National Aeronautics and Space Administration

NASA/TP-2008-214162

International VLBI Service for Geodesy and Astrometry

2007 Annual Report

Edited by
D. Behrend and K.D. Baver

IVS Coordinating Center
May 2008

www.nasa.gov

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076–1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

Preface

This volume of reports is the 2007 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 2007 Annual Report documents the work of the IVS components for the calendar year 2007, our ninth year of existence. The reports describe changes, activities, and progress of the IVS. Many thanks to all IVS components who contributed to this Annual Report.

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

`http://ivscc.gsfc.nasa.gov/publications/ar2007`

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 2007.
- The last section includes reference information about IVS: the Terms of Reference, the lists of Member and Affiliated organizations, the IVS Associate Member list, a complete list of IVS components, the list of institutions that contributed to this report, and a list of acronyms.

Table of Contents

Preface ... iii

About IVS ... 1

IVS Organization ... 2
IVS Component Map ... 4
IVS Directing Board ... 6
IVS Chair's Report ... 8

IVS Coordination ... 11

Coordinating Center Report ... 13
Analysis Coordinator Report ... 16
Network Coordinator Report ... 18
IVS Technology Coordinator Report ... 26

Network Stations ... 31

Badary Radio Astronomical Observatory ... 33
Fortaleza Station Report for 2007 ... 37
Goddard Geophysical and Astronomical Observatory ... 41
Hartebeesthoek Radio Astronomy Observatory (HartRAO) ... 45
Hobart, Mt. Pleasant, Station Report for 2007 ... 49
Kashima 34-m Radio Telescope ... 51
Kashima and Koganei 11-m VLBI Stations ... 55
Kokee Park Geophysical Observatory ... 59
Matera CGS VLBI Station ... 63
The Medicina Station Status Report ... 67
VERA Geodetic Activities ... 69
Noto Station Status Report ... 72
Ny-Ålesund 20 Metre Antenna ... 75
German Antarctic Receiving Station (GARS) O'Higgins ... 78
The IVS Network Station Onsala Space Observatory ... 82
Sheshan VLBI Station Report for 2007 ... 86
Simeiz VLBI Station—New Status ... 88
Svetloe Radio Astronomical Observatory ... 92
JARE Syowa Station 11-m Antenna, Antarctica ... 94
Geodetic Observatory TIGO in Concepción ... 98
Tsukuba 32-m VLBI Station ... 102
Nanshan VLBI Station Report for 2007 ... 106
Westford Antenna ... 109
Fundamentalstation Wettzell - 20m Radiotelescope ... 113
Observatorio Astronómico Nacional – Yebes ... 117
Zelenchukskaya Radio Astronomical Observatory ... 121

Operation Centers ... 125

The Bonn Geodetic VLBI Operation Center ... 127
CORE Operation Center Report ... 129
NEOS Operation Center ... 132

Correlators ... **133**
The Bonn Astro/Geo Mark IV Correlator ... 135
Haystack Observatory VLBI Correlator ... 139
IAA Correlator Center ... 143
VLBI Correlators at Kashima ... 147
Tsukuba VLBI Correlator ... 151
Washington Correlator ... 155

Data Centers ... **159**
BKG Data Center ... 161
CDDIS Data Center Summary for the 2007 IVS Annual Report ... 163
Italy INAF Data Center Report ... 166
Data Center at NICT ... 168
Paris Observatory (OPAR) Data Center ... 172

Analysis Centers ... **175**
Geoscience Australia Analysis Center ... 177
Bordeaux Observatory Analysis Center Report ... 181
Matera CGS VLBI Analysis Center ... 185
DGFI Analysis Center Annual Report 2007 ... 187
FFI Analysis Center ... 191
The BKG/IGGB VLBI Analysis Center ... 193
GSFC VLBI Analysis Center ... 197
MIT Haystack Observatory Analysis Center ... 200
IAA VLBI Analysis Center Report 2007 ... 204
Vienna IGG Special Analysis Center Annual Report 2007 ... 208
Italy INAF Analysis Center Report ... 212
JPL VLBI Analysis Center Report for 2007 ... 214
IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine 218
Analysis Center at National Institute of Information and Communications Technology ... 220
Paris Observatory Analysis Center OPAR: Report on Activities, January - December 2007 ... 224
The IVS Analysis Center at the Onsala Space Observatory ... 228
PUL IVS Analysis Center Report 2007 ... 232
SHAO Analysis Center 2007 Annual Report ... 235
U.S. Naval Observatory VLBI Analysis Center ... 238
USNO Analysis Center for Source Structure Report ... 242

Technology Development Centers ... **245**
Canadian VLBI Technology Development Center ... 247
FFI Technology Development Center - Software Development ... 249
GSFC Technology Development Center Report ... 250
Haystack Observatory Technology Development Center ... 253
Technology Development Center at NICT ... 257
The IVS Technology Development Center at the Onsala Space Observatory ... 261

Bibliography ... **265**
Bibliography ... 267

IVS Information **283**
IVS Terms of Reference 285
IVS Member Organizations 295
IVS Affiliated Organizations 296
IVS Associate Members 297
IVS Permanent Components 308
Addresses of Institutions of Authors Contributing to this Report 312
List of Acronyms 318

About IVS

About IVS

IVS Organization

Objectives

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

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

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

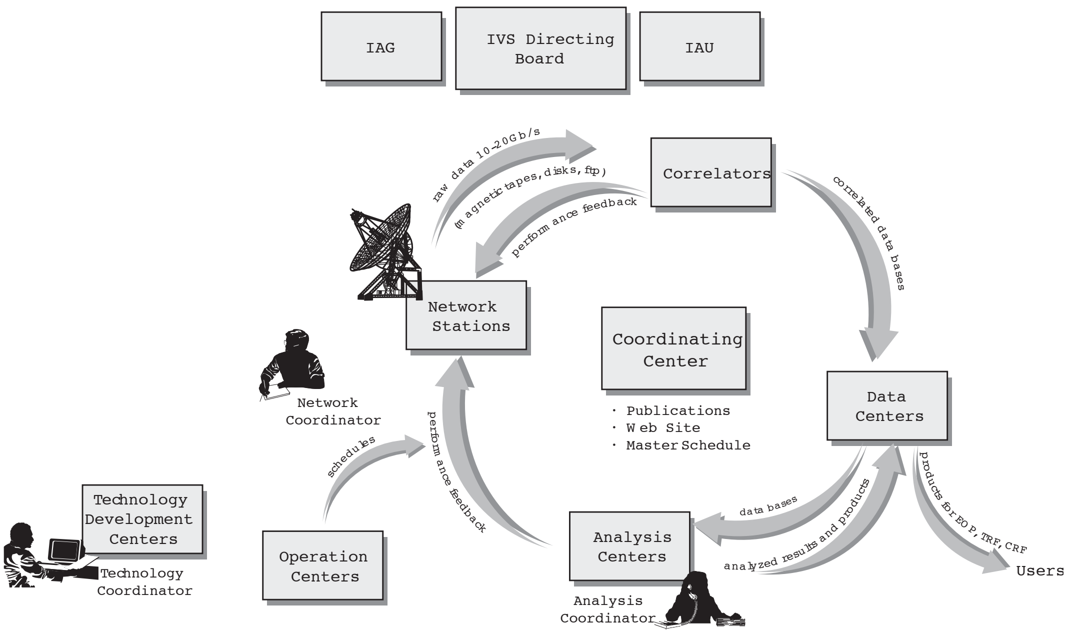
Realization And Status Of IVS

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

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

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

ORGANIZATION OF INTERNATIONAL VLBI SERVICE



IVS Member Organizations

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

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

IVS Affiliated Organizations

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

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)

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

Further significant products are

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

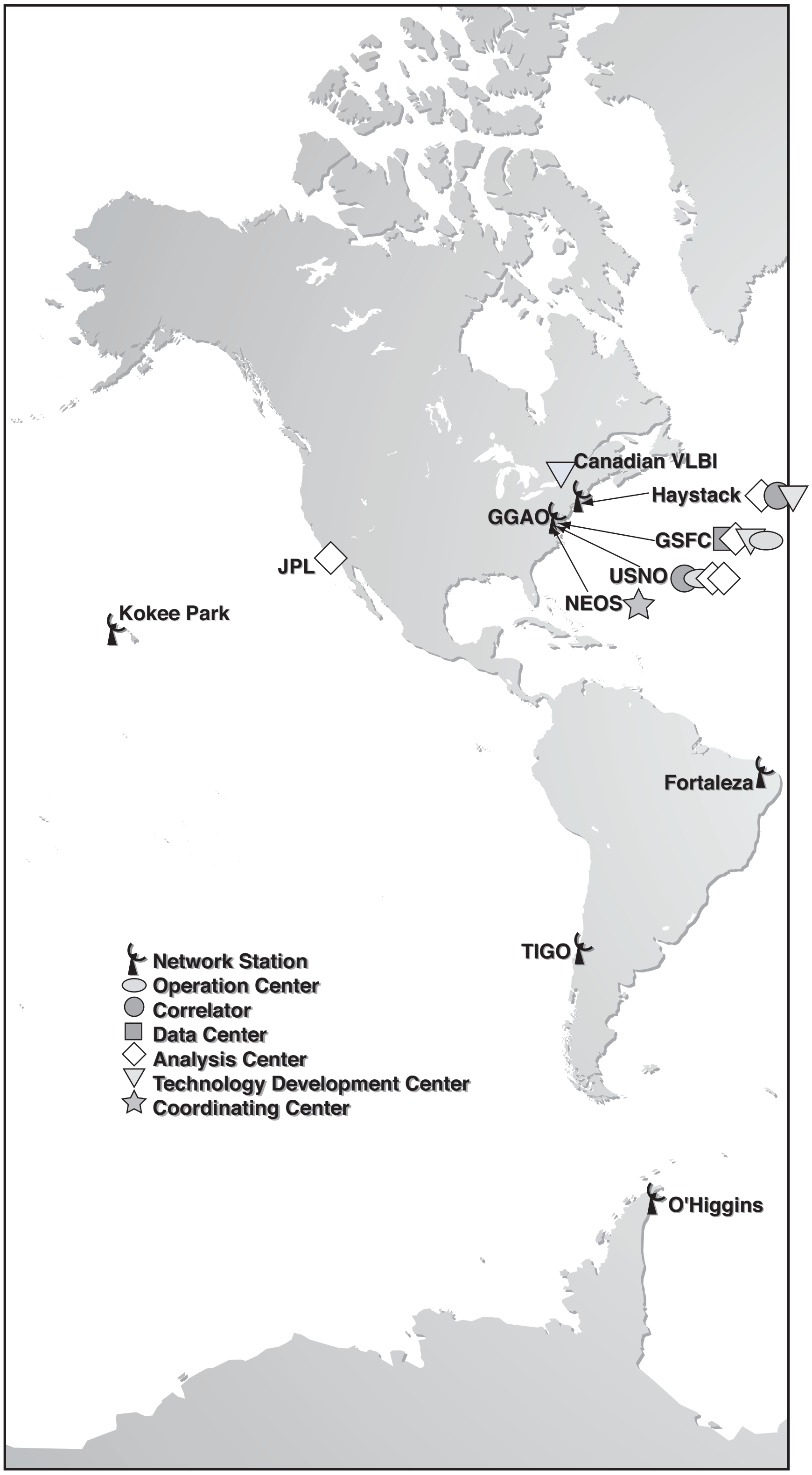
All VLBI data and results in appropriate formats are archived in data centers and publicly available for research in related areas of geodesy, geophysics and astrometry.

IVS Component Map

IVS Components by Country

Country	Qty.
Australia	2
Austria	1
Brazil	1
Canada	1
Chile	1
China	3
France	3
Germany	8
Italy	7
Japan	12
Norway	3
Russia	7
South Africa	1
Spain	1
Sweden	3
Ukraine	2
USA	16
Total	**72**

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




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

IVS Directing Board

NAME: Harald Schuh

AFFILIATION: Vienna University of Technology, Austria

POSITION: Chair and IAG Representative

TERM: ex officio

NAME: Yoshihiro Fukuzaki

AFFILIATION: Geographical Survey Institute, Japan

POSITION: Networks Representative

TERM: Feb 2007 to Feb 2011

NAME: Dirk Behrend

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

POSITION: Coordinating Center Director

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: Patrick Charlot

AFFILIATION: Bordeaux Observatory, France

POSITION: IAU Representative

TERM: ex officio

NAME: Ed Himwich

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

POSITION: Network Coordinator

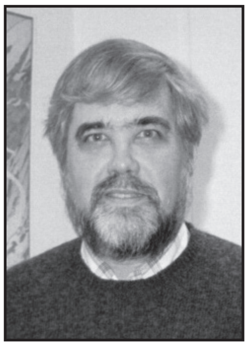
TERM: permanent

NAME: Andrey Finkelstein

AFFILIATION: Institute of Applied Astronomy, Russia

POSITION: At Large Member

TERM: Feb 2007 to Feb 2009



NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

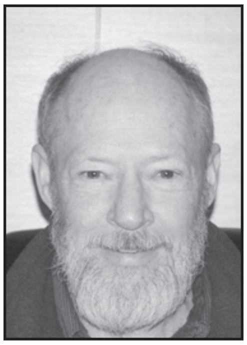
TERM: Feb 2007 to Feb 2011

NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative

TERM: ex officio



NAME: Arthur Niell

AFFILIATION: Haystack Observatory, USA

POSITION: Analysis and Data Centers Representative

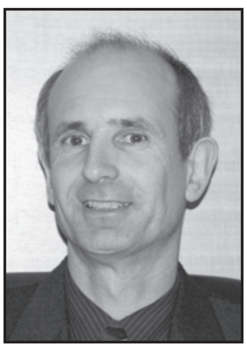
TERM: Feb 2005 to Feb 2009

NAME: Ray Norris

AFFILIATION: Australia Telescope National Facility, Australia

POSITION: FAGS Representative

TERM: ex officio



NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent

NAME: William Petrachenko

AFFILIATION: National Resources Canada, Canada

POSITION: Technology Development Centers Representative

TERM: Feb 2005 to Feb 2009

NAME: Oleg Titov

AFFILIATION: Geoscience Australia, Australia

POSITION: At Large Member

TERM: Sept 2007 to Feb 2009

NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

TERM: permanent

NAME: Xiuzhong Zhang

AFFILIATION: Shanghai Astronomical Observatory, China

POSITION: At Large Member

TERM: Sept 2007 to Feb 2009

IVS Chair's Report

Harald Schuh,
Vienna University of Technology

At the 17th Directing Board Meeting, held on February 24, 2007, Wolfgang Schlüter's term as IVS Chair came to an end and I was elected as the new chair. Wolfgang had served two four-year terms spanning the whole time since the inception of the IVS. I would like to take this opportunity to express my sincere gratitude and warm thanks to Wolfgang, who did an excellent job during all those first years for the IVS. He considerably contributed to the strong role that IVS plays today within the IAG and IAU.

With the 2007 Annual Report the IVS components report about their progress and activities, which were conducted during the service's ninth year of existence. I would like to thank the IVS Associate Members for their contributions over the course of the year, in particular for providing their reports in time. Timely appearance of the Annual Report is always an ambitious goal and is highly appreciated for maintaining this volume as a real information exchange tool for the community and related groups. I thank the editors for the timely release.

In 2007, IVS observing activities could be even extended as compared to the previous year, a fact that in view of the limited resources can be attributed to optimized coordination by the Coordinating Center and strong support from all components. 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 carried out continuously by the Network Stations, the Correlators, the Data Centers, and the Analysis Centers and is the basis for the regular provision of precise IVS products. In the following I would like to emphasize those activities performed in 2007 that go beyond the normal work load.

IVS Contribution to the Global Geodetic Observing System (GGOS)

Integration and combination in the framework of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy will be the main challenge for the international geodesy in the coming decades. GGOS will go beyond the integration of geodetic space techniques (VLBI, SLR, GNSS, DORIS) as it includes also techniques measuring terrestrial gravity, the global Earth gravity field, sea level, and even the magnetic field. Thus, a consistent combination of all geometric and physical techniques will eventually be required. GGOS, which just recently has been changed from an IAG project to a permanent IAG component, will play an essential role in helping to solve environmental and societal problems. Many 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 2007 was to establish the IVS as an efficient and reliable partner within GGOS and also to increase the awareness in the public and in the scientific community about the importance of VLBI.

VLBI2010 and the VLBI2010 Committee (V2C)

The VLBI2010 Committee (V2C), which was established by the IVS Directing Board in September 2005, is tasked with promoting the ambitious goals set by the VLBI2010 report "VLBI2010: Current and Future Requirements for Geodetic VLBI Systems" released by IVS Working Group 3. I am very pleased to know that the VLBI2010 Committee, chaired by Bill Petrachenko, has been extremely busy in 2007 with frequent telecons and additional face-to-face meetings. The results provided so far are very useful and will be summarized in a report with recommendations that can be used as benchmark for new VLBI systems. Members of the V2C are (alphabetically) Dirk Behrend, Johannes Böhm, Brian Corey, Rüdiger Haas, Yasuhiro Koyama, Dan MacMillan, Zinovy Malkin, Arthur Niell, Bill Petrachenko, and Gino Tuccari. I would like to thank them all for taking over the responsible leading role in the realization of the VLBI2010 visions.

The V2C is tasked with providing the specifications for the next generation VLBI system. Part of the VLBI2010 plan is that also non-VLBI2010 antennas (legacy or new) can still take part in geodetic VLBI sessions. Thus, antennas that are slower than the envisaged VLBI2010 antennas and/or that are observing on X-band and S-band only will still be important contributors to the IVS observing program. Right now several countries plan to develop or purchase new VLBI systems and they need the specifications. I highly appreciate that Geoscience Australia (GA), Australia; Auckland University of Technology (AUT), New Zealand; Korea Astronomy & Space Science Institute (KASI) and National Geographic Information Institute (NGII), Korea; and the Bundesamt für Kartographie und Geodäsie (BKG), Germany started activities to implement new telescopes to support the vision of VLBI2010. I would like to congratulate them on these ambitious projects and wish them success for the realization in the next years. With the new antennas and a possible re-opening of a radio telescope at Fairbanks, the global coverage of geodetic VLBI is getting better, but it is still far from being optimal. Thus, ideas and proposals for new stations are more than welcome.

However, VLBI will always be at the top-end, concerning the quality of the results but also concerning the costs compared, for instance, to GNSS receiving systems.

Special Issue on Very Long Baseline Interferometry of the Journal of Geodesy

In June 2007 a Special Issue on Very Long Baseline Interferometry (VLBI) of the Journal of Geodesy (JoG) was published with guest editors nominated by the IVS (Harald Schuh, Axel Nothnagel, and Chopo Ma). Since the establishment of the IVS the coordination of international VLBI has significantly improved yielding valuable scientific and operational results for the whole community inside and outside geodesy. However, the number of relevant scientific publications on VLBI in peer-reviewed journals was still rather small, because most of the scientific discussion and exchange had been done via the proceedings of international and regional VLBI conferences organized under the auspices the IVS. Therefore, it was the right time for a Special Issue on VLBI in the Journal of Geodesy for providing information about the state-of-the-art in VLBI research to a broader community. After the call for contributions had been issued, the editors were pleased to see a strong response from the various IVS analysis groups and also from various users of VLBI results. Manuscripts, some including new areas of application of the VLBI system, such as combination with other geodetic space techniques, were submitted by institutions from all over the world. All manuscripts went through the standard peer-review process of the Journal of Geodesy, ensuring that the quality of the published articles was the same as in a standard issue of the JoG. The result was a Special Issue which should provide the reader with a better understanding of the VLBI technique, the organization of the IVS, as well as a variety of scientific applications such as the celestial and terrestrial reference frames including investigations of the observed radio sources, Earth orientation, and atmospheric sciences (troposphere and ionosphere). As Chair of the IVS and also on behalf of the editorial team, I would like to thank all the contributors to the Special Issue as well as the reviewers, who made it possible to realize this document within a reasonable time frame.

IVS Working Group 4 on "VLBI Data Structures" Established

In September 2007 a new IVS Working Group was established as a response to a strong need of new, common VLBI data structures. This Working Group will examine the data structure currently used in VLBI data processing and investigate what data structure is likely to be needed in the future. It will design a data structure that meets current and anticipated requirements for individual VLBI sessions including a cataloging, archiving, and distribution system. Further, it will prepare the transition capability through conversion of the current data structure as well as cataloging and archiving softwares to the new system. John Gipson, Chair of this new Working Group (IVS WG 4), will give a first presentation at the IVS General Meeting in Saint Petersburg, Russia (March 2008).

Meeting Events in 2007

In April 2007, the 18th Working Meeting on European VLBI for Geodesy and Astrometry (EVGA), the 8th IVS Analysis Workshop, and the 2nd IVS VLBI2010 Working Meeting were held at the Institute of Geodesy and Geophysics, Vienna University of Technology, Austria. All three meetings were successful events with a high number of participants. The scientific organization of the meetings was performed in close collaboration with the IVS Analysis Coordinator and Chair of the EVGA, Axel Nothnagel; the local organizing committee was led by Johannes Böhm and Jörg Wresnik.

The 4th IVS Technical Operations Workshop (TOW) was held at the Haystack Observatory from April 30–May 3, 2007. TOW is an important meeting for exchanging experience in operation and for providing information about new developments. "Hands-on" training and teaching in classes is the key for the success of TOW. It was another very useful meeting of this type and I would like to thank Ed Himwich, Dirk Behrend, and Heidi Johnson and the local organizers at Haystack for their commitment to the TOW.

In September 2007, a face-to-face meeting of the VLBI2010 Committee and the 18th Directing Board Meeting were held at the Institute of Geodesy and Geoinformation of the University of Bonn, Germany. I take this opportunity to thank Axel Nothnagel for making the meetings successful and the stay a very pleasant one. In the week directly following these meetings, the 6th International e-VLBI Workshop was held at MPI, Bonn. Many thanks to the Program Committee and the LOC, chaired by Walter Alef, who were responsible for this very fruitful and efficient meeting.

Summary information about all IVS events and activities is available in the Newsletters 17, 18, and 19. The Newsletter is an excellent means to transfer information to everybody. The editor team, Dirk Behrend, Hayo Hase, and Heidi Johnson, presented interesting and up-to-date information. They once again did an excellent job, which is highly appreciated.

Changes in the Directing Board in 2007

The elections of the two Networks Representatives as well as of the Correlators and Operation Centers Representative for the term 2007 to 2011 were held in December 2006. Yoshihiro Fukuzaki (GSI, Japan) and Hayo Hase (BKG, Germany and TIGO, Chile) were elected to represent the IVS Network Stations, and Kerry Kingham (USNO, USA) was elected as the Representative of the Correlators and Operation Centers. For the at large positions (term 2007 to 2009) Andrey Finkelstein, Russia; Oleg Titov, Australia; and Xiuzhong Zhang, China were elected by the Directing Board in January 2007. In July 2007, the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) appointed Ray Norris (ATNF Australia) as its new representative on the IVS 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 Coordination

IVS Coordination

Coordinating Center Report

Dirk Behrend

Abstract

This report summarizes the activities of the IVS Coordinating Center during the year 2007 and forecasts activities planned for the year 2008.

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 2007

During the period from January through December 2007, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated, with local committees, two IVS Directing Board meetings, in Wettzell, Germany (February 2007) and Bonn, Germany (September 2007). 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. In June 2007 the e-mail lists were changed so that only submissions from e-mail list members and white list members are being accepted and distributed. By the end of 2007 all communications services were ported from the previous HP platform to a Linux platform.
- Publications: Published the 2006 Annual Report in spring 2007. Published three editions of the IVS Newsletter in April, August, and December 2007. All publications are available electronically as well as in print form.
- 2007 Master Schedule: Generated and maintained the master observing schedule for 2007. Coordinated VLBI resources for observing time, correlator usage, tapes, and disk modules. Coordinated the usage of Mark 5 systems at IVS stations and efficient deployment of disk modules.
- 2008 Master Schedule: Generated the proposed master schedule for 2008 and received approval from the Observing Program Committee.
- Meetings: Coordinated, with the Local Committee, the fourth IVS Technical Operations Workshop, held at Haystack Observatory in April/May 2007. Chaired the Program Committee for the meeting. Coordinated, with the Local Committee, the fifth IVS General Meeting,

to be held in Saint Petersburg, Russia in March 2008. Chaired the Program Committee for the meeting.

- Observing Program Committee (OPC): Coordinated meetings of the OPC to monitor the observing program, review problems and issues, and discuss changes.

Figure 1. Logo of the fourth IVS Technical Operations Workshop (TOW).

3. Staff

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

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

4. Plans for 2008

The Coordinating Center plans for 2008 include the following:

- Maintain IVS Web site and e-mail system; implement new station pages.
- Publish the 2007 Annual Report (this volume).
- Coordinate, with the local committee, the fifth IVS General Meeting to be held in Saint Petersburg, Russia in March 2008.
- Publish Proceedings of the fifth IVS General Meeting.
- Support Directing Board meetings in 2008.
- Coordinate the 2008 master observing schedule and IVS resources.
- Publish Newsletter issues in April, August, and December.

Analysis Coordinator Report

A. Nothnagel, S. Böckmann, T. Artz

Abstract

IVS analysis coordination issues in 2007 are reported here. Routine EOP combinations have been changed to solely using datum-free normal equations as input improving the overall agreement between analysis centers to 50 – 60 μas in all components.

1. General Issues

The "Eighth IVS Analysis Workshop" was held at the Vienna University of Technology, Vienna, Austria, on April 14, 2007, in connection with the 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting. The workshop was attended by about 40 participants who enjoyed the hospitality of the Vienna VLBI group.

In his introductory remarks the IVS Analysis Coordinator emphasized that the combination process of VLBI results with other geometric space geodetic techniques (GNSS, DORIS, and SLR) is the most important challenge of IVS analysis activities in the current time frame. Without an improved attitude of the IVS Analysis Centers towards combination requirements and timeliness issues, the IVS will run into the danger of losing its well earned reputation for state-of-the-art products.

Further presentations and discussions included topics like cable calibration, master analysis documentation, pole tide model, 256 Mb/s vs. 1 Gb/s recording, reference temperatures and pressure, current status of the OCCAM software, combination of Intensives, atmospheric refraction issues, implementation of P03 precession, singular value decomposition and cluster analysis, post VLBI solution tools, as well as an introduction to the Working Group on ICRF2. A number of these topics do require more efforts on an international level and all IVS Analysis Centers are asked to volunteer for a more active role in specific aspects of the analysis chain. The large number of individual problem areas cannot be handled efficiently by a few individuals alone. This is the reason why many topics are still on the "To do" list and progress lags behind expectations.

2. IVS Operational Data Analysis and Combination

On January 1, 2007, a new combination process for the two IVS EOP series (rapid and quarterly solutions) has been made operational. Routine combinations of IVS are now being made exclusively on the basis of datum-free normal equations in SINEX format. In 2007, five IVS Analysis Centers (BKG, DGFI, GSFC, IAA, and USNO) contributed to the IVS combined products by providing input in the correct format. 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 the five IVS Analysis Centers are available. The SINEX file submissions should not be later than 48 hours after the correlation is completed. A Web page is automatically updated which states the timeliness of the latest submissions of the R1 and R4 sessions. As can be seen on this Web page, the timeliness requirement is exceeded too often for various reasons in logistics and personnel.

For the quarterly solution, updated every three months, almost all available data of 24-hour sessions from 1984 onwards are used. Since this series is designed for EOP determinations, those sessions are excluded which are observed with networks of limited extension or which are scheduled for a different purpose like radio source monitoring.

The advantage of the new combination strategy is that one common terrestrial reference frame (e.g. ITRF2005) is applied after the combined datum-free normal matrix is generated. Thus, it is guaranteed that an identical datum is used in the combination process for all input series. After datum definition the combined system of normal equations is solved (inverted) and the full set of EOP (pole components, UT1–UTC, and their time derivatives as well as two nutation offsets in $d\psi$, $d\varepsilon$ w.r.t. the IAU2000A model) are extracted. These results are added to the two EOP time series in the IVS EOP Exchange format, the rapid solution file (e.g., ivs07r1e.eops) and the quarterly solution file (e.g., ivs07q4e.eops). Companion files containing the nutation offsets in the X, Y paradigm are routinely generated through a standard transformation process (e.g., ivs07r1X.eops, ivs07q4X.eops). The weighted RMS differences between the individual IVS Analysis Centers and the combined products have been reduced from roughly 80–100 μas to 50–60 μas in all components. On the IVS Analysis Coordinator's Web page additional information about the series, the residuals of the individual contributions w.r.t. the combined solution as well as comparisons with IGS and IERS EOP results are provided routinely.

At the same time the combined SINEX files (datum-free normal equations) are also available on the Web for further combination with other techniques. At present, this is done on an experimental basis only, but the IERS Analysis Coordinator is strongly pushing towards such a routine process.

3. Comparisons of Long-term Station Position Time Series

As part of the quality assessment for the IVS combined products, long-term time series of station positions of each individual IVS Analysis Center, derived from the submitted normal equations, have been compared with each other. Through this, systematic offsets in the height component of up to 1 cm have been detected between solutions analysed with the VLBI analysis software packages OCCAM and CALC/SOLVE. In order to find the reason for these discrepancies several models used in both software packages have been compared in close cooperation with the VLBI group at DGFI (Deutsches Geodätisches Forschungsinstitut, München). It turned out that the systematic offsets were mainly caused by differences in the pole tide model. In the CALC/SOLVE solutions, a model for the annual mean pole was used, which was not in agreement with the IERS Conventions 2003. Therefore, all analysis centers using CALC/SOLVE reprocessed their solutions with the conventional pole tide model according to the IERS Conventions 2003 and most of the discrepancies disappeared. Since the IVS input to ITRF2005 was affected by the same inconsistency, the ITRF2005 may be affected by this oversight, though not to the full extent.

4. Personnel

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

Sarah Böckmann	+49-228-733563	boeckmann@uni-bonn.de
Axel Nothnagel	+49-228-733574	nothnagel@uni-bonn.de
Thomas Artz	+49-228-733563	thomas.artz@uni-bonn.de

Network Coordinator Report

Ed Himwich

Abstract

This report includes an assessment of the network performance in terms of lost observing time for the 2007 calendar year. Overall, the observing time loss was about 11.4%. A table of relative incidence of problems with various subsystems is presented. The most significant causes of loss were antenna reliability (accounting for about 34.6%), receiver problems (14.9%), unclassified problems (14.9%), rack problems (11.4%), and RFI (10.4%). There are prospects for Korea, India, and New Zealand to start contributing to IVS. New antennas are being purchased by Australia and New Zealand. The current situation for the handling of correlator clock adjustments by the correlators, which directly impacts UT1-UTC estimates from VLBI data, is reviewed. This is found generally to be a stable continuation of last year's results.

1. Network Performance

The network performance report is based on correlator reports for experiments in calendar year 2007. This report includes the 135 24-hour experiments that had detailed correlator reports available as of March 4, 2008. Results for 35 experiments were omitted because they were correlated at the VLBA, they have not been correlated yet, or correlation reports were not available on the IVS data centers. Experiments processed at the VLBA correlator were omitted because the information provided is not as detailed as from Mark IV correlators. The experiments that have not been correlated yet include mostly RD, JD, and T2 experiments from the second half of the year, as well as some OHIG experiments. The experiments without reports on the IVS data centers include all experiments processed by the Haystack correlator (10 plus one that has not been correlated yet). In summary, roughly 80% of the scheduled experiments for 2007 are included in this report.

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

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

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

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

For the 135 experiments from 2007 examined here, there are 907 station days or about 6.7 stations per experiment on average. Of these experiment days about 11.4% (or about 103 days) of the observing time was lost. For comparison to earlier years, see Table 1.

Table 1. Lost Observing Time

Year	**Percentage**
1999-2000*	11.8
2001	11.6
2002	12.2
2003	14.4
2004	12.5
2005	14.4
2006	13.6
2007	11.4

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

The lost observing time for 2007 was less than for 2006. It is not clear whether the year-to-year variations in lost observing time reflect real changes in the performance level or simply variations due to inaccuracies in the analysis method. It does seem, however, that despite the approximations in the analysis method, the calculated observing time loss has been running fairly consistently at the 12-14% level for several years. It should be noted that in the CONT05 experiments in 2005, where a special effort was made to achieve high reliability at some of the most reliable stations in the network, an observing time loss of only 4.0% was achieved for 165 scheduled station days. If the observing time losses are converted into VLBI data yield losses, then 2007 had about 23% VLBI data loss, 2006 about 27%, 2005 about 29%, 2004 about 25%, and 2003 about 29%.

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

For the purposes of this report, the stations were divided into two categories: (A) those that were included in 9 or more network experiments among those analyzed here, and (B) those in 6 or fewer. The distinction between these two groups was made on the assumption that the results would be more meaningful for the stations with more experiments. The average data loss from both groups this year were about equal.

There are 17 stations in the 9-or-more experiment category. Twelve stations observed in 44 or more experiments. Of the 17, 10 successfully collected data for approximately 90% of their expected observing time. Four more stations collected 75% or more. Three more stations collected more than 50% of their data. Two stations of the 17 collected only slightly more than 50% of the scheduled data. These statistics are somewhat better than last year. The top 11 stations are heavily exercised and quite reliable from year to year. The three lowest yielding stations had particular problems that have been or are being addressed.

There are 17 stations in the 6-or-fewer experiment category. The range of lost observing time for stations in this category was 0%-72%. The median success rate was about 3.6%, much better than last year. Overall the stations in this category lost about 10.5% of the 60 station days they observed; about 7% of the total analyzed were lost. It is notable that the performance for the stations that were in the fewest experiments has been comparable to the more heavily used stations for two years in a row now.

Although the results are not being reported for individual stations, a few stations deserve special recognition for how much their data collection improved from the previous year. Five stations improved the percentage of data they collected by more than 5%. These stations are Matera, Onsala, Ny-Ålesund, Noto, and Westford.

The losses were also analyzed by sub-system for each station. Individual stations can contact the network coordinator (Ed.Himwich@nasa.gov) for the sub-system break-down (and overall loss) for their station. A summary of the losses by sub-system (category) for the entire network is presented in Table 2. This table includes five years of data sorted by decreasing loss in 2007.

Table 2. Percentage Data Lost by Sub-system

Sub-System	**2007**	**2006**	**2005**	**2004**	**2003**
Antenna	34.6	19.0	24.4	32.9	17.8
Receiver	14.9	20.8	24.2	18.0	25.2
Unknown	14.9	4.0	3.3	10.1	12.6
Rack	11.4	16.3	5.1	6.8	5.0
RFI	10.4	11.6	6.2	5.0	9.3
Miscellaneous	7.6	18.0	8.0	8.0	6.0
Recorder	4.6	3.3	8.9	11.1	10.9
Shipping	1.0	0.0	0.2	1.4	6.1
Software	0.4	0.1	0.5	0.1	0.1
Clock	0.3	4.9	14.5	0.5	3.4
Operations	0.0	2.0	4.7	6.1	3.6

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

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

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

Miscellaneous This category includes several small problems that do not fit into other categories, mostly problems beyond the control of the stations, such as power, weather, and errors in the observing schedule provided by the Operation Centers. Starting with 2006, this category also includes errors due to tape operations at the stations that were forced to use tape because either they didn't have a disk recording system or they did not have enough media. There were very few tape related losses (0.5% overall) in 2007, reflecting the almost complete absence of tape use. This category is dominated by power and weather issues.

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

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

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

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

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

Shipping This category includes data that could not be correlated because the media were lost in shipping or held up in customs or because problems with electronic transfer prevented the data from being correlated with the rest of the experiment's data.

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

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

From the results it can be seen that antenna and receiver problems together account for almost 50% of the losses. This is larger than the last couple of years and is dominated by antenna problems. For 2007 the stations with significant antenna problems include Zelenchukskaya, Fortaleza, Svetloe, and Matera.

Stations with significant receiver problems include Fortaleza, Ny-Ålesund, and Zelenchukskaya. Most of these problems are in the category of reliability problems with the cryogenics, power supplies, and amplifiers. Some stations suffered from an unexplained roll-off in the X-band bandpass, which has been included in this category. Fortaleza is notable for having problems in reliability and roll-off.

The "Miscellaneous" category is smaller than last year and more like the results of earlier years. This is primarily due to a reduction in losses due to power outages.

The "Rack" category was smaller this year than last. The primary cause of losses in this catagory is due to the observed video BW being smaller than scheduled. Three stations: Fortaleza, Shanghai, and Badary had problems with this. However, the situation has now been corrected at all three stations.

The "RFI" category loss level is similar to last year's, which is larger than results from previous years. The higher level is primarily due to the fact that Matera, the station with the most severe RFI problems, was able to observe more since their antenna has been fixed.

The "Clock" category represents less loss than previous years. This is primarily due to the fact that there were no major Maser failures and that the consistency of clock offset reporting from the stations has improved.

The "Recorder" category is down significantly from previous years primarily because almost all recording is done on disk and the problems with the few tape recordings that were made are reported now in the "Miscellaneous" category. The decrease in data loss due to recorder operations from about 11% to about 4% probably represents the "disk dividend" we have been hoping to get as tape use is curtailed.

2. New Stations

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

3. Clock Offsets

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

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

Significant progress was made in 2005 in implementing these recommendations. The calendar year 2006 is the first one in which this approach was applied to all experiments. The greatly improved results obtained that year are reported in the 2006 Network Coordinator's Report. This has continued for 2007. The offset adjustment for Wettzell in 2007 is shown in Figure 1. The scatter of these measurements is very good for Mark IV correlators (Bonn, GSI, and WACO). Generally the variation is at the 0.1 μsecond level, but there are few larger outliers (a couple off the scale of the figure as well) for the Bonn correlator. It is not known if these outliers are due to typographic errors or if the adjustments for these experiments were larger than expected. They should be investigated. In any event, the results are greatly improved compared to years before 2006 where the adjustments were scattered over a range at least 10 times as large.

It is interesting to note that the adjustments for Wettzell used by the GSI (K5) correlator are biased by about 1-2 μseconds, including some jumps, compared to those used by the Mark IV correlators. If this is correct, it would bias UT1-UTC and add jumps to the estimates from GSI correlated experiments compared to Mark IV correlated experiments. As it happens, the GSI correlator is currently used only for "K" type Intensives and domestic Japanese 24-hour experiments. The UT1-UTC precision of these experiments is much less than that of the 24-hour international experiments, around 10-20 μseconds for the "K" type Intensives compared to a few μseconds for R1 and R4 experiments. Consequently, this bias does not significantly impact the results. In 2007 it was realized that the K5 correlator does not include the effect of the clock offset and rate in its calculation of the time-tags and delays that it produces [Y. Koyama (NICT), personal communication]. Thus the correlator clock model is not currently reflected in the UT1 results for the K5 correlator. This will be corrected in the future.

A further issue is how stable the UT1 rate measurements are. This depends on the accuracy of the correlator models for the Maser (and associated station electronics) rates for the observing stations. The desired accuracy of the IVS Working Group 2 report was for 0.3-0.5 μseconds/day. This translates into a clock rate of about 3.5e-12 to 5.8e-12. It would be desirable to have the correlator clock models consistent at a level 10% of that, 3e-13, or better. It turns out that it is possible to determine the station rates at about the level required from the formatter offset values recorded during 24-hour experiments.

A plot of the Correlator Clock Rate Model for Wettzell for 2007 using this approach is shown in Figure 2. It is difficult to see on the scale of the plot, but the clock rates used by the Mark IV correlators (Bonn, GSI, and WACO) vary at about the desired level, about 2e-13 (4e-13 peak-to-peak, i.e., simplifying by saying that the peak-to-peak is about twice the RMS). This is in line with last year's results and is an improvement of a factor of two over previous years. The rates

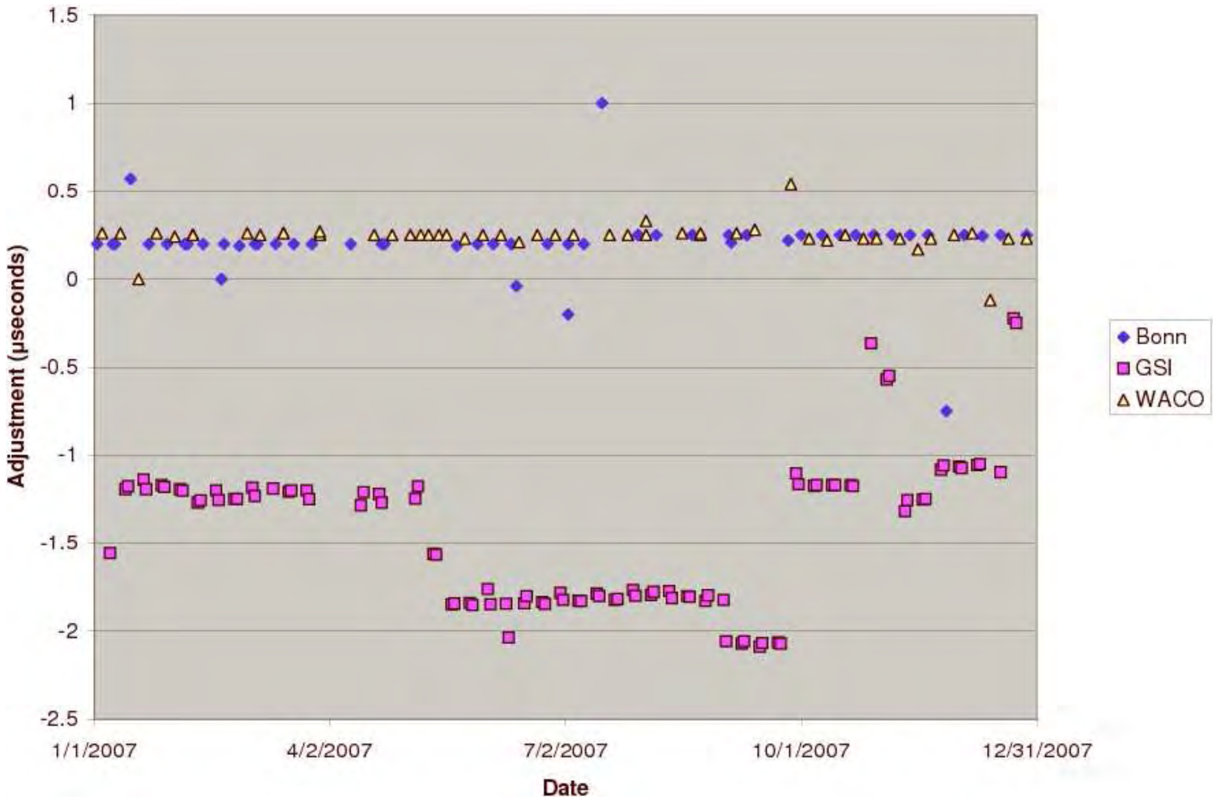


Figure 1. Wettzell Correlator UTC Clock Adjustments

for Wettzell used by the GSI correlator vary by about 1.7e-11 (peak-to-peak). These exceed the desired level by a factor of about three (not 30, as incorrectly reported in last year's report). As with UT1-UTC estimates for GSI, this is probably not an issue, given the lower precision of the experiments processed by this correlator. However, this should probably be improved. The reason for the scatter in the rates used by the GSI correlator is that they are determined from the clock offsets measured during the short span of data collected in the K Intensives [Y. Koyama (NICT), personal communication]. This explains the larger range of the values. The origin of the systematic nature of the rates is not clear, but presumably it is related to some systematic effect that is being sampled by the clock offset measurements. As mentioned previously the correlator clock model is not being taken into account in the results of the K5 correlator. But this is planned for the future.

Another area of concern is that different recording systems may require different adjustments. There is a difference between Mark IV and VLBA formatters of about 0.4 μseconds [K. Kingham (USNO), private communication]. This was accounted for when Kokee changed from using VLBA to Mark IV formatters. A value of 0.26 μseconds was measured between the K5 and the Mark IV formatters, with K5 later than Mark IV [Y. Koyama *et al.*, Timing Offset of the K5/VSSP System, IVS NICT TDC News No. 26, p. 6-8]. This compares well to the value that has been empirically determined from processing of K5 data at Mark IV correlators [K. Kingham (USNO), private communication].

It is also important to consider whether there are offsets between different recording rates within a given recording system. It was recently discovered that there appears to be a 8 μsecond

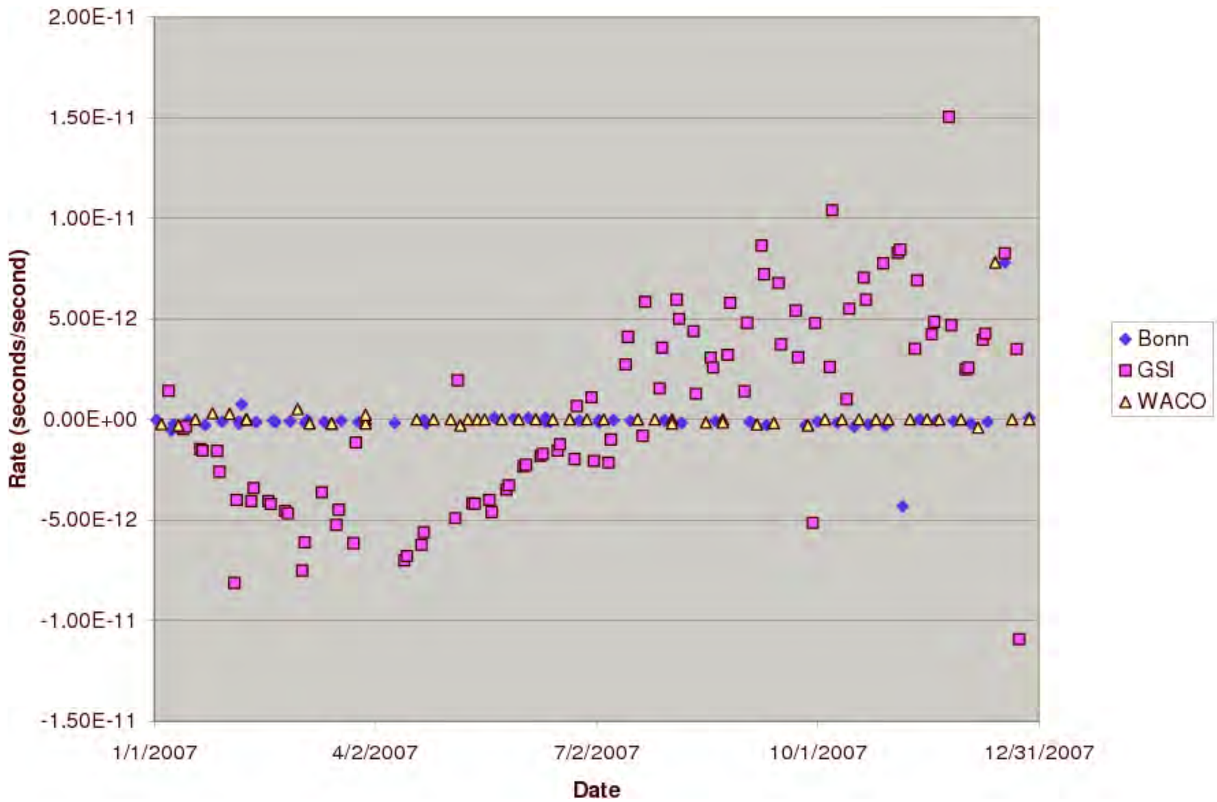


Figure 2. Wettzell Correlator Clock Rate Model

offset for the Mark IV formatter when the tape data rate is 18 MHz as compared to other lower data rates [D. Smythe, Timing Offset of the Mark IV Formatter, Haystack Observatory Mark 5 Memo #047]. This offset essentially affects only 1024 Mb/s recordings and 512 Mb/s 32 track recordings. Otherwise the Mark IV formatter is known to not have an offset between different data rates [D. Smythe (Haystack Observatory), private communication].

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

IVS Technology Coordinator Report

Alan Whitney

Abstract

The efforts of the Technology Coordinator in 2007 included the following areas: 1) support of work to implement a new geodetic VLBI system as outlined in the IVS Working Group 3 "VLBI2010" study, 2) continued development and deployment of e-VLBI, 3) 6th annual e-VLBI workshop held at MPI in Bonn, Germany, and 4) TOW workshop at Haystack Observatory. We will briefly describe each of these activities.

1. VLBI2010 Progress

Progress continues towards the goal of a next generation geodetic VLBI system. Some of the highlights include:

1.1. Development of the First Demonstration Broadband System

A collaboration of Haystack Observatory, NASA/GSFC and Honeywell implemented the first demonstration broadband system on the 5 m MV3 antenna at NASA/GSFC. The system has the following characteristics:

1. A commercial dual linear polarization feed to cover ~2-13 GHz, followed by two LNAs. The feed and LNAs are cooled to ~20 K.
2. Optical transmission of the full RF bandwidth to 'up/down converters' (UDCs) in the base of the antenna. Each UDC selects an arbitrary 500 MHz slice of the RF band and translates it to the proper Nyquist zone for sampling.
3. A digital backend (DBE1) which accepts up to four 500 MHz-wide IFs and separates each into fifteen adjacent 32 MHz-wide channels using polyphase filter band (PFB) technology, though only every other channel is recorded. In the full-up demo system, four dual polarization IFs of 500 MHz width each will be processed through eight PFBs, each IF creating 1 Gbps of data for a total of 8 Gbps.
4. The data are recorded on Mark 5B+ recorders, each capable of supporting 2 Gbps. Current experiments use two Mark 5B+ systems at each site for a total of 4 Gbps. The full-up demo system will use four Mark 5B+ systems at each site for a total of 8 Gbps at each site.
5. The data are processed on a standard Mark IV correlator slowed down by a factor of 2 from the real-time rate.

In November 2007 a successful experiment was conducted using a broadband demonstration system at MV3 (dual linear polarization) and a standard S/X system at Westford (single circular polarization). Results from this experiment appeared as expected except for some unexplained phase differences between cross-correlations of different polarization; this phenomenon is being investigated.

Plans are in progress to also implement the broadband system on the Westford antenna to allow tests of a single baseline with complete broadband systems on both antennas.

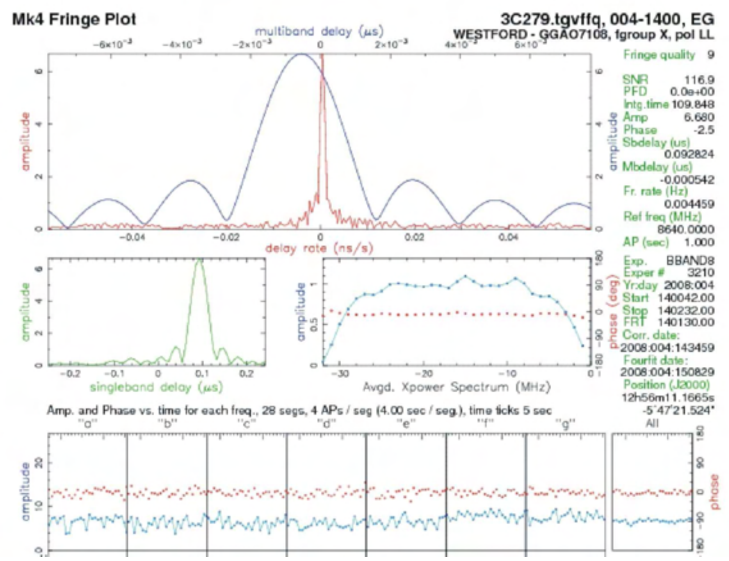


Figure 1. Fourfit plot of fringes from VLBI2010 demo experiment.

The characteristics of the commercial broadband feed currently being used are non-ideal for this work, and efforts are underway to have a new dual linear polarization feed designed by Per-Simon Kildal at Chalmers University, who has designed successful broadband feeds for other frequency ranges. This work is being partially supported by contributions from our Norwegian colleagues; others are expected to contribute to this effort as well. A new feed design could be ready within a year or so. The final VLBI2010 broadband system will broaden the IF bandwidths to 1 GHZ each and raise the data acquisition rate to at least 16 Gbps using a so-called 'burst-mode' technique where data for each individual scan, which may be 5-10 seconds in length, are buffered to high-speed electronic memory. Then, while the antenna is slewing for the next ∼30-45 seconds to the next source, the data are 'dribbled' off to a recording or data transmission system at a rate of ∼4 Gbps. This 4 Gbps rate will be supported by a single Mark 5C system (currently under development) or an e-VLBI data link at each site. One of the outstanding VLBI2010 system design issues is the specification and development of a delay/phase calibration sub-system. Work will proceed on this issue in 2008.

1.2. Antennas for VLBI2010

A 12 m diameter seems to have been pretty much selected for the VLBI2010 application, although at least two designs have been developed:

1. Patriot Antenna of Albion, Michigan, USA offers a 12 m antenna with an azimuth rate of 5 deg/sec and an elevation rate of 1 deg/sec. Australia and New Zealand have both placed orders for this antenna with deliveries expected in 2008. Some debate remains regarding whether these slew speeds are adequate; studies into this subject are still on-going.
2. Wettzell/BKG is developing a high slew speed 12 m antenna for use in their 'twin-antenna' project.

1.3. VLBI2010 Studies

A well-attended VLBI2010 workshop was held on 15 April 2007 in Vienna, Austria in conjunction with the EVGA meeting. Many papers relating to all aspects of VLBI2010 were presented, and many lively and fruitful discussions took place. In general, there was much enthusiasm and support for continued work and much interest in the development of demonstration and prototype hardware and software systems to support the goals of VLBI2010. The next VLBI2010 workshop will be held in March 2008 in St. Petersburg, Russia.

A number of studies related to VLBI2010 are still underway, some of which are attempting to determine the necessary minimum antenna slew speeds needed to create an observing program that will meet the VLBI goal of 1 mm accuracy in 24 hours with 12 m antennas and the associated data acquisition systems that are contemplated. At present, there are no clear-cut answers, but the studies do not seem to indicate that higher slew speed antennas are necessarily substantially better.

2. e-VLBI Development

2.1. New or Enhanced Connections

Additional stations continue to be connected for e-VLBI. Among the notable new connections are Svetloe and, expected soon, Badary. Among the notable upgraded connections are 10 Gbps connections at Onsala, Metsahovi, Westford and the Haystack correlator. Wettzell has upgraded its link to ~600 Mbps. TIGO has recently upgraded its link to at least 32 Mbps for short periods of time and is pursuing a more permanent upgrade. Hobart's connection to the University of Tasmania has been upgraded to 1 Gbps with new fiber, but the connection from Tasmania to mainland Australia is still somewhat of a bottleneck. Fiber to the Fortaleza station has been installed, and Fortaleza's connectivity to the global network is anticipated soon.

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

MPI now conducts 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 now transferred either to MPI or Haystack depending on the target correlator. Syowa K5 data are physically shipped to Japan and electronically transferred to Haystack or MPI. UT1 Intensive data from Wettzell, Japan and Ny-Ålesund are transferred to either MPI or a site near the Washington correlator (where the last couple of km is currently handled via sneakernet!), depending on the target correlator for the data.

2.3. 6th International e-VLBI Workshop Held at MPI, Bonn, Germany

The 6th International e-VLBI Workshop was hosted by MPI and held 17-18 September 2007 in Bonn, Germany. The workshop was attended by some 60 participants from 15 countries. Presentations at the workshop showed rapid progress in e-VLBI on several fronts. In Europe, the JIVE EXPReS project continues to connect European astronomical VLBI telescopes in real-time and conducts regular scientific e-VLBI experiments with up to 5-6 stations at data rates nearing 1 Gbps/station. Australia continues to make rapid progress in connecting its telescopes and has also developed a software correlator system to support real-time observations. A Japanese-Finnish team delivered the database of an Intensive (one hour) session to the analysts only 20 minutes after the conclusion of the observations. A panel discussion on VSI-E led to a charge to re-invigorate the VSI-E working group and to finalize the VSI-E specification within a year. Alan Whitney, as chair of that group, accepted the charge but has since had to pass the baton to Dr. Chester Ruszczyk of Haystack due to a change in Alan's position at Haystack Observatory. All presentations from the Bonn workshop are available at *http://www.mpifr-bonn.mpg.de/div/vlbi/6th_evlbi/*. The next e-VLBI workshop will be held 16-17 June 2008 in Shanghai, China. We all look forward to another valuable and stimulating meeting.

3. TOW2007 Workshop at Haystack Observatory

The 4th IVS Technical Operations Workshop (TOW) was held 30 April—3 May 2007 at Haystack Observatory. The TOW is intended to provide hands-on training and problem resolution in VLBI operations primarily for the technical staff of the stations. The curriculum included operations and maintenance workshops such as equipment operation and checkout, Mark 5A and Mark 5B operations, cryogenic system maintenance, RFI identification and mitigation, and general station troubleshooting. Seminars on such subjects as correlator theory and operations, introduction to Linux, timing systems, phase calibration basics, e-VLBI overview, introduction to the K5 system, and H-maser monitoring and maintenance helped to further inform the participants. And various lectures on 'how VLBI works', science overview, Mark 5 system operation, and impact of operations on data analysis helped to broaden the view of all attendees. All TOW2007 workshop presentations are available at *http://ivscc.gsfc.nasa.gov/meetings/tow2007/notebook.html*.

Network Stations

Network Stations

Badary Radio Astronomical Observatory

Sergey Smolentsev, Roman Sergeev

Abstract

This report provides information about Badary network station: general information, facilities, staff, present status and outlook.

1. General Information

The Badary Radio Astronomical Observatory (BdRAO) was founded by the Institute of Applied Astronomy (IAA) as one of three stations of the Russian VLBI network QUASAR [1]. The sponsoring organization of the project is the Russian Academy of Sciences (RAS). The Badary Radio Astronomical Observatory is situated in the Burytia Republic (East Siberia) about 130 km east of Baikal Lake (see Table 1). The geographic location of the observatory is shown on the IAA RAS [3] Web site. The basic instruments of the observatory are a 32-m radio telescope and technical systems for doing VLBI observations.

Figure 1. Badary Observatory.

Table 1. Badary Observatory location and address.

Longitude	102°14′
Latitude	51°46′
Badary Observatory Republic Burytia 671021, Russia sergeev@ipa.nw.ru	

2. Technical and Scientific Information

The Badary station equipment includes the following main components: a 32-m radio telescope equipped with low noise receivers, a frequency and time keeping system with H-masers, a local geodetic network, a GPS receiver (geodetic) and a GPS/GLONASS K161 receiver (synchronization of time keeping system), a data acquisition system R1001 [2], Mark 5B and S2 recording terminals, control computers, a local computer network and technical service systems. An automatic meteorological station WXT510 (Vaisala) has been installed at Badary. The local geodetic network 2 is adjusted with accuracy 2–3 mm. Characteristics of the radio telescope and other main components of the station are presented in Tables 2, 3, and 4.

The time and frequency system is composed of two hydrogen maser standards CH1-80 as well as GPS/GLONASS receivers for preliminary time synchronization with an accuracy of not more than 100 ns. The frequency stability of the H-masers is presented in Table 4. Local VHF oscillators are locked by a reference signal of 5 MHz and provide 10–20 mW power output signals at frequencies 1.26, 2.02, 8.08, 4.5, and 22.12 GHz. A pulse calibration system includes a pulse generator with a pulse duration of about 50 ps. The Badary Observatory was connected with main line optical fiber glass in December 2007.

Table 2. Technical parameters of the radio telescope.

Year of construction	2000
Mount	AZEL
Azimuth range	±270 (from south)
Elevation range	from $-5°$ to $95°$
Maximum azimuth - velocity - tracking velocity - acceleration	 $1.5°$/s $1.5'$/s $0.2°/s^2$
Maximum elevation - velocity - tracking velocity - acceleration	 $0.8°$/s $1.0'$/s $0.2°/s^2$
Pointing accuracy	better than $10''$
Configuration	Cassegrain (with asymmetrical sub-reflector)
Main reflector diameter	32-m
Sub-reflector diameter	4 m
Focal length	11.4 m
Main reflector shape	quasi-paraboloid
Sub-reflector shape	quasi-hyperboloid
Surface tolerance of main reflector	±0.5 mm
Frequency capability	1.4–22 GHz
Axis offset	−11.5 mm

Table 3. Parameters of receivers.

Wave band	Frequency range	Input noise temperature
13 cm	2.15–2.5 GHz	12 K
3.5 cm	8.2–8.9 GHz	15 K

Table 4. Frequency stability of the CH1-80 H-maser.

Sample time interval	(Allan variance)$^{1/2}$
1 second	$3 \cdot 10^{-13}$
10 seconds	$3 \cdot 10^{-14}$
100 seconds	$1 \cdot 10^{-14}$
1000 seconds	$3 - 5 \cdot 10^{-15}$

3. Technical Staff

Roman Sergeev — Observatory chief,
Nicolay Mitovin — FS, pointing system controls,
Alexander Seryx — front end and receiver support.

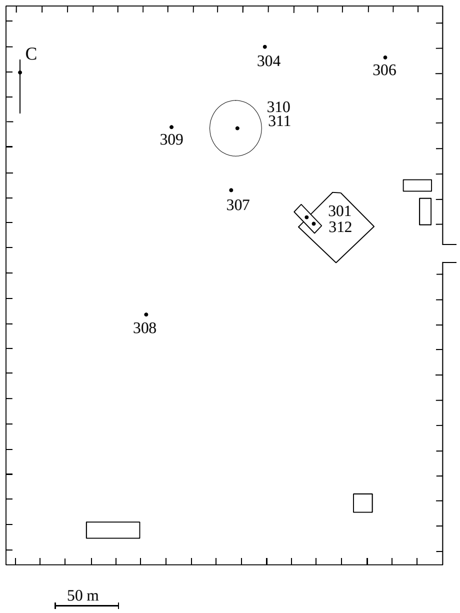
4. Co-location with GPS

A permanent GPS receiver Leica SR520 was installed at Badary during April 2005 (Fig. 2, Fig. 3).

Figure 2. GPS marker.

Figure 3. GPS receiver.

The accuracy of the local geodetic network (LGN) is about 2 mm. However, we still cannot provide an accurate survey of the VLBI radio antenna. In September 2006 a leveling session was carried out to check the LGN marker stability.



The LGN includes ten reference points. 304 and 306–309 are ground markers. 301 and 312 are located on the roof of the laboratory building and are intended for the installation of GPS/GLONASS and DORIS antennas. 310 is the intersection of the radio telescope axes, and 311 is an intermediate marker on the azimuthal platform of the radio telescope.

Figure 4. Local geodetic network at Badary Observatory.

5. Participation in IVS Observing Programs

In 2007 the Badary station started participating in IVS programs. During 2007 the Badary IVS station participated in 13 IVS sessions: 10 IVS-R4, 2 EUROPE, and 1 IVS-T2.

6. Outlook

Our plans for the coming year are the following:

- Final adjustment of all radio telescope systems to satisfy VLBI requirements.
- Participation in 56 IVS observing sessions: IVS-R1, IVS-R4, IVS-T2, and EURO.
- Participation in domestic observational programs for obtaining Earth orientation parameters.
- Surveying the local geodetic network.

References

[1] Finkelstein A., Ipatov A., Smolentsev S. Radio Astronomy Observatories Svetloe, Zelenchukskaya and Badary of VLBI Network QUASAR. In: IVS 2004 General Meeting Proceedings, eds. N. R. Vandenberg, K. D. Baver, NASA/CP-2004-212255, 2004. pp. 161–165.

[2] Fedotov L., Ivanov D., Ipatov A., Ipatova I., Lavrov A., Kosobokov M., Mikhailov A. Institute of Applied Astronomy Technology Development Center. In: IVS 2006 Annual Report, eds. D. Behrend, K. D. Baver, NASA/TP-2007-214151, 2007. pp. 255–258.

[3] http://www.ipa.nw.ru/PAGE/koi8-r/DEPOBSERV/rus.

Fortaleza Station Report for 2007

Pierre Kaufmann, A. Macílio Pereira de Lucena, Claudio E. Tateyama, Francisco A. Tavares F. da Silva

Abstract

This is a brief report about the activities carried out at Fortaleza geodetic VLBI Station (ROEN: Rádio Observatório Espacial do Nordeste), located in Eusébio, CE, Brazil, in 2007. The observing activities consisted of 90 VLBI sessions and continuous GPS monitoring recordings. The installation of optical fiber was completed, and the station switched to a 1 Gbit/s high speed network, to be used in e-VLBI operations.

1. General Information

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

2. Component Description

The largest instrument of ROEN is the 14.2 m radio telescope, an alt-azimuth positioner. It is operated at S- and X-bands, using cryogenic radiometers. The system is controlled by 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 Prof. Pierre Kaufmann, from the São Paulo main office at CRAAM (CRAAE)/Instituto and Universidade Presbiteriana Mackenzie,

Figure 1. Fortaleza's 14.2 m antenna.

receiving scientific assistance from Dr. Claudio E. Tateyama and partial administrative support from Valdomiro S. Pereira and Neide Gea Escolano. Partial technical assistance is given by staff from the Itapetinga Radio Observatory near São Paulo, also operated by INPE/Mackenzie.

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

4. Current Status and Activities

4.1. VLBI Observations

Fortaleza participated in the following geodetic VLBI experiments, as detailed in the table below for the year 2007.

Table 1. 2007 session participation.

Experiment	Number of Sessions
IVS-R1	28
IVS-R4	45
IVS-T2	03
IVS-CRF	03
IVS-OHIG	07
IVS-R&D	02
IVS-CRMS	03

Figure 2. Fortaleza's station team

4.2. Development and Maintenance Activities in 2007

Considerable attention was given to technical maintenance, especially to the following activities: 1) installation of a new cryogenic system, 2) replacement of video converters for the new Mark IV VC modules, 3) repairs of the following circuits, modules or systems: Mark III video converters, Mark III power supplies, and the Mark III IF Distributor module, 4) repairing the UPS system, 5) maintenance of the Web site (http://www.roen.inpe.br) and the local server computer, and 6) painting the steel structure of the 14.2 m antenna.

4.3. GPS Operations

The IGS network GPS receiver operated regularly at all times during 2007. Data were collected and uploaded to an IGS/NOAA computer.

4.4. High Speed Network

The installation of fiber and the switch to a high speed 1 Gbits/s network, to be used in e-VLBI operations, was completed in December 2007. Figure 3 shows details of the connection switch.

Figure 4 illustrates the network fiber path in the Fortaleza metropolitan area. The Fortaleza VLBI Station is labeled INPE-ROEN.

The Brazilian Research Network (RNP) circuit across the country is shown in Figure 5. There

Figure 3. Switch rack for connection to the high speed fiber network.

Figure 4. Fortaleza metropolitan area showing the high speed optical fiber network.

Figure 5. National RNP fiber optic circuits.

are two options available for connecting to the international optical cables: via Rio de Janeiro or via Fortaleza.

5. Future Plans

The completed high speed optical network connection will allow ROEN to participate in e-VLBI experiments. The network is currently being tested.

6. Acknowledgements

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 INPE.

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Mark Evangelista

Abstract

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

1. GGAO at Goddard

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

Figure 1. Installation of new wide band dewar on MV3 antenna.

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

2. Technical Parameters of the VLBI Antenna at GGAO

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

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

Table 1. Location and addresses of GGAO at Goddard.

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

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

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

Parameter	GGAO-VLBI
Owner and operating agency	NASA
Year of construction	1982
Diameter of main reflector d	$5m$
Azimuth range	$0 \ldots 540°$
Azimuth velocity	$3°/s$
Azimuth acceleration	$1°/s^2$
Elevation range	$0 \ldots 90°$
Elevation velocity	$3°/s$
Elevation acceleration	$1°/s^2$
X-band	$8.18 - 8.98\,GHz$
Receiving feed	Cassegrain focus
T_{sys}	$24\,K$
Bandwidth	$800MHz, -2dB$
G/T	$32.1\,dB/K$
S-band	$2.21 - 2.45GHz$
Receiving feed	Primary focus
T_{sys}	$19\,K$
Bandwidth	$240MHz, -2dB$
G/T	$21.2\,dB/K$
VLBI terminal type	Mark IV
Recording media	Mark 5A
Field System version	9.10.2

3. Technical Staff of the VLBI Facility at GGAO

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

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

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

4. Status of MV3 at GGAO

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

Table 4. Participation of GGAO in scheduled VLBI experiments.

Date	Experiment
2007-03-13	RDART4
2007-05-15	T2050

MV3 has installed Mark 5 and e-VLBI hardware and continues to test real-time VLBI from GGAO to Haystack. On January 26, 2007, MV3 recorded two 480MHz bands that covered all of the X-band IF, with two-bit sampling, for an aggregate data rate of ~4Gb/s. Two VSI data streams (each ~2Gb/s) were recorded on two Mark 5B's and the data were transferred to the Haystack correlator via high-speed internet connections. It was also demonstrated, by comparing to simultaneously recorded Mark IV data, that there appear to be no major sources of signal loss in the Digital Back End (DBE) system.

MV3 is a major component in the program to demonstrate that the VLBI2010 broadband delay concept is feasible. In 2007 MV3 participated in two demonstrations. In April the Digital Back End (DBE) and two Mark 5B+'s were used to demonstrate the high data rate acquisition components. Data were recorded at 2 Gigabits per second (Gbps) with the standard geodetic S/X system. Because of the limited bandpasses, the resulting data rates were only 0.9 Gbps at S-band (the full bandwidth) and 1.6 Gbps at X-band (the upper half of the band). After a successful fringe test, a six-hour geodetic session was run.

A major modification of MV3 began in October in order to install the prototype VLBI2010 RF system. The geodetic S/X feed, receiver and supporting structure were replaced with a dewar, constructed by Haystack, containing the broadband Lindgren feed, two low noise amplifiers, and cryogenic refrigerator. Considerable time was spent trying to understand why the efficiency of the new system is lower than expected, but even with this limitation strong fringes were finally obtained with Westford at X-band in November. This was a major milestone in the VLBI2010 program since it demonstrated one band of the complete broadband signal chain which included the feed, LNAs, Up-Down converter (UDC), digital back end, Mark 5B+ recorder, and for one polarization, the use of optical fiber to bring the RF signal from the antenna to the control room.

