backend Recorder Development

In 2010, the Haystack-NRAO collaboration continued to develop the RDBE subsystem (see Figure 1). In its current state, the RDBE is functional as a polyphase filter bank (PFB) processing eight user-selectable 32-MHz channels from a choice of sixteen uniformly-spaced channels in the 512-MHz IF bandwidth. A PFB personality with 8-MHz frequency channels is also planned, to provide compatibility with older data acquisition systems and to allow joint observations with the operational S/X geodetic network. A digital downconverter (DDC) personality is currently under development and will support flexible tuning of LO frequency and bandwidth for multiple baseband frequency channels.

Currently the RDBE produces data in Mark 5B formatted packets at 2 Gbps over its 10 Gigabit Ethernet interface; a VDIF output data-formatting module is currently under development for the RDBE and will provide more flexibility in the data output format. The RDBE also possesses a timing module which can be programmed to start and stop data packet transmission. This feature allows the RDBE to control the data observation start and stop times, hence shifting the time keeping responsibility from the Mark 5 data recorder to the digital backend. The Mark 5C 10Gbps data packet recorder was also demonstrated to reliably record ethernet data packets produced by the RDBE at a data rate of 2 Gbps; 4 Gbps operation is expected in the near future.

In July 2010 a VLBI fringe test was conducted between the Westford 18-m and GGAO 5-m antennas. In this experiment both sites used an RDBE programmed with the 32-MHz PFB personality and a Mark 5C data packet recorder. A 10-minute recording was made on the source 3C84, and fringes were successfully detected.

2. Development of VLBI2010 Receiver Hardware

Haystack Observatory is engaged in the development of a receiver front-end for the new GGAO Patriot 12-m antenna (see GGAO 2010 network station report). This hardware (see Figure 2a) is based on the cryogenic 2-14 GHz Eleven antenna developed at Chalmers University of Technology. In January 2010, noise temperatures were measured at 2-10 GHz with the new feed [1] and a set of Caltech 1-12 GHz LNAs [2]; the measured values were ∼20 K over 3-10 GHz, with somewhat higher values expected above 10 GHz due to higher LNA noise temperatures.

The feed, shown in Figure 2a, is expected to be installed on the Patriot 12-m antenna in early 2011.

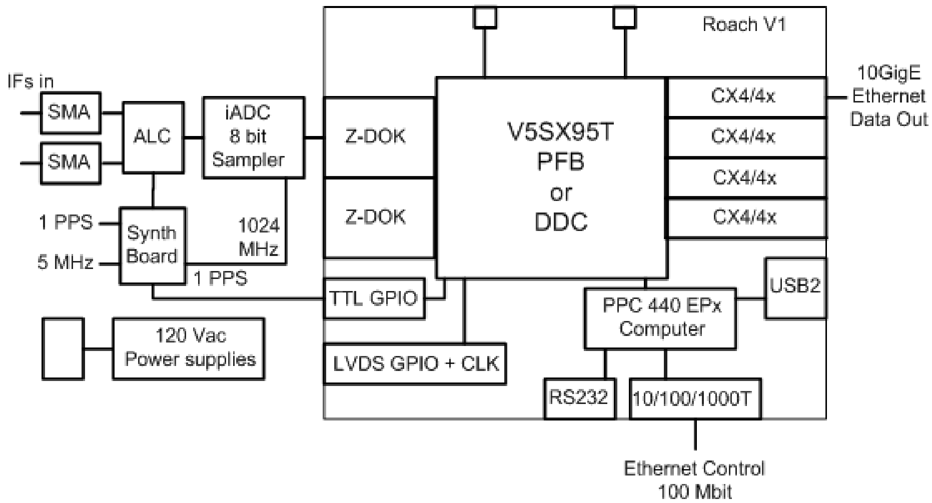

Figure 1. System Block Diagram of RDBE.

In late 2010 Sandy Weinreb and Ahmed Akgiray [3] introduced a new unbalanced broadband QRFH design (see Figure 2b). This feed was designed specifically for the Patriot 12-m antenna and requires only one LNA per polarization. At Caltech a prototype QRFH was constructed, and its radiation patterns were measured; the measurements indicate performance is near the theoretical expectation. This feed is also expected to be evaluated on the Patriot 12-m antenna in 2011.

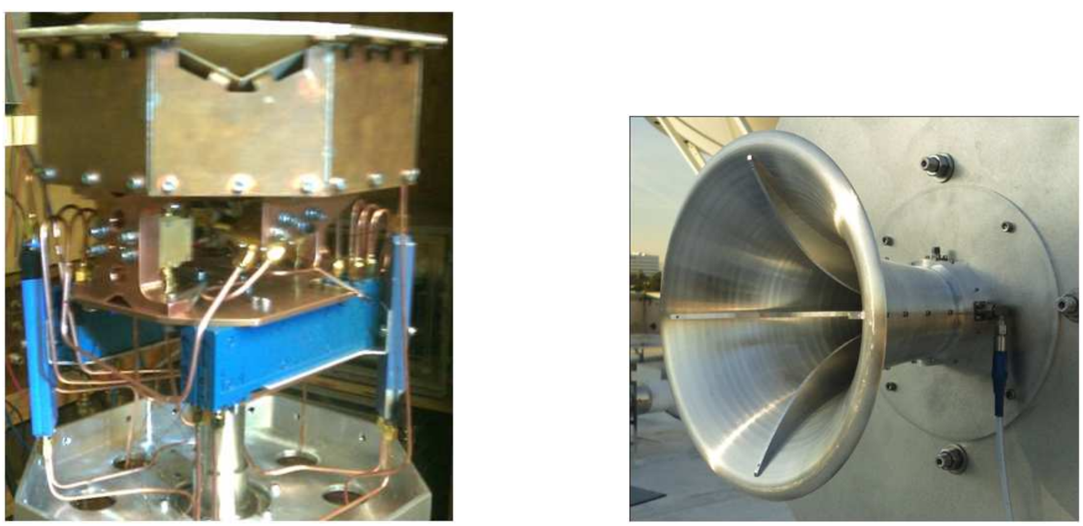

Figure 2. Broadband microwave feeds to be evaluated on the Patriot 12-m antenna at GGAO. (a) Chalmers Eleven Feed, with associated hybrids and LNAs, (b) Caltech QRFH.

A broadband noise-adding radiometer (NAR) system was developed at Haystack to provide VLBI2010 receiver noise temperature diagnostics. The system is based on a MiniCircuits broadband log-detector, which performs an RF power to DC voltage transducer function, and an Arduino microcontroller, which coherently integrates the receiver noise power during on and off states of the calibrated noise source. A block diagram of the NAR system is shown in Figure 3.

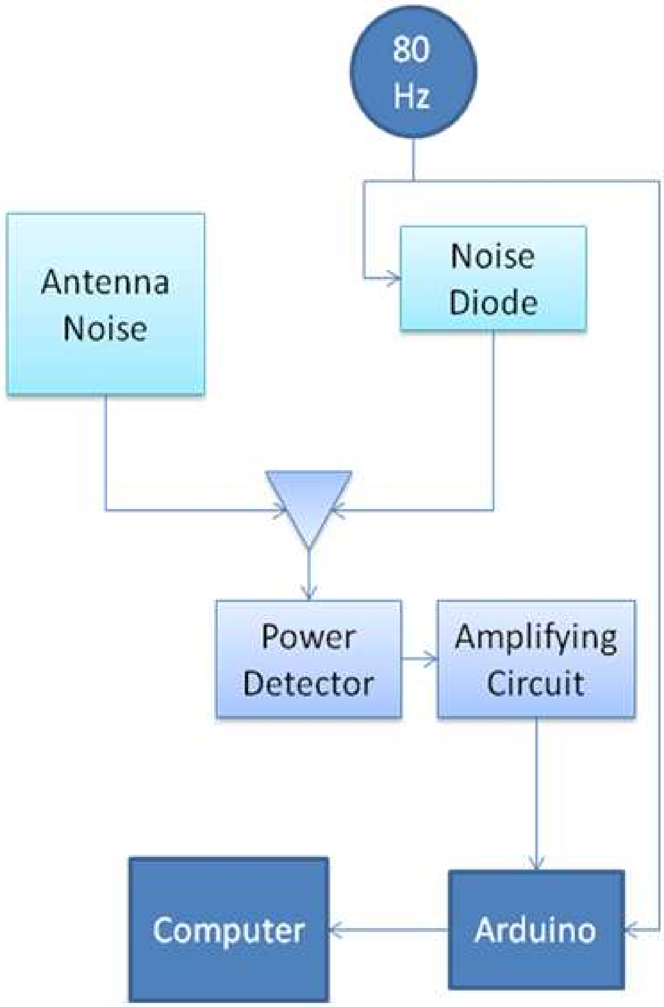

Figure 3. System block diagram of the Arduino-based Noise Adding Radiometer.

3. RFI Compatibility at GGOS Stations

Haystack staff studied the compatibility between a VLBI2010 receiver and both a DORIS ground transmitter and an SLR aircraft radar. The latter two systems have the potential to degrade VLBI data quality and, in the worst case, damage the front-end of the receiver. For a VLBI2010 receiver incorporating LNAs similar to the Caltech LNAs [2], studies [4] concluded that the power received at the feed from a DORIS beacon should be below -80 dBW, and below -70 dBW as received from the SLR radar. Options for inserting an RF barrier between a transmitter and a VLBI antenna are being investigated. The goal is to satisfy these power level restrictions without significantly degrading the DORIS and SLR data products.

4. Monitor and Control Infrastructure (MCI)

MCI collaboration between Wettzell station, NVI, and Haystack continued in 2010. In July 2010, a face-to-face meeting of the VLBI2010 MCI team took place at Wettzell. The main outcome pertinent to the VLBI community was the team sanction of a generalized MCI interface which can be adapted to accommodate arbitrary MCI system architectures. This was deemed necessary in order to accommodate MCI system architectural situations that extend beyond the specific cases encountered at Wettzell, GGAO, and Westford/Haystack. MCI self-identification will be a key feature of this generalization.

Haystack has also outlined a detailed description of the MCI needed for the newly installed Patriot 12-m radio telescope at GGAO. Hardware currently under development jointly by Honeywell-TSI and Haystack will meet the MCI requirements set forth for this system. The SysMon scheduler and IDL2RPC communications interface developed at Wettzell will be incorporated to provide the software backbone for this system.

References

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[2] N. Wadefalk and S. Weinreb, "Data sheet on CITCRYO1-12A, 1-12 GHz Cryogenic HEMT Low Noise Amplifier," California Institute of Technology

[3] A. Akgiray and S. Weinreb, "Wideband Near-Constant Beamwidth Flared Quad-Ridge Horn Feed for Reflector Antennas in Radio Astronomy." Presented at the 2011 National Radio Science Meeting, Boulder, Colorado

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Technology Development Center at NICT

Kazuhiro Takefuji, Tetsuro Kondo, Hiroshi Takiguchi

Abstract

The National Institute of Information and Communications Technology (NICT) leads the development of the VLBI technique and is highly active in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1. TDC at NICT

NICT's IVS Technology Development Center publishes the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" at least once a year in order to inform about the development of VLBI related technology . The newsletter is available through the Internet from the following URL **http://www2.nict.go.jp/w/w114/stsi/ivstdc/news-index.html**.

2. Staff Members of NICT TDC

Table 1 lists the staff members of NICT who are involved in the VLBI Technology Development Center.

Table 1. Staff Members of NICT TDC as of January 2011 (alphabetical).

Name	Works
AMAGAI, Jun	QZSS[1], GPS analysis, TWSTFT[2]
HASEGAWA, Shingo	K5/VSSP32, K5/VSI
HOBIGER, Thomas	QZSS[1], e-VLBI, GPS, GNSS analysis
ICHIKAWA, Ryuichi	MARBLE[3] system, VLBI analysis
ISHII, Atsutoshi	MARBLE[3] system
KAWAI, Eiji	34-m and 11-m antenna system
KIMURA, Moritaka	Giga-bit system, K5/VSI, Software correlator, e-VLBI
KONDO, Tetsuro	K5/VSSP32, Software correlator, e-VLBI
KOYAMA, Yasuhiro	e-VLBI, Group reader
MIYAUCHI, Yuka	Software correlator
SEKIDO, Mamoru	e-VLBI, Delta-VLBI, VLBI analysis
TAKEFUJI, Kazuhiro	ADS3000+ system
TAKIGUCHI, Hiroshi	VLBI analysis, e-VLBI, GPS analysis
TSUTSUMI, Masanori	K5 system, ADS3000+ system

[1] QZSS: Quasi-Zenith Satellite System
[2] TWSTFT: Two-Way Satellite Time and Frequency Transfer
[3] MARBLE: Multiple Antenna Radio-interferometry of Baseline Length Evaluation

3. Current Status and Activities

3.1. RF Direct Sampling

We have successfully carried out a test VLBI experiment with the so-called "RF direct sampling" technique. In a conventional VLBI system, RF signals are converted to IF band and thereafter converted further to baseband using an analog baseband converter. Finally the signals are sampled and converted to digital signals. With recent technology it became possible to sample IF signals directly due to the performance improvement of sampling devices, which led to the development of our digital baseband converter, named ADS3000. Recently a few sampling devices support a wide frequency bandwidth of up to or more than 10 GHz. If RF signals such as those in the 8 GHz band signals can be sampled directly, an IF converter becomes obsolete within the receiving system. This will reduce the costs of the system and increase the reliability of the system. ADX-830 developed by the ELECS INDUSTRY CO. LTD., is a sampler that has an input bandwidth of 30 GHz. We have carried out a test VLBI observation between the 34-m and 11-m antennas at Kashima by using the ADX-830 to evaluate the feasibility of RF direct sampling. Figure 1 shows the corresponding system block diagram. RF direct sampling with sampling modes of 2bit-1024Msps, 1bit-2048Msps, and 1bit-4096Msps were performed at the Kashima 11-m antenna. At the Kashima 34-m antenna, IF signals were sampled by using the ADS-1000 system with a sampling mode of 2bit-1024Msps. We could successfully get fringes except for the 1bit-4096Msps mode (Figure 2).

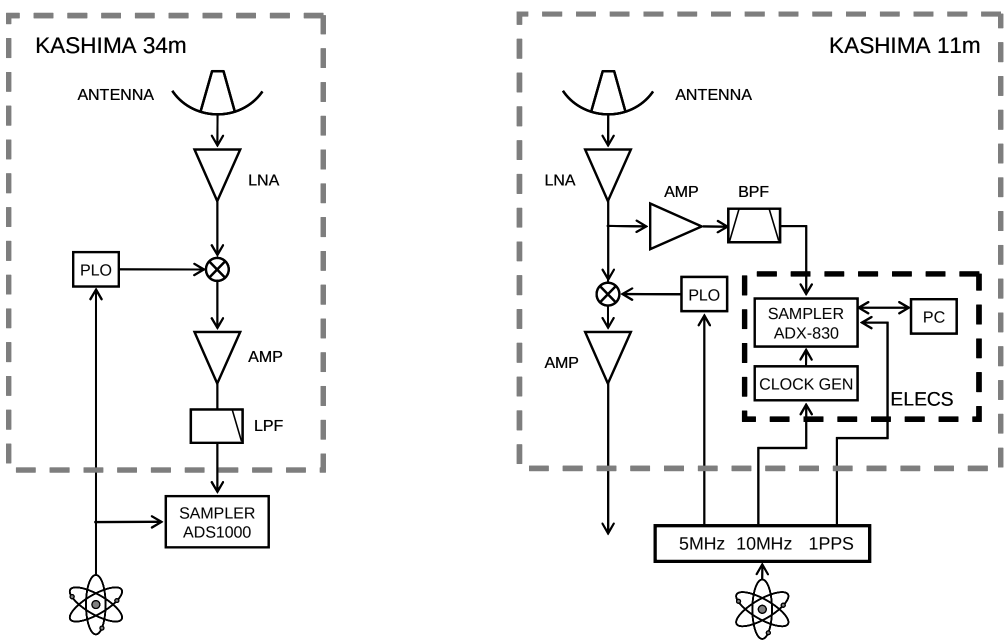

Figure 1. System block diagram for RF direct sampling at the Kashima 11-m antenna.