5. Outlook

In its present configuration, GGAO will mainly support VLBI2010, e-VLBI, and other developmental activities during the upcoming year. Basic plans for 2008 consist of:

1. Continued testing of pre-release versions of PC-FS and new Linux kernel releases.
2. Continued support of Mark 5 and Digital Back End (DBE) hardware development.
3. Continued support of the development and testing of VLBI2010 hardware and software.
4. Continually striving to improve the performance of the entire Mark 5 data collection and station specific equipment.

MV3 is also the other antenna used with Westford as a test bed for e-VLBI research because of the high data rate internet connection through GSFC. In 2007 this connection was used to transfer the data from the VLBI2010 tests soon after the observations, for confirmation of successful fringes. One of the first projects in 2008 will be an attempt to demonstrate an aggregate data rate of approximately 2 Gbps in real time by using two 1 Gbps channels.

Haystack is constructing a second dewar for Westford, as well as seven more UDC's and DBE's so that a full 4-band, two polarization system can be demonstrated. The four bands will span the range from approximately 3 GHz to 12 GHz. In anticipation of this test, time will be spent trying to understand the reduced efficiency and installing optical fiber for both polarizations.

In early January 2008 there will be a six-hour session on one source to evaluate possible systematic differences between the two polarizations.

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck, Marisa Nickola

Abstract

HartRAO, the only fiducial geodetic site in Africa, participates in VLBI, GNSS, and SLR global networks, among others. This report provides an overview of our geodetic VLBI activities and research during 2007. Further developments regarding the proposed new fundamental space geodetic observatory in the Karoo are presented.

1. Geodetic VLBI at HartRAO

Hartebeesthoek is located 65 kilometers northwest of Johannesburg within the World Heritage Site known as the Cradle of Humankind, just inside the provincial boundary of Gauteng, South Africa. The nearest town, Krugersdorp, is 32 km distant. The telescope is situated in an isolated valley which affords protection from terrestrial interference. HartRAO uses a 26-metre equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The telescope was part of the NASA deep space tracking network until 1975 when the facility was converted to an astronomical observatory. The telescope is co-located with an SLR station (MOBLAS-6) and an IGS GNSS station (HRAO). HartRAO joined the EVN as an associate member during 2001. Geodetic VLBI has been allocated 16% of the available telescope time. The allocation for geodetic VLBI was increased from 52 24-hour experiments in 2006 to 58 in 2007.

Figure 1. The 26-m HartRAO radio telescope with the 15-m XDM in the background. The XDM is a testbed prototype for the Karoo Array Telescope (KAT), which, in turn, will be used to test technology leading up to development of the Square Kilometer Array (SKA).

Figure 2. Andrew Masiteng and Richard Moralo install the dichroic reflector, which permits simultaneous observing at 3.5 and 13 cm. The dichroic has to be installed before and removed after every geodetic VLBI experiment.

2. Technical Parameters of the VLBI Telescope of HartRAO

The feed horns used for 13 cm and 3.5 cm are dual circularly polarized conical feeds. The RF amplifiers are cryogenically cooled HEMTs. Tables 1 and 2 contain the technical parameters of the HartRAO radio telescope and its receivers. The data acquisition system consists of a Mark IV terminal and a Mark 5A recorder. The obsolete Mark IV and S2 tape recorders have been removed from the control room. A 22 GHz receiver was installed on the 26-m telescope on the 1st of February 2007 and was put to the test observing Jupiter. The surface upgrade proved its worth when measurements of aperture efficiency showed the surface error near zenith to be 0.5 mm.

Table 1. Antenna parameters.

Parameter	**HartRAO-VLBI**
Owner and operating agency	HartRAO
Year of construction	1961
Radio telescope mount	Offset equatorial
Receiving feed	Cassegrain
Diameter of main reflector d	$25.914\,m$
Focal length f	$10.886\,m$
Focal ratio f/d	0.424
Surface error of reflector	$0.5\,mm$
Wavelength limit	$< 1.3\,cm$
Pointing resolution	0.001°
Pointing repeatability	0.004°

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

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

3. Staff Members Involved in VLBI

Antenna systems technician, Jacques Grobler, and electronics technician, Lerato Masongwa, have joined the Geodetic VLBI Team as trainee operators during the second half of 2007. Table 3 lists the HartRAO station staff who are involved in geodetic VLBI. Jonathan Quick (VLBI friend) has continued to provide technical support for the Field System as well as for hardware problems.

Table 3. Staff supporting geodetic VLBI at HartRAO.

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

4. Current Status

During 2007 HartRAO participated in 58 experiments (table 4), which utilised the telescope time allocated to geodetic VLBI to its fullest extent.

Table 4. Geodetic VLBI experiments HartRAO participated in during 2007.

Experiment	Number of Sessions
R1	32
CRDS	7
OHIG	5
RDV	5
CRF	3
R&D	2
T2	2
CRFS	1
R4	1
Total	58

The 3.5-cm receiver was removed for maintenance on the 22nd of August 2007 and, after replacing the expander, microwave technician Ronnie Myataza ran several tests to verify the receiver's performance.

Ph.D. student Joel Ondego Botai has been researching the effects of the atmosphere on the geodetic VLBI delay observable. To this end, Joel has been investigating limited area Numerical Weather Prediction (NWP) models and resolving high-frequency fluctuations of tropospheric parameters that affect VLBI observations. This should hopefully add value to station-dependent strategies of improving the accuracy of the geodetic VLBI observable.

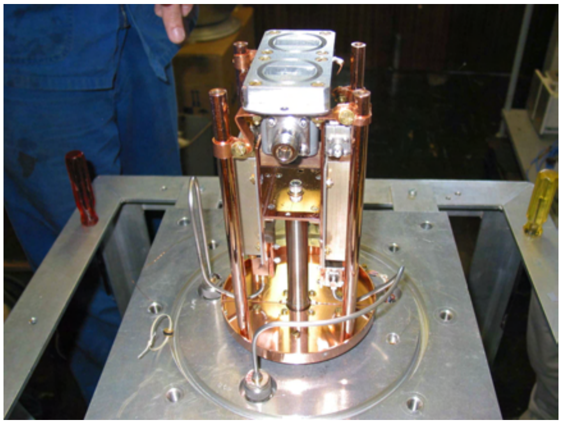


Figure 3. The 3.5-cm receiver being reassembled after repairs.

Figure 4. Some of our geodetic VLBI staff—from left to right, Jacques, Pieter, Marisa, Lerato, Jonathan, and Roelf.

5. Future Plans

Planning towards the development of a new fundamental space geodetic observatory for South Africa, the proposed International Institute for Space Geodesy and Earth Observation (IISGEO), continued during 2007. The possibility of incorporating two KAT-type dishes into the future equipment arsenal of IISGEO has been proposed by the Director of HartRAO, Prof. R. Booth. One such prototype, the 15-m diameter eXperimental Development Model (XDM), has been constructed at HartRAO, and it is expected that future models, such as smaller and lighter next-generation KAT-7 12-m paraboloid and MeerKAT 12-m offset paraboloid dishes, will be able to meet higher specifications of pointing and surface accuracy. This would enable operations for geodetic VLBI purposes in the 2-18 GHz range, compatible with VLBI2010.

The Earth Observation research unit (Space Geodesy & Remote Sensing) was conceived during 2007 in collaboration with the University of Pretoria (UP). It is to be housed at UP and is eagerly anticipated for the coming year. Lectures in Space Geodesy will be presented at undergraduate level from 2008 and such courses extended to Honours level during 2009.

The Space Geodesy Programme is an integrated programme, combining VLBI, SLR, and GNSS, and 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).

Hobart, Mt. Pleasant, Station Report for 2007

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

Abstract

This is a brief report on the activities carried out at the Mt. Pleasant Radio Astronomy Observatory at Hobart, Tasmania. During 2007, the observatory participated in 61 24-hour IVS VLBI observing sessions, and funding commenced for the AuScope VLBI array which will see three new antennas installed across Australia for geodesy.

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 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 changeover between geodetic and astronomical requirements. Standard receiver packages provide for operation at L band and S, C, X, and K bands. There is also the dual frequency S/X geodetic receiver. All of these receivers are cryogenically cooled. The antenna has a maximum slew rate of 40 degrees per minute about each axis. The station is equipped with a Mark IV electronics rack and a Mark 5 VLBI recording system. There is another disk based recording system used by other Australian VLBI antennas.

3. Staff

Staff at the observatory consisted of academics, Prof. John Dickey (director), Dr. Simon Ellingsen, Dr. Melanie Johnston Hollitt, and Prof. Peter McCulloch, who has had a large input into the receiver design and implementation. Dr. Aidan Hotan and Dr. Jamie Stevens are research fellows and have had input into the Linux systems at the observatory. Mr. Brett Reid is the Observatory Manager whose position is funded by the university. In addition we have an electronics technical officer, Mr. Eric Baynes, and we had a half time mechanical technical officer, Mr. Geoff Tonta. For operation of the observatory during geodetic observations we rely heavily on support from astronomy Ph. D. and post-graduate students. In 2007 Dr. Jim Lovell was appointed as Project Scientist for the AuScope VLBI project (see *Future Plans* below).

4. Geodetic VLBI Observations

Hobart participated in 61 geodetic VLBI experiments during 2007. These were divided between the APSG, CRDS, CRF, OHIG, R1, R4, R&D, and T2 programs. All experiments were recorded

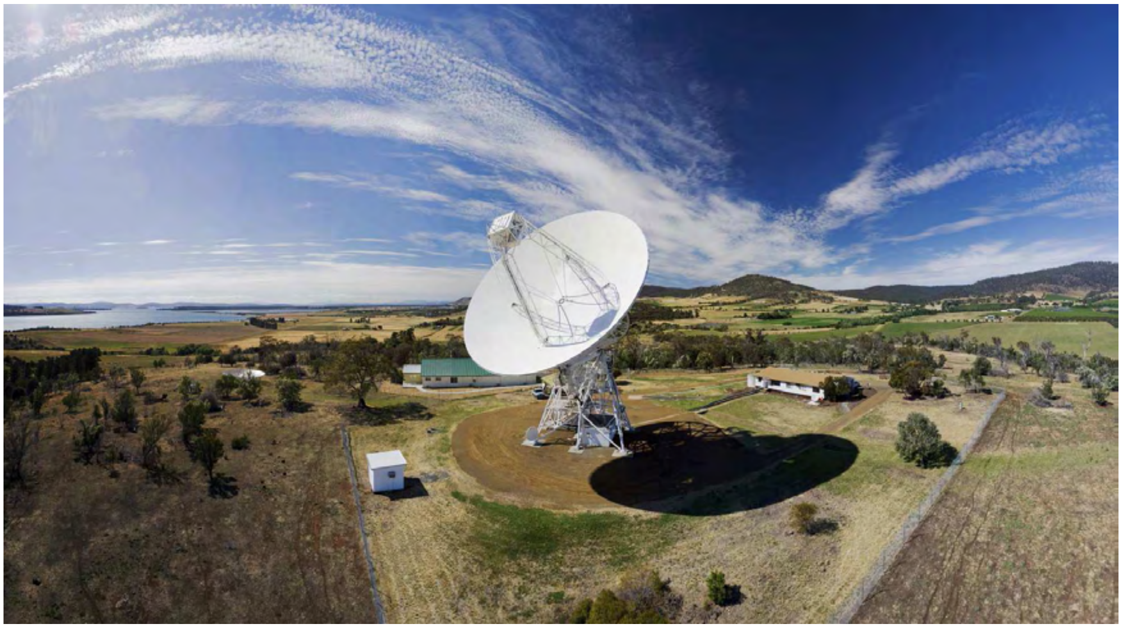


Figure 1. The Mt. Pleasant 26m antenna.

using Mark 5A. In 2007, Hobart increased its support of IVS by commiting to participate in 60 24-hour experiments, an increase of 36% above those performed in 2006. The ARC LIEF (Large Infrastructure and Equipment Funding) funded 10 Gb/s fiber optic link between the Mt. Pleasant VLBI site and the university campus was completed during 2007. Links out of Tasmania are currently limited to 2 × 155 Mbps, which will be upgraded to Gbps rates by the end of 2008.

In 2007 the University completed work on a visitors center and museum at the observatory, funded from the estate of Grote Reber, the world's first radio astronomer. The museum includes a display on the contribution the Mt. Pleasant 26 m antenna makes to geodesy through the IVS.

5. Future Plans

2008 will see the construction of a new 12 m antenna at Mt. Pleasant for geodesy as part of 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. Construction of the other two telescopes will take place in 2009 in Western Australia and Northern Territory. It is anticipated that these antennas will be dedicated to IVS observations for approximately 50% of the time. This five year project, for which funding started in 2007, will vastly improve the capabilities of the IVS in the southern hemisphere. The array will be operated for AuScope by the University of Tasmania with data correlation supported by Curtin University of Technology. The construction and operation of the array is being managed for AuScope by the University of Tasmania.

Kashima 34-m Radio Telescope

Hiroshi Takiguchi, Eiji Kawai, Hiromitsu Kuboki, Tetsuro Kondo

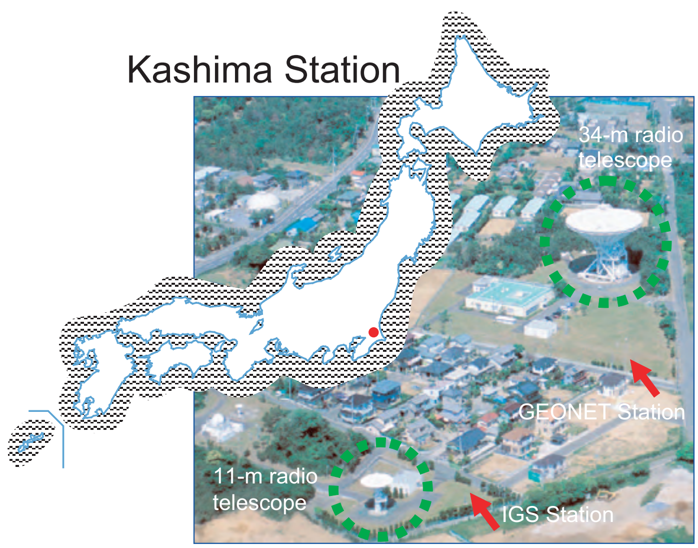
Abstract

The Kashima 34-m radio telescope is continuously operated and maintained by the National Institute of Information and Communications Technology (NICT) as a facility of the Kashima Space Reserch Center (KSRC) in Japan. This brief report summarizes the status of this telescope, the staff and activities during 2007.

1. General Information

The Kashima 34-m radio telescope (Figure 1 left) was constructed by NICT (formerly Communications Research Laboratory) as a main station of the "Western Pacific VLBI Network Project" in 1988. After that project ended, the telescope has been used not only for geodetic purposes but also for astronomy and other purposes [1] [4]. The station is located about 100 km East of Tokyo, Japan and co-located with the 11-m radio telescope and the International GNSS Service station (KSMV) (Figure 1 right). During 19 years of operation, this telescope has been kept in a fairly good condition. This station is maintained by the Space-Time Applications Project of the Space-Time Standards Group of KSRC, NICT.

The Kashima 34-m radio telescope.



The layout map of Kashima station.

Figure 1. The Kashima Station.

2. Component Description

The Kashima 34-m radio telescope can observe L, C, K, Ka, Q, S, and X bands. The main specifications of the telescope and receivers are summarized in Table 1 and Table 2.

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

Table 2. The receiver specification 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	52	0.68	230	L/R
X-wL	8180-9080#	41	53	0.68	290	L/R
X-wH	7860-8360#	-	50	0.68	270	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.
⋆ : changed due to the repair on 19 January, 2007.

The original frequency coverage of the X-band was from 7860 MHz to 8600 MHz. In order to respond to IVS observation, we expanded the frequency range of the X-band receiver up to 9080 MHz [2]. For S-band, we installed the new high-temperature superconductor (HTS) band-pass filter to mitigate the radio frequency interference (RFI) signal due to a third-generation mobile phone system (IMT-2000) [3].

3. Staff

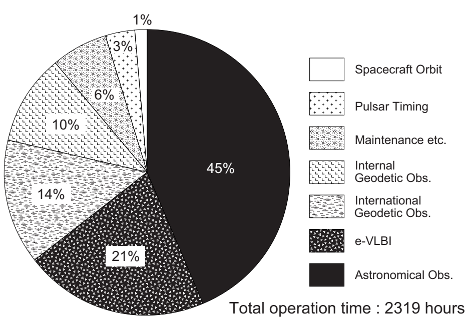
The engineering and technical staff of the Kashima 34-m radio telescope are listed in Table 3. Hiromitsu Kuboki left NICT and Kazuhiro Takefuji joined in December 2007.

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

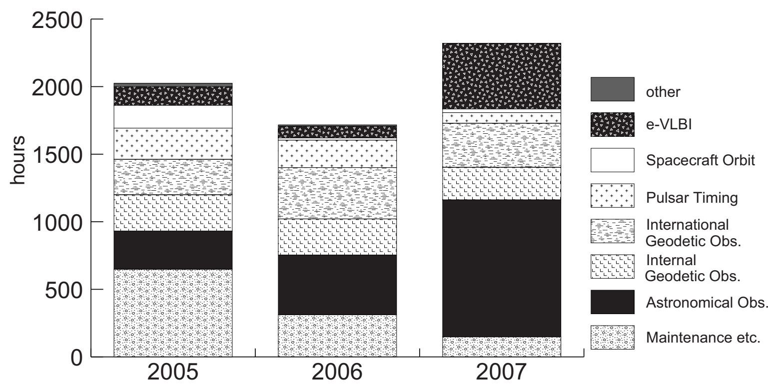
Name	Main Responsibilities
Eiji Kawai	responsible for operations and maintenance
Mamoru Sekido	software and reference signals
Hiromitsu Kuboki	mechanical and RF related parts
Kazuhiro Takefuji	mechanical and RF related parts
Yasuhiro Koyama	international e-VLBI
Tetsuro Kondo	software correlator developments and e-VLBI

4. Current Status and Activities

The 34-m radio telescope contributed to various experiments (such as geodesy, radio-astronomy, space navigation, time transfer). Statistical charts of the telescope operation time according to purpose including maintenance is shown in Figure 2. The total operation time of 2007 was 2319 hours, which is a significant increase compared with the previous year. The main reason for this is that there was no major telescope trouble [4].



Statistical charts of the telescope operation time according to purpose.



Telescope operation time within the last three years.

Figure 2. Statistical charts of the telescope operation time.

The yearly maintenance was carried out from the beginning of August until the end of September. Repair work was done on the backing structure of the telescope as well as on the access ladder of the main reflector and the sub-reflector [4].

Figure 3 shows the block diagram of the current S/X-band receiver system [4].

5. Future Plans

The Kashima 34-m radio telescope is a main telescope of our project and already a lot of observations such as “experiment for the development of a 1.6m antenna system”, “ultra-rapid UT1 experiment with e-VLBI”, and “VLBI experiment for Time Transfer” have been scheduled. Also we are planning the yearly maintenance to keep up the telescope’s good condition. Additionally,

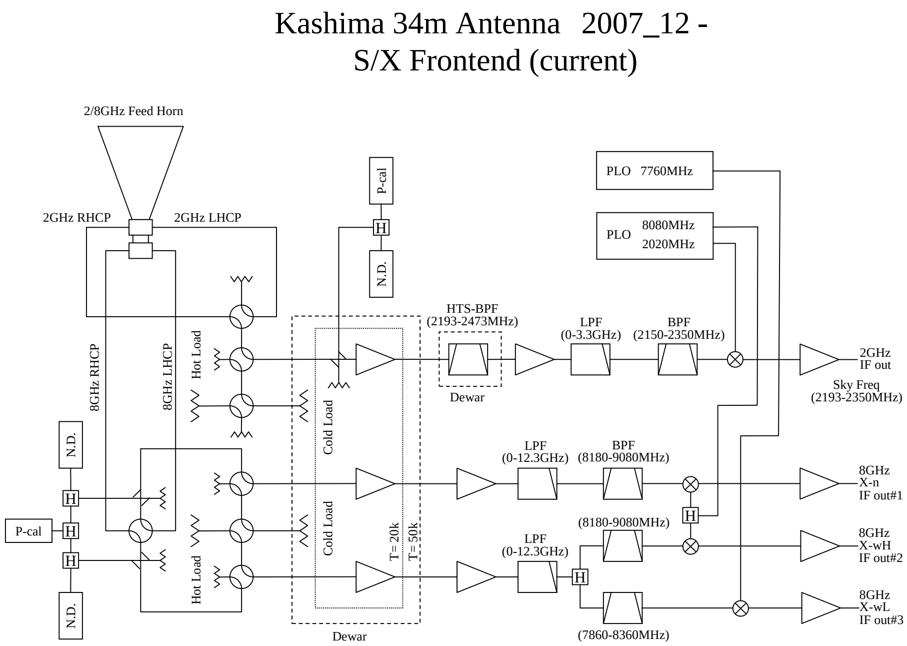


Figure 3. The block diagram of the Kashima 34-m radio telescope S/X receiver after December 2007.

we are planning to restore the following items to improve the telescope's condition:

- Brake malfunction (occurs rarely)
- Creak at the AZ wheel rotation part
- Rust of the backing structure
- Deterioration of the AZ base plate and rail
- Stain of the main reflector

References

[1] Kawai, E., H. Kuboki, Kashima 34-m Radio Telescope, In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, NASA/TP–2007-214151, D. Behrend and K. D. Baver (eds.), 51–54, 2007.

[2] Kawai, E., H. Kuboki, Y. Koyama, T. Kondo, On the expansion of the frequency coverage of an X-band of Kashima 34-m antenna, IVS NICT TDC News, 26, 23-25, 2005.

[3] Kawai, E., J. Nakajima, H. Takeuchi, H. Kuboki, T. Kondo, M. Suzuki, K. Saito, RFI mitigation at a 2GHz band by using a wide-band high-temperature superconductor filter, J. Geod. Soc. Japan, 2007 (in press).

[4] Space-Time Standards Group, NGNC, NICT, Kashima 34-m Radio Telescope 2007 Annual Report, 2008 (in Japanese).

Kashima and Koganei 11-m VLBI Stations

Yasuhiro Koyama

Abstract

Two 11-m VLBI stations at Kashima and Koganei used to be a part of the Key Stone Project VLBI Network. The network consisted of four VLBI stations at Kashima, Koganei, Miura, and Tateyama. Since Miura and Tateyama stations have been transported to Tomakomai and Gifu, Kashima and Koganei 11-m stations are remaining as IVS Network Stations. After the regular VLBI sessions with the Key Stone Project VLBI Network terminated in 2001, these stations are mainly used for the purposes of technical developments and miscellaneous observations. In 2007, a series of geodetic VLBI experiments was performed between Kashima and Koganei 11-m VLBI stations to evaluate the capability of the VLBI technique for precise time transfer between Time and Frequency laboratories to construct Coordinated Universal Time. In addition, efforts to determine the precise orbit of spacecraft were continued by using Hayabusa and Geotail spacecraft. Another series of experiments was also carried out for developments of e-VLBI by using the high speed network connection between the sites.

1. Introduction

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

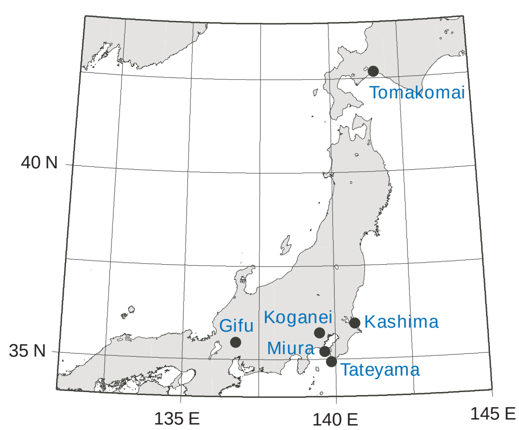


Figure 1. Geographic locations of four KSP VLBI stations and two stations at Tomakomai and Gifu.

Therefore, the primary objective of the KSP VLBI system was to determine precise site positions of the VLBI stations as frequently and fast as possible. To realize this objective, various new technical advancements were attempted and achieved. By automating the entire process from the observations to the data analysis and by developing the real-time VLBI system using the high speed digital communication links, unattended continuous VLBI operations were made possible. Daily continuous VLBI observations without human operations were actually demonstrated and the results of data analysis were made available to the public users immediately after each VLBI session. Improvements in the measurement accuracies were also accomplished by utilizing fast slewing antennas and by developing higher data rate VLBI systems operating at 256 Mbps.

The 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 (Figure 2) are remaining as IVS Network Stations. After the regular VLBI sessions with the Key Stone Project VLBI Network terminated in 2001, 11-m VLBI stations at Kashima and Koganei are mainly used for the purposes of technical developments and miscellaneous observations.


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

2. Activities in 2007

In 2007, we started to perform special purpose geodetic VLBI experiments between Kashima (11-m or 34-m) and Koganei VLBI stations to evaluate the capability of VLBI for precise time transfer. Currently, the International Bureau of Weights and Measures (BIPM) is maintaining and evaluating Coordinated Universal Time (UTC) by assembling many time and frequency standards operated at Time and Frequency Laboratories around the world. The common view GPS time transfer and bi-directional satellite time transfer are mainly used to compare timing signals of time and frequency standard systems. It is necessary to compare the clocks over a long distance and the current accuracy of the time comparison is typically a few hundred picoseconds by using the bi-directional satellite time transfer technique. On the other hand, the clock offsets between two stations is estimated from usual geodetic VLBI experiments and its typical uncertainty of about a few tens of picoseconds. In addition, it is anticipated to achieve 3 to 4 picoseconds of uncertainty for time delay measurements by using multi-frequency wide band phase delay measurements under the VLBI2010 discussions. At Koganei headquarters of NICT, a set of Cesium Atomic Clocks, Hydrogen Maser Frequency Standard systems, and primary frequency standard systems are operated to contribute to the UTC. In addition, optical frequency standard systems are being developed by using Calcium ion and optical lattice clock techniques. It is expected to achieve frequency stability of down to 10^{-16} of Allen Standard Deviation. If such a highly stable optical frequency standard system is realized, it is necessary to perform precise time transfer with the other time and frequency laboratories and the geodetic VLBI technique is expected to improve the current time transfer limitation. We are currently developing a very small wideband antenna system of the aperture of 1.6m in diameter and we would like to demonstrate the capability of the geodetic VLBI technique for precise time transfer. At first, two 24-hours sessions were performed on January 11th and on 22nd. Then a three-day continuous session was performed from February 28th, and a one-week continuous session was performed starting on June 15th. At both 11-m stations, continuous GPS observations were also performed as IGS sites, and these data are used to compare with the results from VLBI observations. The evaluation of the obtained results is still under investigation, but the initial analysis suggested the capability of VLBI methods for precise time transfer of the level of 16 picoseconds.

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

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

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 solar terrestrial environment and 3D image of the Sun and solar storms. The Koganei 11-m antenna is therefore operated everyday even if there is no VLBI sessions to perform.

3. 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 1. The operations 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 1. Staff members of Space-Time Standards Group, KSRC, NICT

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

4. Future Plans

In 2008, we plan to continue the precise time transfer VLBI experiments, e-VLBI developments, and differential VLBI observations to the spacecraft for precise orbit determination. In addition to the VLBI observations and developments, the data downlink from the two STEREO spacecraft will be continued.

References

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

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

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

Kokee Park Geophysical Observatory

Kelly Kim

Abstract

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

1. KPGO

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

Figure 1. KPGO 20m antenna and operations building.

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.

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	

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

3. Staff of the VLBI System at KPGO

The staff at Kokee Park during calendar year 2007 consisted of five people who are employed by Honeywell International under contract to NASA for the operations and maintenance of the

Observatory. VLBI operations and maintenance was conducted by Matt Harms, Chris Coughlin and Kelly Kim. Ben Domingo does antenna maintenance with Amorita Apilado providing administrative, logistical and numerous other support functions.

Figure 2. KPGO Maintenance Day.

4. Status of KPGO

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

We averaged 1.5 experiments per week during calendar year 2000 and increased to an average of 2 experiments of 24 hours each week, with daily Intensive experiments during year 2002 and into 2007.

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

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

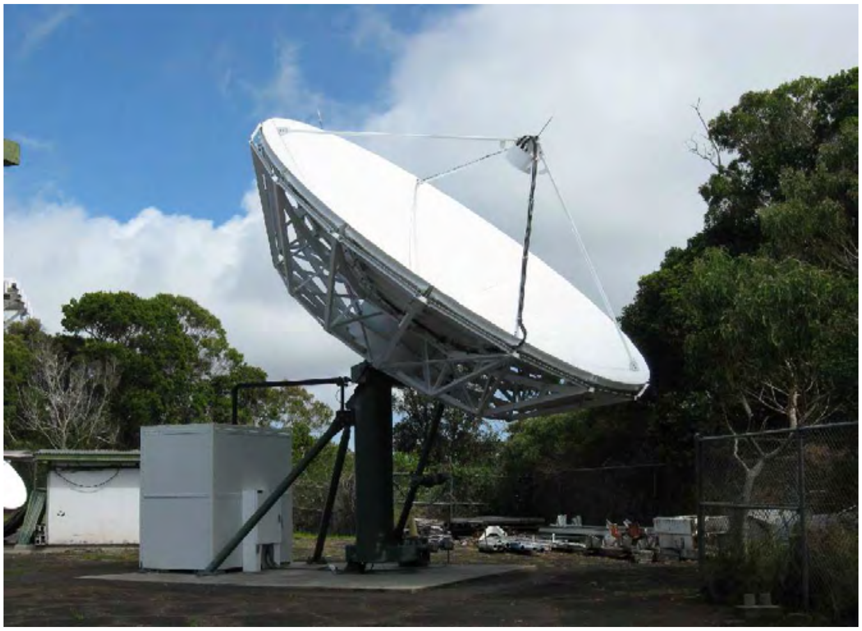


Figure 3. PEACESAT 7m Antenna.

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

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

In mid-2007, we filled the staff vacancy to bring our manpower level back to 100%.

Representatives from the Carnegie Institute removed a seismic station that was installed a few years earlier due to the end of the need to gather data at our location.

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 QZSS. In December, they announced that the first phase of the joint project would begin construction in the spring of 2008.

5. Outlook

We are closer to providing real time e-VLBI, and testing for system performance and data transmission evaluation is being discussed for late 2008. Steps have been taken to secure a wide band pipe needed for this support.

The QZSS project will begin installation of its equipment in 2008 and is looking at an early 2010 timeframe for reaching full operational capability.

We are supposed to participate in the CONT08 series of experiments later this year.

NASA plans to upgrade aging building infrastructure and will be investigating options to bring about the much needed repairs.

Matera CGS VLBI Station

Giuseppe Bianco, Giuseppe Colucci, Francesco Schiavone

Abstract

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

1. General

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

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

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

In May 1990 the CGS extended its capabilities to Very Long Baseline Interferometry (VLBI) installing a 20-m radiotelescope. Since then, Matera performed 761 sessions up to December 2007.

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

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

2. Technical/Scientific Overview

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

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

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

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

Table 1. Matera VLBI Antenna Technical Specifications.

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

3. Staff

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

Table 2. Matera VLBI staff members.

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

4. Status

In 2007, 52 sessions were acquired. All sessions were acquired using Mark 5 only. Fig. 2 shows the total Acquisitions Summary per year, starting in 1990.

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

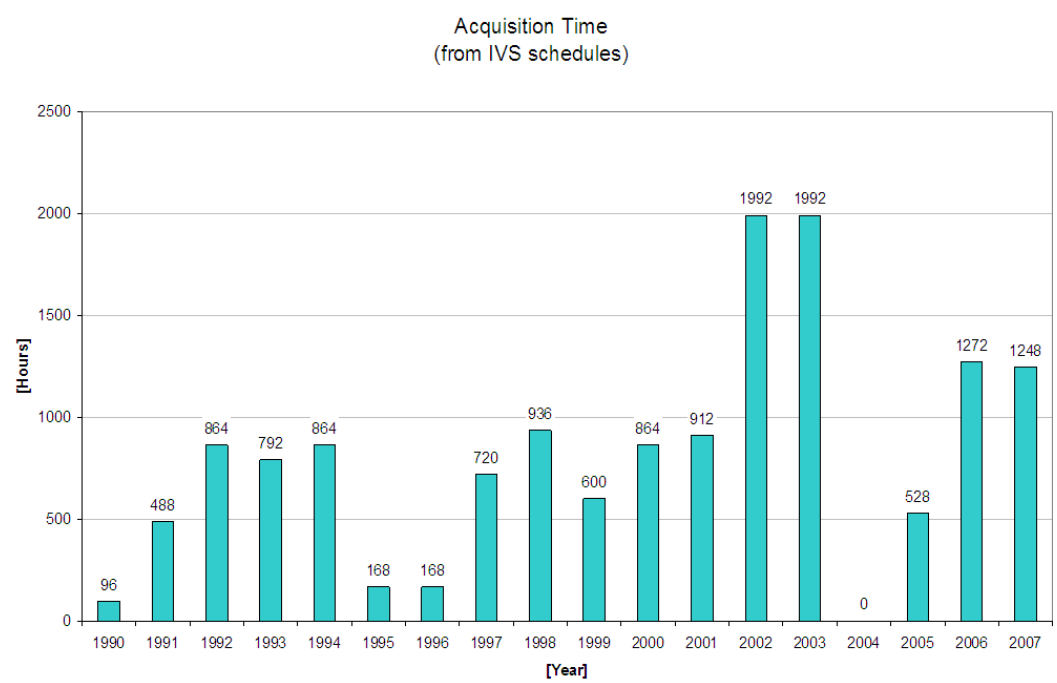


Figure 2. Acquisitions per year.

5. Outlook

The rail works are now on low priority because during last year no significant deterioration has been noted.

The main goal is to replace at least 1 of the 4 azimuth wheels because of cracks on the surface. This important work should be done in May-June 2008.

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.

References

[1] M. Mannarella “Relazione sulle misure effettuate sulla rotaia dell’antenna VLBI“, Telespazio doc. OT-SPA-SM_REL_180010_1140_0222, 21/01/2004.

[2] M. Mannarella “Misure sugli spostamenti indotti sulle piastre e sulla rotaia dell’antenna VLBI“, Telespazio doc. OT-SPA-SM_REL_180010_1320_0661, 06/04/2005.

[3] M. Mannarella “Relazione sull’esito dei lavori di ripristino delle parti ammalorate della fondazione dell’antenna VLBI“, Telespazio Doc. OT-SPA-SM_REL_180010_1320_0732, 27/06/2005.

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 2007 the data from geodetic VLBI observations were acquired using the Mark 5A recording system with good results. Updates of the hardware have been performed and are briefly described.

1. The Medicina 32 m Antenna. General Information

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

The antenna, inaugurated in 1983, has regularly taken part in IVS observations since 1985 and is an element of the European VLBI network. A permanent GPS station, which is part of the IGS network, is installed in the vicinity. Another GPS system is installed 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 of 32 m in diameter, and a secondary mirror, called subreflector, of convex shape and about 3 m in diameter. The subreflector, mounted on a quadrupode, is placed opposite the primary mirror, and focuses the radio waves at its centre, where the receiver system is located. For some observing frequencies, a simplified optical system is enough. The subreflector is therefore shifted from its normal position, and the receiving system is placed at the primary focus: this is the case of the S-X observations. The antenna can operate in the range between 327 MHz and 22 GHz.

The receivers are cooled with cryogenic techniques to improve the system sensitivity. The antenna is flexible in changing the operative receiver: only 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 are taking care of the observations. However, there is a limited number of people that is dedicated to maintain and improve the reliability of the antenna during the observations: Alessandro Orfei is the Chief Engineer, expert in micro-wave receivers; Giuseppe Maccaferri is the Technician in charge of the telescope's backend; Andrea Orlati is the Software Engineer who takes care of the observing schedules and regularly implements SKED&DRUDG and the Field System.

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

4. Current Status and Activities

During 2007 the Field System version 9.9.0 was running routinely. The Mark 5A recording system worked fine; it was upgraded to support 1 Gbit activity via installation of the suggested operating system (Sarge). At the end of the year, we acquired the new MarkB system. All observations are made onto hard disk. New disk frames with a storage capacity of 20 TB will be available for geodetic observations. The 18-26 GHz multifeed system is in the final stage of measurement. First antenna tests are foreseen for the beginning of 2008. The central feed will be the new K band receiver for VLBI: great improvements with respect to the current receiver are expected. The development of the new observing system and control software of the 32 m antenna proceeds. Two PhD students have joined the team. INAF plans to fund the replacement of the elevation wheel. Problems are still present in the ground unit, specifically in the lock of VC 13 and at the cryogenic circuit of the S/X receiver. Final resolution of these problems will be attempted in 2008.

4.1. Optic Fiber Link

Medicina participated routinely in e-VLBI tests and e-VLBI experiments.

5. Geodetic VLBI Observations

During 2007, the Medicina 32 m dish took part in 25 geodetic VLBI sessions, namely 2 IVS-T2, 13 IVS-R4, 2 IVS-R1, 4 EUROPE, and 4 R&D experiments.

VERA Geodetic Activities

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

Abstract

This report describes the status of the VERA network in terms of geodetic VLBI. The main contents are information about the technical parameters of the VERA observation system and a summary of geodetic VLBI activities during 2007.

1. General Description

VERA is a Japanese domestic VLBI network operated by Mizusawa VERA Observatory, NAOJ. Four antennas, Mizusawa, Iriki, Ogasawara, and Ishigakijima, form this array. Each station is equipped with a 20m radio telescope and a VLBI data aquisition system. Observing frequency bands of VERA are S and X, K (22 GHz) and Q (43 GHz). The Iriki 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 the structure and dynamics of our Galaxy by determining 3-D force field and mass distribution. Galactic maser sources are used as dynamical probes, positions and velocities of which can be precisely determined by phase referenced VLBI relative to extragalactic radio sources. The distance is measured as a classical annual trigonometric parallax. VERA standard astrometric observations started in 2003. Distances of several maser sources were measured in 2007.

Geodetic observations with VERA started in late 2002 and have been done routinely since late 2004. Monitoring of positions and movements of VERA sites by geodetic observations contributes to keeping the accuracy of the VERA astrometric measurements. Geodetic observations are made in S/X- and K-bands.

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. Ogasawara and Ishigakijima are small islands in the open sea and their climate is subtropical.

Table 1. General information

Sponsoring agency	Mizusawa VERA Observatory, National Astronomical Observatory of Japan	
Contributing type	Network observing station	
Location	Mizusawa	141° 07’ 57”.2E, 39° 08’ 00”.7N, 75.7m(a.s.l.)
	Iriki	130° 26’ 23”.6E, 31° 44’ 52”.4N, 541.6m(a.s.l.)
	Ogasawara	142° 12’ 59”.8E, 27° 05’ 30”.5N, 223.0m(a.s.l.)
	Ishigakijima	124° 10’ 15”.6E, 24° 24’ 43”.8N, 38.5m(a.s.l.)

2. Technical Parameters

Parameters of the antennas and the front- and back-end systems are summarized in Tables 2 and 3, respectively. The 1 Gbps recorder named DIR2000 is shown in Figure 3.

Figure 1. VERA Iriki antenna (foreground)

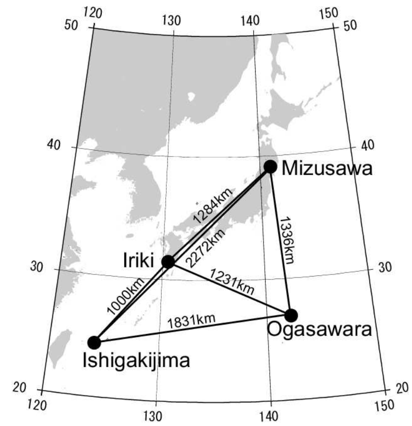


Figure 2. Location of VERA stations

Table 2. Antenna parameters

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

Figure 3. DIR2000: 1 Gbps recorder used in VERA operations.

3. Activities of Geodetic VLBI Observation

Two observation modes are used for geodetic observations. One is the VERA internal geodetic observation. The observing frequency bands are S/X and K and the recording rate is 1 Gbps. The other is the joint observation with the Geographic Survey Institute (GSI) by Mizusawa's participation in GSI's domestic observation sessions called JADE. The purpose of the JADE participation is to obtain VERA's coordinates in the terrestrial reference frame realized by the IVS. Its frequency band is S/X and the recording rate is 128 Mbps. A K5-VSSP data aquisition terminal is used.

During 2007, VERA internal geodetic observations were carried out 20 times. These observations are divided into 17 K-band sessions and 3 S/X-band sessions. We tried changing the geodetic observation frequency from S/X to K. There seems to be no significant systematic difference in the estimated coordinates between S/X and K-bands. As a result, all sessions after October used K-band.

1 Gbps recording mode according to JADE schedule started at all VERA stations. The same observations raw data sent from Tsukuba 32m antenna via G-bit optical fiber network was recorded

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	100K	RHC	HEMT	Helical array
X	8.18–8.60	100K	RHC	HEMT	Helical array
K	21.5–24.5	39±8K	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

by using 1 Gbps recording system in the Mitaka Correlation Center. All VERA antennas were connected with the IVS network immediately due to this observation mode. This observation mode was operated 9 times during 2007.

Joint observations with the 11m telescope of Gifu University started in October. The telescope is linked to Mitaka via optical fiber and it is possible to record Gifu data by using a DIR2000 1 Gbps recorder at Mitaka.

4. Plans for 2008

Regular VERA Internal geodetic observations, the participation in JADE and 1 Gbps recording according to JADE schedule will be continued. Gifu 11m antenna will join semi-regularly the VERA internal observations in K-band and will be able to be regarded as the fifth station of VERA at least for geodetic purposes. Experimental observations with Tsukuba 32m antenna in the same mode will also be made.

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

5. Staff Members

The VERA team of NAOJ consists of 9 scientists, 7 technicians, and 5 post-docs. Among them, the members of the geodesy group are S. Manabe (chief, scientist), Y. Tamura (scientist), T. Jike (scientist), and M. Shizugami (software technician).

Noto Station Status Report

G. Tuccari

Abstract

This brief report summarizes the main activities of the Observatory of Noto in 2007.

1. Antenna, Receivers and Microwave Technology

At present the main issue for the antenna functionality is still the azimuth rail, but news from INAF indicate that the rail and grout replacement could be realized in 2008. If confirmed, this job will probably stop the antenna activity during 2008 summer.

A new antenna driving software has been realized, which is able to support all the functionalities available with the TIW ACU and is able to control with better precision. The new software has also a Web interface.

The 43 GHz receiver is working with only one polarization and the replacement of a front-end amplifier will be done in the next months.

The 86 GHz is still an issue. Functionality measurements will be done in laboratory and a new campaign will be realized during the first months 2008.

2. Acquisition Terminal and Digital Technology

Terminals are in the process of being sent to the stations. On November 5, 2007 a geodetic version of DBBC arrived in Wettzell. The Wettzell DBBC system has 4 IFs and 14 equivalent base band converters. In the same month it was installed and integrated with the other VLBI equipment. Recording of its output is realized by a Mark 5B+ system. Europe90 observation has been done for testing the equipment. Fringes have been found on all channels and data analysis in underway.

The DBBC system for Irbene (Latvia) has been completed and in the first days of February it will be transferred by Latvian colleagues to their station. The Irbene DBBC is a reduced version having two IFs and 2 Core1 boards. As soon as Irbene funds are available to upgrade the system, a few Core2 boards will be added to achieve a complete architecture. At present the system will allow to perform the first observations and tests of the antenna and the 6 cm receiver.

A system similar to the Irbene one has been delivered to the Arcetri Observatory. Main purpose is to use it as a development system for FPGA configurations devoted to the realization of spectrometer, pulsar, total power, and polarimetry back-end. The Arcetri team is part of a FPGA team established to support firmware development on the DBBC platform.

Two additional DBBC systems are almost ready and equipped with 4 IF sections, but waiting for the production of the new Core2 boards. Such terminal for Tigo and O'Higgins will be equipped with four Core2 boards each and will achieve the functionality of 16 equivalent BBCs.

Other complete systems are under construction for Yebes, Noto, Medicina, and SRT. In particular the Medicina unit is expected to support the multibeam 22GHz receiver (7 feeds x 2 polarization x 2 GHz bwd/ea) for VLBI and single dish applications.

The first ADB2 board prototype has been completed and is available for the first test. The board offers several operation modes with demultiplexing in two or four bus. Maximum sampling clock is 2.2 GHz, maximum signal frequency to be sampled is 3.5 GHz, 10-bit representation. A board ADB2 can feed as piggy-back element a FiLa10G, giving the possibility to place the sampling element in the receiver site, connecting the DBBC through optical fibres.

The new processing unit Core2 board, in V5 version, is expected by the end of January for the first tests. The board is compatible with ADB1 and ADB2 and support a minimal equivalent of four Core1 functionality. A piggy-back element can be adopted for additional functionality, like memory bank for pulsar de-dispersion, memory corner or other needs where a significant memory addition is to be adopted. The memory piggy-back is under development.

A multiband fixed tuning configuration is under development and expected in March 08, to be used as an alternative to the standard base band converter configurations.

The FiLa10G boards realization started and the first prototype of the board is expected in two-three months. It can be used as piggy-back board of any ADB2 sampler, giving the possibility to transmit and receive at the same time a high data rate of 20 Gbps + 20 Gbps. The bidirectional functionality can 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 a typical sampling frequency of 2.048 MHz and the full 10-bit data representation, a double optical fibre set meets the full requirement. Two transceivers can be used, with the possibility to populate the board even with one transceiver only. One board can even support the data tx-rx of 2x2 VSI connections and in such case it can still be used as p-b element of an ADB2 or as stand-alone element. Indeed the configuration files can be also loaded by the on-board stand-alone flash memory. The entire triangle connectivity HSI/HSIR to VSI in/VSI out to Optical Fibres is supported.

3. Observation Test, Documentation and More

The Europe89 was observed for 12 hours in September using 8 BBC equivalent in X band and 3 BBC equivalent in S band: fringes have been detected in all the sub-bands. (See figure 1.) Euro90 observed 24 hours at Wettzell with all the standard number of subchannels. A technique to compensate for fractional frequency offset is under evaluation.

The digital system use requires to optimize or to equalize the IF flatness in band: a new version of Conditioning Module is under development to optimize this aspect, but a good equalized band is expected from the receiver. An additional observation test will be realized with the Wz unit and all the other terminals that will be available at that time.

Dedicated Web pages have been added to the Noto Internet server with information about the DBBC system. A document series is in preparation and it started to become available on these pages, so as a page with News.

The integration with the Field System is now under development and expected to be accomplished in the coming weeks. It is realized initially as a collection of station commands, as the software structure the DBBC is able to recognize. The gain information in the different parts of the instrument are recorded in a log that can be available under a specific FS command request for calibration purposes.

4. Geodetic Experiments in Noto during 2007

Noto station observed twelve geodetic experiments during 2007, namely 6 EUROPE, 3 IVS-CRF, 2 IVS-T2, 1 IVS-R&D.

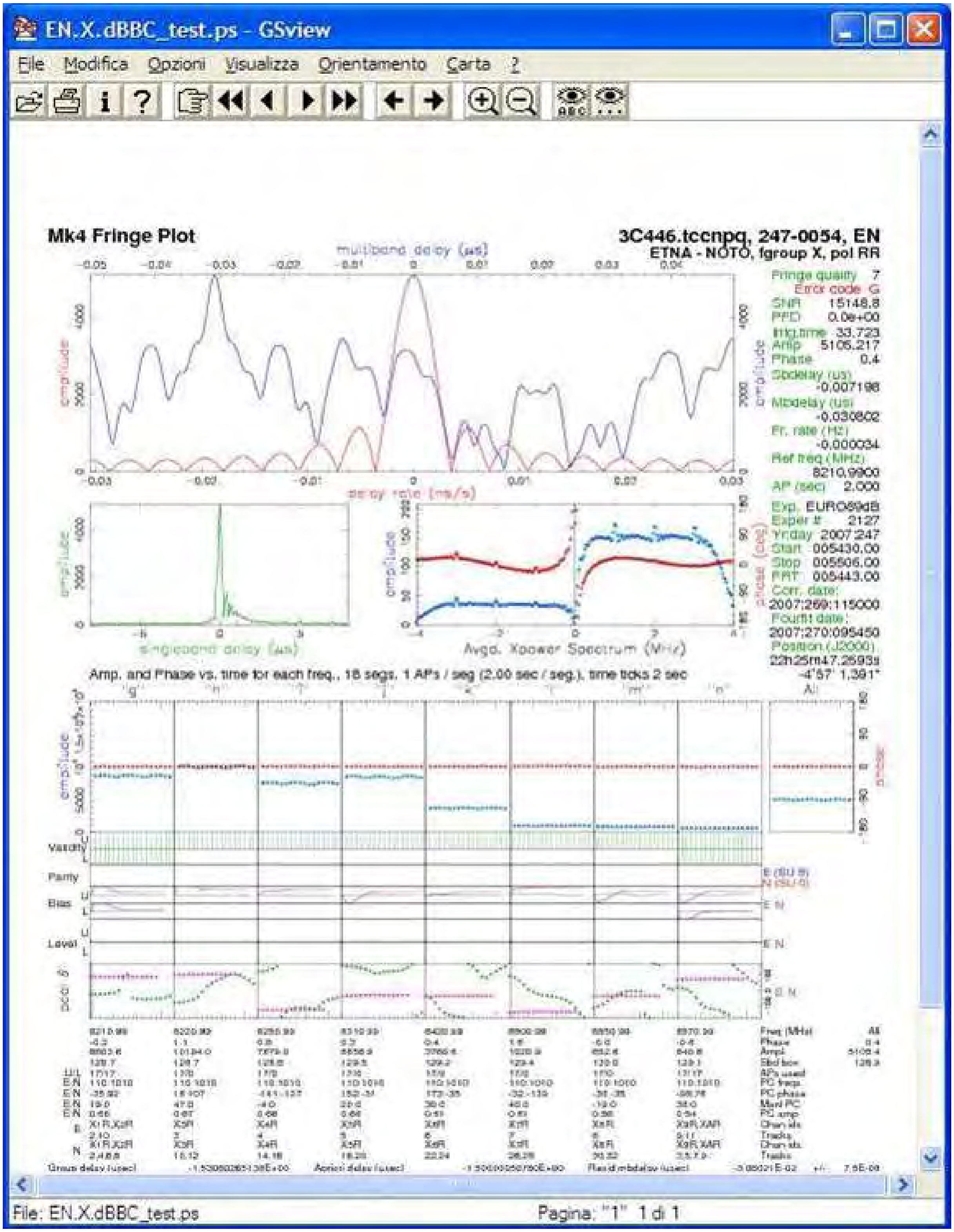


Figure 1. Fringes from Europe89.

Ny-Ålesund 20 Metre Antenna

Helge Digre

Abstract

For the year 2007, the 20-meter VLBI antenna at the Geodetic Observatory Ny-Ålesund has tried to participate in VLBI experiments at the scheduled level and has done 73 of 79 24-hour experiments. Ny-Ålesund has also participated in an e-VLBI test and in e-VLBI experiments, transferring experiment data from Ny-Ålesund to the Haystack Correlator and later to the Bonn Correlator. Ny-Ålesund has done 14 of 19 Intensive experiments. The reasons for the lost experiments were the personnel situation, problems caused by an error in the main power delivery, and a lack of Mark 5 modules at the station. In 2007, Ny-Ålesund has continued to feel some consequences of the reduction in maintenance support and the lack of operator presence, both of which were caused by the reduction in staff that came as a result of the general reduction in the Norwegian Mapping Authority's (NMA) budgets. For 2007, Ny-Ålesund was a two person station until June, when Jan-Ivar Tangen's contract ended. The station was closed for three weeks for summer holiday and became a three person station again in September. In August, a new, second operator, Inge Sanden, was employed and started his training, while in September, a new, third operator, Ole Bjørn Årdal, was employed and started his training. At the beginning of the year, maintenance and repair were done at a minimum level, given the personnel situation, and no responses were made to any alarms, and no errors were corrected during unmanned operation. Towards the end of the year, the station was normally manned while experiments were running, as long as all employees were present in Ny-Ålesund. Ny-Ålesund is a Mark 5 station only.

1. General Information

The Geodetic Observatory of the NMA at 78.9 N and 11.87 W is located in Ny-Ålesund, in Kings Bay, at the west side of the island Spitsbergen, the biggest island in the Svalbard archipelago. In 2007, Ny-Ålesund was scheduled for 79 R1, EURO, RD, and RDV experiments and 19 K07 Intensives. Some X-band experiments were totally cancelled because of systems being down. For the same reason, one X-band experiment ran only 13 hours. Some X-band experiments lost up to 15 hours observing time due to alarms during unmanned operation. Two experiments ended early, and up to 6 hours of observing time were lost because of the installation of e-VLBI equipment. Most of this lost observation time was caused by lack of maintenance and reduction of personnel.

In addition to the 20-meter VLBI antenna, the Geodetic Observatory has two GPS antennas in the IGS system and a Super Conducting Gravimeter in the Global Geodynamics Project (GGP) installed on the site. There is also a CHAMP GPS and a SATREF (dGPS) installation at the station. At the French 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 Statens Kartverk structure in the context of ISACCO, an Italian research project on ionospheric scintillation observations, led by Giorgiana De Franceschi of the Italian Institute of Volcanology and Geophysics (INGV).

2. Component Description

The antenna is intended for geodetic use and is designed for receiving in S-band and X-band. The equipment is Mark 5. The station configuration file can be found on the IVS web site: ftp://ivscc.gsfc.nasa.gov/pub/config/ns/nyales.config. Ny-Ålesund is located so far north that it has daytime aurora in winter and midnight sun from the 20th of April to the 27th of August. The

Figure 1. Ny-Ålesund antenna.

location of the antenna enables signal reception over the North Pole. In 1998, Ny-Ålesund was the only antenna that could receive signals from the Mars Global Surveyor for 24 hours.

3. Staff

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

Hønefoss:	Section manager:	Rune I. Hanssen (through September)
		Line Langkaas (from October)
	Station responsible at Hønefoss:	Svein Rekkedal
Ny-Ålesund:	Station commander:	Leif Morten Tangen[1]/ Helge Digre
	Engineer	Jan-Ivar Tangen to 2007.06.30
	Engineer	Inge Sanden from 2007.08.01
	Engineer	Ole Bjørn Årdal from 2007.09.01

[1]Leif Morten Tangen was granted permission from 2006.11.01 until 2008.03.01. Leif Morten Tangen delivered his resignation in November 2007 and will have a last period in Ny-Ålesund from 2008.02.11 to 2008.03.13.

Helge Digre participated in the TOW 2007.

4. Current Status and Activities

Ny-Ålesund has tried to participate in VLBI experiments at the scheduled level and has done so, mostly as a tag-along station. Ny-Ålesund is a Mark 5A only station. Both the FS and Mark 5 are upgraded to the latest software versions. Two new FS computers were bought last year, and some modifications and testing still must be done before they can be used permanently for experiments. The communication problem with the receiver has been solved. What still remains is a communication problem with the weather station. A direct high-speed data link from Ny-Ålesund Geodetic Observatory to MIT Haystack has been tested. The high-speed data link was supposed to be able to transfer 100 Mbps. The Ny-Ålesund high-speed data link project is a cooperative effort between NMA, UNINETT, NORDUnet, NASA Goddard Space Flight Center, and MIT Haystack Observatory. The responsible person at NMA was Rune I. Hanssen. In the second half of 2007, e-VLBI has been used for transferring the K07 measurements from Ny-Ålesund to Bonn Correlator.

The Super Conducting Gravimeter (SCG) placed on the same fundament as IGS-GPS NYA1 has been running without problems. The yearly service on the system was performed by Dr. Yoshiaki Tamura and Ove Omang in the middle of August. National Astronomical Observatory of Japan, Mizusawa VERA Observatory, which owns the SCG, lent this equipment to NMA starting on 2007.04.01, to keep the recording of the data going. The Geodetic Observatory, Ny-Ålesund, was scheduled to use the last part of 2007 to again become fully manned with three people, operating on a normal basis.

5. Future Plans

Ny-Ålesund will continue to participate in the 80 regular and 53 Intensive experiments for which the antenna is scheduled, and it intends to move from tag-along status to fully operational from the start of 2008. Ny-Ålesund is likely to participate in CONT 2008. We hope that the new Field System computers, which in fact are not so new anymore, will be put into permanent use as soon as possible, as the last of the communication problems was solved the second week of 2008. The National Astronomical Observatory of Japan, Mizusawa VERA Observatory, is lending the Norwegian Mapping Authority their superconducting gravimeter, which is already installed in Ny-Ålesund, so the scientific measuring series can continue. The SCG has to be refilled with liquid Helium each year, and the lift has to be re-certified every year. The insulation in the roof of the Observatory has absorbed a lot of moisture. The plan is to renovate the roof and build a better solution during the summer of 2008, so that similar problems can be avoided in the future.

German Antarctic Receiving Station (GARS) O'Higgins

Wolfgang Schlüter, Christian Plötz, Reiner Wojdziak

Abstract

In 2007 the German Antarctic Receiving Station (GARS) in O'Higgins contributed to the IVS observing program with eight observation sessions. Control software and hardware have been improved with the goal of implementing remote observations.

1. General Information

The German Antarctic Receiving Station (GARS) is jointly operated by the Federal Office of Cartography and Geodesy (BKG) and the German Aerospace Center (DLR). The Institute for Antarctic Research Chile (INACH) coordinated the preparatory activities and logistics prior to the campaigns. The 9m radiotelescope at O'Higgins is used for geodetic VLBI and for downloading of remote sensing images from satellites such as ERS and TerraSAR. The access to the station is organized campaignwise during the Antarctic spring and summer. In 2007 the station was occupied from January to March and from October to December. DLR and BKG jointly send engineers and operators for the campaigns together with a team which maintains the infrastructure, such as the provision of power.

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

At the end of 2007, the cruiseliner "Explorer" sank approximately 50 miles away from O'Higgins. This disaster affected the second campaign dramatically, as all the means of transportation were employed for the rescue of the passengers. The staff had to stay more than 10 days longer at O'Higgins.

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

In co-location with the 9m radiotelescope for VLBI

- two GPS receivers are operated in the frame of IGS all over the year, an Alan Osborn ACT (OHI2), which has a long and stable history and a JAVAD receiver (OHI3) for GPS and GLONASS tracking. During the second campaign 2007 the ACT receiver was replaced by a second JAVAD receiver in order to provide redundancy for the GLONASS tracking.

- a tide gauge is installed, which has been operating for several years with some interruptions caused by destroyed cables from the scratching ice on the rocks. During 2007 the system failed. A replacement by a radar tide gauge system is planned.
- a meteorological station provides pressure, temperature, humidity and wind information, as long as the extreme conditions outside do not disturb the sensors,
- a H-Maser, an atomic Cs-clock, a GPS time receiver, and a Total Accurate Clock (TAC) are employed for the provision of the time and frequency.

The 9m radiotelescope is designed for dual purposes:

- for performing geodetic VLBI and
- for receiving the remote sensing data from ERS 2, JERS, and ENVISAT.

In the second campaign 2007, remote sensing data from TerraSAR were recorded with highest priority.

Figure 1. View to GARS O'Higgins

Figure 2. Transport to Base Frei at King George Island with Hercules C-130

Figure 3. Bridge to Base O'Higgins

2. Technical Staff

The staff members who operate, maintain, and upgrade the GARS VLBI component and the geodetic devices are summarized in table 1.

Table 1. Staff – members

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

3. Observations in 2007

GARS participated in the following sessions of the IVS observing program during the Antarctic summer campaign (January-March 2007)

- IVS T2049 06.-07. February 2007
- IVS OHIG48 07.-08. February 2007
- IVS OHIG49 13.-14. February 2007
- IVS OHIG50 14.-15. February 2007

and during the Antarctic spring campaign (October-December 2007)

- IVS OHIG51 11.-12. November 2007
- IVS OHIG52 12.-13. November 2007
- IVS OHIG53 18.-19. November 2007
- IVS OHIG54 19.-20. November 2007

The observations were recorded with Mark 5A. The data were carried from O'Higgins to Punta Arenas by the staff when they returned home. From Punta Arenas, the disks were shipped by regular air transports to the correlator.

4. Maintenance

The extreme conditions in the Antarctic require special attention to the GARS telescope and to the infrastructure. Corrosion results in problems with connectors and capacitors, which need to be detected. The H-Maser has to be set up into its operation mode as soon as the operators arrive. The antenna, the S/X-band receiver, the cooling system, and the data acquisition system have to be activated properly. Those components that were damaged during the previous campaign usually are replaced. In 2007 two new containers were shipped to O'Higgins to replace worn out systems and to improve the infrastructure, in particular renewing the personal cabins.

5. Technical Improvements

As already reported, the Antenna Control Unit (ACU) was replaced by a completely new system built by VERTEX. Due to some inconsistencies in the operations, the old ACU was still used in 2006 for the observations in order to avoid failures during the VLBI experiments. At the beginning of the first campaign 2007, final tests of the new ACU were successfully carried out. Consequently the new ACU replaced the old system. Thanks to the new ACU and the Mark 5 recording system, remote control of the antenna became more realistic. New software developments that make use of direct access to shared memory following the server–client principle were made. This requires less data transmission via Internet, making the software much more robust. Tests were carried out at the end of the field campaign, during the wait for the transport to the mainland. Such a remote system will support the remote monitoring of GARS in the future.

6. Upgrade Plans for 2008

During 2008 it is planned to increase the observing capabilities, in particular by extending the period of observation, employing the remote control facilities. Such an upgrade will be realized in close collaboration with DLR, which will make use of the facilities throughout the year for the acquisition of data from the planned TerraSAR-Tandem mission. The Internet capabilities will be improved. The upgrade to Mark 5B and the installation of Digital Baseband Converters (DBBC) is planned for 2008.

The IVS Network Station Onsala Space Observatory

Rüdiger Haas, Gunnar Elgered

Abstract

We briefly summarize the status of the Onsala Space Observatory in its function as an IVS Network Station. The activities during the year 2007, the current status, and future plans are described.

1. Staff Associated with the IVS Network Station at Onsala

The staff associated with the IVS Network Station at Onsala remained mainly the same as reported in the IVS Annual Report 2006 [1]. However, one Ph.D. student left the observatory during the year, one new Ph.D. student joined the observatory, and one of the operators left.

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

Function	Name	e-mail	telephone
Responsible P.I.s	Rüdiger Haas	rudiger.haas@chalmers.se	5530
	Gunnar Elgered	gunnar.elgered@chalmers.se	5565
Observatory director	Hans Olofsson	hans.olofsson@chalmers.se	5520
Ph.D. students	Martin Lidberg (until 2007.11.30)	lidberg@oso.chalmers.se	5566
involved in VLBI	Tobias Nilsson	tobnil@chalmers.se	5575
observation	Tong Ning (since 2007.09.01)	tong.ning@chalmers.se	5578
Field system	Biörn Nilsson	biorn@oso.chalmers.se	5557
responsibles	Michael Lindqvist	michael@oso.chalmers.se	5508
VLBI equipment	Karl-Åke Johansson	karlake@chalmers.se	5571
responsibles	Leif Helldner	helldner@chalmers.se	5576
VLBI operators	Roger Hammargren	rogham@chalmers.se	5551
	Fredrik Blomqvist (until 2007.08.31)	blomqvist@oso.chalmers.se	5552
Telescope scientists	Lars EB Johansson	lars.johansson@chalmers.se	5564
	Lars Lundahl	lars.lundahl@chalmers.se	5559

2. Geodetic VLBI Observations for IVS during 2007

In 2007 the observatory was involved in the five IVS-series EUROPE, R1, T2, RDV, and RD07. In total, Onsala participated successfully in 27 experiments. See Table 2. All experiments were recorded on Mark 5 modules, and for many experiments the data were transferred by e-VLBI to the Bonn correlator [2] using the PCEVN-computer [3]. The latter is daisy-chained to the Mark 5 computer to allow us to record in parallel on Mark 5 modules and the PCEVN raid-system and also to simultaneously transfer the data in real-time from the PCEVN to the correlator. In the second half of 2007 we upgraded the PCEVN raid-system to a capacity of 2 TB, i.e. large enough for most of today's IVS experiments.

Radio interference due to UMTS mobile telephone signals continued to interfere with S-band observations.

Table 2. Geodetic VLBI experiments at the Onsala Space Observatory during 2007.

Exper.	Date	e-VLBI transfer	Remarks
EURO-85	01.08	no	o.k.
R1-258	01.09	yes, real-time	o.k.
R1-260	01.22	no	o.k., spurs in X-band
R1-262	02.05	yes, real-time	o.k.
T2-049	02.06	yes, real-time	o.k., noisy S-band phase cal
R1-263	02.12	yes, real-time	o.k., clock jump -1 sec
R1-265	02.26	yes, real-time	o.k., encoder problems, 6 scans lost
R1-270	04.02	no	o.k., encoder problems, 4 scans lost
R1-271	04.10	no	o.k., noisy phase cal
R1-273	04.23	no	o.k., encoder problems, 14 scans lost
R1-274	05.02	yes, off-line	o.k.
RD07-04	06.27	no	o.k.
EURO-88	07.03	yes, off-line	o.k.
RDV-64	07.10	no	o.k.
RD07-05	07.11	no	o.k., spurs in X-band, encoder problems, about 22 scans lost
R1-285	07.16	yes, off-line	o.k., encoder problems, 18 scans lost
R1-291	08.27	yes, off-line	o.k., X-band spurs, RX problems, encoder problems, 2 scans lost
EURO-89	09.03	yes, off-line	o.k., spurs in X-band, encoder problems, 3 scans lost
R1-292	09.04	no	o.k., spurs in X-band
R1-293	09.10	yes, off-line	o.k., spurs in X-band, encoder problems, some scans lost
RD07-07	09.12	no	o.k., spurs in X-band, encoder problems, some scans lost
R1-294	09.17	no	o.k., spurs in X-band, encoder problems, 14 scans lost
R1-295	09.24	yes, off-line	o.k., power failure, 4 hours lost
EURO-90	11.22	yes, off-line	o.k.
T2-052	11.27	yes, off-line	o.k.
RDV-66	12.05	no	o.k.
RD07-10	12.12	no	no correlator report yet

The previously reported problems with the azimuth encoders [4] continued partly during 2007, and a power failure in September caused a loss of about 4 hours of observations. See Table 2.

The new S/X receiver with dual polarization was installed in early July. Unfortunately the filters proved not to be good enough, and spurious phase cal signals affected the first couple of X-band channels for several experiments. See Table 2. To avoid these disturbances, an additional filter for right circular polarization was installed in November.

3. Fennoscandian-Japanese Ultra-rapid dUT1 Measurements

Together with our colleagues in Metsähovi, Kashima and Tsukuba, we started a project for Fennoscandian-Japanese ultra-rapid dUT1 measurements in order to determine dUT1 with very low latency. The project involves real-time data transfer from Fennoscandia to Japan, near real-time data conversion from Mark 5 to K5, near real-time correlation with the Japanese software correlator, creation of VLBI databases, and quick data analysis. It allows the determination of dUT1 within 30 minutes after the end of an observing session, as demonstrated by the baselines Onsala—Kashima and Onsala—Tsukuba. See Table 3.

Table 3. Fennoscandian-Japanese ultra-rapid dUT1-experiments involving Onsala in 2007.

Exper.	Date	Stations	Mbps	tranfer	Correlation	Comments/latency
u7093a	04.03	Onsa - Kash	256	off-line	off-line	dUT1 within 3 hours
u7113	04.23	Onsa - Kash	128	real-time	off-line	dUT1 within 2 hours
u7122	05.02	Onsa - Kash	128	real-time	real-time	correlation within 10 minutes
u7150	05.30	Onsa - Kash	128	real-time	real-time	dUT1 within 28 minutes
u7151a	05.31	Onsa - Kash	128	real-time	real-time	dUT1 within 30 minutes
u7155	06.04	Onsa - Kash	256	real-time	real-time	dUT1 within 31 minutes
u07195	07.14	Onsa - Kash	128	real-time	off-line	
u07196	07.15	Onsa - Kash	256	real-time	off-line	
u7298	10.25	Onsa - Kash	256	real-time	off-line	
a07326	11.22	Onsa - Tsuk	256	real-time	real-time	dUT1 within 30 minutes
b07326	11.22	Onsa - Tsuk	256	real-time	real-time	
u7330a	11.26	Onsa - Kash	128	real-time	off-line	
u7330b	11.26	Onsa - Kash	256	real-time	off-line	
u7330c	11.26	Onsa - Kash	512	real-time	off-line	
u7330d	11.26	Onsa - Kash	128	real-time	real-time	dUT1 within 25 minutes
u7330e	11.26	Onsa - Kash	256	real-time	real-time	dUT1 within 27 minutes
u7330f	11.26	Onsa - Kash	512	off-line	off-line	
u7348a	12.14	Onsa - Kash	128	real-time	real-time	dUT1 within 30 minutes
u7348b	12.14	Onsa - Kash	256	real-time	off-line	

4. Monitoring Activities in 2007

The monitoring of the vertical height changes of the telescope tower by the invar monitoring system at the 20 m telescope [5] was continued.

We also continued the calibration campaign for the Onsala pressure sensor [1]. For this purpose we borrow a Vaisala barometer from the Swedish Meteorological and Hydrological Institute (SMHI). This instrument is calibrated once per year at SMHI. We do parallel manual recordings with the SMHI barometer (Vaisala-SMHI), the Onsala barometer (Setra Systems) that has been used for VLBI for many years, and another Vaisala barometer (new-Vaisala) that was installed in 2007 at the observatory as part of a new weather station. Figure 1 shows time series of differences between these three sensors and the corresponding amplitude spectra.