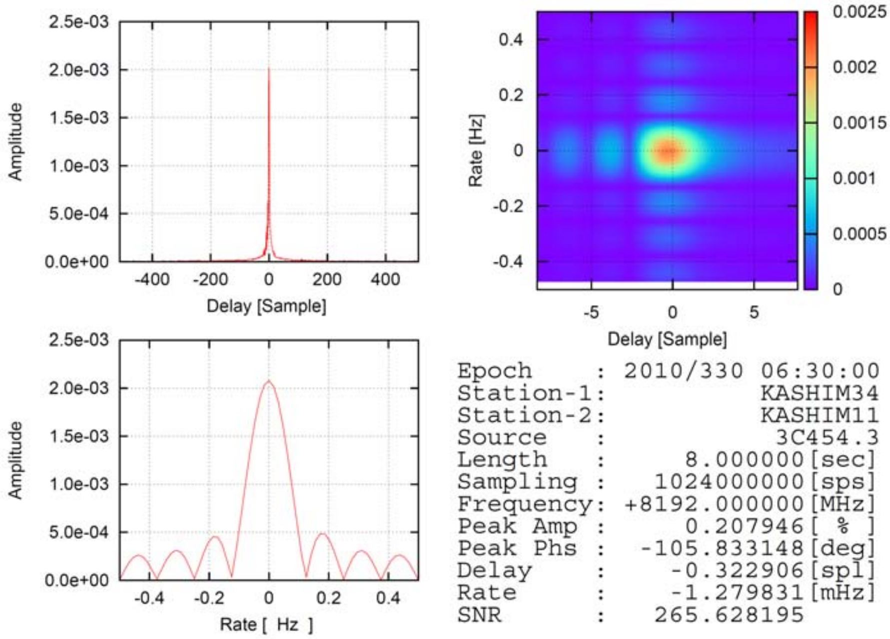

Figure 2. First fringe from RF direct sampling using a 2bit-1024Msps sampling mode of the ADX-830. See the on-line Annual Report for a colored version of the upper right figure.

3.2. Geodetic VLBI using the K5/VSI System

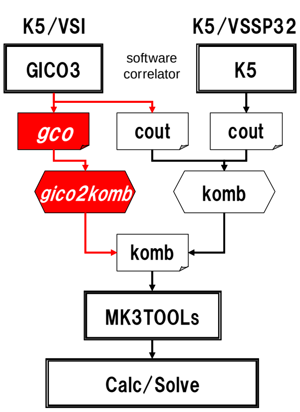

Figure 3. Data flow from the K5 sampling system to the baseline analysis program.

NICT is currently developing two types of sampling systems named K5/VSSP32 and K5/VSI (ADS1000 and ADS3000+). Also, we are developing software correlators corresponding to each system. The K5 software correlator handles data from K5/VSSP32 and is mainly used for geodetic VLBI experiments of Japanese stations as well as for international experiments conducted by GSI. The K5/VSI and GICO3 software correlator forms the other suite of tools, which are mainly used for astronomical purposes. In 2010, we developed new data conversion programs (Figure 3) which enable us to use the K5/VSI system for geodetic VLBI experiments. In order to evaluate the results based on data which was sampled by the K5/VSI system, we carried out a comparison experiment between K5/VSSP32 and K5/VSI system on the Kashima11m—Koganei11m baseline. Table 2 shows the baseline length calculated from the two types of K5 system. Results from two experiments show good agreement. Thus it is concluded that the K5/VSI and GICO3 software correlator can be used for geodetic VLBI experiments without loss of precision.

Table 2. The baseline length calculated from the data which was sampled either with K5/VSSP32 or K5/VSI.

Exp. date	System	Baseline Length	1σ
2010/08/04	K5/VSSP32	109099639.00 mm	0.53 mm
2010/08/04	K5/VSI	109099639.00 mm	0.57 mm
2010/10/01	K5/VSSP32	109099635.43 mm	0.58 mm
2010/10/01	K5/VSI	109099635.58 mm	0.66 mm

3.3. ADS3000+ — First DBBC Fringe Detected

NICT has developed a next-generation ADC called ADS3000+ which supports up to 4-GHz sampling and which is equipped with FPGA chips to realize a digital baseband converter (DBBC) and real-time RFI(CW) suppression.

There are 16ch DBBCs inside the ADS3000+ [1]. The specifications of the DBBC are shown in Table 3. Analog baseband spectra (band character) which are frequency-converted by an image-rejection mixer have a downside shape. The overall band-character of the DBBC shows a flat and symmetric shape. The flat band-character of DBBC is anticipated to increase the SNR. A first DBBC VLBI experiment was carried out in June 2010. The K5/VSSP32 system was deployed at the Koganei 11-m antenna, and ADS3000+ (DBBC) was installed in the Kashima 11-m antenna leading to a baseline of about 140 km. After correlation of the recorded data, first DBBC fringes could be successfully detected. The results are shown in Figure 4.

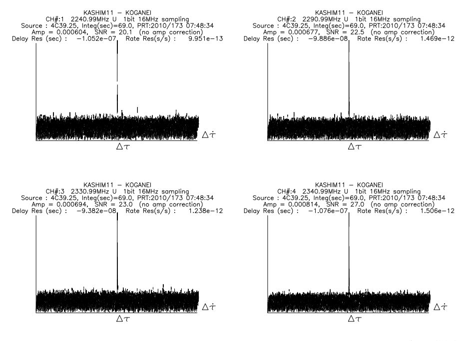

Figure 4. First DBBC fringes between the Kashima 11-m antenna and the Koganei 11-m antenna.

Table 3. Specification of ADS3000+ DBBC mode. One VSI-H outputs 16ch x 2bit or 8ch x 4bit of DBBC, and the VSI clock speed is adjustable. 1024Msps x 4ch is supported by the DBBC for broadband purposes.

Sample speed	Quantization	VSI clock
8Msps	4bit	Fix: 64MHz, Variable 8MHz
16Msps	4bit	Fix: 64MHz, Variable 16MHz
32Msps	4bit	Fix: 64MHz, Variable 32MHz
64Msps	4bit	Fix: 64MHz, Variable 64MHz
1024Msps	2bit	Fix: 64MHz

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[1] Takefuji K., Tsutsumi M., Takeuchi H., and Koyama Y., Current Status of Next-Generation A/D Sampler ADS3000+, IVS TDC News, No. 31, pp.6-9, 2010.

Onsala Space Observatory – IVS Technology Development Center

Miroslav Pantaleev, Rüdiger Haas, Leif Helldner, Lars Pettersson, Karl-Åke Johansson, Benjamin Klein[1]

Abstract

This report briefly describes the technical development relevant for geodetic/astrometric VLBI done during 2010 at the Onsala Space Observatory.

1. A Cryogenic Receiver for VLBI2010 with the Eleven Feed

We have continued our collaboration with the Antenna Group at the Department of Signals and Systems at Chalmers University of Technology concerning the improvement of the Eleven feed design [1]. The activities related to the integration of the Eleven feed in a cryogenic receiver for VLBI2010 are summarized as follows:

- Cryogenic tests to verify the expected system noise performance.
- Design and prototype tests aiming to decrease the size of the feed.
- Design and tests of different descrambling alternatives.
- Development of a model for the system noise temperature.

One Eleven feed was integrated in a test cryostat to measure reflection coefficients and system noise temperatures. Figure 1 shows the construction drawing of the test cryostat and the measured S11 reflection coefficients of the Eleven feed at room temperature and at cryogenic conditions. The reflection coefficient does not change when the feed is cooled to cryogenic temperature. This proves that the mechanical and cryogenic designs are good and that the feed can be used at cryogenic temperatures. The small variations can be explained by the change of the permittivity with temperature. The fact that S11 at cryogenic and at room temperatures are similar confirms that there are no significant deformations of the petals or the twin lead line.

For the noise temperature tests presented already in last year's report we used single ended cryogenic LNAs for the 4–8 GHz band from the Group for Advanced Receiver Development at the department [2], [3]. During 2010 we replaced these with cryogenic differential amplifiers from Sander Weinreb's group at the California Institute of Technology and started tests with these.

Two alternative descrambling solutions allowing a reduction of the number of ports from eight to four were designed, fabricated, and tested. The first alternative is based on an ultra wide-band balun designed as a continuously scaled, gradually curved, end-fire traveling wave structure [5], realized on microstrip, similar to the concept of the Vivaldi antenna. The measured result showed acceptable performance in the operated bandwidth, but generally the performance degraded around 5 GHz. The second alternative aims to resolve these issues. It is based on tapered transitions from symmetrical to single ended ports on microstrip, and a prototype development started.

A model for the system noise temperature was developed [4], based on the multiport network method. Figure 2 shows the predicted system noise temperature over the frequency band from 2 to 13 GHz. However, work is continuing to derive more accurate noise models. There is also ongoing work to verify these simulated results experimentally.

[1]PhD student at Hartebeeshoek Radio Observatory (HartRAO), South Africa

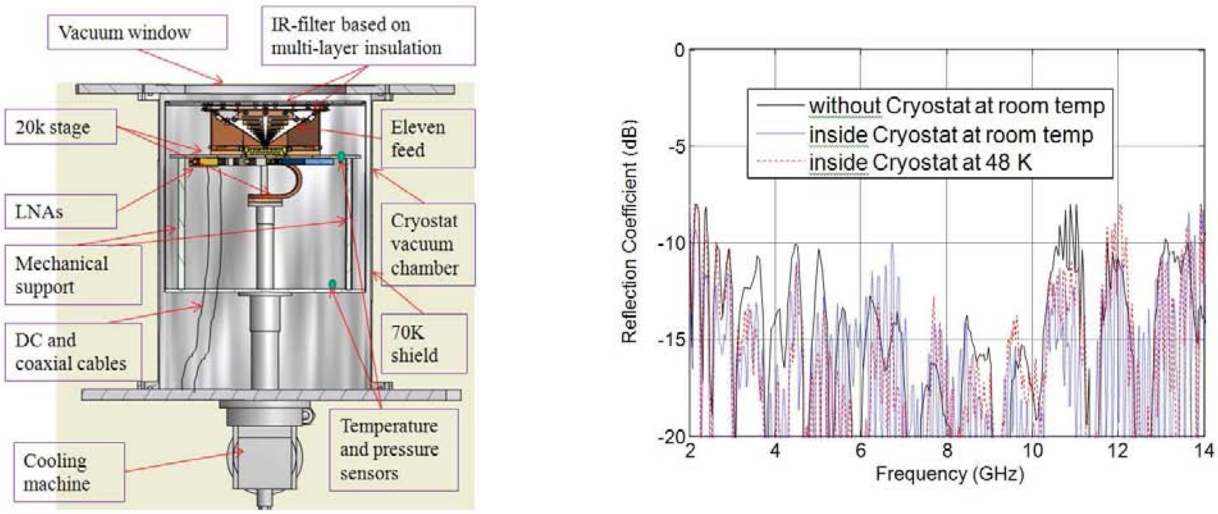

Figure 1. Left: Construction drawing of the test cryostat. Right: Measured S11 reflection coefficients at room temperature without and inside the cryostat, and at cryogenic temperatures inside the cryostat.

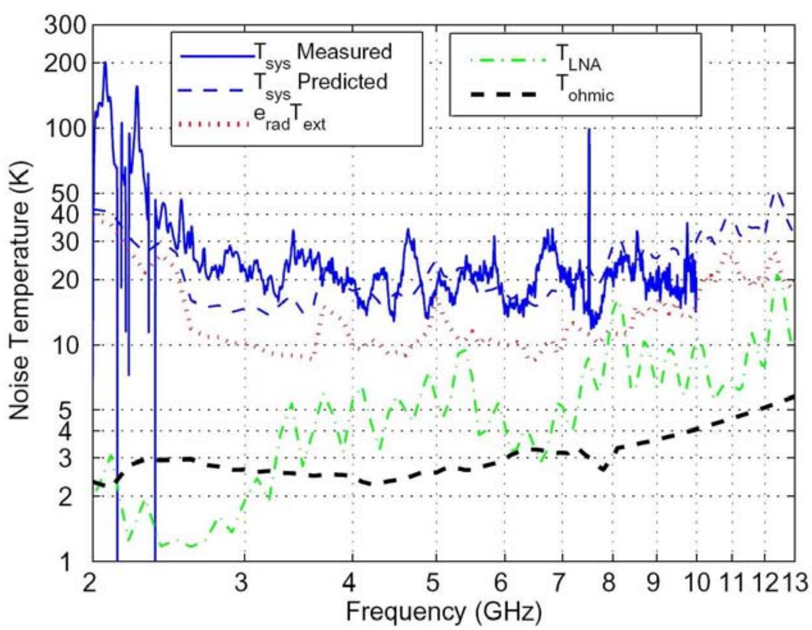

Figure 2. Measured (solid blue line) and predicted (dashed blue line) system noise temperatures T_{sys} when the cryostat with the Eleven feed is pointing at the zenith, including different contributions to T_{sys}. The measurements were done at the Haystack Observatory.

2. RFI Monitoring and Mitigation

A MSc thesis project developed a radio frequency interference (RFI) monitoring system [6]. A software application was developed that communicates with different types of digital receivers (spectrum analyzers) and a control unit for omnidirectional and steerable antennas (Fig. 3). The detection of interference signals uses the generalized spectral kurtosis (GSK) estimator [7]. A file containing frequencies, power levels, and the indication of any interference is saved, and corresponding plots are generated (see Fig. 3).

Another MSc thesis project had the goal of developing a software application which can be used to identify RFI. This work was based on the Interconnect Break-out-Board (iBOB) providing real-time power spectrum density (PSD) estimates with 2048 frequency channels [8]. The PSD estimates are fed into a Spectral Kurtosis (SK) algorithm implemented in MatLab for the calculation and flagging of RFI.

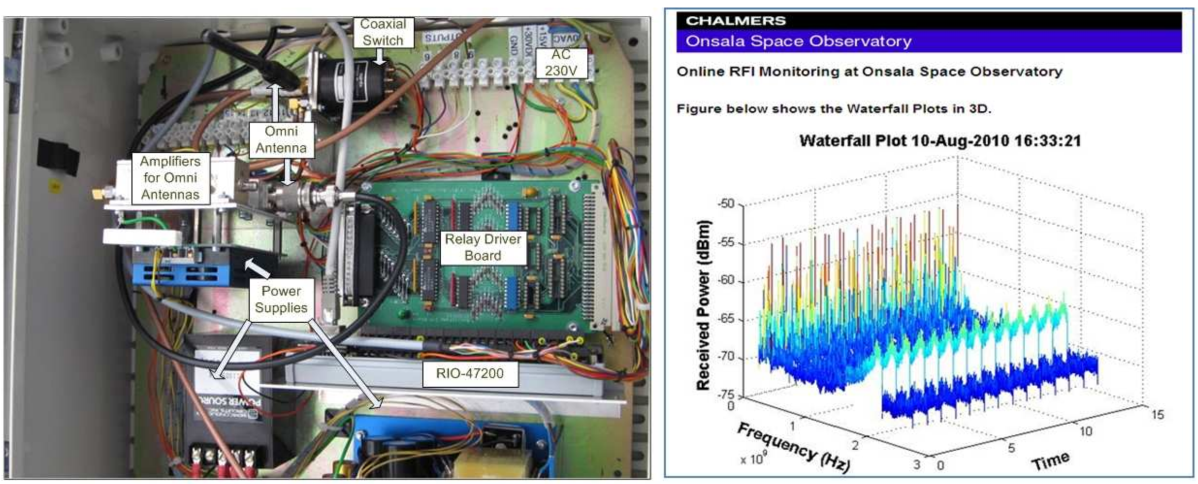

Figure 3. Left: The main antenna control unit. Right: The Web-based interface for RFI monitoring.