The microwave radiometer Astrid was repaired during 2007. The microwave radiometer Konrad was out of service during 2007. We expect Konrad to be in routine operation again in 2008.

The observatory hosts a gravimeter platform, which has been used for repeated absolute gravity measurements for several years. In May three absolute gravity observation teams visited the observatory—from the University for Environment and Life Sciences at Ås, Norway; the Institut für Erdmessung, University of Hannover, Germany; and the Swedish National Land Survey.

During 2007 we started preparing for the installation of a superconducting gravimeter at the observatory. The house for the new gravimeter is expected to be constructed during spring 2008, and the actual superconducting gravimeter is expected to be delivered mid-2008.

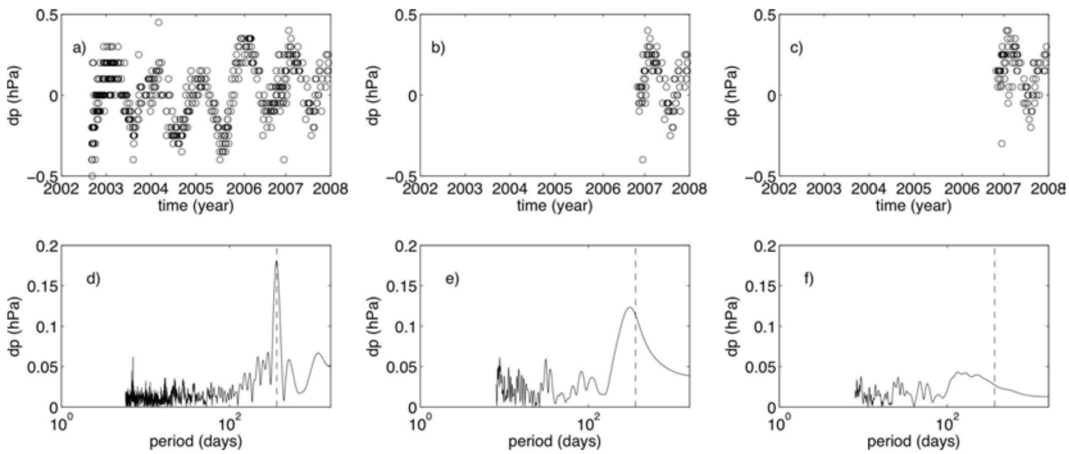


Figure 1. Top: pressure differences (a) Setra - Vaisala-SMHI, (b) Setra - new-Vaisala, (c) Vaisala-SMHI - new-Vaisala. Bottom: corresponding amplitude spectra. The annual period is indicated as a vertical line.

5. Outlook and Future Plans

The Onsala Space Observatory will continue to operate as an IVS Network Station and to participate in the IVS observation series. For the year 2008 a total of 25 experiments in the series EUROPE, R1, T2, RDV, and RD08 are planned. We will also prepare to participate in a possible CONT08 campaign. We aim at an increased and regular use of e-VLBI data transfer using the PCEVN. We will continue to monitor the relevant VLBI system parameters to be able to detect possible error sources as early as possible and to achieve and maintain high data quality. This monitoring activity includes the stability of the telescope, the local tie, the pressure sensor calibration and the operation of microwave radiometers. The new superconducting gravimeter is expected to be in service in the second half of 2008.

References

[1] Haas, R., and Elgered, G.: The IVS Network Station Onsala Space Observatory. In: D. Behrend and K. D. Baver (eds.): *IVS 2006 Annual Report*, NASA/TP-2007-214151, 81–84, 2007.

[2] Haas, R., Wager, J., Mujunen, A., Ritakari, J., Müskens, A., Dulfer, C., Bertarini, A.: e-VLBI data transfer from Onsala and Metsähovi to the Bonn correlator. In: J. Böhm, A. Pany, and H. Schuh (eds.): *Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting*, Geowissenschaftliche Mitteilungen, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, **79**, 27–32, 2007.

[3] Ritakari, J., and Mujunen, A.: A VSI-H Compatible Recording System for VLBI and e-VLBI. In: N.R. Vandenberg and K.D. Baver (eds.) *IVS 2002 General Meeting Proceedings*, NASA/CP-2002-210002, 128–131, 2002.

[4] Haas, R., and Elgered, G.: The IVS Network Station Onsala Space Observatory. In: D. Behrend and K. D. Baver (eds.): *IVS 2005 Annual Report*, NASA/TP-2006-214136, 111–114, 2006.

[5] Elgered, G., and Haas, R.: Geodetic Very-Long-Baseline Interferometry at the Onsala Space Observatory 1997–1998. In: W. Schlüter and H. Hase (Eds.): *Proc. of the 13th Working Meeting on European VLBI for Geodesy and Astrometry*, 60–64, 1999.

Sheshan VLBI Station Report for 2007

Xiaoyu Hong, Qingyuan Fan, Tao An

Abstract

This report summarizes the observing activities carried out at the Sheshan station in 2007. The SESHAN25 radio telescope participated in ten 24-hour VLBI sessions organized by the IVS and twenty-seven VLBI experiments organized by the EVN. Apart from its international VLBI activities, the SESHAN25 telescope spent a large amount of time on the Chinese Lunar Project, including the testing before the launch of the Chang'E-1 satellite, and the tracking campaign after the launch. We also report the updates and developments in the facilities at the station.

1. General Information

The Sheshan VLBI station (also named SESHAN25 in the geodetic community) is hosted by the Shanghai Astronomical Observatory (SHAO), CAS. A 25-meter radio telescope, which was built in 1987, is in operation at multiple centimeter wavelengths. The Sheshan VLBI station is a member of the IVS, EVN, and APT. It takes part in astrometric, geodetic, and astrophysical VLBI experiments, along with other VLBI network stations. In October and November 2007, SESHAN25 was involved in the VLBI tracking of the Chinese Chang'E-1 Lunar satellite. A 5-station correlator at SHAO undertook the VLBI data processing of the Chang'E satellite.

2. VLBI Observations in 2007

In 2007, SESHAN25 participated in 10 IVS sessions. The antenna worked normally in 9 of the experiments. SESHAN25 also participated in the EVN sessions in February and June at 1.3, 6, and 18 cm wavelengths. There were no known problems during the EVN observations. In order to participate in the Chinese Chang'E Lunar Project, SESHAN25 stopped international VLBI activities on October 11, 2007. After the launch of Chang'E-1 on October 24, the telescope carried out daily monitoring of the satellite. The Chinese radio telescopes had great success in the VLBI tracking of the Chang'E-1 satellite. The 5-station correlator processed the real-time data transferred from the observing stations through fiber link. The outputs of delay, delay rate, and the angular positions (RA and DEC) were used for measuring and determining the satellite orbit. Since December 2007, SESHAN25 has observed the Chang'E-1 satellite in its lunar orbit two or three days per week.

3. Development and Maintenance of Facilities in 2007

One of the antenna bearings was broken during the observation of IVS-R1288 on August 6. It cost us a couple of weeks to replace the bearing and repair the drive. After that, we spent several days on adjusting the pointing.

In August 2007, we received eight BBCs and one IF distributor from the IVS. The Shanghai VLBI station then recovered the standard geodetic VLBI setup with 14 BBCs and 2 IF distributors.

We had a new Mark 5A system as a backup in 2007. The FS software package has been kept up-to-date; the current FS version 9.9.2 is in use. A new FS computer was purchased for debugging local station programs. We have updated the clock and weather data acquisition programs and developed a remote monitoring program. The power equipment in the observing dome was reconstructed to guarantee safe and smooth running during VLBI experiments.

A number of e-VLBI test experiments between Shanghai and some European stations were performed in the first half of 2007. The Sheshan station can normally work at a data rate of 256 Mbps. In a demo experiment in Xi'an, China on August 28, Sheshan station achieved a maximum data rate of more than 512 Mbps, and fringes were detected among Chinese, European, and Australian telescopes.

Our five-station hardware correlator currently works at 16 Mbps per station in real-time mode, and 256 Mbps per station for post processing. An e-VLBI system consisting of four Chinese radio telescopes (in Shanghai, Urumqi, Beijing, and Kunming) and a software correlator were developed. The e-VLBI facilities are used in the Chang'E project.

4. The Staff of the Sheshan VLBI Station

Table 1 lists the group members at the Sheshan VLBI Station. The staff is involved in the VLBI program at the station with various responsibilities. Professor Wenren Wei retired in the beginning of 2007, but he will continue working with us in 2008. Bin Li began to serve as the technical friend at Sheshan station in 2007.

Table 1. The staff at the Sheshan VLBI Station.

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

5. Prospects

From January 2008 on, the Sheshan VLBI Station will participate again in IVS and EVN observations. In 2008 SESHAN25 will participate in 16–20 IVS sessions. The telescope will regularly monitor the Chang'E-1 satellite in its lunar orbit for 2–3 days per week in 2008.

Simeiz VLBI Station—New Status

A. E. Volvach, D. Graham

Abstract

We summarize briefly the status of our 22-m radio telescope as an IVS Network Station. In 2007 RT-22 was equipped with a modern Mark 5A VLBI recording system by the National Academy of Sciences of Ukraine. That makes it possible to continue astrophysical and fundamental geodetic VLBI observations.

1. General Information

Figure 1. The Simeiz VLBI station.

The Simeiz VLBI Station (also known as CRIMEA in the geodetic community), operated by Radio Astronomy Laboratory of Crimean Astrophysical Observatory of the Ministry of Education and Sciences of Ukraine, is situated on the coast of the Black Sea near the village of Simeiz, 20 km west of Yalta in the Ukraine.

The RT-22 radio telescope has a steerable parabolic mirror of diameter 22 m and focal length 9 525 mm. The surface has rms accuracy of 0.25 mm and effective area 210 m^2 independent of elevation angle. The antenna has an azimuth-elevation mounting with axis offset -1.8 ± 0.2 mm. The maximal slewing rate is 1.5°/sec. The telescope control system provides a pointing accuracy of 10″.

The foundation pit of the telescope is 9 meters deep and contains 3 meters of crushed stones and 6 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 parameters of the 22 meter radio telescope are presented in Table 1.

Table 1. The antenna parameters of the Simeiz station.

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

The control system of the radio telescope allows the antenna to be pointed and allows the observed source to be tracked in two regimes: autonomous and automatic. All modes of the radio telescope operation—antenna motion, radiometer readings, and data recording—are controlled by the special host computer in automatic regime.

The 2 and 8 GHz receivers and the phase and the amplitude calibration units are installed in the primary focus of the antenna. Table 2 shows the parameters of the 2 and 8 GHz receivers.

Table 2. The receiver parameters of the Simeiz antenna.

Band	Frequency, GHz	Tsys, K	Treceiver, K	Tfeed, K	Tmainlobe, K	Tsidelobes, K
S	2.1 - 2.5	100	40	25	7	28
X	8.18 - 8.68	80	50	5	10	15

The LNA was developed and manufactured by Joint-Stock “Mirrad” with the assistance of the Crimean Astrophysical Observatory and the Main Astronomical Observatory NASU.

The LNAs are uncooled. The feed illuminates the main dish of the antenna over the angle 140° at the level -10 db.

System Equivalent Flux Density (SEFD) was measured using radio sources with known flux densities: Cas-A, Virgo-A, Cygnus-A, and Taurus-A. All measurements of system noise were made using the Field System.

SEFDs were measured as 1100 (X) and 1400 (S) Jy at zenith, which essentially does not differ from the values achieved with the former cooled amplifier.

The weight on the focus legs was reduced from 300 to 3 kg. This significantly eases the process of putting up receivers.

A new pointing model was made with the upgraded receivers.

2. Current Status and Activities

The interdepartmental center for collective use of the RT-22 radio telescope was created within the framework of the Scientific-Research Institute "Crimean Astrophysical Observatory" of the Ukrainian Ministry of Education.

Organizational members of the Center are the Scientific-Research Institute "Crimean Astrophysical Observatory" (Director of SRI "CrAO"—A. M. Rostopchina-Shakhovska), the Main Astronomical Observatory of National Academy of Sciences of Ukraine (Director of MAO—Academician NASU Ya. S. Yatskiv) and the Institute of Radio Astronomy of National Academy of Sciences of Ukraine (Director of IR—Academician NASU L. N. Litvinenko).

The purpose of this Center is an intensification and coordination of the main scientific research in the fields of astrophysics, astrometry, and geodynamics; more complete and effective development and use of instrument possibilities and scientific potential of the national property of Ukraine RT-22 as one of the best radio astronomy instruments of millimeter range; and the effective integration and coordination of facilities and capabilities of the SRI "CrAO", MAO, and IR.

The main objectives of the Center are: development of new methods of scientific research in radio astronomy; to provide a place for the scientific organizations of Ukraine and other countries to carry out research and development with the scientific state-of-the-art equipment under the auspices of the staff of organizations and participants of the Center; organization and implementation of fundamental, applied scientific research; realization of innovative and educational activity, and foreign relations.

Scientific establishments and organizations that need the scientific equipment of the Center to carry out research in either of two observing periods ending January 15 and June 15 should submit a written application for hours, terms, and types of research to the Center. The observation council considers annual plans for the distribution of observation time and introduces them for consideration to the Center administration.

Head of the Center: Volvach Alexandr Evgen'evich, PhD, deputy director of SRI CrAO, tel. +38-0654-23-71-52, e-mail: volvach@crao.crimea.ua.

Observation council Chairman: Vavilova Irina Borisovna, PhD, scientific secretary CSR NASU, tel. +38-044-239-74-90, e-mail: vavilova@nas.gov.ua.

Contact information is provided at the URL: http::/www.crao.crimea.ua/rt22/main.htm

In 2007 RT-22 was equipped with a modern Mark 5A VLBI recording system by NAS Ukraine. That will allow the continuation of astrophysical and fundamental geodetic VLBI observations. On November 22, 2007 Mark 5A was made operational, and the first session (EUROPE-90) was carried out.

Table 3. The current projects.

Very Long Baseline Interferometry	Astrophysics, geodetics, astrometry and radar projects with the international networks. Facilities for VLBI observations at frequencies 612 MHz and 1.6, 2.3, 5.0, 8.4, and 22 GHz are available. These observations are supported by the hydrogen frequency standard with the stability 10^{-14} in the interval 1-24 hours and recording systems Mark 5A and NRTV.
Multi-wavelength monitoring of AGN	Regular monitoring is carried out at frequencies 22.2 and 36.8 GHz.
Molecular line observations at mm wavelength	Observations in molecular lines of maser sources, star forming regions, and other objects have been intensively carried out since 1978 in the range of 1.6 to 115 GHz.
Solar and stellar activity investigations	Station carries out the observations at 8.6, 10.7, 13.3, 15.4, 22.2, and 36 GHz. Stokes parameters of polarization I (intensity) and V (circular polarization) are measured.

During 2007 the Simeiz station regularly participated in various radio astronomy programs including VLBI and single-dish observations of quasars and planets.

3. Future Plans

Our plans for the coming year are the following: to put into operation the Mark 5B+ VLBI recording system and to obtain a new H-maser.

4. Acknowledgments

Authors would to like to thank the Director of MAO, Academician NASU—Ya. S. Yatskiv; the Director of IR, Academician NASU—L. N. Litvinenko; Deputy Director of IR, Academician NASU—V. M. Shulga; and the Director of SRI “CrAO”—A. M. Rostopchina-Shakhovska for their effort in creating the interdepartmental center for collective use of the radio telescope RT-22.

Svetloe Radio Astronomical Observatory

Sergey Smolentsev, Ismail Rahimov

Abstract

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

1. Introduction

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

Figure 1. Svetloe observatory.

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

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

2. Participation in IVS Observational Programs

During 2007 the Svetloe IVS station participated in 46 24-hour IVS-R4, IVS-T2, EURO, R&D and VLBA sessions and in 15 IVS-Intensive sessions. A list of the sessions is presented in 1.

3. Radio Telescope

The railway junctures were joined by electric welding.

Table 1. List of IVS sessions observed at SvRAO in 2007.

Month	IVS-R4	IVS-T2	EURO	R&D	VLBA	IVS-Intensive
January	3		1		1	2
February	2		1			2
March	5					2
April	4			1		2
May	5	1				
June	3					
August	1					
September	3					1
October	5					2
November	4		1			2
December	4					2
Total	39	1	3	1	1	15

4. Co-location GPS

- The GLONASS/GPS receiver “PROTON” was installed as a GLONASS “Control station” in December.
- A TopCon GPS/GLONASS/GALILEO receiver was bought and tested for future installation in place of the Leica GPS receiver.

5. Outlook

Our plans for the coming year are the following:

- Participation in IVS-R1, IVS-R4, IVS-T2, EURO, VLBA and R&D observational sessions.
- Participation in the IVS CONT08 observation campaign.
- Participation in domestic observational programs for obtaining Earth orientation parameters.
- Continued geodetic control of the antenna parameters.

References

[1] Site http://www.ipa.nw.ru.

JARE Syowa Station 11-m Antenna, Antarctica

Koichiro Doi, Kazuo Shibuya

Abstract

The operation of the 11 m S/X-band antenna at Syowa Station (69.0°S, 39.6°E) by the Japanese Antarctic Research Expeditions (JAREs) started in February 1998 and continues till today (January 2008). The number of quasi-regular geodetic VLBI experiments attained 77 at the end of 2007. Syowa Station will participate in six OHIG sessions in 2008.

Data of five OHIG sessions in 2007 were recorded on hard disks through the K5 terminal. They will be brought back from Syowa Station to Japan in April 2008. Data of OHIG44 to OHIG49 sessions observed by JARE47 in 2006 are now being transferred to Bonn Correlator directly by using one of NICT's servers. Analysis results obtained from the data until OHIG43 session indicate that baseline length between Syowa and Hobart is increasing with a rate of 53.8 ± 0.5 mm/yr and the one between Syowa and HartRAO is also increasing with a rate of 11.5 ± 0.4 mm/yr.

1. Overview

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

K5 recording system was introduced to Syowa Station in September 2004. Syowa's recording terminal K4 was fully replaced by K5 simultaneously with the termination of the SYW sessions at the end of 2004. Syowa participated in the OHIG sessions in the austral summer season of 2007. Data transfer through Intelsat satellite link from Syowa Station to NIPR became possible according to the introduction of K5 system, but huge VLBI data transfer is not realistic because of the low transfer speed.

2. Notes on System Maintenance

There is no significant problem in the "mechanical system". The hydrogen maser set (Anritsu RH401A; 1002C) was used for the observations from 2004 to 2007. JARE-48 (2007-2008) re-installed 1001C at Syowa Station; the maser was brought back to Syowa Station in January 2007 after a major overhaul. A backup video-converter was also brought to Syowa Station by the JARE-48. The tube in the Cs frequency comparator and local oscillator has to be replaced with a new one in the near future.

3. Session Status

Table 1 summarizes the status of processing as of January 2008 for the sessions after 2004. The SYW sessions consisted of Syowa (Sy), Hobart (Ho) and HartRAO (Hh). The OHIG sessions involved the Fortaleza (Ft), O'Higgins (Oh), Kokee Park (Kk), Parkes (Pa), TIGO Concepcion (Tc), and Syowa (Sy) antennas. In 2005, Syowa joined the CRD sessions, but after 2006, Syowa participated only in OHIG sessions. The number of OHIG sessions in which Syowa participated during 2007 was five.

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

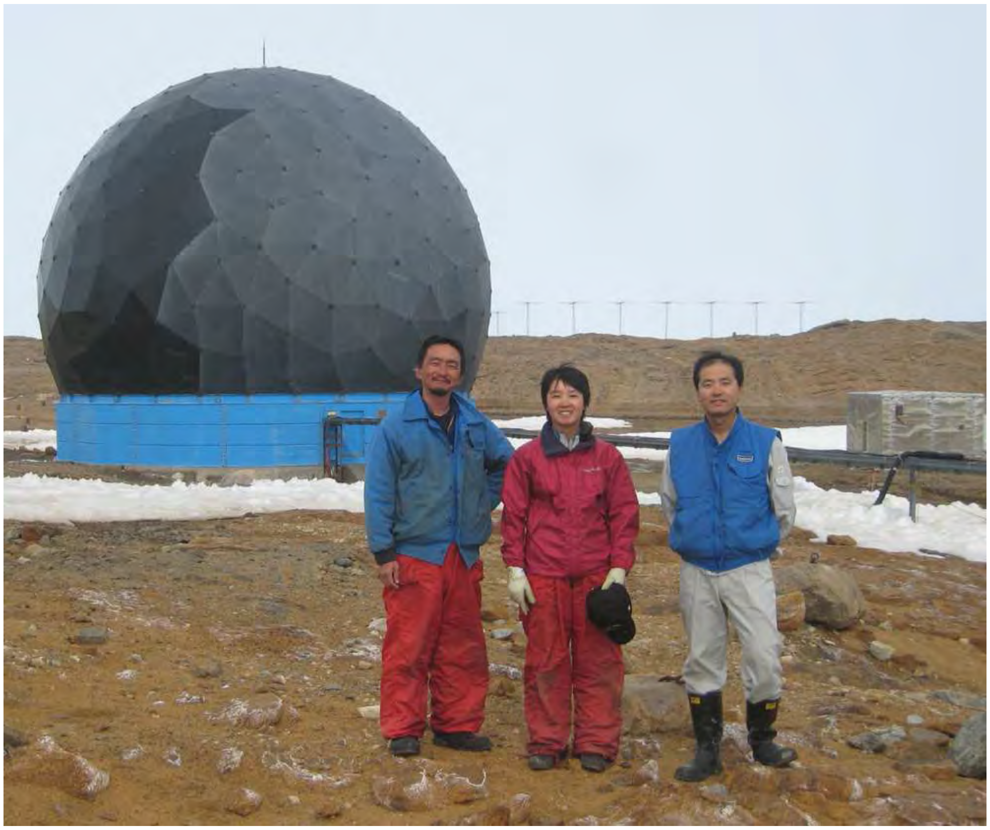


Figure 1. Syowa VLBI staff for JARE-48 (Feb. 2007 - Jan. 2008).

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

- Kazuo Shibuya, Project coordinator at NIPR.
- Koichiro Doi, Liaison officer at NIPR.
- Takanobu Sawagaki (from Hokkaido University), Chief operator for JARE-47 (Feb. 2006 - Jan. 2007).
- Hiroshi Ishii (from NEC), Antenna engineer for JARE-47.
- Naoki Arai (from Electric Navigation Research Institute), Chief operator for JARE-48 (Feb. 2007 - Jan. 2008). (right in Figure 1)
- Sachiko Nagashima (from MontBell Co., Ltd.) Operator for JARE-48. (center in Figure 1)
- Hitoshi Sugawara (from NEC), Antenna engineer for JARE-48. (left in Figure 1)

Table 1. Status of SYW and OHIG experiments as of January 2008

Code	Date	Station	Hour	Correlation	Solution	Notes
OHIG29	2004/Feb/10	Ho, Hh, Ft, Oh, Tc	24 h	Yes	Yes	(J45)
SYW030	2004/Apr/07	Ho, Hh	24 h	Yes	Yes	
SYW031	2004/Aug/18	Ho, Hh	24 h	Yes	Yes	
OHIG32	2004/Oct/16	Ho, Hh, Ft, Oh, Kk, Tc	24 h	No	No	
OHIG33	2004/Nov/09	Ho, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG34	2004/Nov/30	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG35	2004/Dec/08	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
SYW032	2004/Dec/13	Ho, Hh	24 h	Yes	Yes	
OHIG36	2005/Jan/26	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
OHIG37	2005/Feb/02	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	(J46)
OHIG38	2005/Feb/15	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
CRDS18	2005/Apr/11	Ho, Hh	24 h	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	Not yet	Not yet	
OHIG45	2006/Nov/07	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Not yet	
OHIG46	2006/Nov/14	Ho, Hh, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG47	2006/Nov/29	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG49	2007/Feb/13	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	(J48)
OHIG51	2007/Nov/06	Ho, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG52	2007/Nov/07	Ho, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG53	2007/Nov/13	Ho, Hh, Ft, Oh, Kk, Pa, Tc	24 h	Not yet	Not yet	
OHIG54	2007/Nov/14	Ho, Hh, Ft, Oh, Kk, Pa, Tc	24 h	Not yet	Not yet	

(1) 45: DSS45

(J45) JARE-45: op K. Doi eng. K. Fukuhara (J46) JARE-46: op K. Egawa eng I. Okabayashi

(J47) JARE-47: op T. Sawagaki eng H. Ishii (J48) JARE-48: op N. Arai eng H. Sugawara

5. Analysis Results

At the end of 2007, 52 sessions from May 1999 through February 2006 have been analyzed with the software CALC/SOLVE developed by NASA/GSFC. The data of 5 OHIG sessions from OHIG44 through OHIG49 will be analyzed soon.

The length of the Syowa-Hobart baseline is increasing with a rate of 53.8 ± 0.5 mm/yr. The Syowa-HartRAO baseline shows a slight increase with a rate of 11.5 ± 0.4 mm/yr. These results agree approximately with those of GPS. We do not detect a significant change in the Syowa-O'Higgins baseline. Detailed results from the data until the end of 2003 as well as comparisons with the results from other space geodetic techniques are reported in [3].

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

Abstract

2007 was the sixth year of TIGO operation with 107 successful 24-hour observations.

1. General Information

The operation of TIGO is based on an agreement between Chile and Germany, in which Universidad de Concepción, Instituto Geográfico Militar, and the Bundesamt für Kartographie und Geodäsie secured their cooperation until the end of 2011. This year Universidad del Bío Bío finishes its participation in the consortium; however the VLBI staff remains warranted. TIGO is located near the Universidad de Concepción, at longitude 73.025 degrees West, latitude 36.843 degrees South and at an altitude of 180 m, 500 kilometers south of Santiago, Chile's capital.

2. Component Description

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

The atomic clock ensemble of TIGO consists of 2 hydrogen masers, 3 cesium clocks and 3 GPS time receivers realizing the Chilean contribution to the Universal Time scale (Circular T, BIPM).

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

In 2007 the entire TIGO computer network infrastructure was upgraded to 1 Gbps allowing the testing of new e-VLBI protocols and algorithms. Now any existing limiting factor is located outside TIGO facilities.

3. Staff

The VLBI group remained unchanged as compared to 2006. In 2007 the TIGO VLBI group consisted of the persons listed in Table 1. In 2007, Hayo Hase was elected to be an IVS Network Representative on the IVS Directing Board for a four-year term.

4. Current Status and Activities

During 2007 TIGO was scheduled to participate in 111 IVS experiments (see Table 2). The four failed experiments were mainly associated with problems related to cooling.

Apart from the regular IVS observation load, the TIGO VLBI group is involved in three development areas: e-VLBI, Remote Control User Interface for the FS and Sattrack testing.

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

Table 1. TIGO VLBI support staff in 2007.

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

Table 2. TIGO's IVS observation statistics for 2007.

Name	# of Exp.	OK	Failed
R1xxx	41	40	1
R4xxx	51	50	1
R&D	7	7	0
OHIGxx	7	6	1
T20xx	3	2	1
RDVxx	2	2	0
Total	111	107	4

4.1. e-VLBI

During 2007, TIGO continued its participation in the EXPReS project, which aims at connecting 21 VLBI radiotelescopes in 6 continents using high speed networks allowing real-time

VLBI. The previously mentioned TIGO network upgrade was done to support the realization of the objectives of this project.

TIGO also had presence at the 6th International e-VLBI Workshop held in Bonn, Germany on September 17 and 18. Hayo Hase presented the development work of Sergio Sobarzo under the title *Multipath and Singlepath Routing for e-VLBI.* This research aims at a new protocol, which will allow that parallel flows of VLBI data can be sent over different routes using different constraints resulting in an increase of the data transfer speed proportional to the number of alternative routes. Also development work is being done to look into new algorithms for UDP congestion control and congestion avoidance, which can be applied to e-VLBI data.

On July 12th, the First Research Virtual Communities Global Forum was held. TIGO, among 14 other research organizations, made an online presentation in the Networking session called *Connectivity of Chilean NREN.*

4.2. Remote Control User Interface

New improvements were made to the Remote Control Software developed in 2005 (see [2]). Now the client is a standalone application written in Python running in the Linux Graphical Environment (see Figure 2).

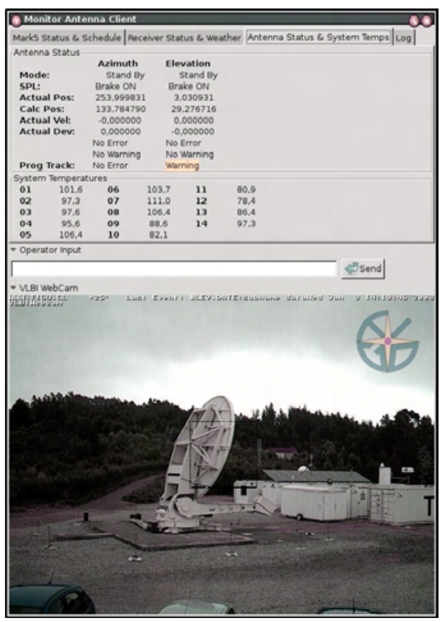


Figure 2. Screenshot of the software for remote control VLBI operation with the Field System. The upper part displays antenna status and receiver temperatures; in the middle there is an operator input area, and at the bottom there is a live image of the telescope. Also there are tabs for Mark 5 status & schedule, receiver status & weather, and log with additional information.

4.3. Sattrack Testing

In January, Michael Moya, a visitor from Chalmers University of Technology in Gothenburg, Sweden, made the final tests of the satellite tracking software at TIGO [3]. Since in the southern sky there are not that many suitable radio sources to perform pointing tests, there was the need to find a way to do these calibrations using artificial sources, like AQUA and TERRA, with carrier signals inside the X-Band. (See Figure 3 for a successful observation.) The written software was included in the FS station software and uses the North American Aerospace Defense Command (NORAD) two line elements (TLE) as input. As a future work this software should be included in the main distribution of the Field System.

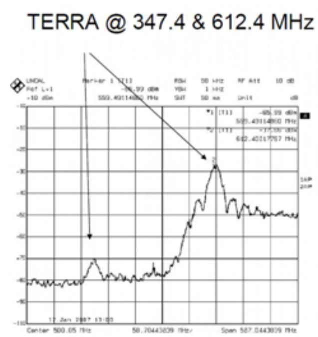


Figure 3. Successful pointing on TERRA using sattrack software [3].

5. Future Plans

The VLBI activities in 2008 will focus on

- execution of the IVS observation program for 2008
- participation in the CONT08 campaign
- continuation of developments:
  - investigations related to e-VLBI
  - remote control user interface for the FS
  - new monitor and control solution for the receiver
- repetition of the local survey

References

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

[2] Gonzalo Remedi, Sergio Sobarzo and Hayo Hase, *Remote Control of VLBI Operations*, Proceedings of the Fourth IVS General Meeting, 2006, pp 127-131.

[3] M. Moya Espinosa and R. Haas, *SATTRACK A Satellite Tracking Module for the VLBI Field System*, Proceedings of the 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, 2007, pp 53-58.

Tsukuba 32-m VLBI Station

Kensuke Kokado, Machida Morito, Shinobu Kurihara, Shigeru Matsuzaka

Abstract

Tsukuba 32-m radio telescope is operated by Geographical Survey Institute (GSI) VLBI group. This report summarizes the current status and the future plans of Tsukuba 32-m VLBI station. We had participated in a total of 164 domestic/international VLBI sessions scheduled at the beginning of this year and some new sessions, such as INT3 and Ultra Rapid dUT1 experiments in 2007. All of the observations have been performed with the K5/VSSP32 system. We had some troubles at our facility, so we ran an overall check of the antenna. In the near future, we plan to do an overall maintenance.

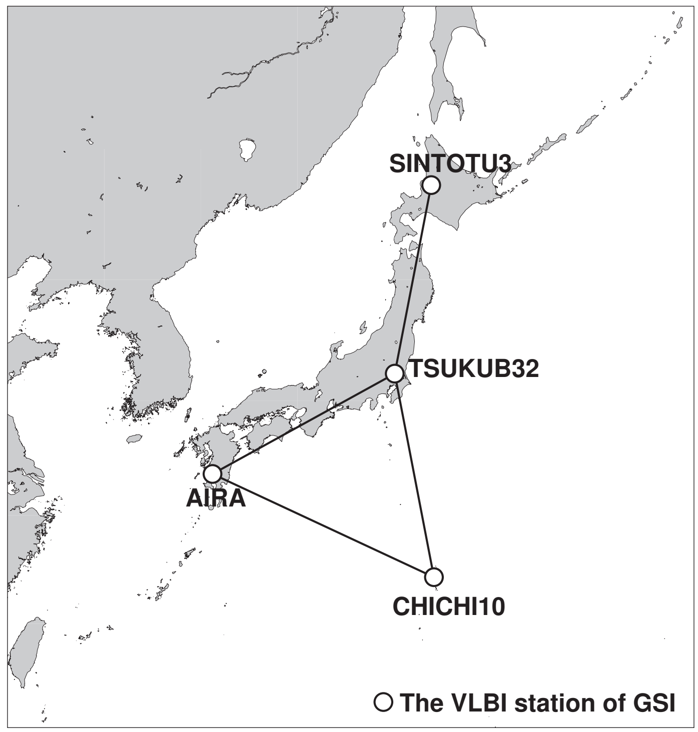


Figure 1. Tsukuba 32-m VLBI station and GARNET (GSI VLBI network).

1. General Information

The Tsukuba 32-m VLBI station (TSUKUB32) is located at GSI in Tsukuba Science City, which is about 50 km to the northeast of the capital Tokyo. GSI has four VLBI stations: TSUKUB32, AIRA, CHICHI10, and SINTOTU3. These four stations form our domestic VLBI network named GARNET (GSI Advanced Radio telescope NETwork). We have performed our domestic VLBI observations using GARNET. A series of the observations is named JADE (JApanese Dynamic Earth observation by VLBI). The main purposes of the JADE series are to define the reference frame of Japan and to monitor the plate motions for the advanced study of crustal deformations. The GARNET stations, centered on TSUKUB32, are located to cover the Japanese mainland.

2. Component Description

In March 2007, we finished the installation and adjustment of K5/VSSP32 [1], which enables us to record at 32 Msps/ch. Since then, we have performed all domestic/international sessions with the K5/VSSP32. After the installation, we moved the previous K5 system (K5/VSSP) to VERAISGK station of NAOJ on Ishigaki Island. VERAISGK has participated in JADE sessions throughout the year. At VERAISGK, we introduced a high-speed optical network. Now, we transfer the data to Tsukuba at about 24 Mbps. We also renewed a Low Noise Amplifier (LNA) for stable refrigeration of X-band receiver at TSUKUB32 station in December 2007.

We made a joint research agreement with Tsukuba University for installing a K-band receiver at TSUKUB32 station. In test observations, we found a noise pattern of standing wave type in the receiver system. Investigations revealed that the water resistant sheet for the feed horn of the antenna reflects part of the radio wave, and that the reflected wave is the cause of the standing wave. After we had changed the water resistant sheet to remove the standing wave, Tsukuba University performed some astronomical observations in December 2007. They succeeded in observing recombination lines of ammonia molecules and ionized gas. Meanwhile, we implemented K-band VLBI observations for finding fringes with KASHIM34 or GIFU11 station. We could find fringes for the first time in May 2007.

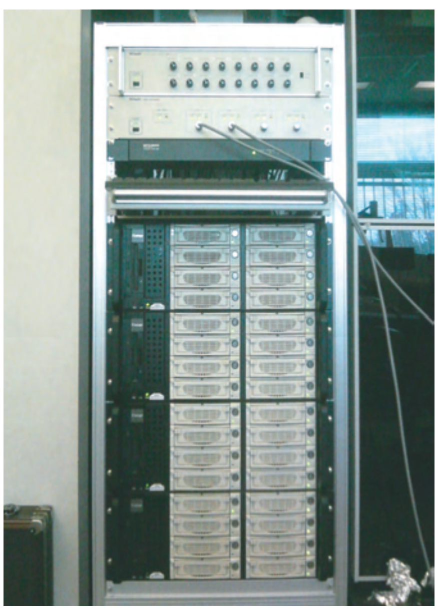


Figure 2. K5/VSSP32

Figure 3. Change of the water resistant sheet

In 2007, we had some problems with the equipment of the station. One of the insulator panels of the antenna was broken by strong wind and fell down to the ground on January 3rd. As a result of immediate investigation, we found three more dangerous panels which lacked the fixation screws. We reinforced these panels on March 23rd and ran an overall check of the antenna in May

2007, because other equipment might have a problem. Another problem was the hydrogen maser, which went down twice (March and November). As we have two hydrogen masers at TSUKUB32 station, we could continue to participate in VLBI sessions switching the main hydrogen masers. However, these masers have a short life expectancy because they were manufactured more than 10 years ago, so we will have to renew them in the near future.

3. Staff

Table 1 shows the regular operating staff of GSI's VLBI observation group. Kazuhiro Takashima (former leader of VLBI group) and Junichi Fujisaku (former operation chief) moved to different departments in April. In their stead, Kozin Wada and Shinobu Kurihara came back to GSI VLBI group after a few years interval. Yoshihiro Fukuzaki is in charge of the analysis of SYOWA experiments and a member of the IVS Directing Board (Networks Representative). Routine operation were mainly performed under contract with Advanced Engineering Service Co., Ltd (AES), over 230 days in 2007. The information about the correlator staff are listed in the report of Tsukuba VLBI Correlator in the correlator section of this volume.

Table 1. Staff list of the GSI VLBI group

Name	Position
Shigeru MATSUZAKA	Director of Space Geodesy Division
Kozin WADA	Deputy Director of Space Geodesy Division
Shinobu KURIHARA	Leader of VLBI group
Etsurou IWATA	Network chief
Morito MACHIDA	Operation chief
Kensuke KOKADO	Technical staff (Observation and Analysis)
Daisuke TANIMOTO	Technical staff (routine observation)
Yoshihiro FUKUZAKI	Researcher, IVS DB

4. Current Status and Activities

The regular sessions are shown in Table 2. TSUKUB32 station participated in a total of 164 domestic/international VLBI sessions in 2007. We have conducted INT3 sessions since August 27th, 2007, with Ny-Ålesund and Wettzell every Monday. The aim is to obtain the UT1 estimate within 24 hours after the session. Therefore, we adapt "e-VLBI" and "Tsunami" protocol which is a UDP/IP based protocol developed by Advanced Network Management Laboratory of Indiana University. We can transfer the data to Bonn correlator at about 300 Mbps using "Tsunami". We also use "Tsunami" to transfer the data to Bonn correlator in IVS-R sessions.

In addition, we had two special experiments in 2007. The first one was the intensive experiment for ultra-rapid UT1 measurement. The goal of the experiment is to obtain the UT1 result within 30 minutes after the end of the last scan. The stations that participated in the experiment are TSUKUB32, KASHIM34, ONSALA60, and METSAHOV, all with high-speed network connections. In the ultra rapid experiment, we used "Tsunami" protocol, because one of the key factors to enable the rapid UT1 measurement is to transfer the data as fast as possible. We transfered the data from the stations in Europe to Japan using the Tsunami protocol and the PC-EVN system. We succeeded in obtaining the UT1 result within 1 hour after the end of the experiment with ONSALA60 on November 22th, 2007.

The second was a special domestic VLBI experiment for geting more precise positions of the Japanese VLBI stations. USUDA64 station of Japan Aerospace Exploration Agency (JAXA) and YAMAGUCH station of Yamaguchi University participated in the experiment together with the four stations of GSI. Further, we performed test observations for geodetic VLBI with UCHINOURA station of JAXA. As we found fringes in X-band, we plan geodetic VLBI sessions for 2008. We expect to get more precise positions of these stations by analyzing the data of these sessions. These results will be used as reference positions for astronomical observations at these stations.

Table 2. The regular sessions at Tsukuba 32-m VLBI station in 2007

Sessions	Code	Number
IVS-R	R1258,R1259 ... R1307,R1308	31
IVS-T	T2052	1
VLBA	RDV66	1
APSG	APSG20,APSG21	2
JADE	JD0701-0712	12
IVS-INT1	I07267,I07268,I07269	3
IVS-INT2	K07007,K07013 ... K07349,K07350	96
IVS-INT3	K07239,K07246 ... K07344,K07351	18
Total		164

5. Future Plans

At present, we make domestic observations in 8 MHz sampling mode, because the video convertors at participating stations cannot accept a wider band than 4 MHz. Therefore, we plan to broaden the frequency range and will perform a fringe test in January 2008.

GSI VLBI group has made co-location surveys for connecting the result of VLBI observations to the geodetic network at all of the GSI VLBI stations. We will conduct a second co-location survey at TSUKUB32 station in February 2008.

References

[1] J. Fujisaku, S. Kurihara, K. Takashima: Tsukuba 32m VLBI station, IVS 2004 Annual Report, February 2005

[2] J. Fujisaku, K. Kokado, K. Takashima: Tsukuba 32m VLBI station, IVS 2005 Annual Report, April 2006

[3] K. Kokado, J. Fujisaku, K. Takashima: Tsukuba 32m VLBI station, IVS 2006 Annual Report, April 2007

Nanshan VLBI Station Report for 2007

Aili Yusup, Na Wang

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 2007.

1. Introduction

The station is located 70 km south of Urumqi, the capital city of Xinjiang Uygur Autonomous Region of China. The station is affiliated with the Urumqi Observatory of the National Astronomical Observatories, CAS. We contribute to IVS in geodetic VLBI observations. The Nanshan VLBI station has participated in domestic VLBI experiments and as one of the VLBI ground stations tracking the Chinese Chang'E satellite. Urumqi also participated in the Japanese SELENE observation. The telescope participated in real-time experiments among the Chinese Network. We are grateful for the kind help and support from the VLBI experts within the IVS. The Urumqi Observatory is willing to continue the collaboration in international VLBI activities.

2. Telescope Status

2.1. Antenna

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

2.2. Receiver

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

2.3. Recording System

Mark 5, Mark IV, Mark II, and K5 recording systems are available now at the Nanshan VLBI station. The performance of the observing system has been improved over the last year. A new FS computer is in use at Nanshan, and the Field System has been upgraded to version 9.9.2 and works well. The p-cal control system has been updated, and the parameters of S/X band receivers are sampled from the FS software.

Table 1. Specifications of receivers

		Parameters		Freq. Range (MHz)	
1.3 cm	LCP	Tsys=190K	DPFU=0.057	22100–24000	
3.6 cm	RCP	Tsys=110K	DPFU=0.093	8100–8900	
6 cm	dual	Tsys=22K	DPFU=0.105	4700–5110	
13 cm	RCP	Tsys=75K	DPFU=0.096	2150–2450	
18 cm	dual	Tsys=21K	DPFU=0.088	1400–1720	
30 cm	LCP	Tsys=160K	DPFU=0.06	800–1200	
49 cm	dual	Tsys=?	DPFU=?	305–345	not tested yet
92 cm	dual	Tsys=?	DPFU=?	560–660	not tested yet

2.4. Time and Frequency System

Nanshan's no. 11 H-maser has been upgraded at ShAO, and it is in good status. The other two H-masers, the No. 13 and the MHM2010 imported from the Symmetricom company in the United States, work well. A new time and frequency system has operated continuously since its installation at the Nanshan station in November 2005, and it works well.

3. Personnel

Table 2. The main staff at 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
Zhengwen Sun	Senior engineer	Microwave, Receiver	sunzw@uao.ac.cn
Xiang Liu	Professor	VLBI friend	liux@uao.ac.cn
Yousuo Dong	Senior engineer	Antenna control	dongys@uao.ac.cn
Maozheng Chen	Senior engineer	Receiver	mzchen@uao.ac.cn
Aili Esamdin	Scientist	Astronomy	aliyi@uao.ac.cn
Jarken Yesembek	Scientist	Astronomy	jerken@uao.ac.cn
Weixia Wang	Senior engineer	Receiver	wangwx@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
Xiangfeng Wang	Engineer	Network, Computer	wangxf@uao.ac.cn

4. Nanshan Geodetic VLBI Observations during 2007

Nanshan participated in the following 6 geodetic VLBI sessions during 2007 as listed in table 3. All experiments were recorded using Mark 5A. The telescope has been kept in a good condition, and all geodetic 24-hour experiments did well in 2007.

Table 3. Geodetic VLBI experiments observed by Urumqi Observatory during 2007.

Experiment	Date	Remarks (problems)
T2049	02.06	OK
T2050	05.15	OK
T2051	07.31	OK
T2052	11.27	OK
APSG20	09.11	OK
APSG21	10.10	OK

5. Future Plan

A new 1.3 cm dual polarization cryogenic receiver will be built in 2008. A dual band for both 92 cm and 49 cm receiver systems will be tested and used in 2008.

Westford Antenna

Mike Poirier

Abstract

Technical information is provided about the antenna and VLBI equipment at the Westford site of Haystack Observatory, and about changes to the systems since the IVS 2006 Annual Report.

1. Westford Antenna at Haystack Observatory

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

Figure 1. The radome of the Westford antenna.

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

Table 1. Location and addresses of Westford antenna.

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

2. Technical Parameters of the Westford Antenna and Equipment

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

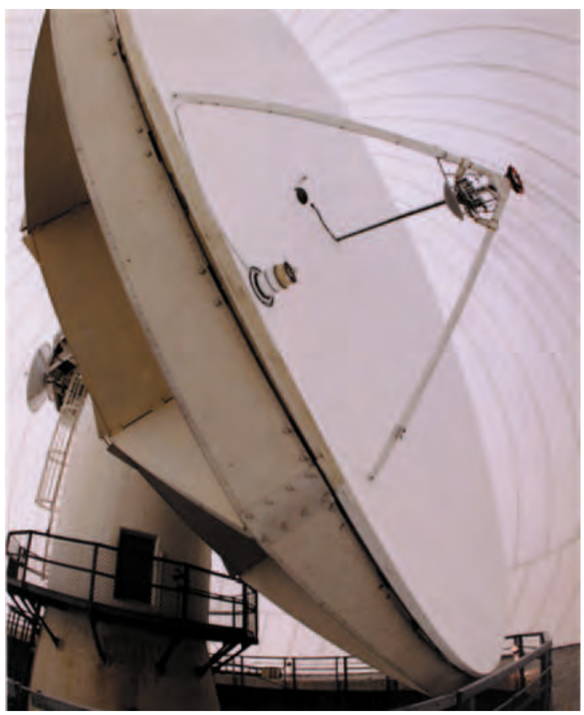


Figure 2. Wide-angle view of Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

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

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

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

10–20 K at X-band and by a smaller amount at S-band. The major components of the VLBI data acquisition system are a Mark IV electronics rack, a Mark 5A recording system, and a Pentium-class PC running PC Field System version 9.9.2. The primary frequency and time standard is the NR-4 hydrogen maser. A CNS Clock GPS receiver system provides independent timing information and comparisons between GPS and the maser. Westford also hosts the WES2 GPS site of the IGS network. A Dorne-Margolin chokering antenna is located on top of a tower ~60 meters from the VLBI antenna, and an Ashtech Model-Z Reference Station receiver acquires the GPS data.

3. Westford Staff

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

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

4. Status of the Westford Antenna

During the period 2007 January 1 through 2007 December 31, Westford participated in 62 24-hour geodetic sessions. Westford regularly participated in the IVS-R1, IVS-R4, IVS-R&D, RD-VLBA, and T2 series of geodetic sessions as well as fringe tests, e-VLBI experiments, and VLBI2010 wideband 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 Development at Westford

Westford continues to play a key role in the development of e-VLBI. In 2007, Westford served as a test bed for:

- continued high-speed e-VLBI development over a dedicated 10 Gbps link to Haystack Observatory and a new 10 Gbps link to the rest of the world,
- integration and testing of e-VLBI technology for the new Mark 5B system, and
- evaluation of new networking equipment for e-VLBI.

The outlook for Westford is that it will play a crucial role in e-VLBI development for VLBI2010 and the broadband development effort as data rates approach 4 Gbps.

6. Outlook

At Westford we anticipate being able to participate in 68 24-hour geodetic sessions in 2008 and to support occasional e-VLBI experiment fringe tests and VLBI2010 wideband development testing.

Fundamentalstation Wettzell - 20m Radiotelescope

Richard Kilger, Gerhard Kronschnabl, Wolfgang Schlüter

Abstract

The 20m Radiotelescope in Wettzell, Germany contributed very successfully and strongly to the IVS observing program again in 2007. Technical changes, improvements, and upgrades have been done to increase the reliability of the entire VLBI observing system.

1. General Information

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

- WLRS (Wettzell Laser Ranging System), a laser ranging system designed for Satellite Laser Ranging (SLR) and Lunar Laser Ranging (LLR) being involved in ILRS; at present, a new laser Satellite Observing System (SOS-W) for low orbiting satellites is under construction.
- GPS receivers, involved in gloabl network IGS, in the European network EUREF, in the national network GREF, and in time transfer experiments.
- G, a large lasergyroscope or ringlaser dedicated to monitoring daily variations of Earth rotation.

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

2. Staff

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

- TIGO systems (see TIGO report in this volume), operated in Concepción, Chile by 3 BKG experts jointly with a Chilean partner consortium (support staff: 11 engineers).
- O'Higgins station (see O'Higgins report in this volume) in Antarctica, jointly operated with the German Space Center (DLR) and the Institute for Antarctic Research Chile (INACH).

Figure 1. 20m Radiotelescope in the rural environment

The staff operating RTW is summarized in table 1. At the end of October Richard Kilger retired; nevertheless he continued to support the TWIN-project, improved the cooling system, and participated in the O'Higgins observations. Dr. Alexander Neidhardt will take over his position in May 2008. Alexander has background as an IT Engineer and currently works for the control system of the new Laser Ranging System SOS-W, which is in its final stage to become operational.

Table 1. Staff - members of RTW

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

3. Observations in 2007

The 20m RT-Wettzell has supported geodetic VLBI activities for 25 years. All successfully observed sessions in the year 2007 are summarized in table 2. According to the IVS 2007 Master

Schedule, RTW ran more 24-hour geodetic VLBI sessions than any other IVS network station, as it has for the last eight years. In addition to the 24-hour sessions, RTW continued to run the daily one-hour INTENSIVE sessions in order to determine UT1-UTC. At the beginning of 1984, RTW observed together with Westford, since 1995 with Greenbank and since 1999 with Kokee Park. These sessions are called INT1 and are performed every weekday. The correlation is done at the Washington Correlator (WACO). On Saturday and Sunday RTW participates in the INT2 sessions together with Tsukuba, Japan, filling the weekend gap with data from Sunday morning to Monday evening. Since August 2008, INT3 sessions were set up on Monday morning, in order to shorten the weekend gap. INT3 includes the network stations Wettzell, Tsukuba and Ny-Ålesund. INT2 data are correlated at the VLBI correlator in Tsukuba; INT3 data are correlated in Bonn. Both VLBI correlators in Tsukuba and Bonn have a fast internet connection and are able to receive the data from the observing stations via e-VLBI in near real time. INT2 and in particular INT3 provide regular UT1-UTC results with the shortest latency. Some efforts to shorten the latency, which is affected mostly by the data transfer between the stations and the correlator, have been made. RTW has strongly improved its internet connection in 2007 from 34 Mbit/sec to 622 Mbit/sec. Today the data transfer via Internet is extended to all correlators which already have fast internet connections (Bonn, Tsukuba and Haystack). The data transfer via Internet to the Washington Correlator is still organized via a center in the Washington area. The last mile problem is solved by car transport to the correlator.

Table 2. RTW observations in 2007

program	**number of 24h-sessions**
IVS R1	52
IVS R4	52
IVS T2	4
IVS R&D	10
EUROPE	6
RDV/VLBA	6
in total	**132**

program	**number of 1h-sessions**
INT1(Kokee-RTW)	213
INT2(Tsukuba-RTW)	83
INT3(Tsukuba-RTW-Ny Al)	16
in total	**312**

In addition to the routine observations, some measurements were carried out to test the 1 Gbps recording capabilities and to test the observation modes for the upcoming SELENE observations, which are requested by the National Astronomical Observatory of Japan. SELENE is a Lunar Project to improve the determination of the gravity field of the moon.

4. Technical Improvements and Maintenance

VLBI observations require high reliability at all participating stations; therefore careful servicing of all components is essential to ensure successfully performed VLBI measurements through the year(s). Additionally the 20m RTW has to be kept on a high technical standard and has to be improved according to technological advancement.

In 2007 the following actions were carried out:

- Implementation of an EVN PC for the data transmission to the Bonn correlator:
  - Combining the EVN PC via VSIC-System with Mark 5A,

  - Extension of the Fieldsystem PC with software to record the data in parallel with Mark 5A and the EVN PC System,
  - The EVN PC transfer is operationally employed for the INT3 data,

- Improvement of the Internet connection:
  - Upgrading from 34 Mbps to 622 Mbps,
  - Testing to verify the usable bandwidth, which shows best values of 500 Mbps,
  - Installation of an additional backup server to improve the reliability,
  - Installation of 6 TB storage capabilities for intermediate data handling of INT data and R1 data,
- Development of a test bed for the RTW motor drives:
  - for testing the status of the motors,
  - for optimizing the drive units,
- Integration of the Digital Baseband Converters (DBBC):
  - replacement of the analog baseband converters,
  - improvement of RTW towards VLBI 2010 requirements,
- Inplementation of the hardware to support the Japanese SELENE Project:
  - collaboration with the National Astronomical Observatory of Japan (NAO),
  - test observations and preparation for tracking the Lunar Orbiter RStar and VStar,
- Fieldsystem Upgrade from Version FS 9.9.2 to FS 9.10.2
- Contributions to VLBI 2010:
  - releasing the specifications for the new VLBI 2010 compatible telescope (TWIN-Telescope Wettzell TTW),
  - requesting bids and contracting a company to manufacture the TWIN-telescopes,
  - considering a broadband feed capable of receiving a frequency band from 1 to 18 GHz.

5. Plans for 2008

During 2008, plans are to maintain the standards in observing quality and quantity. Some dedicated items will be:

- Final integration of the digital baseband converters (DBBC)
- Final integration of the Mark 5B-units
- Proceeding towards the realisation of the VLBI 2010 TWIN-Telescope.

Observatorio Astronómico Nacional – Yebes

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

Abstract

This report updates the description of the OAN facilities as an IVS network station. The new 40-m radiotelescope has seen first light, and commissioning is in progress. First geodetic VLBI observations are expected in 2008.

1. General Information: the OAN Facilities

The Observatorio Astronómico Nacional (OAN) of Spain is a department of the Instituto Geográfico Nacional (IGN, Ministerio de Fomento) and operates a new 40 meter radiotelescope at Yebes (Guadalajara, Spain). The facility also includes an old 14-m radiotelescope, which has been a network station of the IVS, participating regularly in the geodetic VLBI campaigns until 2003, and will now be refurbished to become a tracking station for the next space radiotelescope VSOP-2.

Pictures of the radiotelescopes and of the Yebes site are available in the IVS Annual Reports for 2005 and 2006. A satellite view can be found at the URL `http://tinyurl.com/23ooly`.

Yebes is also the reference station for the Spanish GPS network. A building has been finished to hold the IGN gravimeters.

2. OAN Staff Working in VLBI Projects

Table 1 lists the OAN staff who are involved in VLBI studies, some of whom can be found at the telescope (CAY) address. The VLBI activities are also supported by other staff such as receiver engineers, computer managers, secretaries, and students. Moreover, we expect to contract telescope operators in 2008.

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

Name	Background	Role	Address
Francisco Colomer	Astronomer	VLBI Project coordinator	OAN
Richard Dodson	Astronomer	Marie-Curie fellow	OAN
Susana García-Espada	Engineer	PhD student	OAN
Jesús Gómez–González	Astronomer	General Subdirector for Astronomy, Geodesy and Geophysics	IGN
José Antonio López–Fernández	Engineer	CAY site manager	CAY
Maria Rioja	Astronomer	Scientist (Astrometry)	OAN
Pablo de Vicente	Astronomer	VLBI Technical coordinator	CAY

Figure 1. Photograph of the new X-band receiver, to be installed at the new 40-m radiotelescope.

Figure 2. Photograph of the new S/C/CH-bands receiver, installed at the new 40-m radiotelescope cabin.

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

Parameter	Value	DAR	VLBA4 (14) + VSI-C
Diameter	40 meter	Recorder	Mark 5B
Receivers	2 - 115 GHz	H-maser	KVARTZ CH-1
S/X T_{sys}	100 K	GPS	TrueTime XL-DC
S/X SEFD expected	420 Jy	Weather station	SEAC-EMC

3. Status of the Geodetic VLBI Activities at OAN

The most important developments have been the construction of the S/X band receivers for the 40-m radiotelescope (see Figures 1 and 2), as well as its commissioning and setup for VLBI. All relevant equipment is already available at the Yebes site (e.g., VLBA4/VSI DAR, Mark 5B recorder, H-maser, GPS receiver, weather station).

Thanks to a fruitful cooperation with the geodesy group at Onsala Space Observatory (Sweden), we have re-analyzed the geodetic VLBI data of all campaigns where the old 14-m radiotelescope at Yebes has participated using the best available apriori geophysical models. We compared in particular the time series of station coordinates with the results from an analysis of the Yebes GPS data. This work is part of the PhD thesis of Susana García-Espada and, together with planned local-tie measurements, is of major importance for the combination of the historic VLBI observations performed with the 14-m radio telescope and the future observations with the new 40-m radio telescope.

4. Future Plans

The construction of a new building for the installation of permanent equipment for constant gravity monitoring (FG5–number 211, and A-10–006 absolute gravimeters) is finished (see Figure 3). The construction of a network of concrete pillars around the 40-m radiotelescope to measure its reference point and its local-tie to the old 14-m radiotelescope is delayed and will be performed in 2008. Moreover, the Yebes site will get connected to GÉANT at a rate of 1 Gbps thanks to the EC project EXPReS.

References

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

[2] de Vicente P., Gallego J.D., Bolaño R., Almendros C. “Monitorización del máser de hidrógeno antes y después del traslado al radiotelescopio de 40m”. Informe Técnico OAN 2007-3 (see `http://www1.oan.es/informes/archivos/IT-OAN-2007-3.pdf`).

[3] Cordobés D., de Vicente P., Bolaño R. “Software para corregir la deriva del máser ajustando su cavidad”. Informe Técnico OAN 2007-4 (see `http://www1.oan.es/informes/archivos/IT-OAN-2007-4.pdf`).

Figure 3. Building at Yebes which will hold the gravimeters.

[4] de Vicente P., Almendros C. "Mark IV formatter upgrade with a VSI card". Informe Técnico OAN 2007-9 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-9.pdf).

[5] Cordobés D., López-Pérez J.A., García-García R., López-Fernández J.A., Abad J.A., Martínez G. "Diseño, montaje y medida de ecualizadores para el receptor banda X". Informe Técnico OAN 2007-11 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-11.pdf).

[6] de Vicente P., Bolaño R., Almendros C., Fernández J., Abad J.A. "Upgrading the Mark 5A to Mark 5B". Informe Técnico OAN 2007-15 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-15.pdf).

[7] ETSIT Madrid. "Polarizador y acoplador de banda S para el radiotelescopio de 40 metros". Informe Técnico OAN 2007-17 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-17.pdf).

[8] Malo I., de Miguel A., Fernández J., Abad J.A., Henche S., López-Pérez J.A., Serna J.M., López-Fernández J.A. "FI del Receptor S del Radiotelescopio de 40m del CAY". Informe Técnico OAN 2007-20 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-20.pdf).

[9] Serna-Puente J.M., López-Fernández J.A., Malo I., López-Pérez J.A. "Medidas módulo FI del receptor banda X del Radiotelescopio de 40m del CAY". Informe Técnico OAN 2007-22 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-22.pdf).

[10] López-Fernández J.A., Serna-Puente J.M., Malo I., Tercero F., Yagüe J.M., Abad J.A., Fernández J. "Criostato de los receptores S/C/CH de la antena ARIES XXI del CAY". Informe Técnico OAN 2007-23 (see http://www1.oan.es/informes/archivos/IT-OAN-2007-23.pdf).

Zelenchukskaya Radio Astronomical Observatory

Andrei Dyakov, Sergey Smolentsev

1. Abstract:

This report briefly summarizes the observing activities at the Zelenchukskaya 32-m VLBI station during the year 2007.

2. General Information

Zelenchukskaya Radio Astronomical Observatory was founded by Institute of Applied Astronomy (IAA) as one of three stations of the Russian VLBI network QUASAR. The sponsoring organization of the project is the Russian Academy of Sciences (RAS). The Zelenchukskaya Radio Astronomical Observatory is situated in the Republic Karachaevo-Cherkessiya (Northern Caucasia) about 70 km south of Cherkessk, near to the Zelenchukskaya site (not far from the Radiotelescope RATAN-600). The geographic location of the observatory is shown on the IAA RAS Web site:

http://www.ipa.nw.ru/PAGE/koi8-r/DEPOBSERV/rus_zel.htm

The basic instruments of the observatory are a 32-m radio telescope and technical systems for doing VLBI observations.

Figure 1. Zelenchukskaya Observatory.

Table 1. Zelenchukskaya Observatory location and address.

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

3. Technical and Scientific Information

The technical parameters of the radio telescope RT-32 and other Zelenchukskaya station equipment are presented in the 2005 Annual Report [1].

3.1. Co-location with GPS

A GPS ASHTECH Z-X113 receiver with an ASH 700936D_M antenna Dorne-Margolin/Choke Ring was installed at the observatory during 2006. Observed data are sent to BKG and IGS every hour.

4. Radio Telescope

- The antenna rail was reconstructed by adding a steel supporting construction and rebuilding the concrete under it (Figure 2).

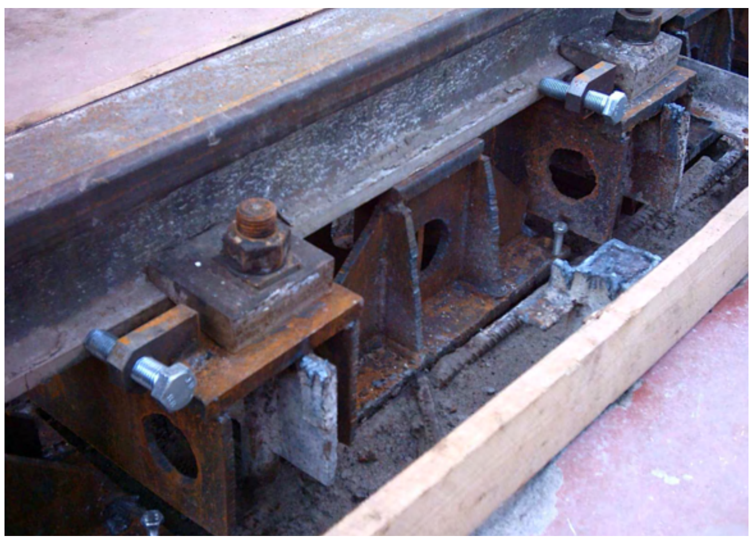


Figure 2. Steel supporting construction under the rail.

- The antenna structure was painted in August 2007 (Figure 3).

Figure 3. Painting of antenna.

5. Participation in the IVS Observing Program

Table 2 summarizes the sessions observed during 2007.

Table 2. List of IVS sessions observed at ZcRAO in 2007.

Month	IVS-R1	IVS-R4	EURO	R&D	VLBA
January	1	3			
February	1	3	1		
March		3			1
April	1	3			
May	1	1			
October		4		1	
November		4	1		
December	1	4		1	1
Total	5	25	2	2	2

During 2007 the Zelenchukskaya IVS station participated in a total of 36 IVS-R1, IVS-R4, EURO, R&D, and VLBA sessions.

6. Outlook

Our plans for the coming year are the following:

- Participation in IVS-R1, IVS-R4, IVS-T2, EURO, R&D, and VLBA observing sessions.
- Participation in the IVS CONT08 observing campaign.
- Participation in domestic observational programs for obtaining Earth orientation parameters.
- Putting into operation the cable length control system (“ground unit”).
- Upgrading the electronic part of the angle data unit.

References

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

Operation Centers

Operation Centers

The Bonn Geodetic VLBI Operation Center

A. Nothnagel, A. Müskens

Abstract

The IGGB Operation Center has continued to carry out similar tasks of organizing and scheduling various observing series as in 2006. The INT3 activities have been added in the second half of the year.

1. Center Activities

The IGGB 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 2007 are the same as in 2006 but augmented with the INT3 activities.

- **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, and Noto 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 third month (4 sessions in 2007) 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):**
  Seven sessions of the Southern Hemisphere and Antarctica Series with the Antarctic stations Syowa (Japanese) and O'Higgins (German) plus Fortaleza, Hobart, Kokee, HartRAO and DSS45 have been organized for maintenance of the VLBI TRF and Earth rotation monitoring. These sessions are clustered in time at periods when O'Higgins is manned depending on logistical circumstances and manpower available. The recording frequency setup is 16 channels and 4 MHz channel bandwidth.
- **UT1 determination with near-real-time e-VLBI (INT3):**
  One of the main applications of the results of the IVS Intensive series is the prediction of UT1 values based on time series of existing UT1 observations. Reducing the latency in providing UT1 results from observations does improve UT1 predictions significantly.

For this purpose another Intensive project was initiated to fill the gaps between the INT2 sessions on Sunday mornings and the INT1 sessions on Monday evenings. Under the short name INT3, the telescopes of Ny-Ålesund, Tsukuba and Wettzell started to observe a new series of one-hour Intensive sessions in August 2007. These sessions are scheduled to start every Monday morning at 7:00 a.m. UT.

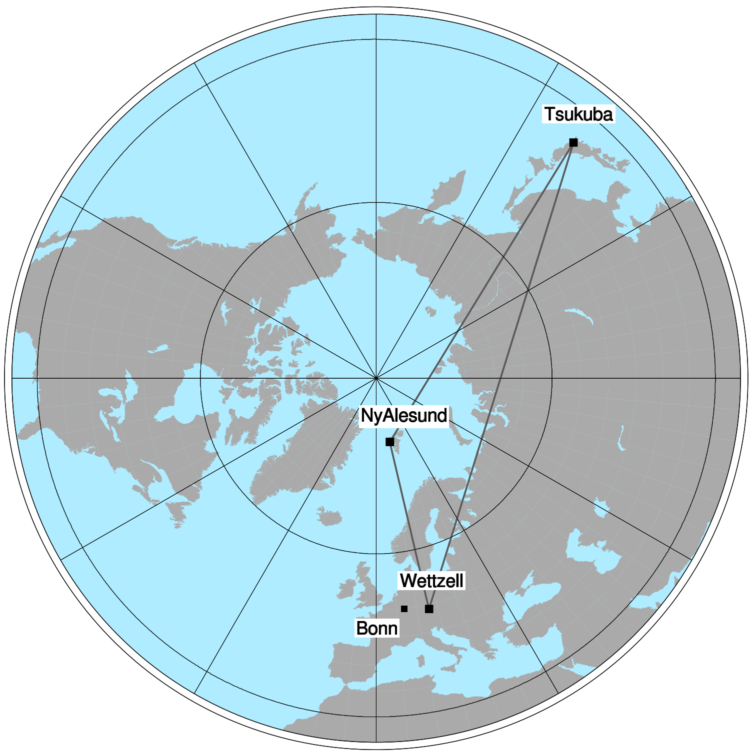


Figure 1. INT3 Network

In order to speed up delivery of the results, the raw VLBI observation data of the three sites is transferred to the Bonn Correlator by Internet connections. For compatibility reasons, the Tsukuba data, initially recorded in K4 format, has to be converted to Mark 5 format after transmission. 16 channels with 8 MHz/channel are recorded resulting in 256 MBit/s. With close to 30 minutes effective observing and recording time, each station has to transfer about 460 GBit (or 58 GBytes) per session. Due to copying procedures and current network capacities, completion of delivery of the raw VLBI data to the correlator is currently about seven hours after the final observation.

2. Staff

Table 1. Personnel at IGGB Operation Center

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

CORE Operation Center Report

Cynthia C. Thomas, Daniel MacMillan

Abstract

This report gives a synopsis of the activities of the CORE Operation Center from January 2007 to December 2007. The report forecasts activities planned for the year 2008.

1. Changes to the CORE Operation Center's Program

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

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

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

RDV: 6 sessions, scheduled evenly throughout the year, 14 to 18 station networks

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

2. IVS Sessions January 2007 to December 2007

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

- IVS-R1: In 2007, the IVS-R1s were scheduled weekly with six to eight station networks. Ny-Ålesund, Westford, and Wettzell participated in most of the IVS-R1 sessions. Fortaleza participated in several IVS-R1 sessions using 4 MHz bandwidth while the other stations used 8 MHz until the end of October. Fortaleza started using 8 MHz bandwidth during R1300 on October 29. Seshan participated in the IVS-R1 sessions with only 8 BBCs during 2007. Both Ny-Ålesund and Zelenchukskaya were tagged along to all IVS-R1 sessions in which the two stations participated.

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

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

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

- R&D: The purpose of the 10 R&D sessions in 2007, as decided by the IVS Observing Program Committee, was to record at 1 Gbit/s data rate to evaluate the geodetic results for sessions one through four. Those experiments also tested the entire data flow from scheduling through analysis for the higher data rate. The purpose of the fifth session was to determine polarization leakage in the receiver on the geodetic VLBI measurables. The purpose of the sixth through tenth sessions was to test 512 Mbps recording mode for possible usage in the CONT08 campaign.

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

Table 1 gives the average formal errors for the R1, R4, T2, and RDV sessions from 2007. The R1 sessions have significantly better formal uncertainties in 2007 compared with 2006. RDV uncertainties are worse in 2007 than 2006. This is probably due to the decrease in the number of sites in the RDV sessions from 2006 (18-19 sites) to 2007 (15-16 sites).

Table 2 shows the EOP differences with respect to IGS for the R1, R4, and RDV series. The level of WRMS agreement for the R1 and R4 sessions in 2007 is within 10-15% of the WRMS IGS difference in 2006. The RDV WRMS IGS differences are larger than in 2006; however, it is difficult to draw any statistically significant conclusions from these differences since there were only 5 RDV sessions that were analyzed at the time of writing.

Table 1. Average EOP Formal Uncertainties for 2007

Session Type	Num	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (μas)	DEPS (μas)
R1	49	45(54)	43(52)	1.9(2.5)	82(111)	33(45)
R4	49	69(73)	73(72)	2.9(3.2)	162(166)	68(67)
T2	1	44(54)	49(55)	2.2(2.5)	107(126)	36(48)
RDV	5	50(40)	53(41)	2.8(1.9)	92(74)	41(31)

Values for 2006 are shown in parentheses

4. The CORE Operations Staff

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

Table 2. Offset and WRMS Differences (2007) 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	52	-20(7)	60(76)	4(15)	77(77)	-1(-4)	19(17)
R4	52	-38(-35)	112(98)	10(36)	125(131)	2(-2)	22(21)
RDV	5	-10(31)	104(16)	-140(22)	86(95)	7(-7)	22(12)

Values for 2006 are shown in parentheses

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
Leonid Petrov	Analysis	NVI, Inc./GSFC
David Rubincam	Procurement of materials necessary for CORE operations	GSFC/NASA
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordinate master observing schedule and prepare observing schedules	NVI, Inc./GSFC

5. Planned Activities during 2008

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2008.

- The IVS-R1 sessions will be observed weekly and recorded in a Mark 5 mode.
- The IVS-R&D sessions will be observed 10 times during the year. The purpose of the R&D sessions in 2008 as determined by the IVS Observing Program Committee is to continue the series of 512 Mbps tests.
- The RDV sessions will be observed 6 times during the year.

NEOS Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 2007. The Operation Center schedules IVS-R4 and the INT1 Intensive experiments.

1. VLBI Operations

NEOS operations in the period covered consisted, each week, of one 24-hour duration IVS-R4 observing session, on Thursday-Friday, for Earth Orientation, together with five daily one-hour duration "intensives" for UT1 determination, Monday through Friday. The operational IVS-R4 network has included VLBI stations at Kokee Park (Hawaii), Wettzell (Germany), Fortaleza (Brazil), Ny-Ålesund (Norway), TIGO (Chile), Svetloe, Badary and Zelenchukskaya (Russia), Hobart (Australia), Matera and Medicina (Italy), and Westford (USA). A typical R4 consisted of 6 to 7 stations.

The regular stations for the weekday IVS Intensives were Kokee Park and Wettzell. During most of the year 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.

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

2. Staff

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

Correlators

Correlators

The Bonn Astro/Geo Mark IV Correlator

Alessandra Bertarini, Arno Müskens, Walter Alef

Abstract

The Bonn Mark IV VLBI correlator is operated jointly by the MPIfR and the IGGB in Bonn and the BKG in Frankfurt. In 2007, e-VLBI transfers became routine for geodetic experiments and, thanks to that, a new intensive series (INT3) was introduced and is correlated in Bonn. Three Mark 5B units have been installed and are in regular use for stream correlation. In late December, the first phase of a Linux cluster dedicated for the software correlator, which will become the long-term future replacement for the hardware correlator, has been installed.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR) (http://www.mpifr-bonn.mpg.de/div/vlbicor/) Bonn, Germany. It is operated jointly by the MPIfR and by Bundesamt für Kartographie und Geodäsie (BKG) (http://www.bkg.bund.de/) in cooperation with the Institut für Geodäsie und Geoinformation der Universität Bonn (IGGB) (http://www.gib.geod.uni-bonn.de). It is a major correlator for geodetic observations and MPIfR's astronomical projects, for instance those involving millimeter wavelengths and astrometry.

2. Present Status and Capabilities

Figure 1. The left-most rack contains the two correlator crates. The racks second and third from left contain two station units with two rack-mounted Mark 5A playback units. The right-most rack contains three Mark 5B units and a Mark 5A unit dedicated for e-VLBI.

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

The correlator is controlled by a dedicated Linux workstation and an HP workstation connected to a Linux file server. Correlation setup, data inspection, fringe-fitting, and data export are done on a second Linux machine connected to the Linux file server. In 2007, about 700 Gbyte of correlated

Table 1. Correlator Capabilities

Playback Units	
Number available:	1 Mark IV tape drive, 8 Mark 5A systems, 3 Mark 5B systems (interchangeable)
Tape types:	Thick, thin
Playback speeds:	80 ips, 160 ips (thin tapes); 135 ips, 270 ips (thick tapes) up to 1024 Mbit/s (Mark 5A)
Formats:	Mark III/Mark IV/VLBA (Mark IV/VLBA w/wo barrel roll, data demod.)
Sampling:	One bit; two bit
Fan-out:	1:1 1:2 1:4
Fan-in:	Not supported
No. channels:	$\leq$ 16 USB and/or LSB
Bandwidth/channel:	(2, 4, 8, 16) MHz
Signal:	Mono, dual frequency; dual polarization
Modes:	128-16-1 128-16-2 128-8-1 128-8-2 128-4-1 128-4-2 128-2-2 256-16-1 256-16-2 256-8-1 256-8-2 256-4-2 512-16-2 512-8-2 1024-16-2
Correlation	
Geometric Model:	CALC 8
Number of boards:	16
Phase cal:	Two tones (Mark 5A/tape), 16 tones (Mark 5B) extraction at selectable frequencies
Pre-average times:	0.2 s to 5 s
Lags per channel:	32 minimum, 2048 maximum; 1024 tested and used
Maximum output:	10 stations: 45 baselines, 16 channels, 32 lags with autocorrelation function (ACF) parallel-hand polarizations only 8 stations: 28 baselines, 16 channels, 32 lags with ACF full pol.
Fringe-fit:	Off-line FOURFIT
Export:	Database, MK4IN to AIPS

data were generated. The total disk space available for data handling at the correlator is more than 10 Tbyte. Data security is guaranteed by using a file system with redundancy (RAID level 5) and by daily back-up of the data on a PC disk.

3. Staff

The people in the geodetic group at the Bonn correlator are:

Arno Müskens: group leader. Scheduling of T2, OHIG, EURO, INT3, and e-VLBI supervisor.

Simone Bernhart: experiment setup and evaluation of correlated data and media shipping. (successor of A. Höfer)

Alessandra Bertarini: experiment setup and evaluation of correlated data, software correlator development, e-VLBI commissioning tests and media shipping. Digital baseband converter (DBBC) testing. PhD student at IGGB since early 2007 to reduce the effect of polarization leakage on geodetic measurables.

Christian Dulfer: e-VLBI development and operations.

Bertalan Feher: setup and trial correlation of INT3.

Frédéric Jaron: e-VLBI support, software support and Web page maintainance.

Four student operators for night shifts and 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 administration and friend of the correlator.

David Graham: technical development, consultant, software correlator development and DBBC development and testing.

Alan Roy: deputy group leader, water vapor radiometer (WVR), technical assistance, FPGA firmware for DBBC for linear to circular polarization conversion.

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 maintaining correlator, playback drives, Mark 5 and development of the DBBC.

Rolf Märtens: technician maintaining correlator hardware, playback drives and Mark 5 playbacks.

One student operator for night shifts and weekends and help with VLBI data export.

4. Status

Experiment Status: in 2007 the Bonn group correlated 48 R1, five EURO, one T2, three OHIG, 18 intensive, one R&D and about 30 astronomical projects.

e-VLBI: near-real-time e-VLBI transfers from Tsukuba, Onsala, Metsähovi, Ny-Ålesund, Wettzell, and Kashima have become regular at the correlator. This reduced the time between observation and correlation since no shipment is required. The data rates achieved ranged from 100 Mb/s with Ny-Ålesund (limited by radio link) to 400 Mb/s with peak up to 800 Mb/s. The transfers are done using the UDP-based Tsunami protocol.

INT3: a third intensive series was introduced in mid-2007 and is scheduled and correlated in Bonn. Thanks to near-real-time e-VLBI transfer, the turnaround between observation and database submission to the analysis center is about seven hours.

Mark 5B: three Mark 5B units are installed at Bonn and are in regular use since Westford, Badary and Parkes antennas are equipped with Mark 5B.

Correlator Status: during 2007 the correlator control software has been partly ported from HP to Linux by the Haystack group. Bonn correlator installed the Linux version of the components that have been released at an early stage. Six tape drives were decommissioned at the end of 2007 to make space for the software correlator cluster, so the number of usable tape drives is now reduced to one unit.

Software Correlator: Validation tests of the DiFX software correlator are being conducted with the support of the Australian group at Melbourne and Perth. First results are very promising and a small publication is being prepared. A new Linux cluster (Fig: 2) was installed in late December.

21 nodes
2 nodes for user interaction
1 I/O node with 20 TB of disk space
1 service node
8 cores per node
20 Gbps InfiniBand interconnections
12 1 GBit inputs for Mark 5 units

Figure 2. Scheme of the Linux cluster. The left rack contains top to bottom: part of the nodes, the service node (with keyboard and monitor), the 20 TB disk RAID, the switches and the panel control. The right rack contains top to bottom: part of the nodes, empty slots for future nodes an the panel control.

DBBC: the Bonn group is involved in the development of a DBBC for the European VLBI Network (EVN). This unit is designed as a full replacement for the existing analogue BBCs. Version 1 is in production; the first unit was delivered to Wettzell in November 2007. Two more units have been integrated and tested in December 2007.

5. Outlook for 2008

Correlator: the tape drive will be maintained in 2008 until the last session with tapes has been correlated. There will be a gradual changeover to Mark 5B, which will further simplify the correlation process since the station units will no longer be needed.

Software Correlator: the software correlator will be installed on the new Linux cluster and first astronomical correlation is awaited by the end of January 2008. The Mark IV hardware correlator and the new software correlator will coexist for some time.

e-VLBI: stream correlation using e-VLBI transfer will continue and e-VLBI tests with other antennas are envisaged. A K-band experiment will be transferred via e-VLBI from Australia to Bonn and copied directly to Mark 5B disks. The net protocol to be used for this transfer is still under discussion.

Personnel Changes: a new post-doc will dedicate 50% of her/his time for the future development for the software correlator.

DBBC: version 2 is under developement to provide broader bandwidth by using a new analogue-to-digital converter (ADC) and more powerful FPGA cores. This will lower costs by implementing four BBCs on a single FPGA. The ADC card prototype is ready for testing. The new card, the FiLa-10G board, provides outputs on optical fiber and testing will begin in the first half of 2008.

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 2007. Linux correlator run-time software was developed and migrated to Bonn. Testing of new observing modes and equipment, primarily Digital Back Ends (DBE), was conducted. Mark 5B capability was migrated to Bonn and Washington, and Mark 5A/B development continues. One real-time e-VLBI test was conducted, and real-time e-VLBI capability was restored. Non-real-time transfers continue, and that software and capability were installed at Bonn. Investigation of 1 Gb/sec EOP results were conducted. Engineering support of other correlators continues.

Figure 1. Partial view of the Haystack Mark IV correlator, showing 2 racks containing three Mark 5A correlator playback units, four Mark 5B DOM correlator playback units with associated correlator interface board units, and a laptop monitor.

1. Introduction

The Mark IV VLBI correlator of the MIT Haystack Observatory, located in Westford, Massachusetts, is supported by the NASA Space Geodesy Program and by the National Science Foundation. The available correlator time is dedicated mainly to the pursuits of the IVS, with a small portion of time allocated to processing radio astronomy observations for the Ultra High Sensitivity

VLBI (u-VLBI) project. The Haystack Correlator serves as a development system for testing new correlation modes, for e-VLBI, for hardware improvements such as the Mark 5B system, and for diagnosing correlator problems encountered at Haystack or at one of the identical correlators at the U.S. Naval Observatory and the Max Planck Institute for Radioastronomy. This flexibility is made possible by the presence on-site of the team that designed the correlator hardware and software. Additionally, some production correlator time is dedicated to processing geodetic VLBI observations for the IVS.

2. Summary of Activities

2.1. Linux Correlator Run-time Software Conversion

This year many run-time programs were migrated to the more contemporary Linux O/S platform Red Hat Enterprise 4. That architecture was installed and is in use at the Bonn correlator. Washington is expected to upgrade roughly at the time of this writing also. Programs converted include the messaging system, opera, and conductor. Considerable performance improvements have been obtained with this conversion at both Haystack and Bonn.

2.2. New Observing Equipment and Methods Testing

Many test experiments related to the application of Digital Back Ends to future observing methods were conducted. These experiments are a part of the VLBI2010 project and a high-sensitivity astronomy project called u-VLBI whose goals include mm-wavelength observations of the galactic center. In particular, the experiments related to VLBI2010 involve the use of the Westford and GGAO antennas as test beds for a new very wide band receiver, and a specially devised observing mode which combines the outputs from two DBE IFs onto one VSI cable, in support of dual polarization observations.

2.3. Mark 5A/5B Recording System Related Projects

Installation of Mark 5B capability was completed at both the Bonn and Washington correlators this year. Testing of Mark 5A and 5B software on the correlator continues. One effort is to correct bad disk-handling limitations on Conduant's SDK 7 version of their software. These limitations have become an impediment to upgrading field stations to later versions of the Mark 5A software. This problem seems close to resolution. Another effort is to add e-VLBI capabilities to the Mark 5B system. This effort is progressing well and should be implemented on the Haystack correlator soon. Help enabling Mark 5B capabilities at the JIVE correlator is a part of this effort.

2.4. e-VLBI

One real-time e-VLBI test was conducted on the Haystack correlator this year, involving one VLA antenna and the Westford antenna. This was a proof-of-concept demonstration for NRAO. e-VLBI efforts have been curtailed for more than a year at the Haystack correlator due to the removal of our high speed link by Lincoln Laboratory. This link was restored at a 10Gbps data rate late in 2007 so resumed testing is planned. Non-real-time transfers have continued through this period, and the software which facilitates this process was installed and is now in use at Bonn, where transfers of data destined for their correlator are conducted on a regular basis. Thirty-two experiments from four stations were transferred to Haystack this year. These non-real-time transfers included data from Kashima and Tsukuba, Japan and Syowa, Antarctica.

2.5. Other Projects

Investigations of poor EOP results from 1 Gb/sec geodetic R&D experiments became a priority this year after a report by Leonid Petrov. Those investigations are continuing. General support of the other correlators continues, with some examples being repair and testing of Bonn input boards, loan of a crate control computer to Bonn to replace a failed unit, and much support for software issues. Many software issues were related to the Linux conversion and installation of Mark 5Bs at both correlators, but there were other support issues not related to these two major upgrades as well.

3. Experiments Correlated

In 2007, thirty-one geodetic-VLBI experiments were processed at the Haystack correlator, consisting of 9 R&Ds, 3 T2s, and 19 test experiments. The test experiments cover a wide assortment of projects, some of which were touched on in the summary above. There was also a large number of smaller tests not included in the above count because they were too small to warrant individual experiment numbers.

4. Current/Future Hardware and Capabilities

Currently, functional hardware installed on the system includes 2 tape units, 7 Mark 5A units, 7 station units, 3 Mark 5B units (DOMs) with their associated correlator interface boards (CIBs), 16 operational correlator boards, 2 crates, and miscellaneous other support hardware. Changes in the above described matrix compared to last year are the addition of one Mark 5B unit (a USNO purchased unit currently borrowed for testing), and the reduction of one functional tape unit due to cannibalization of hardware from the third previously functioning unit. We have the capacity to process all baselines for 10 stations simultaneously in the standard geodetic modes, provided the aggregate recordings match the above hardware matrix. In 2008 expansion of the Mark 5B units may allow for the retirement of Station Units and an increase in available playback units.

5. Staff

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

5.1. Software Development Team

- John Ball - (part time) - Mark 5A/5B; e-VLBI
- Roger Cappallo - real-time correlator software and troubleshooting; system integration; post processing; Mark 5B; Linux conversion; e-VLBI
- Kevin Dudevoir - correlation; maintenance/support; Mark 5A/5B/5C; e-VLBI; Linux con-

version

- Chester Ruszczyk - e-VLBI; Mark 5C
- Jason SooHoo - e-VLBI; Mark 5C
- Alan Whitney - system architecture; Mark 5A/5B/5C; e-VLBI

5.2. Operations Team

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

6. Conclusion/Outlook

Further migration of run-time programs to the Linux platform is expected in the coming year. Expansion of Mark 5B units at all correlators will continue as more field stations convert to Mark 5B. Mark 5C testing should begin. For information regarding the Mark 5C recording system, please refer to the "Haystack Observatory Technology Development Center" report. e-VLBI testing should increase this year with the return of the high speed link. Further testing of Digital Back Ends will continue, with the intent of transforming standard observing techniques to higher data rates in the coming years. This is an exciting time at the Haystack correlator, with many new systems coming on-line, promising vast improvements in all aspects of observing.

IAA Correlator Center

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

Abstract

The 12-board correlator MicroPARSEC equipped with S2-PT terminals was completed in 2007. This correlator is used for processing up to 3-station observations. The new correlator ARC for 6-station VLBI observations processing is under development. The VLBI data of the 3-station observations of the Russian national network Quasar was processed using MicroPARSEC correlator.

1. Introduction

The IAA Correlator Center is located and staffed 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 national VLBI network Quasar.

2. Summary of Activities

2.1. MicroPARSEC Correlator Development

In 2007 the 12-board correlator MicroPARSEC was finished (Figure 1). It is capable of processing simultaneously up to 24 frequency channels to a maximum of 32MHz clock frequency and 2-bit sampling. The correlator is designed to process 2- or 3-station VLBI observations of 16 frequency channels from each station. If handling 3-station experiments, then 3 baselines of 8 frequency channels each are processed simultaneously.

At present the correlator is used for processing VLBI observations for astrometry. As a result, the correlator produces accurate geometric delays stored in NGS files.

Special PCI-standard boards called "MicroPARSEC units" are the main component of the MicroPARSEC correlator. Each unit is designed based on the Altera FPGA technology and contains two XF correlation devices. These units are placed into a special industrial computer (Figure 2).

Currently the correlator is equipped with two S2 playback terminals. In 2008 we are planning to equip it with Mark 5B terminals.

2.2. ARC Correlator Development

A new correlator ARC (Astrometric Radiointerferometric Correlator) development was started in 2007. This correlator will be able to process VLBI signals from 6 station (15 baselines) with 16 frequency channels each simultaneously. The correlator will have 2-bit sampled VSI-H signals at 32MHz maximum clock on its input. The maximum data rate of each station would be 1 Gbit per second. We are planning to equip this correlator with Mark 5B terminals.

The main processing device of ARC is BMC (Basic Module of Correlator), which is very similar to the MicroPARSEC unit (Figure 3). It is designed with FPGA technology in PCI board standard. The XF correlation algorithm is applied. All mathematical algorithms are FPGA's code.

Figure 1. 12-board MicroPARSEC correlator.

Figure 2. Industrial computer chassis with 12 MicroPARSEC units.

In comparison with MicroPARSEC unit, BMC has a larger size. It is Compact PCI 6U device. Also BMC has a greater number of correlation devices—16 instead of 2 in MicroPARSEC unit. Each device represents a single-baseline, single-channel XF correlator for calculating 64 complex delays and picking out calibration signals. BMCs are inserted into the Compact PCI 6U crates.

The correlator includes 15 BMCs and 6 Mark 5B terminals. SDSS (Signals Distribution and Synchronization System) provides Mark 5B with synchronization signals (DPSCLOCK and DPS1PPS) and transmits VLBI data from Mark 5B to BMC (Figure 4). SDSS transfers data streams of each station to 5 BMCs.

BMCs carry out all hardware data processing. Each BMC receives data streams of 2 stations and processes 16 frequency channels per baseline.

The correlator hardware control software is distributed over 4 Compact PCI 6U crates with

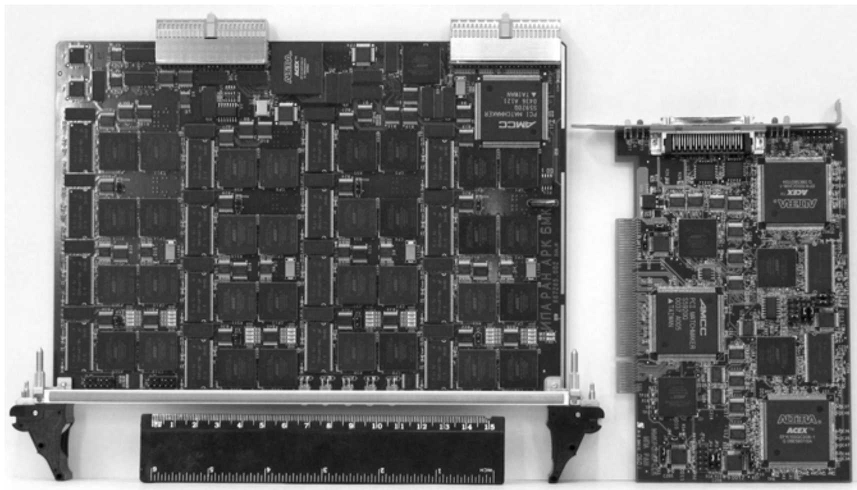


Figure 3. ARC BMC unit (left) and MicroPARSEC unit (right).

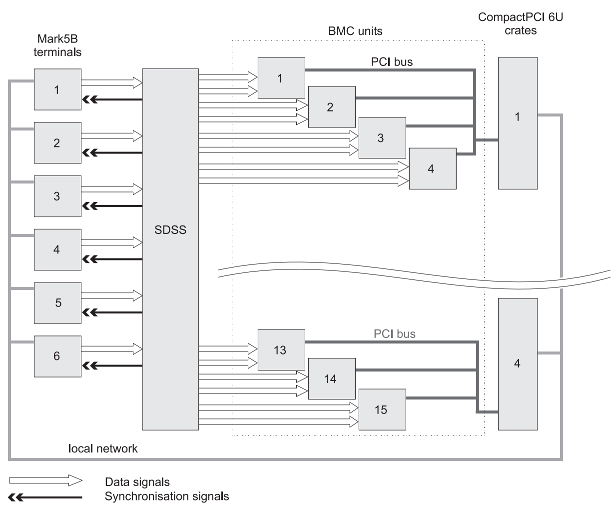


Figure 4. ARC correlator.

BMCs and a personal computer from where management is being carried out. Mark 5B terminal control, crates coordination, and data transfer are realized through the local correlator network.

At the present time the pilot batch of the BMCs have been produced. The correlator prototype construction has been started. We are planing to complete and test the full scale correlator in 2009.

3. Experiments Done

The regular national VLBI observations with the 3-station Quasar VLBI network were continued in 2007. Observational data were processed using the 4-board MicroPARSEC correlator (before February 2007) and 12-board MicroPARSEC correlator (since February 2007). All the processed VLBI observations were 14 24-hour, 3-baseline sessions and 24 8-hour, single-baseline sessions.

The obtained group and ionospheric delay accuracy varies from 50 to 100 picoseconds.

4. Staff

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

VLBI Correlators at Kashima

Mamoru Sekido, Tetsuro Kondo, Moritaka Kimura, Yasuhiro Koyama

Abstract

The software correlator systems developed at Kashima Space Research Center are used for data processing of R&D VLBI experiments. In 2007 the correlation tasks processed were an e-VLBI project for rapid UT1 measurements, the CARAVAN2400 project for reference baseline determination with small diameter antennas, and a project for comparison of time standards with VLBI. An automatic data processing scheme was newly introduced and it has drastically reduced the latency of UT1 determination. The rapid UT1 measurement with e-VLBI was demonstrated at the JGN2 symposium 2008. The automated correlation processing scheme also works efficiently in the other projects. The implementation of the high speed correlation software package GICO3 into the correlation system for the VERA project is in progress under contract with NAOJ.

1. General Information

The VLBI group of Kashima Space Research Center (KSRC) of National Institute of Information and Communications Technology (NICT) has been developing software correlators and the disk-based data acquisition system called K5. The software correlator system works on a cluster of personal computers (PCs), and it has the capacity for automation and for modification of the correlation configuration for specific data processing.

2. Component Description

NICT has developed two kinds of data acquisition systems (DAS): K5/VSI and K5/VSSP [1]. Software correlator adaptations have been developed for each of them. To clearly distinguish the two software correlator packages, Table 1 summarizes their differences. Mainly the 'cor & fx_cor' system has been used for geodetic data processing such as UT1 measurements and the CARAVAN2400 project. In the following, 'K5 software correlator' means 'cor & fx_cor' system, except when clearly stated otherwise (e.g., K5/VSI correlator).

Table 1. Two kinds of K5 software correlators developed at KSRC.

Name of Module	Corresponding DAS System	Number of Data Channel	Processing Speed	Main Developer	Applications
cor & fx_cor	K5/VSSP, K5/VSSP32	4 x 4ch	Medium	T. Kondo	Geodesy UT1
GICO3	K5/VSI	1ch ($\sim$ N)	Fast	M. Kimura	Astronomy VERA Project

2.1. Software Correlator for K5/VSSP ('Cor & Fx_cor')

The K5 software correlator system has been developed by T. Kondo [2] with the aim of geodetic VLBI data processing. It has been originally dedicated for processing the data of K5/VSSP(VSSP32) [3], which is a disk-based VLBI data recording system developed at NICT.

The K5 software correlation package includes the format converter between K5/VSSP and Mark 5 system. Thus it can be used for correlation processing of Mark 5 data via data format conversion. Now the K5 software correlation system has been exported to JIVE under a license agreement and it has been routinely used for fringe detection for VLBI observations of the European VLBI Network.

Some perl script package wrapping for the correlator core software ('cor & fx_cor') was developed in 2007. They provide a communication function to the correlator core which enables an automatic correlation processing with distributed computation on a PC cluster. This capability contributed to the improvement of the latency of the ultra-rapid UT1 measurement. The rapid UT1 measurement has been conducted in a collaboration among NICT, Geographical Survey Institute (GSI) Japan, Onsala Space Observatory (Sweden), and Metsähovi Radio Observatory (Finland). UT1 estimation has become available with 30 minutes of latency by using multiple technologies such as high speed network, data transport protocol 'tsunami', disk-based data recording systems K5/VSSP32 and Mark 5 [4], and PC interface VSI-B [5]. One target of the rapid-UT1 measurement project is the evaluation of the operational stability of pseudo-realtime e-VLBI as well as the stability of the solution. The 'tsunami' protocol [6] made the real-time transfer of observed VLBI data in Mark 5 format possible over intercontinental distances (Onsala, Metsähovi to Kashima,Tsukuba). Then data format conversion from Mark 5 to K5 and cross correlation processing are performed. For utilizing this automated processing, only the clock parameters need to be fixed before the experiment.

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

A VLBI database system based on NetCDF[1] has been developed by T. Hobiger (MK3TOOLS) [7, 8]. After the correlation processing, the MK3TOOLS have been used for the creation of Mark III databases for the analysis with the CALC/SOLVE system. The NetCDF database file is used as intermediate database to generate a Mark III database. Since the MK3TOOLS have a function to generate NGS card format as well, this is used for the analysis with OCCAM analysis system. Automatic analysis procedure for UT1 estimate is being developed by T. Hobiger by using the MK3TOOLS, NGS databases, and the OCCAM software.

Besides UT1 observations, the correlation system has been used for the CARAVAN2400 project [1], a project of time standards comparison with VLBI [1], and some fringe test experiments for supporting VLBI stations of JAXA/ISAS.

2.2. GICO3 Correlator with K5/VSI

GICO3 is a high speed correlation software developed by M. Kimura for the K5/VSI system. Under a contract with National Astronomical Observatory of Japan (NAOJ), a correlation pro-

[1]http://www.unidata.ucar.edu/software/netcdf/

Table 2. e-VLBI sessions for rapid UT1 measurement performed since April 2007. Station codes are as follows, 'Ks':Kashima34, 'Ts':Tsukuba 32, 'On':Onsala, 'Mh':Metsähovi, and 'Wz':Wettzell. The effective band width for the experiments from 3rd April to 4th June are 140.2MHz and 33.1 MHz for X and S-band, respectively. And those for experiments from 14 and 15 July are respectively 280.4 MHz and 48.8 MHz for X and S-band. The experiments on 14 and 15 July were performed by add on to the INT-2 sessions of Tsukuba-Wettzell baseline.

Date 2007	**Baseline**	**Data rate** (Mbps)	**UT1-UTC** (ms)	**UT1-c04** (μ sec.)	**Error** (μ sec.)	**Latency**
03 April	Ks – On	256	-69.6044	-38.5	8	–
23 April	Ks – On	128	-98.4422	15.0	41	1 h 55 min.
02 May	Ks – On	128	-110.0189	-30.4	16	–
18 May	Ks – Mh	128	-130.5832	67.5	98	2 h 38 min.
30 May	Ks – On	128	-143.2703	-14.7	9	28 min.
31 May	Ks – On	128	-143.7011	-83.5	8	–
04 June	Ks – On	256	-144.6447	13.1	6	31 min.
14 July	Ks-On, Ks-Wz	256	-162.0879	6.2	6	–
	Ks – On		-162.1017	-7.6	10	
	Ks – Wz		-162.0715	22.6	8	
	Ts – Wz, On-Ts		-162.0674	26.7	8	
	On – Ts		-162.0725	21.6	7	
	Ts – Wz		-162.0585	35.6	5	
	Ts – Wz(INT2)		-162.0974	-3.3	7	
15 July	Ks – On	256	-162.0186	-30.7	6	–
	Ts – Wz(INT2)		-162.0017	-13.8	8	

cessing system using the software correlator is being developed for the VERA project [9]. The system is designed for processing 10 baselines of cross correlation and 5 stations autocorrelation, simultaneously [10]. The data rate is 1 Gbps for each station. A picture of the correlation system composed of 5 PCs is displayed in Table 3

3. Staff

- Tetsuro Kondo is working for development and maintenance of software correlator package (cor & fx_cor). Data format converter between Mark 5 and K5 is included in the package. He also is in charge of the development of the PC-based VLBI sampler K5/VSSP32 [3].
- Yasuhiro Koyama is project leader of the “Space-Time Application Project” and is in charge of overall activity in our group.
- Mamoru Sekido is in charge of the e-VLBI activity.
- Moritaka Kimura is working on the development of a high speed Giga bit software correlator. He is in charge of the development of software correlators for the VERA project.
- Thomas Hobiger is developing a new VLBI database system using NetCDF. He also is active in research of atmospheric path delay calibration with ray tracing technique.
- Masanori Tsutsumi is working as system engineer for maintenance of computers.

Table 3. Picture and Specification of Software Correlator for VERA Project

Specification parameters of the Software Correlator

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

References

[1] T. Kondo, Y. Koyama, R. Ichikawa, M. Sekido: Technology Development Center at NICT, International VLBI Service for Geodesy and Astrometry 2007 Annual Report, this issue, 2008.

[2] Y. Koyama, T. Kondo, H. Osaki, K. Takashima, K. Sorai, H. Takaba, K. Fujisawa: Evaluation of the K5 system in geodetic VLBI experiments, Technical Development Center News CRL, No.23, 26-30, 2003.

[3] T. Kondo,Y. Koyama, H. Takeuchi, M. Kimura: Development of a New VLBI Sampler Unit (K5/VSSP32) Equipped with a USB 2.0 Interface, IVS 2006 General Meeting Proceedings, edited by Dirk Behrend and Karen Baver, NASA/CP-2006-214140, p.195-199, 2006

[4] Whitney, A.R.: The Mark 5B VLBI Data System, *IVS 2004 General Meeting Proceedings (eds. Nancy R. Vandenberg & Karen D. Baver)*, **NASA/CP-2004-212255**, 177–181, 2004.

[5] Ritakari, J., and A. Mujunen: Gbit/s VLBI and e-VLBI with Off-The-Shelf Components, *IVS 2004 General Meeting Proceedings (eds. Nancy R. Vandenberg & Karen D. Baver)*, **NASA/CP-2004-212255**, 182–185, 2004.

[6] Meiss, M.R.: "Tsunami: A High-Speed Rate-Controlled Protocol for File Transfer", *http://steinbeck.ucs.indiana.edu/ mmeiss/papers/tsunami.pdf*, 2004.

[7] T. Hobiger, Y. Koyama, and T. Kondo: MK3TOOLS & NetCDF - storing VLBI data in a machine independent array oriented data format ,*http://mars.hg.tuwien.ac.at/ evga/proceedings/P03_Hobiger.pdf*

[8] T. Hobiger, R. Ichikawa, M. Sekido, H. Takiguchi, T. Kondo, Y. Koyama: Analysis Center at National Institute of Information and Communications Technology, International VLBI Service for Geodesy and Astrometry 2007 Annual Report, this issue, 2008.

[9] M. Honma et al.: Multi-Epoch VERA Observations of H_2O Masers in OH 43.9 – 0.1, Publ. Astron. Soc. Japan Vol 57 pp. 595-603, 2005

[10] M. Kimura: Development of the software correlator for the VERA system, Technical Development Center News NICT, No.26, 26-27, 2005.

Tsukuba VLBI Correlator

Hiromi Shigematsu, Etsuro Iwata, Morito Machida, Kozin Wada

Abstract

This is a report of the activities at the Tsukuba VLBI Correlator in 2007.

1. General Information

The Tsukuba VLBI Correlator is situated at the Geographical Survey Institute (GSI) in Tsukuba, Ibaraki Pref., Japan. It is a part of VLBI components operated by GSI, together with the Tsukuba 32-m VLBI station (TSUKUB32). There are two K5/VSSP correlator units. Intensive sessions (IVS-INT2), performed on Saturday and Sunday on the TSUKUB32–WETTZELL baseline for monitoring UT1-UTC, have been correlated at the Tsukuba VLBI Correlator. Processing of JADE series (geodetic sessions with domestic VLBI network of GSI, run for 24 hours) is also a major task for the Tsukuba VLBI Correlator.

2. Component Description

Both the K5/VSSP correlator units "system 1" and "system 2" have been in operational use. A component description for both units is presented in Table 1.

Removable disk cartridges from the stations are connected to a data server in an external mounting mode. Each data server can share a couple of the disk cartridges at once through a drive unit. The data servers can perform distributed computing as well as function as correlation servers. File handling and multi-task control is assumed by the management computer. There is no need to assemble a K5/VSSP correlator unit from individual components; an off-the-shelf computer provides sufficient hardware to support a K5/VSSP correlator unit.

Software correlation processing on the K5/VSSP correlation unit is based on the IP-VLBI technology. It has been developed at NICT (National Institute of Information and Communications Technology, Japan). The most essential elements are four kernel programs: "apri_calc", "cor", "sdelay" in correlation package "ipvlbi20080110", and "komb" in "komb20071214". These K5/VSSP packages are licensed by NICT. Based on an agreement about research cooperation between GSI and NICT, the Tsukuba VLBI Correlator is allowed to take advantage of the products. "apri_calc" calculates a priori delay&rate for each scan per single baseline. "cor" executes software correlation. "sdelay" makes coarse fringes directly from correlator output. "komb" is a bandwidth synthesis program to obtain multi-band delays. K5/VSSP also has a conversion program; it can convert K5 to Mark 5 format and vice versa.

The kernel programs have the capability of processing only one single baseline scan. To meet the demands for processing many scans for multi-baselines, a simple way of distributed computing is brought into the unit. Once there is an uncorrelated data set, the task for it is distributed to any vacant correlation server. The auxiliary application software "PARNASSUS" handles the detailed control of processing multiple tasks. The acronym "PARNASSUS" stands for Processing Application in Reference to NICT's Advanced Set of Softwares Usuable for Synchronization. The latest version PARNASSUS 1.3, developed at GSI and released March 2006, is installed in the management computer. PARNASSUS serves the operator as a tool, providing a graphical user

Table 1. Component description of the Tsukuba correlator

	system 1	system 2
management computer	1	1
(CPU)	Intel Pentium 4, 3.0GHz	Intel Pentium 4, 3.0GHz
data servers	23	8
(CPU)	Intel Pentium 4, 3.0GHz	Intel Pentium 4, 3.4GHz
correlation servers	16 (rackmount type computer)	8 (rackmount type computer)
(CPU)	Intel Xeon 3.06GHz (dual CPUs)	Intel Xeon 3.4GHz (dual CPUs)
format	K5/VSSP	
media type	SATA disk cartridge	
kernel program package	ipvlbi20080110, komb20071214	
aid application	PARNASSUS 1.3	
OS	Linux	
operation	JADE	IVS-INT2
installation	April 2005	August 2006

interface and facilitating multi-task control. CALC/SOLVE developed by NASA/GSFC is installed on an HP workstation to produce primary solutions.

3. Staff

A list of the staff at the Tsukuba VLBI Correlator in 2007 is given below. Staff in the observation domain are listed in the report of the Tsukuba 32-m VLBI station in the Network Stations section of this volume. K. Takashima, long time VLBI group member of GSI and the operations manager of the Tsukuba VLBI Correlator for the last four years, has left for a new career in April. In his stead, K. Wada took over the responsibility of GSI's representative member for Observing Program Committee. Routine operations were mainly performed under contract with Advanced Engineering Services Co., Ltd (AES) over 200 days in the 2007 fiscal year (April 2007 through March 2008). AES was asked for 20 additional days of routine operations which were funded by National Astronomical Observatory of Japan (NAOJ). AES was also asked for 13 additional days of routine operations which were funded by Japan Aerospace Exploration Agency (JAXA).

- S. Matsuzaka : Supervisor, Head of Space Geodesy Division (GSI)
- K. Wada : Operations manager (GSI)
- E. Iwata : technical staff (GSI), network expert, system development and consultant
- H. Shigematsu : technical staff (GSI), correlation chief, media library and shipping
- M. Machida : technical staff (GSI)
- K. Nozawa : main operator in routine correlation processing (Advanced Engineering Services Co., Ltd)
- K. Takano : sub-operator in routine correlation processing, (Advanced Engineering Services Co., Ltd)

4. Current Status and Activities

During 2007, 95 Intensive sessions (IVS-INT2) on TSUKUB32-WETTZELL single baseline for UT1, three Intensive sessions (IVS-INT2) on KASHIM34-WETTZELL single baseline for UT1, and 12 24-hour geodetic sessions of domestic network (JADE series) were processed at the Tsukuba VLBI Correlator.

One geodetic session for 24-hour (U07173 session) was processed also at the Tsukuba VLBI Correlator. The U07173 session, conducted under GSI's initiative, aimed at the improvement of both the USUDA64 and YAMAGUCH site positions. USUDA64, 64 m in diameter, belongs to and is funded by JAXA as a tracking antenna for deep space missions. YAMAGUCH, 32 m in diameter, belongs to NAOJ's resources, and is operated by Yamaguchi University as a contribution to observational research in astrophysics under cooperative relationship between NAOJ and Yamaguchi University. Processing of U07173 was funded by JAXA.

Some baselines of the four "ultra-rapid dUT1 e-VLBI" sessions were processed at the Tsukuba VLBI Correlator in the form of test experiments.

Processing of JADE series is usually done with "system 1", while "system 2" has continued operations mainly for processing Intensive sessions. One of our plans came due to add some more servers to "system 2" as expansion. Eight rack-mount-type Linux computers were provided for this work.

Many correlation tasks have been routinely loaded on "system 1" and "system 2". Now two years have passed since the installation of "system 1". Some components went down. This may lead to an overload on the remaining group of machines. The task information in the access control list is generally sorted by classification according to scan number first and then to baseline. There sometimes occured an interruption of the computing process in the middle of a correlation. The cause was likely a full disk drive, which was accessed frequently for reading data files, eventually resulting in an NFS (Network File System) service stop.

5. Plan for 2008

- It is planned to continue to process the TSUKUB32/WETTZELL Intensive sessions (IVS-INT2) with the K5/VSSP system. The sessions are to be performed on both Saturday and Sunday with K5/VSSP (TSUKUB32) and Mark 5 (WETTZELL) systems. The Tsukuba VLBI Correlator is also expected to be responsible for processing 12 geodetic sessions (JADE) of the domestic VLBI network of GSI.
- We will add some more correlation servers and data servers to the existing K5/VSSP correlation units. At the same time, overloaded servers will be replaced with modern Linux machines to recover properly the performance of the K5/VSSP correlation units. In addition, the interface devices of the drive units have been gradually damaged through frequent loading of disk cartridges into the drive slots. The recovery process requires an overhaul of the drive units for both correlator and station use.
- Discussions for the next version of "PARNASSUS" will continue in the advisory team of VLBI correlation domain. The current style of distributed computing appears not to be optimized for obtaining the greatest performance from dual CPUs capacity of correlation server. To make multi-task processing executable on dual CPUs mode effectively, we plan to upgrade PARNASSUS by improving the access control to each correlation server. In order to fix the

sudden interruption of the computing process on a machine, the action plan will address the software and hardware levels. New features will be introduced into PARNASSUS, such as handling each task information in a random manner and sorting access control first by baseline and then by scan number in order to avoid frequent access to a specific data server. The design of interaction among servers will be revised to keep the data processing running.

Washington Correlator

Kerry A. Kingham, David M. Hall

Abstract

This report summarizes the activities of the Washington Correlator for the year 2007. The Washington Correlator provides up to 80 hours of processing per week, primarily supporting Earth Orientation and astrometric observations. An additional 40 hours per week of unattended processing is also provided routinely. In 2007 the major programs supported include the IVS-R4, IVS-INT, IVS-R1, APSG, and CRF (CRF,CRMS,CRDS,CRFS) 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 experiments. All of the weekly IVS-R4 sessions, all of the daily Intensives, and several IVS-R1 sessions were processed at WACO. The remaining time was spent on terrestrial reference frame and astrometry sessions. The facility houses a Mark IV Correlator.

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

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 R1 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 small disks with larger ones.

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

A Mark 5B playback unit was added to the correlator complement of Mark 5's, which now allows the correlator to process 9 stations (8 Mark 5A and 1 Mark 5B) simultaneously. Six sessions requiring at least one tape drive were processed in 2007.

Table 1 lists the experiments processed during 2007.

Table 1. Experiments processed during 2007

52	IVS-R4 experiments
19	CRF (Celestial Reference Frame)
2	IVS-R1
2	APSG (Asia Pacific)
232	Intensives
16	Kk-Sv-Wz Intensives

3. Staff

The Washington Correlator is under the management and scientific direction of the Earth Orientation Department of the U.S. Naval Observatory. USNO personnel continue to be responsible for overseeing 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)	VLBI 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

Figure 2. Roxanne Inniss, Bruce Thornton and Dave Hall keep an eye on processing.

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, and to upgrade to a new correlator control computer. It is expected that the number of playbacks available will increase to 11 with the addition of 2 Mark 5B units before the existing Mark 5A units are converted to Mark 5B.

Plans include bringing a broadband connection to the Correlator in 2008.

Data Centers

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 2007. Included are information about functions, structure, technical equipment and staff members of the BKG Data Center.

1. BKG Data Center Functions

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

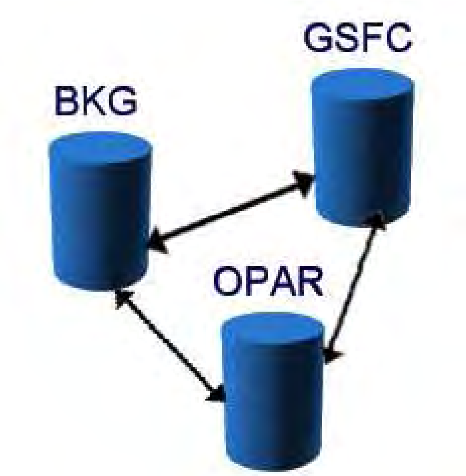


Figure 1. Principle of mirroring

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

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

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

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

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

Structure of BKG IVS Data Center:

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

2. Technical Equipment

DELL Server (SUSE Linux Enterprise 9.5 operating system)
disk space: 300 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 2007 IVS Annual Report

Carey Noll

Abstract

This report summarizes activities during the year 2007 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 raw and analyzed data to facilitate scientific investigation. The CDDIS archive of GNSS (GPS and GLONASS), laser ranging, VLBI, and DORIS data is stored on-line for remote access. Information about the system is available via the Web at the URL http://cddis.gsfc.nasa.gov. The current and future plans for the system's support of the IVS are discussed below.

2. System Description

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

2.1. Computer Architecture

The CDDIS is operational on a dedicated server, cddis.gsfc.nasa.gov. The system has over 3.5 Tbytes of on-line magnetic disk storage; over 1 Tbytes are devoted to VLBI activities. A dedicated DLT tape system is utilized for system backups. The CDDIS is located at NASA GSFC and is accessible to users 24 hours per day, seven days per week.

2.2. Staffing

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

Table 1. CDDIS Staff

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

3. Archive Content

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

The IVS data center content and structure is shown in Table 2 below. (A figure illustrating the flow of information, data, and products between the various IVS components was presented in the CDDIS submission to the 2000 IVS 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 migrate any new data to the appropriate public disk area. These routines migrate the data based on the file name to the appropriate directory as described in Table 2. Index files in the main subdirectories under ftp://cddis.gsfc.nasa.gov/pub/vlbi are updated to reflect data archived in the filesystem. Furthermore, mirroring software has been installed on the CDDIS host computer, as well as all other IVS data centers, to facilitate equalization of data and product holdings among these data centers. At this time, mirroring is performed between the IVS data centers located at the CDDIS, the Bundesamt für Kartographie und Geodäsie in Leipzig, and the Observatoire de Paris.

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

4. Data Access

During 2007, over 150 user organizations accessed the CDDIS on a regular basis to retrieve VLBI related files. These users downloaded over 460K files from the CDDIS VLBI archive last year.

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. Last year we procured new computer hardware that will increase the CDDIS on-line disk storage capacity, ensure system redundancy, and better serve our user community. We hope to be operational on this new system in the spring of 2008.

Table 2. IVS Data and Product Directory Structure

Directory	Description
Data Directories	
vlbi/ivsdata/db/*yyyy*	VLBI data base files for year *yyyy*
vlbi/ivsdata/ngs/*yyyy*	VLBI data files in NGS card image format for year *yyyy*
vlbi/ivsdata/aux/*yyyy*/*ssssss*	Auxillary files for year *yyyy* and session *ssssss*; these files include: log files, wx files, cable files, schedule files, correlator notes
vlbi/raw	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

Italy INAF Data Center Report

M. Negusini, P. Sarti, S. Montaguti

Abstract

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

1. Introduction

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

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

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

2. Computer Availability and Routing Access

To date, the main computer is a Linux workstation, where Mark 5 Calc/Solve version 10 was installed and all VLBI data analysis 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 catalogue. 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/super

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.

The HP 785/B2600 workstation is still maintained. The Internet address of this computer is boira3.ira.inaf.it and the databases are stored in different directories and on different disks as well. The complete list of directories where databases are stored follows:
1 = /data1/mk3/data1
2 = /data1/mk3/data2
4 = /data6/dbase6
6 = /data5/dbase5
5 = /data4/dbase4
7 = /data7/dbase7
8 = /data8/dbase8
9 = /data9/dbase9
The username for accessing the database at the moment is geo. The password can be requested by sending an e-mail to negusini@ira.inaf.it.

The other workstation still working in Bologna is an HP282 computer with Internet address hp-j.ira.inaf.it. The databases are stored in the following directories:
7 = /data8/dbase8
8 = /data10/dbase10
The superfiles are stored in different directories:
/data2/super
/data10/super10
/data9/super9
/data8/super8

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

Data Center at NICT

Yasuhiro Koyama, Mamoru Sekido, Hiroshi Takiguchi

Abstract

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

1. Introduction

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

Table 1. URL of the WWW server systems.

Service	URL
KSP WWW pages	`http://ksp.nict.go.jp/`
IVS WWW mirror pages	`http://ivs.nict.go.jp/mirror/`
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 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 on a daily or bi-daily (once every two days) basis until May 1999. The duration of each session was about 23.5 hours. Within that period, daily observations were performed from March 1 to April 1, 1999 to obtain continuous VLBI data series for various investigations such as studies about the atmospheric delay models and for the improvements of the data analysis technique. The high-speed ATM (Asynchronous Transfer Mode) network line to the Miura station became unavailable in May 1999, and the real-time VLBI observations with the Miura station became impossible. Thereafter, the real-time VLBI sessions were performed with three stations only—Kashima, Koganei, and Tateyama. Once every six days (every third session), the observed data were recorded to the K4 data recorders at three stations, and the Miura station participated in the sessions with the tape-based VLBI technique. In this case, the observed data at three stations except for the Miura station were processed in real-time, and the analysis results were released promptly after the observations completed. A day later, the observed tapes were transported from Kashima, Miura, and Tateyama stations to Koganei station for tape-based correlation processing of the full six baselines. After the tape-based correlation processing was completed, the data set produced with the real-time VLBI data processing was replaced by the new data set.

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

2.2. Other VLBI Sessions

In addition to the KSP regular VLBI sessions, domestic and international geodetic VLBI sessions were conducted by NICT in cooperation with Geographical Survey Institute (GSI) and other organizations. These sessions are listed in Table 2. The observed data of these sessions were correlated by using the K4 correlator and the K5 software correlator at NICT either at Koganei or at Kashima.

In 2007, 35 geodetic VLBI sessions were performed in total. Ultra-rapid e-VLBI sessions were performed based on the proposal submitted to and approved by the IVS Observing Program Committee in May 2007. The purpose of these sessions is to demonstrate e-VLBI capabilities for ultra-rapid data processing after intensive type short period (typically 1 hour) observing schedules. Observed data at one site are transferred to the other site in real-time by using high speed research

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 Comparison	4 sessions, 12 days in total
	Cs-Gas-Cell	1 session
	Spacecraft	Hayabusa: 1 session

networks, and the format conversion and data correlation processing are done immediately after the real-time file transfer. Thus, it is expected to provide the database with a minimum time of latency after each session. Two stations in Japan, Tsukuba and Kashima, and two stations in Europe, Onsala and Metsähovi, are the regularly participating stations, and Wettzell station will participate when regular IVS intensive observation session (INT2) is used for the project. Under the project, we are developing necessary software programs to realize real-time and near real-time data processing and automated data analysis. Our goal is to release the database file on the data center WWW server as soon as possible, as well as to release the analyzed results to the wide community by using e-mail. For this purpose, 29 sessions were scheduled over 15 days. The number of sessions performed on each day varies for different reasons. Sometimes, only one session was scheduled and performed on one day, whereas 6 sessions were scheduled and performed on November 26, 2007.

A series of time transfer sessions were also performed in 2007. 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. At first, two one-day sessions were performed on January 11th and 22nd, 2007. Then a 3-day session was performed from February 28th, and a one-week continuous session was performed from June 15th.

One geodetic VLBI session was performed on the baseline between Kashima 34-m station and Koganei 11-m station to evaluate the performance of the Laser Diode pumped Cesium gas cell type frequency standard system. This frequency standard has been developed by Anritsu Corporation to provide better frequency stability at the short time scale less than one day compared with the normal Cesium beam type frequency standard system. The system has a frequency stability reaching 2×10^{-14} for a time interval of about 1000 seconds. Although the performance of the frequency stability is not as good as hydrogen maser frequency standard systems, it was demonstrated that the system can be used for geodetic VLBI observations.

In addition, one VLBI session was performed on March 7, 2007 to determine the precise orbit of the Hayabusa spacecraft. It was planned to perform maneuver operation of the spacecraft to return to the Earth, and the precise orbit information was necessary.

Figure 1 shows the number of geodetic VLBI sessions and number of valid observed delays used in the data analysis for each year up to the year 2007.

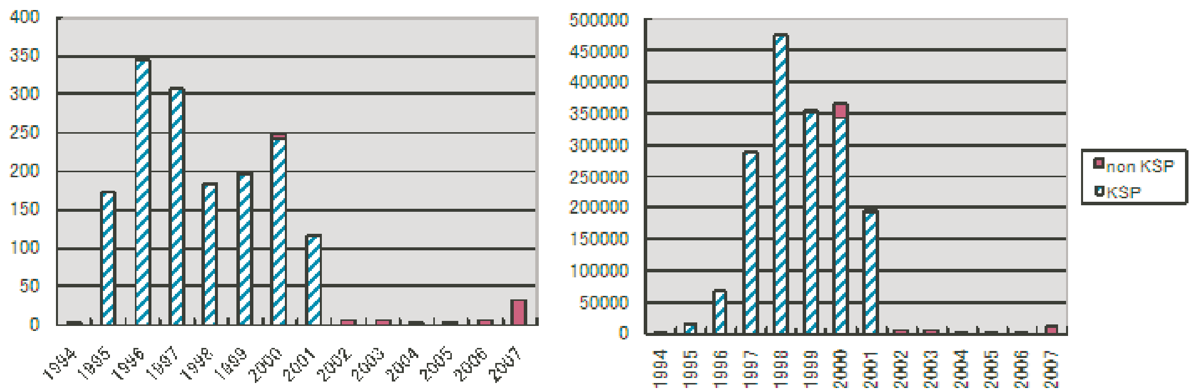


Figure 1. Number of sessions (left) and observed delays (right) used in the data analysis.

3. Staff Members

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

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

Name	Main Responsibilities
KOYAMA Yasuhiro	Administration of Servers, Generation and Archival of Databases
SEKIDO Mamoru	Responsible for e-VLBI sessions
TSUTSUMI Masanori	System Engineer

4. Future Plans

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

References

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

[2] 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

Abstract

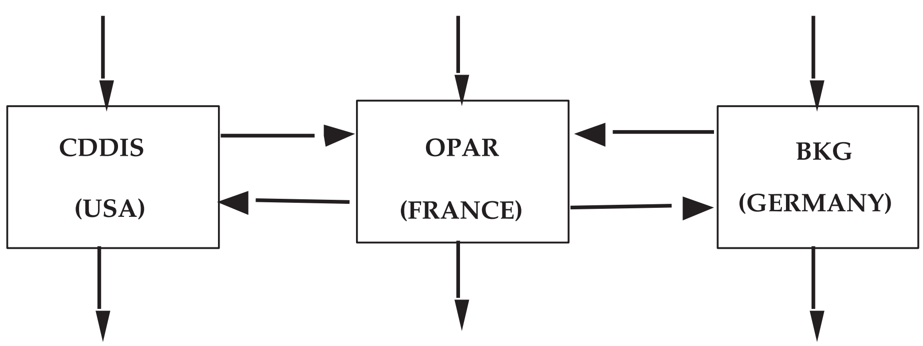
This report summarizes the OPAR Data Center activities in 2007. Included is information about functions, architecture, status, future plans and staff members of OPAR Data Center.