3. Further Technical Development

A number of additional technical projects were carried out in 2010. The upgrade and repair of the microwave radiometer Konrad continued. The system to monitor the vertical height changes of the 20-m radio telescope was upgraded. New temperature sensors were installed and the measurements made available on a Web page, see `http://wx.oso.chalmers.se/pisa/`.

4. Outlook and Future Plans

We will continue to develop the cryogenic receiver for VLBI2010 using the Eleven feed. New prototypes will be produced in 2011. We plan to install an RFI monitoring station at Onsala and will include RFI mitigation in the telescope control system.

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1. Introduction

The following bibliography compiles papers that were published in the field of geodetic and astrometric VLBI during the year 2010. There is no distinction between peer-reviewed, reviewed or proceedings publications. This list is by no means exhaustive.

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IVS Information

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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 Operational Analysis Centers (hereinafter called Analysis Centers), Associate Analysis Centers, and Combination 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.

Combination Centers are committed to quality control the submissions of the Analysis Centers to the IVS Data Centers and to produce combination results from the individual submissions as official IVS products. The products include, but are not limited to, EOP time series derived from session-based results for 24-hour network sessions and 1-hour Intensive sessions. The Combination Centers also contribute to the generation of the official IVS input to International Terrestrial Reference Frame (ITRF) computations. The combination work is done in a timely fashion and in close cooperation with the IVS Analysis Coordinator.

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 and combination 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 and combination 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.
- supervises the formation of the official IVS products, as decided by the IVS Directing Board, produced by the Combination 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 until the next official elections. The position will then be filled for a full term.

An individual can only serve two consecutive full terms on the Board in any of the representative and at large positions. Partial terms are not counted to this limit. After two consecutive full terms, the individual becomes eligible again for a position on the Board following a two-year absence.

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 Commission 1 – Reference Frames
- President of IAG Commission 3 Geodynamics and Earth Rotation
- President of IAU Division I – Fundamental Astronomy
- President of IAU Commission 8 – Astrometry
- President of IAU Commission 19 – Rotation of the Earth
- President of IAU Commission 31 – Time
- President of IAU Commission 40 – Radio Astronomy
- President of URSI Commission J – Radio Astronomy

Individuals are accepted as IVS Corresponding Members upon request to the Coordinating Center.

Last modified: 12 February, 2010

IVS Member Organizations

(alphabetized by country)

Organization	Country
Commonwealth Scientific and Industrial Research Organisation	Australia
Geoscience Australia	Australia
University of Tasmania	Australia
Vienna University of Technology	Austria
Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Geodetic Survey Division, Natural Resources Canada	Canada
Dominion Radio Astrophysical Observatory	Canada
Universidad de 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
Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
Max-Planck-Institut für Radioastronomie	Germany
Istituto di Radioastronomia INAF	Italy
Agenzia Spaziale Italiana	Italy
Politecnico di Milano DIIAR	Italy
Geospatial Information Authority of Japan	Japan
National Institute of Information and Communications Technology	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Auckland University of Technology	New Zealand
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Central (Pulkovo) Astronomical Observatory	Russia
Institute of Applied Astronomy	Russia
Sternberg State Astronomical Institute, Lomonosov Moscow State University	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Korea Astronomy and Space Science Institute	South Korea
Instituto Geográfico Nacional	Spain
Chalmers University of Technology	Sweden
Karadeniz Technical University	Turkey
Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine

Organization	Country
Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
NASA Goddard Space Flight Center	USA
U. S. Naval Observatory	USA
Jet Propulsion Laboratory	USA

IVS Affiliated Organizations

Organization	Country
Australian National University	Australia
University of New Brunswick	Canada
Satellite Geodetic Observatory	Hungary
Joint Institute for VLBI in Europe (JIVE)	Netherlands
Westerbork Observatory	Netherlands
National Radio Astronomy Observatory	USA

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IVS Permanent Components

(listed by types, within types alphabetical by component name)

Network Stations

Component Name	Sponsoring Organization	Country
Radioastronomical Observatory Badary	Institute of Applied Astronomy RAS	Russia
Fortaleza, Radio Observatório Espacial do Nordeste (ROEN)	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Goddard Geophysical and Astronomical Observatory	NASA Goddard Space Flight Center	USA
Hartebeesthoek Radio Astronomy Observatory	Foundation for Research and Development	South Africa
Hobart, Mt. Pleasant Radio Observatory	University of Tasmania	Australia
Kashima 34m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Kashima 11m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Koganei	National Institute of Information and Communications Technology (NICT)	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service (NEOS)	USA
Matera	Agenzia Spaziale Italiana (ASI)	Italy
Medicina	Istituto di Radioastronomia	Italy
Mizusawa 10m	National Astronomical Observatory of Japan (NAOJ)	Japan
Noto (Sicily)	Istituto di Radioastronomia	Italy
Ny-Ålesund Geodetic Observatory	Norwegian Mapping Authority	Norway
ERS/VLBI Station O'Higgins	Bundesamt für Kartographie und Geodäsie (BKG)	Germany
Onsala Space Observatory	Chalmers University of Technology	Sweden
Parkes Observatory	CSIRO Astronomy and Space Science	Australia
Seshan	Joint Laboratory for Radio Astronomy (JLRA), CAS and Shanghai Observatory, CAS	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy RAS	Russia
JARE Syowa Station	National Institute of Polar Research	Japan

Transportable Integrated Geodetic Observatory (TIGO)	Universidad de Concepción (UdeC), Instituto Geográfico Militar (IGM), Bundesamt für Kartographie und Geodäsie (BKG)	Germany, Chile
Tsukuba VLBI Station	Geospatial Information Authority of Japan (GSI)	Japan
Nanshan VLBI Station	Chinese Academy of Sciences	China
Warkworth Observatory	Auckland University of Technology	New Zealand
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (FESG)	Germany
Observatório Astronómico Nacional - Yebes	Instituto Geográfico Nacional	Spain
Radioastronomical Observatory Zelenchukskaya	Institute of Applied Astronomy RAS	Russia

Operation Centers

Component Name	**Sponsoring Organization**	**Country**
Institut für Geodäsie und Geoinformation (IGGB)	Universität Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service (NEOS)	USA

Correlators

Component Name	**Sponsoring Organization**	**Country**
Astro/Geo Correlator at MPI	Bundesamt für Kartographie und Geodäsie, Institut für Geodäsie und Geoinformation der Universität Bonn, Max-Planck-Institut für Radioastronomie	Germany
MIT Haystack Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy RAS	Russia
National Institute of Information and Communications Technology (NICT)	National Institute of Information and Communications Technology (NICT)	Japan
Tsukuba VLBI Center	Geospatial Information Authority of Japan (GSI)	Japan
Washington Correlator	National Earth Orientation Service (NEOS)	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana (ASI)	Italy
Italy INAF	Istituto di Radioastronomia INAF	Italy
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France

Analysis Centers

Component Name	Sponsoring Organization	Country
Astronomical Institute of St.-Petersburg University	Astronomical Institute of St.-Petersburg University	Russia
Geoscience Australia	Geoscience Australia	Australia
BKG/DGFI Combination Center	Bundesamt für Kartographie und Geodäsie and Deutsches Geodätisches Forschungsinstitut	Germany
Observatoire de Bordeaux	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
IGGB-BKG Analysis Center	Institut für Geodäsie und Geoinformation der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	MIT Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy RAS	Russia
Institute of Geodesy and Geophysics (IGG)	Institute of Geodesy and Geophysics (IGG) of Vienna University of Technology	Austria
Italy INAF	Istituto di Radioastronomia INAF	Italy
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Karadeniz Technical University (KTU)	Karadeniz Technical University	Turkey
Korea Astronomy and Space Science Institute	Korea Astronomy and Space Science Institute	South Korea