1. OPAR Data Center Functions

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

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

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



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

2. Architecture

To be able to put a file in a Data Center, operational and analysis centers have to be registered by the IVS Coordinating Center. The file names have to conform to the name conventions. A script checks the file and puts it in the right directory. The total number of OPAR Data Center submission failures is rather small (around five this year); errors mostly consisted of file name errors or files uploaded by mistake. 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/           :   auxilliary files (schedule, log...)
   db/            :   observation files in data-base CALC format
   ngs/           :   observation files in NGS format
   sinex/         :   observation files in SINEX format
ivsproducts/      : provides results from Analysis Center:
  eopi/           :   Earth Orientation Parameters, intensive sessions
  eops/           :   Earth Orientation Parameters, sessions of 24h
  crf/            :   Celestial Reference Frame
  trf/            :   Terrestrial Reference Frame
  daily_sinex/    :   Time series solutions in SINEX format of Earth
                      orientation and site positions
  int_sinex/      :   Daily Intensive solution 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 baseline files
ivs-special/      : specific studies
raw/              : original data (not writable actually at OPAR Data Center)
```

3. Current Status

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

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

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 ensure better access and also make raw data available in the OPAR Data Center, we have acquired new disks to get 3 TB for data storage. Their installation is planned for the beginning of 2008, together with the implementation of the dserver package.

5. Staff Members

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

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

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

Analysis Centers

Analysis Centers

Geoscience Australia Analysis Center

Oleg Titov

Abstract

This report gives an overview about activity of the Geoscience Australia IVS Analysis Center during the year 2007.

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, three EOPs and their rates on a regular basis for IVS-R1 and IVS-R4 networks and their predeccesors (IRIS-A, NEOS-A). The EOP time series from 1983 to 2007 are available. The CRF catalogues using a global set of VLBI data since 1979 are regularly submitted. In addition the GA Analysis Center participates in the statistical analysis of baseline length repeatabilities.

3. Staff

- Dr. Oleg Titov - project manager

4. Current Status and Activities

Several CRF solutions have been prepared using the OCCAM 6.2 software. VLBI data comprising 3555 daily sessions from 25-Nov-1979 to 26-Apr-2007 have been used to compute several global solutions with different sets of reference radio sources. This includes 3,930,655 observational delays from 2066 radio sources observed by 60 VLBI stations.

The last four solutions (aus000a,aus001a,aus002a,aus003a) were submitted within the scope of the IERS/IVS Working Group on the Second Realization of the ICRF. The aus000a solution strategy used all radio sources as global parameters. The aus001a solution strategy used radio sources as close as possible to the ICRF [1]. Coordinates of 102 'other' ICRF sources were treated as local parameters and their positions were estimated for each VLBI session. The rest of the sources were treated as global parameters. The aus002a solution treated as global parameters only 582 radio sources which satisfy two conditions: 1) $z \geq 1$ and 2) not 'unstable' in the classification by Feissel-Vernier [2]. The aus003a solution treated as global parameters only 486 radio sources which satisfy two conditions: 1) $z \leq 1$ and 2) not 'unstable'. Statistics of these solutions are shown in Table 1.

Station coordinates were also estimated using NNR and NNT constraints. Long-term time series of the station coordinates have been established to estimate the corresponding velocities for each station. Due to a limited amount of observations the velocities have been estimated for 55 stations only. Velocities of five stations (DSS65A, MARCUS, METSAHOV, VLBA85 3,

Table 1. Statistics of CRF solutions

Solution	Number of global sources	Number of arc sources	Weighted rms (pks)	chi-squared
aus008a	all		15.4	0.866
aus008b	212 defining	102 other	15.2	0.862
aus008c	582 z≥1	1495	15.1	0.860
aus008d	486 z≤1	1591	15.5	0.905

and ZELENCHK) were not estimated. Tectonic motion for Gilcreek VLBI site after the Denali earthquake is modeled using an exponential function [4].

The adjustment has been done by least squares collocation method, [5] which considers the clock offsets, wet troposphere delays and troposphere gradients as stochastic parameters with apriori covariance functions. The gradient covariance functions were estimated from the GPS hourly values [3].

5. Geodetic Activity of the Australian Radiotelescopes

During 2007 two Australian radiotelescopes (Hobart and Parkes) were involved in geodetic VLBI observations. The GA geodesy group promoted the observations in different ways.

The Parkes 64-meter telescope participated in five geodetic VLBI sessions in 2007. Five sessions are planned for 2008 year. This program is promoted in cooperation with the Australian Telescope National Facility (ATNF). The last two sessions in November were recorded with Mark 5B recorder.

6. New Geodetic VLBI Network

In November, 2006 the geospatial bid within the National Collaborative Research Infrastructure Strategy (NCRIS) capability "Structure and Evolution of the Australian Continent" has been approved. The VLBI part of this bid includes three new modern VLBI sites to be built in different parts of the Australian continent. The proposed design includes small size dish (12 m) with high slewing rate (5 degrees/second) equipped with Mark 5B recorder. First telescope in Hobart is expected to be installed in 2008, two other telescope (Yarragadee, Western Australia and Katherine, Northern Territory) will be built in 2009. The radio astronomy group of UTAS takes responsibility for this network deployment.

7. Baseline Length Repeatability Analysis

Traditionally the baseline length repeatability is used as a measure of the quality of geodetic VLBI data. The repeatability R used to be fit by a linear model as a function of baseline length L only as $R = aL + b$. However, it was shown that the simple linear regression does not fit long baselines properly (e.g., [6], [7]).

It was shown [8] that the repeatability R can be fitted as a function of two parameters: baseline length L and slewing rate of radio dish V. Then the following expression can be given for R:

$$R^2 = \frac{AL^2 + B}{\sqrt{V}(C - DL)}$$

Here A,B,C,D are empirical parameters to be estimated by least squares. Fig 1 demonstrates the empirical values of the repeatabilities versus baseline length (black dots) and their approximation by the proposed formula (circles).

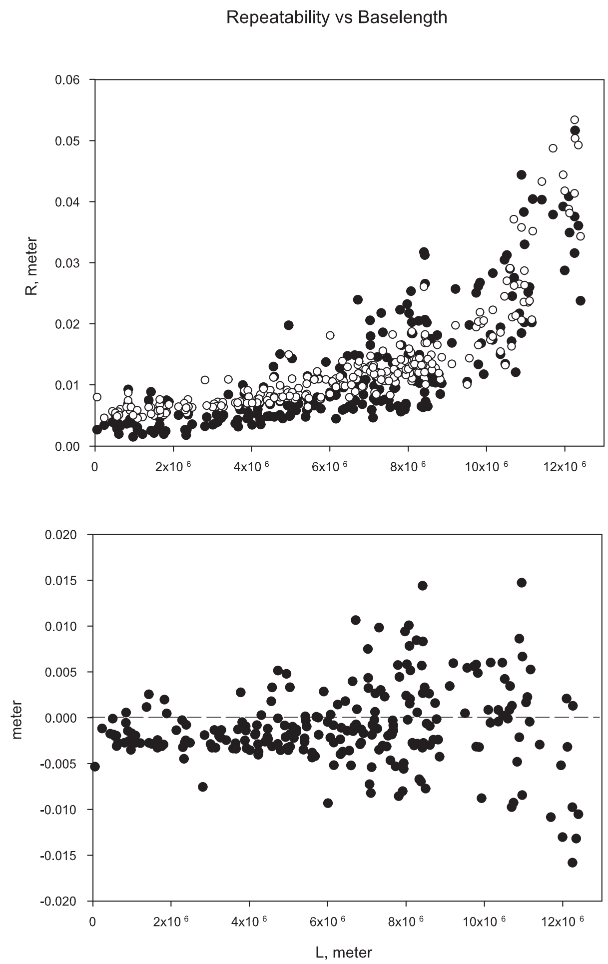


Figure 1. Fitting of the empirical relationship ‘repeatability vs baseline length’ (top) and post-fit residuals (bottom).

The horizontal and vertical uncertainties (σ_h and σ_v) can be also calculated using the same empirical values plus the radius of the Earth R_e as:

$$\sigma_h = \frac{\sqrt{B}}{\sqrt{2\sqrt{V}(C - DL)}}$$

$$\sigma_v = \sqrt{\sigma_h^2 + \frac{2AR_e^2}{\sqrt{V}(C - DL)}}$$

More details are available in [8].

References

[1] Ma, C., E. Arias, T. Eubanks, A. Fey, A.-M. Gontier, C. Jacobs, O. Sovers, B. Archinal, P. Charlot, The International Celestial Reference Frame as realized by Very Long Baseline Interferometry, In: AJ, 116, 516–546, 1998.

[2] Feissel-Vernier, M., Selecting stable extragalactic compact radio sources from the permanent astro-geodetic VLBI program, In: AJ, 403, 105–110, 2003.

[3] Haas, R., private communication.

[4] Titov, O., P. Tregoning, Post-seismic motion of the Gilcreek geodetic sites following the November, 2002 Denali Earthquake, In: International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings, NASA/CP–2004-212255, N. R. Vandenberg and K. D. Baver (eds.), 496–500, 2004.

[5] Titov, O., Estimation of subdiurnal tidal terms in UT1-UTC from VLBI data analysis In: IERS Technical Notes 28, B. Kolaczek, H. Schuh and D. Gambis (eds.), 11–14, 2000.

[6] MacMillan, D. D., D. Behrend, D. Gordon, C. Ma, First Results from CONT05 In: International VLBI Service for Geodesy and Astrometry 2006 General Meeting Proceedings, NASA/CP–2006-214140, D. Behrend and K. D. Baver (eds.), 269–273, 2006.

[7] Lambert, S., Baseline and Site Repeatability in the IVS rapid Network, In: International VLBI Service for Geodesy and Astrometry 2006 General Meeting Proceedings, NASA/CP–2006-214140, D. Behrend and K. D. Baver (eds.), 296–299, 2006.

[8] Titov, O., Baseline length repeatability In: Proc of 18 European VLBI on Geodesy and Astrometry Working Meeting, J. Boehm, A. Pany and H. Schuh (eds.), 64–68, 2007.

Bordeaux Observatory Analysis Center Report

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

Abstract

This report summarizes the activities of the Bordeaux Observatory Analysis Center in 2007. During this period, we have continued the VLBI imaging activity initiated previously. A total of 574 VLBI maps have been produced by full imaging of three RDV sessions. Other activities focus on regular processing of the IVS-R1 and IVS-R4 sessions and calculation of additional structure indices to refine our source categorization based on this criterion. Newly developed activities include simulations to study the imaging capabilities of the next generation VLBI system and, on the observational side, the initiation of a VLBI survey of weak sources that are potential candidates to link the ICRF and the future GAIA frame. Plans for 2008 follow the same analysis and research lines, with also specific contributions in the framework of the Working Group on the Second Realization of the International Celestial Reference Frame.

1. General Information

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

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

In addition, the Bordeaux group is in charge of the VLBI component in the multi-technique GINS software [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 Observatory Analysis Center routinely analyzes the weekly IVS-R1 and IVS-R4 sessions. This analysis is now based on the GINS software, whereas it was carried out with the JPL VLBI estimation software MODEST [2] in previous years. Results derived with GINS have been checked against IVS solutions [3]. In the fall of 2007, we installed the Linux version of GINS (GINS-PC) in Bordeaux, which should facilitate the production of future operational solutions.

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

In addition, the Bordeaux group has been involved in the VLBI2010 activities. This includes studies of source structure effects from wide band delay measurements and simulations of VLBI maps for the evaluation of the imaging capabilities of VLBI2010 test networks.

3. Scientific Staff

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

- Patrick Charlot (50%): overall responsibility for Analysis Center work and data processing. His major research interests include the densification and extension of the ICRF and studies of source structure effects in astrometric VLBI data.
- Antoine Bellanger (100%): engineer with background in statistics and computer science. His main role is to conduct initial VLBI data processing and develop analysis tools as needed. He is also the Web master for the M2A group.
- Géraldine Bourda (50%): postdoc fellow funded by the French space agency (CNES). She is in charge of the VLBI analysis with GINS for combining space geodesy data at the observation level. She is also leading an observing program for linking the ICRF and the GAIA frame.
- Arnaud Collioud (100%): engineer with background in astronomy and interferometry. His task is to process the RDV sessions with AIPS and DIFMAP for imaging the sources. In addition, he develops simulations to study the imaging capabilities of VLBI2010 networks.
- Alain Baudry (10%): radioastronomy expert with specific interest in radio source imaging and astrometric VLBI.

4. Analysis and Research Activities during 2007

As noted above, a significant part of our activity consists of systematic imaging of all extragalactic sources observed during the RDV sessions. During the past year, three such sessions have been processed (RDV26, RDV62, and RDV64), resulting in 574 VLBI images at either X or S band for 200 different sources. See Fig. 1 for a sample of the images derived from the RDV64 session, observed on 2007 July 10. Overall, we have now produced a total of 1122 images for 264 different sources. The imaging work load has been shared between USNO and Bordeaux Observatory since 2007: the USNO group processes the odd-numbered RDV sessions while the Bordeaux group processes the even-numbered ones. In addition, we collaborate with Whittier College (USA) and the Max Planck Institute for Radioastronomy in Bonn for analysis of the earlier RDV sessions.

In order to make these images available, we have developed a prototype database which also includes the structure correction maps and structure indices derived from the VLBI images. Calculation of structure indices is useful to categorize the sources and to identify those that remain astrometrically suitable over time. Based on our VLBI images and those from the Radio Reference Frame Image Database (RRFID), we have obtained 2697 structure indices at X band (from 577 different ICRF sources) and 2388 structure indices at S band (from 492 different ICRF sources), with up to 28 VLBI epochs available for the most intensively observed sources [4]. Among these, there are about 200 sources that are found to be astrometrically suitable at any epoch. Such sources are potential candidates to serve as defining sources in the next realization of the ICRF.

During the past year, we also initiated a new VLBI observational program dedicated to observing 450 weak sources that are potential candidates to link the ICRF and the future GAIA frame. These candidates were selected on the basis of their optical counterpart ($V \leq 18$), their total flux density ($S \geq 20$ mJy) and their declination ($\delta \geq -10°$) so that they can be observed with northern

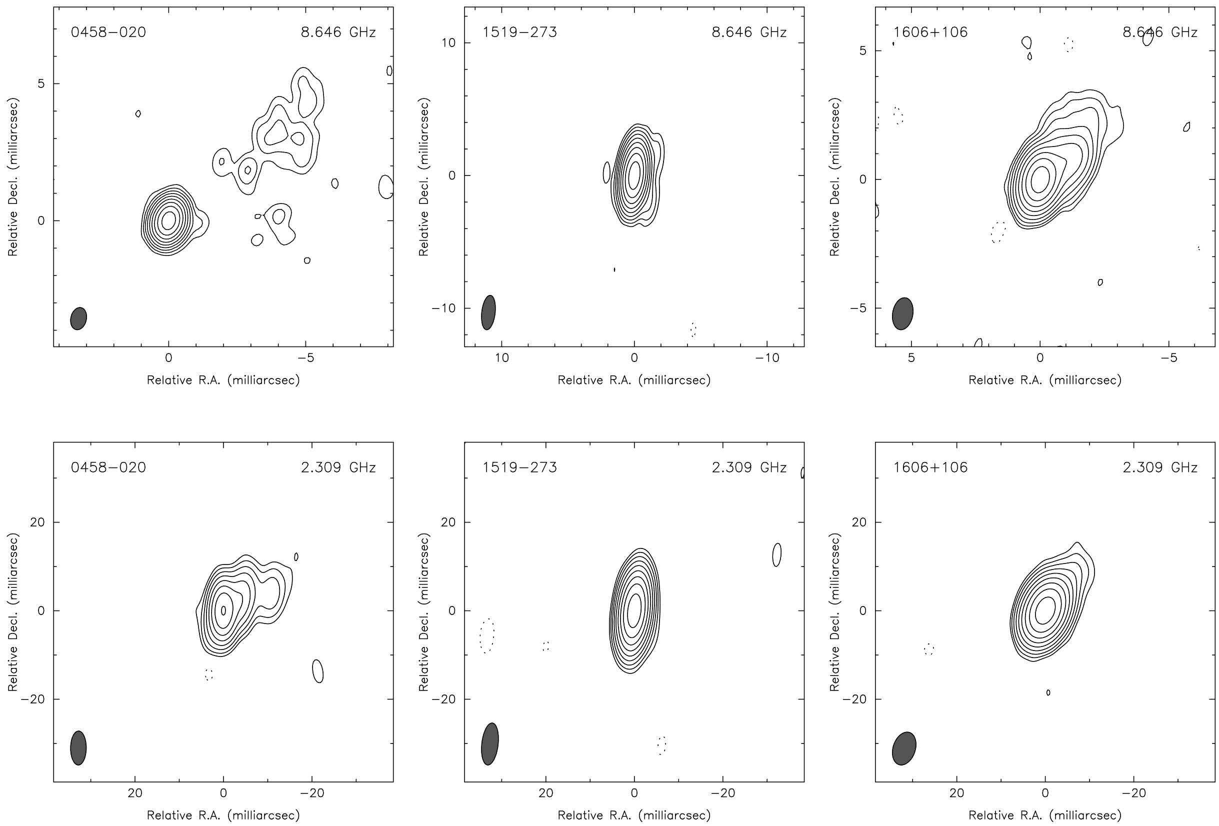


Figure 1. VLBI images at X band (upper panel) and S band (lower panel) for three ICRF sources (0458−020, 1519−273, and 1606+106) as derived from the data of the RDV64 session conducted on 2007 July 10.

VLBI arrays. Pilot observations were carried out with the European VLBI Network (EVN) in June and October 2007 in order to identify which sources are detectable with VLBI. Interestingly, about 90% of the targets turned out to be detected, with typical VLBI flux densities of 25 mJy at X band and 45 mJy at S band [5]. This very high detection rate sets excellent prospects for follow up imaging and precise astrometry on these targets and, in the longer term, for the ICRF–GAIA link.

Another activity that was initiated during the past year is the study of the imaging capabilities of the next generation VLBI system as a contribution to the work of the VLBI2010 Committee. To this end, a pipeline that simulates VLBI images from VLBI2010 schedules has been developed. Based on this pipeline, simulated VLBI images have been successfully produced for various schedules depending on the network configuration, the number of observations per day, and the observing strategy. A major conclusion of this study is that a 16-station network fails to properly reconstruct extended structures for sources at low declination, whereas a 32-station network reconstructs such structures in a reliable way for sources at any declination. Details of the pipeline and results of the simulations will be reported at the forthcoming IVS General Meeting [6].

5. Outlook

For the year 2008, our plans include the following:

- Keep on analyzing the new IVS-R1 and IVS-R4 sessions as they become available and develop appropriate procedures for future operational analysis with GINS.
- Continue the processing of the RDV sessions to monitor the X and S band structural variability of the ICRF sources in cooperation with USNO and other groups that contribute to the imaging of these sessions.
- Continue to evaluate the astrometric suitability of the ICRF sources as new maps become available and categorize the sources according to our structure index criterion.
- Contribute to the work of the IAU/IVS/IERS Working Group on the Second Realization of the ICRF with emphasis on the selection of defining sources and identification of unstable sources.
- Finalize the prototype database that holds our source maps, structure correction maps, and structure indices so that these can be made publicly available through the Web.
- Pursue further our studies of the imaging capabilities of the next generation VLBI system by carrying out additional simulations within the framework of the VLBI2010 Committee.

References

[1] Meyer, U., Charlot, P., Biancale, R.: 2000, GINS: A New Multi-technique Software for VLBI Analysis, IVS 2000 General Meeting Proceedings, Eds. N. R. Vandenberg and K. D. Baver, NASA/CP-2000-209893, p. 324–328.

[2] Sovers, O. J., Jacobs, C. S.: 1996, Observation Model and Parameter Partials for the JPL VLBI Parameter Estimation Software "MODEST"–1996, JPL Publication 83-39, Rev. 6, August 1996.

[3] Bourda, G., Charlot, P., Biancale, R.: 2007, GINS: A New Tool for VLBI Geodesy and Astrometry, Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, Eds. J. Böhm, A. Pany, and H. Schuh, IGG Vienna, p. 59–63.

[4] Charlot, P., Fey, A., Collioud, A., Ojha, R., Boboltz, D., Camargo, J. I. B.: 2008, Source structure: an essential piece of information for generating the next ICRF, Proceedings of the IAU Symposium 248, A Giant Step: from Milli- to Micro-arcseond astrometry, Shanghai, 15–19 October 2007 (in press).

[5] Bourda, G., Charlot, P., Porcas, R., Garrington, S.: 2008, Multi-step VLBI observations of weak extragalactic radio sources to align the ICRF and the future GAIA frame, to be presented at the 5th IVS General Meeting, March 3–6, 2008, Saint Petersburg (Russia).

[6] Collioud, A., Charlot, P.: 2008, Imaging capabilities of the next generation VLBI system, to be presented at the 5th IVS General Meeting, March 3–6, 2008, Saint Petersburg (Russia).

Matera CGS VLBI Analysis Center

Roberto Lanotte, Giuseppe Bianco, Cinzia Luceri

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS) at Matera from January 2007 through December 2007 and the contributions that the CGS intends to provide for the future as an IVS Data Analysis Center.

1. General Information

The Matera VLBI station became operational at the Space Geodesy Center (CGS) of the Italian Space Agency (ASI) in May 1990. Since then it has been active in the framework of the most important international programs. VLBI data analysis activities are performed at CGS for a better understanding of the tectonic motions with specific regards to the European area. The CGS, operated by Telespazio on behalf of ASI, provides full scientific and operational support using the main space geodetic techniques: VLBI, SLR, and GPS.

2. Staff at CGS Contributing to the IVS Analysis Center

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

3. Current Status and Activities

3.1. Global VLBI Solution asi2007a

The main VLBI data analysis activities at the CGS in the year 2007 were directed towards the realization of a global VLBI analysis, named asi2007a, using the CALC/SOLVE software (developed at GSFC). The main characteristics of this solution are:

- Data span:
  1979.08.03 - 2007.12.27 (3463 sessions)
- Estimated Parameters:
  - Celestial Frame:
    right ascension and declination as global parameters for 637 sources
  - Terrestrial Frame:
    Coordinates and velocities for 92 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, east and north horizontal gradients) for all VLBI stations observing in the IVS R1 and R4 sessions was continued during 2007. At present 493 sessions have been analyzed and submitted covering the period from 2002 to 2007. The results are available on the IVS products ftp sites.

3.3. IVS Pilot Project "Time Series of Baseline Lengths"

Regular submission of station coordinate estimates, in SINEX files, was continued during 2007 for the IVS pilot project "Time Series of Baseline Lengths". The series is composed of 3167 sessions, from 1979 to 2007. At the present, an analysis of the differences between the CGS series and those provided by the analysis centers participating in this project is under investigation.

4. Future Plans

- Continue to improve the realization of global VLBI analysis.
- Continue to participate in IVS analysis projects.

DGFI Analysis Center Annual Report 2007

Volker Tesmer, Hermann Drewes, Manuela Krügel

Abstract

This report summarizes the activities of the DGFI Analysis Center in 2007 and outlines the planned activities for the year 2008.

1. General Information

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institution located in Munich. It is run by the German Geodetic Commission (Deutsche Geodätische Kommission, DGK) at the Bavarian Academy of Sciences. The research covers all fields of geodesy and includes the participation in national and international projects as well as functions in international bodies (see also http://www.dgfi.badw.de).

2. Activities in 2007

1. Common signals in homogeneously reprocessed long-term GPS and VLBI height time series

   The intention was to understand how station position time series improve, if latest high-end models are used in geodetic data analysis. One criteria that can be applied is the similarity of annual harmonic signals estimated from GPS and VLBI height series. We used GPS and VLBI height time series with daily resolution (data from 94-07), computing 2 solution runs:

   - Iteration 1: Both series are fully reprocessed and the a priori models were homogenized in both softwares (GPS: Bernese 5.1 @ GFZ, VLBI: OCCAM 6.1 @ DGFI); Nevertheless, not all models were state-of-the-art (e.g., NMF, constant a priori ZD).
   - Iteration 2: Besides the efforts in iteration 1, all models were updated according to the latest state of knowledge (e.g., VMF1, a priori ZD from ECMWF, thermal deformation for VLBI, the VLBI ZD was estimated in full UTC hours as for GPS).

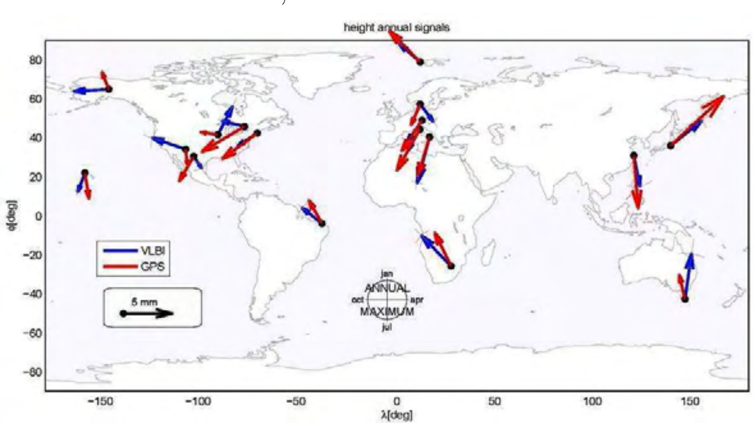


Figure 1. Annual harmonic signals estimated from GPS and VLBI height time series. The arrows illustrate the estimated amplitudes and phases of 17 stations with enough data (dark is VLBI, light grey is GPS). The figure shows the results of iteration 2, which is related to state-of-the-art models.

   Figure 1 illustrates the GPS and VLBI annual signals estimated from the iteration 2 data. Considering the WRMS of the VLBI vs GPS differences in phase and amplitude for all stations (iteration 1 / 2: WRMS amplitude 2.2 / 1.7 mm, WRMS phase 44 / 38 deg), one can assume that the iteration 2 modeling is clearly better.

2. Alternative models to estimate nutation and polar motion rates

   In VLBI data analysis, it is common practice to determine the full set of EOP (dUT1 and LOD, polar motion and their rates as well as nutation offsets) for each 24-h VLBI session. For that, we have a mathematical correlation of the nutation offsets and the terrestrial pole rates, as illustrated in Figure 2 (because nutation offsets are equivalent to a retrograde daily oscillation in the terrestrial frame).

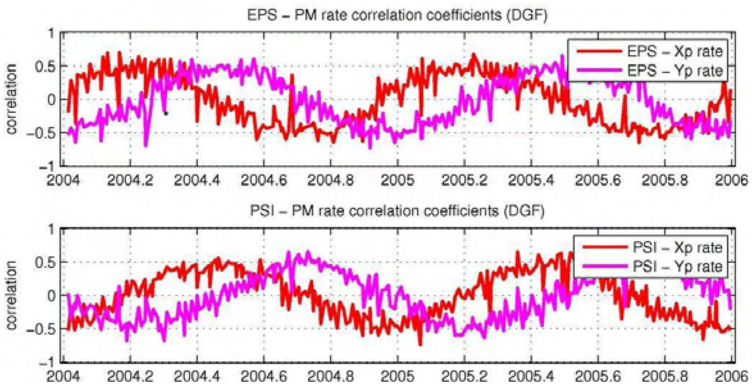


Figure 2. Correlation coefficients between nutation offsets and terrestrial pole rates, estimated from the 2004-2006 session SINEX files, submitted to the IVS by DGFI. The annual variation of the correlation reflects the annual change in phase of the retrograde daily oscillation due to a superposition of the sidereal and the solar day.

   Therefore, efforts were made to estimate nutation parameters not for each session, but for several sessions or even weeks, which would lead to a considerable improvement if the deficiencies of the a priori nutation model are only the free core nutation (FCN, with a period of about 432 days). Like this, we could stabilize the nutation estimates, which thus would help to improve the polar motion rate estimates for each session.

   Preliminary results indicate that the WRMS of the differences between the dX pole rates and the IGS values is getting smaller, the WRMS of the differences of the dY pole rates does not change significantly. An analysis of the daily nutation estimates reveals the reason for the only moderate improvement: the IAU2000A nutation model has small insufficiencies in the shorter periods, like the fortnightly lunar (Mf) 13.661 days period, with residual amplitude of about 0.06 mas. Thus, before repeating these tests, the nutation model has to be improved in the higher frequencies.

3. Effect of analyis options in results from the IVS standard SINEX normal equations

   In close cooperation with the VLBI group of the University of Bonn, the results from two VLBI analysis software packages, OCCAM and Calc/Solve, were compared to detect systematic differences, caused by model differences. The comparisons were carried out with EOP and station position time series calculated from standard normal equations (SINEX files), as used for the official IVS combination (contributions are from DGFI and the NASA Goddard Space Flight Center). In addition, the same comparisons were done with consistent time series generated with all relevant corrections adapted in both software packages (contributions from DGFI and the VLBI group of the University of Bonn, IGGB).

   Comparing the GSFC(IVS)–DGFI(IVS) differences to the IGGB–DGFI differences, systematics became obvious. Many stations had systematic height offsets of about 1 cm in the GSFC(IVS)–DGFI(IVS) case, but not for IGGB–DGFI (horizontal differences were smaller by a factor of 3). These systematic differences turned out to be mainly due to differences in the pole tide model.

4. DGFI contribution to the second realization of the ICRF (ICRF2)

   DGFI takes part in the IVS Working Group for the second realization of the ICRF (ICRF2) by submitting all types of results necessary in this context. The first goal is to identify sources which cannot be assumed to have positions constant in time, by computing and analyzing time series of estimated source positions. DGFI computes such time series using a NNR datum over all sources per session with respect to a homogeneous CRF solution.

   Figure 3 (upper panel) shows the time series of declination components of the source 1741-038, with only NNR conditions applied for each single session. An annual signal can clearly be seen, which is possibly caused by atmospheric mismodeling in data analysis, although the respective source code in OCCAM is fully up-to-date with the latest models in this area of research. If some deformation parameters (see legend of Figure 3) are also estimated (panel in the middle: IERS approach, lower panel: DGFI approach), this signal is absorbed.

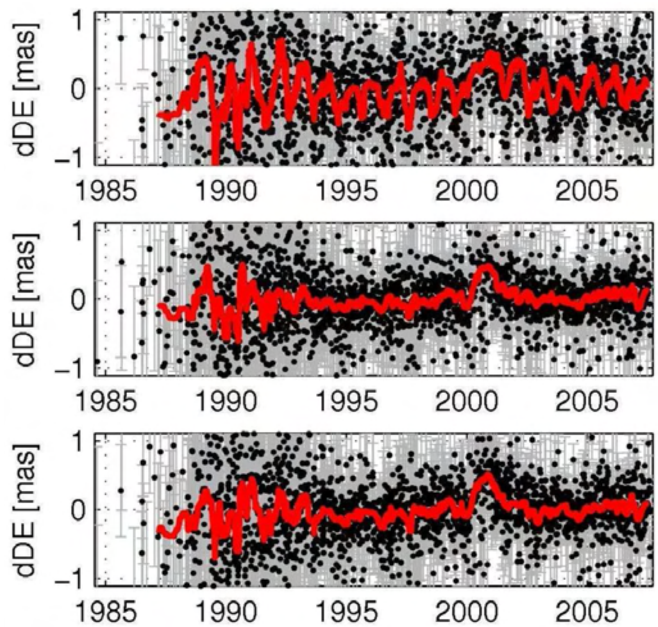


Figure 3. Time series of declination components for the source 1741-038. Upper panel: positions are estimated for each session, with only NNR datum applied. Panel in the middle: with a deformation model also estimated, which is often used in the IERS and the astrometric community (for declination δ: $D_\delta(\delta\text{-}\delta_0) + dz$, for right ascension α:$D_\alpha(\delta\text{-}\delta_0)$). Lower panel: estimated with NNR datum and a simpler but very effective deformation model, developed at DGFI (for declination δ: $dz\cos\delta$). Although still under investigation, the DGFI model fits the data well.

5. IVS Operational Analysis Center at DGFI

   The IVS updated its approach to determine the operational IVS Earth Orientation Parameters (EOP) series from averaging solutions submitted by the different Analysis Centers (which all used inhomogeneous solution setups, different reference frames etc), to computing them from normal equations, which were derived by adding the SINEX files submitted to the IVS by the different Analysis Centers (ACs). These files contain the EOP and station positions for each 24-hour session as SINEX normal equations, which provides a direct relation of the EOP to one definite TRF throughout the whole series (e.g., the ITRF2005). This approach also allows to analyze the input data in a much better way than before and is especially suitable to rigorously reprocess the combination, if necessary. The DGFI IVS AC contributed to this new operational series from its beginning in December 2006 with a recomputed series of datum-free normal equations in SINEX format for VLBI sessions back to 1984 (3050 sessions at the end of 2007).

6. IVS OCCAM Working Group

   Most important for DGFI as IVS AC is to maintain and refine the VLBI software OCCAM to current requirements in close collaboration within the IVS OCCAM Working Group, chaired by Oleg Titov, Geoscience Australia (Canberra, Australia). Other leading members are scientists from the Vienna University of Technology, Austria, the St. Petersburg University, the Institute of Applied Astronomy, both Russia, and DGFI. The latest updates of the software package are related to an optional homogenization effort with the Bernese GPS Software and post-fit analysis tools to analyze station and radio source position time series.

3. Staff

Members of the DGFI IVS AC are Volker Tesmer, Manuela Krügel, and Hermann Drewes.

4. Plans for 2008

In 2008, it is planned to further improve the VLBI software OCCAM, support IVS TRF and CRF preparation activities (submit solutions computed at DGFI and analyze different contributions), and to submit SINEX files for all 24-h sessions to the IVS on an operational basis.

5. Selected Publications

Artz, T., S. Böckmann, A. Nothnagel, V. Tesmer: ERP time series with daily and sub-daily resolution determined from CONT05. J. Boehm, A. Pany, H. Schuh (Eds.): Proc. of the 18th EVGA Working Meeting, 12-13 April 2007, Geowiss. Mitteilungen, Heft Nr. 79, TU Wien, ISSN 1811-8330, 69-74, 2007

Böckmann, S., T. Artz, A. Nothnagel, V. Tesmer: Comparison and combination of consistent VLBI solutions. J. Boehm, A. Pany, H. Schuh (Eds.): Proc. of the 18th EVGA Working Meeting, 12-13 April 2007, Geowiss. Mitteilungen, Heft Nr. 79, TU Wien, ISSN 1811-8330, 82-87, 2007

Heinkelmann, R., J. Boehm, S. Bolotin, G. Engelhardt, D. MacMillan, H. Schuh, E. Skurikhina, V. Tesmer, O. Titov, P. Tomasi: Combination of long time series of troposphere zenith delays observed by VLBI. In: Schuh, H., A. Nothnagel, C. Ma (Eds.): VLBI special issue. Journal of Geodesy, DOI 10.1007/s00190-007-0147-z, 2007

Schuh, H., R. Heinkelmann, J. Sokolova, V. Tesmer: Sub-Commission 1.4 Interaction of Celestial and Terrestrial Reference Frames. IAG Commission 1 Reference Frames, Report 2003-2007, Bulletin No. 20, ed. By H. Drewes and H. Hornik, DGFI, Munich, pp. 46-51, 2007

Tesmer, V.: Celestial Reference Frames and Interaction with Terrestrial Reference Frames. In: Müller, J., H. Hornik (Eds.): National Report of the Federal Republic of Germany on the Geodetic Activities in the years 2003-2007. Deutsche Geodätische Kommission, Reihe B, Nr. 315, München, 11-13, 2007

Tesmer, V.: Effect of various analysis options on VLBI-determined CRF. J. Boehm, A. Pany, H. Schuh (Eds.): Proc. of the 18th EVGA Working Meeting, 12-13 April 2007, Geowiss. Mitteilungen, Heft Nr. 79, TU Wien, ISSN 1811-8330, 103-110, 2007

FFI Analysis Center

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an analysis center focuses primarily on a combined analysis at the observation level of data from VLBI, GPS, and SLR using the GEOSAT software. This report shortly summarizes the current status of analyses performed with the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. Introduction

A number of co-located stations with more than one observation technique have been established. In principle, all instruments at a given co-located station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each co-located site. In addition, a constant eccentricity vector from the reference point of the co-located station to each of the individual phase centers of the co-located antennas is estimated using constraints in accordance with a priori information given by the ground surveys. One set of Earth orientation parameters (EOP) and geocenter coordinates can be estimated from all involved data types. The present dominating error source of VLBI is the water content of the atmosphere which must be estimated. The introduction of GPS data with a common VLBI and GPS parameterization of the zenith wet delay and atmospheric gradients will strengthen the solution for the atmospheric parameters. The inclusion of SLR data, which is 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 accounted for with the GEOSAT software developed by FFI.

After five years of development and extensive validation we are proud to announce that a major revision and extension of the GEOSAT software has been completed. The most important changes implemented have been described in recent IVS Annual Reports. Much more flexibility and automation have been added. Furthermore, the latest and "best" models (mostly following the IERS Standard) and "calibration tables" and "instrumental/geophysical events tables" have been included. Analysis of tracking data to S/C's in deep space has been added. For any technique, the delay due to the troposphere is determined with 3D raytracing using the European Center for Medium-range Weather Forcast Numerical Weather Model. No mapping functions are used and the corrections are determined directly from interpolation in the raytracing files.

2. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

3. Combination of VLBI, GPS, and SLR Observations at the Observation Level

The processing of observations in GEOSAT is performed in three steps: 1) Omc step: for each individual technique generate files of residuals (observed minus calculated, omc) and partials for a period of "one arc" (usually 24 hours). Selected parameters are estimated to generate "small" residuals so that iterating in the filter is not necessary. 2) Comb step: combine omc files for all techniques at the epoch-by-epoch level using a UD (Upper-Diagonal factorized) sequential filter. The result is a SRIF (Square-Root-Information-Filter) array for that specific arc. 3) Global step: combine all arc SRIF arrays to generate a multi-year solution. The estimation is performed with a CSRIFS (Combined Square-Root-Information-Filter-and-Smoother factorized) sequential filter.

To perform the analyses we have a dedicated array of 10 state-of-the-art LINUX work stations, each with 4 cpu's, 6 GB RAM, and 1 TB disk space. The status of the analysis by Jan 2008 is as follows: The omc step is completed for the period 1 Jan 2000 to 31 Dec 2006 with approximately 175 GPS stations, 10-30 SLR stations, and 0-20 VLBI stations daily. This is a tremendeous computation task which took approximately 1 month of computation time. When new and better models become available the computation can automatically be repeated within half the time since the raytracing files can be re-used. The first tests at the Comb step level is presently being performed trying to determine an "optimal" mix of solve-for parameters, constraints, and weighting.

Our plan is to take the seven years of data through all three steps within 1-2 year. The outcome will be new realizations of TRF, CRF, and EOP relying on consistent models and estimation strategies. As a by-product a file of estimated eccentricity vectors will be produced. After that we plan to add 2007 and newer data and also data before 2000. We also plan to estimate GM and some low-order gravity coefficients simultaneously with all the other parameters. This type of analysis is along the lines of the ideas behind the GGOS project where geometry, gravity, and Earth orientation are to be simultaneously and consistently determined.

The BKG/IGGB VLBI Analysis Center

Volkmar Thorandt, Axel Nothnagel, Gerald Engelhardt, Dieter Ullrich, Thomas Artz, Sarah Böckmann, Markus Vennebusch

Abstract

In 2007 the activities of the BKG/IGGB (former GIUB, only renamed) VLBI Analysis Center, as in previous years, consisted of routine computations of Earth orientation parameter (EOP) time series and a number of research topics in geodetic VLBI. The VLBI group at BKG continued its regular submissions of time series of tropospheric parameters and the generation of daily SINEX (Solution INdependent EXchange format) files. Quarterly updated solutions were computed to produce terrestrial reference frame (TRF) and celestial reference frame (CRF) realizations. Routine computations of the UT1—UTC Intensive observations include all sessions of the Kokee—Wettzell and Tsukuba—Wettzell baselines and the networks Kokee—Svetloe—Wettzell and Ny-Ålesund—Tsukuba—Wettzell. At the same time, new models have been implemented in the data analysis software and first contributions to the Working Group on ICRF2 were finished at BKG. At IGGB the emphasis was placed on individual research topics.

1. General Information

The BKG/IGGB VLBI Analysis Center has been established jointly by the Federal Agency for Cartography and Geodesy (BKG), Leipzig, and the Institute of Geodesy and Geoinformation of the University of Bonn (IGGB), formerly Geodetic Institute of the University of Bonn (GIUB). Both institutions maintain their own analysis groups in Leipzig and Bonn but cooperate intensively in the field of geodetic VLBI. The responsibilities include data analysis for generating IVS products as well as special investigations with the goal of increasing accuracy and reliability. BKG is responsible for the computation of time series of EOP and tropospheric parameters, the generation of SINEX files for 24-hour VLBI sessions and for 1-hour Intensive sessions as well as for quarterly updated global solutions for TRF and CRF realizations. Besides data analysis, the BKG group is also responsible for the scheduling of the Tsukuba—Wettzell INT2 UT1—UTC observing sessions. IGGB continues to host the office of the IVS Analysis Coordinator and carries out special investigations in the technique of geodetic and astrometric VLBI. Details of the research topics of BKG and IGGB are listed in Section 3.

2. Data Analysis

At BKG the Mark 5 VLBI data analysis software system Calc/Solve, release of October 10, 2007 [1], has been used for VLBI data processing. It is running under Fortran 90 on a machine with an operating system GNU/Linux 2.6.5-7.97-smp. It includes the new Calc 10 implementation for complying with the IAU 2000 Resolutions and the IERS Conventions 2003. The Calc/Solve software was modified for using the Vienna Mapping Function (VMF1). Applying VMF1 in data analysis requires a daily update of the VMF1 data from the server of the Technical University of Vienna [2]. In addition, an independent technological software environment for the Calc/Solve software is available. The latter is used for linking up the Data Center management with the pre- and post-interactive part of the EOP series production and to monitor all Analysis and Data Center activities (Data Center topics are described in the BKG Data Center report in this issue).

- **Processing of correlator output**
  The BKG group continued the generation of calibrated databases for the sessions correlated at the MPIfR/BKG Mark 5 Astro/Geo Correlator at Bonn (e.g. EURO, OHIG, T2) and submitted them to the IVS Data Centers.

- **Scheduling**
  BKG continued scheduling the INT2 Intensive sessions which are observed on the baseline TSUKUBA-WETTZELL. Altogether 100 schedule files were created in 2007.

- **IVS EOP time series**
  The new EOP time series bkg00010 differs from the previous one by several points. The data analysis was made with the new mapping function VMF1 for modeling the tropospheric delay correction. Mean pole offsets for pole tide were used to be in agreement with the IERS Conventions 2003 recommended values. The modeling for 3 stations was refined by non-linear site position variations estimation (GILCREEK, HRAS, PIETOWN). Furthermore the new official list of the VLBI antenna axis offsets, status May 17, 2007 [3] and the a priori VTRF2005 [4] were used in data processing.

  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 has been computed and the EOP time series bkg00010 was extracted. Altogether 3533 sessions were processed. The main parameter types in this solution are globally estimated station coordinates and velocities together with radio source positions. Minimal constraints for the datum definition were applied to achieve no-net-rotation and no-net-translation for 26 selected station positions and velocities with respect to VTRF2005 and no-net-rotation for 212 defining sources with respect to ICRF-Ext.1 [5]. The station coordinates of the stations BADARY (Russia), CTVASTJ (Canada), DSS65A (Spain), METSAHOV (Finland), ZELENCHK (Russia) were estimated as local parameters in each session.

  VMF1 was used in the new UT1 time series bkgint07 too. In addition to the observations of both baselines KOKEE-WETTZELL and TSUKUBA-WETTZELL, also the networks KOKEE-SVETLOE-WETTZELL and NYALESUND-TSUKUBA-WETTZELL, each with a duration of about 1 to 1.5 hours, were processed regularly. Series bkgint07 was generated with fixed TRF (VTRF2005) and fixed CRF derived from the global BKG solution for EOP determination. The estimated parameter types were only UT1, station clock, and zenith troposphere. A total of 2372 UT1 Intensive sessions were analyzed for the period between 1999.01.01 and 2008.01.07.

- **Quarterly updated solutions for submission to IVS**
  Also in 2007 quarterly updated solutions were computed for the IVS products TRF and CRF. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00010. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is available in SINEX format, version 2.1 and includes station coordinates, velocities, and radio source coordinates together with the covariance matrix, information about constraints, and the decomposed normal matrix and vector.

- **Tropospheric parameters**
  The VLBI group of BKG continued regular submissions of long time series of tropospheric parameters to the IVS (wet and total zenith delays, horizontal gradients) for all VLBI sessions

since 1984. The tropospheric parameters are directly extracted and transformed into SINEX for tropospheric estimates from the results of the standard global solution for the EOP time series bkg00010.

- **Daily SINEX files**
  The VLBI group of BKG also continued the regular submissions of daily SINEX files for all available 24 hours sessions as base solutions for the IVS time series of baseline lengths and for combination techniques. In addition to the global solutions independent session solutions were computed for the parameter types station coordinates, EOP, and nutation parameters. The a priori datum for TRF is defined by the VTRF2005 and the fixed CRF derived from the global complete BKG solution for EOP determination is used for the a priori CRF information.
- **SINEX files for Intensive sessions**
  Due to special requirements from IVS, SINEX files for Intensive sessions were created. The parameter types are station coordinates, pole coordinates and their rates, and UT1 with rate. But only the normal equations stored in the SINEX files are important for further combination with other space geodetic techniques.

3. Research Topics

- **ICRF2**
  The VLBI group at BKG is part of the IVS Working Group for the Second Realization of the ICRF. An important step is the computation of time series for all radio sources. On the basis of former investigations [6] a new set of time series for all radio sources was computed with nearly no change in datum definition. It is planned to investigate the long-term stability of radio sources based on the time series of radio source positions.
- **Subdaily EOP**
  The estimation of subdaily ERP from continuous VLBI campaigns show significant degradations at the session boundaries due to the breaks in observing time caused by the change-over time at the stations from one session to the next of approximately 30 minutes. As a consequence, high-frequency EOP time series with a resolution of less than two hours are disrupted showing severe jumps in the time series unless strong constraints are applied. In order to cope with this problem, a modified solution procedure for continuous VLBI campaigns was implemented. Here, two consecutive sessions are linked through a stacking of the respective elements of the normal equation matrix so that observations before and after the break contribute to the EOP parameters near the break.

  Furthermore, investigations of the impact of different analysis options on the target parameters have been continued. As one result, corrections to the recent precession-nutation model IAU2000a with values reported in the IERS C04 series have improved the results in terms of WRMS w.r.t. GPS solutions since the effect on the retrograde term with a period of one day is significantly reduced.
- **Stability of VLBI solutions**
  We investigated the impact of different analysis options on station positions. It turned out that the station position repeatability is improved up to 10% by applying thermal deformation and advanced troposphere modeling with VMF1 instead of using the NMF mapping

function. On the other hand no significant degradation could be detected by using ECMWF meteorological data instead of measured meteorological information to model the a priori dry hydrostatic zenith delay.

- **Singular Value Decomposition**
  At IGGB the development of a regression diagnostics tool has been completed which helps to analyze the design matrix of a VLBI adjustment by so-called singular value decomposition. With this tool observing schedules of one-hour Intensive sessions can be analyzed. In order to find (groups of) important and less important (and thus negligible) observations, so-called cluster analysis methods are used. The background and first results have been published in a Ph.D. thesis [7].

4. Personnel

Table 1. Personnel at BKG/IGGB Analysis Center

Thomas Artz	IGGB	++49-228-733563	thomas.artz@uni-bonn.de
Sarah Böckmann	IGGB	++49-228-733563	boeckmann@uni-bonn.de
Gerald Engelhardt	BKG	++49-341-5634438	gerald.engelhardt@bkg.bund.de
Axel Nothnagel	IGGB	++49-228-733574	nothnagel@uni-bonn.de
Volkmar Thorandt	BKG	++49-341-5634285	volkmar.thorandt@bkg.bund.de
Dieter Ullrich	BKG	++49-341-5634328	dieter.ullrich@bkg.bund.de
Markus Vennebusch	IGGB	++49-228-733565	vennebusch@uni-bonn.de
Reiner Wojdziak	BKG	++49-341-5634286	reiner.wojdziak@bkg.bund.de

References

[1] GSFC, NASA (2007): Release of Mark 5 VLBI Analysis Software Calc/Solve from October 10, 2007 (web reference: http://vlbi.gsfc.nasa.gov/solve).

[2] VMF1 (2007): (http://mars.hg.tuwien.ac.at/˜ecmwf1).

[3] VLBI antenna axis offsets 2007: (http://vlbi.geod.uni-bonn.de/IVS-AC/data/axis-offsets.txt).

[4] VTRF2005: (http://vlbi.geod.uni-bonn.de/IVS-AC/index.html).

[5] ICRF-Ext.1 (http://hpiers.obspm.fr/webiers/results/Icrf).

[6] Engelhardt G., Thorandt V. (2006): First steps to Investigate Long-Term Stability of Radio Sources in VLBI Analysis. In: IVS General Meeting Proceedings 2006, Concepcion, Chile, edited by D. Behrend and K.D. Baver, NASA/CP-2006-214140, p.281-285.

[7] Vennebusch M.; Singular value decomposition and cluster analysis as regression diagnostics tools in geodetic VLBI; Ph.D thesis, Institute of Geodesy and Geoinformation Bonn, 2007, in press; electronic document: http://hss.ulb.uni-bonn.de/diss_online/landw_fak/2007/vennebusch_markus

GSFC VLBI Analysis Center

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

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2007. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development aimed at improving the VLBI technique.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. It is part of a larger VLBI group which also includes the IVS Coordinating Center, the CORE Operation Center, a Technology Development Center, and a Network Station. The Analysis Center participates in all phases of geodetic and astrometric VLBI analysis, software development, and research aimed at improving the VLBI technique.

2. Activities

2.1. Analysis Activities

The GSFC analysis group routinely analyzes all IVS sessions using the Calc/Solve system, and performs the AIPS fringe fitting and Calc/Solve analysis of the VLBA-correlated RDV sessions. The group submits the analyzed databases to IVS for all R1, RDV, R&D, APSG, NEOS INT01, and INT03 sessions. During 2007, the group processed and analyzed 164 24-hr (54 R1, 53 R4, 6 RDV, 1 R&D, 2 T2, 6 CRF, 10 CRDS, 2 CRMS, 6 EURO, 2 OHIG, 2 APSG, 6 E3, and 14 JADE) sessions and 344 1-hr UT1 (230 NEOS INT01, 97 INT02, and 17 INT03) sessions. We also submitted updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately following analysis. The group also generated a new list of axis offsets and a file of cable cal signs for the IVS. The GSFC Analysis Center maintains a Web site at http://lupus.gsfc.nasa.gov/, where the latest solutions and velocity plots can be found.

2.2. Support Activities

The GSFC VLBI Analysis Center has provided a source position service as part of the RDV program since 1997. Observations of 63 requested sources were made in 2007 for members of the astronomy/astrometry community, and precise positions were obtained where possible.

2.3. Research Activities

The GSFC Analysis Center performs ongoing research aimed at improving the VLBI technique. Several of these research activities are described below:

- Station Dependent Correlations: The group continued studying the effect of applying station dependent noise. Best results were achieved when ∼10 psec of correlated atmosphere noise due to atmosphere mismodeling was applied.

- Source Imaging and Source Selection: A major effort was undertaken to collect and make available all existing maps of geodetic and non-geodetic VLBI radio sources. Using images and visibility plots, all sources were evaluated concerning their suitability as geodetic sources, and a new list of geodetic sources was proposed. The new list rejects many of the old geodetic sources based on structure and resolution effects.
- ICRF2 Preparation: A source position time series file was generated and studied. For each source, the right ascension and declination position WRMS's were computed. Possible methods for selecting the best set of defining sources were studied.
- MK-VLBA Earthquake: A 6.7 magnitude earthquake occurred near the MK-VLBA site on 15 Oct, 2006. Careful evaluation of the data indicates an episodic displacement of (-8, -10, +1) mm at MK-VLBA in its Up, East, and North components.
- Higher Frequency CRF: Members of the analysis group continued working with associates at JPL, USNO, NRAO, and Bordeaux Observatory to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (∼24 and ∼43 GHz). The primary goals are to build up a reference frame for use in planetary spacecraft navigation at Ka band (∼33 GHz), and to build a reference frame less affected by source structure and potentially more precise than the current X/S frame. One K band session was observed in 2007, concentrating on weaker sources and ecliptic sources. To date, the group has conducted 10 VLBA sessions and developed a catalog of 267 sources at K-band and 132 sources at Q-band, with sub-mas positions. Software was developed to insert ionosphere delay corrections into the databases using GPS ionosphere maps. When these ionosphere corrections are applied, an approximately linear bias in declination positions compared to X/S positions is cut in half. Future work will concentrate on observing weaker sources and on densifying the catalog along the ecliptic and in the regions needed for several upcoming Mars missions.
- Source Monitoring: We continued the source monitoring program which began on February 1, 2004. The goals of this program are to observe all geodetic catalog sources at least 12 times per 12 month period and sources in the ICRF at least 2 times per 12 month period. This is done by including the sources which have not met their targets in the weekly R1s. The maximum number of monitored sources in the R1s is restricted to 10. In 2006 we modified the use of the RDVs in the monitoring program. Our goal is to periodically observe all the monitored sources in the RDV sessions with a sufficient number of observations to image each source. For the geodetic sources our target is 6 times in any two year period, and for the other sources in the monitoring program at least once per year. We developed a MySQL database to track which sources and stations appear in each session. This database is updated whenever 1) a schedule is posted to IVS; 2) the GSFC group analyzes and posts a database; 3) the master file is updated. For each source and station, the database contains information about how many observations were scheduled, how many were correlated, and how many were used in the solution. It also contains information about the fit of the solution. In late 2007 we converted one of our machines from an HP machine to a Linux machine. In the process one of the scripts involved in updating the database stopped working. Because of this the source monitoring program did not work as planned during the last few months of 2007 and the first few months of 2008. This error has subsequently been fixed.
- Simulations: We continued work on simulations of the performance of networks of VLBI2010 antennas. Our investigation uses a Monte Carlo procedure to simulate the performance of

different antenna networks and different antenna specifications, where a critical specification is the antenna slew rate. Baseline length and vertical precision (scatter of simulation estimates) are improved as azimuthal antenna slew rates increase up to about 6 deg/sec but not significantly for higher rates. Precision of scale and EOP improves by a factor of 1.5 to 2 as network size increases from 8 to 32 sites.

- Reference Frame Scale: We investigated the systematic effects that contribute to bias and annual variation of the VLBI reference frame scale. The largest effects are antenna thermal deformation, loading, and atmosphere modeling, which explain about 0.35 ppb of the observed annual variation of about 0.5 ppb. Most of the scale bias between SLR and VLBI in the recent ITRF2005 combination was explained.

2.4. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Calc/Solve is a package of approximately 120 programs and 1.2 million lines of code. Several updates were released during 2007.

3. Staff

Members of the analysis group and their areas of activity include: Dr. Chopo Ma (CRF, TRF, EOP, K/Q reference frame development, IVS representative to the IERS, current chairman of the IERS directing board, and ICRF2 development); Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, apparent proper motion, post-seismic studies, and ICRF2 development); Dr. David Gordon (database analysis, RDV processing and analysis, K/Q reference frame development, VLBA calibrator surveys, Calc development, and ICRF2 development): Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis, VLBA calibrator surveys, Calc/Solve development, source mapping and monitoring, Linux migration, GEODYN development, and ICRF2 development); Dr. John Gipson (source monitoring, station dependent noise, improved parameter estimation, and chairman of IVS Working Group 4 on VLBI data structures); and Ms. Karen Baver (UT1 Intensive session analysis, software development, Linux migration, and Web site development and maintenance).

4. Future Plans

Plans for the next year include: participation in the development of the ICRF2, continued source monitoring, revision of the geodetic source catalog, participation in VLBI2010 development efforts, participation in the development of a new VLBI data structure, publication of a refereed RDV geodesy paper, participation in additional K/Q observations and high frequency reference frame development, and performing further research aimed at improving the VLBI technique.

MIT Haystack Observatory Analysis Center

Arthur Niell

Abstract

The contributions of Haystack Observatory to the analysis of geodetic VLBI data focus on improvement in the accuracy of the estimation of atmospheric delays and on the reduction of instrumental errors through analysis. In 2007 most of the effort was related to evaluating error sources for the proposed VLBI2010 system, primarily regarding the sensitivity and performance of the broadband development prototype hardware that has been installed on the MV-3 antenna at GGAO. Since atmosphere delay error continues to be a significant source of geodetic error, a potential method to improve the measurement of wet delay by Water Vapor Radiometer was investigated and is reported here.

1. Geodetic Research at the Haystack Observatory

The MIT Haystack Observatory is located approximately 50 km northwest of Boston, Massachusetts. Geodetic analysis activities are directed primarily towards improving the accuracy of geodetic VLBI results, especially through the reduction of errors due to the atmosphere and to instrumentation. This work, along with operation of the geodetic VLBI correlator and with support of operations at the Westford, GGAO, Fortaleza, and Kokee Park VLBI sites, is supported by NASA through a contract from the Goddard Space Flight Center.

2. Possible Improvement in the Accuracy of Measurements of Atmosphere Wet Delay by Water Vapor Radiometer

Historically, comparisons of zenith wet delay (ZWD) as measured by water vapor radiometers and as estimated from VLBI observations have shown differences of about 1 cm that vary over hours, even though the shorter term variations may be similar. No alternative to the traditional calibration of WVR zenith wet delays through the use of radiosondes has been able to reduce or remove this characteristic difference.

A water vapor radiometer (WVR), when accurately calibrated, measures the brightness temperature of the atmosphere at one or more frequencies. The VLBI observables are delays. For a WVR to be used directly in the estimation of geodetic parameters the WVR brightness temperatures near the time of the VLBI observation must be related to delay. This has traditionally been achieved by using several weeks to several months of radiosonde data taken at a site of similar atmospheric conditions as that where the WVR is used in order to develop a set of regression coefficients between the brightness temperature and delay. Since the relation between brightness temperature and delay is not unique (the same delay can be produced by many distributions of atmospheric water vapor and temperature), there is generally a much larger uncertainty in the delay than would be obtained if the atmospheric distribution were known at the time of the observation.

A possible alternative is to use a Numerical Weather Model to obtain the relation between brightness temperature as measured by a WVR and the corresponding delay that would be produced by the same atmosphere. The proposal is that the NWM forecasts, while not providing delays or brightness temperatures that are accurate enough to be used directly in geodetic estimation, do provide the ratio of brightness temperature to delay with sufficient accuracy to add information. The WVR measurements in themselves will provide the temporal variation of brightness temperature and thus, through the scaling, will provide the temporal variation of the zenith delay. The VLBI measurements can then be used to estimate the offset, and, if necessary, a further scaling factor. By using the WVR data for the temporal variability, as few as one or two parameters might be estimated for the atmosphere within a 24 hour period, rather than from 24 values to more than 100. As long as the number of parameters is considerably smaller than would be required by the VLBI/GPS data alone, the geodetic results should be improved.

To evaluate this proposal, twelve hour forecasts were made using the MM5 Numerical Weather Model with a finest horizontal grid spacing of three kilometers. (The MM5 calculations were done by Mark Leidner of AER, Inc.) The WVR measurements were made at Kokee during CONT02 in October 2002 using a Radiometrics 1100.

The brightness temperatures and derived zenith wet delays, interpolated to the times of the VLBI observations at Kokee are shown in Figure 1. Periods of rain are seen as large increases in brightness temperature.

The MM5 forecasts were initiated every 6 hours and run for 12 hours. Pressure level humidities and temperatures for the last six hours of each forecast were used to calculate zenith wet delays and brightness temperatures at the times of the VLBI observations. The ratio of ZWD to 23 GHz brightness temperature was used to scale the values of 23 GHz brightness temperature measured by the WVR. The values of ZWD obtained the four ways are shown in Figure 2.

Two periods without rain were identified: Oct 22-23 and Oct 26-27. For each of these periods two differences are displayed in Figures 3 and 4: a) the uncorrected WVR ZWD minus ZWD estimated from VLBI, and b) the WVR ZWD obtained by scaling with MM5 minus ZWD estimated from VLBI. The anticipated result was that the biases would be reduced by using the MM5 scaling since it more closely represents the distribution of water vapor at the time of the WVR measurements than the time-averaged retrieval coefficients obtained from the radiosonde data. In fact the biases are reduced for both periods, though not to a negligible value. In the first period the median difference is reduced from 16 mm to 7 mm. For the second period the change is from 13.2 mm to 11.7 mm, but in fact the bias increases for much of the second day.

While the results are promising, the WVR-VLBI difference is not consistently reduced. Potential sources of the remaining error are lack of accuracy of the MM5 forecasts, errors in the calibration of the WVR brightness temperatures, and incorrect calculation of brightness temperatures from the MM5 forecast values of humidity and temperature.

3. Acknowledgements

I thank Mark Leidner for setting up and running MM5, Wolfgang Schlueter of BKG for providing the WVR for use at Kokee, and Walter Schwartz of BKG for running and maintaining the Kokee WVR and for processing data.

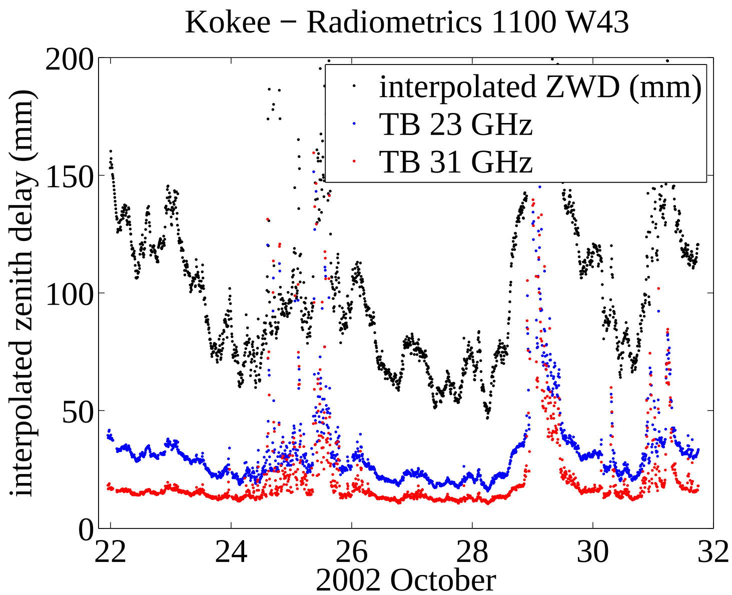


Figure 1. From top to bottom: Zenith Wet Delay (black), brightness temperature at 23 GHz (blue), and brightness temperature at 31 GHz (red) for Kokee during CONT02. The ZWDs are interpolated to the time of the VLBI observations.

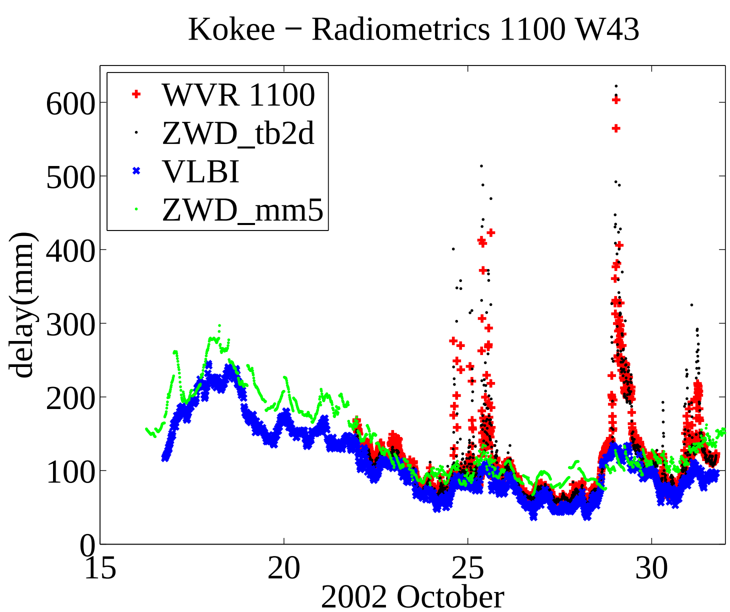


Figure 2. Zenith wet delays for Kokee during CONT02 at the times of the VLBI observations: red cross: as measured by the WVR; black dot (begins on Oct 22) - as calculated from the WVR value of brightness temperature at 23 GHz, scaled by the ratio of delay to brightness temperature from the MM5 forecasts; blue cross - as estimated from VLBI; green dot (begins on Oct 16) - as calculated directly from the MM5 pressure level values of humidity and temperature.

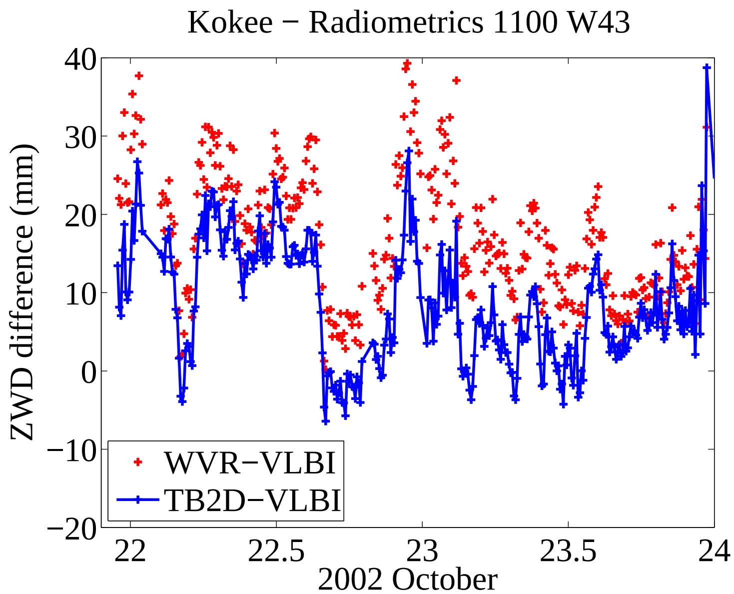


Figure 3. The differences in ZWD derived from WVR 23 GHz brightness temperature with respect to the VLBI estimates for Oct 22-23. red cross - WVR ZWD using radiosonde-derived regression coefficients; blue line - WVR ZWD using MM5 Numerical Weather Model forecast ratios of delay to brightness temperature.

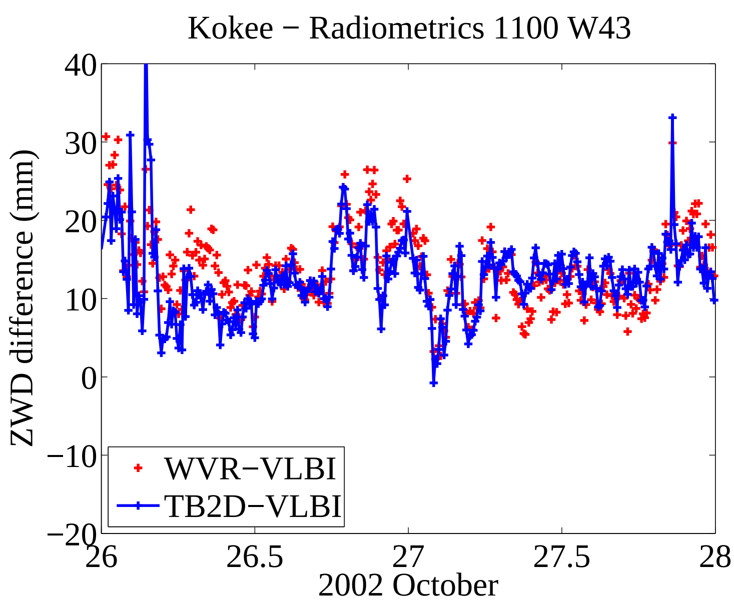


Figure 4. Same as for Figure 3 except for Oct 26-27.

IAA VLBI Analysis Center Report 2007

Elena Skurikhina, Sergey Kurdubov, Vadim Gubanov, George Krasinsky

Abstract

This report presents an overview of IAA VLBI Analysis Center activities during 2007 and the plans for the coming year. The main directions of IAA AC activities are: daily SINEX file generation on a regular basis for IVS-R1 and IVS-R4 sessions; TRF/CRF estimation from global VLBI data analysis; routine computations of Earth orientation parameters (EOP) for submission to IERS; baseline length and tropospheric parameters from 24-h sessions; UT1-UTC from IVS Intensive sessions; time series of source position calculation and analysis at the scope of the IERS/IVS Working Group on the Second Realization of the ICRF; EOP, UT1-UTC, and station position estimation from domestic observation programs; software development, and NGS-file generation.

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. The IAA AC submits to IVS products such as daily SINEX files, TRF, CRF, rapid and long-term series of EOP, baseline length, and tropospheric parameters. Source position time series have been calculated and have been analyzed using the covariance function technique as part of the efforts of the IERS/IVS Working Group on the Second Realization of the ICRF. EOP, UT1-UTC, and station positions were estimated from domestic observation programs RU-E and RU-U. The QUASAR software was further developed. The IAA AC performs NGS-file generation.

2. Component Description

The IAA AC performs data processing of all kinds of VLBI observation sessions.

For VLBI data analysis we use QUASAR and OCCAM/GROSS software. All reductions are in agreement with the IERS Conventions (2003). Both sets of software use NGS-files as input data.

The IAA AC contributes to all IVS products: daily SINEX-files for EOPS and EOPS-rates and station position estimations, TRF, CRF, baseline length, and tropospheric parameters.

QUASAR and OCCAM/GROSS software is supported and developed at the IAA AC.

IVS NGS-files are generated on a regular basis in automatic mode.

3. Staff

– Vadim Gubanov, Prof.: development of the QUASAR software, development of the methods of stochastic parameter estimation.

– Sergey Kurdubov, scientific reseacher: development of the QUASAR software, global solution and DSNX-file calculation.

– Elena Skurikhina, Dr.: VLBI data processing, OCCAM/GROSS software development.

– George Krasinsky, Prof.: development of new Precession-Nutation Theory based on numerical integration of refined differential equations of the Earth rotation.

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 able to calculate all types of IVS products. The capability of SINEX-file generation for IVS-Intensive sessions was added.

- **Global solution**
  In 2007 two global solutions (iaa2007a and iaa2007b) [1, 3] were calculated using the QUASAR software and submitted to IVS. For the last solution all available data from 1979 until the end of 2007 were processed. Stochastic signals were estimated by means of the least-squares collocation technique. The radio source coordinates, station coordinates and velocities were estimated as global parameters. EOP, WZD (linear trend plus stochastic signal), troposphere gradients, and station clocks (quadratic trend plus stochastic signal) were estimated as arc parameters for each session.

  3,984 24-hour sessions with 5,376,127 delays have been processed. 2,760 global parameters have been estimated: 963 radio-source positions and the positions and velocities of 129 VLBI stations (12 with discontinuities).

  Transformation parameters between ITRF2005 and catalogues obtained for two epochs are listed in Table 1. The residuals are 6 mm for 1997.0 and 8 mm for 2005.0. 38 stations were used for the calculations.

Table 1. Transformation parameters between ITRF2005 and obtained catalogue for two epochs.

EPOCH	T1,mm	T2,mm	T3,mm	D, 10^{-9}	R1,mas	R2,mas	R3,mas
2005.0	6.4	-4.8	19.2	-1.6	-0.080	0.139	-0.018
1997.0	4.7	-5.3	5.0	-1.6	-.062	-.090	-.005

  The mean formal errors of the source catalogues are 0.15 mas for right ascension, and 0.11 mas for declination. The WRMS difference vs. ICRF.Ext2 is 0.2 mas in right ascension and declination. (For the statistics on differences, a total of 574 common sources observed in more than 3 sessions and more than 20 times were used).

- **Participation in the IERS/IVS Working Group on the Second Realization of the ICRF**
  Two time series iaa000b and iaa000c with more than 600 sources were calculated using the QUASAR software for VLBI data processing. Most available VLBI observations (excluding DSN and VCS sessions) since August 1979 to May 2007 were used.