Main Astronomical Observatory	Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
National Astronomical Observatory of Japan	National Astronomical Observatory of Japan	Japan
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Norwegian Mapping Authority (NMA)	Norwegian Mapping Authority (NMA)	Norway
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden
Politecnico di Milano DIIAR	Politecnico di Milano DIIAR (PMD)	Italy
Pulkovo Observatory	Pulkovo Observatory	Russia
Sternberg State Astronomical Institute	Lomonosov Moscow State University	Russia
Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
Tsukuba VLBI Analysis Center	Geospatial Information Authority of Japan (GSI)	Japan
U. S. Naval Observatory Analysis Center	U. S. Naval Observatory	USA
U. S. Naval Observatory Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	**Sponsoring Organization**	**Country**
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Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	MIT Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy RAS	Russia
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Onsala Space Observatory	Chalmers University of Technology	Sweden

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List of Acronyms

AAS	American Astronomical Society
AC	(IVS) Analysis Center
ACU	Antenna Control Unit
ADB	Analog to Digital Board
ADC	Analog to Digital Converter
AEB	Agência Espacial Brasileira (Brazilian Space Agency)
AES	Advanced Engineering Services Co., Ltd (Japan)
AGU	American Geophysical Union
AIPS	Astronomical Image Processing System
ALMA	Atacama Large Millimeter Array
AMRFP	Access to Major Research Facilities Program
APEX	Atacama Pathfinder EXperiment (Chile)
API	Application Programming Interface
APSG	Asia-Pacific Space Geodynamics program
APTF	Asian Pacific Time and Frequency
ARC	Astrometric Radiointerferometric Correlator
ASI	Agenzia Spaziale Italiana (Italy)
ASKAP	Australian Square Kilometre Array Pathfinder (Australia)
ATA	Advanced Technology Attachment
ATM	Asynchronous Transfer Mode
ATNF	Australia Telescope National Facility (Australia)
AUT	Auckland University of Technology (New Zealand)
BADW	Bavarian Academy of Sciences (Germany)
BBC	Base Band Converter
BIPM	Bureau Internacional de Poids et Mesures (France)
BKG	Bundesamt für Kartographie und Geodäsie (Germany)
BPE	Bernese Processing Engine
BPF	Band Pass Filter
BVID	Bordeaux VLBI Image Database
BW	Band Width
BWG	Beam WaveGuide
CARAVAN	Compact Antenna of Radio Astronomy for VLBI Adapted Network (Japan)
CAS	Chinese Academy of Sciences (China)
CAY	Centro Astronómico de Yebes (Spain)
CC	(IVS) Combination Center
CC	(IVS) Coordination Center
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project
CGE	Centrum für Geodätische Erdsystemforschung (Germany)
CGS	Centro di Geodesia Spaziale (Italy)
CHAMP	Challenging Mini-Satellite Payload
CIB	Correlator Interface Board

CNES	Centre National d'Etudes Spatiales (France)
CNRS	Centre National de la Recherche Scientifique (France)
CNS	Communication, Navigation and Surveillance systems, Inc. (USA)
COL	Combination at the Observation Level
CONGO	COoperative Network for GIOVE Observation
CORE	Continuous Observations of the Rotation of the Earth
CP	Circularly Polarized
CPO	Celestial Pole Offset
CRAAE	Centro de Rádio Astronomia e Aplicações Espaciais (Brazil)
CRAAM	Centro de Rádio Astronomia e Astrofísica Mackenzie (Brazil)
CrAO	Crimean Astrophysical Observatory (Ukraine)
CRDS	Celestial Reference frame Deep South
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory (now NICT) (Japan)
CSIR	Council for Scientific and Industrial Research (South Africa)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CVN	Chinese VLBI Network
CW	Continuous Wave
DAR	Data Acquisition Rack
DAS	Data Acquisition System
DB	database
DBBC	Digital Base Band Converter
DBE	Digital BackEnd
DDC	Digital DownConverter
DeltaDOR	Delta Differenced One-way Range
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation) (Germany)
DFT	Discrete Fourier Transform
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DGK	Deutsche Geodätische Kommission (Germany)
dGPS	differential GPS
DHC	de Havilland Canada Company
DIIAR	Dipartimento di Ingegneria Idraulica, Ambientale, Infrastrutture viarie, Rilevamento (Italy)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DOM	Data Output Module
DOMES	Directory Of MERIT Sites
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DPFU	Degrees Per Flux Unit
DPN	Dual Pseudo-random Noise
DR	Dichroic Reflector
DRAO	Dominion Radio Astrophysical Observatory (Canada)
DSN	Deep Space Network
DSS	Deep Space Station
D-VLBI	Differential VLBI
ECMWF	European Centre for Medium-Range Weather Forecasts

EDM	Electronic Distance Measurement
EIA	Environmental Impact Assessment
ENVISAT	ENVIronmental SATellite
EOP	Earth Orientation Parameter
ERP	Earth Rotation Parameter
ERS	European Remote Sensing Satellites
ESA	European Space Agency
ESO	European Southern Observatory
ETS-8	Engineering Test Satellite 8
ETS-VIII	Engineering Test Satellite 8
EUREF	EUropean REFerence Frame
EVGA	European VLBI for Geodesy and Astrometry
EVLA	Expanded Very Large Array
e-VLBI	Electronic VLBI
EVN	European VLBI Network
FACH	Fuerza Aérea de Chile (Air Force of Chile) (Chile)
FCN	Free Core Nutation
FES	Finite Element Solution
FESG	Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FFTS	Fast Fourier Transform Spectrometer
FINEP	Financiadora de Estudos e Projetos (Brazilian Innovation Agency)
FPGA	Field-programmable Gate Array
FS	Field System
FTP	File Transfer Protocol
FWF	Fonds zur Förderung der wissenschaftlichen Forschung (Austrian Science Fund)
GA	Geoscience Australia (Australia)
GAPE	Great Alaska and Pacific Experiment
GARR	Gruppo per l'Armonizzazione delle Reti della Ricerca (Italian Academic and Research Network) (Italy)
GARS	German Antarctic Receiving Station (Germany)
GEMD	Geospatial and Earth Monitoring Division (Australia)
GeoDAF	Geodetic Data Archiving Facility (Italy)
GEX	Giga-bit series VLBI EXperiment
GFZ	GeoForschungsZentrum (Germany)
GGAO	Goddard Geophysical and Astronomical Observatory (USA)
GGN	Global GPS Network
GGOS	Global Geodetic Observing System
GGP	Global Geodynamics Project
GICO	GIga-bit COrrelator
GINS	Géodésie par Intégrations Numériques Simultanées
GIOVE	Galileo In-Orbit Validation Element
GISTM	GPS Ionospheric Scintillation and TEC Monitor

GLONASS	GLObal NAvigation Satellite System (Russia)
GLORIA	GLObal Radio Interferometry Analysis
GNS Science	Geological and Nuclear Sciences Research Institute (New Zealand)
GNSS	Global Navigation Satellite Systems
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GOW	Geodetic Observatory Wettzell
GPS	Global Positioning System
GR	General Relativity
GRACE	Gravity Recovery and Climate Experiment (USA)
GRGS	Groupe de Recherches de Géodésie Spatiale (France)
GSD/NRCan	Geodetic Survey Division of Natural Resources Canada (Canada)
GSFC	Goddard Space Flight Center (USA)
GSI	Geospatial Information Authority of Japan (formerly Geographical Survey Institute) (Japan)
GSK	Generalized Spectral Kurtosis
GSOS	GPS Surface Observing System
HartRAO	Hartebeesthoek Radio Astronomy Observatory (South Africa)
HAT-Lab	High Advanced Technology-Lab (Italy)
HEMT	High Electron Mobility Transistor
HF-EOP	High Frequency Earth Orientation Parameters
HIA	Herzberg Institute for Astrophysics (Canada)
HIRLAM	High Resolution Limited Area Model
Honeywell-TSI	Honeywell Technology Solutions Inc. (USA)
HOPS	Haystack Observatory Postprocessing System
HPBW	Half Power Beam Width
HTS	High Temperature Superconductor
HTSI	Honeywell Technology Solutions Incorporated (USA)
HVAC	Heating, Ventilation, and Air Conditioning
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAPG	Institute of Astronomical and Physical Geodesy (Germany)
IAU	International Astronomical Union
IBGE	Instituto Brasileiro de Geografia e Estatistica (Brazil)
iBOB	Interconnect Break Out Board
ICRAR	International Centre for Radio Astronomy Research (Australia)
ICRF	International Celestial Reference Frame
ICRF2	2nd Realization of the International Celestial Reference Frame
IDS	International DORIS Service
IDV	IntraDay Variability
IERS	International Earth Rotation and Reference Systems Service
IF	Intermediate Frequency
IGFN	Italian Space Agency GPS Fiducial Network (Italy)
IGG	Institute of Geodesy and Geophysics (Austria)
IGGB	Institut für Geodäsie und Geoinformation der Universität Bonn (Germany)

IGM	Instituto Geográfico Militar (Chile)
IGN	Institut Geographique National (France)
IGN	Instituto Geográfico Nacional (Spain)
IGS	International GNSS Service
I-JUSE	Institute of Japanese Union of Scientists and Engineers (Japan)
IKAROS	Interplanetary Kite-craft Accelerated by Radiation of the Sun (Japan)
ILRS	International Laser Ranging Service
INACH	Institute for Antarctic Research Chile
INAF	Istituto Nazionale di Astrofisica (Italy)
INGV	Institute of Geophysics and Volcanology (Italy)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
InSAR	Interferometric Synthetic Aperture Radar
IP	Internet Protocol
IRA	Istituto di RadioAstronomia (Italy)
IRASR	Institute for Radio Astronomy and Space Research (New Zealand)
IRIS	International Radio Interferometric Surveying
ISACCO	Ionospheric Scintillations Arctic Campaign Coordinated Observation
ISBN	International Standard Book Number
ITRF	International Terrestrial Reference Frame
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
IYA	International Year of Astronomy
JADE	JApanese Dynamic Earth observation by VLBI
JARE	Japanese Antarctic Research Expedition (Japan)
JAXA	Japan Aerospace Exploration Agency (Japan)
JENAM	Joint European and National Astronomy Meeting
JIVE	Joint Institute for VLBI in Europe
JLRA	Joint Laboratory for Radio Astronomy (China)
JPL	Jet Propulsion Laboratory (USA)
KARAT	KAshima RAy-tracing Tools (Japan)
KAREN	Kiwi Advanced Research and Education Network (New Zealand)
KASI	Korea Astronomy and Space Science Institute (Korea)
KAT	Karoo Array Telescope (South Africa)
KBR	K-Band Ranging
KPGO	Kokee Park Geophysical Observatory (USA)
KSP	KeyStone Project (Japan)
KSRC	Kashima Space Research Center (Japan)
KTU	Karadeniz Technical University (Turkey)
KTU-GEOD	Karadeniz Technical University (KTU), Department of Geomatics Engineering (Turkey)
KVG	Korea VLBI system for Geodesy (Korea)
KVN	Korean VLBI Network
LAB	Laboratoire d'Astrophysique de Bordeaux (France)
LBA	Long Baseline Array (Australia)
LCP	Left Circular Polarization

LEO	Low Earth Orbit
LHC	Left Hand Circular
LINZ	Land Information New Zealand (New Zealand)
LLR	Lunar Laser Ranging
LNA	Low Noise Amplifier
LO	Local Oscillator
LOD	Length Of Day
LPF	Low Pass Filter
LSM	Least Squares Method
MAO	Main Astronomical Observatory (Ukraine)
MARBLE	Multiple Antenna Radio-interferometry for Baseline Length Evaluation
MCB	Monitor and Control Bus
MCI	Monitor and Control Infrastructure
MERIT	Monitoring of Earth Rotation and Intercomparison of the Techniques of Observation and Analysis
MEX	Mars Express
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MOBLAS	MOBile LASer Ranging System
MODEST	MODel and ESTimate
MPI	Max-Planck-Institute (Germany)
MPIfR	Max-Planck-Institute for Radioastronomy (Germany)
MTLRS	Modular Transportable Laser Ranging System
NAO	National Astronomical Observatories (China)
NAOJ	National Astronomical Observatory of Japan (Japan)
NAR	Noise-Adding Radiometer
NASA	National Aeronautics and Space Administration (USA)
NASU	National Academy of Sciences of Ukraine (Ukraine)
NCAR	National Center for Atmospheric Research (USA)
NCEP	National Centers for Environmental Prediction (USA)
NCRIS	National Collaborative Research Infrastructure Strategy (Australia)
NDRE	Norwegian Defence Research Establishment (Norway)
NEOS	National Earth Orientation Service (USA)
NEQ	Normal Equation System
NetCDF	Network Common Data Form
NEXPReS	Novel EXploration Pushing Robust e-VLBI Services
NGII	National Geographic Information Institute (Korea)
NGS	National Geodetic Survey (USA)
NGSLR	Next Generation Satellite Laser Ranging
NICT	National Institute of Information and Communications Technology (Japan)
NII	National Institute of Informatics (Japan)
NIPR	National Institute of Polar Research (Japan)
NMA	Norwegian Mapping Authority (Norway)
NMF	Niell Mapping Function
NNR	No-Net-Rotation

NNT	No-Net-Translation
NOAA	National Oceanic and Atmospheric Administration (USA)
NOFS	U.S. Naval Observatory, Flagstaff Station (USA)
NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NRF	National Research Foundation (South Africa)
NSF	National Science Foundation (USA)
NTT	New Technology Telescope (Chile)
NVI	NVI, Inc. (USA)
Ny-SMAC	Ny-Ålesund Science Managers Committee
OAN	Observatorio Astronómico Nacional (Spain)
OCA	Observatoire de la Côte d'Azur (France)
OCARS	Optical Characteristics of Astrometric Radio Sources
OPAR	Observatoire de Paris (France)
OPC	(IVS) Observing Program Committee
OS	Operating System
OSI	Operator Software Impact
OSO	Onsala Space Observatory (Sweden)
PARNASSUS	Processing Application in Reference to NICT's Advanced Set of Softwares Usable for Synchronization
PCB	Printed Circuit Board
PEACESAT	Pan-Pacific Education and Communication Experiments by Satellite
PERSAC	Pulkovo EOP and Reference Systems Analysis Center (Russia)
PFB	Polyphase Filter Bank
PLO	Phase Locked Oscillator
PMD	Politecnico di Milano DIIAR (Italy)
POLARIS	POLar motion Analysis by Radio Interferometric Surveying
POP	Point of Presence
PPP	Precise Point Positioning
PRARE	Precise RAnge and Range-rate Equipment
PSD	Power Spectrum Density
QRFH	Quad Ridge Feed Horn
QZSS	Quasi Zenith Satellite System (Japan)
RAEGE	Red Atlántica de Estaciones Geodinámicas y Espaciales
RAS	Russian Academy of Sciences (Russia)
RCP	Right Circular Polarization
RDBE	Roach Digital Back End
RDV	Research and Development sessions using the VLBA
REFAG	Reference Frames for Applications in Geosciences
RF	Radio Frequency
RFI	Radio Frequency Interference
RHC	Right Hand Circular
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
ROM	Real Observatorio de Madrid (Spain)
RRFID	Radio Reference Frame Image Database