  Source positions for every source were obtained from single series analysis by fixing the coordinates of all other sources. A priori source positions were used from the ICRF-Ext.2 radio source position catalogue. Station positions were not estimated for either series. The TRF was fixed by ITRF2005, and the CRF was fixed by ICRF-Ext.2. The following parameters were estimated in these solutions: position of one source, EOP (only for iaa000b solution), WZD (linear trend and stochastic), troposphere gradient (east and north), and station clock offset (quadratic trend and stochastic).

We analyzed time series using a covariance function technique adopted for equidistant time series with the aim of exposing more stable sources. The global solutions with different sets of sources for NNR constraints were obtained. Transformation parameters between obtained source catalogues were calculated and compared.

- **Routine analysis**

  In March 2007 the IAA AC started generating daily SINEX files for IVS-R1 and IVS-R4 sessions for rapid solution (iaa2007a.snx) and submitted to IVS SINEX files based on all 24-hr experiments of the Quarterly Solution [3].

  During 2007 the routine data processing was performed with OCCAM/GROSS software using Kalman Filter. IAA AC provided the operational processing of the "24h" and Intensive VLBI sessions. Submitting the results to the IERS and IVS was performed on a regular basis. Processing of the Intensive sessions is fully automated. The EOP series iaa2007a.eops and iaa2005a.eopi, the baseline length series iaa2007a.bl, and the troposphere parameter series iaa2007a.trl were continued. At the moment, the EOPS series contains 3463 estimates of pole coordinates, UT1, and celestial pole offsets, and the EOPI series contains 5821 estimates of UT1. Long-time series of station coordinates, baseline lengths, and tropospheric parameters (ZTD, gradients) were computed with the station position catalog ITRF2005.

- **Station position estimation**

  The station positions of Zelenchukskaya and Badary (Table 2) were calculated in the ITRF2005 reference frame. A priori values for the velocity components were used from GPS data analysis in both cases. The station position of Zelenchukskaya was calculated from the analysis of 76 IVS 24-hour sessions. The station position of Badary was calculated from 24 domestic (2006–2007) and IVS (2007) sessions. The results are presented in Table 2.

Table 2. Station positions and velocities for Zelenchukskaya and Badary, epoch 2000.0, in ITRF2005

Station	Station Position, m			Velocity, mm/year		
	X	Y	Z	V_x	V_y	V_z
Badary	-838200.729 ± 0.008	3865751.573 ± 0.008	4987670.956 ± 0.009	-.0253	0.0002	-.0037
Zelenchukskaya	3451207.821 ± 0.014	3060375.231 ± 0.012	4391914.941 ± 0.015	-.0221	.0141	.0089

- **EOP parameter calculation from domestic QUASAR network observations**

  The regular determination of Earth orientation parameters with QUASAR VLBI-Network Svetloe-Zelenchukskaya-Badary using the S2 registration system started in August of 2006 [4]. Correlation is performed at the IAA correlator. The observations are carried out in the framework of two national programs: 24-hour sessions for the determination of five EOP parameters at three observatories of Network (RU-E programs) and 8-hour sessions for the determination of Universal time at the base Zelenchukskaya–Badary observatories (RU-U programs). Each of these two sessions are carried out twice per month. RMS deviations of EOP values from IERS05 C04 series obtained from RU-E program are 0.88 mas for X-pole and 1.0 mas for Y-pole, 34 μs for UT1-UTC and 0.61 mas for Celestial Pole Offsets (for 17 sessions since Aug 2006 till the end of 2007). RMS deviations of the Universal time values for RU-U program from IERS05 C04 series are 134 μs (for 23 sessions).

- **IVS NGS card generation**
  Operational computation of the NGS cards was continued. NGS cards are computed in automated mode. IAA archive of VLBI observations and products was supported. At present, all available X and S databases and NGS cards are stored.

5. Future Plans

- Continue to submit all types of IVS product contributions and start to submit SINEX files for IVS Intensive sessions.
- Continue investigations of VLBI estimation of EOP, station coordinates, and troposphere parameters, and comparison with satellite techniques.
- Continue the studies in the frame of the IERS/IVS Working Group on the Second Realization of the ICRF.
- Further improve algorithms and software for processing VLBI observations.
- Continue to compute and provide to IVS the NGS cards for every 1-hour Intensive session.

References

[1] Gubanov V. S., Kurdubov S.L. On global solution from VLBI observations. IAA Comm., v. 13, 2005, p.434–439.

[2] Kurdubov S. L. Covariation analysis of stochastic parameters of VLBI observations model. IAA Comm., v. 14, 2006, p.138–157.

[3] Kurdubov S. QUASAR software in IAA EOP service: Global Solution and Daily SINEX. In Proceeding of the 18th European VLBI for Geodesy and Astrometry Working Meeting ed. by Johannes Böhm, Andrea Pany, and Harald Schuh, GEOWISSENSCHAFTLICHE MITTEILUNGEN, Heft Nr.79, 2007, pp. 79-82.

[4] Finkelstein A.M., Skurikhina E.A., Surkis I.F., Ipatov A.V., Rahimov I.A., Smolentsev S.G. USE OF THE QUASAR VLBI NETWORK FOR FUNDAMENTAL TIME-POSITIONING SERVICE 0F GLONASS, AJ Letters (in print).

Vienna IGG Special Analysis Center Annual Report 2007

Harald Schuh, Johannes Boehm, Sigrid Englich, Robert Heinkelmann, Paulo Jorge Mendes Cerveira, Andrea Pany, Emine Tanir, Kamil Teke, Sonya Todorova, Joerg Wresnik

Abstract

In April 2007, the Institute of Geodesy and Geophysics (IGG) of the Vienna University of Technology organized the 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, the 8th VLBI Analysis Workshop and the 2nd IVS VLBI2010 Working Meeting. 69 scientists from all over the world (20 countries) came to Vienna to present and discuss results of recent research in geodetic and astrometric VLBI. Apart from these meetings, the main focus of research in 2007 has been on VLBI2010: Simulation studies have been carried out with three different software packages: (1) the Kalman Filter version of OCCAM, (2) the Vienna VLBI Simulation Software (VVSIM), and (3) a special Precise-Point-Positioning software for VLBI simulations.

1. General Information

The Institute of Geodesy and Geophysics (IGG) is part of the Faculty of Mathematics and Geoinformation of the Vienna University of Technology. It is divided into three research units, one of them focusing on advanced geodesy (mathematical and physical geodesy, space geodesy). Within this research unit, one group (out of four) is dealing with geodetic VLBI.

Figure 1. Members of the VLBI group at IGG and friends at the EGU General Assembly 2007 in Vienna. From left to right: R. Heinkelmann, R. Weber, K. Teke, G. Bourda, P. Swatschina, E. Tanir, M. Opitz, S. Englich, J. Wresnik, A. Korbacz, J. Boehm, M. Kalarus, P.J. Mendes Cerveira, H. Schuh, A. Pany, J. Sokolova, A. Karabatic, V. Broederbauer. Not on the picture: S. Todorova.

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 Boehm	VLBI2010, OCCAM Least Squares Method (LSM), VVSIM
Andrea Pany	VLBI2010, troposphere, turbulence theory
Joerg Wresnik	VLBI2010, OCCAM Kalman Filter, scheduling
Kamil Teke	Least squares method, elevation cutoff angles
Sigrid Englich	Earth orientation, tidal influences
Paulo Jorge Mendes Cerveira	Earth orientation, datum definition
Robert Heinkelmann	Combination, celestial and terrestrial reference frame
Emine Tanir	VLBI intra-technique combination
Sonya Todorova	Ionosphere

3. Current Status and Activities

- **18th EVGA Working Meeting**
  In April 2007, the IGG in Vienna organized the 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, the 8th VLBI Analysis Workshop and the 2nd IVS VLBI2010 Working Meeting. 69 scientists from all over the world (20 countries) came to Vienna to present and discuss results of recent research in geodetic and astrometric VLBI. Thanks to all participants for contributing to these events.
- **Modification of the VLBI software package OCCAM**
  Together with Oleg Titov (Geoscience Australia), chairman of the 'OCCAM Group', and Volker Tesmer (Deutsches Geodätisches Forschungsinstitut, Germany), IGG is involved in the development of the OCCAM software (Titov et al., 2004 [5]). In 2007 the tidal part of atmosphere loading corrections (Petrov and Boy, 2004 [4]) was implemented, and global solutions were run to investigate its influence on geodetic parameters.
- **VLBI2010**
  A Precise-Point-Positioning (PPP) simulator has been developed which uses simulated delay observables consisting of tropospheric wet delays, stochastic errors of station clocks, and thermal noise of VLBI antennas. Different parameterizations of wet zenith delays including gradients and combinations of spherical harmonics with different estimation intervals and constraints were tested (Pany et al., 2007 [3]). Performing a PPP for all stations of a VLBI schedule allows the comparison of different VLBI2010 schedules as well as comparisons with OCCAM results (Wresnik et al., 2007 [6]). VLBI2010 slew rate studies have been performed, and they indicate that more investigations need to be done into scheduling strategies.
- **Troposphere**
  The combination of long time series of wet zenith delays from various IVS ACs has been

continued and described by Heinkelmann et al. (2007a [1]). Additionally, climatic trends have been determined from long time series of wet zenith delays and compared to results from GPS and to values from numerical weather models (Heinkelmann et al., 2007 [2]).

- **Celestial Reference frame**
  Together with guest scientist MSc Julia Sokolova from the Russian Academy of Sciences' Pulkovo Observatory who stayed in Vienna from March to August 2007, comparisons and investigations into the CRF determination were carried out within the IERS/IVS Working Group on the Second Realization of the International Celestial Reference Frame (ICRF2)).

- **Earth rotation**
  ERP long time series were computed with different temporal resolution from VLBI observations from 1984 to 2007 with the software package OCCAM 6.1. Short period variations (5 days to 1 year) in universal time induced by zonal tides were derived from UT1-UTC series with daily resolution (i.e. one estimate per 24 hour session). High-frequency (hourly) polar motion and UT1-UTC variations were estimated for the CONT05 campaign to study the effects of diurnal and semi-diurnal ocean tides on Earth rotation. A theoretical study was carried out to evaluate the benefit of combining VLBI, ringlaser and gravity (from superconducting gravimeters) observations for sub-diurnal Earth rotation parameters. The formulas relating ringlaser and superconducting gravimeter parameterization to VLBI parameterization were presented. The intricacies of geodetic versus geophysical Earth rotation were investigated, and a complete geometric interpretation of the Earth rotation vector was given from the non-linearized skew-symmetric tensor w.r.t. the normalized vector of the so-called celestial intermediate pole (CIP), ignoring precession-nutation of the CIP (Figure 2).

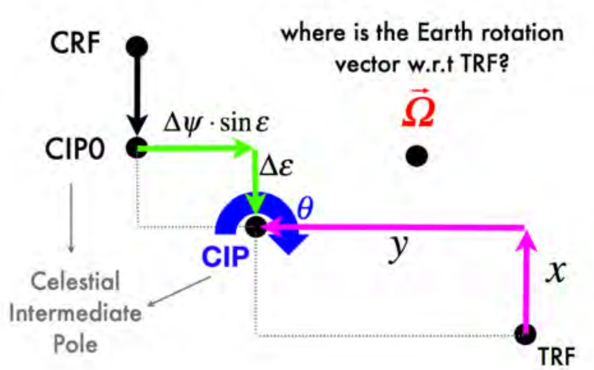


Figure 2. Earth rotation: Theoretical investigations have been carried out to identify the geophysical Earth rotation vector in the terrestrial and celestial reference frame.

- **Datum definition**
  The impact on geodetic parameters was examined using several options for getting rid of the datum deficiency in VLBI analysis. Such options can be minimal conditions or constraints, which can be related by similarity transformations.

- **Solid Earth tides**
  For the displacement due to solid Earth tides, the IERS Conventions 2003 recommend several corrections to nominal values. One of these corrections is the in-phase contribution by using the real Love and Shida numbers h3 and l3 at all degree-3 tides, where only the contribution of the moon is relevant. Using realistic station and source catalogues, VLBI simulations of group time delays were calculated, with a white noise going up to 2 cm and taking into account the solid Earth tides displacement. The goal was to check whether the degree-3 Love and Shida numbers are unambiguously determinable from VLBI observations w.r.t. time span and number of observables.

4. Future Plans

For the year 2008 the IVS Special Analysis Center at IGG plans to continue all investigations mentioned above. However, special emphasis will certainly be put on the simulation studies for VLBI2010 and on research into all aspects of Earth rotation, including its observation with VLBI.

5. Acknowledgements

We are very grateful to the Austrian Science Fund (FWF) for supporting our research projects P16992-N10 (‘VLBI for climate studies’) and P18404-N10 (‘VLBI2010’). We also acknowledge the Austrian Academy of Sciences for funding project 22353 and the German Research foundation (DFG) for funding project SPEED (SCHU 1103/3-1).

References

[1] Heinkelmann, R., J. Boehm, H. Schuh, S. Bolotin, G. Engelhardt, D.S. MacMillan, M. Negusini, E. Skurikhina, V. Tesmer, O. Titov, Combination of long time-series of troposphere zenith delays observed by VLBI, Journal of Geodesy, Volume 81, Issues 6-8, pp. 483-501, 2007.

[2] Heinkelmann, R., M. Schmidt, J. Boehm, H. Schuh Determination of water vapor trends from VLBI observations, Österreichische Zeitschrift für Vermessung und Geoinformation vgi, Volume 2/2007, ISSN 0029-9650, pp. 73-79, 2007.

[3] Pany, A., J. Wresnik, J. Boehm, H. Schuh, Optimum modeling of troposphere and clock parameters in VLBI, Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, 12-13 April 2007, edited by J. Boehm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universitaet Wien, ISSN 1811-8380, 2007

[4] Petrov, L., J.-P. Boy, Study of the atmospheric pressure loading signal in very long baseline interferometry observations, J. Geophys. Res., Vol. 109, B03405, 2004.

[5] Titov, O., V. Tesmer, J. Boehm, OCCAM v. 6.0 software for VLBI data analysis, in N.R. Vandenberg and K.D. Baver (eds.): Proceedings of the 3rd IVS General Meeting, Ottawa, Canada, 2004.

[6] Wresnik, J., J. Boehm, H. Schuh, Monte Carlo Simulations for VLBI2010, Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, 12-13 April 2007, edited by J. Boehm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universitaet Wien, ISSN 1811-8380, 2007

Italy INAF Analysis Center Report

M. Negusini, P. Sarti, S. Montaguti, C. Abbondanza

Abstract

This report summarizes the activity of the Italian INAF VLBI Analysis Center. Our Analysis Center is located in Bologna, Italy and belongs to the Institute of Radioastronomy which is part of the National Institute of Astrophysics. IRA runs the observatories of Medicina and Noto, where two 32m VLBI AZ-EL telescopes are situated. This report contains the AC VLBI data analysis activity and shortly outlines the investigations carried out in Medicina and Noto concerning gravitational deformations of the VLBI telescopes.

1. Current Status and Activity

Terrestrial surveying of VLBI telescope structures continued in 2007. A complete survey of the Medicina VLBI telescope was performed with the aim of determining a new estimate of the GPS-VLBI eccentricity and of determining the kinematic pattern of the S/X receivers located in the primary focus. The latter survey, with the same purpose, has been performed at Noto, too. These data are going to be combined with the laser scanning surveys performed in 2005, and they will also be compared to the results that are being obtained using a Finite Element Model of the antennas. The ultimate purpose is to determine the structural deformations caused by gravity during VLBI observations and to determine how and to what extent the reference points of the instruments are affected. Comparisons between the different approaches do show encouraging agreement and will probably supply interesting results concerning the possibility of determining an elevation dependent signal path variation model.

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 2007, we stored all the 1999—2007 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. Moreover, because of the new server, all the missing databases were downloaded from the IVS data centers in order to complete the IRA catalogue. In the meantime, databases already analyzed and archived on HP workstations were copied to the Linux workstation and analyzed in order to create new Mark 5 Solve superfiles for global solutions.

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, horizontal gradients) of all IVS-R1 and IVS-R4 24-hour VLBI sessions were regularly submitted in form of SINEX files. During the past year, due to several problems, we did not regularly submit results, but we continued our analysis in order to submit new Mark 5 solutions. We have computed long time series of troposphere parameters using all VLBI sessions available on our catalogue in order to estimate the variations over time of the content of water vapor in the atmosphere.

3. Outlook

For the time being, our catalogue finally contains all available experiments. In 2008, 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 catalogue. The regular submission of INAF tropospheric parameters to the IVS data centers will resume as soon as possible.

JPL VLBI Analysis Center Report for 2007

Chris Jacobs

Abstract

This report describes the activities of the JPL VLBI analysis center for the year 2007. We continue to do celestial reference frame, terrestrial reference frame, earth orientation, and spacecraft navigation work using the VLBI technique. There are several areas of our work that are undergoing active development. In 2007, an important development was the effort to move earth orientation and reference frame work to Mark 5 recording and software correlation. Our international collaboration to build celestial frames at K (24 GHz) and Q-bands (43 GHz) has matured to near a part-per-billion accuracy as has our in-house work to build a reference at X/Ka-bands (8.4/32 GHz). We are also studying the use of arrays for spacecraft tracking.

1. General Information

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

1. 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 is used to provide Earth orientation for spacecraft navigation use.
3. Delta differenced one-way range (ΔDOR) is a differential VLBI technique which measures the angle between a spacecraft and an angularly nearby extragalactic radio source. This technique thus complements the radial information from spacecraft doppler and range measurements by providing plane-of-sky information for the spacecraft trajectory.
3. ΔVLBI phase referencing using 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 34m 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 70m network (DSS 14, DSS 43, DSS 63). Typical X-band system temperatures are 35K on the HEF antennas. The 70m and BWGs are about 20K. Antenna efficiencies are typically well above 50% at X-band.

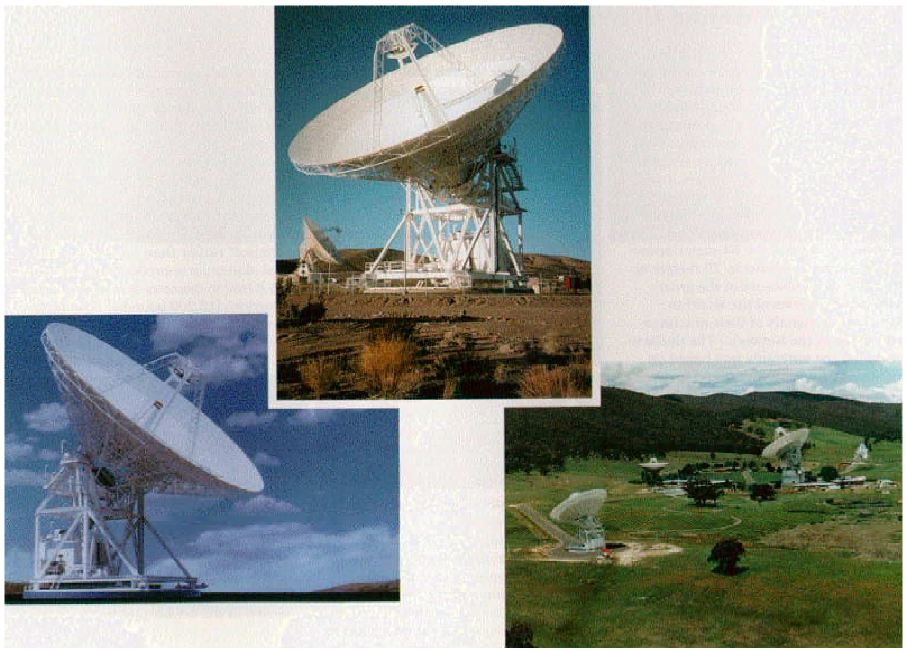


Figure 1. This figure shows the three high-efficiency antennas in the subnet: Goldstone is in the center; Robledo, Spain is on the lower left; and Tidbinbilla, Australia is on the lower right. These antennas were designed to have an optimum efficiency at X-band (8.4 GHz), which was to become the standard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

2. Data acquisition: The DSN sites have Mark 5A VLBI data acquisition systems. Mark IV tapes will still be supported for a few more months. 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 correlation with our software correlator.
3. Correlators: The JPL BlockII VLBI correlator handles the TEMPO and CRF correlations of Mark IV format tapes while the SOFTC software correlator handles Mark 5A format recordings. The ΔDOR data from the VSR systems are also correlated using the SOFTC software correlator running on UNIX workstations. The VSRs and the software correlator have also been used for connected element interferometry tests of antenna arraying concepts.
4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10°$) differential solutions. The TEMPO solutions typically have a

highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. 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 with a brief indication of areas of concentration within the VLBI effort at JPL. Note that not all of the staff listed work on VLBI exclusively as our group is involved in a number of projects in addition to our VLBI work.

- Durgadas Bagri: antenna arraying for spacecraft tracking applications
- Jim Border: ΔDOR spacecraft tracking.
- Mike Heflin: 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.
- Walid Majid: ΔDOR, VLBA phase referencing.
- Chuck Naudet: WVR, Mark IV and Mark 5 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.
- L.D. Zhang: S/X, K, and Q CRFs and TEMPO.

4. Current Status and Activities

In order to support the DSN's move to Ka-band (32 GHz), JPL is leading a collaboration with Goddard Space Flight Center, the U.S. Naval Observatory, National Radio Astronomical Observatory, and the Bordeaux Observatory to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) (Boboltz *et al*, 2007; Lanyi *et al*, 2008). In-house work to build an X/Ka-band CRF is also currently underway (Jacobs & Sovers, 2007).

The advanced Water Vapor Radiometer (A-WVR) continues to be used in research applications. This device can calibrate water vapor induced delays to a fractional stability of roughly a few parts in 10^{15} over time scales of 2,000 to 10,000 seconds and has demonstrated threefold reduction in VLBI residuals on time scales of 100 to 1000 seconds (Bar-Sever *et al*, 2007).

A number of activities are now underway to study the use of antenna arrays for VLBI-based spacecraft tracking including studies on the potential of the VLBA to make phase referencing observations of spacecraft positions (Bagri; Bagri *et al*; Majid & Bagri, 2007).

5. Future Plans

In the coming year we expect to move TEMPO and reference frame VLBI completely to Mark 5 recordings. Data rates will gradually be increased to 1 Gbps as resources allow. We plan to turn our proto-type Ka-band phase calibrator into a set of operational units. Our next generation fringe fitting program is also expected to come online in the next year. We anticipate refereed publications on our high frequency celestial reference frame work. On the spacecraft front, we plan to support a number of missions including the Mars Phoenix lander mission. Research will continue on techniques for using the VLBA and phase referencing VLBI for spacecraft tracking.

6. 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.

References

[1] Bar-Sever, Yoaz E., Christopher S. Jacobs, Stephen Keihm, Gabor E. Lanyi, Charles J. Naudet, Hans W. Rosenberger, Thomas F. Runge, Alan B. Tanner, & Yvonne Vigue-Rodi, 'Atmospheric Media Calibration for the Deep Space Network,' Proc. of the IEEE (Special issue), vol. 95, no. 11, Nov. 2007.

[2] Bagri, D., 'Same-Beam Tracking with the Proposed DSN Array Using a Calibration Signal from Multiple Sources Simultaneously,' IPN Progress Report 42-171, 15 Nov. 2007. http://tmo/progress_report/42-171/171F.pdf

[3] Bagri, D.S., J. I. Statman, and M. S. Gatti, 'Proposed Array-Based Deep Space Network for NASA,' Proceedings of the IEEE, Special Issue on Technical Advances in Deep Space Communications and Tracking, vol. 95, no. 10, October 2007.

[4] Boboltz, D., A. Fey, G. E. Lanyi, C.S. Jacobs, C. J. Naudet, L. D. Zhang, C. Ma, D. Gordon, P. Charlot, E. Fomalont, J. Romney, O. J. Sovers, and B. Geldzahler, 'VLBI Source Positions at 24 GHz' Journees, 17 Sep 2007, Paris, France http://syrte.obspm.fr/journees2007/index.php?page=programme

[5] Jacobs, C.S., and O.J. Sovers, 'Extending the ICRF to Higher Radio Frequencies: Global Aastrometric Results at 32/8 GHz,' 18th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting, Vienna, Austria, 12-13 Apr 2007, http://www.evga.org/Meetings/evga2007_meeting/s4-3.pdf

[6] Jacobs, C.S., and O.J. Sovers, 'Extending the ICRF to Higher Radio Frequencies: Global Aastrometric Results at 32/8 GHz,' AAS, session 021.01, Honolulu, Hawaii, 28-29 May 2007, http://www.aas.org/publications/baas/

[7] Lanyi G., D. Bagri and J. Border, 'Angular Position Determination of Spacecraft by Radio Interferometry,' Proc IEEE, Vol. 95, No. 11, Nov. 2007, p 2193.

[8] Lanyi, G. E., D. Boboltz, P. Charlot, A. Fey, E. Fomalont, B. Geldzahler, D. Gordon, C.S. Jacobs, C. Ma, C. J. Naudet, J. Romney, O. J. Sovers, and L. D. Zhang, 'Astrometry from VLBA Observations at 24 and 43 GHz,' AJ, 2008, in preparation.

[9] Majid, W., D. Bagri, 'In-Beam Phase Referencing with the Deep Space Network Array,' IPN Progress Report 42-169, 15 May 2007. http://tmo/progress_report/42-169/169F.pdf

[10] Majid W., E. Fomalont, D. Bagri, 'Compactness of Weak Radio Sources at High Frequencies – Preliminary Results of VLBA Observations,' presented at VSOP-2 Meeting, Tokyo, Japan, Dec 2007.

IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine

Sergei Bolotin, Yaroslav Yatskiv, Svitlana Lytvyn

Abstract

This report summarizes the activities of VLBI Analysis Center at the Main Astronomical Observatory of the National Academy of Sciences of Ukraine in 2007.

1. Introduction

The VLBI Analysis Center was established in 1994 by the Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine (NASU) as a working group of the Department of Space Geodynamics of the MAO. In 1998 the group started its IVS membership as an IVS Analysis Center. The AC MAO is located in the Central office of the observatory in Kiev.

2. Technical Description

VLBI data analysis at the center is performed on two computers: a Pentium-4 1.9GHz box with 256 MB RAM and a 160GB HDD, and a Pentium-4 3.4GHz box with 1 GB RAM and two 200 GB HDDs. Both computers are running under the Linux/GNU Operating System.

The Main Astronomical Observatory improved its Internet connection in 2007. Now we have a 10 Mbps fiber channel with a 256 kbps backup on leased line.

For data analysis we use the software SteelBreeze which was developed at the MAO NASU. The SteelBreeze software is written in the C++ programming language and uses Qt widget library. SteelBreeze makes Least Squares estimation of different geodynamical parameters with the Square Root Information Filter (SRIF) algorithm (see [1]).

The software analyzes VLBI data (time delay) of 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.

Sergei Bolotin: Senior research scientist of the Department of Space Geodynamics; responsible for the software development and data processing.

Svitlana Lytvyn: A Ph.D. student who is involved in the activities of the AC. Her Ph.D. thesis concerns the stability of VLBI-derived celestial and terrestrial systems.

4. Current Status and Activities in 2007

In 2007 we performed regular VLBI data analysis to determine Earth orientation parameters. "Operational" solutions were produced and submitted to the IVS on a weekly basis. The IERS Conventions (2003) [2] models have been applied in the analysis. In the solution, coordinates of stations and Earth orientation parameters are estimated.

Also, this year 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.

In the frame of preparing the next ICRF realization, the center produced global CRF solution `mao000a`. The catalog is based on the analysis of almost all available dual-band VLBI observations from 1980.04.11 to 2007.05.07, which are usable for simultaneous determination of TRF, CRF, and EOP. In total, 5,905,184 observations acquired on 3,548 VLBI sessions were processed. Coordinates of radio sources, positions of stations and velocities were estimated as global parameters; EOP were estimated as local parameters; clock function and tropospheric parameters (zenith delay and its gradients) were treated as stochastic parameters (random walk model). The CRF solution consists of coordinates of 2,541 radio sources.

For the same set of VLBI sessions time series of radio sources coordinates variations were estimated. For this solution, `mao000b`, we applied the results from previous global solution `mao000a` for initial coordinates and velocities of stations, source positions, and EOP. Coordinates of radio sources were estimated as local parameters. Clock functions and tropospheric parameters were estimated as stochastic parameters (random walk model).

5. Plans for 2008

MAO Analysis Center will continue to take part in operational EOP determination as well as updating the solutions of TRF and CRF from VLBI analysis of full data set of observations.

The improving of the SteelBreeze software will also be continued next year.

Acknowledgments

The work of our Analysis Center would be impossible without activities of other components of IVS. We are grateful to all contributors of the Service.

References

[1] Biermann, G.J., 1977, Factorization Methods for Discrete Sequential Estimation, V128, Mathematics in Science and Engineering Series, Academic Press.

[2] IERS Conventions (2003), IERS Technical Note 32, eds. D.D. McCarthy and G. Petit, Bundesamt für Kartographie und Geodäsie, Frankfurt am Main.

Analysis Center at National Institute of Information and Communications Technology

Thomas Hobiger, Ryuichi Ichikawa, Mamoru Sekido, Hiroshi Takiguchi, Tetsuro Kondo, Yasuhiro Koyama

Abstract

This report summarizes the activities of the Analysis Center at National Institute of Information and Communications Technology (NICT) for the year 2007.

1. General Information

The NICT Analysis Center is located in Kashima, Ibaraki, Japan and is operated by the VLBI group of NICT. Analysis of VLBI experiments and related study fields at NICT are mainly concentrated on experimental campaigns for developing new techniques such as e-VLBI for real-time EOP determination, prototyping of a compact VLBI system, ionospheric and atmospheric path delay studies, and differential VLBI (DVLBI) for spacecraft orbit determination. In addition we analyzed IVS-T2 sessions.

2. Staff

Members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order):

- HOBIGER Thomas, Postdoctoral fellow of the Japan Society for the Promotion of Science (JSPS)/Atmospheric and ionosphere research using VLBI and GPS
- ICHIKAWA Ryuichi, Compact VLBI system development and Atmospheric Modeling
- KONDO Tetsuro, Software Correlator
- KOYAMA Yasuhiro, International e-VLBI
- SEKIDO Mamoru, International e-VLBI and VLBI for spacecraft navigation
- TAKIGUCHI Hiroshi, International e-VLBI and loading effects

3. Current Status and Activities

3.1. Ultra-rapid UT1 Experiments

Data transfer via Internet protocols allows to reduce the latency of UT1 measurements obtained from VLBI. Such experiments, known as e-VLBI, were conducted in cooperation with colleagues from Metsähovi, Onsala, Wettzell, and GSI in order to demonstrate that the estimates of UT1 can be obtained shortly after the last scan has been observed. By the usage of the UDP-based Tsunami protocol, data were sent to Kashima, converted to K5 format, and handed over to our software correlator [2] which is operated in distributed computing mode. Thus it was possible to obtain UT1 estimates, which are proven to be as accurate as the IERS Bulletin-A results, already 30 minutes after the last observation has been made [3]. The experience gained from these experiments is going to be applied to the weekly intensive VLBI sessions and is expected to improve the latency and accuracy of the IERS products.

Table 1. e-VLBI sessions for rapid UT1 measurement performed since April 2007. Station codes are as follows, “Ks”:Kashima34, “Ts”:Tsukuba 32, “On”:Onsala, “Mh”:Metsähovi, “Wz”:Wettzell.

Date 2007	**Baseline**	**Data rate** (Mbps)	**UT1-UTC** (ms)	**UT1-c04** (μ sec.)	**Error** (μ sec.)	**Latency**
03 April	Ks – On	256	-69.6044	-38.5	8	–
23 April	Ks – On	128	-98.4422	15.0	41	1 h 55 min.
02 May	Ks – On	128	-110.0189	-30.4	16	–
18 May	Ks – Mh	128	-130.5832	67.5	98	2 h 38 min.
30 May	Ks – On	128	-143.2703	-14.7	9	28 min.
31 May	Ks – On	128	-143.7011	-83.5	8	–
04 June	Ks – On	256	-144.6447	13.1	6	31 min.
14 July	Ks-On, Ks-Wz	256	-162.0879	6.2	6	–
	Ks – On		-162.1017	-7.6	10	
	Ks – Wz		-162.0715	22.6	8	
	Ts – Wz, On-Ts		-162.0674	26.7	8	
	On – Ts		-162.0725	21.6	7	
	Ts – Wz		-162.0585	35.6	5	
	Ts – Wz(INT2)		-162.0974	-3.3	7	
15 July	Ks – On	256	-162.0186	-30.7	6	–
	Ts – Wz(INT2)		-162.0017	-13.8	8	
25 Oct	Ks – On	256	-208.4180	95.8	640	–
26 Nov	Ks – On	128	-240.0781	75.8	8	–
		256	-240.1118	78.2	16	–
		512	-240.1134	82.5	29	–
		128	-240.1621	76.9	8	25 min.
		128	-240.2628	-2.3	14	27 min
		512	-240.3020	-8.8	30	–

3.2. CARAVAN2400

We are currently developing a “Compact Antenna of Radio Astronomy VLBI Adapted for Network” with a 2.4 m diameter dish, which is named CARAVAN2400. A geodetic VLBI experiment between the CARAVAN2400 and the GSI 32 m antenna at Tsukuba was performed from Jan 31 until Feb 1, 2007. In this experiment, the K5/VSI system was used with a bandwidth of 512 MHz in order to evaluate the performance of an even smaller VLBI system with a 1.6 diameter. The obtained results were well consistent with the one from a previous test using the K5/VSSP system. In addition, another VLBI experiment between Kashima 34 m and Koganei 11 m was performed on July 19, 2007. At Kashima, a Cs gas-cell atomic frequency standard was used instead of the hydrogen maser in order to evaluate its capability for geodetic VLBI experiments. Although the Allan variance of the Cs gas-cell is worse than that of the hydrogen standard by a factor of about ten, the baseline length results were in quite good agreement with the previous experiment.

3.3. MK3TOOLS

A set of programs, summarized under the name MK3TOOLS, allows the creation of Mark III databases from post-correlator output without any dependency on CALC/SOLVE libraries [1]. NetCDF files are utilized as intermediate data-storage and either Mark III compatible databases or NGS files are generated for follow-on analysis (Figure 1). Since all routines can be controlled from the command-line, MK3TOOLS enables the realization of a processing chain without human interactions and allows to generate databases for applications with a high demand on low latency (e.g. e-VLBI). Currently only K5 post-correlation format is supported by MK3TOOLS.

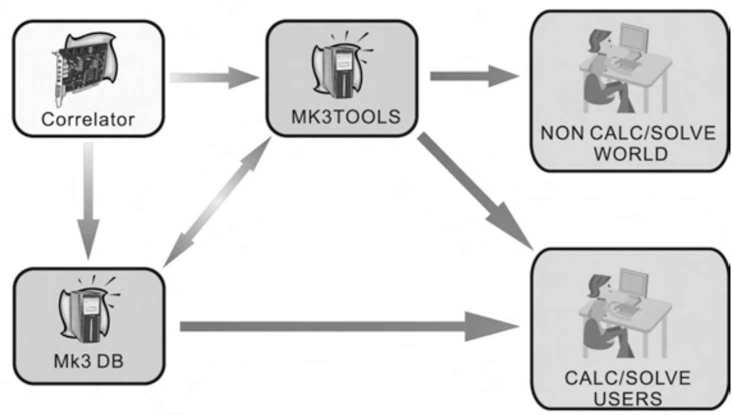


Figure 1. The role of MK3TOOLS between correlator output and analysis

3.4. Differential VLBI for Spacecraft Tracking

Together with JAXA/ISAS, Japan the HAYABUSA satellite has been tracked on March 7th, 2007 with the purpose to test a phased-array tracking system within Japan.

3.5. Kashima Ray-tracing Tools - KARAT

Numerical weather models (NWM) have undergone an improvement of spatial and temporal resolution which makes it possible to utilize them for the computation of electro-magnetic wave propagation characteristics. Until now such models have been used to create mapping functions, which relate slanted observations to vertical ones. In our studies we have tried to handle numerical weather models to obtain directly the troposphere total slant delays in any arbitrary direction by ray-tracing methods. Thus a set of programs, subsumed under the name Kashima Ray-Tracing Tools (KARAT), has been developed which allows to carry out fast and accurate ray-tracing tasks and output the information in standard formats. All modules are designed to fulfill the requirements for real-time processing, but are capable to run in post-processing mode as well. Numerical weather models from the Japanese Meteorological Agency (JMA), covering East Asia (including Japan, Korea, Taiwan, and parts of Russia and China), can be input directly to KARAT.

First tests using GPS have revealed that more than 99% of total troposphere can be modeled by KARAT and that only a simple mapping function is needed to account for the remaining symmetric troposphere delay. Application within VLBI analysis and usage for space-craft tracking is planned for the near future. Moreover KARAT can be used to simulate/evaluate positioning errors of space geodetic techniques associated with water vapor inhomogeneities.

3.6. Phase Ambiguity Resolution Within Next-Generation VLBI

Next-Generation VLBI system designs are aiming at one mm global position accuracy. Thus, it is not only necessary to deploy improved VLBI systems, but also to revise analysis strategies that take full advantage of the observations taken. With the new systems, it should be feasible to resolve phase ambiguities directly from post-correlation data, providing roughly an order of magnitude improvement in precision of the delay observable. As the unknown ambiguities are of integer nature, it has been investigated how they the can be resolved analytically using algorithms which have been developed for GNSS applications. Furthermore, it has been shown that other nuisance parameters can be solved simultaneously with the analytically relevant delay observables. In order to test this, artificial observations were created using parameters from actual design studies and these were used to test the developed algorithms.

4. Future Plans

For the year 2008 the plans of the Analysis Center at NICT include:

- Several international and domestic VLBI experiments for real-time EOP determination using e-VLBI and the K5 system (both VSSP system and PC/VSI system)
- Unattended generation of Mark III databases and automated processing of UT1 experiments
- Differential VLBI experiments for spacecraft tracking and its analysis
- Development of the analysis software for spacecraft positioning using phase delay observables
- Improvement of processing speed and efficiency for the VLBI data correlation using multi-processor and high speed network
- Implementation of KARAT in a multi-processor/multi-core environment and establishment of an on-line ray-tracing service

References

[1] Hobiger T., Y. Koyama and T. Kondo, MK3TOOLS & NetCDF - storing VLBI data in a machine independent array oriented data format, Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, Geowissenschaftliche Mittteilungen, Nr. 79, 194–195, 2007.

[2] Kondo T., M. Kimura, Y. Koyama and H. Osaki, Current status of software correlators developed at Kashima Space Research Center, In: International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings. NASA/CP-2004-212255, 186–190, 2004.

[3] Sekido M., H. Takiguchi, Y. Koyama, T. Kondo, R. Haas, J. Wagner, J. Ritakari, S. Kurihara and K. Kokado, Ultra-rapid UT1 measurements by e-VLBI, submitted to Earth, Planets and Space, 2008.

Paris Observatory Analysis Center OPAR: Report on Activities, January - December 2007

Anne-Marie Gontier, Sébastien B. Lambert, Christophe Barache

Abstract

This report summarizes the activities of the VLBI Analysis Center at the Paris Observatory (OPAR) for calendar year 2007. Quarterly solutions were processed to estimate EOP per session and global terrestrial and celestial reference frames. Additionally, the analysis center organized the operational analysis of weekly IVS-R1 and IVS-R4 sessions for regular submission to the IVS (scheduled to start early 2008). Other activities of the OPAR personnel related to VLBI include two main research topics: (i) the realization of a stable celestial reference frame (in the frame of the IVS/IERS Working Group on the "Second Realization of the ICRF"), and (ii) the analysis of VLBI-derived nutation time series to retrieve deep Earth's interior parameters.

1. Operational Analysis Status

In 2007, the quarterly solutions for Earth's orientation parameter, station coordinates and velocities and radio source coordinates have been submitted regularly to IVS and IERS EOP-PC. For those solutions, all station and source coordinates are estimated as global parameters except for poorly observed sources which are treated as arc parameters. The main difference with other analysis centers' analysis strategies is that we chose to define the orientation of the celestial frame by a no-net-rotation with respect to the ICRF-Ext.2 tie to the [1] (further referred to as MFV) 247 stable sources. The last 2007 solution (2007d, see Figure 1) processed 3,643,608 delays and delay rates in 3,272 sessions. The global postfit rms delay nears 24 ps.

Operational analysis for the production of daily SINEX files has been set up and tested at the end of the year, in order to participate in the IVS SINEX combination. The regular submission of SINEX files to the IVS analysis coordinator's office will begin in early 2008.

The OPAR Web site (http://ivsopar.obspm.fr/) is regularly updated to provide information and data on the latest processings. In addition, we provide some OPAR products in VOTable format as defined by the International Virtual Observatory Alliance (IVOA) on the VO-Corner section of our Web site.

2. Celestial Reference Frame Issues

The production and analysis of time series of radiocenter positions was continued and updated quarterly in 2007. The times series are available at the IVS data center and the OPAR Web site (we provide ASCII data files and plots).

In the framework of ICRF2 elaboration, we investigated the time series in terms of time stability. Our future aim is to derive the best subset of stable radio sources suitable for defining the axes of the next ICRF. In a study presented at the Journées Systèmes de Référence Spatio-Temporels, in Paris [3], we analyzed the position time series of 521 sources observed in more than 10 sessions between 1984.0 and 2007.5 (see Figure 2). It appeared that time series are so noisy or sparse that the only meaningful quantities that can be extracted from the analysis are the weighted rms and a medium-term irregular pattern (through, e.g., a weighted moving average) for each series. We applied a very simple selection scheme only playing with the rms and the slope. The selection

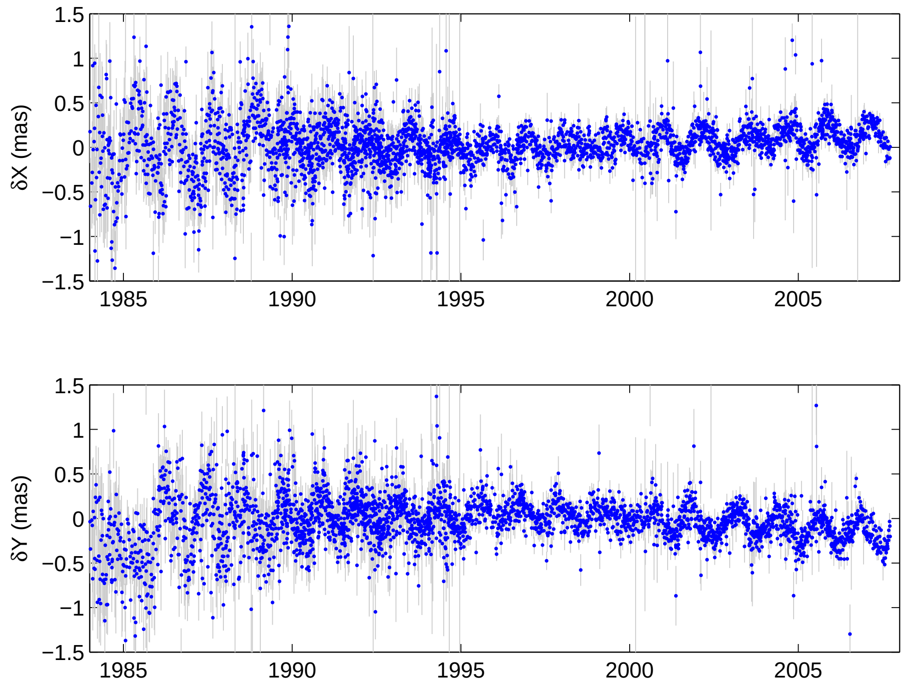


Figure 1. Celestial pole offsets from quarterly solution opa2007d.

parameters have been tuned so that the number of elected sources reaches ∼200. Our subset finally contains 197 sources, of which 32% are part of the 212 ICRF defining sources [6] and 68% are part of the 247 MFV stable sources. The axis stability of the reference frame defined by the above-selected sources was then assessed using a four parameter transformation (3 rotation angles and the tilt parameter dz) between a semi-annual reference frame (defined by the semi-annual coordinates of the selected radio sources) and the reference catalogue ICRF-Ext.2 [2]. It appears that our selection of sources leads to a significantly better stability for the reference frame. It is obvious that this selection must be supplemented by other selections done through other criteria (e.g., refined algorithms, source compactness), particularly since our selection yields a poor number of sources in the southern hemisphere.

3. Geophysics Issues

Since VLBI is a major and powerful technique revealing the deep Earth's interior (along with seismology and gravimetry), one must ask oneself whether the discussions and achievements about the new ICRF can lead to an improvement of the VLBI data in a geophysical sense. Remember that geophysical parameters in the IAU-adopted [7] (referred to as MHB) nutation theory have been adjusted on VLBI nutation time series. If MHB is powerful, it is obviously because of the MHB theoretical framework, but also because of a considerable improvement of VLBI data during the last decade of the XXth century. But, although this theory is very satisfying, challenging questions still remain, like, e.g., the direct observability of the diurnal wobble associated with the free inner core nutation, or, at least, a better determination of its resonant period. Answers to

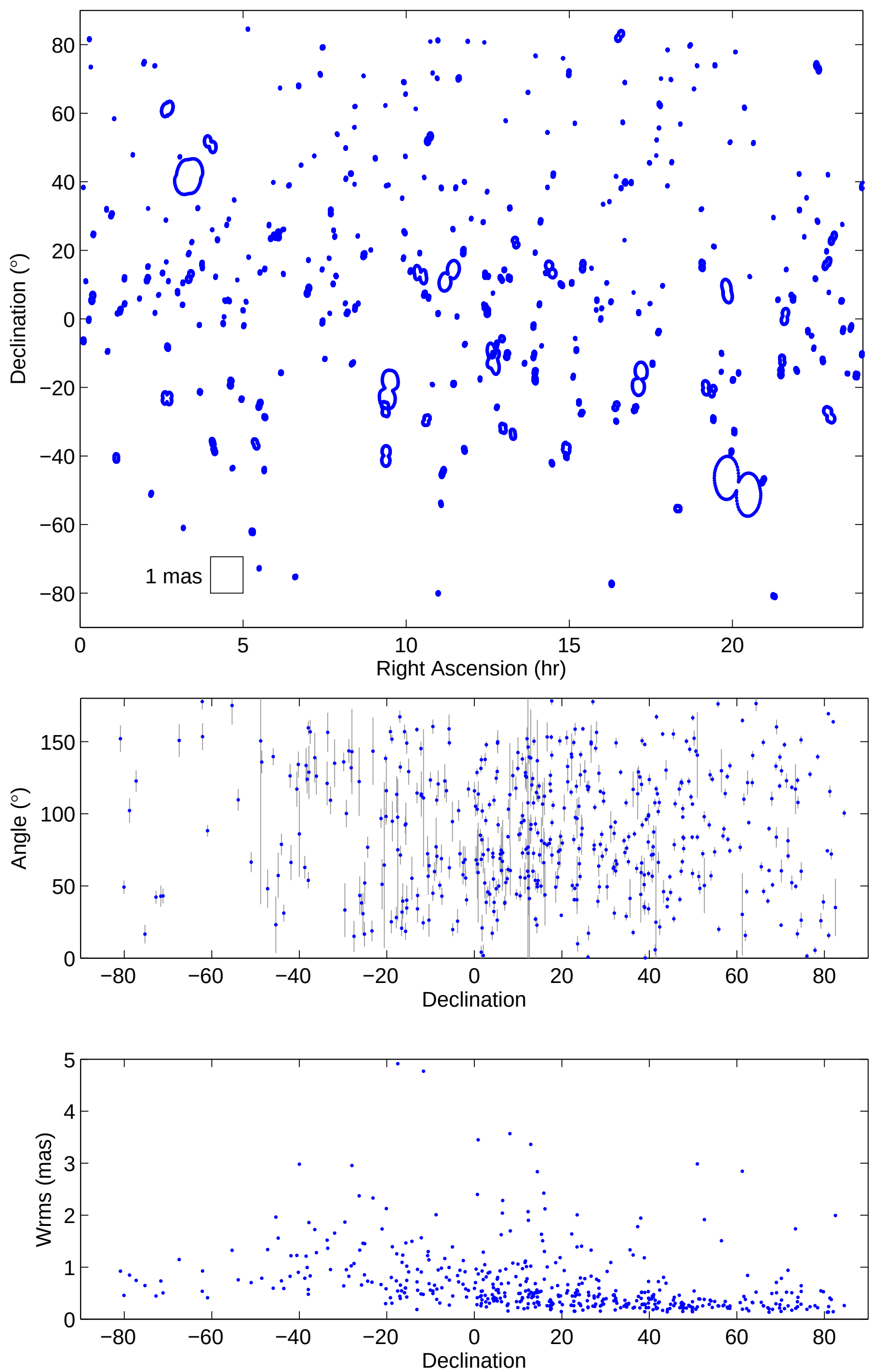


Figure 2. Top: Envelopes of variability (defined as the rms in a given direction) of the 521 radio sources investigated in this study. Middle: Dependence of the angle of maximal variability on the declination. Bottom: Dependence of the rms on the declination.

these questions are currently partly hidden in the noisy nutation residuals and we have either to dig out meaningful information from the noise, or to remove the noise by a wise analysis of VLBI observations at the analysis center level. In the context of the on-going effort to improve the theoretical modeling of the nutation (see, e.g., the recent computation of the torque on the tidally redistributed matter by [4], that was partly omitted in the MHB theory), identifying the various sources of errors in the estimates appears very worthwhile.

Obtaining nutation from VLBI analysis needs to handle correctly the celestial reference frame so that radio source positional instabilities may not unduly perturb the nutation estimates. In a study recently accepted for publication in Astronomy & Astrophysics [5], we tried to estimate the magnitude of these perturbations and to determine their impact on the resonant frequencies associated with the Earth's fluid outer and inner cores. We achieved this playing with the constraints that are applied to the radio source positions during a global analysis. We showed that an additional error of ~15 μas in the estimates of the 18.6 year nutation spectral component and decreasing for shorter periods can be produced by the instabilities in the celestial frame. This leads to an uncertainty of few tenths of day on the fluid outer core resonant period and of 200 on its quality factor, and an uncertainty of less than 100 days on the inner core resonant period and 100 on its quality factor.

References

[1] Feissel-Vernier, M., Ma, C., Gontier, A.-M., & Barache, C. 2006, A&A, 452, 1107 A&A, 452, 1107

[2] Fey, A.L., Ma, C., Arias, E.F., et al. 2004, AJ, 127, 3587

[3] Gontier, A.-M., & Lambert, S.B. 2007, In: N. Capitaine (Ed.), Proc. Journées 2007 systèmes de référence spatio-temporels, Observatoire de Paris, in press

[4] Lambert, S.B., & Mathews, P.M. 2006, A&A, 453, 363

[5] Lambert, S.B., Dehant, V., & Gontier, A.-M. 2007, A&A, in press

[6] Ma, C., Arias, E.F., Eubanks, T.M., et al. 1998, AJ, 116, 516

[7] Mathews, P.M., Herring, T.A., & Buffett, B.A. 2002, J. Geophys. Res., 107(B4), 10.1029/2001JB000390

The IVS Analysis Center at the Onsala Space Observatory

Rüdiger Haas, Hans-Georg Scherneck, Tobias Nilsson

Abstract

This report briefly summarizes the activities of the IVS Analysis Center at the Onsala Space Observatory during 2007. Some examples of ongoing work are presented.

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. As in previous years the main focus was on high-frequency Earth orientation, loading phenomena, and atmospheric water vapor. Some topics are briefly presented in the following.

2. hfEOP from VLBI CONT Campaigns

In collaboration with Anna Korbacz from the Space Research Centre of the Polish Academy of Sciences, we continued our work on high-frequency EOP variations from VLBI CONT campaigns [1]. Anna stayed at Onsala for 2 months on a stipend provided by the Descartes-Nutation consortium. During her stay we worked on the application of various spectral analysis techniques on the VLBI CONT data with a focus on the previously detected ter-diurnal signals [2]. One result of this work is that the possibility that the ter-diurnal signals are caused by the actual VLBI data analysis could be ruled out with high probability. Another result is that predicted high-frequency EOP variations based on a recent ocean model with high temporal resolution cannot explain the detected signals either. Further work on this topic is needed.

3. Ocean Tide and Atmospheric Loading

The automatic ocean tide loading service [3] has been maintained. The transition to a new computer described previously [1] was successful and resulted in faster processing speed in 2007 as compared to earlier years.

4. Contributions to VLBI2010 Simulations

We contributed to the VLBI2010 simulation work by determining equivalent zenith wet delays for VLBI2010 simulation schedules [4]. These tropospheric parameters are determined using a turbulence model [5] together with wind data and tropospheric height scale from a numerical weather model [6]. The turbulence parameters are determined from high-resolution radiosonde data, and a global model for turbulence as a function of latitude was developed. Figure 1 gives an example for these simulations for the Station Ny-Ålesund on Spitsbergen, and shows the scale height, wind speed and direction at the 850 hPa level, and the simulated equivalent wet delay values for 25 continuous days.

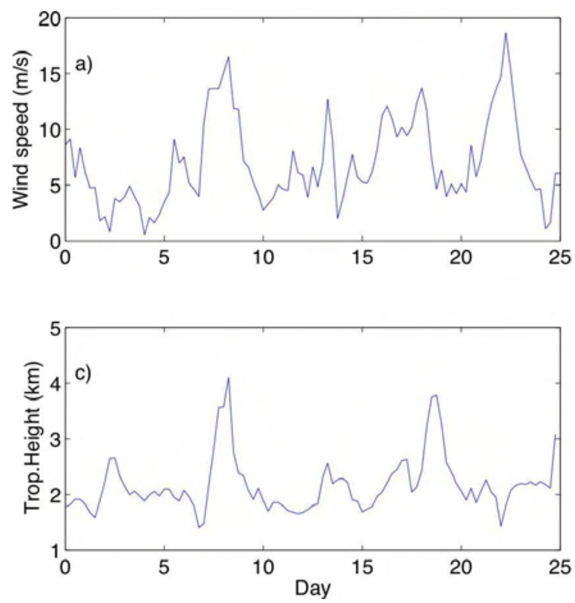


Figure 1. Example of VLBI2010 simulations of equivalent zenith wet delay values for Ny-Ålesund. Shown are a) wind speed, b) wind direction, c) tropospheric height, and d) simulated equivalent zenith wet delays.

5. Contribution to the IVS TROP Project

The submission of solutions of tropospheric parameters of the R1 and R4 experiments was interrupted during 2007 due to the transition of the Calc/Solve analysis from an HP system to a Linux system. We plan to resume participation in this project during 2008.

6. Results from the Fennoscandian-Japanese Ultra-rapid dUT1 Observations

During 2007 we started a collaboration with colleagues at Metsähovi, Kashima and Tsukuba to observe dUT1 with very low latency. Several ultra-rapid dUT1 experiments were observed in 2007. All of them used real-time e-VLBI data transfer from Fennoscandia to Japan and near real-time data conversion, near real-time or off-line correlation, and preparation of VLBI databases and data analysis. Figure 2 shows the network constellation with the long east-west baselines that are well-suited for earth rotation observations. In the best cases dUT1 results were available within 30 minutes after the end of an observing session. We did a post-processing analysis of the experiments and show in Figure 3 the dUT1 of the Fennoscandian-Japanese experiments together with the final VLBI dUT1 values provided by the USNO. Time series of dUT1 after subtraction of a linear trend and the differences between the two series are shown. With the exception of experiments that had severe technical problems causing loss of observations, e.g. October 2007 and November 2007, the agreement between the two series is within about 60 μs. Further studies focussing on the role of scheduling options, data rate, and analysis strategies are ongoing.

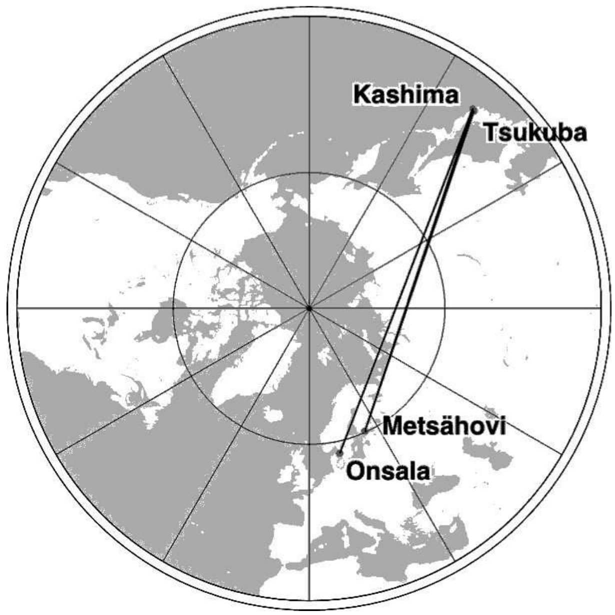


Figure 2. The network configuration for the Fennoscandian-Japanese ultra-rapid dUT1 measurements.

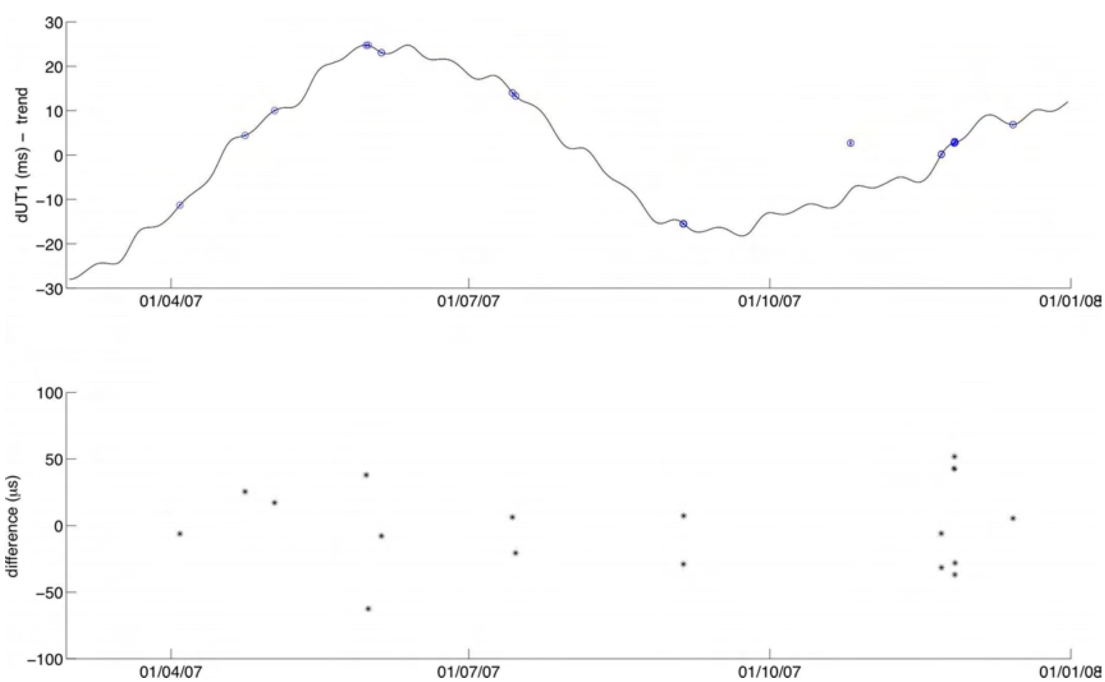


Figure 3. dUT1 values after subrtacting a linear trend. Top: Final UT1 values of the USNO (continuous line) and results of the Fennoscandian-Japanese ultra-rapid dUT1 experiments (circles). Bottom: The corresponding differences.

7. Outlook

The IVS Analysis Center at the Onsala Space Observatory will continue its efforts to work on specific topics relevant for space geodesy and geosciences.

References

[1] Haas, R., Scherneck, H.-G., Nilsson, T.: The IVS Analysis Center at the Onsala Space Observatory. In: D. Behrend and K. Baver: *International VLBI Service for Geodesy and Astrometry 2006 Annual Report*, NASA/TP-2007-214151, 224–227.

[2] Haas, R: Investigating High-Frequency Earth Orientation Variations with Continuous Geodetic VLBI Campaigns. In: D. Behrend and K. D. Baver (Eds.): *IVS 2006 General Meeting Proceedings*, NASA/CP-2006-214140, 316–319, 2006.

[3] Scherneck, H.-G., and Bos, M.: Ocean Tide and Atmospheric Loading. In: N. R. Vandenberg and K. D. Baver (Eds.): *IVS 2002 General Meeting Proceedings*, 205–214, NASA/CP-2002-210002, 2002.

[4] Nilsson, T., Haas, R., Elgered, G.: Simulations of atmospheric path delays using turbulence models. In: J. Böhm, A. Pany, and H. Schuh: *Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting*, Geowissenschaftliche Mitteilungen, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, **79**, 175–180.

[5] Nilsson, T., Elgered, G., and Gradinarsky, L.: Characterizing Atmospheric Turbulence and Instrumental Noise Using Two Simultaneously Operating Microwave Radiometers. In: *Proc. 9:th Specialist Meeting on Microwave Radiometry and Remote Sensing Applications, MicroRad 2006*, 270–275, 2006.

[6] ERA40: `http://data.ecmwf.int/research/era/`

PUL IVS Analysis Center Report 2007

Zinovy Malkin, Julia Sokolova, Natalia Miller

Abstract

The report briefly presents the PUL IVS Analysis Center activities during 2007 and plans for the coming year. Main topics of investigation in that period were comparison and combination of catalogues of radio source positions, analysis of VLBI EOP series, analysis of radio source position and zenith troposphere delay time series.

1. General Information

The PUL IVS Analysis Center was organized in September 2006 and is located at the Central Astronomical Observatory at Pulkovo of Russian Academy of Sciences (Pulkovo Observatory). The main topics of our activity are:

- Improvement of the International Celestial Reference Frame (ICRF), including investigations of radio source catalogues, constructing combined catalogues, investigation of the ICRF stability, and investigation of radio source position time series.
- Computation and analysis of EOP, station position, baseline length and zenith troposphere delay time series.
- Investigation of Free Core Nutation (FCN).
- Comparison of VLBI results with other space geodesy techniques.

The PUL AC's Web page is available at `http://www.gao.spb.ru/english/as/ac_vlbi/`.

2. Scientific Staff

PUL team consists of three scientists:

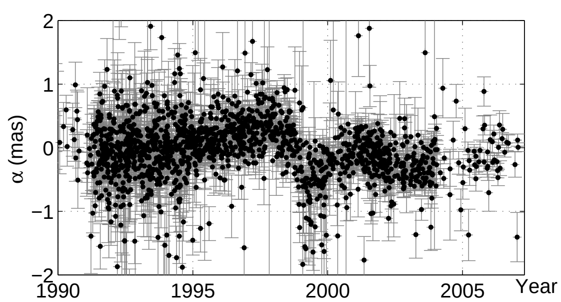
1. Zinovy Malkin (70%) — team coordinator, computation and analysis of EOP, station coordinates and baseline length, development of algorithms and software for data processing and analysis;
2. Julia Sokolova (100%) — global data analysis for deriving radio source catalogues and position time series, comparison and combination of radio source catalogues, time series analysis, development of algorithms and software for CRF studies;
3. Natalia Miller (20%) — investigation of FCN and zenith troposphere delay; application of new mathematical methods to time series analysis.

3. Activities

The activities of the PUL IVS Analysis Center during 2007 included:

- Investigations in the framework of the IERS/IVS Working Group on the Second Realization of the ICRF were continued. Main directions of this activity are comparison and combination of radio source catalogues, computation and investigation of source position time series. The main results obtained in 2007 are the following.

- Two combined radio source catalogues have been constructed and investigated [1]. The first of them provides a stochastic improvement of the current ICRF realization, and the second one allows us to account also for systematic errors in the ICRF. Comparison of the celestial pole offsets obtained from the processing of VLBI observations using ICRF and the combined catalogue has shown improvement of the results. Further improvement is expected after refining the comparison and combination procedures.
- A new method of assessment of the CRF accuracy based on the scatter analysis of the celestial pole offset (CPO) time series is proposed [2]. Several scatter indices based on residual analysis of CPO series with respect to a FCN model and Allan deviation technique and its extensions, which allow the treatment of unequally weighted and multidimensional observations, are investigated. Application of these criteria to several radio source catalogues showed their ability to perform a preliminary assessment of the quality of the CRF realizations.
- Several radio source catalogues and source position time series from a global analysis of VLBI data with the OCCAM 6.2 software were calculated using different modes. Comparison of four lists of reference sources showed significant inconsistencies in source selection. The impact of radio source instability on celestial pole offset estimates was investigated. Analysis showed that variations of radio-source coordinates affect the celestial pole offset estimates (Fig. 1, [6]). These results mainly were obtained during a 6-month visit of Julia Sokolova at the Institute of Geodesy and Geophysics (IGG), Vienna in March–August 2007.
- The first version of a new list of the optical characteristics of geodetic radio sources is compiled. Further development is being performed in cooperation with Geoscience Australia Analysis Center and Pulkovo optical astronomers.



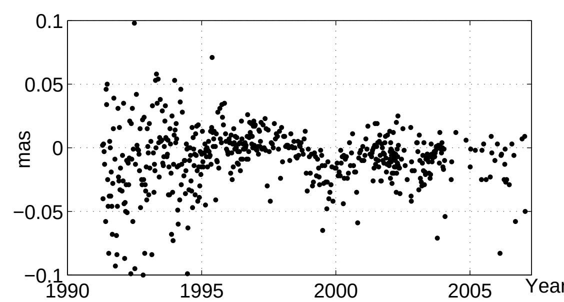


Figure 1. Variations of source 2145+067 positions (left) and differences between two CPO time series (right). For the first CPO series, all the observations were used. For the second CPO series, the observations of 2145+067 were excluded. Source and station positions were fixed in both cases.

- The IVS combined CPO time series was analyzed using several statistical tools, such as spectrum analysis, singular spectrum analysis, or wavelet analysis to investigate both trend and (quasi)periodical components. The results are presented in [4]
- A new VLBI network geometry index, the volume of network, is examined as an indicator of the quality of the EOP obtained from VLBI observations [5]. It has been shown that both EOP precision and accuracy can be described by a power law $\sigma = aV^b$, where V is the volume

of network, in a wide range of network size from domestic to global VLBI networks. The dependence found can be used for comparison of results obtained from different observing programs.

- Several very long and very dense zenith troposphere delay time series provided by the IGG IVS Special Analysis Center as an IVS troposphere product were analyzed by means of the method of Singular Spectrum Analysis (SSA) in both one-dimensional and multi-dimensional modes. The structure of the time series including regular, quasiregular (periodical) and irregular (trend) components was obtained and investigated. Using SSA allowed us to derive nonlinear trends in zenith troposphere delay, and also to research the variation of amplitude and phase of season components with time.
- Regular computation of two refined Free Core Nutation (FCN) time series started in 2006 were continued. They were briefly described in the PUL IVS Analysis Center Report 2006. More detailed description and comparison with other models are given in [3]
- Development of algorithms and software for data processing and analysis was continued.
- PUL archive of VLBI data and products was originated in the end of 2006. At present, all available databases and NGS cards have been stored along with main IVS and IERS products.
- PUL staff members participated in activities of several IVS projects, Working Groups and Committees.

4. Outlook

Plans for the coming year include:

- Continuation of the IVS related studies.
- Development of algorithms and software used for data processing.
- Support of the PUL archive of data and products.

References

[1] Sokolova Ju., Malkin Z. On comparison and combination of catalogues of radio source positions. Astron. Astrophys., 2007, **474**, No. 2, 665–670.

[2] Malkin Z. J. Geod., On accuracy assessment of celestial reference frame realizations. 2007, DOI: 10.1007/s00190-007-0181-x

[3] Malkin Z.M. Empiric Models of the Earth's Free Core Nutation. Solar System Research, 2007, **41**, No. 6, 492–497.

[4] Malkin Z., Miller N. An analysis of celestial pole offset observations in the free core nutation frequency band. In: Proc. 18th EVGA Working Meeting, Vienna, Austria, 12-13 Apr 2007, 93–97.

[5] Malkin Z. On dependence of EOP precision and accuracy on VLBI network. In: Proc. 18th EVGA Working Meeting, Vienna, Austria, 12-13 Apr 2007, 75–78.

[6] Sokolova, J. Effect of the reference radio source selection on VLBI CRF realization. Presented at Journées 2007, Paris, September 17–19, 2007.

SHAO Analysis Center 2007 Annual Report

Jinling Li

Abstract

Our research activities in 2007 focused on the atmosphere delay calibration of VLBA phase-referencing observations, the selection of stable sources for the next realization of the extragalactic celestial reference frame, and the processing of the satellite VLBI tracking data. These activities will be continued next year; in particular, we will prepare the software for the Chinese lunar exploration and Martian exploration. The local survey at Sheshan section of Shanghai Astronomical Observatory will be continued too.

1. General Information

We use CALC/SOLVE for our routine VLBI data analysis. We are developing softwares coded in FORTRAN to deal with the tracking data of satellite by VLBI, ranging, and Doppler. The members involved in the IVS analysis activities are Jinling Li, Guangli Wang, Bo Zhang, Shubo Qiao, Li Guo, Feng Tian, and Zhihan Qian.

2. Activities in 2007

We participated in some IERS/IVS campaigns aimed at comparisons of reference frames and/or Earth Rotation Parameters (EOP). We were able to do the VLBI solutions on a regular base. Our research activities in 2007 also included the atmosphere delay calibration of the VLBA phase-referencing observations, the selection of stable sources, the processing of the satellite tracking data, and a local survey at Sheshan section of the Shanghai Astronomical Observatory (SHAO).

2.1. The Atmosphere Delay Calibration of the VLBA Phase-referencing Data

Comparisons between atmospheric delay derived from GPS and VLBI observations at co-location sites show that the standard deviation of the difference is about several millimeters after a systematic bias is removed. This motivated us to calibrate the VLBA phase-referencing data using tropospheric estimates from GPS observations.

At present only six VLBA sites are co-located with GPS receivers. Table 1 illustrates the peak-to-noise ratio (PNR) of source images, where the second and the third column list the PNR only using geodetic VLBI data and combined GPS and VLBI data, respectively. (In the combined data column, column 3, if GPS data is available at a station, it is used by itself; if no GPS data is available, VLBI data is used.) Differences between the PNRs are very small. We therefore suggest to install GPS receivers at all VLBA sites and to correct for tropospheric effects in VLBA phase-referencing by using only GPS data or a combination of VLBI and GPS data. The precision of this correction will be at the millimeter level, while the geodetic VLBI observations could be omitted or compressed in order to save the observation time of targets.

Table 1. Comparison of PNR of source images.

Source	PNR (VLBI)	PNR (GPS/VLBI)
G350(Maser)	100.1	103.7
1855(QSO)	15.1	16.4
1907(QSO)	15.6	14.1
185X(QSO)	6.7	6.8

2.2. The Selection of Stable Sources

Based on the Calc/Solve system and aiming at the selection of stable sources, we have obtained a series of global solutions for astrometric/geodetic VLBI observations from 1984 to 2006 by changing the settings of the control parameters.

Firstly, a selected working list of sources is sorted by declination and then it is divided into six groups. Mathematically, the i^{th} source belongs to group j where $j = mod(i/6)$, and if $j = 0$ then set $j = 6$. By doing so we obtain similar sky coverage for the six groups. Secondly, take each of the six groups in turn as arc parameters and all the others as global parameters to obtain the global solutions of VLBI data. We allow only one sixth of the sources as arc parameters in order to maintain a uniform reference system. Thirdly, in each of the solutions the frame orientation is constrained to the ICRF, while different solutions may still have their own orientations that are slightly different from the others. We perform small angle rotations of the solutions in order to let the reference systems of all the arc parameters be further unified. Finally, after comparison and statistical analysis of the solutions we proposed a list of 173 candidate stable sources. We also compared the list with those recommended by other authors.

2.3. Data Analysis in the Chang'E-1 Project

As designed in the Chinese lunar exploration project Chang'E-1 (CE-1), the tracking data of satellite consist of range and Doppler measurements from the Chinese United S-Band network as well as delay and delay rate data from the Chinese VLBI network. We are tasked with processing the tracking observations of the CE-1 satellite in real-time and we have independently developed the data reduction software, which provides the instantaneous state vectors (ISVs) including the three-dimensional position and velocity. The software reads in tracking observations with clock, instrument, and propagation corrections in real time, automatically identifies the central gravitational body within the Earth-Moon system, and takes into consideration the perturbations of the non-spherical figure, N-body gravitation, light pressure, atmospheric drag, tidal effects and so on. The satellite ISVs are sequentially reduced with a $5s$ sampling interval.

From the ISVs it is easy to get the corresponding orbit elements and to predict the satellite ephemeris by orbit integration. The ISVs at a specified epoch could be reduced whenever the independent observations related to the wave-front of signal at this epoch are sufficient, that is, enough delay and range observations for the three-dimensional position and enough delay rate and Doppler for the velocity. This reduction is geometrically performed rather than applying dynamical constraints on the observations belonging to different wave-fronts at different epochs, and so the length of the tracking arc is not a crucial prerequisite. It could be used to monitor the quality of tracking data and to identify the evolution of satellite orbit, which satisfies the needs of efficiency and speediness in the view of the implementation of projects. Comparatively, precise orbit determination requires a sufficiently long tracking arc and is mainly applied in scientific studies with high precision requirements as in the post-analysis stage rather than in real time.

On November 5 of 2007, CE-1 satellite successfully entered a lunar orbit. During that period the real-time reduced ISVs from our software very well followed the evolution of the satellite orbit with a time lag of about five minutes, including the delays for the data transfer from the antenna to the correlation center, the correlation, the extraction of the delay and rate, among other things. The next step is to do the synthesis reduction of VLBI observations of satellite and quasars, especially the differential VLBI observations.

3. Plans for 2008

In the past year, the available time of the 25m antenna at Sheshan was almost completely used for the CE-1 project, which blocked the progress of the local survey to connect the reference markers of the SLR, VLBI, and GPS. Now we have local survey network of concrete pillars, a lease contract for survey instrumentation, auxiliary survey equipment such as the target on the antenna and the connections of the pillar to the instrument. The first session of the survey should be completed in 2008.

Other research activities will be continued in 2008, especially, we will get ready in knowledge and software for the Chinese lunar exploration and Martian exploration. We will make softwares to automatically do the analysis of the intensive EOP observations, we will also do some comparisons and combinations of individual EOP time series.

U.S. Naval Observatory VLBI Analysis Center

David A. Boboltz, Alan L. Fey, Jennifer L. Bartlett, Zachary Dugan, 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 2007. Over the course of the year, Analysis Center personnel analyzed biweekly 24-hour experiments with designations IVS-R1 and IVS-R4 for use in-house and continued timely submission of IVS-R4 databases for distribution to the IVS. During the 2007 calendar year, the USNO Analysis Center produced three periodic global Terrestrial Reference Frame (TRF) solutions with designations usn2007a, usn2007b, and usn2007c. Earth orientation parameters (EOP) based on these solutions, updated by the latest 24-hour (IVS-R1 and IVS-R4) experiments, were submitted to the IVS.

Other activities in the 2007 calendar year included the generation of a new Sinex solution, usn2007b, and the continued submission of Sinex files based on new 24-hour experiments to the IVS. In support of the Celestial Reference Frame (CRF), Analysis Center personnel continued a program designed to increase the sky density of ICRF sources, especially in the southern hemisphere. Activities included scheduling, analyzing and submitting databases for IVS-CRF experiments and the production of global CRF solutions designated crf2007a, crf2007b, and crf2007c. In addition, Analysis Center personnel performed research into the next generation ICRF-2 and a future high-frequency reference frame based on the VLBA K/Q-band experiments. Activities planned for the 2008 calendar year include the continued production of EOP/TRF/CRF global solutions and continued research into future reference frames.