RT	Radio Telescope
RTK	Real-Time Kinematic
RTW	Radio Telescope in Wettzell
SAC	Satellite Application Centre
SAI	Sternberg State Astronomical Institute (Russia)
SATA	Serial Advanced Technology Attachment
SBIR	Small Business Innovation Research
SCG	SuperConducting Gravimeter
SDK	Software Development Kit
SEAC	Sociedad Española de Aplicaciones Cibernéticas (Spain)
SEFD	System Equivalent Flux Density
SHAO	SHanghai Astronomical Observatory (China)
SI	Special Issue
SINEX	Solution INdependent EXchange
SK	Spectral Kurtosis
SKA	Square Kilometre Array
SLR	Satellite Laser Ranging
SMHI	Swedish Meteorological and Hydrological Institute (Sweden)
SNAP	Standard Notation for Astronomical Procedures
SNR	Signal to Noise Ratio
SOD	Site Occupation Designator
SPb	Saint-Petersburg (Russia)
SPEED	Short Period and Episodic Earth rotation Determination
SPU	Saint-Petersburg University (Russia)
SPV	Signal Path Variation
SRIF	Square Root Information Filter
SRT	Sardinia Radio Telescope (Italy)
SRTM	Shuttle Radar Topography Mission
SSA	Singular Spectrum Analysis
SSAI	Science Systems and Applications, Inc. (USA)
STEREO	Solar TErrestrial RElations Observatory
TAC	Totally Accurate Clock
TAI	Temps Atomique International (International Atomic Time)
TAL	Terrestrial Air Link
TANAMI	Tracking Active galactic Nuclei with Australia Milliarcsecond Interferometry (Australia)
TanDEM-X	TerraSAR-X add-on for Digital Elevation Measurement (Germany)
TCE	Time Comparison Equipment
TDC	(IVS) Technology Development Center
TEC	Total Electron Content
TEMPO	Time and Earth Motion Precision Observations
TerraSAR-X	Terra Synthetic Aperture Radars X-band (Germany)
TIGO	Transportable Integrated Geodetic Observatory (Germany, Chile)
TLRS	Transportable Laser Ranging System
TRF	Terrestrial Reference Frame

TTW	TWIN-Telescope Wettzell (Germany)
TU	Technische Universität
TUM	Technical University of Munich (Germany)
TWSTFT	Two-Way Satellite Time and Frequency Transfer
UEN	Up East North
UMTS	Universal Mobile Telecommunications System
UNAVCO	University NAVSTAR Consortium
UNICAMP	Universidade Estadual de Campinas (Brazil)
UNITEC-1	UNIsec Technological Experiment Carrier-1 (Japan)
URSI	Union Radio-Scientifique Internationale
USB	Unified S-Band
USB	Upper Side Band
USNO	United States Naval Observatory (USA)
USP	Universidade de São Paulo
UT	Universal Time
UT1	Universal Time
UTAS	University of TASmania (Australia)
UTC	Coordinated Universal Time
u-VLBI	Ultra High Sensitivity VLBI
V2PEG	VLBI2010 Project Executive Group
VC	Video Converter
VDIF	VLBI Data Interchange Format
VERA	VLBI Exploration of Radio Astrometry
VEX	VLBI EXchange format
VHDL	Very High-level Design Language
VieVS	Vienna VLBI Software
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Function
VSI	VLBI Standard Interface
VSI-C	Metsähovi VSI-H Converter board
VSI-H	VLBI Standard Interface Hardware
VSI-S	VLBI Standard Interface Software
VSOP	VLBI Space Observatory Program
VSR	VLBI Science Recorder
VSSP	Versatile Scientific Sampling Processor
VTP	VLBI Transport Protocol
VTRF	VLBI Terrestrial Reference Frame
WACO	WAshington COrrelator (USA)
WEGENER	Working Group of European Geoscientists for the Establishment of Networks for Earth-science Research
WG	Working Group
WVR	Water Vapor Radiometer
WVSR	Wideband VLBI Science Recorder
WWW	World Wide Web

XDM	eXperimental Development Model
ZTD	Zenith Total Delay
ZWD	Zenith Wet Delay

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14. ABSTRACT
This volume of reports is the 2010 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the components of IVS. The 2010 Annual Report documents the work of these IVS components over the period January 1, 2010 through December 31, 2010. The reports document changes, activities, and progress of the IVS. The entire contents of this Annual Report also appear on the IVS Web site at http://ivscc.gsfc.nasa.gov/publications/ar2010.

15. SUBJECT TERMS
Geodesy, astrometry, VLBI, geophysics, Earth orientation, very long baseline interferometry, interferometry, radio astronomy, geodynamics, reference frames, terrestrial reference frame, celestial reference frame, length of day, Earth system science, Earth rotation.

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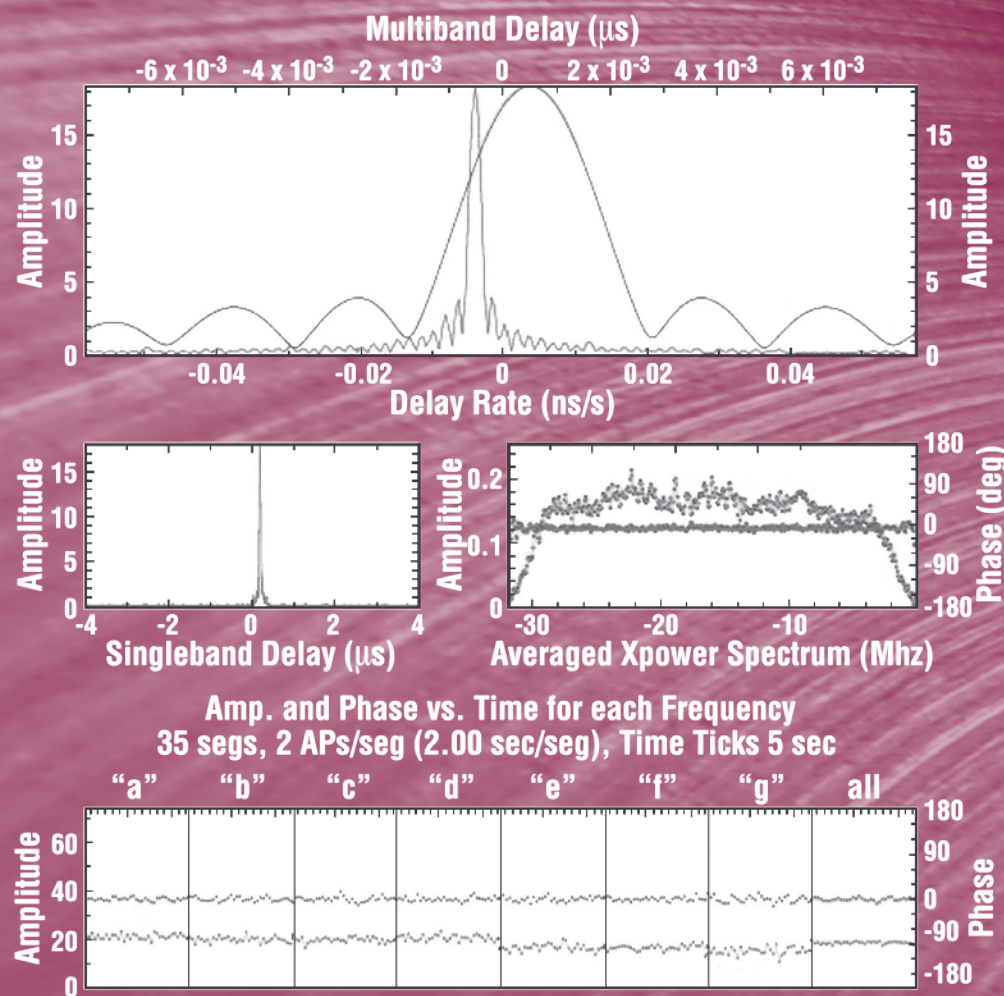

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