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 24-hour experiments, the production of periodic global Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF) solutions, and the submission to the IVS of intensive (EOP-I) and session-based (EOP-S) Earth orientation parameters based on USNO global TRF solutions. Analysis Center personnel maintain the necessary software required to continue these services to the IVS including periodic updates of the GSFC CALC/SOLVE software package. In addition to operational VLBI analysis, USNO personnel engage in research aimed at developing the next generation ICRF. Information on USNO VLBI analysis activities may be obtained at:

`http://rorf.usno.navy.mil/vlbi/`.

2. Current Analysis Center Activities

2.1. Experiment Analysis and Database Submission

During the 2007 calendar year, personnel at the USNO VLBI Analysis Center continued processing of 24-hour (IVS-R1 and IVS-R4) experiments for use in internal USNO global TRF and CRF solutions. USNO is also responsible for the timely analysis of the IVS-R4, and the resulting databases are submitted within 24 hours of correlation for dissemination by the IVS. In addition, Analysis Center personnel continue to be responsible for the analysis and database submission for the periodic IVS-CRF experiments. The primary goal of these experiments is the densification of ICRF sources in the southern hemisphere. In 2007, USNO scheduled and analyzed 15 CRF experiments including IVS-CRF43 through IVS-CRF48, CRF-S11, and IVS-CRDS34 through IVS-CRDS41. The analyzed databases were submitted to the IVS. In the 2007 calendar year, Analysis Center personnel also continued analyzing IVS intensive experiments for use in a USNO EOP-I time series.

2.2. Global TRF Solutions, EOP and Sinex Submission

USNO VLBI Analysis Center personnel continued to produce periodic global EOP/TRF solutions (usn2007a, usn2007b and usn2007c) over the course of the 2007 calendar year. All USNO global EOP/TRF solutions including the most recent solution may be found at:

`http://rorf.usno.navy.mil/solutions/`.

An example of the information available on the Web site is shown in Figure 1. It shows the distribution of the RMS delays and rates for the 3666 24-hour experiments in the latest USNO solution, usn2007c. Session-based Earth orientation parameters derived from our solutions are routinely compared to those derived from GSFC periodic TRF solutions and to the IERS-C05 time series prior to submission to the IVS.

Analysis Center personnel continued to produce an EOP-S series based on the global TRF solutions and continuously updated by new data from the IVS-R1/R4 experiments. This updated

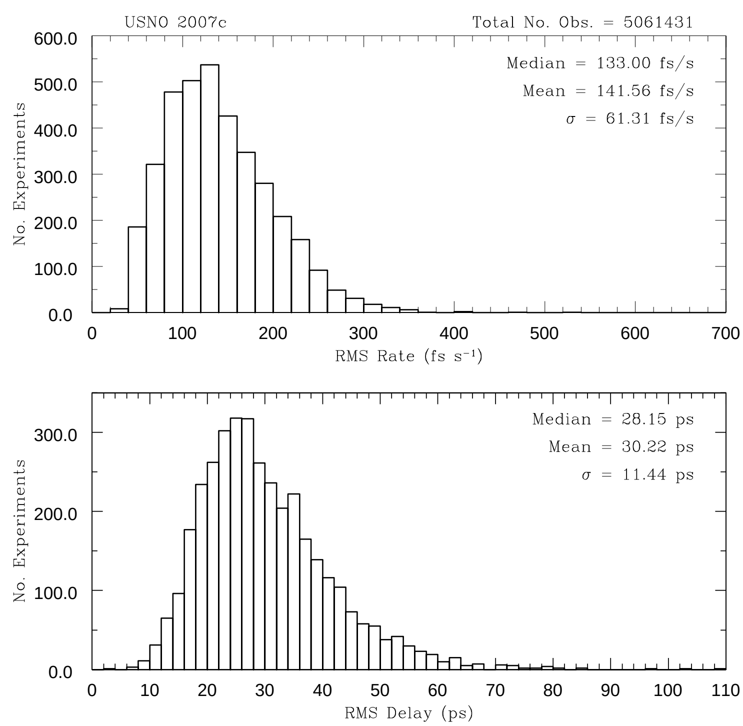


Figure 1. Distribution of RMS delay and rate for the 3666 24-hour sessions in the latest USNO global TRF/EOP solution usn2007c.

EOP-S series is submitted to the IVS twice weekly within 24 hours of experiment correlation and is included in the IERS Bulletin A. Analysis Center personnel also produced an updated Sinex series usn2007b and continued to submit Sinex format files based on the 24-hour VLBI sessions.

In addition to EOP-S and Sinex series, USNO Analysis Center personnel continued to produce and submit to the IVS an EOP-I series based on the IVS intensive experiments.

2.3. Celestial Reference Frame

During the 2007 calendar year, Analysis Center personnel continued work on the production of global CRF solutions for dissemination by the IVS including crf2007a, crf2007b, and crf2007c. These solutions are routinely compared to the current ICRF and are available through the previously mentioned Web site: `http://rorf.usno.navy.mil/solutions/`.

During 2007, Analysis Center personnel performed a variety of CRF related research activities with the purpose of improving the present ICRF and preparing for future VLBI-based reference frames. These activities included: the continued densification of the ICRF in the southern hemisphere through IVS-CRF and ATNF/USNO observations, investigations into the costs and benefits of adding the sources from the VLBA Calibrator Survey (VCS) to the CRF, time series analysis of source position variations for the purpose of source classification for ICRF-2, and production of a CRF based upon the 10 VLBA K-band experiments recorded as part of the K/Q-band high-frequency reference frame program. As an example, Figure 2 shows the sky distribution of the 266 sources with three or more delay observations at K-band (24 GHz). Although there have been only 10 K/Q-band experiments recorded from 2002 to present, the number of observations is 82,354, and the weighted RMS of the differences between the K-band CRF and the ICRF source positions is only a factor of ~2.8 times worse than our latest X/S-band CRF with over 5 million observations.

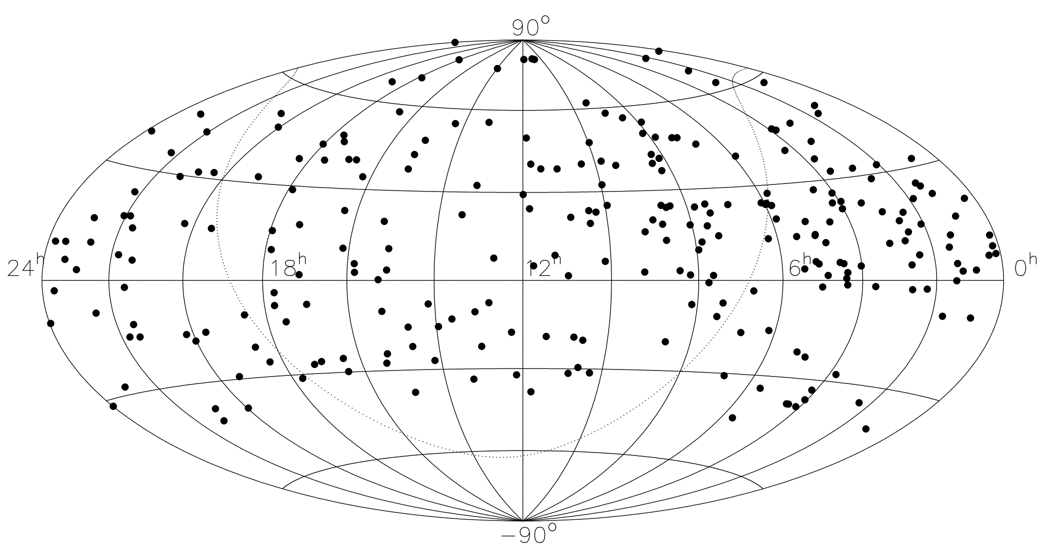


Figure 2. The distribution of the 266 sources with three or more observations at K-band (24-GHz) plotted on an Aitoff equal area projection of the celestial sphere. Observations were taken with the VLBA under the K/Q-band high-frequency reference frame program.

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, Sinex generation and submission, Web page administration, VLBI data analysis.
Alan Fey	Periodic global CRF solutions and comparisons, CRF densification research, Web page administration, VLBI data analysis.
Jennifer Bartlett	VLBI data analysis, EOP and database submission.
Zachary Dugan	VLBI data analysis, EOP and database submission.
Kerry Kingham	Correlator interface, VLBI data analysis.
David Hall	Correlator Interface, VLBI data analysis.

4. Future Activities

For the upcoming year January 2008–December 2008, USNO VLBI Analysis Center personnel plan to accomplish the following activities:

- Continue the processing of biweekly IVS-R1/R4 experiments for use in internal TRF and CRF global solutions and continue submission of IVS-R4 databases for dissemination by the IVS.
- Continue the production of periodic global TRF solutions and the submission of EOP-S estimates to the IVS updated by the IVS-R1/R4 experiments.
- 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 source characterization and the development of the second realization of the ICRF (ICRF-2).
- 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 2007. VLBA RDV experiments RDV61, RDV63, and RDV65 were calibrated and imaged. VLBA high frequency experiment BL122D was calibrated and imaged. Images from these four experiments, together with images from RDV28, were added to the USNO Radio Reference Frame Image Database. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Activities planned for the year 2008 include continued imaging of ICRF sources at standard and higher frequencies and continued analysis of source structure and its variation.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of ICRF sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The Web server for the Analysis Center is hosted by the USNO and can be accessed by pointing your browser to

`http://rorf.usno.navy.mil/ivs_saac/`

The primary service of the Analysis Center is the Radio Reference Frame Image Database (RRFID), a Web accessible database of radio frequency images of ICRF sources. The RRFID contains 4980 Very Long Baseline Array (VLBA) images (a 20% increase over the previous year) of 636 sources (a 23% increase over the previous year) at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 1339 images (a 16% increase over the previous year) of 270 sources (a 1% increase over the previous year) at frequencies of 24 GHz and 43 GHz. The RRFID can be accessed from the Analysis Center Web page or directly at

`http://www.usno.navy.mil/rrfid.shtml`

The RRFID also contains 74 Australian Long Baseline Array (LBA) images of 69 southern hemisphere ICRF sources at a radio frequency of 8.4 GHz.

Shown in Figure 1 is the distribution throughout the sky of the sources which have been imaged at 2.3 GHz and 8.4 GHz.

2. Current Activities

2.1. VLBA Imaging

VLBA experiment RDV65 (2007AUG01) was calibrated and imaged, adding 203 (102 S-band; 101 X-band) images to the RRFID, including images of 48 sources (0048-427, 0054+161, 0102+511, 0103+127, 0111+131, 0137+012, 0137+467, 0208-512, 0209+168, 0325+395, 0410+110,

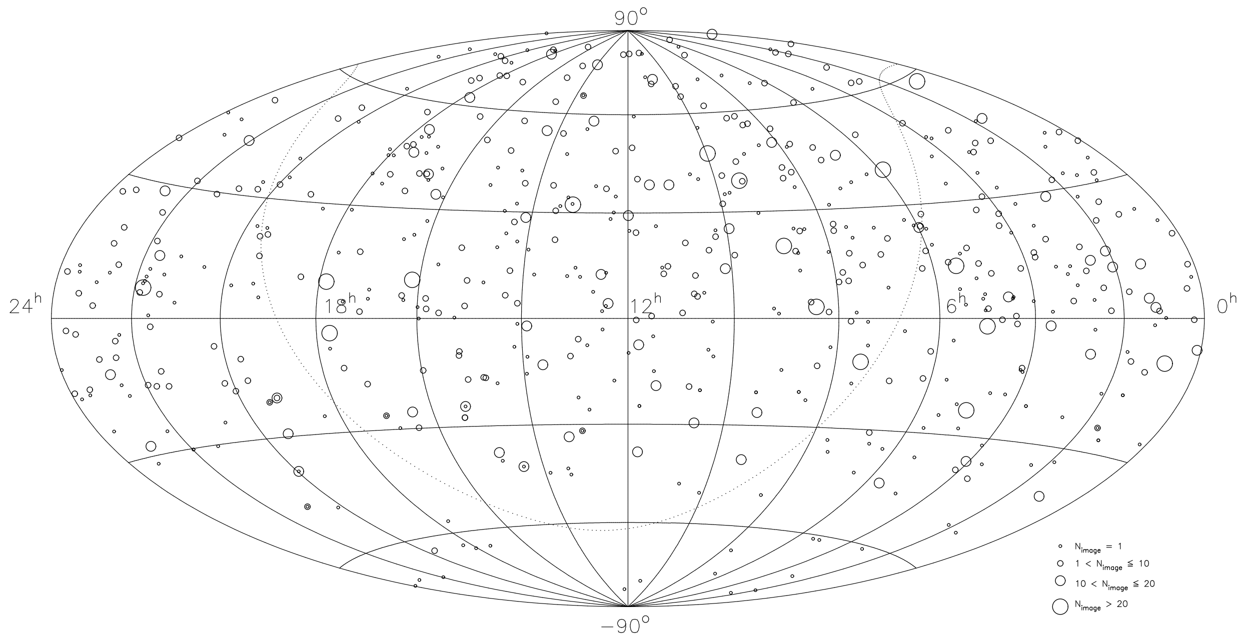


Figure 1. Distribution of the sources which have been imaged at 2.3 GHz and 8.4 GHz shown on an Aitoff equal area projection of the celestial sphere. The size of the open circles indicates roughly the number of times each source has been imaged as indicated by the key.

0411+054, 0423+237, 0537-286, 0645+209, 0723+219, 0906-048, 0927+469, 1003+351, 1010+495, 1046-026, 1055-242, 1100+122, 1107+485, 1117-248, 1143-332, 1200+468, 1241+166, 1246+489, 1412+461, 1421+122, 1541+050, 1623-243, 1627+476, 1639-062, 1645+174, 1645+271, 1648+084, 1745+670, 1746+470, 1820-274, 1822+033, 1908+484, 2013+508, 2018+282, 2135-184, 2304+377 and 2319+317) not previously imaged.

VLBA experiment RDV63 (2007JUN26) was calibrated and imaged, adding 210 (105 S-band; 105 X-band) images to the RRFID, including images of 49 sources (0025+197, 0134+311, 0211+171, 0239+175, 0307+380, 0312+100, 0415+398, 0442+389, 0548+378, 0641+392, 0729+259, 0743+277, 0747+185, 0828-222, 0951+268, 0958+346, 1013+127, 1040+244, 1054+004, 1059+282, 1125+366, 1145+268, 1212+171, 1218+339, 1306+360, 1348+308, 1424+366, 1441+252, 1520+319, 1608+243, 1639+230, 1651+391, 1722+330, 1725+123, 1736+324, 1754+155, 1846+322, 1909+161, 2000+148, 2013+163, 2029+024, 2155+312, 2201+044, 2205+166, 2205+743, 2214+350, 2216+178, 2318-195, and 2358+189) not previously imaged.

VLBA experiment RDV61 (2007JAN24) was calibrated and imaged, adding 217 (109 S-band; 108 X-band) images to the RRFID, including images of 17 sources (0035-024, 0459+252, 0521-365, 0629+160, 0812+020, 1056+212, 1104-445, 1119+183, 1142+052, 1200+045, 1216+061, 1337-033, 1508-055, 1721+343, 1933-400, 2329-384 and OL224) not previously imaged.

VLBA experiment RDV28 (2001MAY09) was calibrated and imaged, adding 186 (93 S-band; 93 X-band) images to the RRFID, including images of 4 sources (0528-250, 0826-373, 1239+376 and NGC6454) not previously imaged. These results were contributed by Glenn Piner and Corey Nichols of Whittier College who calibrated, edited, and imaged the data.

Two 24-hour epochs of full polarization VLBA observations of AGN whose scintillation status (i.e. whether they exhibit scintillation or not) is known, were calibrated, imaged and model fit. This is part of an ongoing program to study the morphology of scintillating and non-scintillating extragalactic sources and to explore the possibility of using the presence of scintillation to identify good new candidate reference frame sources.

Collaborations continue with Glenn Piner at Whittier College and Patrick Charlot of Bordeaux University to calibrate and image several of the VLBA RDV experiments.

2.2. VLBA High Frequency Imaging

VLBA observations to extend the ICRF to 24 and 43 GHz continued in 2007. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO) and Bordeaux Observatory. During the calender year 2007 one VLBA high frequency experiment, BL122D (2007MAR30), was calibrated and imaged adding 185 (K-band only) images to the RRFID including images of 4 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. One celestial reference frame experiment, CRF-S11, was scheduled with antennas at Hobart, Australia, Hartebeesthoek, South Africa and the 70-meter Deep Space Network antenna at Tidbinbilla, Australia.

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 was initiated. The program, called TANAMI (Tracking Active galactic Nuclei with Australia Milliarcsecond Interferometry), will observe a sample of about 44 quasars at 8 GHz and 24 GHz bands, with half of the sample observed every two months. The first epoch of observations was scheduled and observed.

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 2008 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

Technology Development Centers

Technology Development Centers

Canadian VLBI Technology Development Center

Bill Petrachenko

Abstract

The Canadian VLBI Technology Development Center (TDC) is actively involved in theoretical studies to define recommendations for the VLBI2010 system. In addition, two development programs at the Dominion Radio Astrophysical Observatory (DRAO) are of potential interest to VLBI2010. Composite antennas that are light, stiff and cost-effective are being developed for the SKA, and a state-of-the-art correlator is being developed for the EVLA.

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).

A number of the activities of the Canadian TDC were discontinued this year due to the cessation of VLBI operations in Canada. These include the development and maintenance of the S2 VLBI system and the Canadian Transportable VLBI antenna (CTVA).

2. VLBI2010 Committee

Activity within the Canadian TDC is now focussed primarily on supporting recommendations for IVS's VLBI2010. This is being done through Bill Petrachenko's participation as chairman of the V2C. In addition to his leadership role, he has taken an active interest in the feasibility of generating source structure corrections, in particular, the alignment of images at different frequency bands. Simulations are ongoing. He also made significant contributions to defining recommendations for VLBI2010 antenna slew parameters. In collaboration with Toni Searle of NRCan, schedules were generated to test the dependence of position accuracy on source switching interval. These schedules were then processed through the Monte Carlo Simulators at TU Wien by Joerg Wresnik and Andrea Pany and at NASA GSFC by Dan MacMillan. Using the results, it was possible to develop relations between performance and slew parameters to provide a theoretical backing for the VLBI2010 slew parameter recommendation.

3. DRAO Activities

DRAO has a long history of participation in VLBI beginning with the first ever successful fringes in 1967. Expertise exists in a number of relevant disciplines from innovative antenna/feed/receiver design to the design and implementation of large complex digital systems.

Of particular interest to VLBI2010 are the composite antennas being designed for the Square Kilometer Array (SKA) project. These are 12 m antennas based on composite materials that are light, stiff and cost effective. Under the leadership of Dean Chalmers and Gordon Lacy, a first prototype antenna (10 m) was produced in the summer of 2007. Both holography and a laser scanning system verified that the antenna surface is good to at least 15 GHz. A second prototype is expected in spring of 2008. As a result of process development, a significant improvement in surface accuracy is expected.

In addition to the SKA antenna development effort, DRAO, under the leadership of Brent Carlson and Dave Fort, is producing the correlator for the EVLA project. It is one of the most ambitious radio interferometry correlators ever conceived, handling, in real time, 32 stations at a maximum data rate of 96 Gbps per antenna. Although primarily intended for connected element interferometry, it was also designed to be VLBI capable. An adaptation of the EVLA design capable of handling VLBI2010 requirements has been investigated.

Figure 1. Ten meter prototype composite antenna at DRAO being prepared for holographic testing.

FFI Technology Development Center - Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center focuses primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS, and SLR. This report shortly summarizes the latest improvements of the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. The GEOSAT Software

FFI's contribution to the IVS as a Technology Development Center focuses primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS, and SLR. The advantages of the combination of independent and complementary space geodetic data at the observation level are discussed in Andersen ([1]). After five years of development and extensive validation we are proud to announce that a major revision and extension of the GEOSAT software has been completed. The most important changes implemented have been described in recent IVS Annual Reports. Much more flexibility and automation have been added. Furthermore, the latest and "best" models (mostly following the IERS Standard) and "calibration tables" and "instrumental/geophysical events tables" have been included. Analysis of tracking data to S/C's in deep space has been added. The software automatically detects the central body if any (the Earth or a body in the solar system) and accordingly performs the analysis either in a local geocentric frame of reference (if the Earth is the central body) or in a solar system barycenter frame of reference. It is for example in principle possible to calculate the trajectory of the S/C and the orbit and gravity field of the central body. For any technique, the delay due to the troposphere is determined with 3D raytracing using the European Center for Medium-range Weather Forcast Numerical Weather Model. No mapping functions are used and the corrections are determined directly from interpolation in the raytracing files. The tropospheric correction for SLR is rescaled using actual surface met data. For microwave data (GNSS and VLBI) this is of no importance since empirical zenith delay parameters must be estimated.

2. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

GSFC Technology Development Center Report

Ed Himwich, John Gipson

Abstract

This report summarizes the activities of the GSFC Technology Development Center (TDC) for 2007 and forecasts planned activities for 2008. 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, and 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 of development that are currently being pursued.

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 file (both as prepared by DRUDG from the .skd schedule). The FS controls the antenna, data acquisition hardware, and related ancillary equipment needed for making VLBI measurements. All major VLBI data acquisition backends are supported. The FS is customizable to allow it to control station specific equipment. It is used at all the IVS network stations (over 30) and also at many stations that do VLBI only for astronomical observations. The only major observatories not using it are the VLBA and VERA.

During this period some of the new features that were released in FS version 9.10 were:

- Support was added for Mark 5B recorders and sampler modules. This included developing documentation for operations with these systems.
- The FS Linux 6 distribution (based on Debian 'sarge') was developed and deployed. This included changing to use a RAID1 array for the system disks and developing new disk back-up and rotation procedures for RAID disks.
- The 'systests' system test data acquisiton and analysis suite was improved and updated. This included support for new hardware systems and expanded capabilities for analysis and plotting.
- Numerous small bug fixes and improvements were added.

In the next year, several other improvements are expected; among these are: (1) Support for DBBC and DBE racks, (2) a complete update to the documentation and conversion to a more modern format that will be easier to use; (3) conversion of the FORTRAN source to use the g77 compiler; this will enable use of the source level debugger, *gdb* for development and field debugging; (4) use of *fsvue* or Real VNC for remote operation; (5) *chekr* support for Mark 5A and 5B systems; (6) use of the Mark IV Decoder for phase-cal extraction in the field; (7) FS Linux 7 ('etch') development; and (8) support for periodic firing of the noise diode during observations.

3. SKED and DRUDG

The GSFC TDC is responsible for the development, maintenance, and documentation of SKED and DRUDG. These two programs are very closely related, and 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 as input to DRUDG for making the control files and procedures for their station. Catalogs are used to define the equipment, stations, sources, and observing modes which are selected when writing a schedule with SKED.

During 2007 many changes were made to SKED and DRUDG. SKED and DRUDG continue to improve because of changing needs and users' requests. In both SKED and DRUDG, the maximum number of stations was increased to 40, the maximum number of sources to 1000, and the maximum number of scans to 20,000. Many changes were made to SKED to support simulation studies for VLBI2010. Other changes were made to make scheduling easier. The following summarizes some of the SKED and DRUDG changes.

3.1. SKED

The following changes were made to SKED.

- SKED used to have an implicit limit of only scheduling for 24 hours. The user can now schedule for longer than 24 hours.
- Fixed a bug in the calculation of total recorded bits when using Mark5. In most cases, the number of data channels taken is the same as the number of data channels recorded. Sometimes this is not true because Mark5 is limited to recording 4, 8, 16, 32 or 64 channels. If the number of data channels taken is not a power of 2, some channels are duplicated in recording. For example, in the R4's prior to 2006, only 14 data channels were taken, although 16 channels were recorded using Mark5. The first two channels were recorded twice. Another example occurs where some stations do not have the full complement of BBCs. Sked used to calculate the total disk requirement using the amount of data taken. It now uses the amount of data recorded.
- Changes were made to the downtime command to make it more flexible.
- A bug in the time window command was fixed. The command *major last x* is supposed to set the time window to x hours. Here the time window is used in calculating sky coverage and covariance information. We discovered that SKED ignored this parameter and used all observations regardless of the value of x. This was fixed.
- The *fill-in* mode was made more flexible. Previously the minimum sub-net size and the length of idle time before considering were hard-wired. These are now user settable parameters.

- The *master* command was introduced. This has two modes: *master check* checks the schedule against the master file to make sure that the stations and the times are correct; *master get* reads the stations and the times from the master file and modifies the schedule accordingly. The location of the master file must be specified in the `master` line of `skedf.ctl`, e.g.: `master /usr/local/bin/master08.txt`.
- The extended listing command was made more flexible. Previously any time you turned on one option it would turn off all other options. It now toggles the options, and many options can be specified on a line.
- A sky coverage function was added. SKED divides the sky into 13 equal sized pixels at each station. The pixel number for each station, and the total number of distinct pixels covered over the preceding time window can be displayed by turning on the 'sky' extended listing: *xl sky*. The time window considered is specified by the major command: *maj last 0.5* sets a time window of 0.5 hours.

3.2. DRUDG

The following changes were made to DRUDG.

- Many changes were made to support changing specifications.
- Two new rack types were introduced: Mark 5 and VLBA5.
- Dymo printer support was added for FS Linux 6 ('sarge'). The *cups* driver had a bug which we had to work around.
- Various minor bugs were fixed.

Haystack Observatory Technology Development Center

Alan Whitney, Arthur Niell

Abstract

Work at MIT Haystack Observatory is currently focusing on four areas: Mark 5C VLBI data systems, e-VLBI, digital backends, and VLBI2010 progress. We will describe each of these areas.

1. Mark 5C VLBI Data System

The Mark 5C is being designed as the next generation Mark 5 system, with a capability of recording sustained data rates up to 4096 Mbps. It will use the same disk modules as the Mark 5A and Mark 5B, thus preserving existing investments in disk modules. The Mark 5C data interface for both recording and playback will be 10 Gigabit Ethernet, which is rapidly becoming a widely supported standard. The use of 10GigE interfaces comes with some significant implications, however. Firstly, data sources must be designed to provide data streams in a format compatible with the Mark 5C requirements. And secondly, data playback through a 10GigE interface is a good match for a rising generation of software correlators. In the interests of backwards compatibility, the Mark 5C will also support a mode which writes disk modules in Mark 5B data format which can be correlated on existing Mark IV correlators that support Mark 5B. Some other characteristics of the Mark 5C include:

- The standard Mark 5C Ethernet packet format prescribes that each packet contains data from only a single frequency channel. Unlike almost all previous VLBI data systems, which constrain the number of recorded frequency channels to be 2^n, the Mark 5C will allow an arbitrary number of channels to be recorded.
- The Mark 5C will use the same Amazon StreamStor disk interface card as the Mark 5B+, but it will replace the FPDP I/O daughterboard with a newly designed (by Conduant Corporation) 10GigE interface card. Unlike Mark 5A/B/B+, no separate specialized I/O card is needed.
- At data rates above about 2 Gbps, it will be necessary to record to two 8-disk modules simultaneously in so-called 'non-bank' mode, which is not normally used by Mark 5A or Mark 5B/5B+.
- Mark 5C will include a Mark 5B emulation mode to create recorded disks that are in the Mark 5B data format and can be correlated directly on a Mark IV correlator.

The first prototype Mark 5C systems are expected to be available in mid-2008. Additional detailed information about the Mark 5C systems is available in the Mark 5 memo series (*http://www.haystack.edu/tech/vlbi/mark5/memo.html*), particularly memos 57, 58, 61, and 62.

2. e-VLBI Development

Haystack Observatory continues to develop the e-VLBI technique for VLBI data transfers:

- <u>Implementation of automated e-VLBI data transfer capability at MPI correlator</u>: Haystack has worked with the Bonn correlator at MPI to implement an e-VLBI data transfer capability similar to that at Haystack Observatory. This allows the direct transfer to Bonn of data that will be correlated there. Data from Onsala, Ny-Ålesund and Japan are now transmitted regularly to Bonn over their 1 Gbps network connection.

- 10GigE connection to Haystack: A 10 Gigabit network connection from Washington, D. C. to Haystack over the Bossnet network has been inaugurated in cooperation with MIT Lincoln Laboratory. This link is important for e-VLBI data transfers to Haystack and for the testing of the new VLBI2010 demonstration broadband system utilizing the Westford and MV-3 (at NASA/GSFC) antennas.
- Real-time e-VLBI processing of Mark 5B data: Work is nearly complete to support real-time e-VLBI using Mark 5B on the Mark IV correlator. We expect to use this system to demonstrate 2 Gbps real-time e-VLBI in the near future.

3. Digital Backends

In last year's Technology Development Center report, Haystack reported on the successful development of the first generation digital backend system, now called DBE1. The DBE1 system was developed collaboratively with the University of California at Berkeley using the so-called iBob board that was developed as a flexible general purpose radioastronomy signal processing platform using FPGA technology. DBE1 systems have now been successfully used in a number of geodetic and astronomical VLBI experiments. A second generation system, dubbed DBE2, is now being developed at Haystack based on a next generation iBob, dubbed iBob2. The iBob2 is being developed by Berkeley, NRAO, and South Africa as the common platform for digital backend development to meet the specific needs of both NRAO and Haystack. Haystack will design a polyphase-filter-bank (PFB) version of the FPGA code to process two 1 GHz-wide IFs into an 8 Gbps Ethernet packet stream compatible with the Mark 5C data system. NRAO, on the other hand, is planning to emulate several VLBA BBCs on an iBob2 board (dubbed VDBE), which will also produce a Mark 5C-compatible Ethernet data stream. The hardware for both the Haystack and the NRAO systems will be identical; only the FPGA code will be different, allowing an iBob2 system to adopt the personality of either DBE2 or VDBE. The cost of a DBE2/VDBE system is not yet well established, but will likely be considerably less than US$10K. The first prototype DBE2/VDBE systems are expected to be available for testing in mid-2008.

4. VLBI2010

The major innovation of the VLBI2010 concept is the use of a relatively small antenna (~12 m) with a receiver spanning a very wide bandwidth (~2-15 GHz). Observing will utilize four 0.5-1 GHz-wide bands spread across the 2-15 GHz receiver capability in order to gain a group delay precision sufficient to resolve the more accurate phase delay. This concept has come to be known as the *broadband delay* system.

Haystack Observatory has been working with NASA/GSFC and HTSI, along with consultation from Bill Petrachenko and others, to develop a demonstration system using the broadband delay concepts. Several advances in technology are necessary in order to create such a system:

Broadband feed: Only recently have feeds with sufficient bandwidth become available to implement the broadband concept. The feed for our initial tests is a commercial wideband (2-13 GHz) unit, chosen because it is readily available and relatively inexpensive. A specially designed feed for VLBI2010 is expected to become available in a year or two. A complication is that these feeds receive linear polarization, not the circular polarization that we have traditionally used; in order to deal with antenna parallax differences, it will be necessary to capture both linear polarizations.

Digital backend: Digital backends are a necessity for the broadband systems for several reasons: 1) absolute uniformity and repeatability, 2) wide-bandwidth capabilities, and 3) low cost. For the demonstration system, the DBE1 unit designed jointly by Haystack Observatory and the University of California at Berkeley is being used.

High-data-rate data-acquisition system: Multiple Mark 5B+ systems, capable of recording 2 Gbps each, were used at each antenna in the demonstration systems. Processing was done on the Mark IV correlator at Haystack Observatory. The Mark 5C development, described above, will be capable of recording 4 Gbps on each system.

In order to demonstrate that the broadband concept is feasible, we have implemented a broadband demonstration system, using the Westford and MV-3 (at NASA/GSFC) antennas, that utilizes all of the components of a broadband delay system. The combined sensitivity of these two antennas is somewhat less than that of two high-efficiency 12 m antennas but sufficient to demonstrate that the concept is valid.

The broadband demonstration system consists of the above-mentioned commercial feed to cover the frequency range ∼2 GHz to ∼13 GHz in two linear polarizations, along with two low-noise amplifiers (LNAs). The feed and the LNAs are both cooled to approximately 20K, and the output of each LNA is carried over wideband "RF" optical fiber to the control room where the signals are split into four paths corresponding to the four frequency bands. An Up-Down Converter (UDC) translates both polarizations of each band to a common 500 MHz-wide intermediate frequency (IF) that is digitized and filtered by the Digital Backend and recorded on a Mark 5B+ recorder. To observe in four bands requires four UDCs, four Mark 5B+s and two dual-board DBE1s at each site.

One entire broadband system was installed on MV-3 during the last week of October. The Dewar was mounted at the Cassegrain focus in the location of the original X-band feed, as can be seen in Figure 1. For the first test we observed at X-band in the usual geodetic band. Westford used the operational NASA X-band receiver and LO but recorded using a DBE1 and Mark 5B+. Since only one band was being recorded, the data rate was only 2 Gbps.

On 19 November 2007 fringes were found for both linear polarizations from MV-3. Vertical polarization was carried on optical fiber, horizontal on coax. The SNRs on 3C279 were 127 and 117 for 125 seconds of data, close to our predictions. The system temperatures were measured as approximately 45K and 35K on fiber and coax, respectively. Some fringe-phase differences between the polarizations were observed that are not yet understood and are being studied. We have also begun construction of an identical system for Westford where the Dewar will be mounted at prime focus. Eight UDCs and four dual-board DBEs will be constructed to observe in four frequency bands. At that time the next round of testing will evaluate the efficiency of the broadband system mounted on the Westford antenna.

5. Acknowledgements

The broadband demonstration system is funded by NASA's Earth Surface and Interior Focus Area through the efforts of John LaBrecque, Chopo Ma, and Herb Frey.

Figure 1. Jay Redmond and Bruce Whittier installing the Dewar on the 5 m MV-3 antenna.

Important contributions were made by all participants: Arthur Niell and the BBDev Team (in reverse alphabetical order) Bruce Whittier, Mike Titus, Jason SooHoo, Dan Smythe, Alan Rogers, Jay Redmond, Mike Poirier, Chuck Kodak, Alan Hinton, Ed Himwich, Skip Gordon, Mark Evangelista, Irv Diegel, Brian Corey, and Tom Clark.

In addition, the system could not have been put together without the work of Sandy Weinreb and Hamdi Mani of Caltech, whose design of the Dewar, feed, and LNAs has been copied directly. Beyond that they have generously provided advice as we constructed the front end for MV-3. We also want to thank Dan MacMillan, Peter Bolis, Don Sousa, and Dave Fields for their help; Photonics Systems, Inc. and Linear Photonics, Inc. for loaning us the fiber optic link; and Shep Doeleman of Haystack for his significant contributions to the successful implementation of the DBE technology.

Technology Development Center at NICT

Tetsuro Kondo, Yasuhiro Koyama, Ryuichi Ichikawa, Mamoru Sekido

Abstract

National Institute of Information and Communications Technology (NICT) has led the development of VLBI technique and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1. TDC at NICT

National Institute of Information and Communications Technology (NICT) has published the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" at least once a year in order to inform about the development of VLBI related technology as an IVS technology development center. The newsletter is available through the Internet at 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 at NICT who are involved in the VLBI technology development center at NICT.

Table 1. Staff Members of NICT TDC as of December, 2007 (alphabetical).

Name	Works
HOBIGER, Thomas	VLBI analysis
ICHIKAWA, Ryuichi	CARAVAN* system, Delta-VLBI, VLBI analysis
ISHII, Atsutoshi	CARAVAN system
KAWAI, Eiji	34m and 11m antenna system
KIMURA, Moritaka	e-VLBI, Giga-bit system, K5/VSI, Software correlator
KONDO, Tetsuro	e-VLBI, K5/VSSP32, Software correlator
KOYAMA, Yasuhiro	e-VLBI, VLBI analysis
KUBOKI, Hiromitsu	Antenna system, CARAVAN system (left our group in December 2007)
SEKIDO, Mamoru	e-VLBI, Delta-VLBI, VLBI analysis
SHIRATO, Kazuyuki	Antenna system, e-VLBI
TAKEFUJI, Kazuhiro	e-VLBI (joined our group in December 2007)
TAKIGUCHI, Hiroshi	e-VLBI, VLBI analysis
TSUTSUMI, Masanori	e-VLBI, K5 system

* CARAVAN: Compact Antenna of Radio Astronomy for VLBI Adapted Network system

3. Current Status and Activities

3.1. e-VLBI

We have been developing an "ultra-rapid UT1 measurement" system by using an e-VLBI technique in collaboration with Geographical Survey Institute (GSI Tsukuba, Japan), Onsala Space Observatory (Sweden), and Metsähovi Radio Observatory (Finland). The locations of these stations and a block diagram of the data flow and data processing are indicated in Figure 1. NICT and Metsähovi have developed the PC-based VLBI data acquisition systems K5/VSSP and VSI-B, respectively. Additionally Metsähovi developed "real-time Tsunami", which is a UDP-based network data transport software for VLBI. These technologies enabled real-time data transfer in 256 Mbps observation mode. We started the near-real-time UT1-observation project in April 2007. Observation data were transferred from Nordic stations to Kashima with the 'Tsunami' software in real time. Then correlation processing and data analysis was performed with software correlator developed at NICT and CALC/SOLVE software package developed at GSFC. We made an automated pipeline data processing system. Consequently, UT1 determinations with a minimum latency of 30 minutes became available by the end of May 2007. The UT1 data measured by this project is plotted in Figure 2, where the UT1 data by e-VLBI observation is compared with prediction and rapid combined solution of Bulletin-A. The plot indicates that the UT1 values observed on these baselines have the same accuracy level as the rapid combined solution. This e-VLBI project will be continued with the aim of (a) confirming stable operability of ultra-rapid UT1 observation with e-VLBI technology, (b) improving the observation precision using higher data rates, and (c) showing consistency of ultra-rapid UT1 results with standard IVS results.

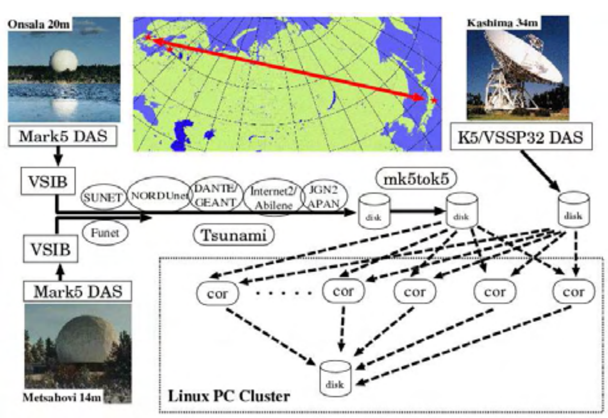


Figure 1. VLBI stations participating in the Ultra-rapid UT1 measurements and a block diagram of the data flow and data processing.

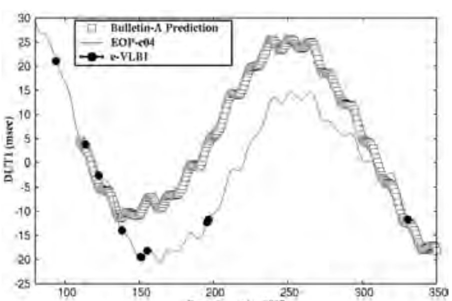


Figure 2. Comparison of UT1-UTC from EOPc04, prediction of Bulletin-A, and e-VLBI observation. A linear trend of UT1-UTC has been removed in advance. It is obvious that UT1 measured by e-VLBI observation has higher precision than prediction values.

3.2. CARAVAN2400 – Contribution to VLBI2010

We have been developing a 2.4 m antenna VLBI system named CARAVAN2400 for various R&D purposes, such as to evaluate the performance of a small antenna system as geodetic VLBI system and to test the design of antenna system in VLBI2010, among other things.

Geodetic VLBI with a Gigabit system. In 2006, first geodetic VLBI observations using the CARAVAN2400 were successfully conducted with Tsukuba 32 m antenna (baseline length is about 54 km) at X-band using a conventional multi-channel back end system. Eight video channel signals, each with an 8 MHz bandwidth in X-band, were sampled using K5/VSSP samplers at both stations. We carried out an experiment again on February 1, 2007, this time to evaluate the performance of a gigabit system (K5/VSI with 1ch×512MHz) by comparing a geodetic result with that observed by multi-channel system (K5/VSSP with 8ch×8MHz) simultaneously. The purpose is to utilize evaluation results to a planned small antenna system dedicated to the precise measurement of a reference baseline maintained by GSI for the calibration of surveying equipment. Both results coincide well with each other as shown in Table 2.

Table 2. Baseline length between CARAVAN2400 and Tsukuba 32m observed by K5/VSSP and K5/VSI

	K5/VSSP (8ch×8MHz)	K5/VSI (1ch×512MHz)
Length (mm)	53814844.5±1.9	53814844.9±4.5

Implementation of a wide-band feed—realizing the smallest S/X band receiving antenna. A quad-ridge horn antenna (QRHA) (Figure 3) that covers 2-18 GHz has been installed at a main focus point of CARAVAN2400 as a wide-band feed in November 2007. Wide-band RF signals received by the QRHA are filtered to S and X bands by a diplexer and fed to a VLBI backend. A fringe test was carried out on December 5, 2007, and fringes were successfully found for both S and X bands (Figure 4).

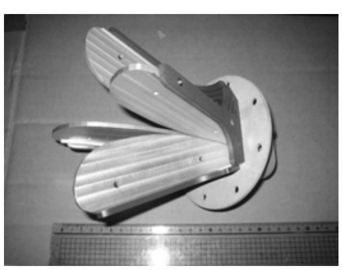


Figure 3. A quad-ridge horn antenna (QRHA). It covers 2-18 GHz.

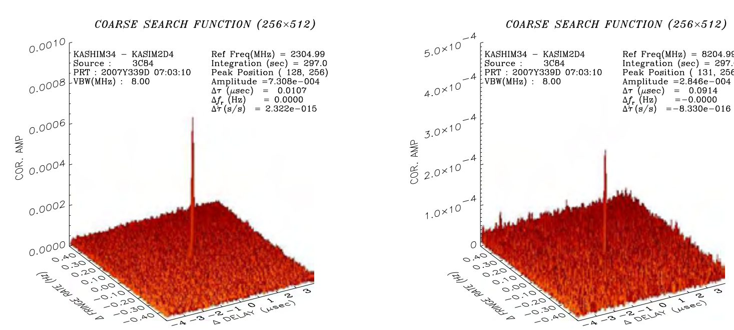


Figure 4. Fringes on S-band (left) and X-band (right) detected by CARAVAN2400 equipped with a QRHA.

3.3. VLBI Using Cs Gas-cell Frequency Standard

A laser-pumped Cs gas-cell atomic frequency standard (Cs gas-cell standard) developed by Anritsu Co. Ltd. [1] is more stable than the conventional Cs frequency standard and cheaper than the hydrogen maser frequency standard. A VLBI experiment was performed between Kashima 34 m and Koganei 11 m on July 19, 2007 in order to evaluate its capability in the geodetic VLBI experiments. At Kashima, the LD-pumped Cesium gas-cell atomic frequency standard (Cs gas-cell standard) was used in place of the hydrogen maser standard. Although the Allan variance of the Cs gas-cell standard is worse by a factor of about ten than that of the hydrogen standard, the analyzed baseline result was almost identical to previous results.

3.4. K5 Samplers

NICT has developed two types of samplers: 1) ADS series sampler equipped with a VSI-H interface; 2) VSSP series sampler not equipped with a VSI-H but directly connectable to a host PC. Samplers developed by NICT are summarized in Table 3. Besides NICT, K5/VSSP32 is now also used routinely for observing at GSI.

Table 3. Specifications of the K5 samplers.

	ADS1000	ADS2000	ADS3000	K5/VSSP	K5/VSSP32
Ref. Sig.	10 MHz 1 PPS	10 MHz 1 PPS	10 MHz 1 PPS	10 MHz 1 PPS	10/5 MHz 1 PPS
# of Input Ch.	1	16	1	4	4
A/D bits	1, 2	2	8	1, 2, 4, 8	1, 2, 4, 8
Sampling Freq. (MHz)	512, 1024	2, 4, 8, 16, 32, 64	2048	0.04, 0.1, 0.2, 0.5, 1, 2, 4, 8, 16	0.04, 0.1, 0.2, 0.5, 1, 2, 4, 8, 16, 32, 64
Output Interface	VSI-H	VSI-H	VSI-H ×2	PCI-bus	USB2.0
Function	—	PCAL detection	DBBC etc.	—	digital LPF

4. Future Plans

We have started, in collaboration with GSI, the development of a 1.6m antenna system equipped with a wide-band feed for the MARBLE (Multiple Antenna Radio-interferometry for Baseline Length Evaluation) project that is a project to measure a reference baseline maintained by GSI by using the VLBI technique for the calibration of surveying equipment. Fringe tests will be carried out in 2008. Regarding a sampler's development, we will make improvements of ADS3000 so as to realize multi-channel DBBC.

References

[1] Ouchi, Y., H. Suga, M. Fujita, T. Suzuki, M. Uchino, K. Takahei, M. Tsuda, and Y. Saburi, A high-stability laser-pumped Cs gas-cell frequency standard, *Proc. 2000 IEEE/EIA International Frequency Control Symposium and Exhibition,* pp.651–655, 2000.

The IVS Technology Development Center at the Onsala Space Observatory

Rüdiger Haas, Magne Hagström, Lars-Göran Gunnarsson, Karl-Åke Johansson, Miroslav Pantaleev, Gunnar Elgered

Abstract

We briefly describe the technical development during 2007 that is related to geodetic VLBI. The work focussed mainly on a new S/X receiver, a new time lab, and the radiometers.

1. The New Dual Polarization S/X Receiver for the 20 m Telescope

The new dual polarization S/X-receiver [1] was installed in the summer of 2007 on the 20 m telescope. In the fall additional filters were installed for right circular polarization, since spurious phase cal signals were detected during several experiments in the low X-band channels. The left circular polarization will be equipped in early 2008 with better filters, too. It is not yet possible to read the temperature and the pressure of the cooling system for the HEMT amplifiers directly with the Field System. Work is in progress to make this possible during 2008.

2. The New Time Lab at the Observatory

In the spring of 2007 a second maser was installed at the observatory in collaboration with SP Technical Research Institute of Sweden. The aim of the project is to establish a time lab at Onsala with two masers, a cesium clock, and equipment for GPS time measurements that contributes to the generation of UTC at BIPM. Another part of the project is the development of accurate time synchronization using the high speed optical fiber connection at Onsala. Figure 1 shows time differences with respect to GPS time as measured with the TAC at the observatory, for the old maser HM01 (Kvarz CHI75), installed in March 1997, and the new maser HM02 (Kvarz CHI-75A), installed in April 2007. Figure 2 shows the two masers and the racks with GPS time receivers and other equipment in the temperature and humidity stabilized time lab.

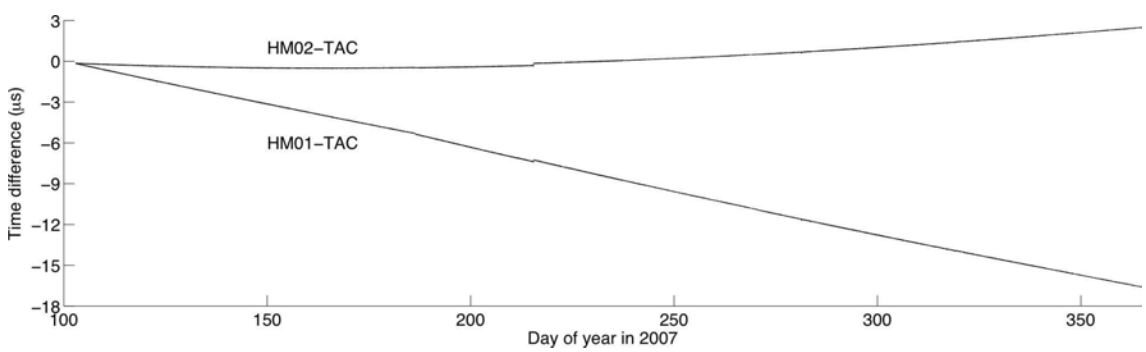


Figure 1. Time differences of the two masers HM01 and HM02 with respect to the GPS-TAC.

Figure 2. Time lab at Onsala: a) Rack with, for example, GPS TAC, several 5 MHz distributions, pulse distribution unit, b) HM01: Kvarz CHI-75 installed in March 1997, c) HM02 Kvarz CHI-75A installed in April 2007, d) Rack with, for example, GPS time receivers, AOG (Auxilliary Output Generator) for UTC generation, and space for the Cesium clock (to be installed during 2008).

3. The Microwave Radiometers at Onsala

Both microwave radiometers, Astrid [2] and Konrad [3], were in maintenance during 2007. The unstable power supply and the hot load in the 31.4 GHz channel of Astrid were repaired, and Astrid has worked again since November. The problems with the azimuth and elevation drives of Konrad have not been solved yet. We expect that the ongoing repair work will be successful and that Konrad will be working again in early 2008.

4. A Superconducting Gravimeter at Onsala

During 2007 we started a project to install a superconducting gravimeter at the observatory. This project involves the construction of a new gravimeter house that will host the superconducting gravimeter and additionally a platform for absolute gravimeter measurements. The location of this new building was chosen based on a stability survey of the bedrock at the observatory with a ground penetrating radar. Construction work will start in early 2008, and we expect the gravimeter to be installed in mid-2008. Work is ongoing to develop and install sensor systems to monitor environmental parameters such as ground water level, sea level, and wind forces.

5. Participation in a VLBI2010 Feed Project

In late 2007 we discussed the possibility of participating in a VLBI2010 feed project in collaboration with the antenna group at Chalmers University of Technology the Norwegian Mapping Authority, the Goddard Space Flight Center, and other potentially interested groups. The project will aim at the design and construction of a prototype for a dual linearly polarized feed horn covering 2-15 GHz that should work in a cooled environment. We hope that this project will be started in early 2008.

6. Outlook and Future Plans

We will work on an improvement of the new S/X receiver, in particular to suppress spurious phase cal signals in the right circular polarization but also to improve the left circular polarization. We will also develop the capability of reading important parameters of the receiver directly with the FS.

The time lab will be equipped with a Cesium clock during 2008, and in collaboration with SP, time synchronization via optical fiber will be developed.

We will focus on an upgrade of the azimuth and elevation drives of the Konrad radiometer, and we expect to have them in place and properly working again in early 2008.

The superconducting gravimeter will be installed during 2008, and we will develop and install various sensors to monitor environmental parameters.

We plan to be a partner in a possible VLBI2010 feed project, especially given the cryogenic expertise that is available at our observatory.

References

[1] Haas, R., Hagström, M., Nilsson, T., Elgered, G.: The IVS Technology Development Center at the Onsala Space Observatory. In: D. Behrend and K. Baver (eds.): *International VLBI Service for Geodesy and Astrometry 2006 Annual Report*, NASA/TP-2007-214151, 263–265.

[2] Elgered, G., and Jarlemark, P.O.J.: Ground-Based Microwave Radiometry and Long-Term Observations of Atmospheric Water Vapor, *Radio Science*, **33**, 707–717, 1998.

[3] Stoew, B., and Rieck, C.: Dual Channel Water Vapour Radiometer Development. In: W. Schlüter and H. Hase (Eds.): *Proceedings of the 13th Working Meeting on European VLBI for Geodesy and Astrometry*, 261–264, 1999.

Bibliography

Bibliography

Bibliography

1. Introduction

The following bibliography compiles papers that were published in the field of geodetic and astrometric VLBI during the year 2007. There is no distinction between peer-reviewed, reviewed or proceedings publications. This list is by no means exhaustive.

2. Geodetic and Astrometric VLBI Publications of 2007

C. Abbondanza, L. Vittuari, P. Sarti, M. Negusini: "An Analysis of Local Tie Vectors Temporal Evolution and Site Stability at Medicina Observatory through Terrestrial and GPS-based Observations". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 188–193, 2007.

W. Alef, A. Bertarini, A. Müskens: "The Bonn Mark IV Correlator for Astronomy and Geodesy". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 21–23, 2007.

W. Alef, D.A. Graham, H. Rottmann, A.L. Roy, A. Bertarini, A.T. Deller, S.J. Tingay: "Software Correlator at MPIfR: Status Report". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 24–26, 2007.

Z. Altamimi, X. Collilieux, C. Boucher: "Preliminary Analysis in View of the ITRF2005". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 685–691, 2007.

P.H. Andersen: "FFI Analysis Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 191–192, 2007.

P.H. Andersen: "FFI Technology Development Center – Software Development". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 246–247, 2007.

D. Angermann, H. Drewes, M. Krügel, B. Meisel: "Advances in Terrestrial Reference Frame Computations". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 595–602, 2007.

T. Artz, S. Böckmann, A. Nothnagel, V. Tesmer: "ERP Time Series with Daily and Sub-daily Resolution Determined from CONT05". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 69–74, 2007.

C.. Barache: "Paris Observatory (OPAR) Data Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 172–174, 2007.

D. Behrend: "Coordinating Center Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 13–14, 2007.

A. Bertarini, W. Alef, B.E. Corey, A. Nothnagel, R.C. Walker: "Effect on Geodetic-VLBI Measurables due to Polarization Leakage in the Receivers". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 50–52, 2007.

A. Bertarini, A. Müskens, W. Alef: "The Bonn Astro/Geo Mark IV Correlator". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 135–138, 2007.

M. Bérubé, A. Searle: "Algonquin Radio Observatory". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 33–35, 2007.

M. Bérubé, A. Searle: "Yellowknife Observatory". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 120–122, 2007.

G. Bianco, G. Colucci, F. Schiavone: "Matera CGS VLBI Station". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 63–66, 2007.

D. Boboltz, A. Fey, D. Hall, K. Kingham: "U.S. Naval Observatory VLBI Analysis Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 233–236, 2007.

S. Böckmann, T. Artz, R. König, H. Müller, A. Nothnagel, N. Panafidina, P. Steigenberger, D. Thaller, V. Tesmer: "Consistent VLBI, GPS and SLR Time Series of Station Positions and Troposphere Parameters". Geotechnologien Science Report No. 11, Observations of the System Earth from Space, ISSN 1619-7399, 60–63, 2007.

S. Böckmann, T. Artz, A. Nothnagel, V. Tesmer: "Comparison and Combination of Consistent VLBI Solutions". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 82–87, 2007.

J. Böhm, H. Schuh: "Forecasting Data of the Troposphere Used for IVS Intensive Sessions". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 153–157, 2007.

J. Böhm, H. Schuh: "Troposphere Gradients from the ECMWF in VLBI Analysis". Journal of Geodesy, 81 (6–8), 403–408, 2007. DOI 10.1007/s00190-007-0144-2.

S. Bolotin, Y. Yatskiv, S. Lytvyn: "IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 214–215, 2007.

G. Bourda, P. Charlot, R. Biancale: "GINS: a New Tool for VLBI Geodesy and Astrometry". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 59–63, 2007.

A. Brzeziński: "A Simple Digital Filter for the Geophysical Excitation of Nutation". Journal of Geodesy, 81 (6–8), 543–551, 2007. DOI 10.1007/s00190-006-0130-0.

R.M. Campbell, A. Szomoru: "Recent Developments at the EVN Mk IV Data Processor at JIVE". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 15–20, 2007.

P. Charlot, A. Bellanger, G. Bourda, A. Collioud, A. Baudry: "Bordeaux Observatory Analysis Center Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 181–184, 2007.

F. Colomer: "Observatorio Astronómico Nacional – Yebes". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 118–119, 2007.

L. Combrinck, M. Nickola: "Hartebeesthoek Radio Astronomy Observatory (HartRAO)". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 44–47, 2007.

J. Dawson, P. Sarti, G.M. Johnston, L. Vittuari: "Indirect Approach to Invariant Point Determination for SLR and VLBI Systems: an Assessment". Journal of Geodesy, 81 (6–8), 433–441, 2007. DOI 10.1007/s00190-006-0125-x.

S. Di Martino, S. La Delfa, G. Patané, M. Negusini: "Studying the Geodynamics of the Etnean Area by Means of VLBI and GPS". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 147–152, 2007.

H. Digre: "Ny-Ålesund 20 Metre Antenna". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 75–77, 2007.

K. Doi, K. Shibuya: "JARE Syowa Station 11-m Antenna, Antarctica". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 95–98, 2007.

A. Dyakov, S. Smolentsev: "Zelenchukskaya Radio Astronomical Observatory". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 123–124, 2007.

B. Engen: "INTENSIVE – A Strategic Approach to Improve Technology and Scientific Results". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 186–187, 2007.

S. Englich: "Determination of Earth Rotation Variations by Means of VLBI and GPS and Comparison to Conventional Models". Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 95 (2), 104–112, 2007.

L.V. Fedotov: "VLBI Terminal in Badary Observatory". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 222–224, 2007.

L. Fedotov, D. Ivanov, A. Ipatov, I. Ipatova, A. Lavrov, M. Kosobokov, A. Mikhailov: "Institute of Applied Astronomy Technology Development Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 255–258, 2007.

M. Feissel-Vernier, O. de Viron, K. Le Bail: "Stability of VLBI, SLR, DORIS, and GPS Positioning". Earth Planets Space, 59 (6), 475–497, 2007.

A. Fey: "The Status and Future of the International Celestial Reference Frame". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 603–609, 2007.

A. Fey, D. Boboltz, R. Ojha, R. Gaume, K. Kingham: "USNO Analysis Center for Source Structure Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 237–239, 2007.

S. Frey, I. Platais, A.L. Fey: "Linking Deep Astrometric Standards to the ICRF". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 111–115, 2007.

J.M. Gipson: "Incorporating Correlated Station Dependent Noise Improves VLBI Estimates". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 129–134, 2007.

A.-M. Gontier, S. Lambert, C. Barache: "Paris Observatory Analysis Center OPAR: Report on Activities, January–December 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 220–223, 2007.

D. Gordon, C. Ma, D. MacMillan, L. Petrov, J. Gipson, K. Baver: "GSFC VLBI Analysis Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 197–200, 2007.

R. Haas, G. Elgered: “The IVS Network Station Onsala Space Observatory”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 81–84, 2007.

R. Haas, M. Hagström, T. Nilsson, G. Elgered: “The IVS Technology Development Center at the Onsala Space Observatory”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 263–265, 2007.

R. Haas, H.-G. Scherneck, T. Nilsson: “The IVS Analysis Center at the Onsala Space Observatory”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 224–227, 2007.

R. Haas, J. Wagner, A. Mujunen, J. Ritakari, A. Müskens, C. Dulfer, A. Bertarini: “e-VLBI Data Transfer from Onsala and Metsähovi to the Bonn Correlator”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 27–32, 2007.

H. Hase, R. Dassing, G. Kronschnabl, W. Schlüter, W. Schwarz: “Twin-Telescope Wettzell (TTW)”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 158–162, 2007.

R. Heinkelmann, J. Böhm, H. Schuh: “Effects of Geodetic Datum Definition on the Celestial and Terrestrial Reference Frames Determined by VLBI”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 200–205, 2007.

R. Heinkelmann, J. Böhm, H. Schuh, S. Bolotin, G. Engelhardt, D.S. MacMillan, M. Negusini, E. Skurikhina, V. Tesmer, O. Titov: “Combination of Long Time-series of Troposphere Zenith Delays Observed by VLBI”. Journal of Geodesy, 81 (6–8), 483–501, 2007. DOI 10.1007/s00190-007-0147-z.

R. Heinkelmann, J. Böhm, H. Schuh, M. Schmidt: “Long-term Trends of Water Vapour from VLBI Observations”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 88–92, 2007.

R. Heinkelmann, M. Schmidt, J. Böhm, H. Schuh: “Determination of Water Vapour Trends from VLBI”. Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 95 (2), 73–79, 2007.

R. Hering, H.G. Walter: “On the Hipparcos Link to the ICRF Derived from VLA and MERLIN Radio Astrometry”. Journal of Geodesy, 81 (6–8), 479–482, 2007. DOI 10.1007/s00190-006-0109-x.

E. Himwich: “Network Coordinator Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 18–25, 2007.

E. Himwich, J. Gipson: "GSFC Technology Development Center Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 248–250, 2007.

T. Hobiger, R. Ichikawa, Y. Koyama, T. Kondo: "Kashima Ray-Tracing Service (KARATS)—Fast Ray-tracing through Numerical Weather Models for Real-time Positioning Applications in East Asia". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 181–185, 2007.

T. Hobiger, R. Ichikawa, Y. Koyama, T. Kondo: "Kashima Ray-Tracing Service (KARATS)—Fast Ray-tracing through Numerical Weather Models for Real-time Positioning Applications". IVS NICT Technology Development Center News, No. 28, 16–19, August 2007.

T. Hobiger, T. Kondo, Y. Koyama, R. Ichikawa, R. Weber: "Effect of the Earth's Oblateness on the Estimation of Global Vertical Total Electron Content Maps". Geophys. Res. Lett., 34, L11113, 2007. DOI 10.1029/2007GL029792.

T. Hobiger, T. Kondo, Y. Koyama, K. Takashima, H. Schuh: "Using VLBI Fringe-phase Information from Geodetic Experiments for Short-period Ionospheric Studies". Journal of Geodesy, 81 (6–8), 389–401, 2007. DOI 10.1007/s00190-007-0142-4.

T. Hobiger, Y. Koyama, T. Kondo: "MK3TOOLS & NetCDF—Storing VLBI Data in a Machine Independent Array Oriented Data Format". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 194–195, 2007.

X. Hong, Q. Fan, T. An: "Sheshan VLBI Station Report for 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 85–87, 2007.

R. Ichikawa, T. Hobiger, Y. Koyama, T. Kondo: "An Evaluation of Geodetic Position Error Simulated Using the Fast Ray Tracing Algorithms through the JMA Mesoscale Numerical Weather Data". IVS NICT Technology Development Center News, No. 28, 20–21, August 2007.

R. Ichikawa, M. Sekido, T. Hobiger, T. Kondo, Y. Koyama: "Analysis Center at National Institute of Information and Communications Technology". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 216–219, 2007.

A. Ishii, R. Ichikawa, H. Takiguchi, H. Kuboki, M. Kimura, J. Nakajima, Y. Koyama, J. Fujisaku, K. Takashima: "Development of a Compact VLBI System for a Length Examination of a Reference Baseline". IVS NICT Technology Development Center News, No. 28, 2–5, August 2007.

P. Kaufmann, A.M. Pereira de Lucena, A. Sombra da Silva, C. Tateyama: "Fortaleza Station Report for 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 36–39, 2007.

E. Kawai, H. Kuboki: "Kashima 34-m Radio Telescope". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-

2007-214151, 51–54, 2007.

R. Kilger, W. Schlüter: “Fundamentalstation Wettzell – 20m Radiotelescope”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 114–117, 2007.

K. Kim: “Kokee Park Geophysical Observatory”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 59–62, 2007.

M. Kimura: “Development of the Software Correlator for the VERA System II”. IVS NICT Technology Development Center News, No. 28, 22–25, August 2007.

K. Kingham, M.S. Carter: “NEOS Operation Center”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 132, 2007.

K. Kingham, B. Luzum, D. Hall: “Washington Correlator”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 155–158, 2007.

H. Kiuchi, S. Okumura, J. Amagai, S. Iguchi, T. Kondo: “Directly Controlled Reference Frequency Wavefront Clock Method Applied to 100-GHz Radio Interferometry and Fringe Simulator”. Radio Sci., 42, RS3012, 20007. DOI 10.1029/2006RS003506.

K. Kokado, J. Fujisaku, K. Takashima: “Tsukuba 32-m VLBI Station”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 103–106, 2007.

T. Kondo, Y. Koyama, R. Ichikawa, M. Sekido: “Technology Development Center at NICT”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 259–262, 2007.

T. Kondo, H. Ohkubo, R. Ichikawa, Y. Koyama: “Current Status of K5/VSSP32 Sampler”. IVS NICT Technology Development Center News, No. 28, 30–33, August 2007.

Y. Koyama: “Kashima and Koganei 11-m VLBI Stations”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 55–58, 2007.

Y. Koyama: “Data Center at NICT”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 168–171, 2007.

Y. Koyama, R. Ichikawa, M. Kanzaki, T. Tanno, H. Nishimura, X. Min: “Development of the Evaluation System for the Verified Position Service”. IVS NICT Technology Development Center News, No. 28, 6–9, August 2007.

M. Krügel, D. Thaller, V. Tesmer, M. Rothacher, D. Angermann, R. Schmid: “Tropospheric Parameters: Combination Studies Based on Homogeneous VLBI and GPS Data”. Journal of Geodesy, 81 (6–8), 515–527, 2007. DOI 10.1007/s00190-006-0127-8.

M. Kudryashova, D. MacMillan, O. Titov: “A Comparison of Intraday Variations of the Earth Orientation Parameters from Different VLBI Solutions”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung

Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 196–199, 2007.

M. Kudryashova, V. Vityazev: "Analysis Center of Saint–Petersburg University". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 177–178, 2007.

S. Kurdubov: "QUASAR Software in IAA EOP Service: Global Solution and Daily SINEX". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 79–81, 2007.

Y. Kwak, Y. Cho, J. Park: "Status of Geodetic Application Research in KASI". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 1–3, 2007.

S.B. Lambert, V. Dehant: "The Earth's core parameters as seen by the VLBI". Astron. Astrophys., 469, 777–781, 2007. DOI: 10.1051/0004-6361:20077392.

S.B. Lambert, V. Dehant, A.-M. Gontier: "Some Issues about the Earths Core and Inner Core through VLBI". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 206–208, 2007.

R. Lanotte, G. Bianco, C. Luceri: "Matera CGS VLBI Analysis Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 185–186, 2007.

K. Le Bail, M. Feissel–Vernier, J.-J. Valette, W. Zerhouni: "Long Term Consistency of Multi-technique Terrestrial Reference Frames, a Spectral Approach". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 692–699, 2007.

J. Li: "SHAO Analysis Center 2006 Annual Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 231–232, 2007.

M. Machida, K. Takashima, H. Shigematsu, E. Iwata: "Tsukuba VLBI Correlator". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 151–154, 2007.

D.S. MacMillan: "VLBI2010 Simulations Using SOLVE". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 163–167, 2007.

D.S. MacMillan, C. Ma: "Radio Source Instability in VLBI Analysis". Journal of Geodesy, 81 (6–8), 443–453, 2007. DOI 10.1007/s00190-007-0136-2.

Z. Malkin: "On Dependence of EOP Precision and Accuracy on VLBI Network". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm,

A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 75–78, 2007.

Z. Malkin: "Empiric Models of the Earth's Free Core Nutation". Solar System Research, 41 (6), 492–497, 2007.

Z. Malkin: "On Accuracy Assessment of Celestial Reference Frame Realizations". J. Geod., 2007. DOI: 10.1007/s00190-007-0181-x

Z. Malkin, N. Miller: "An Analysis of Celestial Pole Offset Observations in the Free Core Nutation Frequency Band". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 93–97, 2007.

Z. Malkin, J. Sokolova, A. Bajkova: "PUL IVS Analysis Center Report 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 228–230, 2007.

Z. Malkin, D. Terentev: "Parameters of the Free Core Nutation from VLBI Data". arXiv:physics/0702152, 2007.

S. Manabe, T. Jike, Y. Tamura, VERA Group: "VERA Geodetic Activities". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 69–72, 2007.

I. Martí-Vidal, J.M. Marcaide, J.C. Guirado: "On the Role of Differenced Phase-delays in High-precision Wide-field Multi-source Astrometry". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 116–121, 2007.

P.J. Mendes Cerveira, J. Böhm, E. Tanir, J. Wresnik, H. Schuh: "Datum Deficiency in VLBI Analysis: Case Study of Session 021020XA". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 209–215, 2007.

P.J. Mendes Cerveira, R. Weber, H. Schuh: "The Instantaneous Earth Rotation – Still Inaccessible?". Österreichische Zeitschrift für Vermessung und Geoinformation (VGI), 95 (2), 113–120, 2007.

A. Mikhailov, A. Lavrov: "IAA RAS Radio Telescope Monitoring System". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 10–14, 2007.

S. Montaguti, L. Vittuari, P. Sarti, M. Negusini: "Medicina and Noto VLBI Radiotelescopes: Gravitational Deformations Evaluated with Terrestrial Laser Scanning". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN

1811-8380, 4–9, 2007.

M. Moya Espinosa, R. Haas: “SATTRACK—A Satellite Tracking Module for the VLBI Field System”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 53–58, 2007.

T. Nagayama, T. Omodaka, T. Handa, H.B.H. Iahak, T. Sawada, T. Miyaji, Y. Koyama: “A Complete Survey of the Central Molecular Zone in NH_3”. Publ. Astron. Soc. Jpn., 59, 869–887, 2007.

J. Nastula, B. Kolaczek, R. Weber, H. Schuh, J. Böhm: “Spectra of Rapid Oscillations of Earth Rotation Parameters Determined during the CONT02 Campaign”. In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 208–214, 2007.

M. Negusini, P. Sarti, S. Montaguti: “Italy INAF Data Center Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 166–167, 2007.

M. Negusini, P. Sarti, S. Montaguti, C. Abbondanza: “Italy INAF Analysis Center Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 212–213, 2007.

A. Niell: “MIT Haystack Observatory Analysis Center”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 201–203, 2007.

A. Niell, A. Whitney, W. Petrachenko, W. Schlüter, N. Vandenberg, H. Hase, Y. Koyama, C. Ma, H. Schuh, G. Tuccari: “VLBI2010: A Vision for Future Geodetic VLBI”. In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 757–759, 2007.

T. Nilsson, R. Haas, G. Elgered: “Simulations of Atmospheric Path Delays Using Turbulence Models”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 175–180, 2007.

C. Noll “CDDIS Data Center Summary for the 2006 IVS Annual Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 163–165, 2007.

A. Nothnagel, S. Böckmann, M. Vennebusch: “Analysis Coordinator Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 15–17, 2007.

A. Nothnagel, J.-H. Cho, A. Roy, R. Haas: “WVR Calibration Applied to European VLBI Observing Sessions”. In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 152–157, 2007.

A. Nothnagel, A. Müskens: "The Bonn Geodetic VLBI Operation Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 127–128, 2007.

R. Ojha, A.L. Fey, P. Charlot, K.J. Johnston, D.L. Jauncey, J.E. Reynolds, A.K. Tzioumis, J.E.J. Lovell, J.F.H. Quick, G.D. Nicolson, S.P. Ellingsen, P.M. McCulloch, Y. Koyama: "Improvement and Extension of the International Celestial Reference Frame in the Southern Hemisphere". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 616–623, 2007.

R. Ojha, A.L. Fey, D.L. Jauncey, J.E.J. Lovell, K.J. Johnston: "Is Scintillation the Key to a Better Celestial Reference Frame?". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 610–615, 2007.

A. Orfei, A. Orlati, G. Maccaferri, F. Mantovani: "The Medicina Station Status Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 67–68, 2007.

A. Pany, J. Wresnik, J. Böhm, H. Schuh: "Optimum Modeling of Troposphere and Clock Parameters in VLBI". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 135–140, 2007.

M. Pearlman, Z. Altamimi, N. Beck, R. Forsberg, W. Gurtner, S. Kenyon, D. Behrend, F.G. Lemoine, C. Ma, C.E. Noll, E.C. Pavlis, Z. Malkin, A.W. Moore, F.H. Webb, R.E. Neilan, J.C. Ries, M. Rothacher, P. Willis: "GGOS Working Group on Ground Networks and Communications". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 719–726, 2007.

B. Petrachenko, M. Bérubé, A. Searle: "Canadian VLBI Technology Development Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 243–245, 2007.

L. Petrov: "Using Source Maps for Scheduling and Data Analysis: Approaches and Strategies". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 141–146, 2007.

M. Poirier: "Westford Antenna". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 110–113, 2007.

J. Redmond, M. Evangelista: "Goddard Geophysical and Astronomical Observatory". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 40–43, 2007.

B. Reid, J. Dickey: "Hobart, Mt. Pleasant, Station Report for 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 48–50, 2007.

W. Schlüter, D. Behrend: "The International VLBI Service for Geodesy and Astrometry (IVS): Current Capabilities and Future Prospects". Journal of Geodesy, 81 (6–8), 379–387, 2007. DOI 10.1007/s00190-006-0131-z.

W. Schlüter, D. Behrend, E. Himwich, A. Nothnagel, A. Niell, A. Whitney: "IVS High Accurate Products for the Maintenance of the GLobal Reference Frames as Contribution to GGOS". In: Dynamic Planet – Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, edited by P. Tregoning and C. Rizos, IAG Symposia 130, ISBN: 978-3-540-49349-5, 735–740, 2007.

W. Schlüter, C. Plötz, R. Wojdziak, A. Reinhold: "German Antarctic Receiving Station (GARS) O'Higgins". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 78–80, 2007.

H. Schuh, J. Böhm, R. Heinkelmann, T. Hobiger, P.J. Mendes Cerveira, A. Pany, E. Tanir, K. Teke, S. Todorova, J. Wresnik: "Vienna IGG Special Analysis Center Annual Report 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 208–211, 2007.

H. Schuh, R. Heinkelmann, J. Sokolova, V. Tesmer: "Interaction of Celestial and Terrestrial Reference Frames". Final Report of Sub-Commission 1.4, IAG Commission 1 – Reference Frames, Bulletin No. 20, Report 2003–2007, H. Drewes and H. Hornik (eds.), 46–51, 2007.

M. Sekido, M. Kimura, Y. Koyama, T. Kondo, H. Takiguchi, H. Harai, T. Ikeda, X. Sugang, M. Hirabaru, C. Ruszczyk, A. Whitney: "e-VLBI Demonstration in the JGN2 Symposium". IVS NICT Technology Development Center News, No. 28, 26–29, August 2007.

M. Sekido, T. Kondo, Y. Koyama, M. Kimura: "VLBI Correlators in Kashima". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 147–150, 2007.

E. Skurikhina, S. Kurdubov, V. Gubanov: "IAA VLBI Analysis Center Report 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 204–207, 2007.

S. Smolentsev, I. Rahimov: "Svetloe Radio Astronomical Observatory". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 92–94, 2007.

S. Sobarzo, C. Jara, E. Oñate, C. Herrera, C. Verdugo, H. Hase, A. Böer, B. Sierk: "Geodetic Observatory TIGO in Concepción". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 99–102, 2007.

J.R. Sokolova, Z.M. Malkin: "On Comparison and Combination of Radio Source Catalogues". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 98–102, 2007.

J.R. Sokolova, Z.M. Malkin: "On Comparison and Combination of Catalogues of Radio Source Positions". Astron. Astrophys., 474 (2), 665–670, 2007. DOI: 10.1051/0004-6361:20077450

P. Steigenberger, V. Tesmer, M. Krügel, D. Thaller, R. Schmid, S. Vey, M. Rothacher: "Comparisons of Homogeneously Reprocessed GPS and VLBI Long Time-series of Troposphere Zenith Delays and Gradients". Journal of Geodesy, 81 (6–8), 503–514, 2007. DOI 10.1007/s00190-006-0124-y.

I. Surkis, A. Bogdanov, A. Melnikov, V. Shantyr, V. Zimovsky: "IAA Correlator Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 143–146, 2007.

H. Takiguchi, T. Hobiger, A. Ishii, R. Ichikawa, Y. Koyama: "Comparison with GPS Time Transfer and VLBI Time Transfer". IVS NICT Technology Development Center News, No. 28, 10–15, August 2007.

E. Tanir, J. Böhm, H. Schuh, V. Tornatore, K. Felsenstein: "VLBI Intra-technique Combination for Kalman Filter and Least-Squares Solutions". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 216–221, 2007.

K. Teke, J. Wresnik, J. Böhm, H. Schuh: "Comparison and Cut off Angle Tests for Observed and Simulated CONT05 Sessions". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 122–128, 2007.

V. Tesmer: "Effect of Various Analysis Options on VLBI-determined CRF". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 103–110, 2007.

V. Tesmer, J. Böhm, R. Heinkelmann, H. Schuh: "Effect of Different Tropospheric Mapping Functions on the TRF, CRF and Position Time-series Estimated from VLBI". Journal of Geodesy, 81 (6–8), 409–421, 2007. DOI 10.1007/s00190-006-0126-9.

V. Tesmer, H. Drewes, M. Krügel: "DGFI Analysis Center Annual Report 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 187–190, 2007.

D. Thaller, M. Krügel, M. Rothacher, V. Tesmer, R. Schmid, D. Angermann: "Combined Earth Orientation Parameters Based on Homogeneous and Continuous VLBI and GPS Data". Journal of Geodesy, 81 (6–8), 529–541, 2007. DOI 10.1007/s00190-006-0115-z.

C. Thomas, D. MacMillan: "CORE Operation Center Report". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 129–131, 2007.

V. Thorandt, A. Nothnagel, G. Engelhardt, M. Vennebusch, T. Artz, S. Böckmann, D. Ullrich: "The BKG/GIUB VLBI Analysis Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 193–196, 2007.

V. Thorandt, R. Wojdziak: "BKG Data Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-

214151, 161–162, 2007.

O. Titov: “Baseline Length Repeatability”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 64–68, 2007.

O. Titov: “Effect of the Selection of Reference Radio Sources on Geodetic Estimates from VLBI Observations”. Journal of Geodesy, 81 (6–8), 455–468, 2007. DOI 10.1007/s00190-007-0145-1.

O. Titov: “Geoscience Australia Analysis Center”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 179–180, 2007.

M. Titus, R. Cappallo, B. Corey, A. Niell, A. Whitney: “Haystack Observatory VLBI Correlator”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 139–142, 2007.

V. Tornatore, P. Charlot: “The Impact of Radio Source Structure on European Geodetic VLBI Measurements”. Journal of Geodesy, 81 (6–8), 469–478, 2007. DOI 10.1007/s00190-007-0146-0.

G. Tuccari: “Noto Station Status Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 73–74, 2007.

G. Tuccari, S. Buttaccio, G. Nicotra, W. Alef, R. Keller, M. Nalbach, M. Wunderlich: “DBBC—A Flexible Environment for VLBI and Space Research: Digital Receiver and Back-end Systems”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 45–49, 2007.

M. Vennebusch, S. Böckmann, A. Nothnagel: “The Contribution of Very Long Baseline Interferometry to ITRF2005”. Journal of Geodesy, 81 (6–8), 553–564, 2007. DOI 10.1007/s00190-006-0117-x.

A.E. Volvach, I.D. Strepka, P.S. Nikitin, L.N. Volvach, N.N. Gorkavyi, L.S. Levitskyi: “Simeiz 22-m VLBI Station”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 88–91, 2007.

A. Whitney: “The Mark 5 VLBI Data System”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 33–38, 2007.

A. Whitney: “Wide-Bandwidth Digital Backend System for VLBI”. In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 39–44, 2007.

A. Whitney: “IVS Technology Coordinator Report”. In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 26–29, 2007.

A. Whitney: "Haystack Observatory Technology Development Center". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 251–254, 2007.

J. Wresnik, J. Böhm, H. Schuh: "Monte Carlo Simulations for VLBI2010". In: Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Heft Nr. 79, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien, ISSN 1811-8380, 168–174, 2007.

J. Wresnik, R. Haas, J. Böhm, H. Schuh: "Modeling Thermal Deformation of VLBI Antennas with a New Temperature Model". Journal of Geodesy, 81 (6–8), 423–431, 2007. DOI 10.1007/s00190-006-0120-2.

A. Yusup, N. Wang: "Nanshan VLBI Station Report for 2006". In: International VLBI Service for Geodesy and Astrometry 2006 Annual Report, edited by D. Behrend and K. Baver, NASA/TP-2007-214151, 107–109, 2007.

IVS Information

IVS Information

IVS Terms of Reference

1. Summary

1.1. Charter

The International VLBI Service for Geodesy and Astrometry (IVS) is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

IVS is an official Service of the International Association of Geodesy (IAG).

1.2. Objectives

IVS fulfills its charter through the following objectives. The primary objective of IVS is to foster VLBI programs as a joint service. This is accomplished through close coordination to provide high-quality VLBI data and products.

The second objective of IVS is to promote research and development activities in all aspects of the geodetic and astrometric VLBI technique. This objective also supports the integration of new components into IVS. The further education and training of VLBI participants is supported through workshops, reports, electronic network connections, and other means.

The third objective of IVS is to interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system. IVS interacts closely with the International Earth Rotation Service (IERS) which is tasked by the IAU and IUGG with maintaining the international celestial and terrestrial reference frames and with monitoring Earth rotation.

To meet these objectives, IVS coordinates VLBI observing programs, sets performance standards for VLBI stations, establishes conventions for VLBI data formats and data products, issues recommendations for VLBI data analysis software, sets standards for VLBI analysis documentation, and institutes appropriate VLBI product delivery methods to ensure suitable product quality and timeliness. IVS closely coordinates its activities with the astronomical community because of the dual use of many VLBI facilities and technologies for both astronomy and astrometry/geodesy.

IVS accepts observing proposals for research and operational programs that conform to the IVS objectives.

1.3. Data Products

VLBI data products contribute uniquely to these important determinations:

- definition and maintenance of the celestial reference frame
- monitoring universal time (UT1) and length of day (LOD)
- monitoring the coordinates of the celestial pole (nutation and precession)

These results are the foundation of many scientific and practical applications requiring the use of an accurate inertial reference frame, such as high-precision navigation and positioning. IVS provides, through the collaborative efforts of its components, a variety of significant VLBI data products with differing applications, timeliness, detail, and temporal resolution, such as:

- all components of Earth orientation parameters at regular intervals
- terrestrial reference frame
- VLBI data in appropriate formats
- VLBI results in appropriate formats
- local site ties to reference points
- high-accuracy station timing data
- surface meteorology, tropospheric and ionospheric measurements

All VLBI data products are archived in IVS Data Centers and are publicly available.

1.4. Research

The VLBI data products are used for research in many related areas of geodesy, geophysics, and astrometry, such as:

- UT1 and polar motion excitation (over periods of hours to decades)
- solid Earth interior research (mantle rheology, anelasticity, libration, core modes, nutation/precession)
- characterization of celestial reference frame sources and improvements to the frame
- tidal variations (solid Earth, oceanic, and atmospheric)
- improvements in the terrestrial reference frame, especially in the vertical (scale) component
- climate studies

To support these activities, there are ongoing research efforts whose purpose is to improve and extend the VLBI technique in such areas as:

- improvements in data acquisition and correlation
- refined data analysis techniques
- spacecraft tracking (Earth-orbiting and interplanetary)
- combination of VLBI data and results with other techniques

2. Permanent Components

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic, astrometric, and other results, and archives and publicizes data products. IVS accomplishes its goals through the types of permanent components described in this section. IVS will accept proposals at any time for a permanent component. Such proposals will be reviewed by the Directing Board. The seven types of IVS permanent components are:

- Network Stations
- Operation Centers
- Correlators

- Analysis Centers
- Data Centers
- Technology Development Centers
- Coordinating Center

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic and astrometric results, and archives and publicizes data products. IVS accomplishes its goals through the operational components described below.

2.1. Network Stations

The IVS observing network consists of high performance VLBI stations.

- Stations can be dedicated to geodesy or have multiple uses (including astronomical observations or satellite tracking applications).
- Stations comply with performance standards for data quality and operational reliability set up by the Directing Board.
- VLBI data acquisition sessions are conducted by groups of Network Stations that are distributed either globally or over a geographical region.

2.2. Operation Centers

The IVS Operation Centers coordinate the routine operations of one or more networks. Operation Center activities include:

- planning network observing programs,
- establishing operating plans and procedures for the stations in the network,
- supporting the network stations in improving their performance,
- making correlator time available at an IVS Correlator,
- generating the detailed observing schedules for use in data acquisition sessions by IVS Network Stations,
- posting the observing schedule to an IVS Data Center for distribution and to the Coordinating Center for archiving.

IVS Operation Centers follow guidelines from the Coordinating Center for timeliness and schedule file formats. Operation Centers cooperate with the Coordinating Center in order to define:

- the annual master observing schedule,
- the use of antenna time,
- tape availability and shipping,
- the use of other community resources.

- President of IAU Commission 19 – Rotation of the Earth
- President of IAU Commission 8 – Positional Astronomy
- President of IAU Commission 31 – Time
- President of IAU Commission 40 – Radio Astronomy
- President of URSI Commission J – Radio Astronomy

Individuals are accepted as IVS Corresponding Members upon request to the Coordinating Center.

Last modified: 7 October, 2007

2.3. Correlators

The IVS Correlators process raw VLBI data and station log files following a data acquisition session. Their other tasks are to:

- provide immediate feedback to the Network Stations about problems that are apparent in the data,
- jointly maintain the geodetic/astrometric community's tape pool,
- make processed data available to the Analysis Centers,
- regularly compare processing techniques, models, and outputs to ensure that data from different Correlators are identical.

2.4. Analysis Centers

The IVS coordinates VLBI data analysis to provide high-quality products for its users. The analyses are performed by Analysis Centers and by Associate Analysis Centers.

Analysis Centers are committed to produce series of Earth Orientation Parameters (EOP) or series of individual EOP components, without interruption and at a specified time lag to meet IVS requirements. In addition, Analysis Centers produce station coordinates and source positions in regular intervals.

The Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Analysis Center makes from IVS recommendations are properly documented. Analysis Centers provide timely feedback about station performance. In addition to these regular services, Analysis Centers may also perform any task of an Associate Analysis Center.

Associate Analysis Centers are committed to regularly submit specialized products using complete series or subsets of VLBI observing sessions. The analysis is performed for specific purposes as recognized by the Directing Board such as exploitation of VLBI data for new types of results, investigations of regional phenomena, reference frame maintenance, or special determinations of Earth orientation parameters. The Associate Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Associate Analysis Center makes from IVS recommendations are properly documented.

2.5. Data Centers

The IVS Data Centers are repositories for VLBI observing schedules, station log files, and data products. Data Centers may mirror other Data Centers to make the distribution and maintenance of data more efficient and reliable.

- Data Centers are the primary means of distributing VLBI products to users.
- Data Centers work closely with the Coordinating Center and with the Analysis Centers to ensure that all the information and data required by IVS components are quickly and reliably available.

Data Centers provide the following functions:

- receive and archive schedule files from Operation Centers,
- receive and archive log files and ancillary data files from the Network Stations,
- receive and archive data products from the Analysis Centers,
- provide access and public availability to IVS data products for all users.

2.6. Technology Development Centers

The IVS Technology Development Centers contribute to the development of new VLBI technology. They may be engaged in hardware and/or software technology development, or evolve new approaches that will improve the VLBI technique and enhance compatibility with different data acquisition terminals. They will:

- design new hardware,
- investigate new equipment,
- develop new software for operations, processing or analysis,
- generate new information systems,
- develop, test, and document prototypes of new equipment or software,
- assist with deployment, installation, and training for any new approved technology.
- After dissemination of the new hardware or software, the centers may continue to provide maintenance and updating functions.

2.7. Coordinating Center

The IVS Coordinating Center is responsible for coordination of both the day-to-day and the long-term activities of IVS, consistent with the directives and policies established by the Directing Board. Specifically, the Coordinating Center monitors, coordinates, and supports the activities of the Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers. The Coordinating Center works closely with the Technology Coordinator, the Network Coordinator, and the Analysis Coordinator to coordinate all IVS activities.

The primary functions of the Coordinating Center are to:

- coordinate observing programs approved by the Directing Board,
- maintain the master schedule of observing sessions, coordinating the schedule with astronomical observing programs and with IVS networks,
- foster communications among all components of the IVS,
- define the best use of community resources,
- develop standards for IVS components,
- provide training in VLBI techniques,
- organize workshops and meetings, including an annual IVS technical meeting,
- produce and publish reports of activities of IVS components,

- maintain the IVS information system and archive all documents, standards, specifications, manuals, reports, and publications,
- provide liaison with the IERS, IAG, IAU, FAGS, and other organizations,
- provide the Secretariat of the Directing Board.

3. Coordinators

Specific IVS activities for technology, network data quality, and data products are accomplished through the functions performed by three coordinators: a Network Coordinator, an Analysis Coordinator, and a Technology Coordinator.

3.1. Network Coordinator

The IVS Network Coordinator is selected by the Directing Board from responses to an open solicitation to all IVS components. The Network Coordinator represents the IVS Networks on the Directing Board and works closely with the Coordinating Center. The Network Coordinator is responsible for stimulating the maintenance of a high quality level in the station operation and data delivery. The Network Coordinator performs the following functions:

- monitors adherence to standards in the network operation,
- participates in the quality control of the data acquisition performance of the network stations,
- tracks data quality and data flow problems and suggests actions to improve the level of performance,

The Network Coordinator works closely with the geodetic and astronomical communities who are using the same network stations for observations. The Coordinator takes a leading role in ensuring the visibility and representation of the Networks.

3.2. Analysis Coordinator

The IVS Analysis Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Analysis Centers. The Analysis Coordinator is responsible for coordinating the analysis activities of IVS and for stimulating VLBI product development and delivery. The Analysis Coordinator performs the following functions:

- fosters comparisons of results from different VLBI analysis software packages and different analysis strategies,
- encourages analysis software documentation,
- participates in comparisons of results from different space geodetic techniques,
- monitors Analysis Centers' products for high quality results and for adherence to IVS standards and IERS Conventions,
- ensures that analysis products from all Analysis Centers are archived and available for the scientific community, and
- forms the official products of IVS, as decided by the IVS Directing Board, using a suitable combination of the analysis results submitted by the Analysis Centers.

The Analysis Coordinator works closely with the geodetic and astronomical communities who are using some of the same analysis methods and software. The Analysis Coordinator plays a leadership role in the development of methods for distribution of VLBI products so that the products reach the widest possible base of users in a timely manner. The coordinator promotes the use of VLBI products to the broader scientific community and interacts with the IVS Coordinating Center and with the IERS.

3.3. Technology Coordinator

The IVS Technology Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Technology Development Centers. The Technology Coordinator is responsible for coordinating the new technology activities of IVS and for stimulating advancement of the VLBI technique. The Technology Coordinator performs the following functions:

- maintains cognizance of all current VLBI technologies and ongoing development
- coordinates development of new technology among various IVS components
- helps promulgate new technologies to the geodetic/astrometric community
- strives to ensure the highest degree of global compatibility of VLBI data acquisition systems

The Technology Coordinator works closely with the astronomical community because of the many parallels between the technology development required for both groups.

4. Directing Board

4.1. Roles and Responsibilities

The Directing Board determines policies, adopts standards, and approves the scientific and operational goals for IVS. The Directing Board exercises general oversight of the activities of IVS including modifications to the organization that are deemed appropriate and necessary to maintain efficiency and reliability.

A specific function of the Board is to set scientific goals for the IVS observing program. The Board will establish procedures for external research programs and will review any proposals thus received.

The Board may determine appropriate actions to ensure the quality of the IVS products and that the IVS components maintain the adopted standards.

4.2. Membership

The Directing Board consists of appointed members who serve ex officio, members elected by the Directing Board, and members elected by the IVS components. The members are:

Appointed members ex officio:

- IAG representative
- IAU representative
- IERS representative
- FAGS representative

- Coordinating Center Director

Through a reciprocity agreement between IVS and IERS the IVS serves as the VLBI Technique Center for IERS, and as such its designated representative(s) serve on the IERS Directing Board. In turn, the IERS Directing Board designates a representative to the IVS Directing Board. This arrangement is to assure full cooperation between the two services.

Selected by Directing Board upon review of proposals from IVS Member Organizations:

- Technology, Network, and Analysis Coordinators (3 total)

Elected by Directing Board upon recommendation from the Coordinating Center (see below):

- Members at large (3)

Elected by IVS Components (see below):

- Correlators and Operation Centers representative (1)
- Analysis and Data Centers representative (1)
- Networks representatives (2)
- Technology Development Centers representative (1)

Total number: 16

The five appointed members are considered ex officio and are not subject to institutional restrictions. The FAGS representative is a non-voting member in accordance with FAGS requirements.

The five members of the Directing Board who are elected by IVS Permanent Components must each be a member of a different IVS Member Organization. All elected members serve staggered four-year terms once renewable.

At large members are intended to ensure representation on the Directing Board of each of the components of IVS and to balance representation from as many countries and institutions and IVS interests as possible. At large members serve 2-year terms once renewable.

A Board member who departs before the end of his/her term is replaced by a person selected by the Directing Board. The new member will serve for the remainder of the original term.

The three Coordinators are selected by the Directing Board on the basis of proposals from IVS Member Organizations. On a two-thirds vote the Directing Board may call for new proposals for any Coordinator when it determines that a new Coordinator is required. Coordinators are encouraged to give at least three months notice before resigning.

4.3. Elections

Election of Board members by the IVS components shall be conducted by a committee of three Directing Board members, the chair of which is appointed by the chair of the Directing Board. The committee solicits nominations for each representative from the relevant IVS components. For each position, the candidate who receives the largest number of votes from the Associate Members will be elected. In case of a tie the Directing Board will make the decision.

4.4. Chair

The chair is one of the Directing Board members and is elected by the Board for a term of four years with the possibility of reelection for one additional term. The chair is the official representative of IVS to external organizations.

4.5. Decisions

Most decisions by the Board are made by consensus or by simple majority vote of the members present. In case of a tie, the chair shall vote but otherwise does not vote. If a two-thirds quorum is not present, the vote shall be held later by electronic mail. A two-thirds vote of all Board members is required to modify the Terms of Reference, to change the chair, or to change any of the members elected by the Directing Board before the normal term expires.

4.6. Meetings

The Board meets at least annually, or more frequently if meetings are called by the chair or at the request of at least three Board members. The Board will conduct periodic reviews of the IVS organization and its mandate, functions, and components. The reviews should be done every four years.

5. Definitions

5.1. Member Organizations

Organizations that support one or more IVS components are IVS Member Organizations. Individuals associated with IVS Member Organizations may become IVS Associate Members.

5.2. Affiliated Organizations

Organizations that cooperate with IVS on issues of common interest, but do not support an IVS component, are IVS Affiliated Organizations. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Individuals affiliated with IVS Affiliated Organizations may become IVS Correspondents.

5.3. Associate Members

Individuals associated with organizations that support an IVS component may become IVS Associate Members. Associate Members are generally invited to attend non-executive sessions of the Directing Board meetings with voice but without vote. Associate Members take part in the election of the incoming members of the Directing Board representing the IVS components.

5.4. Corresponding Members

IVS Corresponding Members are individuals on a mailing list maintained by the Coordinating Center. They do not actively participate in IVS but express interest in receiving IVS publications, wish to participate in workshops or scientific meetings organized by IVS, or generally are interested in IVS activities. Ex officio corresponding members are the following:

- IAG General Secretary
- President of IAG Commission 1 – Reference Frames
- President of IAG Commission 3 – Geodynamics
- President of IAU Division I – Fundamental Astronomy

IVS Member Organizations

(alphabetized by country)

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

IVS Affiliated Organizations

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

IVS Associate Members

Name	Institution	Country	E-mail
Amagai, Jun	National Institute of Information and Communications Technology	Japan	amagai@nict.go.jp
Andersen, Per Helge	Norwegian Defence Research Establishment	Norway	per-helge.andersen@ffi.no
Andreeva, Tatiana	Institute of Applied Astronomy	Russia	ats@urania.rtf32s.nw.ru
Arias, Felicitas	Bureau International des Poids et Mesures	France	farias@si.bipm.fr
Artz, Thomas	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	thomas.artz@uni-bonn.de
Barache, Christophe	Observatoire de Paris	France	Christophe.Barache@obspm.fr
Baudry, Alain	Observatoire de Bordeaux	France	baudry@obs.u-bordeaux1.fr
Bauernfeind, Erhard	Fundamentalstation Wettzell	Germany	bauernfeind@fs.wettzell.de
Baver, Karen	NVI, Inc./GSFC	USA	karen.d.baver@nasa.gov
Beck, Norman	Natural Resources Canada	Canada	beck@nrcan.gc.ca
Behrend, Dirk	NVI, Inc./GSFC	USA	dirk.behrend@nasa.gov
Bellanger, Antoine	Observatoire de Bordeaux	France	bellanger@obs.u-bordeaux1.fr
Berdnikov, Anton	Institute of Applied Astronomy	Russia	anton_ipa@rambler.ru
Bergman, Per	Onsala Space Observatory	Sweden	bergman@oso.chalmers.se
Bernhart, Simone	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	simone@mpifr-bonn.mpg.de
Bertarini, Alessandra	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	abertari@mpifr-bonn.mpg.de
Bianco, Giuseppe	Agenzia Spaziale Italiana	Italy	bianco@asi.it
Bielmaier, Ewald	Fundamentalstation Wettzell	Germany	bielmaier@fs.wettzell.de
Boboltz, David	U. S. Naval Observatory	USA	dboboltz@usno.navy.mil
Böckmann, Sarah	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	boeckmann@uni-bonn.de
Böhm, Johannes	Institute of Geodesy and Geophysics	Austria	johannes.boehm@tuwien.ac.at
Boer, Armin	BKG/Project TIGO	Chile	armin.boer@bkg.bund.de
Bolotin, Sergei	Main Astronomical Observatory	Ukraine	bolotin@mao.kiev.ua

Name	Institution	Country	E-mail
Booth, Roy	Hartebeesthoek Radio Astronomy Observatory	South Africa	roy@hartrao.ac.za
Bougeard, Mireille	Observatoire de Paris	France	mireille.bougeard@obspm.fr
Bourda, Geraldine	Observatoire de Bordeaux	France	bourda@obs.u-bordeaux1.fr
Buttaccio, Salvo	Istituto di Radioastronomia INAF	Italy	s.buttaccio@ira.inaf.it
Cappallo, Roger	MIT Haystack Observatory	USA	rcappallo@haystack.mit.edu
Carlson, Brent	Dominion Radio Astrophysical Observatory	Canada	bcarlson@drao.nrc.ca
Carter, Merri Sue	U. S. Naval Observatory	USA	msc@nofs.navy.mil
Charlot, Patrick	Observatoire de Bordeaux	France	charlot@obs.u-bordeaux1.fr
Collioud, Arnaud	Observatoire de Bordeaux	France	collioud@obs.u-bordeaux1.fr
Colomer, Francisco	Instituto Geográfico Nacional	Spain	f.colomer@oan.es
Colucci, Giuseppe	Telespazio SpA	Italy	giuseppe.colucci@telespazio.com
Combrinck, Ludwig	Hartebeesthoek Radio Astronomy Observatory	South Africa	ludwig@bootes.hartrao.ac.za
Conway, John	Onsala Space Observatory	Sweden	john.conway@chalmers.se
Corey, Brian	MIT Haystack Observatory	USA	bcorey@haystack.mit.edu
Dassing, Reiner	Bundesamt für Kartographie und Geodäsie	Germany	reiner.dassing@bkg.bund.de
Del Rosso, Domenico	Telespazio SpA	Italy	domenico_delrosso@telespazio.it
de-Vicente, Pablo	Instituto Geográfico Nacional	Spain	p.devicente@oan.es
Dewdney, Peter	Dominion Radio Astrophysical Observatory	Canada	ped@drao.nrc.ca
Diakov, Alexey	Institute of Applied Astronomy	Russia	ipazel@mail.svkchr.ru
Dickey, John	University of Tasmania	Australia	John.Dickey@utas.edu.au
Diegel, Irv	Honeywell TSI	USA	irv.diegel@honeywell-tsi.com
Digre, Helge	Norwegian Mapping Authority	Norway	helge.digre@statkart.no
Doi, Koichiro	National Institute of Polar Research	Japan	doi@nipr.ac.jp
Dong, Yousuo	Urumqi Astronomical Observatory	China	dongys@ms.xjb.ac.cn
Drewes, Hermann	Deutsches Geodätisches Forschungsinstitut	Germany	drewes@dgfi.badw.de
Dube, Maurice	SSAI/GSFC	USA	maurice.p.dube@nasa.gov
Elgered, Gunnar	Onsala Space Observatory	Sweden	kge@oso.chalmers.se

Name	Institution	Country	E-mail
Engelhardt, Gerald	Bundesamt für Kartographie und Geodäsie	Germany	gerald.engelhardt@bkg.bund.de
Engen, Bjorn	Norwegian Mapping Authority	Norway	bjorn.engen@statkart.no
Evangelista, Mark	Honeywell TSI	USA	mark.evangelista@honeywell-tsi.com
Fan, Qingyuan	Shanghai Astronomical Observatory	China	qyfan@center.shao.ac.cn
Fedotov, Leonid	Institute of Applied Astronomy	Russia	flv@ipa.nw.ru
Fey, Alan	U. S. Naval Observatory	USA	afey@usno.navy.mil
Finkelstein, Andrey	Institute of Applied Astronomy	Russia	amf@quasar.ipa.nw.ru
Fujisaku, Junichi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Fukuzaki, Yoshihiro	Geographical Survey Institute	Japan	fukuzaki@gsi.go.jp
Gambis, Daniel	Observatoire de Paris	France	daniel.gambis@obspm.fr
Gaume, Ralph	U. S. Naval Observatory	USA	rgaume@usno.navy.mil
Gipson, John	NVI, Inc./GSFC	USA	john.m.gipson@nasa.gov
Gomez, Frank	Raytheon/GSFC	USA	frank.g.gomez@nasa.gov
Gomez-Gonzalez, Jesus	Instituto Geográfico Nacional	Spain	gomez@oan.es
Gontier, Anne-Marie	Observatoire de Paris	France	anne-marie.gontier@obspm.fr
Gordon, David	NVI, Inc./GSFC	USA	david.gordon-1@nasa.gov
Govind, Ramesh	Geoscience Australia	Australia	ramesh.govind@ga.gov.au
Gubanov, Vadim	Institute of Applied Astronomy	Russia	gubanov@quasar.ipa.nw.ru
Haas, Rüdiger	Onsala Space Observatory	Sweden	rudiger.haas@chalmers.se
Hall, David	U. S. Naval Observatory	USA	dhall@usno.navy.mil
Hammargren, Roger	Onsala Space Observatory	Sweden	roger.hammargren@chalmers.se
Hanssen, Rune	Norwegian Mapping Authority	Norway	rune.hanssen@statkart.no
Harms, Matt	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Hase, Hayo	BKG/Project TIGO	Chile	hayo.hase@bkg.bund.de
Heinkelmann, Robert	Institute of Geodesy and Geophysics	Austria	rob@mars.hg.tuwien.ac.at
Helldner, Leif	Onsala Space Observatory	Sweden	helldner@oso.chalmers.se
Herrera, Cristian	TIGO/Universidad de Concepción	Chile	cristian.herrera@tigo.cl
Himwich, Ed	NVI, Inc./GSFC	USA	ed.himwich@nasa.gov
Hirabaru, Masaki	National Institute of Information and Communications Technology	Japan	masaki@nict.go.jp

Name	Institution	Country	E-mail
Hobiger, Thomas	National Institute of Information and Communications Technology	Japan	hobiger@nict.go.jp
Hong, Xiaoyu	Shanghai Astronomical Observatory	China	xhong@center.shao.ac.cn
Honma, Mareki	National Astronomical Observatory of Japan	Japan	honmamr@cc.nao.ac.jp
Huang, Xinyong	Shanghai Astronomical Observatory	China	xhuang@center.shao.ac.cn
Hugentobler, Urs	Fundamentalstation Wettzell	Germany	urs.hugentobler@bv.tu-muenchen.de
Ichikawa, Ryuichi	National Institute of Information and Communications Technology	Japan	richi@nict.go.jp
Ihde, Johannes	Bundesamt für Kartographie und Geodäsie	Germany	johannes.ihde@bkg.bund.de
Ilijin, Gennadiy	Institute of Applied Astronomy	Russia	igen@ipa.rssi.ru
Ipatov, Alexander	Institute of Applied Astronomy	Russia	ipatov@ipa.rssi.ru
Ipatova, Irina	Institute of Applied Astronomy	Russia	ipatova@isida.ipa.rssi.ru
Ishii, Atsutoshi	National Institute of Information and Communications Technology	Japan	ishii@nict.go.jp
Ivanov, D.V.	Institute of Applied Astronomy	Russia	ltf@ipa.rssi.ru
Iwata, Etsurou	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Jacobs, Chris	Jet Propulsion Laboratory	USA	chris.jacobs@jpl.nasa.gov
Jara, Cristobal	TIGO/Universidad de Concepción	Chile	cristobal.jara@tigo.cl
Jike, Takaaki	National Astronomical Observatory of Japan	Japan	jike@miz.nao.ac.jp
Johansson, Jan	Onsala Space Observatory	Sweden	jmj@oso.chalmers.se
Johansson, Karl-Åke	Onsala Space Observatory	Sweden	karl-ake.johansson@chalmers.se
Johansson, Lars	Onsala Space Observatory	Sweden	
Johnson, Heidi	MIT Haystack Observatory	USA	hjohnson@haystack.mit.edu
Johnston, Kenneth	U. S. Naval Observatory	USA	kjj@astro.usno.navy.mil
Kaufmann, Pierre	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	kaufmann@usp.br
Kawaguchi, Noriyuki	National Astronomical Observatory of Japan	Japan	kawagu.nori@nao.ac.jp
Kawai, Eiji	National Institute of Information and Communications Technology	Japan	kawa@nict.go.jp
Kaydanovsky, Michael	Institute of Applied Astronomy	Russia	kmn@isida.ipa.rssi.ru
Kharinov, Mikhail	Institute of Applied Astronomy	Russia	kharinov@ipa.rssi.ru
Kilger, Richard	Fundamentalstation Wettzell	Germany	kilger@fs.wettzell.de

Name	Institution	Country	E-mail
Kim, Kelly	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Kimura, Moritaka	National Institute of Information and Communications Technology	Japan	mkimura@nict.go.jp
Kingham, Kerry	U. S. Naval Observatory	USA	kak@cygx3.usno.navy.mil
Kobayashi, Hideyuki	National Astronomical Observatory of Japan	Japan	hideyuki.kobayashi@nao.ac.jp
Kokado, Kensuke	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Kondo, Tetsuro	National Institute of Information and Communications Technology	Japan	kondo@nict.go.jp
Korkin, Edward	Institute of Applied Astronomy	Russia	korkin@isida.ipa.rssi.ru
Koyama, Yasuhiro	National Institute of Information and Communications Technology	Japan	koyama@nict.go.jp
Krasinsky, George	Institute of Applied Astronomy	Russia	kra@quasar.ipa.nw.ru
Kronschnabl, Gerhard	Bundesamt für Kartographie und Geodäsie	Germany	gerhard.kronschnabl@bkg.bund.de
Krügel, Manuela	Deutsches Geodätisches Forschungsinstitut	Germany	kruegel@dgfi.badw.de
Kuboki, Hiromitsu	National Institute of Information and Communications Technology	Japan	kuboki@nict.go.jp
Kudryashova, Maria	Astronomical Institute of St.-Petersburg	Russia	kudryashova@mercury.astro.spbu.ru
Kurdubov, Sergey	Institute of Applied Astronomy	Russia	ksl@quasar.ipa.nw.ru
Labelle, Ruth	SSAI/GSFC	USA	ruth.e.labelle@nasa.gov
Lambert, Sebastien	Observatoire de Paris	France	sebastien.lambert@obspm.fr
Lanotte, Roberto	Telespazio SpA	Italy	lanotte@asi.it
Lauber, Pierre	Fundamentalstation Wettzell	Germany	lauber@fs.wettzell.de
Lavrov, Alexey	Institute of Applied Astronomy	Russia	lexslavrov@yandex.ru
Li, Bing	Shanghai Astronomical Observatory	China	bing@center.shao.ac.cn
Li, Huihua	Shanghai Astronomical Observatory	China	hhl@center.shao.ac.cn
Li, Jinling	Shanghai Astronomical Observatory	China	jll@center.shao.ac.cn
Liang, Shiguang	Shanghai Astronomical Observatory	China	sgliang@center.shao.ac.cn
Lidberg, Martin	Onsala Space Observatory	Sweden	martin.lidberg@chalmers.se
Lindqvist, Michael	Onsala Space Observatory	Sweden	michael.lindqvist@chalmers.se
Liu, Xiang	Urumqi Astronomical Observatory	China	liux@ms.xjb.ac.cn

Name	Institution	Country	E-mail
Long, Jim	Honeywell TSI	USA	jim.long@honeywell-tsi.com
Lonsdale, Colin	MIT Haystack Observatory	USA	clonsdale@haystack.mit.edu
Lowe, Stephen	Jet Propulsion Laboratory	USA	steve.lowe@jpl.nasa.gov
Lucena, Antonio	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	macilio@roen.inpe.br
Luzum, Brian	U. S. Naval Observatory	USA	bjl@maia.usno.navy.mil
Ma, Chopo	NASA Goddard Space Flight Center	USA	chopo.ma-1@nasa.gov
Maccaferri, Giuseppe	Istituto di Radioastronomia INAF	Italy	g.maccaferri@ira.inaf.it
Machida, Morito	Geographical Survey Institute	Japan	machida@gsi.go.jp
MacMillan, Dan	NVI, Inc./GSFC	USA	daniel.s.macmillan@nasa.gov
Malkin, Zinovy	Pulkovo Observatory	Russia	malkin@gao.spb.ru
Manabe, Seiji	National Astronomical Observatory of Japan	Japan	manabe@miz.nao.ac.jp
Mantovani, Franco	Istituto di Radioastronomia INAF	Italy	f.mantovani@ira.inaf.it
Mardyshkin, Vyacheslav	Institute of Applied Astronomy	Russia	vvm@isida.ipa.rssi.ru
Marshalov, Dmitry	Institute of Applied Astronomy	Russia	dam@ipa.rssi.ru
Matsuzaka, Shigeru	Geographical Survey Institute	Japan	shigeru@gsi.go.jp
McCarthy, Dennis	U. S. Naval Observatory	USA	dmc@maia.usno.navy.mil
Melnikov, Alexey	Institute of Applied Astronomy	Russia	melnikov@quasar.ipa.nw.ru
Mendes Cerveira, Paulo	Institute of Geodesy and Geophysics	Austria	mendes@mars.hg.tuwien.ac.at
Michailov, Andrey	Institute of Applied Astronomy	Russia	agm@isida.ipa.rssi.ru
Miller, Natalia	Pulkovo Observatory	Russia	natmiller@list.ru
Mitchell, Donald	Honeywell TSI	USA	kokee@pele.kpgo.hawaii.edu
Müskens, Arno	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	mueskens@mpifr-bonn.mpg.de
Nakajima, Junichi	National Institute of Information and Communications Technology	Japan	nakaji@nict.go.jp
Nanni, Mauro	Istituto di Radioastronomia INAF	Italy	m.nanni@ira.inaf.it
Negusini, Monia	Istituto di Radioastronomia INAF	Italy	m.negusini@ira.inaf.it

Name	Institution	Country	E-mail
Nicolson, George	Hartebeesthoek Radio Astronomy Observatory	South Africa	george@bootes.hartrao.ac.za
Niell, Arthur	MIT Haystack Observatory	USA	aniell@haystack.mit.edu
Nikitin, Pavel	Crimean Astrophysical Observatory	Ukraine	nikitin@crao.crimea.ua
Nilsson, Biörn	Onsala Space Observatory	Sweden	biorn.nilsson@chalmers.se
Nilsson, Tobias	Onsala Space Observatory	Sweden	tobias.nilsson@chalmers.se
Noll, Carey	NASA Goddard Space Flight Center	USA	carey.noll@nasa.gov
Nothnagel, Axel	Geodetic Institute of the University of Bonn	Germany	nothnagel@uni-bonn.de
Nozawa, Kentarou	Geographical Survey Institute	Japan	aes@garnet.gsi.go.jp
Ogaja, Clement	Geoscience Australia	Australia	Clement.Ogaja@ga.gov.au
Ojha, Roopesh	U. S. Naval Observatory	USA	rojha@usno.navy.mil
Olofsson, Hans	Onsala Space Observatory	Sweden	hans.olofsson@chalmers.se
Oñate, Eric	TIGO/Universidad del Bío Bío	Chile	eric.onate@tigo.cl
Orfei, Sandro	Istituto di Radioastronomia INAF	Italy	a.orfei@ira.inaf.it
Pany, Andrea	Institute of Geodesy and Geophysics	Austria	apany@mars.hg.tuwien.ac.at
Petrachenko, William	Natural Resources Canada	Canada	Bill.Petrachenko@nrc-cnrc.gc.ca
Petrov, Leonid	NVI, Inc./GSFC	USA	Leonid.Petrov@lpetrov.net
Pettersson, Lars	Onsala Space Observatory	Sweden	larsp@oso.chalmers.se
Plötz, Christian	Bundesamt für Kartographie und Geodäsie	Germany	christian.ploetz@bkg.bund.de
Poirier, Michael	MIT Haystack Observatory	USA	mpoirier@haystack.mit.edu
Qian, Zhihan	Shanghai Astronomical Observatory	China	qzh@center.shao.ac.cn
Quick, Jonathan	Hartebeesthoek Radio Astronomy Observatory	South Africa	jon@bootes.hartrao.ac.za
Rahimov, Ismail	Institute of Applied Astronomy	Russia	rahimov@urania.rtf32s.nw.ru
Redmond, Jay	Honeywell TSI	USA	jay.redmond@honeywell-tsi.com
Reid, Brett	University of Tasmania	Australia	brett.reid@utas.edu.au
Rekkedal, Svein	Norwegian Mapping Authority	Norway	svein.rekkedal@statkart.no
Richter, Bernd	Bundesamt für Kartographie und Geodäsie	Germany	bernd.richter@bkg.bund.de
Rioja, Maria	Instituto Geográfico Nacional	Spain	mj.rioja@oan.es
Ruszczyk, Chester	MIT Haystack Observatory	USA	chester@haystack.mit.edu
Salnikov, Alexander	Institute of Applied Astronomy	Russia	salnikov@isida.ipa.rssi.ru

Name	Institution	Country	E-mail
Sarti, Pierguido	Istituto di Radioastronomia INAF	Italy	p.sarti@ira.inaf.it
Schatz, Raimund	Fundamentalstation Wettzell	Germany	schatz@fs.wettzell.de
Scherneck, Hans-Georg	Onsala Space Observatory	Sweden	hans-georg.scherneck@chalmers.se
Schlüter, Wolfgang	Bundesamt für Kartographie und Geodäsie	Germany	Wolfgang.Schlüter@bkg.bund.de
Schuh, Harald	Institute of Geodesy and Geophysics	Austria	harald.schuh@tuwien.ac.at
Schupler, Bruce	Honeywell TSI	USA	bruce.schupler@honeywell-tsi.com
Schwarz, Walter	Bundesamt für Kartographie und Geodäsie	Germany	walter.schwarz@bkg.bund.de
Schwegmann, Wolfgang	Bundesamt für Kartographie und Geodäsie	Germany	wolfgang.schwegmann@bkg.bund.de
Sciarretta, Cecilia	Telespazio SpA	Italy	cecilia@asi.it
Searle, Anthony	Natural Resources Canada	Canada	asearle@NRCan.gc.ca
Sekido, Mamoru	National Institute of Information and Communications Technology	Japan	sekido@nict.go.jp
Shao, Minghui	Urumqi Astronomical Observatory	China	nanshan@ms.xjb.ac.cn
Shibuya, Kazuo	National Institute of Polar Research	Japan	shibuya@nipr.ac.jp
Shigematsu, Hiromi	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Shishikin, Alexandr	Institute of Applied Astronomy	Russia	
Shu, Fengchun	Shanghai Astronomical Observatory	China	sfc@center.shao.ac.cn
Skurikhina, Elena	Institute of Applied Astronomy	Russia	sea@quasar.ipa.nw.ru
Smolentsev, Sergey	Institute of Applied Astronomy	Russia	smolen@isida.ipa.rssi.ru
Smythe, Dan	MIT Haystack Observatory	USA	dsmythe@haystack.mit.edu
Sobarzo, Sergio	TIGO/Universidad de Concepción	Chile	sergio.sobarzo@tigo.cl
Sokolova, Yulia	Pulkovo Observatory	Russia	s0lei@yandex.ru
Sousa, Don	MIT Haystack Observatory	USA	dsousa@haystack.mit.edu
Sovers, Ojars	Remote Sensing Analysis Inc.	USA	ojars@rsasys.com
Stanghellini, Carlo	Istituto di Radioastronomia INAF	Italy	c.stanghellini@ira.inaf.it
Steppe, Alan	Jet Propulsion Laboratory	USA	as@logos.jpl.nasa.gov
Surkis, Igor	Institute of Applied Astronomy	Russia	surkis@isida.ipa.rssi.ru

Name	Institution	Country	E-mail
Takashima, Kazuhiro	Geographical Survey Institute	Japan	takasima@gsi.go.jp
Takiguchi, Hiroshi	National Institute of Information and Communications Technology	Japan	htaki@nict.go.jp
Tamura, Yoshiaki	National Astronomical Observatory of Japan	Japan	tamura@miz.nao.ac.jp
Tangen, Leif Morten	Norwegian Mapping Authority	Norway	leif.morten.tangen@statkart.no
Tanimoto, Daisuke	Geographical Survey Institute	Japan	vlbi@gsi.go.jp
Tanir, Emine	Institute of Geodesy and Geophysics	Austria	etanir@mars.hg.tuwien.ac.at
Tao, An	Shanghai Astronomical Observatory	China	antao@center.shao.ac.cn
Tateyama, Claudio	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil	tateyama@craam.mackenzie.br
Teke, Kamil	Institute of Geodesy and Geophysics	Austria	kteke@mars.hg.tuwien.ac.at
Tesmer, Volker	Deutsches Geodätisches Forschungsinstitut	Germany	tesmer@dgfi.badw.de
Thomas, Cynthia	NVI, Inc./GSFC	USA	cynthia.c.thomas@nasa.gov
Thorandt, Volkmar	Bundesamt für Kartographie und Geodäsie	Germany	volkmar.thorandt@bkg.bund.de
Thornton, Bruce	U. S. Naval Observatory	USA	blt@casa.usno.navy.mil
Titov, Oleg	Geoscience Australia	Australia	Oleg.Titov@ga.gov.au
Titus, Mike	MIT Haystack Observatory	USA	mtitus@haystack.mit.edu
Todorova, Sonja	Institute of Geodesy and Geophysics	Austria	stodo@mars.hg.tuwien.ac.at
Tomasi, Paolo	Istituto di Radioastronomia INAF	Italy	tomasi@ira.inaf.it
Trigilio, Corrado	Istituto di Radioastronomia INAF	Italy	ctrigilio@oact.inaf.it
Tsutsumi, Masanori	National Institute of Information and Communications Technology	Japan	tsutsumi@nict.go.jp
Tuccari, Gino	Istituto di Radioastronomia INAF	Italy	g.tuccari@ira.inaf.it
Ullrich, Dieter	Bundesamt für Kartographie und Geodäsie	Germany	dieter.ullrich@bkg.bund.de
Vennebusch, Markus	Institute for Geodesy and Geoinformation of the University of Bonn	Germany	vennebusch@uni-bonn.de
Venturi, Tiziana	Istituto di Radioastronomia INAF	Italy	t.venturi@ira.inaf.it

Name	Institution	Country	E-mail
Verdugo, Carlos	TIGO/Universidad de Concepción	Chile	carlos.verdugo@tigo.cl
Vespe, Francesco	Agenzia Spaziale Italiana	Italy	vespe@asi.it
Vityazev, Veniamin	Astronomical Institute of St.-Petersburg	Russia	vityazev@list.ru
Volvach, Alexandr	Crimean Astrophysical Observatory	Ukraine	volvach@crao.crimea.ua
Vytnov, Alexander	Institute of Applied Astronomy	Russia	vytnov@isida.ipa.rssi.ru
Wang, Guangli	Shanghai Astronomical Observatory	China	wgl@center.shao.ac.cn
Wang, Jinqing	Shanghai Astronomical Observatory	China	jqwang@center.shao.ac.cn
Wang, Lingling	Shanghai Astronomical Observatory	China	llwang@center.shao.ac.cn
Wang, Na	Urumqi Astronomical Observatory	China	Na.wang@ms.xjb.ac.cn
Wang, Weixia	Urumqi Astronomical Observatory	China	wangwx@ms.xjb.ac.cn
Wei, Wenren	Shanghai Astronomical Observatory	China	wwr@center.shao.ac.cn
Whitney, Alan	MIT Haystack Observatory	USA	awhitney@haystack.mit.edu
Wojdziak, Reiner	Bundesamt für Kartographie und Geodäsie	Germany	reiner.wojdziak@bkg.bund.de
Wooden, William	U. S. Naval Observatory	USA	wooden.william@usno.navy.mil
Xue, Zhouhe	Shanghai Astronomical Observatory	China	zhxue@center.shao.ac.cn
Yatskiv, Yaroslav	Main Astronomical Observatory	Ukraine	yatskiv@mao.kiev.ua
Ye, Shuhua	Shanghai Astronomical Observatory	China	ysh@center.shao.ac.cn
Yusup, Aili	Urumqi Astronomical Observatory	China	aliyu@ms.xjb.ac.cn
Zeitlhöfler, Reinhard	Fundamentalstation Wettzell	Germany	zeitlhoefler@fs.wettzell.de
Zhang, Ali	Urumqi Astronomical Observatory	China	zhangal@uao.ac.cn
Zhang, Jin	Urumqi Astronomical Observatory	China	zhangj@ms.xjb.ac.cn
Zhang, Xiuzhong	Shanghai Astronomical Observatory	China	xzhang@shao.ac.cn
Zhao, Rongbing	Shanghai Astronomical Observatory	China	zhaorb@center.shao.ac.cn

Name	Institution	Country	E-mail
Zheng, Weimin	Shanghai Astronomical Observatory	China	zhwm@shao.ac.cn
Zhou, Ruixian	Shanghai Astronomical Observatory	China	zrx@center.shao.ac.cn

IVS Permanent Components

(listed by types, within types alphabetical by component name)

Network Stations

Component Name	Sponsoring Organization	Country
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 11m	National Institute of Information and Communications Technology (NICT)	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service (NEOS)	USA
Matera	Agenzia Spaziale Italiana (ASI)	Italy
Medicina	Istituto di Radioastronomia	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
Seshan	Joint Laboratory for Radio Astronomy (JLRA), CAS and Shanghai Observatory, CAS	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy RAS	Russia
JARE Syowa Station	National Institute of Polar Research	Japan

Transportable Integrated Geodetic Observatory (TIGO)	Universidad de Concepción (UdeC), Universidad del Bío Bío (UBB), Instituto Geográfico Militar (IGM), Bundesamt für Kartographie und Geodäsie (BKG)	Germany, Chile
Tsukuba VLBI Station	Geographical Survey Institute	Japan
Nanshan VLBI Station	Chinese Academy of Sciences	China
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (FESG)	Germany
Observatório Astronómico Nacional - Yebes	Instituto Geográfico Nacional	Spain
Radioastronomical Observatory Zelenchukskaya	Institute of Applied Astronomy RAS	Russia

Operation Centers

Component Name	Sponsoring Organization	Country
Institut für Geodäsie und Geoinformation (IGGB)	Universität Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service (NEOS)	USA

Correlators

Component Name	Sponsoring Organization	Country
Astro/Geo Correlator at MPI	Bundesamt für Kartographie und Geodäsie and Institut für Geodäsie und Geoinformation der Universität Bonn	Germany
MIT Haystack Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology (NICT)	National Institute of Information and Communications Technology (NICT)	Japan
Tsukuba VLBI Center	Geographical Survey Institute	Japan
Washington Correlator	National Earth Orientation Service (NEOS)	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana (ASI)	Italy
Italy INAF	Istituto di Radioastronomia INAF	Italy
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France

Analysis Centers

Component Name	Sponsoring Organization	Country
Astronomical Institute of St.-Petersburg University	Astronomical Institute of St.-Petersburg University	Russia
Geoscience Australia	Geoscience Australia	Australia
Observatoire de Bordeaux	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
IGGB-BKG Analysis Center	Institut für Geodäsie und Geoinformation der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy	Russia
Institute of Geodesy and Geophysics (IGG)	Institute of Geodesy and Geophysics (IGG) of the University of Technology, Vienna	Austria
Italy INAF	Istituto di Radioastronomia INAF	Italy
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Main Astronomical Observatory	Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
National Astronomical Observatory of Japan	National Astronomical Observatory of Japan	Japan

National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden
Pulkovo Observatory	Pulkovo Observatory	Russia
Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
U. S. Naval Observatory Analysis Center	U. S. Naval Observatory	USA
U. S. Naval Observatory Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	**Sponsoring Organization**	**Country**
Canadian VLBI Technology Development Center	CRESTech, NRCan, DRAO, CSA	Canada
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Onsala Space Observatory	Chalmers University of Technology	Sweden

Addresses of Institutions of Authors Contributing to this Report

(listed alphabetically by country)

Geoscience Australia
PO Box 378
Canberra ACT
2601
Australia
http://ga.gov.au

University of Tasmania, Geoscience Australia
School of Mathematics and Physics
University of Tasmania
Private Bag 37
Hobart 7001
Australia
http://www.phys.utas.edu.au/physics

Institute of Geodesy and Geophysics, Vienna University of Technology
Gusshausstrasse 27-29
1040 Vienna
Austria
http://www.hg.tuwien.ac.at

CRAAM, Universidade Presbiteriana Mackenzie, São Paulo
CRAAM
Instituto Presbiteriano Mackenzie
Rua da Consolação 896
01302-907 São Paulo
SP
Brazil
http://www.craam.mackenzie.br

Instituto Nacional de Pesquisas Espaciais
Estrada do Fio 6000
Bairro Tupuiú
61760-000 Eusébio
CE
Brazil
http://www.roen.inpe.br

Geodetic Survey Division, Natural Resources Canada
615 Booth St.
Ottawa
Ontario
Canada K1A 0E9
http://www.geod.nrcan.gc.ca

Bundesamt für Kartographie und Geodäsie - TIGO
Casilla 4036
Correo 3
Concepción
Chile
http://www.bkg.de

Universidad de Concepción - TIGO
Concepción
Chile
http://www.udec.cl

Shanghai Astronomical Observatory, Chinese Academy of Sciences
80 Nandan Road
Shanghai 200030
People's Republic of China
http://www.shao.ac.cn/english.htm

Urumqi Observatory, NAO, CAS
40-5 South Beijing Road
Urumqi
Xinjiang Uygur Autonomous Region
830011
China
http://www.uao.ac.cn

Observatoire de Bordeaux
BP 89
33270 Floirac
France
http://www.obs.u-bordeaux1.fr

Observatoire de Paris, SYRTE, CNRS/UMR8630
61 avenue de l'Observatoire
F-75014 Paris
France
http://www.obspm.fr
http://ivsopar.obspm.fr

Bundesamt für Kartographie und Geodäsie
Karl-Rothe-Strasse 10-14
04105 Leipzig
Germany
http://www.bkg.bund.de

Deutsches Geodätisches Forschungsinstitut (DGFI)
Alfons-Goppel-Strasse 11
80539 München
Germany
http://www.dgfi.badw.de

Fundamentalstation Wettzell
Bundesamt für Kartographie und Geodäsie and
Forschungseinrichtung Satellitengeodäsie (FESG)
Sackenrieder Str. 25.
D-93444 Kötzting
Germany
http://www.fs.wettzell.de

Institut für Geodäsie und Geoinformation der Universität Bonn
Nussallee 17
53115 Bonn
Germany
http://vlbi.geod.uni-bonn.de

Max-Planck-Institute for Radioastronomy
Auf dem Hügel 69
53121 Bonn
Germany
http://www.mpifr-bonn.mpg.de

Agenzia Spaziale Italiana
Centro di Geodesia Spaziale
C.P. Aperta
Ctr.da Terlecchia
75100 Matera
Italy
http://www.asi.it

Istituto di Radioastronomia–Bologna
Via P. Gobetti 101
40129 Bologna
Italy
http://www.ira.inaf.it

DISTART - University of Bologna
Viale Risorgimento2
40136 Bologna
Italy
http://www.distart.ing.unibo.it

Istituto di Radioastronomia, Medicina
C.P. 14
40060 Villafontana
Bologna
Italy
http://www.med.ira.inaf.it

Istituto di Radioastronomia INAF, Stazione VLBI di Noto
C.P. 161
I-96017 Noto SR
Italy
http://www.noto.ira.inaf.it

Geographical Survey Institute, Japan
Code 305-0811
Kitasato 1-ban
Tsukuba
Ibaraki Pref.
Japan
http://vldb.gsi.go.jp/sokuchi/vlbi/english

Mizusawa VERA Observatory
2-12 Hoshigaoka-cho
Mizusawa-ku
Oshu-shi
Iwate-ken 023-0861
Japan
http://www.miz.nao.ac.jp

National Institute of Information and Communications Technology
893-1 Hirai
Kashima
Ibaraki 314-0012
Japan
http://www2.nict.go.jp/w/w114/stsi/index_e.html

National Institute of Polar Research
1-9-10
Kaga
Itabashi-ku
Tokyo 173-8515
Japan
http://www.nipr.ac.jp/welcome.html

Forsvarets forskningsinstitutt (FFI) (Norwegian Defence Research Establishment)
FFI/E
Box 25
2007 Kjeller
Norway
http://www.ffi.no/

Geodetic Institute, Norwegian Mapping Authority
Kartverksveien
Hønefoss
Norway
http://www.statkart.no

Central Astronomical Observatory at Pulkovo of the Russian Academy of Sciences
Pulkovskoe Ch. 65/1
St. Petersburg
196140
Russia
http://www.gao.spb.ru

Institute of Applied Astronomy of Russian Academy of Sciences (IAA)
nab. Kutuzova 10
St. Petersburg
191187
Russia
http://www.ipa.nw.ru

HartRAO, NRF
PO Box 443
Krugersdorp
1740
South Africa
http://www.hartrao.ac.za

Instituto Geográfico Nacional
Calle General Ibañez de Ibero 3
E-28003 Madrid
Spain
http://www.ign.es/

Observatório Astronómico Nacional
Apartado 112
E-28803 Alcalá de Henares
Spain
http://www.oan.es/

Onsala Space Observatory (OSO)
SE-439 92
Onsala
Sweden
http://www.oso.chalmers.se

Main Astronomical Observatory, National Academy of Sciences of Ukraine
Main Astronomical Observatory
27 Akademika Zabolotnoho St.
Kiev
03680
Ukraine
http://www.mao.kiev.ua

Radio Astronomy Lab of Crimean Astrophysical Observatory
RT-22
Katsively
Yalta Crimea 98688
Ukraine
http://www.crao.crimea.ua

Jet Propulsion Laboratory, California Institute of Technology
Mail Stop 238-600
4800 Oak Grove Dr.
Pasadena, California 91109
USA
http://www.jpl.nasa.gov

Kokee Park Geophysical Observatory
Kokee State Park
P.O. Box 538
Waimea, Hawaii 96796
USA

MIT Haystack Observatory
Off Route 40
Westford, MA 01886
USA
http://www.haystack.mit.edu

NASA Goddard Space Flight Center
Code 698
Greenbelt, MD 20771
USA
http://lupus.gsfc.nasa.gov

United States Naval Observatory
3450 Massachusetts Avenue NW
Washington, DC 20392
USA
http://www.usno.navy.mil/

U.S. Naval Observatory, Flagstaff Station
10391 West Naval Observatory Rd.
Flagstaff, AZ 86001
USA
http://www.nofs.navy.mil

List of Acronyms

AAS	American Astronomical Society
ACF	AutoCorrelation Function
ACU	Antenna Control Unit
ADB	Analog to Digital Board
ADC	Analog to Digital Converter
AER	Atmospheric and Environmental Research, Inc. (USA)
AES	Advanced Engineering Services Co., Ltd (Japan)
AGN	Active Galactic Nuclei
AIPS	Astronomical Image Processing System
AOG	Auxilliary Output Generator
APSG	Asia-Pacific Space Geodynamics program
APT	Asia Pacific Telescope
ARIES	Astronomical Radio Interferometric Earth Surveying program
ASI	Agenzia Spaziale Italiana (Italian Space Agency) (Italy)
ATM	Asynchronous Transfer Mode
ATNF	Australia Telescope National Facility (Australia)
A-WVR	Advanced Water Vapor Radiometer
BBC	Base Band Converter
BdRAO	Badary Radio Astronomical Observatory (Russia)
BIPM	Bureau Internacional de Poids et Mesures (France)
BKG	Bundesamt für Kartographie und Geodäsie (Germany)
BMC	Basic Module of Correlator
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)
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project
CGS	Centro di Geodesia Spaziale (Italy)
CIB	Correlator Interface Board
CIP	Celestial Intermediate Pole
CNES	Centre National d'Etudes Spatiales (France)
CNRS	Centre National de la Recherche Scientifique (France)
CNS	Communication, Navigation and Surveillance systems, Inc. (USA)
CODA	Correlator Output Data Analyzer
CORE	Continuous Observations of the Rotation of the Earth
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)
CRESTech	Centre for Research in Earth and Space Technology (Canada)
CRF	Celestial Reference Frame

CRL	Communications Research Laboratory (now NICT) (Japan)
CSA	Canadian Space Agency (Canada)
CSIR	Council for Scientific and Industrial Research (South Africa)
CSRIFS	Combined Square Root Information Filter and Smoother
CTVA	Canadian Transportable VLBI Antenna
DAR	Data Acquisition Rack
DAS	Data Acquisition System
DBBC	Digital Base Band Converter
DBE	Digital BackEnd
ΔDOR	Delta Differenced One-way Range
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DISTART	Dipartimento di Ingegneria delle Strutture, dei Trasporti, delle Acque, del Rilevamento del Territorio (Italy)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DOM	Data Output Module
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite
DR	Dichroic Reflector
DRAO	Dominion Radio Astrophysical Observatory (Canada)
DSN	Deep Space Network
DSS	Deep Space Station
DVLBI	Differential VLBI
ECMWF	European Centre for Medium-Range Weather Forecasts
EGU	European Geosciences Union
ENVISAT	ENVIronmental SATellite
EOP	Earth Orientation Parameters
EOP-PC	Earth Orientation Parameter Product Center (France)
ERP	Earth Rotation Parameters
ETSIT	Escuela Técnica Superior de Ingenieros de Telecomunicación
EUREF	EUropean REFerence Frame
EVGA	European VLBI for Geodesy and Astrometry
EVLA	Expanded Very Large Array
e-VLBI	Electronic VLBI
EVN	European VLBI Network
EXPReS	Express Production Real-time e-VLBI Service
FAGS	Federation of Astronomical and Geophysical data analysis Services
FCN	Free Core Nutation
FESG	Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FITS	Flexible Image Transport System
FPDP	Front Panel Data Port
FS	Field System
FTP	File Transfer Protocol
FWF	Fonds zur Förderung der wissenschaftlichen Forschung (Austrian Science Fund)

GA	Geoscience Australia (formerly AUSLIG) (Australia)
GAPE	Great Alaska and Pacific Experiment
GARNET	GSI Advanced Radiotelescope NETwork (Japan)
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)
GGOS	Global Geodetic Observing System
GGP	Global Geodynamics Project
GINS	Géodésie par Intégrations Numériques Simultanées
GISTM	GPS Ionospheric Scintillation and TEC Monitor
GIUB	Geodetic Institute of the University of Bonn (now IGGB) (Germany)
GLONASS	GLObal NAvigation Satellite System (Russia)
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GREF	German GPS REFerence network
GRGS	Groupe de Recherches de Géodésie Spatiale (France)
GSD	Geodetic Survey Division of Natural Resources Canada (Canada)
GSFC	Goddard Space Flight Center (USA)
GSI	Geographical Survey Institute (Japan)
HEMT	High Electron Mobility Transistor
HPBW	Half Power Beam Width
HSI	High Speed Input bus
HSIR	High Speed Input Replicated bus
HTS	High Temperature Superconductor
HTSI	Honeywell Technology Solutions Incorporated (USA)
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
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	Instituto Geográfico Nacional (Spain)
IGS	International GNSS Service
IISGEO	International Institute for Space Geodesy and Earth Observation
ILRS	International Laser Ranging Service
INAF	Istituto Nazionale di Astrofisica (Italy)
INGV	Institute of Geophysics and Volcanology (Italy)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)

IP	Internet Protocol
IRA	Istituto di RadioAstronomia (Italy)
IRIS	International Radio Interferometric Surveying
ISAS	Institute of Space and Astronautical Science (Japan)
ISBN	International Standard Book Number
ISV	Instantaneous State Vector
ITRF	International Terrestrial Reference Frame
IUGG	International Union of Geodesy and Geophysics
IVOA	International Virtual Observatory Alliance
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JARE	Japanese Antarctic Research Expedition (Japan)
JAXA	Japan Aerospace Exploration Agency (Japan)
JGN	Japan Gigabit Network (Japan)
JIVE	Joint Institute for VLBI in Europe
JLRA	Joint Laboratory for Radio Astronomy (China)
JMA	Japan Meteorological Agency (Japan)
JPL	Jet Propulsion Laboratory (USA)
JSPS	Japanese Society for the Promotion of Science (Japan)
KARAT	KAshima RAy-tracing Tools (Japan)
KASI	Korea Astronomy and Space Science Institute (Korea)
KAT	Karoo Array Telescope (South Africa)
KPGO	Kokee Park Geophysical Observatory (USA)
KSP	KeyStone Project (Japan)
KSRC	Kashima Space Research Center (Japan)
KVN	Korean VLBI Network
LBA	Long Baseline Array (Australia)
LD	Laser Diode
LIEF	Large Infrastructure and Equipment Funding
LLR	Lunar Laser Ranging
LNA	Low Noise Amplifier
LO	Local Oscillator
LOD	Length Of Day
LSB	Lower Side Band
LSM	Least Squares Method
MAO	Main Astronomical Observatory (Ukraine)
MARBLE	Multiple Antenna Radio-interferometry for Baseline Length Evaluation
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MOBLAS	MOBile LASer
MODEST	MODel and ESTimate
MPI	Max-Planck-Institute (Germany)
MPIfR	Max-Planck-Institute for Radioastronomy (Germany)
MTLRS	Modular Transportable Laser Ranging System
NAO	National Astronomical Observatories (China)

NAOJ	National Astronomical Observatory of Japan (Japan)
NASA	National Aeronautics and Space Administration (USA)
NCRIS	National Collaborative Research Infrastructure Strategy (Australia)
NEOS	National Earth Orientation Service (USA)
NetCDF	Network Common Data Form
NGS	National Geodetic Survey (USA)
NICT	National Institute of Information and Communications Technology (Japan)
NIPR	National Institute of Polar Research (Japan)
NMA	Norwegian Mapping Authority (Norway)
NMF	Niell Mapping Function
NNR	No-Net-Rotation
NNT	No-Net-Translation
NOAA	National Oceanic and Atmospheric Administration (USA)
NOFS	U.S. Naval Observatory Flagstaff Station (USA)
NORAD	North American Aerospace Defense Command
NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NTT	Nippon Telegraph and Telephone Corporation (Japan)
NVI	NVI, Inc. (USA)
NWP	Numerical Weather Prediction
OAN	Observatorio Astronómico Nacional (Spain)
OCA	Observatoire de la Côte d'Azur (France)
OPAR	Observatoire de Paris (France)
OPC	(IVS) Observing Program Committee
OS	Operating System
OSO	Onsala Space Observatory (Sweden)
PARNASSUS	Processing Application in Reference to NICT's Advanced Set of Softwares Usable for Synchronization
PCAL	Phase CALibration
PFB	Polyphase Filter Bank
PNR	Peak to Noise Ratio
POLARIS	POLar motion Analysis by Radio Interferometric Surveying
PPP	Precise Point Positioning
PRARE	Precise RAnge and Range-rate Equipment
QRHA	Quad-Ridge Horn Antenna
QZSS	Quasi Zenith Satellite System (Japan)
RAS	Russian Academy of Sciences (Russia)
RDV	Research and Development sessions using the VLBA
RFI	Radio Frequency Interference
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
RRFID	Radio Reference Frame Image Database
SATA	Serial Advanced Technology Attachment
SDK	Software Development Kit
SDSS	Signal Distribution and Synchronization System
SEFD	System Equivalent Flux Density

SHAO	Shanghai Astronomical Observatory (China)
SINEX	Solution INdependent EXchange format
SKA	Square Kilometer Array
SLR	Satellite Laser Ranging
SPEED	Short Period and Episodic Earth rotation Determination
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
SvRAO	Svetloe Radio Astronomical Observatory (Russia)
SWT	SW Technology (USA)
TAC	Totally Accurate Clock
TANAMI	Tracking Active galactic Nuclei with Australia Milliarcsecond Interferometry (Australia)
TAO	Telecommunications Advanced Organization (Japan)
TDC	Technology Development Center
TEC	Total Electron Content
TEMPO	Time and Earth Motion Precision Observations
TLE	Two Line Elements
TLRS	Transportable Laser Ranging System
TOW	Technical Operations Workshop
TRF	Terrestrial Reference Frame
TTW	TWIN-Telescope Wettzell (Germany)
UBB	Universidad del Bío Bío (Chile)
UD	Upper Diagonal
UDC	Up-Down Converter
URSI	Union Radio-Scientifique Internationale
USB	Upper Side Band
USNO	United States Naval Observatory (USA)
UT	Universal Time
UT1	Universal Time
UTAS	University of TASmania (Australia)
UTC	Coordinated Universal Time
VC	Video Converter
VCS	VLBA Calibrator Survey
VDBE	VLBA Digital BackEnd
VERA	VLBI Exploration of Radio Astrometry
VLA	Very Large Array (USA)
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Functions
VO	Virtual Observatory
VSI	VLBI Standard Interface
VSI-H	VLBI Standard Interface Hardware

VSOP	VLBI Space Observatory Program
VSSP	Versatile Scientific Sampling Processor
VTRF	VLBI Terrestrial Reference Frame
WACO	WAshington COrrelator (USA)
WVR	Water Vapor Radiometer
WWW	World Wide Web
XDM	eXperimental Development Model
ZcRAO	Zelenchukskaya Radio Astronomical Observatory (Russia)
ZTD	Zenith Total Delay
ZWD	Zenith Wet Delay

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
29-04-2008

2. REPORT TYPE
Technical Publication

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
International VLBI Service for Geodesy and Astrometry 2007 Annual Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Dirk Behrend, Karen D. Baver

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Goddard Space Flight Center
Greenbelt, MD 20771

8. PERFORMING ORGANIZATION REPORT NUMBER
2008-00375-0

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING REPORT NUMBER
NASA/TP-2008-214162

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited, Subject Category: 46
Report available from the NASA Center for Aerospace Information,7121 Standard Drive, Hanover, MD 21076. (301)621-0390

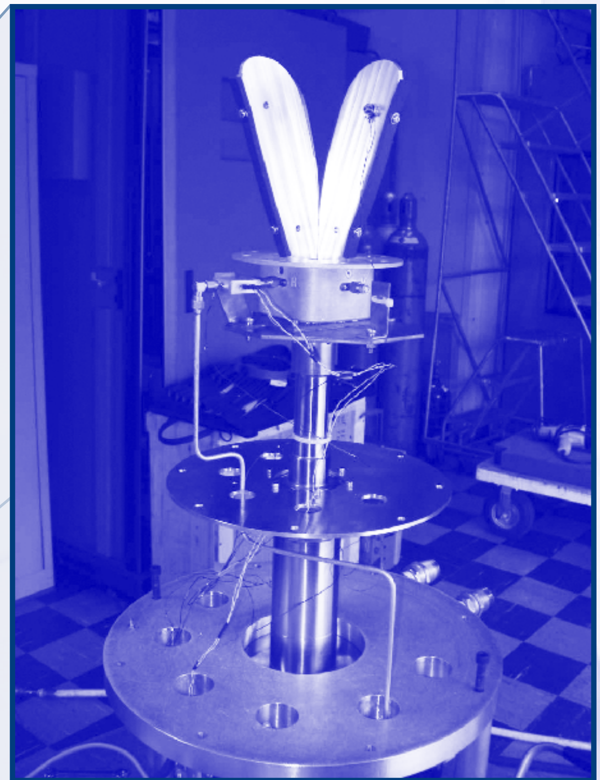
13. SUPPLEMENTARY NOTES
Dirk Behrend, NVI, Inc.; Karen Baver, NVI, Inc.

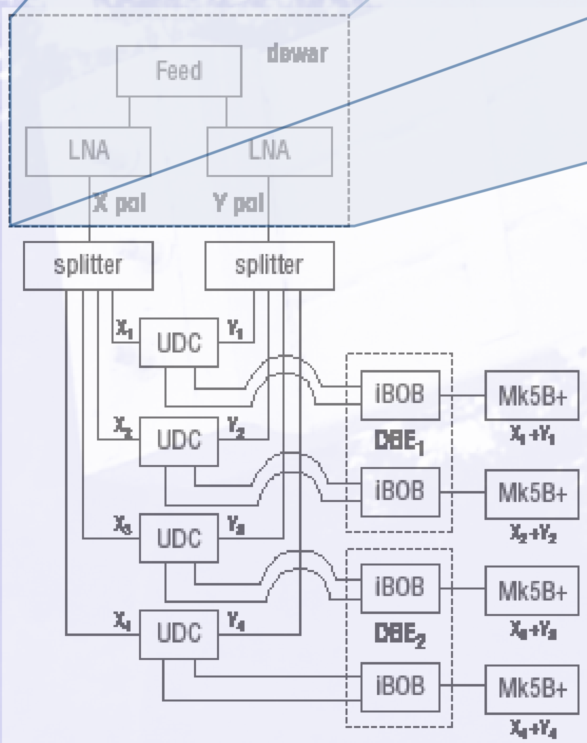
14. ABSTRACT
This volume of reports is the 2007 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the components of IVS. The 2007 Annual Report documents the work of these IVS components over the period January 1, 2007 through December 31, 2007. 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/ar2007.

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.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Dirk Behrend
					19b. TELEPHONE NUMBER *(Include area code)*
Unclassified	Unclassified	Unclassified	Unclassified	324	(301) 614-5939

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18





International VLBI Service for Geodesy and Astrometry

IVS Coordinating Center
NASA Goddard Space Flight Center
Code 698
Greenbelt, MD 20771

http://ivscc.gsfc.nasa.gov
ivscc@ivscc.gsfc.nasa.gov
phone: 301-614-5939
fax: 301-614-6522